Scientific Report 2003

DEPARTMENT 1: Reference Systems and Geodynamics

SECTION 1: Time, Earth Rotation, and Space Geodesy

1. Introduction

1.1. Mission and objectives

The mission of the Section 1 "Time, Earth Rotation, and Space Geodesy" is to contribute to the elaboration of reference systems (terrestrial and celestial) and timescales, theoretically as well as observationally, to integrate Belgium in the international reference frames, and to obtain information on the Earth's interior, rotation, dynamics, and crustal deformation, at local, regional, and global levels. The ultimate goals are the understanding of the dynamics of the Earth's interior and surface deformation.
Additionally to the planet Earth, these objectives have been extended to the other terrestrial planets, Mars, Venus, and Mercury, and to the large moons of the solar system planets. This mission is included in a long-term vision, closely related to the international activity, and to the activities described in the statute of the Royal Observatory of Belgium (ROB).
The activities of Section 1 are divided into five different scientific projects (research and/or operational projects).

(a) Project 1 'TIME – TIME TRANSFER'

The mission of the project 'Time and Time transfer' is to incorporate Belgium in international timescale elaboration. We maintain presently five high-quality clocks for participation in two international timescales: the International Atomic Time (TAI) and the International GPS Service timescale (IGST). These clocks are located in temperature-controlled environment. They are continuously monitored at the nanosecond level, by comparisons between themselves and also with atomic clocks of other laboratories participating to TAI. This comparison is usually performed using code measurements of GPS satellites in common view. The recent scientific developments of the scientists involved in the project concern mainly the improvement of the time transfer by using both code and phase measurements of geodetic receivers, in order to enhance its precision and accuracy. This requests the establishment of new analysis strategies and new softwares, and testing of new equipments.

(b) Project 2 'GNSS-BASED GEODESY AND GEODYNAMICS'

The mission of the project 'GNSS-based geodesy and geodynamics' is to integrate Belgium in international reference frames based on GNSS observations (Global Navigation Satellite System) by delivering the highest quality GPS data through the maintenance of a network of permanent GNSS stations distributed over Belgium. The stations contribute to international networks such as, the IGS (International GPS Service, using the station at Brussels) and the EUREF Permanent GPS Network (EPN, using the stations at Brussels-Dentergem-Dourbes-Waremme).
The scientists involved in the project also contribute to the realization of the reference frames by performing high-quality analysis (at the sub-cm level) of a network of EPN stations (ROB is a data analysis center) and they manage the EPN Central Bureau (CB) that coordinates the EPN network. They also maintain a GPS data center that makes available ROB's GPS data to all user communities.
The geophysical goals related to the Belgian stations are to analyze the velocities of a regional network around Brussels in order to deduce intra-plate tectonic motions, and to study collocation with leveling, gravimetry and GPS in the frame of the European Combined Geodetic Network (ECGN).
Concerning the observation themselves, the participants of this project establish a strategy for renewing the Belgian GPS stations by testing new GPS receivers and by studying rapid downloading protocols, and they prepare the implementation of the future Galileo European positioning system and the modernized GPS system.

(c) Project 3 'EFFECT OF THE EARTH AND PLANETARY ATMOSPHERES IN SPACE GEODESY'

The objectives of the project 'Effect of the Earth and planetary atmosphere in space geodesy' are to monitor the different atmospheric parameters, which influence the precision of GPS applications in order to ensure a better correction of the atmospheric effect on GPS data. The project has two components: "Space Weather and Ionosphere" and "Neutral atmosphere and water vapor". The goal of the part "*Space Weather and ionosphere"* is to assess, in real-time, to forecast, a few hours in advance, and to correct the effect of Space Weather and of the ionosphere on GPS applications. The goal of the part "*Neutral atmosphere and Water Vapor*" is to analyze and to correct the effect of the neutral atmosphere and, in particular, of water vapor on GPS applications. In the frame of these projects, the Integrated Water Vapor content (IWV) of the neutral atmosphere and the Total Electron Content (TEC) of the ionosphere, which are the main parameters which influence GPS, are monitored in real-time using independent data: GPS, ionospheric sounding, radiosonde, water vapor radiometer.

(d) Project 4 'EARTH ROTATION'

The objectives of the project 'Earth rotation' are to better understand and model the Earth rotation and orientation variations, and to study the interaction between the solid Earth and the geophysical fluid dynamics. This allows the scientists involved in the project to understand the associated physics of the Earth interior, to understand the budget of angular momentum of the system composed of the solid Earth, the core, the atmosphere, the ocean, and the hydrosphere in the frame of long term and short term (diurnal and subdiurnal) variations in Earth rotation speed, polar motion, and nutations, to understand the coupling mechanisms between the solid Earth and the geophysical fluid, to analyze Earth rotation data to better understand the physics of the Earth interior and the fluid dynamics.

(e) Project 5 'GEODESY AND GEOPHYSICS OF OTHER PLANETS'

Since the end of the 20th century, the study of the terrestrial planets Mars, Mercury and Venus is again one of the central themes of astronomical and geophysical research, as shown, for example, by the multitude of space missions to these planets by all major space agencies like NASA and ESA. Especially many missions to Mars have been launched and are scheduled, with at present (2004) five spacecrafts (three orbiters, two landers) actively investigating the planet. In the absence of seismometers on these planets, geodesy is one of best tools to probe the planetary interior. Section 1 is involved in and has initiated high-quality research at the international level in the frame of rotation, nutation/libration, gravity field, tides, and interior structure of terrestrial bodies. It studies the feasibility of space missions to these bodies, prepares upcoming space missions and analyses data. A major objective since the beginning of this research in 1998 has been to show the feasibility of a geodesy experiment with a mission involving a network of landers dedicated to geophysics of Mars. Also, the feasibility of radio-science experiments for missions involving a spacecraft around Mars, Venus and Mercury are investigated.

1.2. National and international responsibilities and prizes

Scientists of Section 1 assume many responsibilities in national and international organizations. In Belgium, we are represented in the Belgian National Committees of Astronomy, Geodesy and Geophysics, and Space Research of the Belgian Academy of Sciences and in the FNRS Commission for Astronomy and Geophysics. Internationally, members of Section 1 act as President, Vice-President, or Secretary of several organizations and commissions, such as the Geodesy Section of the AGU (American Geophysical Union), and commissions of the IAU (International Astronomical Union) and IAG (International Association of Geodesy). We are especially strongly involved in the IERS (International Earth rotation and Reference frame Service), with presidents, chairs and members of several bodies, such as the Special Bureau for the Core, and even participate in the IERS Directing Board. We participate in the IGS decisions and activities as well, such as participation in the IGS Governing Board and in Pilot projects. We participate in several space missions for the investigation of the solar system planets with a

PI (Principal Investigator for the NEIGE experiment of the NetLander mission), and several co-Is (Co-Investigator for NEIGE, the seismological experiment of the NetLander mission, the Radio Science experiment of Mars Express…). We participate as Belgian delegate at COST (European Cooperation in the field of Scientific and Technological research) actions. We are also participating in the 'Comité Consultatif pour le Temps et les Fréquences' (CCTF). Section 1 members also contribute to the organization of conferences and workshops. In 2003, we have organized several sessions in the EGU (European Geophysical Union) and AGU general assemblies. We are also often contacted by major science journals for reviewing submitted manuscripts.
We have won Europe's most important science award for excellent collaborative research (300000 euro awarded) for our work on Earth nutation. Furthermore, the head of the section has been awarded the Vening Meinesz medal of the EGU.

2. Research and operational project 'Time and Time transfer'

2.1. Objectives

- To maintain high-quality clocks for participation in the international timescales (mainly TAI and IGS), and for the realization of a local high-quality timescale UTC (ORB) close to UTC.
- To develop strategies and tools for GNSS time transfer in order to improve the precisions of remote clock comparisons, and to perform high-performance analyses of the data gathered at ROB.

2.2. Progress and results

The Time Laboratory of the Royal Observatory of Belgium is one of the 40 time laboratories over the world in which are distributed the 250 atomic clocks used by the BIPM (Bureau International des Poids et Mesures, Paris) for the realization of the International Atomic Time (TAI).

Service

- During year 2003, we maintained our 3 cesium atomic clocks and 2 hydrogen masers in operation and improved the near-real time monitoring of our clocks by comparison with the USNO. The behaviour of local realization of UTC, named UTC (ORB), is now known with respect to the other laboratories' UTC (k) with a one-day delay, at the nanosecond level as accuracy. The plot for each clock is now available in near-real time on the Internet.
- The time links using the geodetic receivers and the ionospheric free code P3, as we have developed in 2001 and 2002, are now used by the BIPM (project TAIP3) in the realization of TAI for half of the time laboratories. We modernized the software for a more general usage by all the laboratories, and responded to all questions from users.
- We developed a remote control system via SMS messages, which are sent in case of air-conditioning, clock or GPS receiver problems.
- We performed the calibration of the two Ashtech Z-XII3T receivers used for positioning and time transfer (stations BRUS and ZTBR) in the frame of the BIPM calibration campaign.

Results

- We improved the carrier-phase based time transfer using the Bernese analysis software by determining optimal ways to deal with the errors on the station coordinates and the modeling of the troposphere.
- We set up a daily run for a network of 10 stations using two separate techniques: codes P3 and carrier phases (paper in preparation).
- We tested a new type of geodetic receiver for suitability to time transfer by common view: the PolaRx2 (Septentrio). We installed two PolaRx2 receivers at the ROB, and the results show variations that we could associate to variable load of the processor inducing internal temperature changes and hence variations of the internal hardware delays (solved now). We also pointed out a remaining

problem of synchronization on the input 1pps. Finally we determined differentially the receiver hardware delays for P1 and P2 and obtained very similar biases for both of the receivers tested, which demonstrates the suitability of the receiver for network use.

2.3. Perspective for next years

The carrier-based time transfer tests will be continued. In addition, we will be compared these results with the code-based results and with e.g. the IGS time scale. We will test different type of geodetic receivers to investigate the receiver-dependent signals that were seen between the Ashtech Z-XXIT and the PolaRX2. We will investigate the impact of adding GALILEO and enhanced GPS on time transfer. We will propose UTC (ORB) as basis for legal time in Belgium.

2.4. Personnel involved

Scientific: Pascale Defraigne (Project Leader, Chef de travaux), Carine Bruyninx (werkleider), Fabian Roosbeek (Chef de travaux)
Technical: Eddy Driegelinck (Calculateur principal)

2.5. Partnerships

(without grants)
BIPM (Bureau International des Poids et Mesures: G. Petit, F. Arias)
NRL (US Naval Research Laboratory: K. Senior)
DLR (Institute of Communications and Navigation, German Aerospace Center: A. Moudrak)

2.6. Publications

2.6.1. Publications with peer system

Defraigne P., Petit G.,
Time Transfer to TAI using geodetic receivers
Metrologia, 40, pp. 184-188.

2.6.2. Publications without peer system

Defraigne P., Bruyninx C., Roosbeek F.
Initial Testing of a New GPS Receiver, the PolaRx2, for Time and Frequency Transfer Using Dual Frequency Codes and Carrier Phases
Proc. PTTI, December 2003, in press

2.6.3. Reports, thesis, etc

de Kerkhove d'Exaerde C.A. (student of ECAM)
Validation des signaux horaires envoyés par le système Teletime."

2 communications at conferences.

2.7. Missions

Research missions (assemblies, symposia, workshops, etc): 2
Operational meetings (commissions, working groups): 1
Field missions: 0

3. Operational and research project 'GNSS-based geodesy and geodynamics'

3.1. Objectives

The mission of this project is to integrate Belgium in international spatial terrestrial reference frames. These reference frames are maintained using space geodetic observations, e.g. GPS. We use space geodesy at different levels: 1) observations (maintenance of a GPS network) 2) research (improvement of the precision of the positioning techniques) 3) data analysis (GPS analysis centre for geodetic and geodynamic applications) and 4) service (EUREF Permanent Network (EPN) activities).

3.2. Progress and results

Observations

A network of 6 permanent GPS stations, distributed over Belgium, has been maintained. Since 2003, these stations provide all hourly tracking data. The software that manages the data flow within the network has been updated in order to improve the reliability of the data flow. Presently, more than 95% of the hourly data arrive within 4 minutes at our central server. In addition, we have created a new utility that allows an easier change of the configuration parameters of a tracking station.
The station in Brussels is integrated in the network of the International GPS Service and four of our stations belong to the European Permanent Network (EPN). As such, several analysis centres to contribute to the realization of European (ETRS89) and international (ITRS) reference systems use their observations.
In addition to the existing network, we have installed at Ukkel a new GPS station that sends its DGPS data in real-time through the Internet. The station participates to the new EUREF-IP project, which aims at setting up and maintaining a real-time GNSS infrastructure using the Internet. Although today's primary objective is to disseminate RTCM corrections over the Internet for precise differential positioning and navigation purposes, various other applications are in sight like real-time orbit determination and ionosphere or troposphere parameter estimation.
Other ROB projects, such as 'Atmosphere in Space Geodesy' and 'Time and Time Transfer' use the data from the GPS stations managed by the members of this project.

Research & Data Analysis

We maintain a high precision (sub-cm positioning) GPS data analysis centre that uses the Bernese software (University of Berne, Switzerland) to analyse GPS data following international state of the art procedures. Our analysis centre acts as one of the EPN Analysis Centres and computes daily coordinates for network of 47 stations. These coordinate solutions contribute to the maintenance of the European and international spatial reference systems (ETRS89 and ITRS).
Our analysis centre has been computing daily station positions since 1996 and we use these daily positions to determine the long-term velocities of a regional network around Belgium in order to deduce intra-plate tectonic motions. Due to the improvement of the computation techniques, a complete reprocessing of the old data since 1996 became necessary. This work was initiated in 2003.
In order to compare the Bernese-based results obtained with an independent source, we have installed and configured of new software for GPS data processing: GAMIT/GLOBK. This software is a comprehensive GPS analysis package developed at MIT and Scripps and allows the estimation of three-dimensional relative positions of ground stations and satellite orbits.
During the year 2003, we have checked, on a daily basis, the data quality of all the EPN and ROB stations by applying the different data quality checks (e.g. number of observed data versus number of predicted data, multipath, and number of cycle slips) we developed. Next to the pure station monitoring, this information is also used to help in the interpretation of the coordinate variations and to improve the reliability of the estimation of the station velocities. These station velocities are presently linked to the

International Reference Frame (ITRF) by using the Bernese GPS analysis software, but we also performed first tests using the minimal constraint approach to fix the network to the ITRF.
We have tested a new GPS receiver, the PolaRx2 (from the Belgian company Septentrio, based at Leuven) and used its code and carrier phase data for precise positioning. We demonstrated that the GPS data from this receiver are of the same quality as the GPS data used within the IGS and EPN networks.
We have started a study of the future GALILEO system in order to define the main working areas for the next years.

Services

We have continued to develop and maintain a comprehensive web site (http://www.gps.oma.be).
We have also continued to host the Central Bureau of the EUREF Permanent Network. The EPN is the network that maintains the European Reference Frame and it is the European contribution to the international reference frame. As EPN Central Bureau we manage a permanent GNSS network of over 150 stations, distributed over more that 30 countries with ±101 participating agencies. In 2003, 23 new stations were integrated in the network.
In addition, we made this year a special effort to stimulate the EPN community to deliver highest quality, reliable GPS data and this in near real-time and real-time. This was possible thanks to continuously performed quality controls and a continuous monitoring the EPN data flow. One of the most important tasks of the EPN Central Bureau is the maintenance and continuously updating of the EPN CB web-site (see http://www.epncb.oma.be/, 2000 pages, ±66.000 hits/month).

3.3. Perspective for next years

During the upcoming years we will continue the maintenance of our GPS network and adapt it to new international guidelines; we continue our participation to international observation networks and will participate to IGS or EUREF projects for real-time data dissemination serving the generation of real-time products.
In addition, we will study all aspects of the interoperability of GPS and the upcoming Galileo system and assess the reliability and accuracy improvements of using a combined GPS/Galileo constellation with respect to GPS and GALILEO individually.
We will also continue with our EPN activities as EPN Central Bureau, EPN data center, and EPN analysis center.
We plan to extend the activities of our analysis centre by starting to process a global GPS network in order to investigate the computation of a GPS-based nutation model. To improve the reliability of our coordinate solutions, we will compare the results from two scientific GPS software packages: GAMIT and the Bernese. We expect to see some major changes in the GPS data analysis procedures in 2004 when a new Bernese version 5 will be installed and tested.
In order to improve the reliability of our methodology used to determine variations in the station coordinates, we plan to study the different methods to combine regional and global GPS solutions.

3.4. Personnel involved

Scientific: Carine Bruyninx (Dr., werkleider), Fabian Roosbeek (Dr., premier assistant), Georges Carpentier (attaché, action 1 MO/33/008),
Technical: Ann Moyaert (programmeur), Dominique Mesmaker (Calculateur principal), Robert Laurent (technicus der vorsing)

3.5. Partnerships

Grants used for this research

Action 1 MO/33/008 (2002-2005) – Ontwikkeling van snelle kwaliteitstesten voor het geodetische “European Reference Frame” GPS netwerk ten behoeve van nieuwe wetenschappelijke toepassingen.

Visitors: 3

3.6. Publications

3.6.1. Publications with peer system

3.6.2. Publications without peer system

Bruyninx C., Carpentier G., Roosbeek F.
EPN Monitoring: Status and Plans
EUREF Publication, eds. J. Torres, H. Hornik, Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, Germany, No 12, pp. 32-42.

Bruyninx C., Defraigne P., Ducarme B., Everaerts M., Pottiaux E., Roosbeek F., Warnant R., Voet P.
Belgian report to the IAG-subcommission EUREF
EUREF Publication, eds. J. Torres, H. Hornik, Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, Germany, No 12, pp 228-231

Ferland R., Altamimi Z., **Bruyninx C.**, Craymer M., Habrich H. and Kouba J.
Regional Networks Densification
Proc. of the IGS Workshop 'Towards Real-time', Ottawa, April 2002, ed. IGS CB, Pasadena, US, pp. 123-132

Ihde J., Adam J., **Bruyninx C**., Kenyeres A. and Simek J.
Proposal for the Development of an European Combined Geodetic Network (ECGN)
EUREF Publication, eds. J. Torres, H. Hornik, Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, Germany, No 12, pp 49-67

Kenyeres A., **Bruyninx C., Carpentier G.**
EPN Special Project on Time Series Analysis: Results of the Retrospective Analysis of the EPN Time Series (1996-2001)
EUREF Publication, eds. J. Torres, H. Hornik, Bundesamtes für Kartographie und Geodäsie, Frankfurt am Main, Germany, No 12, pp 72-72

3.6.3. Publications in press, submitted

Bruyninx C., Carpentier G., Everaerts M., Lejeune S., Pottiaux E., Roosbeek F., Voet P., Van Huele W., **Warnant R.**
EUREF Related Activities in Belgium
Proc. of EUREF Symposium, Toledo, Spain, June 2003

Bruyninx C., Carpentier G., Roosbeek F.
Today's EPN and its network coordination
Proc. of EUREF Symposium, Toledo, Spain, June 2003

Ihde J., Baker T., **Bruyninx C.,** Francis O., Hinderer J., Kenyeres A., Makinen J., Shipman S., Simek J., Wilmes H.
Concept and Status of the ECGN Project
Proc. of EUREF Symposium, Toledo, Spain, June 2003

Kenyeres A., **Bruyninx C.**
Monitoring of the EPN Coordinate Time Series for Improved Reference Frame Maintenance
GPS solutions

Simsky A., Sleewagen J.-M., **Bruyninx C.**
POLARX2, A New GPS Receiver for Geodetic Applications

Proc. of EUREF Symposium, Toledo, Spain, June 2003

3.6.4. Reports, thesis, etc

Bruyninx C., Carpentier G., Roosbeek F., Kenyeres A.
The EUREF Permanent Network: An overview
Poster presented at the IUGG symposium, July 2003, Sapporo, Japan

Ihde J., Baker T., Bruyninx C., Francis O., Hinderer J., Kenyeres A., Makinen J., Rohde H., Simek J., Wilmes H.
Development of a European Combined Geodetic Network
Poster presented at the IUGG symposium, July 2003, Sapporo, Japan

Kenyeres A., **Bruyninx C., Carpentier G**.
Consistency Analysis of the EPN Time Series for Improved Velocity Estimation
Poster presented at the IUGG symposium, July 2003, Sapporo, Japan

Roosbeek F., Bruyninx C.
Novosibirsk GPS data Analysis,
Poster presented at EGS-AGU-EGU meeting, April 2003, Nice, France

Torres J., Adam J., Altamimi Z., Augath W., Boucher C., **Bruyninx C**., Caporali A., Gubler E., Gurtner W., Harsson B., Hornik H.
Status of the European Reference Frame – EUREF
Paper presented at the IUGG symposium, July 2003, Sapporo, Japan

Weber R., **Bruyninx C.**
The International GPS Service
IERS Annual Report 2002, ed. BKG, Frankfurt am Main, pp. 21-24

11 communications at conferences.

3.7. Missions

Research missions (assemblies, symposia, workshops, etc…): 7
Operational meetings (commissions, working groups): 8
Field missions: 4

4. Operational and research Project 'Effect of the Earth and Planetary Atmospheres in Space Geodesy'

4.1. Objectives

The atmospheric refraction remains the main limitation to the precision of the different applications of GPS in Navigation (meter precision), Surveying Engineering (centimeter precision), Geodesy and Geophysics (millimeter precision). The applications which require precise results in real-time are particularly affected by the atmospheric refraction. In the frame of applications in Geodesy and Geophysics (Reference Systems, Tectonics, Earth Rotation, …) which require a millimeter level precision, it is indispensable to understand and to correct the effects of the atmosphere on the computed positions : this is the goal of the project which is divided into 2 main research topics :

- Space Weather and ionosphere: the goal of this project is to assess, in real-time, to forecast, a few hours in advance, and to correct the effect of Space Weather and of the ionosphere on GPS applications.
- Neutral atmosphere and Water Vapor: the goal of the project is to analyze and to correct the effect of the neutral atmosphere and, in particular, of water vapor on GPS applications.

In practice, the lessons learnt when trying to implement a better atmospheric correction for high precision Geophysics also allow to provide support to the GPS user community, in particular, Navigation and Surveying engineering. This service to the public is an important task of the project. In addition, the different studies developed in the frame of these two research programs offer, as a by-product, valuable information about the state of both the neutral (water vapor) and the ionized atmosphere (Total Electron Content). Therefore, several synergies have been established with the Royal Meteorological Institute of Belgium (RMI).

4.2. Progress and results

The strategy used in the project is the following: in a first step, different techniques are developed in order to monitor all the atmospheric "parameters" which have an influence on the precision of GPS applications, in particular, the Total Electron Content (TEC) of the ionosphere and the Integrated Water Vapour Content (IVW) of the neutral atmosphere; the Total Electron Content is the integral of the free electron concentration on the receiver-to-satellite path and the Integrated Water Vapour Content is the integral of the water vapour concentration on the receiver-to-satellite path. In a second step, the information obtained about the TEC and the IVW is used to understand and to correct the influence of the atmosphere on GPS applications.

Space Weather and ionosphere

In 2003, we have developed software able to monitor, in real-time, the TEC and its variability in space and time. The TEC variability is the main parameter that can limit the reliability of both low precision (code-based) and high precision (phase-based) applications of GPS. In addition, using GPS permanent station measurements, we have developed software allowing to reproduce the work conditions of real-time GPS users (low precision applications) and to compute the positioning errors they would have experienced "on the field". Then, these positioning errors have been compared with the information previously obtained on the TEC and its variability in order to extract the part of the positioning error which is due to the ionosphere.

The results of this study are also used to provide support to the GPS community by providing a real-time assessment of the ionosphere effect on the precision of GPS applications. A beta-version of this service is operational (on the web) since September 2003.

We have also proved the correlation between the local geomagnetic activity (measured at Dourbes Geophysical Centre) and the ionospheric variability. Based on this correlation, we will try to issue warning messages a few hours in advance when strongly degraded positioning conditions are expected to occur.

Finally, we have started the development of simulation software in order to generate the measurements that will be made on the signals emitted by the future Galileo constellation. This software will allow to assess the benefits we will get from this new constellation and to start the development of data processing algorithms. At the present time, the software is able to produce a simulated Galileo constellation, to compute its local visibility at any place on Earth and to generate simulated pseudo-range (code) measurements.

Neutral atmosphere and Water Vapor

The neutral atmosphere introduces a delay in the propagation of GPS signals that is called Zenith Total Delay or ZTD (for a propagation at the vertical of the observing station). In an atmosphere in hydrostatic equilibrium, this delay depends mainly on surface atmospheric pressure and on the Integrated Water Vapor Content or IWV. The IVW is the key parameter for the correction of the neutral atmosphere effect on GPS. Therefore, we developed several procedures in order compute the IWV from 3 independent types of data: radiosonde (from the Royal Meteorological Institute), Water Vapor Radiometers (WVR) and GPS measurements.

In 2003, we have analyzed the reliability of the IWV measured by the ROB Water Vapor Radiometer (WVR): a WVR calibration campaign was organized at Wettzell (Germany) in 2002 where 5 WVR's have been in parallel operation during about 60 days. We were able to interpret the observed discrepancies between the different radiometers in terms of WVR hardware and software problems that the manufacturer is trying to fix.
We have also started to process a network of more than 60 permanent GPS stations in Belgium (WALCORS and FLEPOS reference networks). Based on the information about water vapor obtained from 3 types of independent measurements, we are studying the best way to handle the tropospheric error taking into account the density of the network where the neutral atmosphere effect on the different stations is highly correlated. At the present time, this study is based on a benchmark of about one week of data.
In addition, we are processing, in real-time, GPS measurements collected in a network of 12 European stations in order to compute the ZTD's for all these stations. From the ZTD's, it is possible to extract information about water vapor (IWV) which is used for meteorological applications, for example, for the assimilation in Numerical Weather Prediction models. This work is done in the frame of European COST Action 716 and will probably be the opportunity to establish a new synergy with the Royal Meteorological Institute.

4.3. Perspective for next years

The activities carried out in 2003 will go on with in particular:
- Development of a simulation software for phase-based applications;
- Development of warnings for GPS users when extreme Space Weather conditions are expected;
- Replacement of the color system (red, orange, green) by the positioning error level;
- Simulation of the different error sources acting on Galileo signals;
- Study of the best way to handle the tropospheric error in a dense network of GPS stations (more than 60 stations in Belgium), including the ambiguity resolution strategy;
- Study of the possible synergies with the RMI, based on GPS computed ZTD's.

4.4. Personnel involved

Scientific: R. Warnant (Chef de travaux, Project Leader), S. Lejeune (Attaché, Ph. D. grant from FRIA/FNRS, 2002-2006), E. Pottiaux (Attaché, Federal Science Policy - Action 1, 2003-2004), G. Kroonen (student ULg 2002-2003, GEOM22), J. Spits (student ULg 2003-2004, GEOM22).
Technical: Eddy Driegelinck (Calculateur principal).

4.5. Partnerships

List of national partners:

- Royal Meteorological Institute of Belgium – Department of Geophysics – Division "Ionospheric sounding" (Dr. J.-C. Jodogne, Dr. H. Nebdi) and Division "Geomagnetic measurements and instruments" (Dr. J. Rasson) ;
- University of Liège, Department of Geometrology and Geomatics (Prof. R. Arnould).

Several international collaborations are carried out in the frame of different COST Actions:

- COST 271: "Effects of the Upper Atmosphere on Terrestrial and Earth-Space Communications";
- COST 716: "Exploitation of Ground-based GPS for climate and numerical weather prediction application";
- COST 724: "Developing the basis for monitoring, modeling and predicting Space Weather".

Grants used for the project:

- Ph. D. grants from FNRS/FRIA (2002-2006) : " Développement d'un logiciel pour la détection, la correction et la prévision des perturbations induites par l'activité ionosphérique sur le positionnement en temps réel utilisant le Global Positioning System".
- ACTION 1 from Federal Science Policy (2003-2004): "Development of software for the (near) real time processing of the data collected in the permanent ROB GPS network in order to participate in new geophysical applications of GPS in the international networks".
- ESA/PRODEX (April 2003- March 2005): "SIDC Space Weather Pilot Project".

Visitors: 1

4.6. Publications

4.6.1. Publications with peer system

Stankov S. M., **Warnant R.**, Jodogne J.-C.
Real-time reconstruction of the vertical electron density distribution from GPS TEC measurements
Acta Geod. Geoph. Hung. , Vol. 38(4), pp. 377-388.

Stankov S. M., Jakowski N., Muhtarov P., Kutiev I., Heise S., **Warnant R.**
A new method for reconstruction of the vertical electron density distribution in the upper ionosphere and plasmasphere
J. of Geophys. Res. - Space Physics, 108, A5, 1164, doi:10.1029/2002JA009570.

4.6.2. Publications without peer system

Stankov S. M., Jakowski N., Wehrenpfennig A., **Warnant R.**
Index of local response to geomagnetic activity for use in the short-term ionospheric forecast
Proceedings of the COST271 2002 workshop (on cd-rom), Faro, Portugal

Warnant R., Stankov S. M., Jodogne J.-C., Nebdi H.
The monitoring of the ionospheric activity using GPS measurements
Proceedings of the COST271 2002 workshop (on cd-rom), Faro, Portugal

Stankov S. M., **Warnant R.**, Jodogne J.-C.
Operational procedure for real-time reconstruction of the electron profile at a single ionosonde location
Proceedings of the COST271 2002 workshop (on cd-rom), Faro, Portugal

Bruyninx C., Defraigne P., Ducarme D., Everaerts M., Pottiaux E., Roosbeek F., **Warnant R.**, Voet P.
Belgian Report to the IAG-subcommission "EUREF"
Proceedings of EUREF 2002 Symposium, June 05-08 2002, Ponta Delgada, Portugal, pp. 228-231.

Pottiaux E., Warnant R.
First experiences with a Water Vapour Radiometer at the Royal Observatory of Belgium
Proceedings of EUREF 2002 Symposium, Ponta Delgada, 5-8 June 2002, pp. 351-354.

Pottiaux E., Warnant R.
Processing a regional network of EUREF stations for ZWD retrieval. Quality assessment using WVR's and radiosondes
Proceedings of EUREF 2002 Symposium, Ponta Delgada, 5-8 June 2002, pp. 91-96.

Warnant R., Grevesse J., **Pottiaux E.**
Processing GPS measurements during periods of high ionospheric activity
Proceedings of EUREF 2002 Symposium, Ponta Delgada, 5-8 June 2002, pp. 365-368.

Witasse O., Blelly P.-L., Lilensten J., Molina-Cuberos G., Lebreton J.-P., **Warnant R.**

A new Mars ionosphere/airglow Model between 60 and 500 km altitude
Proceedings of the Workshop "Mars Atmosphere Modelling and Observations", Granada, Spain, January 13-15 2003, paper 11-7.

4.6.3. Publications in press, submitted

Morel L., Witasse O., Warnant R., Cerisier, Blelly P.-L., Lilensten J.
Diagnostic of the dayside ionosphere of Mars using the Total Electron Content measurement by the NEIGE/Netlander experiment
Planet. Space Science, in press

Jodogne J.-C., Nebdi H., **Warnant R.**
Comparison of the TEC computed using the NeQuick model, the TEC deduced from GPS measurements and the IEC automatically estimated from the Digisonde data.
Adv. in Radio Science, in press

4.6.4. Reports, thesis, etc

Warnant R.
Assessment of the effect of TEC medium-scale gradients on low-precision DPN-GPS applications using a system of colours
Technical Report of Work Package 211, Solar Influences Data Centre Space Weather Pilot Project, ESA contract 16913/03/NL/LvH.

Warnant R., Nebdi H., **Pottiaux E.**
Near real-time validation of GPS-TEC using ionosonde TEC at Dourbes
Technical Report of Work Package 212, Solar Influences Data Centre Space Weather Pilot Project, ESA contract 16913/03/NL/LvH.

Warnant R., Lejeune S., Pottiaux E.
Assessment of the effect of small-scale TEC gradients on DPN-GPS applications using a system of colors
Technical Report of Work Package 221, Solar Influences Data Centre Space Weather Pilot Project, ESA contract 16913/03/NL/LvH.

4.6.5. Communications

Witasse O., Blelly P.-L., Lilensten J., Molina-Cuberos G., Lebreton J.-P., **Warnant R.**
A new Mars ionosphere/airglow Model between 60 and 500 km altitude
Presented at the Workshop "Mars Atmosphere Modelling and Observations", Granada, Spain, January 13-15 2003.

Warnant R., Morel L., Stankov S. M., Jodogne J.-C., Nebdi H., Jakowski N.
The use of DORIS as a tool to study the Earth ionosphere, Invited Paper
Presented at 2003 IDS Analysis Workshop, Marne La Vallée, France, 20-21 February 2003.

Witasse O., Bougher S. W., Cerisier J.-C., **Warnant R.**, Lebreton J.-P., Blelly P.-L., Fontanari J.
Effects of a dust storm on the coupled Mars thermosphere ionosphere
Presented at the EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003.

Pottiaux E., Becker M., Buerki B., Gyger R., Häfele P., Plötz C., Schlueter W., Schwarz W., Somieski A., **Warnant R.**
The Radcalwet observation campaign: relative and absolute calibration of WVR's
Presented at the EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003.

Pottiaux E., Becker M., Buerki B., Gyger R., Häfele P., Plötz C., Schlueter W., Schwarz W., Somieski A., **Warnant R.**

Calibration and quality assessment of water vapor radiometer observations using radiosonde GPS and VLBI.
Presented at the EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003.

Cugnon P., Van der Linden R., Berghmans D., Vanlommel P., Robbrecht E., Clette F., Zhukov A., Wauters L., Warnant R., Bruyninx C., Nebdi H., Jodogne J.-C., Heynderickx D., Stegen K., Kruglanski M., Roth M., Henry J.-P.
The Solar Influences Data Centre : A Partnership for Space Weather
Presented at the ESA Space Weather Workshop: Developing a European Space Weather Service Network, ESTEC, Noordwijk, The Netherlands, 3-5 November 2003.

Jodogne J.-C., Nebdi H., **Warnant R.**
Comparison of the TEC computed using the NeQuick model, the TEC deduced from GPS measurements and the IEC automatically estimated from the Digisonde data
Presented at Special International Reference Ionosphere (IRI) meeting in honor of Prof.Karl Rawer at the Kleinheubacher Tagung 2003 of U.R.S.I. Deutschland, 2 October 2003.

4.7. Missions

Assemblies, symposia, workshops : 9
Commissions, working groups : 5
Field missions : 0

5. Research project 'Earth rotation'

5.1. Objectives

Understand the Earth rotation variations, to model the effect of the geophysical fluids on Earth rotation, to model the Earth precession and nutations, to understand the associated physics of the Earth interior, to understand the budget of angular momentum of the system composed of the solid Earth, the core, the atmosphere, and the ocean in the frame of long term and short term (diurnal and subdiurnal) variations in Earth rotation.

5.2. Progress and results

- Transfer function for atmospheric and oceanic effect on a three-layer Earth + M. Greff-Lefftz (IPGP, F)), paper in preparation.
- Long term atmospheric effect from the Hadley Center model (+Salstein (AER, USA), Bizouard (Obs. Paris), Ferandez (Univ. La Plata, Ag)), paper accepted.
- Ocean effect on Earth rotation and time variable gravity (+Boy (GSFC, USA) and Goosse (UCL)), paper accepted.
- Routine production of Atmospheric Angular momentum forecast for the geodetic community (+ D. Lucas (ECMWF)).
- Effect of CO_2 increase on the geodetic parameters, from the CMIP project models (+ Boy), paper in preparation.
- Torque approach on diurnal time scale: meteorological consequences (+ Marcus (JPL) and Dickey (JPL), paper in press
- Equatorial atmospheric torque associated with the ENSO cycle (+ Marcus and Dickey), paper in preparation
- Geophysical excitation of geocenter motion (+Dickey, Quinn(JPL), and Marcus), paper in preparation.
- Long term global oscillation in the Earth-atmosphere-ocean system (+ Dickey and Marcus), paper in preparation.

- High frequency atmospheric excitation of the Earth rotation.
- Development of a numerical method of computation of the nutation transfer function (+ Deleersnijder (UCL)).
- Comparison of the different atmospheric angular momentum series and characterization of annual and interannual variabilities (+Koot (UCL)).
- Oscillation related to ENSO oscillation in the atmosphere-ocean system (+ Dickey and Marcus), paper published, press-release in press.
- Geophysical study of the nutation residuals (+ Feissel (IGN, F) and Ma (GSFC, USA)).
- A book on nutation is in preparation (+P.M. Mathews, Univ. Madras, India)

5.3. Perspective for next years

- Geophysical study of the nutation residuals
- Characterization of the atmospheric angular momentum from different model and combination to produce a "better" series
- In collaboration with J. Dickey and S.L. Marcus, study of the interaction between large-scale climate oscillation and the Earth rotation.
- In collaboration with D.A. Salstein and C. Bizouard, test of the validity of Earth rotation prediction using the ECMWF atmospheric angular momentum prediction
- In collaboration with E. Deleersnijder, effect of the CMB topography on the Nutation transfer function.

5.4. Personnel involved

Scientific: O. de Viron (Project Leader, FNRS Chargé de Recherche, Action 2), V. Dehant (Chef de Section), T. Van Hoolst (Chef de travaux), F. Renaud (Chercheur supplémentaire).

5.5. Partnerships

International collaboration:

- Observatoire de Paris (Capitaine, Bizouard, Lambert, Feissel),
- Atmospheric and Environmental Research, Inc. (Salstein)
- Goddard Space Flight Center (Chao, Boy, Kuang, Ma)
- JPL (Dickey, Marcus, Fukumori)
- IPGP (Greff-Lefftz)
- ECMWF (Lucas)
- University of Madras (Mathews)
- Ecole et Observatoire des Sciences de la Terre, Strasbourg (Boy, Legros).

National collaboration:

- Université Catholique de Louvain (E. Deleersnijder, H. Goosse)
- Vlaamse Universiteit te Brussel (P .Huybrecks)

Grants used for this research

- Action 2 (O. de Viron, 2004/01/01 – 2007/12/31)

Visitors: 5

5.6. Publications

5.6.1. Publications with peer system

de Viron O., Dehant V.,

Test on the validity of the Atmospheric Torques on Earth computed from model outputs
J. Geophys. Res., 108(B2), 10.1029/2001JB001196.

Dehant V., Feissel-Vernier M., **de Viron O**., Ma C., **Yseboodt M**., Bizouard C.
Remaining error sources in the nutation at the sub-milliarcsecond level
J. Geophys. Res (Solid Earth), 108(B5), 10.1029/2002JB001763.

Dickey J.O., Marcus S.L., **de Viron O.**
Coherent interannual and decadal variations in the atmosphere-ocean system
Geophys. Res. Letters, 10.1029/2002GL016763, June 2003.

5.6.2. Publications without peer system

Chao B.F., **Dehant V**., Gross R.S., Plag H.P., Ray R.D., Salstein D.A., van Dam T., Van Hoolst T., Watkins M., Wilson C.R.
The Global Geophysical Fluids Center (GGFC) of the International Earth Rotation Service.
in: Proc. IERS Workshop, Munich, Germany, November 2002, IERS Technical Notes, 30, Eds. B. Richter, W. Schwegmann, and W. Dick, pp. 115-120.

de Viron O., Dehant V.
Reliability of atmospheric torque for geodesy
In: Proc. IERS Workshop, Munich, Germany, November 2002, IERS Technical Notes, 30, Eds. B. Richter, W. Schwegmann, and W. Dick, pp. 125-126

Van Hoolst T., Dehant V., Kuang W.
Special Bureau for the Core
in: Proc. IERS Workshop, Munich, Germany, November 2002, IERS Technical Notes, 30, Eds. B. Richter, W. Schwegmann, and W. Dick, pp. 168-179

Ponsar S., Dehant V., Van Hoolst T.
Electromagnetic core-mantle coupling.
In: Proc. IERS Workshop, Munich, Germany, November 2002, IERS Technical Notes, 30, Eds. B. Richter, W. Schwegmann, and W. Dick, pp. 216-219.

5.6.3. Publications in press, submitted

Marcus S.L., **de Viron O**., Dickey J.O.
Atmospheric Contributions to Earth Nutation: Geodetic Constraints and Limitations of the Torque Approach
J. Atmos. Sci., in press.

de Viron O., Salstein D. A., Bizouard C., Fernandez L.
Low frequency excitation of length-of-day and polar motion by the atmosphere
J. Geophys. Res. (Solid Earth), accepted.

de Viron O., Boy J.-P., Goosse H.,
Geodetics effects of the Ocean response to atmospheric forcing in an Ocean General Circulation Model
J. Geophys. Res. (Solid Earth), accepted.

Van Hoolst T.
De evolutie van de kern van de aarde.
Karakter, in press

5.6.4. Reports, thesis, etc

5.6.5. Meeting presentations:

de Viron O., Dehant V.
Atmospheric and oceanic torque on the solid Earth with the IB approximation
AGU-EGU meeting, poster, Nice, France, 6-11 April 2003

Van Hoolst T., Dehant V,
The Special Bureau for the Core of the IERS
EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003.

Dehant V., de Viron O., Feissel-Vernier M., Ma C., **Rivoldini A., Renaud F.**
Free and forced nutation analysis
AGU-EGU meeting, poster, Nice, France, 6-11 April 2003

Renaud F., de Viron O.
Effects of atmosphere tides on Earth's rotation in semi-diurnal frequency band
AGU-EGU meeting, poster, Nice, France, 6-11 April 2003

Dickey J.O., **de Viron O.**
Geodesy and Global Fluid Modeling
AGU-EGU meeting, oral, Nice, France, 6-11 April 2003

de Viron O., Boy J.-P., Goosse H.
Nontidal Ocean Effect on Geodetic Parameters Using the CLIO model
IAG/IAPSO Joint Working Group on Geodetic Effects of Nontidal Oceanic Processes meeting, oral, Nice, France, 10 April 2003

Marcus S.L., Dickey J.O., **de Viron O**.
Earth's variable oblateness: Implications of space geodesy for glacial mass balance
AGU-EGU meeting, oral Nice, France, 6-11 April 2003

Dehant V., de Viron O., Feissel-Vernier M., Ma C., **Rivoldini A., Renaud F**.
Informations on the Earth system from nutations
Session G05 Geodynamics, oral, IUGG General Assembly, Sapporo, Japan, 30 June-11 July 2003

de Viron O., Dickey J.O., **Dehant V.**
Fluid Effects on Earth Rotation: What is Next?
AGU Fall meeting 2003, poster, 8-12 December 2003

Quinn K.J., Dickey J.O., **de Viron O**., Marcus S.L., Fukimori I.
Geocenter Variability and its Excitation: Insight From Geodetic and Global Geophysical Fluid Model Comparisons
AGU Fall meeting, oral, 8-12 December 2003

Dickey J.O., **de Viron O.,** Marcus S.L.
Variability in the Atmosphere-Ocean System and Global Change: Insights via Sea Surface Temperature Analysis
AGU Fall meeting, oral, 8-12 December 2003

Marcus S.L., **de Viron O.**, Dickey J.O.
Interannual Atmospheric Torque and ENSO: Where is the Polar Motion Signal?
AGU Fall meeting, oral, 8-12 December 2003.

5.6.6. Outreach and Website

Production of didactic animation about Earth rotation

- The non-rotating origin, in collaboration with N. Capitaine, S. Lambert, VD.
- Nutations of the Earth and VLBI (+J. Van Marcke).

Maintenance and up-date of the website of the special bureau for the core

5.7. Missions

- 8 missions: Assemblies, symposia, workshops
- 7 missions: Join research

6. Research project 'Geodesy and geophysics of other planets'

6.1. Objectives

A major effort of Section 1 in 2003 has to been to prepare the NEIGE project of the NetLander mission (end of phase B), Unfortunately, after a financial crisis at the French space agency CNES, and severe budget problems for the ESA science missions, the NetLander mission is currently without funding. The specific NEIGE-related studies performed at the ROB are however of sufficient generality to be of use for other missions. The NEIGE project essentially is a radio-science experiment in which the measurements of Doppler shifts of radio links between up to four landers and an orbiter, and between the orbiter and the Earth are used to derive the rotation variations and gravity field of Mars. The rotation variations can be decomposed into precession, nutation, polar motion, and length-of-day variations. These variations give indications about the interior structure of the Mars, such as about the physical state of the core (liquid or solid), and the size and density of the core, and about the seasonal condensation/sublimation cycle of the atmosphere and polar caps.
We also started the preparation of the MaRS experiment within ESA's Mars Express mission to Mars (data collecting starting in January 2004), and the preparation of the Radio-Science experiment on the BepiColombo mission to Mercury (beginning Phase A).

6.2. Progress and results

6.2.1. Simulations

Analytical and numerical simulations have been performed to evaluate the precision that can be obtained by the NEIGE experiment on the orientation parameters of Mars (precession, nutation, polar motion, and length-of-day variations) and on geophysical parameters related to Mars' interior, atmosphere and ice caps dynamics. The simulations show that a high precision of some milliarcseconds can be obtained for the orientation parameters and that important information on the interior and atmosphere can be derived.
Some technical effects that were not considered in the basic simulations and that could possibly deteriorate the solutions have also been studied. In particular, it has been shown that the same precision can still be obtained when satellite wheel desaturations and large errors on the landing positions of the landers are considered.

6.2.2. Internal structure

A tidal catalogue has been calculated for Mars, with particular emphasis on the Phobos-induced tides, and it is shown that tidally induced gravity variations on Mars can be measured with sufficient precision by seismometers to allow a better characterization of the Martian core.
A synergetic probabilistic approach using data from a geodesy experiment, a seismic experiment, and electromagnetic sounding to derive the interior of Mars has been further developed. In particular, the parameterization of the Martian mantle has been improved, with the inclusion of a hypothetic region of partial melt and of the effect of iron on the electrical conductivity of the minerals. The model has also been extended to include the core.

The question whether a possible solid inner core of Mars can be detected from observations of polar motion and nutation of Mars has been studied. Both analytically and numerically, the resonance effects of the rotational normal modes associated with an inner core (the inner core wobble and the free inner core nutation) have been studied. Also, the effect of an inner core on two other rotational normal modes, the free core nutation and the Chandler wobble, has been calculated. It is shown that an inner core could be detected from a radio-science experiment, if the inner core is very large, or if one of the inner core rotational normal modes has a frequency that almost coincides with a seasonal nutation or polar motion frequency.

6.2.3. Crust

A new method that uses spherical wavelets is developed for estimating the local lithospheric thickness from topography and gravity data of Mars. The lithospheric thickness estimates are on the whole in agreement with the estimates of other methods.
The gravity inversion program LOSGRA (J.-P. Barriot) has been installed at the Royal Observatory of Belgium in view of the analysis of Mars Express data in 2004.

6.2.4. Atmosphere/polar caps

Angular momentum transfer between the surface and the atmosphere of Mars, and the level of excitation of polar motion and rotational normal modes by the atmosphere, have been calculated from data from a global circulation model (GCM) of the Martian atmosphere.
Length-of-day variations and seasonal variations in the zonal Martian gravity field due to atmosphere dynamics and mass exchange with the polar caps have been estimated from a GCM, and have been used as input for a numerical simulation to retrieve these quantities from a network geodesy experiment. The simulations have shown that a NEIGE-like experiment can decorrelate length-of-day variations and the degree 2 zonal gravity coefficient. We furthermore showed that with a suitable combination of space geodesy techniques, the normally correlated low order zonal gravity coefficients could all be estimated precisely.

6.2.5. Other planets/satellites

A tidal catalogue for Mercury has been calculated. Further, a large set of Mercury models with different cores has been constructed and the sensitivity of the tides to interior structure parameters has been calculated. It is shown that tides, and in particular the Love number k, can strongly constrain the interior of Mercury. The tidal dissipation in Mercury has been calculated and shown to be small. Its influence on the evolution of Mercury and its magnetic field is only marginal.
A simulation of a radio experiment for Mercury has been initiated.
A model for the evolution of terrestrial planets has been developed.
The transfer function for the libration of Jupiter's moon Europa has been calculated.

6.3. Perspective for next years

The data of the Mars Express radio science experiment MaRS arrive on Earth form 2004 on. The goals are to determine constraints on the condensation/sublimation cycle, the deep interior structure, and surface characteristics of selected regions. Theoretical and simulation studies to constrain the interior structure of terrestrial planets by rotational, tidal, and gravitational data will be continued. Maps will be established of the local lithospheric thickness of Mars. The synergic approach to probe Mars' interior by joint geodetic, seismic and electromagnetic means will also be further pursued, for example for proper inclusion of the core of Mars. In view of the upcoming Mercury missions, the libration of Mercury will be modeled in more detail. Further attention will be devoted the seasonal condensation/sublimation cycle of the Martian atmosphere and polar ice caps, and to variations on long time scales related to, e.g., obliquity variations.

6.4. Personnel involved

T. Van Hoolst (werkleider, co-I NEIGE, Project Leader), V. Dehant (Chef de section, co-PI NEIGE, co-I SEIS, co-I MaRS), P. Defraigne (Chef de travaux, co-I NEIGE, co-I SEIS), O. de Viron (Action 1), M. Beuthe (PRODEX), J. Duron (Action 2), Ö. Karatekin (PRODEX), A. Rivoldini (Action 2), P. Rosenblatt (PRODEX), O. Verhoeven (PRODEX, until 1/9/03), M. Yseboodt (PRODEX)
Technical and administrative personnel: S. Raynal (PRODEX, half-time), S. Willems (PRODEX, until 1/8/03), L. Van Camp (rekenaar)

6.5. Partnerships

- WG MINT aiming to derive the Mars interior properties from the NEIGE, SEIS, and MagNet data,
- WG on 'International Scientific and Technical Netlander',
- WG on 'Netlander Landing sites',

Collaborations with:

- Observatoire Midi Pyrénées (Barriot (PI NEIGE), Vienne, Marty, Balmino),
- University of Cologne (Paetzold, PI MaRS),
- University of Nantes (Mocquet, Vacher, Sotin, Choblet),
- CETP (Menvielle),
- IPGP (Lognonné, PI SEIS)

Grants used for this research:

- PRODEX6 (875000 euro for 2002-2004) and PRODEX7 (170200 euro for 2003-2004)
- Action 2 (Julien Duron 10/2003-9/2007, Attilio Rivoldini 10/2002/-9/2006)
- MAGE (Mars Geophysical European Network), 8/02-8/05
- Tournesol project: "Synergie pour la modélisation de l'interieur des planètes telluriques, basée sur des données séismiques, géodésiques et des sondages électromagnétiques"

Visitors: 8

6.6. Publications

6.6.1. Publications with peer review system

Van Hoolst T., Dehant V., Roosbeek F., Lognonné P.
Tidally induced surface displacements, external potential variations, and gravity variations on Mars
Icarus, 161, 281-296, DOI: 10.1016/S0019-1035(2)00045-2.

Yseboodt M., Barriot J.-P., **Dehant V**.
Analytical modeling of the Doppler tracking between a lander and a Mars orbiter in term of rotational dynamics
J. Geophys. Res. 108(E7), 5076, DOI: 10.1029/2003JE002045.

Dehant V., Van Hoolst T., de Viron O., Greff-Lefftz M., Legros H., **Defraigne P.**
Can a solid inner core of Mars be detected from observations of polar motion and nutation of Mars?
J. Geophys. Res. (Planets), DOI: 10.1029/2003JE002140.

Defraigne P., Rivoldini A., Van Hoolst T., Dehant V.
Mars nutation resonance due to Free Inner Core Nutation
J. Geophys. Res. (Planets), DOI: 10.1029/2003JE002145.

Duron J., Rosenblatt P., Yseboodt M., Karatekin Ö., Dehant V., Van Hoolst T., Barriot J.-P.
Joint estimation of Martian C_{20} and rotation variations from simultaneous geodetic measurements: Numerical simulations of a Network Science Experiment

Geophys. Res. Letters 30(18), 1971, DOI: 10.1029/2003JL082003.

Van Hoolst, T., C. Jacobs
Mercury's tides and interior structure
J. Geophys. Res., 108, 5121, DOI: 10.1029/2003JE002126.

6.6.2. Publications without peer review system

Dehant, V., Barriot, J.-P., **Van Hoolst, T., Defraigne, P., Roosbeek, F., Yseboodt, M.**
Netlander Ionosphere and Geodesy Experiment (NEIGE). Comparison between the nutations of the planet Mars and the nutations of the Earth
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 107-113

Rivoldini, A., Defraigne, P., Dehant, V., Van Hoolst, T.
Free and forced response of a non-rigid Mars with an inner core. II. Numerical Approach.
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 114-119

Van Hoolst, T., Dehant, V.
Tides of the planets Mars and Mercury
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 131-134

de Viron, O., Van den Acker, E., Van Hoolst, T., Defraigne, P., Dehant, V.
Comparison between the atmospheric forcing on Earth and Mars
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 126-130

Yseboodt M., J.P. Barriot, **V. Dehant**,
A simplified analytical formulation of the NEIGE orbiter/lander geodesy observable
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 157-158

Dehant, V., Greff-Leftz, M., Legros, H., Van **Hoolst, T., Defraigne, P., de Viron, O.**
Free and forced response of a non-rigid Mars with an inner core. I. Analytical Approach
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 159-160.

Greff-Lefftz, M., **Dehant, V**., Lognonn\'e, Ph., **Van Hoolst, T.**, Legros, H.
LYCODY: the dynamics of the fluid core from gravity signals
Proc. Journées Systèmes de Référence Spatio-temporels 2001, Brussels, Belgium, ed. N. Capitaine, 214-218.

Dehant V.
A liquid core for Mars?
Science, 300, perspective, 260.

Van Hoolst, T.
Ontstaan, evolutie, en structuur van Mercurius
Heelal 48(3), 66-69

Duron J., Rosenblatt P., Karatekin Ö., Yseboodt M., Dehant V., J., Barriot J.P., Vienne J.,
Simultaneous estimate of the Martian rotation and the C_{20} gravity coefficient variations in the frame of a network science experiment

Proceedings of the "Société Française d'Astronomie et d'Astrophysique (SF2A)", Scientific highlights 2003 (Bordeaux, France, June 16-20, 2003), Eds: F. Combes, D. Barret, T. Contini and L.Pagani, p. 59-62

6.6.3. Publications in press, submitted

Rosenblatt P., Marty J.C., Perosanz F., Barriot J.P., **Van Hoolst T., Dehant V**.
Numerical simulations of a Mars Geodesy Network Experiment: Effect of orbiter angular momentum desaturation on Mars' rotation estimation
Planet. Space Sc., accepted

Dehant, V., Lognonné, Ph., Sotin, C.
Network Science on Mars
Planet. Space Sc., accepted

Vienne J., Barriot J.P., **Rosenblatt P., Yseboodt M., Duron J., Dehant V**.
Numerical simulations of the NEtlander Ionosphere and Geodesy Experiment (NEIGE): landing site position determination from Doppler tracking between an orbiter and landers
In: Proc. International Workshop on Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Lisbon, Portugal, 2003, in press.

Karatekin Ö., Dehant V., Charbonnier J.-M.
Dynamic Stability of Atmospheric Entry Probes
In: Proc. International Workshop on Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Lisbon, Portugal, 2003, in press.

Pletser V., Lognonné Ph., Diament M., **Dehant V**., Quinn K., Zubrin R., Lee P.
Feasibility of an active seismology method to detect subsurface water on Mars by a human crew: Summer 2001 flashline M.A.R.S. campaign first results and lessons learned
Acta Astonautica, submitted

Van Hoolst, T.,
De evolutie van de kern van de aarde
Karakter, in press

6.6.4. Reports, thesis, etc

Yseboodt M.
Détermination des paramètres de rotation de Mars à partir de mesures de poursuite Doppler: Théorie et simulations
PhD thesis, UCL, December 2003, Promoter: V. Dehant,.

Blavier D.
Etude des modes propres de rotation d'une planète à 3 couches: Application à la rotation d'Europe
UCL, June 2003, Advisor: V. Dehant, co-advisor: O. de Viron.

de le Court A.
Modélisation du noyau martien par inversion stochastique des données MagNet, NEIGE et SEIS de la mission NetLander
UCL, June 2003, Advisor: V. Dehant, co-advisor: O. Verhoeven.

Eelen, Y.
Constructie van evolutiemodellen voor terrestrische planeten
K.U.Leuven, June 2003, Promoter: T. Van Hoolst.

Ceulemans, K.
Dissipatie van getijdenenergie voor Mercurius

K.U.Leuven, September 2003, Promoter: T. Van Hoolst.

Witasse, O.
Sensitivity of the electron content to the extreme ultraviolet solar flux and to the neutral atmosphere
NEIGE report n°22, May 2003

Yseboodt M.
Détermination des paramètres de rotation de Mars à partir de mesures de poursuite Doppler: Théorie et simulations
NEIGE report n°23 , October 2003

Karatekin, Ö.
Estimation of rotation parameters of Mars
NEIGE report n°24, October 2003

Karatekin, Ö.
Martian Global scale mass distribution
NEIGE report n°25, October 2003.

Beuthe M.
Localization of the Martian gravitational field with wavelets
NEIGE report n°26: October 2003.

Rivoldini A., Verhoeven O.
Modeling of the Martian Core
NEIGE report n°27, October 2003

Poster collection 2002-2003
NEIGE report n°28, December 2003

Report 2000-2003 NEIGE for PRODEX

MAGE report of activity

6.6.5. Communications

Dehant V.
NEtlander Ionosphere and Geodesy Experiment to Mars
Invited talk, Institute for Applied Mathematics, Madras, India.

Karatekin Ö., Duron, J., Rosenblatt P., de Viron O., Dehant V.
Evaluation of geodetic measurements in the determination of Martian global scale seasonal CO2 cycle
Workshop "Mars Atmosphere Modelling and Observations", Granada, Spain, 13-15 January 2003

Van Hoolst T.
Mars' core from nutations and tides
Invited talk, RAS Planetary Geophysics meeting, London, 13-14 February 2003

Dehant V.
Nutations of the Earth and Mars
Invited talk for the Vening-Meinesz medal, EGS-AGU-EUG joint assembly, Nice, France, 6-11 April 2003

Duron J., Rosenblatt P., Yseboodt M., Lemoine J.-M., Vienne J., **Dehant V**., Barriot J.-P., **Van Hoolst T.**
Simultaneous estimation of the Martian rotation parameters and J_2 seasonal variations in the frame of the NEIGE experiment

EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003

Rivoldini A., Verhoeven O., Vacher P., **Dehant V**., Menvielle M., Mocquet A., Choblet G., **Beuthe M**., Barriot, J.P., **Defraigne, P., de Viron, O**., Lognonné, Ph., **Van Hoolst, T**

A joint inversion method of electromagnetic, geodetic and seismological data for the study of planetary interiors

EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003

Karatekin Ö., de Viron O., **Dehant V**.

Atmospheric angular momentum budget of Mars

EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003

Vienne J., Barriot J.-P., **Dehant V., Yseboodt M., Duron J., Rosenblatt P., Van Hoolst T.**

The NEtlander Ionosphere and Geodesy Experiment (NEIGE): Numerical simulations of Mars orientation determination

EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003.

Dehant V., Karatekin Ö., de Viron O., Van Hoolst T.

Rotational normal modes of Mars, their resonances, and their amplitudes

EGS-AGU-EUG Joint Assembly, poster, Nice, France, 6-11 April 2003

Rosenblatt P., Vienne J., **Duron J**., Barriot J.-P., **Dehant V**., Marty J.-C., Perosanz F., **Yseboodt M., Willems S., Van Hoolst T**.

Numerical simulations of the NEIGE experiment: Effect of angular momentum desaturation and landing sites positions determination on Mars' rotation estimates

EGS-AGU-EUG Joint Assembly, poster, Nice, France, 6-11 April 2003

Yseboodt M., Barriot J.-P., **Dehant V., Rosenblatt P., Duron J., Van Hoolst T**.

Analytical modelling of a Martian lander-Earth radio-link and effect of the Martian rotation parameters

EGS-AGU-EUG Joint Assembly, poster, Nice, France, 6-11 April 2003

Karatekin Ö., Duron J., Rosenblatt P., **Dehant V**.

Estimation of Martian seasonal CO_2 mass exchange from geodetic measurements

EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003

Van Hoolst, T., Jacobs, C.

Sensitivity of the tides of Mercury to its interior structure

EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003

Verhoeven O., Rivoldini, A., Vacher P., **Dehant V**., Menvielle M., Mocquet A., Choblet G., **Beuthe M**., Barriot, J.P., **Defraigne, P., de Viron, O**., Lognonné, Ph., **Van Hoolst, T**.

A joint inversion method of electromagnetic, geodetic and seismological data for the study of planetary interiors

Mars summer school, Atelier `La planète Mars', Les Houches, France, 28 April-9 May 2003

Rosenblatt P., Vienne J., Barriot J.-P., **Dehant V**., Marty J.-C., Perozanz F., **Yseboodt M., Willems S., Van Hoolst T**.

Numerical simulation of the NEIGE experiment

Mars summer school, Atelier `La planète Mars', Les Houches, France, 28 April-9 May 2003

Dehant V., Lognonné P., Sotin C.

Network science

Mars summer school, Atelier `La planète Mars', Les Houches, France, 28 April-9 May 2003

Duron J., Rosenblatt P., Karatekin Ö., Yseboodt M., Dehant V., J., Barriot J.P., Vienne J.,

Simultaneous estimate of the Martian rotation and the C_{20} gravity coefficient variations in the frame of a network science experiment
Presented at the "Société Française d'Astronomie et d'Astrophysique (SF2A)", Bordeaux, France, June 16-20, 2003

Verhoeven O., Rivoldini, A.,Vacher P., **Dehant V**., Menvielle M., Mocquet A., Choblet G., **Van Hoolst, T**.
A joint inversion method of electromagnetic, geodetic and seismological data for the study of planetary interiors
The Next Steps in Exploring Deep Space, ESTEC, Noordwijk, The Netherlands, 22-23 September 2003

Karatekin Ö., Dehant V., de **Viron O**.
Martian global-scale seasonal CO_2 change: comparison of geodetic observations and numerical simulations
Sixth International Conference on Mars, Pasadena, California, US, 20-25 July 2003.

Dehant V.
Missions vers Mars
Invited talk for amateur astronomers, Brussels, 18 September 2003

Dehant V. and the NetLander team
Network science on Mars for the future mission to Mars
The Next Steps in Exploring Deep Space, ESTEC, 22-23 September 2003

Vienne J., Barriot J.P., **Rosenblatt P., Yseboodt M., Duron J**., **Dehant V**.
Numerical simulations of the NEtlander Ionosphere and Geodesy Experiment (NEIGE): Landing site positions determination from Doppler tracking between an orbiter and landers
International Workshop on Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Lisbon, October 6-9, 2003

Karatekin Ö., Charbonnier J.-M., Wang F., **Dehant V**.
Dynamic Stability of Atmospheric Entry Probes
International Workshop on Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Lisbon, Portugal, October 6-9, 2003.

Rosenblatt, P.
Venus
Cercle Astronomique de Bruxelles, 16/10/2003

Rivoldini, A., Renaud, F.
Le signal du marégraphe de Brest vu par ondelettes
Colloque d'ouverture du GDR G2, Paris, France, 12-14 November 2003

Barriot J.-P., **Dehant V**., **Duron J**.
Monitoring Mars LOD Variations from a Circular Equatorial Orbit: Theory and Simulation
AGU Fall meeting 2003, 8-12 December 2003

Defraigne P., Rivoldini A., Van Hoolst T., Dehant V.
Mars nutation resonance due to Free Inner Core Nutation
AGU Fall meeting 2003, San Francisco, USA, 8-12 December 2003

Dehant V., Karatekin Ö., de Viron O., Van Hoolst T.
Mars Polar motion excitation
AGU Fall meeting 2003, San Francisco, USA, 8-12 December 2003

Duron J., Karatekin Ö., Rosenblatt P., Dehant V., Barriot J.P.

Simulation of the effect of higher order zonal gravity field coefficients of Mars on the jointly-estimated time-varying J2, J3 and rotation
AGU Fall meeting 2003, 8-12 December 2003

Yseboodt M., Barriot J.-M., **Dehant V**., **Rosenblatt P**.
Mars Rotational Parameters from Lander-Orbiter and Lander-Earth Radio-Links
AGU Fall meeting 2003, 8-12 December 2003

Van Hoolst, T.
Mercury's tides and core
AGU fall meeting, San Francisco, USA, 8-12 December 2003

Rivoldini A., Verhoeven O., Vacher P., **Dehant V**., Menvielle M., Mocquet A., Choblet G., **de Le Court, A., Van Hoolst, T**.
A joint inversion method of electromagnetic, geodetic and seismological data for the study of planetary interiors
AGU Fall meeting 2003, San Francisco, USA, 8-12 December 2003

Rosenblatt, P.
Mars
Cercle Astronomique de Bruxelles, 15/12/2003

6.6.6. Website and outreach

Press conference for the Mars Express mission, Planetarium, Brussels, December 19 (with press map on the mission). We have performed 3-dimensional movies of the space experiments. These films are all in high resolution and low resolution (.avi or .mpg) (work of JvM)

1. NEIGE_landing.avi: landing of the airbags on the Martian surface.
2. NEIGE_liaison_LO.avi: signal of the radio links between the lander and the orbiter and the orbiter and the Earth.
3. NEIGE_liaison_LO-OT.avi: Earth orientation in space, orbiter orientation with respect to the Earth, radio link between the Earth and the orbiter and between the orbiter and the landers.
4. NEIGE_ liaison_LO-OT_all.avi: Earth orientation in space, orbiter orientation with respect to the Earth, radio link between the Earth and the orbiter and between the orbiter and the landers, signal of the radio links between the lander and the orbiter and the orbiter and the Earth.
5. NEIGE_Doppler.avi: Doppler effect on the radio signal.
6. Lod_Mars.avi: variations of the length-of-day (LOD) of Mars due to CO_2 condensation/sublimation process in the ice caps and atmosphere respectively.
7. Nutation_Mars.avi: nutation of Mars in space.
8. Pm_Mars.avi: polar motion of Mars.
9. NEIGE_lod_pm_nut.avi: variations of the length-of-day (LOD) of Mars due to CO_2 condensation/sublimation process in the ice caps and atmosphere respectively; nutation in space; polar motion.
10. NEIGE_gr_liq.avi: nutations of Mars for a planet with a liquid core and a solid core.
11. NEIGE_oeufs_gr_liq.avi: comparison with the row and cocked eggs; nutations of Mars for a planet with a liquid core and a solid core.
12. NEIGE_iono.avi: effect of the ionosphere on the radio signal.
13. NEIGE.avi: the whole set of films.
14. Mars_express.avi: effect of the gravitational attraction of the masses inside Mars and of the ice caps on the orbit of the orbiter.

6.7. Missions

Research missions (assemblies, symposia, workshops, etc): 28
Operational meetings (commissions, working groups): 30
Field missions (observations, station maintenance, etc): 2

DEPARTMENT 1: Reference Systems and Geodynamics

SECTION 2: Seismology

In 2003 the section seismology conducted most of the typical missions assigned to a Federal Scientific Institute, namely scientific research, scientific expertise, valorization of the external service and the patrimony conservation. All those activities are mainly based on the study of the seismic activity and the present-day crustal deformations in our regions but also in other intraplate areas in the world. These investigations are essential to understand the tectonic deformations and their relationship with seismic activity in continental regions but also to evaluate the economical and environmental consequences of future strong earthquakes.
This report is presented in three different parts. The first one concerns the scientific research projects conducted by the section. The second part presents the operational projects providing the basic information for our scientific research and expertise. The third part reports on the operational projects concerning the international data exchange as well as the information service to the authorities, the public and the media.

SCIENTIFIC RESEARCH PROJECTS

7. Research project « Paleoseismology »

7.1. Objectives

The research project Paleoseismology is an ongoing research project of the section Seismology, which started in 1995. The aim of this project is to identify seismogenic structures in Belgium and neighboring areas, and to search for evidence of paleoearthquakes in the geologic record. This will extend our knowledge of the seismic cycle of slowly slipping faults in the intracontinental context of our region, and ultimately lead to a better assessment of seismic hazard. Since 2000, we have been conducting similar investigations in the Upper Thrace depression (Bulgaria) where two large earthquakes with magnitude 6.8 and 7.0, respectively, occurred in 1928.

7.2. Progress and results

In 2003 paleoseismologic research at the Royal Observatory of Belgium was concentrated on three different regions: the Roer Valley graben (RVG) and surroundings, Bulgaria, and the region between the RVG and the North Sea. Moreover, we are also co-operating with the KUL in archeo-seismological project in SW Turkey.

7.2.1. Paleoseismic research in the Roer Valley graben

Since 1995, the Roer Valley graben is the area where most efforts are directed. We have followed several lines of research, mostly framing within the EC-project SAFE “Slow Active Faults in Europe”:
a) The analysis of the trench excavated in Rotem in 2002 has been completed, and the preliminary results were presented at international and project meetings. In this trench, we observed fault displacement of 75-100 cm of the Weichselian Maas terrace and overlying Late Weichselian eolian sand and loess deposits. Two discoveries – a historic stone pavement just in front of the scarp, buried below colluvium and deformed by liquefaction, and a large gravel dike close to the fault in the footwall – represent the strongest arguments found so far in favour of the co-seismic nature of faulting in the RVG. Radiocarbon dating and pottery fragments suggest that this event may have occurred only about 1000 years ago. Papers describing these important new results are now being prepared.

b) A second project involved the excavation in 2003 of a trench across the Rauw fault at the western limit of the RVG in the Belgian Campine region. This study was framing in a long-term safety analysis for the storage of radioactive waste, supported by NIRAS-ONDRAF. The trench disproved recent activity of this fault, however. The upper sediment layers (Late Pleistocene coversands) were intensely deformed by cryoturbation, but did not show any displacement, while in the underlying Plio-Pleistocene Mol sands only indirect evidence for faulting was found. Further dating should better constrain the age of the oldest undeformed sediments.
c) A new geomorphologic study was started in the epicentral area of the 1692 Verviers earthquake, the largest known historical earthquake on Belgian territory. So far, the causative fault remains unidentified. In cooperation with A. Demoulin (University of Liège), we studied a scarp displacing an erosional surface of Tertiary age using a newly constructed DEM, aerial photographs, mapping of terraces of the Vesdre river, and geophysical site investigations. The data suggest that the older terraces may show a displacement at this scarp. Additional site surveys should further corroborate these findings.

Figure 1. *Faulting evidence (vertical displacement of ~ 0.7 m) at the Rotem2 trench site. The gravels correspond to a late depositional phase (~ 20 ky BP) of the MaasMechelen terrace of the Maas river.*

d) We also cooperated with the Royal Museum for Central Africa (Dr. Philippe Trefois) in the project «Mapping of active faults and related changes in soil and vegetation with hyperspectral and thermal imagery. Roer Graben (Belgium) » in the framework of the CASI-ATM 2003 flight campaign organised by the PPS Science Policy. The collected data will be studied in 2004.
e) In a side project, we conducted a 2-D resistivity survey at Hillensberg, Germany, where we found evidence for the presence of an important fault not exposed in the trench excavated earlier by the Geologische Dienst Nordrhein-Westfalen.

7.2.2. Paleoseismic research in Southern Bulgaria

Since 2000 the Royal Observatory of Belgium is cooperating with the Bulgarian Academy of Sciences in the framework of a bilateral project on the faults in Southern Bulgaria that ruptured during the strong 1928 earthquakes. In 2003 this effort has been continued in the new project "Failles actives et grands tremblements de terre du passé dans la dépression de Thrace" (contract BL/33/B09). During this year, substantial scientific progress has been achieved. The analysis of the trench excavated the year before across the Chirpan fault in Cherna Gora has been completed. We found evidence of at least 4 paleoearthquakes, including the 1928 event, since the Late Glacial to Holocene transition (± 10,000 years BP). Abstracts of the first results have now been submitted for presentation at several international meetings in 2004. As a preparation for a new survey, a geomorphological analysis of Chirpan fault was undertaken from a digital elevation model (DEM) and aerial photographs. In autumn, finally, we conducted an integrated geomorphologic and geophysical survey; we acquired several resistivity profiles across the Chirpan fault and Popovitsa fault, a detailed DEM of the area where Chirpan fault intersects the Omourovo River, and a better characterization of the alluvial deposits and associated paleosoils through boreholes and exposures. The new data shed light on fault geometry and the interaction between fluvial and tectonic activity, and also helped us decide the location of two sites that will be trenched next year.

7.2.3. Paleoseismic research in the area between the RVG and the North Sea

Even though this region has experienced some relatively important earthquakes in historical times (1382, 1449, 1580, 1692, 1828, 1938,…) no active faulting research has been carried out so far. Several neotectonic studies exist, but the information therein has not yet been systematically analyzed in terms of seismic hazard. In a first step, therefore, we are evaluating the relevance of the available literature to a paleoseismologic study, in order to compile a database of potentially active faults. Later, this information will be integrated in a GIS. In a side project, a geomorphologic and geophysical investigation has been carried out on the Gaurin-Ramecroix fault in the area of Tournai (Belgium), which did not provide any evidence of recent activity of this fault.

7.2.4. Research in South-West Turkey

Apart from these main study areas, the ROB is also working in an archeoseismological project in SW Turkey, led by the Structural Geology and Tectonics Group of the University of Leuven. Aim of this project is to identify the fault that generated the devastating earthquake that resulted in the final abandonment of the ancient city of Sagalassos around the middle of the 7th century AD. This year, we have acquired 2-D resistivity profiles at two locations in the vicinity of Sagalassos. These profiles demonstrated that a lineament traversing the Çanakli valley, which was inferred from satellite images, does not correspond to a fault. On the other hand, we found evidence that the limestone front bordering this valley is very likely a normal fault. The absence of a fault scarp indicates, however, that this fault has not been active since the deposition of the youngest sediments.

7.3. Perspective for next years

As the EC-project SAFE is coming to an end this year, much time will be devoted to publication of the results achieved during the past three years. Some additional geophysical studies may be carried out in the area of Rotem in the Roer Valley graben. We will also assist colleagues of the University of Potsdam as they intend to open a trench on the Viersen fault near Kerpen, Germany. More fieldwork will have to be carried out to look for the causative fault of the 1692 earthquake in the Vesdre area. In the framework of our project in Bulgaria two trenches will be excavated this year. Results of the previous surveys will be presented on international meetings, and publications will be prepared. We will implement the database of potentially active faults in the region between the Roer Valley graben and the North Sea within a GIS.

7.4. Personnel involved

Kris Vanneste assumed the scientific direction of the different studies conducted in the framework of this project. He was assisted in the fieldwork and interpretation by Koen Verbeeck (ACTION 1 n° MO/33/011), Toon Petermans (ACTION 3 in support of SAFE-project) and Hilde Béatse. Thierry Camelbeeck is scientific responsible for the different supporting research projects.

7.5. Partnerships

List of national and international partners

- University of Utrecht – Prof. Kabir Roy Chowdhoury (sub-surface geophysics)
- University of Cologne – Dr Klaus Hinzen (archeoseismology)
- University of Potsdam – Prof. Manfred Strecker (active tectonics)
- University Pierre et Marie Curie Paris – Michel Sébrier (active tectonics)
- Institut de géologie de l'Académie des sciences de Bulgarie – Dr Stefan Shanov (geology)
- Laboratoire de géodésie de l'Académie des sciences de Bulgarie – Dr Dimitar Dimitrov (geodesy)
- Université de Liège (department of geography) – Dr Alain Demoulin (physical geography)
- Faculté Polytechnique de Mons – Prof. Yves Quinif (tectonic deformation in caves)
- Royal Museum for Central Africa – Dr Philippe Tréfois (teledetection)
- CEREGE (Aix-en-Provence) – Dr Lionel Siame (cosmonucleides)

Grants used for this research

- European « Slow Active Faults in Europe » project (EVG1-CT-2000-00023): from February 2000 to April 2004.
- ACTION 3 project in support of the European SAFE project: from January to December 2003.
- Bilateral cooperation with Bulgaria (BL/33/09): from January 2003 to December 2005.
- ACTION 1 project « Fault activity in NW Europe and its relationship to fault activity » (MO/33/011).
- The trench excavation across the Rauw fault has been financially supported by NIRAS-ONDRAF.
- The field studies (trench excavation, hand borings, dating…) in Bulgaria have been financed by the paying expertise of the section.

Visitors: 7

7.6. Publications

7.6.1. Publications without peer system

Vanneste K., Petermans T., Verbeeck K., Béatse H.

New paleoseismologic evidence for a historical surface-rupturing earthquake in the Belgian Maas Valley, Lower Rhine Graben area

proceedings of the EGS-AGU-EUG Joint Assembly, Nice, France, April 2003.

7.6.2. Publications in press, submitted

Similox-Tohon D., **Vanneste K**., Sintubin M., Muchez P., Waelkens M.

2-D resistivity imaging: a tool in archaeoseismology. An example from ancient Sagalassos (SW Turkey)

Archaeological Prospection (accepted)

Vanneste K., Radulov A., **Camelbeeck T**., De Martini P., Nikolov G., Pantosti D., **Petermans T**., Shanov S.

Paleoseismological investigation of the fault rupture associated with the M 6.8 earthquake of April 14, 1928 near Chirpan, Southern Bulgaria

Extended abstract submitted for publication in proceedings of the 5th International Symposium on Eastern Mediterranean Geology, to be held in Thessaloniki, Greece, April 2004.

Similox-Tohon D., **Vanneste K**., Sintubin M., Muchez P.
The use of 2D resistivity imaging in active tectonics: examples from different sites in SW Turkey
Extended abstract submitted for publication in proceedings of the 5th International Sympo-sium on Eastern Mediterranean Geology, to be held in Thessaloniki, Greece, April 2004.

7.6.3. Reports, thesis, etc

Geuze A.
Localisation de la faille de Gaurain-Ramecroix par méthode géophysique
Mémoire de licence en géologie de l'Université Libre de Bruxelles (promoteur T. Camelbeeck)

Camelbeeck T.
Rapport des activités réalisées dans le cadre de l'Action 3 en support au projet européen « Slow Active Faults in Europe »
Report to the PPS Science Policy

Verbeeck K. and Camelbeeck T.
Report after 1 year of the project « Fault activity in northwest Europe and its relationship to seismic activity»
Report to the PPS Science Policy

Camelbeeck T.
Annual report (February 2002-January 2003) of the European SAFE project – partner 3 (Royal Observatory of Belgium)
Report sent to the European Commission

Camelbeeck T. and Vanneste K.
Rapport 2003 – projet de coopération bilatérale avec la Bulgarie « Failles actives et grands tremblements de terre du passé dans la dépression de Thrace »
Report to the PPS Science Policy

7.7. Missions

Research missions (number of days)
Kris Vanneste 12 – Koen Verbeeck 8 – Toon Petermans 3 – Thierry Camelbeeck 3

Operational meetings (number of days)
Thierry Camelbeeck 5

Field missions (number of days)
Kris Vanneste 38 – Koen Verbeeck 47 – Toon Petermans 41 – Thierry Camelbeeck 4 – Hilde Béatse 18 – Ali El Bouch 3 - Baudouin Bukasa 3 – Stefaan Castelein 1

8. Research project « Historical seismicity »

8.1. Objectives

As earthquake instrumental data are available only since ~ 1900, they are not sufficient to draw a realistic picture of the long-term seismic activity in northwestern Europe. Historical seismicity studies are then essential to complete instrumental studies. The objectives of this project are twofold: 1. to collect information on the earthquakes having occurred in northwestern Europe before 1900 and implement them in the seismicity database of the ROB, and 2. to analyse these data to better constrain the source

parameters (mainly epicenter and magnitude) of these historical earthquakes and to provide information on their effects on the Belgian territory.

8.2. Progress and results

For more than ten years basic work has been carried out in the field of historical seismicity at the ROB. As a result, a complete list of the destructive earthquakes has been established. We have already, for each of these events, a provisional catalogue of the contemporary sources at our disposal describing the effect of the earthquake on the population and the civil constructions.
We finalized in 2003 an action 1 project dedicated to a more systematic search of information in the numerous potentially interesting historical sources, which up till now have never been consulted. This project allowed us:

- To define with a better precision the epicentral area of the earthquakes of 18 September 1692 and 23 February 1828.
- To obtain detailed information on the effects of historical earthquakes from 1350 to 1900 in many cities in Belgium, The Netherlands, France and Germany (Antwerpen, Deinze, Poperinge, Gent, Brugge, Leuven, Hasselt, Tongeren, Ieper, Kortrijk, Bruxelles, Liège, Mons, Verviers, Namur, Luxembourg, Aachen, Köln, Roermond, Lille, Condé, Dunkerque, Valenciennes, Amsterdam, Den Haag, Arcen, Breust, Sevenum, Voerendaal, etc).

The section seismology is also responsible for the EC-project SAFE working package 2 « Seismological aspects of large earthquakes ». The purpose of this research is to implement the information synthetized from historical earthquakes in methods designed to search for active faults in low deformation tectonic areas.
In seismic hazard studies, it is also important to provide ″scientifically supported" hypotheses on the possible seismogenic structure that generated these earthquakes. We studied specifically the historical context of the 1692 September 18 earthquake (figure 2) because it is the known seismic event with the strongest impact (importance of the destructions, number of deaths, felt area,…) in the North-West of Europe. It occurred in the northern part of the Belgian Ardenne. All the results of these investigations will be included in our report to the European Commission.

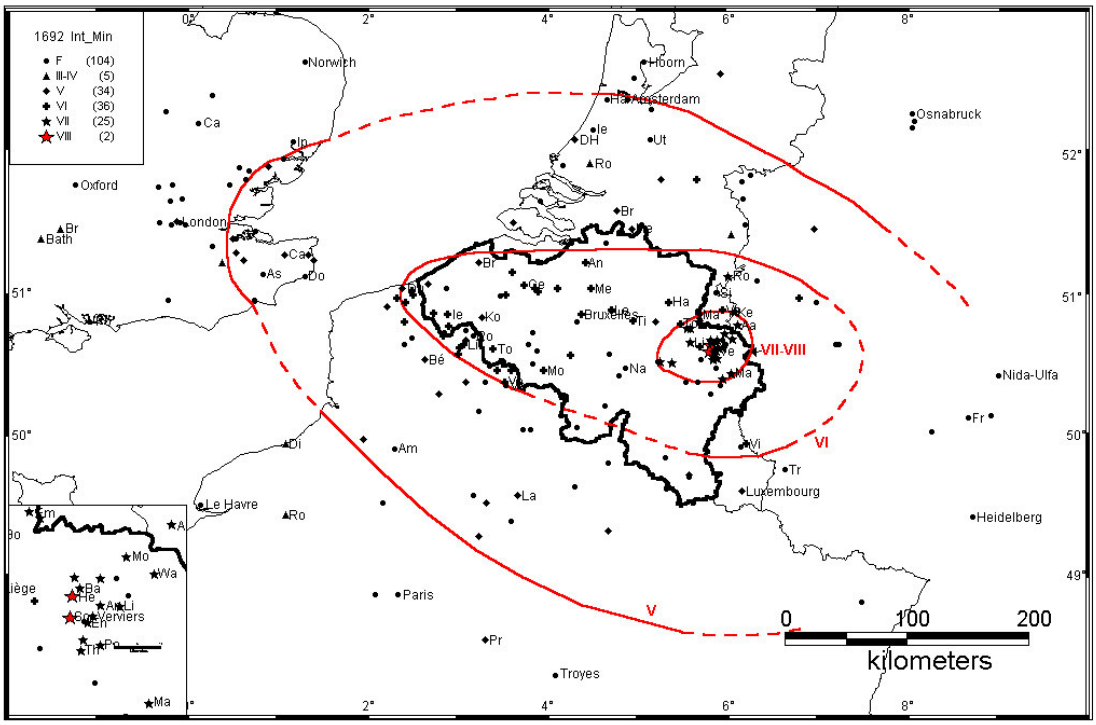


Figure 2. *Macroseismic map of the 18 September 1692 earthquake as a result of our historical investigations*

8.3. Perspective for next years

As the project « Systematic search for and analysis of historical sources concerning destructive earthquakes in our regions from 1350 to 1900 » is now finished, a synthesis of all the historical sources of earthquakes in northwestern Europe will be prepared for publication. A synthesis on the seismological aspects of the earthquakes of 1692, 1756 and 1828 will be done.
All the collected information will be implemented in the database to make them available on the Internet.

8.4. Personnel involved

David Kusman worked 100% of his time for the Action 1 project « Systematic search for an analysis of historical sources concerning destructive earthquakes in our regions from 1350 to 1900 ». Pierre Alexandre supervised his work and carried out the assessment of ancient sources according to the rules of historical criticism. Pierre Alexandre began to introduce historical data in the newly created earthquake database of the ROB. Tom Vanherle participated in some visit to the archives with David Kusman and introduced part of the data in the database. Thierry Camelbeeck coordinated the different aspects of the research

8.5. Partnerships

List of national and international partners

- Jean Vogt from Strasbourg provided original documents concerning the 1692 earthquake

Grants used for this research

- ACTION 1 « Systematic search for and analysis of historical sources concerning destructive earthquakes in our regions from 1350 to 1900 » - contract MO/33/010 – duration 2 years since January 2002.
- The company TRACTEBEL S.A. provided financial support to pay Tom Vanherle (see operational project 14).

8.6. Publications

8.6.1. Publications in press, submitted

P. Alexandre, D. Kusman et Th. Camelbeeck

Le tremblement de terre du 18 septembre 1692 dans le nord de l'Ardenne (Belgique) - Impact sur le patrimoine architectural

à paraître dans Archéosismicité et Vulnérabilité. Environnement, bâti ancien et société, VIème Rencontres du Groupe Aps, 4 et 5 octobre 2002, Perpignan, France.

8.6.2. Reports, thesis, etc

Th. Camelbeeck et D. Kusman

Systematic search for and analysis of historical sources concerning destructive earthquakes in our regions from 1350 to 1900

Final report of the projectMO/33/010 to the PPS Science Policy

8.7. Missions

Field missions (number of days)
David Kusman 60 – Pierre Alexandre 11 – Tom Vanherle 10

9. Research project « Instrumental seismicity »

9.1. Objectives

The main objective of the project is to provide a complete catalogue of earthquakes since 1910 in which all the parameters are homogeneous, particularly the magnitude M. Of course, different methodologies must be applied, depending on the epoch of the available data.

- Since 1985, the date of installation of the modern Belgian seismic network, we have been collecting high-quality digital data on the local earthquakes that occurred in Belgium and the surrounding regions. The source parameters (location, local magnitude, fault-plane solutions) of these earthquakes are determined routinely by simple procedures. They should be improved by: 1) the elaboration of a joint dataset with our colleagues from the Netherlands and Germany; 2) the relocation of all these events using a better constrained crustal velocity model, 3) the evaluation of the seismic moment and source dimensions by specific time series analysis, 4) the calculation of fault-plane solutions using the complete body-wave signal.
- For the earthquakes that occurred before 1985, the data consist of paper seismograms. We continue to collect seismograms and seismic bulletins from European seismic stations in order to obtain a as complete dataset as possible (operational project « Saving and studying seismograms of the Belgian earthquakes »). To evaluate source parameters with these data, it will be necessary to calculate synthetic seismograms.

9.2. Progress and results

In 2003 we mainly focussed our attention on the characterisation of the crustal wave velocity model, indispensable to better locate the earthquakes. Two different aspects have been considered: a) the

experimental project supported by the "Région Wallonne" has been finalised. It consisted of the analysis of quarry blasts recorded by mobile seismic stations along a profile across the Maas River near Huy. A tomographic image of the upper crust (3 to 5 km deep) across the Variscan front has been obtained; b) the inversion of P- and S-wave arrival times from 64 local earthquakes has been used to deduce an average crustal model for our regions.

A working group has been created with our colleagues from the KNMI in the Netherlands and from the University of Cologne in Germany (Rhine Maas Seismology group). Its purpose is to work on a joint program including the determination of regional velocity crustal models and the exchange of digital data and phase measurements for local earthquakes. We tested our ability to exchange data using the year 2001 as a reference.

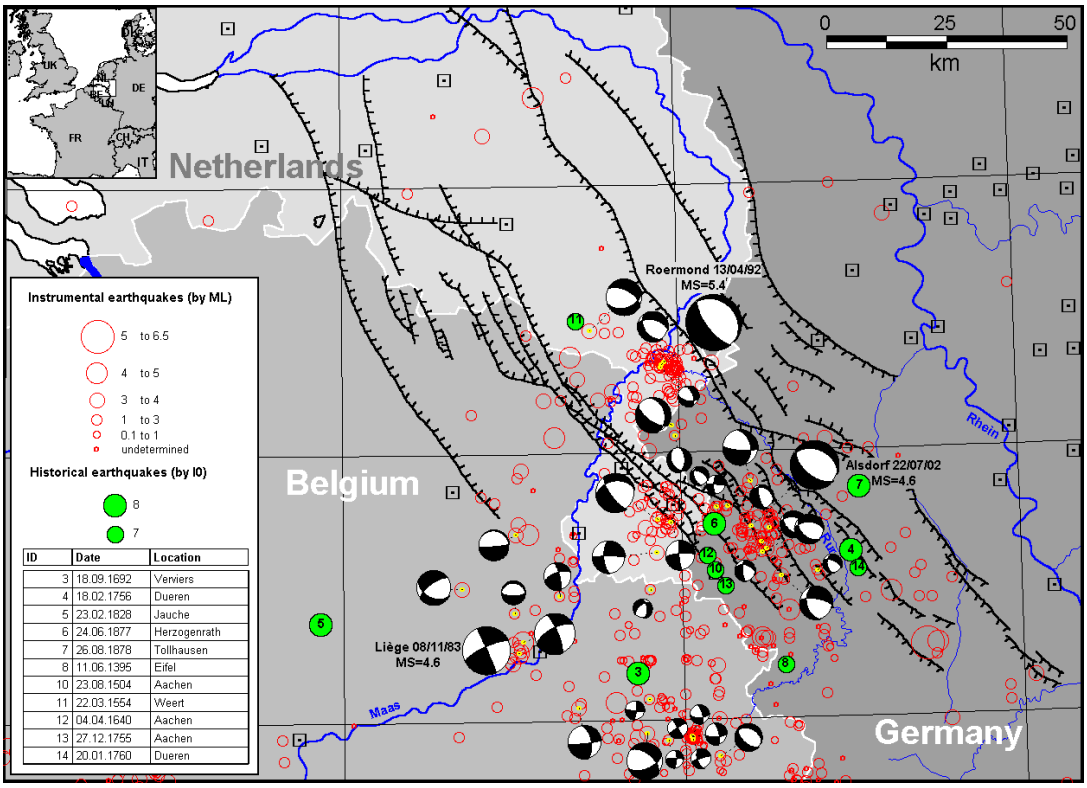


Figure 3. *Seismicity and fault-plane solutions in the eastern part of Belgium and the Roer Graben (from delivrable 3.2. of the EC-project SAFE prepared by the ROB – Novembre 2002)*

9.3. Perspective for next years

In 2004, a common procedure will be used to locate local earthquakes recorded by the Belgian, Dutch and German networks with the data from 2000 to 2003. Our intention in the future is to use this procedure for all the data collected with the Belgian seismic network installed since 1985.

9.4. Personnel involved

Fabienne Collin developped the input-output formats to use with the VELEST-program (inversion of arrival times to deduce velocity model) and directed the study on the crustal structures. She improved her seismic tomography software. Michel Everaerts finalized the report for the "Région Wallonne" interpreting gravity profiles in parallel with the collected seismic data recorded after man-made blasts.

Thierry Camelbeeck was promotor of the work of Valérie Calbini (student in physics at UCL) and coordinates the different aspects of the research.

9.5. Partnerships

List of national and international partners

- Seismic section at the KNMI in De Bilt (The Netherlands)
- Seismic station Bensberg of the University of Cologne (Germany)
- Centre Européen de Géodynamique et de Séismologie à Walferdange (GD Luxembourg)

9.6. Publications

9.6.1. Reports, thesis, etc

Everaerts M., Camelbeeck Th., Collin F.

Rapport final concernant la convention relative à la connaissance de la structure de le croûte supérieure en Wallonie par tomographie sismique (phase probatoire)
Version finale déposée à la Région Wallonne

Calbini V. (Promoteur Th. Camelbeeck)

La structure de la croûte en Belgique par inversion en deux dimensions de données sismiques.
Mémoire de fin d'étude au département de physique à l'UCL

9.7. Missions

Operational meetings (number of days)
Michel Everaerts 1 – Thierry Camelbeeck 3

Field missions (number of days)
Michel Everaerts 5 – Baudouin Bukasa 1

10. Research project « Seismic hazard – Strong-ground motions »

10.1. Objectives

One challenge within the community of seismologists is to provide in every region of the world a realistic evaluation of the strong ground motions that will be generated by future earthquakes. This requires a detailed modelling of the corresponding seismic source, crustal structure and local geological characteristics (site effects). The objective of this project is to develop and apply methodologies for that purpose on the Belgian territory. Two main aspects are considered: 1) To implement existing methods of seismic hazard assessment on the particular case of intraplate regions like in Belgium; 2) To develop methodologies to investigate site effects and implement them in a routine procedure.

10.2. Progress and results

In 2003, scientific investigations started in the framework of the project « Evaluation et réduction du risque sismique en Belgique » have been finalized. This study is the first ever conducted on seismic risk that is based on the real seismic context of Belgium. It completes the seismic hazard map on the bedrock, already realized through a cooperation between the ROB and the University of Liège in the framework of EUROCODE-8, by two fundamental aspects: (a) the definition of elastic response spectra for two different reference earthquakes which should allow us to realize a choice for the National Document of Application for EUROCODE-8; and (b) the evidence that regional site effects in the north of the country should be taken into account by a convenient choice of the response spectra. It appears also that the region of the Mons basin should be studied more intensively in the future, because the study suggests that site effects there could disastrously amplify the impact of strong ground motions.

An aspect of the project was to provide quantitative information on site effects in the northern part of Belgium. In 2002 the ROB performed forty-seven H/V microtremor measurements with 5-second seismometers over an area of about 15.000 km². Most of the results have been analysed in cooperation with the Liège and Grenoble universities in 2003. They show a northward regular increase of the soil fundamental period in agreement with the augmentation of the Mesozoic and Cainozoic soft sediment thickness, from a few meters 40 km south of Brussels to 900 m at the Netherlands-Belgium border. The measured resonance frequency values were consistent with theoretical computations performed at different sites on the basis of existing information and shallow seismic experiments. At one particular site (Uccle) where borehole data were available, microtremor measurements using an array of four seismological stations with different apertures allowed to obtain the low frequency part of the Rayleigh wave dispersion curve, extending the range covered by the analysis of surface waves artificially generated by small explosions. The Vs profile derived from the surface wave inversion corroborates the 1 Hz natural frequency of the site. Array measurements have also been conducted in the framework of the EC-project SESAME.
Comparison of these results with the macroseismic information concerning the M_S = 5.0 1938 earthquake which occurred 50 km west of Brussels, confirmed the hypothesis that the geological structure of the Brabant massif is likely one of the controlling factors of the damage distribution during such an earthquake. Comparison between the intensity map of the 1938 earthquake and the resonance period of sediments obtained by our microtremor study shows a clear relation between both parameters. During the 1938 earthquake, site effects played a prominent role due to the dimension of the source whose corner frequency was about 1 Hz.

10.3. Perspective for next years

We will develop the methodology based on the analysis of ambient noise records (H/V method) in order to estimate the seismic response of a site in terms of *fundamental mode of resonance*. In order to reinforce the methodology, we propose projects aiming at supplementing the first studies carried out in the Brabant massif by integrating the ambient noise analysis technique and by developing numerical tools to calculate transfer functions for 1D and 2D geological structures for some acceptable scenarios in Belgium. This technique will be computerized and integrated in the current tasks of the ROB.
In addition, we will have to collect and store new information related to the soil properties on the studied sites (boreholes and geological data) and to add it to the information provided by the existing seismological database of the section. It will be necessary to create a new structure for the database in order to preserve and extract the collected information in a coherent way and then to build a user interface to integrate further new data.
The application of the chosen methodologies on one or more pilot zones within the cities of Mons and Brussels should validate them and improve their routine use. From the point of view of seismic risk prevention in urban zones, the pilot experiments in Mons and Brussels should provide the arguments for a more systematic evaluation of sensitive zones and cities of Belgium.

10.4. Personnel involved

Thierry Camelbeeck is responsible for this research. Michel Van Camp participates in the analysis of the campain in the Brabant massif. Philippe Rosset joined the section seismology in November 2003 in the framework of a PPS Science Policy project “research help”. He will conduct the methodological investigations and the field works in 2004. Baudouin Bukasa participates in the measurements.

10.5. Partnerships

List of national and international partners

- University of Liège – Mr. F. Nguyen
- University of Grenoble – Prof. D. Jongmans

- Institut de Radioprotection et de Sûreté Nucléaire français – Dr Oona Scotti
- Faculté Polytechnique de Mons – Prof. H. Wilkin and Prof . Y. Quinif

Grants used for this research

- PPS Science Policy -normalisation project NM/33/03 « Evaluation et réduction du risque sismique en Belgique dans le cadre de l'Eurocode 8 » (march 2000 – march 2003).
- PPS Science Policy project "research help
- EC-project SESAME (EVG1-2000-22024)

Visitors: 5

10.6. Publications

10.6.1. Publications with peer system

Teerlynck, H., **Van Rompaey, G.**, Nguyen, F., **Van Camp, M.**, Jongmans, D. and **Camelbeeck, T.**
Use of microtremor measurement for assessing site effects in Northern Belgium – interpretation of the observed intensity during the Ms=5.0 June 11, 1938 earthquake
J. Seismology, 8(1) 41-56, 2004

10.6.2. Reports, thesis, etc

Plumier A., C. Doneux, **Th. Camelbeeck, G. Van Rompaey**, D. Jongmans, M. Wathelet, H. Teerlynck and F. Nguyen.
Final report of the project « Seismic Risk Assessment and Mitigation for Belgium in the frame of EUROCODE 8 »
Report to the PPS Science Policy

10.7. Missions

Research missions (number of days)
Thierry Camelbeeck 3

Operational meetings (number of days)
Philippe Rosset 3 – Thierry Camelbeeck 5

Field missions (number of days)
Philippe Rosset 3 – Thierry Camelbeeck 3 - Baudouin Bukasa 2

11. Research project «Tectonic activity in natural caves »

11.1. Objectives

During the last decade, recent faulting activity was evidenced in different karstic networks in Belgium. In the northern part of the Rochefort cave, some walls are cut by three faults. These fault planes are covered by thin argillaceous slickensides showing a normal displacement and post-dating karstic events. The amplitude of the total relative displacements is some decimeters. To monitor this activity, a geophysical laboratory has progressively been installed in the cave from 1997. It now includes 6 extensometers and 1 broadband seismometer. The main objectives of the project are to determine if these faults are linked to tectonic structures at the crustal scale and to characterize the fault movements (continuous, sudden…).

11.2. Progress and results

The analysis performed in 2003 on the data recorded in the Ramioul cave before, during and after the collapse that occurred in the nearby quarry in 2002 indicates that the technology used allowed to measure very small displacement (few μm) and to follow low-frequency (10^{-6} Hz) deformation.
The measurements of the six extensometers in the Rochefort cave indicate clearly that the faults have not moved suddenly since their stabilisation in 1999. If a continuous movement occurred, it should be at a rate of less than 0.02 mm/year. The measured continuous small amplitude movements (10 to 15 μm) are due to the known periodic movement of the Earth surface and could also be possibly linked to the hydrology inside the cave.

11.3. Perspective for next years

This project is typically devoted to long-term measurements. Thus, the maintenance of the existing instruments will continue in the next years. It has been discussed with the ASBL Grotte de Lorette-Rochefort to improve the power supply inside the cave in order to avoid interruptions in the measurements after power failures.
To study the relationship between the hydrology and our extensometric measurements, we study the possibility to conduct two months of continuous measurements with the FG5 absolute gravimeter of the ROB

11.4. Personnel involved

Michel Van Ruymbeke developped the extensometers, assumes their maintenance and analyses the collected data. Mr. Eric de Kerkhove, as voluntary technician, manages the data from the instruments in the Rochefort and Ramioul caves. Mrs. R. Howard, also as voluntary technician, participated in the analysis of cave data. Mr Liu Shaoming participated, during his three months visit at the ROB, in the data analysis with the purpose of finding tectonic precursors. Thierry Camelbeeck coordinates the project in relationship with the local authorities.

11.5. Partnerships

List of national and international partners

- Faculté Polytechnique de Mons – Professor Yves Quinif
- ASBL Grotte de Lorette-Rochefort
- CERAK
- Seismology State Bureau of China, Wuhan branch

Grants used for this research

The project has been initiated with the help of two FRFC-NFWO projects but presently; no external financial support is available.
Cooperation exists (bilateral project BL33C23) between the ROB and the Seismology State Bureau of China, Wuhan branch. Its purpose is to apply in caves in China the developped technology in the Belgian caves.

Visitors 4

11.6. Publications

11.6.1. Publications in press, submitted

Tshibangu J.-P., van Ruymbeke M., Vandycke S., Quinif Y. and Camelbeeck T.
Studying underground motions in the Ramioul's cave-Belgium
Submitted

11.7. Missions

Research missions (number of days)
Nihil

Operational meetings (number of days)
Michel Van Ruymbeke 3 - Eric de Kerkhove 2 – Thierry Camelbeeck 3

Field missions (number of days)
Michel Van Ruymbeke 8 - Eric de Kerkhove 5

12. Research project « Present-day crustal deformation »

12.1. Objectives

12.1.1. Crustal deformation using gravity and GPS measurements

To understand tectonic activity and the seismic cycle of the slowly slipping faults in intracontinental regions, it is important to evaluate the present- day crustal deformation. To estimate the vertical movements and to formulate hypothesis on their causes, absolute gravity (AG) measurements using the FG5-202 gravimeter have been conducted along a profile twice a year since September 1999 (uplift or subsidence would modify the gravity at a rate of about 1 µGal for 5 mm). This 140 km long profile includes 8 stations across the Belgian Ardenne and the Roer Valley Graben.
The bi-annual rate was chosen to detect problematic stations as fast as possible as well as seasonal effects, and also to lower instrumental white noise effects. During the profile, the FG5-202 stability is controlled at the Membach reference station, where a superconducting gravimeter (SG) is recording the gravity continuously with a resolution of 0.1 µGal (cf. Operational Project #10).
The slow crustal deformations are also monitored using GPS in Bree, Meeuwen and Membach. The objective of the Bree-Meeuwen measurements is to obtain within a few years reliable evaluation of the crustal deformation on the western border fault of the Roer Valley Graben. The Membach GPS station was installed to perform comparisons with the data collected by the FG5 gravimeter.
We also study crustal deformation in Oostende by performing AG measurements yearly closed to the tide gauge. We therefore participate in the ESEAS project (European Sea Level Service).

12.1.2. Support to the study of global geodetic reference frame

The accuracy achieved by geodetic techniques now enables the detection of new deformation modes of the Earth. However, time-dependent displacements of stations usually have magnitude close to the accuracy of each individual technique, and it still remains a challenge to separate the true geophysical motion from possible artefacts inherent to each geodetic technique.
At the CERGA observatory (Grasse, France), both Satellite Laser Ranging (SLR) and GPS time series of the vertical component show an obvious annual signal, and were compared with repeated AG measurements. This study aims at understanding the possible bias affecting each technique in order to improve the vertical reference frame.

12.2. Progress and results

12.2.1. Crustal deformation

At the Membach station, more than five years of GPS, and eight years of AG and SG data have been analyzed. After removing the superconducting gravimeter C-021 instrumental drift, we demonstrated that the SG observations agree with those from the absolute gravimeter FG5-202 at the microGal level. The remaining signal in the SG residuals is, most likely, related to unmodelled environmental effects. The trend that has been identified in the AG data indicates a possible uplift of the Belgian Ardenne of about

3.0±0.5 mm/yr. This inferred uplift is confirmed by the 2.7±0.2 mm/yr uplift observed by continuous GPS performed 3 km away from the Membach geophysical station. This uplift is the most likely explanation of the observed gravity variations in light of presently available data.
Along the profile, the precision, less than 2.0 µGal integrated over more than 24 hours of observations, is quite satisfactory in all stations. Up till now, except for the station Jülich influenced by mining (cf. Research Project #7 "Hydrological effects on gravity"), no gravity rate of change larger than 1.8 µGal/yr has been detected. This is equivalent to uplift not larger than 9 mm/yr, using a deformational gradient of –0.2 µGal/mm.
Other geodetic measurements were undertaken since 1997 in the Eastern Campine block and the Roer Graben. Five years of continuous GPS-measurements indicate already that the relative vertical movement of the two crustal blocks separated by the western border fault of the Roer Graben is less than 0.5 mm/yr, i.e. less than what was previously estimated from levelling differences. As a conclusion, from geodetic measurements, it is still not possible to provide information concerning the characteristics of the deformation (seismic, partly aseismic or aseismic) in the Campine, the Ardenne and the Roer Valley Graben.
Due to a major technical problem (malfunctioning laser), it was not possible to perform AG measurements at Oostende in Dec. 2003; this was delayed to Feb. 2004. No gravity rate of change larger than 0.5 µGal/yr has been detected there.

12.2.2. Support to the study of global geodetic reference frame

At the CERGA station, the annual term has been found to dominate the signal for both SLR and GPS time series, with amplitude an of ~6 mm and a maximum in July. Similar annual terms are also observed on other SLR sites we processed, but usually with a lower magnitude. The AG time series shows a more complex signal. Estimating an annual term to the AG time series leads to a magnitude of 1.7 µGal, equivalent to 8.5 mm, but the frequency analysis indicates a second principal term with a period of 204 days and a magnitude of 13 mm (or 2.6 µGal). However, the lack of data could mask an annual signal. The variations are larger than GPS and SLR. A possible explanation for this discrepancy is the contribution to gravity measurement of water mass variations stored in the karsts.
The AG being absolute is not networking dependent and provides an independent way of measuring the long-term crustal stability at the CERGA observatory, in Grasse (France).

12.3. Perspective for next years

The Ardenne-Roer profile is a long-term project. We plan to continue the profile twice a year up to 2009 at least; then we should be able to constrain any possible long-term trend with accuracy better than 0.5 µGal/yr.
In collaboration with the Proudman Oceanographic Laboratory, we will also investigate the structure of the noise affecting SG and AG data series at the Membach station, in order to identify the noise source(s) and to get a better idea of the ability of AG to monitor vertical crustal deformations. Using the Membach experience, we will evaluate the uncertainties that can be applied to gravity variations observed by repeated AG campaigns. To our knowledge, no studies have yet been published on the error model affecting repeated AG measurements. Accounting for the type of noise is very important when estimating gravity variations and their uncertainties.
Measurements at the Oostende station will occur as usual on a yearly basis, and like the Ardenne profile, this is a very long-term project.
At the CERGA observatory, we plan to apply hydrologic and atmospheric loading models to better understand the possible contribution to the observed signal. We will focus on continental water storage and atmospheric effects on vertical crustal motions, as well as on local effects induced by the karsts. Removing the contribution of deformation to AG measurements will enable to test whether and how the local hydrological effects impact gravity measurements (see also Research Project 7).

12.4. Personnel involved

Michel Van Camp is responsible for all the measurements conducted with the FG5 absolute gravimeter. During the measurements, he has been helped by Stefaan Castelein, Marc Hendrickx, Aydin Ergen (Technical service), Ali El Bouch, Toon Petermans and Koen Verbeeck. The GPS data were analysed by René Warnant. Thierry Camelbeeck coordinates these scientific activities.

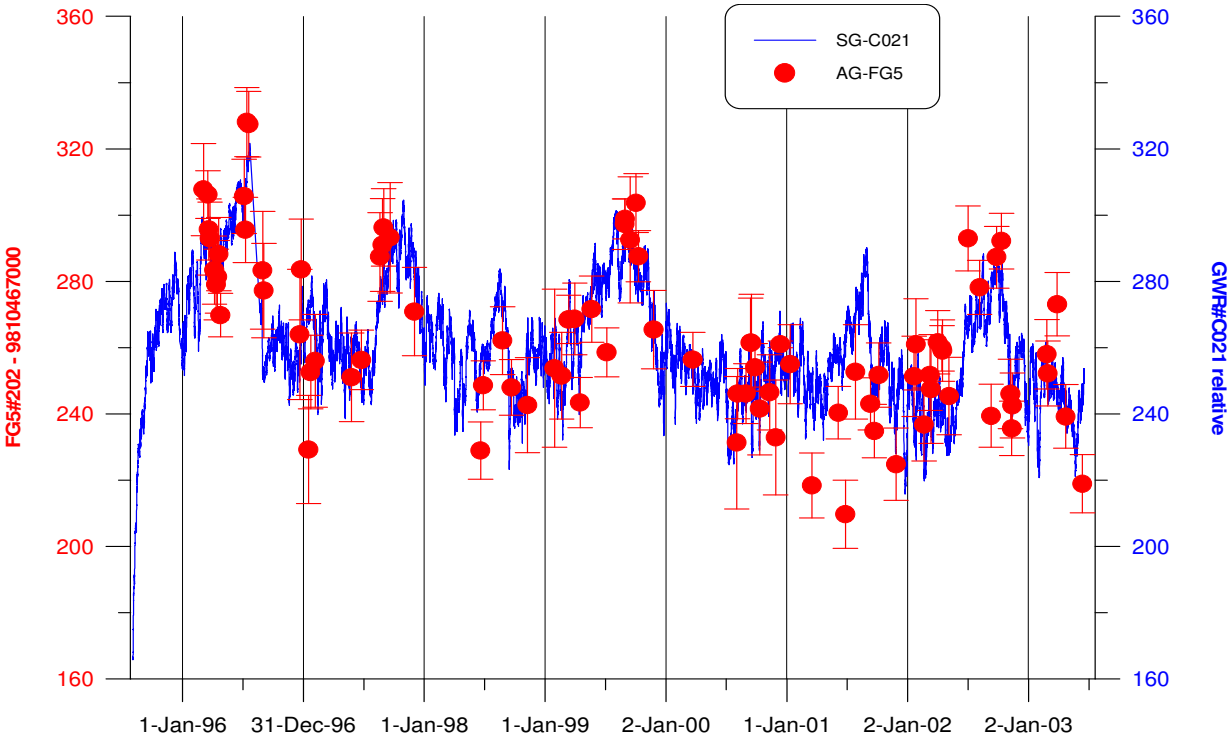


Figure 4. *Continuous Comparison between gravity measurements of the SG C-021 and the AG FG5-202 at the Membach station. The Earth tides, ocean loading and atmospheric effects, and polar motion have been removed. The SG C-021 instrumental drift of 4.3 µGal/yr was evaluated by taking the difference between the residuals of the SG C-021 and of the AG FG5-202. The initial exponential decrease from August to December 1995 is due to the SG C-021 setup. What remains in these corrected SG residuals, from March 1996 to November 2002, is a geophysical trend, mainly linear and we estimate its slope at -0.6 ± 0.1 µGal/Year.*

12.5. Partnerships

List of national and international partners

- AG measurements in Membach: Prof. O. Francis (ECGS), Dr. T. van Dam (ECGS).
- AG measurements in CERGA: J.-M. Nocquet (Oxford); J. Nicolas (Le Mans), E. Gilli (Paris VIII), J. Hinderer (EOST), J.-P. Boy (EOST) and J.-J. Walch (CERGA).
- AG measurements in Oostende: ESEAS : Prof. T. Baker (Liverpool).

Grants used for this research: Program FNRS/NFWO n° 2.4545.00

12.6. Publications

12.6.1. Publications with peer system

12.6.2. Publications without peer system

Van Camp, M., Camelbeeck, T. and Warnant, R.
Intraplate Deformations measured using an Absolute Gravimeter Across the Ardenne and the Roer Graben (North-Western Europe)
Proceedings of the 1st Workshop on International Gravity field research, Graz, Austria, May 8-9, 2003 (extended abstract).

12.6.3. Publications in press, submitted

Francis, O., **Van Camp, M.,** van Dam T., **Warnant R. and Hendrickx M.**
Indication of the uplift of the Ardenne in long term gravity variations in Membach (Belgium)
Accepted by Geophys. J. Int., 2004.

12.6.4. Reports, thesis

Nihil

12.7. Missions

Research missions (number of days)
Michel Van Camp 16 – Thierry Camelbeeck 3

Operational meetings (number of days)
Michel Van Camp 6

Field missions (number of days)
Michel Van Camp 69 - Stefaan Castelein 6 - Marc Hendrickx 3 - Aydin Ergen (Technical service) 13 - Ali El Bouch 1 - Toon Petermans 1 - Koen Verbeeck 1.

OPERATIONAL PROJECTS FOR THE SCIENTIFIC RESEARCH AND EXPERTISE

In support of its scientific research, its scientific expertise and its role of information supplied to the public and the authorities, the section of seismology takes charge of several tools. Their conservation in a good state is fundamental for the continuity of the different activities of the section.

13. Operational/Research project « Seismic and accelerometric networks »

13.1. Objectives

This project concerns the monitoring of the seismic activity in Belgium and the surrounding regions. To be able to locate local earthquakes and to evaluate their source parameters with a good precision, it is necessary to record them with a relatively dense seismic network. The Belgian seismic network set up progressively since 1985 is composed of ~ 25 stations. The stations are equipped with acquisition systems developped at the ROB and, 14 of them are equipped with an ISDN connection to our central station in Uccle.
As traditionnal seismic stations saturated when the strong ground motion is higher than 0.005 g, seismologists generally lost the information when it appeared to be the most essential for the scientific study of earthquakes and for the practical applications that the engineers, architects, insurance companies… are interested in. That is why a network of strong ground motion accelerometers has been

installed, since 1999. The equipments are ETNA stations from Kinemetrics Company and are linked to the ROB by analog telephone lines.
The objectives of this project are the maintenance of the existing stations aa well as the instrumental and software developments in order to improve the data quality and the reliability of the quasi-real time connections to Uccle (see also the operational project 12).

13.2. Progress and results

In 2003 we have developed a new type of 24-bit acquisition system. It was first tested in the station Lessines and gave reliable results. A new amplifier - anti-aliasing filter card is also in development.
There were also numerous technical problems to solve in some of the stations:

1) Wortegem (WOR) - the link between the seismometer in the borehole and the surface has been cut.
2) Uccle (UCC) – the Guralp seismometer had been finally repaired and was reinstalled in 2004.
3) La Chartreuse (LCH) – the stations will be reinstalled when the work for their protection will be conducted. The Région Wallonne, as well as the ROB will provide a part of the financial support. This should be done in 2004.
4) Sart Tilman (STI) – the station worked, but the connection by the internet to Uccle is often cut.
5) Eben-Emael (EBN) – depending on the meteorological conditions, the DCF-signal reception can be so bad that the time information is not correct on the data.
6) Heydt (HEY) – the station worked well, but the ISDN-connection failed very often.
7) Vianden (VIA) – it will be necessary to set up a completely new equipment in place of the old PCM-5000 Lennartz station (still recording on magnetic tapes).
8) Bree (BRE) – the station has been closed considering the proximity of the accelerometric station BREA and of the borehole in Opiter.

Maintaining them at a high level of reliability and developing them by integrating technological advances is essential to the continuity and quality of the various activities of the section.

In 2003 3 new accelerometers were installed in Membach, Theux and Uccle. Presently, the ROB network owns now 14 accelerometer stations (Fig. 5) connected via a Belgacom line, and one without connection. It is now possible to measure ground motion in the epicentral zone of earthquakes with MS > 3.5, such as those of the Hainaut (1965-1967), Liège (1983) and Roermond (1992). A dedicated program has been installed to monitor the accelerometer network. In particular this will allows the ROB to download data automatically from the whole network within 40 minutes after an earthquake strikes (this delay could be much improved by installing new phone connections at the ROB). The network status is checked thoroughly at the ORB once a week.

Figure 5 : *Accelerometer ETNA installed at the Membach station in 2003*

13.3. Perspective for next years

A procedure to calibrate the newly developed 24-bits acquisition systems will be established and the new ones will progressively replace the permanent seismic stations.
The accelerometers must be visited on a regular basis for maintenance and/or repair. In 2004 two additional accelerometers will be installed in the underground laboratory under the site of the SCK/CEN nuclear research centre. This work is done on request of the NIRAS/ONDRAF and in collaboration with the SCK/CEN.
Four other accelerometers will be bought as temporary stations, to monitor aftershock and specific site effects.

13.4. Personnel involved

The permanent scientists of the section (Fabienne Collin, Michel Van Camp, Kris Vanneste and Thierry Camelbeeck) provide a part of their working time on the maintenance and improvement of the quality of the seismic stations. Michel Van Camp is reponsible of the accelerometric network.
Stefaan Castelein has been monitoring the status of the seismic and accelerometric stations. Baudouin Bukasa had repaired the damaged equipments and has been taking charge of the classical maintenance of the seismic stations. Henri Martin has been solving software problems in the stations and implemented the software under LINUX in the newly developped acquisition systems. Giovanni Rapagnani began to test these systems and to develop the procedure for calibrating the whole equipment including the seismometer.

13.5. Partnerships

List of national and international partners

- We assumed the maintenance and the measurements of the three seismic stations in Grand-Duchy of Luxemburg. The stations belong to the « Centre Européen de Géodynamique et de Séismologie » in Walferdange.
- The station HRK (Herkenbosch), located in the Netherlands, results from co-operation with the seismic section of the Netherlands Meteorological Institute (KNMI) in De Bilt.

Grants used for this research:

Giovanni Rapagnani is supported by the ROSETTA-project.

13.6. Publications

13.6.1. Publications without peer system

Camelbeeck, T., Van Camp, M., Martin, H., Van de Putte, W., Béatse, H., Bukasa, B., Castelein, S., Collin, F., Hendrickx, M., Petermans, T., Snissaert, M., Vanneste, K., Verbeeck, K., Verbeiren, R.
De aardbeving van 22 juli 2002 in de Roerdalslenk.
Heelal (Maandblad van de Vereniging voor Sterrenkunde), 48, 7, juli 2003.

Camelbeeck, T., Van Camp, M., Martin, H., Van de Putte, W., Béatse, H., Bukasa, B., Castelein, S., Collin, F., Hendrickx, M., Petermans, T., Snissaert, M., Vanneste, K., Verbeeck, K., Verbeiren, R.
Les effets en Belgique du tremblement de Terre du 22 juillet 2002.
Ciel et Terre (bimensuel de la Société Royale Belge d'Astronomie, de Météorologie et de Physique du Globe), 119, 1, janvier-février 2003.

13.6.2. Publications in press, submitted

Nihil

13.6.3. Reports, thesis

Nihil

13.7. Missions

Operational meetings (number of days): Michel Van Camp 6

Field missions (number of days)
Michel Van Camp 11 - Stefaan Castelein 10 - Marc Hendrickx 3 – Marc De Knijf (Technical service) 4 – Van Damme (Technical service) 1 – Baudouin Bukasa 17 – Henri Martin 29 – Fabienne Collin 12 – Kris Vanneste 5 – Thierry Camelbeeck 3 – Giovanni Rapagnani 2.

14. Operational project « Seismological database – web site»

14.1. Objectives

In 2002, an impulsion has been given to develop a database on the seismic activity in Belgium and the surrounding countries. The main objectives of the project are:

- To obtain, on the same informatic media, all the reliable existing information on the known earthquakes having affected our country,
- To make this information available on internet and so facilitate the transfer of the scientific and technical knowledge on the seismic activity to the potential users,
- To propose a on line macroseismic inquiry on our web site,
- To use the information in the database in standard common procedures to supply statistics, maps,…

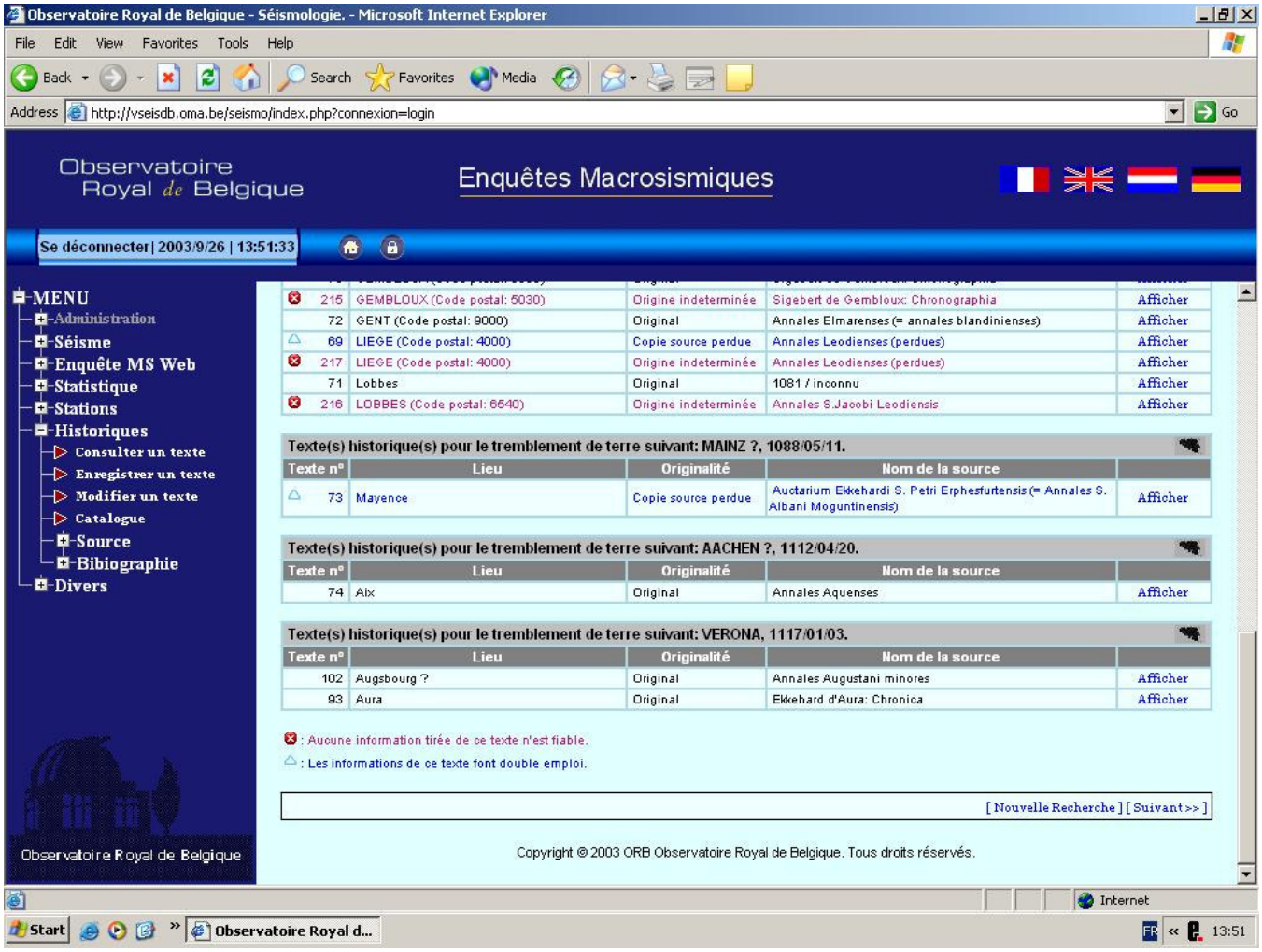


Figure 6. *Extract of the database on the seismic activity in our regions. The menu on the left presents the different sections of the database (which can be consulted). In particular, the page shown on the right is related to the historical earthquake database, in which all original sources can be consulted in its whole.*

14.2. Progress and results

Various aspects of the database have been developed in 2003:

- We developed the software enabling to handle individual questionnaires and to visualize the information from the macrosismic inquiry on the web (developed and tested during the Alsdorf earthquake of 2002 July 22).
- We developed the software enabling to introduce, modify and consult the historical part of the database. The structure of the database has been extensively discussed in order to be able to take the different possible types of information sources into account. Our philosophy in this context is that every person consulting the database should access the information necessary to consult each original document.
- We began to introduce information in the historical part of the database. The responsible scientists shall control this work, partly done by contractual technicians.
- Two earthquake catalogues have been defined in the database. The first one is the traditional catalogue of earthquakes felt in Belgium. A new event is automatically generated when it is measured

on the seismograms of our network. The second catalogue includes all the earthquakes reported by E-mail by the different international seismic centers. A specific program has been written to introduce in the database the phase measurements done for these earthquakes for the Belgian seismic stations and to prepare the data-files to send at the Euro-Mediterranean Seismological Center.

- We also addressed the problem of the specific database for the seismic stations and equipments.

14.3. Perspective for next years

The database will be included in the structure of the presently developed site on internet. An important task will also be to control the information introduced in the historical database.

14.4. Personnel involved

Henri Martin is responsible for the development of the database and the Internet site. Frédéric De Vos assisted him in this task. The structure of the historical database resulted from discussions with Thierry Camelbeeck and Pierre Alexandre.

14.5. Partnerships

List of national and international partners

- University of Cologne (DE)
- KNMI , De Bilt (NL)
- Centre Européen de Géodynamique et Séismologie (LU)
- Ecole et Observatoire de Physique du Globe à Strasbourg (FR)

Grants used for this research

Revenues on expertise of the section have paid Frédéric De Vos.

Visitors: 2

14.6. Publications

Nihil

14.7. Missions

Nihil

15. Operational project « Saving and Studying old Seismograms of Belgian Earthquakes »

15.1. Objectives

The seismic station at Uccle was created in 1898. The first seismographs allowing the recording of local earthquakes were installed in 1904. All the seismograms from these instruments are archived in the basement of the Observatory but it appears necessary to save, for the future, the information they contain. Throughout the years, we also have been collecting data from European stations for the main Belgian earthquakes. The objective of the project is to scan the original seismograms in a first step. The second step will consist in the digitising them.

15.2. Progress and results

We completed the scanning of all the available seismograms from Belgian stations for earthquakes that occurred in our regions since 1904. We participated in the EUROSEISMOS-project (Saving and Studying the Seismograms of the Strongest Euro-Mediterranean Earthquakes). In that frame, we prepared and sent

to Rome all the available seismograms from the Uccle station from 1904 to 1963. We also prepared a copy of the seismic bulletins from the station.

15.3. Perspective for next years

Due to the lack of support in personnel, there is no intending to work at the second step of the project in a near future. A mission will be organised to recover the original seismograms of the Uccle stations that were send in Roma in the framework of the EUROSEISMOS project.

15.4. Personnel involved

Ali El Bouch finished the work of scanning the seismograms from the Belgian and European stations for the earthquakes that occurred in our region. He prepared the seismograms that were sent to Rome in the framework of the EUROSEISMOS project.

15.5. Partnerships

List of national and international partners

- SGA Storia Geofisica Ambiente s.r.l. – Prof. Graziano Ferrari

Grants used for this research

Ali El Bouch has been paid by a SSTC-support (digitization project).

Visitors: 2

15.6. Publications

Nihil

OPERATIONAL PROJECTS ON INTERNATIONAL DATA EXCHANGE AND THE SERVICE TO THE AUTHORITIES, THE PUBLIC AND THE MEDIA

16. Operational project « Seismic alert »

16.1. Objectives

During the discussions with the Crisis Center of the Federal Public Service Home Affairs after the Alsdorf (Germany) earthquake of 22 July 2002, it clearly appeared to the Crisis Center that it was important for them to receive in urgency (less than 1 hour after the event occurrence) confident information on the earthquakes felt in Belgium. Presently, it is not possible for the ROB to assume this task. The objectives of the project are: 1) to study the technical and organisational procedures necessary to be able to realize this emergency mission; 2) to prepare a proposal to inform our Federal Public Service about the technical and financial aspects of that mission; 3) to realize the technical and organisational dispositions of point #1 if manpower and financial support is granted for this new activity.

16.2. Progress and results

In 2003 we tested the possibility to be connected at home by ADSL-connection and to exchange files with our computer in Uccle. We studied all the technical modifications in the present working of the seismic network to reach enough reliability in the data transmission and in the real-time data processing to be able to realize that emergency mission. We prepared a proposition with the technical and financial aspects of the organisation of a seismic watch.

16.3. Perspective for next years

They will depend on the reaction from the SPP Politique Scientifique et Intérieur.

16.4. Personnel involved

Thierry Camelbeeck managed the different parts of the project and wrote the proposition. Henri Martin, Marc DeKnijf (Technical service), Michel Van Camp and Kris Vanneste gave assistance for the technical aspects

16.5. Partnerships

List of national and international partners

The Crisis Center of the Federal Public Service Home Affairs (Mrs Bernaerts)

Grants used for this research

Nihil

Visitors 8

16.6. Publication

16.6.1. Reports, thesis, etc

Camelbeeck T.

Mise en oeuvre d'une alerte sismique et consolidation de l'expertise pour la prévention des tremblements de terre en Belgique par l'Observatoire Royal de Belgique.
Rapport destiné à la Direction de l'ORB et du SPP Politique Scientifique.

16.7. Missions

Operational meetings (number of days)
Michel Van Camp 1 – Thierry Camelbeeck 1,5 – Kris Vanneste 0,5

17. Operational project « International seismic data exchange »

17.1. Objectives

The international exchange of seismic data has a very long history at the ROB. A large part of the routine work of the section is dedicated to the measurements of arrival times, sense of motion, amplitude and period of ground-motions on the seismograms recorded by the Belgian seismic stations for the earthquakes occurring everywhere in the Earth. The main objective of these measurements is to send them to International Centers (EMSC, NEIS, ISC…) where the data from stations worldwide are analyzed in order to provide catalogue of earthquakes and phase arrival time models.

17.2. Progress and results

In 2003 we developed new procedures to perform the measurements of these seismograms, to include them automatically in the new database and to send them at the Euro-Mediterranean Seismological Center (EMSC). We tried to recover a part of the delay accumulated during the last five years due to lack of personnel. We begun to send the data in time from August 2003, but a large number of gaps remain since 1998. We intend to fill them progressively.
The procedure includes the automatic processing of e-mails from international and other national centers, the interface to enter the measurements in the database and the automatic transformation in the adequate format to send the data to the EMSC.

17.3. Perspective for next years

During the next months, the measurements and the source parameters determined from our data will be also included in the data sent to the EMSC. All our measurements for local, regional or teleseismic events will be directly available via the Internet.

17.4. Personnel involved

Fabienne Collin assumed the responsibility for that operational project. William Vandeputte realized the daily measurements whereas Fabienne Collin begon to measure the data which are late. Henri Martin, William Vandeputte and Frédéric De Vos have developed the procedures.

17.5. Partnerships

List of national and international partners

We send our phase measurements at the EMSC (Euro-mediterranean Seismological Center). We collaborate with the ECGS in Walferdange (GD Luxemburg), KNMI in De Bilt (The Netherlands) and the Bensberg network from the University of Cologne (Germany).

Grants used for this research

Nihil

Visitors

Nihil

17.6. Publications

Nihil

17.7. Missions

Nihil

18. Operational project « Information to the authorities, the public and the media – scientific expertise »

18.1. Objectives

This operational project concerns: a) the information given to the authorities, the public and the medias by the personnel of the section of seismology concerning the seismic activity in Belgium and elsewhere in the world, and b) the scientific and technical expertise given by the scientists of the section on the different aspects of earthquake seismology and earthquake engineering. The objective is to prepare the tools (web site, maps, documents…) that should help us to provide answers to external requests.
Since 1999 we actively participated in a museology activity in the Rochefort cave in co-operation with the Société Anonyme des Grottes de Han.

18.2. Progress and results

The personnel of the section answered to numerous questions from the public or private companies by phone, e-mail and post mail. The scientists gave conferences to the public and provided explanations to the visitors at the ROB.

As usual, answers have been given to the medias, in particular:

- Télévesdre, who visited Membach and Uccle on 19 March and 1st April
- The numerous interviews after the Dec. 26 Bam Earthquake in Iran

- Etc…

The section provides also a detailed scientific expertise to the following companies or public administrations:

- NIRAS-ONDRAF: An important research work has been done concerning the Rauw fault, mainly by the analysis of the trench excavated across the fault. We also provided all the technical information to install two accelerometers in Mol, one at the ground surface, the other one in the experimental gallery drilled in the clays for studying the impact of radioactive waste deposits. The ROB will be responsible for the maintenance of the equipments and the analysis of the data.
- TRACTEBEL: In the context of the re-evaluation of the safety of the Belgian nuclear power station, Tractebel has to conduct an investigation on the new data published since 1982 concerning the seismic activity in our regions. We provided a new catalogue of earthquakes located at less than 300 km of Doel and Tihange. We also prepared a complete report including all the published information about the strongest earthquakes having affected our regions since 1382.
- FLUXIS: We conducted a seismotectonic study for the terminal Zeebrugge, evaluating the SSE and OBE levels.
- FRENCH MINISTERY OF EQUIPMENT: As international expert, Thierry Camelbeeck, who reviewed for the IRSN (Institut de radioprotection et de sûreté nucléaire français) the new seismic zoning in France, participated in Paris in a general discussion on Eurocode-8.
- MET (Région Wallonne) : We have been co-operating with the MET for a long time. We kept on sending to the "Service des Barrages" in Verviers a quasi real-time information concerning the large earthquakes in the world which could have perturbated their instruments in the dams of La Gileppe and Eupen.
- GUY CARPENTER: We cooperated with this Company in the evaluation of the seismic risk for insurance companies.
- EUROCODE-8 Committee: We participated in this committee that defines the parameters to introduce in the Belgian Application Document of the paraseismic European code.
- FONDS DES CALAMITES: We have been consulted about the criteria to use to determine when an earthquake is a natural calamity or not.

18.3. Perspective for next years

The web site of the section seismology will be improved to give a better insight of the different activities of the section and to provide basic knowledge in seismology, on the seismic activity in our regions and elsewhere in the world and on the earthquakes that occurred in Belgium. In addition to these improved web pages, the public should get a partial access to our databases.

18.4. Personnel involved

All the persons of the section are involved in this task.

18.5. Partnerships

List of national and international partners: Nihil

Grants used for this research; Nihil

Many visitors

18.6. Publications

18.6.1. Reports, thesis, etc

Camelbeeck T.

Seismotectonic study for the terminal Zeebrugge – SSE and OBE levels
Confidential report for S.A. FLUXIS LNG NV, 36 pages + 5 appendixes

Camelbeeck T.

Catalogue of earthquakes having occurred at less than 300 km from Doel and Tihange – Compilation of the published information for the strongest earthquakes in our regions since 1382
Confidential report for S.A. TRACTEBEL

18.7. Missions

Operational meetings (number of days)
Michel Van Camp 2 – Thierry Camelbeeck – Kris Vanneste

Field missions (number of days)
Michel Van Camp 2 - Thierry Camelbeeck 12.5 – Kris Vanneste

DEPARTMENT 1: Reference Systems and Geodynamics

SECTION 3: Earth Tides and Gravimetry

19. Global and Regional Earth Tides Studies

19.1. Objectives

Interpretation of global Earth tides observations with emphasis on the fine spectrum of the tidal waves, the determination of the liquid core resonance effect (NDFW) in the diurnal spectrum and the detection of the effect of the polar motion on gravity. For that purpose we use principally the global network of superconducting gravimeters (SG), known as Global Geodynamics Project (GGP).
Gravimeters, clinometers and strainmeters are also used to monitor interactions between ground deformation, tidal signals and meteorological parameters.

19.2. Progress and results

We obtained several new results concerning the global response of the Earth to the tidal forces.
We performed a new analysis of 18 years of observations with the Superconducting Gravimeter T003 in Brussels in order to determine the transfer function of the polar motion effects on gravity. The determination of the amplitude factor δ of this "pole tide" is very interesting as it has a 430 days period, far from the other tidal periods. This determination is very difficult due to the weak amplitude of the signal, around $10 nms^{-2}$ peak to peak and the vicinity of the annual period which is perturbed by climatic influences. We obtained a value $\delta = 1.189 \pm 0.017$ in good agreement with the modeling of the oceanic effects at the Chandler period.
We finished an exhaustive study of the GGP network results for the Diurnal (D) and semi-diurnal (SD) waves. We used 11 different oceanic tidal models and evaluated mean corrected factors for 13 D and 9 SD waves, in close agreement with the most recent models of the Earth's response to the tidal forces. We were able to compute the NDFW period in agreement with the most recent results obtained from VLBI observations.
Thanks to the GGP network we performed the first detailed study of the Long Period (LP) spectrum of the tides. We determined the tidal parameters for the main M_f component in 15 stations. A comparison with the tidal oceanic loading evaluation shows that the oceanic models are not so precise for this wave. We were also able to determine for the first time the LP waves derived from the third degree tidal potential although the amplitude of the main constituent with a monthly period reaches only $5 nms^{-2}$ ($0.5\ 10^{-9}$g).
We performed a global analysis of the GGP data bank to show up the inner core translational mode known as "Slichter triplet". Up to now no clear conclusion is possible as well from a theoretical point of view as from the observations. The noise level in the data has improved with the use of a new generation of SG and an harmonic signal at the nanogal level (10^{-12}g) could be detected. One explanation could be that the excitation of the modes is not a permanent one.
Tidal gravity observations allow to study ocean tides attraction and loading effects. Strainmeters and clinometers are used in underground laboratories to study tectonic and tidal deformations of the crust.
We obtained new results from tidal gravity observations concerning the tidal loading effects along the Atlantic coast of France and in Eastern Siberia. The observed tidal factors were compared to 9 different oceanic models. In Eastern Siberia (Khabarovsk station) all the models allow to predict the observed tidal parameters with a RMS errors close to 0.2% and the observations were not able to impose additional constraints. On the Atlantic coast (Chize) however the dispersion of the models reaches 0.5% and the observations will bring additional information.
We analyzed the interactions between temperature and tidal strain observed in the underground laboratory of Protvino, Russia.

We studied the water level fluctuations in deep wells located in the Russian far East.
The results will be presented at the 15th International Symposium on Earth Tides in 2004.

19.3. Perspective for next years

The study of the polar motion effects on gravity will be continued using all the GGP stations with more than 5 years of observation. A possible inner core mode (ICW) with a period close to 6.6 year will be investigated.
With the longest GGP series it will be possible to determine the D and SD waves associated to the lunar perigee (8.847 year) and the lunar node (18.624 year).
The steady improvement of the signal to noise ratio in the SG data should allow the detection of the Slichter modes.
New tidal gravity stations will be installed in Eastern Siberia to continue the study of the interactions between Earth and oceanic tides.

19.4. Personnel involved

B. Ducarme: Research Associate (National Fund for Scientific Research)
L. Vandercoilden: Technician

19.5. Partnerships

List of national and international partners:

- Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan, China - Prof. H. P. Sun
- Institute of Geophysics (UIGGM, SB-RAS), Novosibirsk, Russia - Dr. V. Y. Timofeev
- Geophysical Institute, Bulgarian Academy of Sciences - Prof. A. P. Venedikov

Grants used for this research

- Bilateral Scientific and Technical Cooperation with China: Project "Superconducting Gravimeters observations and Geodynamics", Convention BL/33/C17, 2002-2004
- Bilateral Scientific and Technical Cooperation with Russia: Project "Earth Tidal Observations in Siberia", Convention BL/33/R09, 2002-2004

Visitors: 3

19.6. Publications

19.6.1. Publications with peer system

Ducarme B., Timofeev V., 2002
Activité tectonique et déformation de la croûte dans la région du lac Baïkal
Studii Si Cercetari de Geofizika, Academia Romana, 38, 11-28

19.6.2. Publications without peer system

Timofeev V.Yu, **Ducarme B., van Ruymbeke M.**, Saricheva Y.K., Gribanova E.I.,Revtova E.A., Azdukov D.G., 2002
Experimental tidal models (South Siberia)
Dokladi Akademii Nauk, 382, 2, 250-255

Timofeev V.Yu, **Ducarme B.**, Gornov P.Y., Korchagin F.G., **Everaerts M.**, Zapreeva E.
Tidal variation of gravity and tidal models in the Far East (Zabaikalskoe station)
Proc. "Stress-strain conditions and seismicity of the lithosphere", Irkutsk, 26-29 08 2003, SBRAS-Geo publishing in Novosibirsk, 446-447 (in Russian)

Boyarsky E.A., **Ducarme B.**, Latynina L.A., **Vandercoilden L.**
An attempt to observe the Earth liquid core resonance with extensometers at Protvino Observatory
Bull .Inf. Marées Terrestres 138, 10987-11009

Sun H.P., Xu J.Q., **Ducarme B.**
Search for the translational triplet of the Earth's solid inner core by SG observations at GGP stations
Bull .Inf. Marées Terrestres 138, 10977-10985

19.6.3. Publications in press, submitted

Ducarme B., Venedikov A.P., Arnoso J., Vieira R.
Determination of the long period tidal waves in the GGP superconducting gravity data
Submitted for publication in the GGP special issue of "Jounal of Geodynamics"

Ducarme B., Sun, H.P., Xu, J.Q.
Tidal gravity and tidal loading results from the GGP network
Submitted for publication to "Physics of the Earth and Planetary Interiors"

Jianqiao Xu, Heping Sun, **Ducarme B**.
Global experimental model for gravity tides of the Earth
Submitted for publication in the GGP special issue of "Jounal of Geodynamics"

Ducarme B., van Ruymbeke M., Venedikov A.P., Arnoso J., Vieira R.
Polar motion and non tidal signals in the superconducting gravimeter observations in Brussels.
Submitted for publication to "Physics of the Earth and Planetary Interiors"

19.6.4. Communication, Poster

Ducarme B., H.P.Sun
Tidal gravity and tidal loading results from the GGP network
IUGG General Assembly, Sapporo,Symposium G5,Gravimetric observations and interpretation

J.Q. Xu, H.P. Sun, **Ducarme B**.
Product spectral density of the tidal gravity data observed with global superconducting gravimeters at GGP stations: a search for the inner core translation triplet
IUGG General Assembly, Sapporo, Symposium JSS06, Earth structure and Geodynamics

Ducarme B., van Ruymbeke M., Venedikov A.P., J.Arnoso J., Vieira R.
Polar motion and non-tidal signals in the superconducting gravimeter observations in Brussels
IUGG General Assembly, Symposium G5,Gravimetric observations and interpretation

19.7. Missions

30/06-11/07/03: 23ème General Assembly of the International Union of Geodesy and Geophysics (IUGG) (3contributions), Sapporo, Japan

20. The International Center for Earth Tides

20.1. Objectives

The International Center for Earth Tides is a FAGS and IAG Service, included inside the International Gravity Field Service (IGFS). The Royal Observatory of Belgium (ROB) is hosting ICET since 1958.
The terms of reference of the International Centre for Earth Tides(ICET) are the following:

- to collect all available measurements on Earth tides as World Data Centre C,;
- to evaluate these data by convenient methods of analysis in order to reduce the very large amount of measurements to a limited number of parameters which should contain all the desired and needed geophysical information;

- to compare the data from different instruments and different stations distributed all over the world, evaluate their precision and accuracy from the point of view of internal errors as well as external errors;
- to build a data bank allowing immediate and easy comparison of earth tides parameters with different Earth models and other geodetic and geophysical parameters ;
- to ensure a broad diffusion of the results and information to all interested laboratories and individual scientists.

20.2. Progress and results

Since 1997 the ROB and ICET are responsible of the "Global Geodynamics Project-Information System and Data Centre" (GGP-ISDC, http://etggp.oma.be/). The data owners can upload themselves the original minute sampled data. The data are carefully preprocessed at ICET using a standard procedure, to correct for tares and spikes. The data are then decimated to one hour and analysed. The analysis results are directly communicated to the data owners. This follow up is required to detect quickly the anomalies that could affect the data. Each year CD-ROM's are edited with the raw and corrected minute data as well as the log files and the auxiliary data, when available. In 2003 we edited the CD-ROM's ETGGP#5 and ETGGP#5a with the data from July 2001 till June 2002.

The "Bulletin d'Information des Marées Terrestres"(BIM) n° 138 was printed in 300 copies. Some 275 copies are sent to libraries and individual scientists all over the world. It is devoted to scientific papers concerning tidal research..

ICET contributed to the publication by the "Bureau Gravimétrique International" of a CD-ROM (ISBN: 92-990017-07) collecting all the teaching material of the summer school "Terrestrial Gravity Data Acquisition Techniques", organized in 2001.

ICET made an agreement with Marion Wenzel, wife of late Prof.H.G.Wenzel, who inherited the property rights on the ETERNA tidal analysis and prediction software. ICET is authorized to distribute freely this software among the scientific community for non commercial purposes. This initiative met a great success as some forty CD-ROMS with ETERNA software were requested from ICET in 2003.

The ICET WEB site (http://www.astro.oma.be/ICET/) has been updated and developed. Besides general information including historical aspect and last ICET reports, it proposes to the visitors an access to:

- the general bibliography on Earth Tides from 1870-1997 either by alphabetical order of the first author or following the decimal classification introduced by Prof. P.Melchior;
- the table of content of all the BIM issues, and starting from BIM 133 an electronic version of the papers;
- tidal analysis and preprocessing software available from different WEB sites or on request from ICET.

ICET welcomed in 2003 four guest scientists or trainees: Prof. A.P.Venedikov, Mr. M. Harrop (Open University, UK) as well as Dr. V.Timofeev and Mrs. E.Zapreeva(Institute of Geophysics, UIGGM, Novosibirk, Russia).

Prof. A.P. Venedikov worked during one month at ICET (August 1-29) to apply his tidal analysis techniques to the determination of the long period tidal waves and of the polar motion effect from the GGP data bank. Several papers have been prepared.

Mr. M. Harrop came one week (September 8-12) to receive intensive training on earth tide data processing and analysis.

Dr. V.Timofeev and Mrs. E.Zapreeva stayed 7 weeks from November 3 to December 19 for the analysis of the tidal records obtained in several stations in Eastern Siberia. Several communications have been prepared for the 15thInternational Symposium on Earth Tides (Ottawa, August 2004). Mrs. Zapreeva got also a training in tidal data preprocessing and analysis.

The ICET Director took part to the "International Seminary on the Applications of the Computer Program VAV-03 for Tidal Data Processing" organised in Madrid from October 21 to 24 by the "Instituto de Astronomia y Geodesia" (CSIC-UCM). He presented two lectures. A CD-ROM will be edited.

20.3. Perspective for next years

In 2003 the maintenance of the GGP Data Centre was transferred from the ROB to the GeoForschungsZentrum Potsdam (D), but ICET will still assume the scientific responsibility by evaluating the data and preparing derived products.
ICET will continue to perform the tasks corresponding to its terms of reference, essentially by the diffusion of information and software, the scientific responsibility of the GGP data bank, the data processing, the training of young scientists and the welcome of visiting scientists.
The Center will continue to develop its WEB site. The content of its data bank will progressively become available on the net.

20.4. Personnel involved

B. Ducarme: Research Associate (National Fund for Scientific Research)
L. Vandercoilden: Technician
M. Hendrickx: Technician

20.5. Partnerships

List of national and international partners:

- Bureau Gravimétrique International (BGI) - Prof. J. P. Barriot
- International Geoid service (IGeS) - Prof. F. Sanso
- Global geodynamics Project (GGP) - Prof. D. Crossley
- Instituto de Astronomia y Geodesia (CSIC-UCM), Madrid - Prof. R. Vieira

Grants:

Federation of Astronomical and Geophysical Centers (FAGS)

Visitors: 4

20.6. Publications

20.6.1. Publications with peer system

20.6.2. Publications without peer system

Barriot J.-P., **Ducarme B**
Summer school "Terrestrial Gravity Data Acquisition Techniques"
CD-ROM (ISBN: 92-990017-07) Bureau Gravimétrique International

Ducarme B., Vandercoilden L.
Global Geodynamics Project: CD-ROM ETGGP #5
International Centre for Earth Tides

Ducarme B., Vandercoilden L.
Global Geodynamics Project: CD-ROM ETGGP #5A
International Centre for Earth Tides

20.7. Missions

30/06-11/07/03: 23ème General Assembly of the International Union of Geodesy and Geophysics (IUGG) (3contributions), Sapporo, Japan

21-24/10/03: International Seminary on the Applications of the Computer Program VAV-03 for Tidal Data Processing, Madrid, "Instituto de Astronomia y Geodesia" (CSIC-UCM)

21. Research project « Hydrological effects on gravity »

21.1. Objectives

This project aims at a better understanding of ground water variation effects on gravity measurements performed at the Membach, Jülich and CERGA stations.

21.2. Progress and results

Absolute (AG) and superconducting (SG) gravity measurements have been performed since 1996 at the underground Membach Station (Ardenne, eastern Belgium). Two effects can be distinguished: a seasonal-like one and a long-term geophysical trend.
The first effect is a 5 µGal seasonal-like term most probably and mainly due to hydrological variations. To determine the thickness of the porous unconsolidated layer covering the fissured bed-rock (low-porosity argillaceous sandstone with quartzitic beds) through which the tunnel was excavated, geophysical prospecting has been undertaken above the Membach station. This shows that the thickness of the weathered zone covering the bedrock can be highly variable between zero and 10 meters (possibly due to palaeo mudflows linked to periglacial conditions in the area). This leads to highly variable (in space) saturation capacity of the subsoil above the gallery. The extensive geological researches will allow us to correct the gravity variations induced by the variable mass of water stored in the shallow partially saturated soil. This work can be essential to correct local effects that can mask regional effects such as changes in continental water storage. Local effects, indeed, could prevent the combination of satellite data (e.g. GRACE) with ground-based gravity measurements. On the other hand, studying the local seasonal variations also contributes to investigate the influence of the water storage variations in small river basins on the time dependent gravity field.
After tests and calibration control performed at the RMI, an automatic pluviometer was installed at the Membach station in April 2003.
Since October 2000, AG measurements have been performed twice a year at the Jülich Research Centre close to two opencast brown coal mines. To prevent the mines from being flooded, continuous water pumping has been carried out for 50 years, causing a subsidence of more than 1 cm/yr. Today, we observe a trend of +3.7±1.3 µGal/year, which can be interpreted as a subsidence of -1.8±0.7 cm/yr, comparable to the values obtained by the mining company by repeated levellings and GPS measurements.

21.3. Perspective for next years

- Membach: together with A. Dassargues and M. Vanclooster we plan to install humidity probes above the Membach station and to establish models of the ground water variation effects.
- Jülich: assuming that the seasonal effects are the same each year, other effects being equal, we should be able to confirm the gravity rate of change at the 95% confidence level at the end of 2004, and at the 99% level one year later. The AG Jülich observations are a long-term project and will get an insight into mass redistribution phenomena related to gradual surface subsidence.
- CERGA: together with E. Gilli, we will investigate the ground water effects on the gravity in karstic plateau of the CERGA observatory.

21.4. Personnel involved

Michel Van Camp is the main investigator for this project. Kris Vanneste, Koen Verbeeck and Toon Petermans participate in the project by the realisation of electric tomography profiles. M. Hendrickx, S. Castelein and M. De Knijf maintain the SG.

21.5. Partnerships

At the Membach station, we are collaborating with A. Dassargues (ULg/KUL) and M. Vanclooster (UCL). The rain measurements are performed in collaboration with M. Vandiepenbeeck (RMI, Uccle).

21.6. Publications

21.6.1. Publications with peer system

Van Camp, M.

Man-induced subsidence in Jülich observed by the FG5#202 absolute gravimeter in a noisy environ ment

Proceedings of the workshop: IMG-2002 Instrumentation and Metrology in Gravimetry, Cahiers du Centre Européen de Géodynamique et de Séismologie, Luxembourg, 22, 2003.

21.6.2. Publications without peer system

Nihil

21.6.3. Publications in press, submitted

Francis, O., **Van Camp, M.**, van Dam T., **Warnant R. and Hendrickx M.**

Indication of the uplift of the Ardenne in long term gravity variations in Membach (Belgium)

Accepted by Geophys. J. Int., 2004.

21.6.4. Reports, thesis

Michel Van Camp was member of the Jury of the master thesis: "Caractéristique de la géologie, de la géomorphologie et de l'hydrogéologie du site de la station géophysique de Membach", by Olivier Crommen, University of Liège, Sept. 2003.

21.7. Missions

Research missions (number of days)
For Michel Van Camp, see research project 6

22. Opertional project « Maintaining high precision standards in gravity measurements »

22.1. Objectives

The ROB has a long tradition in gravity measurements and provides a wide expertise to the international geophysical community.
The ROB absolute gravimeter (AG) FG5-202 participates in numerous intercomparison campaigns with other AGs, as well as in calibrating and controlling relative gravimeters.
The ROB cryogenic superconducting gravimeter (SG) CO21 provides continuous gravity recordings at the Membach station. SG and AG are quite complementary: 1) AG calibrates the SG; 2) SG controls mid-term stability of AG; 3) the SG long-term drift is estimated by AG.
Since 1997 the SG of Membach participates in the Global Geodynamics Project (GGP) data base, available on the internet.
We also answer numerous questions and provide Tsoft, free interactive software for time series and Earth tides available on the ROB web site.

22.2. Progress and results

22.2.1. Absolute gravimetry, calibration

Intercomparaisons of AGs provide the most accurate reference in gravity standards. At request of the ECGS, the Fg5-202 of the ROB was compared to the German Fg5-301 and the Luxemburg Fg5-216 in March 2003 and to the French Fg5-206 and the Fg5-216 in June 2003. After a proposition from the ROB and METAS, an international comparison of AGs took place in the Walferdange ECGS laboratory in November 2003. Our Fg5-202 has stood the proof of time and confirmed its reputation of good stability in its measurements at the µGal level.
The ROB AG also measured the gravity at the Nice Observatory in May and November to control the calibration line Nice-Calern.

22.2.2. The superconducting gravimeter

The SG CO21, purchased by the ROB in 1995, has been providing continuous gravity recordings at the Membach station. SG and AG are quite complementary, especially to control the mid-term stability of the AG. The SG is a key-instrument for the Research Project #6 (crustal deformation) and #7 (hydrology). In the framework of the GGP project, the SG is also used for the study of the Earth's normal modes, solid Earth tides and Ocean loading effects.
Finally, the SG is used to check the calibration and the stability of spring gravimeters: the calibration of the ROB Scintrex relative gravimeter was checked in Membach from 2003 Sept. 30 to Oct. 27, in order to ensure the reliability of the vertical gravity gradient measurements performed at the Walferdange ECGS laboratory in the framework of the international comparison of AGs.
The Scintrex gravimeter from METAS (Metrology and Accreditation Switzerland) was being tested and adjusted at the Membach station since December 17 and in the first months of 2004.

22.2.3. TSoft

As every year, improvements have been implemented to that software dedicated to time series analysis, and answers have been provided regularly to numerous questions from Tsoft users.

22.3. Perspective for next years

As the absolute determination of the gravity is essential in geophysics and metrology, new intercomparison campaigns will take place, on a yearly basis at least. In particular, we plan to continue our collaboration with METAS, which is involved in the mass redefinition project.
To ensure the good working of the SG, we plan to renew the data acquisition system at the Membach station.
As SGs are now considered as good low-frequency seismometers, we will develop contacts with seismological international data centre (ORFEUS).
Finally we will continue to develop Tsoft and provide information to the public.

22.4. Personnel involved

R. Verbeiren is the SG titular responsible scientist.
The SG was maintained by M. Hendrickx, M. De Knijf, S. Castelein and M. Everaerts (operations on the compressor and/or liquid Helium refilling). M. Hendrickx and S. Castelein carefully perform the daily remote checking of the SG. M. Van Camp conducted the AG measurements, participated in the general maintenance of the station, measured the vertical gradients and with the help of M. Hendrickx, checked the Scintrex gravimeters.

22.5. Partnerships

List of national and international partners

- BIPM, Sèvres, F (Dr. L. Vitushkin)

- BKG, Frankfurt-a-M. (Dr. R. Falk, Dr. H. Wilmes)
- ECGS, Walferdange, L (Prof. O. Francis)
- EOST, Strasbourg, F (Dr. J. Hinderer, Dr. M. Amalvict)
- METAS, Bern, CH (Dr. P. Richard)
- POL, Liverpool, UK (Dr. S.D.P. Williams, Prof. T. Baker)

22.6. Publications

22.6.1. Publications with peer system

Van Camp, M., Richard, P., Hinderer, J., Amalvict, M., Falk, R., Luck, B., **Hendrickx, M.** and Thies, S.
Intercomparisons of the FG5-101, 202, 206 and 209 absolute gravimeters at four different sites
Proceedings of the workshop: IMG-2002 Instrumentation and Metrology in Gravimetry, Cahiers du Centre Européen de Géodynamique et de Séismologie, Luxembourg, 22, 65-73, 2003.

Van Camp, M.
Efficiency of tidal corrections on absolute gravity measurements
Proceedings of the workshop: IMG-2002 Instrumentation and Metrology in Gravimetry, Cahiers du Centre Européen de Géodynamique et de Séismologie, Luxembourg, 22, 99-103, 2003.

22.6.2. Publications without peer system

Van Camp, M. and Camelbeeck, T.
On the accuracy and precision of a FG5 absolute gravimeter
Proceedings of the 1st Workshop on International Gravity field research, Graz, Austria, May 8-9, 2003 (extended abstract).

Van Camp, M., Camelbeeck, T., Richard, P.
The FG5 absolute gravimeter: metrology and Geophysics.
Physicalia Magazine (Journal of the Belgian Physical Society), 25 (3), pp 161-174, 2003.

22.6.3. Publications in press, submitted

Van Camp, M. and Vauterin P.
Tsoft: graphical and interactive software for the analysis of time series and Earth tide
Submitted to Computers and Geosciences, 2004.

22.6.4. Reports, thesis

Nihil

23. Gravity Field Monitoring in Belgium

23.1. Objectives

Study of the gravity field in connection with the geoid's computation and the determination of the tectonic structures. Monitoring of long term gravity changes by field gravity observations.

23.2. Progress and results

This year the main activity has been the preparation of the data and the computation of a new gravimetric geoid BG03. The gravity data measured in October and December 2002 have been validated and integrated in Belgian gravity data bank. The new covered zone is the northern part of the Kempen (2000km²) and the western part of West-Flandrers. Those data represent a total of 3304 new gravity points.
The geoid is now improved due to three main effects

The use of a complete coverage for the country of the gravity data (data from 96 to 2002).
The use of a new geopotential model (GPM98CR) complete up to degree 720
The use of bathymetric data for the sea area
The new geoid has been adapted to the 21 points GPS of the network BEREF, (It still has to be adapted to the 6000 levelled GPS points from the NGI to obtain the correction surface for the GPS users).
A second research axis has been to continue to interpret the gravity and magnetic anomaly to better understand the tectonic settings for different areas (see publications)
The Belgian Gravity Base Network has been updated and the publication on CD-ROM of its final version (BLGBN03) was finalized.
In 2003 we started the observations of a high precision gravity network in the East of Belgium in the framework of the HARD project for the GPS monitoring of ground motion in the Ardennes-Eifel massive. We want to determine which gravity changes could be associated with an eventual vertical ground motion in ten GPS sites. We performed two campaigns one in spring an one in autumn to detect seasonal effects associated with the water table variations. The simultaneous use of 2 gravimeters allows to get a precision better than 5µgal (50 nms^{-2}).

23.3. Perspective for next years

Continuation of the analysis of the gravity and magnetic anomalies for Belgium and the surrounding countries Continuation of the collaboration with different Belgian and foreign universities and institutions.
In 2004 we plan to continue our gravity monitoring of the 10 GPS sites of the HARD project. We plan to include progressively the permanent GPS sites of the WALCORS network inside the BLGBN network as these sites become fundamental geodetic reference points.

23.4. Personnel involved

M. Everaerts: Senior Scientist
B. Ducarme: Research Associate (National Fund for Scientific Research)

23.5. Partnerships

Belgian Partnerships

- Belgian National Geographic Institute, Geodesy Department - Ph. Lambot
- Dept. of Physical Geography and Quaternary, University of Liège - Prof. A. Demoulin
- Service Géologique de Belgique (SGB), département of l'Institut royal de Sciences Naturelles de Belgique - Dr Piet Laga (chef de Section), Dr W. De Vos
- Université de Louvain-la-Neuve - Prof D. Laduron
- Université Libre de Bruxelles - Prof A. Herbosch
- Departement of geology University of Liège - Prof Poty
- Facultés Polytechniques de Mons - Dr M. Hennebert
- Ghent Universiteit - Prof J. Verniers
- Katolieke Universiteit Leuven - Prof N. Van Den Berghe, Prof M. Sintubin

International Partnerships

- Musée National d'Histoire Naturelle du Grand Duché de Luxembourg (MNHN) - Dr Simon Philippo
- Dept. Physics, University of Luxemburg - Prof. T.Kies
- Université de Lille (UFTL) - Prof. J.-L. Mansy, Prof B. Van Vliet-Lanoë
- Institut de Physique du Globe de Paris - Prof A. Galdeano
- Bureau Gravimétrique International - Prof J-P Barriot
- Le Bureau de Recherche Géologique et Minière en France - Dr F. Hannot, G. Martelet
- International Geoid service (IGeS) - Prof. R. Barzaghi

- British Geological Survey - Dr T. Pharaho
- University of Greenwich - Prof G. Manby
- Commission Géologique du Canada - Dr P. Keating.
- GFZ Potsdam - Dr J. Lamarche
- l'University of Karlsruhe - Prof. W. Fielitz

23.6. Publications

23.6.1. Publications with peer system

Mansy J-L., Manby G.M., Averbusch O., **Everaerts M.**, Bergerat F., Van Vliet Lanoë B., Lamarche J.
Role of Basement reactivation in the formation and inversion of the Weald Boulonnais basis
Tectonophysics. 2003 vol 373 isue 1-4 pp161-179

Bornain S., Kies A., **Everaerts M.**
Mise en évidence de failles à l'aide de la magnétométrie et de la radiométrie dans la région de Stolzembourg, Eislek, Grand Duché de Luxembourg
Geologica Belgica. (2003) 6/1-2 pp25-30

Verniers J., Pharaoh, T., André l., Debacker T., De Vos W., **Everaerts M.**, Herbosch A., Samuelsson J., Sintubin M., Vercoli M.
The Cambrian to mid Devonian basin development and deformation history of eastern Avalonia east of Midlands Microcraton new data and review.
Geological Magazine (special volume on the caledonides 201) 2002 pp 47-93

Sintubin M. and **Everaerts M.**
A compressional wedge Model for the lower Paléozoic Anglo-brabant
Geological Magazine (special volume on the caledonides 201) 2002 pp 327-343

Barzaghi R., Borghi A., **Ducarme B., Everaerts M.**
Quasi-geoid BG03 computation in Belgium
Newton's Bulletin, Bureau Gravimétrique International-International Geoid Service, 1, 75-88

23.6.2. Publications without peer system

Everaerts M., Lambot Ph., **Van Hoolst T., van Ruymbeke M., Ducarme B.**
First Order Gravity Network of Belgium
INCT, Alger, Bulletin des Sciences Géographiques, 11, 2-10.

23.6.3. Publications in press, submitted

Minguely B., Mansy J-L., **Everaerts M**., Mamby G. M.
Apport de la modèlisation gravimètrique et magnétique pour la compréhension de la structure du détroit du Pas-de-Calais données géophysique pour la comprehension de l'évolution géodynamique du Pas de Calais
submitted Acad. Sci (Paris)

23.6.4. Reports, thesis, etc

Thesis presented in 2003 (28/10) by **Steve Bornain** at the UCL
La tectonique cassante dans le région de Stolzembourg (Grand Duché du Luxembourg) à la lumière de données géophysiques (gravimétrie, magnétisme, spectrométrie gamma et émanométrie radon)
Thesis done in collaboration with the ROB

23.6.5. Communication, Poster

Everaerts M.

Un exemple de levé gravimétrique au Grand-Duché du Luxembourg
Réunion des collaborateurs scientifique du Grand Duché de Luxembourg à Mondorf, 22 mars 2003 (communication)

Bornain S., **Everaerts M.**
A study of fault system using geomagnetic measurements and radon emanation in Stolzembourg's area, Eislek, Grand Duchy of Luxemburg
EGS Nice (6-11 avril) Poster

23.7. Missions

Field measurements in the framework of the HARD project (2 persons, 9 days)
Field measurements with MNHN (5 days)
Field measurements with T. Kies (3 days)
1 week at the "Politecnico, Milano" for the computation of the Belgian geoid
30/06-11/07/03: 23ème General Assembly of the International Union of Geodesy and Geophysics (IUGG) (3contributions), Sapporo, Japan

24. Metrology in Gravitation

24.1. Objectives

We want to apply our metrological electrical expertise from our Earth-tides instrumentation to design an adapted gravitational balance to record the long-term modulation of the value of G in an underground site. The technical problems arising from the use of such tools are simulated with a laboratory prototype, based on a horizontal pendulum.

24.2. Progress and results

We have built a horizontal pendulum with electrostatic feedback, such that the gravitational forces acting on the pendulum can be measured. Large masses are supported either side of the pendulum. The gravitational force induced by the motion of the masses can be measured after calibration by two independent means. Firstly it can be determined from a vector diagram, knowing only the angle of deviation and length of the pendulum, and the effect of the earth's gravitational field on the pendulum mass. Secondly we can use an electrostatic force generated by voltage applied between two plates of a capacitance. These two independent processes should give a complementary result. We are currently addressing the practical problems, which arise during the construction and implementation of such a system.

24.3. Perspective for next years

From this expertise we are proposing the development, in an underground site, of a long vertical twin pendulum capable of measuring the universal gravitational constant, G, using pendulum masses as heavy as proves to be possible. The effect of G will be determined by moving a third large independent mass between the two pendulums. By directly monitoring the differential motion of one of the pendulum compared to the other, we will be able to determine the gravitational induction. An electrostatic feed-back loop will be used to keep the distance between the twin pendulum constant; with this proposition, the gravitational effect would then be the only registered effect. The metrological validation of the pendulums will be achieved with a very complex signal record like earth tides. Thus it will be possible to adjust, with a high degree of accuracy, the pendulums and achieve a perfect rejection of common noise. This will confirm the limit of precision of the instrument.,

24.4. Personnel involved

- **M. van Ruymbeke** manages the gravitational balance project

- **S. Naslin** and **E. Pütz** have contributed to the design and implementation of the prototype of the gravitational balance.
- **Mme G.Tuts** has prepared the material for a paper including the different questions concerning the project.
- **Fr. Renders** produces mechanical equipment for the laboratory. He builds the mechanical prototypes and helps with their installation.
- **Liu Shaoming** prepared, during his stay of three months at the ROB, a paper concerning gravitational effects occurring during a solar eclipse.

24.5. Partnerships

Visitors :3

24.6. Publications

24.6.1. Publications with peer system

24.6.2. Publications without peer system

van Ruymbeke M., Shaoming Liu, Mansinha L. & Meurers B.
Search for the Gravitational Absorption Effect using spring and super-conducting gravimeters during the total solar eclipse of August 11,1999.
Bulletin Information des Marées Terrestres, (2003) N°138, pp. 10967-10976

25. Karstic caves Research

25.1. Objectives

We continue to develop systems dedicated to providing a multi parameter approach for the study of changes in a cave environment and to provide a useful analysis method in the recovery of tectonic, climatic and earth-tide signatures on weak signals in a noisy environment. This includes the use and development of novel sensors and data treatment systems (MGR and HICUM software), all of which have been developed at the Royal Observatory of Belgium (ROB).

25.2. Progress and results

Description of tectonic aspects is included in the Dep. 1-Sect.2 Research report 5: **Tectonic activity in natural caves.**
A case study in the Ramioul cave in Belgium, has demonstrated the potential of monitoring movements in a cave in order to predict rock collapse in a nearby quarry. This work indicates that caves can be good 'sensors' for stresses similar to those appearing in tectonics plates.
A laboratory dedicated to the monitoring of geophysical parameters has been set up in the karstic network of the Rochefort caves in Belgium. The instruments used for this work include; drop meters, extensometers, and atmospheric pressure, temperature and light intensity sensors. All of which have been developed at the ROB. The high precision reached by these systems has allowed us to evaluate the effects induced by environmental, seismic, tectonic variations, or other sources. Special attention has also been paid to the permanent monitoring of water-flow. We have considered both the effects of water on other parameters and the origins of the changing flow rate.
The sensors developed at the ROB have proved to be capable of detecting modulations in air pressure, temperature and strain due to earth tides with a high degree of accuracy. The use of EDAS has provided the means for the continuous monitoring of these parameters and sufficient data for their analysis by the stacking method HiCum. Using HiCum, we have compared the signature for the different parameters on S1, S2 and M2 periods. The experiments have demonstrated that the complement of tools developed at the ROB can be used in the monitoring of tectonic movements in caves. The results have also

demonstrated that, whilst caves are a good location for detecting small changes, a multi-parameter approach is essential for the sensible interpretation of results. In addition the air temperature and rock temperature have been found to display different signals, which demonstrate the high dependency of parameters on precise location. This approach has increased our understanding of the mechanisms at work and has enabled us to make a number of tentative hypotheses.
The laboratory has also collaborated at an international level with work in the Villars caves in France and the IRD Brasilia project in Brazil.

25.3. Perspective for next years

Rochefort is in an area of low tectonic activity; further studies should now be carried out using these sensors at sites of greater tectonic activity in order to understand the transfer function. If a link between plate movement and water flow can be established, then water flow monitoring could be a useful tool in the prediction of catastrophic events. Our early results indicate that a connection does exist but caution must be exercised with the drop meters, as the HiCum method depends on a wealth of records for its accuracy and with only hourly records we are working at the limits of accuracy of the methodology. More data is therefore required to confirm this and the further development of water flow monitoring equipment is probably required in order to achieve this.

25.4. Personnel involved

M. van Ruymbeke manages the tasks dedicated to the maintenance of the Rochefort and Ramioul caves. He has supported international projects in the karstic domain in the island of Soqotra (Yemen), in the Villars cave (France) and in caves in Brazil. These projects meet the need to improve the understanding of the processes observed and to gain new paleo-tectonic and paleo-climatologic knowledge.

- **Mr. E. de Kerchove** manages the collection of data from Rochefort and Ramioul caves in a standardized data bank ready for theoretical analysis.
- **Mrs R. Howard** participates in the data treatment of cave records and contributes to the discussion and analysis of our studies on the monitoring of water flow in karst like tectonic hazards for use as a forecasting signature.
- **Mr Liu Shaoming** participated, during his stay of three months at the ROB, to a general discussion and analysis of our studies on the monitoring of a karstic medium to detect the possibility of finding tectonic precursors. A paper is under preparation on this topic.

25.5. Partnerships

- Dept. of Geology, Vrije Universiteit Brussel – Prof. Verheyden Sophie, De Geest Peter
- Faculté Polytechnique de Mons - Prof. Yves Quinif, Prof. Jean-Pierre Tsibangu
- IRD Institut de Recherche pour le Développement, Brasilia, BRASIL - Dr Francis Sondag
- Univ. Paris-Sud, Lab.d'Hydrologie et de Géochimie Isotopique, Orsay - Dr Dominique GENTY

25.6. Publications

25.6.1. Publications with peer system

Sondag Fr., **van Ruymbeke M.**, Soubiès Fr., Santos R., **Somerhausen A**., Seidel A. & Boggiani P.
Monitoring present day climatic conditions in tropical caves using an Environmental Data Acquisition System (EDAS)
Journal of Hydrology, 273 (2003) 103-118

25.6.2. Publications without peer system

25.6.3. Publications in press, submitted

Tsibangu J.-P., **van Ruymbeke M.**, Vandycke, S.,Quinif, Y., Camelbeeck, T.
Studying underground motions in the Ramioul's cave – Belgium
Submitted to European Regional Conference of the International Association of Engineering Geology and the Environment (IAEG) will be held in Liège (Belgium) from 4th to 7th May 2004

25.7. Missions

Missions for the maintenance of Rochefort and Ramioul caves.

26. "The expanding use of EDAS for geodynamical projects"

26.1. Objectives

We are continuing to expand the use of EDAS by developing additional electronic instruments with resistive and capacitive transducers, in order to provide a series of tools operating on standard supplies and compatible with EDAS concept. In addition MGR software is being developed to be more user friendly and accessible and the use of HiCum is being actively promoted. This work is being done in conjunction with a diverse range of projects.

26.2. Progress and results

The implementation of the EDAS concept is continuing with the development of the laboratory at ROB. The EDAS laboratory was transferred to a new site within ROB and was completely reorganized to provide a laboratory to develop instruments, a stock room, a library, an area for meetings and seminars and a new suite of workstations, complete with computers.
A series of experiments using EDAS are in progress in the boreholes of the laboratory in Brussels, completed with climatic and gravimetric monitoring.
Of particular interest are areas where there is a risk of tectonic, volcanic or seismic movement.
To this end we have collaborated with work at different locations.
At Rochefort and Ramioul Caves (Belgium), a series of systems have been built to monitor and to test the principles involved where a multi-parameter approach is required for the study of geophysical phenomenon. Seismic aspects are considered from the various monitoring tools.
We apply EDAS for instruments prototyping and geophysical monitoring purposes at the three sites of Lanzarote Geodynamical Laboratories in collaboration with Pr Ricardo Vieira (Instituto de Astronomía y Geodesia (CSIC-UCM) and with Pr Ramon Ortiz (Depart.de Volcanologia, Museo Nacional de Ciencias Naturales, Madrid).
A data bank with series of more than ten years records is permanently completed.
The MGR software developed with François Beauducel (Observatoire volcanologique et Sismologique de Guadeloupe- Institut de Physique du Globe de Paris) is being adapted to provide a user-friendly interface and the means whereby data can be sent across the Internet to and from a remote site. A program has also been included to provide synthetic data for the validation of HICum.
HiCum has been used to highlight the effect of Earth tides and climatic oscillations on a variety of parameters. Validation of HiCum has been carried out and a paper including this and notes on the HiCum procedure has been published.

26.3. Perspective for next years

The EDAS concept furnishes software and hardware including didactic tools adapted to scientists without technical background. The main objective for 2004 consists to complete existing systems to reach a more effective autonomy of users. The first international "CURSO EDAS" will be organized in May, 2004 with the support of the "Cabildo de Lanzarote" in the meeting rooms of Casa de los Volcanes located in the

Jameos del Agua. The EDAS laboratory is engaged in the Preparation of material for this targeted educational course including different aspects of the EDAS concept, in order to train new users in the process and to encourage the use of EDAS in an even wider range of projects. New abroad partners could be included in the management required to reach such goal.
We plan to continue to develop a new low-power data logging system (picoDAS), which will used in remote sites where the life of the battery needs to be extended.

26.4. Personnel involved

- **M. van Ruymbeke** manages the EDAS laboratory.
- **S. Naslin, E. Pütz** have contributed to the design and implementation of EDAS prototypes.
- **Fr. Renders** produces mechanical equipment for the laboratory. He builds the mechanical prototypes and helps with their installation.
- **Liu Shaoming** participates during his stay of three months at the ROB, to the activities of the laboratory. He focus especially on the application of Rochefort and Ramioul technics to the monitoring of tectonic activity in natural caves
- **E. de Kerchove** manages the collection of data from Rochefort, Ramioul, Brussels and Lanzarote laboratories in a standardised data bank ready for theoretical analysis.
- **R. Howard** has prepared a paper on the Hicum procedure and participates to various tasks of the EDAS laboratory.

26.5. Partnerships

We establish an exchange of experts supported by a bilateral project (Reference BL33C23) with the Wuhan Institute of Seismology belonging the China Seismological Bureau, to adapt EDAS to natural disaster problems.
We have also instigated collaboration with the INCT (Institut National de Cartographie et Télédétection) of Algeria, where our instruments are used to study gravimetry and ocean tides in and around Algiers. A prototype of capacitive tide gauge was installed only few hours before the Tsunami earthquake in 2003 and the records have already excited interest in the geodynamic community.
The EDAS laboratory has partnerships to support projects located at Brasilia (Brasil) with Dr Fr. Sondag of IRD (Institut de Recherche pour le Développement -France), Soqotra (Yemen) with Peter De Geest (Dept. of Geology, VUB), Chize (Centre Littoral de Geophysique, Universite de La Rochelle) and at the Villars caves with Dominique GENTY (Laboratoire d'Hydrologie et de Géochimie Isotopique, Université de Paris-Sud). HiCum has been used with Timofeev in a study of the frequency of earthquakes in and around Lake Baikal (Siberia-Russia).

26.6. Publications

26.6.1. Publications with peer system

26.6.2. Publications without peer system

van Ruymbeke M., Chemaa B., Nechimi M., Sayad H. & Howard R.
Enregistrement par un marégraphe prototype, des variations de niveaux de la mer à Alger Durant le séisme du 21 Mai 2003
Bulletin des Sciences Géographiques, INCT N°12, pp 18-21

van Ruymbeke M., Howard R., Pütz E., Beauducel Fr., **Somerhausen A.** & Barriot J-P.
An introduction to the use of HICUM for Signal Analysis
Bulletin Information des Marées Terrestres, (2003) N°138, pp. 10955-10966

26.7. Missions

Maintenance mission to Chizé (France) January, 2-4
Maintenance mission to Lanzarote (Spain) July, 12-28 & October, 18-29
Mission to Algeria May, 19-26

DEPARTMENT 2: Astrometry and Dynamics of Celestial Bodies

SECTION 4: Astrometry and Dynamics of Double and Multiple Stars

27. Research project "Binaries"

27.1. Objectives

Visual binaries allow a direct calibration of the masses on the lower main sequence via the study of their orbital motions. Wide binaries, especially if they have different spectral types, can be used to calibrate the luminosities and temperatures of single stars and to confront evolutionary tracks and models. Differential magnitudes and colours are gathered along with accurate relative positions with the purpose to investigate the physical status, to improve the orbits and to determine the associated properties such as (photometric) mass ratios. Our goal is to investigate a volume-limited sample of visual binary and multiple stars that is as complete as possible. In parallel, work is being done in the context of the scientific preparation of data on binaries (visual double stars) that will be collected by the ESA astrometric mission GAIA.

27.2. Progress and results

27.2.1. Visual binaries

The CCD data of the observational campaigns on nearby visual double stars performed in recent years at Bulgarian observatories have been reduced. The calibrated results for the components of another 40 visual binaries await to be merged with the rest of the data for further analysis. Accurate relative astrometric and differential multi-colour photometric data were also obtained for the components of 31 visual double stars. These programme stars belong to the intersection of the *Catalogue of Nearby Stars* and the *Hipparcos Catalogue* with parallaxes larger than 0.04" (thus forming part of the revised stellar sample of the Solar neighbourhood). Comparing the relative positions at different epochs, we evaluated the physical association of the systems. We derived the component colours, fractional masses and true separations for 19 probable binaries and total (and component) masses for 12 (10) binaries with published orbits [5].

To collect this type of information for the (close) visual binaries with sub-arsecond angular separation, techniques such as Adaptive Optics (AO) or (speckle) interferometry, which allow higher angular resolution, must be used. We developed such a programme in collaboration with Drs. Prieur and Argyle, as well as within a consortium grouping astronomers from 5 European countries which disposes of a speckle camera (PISCO). A proposal for a common, large speckle monitoring programme of close visual binaries (including nearby close visual binaries, spectrum binaries and eclipsing systems with a third, visual companion) with PISCO was introduced, but was not yet granted telescope time. The aim is to derive the positions and colours of the individual components of those binaries which do not fit well the empirical mean mass-luminosity relation, but which have accurate parallaxes (from the Hipparcos mission). First results of AO-observations obtained with a deconvolution method in the NIR passbands were presented for a sample of nearby F-G and K orbital binaries [3]. A paper is in preparation.

27.2.2. Binaries in future astrometric space missions

At first efforts concentrated on the preparation of the data handling and analysis techniques of double stars for the small astrometric mission DIVA, soon to be stopped after the mission was officially cancelled. As the adopted concepts of reduction and data analysis for DIVA had quite some overlap with those of the ESA mission GAIA, a natural continuation of this work was to turn to the scientific preparation of the data on double stars for the astrometric mission GAIA.

A simulated binary star catalogue down to m_v=15 mag was created in accordance with the observed sky distribution of stars. This catalogue was analyzed for observational properties of visual binary stars, both in a general context without taking any observational constraints into account, and using different observability criteria that model the observational performances of the DIVA mission. The results indicate that several observational bias effects should be considered when analyzing the output catalogs. The number of optical pairs that would be observed, was computed. For distant double stars close to the galactic plane and with a large magnitude difference but no parallax measurement, it will be very difficult to discriminate between a red companion and a low-mass foreground/background star [1]. Similar results were also obtained in the preliminary analysis of visual double star observations with GAIA based on a simulated binary star catalogue extended down to the 20th magnitude [4].

When applying the new image combination tool to DIVA or to GAIA, our conclusions were that, at separations of a few arc seconds, the proposed method is efficient and may reveal very faint objects down to G=24 mag and Δm=8. However, close to a bright companion, detection becomes very difficult [2][7]. More elaborate model fitting techniques must then be used.

27.3. Perspective for next years

The acquisition of the component colours for nearby visual binaries and their exploitation will be pursued. The results of the AO-observations made with the ESO 3.6m will be presented. A speckle-interferometry programme for the monitoring of close visual binaries lacking essential astrometric data (e.g. the triple system DG Leo) will be further developed in the context of the PISCO-collaboration, and/or with other teams. The goal is to improve the accuracy on the component masses of many nearby systems. In the frame of a closer cooperation between actual ROB projects, the impact of speckle observations in the young association Sco-Cen will also be evaluated (see project Sco-Cen in report by Dept. III).

Extensions to the proposed image analysis tool for GAIA will include the study of high-density regions and the estimation of the physical parameters of the new objects found in the combined image. A galaxy model that will take the known binary star distributions into account by incorporating a simulated binary star catalogue will be constructed. This catalogue will be compatible with observed sky distribution of stars down to m_v=24 mag. The integration of binary evolution algorithms into the model will allow the detailed study of different binary populations.

27.4. Personnel involved

- P. Lampens, head of Department
- H. Boffin, senior staff member (on leave of absence since 01.04.03)
- P. Nurmi, scientific collaborator on ESA-PRODEX project (01.10.01 – current date)
- D. Duval, hoofdrekenaar

27.5. Partnerships

27.5.1. List of national and international partners

- R. Argyle, Cambridge University, United Kingdom
- F. Arenou, leader of GAIA Double and Multiple Stars Working Group (Observatoire de Paris-Meudon, France)
- A. Brown, leader of Photometric Data Analysis Task within the GAIA Photometry Working Group (Leiden Sterrenwacht, Nederland).
- J.L. Prieur, Université de Midi-Pyrénées, Toulouse, France
- A. Strigachev, Institute of Astronomy, Sofia, Bulgaria

27.5.2. Grants used for this research

- Federal Science Policy grant for project "Multi-colour astrometry and photometry of visual double and multiple stars." (Dr. A. Strigachev)
- ESA - PRODEX Ref. 14847/00/NL/SFe(IC): "*Double Stars: From Hipparcos to GAIA*"

27.5.3. International responsibilities

- Organizing member of IAU Commission 26 "*Double and Multiple Stars*" (P. Lampens)
- Scientific organizing member of IAU 191 Coll. "*The environment and evolution of double and multiple stars"*, Mérida, Mexico, February 3-7, 2004 (P. Lampens)
- Members of GAIA working groups (H. Boffin, P. Nurmi, P. Lampens)

27.5.4. Visitor(s)

2 (1 visiting scientist from January 9 till April 5, 2003)

27.6. Publications

27.6.1. Publications with peer system

[1] **Nurmi, P., Boffin, H. M. J.,** 2003,
Observational properties of visual binaries as modeled using a synthetic catalogue. I. For visual apparent magnitudes $m_v < 15$
A&A 408, 803

27.6.2. Publications without peer system

[2] **Nurmi, P.,** 2003a,
Combining DIVA images: detecting visual binaries with large magnitude differences
JENAM 2002 Conference, Porto, Sept 3-7, 2002, Journal of Astronomical Data 9, 8

27.6.3. Publications in press, submitted

[3] **Lampens,P.,** Prieur, J.L. and Argyle, R. 2003,
Infrared differential photometry of selected orbital binaries
In Rev. Mex. de Astronomía y Astrofísica, IAU 191 Coll. *The environment and evolution of double and multiple stars*, Mérida, México, February 3-7, eds. C. Allen & C. Scarfe, in press

[4] **Nurmi, P.,**2003b,
Observational Properties of Synthetic Visual Binary Catalog
Proc. IAU Coll. 191 , Rev. Mex. A & A, submitted

[5] Strigachev A., **Lampens, P.** 2003,
Multicolour CCD measurements of nearby visual double stars II
A&A, submitted

27.6.4. Reports, thesis, etc

[6] **Lampens, P.**, Strigachev A., 2003,
Multi-colour astrometry and photometry of visual double and multiple stars
Report on Research Project II, Jul 2003

[7] **Nurmi, P.,** 2003c,
Combining GAIA patches. I: SNR calculations of secondary sources in the ideal case for AF11

GAIA technical report DMS-PN-01, 1-15

27.7. Missions

27.7.1. Assemblies, symposia, workshops : 1 (attended by two members)

27.7.2. Commissions, working groups : 4

27.7.3. Field missions : 2

28. Research project "Asteroseismology"

28.1. Objectives

The overall objective of asteroseismology is to probe the internal structure of pulsating stars. To this aim we observe and study the light and spectral variations of pulsating stars of spectral type B-A-F over a time-scale of several seasons and/or years. Specific attention is given to the study of pulsating components of binary or multiple stars, our goals being a) to improve the knowledge of the pulsation(s) by gaining information on the physical parameters of the variable star exploiting the binary or multiple nature of the system and b) to study the interaction pulsation-binarity in short-period pulsators. Since more than 50 percent of all stars are expected to be binaries, understanding the effects of binarity on the pulsation characteristics is of crucial importance.

28.2. Progress and results

28.2.1. Apparently single pulsating stars

The results of the frequency analyses of little known **δ Scuti stars** were published [4][5]. Two new high-amplitude δ Scuti stars were observed, one of which is probably a low-mass double-mode SX Phe variable [6][7].

28.2.2. Pulsating components in binary or multiple systems

A. The spectroscopic triple star DG Leo

An extensive study of the spectroscopic triple system DG Leo was initiated. DG Leo consists of a close binary and one distant companion forming the wider binary. All three components are potential candidates for pulsations. From new uvby photoelectric photometric time series as well as more than 1000 CCD measurements collected during two seasons, we detected the presence of at least three small-amplitude pulsation frequencies of type **δ Scuti** as well as an additional slow variation which can be explained as being caused by pure ellipsoidal variations [13]. The high-resolution time-series spectra of DG Leo collected at the Observatoire de Haute-Provence in Jan. 2003 were analysed using the *Fourier transform technique of spectral disentangling* developed by P. Hadrava - the first time for such a complex system. Application of this technique allowed to successfully disentangling the component spectra which lead us to unambiguously identify the pulsating component (comp. B in Fig. 1) and to derive the individual atmospheric parameters for all three components of this interesting star. As a result, the components were found to have very similar effective temperatures, superficial gravities, ages and masses. A careful chemical analysis, however, showed that the chemical compositions of their stellar atmospheres are different as mild metallicity was detected in two of them [11][12].

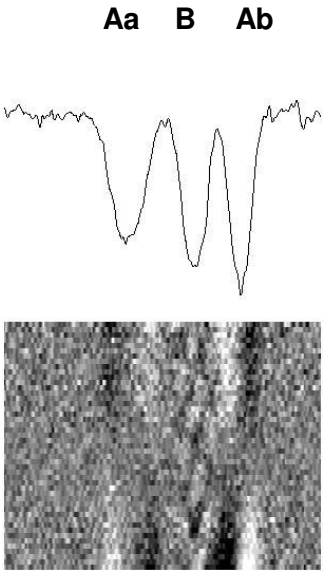


Fig.1 : Residuals of the λ5455 Fe I line are reported in a gray-scaled image as a function of time and radial velocity (lower panel). The upper panel shows the average profile of the line as it was observed for the three components of the system during night 7 (January 13, 2003).

B. The spectroscopic binaries HD 140873 and HD 123515

Both stars are non-eclipsing double-lined binaries for which high-resolution, high-accuracy profiles were gathered with the CAT/CES (ESO, Chile) in 1996-1998. Eccentric orbits of 39 and 26 days were determined for HD140873 and HD123515 respectively. The primary of HD140873 is an apparently monoperiodic **slowly pulsating B star** (SPB) while the primary of HD123515 is a multiperiodic SPB prototype for which currently 4 pulsation frequencies are known. These observations were analysed using the *technique of spectral disentangling (*code *FDBinary* written by S. Ilijic). This technique was successful in the case of HD140873 (Fig. 2, left). For HD123515, spurious features appeared in the secondary component spectrum (Fig. 2, right). Tests with synthetic data sets showed that these features might be induced by the pulsations of the primary [9].

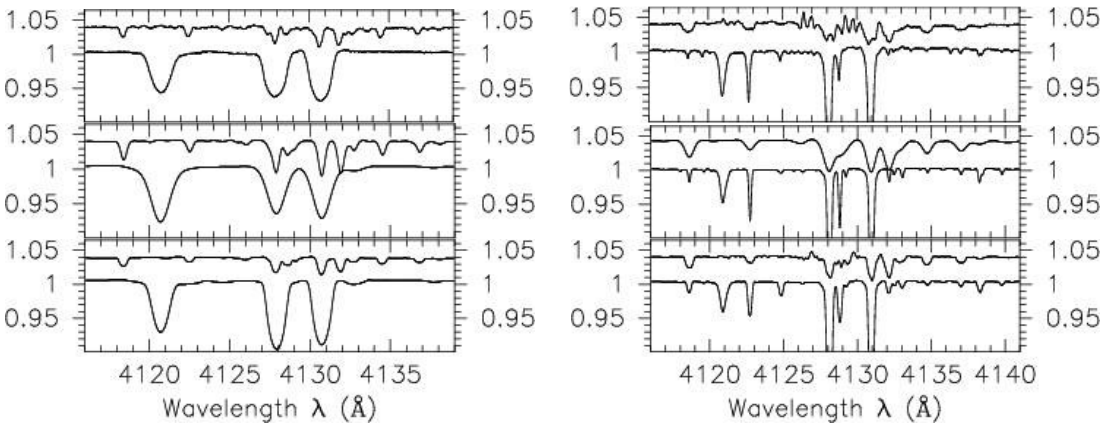


Fig. 2 : FDBinary component spectra found for the primary (lower spectrum) and secondary (upper spectrum) of HD 140873 (left) and HD 123515 (right) when using the observed spectra (top), synthetic spectra without (middle) and with pulsations (bottom) for the primaries.

C. The eclipsing binaries WX Eri, Y Cam and HIP 7666

WX Eri is an eclipsing binary system for which one component was reported to show pulsations of type δ Scuti with periods very close to exact integer parts of the orbital period. This makes the binary an interesting target for investigating the interaction pulsation-binarity. The new photometric data (obtained in South-Africa, Chile, Germany, Spain and Belgium) were used to find the best fitting model for the binary's light curve using the Wilson-Devinney code. We also analysed the residuals but didn't confirm the previously reported oscillations [8].

We participated to the international winter campaign 2002-2003 on the δ Scuti star in the semi-detached eclipsing binary Y Cam (23 nights representing over 100 hrs of data) (action coordinated by Dr. E. Rodríguez, Spain). We also contributed to the analysis of over 2300 CCD observations of HIP 7666, a variable star of unknown type discovered during the Hipparcos mission. The variable is a new eclipsing binary system with a period of only 2.372 days. In addition very short-period oscillations were detected. HIP 7666 is then another member among the few known cases of a δ Scuti star in a detached eclipsing binary [10].

28.2.3. Preparation of the COROT mission

The asteroseismological COROT mission will provide new insights on the Be phenomenon by allowing to study the coincidence between the beating of multiperiodic pulsation and the occurrence of discrete mass ejection in **Be stars**. During this first phase, as many as possible fundamental parameters on the potential targets should be gathered. Using the new code FASTROT which takes into account the first order effects of fast rotation (flattening and gravitational darkening) on stellar spectra, the fundamental parameters (effective temperature, superficial gravity and projected rotation velocity) of 43 potential targets observed at average to high resolution in France (OHP), Chile (ESO) and Brasil (LAN/OPD) in 2003 were determined. These results will be made available through the GAUDI database [14][15].

Two proposals for additional programmes of the COROT mission were introduced: a) on V577 Oph, a δ Scuti star in a detached eclipsing binary system and b) on the candidate-pulsators of the STACC open cluster NGC 2324 (contribution within the BAG).

28.3. Perspective for next years

The on-going extensive, long-term studies of particular short-period pulsators will be continued and completed**.** In the case of DG Leo, we will perform a detailed frequency analysis of the component spectra adopting observational (residuals, moments) and semi-empirical (modeling of the effects of pulsation on stellar spectra) methods in order to address the precise identification of the pulsation modes. This target and others which might cast new insight on the link between *pulsation, multiplicity, rotation and chemical composition* will be investigated in detail and as much as possible through combined photometry/spectroscopy analyses.

We plan to extend the application of the technique of *spectral disentangling* by applying the same approach to a larger sample of observed and/or newly detected double- and multiple-lined stars among various classes of short-period pulsators. Questions such as (1) to which extent can current disentangling codes be used for binary or multiple systems containing a pulsating component, and (2) can the results of the pulsational analysis be improved by subtracting the contribution of the non-pulsating component(s) from the spectra will be addressed through detailed tests with synthetic data (e.g. obtained with the PULSTAR code).

The CCD photometric monitoring of selected δ Scuti stars, which are either poorly known or candidate-targets for additional variability patterns will be pursued. We also intend to explore a few open clusters.

28.4. Personnel involved

- P. De Cat, staff member since 01.11.2003
- Y. Frémat, scientific collaborator on project MO/33/007 (01.01.03 – 14.09.03)

- temporary replacing H. Boffin (15.09.03 – current date)
- P. Lampens, head of Department
- J. Cuypers and H. Hensberge, Dept. III

28.5. Partnerships

28.5.1. List of national and international partners

- T. Arentoft, Aarhus (Denmark)
- J. De Ridder, K.U.Leuven, and the Belgian Asteroseismology Group (BAG) (Belgium)
- H.W. Duerbeck, C. Sterken, VUB, Brussel (Belgium)
- M. Floquet, A.-M. Hubert, C. Neiner , Observatoire de Paris-Meudon (France)
- E. García-Melendo & coll. (Grup d'Estudis Astronómics), Barcelona (Spain)
- R. Garrido, Granada (Spain)
- P. Harmanec, Prague (Czech Republic)
- S. Ilijic, University of Zagreb (Croatia)
- P. Niarchos & coll., University of Athens, Athens (Greece)
- J. Peña & coll., UNAM, Mexico City (Mexico) & coll.
- P. Van Cauteren, Beersel Hills Observatory & VVS (Belgium)
- P. Wils, VVS (Belgium)
- J. Zorec, Institut d'Astrophysique de Paris (France)

28.5.2. Grants used for this research

- Action 1: project MO/33/007: "Variable Components of Binary or Multiple Stars"
- FNRS travel grant to attend the Workshop in Dubrovnik, Croatia (Y. Frémat)
- FWO-project G.0178.02: "Observational study of Stars in Stellar Systems" (cf. report by Dept. III)
- IUAP P5/36: "Modern aspects of theoretical and observational (ground-based and space-born) astrophysics"(cf. report by Dept. III).

28.5.3. Visitor(s): 1

28.6. Publications

28.6.1. Publications with peer system

[1] Neiner, C.; Geers, V. C.; Henrichs, H. F.; Floquet, M.; **Frémat, Y.**; Hubert, A.-M.; Preuss, O.; Wiersema, K. 2003,
Discovery of a magnetic field in the Slowly Pulsating B star ζ Cassiopeiae
A&A, 406, 1019

[2] Neiner, C.; Henrichs, H. F.; Floquet, M.; **Frémat, Y.**; Preuss, O.; Hubert, A.-M.; Geers, V. C.; Tijani, A. H.; Nichols, J. S.; Jankov, S 2003,
Rotation, pulsations and magnetic field in V 2052 Ophiuchi: A new He-strong star
A&A, 411, 565

[3] Neiner, C.; Hubert, A.-M.; **Frémat, Y.**; Floquet, M.; Jankov, S.; Preuss, O.; Henrichs, H. F.; Zorec, J. 2003,
Rotation and magnetic field in the Be star ω Orionis
A&A, 409, 275

[4] Vidal-Sáinz J., García-Melendo, E., **Lampens P.,** Van Cauteren P., Wils P., 2003
Follow-up observations of the δ Sct V350 Peg,
Comm. in Asteroseismology 143, 19

28.6.2. Publications without peer system

[5] **Lampens, P**., Niarchos, P., Gazeas, K., Van Cauteren, P., Manimanis, V., 2002,
The δ Scuti star GSC 4778-00324: a photometric study based on new observations from the campaign 2001-2002
ASP Conf. Ser. 292, Interplay of Periodic, Cyclic and Stochastic Variability in Selected Areas of the H-R Diagram, Brussels, ed. C. Sterken, 133

[6] Wils P., **Lampens P.**, Robertson C.W., Van Cauteren, P., 2003
A new double-mode high amplitude δ Sct
GSC 2583-504, IBVS 5442, 1

[7] Wils, P., Van Cauteren, P., **Lampens, P.,** 2003
NSV 25610: a high-amplitude δ Sct star
IBVS 5475, 1

28.6.3. Publications in press, submitted

[8] Arentoft, T., **Lampens, P.,** Van Cauteren, P., Duerbeck, H.W., García-Melendo, E., Sterken, C. 2003,
On the δ Scuti component of the eclipsing binary WX Eridani
A&A, in press

[9] **De Cat P.**, De Ridder J., **Hensberge H.**, Ilijic S.
Spectroscopic study of the double-lined slowly pulsating B stars HD 140873 and HD 123515
In Proc. of Workshop on *Spectroscopically and Spatially Resolving the Components of Close Binary Stars*, eds. R.W. Hilditch, H. Hensberge & K. Pavlovski, in press

[10] Escolà-Sirisi, J. Juan-Samsó, J. Vidal-Sáinz, **P. Lampens**, E. García-Melendo, J. M. Gómez-Forrellad, P. Wils, 2003,
A δ Scuti star in the new eclipsing binary system HIP 7666
A&A, submitted

[11] **Frémat, Y., Lampens, P., Hensberge, H.,** Arentoft, T., **De Cat, P.,** Garrido, R., Parrao, L., Peña, J.H., Mathias, P., Van Cauteren, P., 2003,
High resolution spectroscopy of the multiple system 20 Leo
In ASP Conf. Ser., IAU 193 Coll. *Variable Stars in the Local Group,* Christchurch, July 3-11, eds. D. Kurtz & K. Pollard, in press

[12] **Frémat, Y., Lampens, P., Hensberge, H.,** 2003,
Spectroscopic disentangling of the triple system DG Leo
In ASP Conf. Ser., *Spectroscopically and Spatially Resolving the Components of Close Binary Stars*, eds. R.W. Hilditch, H. Hensberge & K. Pavlovski, in press

[13] **Lampens, P**., Garrido, R., Parrao, L., Peña, J., Arentoft, T., **Frémat, Y**., 2003,

Two-site photometry of the Delta Scuti star DG Leo. Preliminary results
In Rev. Mex. de Astronomía y Astrofísica, IAU 191 Coll. "*The environment and evolution of double and multiple stars*" Mérida, México, February 3-7, eds. C. Allen & C. Scarfe, in press

[14] Neiner, C.; Hubert, A.-M.; Floquet, M.; Fabregat, J.; Janot-Pachecot, E.; **Frémat, Y.** 2003,
Be stars observed with Corot
SF2A-2003: Semaine de l'Astrophysique Française, eds. F.Combes, D.Barret and T.Contini, in press

[15] Zorec, J.; **Frémat, Y.**; Levenhagen, R.; Leister, N. V.; Chauville, J.; Ballereau, D. 2003,
Are Be stars critical rotators
SF2A-2003: Semaine de l'Astrophysique Française, eds. F.Combes, D.Barret and T.Contini, in press

28.6.4. Reports, thesis, etc

Frémat, Y., Lampens, P., June 2003,
3rd semestrial report, Project M0/33/007 (7 pg)

Lampens, P., Frémat, Y., January 2003,
Action1 proposal: Variable Components in Binary or Multiple Stars (2)

Lampens, P., Frémat, Y., March 2003,
Leaflet for the public (poster)

28.6.5. Seminars, talks : 8

28.7. Missions

28.7.1. Assemblies, symposia, workshops : 4 (sometimes attended by two or more)

28.7.2. Commissions, working groups : 2

28.7.3. Field missions : 4 (observational campaigns) + 3(others)

- Observatoire de Haute-Provence, France: 02 - 17/01/2003 : Spectroscopic observations of DG Leo (Y. Frémat)
- Beersel Hills Observatory: 09/01/03 - 14/03/03, 0.1m telescope + CCD: Differential photometric observations of DG Leo (Lampens, Van Cauteren)
- Beersel Hills Observatory: Jan - Dec 2003, 0.4m telescope + CCD (over 60 nights): Differential photometric observations of selected δ Scuti stars (Lampens, Van Cauteren)
- Hoher List Observatory : 15 - 21/12/2003, 1m telescope + CCD (1 night): Differential photometric observations in open clusters (P. Lampens)

SECTION 5: Astrometry of Solar System Bodies

29. Operational project RUSTICCA

29.1. Objectives

The Project "RUSTICCA", standing for "Revalorising the Ukkel Schmidt Telescope by Installing a CCD Camera", started in 1993 and consists in the installation of a CCD camera on the Ukkel Schmidt

Telescope and modernising the telescope. The main objective of this camera is astrometric observations of minor planets, but also other types of observations have been performed.

29.2. Progress and results

29.2.1. Observations in 2003

In 2003 observations have been performed on 61 nights by 9 observers. They include H. Boffin (8 nights), J. Cuypers (6 nights), H. Debehogne (12 nights), P. De Cat (2 nights), E. Elst (12 nights), P. Lampens (1 night), C. Papadaki (6 nights), T. Pauwels (36 nights) and P. Vingerhoets (13 nights). These observations concerned:

- Astrometry of minor planets (40 nights, H. Boffin, H. Debehogne, P. De Cat, E. Elst, T. Pauwels).
- Photometry of cataclysmic variables (14 nights, H. Boffin, C. Papadaki, T. Pauwels).
- Photometry of the mutual phenomena of the Galilean Satellites of Jupiter, the so-called PHEMU campaign, coordinated by J.-E. Arlot (Bureau des Longitudes) (13 nights, J. Cuypers, P. Lampens, T. Pauwels, P. Vingerhoets).
- Occultations of stars by minor planets (4 events on 4 nights, P. De Cat, T. Pauwels en P. Vingerhoets).

29.2.2. Other activities

Apart from the observations themselves, a lot of work was put routinely in the preparation of the observations, the reductions of the observations, improving the reduction technique, keeping track of the status of the RUSTICCA minor planets (minor planets with a preliminary designation assigned to an Ukkel observation), and updating the observers' manual. The maintenance of the telescope also took a lot of attention, and is described in a separate report.
To identify old observations without sufficient data, a method has been set up and programmed to identify the right ascension and the declination of a photographic plate or CCD frame of which the centre and the scale are unknown.

29.2.3. Summary of the results obtained since 1996

From 1996 to 2003 a total of 9339 positions of minor planets and 9 positions of comets have been published in the Minor Planet Circulars. 152 positions of minor planets (NEO's) have been published in the Minor Planet Electronic Circulars. The total number of preliminary designations of minor planets attributed to observations of the RUSTICCA project amounts to 213. 92 of these minor planets are currently multiple opposition objects, and 39 have been permanently numbered, with the discovery attributed to a RUSTICCA observation. The discoverers with the number of discovered minor planets are: E. Elst (3 minor planets), E. Elst and H. Debehogne (3 minor planets), E. Elst and S. Ipatov (3 minor planets), E. Elst and T. Pauwels (1 minor planet), E. Elst and D. Taeymans (1 minor planet), T. Pauwels (27 minor planets), T. Pauwels and H. Boffin (1 minor planet).
A total of 43 light curves of cataclysmic variables could be established, and 19 light curves of mutual phenomena of the Galilean satellites of Jupiter. The archive consists of 210 CD-ROMs with a total of 17 433 images.

29.3. Perspective for next years

The further automation of the telescope, and the linkage of the dome to the position of the telescope should be accomplished in the next years. Astrometric observations of minor planets are expected to be useful until 2007-2008. At that moment it is expected that with the limit magnitude of the telescope (20.5) most of the objects in the reach of the telescope will be well known or routinely observed elsewhere. By that time new observation programmes will have to be defined.

29.4. Personnel involved

H. Boffin, staff member of the ROB.
J. Cuypers, staff member of the ROB.
H. Debehogne, volunteer, honorary chief of department of the ROB.
P. De Cat, staff member of the ROB.
E. Elst, volunteer, honorary chief of department of the ROB.
P. Lampens, chief of department of the ROB.
C. Papadaki, temporary member of the ROB.
T. Pauwels, head of section of the ROB.
P. Vingerhoets, volunteer, amateur astronomer.

29.5. Partnerships

Data reduction and publication is performed at the Minor Planet Center, Massachusetts, USA.
The CCD camera and the upgrade of the telescope was financed by a LOTTO grant.
Visitors: 3

29.6. Publications

29.6.1. Publications with peer system

Pauwels T., et al.
Positions in the MPEC's: 19 positions of minor planets (MPEC 2003-A54, 2003-S29, 2003-S39).

Boffin H.
Positions in the MPC's: 62 positions of minor planets (MPS 71 373, 71 854, 72 192, 72 280, 72 356, 72 491, 72 764, 72 779, 72 893, 76 076, 76 246, 77 033).

Debehogne H., Elst E.
Positions in the MPC's: 21 positions of minor planets (MPS 73 820, 74 769, 74 898).

Elst E.
Positions in the MPC's: 8 positions of minor planets (MPS 67 781, 95 767).

Elst E., Debehogne H.
Positions in the MPC's: 376 positions of minor planets (MPS 67 523, 67 590, 67 626, 67 686, 67 762, 67 786, 67 819, 67 829, 68 012, 68 211, 68 229, 68 317, 68 409, 68 415, 68 469, 68 605, 68 668, 68 704, 68 749, 68 764, 68 898, 69 069, 69 091, 69 101, 69 112, 69 301, 69 423, 70 115, 70 142, 75 685, 75 783, 75 934, 76 089, 76 093, 76 139, 76 164, 76 225, 76 228, 76 252, 76 285, 76 334, 76 381, 76 389, 76 476, 76 488, 76 503, 77 392, 77 412, 77 492, 77 493, 77 644, 77 646, 80 499, 80 646, 84 956, 85 002, 85 022, 85 039, 85 105, 85 127, 85 236, 85 352, 85 420, 85 483, 85 560, 85 691, 85 699, 85 823, 85 867, 85 873, 86 049, 86 105, 86 270, 86 297, 86 311, 86 319, 86 320, 86 345, 86 359, 86 629, 86 743, 86 757, 87 256, 87 356, 88 163, 95 996, 96 020, 96 108, 96 150).

Elst E., Ipatov S.
Positions in the MPC's: 21 positions of minor planets (MPS 75 659, 82 761, 91 106, 91 909, 92 775).

Elst E., Taeymans D.

Positions in the MPC's: 14 positions of minor planets (MPS 68 270, 71 628, 75 871, 82 660, 86 948).

Pauwels T.

Positions in the MPC's: 2284 positions of minor planets (MPS 67 394, 67 395, 67 407, 67 466, 67 476, 67 489, 67 523, 67 590, 67 626, 67 635, 67 686, 67 694, 67 705, 67 819, 67 828, 67 901, 67 903, 67 916, 67 924, 68 012, 68 211, 68 229, 68 242, 68 301, 68 358, 68 368, 68 396, 68 409, 68 410, 68 411, 68 415, 68 492, 68 530, 68 581, 68 668, 68 863, 68 884, 68 894, 68 941, 69 112, 69 132, 69 193, 69 325, 69 326, 69 644, 69 687, 70 046, 70 142, 70 230, 73 306, 73 489, 73 606, 73 727, 73 978, 74 094, 74 138, 74 151, 74 156, 74 259, 74 389, 74 975, 74 994, 75 057, 75 092, 75 452, 75 531, 75 609, 75 685, 75 782, 75 783, 75 824, 75 825, 75 837, 75 853, 75 860, 75 934, 75 941, 75 954, 76 007, 76 076, 76 081, 76 086, 76 138, 76 196, 76 225, 76 227, 76 245, 76 246, 76 250, 76 252, 76 268, 76 278, 76 285, 76 306, 76 317, 76 334, 76 381, 76 476, 76 488, 76 496, 76 499, 76 503, 76 550, 76 560, 76 608, 76 799, 76 817, 76 855, 76 913, 77 314, 77 353, 77 375, 77 391, 77 392, 77 485, 77 492, 77 521, 77 598, 77 655, 77 862, 78 025, 78 076, 78 117, 78 128, 78 149, 78 258, 78 334, 78 341, 78 449, 78 469, 79 149, 79 418, 79 980, 80 192, 80 225, 81 300, 82 586, 82 612, 82 620, 82 670, 82 671, 82 705, 84 424, 84 425, 84 452, 84 456, 84 458, 84 491, 84 616, 84 642, 84 664, 84 797, 84 801, 84 869, 84 887, 84 900, 84 958, 84 964, 84 999, 85 002, 85 051, 85 059, 85 064, 85 105, 85 111, 85 127, 85 131, 85 177, 85 187, 85 236, 85 239, 85 270, 85 285, 85 326, 85 333, 85 352, 85 357, 85 373, 85 392, 85 412, 85 415, 85 416, 85 420, 85 432, 85 459, 85 476, 85 499, 85 500, 85 517, 85 532, 85 594, 85 619, 85 620, 85 638, 85 661, 85 680, 85 691, 85 692, 85 795, 85 802, 85 809, 85 867, 85 905, 85 979, 86 008, 86 020, 86 052, 86 056, 86 067, 86 074, 86 140, 86 145, 86 146, 86 218, 86 259, 86 268, 86 279, 86 283, 86 284, 86 292, 86 297, 86 298, 86 299, 86 313, 86 315, 86 322, 86 323, 86 327, 86 336, 86 337, 86 359, 86 360, 86 487, 86 512, 86 699, 86 741, 86 795, 86 885, 86 917, 86 928, 87 101, 87 131, 87 137, 87 257, 87 258, 87 260, 87 268, 87 270, 87 274, 87 275, 87 278, 87 284, 87 296, 87 298, 87 303, 87 308, 87 312, 87 315, 87 320, 87 326, 87 329, 87 337, 87 341, 87 362, 87 366, 87 374, 87 414, 87 419, 87 456, 87 461, 87 465, 87 473, 87 506, 87 514, 88 301, 88 317, 88 332, 89 198, 89 252, 89 302, 89 312, 89 314, 89 397, 89 440, 89 447, 89 522, 89 535, 89 539, 89 556, 89 569, 89 581, 89 593, 89 605, 89 610, 89 621, 89 906, 89 972, 89 973, 89 984, 90 050, 90 070, 90 094, 90 119, 90 260, 90 268, 90 322, 90 419, 90 574, 91 053, 93 434, 93 733).

Pauwels T., Boffin H., Positions in the MPC's: 5 positions of minor planets (MPS 91 039).

Pauwels T., De Cat P., Positions in the MPC's: 282 positions of minor planets (MPS 93 544, 93 546, 93 570, 93 572, 93 590, 93 622, 93 631, 93 641, 93 660, 93 661, 93 676, 93 690, 93 693, 93 708, 93 709, 93 711, 93 713, 93 775, 93 787, 93 803, 93 815, 93 820, 93 836, 93 845, 93 968, 93 973, 93 986, 93 993, 94 093, 94 094, 94 140, 94 209, 94 340, 94 358, 94 366, 94 671, 94 798, 94 799, 94 888, 94 889, 94 892, 94 900, 94 909, 94 921, 95 897).

29.6.2. Publications in press, submitted

Stanishev V., Kraicheva Z., **Boffin H.** M. J., Genkov V., **Papadaki C.,** Carpano S.
Accretion Disk Evolution in DW Ursae Majoris: A Photometric Study
Accepted by Astronomy & Astrophysics.

29.7. Missions.

1 research mission, 1 field mission.

30. Research project EDENS

30.1. Objectives

EDENS (European DEep-sky NEO Survey) is the response of Europe and the Spaceguard Foundation on the recommendations formulated by the OECD concerning the protection of the Earth against the threat by minor planets. It aims at conducting a more efficient search for earth-threatening minor planets up to a diameter of about 200 meter.

30.2. Progress and results

In January 2003, the OECD organized a "Workshop on Near-Earth Objects: Risks, Policies and Actions", aiming at formulating recommendations to those countries who wish to participate to tackle the hazard posed by minor planets. In general, it was found that objects up to a diameter of 200 meter pose a risk to the Earth, which is large enough, and cheap enough to handle, so that conducting a systematic search for these objects, and studying how to mitigate the risk would be beneficial for the Earth.
EDENS is the response of Europe on these recommendations. The initiative has been taken by the Spaceguard Foundation, and is more or less the successor of EUNEASO, which never got funding for starting its activities. The proposed method is to use two different telescopes, one for surveying the sky for new objects, the other one for follow-up of the newly found objects. By using a larger telescope for follow-up (the ESO NTT) than for the survey (the ESO 2.2m), EDENS hopes to be more efficient in establishing good orbits of the newly discovered objects than comparable projects in the past.
The first action of the project was to define a NEST Insight STREP proposal to the European Union in the FP6 framework. The form of the proposal was discussed in a meeting held in Garching in October. The proposal was submitted by a subset of the participating institutes. The ROB was not asked to join this subset. At the same time the project has defined five working groups, each dealing with a specific subject within the broader subject of EDENS. T. Pauwels has accepted to become a member of the working groups 1 ("Discovery") and 5 ("Future Programmes").

30.3. Perspective for next years

The initial proposal to the European Union is for 2 years, and is expected to start late 2004 or early 2005. In these two years enough observations should be gathered to give a good evaluation of the proposed strategy.

30.4. Personnel involved

Staff member of the ROB: T. Pauwels.

30.5. Partnerships

List of national and international partners: Spaceguard Foundation, ESO, various European astronomical institutes (it is at this moment not clear yet which institutes will join, and which not).
Grants used for this research: none yet.
Visitors: none.

30.6. Publications

None involving staff of the ROB.

30.7. Missions

2 operational meetings.

DEPARTMENT 3: Astrophysics

SECTION 6: Astrophysics of galactic and extragalactic objects

31. Research project: Asteroseismology

31.1. Objectives

The research domain of asteroseismology refers to the study of the internal structure of pulsating stars through the interpretation of their frequency spectra. In order to achieve this goal, observation and detection of the variability of the stars is necessary. The accurate description of the frequency spectrum when multiperiodicity is present, is the next step. The research carried out here has as objective to detect the interesting variables, with some emphasis on hot stars and on stars in clusters, to find the periodicities in the observed variations and to make that information available for asteroseismological analysis. Because binary stars are important sources of precise stellar fundamental parameters, pulsating variables in binaries are intensively studied.

31.2. Progress and results

The project asteroseismology includes several topics: hot stars, binaries with pulsating components, large scale surveys in the field and in clusters, period analysis methods, preparatory simulations for space missions, analysis of individual stars of different variability type, oscillation theory.... These topics are not listed separately but all are included in this extensive description.

A modified method of direct period search was developed and applied to a large number of data sets of variable stars [14]. Earlier experience had shown that in some observational data sets of variable stars, multiperiodicity was not always recognised as such, and became only apparent when this method was applied. A few illustrative examples were studied in detail and 74 data sets of Hipparcos photometry of B type stars were examined. This lead to a revised list of frequencies in variable stars of the β Cephei and Slowly Pulsating B stars as found in the Hipparcos satellite data. These results were confronted with new ground based data.
Some statistical aspects of period analysis were analysed in detail [3].

In 2003 the first results of the Mercator telescope operated by the "Instituut voor Sterrenkunde," (IVS, KULeuven) became available. This new 1.2-m telescope is located on the Roque de los Muchachos observatory on La Palma, Spain. Since 2001, it has been intensively used to observe variable B, A, and F main-sequence stars and some selected other variables as well in the seven filters of the Geneva photometric system. Our new method and classical methods of period analysis were applied to these data in search for variable stars and periodicities. This has been done in collaboration with the IVS and some members of the BAG (Belgian Asteroseismology Group), and was kicked off by two weeks of intense data analysis at the KULeuven. In total 28 B type variables [11] and 31 A and F type stars [12] were analysed. Periodicity and, in some cases, multiperiodicity was found: 6 bona fide γ Doradus stars were identified [15] and a new short period variable star, probably a δ Scuti star, was discovered as well.

In order to prepare the exploitation of data on B type stars resulting from the future asteroseismological and planet search space mission COROT a "Hare and Hound" exercise was organised [1]. An "unknown" theoretical stellar model (solar, δ Scuti and β Cephei type) was calculated by the theoreticians and COROT data were simulated based on the frequency content of the model. Without a priori knowledge, these data were analysed and asteroseismological conclusions (modes, mass, rotations, chemical composition, …) based on the obtained frequency spectrum were drawn. The exercise in the mass range

of β Cephei stars was by far the most convincing and makes these stars excellent targets for future asteroseismological missions.
As members of the BAG researchers of the ROB introduced proposals for additional programmes for the COROT mission, including "A study of an unbiased sample of O and B stars".

Several β Cephei stars were studied in detail. Very interesting is the star HD 92024, an eclipsing binary with a β Cephei component [13]. The time-series spectroscopy shows profound line-profile variations (LPVs) in the single-lined spectrum due to the pulsations of the β Cephei component. Because the radial velocities from spectral lines were strongly affected by the LPVs, a novel method was developed to measure the projected orbital velocities. On a nightly basis, the LPVs dominate, but the orbital displacements (with a period of 8.3 days) could be seen from night to night. Through a combined spectroscopic and photometric analysis accurate dimensions of the binary components could already be calculated. A quick test indicates the presence of 2-3 frequencies in the residual radial-velocity data.

Assistance was also given in the analysis of spectroscopic data of a large simultaneous photometric and spectroscopic multi-site campaign on the β Cephei star ν Eridani [5]. The high quality data and the advantages of a multi-site campaign made it possible to identify 19 frequencies. 17 of these were also found in the photometric data. This constitutes a very promising start for mode identification and seismic modelling of this star. Also promising is the identification of frequencies in the WIRE data of the β Cephei star κ Scorpii [10]. This star is known to be multiperiodic from old photometric observations. In two short data sets (separated by 152 days) obtained by the star camera of the satellite WIRE (Wide-field Infrared Explorer) the known main period of 4.8 hours is clearly present. The secondary period could also be confirmed, although some other periodicities are present as well. Two longer periods (3.6 and 0.45 days) and a period of 4.2 hours were also found significant in the WIRE data.

The analysis of the long-term multicolour photometry and high-resolution spectroscopy of the two γ Doradus stars HD 12901 and HD 48501 was completed [6][7]. The photometry revealed three frequencies for each of the two stars. The oscillations in the different filters are perfectly in phase within the measurement errors. Mode identification points out that the six modes are all modes of degree one and that the non-adiabatic temperature variations are extremely small, in contradiction to current theoretical predictions. The spectra show that all the observed frequencies are intrinsic to the stars and cannot be due to binarity. Line-profile variations with low amplitudes were also detected.

A photometric investigation is carried out on ω Centauri with the purpose of detecting and studying its variables, and improving the understanding of its complex formation history [4]. The observations are FORS observations (Chile, Paranal) obtained at high angular resolution (seeing better than 0.3"), about 5000 time-series points from the Danish 1.5 meter (La Silla) and observations from the ESO archive (WFI/2.2m, HST, VLT). More than 5000 images were already corrected for instrumental effects. Preliminary ALLSTAR photometry results confirmed the presence of a huge population of blue straggler stars (BSS), among which new candidate variables of the type SX Phe were found. The first results from the ALLFRAME photometry carried out in Rome, based on HST and VLT images, reveal new very detailed features in the MS turn-off and RGB-branch morphology.

With the Nordic Optical Telescope (NOT), selected northern open star clusters are examined for their content of short-period variables of the types δ Scuti and β Cephei [8]. The current cluster monitored with the NOT, NGC 1817, was a cluster already known to host 7 potential δ Scuti stars. Preliminary results from the analysis of the new observations [9], indicate the detection of 14 new variable stars in the cluster. This brings the total number of known variable stars in NGC 1817 up to 19, including 12 multi-periodic δ Scuti stars. One δ Scuti star is member of an eclipsing binary system.

Of several δ Scuti stars a period analysis was performed. A short analysis of HR Lyncis and a re-analysis of the WIRE data of β Cassiopeiae was done as well. Details on observations of other short period variables, including the ones done in the framework of the FWO-project G.0178.02, can be found in the report of Dep. II.

The technique of spectral disentangling was applied to multiple stars with (a) pulsating component(s). This was successfully achieved for the triple star DG Leo. A detailed description of the results obtained on DG Leo and on the first results on slowly pulsating B stars and a general evaluation of the method can also be found in the report of Dep. II.
In the domain of stellar oscillation theory a publication has been finished on the influence of non-adiabatic tides on the orbital evolution of close binaries [2]. Tides are forced oscillations occurring when a star belongs to a multiple system.

31.3. Perspective for next years

The methods for period search will be further refined. The analysis of the periodic variables observed by the Mercator telescope will be completed. A new reduction and analysis of earlier data on γ Doradus stars observed at SAAO (South Africa) in the frame of an international collaboration will be performed. Also, the CORALIE echelle spectra obtained for most of them will be further examined.
The preparatory work for the ESA-satellite GAIA in the context of variable star detection and period search will be resumed. The observations and analyses of short period variables will be continued.
Orbital and dimensional analysis of binary stars will be continued. In the case of HD 92024 the orbital imprint on the light curves, from a larger set of photometric observations, and radial velocities will be removed. Based on all available data, detection of the secondary spectrum and mode identification of the pulsations will be attempted.
The reduction of data of ω Centauri will be finished. A detailed colour- and temporal analysis of the known, and candidate SX Phe variables among the BSS, and a study of period-luminosity relations for the different classes of variables, in particular RR Lyrae stars will start. The ongoing cluster studies will be finished and the study of the individual variables will be initiated.

31.4. Personnel involved

J. Cuypers
H. Hensberge
L.M. Freyhammer, scientific collaborator (IAP P5/36)
C. Schoenaers, attachée (Rosetta programme, until 31/10/2003).
H. Langenaken (4/5)
G. Peeters, (4/5, Dep. II, part-time)
J. Vandekerckhove
P. Lampens, Y. Frémat, P. De Cat (**Dep. II**)
T. Van Hoolst (**Dep. I**)

31.5. Partnerships

31.5.1. List of national and international partners

- Belgian Asteroseismology Group: Instituut voor Sterrenkunde (KULeuven), Institut d'Astrophysique et de Géophysique (Ulg, Liège), Observational Astronomy Group (VUB, Brussel) and others
- Department of Physics, University of Zagreb, Croatia
- Astronomical Observatory of Rome (OAR), Italy
- Astrophysikalisches Institut Potsdam (AIP), Germany
- Department of Physics and Astronomy, Aarhus University, Denmark

- Astronomy Observatory, Niels Bohr Institute for Astronomy, Physics and Geophysics, Copenhagen University, Denmark
- Department of Physics, US Air Force Academy, USA
- Observatoire de Genève, Switzerland

31.5.2. Grants used for this research

- IAP P5/36: "Modern aspects of theoretical and observational (ground-based and space-born) astrophysics" , main promotor: J.P. Swings (Ulg); promotors: C. Waelkens (K.U.Leuven) C. Sterken (VUBrussel) and **H. Hensberge** (ROB).
- FWO-project G.0178.02: "Observational study of Stars in Stellar Systems", promotor: C. Aerts, K.U.Leuven; co-promotor: H. Dejonghe (UG), C. Sterken (VUB), C. Waelkens (K.U.Leuven) and **J. Cuypers** (ROB).

31.5.3. Visitors: 3

31.6. Publications

31.6.1. Publications with peer system (2003)

[1] Thoul, A., Ausseloos, M., Barban, C., Briquet, M., Bourge, P.-O., Cuypers, J., Daszyńska-Daszkiewicz, J., De Cat, P., De Ridder, J., Dupret, M.-A., Montalban, J., Noels, A., Scuflaire, R., Uytterhoeven, K., Aerts, C.:
A Hare and Hound in a BAG: Asteroseismology of Beta Cephei stars,
Communications in Asteroseismology 143, p. 25-28

[2] Willems, B., **Van Hoolst, T**., Smeyers, P.,
Nonadiabatic resonant dynamic tides and orbital evolution in close binaries
Astronomy and Astrophysics 397, 973-985

31.6.2. Publications without peer system (2003)

[3] De Cat, P., Cuypers, J.
Period search zoo: observational questions,
in: "Interplay between Periodic, Cyclic and Stochastic Variability in selected Areas of the H-R Diagram, (ed. C. Sterken) , ASP Conf. Series 292, 377-382

[4] **Freyhammer L.M**., Sterken C.,
On the short-period variability in omega Centauri,
In "Interplay between Periodic, Cyclic and Stochastic Variability in selected Areas of the H-R Diagram", ASP Conf. Series 292, (eds. Christiaan Sterken) 81

31.6.3. Publications in press, submitted (2004)

[5] Aerts, C., De Cat, P., Handler, G., Heiter, U., Balona, L. A., Krzesinski, J., Mathias, P., Lehmann, H., Ilyin, I., De Ridder, J., Dreizler, S., Bruch, A., Traulsen, I., Hoffmann, A., James, D., Romero-Colmenero, E., Maas, T., Groenewegen, M. A. T., Telting, J. H., Uytterhoeven, K., Koen, C., Cottrell, P. L., Bentley, J., Wright, D. J., Cuypers, J.
Asteroseismology of the β Cephei star ν Eridani - II. Spectroscopic observations and pulsational frequency analysis,
Monthly Notices Royal Astronomical Society

[6] Aerts, C., Cuypers, J., Dupret, M.A., Garrido, R., De Ridder, J., Eyer, L.
Photometric Mode Identification in the two γ Doradus stars HD 12901 and HD 48501,
in: Proceedings of the conference "Asteroseismology Across the HR Diagram", (eds. M.J. Thompson, M.S. Cunha, M.J.P.F.G. Monteiro)

[7] Aerts, C., Cuypers, J., De Cat, P., Dupret, M.A.., De Ridder, J., Eyer, L., Scuflaire, R., Waelkens, C.
Long-term multicolour photometry and high-resolution spectroscopy of the two γ Doradus stars HD 12901 and HD 48501,
Astron. Astrophys.

[8] Arentoft, T., **Freyhammer L.M**., Bouzid M.Y., Sterken C., Frandsen S.
Pulsating stars in open clusters,
Communications in Asteroseismology 144, (eds. Michel Breger)

[9] Arentoft, T., **Freyhammer L.M.**, Bouzid M.Y., Sterken C., Frandsen S.
Pulsating stars in the open cluster NGC 1817,
in: Variable Stars in the Local Group (eds. D. Kurtz, K. Pollard), IAU Coll. 193, ASP Conf. Series 310

[10] Cuypers, J., Buzasi, D., Uytterhoeven, K.
The periods of the β Cephei star κ Scorpii as observed by WIRE,
in: Variable Stars in the Local Group (eds. D. Kurtz, K. Pollard), IAU Coll. 193, ASP Conf. Series 310

[11] De Cat, P., De Ridder, J., Uytterhoeven, K., Daszyńska-Daszkiewicz, J., Cuypers, J., Schoenaers, C., Ausseloos, M., Broeders, E., Vanautgaerden, J., De Meester, W., Aerts, C., Van Winckel, H., Waelkens, C., Davignon, G., Raskin, G.
First results of Mercator observations of variable B stars
in: Variable Stars in the Local Group (eds. D. Kurtz, K. Pollard), IAU Coll. 193, ASP Conf. Series 310

[12] De Ridder, J., Cuypers, J., De Cat, P., Uytterhoeven, K., Schoenaers, C., Broeders, E., Vanautgaerden, J., De Meester, W., De Ruyter, S., Aerts, C., Van Winckel, H., Waelkens, C., Davignon, G., Raskin, G.
First results of Mercator observations of variable A & F stars,
in: Variable Stars in the Local Group (eds. D. Kurtz, K. Pollard), IAU Coll. 193, ASP Conf. Series 310

[13] **Freyhammer L.M., Hensberge H**., Sterken C., Pavlovski K., Smette A., Ilijić S.
The eclipsing binary HD 92024: Getting the orbit.,
In "Spectroscopically and Spatially Resolving the Components of Close Binary Stars", ASP Conf. Series, (eds. R.W. Hilditch, H. Hensberge and K. Pavlovski)

[14] Schoenaers, C., Cuypers, J.
Direct detection of multiple periods in variable stars,

in: Variable Stars in the Local Group (eds. D. Kurtz, K. Pollard), IAU Coll. 193, ASP Conf. Series 310

31.6.4. Reports, thesis, …

[15] Schoenaers, C., Cuypers, J., De Ridder, J.
Systematic direct search for multiple frequencies in candidate γ Doradus stars
Poster presented at the Joint European and National Astronomical Meeting (JENAM) and 12th European Meeting for Astronomy and Astrophysics: New Deal in European Astronomy: Trends and Perspectives, Minisymposium: Asteroseismology and Stellar Evolution, Budapest, August 25-30

31.7. Missions

31.7.1. Research missions (assemblies, symposia, workshops, etc)

- 6 meetings and/or workshop with often 2 or 3 members of the group

31.7.2. Operational meetings (commissions, working groups)

- 3 meetings

31.7.3. Field missions (observations, station maintenance, etc)

- 1 mission

32. Research project: Binaries

32.1. Objectives

Binaries are an important source of precise fundamental stellar parameters and hence provide empirical constraints on stellar evolution. In stellar groups, they provide anchor points for the interpretation of the whole stellar population, and need to be identified before the internal velocity dispersion can be measured (gravitationally bound group or not). In closely interacting systems, complex accretion phenomena are studied, especially in nova-like cataclysmic variables and in dwarf novae in outburst.

32.2. Progress and results

The broad project "binaries" includes several subtopics: search for binaries and determination of fundamental stellar parameters in young stellar groups, fundamental stellar parameters of close binaries, accretion processes in cataclysmic variables. Pulsating variables in binaries are reviewed in the projects on asteroseismology of Dept. 2 and 3. Other aspects of research on binaries are dealt with in the report of Dept. 2.

In 2003, a large observational effort was made: spectroscopically, observations at ESO included the full phase coverage of the young triple eclipsing system RV Crt with more than 50 spectra and observation of eclipsing (EB) and double-lined binaries (SB2s) in Sco-Cen. In South Africa (SAAO) and New Zealand (Mt. John), a search for binaries among the fainter members of Sco-Cen was started (with UA, observer C. Nitschelm) and additional observations on eclipsing SB2s in Sco-Cen were obtained. Photometrically, eclipses or complete light curves were scanned in detail for 3 binaries ([5], [10]), in a cooperative financial and scientific effort of NBIfAFG Copenhagen, VUB and ROB over 100 nights. Time-resolved photometry of 12 cataclysmic variables was obtained at SAAO, Hoher List (Germany), Krioneri Observatory and Skinakas Observatory (both in Greece), and with the 0.85 m Schmidt telescope at ROB. Target-of-opportunity observations have lead to the participation in the study of the late-type star HD 73256 with a planet [2], and the recurrent nova IM Nor [4].

Results on the detection of double-lined binaries and on orbits and component spectra of binaries were presented in workshops in Ouro Preto and Dubrovnik ([5], [10], [12], [15]). Other contributions covered the data reduction requirements ([9], see also [1] and [6] for assistance with data reduction for other research groups) and the novel technique of spectral disentangling ([11], [15]) that allows the reconstruction of the individual component spectra from a series of spectra at different orbital phases, using the Doppler information. Note that this technique was applied in 2003 for the first time to multiple systems with pulsating stars (HD 92024 in NGC 3293, DG Leo, HD 123515, HD 140873, see projects on asteroseismology). Important results are:
- characterisation of the third component of AC Vel (EB, SB2) [12], implying it is itself a binary, and disentangling of the spectra of the close binary with similar B-type components, allowing a test of mixing of helium into the photosphere at the phase of hydrogen shell burning.
- identification of a chemically peculiar star (CP) in an eclipsed binary, and the detection of the orbital period and non-synchronous rotation of the CP star, allowing for the first time to map parts of the surface of a CP star by eclipse mapping (April 2004).
- detection of a huge magnetic field (second largest known in a CP star) and large metal overabundances in the two million years young, single star NGC2244-334 in the Rosette Nebula, showing that the time-consuming process of diffusion of species in a stellar atmosphere maybe not always is the prime source of the peculiarities (based on FORS + UVES spectra, [3], [7], [8]).

Other systems with on-going detailed studies include: η Mus (first photometric scan of eclipses after determination of the correct orbital period [5]), RV Crt (a presumed pre-main sequence hierarchical triple; spectra preliminarily disentangled [15]), CPD-59 2628 (O9.5+B0) in Tr 16 on which a cooperation with Keele Univ. was started, GL Carinae (early-B SB2 in an eccentric orbit with fast apsidal motion).

With regard to the accretion disks in cataclysmic variables, the nova-like V795 Her, with a bewildering variety of periodicities, was seen to return in 2003 to its peculiar state of the 80's when it showed a 2.8 hour modulation in the light curve. This modulation was absent when checked in 1999 and 2001 by Boffin. The modulation's long-term behaviour still awaits an explanation. For the nova-like V1193 Ori, the 3.96 hour orbital period from spectroscopy is now confirmed [13] from time-resolved photometry after others failed due to high-amplitude rapid flickering. The accretion disk evolution of DW Uma is discussed in a paper [14] submitted to A&A. Moreover, studies of the cataclysmic variables MCT 2347-3144 [13] and PX And are in progress.

32.3. Perspective for next years

The determination of fundamental stellar parameters is a long-term goal, and will be achieved for the systems in study mainly by applying the technique of spectral disentangling.
The search for spectroscopic binaries in young stellar groups will profit in 2004 from a large observational effort on Sco-Cen, with emphasis on finding long-period candidates (months to few years) which are good candidates, at the distance of Sco Cen, to be resolved spatially by interferometry.
The observational database on the cataclysmic variables will be extended, also with spectroscopy, and analysed with indirect imaging techniques such as eclipse mapping or Doppler tomography.

32.4. Personnel involved

Dr. H. Hensberge, werkleider
Dr. J. Cuypers, werkleider
Lic. L.M. Freyhammer, assistant in the framework of IAP P5/36
Lic. C. Papadaki, Action 2 of the Belgian Science Policy (applicant H. Boffin)
H. Van Diest (until retirement March, 31)

32.5. Partnerships

32.5.1. List of national and international partners

- Astrophysics research group, UA, Antwerp
- Observational Astronomy group (OBSS), VUB, Brussels
- Institut d'Astrophysique et de Géophysique, Ulg, Liège
- Department of Physics and Department of Applied Physics, Univ. Zagreb, Croatia
- NBIfAFG, Univ. Copenhagen, Denmark
- Department of Physics, UFMG, Belo Horizonte, Brazil
- European Southern Observatory (ESO)
- Observatoire de Genève, Sauverny, Switzerland
- University of Western Ontario, London, Canada
- Astrophysics Group, Keele University, UK
- National Observatory of Athens, Greece
- Physics Department, Univ. of Crete, Greece
- Physics Department, Stockholm University, Sweden
- Astrophysical Institute of the Academy of Sciences, Sofia, Bulgaria.

32.5.2. Grants used for this research:

- IAP P5/36:Modern Aspects of Theoretical and Observational (ground-based and space-born) Astrophysics, promotor J.-P. Swings (Ulg), co-promotor: C. Waelkens (K.U.Leuven), C. Sterken (V.U.Brussel) and H. Hensberge (ROB)
- Action 2 by Belgian Science Policy (C. Papadaki)

32.5.3. Visitors: 6

32.6. Publications

32.6.1. Publications with peer system

Sana H., **Hensberge H.,** Rauw G., Gosset E.
The massive binary CPD -41° 7742 I. High-resolution optical spectroscopy
A&A 405, pp. 1063-1073 [1]

Udry S., Mayor M., Clausen J.V., **Freyhammer L.M.**, Helt B.E., Lovis C., Naef D., Olsen E.H., Pepe F., Queloz D. & Santos N.C.,
The CORALIE survey for southern extra-solar planets. X. A Hot Jupiter orbiting HD 73256,
A&A 407, 679 [2]

Wade G.A., Bagnulo S., Landstreet J.D., Szeifert T., **Hensberge H.,** Lo Curto G.
Tracking the formation and evolution of magnetic fields in intermediate and high-mass stars with the ESO VLT
JRASC 97, 209 [3]

32.6.2. Publications without peer system

Duerbeck H.W., Sterken C., Baptista R., Cunha K., Diaz M.P., Dutra C.M., **Freyhammer L.M**., **Hensberge H.,** Jones A.F.,
Spectroscopic and photometric observations of the recurrent nova IM Nor,

In “Interplay of Periodic, Cyclic and Stochastic Variability in Selected Areas of the H-R Diagram”, ASP Conf. Series 292 (eds. Christiaan Sterken), 309 [4]

Hensberge H., Nitschelm C., Bouzid M.Y., Clausen J.V., David M., **Freyhammer L.M.**, Helt B.E., Olsen E.H., Sterken C., Vaz L.P.R.,
η Muscae, a multiple system with a PMS component,
In "Open issues in local star formation" (eds. Jaques Lépine & Jane Gregorio-Hetem), ASSL 299, CD-Rom (ISBN 1-4020-1755-3) [5]

Skoda P., **Hensberge H.**
Merging of spectral orders from fiber echelle spectrographs
In: Astronomical Data Analysis Software and Systems XII, eds. Payne, Jedrzejewski & Hook, ASP Conf. Ser. 295, pp. 415-418 [6]

32.6.3. Publications in press, submitted

Bagnulo S., **Hensberge H.,** Landstreet J.D., Szeifert T & Wade G.A.
Discovery of a huge magnetic field in the very young star NGC2244-334 in the Rosette Nebula cluster
A&A, in press (10 pp.) [7]

Bagnulo S., Landstreet J.D., Szeifert T., Wade G.A., **Hensberge H** & Lo Curto G
A search for magnetic Ap stars in young open clusters using the ESO VLT
In: Proceedings “Magnetic Stars”, Special Astrophysical Observatory, Russia. [8]

Hensberge H.
Do our spectra match the requirements for a precise analysis of SB2s?
In: Spectrocopically and spatially resolving the components of close binary stars, eds. R.W. Hilditch, H. Hensberge & K. Pavlovski, ASP Conf. Ser., 9 pp. (in press) [9]

Hensberge H., Nitschelm C., **Freyhammer L.M.**, Bouzid M.Y., Clausen J.V., David M., Helt B.E., Olsen E.H., **Papadaki C.**, Sterken C., Vaz L.P.R.,
HD 123335, an interesting eclipsing SB2 in Centaurus
In “Spectroscopically and Spatially Resolving the Components of Close Binary Stars”, ASP Conf. Series, (eds. R.W. Hilditch, H. Hensberge and K. Pavlovski) [10]

Ilijić S., **Hensberge H.**, Pavlovski K., **Freyhammer L.M**.,
Obtaining normalised component spectra with FDBinary
In “Spectroscopically and Spatially Resolving the Components of Close Binary Stars”, ASP Conf. Series, (eds. R.W. Hilditch, H. Hensberge and K. Pavlovski) [11]

Ilijić S., **Freyhammer L.M**., Helt B.E., **Hensberge H.,** Pavlovski K., Clausen J.V.,
The invisible component of the triple system AC Velorum
In “Spectroscopically and Spatially Resolving the Components of Close Binary Stars”, ASP Conf. Series, (eds. R.W. Hilditch, H. Hensberge and K. Pavlovski) [12]

Papadaki C., Boffin H.M.J., **Cuypers J.**, Stanishev V., Kraicheva Z. & Genkov V.
Time-resolved photometry of cataclysmic variables

ASP Conference series, in press [13]

Stanishev V., Kraicheva Z., Boffin H.J.M., Genkov V., **Papadaki C.**, & Carpano S.
Accretion Disc Evolution in DW Ursae Majoris : A Photometric Study
Astronomy & Astrophysics, accepted for publication [14]

Torres K.B.V., Vaz L.P.R., **Hensberge H.**
Study of the spectral disentangling code – korel – in eclipsing triple systems. Application to RV Crt
In: Spectroscopically and spatially resolving the components of close binary stars, eds. R.W. Hilditch, H. Hensberge & K. Pavlovski, ASP Conf. Ser., 3 pp. (in press) [15]

32.7. Missions

Symposia, workshops (international, one day national): 2, 3 with several participants
Commissions, working groups: 2
Working missions abroad: 2
Observing runs: 11

33. Research project: Extragalactic objects

33.1. Objectives

Various programs of observations of active galactic nuclei, quasars and high redshift galaxy clusters by means of the present XMM observatory are underway or have been proposed. The main goal of the Large Scale Survey (LSS) consortium is to probe the evolution of the Universe by studying distant (i.e. faint) QSOs.

33.2. Progress and results

In relation with the collaboration in the Liquid Mirror Telescope (LMT) project lead by J. Surdej (Ulg), with ROB interested in gravitational lenses, very recently (November 2003) a project was started to analyse results obtained by the XMM observatory and in the IR and MIR.
The main result obtained at the end of year 2003 is the creation of the catalogue of X-ray point-like sources detected in the XMM-LSS fields (see the URL: http://vela.astro.ulg.ac.be/xmm/LSS).

33.3. Perspective for next years

First the catalogue of X-ray point-like sources will be improved in taking into account the next release of the X-ray sources (April 2004).Then IR and MIR observations, to be obtained with SIRTF, will help us to conduct a new QSO catalog by cross-correlating X-ray and NIR/MIR data. The reduction of these observations will be the main concern for the next year and will lie within the scope of the PhD of C. Libbrecht in Liège (promotor: M.Jean Surdej). With regard to the LMT, an agreement with ESO on the installation of the telescope at La Silla is reached early in 2004.

33.4. Personnel involved

Dr. E. L. van Dessel, head of department III
Lic. C. Libbrecht, PRODEX fellow

33.5. Partnerships

List of national and international partners:
Institut d'Astrophysique et de Géophysique, Université de Liège; Service d'Astrophysique , CEA Saclay (France); European Southern Observatory (Santiago, Chile); Universidad Catolica (Santiago, Chile).

Grants used for this research:
PRODEX "Search for Active Galactic Nuclei with the XMM-Newton Observatory in the XMM-LSS field" (applicant: E. L. van Dessel).
Lotto (financing the detector of the LMT, applicant: E. L. van Dessel).
Visitors: 0

33.6. Publications

None

33.7. Missions

None

34. Research project: Chemical evolution of galaxies

34.1. Objectives

This project is articulated around two main research orientations: (1) the chemo-dynamic evolution of galaxies and (2) the modeling of stellar thermonuclear combustions associated with explosive astrophysical events (thermonuclear supernova and thermonuclear burning at the surface of accreting compact stars. Both research avenues fall into the framework of an international collaboration in astrophysics

34.2. Progress and results

34.2.1. Contribution to the axis "chemo-dynamic evolution of galaxies"

This research project is carried out in the framework of a collaboration between the Observatoire Royal de Belgique (ORB: Dr. Yves Busegnies), the Institut d'Astronomie et d'Astrophysique de l'Université Libre de Bruxelles (IAA-ULB: Prof. Marcel Arnould, PhD student Abdelmalek El Messoudi) and the Institut d'Astrophysique de Paris (IAP: Dr. Nikos Prantzos). The principal objective of this collaborative effort is the development of a Nbody + hydrodynamic code for modelling the coupling between the dynamics of the galactic gas and the nucleosynthesis occurring in the stars of the host galaxy. The Smoothed Particle Hydrodynamics (SPH) Lagrangian method has been selected for that purpose. In a first stage, we investigate the chemo-dynamic evolution of a prototypical spiral galaxy, the Milky Way. This study was kickstarted at the ORB by Dr. Henri Boffin in Nov. 2002. From Nov. 2002 to Apr. 2003, I examined the possible adaptation of Dr. Boffin's hydrocode to the specific problem of galactic simulations. This phase required (a) including the dark matter gravitational component in the available SPH hydrocode, and (b) taking into account heat transfer in the energy balance of the galactic fluid. A large set of numerical tests has been devised and performed in 2003. These tests have clearly shown that if part (a) could be successfully carried out with the hydrocode at hand, serious numerical stability problems have arisen while attempting to implement part (b). Those difficulties have been attributed to the time integration scheme of Dr. Boffin's hydrocode. Since the departure of Dr. Boffin, I have – with the agreement of the other parties involved - redirected the project towards the use of the TREESPH method. More specifically, the hydrodynamic code nicknamed GADGET (Galaxy with Dark matter and Gas IntEract) has been obtained from its authors at the Max-Planck Institut für Astrophysik in Garching-bei-München (Germany). The PhD student Abdelmalek El Messoudi and I have begun analysing this tool that is better suited to the problems to be studied in the present project. A progress report meeting with Dr. Prantzos has been held at the IAP (Paris) in Dec. 2003. After discussing the status of the project, the broad lines of future developments were agreed upon.

34.2.2. Contribution to the axis « thermonuclear combustion

The goal of this multidisciplinary research project is to develop computing tools that will allow the exploration of the multidimensional aspects of the propagation of a thermonuclear combustion front in degenerate stellar plasma. In fine, we will study the nucleosynthesis associated to those reactive flows. During the year 2003, I have initiated many steps (talks, lectures, various meetings) in order to put together a research group involving astrophysicists and experts on terrestrial combustion processes for undertaking the study of explosive phenomena in astrophysics. These efforts have led to our project being joined to the wider research project of the "Groupe de Combustion et Supernovae" of the Centre National de la Recherche Scientifique (France). This vast collaboration also involves the Département d'Astrophysique du Commissariat à l'Energie Atomique (Saclay, France), combustion laboratories from Poitiers and Marseille, and the Département de Mathématiques Appliquées de l'Université de Bordeaux. In Belgium, I have contacted Prof. M. Papalexandris, an expert in the modelling of combustion at the Université Catholique de Louvain. Together, we have initiated collaboration with the IAA-ULB. In parallel to this organisational effort, I have completed the development of an equation of state of the exploding plasma that will be incorporated in 2004 by the various collaborators in their respective hydrocodes. I have performed an analysis of the thermodynamics, the nuclear kinetics and the shock front capture. Concurrently, I pursued the study and the implementation of the physics of thermonuclear plasmas in the SPH method

34.3. Perspective for next years

As far as the chemo-dynamic evolution of galaxies is concerned, the plan for 2004 is to incorporate in the GADGET hydrocode (a) an adequate cooling function for the resolution of the internal energy balance of the galactic gas, (b) a star formation algorithm that represents the transformation of the gas into stellar objects. These two development levels will require a large number of numerical tests in order to stabilize the hydrodynamic computing scheme. After that, we will examine the question of the feedback between the stars and the galactic gas.

Concerning thermonuclear combustion part, there will be a two-pronged approach: (a) in collaboration with Prof. Papalexandris (UCL) and Claire Noël (PhD student at IAA-ULB), we will investigate in 2004 the development of a Riemann Solver suited to the equation of state of degenerate stellar plasma. It will be implemented in a modular way in a hydrocode that should resolve the multidimensional aspects of a shock wave. This tool will then be used for simulating a stellar thermonuclear detonation, particularly the cellular detonation regime. (b) A similar activity, centred on other numerical architectures, is planned with the French laboratories of the "Groupe Combustion et Supernovae".

34.4. Personnel involved

Dr. Y. Busegnies, chercheur supplémentaire and 25% assistant IAP P5/36

34.5. Partnerships

List of national and international partners

- Institut d'Astronomie et d'Astrophysique de l'Université Libre de Bruxelles (IAA-ULB: Prof. Marcel Arnould, PhD student Abdelmalek El Messoudi)
- Institut d'Astrophysique de Paris (IAP: Dr. Nikos Prantzos)
- Département d'Astrophysique du Commissariat à l'Energie Atomique (Saclay, France), combustion laboratories from Poitiers and Marseille
- Département de Mathématiques Appliquées de l'Université de Bordeaux, Université Catholique de Louvain (Prof. M. Papalexandris).

Grants used for this research:
Chercheur supplémentaire (applicant H. Boffin).

IAP P5/36: Modern Aspects of Theoretical and Observational (ground-based and space-born) Astrophysics, promotor J.-P. Swings (Ulg), co-promotor: C. Waelkens (K.U.Leuven), C. Sterken (V.U.Brussel) and H. Hensberge (ROB).
Actions Intégrées franco-belges Tournesol 2003 (03/025-09/12/2002-1485): Evolution chemo-dynamique des galaxies. (extern credit)

Visitors: 0

34.6. Publications

34.6.1. Publications with peer system

34.6.2. Publications without peer system

Busegnies Y., Lehoucq R. and Chièze J.-P.
Propriétés physiques des naines blanches. I – Equation d'état des plasmas stellaires
In: Second report of the Groupe Combustion & Supernovae

Busegnies Y. and Boffin H.M.J.
Les supernovae de type Ia
Ciel et Terre, 119, 2, 2003.

34.6.3. Publications in press, submitted

Busegnies Y., Francois J., Paulus G..
SPH simulations of reactive shock tubes in an astrophysical perspective
Journal of Computational Physics, submitted july 2003, revised: december 2003

34.6.4. Reports, thesis, etc

Progress report on the project « Chemo-dynamic evolution of galaxies » carried out in the framework of the "Action Intégrée Franco-Belge Tournesol 2003" (collaboration between the Institut d'Astronomie et d'Astrophysique de l'Université Libre de Bruxelles and the Institut d'Astrophysique de Paris).

34.7. Missions

Symposia, workshops (international, one day national): 2
Field missions: 1

SECTION 7: Physics of Stellar Atmospheres

35. Hot stars

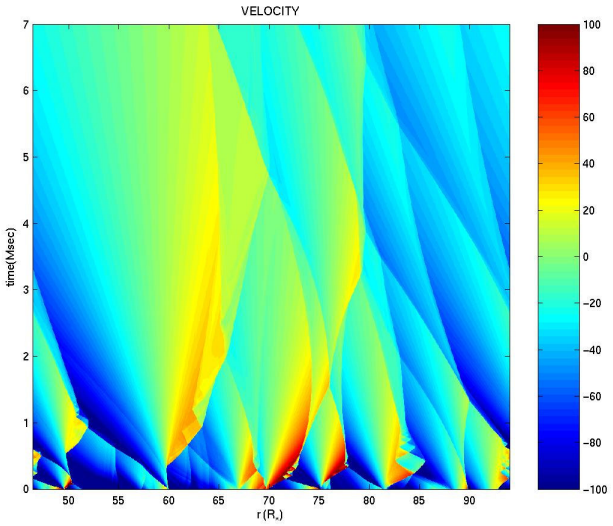
35.1. Objectives

Hot stars have radiatively driven stellar winds. Considerable observational evidence exists that these winds are not smooth, but structured. This project tries to elucidate the nature of this structure, by studying these stars both observationally (at various wavelengths) and theoretically (by constructing models for the hydrodynamics and radiative transfer).

35.2. Progress and results

The O 4 I(n)f star ζ Puppis shows an excess of flux at millimetre wavelengths compared to centimetre wavelengths. Fitting models of a wind containing structure shows that the structure decays substantially, or maybe even disappears, beyond 70 R_*. From the radio observations we derived a mass loss rate of 3.5 x 10^{-6} $M_\odot$/yr. The fact that this is 70 % lower than the Hα mass loss rate is highly significant, and is a further indicator of substantial change in structure between the inner and outer wind (Blomme et al. 2003, A&A 408, 715).

A powerful theoretical method to study the evolution of instability-generated structure in the outer winds of hot stars was developed (in collaboration with S. P. Owocki, University of Delaware). This method makes use of the fact that the outer evolution of structure is a pure gasdynamical problem, in the sense that it does not depend on external forces such as gravity or radiative driving. Practically, this enables us to select a representative portion of the wind and follow it outward, rather than having to evolve the entire wind. The computational advantages of this technique over a standard calculation are considerable.



Using this "pseudo-planar moving periodic box" method, we have evolved stellar wind structure out to a distance of 1300 stellar radii. These simulations show that the wind remains structured out to very large distances. The evolution of the velocity (in km/s) as a function of space and time is shown on the figure on the left. A further use of the moving periodic box method is to test the dependence of hydrodynamical models on the Galilean reference frame in which they were obtained. We showed that the high speed at which the gas flows over the grid in a standard calculation produces a number of artefacts which are difficult to control (Runacres & Owocki, 2004, A&A, submitted).

In collaboration with G. Rauw and his group (Université de Liège) we studied the non-thermal radio emitter HD 168112. We reduced the VLA radio observations that had been taken nearly-simultaneously with two XMM-observations (which were taken five months apart). While the radio flux was already known to be variable, this is the first time that a flux difference as large as a factor of ~6 was found (De Becker et al. 2004, A&A, submitted).

The non-thermal radio emission from single hot stars is due to synchrotron radiation from relativistic electrons accelerated in wind-embedded shocks. We have developed a theoretical model for this and applied it to the non-thermal emitter Cygnus OB2 No. 9. The most important result is that the outer boundary of the synchrotron emission region must lie between 500 and 2200 stellar radii. This means that shocks must persist up to such distances. The results we found are compatible with current hydrodynamical simulations (Van Loo et al. 2004, A&A, in press). We also applied the synchrotron model to all non-thermal radio emitters for which sufficient information is available.

Hot stars are also studied in the context of other projects (asteroseismology, binaries).

35.3. Perspective for next years

The reduction and interpretation of radio and millimetre data on non-thermal and thermal hot stars will be continued. Further observational projects at far-infrared (Spitzer), millimetre (JCMT) and radio wavelengths (VLA, ATCA) will be introduced.

We plan to produce synthetic diagnostics of stochastic structure for a sample of 10 stars of spectral type O to B3 and compare them to observations. The goal is to see to what extent present hydrodynamical models fit the observations, to investigate phenomenologically which model properties should be altered to produce better agreement and to detect certain trends.
We will incorporate a more realistic description of the relativistic electron distribution in the stellar wind into the synchrotron model. The research in modelling the non-thermal radio emission of hot stars will be written down in a Ph.D. thesis.

35.4. Personnel involved

R. Blomme
M. Runacres
S. Van Loo
G. Van de Steene
J. Vandekerckhove

35.5. Partnerships

35.5.1. National partners:

G. Rauw, M. De Becker, A. Detal, P. Eenens, E. Gosset, Y. Nazé, H. Sana (Université de Liège)
M. Goossens (K.U.Leuven)

35.5.2. International partners:

S.P. Owocki (Bartol Research Institute, University of Delaware, USA)
R.K. Prinja and J.S. Clark (University College London, UK)

35.5.3. Grants used for this research:

IUAP 5/36 (M. Runacres)
Action 2 by Belgian Science Policy (S. Van Loo)

35.5.4. Visitor:

None

35.6. Publications

35.6.1. Publications with peer system

Blomme, R., Van de Steene, G.C., Prinja, R.K., **Runacres, M.C**., Clark, J.S.
Radio and submillimetre observations of structure in ζ Puppis
Astron. Astrophys. 408, 715

35.6.2. Publications without peer system

Blomme, R., Runacres, M.C.
The P32Tools model applied to "staring" observations
in: Proceedings of the "ISOPHOT Workshop on P32 Oversampled Mapping", ESA-SP 482, 37

Blomme, R., Runacres, M.C.
Stellar winds of early-type stars
in: Proceedings of the "ISOPHOT Workshop on P32 Oversampled Mapping", ESA-SP 482, 67

Blomme, R., Runacres, M.C.

The memory effect of the ISOPHOT-C100 detector
in: "Exploiting the ISO Data Archive. Infrared Astronomy in the Internet Age", (eds. C. Gry et al.), ESA SP 511, 331

Runacres, M. C.
The outer evolution of structure in radiatively driven stellar winds
Revista Mexicana de Astronomía y Astrofísica (SC), Vol. 15, p. 217

Runacres, M. C., Owocki, S.P.
Clumps and shocks in the outer wind of hot stars
IAU Symposium 212, p.226

Van Loo, S.
Non-thermal radio emission from single hot stars
Revista Mexicana de Astronomía y Astrofísica (SC), Vol. 15, p. 230

35.6.3. Publications in press, submitted

Blomme, R.
Structure in the Stellar Winds of O-type Stars
in: Proceedings of IAU Symposium 210, "Modelling of Stellar Atmospheres", (eds. N.E. Piskunov, W.W. Weiss, D.F. Gray), in press

Blomme, R.
Observational Effects of Corotating Interaction Regions in OB stars
in: Proceedings of IAU Symposium 215, "Stellar Rotation", (eds. A. Maeder, Ph. Eenens), in press

De Becker, M., Rauw, G., **Blomme, R.**, …, **Runacres, M.C., Van Loo, S.**, Pollock, A.M.T.
A quasi-simultaneous XMM-Newton and VLA observation of the non-thermal radio emitter HD 168112
Astron. Astrophys, submitted

Rauw, G., **Blomme, R**., ..., **Runacres, M.C**., ..., **Van Loo, S.**, ...
An XMM-Newton study of 9 Sgr and the Lagoon Nebula
in: Proceedings Symposium "New Visions of the X-ray Universe in the XMM-Newton and Chandra Era", (eds. F. Jansen et al.), ESA-SP 488, in press

Runacres, M. C., Owocki, S.P.
A pseudo-planar, periodic box formalism for modelling the outer evolution of structure in spherically expanding stellar winds
A&A, submitted

Van Loo, S., Runacres, M. C., Blomme R.
Non-thermal radio emission from single hot stars
A&A, in press

35.6.4. Reports, thesis, etc

Van Loo, S.

Yearly report Action 2: Ph.D. Grant

35.7. Missions

- research missions (assemblies, symposia, workshops, etc): 7
- operational meetings (commissions, working groups): 5
- Field missions (observations, station maintenance, etc): 0

Post-AGB Stars and planetary nebulae.
Objectives

The main objective is to study the final stages of evolution of intermediate mass stars, i.e. the evolution from the post-asymptotic giant branch (AGB) stage through the planetary nebula stage.
This evolution is still poorly understood mainly because of a complex interplay among various physical processes between the star and nebula. However, it makes these objects excellent laboratories of astrophysical processes.
Progress and results

G. Van de Steene in collaboration with P. van Hoof and P. Wood (RSAA, Australia) obtained moderately high resolution optical spectra of post-AGB stars. The goal is to obtain a statistically significant sample of post-AGB stars with known stellar temperatures and detailed information on the central star wind, for at least those objects that show P-Cygni type hydrogen emission. This will allow us to test theoretical mass-loss recipes for stellar evolution codes. This will lead to more realistic post-AGB evolution models and a better understanding of the role of post-AGB winds in PN formation.

In collaboration with P. van Hoof (Queens University Belfast), Van de Steene and Ueta have investigated possibilities to determine accurately the stellar properties and chemical composition of these post-AGB stars with winds by constructing a grid of unified NLTE atmospheric models. The parameters of our specific interests have been found to fall in a numerically unstable regime (of the current NLTE codes). Alternative solutions to this problem need to be investigated. Spectral types and temperatures will be determined via other methods.

G. Van de Steene in collaboration with P. van Hoof (Queens University Belfast) studied the shock emission in the bipolar post-AGB star IRAS 16594-4656 (results published in A&A).
Using optical and near-infrared Photometry we determined the total extinction towards this object and derived a distance. The near-infrared spectrum shows strong H2 emission lines and some typical metastable shock excited lines. Based on the rotational and vibrational excitation temperatures, as well as the ortho-to-para ratio, we concluded that H2 is mainly collisionally excited. We managed to obtain further high resolution near-infrared spectra of H2 and [Fe II] with the Phoenix instrument on Gemini-South to investigate the proposed geometry and kinematics. In collaboration with T. Ueta these spectra have been reduced and analysed together with the H2 and polarization images from the HST archive which were retrieved and carefully reduced.

G. Van de Steene in collaboration with G. Jacoby (WIYN telescope, NOAO, USA) wrote up the results of their survey in which they found 94 planetary nebulae (PN) candidates not previously known within 2 degrees of the Galactic Center (A&A in press). For 63 we obtained spectra that are consistent with highly reddened PNe, while 34 could not be recovered spectroscopically and remain unverified. An additional 20 PN candidates were found during follow-up Hα imaging but have not been verified spectroscopically. Based on the total luminosity of the Galactic bulge, the expected number of PNe is ± 250, only 50% more than the 160 PNe candidates now known, with the remainder likely hidden behind dust.

Perspective for next years

During the evolution toward the PN stage drastic changes are observed in the circumstellar structure and kinematics, while the star evolves towards higher temperatures and finally starts to ionize the nebula around it. We will continue to study the formation of PNe by studying several post-AGB stars and their circumstellar shells spectroscopically and via imaging in the optical and at infrared wavelengths.

Publications

Publications with peer system

Van de Steene, G.C., van Hoof, P.A.M.
Shock emission in the bipolar post-AGB star 16594-4656
2003, Astronomy and Astrophysics, 406, 773

Blomme, R., Van de Steene, G.C., Prinja, K.R., Runacres, M.C., Clark, J.S.
Radio and submilimillimetre observations of the wind structure in Zeta Pup
2003, Astronomy and Astrophysics, 408, 715

Publications without peer system

Van de Steene, G.C., Jacoby, G.H,
Chemical composition of new galactic bulge planetary nebulae
in proceedings of Planetary Nebulae: Their Evolution and Role in the Universe, IAU Symposium 209, eds. K. Sun, M. Dopita, & R. Sutherland (San Francisco: ASP), 49

Weldrake, .T.F., Wood, P.R., **Van de Steene, G.C.**
NIR spectroscopy of IRAS 16115-5044
in proceedings of Planetary Nebulae: Their Evolution and Role in the Universe, IAU Symposium 209, eds. K. Sun, M. Dopita, & R. Sutherland (San Francisco: ASP), 129

Publications in press, submitted

Jacoby G.H., Van de Steene, G.C.,
Planetary nebulae near the galactic center: Identifications
2004, Astronomy and Astrophysics, in press

Van de Steene, van Hoof, P.A.M.,
The post-AGB star 16594-4656
in proceedings of Asymmetric Planetary Nebula III: Winds, Structures, & the Thunderbird, eds. M. Meixner, J. Kastner, N. Soker, & B. Balick (San Francisco: ASP), in press

Reports, thesis, etc.

Lezer licentiaatsthesis van Y. Decan, De post-AGB ster IRAS 16559-2957, 2003, K.U.Leuven

Missions

Assemblies, symposia, workshops

- 29/07-01/08/03: Asymmetric Planetary Nebula III: Winds, Structures, & the Thunderbird, Crystal Mountains, WA , USA
- 10-11/04/03: Future Directions in AGB Research, Leiden U., Leiden, The Netherlands

Commissions, working groups

- Herschel PACS Guaranteed time working group meeting, K.U. Leuven

Field missions

- 29/02-29-/03/03: Spectroscopic classification of newly discovered post-AGB stars, La Silla Observatory, ESO, Chile

Miscellaneous activities

- Referee for Astronomy & Astrophysics and New Astronomy
- 22/02/03: Public talk, Volkssterrenwacht Beisbroek.

Personalia

Visitor G. H. Jacoby, WIYN Observatory NOAO, 13-19/11/1003

DEPARTMENT 4: Solar Physics

36. General Department management and project coordination

36.1. Objectives

Overall management and coordination of the projects of the Solar Physics department, including the financial (funding) and human resources (contracts).

36.2. Progress and results

36.2.1. Department management and coordination

- In 2003, F. Clette was in charge of the overall management of the Department as Head of Department *ad interim*, in replacement of P. Cugnon, head of the Department, who was absent for health reasons during most of the year (except in April-May).
- Several new projects selected in 2002 effectively started in 2003 (SHARPP, SWAP, LYRA, ESA Space Weather Pilot Project), in addition to the ongoing projects, (EIT/SOHO, EIT Telescience, PRODEX "Solar Drivers of Space Weather", and OSTC Impulsion to Research). More specifically, the Solar Physics Department experienced an unprecedented and fast growth, more than doubling its activities and science staff in 18 months (7 new contractual positions). This continuously evolving context induced a major administrative workload that justified the recruiting of a secretary. The administrative management has become a central duty in itself, vital and mandatory to allow the science activities of the Solar Physics Department to be pursued.
- A new internal Department organization was introduced in November 2003: a new work organization was defined, which splits the research activities of the Solar Physics Department in 4 distinct groups managed by 4 leaders, with a n overall coordination ensured by the Head of Department. This fundamental modification, implemented at the end of 2003, should allow in 2004 to make the management of the Department activities more efficient and flexible, by a closer proximity between the project leaders and their team. This reorganisation also aims at reviving the solar ground-based instruments, which were on a decay phase, in part because of the growing pressure of the multiple demanding space projects. This should thus partly restore a balance between the short-lived projects and permanent services.

36.2.2. Department Staff

Contractual staff evolution:

- A major recruiting effort was conducted in the second semester of 2003, following the opening of several budgets.
- 6 new contractual staff members were recruited in 2003: A. Ben Moussa (LYRA), D. Lafont (SHARPP), B. Nicula (SWAP), E. Robbrecht (ESA SW), P. Van Lommel (ESA SW), S. Willems (SHARPP).
- 3 contracts came to an end: C. Foullon ("Solar Drivers of Space Weather", 30/9), J-Y Ledent (replacement contract, 31/8) and E. Verwichte (BELSPO Impulse to Research, 31/12)

Permanent staff evolution:

- Mr. P. Janssens (Research Technician) finished his training period in March 2003, and was permanently recruited.
- Position of Principal Constructor: on the other hand, no progress was made regarding the replacement of Mr. D. Lapaige, who retired in Decembre 1999.
- Mr. D. Carré: the almost permanent absence for medical reasons of Mr. Carré, except for 10 days in July, made this lack of staff even worse.

This situation is highly detrimental to the good working of instruments and activities of the Department, in particular of the permanent services. Solutions were actively investigated and actions were initiated.

Staff distribution in 2003:

- "Structure et dynamics of the solar atmosphere" section

– Permanent staff (scientists): David Berghmans
– Contractual staff (scientists): Ali Ben Moussa, Claire Foullon, Samuel Gissot (PhD Student), Jean-François Hochedez, Bogdan Nicula, Erwin Verwichte, Laurence Wauters, Sarah Willems, Andrei Zhukov.
– Contractual staff (support): Dany Lafont

- "Solar activity" section

– Permanent staff(scientists): Frédéric Clette, Pierre Cugnon, Ronald Van der Linden
– Permanent staff (support): Jean-Luc Dufond, Gisèle Evrard-Kesteloot, Paul Janssens, Christian Rondeaux, Arille Vigneron
– Contractual staff (scientists): Eva Robbrecht, Petra Van Lommel,
– Contractual staff (support): Olivier Boulvin, Viviane Herman, Jean-Yves Ledent, Stéphane Walkiers.

36.3. Perspective for next years

– After an adaptation phase, the reorganization initiated in 2004 will be fully implemented.
– A few more scientists will be recruited.
– The preparation of PRODEX8 budget plans for the ongoing projects is expected by mid-2004

36.4. Personnel involved

F. Clette (Head of Department a.i.), D. Lafont (project coordination, administration)
Group leaders (Dec. 2003): D. Berghmans, J-F Hochedez, R. Van der Linden.

36.5. Partnerships

Visitors: 3 visitors (PRODEX office)

36.6. Publications

36.6.1. Reports, thesis, etc

Department annual report

36.7. Missions

10 operational missions in Belgium.

SECTION 8: Structure and Dynamics of the Solar Atmosphere

This section gathers most of the research activities of the Department of Solar Physics (DSP). It specialises in the study of the external layers of the solar atmosphere (chromosphere, transition layer, corona), mainly through the exploitation of images made in the extreme-ultraviolet and visible light and coming from various space instruments to which the DSP is collaborating as Co-Investigator or more recently as Principal Investigator.

The main topics of research involve:

- The detection, the analysis and the modelling of dynamical or eruptive phenomena, from the smallest to the largest observable scales.
- The morphological analysis of magnetic structures in the solar corona
- The extraction of motion in the corona (differential rotation, plasma flows)

In order to derive observational constraints to the proposed mechanisms of coronal heating and solar wind generation and to classify the various active phenomena that disturbs the solar atmosphere and influences the solar–terrestrial relations.

The current research makes use of advanced image processing techniques, developed in collaboration with several specialized groups in Belgium and abroad, and of the systematic exploration of the entire EIT and LASCO archive, from the SOHO mission. The "EIT high-cadence" program, implemented in 2000 by the DSP, is carried out on the long term in this framework, with support from several space instruments.

The expertise acquired by the science team with the SOHO mission over the last decade is now valorised by the participation to future space missions of ESA or NASA (currently STEREO, SDO, PROBA2). The role of the DSP was to participate to the definition of scientific objectives and programs, as well as to contribute to the technical specification of the instrument. Moreover, the DSP also take part in laboratory studies of new technologies for future extreme-ultraviolet detectors, intended for the next generation of solar space instruments (e.g. Solar Orbiter). Many of those projects have started recently in 2002 and 2003 and will ensure the long-term continuation of the research conducted in the DSP.

37. SECCHI: Sun-Earth Connection Coronal and Heliospheric Investigation

37.1. Objectives

SECCHI is an instrument suite on each of the two STEREO spacecrafts of NASA (launch early 2006) consisting of a EUV imager, a coronagraph and a heliospheric imager. The participation of the ROB consists in (the preparation to) the scientific analysis of the SECCHI data, the development of automated recognition software and the use of SECCHI data in the context of operational space weather.

37.2. Progress and results

The PRODEX STEREO/SECCHI project started on July 1, 2003. Two persons have been selected to be hired on the project: Andrei Zhukov (currently at ROB on another project) and Elena Podlachikova (awaiting work permit).

Some instrumental support has been given on the level of the calibration LEDs of the EUV imager and on the shutterless readout of the heliospheric imager. However, the work over 2003 consisted mainly in determining our precise role in the SECCHI consortium. With this goal, we have organized 2 international meetings at the ROB: the *SECCHI consortium science meeting* and *Solar Image Recognition Workshop* (see also SWAP project).

The *Computer Aided CME Tracking* (CACTUS) software that is under development, jointly between the SIDC project, the SECCHI project and the Solar Drivers of Space Weather project, is seen as an important asset for our future contribution to the SECCHI consortium.

Figure: The different instruments within the SECCHI instrument suite (HI at right).

37.3. Perspective for next years

– 17/02/04: internal ROB kick-off meeting
– 22/03/04: STEREO science meeting (Boulder, US)
– 15/04/04: SECCHI consortium meeting
– mid 2004: hiring team, purchase equipment
– mid 2004: true start of project activities, start software development

37.4. Personnel involved

(in alphabetical order):
David Berghmans, Frederic Clette, Jean-Francois Hochedez, Gareth Lawrence (hired Jan 15, 2004), Ronald Van der Linden, Eva Robbrecht, Andrei Zhukov.

37.5. Partnerships

This project is supported by an ESA PRODEX grant (ESTEC reference C90131, ROB reference PRODSTEREO).

SECCHI is an instrument suite build for the NASA STEREO mission by scientists in the following consortium member institutes:

- Naval Research Laboratory
- Max-Planck Institut fur Aeronomie
- University of Kiel
- Rutherford Appleton Laboratory
- Mullard Space Science Laboratory
- NASA Goddard Space Flight Center
- University of Birmingham
- Centre de Spatial Liège
- Lockheed Martin Advanced Technology Center
- Institut d'Astrophysique Spatiale
- Institut d'Optique
- USAF Space Test Program
- Swales Aerospace
- Hytec Incorporated
- Praxis Incorporated
- The Hammers Company
- Boston College

- Smithsonian Astrophysical Observatory
- Royal Observatory of Belgium
- Observatoire de Paris
- Laboratoire d'Astronomie Spatiale
- NASA Jet Propulsion Laboratory
- Science Applications International Corporation
- Stanford University
- University of Michigan
- Southwest Research Institute

37.6. Publications

None yet.

37.7. Missions

– 01/09/03: ESA discussion meeting on International Living with a Star, London

38. SWAP: Sun Watcher using APS detectors and image Processing

38.1. Objectives

SWAP is a novel space telescope that will fly on the PROBA-2 ('Project for onboard autonomy') mini-satellite. The SWAP instrument will deliver images in the extreme ultraviolet of the solar corona and will demonstrate the technical feasibility of the novel optical design, C-MOS APS detectors for EUV sensing and on-board algorithms for advanced autonomous operations.

38.2. Progress and results

The SWAP activities started at the ROB in the beginning of 2003, while the SWAP PRODEX contract started only in July, 1 2003. Together with the Centre Spatial de Liège, the Royal Observatory of Belgium is the leading institute for the scientific exploitation of the SWAP data. The ROB acts as supporting co-Pi institute whenever CSL needs input on the required field of view, the image cadence, the signal to noise level, the spatial resolution, the wavelength passband, etc. In addition, the ROB contributes expertise for the onboard software of SWAP, especially the software to demonstrate onboard image recognition.

Hardware and software alternatives for the SWAP data compression were studied (Bogdan Nicula) taking into account the stringent limitations of the PROBA-2 platform. An algorithm was designed for data reduction, which improved the performances of the general-purpose software compression algorithm proposed. In general, data management and algorithms specifications for SWAP and LYRA (the radiometer on-board PROBA-2) were issued. A method for CCD flat field determination was implemented to characterise the proposed SWAP detector. The properties of the algorithm in terms of convergence and floating-point accuracy were intensively scrutinized.

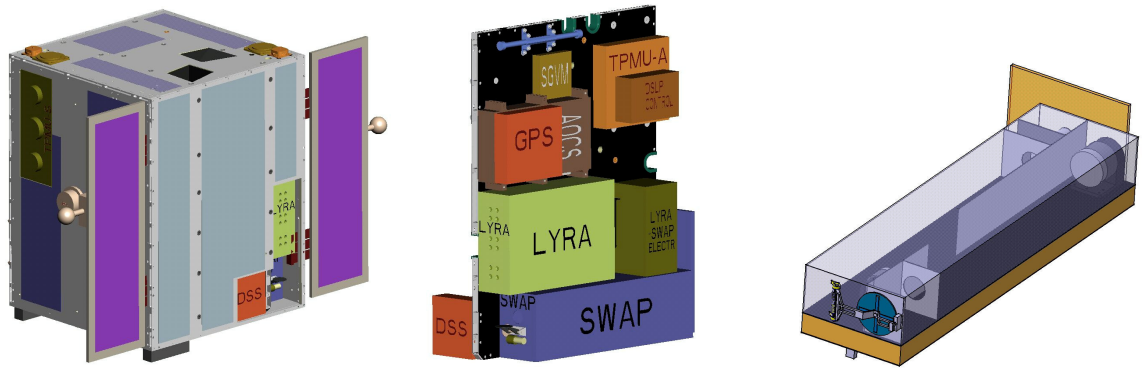


Figure: Some design drawing of the PROBA-2 spacecraft (left), the internal panel on which SWAP is mounted (middle) and the SWAP telescope itself (right). Image courtesy: Verhaert & CSL.

38.3. Perspective for next years

– The system design review of PROBA-2 will be on February, 16 2004.
– The preliminary design review for SWAP is foreseen for March 2004.
– The launch of SWAP on the PROBA-2 platform is foreseen for 2006.
– The ROB will be the PI institute for the SWAP instrument after commissioning.

38.4. Personnel involved

(in alphabetical order):
David Berghmans (science PI), Jean-Francois Hochedez, Gareth Lawrence (hired on SWAP project on Jan 16, 2004), Bogdan Nicula (hired on SWAP project on Aug 16, 2003), Ronald Van der Linden, Laurence Wauters, Andrei Zhukov.

38.5. Partnerships

This project is supported by an ESA PRODEX grant (ESTEC reference C90117, ROB reference PRODSWAP).

SWAP is an instrument build for the ESA PROBA-2 mission by scientists in the following consortium member institutes:
– Royal Observatory of Belgium
– Centre Spatial de Liege
– Max Planck Institut für Aeronomie, Lindau
– University of Padua
Within the SWAP project we also have industrial partnerships with the following companies:
– Verhaert, Kruibeke
– Spacebel, Hoeilaart
– OIP, Oudenaarde

38.6. Publications

38.6.1. Publications without peer system

Defise, J.M., **Berghmans D., Hochedez,** J.F., Lecat, J.H., Rochus, P., Thibert, T., Nicolosi, P., Pelizzo, M.G., Schuhle, U., **Vander Linden R.A.M., Zhukov, A.N.**
SWAP : Sun Watcher using APS detector on-board PROBA-2, a new EUV off-axis telescope on a technology demonstration platform

Proceedings of SPIE CONFERENCE 5171,Telescopes and Instrumentation for Solar Astrophysics, Aug 2003

D. Berghmans, J F Hochedez, J. M. Defise, J. H. Lecat, **B. Nicula, R. Van der Linden, A. Zhukov, F. Clette,** R. Rochus, E. Mazy, T. Thibert, P. Nicolosi, U. Schuehle

SWAP: Sun Watcher using APS Detector on-board PROBA II, a new EUV imager for solar monitoring (Poster presentation)

03-05/11/03: ESA Space Weather Workshop, ESTEC, Noordwijk, The Netherlands

38.6.2. Publications in press, submitted

Jean-Marc Defise, Jean-Hervé Lecat, Emmanuel Mazy, Pierre Rochus, Laurence Rossi, Tanguy Thibert, **David Berghmans, Jean-François Hochedez**, Udo Schühle

SWAP: Sun watcher with a new EUV telescope on a technology demonstration platform

ICSO 2004, 5th International conference on space optics, Toulouse, submitted

38.6.3. Reports, thesis, etc

An online library has been created (development: Laurence Wauters) that contains all the specification documents, technical notes and related material of the SWAP project.

38.7. Missions

– Participation to 2 Science meetings.
– 8 technical meetings have been held with the different industrial contractors and partners of the SWAP project.
– A first calibration campaign was also held at BESSY, Berlin

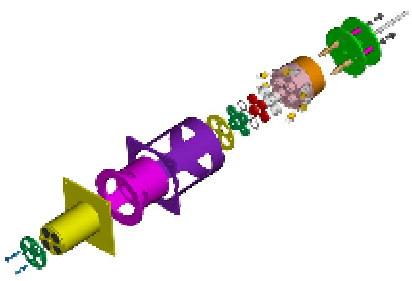
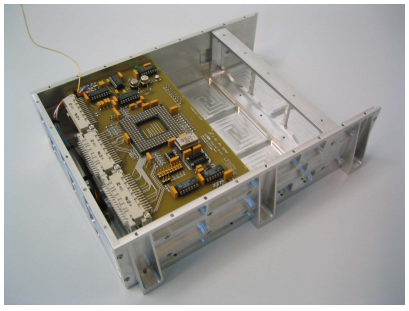
39. LYRA

39.1. Objectives

LYRA (LYman-alpha RAdiometer) is a solar UV radiometer that will embark in 2006 on-board the ESA PROBA-2. The objectives of the instrument are to sample the solar irradiance in 4 passbands relevant to Solar Physics, Space Weather and Aeronomy. It demonstrates solar-blind filters and novel diamond detectors. As PI-institute, the ROB prepares the LYRA Science, and maximizes the future returns by governing the instrument development. Besides, we are responsible for the calibration, the radiometric model and the software workpackages.

39.2. Progress and results

LYRA is being designed, manufactured and calibrated by a Belgian-Swiss-German consortium. Jean-François Hochedez (ROB) is Principal Investigator, Yvan Stockman (CSL) is Project Manager, and Werner Schmutz (PMOD/WRC) is Instrument Scientist.

a/ logo LYRA, b/ exploded view of one unit (out of 3), c/ the LYRA prototype box in Dec'03

After the proposal writing and ESA selection in 2002, the main issues in 2003 have been the project management, schedule and budget. We had built the consortium in '02, and the definition of the respective tasks and associated schedule have proceeded intensively at ROB until the management was transferred to CSL in October '03. A Swiss Belgian agreement on the scientific priorities and authorship was reached and signed in June. After the funding release in July, a first recruiting phase occurred, leading to the hiring of Dr Benmoussa (August), and a second phase in the end of the year causing the selection of Ms Dominique (Jan '04), Dr Theissen (March '04), and Dr Delouille (May '04).
Permanent awareness and control of the instrument development were achieved by a thorough and proactive reviewing of project documents and meetings. On the scientific and technical side, the ROB work has focused on the LYRA channel definition, with the invaluable help of our numerical radiometric model. The porous filter option proposed by our Russian collaborators has triggered the necessary attention for assessing their potential. The writing of the calibration plan has required a lot of coordination. Tens of technical documents have been archived in the SLATE database/web archive. We have carried out studies about the compression and overall flight software schemes. A DEM inversion study is being prepared in collaboration with Dr Matthieu Kretzschmar. Occultations were studied with Dr Gillotay (BISA) and Dr Slemzin (LPI).

39.3. Perspective for next years

2004 is the year of the LYRA detailed design and manufacture (PDR in February and March '04). The calibrated flight instrument is due in March 2005. A lot of work is ahead. After delivery, we will concentrate even more on the Science preparation and ground segment development. The launch is anticipated in 2006. The operations are expected to last more than one year.

39.4. Personnel involved

2003: J-F Hochedez, A.BenMoussa, D.Berghmans, L.Wauters, B.Nicula, R.Van der Linden, S.Gissot, A.Zhukov, F.Clette, D.Lafont

39.5. Partnerships

39.5.1. List of national and international partners

- Royal Observatory of Belgium, Circular Avenue 3, B-1180 Brussels, Belgium
- Physikalisch-Meteorologisches Observatorium Davos (PMOD) and World Radiation Center (WRC), Dorfstrasse 33, CH-7260 Davos Dorf, Switzerland
- IMOMEC, Wetenschapspark 1, Universitaire Campus, B-3590 Diepenbeek, Belgium
- Centre Spatial de Liège - Av. Pré Aily B-4031 Angleur - Belgium
- Max-Planck-Institut für Sonnensystemforschung MPS - D-37191 Katlenburg-Lindau - Germany
- Belgian Institute for Space Aeronomy, Circular Avenue 3, B-1180 Brussels, Belgium
- Istituto Fisica dello Spazio Interplanetario, Consiglio Nazionale delle Ricerche, Roma, Italy
- IMEC, Kapeldreef 75, B-3001 Leuven, Belgium
- Lebedev Physical Institute, Russian Academy of Sciences GSP-1 Moscow, B-333, Russia

Within the LYRA project we also have industrial partnerships with industrial companies: Verhaert (Kruibeke), Spacebel (Hoeilaart), OIP (Oudenaarde)

39.5.2. Grants used for this research

LYRA Preparation to exploitation PRODEX C90121

39.5.3. Visitors

W. Schmutz, M. Nesladek, U. Schühle, Y. Stockman, S. Koller, J.P Halain, K. Haenen, M. Kretzschmar, D. Gillotay, H. Roth, M. d'Olieslaeger, J.M. Defise, P. Rochus, V. Slemzin

39.6. Publications

39.6.1. Publications with peer system

39.6.2. Publications without peer system

J.-F. Hochedez, W. K. Schmutz, M. Nesladek, S. Koller, **D. Berghmans**, **A. Ben Moussa**, J.H. Lecat, J.M. Defise, Y. Stockman, **L. Wauters**, **B. Nicula, S. Gissot,** U. Schühle, D. Gillotay, M. Kretzschmar, H. Roth, E. Rozanov, C. Wehrli, I. Ruedi, **R. Van der Linden, A. Zhukov, F. Clette**, M. d'Olieslaeger, J. Roggen, P. Rochus

LYRA: the Solar VUV radiometer on-board PROBA II

ESA Space Weather Workshop: Developing a European Space Weather Service Network SWENET: Space Weather European Network, 3-5 November 2003, ESTEC, Noordwijk

http://www.estec.esa.nl/wmwww/wma/spweather/workshops/spw_w5/index.html

39.6.3. Publications in press, submitted

J.-F. Hochedez, W. Schmutz, M. Nesladek, U. Schühle, **A. Ben Moussa**, Y. Stockman, S. Koller, **D. Berghmans, R. Van der Linden**, J.P Halain, **B. Nicula, L. Wauters**, K. Haenen, M. Kretzschmar, D. Gillotay, H. Roth, C. Wehrli, E. Rozanov, I. Ruedi, **S. Gissot, M. Dominique, A. Zhukov, F. Clette**, M. d'Olieslaeger, J. Roggen, J.M. Defise, P. Rochus

LYRA: the Solar UV radiometer onboard PROBA-2

July 2004: Advances in Space Research (refereed) – COSPAR

J.-F. Hochedez, W. K. Schmutz, M. Nesladek, Y. Stockman, U. Schühle, **A. Ben Moussa**, S. Koller, **D. Berghmans**, J.P Halain, J.H. Lecat, J.M. Defise, **L. Wauters, B. Nicula**, K. Haenen, D. Gillotay, M. Kretzschmar, **S. Gissot, M. Dominique**, H. Roth, C. Wehrli, **R. Van der Linden, A. Zhukov, F. Clette**, M. D'Olieslaeger, J. Roggen, P. Rochus.

LYRA: the solar VUV radiometer on-board PROBA II

Workshop : SURFACE AND BULK DEFECTS IN CVD DIAMOND FILMS (SBDD) IX, February 18 - 20, 2004 LUC, Diepenbeek-Hasselt, Belgium

39.6.4. Reports, thesis, etc

- Contributions in ~200 documents
- SLATE, an online library, has been developed by Laurence Wauters. It should eventually contain all specification documents, technical notes and related material of the LYRA project
- 19/2/2003: Press folder for ROB, turned into a web page

39.7. Missions

Research missions (assemblies, symposia, workshops, etc): 1
Operational meetings (commissions, working groups): 3 abroad, ~15 Belgian

40. SHARPP: Solar Heliospheric Activity Research and Prediction Program

40.1. Objectives

Development of an array of 6 high-resolution EUV telescopes, called MAGRITTE, as part of the SHARPP coronal imaging experiment on the Solar Dynamics Observatory, SDO (NASA mission to be

launched in 2008): participation to the design, development of the instrument science software and automated algorithms for the real-time data pipeline.

40.2. Progress and results

The SDO/SHARPP project has been selected by NASA on August 19, 2003, as a suite containing 7 EUV imagers and a coronagraph. During Phase A (design), which started in September 2002 for a duration of 1 year, F. Clette coordinated the ROB participation, as Deputy Science PI for the MAGRITTE array of EUV telescopes. This work was carried out in close collaboration with the Centre Spatial de Liège (CSL, P. Rochus, Magritte Instrument PI)) under the overall management of the Principal Investigator, R. Howard of the Naval Research Laboratory.

The SHARPP activities started slowly with the existing ROB staff, as the actual funding by the Belgian OSTC was only released late in 2003 (first financial plan in October 2002; official OSTC agreement on April 30, 2003; PRODEX contract established in September 2003). We provided input regarding instrument specifications and Level-1 spacecraft requirements (wavelength selection, shutter mechanism, concept for the ground software, data pipeline and data catalog/interface). Regular teleconferences were held to coordinates all teams in Europe and the USA. In May, we appealed to ESA to support a European-based contribution to the SDO/SHARPP archive: F. Clette prepared a joint solicitation letter that was co-signed by several Heads of European Solar research Laboratories (J.-C.Vial, E.Antonucci, L.Culhane, R.Harrison, S.Solanki, V.Martinez-Pillet) and sent to H. Opgenoorth (ESA Solar-Terrestrial space program) in May 2003. However, a demanding task was to obtain the attribution of the ROB SHARPP budget, in negociation with the OSTC Delegation, due to cumulative delays of all PRODEX funding.

Unfortunately, SHARPP was abruptly cancelled by NASA on September 24, 2003, just when the Belgian budget was at last released and the ROB SHARPP team could be formed. This unilateral cancellation, which is an exceptional event, was justified by NASA concerns regarding the management by the SHARPP US PI institute (Naval Research Laboratory). Despite ESA attempts to find an alternate solution, the Belgian participation was stopped. Since October 2003, several alternate collaborations and projects have been explored to succeed to this SHARPP involvement and a proposal for an entirely European scaled-down version of MAGRITTE was written and submitted to ESA and NASA, without success.

40.3. Perspective for next years

As the attempts to remain associated with SDO failed, despite the ESA support, the ROB and CSL teams will seek new space experiment opportunities, to exploit the expertise and development work already accumulated during this one-year Phase A. It is not excluded that a purely scientific collaboration will be established in the future with the SDO community, as that mission will be one of the key space solar observatories following the successful SOHO mission, to which the Solar Physics Department participates.

40.4. Personnel involved

SHARPP co-Investigators: D. Berghmans, P. Cugnon, C. Foullon, J.-F. Hochedez, R. Van der Linden and E. Verwichte. In addition, participation of A. Zhukov, D. Lafont, S. Willems.

40.5. Partnerships

Naval Research Laboratory, Jet Propulsion Laboratory, Catholic University of America (USA),
Centre Spatial de Liège, , CPA-Katholieke Universiteit Leuven (Belgium), University of Torino, University of Padua (Italy), Rutherford Appleton laboratory, Mullard Space Science Laboratory (UK), Institut d'Astrophysique Spatiale, Laboratoire d'Astronomie Spatiale, IOTA, LIXAM (France), Max Plank Institute for Aeronomy (Germany).

Funding: the late funding (12 month delay) was approved in April 2003 and was about to be released in September 2003, when the project was stopped. This PRODEX funding was finally cancelled.

Visitors: 3 (IAS, 29/1/03), 7 scientists (job candidates)

40.6. Publications

None

40.7. Missions

1 symposium, 2 workshops.
3 missions to commissions and working groups.

41. Solar Drivers of Space Weather

41.1. Objectives

Study of the physics behind the recurrent structure, heating and acceleration of the solar wind, the acceleration of energetic particles, and the formation and propagation of transients like CMEs and induced shocks from their birth in the solar corona up to their arrival at the Earth's magnetosphere. The contribution of the ROB consists in providing observational input of CMEs and CME related events, into the simulations provided by the others teams in the consortium.

41.2. Progress and results

Since October 2001, C. Foullon has been working on the European PRODEX project "The Solar Drivers of Space Weather", which aims at the development of operational tools for the prediction of solar disturbances affecting Earth, and thus shares common goals with this project. Here, the focus is on Earth-directed coronal mass ejections and their precursors, in particular the role of prominences. Indeed, there are two classes of CMEs. A first class is associated with flares occurring in active regions. Sheared filaments can often be seen in these regions prior to the flare. The second class of CMEs is associated with the eruption of prominences. A prominence has no sunspot association and is a cloud of cold and dense coronal material, with a fairly large extent making it easy to detect. By studying systematically such prominences, it is possible to identify typical onset scenarios and also derive estimates of key parameters of the coronal mass distribution required to validate mass-loading-type models. (e.g., prominence mass and/or coronal cavity). This can then lead to a determination of eruption probabilities for future space weather forecasting.

Algorithms for the automated detection (making use of segmentation) and 3D reconstruction of EUV prominences were developed, using EIT synoptic images. The analysis provides characteristics of the reconstructed volumes of EUV prominences for a given Carrington rotation. This is the first step for future case studies of important events and for extracting statistical properties over longer periods, which could provide valuable and complementary information to the H-alpha filament studies. Early results were presented in June 2003.

In the context of the PRODEX "Solar Drivers of Space Weather" project (D. Berghmans), motion detection techniques, such as the Hough ridge detection in x/t slices, have been implemented as an operational software package called “Computer Aided CME Tracking” or CACTus. This package is completed and analyses coronagraphic images in near real-time to detect coronal mass ejections (see http://sidc.oma.be/cactus) as a support for the forecasting service provided by the SIDC. CACTus is a spin-off product of the present project and is used at the ROB in the daily space weather forecast provided for the “ESA Pilot Project for Space Weather applications”. A paper describing CACTus (Robbrecht & Berghmans, 2004) is in preparation for publication in Astronomy & Astrophysics.

Another spin-off of this project is the involvement of the Royal Observatory of Belgium in the Sun Watcher using APS detectors and image Processing telescope (SWAP) onboard the ESA micro-satellite PROBA-2. This satellite is scheduled for launch in 2006. SWAP will deliver EIT-like images, at a 1-minute time interval and in the 19.5 nm band pass, in order to continuously monitor the 'solar weather'. Based on acquired know-how from this project, a near real-time data-processing pipeline is proposed to detect in the incoming SWAP images solar events that are relevant for space weather. The development of the SWAP data processing pipeline is currently in a definition phase.

41.3. Perspective for next years

This project has ended in December 2003. A request for an extension of this project within PRODEX 8 is considered.

41.4. Personnel involved

(in alphabetical order)
David Berghmans, Claire Foullon, Eva Robbrecht, Ronald Van der Linden, Andrei Zhukov.

41.5. Partnerships

This project is supported by an ESA PRODEX grant (ESTEC reference 14711/00/NL/Sfe(ic), ROB reference PRODSPCWEAT).

This project is a collaboration between 4 Belgian groups:
- Royal Observatory of Belgium
- Katholieke University Leuven
- Belgian Institute for Space Aeronomy
- Von Karman Institute

41.6. Publications

None.

41.7. Missions

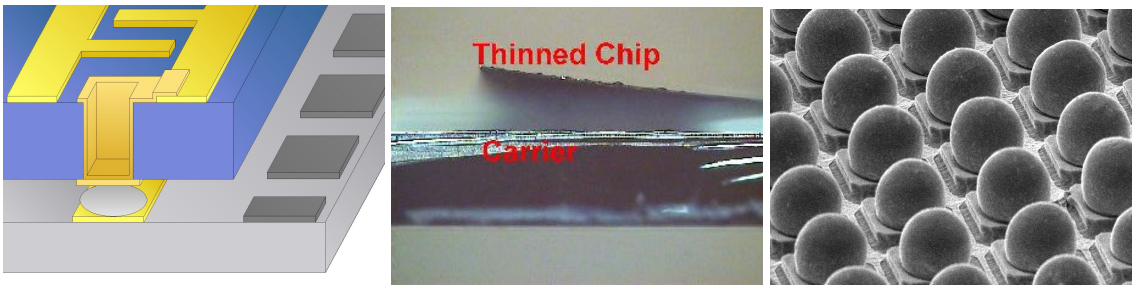
None.

42. BOLD: Blind to the Optical Light Detectors

42.1. Objectives

BOLD is a project aiming at novel UV imaging detectors (solar-blind, radiation hard, etc.). When successful, it will be a considerable asset for Belgium, e.g. in the frame of the Solar Orbiter mission, and more generally for astrophysics, advanced technology and industry. ROB leads this investigation since 1999. Our participations to Solar Orbiter and LYRA are natural offspring's of BOLD.

42.2. Progress and results



(a) Detail of the hybrid imager highlighting the different technological requirements: (i) aggressive thinning of an AlGaN wafer, (ii) the definition of small via holes, (iii) the metallization of the via-holes to contact top to bottom, and (iv) the actual MSM pixel definition compatible with 2D imaging (e.g. < 30um2). (b) Example of a chip after RIE thinning (approx. 10µm thickness) on a carrier wafer showing its (intentional) removal. (c) SEM picture of Indium bumps in a 256x256 element 2D sensor array. The pixel pitch is 25µm and the Indium bump size is 13µm.

Consecutive to several years of work, a solicited proposal (SOW) was requested by ESA to the BOLD consortium in August 2002. After several iterations, the BOLD partners submitted the proposal on April 3. It contained a full technical, management and financial plan for implementing the first phase of the development of imaging sensors based on the AlGaN wide band-gap material. The key technical elements are the use of a WBGS to reach solarblindness and radhardness, and thinning (RIE), via-holes, Indium bumps and flip-chip technologies to interface with CMOS read-out circuitry. Unfortunately, for budgetary reasons, this ESA proposal was left in stand-by, until a very recent expression of revived interest (Feb 2004) by the head of the laboratories at ESTEC.
One of the BOLD collaborators led another proposal in the EU-FP6 context. The submission occurred on October 15, and occasioned intense work from all partners. ROB has contributed several paragraphs, and would have been responsible for the device specifications. The proposal was apparently not accepted by the E.U. (not official as of March '04).

42.3. Perspective for next years

Despite the current failure of the two last attempts towards ESA and the EU, the BOLD concepts remain fully valid and relevant to the future of observational solar physics. The developments led in the frame of LYRA will produce single-pixel devices, and new elements of decision. The stalling of Solar Orbiter possibly driving the position of ESA in late 2003, it would be a shame to loose the leadership and the control of the BOLD endeavour when it is potentially about to start. Given the recent sign of re-interest, we will try to obtain the maximum visibility on ESA perspective. If the prospect is good, the consortium will be put back on track.

42.4. Personnel involved

2003: J-F Hochedez, A. BenMoussa

42.5. Partnerships

42.5.1. List of national and international partners

Active in 2003:

- ESA – ESTEC, Noordwijk, The Netherlands
- IMEC v.z.w., Leuven, Belgium
- CRHEA-CNRS (Centre de Recherche sur l'Hétéroépitaxie et ses Applications), Valbonne, France
- MPS (Max-Planck-Institut für SonnensystemforschungAeronomie), Lindau Germany

- UPM (Universidad Politécnica de Madrid), DIE (Departmento de Ingeniería Electrónica), and ISOM (Institute for Optoelectronics Systems and Microtechnology), Madrid, Spain
- IMOMEC (Institute for Materials Research), Diepenbeek, France
- LGEP (Laboratoire de Génie Electrique de Paris), Gif, France
- LPL (Laboratoire de Physique des Lasers), Villetanneuse, France

42.5.2. Grants used for this research

None yet

42.5.3. Visitors (give only the total number)

5 (always combined with LYRA in '03)

42.6. Publications

42.6.1. Publications without peer system

Hochedez, Jean-Francois E.; Schuehle, Udo H.; Pau, Jose L.; Alvarez, Jose; Hainaut, Olivier; Appourchaux, Thierry P.; Auret, F. D.; Belsky, Andrei; Bergonzo, Philippe; Castex, M. C.; Deneuville, A.; Dhez, Pierre; Fleck, Bernhard; Haenen, Ken; Idir, Mourad; Kleider, Jean Paul; Lefeuvre, Elie; Lemaire, Philippe; Monroy, E.; Muret, P.; Munoz, Elias; Nesladek, Milos; Omnes, Franck; Pace, Emanuele; Peacock, Anthony J.; Van Hoof, Chris A.

New UV detectors for solar observations

Innovative Telescopes and Instrumentation for Solar Astrophysics. Edited by Stephen L. Keil, Sergey V. Avakyan . Proceedings of the SPIE, Volume 4853, pp. 419-426 (2003).

Hochedez, J.-F.; Appourchaux, T.; Belsky, A.; Castex, M. C.; Deneuville, A.; Dhez, P.; Fleck, B.; Hainaut, O.; Idir, M.; Kleider, J.-P.; Lemaire, P.; Monroy, E.; Munoz, E.; Muret, P.; Nesladek, M.; Omnes, F.; Pau, J.-L.; Peacock, A.; Schühle, U.; van Hoof, C.

Imageur diamant et nitrures pour l'observation UV du soleil

Journal de Physique IV (Proceedings), Volume 108, juin 2003, pp.227-231

42.6.2. Publications in press, submitted

Udo Schühle, **Jean-François Hochedez**, José Luis Pau, Carlos Rivera, Elias Muñoz, José Alvarez, Jean-Paul Kleider, Philippe Lemaire, Thierry Appourchaux, Bernhard Fleck, Anthony Peacock, Mathias Richter, Udo Kroth, Alexander Gottwald, Marie-Claude Castex, Alain Deneuville, Pierre Muret, Milos Nesladek, Franck Omnes, Joachim John, Chris Van Hoof

42.6.3. Reports, thesis, etc

- ESA Proposal V2.2. April 3, 2003
- EU FP6 proposal, October 15, 2003

42.7. Missions

Operational meetings (commissions, working groups): 1 abroad, 2 Belgian

43. EIT

43.1. Objectives

EIT is a 4-channel EUV imager of the solar corona and transition region on the ESA/NASA SOHO. The objectives of the instruments are innumerable, ranging from providing context to UV spectrograph, to in-

depth solar physics, and Space Weather nowcast and forecast. The ROB EIT objectives are focussed on the study of various transients (brightening, coronal mass ejections, "EIT waves") and small-scale phenomena (Bright Points), also in their longer-term trends. Our experience with EIT is ported in various manners to its successors (TRACE, SECCHI/STEREO, SWAP, SOLAR ORBITER, etc.)

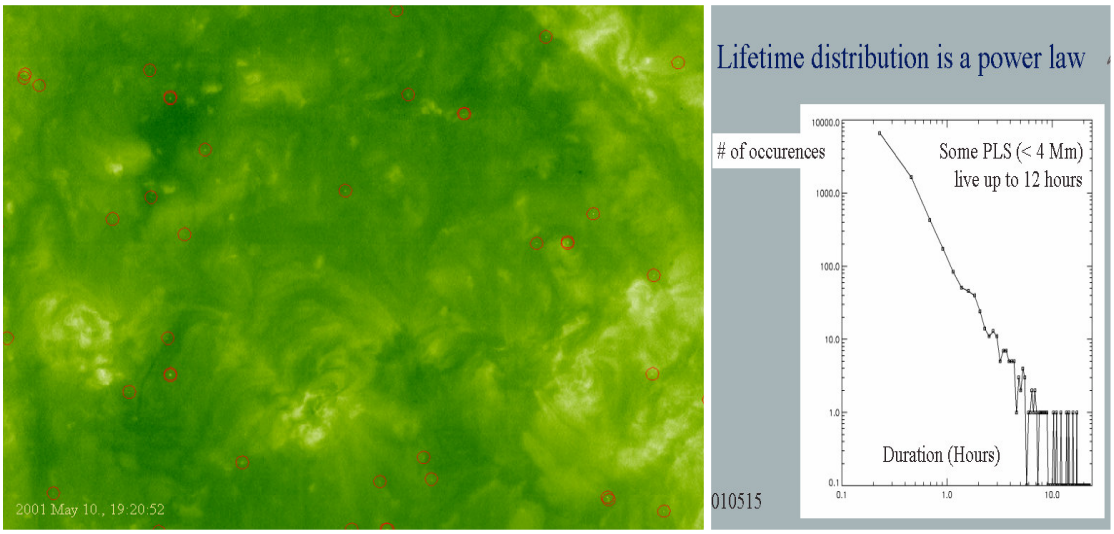
43.2. Progress and results

ROB is a most active EIT co-I institute, analysing the data scientifically, taking part in the image calibration (not in 2003), and the scientific planning.

43.2.1. EIT waves and CME studies

Source regions of Coronal Mass Ejections (CMEs) using EIT are investigated. An EIT wave observed in the 284 Å bandpass of the EIT instrument was found for the first time. This observation confirms that EIT wave is a coronal phenomenon, invisible in the transition region plasma. The observations suggest that EIT waves can be regarded as bimodal. The wave mode represents a wave-like propagating disturbance: propagation of a bright front to large distances, quasi-circular appearance. The eruptive mode is propagation of a dimming and opening of magnetic field lines during the CME lifting. The temperature structure of a classical EUV dimming was revealed.

43.2.2. Analysis of small EIT features



a/ EIT 195 with discontinuous pixels highlighted (circles), b/ Evidence for long-lived PLS

In EIT (or TRACE), there are point-like-structures (PLS) of solar origin, which appear discontinuous -like Diracs- at the 1-pixel scale. They can be statistically distinguished from cosmic-ray-hits (CRH) by using their Lipschitz coefficients. TRACE and EIT images can be cosmetically "cleaned" from the PLS and the CRH. Very small objects appear to live much longer than expectable from their scaling laws lifetime. The same method applied to rebinned image extract BPs, which exhibit a controversial anti-cycle behaviour (factor 9)

43.2.3. Participation to operations

Berghmans & Clette instigated in 2000 special high cadence ("shutterless", SL) campaigns every 3 months. These SL EIT observations are supported by SOHO instruments (EIT, MDI, CDS), and by instruments on other platforms (TRACE, SPIRIT). The scientific aim of the EIT high-cadence synoptic program is to monitor long-term changes in the small-scale dynamics of all kinds of solar structures

(Active Regions, Quiet Sun, Coronal Holes, etc.). The program is thus planned on the long term, and should eventually last for years until EIT or SOHO dies.

43.2.4. Advanced Processing of EUV solar images

See SIP report

43.2.5. Feedback of instrumental and operational experience into future instruments

See SWAP & SECCHI reports

43.2.6. Space Weather applications

See SIDC & Solar Drivers of Space Weather reports

43.3. Perspective for next years

The EIT instrument and the SOHO mission are in very good health and fully operational. On the other hand the next generation of coronal imagers does not appear to be ready in the short term (cf. SDO), and the SXT/Yohkoh, which used to provide somewhat similar data, ceased operations in 2000. We therefore pursue our investment in EIT. Despite intensive research, the wealth of the EIT and SOHO archive is almost "untouched"! We anticipate more results especially from the application of the algorithmic tools that we have developed at ROB in the last years. They have now sufficiently matured to become useful for the physics. The research material related to BPs and differential motion extraction is being prepared for publication. We have requested an Eastern grant (DIMITRUS) to address the DEM analysis of EIT observations, and written an Action 3 proposal (HIC ET NUNC) to better address High cadence campaigns analysis.

43.4. Personnel involved

2003: Hochedez, Zhukov, Gissot, Berghmans, Verwichte, (Clette, Nicula, Van der Linden, Robbrecht, Vanlommel)

43.5. Partnerships

43.5.1. List of national and international partners

- NASA Goddard, Washington DC, USA
- Naval Research Lab, Washington DC, USA
- Institut d'Astrophysique Spatiale, Orsay, France
- Kiepenheuer-Institut für Sonnenphysik
- Centre Spatial de Liège
- Etc.

43.5.2. Grants used for this research

- PRODEX EIT Continuation, PRODEX 90129
- PRODEX STEREO
- "chercheur supplémentaire" position
- Action 1: Systematic analysis of the long-term evolution of the solar upper atmosphere on the basis of the Belgian SoHO/EIT archive.

43.5.3. Visitors (give only the total number)

60 (incl. SIRW)

43.6. Publications

43.6.1. Publications with peer system

Vrsnak, B.; Brajsa, R.; Wöhl, H.; Ruzdjak, V.; **Clette, F.; Hochedez, J.-F.**
Properties of the solar velocity field indicated by motions of coronal bright points
Astronomy and Astrophysics, v.404, p.1117-1127 (2003)

Hochedez, J.-F.; Gissot, S.; Jacques, L.; Antoine, J.-P.
Multiscale Observations of the Solar Atmosphere
GROUP 24: Physical and Mathematical Aspects of Symmetries, July 2002 Colloquium, edited by J-P. Gazeau, R. Kerner, J-P. Antoine, S. Metens, J-Y. Thibon; IOP Publishing, Bristol, 2003

43.6.2. Publications without peer system

Zhukov, A. N.; Veselovsky, I. S.; **Clette, F.; Hochedez, J.-F.;** Dmitriev, A. V.; Romashets, E. P.; Bothmer, V.; Cargill, P.
Solar Wind Disturbances and Their Sources in the EUV Solar Corona
SOLAR WIND TEN: Proceedings of the Tenth International Solar Wind Conference. AIP Conference Proceedings, Volume 679, pp. 711-714 (2003).

Brajsa, R.; Wöhl, H.; Vrsnak, B.; Ruzdjak, V.; **Clette, F.; Hochedez, J. F.;** Rosa, D.; Hrzina, D.
Solar rotation velocity determined by coronal bright points
Hvar Observatory Bulletin, vol. 27, no. 1, p. 13-23.

Gissot, Samuel F.; Hochedez, J.-F.; Dibos, F.; Brajsa, R.; Jacques, L.; **Berghmans, D.; Zhukov, A.; Clette, F.;** Wöhl, H.; Antoine, J.-P.
Extracting the apparent motion from two successive EIT images
Solar variability as an input to the Earth's environment, International Solar Cycle Studies (ISCS) Symposium, 23 - 28 June 2003, Tatranská Lomnica, Slovak Republic, ESA SP Series 535, 853-856 (2003)

43.6.3. Publications in press, submitted

Brajsa, R.; Wöhl, H.; Vrsnak, B.; Ruzdjak, V.; **Clette, F.; Hochedez, J.-F.;** Rosa, D.
Height correction in the measurement of solar differential rotation determined by coronal bright points
Astronomy and Astrophysics, v.414, p.707-715 (2004), accepted

43.7. Missions

Research missions (assemblies, symposia, workshops, etc): 2 abroad
Operational meetings (commissions, working groups): 0
Field missions (observations, station maintenance, etc): 0

44. Solar Image Processing (SIP)

44.1. Objectives

The objectives of image processing are numerous: image enhancement, object extraction, segmentation, motion tracking, etc. Such techniques then serve various solar atmosphere studies using EIT and successors: discrimination/classification of structures, 3-D structure recovery, underlining long-term

trends, etc. They however all share the possibility to effortlessly process in a repeatable "objective" manner huge archives of complex heavy images.

44.2. Progress and results

44.2.1. Active Region extraction and analysis (E. Verwichte, C. Foullon)

This approach, based on clustering and watershed, was applied to the automated detection of coronal active regions (ARs). An earlier step had aimed at multi-channel processing and its application to EIT images taken at 4 different temperatures. The conclusion was that more physical information was needed to detect reliably ARs. Magnetograms segmentation has been done with the tools developed for EIT images. It led to results presented in Verwichte, 2003. The application of the derived magnetic constraint to the coronal image segmentation could not be achieved before the end of this project.

44.2.2. Motion tracking using optical flow methods (S. Gissot, J.-F. Hochedez)

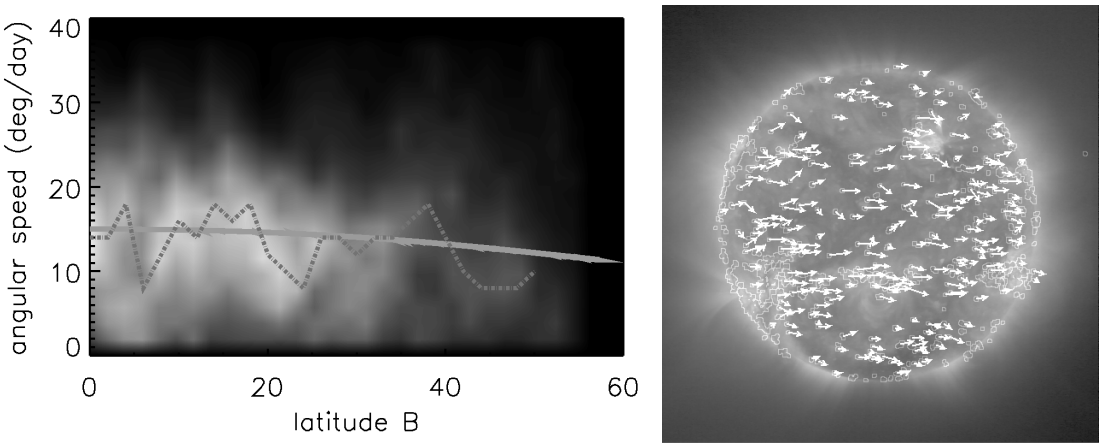


Figure 1 (a) Histogram of angular rotation velocity and latitude. (b) Only the regions satisfying the LK texture criterion, are attributed a velocity field

In 2003, we focused motion estimation on the Lucas-Kanade (LK) approach, which has proven efficient in our case. In addition to the Optical Flow (OF) paradigm (dI=0), LK is explicitly based on the uniform local motion assumption. Combined with a new multi-resolution constraint, we have retrieved the rotation of on-disk pixels. Their distribution is given in figure 1(a). The full line is the classical differential rotation (Brajsa et al 2003), while the dotted line follows the maximum density. This is a solar physics application and a calibration. Ongoing studies address the multiscale region variability by combining texture and similarity criteria: figure 1(b).

44.2.3. Feature extraction by wavelet analysis (J.-F. Hochedez, S. Gissot)

Wavelets have become inescapable, in the data processing outfits. But their usage - beyond compression- is far from pre-determined. Techniques specific to coronal imaging were developed around wavelets. They pre-process the complex input images. The wavelet transform plunges the data into scale-space. For SIP, the Continuous Wavelet Transform (CWT) is more suitable than the discrete wavelet transform; it receives more attention at the FYMA group of Louvain-La-Neuve, with whom we collaborate (Prof. J-P Antoine, L. Jacques, with J-F Hochedez as PhD adviser). Several new tools have been developed and tested in 2003.

1. Normalized contrast transform (NCT). Following Duval-Destin and Torresani, NCT is meaningful to improve contrast in complex images. It enhances the most significant scale at each location. The results are striking, and already revealed an extraordinary faint structure.
2. Localized correlation function (LCF). After Perrin et al., the LCF is an alternative to optical flow. It is useful for motion and stereo tracking (cf. STEREO-SECCHI).

3. Automated detection and long –term trends of small EIT features. We apply the wavelet analysis to Bright Points and smaller coronal structures. They are key in the coronal heating problem, and they are perhaps simpler than large-scale objects. However, small-scale solar features on the solar disk are undistinguishable from cosmic ray hits. Progresses of this long-term study have been presented at Soho13. Discontinuous objects were shown to be of true solar origin.

44.2.4. Automatic detection & characterization of CMEs (D. Berghmans, E. Robbrecht)

CACTUS (based on the Hough transform) addresses directly the needs of forecasting services. It allows the early warning and cataloguing of CME events recorded by the LASCO coronagraph. The detection rate does not reach 100% yet, but the algorithm detected unnoticed events, and is now used daily for the SIDC operational forecasts.

44.3. Perspective for next years

Solar image processing has become a central department activity; and we receive recognition by the international community. It is key to scientific studies, but also to instrumental contributions (SECCHI/STEREO, SWAP, LYRA, and later ESA/Solar Orbiter). Despite the end of the funded SIP research, we pursue it. Proposals have been submitted to study a pseudo-DEM approach for EIT (eastern Europe grant), and shutterless EIT data (Action 3). If accepted, they will influence our mathematical processing. However, pure (i.e. mathematical) SIP developments are extremely valuable, and shall be submitted for new funding. The multi-resolution LK algorithm will cope with brightness variability and noise in EIT images. It will then turn in 2004 to unusual loop motions, off-disk plasma motions and more. Systematic studies of the differential rotation will address long-term trends. A new OF algorithm could be designed for LASCO sequences (CACTUS update). Better transient detection techniques are still needed for EIT and LASCO coronagraph sequences.

44.4. Personnel involved

S Gissot, JF Hochedez, D Berghmans, E Robbrecht, E Verwichte, C Foullon, A Zhukov, F. Clette.

44.5. Partnerships

44.5.1. List of national and international partners

FYMA/UCL/Louvain-la-Neuve
CEREMADE, Paris Dauphine, France

44.5.2. Grants used for this research

PRODEX EIT (JFH)
Chercheur supplémentaire (SG)
Impulsion à la Recherche Scientifique IMPSOHO (EV)
SIDC pilot project

44.5.3. Visitors (give only the total number)

>60, SIRW included

44.6. Publications

44.6.1. Publications with peer system

Vrsnak, B.; Brajsa, R.; Wöhl, H.; Ruzdjak, V.; **Clette, F.; Hochedez, J.-F.**
Properties of the solar velocity field indicated by motions of coronal bright points
Astronomy and Astrophysics, v.404, p.1117-1127 (2003)

Hochedez, J.-F.; Gissot, S.; Jacques, L.; Antoine, J.-P.
Multiscale Observations of the Solar Atmosphere
GROUP 24: Physical and Mathematical Aspects of Symmetries, July 2002 Colloquium, edited by J-P. Gazeau, R. Kerner, J-P. Antoine, S. Metens, J-Y. Thibon; IOP Publishing, Bristol, 2003

44.6.2. Publications without peer system

Gissot, Samuel F.; Hochedez, J.-F.; Dibos, F.; Brajsa, R.; Jacques, L.; **Berghmans, D.; Zhukov, A.; Clette, F.;** Wöhl, H.; Antoine, J.-P.
Extracting the apparent motion from two successive EIT images
Solar variability as an input to the Earth's environment, International Solar Cycle Studies (ISCS) Symposium, 23 - 28 June 2003, Tatranská Lomnica, Slovak Republic, ESA SP Series 535, 853-856 (2003)

Brajsa, R.; Wöhl, H.; Vrsnak, B.; Ruzdjak, V.; **Clette, F.; Hochedez, J. F.;** Rosa, D.; Hrzina, D.
Solar rotation velocity determined by coronal bright points
Hvar Observatory Bulletin, vol. 27, no. 1, p. 13-23.

Foullon, C.
Automated detection and 3D reconstruction of EUV prominences
International Solar Cycle Studies (ISCS) Symposium, 23 - 28 June 2003, Tatranska Lomnica, Slovak Republic, Ed.: A.Wilson, ESA SP-535, 477 - 482. (2003)

Verwichte, E.
The automated analysis of solar active regions
International Solar Cycle Studies (ISCS) Symposium, 23 - 28 June 2003, Tatranska Lomnica, Slovak Republic., Ed.: A.Wilson, ESA SP-535, 169 - 172.

44.6.3. Publications in press, submitted

Brajsa, R.; Wöhl, H.; Vrsnak, B.; Ruzdjak, V.; **Clette, F.; Hochedez, J.-F.;** Rosa, D.
Height correction in the measurement of solar differential rotation determined by coronal bright points
Astronomy and Astrophysics, v.414, p.707-715 (2004), accepted

44.6.4. Reports, thesis, etc

S. Gissot
Motion Analysis of Coronal Images Using Optical Flow Method
Rapport de DEA de physique 2003, Université Catholique de Louvain, sous la direction du Professeur Jean-Pierre Antoine

44.7. Missions

Research missions (assemblies, symposia, workshops, etc): 2 abroad (SG, EV), 1 Belgian (FNRS)

Operational meetings (commissions, working groups): 1 Belgian (JFH @ Thesis SG)
Field missions (observations, station maintenance, etc): 1 abroad, ~5 Belgian
Symposia organized at Uccle: 2 (SECCHI + SIRW)
Courses: ~30 (SG@LLN)
Visitors: 3

45. TELESCIENCE

45.1. Objectives

Telescience is at the junction of Telematics and Science. It is driven by IT advances (internet, storage, database techniques, etc.), and it aims at enhancing scientific studies. This activity at ROB is organized around three objectives: A/ collecting external and internal data to nourish our research and operational services (viz. SIDC), B/ database (DB) development to store, search or retrieve varied data characteristics, and C/ web interfaces between DBs and programs, privileged users or outside world for dissemination.

45.2. Progress and results

A) In 2003, the feeding of our EIT-SoHO archive went on. Since launch, 7,906,135 "Level 0" (LZ) files amounting to 406 GB have been collected and stored in RAID arrays by L. Wauters, S. Willems and J-F Hochedez. In support of forecasting purposes, the Near-real-Time (NRT) "quicklook" images are transferred to the SIDC as well, but selectively erased when the LZ data are available. The LASCO coronagraph data were imported too. A new 1.3 TB RAID on our fileserver was ordered, configured, and populated, for safely storing EIT, LASCO, and the Uccle telescope data. The local storage and maintenance of such large amounts of data is e.g. justified by their systematic analysis carried in the context of our solar cycle research. The individual FITS files are besides not individually accessible thru the web. Our EIT LZ records are complete and thorough from the SOHO launch till nowadays. Occasional data sets requests were made, potentially leading to scientific collaboration or pertaining to education and public outreach actions.

B) Several databases have been constructed by L.Wauters in 2003. Each gather useful descriptive fields related to their main object:

EIT LZ filenames with associated image parameters from the FITS headers. Our DB goes beyond the "NASA catalogue" because it is faster, more flexible, and can be enriched with the results of scientific research

4. Photospheric + chromospheric filenames with associated image parameters from the ROB FITS headers (automatically fed in real time)
5. Space weather SIDC data including forecasting and actual nowcasting (noticeable events, 10cm flux, geomagnetic indices, flares, proton events…, see SIDC report).
6. Wolf number of Uccle observatory

LYRA and SWAP documents (register, manage and search) = SLATE
Dep4 planning, including solar and PREVIWEB duties

It is worth noticing that the databases can by essence be extended. It is of tremendous interest to methodically enrich them. For example, the EIT_LZ one will collect the harmonized outcomes of further image processing (cfr SIP report).

C) The various web pages of the department were further developed in 2003, but not precisely in the frame of the Telescience project, although S. Willems is now the Dep4 webmaster; the present report will therefore not detail these progresses. It will only be reminded that the main entry points are:

1. http://sol.oma.be/ (including access to Dep4 publication database & tool)
2. http://sidc.oma.be / (including access to Previweb and Previmaster)
3. http://lyra-swap.oma.be/ (including privileged access to SLATE)
4. http://bold.oma.be/ (including access to privileged pages)

More in the scope of Telescience is information dissemination. It happens for ROB photosphere/chromosphere images and for SIDC data. The SLATE is a important tool in the management

of the LYRA and SWAP projects; the BOLD private pages were intensively exploited during the two proposal writings in 2003; the same stands for the defunct SHARPP/Magritte proposal, ftp and web sites. Associated to the databases discussed above, L Wauters developed the following interfaces:
http://sol011.oma.be/catalog/select.php3 (EIT LZ)

Uccle telescope (not yet)

1. The PREVIWEB interface has been improved to include the database concept and interact with it. The development phase has been finished in 2003. The test phase will lead to an operational phase.
2. http://sol011.oma.be/webdep4/wolf.php3 (Wolf)
3. http://lyra-swap.oma.be/private/docmanage/index.html (SLATE)
4. http://sol011.oma.be/webdep4/view_planning.php3 (Dep4 planning)

45.3. Perspective for next years

Due to the worldwide archiving acceleration, Telescience activities are anticipated to grow. With STEREO and our PROBA payloads, we expect to import more data than ever before. For LYRA & SWAP, we are responsible for the ground segment (telecommanding scripts and reformatting). As to database exploitation, we foresee important upgrades. The databases should be accessible by IDL programs to allow automated processing of their valuable content, or to authorize automatic populating by Solar Image Processing routines. More sophisticated queries are becoming necessary too (e.g. cadence specification for autonomous extraction of sequences, queries made across our different databases: SIDC, EIT and Wolf number). These developments might occur in the frame of grids or international collaborations such as EGSO or VSO. The PREVIWEB interface will enter operations in 2004 (interactive database population: ability to confront forecasting and nowcasting, study of the recorded solar data and events). A web interface tool for the Uccle images can be developed. Databases will be maintained. The SLATE interface developed for SWAP and LYRA can be ported to department or ROB documents.

45.4. Personnel involved

L Wauters, S. Willems, JF Hochedez, (F. Clette, D. Lafont, O. Boulvin)

The current Dep4-common IT fleet is:

- 3 PC for the SIDC
- 1 fileserver PC managing 2 RAID arrays
- 1PC for the ground telescope cameras (White light and Coronal images)
- 1 Compaq workstation with 1 connected RAID array
- 1 web server
- A scanner and a fax for the SIDC activities
- Backup server

45.5. Partnerships

45.5.1. List of national and international partners

45.5.2. Visitors (give only the total number)

1 (but 10 times)

45.6. Publications

45.6.1. Reports, thesis, etc

Geoffroy Hallard

Gestion des prévisions météorologiques solaires pour l'Observatoire Royal de Belgique
"graduate in informatics" at EPHEC

45.7. Missions

None.

SECTION 9: Solar activity

This section focuses on the characterization, the monitoring and the operational forecasting of solar activity in the optical, radio electric and ultraviolet wavelength ranges. It is also dedicated to the study of the solar cycle, the maintenance of the Sunspot Index database (World Data Center), and the analysis of the impact of solar activity on Earth. Thanks to those service activities, the SIDC (Solar Influences Data analysis Centre), and more generally the ROB, enjoy an increasing credit as a center of expertise regarding all aspects of solar activity and its impact on space weather.

The fundamental objectives are the following:

- The characterisation of solar activity in the photosphere, chromosphere and the corona, through:
  - A permanent service of optical observation from the Uccle solar station (USET), which includes the series of visual sunspot drawings.
  - The development of a digital imaging system for continuous solar monitoring in white-light and H-alpha
  - The exploitation, the modernisation of the Humain Radioastronomy Station, for the determination of the radio flux at several frequencies (absolute daily indices, radio burst patrol)
  - The software creation, development and adaptation for the automated processing and transmission of solar data.
- The development of the SIDC activities, a World Data Center, service of the FAGS and the Regional Warning Center (RWC) of the ISES (International Space Environment Service), through:
  - The creation and execution of research, analysis and forecast programs
  - The maintenance and development of a database accessible through Internet.
  - The prompt distribution of multiple data via e-mail, fax and FTP or Web pages
  - Daily forecasts of solar and geomagnetic activity
  - The broadcasting of PRESTO alert messages for large solar events and disturbances
  - The participation to the ESA space-weather programs.
  - A scientific research on magnetic instabilities in the solar corona, addressing the mechanisms of coronal heating and susceptible to help in identifying the fundamental sources of space weather disturbances, in view of a future application to the forecasting process.
- The diffusion of information about solar activity and research work in the DSP, through educative activities (group visits, public lectures, student training), the development of educational Web pages and the communication with the media (interviews, press releases).

46. The Uccle Solar Equatorial Table (USET)

46.1. Objectives

Optical observations of the Sun and characterisation of its activity:

- Visual observations of sunspot, digitisation and exploitation of drawings
- Digital imaging in white-light (photosphere) for synoptic observations
- Digital imaging in the H-alpha line (chromosphere) for real-time flare patrol observations.

- Development of real-time data analysis and data transmission software.

46.2. Progress and results

46.2.1. Instrument status

The "Uccle solar Equatorial Table" (USET) is now equipped with the following 3 telescopes:

- Visual refractor (D: 160mm, F : 2450mm) with projection screen (25-cm image) for sunspot drawings
- Lichtenknecker refractor (D: 150mm, F: 1600mm) equipped with a full-aperture solar filter (attenuation : 5 densities) and a DALSA CA-D4 CCD camera (1024x1024 pixels, 8 images/s) with 12 bit digital output.
- H-alpha refractor (D: 110mm, F: 1440mm), equipped with a Lyot monochromator (Optique Levallois, N°11, bandwidth :0.7 Å) and a DALSA CA-D4 12-bit digital camera (1024x1024 pixels, 8 im/s).
- Images from both cameras are acquired by a common control PC, through EPIX PXCI-D frame-grabber cards run by a custom software (Visual C++). This computer is located under the dome floor (since 22/1/2003), with the user console conveniently located in the control room at the ground level.

46.2.2. Solar dome maintenance and CCD development

The development and the maintenance of the CCD camera system, commissioned in May 2002, continued in 2003:

- The camera PC was configured as Samba server and UNIX scripts were implemented to transfer the USET images automatically in near-real time to the SIDC servers for archiving and Web publication
- The development of the camera control software continued (training period of an ESI student, A. Deschepper): improvement of the user interface, experimentation of an automated flare detection algorithm for the H-alpha channel (flare patrol mode).
- One of the DALSA cameras failed completely on 25/3/2003: we swapped the cameras in order to continue the observations in the H-alpha channel. The faulty camera had to be shipped back to the manufacturer in Canada and was again in operation on August 14.

Maintenance of the solar dome:

- Indispensable waterproofing work was done on the solar dome by the Vandenbrande company between from June to August. The outside white paint should still be refreshed and the mechanism of the sliding doors still needs to be reinforced.
- Miscellaneous maintenance and improvement work was done on the telescopes: rebalancing of telescopes, optical cleaning and realignment, upgrade of the closing mechanism of the telescope front aperture doors.
- A new dome and telescope control software, running on a PC at ground level, was created and implemented by M. Dufond.
- A new A3 flatbed scanner was purchased at the end of 2003 for the digitisation of the Uccle solar drawings: this scanner will replace an old HP digitizer that was used for the last 25 years but failed in December.

46.2.3. Observations

Visual observations (sunspot drawings):

- Thanks to good weather conditions, 2003 was very productive: a total of 330 drawings were made over 254 observing days (vs 244 drawings over 230 days in 2002), of which 183 days with 1 drawing, 61 days with 2, 7 days with 3 and 1 day with 4 drawings. O. Boulvin made the bulk of these visual observations with the participation of many scientists of the Department.
- All those drawings were digitized, mainly by O. Boulvin, in replacement of D. Carré, who was absent over the whole year, except for 10 days, due to medical incapacity. Those data were processed to

derive the Uccle Wolf number, the evolution and returns of individual active regions. Those detailed results, provided only by the Uccle station, were published monthly in the Sunspot Bulletin of the SIDC.

CCD images:

- Except for the period April-July 2003 (white-light camera failure), the camera system was in continuous operation and provided synoptic images over about 250 days. Starting in June 2003, these images were made available in near-real time in the SIDC "Latest Solar Data" pages, together with imagery from other observatories and spacecrafts, for worldwide access.
- Special observation: during the May 7 transit of Mercury, we made an image sequence in H-alpha. Unfortunately, only this camera was operational at that time, offering a limited spatial resolution compared to what could have been obtained in the white-light channel.

46.3. Perspective for next years

- Continuation of the USET visual and CCD observations.
- Replacement of old the H-alpha telescope and Lyot monochromator by new modern optics.
- Further development of the CCD image acquisition software
- Development of a new sunspot digitisation software based on the recently acquired A3 scanner.
- Further improvements to the instruments: thermostatisation of PC enclosure, camera protection enclosure, study of a dynamical camera mounts (translation stages), upgrade of the declination drive of the USET.

46.4. Personnel involved

Frédéric Clette (Overall management), Jean-Luc Dufond (Technical work),
Processing of Observations: Gisèle Evrard-Kesteloot, Arille Vigneron, Olivier Boulvin
Observers (number of observations): A. Ben Moussa (3), D. Berghmans (14), O. Boulvin (180), D. Carré (10), F. Clette (27), S. Gissot (10), J-Y Ledent (16), E. Robbrecht (11), R. Van der Linden (8), E. Verwichte (7), A. Vigneron (32), A. Zhukov (12)
Camera software development: A. Deschepper (Graduate in Informatics, ESI, Feb.-June 2003)
Mechanical work: F.Renders

46.5. Partnerships

Lotto funding for CCD equipment (1999, Belgian Science Policy)

46.6. Publications

46.6.1. Publications without peer system

Clette, F., Cugnon, P., Berghmans, D., van der Linden, R., Wauters, L. 2002
The new instrumentation of the SIDC/Uccle station
in "Solar Variability: From Core to Outer Frontiers", ESA SP-506, 935.

- Uccle sunspot statistics and sunspot group return tables (exploitation of solar drawings) published monthly in the SIDC Sunspot Bulletins.

46.6.2. Reports, thesis, etc

- Real-time worldwide distribution of the USET images on the SIDC web pages.
- Training report (ESI, Graduate in Computer Sciences, June 2003): A. Deschepper, *"SUNCAP: Développement d'un système de surveillance de l'activité solaire"*

46.7. Missions

None.

47. The Humain Radioastronomy Station

47.1. Objectives

Radioelectric observations of the Sun for flare monitoring and long-term recording of the solar radio in the upper-chromosphere and low corona:

- Continuous observations of the integrated radio flux at 600 MHz
- Monitoring of "atmospherics" at 27 kHz, for real-time solar flare alerts.
- Development of new receivers with real-time digital data output for multi-frequency flux measurements.

47.2. Progress and results

47.2.1. Instruments

- "Wurzburg" 7.5m radiotelescope measuring the integrated solar flux at 600MHz: repairs and improvements were done on the guiding system.
- 6-m radiotelescope: fully refurbished parabolic antenna, ready for new receiver. The antenna is now put in motion (solar tracking) everyday. M. Dufond has been developing a new guiding system (PC, digital encoders, triac-based power controllers, etc.). This system should be installed in the spring of 2004.
- 408MHz radioheliograph: 48 4-m parabolas in a "T" configuration spanning 620m (E-W). Turned off in August 2001, the antennas are periodically kept in motion (weekly basis) to keep them mechanically in working order, and electromechanical maintenance is still carried out on the antennas, in view of their future use for other applications..
- Two "Atmospherics" receivers at 27kHz: the construction of a new modern receiver is still pending.

47.2.2. Station maintenance and site protection

- The overall condition of the station was improved under the impulse of M. Janssens. A new telephone exchange has been installed, as well as an ADSL connection that allows better more continuous exchanges with Uccle. However, a lot of work remains to be done to give clean look, mainly to the infrastructure of the 408MHZ antenna array (high-tension "pipeline").
- Progresses were obtained regarding the transfer of the station buildings to the management of the Building Administration (Régie des Bâtiments"). At the end of 2003, the file was completed and submitted to the Ministry of Finances.
- Humain staff management: in November; introduction of work sheets and a station logbook.

Again this year, continuous attention had to be dedicated to the protection of the perimeter around the station and of the Humain radio frequencies against radio interferences. Most notably concerning:

- The Electrabel wind turbine project: an array of 80m windturbines, in the immediate proximity of the station, is under study since 2002. This year, we provided and requested relevant information through various contacts with administrations (Electrabel, AIB-Vinçotte, IBPT, CWEDD). and we responded to the public inquiry announced in December 2003.
- The renewal of the official protection of the 600MHz band: in coordination with the IBPT and the CRAF (Committee on Radio Astronomy Frequencies), we contributed to the revised motion to be submitted by the Belgian delegation to the ITU (International Telecommunication Union) in 2004.

47.2.3. New collaborations and projects

In the framework of the Department reorganisation introduced in November 2003, a new emphasis was given to the ground-based instruments and observations of the Department, that have been left more and more neglected in recent years, despite their science potential and renewed interest in the framework of

the real-time monitoring and forecasting of solar activity. This situation arose insidiously by lack of support staff and science staff, absorbed by the demanding space projects. In the last two months of 2003, a few initial steps were made concerning the Humain station. Contacts were established with other groups carrying out radio observations of the Sun: mainly, the Trieste Astronomical Observatory and the Dominion Radio Astronomical Observatory. Promising collaborations were initiated and they are expected to develop further in 2004, leading to the construction of new modern receivers for the Humain station.

47.2.4. Observations and data exploitation

The following observations were produced in 2003:

- Integrated 600 MHz flux: calibrations, daily average flux (base long-term index), publication of plots of the daily measurements on the SIDC web pages for worldwide distribution. The 600MHz daily index constitutes one of the longest quantitative time series available to trace back solar activity (about 50 years) and remains the key observation provided by the Humain station.
- Remote atmospherics measurements at 27 kHz: by recording the instantaneous ionospheric response to solar flares, this signal is used for autonomous flare alerts. In 2003, our receivers still remained affected by artificial radio interferences. Now, all receivers have a numerical output and their data are sent to Uccle on a daily basis.
- The analysis and exploitation of the 600MHz and 27kHz daily data was carried out mainly by J-L Dufond with occasional help from O. Boulvin.

47.3. Perspective for next years

- Continuation of the 600MHZ and 27KHz flux measurements, and automated diffusion of these observations on the SIDC web site. Further development of the real-time exploitation, in support to the SIDC forecast and alert services.
- Organisation and maintenance of the existing facilities: in particular, vital repairs to the structure of the Wurzburg antenna and refurbishment of another spare 4-m or 6-m parabola.
- Development of a new project of multi-frequency solar array based on the existing antennas available at the station: submission of a project proposal to BELSPO, collaborative design work.

47.4. Personnel involved

Frédéric Clette (Head of Department a.i.), Jean-Luc Dufond (Ind. Eng., overall technical managment), Viviane Herman (Cleaning) , Paul Janssens (Research Technician, local responsible), Olivier Boulvin (Data processing), Stephane Walckiers (Support Technician).

47.5. Partnerships

Cooperation: Observatory of Trieste (Dr. M. Messerotti, Italy), Dominion Radio Astrophysical Observatory (Dr. K. Tapping, Ottawa, Canada)

47.6. Publications

47.6.1. Publications without peer system

- Monthly publication of the daily 600MHz flux in the SIDC Sunspot Bulletin (Summary of Uccle Ursigrams)

47.6.2. Reports, thesis, etc

- Daily publication of 600MHz flux measurements on the SIDC web pages.

47.7. Missions

4 operational missions in Belgium (F. Clette)
Weekly field missions (J-L Dufond)

48. SIDC: Solar Influences Data analysis Center

48.1. Objectives

The SIDC is a permanent data and service center of the Royal Observatory. Since 1981, the SIDC is the World Data Center for the International Sunspot Index and a data analysis service of the FAGS. In 2000, the SIDC became a Regional Warning Center of ISES, providing continuous monitoring and forecasts of solar and geomagnetic activity. Since 1 April 2003, the SIDC also became part of the ESA Space Weather Applications Pilot Project as one of 20 Service Development Activities. The purpose of this project is to develop a specific space weather application for a targeted user group.

48.2. Progress and results

During 2003, the sudden illness of P. Cugnon has made it necessary to speed up the transfer of his responsibilities as SIDC director. This task has been transferred to Ronald Van der Linden (currently still on an a.i. basis).

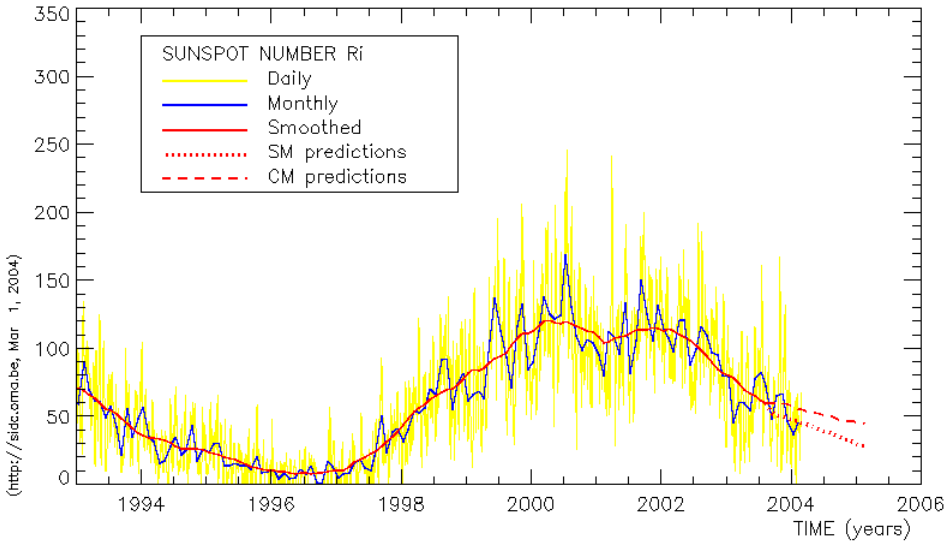


Fig. *1. The daily and monthly sunspot index over the current solar cycle.*

In its capacity as the **World Data Center for the Sunspot Index**, and as a **data analysis service of the FAGS**, the SIDC has produced the International Sunspot number throughout 2003. This is the oldest core activity of the SIDC as a service center, but still also one of its most important results, since it guarantees an international visibility of the SIDC as the source of one of the most important indices of solar activity. As such, it is the solid foundation of all other activities of the SIDC. To be able to continue this service, we rely on the continuous availability of sunspot observations from a worldwide network. We are fortunate enough to possess a fairly large network of observers, to which several more have been added in 2003. The number of stations contributing data varied between 56 and 66 during 2003 (for the provisional numbers this was between 31 and 44). During 2003, the SIDC International Sunspot index has been distributed by fax (25 recipients), e-mail (approximately 350), by postal distribution of the Sunspot Bulletin and SIDC News (420) and anonymous ftp. It is also published regularly in the Quarterly Bulletin Solar Activity (in 2003, we sent the data for the year 1996-1999 there for publication). In addition, the

entire archive of sunspot indices can be consulted on the SIDC website, from where it is retrieved by many visitors. Last but not least, the SIDC sunspot indices are mirrored on scores of websites around the world, where they are picked up by thousands of researchers. In order to get a better view of the use of our data, we have set up a publications page where we gather references of papers making explicit use of the International Sunspot index, and have asked the scientific community to keep us informed about their use of our data.

The SIDC has also operated throughout 2003 as **Regional Warning Center of the ISES**, running a continuous daily service of solar activity and space weather monitoring and forecasting. The work done for these operations included several upgrades and extensions of the 'PreviMaster' and 'PreviWeb' software, which established a *virtual control room* making operations possible from remote systems. All of the scientific staff members involved in the SIDC have contributed to the weekly shifts of 'PreviWeb' duty. A highlight of these activities was certainly the public attention given to Space Weather and the role of the SIDC during the solar storms in October and November of 2003. The SIDC responded in a very timely fashion to these events, sending out various warnings and press releases. Several members of the SIDC team were interviewed for various media and invited for public presentations about the consequences of space weather. The various messages from the SIDC as RWC-Belgium are distributed to about 700 individual e-mail addresses, some of which are further distribution lists at remote sites. The daily ursigrams and fast alerts distributed by RWC-Belgium are also available from our website and are mirrored on many other websites. During 2003, the RWC sent out 73 fast alerts.

Since 1 April 2003, the SIDC also heads a **Service Development Activity of the ESA Space Weather Applications Pilot Project**. For this project, we have established a very fruitful collabarotion with the GPS section of the ROB and with the other institutes in the Space Pole: the IRM and the BISA. The intention of this project is to demonstrate the relevance of Space Weather for selected industries, and in the end to verify if there is a potential market for Space Weather related applications in Europe. Since the kick-off of this project, we have entered into the development phase of such products. We have organized a questionnaire amongst a dedicated group of 'clients' and have started the development of the tools required to deliver the requested service.

48.3. Perspective for next years

The activities of the SIDC as World Data Centre, as data analysis service of the FAGS and as Regional Warning Centre of ISES will continue as before. The transfer of responsibility from P. Cugnon to R. Van der Linden will be completed (and officially communicated where required). Since we are facing the approaching retirement of nearly all the staff involved in the activities relating to the production of the International Sunspot Index, particular attention will be paid to creating documentation on the procedures followed and software used for the reduction and handling of the incoming data. In this process, it should also become apparent which parts of the software need to be rewritten or updated. The switch to electronic methods of data distribution will be strongly encouraged.

The ESA Space Weather Pilot Project will switch from the development phase to the service provision and evaluation phase on 1 April 2004. This project is scheduled to end on 31 March 2005, but may be extended by ESA. In addition, we are actively seeking for other partners and projects to continue the expansion of our space weather activities.

In the coming years, a stronger emphasis will be placed on building a stronger scientific foundation for the Space Weather and solar activity forecasting. This will be achieved through various collaborations, including those coordinated through COST724.

48.4. Personnel involved

Many staff members of the Solar Physics department have contributed to a variable extent to the SIDC activities. The main contributors have been P. Cugnon (statutory), R. Van der Linden (statutory), D. Berghmans (statutory), E. Robbrecht (hired for the ESA Pilot Project), P. Vanlommel (hired for the ESA Pilot Project), A. Vigneron (statutory) and G. Evrard (statutory), with substantial contributions also from F. Clette, L. Wauters, A Zhukov, and occasional assistance from O. Boulvin, D. Lafont, B. Nicula and S. Willems.

48.5. Partnerships

The activities of the SIDC are performed within several international networks:
The SIDC network of solar observers (currently approximately 70).
The International Space Environment Service (ISES), which groups together the Regional Warning Centers throughout the world.
The Federation of Astrophysical and Geophysical data analysis Services (FAGS).
The World Data Center system.
The Space Weather European Network (SWENET) groups all the participants in the ESA Space Weather Pilot Project.

Grants used for this research: for the ESA Space Weather Pilot Project, the SIDC is supported by Prodex through ESA Contract 16913/03/NL/LvH. A small annual grant for operational expenses has until now been paid by FAGS, but this will no longer be the case from 2004 onwards.

Visitors: approximately 10 short visits.

48.6. Publications

48.6.1. Publications without peer system

Vanlommel P., Berghmans D., Van der Linden R., Cugnon, P.,
Ruimteweer: het einde van de wereld?
Heelal, Vol 48, nr 6, pp. 144-149.

P. Cugnon, R. Van der Linden (eds), and the SIDC team,
The Sunspot Bulletin (12 issues), SIDC News (4 issues).
Monthly and quarterly bulletins of the SIDC for distribution of the International Sunspot Number, data obtained in Ukkel and Humain and reviews of solar and geophysical activity.

Cugnon, R. Van der Linden, D. Berghmans, P. Vanlommel, E. Robbrecht, F. Clette, A. Zhukov, L. Wauters, R. Warnant, C. Bruyninx, H. Nebdi, J.-C. Jodogne, D. Heynderickx, K. Stegen, M. Kruglanski, M. Roth, J. de Keyser, J.-P. Henry,
The SIDC project
Conference proceedings of the Space Weather Workshop, ESTEC, Noordwijk (The Netherlands), 03-05 Nov. 2003.

Robbrecht, E., Berghmans, D.
CACTus – Computer Aided CME Tracking
Conference proceedings of the Solar Image Recognition Workshop, ROB, Brussels Belgium

48.6.2. Publications in press, submitted

Vanlommel P., Van der Linden R., Robbrecht E., Berghmans D., Clette F., Wauters L., Zhukov A. and Cugnon P.
Een op hol geslagen zon
Submitted for publication in 'Heelal'

48.6.3. Reports, thesis, etc

R. Van der Linden and the SIDC team
Monthly Reports for the ESA Space Weather Applications Pilot Project (since April)

Robbrecht E., Van der Linden R., Berghmans D., Vanlommel P.
WP410, Final report: Definition of solar monitoring

Berghmans D.
WP411, Final report: Automated solar data processing pipe-lines

P. Cugnon, R. Van der Linden and the SIDC team
Annual Report 2002 for FAGS.

P. Cugnon, R. Van der Linden and the SIDC team
Annual Report 2002 for ISES.

48.7. Missions

Assemblies, symposia, workshops: 9 missions, spread over 4 team members.
Commissions, working groups: 11 missions, spread over 4 team members.
Field missions (including company visits): Approximately 15 missions, spread over 4 team members.

49. Educational and Public Outreach activities at the Solar Physics Department

49.1. Objectives

In symbiosis with the scientific and service-oriented activities, the staff at the Solar Physics department of the ROB spends a significant effort towards interaction with the general public. The aim is familiarise the Belgian population with the ROB in general and its solar physics department in particular, to improve public understanding of solar physics and solar activity, to increase general awareness of the relevance space weather for present-day technology and to generate and foster a public interest in science, especially amongst youths.

49.2. Progress and results

EPO activities cover a very wide field and are very seldom a purpose on its own. Frequently EPO activities are natural effluents of scientific activities or are developed along with a scientific project. The EPO activities of our department are therefore as diverse as the department itself. A non-exhaustive list of developments in 2003 is presented below.

9) Creation of special pages dedicated to explanations in layman's speech of some issues in solar physics and space weather. Typical examples are the "Professor David" pages on sol.oma.be and the "solar highlights pages" on the SIDC website.
10) Guided tours (groups and individuals) of the facilities of the solar physics department, both in Ukkel and in Humain (we notice a strongly growing interest from the amateur astronomer

community for radio astronomy). We take it for granted that participants to these guided tours not only want to see the fine architecture of the Observatory buildings, but also want to learn a bit about current issues in sciences, and we therefore always include a short presentation about the current state of solar activity as seen through the most modern instruments and our current understanding of this activity.

11) We receive regular invitations to make public presentations about solar physics and space weather to varied audiences. We try as much as possible to accept such invitations. In the past year, several of our staff have thus presented such public lectures at many different locations.
12) It has become general knowledge that *the sun is beautiful*, in particular when looked at in the appropriate wavelengths. This has led to some artistic projects involving solar images, for which occasionally we are asked to contribute (see e.g. the SUNBURSTS project with the US sculptor A Tacha (http://homepage.oma.be/hochedez/Sunbursts.pps).
13) During a few weeks with spectacular solar outbursts followed by extreme Space Weather, we have strongly increased the SIDC activities to keep the press and the public informed about the ongoing events. Several press releases were issued; many interviews were made (for TV, radio, newspapers and magazines).
14) We have written texts to serve for the ROB press folder.
15) We have contributed posters and a solar activity video for the Royal visit.
16) As every year, we have responded to many requests for information.

49.3. Perspective for next years

We continue to consider EPO activities as an important part of our work, even if it is to be noted that these activities come in addition to more 'official' tasks and rely heavily on the voluntary cooperation of the individuals. In particular for the French-speaking side this may sometimes lead to unequal distributions of the EPO work due partly to the long-term absence of P. Cugnon.

We will continue to build on past successes to develop further EPO activities. Some of the future space missions in which we are involved will undoubtedly prove ideal opportunities to attract the attention of the public at large. This is expected to be the case in particular for the PROBA-2 mini-satellite, on which we will fly two instruments. These opportunities will be exploited to the full.

Some members of the department are currently involved in a proposal to obtain EU funding (FP6) for public outreach activities in the framework of the European science week. If successful, this would open up the possibilities to develop some material aimed at school projects, to which many members of the department wish to contribute.

It is our intention to continue work on making the website of the SIDC more accessible to non-scientific visitors, e.g. by providing a glossary and more explanatory pages. Subsections of the site may be translated into Dutch and French.

49.4. Personnel involved

All staff of the solar physics department has been involved to a variable degree, with as main contributors D. Berghmans, F. Clette, P. Cugnon, J.-F. Hochedez, E. Robbrecht, P. Vanlommel and R. Van der Linden.

49.5. Partnerships

The solar physics department has good relationship with several groups of amateur astronomers, and we occasionally organise joint events.

Visitors: we have hosted many individual and group visits from interested parties during 2003. Some of these visits were organised centrally by the Observatory, but we also received a number of requests directly to specifically visit the observational and operational facilities of the solar physics department in Ukkel and Humain.

49.6. Publications

49.6.1. Publications without peer system

Vanlommel P., Berghmans D., Van der Linden R., Cugnon, P.,
Ruimteweer: het einde van de wereld?
Heelal, Vol 48, nr 6, pp. 144-149.

49.6.2. Publications in press, submitted

Vanlommel P., Van der Linden R., Robbrecht E., Berghmans D., Clette F., Wauters L., Zhukov A. and Cugnon P.
Een op hol geslagen zon
Submitted for publication in 'Heelal'

49.7. Missions

Field missions (including company visits)
A few missions to Humain to prepare public visits.
About 10 public presentations.

50. Solar ephemeris calculations for the ROB yearbook

50.1. Objectives

Computation of the data and tables for the Sun and Jovian satellites as a contribution to the ROB yearbook for 2004, and of ancillary solar tables in support to other Department activities (SIDC, Humain).

50.2. Progress and results

- The ephemeris calculations were carried out using the usual set of programs in BASIC (Stumpff method)
- A special effort has been made to implement the conversion of raw tables to the new Latex formatting.

50.3. Perspective for next years

Next year, the Department will provide the solar ephemeris for 2005 but will not be anymore in charge of the Jovian satellite ephemeris. The existing programs will be ported to FORTRAN and partly rewritten, and the new versions will be extensively tested.

50.4. Personnel involved

P. Cugnon (Head of Departement), G. Evrard (Principal Calculator), L. Wauters (Assistant), O. Boulvin (Calculator).

50.5. Partnerships

None.

50.6. Publications

50.6.1. Publications without peer system

"Sun" and "Satellites of Jupiter" sections of the ROB 2004 Yearbook.

50.7. Missions

None.

INTERDEPARTEMENTAL ACTIVITIES

51. D4A Project – Digital Access to Aero and Astrophotographic Archives

51.1. Objectives

The aim of this pilot-project (FSP I2/AE/103) is to preserve the historic-scientific information contained in the astrophotographic plate archive of the ROB and in the aerial photographic archives of the NGI and the RMCA. The goal is to acquire the necessary know-how, hardware and software to digitise the information contained in the photographic plates, as well as the associated metadata. The project set out to offer the results to the public and to make them directly usable for scientific research through the modern techniques of the information society.

51.2. Progress and results

The D4A project is building a 2D digitiser facility of high geometric and radiometric resolution and precision. The air-bearing digitiser will be housed at the ROB in a temperature and humidity stabilised clean room with adjacent archive room. The ROB is financing this with a Lotto grant that became available in March 2003 and through a ROB donation. The Ministry of Public Works (Regie) is doing the necessary renovations of the Telescope building that will house the climatised clean room and the plate archive in its basements.

J.-P. **De Cuyper** is project coordinator and directing official in charge of the buying of an air bearing XY-table and a climatised clean room for the D4A digitiser facility. He followed-up the renovation works and worked out together with **Mark De Knijf** and **Eric Vander Putten** the technical specifications for the renovations. Vibration tests done by the Seismology Department and a ground sounding were analysed by H. Van Hoof and J. Verheyen of AGFA-Gevaert Engineering, who worked out the foundation design. In collaboration with D. De Swaef (jurist FSP) demands for following negotiated-buying procedures were introduced and granted by the Minister. Calls for Candidates, including the general and administrative regulations and the minimal technical specifications were written in Dutch, French and English. Together with Lars Winter he developed further the design of the D4A digitiser. They visited twice USNO Washington, DC to do digitisation tests on the StarScan machine: a dotted geometric grid plate, constructed by BV Mulch on our own design, was calibrated; a prototype holder for polyester film with a vacuum flattening of the film sheet onto the supporting glass plate, constructed by **R. Peeters** and **F. Renders** was successfully tested; a digitisation procedure for making a raster image from the individual subimages was worked out and tested in collaboration with C. Sterken VUB (radiometry/photometry) and J. Vanommeslaeghe NGI (geometry/photogrammetry); etc. They also visited twice Aerotech in Pittsburgh Pennsylvania, were they discussed the proposed add-ons: plate holder, turntable and film roll transport. On a demo air bearing XY-table accuracy and repeatability tests were done using the geometric grid plate, giving a 50 nanometer accuracy tolerance. The offered automatic film roll transport system and an automatic plate exchange and stack system was also discussed in collaboration with P. Mol of AGFA-Gevaert Engineering. Together with L. Winter a Benchmark procedure for the delivery and the calibration of the XY-table was worked out, including static, dynamic and bi-directional repeatability testing.

The development of a digital, ODBC compliant, relational database describing the astrophotographic plate archive was continued in collaboration with G. De Decker the informatician of the D4A project. **G. Peeters** extended the ASCII lists of observational metadata for introduction into the database. **G. Peeters** and **D. Duval** continued the prescanning at 250 dpi of the 16 cm plates with the HiD scanner. A jobstudent started the prescanning of the 30 cm plates with the XY15 scanner at the NGI during the month of July. **N. Garcés Troya** on a half time contract continued this work and moved most of the plate collections to an existing plate archive, in the Double Astrograph building, were a Munters air dehumidifier system has been installed.

J.-P. De Cuyper worked together with the partners at the NGI, the RMCA and AGFA-Gevaert on digitisation methods for historic maps, using either a commercial roll scanner or an analogue reduction on duplication colour film, suitable for digitisation on the D4A digitiser. He had contacts with the photography Department of the RIAP concerning the digitisation of Röntgen film and with the Geological Service at RBIN concerning the digitisation of maps.

51.3. Perspective for next years

In the coming two years (phase 2), the D4A project will extend the digital plate catalogue and continue the prescanning of the plates. A webserver, containing the metadata together with thumbnail images will be set-up on Internet, after making a study of the available hardware and software systems in order to optimise the accessibility and the maintenance costs.
The buying of the temperature and humidity stabilised clean room and of the XY-table and the add-ons will be done. The construction of the D4A digitiser will be finished, by working out an optimal diffuse illumination system and acquiring an adapted digital camera. The necessary hardware and software for the digitisation and the data storage, handling and extraction will further be developed and/or acquired. Depending on the type of data contained in the photographs and their type of application, different calibrated end products will be made available.
The project will study the IT problem of digital data archiving and management and liase with national and international working groups studying this problem.

51.4. Personnel involved

- Jean-Pierre De Cuyper
- Thierry Pauwels

- Nidia Garcés Troya
- Georges Peeters
- David Duval

- Eric Vander Putten
- Mark De Knijf
- Roger Peeters
- Francis Renders

- Frederik De Cuyper (jobstudent)

51.5. Partnerships

- National Geographic Institute (NGI), Dir. Joost Vanommeslaeghe, Dir. Herman Prils.
- Royal Museun of Central Africa (RMCA), Prof. Dr. Johan Lavreau, Dr. Max Fernandez.
- AGFA-Gevaert, Mortsel, Aerial Photography & Engineering Devision.
- Vrije Universiteit Brussel (VUB), Astronomical Institute, Prof. Dr. Christiaan Sterken
- Universiteit Antwerpen (UA), Astronomical Institute, Prof. Dr. Mark David
- Sternwarte Bergedorf, Hamburg, Dr. Lars Winter
- United States Naval Observatory, Washington DC, Dr. Norbert Zacharias, Dr. Sean Urban, Dr. Ted Rafferty

51.6. Publications

51.6.1. Publications with peer system

51.6.2. Publications without peer system

De Cuyper, J.-P., van Dessel, E., Pauwels, T., Vanommeslaeghe, J., Prils, H., De Decker, G., Pierre, O., Lavreau, J., Fernandez, M., Tran, T., Sterken, C., David, D., Schots,M., Daelemans,G.:
Digital Access to Aero- and Astrophotographic Archives
In: Astronomical Data Analysis Software and Systems – ADASS XII (eds. H. Payne, R. Jedrzejewski & R. Hook), ASP Conf. Series, Vol. 295, pp 93-95.

De Cuyper, J.-P.
Digital Access to Aerial and Astronomical Archives
DigiCult.Info 5, 41-43

51.6.3. Publications in press, submitted

De Cuyper, J.-P., Winter L. and Vanommeslaeghe, J.
The D4A Digitiser
in Astronomical Data Analysis Software and Systems – ADASS XIII (eds. F. Ochsenbein, M. Allen and D. Egret), ASP Conf. Series, 4p.

De Cuyper, J.-P., Winter L. and Vanommeslaeghe, J.
The D4A Digitiser
The PDPP Newsletter 2, January 2004.

51.6.4. Reports, thesis, etc

Call for Candidates – Negotiated procedure with voluntary previous publication for the purchase, installation and putting into service of a granite based air-bearing XY-table with foot and compressor.
Versions in Dutch, French and English

Call for Candidates – Negotiated procedure for the purchase, installation and putting into service of a clean room with specifically designed air temperature and humidity stabilisation in overpressure.
Versions in Dutch, French and English

D4A Activity Report June 2003

D4A Evaluation Report October 2003

51.7. Missions

51.7.1. Research Missions: 1

12-15/10/03: Astronomical Data Analysis Software and Systems – ADASS XIII, Strasbourg, France. Poster: The D4A Digitiser.

51.7.2. Operational Missions: 30

51.7.3. Field missions: 2 to USA

Frequent missions to NGI, AGFA-Gevaert, RMCA and FSP.

52. Project "Studie van het bereikte, de behoeften, de beperkingen en de prioriteiten betreffende de digitalisering van het wetenschappelijk en cultureel erfgoed van de Federale Wetenschappelijke Instellingen en het Filmarchief van België"

52.1. Objectives

POD Science Policy has initiated a study to determine the needs of the Federal Scientific Institutes to digitise their heritage. It is intended to give to the minister the necessary information to decide about funding digitising projects.

52.2. Progress and results

The POD Science Policy has given the task of the study to the Bureau van Dijk. The study started in early 2002, and was assisted by a follow-up committee consisting of one member of each Federal Scientific Institute. For the ROB this was P. Cugnon till September 2002, and T. Pauwels starting from September 2002. The representative in the follow-up committee acted also at the person gathering the information about the existing collections at the ROB. When we got the news that there was a possibility to rent 33 MEUR from the European Investment Bank, four working groups were established, with the specific task of defining a number of projects spanning each several scientific institutions.
The ROB was represented in three working groups. P. Alexandre represented the observatory in the working group 'Documents'. This working group defined four projects: one for retrocataloguing the libraries, the others for digitising maps, newspapers, posters, and old works. T. Pauwels represented the ROB in the working group 'Scientific Objects', with the help of K. Vanneste and M. Everaerts. This working group defined a project "Web GIS". K. Vermeiren was member of the working group 'Digital management', which defined two projects: 'State of the art regarding the digitisation of the cultural and scientific heritage' and 'Erection of a common cell for technical support of digitisation projects'.
The final report of the study has been delivered in March 2003, and the follow-up committee then gave its comment on the final report.

52.3. Perspective for next years

The study as such is finished. However, we hope that as a result of the recommendations formulated by the study, digitising projects will be financed. At present there is a pilot project (see "Archiving and digitising photographic plates") running at the ROB, aiming at establishing the procedure and installing the hardware for digitising our plate collections. This pilot project should normally end in March 2006, after which we need to define new projects to start an operational phase. The recommendations of this study should help to get such projects financed.

52.4. Personnel involved

Staff members of the ROB: P. Alexandre, M. Everaerts, T. Pauwels, K. Vanneste, K. Vermeiren.

52.5. Partnerships

List of national and international partners: the 10 Federal Scientific Institutions, the Filmarchief van België, the Federal Science Policy, the Bureau van Dijk.
Grants used for this research: none
Visitors: none

52.6. Publications

52.6.1. Reports, thesis, etc.

Rapport van de Begeleidingscommissie en van de Conferentie van de directeurs van de FWI's bij de Studie i. v. m. de digitalisering van het cultureel en wetenschappelijk patrimonium van de FWI's (incl. het Koninklijk Belgisch Filmarchief).

52.7. Missions

9 operational missions.

53. Operational project The Yearbook

53.1. Objectives

Every year the Royal Observatory of Belgium publishes a Yearbook with ephemerides, the most important astronomical phenomena and their visibility in Ukkel and in Belgium.

53.2. Progress and results

In 2003 the Yearbook for 2004 was published. It was produced by P. Cugnon, J. Cuypers, R. Dejaiffe, T. Pauwels, F. Roosbeek and J. Sauval, with the technical assistance of G. Evrard. The final editing was done by T. Pauwels.
The Yearbook 2004 is the first to be produced in LaTeX rather than Ventura. This was necessary since there are no recent updates of Ventura any more, while the version we used does not run on higher than Windows 98. A special style file in LaTeX has been written such that the output generated in LaTeX is virtually indistinguishable from the output generated by Ventura, but the LaTeX option allows much more automation in preparing the Yearbook. Authors adapted their programmes to produce output in LaTeX-format.
With the Yearbook 2005 in mind, the DE405 en DE406 ephemerides have been installed, such that the next Yearbooks can use these more modern ephemerides rather than the older DE200.

53.3. Perspective for next years

Publication of the Yearbooks 2005ff without major changes. Starting with the Yearbook 2005 the chapter of the phenomena of the satellites of Jupiter will be taken over by Department 2 rather than Department 4. The chapters of the planets, eclipses, transits and occultations will use DE405 and DE406 rather than DE200.

53.4. Personnel involved

Staff members of the ROB: P. Cugnon, J. Cuypers, R. Dejaiffe, G. Evrard, T. Pauwels and F. Roosbeek.
Volunteer: J. Sauval, honorary head of section of the ROB.

53.5. Partnerships

Data has been used from *H. M. Nautical Almanac Office* of the Royal Greenwich Observatory, the *Nautical Almanac Office* of the U. S. Naval Observatory, the *Institut de Mécanique Céleste et de Calcul des Ephémérides* (IMCCE) of the Bureau des longitudes and the Observatoire de Paris, the *Central Bureau of Astronomical Telegrams*, the *Minor Planet Center* and *Astronomical Tables of the Sun, Moon and Planet* by Jean Meeus.
Grants used for this research: none.
Visitors: none.

53.6. Publications

53.6.1. Reports, thesis, etc

P. Cugnon, J. Cuypers, R. Dejaiffe, T. Pauwels, F. Roosbeek, J. Sauval
Annuaire de l'Observatoire royal de Belgique—Jaarboek van de Koninklijke Sterrenwacht van België 2004.

53.7. Missions

None

54. Development project Web interface for the Yearbook

54.1. Objectives

The paper version of the Yearbook of the Observatory gives data for Ukkel and for some phenomena also for a selection of places in Belgium. With the possibility of the Internet, it is now easy to make these computations for any place anywhere in the world. Since the programmes already exist, it is sufficient to write a web interface to achieve the stated goal.

54.2. Progress and results

The project to write a web interface has been given as thesis for Raphaël Wastiels, a student at the INRACI. During his stay at the Observatory (27 January–30 May) he wrote an interface for a few representative programmes. T. Pauwels supervised his work, had discussions with his teacher, and checked his "cahier de charge". He produced a map of Belgium, made clickable by the student. The interface has been tested and works fine. However, these programmes make use of commercial software, for which the licence has not been renewed for budgetary reasons. Therefore, we are looking for a cheaper replacement of this commercial software. For the moment we have only a list of routines and their calls that have to be replaced.

54.3. Perspective for next years

Once the commercial software has been replaced by alternative software, the interface can be made public. This should be finalised in the course of 2004.

54.4. Personnel involved

Staff members: T. Pauwels. H. Langenaken, Y. Coene
Student: Raphaël Wastiels

54.5. Partnerships

List of national and international partners: INRACI
Grants used for this research: none
Visitors: 2.

54.6. Publications

None.

54.7. Missions

2 field missions.