# SPACE RESEARCH IN BELGIUM
# 1981

Report to COSPAR - meeting in Ottawa
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## INTRODUCTION

This report has been prepared on behalf of the Belgian National Committee on Space Research of the Académie Royale de Belgique and the Koninklijke Academie van België, for presentation at the XXIVth Plenary Meeting of the Scientific Committee on Space Research (COSPAR) at Ottawa, Canada, 17 May - 2 June 1982.

It summarizes basic and applied space research undertaken by belgian teams in various research institutes and universities. The names of these institutions are listed in Appendix of this report. The work of these groups is made possible by the funds almost entirely supplied by the governement.

## A. BELGIAN INSTITUTE OF SPACE AERONOMY

### 1. Study of the stratosphere

#### 1.1. Multispectral photographs of the stratospheric aerosol layers

This experiment uses balloonborne cameras which photograph the Earth limb from altitudes of about 35 km at sunset. Seven cameras have been used : 2 groups of 3 cameras loaded with black and white films and equipped with filters centered at 440 nm, 650 nm and 860 nm corresponding to blue, red and photographic infrared, and one camera loaded with a color film. The gondola may be oriented relatively to the Sun by telecommand in order to observe the totality of the limb. A microdensitometric study of the photographs leads to the determination of the sky radiance as a function of the solar zenith angle. It is possible to deduce the phase function of the atmospheric scattering and, applying Mie-theory, the size distribution of the aerosol is obtained. In the case of the flight on October 15, 1980, the following radius parameters, were deduced : 0.042 µm at 14 km altitude, 0.15 µm at 17 km, and 0.045 µm at 22 km. For the altitudes of 14 and 22 km these values are smaller than those generally quoted; at 17 km a better agreement exists. This might be due to the fact that other observational techniques have a bias against very small particles and are more appropriate for the aerosol Junge volcanic layer than for the background aerosol.

A new flight was made in October 1981 where the absorption of solar radiation could also be measured by the same photographic technique. The results are currently been interpreted.

#### 1.2. Observation of the minor constituents from the "Pic du Midi"

A second campaign of observation of the atmospheric content by means of a Fourier transform interferometer was conducted in August 1981 at the Observatory of the Pic du Midi (2887 m). The new

observations confirm an upper limit for the $HNO_4$ concentration equal to 5% of the nitric acid value. These results are now interpreted using synthetic spectra computed from the AFGL file and its French equivalent : the Geisa data bank. This study will yield values of nitric acid and chlorofluoromethane 11 and 12 which will be compared with the results of the 1980 campaign.

### 1.3. Observation of the ions in the stratosphere

Two balloon flights have been realized in 1981. The aim of these measurements is to determine the ion composition of the stratosphere between 20 and 35 km. The payload consists of a quadrupole ion mass spectrometer built in a high speed liquid helium cryopump.

The first flight took place on June 12th from the CNES launching base at Gap-Tallard (France). Spectra of positive and negative ions were obtained between 20 and 34 km altitude. The results of this flight have to be analyzed thoroughly, although some preliminar conclusions are already possible :

- The negative ions which have been observed, belong to the families $NO_3^-(HNO_3)_n$ and $HSO_4^-(HNO_3)_\ell\ (H_2SO_4)_m$. At lower altitudes the measurements are disturbed by collision induced cluster break-up in the instrument. Nevertheless it is possible to deduce from the results a decreasing $H_2SO_4$ mixing ratio with decreasing altitude.

- The positive ions belonging to the series $H^+(H_2O)_n$ and $H^+X_\ell\ (H_2O)_m$, X being most likely $CH_3CN$, have also been observed. At lower altitudes heavier ions (mass larger than 150 amu) are observed. The data suggest a possible role of methanol in the positive ion chemistry at altitudes below 30 km.

A second balloon flight was performed on September 14th from the CNES launching base at Aire sur l'Adour (France). This time two mass spectrometers were launched with the same balloon. Due to unfavourable wind conditions the slow descending phase of the balloon could not be realized. Therefore, only data at float altitude were obtained. The study of these data revealed the existence of some minor, so far unknown, negative ions.

Laboratory studies of cluster break up during the sampling process of positive ions allowed a more quantitative study of ion abundances. This permitted a comparison of proton hydrate distributions at different temperatures in the stratosphere. An upper limit for trace gases (such as $NH_3$ and $CH_3OH$) at 35 km altitude was also derived.

## 2. Structure of the terrestrial upper atmosphere

Since the publication of the last COSPAR International Reference Atmosphere (CIRA 1972) valuable progress has been achieved in improving our understanding of the terrestrial thermosphere. As a result, several empirical models are now available for numerous applications. The reliability of these models has been discussed within the framework of known physical phenomena. The most recent published advances deal with longitudinal and universal time effects. Some general shortcomings have been pointed out in order to stimulate further progress.

In particular, in a joint study with the Centre d'Etudes et de Recherches Géodynamiques et Astronomiques (France), total density data were obtained from the accelerometer CACTUS on board of CASTOR-D5B 1975-39A. Numerous and accurate data were obtained between 250 km and 600 km altitude in the equatorial region (± 30° latitude) for a period extending from May 1975 (minimum of solar activity) to February 1979 (already important solar activity). Since

CACTUS data have not yet been used for the construction of empirical thermospheric models, a significant part of the data file has been compared with several thermospheric models in order to provide an external test of the reliability of such models. Standard deviations of the order of 20% are apparent. The most significant differences extend over a few weeks and cannot be represented by the geophysical indices as they are presently used in the empirical models. Such an experimental fact suggests that the mathematical and physical aspects of the empirical models should be refined in order to achieve a better representation of physical reality.

The semi-empirical models of the terrestrial upper atmosphere take into account solar activity effects by using the solar decimetric flux as an index. Such a procedure is a consequence of the lack of continuous determinations of the solar spectrum directly responsible for the physical structure of the upper atmosphere. Variations of the thermopause temperature have been compared to the physical solar illumination of the upper atmosphere. Examples of absorption profiles and ion production rates indicate the need for continuous study of solar variability. Comparison of the kinetic energy available in a column indicate that the absorbed solar energy becomes negligible below approximately 50 km altitude.

## 3. Study of the ionosphere

The continuum theory of incoherently scattered electromagnetic waves has been modified in order to include possible effects of thermally induced chemical fluctuations. These fluctuations are taken into account by introducing fluctuating parts in the production and loss terms of the continuity equations. An equivalent ionospheric model has been developped for three types of ionized species, i.e., electrons and negative and positive ions. A matrix formulation gives simultaneous access to fluctuating parts of each charge component. Numerical results indicate that chemical fluctuations are important over the height range

where negative ions are comparable or greater than the electron concentration. Strong enhancements of the incoherent scatter cross section occur for frequency shifts smaller than approximately 20 Hz. A simple approximation has been given for the contribution of chemical fluctuations.

## 4. Study of the magnetosphere

### 4.1. Field aligned distribution of ionospheric and magnetosheath plasma in a Polar Cusp flux tube

Occasionally magnetosheath plasma is injected impulsively into polar cusp flux tubes. At the front edge of such downwardly propagating clouds of warm plasma, a double electric potential layer is formed. This double layer is a discontinuity of the electric field, due to the tendency of the plasma to maintain charge neutrality in the adjacent regions.

The field aligned plasma and potential distribution within such a layer is determined under the simplifying assumptions that collisions between particles, wave-particle interactions, time variations, and perpendicular gradients can be ignored in a first approximation. The ionospheric plasma is composed of cold electrons, oxygen and hydrogen ions which can escape along magnetic field lines interconnected with the interplanetary magnetic field. The magnetosheath like plasma consists of warm electrons and protons with a truncated velocity in the upward loss cone.

Numerical calculations have shown that the altitude of the double layer, and the maximum value of the electric field intensity do depend strongly on the boundary conditions in the ionosphere and in the magnetosheath.

## 4.2. Formation of the plasmapause

The magnetosphere is an ideal laboratory for the study of plasmas. It contains a large toroïdal region in which ions and electrons of low energy ($\leqq$ 1-2 eV) are trapped. This region is called the plasmasphere. It extends 4 to 5 Earth radii in the equatorial plane. At this radial distance the ionization density decreases rather abruptly. The surface where this density drop is observed is the plasmapause.

The earlier theories for the formation of this discontinuity are controversial. Indeed, it has been shown that the plasmapause is formed at the position where the average gravitational force is balanced by the average centrifugal force on a drifting flux tube rotating around the Earth in the magnetospheric convection electric field. This new mechanism for the formation of the plasmapause takes into account the effect of interchange motion of plasma within the magnetosphere, where earlier models ignored the consequences of this physical mechanism

This theory has recently been elaborated and a numerical model has been developped which allows to calculate the position of the plasmapause as a function of local time. The substorm boundary - an other discontinuity surface in the magnetosphere - is found to be the extension of the equatorial plasmapause up to the magnetopause. This new model is not based on the hypothesis that there is some singularity in the magnetospheric electric field distribution as is implicitely assumed in earlier models for the formation of a plasmapause.

The numerical model has recently been generalized in order to take into account time variations of the plasmapause as a function of universal time and as a function of the geomagnetic activity index $K_p$. The results of this time dependent model have been compared successfully with observations of GEOS 1 for a period of 4 days in July 1977, and will be compared with other experimental results obtained by the whistler technique.

### 4.3. Structure of the magnetopause

The terrestrial magnetopause is the transition layer separating the solar wind plasma from the magnetospheric plasma of ionospheric origin. Its internal structure is now intensively studied experimentally by means of the ISEE satellites. Recently, some observations performed by these satellites have proved the presence of high-speed plasma flow near the magnetopause.

Using a kinetic model describing tangential discontinuities it has been shown that such high-speed plasma jets can be reproduced at the interface separating the magnetosphere from the solar wind. Indeed, using the observations of the ISEE-1 satellite for the magnetopause crossing on 8 September 1978, it has been demonstrated that the ions can have very large velocities (of the order of 500 km/s or more) in the current layer. It is therefore not necessary to appeal for the reconnection theory to explain the presence of such high-speed plasma flows.

### 4.4. Penetration of the solar wind plasma into the terrestrial magnetosphere

The MHD approximation has often been used to describe plasma flows in the magnetosphere or in the interplanetary space. However, it has been shown that solar wind filaments penetrating impulsively into the magnetosphere are not described in a satisfactory way by the magnetohydrodynamic theory. Indeed, this theory neglects the processes linked with the dissipation of the kinetic energy of these plasma elements and with the dipolar interaction between the geomagnetic field and the magnetic field created by plasma elements of finite dimensions.

Therefore, some conclusions based on a magnetohydrodynamic approach can not be extended to plasma elements of finite extent, the

so-called "plasmoids". These solar wind plasmoids penetrate impulsively into the magnetosphere where the integrated Pedersen conductivity may not be neglected.

Furthermore, it has also been possible to formulate an analytical solution describing the magnetic field produced by electrical currents flowing at the surface of an ellipsoidal plasmoid. This solution is analogous to that obtained by solving the problem of the magnetic field produced by a conducting ellipsoid having an uniform magnetization. This model generalizes the case of an infinite filament since this can be viewed as a symmetrical ellipsoid infinitely stretched out along its large axis. The perturbation of the geomagnetic field produced by such a plasmoid will be studied quantitatively.

5. Study of the insolation on the planets

The solar radiation incident at the top of the atmospheres of the planets of the solar system has been studied in detail. The study related to the inner planets has permitted to obtain new results concerning some aspects of the insolation on Mercury and Venus. For the first time, the diurnal insolation has been analyzed in detail for those planets having sidereal periods of axial rotation of the same order of magnitude as the sidereal periods of revolution. Concerning more particularly Mercury, the heliocentric orbite of which is very eccentric, a longitudinal variation in both the instantaneous and the diurnal insolation has been found.

The oblateness effect on the upper-boundary insolation of the atmospheres of the outer planets has also been investigated. It is shown that, in summer, the daily insolation of an oblate planet is increased in one or two regions symmetric with respect to the summer solstice. In winter, however, the flattening effect results in a more extensive polar region, the solar energy input being always reduced when compared to a spherical planet.

Results qualitatively comparable were obtained for the Earth the effect, however, being much less pronounced due to its relatively small flattening.

## 6. Mathematical models of climate

The central theme of this research is the thermodynamic analysis of the climatic system, particularly in connection with its stability properties and its response to various factors of internal or of environmental origin. In view of the variability of the earth-atmosphere system, encountered at time scales ranging from the year to the millenium, it has been suggested that these phenomena could not be properly understood unless a nonlinear theory of climatic fluctuations is worked out. The development of the above theory for energy balance models at the planetary scale had already led to two basic results : (i) the existence of a long time scale associated with the passage between different metastable climatic states triggered by the fuctuations, and (ii) the possibility to amplify a weak external periodic forcing, provided that its periodicity is comparable to the above characteristic passage time.

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## B. ASTROPHYSICAL INSTITUTE OF THE UNIVERSITY OF LIEGE

### 1. Observations of $Mg^+$ resonance scattering with the Pioneer Venus Orbiter

The vertical distribution of the airglow near 2800 A on the Venus dayside has been observed with the ultraviolet spectrometer on board of the Pioneer Venus Orbiter. After correction for off-axis light and Rayleigh scattering, a residual signal is attributed to fluorescence of $Mg^+$ ions at 2796-2802 A in the solar radiation. The densities derived from these measurements vary from $10^3$ to $10^5$ $cm^{-3}$ between 130 and 100 km. A model of meteoroid deposition and vertical transport by eddy diffusion has been developed and compared with observations. The existence of a metallic ion layer may explain in part the presence of the variable ionospheric layer detected on the night side of the planet by the Mariner 10 and Pioneer Venus spacecraft.

### 2. Transport of thermospheric nitric oxide into the mesosphere

A bidimensional model of odd nitrogen between 75 and 275 km has been developed with the National Center for Atmospheric Research (USA). The sensitivity of the global NO distribution to various parameters has been studied for solstice conditions. Important conclusions have been obtained about the eddy diffusion coefficient K and its altitude and latitudinal variations. The role of neutral thermospheric winds has been investigated and results indicate that they only influence the NO density field through perturbations of temperature and $O/O_2$ ratio. The direct effect of winds is only important in the polar night region where photochemical lifetimes are very long.

Besides, this study has shown by which mechanisms magnetic activity controls the global NO distribution and its penetration into the mesosphere.

## 3. Interaction of energetic electrons with the Jupiter and Saturn atmospheres

A model of the interaction of energetic electrons from the plasma torus surrounding Jupiter has been used to interpret the observations of the EUV spectrometers on board Voyager I and II. The calculations are based on the continuous slow down approximation. The vertical distribution of the ionization rate and of various visible and ultraviolet H and $H_2$ emissions have been computed for different spectra of primary electrons. The comparison with the Voyager measurements indicates that an energy flux of at least 8 ergs/cm$^2$ s was present at the time of the encounter with the planet. The particle heating rate is estimated at 4 ergs/cm$^2$ s for Jupiter and 0.1 erg/cm$^2$ s for Saturn. A globally averaged production of $\sim 10^{10}$ H atoms cm$^{-2}$ s is induced by energetic electrons, a value largely exceeding the dissociation rate by solar radiation.

## 4. Halley Multicolour Camera (HMC)

A group of Institutes including the Institut d'Astrophysique de Liège replied to the call for experiments emitted by ESA for the GIOTTO Cometary spacecraft. The experiment is a camera which should take pictures of the nucleus and inner coma of comet Halley. The proposal has been accepted by ESA.

The main investigator is Dr. H.U. Keller of Max Planck Institut für Aeronomie. The consortium comprises also the Laboratoire de Physique Stellaire et Planétaire (LPSP in Verrières-le-Buisson, France) and the Universita di Padova (Italy).

Our contribution to the development of the camera is limited to the qualification tests at the component and system levels. Among these tests are the qualification tests of the CCD detectors, the optical calibration and the vacuum and thermal tests of the camera itself. More-

over, a simulation of the encounter of the spacecraft with the comet has to be performed. This implies to build a mechanical structure which allows to represent the conditions of the flight concerning the attitude of the spacecraft and the viewing of the cometary nucleus for ascertaining the behaviour of the on board microprocessors.

The first phases of these tasks began in 1982, the whole project aiming to the launch of Giotto in 1985. In March 1986, during the 4 hours of the encounter, the HMC shall transmit to the earth 4000 pictures of the nuclear region, improving by a factor 1000 the resolution of the best image obtained from the ground.

## 5. Ultraviolet stellar classification

In 1981, the work on the ultraviolet stellar classification has been carried on by the extension of the bidimensional scheme still established to the stellar spectra obtained with the I.U.E. satellite.

A collaboration with other scientific institutions (Observatoire de Strasbourg, NASA IUE comitee, VILSPA IUE observatory) has been decided in order to :

- increase the observations of normal objects in existing gaps, to complete satisfactorily the initial sample,
- study specific problems to which the reference classification grid may apply (like determination of effective temperature and lumminosity of hot companious of bright cool stars, energy distribution of distant stars ...).

## 6. Calibration of the Faint Object Camera of the Space Telescope

The activities during year 1981 concerning the FOC Calibration can be summurized as follows :

a) Drawing of the different plans necessary for the mechanical manufacturing of the material to be used for FOC calibration

b) Manufacturing of the above mentioned material.

c) Definition of the electronics for command and control of the material necessary for FOC calibration. This essentially concerns a permanent control, with alarm system, of the light flux, the temperature and the pression. These parameters having to remain between defined values.

d) Starting of the manufacturing of the electronic parts.

## 7. Bidimensional photon counting system

A new bidimensional photon counting system (IPCS) has become operational. It is made from one ITT straight channels microchannel plate intensifier, coupled, by optical fibers, with a Westinghouse camera tube.

The system's general properties were studied to define the voltages which optimize the working conditions.

On the other hand, a theoretical study has been undertaken : this study led to quantify the IPCS loss of linearity and resulted in a new concept of photon events centroiding.

## 8. The Far UV-spectrum of the low excitation planetary Nebula HD 138403

The Internal Ultraviolet Explorer (IUE) satellite was used to record the first high resolution ($\lambda/\Delta\lambda \sim 1.2\ 10^4$) far-ultraviolet spectra (1170-2070 A) of the low-excitation planetary nebula HD 138403.

The most prominent spectral features of this object consist of a stellar continuum cut by numerous interstellar lines, on which are superimposed various types (I, VIII, IX) of P Cygni profiles. Those

due to the resonance doublets of N V, C IV, Si II and to the He II λ 1640 line transition indicate the presence of an important mass-loss from the central object, with terminal velocities of the order of 800 km $s^{-1}$.

The only nebular emissions identified in the far UV-spectrum are the C III] λ 1909 intercombination line with its associated $2s^2\ {}^1S_o$ - $2\ s2p^3P^o_2$ magnetic quadrupole transition. Using the rate of the line fluxes measured for these components, we have derived a value $n_e$ = 1.1(± 0.4) $10^5$ $cm^{-3}$ for the electron density in the main nebula.

Furthermore, a remarkable asymmetry in the red wing of the C III] λ 1908.734 emission profile is found to be consistent with the presence of an emission satellite, shifted by + 123 km $s^{-1}$ with respect to the central main component. These data strengthen the hypothesis that a bipolar structure is expanding around HD 138403, via the selective radiative process of edge and/or line locking mechanism(s).

## 9. Publications


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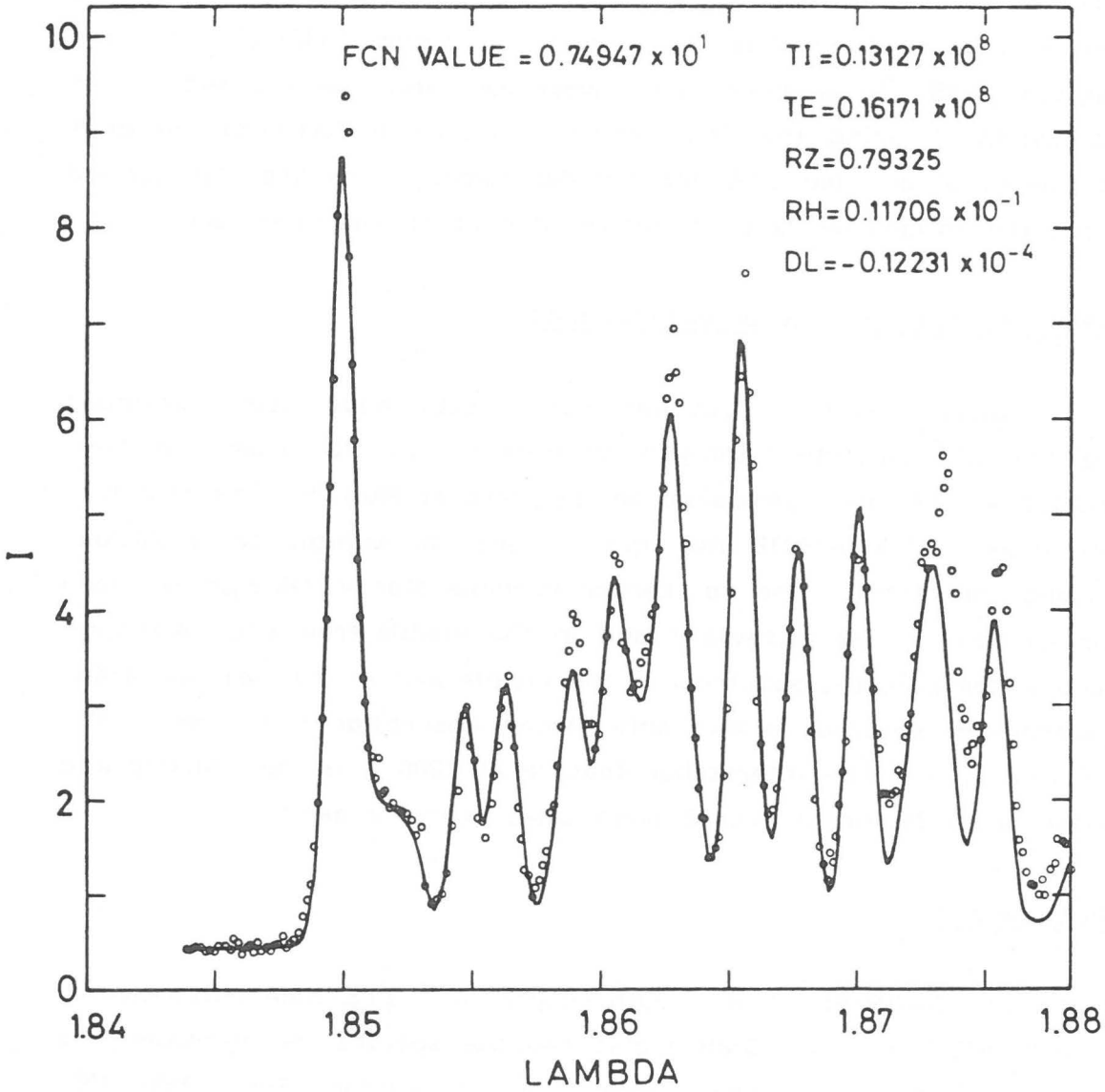
## C. DEPARTMENT OF ASTROPHYSICS OF THE STATE UNIVERSITY OF MONS

### 1. Solar X-ray spectrum

Active solar region observations from SMM satellite (XRP experiment) have been used to test atomic data related to satellite and parent lines of highly charged ions, with two electrons (MgXI, XII, Ca XIX, Fe XXIV, Fe XXV). The agreement is excellent for satellite lines, and permits to determine the temperature of the emiting plasmas. However, the interpretation of intercombination lines and of forbidden lines shows the importance of contributions due to radiative recombinations and to dielectronic recombinations. The computation of these contributions permitted to improve the agreement with the observations Nevertheless, at low temperature, the intensities of intercombination lines remain underestimated by theory. This problem is at present under consideration. These conclusions are confirmed in the case of Tokamak spectra of Fe XXV obtained at Princeton. These spectra display, as well as solar spectra, many satellite lines emitted by Fe XXIII. A complete computation allowed to account for these observations in terms of population ratio Fe XXIII/Fe XXIV. An example of solar X ray spectrum observed from SMM satellite during the May 21, 1980 flare is shown below. Dots represent the observed spectrum in the region of the Fe XXV resonance line with dielectronic satellite lines from Fe XXIV and Fe XXIII. A computed spectrum using data mentioned above is also shown. The least-square fitting is obtained by adjusting parameters $T_i$, $T_e$, $R_Z$ = N(Fe XXIV)/N(Fe XXV) and $R_H$ = N(Fe XXVI)/N(Fe XXV) determining the relative line intensities. The agreement is excellent except for the intercombination line at 1.8589 A. This work is a part of the Meudon-Nice Rutherford-Mons collaboration.


FCN VALUE = 0.74947 x 10^1
TI = 0.13127 x 10^8
TE = 0.16171 x 10^8
RZ = 0.79325
RH = 0.11706 x 10^-1
DL = -0.12231 x 10^-4
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1.84
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## 2. Balloon ultraviolet stellar observations

As a part of the Utrecht-VUB-Mons collaboration, calibrated ultraviolet spectra of the Ap star α 2 C Vn have been analysed. The echelle spectrograph provides spectra in the region 1980-3270 at 0.1 A resolution. 2167 lines have been measured and we proceed to an identification in using the "Wavelength Coïncidence Statistics" program from Cowley et al. Non-LTE line profiles computations are also carried out in order to complete a quantitative analysis of this spectrum.

## 3. Satellite ultraviolet stellar observations

Observations of peculiar hot objects have been continued using the IUE satellite. Analysis of material on HD 51585 has been presented at the IAU symposium on Be stars at Munich. The cool Wolf Rayet object CPD-56°8032 has been shown to exhibit an anomalous abundance of carbon. The hot carbon variable star V 348 Sgr has been observed both in the ultraviolet and in the visible from ESO. Although emissions dominate the spectrum in the visible and in the near infrared the ultraviolet spectrum shows only strong absorption lines from C IV Si IV and Mg II. The interstellar feature at 2200 A is very strong and suggests a reddening of over 2 magnitudes in the V band.

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## D. ASTROPHYSICAL INSTITUTE OF THE VRIJE UNIVERSITEIT BRUSSEL

1. International Ultraviolet Explorer (IUE) : project : "Mass loss of the hot components of Be X-ray binaries" of C. de Loore, M. Burger (Astrophysical Institue of the VUB) and E. Van Dessel (Royal Observatory Brussels, Belgium). The observations were carried out on 9 December 1980, analysed and published.

2. International Ultraviolet Explorer : project : "Mass loss and analysis of the spectrum of the hot Be-component of the pulsating X-ray nova A 0535+26", by C. de Loore, M. Burger (VUB), E. Van Dessel (ROB) and F. Giovanelli (Frascati). The observations were carried out at Villafranca (Madrid) on 1 and 2 November 1981 and are analysed.

3. Simultaneous observing campaign IUE/EXOSAT/Ground Based for the observation of O- and Wolf-Rayet stars, for observation of massive X-ray binaries and for low mass X-ray binaries. C. de Loore is prime investigator for the joint programme on O- and Wolf-Rayet stars, and co-investigator for the programmes on massive and low mass X-ray binaries, together with M. Burger (VUB) and E. Van Dessel (ROB) and many collaborators of other countries.

For the campaign on O-and Wolf-rayet stars 5 IUE shifts were allotted for joint ESA-SERC (United Kingdom) research. The observations will be carried out in collaboration with NASA where also 6 shifts were attributed.

For the X-ray campaign totally 10 shifts were attributed. The aim of the proposed programme is to observe O and WR stars in the soft and hard X-ray region, in the ultraviolet and in the visible, in order to study in detail the outer layers of hot stars. For the explanation of the presence of spectral lines of highly ionised species (e.g. in O VI, N V and C IV) in the ultraviolet spectra of hot luminous stars, various theories exist.

Lamers proposed a warm wind model, while Cassinelli and Olson explained the observations with a hybrid corona and a cool wind. This picture seems to fit the observations for O stars; for WR stars however the ideas are less straightforward and the picture is less clear.

Another way to model the observations is to assume bubbles moving rapidly through a slow wind or to assume slowly moving bubbles in a rapidly streaming wind. The latter two are both unstable wind models capable of explaining the observed X-ray emission, at least qualitatively. The differences are that the shocks are either directed towards or away from the stellar surface. The X-rays should then be produced by these shocks. Variations in the wind can be attributed to these bubbles. In the points where the hot (several $10^6$K) and the cool (several $10^4$K) gasses interact and where the shocks are produced superionisation is generated, and this should be observed in the UV spectra.

Hence it is important to have simultaneous observations in the X-ray and the UV part of the spectrum.

In order to find correlations between the presence and the extent of coronae, O stars of different spectral type should be examined. This can lead moreover to conclusions about possible correlations between the magnitude of the X-ray flux, the ratio between the X-ray and the optical luminosities, spectral types and evolutionary status.

Links seem to exist between mass losses and small changes in the subatmospheric structure. Large dispersions in these parameters are apparent, for a given spectral class, as well as for individual stars over short periods.

An important part of the programme should be devoted to Wolf-Rayet stars. The radiation pressure driven wind models fail to explain the observed variability of their stellar winds, the extremely high mass loss rates, and the X-ray emission in single WR stars, hence not associated with binarity.

Soft X-ray variability has been studied by Snow, Cash and Grady (1981), using the Einstein Observatory. They succeeded in establishing that variability occurs, but they were not able to explore the timescale or to correlate variations with visible and ultraviolet variations. Three stars (15 Mon, δ Ori and τ Ori) show definite X-ray variations between different Einstein observations. The timescales over which changes were seen vary from 5 days (15 Mon) to ∿ 1 year (δ Ori and τ Ori).

An important use of EXOSAT will be to search further for X-ray variability in O stars, on timescales ranging from hours to months.

## 4. Beta Cephei variables

The pulsation of the outer layers of the Beta Cephei-type variables BW Vul and σ Sco was studied on the basis of ultraviolet spectrograms (1200-2000 A) obtained with the International Ultraviolet Explorer. The radial velocity curves of the C IV and Si IV resonance lines are different from the photospheric ones showing that both the photosphere and the C IV and Si IV layers are accelerated upward impulsively, but that the acceleration of the outermost layers is larger than for the photosphere. The varying asymmetry of the C IV and Si IV line profiles indicates the occurrence of mass loss linked with the pulsation of the atmosphere, a mass loss superimposed on the continuous mass loss of these stars. Calculations using the Sobolev approximation with the parametrization of Castor and Lamers yields a temporary mass loss rate of the order of $10^{-9}$ $M_o$/yr for both stars.

## 5. Publications


BURGER, M., DE JAGER, C. and VAN DER OORD, G.H.J., The outer layers of the Beta Cep type variables BW Vul and σ Sco, in : Workshop on pulsating B stars, eds. G.E.V.O.N. and C. Sterken, Nice Observatory, 1981.

BURGER, M., DE JAGER, C., VAN DER OORD, G.H.J. and SATO, N., The pulsation of the outer layers of the Beta Cephei type variable BW Vul, Astron. Astrophys. (in press), 1982.

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HOWARTH, J., WILSON, R., CARTER, B., MENZIES, J., ROBERTS, G., WHITELOCK, P., van DESSEL, L., de LOORE, C., BURGER, M. and SANDFORD, M., IUE and optical observations of V861 Scorpii, Astron. Astrophys., 93, 219-227, 1981.

ROBBRECHT, W., DE LOORE, C. and OLSON, G., A hot corona model for O stars and WR stars, Proc. IAU Symp. 99 "Wolf-Rayet stars", eds. C. de Loore and A. Willis.

## E. ROYAL OBSERVATORY OF BELGIUM

### Space Geodesy and fundamental astronomy

#### a. Observations

The Doppler station operating on the frequencies 150-400 Mhz and 162-324 Mhz has performed continuous observations during the whole period.

The station referenced as TRANET 021 is integrated since 1972 in the tracking network managed by DMAHTC (Defence Mapping Agency Hydrographic and Topographic Center).

The objectives of the Royal Observatory are related to the detection of the polar motion and the irregularities of the Earth rotation.

The number of observed passes is given in the following table :

| Type of Satellite | Number of passes | Objectives |
|---|---|---|
| TRANSIT | 6.664 | Polar Motion<br>Earth gravity field |
| BEACON | 152 | Study of the low atmosphere |
| GEOS-3 | 1.006 | Earth gravity field<br>Geoïd configuration |

A new station completely automated is in process to be turned in operation.

b. Analysis

- The whole set of data acquired between 1972 and 1980 has been reprocessed and has conducted to the identification of periodic variations of the height of the station. They reflect the variations of the orbit introduced mainly by the tropospheric and ionospheric measurement errors. The periods are respectively 4 months, 365 days and about 12 years.

  The longitude displays also a long periodic component while the latitude variations are more randomly distributed.

- In collaboration with several European groups, the Royal Observatory participates to the study of a european geodetic satellite called POPSAT.

c. Publications

PAQUET, P., BARLIER F., BOSSY, L., MEZZANI, L., NOUEL, F. and REIGBER, C., The use of micro-accelerometers for space geodetic experiments, An. Géophysique, A. 37, fasc. 1, pp. 5-10, 1981.

## F. DEPARTMENT OF METALLURGY OF THE CATHOLIC UNIVERSITY OF LEUVEN

An experiment on composites is being prepared for the first Spacelab flight (experiment 1ES315A and B). It will be performed in the Isothermal Heating Facility and its aims are to examine if the space environment is favourable for the production of metallic composite materials by casting and to gain more fundamental insight in the behaviour of solid particles (ceramic or metallic) dispersed in a liquid metal.

In preparatory ground experiments attention is focussed on the skeleton formation by the dispersoids (leading to a thixotropic behaviour of the melt) and on the interaction of the advancing solidification front with the dispersed particles.

Because no mixing facilities will be available during the first Spacelab flight, fully dense samples (prepared by a powder metallurgical technique, including a hot extrusion step) and having a homogeneous distribution of the particles will be used. As observed in many experiments, melting such specimens on earth leads to the destruction of the uniform distribution by Stokes sedimentation, by gravity driven convection, by flotation, by skeleton formation and/or by the particles being eventually pushed forward by the solidification front. To investigate those last two phenomena melting experiments have been performed on earth on extruded particle composites of the systems $Al-Al_2O_3$, Al-SiC, $Cu-Al_2O_3$, Cu-SiC, $Cu-SiO_2$, Cu-W.

### Publications

FROYEN, L. and DERUYTTERE, A., The behaviour of dispersed particles in molten metal matrix composites, 21° Convegno Internazionale Scientifico Sullo Spazio, 25-26 March 1981, Rome.

## G. ROYAL METEOROLOGICAL INSTITUTE OF BELGIUM

### Solar Constant and Earth's Radiation Budget

The absolute radiometer for experiment 1ES021 on Spacelab 1 has been delivered to ERNO for integration. The construction of this instrument has been done with the collaboration of the Space Science Department of ESTEC. A second instrument, constructed and characterized at the RMI, is now tested for qualification at ESTEC. It will serve has a spare model and will be mounted on the "Solar Package" actually at study at NASA.

The study and development program of absolute wide field of view radiometers proceeds. They are intended for the determination of the Earth's radiation budget components. A collaboration between american and european scientists is started on the subject : "Objective Design Methodologies for Earth Radiation Budget Observing Systems".

### Publications


CROMMELYCNK, D., The observation of the solar constant and its variation, challenging space metrology, in Proceedings of the 14th ESLAB Symposium, 16-19 September 1980, Scheveningen, The Netherlands, edited by V. Domingo.

CROMMELYNCK, D., La constante solaire, Ciel et Terre, 97, 1981.

CROMMELYCNK, D., NICODEME, O. and CHEVALIER, A., Mesure de l'effet thermique parasite produit par l'irradiation du diaphragme d'entrée de la cavité du radiomètre absolu, I.R.M., Note technique n°42, 1981.

CROMMELYNCK, D., NICODEME, O. and CHEVALIER, A., Détermination des effets parasites produits par le boîtier qui fixe la géométrie du radiomètre absolu, I.R.M., Note technique n°43, 1981.

CROMMELYNCK, D., Fundamentals of absolute pyrheliometry and objective characterization, I.R.M., note technique n°46, 1981.

## Appendix

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