Annual Report
2000

Astronomical Institute “Anton Pannekoek”
Front cover: Comparison of the 21 µm band in the post-AGB star HD 56126 observed with ISO, and the laboratory spectrum of nano-clusters of TiC. The structure of the clusters is indicated (from von Helden, Tielens, Hony et al. 2000 Science 288, 313).

In the background an image of the emission due to molecular hydrogen in the proto-planetary nebula AFGL 2688, nicknamed the Egg Nebula. The colours reflect the velocities. The red parts originate from a rotating disk while the blue and purple parts are due to a molecular jet. In the foreground a comparison between the '21 micron feature' as detected from proto-planetary nebulae at the top and the resonance measured in titanium-carbide nano-crystals at the bottom. In blue and red around are models of titanium-carbide nano-crystals. The number of atoms in each model corresponds closely to the real number of atoms in the titanium-carbide crystals that have been measured.
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1. REPORT OF THE DIRECTOR

This year we continued on the course set out in previous years, in the framework of the national research school NOVA for which the University of Amsterdam carries the responsibility as "penvoerder". In 1999 NOVA started its ten-year research programme "Astrophysics: Unravelling the History of the Universe" as a national top-research school. Our institute plays a major role in two of NOVA's three research themes: "Late Stages of Stellar Evolution: Physics of Neutron Stars and Black Holes" and "Birth and Death of Stars: the Lifecycle of Gas and Dust".

In January 2000 the Institute put forward its research plan 2000 - 2005 entitled "Frontiers in Astronomy and Cosmic Physics", which was presented to the Faculty and the College van Bestuur (Governing Board of the University). The area and subjects of the planned research are listed in the next chapter (table 1).

In this plan which, of course, is closely connected with NOVA's research programme, the institute expresses its aim that the group of "Low-Energy Astrophysics", led by Dr. L. Waters, should grow out to an international prominence and leadership similar to that of the institute's "High Energy Astrophysics” group. To this end, a modest increase of the institute's permanent staff and funding is requested. The institute's Wetenschappelijke Advies Raad (Science Advisory Board) in its meeting in March 2000 expressed its support for this research plan, which was included in the WAR’s report to the Dean of the Faculty (included in the Appendix).

New appointments in our permanent staff are, of course, extremely important for the future of the institute. A search committee for identifying possible candidates to succeed professor Jan van Paradijs, who died on November 2, 1999, started its work in the spring of 2000 but did not yet reach a conclusion. On April 1st 2000 Dr.R.Fender was welcomed as a new Universitair Docent in the High Energy Astrophysics group.

In the fall of 2000 at the advice of a special nomination committee the College van Bestuur appointed Dr. L. Waters to a full professorship, starting January 1, 2001. During the first 4,5 years this position will be funded as a NOVA overlap-position.

This year three Ph.D. students completed their research and were awarded the doctorate. Six new Ph.D students started their research and one new postdoctoral fellow joined the institute. NWO awarded this year one position for a Ph.D student and one for a postdoctoral fellow.

We were very pleased that on January 1st 2000, NOVA’s Office for Public Outreach (het “NOVA Informatie Centrum”: NIC), housed in the Institute, started its activities with the start of the appointments of the outreach officers A.Jaspers and J.Visser.

Many interesting new research results were achieved this year, of which the highlights are given below. Although all in all we are quite satisfied with the results achieved this year, and the Institute is flourishing, we still feel the enormous loss imparted by the death of Professor Jan van Paradijs in 1999, in the prime of his life. The Institute has not yet fully recoverd from this loss and we expect that it will take at least a few more years to reach a new orientation and course for our future.

Research Highlights in 2000
- The Amsterdam-led Gamma Ray Burst (GRB)-afterglow collaboration (groups in 6 EU countries plus 3 in the US) was awarded an ESO Large Programme for following up GRB afterglows with ESO’s Telescopes in Chile during a two-year period. The collaboration obtained
spectra of a number new GRBs with ESO's Very Large Telescope in Chile and in collaboration with the American colleagues identified the host galaxies of a number of them with the Hubble Space Telescope. Over one half of all GRB redshifts measured so far were determined by our collaboration, among them the highest one found: at z=4.5 (measured by the Danish node of our collaboration). This GRB exploded when the Universe had only 18 per cent of its present size (Vreeswijk, Rol, Kaper, van den Heuvel).

- The awarding of the Christiaan Huygens Prize 2000 for the best Ph.D. Thesis in Space Science and Astronomy of the past 3 years to T. Galama for his 1999 thesis on GRB studies, and the awarding of a NWO Vernieuwing Impuls to Galama (which, unfortunately, he decided not to accept as he preferred to stay at the California Institute of Technology in Pasadena).
- The discovery with NASA's RXTE satellite of a third type of kilohertz Quasi Oscillations (QPO) in three bright galactic X-ray sources by P. Jonker, M. Mendez and M. van der Klis. These "sideband QPO" are an new phenomenon, for which no explanation has been found so far.
- The discovery by J. Homan that the transition from the "soft" to the "hard" spectral state in black-hole X-ray binaries can occur at a variety of intrinsic values of the total X-ray luminosity of the source, and not at just one "transition value" as had been thought for the last 30 years. This has important consequences for the understanding of the cause of this soft-hard transition, in terms of changes in the structure of the hot inner part of the accretion disk around the black hole.
- In close connection with this, R. Fender and colleagues further elucidated the relation between these X-ray spectral states and the occurrence of mass ejections in the form of relativistic jets from the hot inner parts of the black hole accretion disks and were able to cast this into a self-consistent physical model connecting all these phenomena.
- The discovery of "super-luminal" motions (apparently faster than light) during the radio outburst of the black hole "transient" V4641 Sgr by Hjellming, Fender and colleagues and the detection of the first absorption-line radial velocity curve of the relativistic-jet system Cygnus X-3 by Fender and colleagues.
- The reaching of sub-500 nanosecond timing accuracy for the fastest millisecond radio pulsar known: PSR 1937+21, demonstrating that the Westerbork Pulsar Machine PuMa is now capable of world-class pulsar timing (Ramachandran, Stappers, Voûte), and the discovery of a number of Extreme Scattering Events (Ramachandran, Stappers) produced by Astronomical Unit size inhomogeneities in the interstellar medium.
- The discovery by graduate student M. Witte and G. J. Savonije of the phenomenon of "resonance-locking" in the tidal evolution of eccentric-orbit close binaries. Due to this effect very strong tidal energy dissipation occurs in the "resonating" binary components which greatly accelerates the tidal circularisation of orbits. This solved the long-standing problem that the observed timescales for tidal circularisation of binary orbits are many orders of magnitude shorter than those predicted from the classical theory of tidal circularisation by viscous dissipation.
- The discovery by T. Tauris and G. J. Savonije that X-ray binaries with donor stars in the mass range 2 to 6 solar masses and relatively short orbital periods can avoid a phase of Common-Envelope evolution and will evolve with stable mass transfer (and large mass loss) into binary radio pulsars with orbital periods of order one week and consisting of a recycled pulsar and a massive white dwarf (mass range 0.5 to 1.2 solar masses). Half a dozen of such systems is known from observations.
- The detection by G. Nelemans, D. Steeghs et al. of the radial velocity curve of the helium white dwarf AMCVn, proving that this system is indeed a very close double white dwarf system with an orbital period of about 17 minutes.
- The identification of Titanium-Carbide (TiC) nano-crystals as the carrier of the 20.3 micron emission band in the outflows of carbon-rich post-AGB stars (highly evolved red giant stars). TiC grains of pre-solar origin were known from meteoritic analysis, and can for the first time be tied to a special group of post-AGB stars (G. von Helden, X. Tielens D. van Heijnsbergen, S. Hony,
M. Duncan, L. Waters, G. Meijer). Subsequently the TiC was for the first time detected in two planetary nebulae with Wolf-Rayet central stars (S. Hony, L. Waters, X. Tielens).

- The discovery of Carbon-Dioxide (CO$_2$) and SulphurDioxide (SO$_2$) gas-phase emission and absorption in the molecular envelopes surrounding Asymptotic Giant Branch (AGB) stars with moderate mass loss rates. The presence of CO$_2$ correlates with some solid-state bands, suggesting a link between the conditions of the gas envelope and the kind of dust that can condense (I. Yamamura, J. Cami, T. de Jong, K. Justannont, X. Tielens, L. Waters).

- The discovery of extreme isotopic ratios of Carbon and Oxygen in the circumstellar environment of the peculiar post-AGB star HR 4049. These isotopic ratios have never been observed in any other object and suggest a highly non-standard chemical evolution of this object (J. Cami, I. Yamamura).

- The first detection of Iron-Sulfide (FeS) outside the solar system, in two evolved planetary nebulae. This proves that sulphur can be included in the solid phase both as FeS and MgS (S. Hony, L. Waters, J. Bouwman).

- The first extrasolar detection of carbonates (calcite and dolomite) in the ejecta of two planetary nebulae. This discovery shows that carbonates can form from gas-phase condensation and need not trace aqueous alteration in large parent bodies, as had been thought before (F. Kemper, C. Jaeger, L. Waters, F. Molster, J. Bouwman, A. de Koter, Th. Henning).

- The first quantitative fit to the observed spectrum of an intermediate mass pre-main-sequence star using a hydrostatic equilibrium disk model (K. Dullemond, C. Dominik, A. Natta). This model can account for both the spectrum as well as the spatial distribution of emission.

- The discovery by C. Dominik from far infrared measurements with ISO that Vega-like disks surrounding A-type stars (disks larger than our solar system, consisting of dust and ice particles produced by collisions between cometray bodies) survive for some 400 million years. This is just the timescale of the "Heavy Bombardment" phase in the history of the early solar system. Surprisingly, Dominik and colleagues (Habing, Laureijs, Jourdan de Muizon et al.) also found in a few cases such disks still surrounding solar-type stars that are much older (up to several Gyaers).

**Edward P.J. van den Heuvel**
**Director**
2. GENERAL INFORMATION

Mission and Research Themes

The ultimate goal of astronomical research is to understand the Universe and the objects within it in terms of the laws of physics. The structure of the Universe and its development over the course of time, the nature, formation, and evolution of planets, stars, galaxies, clusters and superclusters of galaxies, and the properties of the medium in which these are embedded, are all important objects for study. Cosmological questions concerning the nature and evolution of the Universe relate directly to such questions as the geometry of space-time, the nature of dark matter which constitutes over 90% of the gravitating mass in the Universe but leaves no trace in the form of electromagnetic radiation, the formation of the elements and, ultimately, the origin of the Earth and of life. Furthermore, the Universe provides a unique laboratory for investigating and testing the laws of chemistry and physics under conditions far more extreme than can be reached in laboratories on Earth: astrophysicists study phenomena involving enormous scales of length and mass (the Universe as a whole), huge densities (e.g., neutron stars, black holes), extreme vacua (interstellar and intergalactic media), immense energies (explosive phenomena such as supernovae and quasars), and intense fluxes of particles and radiation (neutrinos, gamma-ray bursts).

Since 1992, all graduate astronomy education in the Netherlands has been concentrated in NOVA, the Netherlands Graduate School for Astronomy. NOVA is a federation of the astronomy institutes at the universities of Amsterdam (UvA), Groningen (RuG), Leiden (RuL), and Utrecht (UU), and also includes the astronomy group at the Free University of Amsterdam (VU). The University of Amsterdam since 1997 carries the responsibility (penvoerderschap) for NOVA.

The mission of the four university institutes that together constitute NOVA is two-fold:
* to train students and young astronomers at the highest international level;
* to carry out frontline astronomical research in the Netherlands.

In 1998 NOVA as selected by the Minister of Science as one of the six “Top Research Schools” in the country, granting it substantial extra funding for a period of ten years, starting 1-1-1999.

NOVA has three main research themes:
1. Formation and Evolution of galaxies: from high redshift to the present
2. Birth and Death of Stars: the life cycle of matter in the Universe

Research at the University of Amsterdam largely concentrates on the last-mentioned two themes, which we, according to the energies of the electromagnetic radiations emitted by the objects, indicate as “Low Energy Astrophysics” and “High Energy Astrophysics”, respectively. These names will be used throughout this report. Through the studies of Gamma Ray Burst sources, the research of the institute now also branches out into the first-mentioned theme. The table on page(…) gives an overview of the present research fields in the Institute.

The Astronomical Institute "Anton Pannekoek" also considers as an important part of its mission: the dissemination of the results of astronomical research to the general public and to schools. NOVA's national Office of Public Outreach is located at the institute.
Institute Management

Scientific Director
Prof. Dr. Edward P.J. van den Heuvel

Business Manager
Mrs. Lidewijde Stolte

Management Assistants
Mrs. Drs. J. Ayal, Mrs. Drs. E. Veenhof

Management Team

Scientific Advisory Committee
Prof. Dr. Ir. J.A.M. Bleeker, director Space Research Organisation of the Netherlands (SRON), Utrecht
Prof. Dr. P. Charles, Universities of Oxford and Southampton (UK)
Prof. Dr. C. Waelkens, Sterrenkundig Instituut, Katholieke Universiteit Leuven, Belgie
### TABLE 1: AREAS AND SUBJECTS OF PLANNED RESEARCH

**HIGH-ENERGY AND RELATIVISTIC ASTROPHYSICS**

*Final Stages of stellar evolution: physics of neutron stars and black holes*

<table>
<thead>
<tr>
<th>AREA</th>
<th>SUBJECT</th>
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</table>
| Physics of Neutron Stars and Black Holes | • Measurement of fundamental parameters of neutron stars (mass, radius rotation period, magnetic field) and black holes (mass, angular momentum)  
• Observed behaviour of matter in ultrastrong gravitational fields; tests of general relativity: frame dragging, last stable orbit  
• Studies of relativistic outflows  
• Study of (binary) radio pulsars; tests of teneral relativity  
• Theoretical studies of the formation and evolution of neutron stars (NS) and black holes (BH) in binary systems; formation rate of double neutron stars and black holes  
• Evolution of stellar populations (clusters) with a realistic binary fraction; dynamical formation of NS and BH binaries  
• Optical identifications, light curves, reshift distributions, cosmological evolution  
• Study of population of parent galaxies as function of redshift  
• Theoretical modeling of bursts; relativistic acceleration mechanisms |

**LOW-ENERGY ASTROPHYSICS**

*Birth and death of stars: the life cycle of matter in the Universe*

<table>
<thead>
<tr>
<th>AREA</th>
<th>SUBJECT</th>
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| Star- and Planet Formation, “Starbursts” | • Studies of protostars and protoplanetary disks: spectroscopy, chemical composition  
• Search for proto-planets around other stars, using VLTI, ALMA, FIRST etc.  
• Study of formation of massive stars in Local Group and “Starburst Galaxies”; relation to chemical evolution and dust formation in galaxies in the early Universe  
• Theoretical modeling of spectra of circumstellar gas and dust |
| Solar System Studies Lab. Astrophysics | • Spectroscopic and photometric studies of planets, comets and asteroids, in order to compare with observed properties of (proto-)planetary systems around other stars, laboratory experiments in light scattering an polarization |
| Late Stages of Stellar Evolution, Mass Loss | • Studies of dense circumstellar matter around highly evolved stars; AGB and post-AGB stars; formation of dust in envelopes of these stars  
• Studies of winds of massive stars and mass loss from luminous blue variables (LBVs) |
3. RESEARCH

3.1 HIGH-ENERGY ASTROPHYSICS OBSERVATIONAL STUDIES

3.1.1 Study of Gamma Ray Bursts (GRB)

The Amsterdam-led European Gamma Ray Burst (GRB) collaboration (consisting of groups in Denmark, France, Germany, Italy, The Netherlands, Spain and the United Kingdom, and associated with three groups in the USA) was awarded by the European Southern Observatory (ESO) in Chile an ESO Large Program for following up the optical and infrared GRB-afterglows in the 2-year period April 1, 2000-April 1, 2002. The PI of this proposal (van den Heuvel) organized on 18 October a collaboration meeting in Rome for coordinating the research, which is largely aimed at following GRBs to be observed with the HETE-II satellite, which was launched in October 2000. Also, of course, the follow-up of bursts observed with the Italian-Dutch BeppoSAX satellite are being followed-up.

A highlight of this year was the awarding of the “Chrystiaan Huygens Prize” for the best Ph.D. thesis in astronomy and space research to Dr. T. Galama for his 1999 thesis “Gamma Ray Burst Afterflows”. Minister L. Hermans of Education, Culture and Science awarded him the Prize in a special ceremony on 19 October 2000 in Voorburg.

Vreeswijk, Rol, Kaper and Van den Heuvel continued the study of GRB afterglows and host galaxies. They were awarded also considerable observing time on the telescopes of the Isaac Newton Group on Palma (PI: Vreeswijk, C. Kouveliotou (US) and N. Tanvir (UK)). In collaboration with PI A. Fruchter, Vreeswijk studied images and high resolution spectra of GRB afterglows and host galaxies with the Hubble Space Telescope. Access to the mm and radio wavelength domain is provided by the James Clerk Maxwell Telescope in Hawaii (PI: Smith) and the Westerbork Synthesis Radio Telescope (WSRT: PI: Rol), respectively.

Although the launch of the HETE-II satellite was delayed to October 2000 and the calibration of the instrument took longer than anticipated, several GRBs, located by BeppoSAX and the InterPlanetary Network, could be followed up. The Amsterdam GRB group was involved in the identification and/or follow-up study of the following Gamma-Ray Bursts (the GCN-numbers are the numbers of the GRB-circulars in which the discovery regarding that burst was first announced): GRB990712 (GCN 752), GRB991208 (GCN 872), GRB991216 (GCN 751), GRB000301A (GCN 569), GRB000528 (GCN 691), GRB000529 (GCN 699), GRB000607 (GCN 720), GRB000926 (GCN 850), GRB001011 (GCN 849), GRB001109 (GCN 886,889), and GRB001204 (GCN 908).

Amongst the science highlights is the identification of the optical afterglow of GRB000131 with ESO's Very Large Telescope, at the record redshift of z=4.5, dating from the time the Universe had only 18 per cent of its present linear size and only 6 pro-mille of its present volume (Andersen et al.). As GRBs are very likely produced by the collapse of a massive star forming a black hole (or, alternatively, by the merging of two neutron stars), GRB000131 corresponds to the most distant stellar event ever detected. Rol et al. presented the first indication of polarization variability in a GRB afterglow. Since synchrotron radiation is intrinsically highly polarized (60-70%), it would be natural to expect polarization in GRB afterglow emission. In the optical afterglow of GRB990510 the predicted polarization had been detected for the first time, though at the percentage level. Apparently, GRB afterglows are depolarized on their way through the surrounding matter. Rol et al. now detected polarization in a second optical afterglow.
(GRB990712), again at the percentage level, but contrary to the polarization angle, the degree of polarization is not constant. Current models cannot yet explain such a variation.

Fig.1.
Narrow-band images of the galaxy ESO 184-G82 with SN 1998bw, which is believed to be related to the Gamma Ray Burst GRB980425, in Hα, Hα continuum, Hβ and HeII. The images on the left have their continuum emission subtracted by using the images on the right. With these filters it is possible to map the star-formation rate in 2-D, to investigate whether the site where the GRB/SN exploded is extraordinary in its star-formation properties. The lines indicate the slit position of the spectrum, which shows a variety of HII emission lines from the GRB/SN region. The plus sign shows the position where SN 1998bw occurred. Images were taken in August 2000 with the Very Large Telescope of the ESO in Chile in the framework of our ESO Large Program.

3.1.2 Studies of Neutron Stars and Stellar Black Holes

3.1.2.1 Soft Gamma Ray Repeaters, Magnetars and Anomalous X-ray Pulsars

Van den Heuvel took part in the program on “Spin and Magnetism in Young Neutron Stars” at the Institute for Theoretical Physics of the University of California in Santa Barbara from October 31 till December 11. This program was centered largely around the newly discovered phenomenon of the “Magnetars”, neutron stars with magnetic field strengths around $10^{15}$ Gauss, some thousand times larger than known until 1998, when C. Kouveliotou and J. van Paradijs
discovered the first “Magnetar”, the Soft Gamma Ray Repeater SGR 1806-20. The surface heating and the resulting X-ray emission from these neutron stars is presumably due to the decay of their ultra-strong magnetic fields. Together with Kouveliotou, Van den Heuvel studied the possible association of the four “Magnetars” known to date with supernova remnants and clusters of massive stars. As a result they advanced the idea that Magnetars are the remnants of the most massive stars, with masses in excess of 50 solar masses. Such stars may lose so much mass during their evolution that they do not collapse to a black hole, but leave a neutron star as a remnant, which however, is very different from the neutron stars originating from stars between 8 and 25 solar masses.

3.1.2.2. Black hole candidates

Investigations continued of the properties of relativistic jets from black-hole X-ray binaries and their relation to the accretion flow, utilising simultaneous radio--infrared--X-ray observations of a number of systems. Building on previous work, it was established that a general property of black hole accretion is the presence of steady radio emission with a flat or inverted spectrum during the ‘low hard’ X-ray state. This radio emission disappears when the black holes are accreting in ‘soft’ disc-dominated states. This can be interpreted as an association between the hard states and the production of a quasi-steady outflow (Fender 2001). By using the JCMT, we were able to show that the self-absorbed synchrotron spectra produced by these jets extend to the millimeter band in both persistent (Cyg X-1 -- Fender et al. 2000) and transient (XTE J1118+480 -- Fender et al. 2001) systems.

![Fig. 2. Close-up of radio (top) and X-ray (bottom) light curves on MJD50698, demonstrating the one-to-one correspondence between spectrally hard X-ray dips and radio oscillation events in the black hole candidate GRS1915+105.](image)
It was further argued that this spectral component is likely to extend to the near-infrared or even optical regimes (Fender 2001; Brocksopp et al. 2001), in which case the total jet power (‘hidden’ as kinetic energy of the flow) is likely to be comparable to the bolometric radiative luminosity (Fender 2001). A crucial factor in these arguments was the radiative luminosity of the jets, which we have established to be probably ≤ 5 % (Fender & Pooley 2000), comparable to values estimated for AGN jets.

Two black-hole transients, XTE J1550-564 and XTE J1118+480 in 2000 spent some time in the low hard X-ray state and produced the flat/inverted radio spectrum, exactly as predicted (Corbel et al. 2001; Fender et al. 2001). Furthermore, in XTE J1550-564 it was found that transitions to the ‘very high state’ produced optically thin emission at the transition but no persistent jet (Homan et al. 2001; Corbel et al. 2001). Further work on the coupling between inflow and outflow revealed an apparent anti-correlation between disc accretion rate and outflow rate in the jet source GRS 1915+105 (Belloni, Migliari & Fender 2000), in agreement with the scenario outlined above.

Other highlights were the detection of apparent highly superluminal motions during the radio outburst of the ‘fast transient’ V4641 Sgr (Hjellming et al. 2000), the first absorption-line radial velocity curve for the jet system Cyg X-3 (Hanson, Still & Fender 2000), and an investigation of the wind from the same system using ISO (Ogley, Bell–Burnell & Fender 2001).

**Fig. 3.** The relation between jet formation and X-ray state for the two extremes, the ‘hard’ and ‘soft’ states. In the low hard state the jet may be a major output channel for the accretion power.

From a comparison between 101 overlapping Ryle telescope radio and Rossi X-Ray Timing Explorer (RXTE) X-ray observations, Klein-Wolt et al. found an intimate correlation between spectrally hard X-ray dips and the radio emission in the black hole candidate GRS 1915+105. The dips found in the X-ray light curves are intervals during which the source is spectrally harder, as
The radio emission is produced by synchrotron-emitting relativistic electrons which are ejected from the system during the spectrally low hard state. During the spectrally soft states the ejection of material from the system, and hence the radio emission is strongly suppressed. From the observed characteristics of the correlation we were able to construct a simple scenario which explains the complex radio and related X-ray behaviour of GRS 1915+105: the same type of emission-mechanism seems to be working on different scales. The central result of this big project is the establishment of a one-to-one correlation between the hard X-ray and the radio emission. This is an important result, which implies that there exists a clear relation between the inflow of material through an accretion disc close to the black hole, and a synchrotron-emitting outflow or jet. Our finding that there is a fundamental difference in the intensity of the radio emission dependent on the duration of the dips provides further clues to the acceleration mechanism for the relativistic electrons (Klein-Wolt, Fender, van der Klis et al. 2001, submitted to MNRAS).

The black hole candidate LMC X-3 in the Large Magellanic Cloud was for the first time directly observed in the black hole low hard state (Homan et al. 2000, Boyd et al. 2000). This was a surprise, as the source, like its cousin LMC X-1 was thought to be permanently in the high soft state. A study of archival data then showed that the long term behavior of the source is in fact caused by transitions between these two states. For all low hard state properties measured - X-ray spectral index, quasi-periodic oscillation frequency, band limited noise, and luminosity - LMC X-3 falls in the range observed for Galactic black hole candidates, indicating that the dominant mechanism responsible for the low hard state and the state transitions is independent of system parameters like compact object mass, inclination, and initial chemical composition.

### 3.1.2.3. X-ray emitting neutron stars with a low magnetic field

**a. Kilohertz quasi-periodic oscillations**

Investigations continued into the kiloHertz quasi-periodic oscillations (kHz QPOs) in the X-ray flux from low-magnetic field neutron stars accreting matter from a companion in a binary star system. These rapid QPOs, discovered with NASA's Rossi X-ray Timing Explorer (RXTE), can reach frequencies of ~ 1350 Hz, making them some of the fastest signals reaching us from outside the Solar system. They are likely produced within a few kilometers of the surface of the accreting neutron star, where the dynamical timescale is of order 1 msec. The oscillations provide a way to gauge the mass and radius of the neutron star, study the accretion flow, and observe for the first time the predicted effects of general relativity in the strong-field regime, such as the existence of a region near the compact star within which, in qualitative departure from Newtonian physics, no stable orbits are possible. Five years after its discovery, with a review article now dedicated to them in the 2000 issue of the Annual Reviews of Astronomy and Astrophysics (van der Klis 2000), the phenomenon can be said to have entered the canon of high-energy astrophysics. The precise mechanism producing the oscillations, their relation to slower QPOs, and the question whether similar signals can be observed from accreting black-holes remain issues that are the subject of vigorous debate.

Until last year, these QPOs were thought to occur in doublets, two QPOs separated in frequency by several 100 Hz were usually seen (although one was sometimes too weak to detect). Theoretical expectations were that more QPOs should exist in the kHz range, but despite intensive searches none were found.
In 2000, Jonker et al. (2000) finally discovered a third kHz QPO in the power spectra of three different sources. The result was obtained by gathering very large amounts of data using the shift-and-add technique pioneered in Amsterdam by Méndez. This new kHz QPO is present simultaneously with the previously-known kHz QPO pair. The new kHz QPO is found at a frequency 50 to 60 Hz above that of the lower kHz QPO in the neutron star low-mass X-ray binaries 4U 1608-52, 4U 1728-34, and 4U 1636-53, respectively. In 4U 1636-53 we were just able to detect a weak fourth kHz QPO, at the same frequency separation below the lower kHz QPO. These new QPOs are now generally referred to as sidebands.

This discovery caused a brief flurry of activity on the part of the theorists (the Lamb and Stella teams, as well Psaltis) as well as some press coverage. The central mystery in explaining the sidebands within the framework of existing theories is that its frequency separation from the kHz QPO is not, as was expected before Jonker's discovery, commensurate with one of the known QPOs at lower frequency. Magnetospheric modulation of the lower kHz QPO as well as a frequency beat taking place inside the marginally stable orbit (Jonker et al. 2000) are conceivable explanations for the phenomenon. Psaltis (2000) proposes an explanation in terms of the so called transition layer model (Psaltis & Norman 2000). Another intriguing possible explanation for the sideband involves Lense-Thirring precession (Stella private comm.). If this is the explanation, the sideband would constitute the first direct detection of a strong-field general relativistic effect. However, the Lense-Thirring precession frequency is maximally ~ 30 Hz (the precise upper value depends on the detailed physical mechanisms at work close to the neutron star and involves the neutron star spin and mass). Since the frequency separation between the lower kHz and the
sideband is ~ 50-60 Hz this can only be explained if a two-fold symmetry allows the phenomenon to manifest itself at twice the fundamental precession frequency. Irrespective of which explanation turns out to be the correct one, this new feature will provide insight in the nature of the flow in the strong-gravity region around neutron stars. (Jonker, Méndez and van der Klis 2000)

Another exciting result was the discovery by Yu, who demonstrated using a novel analysis technique specially designed for the purpose that in Scorpius X-1 (the brightest celestial X-ray source barring the Sun), the frequency and the strength of the kiloHertz QPOs depends on variations in the X-ray flux caused by QPO that is going on simultaneously at the (much lower) frequency of 6 Hz. The kHz QPO frequencies go up when the flux drops and vice versa, opposite to the usual situation and in accordance with theoretical predictions which describe the effect of the X-ray radiation field on the orbiting of matter in the accretion disk (Miller, Lamb, & Psaltis 1998). However, the interpretation of this result is complicated by the fact that this unusual inverse dependence of frequency on flux sometimes also occurs in Sco X-1 in response to other variations in X-ray flux than those at 6 Hz, and research into this issue continues. (Yu, van der Klis and Jonker 2000).

A ~ 700 Hz quasi-periodic oscillation (QPO) was found in the low-mass X-ray binary (LMXB) EXO 0748-676, with properties comparable to those found in similar sources. Because EXO 0748-67 is seen at high inclination (~ 80°), the detection of a kHz QPO shows that the radiation involved in the QPO mechanism must be relatively isotropic, thereby constraining the models for these high frequency QPOs. (Homan and van der Klis 2000).

The timing properties of the atoll source 4U 1728-34 as a function of its position in the X-ray color-color diagram were studied using all available archival data from the RXTE satellite. The results of this analysis confirm the wealth and complexity of the time variability of this source, that can be considered as a prototype of the 'atoll' class of X-ray binaries containing a low-magnetic-field neutron star. The power spectrum of 4U 1728-34 shows several features such as a band-limited noise component present up to a few tens of Hz, a low frequency quasi-periodic oscillation at frequencies between 20 and 40 Hz, a peaked noise component around 100 Hz, one or two quasi-periodic oscillations at kHz frequencies and a very low frequency noise component below ~ 1 Hz. We find that the kHz QPOs are clearly correlated with inferred mass accretion rate, their frequencies increasing when the accretion goes up. The correlations with the other features are rather complex, but by introducing the novel concept of QPOs that enormously change their coherence and can turn into what is usually called 'noise', we were able to demonstrate that the frequencies of all but one feature increase with accretion as well. The one exception, a feature near 100 Hz, is very interesting. It may provide the first link of the neutron star phenomena to several similar QPOs observed in black hole binaries. (Di Salvo, Mendez, van der Klis, Ford, Robba, 2001)

An altogether different type of X-ray oscillations in the several 100 Hz range are those occurring in X-ray bursts. Such 'Type I' X-ray bursts are thermonuclear explosions of accreted matter on the surface of a neutron star with a weak magnetic field. After the launch of the Rossi X-ray Timing Explorer (RXTE), such burst oscillations were discovered in bursts of several neutron stars. The frequency of such an oscillation usually increases by 1-3 Hz to an asymptotic value which is interpreted as the spin frequency of the neutron star. Not all bursts show these oscillations and there is still little understanding of just what determines whether a burst oscillates.
Van Straaten et al. produced an atlas of 21 type I X-ray bursts of the low mass X-ray binary 4U 1728-34. They used spectral fits to analyze the spectral evolution during the bursts and time overlapping dynamical power spectra to study the properties of the ~363 Hz burst oscillations. Ten of the 21 bursts showed radius expansion phases and 15 bursts showed oscillations. Correlations were found between several burst properties and the presence of burst oscillations, as well as with inferred mass accretion rate. Surprisingly, the results with respect to the burst properties were completely different from those obtained in the only similar study until now by Muno et al. (2000) for the source KS 1731-260. (van Straaten, van der Klis, Kuulkers, Méndez 2001)

b. X-ray spectral, optical and infrared studies

The analysis of the broad band (0.1-200 keV) spectrum of the Z source GX 17+2 from a 200 kilosecond observation with the Italian-Dutch BeppoSAX satellite led to the discovery of a variable hard X-ray component in this source. At low inferred mass accretion rate, the tail dominates the spectrum at energies above ~30 keV. It could be fit by a power law of photon index ~2.7, contributing ~8% of the source flux. This component was observed to vary systematically with inferred accretion rate: it gradually faded as the accretion rate increased until it was no longer detectable. This hard component seems to be similar to the power-law tails observed in accreting black holes in the soft high or very high state. This would argue against models based on the presence of an event horizon. The fact that both the flux of this hard component and the radio flux (which is probably due to the presence of jets) are anti-correlated with the mass accretion rate suggests that high velocity electrons of the jet can also be responsible.
for the hard X-ray emission. (Di Salvo, Stella, Robba, van der Klis, Burderi, Israel, Homan, Campana, Frontera, Parmar, 2000).

O'Brien, using rapid optical spectroscopy from Keck II simultaneous with pointed RXTE observations, is investigating the correlated variability on timescale from seconds to days. The Keck observations were taken in 1998, using the Low Resolution Imaging Spectrograph, together with a novel data acquisition system which allowed us to record an optical spectrum covering 3800-9000 A (2.5 A/pix) every 70 milliseconds. While the data reduction and analysis of this vast dataset (more than 1.2 million optical spectra over the 5 nights) are still ongoing, the information contained within this unique dataset will allow us to study the importance of irradiation in LMXBs on short timescales, previously only accessible photometrically. The simultaneous X-ray observations of the Z-sources Cygnus X-2 and Scorpius X-1 allow us to study spectral and timing phenomena in both wavelength regimes. We have so far found significant short-term correlations between the X-ray and optical variability in Cygnus X-2, which are dependent on the position on the Z-diagram. Such correlations together with the spectral information will allow us to use the indirect imaging technique of echo-tomography. This method is capable of determining not only the positions of the reprocessing sites, on micro-arcsecond spatial scales, but also their physical state (density, temperature).

Jonker et al. identified the probable infrared counterpart of the bright galactic X-ray source GX 5-1. They obtained infrared observations with the 3.8 m UKIRT telescope of the field of this bright X-ray source. and using very accurate astrometry were able to tie the IR image to an accurate radio position and perform the identification. Narrow-band photometry suggests excess Brγ emission in the counterpart, supporting its association with an accretion-disc source. (Jonker, Fender, Hambley and van der Klis 2000).

3.1.2.4. Radio pulsars

Long term timing of radio pulsars continued, and a further long term project was began which aims to find and study Extreme Scattering Events in the direction of pulsars. The timing program, which by its nature is a long-term effort, reached adolescence in the past year and is already beginning to show promise. This program is concentrating on measuring improved astrometric and binary parameters for several millisecond pulsars and monitoring a number of long-period pulsars for glitches and changes in their dispersion measure.

A number of milestones were achieved during the year and these included reaching sub 500 nanosecond timing accuracy for the fastest millisecond pulsar known, PSR B1937+21, confirming that WSRT and the pulsar machine (PuMa) are capable of world class pulsar timing. Another important step on the road to quality pulsar timing is absolute timing, determining how well our results can be tied in with those from other observatories. Our timing ephemeris was used to analyse X-ray data from the Chandra satellite of the millisecond pulsar PSR J0218+4232 and not only was our absolute timing accuracy proven, our results were only slightly worse than a timing ephemeris based on a time span 4 times as long.

The second long term program is in the early stages but the results are promising. The so-called Extreme Scattering Events are thought to be caused by AU-sized radio-wave 'lenses" and one way of studying them is by monitoring the pulsar spectra. These events manifest themselves as intense brightening of the observed flux density from pulsars which has a certain narrow-band structure in frequency and is also periodic in time. We are therefore using the extremely high frequency resolution capabilities of PuMa to search for events. Upon discovering an event in progress we trigger intensive monitoring. By studying the evolution of image magnifications and delays, we
will arrive at strong constraints on lens models. At present we have one candidate event for which we have carried out follow up observations and analysis is continuing.

Stappers continued his work on studying pulsar wind nebulae (PWNe) and using them to constrain the nature of the pulsars themselves and also their environments. We presented the results of our survey of 27 pulsars for radio emission from pulsar powered nebulae. This survey using the Very Large Array and Australia Telescope Compact Array was more sensitive over a wider range of possible nebula sizes than any previous survey. Only one new PWN was discovered however our limits on the presence of such nebulae were so strong that we were able to show that the young pulsars in our sample are all located in the low-density regions of the interstellar medium. While for the older pulsars in the sample we showed that the radio luminosity of their relativistic winds is less than $10^{-5}$ of their spin-down luminosity, implying an efficiency at least an order of magnitude smaller than that seen for young pulsars (Gaensler, Stappers et al., MNRAS, 2000, 318, 58). Using limits on the radio emission from the neutron star thought to be at the centre of the Puppis A supernova remnant we showed that it was unlikely that the claim that pulsations had been detected in the X-rays leading to the suggestion that the remnant contained an energetic, young X-ray pulsar (Gaensler, Bock & Stappers, ApJL 2000, 537, 35). This was later confirmed with further X-ray studies.

Jouteux derived a detailed mathematical analysis of the Fourier response of binary pulsar signals whose frequencies are modulated by circular orbital motion. The power spectrum of such signals is found to be $\nu_{\text{orb}}$-periodic over a compact frequency range, where $\nu_{\text{orb}}$ denotes orbital frequency. This insight (due to Ransom) forms the basis for a Partial Coherence Recovery Technique (PCRT) for searching for binary millisecond X-ray and radio pulsars. In order to evaluate the sensitivity of this technique we considered a wide range of simulated binary systems with circular orbits and short orbital periods, and used numerical simulations to investigate the detectability of pulsars in such systems with $P_{\text{orb}} \leq 6$ hours, using the PCRT and three other, widely used, pulsar search methods. These simulations demonstrate that the Partial Coherence Recovery Technique is on average always more, and up to 10 times more, sensitive to pulsars in close binary systems when the data span is more than 2 orbital periods. The systems one may find using such a method can be used to improve the constraints on the coalescence rate of compact objects and they also represent those systems most likely to be detected with gravitational wave detectors such as the Laser Interferometer Space Antenna. (Jouteux, Stappers, Ramachandran, van der Klis et al., submitted).

We also undertook a program of studying pulsars at very high time resolution. As part of this work Jouteux investigated PuMa observations of PSR 0950+08 (Stappers and Ramachandran) at 3.2 microseconds resolution using a continuous wavelet analysis for studying microstructure. The first results show pulse phase longitude resolved structures. Further dual frequency observations with PuMa recording polarisation information should provide a framework for further investigation of any organized radio emission.

### 3.1.3 X-ray Spectroscopy with CHANDRA and XMM-Newton-derivation of basic atomic parameters

This work by A. Raassen focusses on the analysis of the X-Ray spectra obtained with the recently launched X-Ray observatories CHANDRA (NASA) and XMM-Newton (ESA). This scientific work is done in collaboration with the Space Research Organization of the Netherlands (SRON) in Utrecht, which organization has built spectroscopic equipment for both satellites. Since the launches of the two satellites a very large body of excellent data is obtained from a variety of sources. CHANDRA finished the calibration phase at the end of 1999, while XMM-Newton
opened the windows beginning 2000, starting with the calibration phase, testing wavelengths, background, detector efficiency, the SAS-software package. The emphasis of the work, in collaboration with SRON, is on the spectral analysis of the line rich coronae of relatively cool solar like stars. It concerns thusfar the spectra of Capella (CHANDRA and XMM-newton), Procyon (CHANDRA and XMM-Newton), Alpha Centauri (CHANDRA) and YZ CMi (XMM-Newton). For the spectra of these sources the lines have been measured individually, to obtain the individual line fluxes. The He-like resonance-, intercombination- and forbidden-lines of C V, N VI, O VII, Ne IX, Mg XI and Si XIII serve as tool for temperature and density diagnostics in the low wavelength region (lambda < 45 Angstrom (E > .25 keV)). In the wavelength range of the LETGS, above 40 Angstrom, highly ionized Fe-lines appear in the hotter coronal plasma and also provide the determination of densities, especially for flaring regions with higher densities, while for the cooler plasmas moderately ionized Ne, Mg, Si, and Fe lines appear.

A second method applied to these spectra is the global fitting of the temperature and emission measure to the spectrum as a whole. For this purpose SPEX90, developed at SRON, was used in combination with the MEKAL-code. Fig 5 shows the application of this method to the spectrum of Procyon obtained with LETGS in the region that overlaps the RGS1 and RGS2 wavelength range of XMM-Newton between 2 and 35 Angstrom.

![Procyon LETGS](image)

Fig.6

The 3-temperature model (red) describes the spectrum (black) very well. The efforts over the last year have resulted thusfar in publications on the analysis of the XMM-spectrum of Capella in the special XMM issue of A&A (Audard et al), of the LETGS-spectrum in the low-wavelength region of Capella and Procyon (Ness et al.) and of the total LETGS-spectrum of Capella (Mewe et al.). A publication on a combination of XMM-spectra and LETGS-spectra of Procyon is in preparation. Conference contributions on the LETGS-spectrum of Alpha Centauri have been presented (see list of conference presentations).

### 3.1.4 THEORETICAL STUDIES
Stellar Structure and Evolution

Introduction
The stellar structure and evolution group focusses its research on the evolution of binary systems, mostly with one or two compact components (white dwarf, neutronstar or black hole). The research is aimed at understanding the evolution of (i) Cataclysmic Variables (Novae, Dwarf Novae) and Supersoft X-ray Sources, which are systems consisting of a normal star and a white dwarf., (ii) X-ray binaries, which consist of a normal star and a neutron star or a black hole, and (iii) binaries that consist of two compact objects: binary radio pulsars (two neutron stars or a neutron star plus a white dwarf), double white dwarfs and binaries consisting of a black hole plus a compact object.
The last-mentioned groups of close binaries are prime sources of gravitational radiation in the universe, and the study of their rates of formation and evolution is of great importance for the prediction of gravitational wave signals expected to be observed with gravitational wave observatories such as LIGO (USA) and VIRGO (Europe).
The stellar structure and evolution group consisted this year of permanent staff members G.J. Savonije and E.P.J. van den Heuvel, together with EC-postdoc T. Tauris (Marie Curie Fellow) and graduate students M. Witte, G. Nelemans and Jasinta Dewi (Institut Teknologi Bandung, Indonesia who joined the group in March 1999. Guest researchers this year were Dr. L. Yungelson (Russian Academy of Sciences, Moscow), Prof. E. Ergma (University of Tartu, Estonia), Prof.Dr. G. Srinivasan (Raman Research Institute, Bangalore, India).

Summary of research topics and results

Evolution of stellar populations with a high fraction of close binaries
G. Nelemans, together with S. Portegies Zwart (MIT), F. Verbunt (Utrecht) and Dr. L. Yungelson continued the construction of a computer code for calculating the evolution of close binary systems of all kinds of masses, mass ratios and initial orbital separations. The aim of this work is: to calculate the evolution of a representative stellar population (such as a globular star cluster) that is born with a realistic fraction of interacting binary systems.
The ultimate goal of this work is twofold:
1. To calculate, without including effects of stellar dynamics, the formation rates of all types of close double-degenerate binaries in a real stellar population (i.e.: of double white dwarfs, double neutron stars, double black holes and all other kinds of combinations of double degenerates) in order to predict the expected rates in galaxies of bursts of gravitational radiation produced by the coalescence of double degenerate binaries.
2. To have a completely versatile binary evolution code to be coupled to the stellar dynamics code that is being developed by the Institute for computer Science (prof. Sloot, dr Hoekstra, dr van Albada) for the GRAPE computer.

In 1997 Mr. Nelemans was appointed on a position from the “Faculty graduate student pool” for carrying out both parts (1) and (2) of this project. However, this turned out a too ambitious goal, and it was decided that he concentrates on part (1), while for part (2) a second graduate student, Mr. Spinato, was appointed, in the Institute for Computer Science. Half of this position is financed by the Astronomical Institute (Spinoza-grant), the other half by the Institute of Computer Science. In order to test the code developed in part (1) Nelemans, Yungelson and Verbunt calculated for different input assumptions the predicted mass ratios and orbital separations of double helium white dwarfs, and compared these with the distributions for observed systems. This proved to provide a very sensitive test for the input assumptions to be used for critical types of binary evolution, such as common-envelope evolution.
The results on double white dwarfs were summarized in a series of papers by Nelemans, Verbunt, Yungelson and Portegies Zwart, which partly were published and partly submitted for publication in Astronomy and Astrophysics. Nelemans, Portegies Zwart and Verbunt also calculated with the code the background of relatively low-frequency gravitational waves (~ 3m Hz) expected to be produced by the population of double white dwarfs in the galaxy. The results were published by Nelemans at the Moriond Conference (France) proceedings.

**Evolution of X-ray binaries and formation of binary radio pulsars**

- Nelemans, Tauris and Van den Heuvel continued their study of the observed excess space velocities of the black-hole X-ray binaries and derived from this that in the formation process of the black holes in the systems of Cygnus X-1 and Nova Sco 1994 more than 3 solar masses must have been explosively ejected. A paper summarizing these results was published in Astronomy and Astrophysics.

- Savonije, Jasinta Dewi and E. van den Heuvel are studying the evolution of close binaries consisting of a helium star and a neutron star, with the aim to obtain a better understanding of how double neutron star binaries may have formed. These systems are the remnants, after common-envelope evolution, of B-emission X-ray binaries. Dewi and Tauris calculated models for the binding energy of the envelopes of stars in various evolutionary phases, in order to be able to calculate the outcome (orbital period, etc) of B-e X-ray binaries after common-envelope evolution.

- Tauris, Van den Heuvel and Savonije conceived a new model for the origin of binary and millisecond radio pulsars with heavy white dwarf companions. In this model, which in a natural way explains the observed concentration of the orbital periods of most of these systems in the range 1 to 2 weeks, the progenitor of the white dwarf was an intermediate-mass star (2.0 to 6.0 solar masses), in a relatively close initial orbit with a neutron star (orbit period: a few days). They showed that such systems avoid common-envelope evolution and evolve with heavy loss of mass and angular momentum without considerably changing their orbital periods. These results were published by the Astrophysical Journal Letters.

- Van den Heuvel reviewed the present status of our understanding of the Formation and Evolution of neutron stars and black holes in binary systems, for the book “A Centruy of Space Science”, which gives an overview of the achievements of Space Science in the past 50 years.

**Tidal Evolution of binaries**

Savonije and Witte continued their study of the tidal evolution of massive close binary systems. In earlier work (Witte and Savonije 1999a,b) they discovered the importance of resonance locking in binary systems consisting of a compact star orbiting an early type main-sequence companion in an eccentric orbit. Commonly the resonant tidal excitation of non-radial oscillation modes in the normal companion is ignored and only the off-resonant tidal response is taken into account.

The argument being the very small chance of hitting a normal mode resonance and, if it occurs, the enhanced tidal interaction during the crossing of a (narrow) resonance is thought to yield only a small effect on the orbital evolution. However, this analysis is based on fixed oscillation spectra and non-rotating stars. In reality the frequency spectrum of normal modes shifts due to stellar evolution in the normal star, while in orbits with significant eccentricity the tidal forcing consists of many orbital harmonics which can all excite normal modes. Apart from the existence of additional, rotationally controlled oscillation modes in rotating stars, rotation also introduces the possibility of exciting both prograde (propagating in direction of stellar rotation) and retrograde (counter to rotation) oscillation modes. Dissipation (e.g. radiative damping) of the former modes leads to stellar spin-up, while excitation and damping of the retrograde modes will spin the
normal star down. It turns out that very often one or more of the retrograde orbital harmonics
drive a prograde harmonic into resonance, or vice versa. In that case the orbital harmonic which is
driven into resonance does not rapidly cross it but becomes locked due to the counteracting effect
of the prograde and retrograde modes, yielding very efficient tidal evolution of the binary system
over relatively long time spans. This increases the speed of orbital evolution significantly. In a
new study (Witte and Savonije 2001) the compact companion was replaced by another early type
main-sequence star of comparable mass. It turned out that the extra tidal dissipation, now in both
stars simultaneously, of excited normal modes gives rise to even more chance of establishing
resonance locking.
For initial orbits with eccentricity \( e=0.5 \) and an orbital period of 10 days locking occurred in at
least one star typically during 60\% of the time, so that most of the time the system was locked at
resonance. This lead to a decay of the eccentricity from 0.5 to about 0.2 in only about 2 million
years, much faster than without locking effects. The conclusion is that, due to resonance locking,
resonant excitation of normal modes is likely to play a significant role in tidal evolution of
massive binaries.

Evolution of the High Mass X-ray Binaries

Observations obtained with the Hipparcos satellite have shown that high-mass X-ray binaries
hosting an OB supergiant have relatively large runaway velocities (~40 km/s) in comparison with
the Be/X-ray binaries (~15 km/s). Van den Heuvel, Kaper, Bhattacharya and Portegies Zwart
demonstrate that this difference in kinematic properties is a consequence of the formation process
of these two types of systems. The difference in runaway velocity basically results from the
variation of fractional helium core mass with stellar mass, in combination with the conservation
of orbital angular momentum during the phase of mass transfer preceding the formation of the
compact object in the system. Consequently, the more massive OB-supergiant systems have
narrower pre-supernova orbits, and eject relatively more mass during the supernova than the
systems hosting a Be star. This result was published in Astronomy and Astrophysics.

3.2 LOW-ENERGY ASTROPHYSICS

In the year 2000, research focused on the most massive stars in galaxies, the formation of stars
and planetary systems, and on the death struggle of solar type stars, the red giant and asymptotic
giant phase and beyond. In almost all of these studies, observations taken with the Infrared Space
Observatory (ISO) feature prominently. Follow-up observational studies have started using
ground-based telescopes.

3.2.1 The most massive stars in galaxies

Massive stars have been the focus of several studies, investigating the photospheric and wind
properties of these most luminous stars, as well as their immediate surroundings. The evolution of
stars initially more massive than about 50 solar masses can be characterized by three phases: an
initial, relatively quiet (O- and B-type) phase – accounting for about 90 percent of the total
lifetime –, an excessive mass loosing (LBV) phase – lasting about \( 10^5 \) yr –, and a naked core
(Wolf-Rayet) phase – lasting several \( 10^5 \) yr during which the star ends its life in a supernova
explosion. All three phases have been studied.
3.2.1.1 The winds of OB stars

Predictions of the mass-loss rates of O- and B-type stars have been made, using non-LTE line-blanketed model atmospheres together with Monte Carlo simulations of the hydrodynamics of their stellar winds. These calculations allow for a detailed treatment of the many absorption and scattering events that individual photons experience on their way out of the stellar photosphere and wind. Our results show that the inclusion of the effects of multiple scatterings of light particles by spectral lines above the stellar photosphere resolves the long standing problem of the discrepancy between observed and theoretical mass-loss rates. (Vink, de Koter, Lamers).

3.2.1.2 Luminous Blue Variables and related objects

The hot luminous blue variable star AG Carinae and LBV candidate Wra 751 have been studied focussing on dust present in their circumstellar nebula that have formed from material expelled from the stellar surface at some point in their evolution. Interestingly, the derived properties of this dust (solid state composition, and to some extend particle size) as well as the nebular morphology appear very similar to that seen in dust shells surrounding cool red supergiant stars. These RSGs originate from stars initially less massive than 50 solar masses. However, current theories of massive star evolution do not predict such a phase in the evolution of stars more massive than 50 solar masses, as are AG Car and Wra 751. Either LBVs mimic RSG when they expell the mass that will form the nebula, or, alternatively, we need to revise our ideas concerning the evolution of the most massive stars. (Voors, Waters, de Koter, Bouwman, Morris, Barlow, Sylvester, Trams, Lamers).

![Fig.7: Dust fit to the spectrum of the very massive Luminous Blue Variable candidate Wra 751. The large bump in the infrared part of the spectrum is due to thermal emission from dust grains that have formed in material expelled by the central star at some point in its evolution. The derived properties of this dust appear very similar to that seen in shells surrounding less massive red supergiant stars, suggesting Wra 751 may have experienced a cool supergiant phase contrary to what is predicted by current theories of very massive star evolution. (from Voors et al. 2000 A&A 356, 501).]
The Wolf-Rayet star in the \( \gamma \) Velorum binary system has been investigated in detail. In previous studies it was found that the momentum contained in the ions flowing out in a stellar wind, measured in units of the momentum contained in the stellar radiation, exceeds a factor of a hundred. This cannot be explained in terms of any known wind driving mechanism. We have shown that this problem is a result of the neglect of millions of relatively weak spectral lines on the wind-ionization structure of the Wolf-Rayet star. Specifically, one needs to include weak lines that interact with strong resonance lines of helium, as helium controls the ionization stratification of all elements. Including these effects alleviates the wind momentum problem, such that this wind can be driven by the known mechanism of radiation pressure exerted on spectral lines. (De Marco, Schmutz, Crowther, Hillier, Dessart, de Koter, Schweickhardt)

3.2.1.3 Spectroscopy of massive stars in the making

The birth of massive stars occurs in optically obscured star formation regions. Very little is known about the processes that govern their build up and early evolution. A very promising approach to study these objects is by infrared spectroscopy, as at these wavelengths the extinction of dust present at these star forming sites is less severe. Our studies in this direction have first focussed on obtaining IR spectra of well known optically visible massive early-type stars, and aim at identifying and calibrating IR diagnostics sensitive for, notably, the spatial distribution of gas (spherical, disk) and gas temperature, density, and rate of outflow.

Using the near-infrared instrument ISAAC on ESO's Very Large Telescope, Kaper and Bik obtained high-quality K-band spectra of young massive stars deeply embedded in ultra-compact H II regions. At optical wavelengths these newly-born massive stars are highly obscured (extinction 10 – 100 visual magnitudes), but in the K band their photospheres can be detected. The K-band spectra are used to perform a detailed spectral classification, to study the circumstellar envelope (stellar wind, disk?), to search for evidence of binarity, and to measure their rotation rates. Bik spent one month at the University of Cincinnati to work with Prof. M.M. Hanson, one of our collaborators on this project. The ultimate goal of this study is to increase our currently very limited understanding of the formation process of massive stars. A first overview of spectra of massive early-type stars obtained in the ISO post-helium mission was presented, as well as an overview of ISO Be stars spectra, showing a large diversity of line shapes and strengths, indicating that line formation is indeed sensitive to gas properties and distribution. (Lenorzer, Vandenbussche, de Koter, Kaper, Waters, Morris, Trams, Hony, Zaal, Marlborough, Millar).

The hydrogen lines in the infrared spectrum of the Be star \( \gamma \) Cassiopeiae were investigated. Their line strengths and widths suggest that many are optically thick and originate from an inner, high density disk region. Only the \( \alpha \), \( \beta \), and \( \gamma \) members of hydrogen line series contain contributions from the outer regions of the disk. The inner disk may be rotating more rapidly than the stellar photosphere. (Hony, Waters, Zaal, de Koter, Marlborough, Millar, Trams, Morris, de Graauw). The ISO spectra of 16 dwarf and (sub)giant late-O and early-B stars were compared with predictions using non-LTE blanketed model atmospheres. Good agreement was found when a gradient in the turbulent velocity in the stellar atmosphere was used. For these type of stars, the \( \text{Br}\alpha \) and \( \text{Pf}\alpha \) lines allow for a fairly accurate determination of the surface temperature. (de Koter, Zaal, Waters, Lenorzer).

3.2.1.4 Studies of wind variability, pulsations and magnetic fields in hot stars.

The search for the unknown cause of widely observed cyclical wind variability in O stars continued. A very laborious work was completed by de Jong, Henrichs, Kaper, Nichols, Morrison, Scheers, Telteng and may others, resulting in the submission of a paper to Astronomy and Astrophysics entitled: “Simultaneous UV and optical observations including magnetic field
measurements of the O7.5III star ξ Persei", which was part of the thesis work by de Jong (defended February 2000). This concluded the most extensive international campaign on O stars ever organized, held in 1994, which comprised 10 days of nearly continuous UV spectroscopy with the IUE satellite, with groundbased support from 9 observatories around the globe, most of which being 2m class telescopes, but also spectroscopy with the 1m JKT telescope on La Palma played an essential role. A very accurate value for the rotation period of the star was determined to be 2.086(2) day, which was present both in Hα (formed very near the star) and in the UV lines (formed at many stellar radii above the surface). This showed unambiguously the presence of large corotating regions in the stellar wind, which we observe modulated by the stellar rotation. This star is considered to be representatitive for all early-type stars. A new element of this campaign was the attempt to measure the magnetic field of an O star simultaneously with the wind variability, in order to search for possible correlations. Since these magnetic fields are expected to be very weak, in spite of their significant impact on the stellar wind, the 4 meter CFHT telescope was used to study the field of this 4th magnitude star, one of the brightest O stars on the Northern hemisphere. Even this large effort was not succesful to pin down the magnetic field, showing the extreme difficulty to measure such fields with present day instrumentation, giving 70 G error bars, the sofar best obtained value for an O-type star.

The previously found non-radial pulsation period of 3.5 h in ξ Persei (de Jong et al. 1999) was retrieved in the data of this campaign, which confirmed the status of non-radial pulsator for this O star. To date only 8 other O stars are demonstrated to undergo non-radial pulsations, whereas most, if not all, O stars are expected to share this behavior.

A new effort was attempted to detect magnetic fields in B stars with the Musicos Polarimeter attached to the 2 m telescope at the Pic du Midi in France (Henrichs, Neiner, Tijani). The weather conditions were avarage, so that only stars brighter than 4th magnitude could be measured with sufficient precision. The 100 G field discovered a year earlier by Henrichs and de Jong in the B star β Cephei (a pulsating β Cephei variable) was confirmed, and hints for the presence of a weak field in the early B stars V2052 Oph (also a pulsating β Cephei variable) were found. From earlier data obtained with the IUE satellite and unambiguous very accurate rotation period could be derived for this star as 3.6403 d. These measurements are meant to be followed up in the coming years.
Fig. 8: Five nightly averages of magnetic field measurements of the B stars V2052 Ophiuchi, phased with cyclical stellar wind behavior, as observed with the IUE satellite. The correlation is weak, but sufficiently promising to continue these observations.

3.2.2 Star formation and Vega type stars

3.2.2.1 Proto-planetary disks around Herbig Ae/Be stars

Star formation studies concentrated on the pre-main-sequence evolution of intermediate mass stars, the Herbig Ae/Be stars (HAEBEs); these objects have large amounts of circumstellar gas and dust, probably in a disk-like geometry, left over from the star formation process. There is growing evidence that these disks are the site of on-going planet formation.

2-200 µm spectra of HAEBE stars taken with the Infrared Space Observatory (ISO) have been analysed in order to derive quantitative information about the composition of the dust in these systems. Studies focussed on two of the best known stars, AB Aur and HD~163296; these stars have roughly the same age and stellar mass. The dust surrounding these two stars shows
remarkable differences: the silicates in HD 163296 show a higher degree of crystallinity, and also
the average grain size in this star is larger than in AB–Aur. Both the large grains, as well as the
crystalline silicates are not found in interstellar space, they must be produced in the proto-
planetary disk. These changes point to coagulation (in order to produce the large grains), and to
thermal annealing (to produce the crystals) of the dust; however, other processes, such as low-
temperature crystallisation, may also be at work (Bouwman, de Koter, Dominik, Meeus, Waters,
Waelkens).

3.2.2.2 VEGA-like stars

Dominik has continued studies of Vega-like disks. Vega-like disks are the tenuous dust disks
around main sequence stars. They differ from pre-main-sequence disks in the amount of dust, in
the dust properties and in the dust origin. While in pre-main-sequence disks the dust is
primordial or condensed in the disk, the dust in Vega-like disks is derived from collisions
between cometary bodies in the system. This supply only lasts as long as the cometary cloud
itself. Using the ISO observations, we derived a life-time of the Vega-like disks of about
400–Myrs. This lifetime is in remarkable agreement with the duration of the Late Heavy
Bombardment in the solar system as measured by crater counts on the Moon and the Jupiter
satellites Ganymede and Callisto. The derived lifetime of 400–Myrs is mainly based on A stars.
A few late-type stars with disks seem to have larger ages of up to a few Gyrs. However, the age
determinations of these stars are less secure. (Habing, Dominik, Laureijs, Jourdain De Muizon et
al.). In a similar study of nearby G dwarfs, several excess stars were detected, two with dust
masses similar to β Pic (Decin, Dominik, Malfait,
Mayor, Waelkens).

Fig.9: Fraction of stellar radiation absorbed by circumstellar dust grains around nearby main-
sequence stars. The circles are measurements, the crosses upper limits. The leftmost point is
beta Pictoris. After 400 Myrs, only very few stars keep a detectable disk (from Habing, Dominik
3.2.3 Late stages of stellar evolution

3.2.3.1 CO$_2$ in AGB stars

ISO spectroscopy of AGB stars have revealed the presence of $^{12}$CO and $^{13}$CO$_2$ emission and/or absorption bands between 13 µm and 17 µm in many oxygen-rich stars. In a detailed study of EP Aqr, a star with strong emission bands, the physical conditions in the CO$_2$ emitting layers were analysed. Temperatures in the range 350-700 K were found for most of the emission bands, but the 15 µm band also shows evidence for a more extended cool layer, with T ~ 100 K. The CO$_2$ extends from close to the photosphere into the dust forming layers, and is believed to be produced by reactions between CO and OH (near the star) and between CO and O (further away). The model calculations suggest a $^{12}$C/$^{13}$C ratio of order 10 (Cami, Yamamura, de Jong, Tielens, Justtanont, Waters).

3.2.3.2 Dust reservoirs in silicate-carbon stars

Yamamura, Dominik, de Jong, Waters and Molster have studied ISO observations of the silicon carbon star V778 Cyg. Silicate carbon stars are highly evolved AGB stars which show a very complex spectrum in the infrared. While most dust forming stars can be classified as either silicate-forming (oxygen-rich) or carbon-dust forming (carbon-rich) stars, the silicate-carbon stars stand out because they show the signature of both dust classes together in their spectrum. In the short wavelength range, the emission from PAHs are prominent, while in the longer wavelength range the silicate features are present. Studying the ISO spectrum of V778 Cygni we showed that the silicate dust component is stationary. This implies that older theories linking the double nature of the spectra to a very recent switch in the wind chemistry must be ruled out. Instead, a local reservoir for the oxygen-rich dust must exist in these systems which are believed to be binaries. The two logical locations for such a reservoir are a circumstellar disk, and a circum-binary disk. We were able to show that binaries fall into two classes. Close binaries may form a circum-binary disk through common envelope evolution. In wide binaries like (presumably) V778 Cygni, the formation of a circum-binary disk during the oxygen-rich mass-loss phase is not possible. The dust must instead be stored in a disk circling the main-sequence companion of the AGB star. (Yamamura, Dominik, De Jong, Waters, Molster).
3.2.3.3 Dust formation and structure formation in AGB winds

Dominik has worked with Icke and Simis (Leiden) on the hydrodynamics of dust forming winds around AGB stars. In the winds of AGB stars, dust particles are condensing. Their presence has large influences on the thermal and dynamic structure of the wind itself. Using a one-dimensional two-fluid hydrodynamics code, they studied such winds selfconsistently including the chemistry and dust formation. It was shown that the decoupling of dust and gas can in some parts of the parameter space lead to large variations in the mass loss rate of the star, dominated by a time scale given by the sound-crossing time of the subsonic wind region, about 500 years. Far from the star, the high-frequency components of this variations merge into the larger variations. The resulting density contrasts in the outer regions of the wind correspond well to the concentric rings seen in many planetary nebulae (Simis, Dominik, Icke).
3.2.3.4 TiC in proto-planetary nebulae

The end of the Asymptotic Giant Branch (AGB) is marked by a sudden drop in the mass loss rate and a rapid increase in the temperature of the star. The phase between the AGB and the onset of ionisation of the AGB ejecta (the birth of a so-called Planetary Nebula, (PN)), is the proto-planetary nebula (PPN) phase; these stars are surrounded by the AGB remnant which has not yet been ionized because the central star is too cool. A group of PPNe is known for their prominent emission band near 21 µm, and are named “21 micron sources” after this band. The carrier of the band has been a mystery since its discovery in 1989. Laboratory measurements of small TiC nanocrystals using the FELIX experiment in the FOM Rijnhuizen laboratory have revealed an emission band at 20.3 µm which matches well that seen in the “21 micron” sources. The identification of this band with the refractory TiC implies that extreme densities must have prevailed in the dust forming layers of the stars while these were on the AGB, with correspondingly high mass loss rates (~10^{-3} M/yr) (Von Helden, Tielens, Hony, Denizman, Duncan, Waters, Meijer).

![Fig.11: Comparison of the 21 µm band in the post-AGB star HD 56126 observed with ISO, and the laboratory spectrum of nano-clusters of TiC. The structure of the clusters is indicated (from von Helden, Tielens, Hony et al. 2000 Science 288, 313).](image)

3.2.3.5 The planetary nebula NGC 6543

Planetary Nebulae (PNe) provide stunning pictures, revealing the geometry of the AGB remnant as it interacts with the fast wind of the central star. The Cat's Eye Nebula is among the most beautiful examples of PNe. We studied the optical line spectrum of this object, catalogued as NGC 6543, to search for chemical abundance gradients in the nebular gas. For none of the elements investigated could we discern any positional variation, except for helium. In principle,
this provides a record of the mass-loss history of the central star. The nebular age (14000 yr) is derived. Relative to our Sun, the progenitor may have been deficient in heavy elements, except for Ne and Ar (Hyung, Allee, Feibelman, Lee, de Koter).

3.2.3.6 C-rich molecules in astrophysical environments

Polycyclic Aromatic Hydrocarbons (PAHs) are believed to be the carriers of the famous emission bands near 3.3, 6.2, 7.7, 8.6 and 11.3 µm. These bands are ubiquitous in interstellar space, in the ionized regions around young stars, and in the C-rich ejecta of (Proto-) Planetary Nebulae. Spectroscopy with the Short Wavelength Spectrometer (SWS) of the ISO satellite has revealed a new emission plateau between 15 and 20 µm, which can be attributed to C-C-C bending modes of PAH molecules; these bending modes cause in-plane and out-of-plane distortions of the carbon skeleton and are an excellent probe of the structure of the molecule. Most of the 15-20 µm emission is probably due to large PAHs, but the 16.4 µm band is likely associated with smaller molecules (van Kerckhoven, Hony, Peeters, Tielens, Allamandola, Hudgins, Cox, Roelfsema, Voors, Waelsens, Waters, Wesselius).

3.2.4 Theory Work - Dust-driven winds/numerical hydrodynamics

In collaboration with Icke and Dominik, Yvonne Simis (Leiden) continued her Ph.D. research on dust driven winds from evolved late-type stars. The numerical code written for this purpose is a self-consistent hydrodynamics code for two-fluid time dependent calculations in spherical symmetry. Physical processes included in the model are the nucleation, growth, and thermal evaporation of grains; equilibrium gas chemistry; a microscopic model for gas-grain collisions; first-order radiative transfer; and stellar pulsation driven by the photosphere of the star (inner boundary condition). The computations using the stellar parameters of the extreme carbon star IRC+10216, explained the concentric shells that have recently been observed around this object. The time scale of the oscillation that drives these rings is of the order of hundreds of years. Responsible for this effect is a subtle mechanism, involving an intricate nonlinear interplay between gas-grain drift, grain nucleation, radiation pressure, and envelope hydrodynamics. Until now, the origin of these shells - observed also in other post-AGB objects and planetary nebulae - was unknown. The role of grain drift turns out to be essential. In previous calculations by other groups the shells were not found because either grain drift, or a self consistent description of the grain chemistry were not part of the model.

The same hydrocode was adapted by Kamp and Simis to study the problem of the metal-poor λ Bootis stars, in which gas could reaccrete after grains have formed. Simis's detailed two-fluid treatment of dust forming flows is ideally suited to the study of such peculiar stars. Currently, the hydrodynamics code is being adapted to nonspherical configurations, in particular accretion (or excretion) disks. In the near future, we hope to include more detailed radiative transfer, for example by using the methods pioneered by our former group member Dullemond (Munich).

Icke rekindled the flame of bipolar nebulae, inspired by the remarkable observations that Van Winkel (Leuven) made of the Red Rectangle. The inward-curving shocks enclosing the prongs of this X-shaped nebula suggest that the effective adiabatic constant of the gas is close to unity (almost-isothermal flow), due to strong radiative cooling. Simulations of this type of flow produced dramatic results, including the prediction of a Mach-stem feature on the axis of the nebula, which had not been seen before. Subsequent data taken by Van Winckel showed that this feature is indeed present in the light of Hα. When this type of flow is computed for ordinary bipolars, the outer shells become strongly unstable, leading to the formation of series of rings and ripples propagating upwards. This is in excellent agreement with the observations.
3.3 FAINT SKY VARIABILITY SURVEY (FSVS)

3.3.1 Main Objectives of the Survey

The Faint Sky Variability Survey (FSVS) is an international effort (led by the University of Amsterdam, PI: E.P.J. van den Heuvel) to perform the first deep wide-field, multi-colour (BVI), time-sampled CCD photometric and astrometric survey of sources towards moderate and high galactic latitudes. The survey started in 1998 and is expected to be completed in 2001. Using the Wide Field Camera at the Isaac Newton Telescope on La Palma, we observe each of our fields to detect sources as faint as 25th magnitude in V and B and 24.2 in I. The V-band observations consist of an irregular time-series to detect photometrically variable objects on timescales between 12 minutes and 5 days, with a re-visit at one year. To date, we have observed about 16 square degrees of sky containing over 100,000 point sources (including thousands of variables) and over 300,000 extended sources. The FSVS dataset is applicable to a wide range of astrophysical projects including a search for faint cataclysmic variables, identification of very low-mass stars and nearby objects (late M & L stars and brown dwarfs), statistics of eclipsing binaries, cool white dwarfs, trans-Neptunian objects, and RR Lyrae stars. Apart from galactic sources, the FSVS can also be used for extra-galactic projects as well. Two preliminary papers have been submitted and include details of how we will make our data available over the internet.

3.3.2 Summary of Observations to Date

WFC Observations

Since the start of the FSVS in 1998, we have been able to carry out three observing runs: in November 1998, May 1999 and January 2000. The first two runs were very successful: we were able to cycle through 18 fields (each 0.29 sq. degrees) for ’98 and 12 fields for ’99 covering a total of 8.7 square degrees with the time sampling requirements as outlined in our original proposal. Both runs contained photometric nights, allowing us to put the magnitudes on a standard scale.

The January 2000 run was mostly cloudy. Only 5 new fields have been observed with the required time sampling. On two photometric nights BVI observations have been made of twelve new fields and seven fields of the November 98 run have been reobserved to monitor long term variability and obtain accurate astrometric information.

Most of our fields are at intermediate Galactic latitude, near 30 degrees. Several of the November 98 and January 00 fields were also chosen to be close to the ecliptic. This choice was to aid in the detection of trans-neptunian objects (TNO’s). All fields were observed within a zenith distance of 30 degrees. Two of the May 99 fields (field numbers 27 and 31) overlap with Chandra fields. This same strategy will be used for the upcoming run in May 00.

Follow-up Spectroscopy

Follow-up spectroscopy of sources selected from our WFC survey has started at the William Herschel Telescope, the 3.5m APO telescope and the 10m Keck telescope. The WHT data, obtained with the AUTOFIB/WYFFOS spectrograph in December 1999, is the largest set collected so far. Two-hundred forty sources were selected based on their variability and/or red colours. The throughput of the WHT AUTOFIB/WYFFOS imposes a magnitude limit of V~19, allowing only a limited sample of objects to be observed. Analysis of these data is in progress.
APO spectroscopic observations obtained in January of 2000 concentrated on four 'bluer' sources (those lacking an I band and/or a V band measurement) in order to provide a test of candidate selections and a calibration for the colour space in the FSVS dataset. For example, one of the observed sources, FSVS074914.92+204318.0, is a normal mid-G dwarf type star that was missing an I band measurement due to its lack of detection above our I band photometric plate limit. The B-V colour found matches that expected for a G star. However, this otherwise normal star is found to exhibit low level variability in the FSVS.

A proposal is under review for follow-up spectroscopy in the NIR at UKIRT to investigate the reddest colour objects from the FSVS dataset.

Photometric Follow-up

Photometric follow-up of the brighter sample of variables found in the FSVS is being done using the Wyoming 2.3m Opt/IR Telescope and the CfA 1.2m telescope at the Fred Lawrence Whipple Observatory on Mt. Hopkins, Arizona. The Whipple telescope is equipped with a 4-CCD mosaic camera covering 22'x22'. For the variables with V<22, we will use this telescope to obtain better sampled light curves for the short-period variables found in the FSVS. The first of these follow-up runs started May 6, 2000 and covers 9 fields of the May 99 WFC run. The Wyoming telescope will be used to obtain multi-colour photometry for our most interesting blue variables.

Summary of Progress in Reduction, Analysis, and Findings to Date

We have fully reduced, assigned magnitudes to, and produced light curves for all 100,000 point sources from our survey to date. We also have lightcurves for the 300,000 extended sources as well. Objects have been separated into candidate groups by 1) long and short term variability types to investigate the forms and sources of variability seen in the faint sky, 2) colours to calibrate our BVI colour space with better known astrophysical sources such as main sequence type stars, and 3) extreme colour sources (photometry lacking detections in one or two filter measurements) to explore rarer and unknown sources such as very low-mass objects or sources with colours that do not correspond to a known astrophysical object.

Cataclysmic variables and very low-mass object candidates from the FSVS photometry dataset are also being matched to on-line datasets including 2MASS in order to extend the known spectral energy distribution of the sources. However, we find very red candidates that are fainter than what 2MASS can observe indicating the usefulness of the faintness limits of the FSVS in the I band.

See the reference papers listed at the end of this report for more details of the present status (preprints available) and at least three talks on the FSVS results were presented at the "New Era of Wide-Field Astronomy" conference held in August 2000 in Preston, Lancashire, UK.

From the November 98 sample, covering ~5 sq. degrees we have selected 18 prime RR Lyrae candidates. Three of these 18 are at magnitudes between 17 and 20 and the rest have magnitudes V>20. Recently, a first search for RR Lyraes in the Sloan Digital Sky Survey (Ivezic et al., 2000) picked up 60 candidates between 17<V<20 in a 100 sq. degree area. For this magnitude range our numbers agree very well with the SDSS number, which is in accordance with current galactic halo models which predict a cut-off at a distance of d~50 kpc. The SDSS collaboration also reports finding no RR Lyrae candidates fainter than 20th magnitude. This is in stark contrast to the 15 candidates we have selected from our sample. Even if a fair fraction of these turn out to be...
of a different nature, the detection of RR Lyraes at V>20, corresponding to distances d>70 kpc, will change the current ideas of the structure of the Galactic halo. Our candidate sample includes RR Lyraes out to a distance of 150 kpc. The candidates are selected based on colour and variability.

Using the FSVS datasets, the environments of quasars in the context of large scale structure is being studied by I. Machura and R. Clowes at the University of Central Lancashire. The goal of the study is to investigate whether quasars trace the mass (galaxy) distribution, if so how, and determine the galaxy environment that favors the formation of quasars. The FSVS dataset provides a deep and wide-field source to confirm membership of quasars in clusters by photometric redshift, define the periphery of the clusters more precisely with the deep faintness limit at 25 mags and fainter with coadded images, test for quasar formation by galaxy mergers/interactions to the faintness limit, and test for quasar formation by merging clusters out to intermediate redshifts of z <0.9.

Summary of Effort and Resources Attached to the Survey

Most of the FSVS survey work has been carried out by five investigators (Everett, Groot, Huber, Vreeswijk, and Howell) who have dedicated an cumulative effort equivalent to 3-4 man years. The hardware used is standard; reduction and analysis is performed using Unix workstations and raw data is now pipelined to reduced light curves for distribution, allowing others to efficiently apply the results to a wide variety of investigations. Currently the reduced survey images total approximately 70 Gbytes and the data tables are 1.5 Gbytes. The time to fully reduce the data from a week-long observing run is now 2-3 weeks. The aforementioned five investigators, as well as Co-Is (eg., D. Davis [TNO], N. Tanvir [RR Lyr], P. Charles [globulars], R. Clowes [variable QSO's]), have used the FSVS data catalogues for research. Meanwhile, observing at the INT has become efficient requiring only the standard situation of a telescope operator only on the first night of each run.
4. ONDERWIJS (this section is in Dutch language)

4.1. Inleiding

Binnen de opleiding “Natuur- en Sterrenkunde” is Sterrenkunde een aparte doctoraalstudie met twee afdstudeerrichtingen: Algemene Sterrenkunde en Computationele Sterrenkunde. Tussen de 60 en 70 procent van de studie voor het doctoraal examen omvat dezelfde vakken als het basispakket wis- en natuurkunde van de studie natuurkunde. Het Sterrenkundig Instituut verzorgt alle colleges en practica in de sterrenkunde, de begeleiding van de onderzoekstages voor het doctoraal examen sterrenkunde, alsmede de opleiding tot de promotie in de sterrenkunde.

In §4.2 wordt een overzicht gegeven van het volledige sterrenkundige deel van het onderwijspakket voor het doctoraal examen sterrenkunde (colleges verplicht voor computationele sterrenkunde tussen haakjes). §4.3 geeft een overzicht van het aantal doctoraalexamens en promoties in 2000. §4.4 geeft een overzicht van de colleges gegeven in 2000, met de bijbehorende docenten. Een volledig overzicht van de studie voor het doctoraal examen sterrenkunde (inclusief de wis- en natuurkunde vakken) is in de Appendix XI gegeven.

Sterrenkunde is traditioneel een belangrijk bijvak en keuzevak bij de studie natuurkunde en deels ook bij wiskunde. Het grootste deel van de onderwijsinspanningen van het instituut is gelegen in dit bijvak- en keuzevakonderwijs. Deze colleges vallen voornamelijk in de eerste twee studiejaren.

Het college sterrenkunde IA (Van der Klis) en de bijbehorende werkcolleges zijn verplicht voor alle eerstejaars studenten wis-, natuur-, en sterrenkunde. Voor laatstgenoemde studenten is ook het practicum I Sterrenkunde verplicht.

In het tweede jaar – de colleges sterrenkunde IIA en IIB – is de sterrenkunde een belangrijk keuzevak, dat door een groot deel van de natuurkunde studenten wordt gevolgd, evenals het practicum sterrenkunde 2.

De meer gespecialiseerde colleges in het 3e en 4e jaar (doctoraalfase)*, waarin diep op de stof wordt ingegaan worden voornamelijk gevolgd door de hoofdvakstudenten sterrenkunde. Dit betreft relatief kleine aantallen studenten. Een vijftal basiscolleges behoren hier tot de verplichte stof van de hoofdvakstudenten sterrenkunde, de overige colleges zijn capita en keuzecolleges.

Naast de opleiding voor het doctoraal examen is de primaire onderwijsactiviteit van het instituut: de opleiding tot zelfstandig onderzoeker, welke plaatsvindt in het kader van de Toponderzoekschool NOVA.

Het Sterrenkundig Instituut en het Centrum voor Hoge Energie Astrofysica zijn in feite inhoge mate een “graduate school”, met thans een twintigtal promovendi. In het jaar 2000 behaalden een drietal promovendi de doctorsgraad (§4.3).

4.2. Sterrenkundige deel van de opleiding tot het doctoraal examen Sterrenkunde

1e jaar: College Inleiding sterrenkunde/astrofysica IA (1e trimester, met werkcollege en practicum I), verplicht voor alle studenten wis-, natuur- en sterrenkunde, gevolgd door IB (2e trimester), verplicht voor alle studenten natuur- en sterrenkunde.


* Tot heden was de cursusduur van de opleiding Natuur- en Sterrenkunde 4 jaar. Met ingang van 1 september 1999 werd de cursusduur verlengd tot 5 jaar. In de komende jaren zal dit leiden tot een ingrijpende verandering van de studieopzet. Het huidige verslag betreft nog de 4-jarige cursusduur.
**3e en 4e jaar:** 5 verplichte doctoraal colleges (+werkcolleges): Bouw en evolutie van sterren, Steratmosferen, Interstellaire en circumstellaire materie (of Numerieke sterrenkunde), Kosmologie en Hydrodynamica van vloeistoffen en plasma’s.

**Keuzecolleges:** Radioastronomie, Hoge energie astrofysica, Interacademiaal college (wisselt).

**Eigen werk:** II en IV, Waarneemstage, Onderzoekstage

**Colloquium:** wekelijks – verplicht in 3e en 4e jaar.

**Post-doctoraal:** In het kader van NOVA, wisselend:
- Massaverlies van sterren, Late evolutiestadia
- Infrarood astronomie
- Geavanceerde dynamica van sterrenstelsels
- Technieken van ruimte onderzoek en sterrenkunde.

### 4.3 Doctoraal examens en promoties in 2000

**Doctoraal Examens (“Masters degrees” awarded)**
In 2000 deden 4 studenten met goed gevolg het doctoraal examen:

- E.J. Rijkhorst 31-1-2000
- S. van Straaten 31-1-2000
- M. Klein Wolt 27-3-2000
- F. Fortuin 30-10-2000

**Promoties (Ph.D. degrees awarded)**

- P.A. Zaal 12 januari Observations and analysis of early-type stars at infrared wavelengths
- J.A. de Jong 8 februari On the origin of cyclical variability in the winds of massive stars
- F.J. Molster 15 juni Crystalline silicates in circumstellar dust shells

**Studentenaantallen hoofdvak sterrenkunde (Number of astronomy students)**
In het studiejaar 2000/2001 zijn er 13 studenten met sterrenkunde begonnen, waarvan er 10 zijn doorgegaan.
Voor het hoofdvak sterrenkunde zijn er 29 (3) studenten actief. In totaal dus 39(3).
Tussen haakjes: aantal vrouwelijke studenten.

### 4.4 Onderwijs en voorlichtingsactiviteiten van de staf in 2000

(Colleges aangeduid met I: propedeuse, de andere colleges en practica doctoraalfase)

**Rooster 1999-2000**

2e trimester 13 december 1999 t/m 31 maart 2000

- G. Hammerschlag (coörd.) Sterrenkunde IB (werkcollege) 2 uur/week
- H. Henrichs Sterrenkunde IIA 4 uur/week
- L. Kaper Sterrenkunde practicum 2 3 uur/week
- E. van den Heuvel Sterrenkunde IB 2 uur/week
- M. van der Klis (coörd.) Sterrenkunde practicum 1 6 uur/week
- V. Icke Kosmologie (3³⁄4e jaar) 2 uur/week
- E. van den Heuvel Wereld- en Mensheidsgeschiedenis 4 uur (1 week)
- L. van den Horn Hydrodynamica 2 uur/week
3e trimester 3 april 2000 t/m 7 juli 2000
M. van der Klis / L. Waters Sterrenkunde IIB 4 uur/week
M. van der Klis / L.J.v.d.Horn(coörd.) Hoge-energie astrofysica 4 uur/week
T. Raassen Highlights I 2 uur/week
H. Dickel Molecular clouds 2 uur/week
E. van den Heuvel / R. Fender Astrofysica van compacte sterren 4 uur/week

Rooster 2000-2001
1e trimester 6 september 2000 t/m 10 december 2000
G. J. Savonije Bouw- en evolutie van sterren (hoorcollege) 2 uur/week
M. Witte Bouw en evolutie van sterren (werkcollege) 2 uur/week
V. Icke Kosmologie 2 uur/week
T. Raassen Keuzevoorzicht/studentenseminar 2 uur/week
M. van der Klis Sterrenkunde IA 2 uur/week
A. de Koter Stralingstransport en steratomospheren 2 uur/week
Promovendi Sterrenkunde IA werkcollege 4 uur/week
G.J. Savonije Studiekeuzevoorzicht 1 uur (1 week)
C. Dominik Werkcollege II 2 uur/week

Medewerkers aan werkcolleges en practica

Werkcollege sterrenkunde Ia
R. Dijkstra, S. Hony, P. Vreeswijk, S. van Straaten

Werkcollege sterrenkunde IB
C. Kemper, G. Nelemans

Werkcollege interstellaire en cirumstellaire materie
R. Waters

Sterrenkunde practicum1 (1e jaars)

Sterrenkunde practicum 2(2e jaars)
J. Homan, L. Kaper (coördinator),
G. Savonije (afhandelen oude practica)

Project ‘compacte sterren’ (2e jaars)
G.J. Savonije, L. van den Horn

Project ‘Hubble Deep Field’ (2e jaars)
A. de Koter

Project ‘Super luminal motion in relativistic jets’ (2e jaars)
R. Fender

Begeleiding onderzoek-stage 4e jaars studenten

H. Henrichs
E. ten Kulve, B. Plaggenborg
V. Icke
E.J. Rijkhorst

L. van den Horn
A. Honingh, A. van der Horst (met L. Kaper)

L. Kaper
F. Huthoff, S. Schroder, G. Spil, A. Tijani

M. van der Klis
M. Klein Wolt, T. Reerink, R. Schnerr, S. van Straaten (met E. Ford)

A. de Koter
R. Mokiem

G.J. Savonije en L. van den Horn
A.J. van Marle

R. Waters
A. van Blokland, R. Dijkstra (met P. Morris), F. Fortuin (met M. van den Ancker), S. Hoogzaad (met F. Molster), A. Volp (met M. van den Ancker)

Andere onderwijs activiteiten

A. van Boekel
Bijdrage constructie zonnetelescoop voor waarneempracticum

H.R. Dickel
Lecture course on “Molecular Clouds” (spring quarter 2000)

A. de Koter

P. Vreeswijk
College over Gamma-uitbarstingen voor 3e/4e jaars natuurkunde studenten, Technische Universiteit Eindhoven, 24 februari.

Voorlichting:
- Aansluitingsproject VWO,

- Voorlichting op locatie:
  College en praktikum, verzorgd door H.F. Henrichs, m.m.v. P. Jonker, M. Klein Wolt, M. Witte en A. Bik, 9 juni, ca. 35 leerlingen.
  College en praktikum, verzorgd door H.F. Henrichs, m.m.v. M. Klein Wolt, R. van Boekel, S. van Straaten, M. de Dood en E. Glebbeek, 17 november, ca. 25 leerlingen.
- **Scholenbezoek**, 
  F. Kemper, m.m.v. Rohied Mokiem (student): gastcollege Zaanlands Lyceum, Zaandam, 9 maart, circa 20 deelnemers; St. Nicolaaslyceum, 20 november

- **Masterclass**, 
  L. Kaper, m.m.v. A. de Koter, M. Heemskerk, E. Rol en P.M. Vreeswijk “Zware sterren: de fabrieken van het heelal”, Universiteit van Amsterdam, 27-28 maart

- **Algemene voorlichtingsdag**, 
  M. van der Klis, 11 maart
  A de Koter, 21 oktober

- **Bezoek eerstejaars studenten**, 
  ca. 60 eerstejaars studenten natuurkunde en sterrenkunde, i.h.k.v. de facultaire introductieweek, 7 september, verzorgd door L. Waters en H. Henrichs

- **Wetenschapsdag/Open dag WCW**  
  8 oktober, o.l.v. Jane Ayal, m.m.v. ca. 35 leden van het Sterrenkundig Instituut; bezoekersaantal ca. 2000 personen.

**Postdoctoraal onderwijs:**

NOVA-Herfstschool, Dwingeloo, L. Kaper, “Observations and evolution of massive stars”.

5. PUBLIC OUTREACH ACTIVITIES, AWARDS, PRIZES, ETC

The main public activities of the institute staff members concern: public outreach, i.e.: popularization of astronomy towards the general public. In this field the following activities took place in 2000:

- A number of popular lectures by staff members presented in various parts of the country, to groups of amateur astronomers, school children and interested general public (see list of popular presentations in this report).
- Several interviews on radio and television about astronomical topics that were in the news: Dr. Kaper, Dr. Henrichs, prof. Waters.
- E.P.J. van den Heuvel, as one of the founders of the Zeiss Planetarium Artis, continued as a member of the Board of the Amsterdam Zoo 'Artis'. In this capacity he is responsible for the Planetarium, which hosts between 200,000 and 300,000 visitors per year.
- Dr. Henrichs advised the Netherlands Railroad Company about the construction of a large sun dial for the front part of the building of the Amersfoort Railroad Station.

On January 1, 2000, the public outreach office of the Netherlands Research School for Astronomy (NOVA) started in the UvA Astronomical Institute, with two public outreach officers: Mr. A. Jaspers and Mr. J. Visser. The first tasks of the NOVA Information Center (NIC) were:

- To develop a brochure about NOVA’s work- and researchgoals, in Dutch as well as in English languages. This task was successfully completed with the production of these two very nice color-brochures.
- To develop NOVA’s web-site (www.astronomy.nl). Part of this work was completed in 2000.

Further activities of the NIC include:

- Publication of press releases about new developments in Dutch Astronomy.
- Development of a WEB-encyclopedia on general astronomy.
- Production of exposition materials.

The two NIC officers played an important role in setting up various expositions, such as for the opening of the interferometry-center NEVEC on May 26 in Leiden.

5.1 Popular publications

M. van der Klis
- De zoemtoon van relativiteit, Natuur en Techniek 68, 26-29, 2000.

5.2 Popular lectures

H. Henrichs
- Mars in close-up, Artis Planetarium, Amsterdam, 1 februari

E.P.J. van den Heuvel
- Astronomisch Onderzoek en de Maatschappij, Tweede Kamer Commissie Onderwijs en Wetenschappen, Perscentrum Nieuwspoort, Den Haag, 9 februari
- Oerknal: feit of fantasie?, Artis Planetarium, Amsterdam, 7 maart
- Supernovae, Symposium Nederlandse Vereniging voor Weer- en Sterrenkunde, Amsterdam, 14 oktober
- Cosmologie, de Grote Vragen, Cursus Sterrenkunde voor beginners, Artis Planetarium, Amsterdam 18 december.
L. van den Horn
- *In de keuken van de kosmos*, Nationale Wetenschapsdag (thema: Huis, tuin en keuken), NVWS Oostzaan, 8 oktober

V. Icke
- *Einstein voor beginners*, Theater AdHoc, Maastricht, 7 januari
- *Winteravondlezing*, Haagse Vestiging UL, 19 januari
- *Ons beeld van het Heelal*, Comenius, 20 januari
- *Lerarencursus ANW*, Space Expo, 24 januari
- *Ideeënfabriek*, Haagse vestiging UL, 9 februari
- *Het oerknalmodel*, Studium Generale UL, Leiden, 15 februari
- *Ideeënfabriek*, Haagse vestiging UL, 8 maart
- *ICT in de Sterrenkunde*, LIACS, 24 maart
- *Sterrenkunde*, Weekendschool, Amsterdam, 26 maart
- *Sterrenkunde*, Montessorischool, Zeist, 30 maart
- *Kernfusie in de Oerknal*, Studievereniging Scheikunde UL, 30 maart
- *Sterrenkunde*, Weekendschool, Amsterdam, 2 april
- *Kosmologie vandaag*, Studium Generale, Nijmegen, 18 april
- *Kunst en sterrenkunde*, Sandberg Instituut, Amsterdam, 26 april
- *Gastles Sterrenkunde*, Fioretti College, 8 mei
- *De vorm van de ruimte*, Studium Generale, Utrecht, 12 mei
- *Lerarencursus ANW*, Nemo, Amsterdam, 15 mei
- *Interview*, De Baak, Noordwijk, 23 mei
- *Dying suns*, NL Supercomputer Day, Noordwijk, 26 mei
- *Ideeënfabriek*, Haagse vestiging UL, 30 mei
- *Botsende sterrenstelsels*, ANW course, Leiden, 8 juni
- *Het uitdijende heelal*, Rectorendag, Leiden, 10 juni
- *Bessensap*, NOW, Amsterdam, 25 september
- *Wegen door het Heelal*, Ministerie V&W, Den Haag, 10 oktober
- *Vijf jaar na DeciBel*, KNP Telecom, 11 oktober
- *Cosmology, not philosophy*, Studium Generale VU, Amsterdam, 23 oktober
- *Tussen science en science fiction*, Studium Generale UU, Utrecht, 13 november
- *Lerarencursus ANW*, Planetarium Artis, Amsterdam, 14 november
- *De Leidse Aratea*, Kopstukken UL, Leiden, 16 november
- *Dagelijks quantummechanica*, Studium Generale KUB, Tilburg, 23 november
- *Leidse sterrenkunde*, Cleveringa Lezing, Genève, 27 november
- *Dagelijks quantummechanica*, Rotary Club, Leiden, 7 december
- *Sonic Acts*, Paradiso, Amsterdam, 7 december

T. de Jong
- *Zonsverduisteringen en kleitabletten*, Artis Planetarium, Amsterdam, 4 april
- *Een kijkje in de keuken van het heelal*, Nationale Wetenschapsdag, SRON Utrecht, 8 oktober

L. Kaper
- *Waarnemen met de grootste telescoop ter wereld: nieuwe resultaten verkregen met ESO’s VLT*, Weer- en Sterrenkundig Kring Zaanstreek, Oostzaan, 23 maart

L. Voûte
- *Drie ruimtereizen in één*, Artis Planetarium, 4 januari
- *Een reis door de ruimte, de tijd en de wetenschap*, Six-kazerne, Amsterdam, 13 april
L.B.F.M. Waters
- Resultaten van de ISO satelliet, NVWS Alkmaar, 28 januari
- De evolutie van zon-achtige sterren, NVWS Hilversum, 18 februari
- Vorming van sterren en planeten, Belgische amateursterrenkunde vereniging, 30 september
- Sterrende sterren, Artis Planetarium, Amsterdam, 7 november

5.3 The Astronomical Institute in the press

- ‘Science’ zet Amsterdam in het zonnetje, Maarten Keulemans, Folia 19, 14 januari
- De illustere veertig-21-Ed van den Heuvel, sterrenkundige (1940-), Arjen Fortuin, Folia 20, 21 januari
- Nederlandse astronomen in top tien, Piet Smolders, Telegraaf, 22 januari
- Het Galactische rijk mag weer bestaan – gezocht: buitenaardse wezens, Maarten Keulemans, Folia 28, 17 maart
- Focus, Maarten Keulemans, Folia 29, 24 maart
- Poollicht dit jaar vaker te zien, Noordhollands Dagblad, 8 april
- Kristallijne revolutie in de ruimte, Eddy Echternach, Haagse Courant, april
- Jan van Paradijs, necrologie, Physics Today, april
- Evolutie Zonnestelsel opnieuw bekeken, Eos Magazine, april
- Eta Carinae Untangled, Sky and Telescope, april
- De illustere veertig – 7- Anton Pannekoek, sterrenkundige (1873-1960), Arjen Fortuin, Folia 34, 12 mei
- Wéér geen Apocalyps, Maarten Keulemans, “Voellicht”, Folia 34, 12 mei
- GRS 1915+105, een morsige veelvraat, Rob Fender en Tomaso Belloni, N&T wetenschapsmagazine, mei
- Power Pulses, How magnetars differ from neutron stars, Secrets of the Universe, 12 juni
- Flikkerende ster bevestigt Einstein, Govert Schilling, Volkskrant, 28 augustus 2000
- Neutron Stars Imply Relativity’s a Drag, Govert Schilling, Science, vol.289, 1 september
- UvA-sterrenkundigen zien ‘vervormde’ ruimte, Maarten Keulemans, Folia 02, 1 september
- Amsterdamse ontdekking titaniumcarbide gepubliceerd in Science, Bêta Bulletin, no.4, najaar 2000
- Met dat sterretje waren ze al dertig jaar bezig, Bas den Hond, Trouw, 20 oktober
- Onmogelijke missie scoort een monster, Govert Schilling, Volkskrant, 16 december

5.4 Interviews and appearances on radio/tv

V. Icke
- Hoezo millenniumprobleem?, Radio Rijnmond, 3 januari
- Interview, Radio West, 10 januari
- Interview, VPRO, 31 januari
- Interview, VPRO Blauw Licht, 1 maart
- Het weer in het Heelal, RTL 4, 11 maart
- Vragen in de Sterrenkunde, KRO, 15 maart
- Kunst en Wetenschap, 22 maart
- Planetaire nevels, VPRO-tv, 9 augustus
- Het einde van de Zon, VPRO Zuiderlicht, 5 september
- Een geweldige tijd!, VARA Witteman, 1 oktober
- Een geweldige tijd! Discussie, VARA Witteman, 4 november
5.5 Prizes, Distinctions, Special Celebrations

T. Galama
Christiaan Huygensprijs 2000, awarded by Minister Hermans in Voorburg, on October 19, 2000.

5.6 Memberships of learned Societies

E.P.J. van den Heuvel
Member Koninklijke Nederlandse Akademie van Wetenschappen, Amsterdam
Member Hollandse Maatschappij van Wetenschapppen, Haarlem
Member Academia Europea, London
Member New York Academy of Sciences
Member Nederlandse Astronomen Club
Member Netherlands Physical Society NNV
Member International Astronomical Union
Member European Astronomical Society
Member Astronomical Society of India

T. de Jong
Member International Astronomical Union
Member American Astronomical Society
Member Royal Astronomical Society
Member European Astronomical Society

R. Strom
Fellow Royal Astronomical Society

R. Waters
Member International Astronomical Union
Member Nederlandse Astronomen Club
Key researcher Nederlandse Onderzoeksschool voor Astronomie (NOVA)
6. STAFF and BUDGET

The scientific staff working at the institute and the vacant positions on December 31, 2000 are listed below.

theme 1 = High energy Astrophysics
theme 2 = Low energy Astrophysics

A. University funded permanent staff/positions

<table>
<thead>
<tr>
<th>Name</th>
<th>Theme</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.P.J. van den Heuvel (HL)</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>Vacancy position Prof. van Paradijs (HL)</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>M. v.d. Klis (HL)</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>T. de Jong (HL)</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>L.B.F.M. Waters (UHD)</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>G.J. Savonije (UHD)</td>
<td>1+2</td>
<td>1.0</td>
</tr>
<tr>
<td>H.F. Henrichs (UHD)</td>
<td>1+2</td>
<td>1.0</td>
</tr>
<tr>
<td>L.J. van den Horn (UHD)</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>A. de Koter (UD)</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>G. Hammerschlag-Hensberge (UD)</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>A. Raassen (UD)</td>
<td>1</td>
<td>0 (0.125)</td>
</tr>
<tr>
<td>Vacancy (2001) Ground-based observational astron. (UD)</td>
<td>1+2</td>
<td>1.0</td>
</tr>
<tr>
<td>Th. Nieuwenhuizen (UHD ITFA)</td>
<td>-</td>
<td>(0.2)</td>
</tr>
</tbody>
</table>

B. Externally funded permanent staff/positions

<table>
<thead>
<tr>
<th>Name</th>
<th>Theme</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. R.P. Fender (NWO-Spinoza, UD)</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>V. Icke (UL, bijz. HL)</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>R. Strom (ASTRON; HL b.b.)</td>
<td>1+2</td>
<td>0.2</td>
</tr>
<tr>
<td>J. Hovenier (Vrije Univ., HL b.b.)</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>H. Spruit (AUV CHEAF bijz.HL)</td>
<td>1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Present staff UvA Astronomy

Postdocs and Fellows

- Dr. L. Kaper (KNAAW-Fellow)
- Dr. C. Dominik (NWO-Pionier)
- Dr. K. O’Brien (EU-TMR)
- Dr. Q.Z. Liu (Chinese Acad. of Science)
- Dr. J. Dennet-Thorpe (buiten bezwaar)

\[1\] 0.125 SRON + 0.25 Faculty funded, for a period of 10yrs from 1-1-’99
\[2\] We pay these positions from our budget, but they are not part of our official formation (due to WINS-reorganisation)

\* buiten bezwaar = not funded by the UvA
Dr. M. Fluks (private funding)
Dr. B. Stappers (NWO-Spinoza)
Dr. Ramachandran (ASTRON-postdoc)

Guest researcher (permanent)
Dr. H.R. Tjin A Djie (private funding)

Graduate Students
There are at present a total of 24 graduate students working at the Institute of which 18 are externally funded, mainly from NWO-GBE, from the Spinoza-grant to E. van den Heuvel, the Pioneer Grant to L. Waters and from NOVA (Nederlandse Onderzoekschool voor Astronomie). There are officially 8 University-funded AIO-positions, of which at present three have to remain vacant because of insufficient University budget.

Formation Scientific Staff
We summarize below the allocation of permanent positions (formation) as given above under A.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>HL</th>
<th>UHD</th>
<th>UD</th>
</tr>
</thead>
<tbody>
<tr>
<td>fte</td>
<td>3.2</td>
<td></td>
<td>3.5 (+0.2)*</td>
<td>3.2 (+0.125)*</td>
</tr>
</tbody>
</table>

C. Allocation of supporting staff
The supporting staff indicated below in the table belongs to the central formation of the Science Faculty:

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>Co-manager</th>
<th>Secretaries</th>
<th>System manager</th>
<th>Librarian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td></td>
<td>Mrs. L. Stolte</td>
<td>Drs. E. Veenhof, Drs. J. Ayal</td>
<td>Mr. D. Edel</td>
<td>Mrs. E.S. van Iterson</td>
</tr>
<tr>
<td>Fte</td>
<td>0.8</td>
<td>0.8 and 0.3</td>
<td>1.0</td>
<td>0.3</td>
<td></td>
</tr>
</tbody>
</table>

Supporting Staff belonging to the Institute formation
- Dr. M. Heemskerk - software specialist 1.0 fte
- Drs. J. Ayal - secretary (0.4 ASTRON + 0.3 Institute)
- Mrs. L. Stolte - co-manager (0.2 NWO-Spinoza)

Budgets: UvA and External
Below we present the allocated budget from the university through the Science faculty, as well as the present level of external funding. As to the UvA budget for the API, this mainly represents salary costs for staff and Ph.D. students. A modest amount of about 110 Kfl/year is used for material support, computers, travel, etc.
[For a largely observational/experimental institute like the API this is highly inadequate]. The external sources are the Spinoza Grant to E. van den Heuvel (till 2001), the NWO-Pioneer Grant to L. Waters (till 2002), which together add up to about 1.16 Mfl/yr, plus additional funding from

* We pay these positions from our budget, but they are not part of our official formation (due to faculty-reorganisation)
NWO, KNAW, EC and the "Top-Research-School" Grant to NOVA (1999-2005). The amounts to be expected from this grant (in order 1 Mfl/yr) are not yet precisely known, therefore the amounts from 2001 onwards are rough estimates.

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>UvA budget (Kf)</td>
<td>1855</td>
<td>1749.6</td>
<td>1820</td>
<td>1887</td>
<td>2038</td>
<td>2038</td>
</tr>
<tr>
<td>External</td>
<td>~1800</td>
<td>1830</td>
<td>1800</td>
<td>2000</td>
<td>~1800</td>
<td>~1400</td>
</tr>
</tbody>
</table>

The “jump” in budget per January 1, 2001 is due to two factors: in that year a 3-year temporary extra budget cut of 5% (which started 1-1-1998) ends and a structural budget increase for two permanent positions (250 Kfl/yr) is allotted as a compensation for the termination of the Spinoza funding that ends that year.

The latter is part of an agreement made in October 1995 between the Faculty WINS and the Algemeen Bestuur of NWO. However, the Faculty so far has not decided to allot the full 250 K/yr from 1-1-2000 on, and has committed itself to 80 K/yr of this amount from 1-1-2001 on. The Institute is still in a discussion with the Faculty about the remaining 170 K/yr that were originally decided to be committed by the Faculty in 1995.

The 80 Kfl/yr for “Spinoza” plus the 5% increase should have resulted in a budget increase by about 160 Kfl/yr. Due to not completely correcting for inflation this became 151 Kfl/yr.

D. Comparison with the other University Astronomy Institutes in the country

While the University of Amsterdam plays a leading role in the Top-research school NOVA, tables 1 and 2 show that its university staff and funding are the smallest of those of the four participating universities, whereas its external funding is largest.

Table 1: University funded scientific staff

<table>
<thead>
<tr>
<th>University</th>
<th>Full Professors</th>
<th>UHD + UD</th>
<th>Graduate Students</th>
<th>Postdoc Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>UvA (Amsterdam)</td>
<td>3.2</td>
<td>4.7(^a)</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>RU (Groningen)</td>
<td>5.3</td>
<td>9.7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>RU (Leiden)</td>
<td>7.0</td>
<td>11.0</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>UU (Utrecht)</td>
<td>5.2</td>
<td>5.3</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>VU (Amsterdam)(^b)</td>
<td>1.0</td>
<td>1.0</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>20.7</td>
<td>31.0</td>
<td>29</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^a\) in 2001: 6.7
\(^b\) will be terminated in 2001
Table 2: Yearly budgets (university funding) for astronomy per university, in kfl. Given are the direct costs (personnel-costs plus material budgets) as presented in the budgets of the respective faculties for 1998. In the case of the University of Amsterdam this also includes the financial support for the staff-component C, provided by the faculty bureau. The last column gives the combined total external funding, such as from NWO (Spinoza, Pioneers, Graduate students, postdocs), EC, KNAW and other sources.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UvA (Amsterdam)</td>
<td>Personnel</td>
<td>1787</td>
<td>1836</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>RU (Groningen)</td>
<td>Personnel</td>
<td>3482</td>
<td>640</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>625</td>
<td></td>
</tr>
<tr>
<td>RU (Leiden)</td>
<td>Personnel</td>
<td>3644</td>
<td>1403</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>760</td>
<td></td>
</tr>
<tr>
<td>UU (Utrecht)</td>
<td>Personnel</td>
<td>2254</td>
<td>802</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>279</td>
<td></td>
</tr>
<tr>
<td>VU (Amsterdam)</td>
<td>Personnel</td>
<td>410</td>
<td>273</td>
</tr>
<tr>
<td></td>
<td>Material</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX I

INSTITUTE STAFF on 31-12-2000

Gewoon Hoogleraren
Prof.Dr. E.P.J. van den Heuvel
Prof.Dr. M. van der Klis
Vacature

Deeltijd- en Bijzonder Hoogleraren en gasthoogleraren
Prof.Dr. J. Hovenier (affiliated prof.: Vrije Univ. Amsterdam)
Prof.Dr. V. Icke (bijz. h.l., Stichting Beta-Plus)
Prof.Dr. T. de Jong (0.2 fte)
Prof.Dr. R. Strom (affiliated prof.; NWO Foundation ASTRON, Dwingeloo)
Prof.Dr. H. Spruit (Max Planck Institut für Astrophysik, Garching; bijz.h.l. Amsterdamse Universiteits Vereniging)

Universitaire hoofddocenten
Dr. H. Henrichs
Dr. L.J. van den Horn (0.5 fte)
Dr. G.J. Savonije
Prof.Dr. L.B.F.M. Waters (deeltijd hoogleraar K.U. Leuven)

Universitaire Docenten
Dr. R. P. Fender (NWO Spinoza)
Mw. Dr. G. Hammerschlag-Hensberge (0.2 fte)
Dr. A. de Koter
Dr. T. Raassen (0.125 fte +0.25 fte Fac.)

KNAW-Fellow
Dr. L. Kaper

Emeriti
Prof.Dr. P.S. The
Dr. H.R.E. Tjin A Die

Postdocs (met financieringsbron)
Dr. C. Dominik (FOM-MPRA))
Dr. K. O’Brien (EU-TMR)
Dr. Q.Z. Liu (Chinese Acad. of Science)
Dr. R. Ramachandran (NWO-ASTRON)
Dr. B.W. Stappers (NWO-Spinoza)
Dr. J. Dennet-Thorpe (buiten bezwaar)
Dr. M.A. Fluks (buiten bezwaar)

Ph.D. students (met financieringsbron)
Drs. A. Ankay (Turks Ministerie van O&W)
Drs. A. Bik (NOVA)
Drs. P. Blondel (buiten bezwaar)
Drs. R. van Boekel (NOVA)
Drs. J. Bouwman (NWO)
Drs. J. Cami (1e geldstroom)
Mw. Drs. J. Dewi (NWO-Spinoza)
Drs. R. Dijkstra (NOVA)
Drs. J. Homan (NWO-Spinoza)
Drs. S. Hony (NWO-Pionier)
Drs. P. Jonker (NWO-Spinoza)
Ms.Sc. S. Jouteux (NOVA)
Mw. Drs. C. Kemper (1e geldstroom)
Drs. M. Klein-Wolt (1e geldstroom)
Mw. Drs. A. Lenorzer (NWO)
Drs. A. van der Meer (NOVA)
Mw.Drs. G. Meeus (NOVA)
Mw.Drs. C. Neiner (ULP, Straatsburg)
Drs. G. Nelemans (Facultaire Pool)
Drs. E. Rol (1e geldstroom)
Drs. S. van Straaten (NWO)
Drs. L. Voûte (buiten bezwaar)
Drs. P. Vreeswijk (NWO-Spinoza)
Drs. M. Witte (1e geldstroom)

Co-manager
Mw. L. Stolte (1,0 fte) (0,8 fte 1e geldstroom, 0,2 fte NWO-Spinoza)

Scientific software engineer
Dr. M.H.M. Heemskerk (1,0 fte 1e geldstroom)

System manager
D. Edel (1,0 fte 1e geldstroom)

Management-assistants
Mw.drs J. Ayal (0,4 fte ASTRON, 0,3 fte 1e geldstroom, 0,3 NWO-Spinoza)
Mw.drs. H.M. Veenhof (0,8 fte 1e geldstroom)

Librarian
Mw. E. S. van Iterson (0,6 fte, bibliotheekformatie)
APPENDIX II

COMMITTEE MEMBERSHIPS

Facultaire commissies

R. Fender
Organisatie Open Wetenschapsdag Sterrenkunde

H. Henrichs
Examencommissie Faculteit WINS
Bibliotheekcommissie Sterrenkundig Instituut
Huisvestingcommissie Faculteit NWI

E.P.J. van den Heuvel
Ondernemingsraad Faculty NWI, University of Amsterdam

L. van den Horn
Onderwijscoördinator WNS

M. van der Klis
Member Computer Netwerk Groep Gebruikers Commissie
Member Opleidingscommissie Natuur en Sterrenkunde

A. de Koter
Colloquiumcommissaris of Colloquia at the Astronomical Institute

A. Raassen
Lid Ondernemingsraad van de Faculty NWI

G.J. Savonije
Studiecoördinator sterrenkunde
Stagecoördinator sterrenkunde
Lid studierichtingcommissie van de faculteit

Universitaire commissies

E.P.J. van den Heuvel
Universitaire Onderzoek Commissie
APPENDIX III

SCIENCE POLICY FUNCTIONS

R. Fender
- Member management team Astronomical Institute
- Member of Scientific Advisory Committee for “3rd micorquasar workshop”

M. Heemskerk
- Secretaris Nederlandse Astronomen Club

E.P. J. van den Heuvel
- Chairman, Board of the Netherlands Research School for Astronomy NOVA
- Chairman Netherlands Foundation for Research in Astronomy (NFRA/ASTRON/NWO)
- Member, Board of the Amsterdam zoological garden Artis
- Chairman Leids Kerkhoven Bosscha Fonds, Leiden
- Member, Board of Directors Leids Sterrewacht Fonds Leiden
- Member, Board of Directors “Jan Hendrik Oort Fonds”, Leiden
- Member, Science Advisory Board (Wetensch. Raad), Space Research Organisation of the Netherlands (SRON)
- Member, NWO, Advisory Committee for Astronomy (ACA)
- Member, SAX Science Steering Committee for Italian-Dutch BeppoSAX satellite, Rome
- Member, Netherlands Committee for Astronomy (NCA)
- Member, Kamer Sterrenkunde, VSN
- Member, International Advisory Board, Inter University Centre for Astronomy and Astrophysics, Puna, India (1998-2004)
- Member, Evaluation Committee Swedish Astronomy (2000)
- Foreign Member of Jury on Mathematics & Physics of Flemish National Science Foundation, Brussels (1997- )
- Member, Franqui Prize Jury, Brussels, Belgium (1996 - )
- External Advisor for Founding Group of Experimental Astronomy ETH Zürich (1999-2000)
- Elector, Plumian Professor Chair, University of Cambridge, UK (1998 - )
- Member, ESO Council, Garching, Germany (till July 1, 2000)
- Member, Jury Deutsche Forschungsgemeinschaft SFB Astro Particle Physics, Garching (1993- )
- Co-editor “New Astronomy” (Elsevier), Amsterdam
- Co-editor Astronomische Nachrichten (J. Wiley Publishers) Berlin
- Member Editorial Board “Astrophysics and Space Science” (Kluwer Academic Publishers) Dordrecht
- Member Editorial Board “Astrophysics and Space Science Library” (Kluwer Acad. Publishers) Dordrecht
- Chairman, Sectie Astrofysica, Dutch Physical Society, NNV
- Chair, Amsterdams Fonds voor Astrofysica
- Chair, Scientific Organizing Committee “Jan van Paradijs Memorial Symposium” (June 2001)
- Member, Jury “Christiaan Huygens Prijs 2000”, KNAW
- Member, “Raad voor Natuur- en Sterrenkunde”, KNAW
J. Hovenier
- Member (Vice Chairman) of the Board of the Space Research Organisation of the Netherlands SRON
- Chairman Science Advisory Board of SRON
- Board member NCA
- Board member Kamer Sterrenkunde
- Board member NOVA
- Member Adviescommissie GBE van NWO

V. Icke
- Board Science Museum “Mew Metropolis”, Amsterdam

J. de Jong
- Bestuur Volkssterrenwacht Copernicus, Haarlem

T. de Jong
- COSPAR, National Committee
- Instrument Science Team for CONICA/ESO-VLT
- Adjunct Director SRON
- Lid Wetenschappelijke Commissie NLR/NIVR
- Lid Begeleidingscommissie Remote Sensing (BCRS)
- Lid Begeleidingscommissie SCIAMACHY (BESC)
- Lid Begeleidingscommissie OMI (BOMI)

P. Jonker
- Penningmeester Nederlandse Astronomen Club

L. Kaper
- Member ESO Observing Program Committee, High-mass star panel
- Member ASTRON Programma Commissie
- Member VLT/UVES Instrument Team, European Southern Observatory
- Member VLT/SINFONI Science Team, European Southern Observatory
- Member board Vereniging van Akademie Onderzoekers
- Member Programma Commissie Nederlandse Telescoop
- Member ESO Contact Committee
- Member Hubble Space Telescope Time Allocation Committee, panel Galaxy 2

A. de Koter
- Minnaert Commissie, NOVA publieksvoorlichting, member representing Amsterdam

M. van der Klis
- Network coordinator NOVA network “High-Energy Astrophysics”, Netherlands Research School for Astronomy (NOVA)
- Node chief, EU TMR Network “Accreting onto Black Holes, Compact Stars and Protostars
- Member Board of reviewing editors, Science Magazine
- Member, NASA Rossi X-ray Timing Explorer (RXTE) Scientific Working Group
- Member, NASA’s Rossi X-ray Timing Explorer (RXTE) Scientific Committee
- Member, European Pulsar Network
- Member, GRAIL collaboration
- Member, Rossi XTE Users Committee
- Member, BeppoSAX Time Allocation Committee
- LASTE principal investigator (shared among 5 ESA-country astrophysicists); Amsterdam
- Member, Constellation-X Scientific Working Group
- Member, XEUS Scientific Working Group
- Project Scientist, NOVA PuMa 2 project
- Member, PuMa Raad van Toezicht
- Member, NOVA Instrument Steering Committee
- Member, Science Advisory Board (Wetensch. Raad), Space Research Organization of the Netherlands (SRON)
- Member, NWO GBE (GebiedsBestuur Exact) jury projectvoorstellen
- Member, Board Kapteynfonds
- Member, Board Pastoor Schmeyts Prijs

**G.J. Savonije**
- Lid onderwijsie NOVA

**B.W. Stappers**
- Member, Raad van Toezicht PuMa II
- Chair, Technical Committee PuMa II
- Member, LOFAR Science Committee
- Chair, PuMaScI (Dutch Pulsar Community Science Group)

**R.G. Strom**
- Member of the European VLBI Network Program Committee (3 meetings in 1999)
- Member of evaluation committee, Marie Curie Programmes of the EC
- Co-chair of Scientific Organizing Committee of IAU Colloquium 182: to be held in Guiyang, China, 17-21 April 2000
- Corresponding member, International Union of Radio Science (URSI)
- Member, Commissions 28, 34 and 40, International Astronomical Union;

**L.B.F.M. Waters**
- Co-I Short wavelength spectrometer of Infrared Space Observatory (ISO)
- Member, ESO Interferometry Science Advisory Committee
- Member NWO beoordelingscommissie Astronomie, Gebiedsbestuur E
- Co-pi Mid-infrared Instrument for VLTI MIDI
- Co-PI MIDI (Very Large Telescope Interferometry Project of ESO)
- Member ESO, VLTI Steering committee
- Chairman, Dutch Science Team for VISIR
- Co-chair, NOVA VLTI team
- Member, NWO-GBE jury projectvoorstellen
- Member, 1999 Hubble Space Telescope time allocation Galactic Panel
- Member, management team Astronomical Institute
- Coordinator, INTAS programme ‘Theoretical and experimental investigations of light scattering by heterogeneous non-spherical cosmic grains’
- Member, science team for HIFI, the heterodyne receiver for FIRST
- Member Board of Directors, James Cleark Maxwell Telescope
- Member VLTI Implementation Committee of the European Southern Observatory (ESO)
- Member MIDI science team
- Member VLT Science Demonstration Team
APPENDIX IV

VISITING SCIENTISTS

Prof. Dr. Helene Dickel, University of Illinois, USA  
CHEAF visiting Professor  
January - June

Dr. Qingzhong Liu, Purple Mountain Observatory, China  
21 January – 12 January 2001

Dr. Tiziana di Salvo, University of Palermo, Italy  
23 January – 29 February

Dr. Issei Yamamura, Institute of Space and Aeronautical Science (ISAS), Japan  
6 February – 11 February

Prof. Dr. John Brown, Univ. of Glasgow (Astronomer Royal for Scotland), UK  
6 February – 8 February

Prof. Dr. Stan Owocki, Univ. of Delaware, USA  
6 February – 8 February

Dr. Tomaso Belloni, Osservatorio di Astronomico di Brera, Italy  
28 February – 1 March

Dr. Wenfei Yu, Chinese Academy of Sciences, China  
3 March – 3 June

Dr. Tiziana di Salvo, University of Palermo, Italy  
26 March – 31 May

Prof. Dr. Radhakrishnan, Raman Research Institute, Bangalore, India  
30 April – 1 July

Dr. Kees Dullemond, MPA, Garching, Germany  
3 April – 8 April

Dr. Issei Yamamura, Institute of Space and Aeronautical Science (ISAS), Japan  
1 May – 3 May

Dr. Sean Dougherty, Dominion Radio Astronomical Observatory (DRAO), Canada  
14 May – 22 May

Prof. Dr. Ene Ergma, Theoretical Phys. and Astrophys. Dept., Tartu Univ., Estland  
14 May – 9 June

Dr. Chryssa Kouveliotou, Univ. of Alabama, Huntsville, USA  
CHEAF visiting Professor  
3 June – 31 July

Dr. Orsola DeMarco, University College, London, UK  
19 June – 21 June

Dr. Andrew Fruchter, STScI, Baltimore, USA  
27 June – 11 July

Dr. Mikako Matsuura, LIRA, Japan  
30 June – 4 July

Dr. Ersin Gogus, Univ. of Alabama, Huntsville, USA  
14 July – 21 July

Dr. Pete Woods, USRA/NSSTC, Huntsville, Alabama, USA  
16 July – 21 July

Prof. Dr. Ralph Wijers, Dept. of Physics and Astronomy, State Univ. New York at Stony Brook,  
20 July – 30 July

Olga Bitzaraki, University of Athens, Greece  
24 July – 8 August

Rosina Iping, University of Guam  
26 July – 9 August
Dr. Kees Dullemond, MPA, Garching, Germany  
27 July – 28 July

Prof. Dr. Peter Conti, University of Colorado, Boulder, USA  
17 August – 19 August

Prof. Dr. G. Srinivasan, Raman Research Inst., Bangalore, India  
CHEAF visiting Professor  
20 August – 21 September

Dr. Lev Yungelson, Inst. of Astron. of the Russian Acad. of Sciences, Russia  
24 August – 17 November

Dr. Pat Morris, Infrared Processing and Analysis Center (IPAC), Caltech, USA  
6 September – 14 September

Prof. Dr. Antonella Natta, Univ. of Florence, Italy  
CHEAF visiting Professor  
2 October – 30 October

Dr. Michel Tagger, CEA-Sacley, France  
30-31 October

Dr. Frank Molster, MVA Inc., USA  
23 October – 15 November

Dr. Issei Yamamura, Institute of Space and Aeronautical Science (ISAS), Japan  
28 October – 14 November

Dr. Martin Hendry, Univ. of Glasgow, UK  
9-10 November

Dr. Frans Rietmeijer, Institute of Meteoritics, Univ. of New Mexico, USA  
5 November – 9 November

Dr. Mark Finger, NASA/Marshall Space Flight Center (MSFC), Huntsville, USA  
19 November – 16 December

Dr. Matt Scott, NASA/Marshall Space Flight Center (MSFC), Huntsville, Alabama, USA  
19 November – 16 December
APPENDIX V

COLLOQUIA AT THE “ANTON PANNEKOEK INSTITUTE”

Thursday 6 January, graduation colloquium
Steve van Straaten, Astron. Institute, Amsterdam, Relations between Timing Features and Colors in the X-Ray Binary 4U 0614+09

Thursday 13 January, graduation colloquium
Erik-Jan Rijkhorst, Astron. Institute, Amsterdam, Thick Gravitational Lenses

Thursday 20 January
Thomas Tauris, Astron. Institute, Amsterdam, 2.5 years at Anton Pannekoek with neutron stars: from pulsars to X-ray binaries to crustal physics

Monday 24 January
Ton Raassen, Astron. Institute, Amsterdam & SRON Utrecht, New results from CHANDRA

Monday 31 January
Rob Fender, Astron. Institute, Amsterdam, Relativistic jets from X-ray binaries: recent advances

Thursday 3 February
Prof. Ir. W. Reinold de Sitter, Technische Universiteit Eindhoven, Zoals het vroeger was is het nooit geweest

Monday 7 February
Stan Owocki, Univ. of Delaware, The Rocket Science of Be-star disks

Thursday 10 February, graduation colloquium
Rien Dijkstra, Astron. Institute, Amsterdam, Ceres, Pallas, Juno, Vesta and Hygiea: five large asteroids investigated with ISO-SWS

Thursday 17 February
John Heise, SRON Utrecht, Gamma Ray Bursts without gamma rays

Friday 10 March, CHEAF colloquium
Frans Klinkhamer, Univ. of Karlsruhe, Lorentz non-invariance, CPT violation, and Cosmology

Tuesday 14 March, graduation colloquium
Marc Klein-Wolt, Astron. Institute, Amsterdam, A "lego" model for the Black Hole Candidate GRS 1915+105

Thursday 30 March
Norbert Langer, Univ. of Utrecht, Evolutionary models of massive close binaries

Thursday 6 April
Harvey Butcher & Michiel van Haarlem, ASTRON, Dwingeloo, LOFAR opening a new spectral window on the universe
Thursday 13 April
Jerome Orosz, Univ. of Utrecht, *Optical Observations of Stellar Black Holes*

Friday 28 April
Jos de Bruijne, Universiteit Leiden, *Astrometry from space: a Hipparcos study of young stellar groups*

Thursday 4 May
Frank Verbunt, Universiteit Utrecht, *The Earth-Moon system*

Thursday 25 May
Mike Garrett, JIVE Dwingeloo, *Faint Radio Sources in the Hubble Deep Field*

Friday 9 June
V. Radhakrishnan, Raman Research Institute, Bangalore, India, *Radio observations of interstellar atomic hydrogen: Appearance and Reality*

Monday 19 June
Orsola DeMarco, University College London, *The Far Ultraviolet Spectroscopic Explorer and the wind of hot stars*

Friday 23 June
Neil Evans, Univ. of Leiden, *Can We Prove that Stars Form by Gravitational Collapse?*

Friday 30 June
John R. Dickel, University of Illinois at Urbana, *Supernova Remnants and their Neutron Stars*

Thursday 27 July
Jeroen Homan, Astronomical Institute of the University of Amsterdam, *XTE J1550-564, a new interpretation of black hole behavior*

Friday 28 July
Ralph Wijers, SUNY Stony Brook, U.S.A., *Gamma-Ray Bursts from Massive Stars in Giant Molecular Clouds*

Tuesday 1 August, graduation colloquium
Arjan Volp, Astronomical Institute of the University of Amsterdam, *Transitional YSOs: Candidates from flat spectrum IRAS sources*

Friday 18 August, NOVA Colloquium
Peter S. Conti, University of Colorado, Boulder, U.S.A., *Near IR imaging and spectroscopy of optically obscured galactic giant HII regions: discovery of clusters and the identification of the exciting stars*

Thursday 14 September
Jayaram Chengalur, GMRT Pune, India, *21cm observations of Damped Ly-alpha Systems*

Thursday 21 September
Jennifer Sokoloski, University of California, Berkeley, U.S.A., *Magnetism and Rapid Variability in Symbiotic Stars*
Friday 22 September, graduation colloquium
Finne Fortuin, Astronomical Institute of the University of Amsterdam, *A study of IR Recombination Lines in Herbig Ae/Be stars*

Thursday 12 October
Paul Groot, Harvard Smithsonian Center for Astrophysics, *The Faint Sky Variability Survey*

Thursday 19 October
Gerry Brown, State University of New York at Stony Brook, U.S.A., *Evolution of High Mass Black Holes in the Galaxy*

Monday 23 October
Antonella Natta, Osservatorio di Arcetri, Firenze, *The Formation of Massive Stars: Open Questions*

Tuesday 31 October
Michel Tagger, Service d'ASTrophysique, CEA Saclay Paris, *Accretion-Ejection Instability and the low-frequency QPO in X-ray binaries*

Thursday 2 November
Henny Lamers, Universiteit Utrecht, *The formation of very massive stars in the bulge of the Whirlpool galaxy and the implication for starformation in the early Universe*

Thursday 9 November, NOVA Colloquium
Frans Rietmeijer, Astronomical Institute of the University of Amsterdam, *Laboratory Analyses of Collected Cometary Dust*

Friday 10 November
Martin Hendry, Univ. of Glasgow, *Gravitational microlensing as a tool for stellar astrophysics*

Thursday 30 November
Karel van der Hucht, SRON Utrecht, *The observed Wolf-Rayet population compared to other massive stars in the Milky Way and other Local Group galaxies*

Thursday 7 December
Jane Dennett-Thorpe, Astronomical Institute of the University of Amsterdam, *The local ISM and AGN*

Monday 11 December, graduation colloquium
Seppe Hoogzaad, Astronomical Institute of the University of Amsterdam, *The properties of water ice and other dust components round HD161796*

Friday 22 December, Christmas colloquium
Emeritus Prof. André Köbben, Culturele Antropologie Univ. van A'dam & Leiden, *Gemengde Gevoelens*
APPENDIX VI

A. PARTICIPATION IN SCIENTIFIC MEETINGS

(Details about the scientific talks presented at these meetings at these meetings are given in the next section (B))

MIDI consortium meeting, Max Planck Institute for Astronomy, Heidelberg, Germany, January 10-11
R. Waters

“ISO beyond the peaks”, 2nd ISO workshop on analytical spectroscopy, Madrid, Spain, February 2 – 4
S. Hony (talk)
C. Kemper
A. de Koter (poster)
A. Lenorzer
F. Molster
R. Waters (talk)

International Astronomical Union (IAU) Task Group on Designations, Strasbourg, France, February 24-28
H. Dickel

MIDI Final Design Review, ESO, Garching, Germany, February 29
R. Waters

“Star 2000”, Conference on stellar astronomy, Max Planck Institute for Astronomy, Heidelberg, Germany, March 19–25
G.A. Nelemans

“Rossi 2000: Astrophysics with the Rossi X-ray timing explorer”, NASA’s Goddard Space Flight Center, Greenbelt, USA, March 22-24
R. Fender (invited talk)
J. Homan (poster)
P. Jonker (talk)

SPIE meeting Munich, Germany, March 27-29
R. Waters

“High-energy spectroscopic astrophysics”, 30th SAAS FEE course, Diablerets, Switzerland, April 3–8
P. Vreeswijk

ALMA workshop (preparing for Atacama Large Millimeter Array), Leiden, April 7
R. Waters (talk)

International Astronomical Union Symposium 2000 “The Formation of Binary Stars, Potsdam, Germany, April 8-13
H. Dickel (talk)
Joint AstroParticle & High Energy Physics theory seminar, ITF/Nikhef, Amsterdam, April 17
L. van den Horn (talk)

“Oort Workshop on Black Holes”, Leiden, April 17-19
E.P.J. van den Heuvel (invited talk)

International Astronomical Union Colloquium 182 “Sources and Scintillations: Diffraction and Scattering in Astronomy”, Guiyang City, China, April 17-21
R. Ramachandran

Radio Imaging School, Jodrell bank, Radio Observatory, Manchester, UK, April 25–28
R. Fender (invited talk)
E. Rol

“Oort Symposium” commemorating Prof. J.H. Oort’s 100th birthday, Leiden, April 25–27
C. Neiner
H.F. Henrichs
L. Kaper
E.P.J. van den Heuvel (invited talk)

MIDI meeting ASTRON, Dwingeloo, May 3-4
R. Waters

ISSI Workshop on interstellar dust, Bern, Switzerland, May 8–12
F. Molster
R. Waters

Nederlandse Astronomen Conferentie, Dalfsen, May 10–12
S. Hony (poster)
P. Jonker (talk)
L. Kaper (talk)
C. Kemper (talk)
A. de Koter (invited talk)
C. Neiner (poster)
G.A. Nelemans (talk)
M. Witte (talk)
R. van Boekel

Max Planck Institut für Astrophysiks, Garching, Germany, May 14-19
R. Fender (talk)

Discussion Future of Dutch Astronomy, instigated by Advies Commissie Astronomie van Gebieds Bestuur-E, NWO, Tiel, May 18–19
E.P.J. van den Heuvel
A.de Koter
L. Kaper
H.F. Henrichs
T. de Jong
L.B.F.M. Waters
JIVE, Dwingeloo, May 26  
R. Fender (talk)

JENAM 2000, Moscow, Russia, May 29 – June 2  
H. Dickel (talk)

Musicos workshop on Stellar Pulsations, ESTEC, June 4–7  
C. Neiner (talk)

Astronomy in Ukraïne 2000 and beyond, Kiev, Ukraïne, June 5–7  
H. Dickel

International School of Space Chemistry on “Solid State Astrophysics”, Erice, Italy, June 5–16  
S. Hony (talk)  
C. Kemper

Lorentz Center workshop on the origin and evolution interstellar PAHs, Leiden, June 22  
S. Hony (talk)  
R. Waters (talk)

“Gamma Ray astronomy 2000”, Max Planck Institute for Astronomy, Heidelberg, Germany, June 25-30  
R. Fender (invited talk)

“Evolution of binary and multiple star systems”, Bormio, Italy, June 25 – July 1  
J. Dewi  
G. Savonije (talk)  
E.P.J. van den Heuvel (invited talk)

MIDI science team meeting, Observatoire de Nice, France, June 30–July 3  
R. Waters  
R. van Boekel (talk)

“Workshop on Nuclear Physics”, Trento, Italy, July 1-3  
E.P.J. van den Heuvel (2 invited talks)

“The ninth Marcel Grossmann Meeting on General Relativity”, Rome, Italy, July 2–8  
P. Jonker (talk)

“Post-AGB objects as a phase of stellar evolution”, Torun, Poland, July 7  
S. Hony (talk, poster)

MIDI consortium meeting, Max Planck Institute for Astronomy, Heidelberg, Germany, July 19-21  
R. Waters

General Assembly, International Astronomical Union, Manchester, UK, August 7-13  
A. Bik  
L. Kaper  
R. Waters (talk)
E.P.J. van den Heuvel (official representative of the Netherlands)

“The influence of binaries on stellar population studies”, Brussels, Belgium, August 21–25
L. Kaper
G.A. Nelemans (poster)
E.P.J. van den Heuvel (member of Scientific Organisation Committee/Discussion Chair)

3rd Microquasar workshop, Granada, Spain, September 11-13
R. Fender (invited talk)

NOVA/ESO school on interferometry, Leiden, September 19
R. Waters (talk)
R. van Boekel

Herbsttagung der Deutschen Astronomischen Gesellschaft, Bremen, September 20
C. Dominik

Dwingeloo discussion meeting on neutron Stars, ASTRON, Dwingeloo, September 21–22
G.A. Nelemans (talk)
B.W. Stappers (talk)
M. Witte (talk)
R. Ramachandran (talk)
E.P.J. van den Heuvel (talk)
R. Fender (talk)

“Similarities and universalities in relativistic flows”, EC conference, Mykonos, Greece, October 1-5
R. Fender

“Spin and magnetic fields of young pulsars” Institute of Theoretical Physics, Santa Barbara, USA, October 2-6
B.W. Stappers

“Gamma Ray Burst in the afterglow era”, 2nd workshop, Rome, October 16–21
E. Rol
P. Vreeswijk (talk)
E.P.J. van den Heuvel (invited talk)

NOVA Fall School, Dwingeloo, October 23–27
A. Bik (talk)
R. Dijkstra (talk)
S. Hony (talk)
C. Neiner (talk)
E. Rol
S. van Straaten (talk)
L. Kaper (teacher)

“Herbig Ae/Be stars, international workshop on intermediate mass pre-main-sequence stars, Amsterdam, October 25–27
C. Dominik (talk)
F. Kemper
R. Waters (organiser)

INTAS coordination meeting, Amsterdam, October 28
R. Waters

Observatory of Milano, Merate, Italy, November 7
R. Ramachandran (talk)

12th Winter school “Spectropolarimetry”, Institute of Astrophysics Canarias, Tenerife, Spain, November 13-24
C. Neiner (poster)

JCMT board meeting, Hilo, Hawaii, November 14-19
R. Waters

University of Sydney, November 23
R. Fender (talk)

MIDI Science team meeting, Max Planck Institut für Astronomie, Heidelberg, Germany, November 28
R. Waters

Australia National Telescope Facility, November 30
R. Fender (talk)

MIDI consortium meeting, ASTRON, Dwingeloo, December 6-7
R. Waters

Raman Research Institute, Bangalore, India, December 15
R. Ramachandran (talk)

“Cosmic explosions”, winterschool, Jeruzalem, Israel, December 27 – January 5
P. Vreeswijk (talk and poster)

B. SCIENTIFIC TALKS at ASTRONOMICAL INSTITUTES and CONFERENCES

A. Bik
- Catching Massive Stars at Birth?, Nova Fallschool, ASTRON, Dwingeloo, October 24

R. van Boekel
- Model predictions for MIDI observations of circumstellar disks, Nice, July 3

H. Dickel
- Colloquium on “Molecules in Space”, Strasbourg Observatory, Strasbourg, February 24-28
- Lead lunch discussion “New International Astronomical Union Concepts of Binary/Multiple Star Designation”, Potsdam, Germany, April 8-13
- Designations of astronomical sources and International Astronomical Union Task Group on Designations, Moscow, Russia, May 29 – June 2
- The star forming regions W49 A North and W58 C, Kiev, Ukraïne, June 5-7
C. Dominik
- *Vega-like stars*, University of Florida, Gainsville, Florida, January 21
- *Dust coagulation*, TU Braunschweig, May 23
- *Vega-like stars*, University of Groningen, June 16
- *Collisional evolution of vega disks*, Herbsttagung der Deutschen Astronomischen Gesellschaft, Bremen, September 20
- *Collisional evolution of vega disks*, “Herbig Haebe stellar discs column between accretion debris”, Amsterdam, October 26

C. Dijkstra
- *The atmospheres of evolved stars*, ASTRON, Dwingeloo, October 24

G. Dubus
- *The disc instability model*, Max Planck Institut für Astrophysik, Garching, Germany, January 14
- *The disc instability model*, University of Southampton, UK, 15 March
- *The physics of accretion*, INTEGRAL Workshop, Toulouse, France, 16 – 17 May

R. Fender
- *Relativistic jets from X-ray binaries: recent developments*, Astron. Institute, Univ. of Amsterdam, January 31
- *The balance of power: accretion and outflow in X-Ray Binaries*, MPA, Germany, May 18
- *The balance of power: accretion and outflow in X-Ray Binaries*, JIVE, Dwingeloo, May 26
- *The disc: jet connection in X-Ray Binaries*, Workshop on compact objects, Dwingeloo, September 21-22
- *The disc: jet connection in X-Ray Binaries*, University of Sydney, November 23
- *The disc: jet connection in X-Ray Binaries*, Australia National Telescope Facility, November 30

E. Ford
- *Probing neutron stars with x-ray timing observations*, Observatorio di Roma, Italy, 10 February

E.P.J. van den Heuvel
- *The Scientific Legacy of Jan van Paradijs*, Algemeen Natuurkundig Colloquium, Universiteit van Amsterdam, January 20
- *In Memoriam Jan van Paradijs*, Nederlandse Astronomen Club, Amsterdam, March 6
- *Black Hole X-ray Binaries*, Seminar Theoretical Physics, Utrecht University, March 15
- *The Legacy of Jan van Paradijs in Gamma Ray Burst Research*, Ehrenfest Colloquium, Leiden University, March 29
- *Black Holes Resulting from the Collapse of Massive Stars*, Oort Workshop on Black Holes, Leiden University, April 18
- Information on nuclear Equation of State derived from X-ray Binaries and Binary Pulsars, Trento Workshop on Nuclear Physics, Trento, Italy, July 3
- Formation of binary radio pulsars with massive white dwarf companions, Dwingeloo Workshop on Neutron Stars, ASTRON, September 22
- The Scientific Legacy of Jan van Paradijs, 2nd Symposium “Gamma Ray Bursts in the Afterglow-Eva”, Rome, October 16
- Formation of binary radio pulsars with massive white dwarf companions, Institute for Theoretical Physics, University of California, Santa Barbara, November
- KiloHertz Quasi-Periodic Oscillations in X-ray Binaries, Institute for Theoretical Physics, UC Santa Barbara, November
- Black Hole X-ray Binaries, Astronomy Colloquium, RU Groningen, December 14

J. Homan
- XTE J1550--564: a new interpretation of black hole behavior, American Museum of Natural History/ Rose Center for Earth and Space Science, New York, USA, 8 August
- XTE J1550--564: a new interpretation of black hole behavior, Columbia University, New York, NY, USA, 11 August
- XTE J1550--564: a new interpretation of black hole behavior, NASA Goddard Space Flight Center, Greenbelt, MD, USA, 15 August
- XTE J1550--564: a new interpretation of black hole behavior, MIT Center for Space Research, Cambridge, MA, USA, 21 August
- XTE J1550--564: a new interpretation of black hole behavior, Harvard Center for Astrophysics, Cambridge, MA, USA, 23 August

S. Hony
- The CH out-of-plane bending modes of PAH molecules in astrophysical environments, “ISO beyond the peaks”, 2nd ISO workshop on analytical spectroscopy, Madrid, Spain, February 2-4
- The CH out-of-plane bending modes of PAH molecules in astrophysical environments (poster), Nederlandse Astronomen Conferentie, Dalfsen, May 10-12
- The CH out-of-plane bending modes of PAH molecules in astrophysical environments, International School of Chemistry on Solid State Astrophysics, Erice, Italy, June 5-16
- The CH out-of-plane bending modes of PAH molecules in astrophysical environments, Workshop on the origin and evolution of interstellar PAHs, Leiden, June 22
- On the carrier of the 20 en 30 micron features (talk) & PAH around PNe with [WC] central stars (poster), “Post-AGB objects (Proto-Planetary Nebulae) as a phase of stellar evolution”, Torun, Poland, July
- Carbon rich dust around evolved star, Nova Herfstschool, Dwingeloo, The Netherlands, October 23-27

L. van den Horn
- Basic big bang and beyond, Joint AstroParticle & High Energy Physics theory seminar, ITF/Nikhef, Amsterdam, April 17

P. Jonker
- 1Hz quasi-periodic oscillations in three dippers, Nederlandse Astronomen Conferentie, Dalfsen May 10–12
- A third kHz quasi-periodic oscillation in three atoll sources, The ninth Marcel Grossmann meeting, Rome, Italy July 2-8
- *The Third kHz QPO in the X-ray Emission of Three Neutron Stars; A Sign of General Relativistic Effects?*, CalTech, Pasadena: November 27
- *The Third kHz QPO in the X-ray Emission of Three Neutron Stars; A Sign of General Relativistic Effects?*, Univ. of Berkeley, Berkeley, November 29
- *The Third kHz QPO in the X-ray Emission of Three Neutron Stars; A Sign of General Relativistic Effects?*, Center for Astrophysics, Boston, December 6
- *The Third kHz QPO in the X-ray Emission of Three Neutron Stars; A Sign of General Relativistic Effects?*, MIT, Boston, December 7

**L. Kaper**
- *High-mass X-ray binaries and OB-runaway stars*, colloquium Physics and Astronomy Dept. Vrije Universiteit, Amsterdam, April 4
- *Probing the young massive stars in ultra-compact H II regions*, SUA-meeting, Brussels, April 7
- *Catching massive stars at birth*, Nederlandse Astronomen Conferentie, Dalfsen, May 9
- *Probing the young massive stars in ultra-compact H II regions*, Astronomisches Institut, Ruhr Universität Bochum, Germany June 27
- *Nomenclature of X-ray binaries*, “Designation of stellar binaries” multi-commission meeting General Assembly IAU, Manchester, UK, August 11
- *Observations of high-mass X-ray binaries and OB-runaway stars*, invited review at “The influence of binaries on stellar population studies”, Brussels, August 22
- *Observations and evolution of massive stars*, Nova Fall School, Dwingeloo, October 23-27
- *Probing the young massive stars in ultra-compact H II regions*, colloquium Leidse Sterrenwacht, Universiteit Leiden, December 7
- *Probing the young massive stars in ultra-compact H II regions*, colloquium Kapteyn Instituut, Universiteit Groningen, December 8

**F. Kemper**
- *Crystallinity versus mass-loss rate in asymptotic giant branch stars*, Nederlandse Astronomen Conferentie, Dalfsen, May 11
- *Crystallinity versus mass-loss rate in asymptotic giant branch stars*, International School of Space Chemistry “Solid State Astrochemistry”, Erice, Italy, June 5-16

**M. Klein Wolt**
- *New insights in the behaviour of the black hole candidate GRS1915+105*, Sterrenkundig Instituut, Univ. Utrecht, June 22

**A. de Koter**
- *Discovery of a massive equatorial torus in the eta Carinae stellar system*, Nederlandse Astronomen Club, Amsterdam, March 6
- *Discovery of a massive equatorial torus in the eta Carinae stellar system*, Kapteyn Sterrenkundig Instituut, Groningen, June 23
- *Discovery of a massive equatorial torus in the eta Carinae stellar system*, Nederlandse Astronomen Conferentie, Dalfsen, May 11

**F. Molster**
- *Crystalline silicates: a new world opened by ISO*, Vrije Universiteit, Amsterdam, April 18

**C. Neiner**
- *Preliminary results on the Be star omega Ori from the Musicos 98 campaign*, Musicos workshop, ESTEC, June 4-7
G.A. Nelemans
- *Formation and Evolution of close double white dwarfs*, Institute of Astronomy, Cambridge, UK, May 3
- *Formation and Evolution of close double white dwarfs*, University of Southampton, May 4
- *Formation and Evolution of close double white dwarfs*, Mullard Space Science Laboratory (University College London), May 9
- *Formation and Evolution of close double white dwarfs*, NAC, Dalfsen, May 11
- *Formation and Evolution of close double white dwarfs*, State University of New York, Stony Brook, USA, July 5
- *Runaway velocities of Black-hole and Neutron star binaries*, State University of New York, Stony Brook, USA July 11
- *The Most Compact Mass-Transferring Binaries*, Harvard University, Cambridge, USA, August 3
- *Detached and semi-detached double white dwarfs*, Workshop on Neutron Stars, Dwingeloo, September 22

R. Ramachandran
- *High-resolution spectroscopy with baseband recording*, Dwingeloo, August
- *Discrete scattering events in the interstellar medium*, Dwingeloo Discussion Meeting on Neutron Stars, September 22
- *Discrete irefractive scattering events in the interstellar medium*, Observatory of Milano, Merate, Italy, November 7
- *Microstructures of Pulsars*, Raman Research Institute, Bangalore, India, December 15

G. Savonije
- *Tidal evolution of massive, eccentric binary systems: effects of resonance locking*, “Evolution of binary and multiple star systems”, Bormio, Italy, June 29
- *Tidal evolution in massive binary systems*, NORDITA, Copenhagen, November 21

B.W. Stappers
- *Pulsar timing using PuMa and WSRT*, Meeting Dwingeloo, September 22

S. van Straaten
- *Neutron Stars and Blackhole Candidates in Low Mass X-ray Binaries*, Dwingeloo, October 26

P. Vreeswijk
- *Rapid spectroscopy of GRB afterglows*, “Gamma-ray bursts in the afterglow era”, Rome, Italy, October 18
- *Looking for orphans afterglows with the FSVS*, “Cosmic explosions”, Jeruzalem Winter School, Israel, December 29

L. Waters
- *The life cycle of interstellar dust*, workshop "ISO beyond the peaks", Madrid, February 2-4
- *ALMA observations of circumstellar disks*, Leiden, at ALMA workshop, April 7
- *Crystalline silicates in space*, at ISSI workshop on interstellar dust, Bern, Switzerland, May 8-12
- *Building Planets*: colloquium, AMOLF, Amsterdam, May 29
- The evolution of circumstellar dust in C-rich evolved stars, Leiden, Lorentz center workshop on interstellar PAHs, June 22
- Crystalline silicates, at Joint discussion 1, IAU General Assembly, Manchester, U.K., August 9
- Dust in proto-planetary nebulae, at Joint Discussion 4, IAU General Assembly, U.K. August 13
- Circumstellar matter and interferometry, at NOVA/ESO school on interferometry, Leiden, September 19

M. Witte
- Tidal evolution of eccentric binary orbits, Dwingeloo discussion meeting on Neutron Stars, September 22
- Orbital evolution of eccentric binary systems due to resonant excitation of stellar oscillations, Nederlandse Astronomen Conferentie, Dalfsen, May 11
OBSERVING SESSIONS

G. Dubus
ESO, NTT, Chile, 27–28 August

L. Kaper

F. Kemper
James Clark Maxwell Telescope, Hawaii, 5 – 11 July

C. Neiner
TBL, Pic du Midi, France (spectropolarimetry), 19 – 26 June, 29 June – 16 July, 21 – 28 September, 16 – 21 December

G.A. Nelemans
JKT, La Palma, February 11-21

E. Rol
Dutch Telescope, La Silla, Chile, 21 November – 20 December

P. Vreeswijk
Marly telescope (EROS collaboration), La Silla, Chili, 19 January – 2 February
Isaac Newton Telescope, La Palma, 28 May – 3 June

R. Waters
JCMT observing run, Hawaii, July 5-12
APPENDIX VIII

WORK VISITS TO INSTITUTES ABROAD

A. Bik
- University of Cincinnati, USA, November 8-22

C. Dominik
- Max Planck Institut für Astrophysik, Garching, Germany, October 29 – November 5

G. Dubus
- Max Planck Institut für Astrophysik, Garching, Germany, January 7–14
- Institut d’Astrophysique, Paris, France, April 28 – May 5
- Princeton Institute for Advanced Study, USA, July 24 – August 4

R. Fender
- Max Planck Institut für Astrophysik, Garching, Germany, May 14-19
- Research Centre for Theoretical Astrophysics, Univ. of Sydney, Australia, November 23-30

E. Ford
- Observatorio di Roma, Italy, January 10 – February 17

E.P.J. van den Heuvel
- “Sax Science Steering Committee” for Italian-Dutch Satellite BeppoSAX, ASI, Rome, January 17
- Adviescommissie Fysica en Astronomie, NFWO-Vlaanderen, Brussel, January 21
- ETH-Zürich, Advisory Committee Chair in Experimental Astrophysics, March 21-22
- European Southern Observatory, Garching, Germany, Committee of Council, April 4
- Jury International Franqui Prize, Brussels, Belgium, April 28-29
- Meeting of Electors, Plumian Professorship, Cambridge University, UK, May 9-10
- Adviescommissie Fysica en Astronomie, NFWO-Vlaanderen, Brussels, Belgium, May 11-12
- European Southern Observatory Council, Garching, Germany, June 13-14
- Visiting Committee Swedish Astronomy (Stockholm, Uppsala, Gotheburg, Lund), June 17-22
- ETH-Zürich, Advisory Committee Chair in Experimental Astrophysics, June 23-24
- International Advisory Board Interuniversity Center For Astronomy and Astrophysics (IUCAA), Puna, India, July 8-16
- Raman Research Institute and Indian Space Institute, Bangalore, India, July 17-20
- “Sax Science Steering Committee” (SSSC), ASI, Rome, Italy, October 25-26
- Institute for Theoretical Physics, University of California, Santa Barbara, October 31–November 23 and November 27-December 10

J. Homan
- Harvard Center for Astrophysics, MIT/Center for Space Research, Cambridge, USA, March 28 – April 4

S. Hony
- University of Jena, Astrophysical Laboratory, Germany, May 16–17

P. Jonker
- MIT Center for Space Research, Cambridge, USA, March 26 – April 6
- Center for Astrophysics, Cambridge, USA, March 26 – April 6
L. Kaper
- European Southern Observatory VLT/UVES Commissioning III, Paranal, Chile, January 8–18

C. Kemper
- University of Jena, Astrophysical Laboratory, Germany, May 16–17
- University of Jena, Astrophysical Laboratory, Germany, December 4–8

A. de Koter
- University of Jena, Astrophysical Laboratory, May 16–17

G.A. Nelemans
- Institute of Astronomy, University of Cambridge, UK, May 2-3
- Astrophysics Group, University of Southampton, UK, May 3-9
- Mullard Space Science Laboratory, Univ. College London, UK, May 10
- State University of New York at Stony Brook, USA, July 3-20
- Boston University, Boston, USA, July 24-30
- Harvard University, Center for Astrophysics, Cambridge, USA, July 31-August 8

R. Ramachandran
- Observatory of Milano, Merate, Italy, November 7
- Raman Research Institute, Bangalore, India, December 15

E. Rol
- Radio Sterrenwacht, Dwingeloo January 24–February 5
- University of Huntsville, Alabama, USA, September 11–October 6

G. Savonije
- Northern Institute for Theoretical Physics and Astrophysics, NORDITA, Copenhagen, November 18–23

B.W. Stappers
- MIT, Center for Space Research, Cambridge, USA, June 28-29

R. Waters
- University of Western Ontario, Canada: thesis defense of Carol Millar, March 22-26
- Friedrich Schiller University, Jena, Germany, May 16-17
- California Institute of Technology (Caltech), Pasadena, USA, July 13-14
APPENDIX IX

SCIENTIFIC PUBLICATIONS

IX.1 Books


IX.2 Dissertations


IX.3 High Energy Astrophysics

Publications in international refereed journals


**GCN Circulars**


**IAU Circulars**


**Publications in conference proceedings**


81


Yu, W., Klis, M.B.M. van der, Jonker, P.G. & Li, T.P. (2000). Dependence of the Kilohertz QPO Frequency on the X-ray Variabilities at Lower Frequencies in Sco X-1. In American Astronomical, Society (Ed.), HEAD meeting #32, Late Abstracts #44.06.

Publications in non-refereed journals


Populariserende publicatie


IX.4 Low Energy Astrophysics

Publications in international refereed journals


**Publications in conference proceedings**


**Populariserende publicatie**


**Abstract**

# APPENDIX X

## Phonenumbers and e-mail addresses

<table>
<thead>
<tr>
<th>Phone</th>
<th>Name</th>
<th><a href="mailto:user@astro.uva.nl">user@astro.uva.nl</a></th>
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<tr>
<td>7491</td>
<td>J. Ayal</td>
<td>jane</td>
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<td>A. Bik</td>
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<tr>
<td>*025097</td>
<td>P. Blondel</td>
<td><a href="mailto:blondel@sara.nl">blondel@sara.nl</a></td>
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<td>L. van den Horn</td>
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<td>V. Icke</td>
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<td>7489</td>
<td>L. van Iterson</td>
<td><a href="mailto:liesbeth@wins.uva.nl">liesbeth@wins.uva.nl</a></td>
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APPENDIX XI

OVERZICHT VAN DE STERRENKUNDESTUDIE (uit studiegids)

5.4 DE DOCTORAALSTUDIE STERRENKUNDE (4 jaar)

5.4.1 Opbouw van de studie
Hieronder is een schematische opbouw weergegeven van het doctoraalprogramma van de vierjarige studie sterrenkunde vanaf het derde jaar, zoals die in het cursusjaar 2000-2001 wordt gegeven. Voor het tweede jaar van de vierjarige studie zie studiegids 1999-2000. Met ingang van dit cursusjaar is het tweedeaarsprogramma gewijzigd, zie par. 5.1.4. Overgangsregelingen staan in par. 5.3.12.

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Het studieprogramma voor het doctoraalexamen sterrenkunde, heeft een omvang van 126 studiepunten en omvat de volgende onderdelen:
- het verplichte pakket 53 studiepunten
- het differentiatiepakket 28-32 studiepunten
- het stagepakket 34 studiepunten
- communicatie & presentatie & arbeidsoriëntatie 7 studiepunten
- vrije keuze 0-4 studiepunten

Er bestaat een mogelijkheid om dubbel doctoraal natuurkunde en sterrenkunde te doen (par. 5.3.8).

Studenten hebben de mogelijkheid om een majorprogramma sterrenkunde (par. 5.5.6) te combineren met een minorprogramma ter grootte van 42 studiepunten van een andere opleiding. Daarnaast bestaat de mogelijkheid om een doctoraalexamen sterrenkunde vrije richting (par. 5.5.7) af te leggen.

Het verdient aanbeveling om bij het begin van het Eigen werk IV het gekozen vakkenpakket via de studie-adviseur ter goedkeuring voor te leggen aan de examencommissie. Bij de beoordeling wordt wat betreft de keuzevakken WNS gelet op het niveau en de samenhang van de opgenomen vakken. De minimale omvang van het vakkenpakket is 126 studiepunten, de maximale omvang wordt nog nader vastgesteld.

5.4.2 Het verplichte pakket
Het verplichte pakket omvat voor alle afstudeerrichtingen examenonderdelen met een totale omvang van 53 studiepunten.

5.4.3 Het differentiatiepakket
Voor elke afstudeerrichting binnen het doctoraalprogramma sterrenkunde is een aantal vakken opgenomen dat voor die afstudeerrichting vereist, dan wel van belang is.
5.4.4 Het stagepakket
Het Eigen werk in het stagepakket is het belangrijkste onderdeel van de studie, dat bestaat uit het meewerken aan een onderzoeksproject op een instituut waar wetenschappelijk onderzoek wordt verricht. De student werkt ongeveer een jaar op basis van halve werktijd in een groep astronomen en leert er zelfstandig onderzoek te doen. Uit het aanbod van mogelijke plaatsen moet een keuze gemaakt worden. Neem hiervoor contact op met de onderwijscoördinator dr. G.J. Savonije, tst. 7497. Het boekje ‘Eigen werk’, dat verkrijgbaar is op de studentenadministratie, biedt een overzicht van onderzoeken waaraan kan worden deelgenomen. De begeleiders van het Eigen werk staan daar met naam en telefoonnummer genoemd.
Het Eigen werk bestaat uit twee afzonderlijke delen:

- Eigen werk III: dit is het deel Eigen werk in het tweede doctoraaljaar met een omvang van 7 studiepunten.
- Eigen werk IV: dit heeft een omvang van 27 studiepunten en wordt uitgevoerd op het Sterrenkundig Instituut ‘Anton Pannekoek’. De waarneemstage (2 studiepunten) heeft als doel het opdoen van praktische ervaring met waarneemwerk op een sterrenwacht en kan doorgebracht worden op een radiosterrenwacht (b.v. in Dwingeloo/Westerbork), of op een sterrenwacht of satellietgrondstation in binnen- of buitenland (dit laatste is alleen het geval als dit in het kader van het overige afstudeerwerk past). Gedurende het tweede en derde doctoraaljaar is deelname aan het sterrenkunde-colloquium verplicht. Ook dit onderdeel heeft een omvang van 2 studiepunten. De onderzoekstage zelf omvat 23 studiepunten en wordt afgerond met het schrijven van een scriptie en het geven van een colloquium over deze scriptie. Dit colloquium moet worden afgesproken met de colloquium-coördinator dr. A. de Koter, tst. 7496. De scriptie zal ter discussie staan tijdens het af te leggen doctoraalexamen.

5.4.5 Communicatie, presentatie en oriëntatie
Tijdens het onderzoek voor het Eigen Werk zal er geregeld een tussentijdse voordracht over het verrichte onderzoek of de bestudeerde literatuur moeten worden gegeven. Dit wordt gecoördineerd door de stagebegeleider. Deze zal er op toezien dat de communicatieve vaardigheden van de student worden getraind. Voor een juiste invulling van de studiepunten zie bij de vakomschrijving.

5.4.6 Vrije keuze
De vrije keuze bestaat uit doctoraalvakken, bij voorkeur of uit vakken uit de natuurkunde, sterrenkunde, wiskunde of informatica of uit samenhangende vakken daarbuiten, gekozen uit het aanbod dat aan een Nederlandse universiteit wordt gedoceerd.

5.4.7 Doelstellingen van de opleiding en eindtermen
Bij de beëindiging van de opleiding dient de student zich de volgende kwaliteiten op het gebied van kennis, inzicht en vaardigheden te hebben verworven:

Ruime theoretische en praktische kennis en vaardigheden op het gebied van de natuur- en sterrenkunde op een zodanig niveau, dat op zelfstandige wijze vragen op het gebied van de sterrenkunde kunnen worden geformuleerd en geanalyseerd; kennis van de wiskunde en de informatica met een omvang en diepgang zoals nodig voor de beoefening van de sterrenkunde; inzicht in de betekenis van de sterrenkunde in de context van de wetenschap en de samenleving.
5.5 DE DOCTORAALPROGRAMMA'S STERRENKUNDE (4 jaar)

5.5.1 Het eerste doctoraaljaar zie: studiegids 1999-2000

5.5.2 Het tweede doctoraaljaar

Het tweede doctoraaljaar bestaat naast de resterende vakken uit het verplichte pakket met een omvang van 11 studiepunten voornamelijk uit vakken behorende tot het differentiatie pakket. Keuzevakken behoeven altijd de goedkeuring van de examencommissie.

<table>
<thead>
<tr>
<th>studiepunten</th>
<th>trimester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natuurkunde Theorie III:</td>
<td></td>
</tr>
<tr>
<td>Klassieke fysica III A</td>
<td>3</td>
</tr>
<tr>
<td>Quantumfysica III A</td>
<td>3</td>
</tr>
<tr>
<td>Klassieke fysica III B</td>
<td>2</td>
</tr>
<tr>
<td>Quantumfysica III B</td>
<td>3</td>
</tr>
</tbody>
</table>

Het doctoraalexamen kent de volgende afstudeerrichtingen:
- algemene sterrenkunde
- computationele sterrenkunde

5.5.3 De afstudeerrichting algemene sterrenkunde

Het programma voor het doctoraalexamen sterrenkunde, afstudeerrichting algemene sterrenkunde, omvat de volgende onderdelen:

<table>
<thead>
<tr>
<th>studiepunten</th>
<th>trimester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verplicht pakket</td>
<td>53</td>
</tr>
<tr>
<td>Differentiatiepakket</td>
<td>28</td>
</tr>
<tr>
<td>Hydrodynamica van vloeistoffen en plasma's</td>
<td>4</td>
</tr>
<tr>
<td>Steratmosferen</td>
<td>4</td>
</tr>
<tr>
<td>Interstellaire en circumstellaire materie</td>
<td>4</td>
</tr>
<tr>
<td>Bouw en evolutie van sterren</td>
<td>4</td>
</tr>
<tr>
<td>Kosmologie</td>
<td>4</td>
</tr>
<tr>
<td>Keuze in Sterrenkunde</td>
<td>8</td>
</tr>
<tr>
<td>Eigen werk:</td>
<td>34</td>
</tr>
<tr>
<td>Eigen werk III</td>
<td>7</td>
</tr>
<tr>
<td>Eigen werk IV</td>
<td>27</td>
</tr>
<tr>
<td>Colloquium</td>
<td>2</td>
</tr>
<tr>
<td>Waarneemstage</td>
<td>2</td>
</tr>
<tr>
<td>Onderzoekstage</td>
<td>23</td>
</tr>
<tr>
<td>Communicatie, presentatie en oriëntatie:</td>
<td>7</td>
</tr>
<tr>
<td>Vrije keuze:</td>
<td>4</td>
</tr>
</tbody>
</table>

De colleges uit het differentiatiepakket zijn geavanceerde colleges waarin de hoofdonderdelen van het vak verder worden uitgediept. De vier verplichte colleges worden om het jaar gegeven, als volgt:

<table>
<thead>
<tr>
<th>00/01</th>
<th>01/02</th>
<th>02/03</th>
<th>03/04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steratmosferen</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Interstellaire en circum stellaire materie</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Bouw en evolutie van sterren</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Kosmologie</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

Voor het vijfde en zesde college kan er een keuze worden gemaakt uit een aantal caputcolleges sterrenkunde over speciale onderwerpen, zoals moleculaire wolken, hoge-energie-astrofysica, etc. Daarnaast is er het interacademial college sterrenkunde dat start in januari en waarvan het onderwerp van jaar tot jaar wisselt.
5.5.4 De afstudeerrichting computationele sterrenkunde
Het programma voor het doctoraalexamen sterrenkunde, afstudeerrichting computationele sterrenkunde, omvat de volgende onderdelen:

<table>
<thead>
<tr>
<th>studiepunten</th>
<th>trimester</th>
</tr>
</thead>
<tbody>
<tr>
<td>53</td>
<td></td>
</tr>
</tbody>
</table>

Verplicht pakket 53

Differentiatiepakket 32

<table>
<thead>
<tr>
<th>Studiepunten</th>
<th>Trimester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steratmosferen</td>
<td>I</td>
</tr>
<tr>
<td>Bouw en evolutie van sterren</td>
<td>I</td>
</tr>
<tr>
<td>Kosmologie</td>
<td>II</td>
</tr>
<tr>
<td>Numerieke sterrenkunde</td>
<td>II</td>
</tr>
<tr>
<td>Architectuur en parallel rekenen</td>
<td>I</td>
</tr>
<tr>
<td>Parallel wetenschappelijk rekenen en simulatie</td>
<td>III</td>
</tr>
<tr>
<td>Keuze binnen ‘Computational science’ of ‘Sterrenkunde’*</td>
<td>6</td>
</tr>
</tbody>
</table>

Eigen werk: 34

| Eigen werk III | 7 | III |
| Eigen werk IV | 27 |
| Colloquium | 2 | I-III |
| Waarneemstage | 2 |
| Onderzoekstage | 23 | I-III |

Communicatie, presentatie en oriëntatie: 7

De sterrenkundecolleges uit het differentiatiepakket zijn geavanceerde colleges waarin de hoofdonderdelen van het vak verder worden uitgediept. De colleges worden om het jaar gegeven (zie voor schema 5.5.3).

* Hierbij mag ook het college Hydrodynamica worden gekozen.

5.5.5 Het dubbeldoctoraal sterrenkunde en natuurkunde
Na het afleggen van de propedeuse sterrenkunde/natuurkunde is het mogelijk een dubbeldoctoraal programma sterrenkunde en natuurkunde te volgen. Het programma bestaat uit een combinatie van de opleiding sterrenkunde en de afstudeerrichting experimentele/theoretische natuurkunde. Het totale aantal studiepunten bedraagt 158. Een student die belangstelling heeft voor dit programma dient zo spoedig mogelijk contact op te nemen met de studieadviseur.

Hieronder is de opbouw van het doctoraalprogramma vanaf jaar 3 schematisch weergegeven.

<table>
<thead>
<tr>
<th>2000-2001</th>
<th>trimester I</th>
<th>trimester II</th>
<th>trimester III</th>
</tr>
</thead>
<tbody>
<tr>
<td>3e jaar</td>
<td>Klassieke fysica III A</td>
<td>Klassieke fysica III B</td>
<td>Eigen werk III</td>
</tr>
<tr>
<td></td>
<td>Quantumfysica III A</td>
<td>Quantumfysica III B</td>
<td>Presentatie Eigen werk III</td>
</tr>
<tr>
<td></td>
<td>Steratmosferen/Bouw en</td>
<td>Statistische fysica III A</td>
<td>Statistische fysica III B</td>
</tr>
<tr>
<td></td>
<td>evolutie van sterren</td>
<td>Kosmologie/Interstellaire en</td>
<td>keuzevakken</td>
</tr>
<tr>
<td></td>
<td>Hydrodynamica</td>
<td>circumstellaire materie</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>keuzevakken</td>
<td></td>
</tr>
<tr>
<td>4e en 5e jaar</td>
<td>Eigen werk IV</td>
<td>Eigen werk IV</td>
<td>Eigen werk IV</td>
</tr>
<tr>
<td></td>
<td>Steratmosferen/Bouw en</td>
<td>Kosmologie/Interstellaire en</td>
<td>keuzevakken</td>
</tr>
<tr>
<td></td>
<td>evolutie van sterren</td>
<td>circumstellaire materie</td>
<td></td>
</tr>
<tr>
<td></td>
<td>keuzevakken</td>
<td>keuzevakken</td>
<td></td>
</tr>
</tbody>
</table>
5.5.6 Het majorprogramma sterrenkunde
Er bestaat de mogelijkheid om een majorprogramma sterrenkunde te combineren met een minorprogramma ter grootte van 42 studiepunten bij een andere opleiding. Het minorprogramma wordt gevolgd in het derde en/of vierde jaar van de studie. Studenten die het majorprogramma willen volgen, dienen voor aanvang van het tweede doctoraaljaar contact op te nemen met de studieadviseur.
Het majorprogramma sterrenkunde bestaat naast het eerste doctoraal jaar (zie gids 1999-2000) uit de volgende onderdelen:

<table>
<thead>
<tr>
<th>studiepunten</th>
<th>trimester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klassieke fysica III A</td>
<td>3</td>
</tr>
<tr>
<td>Quantumfysica III A</td>
<td>3</td>
</tr>
<tr>
<td>Steratmosferen of Bouw en evolutie van sterren</td>
<td>4</td>
</tr>
<tr>
<td>Klassieke fysica III B</td>
<td>2</td>
</tr>
<tr>
<td>Quantumfysica III B</td>
<td>3</td>
</tr>
<tr>
<td>Interstellaire en circumstellaire materie of Kosmologie</td>
<td>4</td>
</tr>
<tr>
<td>Presentatie Eigen werk III</td>
<td>2</td>
</tr>
<tr>
<td>Stage en scriptie sterrenkunde</td>
<td>12</td>
</tr>
<tr>
<td>Presentatie stage en scriptie sterrenkunde</td>
<td>2</td>
</tr>
</tbody>
</table>

5.5.7 Het doctoraalexamen sterrenkunde vrije richting

5.5.8 Overgangsregelingen zie 5.3.12