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PREFACE

Below follows the Biennual Report of the Stockholm Observatory for 1997-1998. The foremost thing we notice as editors, is the large growth of scientific output of the Stockholm Observatory in terms of refereed papers since 1993. Using the previous Stockholm Observatory Report, covering the period 1988-1996, one finds that the annual output during 1988-1993 was about 10 refereed papers per year, during 1994-1995 it was about 15 refereed papers per year, in 1996 it rose further to a level of about 40 refereed papers per year and has remained there since. Thus, between 1993 and 1996, the scientific output in terms of refereed papers quadrupled, which is remarkable. One of the causes is probably the increase of junior scientific staff which continued during 1997-1998, with the arrival of six new people and the departure of two. The junior positions are only temporary ones mostly financed by soft funds, and a continued high scientific output will be required in order to maintain the size of the junior scientific staff.

Sylvain Bontemps from France and Adrick Broeils from the Netherlands, both of which greatly contributed to the research activities in the infrared group and galaxy group, respectively, left during the period 1997 and 1998. Helmuth Kristen obtained his PhD and left for a post-doc position at the Center for Astrophysics, Harvard, and Daniel Hartstein left after obtaining a licentiate degree. The Stockholm Observatory saw the return of two of its PhDs, Erik Gullbring from his NFR postdoc at the Center for Astrophysics, Harvard, and Mats Löfdahl from his position at Lockheed-Martin Advanced Technology Center, Palo Alto, California. Cecilia Kozma, also PhD of the Observatory stayed on as an NFR research associate. Another two people joined the staff on the research associate level, Kay Justtanont from Thailand and Juri Poutanen from Russia. Finally, a new postdoc arrived, Andrei Beloborodov from Russia. The Observatory saw the retirement of research engineer Kurt Sundewall who for decades has not only been invaluable for the engineering efforts, but also for contributing so much to the social activities, including poems of the day and song texts written for important occasions and celebrations. Monica Huldtgren also left after having worked in the infrared group for many years.

The development of the new *Stockholm Centre for Physics and Astronomy* was stalled due to various appeals during period 1997-1998. In 1998, one appeal reached the highest court, *regeringsrätten*, where it was overthrown except for some details, and the matter was sent back to the Government for reconsideration. This was the state at the end of 1998. The move of Stockholm Observatory to the new Centre is now scheduled for the summer of 2001.

During this period basic science was facing budget cuts, in particular, a large cut in the budget for Sweden's participation in large international facilities, the two most expensive being CERN and ESO. Observatory staff participated in committee work of the Swedish Natural Science Research Council (NFR) generating a report arguing for the strong needs of Sweden to remain a member of ESO, in particular considering that the Very Large Telescope project will be completed during the next few years. The threat of leaving ESO was fortunately largely removed during the fall of 1998.

In spite of the economical difficulties facing many University departments, Stockholm Observatory has been able to more or less balance its budget during 1997 and 1998. Together with the large scientific output, the continued growth of the Observatory, the success of the Observatory scientific staff in obtaining external funding, and the likely start of the building of the *Stockholm Centre for Physics and Astronomy*, this has generated a base for optimism for the future.

May 1999

The Editors

STOCKHOLM OBSERVATORY REPORT 1997 – 1998

Juri Poutanen, Roland Svensson (Eds.)

Stockholm Observatory, SE-133 36 Saltsjöbaden, Sweden

1. INTRODUCTION

Stockholm Observatory [Stockholms Observatorium] is beautifully located in the archipelago 18 km southeast of Stockholm. The Research Station for Astrophysics of the Royal Swedish Academy of Sciences [Kungliga Svenska Vetenskapsakademien - KVA] is also located at Stockholm Observatory. The scientific staff, during 1997-98, included five professors, eight associate professors and senior researchers, one university lecturer, seven research associates and four postdoctoral fellows. About 1/3 of the staff is of foreign nationality.

At Stockholm Observatory observational, theoretical and experimental work is carried out. The fields of research include the interstellar medium and star formation, young stars and planetary systems, solar physics, AGB-stars and planetary nebulae, supernovae, galactic structure and dynamics, observational cosmology, high energy astrophysics (including research on active galactic nuclei, Galactic X-ray binaries, gamma-ray bursts, and pulsars), as well as infrared equipment development. Stockholm Observatory has access to all European Southern Observatory (ESO) instruments, the Nordic Optical Telescope (NOT), the Swedish solar telescope on La Palma, the Swedish-ESO Submillimetre Telescope (SEST) and the Onsala telescopes, and European Space Agency (ESA) projects such as Hubble Space Telescope (HST), Infrared Space Observatory (ISO), the astrometry satellite HIPPARCOS, X-ray Multimirror Mission (XMM), as well as being involved in the Odin satellite project and ESA's International Gamma Ray Astrophysics Laboratory (INTEGRAL). Other instruments, such as the Keck telescope, the Very Large Array (VLA) the Australia Telescope (AT), the IRAM PdB mm-wave interferometer as well as the space based Compton Gamma-Ray Observatory (CGRO), the Advanced Satellite for Cosmology and Astrophysics (ASCA), and the Rossi X-ray Timing Explorer (RXTE) are also extensively used.

2. STAFF

2.1. Faculty

All positions are full-time {100%} except for a few cases where the relevant part-time percentage is written inside {}. The external financial sources have been indicated. Where no source is indicated, the financial source is Stockholm University.

Artymowicz, Pawel: Associate Professor (NFR) [NFR forskare]
Beloborodov, Andrei: Postdoctoral Fellow (NFR, from Oct 1997)
Björnsson, Claes-Ingvar: Associate Professor (NFR: 50%)
Bontemps, Sylvain: Postdoctoral Fellow (ESA, until Sept 1998)
Broeils, Adrick: Postdoctoral Fellow (NFR, until Sept 1997)
Fransson, Claes: Professor
Gahm, Gösta: Professor
Gullbring, Erik: Postdoctoral Fellow (NFR, Sept-Dec 1998)
Högbom, Jan: Associate Professor Emeritus
Justtanont, Kay: Research Associate (US, from Jan 1998)
Kiselman, Dan: Research Associate (KVA)
Kozma, Cecilia: Research Associate (NFR, from June 1998)
Larsson, Stefan: Research Scientist (RS) [RS forskare]
Lindblad, Per Olof: Professor Emeritus
Liseau, René: Associate Professor (RS)
Lodén, Kerstin: Associate Professor Emerita
Lundqvist, Peter: Research Associate (RS: 40%, NFR: 40% in 1998)
Löfdahl, Mats: Research Associate (KVA, from June 1998)
Mellema, Garrelt: Research Associate
Nordh, Lennart: Associate Professor (RS: 50% before and 100% from Oct 1998)
Olofsson, Göran: Associate Professor (RS)
Olofsson, Hans: Professor
Poutanen, Juri: Research Associate (from Nov 1997)
Sandqvist, Aage: Associate Professor (NFR: 25%, RS: 25%, Esselte Almanacksförlag: 50%)
Scharmer, Göran: Professor (KVA)
Sundman, Anita: University Lecturer {50%}
Svensson, Roland: Professor

NFR - Swedish Natural Science Research Council [Naturvetenskapliga Forskningsrådet]
RS - Swedish National Space Board [Rymdstyrelsen]
KVA - The Royal Swedish Academy of Sciences [Kungliga Vetenskapsakademien]
ESA - European Space Agency
US - position for underrepresented sex financed by SU, NFR, and Swedish Goverment
SU - Stockholm University

2.2. Technical Staff

Asrari, Behrouz: System Manager (until August 1998)
Florén, Hans-Gustav: Research Engineer
Huldtgren, Monica: Project Assistant (RS, until May 1998)
Larsson, Birgitta: Research Assistant (KVA, until May 1998)
Sundewall, Kurt: Research Engineer (retired Nov 1997)
Wänn, Uno: Research Engineer
Wang Wei: System Engineer (KVA)

2.3. Administrative Staff

Olofsson, Lena: Senior Administrative Officer [byrådirektör]
Schober, Jan: Librarian {50%}
Tannenberg, Anne-Marie: Senior Administrative Officer

2.4. Graduate Students

The graduate students at Stockholm Observatory during the report period are listed below with the starting (or finishing) dates of their graduate studies following their names. In many cases, graduate students receive full-time economic support from Stockholm Observatory in terms of 80% Study grant [utbildningsbidrag] or Graduate studentship [doktorandtjänst], and 20% position as Teaching Assistant [assistent], the latter may also contain administrative duties in addition to teaching duties. Sometimes, students are partially supported as Research Assistants by research grants from the different research councils (NFR, RS), KVA or foundations (GG, KKS), or international organizations (NOTSA).

Andersson, Andreas (from July 1997)
Brandeker, Alexis (from Oct 1998)
Dahlén, Tomas
Gonzalez Delgado, David (NOTSA, from Jan 1997)
Hartstein, Daniel (until July 1997)
Kaas, Anlaug Amanda (RS)
Kristen, Helmuth (RS, until May 1998)
Larsson, Bengt (RS)
Nymark, Tanja (from Aug 1997)
Näslund, Magnus (GG, KKS)
Rouppe van der Voort, Luc (KVA, from April 1997)
Ryde, Felix
Schöier Larsen, Fredrik (NFR)
Sollerman, Jesper (RS)
Wold, Margrethe (US, from Jan 1997)

GG - Göran Gustafsson Foundation
KKS - Stiftelsen för Kunskaps och Kompetensutvekling/ Foundation for Knowledge and Competence Development
NOTSA - Nordic Optical Telescope Scientific Association

2.5. Board of the Observatory

The board consists of regular members, and deputy members who may substitute when regular members are unable to participate. The present mandate period runs from Jan 1997 to Dec 1999. The present board consists of the Director, the Deputy director, three representatives (with three deputies) from the faculty, one representative (with deputy) from the technical/administrative (T/A) group, one representative (with deputy) from the graduate students, and one representative (with deputy) from the undergraduate students (the graduate and undergraduate student representatives are elected on a one year basis).

Hans Olofsson (Director)
Claes Fransson (Deputy director)
Göran Olofsson (faculty repr.)
Claes-Ingvar Björnsson (faculty repr.)
Roland Svensson (faculty repr.)
Aage Sandqvist (1st deputy faculty repr.)
Stefan Larsson (2nd deputy faculty repr.)
Gösta Gahm (3rd deputy faculty repr.)
Behrouz Asrari (T/A repr. until Aug 1998)
Anne-Marie Tannenberg (deputy T/A repr. until Aug 1998)
Uno Wänn (T/A repr. from Sept 1998)
Hans-Gustav Florén (deputy T/A repr. from Sept 1998)
Helmuth Kristen (grad. stud. repr. until Oct 1997)
Fredrik Larsen (grad. stud. repr., deputy until Oct 1997, regular from Nov 1997)
Andreas Andersson (deputy grad. stud. repr. from Nov 1997)
Mikael Helldén (undergrad. stud. repr., until Feb 1998)
Anders Gavler (undergr. stud. repr., deputy March 1997 - Feb 1998, regular March - Aug 1998)
Georgios Dimitriadis (undergr. stud. repr., deputy March -Aug 1998, regular from Sept 1998)

3. RESEARCH

3.1. Young Stars and Star Formation Regions

(S. Bontemps, H.-G. Florén, D. Hartstein, M. Huldtgren, A. Kaas, Bengt Larsson, R. Liseau, L. Nordh, G. Olofsson, Aa. Sandqvist)

One of the great challenges of modern astrophysics is the proper understanding of the interstellar processes that lead to new generations of stars and planets. The research of the group in the field of stellar formation is oriented along three major lines: (i) The study of the media forming stars, with particular emphasis on the understanding of the initial physical and chemical conditions as functions of space and time. (ii) The study of ensembles of very young stellar objects, in order to empirically determine the mass distribution spectrum at stellar birth. The functional form of this spectrum appears universal, i.e., it is the same in our Galaxy and in external galaxies, and our primary objective is to understand to what degree the memory of the initial cloud condition is 'frozen in' into this function. (iii) The study of the dynamics of forming stars, especially during the earliest, protostellar, phases. The physics of the apparently co-existent mass building infall and angular momentum shedding mass outflows are not well understood, but this understanding is clearly important as these processes limit the final stellar mass and incorporate the formation of planets. A short description of our research linked to the space platforms is presented, followed by projects performed mainly with ground-based instruments.

The PIROG 8 experiment (H.-G. Florén, G. Olofsson)

PIROG 8 with a newly developed receiver for observing the 425 GHz O_2 line was launched from the CNES balloon-base in southern France on Sept. 25, 1997 giving an 8 hr flight at float altitude. The main target was the giant molecular cloud associated with NGC7538 and its O_2 425 GHz line was observed for about two hours. In order to connect our O_2 observations to the CO abundance, the $C^{18}O$ (1–0) line was observed with the Onsala 20 m telescope and from the 8×9 arcmin map we derived the PIROG beam weighted spectrum. From these data it was concluded that the O_2 abundance is less than 4% of the CO abundance which is the lowest upper limit yet determined for a Galactic cloud. Current chemistry calculations predict far more (by an order of magnitude) molecular oxygen and there is at present no convincing explanation why the abundance is much lower than expected.

ISO (Infrared Space Observatory)

- ISOCAM, A survey of nearby star formation regions (S. Bontemps, M. Huldtgren, A.A. Kaas, L. Nordh, G. Olofsson)

  ISOCAM covers $2-18\,\mu$m, using a Short Wave (SW, 2 - 5.5 μm) InSb detector and a Long Wave (LW, 5 - 18 μm) Si:Ga array. In spite of its small array (32×32 pixels), the LW turned out to compete successfully with larger groundbased arrays, mainly due to the very small local background of ISOCAM and the absence of atmospheric absorption bands.

  The group has focused its efforts on an extensive survey of nearby star formation regions lasting for the full mission (Jan 1996 - Apr 1998). Most of the data reductions were performed during 1997-98. The aim is to improve our knowledge on the mass distribution of young stars (the Initial Mass Function, IMF) and the star formation efficiency in clouds with different physical properties. It is found that the number of stars in the regions studied so far increases steeply with decreasing mass. Typically 25% of the detected young stars have masses below $0.1\,M_\odot$ and most of these will fade away as brown dwarfs. The observed mass distributions were found to have a power law exponent of -1.4, which is close to the power law for the "clumps" identified by radio observations of molecular clouds. This implies that only 25% of the mass of all objects below $1\,M_\odot$ would reside in objects below $0.1\,M_\odot$. This conclusion on the total brown dwarf mass is, however, very sensitive to the details.

- Star Formation with the ISO-LWS: First results of our science programme (B. Larsson, R. Liseau, G. Olofsson)

  The LWS (Long Wavelength Spectrometer) aboard ISO has successfully collected science data during February 1996 through May 1998. Through LWS science team membership, the group has obtained data within the Guaranteed Time programme. In addition, as the PI of Open Time observations, the group is organising the reduction and analysis of these data sets (see http://isowww.estec.esa.nl:80/). Below, a brief account is given of the first results:

  Detection of molecular line-emission from shocked flows. In addition to H_2O-vapour, molecular line emission from OH and high-J CO has been discovered. The emission originates in regions of interaction between mass outflows from a (proto-)stellar object and the ambient molecular cloud. The emitting gas is heated to modest temperatures by relatively mild shocks, and detailed model fitting of the far-infrared line spectrum led to estimates of the order of room-temperature. This 'luke-warm' molecular gas represents a previously unseen phase of the interstellar medium in low-mass (solar type) star forming regions with properties different from that observed in the optical and in the near-infrared.

  Mass loss from young stellar objects: relation to the central mass. After this initial discovery, it came therefore as a surprise to find, from a spectroscopic LWS-survey of 17 Herbig-Haro objects in 7 different star forming regions, that detectable molecular line emission appears to be a rare event. Instead, the far-infrared spectra of such flows are dominated by fine-structure emission from neutral atomic oxygen, [O I] $63\,\mu$m. This is indicative of the presence of considerably stronger shocks, dissociating most of the molecules.

HST observations of L 1551 (R. Liseau)

The primary objective of the group's ongoing HST observations of an outflow source is directed towards the momentum problem and includes the temporal evolution of the 3D velocity fields in a supersonic jet at the highest attainable spatial resolution. The source L1551 IRS 5 was selected on the basis of its favourable aspect in the sky, of its short jet length, and of the important fact that momentum is transferred to the associated molecular outflow within the HST field of view at a rate comparable to that on spatial scales more than a hundred times larger, i.e. $> 10^5$ AU. IRS 5 at 150 pc is the most nearby known source of its kind allowing a smallest spatial resolution of a few AU with the HST (WFPC 2) to be compared with a resolution of > 50 AU with NOT. The high resolution allows comparison with modern numerical hydrodynamical calculations required for determination of the momentum carried by the jet.

The first observing runs with the HST was completed during 1996, resulting in truly perplexing detail and beauty. Combining ground based spectroscopic data, obtained at the NOT, with the HST data we were able to demonstrate that the presently observed jet does not carry sufficient momentum to drive the large scale molecular outflow, as has commonly be assumed. Furthermore, we discovered that there exist two independent jets, each probably fed by either protostar of the close binary (40 AU separation).

Odin (H.-G. Florén, B. Larsson, R. Liseau, L. Nordh, G. Olofsson, Aa. Sandqvist)

Odin is the result of a unique collaboration between astronomers and aeronomers. The satellite is aimed for studies of both astronomical targets and the Earth's atmosphere. The main instrument is a radiometer, fed by a 1.1 m telescope, operating in four selected sub-mm bands plus one band at 119 GHz. This instrument will be used by both disciplines. The astronomy observations will concentrate on galactic studies of molecular clouds, with and without ongoing star formation. Diagnostically important lines of H_2O vapour, molecular oxygen, carbon monoxide and neutral carbon can be observed with a hitherto unprecedented sensitivity. Odin will therefore allow us to further develop our PIROG science and, in particular, the studies based on the ISO/LWS programmes. The Odin astronomy programme consists of several sub-programmes; members of our group are lead scientists for three major sub-programmes, one concerning giant molecular clouds, one focusing on star-formation in dense molecular cores and one aiming for a large-scale survey of the Galactic plane, including special studies of the Galactic Centre. Nordh is Programme Scientist and chairman of the international Odin Science Team.

On the technical side, the Stockholm Observatory has been responsible for the cryostat for housing the mixer blocks and the pre-amplifiers, work being done in collaboration with the Swedish Space Corporation and ACR Electronic. The group is also participating in the software development for scheduling the observations.

FIRST (H.-G. Florén, R. Liseau, L. Nordh, G. Olofsson)

During 1997, the group has been invited to participate in two of the instruments on FIRST (Far InfraRed and Sub-millimetre Space Telescope). FIRST is the natural continuation of ISO, as it extends the wavelength coverage into the sub-mm range, improves the spatial resolution in the far infrared, and introduces high spectral resolution with heterodyne techniques. The actual instruments are a bolometer camera/spectrometer (SPIRE) and a heterodyne spectrometer (HIFI). In the present planning, we are responsible for the software simulator for SPIRE and we have also suggested a Swedish solution of the auto-correlators for HIFI (a further development of the Odin auto-correlators). FIRST is expected to be launched in 2007.

Near infrared variability observations of the Serpens star formation region using NOT (A.A. Kaas, G. Olofsson)

Based on repeated observations with an infrared camera (called ARNICA and belonging to the Arcetri Observatory, Florence) attached on the NOT, young, variable stars were searched for. As many as 55 stars showed significant variations and 39 of these were not previously recognised as young stars. Many of these stars are quite faint and will probably end up as brown dwarfs. This result shows that variability is a common feature for low-mass as well as high mass stars contracting towards the main sequence and that variability investigations in the near infrared are useful in pin-pointing embedded young stars.

3.2. The Interstellar Medium

Several groups work on problems related to the interstellar matter and its distribution and physics. Some of the research is already described in § **??**. Other directions covering the star formation regions and molecular clouds in our own Galaxy as well as in other galaxies are presented here.

The molecular medium in external galaxies (A. Andersson, H. Olofsson)

The star formation history and the compositions of stellar generations, the present as well as past ones, are closely coupled to the nature of the interstellar medium (ISM). In particular, the molecular component of the ISM is important since it contains the main birth-sites of stars. The Magellanic Clouds are excellent targets for studying the rôle of the environment in the formation and the evolution of molecular clouds and stars. Therefore a major study of different molecular species, including isotopic variants, have been performed in selected regions of the SMC and LMC. Molecular abundances have been estimated, and found to be significantly lower in the LMC than in the Galaxy, and even more so in the SMC. This is an effect of both the lower metallicity and the higher interstellar UV radiation field in some regions. The $C^{18}O/C^{17}O$ ratio have been used to study the star formation history in the LMC. Global maps of the distribution of the molecular medium in external galaxies are very rare. A significant contribution to this area is a CO(1-0) mapping project of the southern, barred, grand-design spiral galaxy M83. The galaxy is inclined so that both distribution and kinematical studies can be performed. About 6×8 arcminutes have now been covered.

Interstellar filaments and fragments (G. Gahm, A. Kaas, H. Kristen)

Several investigations have been devoted to understand the physics, maintenance and evolution of extended filamentary structures in quiescent molecular clouds with no on-going star formation. Individual filaments are often composed of clumps or subfilaments. The linear polarization and extinction of light from distant stars passing through nearby molecular clouds was studied. Polarimetric observations at the NOT have been obtained and numerical calculations of the polarization produced by elongated dust grains aligned in magnetic fields have been made. Due to a higher gas-grain collision frequency within the cloud, the polarization caused by the cloud may well be dominated by background/foreground polarization, as is also demonstrated by the observations.

Special attention is given to small-scale, helical, interstellar filaments, like the "elephant trunk" structures in the Rosette nebula, which were studied with the NOT. The observed sinusoidal filaments are suggested to be helices lined up by magnetic fields. We propose that the Rosette elephant trunks form an interconnected system of rope-like structures which are relics from filamentary skeletons of magnetic fields in the primordial cloud. An interesting consequence of helical magnetic fields is the implication that electric currents are driven through the filaments.

Stochastic mass fractionation of a molecular cloud was simulated numerically. It was found that geometry alone may constrain the resulting mass spectrum of molecular cloud clumps. Further fragmentation of the cloud clumps, under the assumption of a lower limit of the self-similar regime, produces a mass spectrum that has qualitative and quantitative similarities with the empirically determined stellar initial mass function.

3.3. The Physics of Star and Planetary System Formation

Evolution of accretion discs in T Tauri stars (E. Gullbring)

While pre-main-sequence stars (PMS) of ages less than a few Myr are surrounded by optically thick circumstellar discs, older stars of ages 30 - 100 Myr, found in nearby young open clusters, show no strong signatures of disc emission. This suggests that disc material vanish into larger bodies, possibly planets, and/or through mass accretion onto the central star on time scales less than 30 Myr. To gain observational progress in the understanding of the time-scales and processes involved in the disc-clearing there is a need for samples of 10 Myr old stars. A successful identification of a 10 Myr old cluster will open up unprecedented possibilities to study the full history of PMS stars and their surrounding discs. For this reason, we are presently undertaking a search for 3 - 10 Myr young open clusters and have collected multi-color ccd-photometry of candidate clusters both in the northern and southern hemisphere. This search has provided us with three promising cluster candidates, likely to host a population of 10 Myr old stars. We have collected and are proposing for multi-object spectroscopy of the PMS-candidates in these clusters to reject non-members of the clusters and then to accurately determine the age of the cluster.

On the theoretical side, this project aims to model time-evolution of accretion discs and the processes responsible for converting the energy-flux of the accretion flow into radiation. The standard scenario used in the analysis of optical and UV emission from young stars is the magnetospheric model where the disc material is elevated from the disc plane and channeled onto the stellar surface. An essential prediction from this model is the formation of a shock at the impact region. We have developed a new numerical model to calculate the emission from this region. To further test this model we have been awarded two observing runs (23 orbits) with the HST using the STIS instrument during Cycle 8. These observations will provide tests of the geometrically distribution of the emitting gas and theories of the mass-loading of magnetic field lines at the magnetosphere-disc interface. Analysis of the UV emission lines will also provide improved calibrations between ultraviolet continuum emission and accretion luminosities, and thus improve estimates of mass accretion rates for T Tauri stars.

Optical spectroscopy of T Tauri stars (G. Gahm, E. Gullbring)

The brightness variability of T Tauri stars is manifested in the emission lines. Both line fluxes and line profiles are variable on a vast range of time scales. The results that certain parts of the Balmer line profiles show periodic brightness variations as well as irregular variations on time scales shorter than one hour suggest that the line emission arises in a small region, locked to the stellar rotation. Another noticeable property of the profile variations is that for lines with blue shifted wind absorption, the time scale of variability in the wind component is much longer than for the rest of the line profile. This suggest different origins of the absorbing and the emitting gas. For this reason, several T Tauri stars have been monitored both at high spectral resolution using the SOFIN spectrograph at NOT, and simultaneously photometrically with the Swedish 60cm reflector on La Palma.

Theory of Binary Star and Planetary System Formation (P. Artymowicz)

The research is mostly concentrated on studies of the dynamics of binary star formation, Beta Pictoris-type planetary systems, and planet formation in discs.

A pre-main sequence binary star system may contain two circumstellar discs and a circumbinary disc. Disc structure and evolution are modified by the binary, and vice versa, due to resonant emission of waves. Disc gap size and shape, as well as the characteristic features at its edge are indicative of binary star parameters. Artymowicz and Lubow have overturned a decade-long conviction that gas cannot accrete from circumbinary discs onto the binary stars or their discs, and thus resupply them. Their theory of mass flow through gaps received strong support from the photometry and spectroscopy of PMS binaries, imaging, and other observations.

Within the past decade, astronomers have found direct evidence of extrasolar planetary systems, and we contributed to several theories addressing their surprising diversity. We challenged two recent theories connecting the nature of Vega/Beta Pictoris-type systems (planetesimal/dust discs surrounding at least 15 percent of normal stars) with the ISM dust bombardment, showing instead that dusty discs evolve from high to low dustiness stage as a result of internal dust erosion and the so-called dust avalanches.

High-resolution hydrodynamical simulations of disc-planet interaction (cf. http://www.astro.su.se/~pawel) were produced. They showed that mass can flow through a gap created in the disc by the protoplanet. This opens a possibility that super-Jovian mass planets recently found may have formed in discs (and need not be brown dwarfs). Moreover, disc-planet interaction will also produce the observed high eccentricities of orbits of the superplanets.

Outflow collimation in young stellar objects (G. Mellema)

In order to understand the formation of jets from young stars, the amount of collimation caused by the interaction of an outflow from a proto–star with the aspherical accreting environment was studied. Both the low and high cooling regimes were analysed and it was found that in both cases perfectly collimated beams can be formed. Time and length scale considerations indicate that the interaction cannot be solely responsible for the collimation and that other process such as magnetic collimation are important as well. This work does show that the influence of the environment can be substantial for the collimation of proto–stellar jets.

3.4. AGB Stars and Planetary Nebulae

The large majority of all stars in the Universe that have left the quiescent central hydrogen burning phase, i.e., the main sequence, will reach their final evolutionary stage as stars on the asymptotic giant branch (AGB). This will also happen to our own Sun in about 8 billion years from now. An AGB-star is a cool, luminous, and pulsationally unstable red giant star. It will gradually develop an intense wind that removes material from the surface at an increasing rate as the end is approached. This will have a profound effect on the evolution of the star, and it will eventually terminate its life as a star. Furthermore, the wind also carries the results of internal nuclear processes, activated during the AGB evolution, and hence contributes to the chemical evolution of the cosmic gas. The mechanism(s) behind the mass loss is not yet identified, but the regular pulsations of the star and the formation of molecules and microscopic dust particles in its atmosphere are believed to play a major rôle. When the 'star' leaves the AGB the mass loss appears to change its characteristics (less material is ejected, but at much higher velocities), and the surface temperature increases rapidly. The interaction of the fast post-AGB wind and the AGB wind, and the increasing ionizing flux produces a planetary nebula (PN). The research at Stockholm Observatory centres on the AGB mass loss and the formation and evolution of PNe. This presents an interesting astrophysical phenomenon, where an intricate interplay between different physical and chemical process takes place.

AGB Stars (D. Gonzalez Delgado, K. Justtanont, H. Olofsson, F. Schöier Larsen)

- Probing the low mass loss rate end of AGB-stars

  In order to put constraints on the possible mechanism(s) for the mass loss it is important to observationally determine the mass loss characteristics of stars with different pulsational behaviour. A major survey of circumstellar CO radio line emission of irregular and semiregular variables have therefore been performed. The result is a significant increase in the number of detected objects, and essentially all objects are observed in more than one transition. Work on detailed modelling of the data has started. Some objects exhibit very peculiar line profiles, and the Owens Valley mm-wave interferometer has been used to study in detail the CO line emission from one object, RV Boo. As an alternative to probing the circumstellar properties by CO radio line emission, methods are developed to use resonance line scattered light from NaI and KI, and light scattered in the vib-rotation lines of CO. The first positive results have already been obtained.

- AGB-stars with highly episodic mass loss

  Based on a survey of circumstellar CO radio line emission towards a sample of optically bright carbon stars it has become evident that some of these stars must have experienced a recent period of highly variable mass loss. The IRAM PdB mm-wave interferometer has been used to study in great detail the CO emission towards two of these stars, TT Cyg and U Cam. The TT Cyg observations reveal a remarkably thin (width/radius$<$0.05), very close to spherically symmetric, shell consisting of CO radio line emitting clumps that is centred on the star. The cause of the shell is not clear, but a mass ejection about 7000 year ago due to a He-shell flash is an attractive explanation. Also here alternative methods for probing the circumstellar medium are developed, and the first results in terms of images of these detached shells in dust scattered light have been obtained.

- Chemistry in circumstellar envelopes

  Molecules, some of them quite complex by astronomical standards, are present in the circumstellar envelopes as a result of chemical reactions in the stellar atmosphere as well as in the envelope itself. These molecules may be used also as probes of the stars, e.g., their elemental composition. This is not an easy task, but it has been shown that even simple observational quantities like line intensity ratios may be used to discriminate between stars of different chemical compositions, e.g., whether $C/O<1$ or >1. Of particular interest in this connection are the S-stars whose C/O-ratio balances very close to unity. Some initial results on these objects have been obtained. The results of a major survey of circumstellar molecular line emission from a sample of optically bright carbon stars will shed further light in this area. More than 300 lines from five different molecular species have been detected and the survey is observationally completed.

- Modelling the circumstellar molecular line emission

  A model for interpreting in more detail the circumstellar molecular line emission has been developed. It is based on the versatile Monte Carlo method, and it includes the energy balance equation for the gas. The effects of over-lapping lines are also included. Using this a successful modelling of CO far-infrared (from ISO LWS) and radio lines from the extreme carbon star IRAS15194-5115 have been done. The star is peculiar because of its very low ^{12}C/^{13}C-ratio ($\sim$5) despite it being highly evolved on the AGB. The model is now being applied to HCN and CN interferometer data on five carbon stars, and ^{12}CO and ^{13}CO data on a number of carbon stars (for which there exists photospheric ^{12}C/^{13}C-ratio estimates that have been intensively debated recently in the literature).

- ISO results on AGB-stars and supergiants

  Since the launch of the ISO, there have been many discoveries in the field of late-type stars. Spectroscopy of these stars reveals many absorption bands which are inaccesible from the ground. Fitting the molecular absorption bands leads one to estimate the excitation temperatures where they arise and hence gives us clues as to where in the circumstellar envelope the absorption occurs.

  One of the main discoveries is the pump line (in absorption at 34.6μm) for the OH maser seen in the radio at 1612 MHz. This, along with OH lines in the far-IR seen by other groups, confirms the radiative pumping theory. The detection was done towards a supergiant with a very high mass loss rate. For supergiants with low mass loss rates emission lines due to atomic fine structure lines of [Fe II] and [Si II], which are thought to radiatively cool the gas in the circumstellar envelope, have been detected. Dust grains condensed in oxygen-rich (C/O<1) outflows show signatures at 10 and 18μm which are due to silicates. Generally, these features are broad and are thought to be associated with an amorphous (disordered) structure of the dust. However, emission bands in the far-IR due to crystalline silicates have been detected in a few high mass loss rate stars. The formation process of crystalline grains is unclear.

  A subgroup of low mass loss rate AGB-stars are known to exhibit a weak dust emission feature at 13μm, as well as weak silicate emission at 10μm. These stars are found to exhibit emission bands between 13-16μm which are due to gaseous CO_2. The association between dust and and gas emission is thought to be due to shocks in the stellar atmosphere. As the mass loss rate gets higher, the signatures of both are either swamped by stronger 10μm silicate dust emission, or the carrier of the 13μm dust feature and the CO_2 are destroyed.

- Early post-AGB objects

  Some work on early post-AGB objects has also been done. Strong maser emission in rotational lines in vibrationally excited states of SiO have proven to be an important probe of the conditions in the dynamical atmospheres of AGB-stars. In a survey of such emission from objects believed to be at the tip of the AGB and beyond (i.e., they are highly obscured), it was clearly shown that SiO masers are only associated with pulsating stars. CO observations of the peculiar object HD101584 revealed a circumstellar molecular envelope with properties very similar to those of wellknown early post-AGB objects. A substantial fraction of the molecular gas has been accelerated to very high velocities (>100 km/s), by a mechanism that must be different from radiation pressure.

Planetary Nebulae (G. Mellema)

- Multi-wavelength studies of young PNe

  Two young PNe, NGC 7027 and BD+30 3639 were studied. Since dust extinction is expected to be important in these young objects, the optical observations were complemented with radio-interferometer data obtained with the MERLIN and VLA telescopes. The resolution in our radio maps is similar to that of the HST. Dust extinction was found to play an important role in NGC 7027 and less so in BD+30 3639. The interpretation of the optical spectroscopy is still in progress.

- The formation of bipolar PNe

  Hydrodynamic modelling of the formation of aspherical PNe including the effect of the evolution of central star showed that stars of different masses may produce nebulae of different morphology. The reason is that in the case of more massive central stars the fast increase in the UV flux produces a fast moving R–type ionization front which leaves the original aspherical density distribution of the circumstellar matter relatively undisturbed. In the case of lower mass stars the increase in UV photons is much more gradual and the ionization front is the slower D–type, which modifies the density distribution of the circumstellar material. This means that more massive central stars are more likely to produce more extreme bipolar nebulae.

- Hydrodynamics with realistic ionization and cooling (G. Mellema, P. Lundqvist)

  In order to study flows in which photo-ionization and shocks both play a role in exciting the gas it is necessary to follow the ionization states of the different ions in a non–equilibrium fashion, taking into account both collisional and photo–ionization, radiative and dielectronic recombination, and charge exchange. Once the ionization states of the ions are known, the non–equilibrium cooling rates can also be calculated. A number of subroutines have been developed which can be combined with a hydrodynamic calculation. Using these routines for the first time the two-dimensional structure of a radiative bow-shock of a jet was calculated. The structure of a bow shock around a run–away O–star (in which case the photo–ionization is also important) was also modelled.

- Photoevaporating clumps in PNe (G. Mellema, P. Lundqvist)

  In an attempt to find an explanation for FLIERs, the pairs of bright low–ionization knots seen in many PNe, the evolution of a neutral clump of material exposed to ionizing radiation was modelled. Both a simplified analytic description and a detailed numerical model (applying the realistic ionization and cooling routines mentioned above) were used. The two models agree remarkably well, and some of the properties of FLIERs, such as their high [N II]/Hα ratio, can be explained. However, the HST images of FLIERs show more complicated morphologies than can be reproduced with our simple model. A similar model was also applied to study the evolution of dense clumps being ionized by quasars, the objects responsible for the Lyα forest.

3.5. Supernovae

(C. Fransson, C. Kozma, P. Lundqvist, T. Nymark, J. Sollerman)

Supernovae represent the last stage of stellar evolution. They are responsible for the majority of the heavy elements in the universe, are sites of particle acceleration, and are the birth places for neutron stars and black holes. The supernova group at Stockholm Observatory continues to become heavily involved in various observational projects on supernovae. Observations have concentrated on those obtained with the HST in connection with the Supernova INtensive Studies (SINS) collaboration, and the STIS instrumental team at Goddard Space Flight Center. The large data base gathered by IUE has also continued to be analyzed. SN 1987A was also observed with ISO in 1998, and a substantial amount of ground-based data have been gathered using telescopes at ESO, La Silla and with NOT. Much of the group's efforts have been to model these and other observations. The research has during 1997-1998 focused mainly on SNe 1987A, 1993J, 1994W, 1995N, 1996N and 1998S, but has ventured into other areas as well.

Radiation-hydrodynamics of SN 1987A (P. Lundqvist)

Radiation-hydrodynamical multi-group simulations of SN 1987A have been performed to model the shock breakout of the supernova, and the evolution of the emission from the ejecta during the subsequent $3-4$ months. The emission has been compared with the bolometric light curve, as well as individual optical and IUE bands. The best models have energies in the range $E = (1.10 \pm 0.25) \times 10^{51}$ ergs, and the agreement with observations is better than in earlier, flux-limited diffusion calculations for the same explosion energy. The color temperature during shock breakout agrees with earlier calculations, but the structure of the outermost ejecta does not show the pronounced density spike present in earlier results. Such a spike is a result of incorrect radiative transfer. The maximum velocity of the ejecta in the new models (i.e., $30,000-40,000$ km s^{-1}) is similar to that indicated by Mg II $\lambda 2800$ in early IUE spectra.

Modelling the spectral evolution of SN 1987A (C. Kozma, C. Fransson)

The temperature, ionization and line emission of the ejecta of SN 1987A has been modelled between $200-2000$ days in its nebular phase, using a time-dependent model. The modelling of the evolution of the temperature and ionization of the various abundance zones shows that the metal-rich core undergoes a thermal instability, often referred to as the IR-catastrophe, at $600-1000$ days. The hydrogen-rich zones, on the other hand, evolve adiabatically after $500-800$ days. It is found that freeze-out of the recombination is important in the hydrogen and helium zones. The temperature and ionization of the supernova ejecta determine the evolution of the observed emission lines. The IR-catastrophe is seen in the metal lines as a transition from thermal to non-thermal excitation, most clearly in the [O I] $\lambda\lambda 6300$, 6364 lines, and from the evolution of the [Fe II] lines. The distribution of hydrogen, helium, and oxygen is determined from the line profiles. It is also shown that most lines have contributions from more than one composition region. For example, the [Fe II] lines have a large contribution from primordial iron residing in the hydrogen-rich regions. A main reason for this modelling is to study the nucleosynthesis that took place in the progenitor, as well as in the supernova explosion. By comparing the model calculations with observations masses for hydrogen, helium, nitrogen, oxygen, neon, magnesium and stable nickel is estimated for the supernova ejecta.

Circumstellar matter around SN 1987A (P. Lundqvist, C. Fransson)

The emission from the inner ring around SN 1987A has been monitored by IUE, and from those observations it is evident that the gas in the ring is CNO-processed and thus circumstellar. In particular, the N/C and N/O ratios are found to be 6.1 ± 1.1 and 1.7 ± 0.5, respectively, and from the evolution of the emission, a distance to the LMC of 48.6 ± 2.2 kpc is derived. The size of the ring, and the density of its gas are estimated, and compared to hydrodynamical simulations. The more recent (1997 and onwards) evolution of the circumstellar emission is discussed in papers concentrating on observations with HST/STIS. One of the findings is a hot spot on the inside of the ring. The spot is most likely a region of the ring which has already been overtaken by the circumstellar shock. Another major finding is the broad (extending to nearly 20,000 km s^{-1}) Lyα and Hα emission, which is evidence of the ejecta interacting with an H II-region inside the inner ring. The geometry of this region appears to correspond to the asymmetric structure derived from radio emission. Diffuse Lyα emission is also seen from supernova debris inside the reverse shock. This emission may be due to excitation by nonthermal particles accelerated by the shock. The ejecta and the ring were also observed with HST/NICMOS, and images in He I λ10830 and Pα were obtained. This is used together with optical images to constrain the ionization and temperature of the gas. In order to prepare for future HST/STIS and FUSE observations, the expected emission in narrow lines from the H II-region was calculated. The strongest lines are N V λ1240 and O VI λ1034, and the relative strength of these lines probes the density of the gas. Together with the intensity of the radio and X-ray emission, this can be used to model the structure of the circumstellar gas, and hence the mass loss history of the progenitor. In this analysis it is argued that the spectral type of the progenitor, Sk -69.202, was not much earlier than B2 Ia, which corresponds well to the pre-explosion classification.

Particle acceleration and radio emission from supernovae (C. Fransson, C.-I. Björnsson)

A model for the radio emission from SN 1993J has been presented, and the radio light curves of the supernova are found to be well fit by a synchrotron spectrum, suppressed by external free-free absorption and synchrotron self-absorption. A standard r^{-2}-wind is assumed, and found to be adequate. The ratio of magnetic and thermal energy density behind the shock, is ~ 0.14. The injected electron spectrum has a power law index of -2.1, consistent with diffusive shock acceleration, and the number density scales with the thermal electron energy density. The total energy density of the relativistic electrons is, if extrapolated to $\gamma \sim 1$, $\sim 5 \cdot 10^{-4}$ of the thermal energy density. The free-free absorption required is consistent with previous calculations of the circumstellar temperature of SN 1993J, $T_{\rm e} \sim (2-10) \cdot 10^5$ K.

Late light curves of supernovae (J. Sollerman, P. Lundqvist)

Observations of SN 1994W with British telescopes and NOT on La Palma showed a steep decline of the light curve around $\sim 100-120$ days. This is interpreted as due to a very low amount of ejected ^{56}Ni, which for a high mass progenitor could indicate fall-back of material onto a newly formed black hole. Later, observations of SN 1997D showed a low ^{56}Ni abundance also for that supernova. SN 1997D is modelled as the explosion of a 25 solar mass star, which again implies the formation of a very massive compact object in the center. To investigate the late time emission of core-collapse supernovae, a monitoring program has been conducted using the large ESO telescopes at La Silla. The first supernova analyzed was SN 1996N. This well observed supernova provides clues to the relation between supernovae of Type II and Type Ib/c. The observed blueshifts of the emission lines could indicate large scale asymmetries in the supernova explosion.

Circumstellar interaction of supernovae (C. Fransson, P. Lundqvist)

A supernova which caught much attention in 1998 was the bright SN 1998S. It was brighter than $U = 12$ at maximum, and was observed with a number of telescopes, including the *HST* by SINS. SN 1998S was the third core-collapse supernova (in addition to SNe 1987A and 1993J) for which high-quality UV spectra were taken during an extended period of time. Conspicuous circumstellar narrow lines were seen on top of the usual broad components. It is evident that the supernova ejecta interact with a dense stellar wind, presumably as dense as that around SN 1979C. Non-LTE analysis of the early spectrum was performed, and this indicates that Comptonization of the photospheric spectrum by hot electrons as a result of circumstellar interaction is needed.

Pulsars (P. Lundqvist, J. Sollerman)

In addition to supernovae, the members of the group have also studied pulsars. The Crab pulsar's near-UV spectrum ($1600 - 3200$ Å) was studied with HST/STIS in time-tag mode which provides 125 μs time resolution. Spectra of the main pulse, the interpulse, and the individual rising and falling edges are similar to the total spectrum within the limits of photon statistics. A standard extinction curve with $E(B-V) = 0.55 \pm 0.05$ appears to apply. Several interstellar absorption lines are seen, but the equivalent widths of Mg I, Mg II and Fe II are lower than expected from the $E(B-V)$ derived. A deeper exposure in the far-UV ($1140 - 1720$ Å) was scheduled, and was performed on January 22, 1999. The group also studied PSR 1706-44 using the science verification observations with the test camera on VLT-UT1. (VLT is the ESO's Very Large Telescope. This made the supernova group the first in Sweden to analyze and publish VLT data.) PSR 1706-44 is a Vela-like pulsar with similar pulse period (~ 0.1 s) and spin-down age ($\sim 10^4$ years). The excellent seeing at Paranal made it possible to put a 3σ limit on the optical flux from PSR 1706-44 at $V = 25.5$ if the pulsar is not close to a projected bright star. This provides important input to models of the pulsar emission as the relationship between optical pulsed emission and those in the X-ray or γ-ray bands is unclear. (PSR 1706-44 has been detected in both X-rays and γ-rays.)

3.6. Galaxies and the Milky Way
(A. Broeils, J. Högbom, H. Kristen, P.O. Lindblad, K. Lodén, M. Näslund, Aa. Sandqvist**)**

The Galaxy group at Stockholm Observatory focuses on the physics of spiral galaxies including the Milky Way, especially the structure and dynamics of barred systems, nuclear activity including the Galactic Centre, and dark matter. Detailed studies are performed using the ESO telescopes, NOT, and HST in the optical and infrared, and the VLA, AT and SEST in the radio regime.

The Galactic centre and the Galactic plane (H. Kristen, Aa. Sandqvist)

The group is principal investigator for an Odin project that will map the Galactic plane in the molecules of O_2, H_2O and CO. This is coordinated with observations with the infrared ISO satellite. In collaboration with the Harvard-Smithsonian Center for Astrophysics we analyse ISO polarimetry data to map the magnetic field in the Milky Way.

The Galactic nucleus, at a distance of about 8 kpc and hidden behind about 30 magnitudes of visual extinction by cool interstellar dust along the line of sight, cannot be studied at visible, ultraviolet or soft X-ray wavelengths. The available information about this nearest centre of a galaxy comes from measurements at γ-ray, hard X-ray, infrared, (sub)millimetre and radio wavelengths. The research concentrates on the distribution and kinematics of molecular cloud structures and their physical and chemical properties, as well as their interactions with the radio continuum components, from the inner parsec out to about a hundred parsecs from the Galactic Centre. The centre of the Milky Way in the emission and abroption lines of different molecules with the SEST and the VLA is being mapped. Furthermore, the group is principal investigator of the Odin Galactic Centre Region program.

Research with the HIPPARCOS satellite (P.O. Lindblad, K. Lodén)

A new scheme to determine the gravitational force perpendicular to the galactic plane as a function of the distance to the plane from stellar distances from the plane, velocity component perpendicular to the plane and ages has been applied to young runaway stars using narrow band photometry and Hipparcos astrometric data. This test of the method gives a run of the force in agreement with results of Bahcall. Hipparcos data have also been used to derive an improved velocity field for stars in the local stellar system called Gould's Belt. The galactic rotation parameters for young stars within this system differ drastically from those for stars outside. These differences are discussed in terms of an expansion and rotation of the Gould Belt.

Structure of galaxies (A. Broeils, H. Kristen, J. Högbom)

The general structure of galaxies and their composition of stars of different ages as well as the existence of "dark" unseen matter are studied at Stockholm Observatory by deep CCD photometry in the optical and near-infrared regions, complemented by observations in the 21-cm line of interstellar hydrogen with large radio interferometers.

The spiral structure of galaxies is the manifestation of a density wave in the stellar population and in the interstellar matter. Star formation is triggered in interstaller matter compressed in this density wave. The case of so-called barred galaxies, where the spiral structure is caused by the gravitational influence of the bar, seems to be best understood. Mapping of the velocity field from interstellar emission lines for six isolated barred spiral (SB) galaxies, carried out at the observatory, compared with computer simulations of such systems, demonstrates how the spiral structure is created by the influence of a series of gravitational resonances caused by the rotation of the bar. The bar also forces interstellar matter into the nuclear region, thus seemingly providing fuel for nuclear activity and for extensive ejection of excited gas and relativistic plasma from the nucleus normal to the symmetry plane of the galaxy. No evidence is found supporting the hypothesis of a low amount of dark matter being characteristic of SB galaxies. The presence of companion galaxies is found to correlate with an increased statistical spread in the neutral hydrogen (HI) extent. It is concluded that the selection of galaxies with large HI extent may introduce a bias towards tidally interacting systems.

An in-depth study of the dynamics of the SB galaxy NGC 1300 is presented. Multi-wavelength data yield an estimate of the velocity field and gravitational potential. Subsequent hydrodynamical simulations are able to reproduce the morphology and kinematics in the bar region using a pure bar perturbing potential. To reproduce the spiral structure a weak spiral component has to be added, indicative of stellar spiral response to the bar and/or self-gravitating gas in the arms. Two separate models, differing mainly with respect to pattern speed and associated resonance structure, are found to reproduce the observations.

Circumnuclear activity (H. Kristen, P.O. Lindblad, Aa. Sandqvist)

One of the very interesting discoveries by the Hubble Space Telescope (HST) is the resolution of circumnuclear star forming regions in several galaxies into a large number of bright very compact objects, each several hundred times more luminous than the brightest clusters in the Milky Way. They have been proposed to be young globular clusters. We discovered 42 such objects in the nuclear region of the galaxy NGC 1365. It turns out that one of them coincides very closely with one of the brightest compact radio continuum sources that we have found previously, indicating that this source is a single object and may belong to the rare class of radio supernovae. In the [OIII] $\lambda\,5007$ line, the HST also resolves individual clouds within the conical outflow from the nucleus, some of which gather in larger agglomerations. From SEST observations of the nuclear region in the $J = 3 - 2$ CO emission line we have discovered a circumnuclear molecular torus. We have ground based observations of circumnuclear activity also in a number of other galaxies, in particular NGC 1358 for which we have data obtained at NOT and with the ESO 2.2-m telescope. These data are being reduced.

Galaxy photometry (M. Näslund)

We have performed a deep photometric study of the edge-on spiral galaxy NGC 4565. Least-square fitting of the light distribution by using exponential- like functions revealed several disc components and a sharp radial cutoff. However, the most spectacular discovery was that of an extended optical warp that overlaps with the previously known gaseous warp. This optical counterpart puts important constraints on the theories for the formation of such warps, since the detection at optical wavelengths implies that stars have formed out of the gas. Because only a few galaxies have been studied down to these faint levels, the question whether faint stellar warps are common arises. We will follow up this detection with data we have – at radio, infrared and optical wavelengths – on the edge-on galaxy UGC 9977.

3.7. Observational Cosmology (T. Dahlén, C. Fransson, M. Näslund, M. Wold)

The emphasis of the group on observational cosmology has up to now mainly been on the study of clusters of galaxies at high and low redshifts, as well as their relation to active galactic nuclei (AGN). New directions also include modeling of early supernova activity, as well the use of supernovae as cosmological probes. In the latter field the group is collaborating with especially the cosmology group at the Dept. of Physics at Stockholm University.

Clusters of galaxies (T. Dahlén, C. Fransson, M. Näslund)

The evolution of the luminosity function of clusters of galaxies at redshifts of 0.2 ¡ z ¡ 0.6 is studied, using the NOT telescope. Using subtraction technique, we have determined the R-band luminosity function for MS2255.7+2039 at z=0.29 down $M_R = -16$. It is found that, in agreement with clusters at lower redshift, the luminosity function is considerably steeper than a standard Schekter luminosity function at the faint end, as predicted by hierarchical clustering scenarios.

We have also studied a distant cluster at z=0.54 in U, B, V, R and I in order to test the use of photometric redshifts to select cluster members for determination of the luminosity function, as well as color variations within the cluster. Observations have been obtained at NOT and we have also made simulations to determine the accuracy of this technique as the limiting magnitude is approached. As a spinoff, one should also be able from the colors to find distant background objects, using the Lyman break method.

The nature of galaxy cluster environments around AGN (M. Wold)

In this project, we investigate the environments around different types of AGN in terms of galaxy clusters. The cluster richnesses are determined as well as the brightnesses and colours of the cluster galaxies. The galaxy clusters around the different AGN classes are then compared in order to test the unified model of radio-loud quasars and galaxies, as well as to investigate the nature of the environmental differences between radio-loud and radio-quiet AGN.

The dynamics of the galaxy clusters is also investigated by using weak gravitational lensing techniques. By measuring the distortion of images of galaxies behind the cluster, a map of the projected mass density in the cluster can be constructed.

Supernovae at high redshifts (T. Dahlén, C. Fransson)

In preparation for New Generation Space Telescope (NGST), members of the supernova group have used different assumptions for the combination of dust extinction and star formation up to redshifts $z \gtrsim 5$, as well as detailed modelling of supernova properties, to estimate the number of supernovae that should be observable with this telescope. Realistic light curves and spectral shapes that evolve with time for the different types supernovae are used. It is found that NGST should be able to detect several tens of core-collapse events in a single detection if the observational limit in the range $1-5$ μm is 1 nJy and the field is 16 square arcmin. The observable number of Type Ia supernovae is also estimated. Due to the time delay between the formation of the progenitor star and the explosion of the supernova, there are additional aspects that have to be considered when interpreting observational rates of these supernovae.

3.8. High Energy Astrophysics
(A.M. Beloborodov, C.-I. Björnsson, S. Larsson, J. Poutanen, F. Ryde, R. Svensson)

The group specializes in observational and theoretical high energy astrophysics with emphasis on radiation processes in highly energetic plasmas and interpretation of the broad band observations of active galactic nuclei (AGN), X-ray binaries, pulsars, and γ-ray bursts. Observations are both space-based (ASCA, CGRO, RXTE) and ground-based (NOT, ESO, etc.). Archival data are also used. The group participates in the experimental team for the Spectrum Röntgen-Gamma (SRG) satellite and is Co-Investigator for the Joint European X-ray Monitor (JEM-X) on INTEGRAL.

Galactic black holes (A.M. Beloborodov, J. Poutanen)

Galactic black holes (GBH) radiate in one of several spectral states, switching from one to another for reasons that are as yet not understood. The long standing questions are the geometry of the X/γ-ray emitting region ("corona") and the radiative mechanisms generating the spectrum. There is a consensus that thermal Comptonization is responsible for the hard state spectra of these sources that cut off at

$\sim$100 keV. The origin of the soft state spectra extending up to ~ 1 MeV is a matter of debate. A hybrid, thermal/non-thermal model was developed where such spectra are produced by Comptonization of soft photons from the cool accretion disc by basically non-thermal electrons in the corona.

An important feature in the GBH spectra is the so called Compton reflection component that arises due to reflection/reprocessing of coronal emission by the accretion disc. The observed small amplitude of this component (the lack of reflector) was interpreted as a signature of the transformation of the thin accretion disc in the vicinity of the black hole into a hot geometrically thick flow emitting hard X-rays. However, the physical reasons for such a transition remain unclear.

An alternative model was then suggested: the lack of reflection is due to mildly relativistic bulk motion ($v/c \sim 0.3$) of the coronal plasma away from the reflector. Bulk motion causes aberration reducing the X-ray emission towards the disc, which leads to a small reflection. The model predicts a correlation between the spectral slope and the amount of reflection that successfully reproduces the recently observed correlation. These findings favour the picture where the corona consists of compact magnetic flares dominated by $e^{\pm}$ pairs which are ejected away from the reflector by the pressure of the reflected radiation.

The picture of energy release in compact magnetic flares helps to resolve a long standing mystery of large time lags between coronal emission at different X-ray energies. These lags reach a few tenths of a second, exceeding by orders of magnitude the light-crossing time of the emitting region. It was proposed that the time lags are related to the time scales of the spectral evolution of individual magnetic flares which may be comparable to the Keplerian time scales at 3–100 gravitational radii from the central black hole. The overall temporal variability was then modelled using a flare avalanche model in which each flare has a certain probability to trigger a neighbouring flare, thus occasionally producing long avalanches. The proposed model describes well the time-averaged spectra as well as temporal characteristics such as the power-density spectrum, the time/phase lags, and the coherence function of Cygnus X-1.

Magnetic white dwarfs (S. Larsson)

AM Herculis systems are binary stars with mass transfer onto a highly magnetic white dwarf. The mass flow is funneled by the magnetic field towards the polar caps of the white dwarf. The shocked plasma above the polar cap provides a unique laboratory to study the properties of high energy plasma in strong magnetic fields. We are involved in a study of quasi-periodic oscillations in this polar cap plasma. In 1998 we observed a couple of sources with RXTE and made simultaneous optical observations with 2.3m National Australian telescope at Siding Springs.

Pulsars (C.-I. Björnsson)

For pulsars, the small dispersion in the observed relation between period and intrinsic opening angles of the conal emission regions was used to study their geometry. Applying this direct method showed the corresponding hollow cones to be consistent with them being close to circular. It was further shown that there is no observational evidence for an evolution with pulsar age of the angle between the cone axis and the rotation axis.

Active galactic nuclei (S. Larsson, J. Poutanen, F. Ryde, R. Svensson)

The environment of the putative massive black hole in the central engines of AGN is studied by using existing observations from the entire wavelength range (radio to γ-rays) as well as performing observations in the X/γ-ray region. Both γ-ray loud (blazars) and γ-ray weak (quasars and Seyfert Galaxies) sources are studied. In blazars, the multi-wavelength spectra of core-dominated flat spectrum radio-loud quasars (FSRQ) were used to study properties of jets in AGN. In Seyferts, the UV to soft γ-ray continuum is modelled in order to study the geometry and physical conditions in the coronal regions of the black hole accretion disc. ASCA observations of the Seyfert 2 galaxy NGC 7172 from May 1995 obtained by the group have been analysed. Combining them with the public CGRO OSSE data for the broad band spectral fits, it was shown that the spectrum cuts off at $\sim$ 100 keV, supporting *thermal* Comptonization as an origin of the hard X-ray continuum. The ASCA data showed significant variability in the spectral index as compared with the previous Ginga data. OSSE observations of the Seyfert 1 galaxy NGC 3516 from June-Oct 1997 obtained by the group were combined with public ASCA data from 1994 and 1995. Model fitting showed that NGC 3516 have properties fairly normal for Seyfert 1 galaxies, contrary to some previous expectations. Simultaneous observations by RXTE and OSSE of our closest Seyfert 2 galaxy, the Circinus Galaxy, were obtained by the group in Oct and Nov 1998 for the purpose of studying the effects of the nuclear molecular torus on the X-ray spectrum.

Optical/UV polarization in quasars (A.M. Beloborodov, J. Poutanen)

Optical/UV radiation from accretion discs in quasars are likely to be partly scattered by a hot plasma enveloping the disc. It has been investigated whether the scattering may produce the mysterious steep rises in polarization observed blueward of the Lyman limit in some quasars. Two models have been suggested and assessed:
i) The primary disc radiation with a Lyman edge in absorption passes through a static ionized "skin" covering the disc, which has a Thomson optical depth $\tau_T \sim 1$. Electron scattering in the skin smears out the edge and produces a steep rise in polarization at $\lambda < 912$ Å.
ii) The scattering occurs in a hot coronal plasma outflowing from the disc with a mildly relativistic velocity. The second model better explains the rise in polarization. Presently, the outflow model is the only known model reproducing successfully the whole pattern of polarization in non-blazar AGNs from the optical to the UV.

Accretion disc theory (A.M. Beloborodov)

Super-Eddington accretion discs were then studied numerically. It was found that a disc with a large viscosity parameter ($\alpha > 0.03$) gets strongly overheated at super-Eddington accretion rates. The emission of the overheated relativistic discs may contribute to the X-ray spectra from quasars.

Gamma-ray bursts (A.M. Beloborodov, J. Poutanen, F. Ryde, R. Svensson)

Gamma-gay bursts (GRBs) have amazingly different time profiles. It is sometimes claimed that "if you have seen one GRB, you have seen ... one GRB". Statistical studies of large samples of GRBs, on the other hand, have great potential for determining some common characteristics of all GRBs. In order to find signatures of the cosmological expansion in the time profiles of GRBs, the averaged peak-aligned time profiles (ATP) of the whole available sample of (useful) GRBs (about 1300) observed by the Burst and Transient Source Experiment (BATSE) on board of the CGRO were analysed. One would expect that weak bursts (that are produced at large redshift) would show the so called "time-dilation" effect in their ATPs when comparing with the bright ones (presumably produced close by). It turns out that the ATP's rising slope hardly changes with brightness. This strongly rules out the simplest interpretation of the "time-dilation" observed for the ATP's decaying slope as being caused only by cosmological expansion. It was shown that simple bursts (dominated by a single smooth pulse) and complex bursts (consisting of overlapping pulses) have significantly different peak brightness distributions: a complex burst appears intrinsically stronger than a simple burst. This could mean that the amplitude of individual pulses is, probably, a better standard candle than the peak brightness. This can put constraints on the physical models of GRBs.

Trying to find regularities in the process generating the extremely diverse time behaviour of GRBs, Fourier analysis was applied to $\sim$ 200 light curves of long bursts. A simple behavior of their power density spectra (PDSs) was discovered: the PDS is a power law of index $-5/3$ plus standard (exponentially distributed) statistical fluctuations superimposed onto the power law. The intrinsic $-5/3$ power law is reproduced with high accuracy ($-5/3 \pm 0.02$) when averaging the PDSs of individual bursts. A simple quantitative description of the GRB temporal behavior was thus obtained, which has been a long sought goal. The power law is a signature of the physical process generating GRBs. The coincidence with the Kolmogorov law is intriguing and suggesting fully developed turbulence in the ejecta of the GRB explosions.

The energy spectra of GRBs and their time evolution are also analyzed. The behaviour of the instantaneous (i.e., temporally resolved) spectra are of interest as they directly reflect the physics of the underlying emission processes. Especially, the spectral evolution within individual pulses is studied. The connection between the spectral and the intensity evolution has been formulated in a compact form. It was also demonstrated in what way the instantaneous spectra are related to the generally studied time-integrated pulse spectrum. It was shown how this can be used when studying observed GRB spectra.

Many detectable GRBs escaped detection (triggering) by BATSE because of too low intensity, or, so called, dead-time intervals. Such GRBs can be found in the daily count rate records which are accumulated during the full CGRO operation. Analysing the 32 Gb of archival data using an advanced triggering procedure about 1350 non-triggered GRBs were found (1.6 times more than the BATSE team found in the same data using a different technique) which doubles the available sample of GRBs. Most importantly, the efficiency of the search was measured with a novel "test burst" technique. A database of non-triggered GRBs is publically available at http://www.astro.su.se/groups/head/grb_archive.html. The research on GRBs is done in close collaboration with Dr. Boris Stern and Yana Tikhomirova (Moscow).

Instruments

The high energy astrophysics group is part of the team that will deliver the X-ray monitor, JEM-X, for the INTEGRAL-satellite. INTEGRAL is an ESA satellite dedicated to spectroscopy and imaging of hard X-ray and gamma-ray sources. The launch of the satellite is scheduled for 2001. The group in Stockholm participates in the development of the science software for JEM-X. JEM-X is a coded mask instrument, so task of the software is to deconvolve detector images and extract lightcurves and spectra for individual sources.

3.9. The Sun

(G. Scharmer, D. Kiselman, Birgitta Larsson, M. Löfdahl, L. Rouppe van der Voort, Wang Wei)

The Research Station for Astrophysics of the Royal Swedish Academy of Sciences runs a 0.5-m solar telescope on the Canary Island of La Palma. The research in solar physics takes advantage of the superb observing site to study small-scale solar phenomena such as granulation, sunspot structure, and small magnetic elements. This is done with techniques for imaging, spectroscopy, and polarimetry that are being developed in Stockholm and on La Palma to allow sub-arcsecond resolution.

The telescope is used by many guest observers for solar (and planetary) studies. Many of their observing programs are collaborations with the scientific staff based in Stockholm. Essentially all the observational programs are designed to take advantage of the high spatial resolution obtainable. An example of this is the studies of the small photospheric bright points that are especially bright when imaged in the wavelength of the G band and are tracers of enhanced magnetic fields. These bright points are barely resolved at the diffraction-limit of the telescope, and the phase-diversity technique for wavefront sensing and image restoration has been frequently employed in their study.

During 1997 and 1998 several observational runs were made in coordination with observations by the SOHO and TRACE spacecraft. The TRACE programs led to the discovery of a new kind of coronal emission from active regions called "moss", which does not have a simple correspondence to the photospheric magnetic field.

Other scientific projects of the Stockholm staff include observational and theoretical studies of photospheric line formation processes aimed at improving abundance analysis work, observations of H-β wings for testing photospheric convection models, studying the structure and dynamics of sunspot penumbræ, and magnetographic studies of weak solar magnetic fields.

On the instrumentation side, the correlation tracker that allows precise tracking and image stabilization has been made more efficient and reliable, more cameras have been added and the computer interfaces of the cameras have been improved; some of this development was performed in collaboration with researchers at Compaq's (formerly Digital Equipments') systems research center. The properties of the magnetographic setup have been investigated in order to improve it. The development of an adaptive optics system using new methods for wavefront sensing has started. Such a system will be essential for the new solar telescope which was designed during the period. Funding of the new telescope, which will be of twice as large aperture as the current one, has been secured and construction work has started. The new telescope is planned to replace the current one in early 2001.

4. HONOURS and AWARDS

Dan Kiselman has received the Benzelius Award (15000 SEK) from the Royal Society of Sciences in Uppsala in 1997 for outstanding research in the theory of radiative transfer in inhomogeneous media with departures from thermodynamic equilibrium and applied to analysis of stellar spectra with applications to the early evolution of the Galaxy and the Universe.

5. PhD and LICENTIATE THESES

Hartstein, D.: 1997, *Spectral Line Investigation of Young Stellar Objects*, Licentiate Thesis

Näslund, M.: 1998, *Deep Photometry of Galaxies. To See or not to See*, PhD Thesis

Kristen, H.: 1998, *Dynamics of the Interstellar Matter in Galaxies. Isolated Barred Spiral Galaxies, Cloud Formation Processes*, PhD Thesis

6. MASTER THESES

Andersson, Andreas: Jan 1997, *Molecular Gas in the Giant Spiral Galaxy M101*

Sandin, Christer D.: 1997, *Polarimeter MK-II* (10p)
and May 1998, *A Supernova Line Model Using a 20-level Pure Hydrogen Composition with an Expanding Envelope* (10p)

Brandeker, Alexis: June 1998, *The Fractal Structure of Insterstellar Clouds*

Gavler, Anders: Nov 1998, *The X/γ-spectra of the Seyfert 1 Galaxy NGC 3516*

7. UNIVERSITY COURSES

Stockholm Observatory is the department of astronomy at the Stockholm University. As such, it offers a number of undergraduate and graduate courses in astronomy and has programs leading to the licentiate and PhD degrees. The directors for undergraduate studies [studierektorer för grundutbildningen] are Claes-Ingvar Björnsson (1997 and 50% responsibility for 1998) and Anita Sundman (50% responsibility for 1998). The counsellors for undergraduate studies [studievägledare för grundutbildning] was/is Jesper Sollerman (until Sept 1997), Tomas Dahlén (from Sept 1997). The director for the Graduate School [studierektor för forskarutbildningen] is Roland Svensson. Lecturers of the courses are given in parenthesis. (1p corresponds to one week of full-time studies.)

7.1. Undergraduate Courses

Introductory Courses in Astronomy [Översiktskurser i Astronomi]
Prerequisites: General Admission [Grundläggande Behörighet]
Introductory Course to Astronomy (5p) Orienteringskurs i Astronomi (every summer, M. Näslund; fall 1997, A. Sundman)
Structure of the Universe (5p) Universums Byggnad (spring 1998, M. Näslund)
Planets and Life in the Universe (5p) Om Planeter och Liv i Universum (fall 1998, Aa. Sandqvist)
Astronomy and Cosmology through the Ages (5p) Astronomiska Världsbildens Utveckling (spring 1997, J. Schober)
Prerequisites: High School Mathematics and Physics [Gymnasium matematik och fysik från Naturvetenskapliga eller Tekniska Programmet]
Modern Astronomy (10p) Modern Astronomi (spring 1997, A. Sundman and G. Gahm; fall 1997, R. Liseau and Aa. Sandqvist; spring 1998, A. Sundman, R. Liseau and S. Larsson; fall 1998, G. Gahm)

Basic Courses in Astronomy [Grundkurser i Astronomi]
Prerequisites: University Mathematics (40p) and Physics (60p)
Atomic and Molecular Physics (5p) Atom- och Molekylfysik (every spring, C.-I. Björnsson)
Observational Techniques in Astronomy (5p) Astronomisk Observationsteknik (every spring, G. Olofsson)
Stellar Atmospheres (5p) Stjärnatmosfärer (1997, R. Liseau; 1998, K. Justtanont)
Structure and Evolution of the Stars (5p) Stjärnornas Struktur och Utveckling (every spring, G. Mellema)
Cosmology (5p) Kosmologi (every fall, C. Fransson)
Radiation Processes in Astrophysics (5p) Astrofysikaliska Strålningsprocesser (every fall, R. Svensson)
Physics of the Interstellar Medium (5p) Interstellära Mediets Fysik (every fall, P. Lundqvist)
Galaxies and Galactic Dynamics (5p) Galaxer och Galaktisk Dynamik (every fall, P. Artymowicz)

Advanced Courses in Astronomy [Påbyggnadskurser i Astronomi]
The Sun (5p) Solen (not taught 1997, 1998)
Physics of the Planetary System (5p) Planetsystemets Fysik (not taught 1997, 1998)
Active Galaxies (5p) Aktiva Galaxer (not taught 1997, 1998)

High Energy Astrophysics (5p) Högenergiastrofysik (not taught 1997, 1998)
Degree Project in Astronomy (10/20p) Examensarbete i Astronomi

7.2. Graduate Courses

The Graduate School at Stockholm Observatory has a programme consisting of a 60 p courses (40p Basic Courses and 20p Additional Courses) and 100p PhD thesis work. The Basic Courses are given on a rolling two-year schedule and consist of six 5p compulsary courses and two exercises chosen from a menu of numerical and observational exercises. The observational exercises are under development. Some courses are taught in collaboration with, or by, the Physics Dept, Stockholm University or Uppsala Observatory. Some courses may also be of the self-study type. During 1997-98, the following courses were taught:

Basic Courses [Baskurser]
Galaxies: Formation, Structure and Dynamics (5p) Galaxer: Bildning, Struktur och Dynamik (spring 1997, P. Artymowicz)
Cosmology (5p) Kosmologi (spring 1997 , Lars Bergström, Physics Dept)
Stellar Structure and Evolution (5p) Stjärnornas Struktur och Utveckling (spring 1997, Bengt Gustafsson, Uppsala Observatory)
Interstellar Matter (5p) Interstellär Materia (spring 1998, P. Lundqvist)
Stellar Atmospheres (5p) Stjärnatmosfärer (spring 1998, G. Scharmer)
Gas Dynamics (5p) Gasdynamik (spring 1998, R. Svensson)

Numerical Exercise in Galactic Dynamics (4p) Tillämpningsuppgift i Galaxdynamik (spring 1997, P. Artymowicz)
Numerical Exercise in Interstellar Matter (5p) Tillämpningsuppgift i Interstellär Materia (spring 1998, P. Lundqvist)
Numerical Exercise in Stellar Atmospheres (5p) Tillämpningsuppgift i Stjärnatmosfärer (fall 1998, D. Kiselman)

Additional Courses [Tillvalskurser]
Atomic and Molecular Physics (5p) Atom och Molekylfysik (every spring, C.-I. Björnsson)
Radiation Processes in Astrophysics (5p) Astrofysikaliska Strålningsprocesser (every fall, R. Svensson)
Molecular Astrophysics (5p) Molekylastrofysik (fall 1997, R. Liseau, H. Olofsson)

8. SYMPOSIA and WORKSHOPS

A number of symposia and workshops have been held under the auspices of, or in collaboration with, Stockholm Observatory:

The Crafoord Symposium: Late Stellar Evolution and Nucleosynthesis, Sept 30 - Oct 1, 1997, Royal Academy of Sciences, Stockholm, Sweden (Organizing Committee: Claes Fransson, Peter Lundqvist, Hans Olofsson)

Star Formation with the Infrared Space Observatory (ISO), June 24 – 26, 1997, Lisbon, Portugal (Scientific Organizing Committee: René Liseau)

Nordic Symposium: Use of the Spectrum-X-Gamma and INTEGRAL Missions, September 14 – 16, 1997, Copenhagen, Denmark (Scientific Organizing Committee: Roland Svensson)

Nordic Workshop on Gamma Ray Bursts, December 1, 1997, NORDITA, Copenhagen, Denmark (Organizing Committee: Roland Svensson, Boris Stern, Juri Poutanen)

International Workshop on High Energy Processes in Accreting Black Holes: Observational and Theoretical Advances due to Ongoing Space Missions, June 30 - July 4, 1998, Gräftåvallen, Sweden (Organizing Committee: Juri Poutanen, Roland Svensson)

Broad Band X-Ray Spectra of Cosmic Sources, Symposium during the 32nd COSPAR Scientific Assembly, July 12-19, 1998, Nagoya, Japan (Scientific Organizing Committee: Roland Svensson)

Nobel Symposium on Particle Physics and the Universe, Aug 20-25, 1998, Haga Slott, Enköping, Sweden (Organizing Committee: Claes Fransson)

9. GUESTS

A large number of guest scientists have visited Stockholm Observatory (d – days, w – weeks, m – months).

Baron, E. (Univ. of Oklahoma, USA), Oct 1998, 1w
Begelman, M.C. (Univ. of Colorado, USA), July 1998, 1w
Berdyugina, S. (Oulo University, Finland) Dec 1997, 1w
Björnsson, G. (Reykjavik Science Institute, Iceland), Mar-July 1998, 2m
Bergman, P. (Onsala Space Observatory, Sweden), June 1997, 1w; Dec 1998, 1w
Blinnikov, S. (ITEP, Moscow), May+Dec 1998, 4w+3w
Bodenheimer, P. (UCSC, USA), Mar/Apr 1998, 1w
Bryce, M. (University of Manchester, UK), April 199?, 1w
Chen, P. (Yunnan Observatory, China), Oct/Nov 1997, 4w
Chugai, N. (INASAN, Moscow), May 1998, 4w
Conway, J. (Onsala Space Observatory, Sweden), April 1997, 3d
Coppi, P.S. (Yale University, USA), August 1997, 2w, July 1998, 2w
Dorch, B. (University of Copenhagen, Denmark), 1997, 5w
Hagen-Thorn, V. (St. Petersburg University, Russia), July 1998, 1w
Hansteen, V. (University of Oslo, Norway), Mar 1997, 3d
Heap, S. (Goddard SFC, USA), Mar 1998, 1w
Igumenshchev, I. (Göteborg University, Sweden), June 1998, 2w
Illarionov, A. (Lebedev Phys. Institute, Moscow), June/July 1998, 1m
Iyudin, A. (MPE, Garching, Germany), Sept 1997, 1w
Justtanont, K. (SRON, Groningen, The Netherlands), Feb 1997, 4d
Kerschbaum, F. (Vienna Observatory), June 1998, 2w
Kjellsen, H. (Aarhus, Denmark), Oct 1997, 3d
Krolik, J.H. (Johns Hopkins University, USA), July 1998, 1w
Li, H. (Los Alamos Nat. Lab., USA), July 1998, 1w
Meikle, P., (Imperial College, London, U.K.), April 1997, 1w
Nyman, L.-Å. (ESO, Chile), Sept 1997, 3d; Oct 1997, 3d
Nymark, T. (Tromsö Univ., Norway), Jan 1997, 3d
Olberg, M. (Onsala Space Observatory, Sweden), Jan 1997, 1w
Palous, J. (Astronomical Inst., Prague, Czech Republic), Mar 1997, 1w
Pantin, E. (Saclay, France), Mar 1998, 2w
Petrov, P. (Oulu University, Finland), Nov/Dec 1998, 2w
Ryde, N. (Uppsala Observatory, Sweden), Oct 1998, 1w
Sikora, M. (Copernicus Astron. Center, Warsaw, Poland), July 1998, 1w
Sorokina, E. (Sternberg Institute, Moscow), Mar+Dec 1998, 2w+4w
Stern, B. (Inst. for Nuclear Research, Russia), 1997, 3m, 1998, 4m
Stuik, R. (Sterrekundig Inst., Utrecht, The Netherlands), Feb 1997, 3d
Tikhomirova, Ya. (Lebedev Phys. Institute, Moscow), Nov/Dec 1998, 2m
Volk, K. (University of Calgary, Canada) Jan 1997, 1w; May 1998, 2w
Zethson, T. (University of Lund, Sweden), Nov 1997, 3d

10. SEMINARS

The usual seminar day and time is Friday at 10:30. The location is the main lecture room at Stockholm Observatory. The seminar organizers were Peter Lundqvist in 1997 and Claes Fransson and René Liseau in 1998.

1997

January 27, Tanja Kramer Nymark (University of Tromsö) Irradiation in tight binary systems: AM Canum Venaticorum

January 31, Garrelt Mellema (Stockholm Observatory) Collimating jets from young stars

February 7, Rolf Walder (ETH Zürich) Wind dynamics in binary systems

February 13, Benoit Mandelbrot (T.J. Watson Research Center, IBM; Yale University) Fractals in astrophysics and physics

February 21, Robert Cumming (Stockholm Observatory) Why exploding stars look different from one another: the rebirth of the supernova classification system

February 28, Malcolm Fridlund (ESTEC) Herbig-Haro objects, with emphasis on those in L1551

March 7, Viggo Hansteen (Department of Theoretical Astrophysics, Oslo) A new view on the solar wind

March 17, Peter Roelfsema (SRON, Groningen) Results from the ISO Short Wavelength Spectrometer

March 21, Lars Bergström (Department of Physics, Stockholm) High-energy gamma ray and neutrino astronomy

April 4, John Conway (Onsala Space Observatory) Spectral line VLBI observations of circumnuclear gas in AGNs

April 11, Juri Poutanen (Uppsala Observatory) X-rays and gamma rays from black holes in AGNs and X-ray binaries

April 16, Peter Meikle (Imperial College, London) SN 1987A: Ten years on

April 18, Leif Festin (Uppsala Observatory) New brown dwarfs in the Pleiades

April 25, Adrick Broeils (Stockholm Observatory) Mass models and mass-to-light ratios of spiral galaxies

May 7, Daniel Hartstein (Stockholm Observatory) Spectral line investigations of young stellar objects (Licentiate thesis)

May 21, Michael Bode (Liverpool) & David Carter (RGO) The Liverpool Telescope Project

May 23, Göran Östlin (Uppsala Observatory) Star- and globular cluster formation in blue compact galaxies

May 30, Åke Nordlund (Copenhagen Astronomical Observatory) Supersonic MHD-turbulence and star formation

June 6, Sylvain Bontemps (Stockholm Observatory) ISO Mid-infrared photometry of young stars in the Rho Ophiuchi cloud

September 5, Claes-Ingvar Björnsson (Stockholm Observatory) The initial phases of outbursts in compact radio sources

September 19, Mats Carlsson (Department of Theoretical Astrophysics, Oslo) The new chromosphere

September 23, Anatoli Iyudin (Max Planck Institute, Garching) COMPTEL observations of X-ray binaries at MeV energies

October 10, Hans Kjeldsen (Theoretical Astrophysics Center, Aarhus) Probing the interior of stars by use of seismic analysis techniques

October 17, Birger Schmitz (Department of Marine Geology, Gothenburg) Cosmogene historical geology: Dinosaur extinction 65 million years ago and rain of stones 480 million years ago

October 24, Dan Kiselman (Stockholm Observatory) Lithium and Li-I lines in the Sun and elsewhere

November 4, Göran Olofsson (Stockholm Observatory) The PIROG 8 experiment and interstellar O_2

November 14, Pei-Sheng Chen (Yunnan Observatory, Kunming, China) IRAS spectra of OH/IR stars

November 21, Torgil Zethson (Department of Physics, Lund) Radial velocities in Eta Carinae

November 28, Fredrik Quist (Lund Observatory) Aperture synthesis and the Hipparcos transit data...and beyond

December 12, Cathy Horellou (Chalmers, Gothenburg) Collisional ring galaxies, observations and models

December 19, Svetlana Berdyugina (Division of Astronomy, Dept. of Geophysics; Oulu) Surface inhomogeneities on RS CVn stars

1998

January 13, Ulf Torkelsson (Institute of Astronomy, Cambridge) Magnetic fields in accretion discs

January 13, Erik Gullbring (Center for Astrophysics, Harvard): Accretion and disc evolution of T Tauri stars

January 16, Lars E.B. Johansson & Arto Heikkilä (Chalmers, Gothenburg) Molecular gas in the Magellanic Clouds

January 16, Per Elmfors (Department of Physics, Stockholm) Neutron star kicks

February 13, Claes Fransson (Stockholm Observatory) Circumstellar Interaction in Supernovae: the case of 1993 J in the galaxy M 81

February 20, Glenn White (QMW University of London) The Fingers of the Eagle Nebula: Pointers to the Earliest Stages of Star Formation

March 6, Mats André (Umeå University) Ion Outflow from the Upper Atmosphere and the Ionophere- An Example of Energy Concentration in Space Plasmas Observed by the Freja Satellite

March 13, Eric Pantin (Instituut voor Sterrenkunde, Belgium;) and Sally Heap (Goddard Space Flight Center, USA) Beta Pictoris: new observations of a young planetary system

March 20, Malcolm Fridlund (ESA-ESTEC, Astrophysics Division, Netherlands) Sweden in Europe in Space

March 27, Göran Scharmer (Stockholm Observatory) The Future Swedish Solar Telescope

April 2, Peter Bodenheimer (University California in Santa Cruz, USA) Formation of Brown Dwarfs and Giant Planets

April 8, Myfanwy Bryce (University of Manchester, UK) Observational studies of young planetary nebulae

April 17, Jenni Adams (Institutionen för teoretisk fysik, Uppsala Universitet) Inflation: Everything from Nothing

April 24, 10:30 Philippe André (Service d'Astrophysique, CEA-Saclay, France) Submillimeter observations of the initial conditions of star formation

May 5, Christer Sandin (Stockholm Observatory) A supernova line model using a 20-level pure hydrogen composition with an expanding envelope (Master Thesis)

May 8, Nikolai Chugai (INASAN Moscow, Russia) Why supernovae are luminous?

May 15, Sergei Blinnikov (ITEP Moscow, Russia) Gamma ray burst afterglow models

May 19, Helmuth Kristen (Stockholm Observatory) Dynamics of the Interstellar Matter in Galaxies. Isolated Barred Spiral Galaxies, Cloud Formation Processes (PhD Thesis)

May 20, John Beckman (IAC Teneriffe, Spain) Density Bounding in high luminosity HII regions in disc galaxies

May 25, Magnus Näslund (Stockholm Observatory) Deep Photometry of Galaxies. To See or not to See (PhD thesis)

May 29, Margaret S. Burbidge (University California in San Diego, USA) Observations of X-Ray Quasars Near Galaxies With Active Nuclei

June 5, Clas Blomberg (Theoretical Physics Dept. KTH, Stockholm) Early Earth and the Origin of Life

June 10, Alexis Brandeker (KTH: The Royal Institute of Technology/Physics, Stockholm) Fractal Interstellar Clouds (Master Thesis)

June 12, Franz Kerschbaum (Institut für Astronomie der Universität Wien, Österreich) ISO-SWS observations of AGB-variables

July 8, Cecilia Albertsson (KTH: The Royal Institute of Technology/Physics, Stockholm) Broad Emission Lines in Active Galactic Nuclei - The Symbiosis Model

August 28, Ewine van Dishoeck (Leiden University, The Netherlands) ISO-SWS spectroscopy of young stellar objects

September 4, Jens Ergon (The Royal Institute of Technology, Stockholm) Density Functional Calculations of Iron - An Example of the Virtual Laboratory of Modern Material Science

September 11, Ulf Lindström (Physics Department, Stockholm University) String Theory

September 25, Ariel Goobar (Physics Department, Stockholm University) The fate of the universe: measurements of the mass density and cosmological constant from 42 High-Redshift Supernovae

October 2, Susanne Höfner (Institut für Astronomie, Vienna, Austria) Models of AGB stellar atmospheres: Dynamics, Molecules and Dust

October 9, Dainis Dravins (Lund Observatory, Sweden) The Twinkling and Untwinkling of Stars: Atmospheric Intensity Scintillation, and Methods for its Correction

October 16, Edward Baron (Dept. of Physics & Astronomy, Univ. of Oklahoma, Norman, USA) Type Ic supernovae and their connection to gamma-ray bursts

October 30, Francoise Monnoyeur (History of Science Centre, Royal Academy Sciences, Stockholm) The infinity of the universe as a false question

November 6, Curt Mileikowsky (KTH: The Royal Institute of Technology, Stockholm) Natural transfer of viable microbes from one planet to another

November 25, Roy Booth (Onsala Space Observatory, Onsala) The Large Millimetre Array

November 26, Anders Gavler (Stockholm Observatory) The X/γ-spectra of the Seyfert Galaxy NGC 3516 (Master Thesis)

December 3, Mikael Lerner (Onsala Space Observatory, Onsala) Bar-driven mass relocation in galactic discs

December 7, Matt Delaney (Space Science and Advanced Materials Physics Dept., Dublin) Infrared Space Observatory imaging of gamma-ray burst locations

December 11, Boris Stern (Moscow, Russia) Doubling the number of detected gamma ray bursts by scanning the GRO data archive

December 18, Per Bergman (Onsala Space Observatory, Onsala) Complex Molecules in Sgr B2

11. ACTIVITIES for the GENERAL PUBLIC

Stockholm Observatory has a regular program of activities for the general public. Twice a month from October till March, the observatory makes available its 10-m-long 0.5m- and 0.6m-diameter double refractor for observations of the Moon, planets, and nebulae. Attendance is by reservation for individuals, groups or school classes. Lectures are also given by the observatory staff at these occasions. Because they are very popular they are fully booked early, and in order not to disappoint too many people, the Stockholm Observatory also has an approximately annual "Open House" on a Saturday or Sunday, at which no reservations are needed. These Open Houses may be timed to coincide with a celestial event such as a solar eclipse or the appearance of a bright comet. During 1997-98, such occasions were "Comet nights" on April 2, 3, and 8, 1997 in connection with comet Hale-Bopp, and the Open House on April 26, 1998. The Stockholm Observatory has a stand at the popular Saltsjöbaden Festival that takes place near Grand Hotel, Saltsjöbaden in early June every year.

Twice a week, an astronomer is on telephone-duty for questions from the general public. Other staff members are available for consultation by secondary and high school students. Stockholm Observatory also accepts apprentice students from secondary schools for one-week internships at the Observatory. A program of collaboration is ongoing with a nearby upper secondary and high school (Saltsjöbadens Samskola) which has a special astronomical curriculum. Finally, some of the faculty members and graduate students are very active in media such as radio, TV and the press. A number of astronomical articles in the newspapers, about twenty TV- and radio-programs have appeared that are based on interviews with the researchers from Stockholm Observatory. More than 50 popular lectures have been given in different cities all over Sweden.

Gösta Gahm has together with Nils Brenning (Royal Institute of Technology) been projecting Sweden Solar System (SSS), the world's largest model of the solar system, with activities planned at each planet station. In 1997-98 seven of the ten solar system stations were inaugurated at various locations in Sweden, with the Globe in Stockholm being the Sun. At some stations there are plans for more advanced models, and asteroids/comets have entered the scene as well. Several connecting exhibitions were designed, for instance at the Science Festival, SU in April 1998, when also the official "startskott" of the SSS took place. This project has received considerable attention in daily newspapers and magazines in the country, and also abroad. Several national and local radio and TV channels paid attention to the project.

Stockholm Observatory (Claes-Ingvar Björnsson, Stefan Larsson, Magnus Näslund and Hans Olofsson) received a grant from the KK-foundation to use astronomy to promote and popularize physics in high schools.

Stockholm Observatory has an intimate relationship with COSMONOVA, the Planetarium/Omnitheatre located at the Swedish National Museum of Natural History in Stockholm. Aage Sandqvist has been the astronomical consultant to Cosmonova since 1972, vice-chairman of the Swedish Omnitheatre (Cosmonova) Foundation since 1991, and in 1997 he was deeply involved in Cosmonova's new planetarium/omnitheatre production "Unknown Dimension" (Okänd Dimension). As a token of appreciation of his continuing efforts, Cosmonova is placed at the disposal of Stockholm Observatory twice a year, and free of charge, for presentations of astronomical programs to astronomy students at Stockholm University and Saltsjöbadens Samskola.

12. LIST of PUBLICATIONS

12.1. Scientific Publications in Refereed Journals

1. Abramowicz M.A., Bao C., **Larsson S.**, Wiita P.J., 1997, *On the variability coherence observed in black hole candidates at different X-ray energies*, ApJ, 489, 819

2. **Artymowicz P.**, Clampin M., 1997, *Dust Around Main Sequence Stars: Nature or Nurture in the ISM?*, ApJ, 490, 863

3. Asplund M., Gustafsson B., **Kiselman D.**, Eriksson K., 1997, *Line-blanketed model atmospheres for R Coronæ Borealis stars and hydrogen-deficient carbon stars*, A&A, 318, 521 (erratum, A&A, 323, 286)

4. Baluteau J.-P., Cox P., Cernicharo J., Pequignot D., Caux E., Lim T., Swinyard B., White G., Kessler M., Prusti T., Barlow M., Clegg P.E., Emery R.J., Furniss I., Glencross W., Gry C., Joubert M., **Liseau R.**, Nisini B., Saraceno P., Serra G., Armand C., Burgdorf M., Di Giogio A., Molinari S., Price M., Texier D., Sidher S., Trams N., 1997, *Detection of [O I] 63μm in absorption toward Sgr B2*, A&A, 322, L33

5. **Beloborodov A.M.**, 1998, *Super-Eddington Accretion Disc around a Kerr Black Hole*, MNRAS, 297, 739

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7. **Beloborodov A.M., Stern B., Svensson R.**, 1998, *Self-similar Temporal Behavior of Gamma-Ray Bursts*, ApJ, 508, L25

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A&AS- Astronomy and Astrophysics Supplement Series
ApJ- The Astrophysical Journal
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AJ- The Astronomical Journal
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Ap&SS- Astrophysics and Space Science

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12.4. Popular Science Publications

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12.5. The Swedish Almanac [Den Svenska Almanackan]

The Swedish Almanac [*Den Svenska Almanackan*] is the official astronomical almanac in Sweden, with roots going back to the sixteenth century. From 1749 to 1972, it was published with exclusive almanac rights by the Royal Swedish Academy of Sciences (KVA). Subsequently, it has been published by Esselte Almanacksförlag in collaboration with Stockholm Observatory. Its editor since 1977 is Aage Sandqvist. A simpler, but much more widely distributed, version of this almanac (*Den Vanliga Almanackan*) contains in addition a considerable amount of non-astronomical matter, but the astronomical part of the latter almanac is also produced in collaboration with Stockholm Observatory. The editor for the astronomical part of this almanac since 1977 is also Aage Sandqvist. Both *Den Svenska Almanackan* and *Den Vanliga Almanackan* are published each year.

13. COMMITTEE MEMBERSHIPS

Faculty members are often involved in the work of national or international committees. The membership list presented here is not complete, but gives an indication of the role played by the faculty in national and international committees.

Claes-Ingvar Björnsson: *National* - Astronomy representative on the Manne Siegbahn Memorial Lecture Committee; Member of the Swedish National Committee for Astronomy (1997); Member of NFR's ESO-NOT Committee; *International* - Sweden's national representative in IAU Commission 46

Gösta Gahm: *National* - Member of the board for the Onsala National Facility; Member of the board for Stiftelsen Observatoriekullen

Claes Fransson: *National* - Member of the Royal Academy of Sciences; Member of NFR's ESO-NOT Committee; Member of the Swedish National Committee for Astronomy (1998); *International* - Chairman of Nordita astrophysics committee; Member of Nordita board

Dan Kiselman: *National* - Secretary of the Swedish Astronomical Society

Per Olof Lindblad: *National* - Member of the Royal Swedish Academy of Sciences; *International* - Member of the General Prize Committee of the Balzan Foundation; Foreign member of the Norwegian Academy of Science and Letters

René Liseau: *International* - Swedish representative in the Scientific Advisory Group to ESA for the Cornerstone 5 candidate Infrared Space Interferometer Darwin

Peter Lundqvist: *International* - Member of the NOT Observing Programme Committee (1997); ESA representative in one of the HST Cycle 8 review panels (1998); Deputy member of the ESO Observing Programme Committee

Lennart Nordh: *National* - Member of the Swedish National Committee for Astronomy; *International* - member of ESA's Science Programme Committee

Göran Olofsson: *National* - Member of NFR's ESO-NOT Committee; *International* - Member of NOT Scientific and Technical Committee

Hans Olofsson: *National* - Member of the Swedish National Committee for Astronomy (1997); Chairman of the Observing Proposal Programme Committee of the Swedish National Facility for Radio Astronomy, Onsala Space Observatory

Aage Sandqvist: *National* - Vice-Chairman of the Swedish Omnitheatre (Cosmonova) Foundation; *International* - Chairman-Elect of the Board of Directors for the European Journal *Astronomy and Astrophysics*; Swedish representative on the European Astrophysics Doctoral Network (EADN)

Roland Svensson: *National* - Member of NFR's Program Committee for Physics (PuF), renamed to Physics Committee (FK); Member of Subcommittee 3 of NFR's PuF evaluating astronomy applications annually; Member of NFR's ESO-NOT Committee; Member of the Swedish National Committee for Astronomy; Member of NFR's CERN committee

Göran Scharmer: *National* - Member of the Royal Swedish Academy of Sciences; Member of the Swedish National Committee for Astronomy