2006

NORDIC OPTICAL TELESCOPE

ANNUAL REPORT

The spiral galaxy NGC 2841

NOT ready for action

Front cover: The spiral galaxy NGC 2841; composite image in blue, green, and red light. Photo: J. Näränen, NOT and Helsinki University.

NORDIC OPTICAL TELESCOPE

The Nordic Optical Telescope (NOT) is a modern, well-equipped 2.5-m telescope located at the Spanish Observatorio del Roque de los Muchachos on the island of La Palma, Canarias, Spain. It is operated for the benefit of Nordic astronomy by the Nordic Optical Telescope Scientific Association (NOTSA), established by the national Research Councils of Denmark, Finland, Norway, and Sweden, and the University of Iceland.

The governing body of NOTSA is the **Council**, which determines overall policies, approves the annual budgets and accounts, and appoints the Director and Astronomer-in-Charge. A **Scientific and Technical Committee** (STC) advises the Council on the development of the telescope and other scientific and technical policy matters.

An international **Observing Programmes Committee** (OPC) of independent experts, appointed by the Council, performs peer review and scientific ranking of the observing proposals submitted. Based on the ranking by the OPC, the Director prepares the actual observing schedule.

The **Director** has overall responsibility for the operations of NOTSA, including staffing, financial matters, external relations, and long-term planning. The staff on La Palma is led by the **Astronomer-in-Charge**, who has authority to deal with all matters related to the daily operation of NOT.

The membership of the Council and committees in 2006 and contact information to NOT are listed at the end of this report.

The NOT Annual Reports for 2002-2006 are also available at: http://www.not.iac.es/news/reports/

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Volcanoes and rainbow

Editor: Johannes Andersen
Layout: Anne Marie Brammer

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THE STAFF

No changes in the NOT staff occurred in 2006; however, Peter Brandt had to take an extended sick leave due to after-effects of his illness two years ago. The succession of students continued at an even livelier pace than in 2005: Danuta ('Danka') Paraficz extended her stay for another year to embark on her PhD project, while Karianne Holhjem (Norway; Synnøve Irgens-Jensen Distinguished Research Student), Tine Bjørn Nielsen (Denmark), and Dmitrij Sharapov (Uzbekistan) left us at the end of the year. In return, Lars Glowienka (Denmark) joined us early in 2006, Christina Henriksen (Denmark) and Helena Uthas (Sweden) in the second half of the year. The NOT team in 2006 is presented below.

As part of the agreements with Spain, NOTSA provided stipends for Ph.D. students Antonio López Merino, Copenhagen University, and Laia Mencia Trinchant, Stockholm, also in 2006.

Francisco Armas
Administrator

Thomas Augusteijn
Astronomer-in-Charge

Peter Brandt
Mechanic

Ricardo Cárdenes
System manager

Jacob W. Clasen
Software specialist

Graham Cox
Electronics engineer

Amanda Djupvik
Senior Staff Astronomer

Loida Fernández
Secretary

Lars Glowienka
Student

Christina Henriksen
Student

Karianne Holhjem
Student

Eva Jurlander
Accountant

Tine Bjørn Nielsen
Student

Danuta Paraficz
Student

Carlos Pérez
Electronics technician

Tapio Pursimo
Staff astronomer

Dmitrij Sharapov
Student

Peter M. Sørensen
Software specialist

Ingvar Svärdh
Software engineer

John Telting
Staff astronomer

Helena Uthas
Student

The NOT Annual Reports are meant to give you a taste of the research and other activities at NOT during the year. The report for 2006 is the fifth I have the pleasure to present, and I hope you will find it of interest.

Our staff on La Palma was unchanged in 2006, except that Peter Brandt had to take sick leave in the autumn; we wish him a successful recovery and look forward to have him back in 2007. The student group became livelier than ever as Lars Glowienka (Aarhus) joined Danka, Karianne, Tine, and Dmitrij in January, Christina Henriksen (Copenhagen) followed in September, and Helena Uthas (Lund) arrived in November (see portraits on the facing page). We hope to maintain the group at its present strength and high morale also in the future!

In sad contrast, we were shocked to learn that our former Astronomer-in-Charge Hugo Schwarz died in a traffic accident in Chile on October 20, 2006. Hugo came to NOT in 1995 at a very critical time, and his role in shaping the present NOT cannot be overestimated: *"NOT went from failure to success during that period!"*, as he said with justified pride in our Annual Report for 2004. After his move to Cerro Tololo Observatory in 2000, Hugo came back to La Palma frequently to observe or just visit, and a large number of friends and colleagues will miss him greatly.

Most other developments during the year were favourable. The new telescope cooling and control systems went through extensive burn-in periods, after which the old systems were physically removed and the new ones have worked well. The fibre-fed high-resolution spectrograph FIES was also taken into regular use with the first visiting astronomers during the year (see p. 24).

Another milestone was the completion of the international evaluation of NOT in March 2006; the report is available at *http://www.not.iac.es/news/reports/*. We were of course pleased by the panel's statement that "The NOT is a high quality telescope, efficiently operated at costs comparable with (if not lower than) those of similar facilities". It also strongly endorsed the concept we have developed for the future, where NOT would become part of an integrated European mid-size facility on La Palma.

Taking this model from concept to reality is more easily said than done, however. Much progress was made in 2006 to define a common Nordic set of priorities for the future of NOT, culminating in a meeting with representatives of all Nordic user groups. Briefly, the conclusions of that meeting (see *http://www.not.iac.es/news/reports/*) were to focus the role of NOT, within the final common facility as well as in the interim, on projects on transient and other variable objects in which Nordic groups are strong. The instrumentation should evolve towards a small set of permanently mounted instruments to promote flexibility, the observing strategy move towards full queue scheduling. The educational use of NOT should be strengthened and also be better coordinated at the Nordic level.

We are currently working to prepare the implementation of this far-reaching policy revision, which has been approved by the Council. At the same time, NOTSA participates actively in the effort by the EU-funded networks ASTRONET and OPTICON to establish a comprehensive, long-term planning framework for European astronomy as a whole, which will prepare the general political background for our future activities (see more on p. 5). Much of 2007 will be taken up by this broad programme.

Finally, I thank all the contributors to this report and hope you will enjoy reading it. Unsigned text and photos are by the undersigned, while credit for the layout and production is again due to Anne Marie Brammer.

Johannes Andersen
Director and Editor

Up-to-date information on activities at NOT is maintained at our web site, http://www.not.iac.es. Some of the most significant developments in 2006 are summarised here.

Personnel

Our small staff operates without reserves or redundancies, but remained intact most of 2006. Unfortunately, in the autumn Peter Brandt had to take extended sick leave to recover from the after-effects of a serious infection; we look forward to have him back in 2007.

Meanwhile, the student group swelled to record numbers as Danka Paraficz (Copenhagen), Karianne Holhjem (Oslo), Tine Bjørn Nielsen (Aarhus), and Dmitrij Sharapov (Tashkent) were joined by Lars Glowienka (Aarhus) in January, Christina Henriksen (Copenhagen) in September, and Helena Uthas (Lund) in November. Tine and Dmitrij returned home at the end of the year, while Karianne will pursue her PhD in Germany, Danka hers during another year at NOT. We trust that they profited from their time at NOT; we enjoyed their company!

Christmas 2006 in the sea-level student office.

Facilities and instruments

Our three-year facility upgrade programme saw its final completion in 2006, as the new telescope control and cooling systems proved sufficiently stable for the old systems to be physically removed. The recovered space in the building allows us to remodel the control room and improve efficiency and comfort for the observers. The bench-mounted spectrograph FIES was also commissioned for general use and first performance tests made – see p. 24 for details on the results.

An unpleasant surprise occurred in the spring when the science grade array in NOTCam suddenly failed after just a few thermal cycles. Negotiations with Rockwell on the possible causes for this mishap led to a favourable offer for an excellent replacement array, which we accepted. The new array will be installed in 2007 after a minor upgrade of the array electronics, the engineering grade array providing acceptable performance in the meantime.

Education

Hands-on training at NOT for a new generation of scientists in a world of increasingly "hands-off" 8-m telescopes is becoming ever more popular, both our visiting programme for individual research students (see above) and the regular university courses and summer schools offered to larger student groups. In 2006 we hosted both a NORDFORSK sponsored summer school at the PhD level and two visits by high school classes, who combined a short spell of hands-on observing at NOT with other forms of study on La Palma. See more about these courses on p. 22, and about the future organisation of these activities at NOT below.

International evaluation of NOT

The reorganisation of our administrative procedures and the preparation of an outline plan for the future of NOT are described in earlier Reports. Before addressing these issues in specific terms, the Joint Committee of the Nordic Natural Science Research Councils (NOS-N), at the proposal of the NOTSA Council, decided to commission an international evaluation of NOT by a panel of international experts. Their remit was, in summary, *"To advise on suitable strategies for achieving a scientifically valuable and operationally cost-effective role for NOT over the next 10-20 years"*.

Based on an extensive material of reports, national "Town meetings", interviews, and a site visit, the report of the panel was submitted to the Council and NOS-N in March 2006 (see *http://www.not.iac.es/news/reports/*). We were pleased that the panel confirmed that NOT is indeed both a scientifically valuable and cost-effective operation, and that the way to maintain it so in the future is to join a larger European collaboration, as we have proposed, but also that some initial investment is required before that goal can be achieved. The use of NOT in science education was seen as a very valuable development, now as well as in the future.

Students at the controls of NOT, March 2006.

There remains for us to implement these recommendations in practice – not a small or simple task. The steps we are taking in this direction are described in the following. But first, an outline of the rapidly developing European scene is in order.

Coordination in European astronomy: ASTRONET and OPTICON

As the restructuring of Europe itself proceeds and plans for ever more ambitious research infrastructures mature, it becomes increasingly clear that the traditional fragmentation of planning and decision making in European astronomy by discipline and national borders is inadequate to meet the challenges of tomorrow. Accordingly, concerted efforts are under way to provide a comprehensive plan for the development of European astronomy over the next 15-25 years – at all wavelengths or particle types, on the ground and in space, including all European communities, and considering the coordinated development of theory, computing, and human resources as well as new technology and expensive hardware.

The driving forces in these efforts are the EU-funded networks ATRONET, OPTICON, and RadioNet, initiated by those same funding agencies that will, in some way or other, provide the main investments in whatever future European astronomy will have – including those channelled through ESO and ESA.

The specific tasks of ASTRONET and OPTICON were described in the report for 2005, but their relative roles have become more clearly defined in the past year. With its relatively modest four-year ERA-Net grant of 2.5 MEuro, ASTRONET focuses on defining a coherent long-term strategy comprising both scientific, technical, and financial issues as well as planning and management procedures on a broad European front, but does not fund any actual research or development. In 2006, the overarching *Science Vision* report was prepared for iteration with the community; the next step, the *Infrastructure Roadmap*, will ramp up in early 2007 (see *http://www.astronet-eu.org*).

OPTICON, on the other hand, uses its 19-MEuro grant in FP6 to promote hands-on cooperation in European optical/IR astronomy and drive a concerted R&D programme aimed at the next generation of observing facilities. Through a balanced portfolio of intensified networking, development of enabling technologies, and more efficient European use of existing research facilities – such as NOT – OPTICON thus helps to create the practical conditions for the realisation of the grand plans prepared by ASTRONET. The OPTICON proposal for FP7 is being prepared with this overall strategy in mind.

The long-term future of NOT

As a full partner in both ASTRONET and OPTICON, NOTSA is centrally placed in these efforts, which must underpin any rational planning for the future of NOT itself. The ASTRONET *Infrastructure Roadmap*, if completed as planned, will provide a much more complete and rational framework for defining the future role of NOT than exists today. However, it will only become available in late 2008, and preparations must start already now.

As a basis for these preparations, a clear set of scientific goals and priorities for the future role of NOT needs to be agreed – something unprecedented in Nordic astronomy. We started this process in the summer and early autumn of 2006 by contacting all Nordic user groups and collect their plans, wishes, and priorities for the future. In parallel, our four Instrument User Groups (IUGs) reviewed the status and options for competitive instrumentation within their fields. The process concluded with a meeting of all group representatives as well as IUG and STC members on November 8-10, 2006, where all aspects of the future of NOT were thoroughly debated. A gratifying degree of consensus was in fact reached. A short report (see *http://www.not.iac.es/news/reports/*) summarises the conclusions of the meeting, which have been endorsed by the NOTSA Council.

In short, NOT should focus on front-line performance on transient and other variable sources, with a fixed set of standby instruments used in full service mode. Moreover, the procurement of new instruments and the conduct of training activities at NOT should be organised much more professionally and transparently in the future. And an invitation to increased time sharing between the telescopes on La Palma should be issued very soon. At the turn of the year, we are already busy implementing all of these recommendations.

NOT was created to enable Nordic astronomers to do science. The primary scientific output from NOT is in the form of professional publications in international journals (see p. 29), but a few highlights from the year are given here for a more general readership. The individual contributions have been edited for clarity and conciseness; the Editor apologises for any inadvertent errors in the process.

COSMOLOGY AND FORMATION AND EVOLUTION OF GALAXIES

According to present models, the formation and evolution of the Universe are controlled by totally unknown forms of dark energy and dark matter. Understanding these constituents and how they shaped the Universe we see today and its visible building blocks – the galaxies – is a central theme of observational cosmology. We need to clarify the physical processes that took us from the Big Bang to today's world of galaxies, stars, planets, and life.

Measuring the lumpiness of matter in the Universe

A few hundred thousand years after the Big Bang, matter (including the 85% dark matter) was almost uniformly distributed in the universe, with only tiny density fluctuations (of order 1:100.000). Since then, gravitational forces have greatly enhanced these density fluctuations into increasingly large and massive structures, which eventually underwent gravitational collapse. Massive clusters of galaxies represent the end point of this evolution: They constitute the extreme high-mass end of the statistical distribution of matter density fluctuations today. The number of such clusters is thus extremely sensitive to all parameters that govern structure formation in the universe, including the underlying cosmological model and the composition of the unknown dark matter.

***Fig. 1:** The galaxy cluster Zwicky 3146, observed with ALFOSC (two hours in the V and I bands). From the weak gravitational distortion of the faint galaxy images, the cluster mass is found to be 9 10^{14} solar masses, a rather typical value.*

NOT has played a crucial role in making a first measurement of the number density of very massive clusters, based directly on weak gravitational lensing, which measures the average gravitational distortion of the images of distant galaxies along nearby lines of sight. The great advantage of this method is that it probes *all* gravitating matter directly, independent of any assumptions about the relationship between dark and luminous matter and/or the dynamical state of the cluster. This avoids the serious systematic uncertainties that have affected previous efforts to constrain the matter density fluctuations from observations of the galaxy clusters themselves.

The NOT results are based on a statistical analysis of the shapes of faint galaxies behind clusters, as seen in deep images (Fig. 1), to extract an unbiased measurement of the total mass of each cluster. By analysing a statistically well-defined sample of 35 clusters, we could put strong constraints on a combination of the present-day matter density in the universe (Ω_m) and the matter fluctuations on cluster scales, σ_8 (Fig. 2).

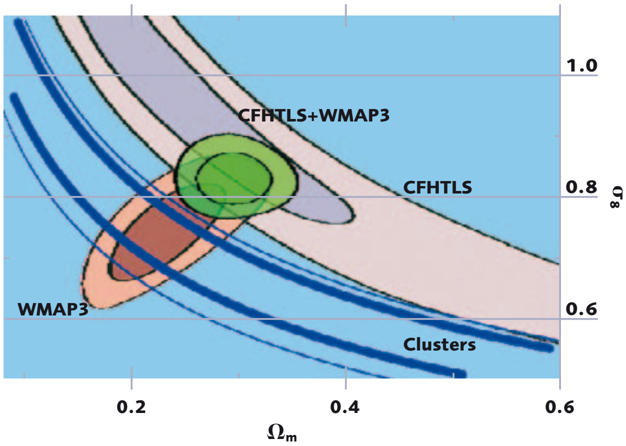


***Fig. 2:** Present-day matter density in the Universe, Ω_m, vs. the matter density fluctuations on cluster size scales (8 Mpc), σ_8. The contours limit the acceptable parameter combinations based on the CFHT Legacy Survey of galaxy clusters (grey), from measurements of the cosmic microwave background with the WMAP satellite (brown), and from a combined analysis (green). The blue curves give 68% (thick) and 95% confidence limits (thin) on the same parameters as derived from the NOT cluster survey.*

These data also set an upper limit on the sum of the neutrino masses ($M_\nu < 1.43$ eV; 95% confidence limit), from a combination of the NOT cluster survey and measurements of temperature fluctuations in the cosmic microwave background using the WMAP satellite (Fig. 3). This constraint is considered "robust" because it relies on two different diagnostics, both based on relatively simple and well-understood physics.

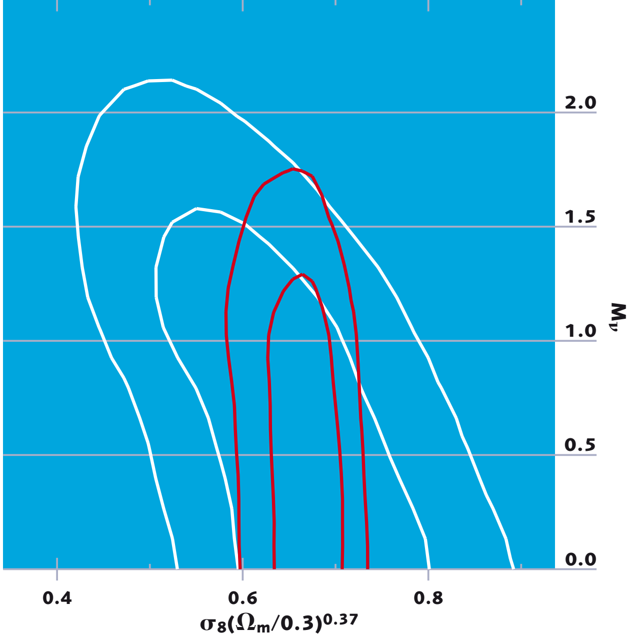


Fig. 3: The sum of the neutrino masses (M_ν) vs. the combination of Ω_m and σ_8 that is most sensitive to the frequency of massive clusters. The white and red lines show the limits derived from the WMAP data before and after adding the information from the NOT survey.

Efforts are now under way, with both NOT and larger telescopes, to improve these constraints by observing more clusters and improving the mass measurements of clusters observed earlier with NOT.

H. Dahle, J.R. Kristiansen, Ø. Elgarøy, Oslo

New light on Gamma-Ray Bursts

Target-of-Opportunity observations of Gamma-Ray Bursts (GRB) are a very active field of research at NOT, and the programme has been triggered every few nights in 2006 as new GRBs have been discovered by the *Swift* satellite (see Annual Report 2004, p. 8). Any immediate findings are reported directly in the form of *GRB Coordinate Network* (GCN) circulars, enabling researchers worldwide to identify and study the optical afterglows. Our group issued over 50 GCN circulars during 2006, many of them based on NOT data.

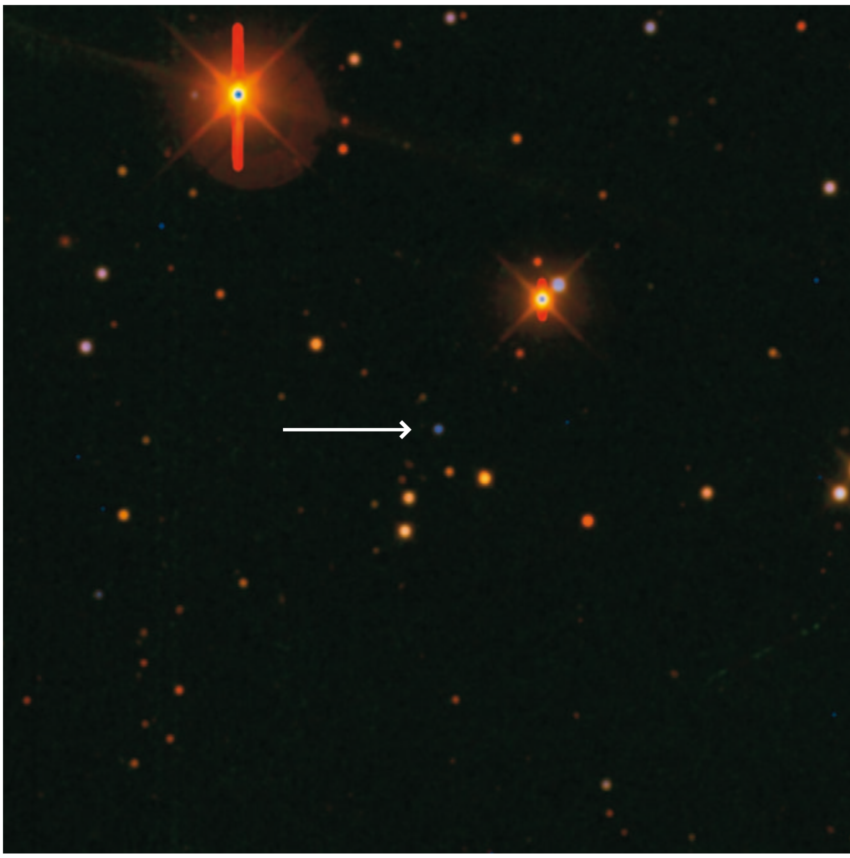
In 2003, we conclusively linked a long GRB to a supernova explosion (Hjorth et al. 2003, *Nature* **423**, 847). GRB=SN seemed to be the simple formula that explained the most energetic explosions in the universe. So what has happened since then? Part of the answer comes from the study of X-Ray Flashes (XRFs), which are the softer cousins of the GRBs and received a lot of attention in 2006. Could they be the same basic phenomenon as the GRBs, but perhaps viewed from a different direction?

XRF 060218 was a nearby burst (z=0.03), and we managed to show that it was connected to a supernova. Combining data from NOT and the Danish 1.5m telescope on La Silla, we obtained very nice light curves in several bands, and a coordinated VLT campaign provided superb spectroscopic coverage as well. But the burst was very unusual in continuing for all of 2000 seconds, while most GRBs show off for only a few seconds or even less. And the supernova we found was fainter than those usually accompanying GRBs. Tentative evidence for a supernova was also found in another XRF (050824, z=0.83), but this one had a fast rising light curve. So not all GRB-supernovae are alike.

The situation got even worse during the summer, when two nearby GRBs were shown to not host supernovae at all. Hectic nights and days were spent during the NOT summer school (see p. 22) to unravel this puzzling story. In summary, the simple SN=GRB picture began to crack during 2006.

In the long run, we hope that a better understanding of GRBs will enable us to use them to probe the star formation in the very early universe. For this, you need distant objects, and GRBs are distant objects indeed: We found the mean redshift of a sample of *Swift* GRBs to be z=2.8, with many contributions from NOT, including the record holder for 2006, GRB 060927 at a hefty z=5.47. We also demonstrated that such distant GRBs can indeed help us probe the chemical evolution in the universe, using GRB 060206 at z=4.0, which was discovered and had its redshift determined with NOT.

Fig. 4. The Gamma-Ray Burst GRB060218 = XRF060218 = supernova SN2006aj. Photo: J.-E. Ovaldsen, J. Selj.



So, what can we expect for the future? Clearly, GRBs must eventually become old hat? Maybe, but we also thought so before 2006, which was full of GRB surprises. There clearly remain many interesting questions in the GRB business, and it is fascinating that NOT continues to deliver so much to this field.

J. Sollerman and colleagues, DARK; Copenhagen, Oslo, Reykjavik, and Stockholm

A turbulent, ionized intergalactic medium at high redshift

Matter between the stars – *interstellar matter (ISM)* – has a very clumpy distribution in the Galactic disk and consists variously of ionized, neutral, and molecular gas containing dust, in mixtures varying with local conditions. Matter between the galaxies – *intergalactic matter (IGM)* – is much more distant, much more rarefied, and thus much more difficult to study than the ISM, especially at large distances, i.e. at high redshift. But there are ways to derive clues to its structure nevertheless. New NOT observations have helped to understand the possible inhomogeneity of the IGM at high redshifts, and how it has changed over time.

The first step was radio observations of a large sample of 482 quasars with the Very Large Array (VLA) in the USA at a wavelength of 6 cm. 53% of the sources showed variable radio emission on time scales shorter than a day – intra-day variability (IDV). At this wavelength, IDV is caused primarily by interstellar scintillation in a medium with varying electron density – i.e. degree of ionization – not by variability in the source itself. In addition to the varying signal strength, scintillation also “washes out” the images of very distant point sources, because the radio waves are also deflected by the ionised IGM clouds – just like seeing and scintillation at optical wavelengths are due to the same inhomogeneities in the Earth’s atmosphere.

Thus, radio waves from greater distances in the universe will pass more clouds in the IGM, which will tend to increase the smearing of the images while reducing the amount of scintillation. The smearing remains too small to observe directly with any technique, but the scintillation can be observed as IDV. So were the stable sources primarily those at the greatest distance, i.e. the highest redshifts?

In the literature, redshifts were found for only 150 of the targets, so another 40 were observed with NOT. And indeed, the most distant quasars (z>2) showed significantly less IDV than the more nearby ones. Cosmological effects do broaden the image of very distant sources, but not enough to explain the result. We thus learn that the IGM in the early universe was clumpy, and that some mechanism (e.g. supernovae) existed which injected enough energy into it to ionize it. A couple of statistical effects that could weaken this result are now being addressed through new observations.

T. Pursimo, NOT; D. Jauncey, J. Lovell, Australia; R. Ojha, J.-P. Macquart, M. Dutka, USA

The star formation history of dwarf galaxies

Dwarf galaxies are the dominant galaxy population. For example, in the Local Group, dwarf elliptical galaxies alone outnumber high-luminosity galaxies by a factor of 6, and over 50% of the galaxies in the Virgo cluster are dwarf ellipticals. If more massive galaxies were assembled by early mergers of dwarf galaxies, the dwarfs we observe today are the survivors of an initially much richer population.

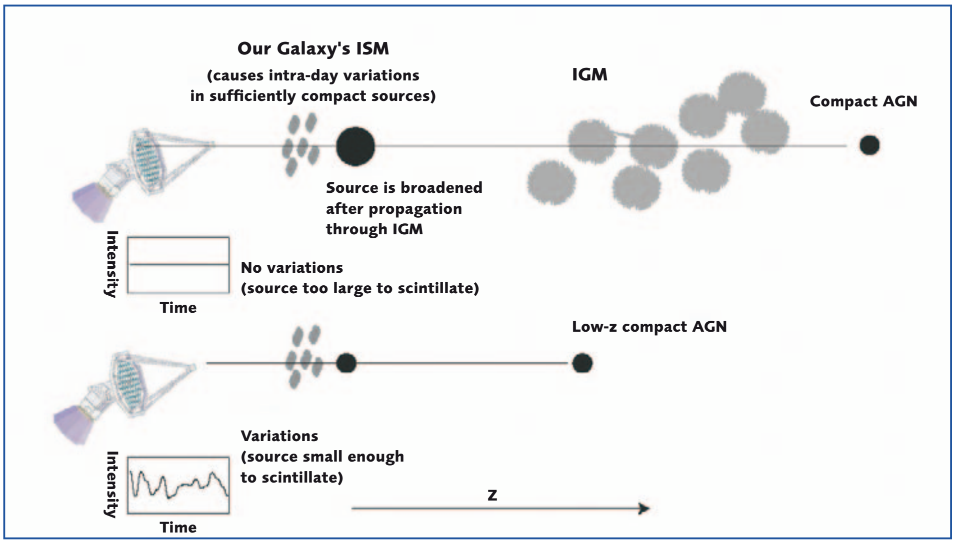


Fig. 5. Schematic diagram of the path of radio waves from quasars at different distances (right) through the IGM to the observer (left).

Fig. 6. NGC 1427A, a dwarf galaxy in the Fornax cluster. Photo: NASA, ESA, and the Hubble Heritage team.

Today's dwarf galaxies (Fig. 6) are the closest modern counterparts of the fragments that presumably formed galaxies early on. Their star formation histories may tell us how the physical conditions were in the early Universe, and how galaxies evolved. Dwarf galaxies tend to have low metallicity and just a few star formation episodes, so they should be much simpler systems than the more massive galaxies.

Dwarf galaxies fall in two main groups: the quiescent and the star forming ones. The quiescent group includes dwarf elliptical (dE) galaxies and the fainter dwarf spheroidal (dSph) galaxies, while the star forming dwarfs include dwarf spiral, irregular (dIrr), and blue compact (BCD or H II) galaxies. Quiescent and star forming dwarfs are distributed very differently in space, with the dEs and dSphs occurring almost only in clusters and groups, while the active dwarfs reside predominantly in the field.

We have a reasonable knowledge of dwarf galaxies, but are only beginning to understand their evolution. Environment clearly plays a very important role. Key questions are: Why is the stellar mass vs. metallicity relation so tight? Are galactic winds in clusters crucial for the evolution of dwarf galaxies? Are dEs and dSphs indeed dwarf spirals/irregulars in which star formation ceased long ago (several Gyr)? What is the star formation history in the first place?

To answer questions such as these we have started a detailed study of dwarf galaxies, aiming to derive masses and abundances of several elements in the member stars as clues to their star formation histories, using state-of-the-art stellar population models.

Taking advantage of the International Time Programme (ITP), we have observed a complete magnitude-limited sample of cluster galaxies in the Virgo cluster and a similar comparison sample of field galaxies, including both quiescent and star forming dwarfs. NOT was mainly used for imaging and near-infrared photometry, which is important in these often dusty objects, since it allows us to measure the mass of the old stellar population, unaffected by dust obscuration and blue light from young stars.

The data analysis is still ongoing, but we do find that the quiescent dwarfs are generally metal-poor. However, they are not all not old, as expected if they were the building blocks of larger galaxies in a hierarchical formation scenario; ages range from ~3 to 15 Gyr. Moreover, we find that the detailed abundance ratios are close to solar. This implies that the stellar populations in quiescent dwarfs are similar to those in the disk of the Milky Way, i.e. star formation is slow, contrary to giant elliptical galaxies, where star formation is very efficient – showing again that the dwarf galaxies of today are not the building blocks of the larger galaxies that formed earlier. Correlations between galaxy properties and cluster environment are still being studied in detail.

R. Peletier, Groningen, and colleagues from the MAGPOP consortium

Interactions and starburst phenomena in Wolf-Rayet galaxies

Some galaxies show evidence of a recent, violent episode of star formation, a so-called starburst. Some of these galaxies also show emission lines from Wolf-Rayet stars, which are young, very massive stars in an advanced stage of evolution. We have performed a detailed analysis of 20 such W-R galaxies to test the recent suggestion that galaxy interactions could be the main triggering mechanism for massive star formation in dwarf galaxies. In order to perform a thorough analysis, we combine optical and near-infrared (NIR) broad-band and H_α images with optical spectroscopy at several resolutions. Additional X-ray, far-infrared, and radio data were compiled from literature.

Deep, high-resolution images in broad optical and NIR bands have been used to study the morphology of the stellar population, looking for signs of interaction processes with similar or low surface brightness galaxies. The optical images were mainly obtained with ALFOSC at NOT (see Fig. 7 for a sample). The quality of these data allowed us to detect faint features around some of the galaxies, including tails, tidally distorted dwarf galaxies and arcs, and other dwarf galaxies. Colour measurements have permitted to analyse their stellar populations and the age of the last burst of star formation.

An interesting object is the WR galaxy Tol 9, 43 megaparsec away (Fig. 8). The images reveal several independent objects in its neighbourhood and a bridge from Tol 9 towards a dwarf companion located 10 kpc away, indicating a probable interaction between the galaxies. No ionized gas is detected in the bridge, and its colours suggest that it is dominated by relatively old stars.

Observations of ionized gas (Hα) in the galaxies themselves have been used to study the distribution, activity, chemical composition, and motions of star-forming regions and young stars throughout these galaxies (e.g. Fig. 7d,e and Fig. 8). These data have been used to estimate the mass of the gas, the number of ionizing young stars, and the star formation rate (SFR) of each burst. We find a total gas mass of ~3 10^6 solar masses distributed in an expanding bipolar bubble, and with an SFR of about 2 solar masses per year. The age of the most recent burst is around 4-6 million years, but there is also a more evolved underlying stellar population, with ages of 1-200 million years or older.

However, our main conclusion is that ~80% of the galaxies we studied show clear interaction features such as plumes, tails, tidally distorted companions, regions with very different chemical abundances, perturbed kinematics of the ionized gas, or lack of neutral gas. We thus confirm the hypothesis that interaction with or between dwarf objects triggers the star formation activity in Wolf-Rayet galaxies.

A.R. López-Sánchez, C. Esteban,
J. García-Rojas, IAC, La Laguna

Fig. 8. The starburst galaxy Tol 9 (right of centre) and the beautiful spiral galaxy ESO 436-46 (left), observed with ALFOC in blue, green and Hα light. The peculiar Hα emission in Tol 9 suggests a kind of galactic wind in this galaxy.

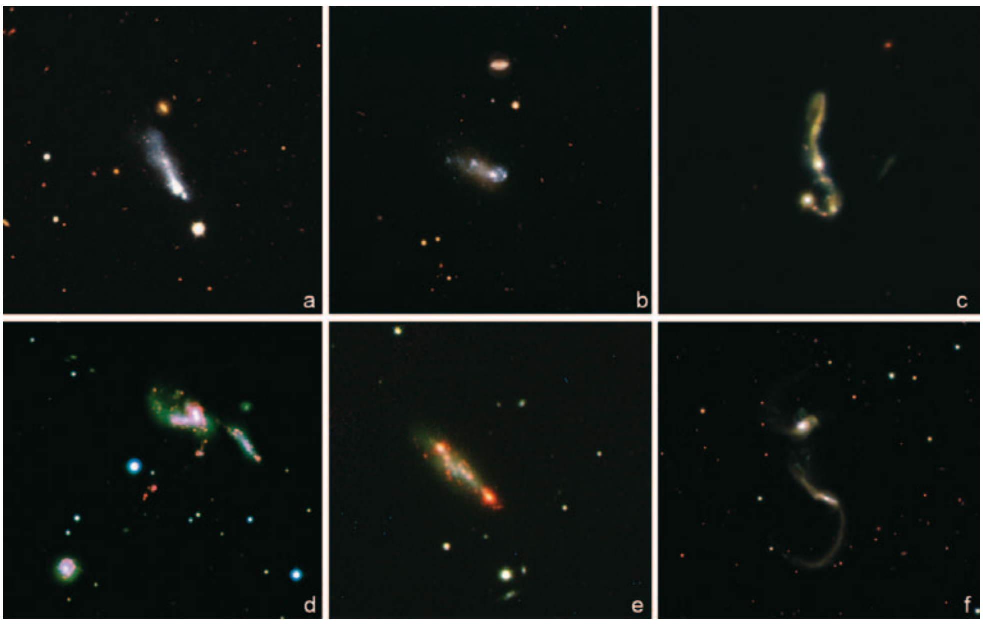


Fig. 7. Six of our WR galaxies, observed with ALFOSC in blue/UV, green, and red light; d+e also in the emission line Hα.

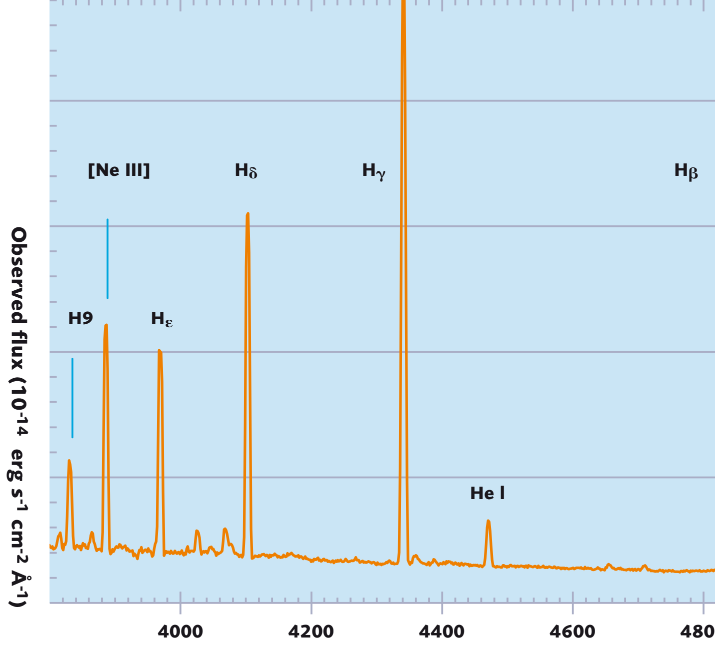
Detailed modelling of Galactic H II regions

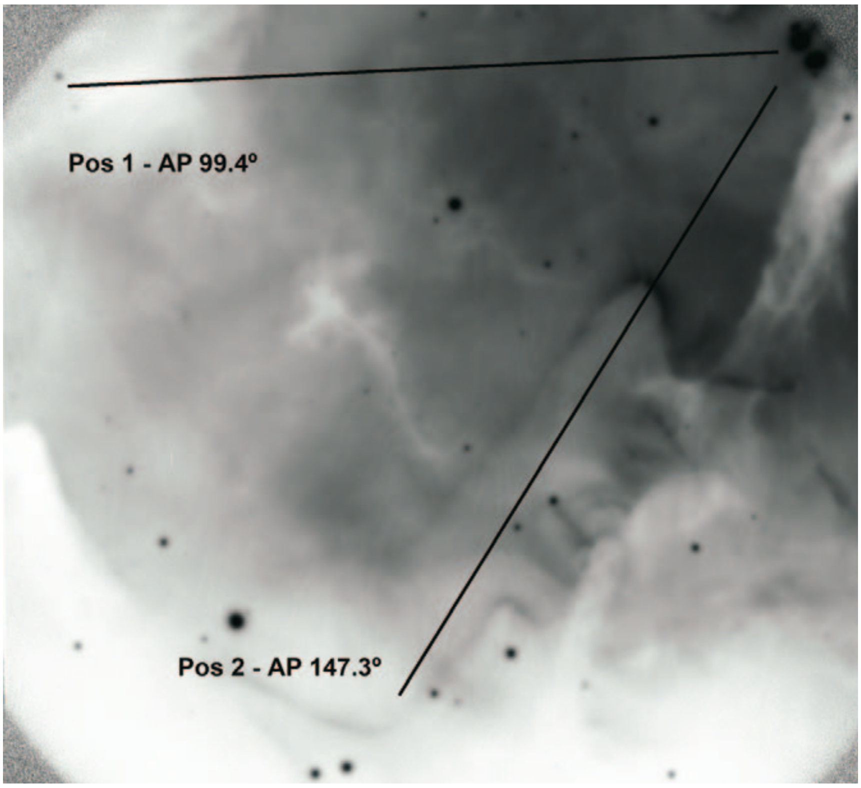
Intense far-ultraviolet radiation emitted by early-type (OB) stars ionizes the surrounding interstellar medium, creating the so-called H II regions. These regions can be used to derive properties of the associated stellar population (e.g. initial mass function, star forming rate, age), and such properties as the chemical composition of the local galactic region. However, the properties of H II regions depend strongly on the far-UV radiation of the most massive stars in the area, which we generally cannot observe directly, so predictions from models of hot-star atmospheres are of crucial importance.

The outer layers of hot luminous stars are extended and transparent, mixing radiation from regions with very different temperatures, and the UV radiation absorbed by hundreds of thousands of metal lines in the upper atmospheric layers drives the development of strong stellar winds. All these effects must be included in models of hot-star atmospheres. Yet, even the newest such codes, which include a more realistic description of these physical processes, produce quite different ionizing effects.

As the far-UV radiation from the stars cannot be measured directly, the nebulae they ionize have been used as tools to check the predicted fluxes. However, such studies are complicated by the fact that the structure of the H II region itself depends on the distribution and chemical composition of the gas, dust, and ionizing stars in the region. We have therefore started a very detailed study of a sample of bright Galactic H II regions with simple geometries and ionized by a single massive star, using narrow-band images and spectra obtained with NOT and with the INT.

The Trifid nebula (Fig. 9) and its single ionizing star, HD 164492A, is a good example. Images of the nebula in several narrow-band filters of singly and doubly ionized atoms provide information on the distribution and excitation of the gas and the presence of absorbing dust, allowing us to estimate the total ionizing UV flux, but also to plan our spectroscopic observations optimally. The spectra then allow us to map the chemical composition and other properties of the nebula in detail (Fig. 10). Similarly, an accurate fit to the spectrum of the central star allows us to determine its basic properties (mass, size, luminosity) reliably as well. The detailed comparison of the observations with recent hot-star models is currently under way.





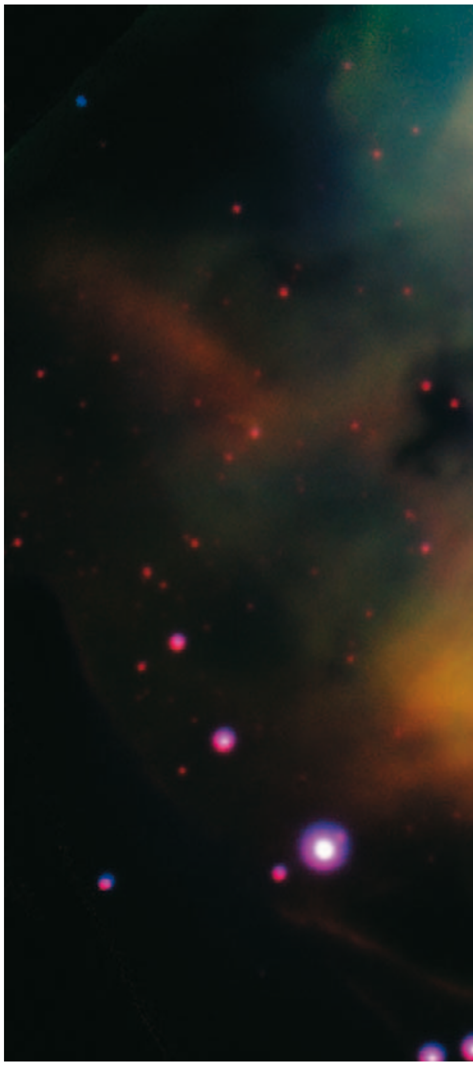


Fig. 9. Right: A ce the Trifid Nebula (M 20) in the light of ionized hydrogen (green), oxygen (blue), and sulphur (red), observed with ALFOSC. Left: Slit positions for the detailed spectroscopic analysis.

S. Simón-Díaz, Paris; A.R. López-Sánchez, J. García-Rojas, C. Esteban, La Laguna

Chemical composition and age of "Red Clump" stars of the Galaxy

Stars spend most of their lives burning hydrogen into helium in their central regions – the so-called main-sequence stage. When hydrogen is exhausted in the centre, hydrogen burning continues in a thin shell around the helium core; the star then cools and expands, becoming a red giant star. When the central temperature becomes high enough, helium starts burning into carbon, and the star spends most of the rest of its active life in this stage, characterised by a well-defined (low) temperature and (high) luminosity, which are fairly independent of the mass and chemical composition of the star. Therefore, the stars tend to pile up in a small area of the colour-magnitude diagram, commonly referred to as the "red clump".

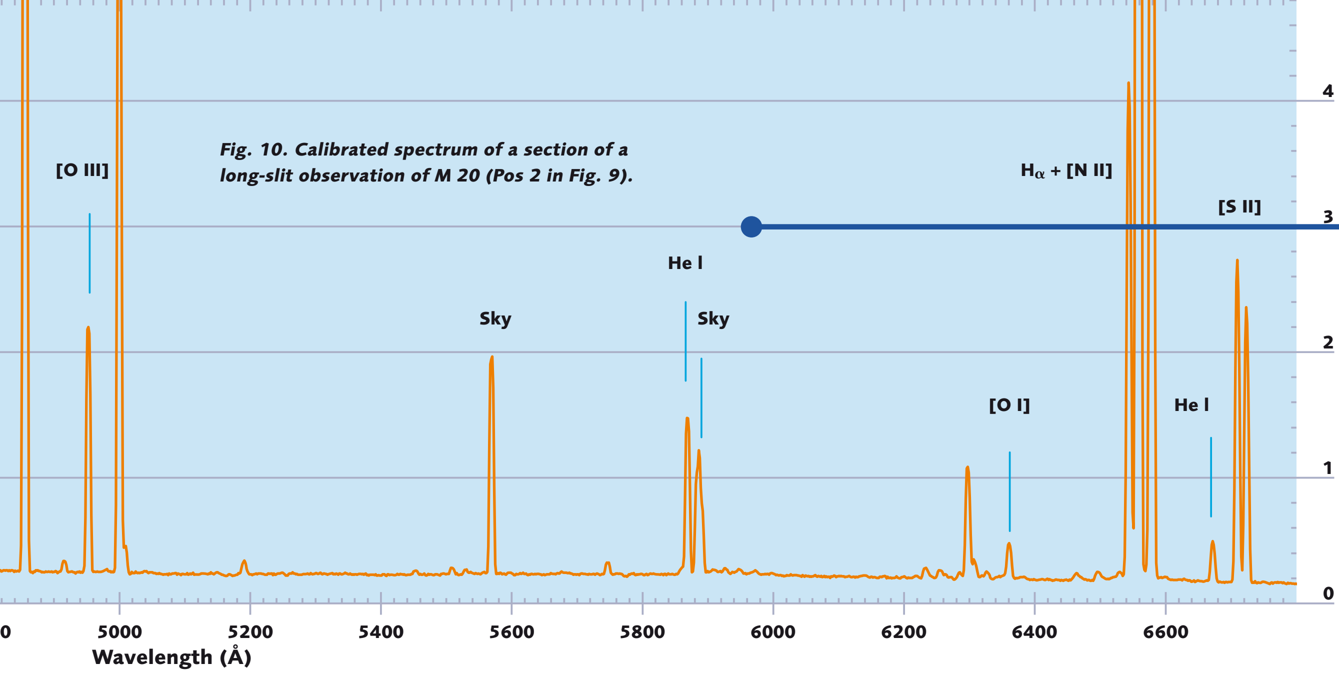
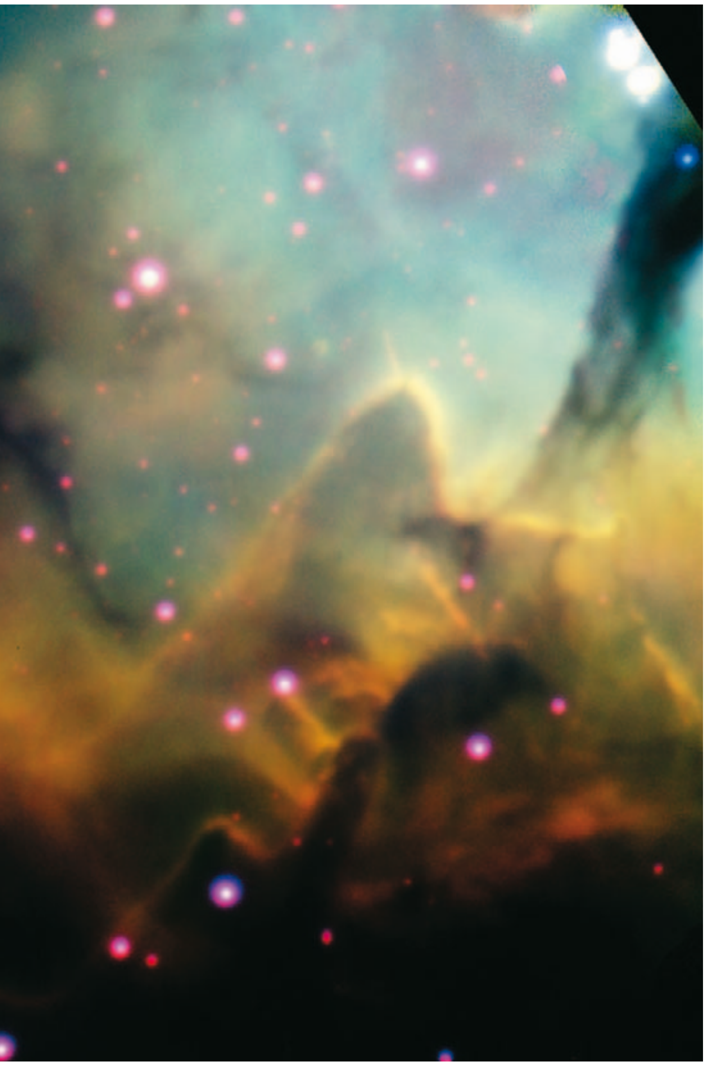


Fig. 10. Calibrated spectrum of a section of a long-slit observation of M 20 (Pos 2 in Fig. 9).



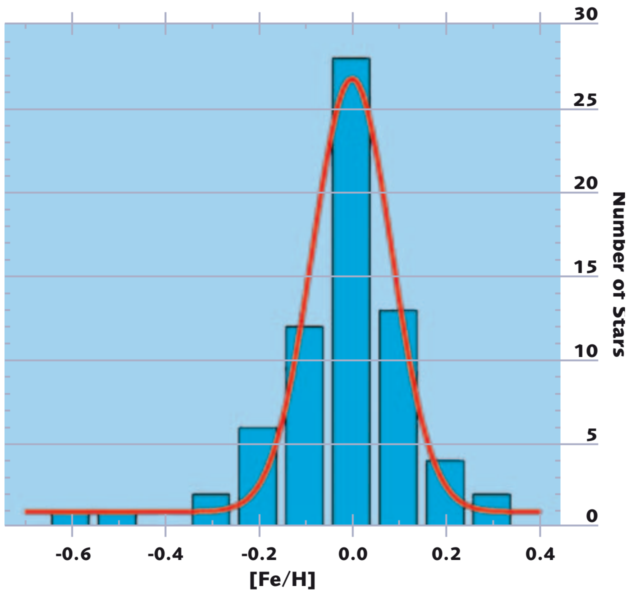


Fig. 11. Distribution of iron abundances (logarithmic, relative to the Sun) in our sample of red clump giants.

Because these core-helium burning clump stars are luminous and have a well-defined brightness and stage of evolution, they are valuable indicators of ages and distances in star clusters, the Milky Way, and Local Group galaxies. It is therefore important to investigate their distributions of masses, ages, colours, magnitudes, and chemical compositions, which may provide useful constraints on chemical evolution models of the local Galactic disk. They are also excellent probes of mixing processes in evolved stars. There have, however, been few attempts so far to map the distribution of chemical abundances for the clump stars.

We have used NOT and the high-resolution spectrograph SOFIN to determine logarithmic iron abundances ([Fe/H]) for 45 Galactic clump stars. The metal content of the stars ranges from -0.60 to +0.25 dex (1/4 to 2X that of the Sun); however, the majority of the stars concentrate in a narrow peak with a mean value of [Fe/H] = -0.04 ± 0.13 (Fig. 11). This confirms that nearby clump stars are, on average, relatively young objects, which reflect primarily the solar-like chemical composition prevailing in the local disk during the last few Giga-years. These results are in perfect agreement with recent, and quite independent, theoretical studies based on results from a large data set from the HIPPARCOS satellite.

G. Tautvaišienė, E. Puzeras, Vilnius; B. Edvardsson, Uppsala; I. Ilyin, Potsdam

FORMATION, STRUCTURE, AND EVOLUTION OF STARS

Stars form in dense clouds of gas and dust. As they evolve, they illuminate their parent cloud and build up heavy elements that enrich the next generation of stars when the parents end their lives as white dwarfs, neutron stars, or black holes. Thus, stars are key actors and drivers also of galactic evolution. Theoretical models describe the main features of stellar evolution well and enable us, e.g., to determine stellar ages, but the processes are complex, and much remains to be understood. We report here on several such projects.

A newborn star cluster in the Serpens cloud

Low-mass stars are thought to form by collapse of a dense cloud of molecular gas and dust. At first, the newborn star and its environment are completely hidden, except in the radio region, by the parent dust clouds, still of similar or larger mass as the star. In the next stage, the newborn star and the disk of material still falling onto it – a so-called accretion disk – become visible at about equal brightness levels in the optical and near- to mid-infrared regions, but displaying a wide range of temperatures distributed throughout the system. Finally, the young star emerges as a basically normal-looking, if fast-rotating star (a so-called T Tauri star), with weaker traces of the surrounding material in the form of a thin, equatorial disk that still causes emission in certain spectral lines and sometimes excess infrared dust emission, but is otherwise quickly disappearing into invisibility.

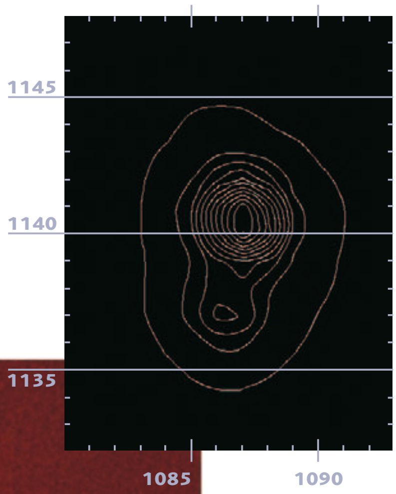
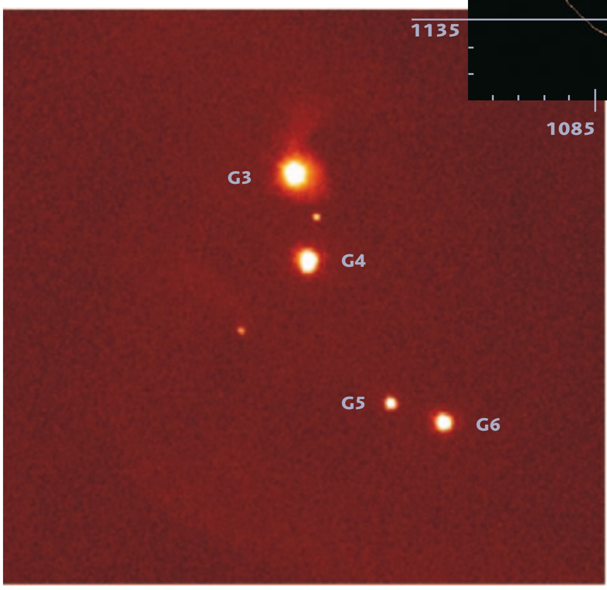


Fig. 13 (above). Contour plot of the intensity distribution around the newly discovered young binary star G4.

Fig. 12 (below). A recent (unpublished) ALFOSC image in the I-band of the optical group Ser/G3-G6, taken in good seeing conditions. The young star G4 is resolved for the first time into a close double with 0.67" separation, corresponding to a projected separation of 150 AU (1 AU = the mean Sun-Earth distance).



These three stages in the evolution of Young Stellar Objects (YSOs) are referred to as “Class 0, I, and II/III”, respectively, with the so-called ‘flat-spectrum sources’ intermediate between Class I and II. Because they are so deeply embedded in dense clouds that are opaque to optical light, observations spanning the radio, (near-to-far) infrared, and optical regions are needed to obtain a proper picture of these newborn stars and their evolution. As part of such a study, we have observed a relatively unknown star forming region in the Serpens interstellar Cloud, about 45’ to the south of the well-known, very active Cloud Core, using infrared and radio observations at wavelengths from 2.1 μm to 3.6 cm from NOT (using Arnica, SIRCA, and NOTCam), the 2MASS survey, the ISO satellite, and the IRAM and VLA radio observatories. From these data, we have discovered a new embedded cluster of YSOs (Fig. 12).

The shape of their spectral energy distributions divides the YSOs into 2 Class 0 sources (the youngest and shortest-lived phase), 5 Class I and 5 flat-spectrum sources, and 31 Class II sources. These number ratios are quite typical for star formation regions and indicate the relative lifetimes of these stages of evolution. The deeply obscured protostars are located mainly to the NE and SW of a group of optically visible pre-main sequence stars named Ser/G3-G6 after the four brightest ones, which were previously found to be Classical T Tauri (=very young) stars, and here independently found to be Class II objects. The Class II objects extend well into the brown dwarf mass regime for any reasonable assumption on age; a best age of about 2 million years is found for these stars – still quite young.

Numerous bright Herbig-Haro objects (see below) are seen in deep NOTCam images of the NE core. The most likely interpretation of the complex morphology is that two bipolar outflows are crossing each other along the line of sight. The suggested driving sources are a Class 0 source and a double Class I source. Some of the new sources also turn out to be binary stars (Fig. 13), a possibly common occurrence among YSOs and worthy of further study.

A.A. Djupvik, NOT; P. André, F. Motte, Saclay/Paris; S. Bontemps, Bordeaux; G. Olofsson, M. Gålfalk, H.-G. Florén, Stockholm

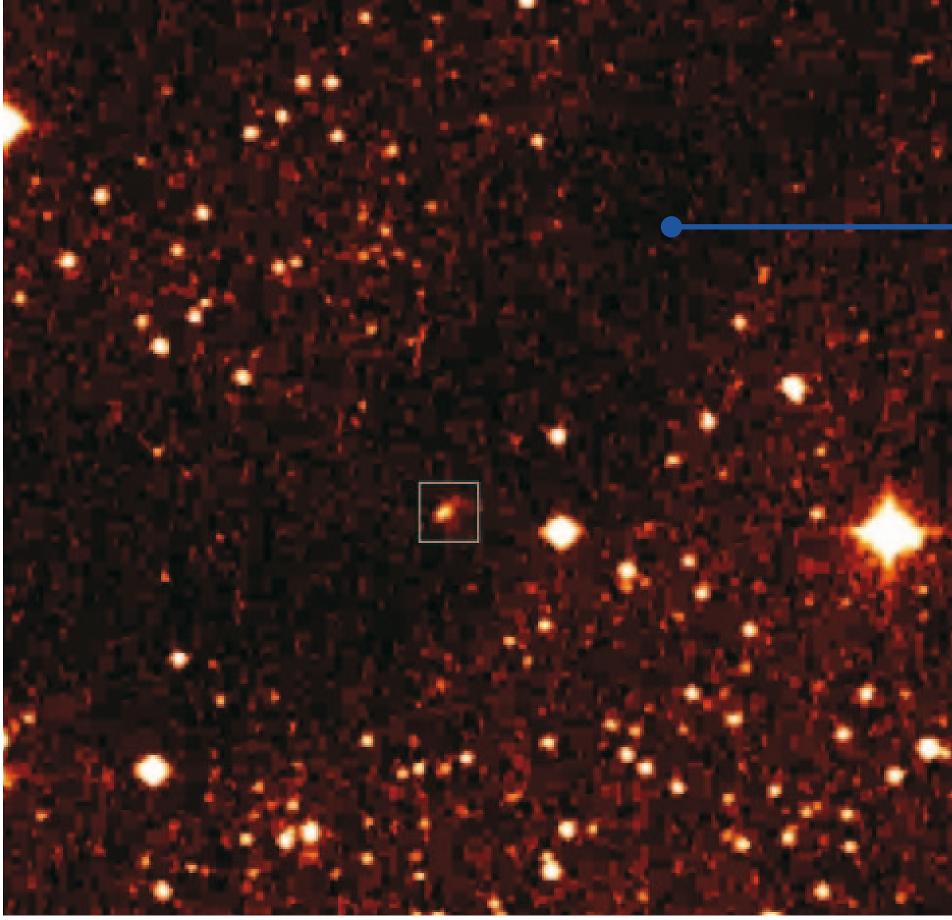


Fig. 14. The field of HHL 73 in red light from the Digitized Sky Survey. HHL 73 (in the box) is near the western border of a highly obscured region with signs of recent star formation activity (field: 7' x 7').

Resolving the morphology of a Herbig-Haro-Like object

Herbig-Haro-like objects (HHLs) appear as bright nebulosities in optical images of star-forming regions, especially in red light. Spectroscopic observations of HHLs indicate that some of them are just reflection nebulae, seen because they scatter light from stars associated with the nebulosity in the direction of the observer. Another group of HHLs are "true" Herbig-Haro objects, i.e., the optical manifestation of the shock produced when a high-velocity jet of gas from by a newborn star hits the gas in its environment. In the latter case, HHLs are direct tracers of star formation activity.

The object HHL 73 is associated with a dark cloud complex in Cygnus, at a distance of 900 pc. It shows a comet-like shape in broad-band images in red light (Fig. 14) and is located near the western border of a highly obscured region, where we know that star formation has occurred recently.

In order to disentangle the true nature of HHL 73, we observed the field in August 2006 with ALFOSC at NOT. Images through narrow-band filters were used to isolate light emitted from hydrogen (H_α) and in forbidden sulphur lines ([S II]); emission from these lines is strong in shocked gas. We also obtained images in nearby narrow bands, excluding these lines, to measure the continuum (stellar) emission. Combining the two sets of images would allow us to check whether the red emission from HHL 73 corresponds mainly to continuum emission (as would be the case of starlight from a reflection nebula) or whether, on the contrary, it is mainly due to line emission (as would be the case for shock-excited gas).

Our NOT images show that the red emission of HHL 73 is indeed mainly due to emission lines, and thus to shocked gas rather than neighbouring stars. But the good spatial resolution achieved with NOT also allowed us to resolve the morphology of HHL 73 in unprecedented detail (Fig. 15). The emission appears to split in two components of different surface brightness, with a darker lane between them. Furthermore, a collimated emission tail showing a couple of brightness enhancements ("knots") emanates from the northwestern component of HHL 73 and extends about 4" toward the west, suggesting the discovery of a micro-jet. Further analysis, including spectroscopic data, is currently under way.

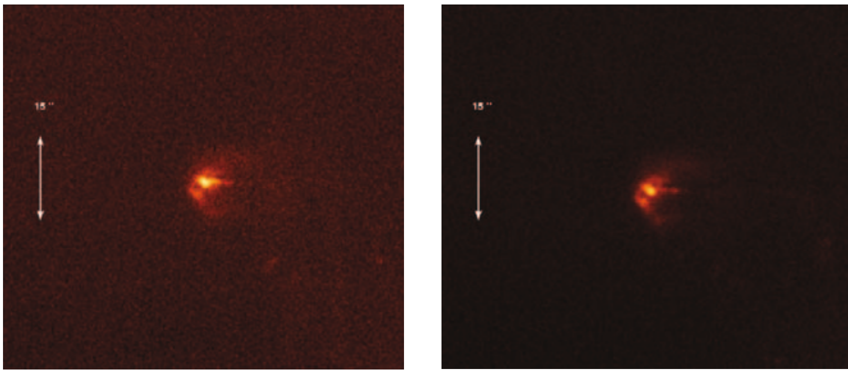


Fig. 15. Detailed view of HHL 73 with ALFOSC at NOT in the light of the H_α (left) and [SII] emission lines (right). Note the resolution of the emission into two components and the 4" long micro-jet pointing westward (to the right).

R. López, R. Estalella, Barcelona;
G. Gómez, B. García-Lorenzo, La Laguna

The origin of H_α emission in the β Cephei system

Be stars are young, massive, fast-rotating stars that show intermittent emission in their hydrogen lines. This fast rotation is a requirement for the formation of a disk of gas around the star, which is thought to be fed by material that is somehow flung from equatorial regions of the star. In turn, the gas in this disk gives rise to the observed emission. Compelling evidence exists to show the general correctness of this picture.

However, although the pulsating, magnetic B1 IV star β Cephei is a very slow rotator, it still shows H_α emission episodes like normal Be stars. Does this example contradict current theories, or is there another explanation? We decided to investigate the hypothesis that the H_α emission stems not from β Cep itself, but from a companion that has not been detected so far. β Cep is indeed known to be a close binary system with an orbital period of about 90 years, the angular separation of which has been resolved by speckle techniques, but the fainter component remains invisible in "traditional" spectroscopy.

However, if the components of a close binary are placed together on a long spectrograph slit, and one star in the system has emission, as in the case of β Cep, the spatial position of the spectrum will be shifted towards that star in the H_α line. Thus, the technique of "spectro-astrometry" enables one to measure the relative spatial position of the stars from those of spectral features in a long-slit spectrum.

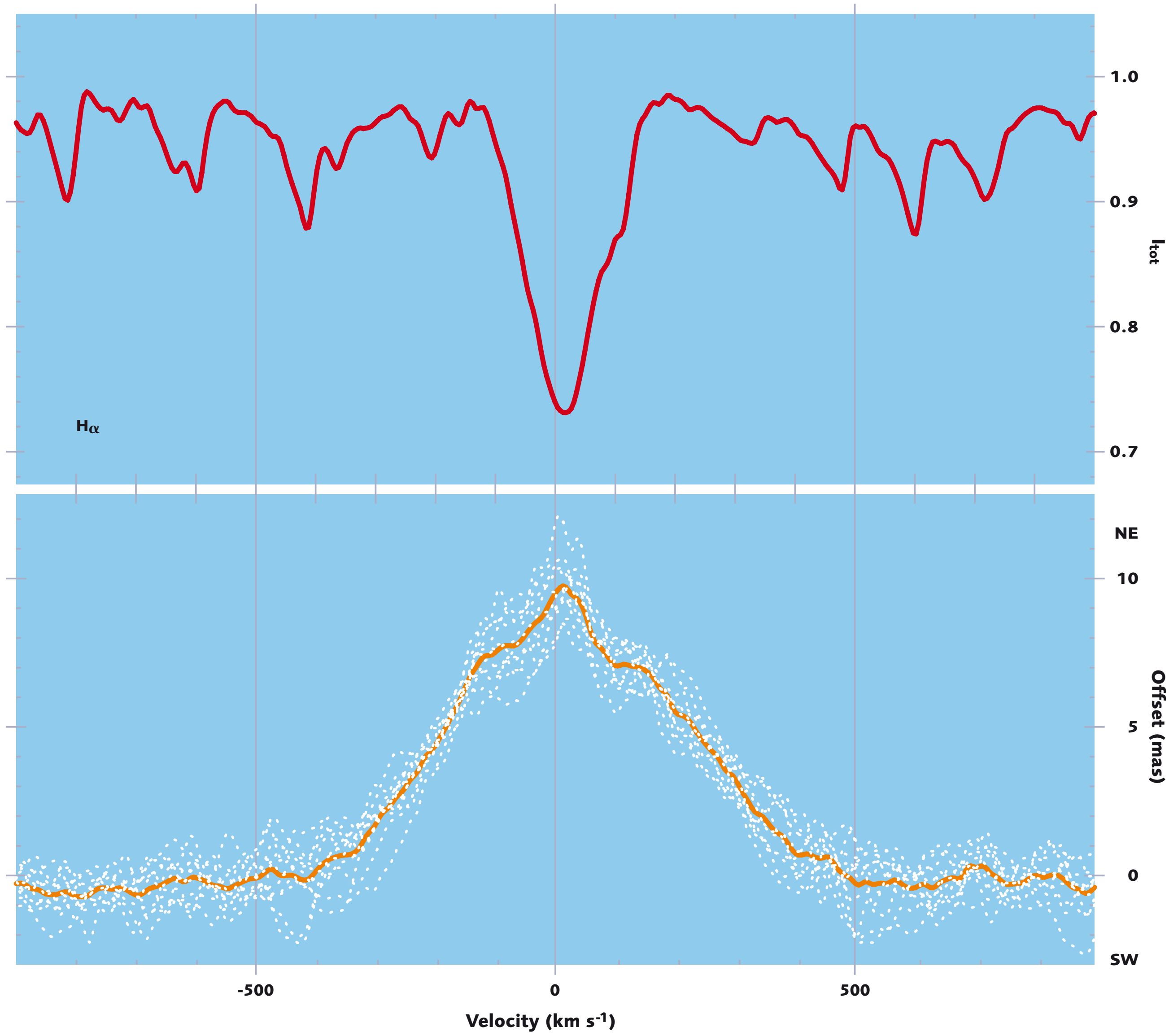


Fig. 16. Spectro-astrometric observations of the H_α line of the system. Top: Average spectrum (wavelength increasing from left to right). Bottom: Spatial position of the spectrum (bottom) along the slit, which is aligned on the line connecting the two stars; all 11 spectra are shown separately by dotted lines. A clear spatial shift of about 10 milli-arcseconds towards the secondary is observed in the centre of the H_α line, but not outside it.

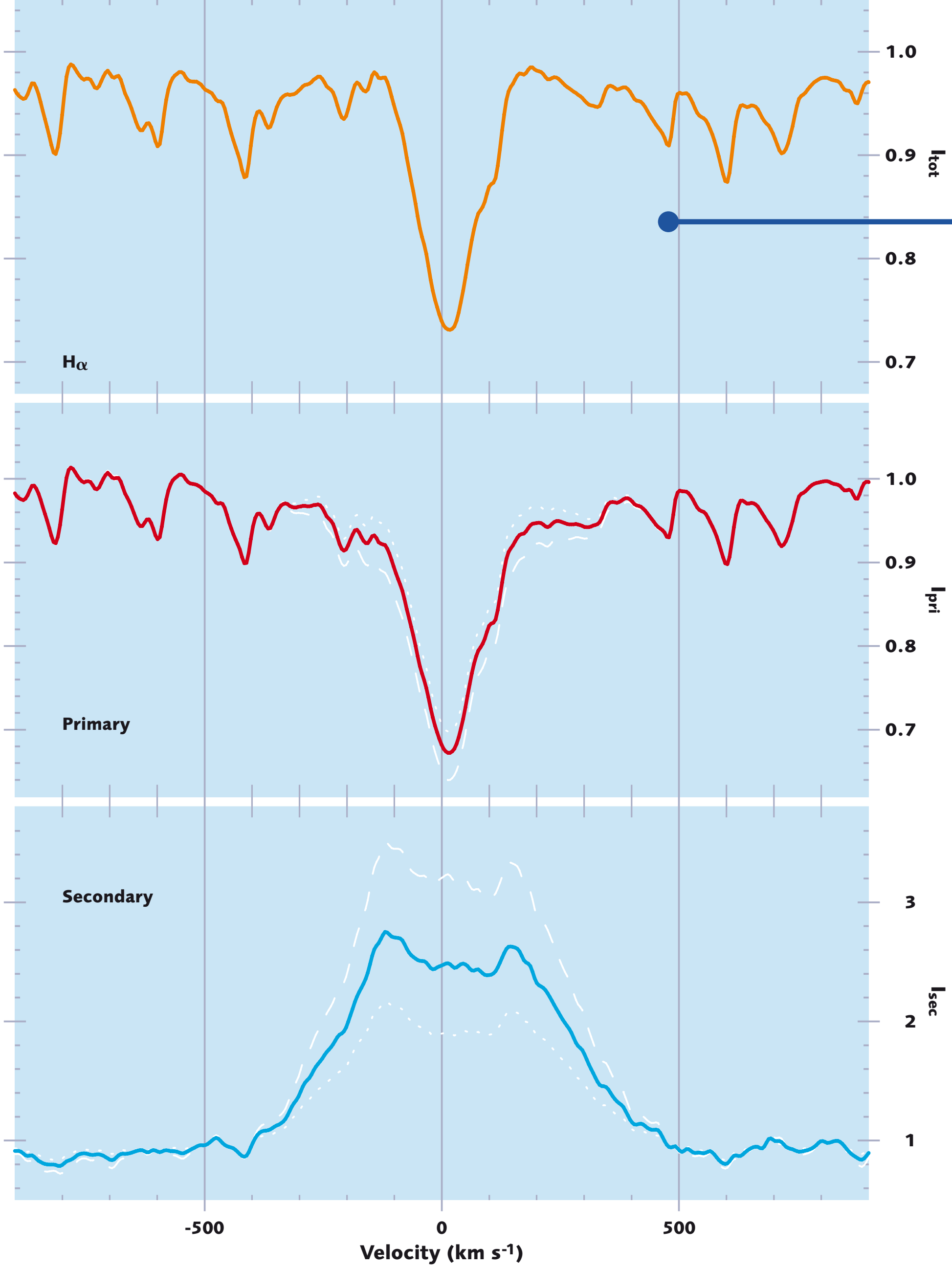


Fig. 17. Spectra of the stars in β Cep before and after spatial separation. Top: Average (combined) spectrum; below: separated line profiles of the primary (middle) and secondary star (bottom). The spectra have been split assuming spatial separations of 0.07, 0.1, and 0.15 arcsec (dashed, full, and dotted lines, respectively); 0.1arcsec is the best estimate from the speckle data. The double-peaked H_α emission line of the secondary is typical of classical Be stars.

We have separated the spectra of the two binary components of β Cep around H_α with spectro-astrometric techniques, using 11 long-slit spectra obtained with ALFOSC at NOT. The spectrograph slit was oriented along the line connecting the two binary components on the sky as computed from the orbital parameters derived from the speckle measurements. By analysing these spatially resolved spectra (Fig. 16-17), we find that the emission in β Cep is not related to the primary star, but is due to its companion, 3.4 magnitudes (some 25 times) fainter. The double-peaked emission extends over the range -400 to +400 km/s, typical of "normal" fast-rotating Be stars with a spectral type around B6-8.

Thus, by identifying the companion of β Cep as the origin of the H_α emission, we have resolved the enigma why β Cep can show hydrogen emission despite being such a slow rotator.

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R.D. Oudmaijer, Leeds; J.H. Telting, NOT

A rotating jet in the Butterfly Nebula

Planetary nebulae are tenuous envelopes of gas ejected by low-mass stars in a late, short-lived stage of their evolution. Observations at high spatial resolution reveal delicate, colourful structures that make planetary nebulae some of the most beautiful sights in the sky. A significant fraction of these objects deviate markedly from the expected spherical symmetry around the central object – the naked core of the original star. Instead, they show axial symmetry or bipolar structures for reasons that are unknown, but might suggest that the central object is a binary star.

The *"Butterfly Nebula"* (Fig. 18), also known as M 2-9, is one of the most beautiful and fascinating of these objects. With its markedly bipolar morphology, M 2-9 has long been considered a key object to understand why a large fraction of the parent stars lose spherical symmetry at the end of their evolution and produce the great variety of exotic shapes observed in planetary nebulae. It consists of a pair of ionized bubbles or "bulbs", surrounded by long, collimated lobes that end in dusty blobs, which reflect the

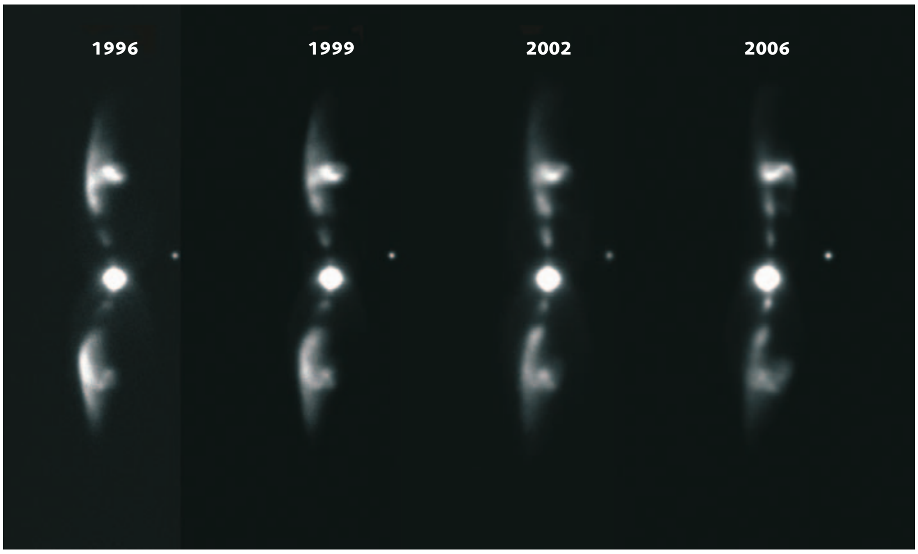


Fig. 19. Selected images of M2-9 obtained at NOT in [OIII] light over the last 10 years, showing the lateral motion of the rotating jet.

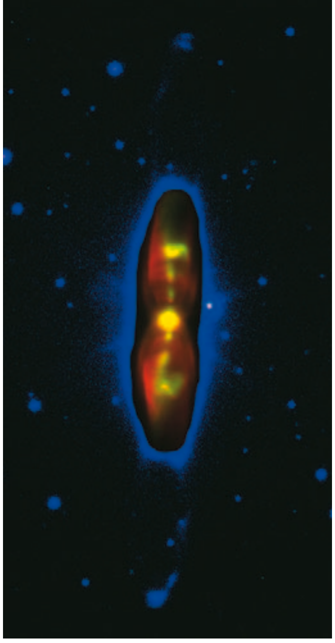


Fig. 18. The Butterfly Nebula observed with ALFOSC in 2006. The cuts have been optimised to highlight details in the centre as well as the faint outer regions. Hydrogen emission is shown in blue, outlining the outermost dusty blobs. In the inner part, red shows hydrogen and ionized nitrogen (N II), while [O III] is shown in green.

light of the innermost core like a mirror. The blobs expand visibly on the sky, at a speed of 165 km/s as determined from the spectrum; combining the two measurements yields a distance of about 2000 light-years. However, the central source of M 2-9 is hidden behind a dense veil of gas and dust, and its nature remains basically unknown. Clues must be found from the nebula itself.

The most spectacular feature of the Butterfly Nebula is the emission pattern in the inner bulbs. This pattern rotates around the axis of symmetry of the nebula in ~100 years, with a peculiar "mirror" symmetry relative to the equatorial plane rather than the point or axial symmetry normally seen. This motion has been monitored since the 1980's, with NOT providing the best set of images since 1996. The rotating pattern is best visible in the line of doubly ionized oxygen, [O III] (Fig. 19), because this ion quickly recombines and its light therefore provides the most precise indication of where a beam from the central object hits the wall of the bulbs and excites the emitting gas in the moving pattern. Moreover, the present time is particularly favourable, because the illuminating beam is now pointing toward us so its lateral motion can be studied with little dependence on projection effects.

We have found a delay in the illumination with increasing latitude, which indicates that the rotating beam is not made of light, but is actually a beam of high-speed particles ejected from the central source. When these particles hit the walls of the inner bulbs, they excite the gas and excavate the bipolar lobes of the magnificent Butterfly Nebula in the gas surrounding the star. This supports current theoretical models, involving multiple, precessing jets to explain the sudden switch to markedly non-spherical structures in the latest stages of stellar evolution. Precisely how these beams are produced remains to be explained, however. The late Hugo Schwarz had a special affection for the Butterfly Nebula and would no doubt have remained a leading figure in the field, had he not died so prematurely.

R. Corradi, ING, La Palma

EXTRASOLAR PLANETARY SYSTEMS

The first planet outside the Solar System was found in 1995. Over 200 exoplanets have been discovered since then, most of them from measurements of the tiny velocity changes they induce in the host star. These observations require special instruments, available at only a handful of telescopes around the world. However, other techniques are gradually coming into use, also at NOT; we report here on two such projects in the past year.

Finding earth-sized exoplanets by timing planetary transits

Of the more than 200 known exoplanets, 14 are seen transiting the disk of their host star, so their orbital inclinations are known. These objects are extremely important because their sizes, masses, and densities can be accurately determined; comparison with models then gives vital clues to how these solar systems were formed. It is clear that they could not have formed so close to their host star as they are now, but the reason for their migration from more distant orbits is still unknown.

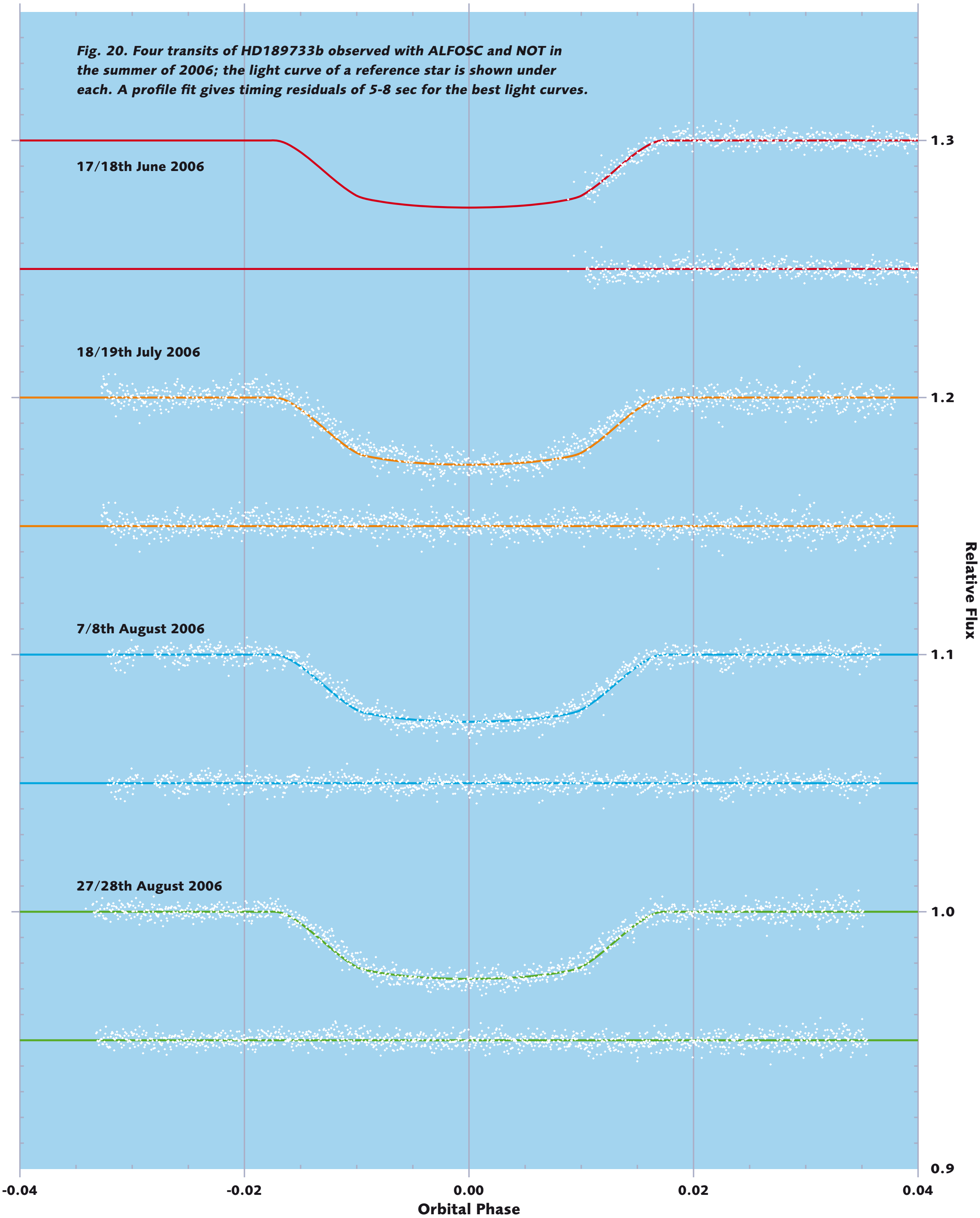
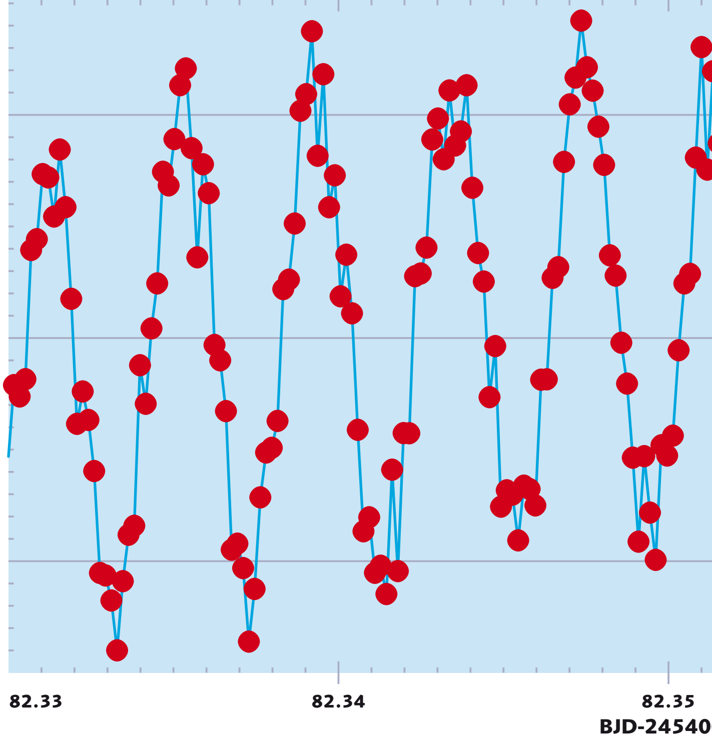


Fig. 20. Four transits of HD189733b observed with ALFOSC and NOT in the summer of 2006; the light curve of a reference star is shown under each. A profile fit gives timing residuals of 5-8 sec for the best light curves.

But transiting exoplanets offer other opportunities for study. For example, the host stars's light shines through the atmosphere of the planet during the transit, so the latter can be studied from spectra obtained during this time. And transit detection is the way the space missions CoROT and Kepler will attempt to find earth-sized planets. Moreover, any perturbations from a second planet in the system will affect the observed mid-transit times of the hot Jupiter.



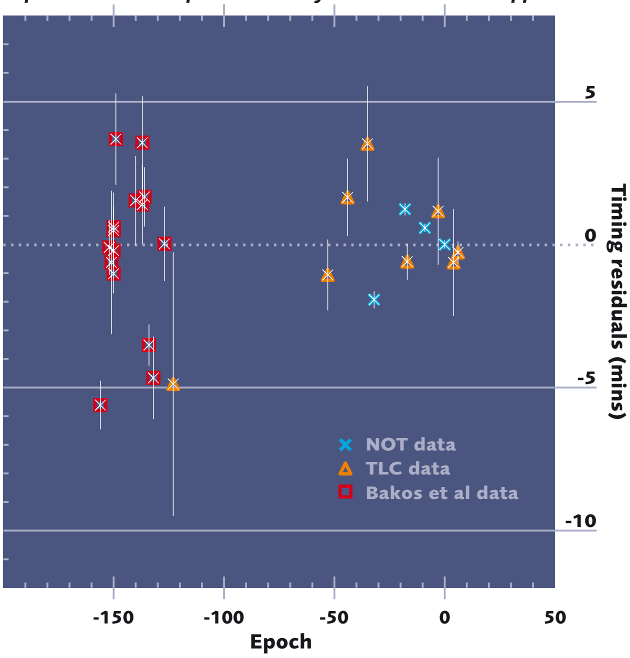
The size of these variations depends on the mass of the perturber, but an earth-sized planet in a 50-day orbit could in principle give variations of ~5 seconds. These are still not easy to measure: A ‘deep’ transit is at most 2% deep!

Nevertheless, we have started a program to measure these weak signals with NOT and ALFOSC. In order to maximize our S/N and on-source time, we read only a small part of the CCD containing the slightly out-of-focus target and several comparison stars. Fig. 20 shows a series of transits of the hot Jupiter HD189733b obtained in the summer of 2006. Other groups are active in this area, using mostly 1m-class telescopes, but the accuracy of mid-transit times from the NOT data is roughly 5 times better than other published ground-based data, and over 3 times better than results from HST.

Timing residuals from the predicted transit times, when plotted against the transit epoch, should yield a straight line corresponding to the constant period prevailing in an isolated two-body system. Fig. 21 shows such a plot along with data from other groups, demonstrating the superior timing accuracy obtained from the NOT data. More transits observed at a similar resolution will make it possible to detect the presence of perturbing Earth-sized planets, certainly if they are on resonant orbits.

N. Gibson, D. Pollacco, Belfast; M. Hrudkova, I. Skillen, C. Benn, ING, La Palma; T. Augusteijn, NOT; J. Irwin, Cambridge, UK

Fig. 21. Timing residuals vs. transit epoch for three different experiments. The superior accuracy of the NOT data is apparent.



Detection of a giant planet orbiting a hot evolved star. Almost all the over 200 known exoplanets orbit main-sequence stars like our Sun and have been detected either by high-precision spectroscopy using narrow lines or by transits across the stellar disk (see above). These methods do not work for compact objects like white dwarf stars or subdwarfs, which are so small – with radii of 1-100 Earth radii – that transits across them are unlikely to be observed. Furthermore, their spectral lines are broad and diffuse, so the tiny shifts in their spectra due to the reflex motion of the planet host star are impossible to detect.

The only chance of detecting planets around compact stars is if the star has a “stable clock” and we can measure its variations due to the light travel time across the variable distances from the barycentre of the system. By this method the first exoplanets were detected around pulsars in 1992. Using NOT and other telescopes, we can now report the first detection of a Jupiter-mass planet around an evolved star which, unlike the pulsars, has not experienced a supernova explosion.

The story starts during a NOT run in October 1999, testing the new multi-window fast-photometry software for ALFOSC. The last night we discovered that a star with the name HS 2201+2610 showed very nice pulsations with an apparently single period of about 350s. HS 2201 is an extreme horizontal branch star, with a temperature of nearly 30 000 K, and should have burnt almost all its central helium supply. After a strong mass-loss episode removed almost all the stellar envelope, the final product is a hot sdB star with a thin hydrogen envelope, which should eventually become a carbon-oxygen white dwarf.

It has been proposed that the presence of planets (with a separation <~5 AU) can enhance mass loss, so we have fol-

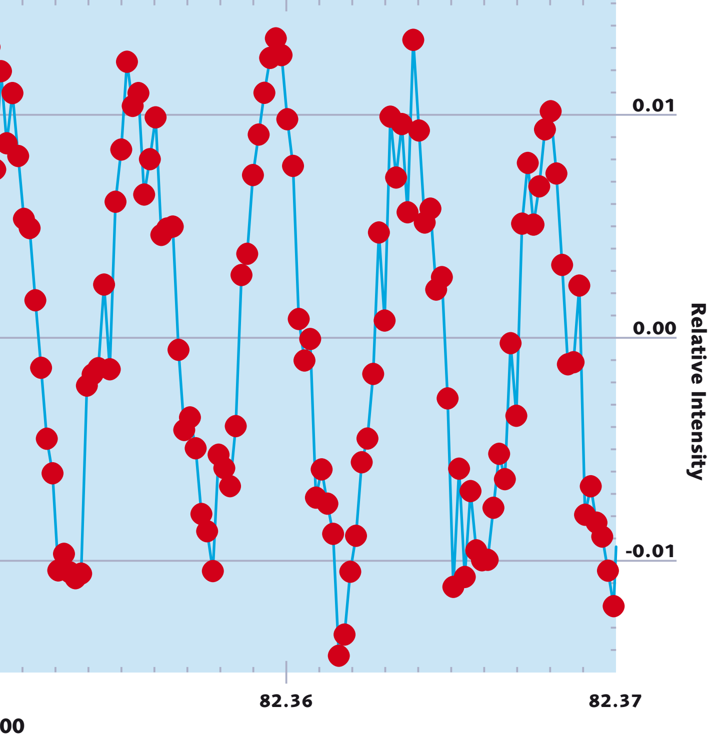


Fig. 22. One hour of the light curve of HS 2201+2610, observed with ALFOSC on December 12, 2006. The time step is 20 seconds.

lowed HS 2201 with a total of 410 hrs of time-series photometry on seven 1-3 m class telescopes in order to check for any changes in the pulsation period, which could indicate structural changes. Fig. 22 shows a typical piece of the light curve, while Fig. 23 illustrates the variation in the observed arrival times of the pulse maxima, averaged over each observing run. The upper panel shows a best-fit period which increases by about 1 second per 20 000 years – a stable pulsator indeed! This slow period change reflects structural changes in the star on its way to become a white dwarf.

However, a more careful analysis reveals additional systematic oscillations in the observed timings. The lower panel of Fig. 23 shows the residuals from the upper curve, indicating that the distance of the sdB star from us varies regularly by a total of about 5.3 light-seconds with a period of 1167±45 days. This can be explained as reflex motion induced by a planet ~1.7 AU from the host star and a mass Msini=~3.2 M_{JUP} , where *i* is the inclination of the orbit as seen from us. The minimum temperature of the planet is 440 K. This is the first time that a planet is found around a pulsating star by the timing method and opens new perspectives for studying the evolution of planetary systems of evolved stars.

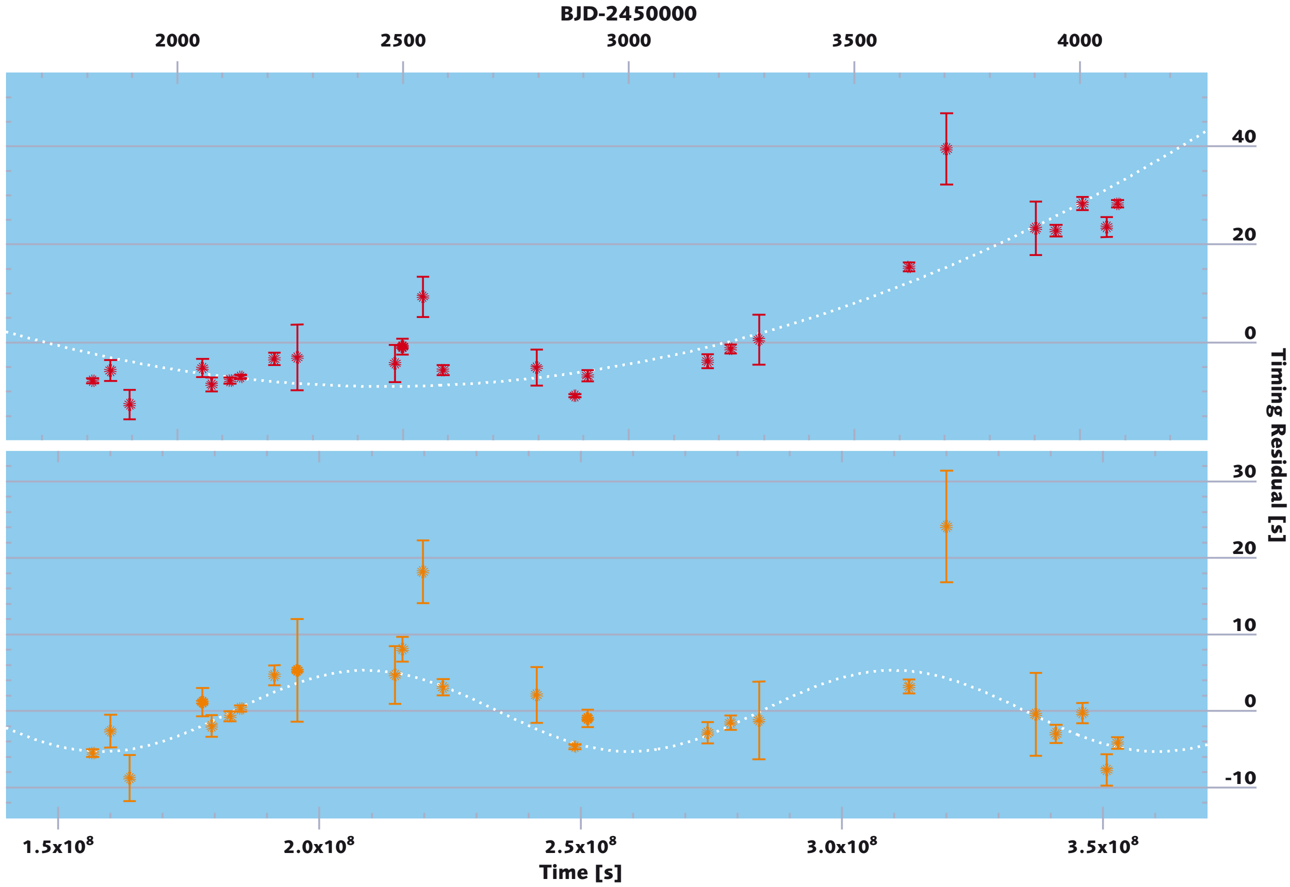


Fig. 23. Residual diagram for the main pulsation frequency of HS 2201. Upper panel: The main long-term variation, fit by a constantly increasing period (see text). Lower panel: Residuals from the upper curve, with a sinusoidal fit. The number of measurements averaged in each point varies from 237 (largest error bars) to 26081 (first point on the left). The total number of photometric observations is 108899.

R. Silvotti, Napoli; R. Østensen,
Jan-Erik Solheim, Oslo; and collaborators

EDUCATION

2006 saw a familiar activity return to La Palma: A Nordic-Baltic summer school, sponsored by NORDFORSK, was held at NOT in July. A report has been prepared by one of the students and is presented below. But we also had a new experience of receiving visits by two high-school classes, who were studying astronomy as part of the physics curriculum and were keen to get their hands onto a real telescope. An account of these visits also follows below. Overall, the reaction by the students was most enthusiastic – so much so, in fact, that the Council warned us not to let these activities get out of hand!

The Nordic Research School on Observational Astrophysics

The 2006 Nordic Research School on Observational Astrophysics (sponsored by NORDFORSK) was held at the NOT from June 27 to July 8. About 60 students applied (50% women!); out of these, 19 students from more than eight different countries were selected to attend the school. The successful applicants were given the opportunity to choose between four different projects on stellar magnetic activity, galaxy clusters, star clusters or supernovae before arriving at the school, and were given background reading material so as to be well prepared when the school started.

The first week was devoted to lectures on how to use the telescope, both in optical and IR (photometry and spectroscopy), and how to reduce the data obtained. A lecture was also given on the Swedish Solar Telescope (SST). Planning the project observations was also done during the first week, as well as very interesting visits to the different telescopes at the mountain. Each group spent two half days at the SST, where we had the opportunity to perform observations and tests. We also visited the William Herschel Telescope and the construction of the Gran Telescopio Canarias.

The major part of the school was devoted to the projects. Depending on the chosen project we were divided into four groups. Each group had a tutor supervising the project work. Several days were spent planning the observations, and both photometry and spectroscopy with ALFOSC and NOTCam were performed. One group were the first users ever to use the highest resolution mode available with NOTCam, and another made MOS-plates to do multiple-object spectroscopy.

The weather was very good throughout the school, and there were no technical problems. After the data were obtained, reductions were made; and most groups managed to reduce most of their data within the two weeks at the school. On the last day – still tired after spending many nights at the telescope and with reductions - all the groups presented their results to each other and to the teachers.

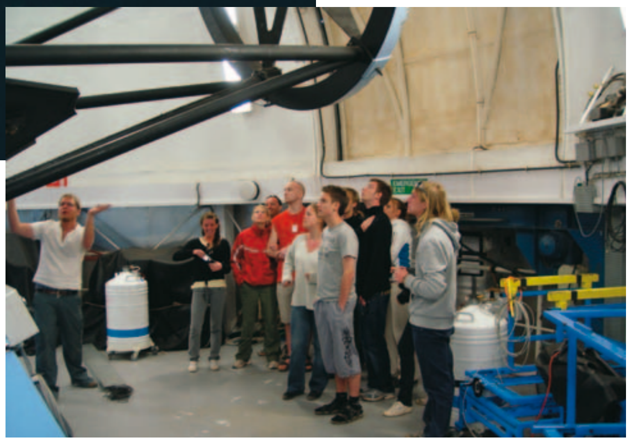
After the school, the groups wrote reports on their projects. Both the presentations and the reports are available at http://www.aip.de/People/hkorhonen/school.html. The supernova group published an IAU-CBAT circular during the school itself, reporting on the classification of supernova SN2006dm. The group investigating stellar magnetic activity wrote an article, soon to be submitted to Astronomische Nachrichten, on the results they obtained at the school and during the additional analysis performed after the school.

As a student at the school I learnt many things. This was the first time I and many of the other students used an optical/IR scientific facility, and still we were able to obtain very interesting results. The learning environment was very relaxed, and besides the perhaps more tangible knowledge attained at the school, I believe that many of us felt that we learnt much about collaborating with others. To help us we had great teachers, and the NOT students assigned to each group were invaluable as well.

Sofia Ramstedt, Stockholm

Students and faculty of the NORDFORSK Summer School 2006 posing in front of the Residencia.

The "Antennae" galaxies observed by the high-school group.



Lars Glowienka gives a tour of NOT (below) and shows how a filter works (left).

High school astronomers meet NOT

In March and April 2006 two classes from Danish high schools (Herlufsholm and Odder Gymnasium) visited NOT with their physics teachers, who had negotiated half a night of observing time for each class. Both teachers are fully trained astronomers and had prepared the students thoroughly before the visit, so that the observing time could be used efficiently, both at the telescope and in terms of the educational returns.

The groups arrived at NOT in the afternoon and were introduced to the telescope and instruments, then split up in several smaller groups as required by the cramped space in the control room. Each group was assigned time to observe a small project they had prepared beforehand, while the rest of the group relaxed in the service building. After the visit, the data were reduced and analysed and formed the basis for short reports to the teacher.

As charter tours were used, the classes spent about a week on La Palma accompanied by two teachers, one of whom was the physics/astronomy teacher, while the other taught Spanish or sports. Thus, the rest of the time was spent either practicing Spanish language and culture, or hiking, snorkelling, and camping in the beautiful nature of the island – guaranteeing the success of the trip even in case of bad weather on the observing night. In the event, both nights were clear and both visits fully successful.

A personal account from one of the teachers:

"We came to La Palma after more than 3 months of preparation. My class was divided into groups of 3-5 students, with each group choosing a subject and filling out a NOT proposal with the "scientific justification" for the project and a detailed plan for the ~45 minutes of observing that each group had at NOT.

Projects ranged from dark matter, supernovae, and spiral galaxies to Jupiter and Saturn, so a wide range of broad and narrow-band filters and even long-slit spectroscopy were used. Many thanks to our expert support astronomer Lars Glowienka, who spent hours preparing the telescope for us, helped us through the night, and even gave each group an extended tour of the telescope.

Their results were all very impressive. For example, the dark-matter group managed to get three spectra and a colour composite of the Galaxy NGC5746, used the spectrum to derive rotational velocities, and calculated the dark matter content of the galaxy – pretty amazing with just 45 minutes of NOT time!

The trip was an incredible success. The students felt like real experts and gave short lectures to other students and parents after returning from La Palma, and the local media covered the trip both before and after our visit to La Palma. Thanks to NOT and its staff for giving us all this experience for life!"

Mathias Egholm, Odder Gymnasium

Lars Glowienka checks the optical alignment of FIES.

The report for 2005 described the concerted three-year programme conducted in 2003-2005 to upgrade the instrumentation and associated services at NOT. The final steps of this project were completed in 2006, as the old telescope control and cooling systems were decommissioned and physically removed, the last major invoices paid, and routine use began. Comments from observers have been very positive so far.

The last major task in this area in 2006 was the completion and commissioning of the fibre-fed spectrograph FIES. FIES is a bench-mounted, high-resolution échelle spectrograph offering resolutions up to R = 65 000 with fixed spectral coverage and permanently available for flexible scheduling. To ensure high mechanical and thermal stability, it is installed in a separate building next to the telescope. We report the results of the first 10-night commissioning run in the winter of 2006/7.

The fibre head contains four fibres, offering three different spectral resolutions: R = 25 000, 45 000 and 65 000; the fourth fibre serves for measuring the sky background. For the two lowest-resolution fibres, we measure efficiencies of 9% and 7% in reasonable seeing (~1"), including the telescope and atmosphere. These are close to the design values, while we still lack some sensitivity at the highest resolution. The problem has been traced to the mounting of the fibre ends and will be solved in 2007.

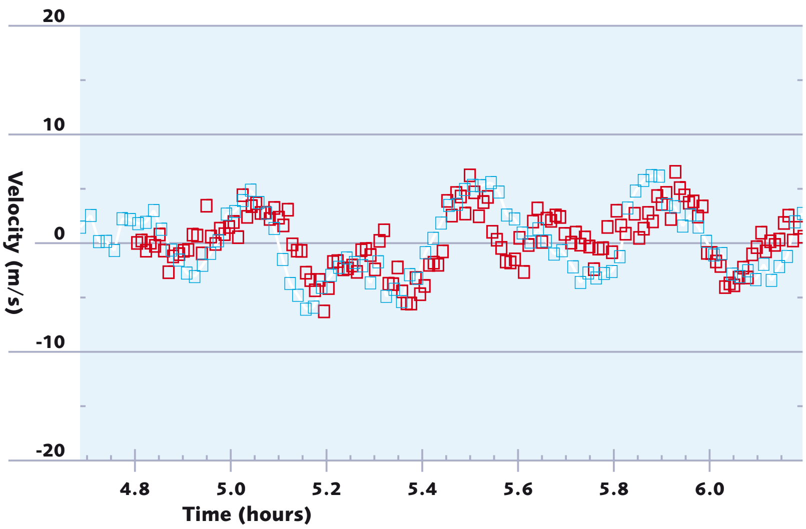
An important goal has been to make FIES as user-friendly as possible, both in visitor and service mode. Much work has therefore been invested in streamlining both the control and pipeline reduction software, combined into the *FIEStool* package. A series of observing scripts makes the observations maximally efficient, as they execute a complete observing package for an object, including the calibration spectra. A script executed in the afternoon generates all the calibration frames needed for the following night. From these frames, the files needed by *FIEStool* can be generated. For a quick-look check, one can use the same files during an entire observing run.

During the observations, *FIEStool* will automatically recognize the arrival of a new exposure, identify the type (resolution) of the exposure, and start extracting the spectrum from the frame. After about 1 minute, the calibrated spectrum is plotted on the monitor of the data reduction workstation. The reduction procedure is fine-tuned for the specific properties of FIES and performs all the necessary steps, such as subtraction of bias level and scattered light, flat-fielding, order extraction, spectrum normalization, fringe correction, and wavelength calibration, leaving the observer with fully-reduced spectra ready for scientific analysis.

One mode of operation at the highest resolution (R = 65 000) includes simultaneous exposure of a ThAr spectrum. This is achieved through a series of 'flashes' of light from the calibration unit. For general use we divided the ThAr light in 10 flashes evenly distributed over the stellar exposure, but for short exposures (15-30 sec), only 3 flashes were used. With ordinary, separate ThAr frames, FIES yields a velocity precision of <150 m/s; with the simultaneous ThAr technique, a precision of <15 m/s is reached – even better with special reduction techniques (see below).

Observing with FIES was a very positive experience. Target acquistion was easy and efficient: A target is ready on the fibre ~3 min after the previous exposure – even faster if the guide star position is known from a previous pointing. The instrument is flexible and can be used in almost every type of atmospheric conditions; only the combination of a bright Moon, thick cirrus, and bad seeing prevented us from getting good spectra of stars at V = 14.5. In 2007, an Atmospheric Dispersion Corrector (ADC) will be installed in the adaptor to permit FIES to operate efficiently at all telescope altitudes.

S. Frandsen, Aarhus; E. Stempels, St. Andrews; J. Telting, NOT



Simultaneous radial-velocity observations of Procyon with HARPS at the ESO 3.6m telescope (red points), and with FIES at NOT (blue points). The FIES data have random errors of ~5 m/s per point, but have been smoothed in this figure.

NOT exists to provide observing opportunities for Nordic astronomers. The competition for time is strong, and the time allocation procedure must be competent, impartial, and transparent.

Time allocation procedure

Observing proposals are invited in May and November for the semesters beginning October 1 and April 1, respectively. The Call for Proposals is announced widely, and all necessary material is provided at http://www.not.iac.es/observing/proposals/. 20+5% of the time is reserved for Spanish and international projects.

An independent Observing Programmes Committee (OPC) of five respected Nordic scientists appointed by the Council (see inside back cover) provides scientific peer review of all observing proposals, rankings on a numerical scale, and feedback to proposers on any perceived problems. Each member has a substitute to ensure proper review of all proposals and avoid potential conflicts of interest. Based on the OPC rankings and practical constraints (e.g. object visibility or Moon phase) the Director drafts a schedule, which is checked by the OPC before applicants are notified of the outcome.

'Fast-track' proposals for up to 4 h of observing time with a standard instrument configuration are accepted at any time, using a simplified web-based application form. OPC review is completed within a few days, and if approved, the project is scheduled for execution in service mode on the service nights scheduled each semester.

To promote competition and high scientific standards, all proposals are received and reviewed on an equal footing. European astronomers may, in addition, be eligible for EU financial support for their approved projects under the OPTICON trans-national access programme (see http://www.otri.iac.es/opticon/ for details).

Observing time in 2006

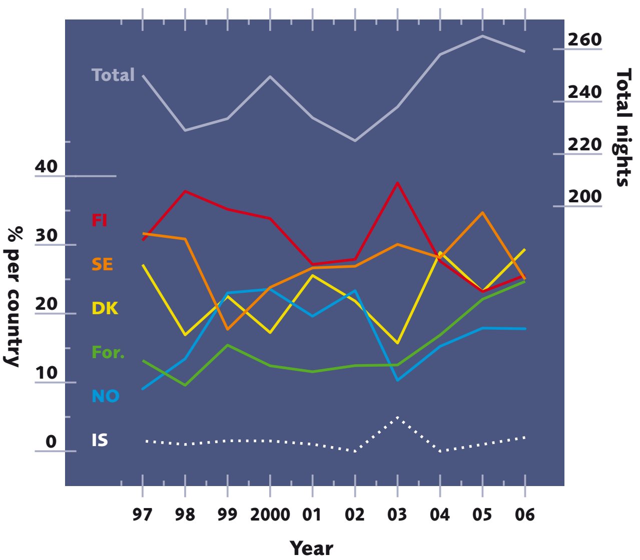
Observing statistics are compiled by allocation period, and this report covers the period April 1, 2006, to April 1, 2007. The "pressure factor" (nights requested/nights available) remained high at 1.9. In total, 317 nights were used for scientific observations (i.e., excluding technical time). Subtracting Spanish and international time, 258.2 nights were allocated to scientific projects ranked by the OPC, including 11 nights for training courses organised by Stockholm University and NORDFORSK. Of these, 64 nights or 25% went to non-Nordic ("foreign") projects and 13 nights or 5% to projects by NOT staff; the remaining 181 nights were distributed as follows: Denmark 53.5 (29%), Finland 47.6 (26%), Iceland 5 (2%), Norway 32.5 (18%), and Sweden 45.6 (25%). Note that some "foreign" projects have Nordic P.I.s in long-term positions abroad.

The OPC hard at work reviewing proposals in Lund, December 2006. Left to right: Sofia Feltzing, Kari Nilsson (OPC Chair), Johannes Andersen, Frank Grundahl, Håkon Dahle. Photo: Vilhelm Sigmundsson, OPC.

The use of different instruments is also of interest. In 2006, instrument use was as follows: ALFOSC 225.5 nights (62%), NOTCam 42 (12%); MOSCA 36 (10%), SOFIN 24.5 (7%), FIES 24 (7%), TurPol 7 (2%), and visitor instruments 6 nights (2%). Compared to 2005, the numbers reflect an increased use of MOSCA and FIES and a decline in demand for SOFIN (and TurPol).

Long-term trends in time allocation

Viewed semester by semester, the distribution of observing time on nationality, subject, and instrument shows large fluctuations. For planning purposes, it is important to recognise the underlying long-term trends in the demand for observing time. Some of these are listed in the following:



Nights allocated annually by NOT over the decade 1997-2006, and the Nordic and "foreign" shares of the time.

Service observing is becoming increasingly popular and accounted for some 60 nights in 2006, counting technical nights when observations were made in service mode (69 nights in 2005, 50 in 2004). Unfortunately, the 'fast lane' option for short programmes has so far been less successful than intended, because just those nights were often hit by bad weather.

Outside interest in NOT, as measured by approved "foreign" projects, rose from a long-standing average of 10-12% of the Nordic observing time to 17, 22, and 25% in 2004-6. This is no doubt largely due to the OPTICON Transnational Access Programme (see above), which actively encourages proposals from non-Nordic astronomers in return for Nordic access to several night-time and solar telescopes all over the world.

National percentages of observing time are allowed to fluctuate considerably relative to the national contributions to the budget, due to the policy of allocating observing time with scientific merit as the primary criterion. The figure shows the distribution of observing time for Nordic and "foreign" projects over the last decade, as well as the total number of nights allocated annually by NOTSA. Over the last five years, the Nordic time has been distributed with 23.8% to Danish projects, 28.6% to Finland, 1.5% to Iceland, 17.0% to Norway, and 29.0% to Sweden. Staff and "foreign" time account for 5.6% and 17.9% of the total.

The edge-on spiral galaxy M104.
Photo: J. Näränen

FINANCIAL MATTERS

NOTSA is a non-profit organisation and spends all the funding it receives from the Associates to operate NOT for the benefit of Nordic astronomy. Budgets and accounts are approved annually by the Council; the Director is then responsible for operating NOT within those budgets and according to the Financial Rules. For the years 2006-2009, the Council has appointed the National Auditing Office of Iceland to audit NOTSA's accounts.

Accounts for 2006

NOTSA's accounts for 2006 are summarised in the table on p. 28. The approved budget for 2006 and the results of 2004 and 2005 are listed for comparison. The budget lines contain the following items:

Directorate covers directorate staff, operations, committee travel, financial charges, stipends to Spanish Ph.D. students at Nordic universities, OPTICON and ASTRONET meetings, and the Annual Report.
La Palma staff includes all staff, students, and visitors on La Palma, training courses etc.
La Palma infrastructure includes the NOT facilities on the mountain and at sea level; electricity, water, and cleaning; computer networks; and cars and other transportation.
La Palma operations cover staff accommodation and meals at the observatory; communications and shipping; telescope, laboratory, and office equipment and consumables, etc.
Telescope and instrument operation and maintenance comprises operation, repair, and upgrade of telescope and instruments, cryogenics, electronics, optics, and data acquisition and archiving equipment.
Development projects indicate investment in major new facilities or instrumentation as approved by the Council on a case-by-case basis. No new projects were approved for 2006, so little expense was incurred.
Contributions were divided into a basic contribution of 1 258 900 Euro (shared as follows : Denmark 19.8%, Finland 29.7%, Iceland 1%, Norway 19.8%, and Sweden 29.7%), and additional contributions generously agreed by the first four Associates.
Other income is mainly income from the OPTICON and ASTRONET EU contracts, and bank interest.

Financial developments in 2006

As seen in the table, the costs of the directorate, staff, facilities, and operations were essentially on budget in 2006. Staff costs increased in 2005 as expected for the new contracts, but remained within budget also in 2006. Telescope operation and maintenance was higher than budgeted, due to the delayed final payment on the new telescope cooling system and to the renewal of power amplifiers for the dome drives, etc. Instrument operation and maintenance was higher as well, primarily due to the need to replace the failing science grade array for NOTCam.

Telescope development projects were completed in 2005. Special development projects were essentially completed as well; only the final fibre bundle and a few other minor items for the FIES spectrograph were added in 2006.

Other income was essentially on track in 2006. Overall, the deficit in 2006 was some 45 kEuro larger than budgeted, due primarily to expenses deferred from 2005. As the corresponding reserves were forwarded as well, 2006 ended with financial reserves some 90 kEuro above budget.

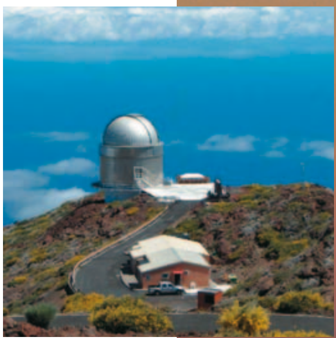
Outlook

The budgets for 2003-2006 have operated with substantial deficits, covered by our initially large cash reserve. For the years 2003-2005, this was the agreed way to fund the facility upgrade programme approved by the Council. However, from 2006, the deficit arises because not all Associates have been in a position to raise their contributions to cover the cost of legalising our staff contracts. Our reserves have been sufficient to avoid cash flow problems in 2006, but additional income will be needed to maintain our services in the longer term. Efforts to address this issue will continue in 2007.

View of Caldera de Taburiente.

FINANCES

BUDGET LINE	Expenses 2006 Euro	Budget 2006 kEuro	Expenses 2005 kEuro	Expenses 2004 kEuro
Directorate	220 715	274	185	193
La Palma staff	1 051 909	1 065	1 071	792
La Palma infrastructure	141 891	145	139	159
La Palma operations	116 143	99	103	113
Telescope operation and maintenance	113 967	40	22	86
Instrument operation and maintenance	61 325	50	37	46
Telescope development projects	83	0	33	19
Special development projects	13 718	0	62	3
Total expenses	**1 719 751**	**1 673**	**1 653**	**1 412**
Contributions	1 436 400	1 434	1 231	1 207
Other income	96 431	98	284	32
Total income	**1 532 831**	**1 532**	**1 515**	**1 239**
Result of the year	**-186 920**	**-142**	**-138**	**-173**
Reserves at beginning of the year	556 969	419	695	868
Reserves at end of the year	370 049	277	557	695



Full moon rising at sunset. Photo: A. Somero, NOT and Helsinki Univ.

Publications are the standard measure of scientific output, for observatories as well as for individuals, and users are asked to report refereed papers based on NOT data to our data base (see http://www.not.iac.es/news/publications). Papers reported in 2006 are listed below; for multi-author papers, the first six names and the total number are given.

International refereed publications:

Ayres, T.R., Harper, G.M. et al.: *"The remarkable far-ultraviolet spectrum of FK Comae Berenices: King of Spin"*, 2006, ApJ **644**, 464

Balland, C., Mouchet, M., Pain, R., Walton, N.A., Amanullah, R., Astier, P., et al.: *"Spectroscopy of twelve type Ia supernovae at intermediate redshift"*, 2006, A&A **445**, 387

Bettoni, D., Moles, M., Kjærgaard, P., Fasano, G., Varela J.: *"The scaling relation of early-type galaxies in clusters"*, 2006, A&A **452**, 811

Buta, R., Laurikainen, E., Salo, H., Block, D.L., Knapen, J.H.: *"Fourier Dissection of Early-Type Galaxy Bars"*, 2006, AJ **132**, 1859

Caballero, J.A., Martín, E.L., Zapatero Osorio, M.R., Béjar, V.J.S., Rebolo, R., Pavlenko, Ya., Wainscoat R.: *"S Ori J053825.4024241: a classical T Tauri-like object at the substellar boundary"*, 2006, A&A **445**, 143

Campins H., Ziffer J., Licandro J. et al.: *"Nuclear Spectra of Comet 162P/Siding Spring (2004 TU12)"*, 2006, AJ **132**, 1346

Creevey, O.L., Brown, T.M., Jimenez-Reyes, S., Belmonte, J.A.: *"Interested in observing TrES-Her0-07621?"*, 2006, ASPC **349**, 387

Dahle, H.: *"The Cluster Mass Function from Weak Gravitational Lensing"*, 2006, ApJ **653**, 954

Djupvik, A.A., André, Ph., Bontemps, S., Motte, F., Olofsson, G., Gålfalk, M., Florén, H.-G.: *"A multi-wavelength census of star formation activity in the young embedded cluster around Serpens/G3-G6"*, 2006, A&A **458**, 789

Duffard, R., de Leon, J., Licandro, J., Lazzaro, D., Serra-Ricart, M.: *"Basaltic asteroids in the Near-Earth Objects population: A mineralogical analysis"*, 2006, A&A **456**, 775

Fynbo, J.P.U., Starling, R., Ledoux, C., et al.: *"Probing Cosmic Chemical Evolution with Gamma-Ray Bursts: GRB060206 at z=4.048"*, 2006, A&A **451**, L47

Gahm, G.F.: *"Enhanced activity in close T Tauri binaries"*, 2006, Ap&SS **304**, 149

Gahm, G.F., Carlqvist, P., Johansson, L.E.B., Nikolic, S.: *"Rotating elephant trunks"*, 2006, A&A **454**, 201

Gameiro, J.F., Folha, D.F.M., Petrov, P.P.: *"The veiling spectrum of DI Cephei and its relationship to emission line profiles"*, 2006, A&A **445**, 323

Gandhi, P., Fabian, A.C., Crawford, C.S.: *"4C +39.29 – extended emission around a powerful type 2 quasar"*, 2006, MNRAS **369**, 1566

Gonzalez Perez, J.M., Solheim, J.-E., Kamben, R.: *"A search for photometric variability of hydrogen-deficient planetary-nebula nuclei"*, 2006, A&A **454**, 527

Gorlova, N., Lobel, A., Burgasser, A.J., Rieke, G.H., Ilyin, I., Stauffer, J.R.: *"On the CO near-infrared band and the line-splitting phenomenon in the yellow hypergiant ρ Cassiopeiae"*, 2006, ApJ **651**, 1130

Gorosabel, J., Castro-Tirado, A.J., Guziy, S., de Ugarte Postigo, A., et al.: *"The short-duration GRB 050724 host galaxy in the context of the long-duration GRB hosts"*, 2006, A&A **450**, 87

Gorosabel, J., Castro-Tirado, A.J. et al.: *"Revealing the jet structure of GRB 030329 with high-resolution multicolor photometry"*, 2006, ApJ **641**, L13

Gruendl, R.A., Guerrero, M.A., Chu, Y.-H., Williams, R.M.: *"XMM-Newton observations of the bipolar planetary nebulae NGC 2346 and NGC 7026"*, 2006, ApJ **653**, 339

Herczeg, G.J., Linsky, J.L. et al.: *"The origins of fluorescent H2 emission from T Tauri stars"*, 2006, ApJS **165**, 256

Jakobsson, P., Levan, A., Fynbo, J.P.U., Priddey, R., Hjorth, J., Tanvir, N. et al.: *"A mean redshift of 2.8 for Swift gamma-ray bursts"*, 2006, A&A **447**, 897

Jakobsson, P., Fynbo, J.P.U., Ledoux, C., Vreeswijk, P., Kann, D.A., Hjorth, J. et al.: *"HI column densities of z > 2 Swift gamma-ray bursts"*, 2006, A&A **460**, L13

Justtanont, K., Olofsson, G., Dijkstra, C., Meyer, A.W.: *"Near-infrared observations of water-ice in OH/IR stars"*, 2006, A&A **450**, 1051

Keel, W,C., White, R.E., Owen, F.N., Ledlow, M.J.: *"The spiral host galaxy of the double radio source 03131921"*, 2006, AJ **132**, 2233

Kun, M., Nikolic, S., Johansson, L.E.B., Balog, Z., Gaspar, A.: *"Low-mass star formation in Lynds 1333"*, 2006, MNRAS **371**, 732

Laurikainen, E., Salo, H., Buta, R., Knapen, J., Speltincx, T., Block, D.: *"Morphology of 15 southern early-type disk galaxies"*, 2006, AJ **132**, 2634

Law, N., Mackay, C., Baldwin J.: *"Lucky Imaging: High Angular Resolution Imaging in the Visible from the Ground"*, 2006, A&A **446**, 739

Law, N., Hodgkin, S., Mackay, C.: *"Discovery of five very low mass close binaries, resolved in the visible with Lucky Imaging"*, 2006, MNRAS **368**, 1917

Levan, A.J., Fruchter, A.S., Rhoads, J., et al.: *"Infrared and Optical Observations of GRB 030115 and its Extremely Red Host Galaxy: Implications for Dark Bursts"*, 2006, ApJ **647**, 471

Levan, A.J., Tanvir, N.R., Fruchter, A.S. et al.: *"The Faint Afterglow and Host Galaxy of the Short-Hard GRB 060121"*, 2006, ApJ **648**, L9

Lindfors, E.J., Turler, M., Valtaoja, E., Aller, H., Aller, M., Mazin, D. et al.: *"Synchrotron flaring in the jet of 3C279"*, 2006, A&A **456**, 895

Lopez, R., Estalella, R., Gomez, G., Riera, A.: *"Optical imaging of L723: The structure of HH 223"*, 2006, A&A **454**, 233

Lopez-Sanchez, A.R., Esteban, C., Garcia-Rojas, J.: *"Star formation and stellar populations in the Wolf-Rayet(?) luminous compact blue galaxy IRAS 08339+6517"*, 2006, A&A **449**, 997

Maiorano, E., Masetti, N., Palazzi, E. et al.: *"Physics of the GRB 030328 afterglow and its environment"*, 2006, A&A **455**, 423

Moss, C.: *"Enhanced mergers of galaxies in low-redshift clusters"*, 2006, MNRAS **373**, 167

Muinonen, K., Virtanen, J., Granvik, M., Laakso, T.: *"Asteroid orbits using phase-space volumes of variation"*, 2006, MNRAS **368**, 809

Nilsson, R., Uthas, H., Ytre-Eide, M., Solheim, J-E., Warner, B.: *"New pulsating white dwarfs in cataclysmic variables"*, 2006, MNRAS **370**, L56

Paraficz, D., Hjorth, J., Burud, I. et al.: *"Microlensing variability in time-delay quasars"*, 2006, A&A **455**, L1

Pian, E., Foschini, L., Beckmann, V., Soldi, S., Türler, M., Gehrels, N. et al.: *"INTEGRAL observations of the blazar 3C 454.3 in outburst"*, 2006, A&A **449**, L21

Pozzo, M., Meikle, W.P.S., Rayner, J.T. et al.: *"Optical and infrared observations of the Type IIP SN 2002hh from days 3 to 397"*, 2006, MNRAS **368**, 1169

Raiteri, C.M., Villata, M., Kadler, M., Ibrahimov, M.A., Kurtanidze, O.M., Larionov, V.M. et al: *"Multifrequency variability of the blazar AO 0235+164. The WEBT campaign in 2004-2005 and long-term SED analysis"*, 2006, A&A **459**, 731

Ramsay, G., Napiwotzki, R., Hakala, P., Lehto, H.: *"RApid Temporal Survey (RATS) II. Followup observations of four newly discovered short-period variables"*, 2006, MNRAS **371**, 957

Sbarufatti, B., Falomo, R., Treves, A., Kotilainen, J.: *"Optical spectroscopy of BL Lacertae objects. Broad lines, companion galaxies and redshift lower limits"*, 2006, A&A **457**, 35

Schinnerer, E. et al.: *"Molecular Gas Dynamics in NGC 6946: A Bar-driven Nuclear Starburst 'Caught in the Act'"*, 2006, ApJ **649**, 181

Schnerr, R.S., Henrichs, H.F., Oudmaijer, R.D., Telting, J.H.: *"On the H_α emission from the β Cephei system"*, 2006, A&A **459**, L21

Sollerman, J., Jaunsen, A.O., Fynbo, J.P.U., Hjorth, J., Jakobsson, P., Stritzinger, M. et al.: *"Supernova 2006aj and the associated X-Ray Flash 060218"*, 2006, A&A **454**, 503

Swinbank, A.M., Bower, R.G. et al.: *"Galaxies under the cosmic microscope: resolved spectroscopy and new constraints on the z = 1 Tully-Fisher relation"*, 2006, MNRAS **368**, 1631

Taubenberger, S., Pastorello, A., Mazzali, P.A., Valenti, S., Pignata, G., Sauer, D.N. et al.: *"SN 2004aw: confirming diversity of Type Ic supernovae"*, 2006, MNRAS **371**, 1459

Telting, J., Østensen, R.: *"Time-resolved spectroscopy of the bright sdBV Balloon090100001"*, 2006, A&A **450**, 1149

Telting, J., Schrijvers, C., Ilyin, I., Uytterhoeven, K. et al.: *"A high-resolution spectroscopy survey of beta Cephei pulsations in bright stars"*, 2006, A&A **452**, 945

Villar-Sbaffi, A. St-Louis, N. et al.: *"An extreme case of a misaligned highly flattened wind in the Wolf-Rayet binary CX Cephei"*, 2006, ApJ **640**, 995

Roque de los Muchachos seen from the south

Villata, M., Raiteri, C.M., Balonek, T.J., Aller, M.F., Jorstad, S.G., Kurtanidze, O.M. et al.: *"The unprecedented optical outburst of the quasar 3C 454.3"*, 2006, A&A **453**, 817

Voss, B., Koester, D., Østensen, R., Kepler, S.O., Napiwotzki, R., Homeier, D., Reimers, D.: *"Discovery of seven ZZ Ceti stars using a new photometric selection method"*, 2006, A&A **450**, 1061

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In addition, NOT staff and students have co-authored no fewer than 26 *Gamma-Ray Burst Coordinate Network* (GCN) communications and 4 *Minor Planet Circulars*.

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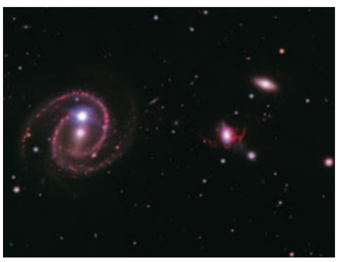

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2006

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The spiral galaxy ESO 436-46 and the starburst galaxy Tol 9

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