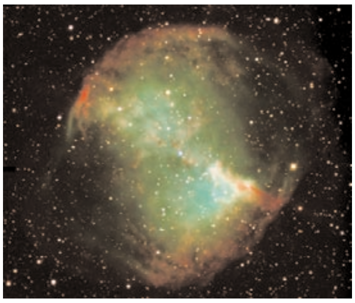
2002

NORDIC OPTICAL TELESCOPE

ANNUAL REPORT

The planetary nebula NGC 6853 (the "Dumbbell Nebula").

NOT in winthertime.



Front cover: The planetary nebula NGC 6853 (the "Dumbbell Nebula") imaged by R. Corradi in blue, yellow, and red light with NOT, using the new 4096x4096 mosaic CCD camera built at Copenhagen Observatory with funding from the Carlsberg Foundation.

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, Canaries, Spain. It is operated for the benefit of Nordic astronomy by the Nordic Optical Telescope Scientific Association (NOTSA), established by the Associates, i.e. 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. The Council appoints a **Scientific and Technical Committee** (STC) to advise it on the performance and plans for the telescope and other scientific and technical policy matters.

An **Observing Programmes Committee** of independent, experienced scientists is appointed by the Council to perform peer review and scientific ranking of the observing proposals submitted. Each OPC member has a substitute to broaden the scientific basis for the review, ensure that a full OPC can always meet, and resolve any potential conflicts of interest. Based on this ranking, the Director prepares the actual observing schedule.

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

NOTSA's policies and plans for the future are described in articles in this Report. Names of current Council and Committee members and contact information to NOT itself are listed on the inside back cover.

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Editor: Johannes Andersen
Layout: Anne Marie Brammer

The NOT and new Director J. Andersen looking forward to a bright future.

P. Brandt and C. Perez dismounting the secondary mirror before aluminization.

PREFACE

Stepping into a success story is a delightful feeling. Succeeding Vilppu Piirola as Director of NOTSA is such an experience: Telescope reliability is outstanding, user satisfaction gratifying, staff morale high, finances healthy, and the NOT Annual Report a model of attractiveness and prompt appearance. But it is a tough act to follow!

In tackling it, my first pleasant duty is to thank Vilppu, personally and on behalf of the staff and user community, for his dedicated and tireless efforts as Director of NOTSA for the last seven years. We look forward to see him again as our most treasured user, a role I know he will relish. Many happy returns, Vilppu!

However, a Director is not hired to reflect on past glories, but to make sure that NOT continues to perform well, now and in the future. Hardly had I met the staff and been presented with my impressive official Director's cap (see next page) before I found myself in the dome undoing bolts, pulling chains and pulleys, pushing mirror carts, and vacuum cleaning the mirror cell. In the end, the throughput of the telescope had improved 30-60% from IR to UV. And several other technical improvements have been initiated, as you can read later in this Report.

So yes, NOT will do fine in 2003. But what role will it play in Nordic astronomy in 2006 or 2010? The answer will determine in which directions NOT must begin to develop already now. And looking back is a poor guide to the future: A new generation of not only larger, but also much better telescopes than ever before has entered the scene in force, and most of our users have or will have access to them. It is in the face of such competition we must ensure that NOT remains a cost-effective facility in terms of the scientific returns of their astronomical communities.

But what is the key science we should plan for? To find out, we distributed questionnaires to all Nordic NOT user groups in the spring of 2002, to collect their scientific plans and priorities for the near and long-term future. The response was gratifyingly vigorous, and the replies have been analysed to derive the main trends and policies that will be needed to maintain NOT as an effective scientific tool for our user community. More details are given in the article on p. 6, but a number of initiatives have already been taken to improve the performance of NOT in the near term and prepare for more radical upgrades later.

The future of NOT must be seen in a broad international context. OPTICON, the EU-funded Infrastructure Coordination Network, is working to prepare joint plans for the future coordinated development and use of the European optical-infrared observing facilities as a whole. Part of this plan is to rationalise the operation of the existing 2-4-m telescopes. By increasing the specialization of their instrumentation, each of them to become more powerful in its chosen field as well as more cost-effective. And by making all of them accessible beyond their traditional communities, users will retain access to a broad spectrum of facilities, only on different telescopes rather than a single one (see more on p. 6).

NOTSA has been very active in this effort on behalf of the Nordic astronomical communities. As directed by Council, our objective has been the long-term health of Nordic astronomy rather than a short-term gain for our telescope. Rapid progress has been made in 2002, and I expect that a single, unified proposal for support to European optical-infrared astronomy under Framework Programme 6 will be submitted by April 2003. I am confident that, by 2006 or 2010, the OPTICON initiative will be seen as a decisive step towards a better-organised European astronomy.

But meanwhile the telescope is ours to run, and the main body of this report is devoted to highlights of the science that has been carried out at NOT in 2002. Its use in training research students is also illustrated.

The following pages give short accounts of several of the research projects carried out at NOT in 2002, as told by the researchers themselves. The articles have been grouped into chapters by subject, each with a brief introduction to outline the context for the non-specialist. I thank all contributors and hope that my editing of their texts to fit the available space and achieve a certain uniformity of style will still do justice to their exciting work. Individual articles are credited as appropriate; unsigned text is by the Editor.

I hope you will enjoy the following pages and the new layout by Anne Marie Brammer, whom I thank for a pleasant co-operation. I already look forward to report next year on the achievements of 2003!

Johannes Andersen
Director

Johannes Andersen

MEET the Staff

Considerable changes in the staff took place in 2002: Dr. Johannes Andersen succeeded Dr. Vilppu Piirola as Director of NOTSA on May 1. Dr. Thomas Augusteijn, with many years of experience from Chile and La Palma, took up his position as Astronomer-in-Charge on August 1, succeeding Dr. Tim Abbott, who returned to Chile. Peter Meldgaard Sørensen from the British group joined us as Software Specialist on November 1, 2002. Among the NOT students, Mathias Egholm returned to Denmark in October, and Silva and Arto Järvinen and Geir Oye began new one-year terms on January 1, 2003. As of that date, the regular NOT staff consists of the following persons:

Johannes Andersen
Director

Francisco Armas
Administrator

Thomas Augusteijn
Astronomer-in-Charge

Peter Brandt
Mechanic

Jacob W. Clasen
Software specialist

Graham Cox
Electronics engineer

Loida Fernández
Secretary

Eva Jurlander
Accountant

Arto Järvinen
Ph.D. student

Silva Järvinen
Ph.D. student

Amanda Kaas
Senior Staff Astronomer

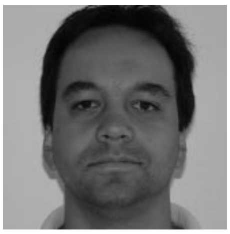
Geir Oye
Student assistant

Carlos Pérez
Electronics technician

Tapio Pursimo
Staff astronomer

Peter M. Sørensen
Software specialist

Ingvar Svärdh
Software engineer



John Telting
Staff astronomer

Markku Verkkoniemi
System manager

In accordance with the international agreements establishing the Canarian observatories, NOTSA also provides stipends for two Spanish students to get their Ph.D.s at Nordic Universities. In 2002, these were Miguel de Val Borro (Stockholm), Ana García Pérez (Uppsala, until Oct. 1, 2002), and Antonio Lopez Merino (Copenhagen, from Oct. 1, 2002).

INTERVIEW WITH DR. JENS HJORTH, COPENHAGEN UNIVERSITY, DENMARK

Jens Hjorth is active in a wide range of extragalactic research, from gamma-ray bursts and gravitationally lensed quasars to dust properties in distant galaxies. He has used NOT extensively for the last decade. We have asked him:

Jens, you use just about every major observing facility on and above the ground in your research. Why also NOT?

Oh, there are several reasons. First, it is a valuable complement to ESO; one should not use the VLT for work that NOT can do, and travelling to La Palma is a lot less hassle than to Chile. Plus NOT is in the northern hemisphere, of course. But the synergy with the large facilities is important: We have obtained lots of time at the VLT, Keck, HST, and XMM on proposals which simply would not have been successful without our previous work at NOT. Then I also involve many students in my projects, and observing at NOT has been a tremendous experience for them. I strongly believe that training students at all levels is an essential scientific activity, not a waste of telescope time!

What do you consider NOT's special technical strengths for the kind of work that you do?

The good image quality has been NOT's hallmark over the last decade and has been essential in most of our projects. But NOT is no longer unique in this respect, and competition is getting very tough. One strength we have used is the good UV performance of ALFOSC, although also this could be improved. The standby camera, which allows us to do both snapshots of transient sources and regular monitoring of, e.g. gravitational lenses, is a unique resource. What is also valuable – and surprisingly rare! – is NOT's ability to point very close to the horizon, allowing us to follow sources after everybody else has run into the limit switches. And the recent near-infrared capability with NOTCam has opened a whole new range of applications for us.

Are there other aspects of NOT's operations that you find particularly valuable as seen from the user's perspective?

NOT's informal, family-style operation, where regular observers accept to take limited amounts of data for other projects (after OPC approval, of course), has enabled us to complete some great projects that would not have been possible otherwise. Understandably, there have been a few grumbles, but as a whole the community has been most cooperative. Being able to know everybody on the staff gives quick and effective communication. A key feature of NOT – this may surprise you! – is that we get the data immediately and semi-automatically after the end of an exposure; at the VLT it may take months. This can give you a critical edge when the trail is hot.

A host of new facilities are becoming available every year at ESO and elsewhere. Will you still use NOT in, say, five years?

Well, I have no idea what I will be doing then! (laughs), but why not? It will depend on whether NOT will focus on being competitive in the right scientific niches at the time. I am sure there will be plenty of opportunities, but everybody will have to keep their eyes open; I don't own a crystal ball!

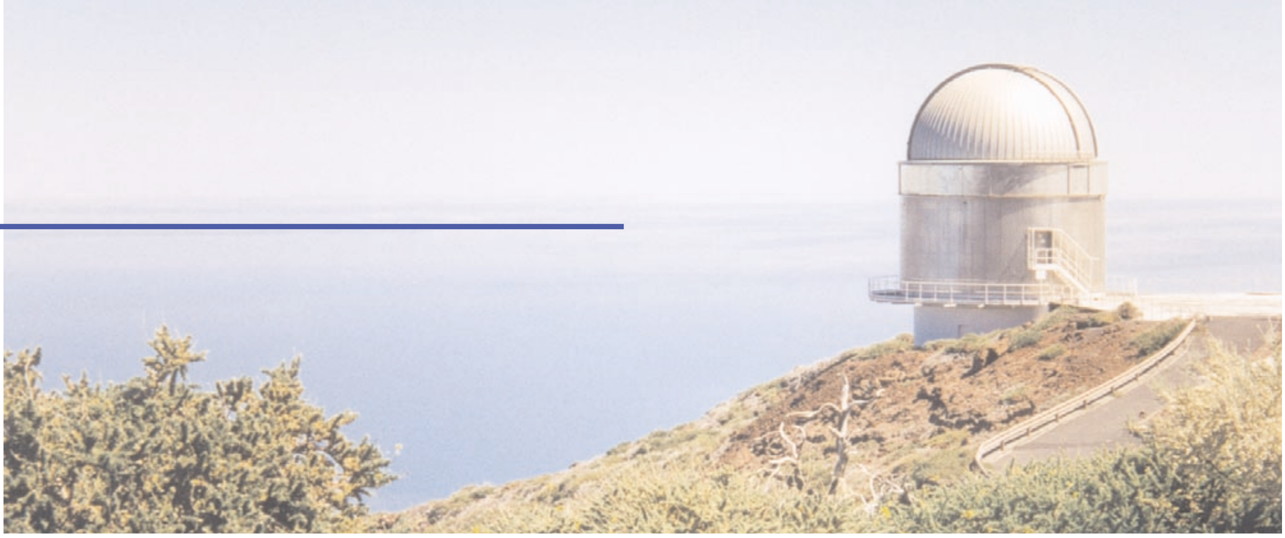
What scientific priorities, and which new instrumentation would you like to see then?

Above all, I believe NOT should focus on being maximally productive in important areas of science, even if those areas may not be my own by then. But one must begin where we stand now, and I would recommend to develop NOT's current strengths (or potential strengths) even further: Rapid (preferably even more automated) response to targets of opportunity, including immediate access to the data; and automatic, on-line "quick-look" data reduction plus pipeline reduction software delivering a simple, standard product together with the raw data. Then I would personally very much like to have a medium resolution UV-sensitive spectrograph with low- (zero-?) noise CCDs available as a standby instrument. Finally, NOT's importance in training students in real hands-on astrophysics will, I am convinced, increase even further.

Would you foresee any major changes in the way we should operate the NOT?

NOT's impact could, I think, be improved by encouraging people to submit really large, ambitious programs rather than today's typical 3-5-night projects. Involving staff members more directly in such projects would, I am sure, be of benefit to both sides. Another way – more uncertain, but potentially also more rewarding – would be to accept "risky" proposals, where good people get a chance to try those far-out ideas you never get time for at the big, streamlined places. And in general, the trend towards flexible use and increased service observing should be encouraged.

Thanks very much for your time and thoughts. Advice like this will help us stay abreast.



CHARTING THE COURSE AHEAD

These are exciting times for astronomy. Scientific discoveries are made at a breathtaking rate, and the range of tools available on the ground and in space to push the frontiers even farther has never been greater. The limits to what we can do are thus neither a lack of exciting challenges nor a lack of observational or computational facilities with which to pursue those studies, but finite resources – financial and above all human. For astronomers and funding agencies alike it is therefore a key priority to ensure that those resources are deployed as effectively as possible.

The facilities currently offered at NOT are the result of the Core Instrument Plan, prepared by the NOT Scientific and Technical Committee (STC) in 1995-96. Based on a survey of user interests and priorities, it responds in a cost-effective way to those expressed needs. While a variety of technical and staffing circumstances have delayed parts of the Plan, most of the intended capabilities are in fact now available to observers or should become so in 2003 (see p. 27). As this Report documents, they are being used effectively by Nordic astronomers to address a wide range of cutting-edge science.

However, given the time elapsed, this does not allow us to rest on our laurels. Rather, it provides an opportunity to review our strategies for the rest of the decade.

There are several reasons why in-depth re-thinking is needed at this time. First and foremost, scientific frontiers are moving constantly: When the Core Instrument Plan was prepared, the first extrasolar planet had just been discovered, the nature of gamma-ray bursts was an utter enigma, and the idea of an accelerating Universe a bad joke!

Over the same time, a new generation of 8-m telescopes – notably ESO's Very Large Telescope (VLT) – has entered full-scale operation with performance levels that could only be dreamt of before. In a few years, the international millimetre interferometer ALMA (also in Chile) will add a completely new dimension to the ground-based facilities. The Hubble Space Telescope, after several upgrades, continues to drive the frontiers in several fields, joined by a new fleet of space observatories (Chandra, XMM, INTEGRAL, ...) which make even greater demands on the ground-based observatories. When Finland hopefully joins ESO in the foreseeable future, the great majority of NOT's users will have access to all these facilities as well as to NOT. Which role should NOT play in this picture?

The NOT User Group Survey

In addition to asking users individually (see e.g. page 5), we decided to distribute questionnaires to all Nordic research groups using NOT to sound out their plans and priorities for the future. The response was gratifying, with replies received from 21 groups comprising 59 tenured scientists, 38 postdocs and visitors, and 129 M.Sc. and PhD students. Although there is some overlap, their estimated current use of NOT indicates that good coverage of the user community was achieved. Encouragingly, they expect their use of NOT to rise by a healthy 20% through 2006 (and by 10% in the more distant period 2007-2010).

NOT is clearly seen primarily as an imaging telescope. Optimum image quality, maximum sensitivity from UV through near-IR, and a wide field have top priority, with imaging polarimetry and fast photometry considered important too. Spectroscopy is also in demand, at high and low resolutions, with wide wavelength coverage and optimum sensitivity as top priority, and spectropolarimetry showing much promise. And many wish to have most of these capabilities available on standby and deployable at short notice (see also later).

Opinions on operational philosophy were divided between wishes for fast, efficient reaction to unexpected events (gamma-ray bursts, supernovae, near-Earth asteroids), or for long observing periods to follow variable objects for weeks or months. A clear majority wants projects to be scheduled more flexibly to better accommodate time- or seeing-critical projects ('science driven scheduling'), and at least partly executed by NOT staff (service observing). Experiments on how to do this in practice will be made in 2003.

Training students in hands-on research is another profitable use of a medium-size telescope like NOT. A large majority of users support such use of NOT, at a level up to ~10% of the total observing time. Again, actual pilot courses will begin already in 2003 (see also p. 26).

The OPTICON Initiative

The EU-funded Infrastructure Coordination Network OPTICON was founded in 2000 by 14 European funding agencies and/or telescope operators, including NOTSA. Its goal is promote better coordination in European astronomy, including plans for joint proposals that could be submitted to the EC under the 6th Framework Plan (2004-2007).

OPTICON has made remarkable progress towards its goals in 2002. The resulting plans will define a new framework for European astronomy until 2008, and taking part in their preparation has had high priority in 2002. The essential elements are as follows:

A trans-national access scheme for all modern European 2-4m telescopes will open these facilities to users from outside the "owner" communities. Included are the major telescopes in the Canaries, the UKIRT and CFHT (French share) on Hawaii, the AAT and UK Schmidt in Australia, the 2-m telescopes at Pic du Midi and Haute-Provence, France, the Calar Alto 2.2-m and 3.5-m telescopes in Spain, and the ESO 3.6m, NTT, and 2.2m telescopes on La Silla, in Chile. Observing proposals will be submitted and reviewed by the standard procedures of each facility, and the performance of all will be constantly monitored to optimise the effectiveness of the programme. EU funding will cover travel costs for the observers and reimburse the nightly share of the operational cost to the telescope operators. The programme will also be open to astronomers from the new EU countries, several of whom have already used NOT in the past.

Networking activities are another major component of the Inte-grated Infrastructure Initiative (I3) proposal for FP6. Some will foster closer cooperation between the European communities in such fields as optical-IR interferometry, adaptive optics, UV astronomy, etc. Others will maintain coordination and better contacts with other disciplines, e.g. radio astronomy including ALMA, with space astronomy, and with the Europe-wide effort to develop standard data base and archiving tools known as the Astrophysical Virtual Observatory (AVO).

A third component of the OPTICON I3 proposal is a series of Joint Research Projects (JRPs). These collect previously fragmented national research efforts into synergistic joint projects that will avoid duplication of effort and make the results available to the entire European community. Typical areas are next-generation adaptive optics, fast optical-IR detectors, friendly user interfaces for optical interferometers, and innovative ways to map large focal planes to detectors in optical-IR imaging and spectroscopy.

Moreover, OPTICON contacts to the previously competing groups developing designs for a European next-generation telescope in the size range 30-100 meter have led to the formation of a single consortium to pursue these studies, no doubt the most effective way to advance the project.

In parallel, the AVO group continues EU-funded studies of future data structure and archiving models, in close collaboration with the US National Virtual Observatory. Thus, the next generation of data from all major European telescopes – including NOT – should conform to the AVO standards and might then be automatically archived in a common European AVO node.

NOT takes part in the OPTICON access sprogramme, and the networks will also be open to Nordic astronomers. The JRP that NOT has decided to join concerns the further development of fast-readout CCD techniques, the potential of which was convincingly demonstrated by Tubbs et al. at NOT (see p. 24-25).

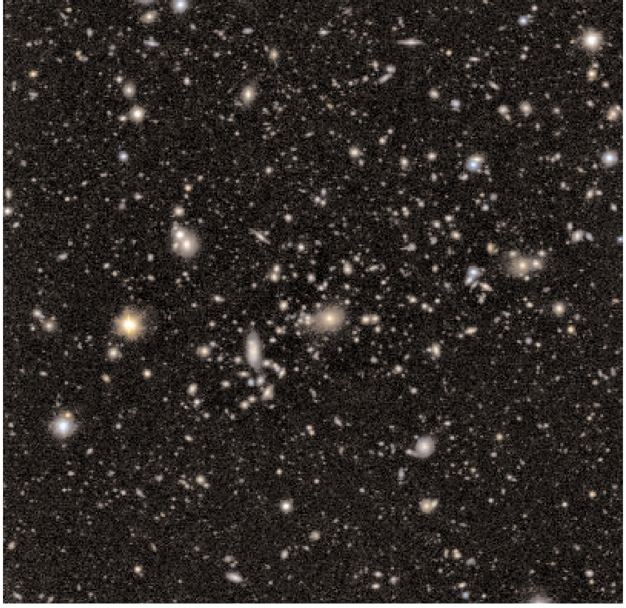
Short- and Long-Term Planning for NOT

The User Group Survey has provided guidelines for the way NOT should develop over the next few years. Some first steps have been taken already (see p. 27). Before undertaking more ambitious projects for the future, we must remember that certain key components of the telescope – notably the control system and the instrument adapter and autoguider – are ~15 years old and increasingly difficult to maintain. A systematic upgrade programme for such items must also be an integral part of the preparations for new instruments.

Some of the necessary measures are ripe for action, and a plan has been prepared and approved by Council to address them over the next 2-3 years, using our financial reserves. Others will require careful scientific and technical review and assurance of realistic financial and human resources. Groups of experienced users will be invited to assist us in an in-depth analysis before decisions are taken.

Finally, we always welcome the constructive thoughts and suggestions of all our users regarding the future equipment and use of NOT. We will endeavour to give constructive consideration to all suggestions received. Planning for the future is a continuing process!

The following pages report on some of the exciting scientific results obtained at NOT in 2002. Texts were contributed by the individual researchers who are credited at the end of each contribution, but have been extensively edited to fit within the available space. Chapter headings and brief introductions have been added by the Editor. Papers have been collected in the list on p. 30.



GALAXY CLUSTERS AND THE DISTANT UNIVERSE

Galaxy clusters are the largest bound structures in the Universe and presumably originate from the largest density fluctuations in the early Universe. They are good tracers of the large-scale distribution of total mass – including those 90% which exist in an unseen and so far unknown dark form – and thus complement more local studies. Another probe into conditions in the far corners of the Universe is provided by the recently-identified optical afterglows of the mysterious gamma-ray bursts, which are direct messengers of a class of extremely violent events in primitive galaxies. We report on two such projects:

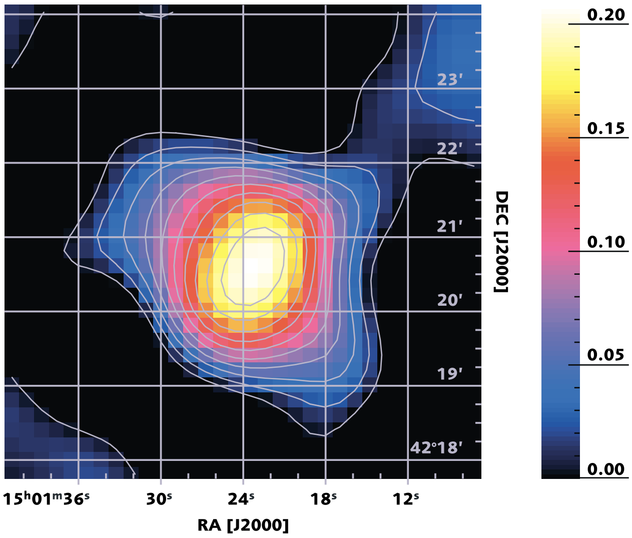


Fig. 1. The galaxy cluster RX J1501.3+4221 at z = 0.29 (ALFOSC, 2 x 1.5h in V and I colours). The cluster is dominated by the large yellowish elliptical galaxy near the centre.

Fig. 2. Contour plot of the smoothed, projected mass distribution of RX J1501.3+4221 as derived from Fig. 1. The mass scale is in units of the critical density for lensing. The peak coincides with the brightest cluster galaxy.

Weak Lensing by Massive Clusters of Galaxies

The gravitational attraction of galaxy clusters produces a lensing effect, which systematically distorts the images of even more distant galaxies in the field. This provides a unique way to directly map the projected mass distribution at intermediate redshifts along any line of sight that is not heavily obscured by Galactic foreground extinction or bright objects. Massive clusters of galaxies give rise to the most significant weak gravitational lensing signals. The technique requires deep imaging in sub-arcsecond seeing, a perfect task for NOT, which will become even more efficient when the wide-field camera FRED is completed.

Weak lensing observations of a volume-limited sample of 39 exceptionally X-ray luminous (and therefore very massive) galaxy clusters at redshifts $0.1 < z < 0.3$ have been made with ALFOSC, more than doubling the total number of clusters with a measured weak lensing signal. Contrary to earlier results by others, good agreement is found for most clusters between lensing-based and virial mass measurements, the latter employing spectroscopic determinations of the velocity dispersion of the cluster galaxies.

Several additional mass concentrations have been discovered along the line of sight to some of the clusters, based on the weak lensing effect. These mass-selected (sub-)clusters seem to be X-ray underluminous, a suggestion now followed up with the XMM and Chandra X-ray satellites. Meanwhile, the initial sample is being expanded to include more X-ray luminous clusters with redshifts up to $z = 0.4$, and also to clusters selected based on optical richness, so as to identify any biases associated with the different cluster selection methods.

About 30% of the clusters show evidence of substructure, indicating that they are not in dynamical equilibrium. The observed dark matter distribution in the clusters is consistent with numerical simulations of structure formation in a standard cold dark matter-dominated universe, although the observations exclude recent simple models for self-inter-acting dark matter. (H. Dahle, P.B. Lilje and R. Irgens, Oslo; K. Pedersen, Copenhagen; S.J. Maddox, Nottingham).

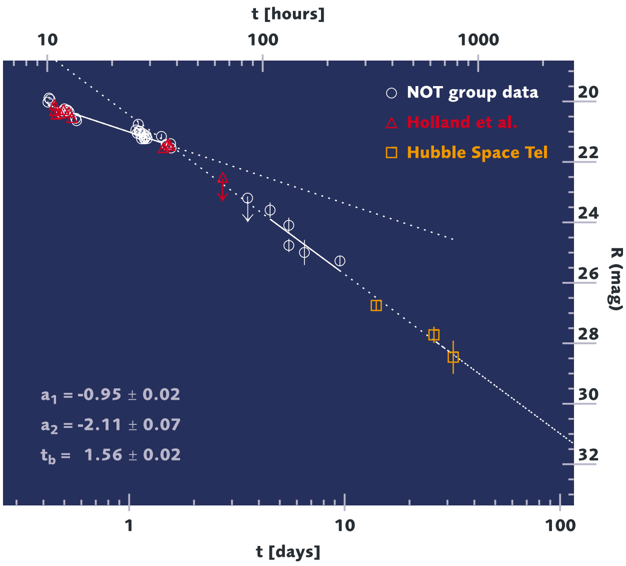


Fig. 1. *R-band light curve of GRB 011211 from NOT (circles), Holland et al. (AJ, 124, 639; triangles), and HST (squares). Dotted lines are extrapolations of linear fits to the data points. Time is measured since the GRB itself.*

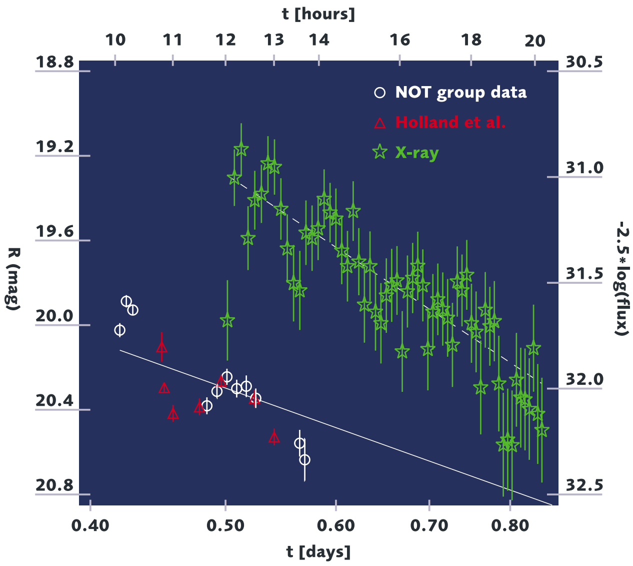


Fig. 2. *The earliest part of the light curve of Fig. 1, showing the oscillations. The X-ray continuum flux is also plotted (green asterisks and right-hand y-axis). The solid line is a fit through the pre-break optical light curve, while the dashed one is a fit through the X-ray points. The X-rays (dashed line) decline faster than the optical light (solid line).*

Relativistic Oscillations in a Gamma-Ray Burst Jet

The basic energy source for cosmic Gamma Ray Bursts is still hotly debated. But whatever the cause, the result appears to be a relativistic fireball, a rapidly expanding cloud of matter and radiation. Its collision with the environment in the host galaxy leads to emission over a wide wavelength range, including X-rays and optical. This afterglow may remain detectable for weeks or months after the initial high-energy event, which typically lasts only a few seconds at most.

The external medium could either be a product of the (similarly unknown) GRB progenitor object, or the more or less uniform interstellar medium. Its interaction with the fireball produces a shock that accelerates electrons to an approximate power-law distribution of ultra-relativistic energies. The electrons, in turn, emit synchrotron radiation which declines as a power law in time and frequency, F ~$t^{\alpha}{*}\nu^{\beta}$. The decay rate, a, depends on the nature of the fireball and the density structure of the surrounding medium. Observed afterglows typically have an initial α_1 ~ -1, often dropping after 1-3 days to α_2 ~ -2 or even steeper.

Under most fortunate circumstances, the optical afterglow of the burst GRB 011211 was discovered with the NOT after only 9.6 hours, leading to follow-up observations from other ground-based observatories, the Hubble Space Telescope (HST), and the XMM-Newton X-ray observatory. As a result of NOT's flexible mode of operation and broad range of instrumentation, the Nordic group could present some of the most challenging results among the papers that followed this unique event.

Fig. 1 shows the light curve of the optical afterglow, with the contribution of the host galaxy subtracted (using HST data). The two lines show a broken power-law fit to the light curve up to day 14, when HST observations began. The most plausible model of the ambient medium exposed to the burst is described by a jet expanding into an environment of constant mean density, rather than a fossil wind from the GRB progenitor.

A peculiar feature of this afterglow is the rapid variability superimposed on the smooth initial power-law decline, seen in both optical and X-rays (Fig. 2). Such variations have been reported only twice before and were interpreted as due to either microlensing or density fluctuations in the ambient medium. Perhaps the most important aspect of the variations in GRB 011211 is their short time scale (less than one hour) compared to the overall initial decline (~11 hours). This is a strong indication that they cannot result from spherically symmetric perturbations, because they would smear out the overall light variations; initial oscillations in the relativistic jet is the most promising explanation (PI H. Pedersen, Copenhagen, on behalf of the Nordic Target-of-Opportunity GRB group; Páll Jakobsson, Reykjavík/Copenhagen).

NORMAL AND ACTIVE GALAXIES IN THE LOCAL UNIVERSE

In the local universe, single and cluster galaxies may be studied in detail, allowing deeper insight into the structure and evolution of galaxies of many types. Galaxies with active nuclei, presumably powered by massive black holes, are of particular interest, as one may hope to learn more about the surroundings of these nuclei and their prodigious energy output.

The Supergalactic Plane Probed by Nearby Dwarf Galaxies

Of the ~300 elusive low surface brightness dwarf galaxies known within 10 Mpc from the Milky Way, roughly 70% are members of seven nearby galaxy groups including the Local Group. Each group contains one or more massive spiral galaxies accompanied by a population of dwarf elliptical (dE) satellite galaxies. On a larger scale, these seven groups and the galaxies between them form a huge two-dimensional structure, the Supergalactic Plane which defines a locus of early galaxy formation in the local Universe.

The and dynamics of nearby galaxies and groups could set limits on the mass and dark-matter content of the Local Group. But despite diligent work over the last two decades, the nature of the Supergalactic Plane and the embedded galaxy overdensities remains unclear. Dynamical studies are generally hampered by small-number statistics, because distances and velocities are known for only the few brightest, high surface brightness members of each group. The more numerous, but also more elusive low-luminosity dE galaxies must be included if we want to really understand the structure of nearby galaxy groups and search for cosmological fingerprints in the Supergalactic plane.

Unfortunately, measuring velocities and distances for dE galaxies by conventional techniques is difficult and requires long integration times on many stars with large telescopes. A more practical and equally accurate distance indicator, the Surface Brightness Fluctuation method, is based on the discrete sampling of a galaxy image with a CCD detector and the derived pixel-to-pixel fluctuations in the light of the unresolved red giant stars. 1-3 hours at a 2m-class telescope under good seeing allows us to measure the distance of a nearby dE galaxy to ~10% accuracy.

This new distance indicator and the excellent NOT site are the basis for an ambitious project to measure distances and velocities for all known dE galaxies within 10Mpc from the Milky Way. Data for a first series of galaxies were obtained in 2001 and 2002. As an example, six square fields in the dE galaxy DDO113 (Fig. 1) were Fourier-analysed to yield the fluctuation power spectra (Fig. 2) and a distance of 3.1 Mpc from the Milky Way. More observations with NOT are planned to acquire the necessary data on all nearby dE galaxies and explore of the structure of the Supergalactic Plane in unprecedented detail (H. Jerjen, Mt. Stromlo; R. Rekola, L. Takalo, M. Valtonen, Turku).

Fig. 1: R-band image of the dwarf galaxy DDO113 with six square sample fields indicated (field: 2.5' x 2.5'; North is up, East to the left).

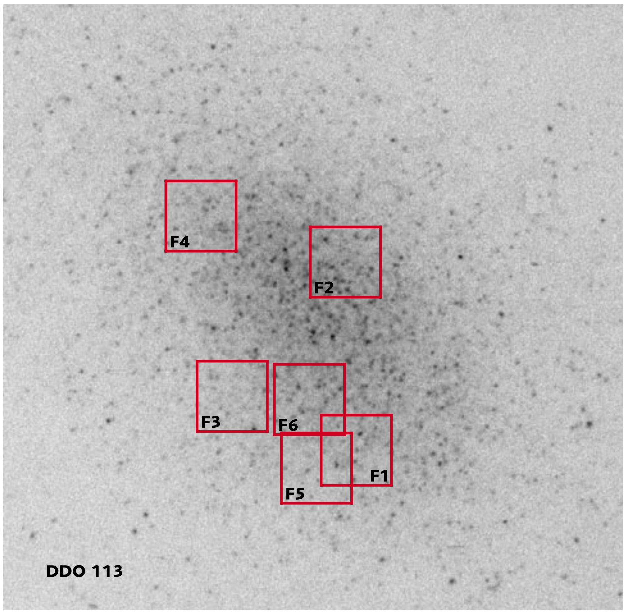
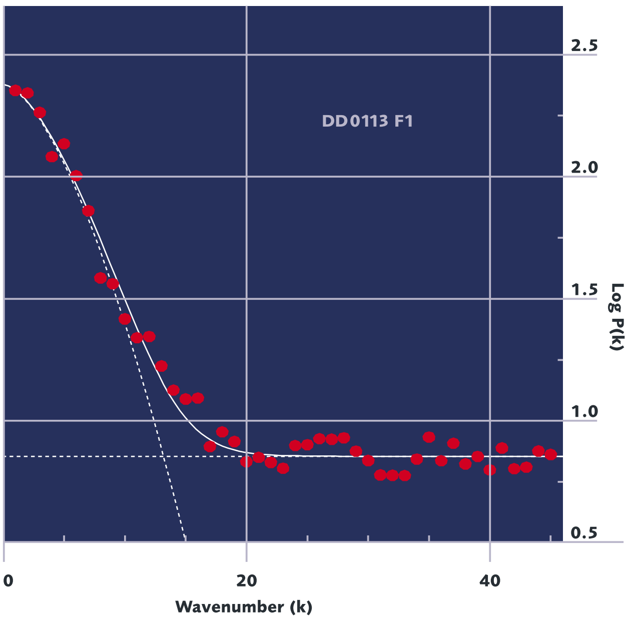


Fig. 2: Power spectrum of the brightness fluctuations in Field 1 in Fig. 1 (dots) and solid lines representing a two-component model fit to the data.



Constraints on the Evolution of Early-type Galaxies

Classical wisdom has it that early-type (elliptical and S0) galaxies in clusters formed about 14 Gyr ago and slowly changed their colours and luminosities due to pure stellar evolution until they reached the red colours we see today. Because the colours of elliptical and SO galaxies are similar they are usually treated as a single class of objects, although totally different formation processes have been proposed for the two Hubble types.

For elliptical galaxies, there are two different basic formation scenarios: *(i)* monolithic collapse at high redshift, or *(ii)* hierarchical merging of smaller disk galaxies. S0 galaxies are thought either to have formed as we see them today, or to have started as spiral galaxies which rapidly lost their gas in the hot, dense cluster environments. The latter would explain why Butcher and Oemler found the relative fraction of blue (spiral?) galaxies in clusters to increase at redshifts > 0.2. In addition, recent HST observations have shown that the fraction of S0 galaxies in cluster cores drops considerably relative to the number of spirals over the redshift range from 0 to 0.5. Yet, no difference in stellar populations between elliptical and S0 galaxies has ever been found.

However, very recent studies using high-quality line-strength data suggest real differences in luminosity weighted ages between E and S0 galaxies in nearby clusters. In order to extend such studies to larger distances and test for strong evolutionary differences between ellipticals and S0s, an unbiased sample of X-ray emitting galaxy clusters at redshift 0.2 has been observed with NOT and ALFOSC in Multi-Object Spectroscopy (MOS) mode (see p. 24).

Satisfactory line indices could be determined for several of the brightest galaxies in moderate exposure times. The hydrogen Hβ line and magnesium Mgb line indices are particularly interesting: A strong Hβ is a signature of a young stellar population, while strong Mgb indicates high metallicity. The data are being analysed and will no doubt lead to deeper insight in galaxy mergers in clusters and the transformations from one Hubble type into another (H.E. Jørgensen, P.K. Rasmussen, L. Hansen and L.F. Olsen, Copenhagen).

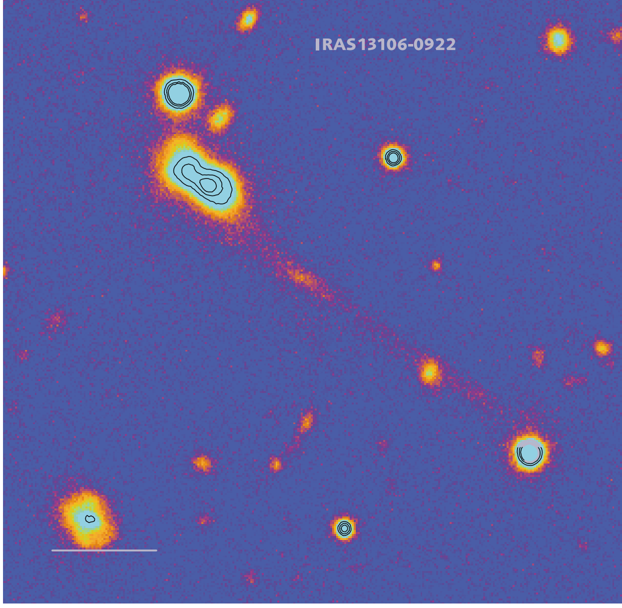


***Fig. 1.** R-band image of the ULIRG IRAS 13106-0922. A double nucleus is clearly detected, together with a very extended, low surface brightness tidal tail to the South-West. The bar corresponds to 10".*

Ultra Luminous InfraRed Galaxies (ULIRGs)

The most conspicuous discovery by the infrared satellite IRAS was a new population of galaxies – the ULIRGs – emitting copiously at far infrared (FIR) wavelengths, with total energies comparable to the most luminous quasars. An earlier study (Veilleux et al. 1999) showed that the percentage of starburst-like nuclei and Seyfert galaxies in ULIRGs changes as a function of IR luminosity: Most nuclei are starburst-like at low LFIR, while up to 60% of the most luminous ULIRGs are Seyfert-like. Merger processes may be the explanation for such behaviour.

To analyse any differences in morphology between activity class, a program has been initiated to observe a representative subsample of 21 of the ULIRGs with IR luminosity larger than $2x10^{12}$ L_{sun}. Deep R-band images have been obtained with ALFOSC in fairly good seeing and appear to be of excellent quality: HST data for some of these galaxies confirm that the main features of interest (double nuclei, inner morphological distortions...) can be well traced in the ALFOSC images which, in addition, allow to trace the long tidal tails seen in some objects (see Fig. 1).

Regardless of activity class, all the galaxies show strongly perturbed morphology, typical of advanced mergers. The sample was separated into two families: Galaxies with a single nucleus, and those with multiple nuclei and/or visible close interaction between two galaxies. The strongest activity appears in the single-nucleus galaxies. Further, starburst galaxies appear to show very extended tidal tails while other types do not, suggesting that the most advanced mergers lead to the most active galaxies. In contrast to earlier reports (Veilleux et al. 2002), we find a larger population of disk-like systems, a very important result for understanding merger evolution and due to the very good spatial resolution and great depth of the NOT data (I. Márquez and J. Masegosa, Granada).

The RASS-FIRST Active Galactic Nuclei Survey

Large-area surveys allow us to construct samples with enough objects for meaningful statistical analysis, probe the faint end of the luminosity function which contains most of the objects reside, and obtain less biased statistics for the population under study. Further, cross-correlating surveys at different wavebands (e.g. radio, optical, and X-ray) enables one to efficiently select specific kinds of objects or study the broadband spectral characteristics of a wide variety of objects.

The ROSAT soft X-ray All-Sky Survey (RASS) contains about 80.000 X-ray sources. Due to the low positional accuracy of ROSAT (about 30”), a large majority of them remain unidentified. However, cross-correlating the RASS catalogue with the 1.4 GHz FIRST (Faint Images of the Radio Sky at Twenty centimetres) radio survey results in a RASS-FIRST catalogue which contains 843 objects where one X-ray source matches one radio source. These sources are probably compact Active Galactic Nuclei (AGNs).

458 of the ”single” matched sources have been identified from Palomar plates and classified by optical spectroscopy. About 70% turn out to be AGNs (45% QSOs, 33% Seyfert galaxies or radio galaxies, and 22% BL Lac objects). Importantly, the radio loudness parameter ($F_{radio}/F_{optical}$) was distributed evenly, without the bimodality seen in some previous studies. Some radio-weak BL Lac objects, previously thought to be non-existing, were also found.

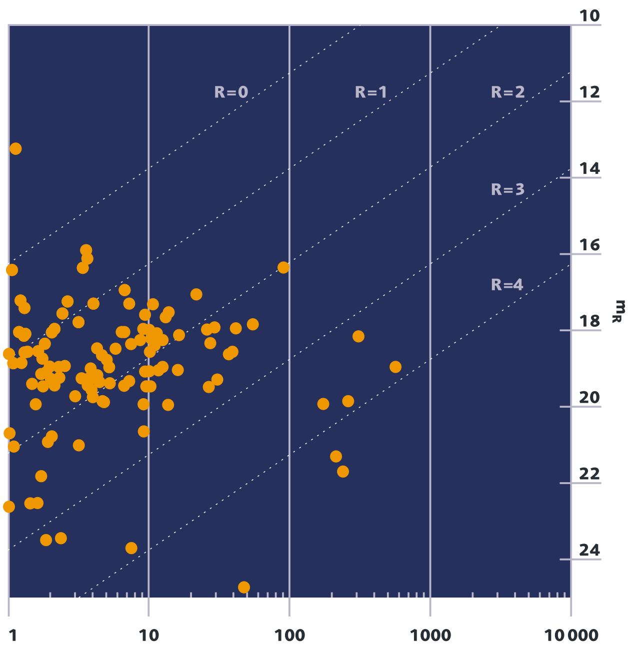


Fig. 1. 1.4 GHz radio flux versus R-band magnitude for the 114 RASS-FIRST sources with optical identifications. The diagonal lines denote constant radio loudness parameter ($F_{radio}/F_{optical}$).

A programme has therefore been initiated to identify and classify the remaining 358 sources. The aim is study to the distribution of AGN types among the faint RASS-FIRST sources and the connection between the host galaxy and the active nucleus. The frequency of radio weak objects among the whole BL Lac population is also an open issue, and one might hope to identify very low luminosity objects filling the gap between BL Lacs and FR I radio galaxies.

So far, R-band images have been obtained for ~150 sources and spectra for about 20, and 114 sources now have optical identifications. Fig. 1 shows the F(1.4GHz) – R-magnitude diagram of these sources. About half of them are clearly resolved, i.e the host galaxy is visible in the ”raw” image (K. Nilsson, Turku; J.Heidt, Heidelberg; W.Brinkmann, Garching; T. Pursimo, NOT).

Host Galaxies of BL Lacertae Objects

BL Lacertae objects are a subgroup of active galactic nuclei whose defining characteristics are rapid flux variations over the whole electromagnetic spectrum, high polarization, and almost total lack of optical emission lines. Recent imaging studies have shown that they reside almost exclusively in the nuclei of luminous elliptical galaxies. There is also growing evidence showing that they are actually low-luminosity radio galaxies with a relativistic jet pointing nearly towards us.

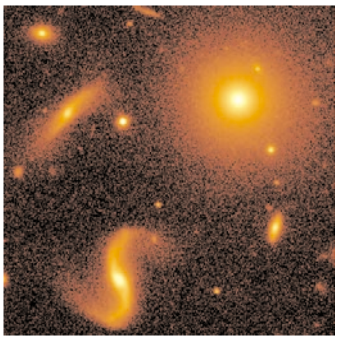


Fig. 1. The nearby BL Lac RGB1532+302 (z = 0.064). Its bright, large host galaxy (upper right corner; M_R = -23.1, r_{eff} = 8.5 kpc) is surrounded by a small group of spiral galaxies. The active nucleus contributes only ~5% of the total light.

Studying the host galaxies can give important clues to the origin of their activity. E.g., the role of the galactic environment in triggering and maintaining the nuclear activity is still unknown. And because the properties of the host galaxies do not depend on orientation, they also provide a way to study the parent population of BL Lacs.

NOT has been used in an imaging study of 100 BL Lacs, all of which are both X-ray and radio emitters. R-band images of the host galaxies were analyzed using a two-dimensional surface brightness fit that separates the nuclear emission from the light of the host galaxy. The host galaxy was resolved in 62 cases, and 37 new host galaxies were found.

The hosts are found to be large, luminous elliptical galaxies, basically very similar to inactive large ellipticals. This indicates that the galactic environment has little effect on the nuclear activity; perhaps every galaxy may enter an active phase at some stage during its evolution. Contrary to some previous studies, no clear example of a disk-dominated (i.e. spiral) galaxy was seen. However, a dozen optically weak nuclei were found, supporting the view that the BL Lac sequence continues to lower luminosity than previously thought (K. Nilsson, L.O. Takalo, A. Sillanpää, Turku; T. Pursimo, NOT; J. Heidt, Heidelberg).

Nuclear Stellar Population of Low-Luminosity AGN

Low-luminosity active galactic nuclei (LLAGNs) are the most common type of galactic nuclear activity and are found in one third of the bright galaxies. However, their physical origin and energy source are still controversial: LLAGNs could be powered by accreting black holes (BH) or by massive nuclear starbursts. If BHs are the energy source, LLAGNs would represent the low end of the AGN luminosity function in the local universe. On the other hand, if hot stars are the dominant source in LLAGNs, massive nuclear starbursts may play an important role in the formation and evolution of galaxy bulges. Therefore, it is important to investigate the nature of LLAGNs.

Fig. 1. Nuclear spectra of LLAGNs observed with ALFOSC, showing features from an intermediate-age stellar population.

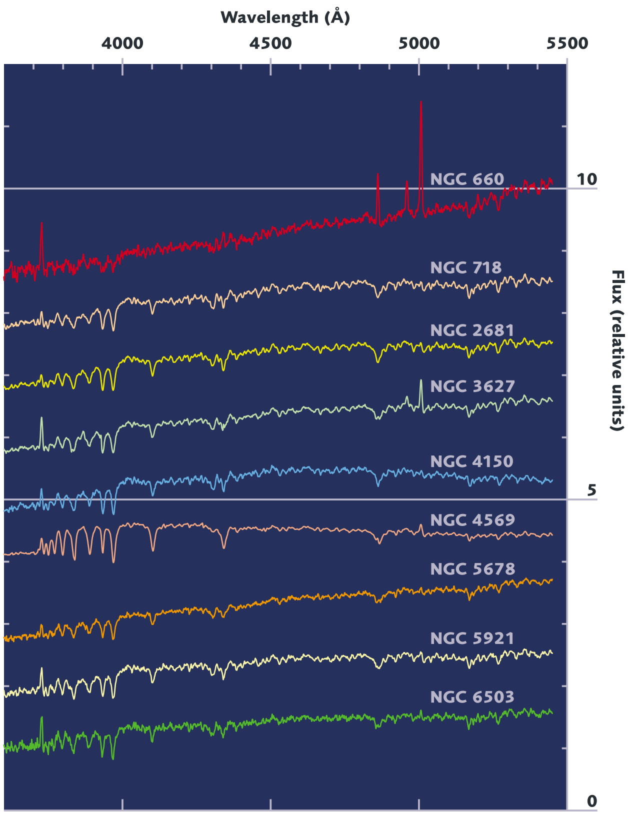


Photo-ionization models suggest that some LLAGN spectra can be reproduced by short starbursts with ages of 3-6 Myr, when the ionizing continuum is dominated by emission from Wolf-Rayet stars (WR). This scenario offers a simple and testable prediction: WR stars should be present in a significant fraction of LLAGNs, detectable through their broad HeII emission lines at 4686 Å.

Spectra of 50 LLAGNs have therefore been observed with ALFOSC in very good seeing. None of the nuclei shows WR features at 4686 Å, suggesting that massive hot stars contribute very little to the optical light of LLAGNs. However, 1/3 of the nuclear spectra do show higher-order Balmer lines in absorption (see Fig. 1), which indicates that intermediate-age stars contribute significantly to the nuclear optical light of these early-type galaxies (R. González Delgado and E. Pérez, Granada; R. Cid and T. Storchi-Bergmann, Brasil; T. Heckman, Baltimore; H. Schmitt; NRAO).

FORMATION, STRUCTURE AND EVOLUTION OF STARS

The life of a star takes it from its birth in a dense interstellar cloud to its more or less violent death, leaving behind a black hole, a neutron star, or a white dwarf star. Interaction between the stars of a binary system may change their evolution into paths that are quite different from those of single stars. The theoretical understanding of stellar evolution is well developed, but the processes are complex and accurate observations are needed to guide the theory.

Disks or Winds in FU Orionis Stars?

Solar-mass stars in the pre-main sequence (PMS) phase of evolution are surrounded by a proto-planetary disk from which matter accretes onto the newly-formed star, accompanied by massive outflows in the form of winds and jets.

The FU Ori stars (or Fuors) present an extreme case of PMS activity, characterised by flare-ups resembling those of classical novae, but of smaller range and much longer time scales. They are believed to be solar-mass PMS stars powered by sudden bursts of enhanced mass accretion. The spectrum would then originate from the accretion disk rather than from the star itself.

Spectral-line diagnostics used to infer a disk geometry are ambiguous, however. Another way to check whether the spectrum is due to a spherical object or a disk is to search for rotational modulation of the spectral lines. Modulations due to surface inhomogeneities (spots) are commonly seen in rotating T Tau stars, but disks are always seen at the same aspect and periodic line variations are then not expected.

The two classical Fuors FU Ori and V1057 Cyg were observed with the SOFIN spectrograph at several epochs in 1996 – 2001. Both stars show rapid rotation and high mass-loss rate. In FU Ori the largest variations are seen in the blue-shifted Hα absorption, which originates in the stellar wind (Fig. 1). This absorption varied regularly with a period of 14.8 days and stable phases over three years, suggesting that FU Ori is a stellar object with this rotational period; but faster quasi-periodic photospheric line modulations are superimposed.

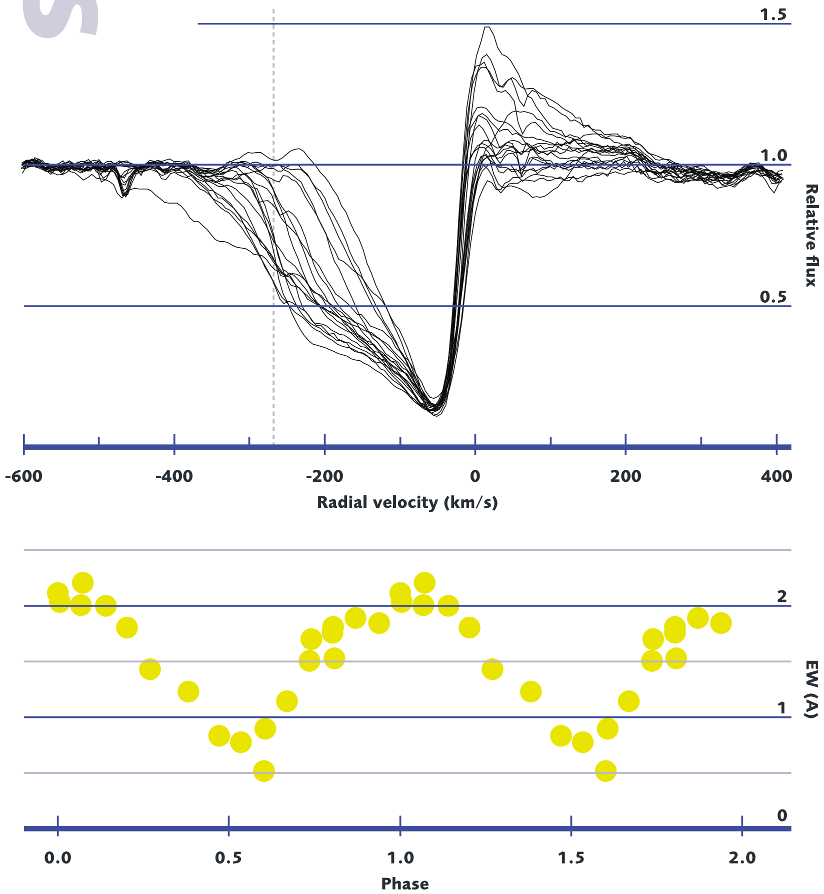


Fig. 1. Upper: Hα line profiles in FU Ori in 1997-1999. Lower: Phase diagram for P = 14.847 days of the equivalent width (EW, Å) of the P Cyg absorption within the velocities marked by dashed lines in the upper panel.

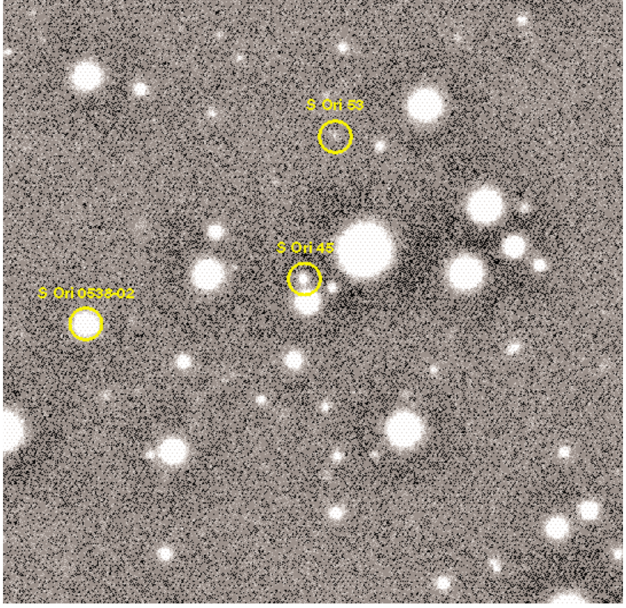


Fig. 1. i-band image centered on S Ori 45. A massive brown dwarf, S Ori J053829.0-024847, and a 10 Jupiter-mass free floating planet, S Ori 53, are shown. Their projected distances to S Ori 45 are 19000 and 13000 AU, respectively.

If the wind is governed by the star's magnetic field, a stable axially asymmetric field might cause the observed line modulation over many rotational cycles. The more rapid photospheric line variations profiles might then reflect a more complicated stellar surface structure. From the observed period and rotational velocity, vsini = 70 km s^{-1}, we estimate a stellar radius of Rsini = 20.4 R_{sun}. The star would then rotate near the break-up speed, which might be a cause of its instability (P. Petrov, Crimea; R. Dümmler, Oulu; G. Herbig, Hawaii).

Weather on Brown Dwarf Stars

Brown dwarfs bridge the gap between the lowest-mass stars and the most massive exoplanets, from 72 to 13 times the mass of Jupiter (0.013 – 0.070 M_{sun}). Because of their very low masses they do not burn hydrogen in their interiors. Brown dwarfs have very cool atmospheres, from ~3000 K in the very young, massive brown dwarfs to ~700 K in the oldest and lowest mass T-spectral type dwarfs. They are extremely faint and red objects, but since their discovery in 1995 (Teide 1 in the Pleiades star cluster and GJ 229 B around an M2 star), many of them have been detected and investigated.

It has been claimed that several very low mass stars and brown dwarfs present photometric variability both in far red and near infrared bands, at the ~0.1% level. The origin of this variability would be explained by the presence of a heterogeneous cover of dust clouds ('weather') or dark spots on the surface of the object. ALFOSC has been used to search for such variability in a few very low mass stars and brown dwarfs in the field. A young brown dwarf in the nearby s Orionis star cluster, S Ori 45, has also been monitored. This star, with an age of 2-4 Myr and a likely mass of 25 M_{Jup}, seems to possess a modulation at a period of about 2.6 h, which could be due to an accretion disk.

Photopolarimetry provides a new way to study the physics of the cool atmospheres of these objects. Both a very short rotation period, deforming the star due to centrifugal forces, and a heterogeneous distribution of dust in the photosphere are among the mechanisms that could produce linear polarization. Magnetic fields, manifested in dark spots, should also be taken into account. We have used ALFOSC again to attempt to determine the degree of polarization of three L-type dwarfs. Careful analysis of these difficult measurements is needed before a positive result can be claimed (J.A. Caballero, IAC).

Pulsation Survey of Early-Type Main-Sequence Stars

Early B-type main-sequence stars can be unstable against radial and low-degree non-radial pulsations (b Cephei stars). Studies of these pulsations can bring unique insight into the structure of the stars. Light variation is the traditional indicator of pulsations; however, spectral line profile variations are a more efficient, yet little-explored way to detect radial or low- and intermediate-degree non-radial pulsations (NRP). A high spectral-resolution survey of 36 northern O9.5-B2.5 II-V stars has therefore been initiated at NOT to look for signatures of NRP in the Si III lines at 4567 and 4574 Å, using the SOFIN spectrograph. The efficiency of SOFIN has recently improved dramatically due to upgrades of both the optics and the CCD detector, and most stars have been observed more than once.

Line-profile structure in the form of quasi-absorption and emission bumps is a good diagnostic of NRP in fast-rotating stars with rotationally broadened lines. Stars with only one spectrum were checked for clear presence of such bumps in the Si III lines; for stars with more than one spectrum it was verified if the bumps moved through the line profile in the manner characteristic of NRP (”Doppler mapping”).

Doppler-mapped NRP bumps are most apparent in stars with rotations in the range 50 – 250 km s^{-1}. For slower rotations, the line broadening is too small to resolve features on the stellar disk; for faster rotation, the lines are so shallow and broad that the detection of bumps becomes very difficult. In all, NRP-like bumps are found in 18 of the 31 stars, consistent with the results of a southern-hemisphere survey by the same group. This confirms that many early B-type stars do in fact pulsate, and that high-resolution spectroscopy is an efficient means to detect such stars (J. Telting, NOT; K. Uytterhoeven, Leuven; I. Ilyin, Oulu).

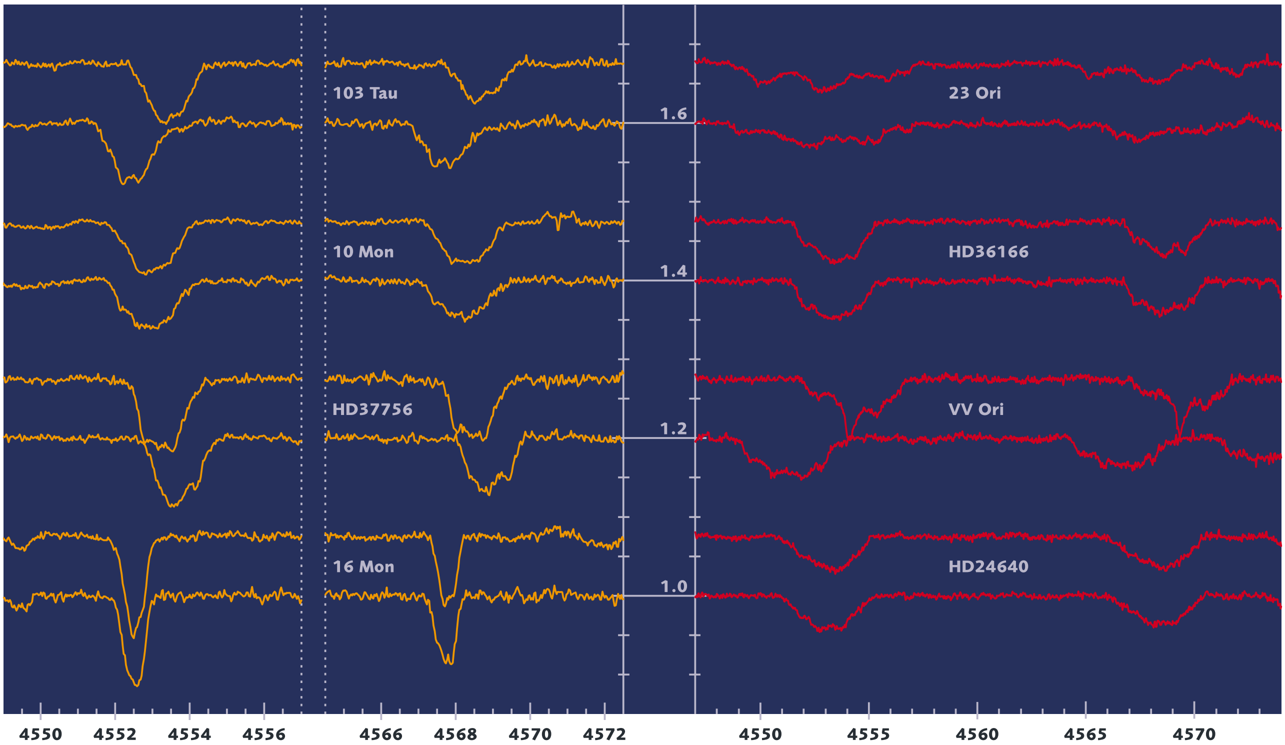


Fig. 1. Sample spectra of stars with clear evidence for NRP in the Si III 4552, 4567 Å lines. The rotational velocity increases from 16 Mon (vsini ~35 km s^{-1}) to 23 Ori (vsini ~295 km s^{-1}).

Chemical Homogeneity of Galactic Glump Giants

Low-mass evolved (giant) stars exhibit chemical anomalies which are not predicted by standard stellar evolution theory. In particular, the abundances of CN and the carbon isotope ^{13}C are enhanced in a way that indicates that processed matter from deep inside the star has somehow been brought to the surface. Compared to the recently-proposed ”cool bottom processing” model of extra-mixing, the observed ^{12}C/^{13}C ratios in solar-metallicity stars are slightly higher than predicted, while somewhat more metal-poor stars agree well with the model. Carbon and nitrogen abundance ratios in metal-rich and metal-poor stars also agree well with the model, while intermediate-metallicity stars have much lower C/N ratios than predicted.

Abundance changes are most clearly seen in evolved helium-core burning ('clump') stars, because they reflect the entire evolution on the giant branch. High-resolution, low-noise spectra for 17 such stars as identified from distances measured by the HIPPARCOS satellite have been obtained with the SOFIN spectrograph on NOT, and another 18 stars at the Elginfield Observatory in Canada. These stars form a homogeneous sample with no obvious divisions by metallicity. Compared to disk dwarfs, C is depleted, Na and Al are slightly enhanced, and O and Mg unaltered. Determination of abundances for ^{13}C, N, and 20 other elements is in progress (G. Tautvaišiené and E. Puzeras, Vilnius; B. Edvardsson, Uppsala; I. Ilyin, Oulu. Supported by the European Commission).

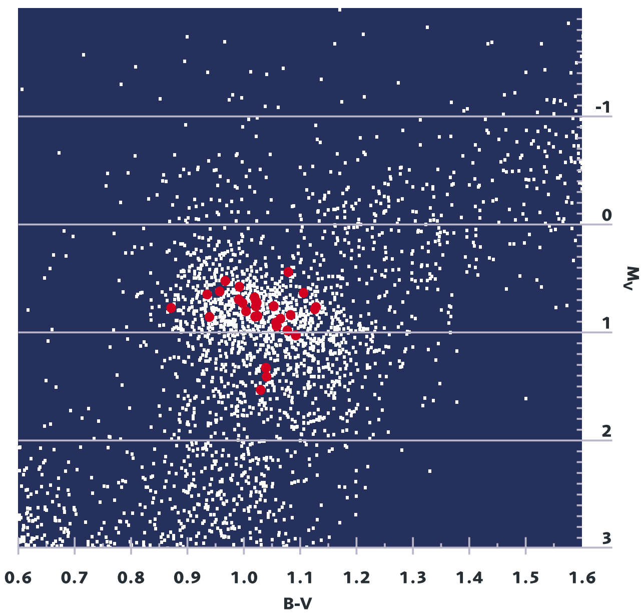
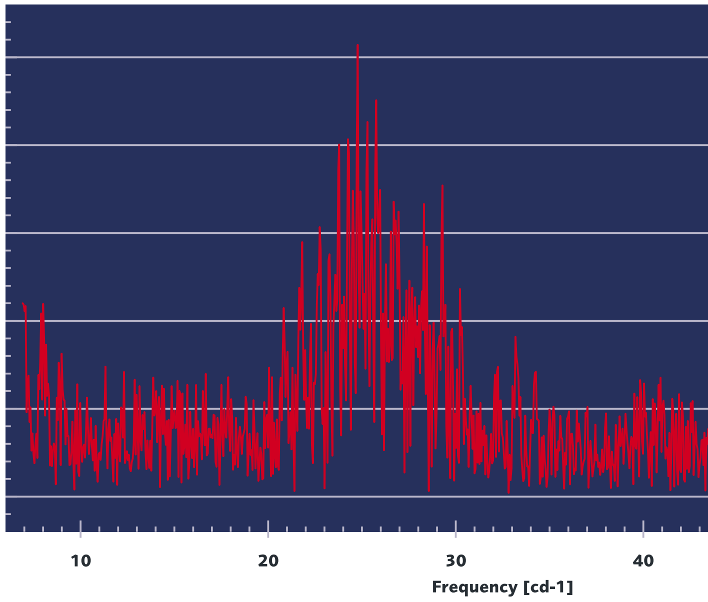


Fig. 1. Colour-magnitude diagram for giants with accurate HIPPARCOS parallaxes and Tycho colours. Programme stars are shown as red circles.



Spectroscopic Studies of Delta Scuti Stars

Among the most promising targets for asteroseismology are the δ Scuti stars, which have rich sets of readily observable oscillation modes. Unfortunately, each star oscillates in a seemingly random subset of modes, making mode identification difficult, and the rapid rotation of most stars causes the oscillation frequencies to shift, complicating matters further.

One approach to this problem is to observe several stars in a cluster. These stars share basic parameters like distance, metallicity, and age, restricting some degrees of freedom in the models. An international, 3-month-long multi-site campaign was organised in early 1998 to determine accurate oscillation frequencies in BN Cnc, a member of the Praesepe open cluster. During a few weeks in February 1998, spectra of BN Cnc were obtained with NOT and also at Thüringen, Okayama, Bangalore, and McDonald Observatories. Modes can then be studied from synthetic line indices, which efficiently measure the temperature and spatial sensitivity of selected spectral lines (see Fig. 1 and Dall 2000). Mode identification relies on different absorption lines to probe different pulsation modes.

For non-rotating stars the Balmer lines are sensitive to pulsation because of the strong limb darkening in these lines, while photometry has very weak centre-to-limb sensitivity. Thus, combining photometry and Balmer line indices allows to identify pulsation modes with different spatial patterns on the stellar surface. BN Cnc is the first rapidly-rotating δ Scuti star to which this technique has been successfully applied, making it a very interesting object for stellar modelling. The dominant modes seem to be radial or l = 1 modes, but also higher-order modes appear to be present (T. Dall, S. Frandsen et al., Århus).

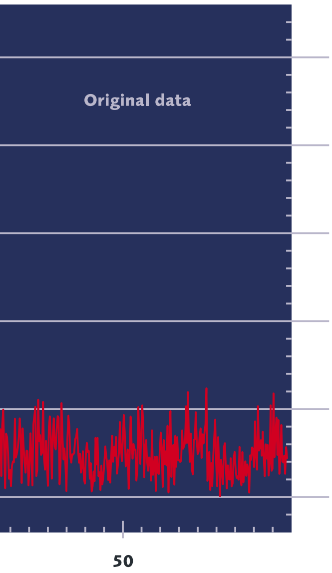


Fig. 1. Amplitude spectrum of the Hα line index in BN Cnc. Although the modes are not well resolved, their amplitudes can be extracted with high precision because the frequencies are accurately known from the photometric campaign.

A Binary Nucleus in a Planetary Nebula

Planetary nebulae (PNe) are short-lived episodes in the evolution of stars towards the white dwarf stage. The PN represents the loss of the outer envelope of the star, while its core appears as a future white dwarf. A white dwarf is a dead star without its own energy production – it just radiates its accumulated energy reserve while slowly cooling down. Almost all white dwarfs have the same mass (0.6 M_{sun}), which tells us that the PN stage is quite efficient in getting rid of excessive mass.

But what happens in the PN stage if the star is in a binary system? It may still retain a close companion, but friction in the expanding atmosphere causes the orbit to shrink, and PN nebula will not be spherical, only axially symmetric around the orbital axis. We then call the PN bipolar. To verify this scenario, the central stars of bipolar PNe have been searched for pulsations with NOT. The pulsation pattern is due to cyclic variations of internal conditions in the star and can give information about the star's evolutionary history.

Pulsations indeed were detected in two bipolar PNe. Of these, NGC 246 displayed a remarkable light curve (Fig. 1). For the first 4000 s the variations were irregular; then a very regular modulation suddenly appeared. A powerful signal is detected at a period of 1460 s, its power increasing until the end of the run. It is not believed that internal pulsation in the star can turn on so fast, so a structure change in a disc surrounding the central star, possibly caused by an orbiting small object, is more likely (J. González Pérez and J.-E. Solheim, Tromsö).

RX J0806+15: The Shortest-Period Binary

When both stars in a binary system evolve to the white dwarf stage, interaction with the stellar envelopes in the red-giant and PN stage leads to a loss of angular momentum. This causes the orbit to shrink and the period to shorten drastically. Accretion onto these compact stars turns the binary into a strong X-ray source. If the two stars eventually merge the result is expected to be a Type Ia supernova, presumed to be the main source of iron-like elements in the universe. It is therefore of obvious interest to identify the very closest systems of this type.

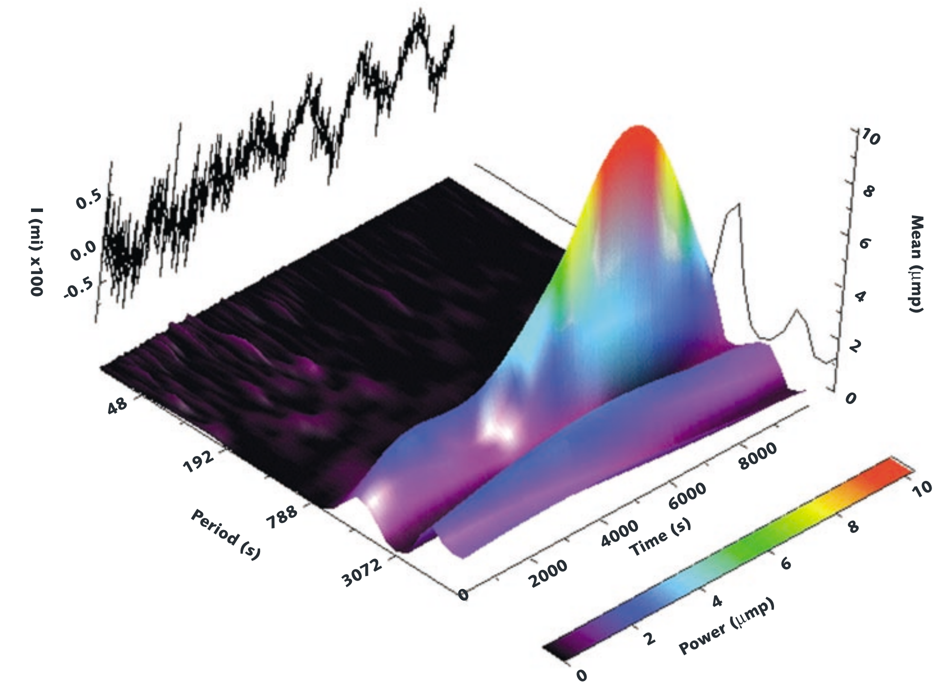
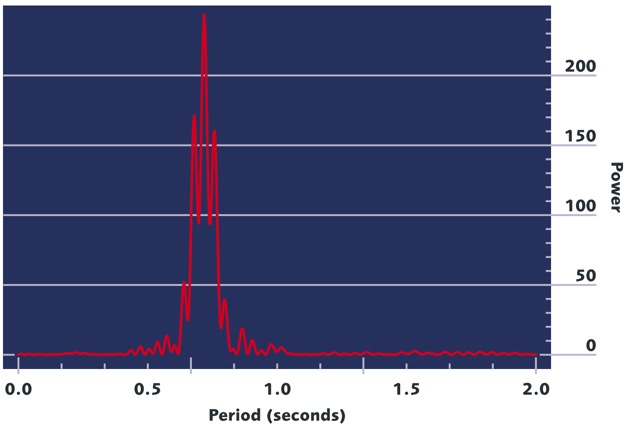


Fig. 1. 3-D illustration of the light variations in NGC 246 on July 24, 2000. The light curve is shown to the left, and the central surface shows the evolution of power at periods of 3-3600 s. The steep "mountain" identifies the periodic signal turning on after ~1 hour.

The X-ray source RX J0806+15 was discovered with the ROSAT satellite, and its X-ray light curve showed strong modulation at a period of 321.5 sec. Optical observations were made with NOT in January 2002 in order to detect its optical counterpart. Using ALFOSC in fast-readout photometric mode allowed to reach a time resolution of about 20 seconds in the photometry, not easily achieved in most optical observatories.

A variable optical counterpart was identified, with a period consistent with the X-ray period. We find no convincing evidence for a second period in the data, implying that the 321.5 sec period is indeed the orbital period. This makes RX J0806+15 the shortest-period stellar binary system yet known. We conclude that the system is most likely a double-degenerate binary consisting of two white dwarfs. This discovery is very interesting, since short period massive systems like RX J0806+15 are expected to be the strongest constant sources of gravitational waves in the universe. They are thus prime targets for future gravitational wave space missions like ESA's LISA (P. Hakala, Turku; G. Ramsay and Mark Cropper, London).



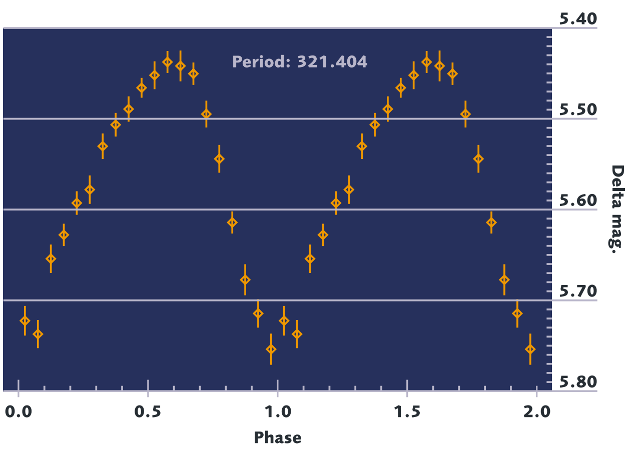


Fig. 1. The power spectrum of the NOT photometry.
Fig. 2. The NOT light curve plotted with the best period.

STELLAR SURFACE STRUCTURE

Conventional models of stellar structure assume that stars are spherically symmetric. We know from the Sun that this is an oversimplification, and some types of star have large-scale surface features that carry essential information on their structure and evolution. As the star rotates, these features move in and out of sight, and the light they add or subtract is Doppler shifted to different wavelengths. The information from a dense series of spectra taken over a rotational period can be inverted to produce a surface map of the star. This Doppler imaging technique has been used extensively at NOT.

Evolution of Magnetic Regions in FK Comae Active Stars

FK Comae type stars are rapidly rotating late type giants which show strong chromospheric and spot activity, associated with magnetic regions. By observing the spots, we can study the behaviour of stellar magnetic activity and detect differential rotation, as seen for sunspots on the Sun. Differential rotation is a key ingredient in models of stellar magnetic activity.

The spot activity of FK Com stars is best studied by Doppler imaging, which requires spectra of high resolution and high signal-to-noise ratio. The SOFIN échelle spectrograph at NOT is ideal for the task, and HD 199178 and FK Com have been observed since 1993, a typical data set for one Doppler image consisting of ~10-20 spectra over ~10 consecutive nights. Optimum spectral regions are around 6400 Å and 7500 Å; resolutions range from ~30.000 to ~80.000, depending on the rotational broadening of the stellar lines. Excellent images were obtained for both stars in 2002 (see Fig. 1).

Spots on FK Com stars are usually concentrated in one or two high-latitude active regions. Studies over long periods reveal major changes in the spot pattern, analogous to Solar activity cycles. FK Com has even shown a ”flip-flop” episode, when the magnetic activity rapidly shifted by 180° in longitude from June 1997 to January 1998. Our temperature maps (Fig. 2) show that the main spot group then ”jumped” in rotation phase from 0.0 to 0.5, as indeed predicted by models of the flip-flop mechanism. In August 2002 the spot activity was considerably reduced, illustrating the cyclical spot activity in FK Com. In contrast, HD199178 has apparently maintained a persistent high-latitude cool spot structure for ~8 years (T. Hackman and H. Korhonen, Oulu).

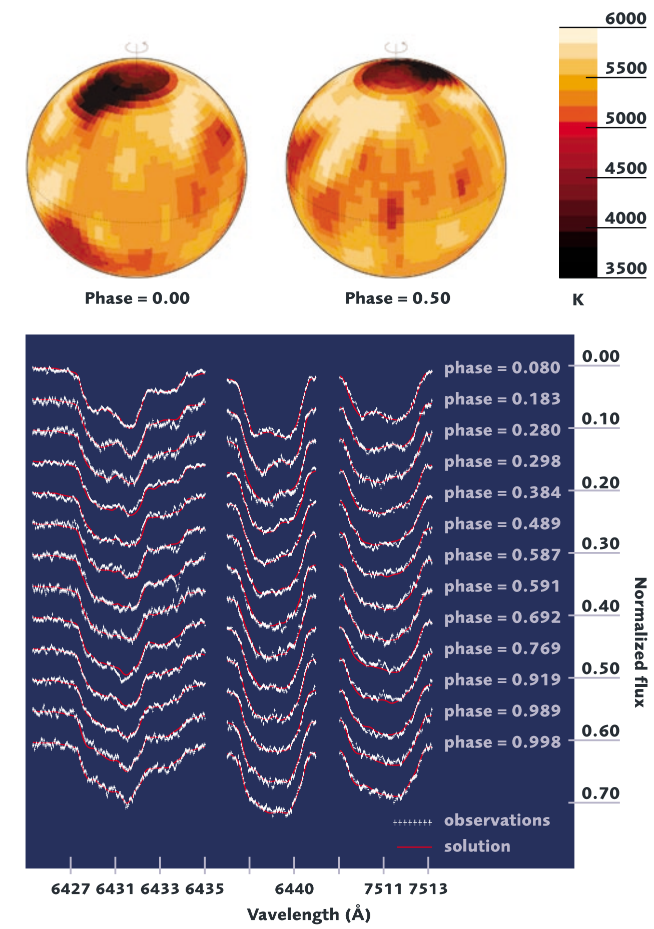
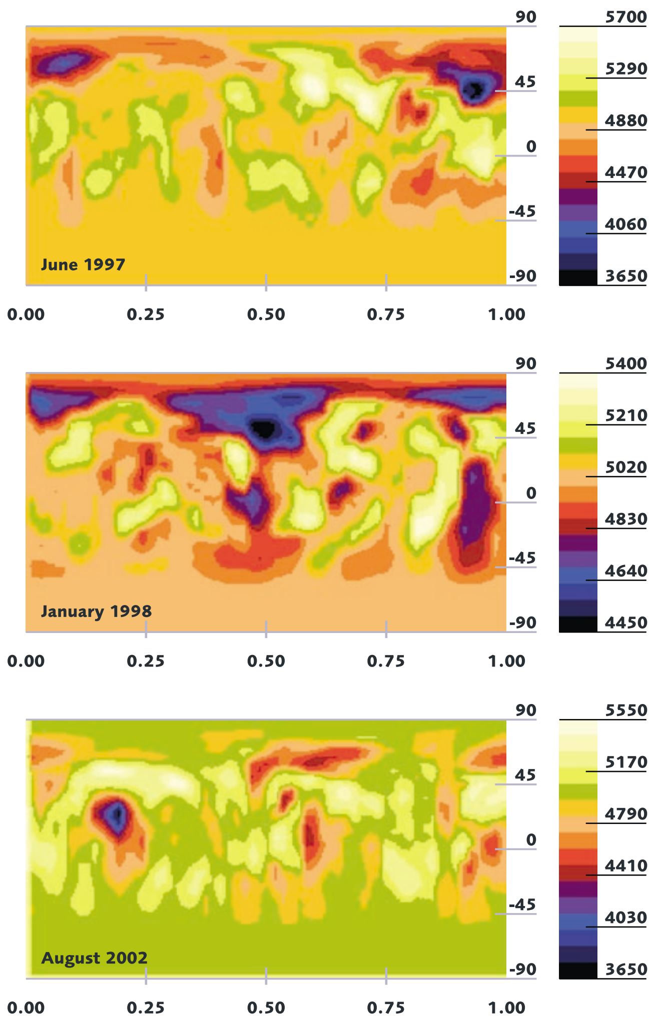


Fig. 1. Doppler image and spectra of HD 199178 from July 1998

Fig. 2. Doppler images of FK Com in semi-Mercator projection



Emission and Zeeman Spectra of Chemically Peculiar Stars

The ultra-stable atmospheres of chemically peculiar stars continue to challenge standard theories. The high spectral resolution of SOFIN at NOT has been used to search for emission lines and magnetic field signatures in B type stars.

Spectra of chemically peculiar HgMn and He-weak stars as well as chemically normal late B-type main-sequence stars in the red region have been searched to find weak emission lines from high excitation states of several elements, in particular Mn II (multiplet 13), Cr II, Ti II, and P II. The emission is strongest in two members of the P-Ga He-weak subgroup, while stars from the Si and Ti-Sr subgroups show no emission. The emission does not appear to depend only on the stellar effective temperature, in contrast to earlier results. The mechanism responsible for producing these emission lines is under investigation.

The strength of magnetic fields in Ap stars can be determined from the separation of Zeeman components in the magnetically sensitive lines Fe II 6147 and 6149 Å. This

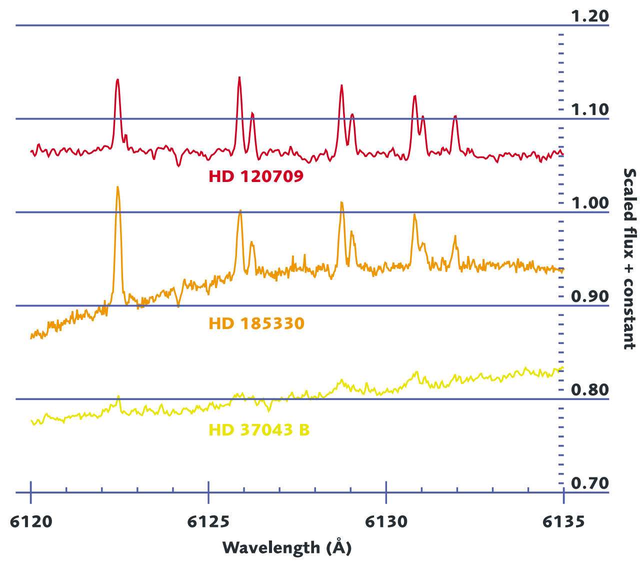


Fig. 1. Spectra of three P-Ga He-weak stars, including the two with the strongest emission lines of Mn II.

approach is particularly useful for stars with strong fields since the Zeeman pattern can be resolved. However, for weak fields the lines are only broadened, and the technique is not applicable. High resolution SOFIN spectra for several stars covering a range of magnetic field strength are being used to test a synthetic spectrum fitting method for determining magnetic-field strengths in the weak field case (G. Wahlgren, S. Ivarsson, and K. Nielsen, Lund).

Abundance Patterns and Field Structure on Magnetic Stars

Magnetic fields are believed to be responsible for creating and supporting stellar surface structures, be they cool spots on active late-type stars or abundance patterns in the atmospheres of chemically peculiar (CP) stars. Studying the unique, strong and well-organised magnetic fields of CP stars is essential for our understanding of the development and evolution of stellar magnetospheres in general. And the development of high-resolution spectropolarimeters has now made it possible to obtain full information on the magnetic field and abundance spot distributions from polarization profiles of spectral lines.

A special code for magnetic Doppler imaging in four Stokes parameters has recently been developed. This makes it possible to reconstruct the entire magnetic field vector and abundance distribution on a stellar surface from one complete set of polarization spectra, without any a priori assumptions about its structure. This code has been successfully applied to a set of spectropolarimetric observations of the classical magnetic CP star α^2 CVn, obtained with SOFIN at NOT. Reconstruction of the surface magnetic geometry and abundance distribution revealed fine details of the complex interaction between magnetic field and abundance spots. Analysis of other magnetic CP stars is expected to lead to a new degree of understanding of the nature of stellar magnetospheres and their interaction with other surface structures (O. Kochukov and N. Piskunov, Uppsala).

EXOPLANETS AND THE SOLAR SYSTEM

The discovery of the first extrasolar planet in 1995 has led to a great boom in this line of research, using many innovative techniques. The realisation that the extrasolar planetary systems found so far are quite unlike our own has also led to renewed interest in the Solar System, but now on a broader background than before. NOT is also active in this fields.

Hunting Planets in an Old Star Cluster

All the ~100 known extrasolar planets have been found from Doppler measurements of the reflex motion of their parent star, caused by the gravitational pull of the planet. One limi-tation of this technique is that only one star can be observed at a time. However, extrasolar planets can also be found from the dip in apparent brightness of a parent star caused by the transit of a planet in front of the stellar disk, analogous to the effect of a solar eclipse. Monitoring many thousand stars in a star field simultaneously for several nights allow to detect the small, but periodic light variations due transits of those rare stars whose planetary orbit(s) are seen precisely edge-on.

One goal of exoplanet studies is to compare the occurrence of planetary systems in star clusters of different density. In 1999, some 40.000 stars in the globular cluster

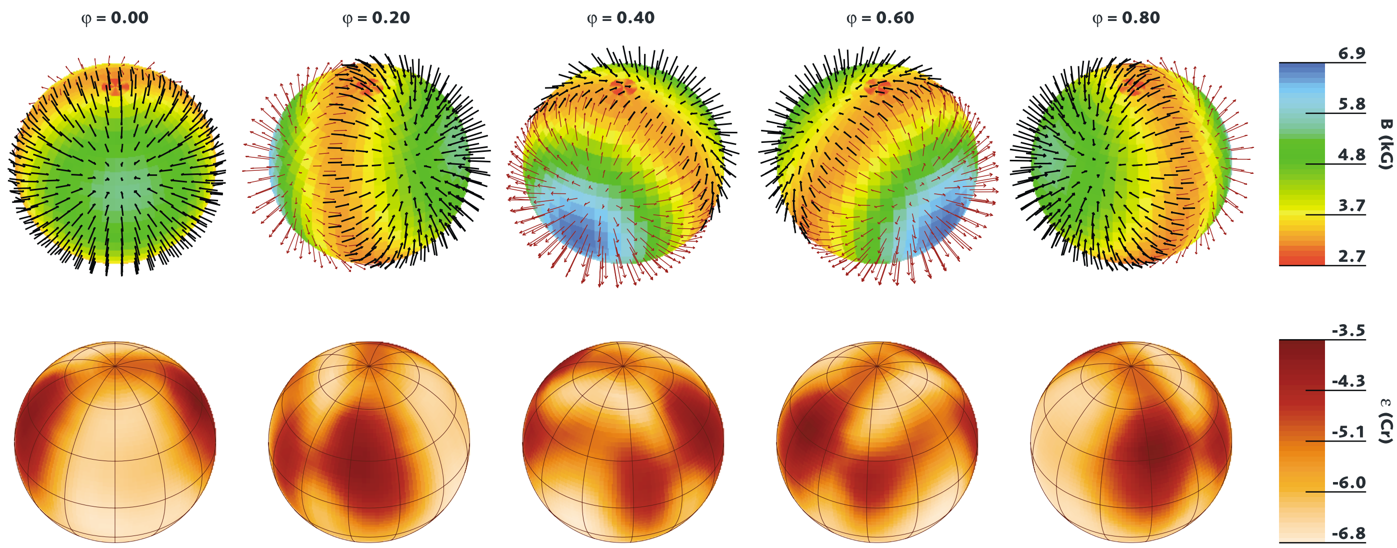


Fig 1. Magnetic field geometry (upper) and chromium abundance distribution (lower panel) of α^2 CVn reconstructed from Stokes I and V spectra from SOFIN.

Part of the observed field in NGC 6791. Images in red, green and blue are combined to show the hottest stars as blue, the coolest stars as red. Streaks in the brightest stars are due to saturation of the detector.

47 Tuc were monitored for 8 days with HST, but not a single planetary transit was observed. The suggested explanation is that, first, 47 Tuc is very dense and may destroy or inhibit the formation of planetary systems; second, 47 Tuc is relatively metal-poor, and extrasolar planets are known to prefer more metal-rich host stars.

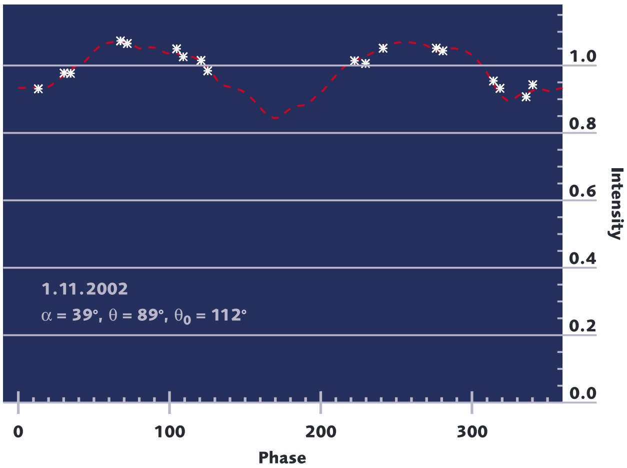
The old open star cluster NGC 6791 should be a more promising target, as it is much less dense in stars than 47 Tuc and quite metal-rich. NGC 6791 was therefore observed continuously with NOT and ALFOSC during 8 summer nights in 2001. The resulting ~1000 images, totalling ~16 Gbyte, allowed to monitor ~4000 stars at the same time. Despite initial predictions that ~5 transits should appear in these data, none was in fact found after reduction of the data. To check whether cluster environments are too hostile for planetary systems to form at all, an intensified search for transits in NGC 6791 was conducted in 2002, using telescopes in Hawaii, Mexico and Italy; these data are now being reduced.

Although the search for planets in NGC 6791 was unsuccessful, the data have resulted in an extremely deep and accurate colour-magnitude diagram for the cluster, and have also led to the discovery of a new eclipsing binary star in the cluster. The combination of these two types of data will make NGC 6791 a very stringent test of models for old, metal-rich stars. The project also serves as a valuable testing ground for methods for detecting transiting planets in the light curves to be obtained by the ESA satellite EDDINGTON from 2007 (F. Grundahl et al., Århus).

Recovery and Light Curves of Trans-Neptunian and Near-Earth Objects

The Near-Earth and Trans-Neptunian Objects (NEOs and TNOs) are two subgroups of minor bodies in the Solar System. There are great differences between them: NEOs are generally small, rocky asteroids that have been deflected inwards towards the Earth from the asteroid Main Belt by the gravitational pull of the giant planets. The realization that NEOs do hit the Earth from time to time has given these objects considerable recent publicity (or notoriety). TNOs, in contrast, are large icy bodies residing in the outer Solar System. They are presumably samples of near-pristine material from its formation and may form the innermost part of the Oort cloud, the main reservoir of fresh comets.

Fig. 1. NOT photometry of the NEO (4957) Brucemurray, with the prediction of a physical model (dashed line).



NEOs and TNOs are observationally similar, however, in that a sufficiently long arc of their orbit must be followed after their initial detection to allow observers to find them again at their next appearance a year or more later. Unless they are recovered at that time, their orbits remain indeterminate and they are lost. As another similarity, our main information on the composition and shapes of both NEOs and TNOs is derived from determinations of their colours and light variations as their rotation changes their appearance as seen from Earth. A Nordic group is being formed to organise an effective collaboration in these tasks.

Recovery observations of TNOs have been carried out, based on ephemeris predictions using the new orbit computation method of statistical orbital ranging. The successful use of this technique at NOT has set the scene for the development of a new web site for transneptunian ephemeris predictions, titled TNOEPH, now available at *http://asteroid.lowell.edu*. In addition, light curve observations have been obtained for the NEO (4957) Brucemurray (Fig. 1), which were critical for determining its shape (J. Virtanen, S. Kaasalainen, P. Muhli, M. Kaasalainen, and K. Muinonen, Helsinki; T. Grav, Oslo).

Surface Composition of Mercury

The reflectance properties of planetary surfaces such as those of the Moon, Mercury, and asteroids are controlled by their mineral composition and degree of maturation ("weathering"). Absorption is predominantly due to iron or titanium rich minerals; ferrous iron (FeO) reduces the spectral reflectance; metallic iron reduces the reflectance and increases the spectral slope, while neutrally opaque minerals (containing FeO and TiO_2) reduce both reflectance and spectral slope. The effects of maturation and composition may thus be decoupled from the contrasting spectral effects of different minerals. The distribution of grain sizes and the processes that created it are important too. ALFOSC has been used to obtain low-resolution disk-resolved reflectance spectra of Mercury's surface and gain insight into the composition of the regolith and the light scattering properties of Mercury's surface.

These observations are truly challenging: Due to Mercury's maximum distance from the Sun of 28°, observations must be performed during twilight, yet within NOT's (generous!) pointing limit of 6 degrees above the horizon. The resulting observing windows are a mere 45 minutes. The huge air mass requires special procedures to remove the telluric absorption from Mercury's spectrum by interspersing observations of nearby stars in real time. Despite air masses of 4-5, the average seeing as derived from spectral profile modelling was only 1.0" in 1999 and 1.4" in 2002. Much credit is due to the OPC and NOT management for granting time and permission to literally push the telescope to its limits, and to the staff for invaluable assistance during the observations.

Three interesting results are derived from the reduced Mercury spectra: *(i)* the spectral slope is constant over the full wavelength range, which has not been seen for any other solar system object (Fig. 2); *(ii)* the dependence of spectral slope on emission angle is much stronger than for lunar samples returned by Apollo, and *(iii)* the spectral slope is stronger than for even the most mature ("space-weathered") lunar deposits. The expected ferrous iron absorption band near 900 nm is absent in Mercury, signifying a very low abundance of crystalline Mg and Fe-rich silicates and/or the presence of a component (metallic iron) reducing the contrast of the band. The strong slope in itself indicates a high abundance of submicroscopic (nm-size) metallic iron particles compared to the Moon.

The results of detailed spectral modelling gives exciting new insight into the properties of Mercury's regolith and verifies results from other studies. We can conclude with considerable confidence that the immature minerals of Mercury's surface were initially more iron and titanium poor than for the Moon, in agreement with the general increase in FeO abundance with heliocentric distance observed for the other terrestrial bodies. This low concentration of FeO could probably be supplied by late impacts of objects from larger heliocentric distances, a result which must be reconciled with the apparently contradictory requirement for Mercury's high density to be explained by a very large iron-rich core (J. Warell, Uppsala).

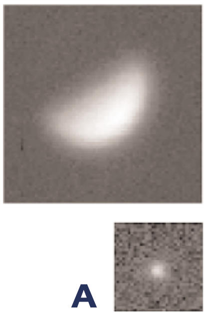


Fig. 1. Positions of the ALFOSC slits (black lines) on the sky and disk of Mercury for the 1999 June 20 and 22 observations (panels B and C). The circle shows the typical 1" seeing disk (the slit width was 0.7"). Panel A shows typical short-exposure images of Mercury and the nearby calibration star, at an altitude of 17°.

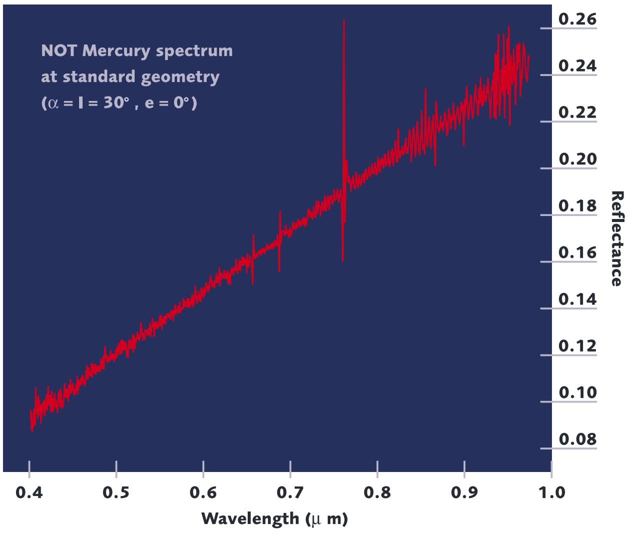
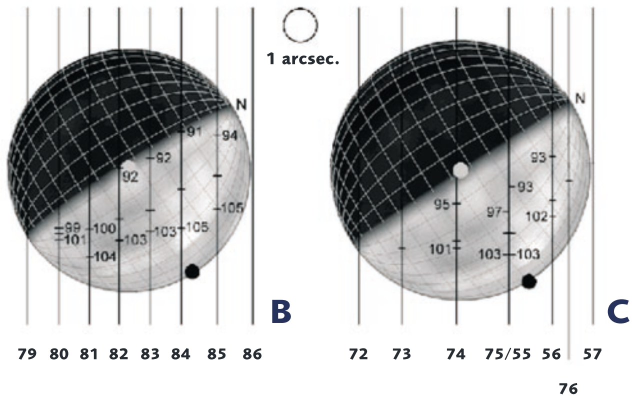


Fig. 2. NOT reflectance spectrum of Mercury for the wavelength range 400-1000 nm, calculated at standard geometry. The noise spike at 770 nm is due to the strong telluric A-band.

Photometric Survey of the Irregular Satellites

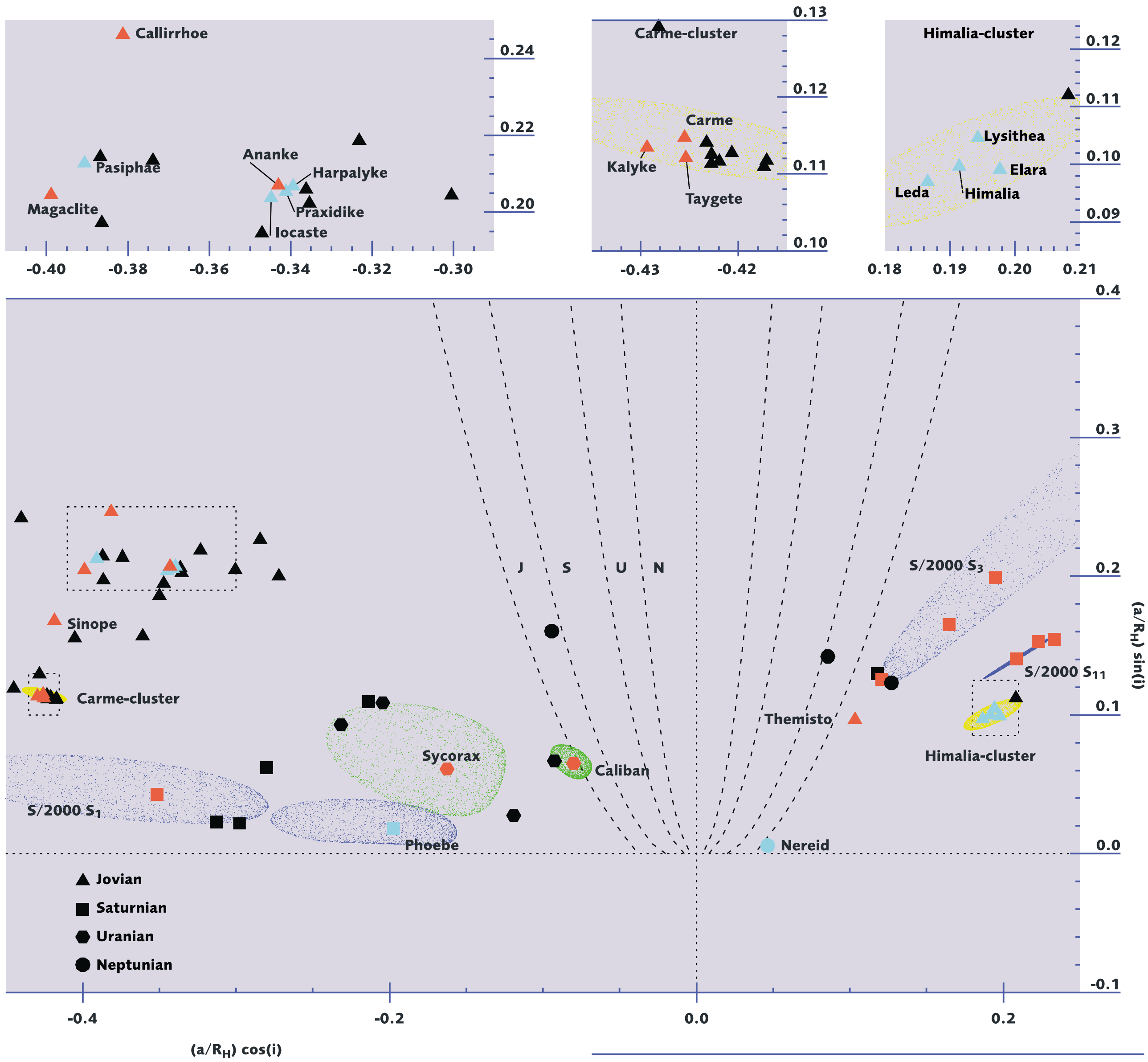
The satellites ("Moons") of the giant planets fall in two groups, regular and irregular. The regular satellite orbits are prograde, nearly circular, and very close to the equatorial plane of their host planet, and the regular satellites were probably formed much like the Solar System, i.e. from a circumplanetary disk of gas and dust. In contrast, irregular satellites have orbits that are highly inclined, eccentric, and retrograde and prograde in similar numbers. They are typically small (~100 km) and have larger semimajor axes than the regular satellites. These characteristics suggest that the irregular satellites formed outside the circumplanetary disk and were captured later.



It was recently found (Fig. 1) that most newly-discovered irregular satellites cluster into more groups than the original two (pro- and retrograde): The new Jovian retrograde irregulars divide into at least three subclusters, the Saturnian irregulars into two prograde and a retrograde cluster. This suggests that most of the current irregulars are fragments from the collisional disruption of previously captured progenitor satellites rather than independent captures. If so, satellites within a cluster should have similar colours.

This prediction has been tested with broad-band BVRI photometry with ALFOSC on NOT, and with the Magellan and MMT 6.5m telescopes. The irregular satellites are found to be either grey or reddish, and objects within a dynamical cluster do indeed have similar colours, suggesting a common progenitor. The Jovian clusters are immediately apparent, while the more dispersed Saturnian and Uranian clusters are harder to spot. Assuming that the most massive body in each cluster remains close to its original orbit, one can compute the probable dispersion of the fragments in semi-major axis and inclination. The observed clusters can be understood in the limit of small velocity changes (T. Grav and K. Aksnes, Oslo; M.J. Holman, Cambridge MA; B.J. Gladman, Vancouver).

Fig. 1. Polar plot of mean semi-major axis a vs. mean inclination angle i. Objects with photometry have been coded according to their observed colour. The unobserved objects have black symbols.



PROGRESS IN INSTRUMENTATION

The general status of the NOT instrumentation in 2002 is the subject of a later chapter. Here we describe some new developments in 2002 which are of particular scientific interest.

MOS-Mode Observations of Galaxy Clusters

The Andalucia Faint Object Spectrograph and Camera (ALFOSC) is by far the most popular instrument on NOT. As the main workhorse of the telescope, it is in fact mostly used for imaging and photometry only. Its several intermediate and low dispersion spectroscopic modes have so far been used relatively little, and then primarily for long slit spectroscopy.

However, ALFOSC is also designed for Multi-Object Spectroscopy (MOS-mode), an option which has now been working for some time. Using this mode requires a bit of careful planning: Pre-imaging of the fields must be done at the right position to place the targets in the central 1/3 of the rows of the CCD. From these images the slit positions must then be determined. A special IDL program helps the user define the layout of the MOS slit plate and generates an instruction file from which the MOS-plates are made on a CNC-controlled milling machine before the spectroscopic observations. The MOS-plates can be made in advance at NOT or elsewhere once the CNC-files have been created.

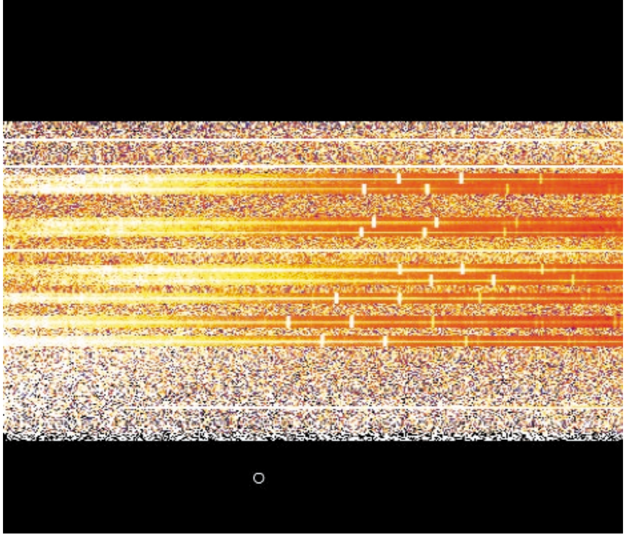


Fig. 1. MOS spectra of 9 galaxies in Abell 1677 in the range ~400-700 nm. The double vertical lines in each spectrum are the night sky emissions at 558 and 589 nm; the faint horizontal lines through them are the galaxy spectra, and the four bright horizontal lines are (over-exposed) spectra of stars used for aligning the MOS plate.

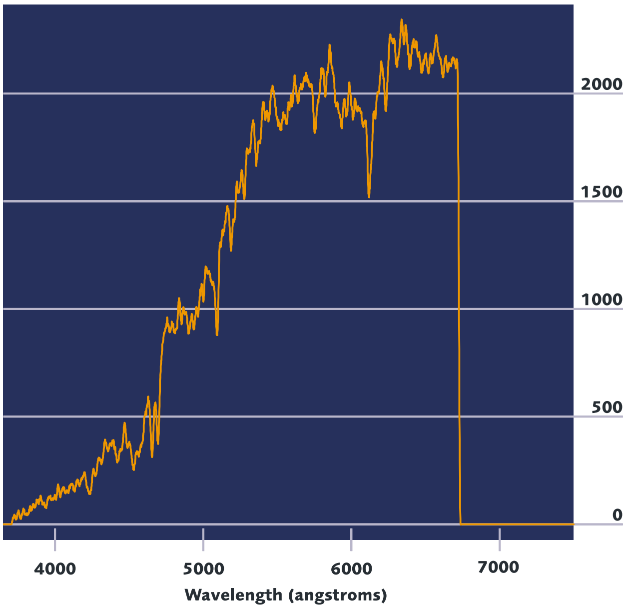


Fig. 2. Resulting spectrum for one of the galaxies in Fig. 1 (5 exposures totalling 2.5 hours integration). The 1.8" slit corresponds to a spectral resolution of 12 Å as measured from the sky lines. The redshift is 0.1834±0.0001.

At the telescope, special target acquisition programmes ensure proper alignment of the MOS slits with the science targets in the field to within ~0.2”. The alignment takes about 20 min, but is well invested: 10-15 spectra are then easily obtained in one shot if the targets are well distributed over the field.

As an example, MOS observations of a galaxy cluster at a redshift ~0.2 are shown here. At this distance, the 6.5’ square ALFOSC field gives good field coverage, and 10-12 cluster galaxies can typically be covered per MOS-plate. A total exposure time of 2.5 hours with grism 7 yielded spectra with sufficient S/N and resolution that Lick line indices for Hβ and Mgb could be obtained with good accuracy, enabling us to determine the age and metallicity of the cluster galaxies (see article on p. 11). Sample spectra of early-type galaxies in Abell 1677 are shown in the figures (P. Kjærgaard, H.E. Jørgensen, L. Hansen, and L.F. Olsen, Copenhagen).

Diffraction Limited Images with NOT

The spatial resolution of images from ground-based telescopes is normally limited by the smearing effects of the Earth’s turbulent atmosphere. However, experiments with high-speed cameras at NOT have found that rare moments exist when the air is quiet over the full aperture of the telescope, yielding a diffraction-limited image for maybe 0.01 seconds at a time. The recent development of the very fast, very low-noise ”L3Vision” CCDs allows to capture those ”lucky” moments of excellent observing conditions and assemble them into images of vastly superior spatial resolution.

This technique presents several advantages as compared to conventional adaptive optics (AO) techniques, where the wavefront distortions are measured and corrected in real time by a small deformable mirror. First, by looking through a large patch of calm air, one obtains a large

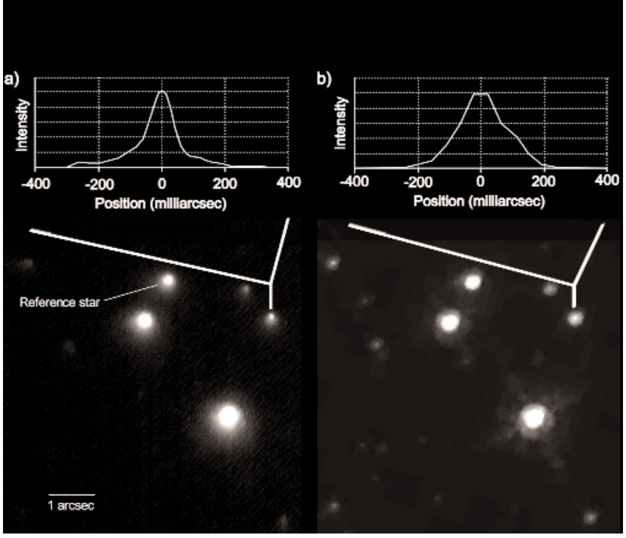


Fig. 1. The centre of the globular cluster M13 as observed with NOT/LuckyCam (left) and the Hubble Space Telescope/WFPC2 (right). A cut through the image profiles is shown at top.

corrected field (60” or more) with uniform image profiles (point-spread functions, or PSF). AO systems typically give a corrected field of a few arc-seconds only, and with a highly variable PSF.

A reference star is needed in every frame to assess the sharpness of the image. But because faint stars can be used in a large field, suitable stars can be found essentially everywhere in the sky, again quite unlike standard AO. Last, but not least, this performance is achieved for negligible investment in hardware, problems in managing powerful laser beams, etc. But of course there is a price to be paid: Typically only 1-2% of the images are of the very best quality, and the rest may not be useful.

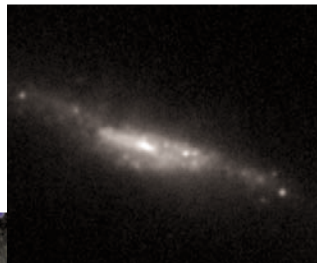
NOT is renowned for its excellent seeing conditions – a key requirement for the method to work well – and its 2.5-m diameter is close to the ideal for observations at the most sensitive wavelength in good seeing. Test observations were therefore made with an experimental camera at NOT in the summer of 2002, with excellent results: Fig. 1 shows a sample image created from the sharpest 1% of 6000 short frames taken over six minutes near the core of the globular star cluster M13. The I = 12.7 reference star (labelled) was used for exposure selection and recentering before co-adding, and stars fainter than I = 18 are visible. The right-hand panel shows an image taken at a similar wavelength with HST/WFPC2. The image cores are sharper in the NOT image (in part due to our better sampling), demonstrating the great potential of this technique if implemented as a standard option at NOT (R. Tubbs, C. Mackay, J. Baldwin, Cambridge; G. Cox, NOT).

3-5 Micron Imaging with the SIRCA camera.

The main driver for SIRCA (the Stockholm IR CAmera) was to open up the L (3.5 µm) window for imaging. Obtaining an array with the required performance is not easy, but finally a solution was found in the 320x256 InSb array from Indigo Systems, which is used in SIRCA for the first time in astronomy. It handles the high thermal background well and has high quantum efficiency (close to 100%) and very few dead pixels. Read-out is very quick (10 ms), so even with the short typical integrations (~200 ms), the time lost for readout is small. The only drawback is a rather high dark current, which limits the sensitivity near 2 µm, but in the L band, thermal background dominates the dark signal in any case. The cooled mirror optics include a wobbling mirror that mimics a wobbling secondary telescope mirror; a channel designed to work at 10 µm is also provided, but not yet in use. SIRCA has filters for the standard broad bands as well as the 3.07 µm ice band and 3.28 µm ’PAH’ band.

Despite poor weather during the test run in December 2002, the few photometric hours still allowed an evaluation of the performance of the camera. Combined chopping and ’nodding’ (moving the telescope) were planned for proper cancellation of the sky signal (10^4-10^5 times brighter than the faintest sources detected) but surprisingly, only ’nodding’ was needed. One hour of observation (80 nodding cycles, 16.000 frames total) thus resulted in the L’ image of the starburst galaxy M82 shown in Fig. 1. The noise level is 0.01 mJy/pixel (1σ), corresponding to 0.05 mJy (or L = 16.7 mag) per arcsec^2. Use of the narrow-band filters is illustrated in Fig. 2 (G. Olofsson, Stockholm).

Fig. 1. A 1-hour L-band image of the starburst galaxy M82.



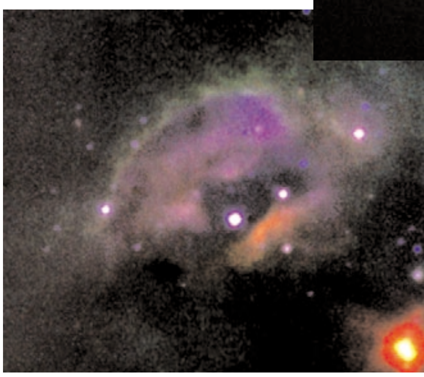


Fig. 2. PAH emission outlining the border of the compact HII region W3; a composite of images at 2.2 µm (blue), 3.28 µm (PAH, green), and 3.75 µm (red).

Remote Observations From a Nordic Summer School

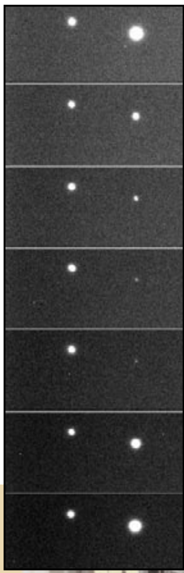
Every year the Nordic Academy for Advanced Studies (NorFA) provides support for Nordic or Nordic-Baltic research schools for Ph.D. students. Two Nordic courses in astronomy were held at La Palma in the early 1990s to train students in the use of NOT. August 19-20, 2002, saw the first use of NOT for remote observations during the Nordic-Baltic school on ”Astrophysics of Interacting Stars” at Moletai Observatory, Lithuania, with 22 participants.

The remote observing session was based on the ”Dynacore” system developed earlier with EU support (cf. ”The NOT in the 2000’s”, p. 190). It was reactivated by NOT staff and Finnish programmer Simo Aro, with Thomas Augusteijn in charge of operations on La Palma. Dynacore supports remote control of the standby CCD camera (StanCam), images being transmitted to the remote observer. Interacting stars vary rapidly – and are therefore good demonstration objects – and all the students wanted to measure such short-term light variations. To do so efficiently, a readout pattern was defined to concentrate on the variable object and one or two nearby comparison stars in a smaller ”window” on the CCD detector.

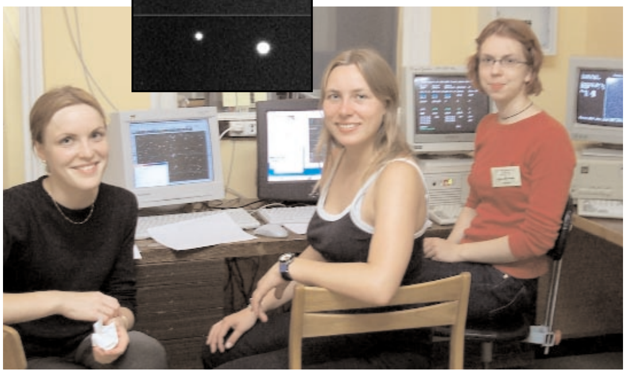
Many of the students had never observed before, and the first week was spent planning and performing observations with the telescopes at Moletai. The evening of August 19 was clear and calm at La Palma, and students and lecturers gathered in the large lecture hall of Moletai Observatory, with the image from the telescope control computer projected on a screen to let everybody watch.

The students were organised in seven observing teams, each of which observed their favourite objects for a period during the night. One student, Rima Stoncute of Lithuania, was appointed as ”Observatory Controller”, in charge of the use of the telescope. She had a hard task, coping with since many unexpected events: Bugs in the program, loss of connection, a sudden gamma-ray burst which interrupted everything (see p. 9) but was seized upon by one of the groups, and of course errors due to inexperienced observers. Excitement was great, and the first image appearing on the screen was greeted with loud applause for NOT and the people that made this possible.

A spectacular discovery was made during the night. Previously, all that was known about SDSS J015543.4+002807.2, an object from the Sloan Survey, was a strongly variable emission spectrum which for brief periods changes into an absorption spectrum. Hence, it could be an eclipsing object of some kind, but no photometry had ever been done. Fig. 3 shows the sequence of images obtained, one per minute. Suddenly, the target almost disappeared between two exposures, indicating a very steep and deep eclipse (in fact, there is main eclipse, an unprecedented 6 mag deep, and a shallower one; both last ~45 min). Other characteristics of the light curve place the object among the so-called AM Her stars or Polars, in which matter accretes from the secondary star along the magnetic field lines.



The dramatic eclipse discovered by the students on August 19, 2002.



Three of the students in action.

Participants in the 2002 Moletai Summer School.

Photos: Edmund Meistas

Six of the seven observing projects resulted in data; five of these are described in a book ”Student Assignments and Observing Projects” produced by the students during the School and already published. The students were very excited and happy to participate in this remote observing night, and we hope that more students will get this opportunity in the future.

Jan-Erik Solheim,
Organiser of the Nordic-Baltic research school 2002.

Telescope

The telescope continued to operate reliably throughout 2002, with very little technical downtime. Both telescope mirrors were realuminised in May, resulting in a 30-60% increase in overall transmission from red to UV. At the same time, the centre piece of the telescope was machined to be accurately circular and concentric with the optical axis facilitate optical alignment. Regular monitoring of the mirror conditions and cleaning as required has been initiated.

The Telescope Control System is ageing, and spare parts are ever more difficult to obtain. Work on its successor is under way, but progress has been slow due to conflicting demands on the development engineer, Ingvar Svärdh. With the staff now up to its full complement, these pressures have been relieved, and rapid progress was being made at the end of the year. The next stages of the project, which will integrate the controls of the telescope (including the active optics system), adapter and autoguider, and all facility instruments, are being designed.

Instruments

The focal reducer **ALFOSC** remains the primary workhorse at NOT: It was used on 65% of all scheduled science nights in 2002. ALFOSC is on long-term loan to NOT from Instituto de Astrofísica de Andalucía, Spain, and Copenhagen Observatory, and all parties agreed in 2001 to provide a better-optimised optical camera for it. In mid-2002 it was realised that even better performance could be obtained with a CCD of better spatial resolution, and the optical design was modified accordingly. By the end of the year, the new CCD was delivered by IJAF as part of the Danish contribution to NOT's CCD upgrade project, and the optics were near completion. The new optics and CCD will be installed in 2003. The new motorised polarizer unit, nicknamed FAPOL, was installed and tested during 2002.

The near-infrared camera **NOTCam** performed smoothly and reliably after entering regular use by visiting astronomers from mid-2002. NOTCam was used for 14% of the science time at NOT in 2002, a fraction that will increase in 2003. Some interference noise persists in narrow-band images, and a few software issues remain to be completed, but the general level of satisfaction is high. The User Group Survey found the extension of NOTCam to spectroscopy to be in much demand. Accordingly, a grism design has been developed and potential suppliers contacted by the end of 2002.

The 4096x4096-pixel mosaic camera **MOSCA I** has been commissioned, but not without unpleasant surprises. During a test run in January 2002, troubleshooting of one problem in a CCD was compounded by another in the controller, destroying a few components which were quickly replaced. During the reinstallation of the four CCDs, another mishap necessitated further replacement and realignment of CCDs and delays in commissioning the camera. MOSCA was finally brought to La Palma again in October, tested on the telescope without any problem by NOT staff, and saw its first use by visitors in November. It has subsequently performed flawlessly (see front cover).

In the 90 mm diameter Strömgren $uvby\beta$ **filter set**, designed to fit the MOSCA field, the u filter had an unacceptable red leak due to inadequate blocking. After repeated repair attempts by the manufacturer, it finally returned in late 2002 and now appears to perform satisfactorily.

The cryostat for the second mosaic CCD camera **(MOSCA II)** was completed during the year. Two E2V 2048x4096 CCDs were delivered, but the "fringe suppressed" type ordered did not meet specifications and normal CCDs were chosen instead. The focal reducer **FRED**, for which MOSCA II is intended, made good progress towards during the year, but a specific delivery date has not yet been fixed.

StanCam is mounted permanently in the adapter, always ready for use in any unexpected event. It has required liquid nitrogen fillings twice per day, and excessive work-load on the staff. Therefore, a cryostat back end with a CryoTiger closed-cycle cooler, requiring no daily maintenance, has been contracted from Copenhagen and will complete the Danish share of the NOT CCD upgrade programme. The project was completed in January 2003.

The fiber-fed échelle spectrometer **FIES** (P.I. S. Frandsen, Århus) has had a somewhat undefined status at NOT. The User Group Survey led to the clear conclusion that FIES could play a significant role at NOT in the future by providing much better conditions for several high-profile programmes. Accordingly, the STC and Council agreed that NOT should contribute to the timely completion of FIES. The project includes a new separate building, fully optimised optics, a modern CCD camera cooled by a CryoTiger, and a full software system, including pipeline reduction facilities. FIES will also be used as a prototype of the integrated observation sequencing system that will eventually become the standard at NOT, and manpower and funding will be shared by NOT and the involved Danish institutes. At year's end, the project was moving forward rapidly.

Visitor instruments

In 2002, visitors made successful use of self-developed instrumentation in the areas of high spatial resolution and mid-infrared imaging (see reports p. 24-25).

The view from the mountain is never the same ...

General

Observing time is our most precious asset, and competition for it is fierce. Investing it in the very best scientific projects is imperative, and the peer review and selection of the successful proposals must be done in a competent, impartial, and transparent manner. This is the responsibility of the Observing Programmes Committee (OPC), consisting of five respected scientists appointed by the Council.

Applications for observing time are invited approx. May 1 and November 1 each year, for the semesters beginning the following October 1 and April 1, respectively. The Call for Proposals is announced widely, and all proposal forms and other information are available at the NOT web site.

Upon receipt of the proposals, they are peer reviewed for scientific merit and ranked by the OPC. Based on this ranking, the Director prepares the actual observing schedule, taking into account such practical constraints as object visibility and seasonal variations in demand, but the Director has no voice in the scientific review process. The OPC reviews the draft schedule before it is made public.

As part of the agreements establishing the observatory on La Palma, 20% of the observing time is reserved for Spanish astronomers and 5% for international projects. But, in order to encourage competition and keep scientific standards high, proposals by non-Nordic scientists are received, reviewed, and approved on an equal footing with Nordic proposals. In recent years, EC financial support has been available for eligible projects by non-Nordic astronomers.

Observing time in 2003

Observing statistics are compiled by allocation period, and this report covers the period April 1, 2002, to April 1, 2003. The over-subscription factor (nights requested / nights available) remained high at 2.0. In total, 225 nights were spent on scientific projects ranked by the OPC (the rest is Spanish, international, and technical time). Of these, 28 or 12 % were for non-Nordic projects; the remaining 197 were distributed as follows: Denmark 43 (22%), Finland 55 (28%), Iceland 0 (0%), Norway 46 (23%), and Sweden 53 (27%).

The demand for individual instruments is also of interest. In the above period, 306 nights in total were used for scientific observations (including Spanish time etc.). The nights used with each instrument were distributed as follows: ALFOSC 199 (65%), NOTCam 43 (14%); SOFIN 29 (9%), MOSCA 15 (5%), Turpol 7 (2%), and others 13 (4%). Fluctuations from semester to semester are appreciable, given the small total numbers, but the use of the new instruments NOTCam and MOSCA is clearly on the rise.

Longer-term trends

The observing schedules for the last several years, including those for 2002, are freely available at the NOT web site. The OPC also maintains a record of the amounts of observing time requested and actually allocated. The latter are a better measure, both of the distribution of good proposals and of the actual use of the telescope, and the trends in the national use of NOT in 1997-2002 are shown above.

Three features of the figure merit comment: First, there are sizeable variations from year to year for all countries. Closer examination of each year reveals a close connection to the impact of particularly active user groups, and to the arrival of new instruments particularly suited to their interests. Second, 'foreign' use of NOT remains fairly stable at ~12 % of the Nordic time. And third, the curves seem to converge to stable levels over the last 2-3 years.

Observing proposals are reviewed and ranked based on scientific merit, without regard to the national shares of the NOT budget. However, were a serious imbalance between the use of NOT by a national community and its financial contribution to develop over a longer period, some corrective action would be in order.

In fact, the national percentages of the Nordic time averaged over the last 3 years turn out as follows (the corresponding budget shares in parentheses): Denmark 20 (20) %, Finland 31 (30) %, Iceland 1 (1) %, Norway 21 (20) %, and Sweden 27 (30) %. Given the developments seen in the figure and the new instruments entering operation, matters appear to be in a quite satisfactory state, but developments will be monitored closely.

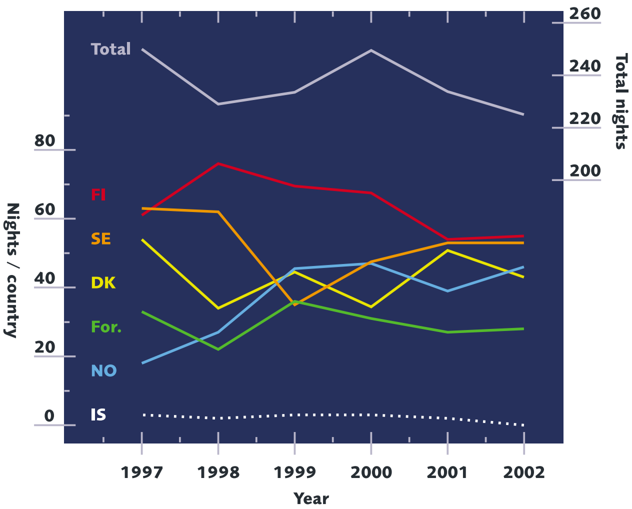


Fig: Nights awarded annually to projects from each Nordic country, to "foreign" projects and their sum, over the years 1997-2002.

EXPENDITURES IN 2002*

Operations Chapter:	Directorate EUR	La Palma EUR	Total EUR	Budget 2002 KEUR	Total 2001 KEUR
Operation and Maintenance					
Remunerations		576.427	576.427	555	501
Components and Materials		4.089	4.089	10	5
Shipping, consultance, etc.	371	4.620	4.991	10	13
Telescope operation & maintenance		39.753	39.753	20	64
Subtotal	**371**	**624.889**	**625.259**	**595**	**583**
Management					
Management	93.056		93.056	92	85
Overhead	0		0	5	5
Travel expensses	50.816	19.212	70.028	80	82
Subtotal	**143.871**	**19.212**	**163.084**	**177**	**172**
Group Expenses					
Accommodation at ORM		18.565	18.565	22	16
Common facilities		11.547	11.547	20	13
Sea-level facility		25.258	25.258	30	28
Electricity and water		24.853	24.853	30	29
Telephone	189	5.244	5.433	10	8
Postage, paper, books	122	763	885	6	3
Cleaning		8.469	8.469	7	8
Cars and Transport		9.037	9.037	15	24
Laboratory equipment	57	6.378	6.435	2	0
Kitchen consumables		1.600	1.600	1	1
Computers	2.807	48.657	51.464	35	46
Various	9.477	5.704	15.181	10	8
Spanish students	33.248		33.248	30	28
Representation	5.024	5.260	10.284	4	3
Conferences, education		6.403	6.403	10	1
Subtotal	**50.925**	**177.737**	**228.662**	**232**	**217**
Development Chapter:					
Telescope and instrumentation	96.659	71.642	168.301	150	98
Buildings		3.957	3.957	11	4
Subtotal	**96.659**	**75.598**	**172.258**	**161**	**102**
OPTICON meetings	18.391		18.391		0
Total expenditure	**310.217**	**897.437**	**1.207.654**	**1.165**	**1.074**
Total income			**1.326.020**	**1.165**	**1.267**
Result of the year after exchange losses			**118.215**	**0**	**181**

Minor adjustments between items are possible as a result of the auditing in April 2003.

PUBLICATIONS

Publications are one of the standard measures of scientific output. When applied to observatories, they fundamentally measure the productivity of the community of observers rather than of the telescope per se. Nevertheless, there obviously is a correlation between the scientific level of the users, the demand for their telescopes and instruments, and the quality of each of these facilities.

Accordingly, users are requested to report all papers based on NOT data to our web-based list of such publications. As decided by the NOT Council, the list maintained there and printed below is restricted to publications in international, refereed journals. As we depend on observers to submit what they publish, we cannot guarantee that the list is complete, but is does show a healthy increase of ~10% since 2001.

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"Magnetic activity in the young solar analog LQ Hydrae. I. Active longitudes and cycles", 2002, A&A **394**, 505

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"Molecular line scattering and magnetic field effects: Resolution of an enigma", 2002, A&A **388**, 1062

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"The Afterglow of GRB 010222: A Case of Continuous Energy Injection", 2002, ApJ, **579**, L59

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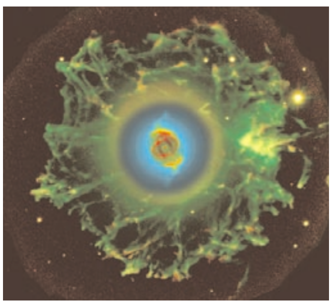
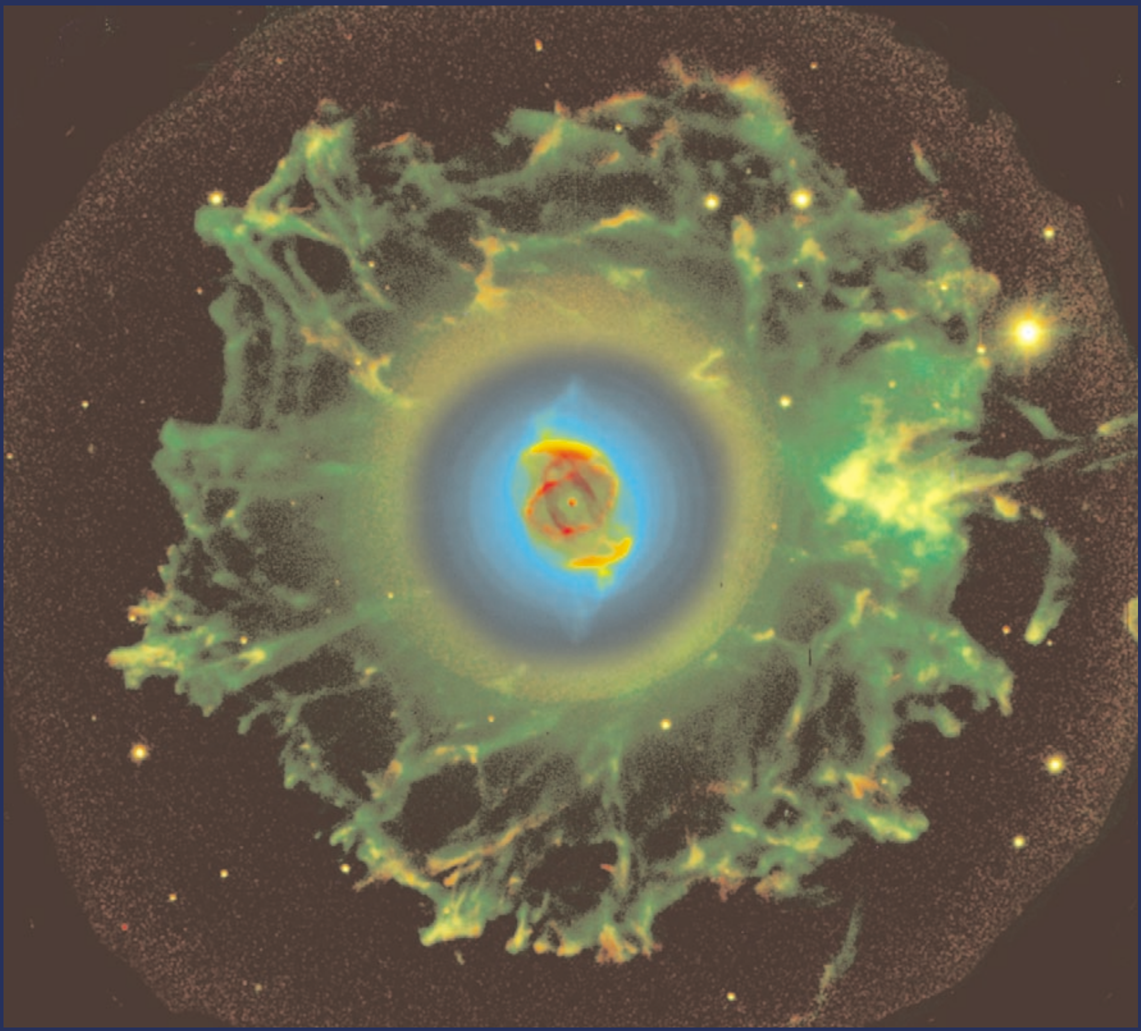


***Back cover:** The planetary nebula NGC 6543 (the "Cat's Eye Nebula") imaged by R. Corradi in the emission lines of ionized oxygen (green and blue) and nitrogen (red) with NOT and ALFOSC. This is the deepest image ever taken of this famous object, which is 5' or 5 lightyears in diameter. The centre is a million times brighter than the faint outer regions, and the colours have been chosen to highlight the delicate structure present throughout this remarkable object. Planetary nebulae are briefly described on p. 17.*

2002

NORDIC OPTICAL TELESCOPE



The planetary nebula NGC 6543 (the "Cat's Eye Nebula").

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