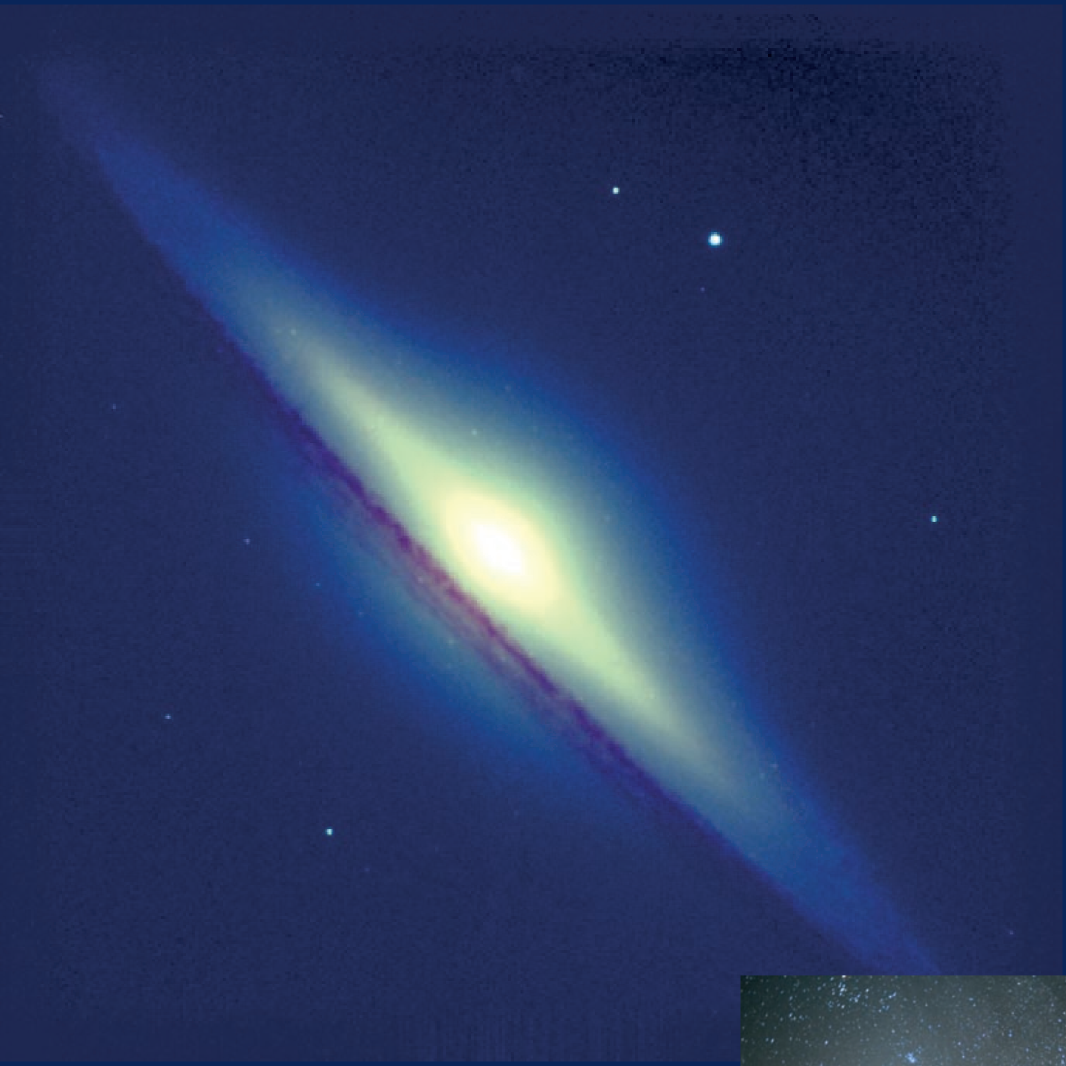
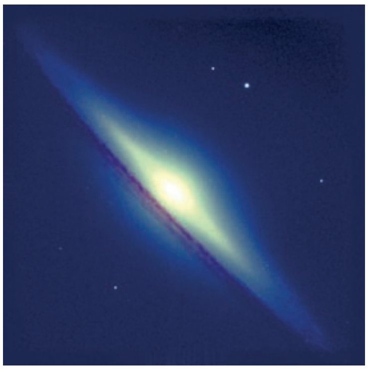
2010

NORDIC OPTICAL TELESCOPE

ANNUAL REPORT



The "Sombrero" galaxy Messier 104 in infrared light



Front cover:
The "Sombrero" spiral galaxy Messier 104, imaged with NOTCam in three bands of near-infrared light by Amanda Djupvik.

NORDIC OPTICAL TELESCOPE

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

The chief governing body of NOTSA is the Council, which sets overall policy, approves the annual budgets and accounts, and appoints the Director and Deputy Director. A **Scientific and Technical Committee** (STC) advises the Council on scientific and technical policy.

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

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

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

The NOT Annual Reports 2002-2010 are available at:
http://www.not.iac.es/news/reports

CONTENTS

Photos: J. Andersen (top); G. Bakos (bottom).

Editor: Johannes Andersen
Layout: Anne Marie Brammer

2

THE NOT TEAM

Few changes occurred in the staff in 2010, but four new faces joined the student group, as others left. Meet us all below:

Johannes Andersen
Director

Francisco Armas
Administrator

Thomas Augusteijn
Deputy Director

Peter Brandt
Mechanic

Ricardo Cárdenes
System manager

Jacob W. Clasen
Software specialist

Graham Cox
Senior electronics engineer

Anlaug Amanda Djupvik
Senior staff astronomer

Juliet Datson
Student

Loida Fernández
Secretary

Søren Frimann
Student

Eva Jurlander
Accountant

Erkki Kankare
Student

Raine Karjalainen
Postdoc

Tiina Liimets
Student

Johan Lindberg
Student

Marjaana Lindborg
Student

Ricky Nilsson
Student

Carlos Pérez
Electronics technician

Tapio Pursimo
Staff astronomer

Peter M. Sørensen
Software specialist

Ingvar Svärdh
Senior software engineer

John H. Telting
Senior staff astronomer

Anders Thygesen
Student

Paul A. Wilson
Student

PREFACE

2010 offered an extraordinary variety of diverse events. Perhaps the most spectacular one was the eruption of the Icelandic volcano Eyjafjallajökull, which paralysed European air traffic for months and made travel for observers and staff to and from La Palma somewhat of a gamble. Fortunately our staff managed to rescue most of the science by quick improvisation.

The major non-scientific event of 2010 on La Palma was the festivities of the famous "bajada" of the Virgin from her chapel at Las Nieves to a month-long residence at the cathedral of Santa Cruz. Although it is also a major tourist attraction, including the famous "dance of the Dwarfs", this remains a quintessentially Palmeran five-year event, which the undersigned was privileged to attend for the first time.

An almost equally momentous event was the retirement of Paco Armas, who has been a landmark of the NOT from before it was even decided where to build it. Fortunately, we have found an able successor, Raquel López, whom you will meet in next year's report. We wish Eileen and Paco all the best for their new life and look forward to see Paco in the office from time to time. Our NordForsk postdoc for two years, Raine Karjalainen, also left us at the end of August, but accepted a permanent job with the Isaac Newton Group of telescopes.

The student office remained busy, as Juliet Datson, Erkki Kankare, Tiina Liimets, Johan Lindberg and Thomas Ottosen left to pursue their studies at their respective universities. They were replaced during the year by Anders Thygesen, Ricky Nilsson, Søren Frimann and Marjaana Lindborg, who are forming an equally great team, which also interacts well with the ING students

The 30-year period of the international agreement establishing the observatory on La Palma ends in May 2012. The world has changed vastly since ~1980, and a strong need was felt for a new paradigm for the future. Denmark, Norway and Sweden therefore decided to withdraw from the Agreement and seek other arrangements after 2012. Starting with a review of our scientific priorities, we are proposing a more project-oriented strategy for our future operation, which is being considered by the Nordic research councils. Stay tuned!

This strategy is in line with the push for better coordination of the European 2-4m telescopes as proposed by the *European Telescope Strategy Review Committee (ETSRC)*, appointed by ASTRONET. Its report underlined the need for more rational ways to plan and operate these facilities in the future, as we have long advocated. Following this advice, the owner agencies took the decision of principle to rationalise the instrument suite across the whole network and allocate all the time jointly. Implementing this policy will be neither easy nor fast, but the process is under way, and ASTRONET will follow it up under a new EC contract for 2011-2014.

In parallel, OPTICON introduced a common proposal submission and time allocation procedure for all telescopes in its Trans-National Access programme. Following this success, the NOTSA Council decided that *all* European proposals for NOT observing time would in future have to pass through this channel, with a generous donation of time to OPTICON. We note with satisfaction that the NOT has been outstandingly successful in this direct competition with all the European 2-4m telescopes.

The report brings you up to date on events at the NOT in 2010. As usual, the lion's share of the text is devoted to the highlights of science done with or published from the NOT during the year, supplemented by a few relevant facts about our operations – including the 90 papers published from NOT data during the year, an all-time high. I thank the authors for explaining their work to us, and Anne Marie Brammer for another professional report from the NOT. Unsigned text and photos are by your Editor.

Johannes Andersen
Director & Editor

Johannes Andersen

4

EVENTS IN 2010

Photo: H. Dahle.

Below are a few highlights of life at the NOT 2010. More information on education, observing time, finances and publications is provided in later sections and at our web site.

Planning for the future

With large European investments in new huge optical and radio telescopes being discussed in a highly constrained financial climate, an optimum strategy for a 2-4m telescope is a matter of survival. This requires defining the most competitive user groups with the potential to use the capabilities of the NOT for outstanding science, and to give those fields of research priority in developing our capabilities. The science highlights and publication lists in successive Annual Reports reflect this strategy in both the volume and scientific profile of research at the NOT.

To this end, we again surveyed our Nordic and European users over the summer of 2010 to distil their scientific plans and priorities for the future and assess their need for new capabilities at the NOT and/or other 2-4m telescopes. It was evident that the key to our future is in reinforcing our strengths in the study of transient and variable objects: Rapid, precise and flexible reaction to transient events on timescales from minutes to weeks, accurate translation of observers' needs into instructions for action, and timely feedback to the P.I. in real time. We will sharpen this role of the NOT within the future European network of telescopes, in particular those on La Palma.

ASTRONET and OPTICON

As noted in previous reports, the agency network ASTRONET has established a Roadmap for the development of European astronomy as a whole, comprising synergies, infrastructures, networking and human resources across the discipline. On this background, the *European Telescope Strategy Review Committee (ETSRC)* presented its plan for rationalising the European 2-4m telescopes by specialising them individually while letting users access them collectively. The decision in 2010 by the agencies to adopt this policy in principle will long be remembered as a watershed in European astronomy. For the undersigned, 2010 also ended a five-year period as initial Chair of the Board as ASTRONET begins a new four-year EC contract, a major, but most rewarding task.

The OPTICON network supports European cooperation in optical-infrared astronomy, i.a. through its Trans-National Access programme. In 2010 OPTICON took a major step by not just funding pre-assigned time slices on individual telescopes, but created an actual "market" for telescope time by prototyping the future joint time allocation process. Thus, all proposals for OPTICON time were submitted, reviewed and approved together in free competition, subject only to ceilings imposed by each telescope and by total available funding. We are gratified that the NOT fared extremely well in this direct competition with the best 2-4m telescopes in Europe.

Education

Our initiative, with Onsala Space Observatory, to organise joint optical-radio summer courses was supported again by NordForsk (see p. 28). The 2010 course, at Onsala, focused on extragalactic astronomy in anticipation of the first results from ALMA, and will be followed by another NordForsk course at Tuorla in 2011. These courses are an established success, which we intend to pursue and expand beyond the Nordic market.

Instrumentation

Our core instruments remain very competitive, but the need to schedule ALFOSC, NOTCam and MOSCA in fixed blocks is an impediment when reacting to transient events over the full optical-NIR wavelength range. We therefore plan to study a combined imager and spectrograph that would eliminate the need for instrument changes in the future. As as a copy of the high-precision spectrograph HARPS will soon be installed at the Galileo Telescope for critical exoplanet work, we will add a spectropolarimetric option to FIES for accurate measurements of stellar magnetic fields, with the same flexible scheduling as now. The new NOT will be meaner and leaner than before, but it will fill a more competitive role in the future complement of European telescopes.

The core mission of the NOT is to enable Nordic astronomers to do science. Formal publications from such projects are listed on p. 32; a few highlights are provided here for a more general readership. Contributions have been edited to fit the available space, and for consistency of style.

COSMOLOGY AND THE FORMATION AND EVOLUTION OF GALAXIES

The composition, evolution and expansion of the Universe appear to be dominated by dark energy and dark matter. Yet, their nature remains totally unknown. A major goal of observational cosmology is to understand these key components of the Universe and their role in its evolution. In parallel, we need to understand how the 'normal' (baryonic) matter which we *do* understand evolved from a diffuse gas of hydrogen and helium to today's complex world of galaxies, stars, planets, and life.

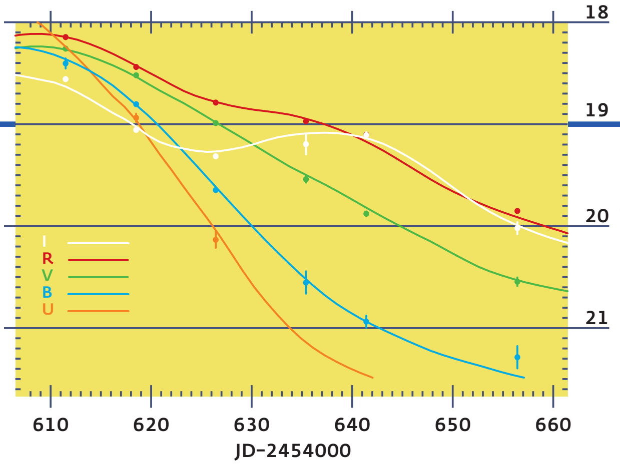
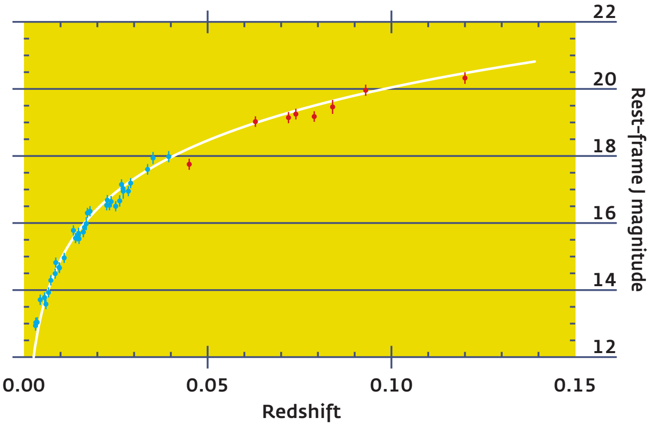


***Fig. 1.** With ~5 UBVRI observations from the NOT, we can fit a multi-colour light curve template to measure the time of maximum light, the width, and the SN peak magnitude. SN20080516-000 at redshift z = 0.072 is shown as an example.*

Measuring the expansion of the Universe

Using Type Ia supernovae (SNe Ia) as cosmic yardsticks led to the spectacular discovery that the expansion of the Universe is accelerating, rather than slowing down, due to a new force in Nature called "dark energy" (DE). Understanding DE is a fundamental goal in physics and requires as many complementary lines of attack as possible in order to understand the systematic errors of each technique. The Hubble diagram of SN peak brightness (i.e. distance) vs. redshift (Fig. 1) allows us to measure the Hubble parameter, the mass density of the universe, and the amount and nature of the DE.



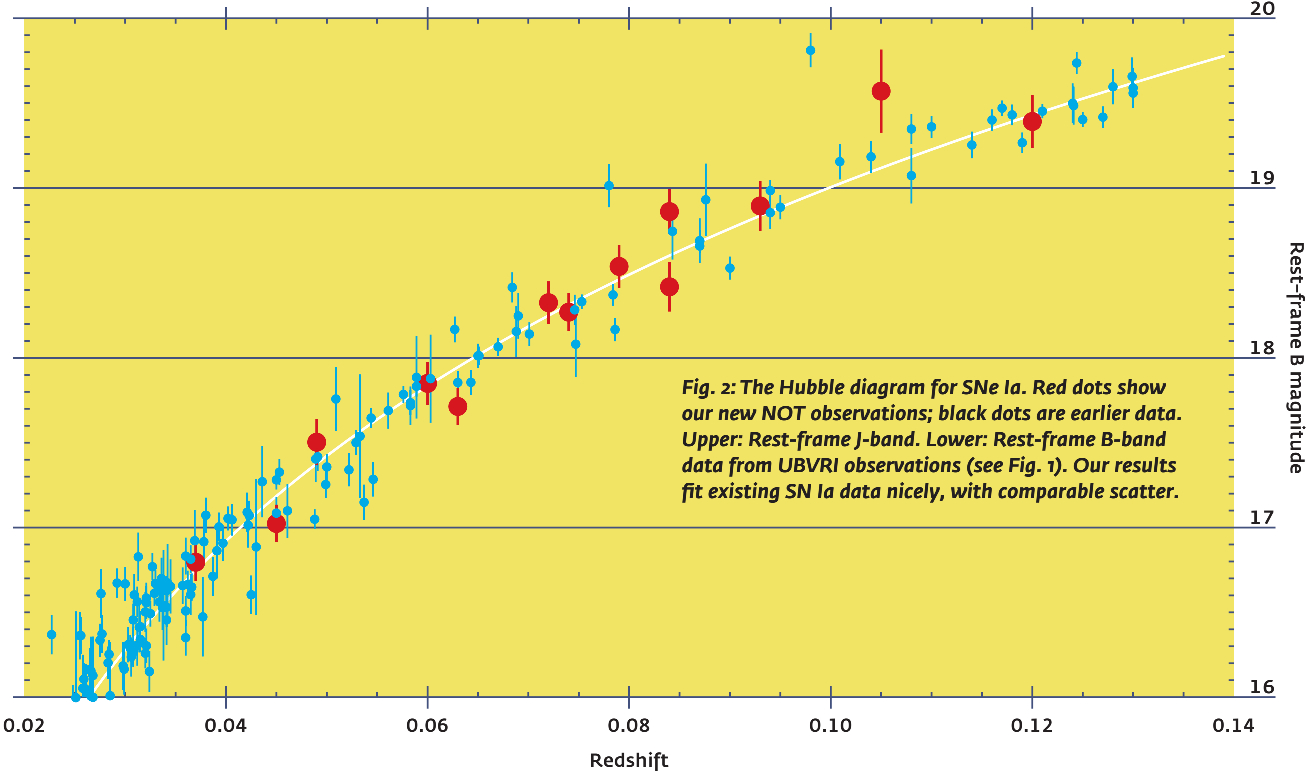


***Fig. 2:** The Hubble diagram for SNe Ia. Red dots show our new NOT observations; black dots are earlier data. Upper: Rest-frame J-band. Lower: Rest-frame B-band data from UBVRI observations (see Fig. 1). Our results fit existing SN Ia data nicely, with comparable scatter.*

SNe Ia (see below) are first discovered and characterised in optical light from UV to deep red (the *UBVRI* bands). In particular, the time of the explosion is fixed from the *B*-band maximum (see Fig. 1). There are, however, dramatic advantages in observing SNe Ia in near-infrared (NIR) light: The major uncertainty in using SNe Ia for cosmology is the correction for extinction by interstellar dust in optical light, and these corrections are much smaller in the NIR than in the optical. In addition, the NIR peak brightness requires no correction for the width of the light curves, as used in the optical.

Dust in SN host galaxies has different properties than in our own Galaxy. Thus, in precision cosmology we must check whether these properties might correlate with the intrinsic colours and/or brightness of the SN. In order to understand the extinction laws in SN host galaxies and pin down the systematic uncertainties in SN Ia distances, it is therefore critical to combine optical and NIR data. However, the need to obtain frequent high-quality optical *and* NIR observations has been a major obstacle.

It has been shown that a smooth light curve template describes the rest-frame *J* and *H*-band light curves (1.2 and 1.6 μm) during ~10 days after *B*-band maximum with great accuracy (Fig. 1), so the peak NIR magnitude of a SN Ia can be accurately measured even with a single observation in this period. Thus, observations with NOTCam have allowed us to extend the NIR Hubble diagram from redshift 0.04 to 0.12 – see Fig. 2, which compares the *J*-band and *B*-band Hubble diagrams.

V. Stanishev and A. Goobar (PI)

Precision cosmology and massive star formation with new supernova discoveries

For the first time in history, the *PanSTARRS1* (PS1) and *Palomar Transient Factory* (PTF) surveys are yielding a steady supply of hundreds of supernovae (SNe) per year. This permits us to construct complete, volume-limited samples of SNe for statistically robust studies. With this flood of new discoveries, the time required to properly exploit this goldmine becomes prohibitive for any single group or telescope. We have therefore initiated an ambitious international programme to classify and follow the newly detected SNe, using a suite of telescopes.

The *Panoramic Survey Telescope and Rapid Response System 1* (PS1), is a 1.8m telescope at Haleakala, Hawaii, with a 1.4-billion pixel CCD camera and a 7 square degree field-of-view. It is able to survey the entire visible sky from Hawaii once every 20 days. The PTF is another recent transient search using the Palomar 48" telescope with the former CFHT 12×12-kpixel CCD camera, giving an 8 square degree field-of-view.

For Type Ia supernovae, our main goals include the construction of a low-redshift dataset, which is key to reducing the systematic errors in high-redshift SN samples, and to understand the interplay between SN behaviour and environment (see above). For the core-collapse supernovae that mark the death of massive stars, key goals include a new determination of metallicity-dependent supernova rates, which will improve previous analyses by a factor of 20. Studies of individual explosions of the most massive stars will also lead to a better understanding of the progenitors, explosion physics, and feedback into the environment.

The NOT schedule includes a mixture of bright, grey, and dark time. By coordinating with Nordic partner programmes, we can optimally select SN candidates for classification and at the same time allocate sufficient resources to monitor interesting targets.

The PS1+PTF survey strategies cover previously unexplored parameter regions of space, opening tantalising opportunities for finding new types of stellar explosions. Indeed, our early results demonstrate that this strategy is already bearing fruit: Below, we describe our discovery of SN 2010gx, one of only a handful of new ultra-luminous transients, for which the NOT secured the first spectrum.

R. Kotak, S. Smartt, Belfast; S. Mattila,
E. Kankare, Turku; and several colleagues

Ultra-bright supernovae in faint galaxies

The Pan-STARRS1 (PS1) all-sky survey is able to discover supernovae (SNe) uniquely free of any host galaxy bias, as it covers also the previously neglected dwarf star-forming galaxies of low metallicity. Other local SN searches have so far targeted luminous (and thus metal-rich) galaxies, which are expected to exhibit the highest SN rates. PS1 has already begun to discover SNe in the low surface brightness dwarf galaxies, which were typically missed in previous surveys, and will be able to provide an accurate measure of their local SN rates without this host galaxy luminosity bias.

SN 2010gx was originally discovered by the Catalina Realtime Transient Survey and the PTF survey (see above). The PS1 survey found it to reside in a host galaxy of low luminosity, similar to the Large Magellanic Cloud (LMC). Spectroscopic observations were then pursued with the NOT, William Herschel and Gemini South Telescopes (see Fig. 3).

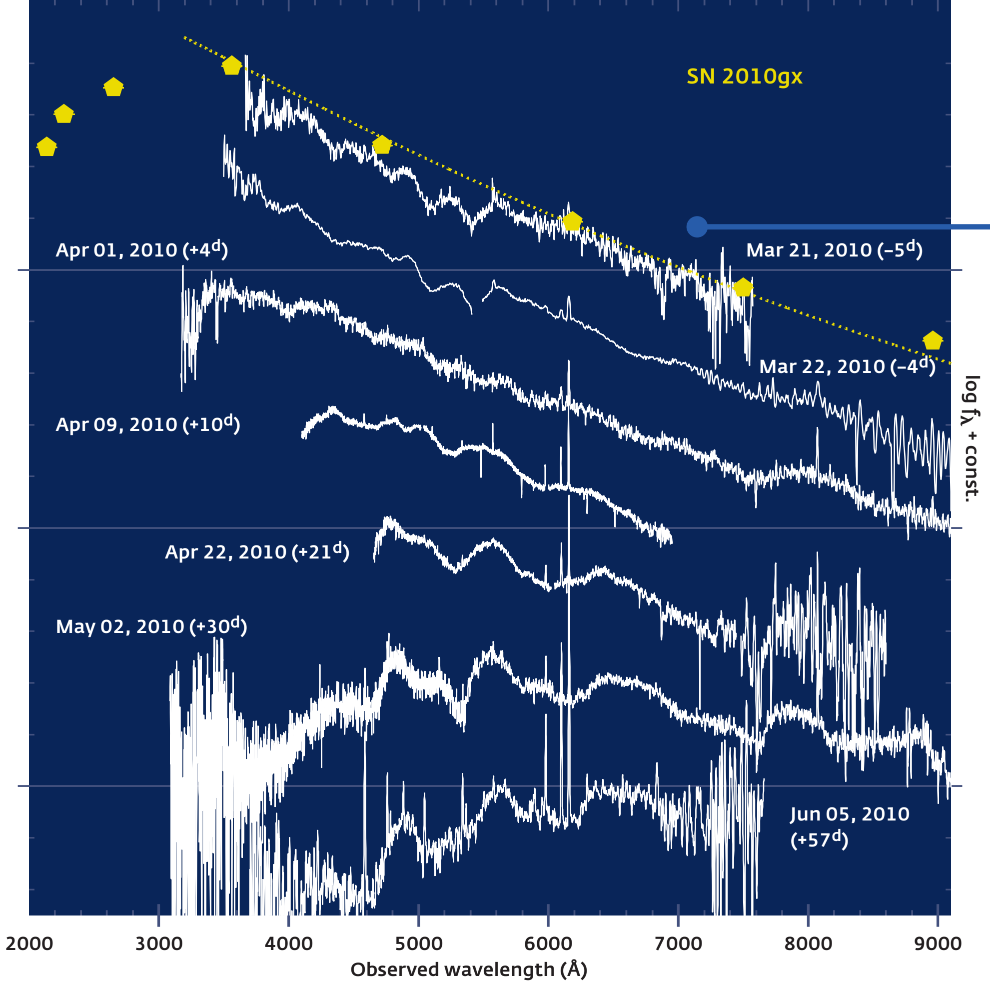
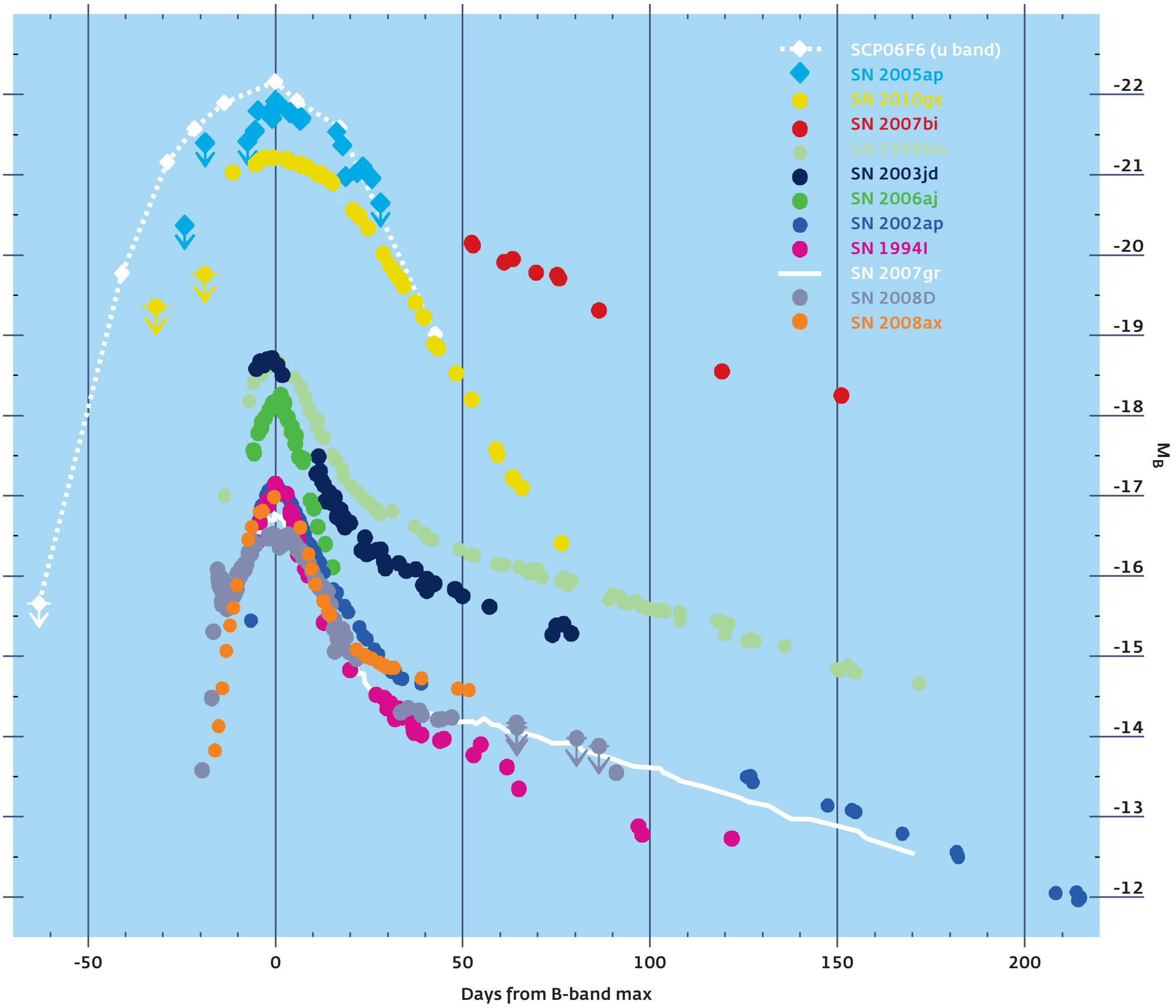


Fig. 3: Initial UV-optical spectral energy distribution of SN 2010gx (from the Swift satellite and the Liverpool Telescope), and the evolution of the spectrum over the next 75 days.

Fig. 4: B-band absolute light curves of SN 2010gx, compared to other ultra-bright transients and classical type Ib/c SNe.



Our NOT spectra were dominated by a blue continuum and prominent broad O II absorption lines, but it later developed features similar to type Ic SNe. SN 2010gx was therefore initially linked to this type of events. However, at a redshift of $z = 0.23$, its absolute optical peak luminosity of ~-21.2 was 2.5-5 magnitudes brighter than those of classical type Ib/c SNe (see Fig. 4).

Thus, the nature of this event remains enigmatic: It does not comfortably match any of the known SN scenarios, i.e., core-collapse and ^{56}Ni -powered explosions, nor the more exotic pair-instability, pulsational pair-instability or magnetar-powered supernova events. In the next few years, the PS1 and other large all-sky surveys will be able to discover large numbers of such new types of stellar explosions.

Both of the above investigations rely on the PS1 Survey, which is based on the Institute for Astronomy at the University of Hawaii in Manoa and supported by a large international consortium of institutes.

S. Mattila, E. Kankare, Turku; R. Kotak, A. Pastorello, S. Smartt, Belfast; and colleagues

---

NOT Cluless: Distant supernovae magnified by massive galaxy clusters

Massive galaxy clusters in the Universe can act as powerful gravitational telescopes and magnify extremely distant background galaxies and their supernovae (SNe). This effect offers unique opportunities to observe objects that are otherwise too faint to be detected. Light amplification factors up to ~70 have been observed, and factors of 5 to 10 are very common, giving NOT the discovery power of a >8-m class telescope.

Fig. 5 shows the central one arc-minute radius of the galaxy cluster Abell 1689, imaged with ALFOSC. The field covers the amplification profile of the cluster, ranging from several magnitudes at the centre to 0.25 mag in the outskirts. We have exploited this remarkable magnifying power to discover several background SNe up to a redshift $z = 1.7$ by monthly monitoring of A1689 in optical light at the NOT and in near-infrared (NIR) light at the ESO VLT. We also have accurate spectroscopic redshifts of all the SN host galaxies.

In this way, core-collapse (CC) SNe at redshifts of $z \sim 0.7$ can be studied with a modest-size telescope such as the NOT. Since their progenitors are very massive short-lived stars, the SN rate reflects the star formation rate (SFR) at the time. Thus, the SN rate provides an independent measurement of the cosmic SFR at $z \geq 0.7$.

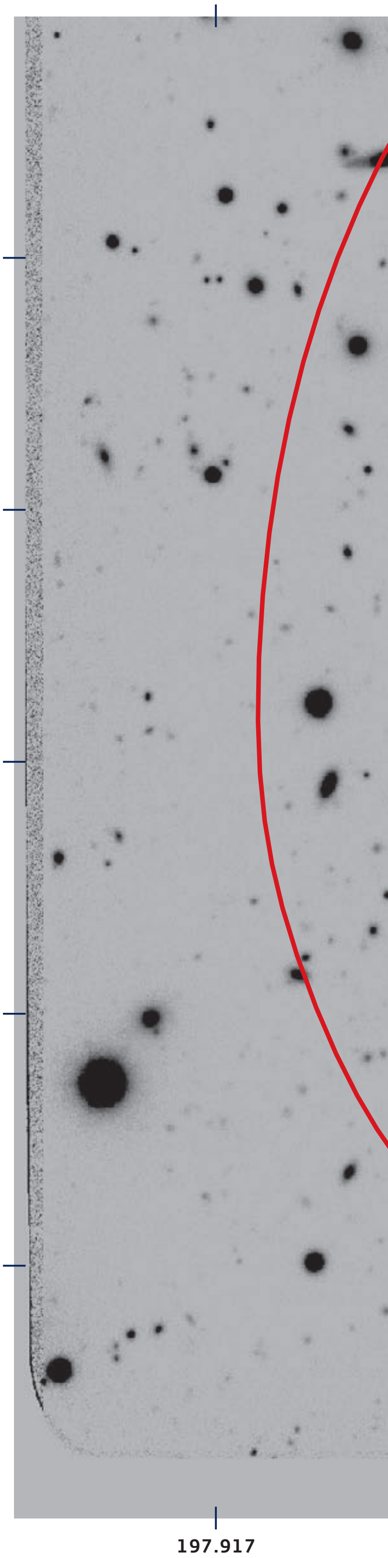


Fig. 5. NOT i-band image of the galaxy cluster A1689. Red, pink, blue, and magenta contours show amplifications of Δm = 0.5, 1, 2, and 3 mag for sources at z = 2. Circles are strongly lensed background galaxies with spectroscopic redshifts and time delays below (green) and above 5 years (orange); objects with photometric redshifts are shown in red. Stars mark the positions and redshifts of SNe found in our surveys.

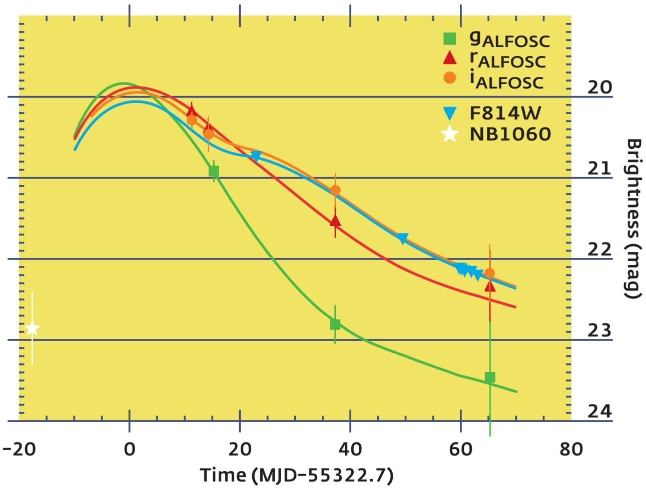
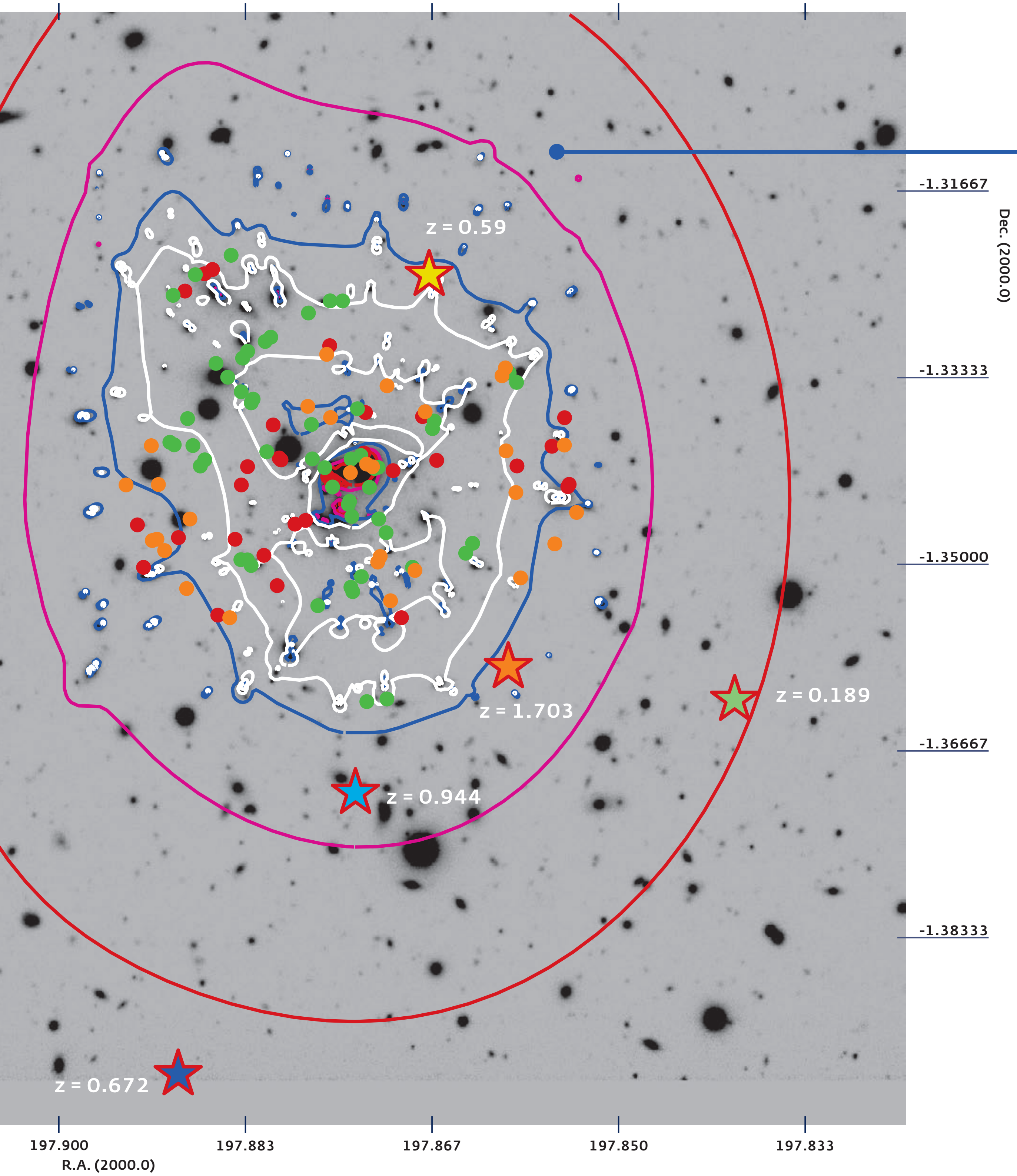


Fig. 6. Preliminary light curves for SN2010lw, discovered at NOT in a galaxy in A1689. IR data from the ESO VLT and Hubble Space Telescope (HST) are also shown.



Type Ia supernovae, in contrast, are believed to arise from merging binary stars. They are used extensively in cosmology (see above), but the nature of their progenitors is still largely unknown: Models predict different time-delays between star formation and SN explosion for different mechanisms. Therefore, we are now extending our survey to several new clusters in order to study the rates of high-redshift Type Ia SNe, with SNe Ia in the cluster galaxies as a by-product (see Fig. 6). Future exciting discoveries should include multiple images of strongly lensed SNe.

A. Goobar, R. Amanullah, J. Nordin,
J. Jönsson, K. Paech, Stockholm

The enigmatic “Christmas” Gamma-Ray Burst

The study of transient objects in the Universe, such as Gamma-Ray Bursts (GRBs), supernovae etc. is gaining increasing importance with rapid-detection facilities on the ground and in space. The optimised scientific strategy, flexible operation, stable instruments, and friendly cooperation of the staff and visiting observers make the NOT a very competitive player in this field.

A recent example is GRB 101225A, detected by the *Swift* satellite on Christmas Day 2010. Its was detected at γ-ray frequencies with a duration of ~3000-4000 s, much longer than most GRBs. X-ray observations by *Swift* also revealed

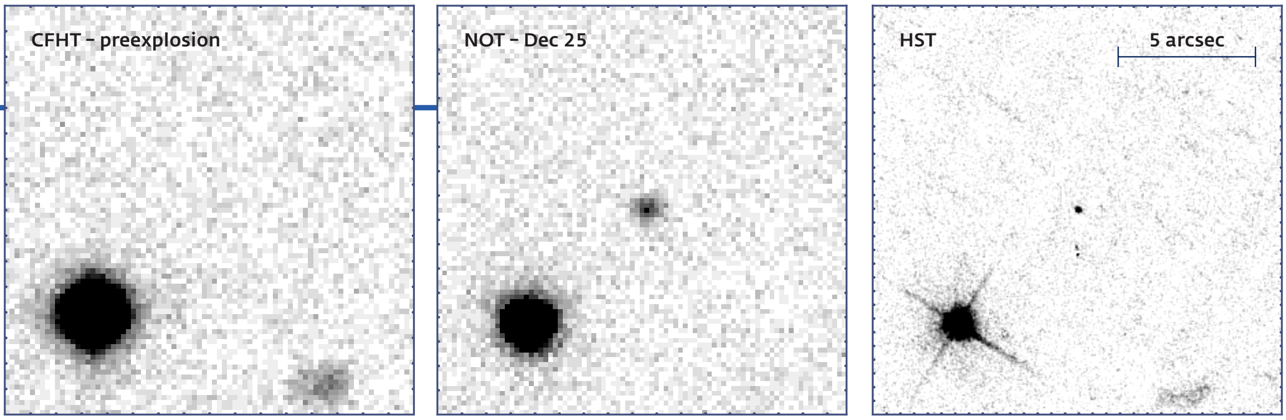


Fig. 7. The field of GRB 101225A (15"×15"). Left: Pre-explosion PANDAS image from 2007, showing no permanent source at the GRB position. Middle: NOT V-band image of the afterglow from the night of discovery. Right: HST image in red light ~19 days after the burst, showing a point-like source.

a bright X-ray afterglow. Observations at the NOT first identified the optical afterglow (Fig. 7, middle).

The multi-band light curve of the afterglow was followed by a suite of observatories over the following weeks. They show a clear blue-to-red spectral evolution, never seen before among GRBs (Fig. 8). Spectra from the WHT, GTC, and Gemini telescopes all lack strong absorption or emission lines, so an unambiguous redshift cannot be determined. Intense *R*-band monitoring with the NOT was followed by imaging at the HST, which limited the size of the source to less than 0.08? (Fig. 7, right). Moreover, a deep image of the field of the GRB – not far from the Andromeda galaxy – from the PANDAS survey at the Canada-France-Hawaii Telescope (CFHT) showed no persistent source (e.g. a host galaxy) before the explosion to a limit of *g* ~ 26.5 (Fig. 7, left).

Altogether, the peculiar properties of this event defy any known GRB model, so the nature of this event remains an enigma. The model currently favoured by most theoreticians is that of a rare Galactic event, possibly involving a planet being swallowed by an M-dwarf.

D. Xu, P. Jakobsson, D. Malesani, J. P. U. Fynbo;
Copenhagen and Reykjavík

Fig. 8. Multi-band light curves of the afterglow of GRB 101225A from Swift, NOT, and others. The spectral bands are colour-coded; most R-band data (red) are from the NOT. Filled circles are detections; inverted triangles are 3-σ upper limits. The evolution from blue to red colours is clear.

Formation of massive stars in nearby galaxies

Sites of recent massive star formation are marked by emission nebulae of hot, ionized hydrogen gas in the host galaxies. Massive star forming regions in 156 nearby galaxies have been studied in a large, ambitious programme using the NOT and several other telescopes on La Palma, in part via the CAT service programme. The excellent image quality of the NOT is used to obtain deep narrow-band images of the active, hydrogen-emitting regions, highlighted by subtracting the light of the underlying older population of stars in each galaxy.

Fig. 9 shows the spiral galaxy NGC 4041, observed with ALFOSC at the NOT. The emission regions marking the formation sites of young, massive stars are shown in bright red, while the background image traces the smooth population of older stars, which highlights the spiral structure of the galaxy.

This project also comprises observations at submm wavelengths with the James Clerk Maxwell Radio Telescope on Mauna Kea, Hawai'i. These will be used to study the line and continuum emission of interstellar molecules and dust in star forming regions. Together with archival images, these new data will allow us to study in depth the relation between the different stages of cold and warm gas, dust and star formation across the whole range of galaxy types in our sample.

J. Knapen, J.R. Sánchez-Gallego, La Laguna

Fig. 9. NGC 4041, a spiral galaxy at a distance of 23 Mpc. The ALFOSC image shows the continuum-subtracted Hα emission in red, with the R-band continuum image as background.

FORMATION, STRUCTURE, AND EVOLUTION OF STARS

Stars form in dense interstellar gas clouds. As they evolve, they build up heavy elements in their interiors and, depending on their mass, fade away as white dwarfs or explode violently as supernovae. Their remains then form the raw material for new stars. Theoretical models of this stellar life cycle enable us to estimate the ages and understand the chemical role of the stars we observe, but more work is needed.

A spectroscopic survey of OB stars in the northern Milky Way

Massive stars play a crucial role in the dynamical and chemical evolution of galaxies: They have a strong mechanical impact on their surroundings due to their intense winds. They also enrich the chemical composition of the surrounding interstellar medium in heavy elements generated in their interior. Massive stars are the major source of ionizing UV radiation, and hence are closely related to the formation and evolution of emission nebulae. In the early Universe, massive stars probably also played a decisive role in re-ionizing the primordial gas and in the formation of the first galaxies. Thus, the study of massive stars is of great importance in understanding the formation and evolution of the Universe.

Despite great recent advances, our knowledge of the physical characteristics and evolution of OB (i.e. very massive) stars is still based on single-epoch observations of very limited samples; indeed, only ~20-30 O-stars have reliable stellar properties and wind parameters. To make progress, we need to analyse many more stars in environments of different metallicity. The FIES high-resolution spectrograph enables us to achieve this goal for a large sample of bright OB stars in the northern Milky Way.

The IACOB project aims to assemble a database of homogeneous high-quality, high-resolution. multi-epoch FIES spectra of Galactic OB stars. Our survey is almost complete for O-type stars brighter than $V = 8$ and with $\delta > -27°$ and also contains spectra for 83 early B-type stars of all luminosity classes (including time-series observations of a dozen B supergiants). In all, we now have ~950 spectra of over 180 stars (see Figs. 10 and 11).

The scientific analysis of the database includes *(a)* a determination of reliable, homogeneous stellar and wind parameters for the whole sample; *(b)* an investigation of macroturbulence and pulsation in massive stars (see be-

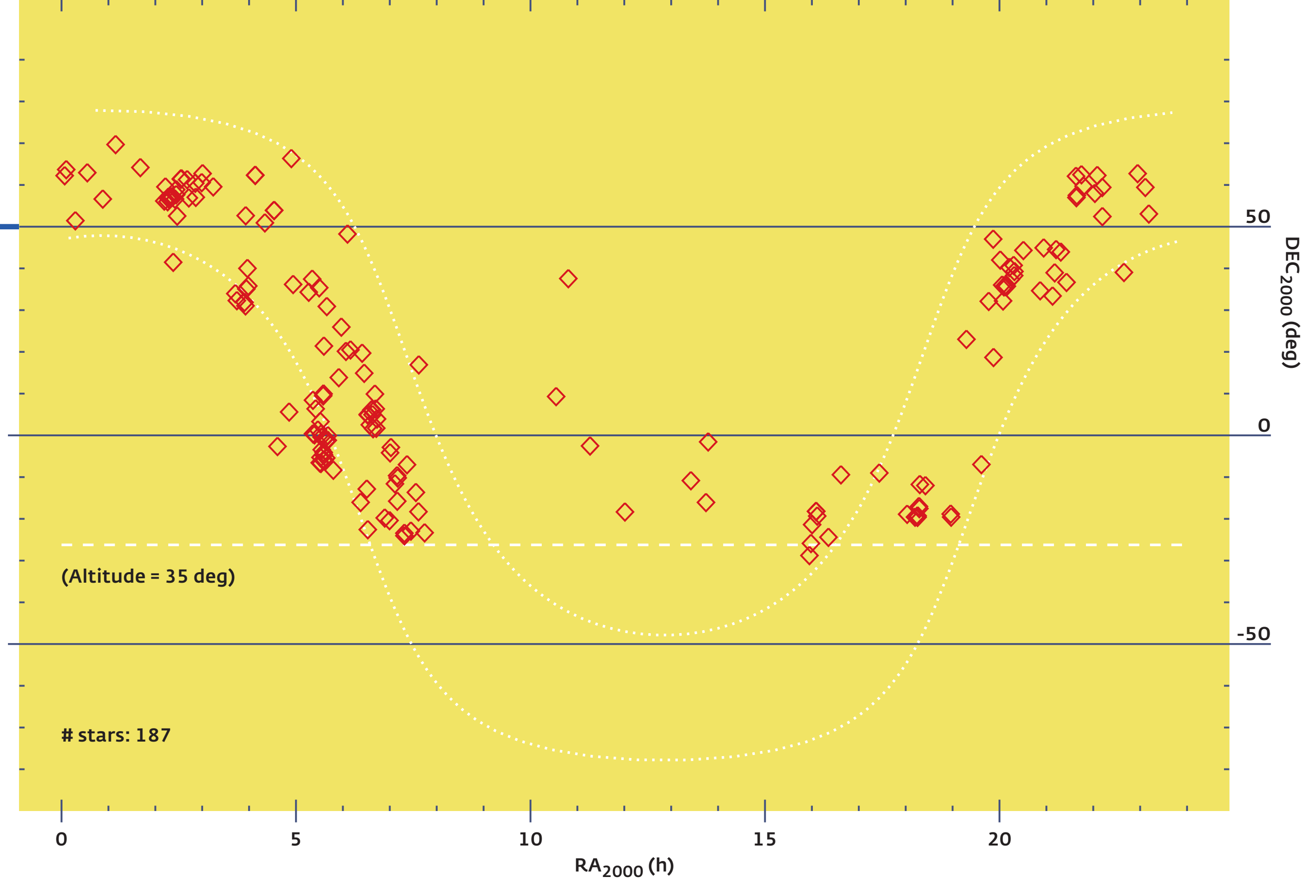


Fig 10: Distribution on the sky of the observed stars. The Galactic plane (|b| ≤ 15°) and the southern limit are indicated.

low); (*c*) determination of accurate chemical abundances in B-type stars; and (*d*) detection of binary and multiple stars. The IACOB database will eventually be made public for scientific and educational use.

S. Simón-Díaz, La Laguna

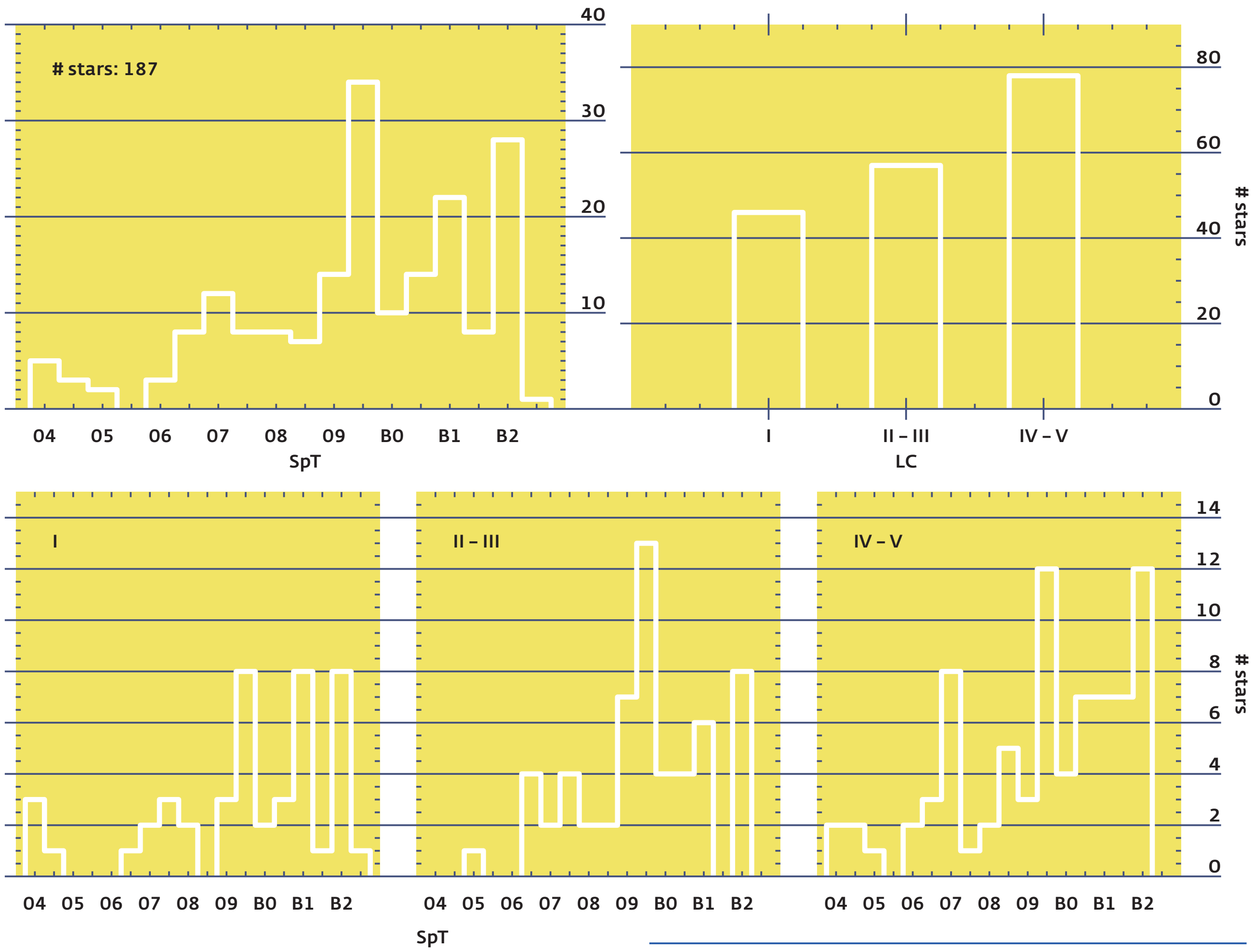


Fig 11: Distribution of the IACOB stars on spectral type and luminosity class.

Chemical signatures of evolution of high-mass binary stars

One of the great successes of stellar astrophysics is our theoretical understanding of the structure and evolution of stars. Recent models of high-mass stars, including the effects of rotation, predict telltale changes in atmospheric chemical abundances as the stars evolve. Some elements (e.g. He and N) should be enhanced, some (e.g. O) are unchanged, and others (e.g. C) should be significantly depleted.

Eclipsing binaries offer unique opportunities to test theoretical predictions of the physical properties of stars. Above all, their masses and radii can be measured to better than 1%, independently of theory. A difficulty in studying the fast-rotating stars in high-mass binaries is that their spectral lines are strongly blended together. However, the technique of "spectral disentangling" enables us to recover the individual spectra and orbital parameters of the two stars from a set of observed composite spectra (Fig. 12). Combined with photometry, these parameters yield the precise masses and radii of the two stars, and the disentangled spectra can be used for a detailed chemical abundance analysis.

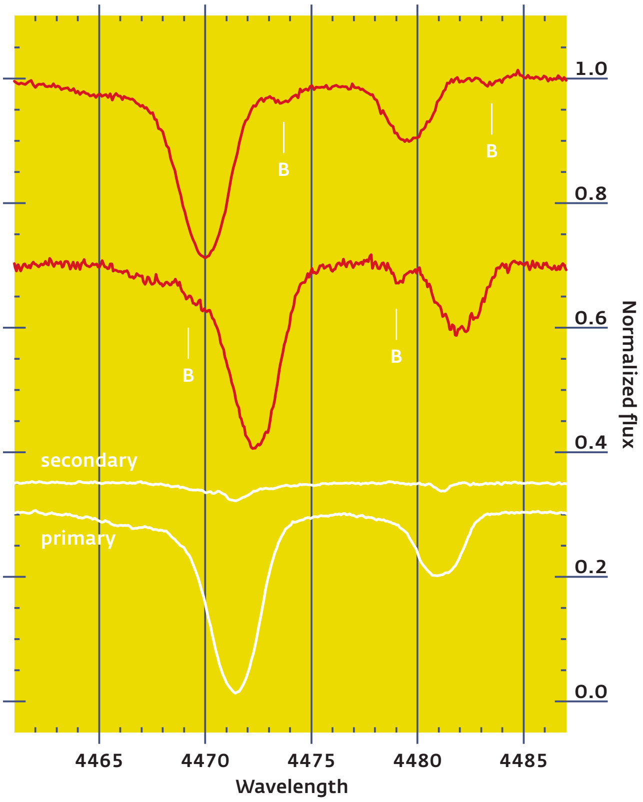


Fig. 12. The spectrum of V380 Cyg near the lines of He I (4471 Å) and Mg II (4481 Å). The top two spectra were obtained near maximum line separation; the weak lines of the secondary star are marked with a 'B'. Below are the disentangled mean spectra of the two stars.

The massive eclipsing binary V380 Cygni is an excellent tracer of stellar evolution, because the primary star is quite evolved, whereas the lower-mass secondary is not. We observed the star with FIES in 2006 and combined our data with spectra from telescopes at Ondřejov, Calar Alto and Victoria. An analysis of the spectra with published photometry yielded masses and radii with errors of only 1-2%. From the disentangled spectrum of the primary star we also measured the chemical composition of the photosphere, which shows *no* evidence for the chemical evolution predicted by models of rotating stars (Fig. 13). Moreover, the models also fail to match the luminosity of the star. Work is underway to explore this discrepancy further and assess whether the properties of stars in close binaries may differ from those of single stars.

K. Pavlovski, J. Southworth, Zagreb and Keele; and colleagues

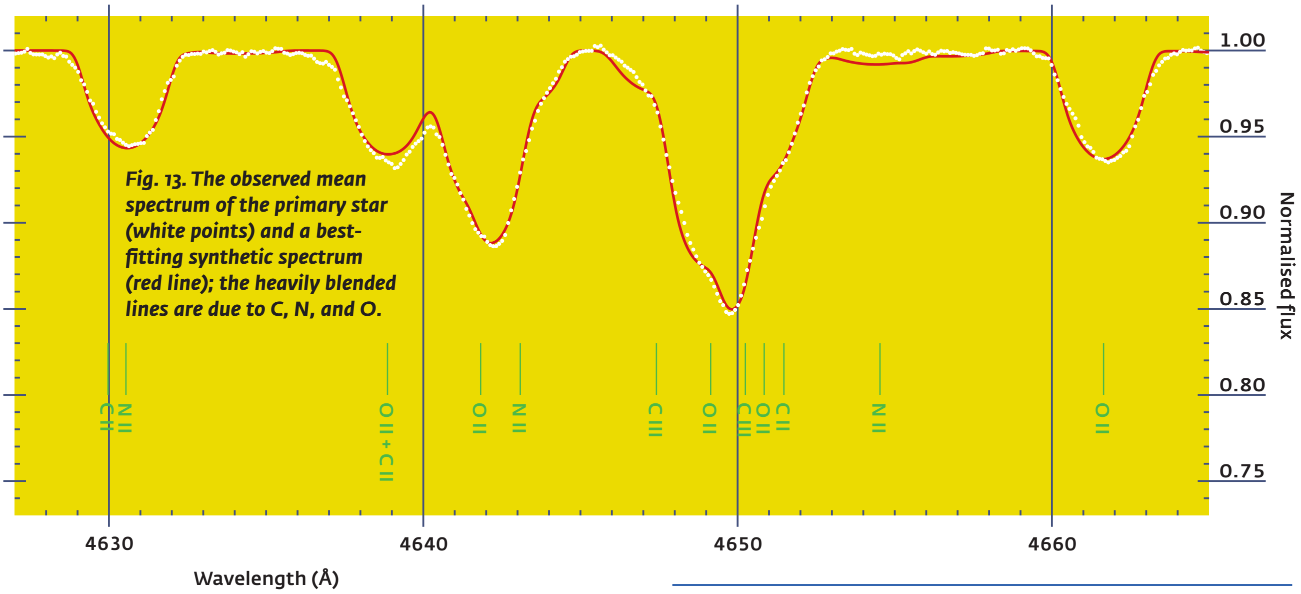


Fig. 13. The observed mean spectrum of the primary star (white points) and a best-fitting synthetic spectrum (red line); the heavily blended lines are due to C, N, and O.

Evidence for a black hole in the X-ray binary XTE J1859+226

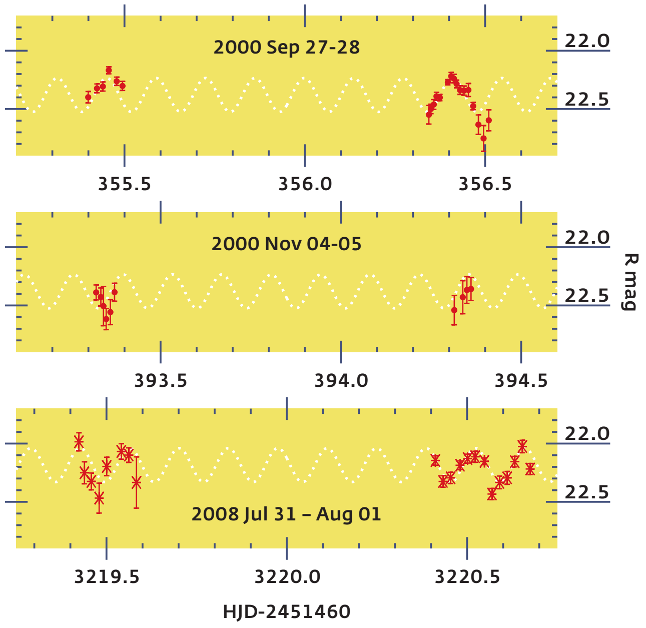
The mass distribution of stellar-mass black holes has crucial impact on fundamental physics, but can only be determined from studies of X-ray binaries. Only 16 transient X-ray binaries are known to host black holes, so many more dynamically measured masses are needed to set useful constraints on the mass spectrum.

Here we present the results of time-resolved optical photometry and spectroscopy of one such binary, the X-ray transient XTE J1859+226 (V406 Vul). Photometric observations taken in 2000 with the Isaac Newton Telescope (INT), and in 2008 with the NOT+ALFOSC, reveal the presence of an ellipsoidal light modulation due to the changing aspect of the secondary star (Fig. 14). Further photometry obtained in 2010 with the NOT and William Herschel Telescope (WHT) found that the system was now ~1 mag brighter than its quiescent level, and the ellipsoidal modulation was diluted by strong flaring activity (Fig. 15). Spectra from 2010 with the 10.4-m Gran Telescopio de Canarias (GTC) also revealed radial velocity variations of ~500 km s^{-1} in just 3 h.

We performed a simultaneous fit to the quiescent photometry and spectroscopy, using sinusoids to represent the secondary star's ellipsoidal light and radial velocity variations. This yields an orbital period of 6.58±0.05 h and a radial-velocity semi-amplitude of K2 = 541±70 km s^{-1} for the secondary star. The implied mass function is $f(M)$ = 4.5±0.6 $M_\odot$, significantly lower than previously reported, but still consistent with the presence of a black hole in XTE J1859+226. Furthermore, the lack of eclipses in our quiescent light curves sets an upper limit to the inclination of 70°, which yields a lower limit to the black hole mass of 5.4 $M_\odot$.

J.M. Corral-Santana, J. Casares, T. Shahbaz, C. Zurita, I.G. Martínez-Pais, P. Rodríguez-Gil, La Laguna

Fig. 14. Top and middle panels: INT photometry of XTE J1859+226 taken in 2000. Bottom: NOT photometry from 2008, showing a dominant ellipsoidal modulation due to the secondary star. The dotted line shows a simulated light curve with the best-fit period of 6.58 h.



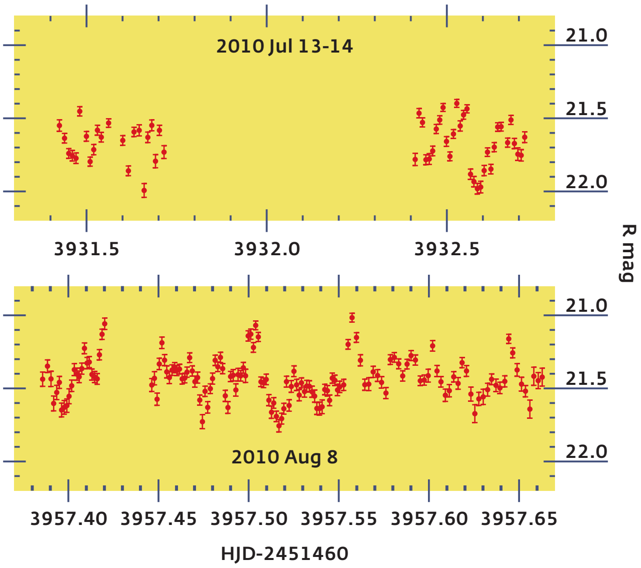


Fig. 15. Optical photometry from 2010 July 13-14 using the NOT (top), and from August 8 using the WHT (bottom). The system is now ~1 mag brighter than its previous quiescent level, and a strong flickering activity nearly masks the ellipsoidal light modulation.

The origin of hot “runaway” stars

Faint blue stars near the Galactic poles are predominantly white dwarf and hot subdwarf stars. Nevertheless, apparently normal early-type stars are occasionally discovered far from the Galactic plane and from any star-forming region. These “runaway” stars are generally believed to have formed recently in the Galactic disk, but were ejected soon thereafter with velocities of several hundred km s^{-1}. A few objects even appear to be ejected from the Milky Way altogether.

Three basic ejection mechanisms for the runaway stars have been suggested: Tidal disruption of a binary system by the supermassive black hole at the Galactic center (the Hills mechanism); disruption of a binary system by a supernova explosion of the primary star; and purely dynamical interactions in star clusters, e.g., through close binary-binary encounters. What fraction each of these scenarios may contribute to the total population of runaway stars in the Galactic halo remains an open question.

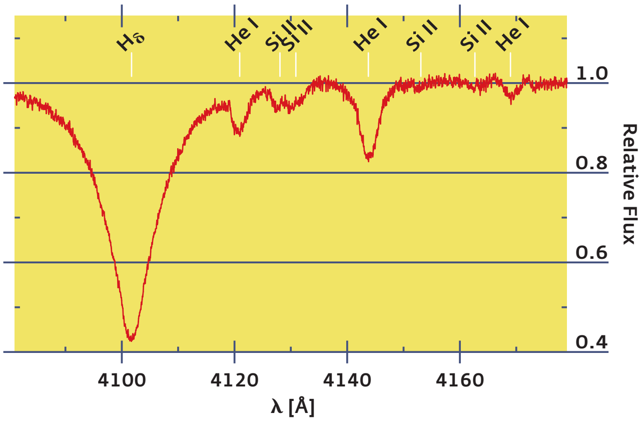


Fig. 16. FIES spectrum of one of our targets, showing lines of hydrogen, helium, sulphur and silicon.

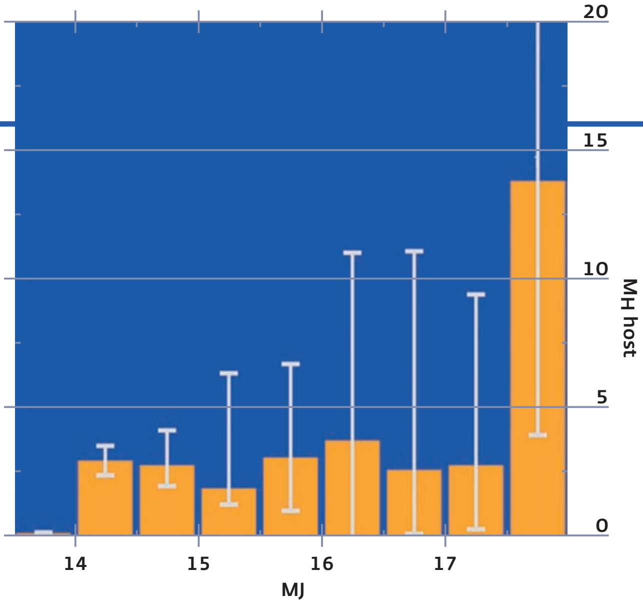


Fig. 17. The number of brown dwarfs from the CFBDS as a function of J-band magnitude.

The mechanism responsible for ejecting an individual star can be distinguished by a combined kinematic and spectroscopic investigation. The space velocity contains information on the birthplace of the star in the Galactic disk, arguing for or against the Hills mechanism. The kinematic study also allows the ejection velocities to be derived, giving constraints on the possible progenitor systems and enabling us to discriminate between different ejection models. Quantitative spectroscopy yields the atmospheric parameters and elemental abundances of the star, which determine its evolutionary stage and age. The composition is a signature of the binary supernova ejection mechanism, as this scenario likely implies pollution of the atmosphere of the runaway star by freshly produced heavy elements, such as silicon or sulphur.

High-quality spectra are necessary for such an analysis. The FIES spectrograph provides the spectral resolving power and wide wavelength coverage needed for a detailed spectroscopic investigation and is therefore ideally suited for our project. Fig. 16 shows a sample region of a FIES spectrum from our observing run, which we are using to unveil the origin of the star.

A. Irrgang, U. Heber, Bamberg

The Canada-France Brown Dwarf Survey

Brown dwarfs are an intermediate stage between stars and giant planets. Their mass, about 70 Jupiter masses, is too low to maintain nuclear burning in their interiors over a long time. Thus, a brown dwarf keeps cooling forever after its formation, in contrast to a star like our Sun, which maintains its high internal temperature through thermonuclear fusion reactions.

Since the first brown dwarfs were found in 1995, almost a thousand brown dwarfs have been discovered in large-scale surveys. Our own *Canada-France-Brown-Dwarf Survey* (CFBDS) is based on deep multi-colour optical imaging with MegaCam at the CFHT. Candidate brown dwarfs and high-redshift quasars are initially identified on the optical images from their very red *i*'-z' colours. Near-infrared *J*-band imaging is then needed to separate the quasars from the brown dwarfs.

We have carried out this near-IR imaging, mainly with the NTT on La Silla, and the NOT on La Palma for our Northern targets. The excellent seeing at the NOT is good for this project, because sensitivity depends strongly on seeing for our faint point sources.

Besides pinpointing rare high-redshift quasars that bring important clues on the reionization of the Universe, the *J*-band photometry very effectively rejects any remaining observational artefacts, as well as the many low-mass M-stars that are scattered into the brown dwarf/quasar colour domain by unusually large observational noise. This *J*-band follow-up of all our candidates has so far yielded 70 of the extremely cool T dwarfs and more than 200 L or very late-M dwarfs. The well-defined selection criteria of our survey make it is especially valuable for investigations of the luminosity function and space density of brown dwarfs. They also allow us to search for the coolest brown dwarfs and investigate the physics of brown-dwarf atmospheres below 650K, close to the temperature of giant planets.

The peak in the faintest bin of Fig. 17 suggests that many brown dwarfs should be found at very late spectral types, as expected because brown dwarfs should continue cooling to very low temperature, whatever their mass,.

C. Reylé, P. Delorme, C. Willott, X. Delfosse, L. Albert, T. Forveille, E. Artigau, L. Malo, D. Arzoumanian, Besançon

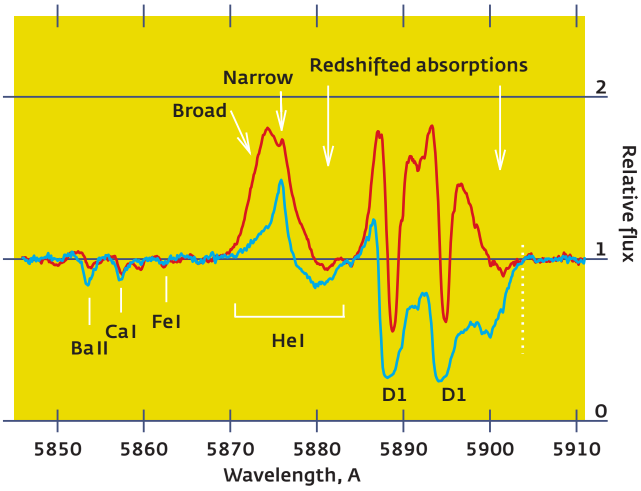


Fig. 18. The He I and Na lines in RW Aur A, in two extreme states. The stellar absorption lines are weak due to overlying emission (veiling). Broad and narrow emission components arise in different locations around the star; the broad redshifted absorption lines indicate infalling gas with velocities up to 400 km s^{-1}.

Chromospheres in classical T Tauri stars.

Classical T Tauri stars (cTTS) are newborn stars of about one solar mass, surrounded by cool, dusty disks. They accrete gas that flows along magnetic field lines to the stellar surface. cTTS can be exceedingly active: Dramatic changes occur on timescales of hours or days, both in brightness and in the spectrum. To study this variability one needs a long series of high-resolution spectra.

The photospheric absorption lines in cTTS are typically much shallower than in normal cool stars. This “veiling” is due to continuous emission from the shock-heated accretion region and is traditionally used to derive mass accretion rates in cTTS; Fig. 18 shows an extreme example of the variation in these spectral signatures.

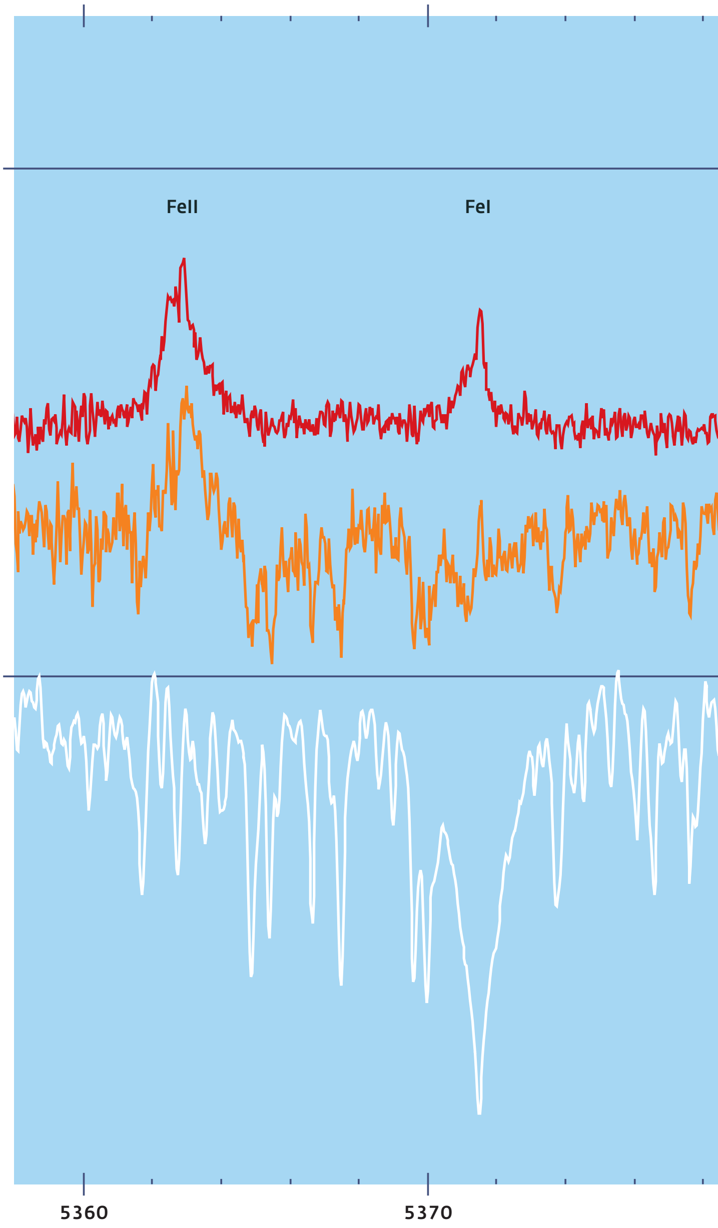
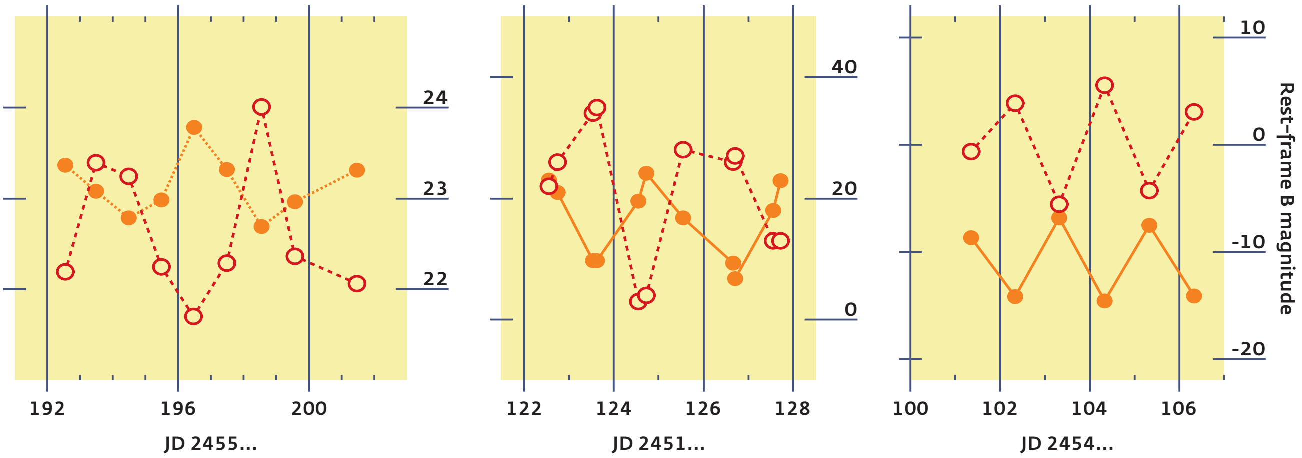


Fig. 20. Radial-velocity variations of photospheric (filled circles) and narrow emission lines (open circles) in DR Tau, RW Aur and DI Cep arise in the opposite exposed and heated sides of the rotating star.



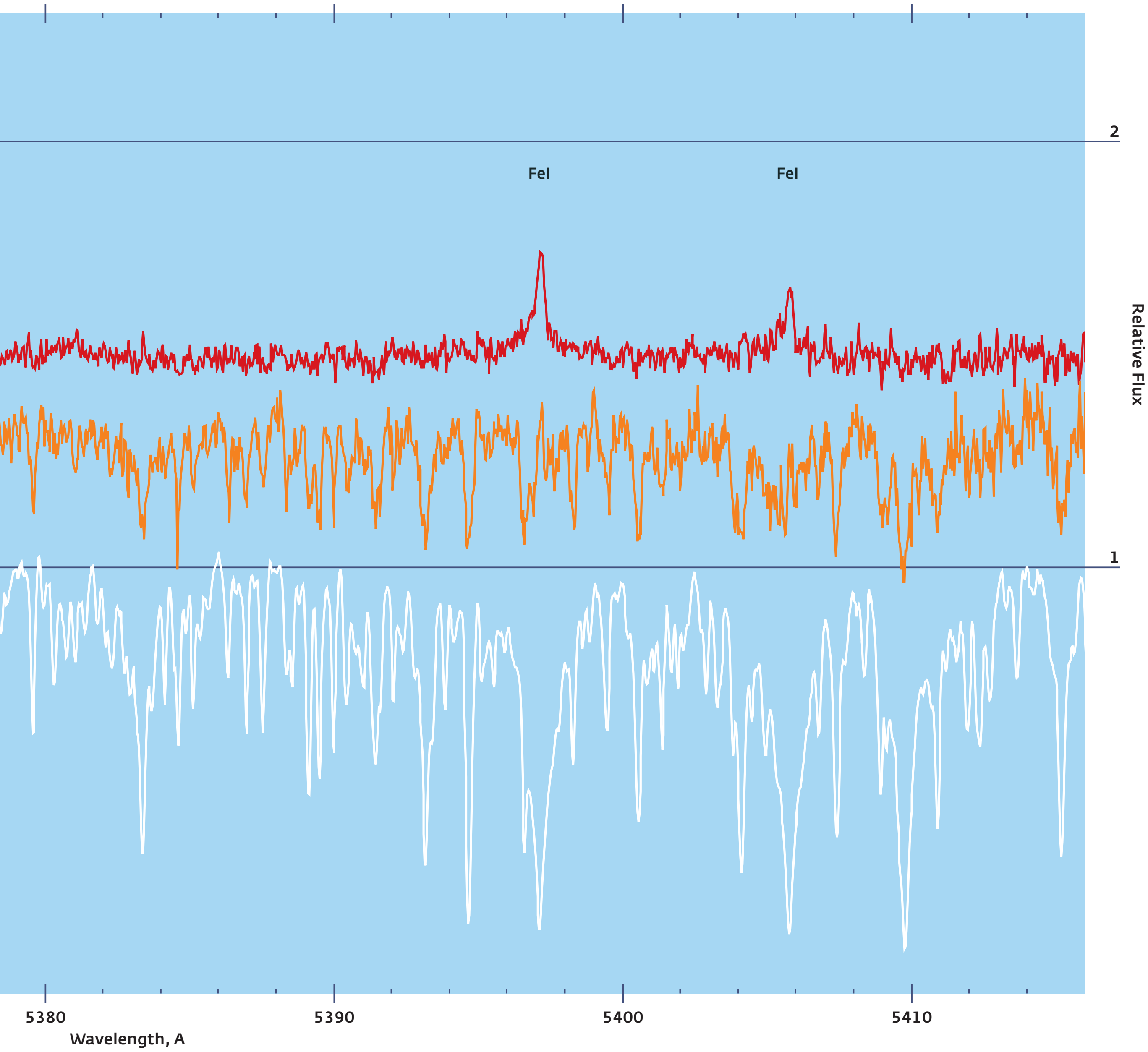


Fig. 19: Spectrum of DR Tau in states of low (blue) and high veiling (red), compared to a normal K7 V star (bottom). High veiling flags episodes when gas falls into to the star at high speed.

Our high-resolution monitoring with FIES of one of the most active cTTS, DR Tau, in 2007 and 2010 revealed a narrow emission line spectrum similar to the solar chromospheric spectrum, suggesting that these features are due to enhanced solar-type activity. We also found that the veiling in DR Tau varies from practically zero to more than 10 times the stellar continuum intensity in just a few days. If this is due only to excess continuous emission, the brightness of the star should show the same change, which it did not. Instead, we found two different sources of veiling: One is indeed excess continuum emission, but the other consists of narrow emission lines filling in the absorption lines; it completely dominates at times of enhanced accretion (see Fig. 19).

The radial velocities of photospheric and chromospheric lines also vary in anti-phase (Fig. 20). This is caused by an area of enhanced chromospheric emission, which is offset from the pole of rotation and associated with a small hot spot at the footprint of the accretion funnel. This seems to be a common property of cTTS and suggests that the magnetic axes in cTTS are generally tilted relative to the rotational axes.

P. Petrov, S. Artemenko, Crimea; G. Gahm, Stockholm;
E. Stempels, Uppsala; F. Walter, Stony Brook

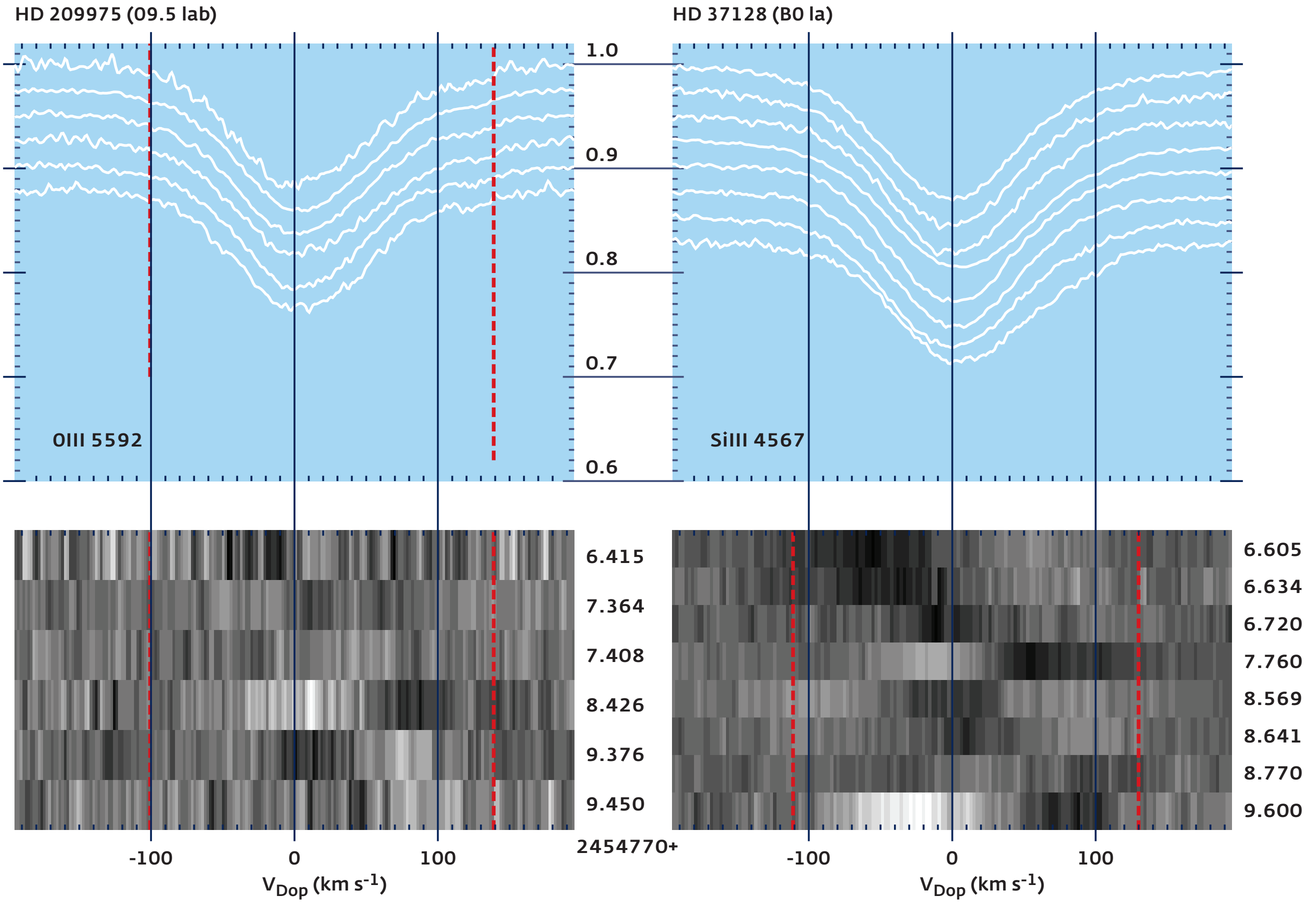


Fig. 21. Line-profile variations over ~3 days as found in four B-type Sgs observed with FIES. Time (days) increases down the vertical axis; radial velocity from left to right.

Turbulence vs. pulsations in OB-type stars

Absorption lines in stellar spectra are broadened by the Doppler effect of gas motions in the stellar atmosphere, averaged over the disk, including rotation of the star itself. These motions are slow in slowly rotating solar-type stars, which show sharp lines. In contrast, hot, massive OB stars typically spin very fast and show broad, shallow lines. As OB stars evolve and become hot, very large and luminous supergiants (Sg), their rotation is expected to slow down due to the conservation of angular momentum and the braking effect of their strong stellar winds. Sg OB stars should therefore show sharp spectral lines.

Contrary to expectation, the most luminous Sg B stars were found already half a century ago to have broad, diffuse spectral lines, presumed to arise in large-scale turbulent motions in the outer layers of the star. However, more recent high-resolution spectroscopic investigations of rotation vs. other line broadening mechanisms showed that: *(i)* non-rotational broadening increases from late to early B-types, and *(ii)* if interpreted as turbulent motions, these would be highly supersonic. Since the extra broadening is present in lines that are formed very deep in the stellar photosphere where significant velocity fields are not expected, its interpretation in terms of turbulent motions is improbable.

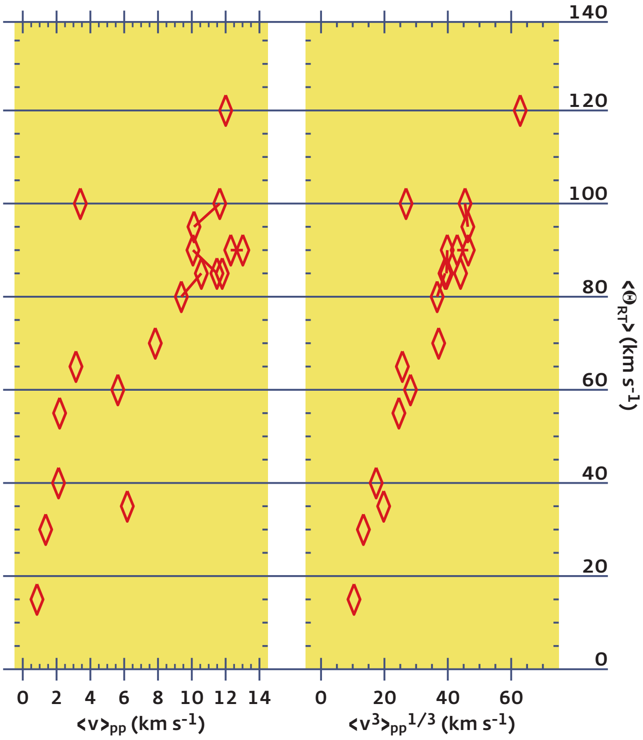
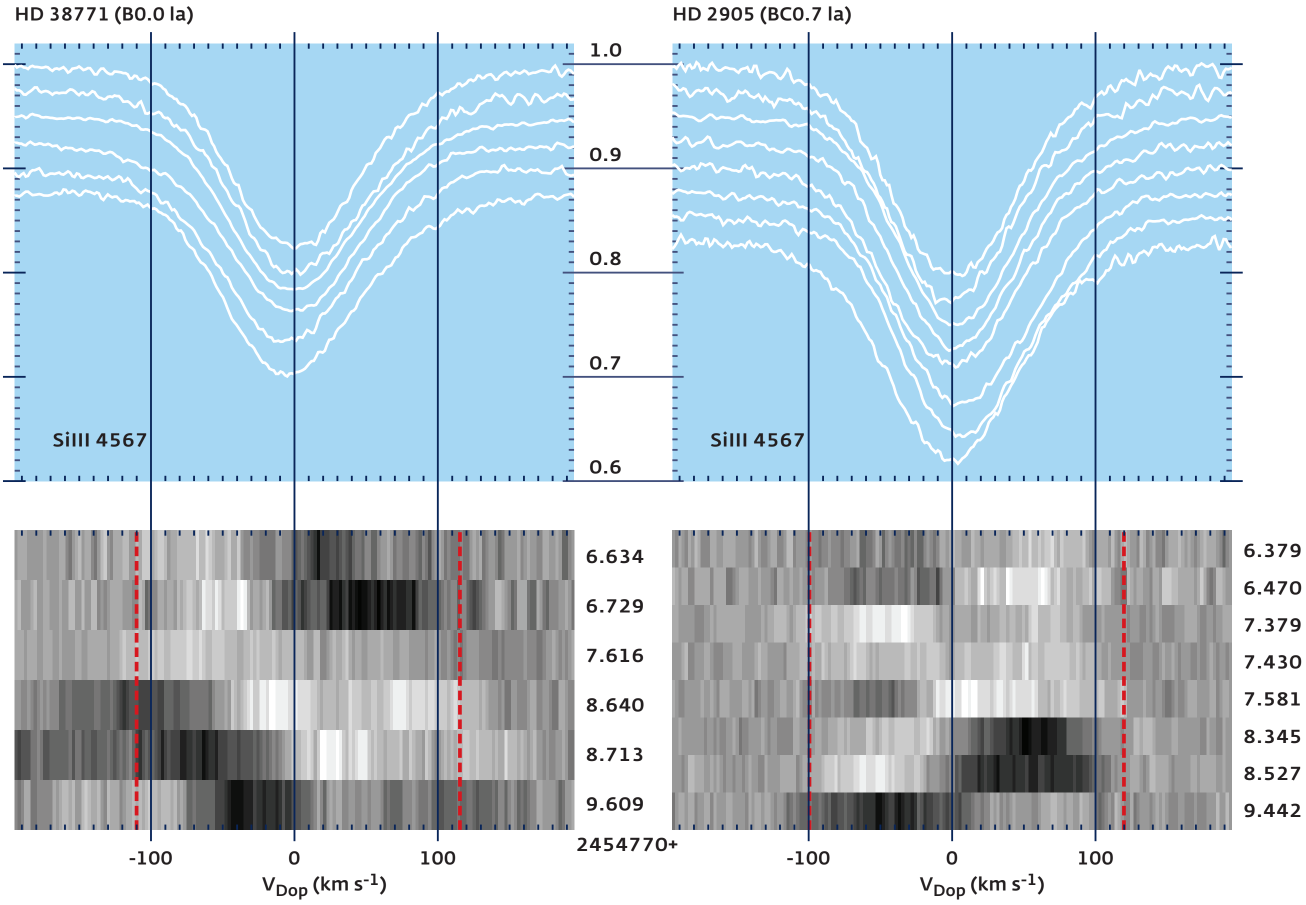


Fig 22. Observed relation between the average macroturbulent velocity (Θ_{RT}) and the degree of asymmetry of the line profile.



A different physical mechanism, stellar oscillations, might be a more likely cause of the extra line broadening in Sg B stars. Thus, the light and line profile variations seen in many Sg OB might be due to pulsations, and the excess broadening might be due to gas motions in many superimposed non-radial oscillation modes. Because pulsations produce asymmetric line profiles, this hypothesis can be confirmed observationally (see Fig. 21).

Observations with FIES recently enabled us to advance in investigating this puzzle. Spectroscopic time series of 13 early Sg Bs (plus 2 early B dwarfs and 2 late Sg Bs) provided the first clear observational evidence for a correlation between excess broadening and the line-profile variations seen in early B and late O supergiants (Fig. 22): The larger the broadening, the larger the observed asymmetry variations in the photospheric line profiles (see paper listed on p. 35)

This result is very encouraging, but more work is needed before we can firmly conclude that the excess line broadening in hot supergiant stars is in fact due to stellar pulsations.

S. Simón-Díaz, La Laguna

A dynamo wave on an active late-type star

The spots and other surface features seen on the Sun are much more pronounced in faster-rotating active stars. Solar-like activity cycles and magnetic field reversals are also observed in such stars. The opportunity to observe similar phenomena on analogues to the young Sun is a powerful motivation for studying these stars as guide to the Solar eruptions that sometimes affect us even here on Earth.

We have collected a nearly 20-year long time series of spectroscopic observations of active, rapidly rotating late-type stars with the SOFIN spectrograph at the NOT. Surface temperature inversions in integral light have revealed the existence of two persistent active longitudes at high latitudes on several of our target stars; spectro¬polarimetry is the key to derive the magnetic field configuration on these objects.

In one of our key objects, the active RS CVn binary star II Peg, the spot-generating mechanism rotates with a period shorter than the rotational period of the star itself. This confirms an old prediction from dynamo models that rapid rotators exhibit azimuthal dynamo waves, which can have different rotation velocities than the stellar photosphere. During the years 2004-2010, the spot coverage of the star has decreased, which may be related to a cyclic

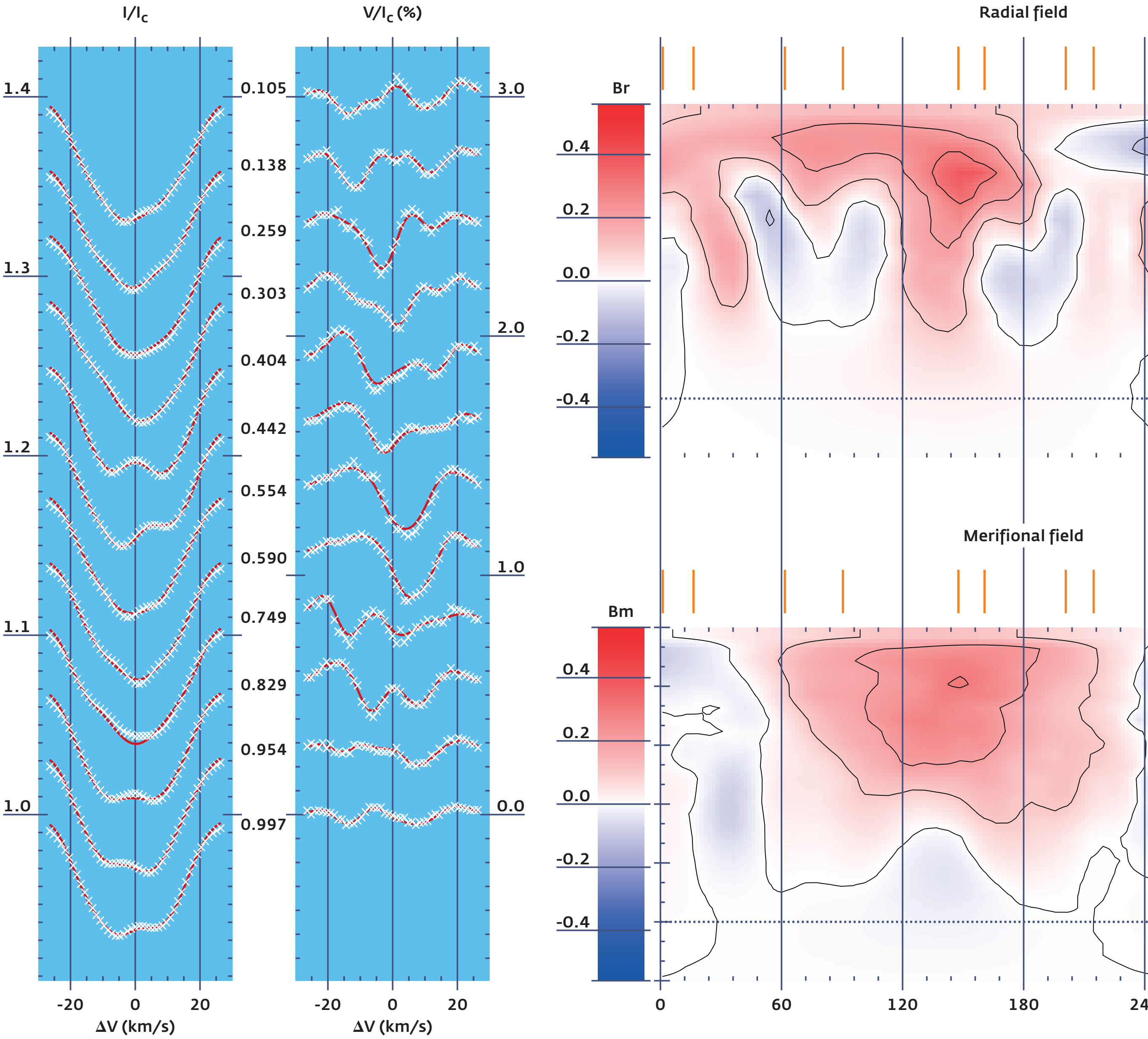


Fig. 23: Observed direct and polarised line profiles of the RS CVn star II Peg during September 2009, and the surface temperature and magnetic field maps retrieved by Zeeman Doppler imaging.

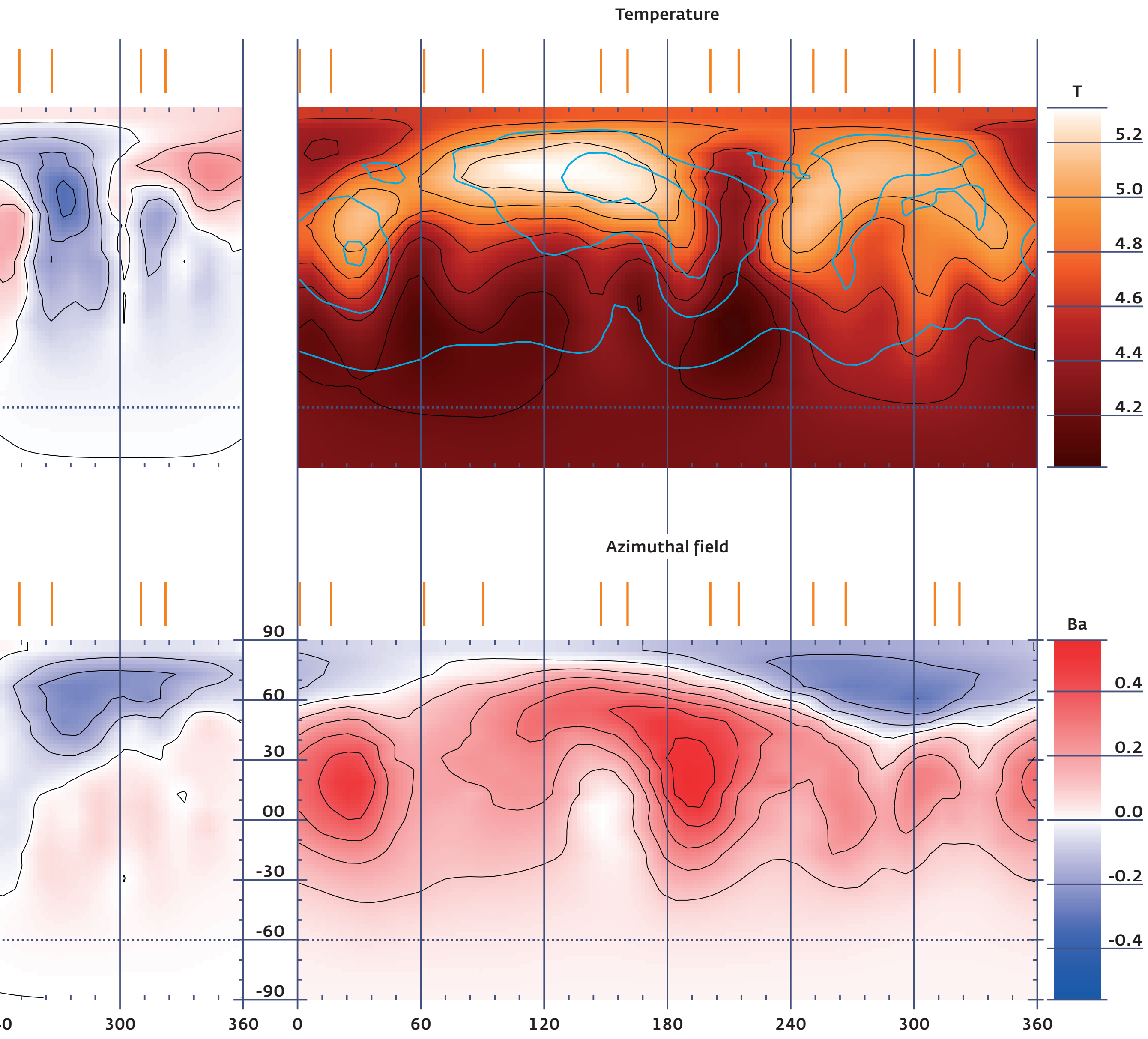
behaviour similar to the solar magnetic cycle (the magnetic field configuration of II Peg in September 2009 is shown in Fig. 23). The final proof of such a cycle would be a polarity reversal of the magnetic field, documented through magnetic Doppler inversions of the SOFIN data. We will continue to follow this and similar objects, based on our unique long-term database.

I. Tuominen, T. Hackman, P. Käpylä, M. Lindborg, M. Mantere, Helsinki; I. Ilyin, Potsdam; O. Kochukhov, N. Piskunov, Uppsala

Chemical 'weather' on HgMn stars

A subclass of late-A to early-B type chemically peculiar stars, the mercury-manganese (HgMn) stars, exhibit an overabundance of Hg, Cr, Mn, Y, Sr, and other heavy chemical elements. High-resolution spectroscopy revealed a decade ago that several HgMn stars are spectroscopic variables. More detailed studies showed that some of the overabundant chemical elements occur in spots on the stellar surface. This discovery gave rise to the idea that the observed inhomogeneities can be formed under the influence of a magnetic field.

However, a number of spectropolarimetric surveys of HgMn stars found no significant magnetic fields, setting



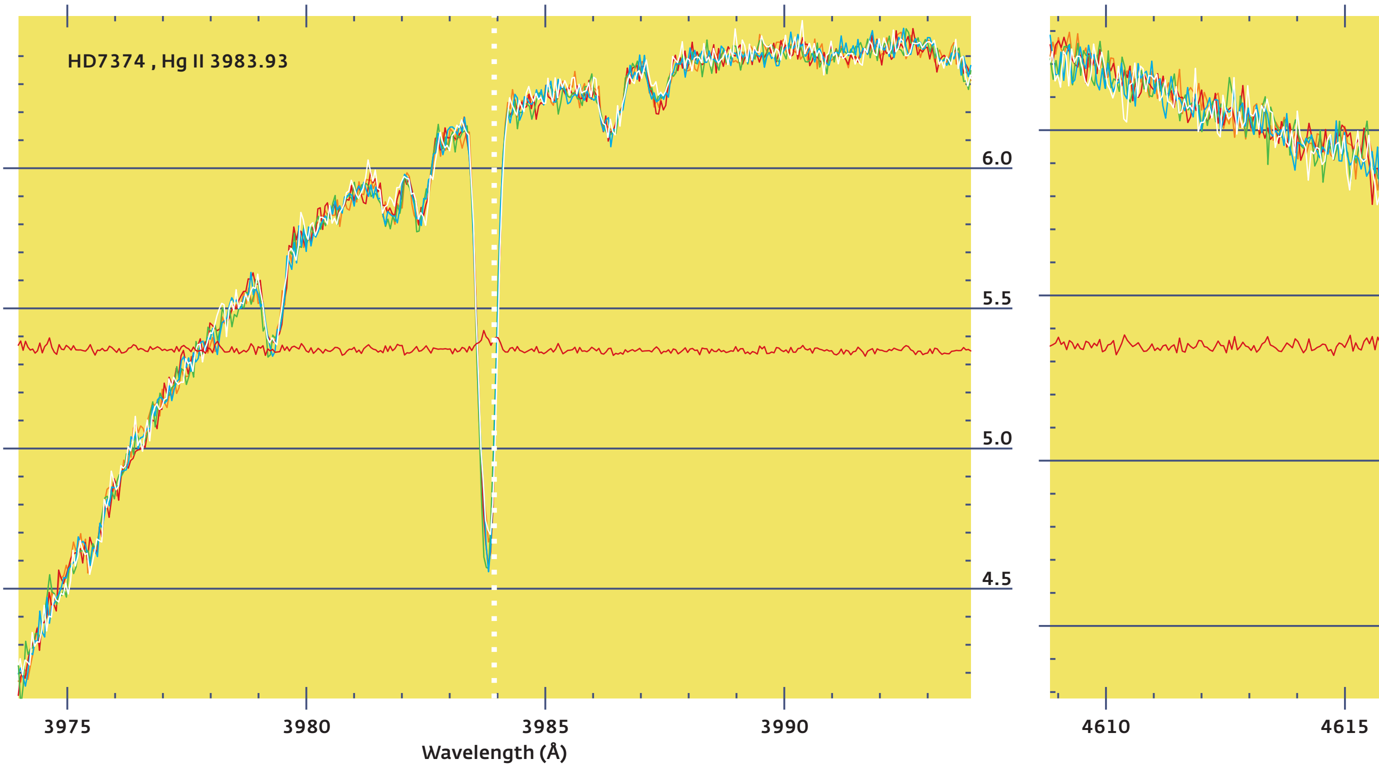
an upper limit of 2-10 Gauss to the longitudinal field strength, at best. This implies that none of the stars studied to date has a strong global magnetic field that could be the main mechanism of spot formation.

On the other hand, the list of spotted HgMn stars studied so far is short: Only α And, HR 1185, HR 8723, AR Aur, φ Phe, HD 53244, and HD 221507, and time coverage is spotty. We therefore decided to perform not only spectropolarimetric observations, but also a spectroscopic survey in order to provide rotational periods and phase coverage for a large sample of HgMn. The main aim of this part of the project was to determine the frequency of spotted HgMn stars and search for distinct characteristics of the physical processes that might explain this puzzling phenomenon.

In August 2010 we observed 30 HgMn stars over six half-nights at the NOT, using FIES in the medium-resolution mode. The stars HD 7374 and HD 220575 were observed during five consecutive nights. Our analysis is still preliminary and limited to those spectral lines that have been reported variable in previous studies. However, while the Hg line in HD 7374 remained nearly constant during our observations, the Cr line in HD 220575 showed clear variations over the period (Fig. 24), revealing the passage of “chromium clouds” across the surface of the star.

V. Makaganiuk, Uppsala

Fig. 24. Line profiles in the HgMn stars HD 7374 (top, Hg II at 3983 Å over four nights) and HD 220575 (bottom, Cr II 4619 Å over five nights); the interesting lines are marked by green dashed lines. The solid red line shows the standard deviation of the spectra; a bump signals a variable spectral line.



Protoplanetary discs around young stars

Discs around young stars are a common feature of the accretion stage of the star formation process, and their evolution leads to the formation of planetary systems. The percentage of protoplanetary discs around young stars ranges from 50 to 100%, at least for young star-forming regions in the age range 0.3 - 30 Myr. It has also been postulated – and supported by observational evidence – that protoplanetary discs evolve on time scales of a few million years. Depending on the stellar mass, they become a substantially different kind of disc, the so-called debris discs. In these, most of the gas from the first stage has disappeared and the observed thermal emission comes from dust produced by the collision of planetesimals. The gas component in protoplanetary discs presumably contains a substantial part of the mass of the whole disc and dominates its dynamics, but it is much more difficult to observe than the dust.

Our observing run with NOTCam in 2009 was devoted to collecting complementary data to observations that are being obtained within the Open Time Key Programme GASPS of the Herschel Space Observatory (GAS in Protoplanetary Systems, PI W.R.F. Dent). The main goal of GASPS is to study the warm disc atmosphere with far-infrared spectroscopy to measure the gas content and excitation conditions, and with far-IR photometry to constrain the dust distribution.

With NOTCam we obtained *K*-band spectra for some 40 young stars with discs, mainly in the Taurus region. This spectral range contains features such as the H_2 line at 2.12 μm and Brγ at and 2.17 μm. The latter is commonly used as a tracer of accretion, and the resulting mass accretion rates can be cross-checked with indicators in other spectral intervals, such as the ultraviolet continuum or Hα. The overall appearance of the spectra also helps to refine the spectral type of the targets – see Fig. 25, which shows a region of the *K*-band spectrum of FS Tau (an M1+M4 binary).

B. Montesinos, Madrid

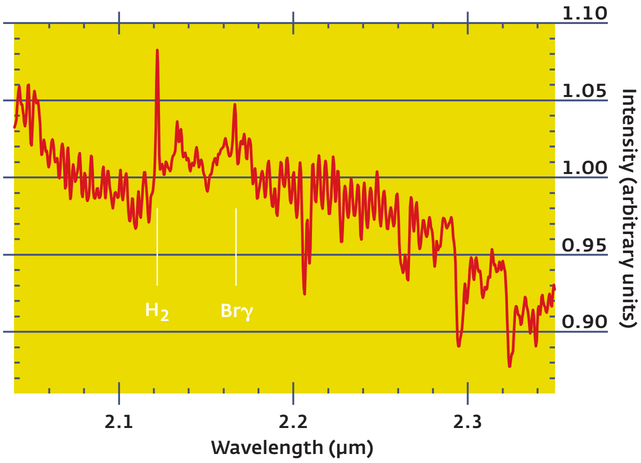
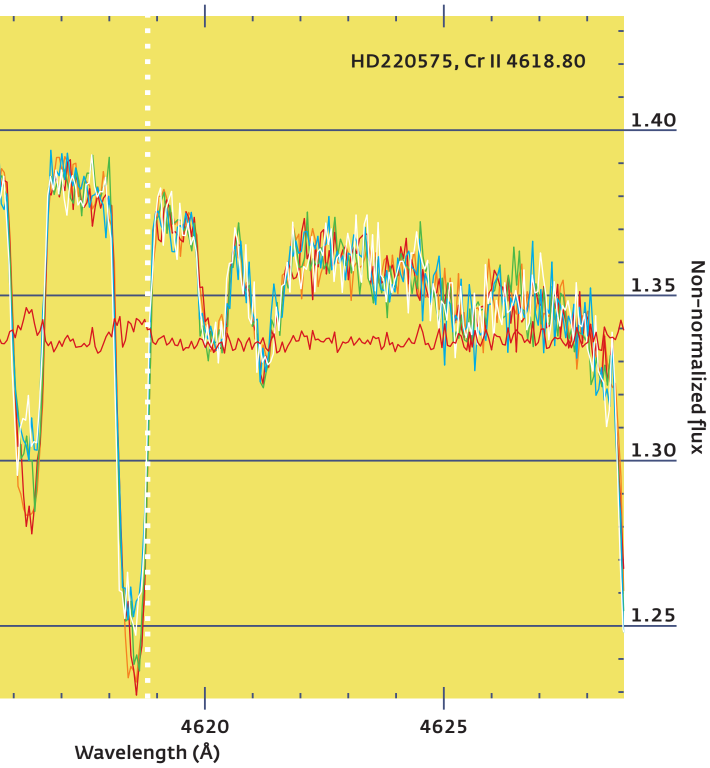


Fig. 25. K-band spectrum from NOTCam of the young cool binary star FS Tau. The emission lines of H_2 and Brγ are labelled.



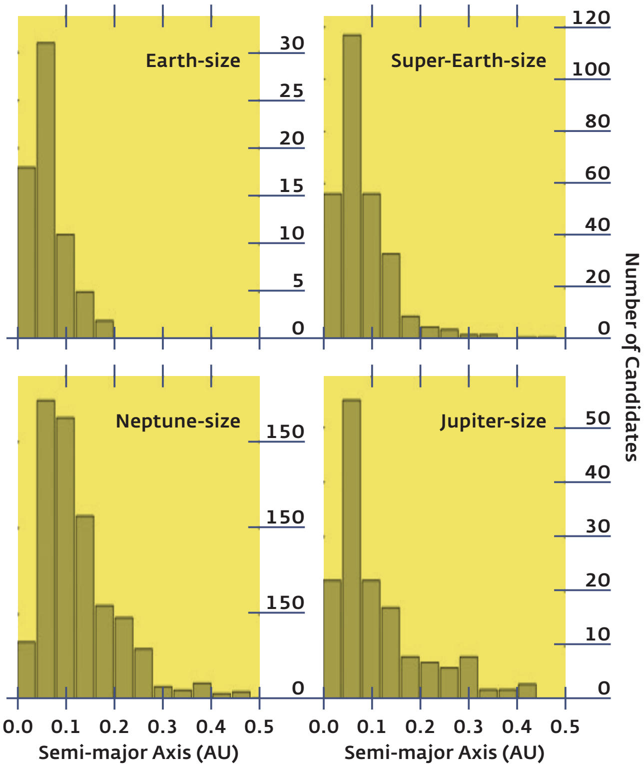


Fig. 26. Number of Kepler planet candidates vs. orbital semi-axis major. Earth-size refers to $R_p < 1.25\ R_\oplus$, super-Earth-size to $1.25\ R_\oplus < R_p < 2\ R_\oplus$, Neptune-size to $2\ R_\oplus, < R_p < 6\ R_\oplus$, and Jupiter-size to $6\ R_\oplus < R_p < 15\ R_\oplus$ (Borucki et al. 2011).

PLANETARY SYSTEMS IN THE UNIVERSE

Until just 15 years ago, the only planetary system we knew was our own. Today, planets around other stars are a booming field of research, thanks to discoveries by ground- and space-based surveys and a rich variety of complementary ground-based observations.

Transiting exoplanet discoveries with the Kepler mission

The Kepler space mission uses a 0.95-m telescope with a huge CCD camera to monitor the brightness of about 150,000 stars in field of 105 square degrees (roughly the whole sky between the bright stars Vega and Deneb!). Its extreme photometric precision (down to 20 parts per million) allows it to detect transits of even small planets and thus determine the frequency and characteristics of planets and planetary systems. Kepler was launched in March 2009 and recently released its first four months of data with over 1200 planet candidates (see Fig. 26).

Potential planets are sorted into five classes: 68 candidates of roughly Earth-size ($R_p < 1.25\ R_\oplus$), 288 of super-Earth size ($1.25\ R_\oplus < R_p < 2\ R_\oplus$), 662 of Neptune-size ($2\ R_\oplus, < R_p < 6\ R_\oplus$), 165 of Jupiter-size ($6\ R_\oplus < R_p < 15\ R_\oplus$), and 19 up to twice Jupiter-size ($15\ R_\oplus < R_p < 22\ R_\oplus$). 54 planet candidates reside in the habitable zone, where liquid water can exist. They range from Earth-size to larger than Jupiter; six are less than twice the size of the Earth. Over 74% of the new planetary candidates are smaller than Neptune.

Candidates are first checked for obvious false signals (blended eclipsing binaries or other non-planetary objects). A key step is to obtain spectra of modest signal-to-noise (S/N) ratio of the host stars to derive precise stellar parameters and detect stellar-mass companions via their large radial-velocity variations. The surviving candidates are then followed up with high-precision radial velocities for determination of the companion mass.

The NOT and FIES participate very actively in the Kepler follow-up along with a suite of other medium-size telescopes. Although the lowest-mass candidates require larger telescopes with special instruments (such as the 10m Keck), the NOT spectra are of crucial importance, as the mass and radius of the planet are directly proportional to those of the host star, in turn derived from its spectroscopic parameters.

The NOT also supplies reconnaissance spectra and precise radial velocities for discoveries from the ground based

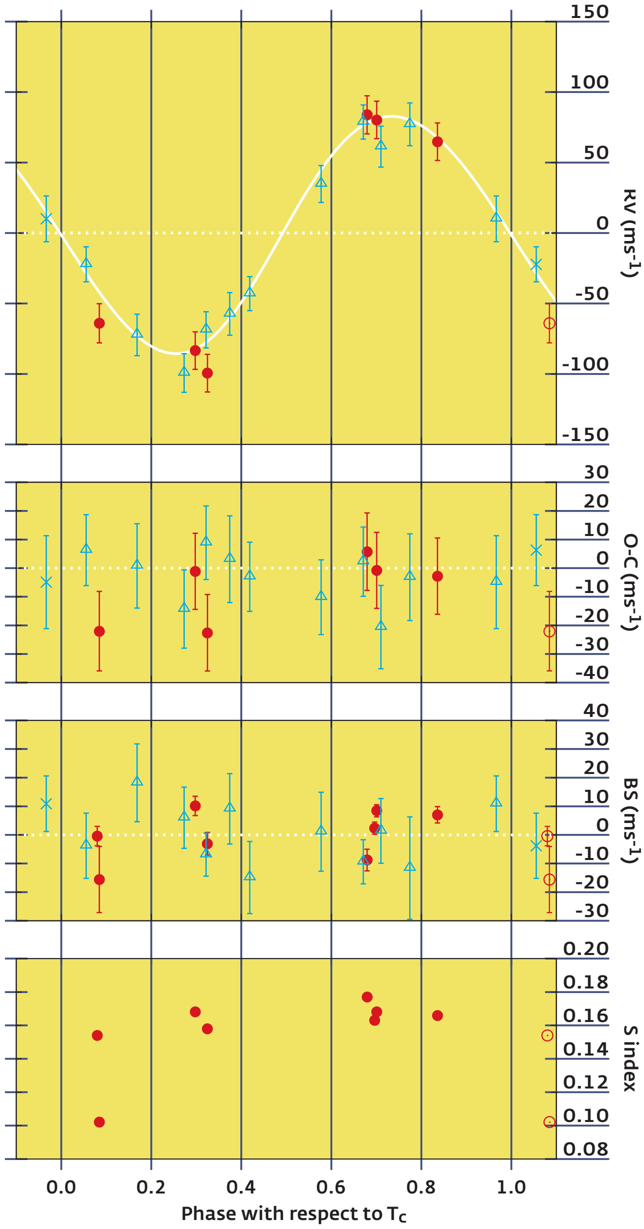


Fig. 27. Top: Radial velocities of HAT-P-28 from Keck/HIRES (filled circles) and FIES (open triangles) as a function of orbital phase from mid-transit, with our best-fit orbit. Second panel: Residuals from the fit; the scatter is 16.1 $m\ s^{-1}$ for Keck/HIRES and 10.1 $m\ s^{-1}$ and for FIES. Third panel: Line bisector spans, and Bottom: Chromospheric activity index S from Keck as functions of orbital phase. Note the different vertical scales.

wide-field transit survey HATNet. This is even more critical than for Kepler, because the less precise photometry contains more false positives. Fig. 27 shows a joint NOT+Keck orbit for the planet HAT-P-28b; note that the NOT velocities have the smallest scatter (!). Line asymmetries and chromospheric emission indices that might indicate stellar activity are also shown; they show no correlation with orbital phase.

L. Buchhave, Copenhagen; and the Kepler follow-up team

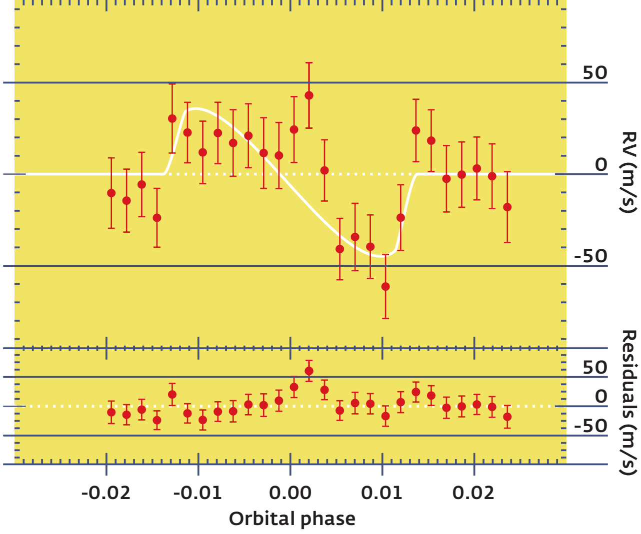


Fig 28: The observed radial-velocity shift (RM effect) as WASP-38b passes in front of its host star. The symmetrical shape shows that its orbit is well aligned.

Orbital evolution of extrasolar planets

The discovery of now ~500 exoplanets has revolutionised our understanding of planet formation and evolution. A quarter of these exoplanets are Jupiter-sized bodies orbiting with periods of just a few days. Theory predicts that these planets, known as 'hot Jupiters', formed far from their host stars, where there is enough cool material to create such massive bodies. However, the mechanism by which they then migrate to their present location is a hotly debated topic.

Several processes have been proposed to explain this migration, including interactions with the proto-planetary disc or gravitational perturbations by other planets or stars. The degree of alignment between the planet's orbit and the rotation axis of the star is a clue to distinguish between them, and this can be measured if the planet is seen to transit the disk of its host star. During the transit, the planet not only dims the overall brightness of the star, but also distorts the shape of its spectral lines. This distortion causes a displacement of the net position of the lines and is measured as a radial-velocity shift known as the Rossiter-McLaughlin (RM) effect.

By observing the shape of this radial-velocity shift during transit we can reconstruct the trajectory of the planet across the stellar surface. In 2010, we used FIES to observe the RM effect caused by the planets WASP-38b and HAT-P-8b. Both appear to have well aligned orbits (Figs. 28 and 29). This may suggest that they underwent a rather gentle migration process, such as a planet-disc interaction. In contrast, about one-third of the observed planets are found to have misaligned orbits (see below). This indicates that more violent processes, perhaps involving a third body, must be at work in these systems. It is possible that WASP-38b and HAT-P-8b also underwent such processes, but became aligned over time. Continued studies will help determine the nature and relative importance of the mechanisms involved in the evolution of planetary systems.

E. Simpson, D. Pollacco, Belfast; I. Skillen, ING;
P. Sørensen, P. Wilson, NOT

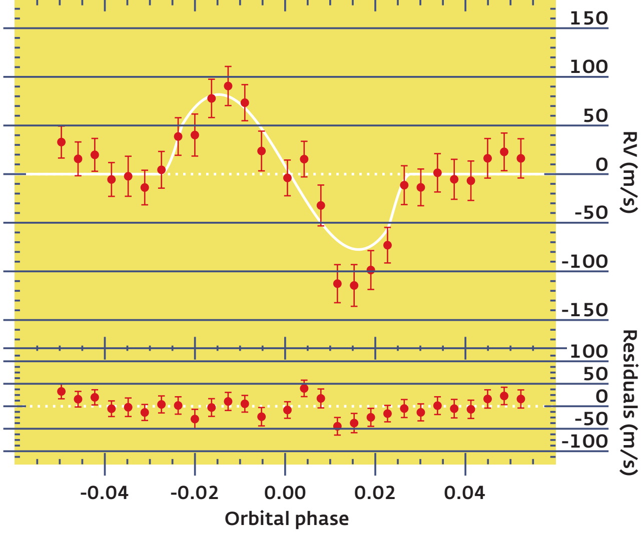


Fig 29: The RM effect in HAT-P-8b. It is similar in shape to WASP-38b and is also well aligned.

Doppler imaging of a hot Jupiter in a retrograde, tilted orbit

Another way to characterise the orbit of a transiting exoplanet is through Doppler imaging as its shadow crosses the disk of the host star, like a star spot on a rotating star (see above). The orbital properties of the planet can then be determined even though the star itself may be too hot and/or rotate too fast to measure the accurate radial velocities needed to determine the mass of the planet.

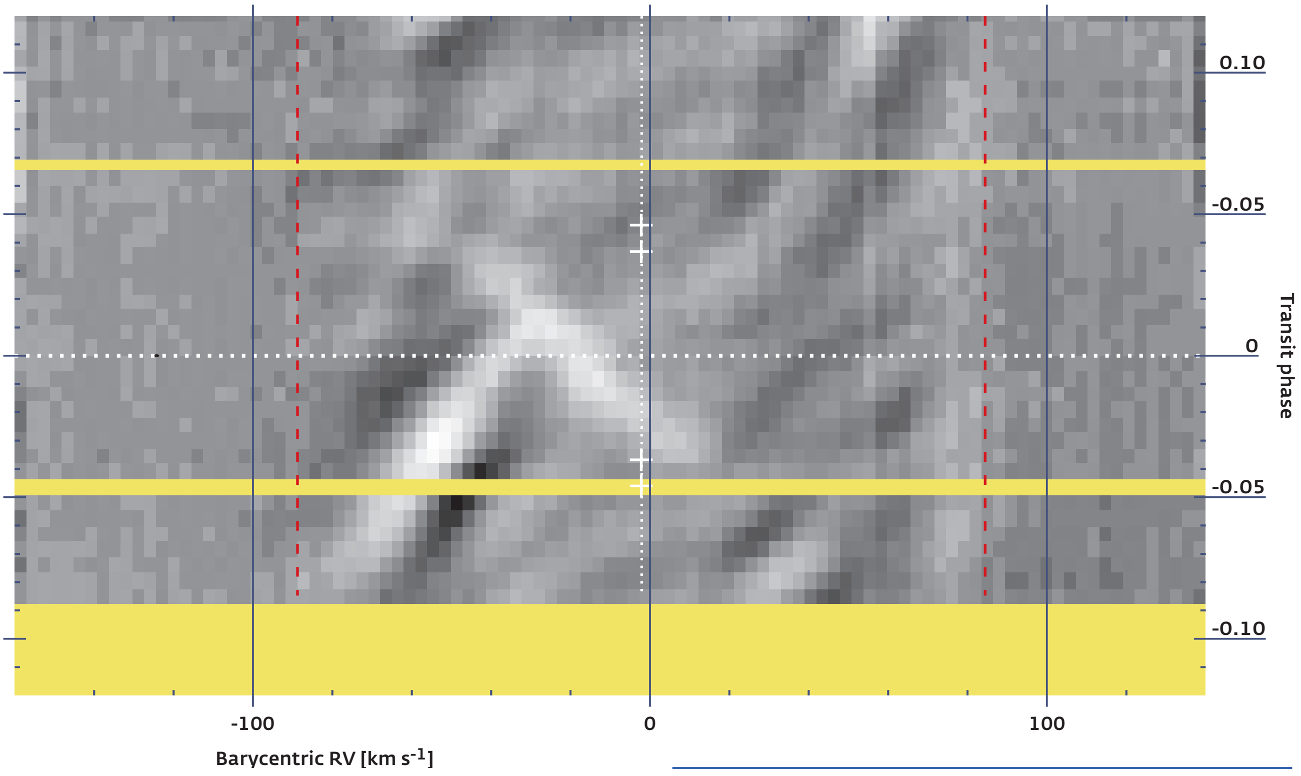
The transiting hot Jupiter WASP-33b is such a case. The host is a young A-type star rotating at an equatorial speed of 90 km s^{-1}. The broad stellar lines preclude a precise determination of the mass of WASP-33b, but time-resolved spectroscopy provides direct information on its orbit: The shadow of the planet creates a bump in the spectral line at a radial velocity corresponding to its position above the rotating stellar disk, which can be followed through the transit.

Fig. 30: Time-resolved line profiles of WASP-33 (time increasing from the bottom; velocity from left to right). Ingress and egress of the transit are marked by double ticks. The lines spiralling beyond the transit mark non-radial pulsations travelling with the star; they are crossed by the track of the planet orbiting in the opposite sense. Gaps occur when calibration spectra were taken.

Fig. 30 shows the time-resolved spectrum of WASP-33, followed through the transit (bottom to top). First, a high-S/N mean line profile was created by combining all the lines in each 8-min spectrum. Then an average symmetric profile was subtracted to highlight the subtle features superimposed on each mean profile. This reveals a spiral-like pattern of stationary pulsation waves travelling from the approaching (blue-shifted) to the receding (red-shifted) side of the star, independent of the transit.

The short planet track is starkly different: First, the planet enters the receding side of the disk and exits the approaching side; i.e. *opposite* to the rotation of the star. Second, it does not cross the disk centrally, but the orbit is slightly inclined to our line of sight. Third, it enters and exits the disk at different velocities, hence distances, from the stellar rotation axis, so its orbit must be inclined from that axis. Finally, this configuration was reached with a host star less than 400 Myr old. A detailed model fit provides the details.

A. Collier Cameron, St. Andrews, and the SuperWASP team; J. Andersen, T. Augusteijn, J. Telting, NOT



Exoplanets as blue as Neptune

Most of our knowledge of exoplanet properties relies on the transiting systems (se above). However, polarimetry is a powerful tool for exploring even non-transiting exoplanets directly: Starlight scattered by the planetary atmosphere exhibits linear polarization, which varies as the planet orbits the star. This variation is a function of the orbital and physical parameters of the planet, notably its mass, radius and density, and is also a direct probe of its atmosphere.

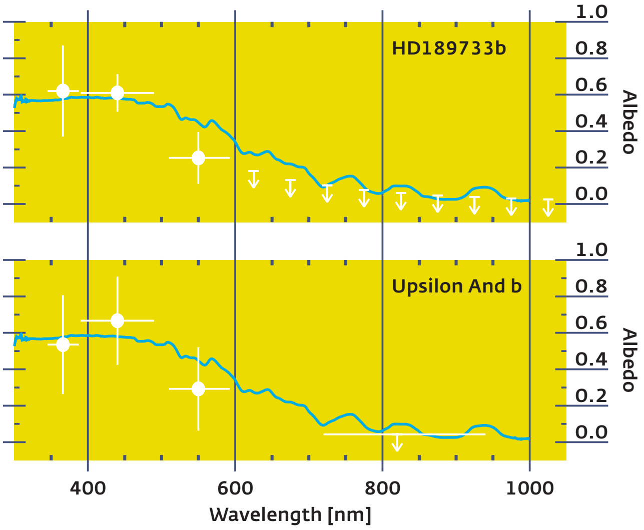


Fig. 31. Geometrical albedos of Neptune (blue curve), HD189733 (top) and υ And (bottom), derived from our UBV polarimetry (dots). 1-σ error bars and upper limits (downward arrows) are shown. Like Neptune, the exoplanets reflect most of the light in the blue.

Demands on observational accuracy are extremely high, but TurPol at the NOT is the world's most accurate night-time polarimeter at blue wavelengths, so in 2008 we started a polarimetric survey of nearby hot Jupiters. With TurPol we can achieve a polarimetric accuracy of $\leq 10^{-5}$ on a nightly basis and detect the light reflected from the planet.

The transiting hot Jupiter HD189733b is only 0.03 AU from its host star (ten times closer than Mercury to the Sun). Methane and water have been detected in its atmosphere. Our observations revealed a strong wavelength dependence of its geometric albedo with a maximum in the blue, strikingly similar to Neptune, which appears blue due to Rayleigh scattering on hydrogen molecules and to absorption by methane in the red (Fig. 31a). The non-transiting hot Jupiter υ And b shows a very similar spectral shape (Fig. 31b).

Our *UBV* measurements of the Stokes *q* and *u* parameters of υ And b, 0.06 AU away from its host star, show the polarization to peak between the elongations and periastron epoch of the slightly eccentric orbit (Fig. 32). The polarization in *q* and *u* is about $6\pm1\times10^{-5}$ in *B*; somewhat smaller in *U* and about a factor two lower in *V*. Averaging the *UBV* bands yields a mean optical amplitude of $49\pm5\times10^{-6}$, the highest accuracy achieved so far.

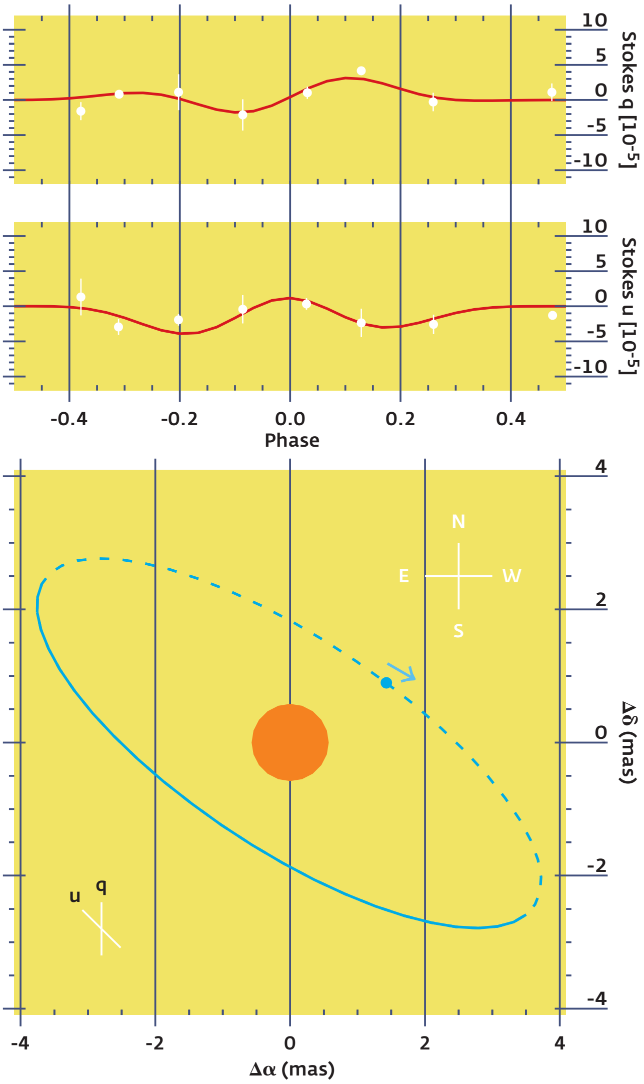
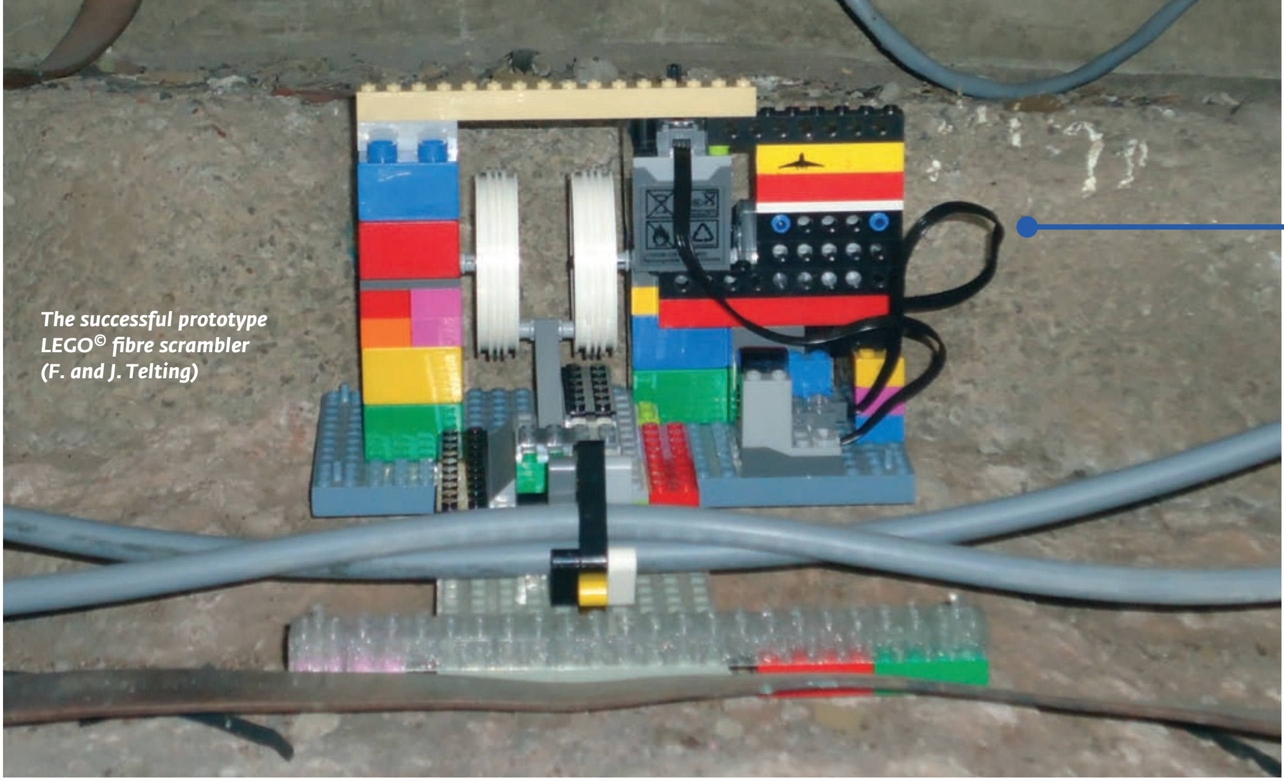


Fig. 32. Top: TurPol measurements of Stokes q and u for the hot Jupiter υ And b, averaged over UBV (dots). The red curve is the model fit. Bottom: The orbit of the planet as projected on the sky.

Our data yield a first determination of the orbital inclination (111°), an average effective size of the planet of 1.36 R_{Jup}, a mean density of only 0.36 g cm^{-3} and a surface gravity of $\sim 10^3$ cm s^{-2}. These identify υ And b as a rather inflated hot Jupiter, similar to the transiting planets HD209458b, WASP-1b, HAT-P-9b, and others.

The high blue albedos indicate the presence of high-altitude clouds, which are expected for some very hot Jupiters. This is in line with an unidentified absorption in the UV in υ And b that can cause a temperature inversion in the upper atmosphere. Altogether, our data demonstrate the power of polarimetry for direct studies of exoplanetary atmospheres, especially for non-transiting planets.

S. Berdyugina, Freiburg and Turku;
A. Berdyugin, V. Piirola, Turku


The successful prototype LEGO© fibre scrambler (F. and J. Telting)

The task of refining a fully streamlined operation of the telescope and instruments continues. Specific points of attention in 2010 were the integration of the new CCD controller with the sequencer system and various experiments to improve the precision of radial velocities measured with FIES. Planning for the next steps also entered an active stage.

Telescope

2010 saw the final stage of the renewal of the building drive and encoders. After a several months of flawless operation with the old system on standby, the new motors, solid state power amplifiers, and encoders were moved permanently to the telescope control system and the old units removed. With a full set of spares, the system should be ready for another 20 years of active and ever more efficient life.

The last manual component of the old dome design is the side ports for ventilation of the telescope chamber at sunset. They serve us well for the time being, but it would be good to include them in the system that controls everything else, including our safety system. We are considering how to do this.

Instrumentation

Production of the Copenhagen next-generation detector controller continues as a joint project under NOT control, ensuring compatibility with our integrated observing system, the sequencer. Based on a cooperative agreement and mutual visits between Yunnan Observatory, China, and NOTSA, this is also a joint project for the NOT and the Yunnan 2.5m telescope at Lijiang. The controller was installed at Lijiang on a Copenhagen-built FOSC in September, then on two complete CCD camera systems for the Sternberg Astronomical Institute, Moscow. Production of the field model is now proceeding on an assembly-line basis; commissioning at the NOT and other observatories is foreseen in 2011, first on ALFOSC, then at NOTCam and FIES.

ALFOSC and NOTCam continue to work well and remain very competitive; the latter received new high-quality filters for the Y and Z bands (1.0 and 0.9 µm) – see the front cover. Yet, the need to change instruments is an impediment to full flexibility when observing rapidly varying transients across the full optical-NIR wavelength range. In 2011 we therefore plan to contract a full feasibility study for a new, powerful combined imager and spectrograph for the NOT, patterned after the very successful Xshooter at the ESO VLT; this would then become the permanent instrument at the main focus.

The new fibre bundle for FIES gave improved throughput and a working sky fibre. Unexpectedly, however, the accuracy of radial-velocity measurements with the medium-resolution fibre degraded considerably, which is a problem for spectroscopic follow-up of exoplanet discoveries (see previous pages). Several remedies were tested, but without decisive success. One possibility was that a variable non-uniform illumination might propagate from the fibre entrance to the exit, but might be averaged out by moving a section of the fibre slightly, but frequently during the integration.

As a test, an interim fibre "shaker" or "scrambler" to move the fibre cable a few cm every couple of seconds was built from LEGO building blocks, motors and controllers, courtesy of Felix Telting (see photo). The test was very promising, but as the owner eventually demanded his LEGO back, we are now designing a more permanent device.

EDUCATION

Students observing with the NOT from summer school at Onsala.

General

As part of the future role of the NOT in European astronomy, we now offer a full suite of educational services for students at levels from high school to PhD. These range from on-site or off-site observing courses by remote access from any classroom in the world to our Research Studentships, where students enjoy a year of hands-on training on La Palma. A general overview of these services was given in the Annual Report for 2009, and a step-by-step handbook, with links to previous events, is now provided at *http://www.not.iac.es/education/* .

Multi-wavelength courses

In 2009 we ventured beyond the traditional borders of optical and near-infrared (NIR) astronomy: Future Nordic astronomers will use a full range of ground- and space-based observing facilities from X-rays to radio waves, and a multi-wavelength approach will be essential for success. As Nordic astronomers also have access to front-line X-ray, optical, infrared and millimetre facilities through the European Southern Observatory (ESO) and the European Space Agency (ESA), students will want to know how to use them.

NOTSA and Onsala Space Observatory, Sweden, are leading this approach at the Nordic level, with support from NordForsk. A first grant helped us to engage a postdoc in this development. As a direct spinoff, we are organising a series of Nordic *Research Infrastructure Training Courses* together with the FINCA Centre and Tuorla Observatory, Finland. The first course, *Star Formation in the Milky Way and Nearby Galaxies*, took place at Tuorla in June 2009; the second one, *Extragalactic Astronomy in the ALMA Era*, at Onsala on June 14-23, 2010. A third course, *Young Stars Across Time and Wavelengths*, again at Tuorla, is already approved for June 2011.

The courses offer hands-on observations with the NOT in remote mode at optical wavelengths, and with the 20-m Onsala radio telescope at millimetre wavelengths. With new data from the *Spitzer* and *Herschel* space observatories and the impending commissioning of ALMA, emphasis will progressively shift from the smaller Nordic facilities to the new ground- and space-based instruments and to archival research, but the hands-on element will be preserved. A total of 60 mostly Nordic-Baltic students were selected from 130 applicants for these three courses, with an exact 50/50% balance between females and males, reflecting the good balance already seen among the applicants.

Daytime lectures on theory and reduction and interpretation of the observations are given by international experts. Pre-defined observing projects are conducted in groups of typically 4 students, with reports prepared in the format of research papers for a major international journal. The courses are demanding, rated at the equivalent of 6 ECTS, but students have been very enthusiastic and hard-working and clearly enjoyed themselves, as also evident in their course evaluations. Sauna and barbecue parties on the weekend provide relief from the long working days and help to form lasting friendships among the young generation.

Research Studentships

The pinnacle of our educational offers is the NOT Research Student programme. It offers up to six students the opportunity to spend ~one year on La Palma to familiarise themselves with all aspects of modern observational astronomy in an international setting while working on their PhD or MSc theses. Some 35 students so far have participated in this programme over the last decade, over 80% of whom are still active in astronomy or related professions – another very tangible benefit from the NOT.

Our 2009-2010 "Synnøve Irgens-Jensen Distinguished Research Student", Tiina Liimets of Estonia, presents her farewell gift to the NOT group to Thomas Augusteijn.

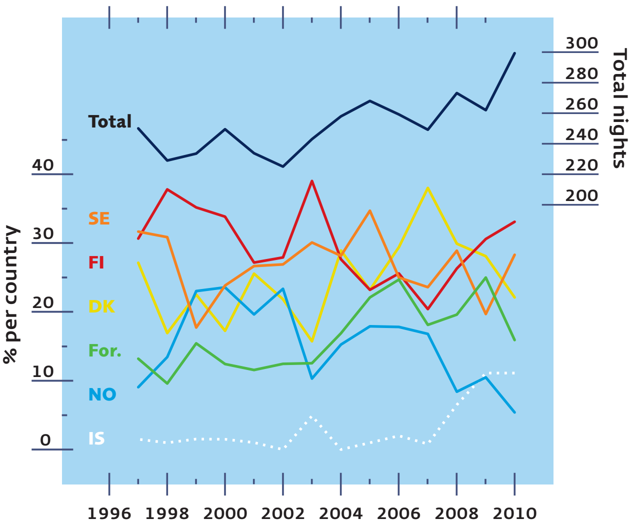
Observing time is the key scientific asset of a telescope. Competition for time is strong, so the review and allocation process must be seen as competent, transparent, and impartial.

Time allocation procedure

Calls for Proposals for observing time at the NOT are announced widely. Proposal deadlines are the first working days of May and November for the semesters beginning the following October 1 and April 1. However, projects needing up to 4 hours of observing time can be proposed at any time by a simplified 'Fast-track' procedure; (see *http://www.not.iac.es/observing/proposals/*); approved projects are then executed in queue mode by the NOT staff on regularly scheduled service nights.

The *Observing Programmes Committee* (OPC; inside back cover), appointed by the Council, peer reviews the proposals; each member has a substitute to broaden scientific coverage and resolve any conflicts of interest. The OPC ranks the proposals on a numerical scale and advises applicants on potential improvements; technical feasibility is assessed by the NOT staff, with separate feedback to proposers. The Director then prepares the observing schedule based on the OPC ranking and such practical constraints as object visibility, Moon phase, etc.

NOT observing proposals were traditionally reviewed regardless of national origin. "Foreign" interest in NOT was always keen, and the OPTICON trans-national access programme (see *http://www.astro-opticon.org/fp7/tna/*) raised the level of such (unpaid!) time to an untenable ~25%. The NOTSA Council therefore decided that all non-Nordic proposals must in the future be submitted to the common OPTICON proposal submission and review procedure comprising most European 2-4m telescopes, with a total cap of 15% or 40 nights per year. This rule was introduced in 2010, and the pressure for NOT time allocated through OPTICON has been dramatic.



Total nights allocated annually by NOT in 1997-2010 (top), and the Nordic and "foreign" shares.

Observing time in 2010

Observing statistics are compiled by allocation period, so this report covers the year April 1, 2010, to April 1, 2010. The *"pressure factor"* (nights requested/nights avail¬able) was 2.1. In total, 314 nights were used for scientific observations, including the 25% of all time that is reserved for Spanish and CCI international projects. 243 nights were available to the Nordic community, including training courses (11 nights). 22 nights or 7% were allocated to projects by NOT staff and 47.5 nights or 16% to non-Nordic ("foreign", predominantly OPTICON) projects. The remaining Nordic time was distributed as follows: Denmark 51 nights (22%), Finland 76 (33%), Iceland 25 (11%), Norway 13 (5%), and Sweden 65 (28%), assigning "nationality" by the affiliation of the P.I.

Instrument use, including fast-track and technical time, was as follows: ALFOSC 137.5 nights (36%), FIES 121 (31%), NOTCam 78 (20%), MOSCA 16 (4%), SOFIN 17.5 (4%), TurPol 14 (4%), and visitor instruments 3 nights (1%).

Service observing was provided on a total of 99 scheduled service nights in 2010, again an increase from 2009, but also on parts of many technical and visitor nights. The "fast-track" proposal option also sees increasing demand, with a total of 46 accepted proposals in 2010; 35, 9, and 2 of these were rated as Grade 1, 2, and 3, respectively (1 is highest). Projects remain in the queue for up to three semesters (two full years) if necessary. Completion rates for the 90 proposals received in Periods 38-41 were 89, 95, and 80% for Grades 1, 2, and 3, respectively, but only ~50% for the winter semester 2010-11, which had a record 38% of poor weather.

The national distribution of time fluctuates considerably over time because observing time is allocated by scientific merit, not as national quotas set by the budget (see figure). Over the last five years, the Nordic time was shared with 28% to Danish projects, 28% to Finland, 6% to Iceland, 11% to Norway, and 25% to Sweden.

The spiral galaxy NGC 7479. Photo: Paul A. Wilson.

FINANCIAL MATTERS

NOTSA is a non-profit organisation funded to operate NOT as a tool for Nordic astronomy. Annual budgets are approved by the Council, and the Director is responsible for managing the operation within budget as specified in the Financial Rules*. For 2010-2013, NOTSA's accounts are audited by the* Office of the Auditor General of Norway*, assisted by a Swedish auditor to comply with Swedish regulations.*

Accounts for 2010

NOTSA's accounts and budget for 2010 are summarised and compared with the accounts for 2009 in the table below. Budget headings cover the following items:

Directorate: Directorate staff and operations, committee travel, audits and bank charges, stipends to Spanish Ph.D. students at Nordic universities, OPTICON and ASTRONET expenses, and this Annual Report.

La Palma staff: Salaries, social charges and training courses, etc. for staff and students on La Palma.

La Palma infrastructure: Telescope and office facilities; electricity, water, and cleaning; computers and networks; and cars and other transportation.

La Palma operations: Accommodation and meals at the observatory for staff and students; communications and shipping; telescope, laboratory, and office equipment and consumables, etc.

Telescope and instrument operation and maintenance: Operation, repair, and spare parts for the telescope and instruments; cryogenics, electronics, optics, and data acquisition and archiving equipment.

Development projects: Major telescope or instrumentation projects, notably new CCD cameras and controllers.

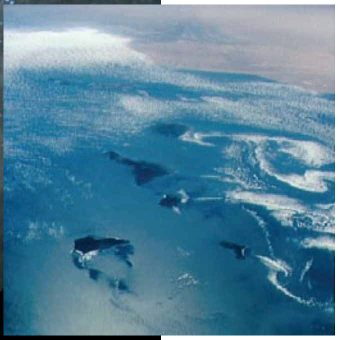
Contributions: A *basic contribution* of € **1 404 100** is shared between Associates as specified in the Agreement (Denmark 19.8%, Finland 29.7%, Iceland 1%, Norway 19.8%, and Sweden 29.7%); *additional contributions* of € **303 000** were contributed in the same proportions.

Other income: Includes bank interest, EC refunds for OPTICON access time, NordForsk grants etc.

Financial result of 2010

As seen in the table, expenses and income in 2010 were essentially on budget; 123 k€ for the provision of new detector systems were transferred to 2011. Funding for the next NordForsk course was received in 2010, but is credited to 2011, when those expenses will occur.

BUDGET LINE	Expenses 2010 Euro	Budget 2010 kEuro	Expenses 2009 kEuro
Directorate	227 746	228	250
La Palma staff	1 202 486	1 202	1 217
La Palma infrastructure	162 550	179	174
La Palma operations	114 300	130	133
Telescope operation and maintenance	9 691	25	17
Instrument operation and maintenance	18 119	43	38
Telescope development projects	94 201	70	1
Special development projects	0	0	0
Total expenses	**1 829 093**	**1 877**	**1 829**
Contributions	1 707 100	1 707	1 624
Other income	64 610	60	146
Total income	**1 771 710**	**1 767**	**1 769**
Result of the year	**-57 383**	**-110**	**-60**
Reserves at beginning of the year	390 164	390	450
Commitments forwarded to 2011	+123 000		
Reserves at end of the year	455 781	280	390



Photos:
Left: H. Dahle;
below: NASA.

PUBLICATIONS

Publications are the standard indicator of scientific output, and lists of refereed papers based on NOT data are given at http://www.not.iac.es/news/publications. Papers published in 2010 are listed below; for papers with 9 or more authors, the first six names and the total number are given.

International refereed publications

Barzdis, A.: *High-resolution spectroscopy of two metal-poor red giants: HD 232078 and HD 218732*, 2010, MNRAS **408**, 1452

Botticella, M. Trundle, C., Pastorello, A., Rodney, S., et al.: *Supernova 2009kf: an ultraviolet bright type IIP supernova discovered with Pan-STARRS 1 and GALEX*, 2010, ApJ **717**, L52

Bouchy, F., Hebb, L., Skillen, I., Collier Cameron, A., et al.: *WASP-21b: a hot-Saturn exoplanet transiting a thick disc star*, 2010, A&A **519**, A98

Bretherton, C.F., James, P.A., Moss, C., Whittle, M.: *Star-forming galaxies in low-redshift clusters: comparison of integrated properties of cluster and field galaxies*, 2010, A&A **524**, A24

Bruntt, H., Bedding T., Quirion, P.-O., Lo Curto, G., et al.: *Accurate fundamental parameters for 23 bright solar-type stars*, 2010, MNRAS **405**, 1907

Buchhave, L.A., Bakos, G., Hartman, J.D., et al.: HAT-P-16b: A 4 M_J Planet Transiting a Bright Star on an Eccentric Orbit, 2010, ApJ **720**, 1118

Buta, R., Laurikainen, E., Salo, H., Knapen, J.: *Decreased Frequency of Strong Bars in S0 Galaxies: Evidence for Secular Evolution?*, 2010, ApJ **721**, 259

Casasola, V., Hunt, L., Combes, F., et al.: *Molecular gas in NUclei of GAlaxies (NUGA) XIII. The interacting Seyfert 2/LINER galaxy NGC 5953*, 2010, A&A **510**, A52

Chaplin, W., Appourchaux, T., Elsworth, Y., García, R. et al.: *The asteroseismic potential of Kepler: first results for solar-type stars*, 2010, ApJ **713**, L169

Clausen, J. V., Frandsen, S., Bruntt, H., et al.: *Absolute dimensions of eclipsing binaries. XXVIII. BK Pegasi and other F-type binaries: Prospects for calibration of convective core overshoot*, 2010, A&A **516**, A42

Coe, D., Benítez, N., Broadhurst, T., and Moustakas, L.: *A high-resolution mass map of galaxy cluster substructure: LensPerfect analysis of A1689*, 2010, ApJ **723**, 1678

Collier Cameron, A., Guenther, E., Smalley, B., McDonald I., et al.: *Line-profile tomography of exoplanet transits - II. A gas-giant planet transiting a rapidly-rotating A5 star*, 2010, MNRAS **407**, 507

Contreras, M., Vázquez, R., Miranda, L., Olguín, L., et al.: *Observational study of the multistructured planetary nebula NGC 7354*, 2010, AJ **139**, 1426

Corradi, R.L.M., Munari, U., Greimel, R., Rubio-Díez, M.M., Santander-García, M., Rodríguez-Gil, P. et al.: *The ongoing outburst of the new symbiotic star IPHAS J190832.31+051226.6*, 2010, A&A **509**, L9

Corradi, R.L.M., Valentini, M., Munari, U., Drew, J.E., et al.: *IPHAS and the symbiotic stars . II. New discoveries and a sample of the most common mimics*, 2010, A&A **509**, A41

Covino, S., Campana, S., Conciatore, M. L., D'Elia, V. et al.: *Challenging gamma-ray burst models through the broadband dataset of GRB 060908*, 2010, A&A **521**, A53

D'Andrea, C. Sako, M. Dilday, B. Frieman, J. et al.: *Type II-P supernovae from the SDSS-II supernova survey and the standardized candle method*, 2010, ApJ **708**, 661

Decarli, R., Dotti, M., Montuori, C., Liimets, T., Ederoclite, A:. *The peculiar optical spectrum of 4C+22.25: Imprint of a massive black hole binary?*, 2010, ApJ **720**, L93

Decarli, R., Falomo, R., Treves, A., Kotilainen, J., et al.: *The quasar ($M_{BH} - M_{host}$) relation through cosmic time - I. Data set and black hole masses*, 2010, MNRAS **402**, 2441

Delgado, A.J., Djupvik, A.A., and Alfaro E.J.: *Analysis of the stellar population in the central area of the HII region Sh 2-284*, 2010, A&A **509**, A104

Dilday, B., Bassett,, B. Becker, A., Bender, R. et al.: *A measurement of the rate of type Ia supernovae in galaxy clusters from the SDSS-II supernova survey*, 2010, ApJ **715**, 1021

Dilday, B., Smith, M., Bassett, B., Becker, A. et al.: *Measurements of the rate of type Ia supernovae at redshift $\leq$0.3 from the Sloan Digital Sky Survey II supernova survey*, 2010, ApJ **713**, 1026

Dunham, E., Borucki, W., Koch, D., Batalha, N., et al.: *Kepler-6b: A Transiting Hot Jupiter Orbiting a Metal-rich Star*, 2010, ApJ **713**, L136

Fraser, M., Takáts, K., Pastorello, A., Smartt, S. et al.: *On the progenitor and early evolution of the type II supernova 2009kr*, 2010, ApJ **714**, L280

García-Gil, A., Muñoz-Tuñón, C., Varela A.: *Atmosphere Extinction at the ORM on La Palma: A 20 yr Statistical Database Gathered at the Carlsberg Meridian Telescope*, 2010, PASP **122**, 1109

Gendre B., Klotz A., Palazzi E., et al.: *Testing gamma-ray burst models with the afterglow of GRB 090102*, 2010, MNRAS **405**, 2372

Gezari, S., Rest, A., Huber, M., Narayan, G., Forster, K., et al.: *GALEX and Pan-STARRS1 Discovery of SN IIP 2010aq: The First Few Days After Shock Breakout in a Red Supergiant Star*, 2010 ApJ **720**, L77

Gorosabel J., de Ugarte Postigo A., Castro-Tirado A. et al.: *Simultaneous polarization monitoring of supernovae SN 2008D/XT 080109 and SN 2007uy: isolating geometry from dust*, 2010, A&A **522**, A14

Grillo, C., Eichner, T., Seitz, S., Bender, R., Lombardi, M., Gobat, R., Bauer A.: *Golden gravitational lensing systems from the Sloan Lens ACS Survey. I. SDSS J1538+5817: one lens for two sources*, 2010, ApJ **710**, 372

Hayden, B., Garnavich, P., Kessler, R., Frieman, J. et al.: *The rise and fall of type Ia supernova light curves in the SDSS-II supernova survey*, 2010, ApJ **712**, 350

Hayden, B., Garnavich, P., Kasen, D., Dilday, B., et al.: *Single or double degenerate progenitors? Searching for shock emission in the SDSS-II type Ia supernovae*, 2010, ApJ **722**, 1691

Holland, S.T., Sbarufatti, B., Shen, R.F., Schady, P. et al.: *GRB 090417B and its Host Galaxy: A Step Toward an Understanding of Optically Dark Gamma-ray Bursts*, 2010, ApJ **717**, 223

Hrudková, M., Skillen I., Benn C.R., Gibson N.P., Pollacco D., Nesvorný D. et al.: *Tight constraints on the existence of additional planets around HD 189733*, 2010, MNRAS **403**, 2111

Hubrig, S., Ilyin, I., Schöller, M.: *Measurements of mean longitudinal magnetic fields in the Of?p stars HD 108 and HD 191612*, 2010, AN **331**, 781

Hubrig, S., Savanov, I., Ilyin, I., González, J. F., et al.: *The magnetic field and the evolution of element spots on the surface of the HgMn eclipsing binary AR Aur*, 2010, MNRAS **408**, L61

Irwin, J., Buchhave, L.A., Berta, Z., Charbonneau, D. et al.: *NLTT 41135: A field M dwarf + brown dwarf eclipsing binary in a triple system, discovered by the MEarth observatory*, 2010, ApJ **718**, 1353

Järvinen, S., Berdyugina S.: *Imaging of stellar surfaces with the Occamian approach and the least-squares deconvolution technique*, 2010, A&A **521**, A86

Joshi, S., Ryabchikova, T., Kochukhov, O. et al.: *Time-resolved photometric and spectroscopic analysis of the luminous Ap star HD103498*, 2010, MNRAS **401**, 1299

Kann, D., Klose, S., Zhang, B., et al.: *The Afterglows of Swift-era Gamma-ray Bursts. I. Comparing pre-Swift and Swift-era Long/Soft (Type II) GRB Optical Afterglows*, 2010, ApJ **720**, 1513

Kocevski, D., Thöne, C., Ramirez-Ruiz, E., Bloom, J. et al.: *Limits on radioactive powered emission associated with a short-hard GRB 070724A in a star-forming galaxy*, 2010, MNRAS **404**, 963

Koch, D., Borucki, W., Rowe, J., Batalha, N. et al.: *Discovery of the Transiting Planet Kepler-5b*, 2010, ApJ **713**, L131

Koester, B., Gladders, M., Hennawi, J., Sharon, K. et al.: *Two Lensed $z\sim3$ Lyman Break Galaxies Discovered in the SDSS Giant Arcs Survey*, 2010, ApJ **723**, L73

Korhonen, H., Vida, K., Husarik, M., Mahajan, S.: *Photometric and spectroscopic observations of three rapidly rotating late-type stars: EY Dra, V374 Peg, and GSC 02038-00293*, 2010, AN **331**, 772

Latham, D.W., Borucki, W., Koch, D., Brown, T. et al.: *Kepler-7b: a transiting planet with unusually low density*, 2010, ApJ **713**, L140

Laurikainen, E., Salo, H., Buta, R., Knapen, J., Comerón, S.: *Photometric scaling relations of lenticular and spiral galaxies*, 2010, MNRAS **405**, 1089

de León, J., Licandro, J., Serra-Ricart, M., Pinilla-Alonso, N., Campins H.: *Observations, compositional, and physical characterization of near-Earth and Mars-crosser asteroids from a spectroscopic survey*, 2010, A&A **517**, A23 de León, J., Campins,H., Tsiganis, K., Morbidelli, A., Licandro, J.: *Origin of the near-Earth asteroid Phaethon and the Geminids meteor shower*, 2010, A&A **513**, A26

López, R., García-Lorenzo, B., Sánchez, S., et al.: *The complex structure of HH 110 as revealed from Integral Field Spectroscopy*, 2010, MNRAS **406**, 2193

López-Sánchez, Á.: *Massive star formation in Wolf-Rayet galaxies - V. Star-formation rates, masses and the importance of galaxy interactions*, 2010, A&A **521**, A63

López-Sánchez, Á.R. Esteban, C.: *Massive star formation in Wolf-Rayet galaxies. IV. Colours, chemical-composition analysis and metallicity-luminosity relations*, 2010 A&A **517**, A85

López-Sánchez, Á.R., Esteban, C.: *Massive star formation in Wolf-Rayet galaxies. III. Analysis of the O and WR populations*, 2010 A&A **516**, A104

López-Santiago, J., Montes, D., Gálvez-Ortiz, M.C., et al.: *A high-resolution spectroscopic survey of late-type stars: chromospheric activity, rotation, kinematics, and age*, 2010, A&A **514**, A97

Lüftinger, T., Kochukhov, O., Ryabchikova, T. et al.: *Magnetic Doppler imaging of the roAp star HD24712*, 2010, A&A **509**, A71

Maguire, K., Di Carlo, E., Smartt, S., Pastorello, A. et al.: *Optical and near-infrared coverage of SN 2004et: physical parameters and comparison with other Type IIP supernovae*, 2010, MNRAS **404**, 981

Margutti, R., Genet, F., Granot, J., Duran, R. et al.: *GRB081028 and its late-time afterglow re-brightening*, 2010, MNRAS **402**, 46

Martín, E., Phan-Bao, N., Bessell, M. et al.: *Spectroscopic characterization of 78 DENIS ultracool dwarf candidates in the solar neighborhood and the Upper Scorpii OB association*, 2010, A&A **517**, A53

Martínez, M., Del Olmo, A., Coziol, R., Perea J.: *AGN population in Hickson compact groups. I. Data and nuclear activity classification*, 2010, AJ **139**, 1199

Melandri, A., Kobayashi, S., Mundell, C., Guidorzi, C. et al.: *GRB 090313 and the origin of optical peaks in gamma-ray burst light curves: implications for Lorentz factors and radio flares*, 2010, ApJ **723**, 1331

Meléndez, J., Casagrande, L., Ramírez, I., Asplund, M., Schuster, W. J.: *Observational evidence for a broken Li Spite plateau and mass-dependent Li depletion*, 2010, A&A **515**, L3

Metcalfe, T., Monteiro, M., Thompson, M. et al.: *A precise asteroseismic age and radius for the evolved sun-like star KIC 11026764*, 2010, ApJ **723**, 1583

Micheva, G., Zackrisson, E., Östlin, G., Bergvall, N., Pursimo, T.: *The faint outskirts of the blue compact galaxy Haro 11: is there a red excess?*, 2010, MNRAS **405**, 1203

Moreno, F., Licandro, J., Tozzi, G.-P., Ortiz, J.L., Cabrera-Lavers, A., Augusteijn, T. et al.: *Water-ice-driven Activity on Main-Belt Comet P/2010 A2 (LINEAR)?*, 2010, ApJ **718**, L132

Nissen, P.E., Schuster, W.J.: *Two distinct halo populations in the solar neighborhood; eidence from stellar abundance ratios and kinematics*, 2010, A&A **511**, L10

Oláh, K., Korhonen, H., Vida, K., Ilyin, I., Dall, T.H., Järvinen, S.P. et al.: *Young solar type active stars: the TYC 2627-638-1 system*, 2010, A&A **515**, A81

Pandey, S., Swenson, C., Perley, D., Guidorzi, C. et al.: *GRB 090902B: Afterglow observations and implications*, 2010, ApJ **714**, 799

Pastorello, A., Botticella, M., Trundle, C., et al.: *Multiple major outbursts from a restless luminous blue variable in NGC 3432*, 2010, MNRAS **408**, 181

Pastorello, A,. Smartt, S., Botticella, M., Maguire, K,. et al.: *Ultra-bright optical transients are linked with type Ic supernovae*, 2010, ApJ **724**, L16

Puzeras, E., Tautvaišienė, G., Cohen, J., Gray, D., et al.: *High-resolution spectroscopic study of red clump stars in the Galaxy: iron-group elements*, 2010, MNRAS **408**, 1225

Ramsay, G., Kotko, I., Barclay, T., Copperwheat, C., Rosen, S., Simon Jeffrey, C. et al.: *Multi-wavelength observations of the helium dwarf nova KL Dra through its outburst cycle*, 2010, MNRAS **407**, 1819

Rau, A., Roelofs, G.H.A., Groot, P.J., et al.: *A Census of AM CVn Stars: Three New Candidates and One Confirmed 48.3-Minute Binary*, 2010, ApJ **708**, 456

Reig, P., Zezas, A., Gkouvelis, L.: *The optical counterpart to IGR J06074+2205: a Be/X-ray binary showing disc loss and V/R variability*, 2010, A&A **522**, A107

Reylé, C., Delorme, P., Willott, C.J., Albert, L. et al.: *The ultracool-field dwarf luminosity-function and space density from the Canada-France Brown Dwarf Survey*, 2010, A&A **522**, A112

Rowlinson, A., Wiersema, K., Levan, A., Tanvir, N. et al.: *Discovery of the afterglow and host galaxy of the low-redshift short GRB 080905A*, 2010, MNRAS **408**, 383

Sánchez Contreras, C., Cortijo-Ferrero, C., Miranda, L., Castro-Carrizo, A., Bujarrabal V.: *Fast, gusty winds blowing from the core of the pre-planetary nebula M 2-56*, 2010, ApJ **715**, 143

Schwamb, M., Brown, M., Rabinowitz, D., Ragozzine, D.: *Properties of the distant Kuiper belt: results from the Palomar distant solar system survey*, 2010, ApJ **720**, 1691

Simón-Díaz, S.: *The chemical composition of the Orion star forming region. I. Homogeneity of O and Si abundances in B-type stars*, 2010, A&A **510**, A22

Simón-Díaz, S., Herrero, A., Uytterhoeven, K., Castro, N., Aerts, C., Puls J.: *Observational Evidence for a Correlation Between Macroturbulent Broadening and Line-profile Variations in OB Supergiants*, 2010, ApJ **720**, L174

Steffen, J., Batalha, N., Borucki, W., Buchhave, L.A. et al.: *Five Kepler target stars that show multiple transiting exoplanet candidates*, 2010, ApJ **725**, 1226

Street, R., Simpson, E., Barros, S., Pollacco, D. et al.: *WASP-24 b: A new transiting close-in hot Jupiter orbiting a late F-star*, 2010, ApJ **720**, 337

Tautvaišienė, G., Edvardsson, B., Puzeras, E., Barisevičius, G., Ilyin I.: *C, N and O abundances in red clump stars of the Milky Way*, 2010, MNRAS **409**, 1213

Thöne, C., Kann, D., Jóhannesson, G. et al.: *Photometry and spectroscopy of GRB 060526: a detailed study of the afterglow and host galaxy of a z = 3.2 gamma-ray burst*, 2010, A&A **523**, A70

Torrejón, J., Negueruela, I., Smith, D., Harrison, T.: *Near-infrared survey of high mass X-ray binary candidates*, 2010, A&A **510**, A61

Väisänen, P., Kotilainen, J., Juvela, M., Mattila, K. et al.: *A far-infrared survey at the North Galactic Pole - I. Nearby star-forming galaxies and effect of confused sources on source counts*, 2010, MNRAS **401**, 1587

Villforth, C., Nilsson, K., Heidt, J., Takalo, L.O., Pursimo, T. et al.: *Variability and stability in blazar jets on time scales of years: Optical polarization monitoring of OJ287 in 2005-2009*, 2010, MNRAS **402**, 2087

Vornanen, T., Berdyugina, S., Berdyugin, A., Piirola, V.: *GJ 841B - the second DQ white dwarf with polarized CH molecular bands*, 2010, ApJ **720**, L52

Willott , C.J., Delorme, P., Reylé, C., Albert, L., Bergeron, J., Crampton, D. et al.: *The Canada-France High-z Quasar Survey: Nine New Quasars and the Luminosity Function at Redshift 6*, 2010, AJ **139**, 906

Zapatero Osorio, M., Rebolo, R., Bihain, G., Béjar, V. et al.: *Infrared and kinematic properties of the substellar object G 196-3 B*, 2010, ApJ **715**, 1408

Zhang, Z., Pinfield, D., Day-Jones, A., Burningham, B. et al.: *Discovery of the first wide L dwarf + giant binary system and eight other ultracool dwarfs in wide binaries*, 2010, MNRAS **404**, 1817

Østensen, R.H., Oreiro, R., Solheim, J.-E., Heber, U. et al.: *A survey for pulsating subdwarf B stars with the Nordic Optical Telescope*, 2010, A&A **513**, A6

Østensen, R.H., Silvotti, R., Charpinet, S., Oreiro, R., et al.: *First Kepler results on compact pulsators I. Survey target selection and the first pulsators*, 2010, MNRAS **409**, 1470

Other publications

Baran, A., Telting, J.H., Østensen, R., Winiarski, M., Drozdz, M., Koziel, D., Reed, M., Oreiro, R., Silvotti, R., Siwak, M., Heber, U., Papics, P.: *Constraining the degree of the dominant mode in* QQ Vir, 2010, Ap&SS **329**, 199

Barisevičius, G., Tautvaišienė, G., Berdyugina, S., Chorniy, Y., Ilyin, I.: *Chemical Composition of the RS CVn-type Star 29 Draconis*, 2010, BaltA **19**, 157

Creevey, O. L., Telting, J., Belmonte, J. A., Brown, T. M., Handler, G., Metcalfe, T. S., Pinheiro, F., Sousa, S., Terrell, D., Zhou, A.: *Constraints of a pulsation frequency on stellar parameters in the eclipsing spectroscopic binary system V577 Oph*, 2010, AN **331**, 952

Oreiro, R., Telting, J. H., Østensen, R. H., Briquet, M., Aerts, C., Heber, U., Vučkovic, M.: *Synthetic pulsational line profile variations*, 2010, Ap&SS **329**, 211

Tautvaišienė, G., Barisevičius, G., Berdyugina, S., Chorniy, Y., Ilyin I.: *Chemical Composition of the RS CVn-type Star Lambda Andromedae*, 2010, BaltA **19**, 95

Østensen, R. H., Telting, J. H., Oreiro, R., Heber, U., de Beck, E., Reed, M.: *Time-resolved spectroscopy of the sdBV V338 Serpentis*, 2010, Ap&SS **329**, 167

OTHER PUBLICATIONS BY NOT STAFF

Refereed publications

Augusteijn, T., Tappert, C., Dall, T., Maza, J.: *Cataclysmic variables from the Calán-Tololo Survey - II. Spectroscopic periods*, 2010, MNRAS **405**, 621

Juul Hansen, C., Nordström, B., Bonifacio, P., Spite, M., Andersen, J., Beers, T.C. et al.: *First Stars XIII. Two metal-poor RR Lyrae stars*, 2010, A&A **527**, A65

Kawaler, S. D., Reed, M. D., Østensen, R. H., Bloemen, S., Kurtz, D. W., Quint, A. C., Silvotti, R., Baran, A. S., Green, E. M., Charpinet, S., Telting, J., Aerts, C., Handler, G., Kjeldsen, H. Christensen-Dalsgaard, J., Borucki, W. J., Koch, D. G.: *First Kepler results on compact pulsators - V. Slowly pulsating subdwarf B stars in short-period binaries*, 2010, MNRAS **409**, 1509

Kawaler, S. D., Reed, M. D., Quint, A. C., Østensen, R. H., Silvotti, R., Baran, A. S., Charpinet, S., Bloemen, S., Kurtz, D. W., Telting, J., Handler, G., Kjeldsen, H., Christensen-Dalsgaard, J., Borucki, W. J., Koch, D. G.: *First Kepler results on compact pulsators - II. KIC 010139564, a new pulsating subdwarf B (V361 Hya) star with an additional low-frequency mode*, 2010, MNRAS **409**, 1487

Reed, M. D., Kawaler, S. D., Østensen, R. H., Bloemen, S., Baran, A., Telting, J. H., Silvotti, R., Charpinet, S., Quint, A. C., Handler, G., Gilliland, R. L., Borucki, W. J., Koch, D. G., Kjeldsen, H., Christensen-Dalsgaard, J.: *First Kepler results on compact pulsators - III. Subdwarf B stars with V1093 Her and hybrid (DW Lyn) type pulsations*, 2010, MNRAS **409**, 1496

Torres, G., Andersen, J., Giménez, A.: *Accurate masses and radii of normal stars: Modern results and applications*, 2010, A&ARev **18**, 67

Østensen, R. H., Green, E. M., Bloemen, S., Marsh, T. R., Laird, J. B., Morris, M., Moriyama, E., Oreiro, R., Reed, M. D., Kawaler, S. D., Aerts, C., Vučkovic, M., Degroote, P., Telting, J. H., Kjeldsen, H. Gilliland, R. L., Christensen-Dalsgaard, J., Borucki, W. J., Koch, D.: *2M1938+4603: a rich, multimode pulsating sdB star with an eclipsing dM companion observed with Kepler*, 2010, MNRAS **408**, L51

Published conference proceedings

Barbuy, B., Spite, M., Hill, V., Primas, F., Plez, B., Cayrel, R. et al.: *HST-STIS Abundances in the uranium-rich very metal-poor star CS 31082-001*, 2010, in Chemical Abundances in the Universe: Connecting the First Stars to Planets (Proc. IAU Symp. 265), K. Cunha, M. Spite & B. Barbuy, eds. Cambridge Univ. Press, 119

Djupvik, A.A., Andersen, J.: *The Nordic Optical Telescope*, 2010, in Highlights of Spanish Astronomy V, J.M. Diego et al. (eds.), ApSpSci Proc. **6**, Springer, 211

Telting, J., Østensen, R., Oreiro, R., Heber, U., Vučkovic, M., Randall, S., Baran, A.: *Time-resolved high-resolution spectroscopy of the pulsating sdB star QQ Vir (PG1325+101)*, 2010, Ap&SS **329**, 163

In addition, NOT staff participated in several electronic reports on GRB and minor planet discoveries.

CONTACT ADDRESSES

NOT Operations Group:
Telescopio Nordico
Apartado 474
E – 38 700 Santa Cruz de La Palma
Canarias, Spain

Tel: +34 922 425 470
Fax: +34 922 425 475
E-mail: staff@not.iac.es
WWW: www.not.iac.es

Telescope buildings:
Control room: +34 922 405 660
Service building: +34 922 405 663
Fax: +34 922 405 665

Office of the Director:
Dr. J. Andersen, NOT Director
The Niels Bohr Institute
Astronomy Group
Juliane Maries Vej 30
DK – 2100 Copenhagen Ø
Denmark

Tel: +45 353 25934
Fax: +45 353 25989
E-mail: ja@not.iac.es or
ja@astro.ku.dk

ASSOCIATES AND COUNCIL REPRESENTATIVES

Denmark: The Danish Natural Science Research Council
Prof. Jørgen Christensen-Dalsgaard
Dr. Hans Kjeldsen
Finland: The Academy of Finland
Dr. Antti Väihkönen
Dr. Leo Takalo
Iceland: The University of Iceland
Prof. Gunnlaugur Björnsson
Prof. Einar Gudmundsson
Norway: The Research Council of Norway
Dr. Bjørn Jacobsen (Vice-Chairperson)
Prof. Per B. Lilje
Sweden: The Swedish Research Council
Prof. Nikolai Piskunov (Chairperson)
Dr. Per Karlsson

SCIENTIFIC AND TECHNICAL COMMITTEE

Dr. Hans Kjeldsen (Denmark, Chairperson)
Dr. Leo Takalo (Finland)
Prof. Gunnlaugur Björnsson (Iceland, Vice-Chairperson)
Prof. Per B. Lilje (Norway)
Prof. Nikolai Piskunov (Sweden)

OBSERVING PROGRAMMES COMMITTEE

Dr. Christoffer Karoff (Denmark)
  Dr. Johan Fynbo (subst.)
Dr. Dr. Thomas Hackman (Finland, Chairperson)
  Dr. Seppo Mattila (subst.)
Dr. Vilhelm Sigmundsson (Iceland)
  Dr. Einar Juliusson (subst.)
Dr. Håkon Dahle (Norway)
  Dr. Sven Wedemeier-Böhm (subst.)
Dr. Nils Ryde (Sweden)
  Dr. Oleg Kochuchov (subst.)

Back cover:
The Roques de los Muchachos seen from the NOT,
silhouetted against the Centre of the Milky Way
Photo: H. Dahle

2010

NORDIC OPTICAL TELESCOPE

Roques de los Muchachos and the Milky Way

NORDIC OPTICAL TELESCOPE
Grupo Nordico
Apartado 474
E – 38 700 Santa Cruz de La Palma
Canarias, Spain
www.not.iac.es