



1.8-m MOA telescope at Mt John

**Astronomy at the University of Canterbury
Department of Physics and Astronomy
and Mt John University Observatory —
annual report 2006**

Director: Prof. J.B. Hearnshaw

Report for the period 1 January 2006 to 31 December 2006

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1. Introduction

This is the twenty-eighth annual report of the astronomy group at the department of Physics and Astronomy and Mt John University Observatory. The first report appeared in 1979 and they have been published each year in *Southern Stars* and (until 1995) also in the *Quarterly Journal of the Royal Astronomical Society* (London). Since 1997 the reports are also available on the internet. As there has been some discussion on the usefulness of these reports, I will present here my view as Mt John director.

I see four reasons for producing an annual report:

- It provides accountability for the significant sums of money the University of Canterbury commits to astronomy.
- The report tells future potential students that Canterbury has a flourishing and active astronomy research group – indeed by far the major one in New Zealand.
- The report provides useful information to future scientific visitors and collaborators about our research interests and publications, and about weather statistics at Mt John.
- The report provides an historical record of our activities and outputs which will be useful for anyone who wishes to find out what was happening in Canterbury astronomy up to a few decades ago.

I think the most important of these is the first. We are under ever increasing pressure to justify our expenditure in terms of outputs. In our case outputs are in the form of

publications, student training, student degrees including completed PhD and MSc theses, and also public outreach, which is a considerable activity at Mt John as well as at the Southern African Large Telescope (SALT). Astronomy is unusually expensive amongst the sciences, but fortunately Canterbury astronomers are unusually productive. It is important that those who fund us know this fact and can see how university funds are being spent.

There has been discussion that Canterbury should host New Zealand's National Observatory. Such was the recommendation of a report commissioned by the Ministry of Research, Science and Technology and written by Professor Michael Bessell (ANU, Canberra) in 2005. If that comes about, it would have to be recognized and funded by the Ministry of Research, Science and Technology and there would need to be a resultant contribution to the funding of both Mt John and SALT. Mt John is now used by many groups from most of New Zealand's universities and several overseas universities for research in astronomy, atmospheric physics and geophysics.

2. Staff

In 2006 Professor Phil Butler continued as Head of Department until November. Assoc. Professor Roger Reeves commenced his term as Head in December. Prof. John Hearnshaw continued as Mt John director and Alan Gilmore as Mt John superintendent. Dr William Tobin continued as deputy director of Mt John until April, when he retired.

Dr Michael Albrow continued as University of Canterbury representative on the SALT (Southern African Large telescope) Science Working Group. Albrow visited the Institut d'Astrophysique de Paris for two weeks in December to attend a PLANET meeting. He was elected as an inaugural member of the PLANET science committee.

Assoc. Prof. Peter Cottrell continued as the University of Canterbury's Director on the SALT Board and attended Board meetings in South Africa in May and October. He also continued to serve on the Organizing Committee of IAU Commission 27, Variable Stars until the 2006 IAU General Assembly, when he completed his 6-year tenure on the Commission. Cottrell was appointed to the Editorial Board of the Publications of the Astronomical Society of Australia in November 2006, initially for a three-year term. Cottrell became Deputy Head, department of Physics & Astronomy to the incoming Head, Associate Professor Roger Reeves.



1.0-m McLellan telescope dome and accommodation building at Mt John

Hearnshaw served on the board of IAU Division IX (Optical and infrared techniques) until August; he also continued to serve on the organizing committee of IAU Commission 46 (Astronomy education and development) and he chaired the Commission 46 Program Group for the World-wide Development of Astronomy (PGWWDA). Hearnshaw continued to chair the Royal Society of New Zealand Committee on Astronomical Sciences (RSCAS) during 2006. Hearnshaw served on the Scientific Advisory Committee of the Inter-University Centre for Astronomy and Astrophysics in Pune, India as one of three foreign members on the nine-person committee. In January he visited Pune for a week-long meeting of the committee and he served as chairperson. He also spent a week at the Indian Institute of Astrophysics in Bangalore and gave two seminars there. He visited, while there, the Vainu Bappu Observatory near Kavalur.

Hearnshaw was chair of the Scientific Organizing Committee of a two-day special session of the IAU 26th General Assembly in Prague, on 'Astronomy for the developing world'. He also served on the organizing committees of the Young astronomers' consulting service at the Prague IAU General Assembly, and of the Young astronomers' lunch debate. Hearnshaw was appointed to the Scientific Organizing Committee of the 10th IAU Asia-Pacific regional Meeting, to be held in Kunming, China in 2008.

Hearnshaw presented an invited talk to members of the Royal Society Council in June on astronomy at the University of Canterbury and the work of Mt John. Also in June he gave a public lecture on Matariki - the Pleiades, jointly with PhD student Pauline Harris, to mark the Maori new year. In September he gave a talk in Tekapo to the University of Canterbury Alumni Association on the occasion of their annual visit to Mt John.

In July Dr Karen Pollard became President of the Royal Astronomical Society of New Zealand. She was vice-president before then. She also was a committee member of the RSNZ's Committee on the Astronomical Sciences. In 2006 Pollard continued her work on the Scientific Organizing Committee of IAU Commission 27 "Variable stars".

In April Tobin retired after almost 19 years' service at the University of Canterbury. Amongst his final tasks as Deputy Director of the Observatory was updating the Astronomy Group and Mt John webpages (available via <http://www.phys.canterbury.ac.nz>). He has moved to France where he continues to work on the history of astronomy and unfinished astrophysics projects from Canterbury.

Professor Jack Baggaley continued to serve on the organizing committee of IAU Commission 22, Meteors, meteorites and interplanetary dust. He is also a member of the IAU working group for Meteor Shower Nomenclature. In 2006 Baggaley was awarded the University of Canterbury's research medal for his work on meteor orbits and interplanetary dust.

Gilmore was elected president of IAU Commission 6 (Astronomical telegrams) in August, and he was also elected at the same time to the organizing committee of IAU Commission 20 (Positions and motions of comets). He served as RASNZ Newsletter editor. Pam Kilmartin continued as a member of the IAU Division III (Planetary Systems Sciences) working group for Small Bodies Nomenclature (SBN). She also served as secretary of RASNZ. Gilmore gave talks at Stardate South Island at Staveley in February, at the Dunedin Astronomical Society in October and at the Temuka and Timaru North Rotary in November.

Dr Christine Botzler, from Universität München, Germany, was a postdoctoral fellow in the department from June to December working for the MOA project (see section 9). She was funded by the Deutsche Forschungsgemeinschaft. Dr David Ramm continued as a research associate in astronomy in the department during 2006.

In March, Mike Clark retired from the Department. He was for many years Resident Superintendent at Mt John until he transferred to duties in Christchurch in April 1996.

3. Students

The following students continued throughout the year with their Ph.D. research: Malcolm Cropp: CCD photometry of Galactic clusters (supervisors Albrow and Tobin); Mita Gopal: CNO abundances in the globular cluster ω Centauri (supervisors Albrow, Cottrell and Pollard); Siramas Komonjinda (international student, Thailand): An analysis of southern spectroscopic binaries with nearly circular orbits (supervisors Hearnshaw and Ramm, also Tobin until April); Veronica Miller: A search for extra-solar transiting planets in the Galactic Plane (supervisors Albrow and Jean-Phillipe Beaulieu, IAP, Paris); Judy Mohr: Optical atmospheric turbulence using SCIDAR techniques (supervisors Cottrell, and Drs R.A. Johnston, R.G. Lane, M.D. Albrow); Clare Worley (from Mar 2006): Chemical abundance variations in stars in globular clusters (supervisor Cottrell); Elizabeth Wylie (until August 2006): Nucleosynthesis and s-process element formation in giant stars (supervisor Cottrell); Andrew Rakich: Simple four-mirror anastigmatic systems with at least one infinite conjugate (supervisors Hearnshaw and Tobin; external supervisors Norman Rumsey, Lower Hutt, and Dr Craig Smith, EOS, Canberra); Duncan Wright: A study of non-radially pulsating stars (supervisors Pollard and Cottrell). Mona Mostafavi (international student from Iran) commenced a PhD on gravitational microlensing in August (supervisor Hearnshaw), but was forced to withdraw early in 2007 for health reasons.

Wylie submitted her thesis 'Nucleosynthesis and s-process element formation in giant stars' in August and graduated in December. Komonjinda gave a talk on her doctoral research to the Canterbury Astronomical Society in February. Gopal received a New Zealand Postgraduate Study Abroad Award from Education New Zealand for travel to South Africa to work on the commissioning of the multi-object spectroscopy mode of the Robert Stobie spectrograph on SALT in June and August. In September and October, Miller spent three weeks at the Max Planck Institute for Astronomy in Heidelberg, Germany, working with Dr Cristina Afonso on searching for planetary transits using observations from the European Southern Observatory, La Silla.

The following student undertook MSc thesis research in 2006: Tamsyn McLelland: An historical survey of gravitational microlensing (supervisors Hearnshaw and Pollard). She is a half-time extramural student resident in Wellington. Hearnshaw co-supervised Fabiola Díaz (Universidad de Los Andes, Mérida, Venezuela) for her master's research on the spectrum of the peculiar asymptotic giant branch star, HD101584.

Three students undertook ASTR480 research projects in 2006. They were Christopher Henderson: Constraints on the distance scale of the galactic HI shell GSH 337-00-05 (supervisors Hearnshaw and Ramm); Rachel Soja: Jupiter's gravitational sphere of influence (supervisor Baggaley); Robyn Woollands: Radial-velocity variations in the δ Scuti binary star, RS Cha (supervisor Pollard, with assistance from Wright and Ramm). Jeffrey Simpson undertook an ASTR391 research project (Colour-magnitude diagrams of NGC2419) over the 2006–07 summer, supervised by Albrow. Michele Bannister also did a summer ASTR391 research project (Transects across polygonal patterned ground in the

Dry Valleys of Antarctica: geophysical data for comparison to polygonal features on Mars), supervised by Cottrell and D. Nobes (Geological Sciences).

Two senior undergraduate astronomy students, Michele Bannister and Emily Brunsten, were selected to attend the Winter School in astronomy at the Swinburne University of Technology in Victoria, Australia in July.



Prof. Klaas de Boer and his wife from the Argelander Institute, Bonn, Germany. Klaas was an Erskine fellow in the department during term 1, 2006

4. Visitors

Professor Klaas de Boer from the Argelander Institute of Astronomy at the University of Bonn, Germany, was an Erskine fellow in the department from mid-February until the end of March. He gave a lecture course on the physics of the interstellar medium to our fourth-year students, as well as two department seminars and a lecture to the Canterbury Astronomical Society.

Dr Torsten Boehm, from the Observatoire Midi-Pyrénées, Toulouse, France, visited the department and Mt John in January, in order to observe the variable star RS Cha. He gave a seminar in the department at the end of January on asteroseismology. He returned to Mt John for another observing run from the end of December into January 2007.

Dr Brian Marsden, Director Emeritus of the IAU Central Bureau of Astronomical Telegrams, visited Mt John with his wife in January.

Professor Gary Davis, the director of the Joint Astronomy Centre in Hilo, Hawaii and of the James Clerk Maxwell Telescope on Mauna Kea, visited the department briefly in

February. Professor Roy Sharp, Vice-chancellor of the University of Canterbury, visited Mt John with his wife in February.

Drs Barry Welsh and John Vallergera from the Space Sciences Lab at the University of California, Berkeley, visited the department on their way to observe at Mt John in March. Dr Vallergera gave a seminar to the astronomy group on CCD and other electronic detectors. Welsh returned for further observing runs at Mt John to use the Hercules spectrograph in July and October.

Dr Kenji Bekki, School of Physics, University of New South Wales, visited the Department in March and gave both a talk to the Astronomy Group and a Department seminar.

Dr Russell Cannon (former Director of the Anglo-Australian Observatory) visited the Department in November for the PhD thesis examination of Elizabeth Wylie.

Professor Jay Pasachoff (Williams College, Massachusetts) and Drs Thomas Widemann and Bruno Sicardy (Observatoire de Paris-Meudon, France) visited the department and Mt John in June in order to observe an occultation of a star by Pluto (unfortunately a major snow storm prevented the observation on 12 June). Pasachoff gave a seminar in the department on occultations and eclipses.

Professor Anthony Fairall from the University of Cape Town visited the department in June while on a tour of New Zealand as the Carter Observatory Memorial Lecturer. He presented a seminar in the department on 'Mapping the cosmic labyrinth'. Dr Arne Henden, the director of the American Association of Variable Star Observers (AAVSO) visited the department in July and gave a lecture on 'Our violent universe'. Dr Jill Tarter, director of the SETI Institute, Mountain View, California, visited the university in August and lectured at the Aurora School (see section 5) and gave a public lecture on the search for extraterrestrial intelligence.

Dr Edwin Budding (formerly Carter Observatory, Wellington, and lately of Canakkale University, Turkey, visited Mt John with his Turkish PhD students Volkan Bakis and his wife Hicran Bakis on several occasions in May, August and September. They observed eclipsing binary stars using the Hercules and MRS spectrographs on the 1-m McLellan telescope.

Dr Takahiro Sumi, STELab, Nagoya University, Japan, visited the department in August and gave a seminar on gravitational microlensing, following his observing run at Mt John.

Dava Sobel visited the Court Theatre in Christchurch for the launch of her recent novel 'The Planets'. Cottrell was invited by the organizers of the Christchurch Writers and Readers Week Committee to introduce Dava Sobel on this occasion.

Dr Slava Kitaev (Auckland University of Technology) visited the department in October and gave a seminar on his proposal to observe deuterium radiation from the early universe with a radio telescope.

Dr Steve Maddox and his wife, Dr Loretta Dunne, from the School of Physics and Astronomy, the University of Nottingham, spent several months in the department on sabbatical from October. Maddox gave a seminar on the large-scale structure of the universe in October and Dunne gave a seminar on the cold universe, from far-infrared and sub-millimetre observations, in November.

Professor Chayan Boonyarak (astronomer and Dean of Science, Naresuan University, Phitsanulok, Thailand) visited the department in October. Professor Larry Marschall (Gettysburg College, Pennsylvania, USA) visited the department for several weeks in October and November. He gave a departmental seminar early in November on 'The transit of Venus – the space race of the nineteenth century'.

Dr Denis Sullivan (Victoria Univ. Wellington) visited Mt John on three occasions, in April, May and June to test his new frame-transfer CCD photometer on the 1-m McLellan telescope.

Bill Allen (Vintage Lane Observatory, Blenheim) made observations of η Carinae on the O.C. telescope at Mt John in December.

About one dozen different school groups visited Mt John during the year and were shown round by Gilmore.

5. Aurora School in Astronomy

The AURORA school in Astronomy for 2006 was held in the last week of the University lecture break (first week of the high school holidays) and was attended by twenty year 12 and year 13 students. The School participants came from all over the country from Invercargill to Auckland, although about half were from Canterbury high schools. We were fortunate enough to have two overseas astronomers visiting New Zealand at the time and we were able to organise for them to give talks to the group. Dr Jill Tarter (director of SETI research, SETI institute) spoke about interferometry and Dr Arne Henden (Director, American Association of Variable Star Observers, AAVSO) spoke to the students about variable star observing programmes. Talks from Hearnshaw, Albrow, Dr David Wiltshire, Pollard, Pauline Harris, Michele Bannister, Baggaley, Andrew Brown and some computer and astronomy laboratories rounded out the on-campus activities for the week.

It had been intended to spend two nights at Mt John but heavy snowfalls meant that the school went to the observatory a day late. Chains had to be used to get up the mountain where the temperature was -6°C at 8.00 p.m. The sky was very clear and the students with Pollard supervising managed to see numerous interesting objects

including planets, moons, stars, clusters, nebulae and galaxies using the OC and the 1.0 m telescope. They also had a tour of the MOA telescope and were able to watch the observers there obtaining microlensing observations.



Students on the 2006 Aurora School in astronomy visit Tekapo. Mt John is in the background

6. Conferences

Seven members of the Canterbury astronomy group attended the RASNZ 2006 annual conference in New Plymouth from June 30 to July 2. They were Gilmore, Hearnshaw, Kilmartin, Komonjinda, Petterson, Pollard and Woollands. Talks presented were as follows: Hearnshaw on the MOA project and on his work on promoting astronomy in developing countries; Komonjinda on binary star orbits; Petterson on astronomy educational software, Pollard on the search for extrasolar planets and Woollands on the variable binary star, RS Cha.

Four Canterbury astronomers attended the annual conference of the Astronomical Society of Australia in Canberra in July; they were Cottrell, Mohr, Worley and Wylie. Wylie gave a talk on 's-process abundances in 47 Tucanae' which earned her a highly commended rating in the students' talks category. Cottrell and Mohr also gave talks,

respectively on SALT and initial SALT data, and on ‘Optical atmospheric turbulence using SCIDAR techniques’.

In September Pollard and Wright attended the Vienna conference on asteroseismology in Vienna, Austria. Wright received funding from the Dennis William Moore fund, the Canterbury branch of the Royal Society of NZ and the Royal Astronomical Society of NZ. Both Pollard and Wright presented poster papers there. They were: ‘Analysis tools for non-radially pulsating objects’ (Wright, Pollard, Cottrell) and ‘Coordinated observational campaigns for non-radially pulsating objects’ (Pollard, Wright, Cottrell, Woollands, Ramm, Boehm).

Five Canterbury astronomers attended the 26th General Assembly of the International Astronomical Union in Prague in August. They were Baggaley, Gilmore, Hearnshaw, Kilmartin and Komonjinda. Baggaley served as the official NZ representative of the Royal Society. At the General Assembly, Hearnshaw organized a two-day special session ‘Astronomy for the developing world’. About 280 astronomers from 61 different countries participated. He gave a paper there on ‘A survey of published astronomical outputs from 1976 – 2005’. Komonjinda presented a poster paper (with Hearnshaw and Ramm) on the effect of starspots on the observations of the spectroscopic binary, ζ TrA at IAU Symposium 240, which was also in Prague at the time of the General Assembly. Díaz and co-authors (including Hearnshaw) presented a poster paper on ‘Radial-velocity analysis of the post-AGB star, HD101584’, also at IAU Symposium 240. Hearnshaw presented the triennial report of the IAU Commission 46 Program Group for the World-wide Development of Astronomy at the Comm. 46 business meeting at the General Assembly.

Cottrell attended the 8th Torino Workshop on ‘Nucleosynthesis in AGB stars’ in Granada, Spain, in February and presented papers on SALT and on the results from Wylie’s thesis work on s-process abundances in 47 Tucanae giant stars. He also attended the Australian High Energy Physics AUSHEP06 meeting in Christchurch in October and gave a talk on SALT and its potential for linking with high-energy physics observations.

In October Tobin attended the First ARENA Conference on ‘Large astronomical infrastructures at Concordia, prospects and constraints for Antarctic optical/IR astronomy’ in Roscoff, Brittany, France. He presented a poster entitled ‘Teaching Antarctic astronomy’ based on his experience in Canterbury’s ANTA101/102 courses between 2002 and 2005.

Miller attended the ‘Transiting extrasolar planets’ workshop at the Max-Planck Institute for Astrophysics in Heidelberg, Germany in September. Mohr attended the ‘Image and Vision Computing’ New Zealand conference on Great Barrier Island in November, and she presented the image processing aspects of her work. She was awarded travel grants from the Dennis William Moore Fund, the Royal Society of New Zealand (Canterbury Branch) and the Royal Astronomical Society of New Zealand to attend this conference.

7. Southern African Large Telescope

SALT is operated by a not-for-profit company registered in the Republic of South Africa, with governance by twelve SALT Board Directors. SALT's assets include the 11m SALT facility and its suite of instruments with a total value in excess of \$US30 million.

This year marked the beginning of commissioning observations with the imaging camera (SALTICAM) and the low- to medium-resolution spectrograph, the Robert Stobie Spectrograph (RSS). A number of RSS observations were obtained for University of Canterbury personnel as a result of a call for performance verification proposals. RSS spectra of individual stars in globular clusters 47 Tucanae and ω Centauri and integrated globular cluster spectra were obtained for Albrow, Cottrell, Gopal and Worley.

The SALT high resolution spectrograph, designed by the University of Canterbury team, went out for competitive tender for the construction phase. The University of Canterbury was issued 335,000 shares in the SALT Foundation Pty Ltd for its work on the SALT HRS design.

8. Instrumentation

In December 2005 the Department received a new CCD camera from Spectral Instruments in Tucson, Arizona using grant funding from the University's Research Committee in 2003 and 2004. This SI 600 series camera included a Fairchild 4k \times 4k CCD486 thinned and back-illuminated chip with 15-micron pixels and cryo-cooler, and was purchased for high resolution spectroscopy on the Hercules spectrograph.

In 2006, work was commenced in the department to test and commission this camera. The work was undertaken by PhD student Duncan Wright over several months while his PhD enrolment was suspended.

The new camera was taken to Mt John in March for initial tests. Unfortunately an accident while installing the cryo-cooler unit in a special cabinet resulted in one of the high-pressure refrigerant lines being punctured, and the whole camera had to be returned to Spectral Instruments for the refrigerant in the cryo-cooler to be purged and refilled. The camera was used successfully for several months until the CCD chip failed in December. It was returned to Spectral Instruments a second time and a new chip installed under warranty.

Frost built a new mounting system for this camera on the Hercules spectrograph, with a digital encoder and readout for the focus control. Ritchie designed and built a new temperature control system for the Hercules room, designed to maintain the temperature at 20.0 C at all times and seasons.



New 4k by 4k Spectral Instruments CCD camera mounted on the Hercules spectrograph

The McLellan 1-m telescope lower support bearings were adjusted by Frost and Kershaw in November 2006, and this resulted in an immediate improvement in the smoothness of telescope tracking. The 1-m mirror was aluminised in November and major structural work was carried out in July on the 1-m rising floor screw jack mounts. This was to allow future maintenance, in particular replacement of screw jacks to be carried out at a later date.

An Apogee Alta U47 (1024 × 1024 pixel) CCD camera and filter wheel with I72, red, visible, blue, and a ultraviolet filters was installed on the Boller and Chivens telescope by the MOA group in 2006 at the start of the bulge season. Frost also fixed the tracking on the B&C telescope by replacing the chain linkage from the stepper motor to the RA worm with a belt linkage.

9. Other research

This section briefly mentions some other research undertaken within the astronomy group at Canterbury which is not mentioned in other sections of this report, or it expands on some items briefly covered elsewhere.

Pollard continued as co-PI (in collaboration with Albrow) on the Marsden-funded research on the search for extra-solar planets. As part of the PLANET collaboration involving coordinated photometric observations and analysis of gravitational microlensing events, the 2005 Galactic Bulge observing season culminated in the discovery of the lowest-mass extra-solar planet discovered to date, at 5.5 Earth-masses. A paper announcing the discovery was published in the 26 January 2006 edition of *Nature* and generated quite a lot of international media interest.

A new software package for online image-subtraction photometry written by Albrow and C. Coutures (Institut d'Astrophysique de Paris) was deployed to PLANET telescopes in 2006 and used for the reduction of all PLANET images. The software is based on C. Allard's ISIS routines and its implementation (replacing DoPHOT) has made an impressive improvement to the data quality.

Fifteen astronomers from around the world attended a two-week meeting of the PLANET collaboration in Christchurch in January.

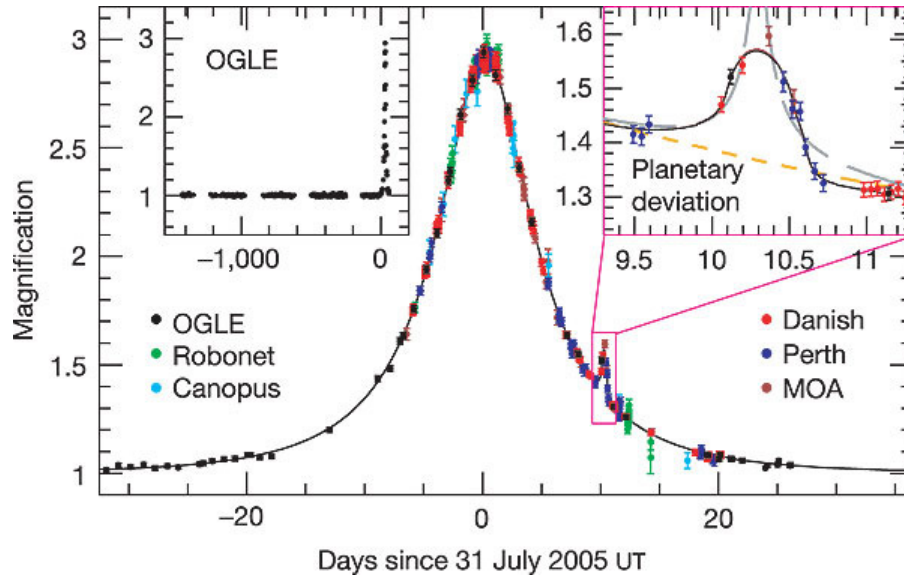
The MOA (Hearnshaw, Kilmartin, Tristram) and PLANET (Albrow, Pollard) collaborations contributed observations to the microlensing event OGLE-2006-BLG-109 in March and April. This event was analysed by Dr B.S. Gaudi at Ohio State University and the analysis led to the discovery of two more sub-Jupiter-mass extrasolar planets orbiting the host star at 2.3 and 4.6 A.U.

Hearnshaw working with MSc student Henderson has commenced a collaboration with Dr B. Welsh, Space Science Lab, University of California, Berkeley, to determine the structure of the interstellar gas in the solar neighbourhood from observations of interstellar lines in the spectra of early-type stars, using the Hercules spectrograph at Mt John.

Komonjinda, with Hearnshaw and Ramm, undertook an analysis of the small perturbations in the radial velocity curve of ζ TrA that had been observed earlier by Skuljan et al. using the Hercules spectrograph. Her analysis used the Wilson-Devinney binary star code. She concluded that starspots could account for perturbations of the Keplerian orbit at the 5 m/s level.

This work included a detailed analysis of the single-lined spectroscopic binaries HD159656, which has a solar-type primary, as well as β Reticuli and ν Octantis, both of which have K-giant primaries. The K-giant systems also have astrometric solutions, and collaboration with Dr Dimitri Pourbaix (Institut d'Astronomie et d'Astrophysique

Brussels, Belgium) has provided a spectroscopic-astrometric solution for each K giant. Different statistical methods have been applied to the Hercules data so as to yield significant improvements to the precision of the spectroscopic orbital solutions.



Light curve of the microlensing event OGLE-2005-BLG-390 from which the discovery 5.5 Earth-mass extrasolar planet was announced by OGLE, PLANET and MOA groups early in 2006. The planet caused the small spike about 10 days after maximum brightness.



Artist's impression of the new planet OGLE-2005-BLG-390Lb

10. The MOA project

The MOA (Microlensing Observations in Astrophysics) is a joint project of Massey, Auckland, Canterbury and Victoria universities in collaboration with Nagoya University in Japan. The aim is to discover and observe gravitational microlensing events, especially in the Galactic Centre, which result in the brightening of stars caused by gravitational bending of light rays caused by objects at intermediate distance along the line of sight. MOA involves about two dozen scientists at five universities. The principal goal is the discovery of extrasolar planets through analysis of microlensing events. The MOA 1.8-m telescope belonging to Nagoya University and sited at Mt John, was installed in 2004. MOA's website is at <http://www.phys.canterbury.ac.nz/moa/>.

The routine observing campaign by the new telescope on the Galactic Bulge commenced in April 2006 and has been proceeding smoothly since that time. New microlensing events were being announced on the MOA website and 168 events were reported for the 2006 bulge season, which is about a three times greater discovery rate than was possible using the smaller B&C 60-cm telescope at Mt John.

During the 2006 year, the MOA 1.8-m telescope has been working on every fine night and collecting data in the Galactic Bulge during the winter months and in the Magellanic Clouds in the summer. Early alignment and image quality problems have been eliminated, and the telescope is now in routine operation.

MOA is supported by a major grant from the Marsden Fund announced in late 2005, which provides for NZ observers and graduate students working on the project for the following three years. The grant is administered through Dr Ian Bond at Massey University, Albany. MOA is a joint project involving astronomers at Massey, Auckland, Canterbury and Victoria universities and Nagoya University in Japan. Paul Tristram was employed as a MOA observer from March to October and Pam Kilmartin was also employed as a part-time MOA observer. Both were funded through the Marsden grant awarded to the project in September 2005.

The MOA telescope contributed several key data points to the observations of the microlensing event OGLE-2005-BLG-390Lb from which the discovery 5.5 Earth-mass extrasolar planet was announced by OGLE, PLANET and MOA groups early in 2006 (see section 9 above).

11. Weather at Mt John

(data compiled by Pam Kilmartin)

The weather at Mt John in 2006 was close to the mean of recent past years (since 1992) in so far as observing conditions go.

In June there was a severe snow storm at Mt John on the night of June 11 which isolated the observatory and cut power and communications for several days. There were 12 people trapped on the summit, including observers from the USA and France to observe the Pluto occultation on June 12. The weather thwarted their observing.

Table 1 below compares 2006 weather with that of recent past years, while Table 2 gives a breakdown of 2006 weather month by month. August, June and May (in that order) had the greatest number of photometric hours; in 2005 the best months were April, March and then July. In 2006 there were 1124 photometric hours (32% of the total night-time hours) at Mt John. This makes the weather for observing in 2006 one of the better years of the century so far, exceeded only by 2003 (1275 photometric hours, 37%).

Table 1: Table of Mt John weather, 1992-2006, giving the nights usable for photometry and spectroscopy

| Year | Photometric | | Partly phot. | | Spectroscopic | | Unusable | |
|------|-------------|-----|--------------|-----|---------------|-----|----------|-----|
| 1992 | 73 | 20% | 47 | 13% | 80 | 22% | 166 | 45% |
| 1993 | 63 | 17% | 61 | 17% | 75 | 21% | 166 | 45% |
| 1994 | 66 | 18% | 59 | 16% | 95 | 26% | 145 | 40% |
| 1995 | 73 | 20% | 61 | 17% | 105 | 28% | 126 | 35% |
| 1996 | 72 | 20% | 77 | 21% | 104 | 28% | 113 | 31% |
| 1997 | 79 | 22% | 84 | 23% | 86 | 24% | 116 | 32% |
| 1998 | 97 | 27% | 74 | 21% | 71 | 19% | 123 | 34% |
| 1999 | 90 | 25% | 43 | 12% | 105 | 28% | 117 | 32% |
| 2000 | 66 | 18% | 84 | 23% | 104 | 28% | 112 | 31% |
| 2001 | 76 | 21% | 73 | 20% | 109 | 30% | 107 | 29% |
| 2002 | 56 | 15% | 69 | 19% | 136 | 37% | 104 | 29% |
| 2003 | 94 | 26% | 80 | 22% | 80 | 22% | 111 | 30% |
| 2004 | 61 | 17% | 79 | 22% | 82 | 22% | 144 | 39% |
| 2005 | 53 | 14% | 70 | 19% | 116 | 32% | 126 | 35% |
| 2006 | 86 | 23% | 61 | 17% | 102 | 28% | 116 | 32% |

Table 2: Table of usable nights distribution, 2006

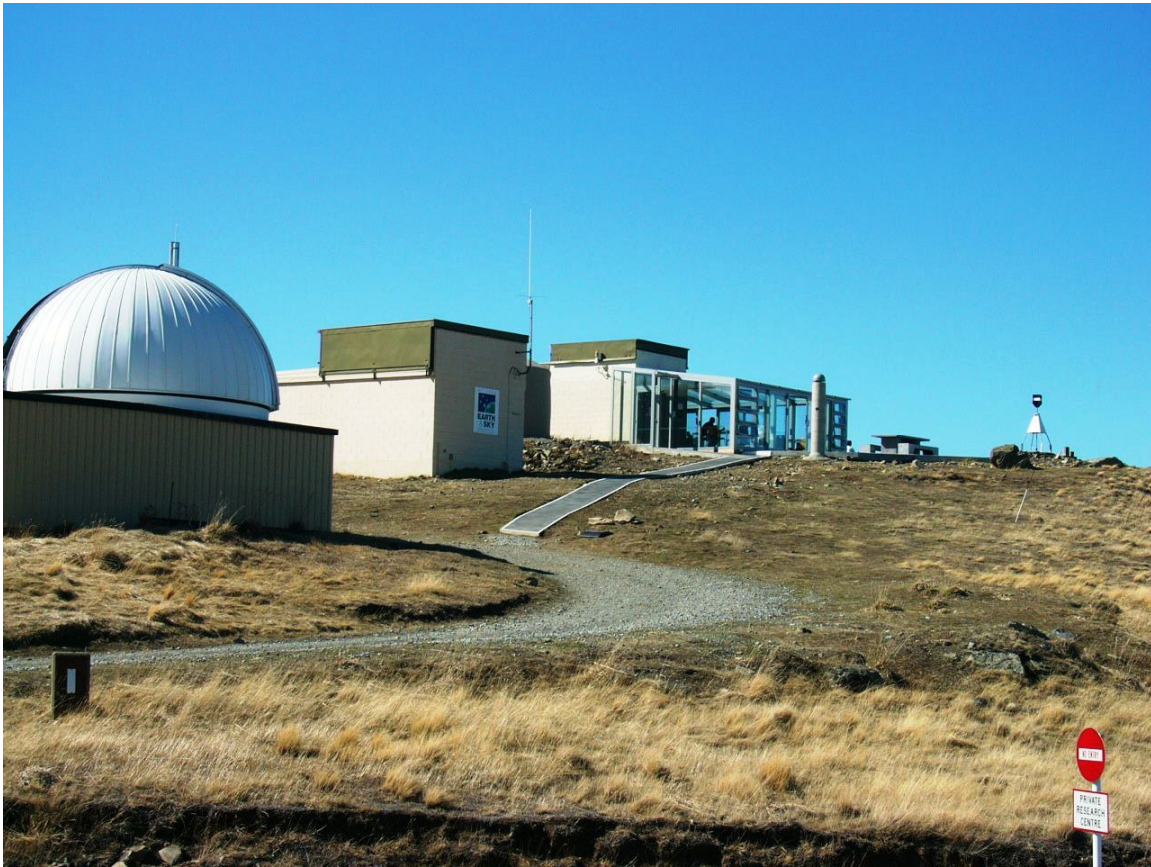
| Month | Nights fully photometric | Nights fully or partly phot. | Hours photometric | Per cent hours photometric |
|-------|--------------------------|------------------------------|-------------------|----------------------------|
| Jan | 8 | 2 | 55 | 29% |
| Feb | 8 | 1 | 64 | 28% |
| Mar | 5 | 7 | 79 | 27% |
| Apr | 3 | 8 | 54 | 16% |
| May | 10 | 3 | 136 | 36% |
| Jun | 10 | 4 | 151 | 39% |
| Jul | 9 | 3 | 126 | 33% |
| Aug | 10 | 10 | 161 | 45% |
| Sep | 9 | 7 | 126 | 42% |
| Oct | 8 | 7 | 100 | 36% |
| Nov | 1 | 5 | 30 | 15% |
| Dec | 5 | 4 | 42 | 23% |
| Total | 86 | 61 | 1124 | 32% |

12. Public outreach: Earth and Sky Ltd and Townsend Observatory

Earth and Sky Ltd (ESL) was founded in 2004 at Tekapo and is a company to which the University of Canterbury has granted exclusive tourists rights on Mt John. The company has continued to develop day-time tours of the observatory and its facilities. Night-time tours are also provided, using a 40-cm Meade telescope recently installed by ESL in the vacant 16-inch dome on Mt John in 2006, as well as other small telescopes.

In November 2006, ESL completed the construction of the Astrocafe on Mt John. The Astrocafe is an extension to the unused Bamberg building that once housed small astrographic cameras. The Astrocafe now provides a day-time café for visitors to Mt John and an excellent vantage point to admire the panoramic view and a stepping off point for day-time observatory tours.

Public outreach was continued at the Townsend Observatory, Arts Centre, Christchurch on Friday evenings during the 2006 winter months. The observatory is owned by the University and operated by the Department of Physics and Astronomy. These free public sessions use the classic Cook six-inch refractor at the observatory. Josephine Reid and Andrew Brown were appointed as Townsend observers for 2006. The dome was open to the public for eighteen sessions between April and September.



Earth and Sky Astrocafe on Mt John (in centre). The OC telescope is on the left

13. Undergraduate and graduate programme

The following is a summary of courses offered in astronomy in 2006 (and in recent years). These courses are part of the BSc, BSc Hons, and MSc degrees and also of the Postgraduate Diploma in Science. At Canterbury it is possible to major in astronomy for all these qualifications. Most students in astronomy courses are however doing a BSc and majoring in physics or other science subjects with astronomy as a minor component.

ASTR/PHYS109: This course was introduced in 2001 and has continued to flourish with an enrolment of typically 150. The course has no lab class and uses no mathematics. It caters for BA and BSc first-year students who do not plan to progress further in astronomy.

ASTR112: This is our standard first-year astronomy course for BSc students and covers topics in the Sun and stars, the Milky Way Galaxy and extragalactic astronomy and cosmology. Thirty-nine students enrolled in 2006. Twelve of the first-year students taking this paper went on to do the second-year astronomy paper (ASTR212) offered in semester 2 of the same year. As in previous years, a day-time field trip to Mt John was organized in March for the ASTR112 class.

ASTR212: This course (along with ASTR211 offered in alternate years) has a solid enrolment of around 30 students. The course covers the Solar System and planetary exploration, with all the latest on space probes, and also dynamical astronomy to understand the intricacies of planetary (and binary star) orbital motions.

ASTR/PHYS381: Every year a field trip to Mt John is organized for undergraduates who are doing the third-year laboratory course. This year six students participated in a two-night trip in late September. During the visit, the students were shown a number of interesting celestial sights through the OC telescope by Gilmore, who also instructed the students on the use of the telescope and instrumentation for CCD photometric observations. The students acquired time-series images of an asteroid and an eclipsing binary star that were analysed as part of their laboratory project work.

ASTR321: Techniques in observational astronomy. The course covers aspects of stellar photometry and spectroscopy, including data acquisition and reduction methods.

ASTR322: Theoretical and observational cosmology.

ASTR323: Stellar structure and evolution.

All the third-year courses above are also offered as fourth-year courses (at BSc Hons or MSc levels).

ASTR424: Radiative transfer processes in astrophysics. This course covers the theory of stellar atmospheres and of line formation in stellar spectra, and also theoretical aspects of the interstellar medium.

14. Publications

(Canterbury authors are in bold face)

(a) Chapters in books

Hearnshaw, J. B. Astronomy in New Zealand. Organizations and Strategies in Astronomy, Volume 6. Edited by André Heck, Astrophys. and Space Sci. Library Vol. 335. Publ. by Springer, p.63-86 (2006)

(b) Refereed journal papers

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Pietrzyński, G.; Soszyński, I.; Szewczyk, O.; Wyrzykowski, Ł.; Paczyński, B.; Abe, F.; Bond, I. A.; Britton, T. R.; **Gilmore, A. C.**; **Hearnshaw, J. B.**; Itow, Y.; Kamiya, K.; **Kilmartin, P. M.**; Korpela, A. V.; Masuda, K.; Matsubara, Y.; Motomura, M.; Muraki, Y.; Nakamura, S.; Okada, C.; Ohnishi, K.; Rattenbury, N. J.; Sako, T.; Sato, S.; Sasaki, M.; Sekiguchi, T.; Sullivan, D. J.; **Tristram, P. J.**; Yock, P. C. M.; Yoshioka, T. Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing. *Nature*, 439, pp. 437-440 (2006)

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Wright, D. J.; Lynas-Gray, A. E.; Kilkenny, D.; **Cottrell, P. L.**; Shobbrook, R. R.; Koen, C.; van Wyk, F. W.; **Kilmartin, P. M.**; Martinez, P.; **Gilmore, A. C.** A photometric and spectroscopic study of the hottest pulsating extreme helium star, V2076 Oph (HD 160641) *Mon. Not. Roy. Astron. Soc.*, 369, pp. 2049-2058 (2006)

Wylie, E. C.; **Cottrell, P. L.**; Sneden, C. A.; Lattanzio, J. C. Heavy-Element Abundances in Giant Stars in 47 Tucanae. *Astrophys. J.*, 649, pp. 248-257 (2006)

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(c) Conference papers

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McMillan, R. S.; Read, M. T.; **Gilmore, A. C.** Comet P/2006 F4 (Spacewatch)
IAU Circ., 8695, 1 (2006)

McNaught, R. H.; Burton, D. M.; **Gilmore, A. C.**; Nakano, S.; Marsden, B. G.
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McNaught, R. H.; **Gilmore, A. C.** Comet C/2006 K1 (McNaught)
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