

IRIS2: Going Wide in the Infrared

Stuart D. Ryder (AAO)

Abstract. Following the success of its first infrared array camera and spectrometer IRIS, the AAO set out to build what was then the widest-field infrared camera and spectrometer on any 4m-class telescope. IRIS2 also made possible multi-slit spectroscopy in the near-infrared for the first time, using a fore-dewar that enabled rapid thermal cycling and switching of slit-masks without the need to warm up the entire instrument.

1. Introduction

While the debut of the Infrared Imager and Spectrometer (IRIS; Allen et al., 1993) marked a revolution in near-infrared (NIR) astronomy on the AAT, 1024^2 arrays with much smaller pixels began to become available in the mid-1990s. Accommodating one or more of the *I*, *J*, *H*, or *K* bands on the IRIS array limited the spectral resolution to no more than 400. While the idea of installing a 256^2 array within the existing IRIS dewar was considered, the Advisory Committee for Instrumentation on the AAT (ACIAAT) recommended in July 1996 that the next instrument the AAO build after 2dF should be the Infrared Imager and Spectrograph 2 (IRIS2).

Peter Gillingham and Damian Jones came up with an all-refracting, nine element camera and collimator design which at the f/8 Cassegrain focus would yield a plate scale of 0".45 per pixel, and thus a field of view 7'.7 on a side. In addition to being one of the widest field infrared cameras in the world at the time, IRIS2 would also deliver spectroscopy in each of the *J*, *H*, and *K*-bands at resolutions of 1500 (using silica grisms) or 2400 (using sapphire grisms), with either a single long slit or one of up to three multi-slit masks. Although intended to operate at different pixel scales using the f/15 or f/36 top ends, IRIS2 has only ever been used at the f/8 focus. The full design and characteristics of IRIS2 are described in Tinney et al. (2004). Future upgrade paths planned for IRIS2 included a “jukebox” arrangement for holding up to 10 multi-slit masks; a polarimetry capability; and retrofitting a 2048^2 array to deliver smaller pixels over the same field of view, and to capitalise on an envisaged tip-tilt capability. None of these has ever been implemented.

Stuart Lumsden was the original Project Scientist for IRIS2 until his move to the University of Leeds at the end of 1998. Chris Tinney took over that role, and late in 1999 Stuart Ryder joined the project as IRIS2 Commissioning Scientist. IRIS2 saw “first light” on 26 October 2001 with an engineering-grade array, which was replaced by the science-grade array 6 months later. Since then it has been scheduled on approximately 15% of all nights on the AAT. Early in 2000, the AAO submitted a concept design study for a clone of IRIS2 (IRIS2g) to be built as a “fast-track” infrared imager and multi-object spectrograph for Gemini South. Ironically, ten years after the FLAMINGOS-2 instrument was selected ahead of IRIS2g for that role, it has only just begun commissioning.

2. Technical Challenges & Innovations

As with all good instruments, IRIS2 pushed the boundaries of what was thought to be technically feasible. Among the most notable challenges faced were:

- **Dual-dewar Operation** – IRIS2’s dual-dewar design means that only the smaller fore-dewar containing the slit wheel needs to be thermally cycled whenever multi-slit masks are exchanged, while the larger main dewar, with the remaining wheels and delicate detector array, is kept cold constantly.
- **AAO2 Detector Controllers** – IRIS2 was the first instrument to employ the new AAO2 optical detector controllers developed in-house, using dedicated video boards to read out each quadrant of IRIS2’s array simultaneously. These controllers enabled readout times as short as 0.6 seconds while delivering a quite respectable read noise of 15 electrons in imaging mode, and as low as 5 electrons in spectroscopic mode.
- **Cryogenic Stepper Motors** – Each of the four wheels within IRIS2, as well as the detector translator stage (for focusing), is driven separately by cryogenically-rated AML stepper motors via worm gears. During early cold tests these stepper motors were found to rapidly seize up, necessitating the replacement of the ceramic ball bearings with steel ball bearings, and an increased radial clearance around the bearing housings.
- **Sapphire Grisms** – Sapphire has a higher refractive index than silica, enabling a greater dispersion. Commissioning revealed that the throughput of the R~1500 silica grisms was distinctly poorer than the R~2400 sapphire grisms, and they were removed. Sapphire’s birefringence however can produce overlapping polarised spectra if the crystal and camera optical axes are not aligned, and sadly this was found to be the case with IRIS2’s original sapphire grisms, which then had to be replaced by a different supplier.
- **Graphical User Interface** – IRIS2’s subsystems (detector, wheels, etc.) are controlled by independent tasks running on multiple computers, which communicate with each other using the AAO’s DRAMA environment. The observer interacts with IRIS2 through one main Graphical User Interface (GUI) which displays the status of IRIS2 and allows manual control of each mechanism. Due to the repetitive nature of infrared observing (dithering on-sky, nodding along the slit, etc.) observing is most efficiently carried out using standard sequences of commands, with the observer only having to input the source name, exposure parameters, select the filter/grism, and telescope offset pattern. ESO’s Skycat tool provides the real-time display of the accumulated exposure (with optional sky subtraction), and the ability to accurately acquire targets on to the slit. Observers can call up targets from online catalogs and slew the telescope themselves, though the night assistant is still required to establish guiding for spectroscopy.
- **Data Reduction Pipeline** – Following the lead of the 2dF data reduction pipeline 2dfdr, it was felt that IRIS2 needed to have a data reduction pipeline that could run at the telescope with a minimum of user interaction. Fortunately the Joint Astronomy Center in Hawaii had implemented just such a generic data reduction system (ORAC-DR; Cavanagh et al., 2003) for all of the instruments on UKIRT and JCMT. ORAC-DR routinely produces publication-quality imaging mosaics within minutes of the

observations being completed, and can even determine a World Coordinate System and a photometric calibration on the basis of 2MASS sources identified automatically within the field.

- **Multi-Object Spectroscopy** – The multi-slit masks for IRIS2 are laser cut from blackened brass sheet by the Centre for Lasers and Applications at Macquarie University. While 10–20" long slits enable 20–40 targets per mask, use with a narrow-band filter to isolate a single spectral feature (e.g. the J_{cont} filter to catch H α at redshift 0.83) has enabled the design of masks to observe over 200 cluster galaxies at once.

3. Triumph...and Disaster

On 11 October 2002, IRIS2 won the Bradfield award for outstanding engineering achievement from the Sydney Division of the Institution of Engineers Australia. Its predecessor IRIS won the same award back in 1993. IRIS2 then went one better, picking up an Engineering Excellence Award at the national awards ceremony held in Canberra a month later. It was included in an Engineering Innovation exhibition at Sydney's Powerhouse Museum during 2003.

In late-May 2005, problems were encountered reading out IRIS2. Upon warming up and opening the main dewar, AAO technical staff were horrified to discover that the HgCdTe detector layer had separated completely from the silicon multiplexer layer underneath, and even taken a chunk out of it. After much soul-searching and discussions with the array manufacturer Rockwell Scientific, it was concluded that this failure was a thermal stress vulnerability of the early HAWAII-1 arrays, and not the fault of any AAO personnel or procedures. The engineering-grade array was pressed back into service until a replacement science-grade array was delivered by Rockwell (at no cost) and installed into IRIS2 nearly a year after the original failure.

4. Science Highlights

Among the many notable scientific achievements of IRIS2, space permits mention of only a few:

- **GRB 01121** – Barely a month after commissioning, IRIS2 observed the K -band afterglow of a gamma ray burst for 7 hours, despite being below the pole and telescope offsets having to be applied manually for most of that time (Price et al., 2001).
- **T dwarfs** – The presence of broad methane absorption features in their near-infrared spectra distinguishes the class of T dwarfs with $T_{\text{eff}} \sim 1000$ K. The complementary CH_{4s} and CH_{4l} filters in IRIS2 sample the H -band continuum and any methane absorption respectively, which enabled Tinney et al. (2005) to rapidly confirm actual T dwarfs from among thousands of candidates in 2MASS, as well as assign their sub-type.
- **Local Sphere of Influence Survey** – The 2MASS survey revolutionised NIR astronomy, but is virtually blind to dwarf galaxies. RSAA PhD student Emma Kirby used IRIS2 to go 4 magnitudes deeper in H -band than 2MASS to measure the mass-to-light ratio in a number of dwarf galaxies within 10 Mpc of the Milky Way (Kirby et al., 2008).
- **OH suppression** – In Dec 2008 IRIS2 demonstrated the first “on-sky” use of the OH-suppressing fibre Bragg grating technology developed by Joss

Bland-Hawthorn and colleagues, paving the way for complete OH-suppression fibre feeds like GNOSIS on the AAT and Gemini (Bland-Hawthorn et al., 2009).

Acknowledgements

IRIS2 would not have been as successful as it has been without the combined efforts of AAO staff, past and present, in particular Jeremy Bailey, John Barton, Jurek Brzeski, Vlad Churilov, John Collins, John Dawson, Bob Dean, Simon Ellis, Chris Evans, Tony Farrell, Gabriella Frost, Peter Gillingham, Roger Haynes, Peter Innes, Alan Lankshear, Stuart Lumsden, Don Mayfield, Chris McCowage, Rolf Muller, Keith Shortridge, Greg Smith, Darren Stafford, Chris Tinney, Lew Waller, and Denis Whittard. Special thanks also to Brad Cavanagh (JAC) for making ORAC-DR available for use with IRIS2.

References

- Allen, D. A., et al., 1993, *Proc. ASA* **10**, 298-309.
Bland-Hawthorn, J., Ellis, S., Haynes, R., and Horton, A., 2009, *AAO Newsletter*, No. 115, 15-17.
Cavanagh, B., et al., 2003, in *ASP Conf. Ser.*, Vol. 295, eds. H. E. Payne, R. I. Jedrzejewski, & R. N. Hook (San Francisco: ASP), pp. 237-240.
Kirby, E. M., Jerjen, H., Ryder, S. D. and Driver, S. P., 2008, *Astron. J.* **136**, 1866-1888.
Price, P. A., et al., 2001 *Ap. J. Lett.*, **572**, 51-55.
Tinney, C. G., et al., 2004, *Proc. SPIE* **5492**, 998-1009.
Tinney, C. G., et al., 2005, *Astron. J.* **130**, 2326-2346.



Figure 1. Good times and bad times. (*left*) IRIS2 receives an Engineering Excellence Award from the Deputy Prime Minister John Anderson (far left). IRIS2 Commissioning Scientist Stuart Ryder (second from left) holds the award, while Head of Mechanical Section John Dawson (centre) and AAO Director Brian Boyle (right of centre) hold the plaque.

(*right*) The sight that greeted AAO staff when the IRIS2 main dewar was opened up at the end of May 2005. The HgCdTe detector layer (left) has completely separated from the silicon multiplexer (right) layer, taking a chunk of silicon with it. This failure was traced to stresses introduced during fabrication.