A Coudé Auxiliary Feed for the AAT: a Focus for International Co-operation in Optical Astronomy

P. Gillingham and M. Pettini, *Anglo-Australian Telescope, Coonabarabran NSW 2357*
M. Bessell, *Mount Stromlo and Siding Spring Observatories, Private Bag, Weston ACT 2611*
L. Cram, *School of Physics, University of Sydney, NSW 2006*
K. Ogura, *Kokugakuin University, Tokyo, Japan*

Abstract: In 1988, a very powerful and versatile coudé echelle spectrograph was installed at the Anglo-Australian Telescope. Since then it has been winning about 30% of AAT time and has been highly productive scientifically. Therefore, using a coudé auxiliary telescope (CAT) to give the spectrograph more use and to free the AAT for other work is a very attractive possibility, particularly if the CAT can give a sensitivity similar to that obtained with the 3.9-metre telescope. While a conventional CAT with such performance would be very expensive, a much cheaper instrument should approach this goal, at least for high resolution spectroscopy. Even so, the cost could not be met in a reasonable time within the AAO's budget; hence, additional international collaboration is being sought.

1. Introduction

The AAT building was designed to accommodate a feed to the coudé focus from an auxiliary telescope, to be sited on a tower to the ENE of the dome. With the installation in 1988 of the University College London coudé Echelle Spectrograph (UCLES), interest in providing a coudé auxiliary telescope (CAT) was re-awakened.

The CAT originally envisaged for the AAT would have been a relatively small instrument, with an aperture diameter maybe 1.0 or 1.5 metre, feeding the coudé instruments via a train of mirrors. Although such a feed would be useful, it should be possible, by exploiting novel design approaches and accepting some limitations of the versatility of the feed, to provide a performance approaching that of the 3.9-metre feed for a cost in reasonable balance with the cost of the existing and planned coudé spectroscopic instruments. By making more use of these instruments and freeing the 3.9-metre telescope for observing work it alone can do, a large aperture coudé auxiliary telescope should provide a very cost-effective solution to the demand for additional observing time.

2. The Existing and Planned AAT Coudé Spectrographic Instruments

UCLES provides a choice of two 20 by 40 cm echelle gratings with cross-dispersion by a train of three silica prisms (so it has good transmission from 300 nm to beyond 2 μm wavelength, low scattered light, and reasonably uniform order separation). The cross-dispersed multi-order format gives high resolution together with a wide spectral range on the restricted area of electronic image detectors. Used with the IPCS (Image Photon Counting System) detector, which has high sensitivity through the near ultraviolet and visible together with extremely low dark noise, UCLES is ideally suited to record the spectra of faint objects which would otherwise be beyond the reach of high-resolution spectroscopy. The spectrograph currently has a camera with 70 cm focal length. With the IPCS, this camera gives a resolving power $\lambda/\Delta\lambda$ up to 115 000 and with CCDs, up to about 60 000. There are plans for providing a faster camera giving $\lambda/\Delta\lambda$ around 30 000, together with simultaneous coverage over 320 nm to 700 nm and a wide slit (about 1.2 arcsec). A project to provide an ultra-high resolution mode ($\lambda/\Delta\lambda$ approaching 1 000 000) has been funded.

3. Scientific Applications of UCLES

Strong demand for observing time on UCLES has won about 30% of nights, against heavy competition from the many other AAT instruments. In the two years of its operation, a number of very significant scientific results have been produced which were not attainable with other instruments in Australia and with very few, if any, in the world. Three examples are outlined here.

(a) Galaxies and intergalactic matter in the early universe

The details of absorption due to intergalactic clouds (the Lyman-alpha forest) in the spectrum of the quasar Q2206−199N (with redshift $z = 2.559$) have been observed by a group from the AAO, Sydney University and University College London. The lines of the Lyman-alpha forest were found to be much narrower than expected, implying cloud temperatures less than 5000 K rather than the generally accepted value of about 30 000 K. This result, together with other indications from the data, suggests that the intergalactic gas may be in the form of dense sheets rather than the tenuous spherical structures considered until now by most theoretical models.

(b) Stellar abundance studies

UCLES is having a major impact in studies of the metal abundances of stars, not only because of its resolving power but also because of its high efficiency in the ultraviolet, where some of the lines most suitable for abundance measurements in metal-poor stars are found. A group from Mount Stromlo and Siding Spring Observatories (MSSSO) confirmed that a number of stars, suspected from earlier low-resolution surveys of being metal-poor, indeed have abundances as low as 1/100 to 1/1000 of solar values.

In a related study, the abundance of beryllium has been measured in metal-poor stars, improving earlier estimates of this quantity by more than an order of magnitude. By showing that the abundance of beryllium tracks that of iron over three orders of magnitude in metallicity, from stars of solar composition to stars with 1/1000 of the iron content of the Sun, the MSSSO astronomers have been able to place stringent upper limits on the primordial abundance of beryllium, which in turn can be used to test recent non-uniform density models of Big Bang nucleosynthesis.

(c) Search for stellar non-radial oscillations

The compact format, good spectral resolution, and remarkable stability of UCLES have been particularly important in a series of observations by a Sydney University group to detect non-radial oscillations in the late-type stars α Cen and β Hyi. The power spectrum of such oscillations offers a powerful way to explore the internal structure of stars. Following steady improvements in the instrumental arrangement, it is now possible to measure the radial velocity of β Hyi ($V = 2.5$) with an rms

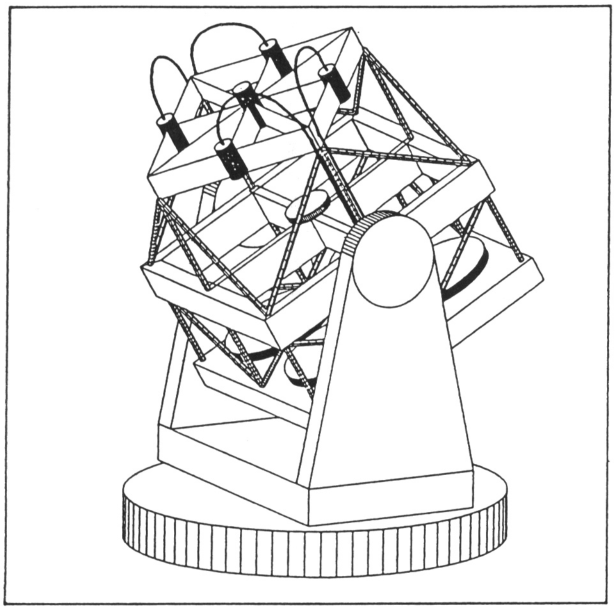

Figure 1 – A possible compact CAT design with four mirrors, each 1.2 metres diameter and feeding fibres at its prime focus

uncertainty of 2 $m\,s^{-1}$ in a 60 second exposure. The power spectrum of a time series (obtained in intermittent cloud) has revealed some evidence of oscillations, with an amplitude of 70 $cm\,s^{-1}$ and a period of seven minutes.

4. Possible Design for an Economical Coudé Feed

If we restrict the application of the CAT to on-axis spectroscopic work and if, in addition, we do not require it to work into the ultraviolet, then it appears that considerable savings can be made in the CAT optics, mounting, and relay system by exploiting optical fibres and a multi-mirror telescope layout. Figure 1 shows how a CAT might look in such a case. Each mirror, at its prime focus, feeds one fibre for the target object and one, or preferably a few, fibres for comparison sky. The fibres would be just long enough (10 metre has been assumed) to take the light off the CAT mount, where it would be transferred through image stacking and relay optics over the additional 50 metres or so to the spectrograph slit.

A careful estimation has been made of the efficiency of such a system. With four mirrors each 1.2 metres in diameter, in median seeing, the flux through the slit when operating UCLES at a resolution of 70 000, would be comparable (within about 10%) to that with the 3.9-metre coudé train down to a wavelength of about 400 nm.

Figure 2 shows the possible appearance of the CAT on its tower, in the position intended in the original AAT design. Advantage can be taken of the immensely stiff concrete cylindrical shell of the AAT building to provide lateral and angular location of the top of the CAT tower. Wind-induced vibration, which might otherwise plague such a mounting, especially in the accelerated flow next to the dome, will be eased by the very compact telescope optical assembly and may additionally be countered using the novel 'inertial drive' concept (Gillingham 1989, 1990).

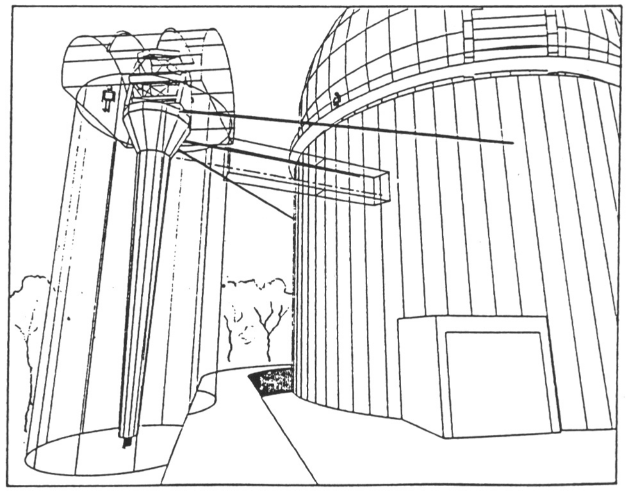

Figure 2 – The CAT as it might appear next to the AAT dome

5. Advantages of Wider International Collaboration on CAT

Although no detailed estimation of costs has yet been made, it seems that a very powerful coudé auxiliary feed could be provided for a cost comparable with that of the existing coudé spectroscopic instrumentation, providing very good value, since it could treble the coudé spectroscopic output and release something like 25% of the 3.9-metre telescope's time for other work. However, the cost would be too high to be met within the AAO's budget without long delay. So the merits of wider international sharing in the use of the AAT coudé facility, in return for help in building the CAT, are being canvassed. The AAT Board has indicated willingness to consider seriously any such proposal.

Informal discussion of collaborative possibilities has been initiated with Japanese astronomers, with considerable interest being shown by some. However, the fact that full budgetary approval for the Japanese National Large Telescope was still being sought has, so far, inhibited progress. It is possible that the governments of Japan, Australia, and Britain may be more inclined to support the AAT CAT project if its use is shared by astronomers of economically disadvantaged countries. The practicalities of such a scheme need careful thought but it has the potential to contribute very significantly to scientific collaboration, especially in the Asian-Pacific area.

6. Conclusion

There is a very good opportunity to increase the productivity of the AAT by building a coudé auxiliary feed. In the process, links may be strengthened between Australia and Britain and the many countries for which access to the AAT coudé instrumentation would give a large boost to their observational astronomy.

Gillingham, P. R., 1989, *Astrophys. Space Sci.*, **160**, 225.
Gillingham, P. R., 1990, "The Merits of Inertial Drives for Ground-based Optical Telescopes", SPIE Conference 1236: Advanced Technology Optical Telescopes IV.