firm that both the central and the eastern parts of the arc really present the same spectral energy distribution: therefore it is now proved that the eastern end of the structure belongs to the arc!

Moreover, a narrow emission line is clearly observed at 6427 Å all along the arc spectrum. The assumption that it is the [O II] λ 3727 line leads to a redshift z = 0.724, a value confirmed by the detection of absorption features corresponding to the Ca II λλ 3933, 3968 Å and the 4000 Å break, the CN band at 3883 Å, the MgII λ 2800 Å line and several Balmer lines, all at the same redshift. These features are typical of a blue galaxy, redshifted at z = 0.724.

A complete discussion of these data is out of the scope of this paper and will be presented in a letter to *Astronomy and Astrophysics*. Nevertheless it is obvious now that all these results confirm that the arc in A 370 does result from the gravitational lensing of a background galaxy at a redshift of 0.724. With respect to the model presented by Soucail et al., (1987 b) the only difference is that the mass of the lens is lowered by a factor of 1.30.

It is clear that the observations of such giant arcs in distant clusters of galaxies will open new fields of investigation for gravitational lensing phenomena with probably important consequences on observational cosmology to study the distribution of dark matter in the universe.

In particular, one can imagine to use the rich clusters of galaxies as "gravitational telescopes" to search for more distant objects in the universe (Nottale and Hammer, 1984).

References

Fort, B., Mellier, Y., Picat, J.P., Rio, Y., Lelièvre, G., 1986, *Proc. SPIE* **627,** 321.

Lynds, R., Petrosian, V., 1986, *Bull. Amer. Astron. Soc.* **18,** 1014.

Nottale, L., Hammer, F., 1984, *Astron. Astrophys.* **141,** 144.

Soucail, G., Fort, Y., Mellier, Y., Picat, J.P., 1987 a, *Astron. Astrophys.* **172,** L 14.

Soucail, G., Mellier, Y., Fort, B., Hammer, F., Mathez, G., 1987 b, *Astron. Astrophys.* **184,** L 7.

Lunar Occultations at La Silla

A. RICHICHI, ESO

1. Introduction

Lunar occultations provide the means to obtain high angular resolution down to the milliarcsecond level in the optical and near infrared spectral regions, by analysing the diffraction pattern produced when a source disappears behind (or reappears from) the limb of the Moon. This technique has its main application in the measurement of angular diameters of stars. In particular, it is noteworthy to stress that the majority of all known angular diameters have been measured in this way – see for instance the reviews by McAlister, 1985 and White and Feierman, 1987. In fact, a resolution of one milliarcsecond (mas) at $\lambda = 1 \div 3$ μm is far beyond the possibilities of any other available technique, at present and what can be foreseen in the immediate future (with the possible exception of future long-baseline Michelson interferometry).

In June 1987, observations in the near infrared of lunar occultations were performed at La Silla. The programme – proposed by A. Richichi (ESO), F. Lisi and P. Salinari (Arcetri Observatory, Italy) – had several goals. First of all, our knowlege of the relation between temperature (easily obtained if the diameter and the total flux are known) and spectral type for cool stars is still largely unsatisfactory. According to a review by J. Davis until 1984 there were only 32 stars with a diameter known at the 5% level or better – the minimum for a useful check of current theories with observations – and many of them were early-type stars or cool supergiants. Therefore, we felt that if observations with the instrumentation at La Silla proved feasible, one could hope to significantly improve in the set of measured diameters by observations of occultations in the low-declination portion of the zodiacal belt. This area is very rich of cool giants, especially in the Sagittarius-Scorpius region. In addition, preceding work at the Infrared Telescope of the Gornergrat Observatory (TIRGO), had shown that occultations could also lead to the discovery of compact circumstellar structures (Richichi et al., 1987); therefore many objects in our sample were selected with this aim. Finally, the high resolution provided could lead to serendipitous discoveries, such as the detection of close binaries.

2. The Observations

We travelled to La Silla with a set of about 30 sources that were due to be occulted in a three-night period (10–12 June 1987). They had been selected, not only on the basis of their expected angular diameter being at reach of the technique, but also because of their visual and infrared colours indicating the possible presence of circumstellar dust. They included sources from the SAO, TMSS, IRAS, AFGL catalogues and others. Since most of them had no published data regarding their near-infrared fluxes and/or are strongly variable, we did photometry in the standard J, H, K, L, M broad band filters and in some cases also with the narrow-band circular variable filters (CVF) and in the 10 μm spectral region with the bolometer. Also, for many of the sources it was necessary to determine an accurate position because the error on the given coordinates was often too large. All these preliminary observations were accomplished during a preceding 6-night period at the 1.0-m telescope. They allowed us to move to the 3.6-m for the occultation period with a selected list of "best objects", but they also produced data on many poorly studied objects and revealed some interesting peculiarities.

The observations were carried out at the 3.6-m, using the infrared speckle detector and the Fast Photometry data acquisition programme. This configuration has several advantages: it allows to perform observations at 1 kHz rates with a relatively strong signal, to use the near-infrared filters, and finally to perform also speckle interferometry during the intervals between successive occultations. The fast sampling is necessary because typically all of the critical information is encoded in the central 0.1 ÷ 0.3 seconds of an occultation event. Also the advantage of operating in the near infrared, rather than in the optical, is crucial; the event is slower (roughly by a factor of two), the sources often have their peak emission at wavelengths around 1 μm, and – last but not least – the background level is much lower, because it is mainly composed of scattered sunlight (λ^{-4} law).

Finally, we also had the possibility of a quick switch from Fast Photometry mode to Speckle mode, allowing to collect interferometric data on the same sources that were to be occulted: this means to merge information at the 1-50 mas angular scale of the occultation technique with that at the 0.1-1 arc-

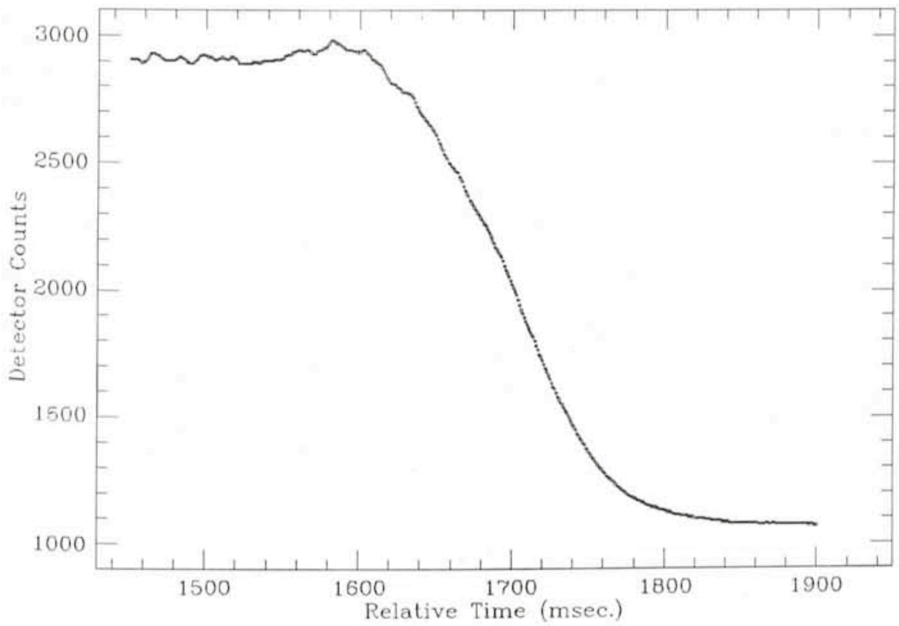

Figure 1.

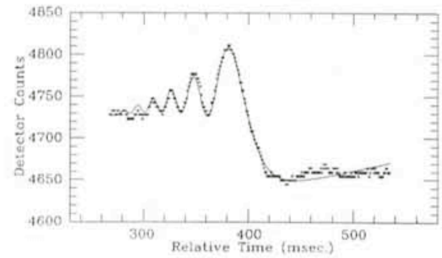

Figure 3.

second scale of speckle interferometry, providing a deeper insight into possible compact circumstellar features.

3. The Results

We attempted to record about a dozen events in two nights (the events occurring during the first night could not be observed due to technical problems). While we succeeded in observing all of the disappearances, the following night we lost many reappearances because it was not possible to use the autoguider of the 3.6-m telescope. Nevertheless, we ended up with at least 4 recorded events. We believe this is a satisfactory result, if we consider that the technique was being tested for the first time and that the observing conditions were less than optimal. In particular, the phase of the Moon was full during our observations, then hampering many procedures such as direct guiding on the monitor or off-axis guiding and giving rise to an extremely high background level.

A detailed analysis of the occultation data is still in programme, and therefore we cannot give the final conclusions. In any case, the most interesting results are surely those concerning the occultations of Antares (α Sco) and SAO 185573. In the first case, we observed an immersion of the bright M 1.5 Ib supergiant through a CVF filter, and the lightcurve is shown in Figure 1. It can be seen that, due to the large angular diameter of the source, almost all fringes in the diffraction pattern are smoothed out, and only a small bump just before the rapid fall is left. We are not yet able to give a definite value for the angular diameter, because we still have to perform detailed calculations. There is evidence of values around or maybe slightly less than the 40 mas given in the literature which is the average of measurements obtained using different techniques (Michelson interferometry, speckle interferometry and lunar occultations) at different wavelengths.

We would like to remark that the signal-to-noise ratio is very good, of the order of 100 in the portion of the lightcurve before the occultation and of the order of 500 after the event. Therefore, it will be possible to determine, in addition to the diameter, other fundamental parameters such as the limb darkening coefficient or (eventually) any significant departure from the expected spherical geometry.

The occultation curve (a reappearance) for the K 5 giant SAO 185573 is shown in Figure 2, together with a preliminary best fit to the data. The diameter of this bright star ($V = 6.8$, $K = 1.7$) had never been measured before: it is an example of how the southern part of the zodiacal belt is still largely unexplored from this point of view. Also in this case the S/N ratio is excellent, and we are confident that the final error on the diameter – which by a first estimate is found to be in the 4.0–4.5 mas range – will probably be of the order of 1 %.

The other two occultations that have been detected so far in the data (there may possibly be others) are those of the variable star WX Sco ($V \sim 12 - 13$, $K = 3.0$) and the weak SAO 184535 ($V = 8.0$, $K = 5.1$). A first analysis of the lightcurve of WX Sco (shown in Figure 3 together with a preliminary fit) indicates that the source is unresolved and yields thus an estimate of the "maximum resolution" of the 3.6-m under the given observing conditions: this limit is about 2.0 mas, and is determined mainly by the broad bandpass of the K filter ($\Delta\lambda = 0.4$ μm).

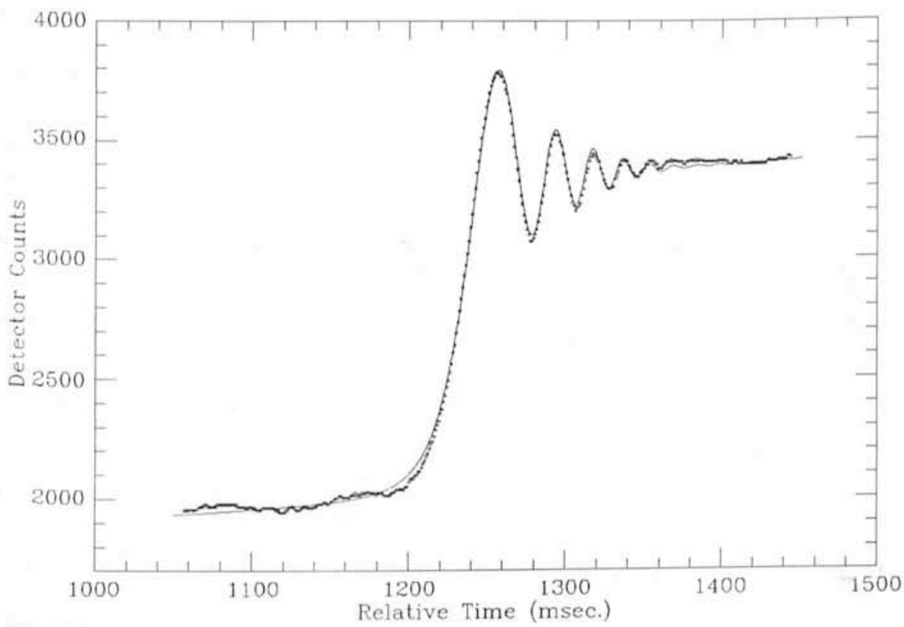

Figure 2.

4. Conclusion

In the first ever observed lunar occultations at La Silla, we measured for the first time the angular diameter of SAO 185573 with very high accuracy. We also recorded the occultation of Antares (α Sco) with very good S/N ratio, and this will allow a detailed study of the outer layers of this bright supergiant. Other occultations were recorded, showing the possibilities and the limits of the 3.6-m telescope in this mode of operation.

But what seems more important to us is the fact that the feasibility of lunar occultations at La Silla has now been demonstrated, and that the results are of the best quality. If lunar occultations were observed on a routine basis at La Silla, maybe taking advantage of future developments of the remote-control facility, a relatively large number of new diameter determinations could be easily collected. This would help to gain new knowledge about the calibration of fundamental quantitities of cool stars and probably lead to the discovery and the study of circumstellar dust shells and binary systems. There is no doubt that the angular resolution of the present method is superior to all other techniques at least in the infrared.

5. Acknowledgements

Our work would not have been possible without the help of many people before, during and even after the observations. In particular, we are grateful to P. Bouchet, U. Weilenmann and the infrared technical staff at La Silla, to C. Perrier for his help during one whole night with the specklegraph, to F. Gutierrez and S. Vidal for their help with the Fast Photometry software, to the night assistants R. Vega and H. Herborn.

References

Davis, J., 1984, in "Calibration of Fundamental Stellar Quantities", IAU Symp. no. 111, Peterson, D. and White, N. eds.

McAlister, H.A., 1985, *Ann. Rev. Astron. Astrophys.*, **23,** 59.

Richichi, A., Salinari, P., Lisi, F., 1987, *Astroph. J.*, in press.

White, N.M., Feierman, B.H., 1987, *Astron. J.*, **94,** 751.

The Large Intractable Nova Shells

H.W. DUERBECK, Astronomisches Institut der Universität Münster, F.R. Germany

Despite the fact that nova outbursts seem to be well understood – at least in principle –, the fine structures of the eruptions remain enigmatic. Novae are believed to be binary stars, composed of a white dwarf and a tightly bound cool dwarf secondary which dumps unprocessed material onto the surface of the primary at a rate of 10^{-8} $M_{\odot}$ per year, i.e. 600,000 million tons per second. After perhaps thousands of years – the order of magnitude is still uncertain – enough material has accumulated on the surface of the white dwarf to give rise to a thermonuclear runaway in the electron-degenerate, hydrogen-rich layer. The accreted matter plus some carbon-oxygen-rich white dwarf material, which was mixed into it during the accretion process, is partially processed in the CNO cycle, and, over a time interval of weeks to years, ejected into space with a speed of several hundred to a few thousand km/s. Thus the nova shell is formed.

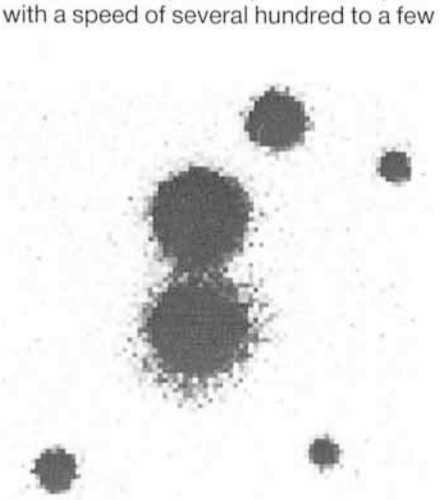

Figure 1: *The shell surrounding nova BT Mon, taken through an Hα filter.*

Faithfull readers of the *Messenger* may still remember the report on the discovery of shells around southern novae *The Messenger* No. 17, June 1979, page 1). In that article, photographs of the shells of RR Pic, CP Pup and T Pyx, taken at the prime focus of the ESO 3.6-m telescope, were presented. In early 1987 a combined study, based on imaging and spectroscopy with the ESO 2.2-m telescope, helped to illuminate more facets of nova remnants and their evolution. We even added a new nova nebula to the small list of known objects. The shell of BT Mon, which erupted in 1939, was first postulated from spectroscopic evidence (Marsh et al. 1983). Now it is seen in Figure 1, very weak and with a nearly circular outline.

The determination of shell properties of novae: geometry, kinematics, temperature, density, and chemical composition as functions of space and time is a largely unsolved task. The variety of light curve types for different nova outbursts reflects to some degree the temporal behaviour of mass ejection. However, almost nothing is known about the late phases of the outburst and the transition to a quiescent wind from the central object.

Spectra taken during the nova outburst display emission lines whose structures indicate that matter is generally not ejected in simple spherical shells. The absorption lines show that gas clouds given off at later times have higher velocities than those of the principal mass ejection. The high velocity material must interact with the previously ejected clouds. Estimates of the times, after which clouds of different velocities meet, agree well with the times at which certain ionized species are first observed in the spectra. The kinetic energies which might be transferred during inelastic collisions have just the right values to account for the observed ionization stages. The appearance of high excitation ("coronal") emission lines in the spectra of some novae during late stages might be attributed to the interaction of the highest velocity material with the principal shell. But is all high-velocity material decelerated by collisions, or can we still observe some of it?

Combining several CCD frames of a

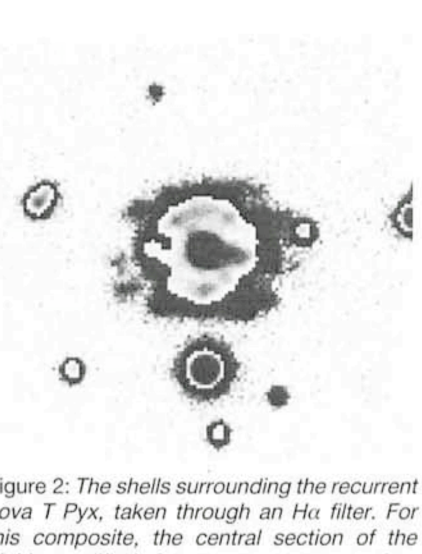

Figure 2: *The shells surrounding the recurrent nova T Pyx, taken through an Hα filter. For this composite, the central section of the highly amplified picture was set to zero, then a lower amplification image of the well-known central nebula was inserted.*