Lunar occultation of the quasar 3C273 observed on Calar Alto

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In lunar occultations, high spatial resolution information on the object is contained in the occultation light curve. This allows to obtain one-dimensional spatial resolutions far beyond the diffraction limit of the observing telescope, be it in optical or radio astronomical application. It was in 1962 when a now famous lunar occultation of 3C273 (measured in the radio domain) allowed to establish the quasi-stellar nature of this radio source by proving its small angular size and by reducing the uncertainty in its position from several arcmin to a few arcsec. Two Saros cycles later, on May 31, 2001, 19:59 UT, again a lunar occultation occured, this time observable from Calar Alto. We wanted to take advantage of this opportunity by near-infrared observations. Ideally, these observations at much shorter wavelength take the process one step further, and we should be able to establish an upper limit to the size of the central regions of this active galaxy and to have a close look at the innermost parts of its jet. The angular resolution offered by our observation is in the milliarcsec range and about 50 times better than what HST can achieve. Figure 1 shows the occultation of the 9^{th} magnitude K0 star SAO 119449 occuring two hours later in the same night. The fit of parametrised profiles to the light curve shows the star unresolved in these observations with an upper limit for its diameter of 1.6 milliarcsec.

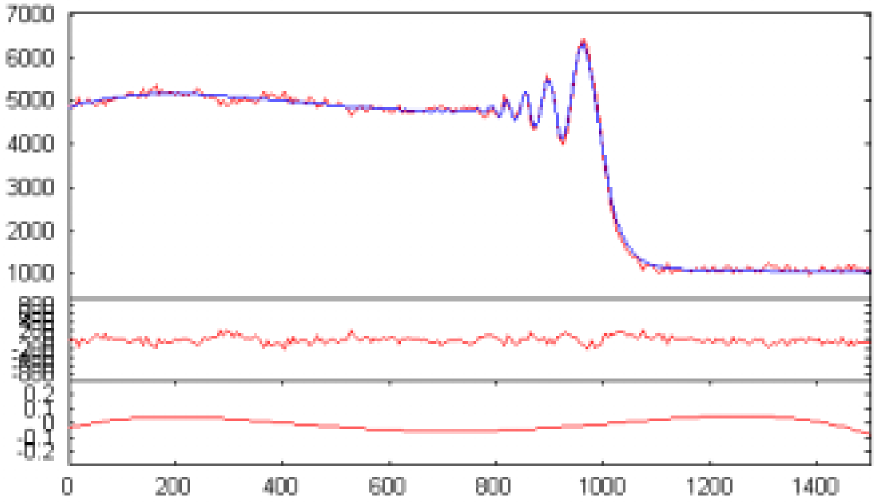

Figure 1: Lunar occultation of SAO 119447, observed at 2.2 μm on the 3.5 m telescope on Calar Alto on the night of May 31, 2001. The horizontal time axis is given in ms, the signal is measured in arbitrary digital units. The upper part shows the observed light curve and the smooth model fit, which also allows for some low-frequency scintillation. The lower boxes show the residuals and this low-frequency scintillation component. The individual integration time per point on the light curve was 3 ms, and the frame rate 167 Hz.

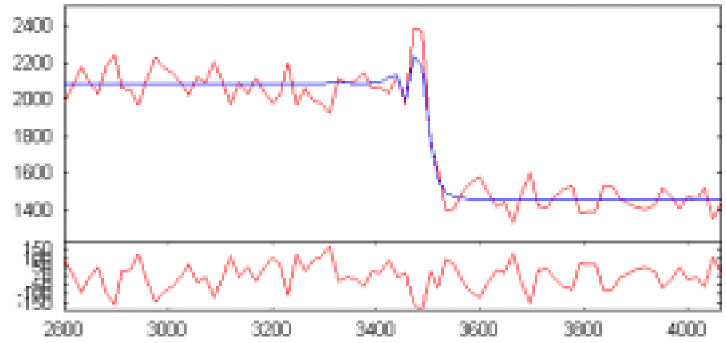

Figure 2: Occultation of 3C273 on May 31, 2001. The time scale is in ms, the signal in arbitrary digital units. In the upper part the measurements and the smooth model fit are overplotted, the lower box shows the residuals. An upper limit for the size at 2.2 μm of 6.7 milliarcsec resulted from these observations. Because of the faintness of the object, the individual integration time per point was set to 8 ms, with a resulting frame rate of 62.5 Hz.

To observe such a lunar occultation on the quasar 3C273 with its moderate brightness of K $\approx$ 9.7 mag (80 mJy), a near-infrared detecting system is needed which is both fast and sensitive. On Calar Alto this possibility is given by the Omega-Cass camera on the 3.5 m telescope. With its 1024x1024 pixel HdCdTe array ("HAWAII detector") it provides the necessary sensitivity, and the fast readout in millisecond time is achieved by reading out subarrays ot typically 32x32 pixel, corresponding to 6.4″x6.4″ or 9.6″x9.6″ depending on the optics chosen. This promises an effectiveness for lunar occultation observations not easily to be found at other observatories and allowed us to have a closer look into the inner regions of 3C 273, with an expected spatial resolution of about 5 milliarcsec. We cannot guarantee that this gain in spatial resolution will lead to qualitatively new insights, but it is tempting to try it. And director Hans-Walter Rix was kind enough to invest director's discretionary time into this undertaking.

In any case we were following two questions which only can be treated with high angular resolution. From VLBI observations it is known that among the knots moving out along the jet there is a particularly bright one, called "C2" at 25 milliarcsec from the quasar. Since its discovery in 1989 it should have moved by now to a distance of 34 milliarcsec, within the resolution of our observations. Its brightness is not known. Extrapolations from the radio brightness (2 Jy at 1.7 GHz) to the near-infrared based on the spectral indices determined for the outer knots of the jet (Röser and Meisenheimer 1991, Jester et al. 2001) leads to an estimate of 1 % of the quasar brightness, not brighter than K = 15 mag. This means that we cannot normally expect to see this inner knot of the jet, but if it is revealed by the occultation observations this will prove that its spectral index is quite different from that of the outer portions of the jet. As a second topic we wanted to search for the central cusp of the stellar distribution of the underlying galaxy. Extrapolating from the 2.0″ found in M87 to this quasar, 50 times more distant, we may expect a size of 40 milliarcsec, again within the reach of our observations.

On May 31 the sky was clear over Calar Alto and we could observe the occultation. The relevant second of the occultation light curve is shown in Figure 2. The observations were successful but only showed an unresolved near-infrared source with an upper limit to its size of 6.7 milliarcsec. Unfortunately, no structures in the central part of 3C273 did show up. But the limit on size is a good and valid result, and it encouraged us to try a second time to find evidence for measurable circumnuclear structures.

Indeed, the conditions were not yet optimum during the observations on May 31. Each subarray integration of 8 ms had to be followed by an equal time interval reserved for readout. An ”integrate while read” mode would allow to double the frame rate with the same integration time or to double the integration time at the same frame rate, a gain by a factor of two in these sky-noise limited measurements. Also, the camera wheel was stuck during these observations with a less favourable magnification, forcing us to distribute the light over more pixels than necessary. Here again, some gain in signal-to-noise ratio and speed could be expected. Finally, during the occultation on May 31 the moon was occulting the inner jet knot first, while the quasar still contributed its full brightness. The reverse sequence of events would happen with a reappearance of the object behind the dark limb of the moon: the faint jet knot would appear before the quasar, and thus would be easier to detect against the lower, scintillation-free background signal.

When a second occultation of 3C273 came up in the morning of December 9, 2001, it happened to be such a reappearance event, and the technical improvements mentioned above had been implemented. It was just the clouds which prevented us from an attempt to do still better than shown in Figure 2. And, as well known, a lunar occultaion is a one-second-get-it-or-miss-it event. An exaggerated example of how it may look if several components of an object reappear from behind the dark limb of the moon is shown in Figure 3. If only a partial success, our observations of 3C273 during the last year can be taken as a good example of an interesting capability of Calar Alto, which is not so well known among its users. The results of the successful occultation observation in May will soon find their use in combination with the somewhat less resolved but much more sensitive observations of the CONICA near-infrared camera on the VLT. In particular the lunar occultation observations will limit the brightness of the central cusp of stellar distribution.

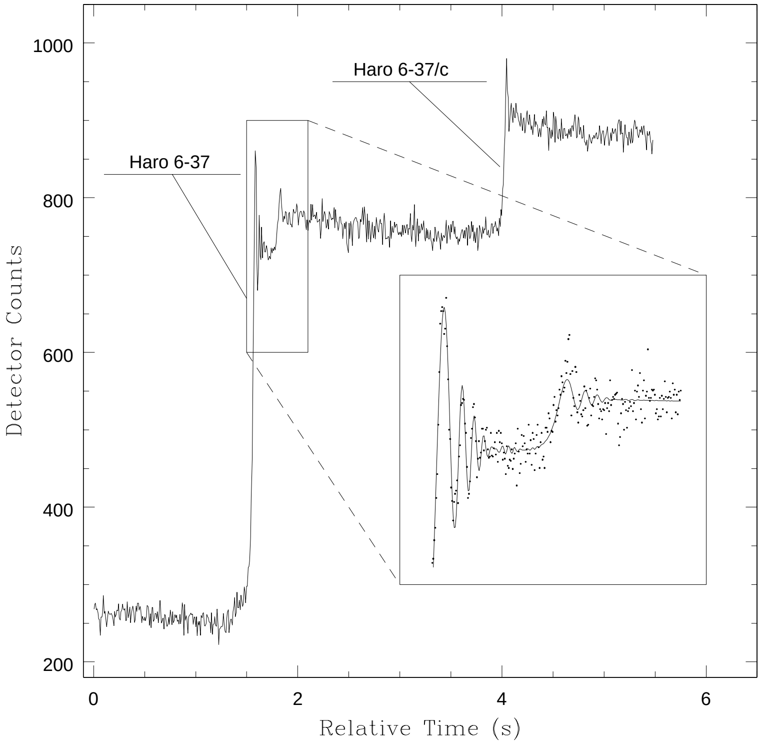

Figure 3: Reappearance of the three components of the young star Haro 6-37 from behind the dark lunar limb during an occultation on November 16, 1997 (Richichi et al. 1999)

References

Röser, H.-J. and Meisenheimer: *The synchrotron light from the jet of 3C273*, A&A **252**, 458
Jester, S. et al.: *HST optical spectral index map of the jet of 3C273*, A&A **373**, 447
Richichi, A., Köhler, R., Woitas, J., Leinert, Ch.: *Discovery of a close companion to the young star Haro 6-37*, A&A **346**, 501