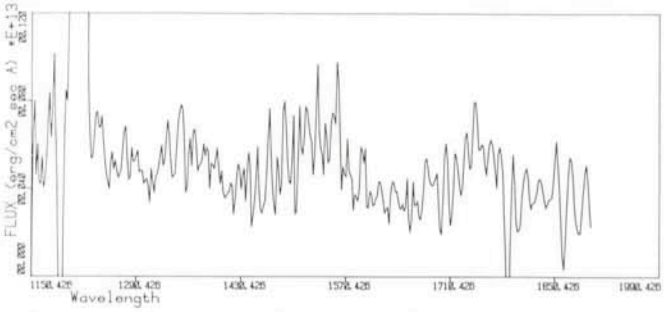
- to obtain high-resolution spectra of stars of all spectral types,
- to study gas streams within binary star systems,
- to observe at low resolution faint stars, galaxies and quasars,
- to obtain spectra of planets and comets,
- to improve the knowledge of the physical conditions in the interstellar matter by measuring its effect on the stellar spectra.

After the first few months of observations an exciting body of data has already accumulated on a large number of objects, from planets to QSOs. At the end of September, a full issue of *Nature* will be devoted to the data obtained in the very first period of observations.

Here we would like to present the preliminary results of an observation of the jet in M87, which represents a case of this instrument used at the limits of its technical possibilities. The radio galaxy Virgo A (NGC 4486, M87) is a bright elliptical in the Virgo cluster. It is known since 1918 to contain a very peculiar feature near its centre, which looks like a jet emerging from the nucleus. The total magnitude of this feature is $m_B = 15.8$, but it consists of several bright spots, among which the brightest has $m_B = 16.77$. The optical spectrum is a featureless continuum which follows a power law with a spectral index $n = 1.7$ ($F(\nu) \alpha \nu^{-n}$) and is highly polarized.

The soviet astrophysicist L. Shklovski suggested in 1956 that the optical radiation is produced via the synchrotron process by relativistic electrons and positrons in a magnetic field. It was the first extragalactic source with spectral and polarization properties similar to those of the Crab nebula continuum. One of the main problems it poses is how the electrons get continuously accelerated to catch up with the synchrotron losses, which become more and more severe as the emission frequency increases. The first aim of our measurement with IUE was therefore to measure how the continuum extends into the far UV.

On July 24, 1978, we pointed the IUE telescope in the direction of M87, whose nucleus is bright enough to appear as a diffuse spot on the TV screen. The jet itself is too faint to be seen in the picture, so, in order to position the entrance slot of the spectrograph on it, we made use of the possibility offered by IUE to guide an observation in the "blind" offset mode. We therefore moved the telescope off by 12" from the centre of the galaxy in the appropriate direction and then selected a bright star in the field of view for the automatic guide. After 6^h30^m of exposure time with the short-wavelength camera we saw on the screen the spectrum of the brightest knot of the M87 jet. Unfortunately, some fairly wide sections of the spectrogram were disturbed by a comparatively strong microphonic noise produced during the read-out of the camera. (This happens rather rarely.)



A preliminary version (there are still problems with the calibration of the IUE camera) of the spectrum after the subtraction of the background is presented in the figure. It tells us two important things: the first is that the optical continuum appears to extend into the far UV without changing the slope of the power law. The second is that, despite of the noise, there is one emission feature in the spectrum which looks undoubtedly real (we have carefully inspected the raw image of the spectrogram to make sure that it is not a fake). This feature sits at 1556 Å, which corrected for the redshift of M87 corresponds to the line CIV λ1549, the most prominent line after Lyα found in this range of wavelengths in high redshift QSOs and also in the spectra of 3C 273, NGC 4151 and NGC 1068 obtained with IUE. (Because of the large aperture of the slot, the strong Lyα line at 1216 Å is due to geocoronal light.)

This result is particularly important, because it immediately implies that the brightest knot at least cannot be moving at a large speed (say greater than a few hundred km sec^{-1}) relative to the galactic nucleus. This represents a strong constraint for dynamical models of the jet involving ejection of matter from the nucleus of the galaxy.

Optical Pulsations from 4U 1626–67 Discovered with the ESO 3.6 m Telescope

S.A. Ilovaisky, C. Motch and C. Chevalier

A little over a year ago, Drs. Claude Chevalier and Sergio Ilovaisky reported the optical identification of the X-ray source LMC X-4 (cf. Messenger *No. 9, p. 4). Now, together with Dr. Christian Motch, also from Observatoire de Meudon, France, they have succeeded in measuring optical pulses in a* 19^m *star with the same period as the southern X-ray source 4U 1626-67, and therefore identical with this source. To obtain a high time-resolution,* $0^s.8$*, it was necessary to use the 3.6 m telescope. Contrary to other X-ray sources, no Doppler shift has yet been detected in 4U 1626-67.*

Much excitement has been generated in the astronomical community by the publication of more than 50 accurate positions (± 20" to 30") of galactic X-ray sources obtained with the Rotation Modulation Collimator (RMC) experiment on the SAS-3 satellite. Even more numerous and accurate X-ray positions are expected as a result of the sky survey being carried out at this moment by the giant HEAO-1 satellite. With this improved positional information, *optical identifications* can now be attempted with a high degree of confidence inside the small X-ray error circles.

Preliminary photometric detective work carried out by Jeffrey McClintock and colleagues at Cerro Tololo last year singled out two sources for further study: the X-ray burster MXB 1735-44 and the X-ray pulsar 4U 1626-67. In both error circles faint blue stars with unusual colours (V = 17.5, B-V = +0.2, U-B = –0.8 and V = 18.6, B-V = +0.1, U-B = –1.2, respectively) were found. These two suggested optical counterparts have been scrutinized in detail

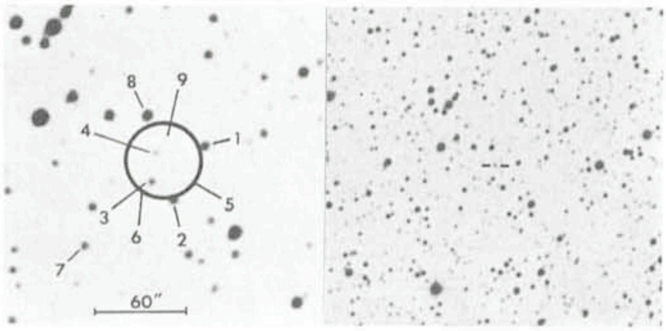


Fig. 1: *Optical identification of 4U 1626-67. To the left the SAS-3 RMC position with a 50" diameter 90 per cent confidence circle. Pulsations were detected from star No. 4, which is also indicated in the right hand figure, reproduced from the ESO QBS Atlas.*

this season: MXB 1735-44 from Cerro Tololo in June 1978 and 4U 1626-67 from La Silla in May, and in both cases the optical observations have successfully shown that the suggested stars are indeed the correct ones: precisely the same *time-signature* known in X-rays has been discovered in each star. For 4U 1626-67 we found optical pulsations at exactly the X-ray period (7.68 seconds) and for MXB 1735-44 three sharp optical bursts identical in shape and duration (0.1 sec rise and 10 sec decay) to the X-ray bursts were observed by a joint Harvard-MIT group, one being exactly simultaneous with an X-ray burst observed with SAS-3.

Optical Observations

During our observing run at the 3.6 m in May 1978—our first at this telescope—the weather was particularly bad with cirrus clouds and 100 km/h winds and it really looked as if we would not observe much, if at all. But on the second half of the night of 2/3 May we decided to attempt high-speed photometry of the 4U 1626-67 candidate for about 1 h—through thin cirrus and with some wind—using our own special equipment brought from Meudon. Observing conditions on the Cassegrain cage were not ideal, due to a severely inclined cage floor (more than 40° with respect to the horizontal!), but we managed to locate the almost nineteenth-magnitude star and put it in the photometer aperture.

Fourier analysis of the data was done back home in Meudon a few weeks later, and how pleasant was our surprise when the computer print-out showed a huge spike in the power spectrum at $7\overset{s}{.}6805$, almost exactly the predicted geocentric X-ray period at the date of the observations! A portion of the spectrum is shown in figure 2 and the light curve—the data folded modulo the best period—in figure 3, where the pulse is repeated for clarity. Our observations were made in white light using an S-13, low-noise, uncooled photomultiplier. The time resolution was $0\overset{s}{.}9$ with counts being actually accumulated only for $0\overset{s}{.}8$. A highly stable quartz-crystal oscillator integrated into our microprocessor-controlled photometer gave us strictly equi-spaced integrations—a must for Fourier analysis. The high signal-to-noise ratio obtained for this faint object with our system (a net star-sky signal of 1100 counts/sec with a sky count of 3800 c/s using a 10" aperture) has encouraged us to plan re-observing the star next season with better time resolution ($0\overset{s}{.}1$). We are already re-programming the microprocessor and hope for improved weather conditions!

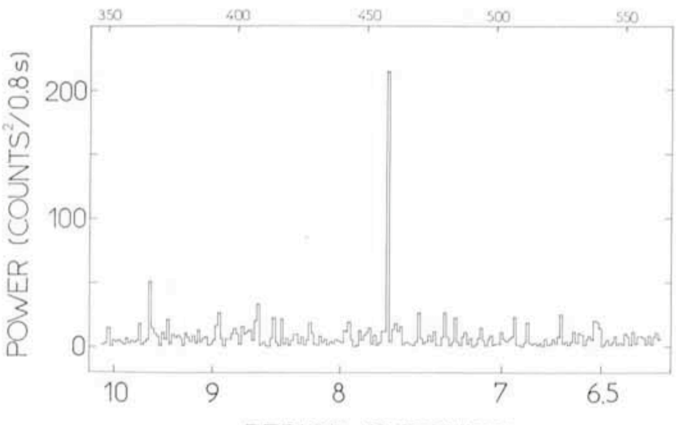


Fig. 2: *A small part of the power spectrum of the 4U 1626-67 optical counterpart. The strong peak corresponds to a period of 7.6805 sec.*

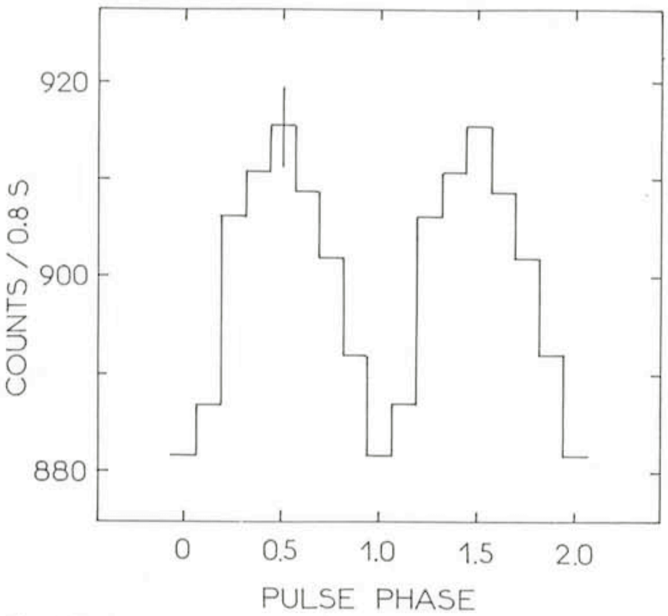


Fig. 3: *The light-curve of 4U 1626-67. Note the relatively sharp rise and gradual decrease.*

The Nature of 4U 1626-67

With an amplitude of 4 per cent this source turns out to be the one showing the largest optical modulation of the optically identified X-ray pulsars in binary systems (Her X-1, Vela X-1, 3U 1700-37 and 3U 1223-62). However, and this is where the 4U 1626-67 system is really mysterious, there is no trace in the X-ray data of any Doppler effect. This effect, normally seen in other X-ray pulsars, is due to orbital motion of the compact X-ray source around the centre of mass of a binary system in which the optical primary is the more massive component—and the one we *see*—and where orbital periods range from 2 to 40 days. The optical pulsations detected in these systems are thought to be due to X-ray heating of the material close to the X-ray source, where X-ray photons are absorbed and quickly re-emitted as optical photons.

The absence of a Doppler effect on the 4U 1626-67 system led theoreticians to conclude that the orbital period was most likely very short ($P \leq 0.3$ day) in order to have escaped detection and that the companion optical star was a low-mass, low-luminosity object, actually of lower mass than the X-ray source! In such a highly compact binary system, it was argued, X-ray heating of the companion would dominate and strong optical pulses might be detected. This prompted our observations, which indeed revealed strong pulses, but not even half as strong as predicted. Our data show no Doppler effect within one hour. Perhaps future observations might reveal this effect and thereby determine the orbital period—or are we in for more surprises?