Multi Object Spectroscopy with the ESO Multi Mode Instrument at the NTT

First successful test of the MOS mode of EMMI using a new plate punching unit operating under computer control inside the instrument

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1. Low Dispersion Spectroscopy with EMMI

EMMI, the ESO Multi Mode Instrument recently installed at the 3.5-m NTT (D'Odorico, 1990, Dekker, D'Odorico and Melnick, 1990) is a dual-channel focal reducer/spectrograph designed for high efficiency observations and for a wide range of resolving powers. Figure 1 shows the instrument layout. Low dispersion spectroscopy ($R \leq 1600$ for a 1-arcsec slit) is possible in the red arm ($\lambda\lambda$4000–10000 Å, upper right part of Figure 1) with a choice of 6 grisms which can be inserted in the parallel beam space of the focal reducer. In this observing mode, where EMMI operates like EFOSC1 and EFOSC2, the two focal reducer/low dispersion spectrographs mounted at the ESO 3.6-m and 2.2-m telescopes. The corrected field of view is 10 × 10 arcmin. The scale in the telescope and in the detector focal planes are 186 μm and 43 μm per arcsecond respectively. At the time of this test a 1024 × 1024, 19 μm square pixels THX 31156 CCD was used as a detector. This CCD is characterized by a peak quantum efficiency of 50% at 7000 Å, very high cosmetic quality and a read-out noise of 4–5 e^-/pixel. With this detector the field in imaging is 7.6 × 7.6 arcmin.

2. Multi Object Spectroscopy in EMMI

As in the EFOSC-type instruments, EMMI has an aperture wheel in the focal plane of the telescope where 4 long slits of different width are usually mounted and one position is left free for direct imaging. For MOS observations with EFOSC1 at the 3.6-m telescope, special aperture plates can be prepared from punching files derived from direct images of the target fields. The punching machine PUMA2 located in the telescope control room generates round holes with a minimum diameter of 2.1 arcsec, and these can be combined to make rectangular slitlets. The aperture plates are later mounted in the instrument and, after a proper alignment procedure, used for MOS observations.

When designing the MOS unit for EMMI (usually identified as *starplate unit*) we took into account the experience with EFOSC1 and tried to improve some aspects of the observing procedure. It was decided to install the plate punching on the instrument itself with the aim of simplifying the plate alignment procedure and to have a fully hands-off procedure for this observing mode. Secondly, a punching device of new design was conceived to improve the reliability and the quality of the slitlets in the aperture plates. A further ad-

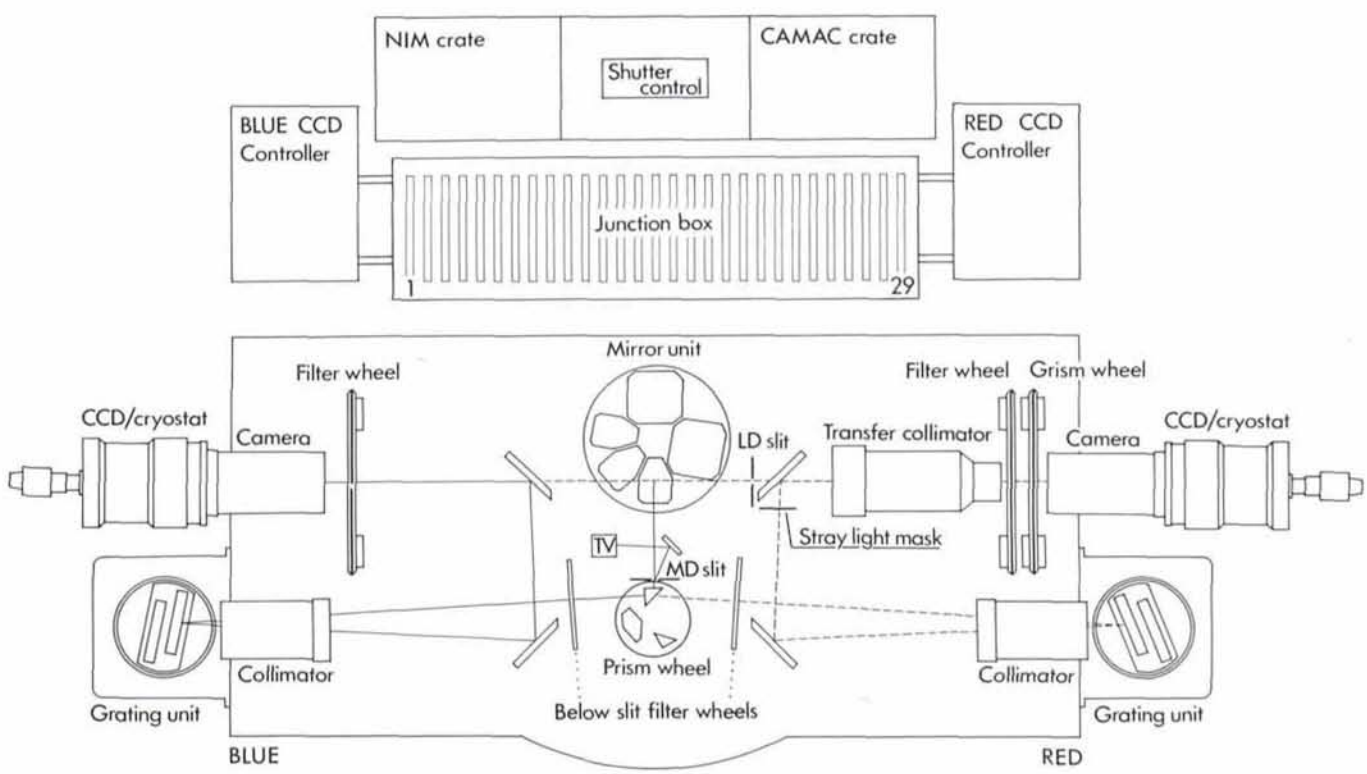

Figure 1: *An overview of the main components of EMMI. Multiple Object Spectroscopy at low resolution is carried out as explained in the text by using MOS plates inserted in the aperture wheel of the focal reducer mode (identified as LD slit in the drawing). The punching of slitlets in the plates is carried out in EMMI itself by an ad-hoc designed "starplate unit".*

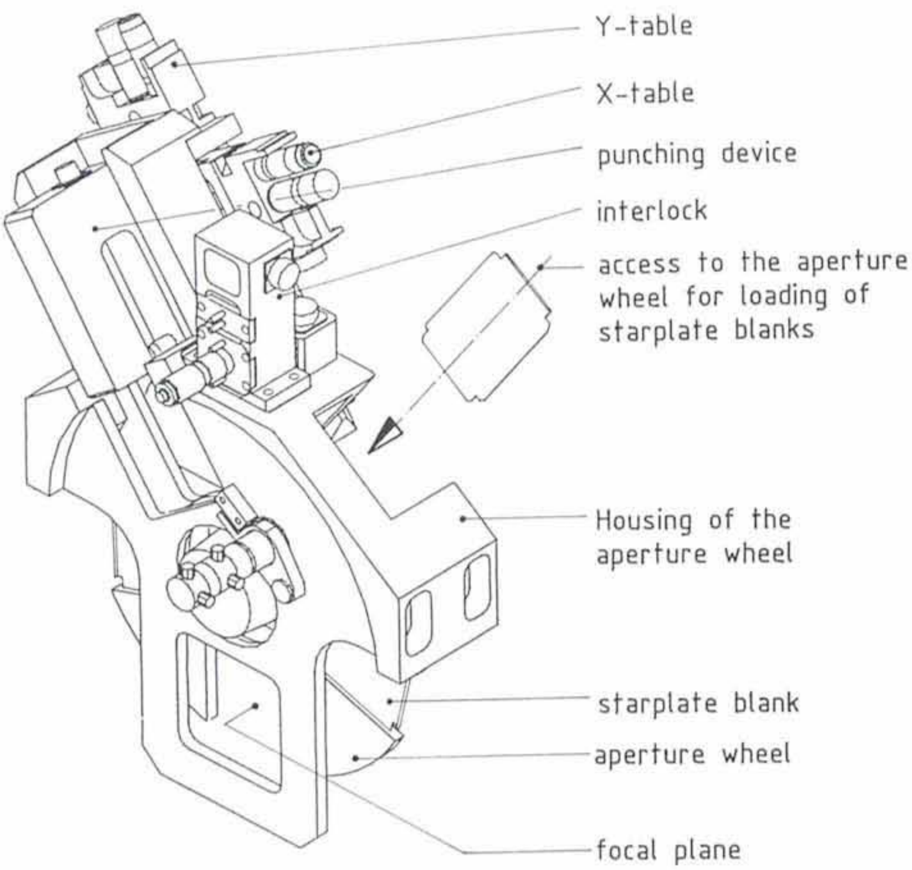

Figure 2: *A CAD drawing of the starplate unit with identifications of the main components.*

vantage of MOS in EMMI is the field of view which is 5 × 8 arcmin approximately, an area 3–4 times larger than in EFOSC1.

For the MOS work up to four of the long-slit plates in the aperture wheel can be replaced by starplate blanks of identical geometry. A punching device, mounted on a cross-table fixed on the EMMI structure, is then used to punch short slits in the blanks. The punching units are equipped with tools which determine the minimum slit width and length. While the slit length can be increased by multiple punching along the slit, the slit width can only be changed by replacement of the complete punching unit (equipped with tools of the desired slit width). Figure 2 is an isometric view of the starplate unit of EMMI showing the subunits: aperture wheel, interlock, x-table, y-table and punching device.

The aperture wheel, mounted in the focal plane of the low-resolution mode of EMMI, is driven by a DC-motor with tachogenerator and positioned by an incremental encoder like all servo-controlled units in EMMI. The selected plate is placed in the optical path of the instrument by the proper software instruction. For loading or removal of starplates the aperture wheel is easily accessed to form the EMMI service platform.

The interlock has a dual function. Mounted on the aperture wheel housing it mechanically locks the aperture wheel during punching of the slits and prevents an inward motion of the punching device when the starplate is not in the punching position. The positioning of the punching device across the slit (direction of the spectral dispersion) is provided by *the x-table*. The range of its movement is 56 mm which corresponds to a field width of 5 arcmin. The positioning accuracy is ± 8 microns or ± 0.04 arcsec. The limited space available for the starplate unit did not allow a clamping system for the x-table. Therefore, during punching, EMMI should not be rotated and the x-table should always be in the same orientation with respect to the gravity, preferably in the horizontal position with the punching device on top.

The movement of the punching device into the punching field of the starplate, positioning of the punch along the slits and elongation of the slits, is provided by *the y-table*. The movement range is 116 mm of which only 90 mm (8 arcmin) can be used for punching in EMMI.

The most complex part of the starplate unit is *the punching device*. It required some development effort and the application of new technologies. Figure 3 shows the punching device with tools in its final version. From outside it looks like a miniature sewing-machine. Inside its light-weight but stiff body are the punch-motor with control switch, the linear guide and support of the punch, a cross-table to support and adjust the die, and a clamping system to lock the device distortion-free and stable on the x-table. The punching tools are fabricated from

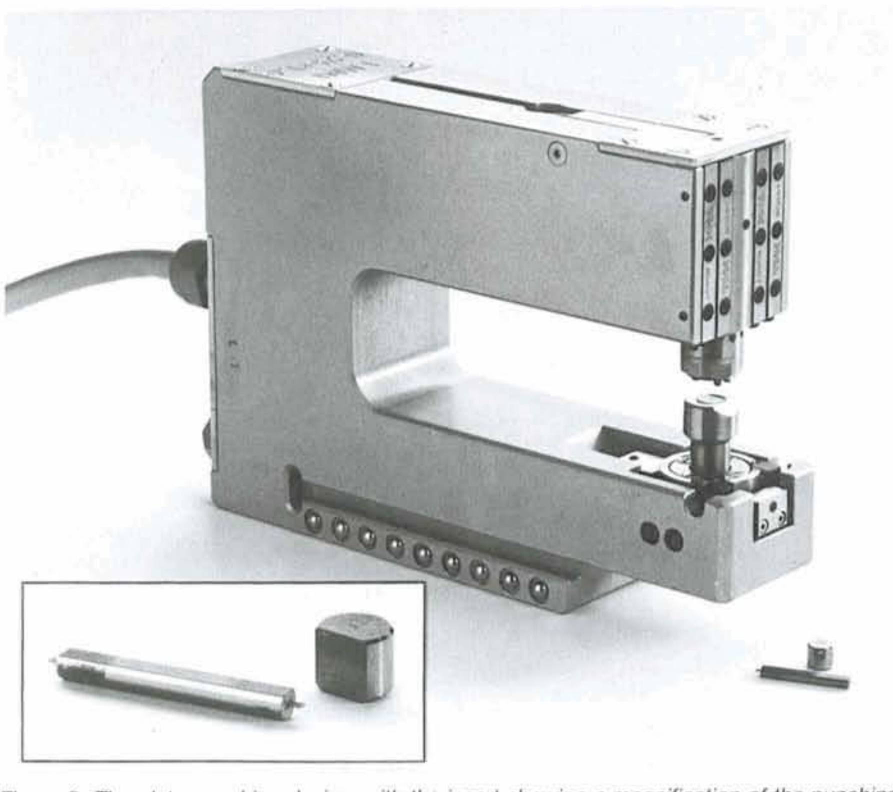

Figure 3: *The plate punching device, with the insert showing a magnification of the punching tool. The dimensions of the device are 170 × 120 × 40 mm, the weight is 1.6 kg.*

carbide using the spark erosion technique. The chips produced during the punching are stored in a container below the die, sufficiently large for approximately 10,000 punches.

The starplates are consumables and designed therefore for cheap manufacture in small series. This is achieved by wire-cutting of approximately 50 plates at once. After the cutting, one side of the starplate is reinforced by a bend to achieve better flatness in the unsupported region when mounted in the aperture wheel. An anti-reflecting black painting of the starplate surface is used to avoid ghosts in the spectrum. Table 1 summarizes the characteristics of the MOS mode of EMMI.

3. First Astronomical Results

A first test of the MOS mode of EMMI and in particular of the operation of the starplate unit was carried out during the EMMI commissioning period in October. First we obtained one 1-minute direct image of a field from the Key Programme "A Redshift Survey of galaxies with $z \leq 0.6$" (de Lapparent et al., 1989). The goal of this programme is to obtain a complete catalogue of 700 galaxies brighter than R=20.5 over 0.4 deg^2 near the south galactic pole for studying the large-scale structure at $z \simeq 0.3$. All galaxies in the catalogue will have BVR photometry and low-resolution spectroscopy for redshift measurements. The direct image in the red arm of EMMI did show several galaxies with angular sizes up to ~6 arcsec and R magnitudes in the range 17–21. Eight galaxies were selected for the preparation of the punching file, using an improved version of the software which is used for the same purpose in EFOSC1. The actual punching in the starplate unit took about 2 minutes, the dimension of the tool used corresponded to 1.3 × 8 arcsec. The plate was then moved to the optical path of the instrument and used in combination with the EMMI grism No. 3 for two 1-hour exposures on the eight galaxies. Figure 4 shows one of these exposures. No alignment of the galaxies with the slitlets was needed for the first exposure. A minimal telescope offset (≤ 1 arcsec) was needed for optimal centring before the second exposure.

A preliminary reduction of these data has been carried out to estimate the capability of this observing mode. After bias subtraction, the two 1-hour MOS exposures were flatfielded with a halogen lamp used as source through the grism and aperture plate. This procedure is necessary to remove non-uniformities up to 10% of the transmission along the slitlets. This effect has been traced to remnants of the black paint

TABLE 1: *MOS in EMMI*

Punching area on the starplates:	56 × 90 mm (5 × 8 arcmin)
Minimum slit width:	150 microns (0.8 arcsec)
Minimum slit length:	1.2 mm (6.5 arcsec)
Maximum number of slits/starplate:	52
Flatness of punched starplates:	< 0.3 mm peak-to-peak
Punching time of 40 slits:	approx. 5 minutes
Life-time of the punching tools:	> 10.000 punches
Thickness of the starplates:	120 to 200 microns, depending on the desired slit-width
Material of the starplates:	copper alloy with 2% beryllium

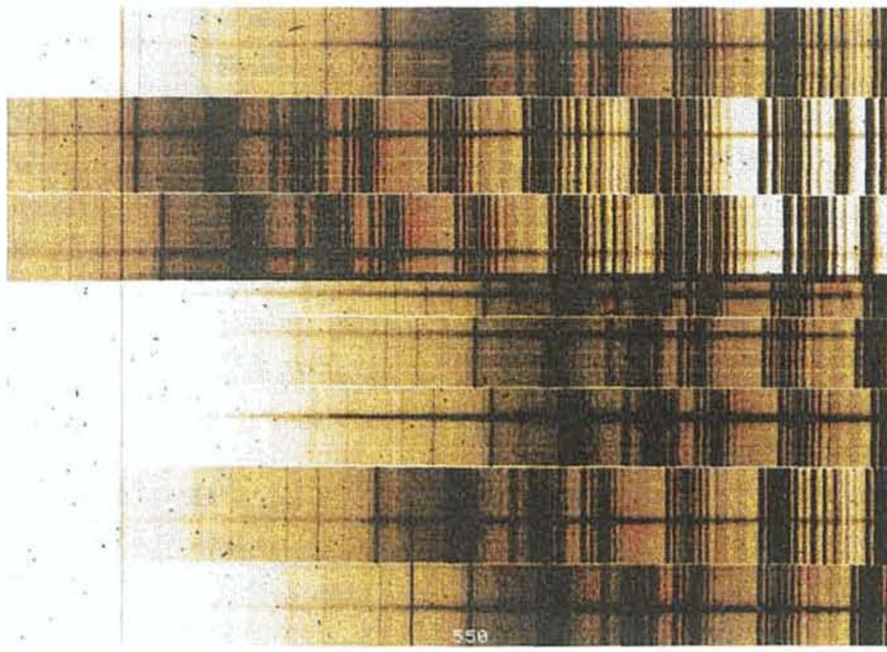

Figure 4: *A one-hour MOS exposure on a galaxy field obtained with EMMI at a resolution ~10Å. The eight targets are galaxies with 2–6 arcsec in size and integral R magnitudes between 17.5 and 19.5.*

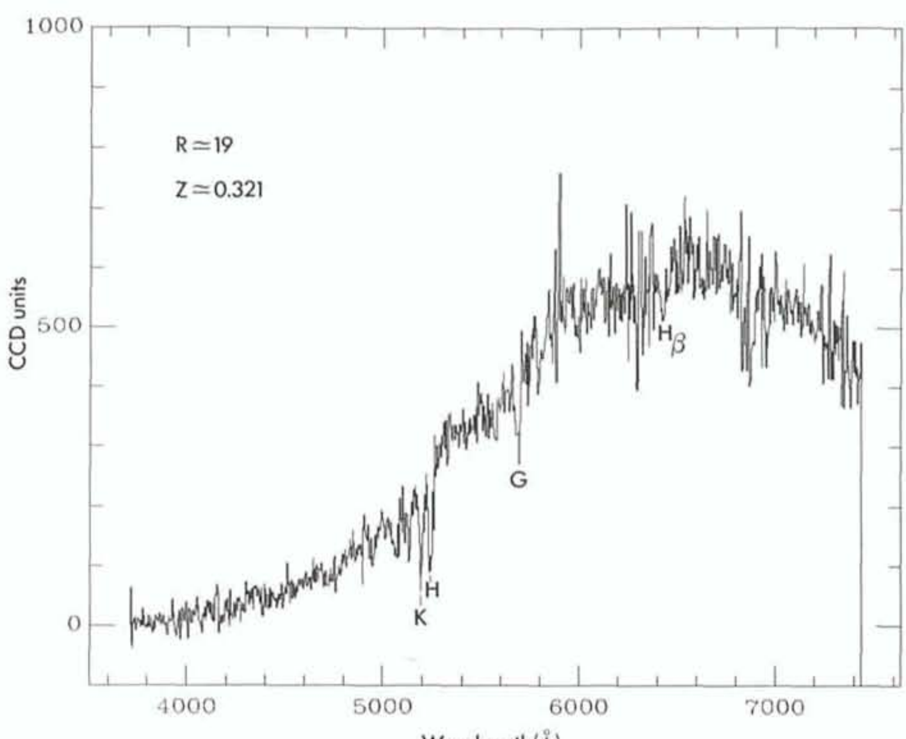

Figure 5: *The sum of two one-hour reduced spectra of a galaxy of R ~ 19 (the first spectrum from the bottom in Figure 4).*

used on the plates in the punched slits and it should hopefully be eliminated in the future by the use of a different paint.

Removal of radiation events on the CCD (of the order of one per row) was done by a two-step filtering procedure which does minimal damage to the data. First, all pixels exceeding by more than a factor of 2 the value of the pixel at the same position on the other 1-hour exposure were replaced by the pixel value from the other exposure. Second, a median filtering over a few pixels perpendicular to the dispersion direction with a high threshold for data modification was applied and further removes all but a couple of events. This second filtering was necessary for removing the cosmic rays affecting identical pixels in both exposures.

Each object spectrum was finally extracted using all rows within the half width of the object profile along the slit, and was calibrated in wavelength using He and Ar calibration exposures. The resulting dispersion is ~ 3.7 Å/pixel, the resolution ~ 10 Å. As much sky as available in each slit was independently wavelength calibrated and then removed from the corresponding object spectrum. A long slit calibration procedure with a signal-weighted extraction procedure will clearly yield a cleaner sky subtraction, a crucial problem for faint and extended objects, and a better S/N ratio in the extracted data but it has not yet been applied to this set of data. Figure 5 shows the sum of the two 1-hour spectra for a galaxy with R ~ 19. The H and K lines, the G band and the Hβ absorption line are clearly identifiable and yield z ≃ 0.321. The S/N ratio of the spectrum at 5500 Å is ~ 15.

The eight galaxies observed in this first MOS field with EMMI have R magnitudes ranging from ~ 18 to ~ 20. The derived redshifts range from z ≃ 0.120 to z ≃ 0.431. The sum of the two 1-hour exposures is sufficient in all objects for rough (Δz ~ 0.001) but reliable redshift measurement using the positions of the H and K lines or the [OII] and other emission lines. Cross-correlation analyses with a reference spectrum will yield smaller uncertainties in the redshift measurement.

In conclusion, the first tests of the MOS mode of EMMI have proven that the multi-slitlet plates can be prepared at the instrument with the required quality and immediately used for astronomical observations without manual intervention.

The results from the quick reduction of the data from the October run can be used for an estimate of the capability of the system. Assuming an optimal extraction procedure of the spectra, it should be possible with EMMI to measure the redshift of as many as 15 objects down to an R magnitude of 21–22 in a field of 5 × 8 arcmin with three 1-hour exposures.

The MOS mode of EMMI will be released to visiting astronomers in the course of Period 47 (April-September 1991).

4. References

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Dekker H., D'Odorico S., and Melnick J., 1991, *ESO Operating Manual* No. **14.**

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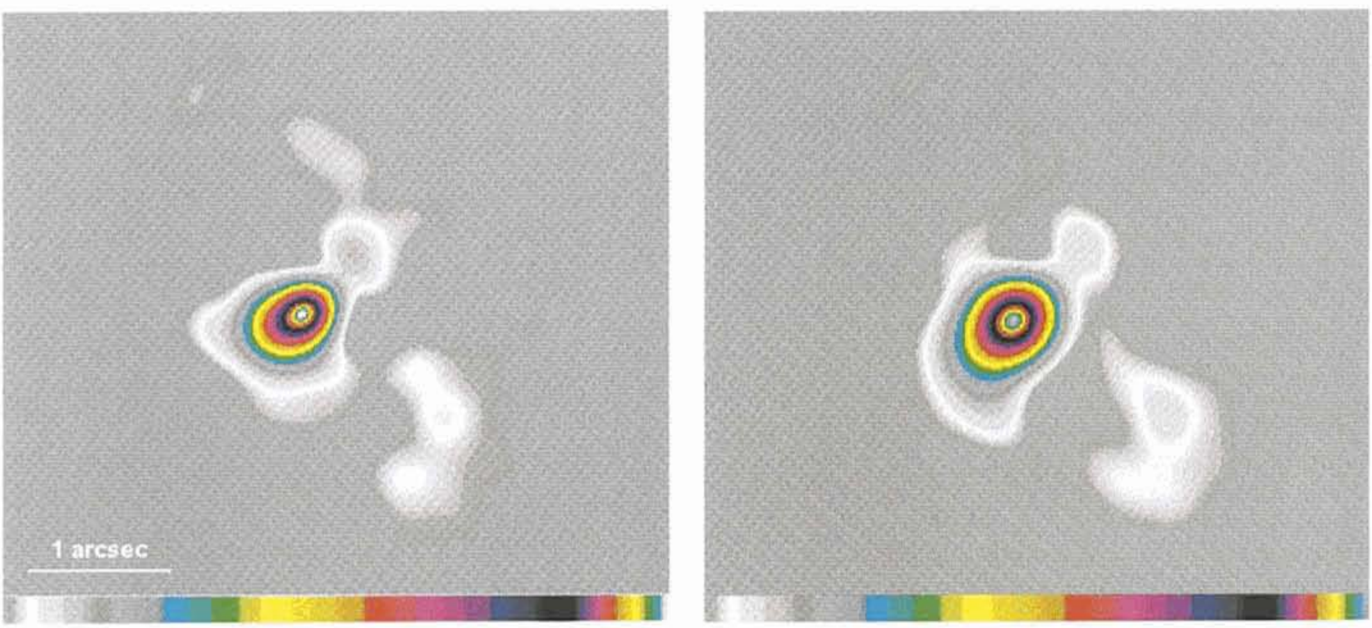
New Year's Eve with Adaptive Optics

From December 31, 1990 through January 8, 1991 a second observing run with the VLT adaptive optics prototype system – fully devoted to scientific programmes – took place. During this period, astronomers could benefit not only from diffraction-limited images which are now given routinely by the adaptive optics system, but also from new features like a coronograph, designed and built at Observatoire de Meudon, and an infrared wavefront sensor. For standard observation the Electron-Bombarded CCD (EB-CCD) of the visible wavefront sensor (see *The Messenger* No. 62, p. 64) is used for wavefront sensing, allowing objects up to the 13th magnitude to serve as reference sources.

The observations with the adaptive optics prototype system started with the



ηCarinae in the L- (left) and M-band (right). Both images are composed of five sub-images (four quadrants and additional frame in the centre) like a mosaic. The scales for both images are the same. The two mosaics have been deconvolved with the measured point spread function at the corresponding wavelength. These observations show new features around the central object (some people say it looks like a carrot-eating vizcacha).