noticeably compromised by clouds). The signal-to-noise ratio per spectral resolution element (0.1 Å or ~3 pixels), was slightly better than 300. For the centre of this order we estimate an overall efficiency (incl. atmospheric extinction) of roughly 0.03%, down by nearly two orders of magnitude from the efficiency measured with CCD No. 8 at 4000 Å (Pasquini, L., D'Odorico, S.: 1989, CASPEC, *ESO Oper. Man.* No. 2).

In Figure 1, the interstellar CH lines at 3137.5, 3143.2, and 3146.0 Å with equivalent widths of about 3.7, 7.0, and 4.0 mÅ, respectively, are easily seen. But there is no feature in excess of 1 mÅ at 3130.4 Å. This value corresponds to the strongest feature within 0.2 Å of the expected position of Be II whereas the signal-to-noise ratio suggests a formal upper limit of 0.3 mÅ. Impressive though these numbers may be, they are only about the same as the ones inferred by York and Snow (1982, *Astrophys. J.* **255,** 524) from their observations with the *Copernicus* satellite.

In the final analysis, our experiment was only a successful and very promising feasibility study (which also included the reduction of our data with the echelle package in MIDAS). Nevertheless, we believe that it is perhaps worth reporting it to the readers of the *Messenger*, and we certainly feel encouraged to make another attempt.

We thank Fons Maaswinkel and Bernard Delabre for their expert advice on the choice of instruments and instrument modes and Alain Gilliotte and Philippe Carton for their competent and tireless efforts to get CASPEC properly set up.

EMMI, the ESO Multi-Mode Instrument, Successfully Installed at the NTT

S. D'ODORICO, ESO

The EMMI Project

In November 1985, a conceptual proposal for a spectrograph for the 3.5-m New Technology Telescope was presented at the 16th meeting of the ESO Scientific Technical Committee. The initial concept had been put forward the year before by J.L. Tanné and the author and later modified and improved by Hans Dekker; Bernard Delabre was responsible for the optical design and Heinz Kotzlowski for the mechanical layout.

The execution of the project started at

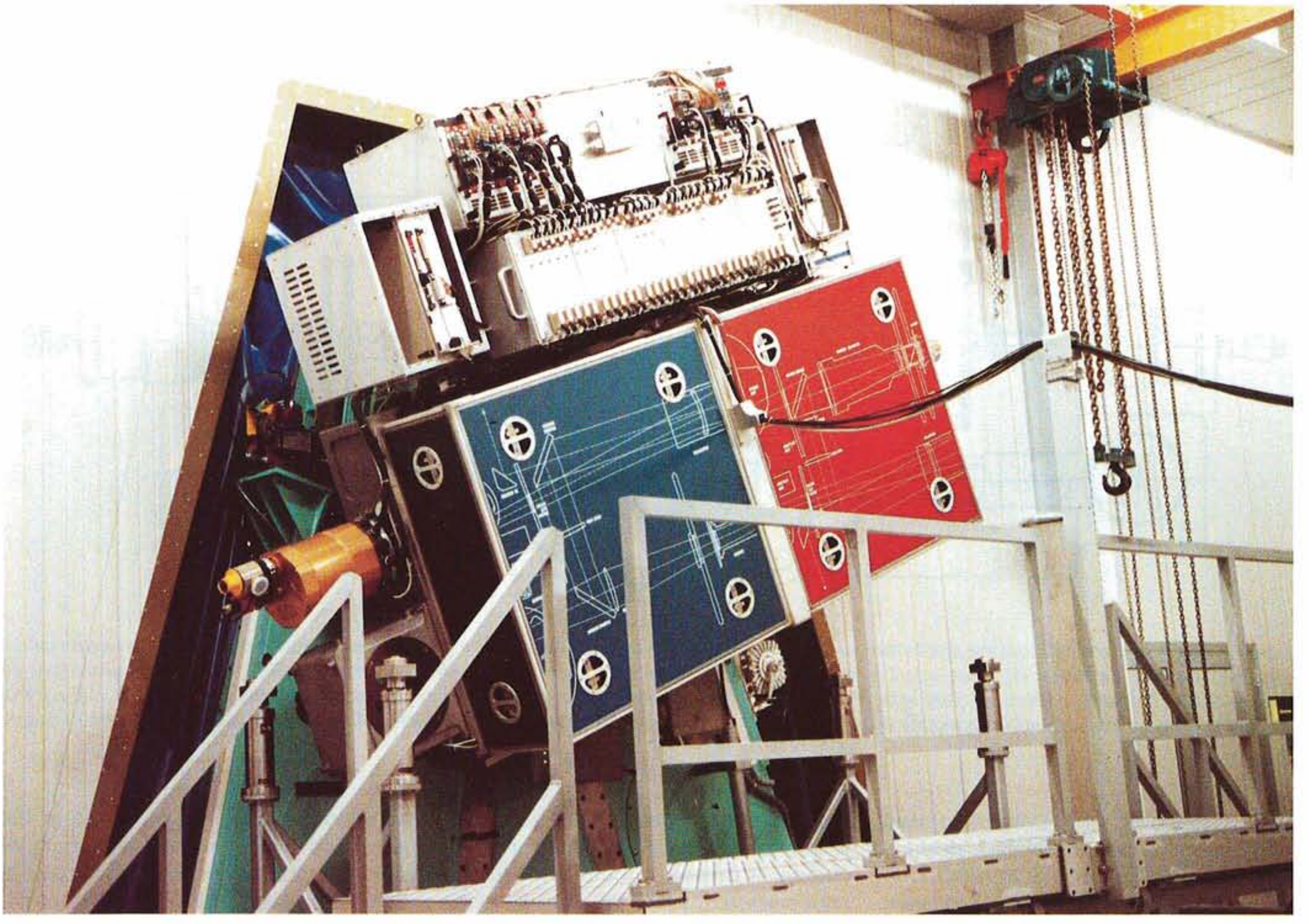

Figure 1: *EMMI mounted at the Nasmyth focus B of the NTT. The light-blue painted fork of the telescope is visible in the aperture of the air-conditioned instrument room. The adaptor/rotator is hidden by EMMI and its electronics. The colours of the panels of the cover identify the blue and red channels and show the optical path of the light in the instrument. The service platform in the forefront is also used to support the instrument when it is dismounted from the adaptor.*

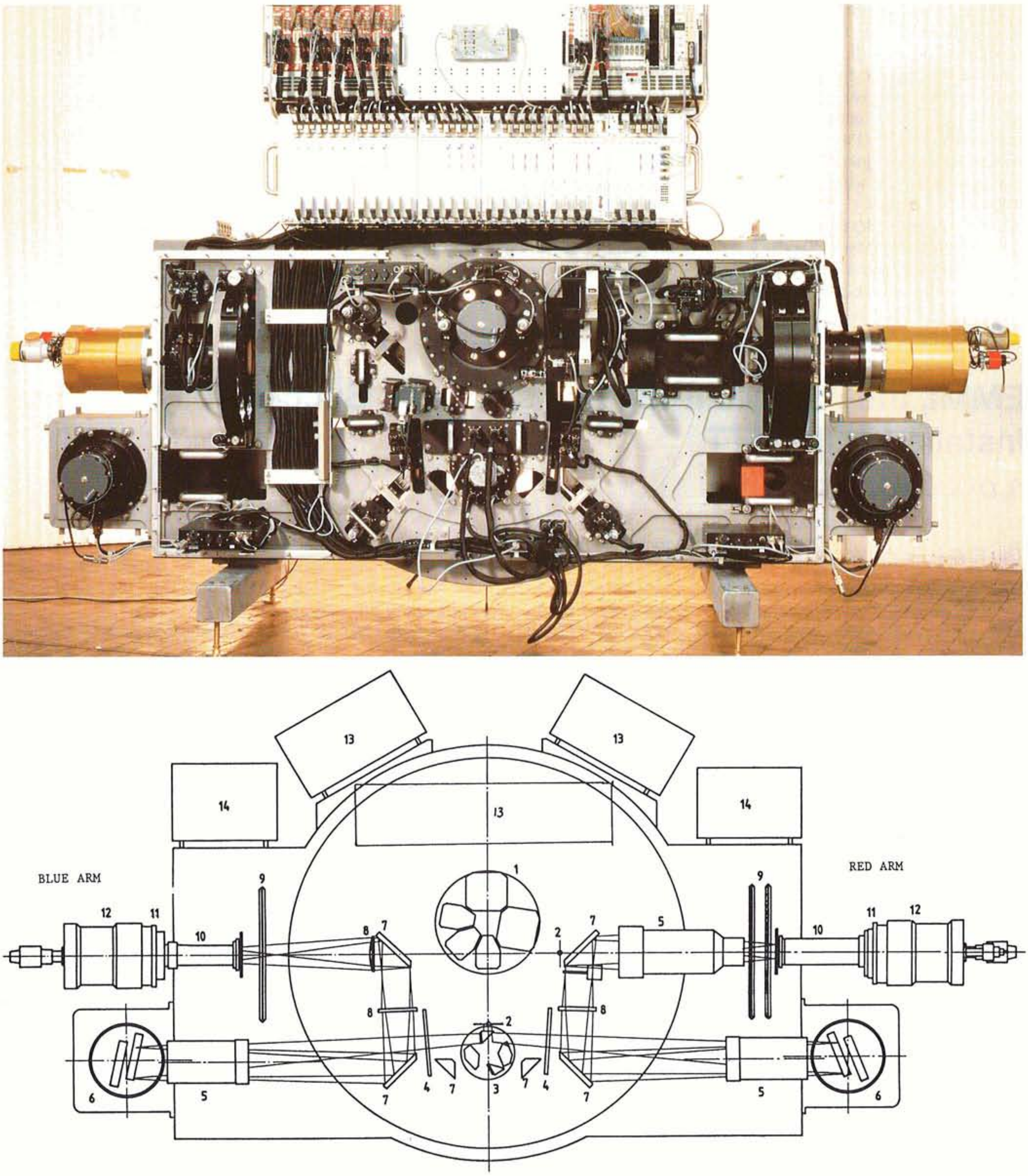

Figure 2: *EMMI is shown without the protective cover in this photograph taken at the end of the integration period in Garching. The sketch below identifies the main functions: (1) mode selection mirrors, (2) adjustable slit, (3) beam-splitter wheel, (4) below slit filter wheels, (5) collimators, (6) grating units, (7) folding mirrors, (8) field lens, (9) grism and filter wheels, (10) cameras, (11 and 12) detector heads and cryostat, (13) control electronics, mounted eventually in a slightly different way in the real thing, (14) detectors electronics, not installed at the time of the photograph.*

the beginning of 1986. Both the optical and the mechanical detailed designs were entirely conceived at ESO; the same is true for the electronic hardware (including the control cameras for the two detectors) and the software. The mechanical parts, the optical and the electronic components were procured mainly from European industries, usually with the standard ESO tendering procedure. A review of the main industrial subcontractors for EMMI is given in the insert on page 54.

About 5 years after its conception EMMI (the ESO Multi-Mode Spectrograph as it came to be named) has been installed and successfully tested at the telescope (Fig. 1). While written three weeks only after the first observations, this paper gives a brief overview of the project and wants to make prospective users aware of its capabilities. A description of the optical design and of the original performance goals can be found

Figure 3: *The "EMMI's corner" of the control room. From the left, in the lower row, a Ramtex dedicated to the user's interface displaying the layout of EMMI and the functions on line (a mouse is used to select other display options), a terminal for the exposure definition and a Ramtex displaying a long slit spectrum. In the row above two monitors for guiding and a graphic display.*

EMMI is the first optical instrument for astronomical observations which offers wide field imaging, long slit, low and medium resolution spectroscopy and echelle spectroscopy on line, with the possibility to switch from one mode to the other in a matter of seconds. Only the Hubble Space Telescope, with its 5 focal plane instruments, offers a similar broad choice of observational capabilities: the two differ so much in terms of the scientific goals that a comparison, however tantalizing, is not possible.

The complexity of the dioptric optical design of EMMI does not penalize the efficiency: in all modes this is as high or better than similar instrumentation at the other ESO telescopes (see the curves of the optical transmission of the optics in the March 1990 issue of the *Messenger*).

With its wide choice of observing modes, EMMI makes possible to select the observing programme according to the conditions of the atmosphere, in particular the seeing and the sky brightness, and to complete within a night a

in Proc. SPIE 627, p. 339 (1986). More information will be available in the Operating Manual (a first draft will be prepared by November 1990) and in dedicated technical reports, to be issued in 1991.

As stated in the minutes of the 1985 STC meeting "key factors in the definition of the instrument were the expected excellent image quality at the NTT, the need to complement and when possible to improve 3.6-m instrumentation and the desire to minimize change-overs and maintenance". The concept which was finally adopted is that of a dual beam instrument, fully dioptric and based on the white pupil principle. The main advantages of this type of design are a very high efficiency in both channels, easy conversion from the grating to the imaging and grism spectroscopy modes, and relatively cheap optics due to their small size. The instrument can be easily adapted to a new detector by building a proper camera: we took advantage of this option when the CCD originally foreseen, a 2048^2 pixel chip, was not delivered as planned. The depth of the 1.5-ton instrument is 28 cm only to keep the momentum on the adaptor small and increase the stiffness. The symmetrical supporting structure gives easy access to all the parts of the instrument even when this is mounted at the telescope. The various moving functions, most of them of new design, are built in a way to optimize reliability and minimize maintenance (Fig. 2).

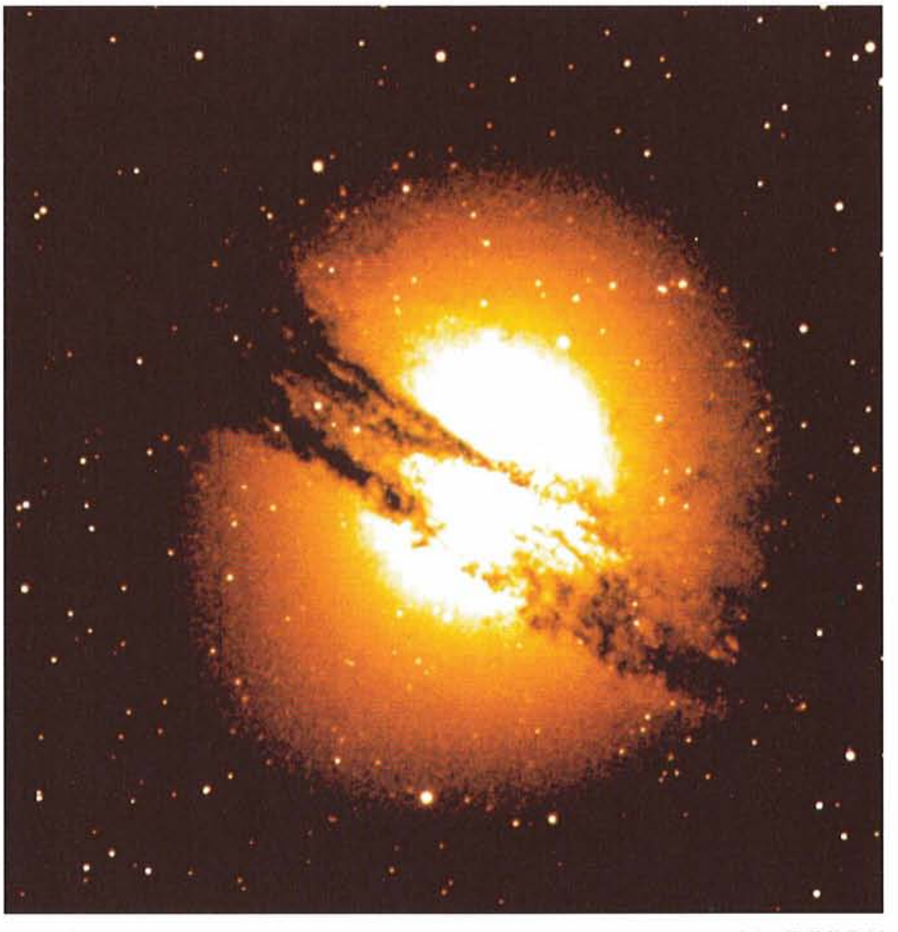

Figure 4: *A 300 s exposure of NGC 5128 in the Z colour exemplifies the size of the EMMI field with the present Th 1024 pixel detector (7.5 × 7.5 arcmin in red channel). The FWHM of the stellar images in this exposure is 0.85 arcsec. The present pixel size in the red channel (0.44 arcsec) is not well suited to exploit the intervals of best seeing at the NTT. ESO plans to introduce a CCD with a pixel size of 15 microns, corresponding to 0.35 arcsec, and it is building a CCD camera for direct imaging, to use in parallel with EMMI, with a pixel size of about 0.1 arcsec.*

MAIN INDUSTRIAL SUBCONTRACTORS

OPTICS:	Galileo (Italy) and Fisba (Switzerland)
COATINGS:	Matra (France)
FILTERS:	Andover (USA) and Soptel (France)
GRISMS and GRATINGS:	Milton Roy (USA)
DETAIL DESIGN:	Techno (FRG)
STIFFNESS ANALYSIS:	BCV Progetti (Italy)
MECHANICAL STRUCTURE:	De Pretto-Escher Wyss (Italy)
MECHANICAL FUNCTIONS:	Enraf-Nonius (the Netherlands), Technica (Switzerland), Geissler (FRG), Kern (FRG)
COVER:	Brunet Sicap (France)
SERVICE PLATFORM:	Genius-Klinkenberg (the Netherlands)
OPTICAL ENCODERS:	Heidenhain (FRG) and Litton (USA)
MOTORS:	Portescap (Switzerland), Faulhaber (FRG), Inland (USA)
LIMIT SWITCHES:	Baumer (Switzerland)
CCD MOUNTINGS:	NTG (FRG)
CCDs:	Thomson (France)

programme which requires data of different formats.

The first months of operation of EMMI will be used to gather experience on the best way to operate it at the telescope. Some procedure of flexible scheduling will have to be introduced to exploit the periods of best seeing at the NTT for the programmes which require it at most.

Another concern is represented by the difficulty a visiting astronomer (who sees the instrument 5–6 nights a year only) may encounter in making his/her way efficiently through the various observing options. If this will prove to be the case, the introduction of some form of service observing, with its pros and cons, will have to be properly debated.

Present Capability and Future Prospects

The Application Form for Observing Time at La Silla in Period 47, distributed in August 1990 includes a description of the current operating modes of EMMI and a list of the filters, gratings and grisms which are currently available.

The modes successfully tested in July are:

- direct imaging in the red channel (spectral range 400–1100 nm, field 7.5 × 7.5 arcmin, pixel size 0.44 arcsec) with the choice of 8 filters in a single run.
- grism spectroscopy in the red channel with a 7.5 arcmin slit or slitless up to Rs (resolving power by slit width in arcsec) about 1000 and with a choice of 8 grisms.
- 6-arcmin slit grating spectroscopy in the red channel with Rs between 1300 and 5500. Two gratings can be mounted at any given time.
- echelle spectroscopy in the red channel at Rs = 7700.
- direct imaging in the blue channel (spectral range 300–500 nm, field 4.9 × 4.9 arcmin, pixel size 0.29 arcsec) with the choice of 8 filters in a single run.
- 4.5-arcmin grating spectroscopy in the blue channel with Rs between 400 and 11000. Grating housing as in the red.

Two THX Thomson CCDs (1024^2, 19 μm square pixels) are presently used as detectors in the two channels. The CCDs have been coated at ESO with special dyes to enhance the UV-blue response. The quantum efficiency curve has a peak of about 50 % at 600 nm and levels down to about 19 % in the UV-blue region. The read-out noise mea-

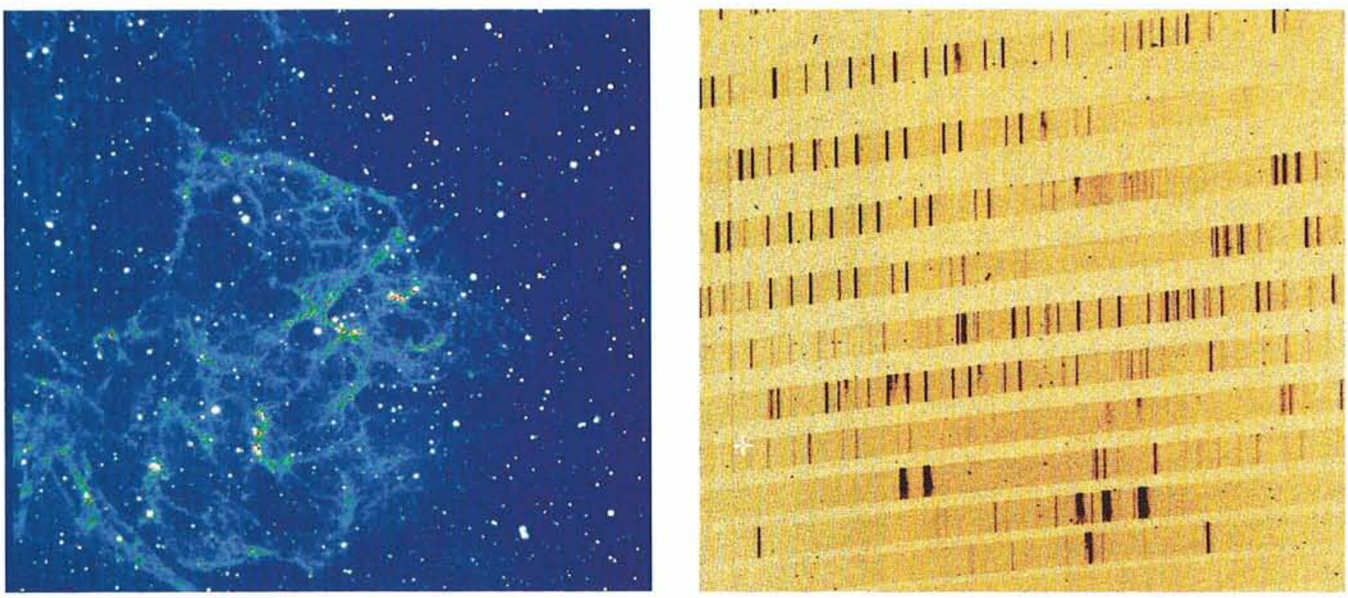

Figure 5a, b: *These two scientific exposures, a large field direct image and an echelle spectrum, have been obtained with EMMI at a time separation of a few minutes. Image (a) is a 600 s direct exposure of the supernova remnant RCW 89 taken in the red arm through an interferential filter centered on Hα. Image (b) is an echelle spectrum of a bright filament selected from the previous exposure. The spectral range covered by the 10 orders shown in the spectrum is 610–980 nm, the resolution 45 km/s, the length of the slit 20 arcsec.*
The emission lines from the remnant can be distinguished from the sky lines for their non-uniform, structured appearance, caused by density and velocity fluctuations. Visible in the three orders at the bottom are the [O I] 630 nm, [N II] 654.8, 658.4 nm, Hα and [S II] 671.7, 673.1 nm emission lines; in the two orders at the top the [S III] 906.9, 953.2 lines.

sured at the telescope is 4–6 electrons, the dark current is less than 3 e^-/pixel/hour at 140 °K.

The global efficiency curves for all observing modes have been computed from the transmission curves of the optics, filters, grisms and grating and from the efficiencies of the CCDs, all measured in the ESO laboratories. They are available in graphic and digital forms. Most important, they have been confirmed by the observations. As data are being reduced, it appears that the combination of highly efficient optics, low read-out CCDs and sub-arcsec images at the NTT will bring the performance of the instrument above the original expectations.

Many technical aspects of EMMI deserve to be described in detail and this will be properly done in the future technical reports. There are two points worth mentioning here. There is a need in EMMI to minimize the flexures because of the large rotation rates which occur close to the zenith in an Alt-Az telescope. Even if these can be avoided by properly planning the time of the observations, the tests at the telescope have shown that the flexures in the most critical modes (the red and blue medium dispersion) are well below 10 μm, the performance goal, for rotations up to 100 (red channel) and 180 degrees (blue channel). Further optimization work is going on at some of the critical units to further improve these values.

Another source of initial concern, the grating units, have proved to be reliable and accurate "in the field". One housing mounts two gratings back to back which can be remotely selected and positioned. The positioning can be reproduced and it is stable to better than 1/10 of a pixel, an achievement which has been made possible by a control unit of new design.

The final EMMI control programme, which integrates the operation of telescope, adaptor, instrument and of the two detectors, was being tested in July and was not used during most of the observations. The hardware set-up display is however already in place. The "EMMI" corner in the control room of the NTT is shown in Figure 3.

EMMI will undergo another commissioning period in October before being offered to the first regular users. At that time, besides installing the user interface of the software, we will test three operation modes which are foreseen to become fully operative in period 47 (starting April 91). These are the dichroic beam-splitter for spectroscopy in the two channels at the same time, echelle spectroscopy with a 31.6 grooves/mm echelle giving a resolving power of 28,000 in the red channel and multiobject spectroscopy using "punched" slits in an aperture plate.

It is important to note that the pixel size in the red channel of EMMI (0.44 arcsec/pixel with the Thomson CCD) is larger than originally foreseen and does not permit to exploit the optical quality of the telescope when the atmospheric seeing is very good. We had originally planned and built a slower camera to be

THE EMMI PROJECT TEAM

P. Biereichel:	CCD Software
B. Buzzoni:	Testing of the optical components
S. Deiries:	CCD and dewars integration and testing, CCD coating
B. Delabre:	Optical design
H. Dekker:	Optical concept, procurement of the optical elements, testing of the instrument off and on the telescope (Project Coordinator)
S. D'Odorico:	Astronomical specifications and project supervision (Project Responsible)
G. Hess:	CAD design and drafting. Preparation of the Call for Tenders for mechanical parts. Documentation
G. Huster:	Design of the CCD mounting head
H. Kotzlowski:	Mechanical concept and design of the overall instrument and its functions. Supervision of realization. (Coordinator of mechanics)
J.L. Lizon:	Integration, testing and optimization of the instrument functions and of the overall instrument in the Garching laboratory and at the observatory.
A. Longinotti:	CCD VME software, EMMI software
W. Nees:	Design, procurement and testing of the control electronics
T. Oosterloo:	Commissioning at the telescope and analysis of the results
G. Raffi:	Overall EMMI software
R. Reiss:	CCD control system and detector optimization
J. Roche:	Ramtex user interface

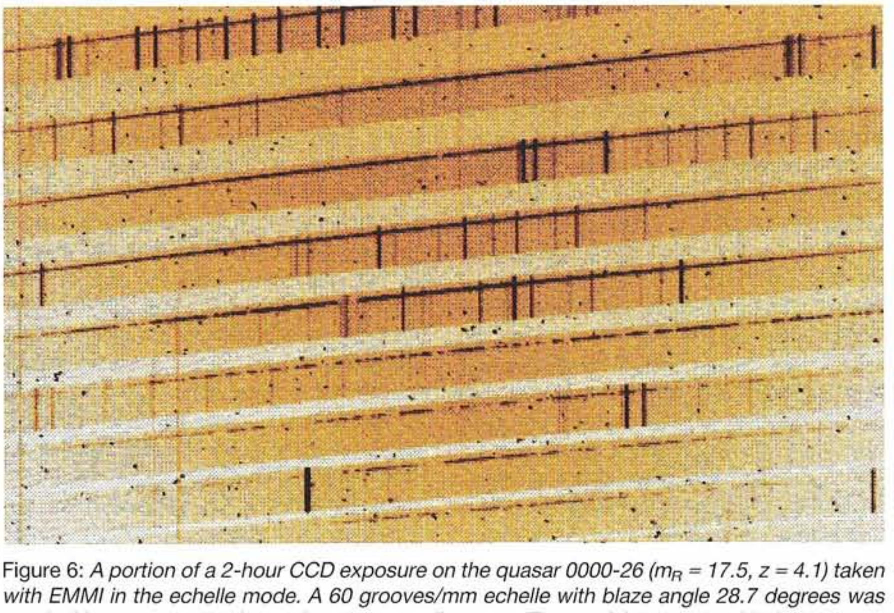

Figure 6: *A portion of a 2-hour CCD exposure on the quasar 0000-26 (m_R = 17.5, z = 4.1) taken with EMMI in the echelle mode. A 60 grooves/mm echelle with blaze angle 28.7 degrees was used with a 360 grooves/mm grism as cross disperser. The resolving power with the 1-arcsec slit used for this observation is 39 km/s. The spectral range covered in one frame is 420–800 nm, this figure shows the range 520–750 nm only. The length of the slit as shown by the height of the sky lines is 20 arcsec. In this observing configuration the global efficiency of the observation (product of the transmission of the atmosphere, telescope, instrument optics and detector) has a peak value of 7%. This high value combined with the small slit losses (courtesy of the average good seeing at the NTT) and the low read-out noise of the CCD (4 e^-/pixel) permits to reach good S/N in the spectra of objects as faint as mag. 18–19 in a few hours integration. In this example, the Lyman α emission of the quasar is visible in the central orders, a portion of the Lyman α forest in the lower ones. The S/N in the extracted orders varies in the range 20–30.*

used with a 2048^2 CCD from Tektronix, which has not yet materialized on the market. A faster camera was then built to match smaller CCDs without too severe losses of the spectroscopic capabilities, but paying a price in terms of sampling frequency of the images in the detector plane. Two actions are underway to improve the situation by the beginning of 1991: ESO will install a CCD of smaller pixel size (0.35 arcsec/pixel) on the red channel and is building a CCD camera to be permanently mounted at the other nasmyth focus (pixel size about 0.1 arcsec) to exploit the windows of exceptional seeing (hopefully down to about 0.3 arcsec FWHM).

Examples of Astronomical Observations

The commissioning period in June–July was centred on the full moon and plagued by the first heavy rain of the year. It was however still possible to collect a number of astronomical observations. Many of them were obtained with a specific goal in mind (e.g. stability tests during long integration, measurements of the absolute efficiencies in the various observing modes, testing of the photometric accuracy and of the image quality, testing of polarization effects by mirror 3, etc.). The analysis of the data will further verify these aspects of the performance of the instrument at the telescope and will serve as input to the operating manual. We also obtained astronomical observations for illustrative or scientific purposes and four examples are shown in Figures 4 through 6.

The analysis of the first EMMI observations has just started but the preliminary reductions confirm that EMMI is up to or better than the target specifications (see e.g. the limiting magnitudes in Table 4 of the 1986 paper quoted above). The combination NTT-EMMI is likely to become a powerful tool for a wide range of astronomical programmes. Good luck to the future observers!

Acknowledgements

The successful maiden voyage of EMMI is the result of the efforts of several persons at ESO. Some contributed to a very specific task only, others have spent a large fraction of their working time in the last four years on the project.

The table at page 55 is an attempt to identify the EMMI project team and their tasks using a few words only: as such it is hardly exhaustive and it might be unfair to a few.

If someone discovers himself forgotten, would he please blame the stress of 20 days and nights of commissioning and forgive me. All have to be praised for their skill, patience and care: they managed very well indeed. A special, personal thank-you goes to Hans Dekker for overseeing the project with an optimism which fortunately is superior even to mine and to Jean-Louis Lizon for the infinite numbers of hours that he has spent in Garching and at La Silla carefully dealing with EMMI's 29 functions, one by one and together.

New 2D IR Array Detectors for Imaging and Spectroscopy at ESO

A. MOORWOOD, ESO

The lack of recent news in the *Messenger* may have created the impression among some infrared observers that perhaps not much has been going on in Garching to upgrade the performance of the infrared instrumentation on La Silla since IRAC was offered in April 1989. In fact, this has been a period of particularly intense activity aimed at expanding our infrared capabilities on La Silla in several areas considered to be both of immediate scientific interest and important preparatory steps on the road to implementing the VLT instrumentation plan. Our overall aim is to provide La Silla with first class imaging plus some low resolution spectroscopic capabilities throughout the infrared from 1 μm to ~17 μm plus an upgraded IRSPEC for 1–5 μm medium resolution long slit spectroscopy before we reach the period of peak effort required on the VLT instrumentation. This is an ambitious goal, at the limit of our resources, and a key element is of course the procurement of high performance array detectors which, given the rapid evolution in this field, their high cost and the need to obtain import/export approval, is not a trivial exercise by any means. In addition to our ongoing negotiations with Philips Components for a replacement 64 × 64 Hg : Cd : Te array for IRAC, therefore, we have also been in contact since early in 1989 with several other major detector manufacturers with the aim of procuring 2 D IR array detectors for the upgrade of IRSPEC at the NTT and to equip the new IRAC 2 cameras being developed to accommodate 256 × 256 format arrays. During the same period we have also been developing a new VME based acquisition system capable of handling the various different readout schemes and formats anticipated, expanding our laboratory test facilities, designing and tendering for the IRAC 2 cameras, preparing for the transfer of IRSPEC to the NTT and finalizing the technical specification of a 10-μm camera/spectrometer to be built in collaboration with the Service d'Astrophysique, CEN, Saclay.

Following a number of events within the space of a few weeks around the end of June and early July it is now possible to report here some positive results of these efforts. The most concrete is the delivery of an engineering and the first of two 58 × 62 InSb science grade arrays from the Santa Barbara Research Center whose procurement started with our request for quotation in January 1989 and is illustrative of the leadtime involved in obtaining such devices. Exhibiting dedication beyond the call of duty, Gert Finger braved 50 °C heat during one of the worst forest fires in Californian history to collect the latter at the beginning of July. Only a few days later, during a visit to Garching by Dr. K. Vural, head of the Imaging Devices Division of the Rockwell Science Center, we were able to draw up the technical specifications for a 256 × 256 Hg : Cd : Te array whose procurement had been approved by the STC and Finance Committee in May. Towards the end of July, in fact about a month after the effective kick off following the preliminary design review, the contract for the 10-μm camera was signed at Saclay. One disappointment has been the fact that we have been unable so far to replace the 64 × 64 Hg : Cd : Te array in IRAC both to offer improved perfor-