"Remote" Science with the NTT from Italy

PRELIMINARY SCIENTIFIC RESULTS

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1. Introduction

We report here on the preliminary analysis of the observations carried out with the NTT telescope during the final test of the "Second Level Remote Observing Project" at the Astronomical Observatory of Trieste (OAT). The test took place during the nights of 9, 10 and 11 June 1992. Details on the "remote observing" project can be found in the article by Balestra et al. on page 1 of this issue of the *Messenger*.

A preliminary constraint to the planning of the observations was imposed by the people responsible for the test, who required frequent changes between different instrumental configurations, in order to better evaluate the response of the distributed system to a heavy load. Furthermore, tune-up and communication problems occurred at different times of the test nights requiring either a reshuffling of the scheduled observations or the loss of some calibrations and/or astronomical targets. In particular, several exposures which were planned during the dark time at the end of one night were postponed to grey time of the following night.

We believe however that, during the test nights, an acceptable compromise was reached between the technical requirements of the test itself and the wish of a full use of the nights for real astronomical work.

All the targets pointed were selected within research projects currently ongoing at the OAT. These projects are: T Tauri stars (MF), Lithium abundance (PM), high velocity clouds (GV, MC), Planetary Nebulae (FP, PB), Seyfert galaxies (MN), distant clusters of galaxies (MN, MR), gravitational lenses (MN, MR). The following is a brief description of the research projects and an assessment of the quality of the data obtained.

2. The Observations

2.1 NaI D Variability in the T Tauri Star Sz 68

We have performed echelle spectroscopy of a T Tauri Star (Sz 68) with the NTT using the EMMI spectrograph in the REMD mode: grating #10, grism #5, decker 5 arcsec. The detector was a CCD THX 31156 (ESO #18) with 1024×1024 square pixels, 19 μm in size. The instrument is described in Dekker et al. (1991). This detector has been used for all the observations described in this paper. With a slit of 1.2 arcsec, a resolution R~25,000 is obtained; this can be verified from well-separated lines of a thorium comparison spectrum. Wavelength calibration was performed for each order by a polynomial, fitted to 12 lines at least; the r.m.s. of the residuals is about 0.5 kms^{-1}.

Figure 1 shows the spectrum of Sz 68 (V=10.5), in the region of the NaI D doublet. With an exposure of 1 hour, a S/N ratio of about 200 has been achieved. This object is a target of a more general research, concerning the basic observational parameters of T Tauri stars: projected rotational velocities and inclination angles, spectral types, luminosities, effective temperatures, element abundances, etc. In particular, Sz 68 belongs to a sample of T Tauri stars for which the velocity fields in the circumstellar environment are under investigation. Sz 68 has shown clear variability of the NaI D line profiles: multiple blue-shifted absorption components are present, with variable intensity and position. This might indicate the existence of a complex circumstellar structure, varying with time.

So, the spectrum in Figure 1 can be compared – taking into account the different instrumental resolution – with preceding observations, made in 1985 (Finkenzeller and Basri 1987), in 1989 (Franchini et al. 1992 a), and in 1991 (Franchini et al. 1992 b). While the actual configuration appears to be rather similar to the ones observed in 1991 and 1985 (with the blue-shifted component at about the same v_{rad}), the same cannot be said for 1989 (when the main blue-shifted component – relative to the star – was at more than –90 km s^{-1}). Clearly

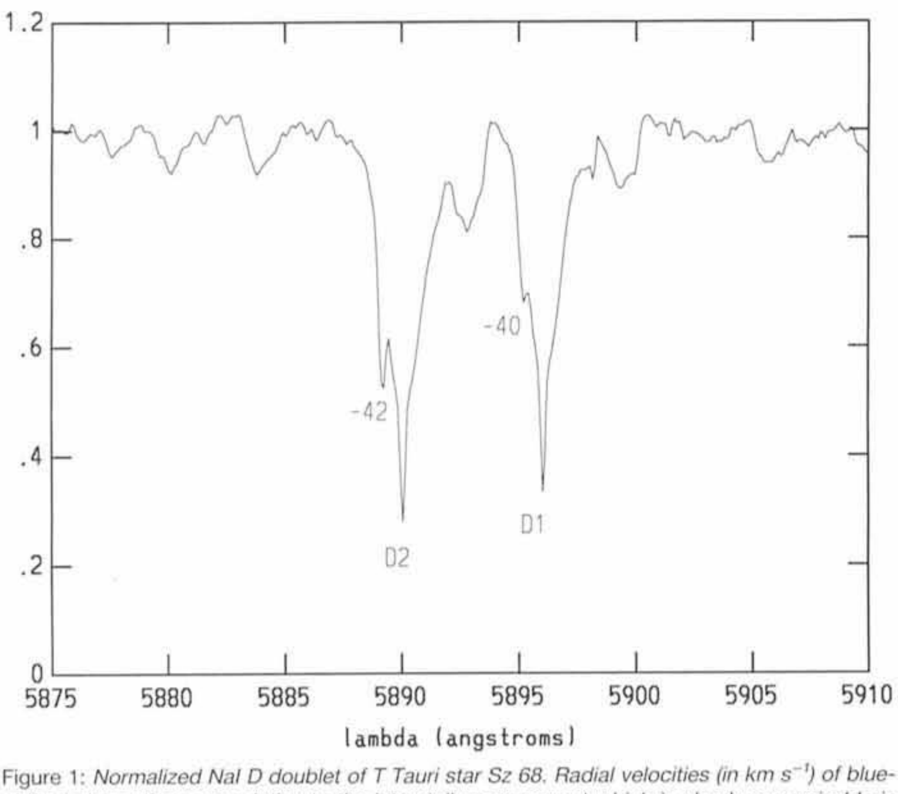

Figure 1: *Normalized NaI D doublet of T Tauri star Sz 68. Radial velocities (in km s^{-1}) of blue-shifted absorptions are relative to the interstellar component which is clearly recognizable in the stellar profiles.*

the time intervals between these observations are too wide to allow a complete reconstruction of the evolution of a given absorption component. However, more detailed analysis of the present data, together with those of 1991, may provide a quantitative interpretation of this variability, in terms of mass ejection events and/or sudden changes in the physical properties of the circumstellar material.

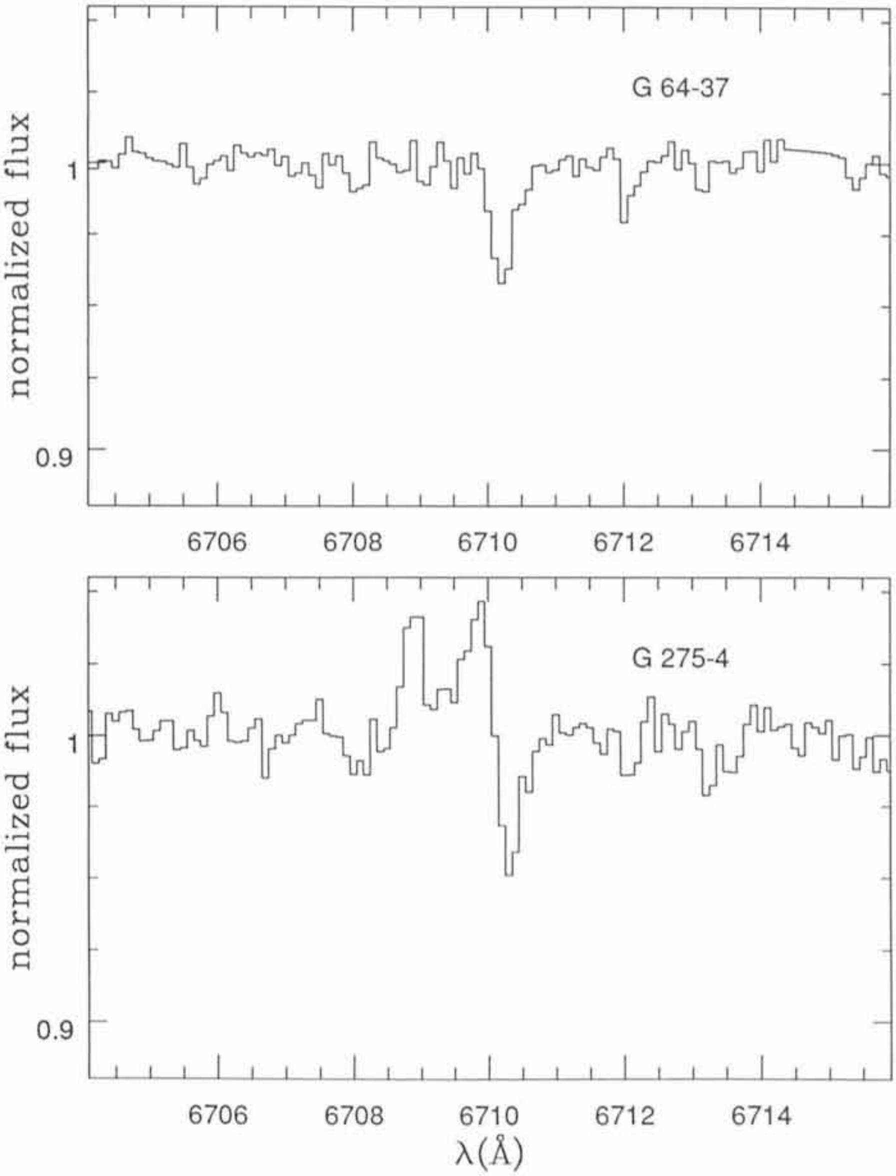

Figure 2: *The LiI spectral region for G 64-37 (top panel) and G 275-4 (bottom panel). The spectra are not corrected for the earth motion.*

2.2 Lithium in the Halo Dwarfs G 64-37 and G 275-4

The abundance of lithium in the Population II stars hotter than 5500 K shows a characteristic *plateau* around log N(Li)=2.1±0.1 (where log N_H=12), in striking contrast with that observed in the younger population where the abundances are scattered over three orders of magnitude. Although this is not fully understood, the most straightforward explanation remains the absence of any significant lithium depletion in halo dwarfs, and thus the atmospheric abundance reflects the pristine lithium abundance of the interstellar gas from which these old stars formed. It appears very probable that the lithium in the old halo dwarfs is primordial in origin. In fact the good agreement between the lithium abundance observed in the halo dwarfs and the theoretical predictions of the big-bang theory is very impressive. According to the theory, the lithium yields are particularly sensitive to nucleon density, and the knowledge of the precise amount of primordial lithium allows a determination of the η value ($\eta=n_\gamma/n_b$), which is related to the critical mass Ω. The astronomical relevance of lithium has been recently discussed by Lemoine et al. (*The Messenger* No. **67**, p. 40).

Lithium observations in the Population II stars are severely limited by the intrinsic faintness of the known halo dwarfs and by the relatively small equivalent widths of the lithium line. We used the EMMI spectrograph on the NTT to observe the halo dwarfs G 64-37 and G 275-4, taken from the sample of Ryan et al. (1991). The observations have been performed with the REMD EMMI mode using the 31.6 grooves/mm grating 10 and grism 3 as a cross disperser. S/N ratios of ≈ 180 and ≈ 100 are achieved for exposures of 3600 sec for G 64-37 (V=11.1 mag) and of 3800 sec for G 275-4 (V=12.2 mag), respectively. The resolving power measured from the thorium lines is of ≈ 26,000.

Interest in these two objects stems specifically from their particularly low metal abundances. The abundances of G 64-37 and G 275-4 are of [Fe/H] =−3.38 and −3.70, respectively. So far there are only few objects studied for lithium with metallicity below [Fe/H]<−3.0. In particular, the lowest metallicity dwarf in which lithium has been detected is G 64-12 with [Fe/H]=−3.5, but the spectroscopic binary CS 228876-32, with metallicity [Fe/H]=−4.2, surprisingly does not show any lithium (Molaro 1991).

The regions around the LiI 6707Å resonance line for both the stars are shown in Figure 2. It can be seen from the figure that the lithium features are clearly present in both halo dwarfs. The redshift of the absorptions corresponds to V_{hel} ≈ 114 km s^{-1} for G 64-37 and V_{hel} ≈ 142 km s^{-1} for G 275-4, in agreement with the displacement observed by the stellar NaI lines. Unfortunately, the blue wing of the line in G 275-4 is contaminated by an emission remnant of a previous observation, and the equivalent width could be slightly greater than observed. However, the presence of the lithium line in G 275-4 by itself is of interest since it extends down to [Fe/H]=−3.7 the metallicity range in which lithium is observed. In the case of G 64-37 the equivalent width of the lithium line is of 17 mÅ. According to Ryan et al. G 64-37 has a T_{eff} of 6350 K and is one of the hottest dwarfs in the present sample of Population II stars. An accurate determination for the lithium abundance will be presented elsewhere, but a comparison with HD 84937 and G 64-12, which have similar T_{eff} and similar line strength, indicates that the lithium abundance for G 64-37 should be also at the *plateau* level.

2.3 Interstellar/Intergalactic NaI Absorptions at High Galactic Latitudes

Interstellar observations in the direction of distant sources at high galactic latitudes are important to cast light on the high-velocity clouds (HVCs) phenomenon. HVCs were discovered at 21 cm, but are extremely difficult to detect in absorption in the optical (see e.g. Keenan et al. 1988). In the framework of the investigations on the interstellar/intergalactic medium carried on at the OAT, we observed the halo star PG 1303-114 (V = 14.0) and the extragalactic object 2155-304 (V = 13.1) in a search for NaI absorption lines. For both objects we used the EMMI spectrograph in the REMD echelle mode with the grating #10 and the grism #3. The resolution in the region of the NaI doublet was measured from the FWHM of several lines in a spectrum of the Thorium calibration lamp. We found $\Delta\lambda \simeq 0.23$Å, corresponding to $\simeq$ 12 km s^{-1}.

PG 1303-114 belongs to a sample of halo sub-dwarfs (sdO and sdB) for which a determination of the distance was performed by Moehler et al. (1990). In the framework of a collaboration with the Sternwarte of Bonn we are currently analysing this sample of stars in order to study the gas distribution at large z distances. PG 1303-114 is one of the few stars of our sample which were observable from La Silla at the time of the present observations. In Figure 3 we show the portion of the EMMI spectrum of PG 1303-114 in the NaI region. The exposure time was one hour and the resulting signal-to-noise ratio S/N $\simeq$ 50 (1 σ level). An interstellar absorption component close to rest velocity is visible at the red side of the NaI atmospheric emissions: this component is probably due to local gas in the galactic disk. No absorption components are detected at higher or lower radial velocities outside the 3 σ level. The minimum detectable equivalent width is of about 14 mÅ, corresponding to an upper limit N(NaI) $< 7 \times 10^{10}$ atoms cm^{-2}. By adopting the interstellar NaI-HI correlation derived by Ferlet et al. (1985), this in turn implies N(HI) $< 10^{19}$ atoms cm^{-2} in the direction of the star, which is located at about 1.5 kpc from the Sun at a galactic latitude b = +51°. If the lack of high-velocity absorption components will be confirmed also in the other lines of sight of our sample, then the idea that high-velocity gas is generally located at $|z| > 1$ kpc will receive a sound observational support.

The BL Lac 2155-304 was observed by Morton and Blades (1986) with the AAT in CaII and NaI at a resolution of 17 km s^{-1} and 24 km s^{-1} respectively. They found an absorption component at $V_{LSR} \simeq -8$ km s^{-1} in CaII, but only an upper limit of 83 mÅ in NaI. We decided therefore to re-observe this object in the red spectral range in order to search for NaI absorptions with a higher sensitivity and spectral resolution. In Figure 3 we show the NaI spectrum of 2155-304; the exposure time was one hour and the resulting S/N $\simeq$ 60. A NaI absorption of $\simeq$28 mÅ is clearly present at the blue side of the D2 atmospheric emission. The radial velocity of this feature, $V_{LSR} \simeq -9$ km s^{-1}, is in very good agreement with that of the CaII component detected by Morton and Blades. The D1 absorption at the same velocity is visible as a weak feature close to the noise level. A preliminary estimate of the NaI column density in our spectrum, combined with the CaII column density estimated by Morton and Blades, gives NaI/CaII $\simeq$ 0.15. This low value of the NaI/CaII ratio is characteristic of high-velocity interstellar gas in our Galaxy. This suggests that the $\simeq -9$ km s^{-1} component may be produced in high-velocity gas with a low projected velocity along the line of sight.

An exciting feature of the 2155-304 spectrum is the presence of a D1 and D2 absorption at $V_{LSR} \simeq -90$ km s^{-1}, both marked in the lower panel of Figure 3. These absorptions are close to the detection limit, but the fact that the line of sight to 2155-304 (l = 18°, b = −52°) falls in a region of the sky where HVCs with negative velocities are predominant (Wakker and van Woerden 1991) encourages us to believe that they are real.

The presence of the −90 km s^{-1} component, if confirmed by future observations, would provide an almost unique opportunity to study a HVC by means of absorption line spectroscopy.

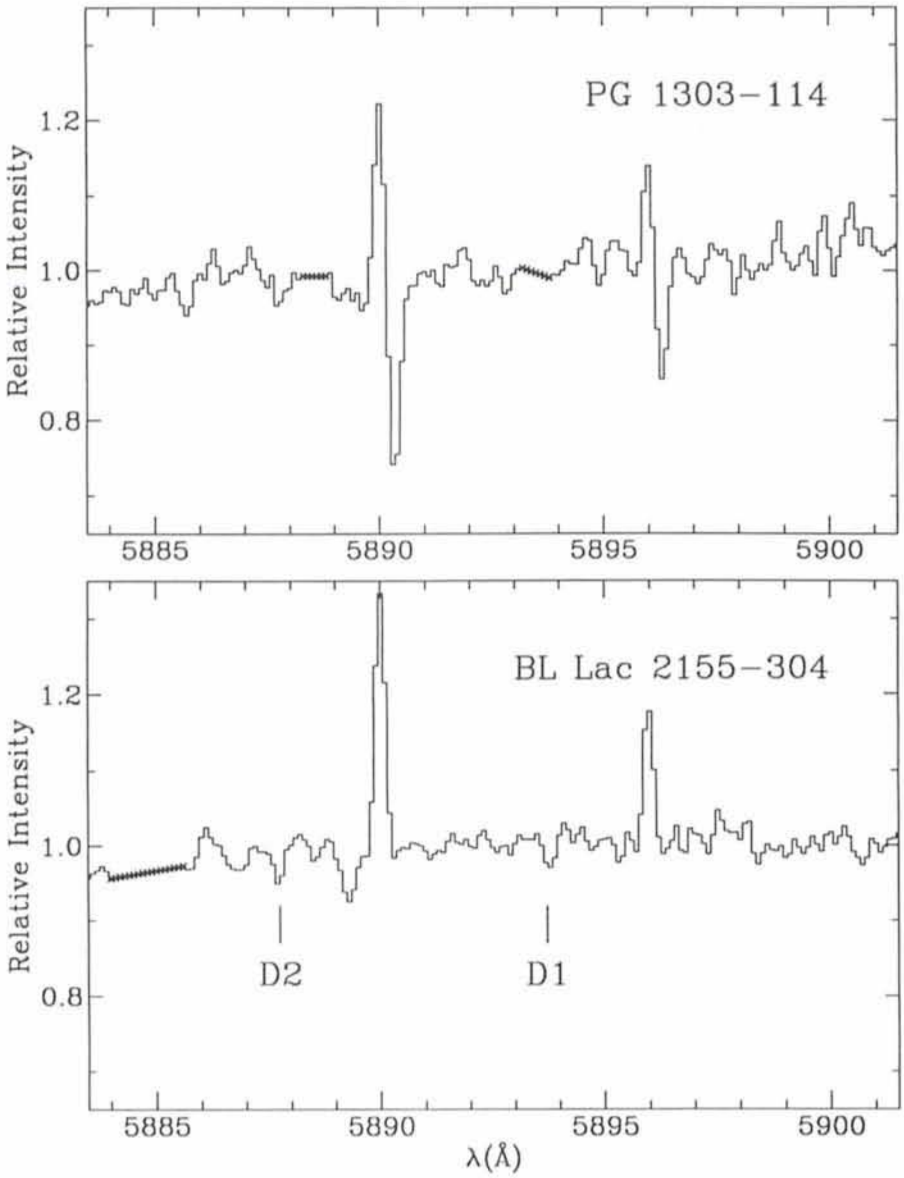

Figure 3: *Interstellar NaI absorptions in the direction of the two high-latitude background sources PG 1303-114 and 2155-304. Emission lines at rest velocity are atmospheric. Telluric absorptions were removed by using the spectrum of the bright star HR 5625 as a template. Portions of the spectra cleaned up of cosmic events are marked with crosses.*

2.4 Detection of PN Candidates in Two Galaxies of the Virgo Cluster

The use of PNe as standard candles has been described in a series of papers (e.g. Ciardullo et al. 1991 and the previous papers in the series), and has been applied to the determination of the distance of the Virgo Cluster (Jacoby et al. 1990) from data taken at the KPNO and CFHT telescopes. The method used by the above authors relies on images taken through a narrow band filter centred on [OIII]λ5007, redshifted at the systemic velocity of the cluster being analysed, and images taken through and intermediate-band filter of FWHM ≈ 300 Å. Jacoby et al. (1990) performed the detection by "blinking" the on-band and the off-band images and selecting as candidates those objects which were detected on the on-band images but not on the off-band ones.

Is it possible to carry out this kind of scientific investigation on the NTT? This question was raised in the framework of a collaboration including OAT scientists (FP, PB), a group at the Sternwarte München led by R.P. Kudritzky, and I.J. Danziger, P. Mazzali and L.B. Lucy at ESO. The "second-level" Remote Observations technological experiment carried out at OAT gave us a chance to test the feasibility of such observations.

Using the general philosophy of Jacoby et al. (1990), we tested the performance of the filters available on EMMI. Due to the lack of an intermediate-band filter in an emission-line-free region, similar to that used by the American investigators, we used filter #591 ([OIII] redshifted at 6000 km/s bandwidth 61 Å) and #606 (V) as off-band filters and filter #589 ([OIII], bandwidth 56 Å) as on-band filter. Hα images would have been desirable to help the PNe-HII regions discrimination but could not be secured, in the limited observing time available.

For our test we selected two spiral galaxies in the Virgo Cluster: NGC4639 and NGC3627. These targets were selected since they have been the host galaxies of two recent and well-observed type Ia supernovae: 1990N (Leibundgut et al. 1991, Mazzali et al. 1992) and 1989B (Barbon et al. 1990), and thus present the opportunity to compare two different distance determination methods: the PNLF and the maximum brightness of SNe Ia. The images were taken in EMMI RILD mode; the detailed observation log is reported in Balestra et al. (1992). The Remote MIDAS facility allowed us to have an on-line quick look at the images, after acquisition. This was extremely useful both for identification purposes and to assess the image quality; on one occasion this check led us to take a second exposure with a longer exposure time.

Some preliminary work has been done at a very early stage using images which were transferred from La Silla to OAT through the network link. Subsequent data reduction work, aimed at the detection of PNe candidates, was done off-line at OAT on an HP/Apollo 4000/425 workstation running MIDAS. The images were bias subtracted and divided by sky-flat-fields. On each of the calibrated images we ran an automated object finder (MIDAS invent context) and, for the time being, the identifications are then checked visually.

As can be seen from the two images of NGC4639 reproduced here (Fig. 4), there are many objects which are detected in [OIII] but not in V; such objects are our PN candidates. The redshifted [OIII] filter proved to be less effective than the V filter, probably because, due to the limited observing time and the fact that this filter is narrow, this image is not deeper than the on-band [OIII] image. Before we can claim that our candidates are PNe we must worry about: (1) detection of spurious objects; (2) missing true PNe. There are substantially three types of objects which we can expect to detect in the [OIII]λ5007 filter: HII regions, Novae and PNe. Novae are likely to contaminate the sample only marginally since we expect PNe to be much more numerous than Novae in outburst at any given time. Therefore, the only objects we really have to worry about are HII region galaxies. HII regions should appear to be extended and moreover their ratio of [OIII] magnitude to V should be lower than that of PNe, since HII regions are usually of lower excitation than PNe.

The other concern is that a true PN may be detected also in V, since this filter includes Hα and [OIII[λ5007, although the contribution of the continuum from the central stars of PNe should be negligible with respect to the galaxy background. Anyhow, in this filter the contrast with the galaxy background is lower, which makes the detection more difficult. In order to avoid detecting PNe in the V images, one should keep the detection threshold rather high, yet low enough to detect safely all the HII regions.

The next step of this work, to be carried out in collaboration with the Sternwarte München and ESO groups, will be to discriminate PNe from HII regions in our candidate list and perform astrometry and photometry on the candidates. It is not clear whether the images we have will allow a satisfactory discrimination against HII regions, Hα images may prove to be necessary in this respect; yet we believe the feasibility of this project to be now well established.

2.5 Distant Clusters: EMSS Source 2137.3-2353

The target of our observations belongs to a list of 'distant' ($z > 0.2$) clusters of the Southern Sky, identified as X-ray sources withing the Einstein Medium Sensitivity Survey (Gioia et al. 1990, Stocke et al. 1991) and lacking good optical images. The list has been compiled in collaboration with astronomers of several Italian Institutes. The purpose of obtaining images for the clusters in the list is to create a good statistical sample with well-determined optical and X-ray properties. This sample is necessary in order to analyse the evolution of the relation between the galaxis of the cluster galaxies and the ICM from local to distant clusters. That the local relation between galaxies and gas should change in the redshift range $0.2 \leq z \leq 0.6$, is suggested by several evidences (e.g. Garilli et al. 1992, Fabricant et al. 1991, Henry et al. 1992, Nesci et al. 1991). In particular there seems to be a trend for clusters of given richness to be less X-ray bright and richer of blue galaxies as the redshift increases. This trend is predicted by some current cosmological models (e.g. Evrard 1990).

Among the objects of the list we have observed the source 2137.3-3553 ($z=0.313$, $F_x=21.78$ 10^{-13} erg cm^{-2} sec^{-1}) since it was observable at a small zenithal angle. We have taken VRI images with EMMI in the RILD configuration and the only CCD available during the test, the Thompson 1024×1024 CCD (ESO #18). The scale on the CCD is .44 arcsec/pixel and the field is 56.3 arcmin^2. The seeing during our observations was ≈ 1 arcsec.

The total exposure time in each of the three colours V, R and I is of 45 minutes, 20 minutes and 30 minutes respectively.

After the bias subtraction and the flat-field correction, a preliminary photometry in the V band shows that we have reached V ≈ 23. As soon as all the frames will be properly co-added, we will separate galaxies from stars and use a colour-colour diagram to identify background/foreground objects. The final result we expect from our observations is the measurement of the main properties of the distribution of galaxies in the cluster, such as the richness and the content and space distribution of 'blue' galaxies.

2.6 Candidate Einstein Ring PKS 1830-211 2

PKS 1830-211 is a flat-spectrum source which shows two lobes in the

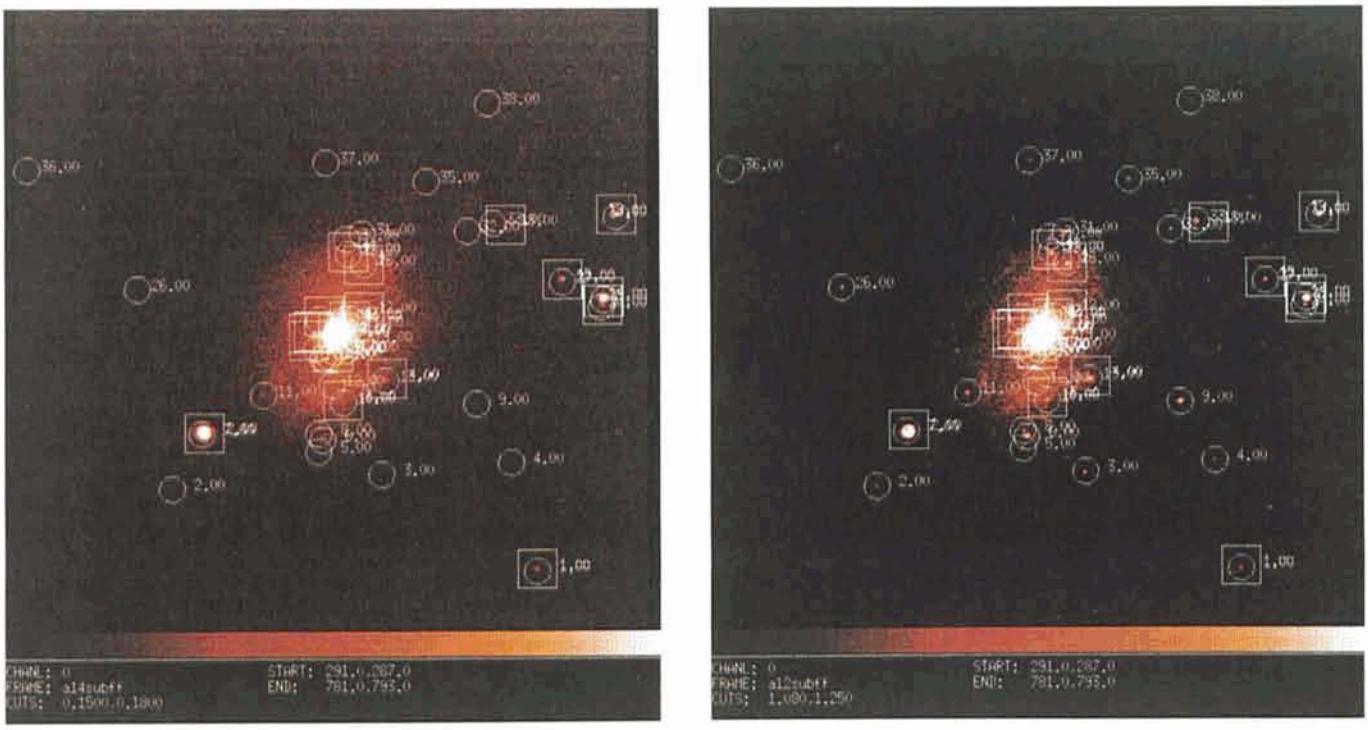

Figure 4: *Two images of NGC4639 taken with EMMI in RILD mode. On the left-hand side the image taken through the V filter, on the right-hand side the image taken through the [OIII]λ5007 filter. Circles surround the positions of objects detected in the [OIII] image, while squares surround the positions of objects detected in the V image. The objects which are detected in the [OIII] image, but not in the V image, are PN candidates. The low cut has been kept lower in the V image to stress the absence of detectable objects.*

radio (VLA and VLBI observations; Rao and Subrahmanyan 1988, Subrahmanyan et al. 1990, Jauncey et al. 1991). The separation of the two radio lobes is 1 arcsec. The shape and spectra of the radio 'lobes' (NE and SW) suggest that PKS 1830-211 is a strong Einstein Ring (Rao and Subrahmanyan 1988, Subrahmanyan et al. 1990, Jauncey et al. 1991). This kind of gravitational lenses are particularly interesting since they can be very powerful cosmological tools, allowing, in principle, the determination of the Hubble constant and the mass distribution of the lensing galaxies.

Optical observations of PKS 1830-211 have failed, so far, to reveal the counterparts of the two radio components (Subrahmanyan et al. 1990, Djorgovsky et al. 1992). Djorgovsky et al. (1992) have recently presented the whole set of data they used in search for optical counterparts of the candidate radio ring. The optical data include CCD images taken with the ESO 3.6-m (BVR bands) and ESO NTT (BRI bands) telescopes and with the Palomar 200-inch telescope (K and Gunn 'i' bands).

We had planned our remote observations with SUSI, which, however, was not available for the test run. We decided to use EMMI in the RILD configuration (see section 2.5). Our primary goal with EMMI was to reach a fair depth and obtain good magnitudes for the objects in the field of PKS 1830-211, rather than identify and/or separate the possible optical components of the radio source. In fact, as far as angular resolution is concerned, our observations cannot compete with those of Djorgovsky et al. from the NTT with SUSI (0.13 arcsec/pixel) and a seeing of 0.75 arcsec. However, their night was not photometric and magnitudes were only roughly estimated.

We have taken 5 frames in the I band centred on the position of the radio source PKS 1830-211. Each frame has been exposed for 10 minutes. After the first three exposures we have offset the telescope 4″ (or 10 pixels) eastward.

A preliminary analysis of the fields shows that the PSF has a FWHM slightly smaller than 1 arcsec and that we have reached $I \simeq 18.5$ in each frame. Unfortunately, this is not faint enough for our purposes. The reason is that the brightness of the sky was too high at the time our observations took place: the moon was still up, even if very low.

2.7 Seyfert Galaxies

One of the most interesting questions in extragalactic astronomy is what triggers the activity in the nuclei of some galaxies (AGNs): e.g. Norman et al., Scoville et al. suggested a relationship between AGNs and starburst activity in the sense that the starbursts are the evolutionary precursor of AGNs; on the other hand (e.g. Daly) the energy released by an AGN could trigger star formation in the surrounding galaxy. This interrelation may reflect in peculiar morphologies and/or colours in regions surrounding the nucleus. With this problem in mind we started a programme to observe both in the infrared and optical bands galaxies hosting AGN. Pilot observations were conducted during this test: targets are selected from the CfA list (Huchra et al.), 5 galaxies were selected on the basis of observing time constraints and because we already have multi-aperture photometry in J, H, K infrared bands for these objects. Images were taken in V and R bands with exposure times ranging from 120 to 420 sec; the seeing was $\approx$ 1 arcsec; preliminary analysis shows that we reached at least 26 mag arc^{-2} in shorter exposures.

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who gave some very important suggestions on NTT instrumental set-ups and observing procedures, and to the La Silla night assistant M. Pizzaro who played an essential role for the success of the observing run.

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The Giant Arc in EMSS2137-23

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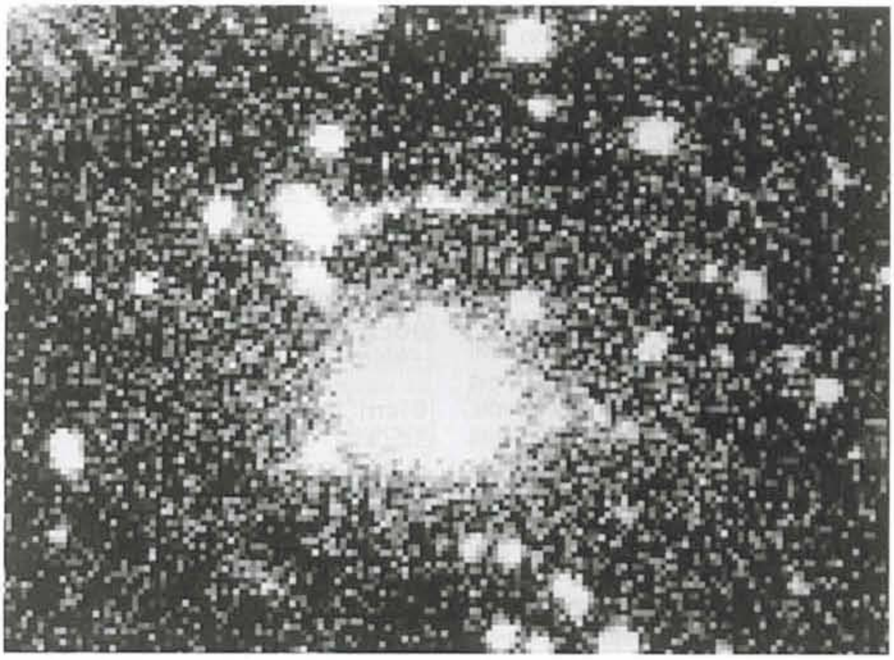
During the three nights devoted to the test of the 'second level remote observing' we observed the cluster EMSS 2137-23 with NTT and EMMI. This cluster is a rather bright EMSS source and has a redshift z ≃ 0.32. These characteristics make EMSS2137-23 a perfect candidate for the study of the relation between the gas and the galaxian components of a non-local cluster. We wanted to obtain photometry for the galaxies of the clusters in order to build a magnitude limited sample. Details of the observations are found in the article by Franchini et al. in this issue.

The choice of the cluster was very fortunate, since our images also revealed a giant gravitational arc and several arclets surrounding the cD galaxy of the cluster. However, after our observations had taken place we learned that this arc had already been discovered by Fort et al. in 1991, also with the NTT. (See also the article by G. Soucail in this issue of the *Messenger*.) Our images of the arc are of good quality (see the figure).

Because of our original project on this cluster we also have redshifts for about 50 galaxies in the field (the redshifts are available to us thanks to a collaboration with Dan Fabricant at the Center for Astrophysics). The fact that the arc is in a cluster for which we have such a complete set of optical and X-ray information makes the study of this arc particularly interesting for the determination of the mass distribution within the cluster and for the verification of the model of the lens. Before building the model, in collaboration with Emilio Falco (CfA), deeper images will be needed in order to confirm the several candidate arclets, which set very important constraints on the model itself.

We moreover note that at least one substructure of the main arc is probably bright enough to be observed spectroscopically (the integrated magnitude of the feature is R ≃ 21.5 and its surface brightness is ≥ 5 % of the sky). The spectroscopy of the arc would reveal the nature of the lensed object, something that has been possible only in four cases so far.



This image shows the compact cluster of galaxies EMSS2137-23 and the 15 arcsec long "giant arc", just north of the centre of the cluster, as obtained in June 1992 with the ESO 3.5-m New Technology Telescope (NTT) and the ESO Multi-Mode Instrument (EMMI) during remote observations from the Trieste Astronomical Observatory. The frame is a combination of 5 exposures in V, R and I, with a total exposure time of 95 min. The seeing was ~ 1.0 arcsecond. 1 pixel = 0.44 arcsecond. The field measures 70 × 52 arcsec; north is up and east is to the left.