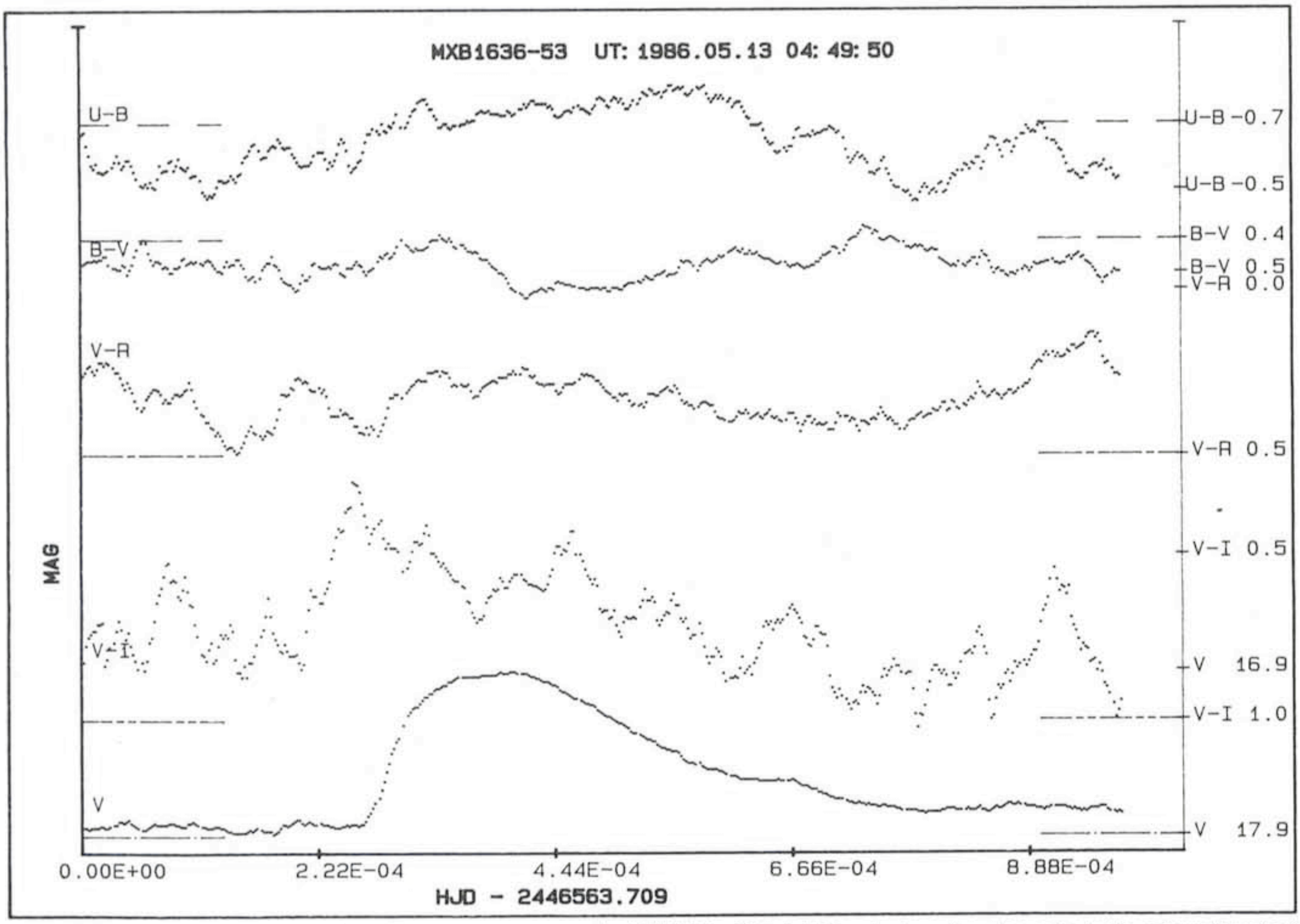

Figure 6: *Burst 2 and its colour variations. The curves were smoothed (FWHM = 50 points) in order to reduce the noise in the colours (1 point ≙ 320 msec).*

cated (see Fig. 6). A detailed analysis, however, requires more than two samples in order to enable the separation of individual characteristics from the general behaviour and to improve the signal-to-noise ratio. These considerations led to a successful application for further observations in July 1987, possibly in collaboration with ASTRO-C, the new Japanese X-ray observatory.

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Line and Continuum Imaging

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The study of line emitting objects often requires to image separately the line emission from the continuum one, in order to discriminate the different physical components. This is generally not possible with the broad bands of the standard photometric systems, like UBVRI. Rather one should use narrower bands selected according to the wavelengths of the emission lines. I discuss here the techniques to obtain pure and calibrated line and continuum images. "Pure" means that the line image is free from the contribution of the continuum and *vice versa*.. Since narrow-band imaging is not a new technique, I will restrict myself to the considerable improvements recently offered by the availability of linear and calibratable detectors, of interference filter sets and of powerful and versatile image reduction systems. Although I will concentrate here on images of active galaxies obtained with the ESO telescopes and CCD cameras at La Silla and reduced using MIDAS, the following discussion can be applied with small modifications to any class of line emitting objects and to other sites, detectors and reduction systems. I will first give some hints on how to conduct the observations and then discuss the reduction procedure. A technical note containing more detailed information is available from the author for those interested in actually using these techniques.

Observing Hints

It is necessary to obtain exposures both with a filter centred on the emission line and with a filter on the nearby continuum. The latter is used to derive the

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morphology of the component of the object, which emits continuum radiation, and to subtract the continuum contamination in the line exposure. The final quality of the images depends considerably on the filter selection. The line filter should be very narrow, compatible with the radial velocity range of the line emitting material, in order to minimize the continuum (and sky) contamination and to allow a proper correction of the wavelength-dependent nonuniformities (interference fringes) by flat-fielding. The transmission curve of the filter should be examined to check that the line falls where the transmission is high and that there are no other emission lines within the filter bandpass. Regions of rapidly varying transmission (filter wings) should be avoided, since a small filter tilt or even the converging beam of the telescope can change the transmission considerably. In practice 20–50 Å wide filters can be used. Image quality interference filters exist in the ESO filter set for common emission lines. For the [O III] λ 5007 and Hα lines such filters are available to cover a range of redshifts for extragalactic objects. The continuum filter can be broader (100–200 Å) to increase the S/N ratio, but must be free of lines over its entire range. A (nuclear) spectrum of the source is a useful help in the filter selection.

It is advisable to take – at least – two exposures of the object in each filter to eliminate cosmic ray signatures and to check on the detection of faint features. Some observers offset the telescope slightly – a few arcseconds – between the first and second exposure. This allows to eliminate permanent CCD defects like bad columns, but requires rebinning of one image before it can be compared with the other one, thereby decreasing its resolution and therefore making the comparison of the two images more problematic. I prefer to take the two images in the same conditions as far as possible. Exposure times in the continuum filter can be shorter, e.g. inversely proportional to the filter width. Telescope focus should be checked frequently, since it changes during the night and with the filter thickness.

As usual, dark exposures should be taken and subtracted from the object exposures. The dark signal is so linear with the exposure time that it is sufficient to take darks at a few exposure times and interpolate between them. An exception to this linearity are the so-called "bias" exposures (i.e. 1 sec. darks), which have higher signal than expected from the extrapolation of longer dark exposures. This might be due to the heating of the CCD produced by its frequent reading while taking a series of very short exposures. Even the technique of measuring the "bias" level from the "overscan" area of a CCD frame (i.e. the few columns following the physical pixels) must be used very carefully, since this area is contaminated by the signal in the rest of the CCD, because of charge transfer inefficiencies. There is in fact no need to measure and subtract the "bias" separately: the dark subtraction removes sufficiently well all *additive* components, before flat-fielding deals with the *multiplicative* ones. Small residuals would anyway be removed by the sky subtraction process. I have noticed that the dark signal increases considerably and shows an horizontal line in the middle of the field (for the RCAs) if the CCD has been exposed to high ambient illumination (e.g. while mounting it). This persistence effect can last for days. Simple precautions can be taken to avoid it.

Flat-field exposures should obviously be obtained for every filter. Good results can be reached with dome flats using day light. The illumination from internal lamps is usually not sufficiently uniform. Experience has shown that flat-fields and darks are good for a whole run, provided that no modifications are made to the CCD camera or to the filters on the filter wheels. Hopefully in the near future this will become true on longer time scales, so that the observer could take the calibration exposures from an archive.

A good spectrophotometric standard star (e.g. from Oke, 1974, *Ap.J. Suppl.* **27,** 21) must be observed each night through all the filters used during that night. The star should be well exposed, but below saturation, and exposure times longer than 10 seconds should be used, so that the inaccuracy due to the uncertainty of the exact exposure time is negligible. If these two latter requirements are incompatible, it is acceptable to defocus the telescope.

Reduction Procedure

After the usual dark subtraction and flat-fielding, a major problem in the reduction of long exposure CCD frames is the elimination of cosmic ray signatures. These are not only a cosmetic problem, but can affect considerably the flux measurement and are difficult to distinguish from stars in poorly sampled images (e.g. EFOSC). Cosmic rays can be removed by median filtering, but better results are obtained with the MIDAS command AVERAGE/WINDOW (FCOMPARE in IHAP). This command computes a special average of two or more aligned exposures: for each pixel the average is computed using only the pixel contents in the original frames, which do not deviate from the median of the contents of that pixel by more than an allowed uncertainty, related to the expected noise level. The other pixel contents are presumed to be contaminated and discarded from the average. Differences in exposure time and background level in the original images are accounted for by special frame descriptors. The allowed uncertainty is computed separately for each pixel and is made up of two parts: a constant one, which is related to the read-out noise and depends only on the input parameter BGERR, and a second one, which is related to the photon noise and depends on the pixel content through the input parameter SNOISE.

Table 1 lists the recommended values of these parameters for some of the CCDs commonly used at La Silla. These values have been derived empirically from the width of the main peak in the histogram of the difference between two short exposure darks (for BGERR) and of the difference of two well-exposed flat-fields (for SNOISE). They provide rejection of the cosmic ray signatures larger than four times the r.m.s. read-out noise or six times the r.m.s. photon noise. These rather high rejection thresholds ensure that the original images are modified only where it is strictly necessary. They can be lowered for some applications, like the cleaning of dark exposures. The higher threshold recommended for the photon noise allows for the differences in the original images which often occur in regions of large gradients (e.g. the wings of the stellar profiles) because of seeing variations or residual misalignments. It is useful to check the result of the AVERAGE/WINDOW command by comparing it with a normal average of the original

TABLE 1

CCD	Gain*	Read-out noise* e^-	Gain factor* $e^- ADU^{-1}$	BGERR	SNOISE
#3	G50	40	10.5	10.4	1.40
#5	G30	49	13.5	10.2	1.16
#7	G100	18	6.0	5.6	1.65

* From "CCD detectors available at La Silla", ESO Techn. Rep. by P. Sinclaire, June 1986.

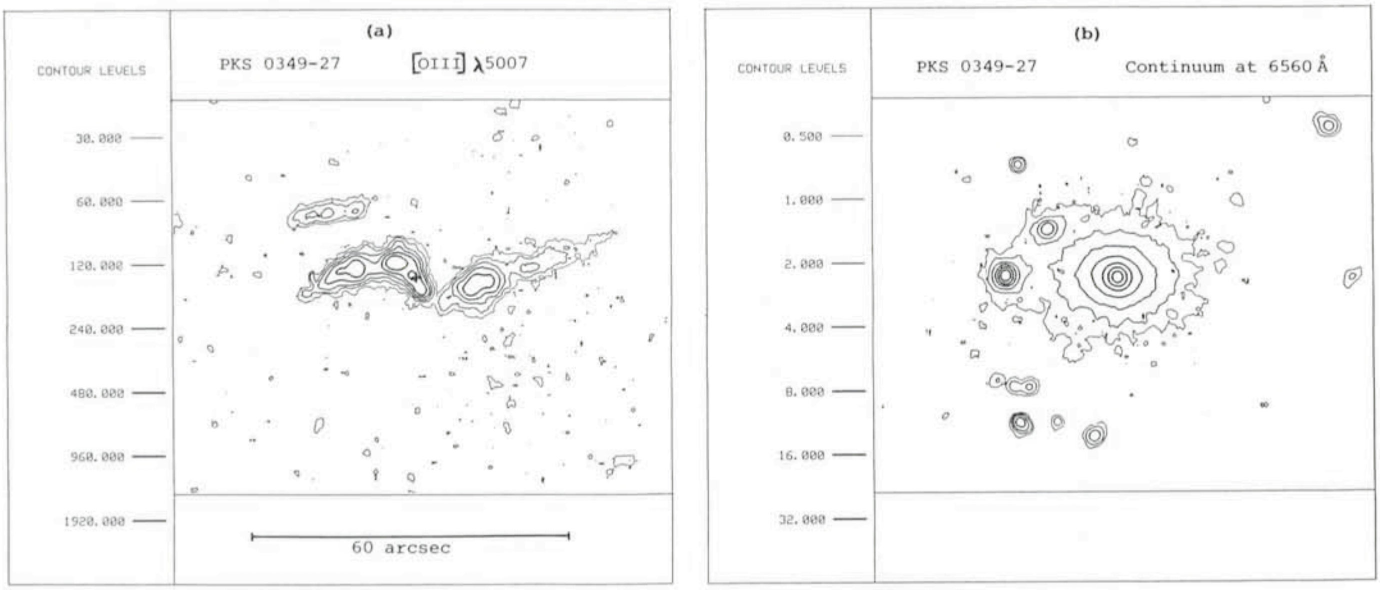

Figure 1: *contour plots of [O III] λ 5007 (a) and continuum (b) images of the radio galaxy PKS 0349-27 derived from CCD exposures obtained with the 2.2-m telescope at La Silla. The cross marks the position of the galaxy nucleus. Contour levels are listed on the left and are in units of 10^{-18} ergcm^{-2} s^{-1} arcsec^{-2} for the line image and of 10^{-18} ergcm^{-2}s^{-1}Å^{-1} arcsec^{-2} for the continuum one.*

CCD frames: the difference should be positive restricted to the pixels affected by cosmic rays. The input parameters to the AVERAGE/WINDOW command can alternatively be derived from the CCD characteristics:

$$\mathrm{BGERR} = 2.75\frac{N}{F};\ \ \mathrm{SNOISE} = 4.25\sqrt{\frac{1}{F}}$$

where N is the CCD read-out noise (in e^-, r.m.s) and F is the gain factor (in $e^- ADU^{-1}$).

As mentioned earlier, the "pure" line image is obtained – after sky subtraction – from the exposure in the line filter by subtracting a properly scaled copy of the continuum exposure. The determination of this scaling factor is a critical one, since the final line fluxes will depend strongly on it in the regions where the continuum is bright. Different methods can be used to derive the scaling factor, depending on the application. One is to ensure that stellar images are well subtracted, at least on average, in the final line – continuum image. Unfortunately it is usually not justified to assume that the spectrum of the continuum component of the object under study has the same shape than the average spectrum of the stars in the field. Moreover for extragalactic objects even a small redshift can change considerably the relative amount of continuum radiation falling in the two filters. A way to solve these difficulties for extragalactic objects is to use, instead of stars, other galaxies in the field at the same redshift as the object under study, but without emission lines. Clearly this method can be used only very rarely. The scaling factor can also be evaluated by "trials and errors", that is by increasing it until one starts to have negative values in the line-continuum image. Good results are produced in this case only for objects which have regions of bright continuum but no line emission. A more general method, which I have finally adopted for the imaging of active galaxies, is to evaluate the scaling factor directly from the observations of the standard star and from the relative exposure times. The best results with this method are obtained if some assumption can be made on the shape of the continuum spectrum to be subtracted, so that differences in its average value in the two filters can be compensated for. For example in the case of radio galaxies, the spectrum of the "standard" elliptical galaxy given by Yee and Oke, 1978 (*Ap. J.* **226,** 753) has been used successfully.

Last but not least the images are flux calibrated using the observations of the standard star and the assumption that the latter were taken in the same conditions as the object exposures except for the airmass. First from the measured count rate C_s (in $e^- s^{-1}$) of the standard star and from its flux $f_{\lambda s}$ tabulated in the literature we compute the equivalent area S:

$$S = \frac{h \cdot c \cdot C_s}{\int f_{\lambda s}(\lambda) \cdot A(\lambda, a_s) \cdot E(\lambda) \cdot \varphi \cdot d\lambda}$$

where A is atmospheric transmission for the airmass a of the observation ($A = 10^{-0.4aK(\lambda)}$, $K(\lambda)$ being the atmospheric extinction in magnitude per airmass) and E is the efficiency of the telescope + filter + detector combination, derived by multiplying the measured efficiencies of the single components. Then the images of the object can be flux calibrated if an assumption can be made on the shape of its spectrum (within the filter band). Two cases are examined here:

1. In the line-continuum image the radiation from the object is concentrated at the wavelength λ_e of the emission line; then the flux $F_{\lambda o}$ at λ_e can be computed from the measured count rate C_o:

$$F_{\lambda o} = \frac{h \cdot c \cdot C_o}{S \cdot A(\lambda_e, a_o) \cdot E(\lambda_e) \cdot \lambda_e}$$

2. For the continuum image the average flux density within the filter band is:

$$f_{\lambda o} = \frac{h \cdot c \cdot C_o}{S \cdot \int A(\lambda, a_o) \cdot E(\lambda) \cdot \lambda \cdot d\lambda}$$

For a good calibration it is important that the wavelength dependence of E is evaluated correctly. On the contrary, the absolute value of E is not critical. If an error of, say, a factor of two is made in the evaluation of the detector quantum efficiency, this factor is taken into account by the equivalent area S computed from the standard star observation and will not affect the flux calibration. If, on the other hand, even the absolute value of E is evaluated correctly (and the night is photometric), then S is equal to the collecting area of the telescope. For most of the standard start observations, which I have obtained with the CCDs at La Silla, S is equal to the collecting area of the telescope within 20%. The value of S provides then a useful check on the instrument performance and on the observing conditions. For calibration of narrow-band images I have prepared a database of MIDAS tables containing filter transmission curves, detector efficiencies, mirror reflectivities, etc. This database is useful also in the preparation of the observations for estimating the exposure times.

Figure 1 shows the results of the application of these techniques to the imaging of a radio galaxy, showing how well the ionized gas can be separated from the stellar component in a case where the two have a clearly different structure.

Velocity and Velocity Dispersion Fields of NGC 6684: An SB0 Galaxy with a Ring

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1. Observations

NGC 6684 is a southern S0 galaxy of magnitude B = 11.35 showing a bright bar aligned about 20° from the minor axis of the disk and encircled by an elongated luminous ring (b/a = 0.77). This galaxy has been observed within a programme of study of stellar motions in barred galaxies, a subject which in the recent years has been analysed by many theoretical works but that has been studied observationally only by few authors. Among the galaxies for which the whole stellar velocity field is known, the velocity dispersion field has been studied only for NGC 936 (Kormendy, 1984).

NGC 6684 was observed in May 1983 and March 1984 at the 3.6-m telescope of the European Southern Observatory at La Silla, Chile. The spectra were taken using the Cassegrain Boller and Chivens spectrograph plus a 3-stage EMI image tube and setting the slit at four different position angles corresponding to the apparent major and minor axes of the disk, the bar major axis and to a P.A. at 45° from the major axis. The spectra of some early K-type giant stars were recorded each night, for use in the reductions as template stars of zero velocity dispersion. The exposure times were ranging from 30 to 55 minutes. The slit was set to a width of 1.5 arcseconds on the sky and to a length of 1.9 arcminutes. The plate scale along the slit image was 38.5 arcsec mm^{-1}, and the dispersion was 39 Å/mm.

The spectroscopic observations of the galaxy were associated to a morphological study based on two 15-minute V frames taken with the 320 × 512 RCA CCD of the 1.5-m Danish telescope on the night of May 6/7, 1986 and on the analysis of the galaxy images on ESO (B) and ESO/SRC (J) charts. In the following we describe some of the more interesting results arising from our observations.

Data Reduction and Analysis

All the spectra have been digitized with the ESO PDS microdensitometer using a 12.5 × 50 μ slit and considering a wavelength interval of 3800–4500 Å. No emission lines were detected in the spectra, but Ca II H and K absorption and G-band are well defined. All the PDS images were calibrated in intensity and wavelength and sky subtracted using the ESO-IHAP procedure at the Padova HP computer centre. The resulting images were continuum flattened and analysed with the Fourier Quotient Technique described in Bertola et al. (1984), giving simultaneously the radial velocity, the velocity dispersion and the line-strength parameter for each scan line of each spectrum. The curvature of the spectral lines has been measured from a full slit comparison spectrum by measuring with the Grant 2 coordinate machine of ESO the position of 12 spectral lines. It has been found quite negligible, producing a shift lower than

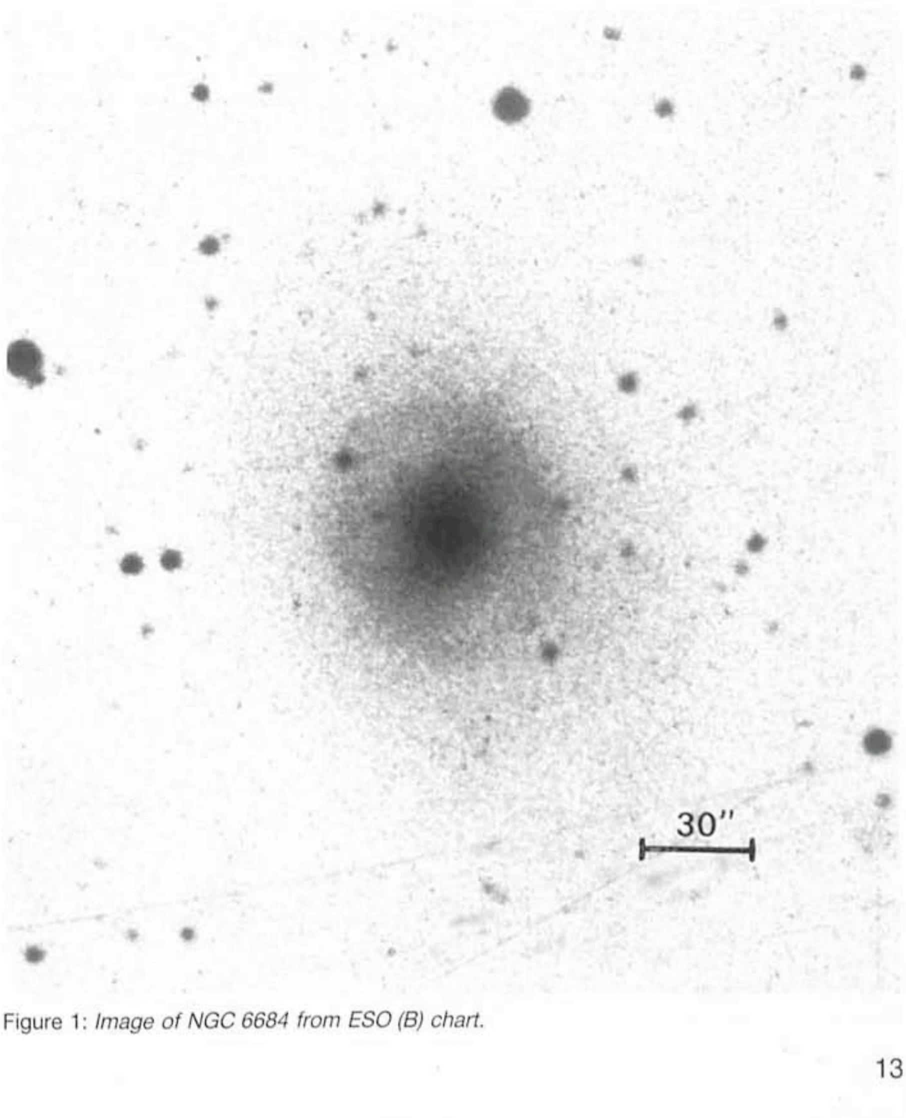

Figure 1: *Image of NGC 6684 from ESO (B) chart.*