SLITLESS SPECTROSCOPY WITH PHOTOGRAPHIC AND CCD DETECTORS ACROSS LARGE FIELDS

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ABSTRACT. We present a new survey of emission line galaxies, performed with the ESO 1 m Schmidt telescope equipped with the 4° objective prism using IIIa-J photographic emulsion. The plates are digitized with the MAMA microdensitometer. A subsequent reduction of the block scans gives redshifts with a mean accuracy of 160 km/s^{-1}, and spectrophotometric measurements of the intensity and equivalent widths of the principal emission lines. A brief discussion is given of the possible extension of quantitative reduction of slitless spectroscopy to archive plates and future large CCD array frames.

1. Introduction

Slitless spectroscopy has been and is still widely used to discover peculiar objects (stars with peculiar spectra, planetary nebulae, QSOs, active galaxies with emission lines, etc.) in wide-field surveys. It uses either large objective prisms on Schmidt telescopes or grens/grisms grating setups on prime-focus cameras of 3 - 4 m class reflectors. Here we present a new survey for active galaxies conducted with the ESO 1 m Schmidt.

2. Context and Motivations

Numerous searches for active extragalactic objects have been already conducted in the visible part of the spectrum. These surveys produce not only large samples of active galactic nuclei (Seyferts, LINERS and QSOs) but also a numerous population of starburst galaxies, in which the 'activity' is due to enhanced stellar formation.

Optical (visible) surveys may be classified from their selection process:

1) colour selection looks for ultraviolet excess in the continuum of the objects, produced by the population of massive stars born in the star formation burst. One uses either multicolour direct imagery (Haro 1956; Kiso: Takase & Miyauchi-Isobe 1984; Montreal survey: Coziol et al. 1993) or very low dispersion objective prism spectra (First and Second Byurakan Surveys: Markaryan 1967; Markaryan & Stepanian 1983; Case survey: Pesch & Sanduleak 1983);
2) emission-line selection is achieved by slitless spectroscopy with objective prisms. (Tololo survey: Smith 1975; UM survey: MacAlpine et al. 1977; Case survey, op cit.; Wasilewski

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1983; Calan-Tololo survey: Peña et al. 1991).

However, systematic differences in the populations sampled by the two methods appear (Comte et al. 1993). These differences are very probably due to different coverage of the range of excitation classes, and hence of the evolutionary status of the starburst.

Most survey catalogues have a quite small information content and therefore a time-costly follow-up is necessary to derive useful astrophysical conclusions. However, with the advent of high accuracy fast microdensitometers, even large Schmidt objective-prism plates may yield, thanks to a thorough reduction, quantitative precision redshifts and semi-quantitative spectrophotometry.

3. Instrumental Setup

We used the 1 m ESO Schmidt telescope (plate scale: 67.5 arcsec $\cdot$ mm^{-1}; field 5°) with its 4° objective-prism (reciprocal dispersion: 450 Å $\cdot$ mm^{-1} at Hγ). Hypersensitized IIIa-J plates exposed 110 minutes (sky limited) give filiform spectra. These prism plates are associated with 'bicolour' direct IIIa-F plates (U and R exposures on the same plate, separated by 30 arc seconds along the delta axis), taken in a parallel survey for ultraviolet excess objects. The candidate objects are selected by eye inspection at the microscope. Around each candidate, the plates are digitised with the MAMA† microdensitometer at Observatoire de Paris. Block scans with 20 x 20 micron pixels, with a step 20 µm, are recorded. Density-intensity calibration is provided by spot sensitometer exposures.

4. Redshift Measurement

For a small prism angle A and a focal length f the position difference between two lines λ_1 and λ_2 in a spectrum is given by:

$$\Delta X = X_2 - X_1 = f \cdot A \cdot |n_2 - n_1| \qquad (1)$$

n_i being the refractive index of the prism material for λ_i (given by the glass manufacturer). We use a 'local' wavelength calibration provided by the spectra of field stars deriving the f·A product valid across a restricted area of 10 x 10 arc minutes around each candidate galaxy. This is achieved using a composite spectrum (to improve the signal-to-noise ratio) built from the coaddition of 5 to 8 field star spectra after recentring on the deep Ca II H line core. The f·A product is derived by solving Equ. 1 for several pairs of absorption lines in the composite spectrum and averaging.

The redshift z of the galaxy is then derived by two independent procedures:

1) if at least 2 widely spaced emission lines are present (e.g. [OII] 3728 and [OIII] 5006 or [OII] and H β), we solve Equ. 1 for this (these) pair(s) of lines using the local f·A value;
2) we use the direct image of the field to predict the position of a zero redshift Ca II H line in the galaxy spectrum. The position difference with an observed redshifted emission line gives the redshift by solving Equ. 1. The agreement between the two methods is excellent and has been checked between 0 and 20,000 km/s^{-1}.

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† MAMA (Machine à Mesurer pour l'Astronomie) is developed and operated by CNRS/INSU (Institut National des Sciences de l'Univers) and located at l'Observatoire de Paris.

The final adopted value of the redshift is a weighted average of the values given by the two methods. Comparing our redshifts with literature values on 15 galaxies, we derive a mean error of $\delta_V = 160$ km/s^{-1} in the range 0 to 5000 km/s^{-1} where these external calibrations are available (Fig. 1). This accuracy is well suited to luminosity function estimates and large structure tracing. Figure 2 shows the histogram of our recession velocities (on a sample of 97 emission line galaxies found in 50 square degrees) compared with recession velocities of absorption line galaxies in Dressler's catalogue across the same sky area (Dressler 1991).

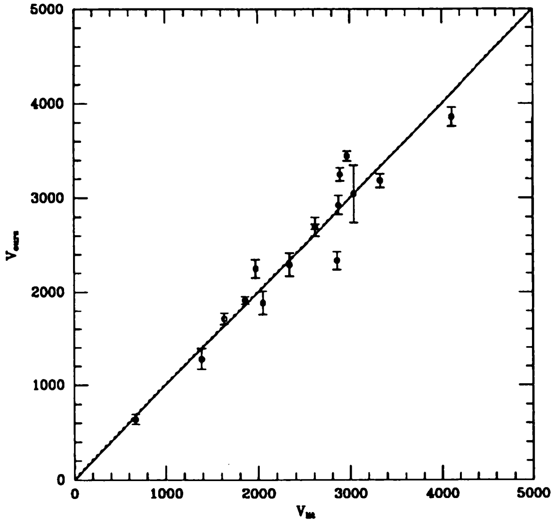

Figure 1. Comparison between recession velocities measured on the prism plates (ordinates) and literature values (abscissae) on the same galaxies.

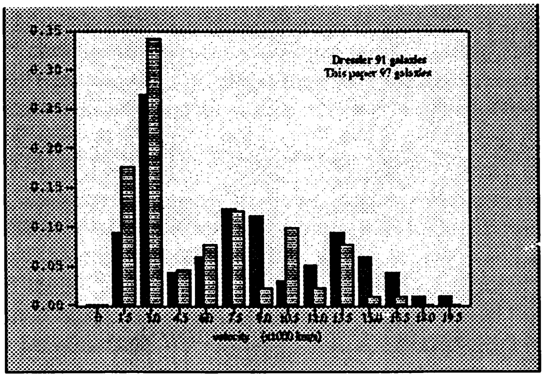

Figure 2. Dark shade: distribution of 97 observed heliocentric velocities measured on the prism plates; light shade: distribution of 91 heliocentric recession velocities of absorption line galaxies given by Dressler (1991) across the same sky area (see text). The samples do not overlap.

5. Spectrophotometry

To retrieve useful spectrophotometric information from the prism plate spectra we follow several steps:

1) we rebin the galaxy spectrum on a linear wavelength scale;
2) we search for A0 - A5 type stars on the plates. We build a composite spectrum with them (by coaddition with reference e.g. on the core of the Hγ line). The composite spectrum is rebinned on a linear wavelength scale;
3) we calibrate the instrumental response (telescope * prism * emulsion) by comparing the rebinned composite A0 - A5 spectrum with an average A0 - A5 spectrophotometric standard star spectrum;
4) we divide the observed galaxy rebinned spectrum by the instrumental response (Fig. 3);
5) we measure the relative intensities and equivalent widths of the main galaxy emission lines.

Only two thirds of the sample have a sufficient signal-to-noise to give correct measurements. The remaining third yields only upper limits of the intensity ratios or of the equivalent widths. The preliminary results indicate a behaviour already observed in other samples of emission line galaxies. Figure 4 shows the histogram of observed equivalent widths of [OIII]5006 on a subsample of 60 emission line galaxies observed in 50 square degrees.

6. Future Prospects

The kind of efforts that we have invented in the retrieval of a maximum astrophysical output from

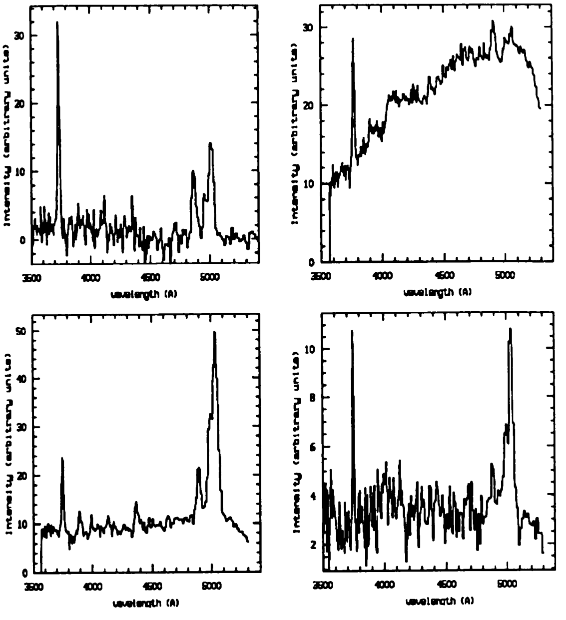

Figure 3. Examples of emission line galaxy spectra. [OII], Hβ and [OIII] lines are clearly visible. The linewidths at the green end are not representative of the true linewidths.

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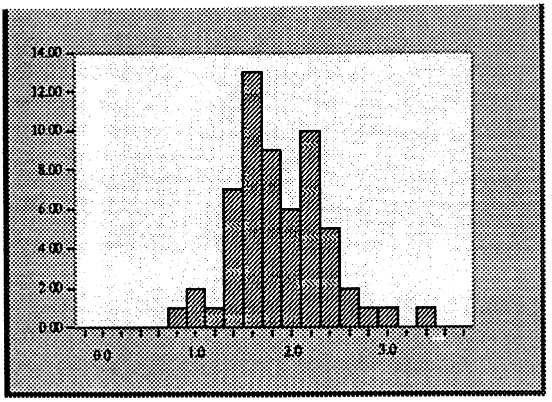

Figure 4. Distribution of the logarithm of the equivalent width of the [OIII] doublet observed in 60 emission line galaxies (see text). This histogram is incomplete towards the faint equivalent widths end because only good quality spectra have been measured.

survey photographic plates may be developed by others in other directions.

1) Use of archive plates: there exists a considerable number of objective prism plates taken for various purposes (QSO search, active galaxy search, peculiar stars search: carbon stars, WR stars, etc.). These archives may now be revisited because machines for digitization and computers for a complete reduction are now available. A welcome progress in the reduction scheme would then be the automatization of the object search.
2) Detector progress: CCDs have decisive advantages over photographic emulsions: linear response to incident flux, high quantum efficiency, large dynamics, direct digital readout, more uniform spectral sensitivity, etc. They also have two drawbacks: they are not available in large formats (the building of a CCD array is mandatory to cover a large field) and they are flat (if focal plane curvature is present, one needs either a flattening optics or a complex geometry of the CCD array). The sampling problems have been revisited by Dr. Monet at this colloquium, so we do not insist on that. Let us simply recall some possible applications. CCDs may be used on:
   a) existing Schmidt telescopes equipped with large prisms (cf. the talk by Dr. Sekiguchi);
   b) existing prime focus cameras on 3 - 4 m class telescopes, featuring Grisms or Grens adapted to the detection of faint emission-line objects in 50 arc minutes to 1 degree fields. Focal reducers at Cassegrain focus are also powerful detection machines (see the talk by Dr. Azzopardi) but their field is smaller (5 to 10 arc minutes);
   c) specially designed new telescopes: this is the purpose of the LITE project presented at this colloquium by Dr. Vigroux.

Scientific problems which may be attacked are innumerable; let us simply recall that 'mass' spectrophotometry, with a much better accuracy (due to the linearity of the response even at low signal-to-noise) may be performed in large field surveys; redshifts of absorption line only galaxies may be obtained by slitless spectroscopy with a comparable accuracy as those derived on emission lines (this is very difficult with photographic plates because the effective wavelength of the 4000 Å break, the highest contrast feature on faint objects observed at low dispersion, slightly moves with the signal-to-noise of the spectrum, and hence is apparent magnitude dependent).

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