Astronomical Data Analysis Software and Systems VII
ASP Conference Series, Vol. 145, 1998
R. Albrecht, R. N. Hook and H. A. Bushouse, eds.

Slitless Multiobject Spectroscopy with FOSC Type Instruments

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Abstract. We present a simple, effective technique that allows the contemporary spectroscopy of all the objects, up to a limiting magnitude, contained in a ~ 100 arcmin^2 field. This technique makes possible the immediate and unambiguous identification of peculiar objects included in the field. A data analysis procedure that produces the final results in a very short time has also been developed. As a test of this technique, we present the results* obtained for the peculiar young open cluster Berkeley 87. We show that this technique should also be quite useful in emission line and WR star surveys, and illustrate the software procedures developed to make the wavelength and flux calibration of these spectra.

(*) Based on data collected at the Loiano Observatory

Modern hard X-ray satellites allow the real time positioning of transient high energy sources with a precision of $\sim$10′–30′. In some cases, as for the gamma-ray bursts, the fast identification of the optical counterpart is a crucial item to unveil the physical nature of the emitting object. On the other hand, no other way to make their identification in the optical range has been so far found, but making the spectroscopy of all the objects included in the error box, and looking at the objects which show a peculiar (e.g emission line) optical spectrum. Of course, within a sky area of order of some 10^2 arcmin^2, there is an enormous number of objects and it is unlikely that we can obtain all their spectra in a reasonable time period. This fact usually overcomplicates the identification of the optical counterpart of the high energy cosmic sources, at the risk of substantially diminishing the scientific potential of the imaging hard X-ray and gamma-ray telescopes.

For this reason, we have developed a technique, that allows the simultaneous spectroscopy of all the objects included in a square field of view with $\sim$10′ side, using the widely used FOSC-type optical spectrometer and camera focal-plane instruments. The technique is based on the use of a slitless low dispersion grism coupled with a broad-band filter, which perform an "objective prism like" spectrogram of all the objects present in the field, without serious overlap of adjacent spectra. For instance, the use of the very common grisms with $\sim$400-800 nm bandpass and of the Johnson R filter will make an imaging spectroscopy of $\sim$ 200nm centered on Hα, and emission line and peculiar spectrum objects are easily identified.

We tuned this technique on the Bologna Faint Object Spectrometer and Camera -BFOSC- instrument (Merighi et al. 1994), mounted at the Cassegrain focus of the Bologna Astronomical Observatory "G.B. Cassini" 1.52 m telescope, sited near Loiano (Italy) at about 800 m altitude on the Appennine Mountains.

In order to test this technique, we used the peculiar open cluster Berkeley 87, an intriguing object, that we have studied for more than 10 years (e.g., Norci et al. 1988; Polcaro et al. 1989; Polcaro et al. 1991; Manchanda et al. 1996). Actually, most members are young, heavily reddened OB stars, but a few are much more evolved objects, such as the WO star Sand 5 and the M3.5I variable BC Cyg making the evolutionary status of the cluster extremely uncertain. The cluster member n.15 in the Turner and Forbes (1982; hereafter TF82) list is an emission line star (V=11.8) also known as V 439 Cyg and MWC 1015 (Merril and Burwell, 1949). This star dramatically changed its spectrum from late to early type in a few decades; furthermore, some absorption lines that were still present in 1986 and 1987 completely disappeared in 1988. The star is characterized by a strong IR excess and a peculiar position in the HR diagram, suggesting that it should be considered as an intermediate RGS/LBV star (e.g., Polcaro and Norci, 1997 and references therein). Three other cluster members (no. 3, no. 9 and no. 38 in the TF82 list) are emission line stars.

On June 24, 1997 (23:11:55 UT), we took a 30 s R filter exposure of the central (9 x 9 arcmin^2) region of Berkeley 87, shortly followed (23:18:34 UT) by a slitless 300 s image through the R filter and the grism no. 4 (Fig 1). The Hα emission of stars no. 3, 9, 15 and 38 and the WR spectrum of Sand 5 where immediately visible after a short tuning of the contrast. The direct overlap of these two images using the IRAF task *imarith* on the recorded FITS files allowed a prompt and unambiguous correlation between the objects and the spectra.

The whole procedure, including the overlap, took less than half an hour.

Notice also that our short exposure allowed the immediate identification of the Hα emission of the V=14 star no. 38 and of the WR spectrum Sand 5 (V=13.8) without saturating the Hα emission of the V=7.81 star no. 3. In absence of such a bright object (or if we do not care if we saturate its spectrum) a longer exposure should allow the identification of emissions also in much fainter objects.

A careful analysis of the slitless spectral image demonstrated that this technique has a field of application much wider than the fast identification of peculiar objects described above.

Actually, after debiassing and flat-fielding (using standard IRAF procedures) by means of a 10 s flat-field taken through the R filter, we obtained a pretty clean image from which 25 good quality, not overlapped spectra of stars up to V=16 were extracted. The comparison of this multiobject spectroscopy with long slit spectra of a few objects in the same field taken on the same night through the same grism, which were wavelength calibrated by means of a He-Ar comparison lamp and flux calibrated using the standard star Kopf 27, shows that the pixel-wavelength relationship was not affected by the lack of the slit and the presence of the photometric filter, but just shifted in pixels, due to the different declination of the stars in the field, and cut between 550 nm and 780 nm due to the combined effect of the filter and grism transmission curves. Thus, the wavelength calibration is easily obtained, with a precision of ±0.5 nm from the position of the stellar image, the 550 nm cut-off and the red telluric absorptions.

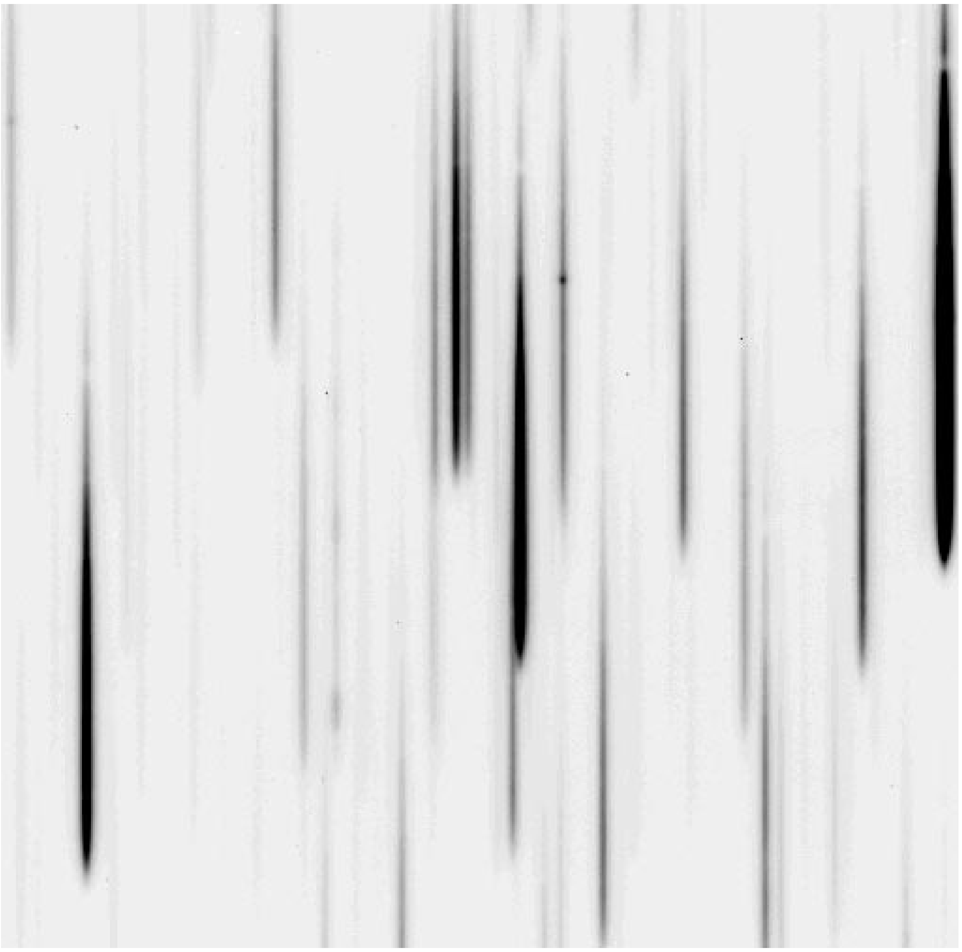

Figure 1. Figure 1: Slitless red spectral image of the open cluster Berkeley 87. The field is 9 x 9 arcmin^2. North is at the top and East to the left. The Hα emission line in star no.38 (top left) and n. 15 (top centre) and the WR spectrum of star n.29 (Sand 5, bottom centre) is clearly visible.

A further benefit was obtained from the slitless technique: the night sky lines (and mainly the antropic lines that are quite strong at the telescope site, due to the close proximity of the city of Bologna) as well as the numerous nebular lines (mainly, but not only, Hα) due to the intracluster matter (see e.g., Polcaro et al. 1991) result in a limited increase of the background level, so that spectra was much cleaner than those obtained in previous runs by means of slit spectroscopy. Furthermore, the absence of the slit eliminates the light loss due to the poor seeing (3.5 arcsec in the night of our experiment) so that the signal-to-noise ratio was much higher than that of "classical" spectra. In this way we were able to unveil narrow Hα emission cores in the cluster members no. 26, no. 31 and no. 32. Furthermore, once the wavelength calibration of each individual spectrum was achieved, we recognized (from the comparison of the debiassed and flat-fielded slitless spectra in reduced CCD counts and of the long slit flux calibrated spectra of the same objects) that, due to the linearity of the CCD detector used in the BFOSC instrument, the flux calibration curve was the same for the whole image. Thus the flux calibration of the slitless spectra was also straightforward.

Our test demonstrates that the use of the slitless spectrometry technique with the modern FOSC type instruments does not only allow the immediate identification of spectroscopically peculiar objects in a field of the same order of magnitude of that of a "typical" hard X-ray instrument. It also shows how this technique can be used to obtain, without the need of either new hardware or of large telescopes or high quality skies, much valuable scientific information: for instance, we identified in a single short test-shot three previously unknown emission line stars.

We now plan to apply the method to a search for emission line and WR stars in young clusters.

We thank the night assistants of the Loiano observatory, Mr. G. Tessicini and Mr. E. Delogu, for their help during our experiment

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