AUTOMATIC ANALYSIS OF OBJECTIVE PRISM SPECTRA

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ABSTRACT

An automated system to measure and analyse large numbers of objective prism spectra from photographic plates using the Automated Plate Measuring (APM) facility at Cambridge is described. The system is being applied in a number of ways including automated quasar detection and subsequent clustering analyses, galaxy redshift surveys, and wide field searches for rare objects, such as carbon stars.

1. INTRODUCTION

The availability of large numbers (>50) of high quality low dispersion objective prism plates from the United Kingdom Schmidt Telescope (UKSTU) in Australia, together with increasing numbers of 4 metre telescope grism plates makes detailed spectral studies of significant areas of sky (hundreds of square degrees) a realistic possibility. The large number of spectra involved (typically >2000 per square degree to $m_J \sim 20$ at high galactic latitudes) means the use of high speed plate scanning facilities such as APM (Kibblewhite et al. 1983) or COSMOS (Stobie et al. 1979) is essential. The application of such plate scanning facilities can be regarded as an obvious development from the earlier human plate searches that have laid so much of the groundwork for the automated techniques now being developed. Crucial advantages in an automated, machine based approach include; (a) greatly improved homogeneity in selection procedures applied over large areas, (b) selection procedures are readily quantifiable and (c) large increases in speed are possible.

2. THE SPECTRUM MEASUREMENT SYSTEM

The APM Prism Reduction System (PRS) is based on a scan of a deep direct plate of the field to be studied. The APM control computer contains the complete SAO astrometric catalogue, and an initial alignment procedure provides coordinate transformations to convert machine

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X-Y coordinates to right ascension and declination. The direct plate measurement provides complete lists of objects with positions accurate to 0.2 arcseconds, and a wide range of photometric and profile information. Magnitude limted samples may be derived from the data, and further subdivisions into object classes may be made - e.g. stellar, non-stellar or compact objects. A similar alignment procedure for the spectrum plate places the direct and spectrum images on the same celestial system, giving the exact position of all spectra corresponding to the object samples defined by the direct data. A global fit of the centroids of the direct images to the photographic emulsion cutoffs of the spectra allows the removal of second order geometrical distortions due to the prism, and establishes a precise wavelength zero point for all spectra, limited only by the object coordinate accuracy of 0.2 arcseconds. This procedure results in; (a) the virtual elimination of spurious images (due to noise) on the spectrum plate, (b) the ability to assign precise wavelength scales to objects (strong line quasars with no visible continuum for instance) which do not possess visible emulsion cutoffs, (c) the removal of all overlapping and confused spectra, and (d) reliable photometric and image classification data being available for all objects with measurable spectra.

An important feature of the PRS is the relatively complex measurement procedure, allowing the maximum possible signal to noise ratio to be obtained in the final one dimensional spectra. The mean profile shape of each spectrum is calculated by using the spectrum marginal sum perpendicular to the direction of prism dispersion. The calculation allows for any change in the intensity of the sky background over the extent of each spectrum. This mean spectrum shape is defined by the image profile and is effectively constant along the spectrum-saturation effects not withstanding. A smooth monontonic function is fitted to this marginal sum - thereby reducing problems due to nearby overlapping images - and used as a weighting function in the calculation of the intensity variation along the spectrum. The intensity at each wavelength is found by comparing the calculated mean spectrum profile shape with crossections of the data at each wavelength. Technically the determination of the object intensity scale factor k, at each wavelength is made by minimising the weighted sum of the squared error residuals between the data D_i and the spectrum profile P_i. For random noise this gives the most probable value for the intensity at each wavelength bin,

$$\text{minimize} \qquad \Sigma\,(D_i - k \times P_i)^2/\sigma_i^2 \qquad \text{with respect to } k$$

where σ_i^2 is the noise variance at density D_i. The scale factor k that minimizes the sum is simply given by the weighted sum

$$k = \frac{\sum_i P_i \times D_i/\sigma_i^2}{\sum_i P_i^2/\sigma_i^2}$$

The use of such a 'matched' estimator reduces the noise in the computed spectra by typically a factor two over straight forward integration. Spectra for brighter saturated images are obtained using the points in the sum that are unsaturated - effectively scaling just the wings of the profile onto the wings of the spectrum. The final spectra are output to magnetic tape and further processing takes place using the one dimensional intensity versus wavelength spectra - typically 50000 spectra are obtained from a high quality UKSTU IIIaJ plate.

3. SPECTRUM ANALYSIS PROCEDURE

The nature of subsequent processing depends on the type of project undertaken. Three main types of project can be distinguished; (a) sophisticated analysis of particular types of spectra - e.g. galaxy redshift determinations (Cooke et al. 1983 and this conference), (b) detection of specific types of rare objects with well defined, previously known spectra - e.g. metal poor stars and carbon stars, (c) general searches for complete samples of spectra that can not be unambiguously classified as main sequence stars or normal galaxies, in this case the type of spectra to be identified are not known beforehand. Subsets of such spectra are quasars and emission line galaxies. Examples of all three types of programme are already underway or are about to start.

The techniques for estimating galaxy redshifts are described by Cooke et al. (1983). In the case of specific object searches, template matching appears to be the most satisfactory approach and is being employed. Much of the work involved in this procedure is related to modelling the effects of the atmosphere, prism/telescope optics and the photographic process. Perhaps the most challenging projects however are of type (c) and considerable work has gone into developing a system that will identify all spectra that are not classified as main sequence stars or normal galaxies.

The PRS data are particularly suitable for this application and software is available to identify objects with specific features - emission lines, absorption lines, continuum breaks, strong uv excess - as well as more general techniques that examine all images on a plate and use cluster analysis techniques to identify anomalous objects in a wide range of parameter spaces. Objects identified by the latter technique include those with anomalous overall continuum slopes, peculiar colours, and featureless spectra.

The detection of objects exhibiting emission or absorption features provides an example of the techniques: an object continuum spectrum is defined using a combination of median and linear filtering techniques. The noise is determined globally as a function of wavelength and intensity from all the spectra, using the original spectra and the continuum fits. Then 'matched' filters are stepped along each spectrum to identify emission/absorption features. The filter technique is directly anal gous to that used in the measurement of the spectra, although a Gaussian shape

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is used as little is gained from more sophisticated profile shapes. In order to detect resolved lines the procedure is repeated a number of times with the continuum-defining filter lengths increased, and the width of the matched filter enlarged. This 'matched' filter approach again offers large increases in the ability to reliably detect lines relative to the more common box filter technique. A catalogue of detected lines with associated detection probabilities can be derived in about an hour for a complete Schmidt plate data set of 50000 images.

4. SUMMARY

A fast automated spectral analysis system (based on the APM at Cambridge) applicable to a wide range of astronomical research is now in operation. Techniques for automated detection of quasars and other peculiar objects have been developed and surveys of large areas of sky are now underway.

5. REFERENCES

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