THE AUTOMATED DETECTION OF VARIABLE OBJECTS ON SCHMIDT PLATES

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This paper will review progress on the automated detection of variable objects on Schmidt plates, describe the various populations of variables which have been discovered, and summarise some of the most interesting results to date. So far, the searches have been based on sequences of a dozen or more sky limited UK 1.2m Schmidt plates taken on timescales from one day to several years. The plates were measured on the COSMOS measuring machine at the Royal Observatory, Edinburgh which typically detects between 100,000 and 200,000 images in the central 16 deg^2 of each plate. The measures for each field are combined, and calibrated using deep electronographic sequences, to give data sets of some 100,000 objects, complete in the magnitude range B = 13-21. The procedure is described in some detail by Hawkins (1983a) and results in a sequence of magnitudes accurate to about 0.1m for each object in the measured area. Field effects across the plates are allowed for, and an extensive set of diagnostics allows the distribution of errors as a function of magnitude, and on each plate, to be monitored.

The availability of a sequence of a dozen or more magnitudes for each object in the field enabled searches for variables to be undertaken according to various criteria. In the first instance a simple r.m.s. criterion was used, with checks designed to exclude spurious variation from plate flaws, proximity to bright stars and overlapping images. A number of variables were found in this way (Hawkins, 1981) and preliminary classifications made from an objective prism plate. In this early search it was clear that two types of variation were dominant - over a timescale of a day or less and over a year or more. This prompted the development of algorithms specifically designed to isolate the two populations.

By far the most numerous type of variable comprised those with timescales of a year or more. These objects were largely confined to the magnitude range B = 18-21 and spectra taken with the AAT showed them to consist of a population of quasars and active galaxies. A complete sample of these objects was obtained according to well-

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defined criteria, the most important of which was that the objects should vary by 0.3 mag over one year, but remain essentially constant within each year. The selection procedure is described in detail by Hawkins (1983a), and resulted in a complete sample of 77 objects, some 3% of all quasars. Detecting quasars by variability involves selection effects which are different from, and on the whole less serious than, those associated with other methods of compiling optical samples. In particular, the whole procedure may be carried out according to objective criteria, and systematic and random errors may be quantified.

The statistical analysis of several samples of variable quasars has now been carried out (Hawkins 1983a,d) in two high galactic latitude fields about 12° apart. The number/magnitude relation shows an increase by a factor of 5 per magnitude down to B = 21. There is as yet no definite indication of a change of slope in the range B = 18-21, but larger samples will soon be available which should clarify the situation. Since colour is not used either explicitly as in the case of UVX objects, or implicitly as for objective prism searches, in the definition of the sample, the colour distributions of the sample members can be investigated. This has revealed a reddening towards fainter magnitudes, clearly seen in the B/B-R relation but even more evident in the B/U-B relation (Hawkins, 1983d). It is however worth pointing out that even at the sample limit of B = 21, nearly all objects still have negative U-B colour. The reddening can in principle be accounted for either as a pure redshift at high z, or as a luminosity effect combined with a redshift cut-off. In this case the fainter end of the sample becomes dominated by low luminosity objects which are red due to the contaminating effect of an underlying red galaxy.

There are now several reasons for believing that the reddening is a luminosity effect. There is an increasing proportion of resolved objects in the faint red part of the colour-magnitude diagram implying a low luminosity regime. Furthermore when the colour of the faintest sample members is monitored as they vary, there is a tendency for the objects to become redder as they get fainter. This is not observed for bright objects in which the nucleus presumably dominates the galaxy light. There is also some evidence from redshifts obtained at random for faint red members of the sample that very high z objects do not dominate. On the contrary the redshifts measured tended to be low to moderate, but any definitive statement along these lines must await complete redshift coverage.

The availability of samples from two fields separated by about 12° has enabled the comparison of quasar members over this angular separation. The two samples were chosen according to essentially identical criteria, based on the requirement that they should vary by 0.3 mag over a 1 year and a 3 year baseline. The two samples contained 80 and 71 objects from Schmidt fields 287 and 401 respectively. These two numbers are clearly compatible with a uniform

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quasar distribution and form a first step to establishing the distribution on all angular scales.

In the magnitude range B = 13-18, the dominant type of variable was found to have a timescale of variation of 1 day or less. Follow up spectra on the AAT revealed that these objects are mainly RR Lyrae stars. A complete sample was obtained in field 287 at Galactic latitude -47° on the basis of well defined selection criteria, the main requirement being that the r.m.s. variation on 14 plates was greater than 0.20 mag. The sample has been used to examine the structure of the Galactic halo to a galactocentric distance of 60 kpc, about twice as far as any comparable method. A power law relation for the space density, with an index of -3, was found to hold out to 60 kpc. This is of great interest, as the globular cluster distribution which also has an index of -3 appears to cut off at about 30 kpc. The radial velocities of most of the sample were also obtained and used to provide an estimate of the mass of the halo, giving a value in excess of $1.4 \times 10^{12}\ M_{o}$. This is based partly on a lower limit set by an RR Lyrae star of unusually large velocity (Hawkins, 1983c) and partly on the velocity dispersion of the sample as a whole. It was also possible to obtain an estimate of the dynamical mass density as a function of radius, giving a power law relation with index -0.7.

A third category of variable objects found comprised cataclysmic variables. In the first instance they were included among the RR Lyrae stars, but their large amplitudes of 2-3 magnitudes and erratic behaviour clearly distinguished them (Hawkins, 1983b). A complete and well-defined sample of 3 objects was obtained, all of which were observed on the AAT, and each in its way turned out to be rather unusual. All were characterised by rather small amplitudes compared with prototype examples, and being very faint (B = 18-21) are apparently among the most distant of such objects known.

The present survey has answered the question of what populations of variable objects are present on deep Schmidt plates. There are undoubtedly rare objects of other types which will be discovered as new fields are examined, and the magnitude limit extended. This should also help to improve statistics for the currently identified populations. The technique has already found the faintest known Galactic RR Lyrae stars, and promises to be a powerful method of finding very high redshift (z > 3.5) quasars.

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