COMPLETE SAMPLES OF VARIABLE QUASARS

M.R.S. Hawkins
Royal Observatory
Blackford Hill
Edinburgh EH9 3HJ
Scotland

ABSTRACT. The merits of selecting samples of quasars for statistical analysis on the basis of optical variability is discussed. Samples selected this way are essentially uncontaminated by spurious objects, and contain no serious redshift biasses. A preliminary sample from a long term survey suggests a timescale of variation for quasars of about four years, and indicates a fall off in numbers at around B = 20.

We have heard over the last two days of a number of ways of selecting samples of quasars. I want to describe a new approach which involves using the fact that quasars vary in luminosity to detect them. Most methods of selecting quasars have drawbacks, and in particular, selection effects which are typically a function of redshift, and sometimes of apparent magnitude or luminosity. For example, methods relying on objective prism or grism plates are very much more efficient at finding quasars in redshift ranges where two lines are visible, or where Lyman alpha is present, and so such surveys are of limited use in measuring quasar properties as a function of cosmological epoch. Ultraviolet excess surveys give uniform coverage to a redshift of about 2, but give no knowledge of the quasar distribution beyond this point, and have the practical difficulty that many other objects apart from quasars have an ultraviolet excess. Multicolour searches are now proving very useful in finding quasars, especially high redshift objects, but even here there are difficulties at certain redshifts where quasars have colours similar to stars in all optical wavebands. For example, quasars of redshift 3 have colours very similar to A-stars.

The detection of quasars from their optical variability is a relatively new approach and offers several advantages over other methods and one or two drawbacks. Perhaps the most important feature of the technique is that there are no preferred or inaccessible redshift ranges. There will be a time dilation effect which will tend to make high redshift objects vary more slowly, but provided the survey is conducted over a sufficiently long time base this effect can be minimised, and in any case can be corrected for. An additional advantage of such a survey is that the resulting sample is well suited to the study of quasar variability itself, with large samples of several hundred objects

A. Hewitt et al. (eds.), Observational Cosmology, 691–694.

observed over many years. This leads to the main drawback of the method, that many, even hundreds, of wide field plates are required over many years to detect a complete sample of quasars.

The survey which I have been undertaking was started in 1978, although archival material was available back to 1975. The observational programme consists in taking 3 or 4 sky limited plates per year in each of three passbands with the UK Schmidt Telescope. The emulsions are IIIa-J, IIIa-F and IV-N with appropriate filters, and the plates are measured with the COSMOS measuring machine at the Royal Observatory, Edinburgh. Some 200,000 objects are detected in the central 16 square degrees of the field and after calibration this data set may be used to search for variables. In order to eliminate spurious candidates an algorithm which looks for variation from year to year, but allows only small variations within each year is used, and this has been found to provide an essentially uncontaminated sample of quasars.

A subsidiary programme has been completed to look for quasars which vary on a timescale of weeks or months, and it is clear that such objects are very rare. Considerable effort has been put into verifying that candidates detected on the basis of variability are indeed quasars (e.g. Hawkins, 1986). To this end, some fifty objects have been observed spectroscopically, and essentially all have been confirmed as quasars.

The lastest sample which has been analysed was selected from a 6 year baseline and comprised about 400 objects in 16 square degrees to $B = 21$ with amplitude greater than 0.3 magnitudes. The overwhelming majority of objects showed an ultraviolet excess with $(U-B) < -0.35$. The remaining objects are red and of great interest as they would appear to be excellent candidates for very high redshift quasars. Some idea of the completeness of the survey can be gained by noting that of all UVX objects in the field, some 35% are included in the variability sample, and about 70% show significant variation, but not sufficient to fulfill the criteria for inclusion in the sample.

The magnitude range covered by the sample is $B = 18-21$, and the number magnitude relation for the sample may be measured over this interval. The slope varies from a factor of six per magnitude at the bright end to four per magnitude at the sample limit, and the turn over in quasar numbers is very evident in this critical regime. Further analysis of the evolution of the luminosity function must await the measurement of redshifts for the sample.

Since the sample contains by definition variable quasars, it is possible to examine the statistics of quasar variability. As a first step the auto correlation function for quasar magnitudes was derived for the whole sample. This shows an initial steep drop followed by a flattening at about 4 years, implying that the timescale of variation for the sample as a whole is about 4 years. This is exemplified by the fact that if a sample of quasars is selected on a one year baseline, only about 2% of the UVX objects are included. It is also consistent with the very small numbers of quasars detected on a timescale of weeks or months.

Several more years of data gathering are still necessary before a definitive sample can be expected, and the large task of obtaining several hundred redshifts remains. However, due to the unbiassed way in which the sample will be selected, subsequent analysis should throw much light on the question of quasar evolution.

REFERENCE

Hawkins, M.R.S., 1986. Mon. Not. R. astr. Soc. 219, 417.

DISCUSSION

FILIPPENKO: Have you checked whether there are many previously-discovered QSOs on your plates which do not vary?

HAWKINS: There were very few previously known quasars in the field. Examination of the percentage of UVX objects which do not vary gives an answer to your question. The statistics are that roughly 35% were included in the sample, and another 35% varied significantly, but not enough to satisfy the selection criterion.

MILEY: Have you carried out an objective prism survey of the same fields to catch the non-variable quasars? It would be interesting to compare the properties of the non-variable to the variable QSOs.

HAWKINS: I am in the process of carrying out such a survey with Paul Hewett. Preliminary work with the brightest quasars shows no obvious differences.

WALSH: It would be interesting to compare these results with a sample of bright QSOs. Allen and Keel have done CCD photometry on the PG sample over a period of about one year to an accuracy of 0.01 mag. They find very few that vary by more than 0.1-0.2 mag. These objects are mostly low z, so the (1+z) correction must be remembered, but it would be interesting to see the results of more extended observations.

HAWKINS: This appears to be consistent with my results. Only about 2% of UVX objects were detected as variables ($\delta m > 0.3$) over a year, whereas some 30% were detected over 5 years.

WORRALL: Do you have plans to investigate the radio properties of your objects? It would be interesting to examine whether or not the variability criterion preferentially selects radio brighter QSOs.

HAWKINS: I have surveyed half of the sample with Lance Miller at the VLA, and we came up with the surprising result that only three objects out of about 200 were detected. One of these was a Parkes source about a hundred times brighter than our threshhold, and one a double source.

BAHCALL: Can you tell whether the strength of the variability depends on the absolute magnitude of the QSO; e.g., do brighter objects vary more strongly than fainter ones?

HAWKINS: I cannot answer this question for sure yet, but indications are that there is little or no correlation between variability and brightness.

https://doi.org/10.1017/S0074180900159789 Published online by Cambridge University Press