AN OPTICAL SURVEY FOR VERY FAINT QUASAR CANDIDATES

Donald Hamilton
The Department of Physics
The University of Chicago
Chicago, Illinois, U.S.A.

1. INTRODUCTION

In recent years the development of fast optical telescopes with large corrected fields, of fine-grained, high DQE emulsions such as IIIa-J/F, and the use of rapid scanning microdensitometers and computers, have all made deep photometric studies of large areas of the sky tractable. I am in the process of conducting such a survey using the prime focus cameras of the CTIO and KPNO 4-meter telescopes. Sky-limited plates are taken in four colors defined by filter/emulsion characteristics. Pertinent information about the photometric system is given in Table 1. The large database from this survey of about fifteen areas of the sky is being used to address many problems both extragalactic and galactic in nature. A preliminary report on studies of faint blue stellar objects, quasar candidates, will be presented here for seven of the fifteen fields. Table II lists some information about the fields used for this study.

2. PROCEDURES

The ujfn plates were digitized using the KPNO PDS by raster scanning a 6600 by 6600 pixel area with a 20 micron square aperture in 20 micron steps. At the scale of the 4-meter triplet corrector (18.6 "/mm) our scanned area is no larger than 0.47 sq. degs. Unfortunately, poor placement of the guide probe, nonzero relative displacements between the multicolor plates, and bright stars ultimately reduce the usable area. Because of computer disc space problems, only two-thirds of the images for three out of the seven fields could be reduced.

The digital images are then put through a series of very sophisticated reduction programs collectively known as the Faint Object Classification and Analysis System or FOCAS. Details about FOCAS may be found in Valdes (1982a). A detailed description of the resolution classifier can be found in Valdes (1982b). The advantage of the resolution classifier is that it uses the full image data unlike the r_2 classifier of Kron (1980). Based on my experience, once the proper

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Table I: PHOTOMETRIC SYSTEM

Bandpass	Emulsion	Filter	Typical Exposures
u	IIIa-J *	UG5	160 min
j	IIIa-J *	GG385	50
f	IIIa-F *	GG495	60
n	IV-N †	RG695	50

Notes: *(†) emulsion hypersensitized by baking (soaking) in forming gas ($AgNO_3$ solution)

Table II: FIELD CHARACTERISTICS

Field	ℓ^{II}	b^{II}	E^*_{B-V}	Useful Area (sq. deg.)
SA 57	66°	86°	0.ᵐ005	0.46
SA 68:1	111	−46	0.030	0.44
2				0.30
3				0.30
SA 28:2	176	39	0.010	0.41
Hercules 1	90	36	0.015	0.44
2				0.30

Notes: * reddenings derived from Burstein and Heiles (1982)

classification rules have been determined, the resolution classifier is far superior to r_2. The percentage of misclassifications based on r_2 are on the order of 50% at the faint end, but for classifications based on the resolution classifier it is no larger than about 10%. Classification based solely on color also confirms the resolution classifier's efficiency.

3. SELECTION OF QUASAR CANDIDATES

From the large multicolor catalogs I extracted objects which were detected only on the u, j, and f plate material. The additional requirement of an n-detection imposes a bias against blue objects. Although, with the full four-color data one can easily separate nonthermal from stellar continua.

Photometric zero-points were determined generally from photoelectric measurements of faint stars in the fields or by adjusting the zero-point so that the sky surface brightness was some assumed value. I estimate that the zero-points are determined to within approximately 0.5 mag. I am in the process of determining the photometric calibration to much higher precision.

Selection of objects for quasar candidates involves two selection criteria: one of image, and one of color.

3.1 Image Criteria

The determination of whether a particular object is resolved depends on many parameters such as seeing, depth, local graininess, local scattered light, and even wavelength. Also important is how well our noiseless stellar template represents a real stellar image. There are many ways to choose classification criteria. For instance, one could demand that selected objects be unresolved on one, two, or even three of the multicolor plates. Classifications based on two or more colors while improving sample purity also lower the sample from its true size. I feel it is best to decide classification based on only one color, preferably that plate material with the best signal-to-noise ratio, e.g., that of j or f.

Classifications based on the ultraviolet plate material will be less reliable than that based on the redder, higher signal-to-noise

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bandpasses. The major contamination of the blue star counts will be from faint blue galaxies. Generally these galaxies have compact cores in the near-ultraviolet and blue, but in the red the underlying disc is sufficiently strong to produce a much more extended image. Also, because of atmospheric refraction, ultraviolet images can be elongated, thus reducing resolution sensitivity.

For this quasar survey we have used the image data of the j-plate material and selected only objects with unresolved images. An intercomparison of classifications based on the f-plates with that of the j-plates has not yet been done.

3.2 Color Criteria

Quasar candidates were chosen on the basis of their position in the (u-j) vs (j-f) diagram. This was done for several magnitude intervals. I decided not to count objects brighter than j = 20.5 to avoid any potential saturation problems. A bright-end cut-off this faint ensures that all photometric measurements are on the linear part of the HD curve. The faint-end cutoff was determined by the galaxy completeness limit of about j=24.0. Quasars lie below the subdwarf distribution at about (u-j) = -0.20. Our color criteria are (u-j) < -0.5 and (j-f) < 0.8. Choosing the red (u-j) limit of -0.5 produces a bias against redder quasars. I have corrected for this incompleteness by examining the (U-B) distribution of quasars selected from the radio-selected samples of Schmidt (1968) and of Wills and Lynds (1978). This procedure assumes that there is no color difference between radio- and optically-selected quasars. This correction amounts to about 12%.

3.3 Contamination

Counts of color-selected quasars suffer from three sources of contamination: Galactic stars, narrow emission-line/blue unresolved galaxies, and resolved blue galaxies. Only a spectroscopic survey will eliminate the first two, and good image discrimination will remove most of the third. This resolved galaxy contamination is not the same between fields since the centroid of the galaxy distribution with respect to the stellar locus in two-color diagrams changes from field to field. (These differences are probably indicative of different spatial distributions.) Also, the contamination is a function of the apparent magnitude, since galaxies become progressively bluer at the fainter levels.

The quasar counts of Koo and Kron (1982) suffer from poor image discrimination, as follow-up spectroscopy has confirmed (Koo 1983). Contaminations up to 50% at their faint end are apparently present. In a more recent analysis Koo (1983) presents counts for SA57 corrected for both resolved and unresolved blue galaxies. Corrections for unresolved galaxies are about 10% at j = 22.5 (Koo 1983). The narrow emission-line unresolved galaxies contaminating these faint quasar samples are presumably analogous to B264 (Arp 1970) and B234 (Braccesi et al. 1968).

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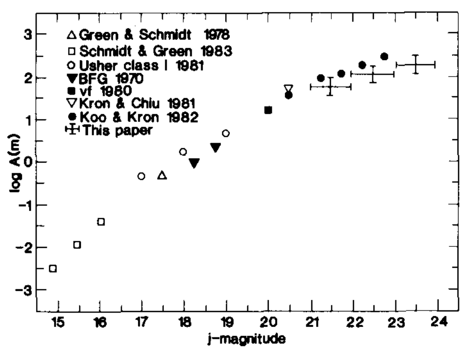
4. DIFFERENTIAL COUNTS

In Figure 1 I present differential counts (number per square degree per magnitude interval) for this survey averaged over our seven fields. The vertical error bars represent the standard deviation of the seven fields. Also presented are counts from other surveys: Schmidt and Green (1983), Green and Schmidt (1978), Usher (1981), Braccesi et al. (1970) (BFG), Formiggini et al. (1980) (vf), Kron and Chiu (1981), and from Koo and Kron (1982) (KK). I have not corrected our counts for unresolved narrow emission-line objects as these corrections are not known precisely. Also, no corrections for Galactic dust absorption has been made since they are quite small as Table II indicates.

These counts are systematically lower than that of KK. We attribute the predominant difference to a much improved star/ galaxy separation. Also, the data in Figure 1 is an average, whereas the data of KK involves only one field, that of SA68:1. This field appears to yield systematically higher number-counts that the remaining six fields, as indicated in the interfield comparisons of Figure 2. It is also interesting to note that our counts show a brighter turn-over than that of KK.

The differences in the number-counts between various fields might be due to some instrinic property of the field like superclustering or a patchy intercluster medium. Also, such behavior could be due to poorly-determined zero-points, plate characteristics, or nonuniform blue galaxy contamination. The interfield dispersion may be magnitude dependent. If the interfield dispersion is real, it will ultimately limit how well the quasar evolution function will be determined. It might even turn out that the particular form of the evolution function is field-dependent.



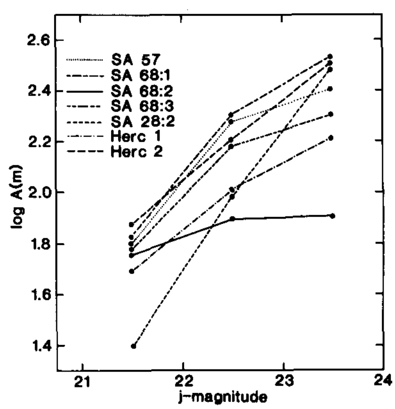


Fig. 1. (left): differential counts; new data represents a mean of the seven fields.
Fig. 2. (right): differential counts for the seven individual fields.

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I do not feel that the number-count data, as it currently stands, warrants detailed modelling for evolutionary/luminosity effects. Photometric zero-points will need to be accurately determined. Nevertheless, it is my qualitative impression that pure density evolution can be ruled out because of the steep rise in the number-counts it predicts. It seems entirely possible that pure luminosity evolution might adequately describe the data presented here.

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