Slit Spectroscopy of Candidates from Automated Quasar Detection on UKSTU Prism Plates[1]

K. Beuermann
Institut für Astronomie und Astrophysik
Technische Universität
Berlin, F.R. Germany, and
Max-Planck-Institut für Extraterrestrische Physik
Garching bei München, F.R. Germany

R.G. Clowes
Royal Observatory, Blackford Hill
Edinburgh, Scotland, UK

Abstract

A search for quasars is being performed in ESO/SERC fields 86, 119, and 120 at and near the South Ecliptic Pole (just outside the LMC). This area will be extensively covered by the ROSAT all-sky soft X-ray survey. The present search aims at providing a data base of optically selected extragalactic objects which may later be compared with the sample of X-ray selected objects. The quasar candidates were identified on objective prism plates from the UK Schmidt telescope (UKSTU) by visual means in field 86 and by employing Automated Quasar Detection (AQD) in fields 119 and 120. Slit spectra were subsequently obtained for 39 candidates in field 119 and 3 candidates in field 86, using the ESO/MPI 2.2 m telescope at La Silla, Chile. The results demonstrate that an automated quasar search can be successfully be performed in these comparatively crowded star fields.

1 Introduction

Visual and automated searches of objective prism plates represent a well-established technique to identify a large number of quasar candidates (*e.g.* Clowes and Savage 1983, Barbieri and Cristiani 1986). Visual searches are useful in crowded fields but suffer from subjective selection criteria. Automated Quasar Detection (AQD) is the generic name for a system of software and procedures developed at the Royal Observatory in Edinburgh (ROE) that allows quasar candidates to be automatically discovered from measurements of objective prism plates (Clowes *et al.* 1984, Clowes 1986). It is based on the COSMOS fast plate-measuring machine at ROE (MacGillivray and Stobie 1984) and typically uses plates from the UK Schmidt telescope (UKSTU).

The present program was initiated in view of the ROSAT all-sky soft X-ray survey (Trümper 1984). This survey will cover the areas near the North and South Ecliptical

[1]Based on observations collected at the European Southern Observatory, La Silla, Chile, with the 2.2 m telescope of the Max-Planck Society

Poles (NEP and SEP) with the highest exposure integral. Here, the survey will be deeper than on the average over the sky. Furthermore, X-ray sources near the poles will be in view longer than near the equator with a maximum of 180 days at the poles. For the brighter X-ray sources near the poles, X-ray variability studies may, therefore, be performed in the course of the ROSAT survey.

We have initiated an optical search for quasars and AGNs at and near the South ecliptic pole. The SEP ($\alpha, \delta = 6^{h}, -66.^{\circ}5$) is located about 3° from 30 Doradus at the fringes of the hydrogen envelope of the LMC. The star density in this region (ESO/SERC field 86) is still comparatively high and crowding was considered too severe for AQD to be employed. Instead, a visual search for emission-line AGNs and quasars was performed in two sections of field 86, using the TV blink comparator at ROE.

Because of the high star density in field 86, we decided to employ AQD in two fields near the SEP, ESO/SERC fields 119 and 120. The fields were selected for three reasons: (1) The star density is sufficiently low to permit the use of AQD. (2) The fields receive a reasonably high exposure during the ROSAT survey since the plate centers are separated from the SEP by only about 6° and 8°, respectively. (3) The fields are located sufficiently far outside the hydrogen envelope of the LMC to permit soft X-ray studies of extragalactic background objects. The H I column densities in fields 119 and 120 range from $1.7 \cdot 10^{20}$ to $6.0 \cdot 10^{20}$ H atoms cm^{-2} which corresponds to optical depths $\tau = 1$ against photoabsorption in cold matter for soft X-rays of 0.22 and 0.36 keV, respectively.

The aim of the present initial study is (1) to test the quasar selection criteria, (2) to study the contamination of the quasar sample by blue stars of LMC membership, and (3) to study the completeness of quasar detection as a function of star density. To this end, slit spectoscopy of so far 42 candidates was performed and first results of this program are presently reported.

2 Automated Quasar Detection (AQD)

AQD was developed at ROE to remove from an inherently powerful technique the drawbacks of visual scanning which include unknown and time-varying selection criteria, wastage of information, and tedium. A long period of software development was necessary, but the final result realizes the full potential and allows large numbers of quasars to be discovered in large areas of the sky with pre-defined and constant criteria, recording of all important data, and relatively little tedium. The initial version of AQD was described by Clowes *et al.* (1984) and the current version by Clowes (1986).

The following options are available for finding quasars, or indeed, for finding other classes of objects with appropriately distinctive spectra:

- emission lines
- absorption lines
- continuum discontinuities
- ultraviolet excess

- red excess

Of course, emission lines and ultraviolet excess are the most productive options for quasars, and the others are intended for the rarer types such as BAL and high redshift quasars. The options of emission lines and ultraviolet excess only were used for field 119. Furthermore, galaxy-like images were downgraded, thereby effectively eliminating nearby AGNs.

The limiting values of the spectral selection criteria were deliberately set quite low. Consequently many candidates were selected, most of which will not be quasars. The purpose here is to make all potential candidates available so that the grading of candidates and re-selections can then be performed on this much amller database according to the needs of particular applications. The standard grading process has been used for field 119. In this, star-like images, ultraviolet excess, and emission lines all make positive contributions to the grade. Features that atre apparently stellar (usually for F stars) make negative contributions. The procedure presently used discriminated against galaxy-like images. Our sample will, therefore, not contain Seyfert galaxies which are potential powerful X-ray sources. In the future, because the aim is to discover AGNs and not only quasars, it will be necessary to devise a slightly different scheme.

In the following, we list some important features of AQD. A more thorough discussion may be found in Clowes (1986):

- The usual magnitude range is $B \sim 17.0 - 20.5$.
- AQD excels at detecting quasars in the range $z \sim 1.8 - 3.0$, but can, in fact, detect quasars at all $z < 3.0$.
- Many quasar candidates are so obvious that while spectroscopy is important for establishing the identifications of lines and for accurate redshifts, it is not strictly necessary for their confirmation.
- AQD is well suited for projects that require large numbers of quasars and/or coverage of large areas of sky.
- The photographic requirements are easily satisfied. A minimum of one objective-prism plate and a sky-survey direct plate are required.
- All objects have celestial coordinates accurate to ~ 1 arcsec.
- The CPU requirements are comparatively small on a small VAX (usually ~ 40 hours on a VAX 11/780 for one UK Schmidt field).
- Losses from overlapping spectra may be made negligible by also processing a second prism plate with the dispersion direction rotated by 90° relative to the first.
- The maximum area which can be measured by COSMOS in a single measurement is $286.7 \times 286.7\,\mathrm{mm}^2$, which for a UKSTU plate is ~ 28.6 square degrees.

3 Selection of quasar candidates in fields 86, 119, and 120

Table 1 lists the prism plates presently available. In field 86, a visual search in two sections, covering a total of 5 square degrees, yielded a total of 74 quasar candidates.

Table 1. UKSTU objective prism plates of ESO/SERC fields 86, 119, and 120. All plates were taken on IIIa-J emulsion without filter.

ESO/SERC Field	Plate Number	Status
86	UJ9076P	visual search
119	UJ10739P	COSMOS, AQD
119	UJ11514P	COSMOS
120	UJ10725P	
120	UJ10743P	
120	UJ11484P	COSMOS

The emission-line criterion only was used. *Fig. 1a* shows an example of the direct plate and the prism plate as photographed from the TV screen. The figure illustrates the problems encountered by crowding and by overlap of the prism spectra near the SGP. *Fig. 1b* displays the corresponding slit spectrum.

In field 119, quasar candidates were identified by AQD using a combination of emission lines and ultraviolet excess as selection criteria. As a consequence, the sample may contain more blue stars than a comparable sample based on the presence of strong emission lines only. So far, only one plate was processed completely (UJ 10739P) and no effort was made to resolve overlaps which affect about 40 % of all spectra in field 119. This will be possible in the future by using plate UJ 11514P taken with the prism rotated by 90°. In the present form, the quasar search is therefore definitively incomplete. Furthermore, as noted above, it cannot presently qualify as an AGN search because we discriminated against galaxy-like images.

In this first step of the program, a total of 64 new quasar candidates with blue magnitudes between 16.4 and 19.9 were identified in field 119. This field contains two previously known quasars, PKS 0506-61 and PKS 0522-611 with $V = 16.9$ and $V = 18.1$, respectively, which were both rediscovered in the survey.

4 Slit spectroscopy

Slit spectroscopy of a number of the selected candidates from field 119 was performed on 20–26 October 1987 using the ESO/MPI 2.2 m telescope at La Silla, Chile, equipped with the B&C spectrograph and a thinned, backside illuminated CCD chip (RCA 501 EX) with 30 μm pixel size as detector. All spectra were taken at low spectral resolution with ESO grating number 13 (450 Å/mm), covering the wavelength range from 3380 Å to 10220 Å (FWHM resolution 1.5 pixels or 20 Å). The slit width was 2 arcsec and the seeing on 20–24 October was better than 1.5 arcsec, in part better than 1 arcsec. Flux calibration was achieved by observing standard stars three times a night (Wolf 1346, BD 17°4708, 40 Eri B).

Of the 64 quasar candidates in field 119 slit spectra were taken of 39. In field 86, lower priority and bad weather left us with only 3 good spectra. Slit spectra of the candidates in field 119 were taken starting with the brighter candidates. Of the total of 42 objects observed spectroscopically, 20 tuned out to be quasars with redshifts between $z = 0.38$ and 2.70, 2 were extragalactic H II regions with $z = 0.050$ and 0.065,

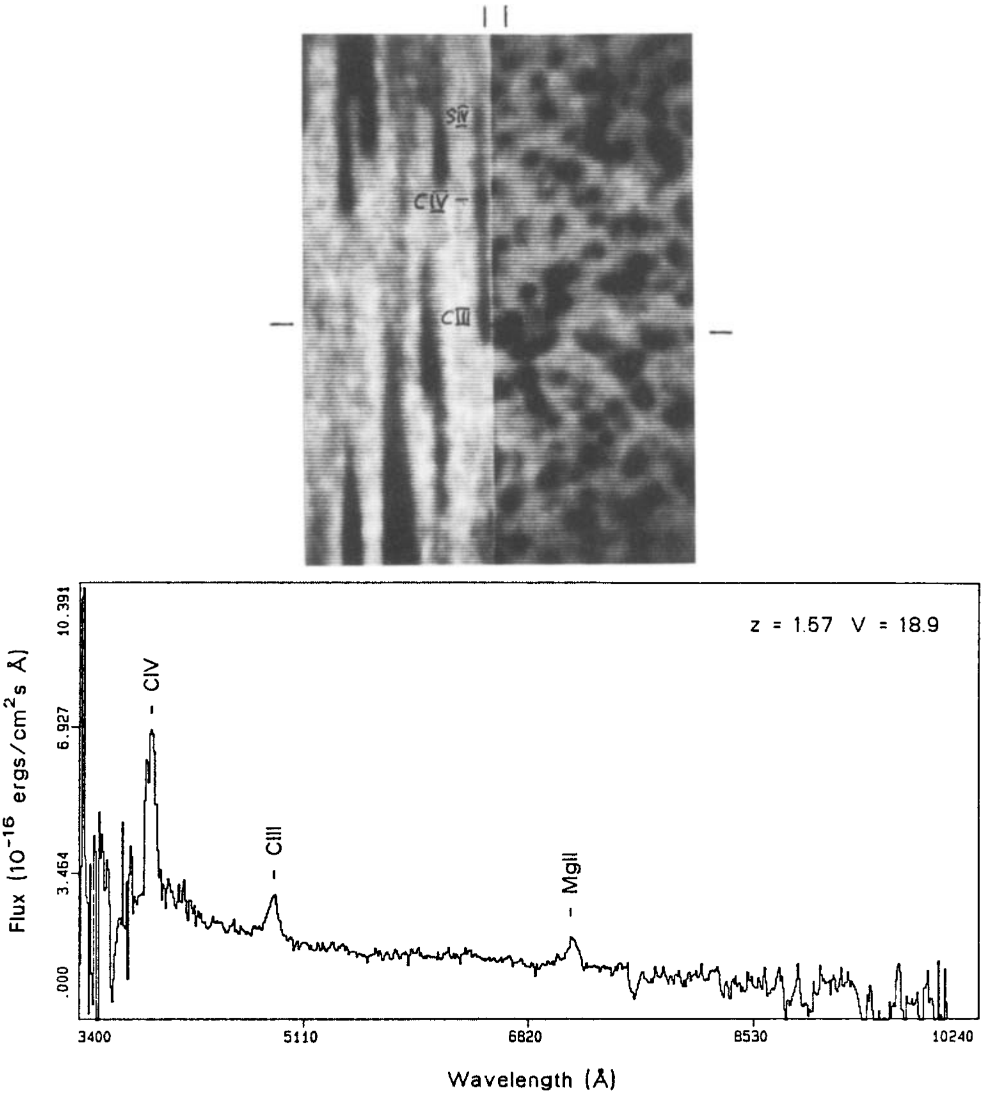

Fig. 1. (a) Quasar at α, δ (1950) $= 05^h53^m57\overset{s}{.}9$, $-66°21'48''$ at a separation of 37 arcmin from the South Ecliptical Pole. The direct image (ESO/SERC J-plate) and the prism plate are shown as photographed from the screen of the TV comparator at ROE. The object is identified by tick marks, west is on top, north to the left. The picture illustrates the problems encountered by crowding and overlap of prism spectra near the SEP. (b) slit spectrum of the object yielding $z = 1.57$, V = 18.9.

18 were stars, 2 of uncertain nature. There is no definite brightness limit for these objects but typically they are brighter than $V = 19$.

Fig. 2a shows the distribution of the objects identified in field 119 as a function of apparent visual magnitude, separately for stars, quasars, and extragalactic H II regions. *Fig. 2b* shows the z-distribution of all non-stellar objects. The maximum near $z \simeq 2$ for prism-selected quasars (Hewitt and Burbidge 1987) is also borne out in this study. *Fig. 2c* shows the distribution in absolute V-magnitude. Following Véron-Cetty and Véron (1987), M_v was calculated using $H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ and a continuum optical spectral index of F_ν equal to 0.7. *Fig. 2c* demonstrates that all objects identified as extragalactic except for the two nuclear H II regions qualify as quasars, having $M_v < -24.0$. With respect to the ROSAT X-ray survey it is noteworthy that the X-ray emitting AGNs cluster at lower z-values and that spectroscopically a large fraction of them qualify as Seyfert 1 nuclei. As noted in Sect. 2, our present procedure discriminates against these objects. We plan, however, to extend our search to low-z AGNs by using different options in selecting the candidates.

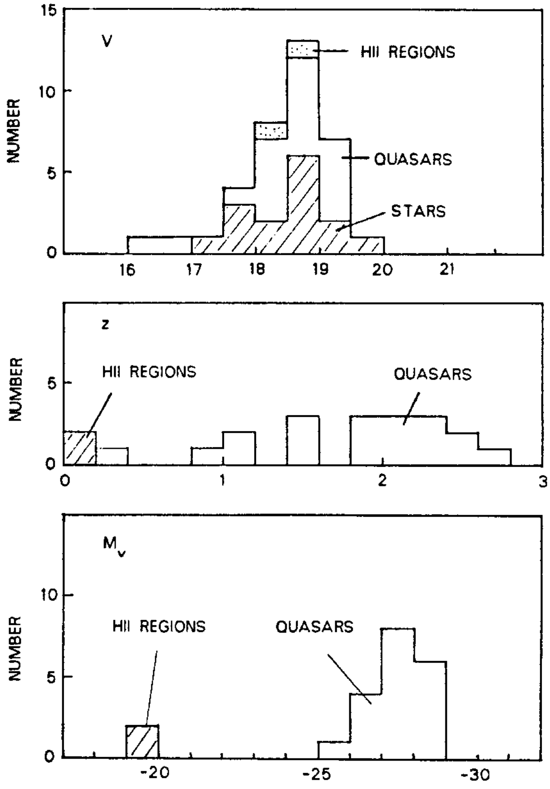

Fig. 2. Brightness- and z-distributions of objects identified by slit spectroscopy in field 119. (a) Distribution in apparent V magnitude, (b) z-distribution of all extragalactic objects, (c) distribution in absolute visual magnitude for all extragalactic objects. $H_0 = 50\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $q_0 = 0$, and a nonthermal spectral index of 0.7 were assumed.

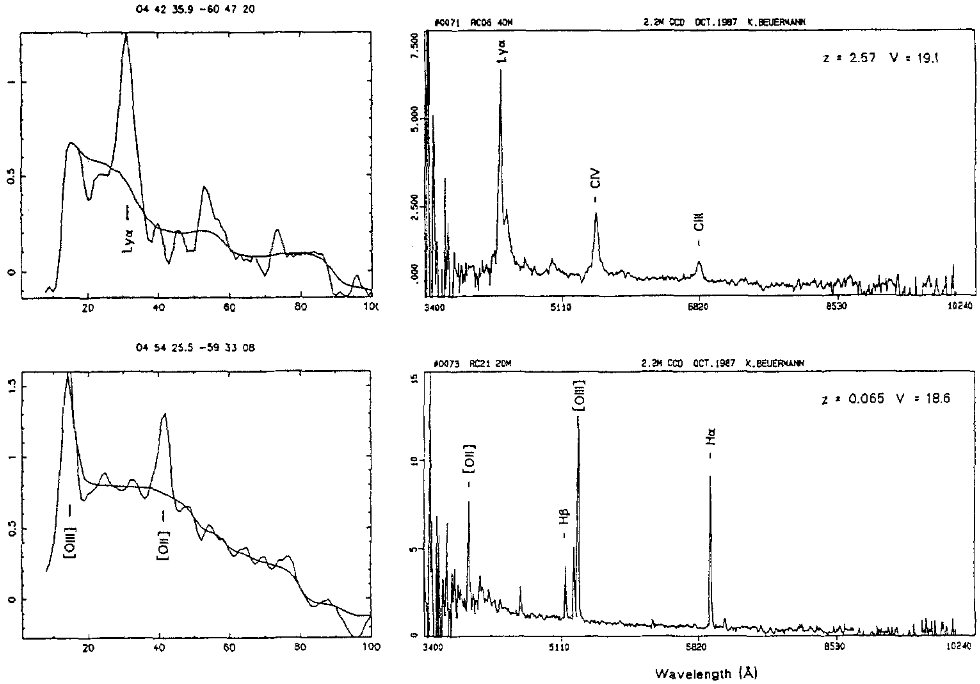

Fig. 3. Comparison of prism and slit spectra for selected objects. In the prism spectra, pixel 10 corresponds to the cutoff of the IIIa-J emulsion at 5380 Å, pixel 39 is at 4009 Å, and pixel 66 at 3397 Å. Ordinates are in relative units for the prism spectra and in 10^{-16}ergs cm^{-2} s^{-1} Å^{-1} for the slit spectra. (a) strong-line quasar with $z = 2.57$, (b) extragalactic H II–region with $z = 0.065$

In *Fig. 3.*, we compare selected prism and slit spectra of objects identified in field 119. Panel (a) shows a strong-line quasar with $z = 2.57$, V = 19.1, panel (b) an extragalactic nuclear H II region. Such objects are easily identified in prism spectra and do not necessarily require slit spectroscopy for confirmation. Quasars of somewhat lower redshift are easily recognized as being extragalactic because Ly α, Si IV, and C IV may be identified in the prism spectra if sufficiently strong. Problems arise for objects of lower redshift with weak emission lines if the dominant line is near 4000 Å($z \simeq 1.5$ for C IV, $z \simeq 1.0$ for C III, and $z \simeq 0.4$ for Mg II), because these may be mixed up with blue stars. These examples demonstrate that liberal use of the selection criteria is called for and that subsequent slit spectroscopy is necessary in the maximum degree of completeness is to be achieved.

5 Discussion

The present study demonstrates that Automated Quasar Detection (AQD) may successfully be employed in the comparatively crowded star fields near to but outside the LMC. Our results for field 119 are preliminary because plate UJ 10739P was not optimal and the plate taken with the prism rotated by 90° (UJ 11514P) has not yet been fully processed. Contamination by blue stars was not found to be excessive

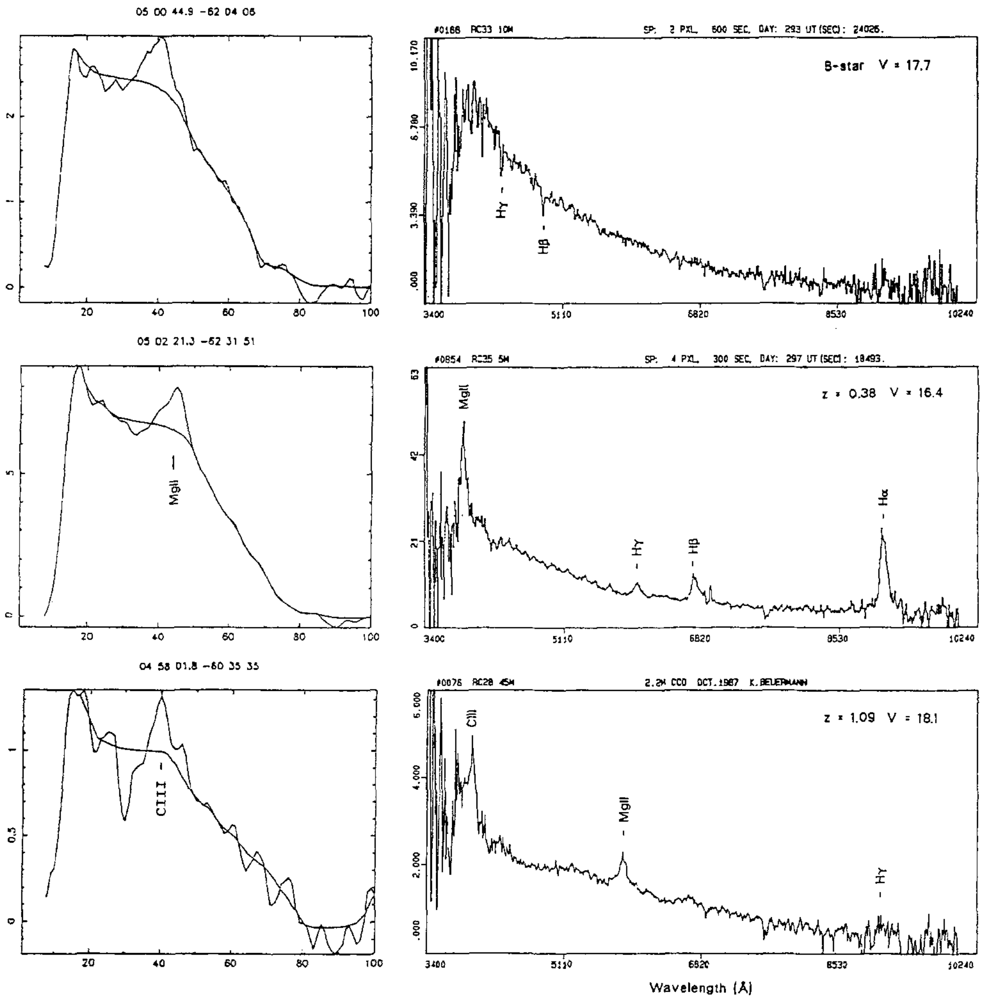

Fig. 3. cont.
(c) B star, (d) quasar with Mg II line near 3900 Å, and (e) quasar with C III line near 4000 Å.

considering the proximity of the LMC and the liberal selection criteria.

The number of identified quasars above an effective brightness limit of about $V = 19$ is 0.7 per degree^2. Considering the fraction of candidates for which slit spectra are not yet available and the loss due to non-recovered overlaps, the corrected rate is approximately 1.5 quasars per degree^2 brighter that $V = 19$. This number is comparable to that found in independent surveys (Clowes and Savage 1983, Barbieri and Cristiani 1986) and further demonstrates that AQD operates successfully as the star densities encountered in field 119.

While appropriate selection criteria can almost entirely discriminate against blue stars, application of such criteria will cause a loss of completeness among weak-line quasars at certain redshifts below 1.8. For 7 out of 20 identified quasars, some other line than Ly α was the dominant line within the sensitive wavelength range of the J–emulsion. We have attempted to keep the success rate at $z < 1.8$ reasonably high by not systematically discriminating against blue objects with a possible line in the prism spectrum near 4000 Å. Comparison of the prism and slit spectra shows that our criteria are reasonable because on the one hand about 1/3 of all identified quasars have $z < 1.8$ while on the other hand the load on observing time by including blue stars is still tolerable (40 % of all spectra taken).

Continuation of the present program will provide a sample of quasars and AGNs near the SEP which can be further studied prior to the launch of ROSAT and provide an important data base for comparison with the sample of X-ray emitting extragalactic objects. The brighter optical quasars may also provide information on the interstellar medium in the fringes of the LMC. The survey plates will ultimately also allow stellar X-ray emitting objects in the outer parts of the LMC to be identified and their optical properties to be studied.

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References

Barbieri, C., Cristiani, S., 1986. *Astr. Astrophys. Suppl.*, **63**, 1.
Clowes, R.G., 1986. *Mitt. Astr. Ges.*, **67**, 174.
Clowes, R.G., Savage, A., 1983. *Mon. Not. R. astr. Soc.*, **204**, 365.
Clowes, R.G., Cooke, J.A., Beard, S.M., 1984. *Mon. Not. R. astr. Soc.*, **207**, 99.
Hewitt, A., Burbidge, G., 1987. *Astrophys. J. Suppl.*, **63**, 1.
MacGillivray, H.T., Stobie, R.S., 1984. *Vistas Astr.*, **27**, 433.
Trümper, J., 1984. *Physica Scripta*, T7, 209.
Véron-Cetty, M.-P., Véron, P., 1987. *ESO Scientific Report No. 5.*