QSO SURVEYS AND QUASAR EVOLUTION

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Summary - Recent results of QSO surveys are reviewed and QSO's cosmic evolution reconsidered.

1 - INTRODUCTION

For the sake of conciseness, let me refer to the paper I wrote a few years ago together with some Bologna colleagues in which we analyzed the available evidence concerning the space distribution and evolutionary properties of QSOs (Braccesi et al. 1980).

Since that time extremely valuable new information has been gathered, thanks to the work of many researchers. This information, which is only partially published, is summarized below.

1 - Almost complete information on the Green and Schmidt bright quasar search is now available in the synthetic form of a Hubble diagram (Schmidt and Green, 1982). The sample includes 108 quasars, down to an average magnitude B=16.2, found in a 10700 sq.deg. area.

2 - Combining the results by Steppe (1978) and Berger and Frignant (1977), Steppe, Véron and Véron (1979) have produced a very reliable list of UVX quasar candidates which includes 21 objects down to B=18.9 found in a 20.6 sq.deg. area centered on S.A.57.

3 - Marshall et al. (1982a) published spectral information on a complete sample of BFG objects (Braccesi et al. 1970) which includes 22 quasars down to B=18.25 in a 37.2 sq.deg. area and on a complete sample of 13h+36° vf UVX objects (Formiggini et al. 1980). This second sample contains 10 quasars down to B=19.2 in a 1.72 sq.deg. region.

4 - Extending the previous work, Marshall (1982) and Kron (1982) have completed the spectral observations of the 13h+36° vf UVX quasar candidates down to B=19.75 finding that most of the observed objects were quasars. No systematic spectral difference has been found between the objects classified as "stellar" and "extended" by Bonoli

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et al. (1980), a result which has been question by Véron and Véron (1982). Further work on P.S. IIIa-J plates is going on in Bologna on this important point. It is not irrelevant to add that the fuzziness of a number of UVX objects found by Bolton and Savage (1978) in the 2204-1855 field is now ascribed to "an artifact of the singlet corrector" then in use on the U.K. Schmidt (Savage, 1982).

5 - Four fields, 25 sq.deg. each, have been searched for quasar candidates by the U.K. Schmidt Telescope Unit. For a substantial fraction of the objects redshifts have been determined mainly from objective prism plates, which did permit extending the search even to the higher z's. The detailed results are being prepared for publication. The authors and the most relevant data are listed in the following table:

Field	Authors	quasars/sq.deg. B<19.5	B<19.75
0200-50	Savage,A. and Bolton,J.B.	2.8	4.0
2203-1855	Savage,A. and Bolton,J.B.	2.2	3.6
0053-2803	Clowes,R.G. and Savage,A.	4.3	5.1
0112-35	Savage,A.,Trew,A.,Chen,J. and Weston,T.	5.5 (x)	6.9 (x)

(x) J magnitudes.

The large difference in the number of quasars found in the first and last two fields is attributed by Savage (1982) to the improved observing set-up and the better seeing conditions existing when the last two fields were observed. In the following discussion only the data concerning the last two fields will thus be considered.

6 - Kron and Chiu (1981) have examined with a variety of techniques the stellar objects in a 0.1 sq.deg. area near S.A.57 . In this area they found 8 quasars down to J=21 .

7 - Koo and Kron (1982) have made extensive multicolour studies of all the objects with B<23 in a 0.3 sq.deg. field centered on S.A.68 . In this area they found the following numbers of UVX quasar candidates: 24 at B<21.5 , 40 at B<22 , 65 at B<22.5 , 105 at B<23 .

8 - CTIO spectral surveys of high-z objects have been thoroughly discussed by Osmer (1980). The Curtis Schmidt survey covers 375 sq. deg., the 4 m survey 5.1 sq.deg. In spite of the many efforts made (see also Clowes 1981 and Woltjer and Setti 1982) the inconsistency between the C.S. and the 4 m results is not fully understood.

This wealth of data improve considerably the factual knowledge with respect to 1979, when the paper I mentioned at the beginning was written. Not only the number of available z's has substantially increased but, mainly thanks to the work of Green and Schmidt, the coverage of the Hubble plane has been considerably extended toward the brighter magnitudes. Furthermore, a sufficient number of complete samples of UVX quasar candidates has been observed spectroscopically to allow one to base the study of the number-magnitude relation on sounder grounds.

2 - THE NUMBER-MAGNITUDE RELATION FOR UVX QUASARS

Figure 1 shows the number-magnitude relation for UVX, for spectroscopically confirmed samples of quasars. Continuous spectrum objects and extragalactic H II regions have been excluded. Also shown in the

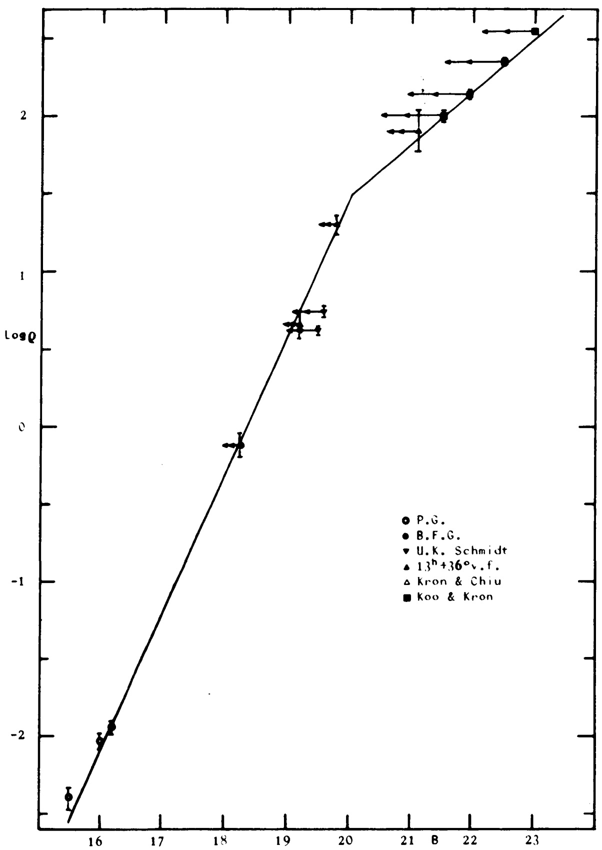

Fig. 1 - The number-magnitude relation for UVX quasars, objects/sq.deg. Error bars indicate 1σ statistical uncertainty. Horizontal arrows show tentative correction for galactic absorption based on neutral hydrogen columns.

figure are the Koo and Kron (1981) UVX object counts. The results of the Palomar Bright Quasar Search have been corrected for 20% losses (Green and Schmidt 1978), those for the BFG objects for a 23% loss (Braccesi et al. 1980).

Up to B=19.75 the experimental points, except those from the U.K. Schmidt, are nice fitted by the relation:

$$\text{Log } N(B) = 2.20\ ((B-18.30)/2.5) \quad \text{objects/sq.deg.} \qquad (1)$$

which is nearly coicident with that given by Braccesi et al. (1980). The main difference with our previous work is that there we assumed a careful colour selection could lead to the inclusion among UVX quasar candidates of objects with z up to 2.5, whereas we now know that the real limit is about 2.15.

With regard to the two apparently discordant points from the U.K. Schmidt, it is interesting to see the results which are obtained when one applies the corrections for interstellar absorption based on the galactic neutral hydrogen column densities, as suggested by Teerikorpi (1981). These corrections are shown by the horizontal arrows in fig.1 , the two end points of the arrows correspond to the double valued relation found between the hydrogen column density and absorption.

One can see that, because of the larger corrections found for the U.K. Schmidt points, all the values in the $18.25 < B < 19.75$ range become, when corrected, consistent with each other. Also the points of Koo and Kron (1981) seem to require a large correction; this will not change the very different slope for the counts found at these very faint magnitudes, 1.00 instead of 2.20, but the magnitude at which the slope changes will be moved from B=20.0 to B=20.4. To apply this correction to the Palomar Bright Quasar Survey, objects should be considered one by one. Certainly, a somehow less steep slope in the range $15.5 < B < 18$ will result.

This discussion of the possible effects of galactic absorption has been introduced mainly to remind us that these effects are large enough to require to be taken properly into account before definitive results on the number-magnitude relation for quasars could be obtained.

3 - THE SPACE AND ABSOLUTE MAGNITUDE DISTRIBUTION OF QUASARS

While the number of quasars increases very rapidly with apparent magnitude, and thus only carefully selected samples with accurate magnitudes can be used in the study of the number-magnitude relation, the fractional distribution in z changes only very slowly. This justifies the use of miscellaneous data to provide a better and more statistically significant coverage of the Hubble plane.

As shown by Braccesi et al. (1980), one can take advantage in this way of a larger sample of objects, using the previously established number-magnitude relation to obtain the normalizations needed to derive the surface densities as a function of apparent magnitude and redshift. When this has been done, in order to compute the space densities as a function of z and absolute magnitudes, one only needs to choose a cosmological model.

These computations have been repeated, strictly following the procedures outlined in the above mentioned paper, taking, as previously, H=50 and $q_o=0$. The number of objects included in the analysis has been increased from 164 to 263, but even more important is the fact that, as stressed before, the coverage of the Hubble plane is now more extended in the magnitude domain.

The results of the analysis are given in Fig. 2 which shows the run of the isodensity lines for UVX quasars -- i.e., quasars with $z < 2.15$ -- as a function of absolute magnitude and look-back time. The points in the plot are statistically independent, one from the other, and the overall consistency of the picture appears very rewarding. Also shown in the figure is the local density of Seyfert I nuclei, taken from Véron 1979, and the density of high-z ($2.5 < z < 3.5$) quasars derived from Table 4 of Osmer (1980) paper. It should be added that

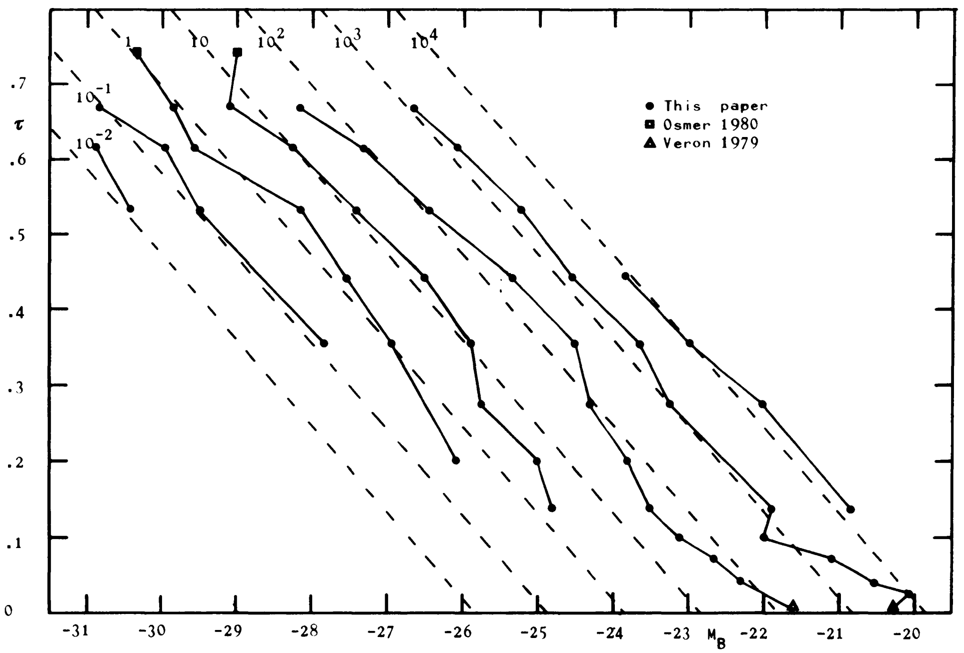

Fig. 2 - Quasars isodensity lines (objects/Gpc^3.magn.) as a function of absolute magnitude and look-back time. Broken lines show the predictions from the evolutionary model summarized by relation 2.

the densities we have derived for the UVX quasars in the highest redshift interval ($1.85 < z < 2.5$) are in good agreement with those computed from Osmer's table for the $1.8 < z < 2.5$ domain.

The isodensity lines in Fig. 2, in spite of the very large interval in z and absolute magnitude they cover, are, on the whole, surprisingly straight, parallel and equidistant. The space density of quasars, as a function of absolute magnitude and look-back time, may thus be represented by:

$$\text{Log } \rho = 9.0\ \tau + (M_B + 23.75) \quad \text{quasars/Gpc}^3\text{.magn.} \qquad (2)$$

namely by a luminosity independent exponential increase of density with look-back time and a straight luminosity function. Nothing peculiar seems to happen at M_B=-24 where a tentative division between quasars and Seyferts is suggested by Woltjer and Setti (1982). These authors, however, noticed "a strong evolution" even for the M_B>-24 objects, an evolution which may now look less "surprising." Schmidt and Green (1982) have proposed a luminosity dependent density evolution, but no evidence of this emerges from the data summarized in Fig. 2.

Relation (2) can be reconciled with the bending of the number-magnitude relation at $B_4 \sim 20$ only if we consider the highest isodensity line shown in Fig. 2, 10^4 quasars/Gpc^3.mag., as the point where the very steep luminosity function we have found should undergo a very substantial flattening, and not an artifact of selection effects. This point has been

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verified by comparison of the model with the original data and unmistakably found to be so. With this further specification, relation (2) describes a pure luminosity evolution model in which a constant number of objects are dimming with a time constant of 0.12 the age of the universe or 2.2 billion years independently from the epoch or the absolute magnitudes.

The property of the luminosity evolution models of predicting in a straightforward way a flattening of the number-magnitude relation has been recently discussed by Bònoli et al. (1980), Cheney and Rowan-Robinson (1981), Mathez and Nottale (1982) and Marshall et al. (1982b) mainly in connection with Koo and Kron (1982) results on the flattening of the number-magnitude relation of quasars at the very faint magnitudes or with the problem of the quasar contribution to the X-ray background. It must be said that the models which have been proposed are considerably different from each other. Let us hope that the model presented here might represent a stable first-order approximation to the real cosmological evolution of the quasar population.

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DISCUSSION

Segal: In the 1980 Ap. J. we published an analysis of your earlier complete optical quasar sample within the non-evolutionary, non-parametric, chronometric cosmology, showing consistency with absence of evolution and a turnover in the N(< m) relation slightly faintward of 20th magnitude. This analysis made a statistically optimal, non-parametric allowance for the observational magnitude cutoff. Is there any reason to doubt that the more recent observations that you cite are also consistent with the chronometric cosmology, and thus with the real physical absence of evolution in the quasar population?

Braccesi: I worked in the usual cosmological frame. I must add that I was not able to get a personal opinion on chronometric cosmology because of the mathematical difficulties of your book, which are too great for me.

Kron: You are advocating a large total absorption in the direction of SA 68 (b = - 46°). The galaxy counts in the direction of SA 57 (b = + 86°) and SA 68 are similar, indicating that absorptions in the two directions are not greatly different.

Braccesi: The values I presented for the absorption are possibly wrong. What I wanted to underline is the need to get a better knowledge of the phenomenon.

(Kiang asked if the data permit one to distinguish between a density evolution and a luminosity evolution. Ed.)

Braccesi: Relation 2 may describe both a density or a luminosity evolution. The relevant point is whether one limits its domain to a given lowest absolute luminosity or a given highest constant space density. As I said, to fit the counts, and to get correct fractional distributions in z, one is forced to choose a limiting space density, i.e., a luminosity evolution model.

Schmidt: The Palomar Bright Quasar Survey contains 114 objects in its final form. Green and I have submitted a paper describing the Survey for publication and preprints will be distributed soon. In our derivation of evolution, we find that the increase in space density is very strongly dependent on optical absolute luminosity and that the luminosity function is curved at all redshifts. Both of these results appear to be at variance with Dr. Braccesi's results.

Braccesi: I hope the results presented here will make the subject of a more extended paper in which all the details of the analysis will be presented. We will then be able to compare the procedure and understand the origin of the different conclusions.

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