DISTRIBUTION IN DEPTH OF QUASARS

Maarten Schmidt and Richard F. Green
Hale Observatories[1], California Institute of Technology

We discuss the distribution in depth of different kinds of quasars: quasi-stellar radio sources with steep radio spectrum, those with flat radio spectrum, and optically selected quasars. All exhibit an increase of space density with distance to a different degree. The optically selected quasars, in particular, show a steep increase of surface density with magnitude. The steepness of the increase is inconsistent with a uniform distribution of quasars in the local hypothesis. In the cosmological hypothesis the co-moving space density of optically selected quasars increases by a factor of 100,000 to a redshift of 2, and by factors of 1000 and 10 for steep-spectrum and flat-spectrum radio quasars, respectively.

The distribution in depth of quasi-stellar radio sources has been studied on the basis of samples from the 3CR, 4C, Parkes, and 6-cm NRAO catalogues; see Schmidt (1978), and Wills and Lynds (1978). Since samples are selected to optical and radio limits simultaneously, the V/V_{max} method (Schmidt 1968) is used in the analyses. Quasars with steep radio spectrum and flat spectrum show different $\langle V/V_{max}\rangle$ values, typically 0.67-0.70 and around 0.59, respectively. If we interpret the results in terms of a density law

$$\rho = \rho_o^{\;K(t-t_o)/t_o}$$

where t is the cosmic epoch and t_o the age of the Universe (we assume a $q_o = 0$ Friedmann model), then:
$K = 10\text{-}12$ for quasars with steep radio spectrum,
$K = 4$ for quasars with flat radio spectrum.

Samples of optically selected quasars are very scarce. In fact, the only published sample is that of Braccesi, Formiggini, and Gandolfi (1970). Spectroscopic work on the 175 objects is far from complete. A complete sample is constituted by 17 quasars with redshifts brighter than $B = 18$ over an area of 36 square degrees (Green and Schmidt 1978). We report on the preliminary results of the Palomar Bright Quasar Survey of optically selected quasars brighter than $B \approx 16$. The survey is based on double (U, B)

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exposures obtained by Green with the 18-inch Schmidt telescope over an area of approximately 10,000 square degrees. He selected as candidates some 3000 stellar objects with an ultraviolet excess. We have taken spectra of essentially all these objects and have found around 105 quasars, of which some 25 were known previously (half of them radio sources). Results are still tentative, since the limiting magnitude in each of the many Schmidt fields is yet to be determined precisely.

The counts of quasars in this survey, in the Braccesi sample to $B = 18$, and the unpublished Sandage-Usher surface density to $B = 18.5$ show $\log N (< B) = 0.93B + \text{const.}$, corresponding to an increase of the surface density by a factor of 8.5 per magnitude.

Such a steep count slope is incompatible with any local hypothesis of quasars in which the space distribution is uniform. In the latter case we expect $\log N (< B) = 0.60B + \text{const.}$, regardless of the shape of the luminosity function. The steep slope observed requires that the space density of local quasars increase with distance, approximately as $r^{3/2}$.

In the cosmological hypothesis, the steep slope of the counts requires $K = 18$ if the space density varies exponentially with cosmic time. The corresponding space density (in co-moving coordinates) at redshift 2 is some 100,000 times the local density.

The density increase appears to depend on the intrinsic optical luminosity of the quasars. Observed numbers of intrinsically luminous quasars in our survey, in the Braccesi sample, and in objective prism surveys (see next paper by P. Osmer) suggest a very steep increase, i.e., $K > 18$. Counts of faint stars reported by Tyson in this Symposium limit the rate of evolution of intrinsically weak quasars to $K < 18$. With luminosity-dependent evolution of quasars their luminosity function will change with redshift.

Our criterion of ultraviolet excess for candidate objects discriminates against redshifts larger than 2.3. We will soon be able to predict the number of quasars expected for $B > 18$, $z > 3.5$, which is of interest in connection with the continuing suspicion that there is a redshift cutoff or at least a sharp decrease in evolution at a redshift around 3.5 (see next paper by P. Osmer).

We are planning to obtain radio observations of the new sample of quasars. This should help in establishing the radio luminosity function of quasars, which is needed to interpret the lesser evolution for radio quasars referred to above.

Also planned are X-ray observations of the optically brighter quasars with HEAO-2. This should allow improved estimates of the X-ray background contributed by faint quasars, discussed elsewhere in this Symposium.

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NOTES

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DISCUSSION

Segal: The chronometric cosmology is an inherently non-evolutionary cosmology that predicts an infinite $\partial \log N/\partial m$ for objects of spectrum $\nu^{-\alpha}$, $\alpha < 1$, just before it vanishes identically (in a single luminosity class), as appears consistent with the observed quasar counts and indicated constraints on the counts at fainter magnitudes based on X-ray observations with the Einstein satellite, in addition to which its other predictions have been shown consistent with all substantial published quasar samples. I wonder whether you are aware of any empirical basis within quasar observations for non-acceptance of the chronometric hypothesis (without prejudice to other possible hypotheses)?

Narlikar: I do not see why the steep slope (of 8.5 per magnitude) of the log N-apparent magnitude of quasars is "fatal" for the local hypothesis. In the local hypothesis the distance variation is not large since all observed quasars are claimed to be at distances of 30-100 Mpc. On the contrary, the variation in intrinsic luminosity is expected to be very large. The data on the number counts which you have presented today does not seem convincing enough to claim that the departure from the Euclidean value (of ~ 4 per magnitude) has any significance in the context of the local hypothesis. I think the numbers are still too small: the highest point at B = 18 is based on only 17 quasars.

Schmidt: If a slope of 4 per magnitude held for quasar counts between B = 16 and B = 18, then Braccesi's sample should have contained only 4 quasars with B < 18, rather than the 17 observed. Independent confirmation of the steep slope of 8.5 per magnitude is provided by the Sandage-Usher determination of a surface density of 1.3-1.6 per square degree for B < 18.5.

Davis: With the density and evolution of QSO's as determined by your survey, how does the QSO density at Z ~ 1 or 2 compare to the galaxy density at that epoch?

Schmidt: The steeper evolution now found for optically selected quasars will leave space densities at z ≈ 1 fairly unchanged. Densities will be lower at low redshift, higher at larger redshifts.

Koo: Since the optically selected QSOs were based upon ultraviolet excess, and since you have spectroscopic data for these objects, would you please comment on the distribution of the spectral index of the continuum and its possible effects on the problem of missing a large number of redder QSOs?

Schmidt: As you would expect on the basis of our criterion of ultraviolet excess, all quasars found had fairly flat optical spectra. We would almost certainly have missed the class of very red quasars (such as 3C 181). These represent about 6 per cent among 3CR quasars (3 out of 50) and probably a smaller percentage of 6-cm NRAO quasars. The bias against red quasars exists both in our survey and in the Braccesi sample, so it is unlikely that the slope of the counts has been affected.