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On the redshift of the quasistellar objects

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Cosmologia. — *On the redshift of the quasistellar objects.* Nota di CESARE BARBIERI, presentata (*) dal Corrisp. L. ROSINO.

RIASSUNTO. — Lo scopo di questo lavoro è di riconciliare le ipotesi cosmologica e locale sulla natura degli oggetti quasi stellari. Assumendo come punto di partenza che larga parte del redshift sia di origine gravitazionale, vengono ricavate due relazioni esprimenti massa, raggio e distanza dell'oggetto stellare in funzione delle quantità osservabili densità di flusso, larghezza delle righe e diametro apparente.

L'oggetto 3 C 273 risulta avere massa $10^{12}\,M_\odot$, raggio 1 parsec e distanza 70 Mpc. Viene poi brevemente discussa una semplice ed attraente spiegazione della relazione log cz — V: le galassie potrebbero essere generate da oggetti stellari in espansione.

The cosmological nature of the quasistellar objects has been questioned by several authors with variety of arguments, such the variability and the resulting small dimensions or the extraordinary energy content. On the other hand these objects are extragalactic, as shown by Greenstein and Schmidt [1] who after a careful discussion strongly favour the cosmological hypothesis.

The aim of the present paper is to reconcile the local and cosmological ideas assuming as a starting point that a large part of the redshift is gravitational and using the available observational data to deduce distance, mass and radius of the resulting model.

Let a mass M be confined in a sphere of radius R ; ΔR ($\ll R$) be the thickness of the shell containing ionized gases and originating the emission line–spectrum. As is well known, the gravitational redshift z_g and width w_g are (for small z_g):

$$z_g = \frac{\Delta\lambda_g}{\lambda} = 1.47 \times 10^5 \, \frac{M/M_\odot}{R} \tag{1}$$

$$w_g = \frac{\Delta R}{R}\,\Delta\lambda_g = \frac{\Delta R}{R}\, z_g \lambda \tag{2}$$

where R is in centimeters and $M_\odot (2 \times 10^{33}\,\text{gm})$ is the mass of the Sun. The observed redshift is the sum of the cosmological one z_c and gravitational z_g:

$$z = z_c + z_g\,. \tag{3}$$

Proceeding as in [1] let us equate the observed brightness F of H_β to the emission from a volume $4\,\pi R^2\,\Delta R$ of ionized hydrogen at a distance r:

$$4\,\pi r^2\, F(H_\beta) = E(H_\beta)\, 4\,\pi R^2 \Delta R$$

where $E(H_\beta)$ is the emissivity in H_β.

Introducing (2) with $\lambda = 4861$ Å in this formula and putting

$$\frac{2\,R}{r} = \frac{\theta''}{2.06 \times 10^5}$$

(*) Nella seduta del 10 dicembre 1966.

where θ'' is the apparent diameter in sec of arc, we obtain the relation:

$$R = 8.25 \times 10^{14} \frac{z_g F(H_\beta)}{w_g E(H_\beta)(\theta'')^2} \text{ cm} \tag{4}$$

From the Hubble's law $r = cz_c/H$ Mpc we have also

$$R = 2.37 \times 10^{22} z_c \theta'' \qquad (H = 100 \text{ Km sec}^{-1} \text{Mpc}^{-1})$$

and a second relation can be deduced from (4):

$$\frac{z_c}{z_g} = 3.48 \times 10^{-8} \frac{F(H_\beta)}{w_g E(H_\beta)(\theta'')^3} . \tag{5}$$

Therefore the unknown quantities M, R, z_g, z_c are expressed through (4) and (5) as functions of w_g, $F(H_\beta)$, $E(H_\beta)$, θ'', which are at least in principle obtainable from the observations. Indeed, the gravitational broadening in the present hypothesis is a large part of the total width, then sufficiently well known. The critical parameter is the apparent diameter of which the observational techniques (fringe visibility, lunar occultations, scintillation in solar and interplanetary plasma) yield only an upper limit.

This difficulty, however, can be overcome by introducing in our model the radio features of NGC 1275, 3C 279 and 273 B. That is, let the central core be a small–diameter synchrotron radiation source having a flat spectrum ($\alpha = 0$) that becomes self–absorbed at some wavelength: the angular diameter can be calculated [2] from

$$S = 2.0 \times 10^{-18} F(\alpha)(\theta'')^2 B^{-1/2} \nu^{5/2} \tag{6}$$

where ν (c/s) is the frequency at which the optical depth is ≥ 3, S is the corresponding flux density in flux units (10^{-26} W m^{-2} c/s^{-1}), B is the magnetic field in gauss, $F(\alpha) = 0.75$ for $\alpha = 0$.

Omitting the obvious developments of (4) and (5) following from (6) let us perform the calculations relative to 3 C 273, whose redshift is 0.158. Assuming for the electron temperature and density the values $T_e = 15.000^\circ$ K, $N_e = 3 \times 10^6$ [1, 3], the emissivity in H_β by recombination is $E = 3.4 \times 10^{-13}$. The observed brightness is $F = 3.4 \times 10^{-12}$ erg sec^{-1} cm^{-2}.

The radiospectrum of 3 C 273 B becomes self-absorbed near 1000 Mc/s. According to the von Hoerner's restoration [4] the optical depth of the central core is $\simeq 1$ around 400 Mc/s and the spectrum is completely thick near 245 Mc/s ($S \simeq 3$ f.u.). Inserting these values in (6) we find $\theta'' = 5 \times 10^{-3}$ for $B = 10^{-4}$ gauss.

Finally

$$R = 1.18 \times 10^{20} \qquad z_c = 3.3 \times 10^{20} \frac{z_g}{w_g}$$

$$\frac{z_c}{z_g} = \frac{2.78}{w_g} \quad , \quad z_c + z_g = 0.158 .$$

The gravitational width of H_β has to be now evaluated. The total width is about 50 Å but in the emitting region some mechanism of broadening other than gravitation is certainly present. Burbidge, Burbidge, Hoyle and Lynds [5] suggest the electron scattering as principally responsible and find that widths of 20 ÷ 30 Å are expected for $T_e = 10.000 \div 30.000^0$ K. Therefore the calculations have been performed in two cases, $w_g = 30$ Å and $w_g = 10$ Å: the resulting values are shown in Table I.

TABLE I.

	$w_g = 30$ Å	$w_g = 10$ Å
z_g	0.145	0.124
z_c	0.013	0.034
r (Mpc)	40	100
R (cm).	1.58×10^{18}	4.06×10^{18}
2 R (pc)	1.0	2.5
ΔR (cm)	6.8×10^{16}	6.8×10^{16}
$M/M_\odot$	1.55×10^{12}	3.4×10^{12}
ρ (gm/cm³)	1.9×10^{-10}	2.4×10^{-11}

This set of data must be taken with due caution; the model, however, offers many attractive features (and terrible questions of structure):

a) the dimensions turn out well consistent with the variability.

b) the distances are considerably reduced and the resulting intrinsic luminosities are lowered to the values found in normal galaxies. Some problems about density and temperature of the intergalactic medium arising from the lack of strong absorption shortward of Ly_α in the spectrum of 3 C 9 are avoided.

c) the great dispersion in the relation log cz — V for quasars (fig. 1) has a simple explanation, suggested by the appearance of the figure itself and by the evolution of the radiospectrum [2]. Let us introduce at some instant of the life–time of the stellar object an expansion in radius from, say, 1 to 10^3 parsecs: the gravitational redshift diminishes more and more and our quasar reaches the region, and structure, of a galaxy. This evolution would last a time not exceeding 1/10 of the life in form of very compact object, as far as may be judged by comparing the number of points in the quasar main region (Δ log $cz \simeq 0.8$ above the galaxy-line) with the number in fringes pointing to the region of the galaxies.

3 C 277.1 and 1217 + 02 seem near the end of their path across the (log cz — V) plane, particularly 3 C 277.1 (V = 18, log cz = 4.98). In fact from the list published in [5] we derive that in 1217 + 02 the line–widths

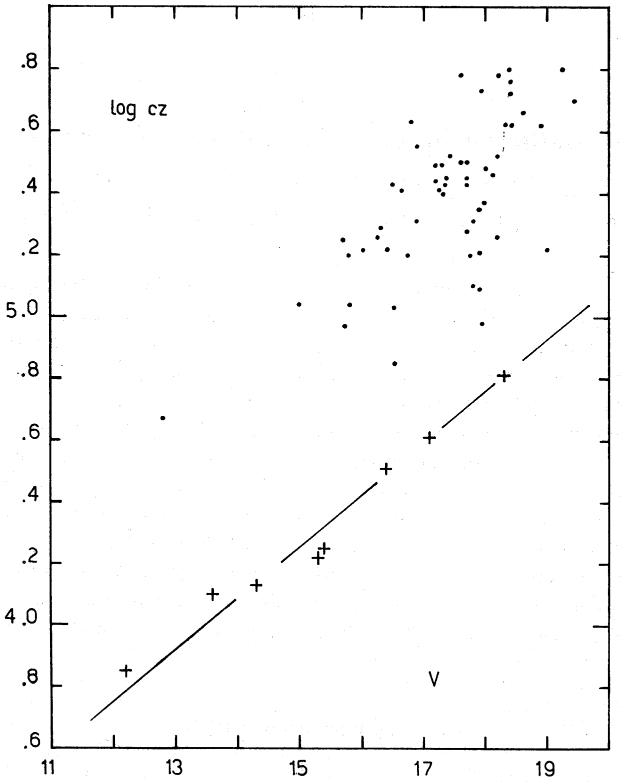

Fig. 1. – The V — log *cz* relation. Dots: quasistellar radio sources. Crosses: radio galaxies.
(A. SANDAGE, « Ap. J. », *145*, 1 (1966).

are always ≤ 30 Å, and that in 3 C 277.1 the Mg II λ 2798 *is exceedingly narrower* than in any other object.

The quasistellar objects therefore would be the parents of the galaxies. We recall the strong analogy between this model and the ideas, in favour of formation of new galaxies and arms at expense of prestellar matter present in nuclei, long defended by Ambartsumian [6].

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