A STUDY OF THE HUBBLE FLOW

E. Joseph Wampler
European Southern Observatory
Karl-Schwarzschild-Str. 2
D-8046 Garching bei München, F.R.G.

ABSTRACT. It is found that the Hubble diagrams for quasars and giant radio galaxies are very similar. Either the evolution of giant branch stars in the galaxies closely matches the evolution of the quasar non-thermal emission or the cosmological deceleration parameter q_o is close to 3.

1. INTRODUCTION

Lilly and Longair (1984) have shown that a Hubble diagram that uses 2.2 μ photometry of a complete sample of 3CR radio galaxies either shows strong galaxy luminosity evolution at high redshift or indicates a very high value for q_o. For this sample there is expected to be little contribution to the 2.2 μ magnitudes either from a non-thermal nuclear continuum or from strong emission lines. If the observed effect is due to luminosity evolution it must result from a decrease in giant branch luminosity as the Universe ages.

Quasar data also show strong evolutionary effects (Schmidt and Green, 1983) or indicate a high value for q_o (Wampler and Ponz, 1985). Baldwin (1977) showed that the equivalent width of the CIVλ1548 emission line in quasars is luminosity sensitive allows quasar magnitudes to be corrected for luminosity effects. Since the "Baldwin relationship" seems to be independent of redshift (Wampler et al., 1984), corrected quasar magnitudes should be largely free of luminosity bias.

2. ANALYSIS

Complete samples of radio loud quasars from Wampler et al. (1984), radio quiet quasars from Schmidt and Green (1983) and from Osmer and Smith (1980) were supplemented with a few additional quasars to form a quasar Hubble diagram with magnitudes corrected for luminosity spread using the "Baldwin relation". Since the quasar data overlapped the galaxy data in redshift the quasar magnitudes were adjusted by 6.75 mag. so that the two sets of data could be used together in a plot of

A. Hewitt et al. (eds.), Observational Cosmology, 147–150.

https://doi.org/10.1017/S007418090015911X Published online by Cambridge University Press

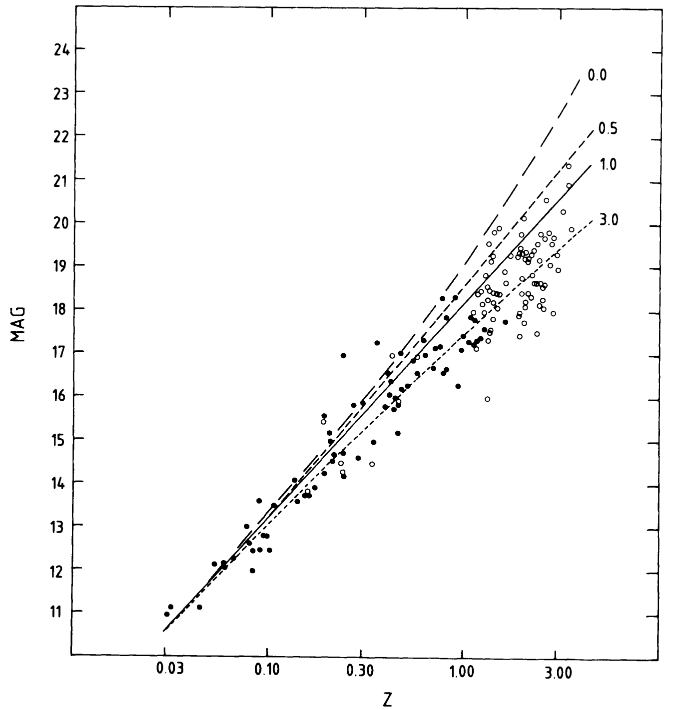

Fig. 1. The Hubble diagram for 3CR radio galaxies (•) and quasars (o).

the composite Hubble diagram. This is shown in Fig. 1. It is clear from Fig. 1 that both sets of data show a similar smooth departure from the predictions of low q_0 Friedmann models. The data are reasonably well fit by Friedmann models with $q_0 \approx 3$. Taking the two sets of data separately the squares of the residuals from Friedmann curves were calculated as a function of q_0. These are plotted in Fig. 2. It can be seen that both sets of data indicate similar, high values for q_0. The minimum r.m.s. scatter in the quasar data is about 0.8 mag while for the galaxy data it is about 0.6 mag.

3. DISCUSSION

At present it is not possible to decide if the apparent brightening of the magnitudes at high z is due to luminosity evolution or indicates a high value for q_0. If it is due to evolution then the amount required for giant branch stars in luminous radio galaxies must approximately equal the evolution of the UV non-thermal evolution in quasars. In both cases the rate of evolution approximately agrees with the amount expected from geometrical effects in a Friedmann cosmology with a high value of q_0. For quasars the evolution must shift the zero-point of the "Baldwin relationship" but not its slope since a universal "Baldwin relationship" would remove the luminosity evolution.

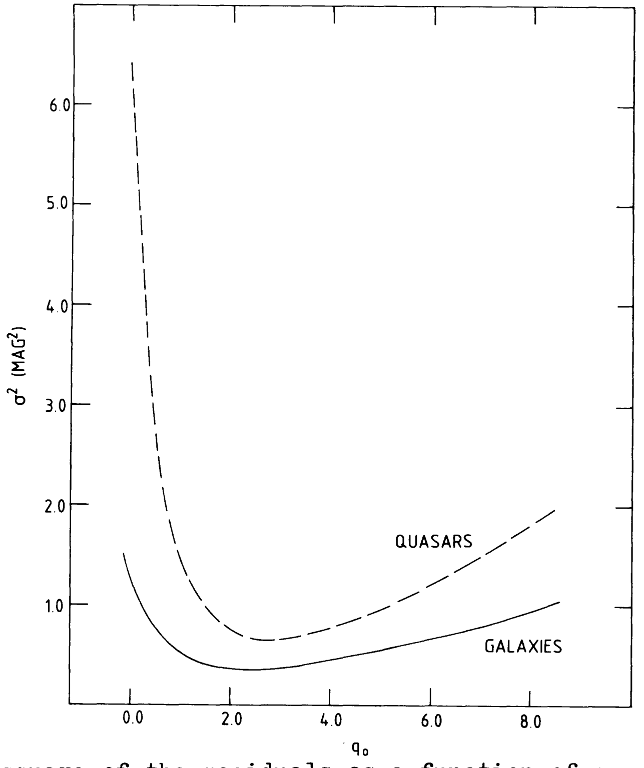

Fig. 2. The square of the residuals as a function of q_o.

If $q_o \approx 3$ there is an age problem unless H_o is very low or unless the cosmological constant Λ is positive. For currently accepted values of H_o (40 km/sec/Mpc $\lesssim H_o \lesssim$ 80 km/sec/Mpc) if $\Lambda = 0$ and $q_o = 3$ the age of the Universe is less than the age of pop. II stars in the Galaxy. A positive value for Λ is required to increase the age of the Universe. A very slight positive vacuum energy would give a high enough Λ to satisfy the data. The inflationary model of the Universe requires that in the past the vacuum energy was > 0.

The results given here are discussed in more detail in Wampler (1987).

REFERENCES

Baldwin, J.A. 1977, Astrophys. J., **214**, 679.

Lilly, S.J., and Longair, M.S. 1984, Mon. Not. R. astr. Soc., **211**, 833.

Osmer, P., and Smith, M.G. 1980, Astrophys. J. Suppl., **42**, 333.

Schmidt, M., and Green, R.F. 1983, Astrophys. J., **269**, 352.

Wampler, E.J., Gaskell, C.M., Burke, W.L., and Baldwin, J.A. 1984, Astrophys. J., **276**, 403.

Wampler, E.J., and Ponz, D. 1985, Astrophys. J., **298**, 448.

Wampler, E.J. 1987, Astron. Astrophys., submitted.

DISCUSSION

RUBIN: I think I do not understand what you mean by a complete sample. Isn't there an observational selection which means that at any z the velocities will be available for the brighter galaxies, but not for the fainter galaxies? Could your distribution be incomplete for fainter galaxies at each z?

WAMPLER: It is believed that powerful radio sources are bright galaxies. If this is not so then the 5-10 blank fields (out of ~80 radio galaxies) in the 3CR catalogue may be nearby, faint galaxies. If they were at just the right place in the Hubble diagram they could change the conclusions for galaxies a little, but not much. The quasars are all much brighter and the Baldwin correction removes most of the distortion in the Hubble diagram caused by selection effects.

https://doi.org/10.1017/S007418090015911X Published online by Cambridge University Press