The Universe at Low Radio Frequencies
IAU Symposium, Vol. 199, 2002
A. Pramesh Rao, G. Swarup and Gopal-Krishna, eds.

Large Scale Structure Among $z \sim 2$ Quasars as a Cosmological Standard Ruler

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Abstract. The peak in the power spectrum at $\approx 130h^{-1}$ Mpc at low redshifts provides *a standard ruler in comoving space.* This scale is shown to be present in the observed quasar distribution at $z \sim 2$. This implies strong constraints on the density parameter, Ω_0, and weaker constraints on the cosmological constant, λ_0. Independently of λ_0 (in the range $\lambda_0 \in [0, 1]$), the constraint is $0.1 < \Omega_0 < 0.45$ (68% confidence limit).

Combination of the power spectrum peak method with very independent results from the supernovae Type Ia method yields $\Omega_0 = (0.30 \pm 0.11) + (0.57 \pm 0.11)(\lambda_0 - 0.7)$, $0.55 < \lambda_0 < 0.95$, (68% confidence limits) *without assuming* $\Omega_0 + \lambda_0 = 1$. This supports the almost flat, perturbed Friedmann-Lemaître-Robertson-Walker model, independently of any cosmic microwave background observations.

We all hope that the GMRT will be useful for many cosmological studies. This implies a need to know — or else to measure — the curvature parameters (the density parameter, Ω_0, and the dimensionless cosmological constant, λ_0). The following method and result may help.

It is now well established that galaxies are distributed at the present epoch, i.e. at $z \sim 0$, in large scale structure in what may be termed walls, voids and filaments (e.g. de Lapparent, Geller & Huchra 1986; Broadhurst et al. 1990; Einasto et al. 1994; Broadhurst 1999) at $L_{\rm LSS} \approx 130 \pm 10h^{-1}$ Mpc.

This power spectrum peak is a comoving scale, to which the bottom-up formation of galaxy or cluster dark matter haloes is not expected to have reached in a Hubble time. It is difficult to see how this *length* scale could be affected by evolution or by questions of bias, although the *amplitude* of the signal might be biased.

Hence, this scale provides what is potentially one of the most robust cosmic standard rulers, and has been implicitly or explicitly applied before in the redshift direction (Deng, Xiaoyang & Fang 1994; Broadhurst & Jaffe 2000).

To avoid redshift selection effects, Roukema & Mamon (2000) used only the *tangential* distribution of the homogeneous quasar catalogue of Iovino, Clowes & Shaver (1996) of $N \sim 1000$ quasars at $z \sim 2$.

https://doi.org/10.1017/S0074180900168536 Published online by Cambridge University Press

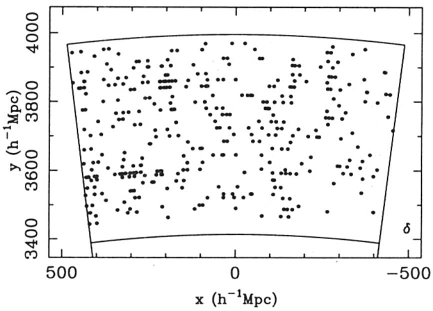

Figure 1. Wedge diagram for the $z \sim 2$ 'declination' subsample of the $z \sim 2$ Iovino et al. (1996) quasar catalogue, for $(\Omega_0 = 0.3, \lambda_0 = 0.7)$. Voids consistent with $L_{\mathrm{LSS}} = 130 \pm 10h^{-1}$ Mpc are clearly visible despite redshift selection effects.

Two-dimensional wedge diagrams (Fig. 1) and 1-D fourier analysis in the tangential direction clearly show that large scale structure exists among the quasars of the Iovino et al. (1996) catalogue at $z \sim 2$ at the expected scale, and that this provides a constraint in the (Ω_0, λ_0) plane.

The stronger constraint found is on Ω_0, i.e. $0.1 < \Omega_0 < 0.45$, independently of $\lambda_0 \in [0, 1]$ (fig. 11, Roukema & Mamon 2000, 68% confidence limits).

This method and the supernova type Ia method (e.g. Perlmutter et al. 1999) both use *empirical standards* which are not quite understood theoretically, and are independent by (i) choice of astrophysical object, (ii) redshift range, and (iii) standard ruler vs standard candle. Combination of our result and that of Perlmutter et al. results in fig. 13 of Roukema & Mamon (2000): $\Omega_0 = (0.30 \pm 0.11) + (0.57 \pm 0.11)(\lambda_0 - 0.7)$, $0.55 < \lambda_0 < 0.95$, (68% confidence limits).

Hence, the Universe is shown to satisfy an almost flat, perturbed FLRW model, *independently of any cosmic microwave background observations.*

This standard ruler should exist among any class of extragalactic objects seen by the GMRT, though may be weak at $z \gg 2$ or for other object classes.

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https://doi.org/10.1017/S0074180900168536 Published online by Cambridge University Press