

MILLIARCSECOND RADIO STRUCTURE OF AGN AS A COSMOLOGICAL PROBE

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Abstract.

Recent achievements in Very Long Baseline Interferometry (VLBI) allow the reconsideration of milliarcsecond radio structure of Active Galactic Nuclei (AGN) as a “standard object”. The basic concept of this approach is described and illustrated.

1. Introduction

An idea to use extended radio sources as cosmological standard rods in order to measure parameters of cosmological models had been first suggested by Hoyle (1959). Since then a number of studies of the behaviour of radio source linear size on kiloparsec scales as a function of redshift resulted in a conclusion on the dominance of intrinsic evolutionary effects in source structures rather than universal cosmological effects (*eg.* Kapahi 1989; Barthel and Miley 1988; Singal 1993 and references therein). An application of kiloparsec radio structures in cosmology remains a challenge, though not a hopeless one (Daly, these Proceedings).

Recently a few attempts have been made to apply Hoyle’s idea to milliarcsecond (*i.e.* parsec scales) radio structures of AGN (Kellermann 1993; Gurvits 1993, 1994; Pearson *et al.* 1994). The approach is based on measurements of sizes of AGN obtained with VLBI. A number of follow up

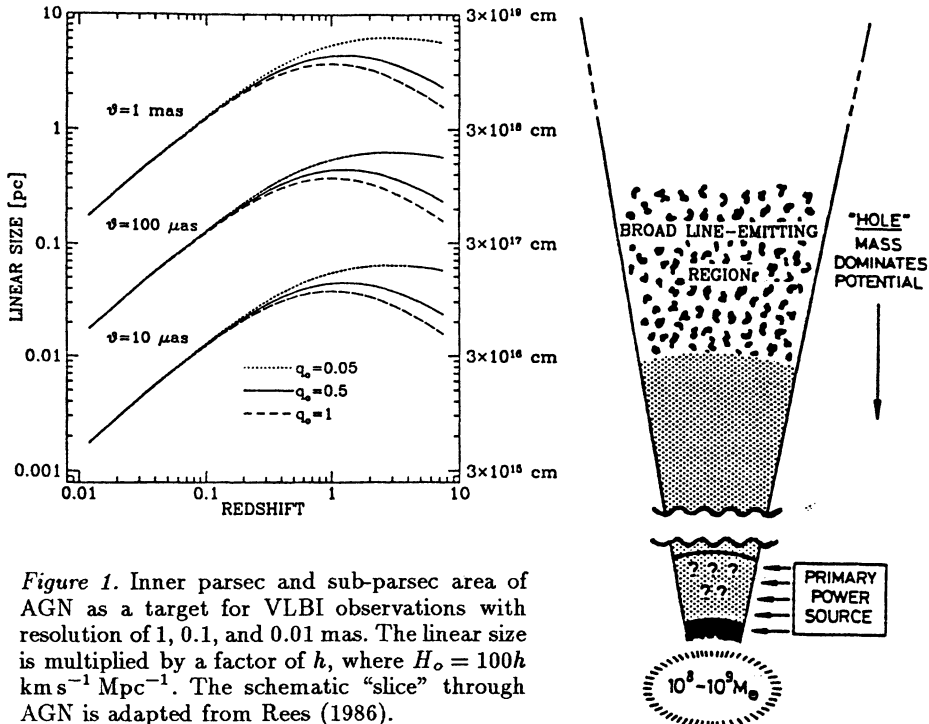


Figure 1. Inner parsec and sub-parsec area of AGN as a target for VLBI observations with resolution of 1, 0.1, and 0.01 mas. The linear size is multiplied by a factor of h , where $H_0 = 100h \text{ km s}^{-1} \text{ Mpc}^{-1}$. The schematic “slice” through AGN is adapted from Rees (1986).

publications indicate a reasonable interest in the approach (Krauss and Schramm 1993; Kayser 1994; Stelmach 1994; Jackson and Dodgson in these Proceedings). Leaving aside various technical details of the use of milliarc-second radio structures of AGN as a standard rod, I concentrate here on the basic concept of the approach.

2. Inner Parsecs of AGN as a Standard Object

At present a typical resolution of about 1 mas in VLBI at GHz frequencies allows to “see” the inner part of AGN in the range of linear sizes approximately 0.1 – 10 pc for redshifts $0.01 < z < 10$ (Fig. 1).

Various features of continuum radio emission from AGN are well described in a “zero” approximation by rather simple theoretical models (eg. Slysh 1963; Pacholczyk 1970; Kellermann and Owen 1988). These models are based on three assumptions: (i) compact radio components emit synchrotron radiation; (ii) synchrotron self absorption is a typical feature of their radio continuum spectra; (iii) Doppler boosting may play a significant role in sources structural and spectral appearance. Using these assumptions the source linear size, l , can be expressed as

$$l \sim S_m^{\frac{1}{2}} \cdot B^{\frac{1}{4}} \cdot (1+z)^{\frac{1}{4}} \cdot \nu_c^{-\frac{5}{4}} \cdot f(p)^{\frac{5}{4}} \cdot \delta^{-\frac{1}{4}}$$

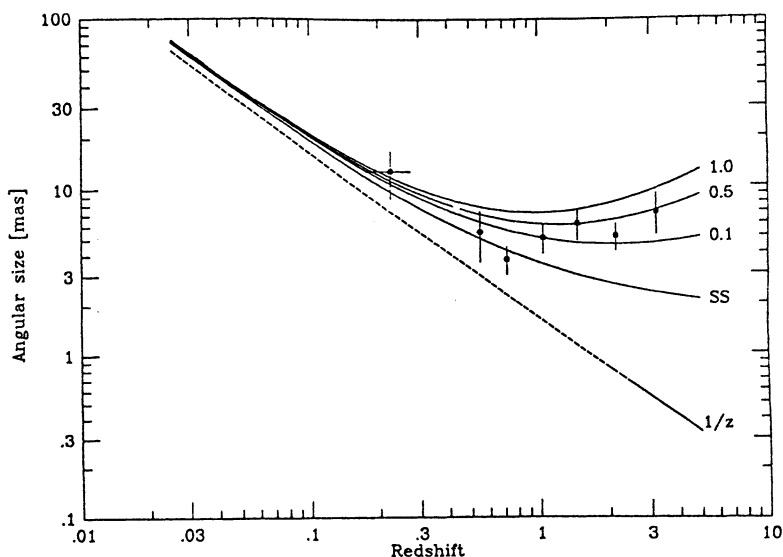


Figure 2. An example of the dependence “apparent angular size – redshift” for a sample of radio cores of 71 quasars (Gurvits *et al.* 1994). Solid curves present cosmological models with $\Lambda = 0$ and various values of q_0 .

where S_m is the maximum flux density of the component, B is the magnetic field strength, ν_c is the self-absorption cutoff frequency, f is a weak function of the index p of power law distribution of synchrotron electrons, and $\delta = \gamma^{-1}(1 - \beta \cos \alpha)^{-1}$ is the correction for the relativistic Doppler factor with the Lorentz factor γ , and the angle between the plasma motion direction and the line of sight α (see Kellermann and Owen 1988 for more discussion).

Just a glance at this formula can provide a meaningful conclusion, *i.e.* source size is a weak function of key physical parameters. Indeed, the least known parameters, the magnetic field strength B and the Doppler correction factor δ are to the power of $\pm 1/4$. The function $f(p)$, as noted above, is a weak function of its only single parameter p . Other parameters are better constrained to some extent, as the flux density S_m and the cutoff frequency ν_c are direct observables. Thus, a careful selection of sources can minimize a bias due to a spread in these two parameters. Therefore, one can expect a not too wide range of source linear size, that are emitting in accordance with the formula above.

This conclusion points to the possible usefulness of AGN’s parsec scale radio structure in cosmological studies. Inevitable complications of this suggestion, due to deviations from the simple model for AGN radio emission, will be conclusive for better understanding of AGN radio emission.

A number of recent observational programmes will provide a reasonable number of VLBI images (more than 200) of AGN in the redshift range of $0.01 < z < 4.0$ (Taylor *et al.* 1994, Thakkar *et al.* 1994, Gurvits *et al.* 1994

and references therein). Fig. 2 presents an example of observational data of the “ $\theta - z$ ” dependence, adapted from Gurvits *et al.* (1994). The sample presented is composed mainly from the Kellermann (1993) data with an addition of three quasars at $z > 3$. A simple “demonstrational” regression analysis applied to these data implies the best fit for the deceleration parameter value $q_0 = 0.5 \pm 0.4$ with the postulating value $\Lambda = 0$. This example as an indication on the fruitfulness of the approach rather than a cosmologically meaningful conclusion. The latter one is a subject for the analysis of future results of VLBI surveys.

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