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GIANT RADIO GALAXIES IN VIEW OF THE DYNAMICAL EVOLUTION OF THE FR II-TYPE POPULATION

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Abstract. The time evolution of giant ($D > 1$ Mpc) lobe-dominated galaxies is analyzed on the basis of dynamical evolution of the entire FR II-type population.

Key words: galaxies: active – radio continuum: galaxies

1. INTRODUCTION

One of the general questions concerning the largest radio galaxies is: do they reach their extremely giant sizes due to (i) exceptional physical conditions in the intergalactic medium, (ii) extraordinary intrinsic properties of the AGN, or simply (iii) because they are extremely old? To answer this question, a number of attempts were undertaken to recognize properties other than size which differentiate giants from normal-size sources. As a result of these attempts, it is considered that their large sizes result from a combination of the above reasons.

In this contribution we analyze whether properties of giant radio galaxies observed in a selected representative sample can be explained by a model of the dynamical evolution of the classical double radio sources in cosmic time, and what factor (if there is one) is primarily responsible for their giant size. Two recent analytical models, published by Kaiser et al. (1997, hereafter KDA) and Blundell et al. (1999), are very convenient for this purpose. These two models differ in predictions of the time evolution of the source luminosity (there is no space in this contribution to go into details). In summary, basic physical parameters, i.e., the jet power $Q_{\rm jet}$, the central density of the galaxy nucleus ρ_0, the energy density and pressure in the lobes or cocoon (u_c and p_c), and the total energy of the source $E_{\rm tot}$ are derived from the model for each member of the sample to fit its age, redshift, radio luminosity, projected size and axial ratio. Next, these parameters are compared with (1) the relevant parameters derived for normal-size sources in a comparison sample, and (2) the parameters determined from observational data, i.e., the age, equipartition energy density $u_{\rm eq}$, equipartition energy $U_{\rm eq}$, etc., calculated under 'minimum energy' conditions.

A description of the observational data used, application of the analytical model, fitting procedure, etc. (cf. Machalski et al. 2004), are beyond the scope of this contribution.

2. RESULTS OF THE MODELING

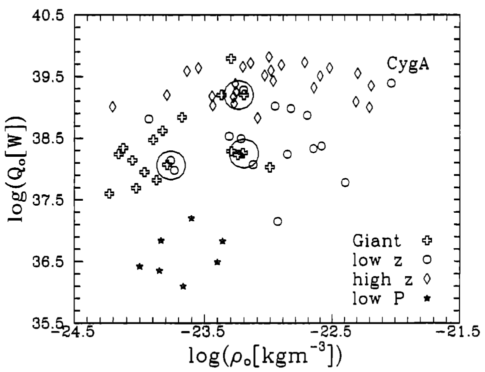

Fig. 1. Plot of the jet power $Q_{\rm jet}$ against the core ρ_0. The 'clans' of sources with similar $Q_{\rm jet}$ and ρ_0 are marked by the large circles.

A distribution of the above parameters on the $\log(Q_{\rm jet})$ – $\log(\rho_0)$ plane is shown in Figure 1. As both parameters should be independent, we test whether the observed distribution is or is not biased by possible selection effects. The data obtained imply that $Q_{\rm jet}$ correlates, in the order of the significance level, with the luminosity $P_{1.4}$, redshift z and age t. Calculating the Pearson partial correlation coefficients, we found no significant correlation between $Q_{\rm jet}$ and ρ_0 when z (or $P_{1.4}$) and t are kept constant.

In view of the above, one can see from Figure 1 that (i) among the sources with a comparable $Q_{\rm jet}$, giant sources have an average ρ_0 smaller than its corresponding value in normal-size sources, (ii) giants have at least ten times more powerful jets than much smaller low-luminosity sources of a comparable ρ_0, and (iii) for a number of sources in the sample, the derived values of their fundamental parameters $Q_{\rm jet}$ and ρ_0 are very close, while their ages and axial ratios are evidently different. Thus, in view of the model assumptions they may be considered as 'the same' source observed at different epochs of its lifetime. Such bunches of three to five sources (hereafter called 'clans') are indicated in Figure 1 with the large circles.

In view of the dynamical model applied and as a result of the Pearson partial-correlation coefficients calculated between those parameters, we find that the linear size of a source strongly depends on both its age and the jet power, while the correlation with age is the strongest. However, the size also anti-correlates with central density of the core. That anticorrelation seems to be weaker than the correlations with $Q_{\rm jet}$ and t and become well pronounced only when all three remaining parameters ($Q_{\rm jet}$, t and z) are kept constant.

3. EVOLUTIONARY TRACKS OF SOURCES

In the papers of KDA and Blundell et al. the tracks of radio luminosity P_ν versus linear size D were derived for imaginary sources with assumed values of $Q_{\rm jet}$, ρ_0, z and other free parameters of the model. In our approach we are able to calculate such evolutionary tracks for *actual* sources. In Section 2 the 'clans' of sources have been pointed out. Three of six clans are marked in Figure 1. Since the dynamical model assumes constant $Q_{\rm jet}$ during the source lifetime, and a nucleus density ρ_0 is *a priori* constant, members of such a clan can be considered as 'the same' source observed at a number of different epochs throughout its life. The observed parameters of these members can verify predictions of the model. However, fits of the P–D tracks predicted with the original KDA model to the observed parameters of sources have appeared unsatisfactory. Much better fits of the modeled tracks to observational data of the 'clan' members are found with the cocoon's axial ratio (AR) evolving in time. This, in turn, implies a time evolution

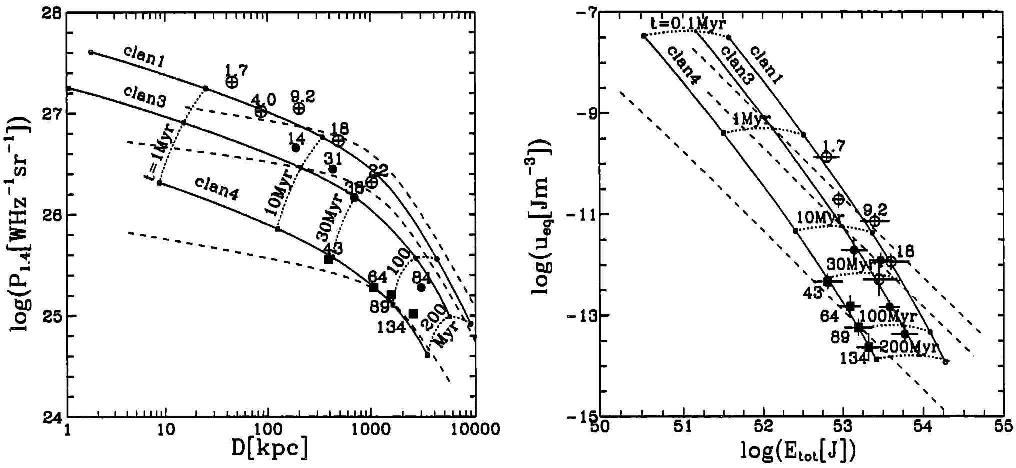

Fig. 2. Panel (a): evolutionary $P - D$ tracks and panel (b): $u_{\rm eq} - E_{\rm tot}$ tracks fitted for three clans of sources with evolving axial ratio AR (solid curves). The markers of the same predicted age on each curve are connected by dotted lines. The members of each clan are marked by different symbols. Their actual age is indicated by a number behind the symbol. The dashed curves indicate relevant tracks but calculated with a constant AR, as in the original KDA model.

of a ratio of the jet head pressure to the cocoon pressure, P_{hc}.

The evolutionary $P - D$ tracks for the three clans are shown in Figure 2(a) by solid curves. The markers of the same time are put on these tracks. The dashed curves show the relevant tracks calculated from the original KDA model, i.e., with a constant AR taken as the mean of axial ratios in a given clan. It is clearly seen that the evolving AR much better fits the observed changes of P on D.

The model also allows a prediction of the source's evolution on the energy density vs. total energy plane which is shown in Figure 2(b). It is worth emphasizing that the predicted evolutionary u_c vs. $E_{\rm tot}$ tracks are steeper and curved in respect to those expected from the original KDA model. Moreover, the steepening increases throughout the source lifetime. This is caused by the non-constant adiabatic losses and inflation of the cocoon in time, as well as by faster decrease of the cocoon pressure in very large sources. Quantitatively this process is evaluated by a substitution of the evolving (increasing) value of the pressure ratio $P_{hc}(t)$ into equation describing $E_{\rm tot}$ (cf. Machalski et al. 2004).

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