Fundamental parameters of FRII radio galaxies & their impact on clusters' environments

Anna D. Kapińska
Institute of Cosmology & Gravitation, University of Portsmouth, U.K.

Philip Uttley
Anton Pannekoek Institute, University of Amsterdam, Netherlands

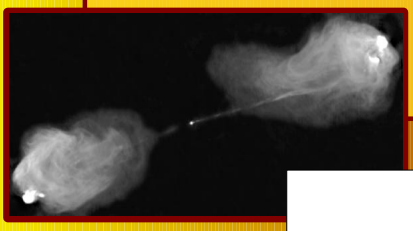
Further information:
anna.kapinska@port.ac.uk
http://research.icg.port.ac.uk/~kapinska

I. Introduction

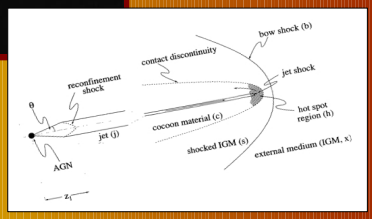
Radio galaxies and quasars are among the largest and most powerful single objects known and are believed to have had a significant impact on the evolving Universe and its large scale structure. Even simple analytical models of time evolution of these objects can link their observable radio lobe luminosity densities and linear sizes to the underlying fundamental parameters of these sources (lifetimes, kinetic luminosities, ambient gas densities). We investigate these parameters which are crucial for understanding AGN feedback in galaxy clusters.

II. FR II radio sources

Radio galaxies and radio-loud quasars are usually divided into two Fanaroff-Riley classes, FRI and FRII. FRIs are edge-darkened and have turbulent morphology, FRIIs are limb-brightened objects with symmetrical structure. Unlike the FRI type objects, semi analytical models of FRIIs' growth during their lifetimes have been developed. Here we use the model of *Kaiser & Alexander (1997)* and *Kaiser et al. (1997).*



Left:
Cygnus A, archetypal FRII radio galaxy (4.8 GHz)
Credits: Perley & Carilli



Right:
Sketch of FRII class radio source elements used for the analytical evolutionary model.
From: Kaiser et al. 1997

III. Method

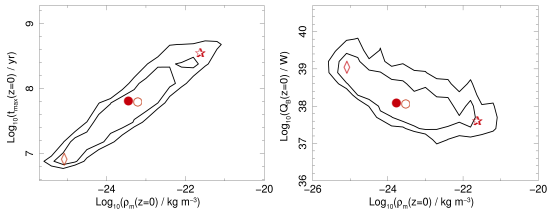
In Kapinska, Uttley & Kaiser (2012) we investigate fundamental parameters of FRIIs through multi-dimensional Monte Carlo simulations. We fit simulated and observed radio luminosity functions (RLFs). We use the maximum likelihoods to find the best fitting fundamental parameters which can reconstruct the observed RLFs. A sample of estimated confidence intervals of fundamental parameters is displayed in Figure 1. Parameters are highly degenerate and span wide range of possible values;

is the scale of the impact of FRIIs on the clusters' environment robust despite the degeneracy?

Four simulated data sets were chosen (red markers) from confidence intervals (here 95% and 99% plotted) for tests.

Notes.
(i) Q_B refers to kinetic luminosity break of Schechter function.
(ii) Data sets ○/● differ significantly from each other in the strength of fundamental parameters' redshift evolution (not shown here).

Figure 1: Confidence intervals.

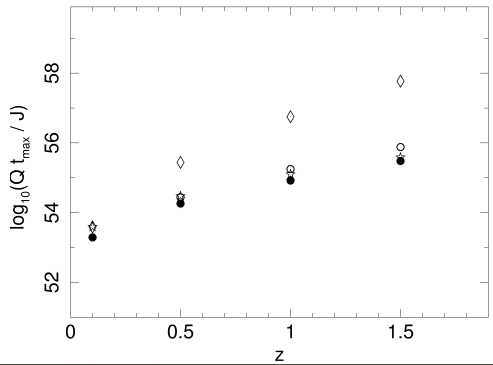


IV. Results: The total power produced by FRIIs

The total produced power, $U_{tot} = Q\ t_{max}$, where Q is the kinetic luminosity and t_{max} the total lifetime of an FRII, was calculated for a typical radio source of each data set (Figure 1), and the results are displayed in Figure 2.

Figure 2:

The average total power of FRIIs produced during their lifetime.



1. Strikingly, $Q\ t_{max}$ in each case is nearly the same despite enormous differences between fundamental parameters which define each data set.

2. The total power produced by FRIIs seems to undergo non negligible redshift evolution $U_{tot} \propto (1+z)^n$, $n \in [5.0 - 6.5]$.

(!) Q_B used in data set marked with diamonds ◊ is particularly unrealistic and does not represent a typical radio source at $z > 0.5$.
For details see:
Kapinska & Uttley, MNRAS, to be submitted.

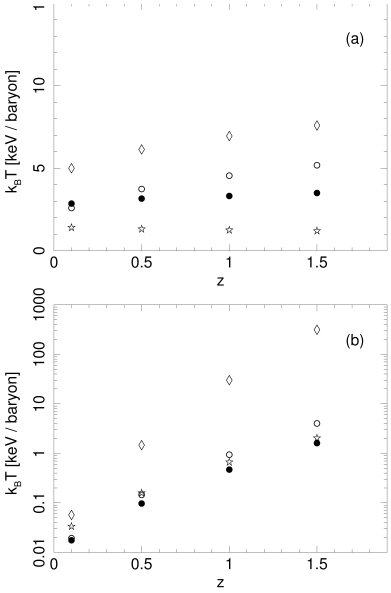
V. Results: The total injected power per baryon

Assuming that radio sources are centrally located, all FRIIs' power goes into heating the environment and there exist some very efficient energy – heat transfer mechanism so that the total injected power is evenly distributed over a sphere of a (a) radius 1 Mpc or (b) mass of $10^{14} M_\odot$ we find the total injected power of FRIIs per baryon. Results are displayed in Figure 3.

Figure 3:

FRIIs' total injected power per baryon.

(a) evenly distributed over a sphere with radius = 1Mpc, gas density and its profile given by the simulations of Kapinska, Uttley & Kaiser (2012), and evolves with redshift



(b) evenly distributed over a sphere with mass = $10^{14} M_\odot$, the cluster's mass does not change with redshift

VI. Conclusions

We find the total power produced by FRII radio sources during their lifetimes to be very robust despite strong degeneracy between their estimated fundamental parameters (lifetimes, kinetic luminosities and gas densities of their environments), and to undergo evolution with redshift. Such a result points to a compelling indicator of the scale of AGN feedback in groups and clusters of galaxies.

The total injected power per baryon strongly depends on gas density, and although not tightly constrained converges to values of 0.01 – 5 keV/baryon despite an enormous range of fundamental parameter sets. Results estimated here for a cluster mass of 10^{14} $M_\odot$ can be easily scaled to the actual masses of groups and clusters of interest.

For details keep an eye on: *Kapinska & Uttley, MNRAS, to be submitted*
Kapinska, Uttley & Kaiser, MNRAS, submitted