Radio Jets along the FR Divide as a Measure of Cluster Environment and Feedback

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Introduction

Radio jets are natural probes of cluster environment

They are visible gauges of environmental changes in density, pressure, and dynamics.

Need to look at morphology for clues of interaction

This study has the potential to enlighten multiple fields:
- Cooling flow problem in galaxies and clusters
- Cause of FRI vs FRII divide in jets
- Role of jets in galaxy and cluster evolution

Main Idea

To investigate the Fanaroff-Riley divide as radio jets evolve through the PD diagram, we consider environmental influences on FRI and FRII sources, and conversely study the feedback from well-constrained jets on the ICM

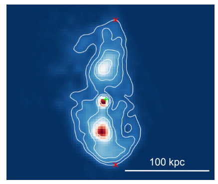
Fanaroff-Riley Dichotomy

(Fanaroff and Riley 1974)

When radio-loud galaxies are classified by morphology, two distinct populations emerge.
But the dominant cause of this so-called Fanaroff-Riley (FR) dichotomy remains unclear.
Unraveling the origin of these two groups of galaxies will reveal the extent of AGN-environment interaction.

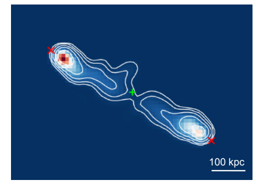
Two Morphology Types:

FRI



Left: FRI galaxy 4C12.42
Right: FRII galaxy 4C37.29
at 1.4GHz from the FIRST survey.
An automated process measures jet length away from optical position (green cross) out to red Xs, allowing robust measurements and classification

FRII

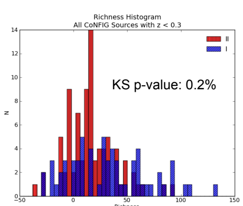


Classifying a sample of radio galaxies by their extended morphology also divides the sample into distinct groups of high and low luminosity, with a divide at ~$10^{24.4}$ W Hz^{-1} sr^{-1} at 1.4 GHz

FRI vs FRII

As a whole, FRI and FRIIs have different radio luminosities, environmental richness, and line emission strength

- We use the **CoNFIG sample** of radio-loud galaxies (Gendre et al. 2010 & 2012 *in prep*; 858 sources)
- K-S tests confirm different underlying distributions for FRI and FRII, for a variety of intrinsic parameters

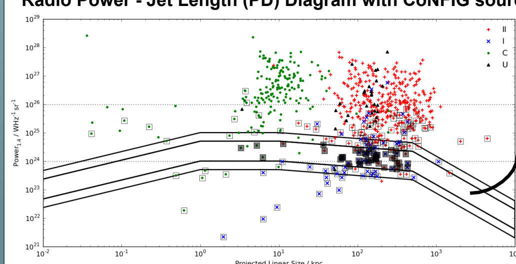


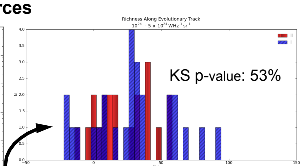
Example: Environmental richness as determined by the density of SDSS sources in a sphere of 1 Mpc, background-subtracted. Good statistics for z < 0.3. Total richness histogram shows FRIIs in poor environments and FRIs across a range of rich and poor environments.

FRI vs FRII along Evolutionary Tracks

But: do FRI and FRII sources along an evolutionary track have similar properties? (i.e. is it possible for FRII to evolve into FRI?)…

Radio Power - Jet Length (PD) Diagram with CoNFIG sources





…studies suggest yes.

By selecting out subsamples of FR sources along analytic evolutionary tracks (black lines; Kaiser & Alexander 1997; and Kaiser & Best 2007), it is found that these sources are likely to be from the same underlying distribution for richness (shown here) and emission line strength.

CoNFIG and UV / X-Ray Ratio

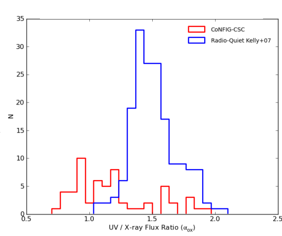
Radio-loud sources likely play a major role in heating the ICM

To test this, consider UV to X-ray flux ratio for the radio-loud CoNFIG sample and a radio-quiet sample from Kelly et al. 2007.

$$\alpha_{\rm ox} = -\frac{\log(f_x/f_{uv})}{\log(\nu_x/\nu_{uv})}$$

CoNFIG with Chandra Source Catalog & SDSS
- UV: SDSS u' band (350 nm)
- X-ray: Chandra ACIS (2.3 keV effective energy)
- 60 sources

Radio-Quiet (Kelly+ 2007)
- UV: SDSS (250 nm)
- X-ray: Chandra ACIS (2 keV)
- 174 sources



The CoNFIG radio-loud sources have a clear excess of X-ray flux, compared to the radio-quiet control sample

Assuming the majority of X-ray radiation comes from the heated ICM, the presence of jets may significantly contribute to the ICM heating. With the well-defined jet sizes of the CoNFIG sample, it is possible to constrain jet power.

Can this power make up the excess ICM heating?

Under progress: Only 60 CoNFIG sources used in this study, but a variety of X-ray data exists for ~220 CoNFIG sources and will better constrain the excess X-ray flux detected in radio-loud sources. Care must also be taken to consider primarily the heated environment, and not the jet or AGN. Watch this space.

Future Work

- Consider X-ray luminosity for separate FRI and FRII populations (i.e. binned as a function of radio luminosity). This will indicate efficiency of radio-loud environment feedback for different jet types and powers.
- With higher resolution follow-up observations from eMERLIN and EVLA, examine detailed jet morphologies along the FR divide for signs of environmental influence or evolution from FRII to FRI
- Case-by-case study of 'unusual' sources: high-luminosity FRI sources, low-luminosity FRIIs, bent or distorted jets from environmental influence, etc.
- Does knowledge of a galaxy's location on the PD diagram (thus on the evolutionary track) and its local environment resolve these outliers?

References

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