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.

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, 885 sources)
• K-S tests confirm different underlying distributions for FRI and FRII, for a variety of intrinsic parameters

FRII

FRI

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 FRIs in poor environments and FRIIs 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

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.

\[
\frac{\alpha_{uv}}{\alpha_{x}} = \frac{\log(\frac{I_{uv}}{I_{x}})}{\log(\frac{I_{x}}{I_{uv}})}
\]

CoNFIG with Chandra Source
• 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?

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 FRI to FRII.
• 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
• Gendre et al. 2012 in prep.