The cluster environment of high redshift FRI radio galaxies

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Radio morphologies, Fanaroff & Riley (1974)

- **FRIs**: Jet decelerates to $v \ll c$ at $\sim 1\text{kpc}$
- **FRII**: Relativistic jet on scales $\sim 100\ \text{kpc}$ up to $\sim 1\text{Mpc}$
- **FRI / FRII divide**: $L_{178\ \text{MHz}} < 2 \times 10^{26} \ \text{W Hz}^{-1}$

Zirbel, 1996
FRIs

Locally:

• “starved quasar”: faint optical nuclear emission, Chiaberge et al. 1999, Leiptzki et al. 2009, Baldi et al., 2010

• Host galaxy: mainly giant elliptical (cD) with the most massive BHs, Donzelli et al. 2007, Zirbel & Baum 1997,

• 70% of them in rich clusters, at variance with FRIIs; Hill & Lilly 1991; Zirbel 1997.

At high redshift:

• The most distant FRI known (z~1), Snellen & Best 2001

• FRIs candidates at z~1-2, Chiaberge et al. (2009)
FRIs at $z \sim 1-2$  Why?

Clusters
- Beacons for HIGH REDSHIFT CLUSTERS
- Link between $z > \sim 2$ protoclusters and clusters
- Formation and evolution of the red sequence

AGN
- Cosmological evolution unknown
- Hints for strong evolution up to $z \sim 0.7$ (Sadler et al., 2007)
- Formation and evolution of the most massive galaxies and Bhs
- Feedback: BH accretion - environment
The sample

- **FRIs** candidates sample $z \sim 1-2$, Chiaberge et al., 2009 (C09)
- **COSMOS** field (2sq degree)
- Mainly based on radio (FIRST) and optical selection, NOT on redshifts

**Redshifts**

- **Accurate redshifts** (Baldi et al., submitted) are required to redefined the sample in radio power
- **A few spectroscopic-z**: zCOSMOS, Lilly et al., 2007; Magellanic, Trump et al., 2007
- **Photo-z**: SED modeling (stellar populations and dust components)
Cluster around LLRGs?

Cluster environment around Low Luminous Radio Galaxies? (FRIs)

The C09 sample redefined in radio power

- 22 LLRGs
- 11 High Luminous Radio Galaxies (HLRGs)
Two cluster candidates

Figure: Field of COSMOS-FRI 01, cluster from visual inspection

Figure: Field of COSMOS-FRI 026, cluster?
Cluster search techniques

- Generally they find **only virialized systems**
- **SZ effect**, only a few at $z>1$ (e.g. Marriage et al., 2001; Song J. et al., 2012)
- **X-ray** (Rosati et al., 2002): $B \sim (1+z)^{-4}$
- **Red-sequence**: just forming between $z \sim 1-2$
  - **Color techniques** (e.g. Papovich et al, 2008, $z>1.2$)
  - **Search around radio galaxies** (Miley & De Breuck 2008, Galametz et al. 2012) only FRIIs adopted
Poisson Probability Method (PPM)
Castignani et al., in prep

A new method is required

- **Differential counts**: cumulative number counts affected by high Poissonian fluctuations
- **NO virialization** required
- $z \sim 1-2$: redshift desert $\rightarrow$ method based on photo-z

PPM $\rightarrow$ photo-z and differential number counts
PPM, how does it work?
PPM, how does it work?

number counts within a redshift slice $\Delta z$
centered at a given redshift $z$
PPM, how does it work?

Only the closest consecutive $P(>N_{\text{avg}}) > 0.4$ annuli are selected.
PPM, how does it work?

cumulative number counts for the selected annuli: $P(>N_{bg}) = ...$

$3\sigma$ overdensity
PPM, how does it work?

PPM plot legend: Overdensities

- > 2 sigma
- > 3 sigma
- > 4 sigma
PPM plots

>4σ, LLRG
PPM plots

$>4\sigma$, LLRG
PPM plots

>2σ, LLRG
Detection results

Technicalities: Smoothing procedure, overdensities evaluated at $\Delta z=0.28$ within photo-z uncertainties

FRIs candidates + PPM: Highest efficiency in finding high-z clusters!

- LLRGs: $14/22 \rightarrow 64\%$
- HLRGs: $7/11 \rightarrow 64\%$

...in agreement with what found locally
Conclusions

FRIs plus PPM → z~1-2 cluster search around FRIs candidates

- 64% cluster detection success
- High redshift FRIs are in dense environment, as found locally

Future work...

- Weak lensing signal from the stacking of our cluster candidates (in progress...)
- CM plots, red sequence??
- PPM can be applied to wide field surveys, e.g. SDSS
- Chandra Deep field(s) North/South, SDSS Stripe 82:

~3000 FRIs expected → cosmological and statistical studies
The sample. Chiaberge et al., 2009 (C09)

- $L_{\text{radio}}$ vs z scatter plot $\rightarrow$ flux limited selections fail at z~0.7
- COSMOS (Scoville et al 2007), 2sq deg: deep and broadband
- selection NOT based on redshifts!!!
Gravitational arcs in the field of COSMOS-FRI 01!!

Figure: COSMOS-FRI 01, arcs