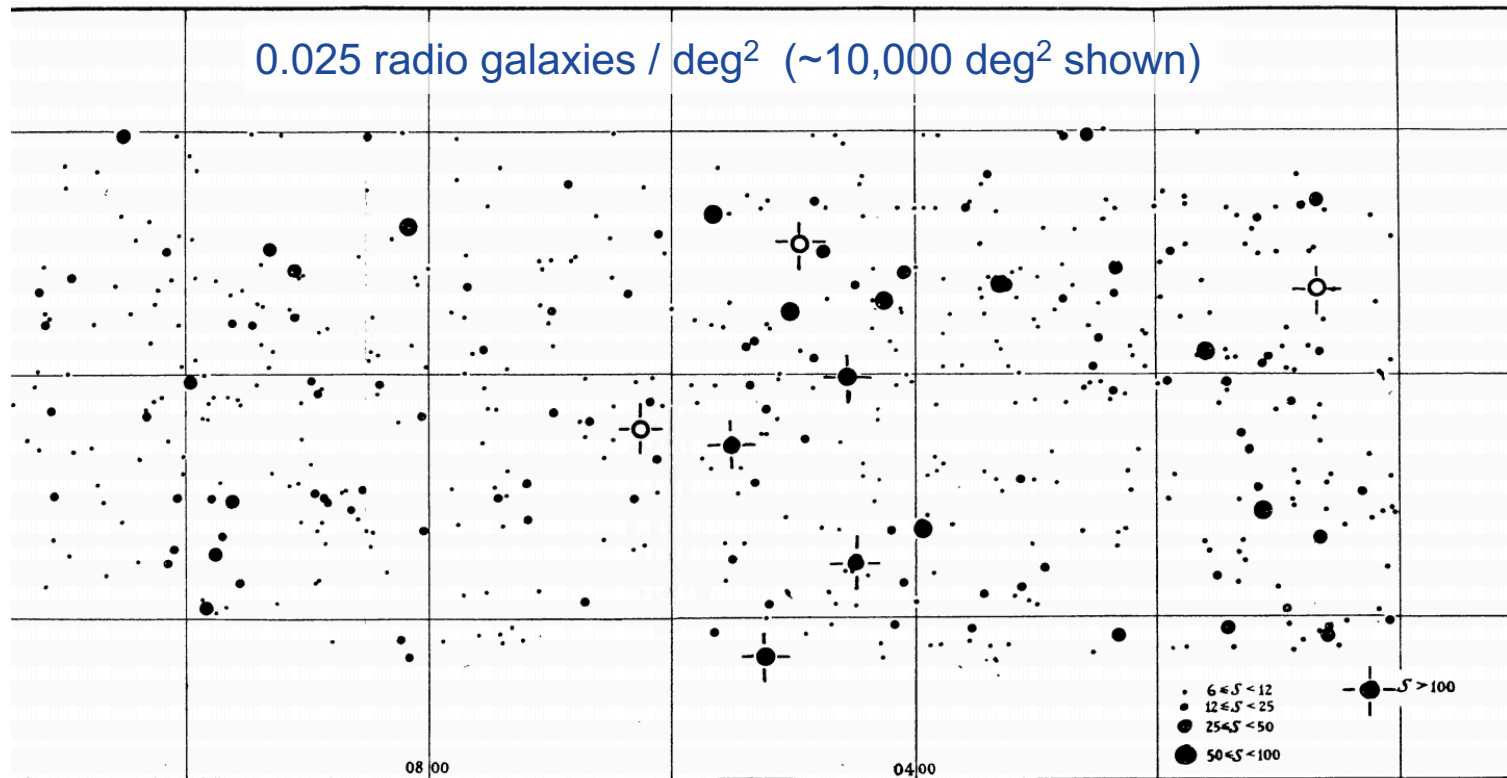


RADIO-GALAXY PHYSICS AND ENVIRONMENTAL IMPACT

Judith Croston

with thanks to Beatriz Mingo, Judith Ineson, Martin Hardcastle, Brendan Webster, LoTSS DR1: T. Shimwell, C. Tasse, W. Williams, K. Duncan, J. Sabater, P. Best, H. Röttgering, & many more...

Radio galaxies at metre wavelengths (1961)



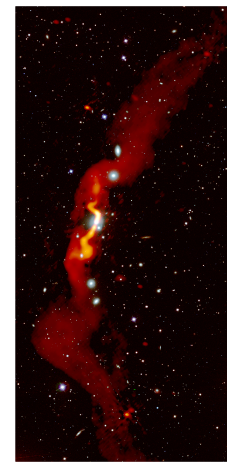
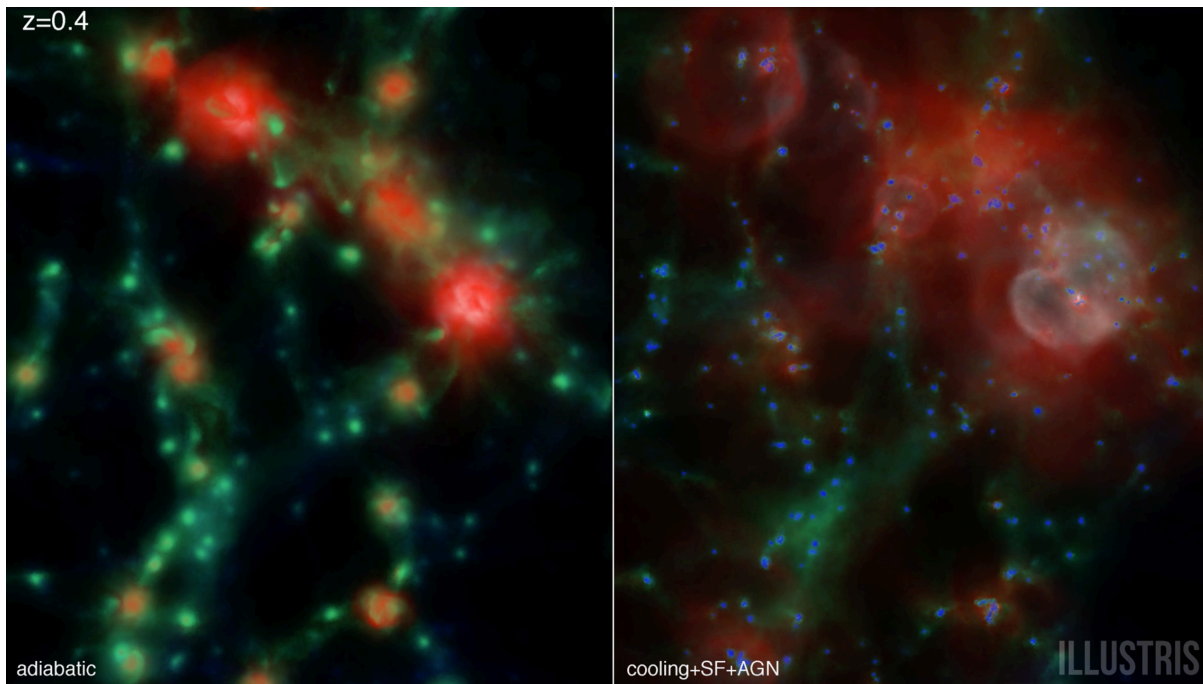
Radio galaxies at metre wavelengths (2019)

>500 radio galaxies / deg² (~15 deg² shown)



LoTSS (Shimwell+ 2019)

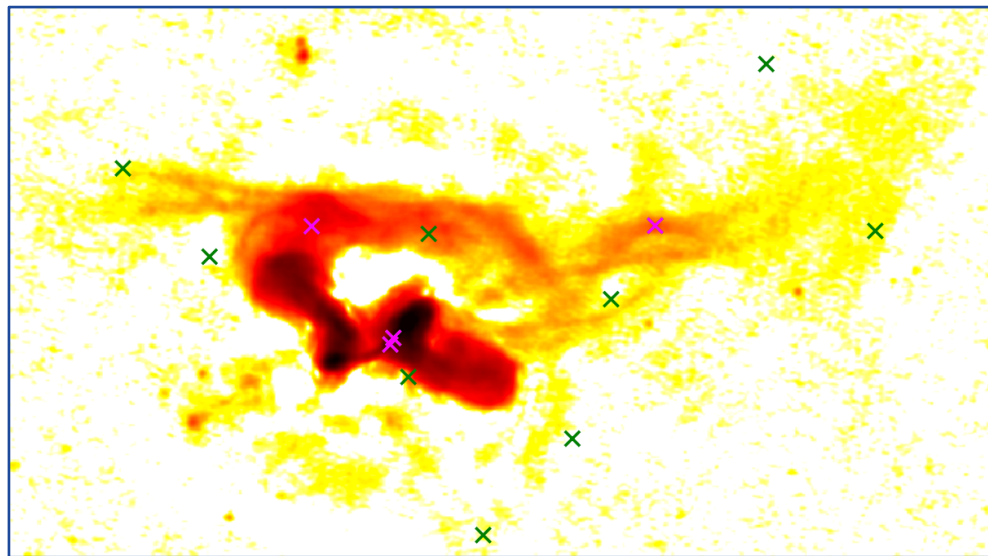
Radio AGN and galaxy evolution



(Illustris collaboration)

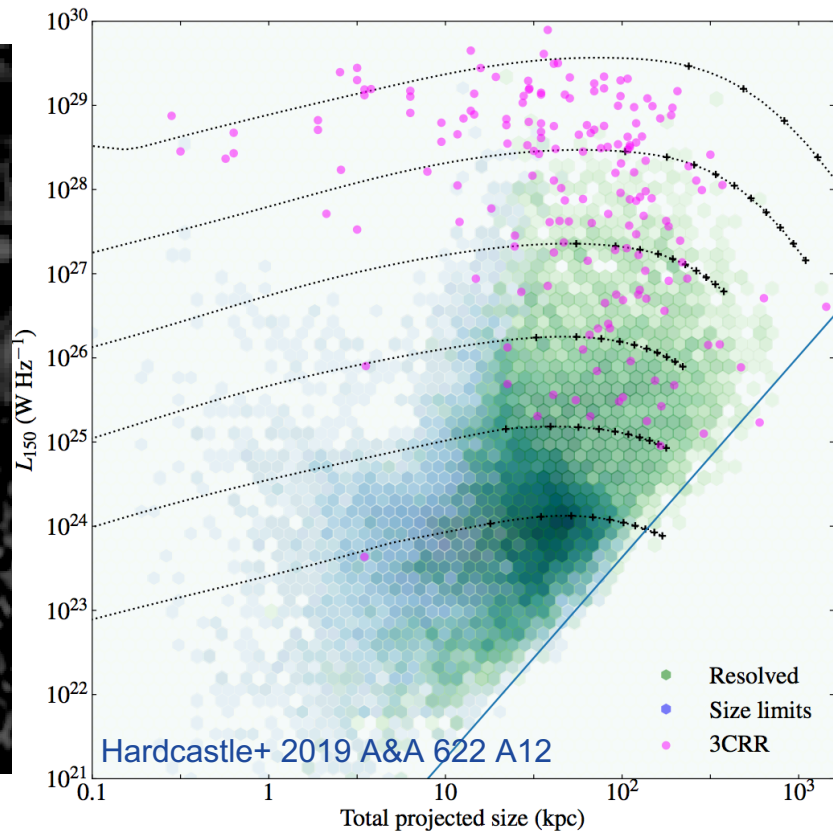
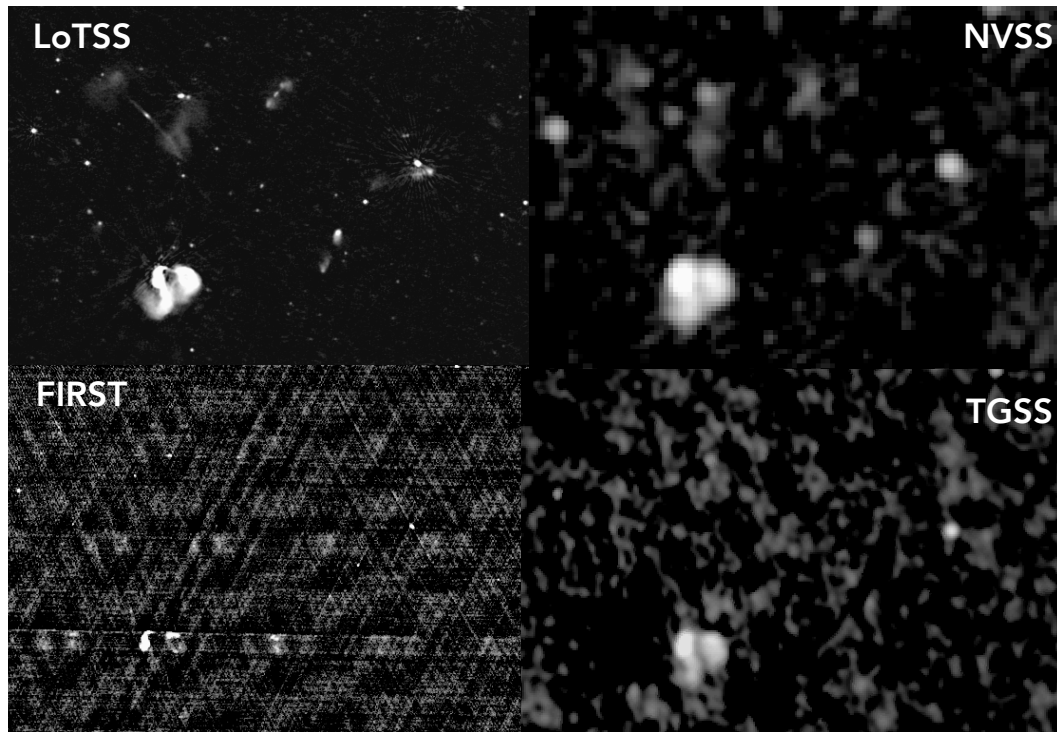
What do we still have to learn?

- Life cycles of radio galaxies
- Physics and inference of energetic impact
- Populations, environments and evolution

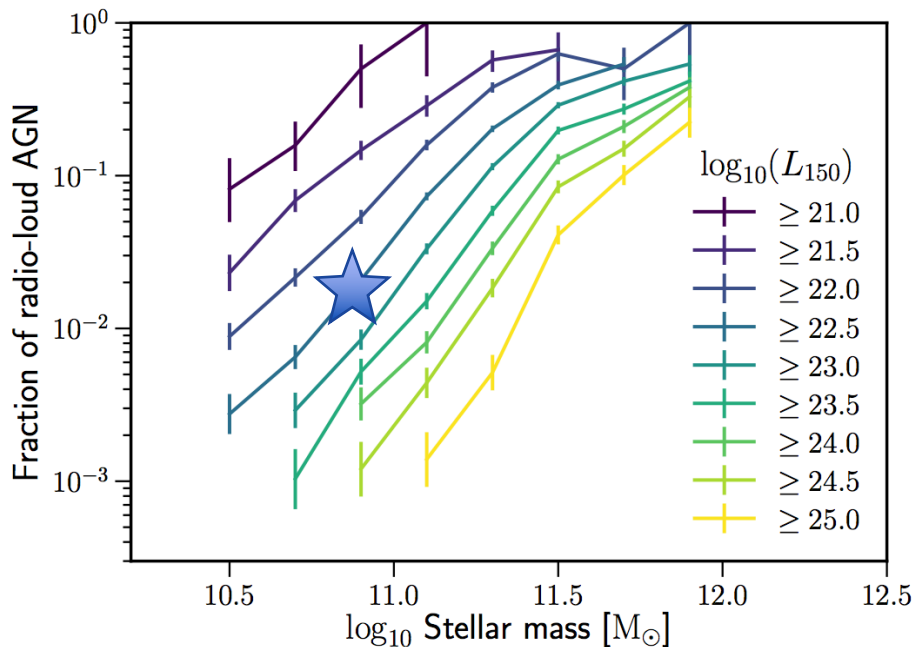


Hardcastle+ (in prep)

The LoTSS view of radio galaxies

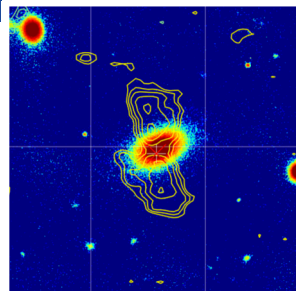


Life cycles of radio galaxies

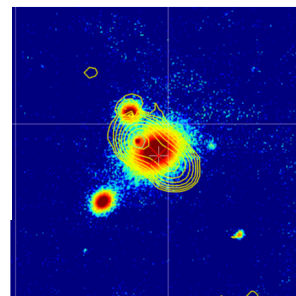


Sabater+ 2019

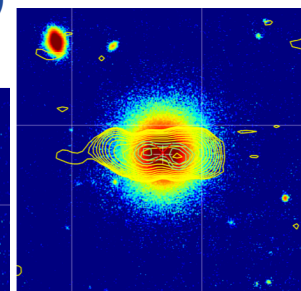
MW-like galaxies switched on at 10^{24} W/Hz $>$ 0.1% of the time, \sim few Myr \Rightarrow 10-kpc jets ($E \sim 10^{56}$ erg)



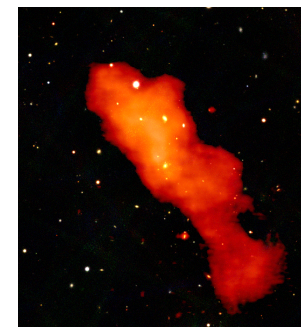
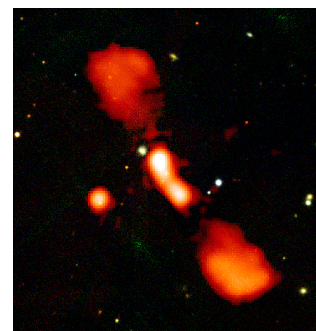
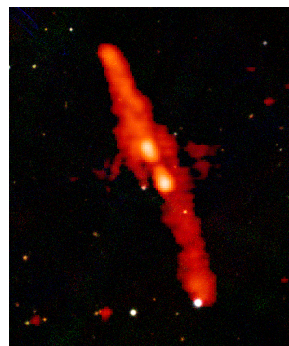
Small (young?)
radio galaxies



Restarting & remnant
radio galaxies

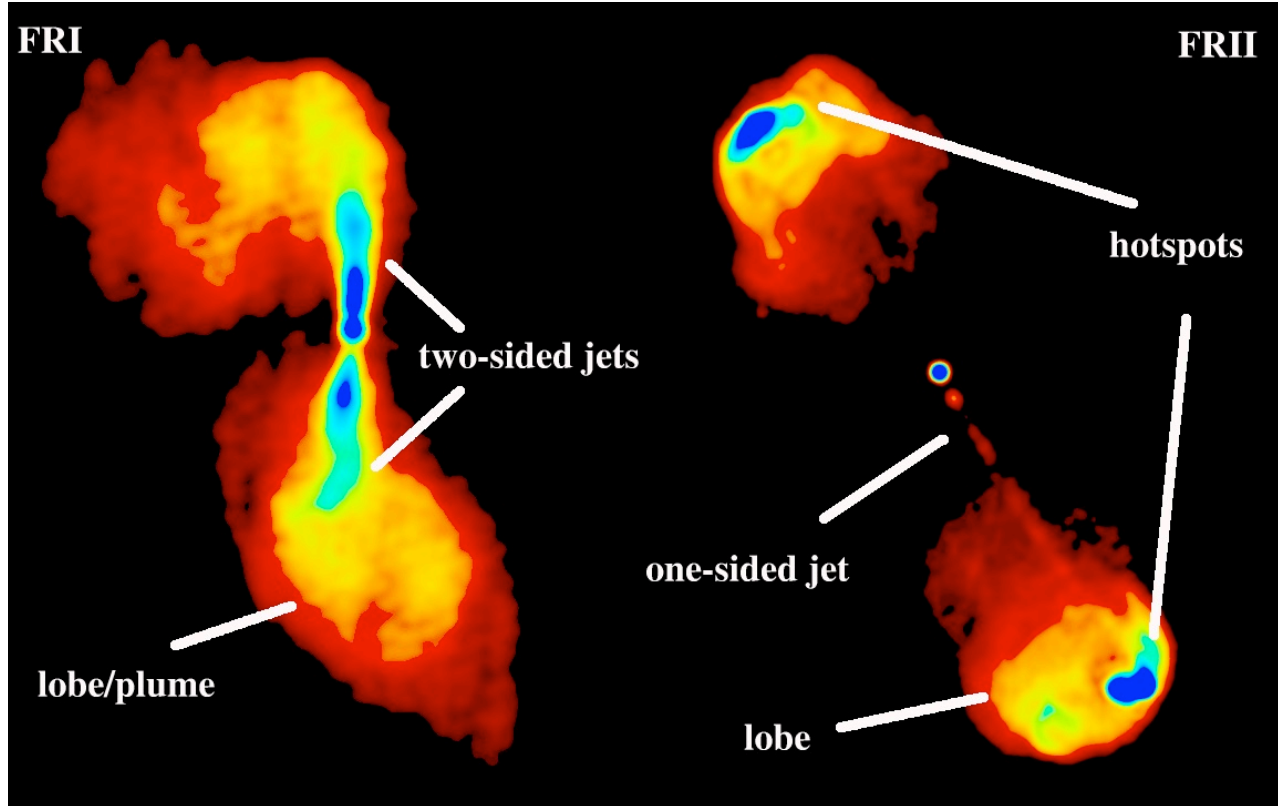


Webster+ in prep

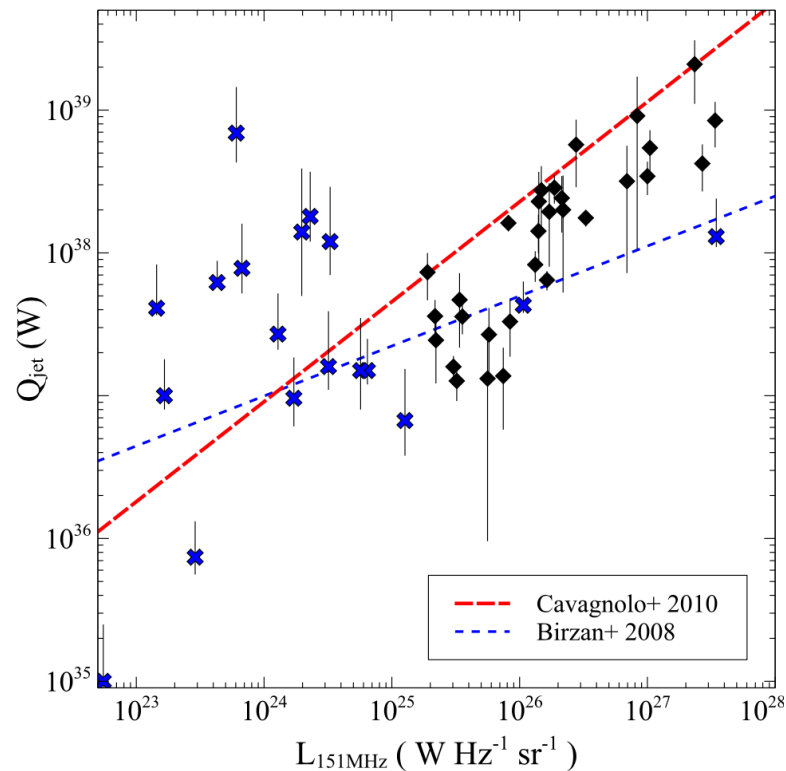
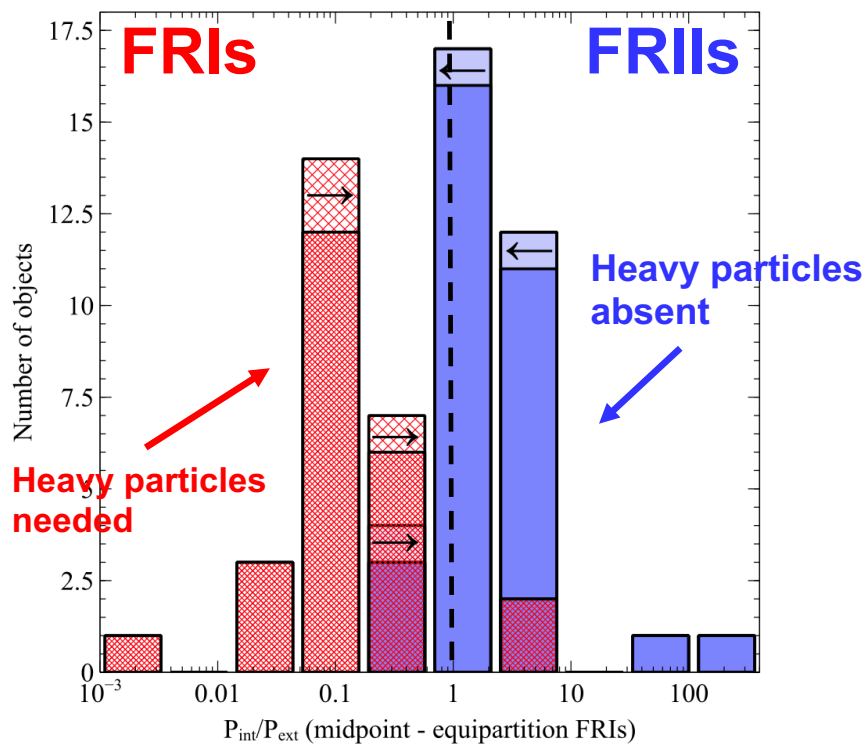


see Brienza+ 2016, Mahatma+ 2018, 2019

Do we still have new things to learn about “ordinary” radio galaxies?

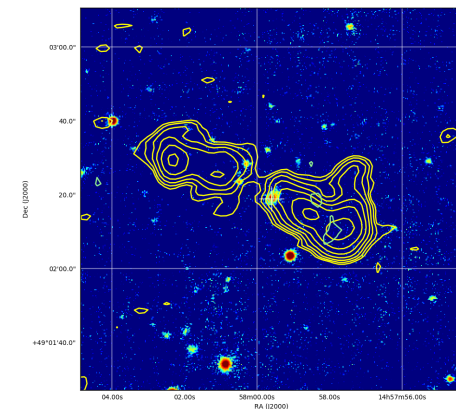
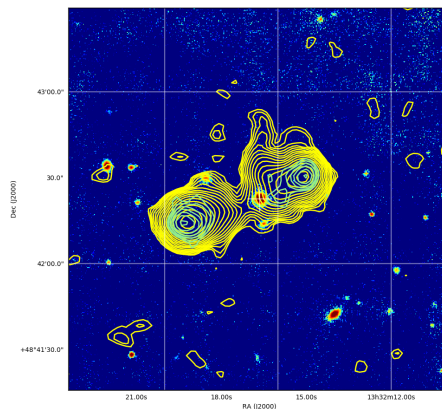
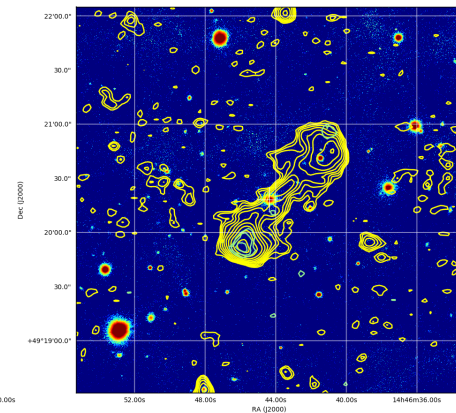
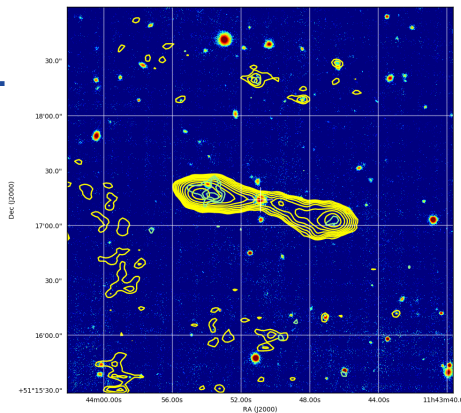
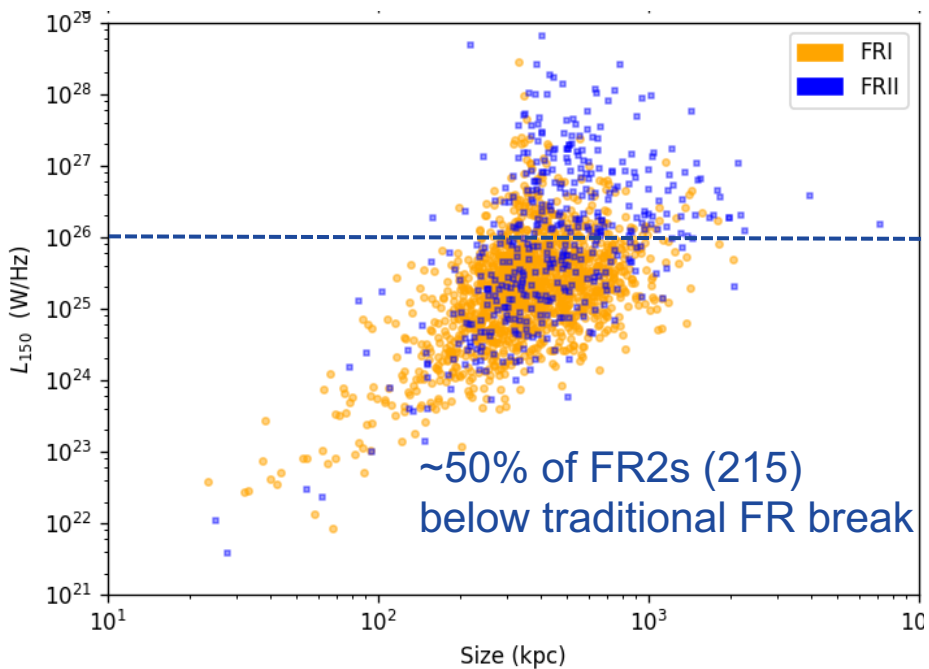


Morphology matters for energy estimates



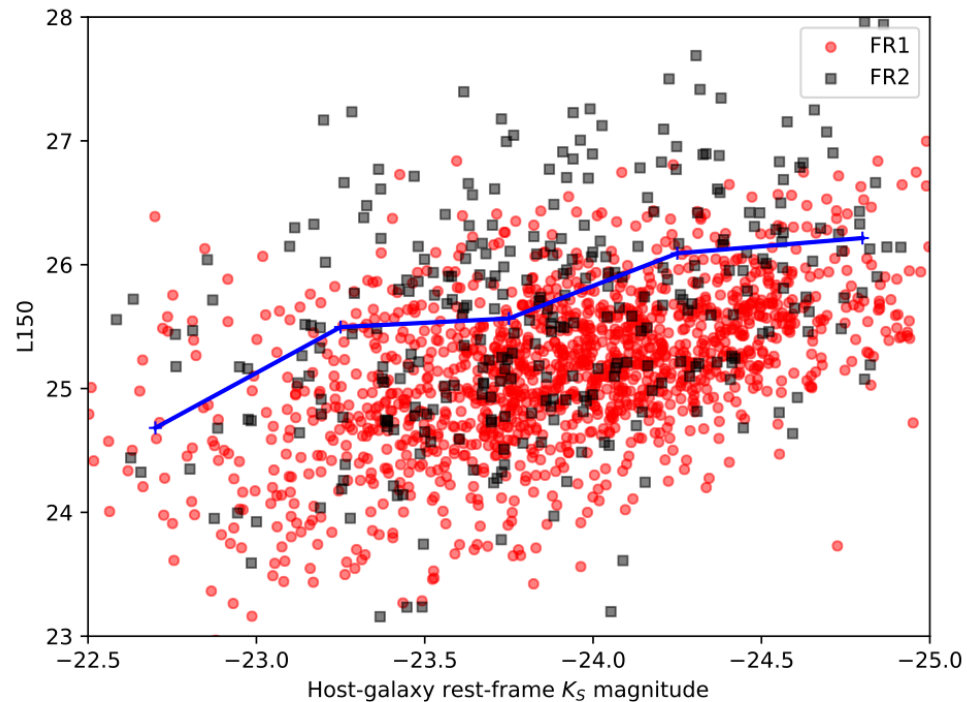
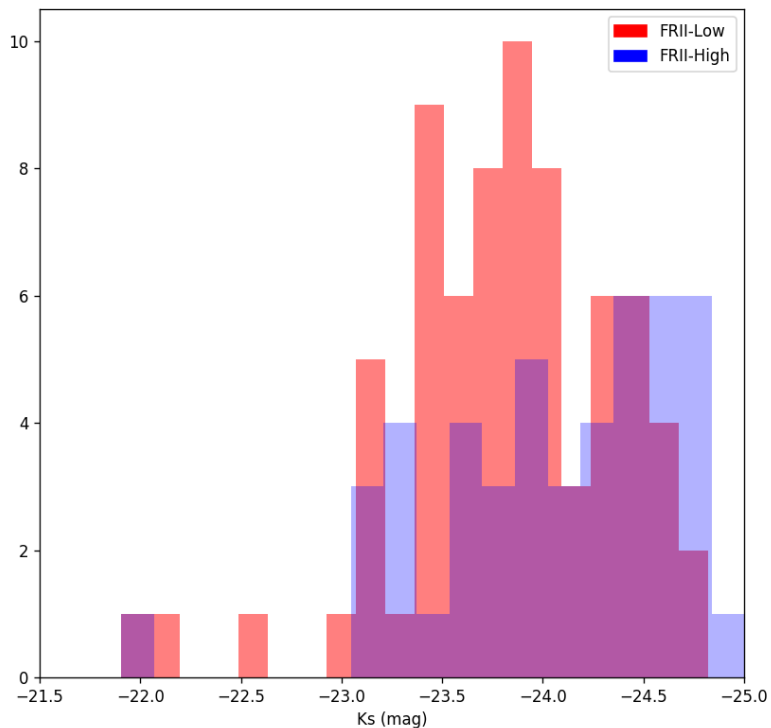
A new population of low-luminosity FRIIs?

B. Mingo in prep.



The role of jet/environment interaction

B. Mingo in prep.

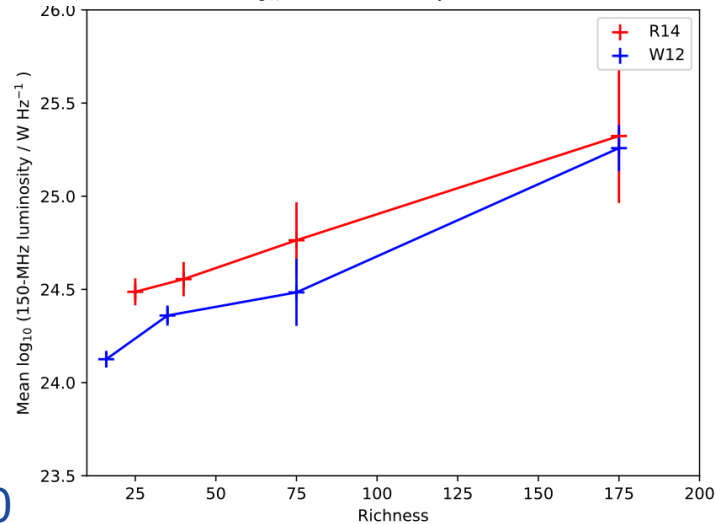
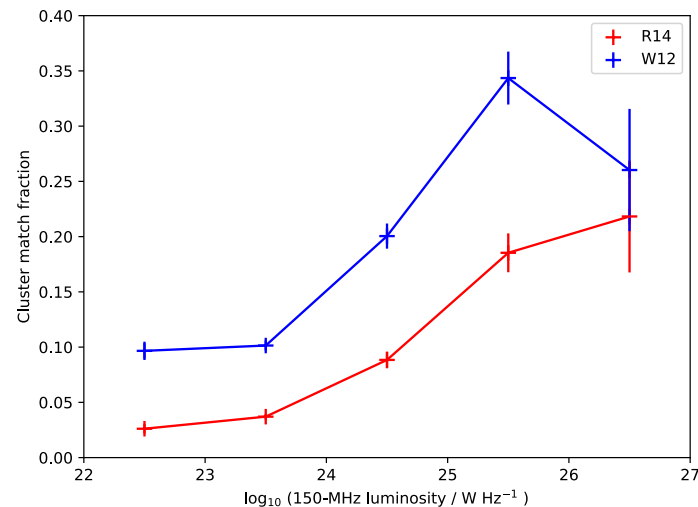


cf Ledlow & Owen 1996

Large-scale environment matters

- LoTSS DR1 AGN matched with SDSS cluster catalogues
- 900 jet/cluster matches
- Cluster match fraction and environmental richness both linked to radio luminosity (cf Ineson+ 2015)
- Most radio galaxies (even at high luminosity) are in galaxy groups.
- Environment depends on FR class **and** accretion mode

Croston+ 2019 A&A 622 A10



Some future prospects for AGN with LoTSS

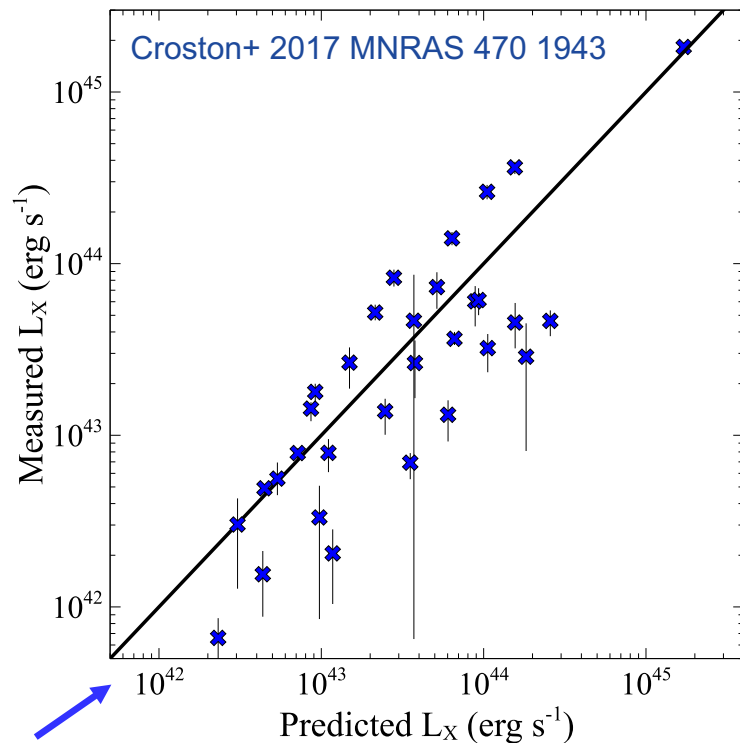


The Open
University

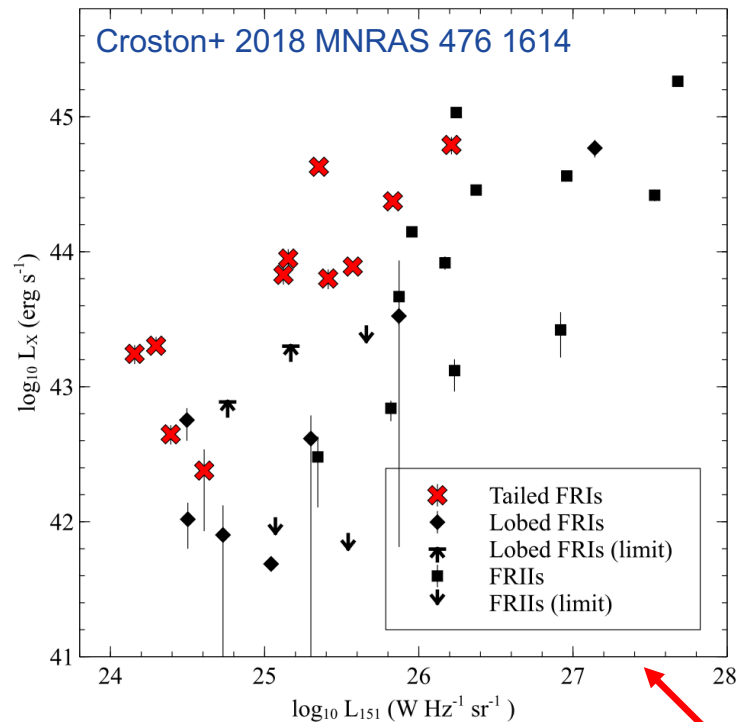
50
YEARS

- Morphological and size evolution as a tracer of environmental changes (FRIs at $z \sim 2$!)
- Determining energetic impact at $z > 1$
- Finding and characterizing baryon distributions of group-scale halos at $z > 1$ (Croston+ 2017 MNRAS 470 1943)
- Life cycles as a function of host galaxy, wider environment, and z
- Robustly link together AGN evolution and cluster relic and halo emission.

Finding high-z groups with radio surveys



Morphologically regular FRIs
("classical doubles")



Tailed FRIs



Summary

- Radio+X-ray studies over the last decade have provided systematic view of radio-galaxy physical conditions.
- FRI and FR II radio galaxies have different particle content, likely caused by disruption and entrainment in FRIs
- Radio galaxies mainly inhabit galaxy group environments
- Sensitive low-frequency surveys are complicating the picture with new populations, but we are learning a lot about life cycles
- Excellent prospects to determine evolution of key properties and high redshift feedback role of radio AGN with LoTSS