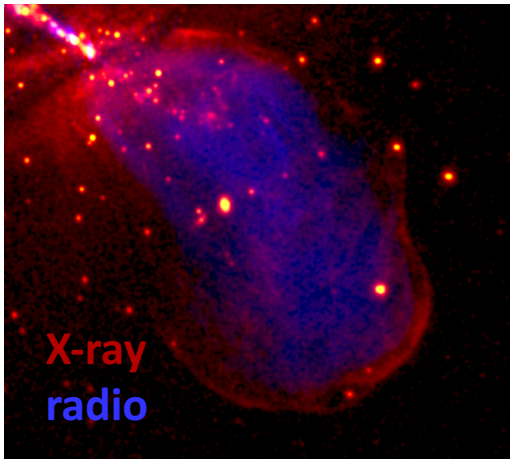
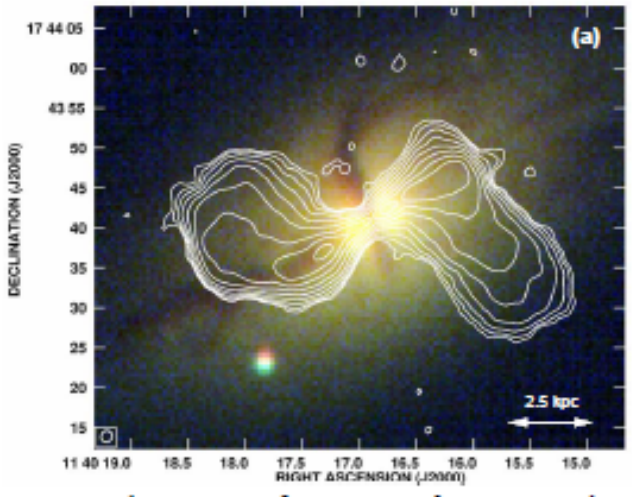
Jet populations, environments & what we're learning from LOFAR surveys

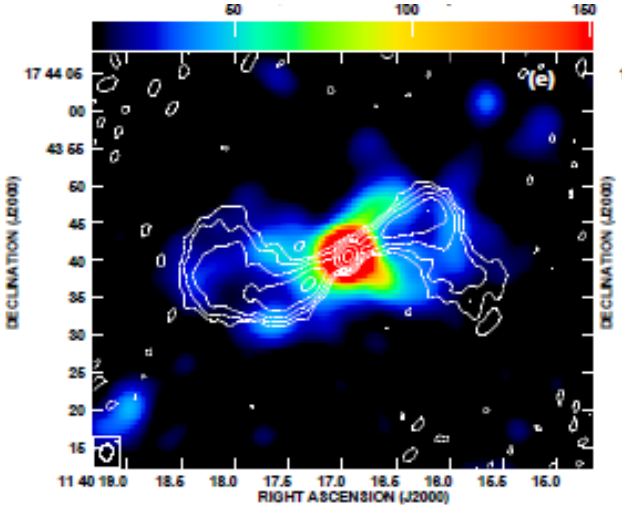
Judith Croston

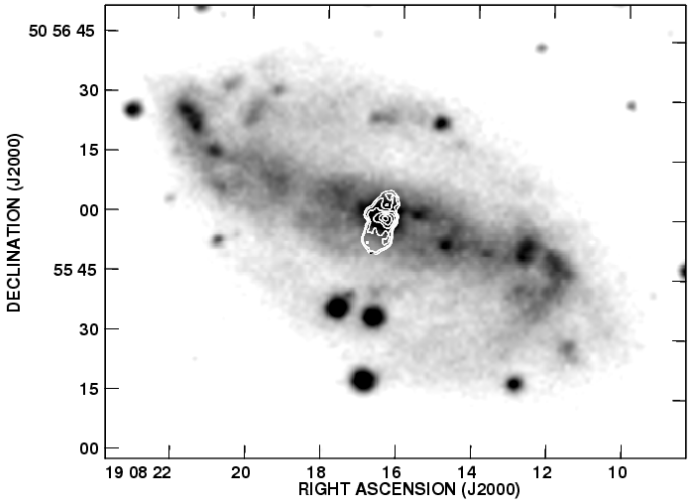
Thanks to: B. Webster, J. Ineson, B. Mingo
LoTSS DR1: T. Shimwell, M. Hardcastle, C. Tasse, W. Williams, K. Duncan, J. Sabater, P. Best, H. Röttgering and many others…

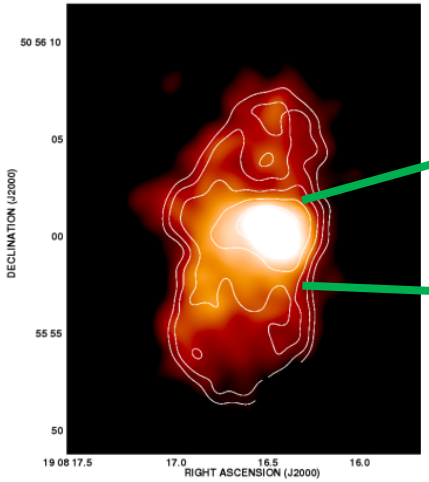
Radio jets have measurable impact on galaxy (few kpc) scales

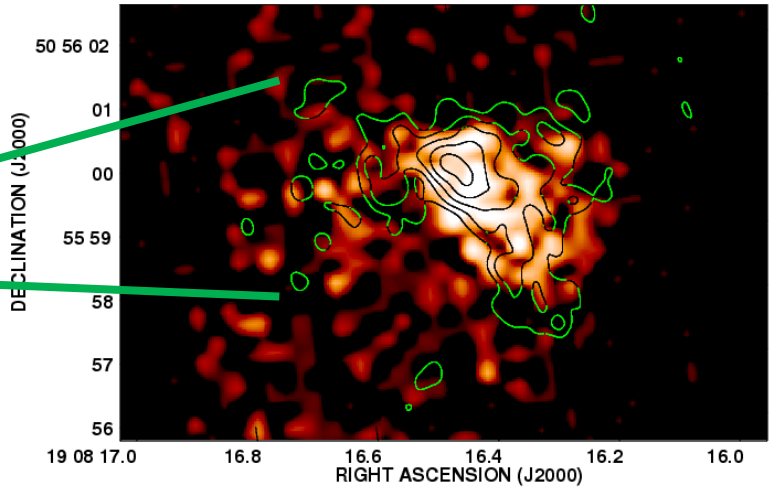






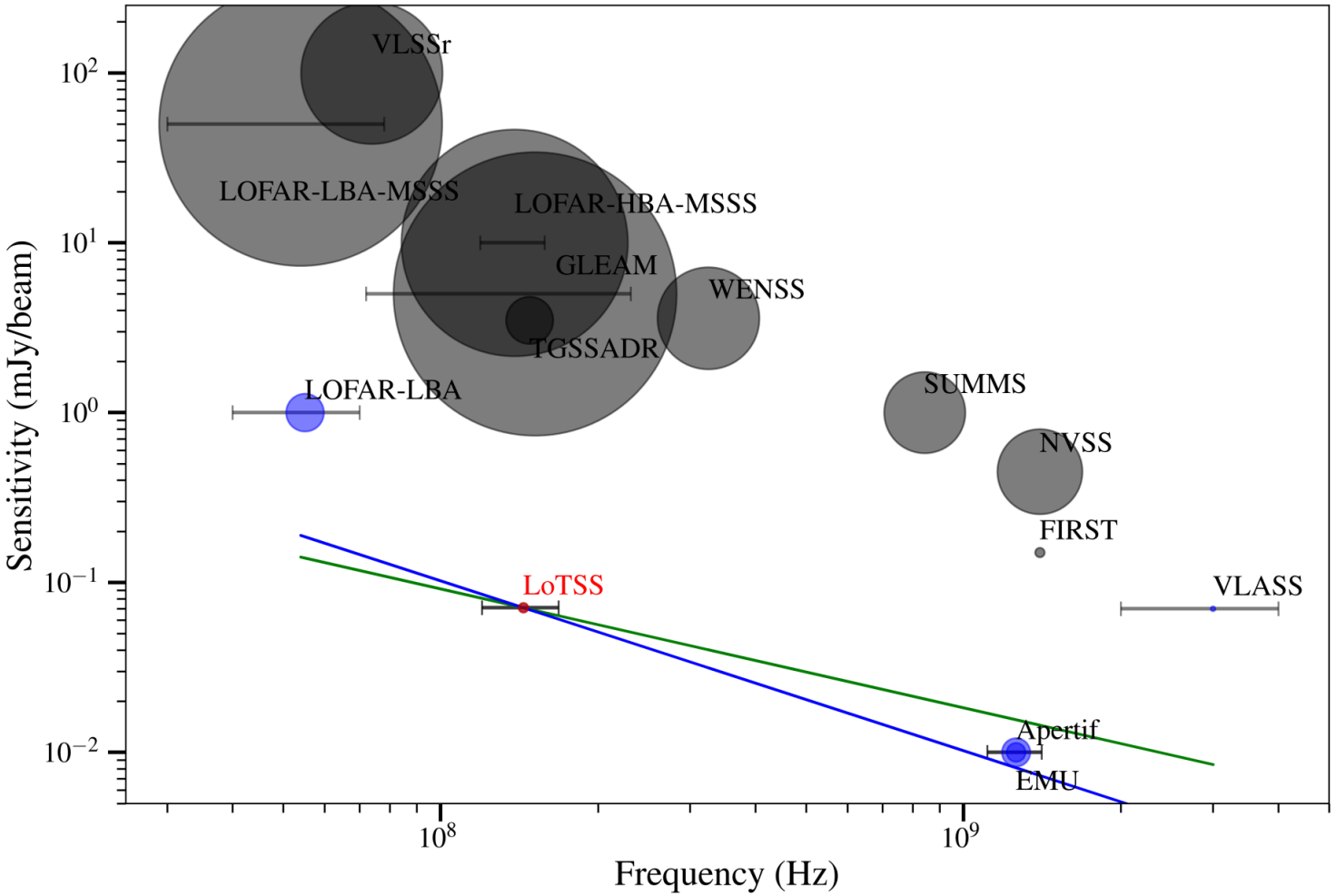




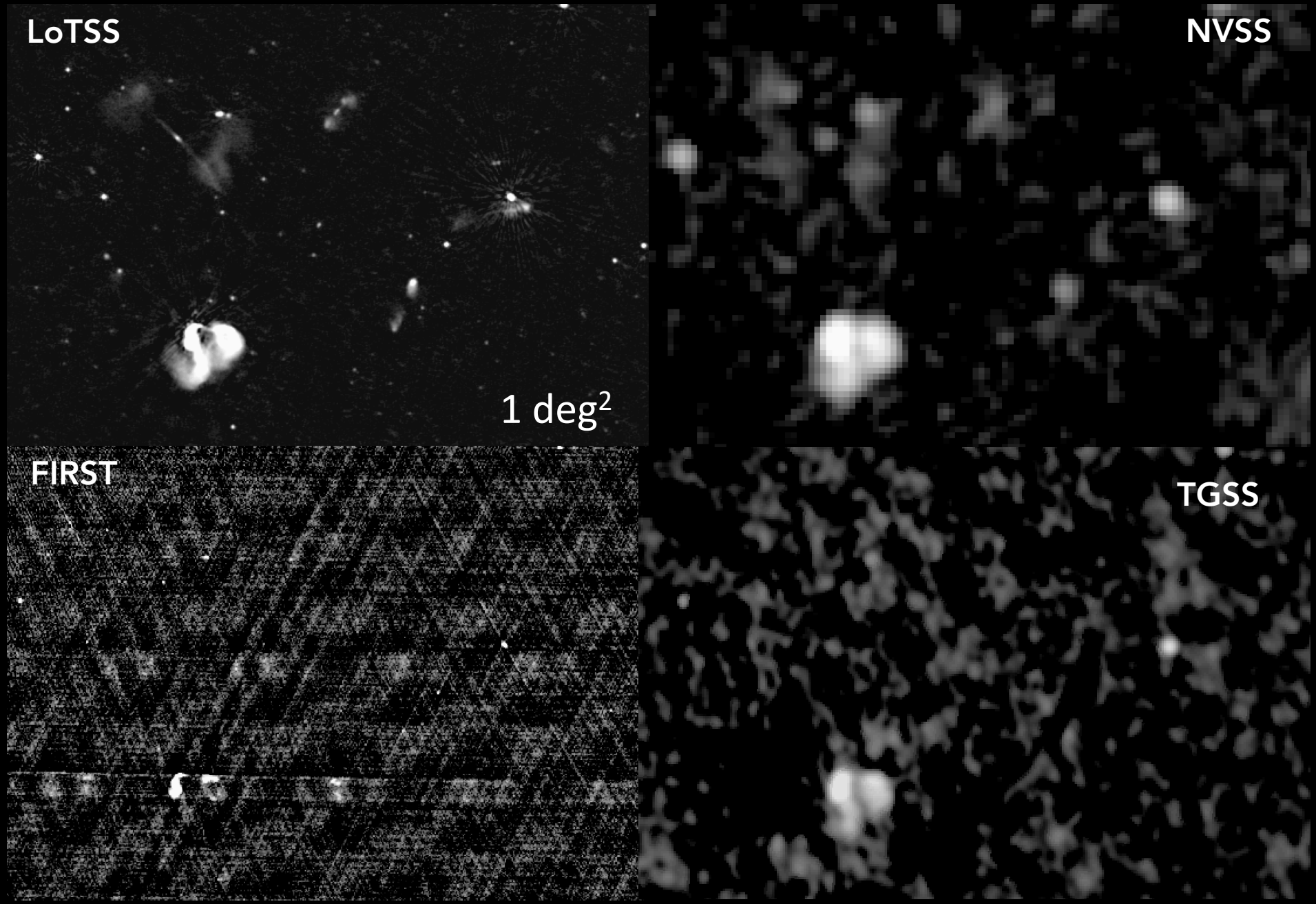


JC et al. 2009 MNRAS 395 1999, JC et al. 2007 ApJ 660 191, Heesen, JC et al. 2014 MNRAS 439 1364, JC et al. 2008 ApJ 688 190

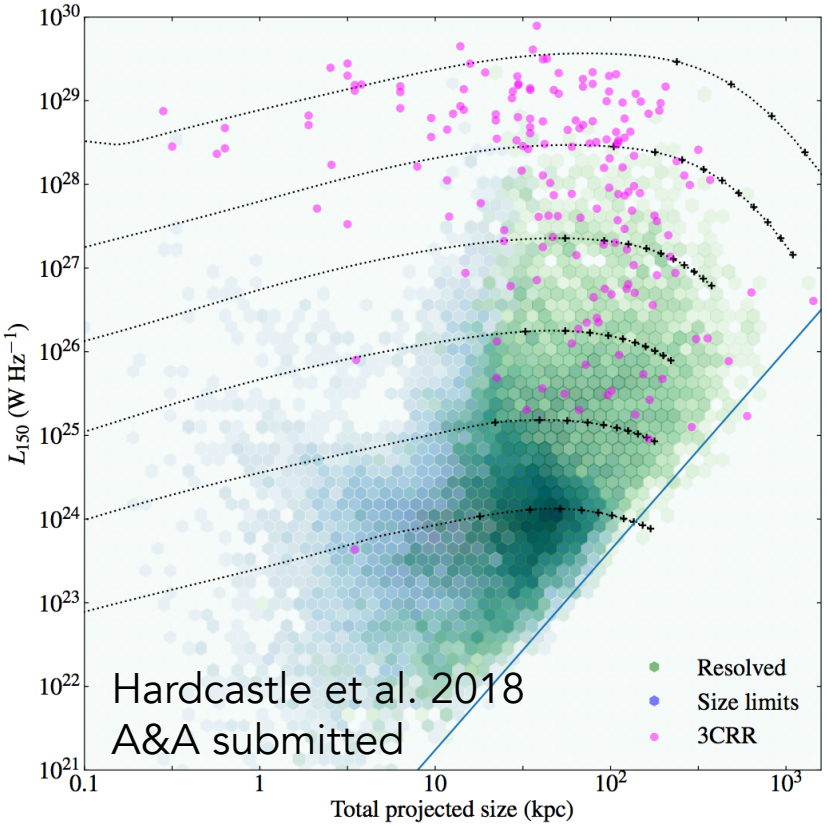
The LOFAR Two-Metre Sky Survey (LoTSS)

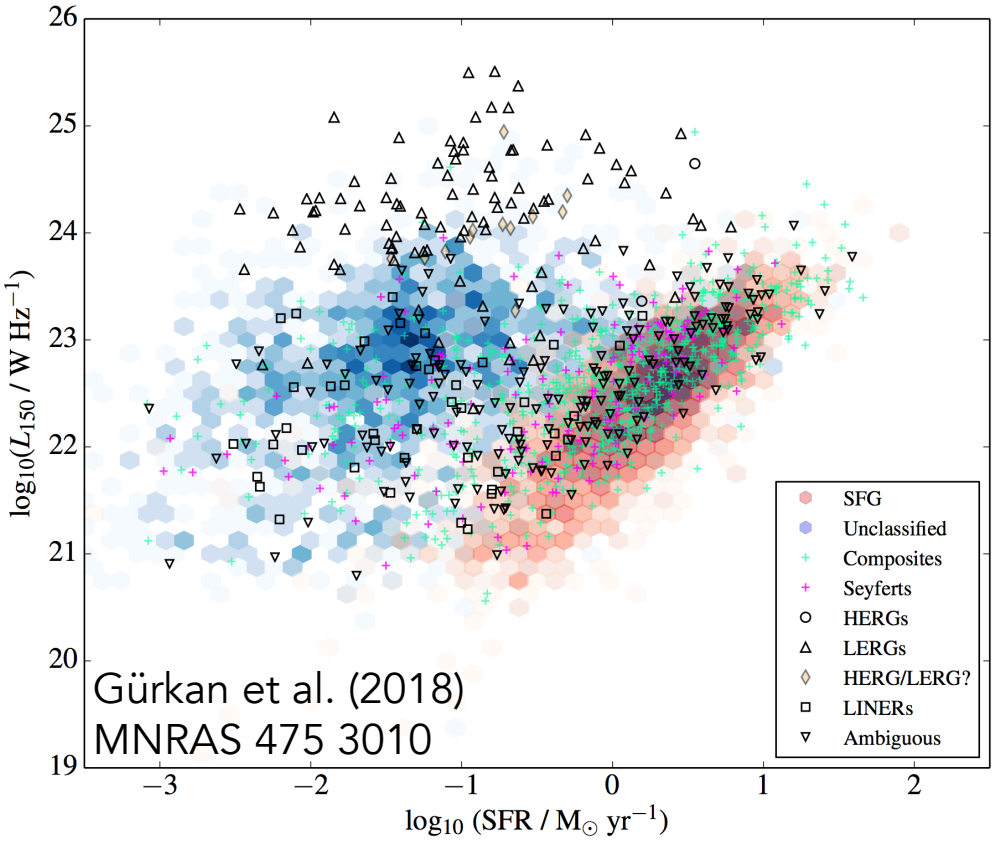


LoTSS Data Release 1: Shimwell et al. (2018, A&A, submitted),
Williams et al. (2018, A&A, submitted), Duncan et al. (2018, A&A, in press)


LoTSS
1 deg2
NVSS
FIRST
TGSS

The LoTSS AGN population



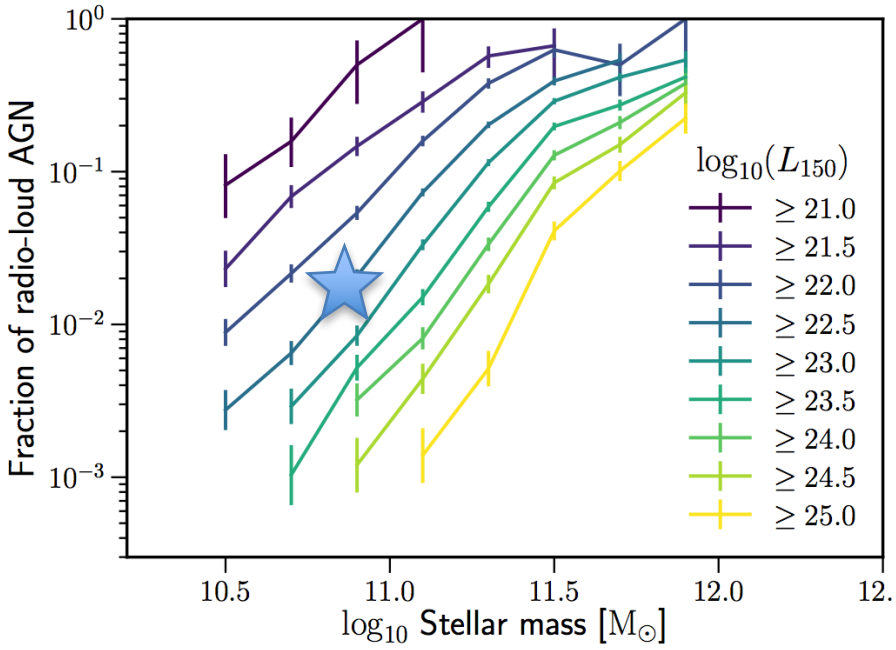


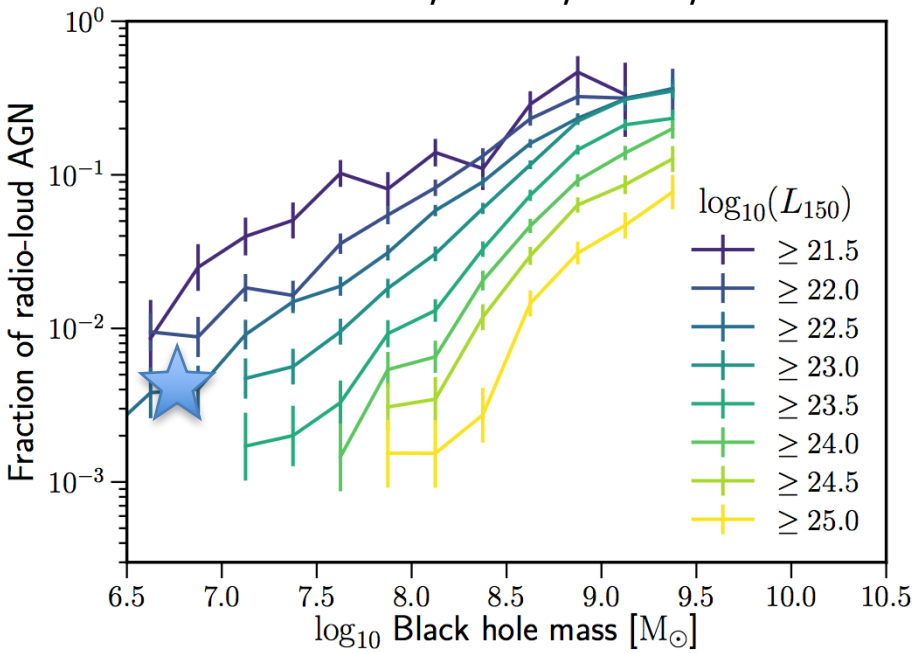
70% of LoTSS AGN have sizes < 20 kpc: these span a wide range of luminosity and host galaxy properties (mainly $M_* > 10^{10}$ $M_\odot$)
(cf. Baldi+ 2015 A&A 576 38, Sadler+ 2014 MNRAS 438 796)

Radio "excess" common – what fraction of these are jets?

LoTSS AGN at z<0.3

Sabater et al., 2018, A&A, submitted



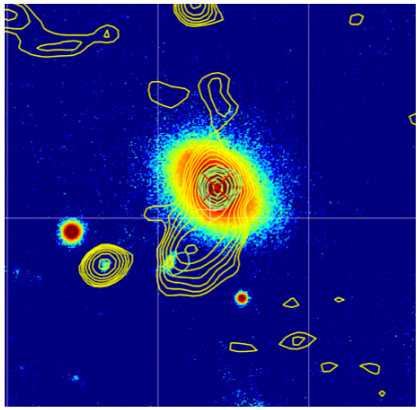


100% of galaxies with ~ log(M_*) = 11.0 host a radio-loud AGN

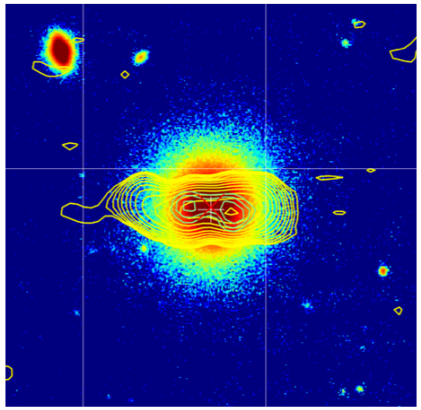
M_* appears to be a stronger driver of AGN activity than M_{BH}

MW-like galaxies switched on at 10^{24} W/Hz > 0.1% of the time, ~few Myr = typical lifetime of 10-kpc jets (E ~ 10^{56} erg)

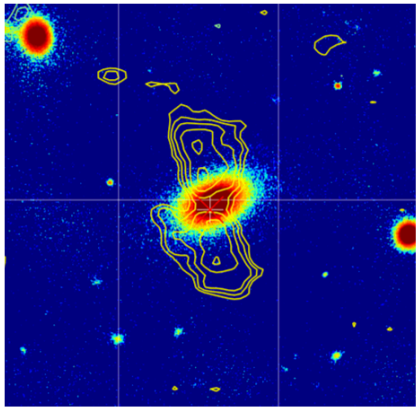
Galaxy-scale jets in LoTSS



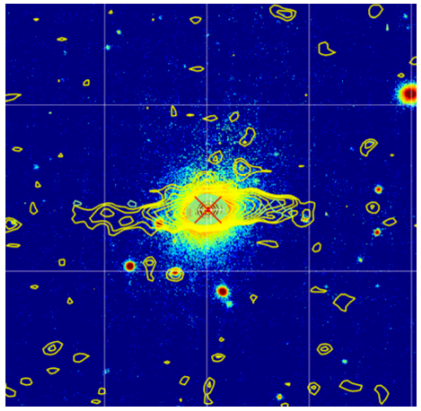
(b) ILTJ120326.62+545201.9



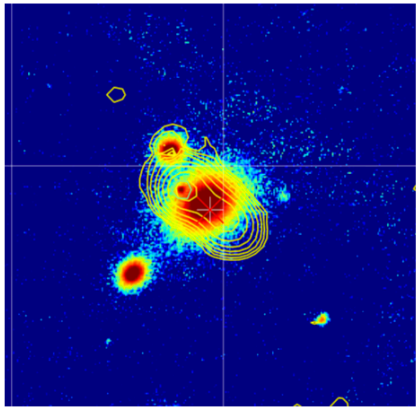
(c) ILTJ120645.21+484451.1



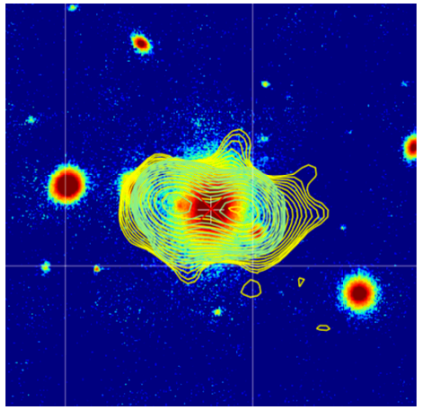
(e) ILTJ122037.82+473910.2



(f) ILTJ124627.85+520222.1

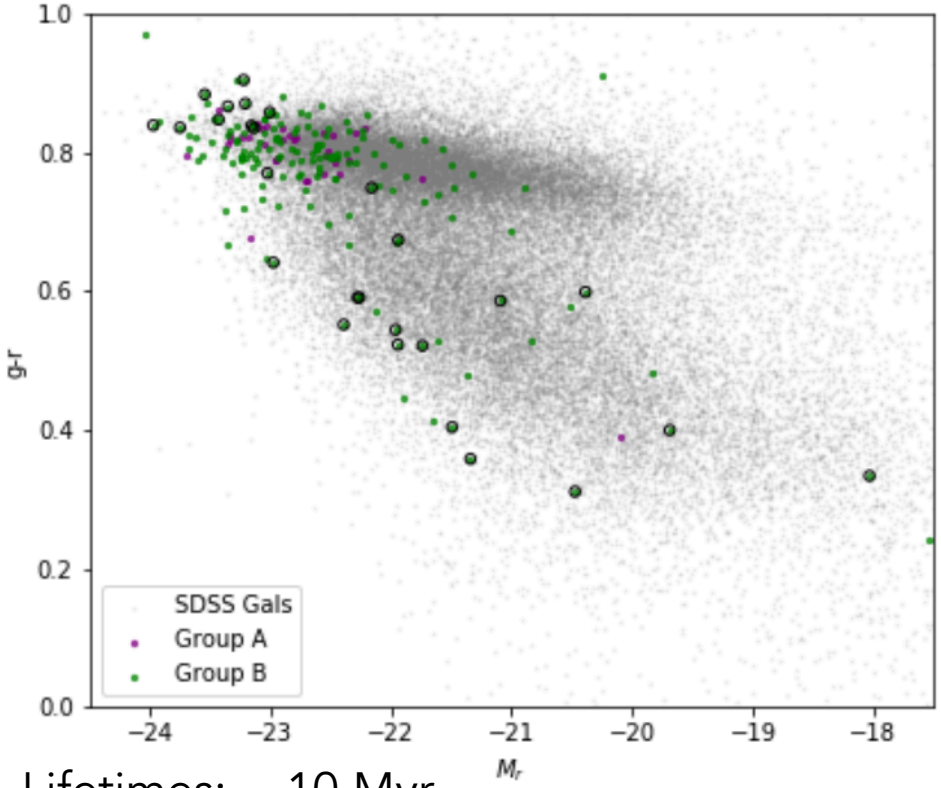


(h) ILTJ130148.36+502753.3



(i) ILTJ145604.90+472712.1

Webster et al., in prep



Lifetimes: ~ 10 Myr

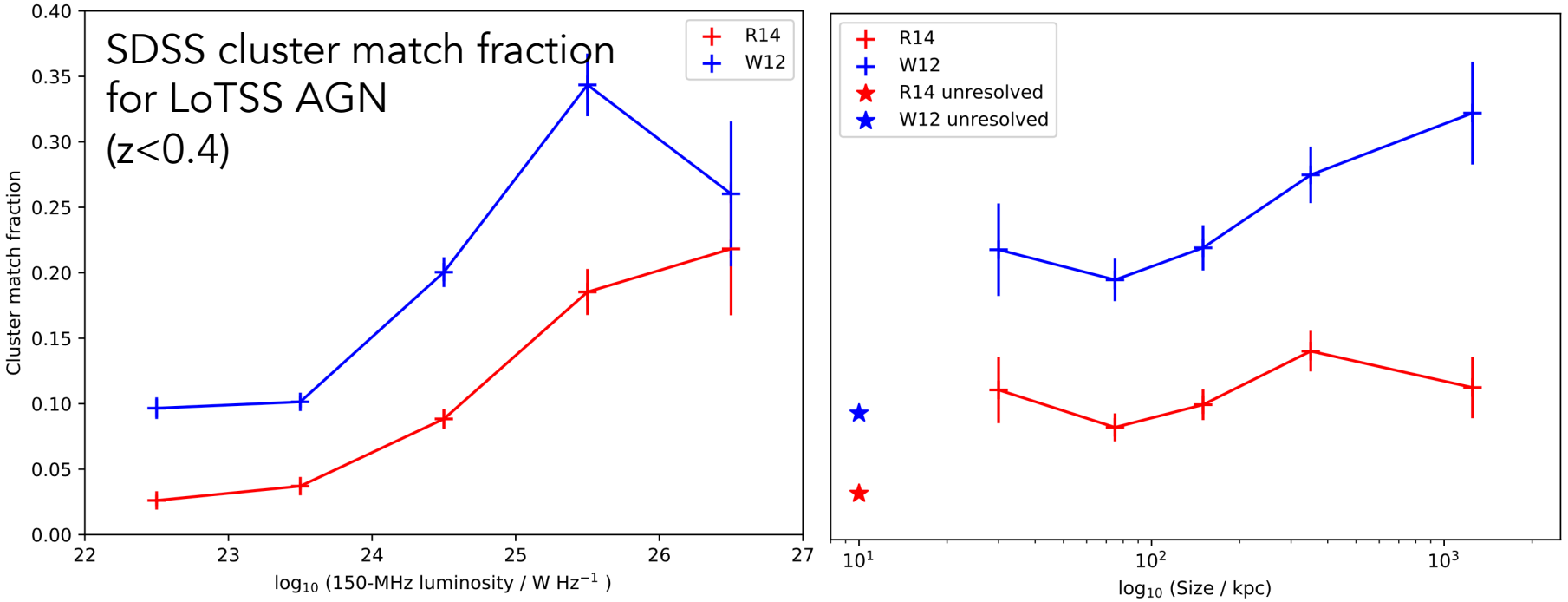
Energy transferred to inner 20 kpc:

~ 10^{56} – 10^{57} erg

(cf. Croston et al. 2007 ApJ 660 191)

Where is the jet energy going?

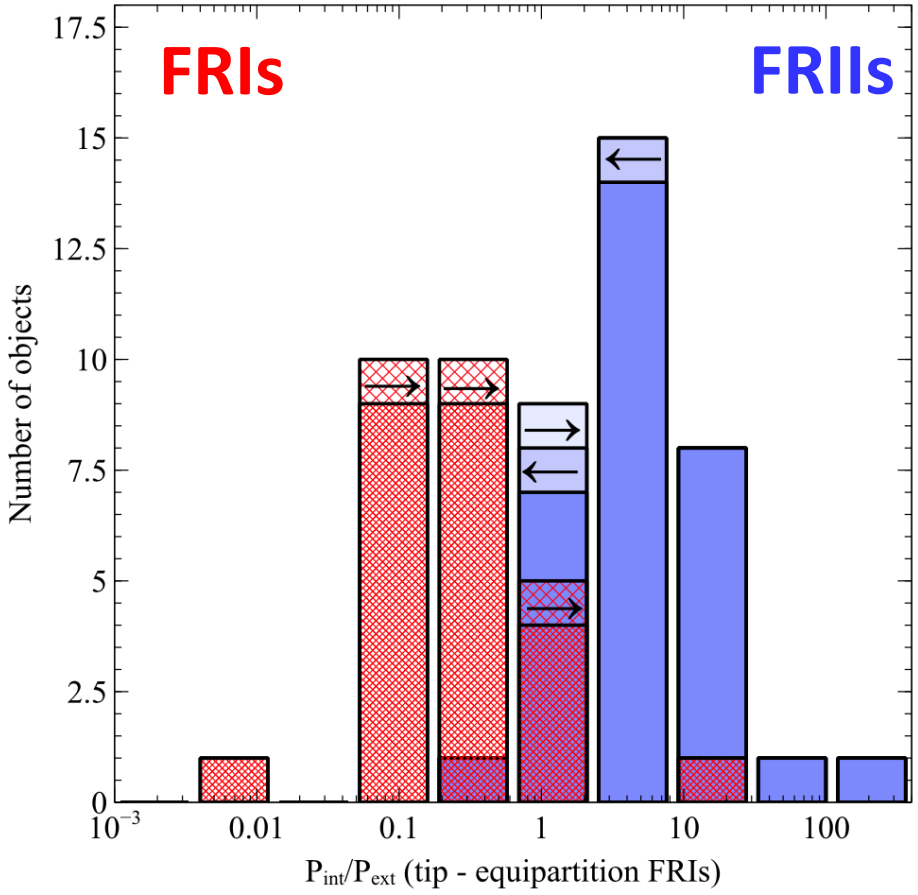
Croston et al., 2018, A&A, submitted

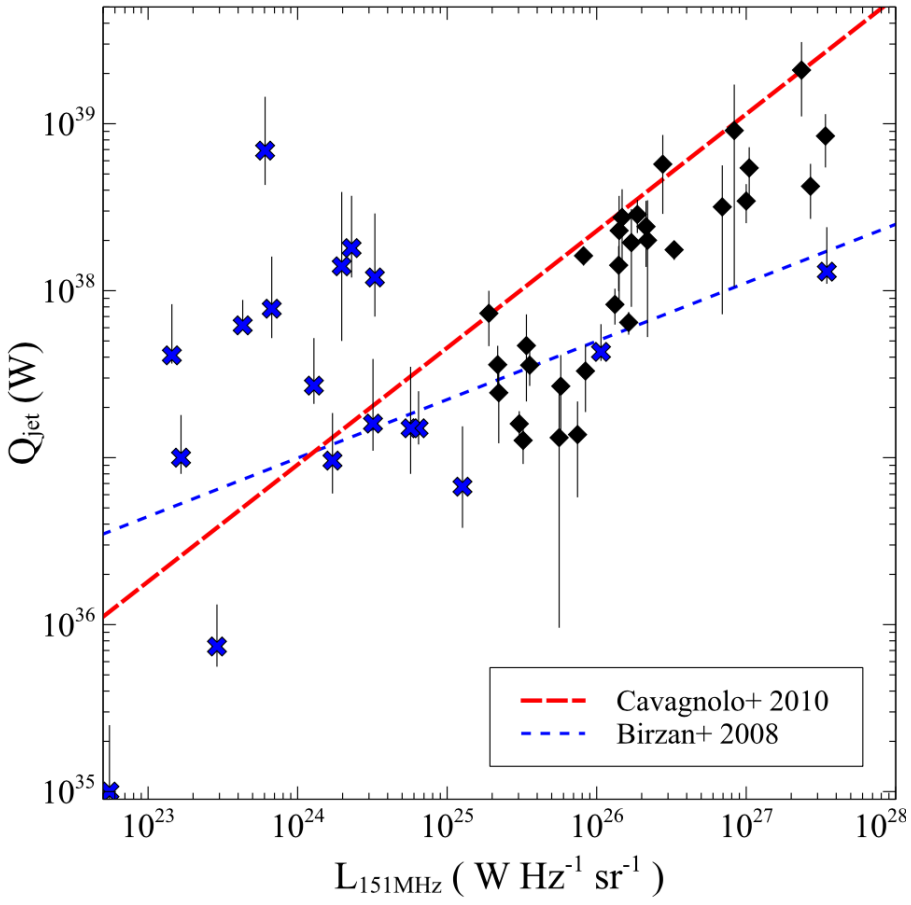


- Only rarely in haloes with $M_{200} > 10^{14}\ M_{\odot}$
- More than 60% of even the most luminous radio galaxies at z<0.4 are in poor environments
- 90% of sub-20kpc jets are located in poor environments

See also Best 2004 MNRAS , Ineson+ 2015 MNRAS 453 2682

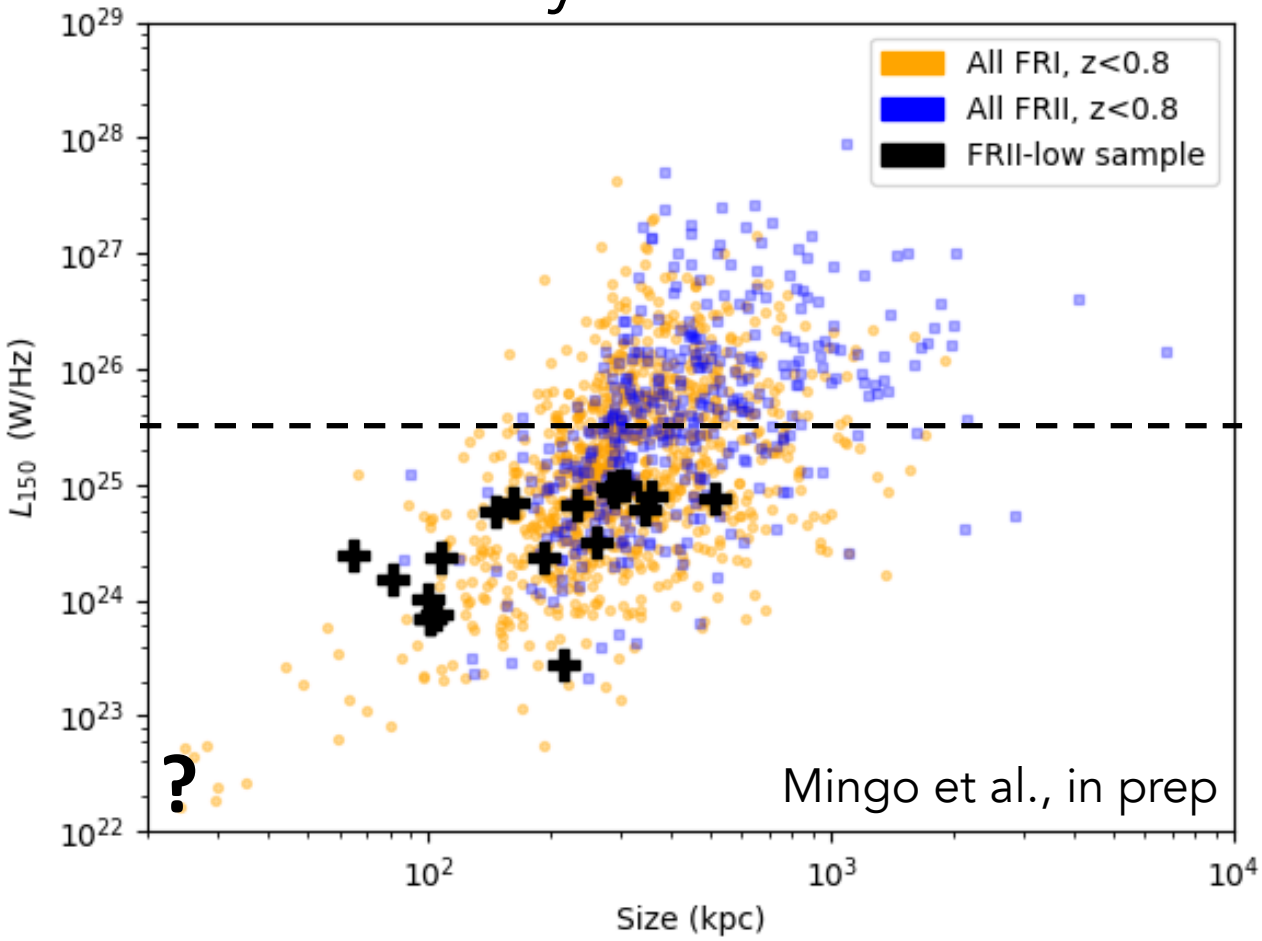
How much energy?

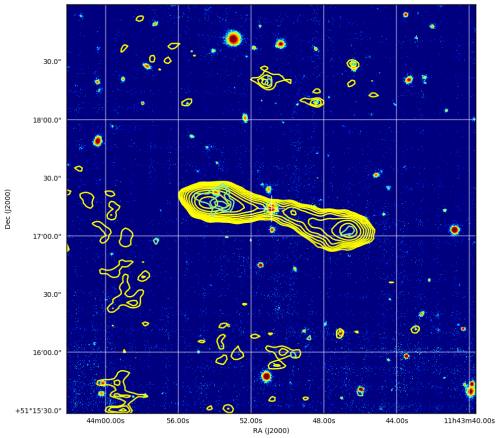


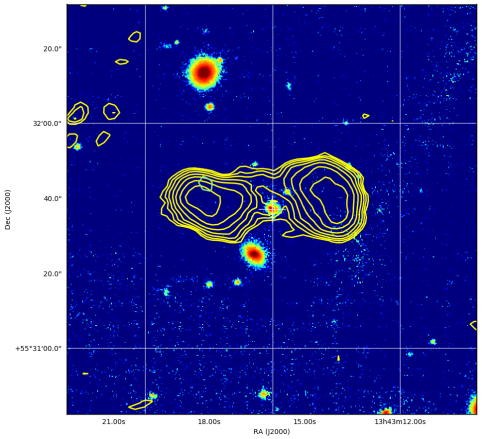


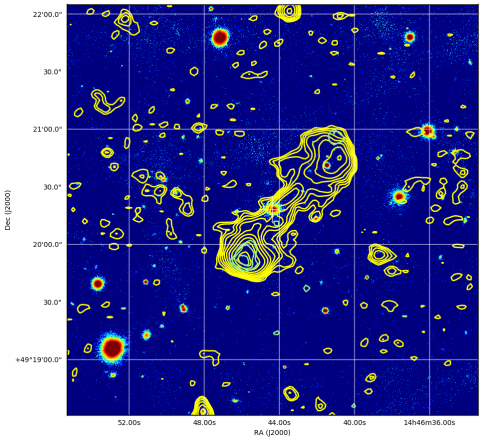
Croston et al. 2018 MNRAS 476 1614

Energetic impact of low-luminosity & small sources







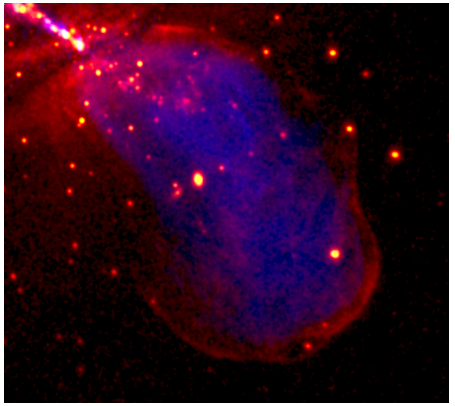


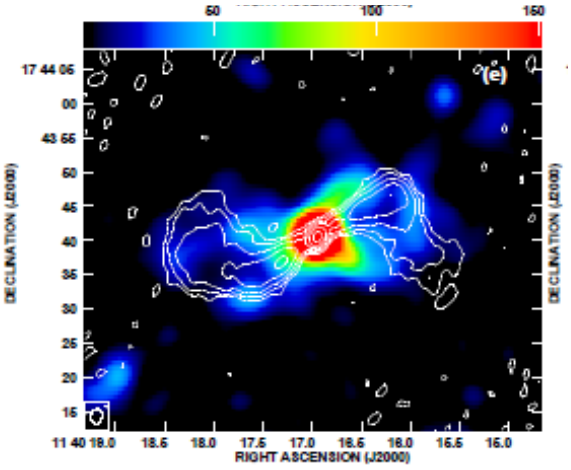
FRI and FRII morphologies exist to smallest sizes/luminosities

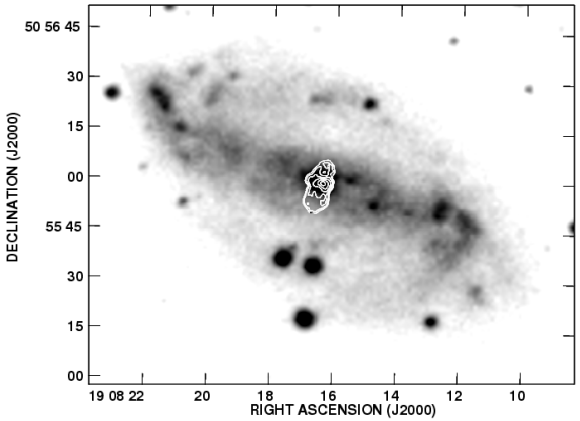
Entrainment increasingly affects L_R/L_{mech} ratio to low luminosities – linked to SFR?

Summary

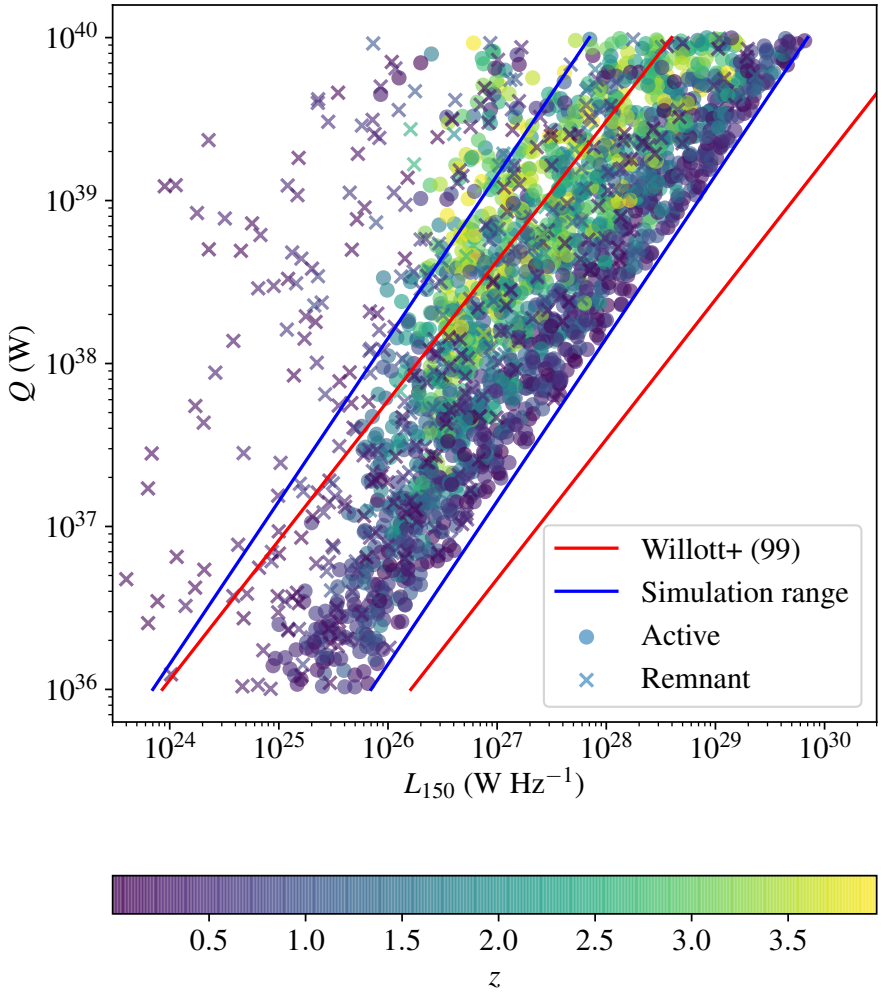
- Coming soon: first science from the LOFAR Two-Metre Sky Survey (LoTSS).
- Systematic view of galaxy-scale jet population (known impact via shock-heated gas and CR acceleration), and the sub-kpc RL AGN population (impact less well understood).
- M_* stronger driver than M_{BH} for RL AGN activity & 100% of local galaxies with $M_*>11$ have AGN-associated radio emission (Sabater+ 2018)
- Most RL AGN, including at high luminosities, don't live in clusters. Small AGN (<20 kpc) avoid clusters.
- Energy estimates from L_R fraught with difficulty – impact of entrained material on L_R/L_{mech} increasingly important at low luminosities.
- Great prospects to study galaxy-scale AGN impact to z~1 with WEAVE-LOFAR and international baselines (sub-arcsec resolution).

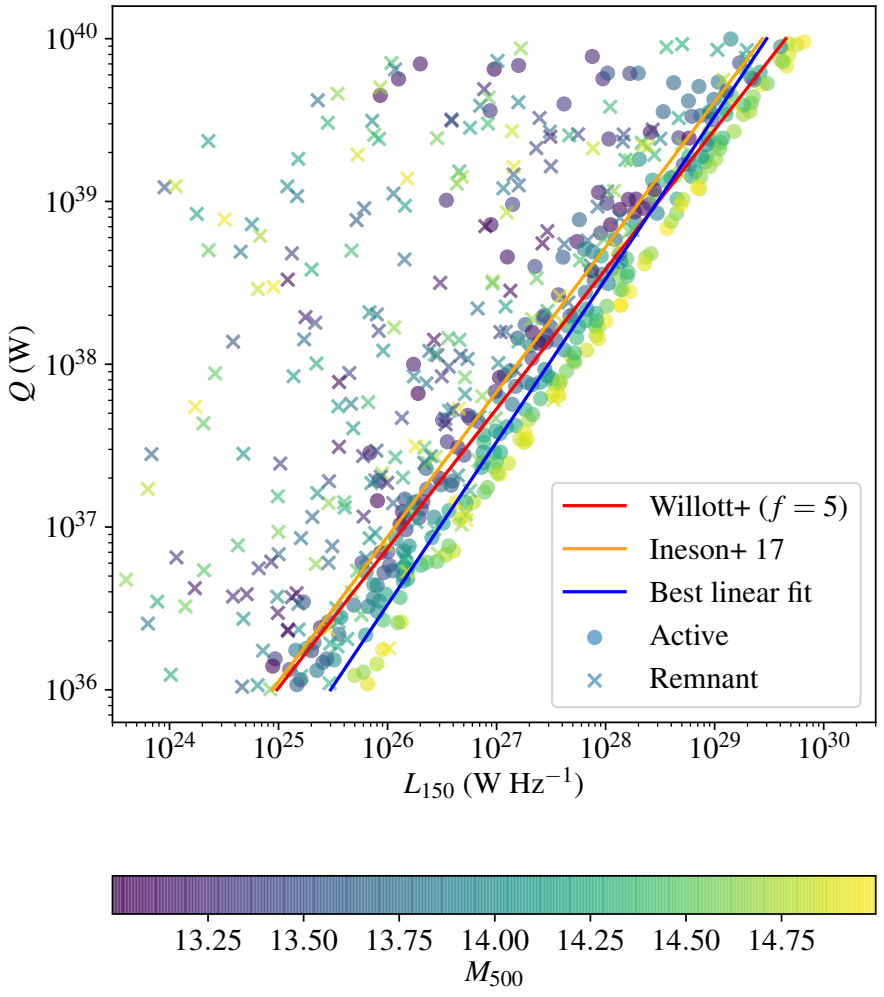






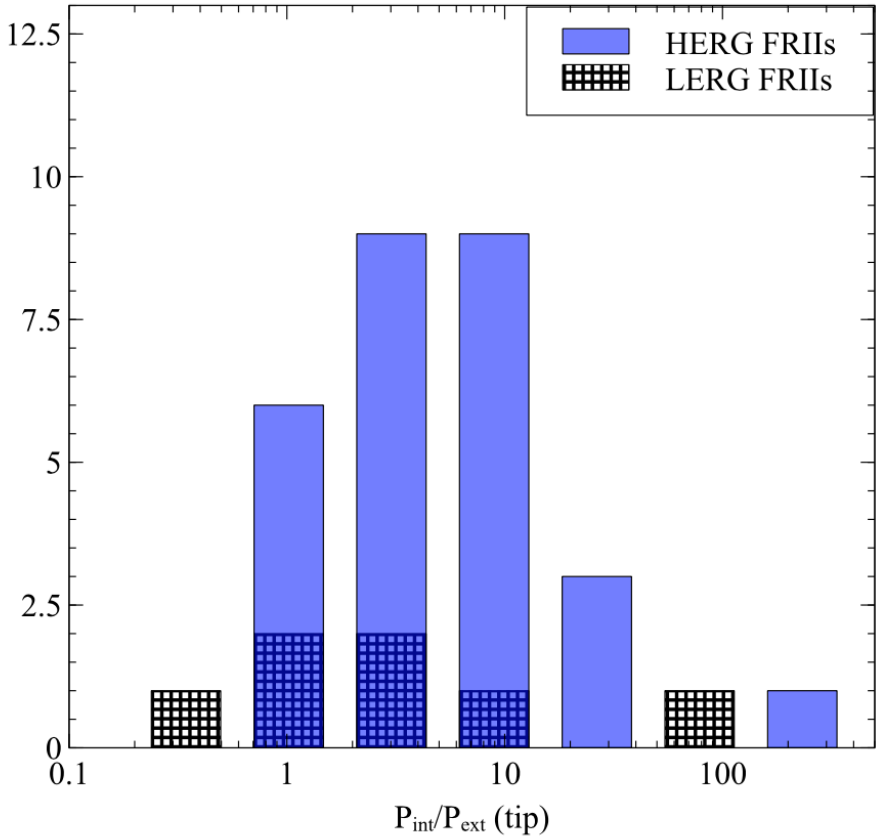
Beware at high redshift

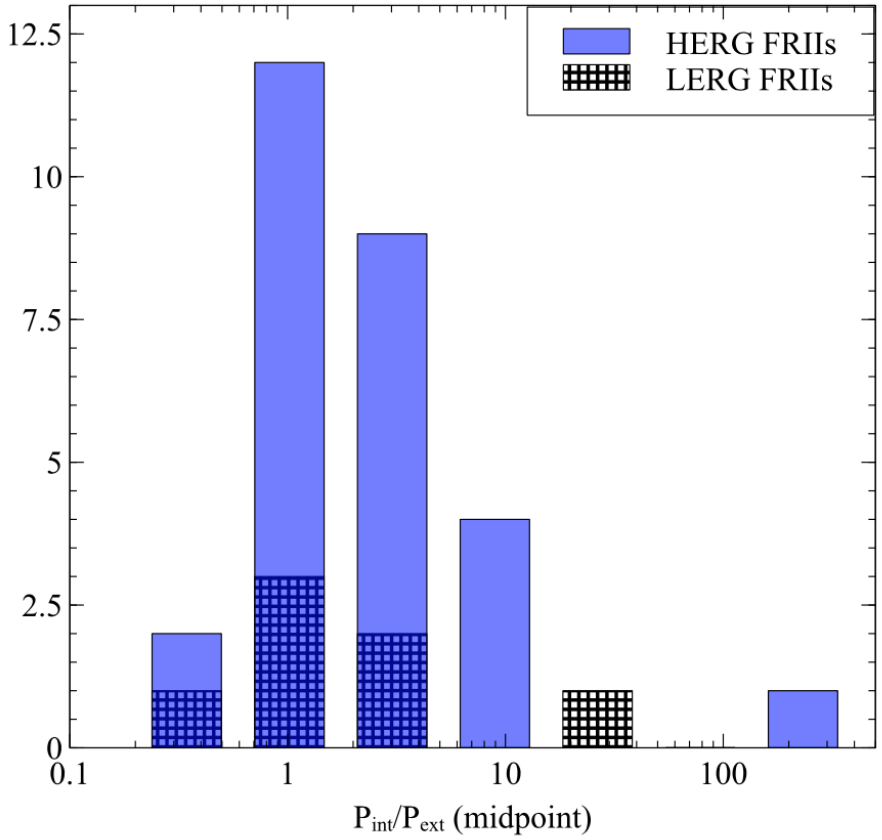




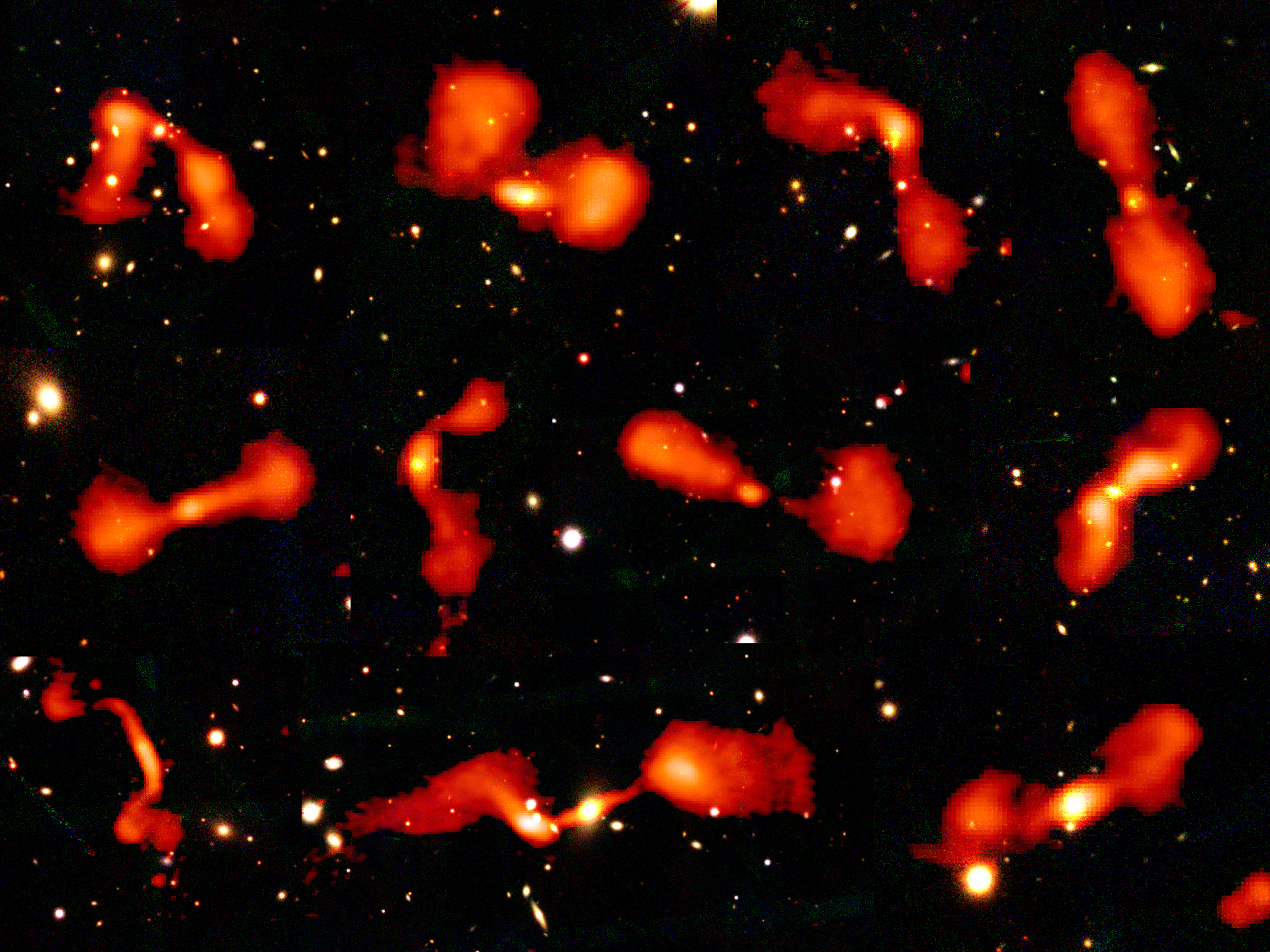
Hardcastle 2018 (MNRAS 475 2768)

Does particle content depend on morphology or accretion mode?

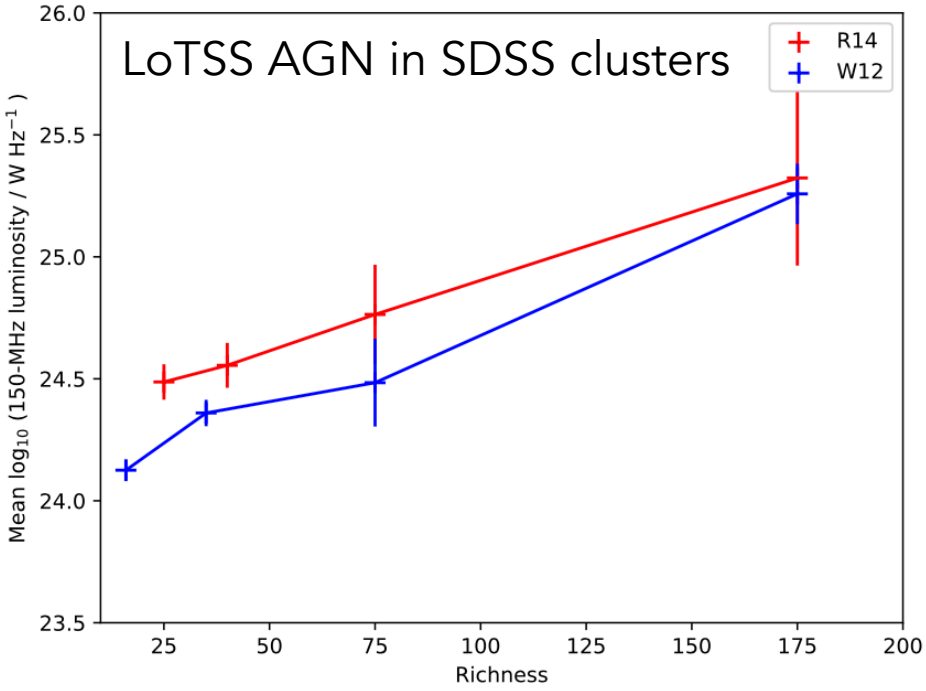




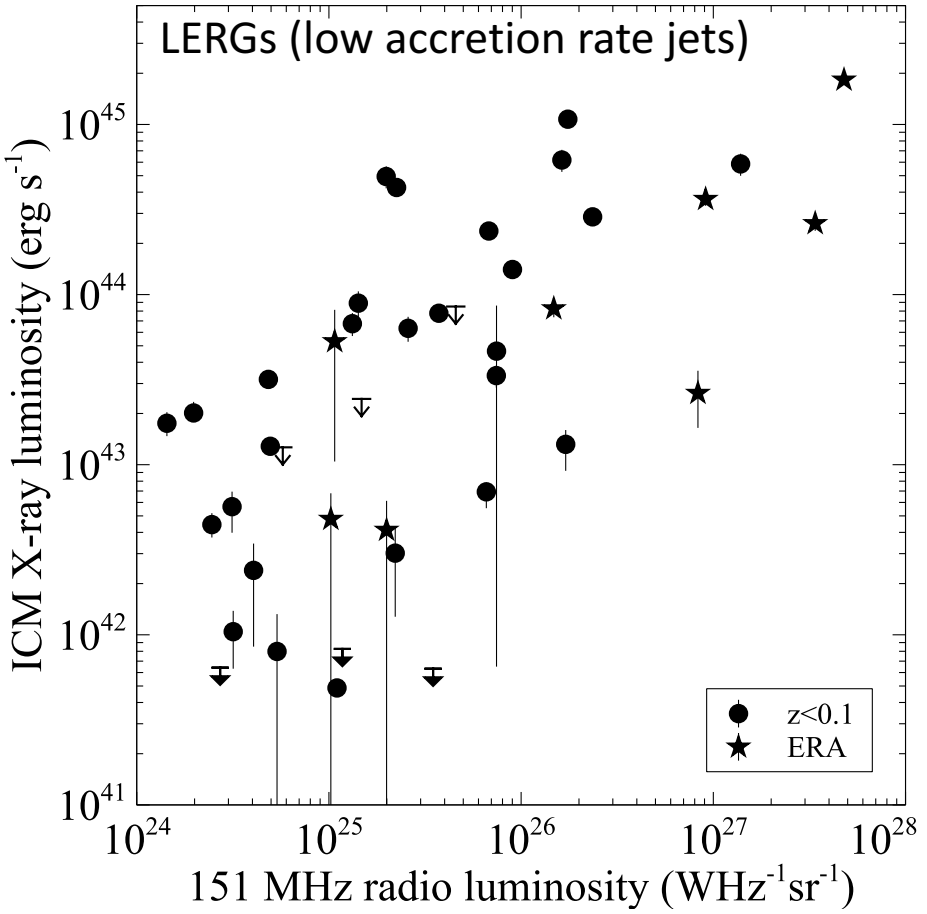
Croston+ 2018 (MNRAS 476 1614)



But large-scale environment *does* affect jet properties

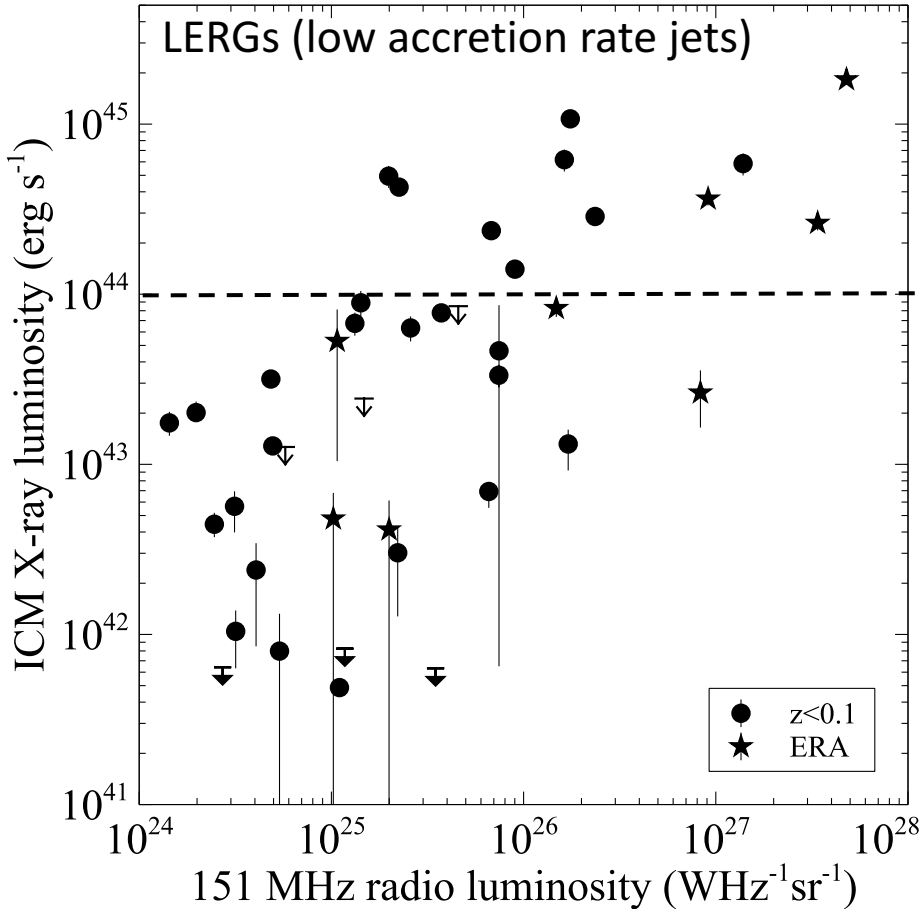


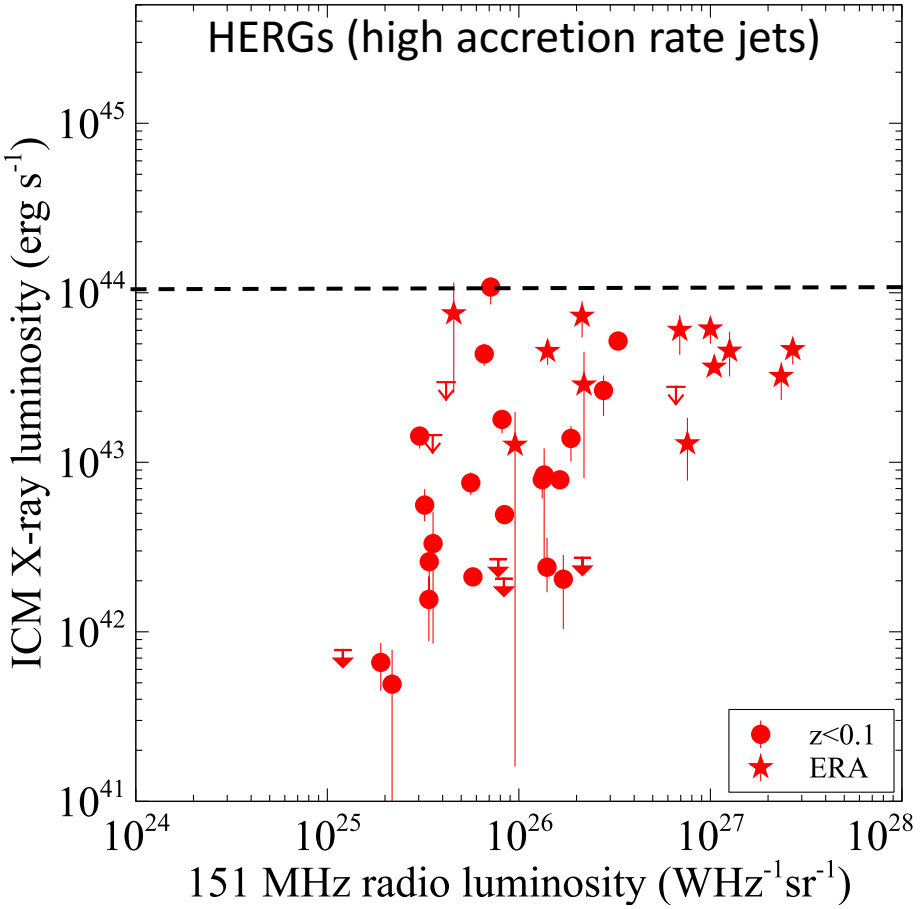
Croston et al., 2018, A&A, submitted



Ineson et al. 2015 MNRAS 453 2682

Accretion-mode dependent jet/environment connection





Ineson et al. 2015 MNRAS 453 2682