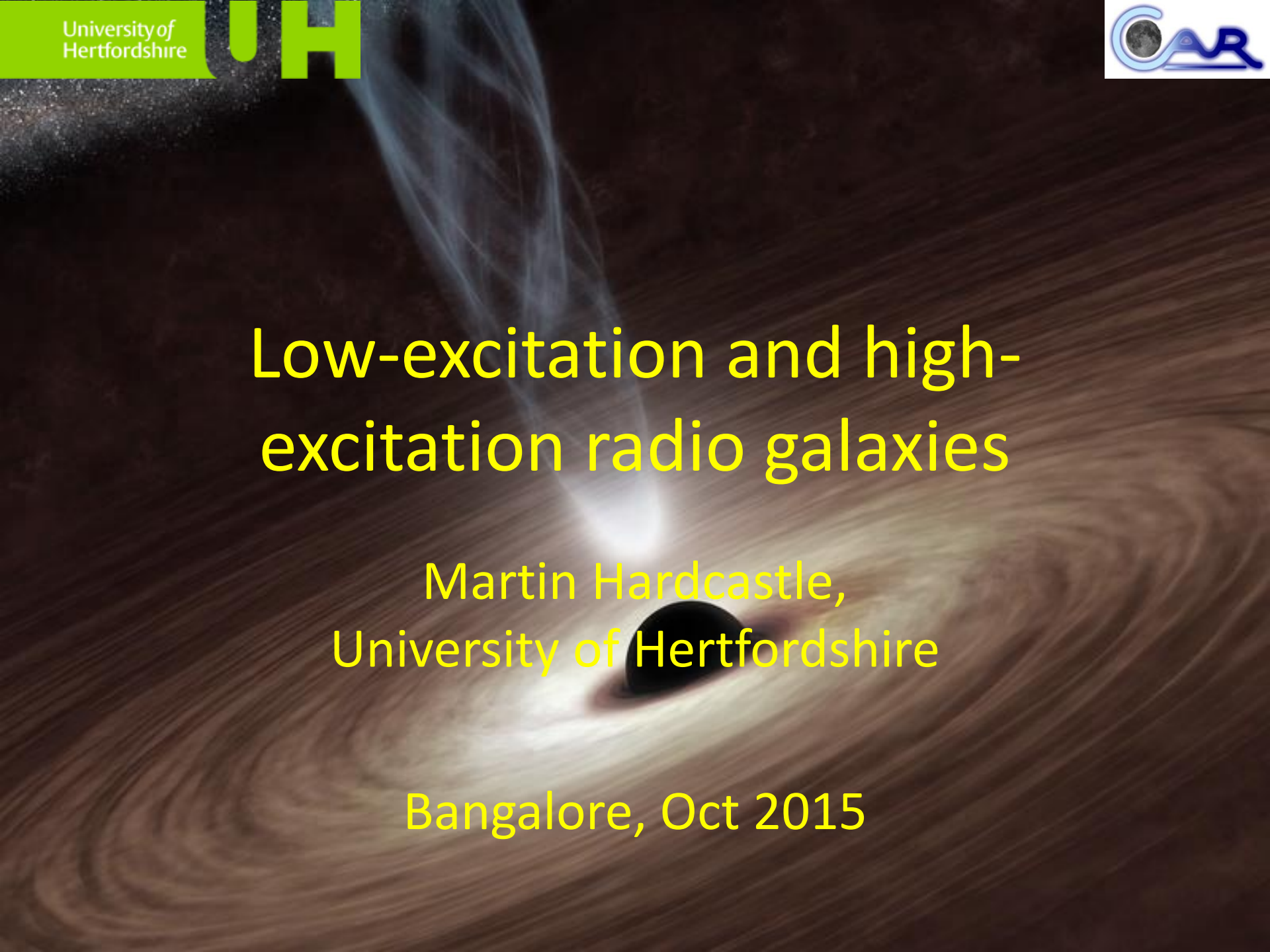


Low-excitation and high-excitation radio galaxies

Martin Hardcastle,
University of Hertfordshire

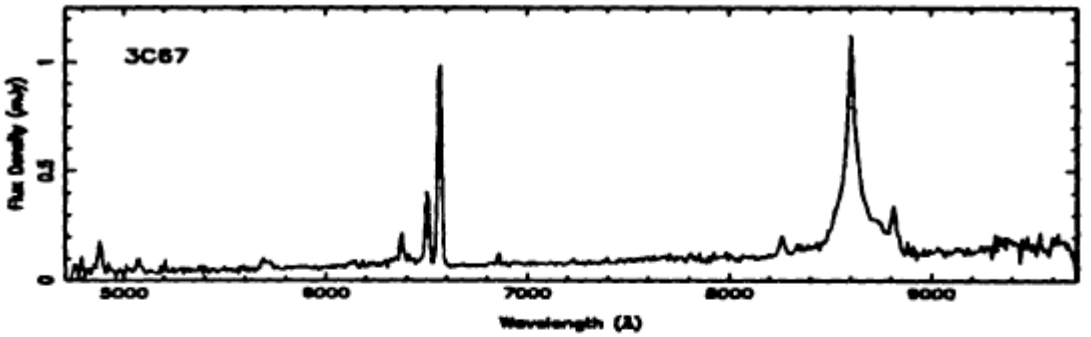
Bangalore, Oct 2015

Outline

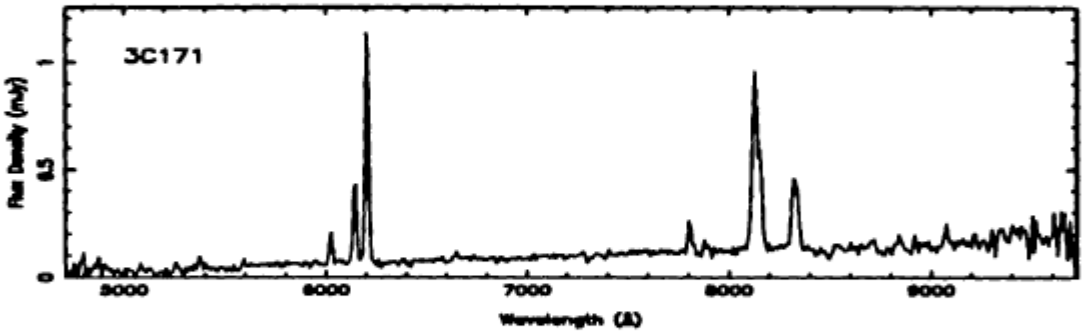
- Observational history
- Two accretion modes?
- Models for the dichotomy
- Tests of predictions
- Future work

Observational history 1: lines

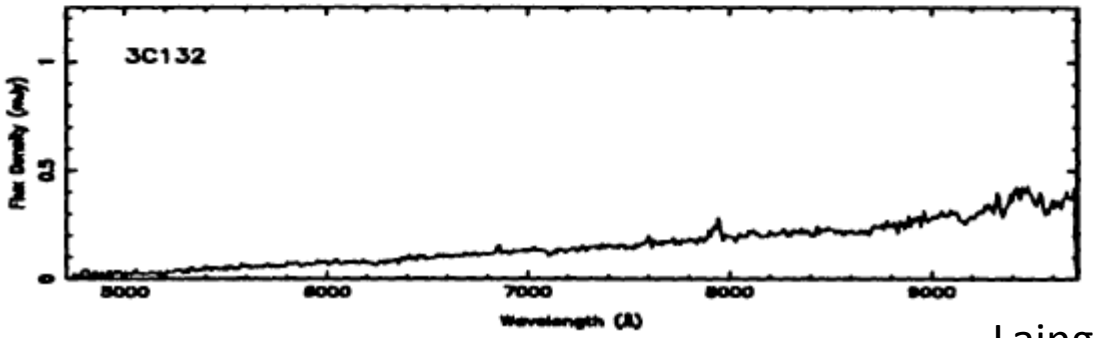
BLRG (‘Seyfert-1-like’)



NLRG (‘Seyfert-2-like’)

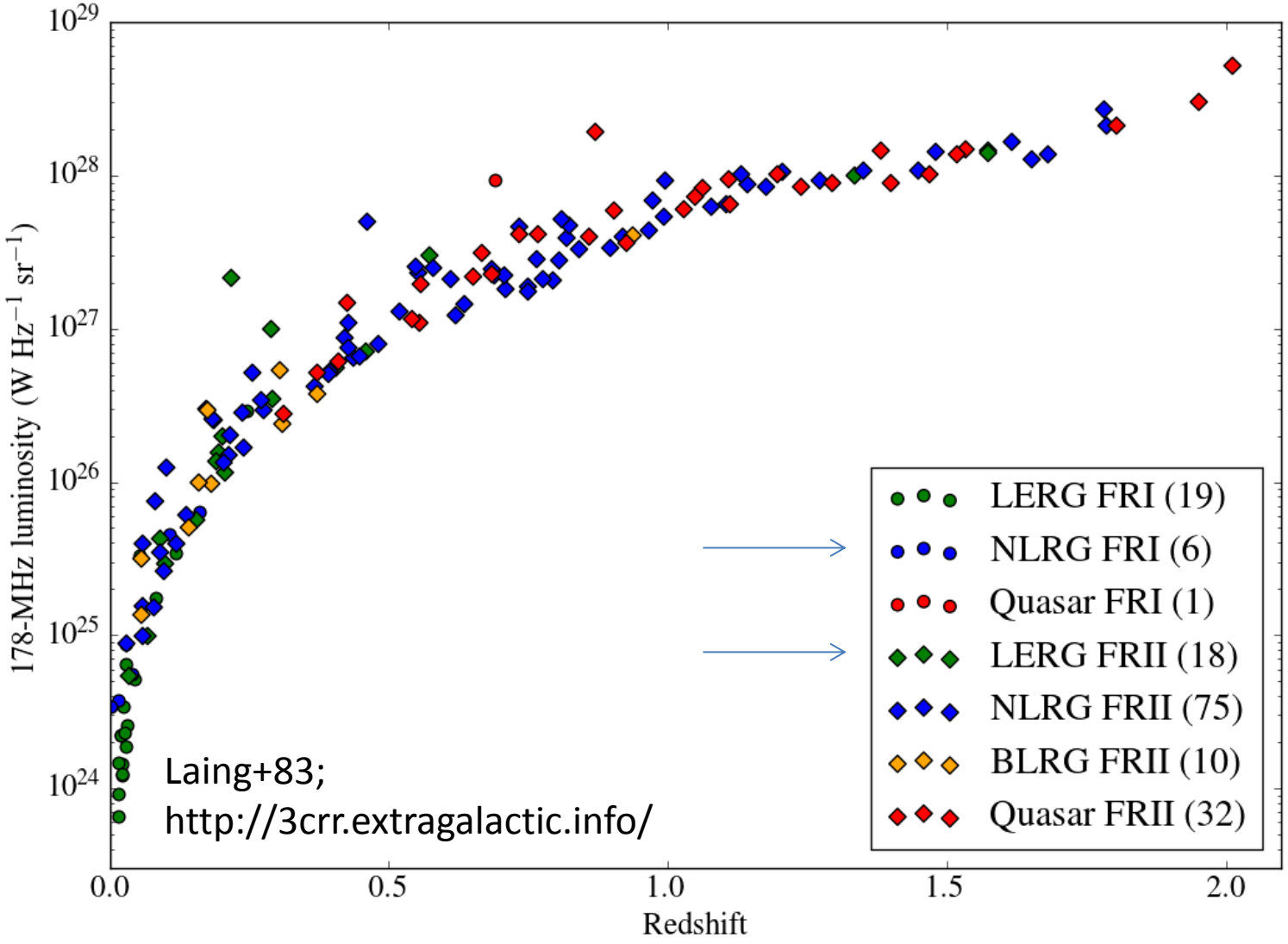


LERG (‘galaxy-like’)

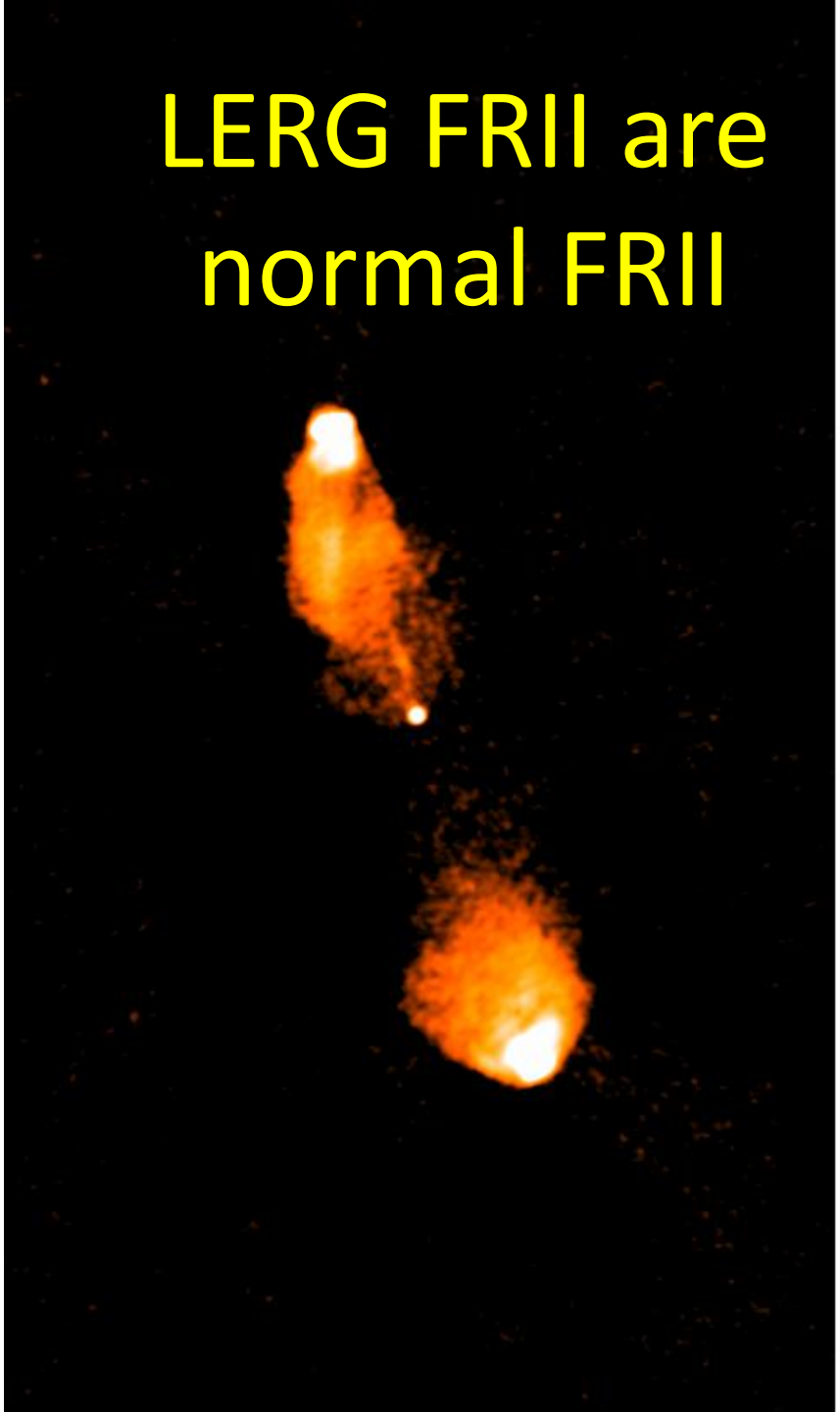


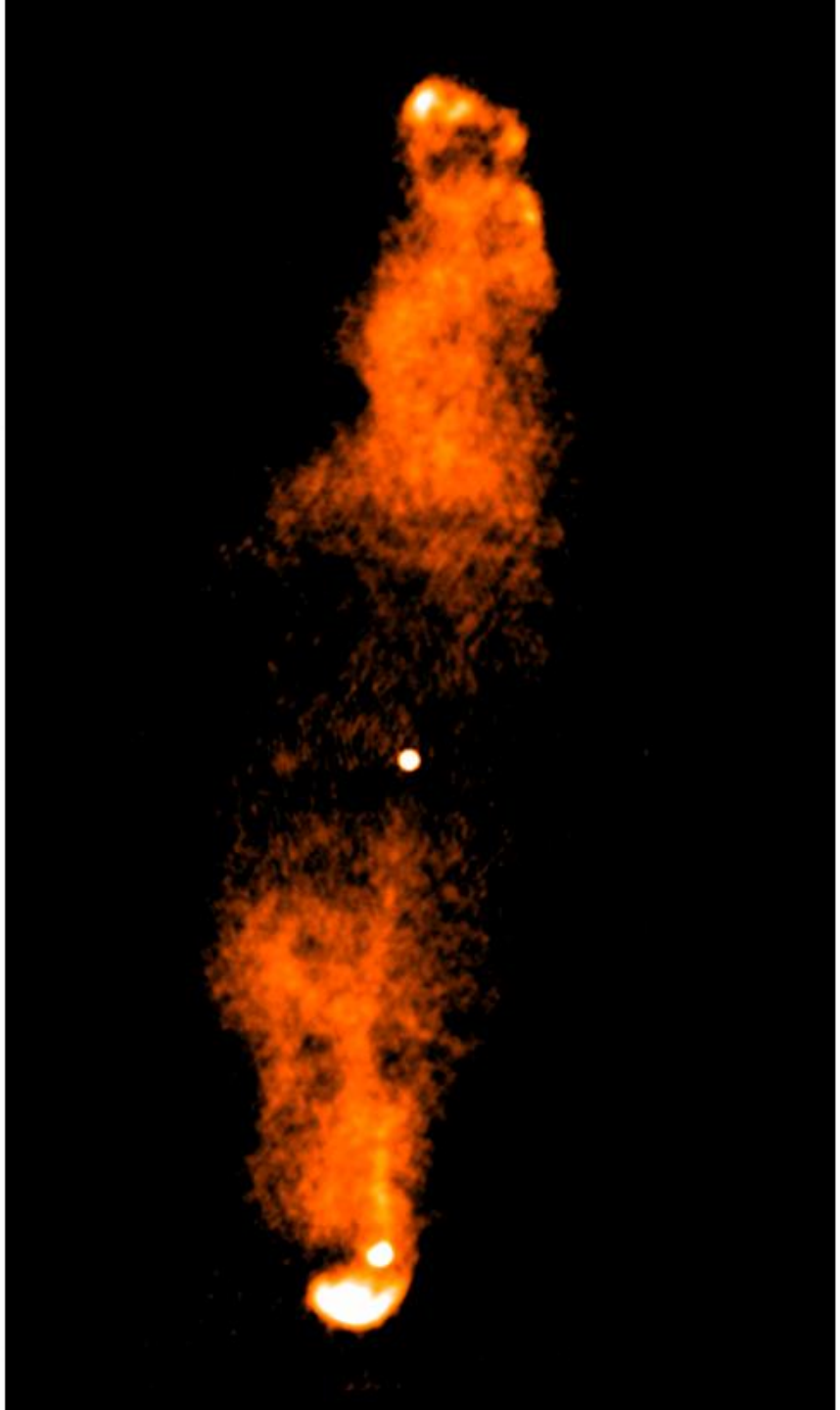
Laing+ 94

Demographics – 3CRR



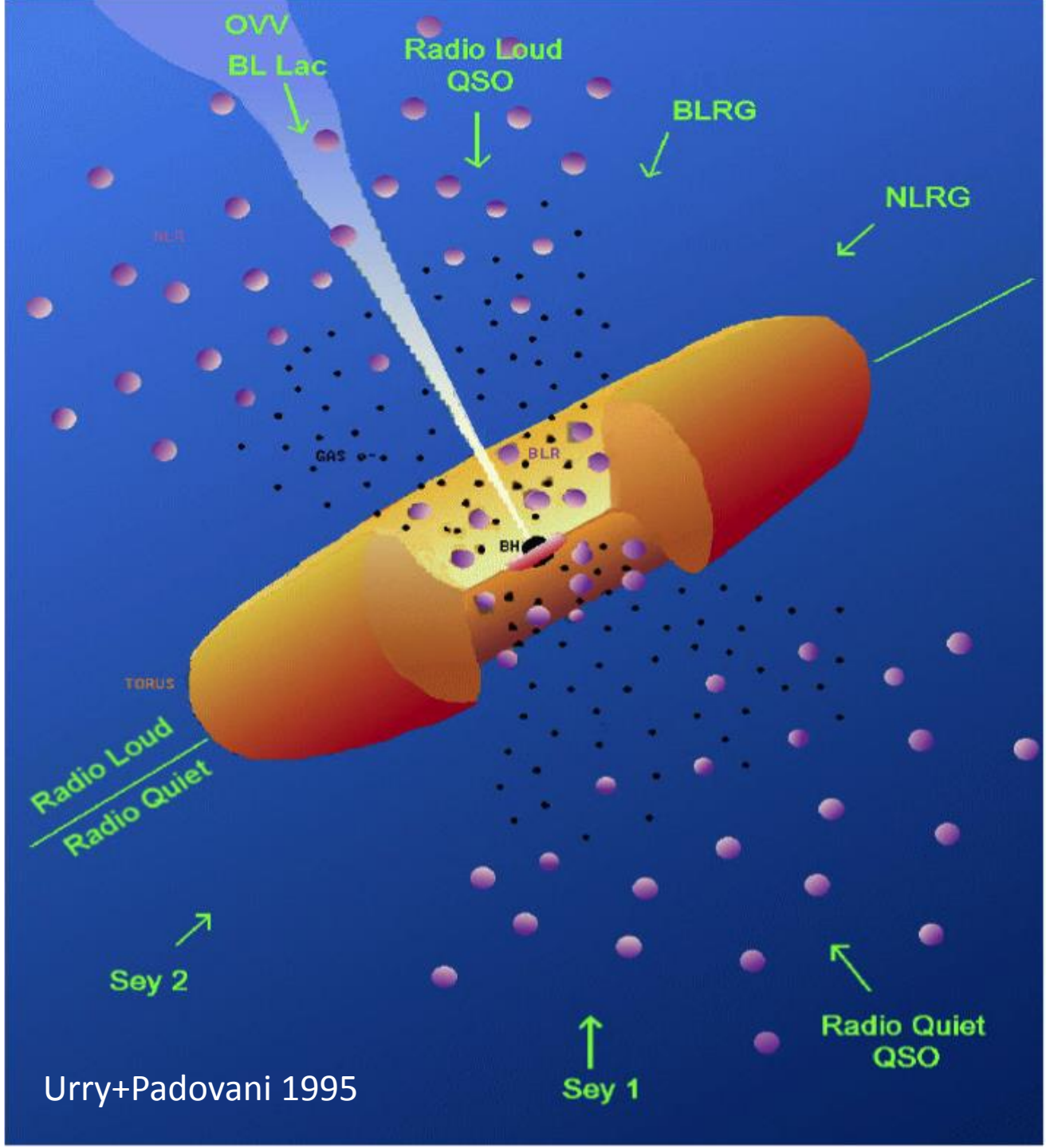
LERG FRII are normal FRII



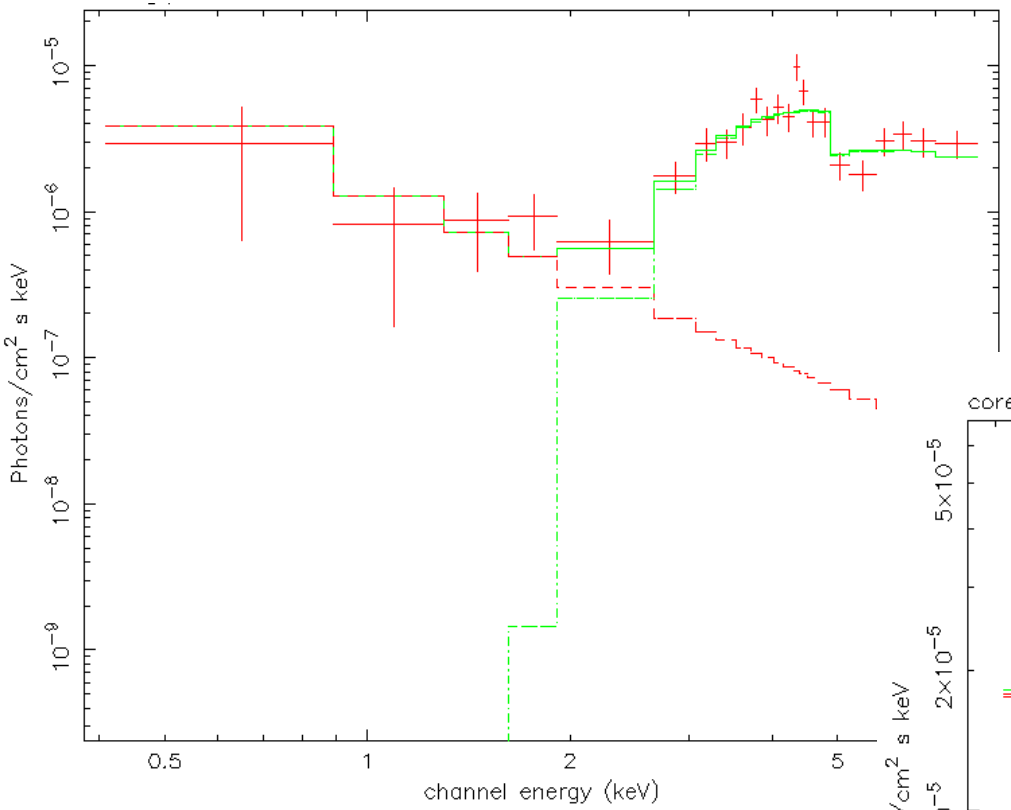


Orientation -based unified models

Either LERGs have no NLR (so can't unify w/ quasars) or it's obscured (so can't unify w/ quasars).
Treating the LERGs as a separate non-unified population and the BLRGs as low-L quasars solves low-z problems for the Barthel (1989) RL unified model (Hardcastle + 1998).

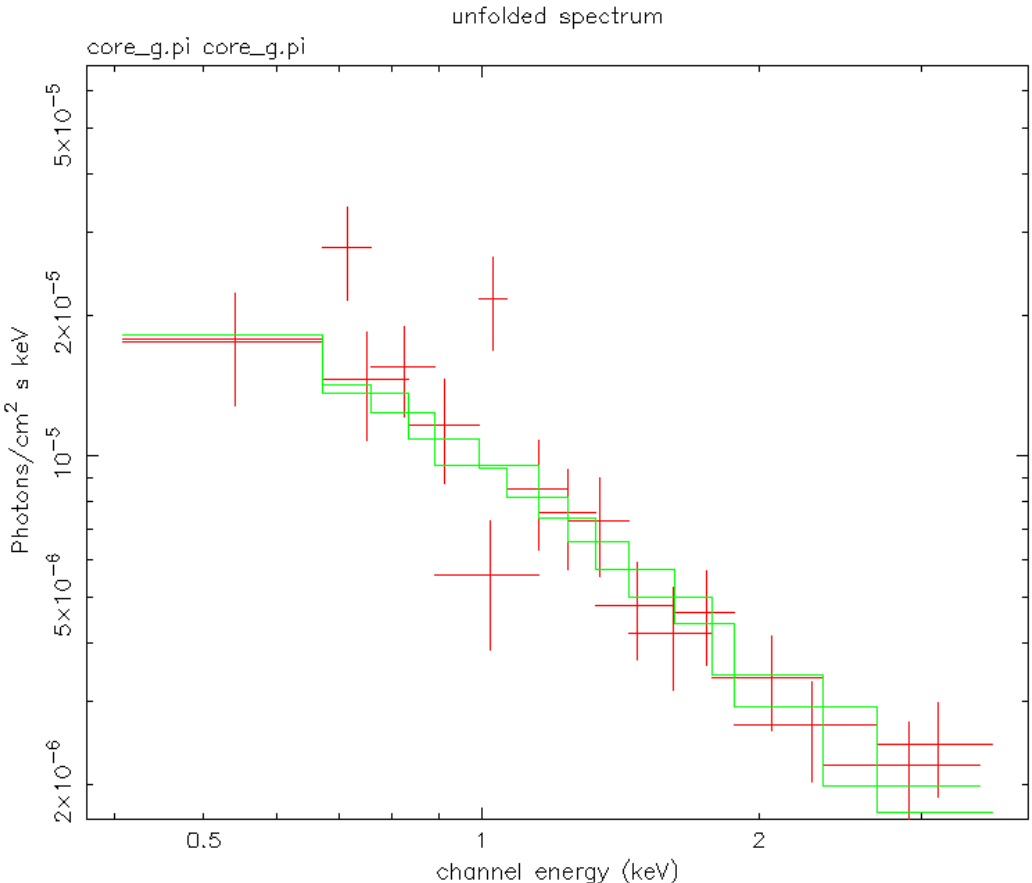


Observational history 2: X-rays



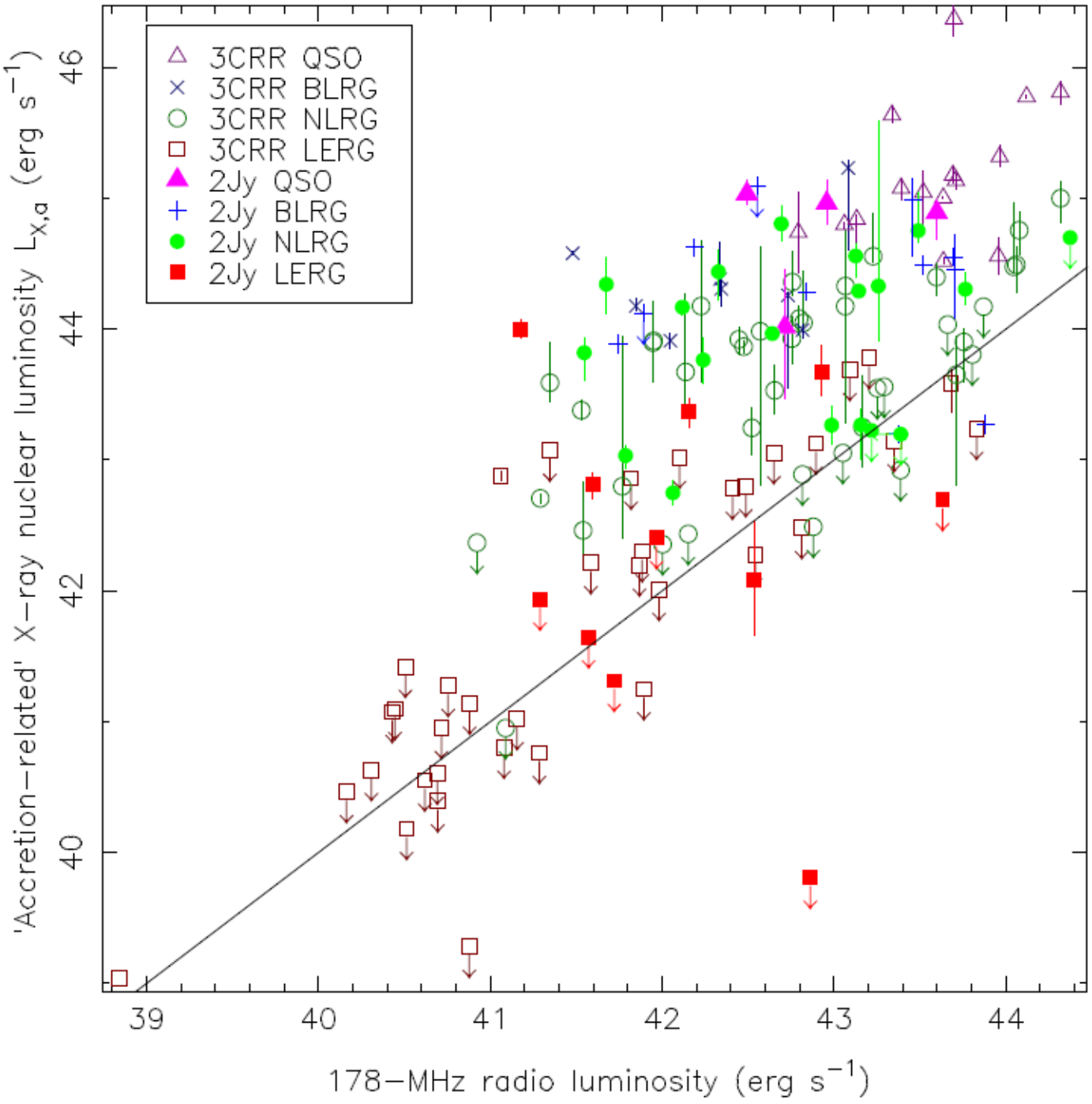
NLRG (3C295)

LERG (3C401)



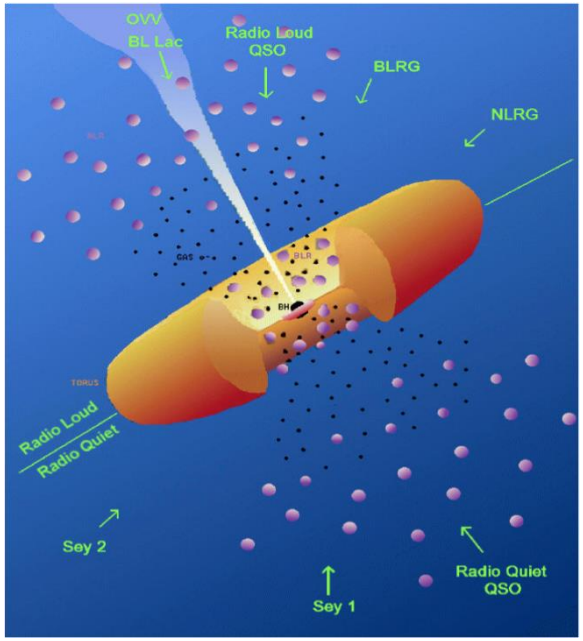
Either LERG have no accretion-related component or it is so heavily obscured that we can't see it (Hardcastle+ 06)

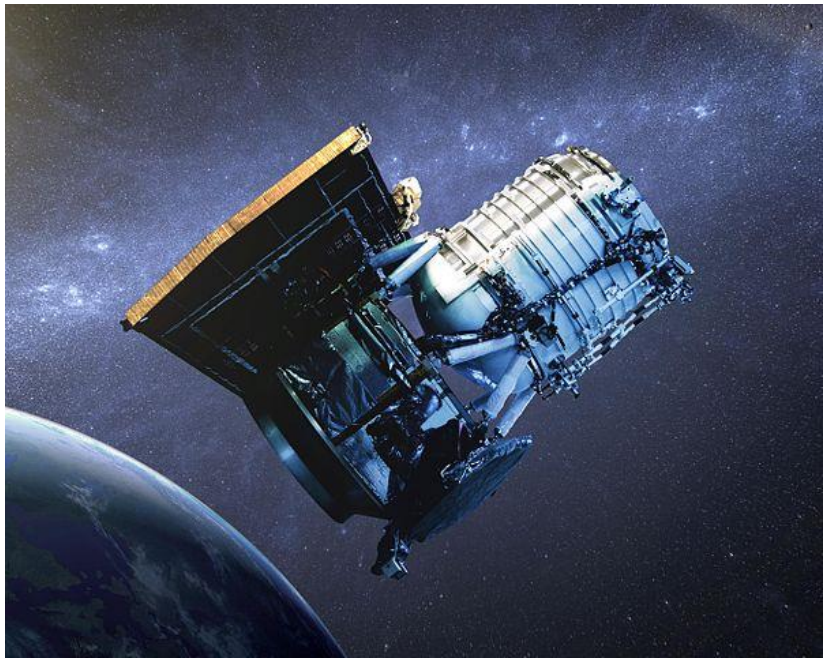
Observational history 2: X-rays

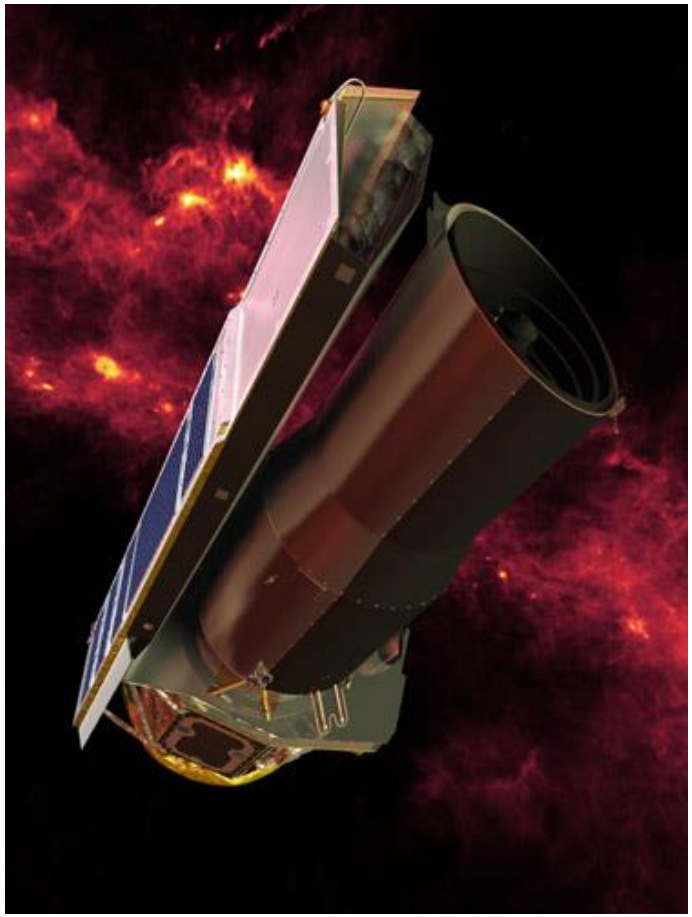


Mingo+ 14

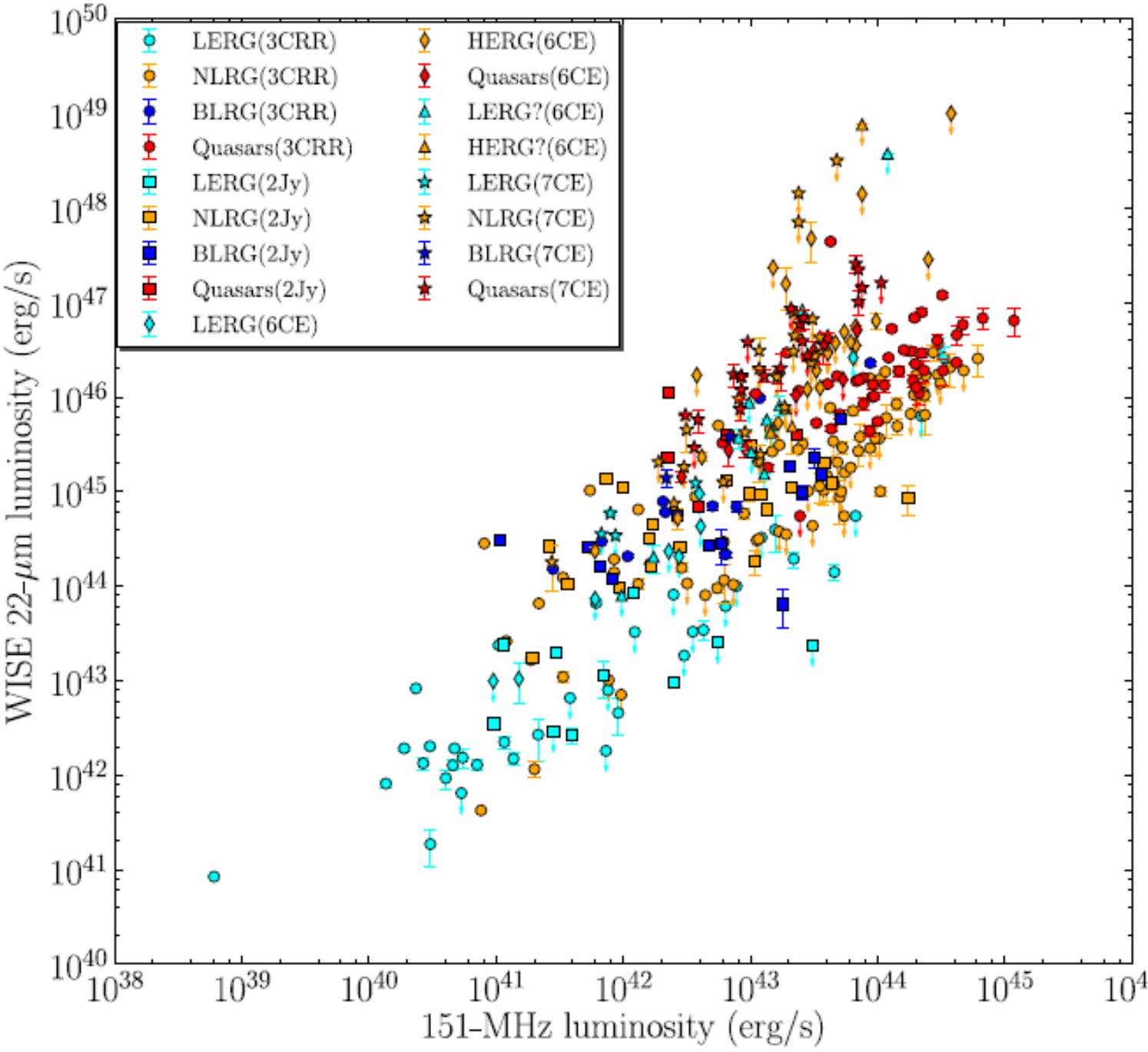
Observational history 3: mid-IR







Observational history 3: mid-IR



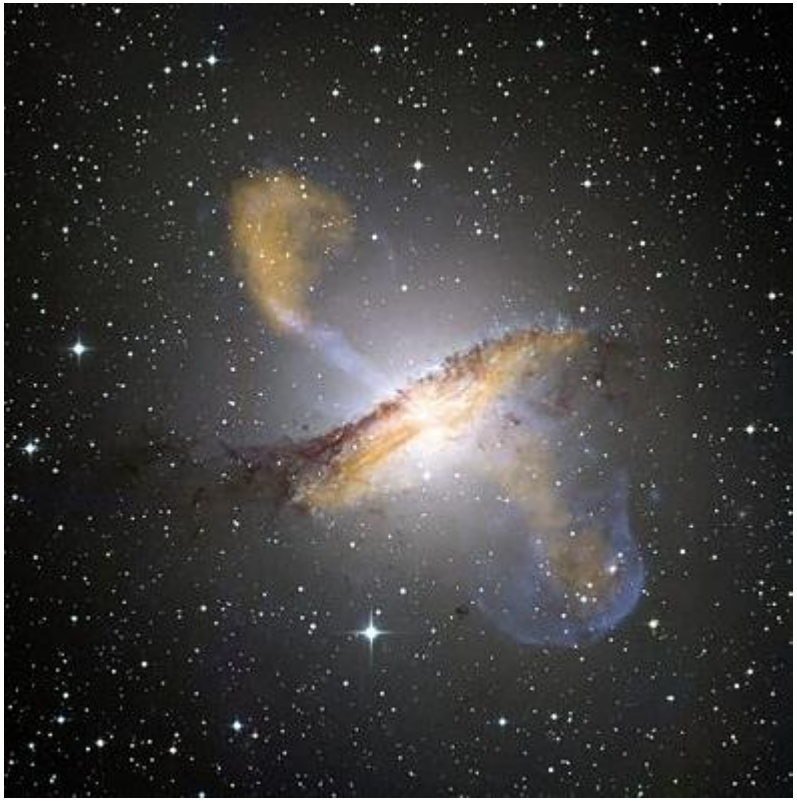
Gurkan+14

Accretion mode

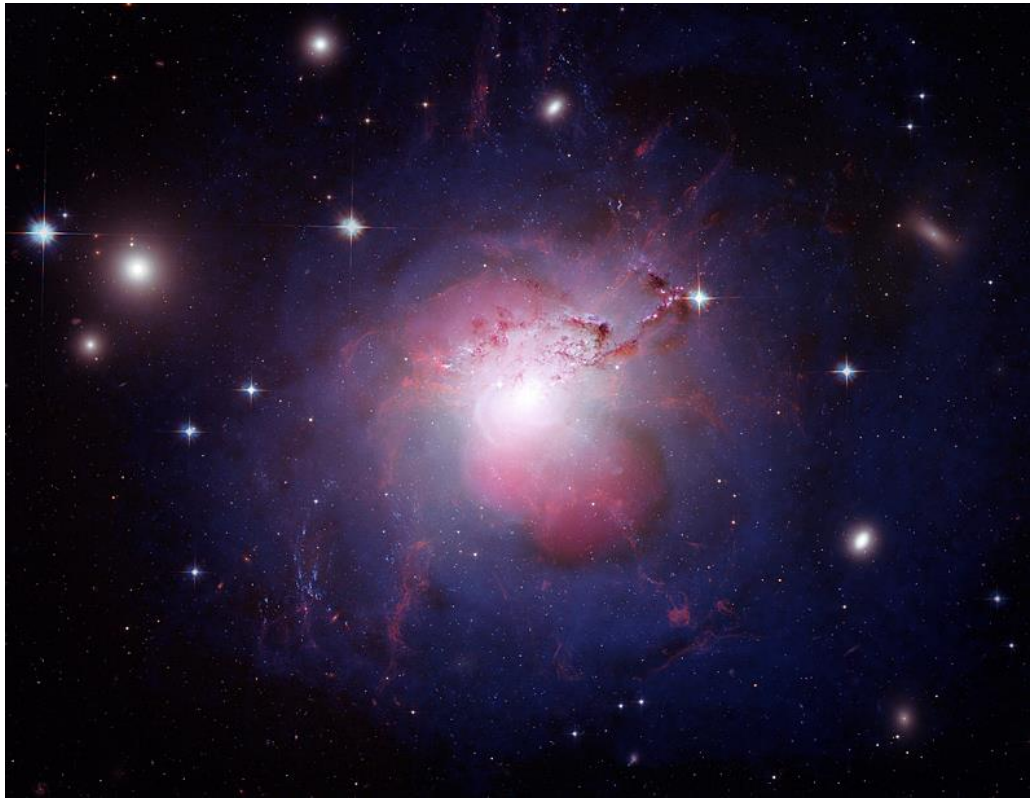
- No emission lines + no obscured X-ray + no torus => no radiatively efficient accretion
- LERGs and HERGs operate in a different accretion mode! (Chiaberge+02; Marchesini+04; Ogle+06; Hardcastle+06; Hardcastle+09; Mingo+14)
- Important implications for
  - Unification (LERGs & HERGs are not the same population)
  - Jet generation (jets can be generated both with and without a radiatively efficient disk)
  - Population studies (need to be sure which population you are looking at)

Fuelling of AGN

- Two fuel sources invoked…

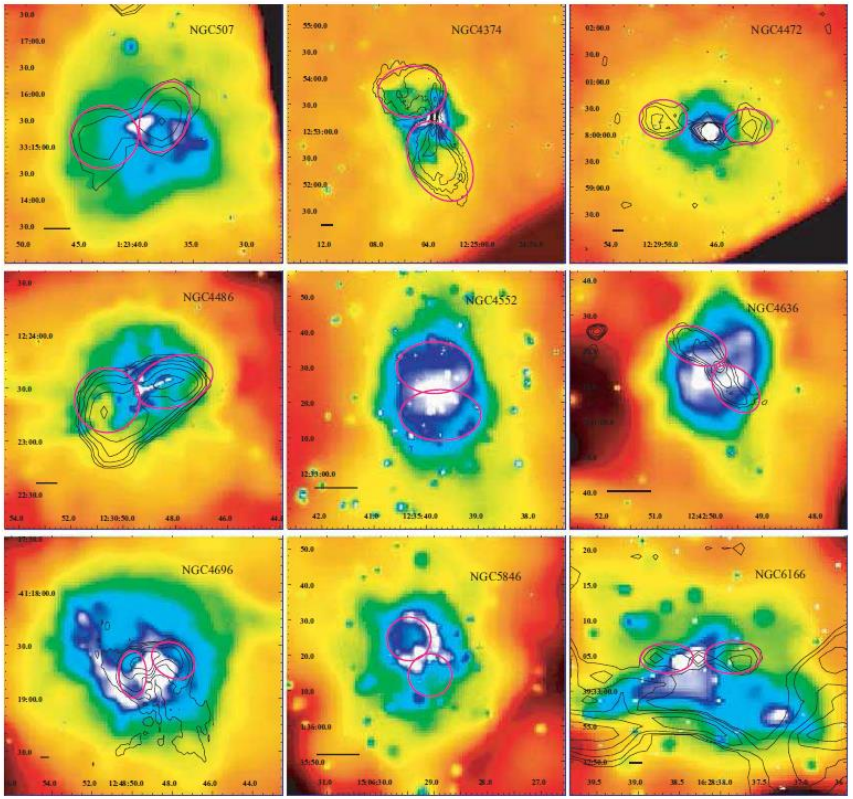


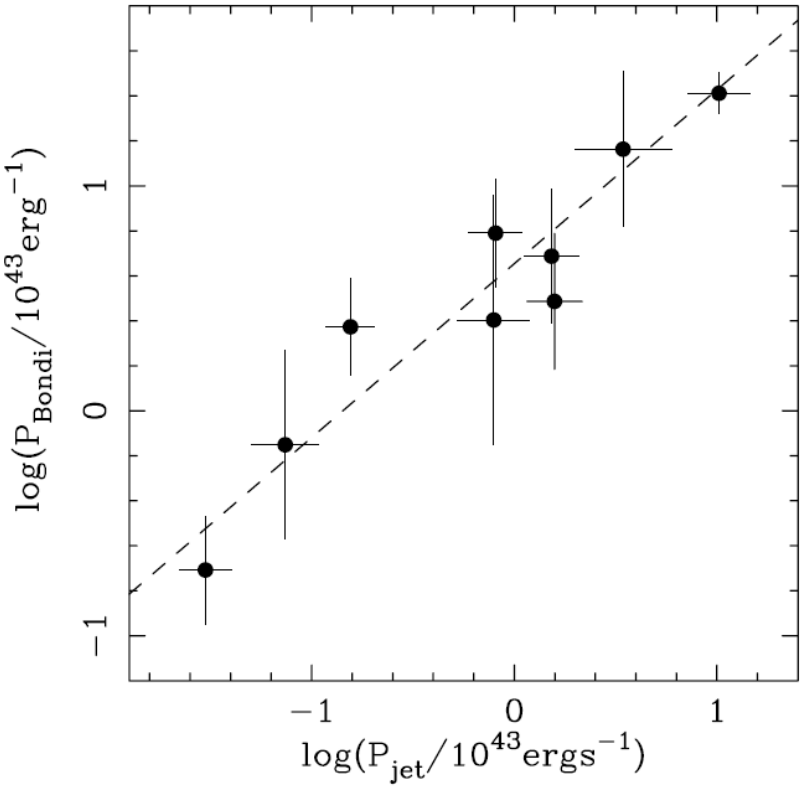
Cen A – e.g. Hardcastle+ 07



Perseus A – e.g. Fabian+05

Bondi accretion?

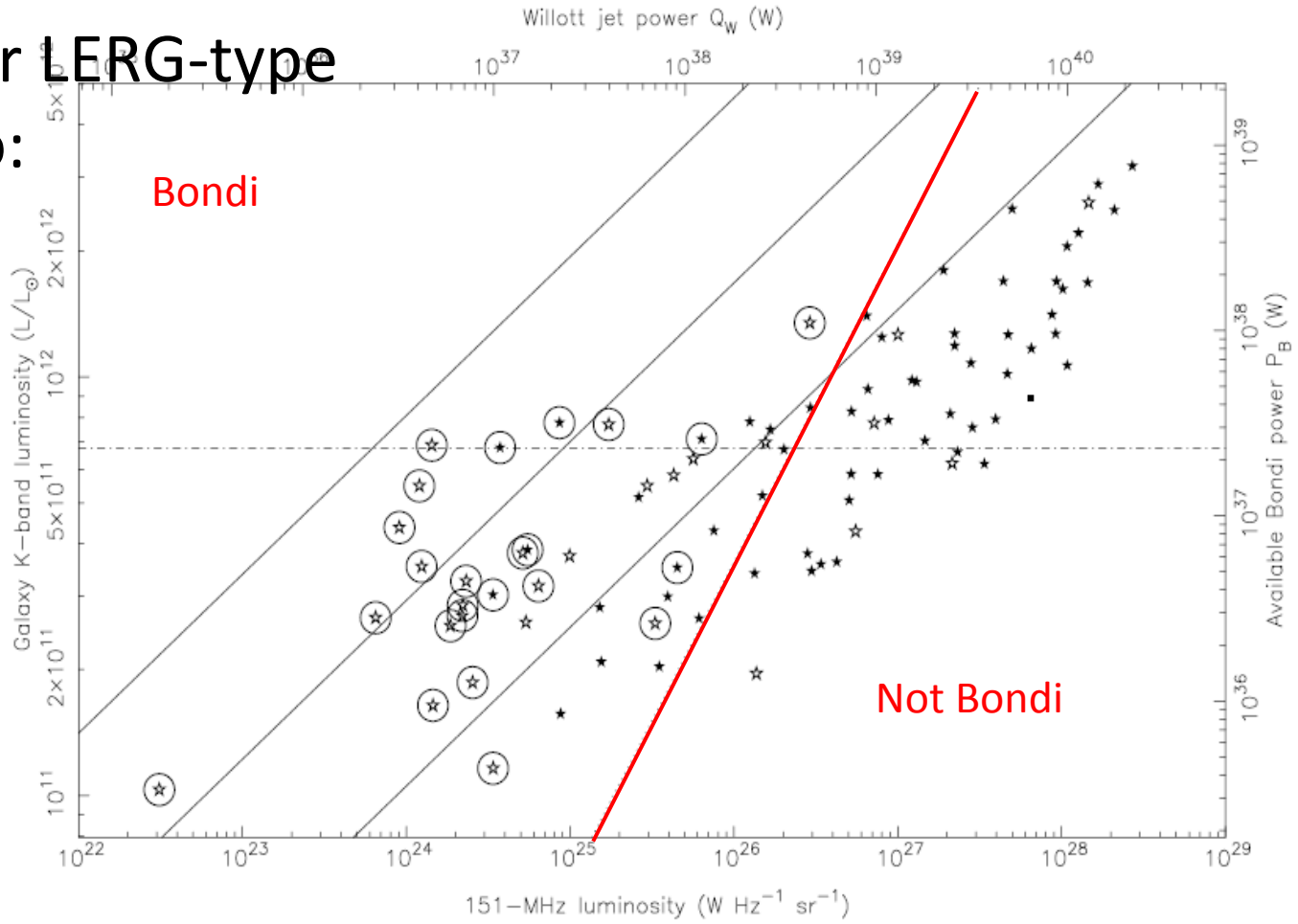




Allen+06

Connecting fuelling and accretion mode

- Bondi accretion can only power LERG-type objects, so:



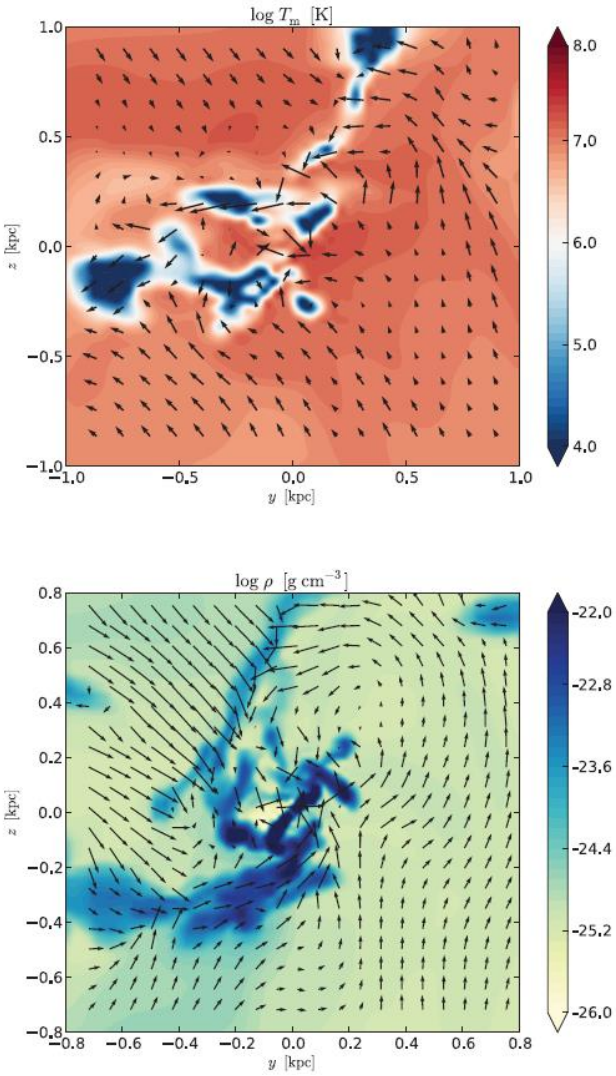
Hardcastle+ 07

Connecting fuelling and accretion mode

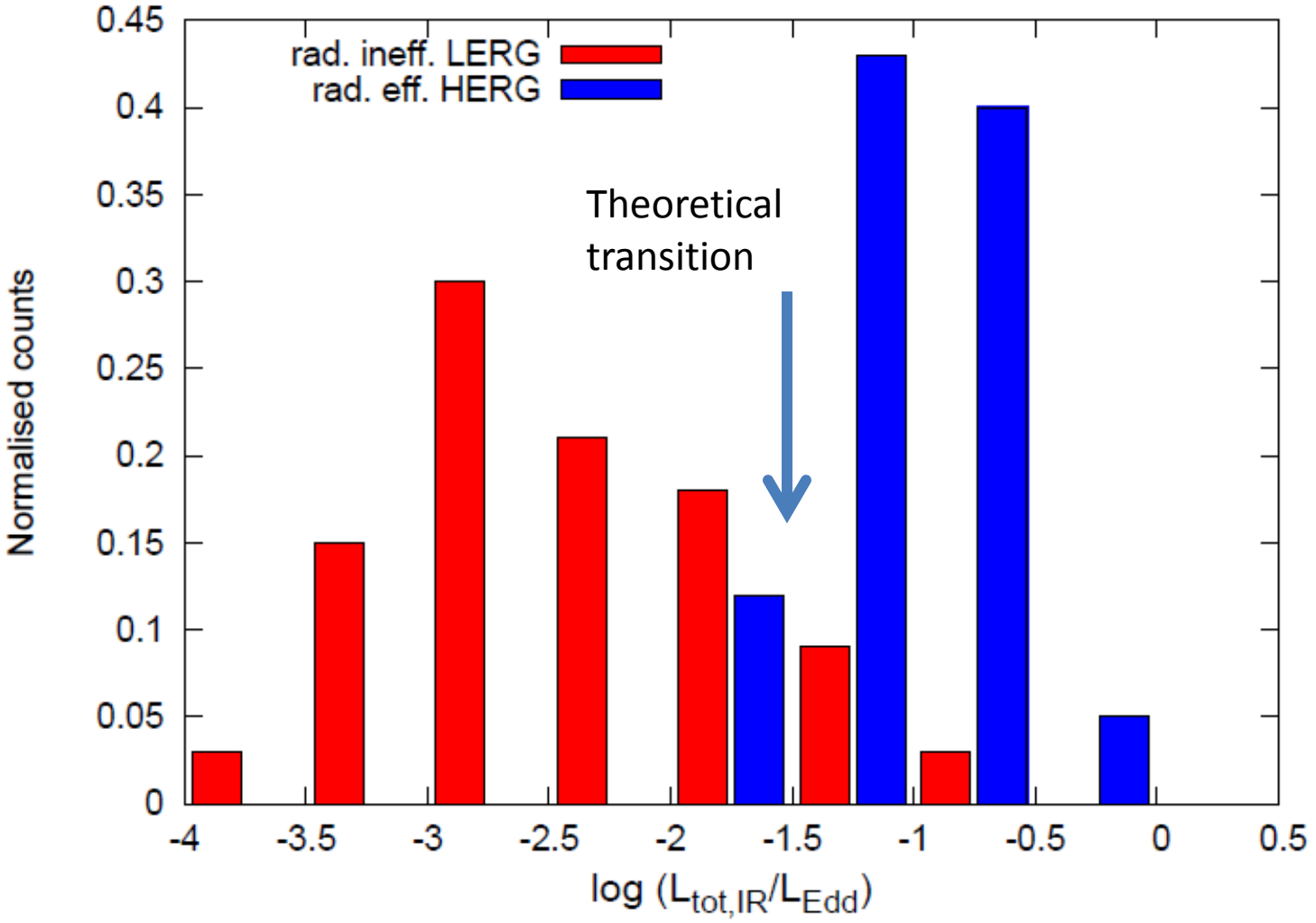
- Hardcastle+07: what if all LERGs are fuelled by hot-gas accretion and vice versa (‘hot mode’)?
- Bondi accretion would not give rise to a radiatively efficient disk (too hot)
- Luminous RG (mostly NLRG/quasars) need some mechanism other than Bondi, could be accretion of cold gas (‘cold mode’)
- Nicely explains differences between low-luminosity (low-z) and high-luminosity (high-z) samples.

But…

- Bondi accretion may not work! (still being argued; see Pizzolato+Soker 10, Narayan+Fabian 11, McNamara+Nulsen 12).
- Allen+06 may have been too optimistic (e.g. Russell+13).
- Accretion from hot phase may go via cooling instability and subsequent *cold* ‘rain’ (Pizzolato+Soker 05,10; Gaspari+13)
- The most luminous cluster-centre objects
  - May be too powerful for Bondi (e.g. Russell+13)
  - May be radiatively efficient (cf. Perseus A, Phoenix cluster)
- Simpler model: LERG/HERG dichotomy may be a simple *scaled accretion rate* switch (‘Eddington switch’) – Best+Heckman 12, Mingo+ 14



Accretion switch current status



L_tot,IR here is total radiative+kinetic luminosity estimated from IR and radio – Mingo+ 14

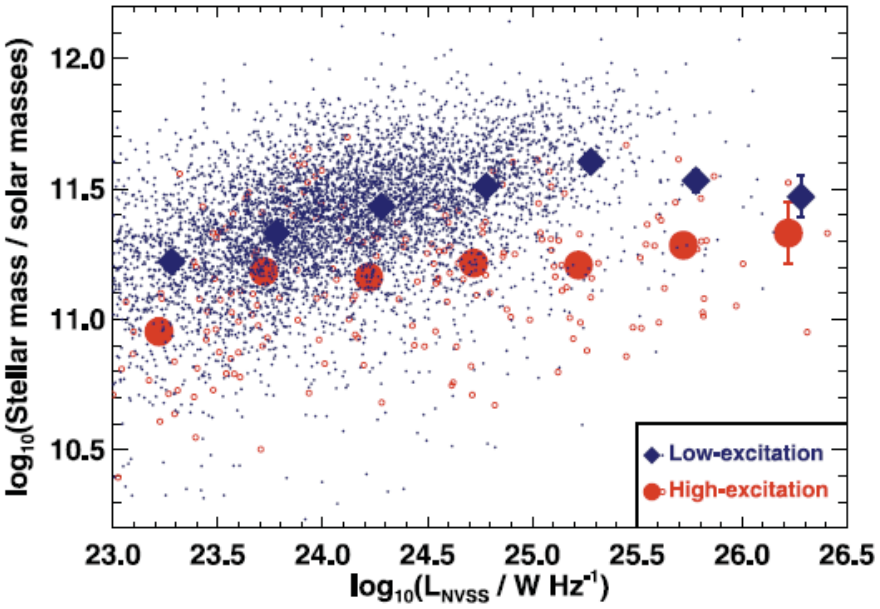
Consequences

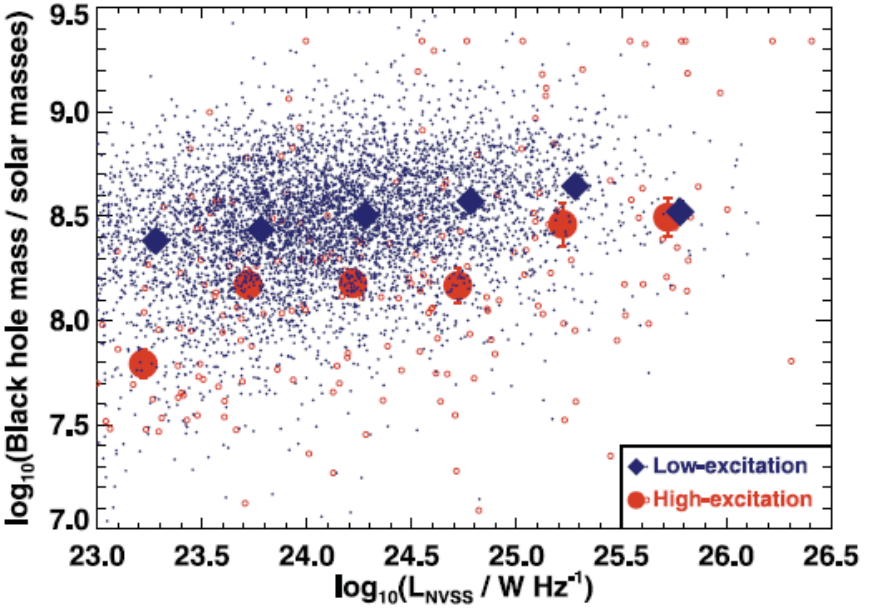
- LERGs are associated with massive galaxies (=> massive black holes) and/or low accretion rates; most will be driven by hot-gas accretion from ICM or stellar winds
- HERGs are associated with high accretion rates and/or lower-mass galaxies; most will be driven by accretion of merger-supplied cold gas
- Statistical association not one-to-one correlation but otherwise compatible with the predictions of Hardcastle+07.

Predictions

- (powerful) LERGs favour massive galaxies, rich environments, little sign of merger, low star formation rate, evolve weakly with cosmic time
- HERGs favour lower-mass galaxies, poorer environments, relatively high merger rate, higher star formation rate, evolve strongly with cosmic time

Galaxy mass and M_BH



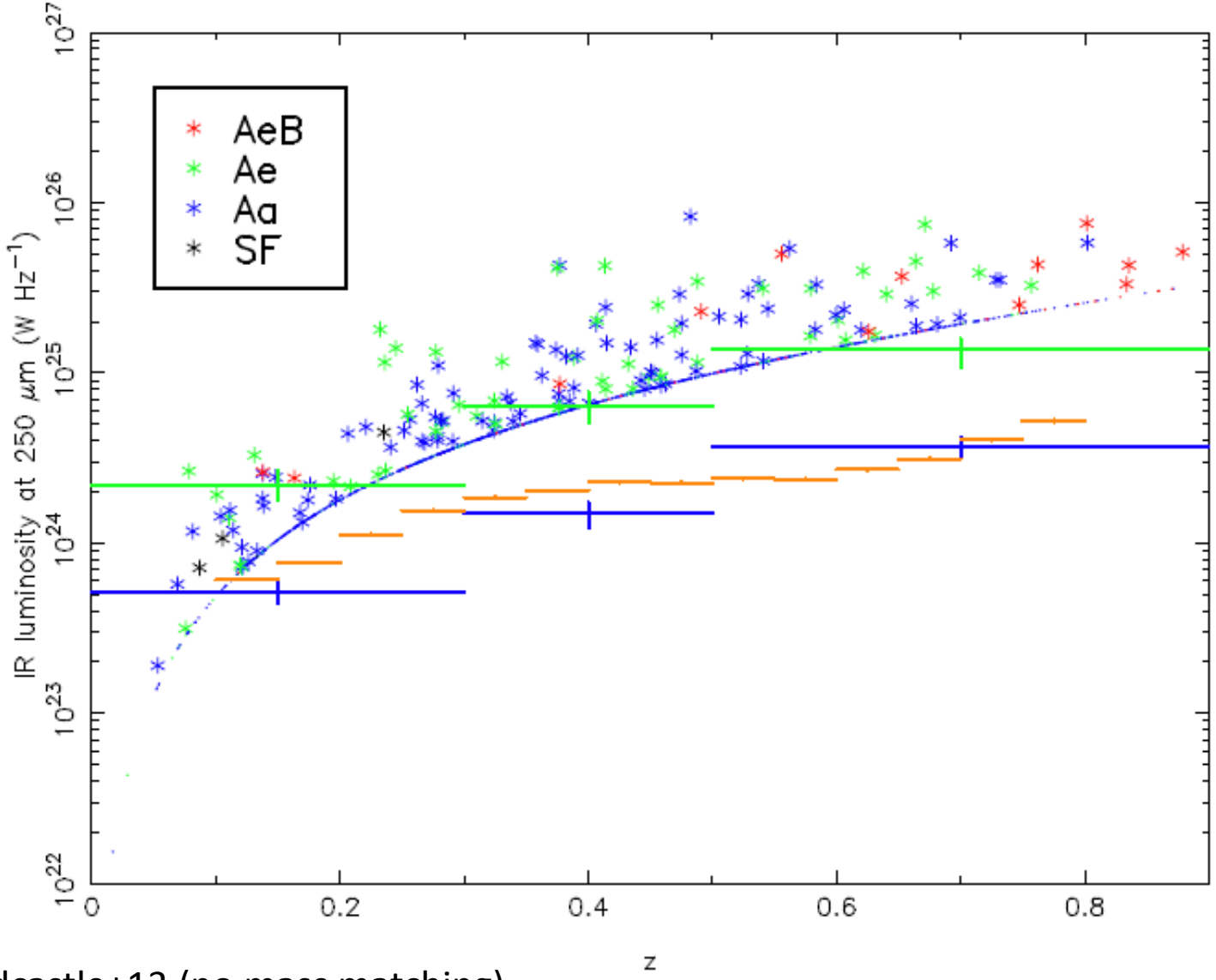


At a given radio power HERG do indeed occupy less massive galaxies than LERG, and have less massive BH (Best+Heckman 2012)

Interaction/merger

- Ramos Almeida+12: NLRG show significantly more signs of tidal disruption/merger than a comparison sample of normal galaxies; LERG do not
- Explains discrepancy between results on powerful and low-power RGs dating back to Heckman+86.
- No evidence for merger/interaction triggering of LERGs in a large sample – Ellison+15

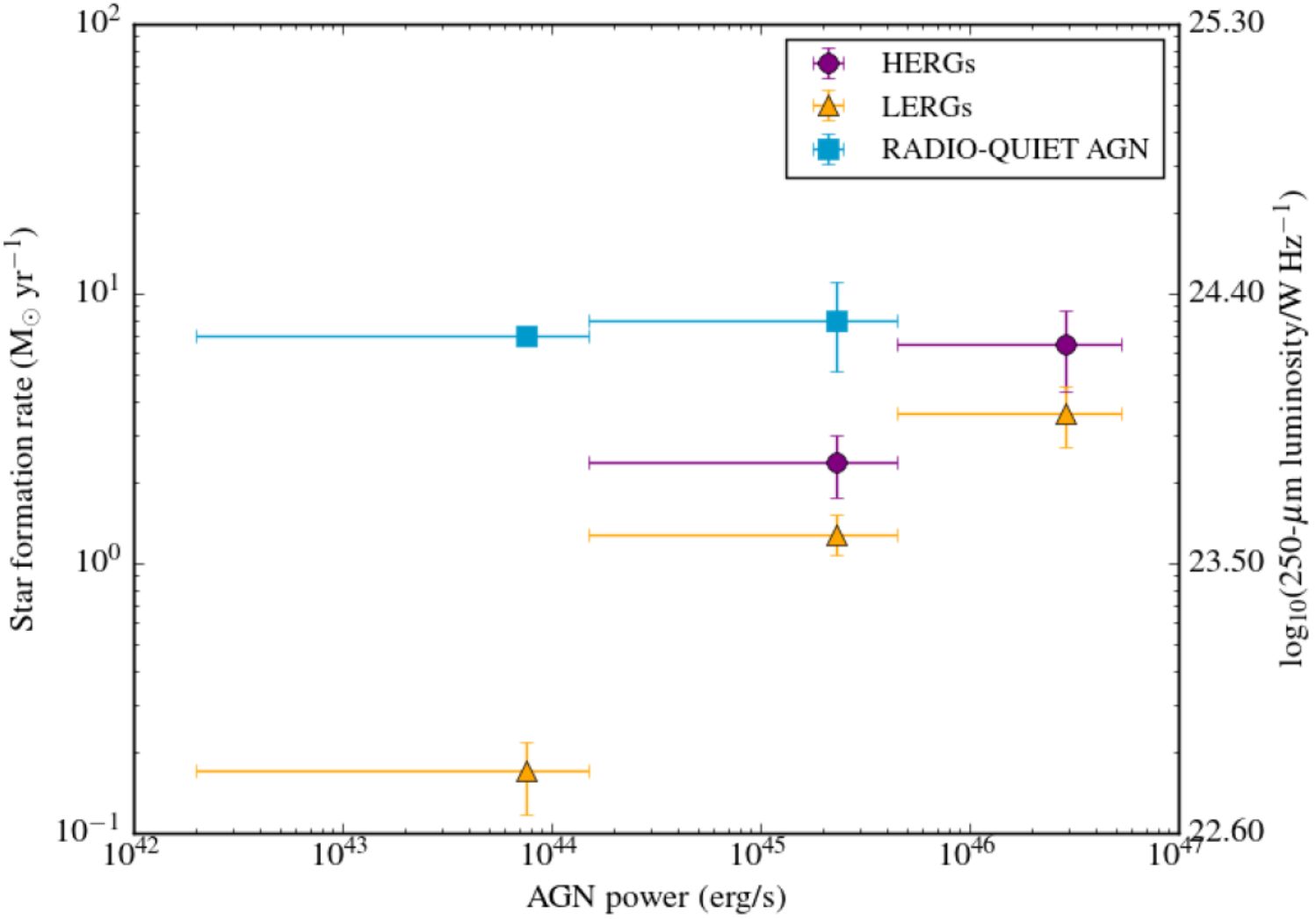
Star formation



HERG
LERG
Comparison
SF

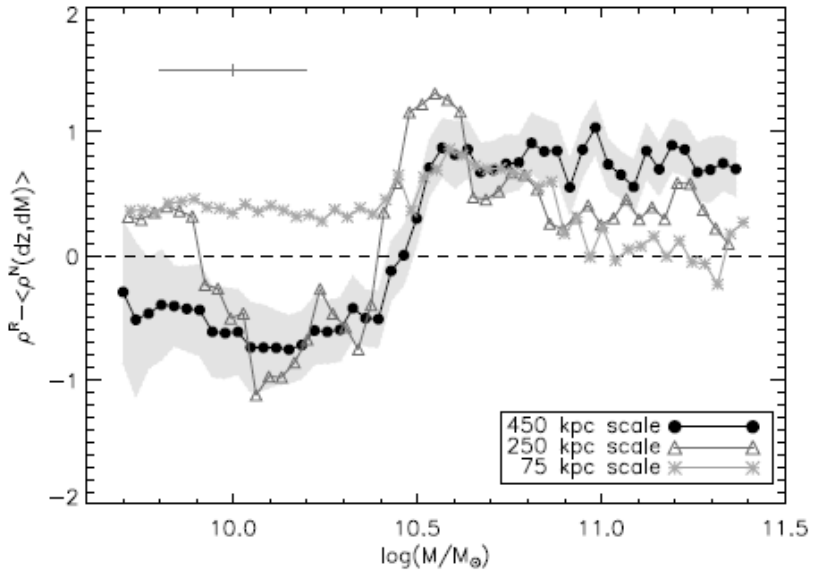
Hardcastle+13 (no mass matching)

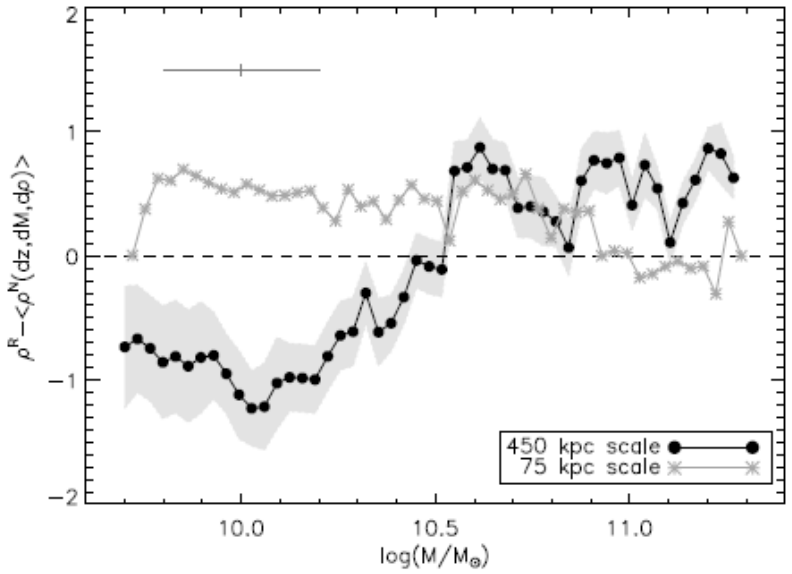
Star formation



Gurkan+15; mass-*matched* samples binned by AGN power (radiative + kinetic)

Environment

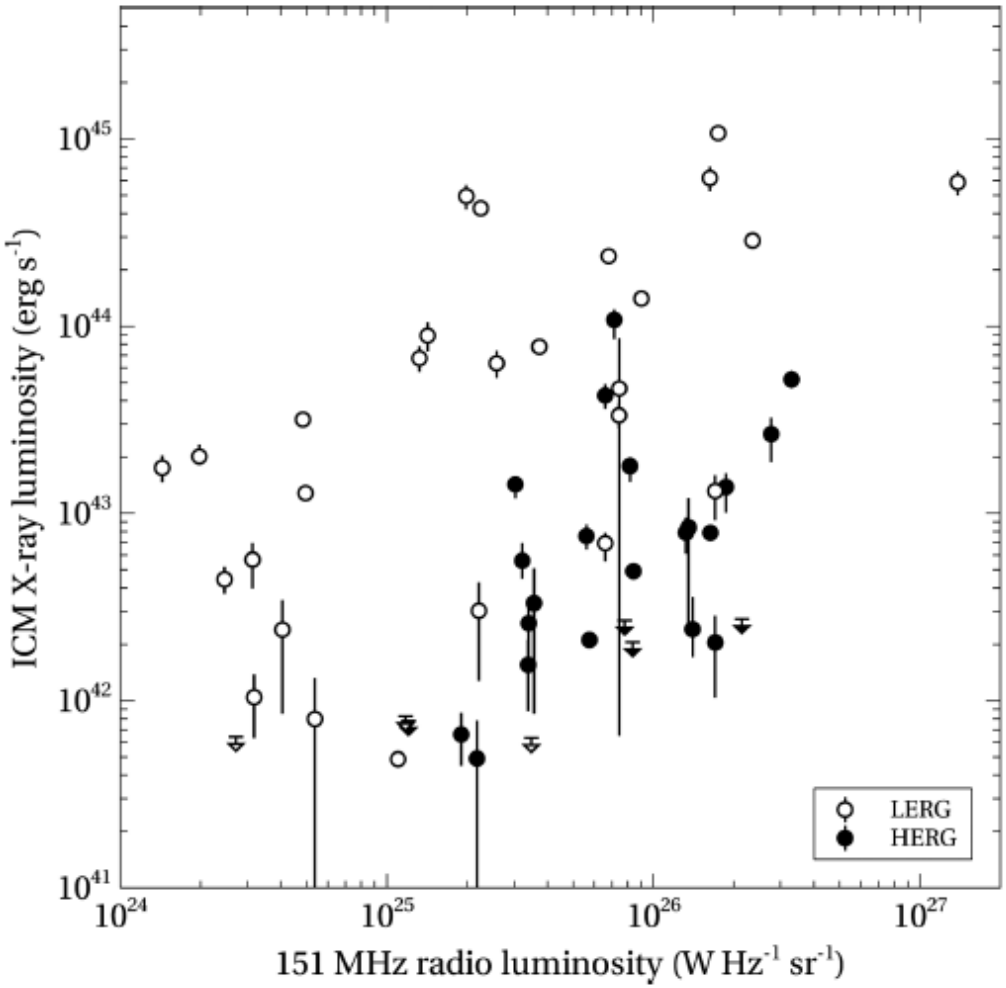




HERG LERG

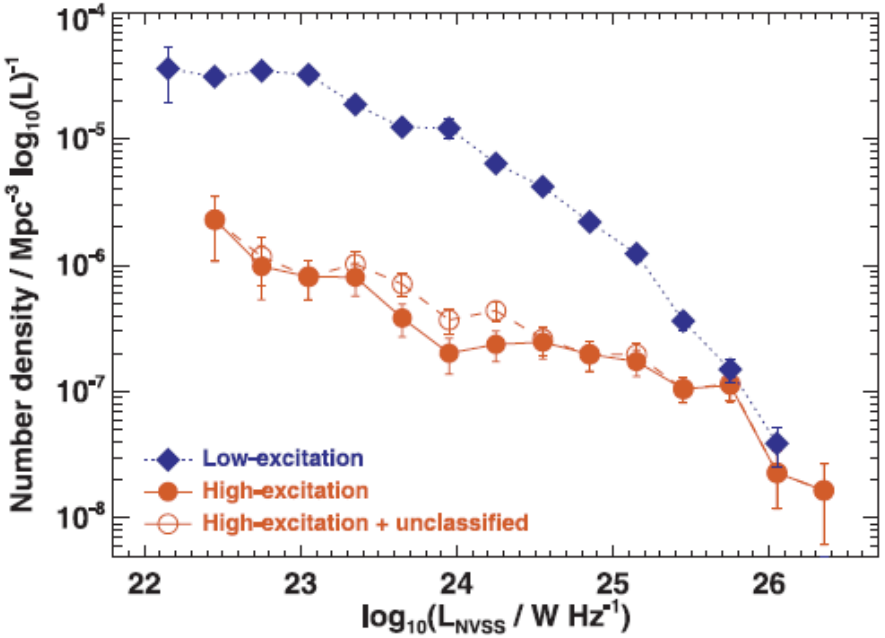
Tasse+ 08

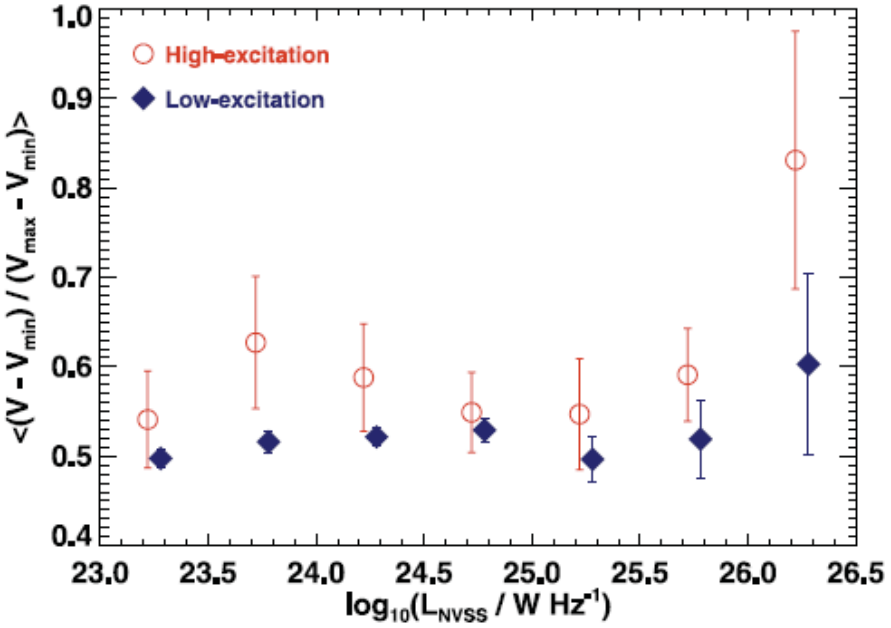
Environment



Ineson+15

Evolution





Best+Heckman 12: see also Smolcic+ 09; Williams+ in prep confirms trend to high z

Summary

- HERG/LERG are different accretion modes
- They produce identical jets; jet generation must be independent of what large-scale accretion flow is doing. (Large range in Ljet/Lrad even for HERGs: implies other controlling parameters, e.g. advection of B or spin.)
- Everything consistent with the accretion switch model – implies consistency with the H+07 predictions
- LERGs are not all ‘switched off HERGs’ (or environment/host galaxy differences would not exist over the sample) BUT nothing prevents an individual object changing type
- Future work will involve classifying large samples of LERG/HERG (e.g. by IR properties) and looking for evolution to high z