Understanding mechanical feedback from HERGs and LERGs

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HERGs

High Excitation Radio Galaxies/ cold mode/ quasar mode/ radiative mode:

- ★ Cold gas accreted 1-10% Eddington rate.
- ★ Form a stable accretion disk.
- ★ Radiate efficiently across whole EM spectrum.
- ★ Display typical AGN characteristics.
- ★ Show high-excitation lines in optical spectra.
- ★ More prevalent at earlier epochs.
- ★ Tend to be hosted by optically bluer galaxies.
- ★ Dominate at higher luminosities.

LERGs

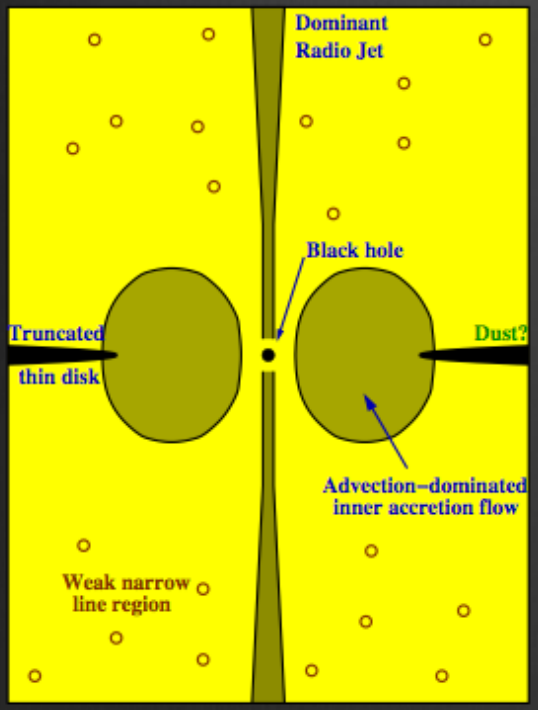
Low Excitation Radio Galaxies/ hot mode/ radio mode/ Jet mode:

- ★ Accrete from hot gas at < 1% Eddington rate.
- ★ Radiate inefficiently and lack high-excitation optical lines.
- ★ Emit the bulk of their energy in kinetic form as powerful jets.
- ★ Hosted by massive galaxies, often at the centre of a group or cluster.
- ★ Dominate at lower luminosities ($L < 10^{26}$ W/Hz)

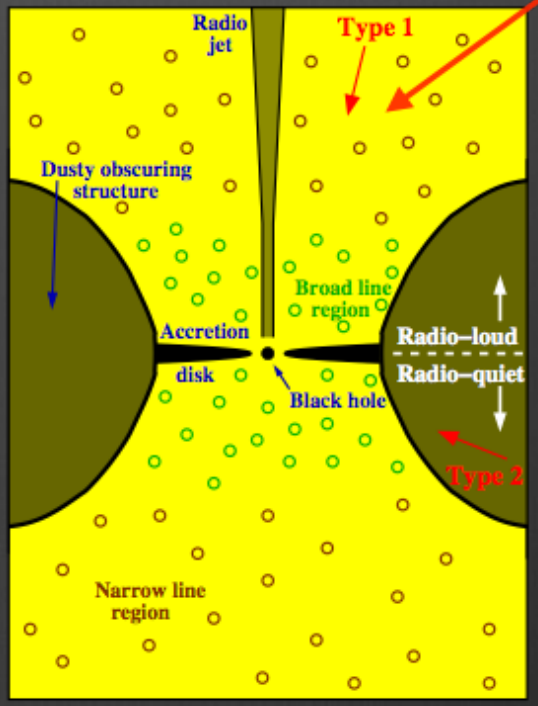
See Best et al. (2005), Hardcastle et al. (2007), Best & Heckman (2012).

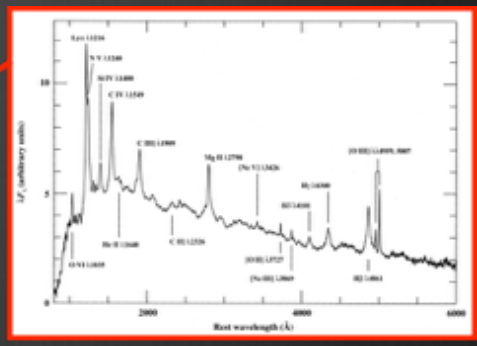
Accretion modes

LERG



HERG





Heckman & Best (2014)

JVLA survey of Stripe-82

★ ~100 sq. deg. field near the equator

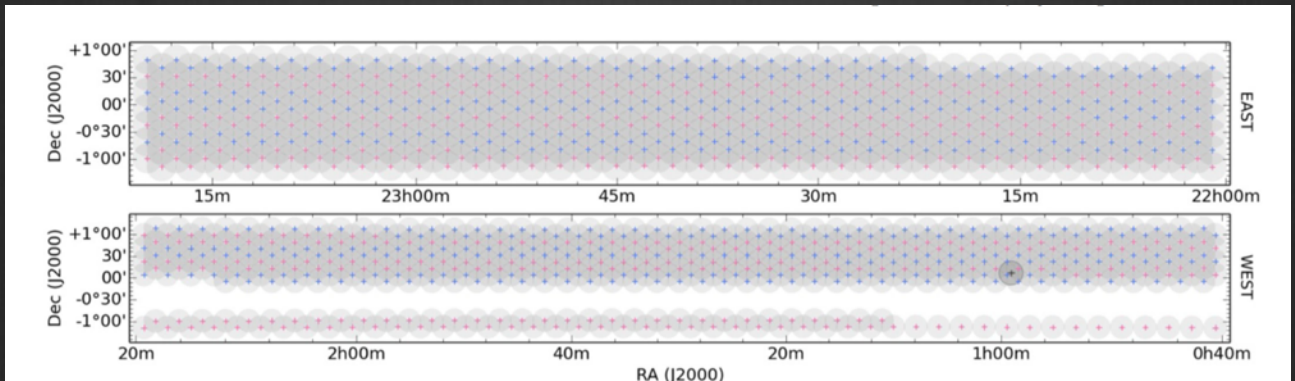
★ JVLA survey at 1-2 GHz - see Heywood et al. (2016)

★ 16 x 10 arcsec resolution, 88 uJy/beam

★ Additional JVLA data with higher resolution (1.5 arcsec) - important for cross-matching (Hodge et al. 2011)

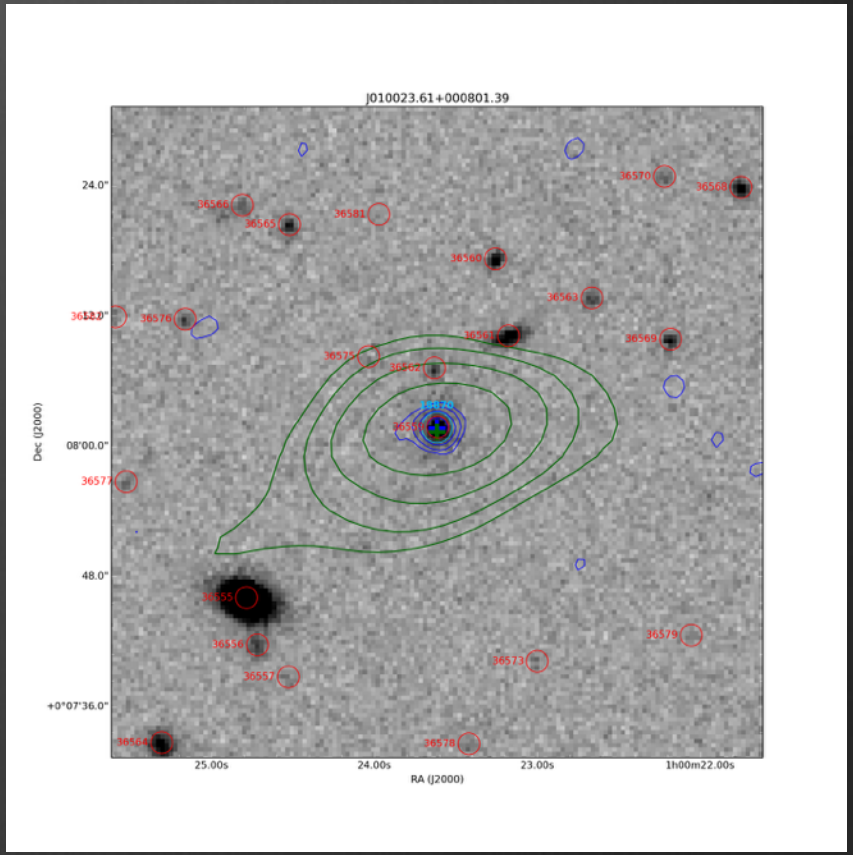
★ Lots of ancillary data!

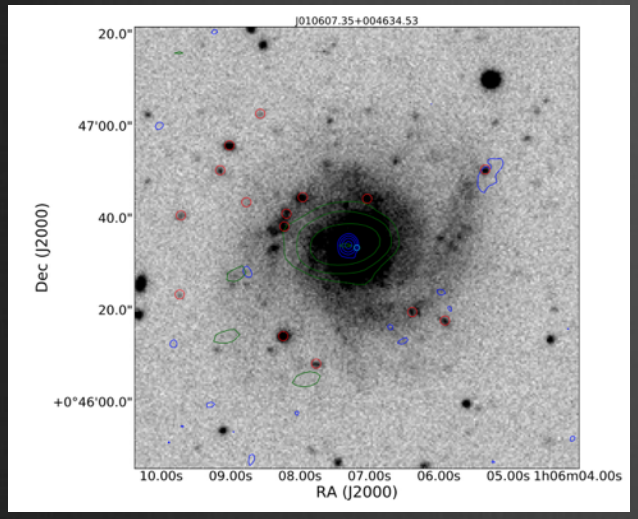
★ SDSS optical, UKIDSS and VHS near-IR, HerMES far-IR

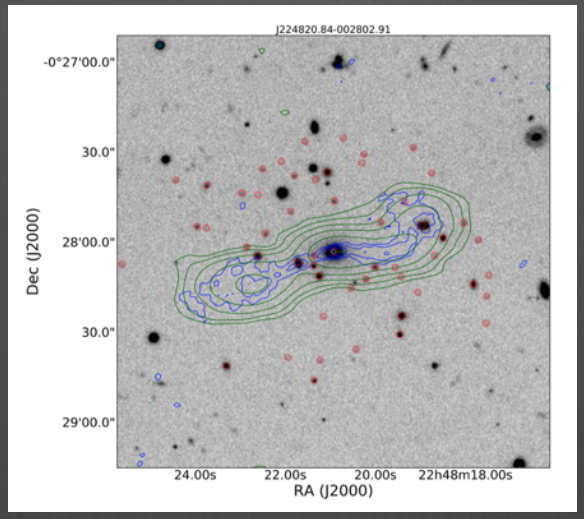


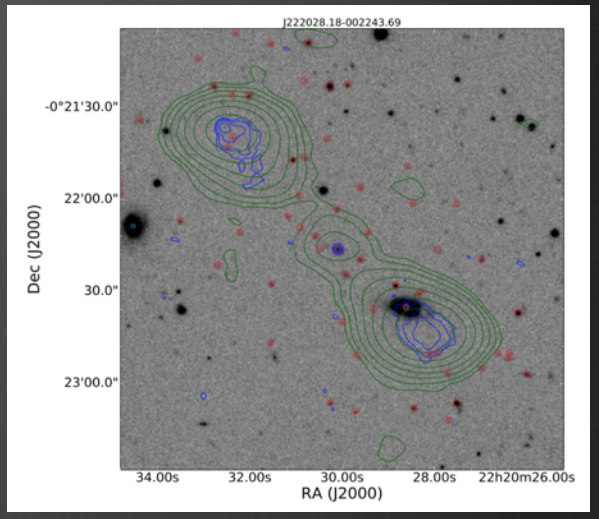
Cross-matching

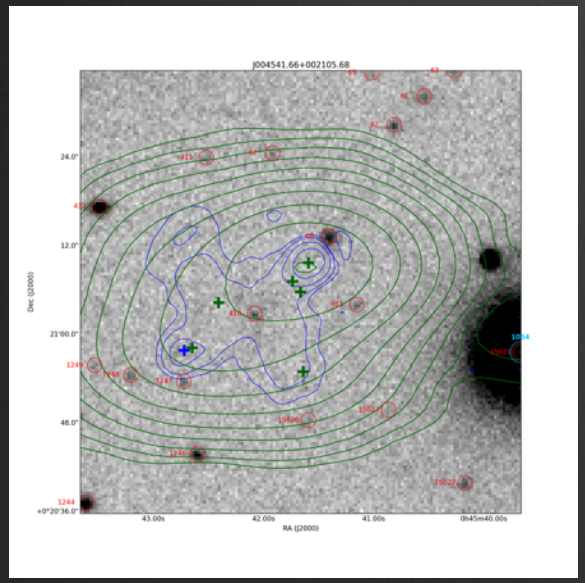
- ★ Matched ~11,000 radio components by eye.
- ★ XMATCHIT code - Prescott et al. (2018) - https://github.com/MattPrescottAstro/
- ★ Each source was classified by three people.
- ★ Each source where there was a disagreement was looked at again.
- ★ Also classified by morphology - compact, FRI, FRII or unsure.

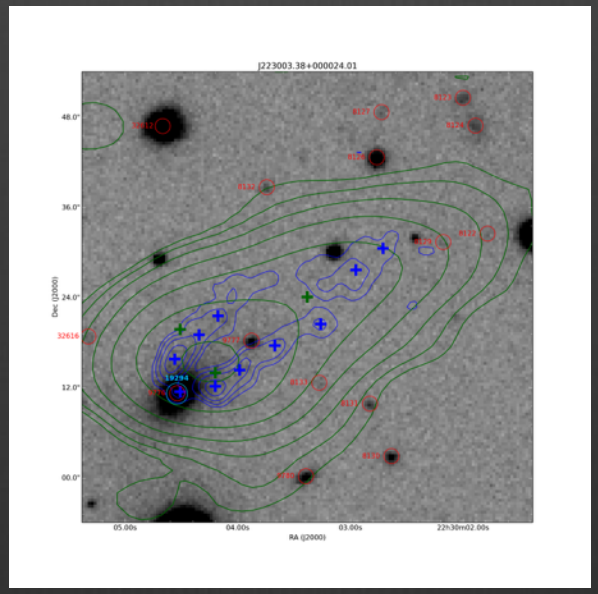


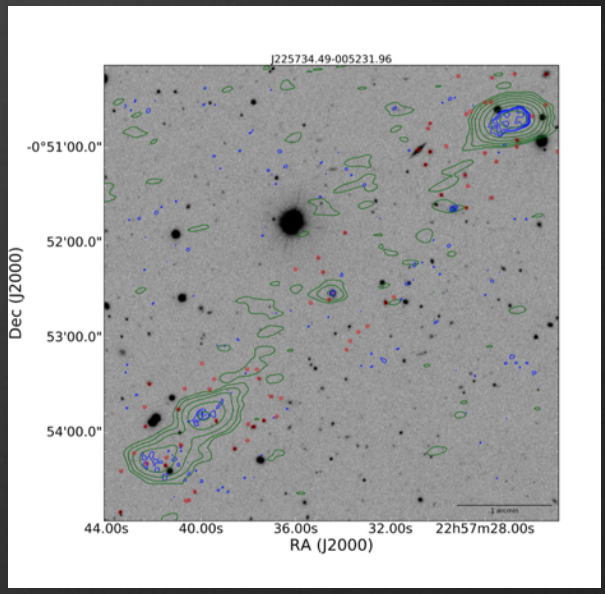










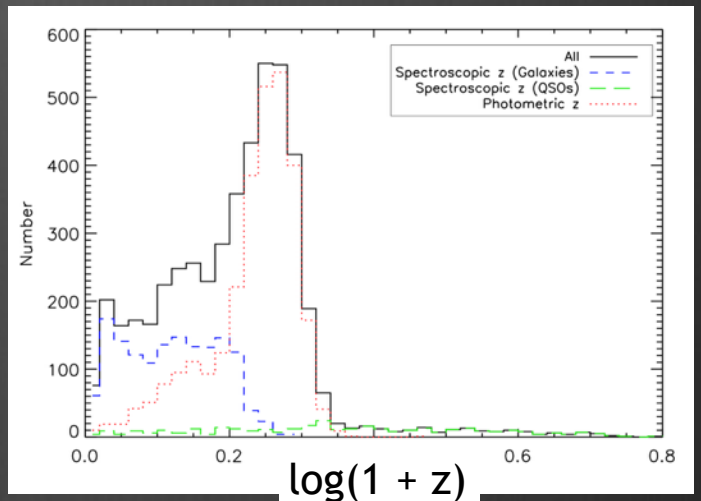


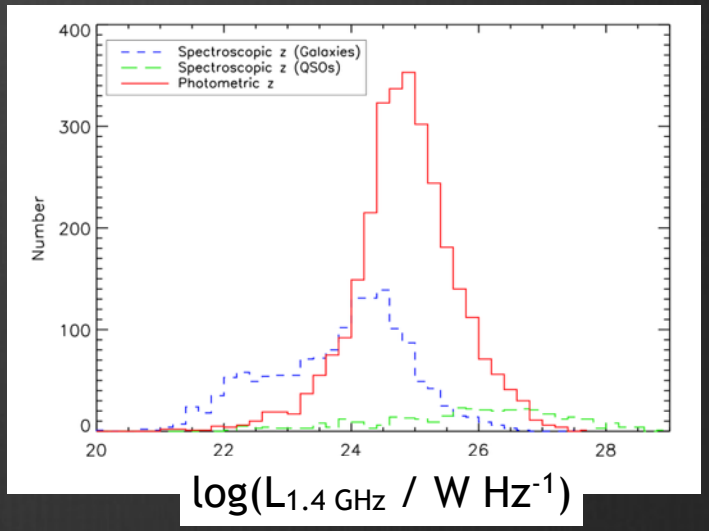
HERGs and LERGs in Stripe 82 — Imogen Whittam

Matched sample

- ★ ~7000 out of ~11000 radio components have an optical counterpart
- ★ Total of ~5000 radio sources with a match
- ★ 1997 with spectroscopic redshifts
- ★ 2799 with photometric redshifts

Full matched catalogue is available on Vizier





Prescott, Whittam et al. (2018)

Matched sample

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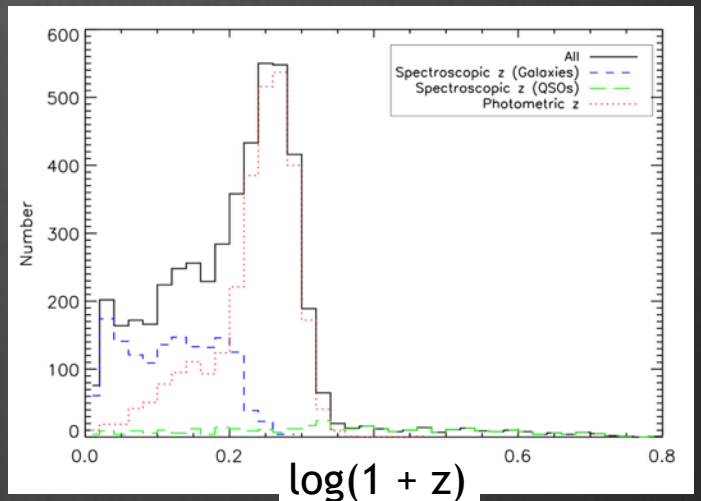
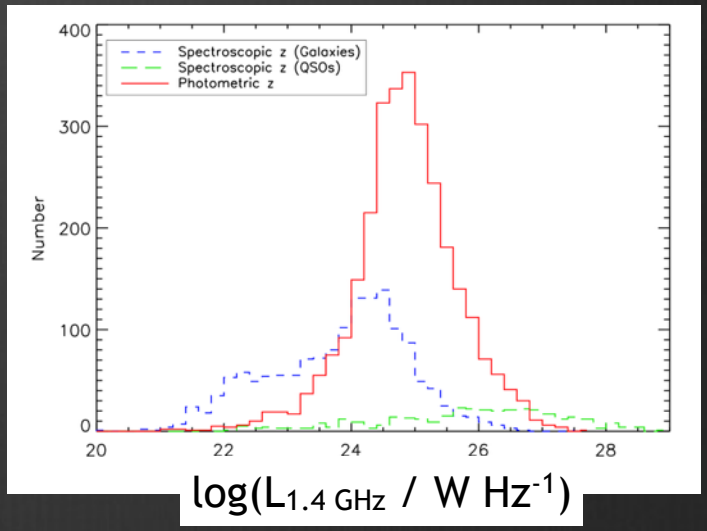
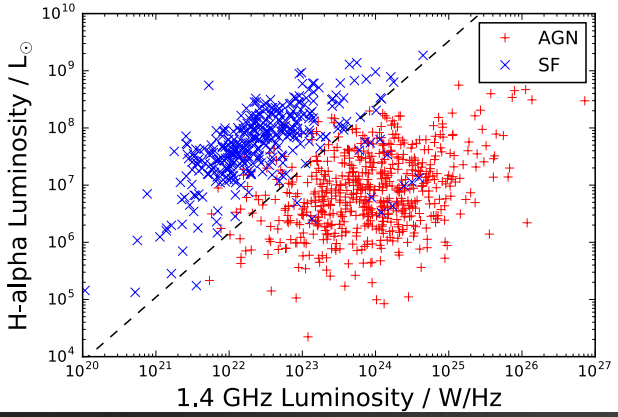
Sample used here: spectroscopic sample with $z < 0.7$ — 1440 sources

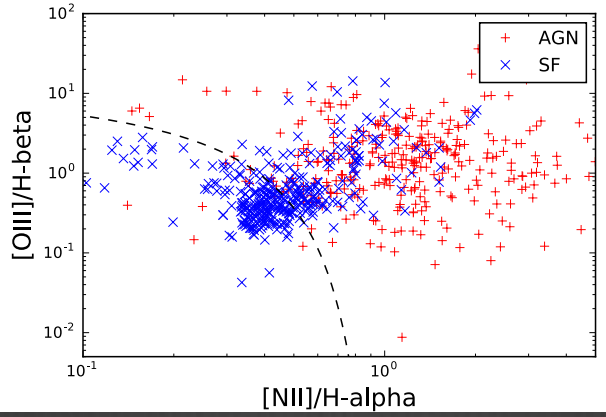


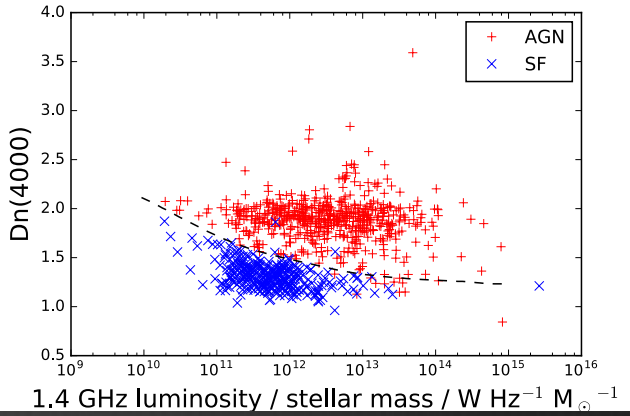


Prescott, Whittam et al. (2018)

Separating AGN from SFGs







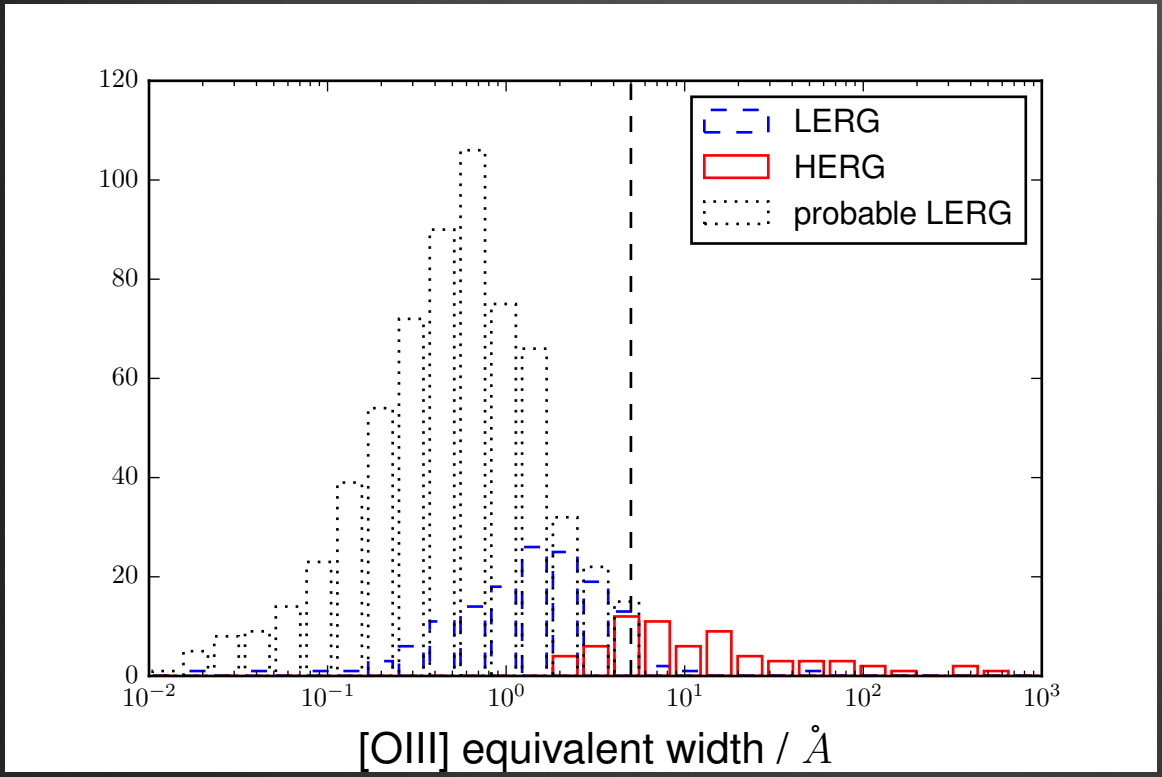
Prescott, Whittam et al. (2018)

★ Combination of three criteria above used.

★ AGN = 1161, star-forming galaxies = 340.

Classifying sources as HERGs and LERGs

- ★ Use same classification scheme as Best & Heckman (2012).
- ★ Uses combination of line ratios (e.g. Buttiglione et al. (2010) Excitation Index, Kewley et al. (2006) BPT diagrams) and [OIII] equivalent width.
- ★ Additional 'probable LERG' class for sources without good enough line measurement to be classified using full criteria with [OIII] EW < 5 Ang.
- ★ HERGs = 60, LERGs = 149, Probable LERGs = 600.



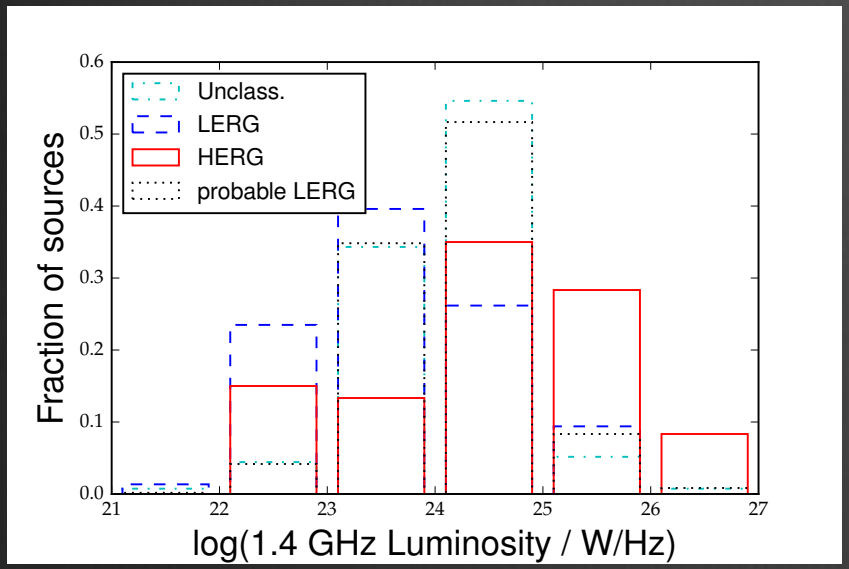
Whittam et al. (2018)

HERGs = 60
LERGs = 149
Probable LERGs = 600

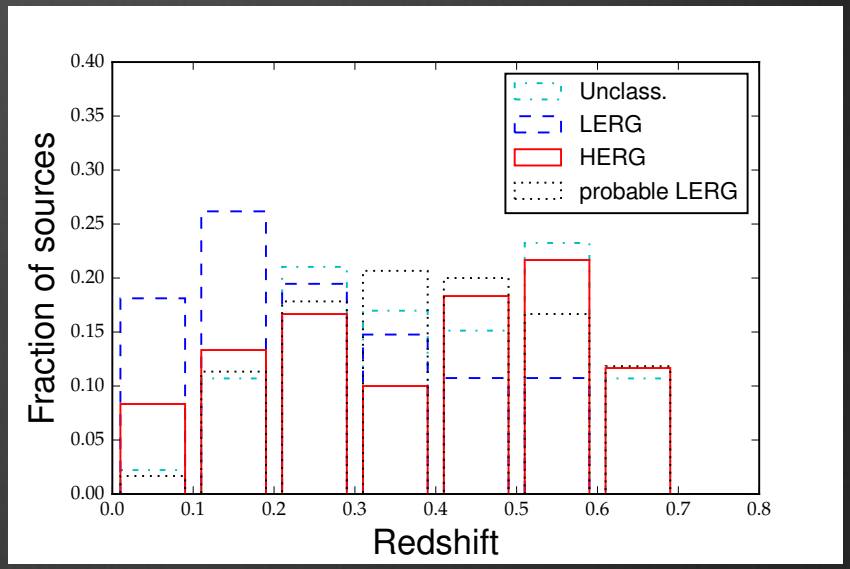
No clear dichotomy in [OIII] equivalent width distribution.

Properties of HERGs and LERGs

Luminosity

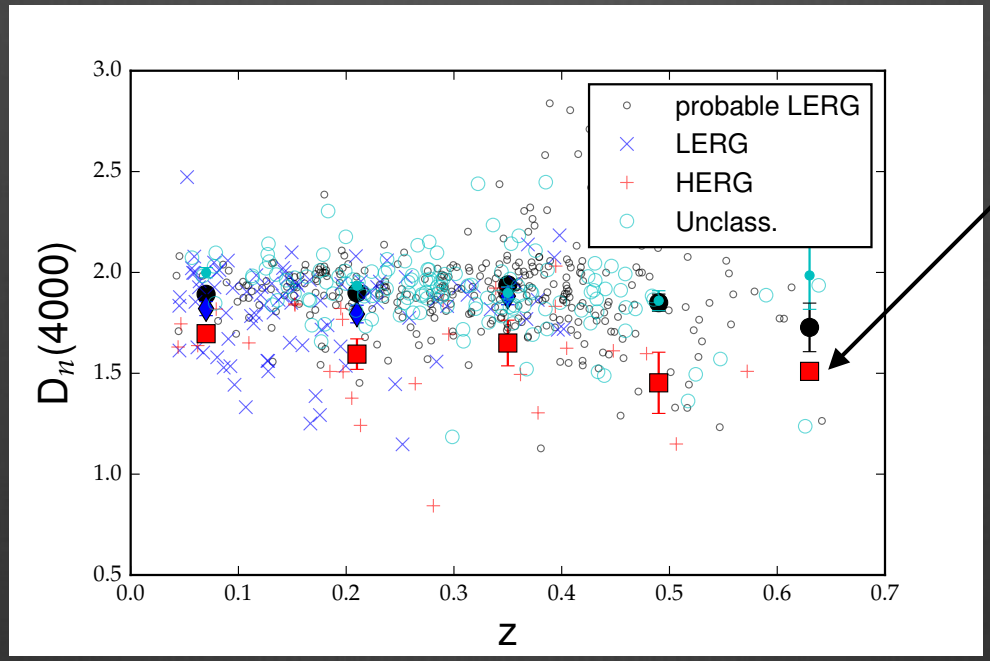


Redshift



Properties of host galaxies - stellar age

Older stellar population

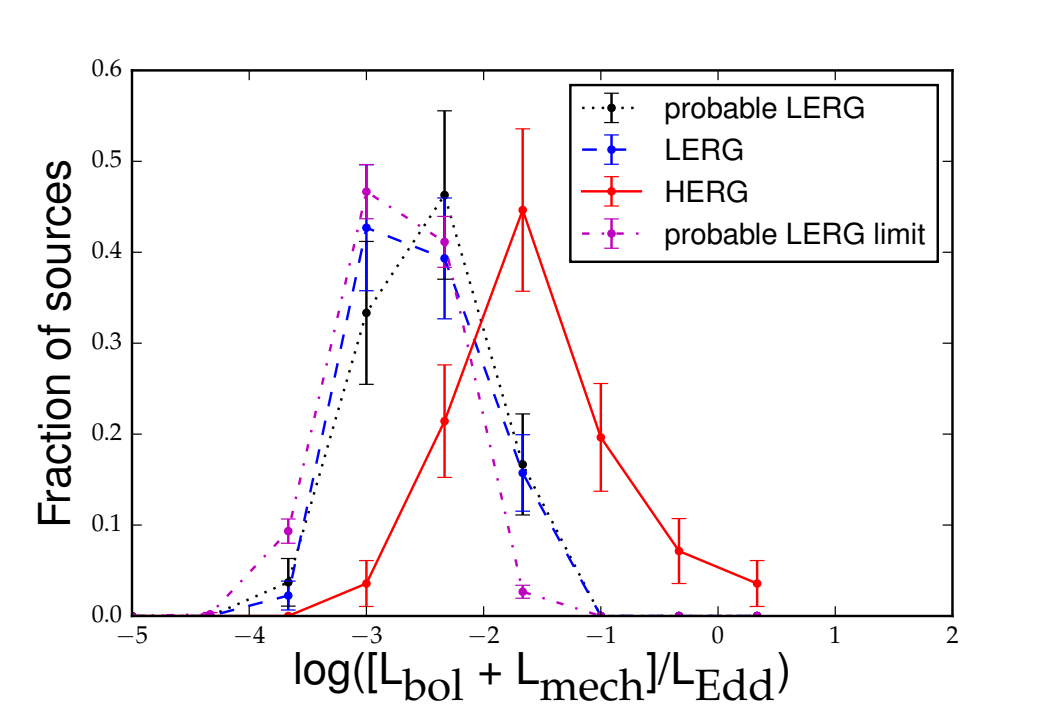


Solid shapes are mean in each redshift bin.

★ Using info from Portsmouth emission line catalogue (Thomas et al. 2013)

★ HERGs tend to be found in galaxies with a younger stellar population.

Accretion rates



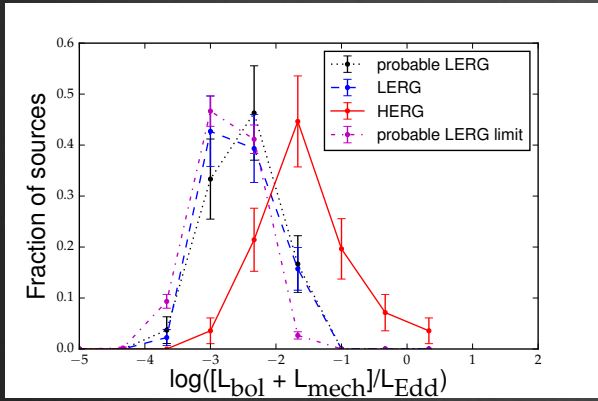
$L_{bol} \sim L_{[OIII]}$
(Heckman et al. 2004)

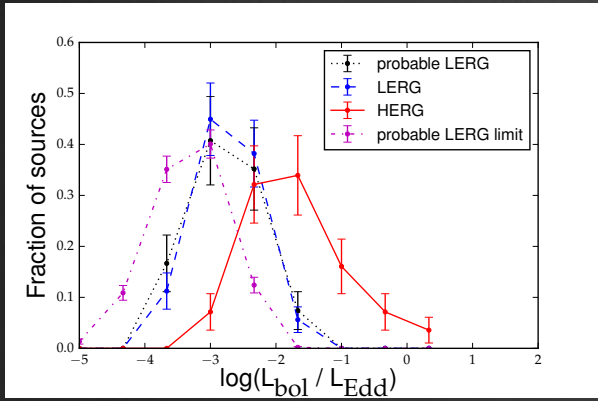
$L_{mech} \sim L_{1.4\ GHz}$
(Cavagnolo et al. 2010)

$L_{edd} \sim M_{BH} \sim M_*$
(Häring & Rix 2004)

Accretion rate = $(L_{bol} + L_{mech}) / L_{edd}$

Bimodal distribution?





Our sample

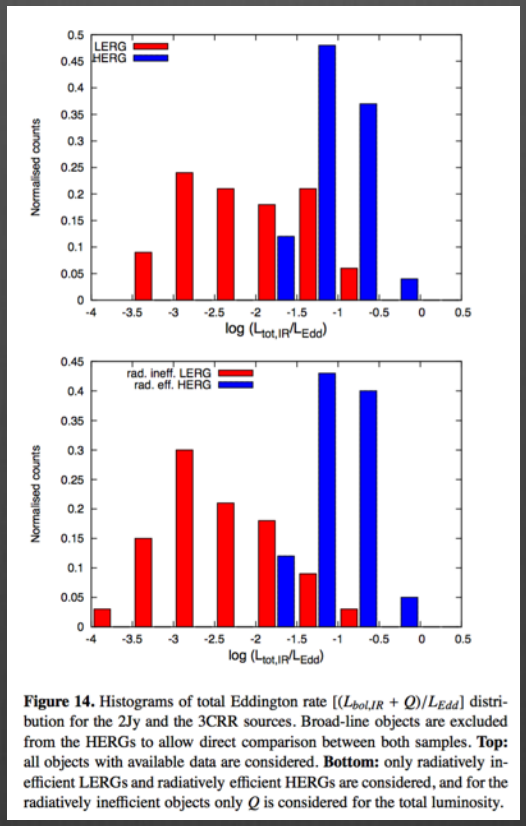
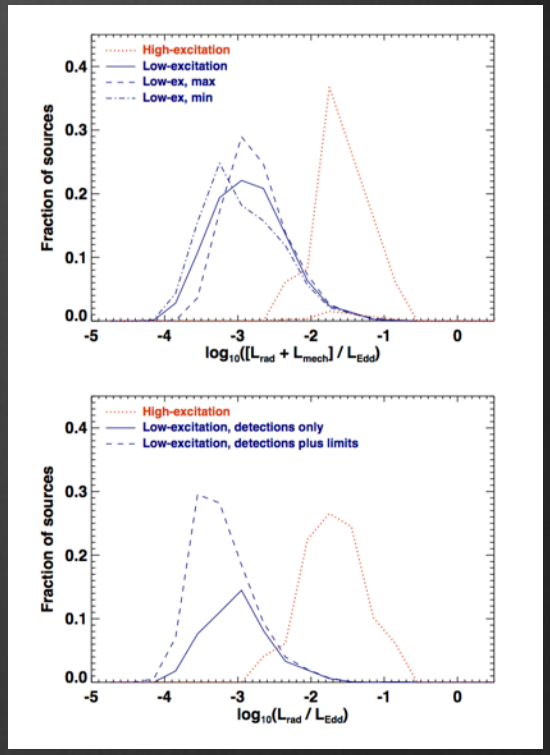


Figure 14. Histograms of total Eddington rate $[(L_{bol,IR} + Q)/L_{Edd}]$ distribution for the 2Jy and the 3CRR sources. Broad-line objects are excluded from the HERGs to allow direct comparison between both samples. **Top:** all objects with available data are considered. **Bottom:** only radiatively inefficient LERGs and radiatively efficient HERGs are considered, and for the radiatively inefficient objects only Q is considered for the total luminosity.

Mingo et al. (2014)

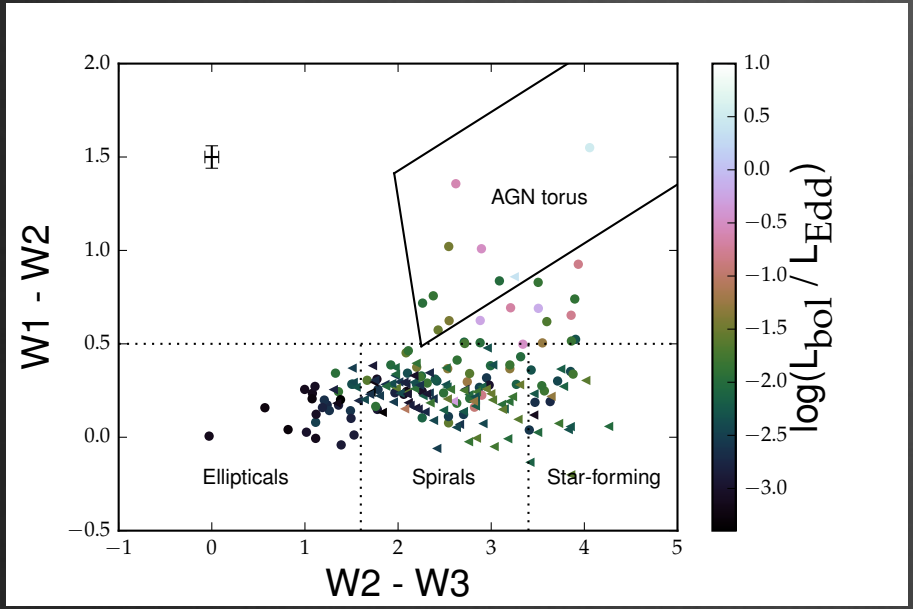


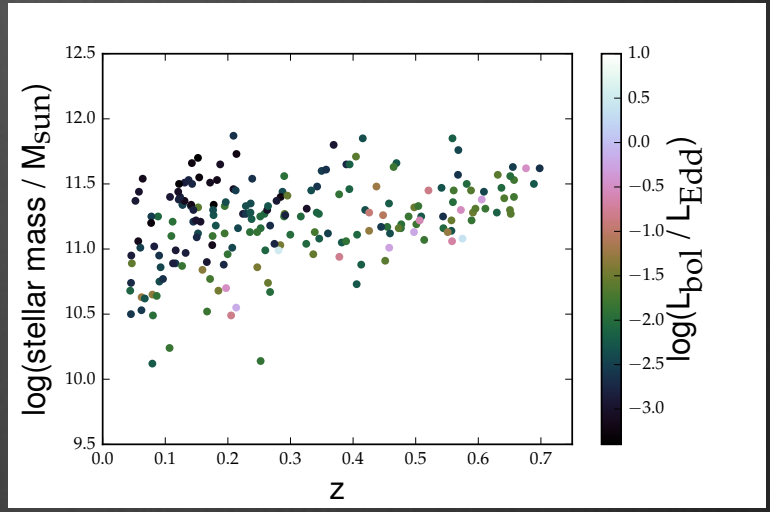
Best & Heckman (2012)

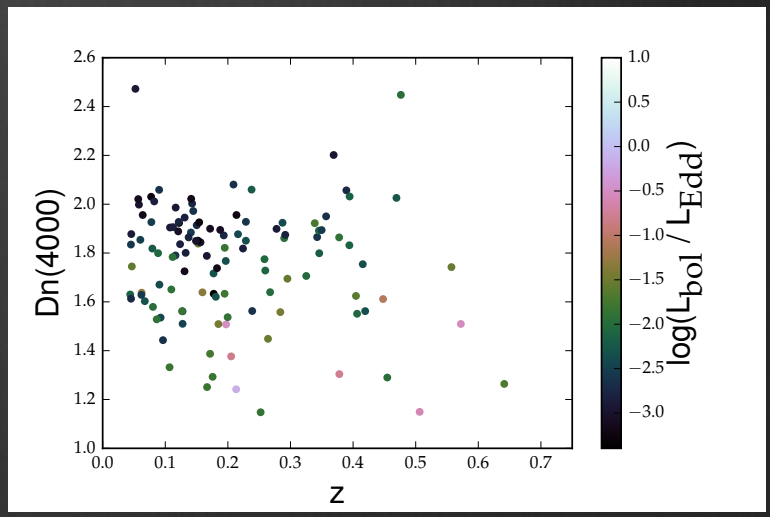
★ Dichotomy is less clear in our sample compared to previous work.

★ Also no dichotomy in [OIII] EW or Excitation Index — any division is perhaps arbitrary.

Properties as a function of accretion rate







★ Continuous distribution of properties with accretion rate rather than a dichotomy?

AGN feedback in hydro sims

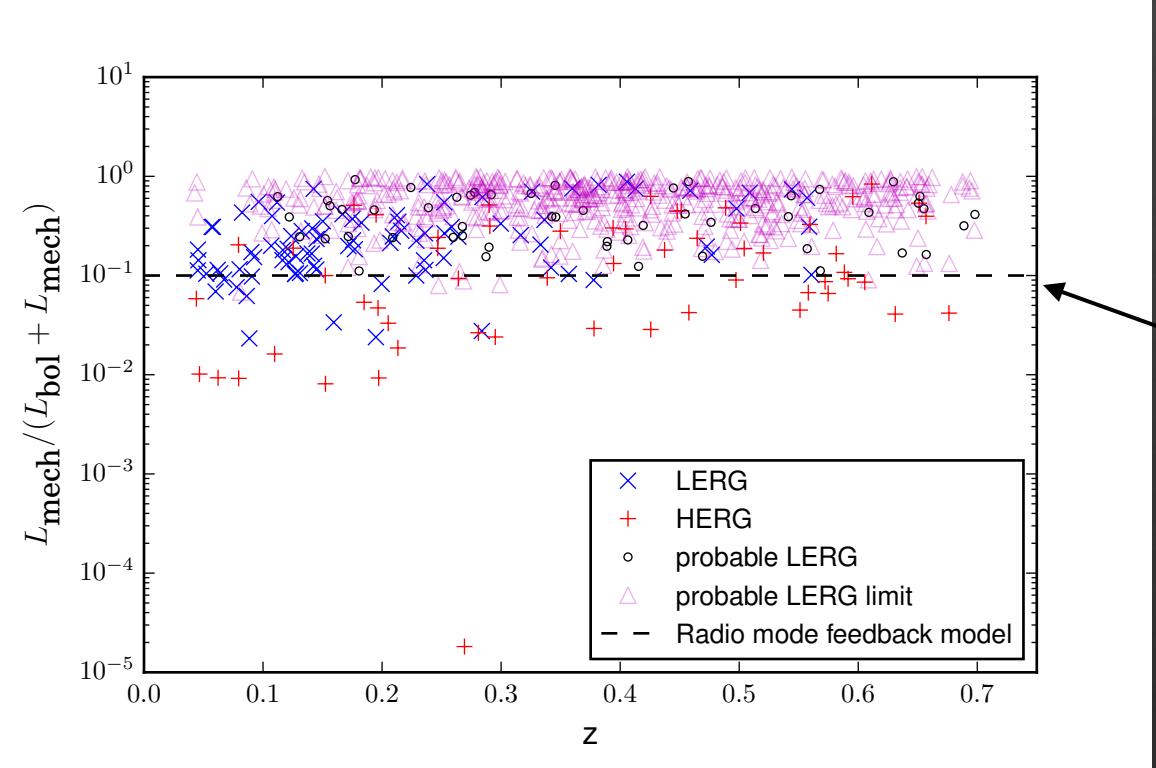
★ Feedback is a key component of hydro sims - required to quench SF.

★ Some sims (Horizon-AGN, Illustris) implement quasar and radio mode feedback separately, others (EAGLE, MUFASA) do not.

★ All leading sims assume the energy deposited back in the ISM scales directly with accretion rate - is this true?

Vogelsberger et al. (2013)

Fraction of total accreted energy deposited in ISM in mechanical form.



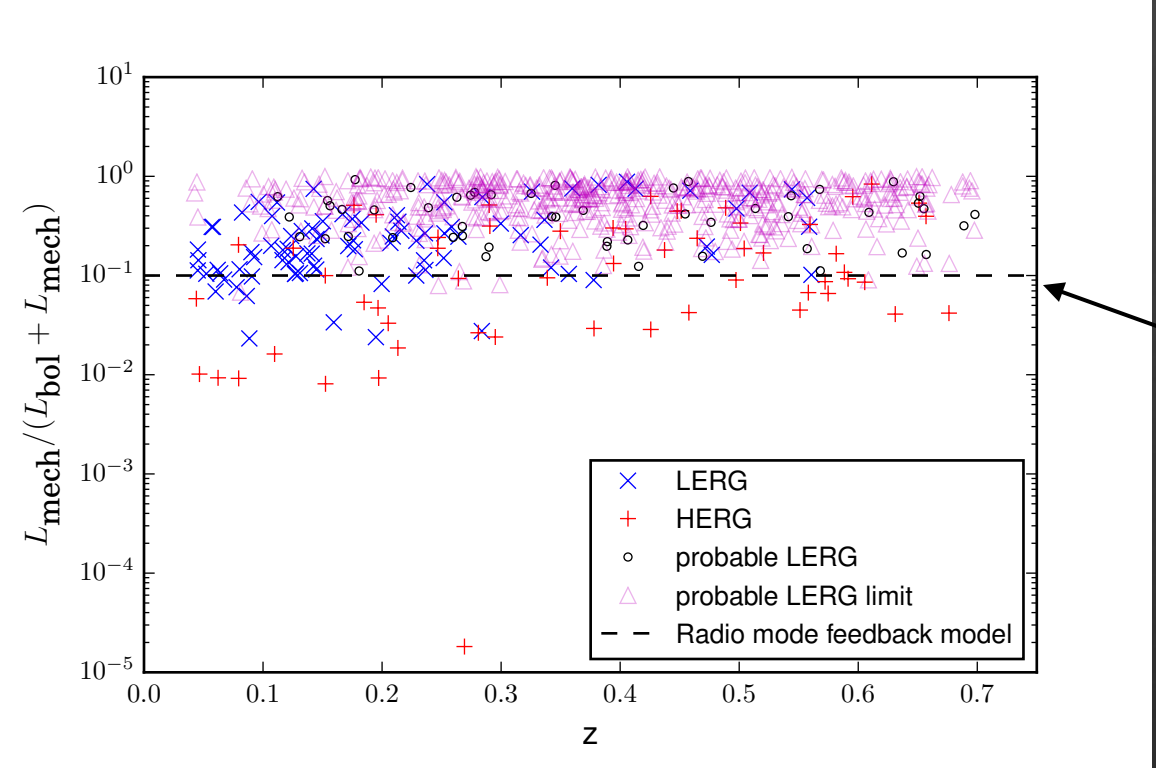
Radio mode feedback from Horizon-AGN

$$\epsilon_{\rm f}\epsilon_{\rm r}\dot{m}_{\rm accr}c^2$$

Whittam et al. (2018)

See Leah Morabito's poster (4K)
"AGN feedback from radio galaxies"

Fraction of total accreted energy deposited in ISM in mechanical form.



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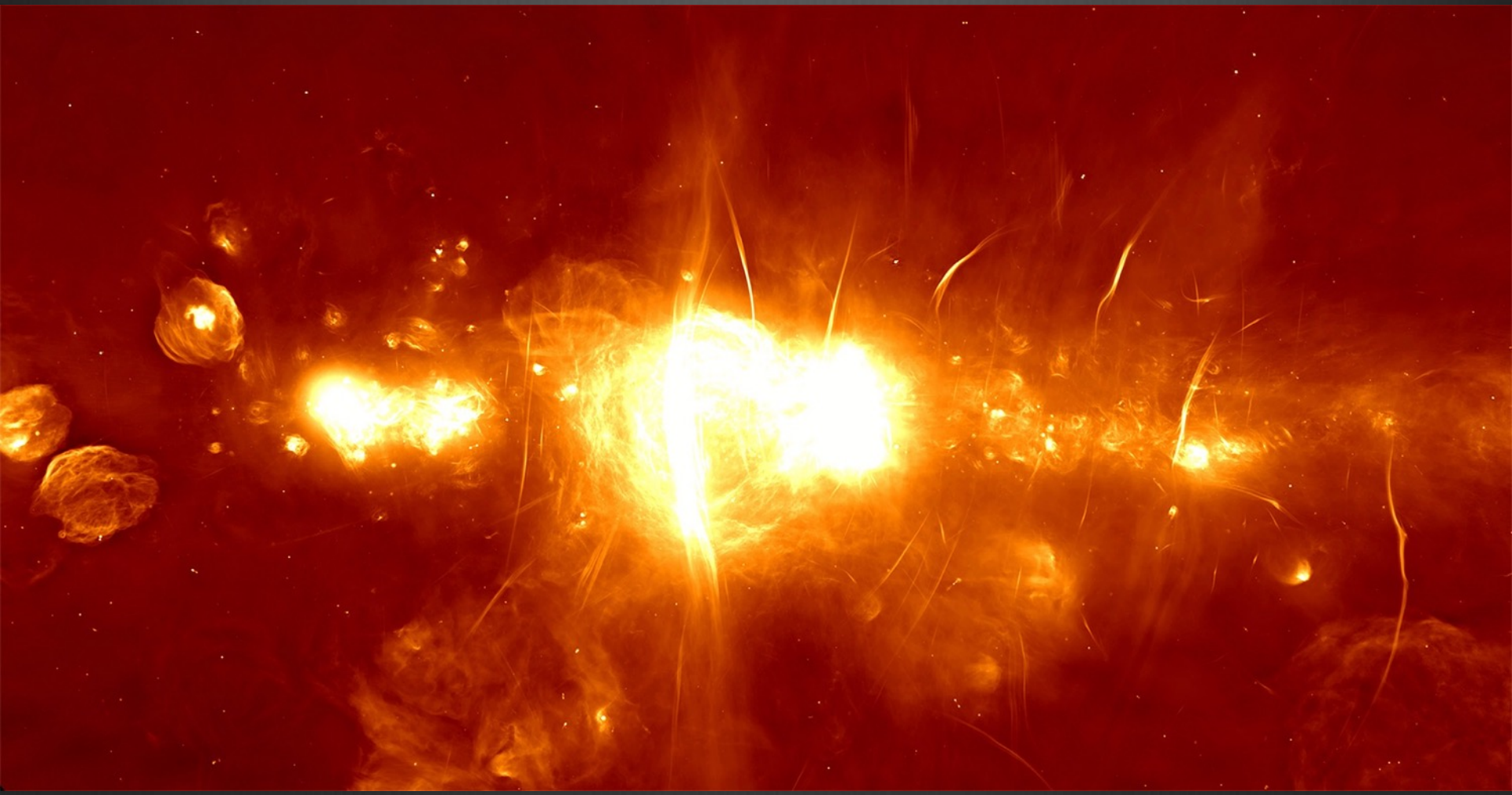
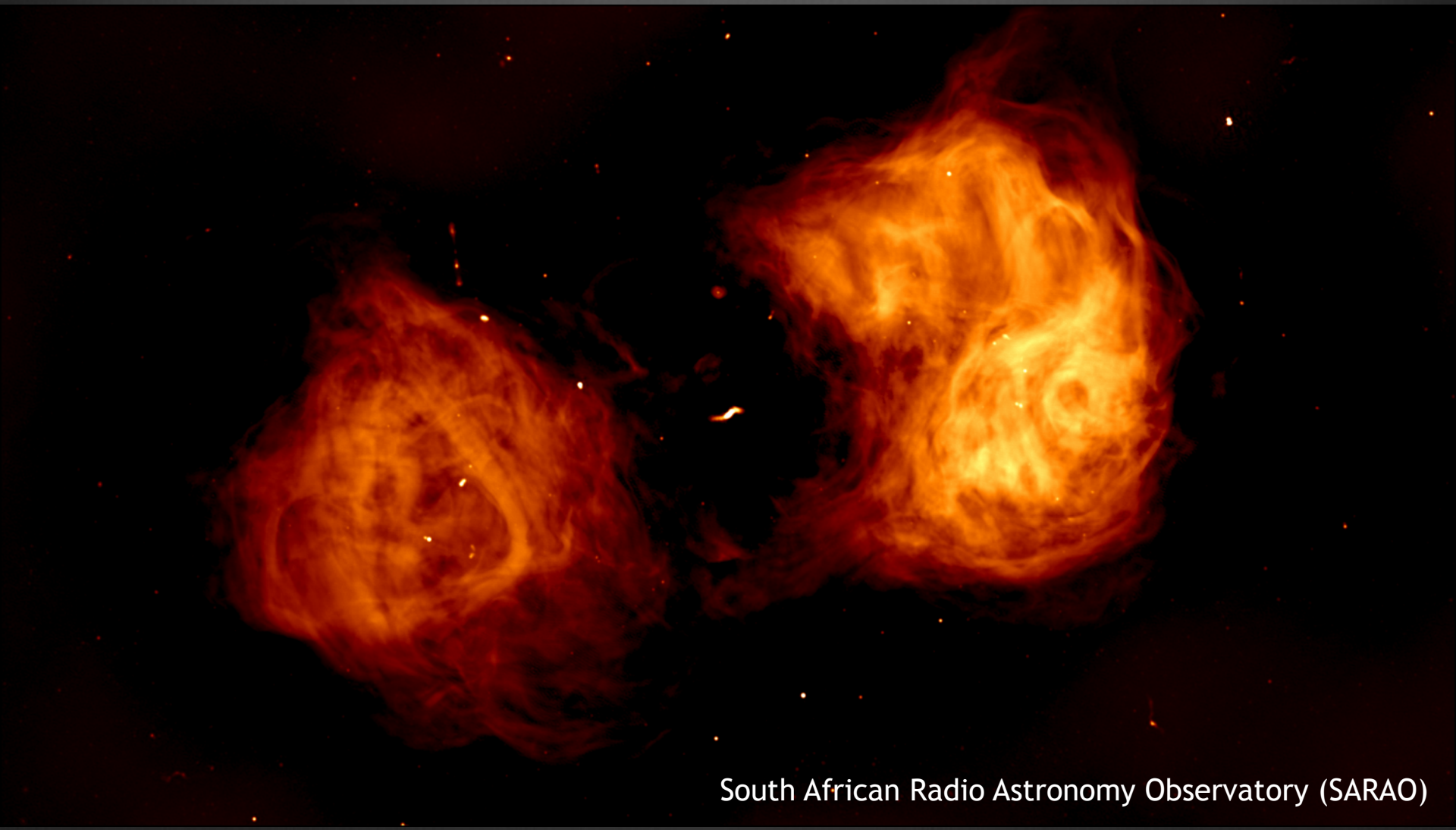
Whittam et al. (2018)

MeerKAT



South African Radio Astronomy Observatory (SARAO)

MeerKAT



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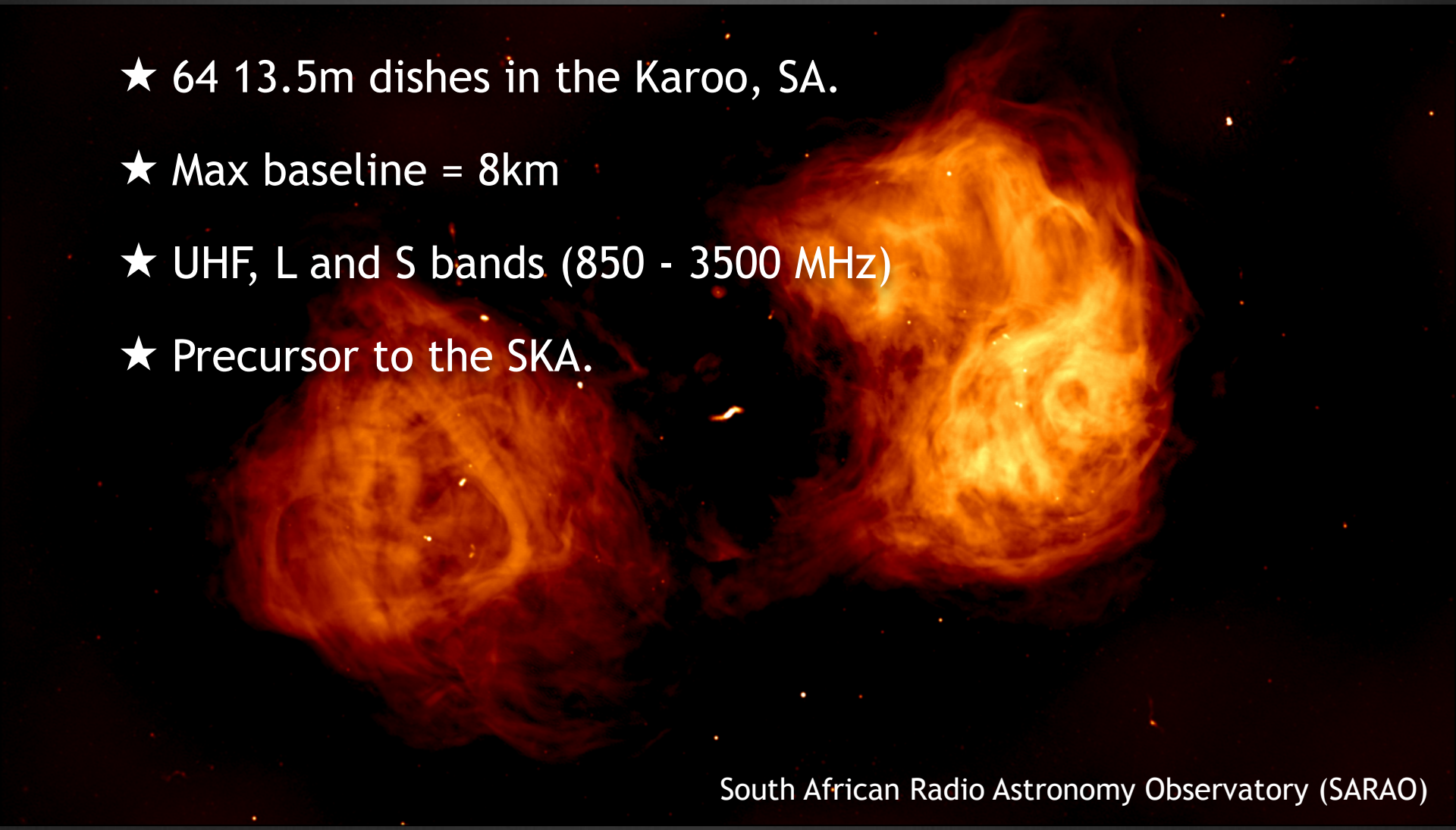


★ 64 13.5m dishes in the Karoo, SA.

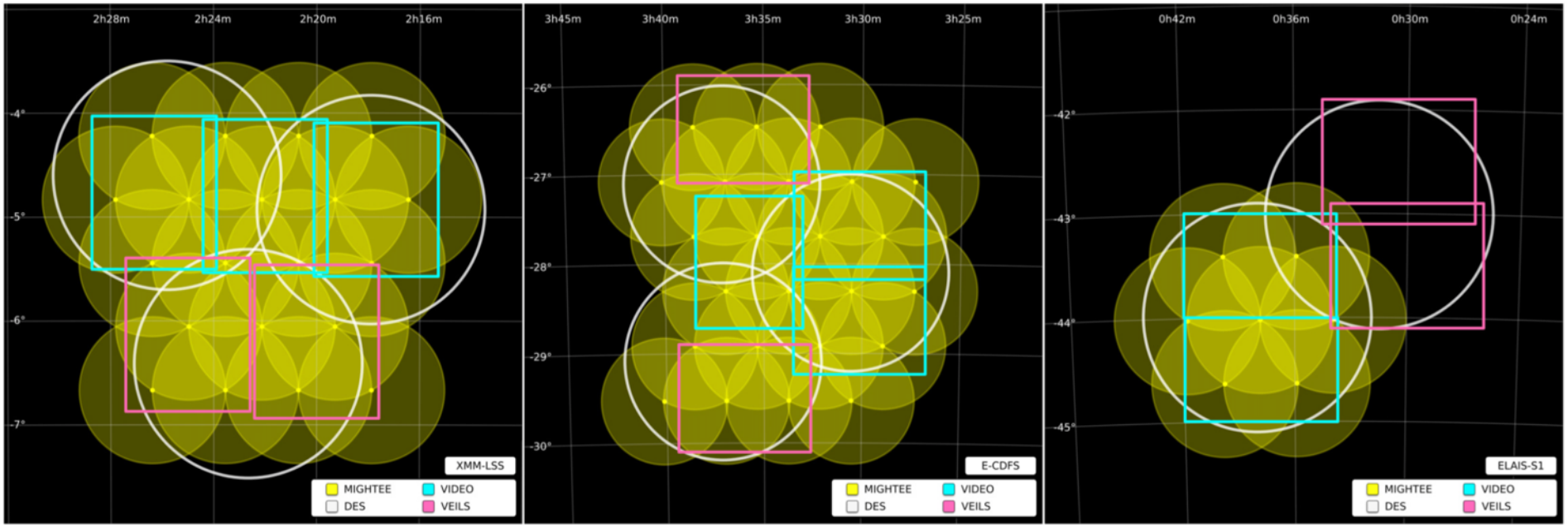
★ Max baseline = 8km

★ UHF, L and S bands (850 - 3500 MHz)

★ Precursor to the SKA.

South African Radio Astronomy Observatory (SARAO)

MIGHTEE



Jarvis, Taylor et al. arxiv.1709.01901

★ Covers 20 deg^2 across 4 fields.

★ L-band (900-1600 MHz)

★ ~1 uJy/beam rms (factor of 4 deeper than JVLA-COSMOS)

★ Also, S-band to 1.5 uJy/beam rms in 7 deg^2

Radio galaxies with MIGHTEE

- ★ Depth (1 uJy/beam) means we will detect radio galaxies out to z ~ 6.
- ★ Will detect 20x as many low-accretion rate sources at z > 1 than VLA-COSMOS survey.
- ★ Covers 20 deg^2 across 4 fields - large cosmological volume - will probe dense and sparse environments.
- ★ Great multi-wavelength data in the MIGHTEE fields.

Conclusions

- ★ Investigated the properties of HERGs and LERGs selected from a JVLA survey of Stripe 82.
- ★ HERGs tend have host galaxies with younger stars and smaller stellar masses - agrees with other work.
- ★ HERGs have higher accretion rates than LERGs, although there is some overlap in our sample.
- ★ Mechanical feedback may be underestimated in most hydro sims.
- ★ MIGHTEE has huge potential for this kind of study.