The Effect of Environment on Black-Hole Accretion Properties

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Why bother about the environment?

- ✓ Gas sourced from an AGN's close environment
- ✓ Gas accretion in AGN fuelling and triggering
- ✓ Properties of AGN in mid-IR, and optical been found to correlate with accretion-mode (Best & Heckman 2012)
  - ✓ Luminosity cut-off radio and mid-IR
  - ✓ Gas excitation levels
  - ✓ Population density of radio galaxy

"environment" is quite a broad term though

- ✓ mergers
- ✓ tidal perturbations
- ✓ hot or cold gas
- ✓ over or under-density
- ✓ cluster or field
- ✓ proximity to neighbours in group or cluster

definitions sometimes overlap and contradict so constraining parameters is important

Key Results So Far - Literature

- ✓ Jones et al (2015): 30 WISE/radio-selected AGNs reside in over-dense regions populated by active, luminous and dusty galaxies
- ✓ Silverman et al (2011): X-ray selected (zCOSMOS), AGN host fraction higher in pairs (< 75 kpc separations) than in isolated galaxies (mass-matched)

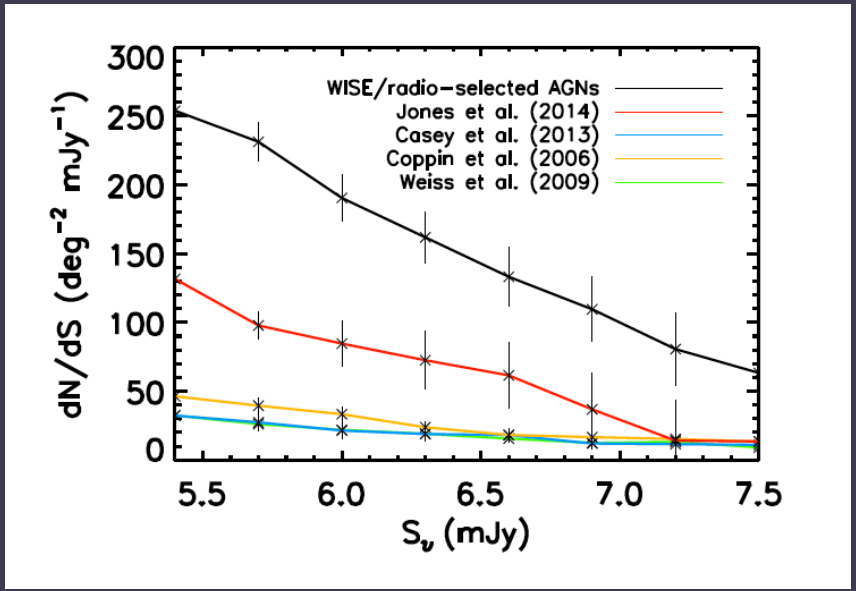

fig.1: Jones (2015)

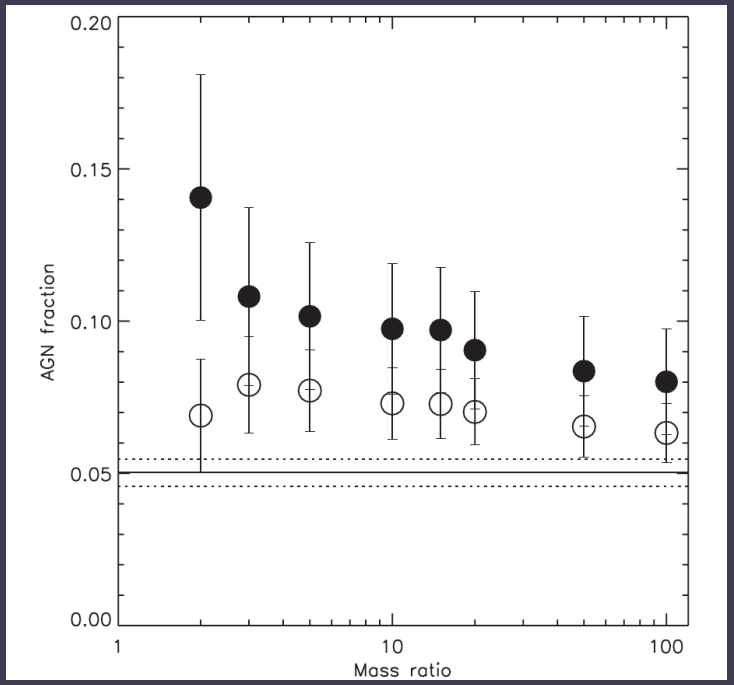

fig.2: Silverman (2011), dark dots: close kinematic pairs

Key Results So Far - Literature

- ✓ Malavasi et al (2015): low-power radio AGN reside in denser regions
- ✓ Best (2004): optical and radio-selected SF galaxies more likely found in under-dense areas

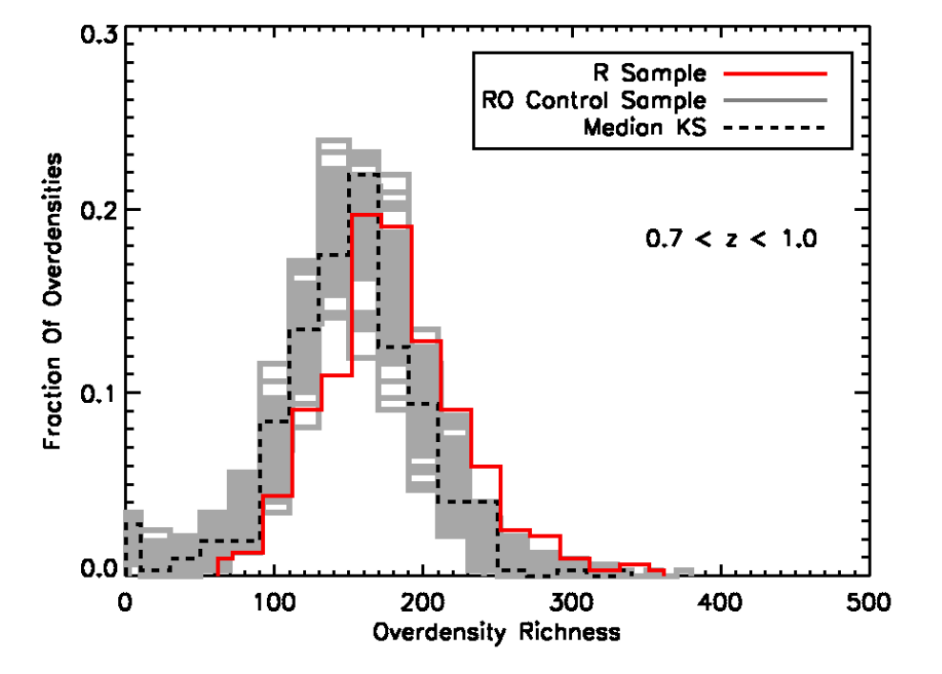

fig.3: Malavasi (2015)

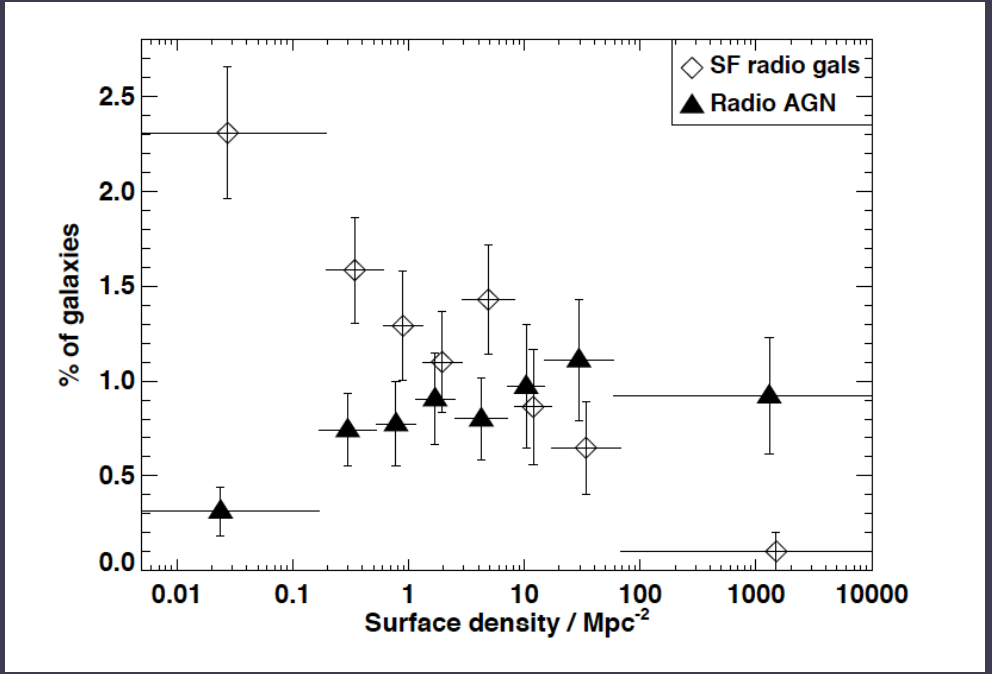

fig.4: Best (2004)

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Key Results So Far - Literature

- ✓ Burton et al (2013): far-IR detected & SF (5 sol mass /yr) galaxies more probable less dense regions
- ✓ Kauffman (2004): sSFR decreases from under-dense to denser regions; at fixed mass, SF and nuclear activity depend strongly on local density

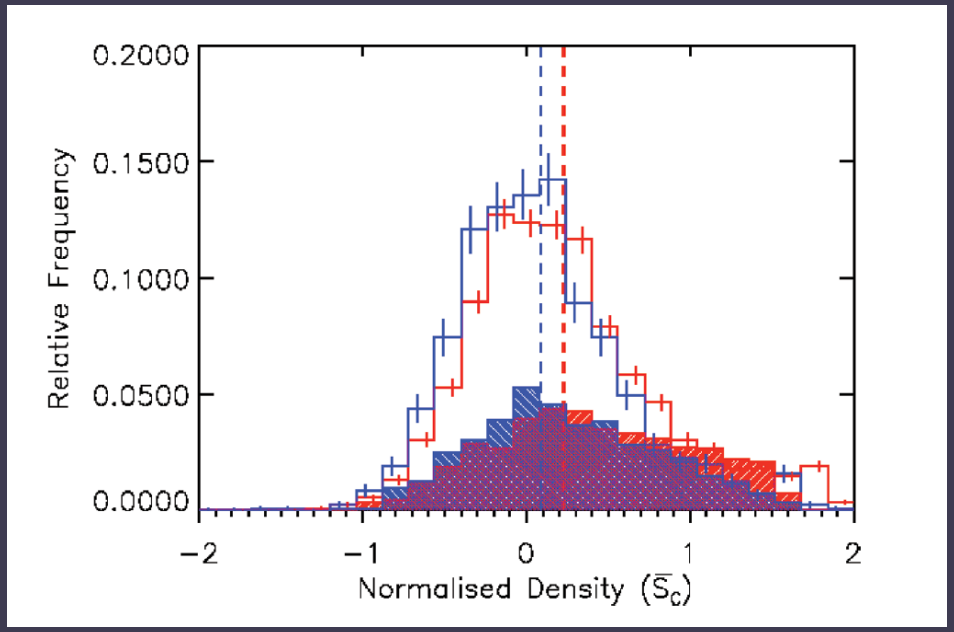

fig.5: Malavasi (2015)

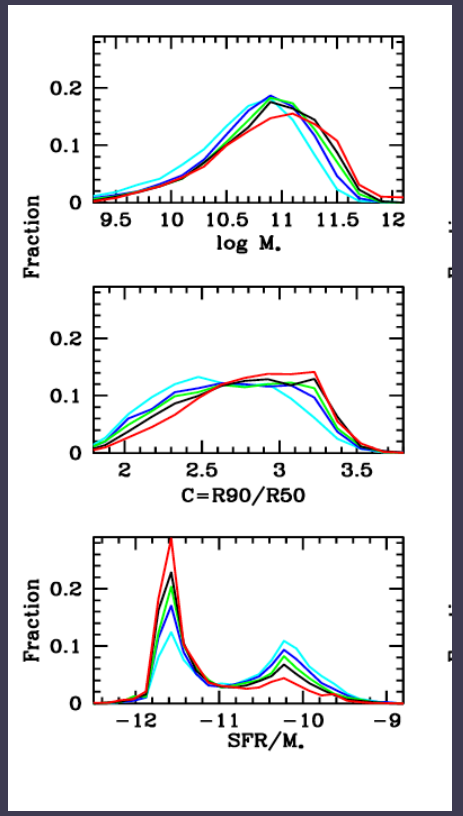

fig.6: Kauffman (2004)

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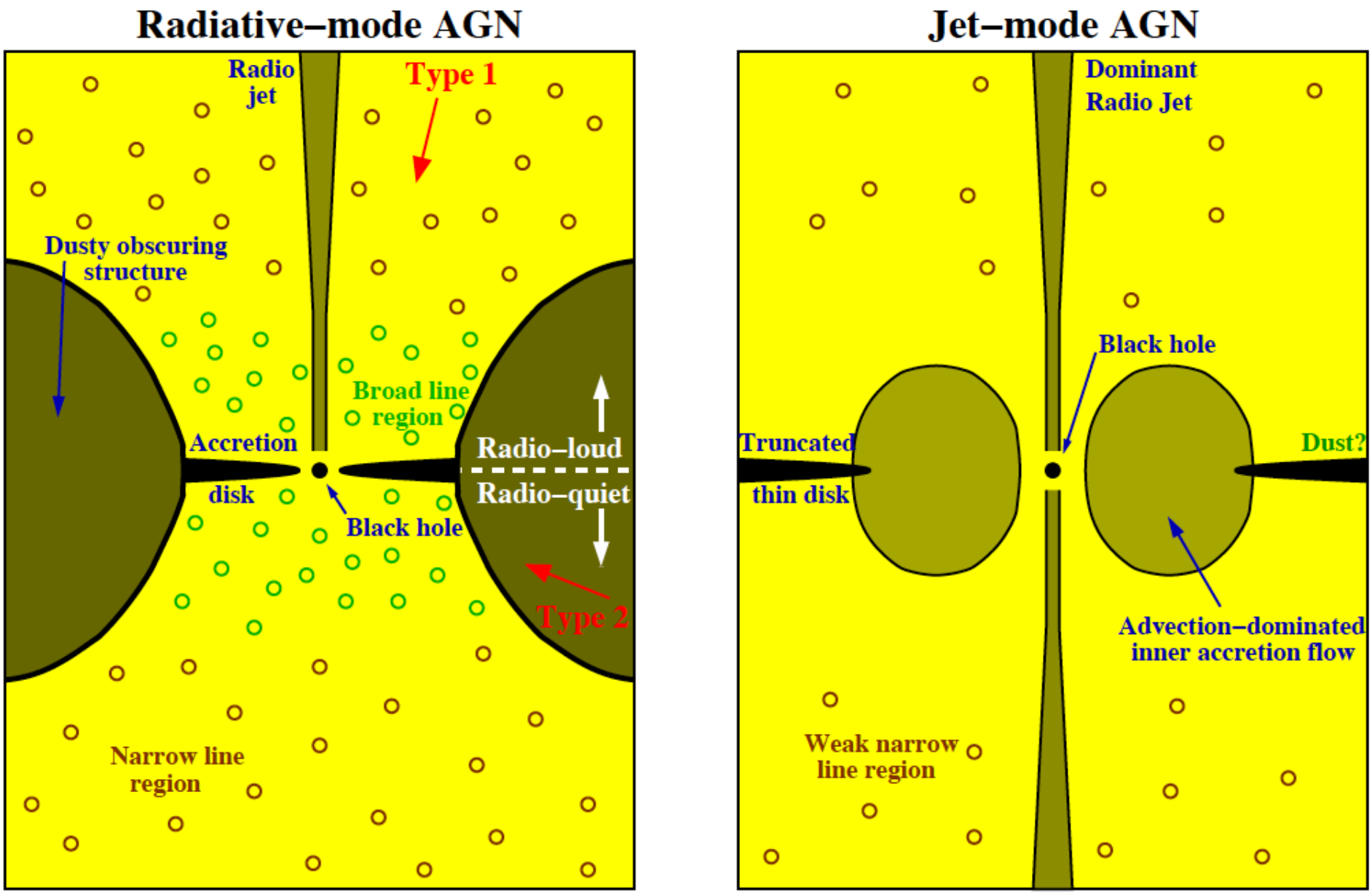
Our Favourite Dichotomy

Best & Heckman (2012):

- ✓ **HERGS:**
  - ✓ radio peak
  - ✓ cold accretion
  - ✓ more diffuse environments
  - ✓ bluer, SF, lower M_{BH}
  - ✓ low excitation
  - ✓ jet mode
- ✓ **LERGS:**
  - ✓ optical & IR peak
  - ✓ hot accretion
  - ✓ denser environments
  - ✓ redder, deader, higher M_{BH}
  - ✓ high excitation
  - ✓ radiative mode


Radiative–mode AGN
Radio jet
Type 1
Dusty obscuring structure
Broad line region
Accretion disk
Radio–loud
Radio–quiet
Black hole
Type 2
Narrow line region
Jet–mode AGN
Dominant Radio Jet
Black hole
Truncated thin disk
Dust?
Advection–dominated inner accretion flow
Weak narrow line region

AGN activity in the optical

- ✓ Sabater et al 2013:
  - ✓ HERG and LERG show increased optical and radio nuclear activity with local density (fig 2), respectively
  - ✓ cold & warm gas supply affected by **LSE**
- ✓ Sabater et al 2014:
  - ✓ effect of local density minimal when M & SF are constrained

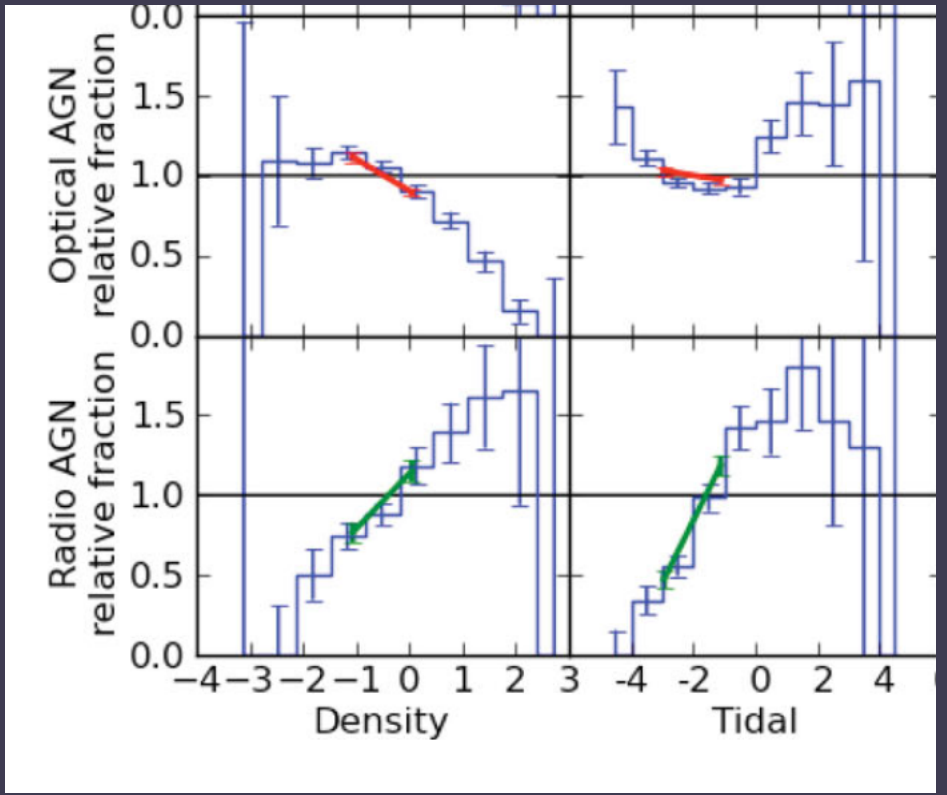
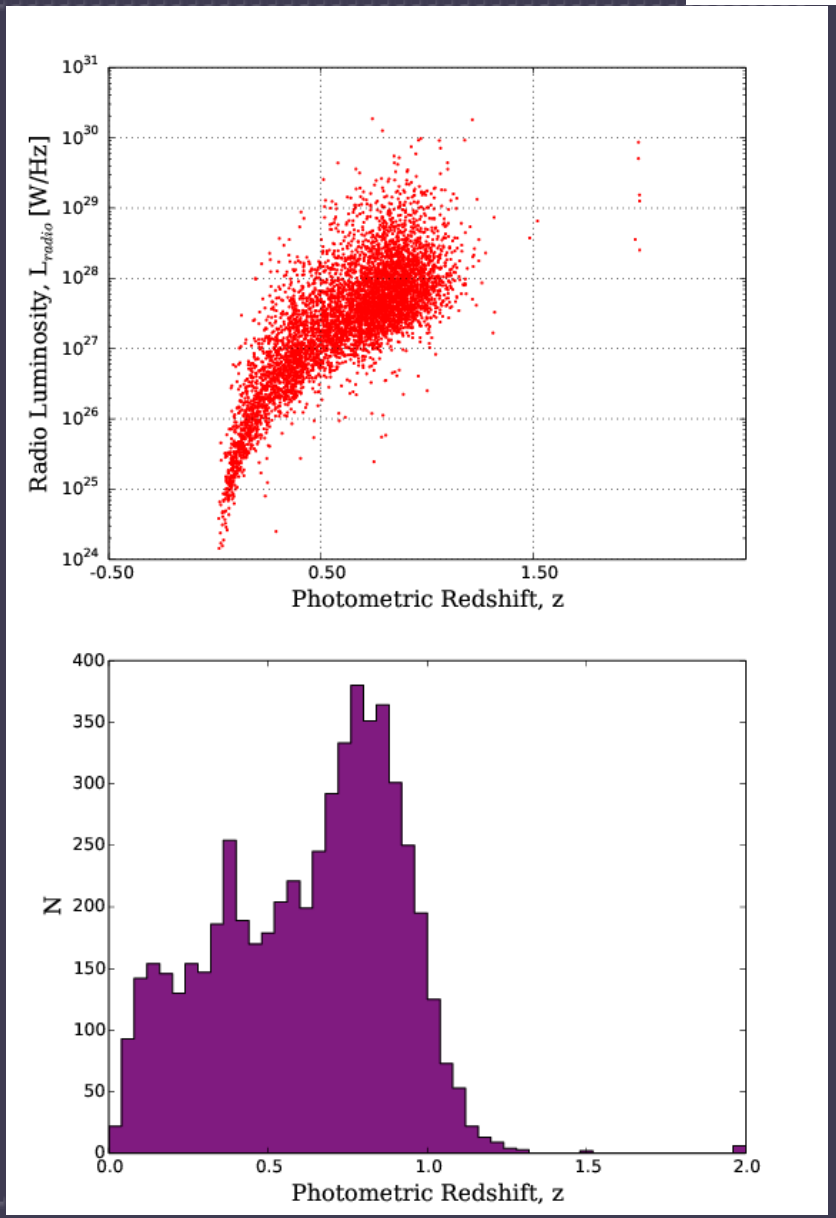


fig.8: Sabater (2013)

supply of cold gas **crucial** for optical nuclear activity

Sample Selection

- ✓ 16354 VLA-selected radio (1.4GHz i.e. L-band)
  - ✓ radio-selected assumed AGN
- ✓ SDSS Stripe82 region
- ✓ intermediate redshift: z ~ 1.25
- ✓ wide sky area: 92 deg^2
- ✓ flux limit at 50mJy
- ✓ rms noise 2 microJy/beam
- ✓ optical counterparts identified - SDSS Photometric Redshift Catalog



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Finding Neighbours

- ✓ surface density parameter - most reliable method (Cooper et al, 2014)
- ✓ Nearest neighbour search for AGN in SDSS Stripe82 using STILTS
- ✓ Neighbours arranged into groups with common AGN

- ✓ Issues with STILTS search:
  - ✓ edge effects of survey limit neighbour search
    - ✓ groups with only 2 members (density measure negligible)
  - ✓ AGN counterpart identified more than once
  - ✓ AGN counterpart missing from some groups

significant portion of counterparts get knocked out

Finding Neighbours

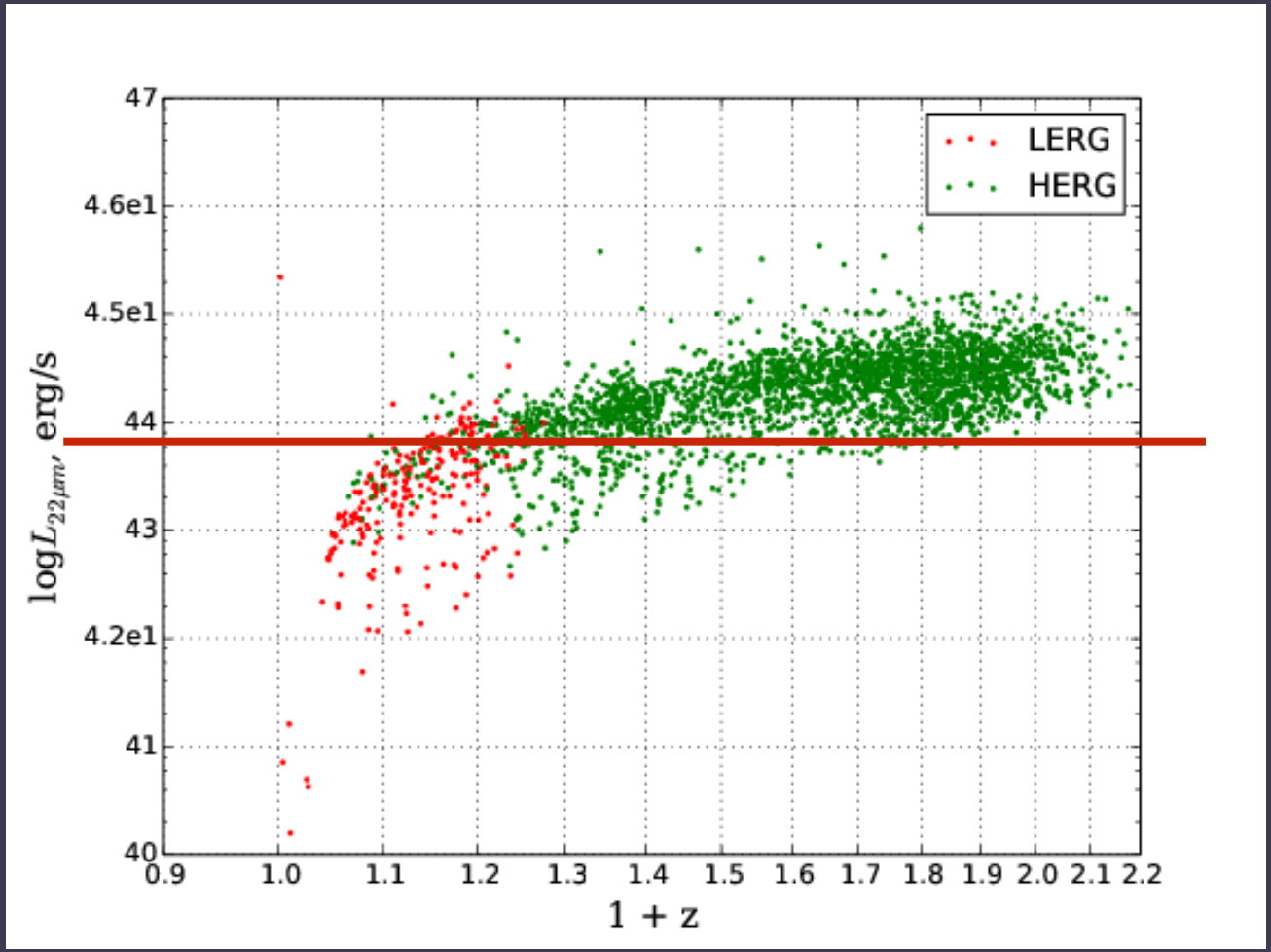
- ✓ **SURFACE DENSITY MEASURE (Karouzos et al, 2014)**

$$\Sigma_n = \frac{n}{\pi d_n^2}$$

- ✓ **AGN Sample:**
  - ✓ distance to the n^{th} nearest neighbour within cylinder
  - ✓ constrained in redshift: $\Delta z < 0.2(1+z)$
  - ✓ search cone radii spanning 20”.0 - 50”.0 (intervals of 10”.0)
  - ✓ close environment
- ✓ **Control Sample:**
  - ✓ average 10 nearest neighbours per AGN
  - ✓ stellar-mass matched (K-mag)
  - ✓ search cone annulus spanning 60”.0 - 100”.0 (intervals of 10”.0)
  - ✓ extended environment
  - ✓ plan to extend "control" environment even further

Accretion Mode Dichotomy

- ✓ $L_{W4} > 5 \times 10^{43}$ erg/s (Gurkan et al, 2014) - > HERG, below LERG
- ✓ Reliable method for separating HERG and LERG population
- ✓ Assuming that sample are radio-loud AGN



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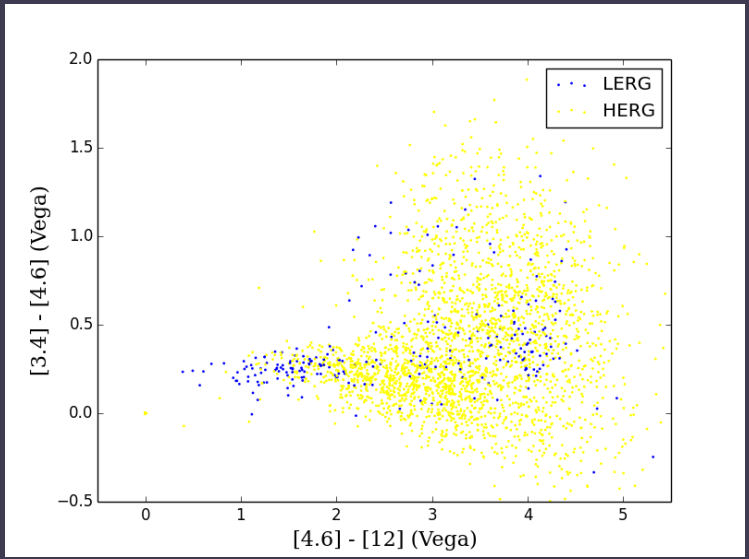
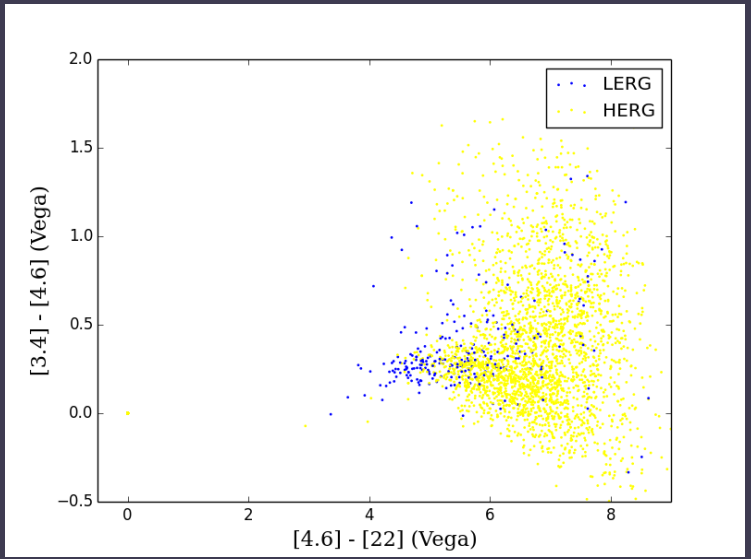
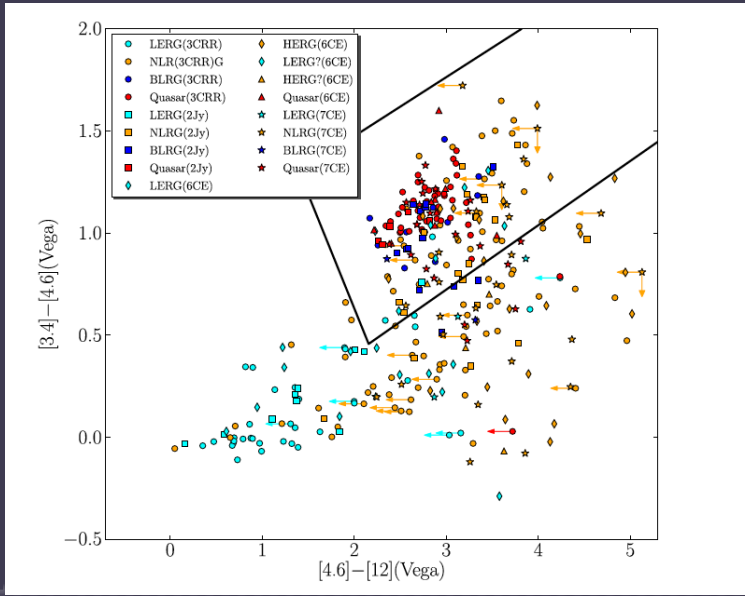
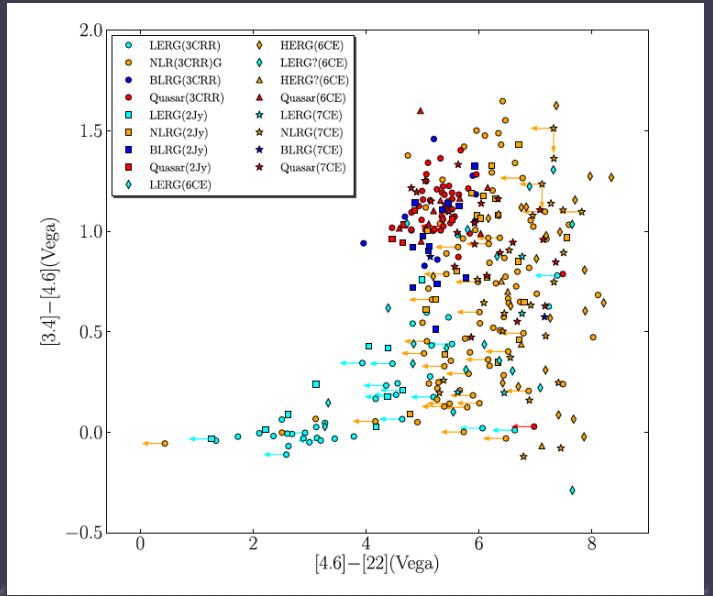
Preliminary WISE colour-colour









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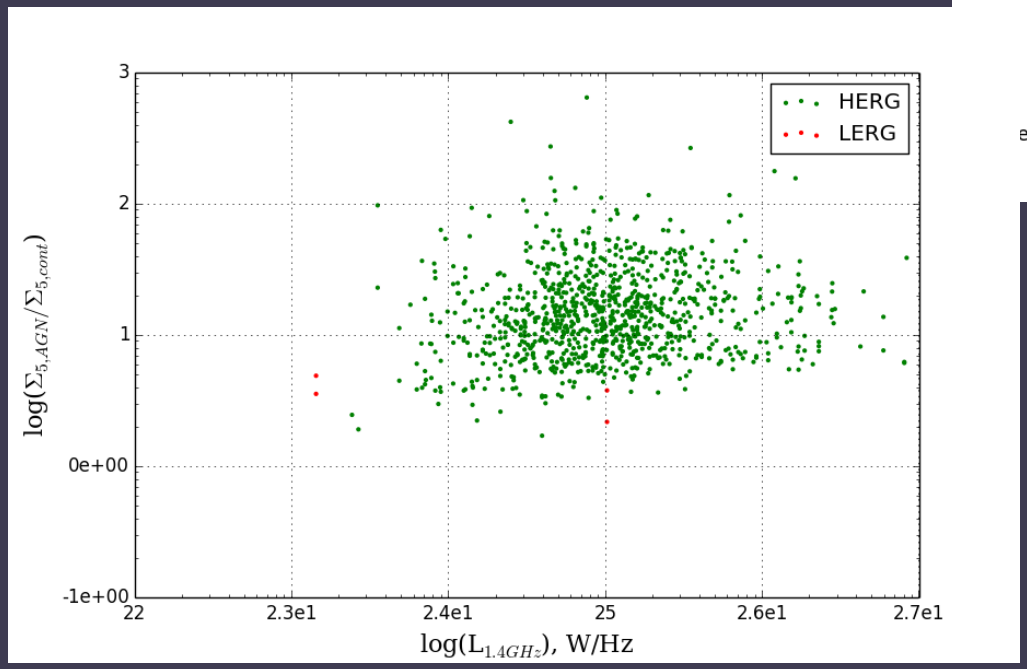
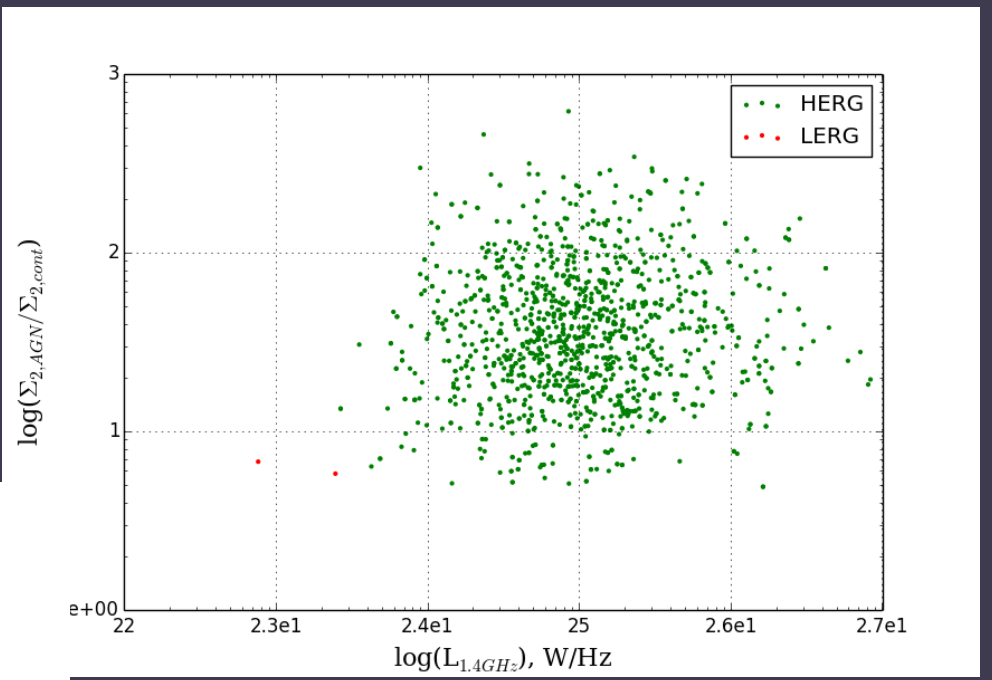
Preliminary Environment Measure

- ✓ AGN sample: surface density measure in closer environment (< 20”.0)
- ✓ control sample: surface density in extended environment (60”.0 - 85.0”)





- ✓ surface density algorithm selects out most LERGS:
  - ✓ eliminated paired groups ?
  - ✓ dichotomy ?
  - ✓ LERGs underrepresented ?

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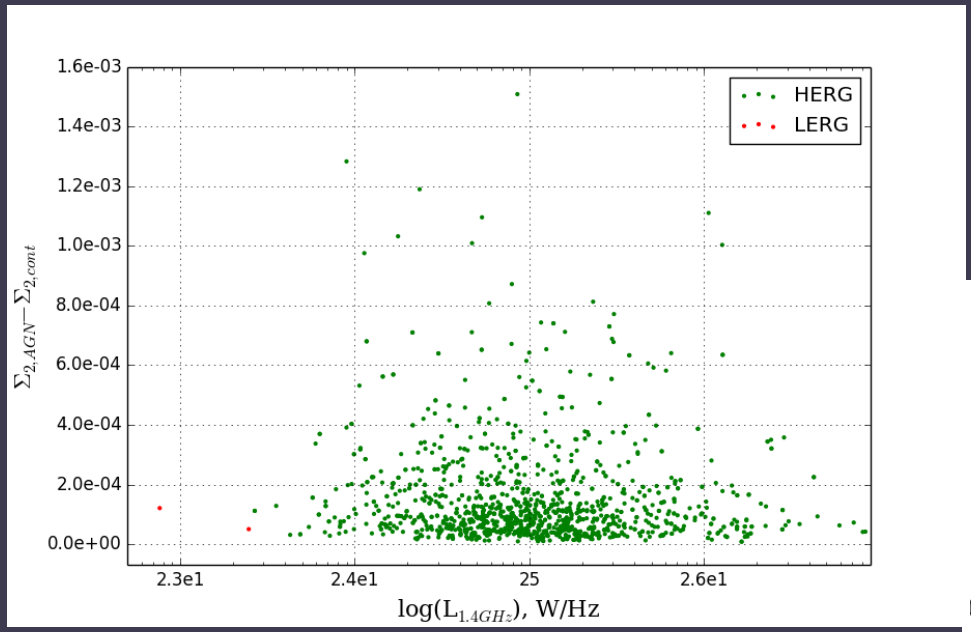
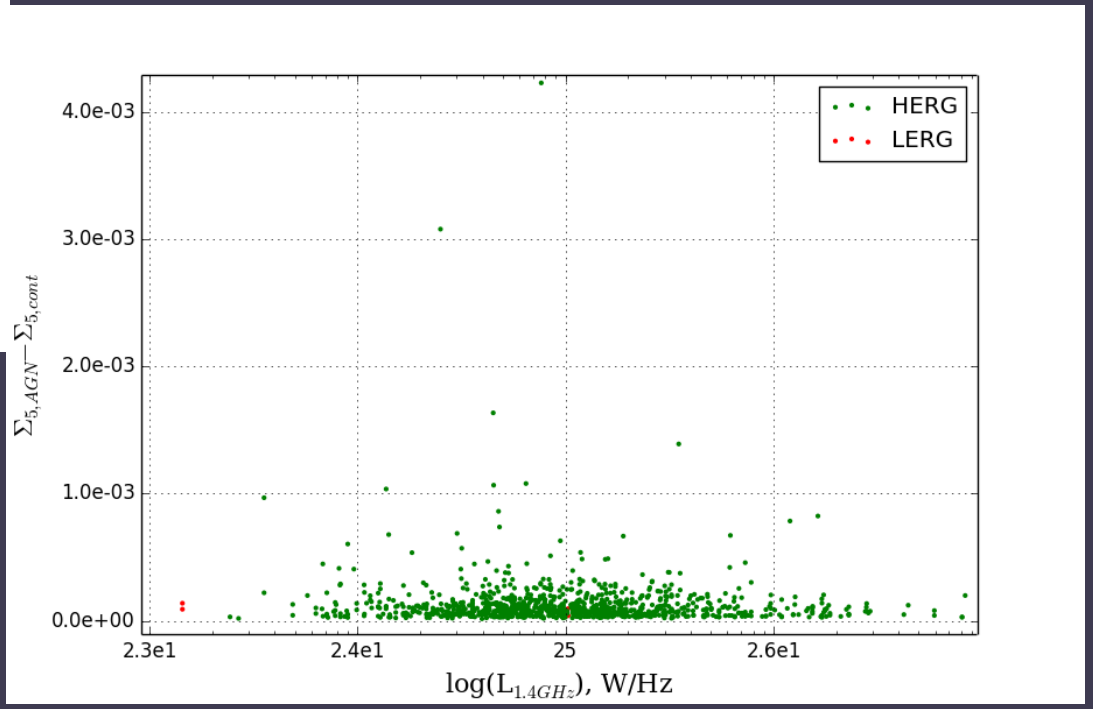
Where did all the LERGs go?



- ✓ few LERGs have homogenous density
- ✓ for HERGs environment changes steeper



- ✓ not statistically viable
- ✓ due to minimal LERG contribution to sample when measuring density

Need improvements in algorithm and control sample selection

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Summary

- ✓ 50mJy source selection from VLA survey of Stripe82 to find radio galaxies
- ✓ Separate population by HERG-LERG dichotomy to define accretion mode
- ✓ Use STILTS to identify neighbouring galaxies of AGN sample
- ✓ Surface-density measure algorithm selects out AGN below the HERG-threshold
- ✓ Measuring density in closer and slightly extended environment provides unclear correlation between accretion-mode and environment
- ✓ LERG environments homogenous from closer to more extended, HERGs show steep change in density