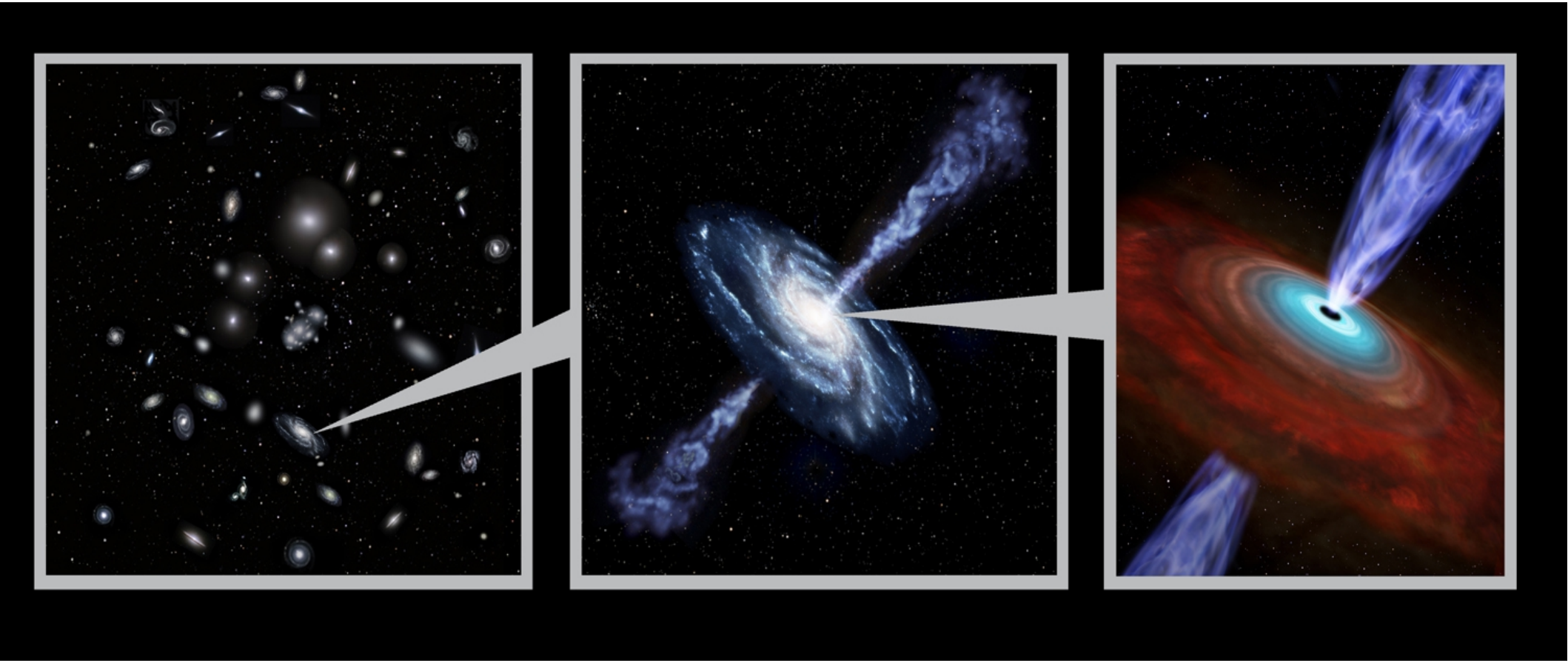
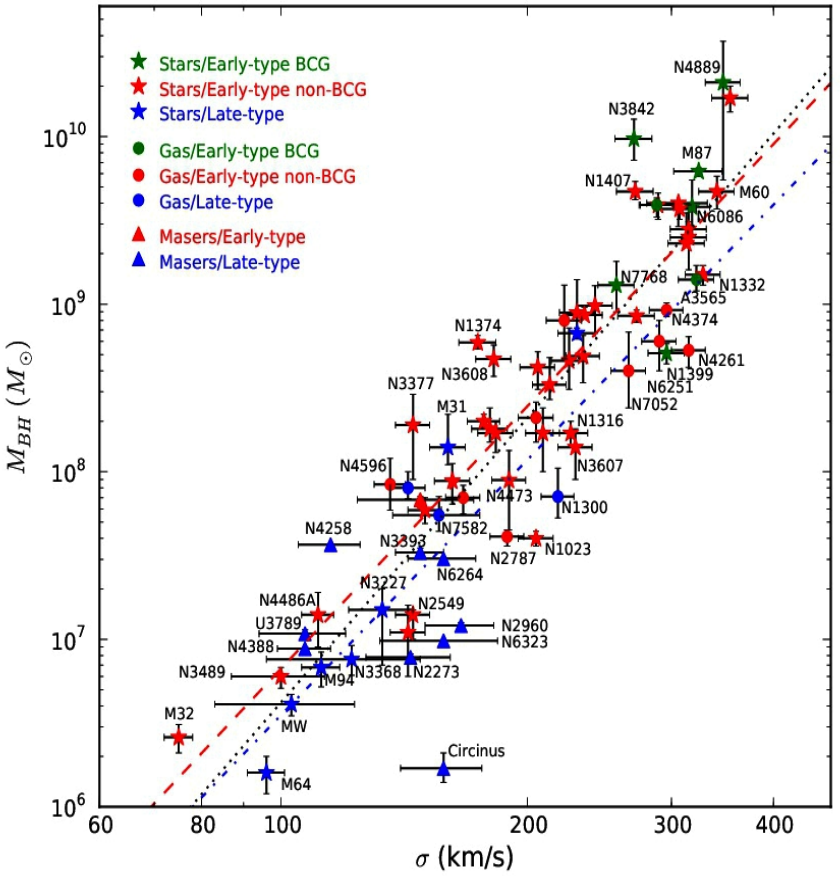
Black Holes and Active Galactic Nuclei across the Universe

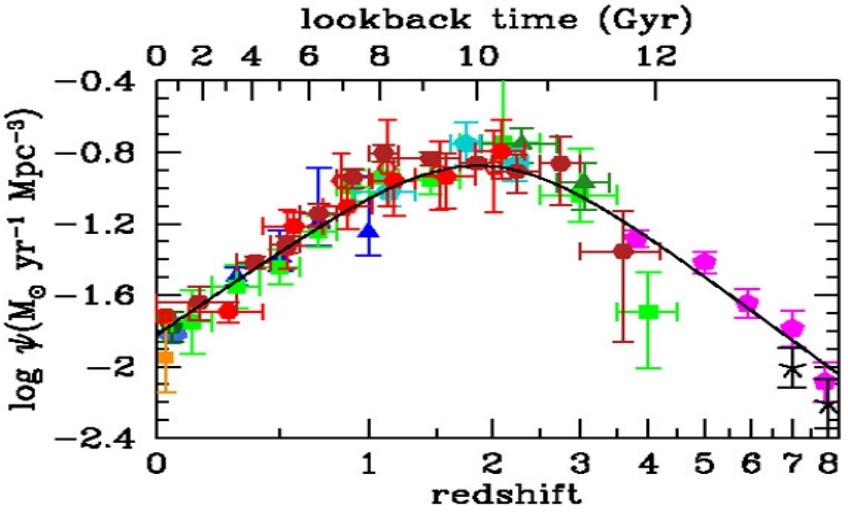


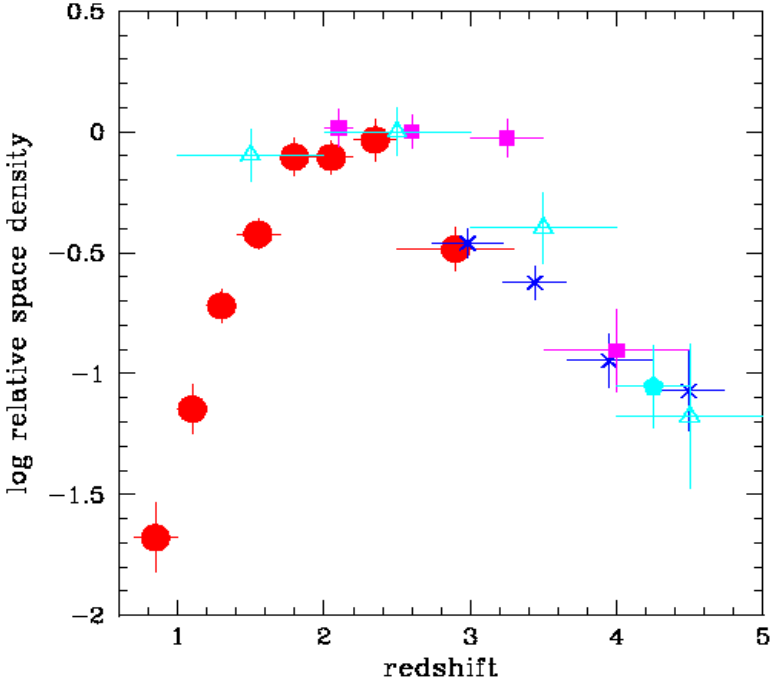
Indirect observational evidence that black hole formation/growth may influence/regulate the formation of the host galaxy

Relation between black hole mass (parsec-scale measurements) and bulge velocity dispersion (kpc-scale)



Cosmic star formation rate density and quasar space density show similar evolution.

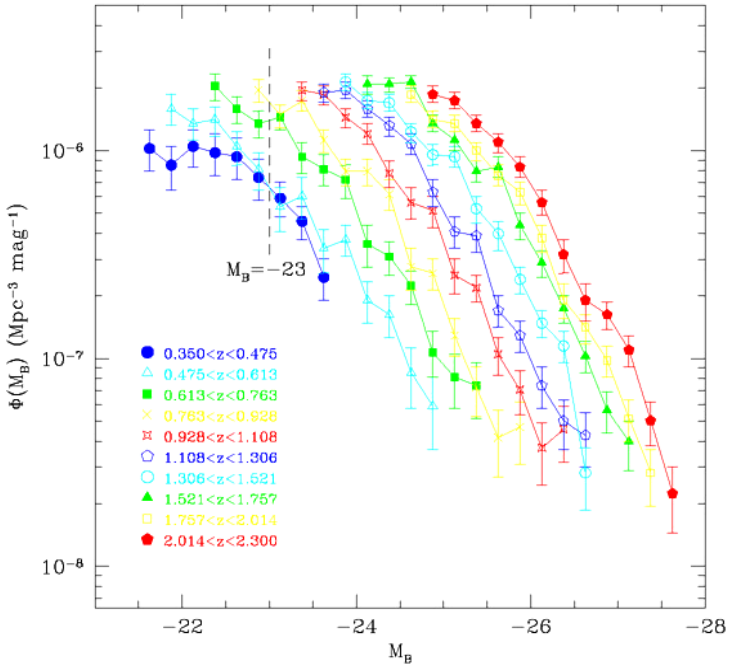


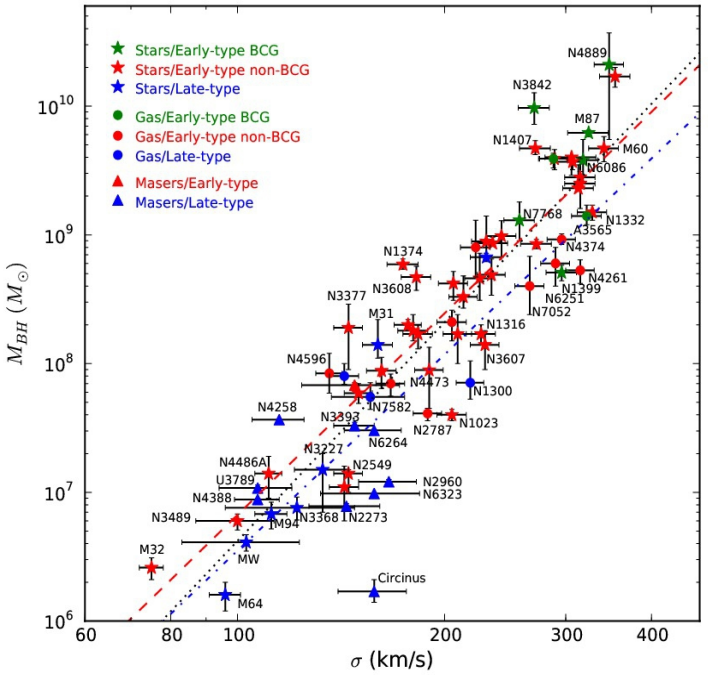


Some popular theoretical conjectures about the physical processes that link the formation of black holes and galaxies

1) Following the formation of a “seed” black hole at high redshifts, black hole growth occurs during major merging events that are visible as quasars (Kauffmann & Haehnelt 2000)

Model assumption: during a merger a fixed fraction of available gas is accreted by black hole, 0.1 Mc^2 of the rest mass energy is radiated.
In addition to the properties of the galaxy population, models shown to reproduce 2 key observables: black hole mass/bulge mass relation and QSO luminosity function evolution.

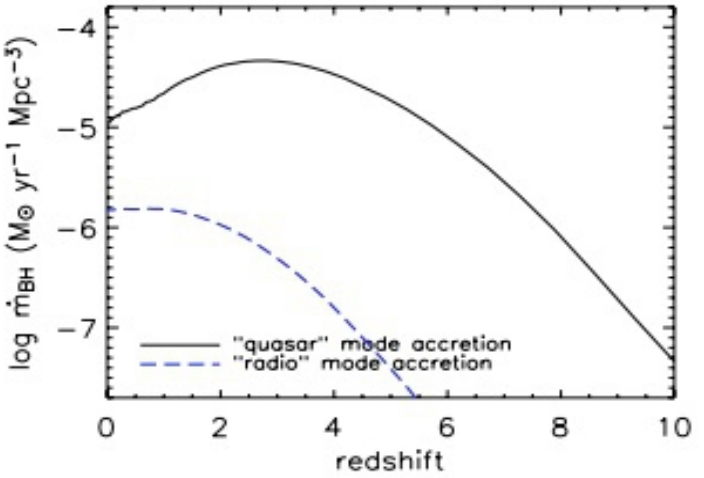


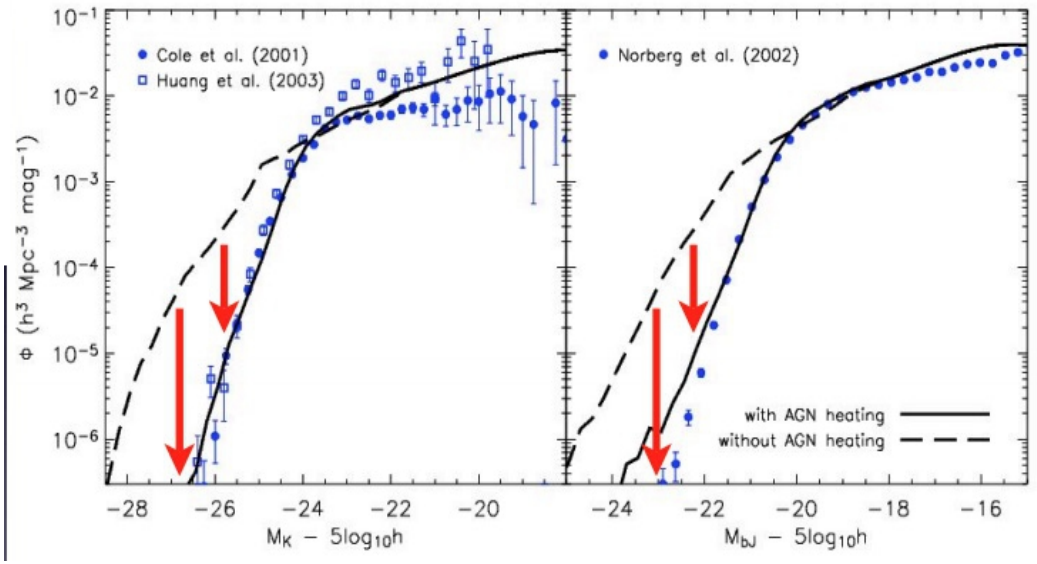


2) Black hole growth causes significant energy to be transferred to the gas in and around galaxies on scales of hundreds of kiloparsecs, which influences the future evolution of the galaxy – i.e. the black hole does not merely form long with the galaxy, it regulates galaxy growth and star formation.

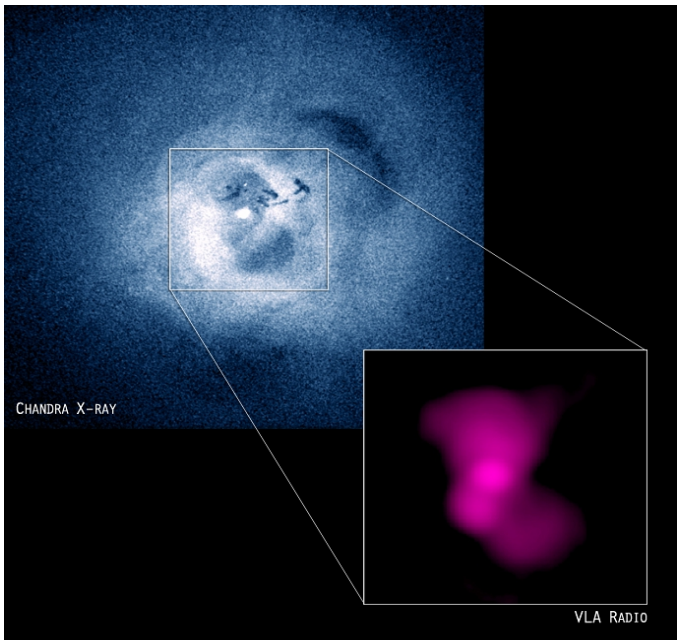
TWO CLASSES OF AGN FEEDBACK MODEL:

A) Those that focus on the role of AGN feedback in regulating the build-up of the most massive galaxies in the local Universe.
(the feedback sources that heat the gas on large scales are NOT those that mark out the main phases of black hole growth)



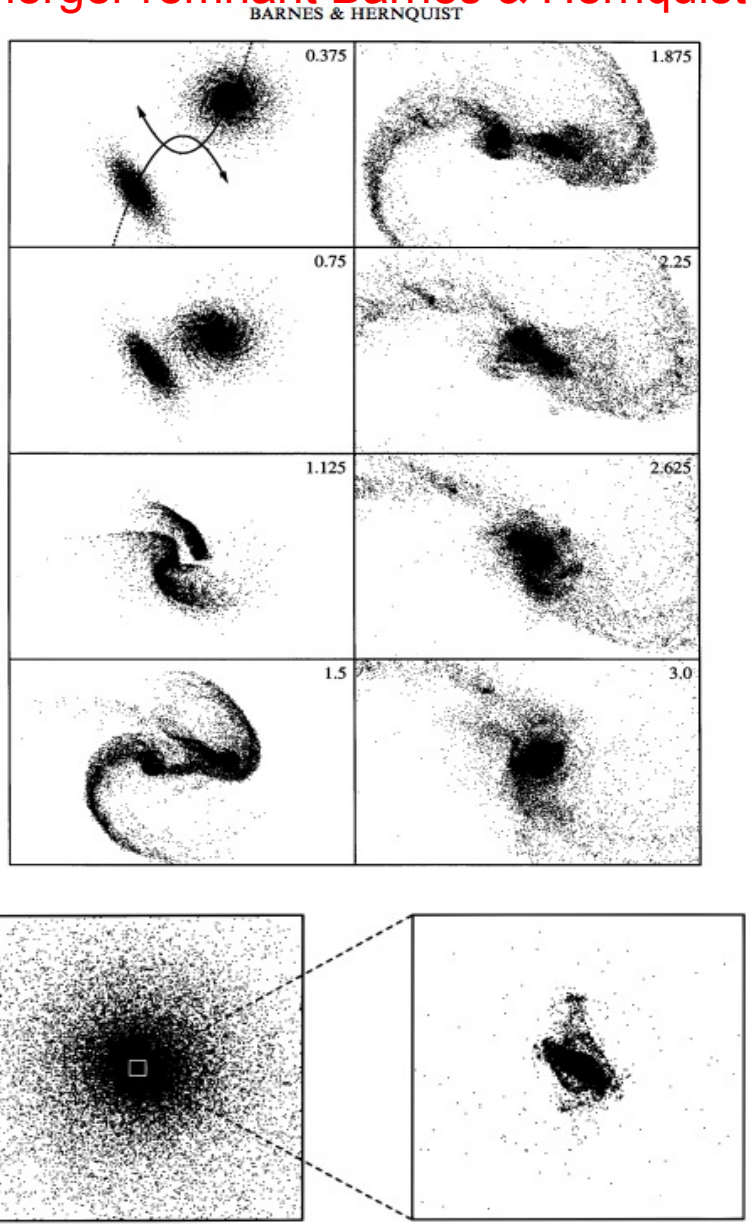


Croton et al 2006

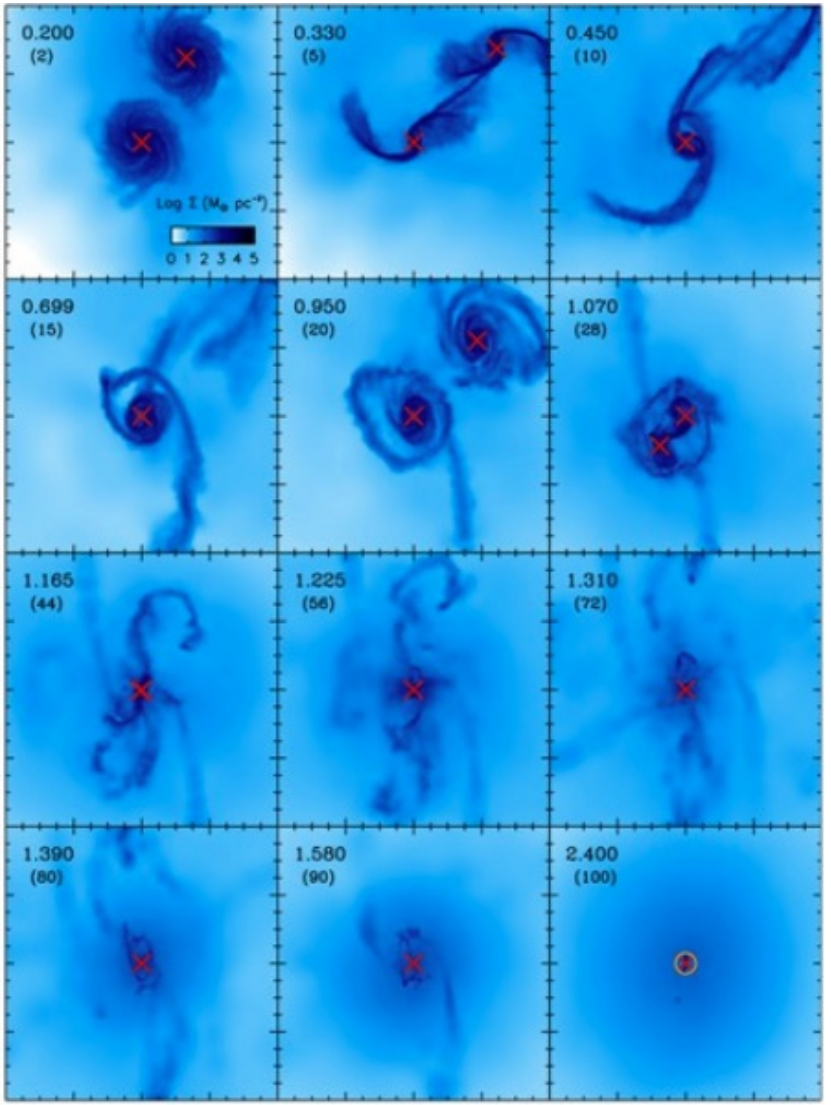


2) Those that include feedback as part of the merging events that form black holes and fuel quasars. These models do not usually attempt to make detailed predictions for the statistical properties of the galaxy population.

1996: too much gas sinks to the center of the merger remnant Barnes & Hernquist



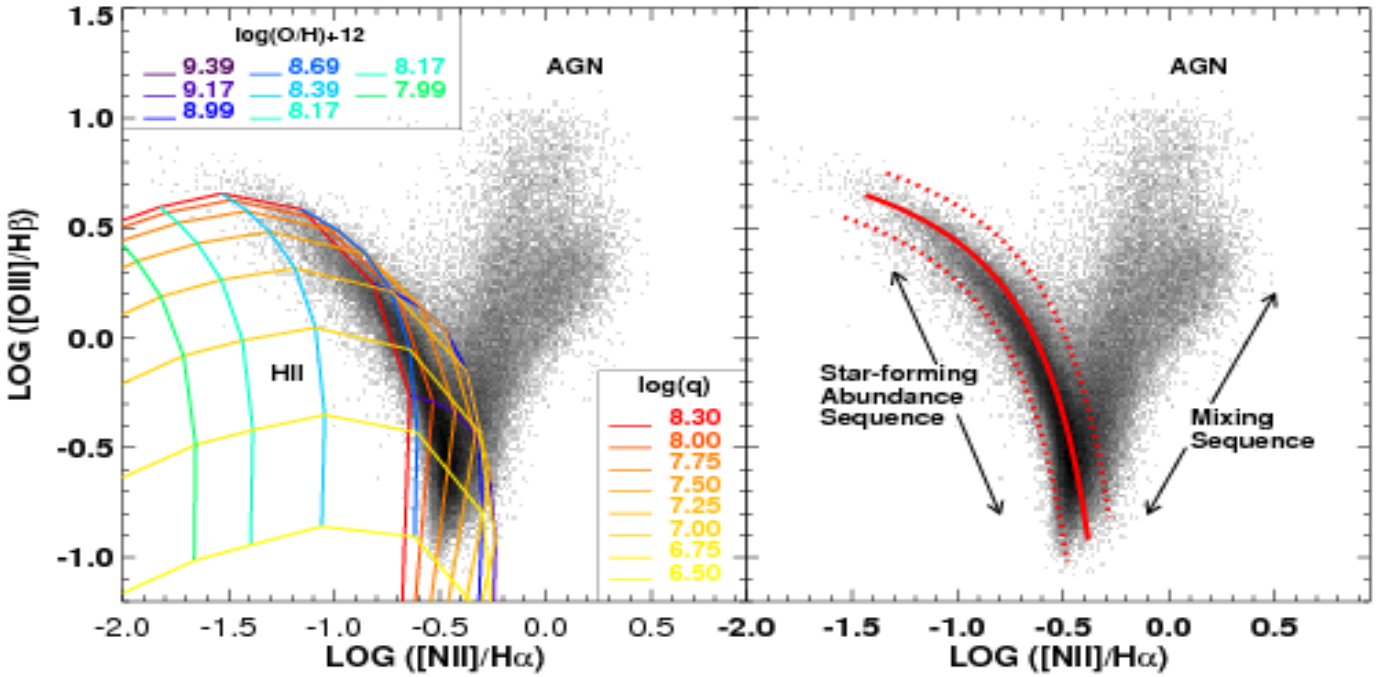
2005: the gas is blown out in a “wind” Di Matteo, Springel, Hernquist

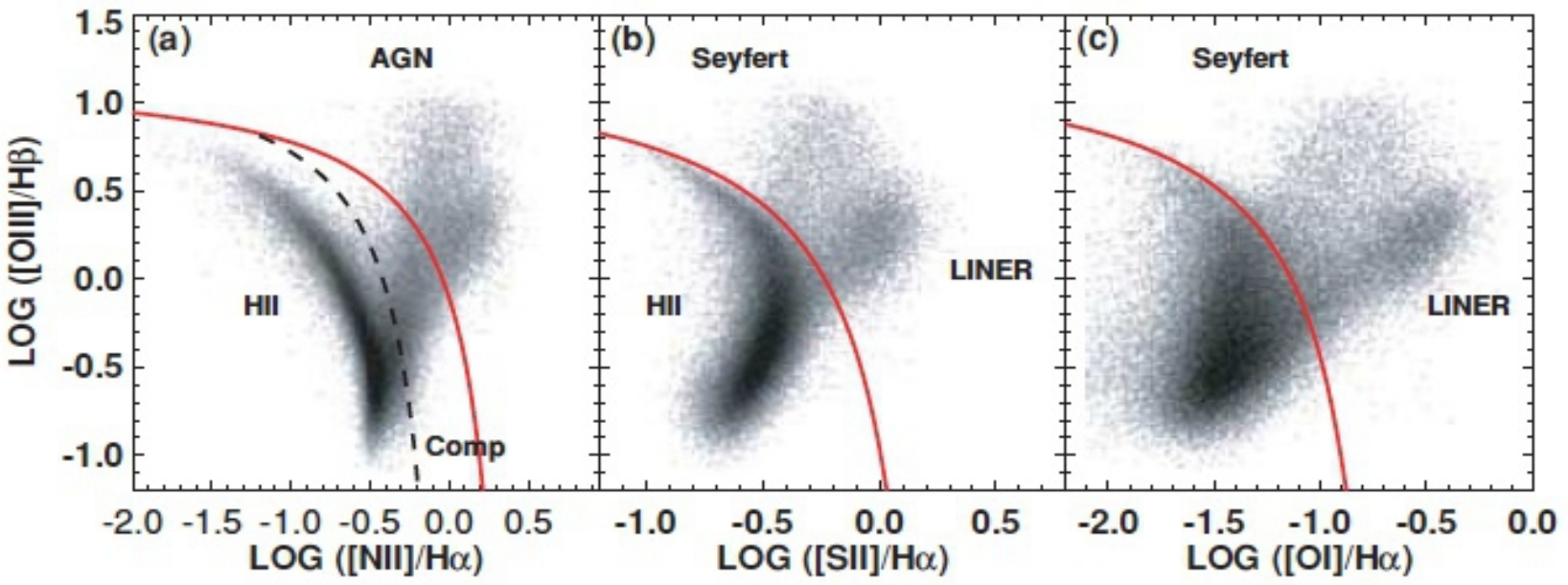


Status of Observational Constraints

Sloan Digital Sky Survey

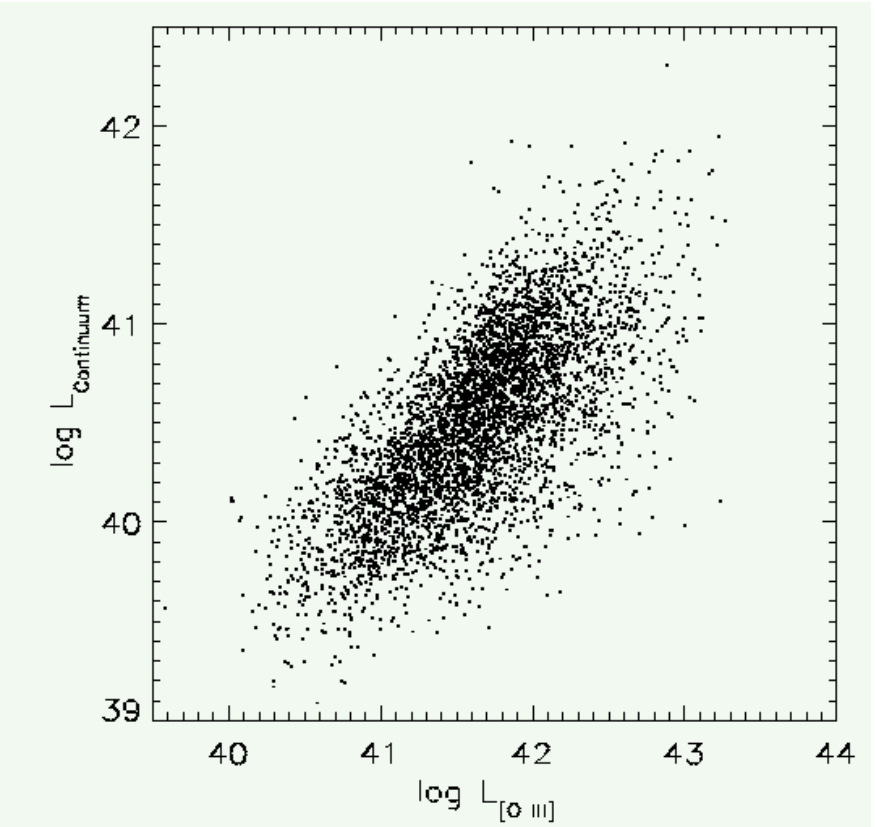
Emission line diagnostic diagrams for identification of AGN through emission-line ratios



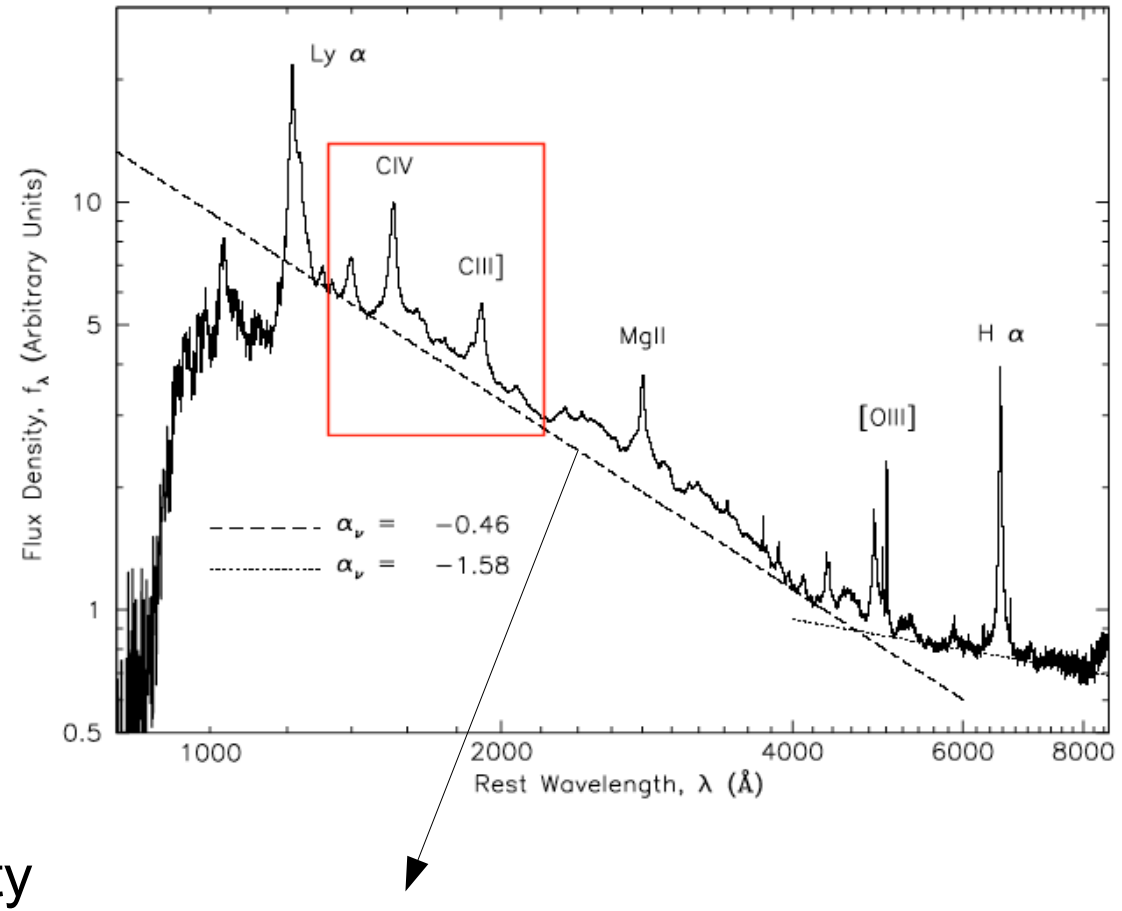


Accretion

The [OIII] Line Luminosity as a Black Hole Accretion rate indicator

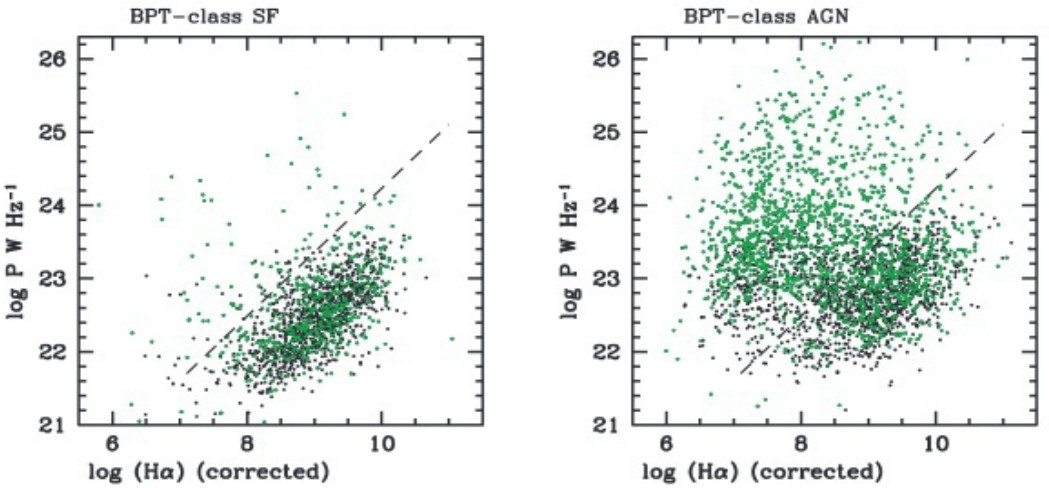


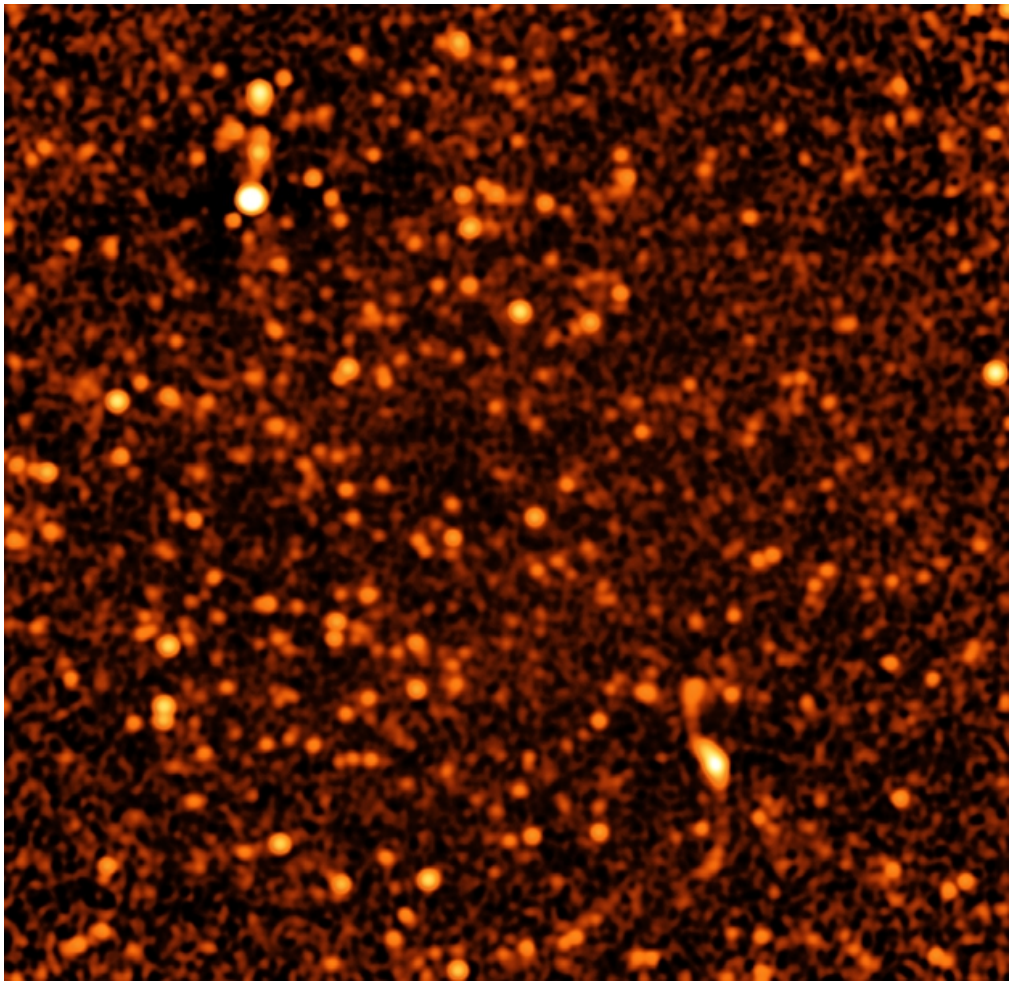
Correlation of [OIII] luminosity with bolomertic continuum luminosity for Type 1 AGN



Continuum is from accretion disk

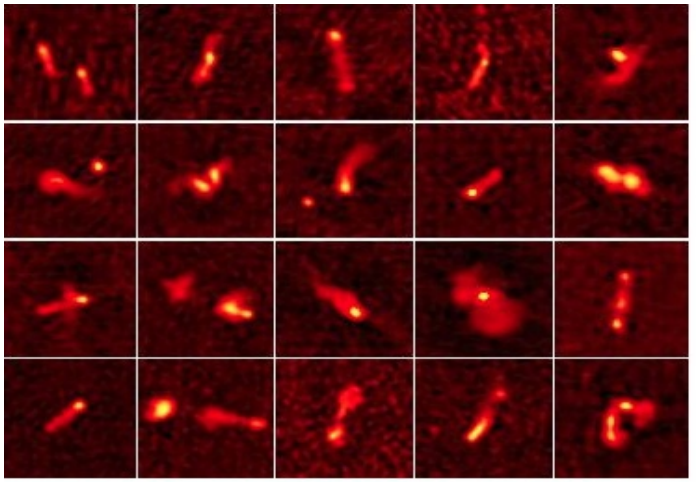
Deep wide-field radio surveys can be cross-correlated with SDSS optical surveys





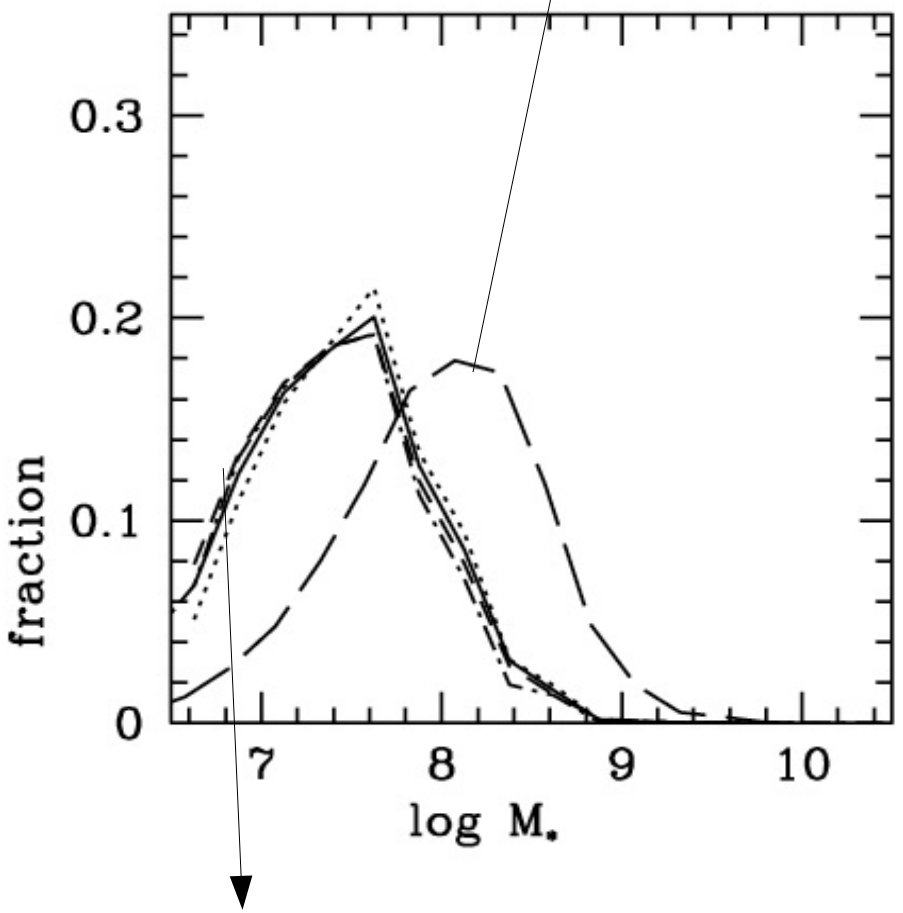
Radio synchrotron emission arises from electrons accelerated in supernovae shocks: correlation between radio emission and star formation rate as measured by Halpha emission

Radio AGN can be identified by their excess radio luminosity with respect to this correlation

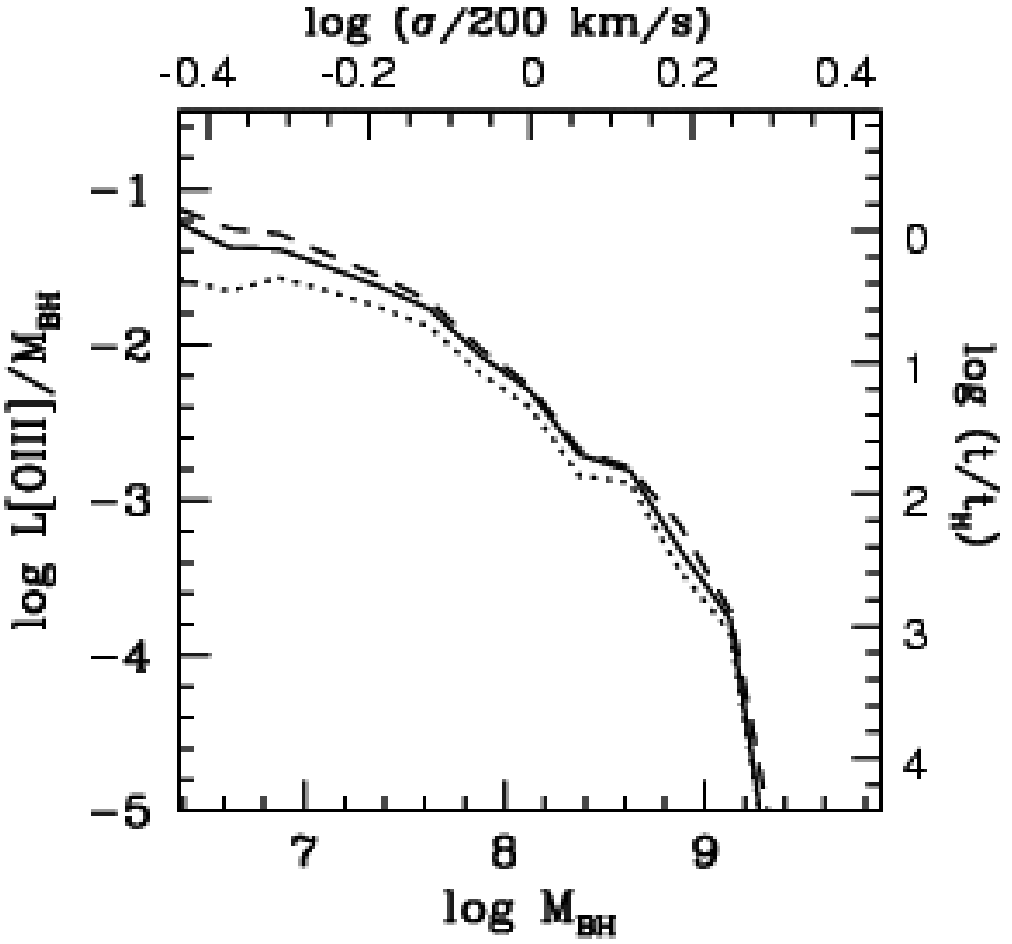


Which black holes are currently accreting?

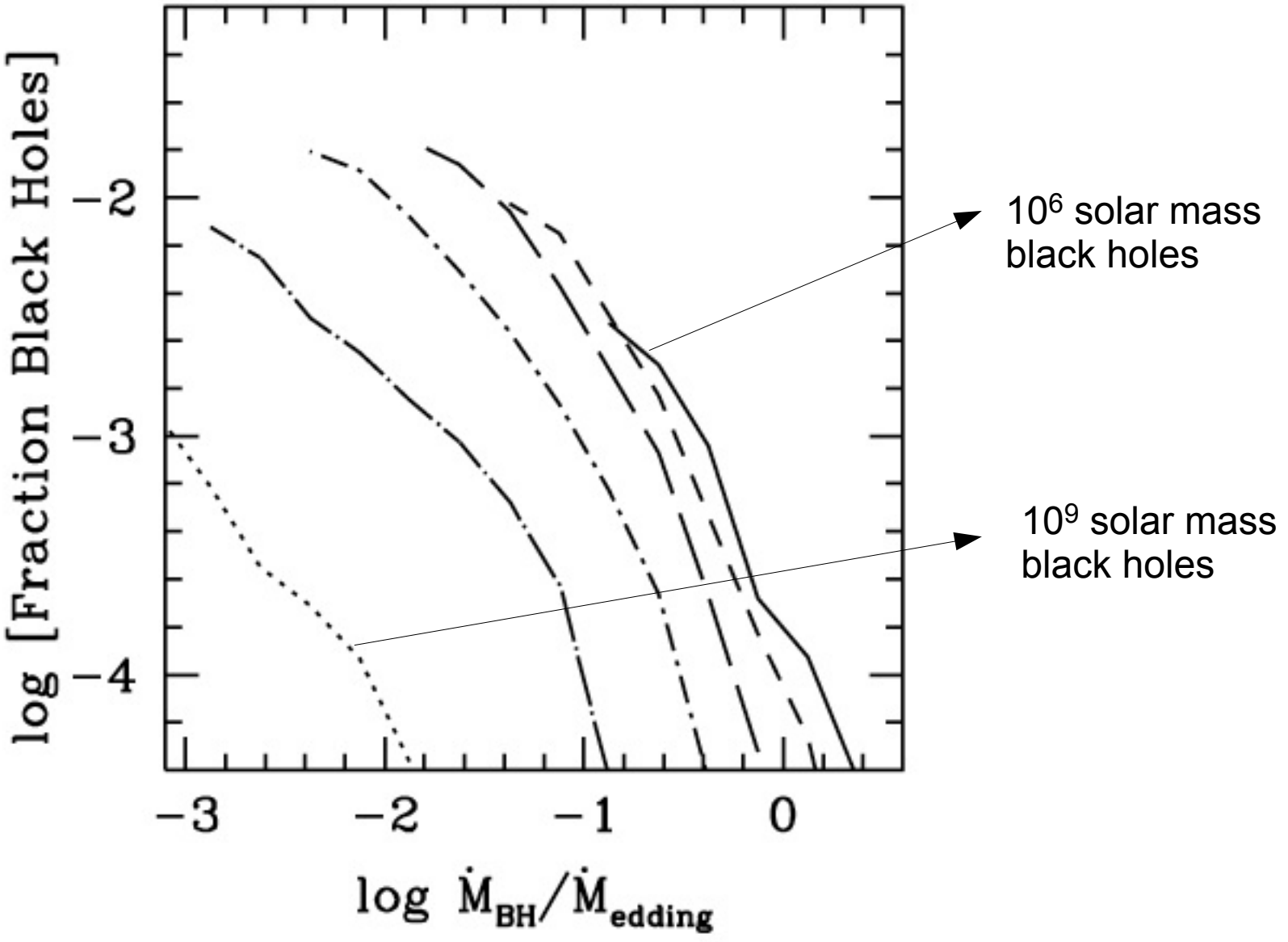
Distribution of Σ $M_{black\ hole}$

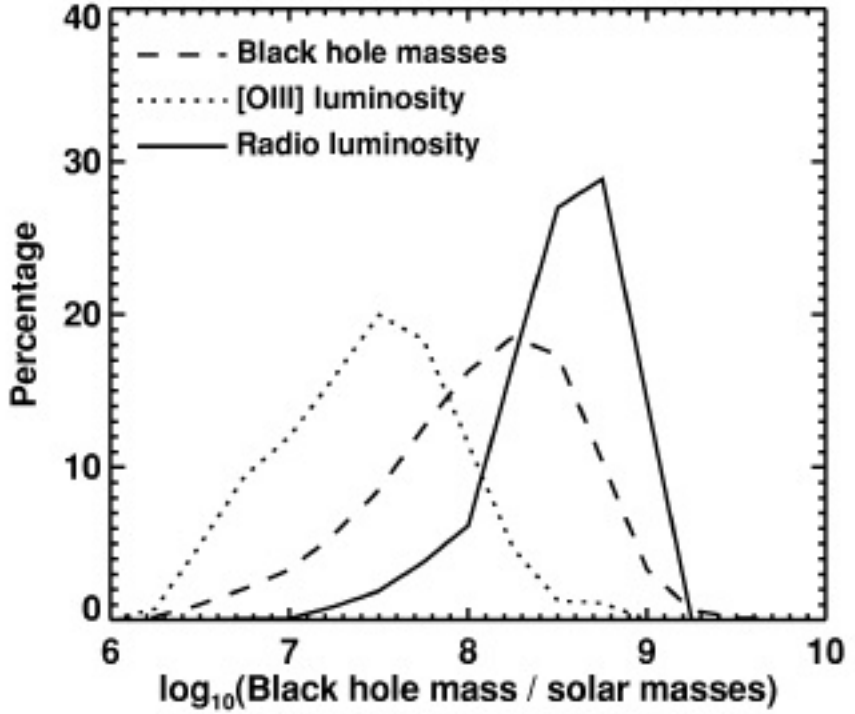


Distribution of Σ L[OIII] as a function of $M_{black\ hole}$

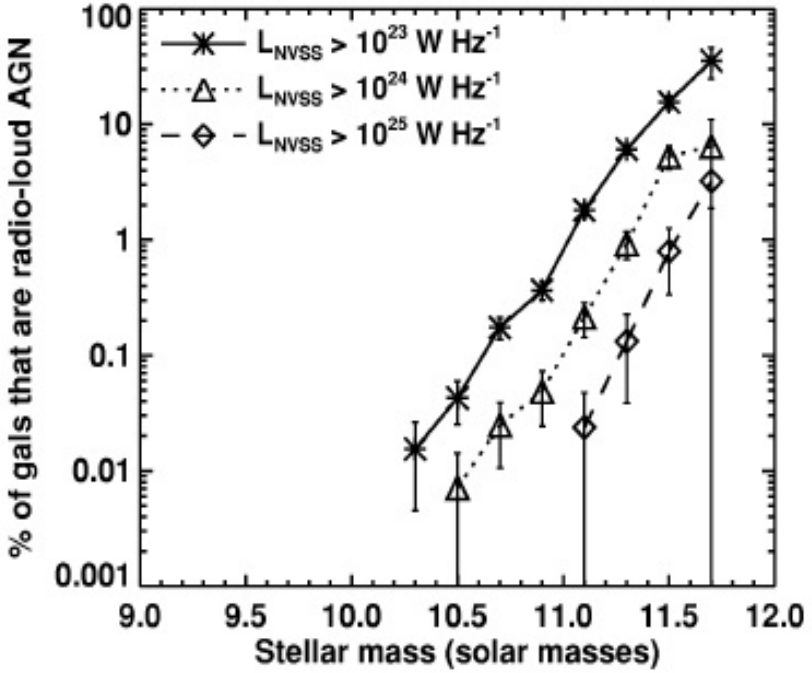


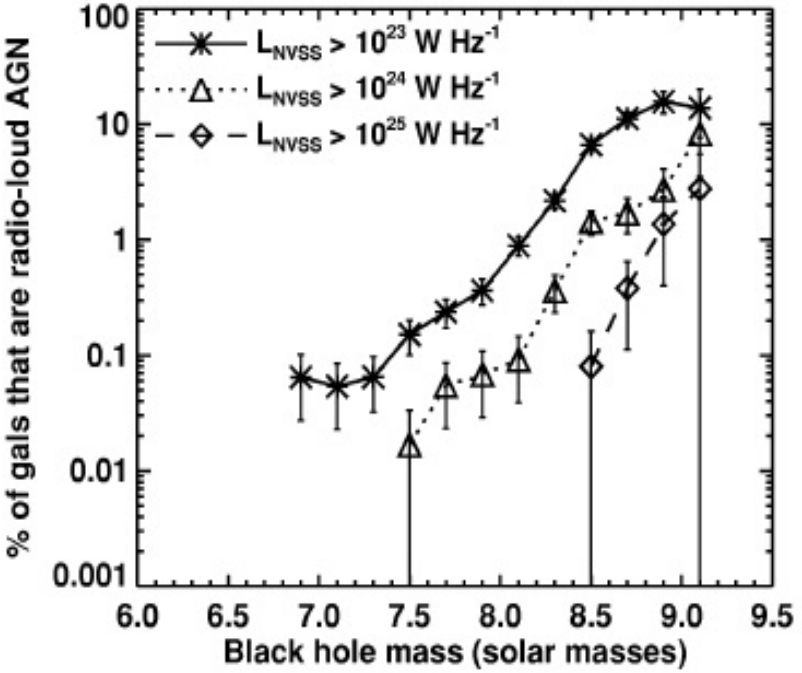
Distribution of accretion rates (in units of the Eddington accretion rate) for black holes of different mass

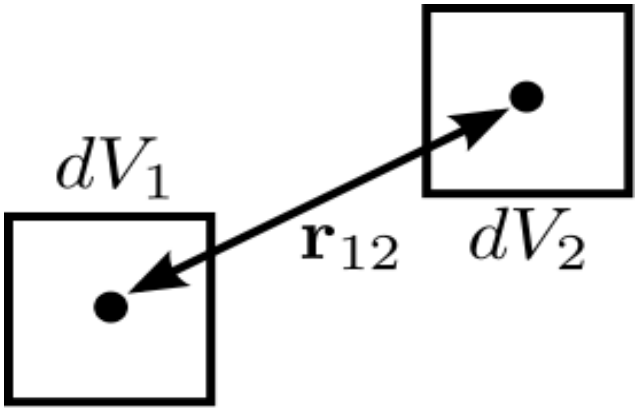




Which black holes are currently most energetically important for feedback as measured by radio synchrotron emission?

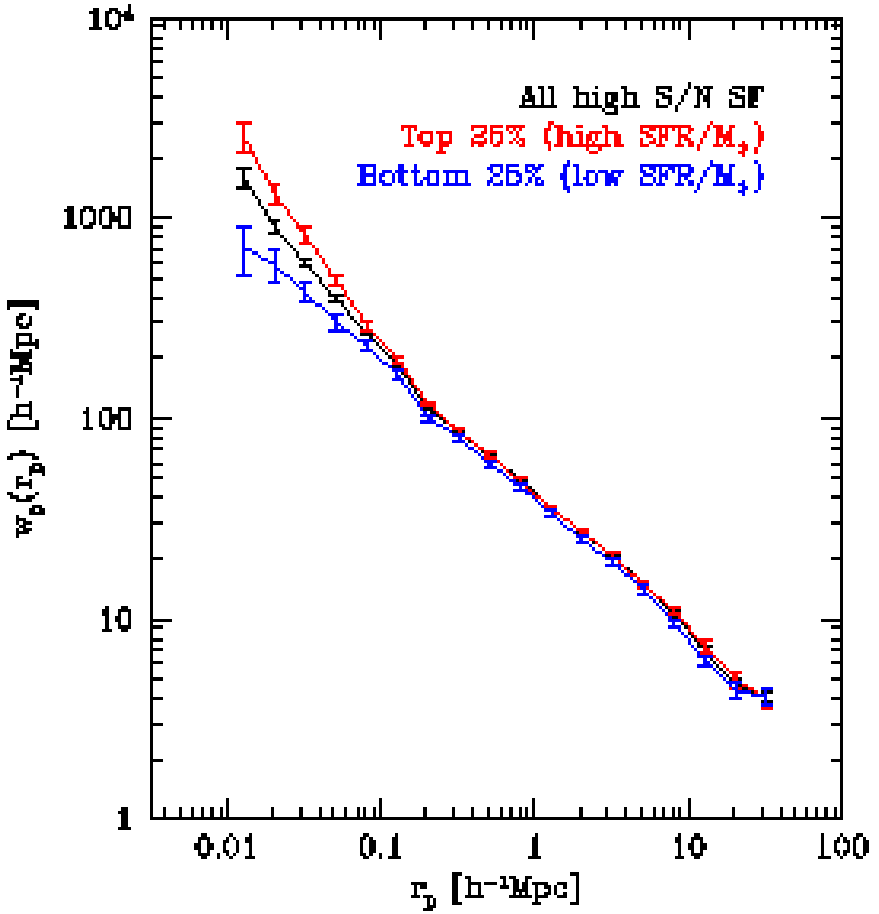


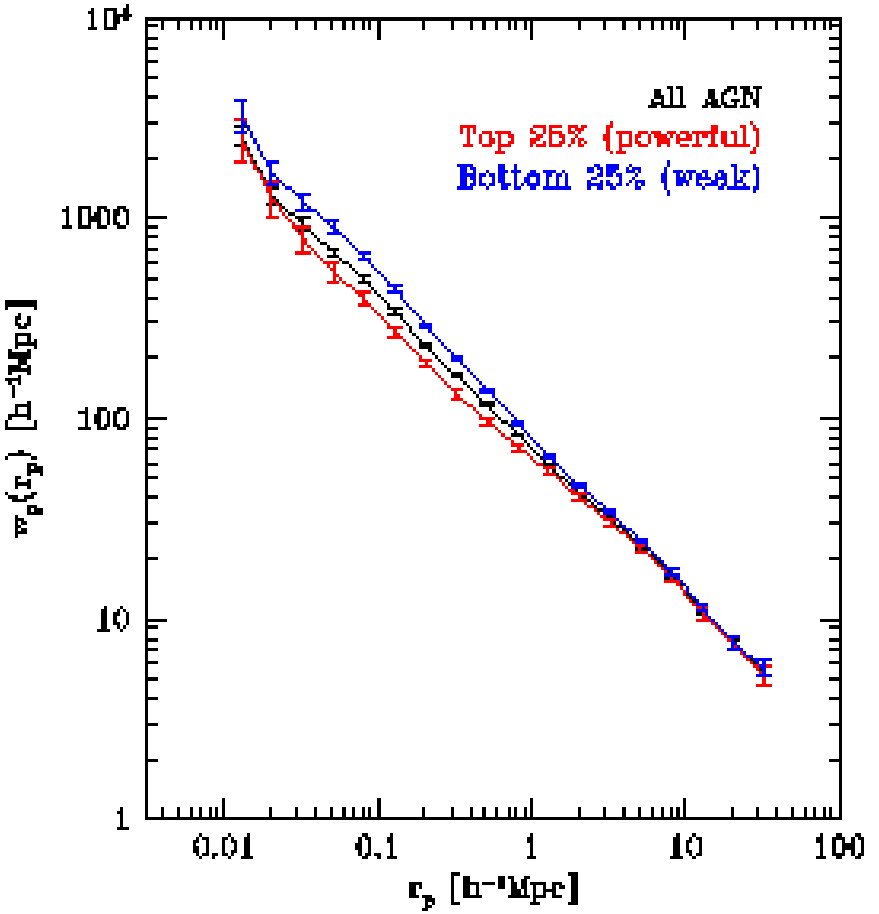




Two-point correlation function defined as the excess probability to find two galaxies separated by distance r, compared to a randomly-distributed sample.

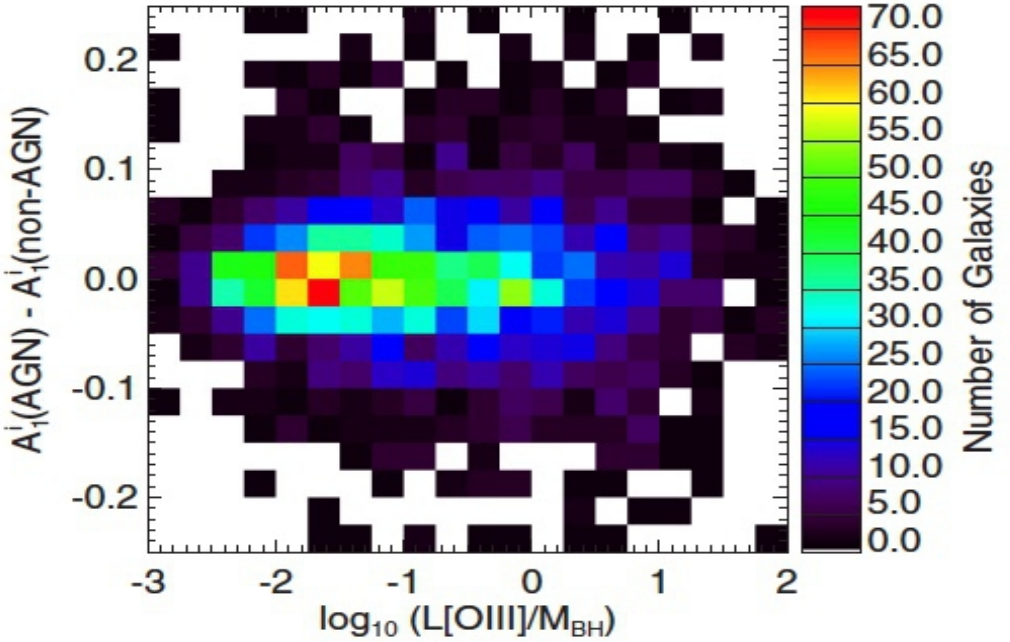
The cross-correlation function star-forming galaxies compared to AGN.





Lopsided galaxy

Symmetric galaxy



No evidence for excess of lopsided AGN hosts compared to matched control samples of non-AGN

The bulk of the black hole growth since z~1 occurs in a secular universe: No major merger-AGN connection

Mauricio Cisternas, Knud Jahnke, Katherine J. Inskip, Jeyhan Kartaltepe, Anton M. Koekemoer, Thorsten Lisker, Aday R. Robaina, Marco Scodeggio, Kartik Sheth, Jonathan R. Trump, Rene Andrae, Takamitsu Miyaji, Elisabeta Lusso, Marcella Brusa, Peter Capak, Nico Cappelluti, Francesca Civano, Olivier Ilbert, Chris D. Impey, Alexie Leauthaud, Simon J. Lilly, Mara Salvato, Nick Z. Scoville, Yoshi Taniguchi

AGN Host Galaxies at $z \sim 0.4$-1.3: Bulge-dominated and Lacking Merger-AGN Connection

N. A. Grogin[1], C. J. Conselice[2], E. Chatzichristou[3], D. M. Alexander[4], F. E. Bauer[5], A. E. Hornschemeier[1], S. Jogee[6], A. M. Koekemoer[7], V. G. Laidler[7], M. Livio[7] +Show full author list

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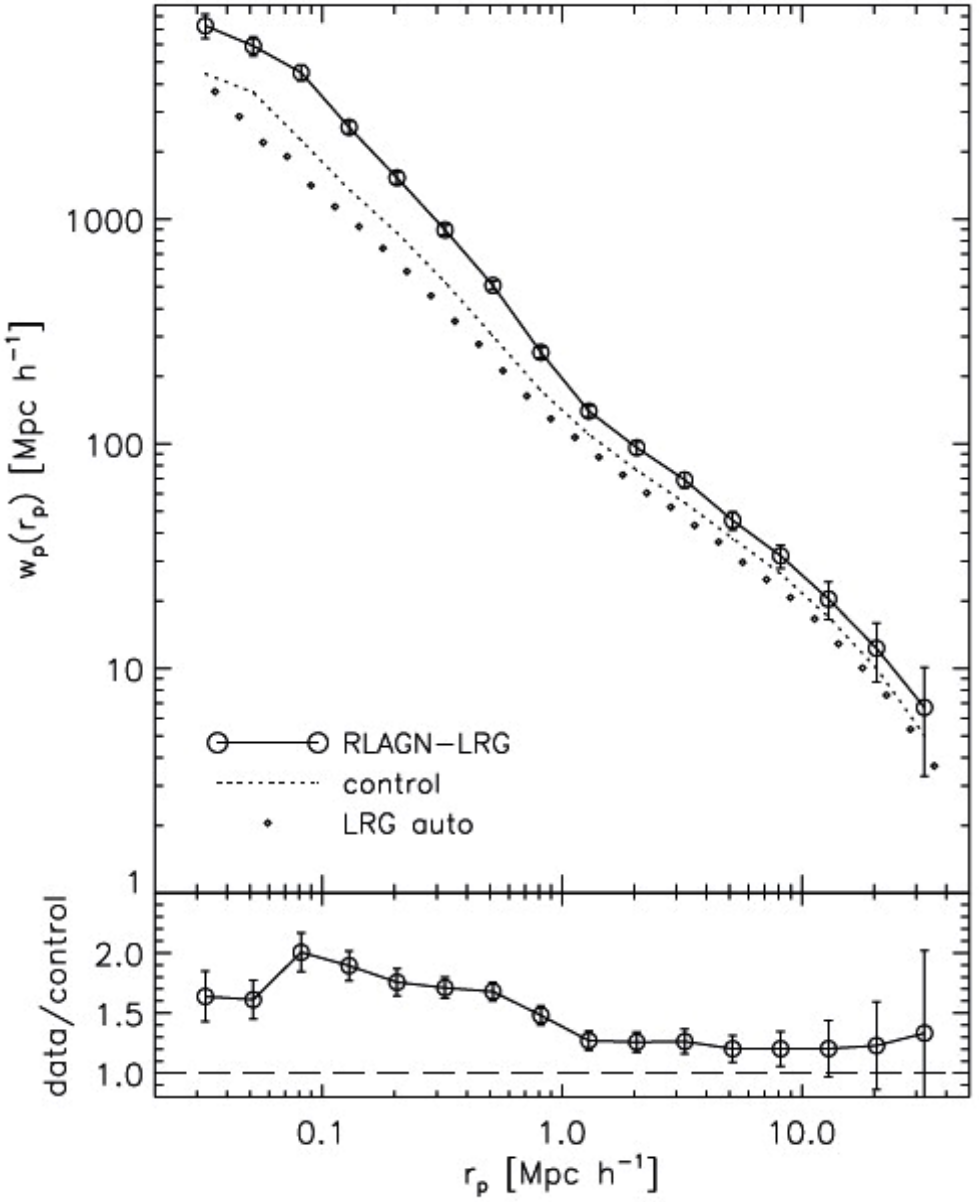
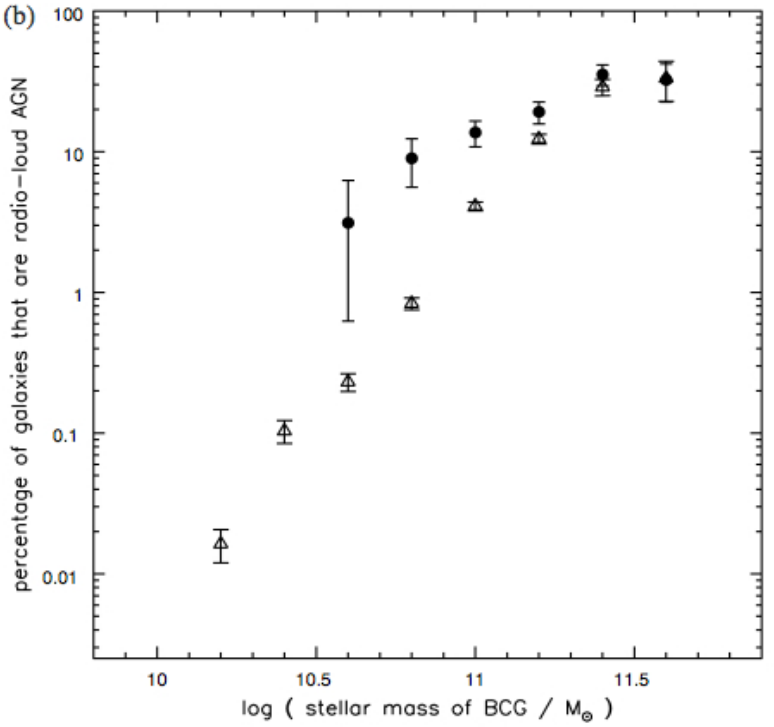
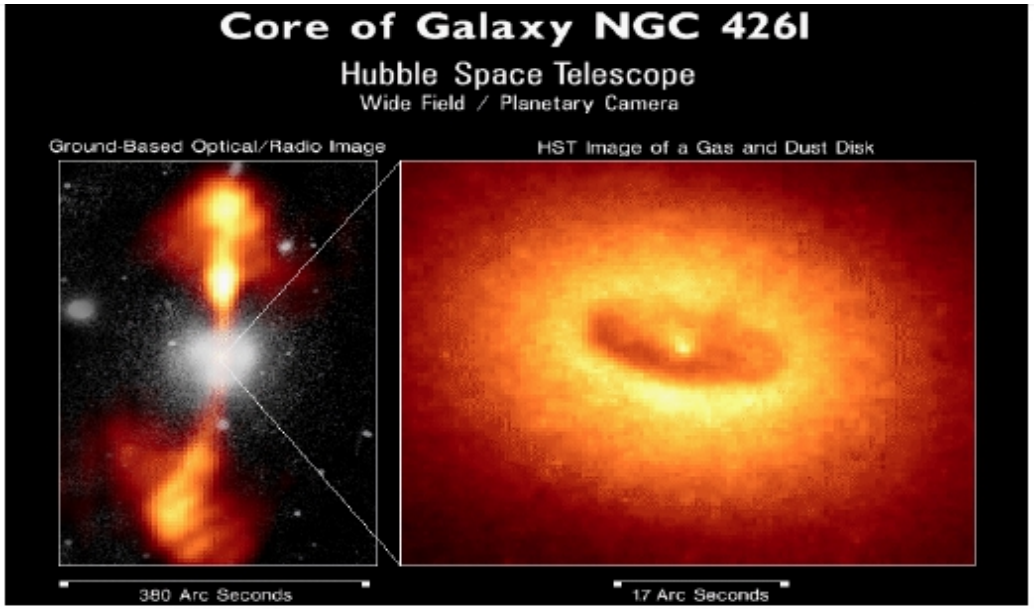
The Astrophysical Journal Letters, Volume 627, Number 2

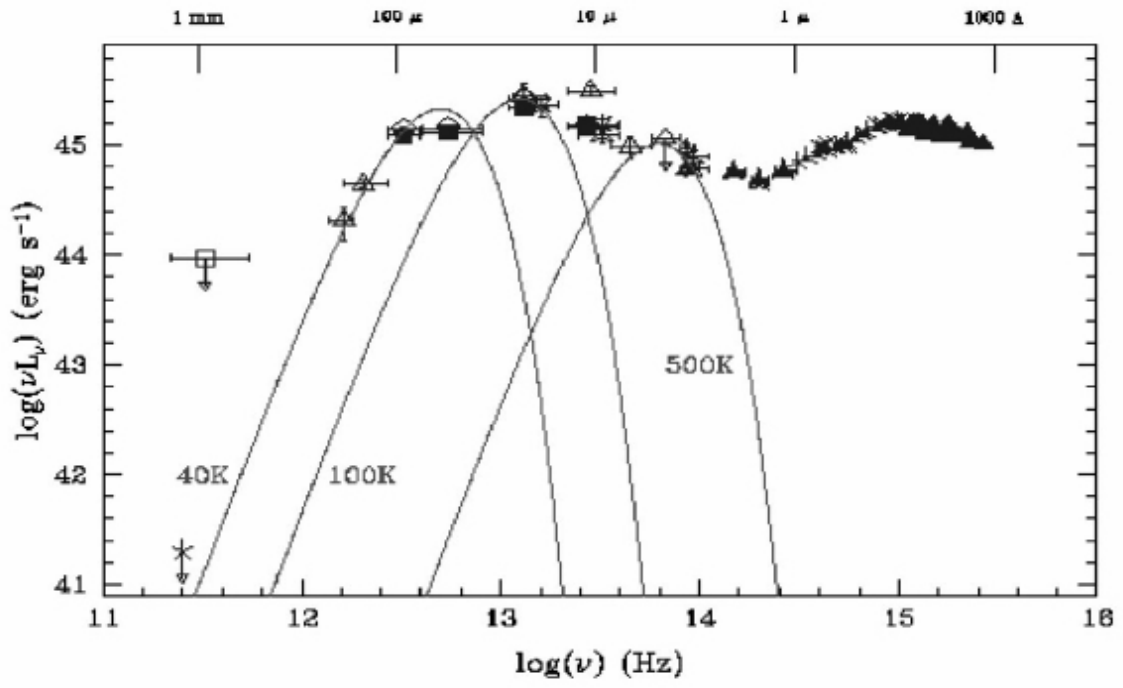
Radio-loud AGN are more strongly clustered than control samples – frequently found in the BCG (brightest cluster galaxy)





CAVEAT: analyses so far have been confined to the full sample of AGN, dominated by number by low-luminosity, low accretion-rate systems

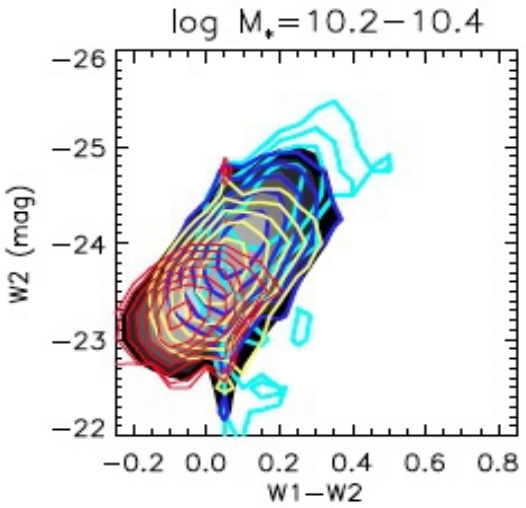


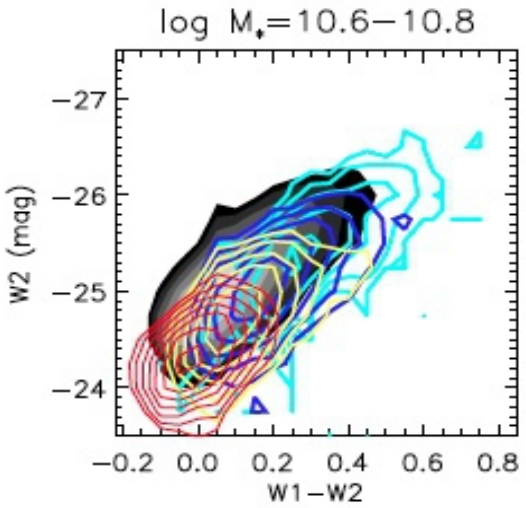


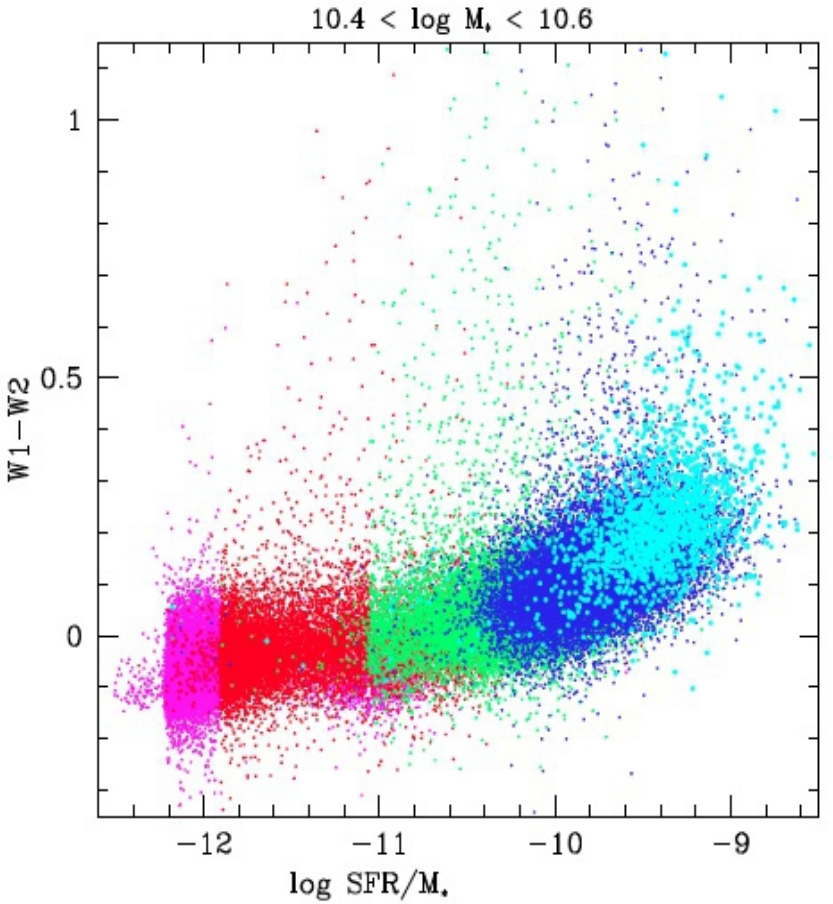
In recent work, I have considered AGN selected by their mid-IR properties. Strong mid-IR emission is an indicator of dust heated to high temperatures, as would be expected for the central regions of an AGN

STEP 1: Select galaxies with mid-IR colours that are too red to be explained by their stellar populations ==> clear evidence of hot dust emission

(Note that most previous statistical studies stop here and call these object AGN)

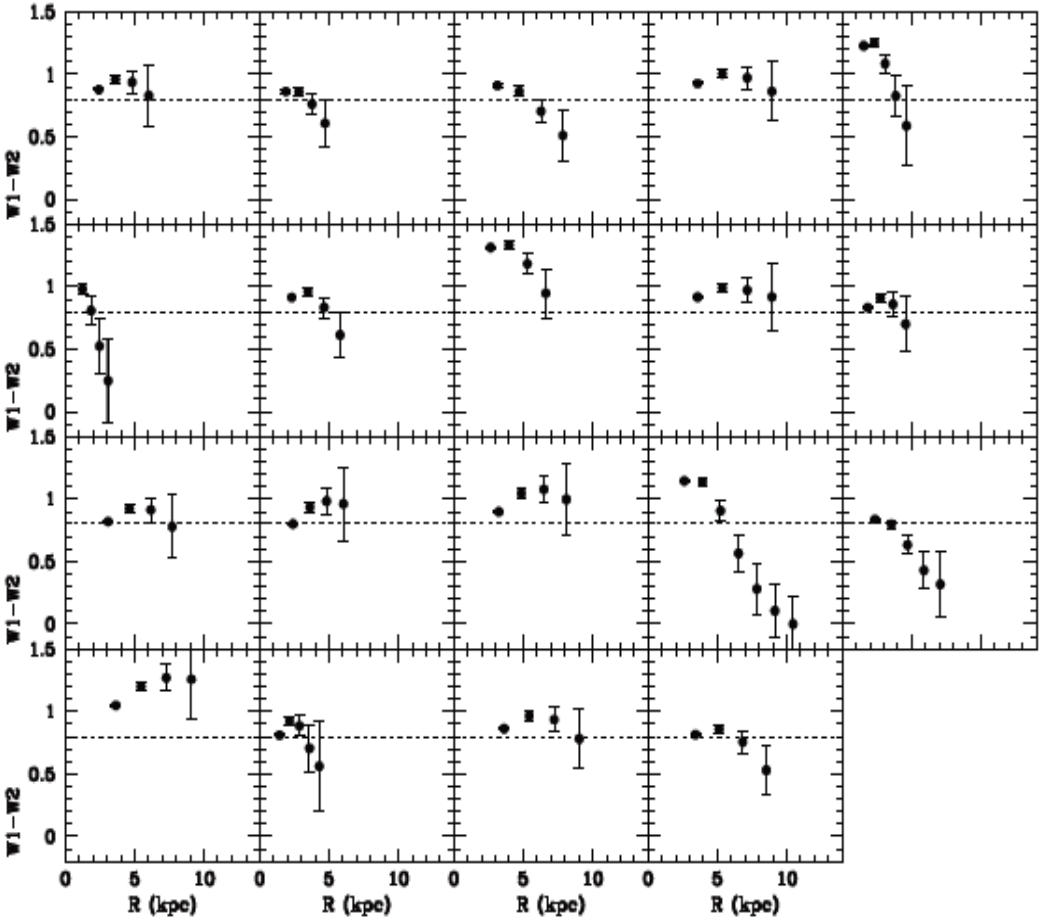






STEP 2: Sanity check on the AGN hypothesis. Do we see evidence for centrally peaked W2 emission consistent with a torus?

Answer: In 98% of cases, the answer is NO.

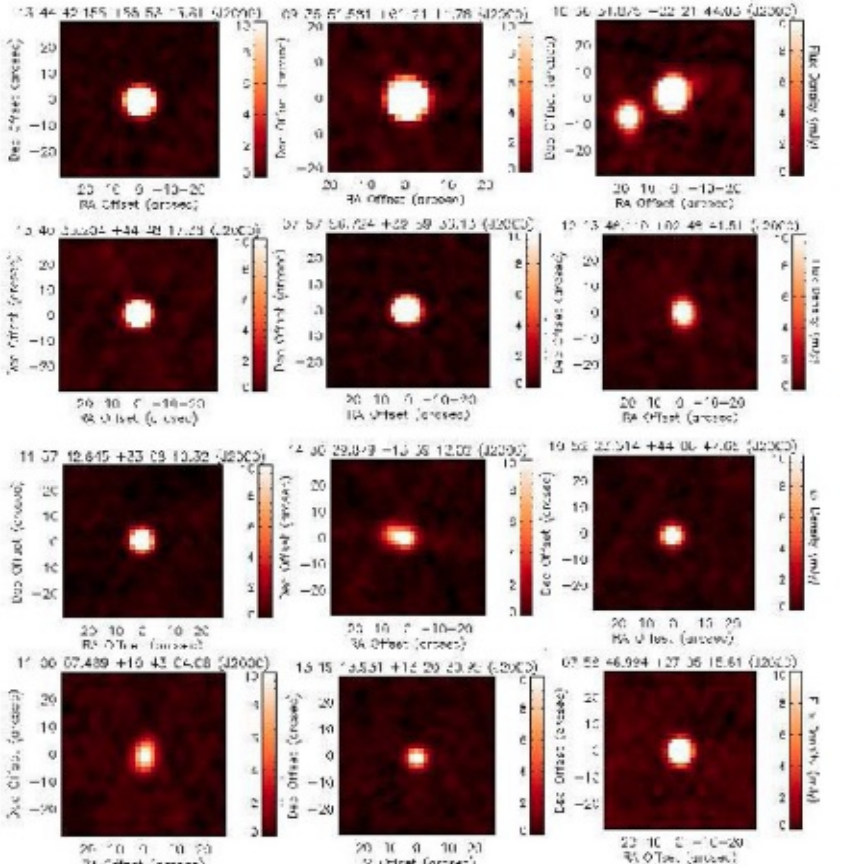


What are the non-AGN with strong mid-IR emission?

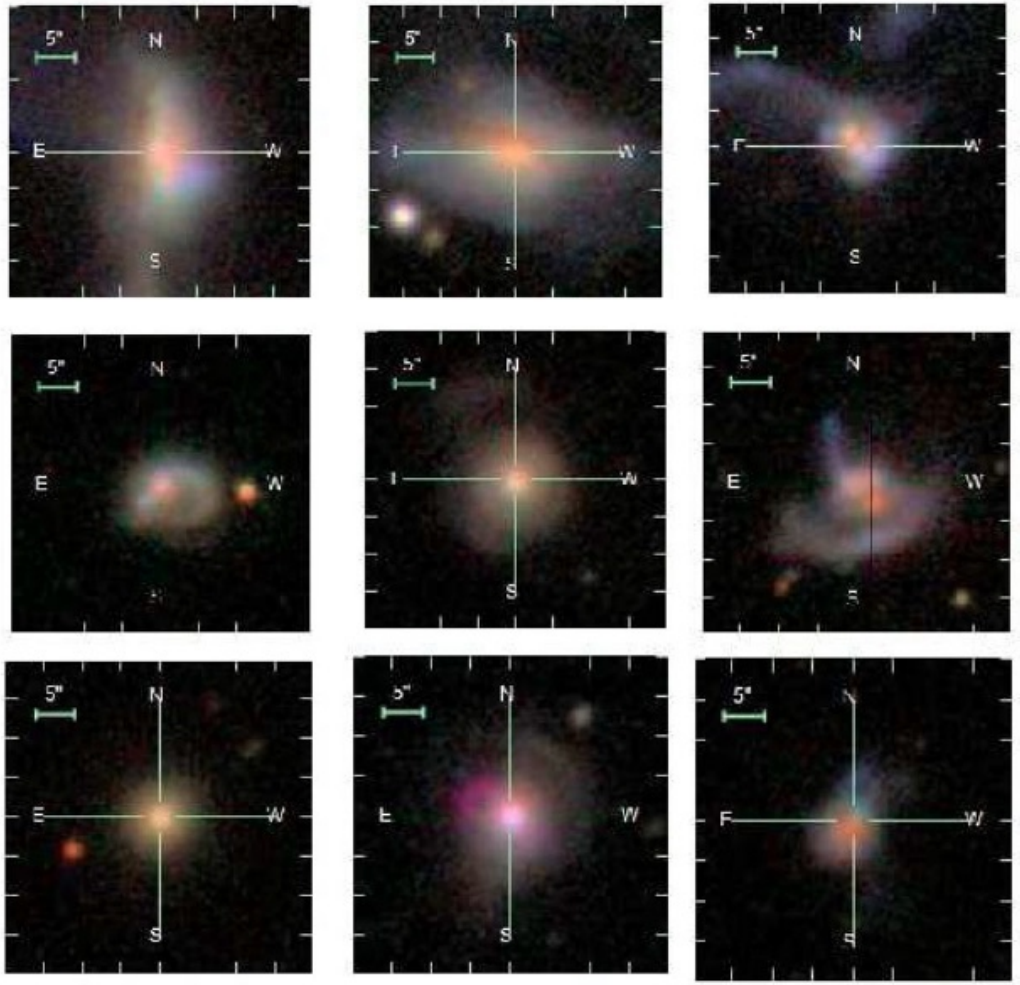
Hot dust in ellipticals imaged in the X-ray has been found to follow the plasma distribution Indicating stochastic heating by hot electron collisions.

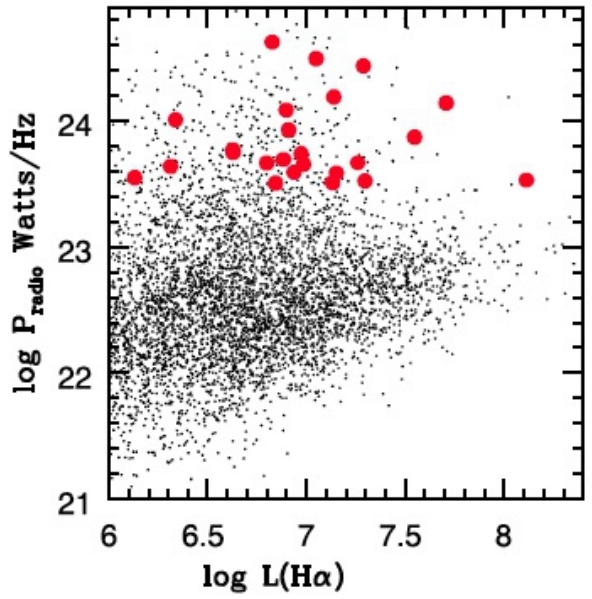
What is the best predictor for Centrally peaked mid-IR emission?

Answer: detection of radio emission

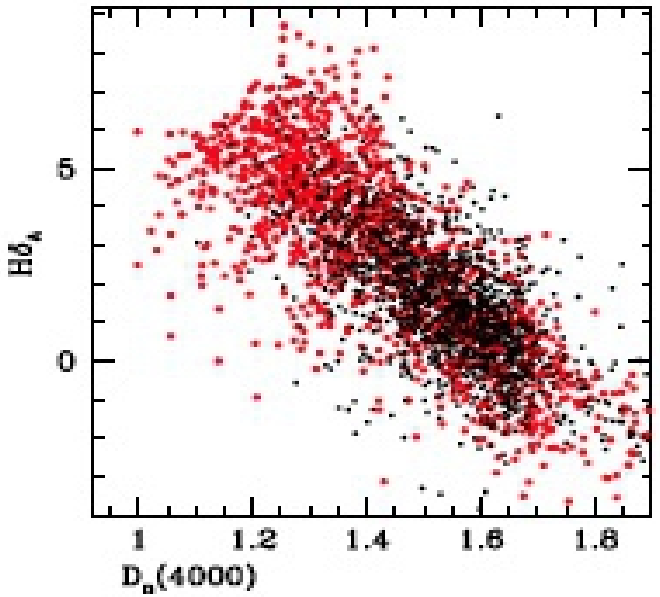


Radio emission is unresolved in FIRST images. Radio luminosities lie well above the locus of star-forming galaxies. 80% of the host galaxies are clear mergers or lopsided/disturbed systems.





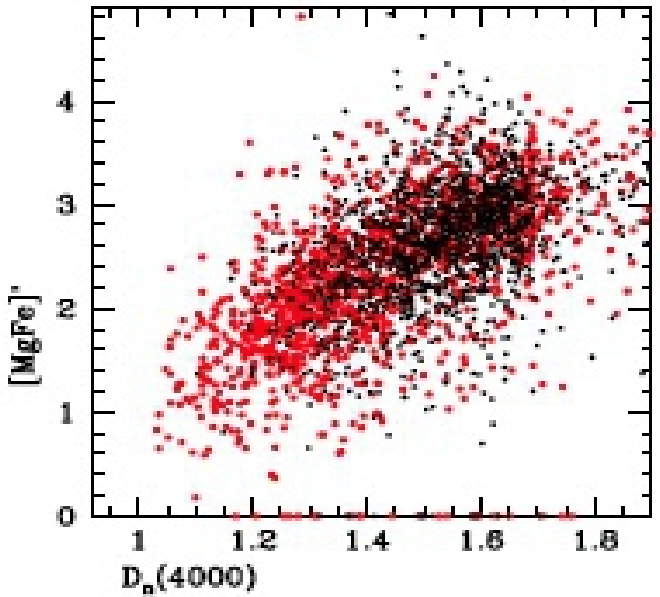
HOST GALAXY PROPERTIES OF MID-IR BRIGHT AGN



RED – mid-IR AGN

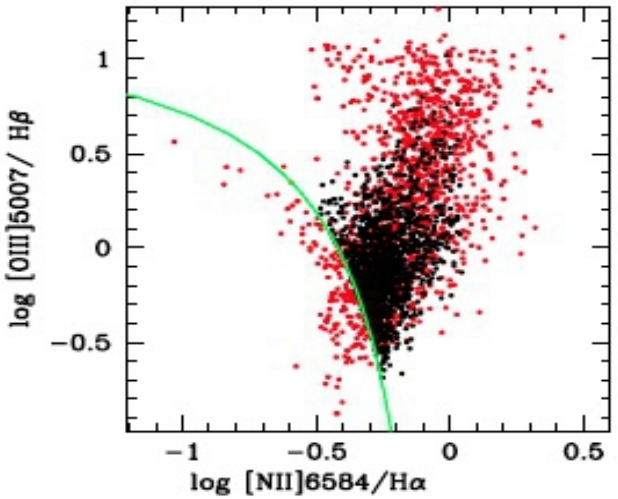
BLACK- control sample of AGN selected optically

Many “post-starburst” objects with small 4000 Angstrom break strength and large EQW of Balmer absorption features

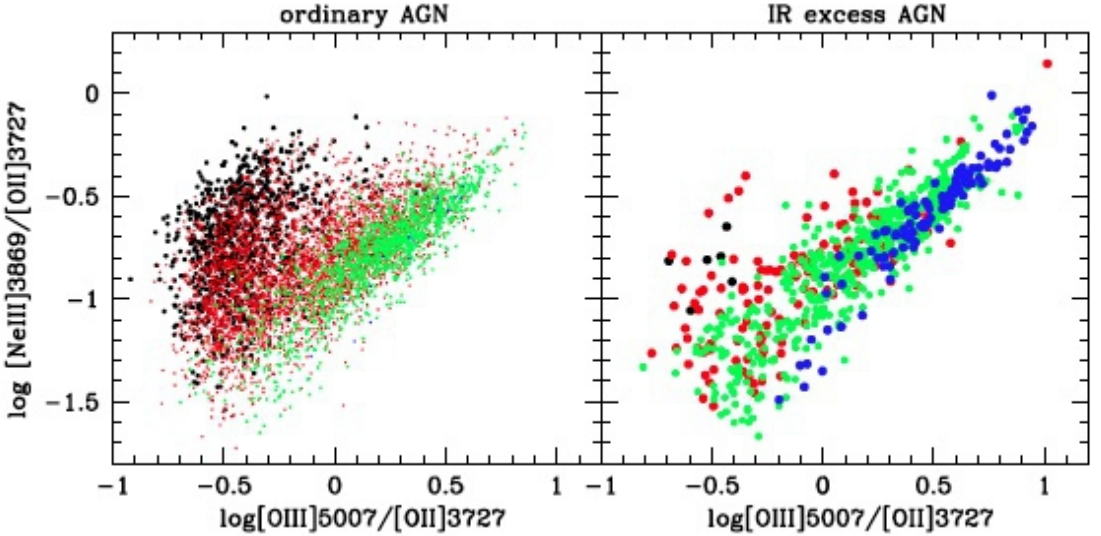


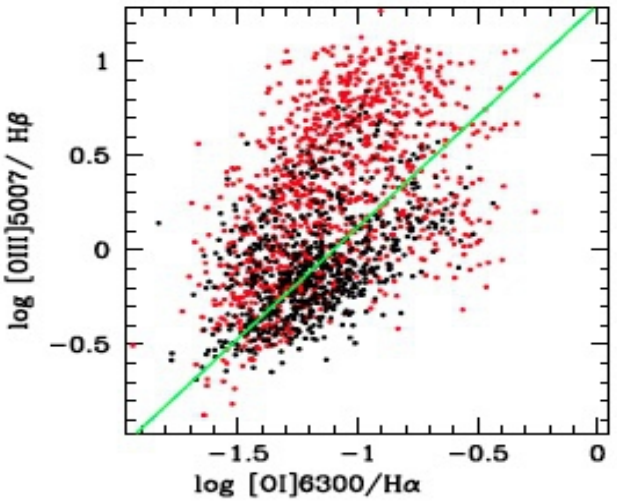
Systems with young stellar ages have low stellar metallicties.

MID-IR BRIGHT AGN HAVE GAS WITH HIGH IONIZATION. THE HIGHEST IONIZATION SOURCES ARE ALSO THE MOST LUMINOUS ONES AND ARE IN HOST GALAXIES WITH YOUNG STELLAR POPULATIONS

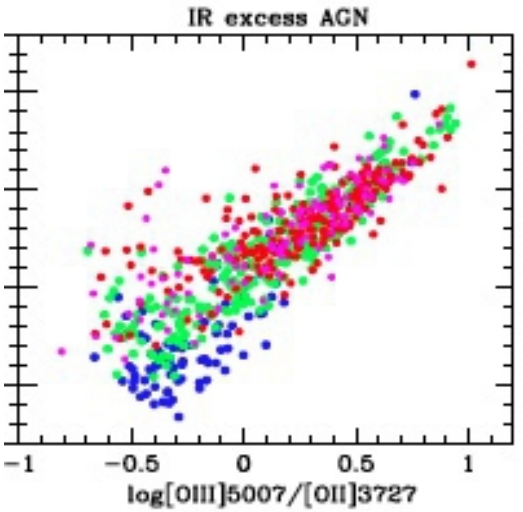


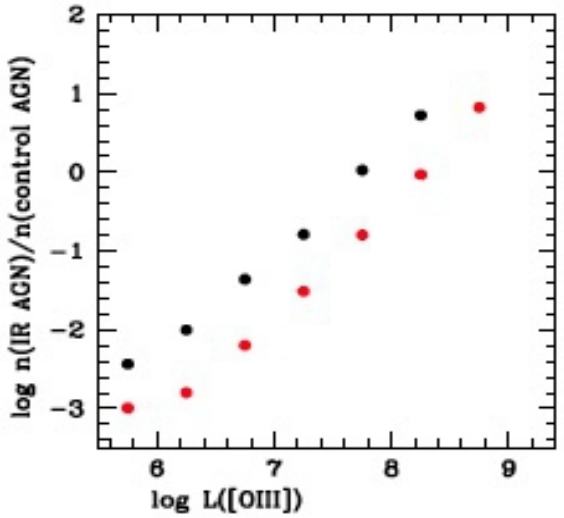
colour-coded by luminosity

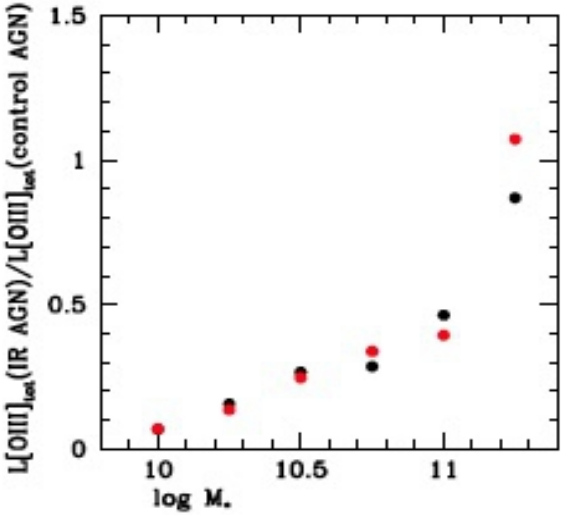




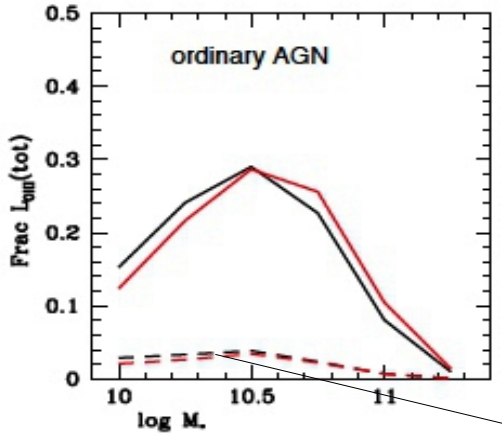
colour-coded by stellar age

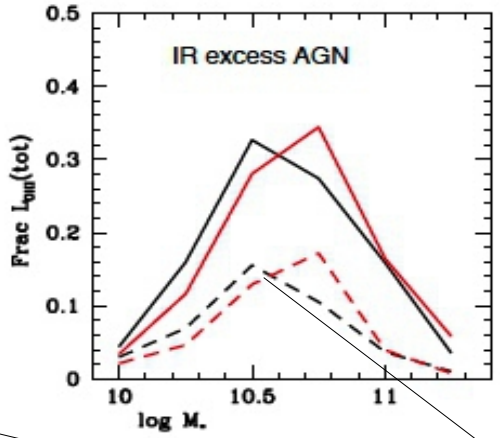




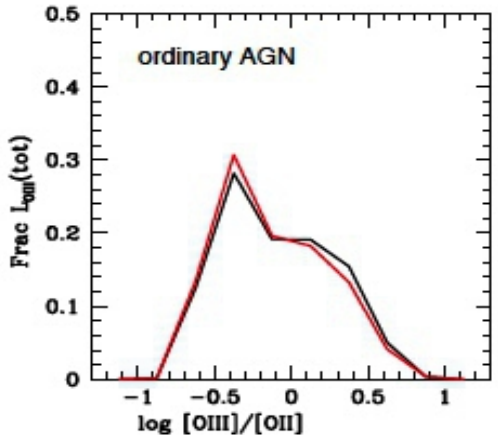


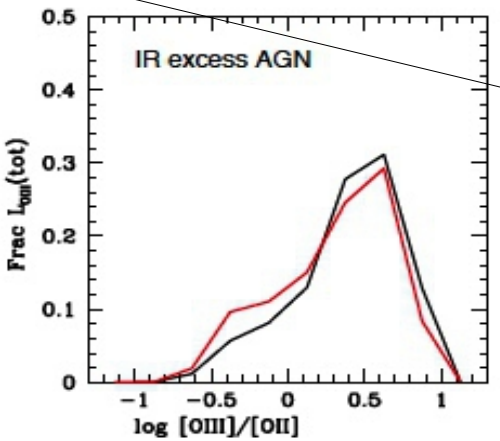
Ratio of mid-IR bright sources to control sample AGN as a function of AGN luminosity and galaxy mass





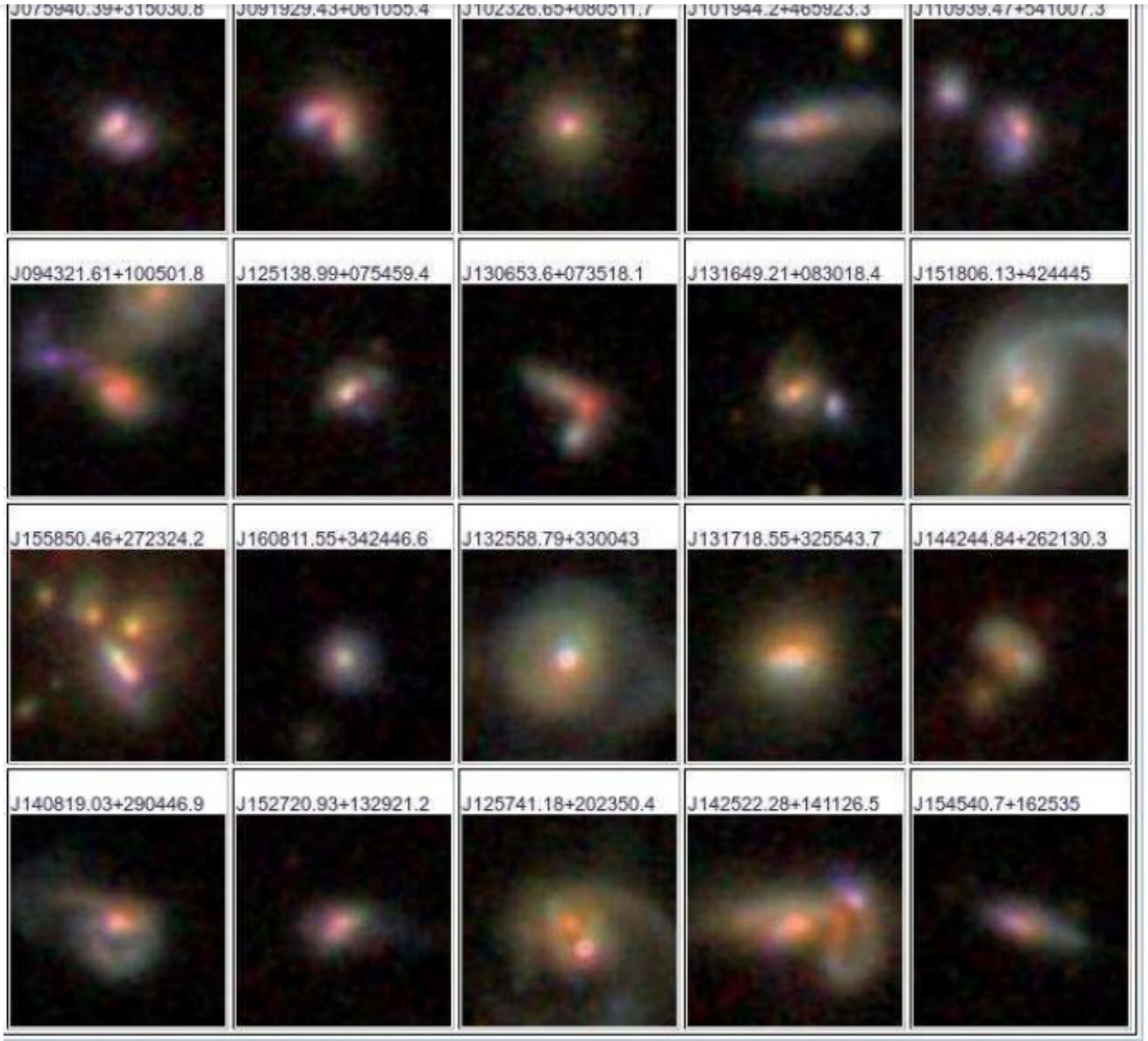
Partition function of total integrated [OIII] luminosity as a function of stellar mass (top) and ionization parameter (bottom)



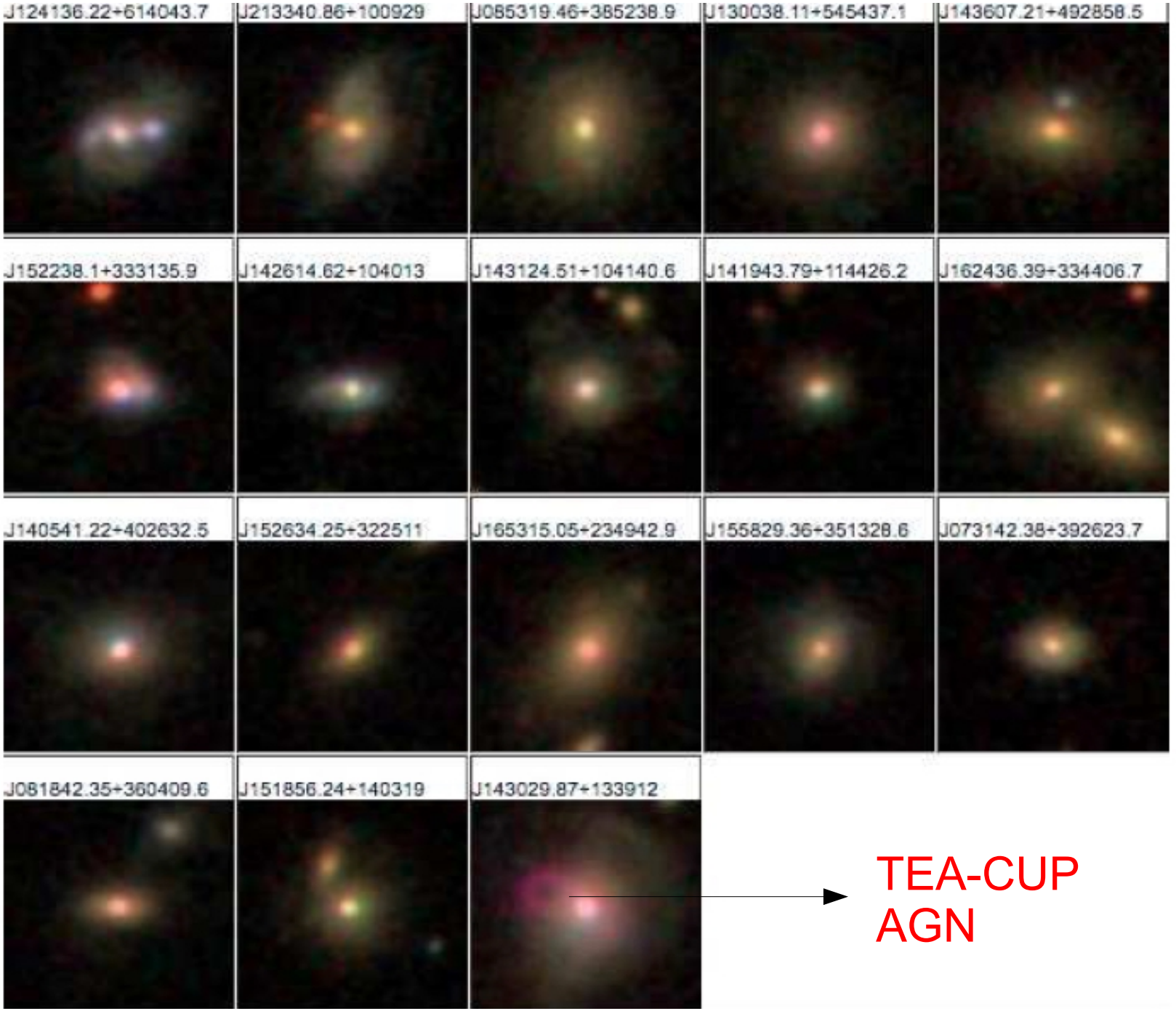


Post-starburst contribution

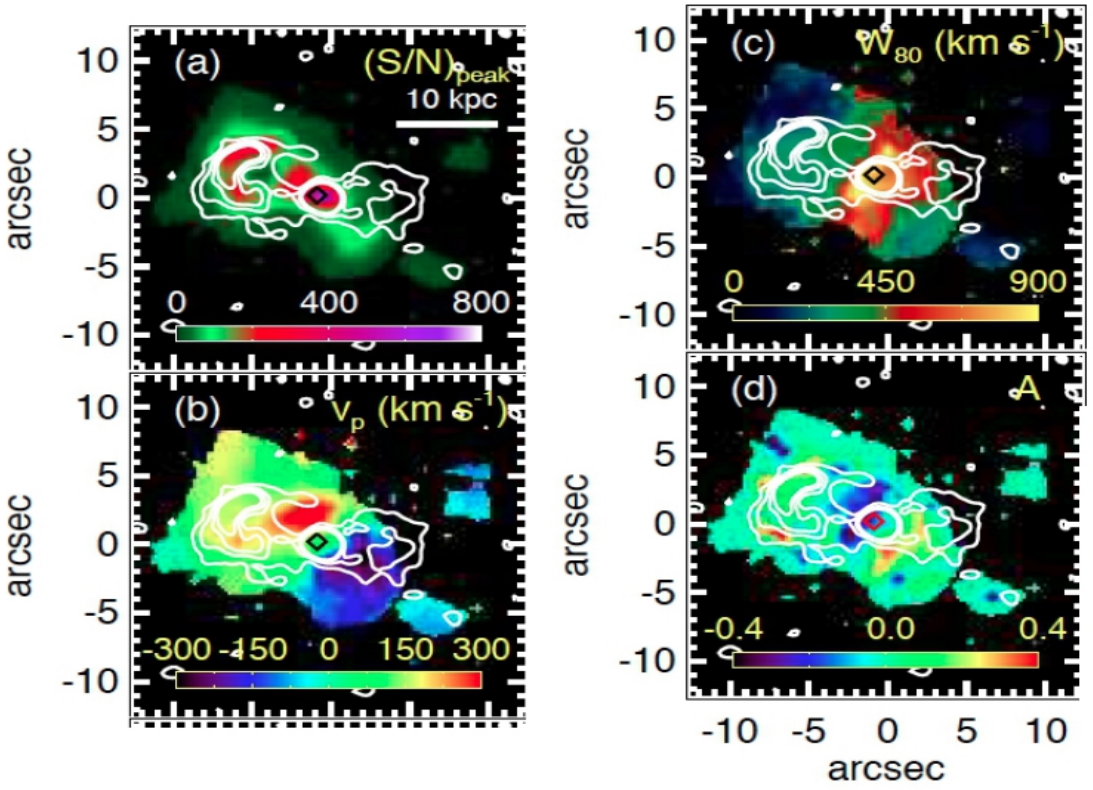
MID-IR BRIGHT AGN WITH YOUNGEST STELLAR AGES

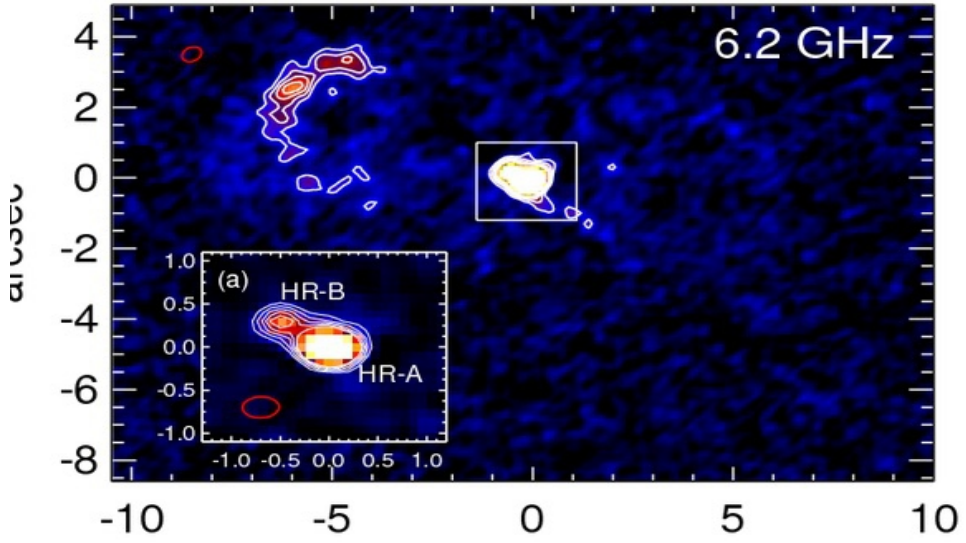


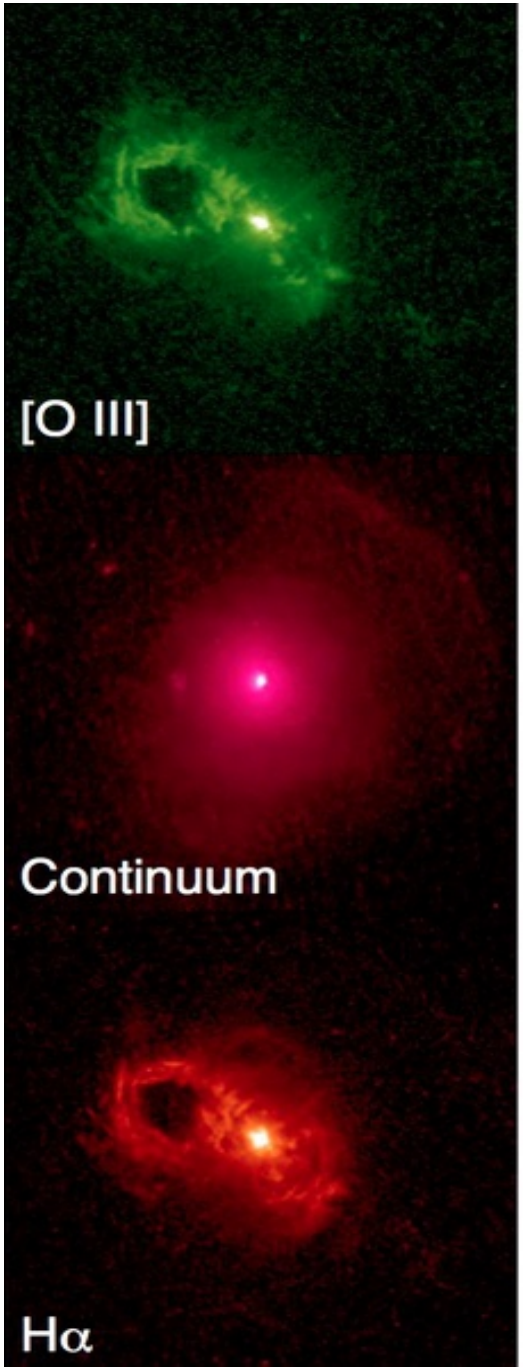
MID-IR BRIGHT AGN WITH HIGHEST LUMINOSITIES



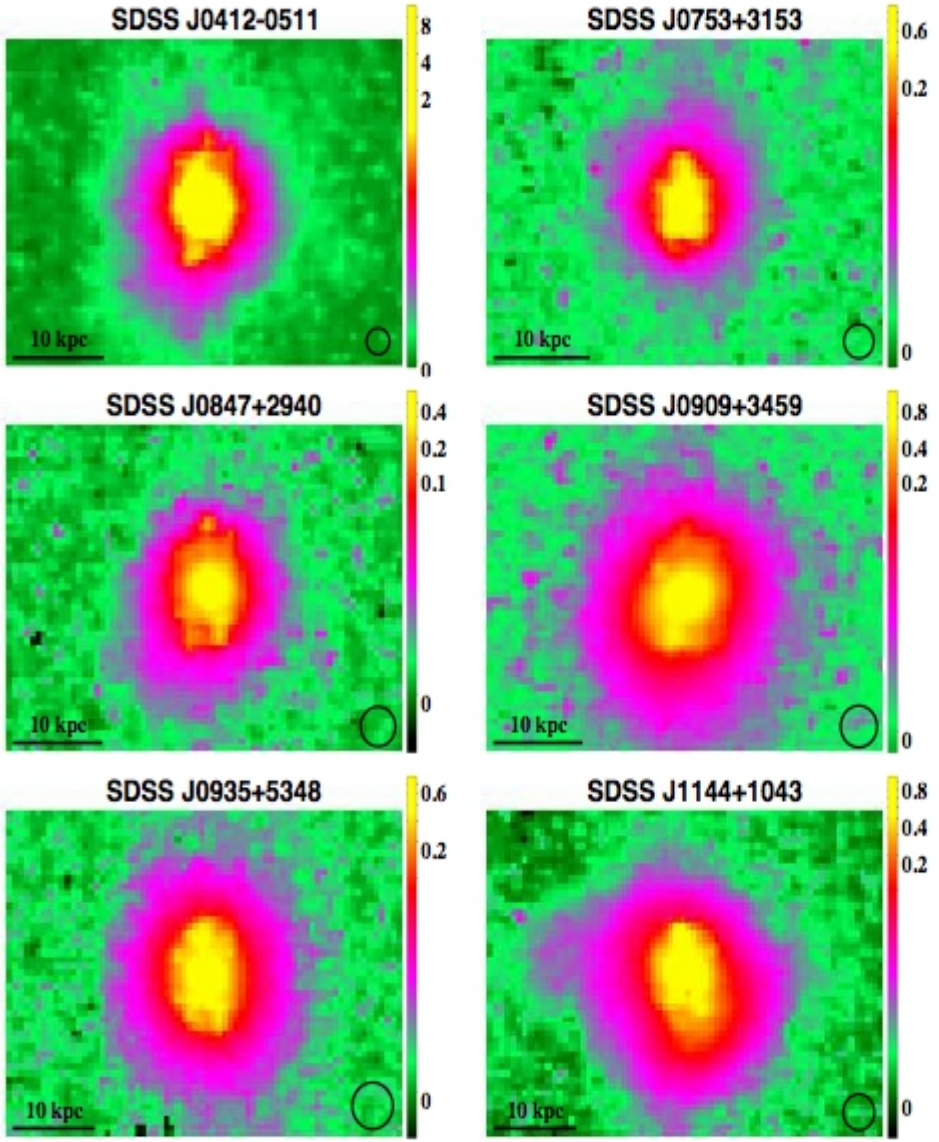
Tea Cup AGN has resolved radio emission and a 740 km/s ionized gas outflow.

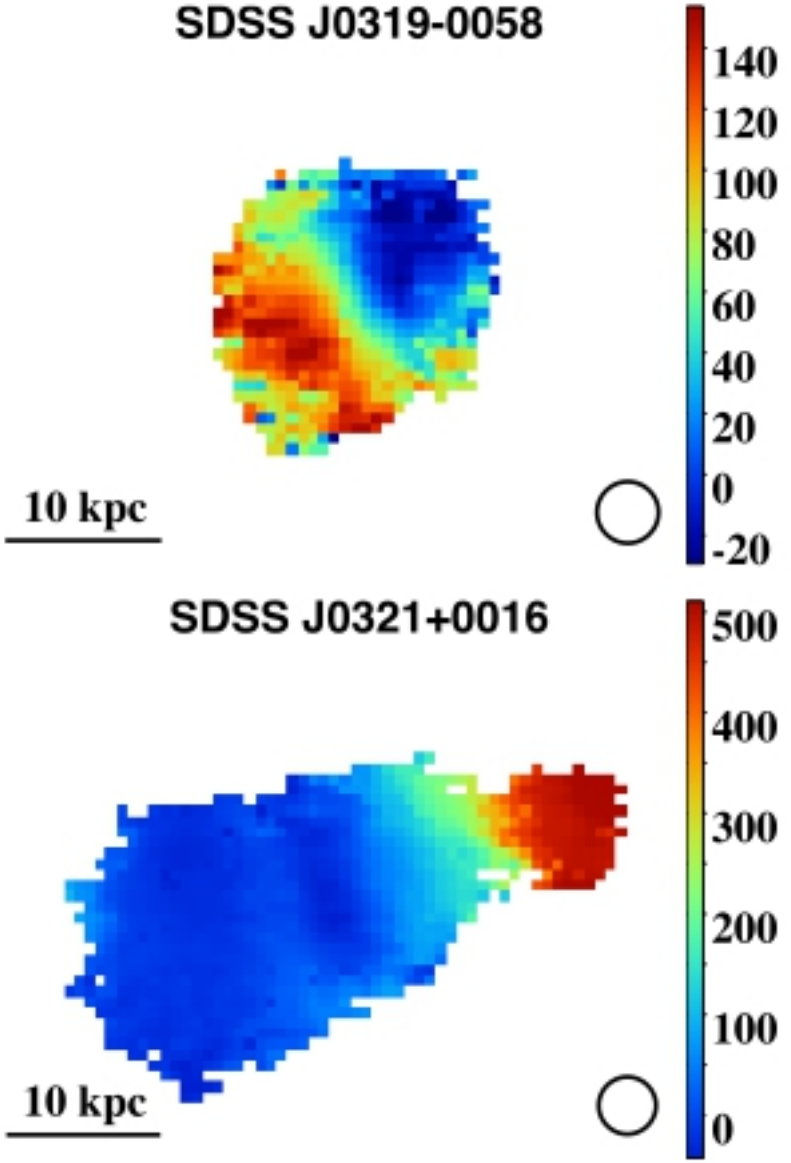






The teacup AGN are similar to the high-z Type II quasars studied by Zakamska, which have ionized gas “halos” extending out to radii of 50 kpc with round morphologies and show comparable outflow velocities





NEW CONCLUSIONS

1) I present a new AGN selection method that picks out objects with significant host dust emission in their central regions. This is a rare class of object: 1300 out of ~80000 AGN in the SDSS main sample

2) Unlike the parent sample, the host galaxies of these systems are almost all mergers or disturbed galaxies. Their stellar populations frequently show post-starburst signatures

3) The selection on mid-IR properties selects the AGN with the highest [OIII] luminosities and ionization parameters. The most [OIII]-bright objects in our sample have very similar properties to the Type II quasars studied by Zakamska and probably represent the subset of systems at a late stage of the merging process.

4) Even in the local Universe, the mid-IR bright AGN dominate the integrated [OIII]luminosity produced by AGN in the most massive galaxies.

==> We are now able to pick out the long sought-after merger/quasars from large surveys.