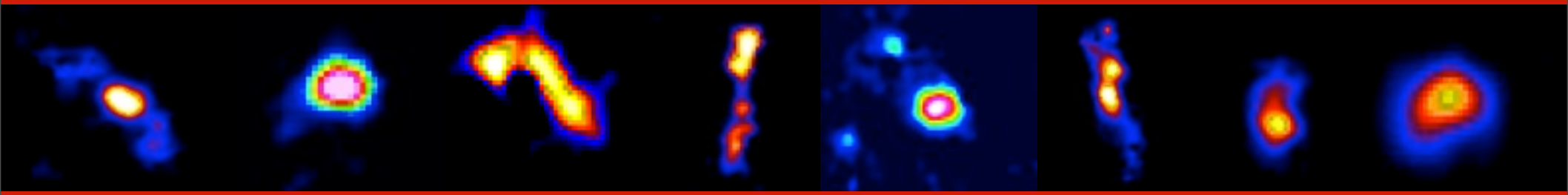
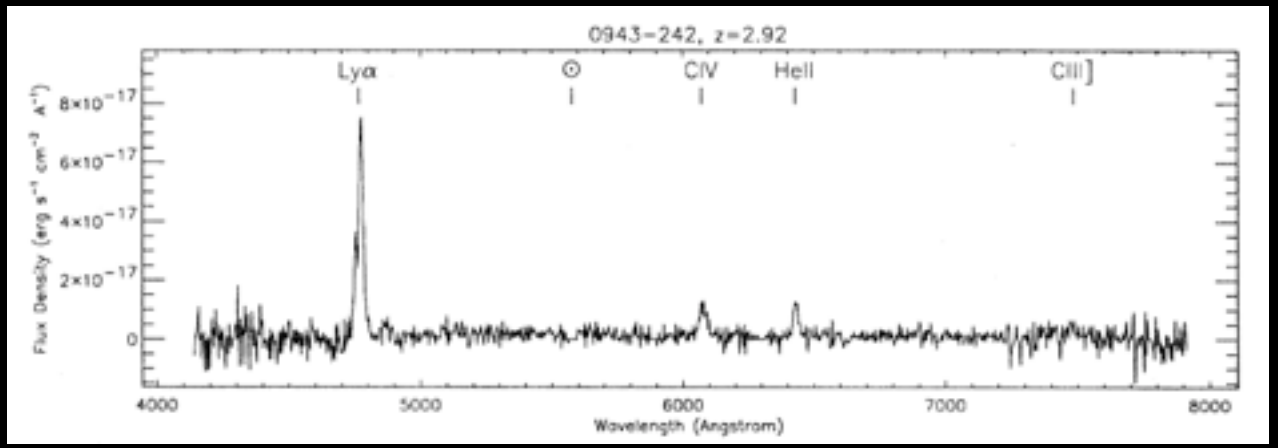
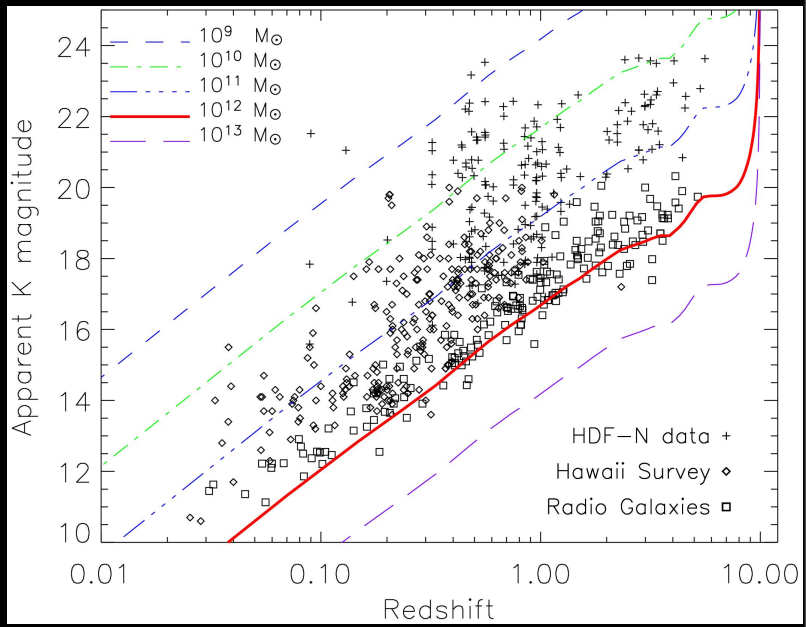
The AGN-Galaxy connection (in type 2 AGN)

Carlos De Breuck (ESO)







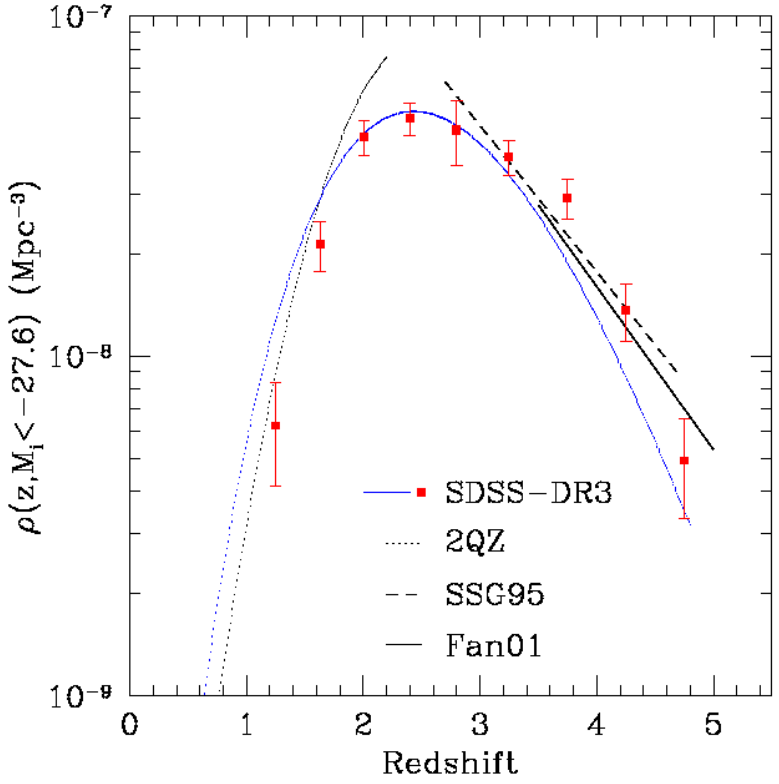
The importance of AGN

➕ AGN mark the most powerful episode in the life of a galaxy, and can have a profound impact on its evolution.

➕ AGN are bright ⇒ easy to find out to high redshifts.

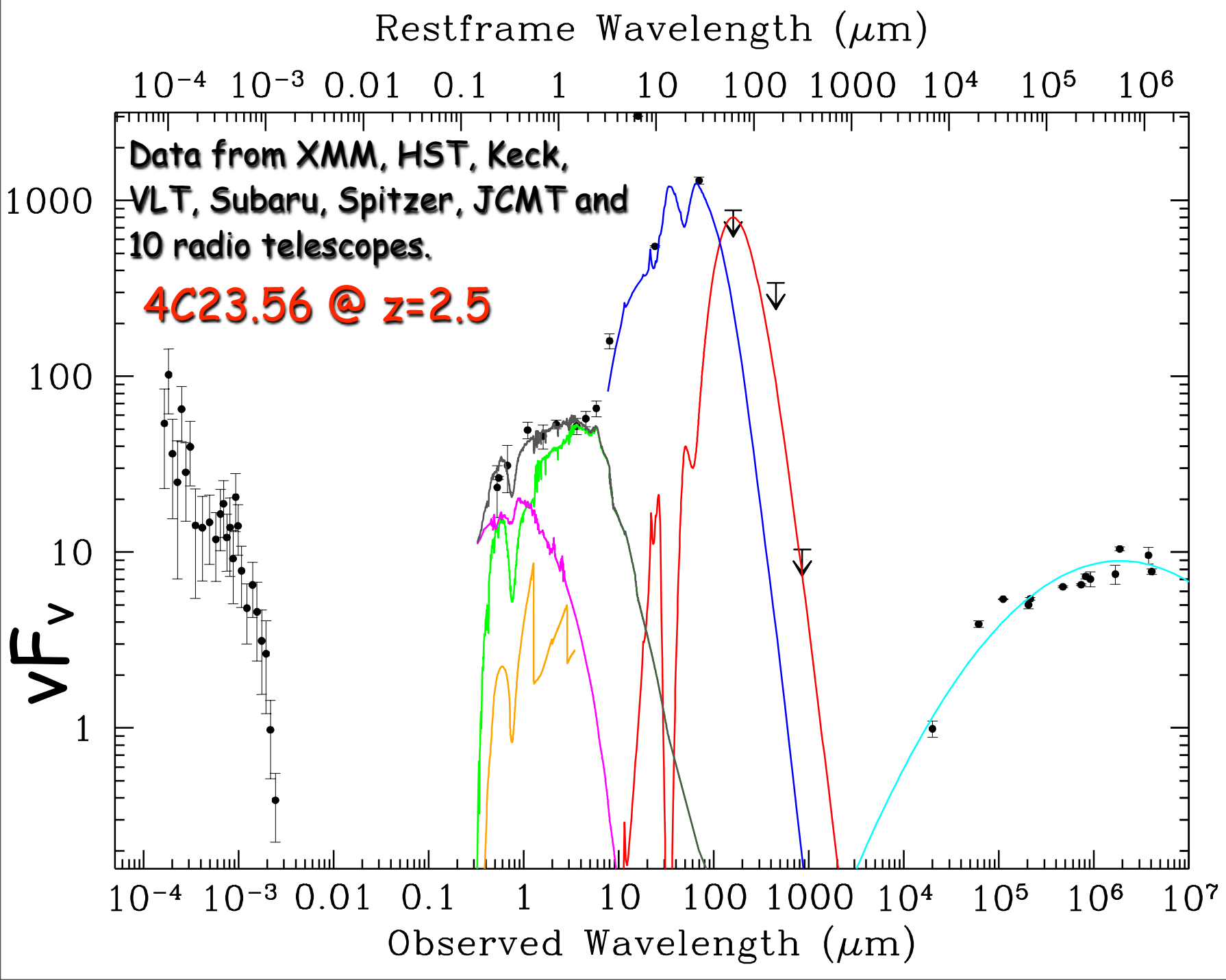
➕ AGN are more common at z~2 than at z=0, making them powerful probes of the high-z Universe.

➖ AGN emission can outshine the host galaxy.

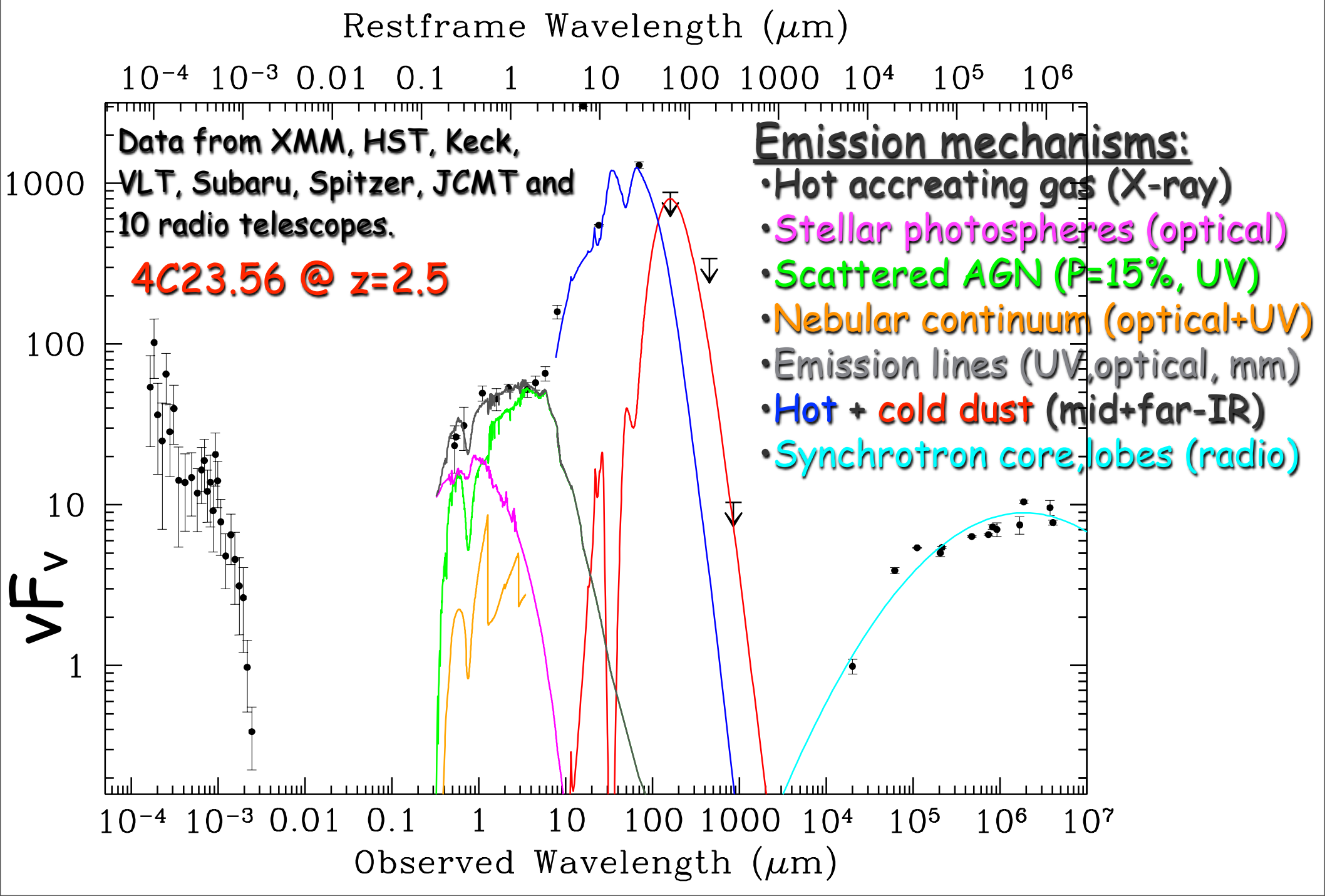


Richards 2006
Fan + 2005

AGN and stellar emission across the SED

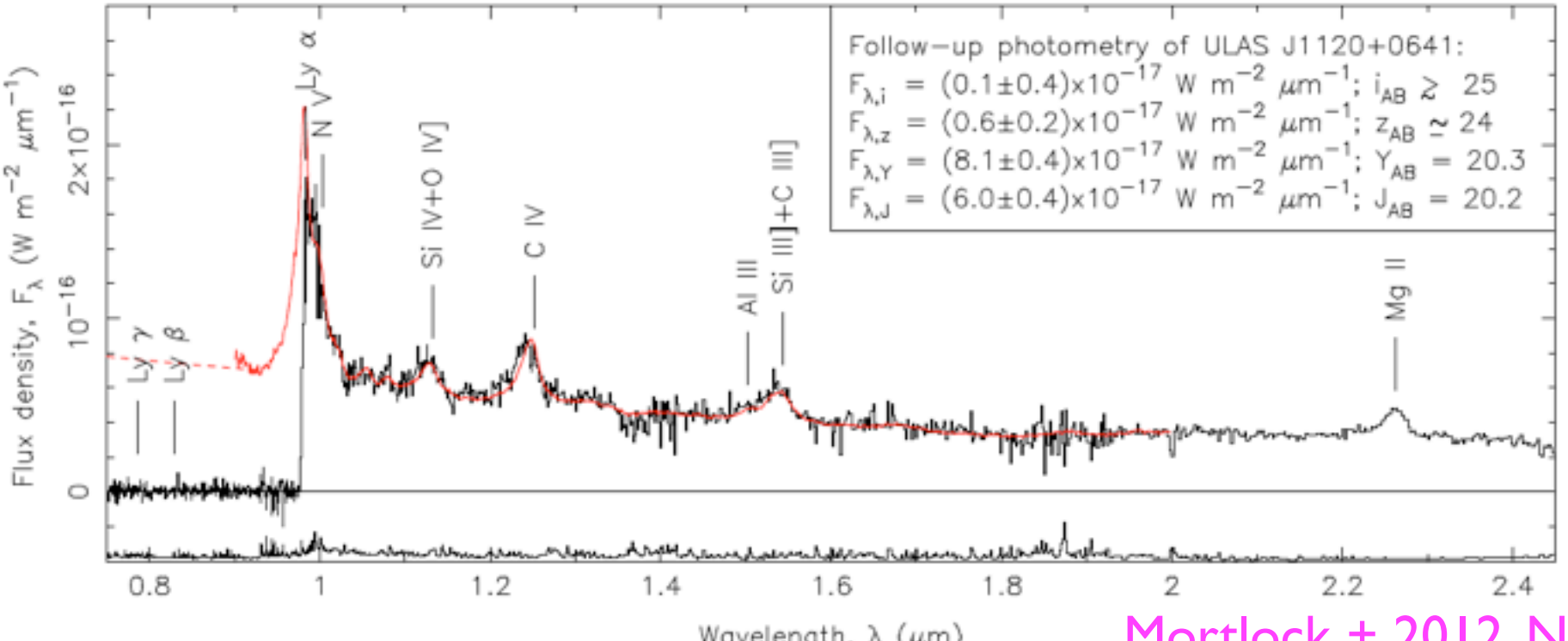


AGN and stellar emission across the SED



Surveys for Type 1 AGN

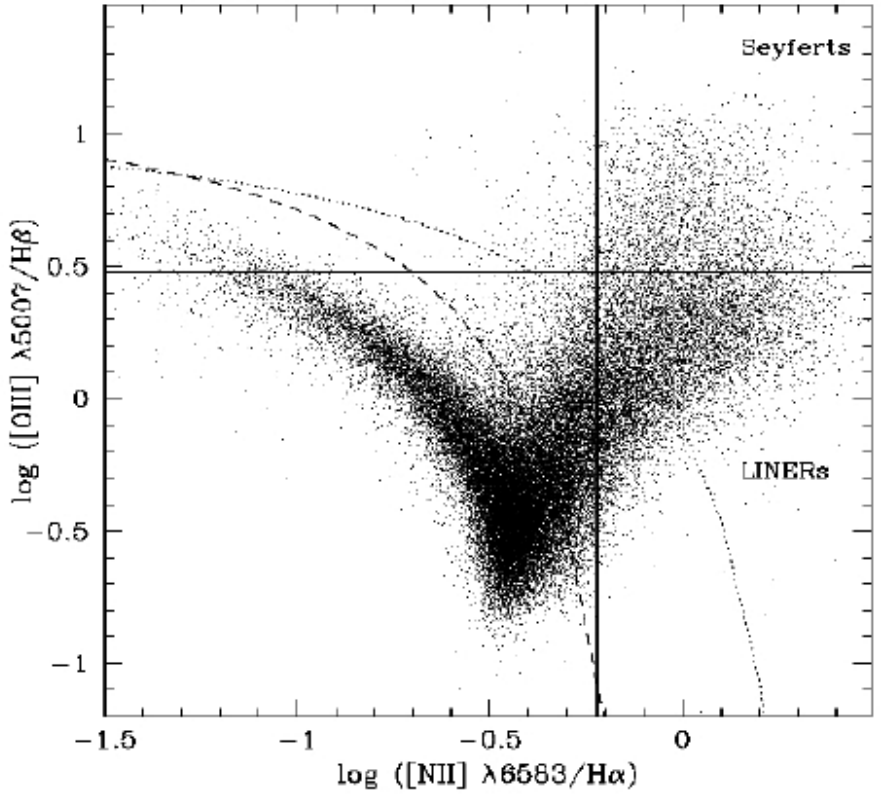
- Spatially unresolved at all λ, except radio.
- >90% selected by optical colour (UV excess or Lyman break).
- UKIDSS and VISTA making important contributions, especially at the highest redshifts.
- Studies of host galaxies require AO + detailed PSF subtraction (e.g. SINFONI/NACO).



Mortlock + 2012, Nature

Surveys for Type 2 AGN

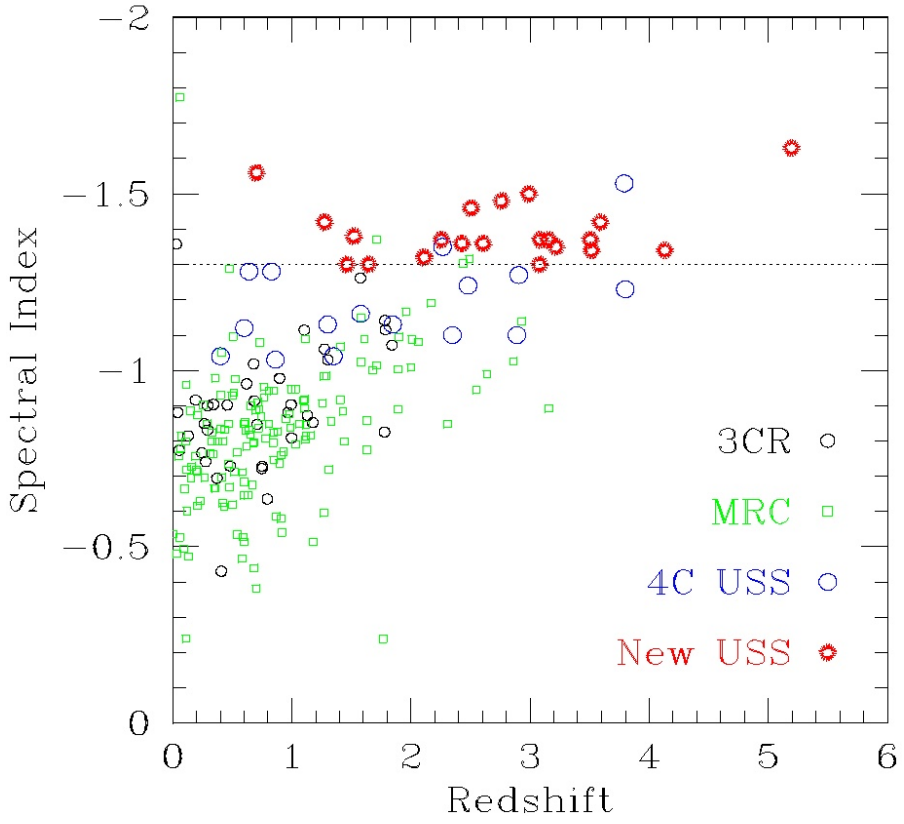
- Torus acts as natural coronograph, allowing a direct view of the host galaxy.
- First found as identifications of bright radio sources in the 1960s (when ESO was founded!).
- Now also selection in optical, mid-IR and X-ray.
- In low-luminosity AGN, line ratios are needed to separate AGN and starbursts.



Kauffman + 2003

Surveys for Radio Loud Type 2 AGN

- Radio galaxies were the most distant galaxies known till the mid-1990s.
- Identification and optical spectroscopy very expensive.
- Additional selection techniques were developed to identify the most distant radio galaxies.
- Most successful technique: ultra-steep spectrum.

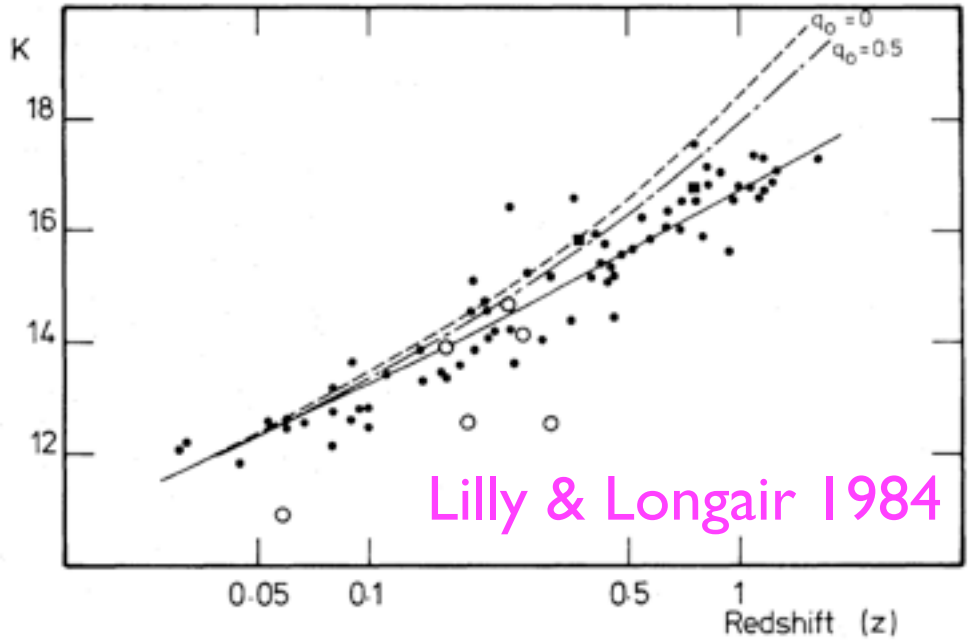


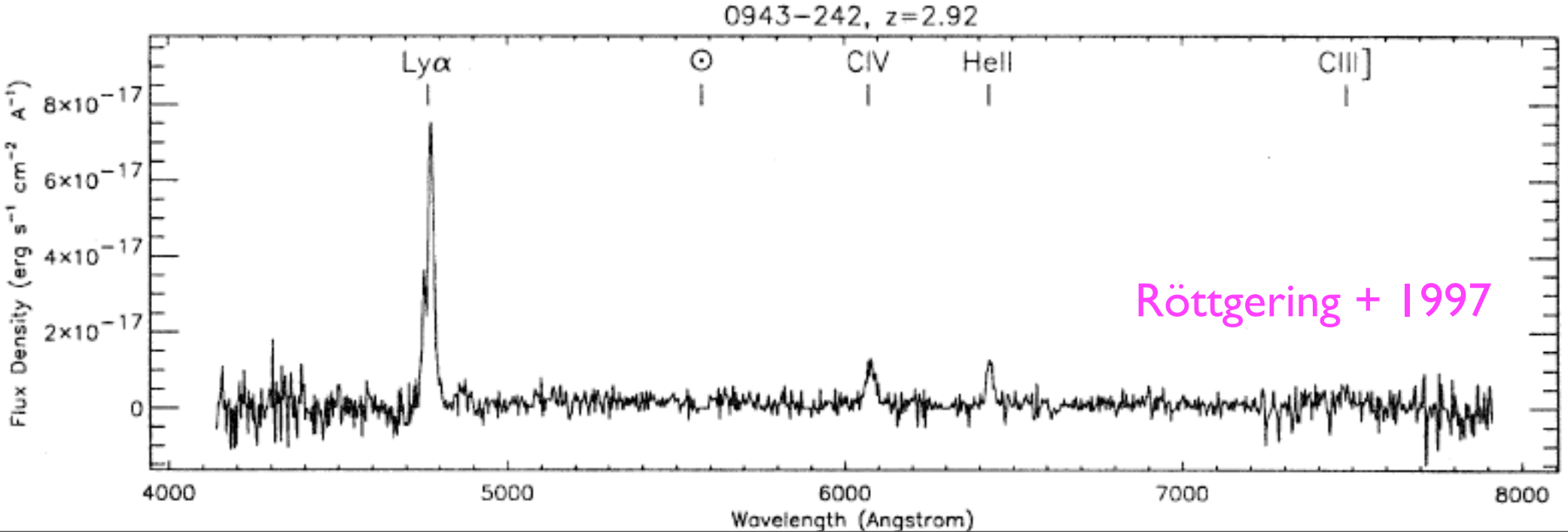
- Uses concave shape of radio spectrum.
- k-correction shifts steeper part to observed wavelengths.
- ~2/3 of sources @ z>2.

De Breuck + 2000-2004

Identification & redshift determination

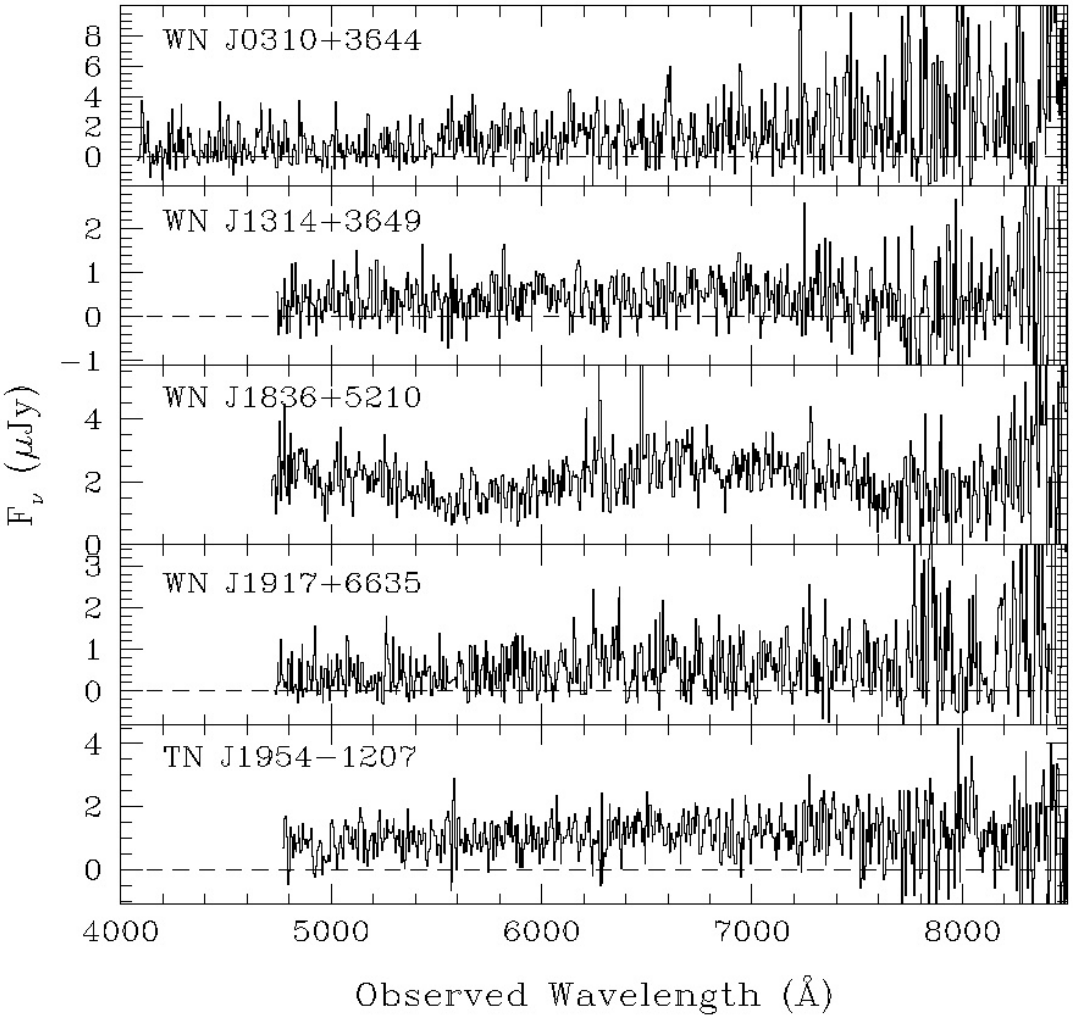
- Host galaxy identification most efficient in K-band.
- K magnitude is a good redshift indicator.
- NTT key programme in mid 1990s provided 64 redshifts.





Redshift determination failures

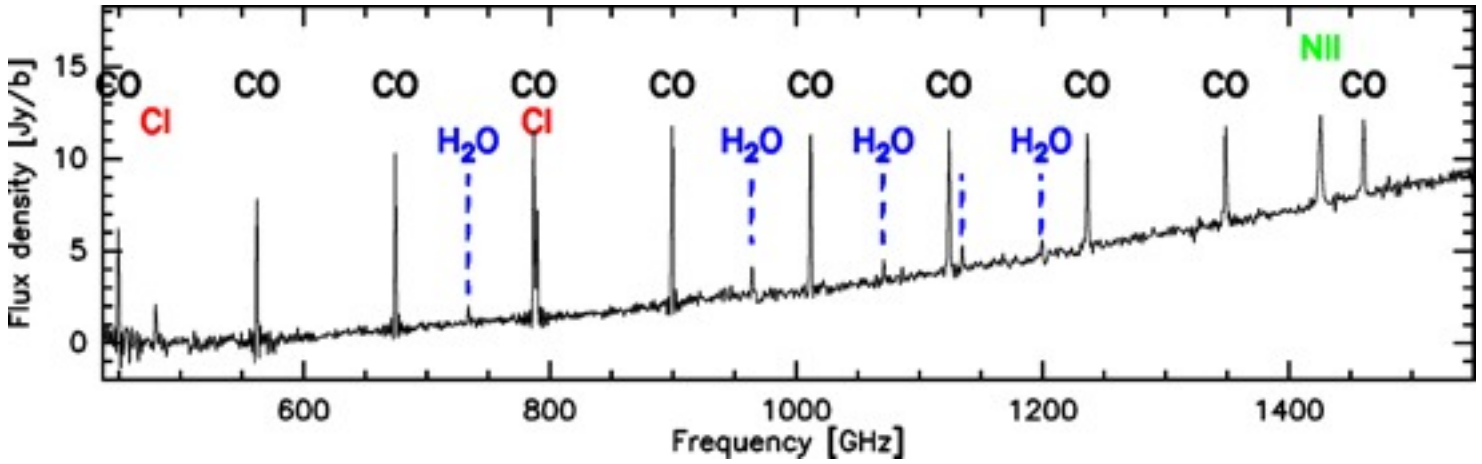
- 30% of radio sources fail to yield a redshift after a few hour integrations with VLT/Keck.
- Either no emission at all, or featureless continuum.
- Very obscured galaxies? Confirmed by high submm detection rate.
- Future prospect: molecular/atomic line spectroscopy with ALMA!

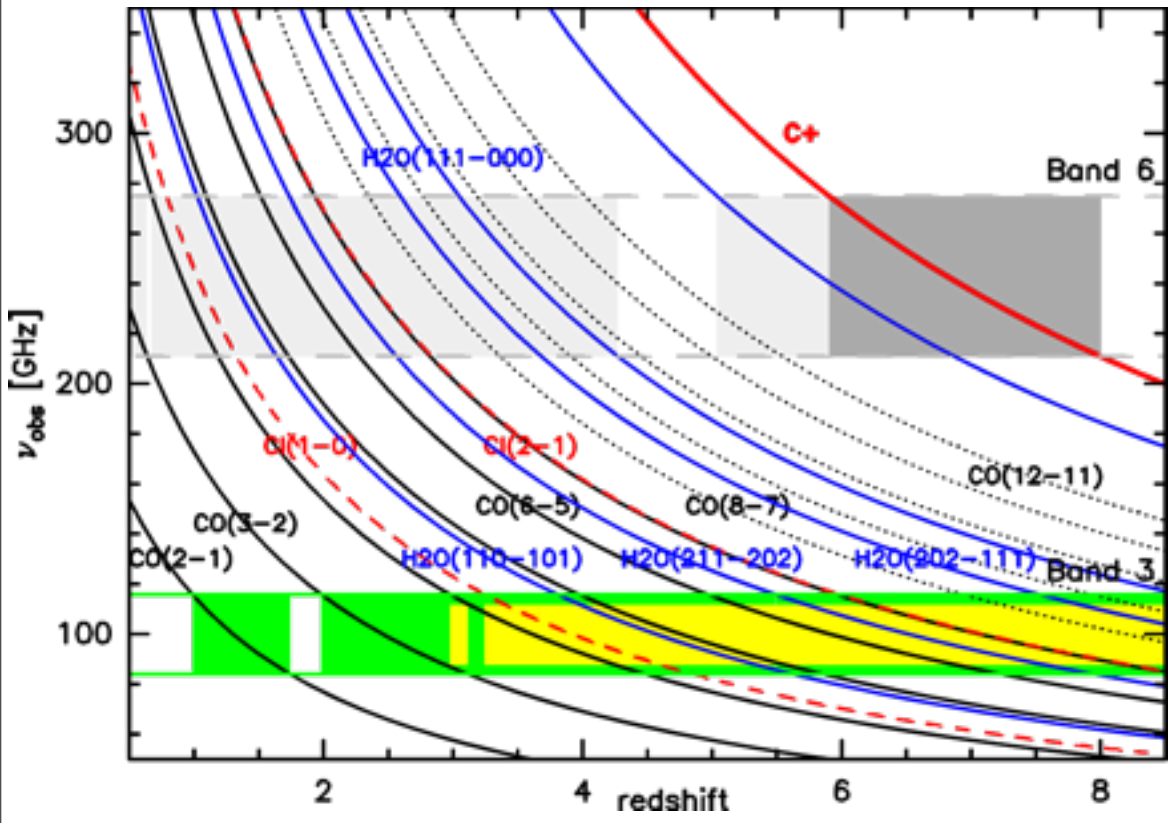


De Breuck + 2001

Blind redshifts from 3mm scans

SPIRE FFTs NGC6240 (Hercules KP, PI: P. Van der Werf)



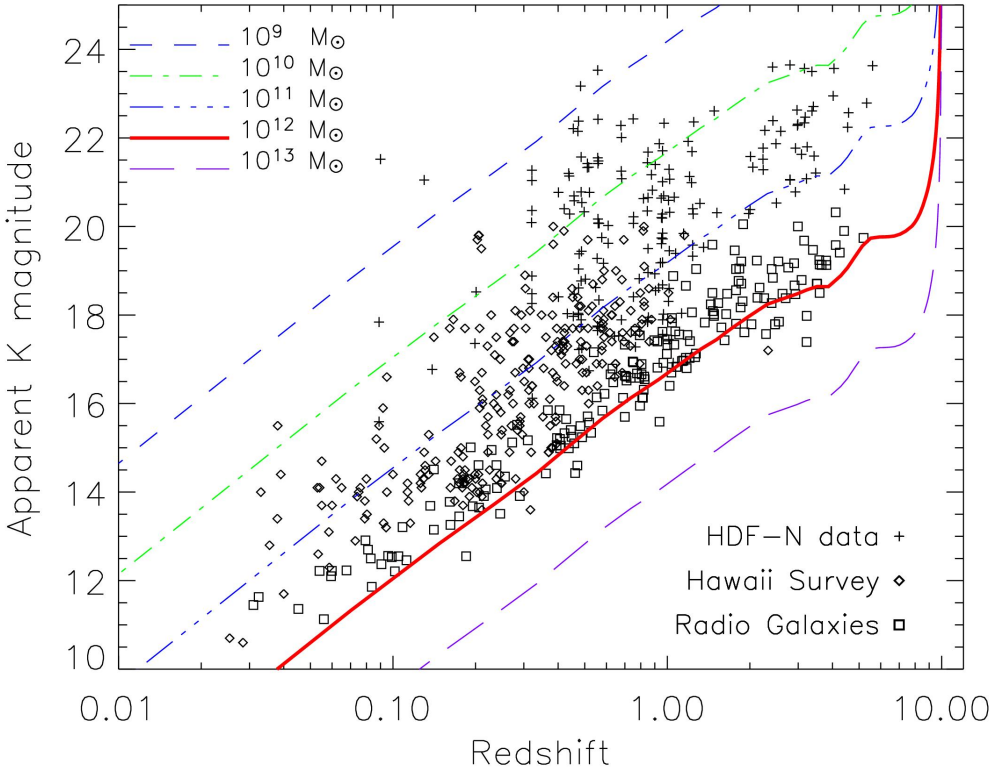


- 84-115 GHz covered in 5 tunings.
- Small 1.7<z<2 redshift desert.
- Multiple lines for z>3.
- No prior identification needed.
- Only 20min with ALMA!

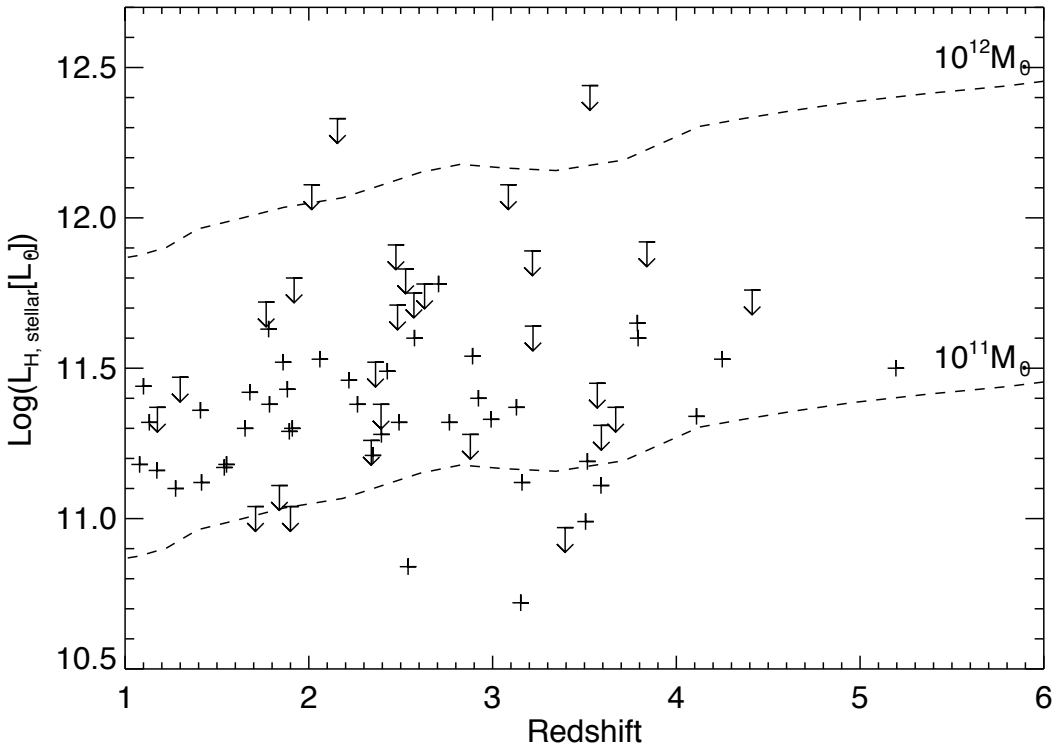
Weiß + 2012, to be submitted

Stellar masses of radio galaxies

Rocca-Volmerange + 2004



Seymour + 2007, De Breuck + 2010

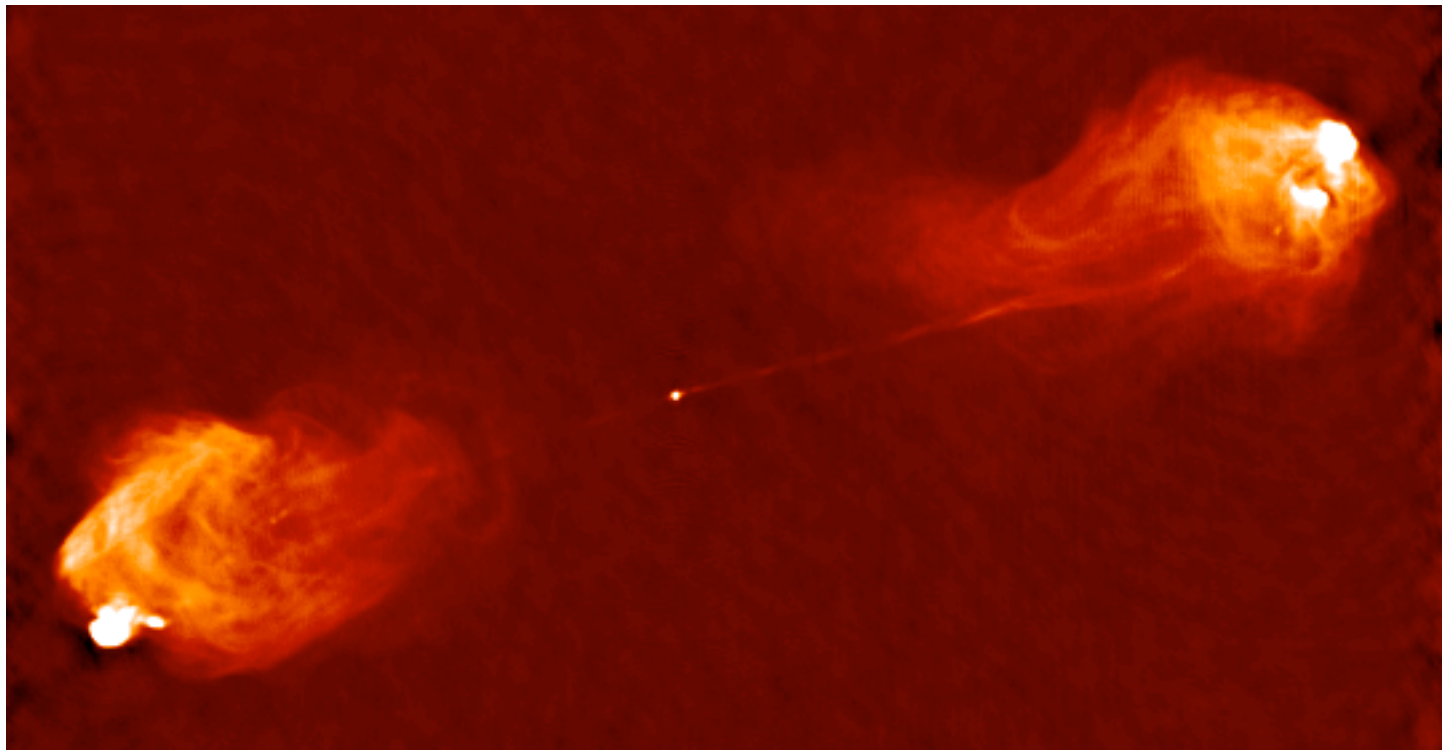


- Observed K-z relation suggests high stellar masses.
- Confirmed by Spitzer observations, sampling the peak of the stellar population when AGN contributions are lowest.
- Majority of RGs have masses ~3×10^{11} M_{sun}.
- Still ongoing star formation revealed by bright submm emission.

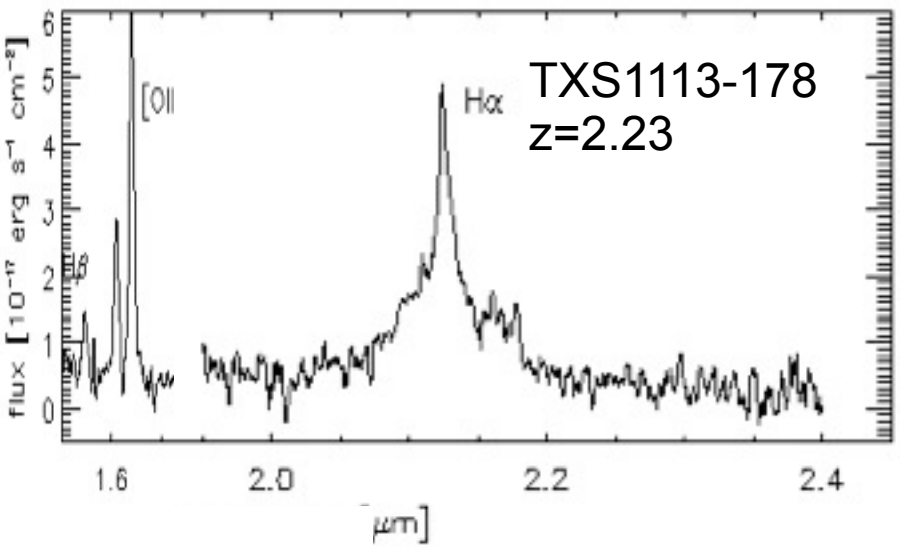
Why radio galaxies are ideal laboratories to study AGN feedback

They have already accumulated most of their stellar mass, but are still forming stars at z>3.

Needs a strong feedback process to stop them growing for good: powerful radio source?



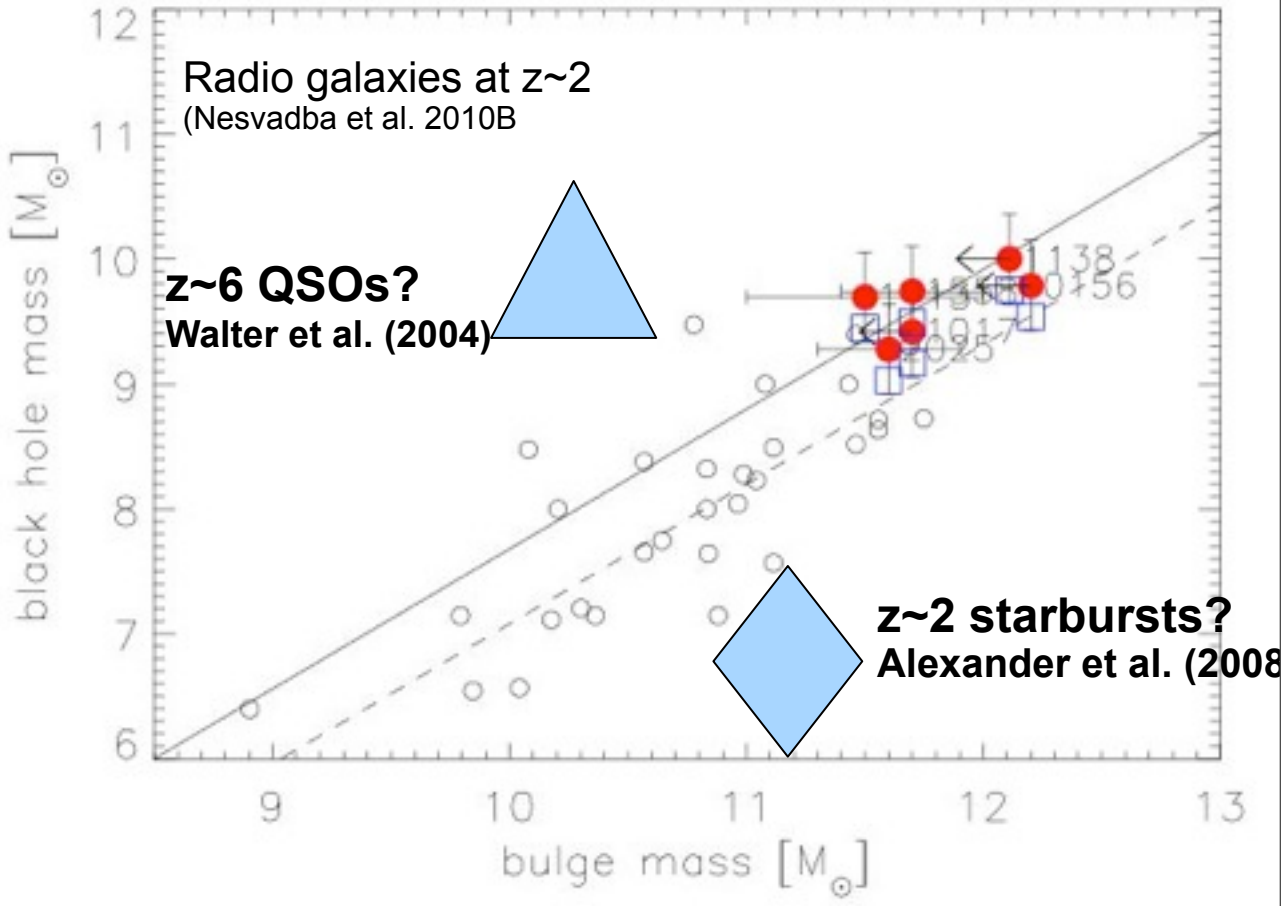
Black hole masses & Eddington ratios



- BLR are usually completely obscured in type II AGN.
- 20% of z>2 RGs show nuclear broad-line regions in SINFONI data.

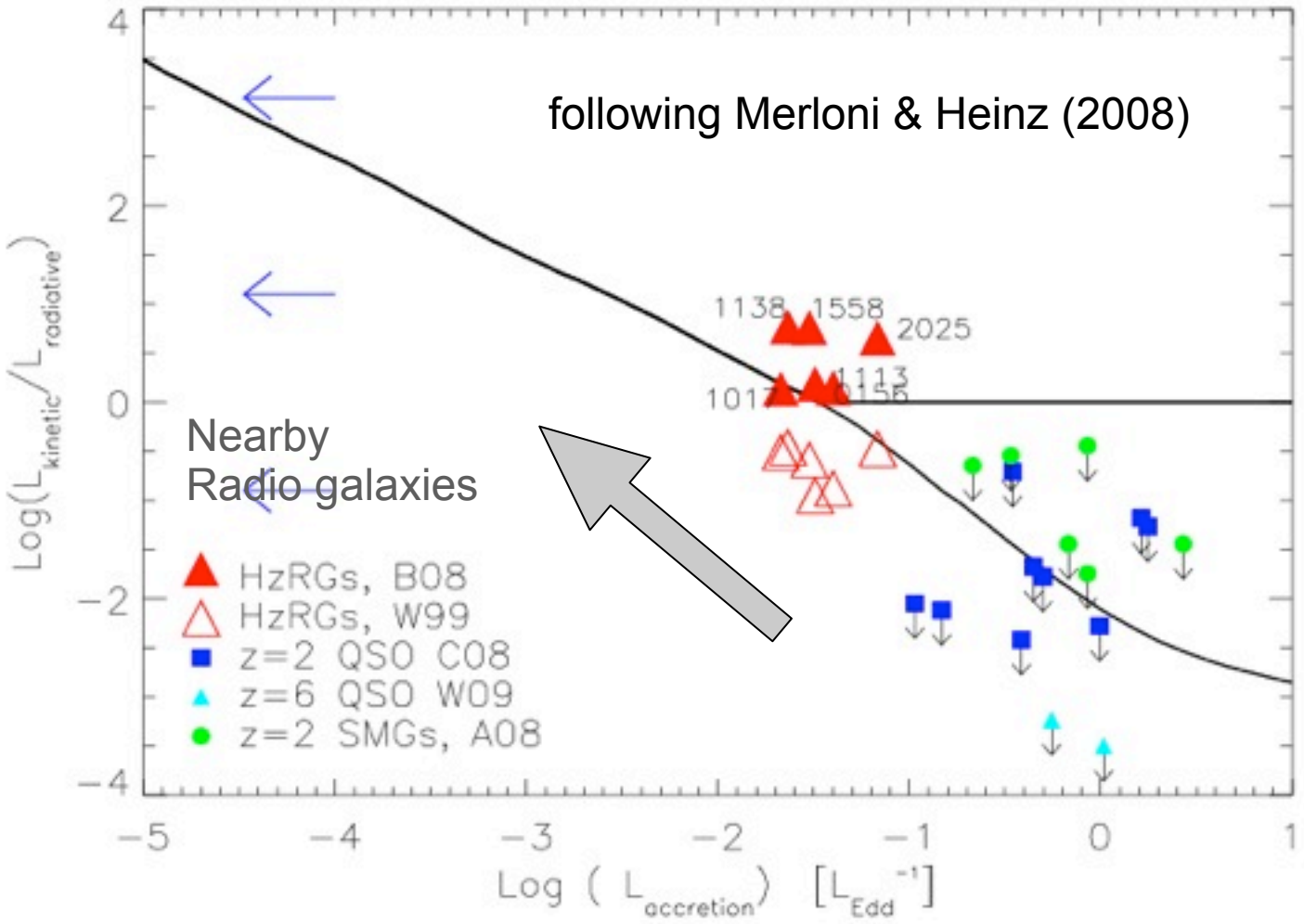
- M_{BH} a few 10^9 M_{Sun} (higher inclination may half M_{BH})
- Appears slightly offset from local M_{bulge} - M_{BH} relation.
- Bolometric luminosity at few % Eddington, lower than other populations with similar M_{BH}

→ nearing end of active growth phase?



Transiting objects from "Quasar" to "Radio" mode?

- Calculate L_{kin} using Willott et al 1999 (▲) and Bîrzan et al 2008 (Δ) relations.
- Transition from "Quasar" to "Radio" mode feedback marks the end of the phase of active growth.



Nesvadba + 2010b

“ The Cocoon model ”

Fairly good (basic) understanding of how jets may work

radio jet
mechanical power

inflates

“cocoon”
hot overpres-surized gas, X-ray

accelerates

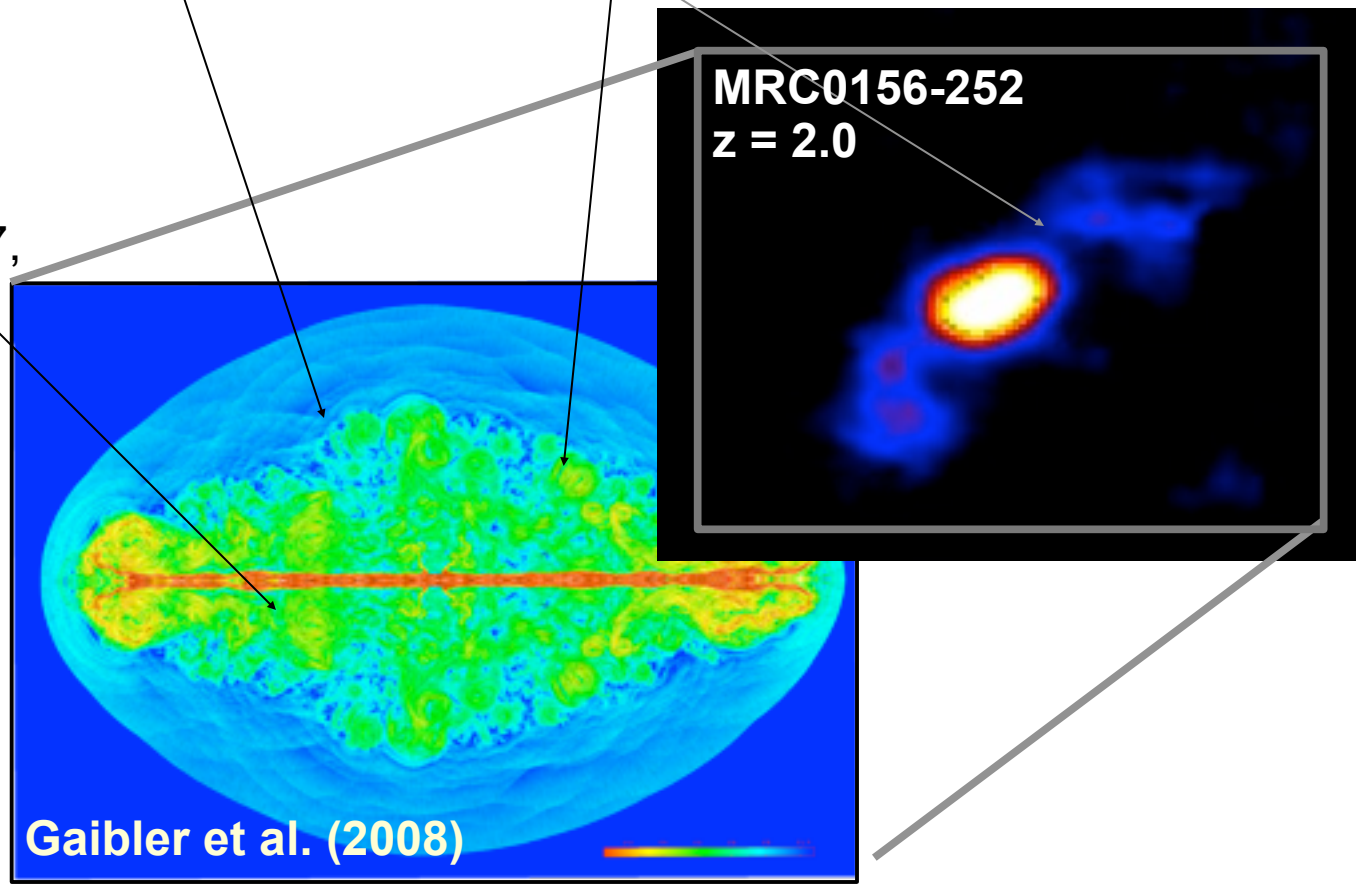
embedded cold/ warm clouds
molecular, atomic, T~10-10^4 K

→ ????

In agreement with hydro models of radio jets
(e.g. Sutherland & Bicknell 2007, Krause 2007)

strongest interactions w/ young radio sources
(e.g., Holt et al. 2008)

dissipation times of gas kinetic energy ~ jet lifetime
(Nesvadba et al. 2010a)



Ionized gas halos with sizes comparable to radio jets

(~50 radio galaxies at z~1.5-3.5 with NIR-IFU data

200

P(500 MHz) [10^{27} W Hz^{-1})

1

~50 kpc

Morphologies of the warm ionized gas ([OIII]5007, Hα, ...)

always: D(gas) < D(radio)

~ SINFONI resolution

0

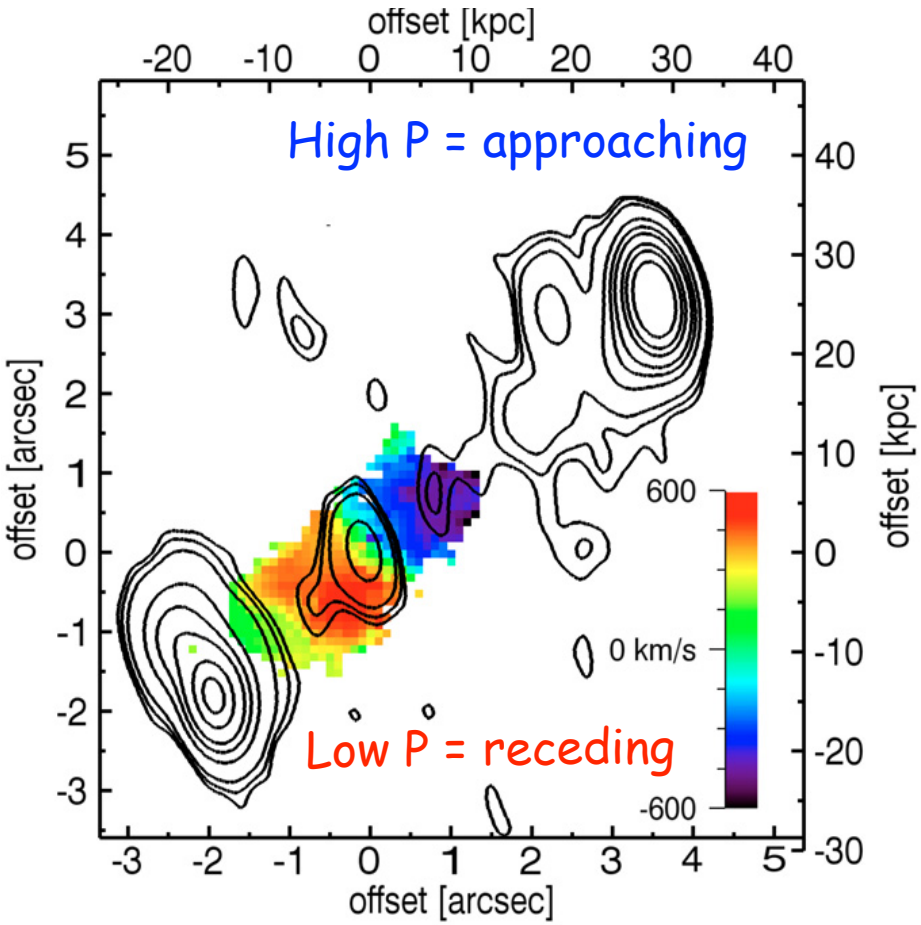
Full jet in SINFONI FOV

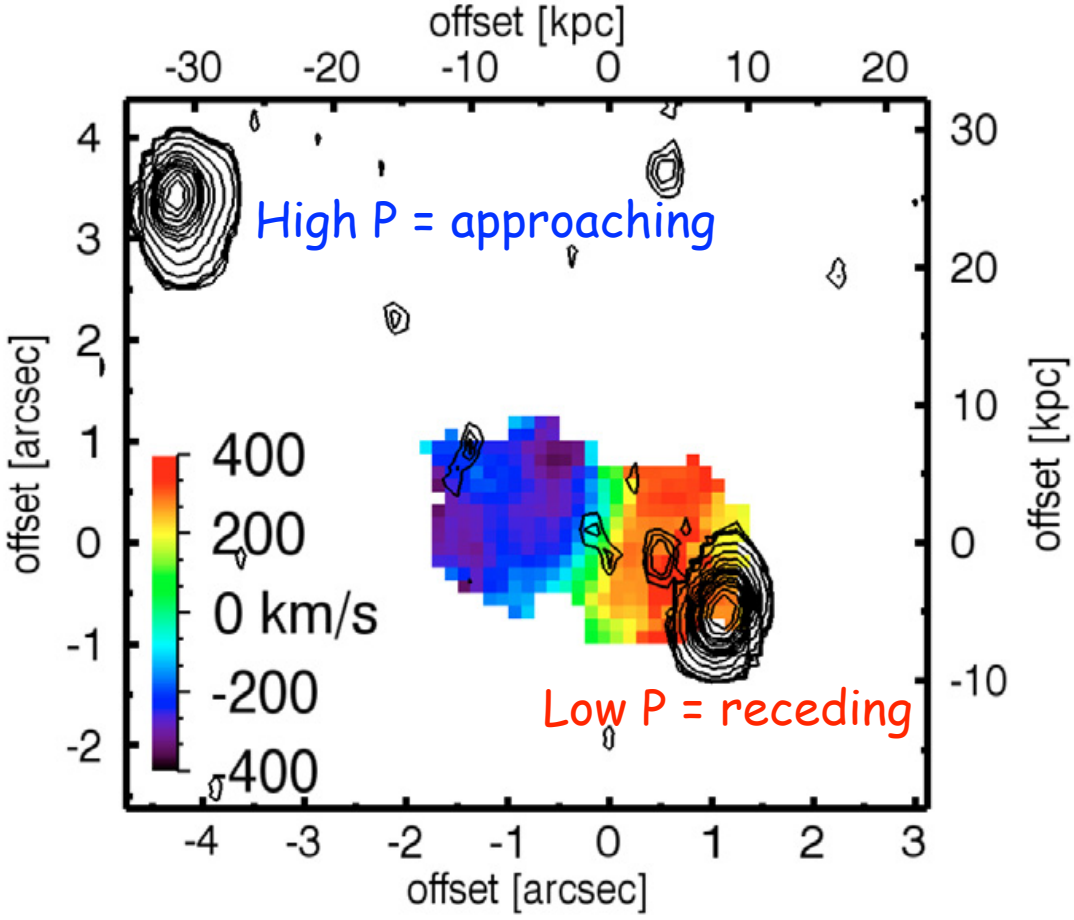
350

Radio size [kpc]

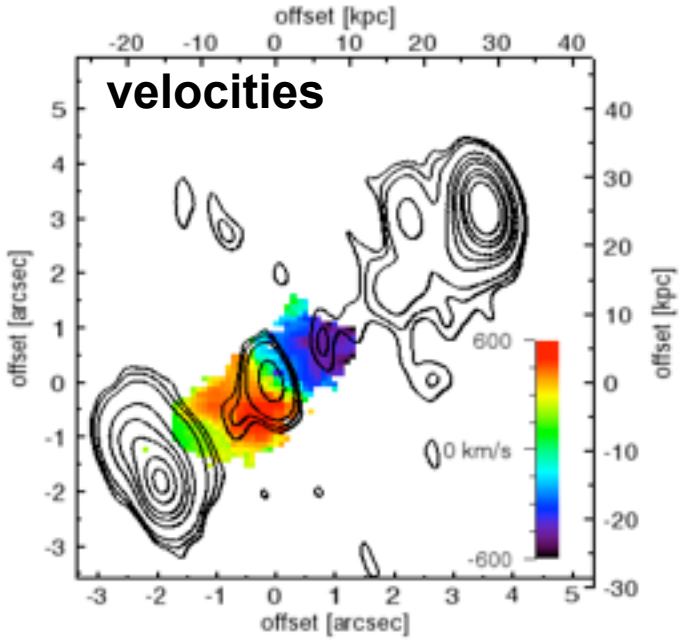
Are these really outflows?

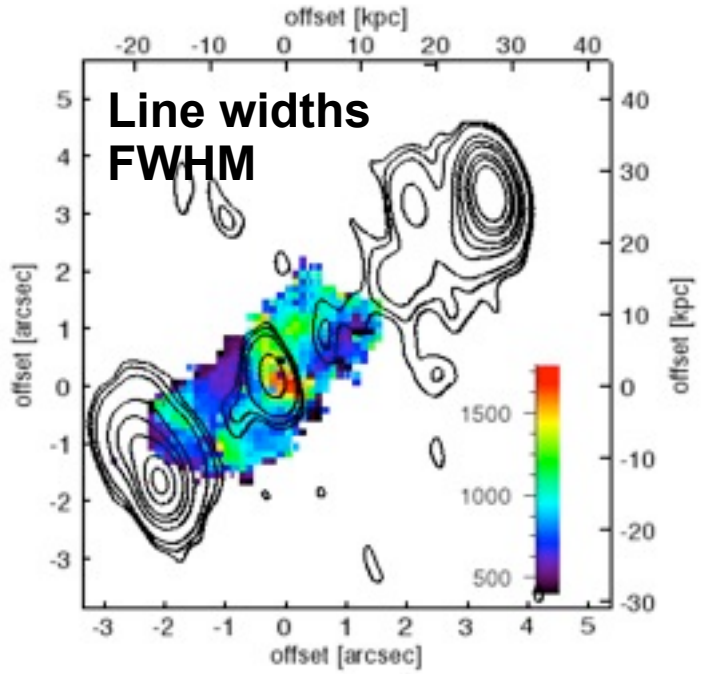
- Laing-Garrington effect: most depolarised radio lobe is receding as it passes through longer line-of sight.
- Consistently indicate bipolar outflows with velocity offsets ~ 1000 km/s and V~1000 km/s (too large for rotation).





Energetics and other constraints





Characteristic: blue / redshifted bubbles

- velocity offset 1000 km s^{-1} (>> rotation)
- Line widths ~ 1000 km s^{-1}

Gas extends along jet axis to R >> R_{stars}

- only extended gas where extended radio sources
- aligned with radio source (with 2 exceptions)

$M_{gas,ion}$ ~ 10^{10} M_{sun} ~ $M_{gas,\ mol}$

- Hα flux, extinction, electron densities measured
- starburst galaxies: M_{mol} / M_{ion} ~ 10^{2-3}

$E_{kin,gas}$ ~ 10^{59-60} erg

- ~ binding energy of a massive host galaxy
- 0.1 - 0.2 % of the rest-mass energy equivalent of the SMBH
- 1-10% of the jet power

$T_{outflow}$ few x 10^7 yrs ~ AGN lifetime

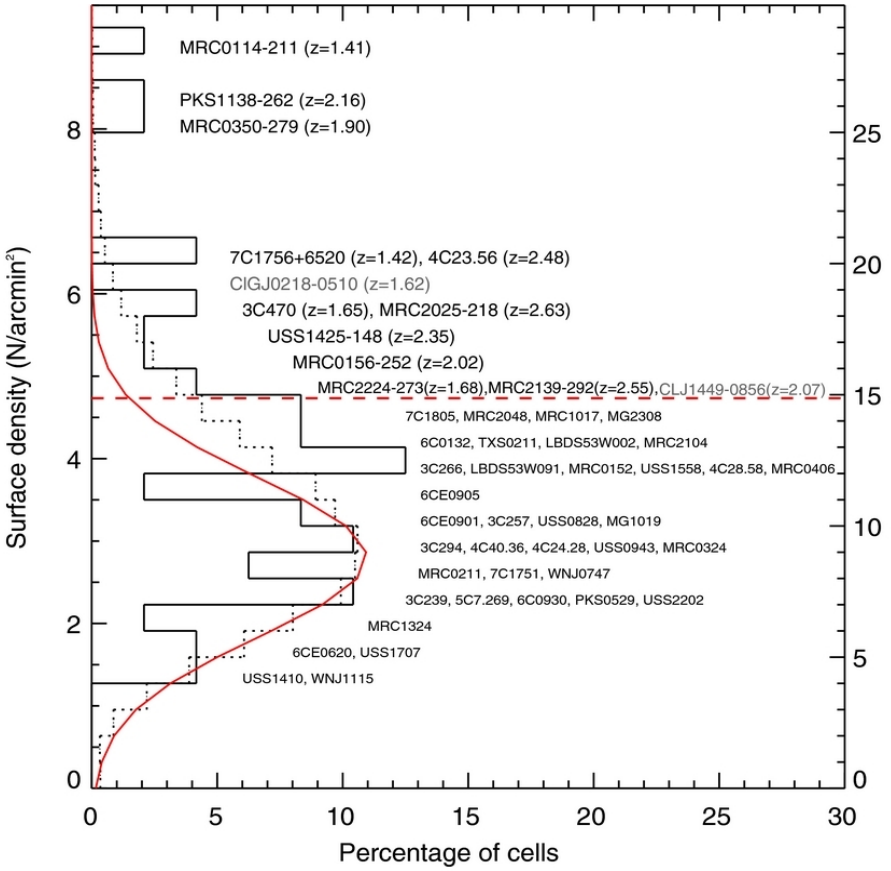
- > characteristic time of a starburst ~ 10^8 yrs

Expected characteristics of AGN-driven winds quenching intense starbursts in massive high-z galaxies

The environments of distant radio galaxies

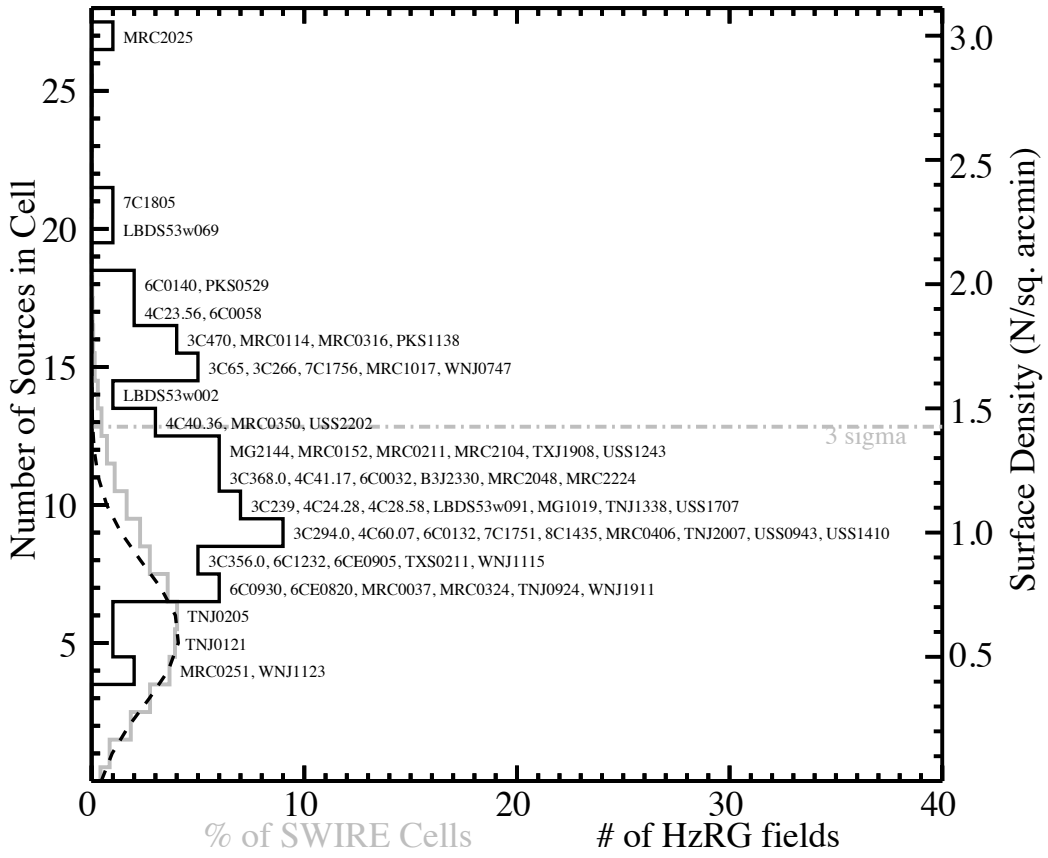
- Fields of radio galaxies statistically overdense in terms of evolved and star-forming galaxies.

old galaxies: [3.6]-[4.5]>-0.1



Galametz + 2012

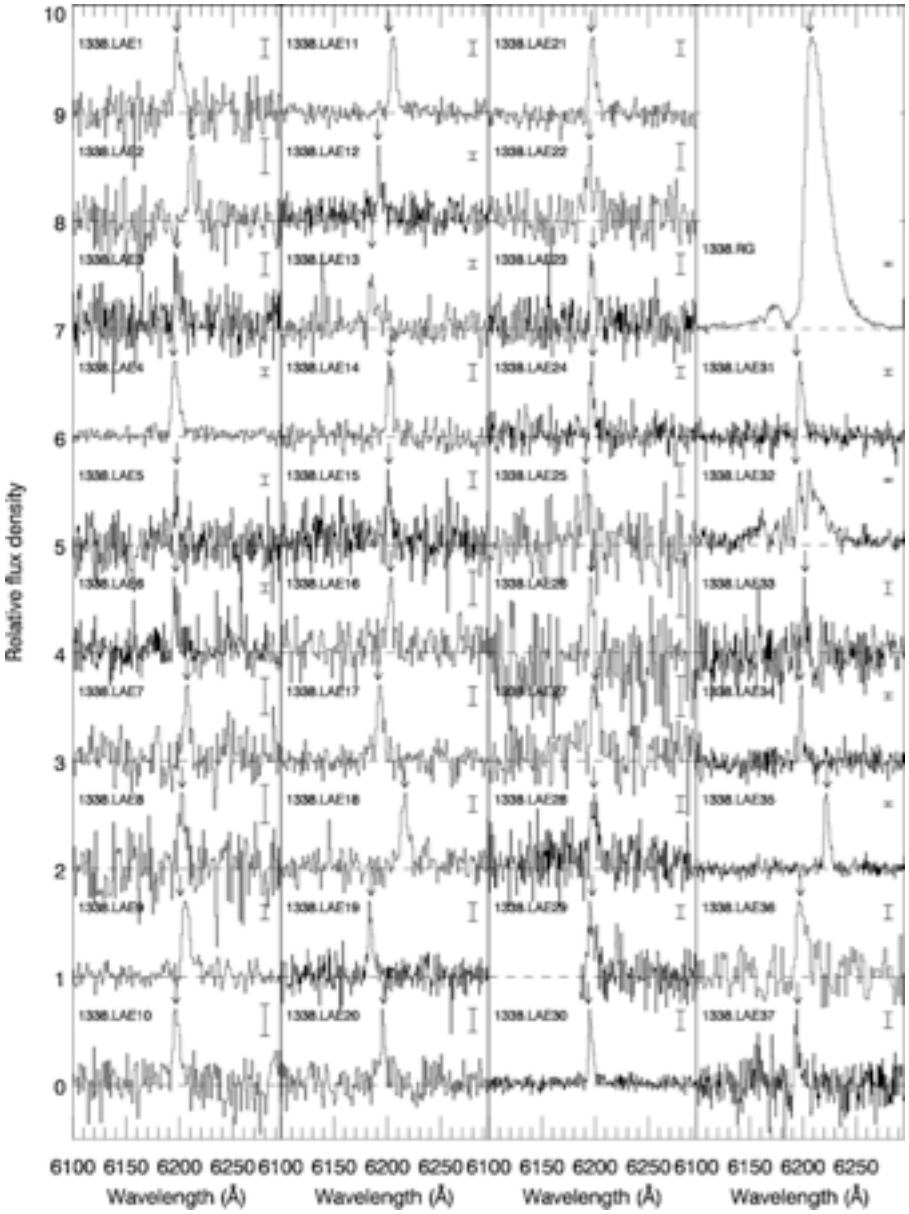
Star-forming galaxies at 24μm

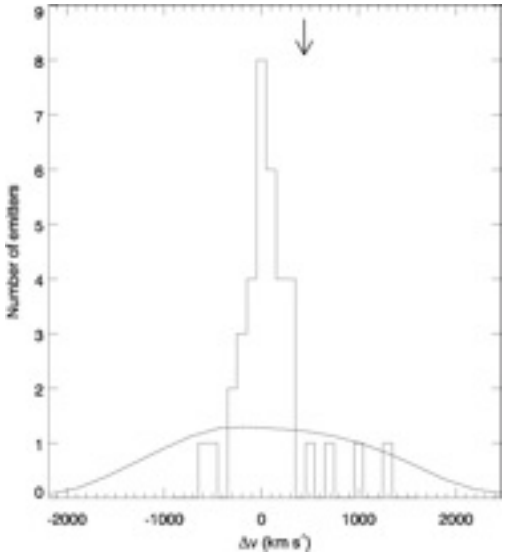


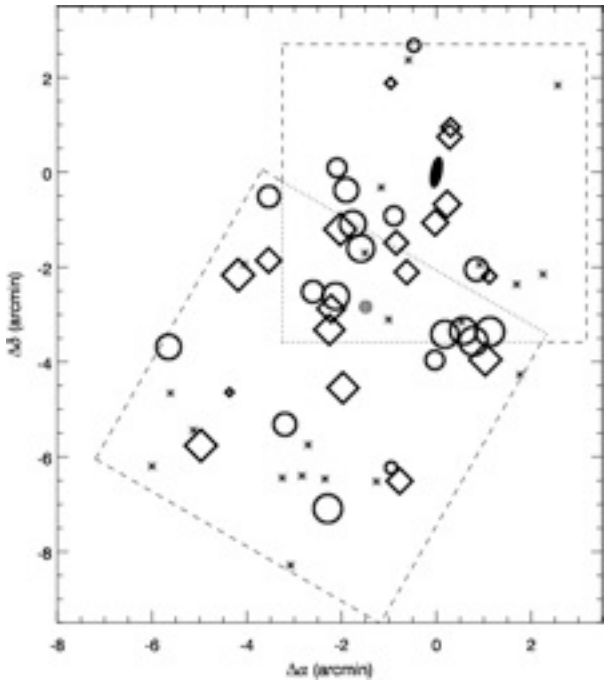
Mayo + 2012

Ly-alpha emitters around distant RGs

- VLT large programme in 2001-2003 found that 6 out of 8 fields at 2<z<5.2 are statistically overdense.



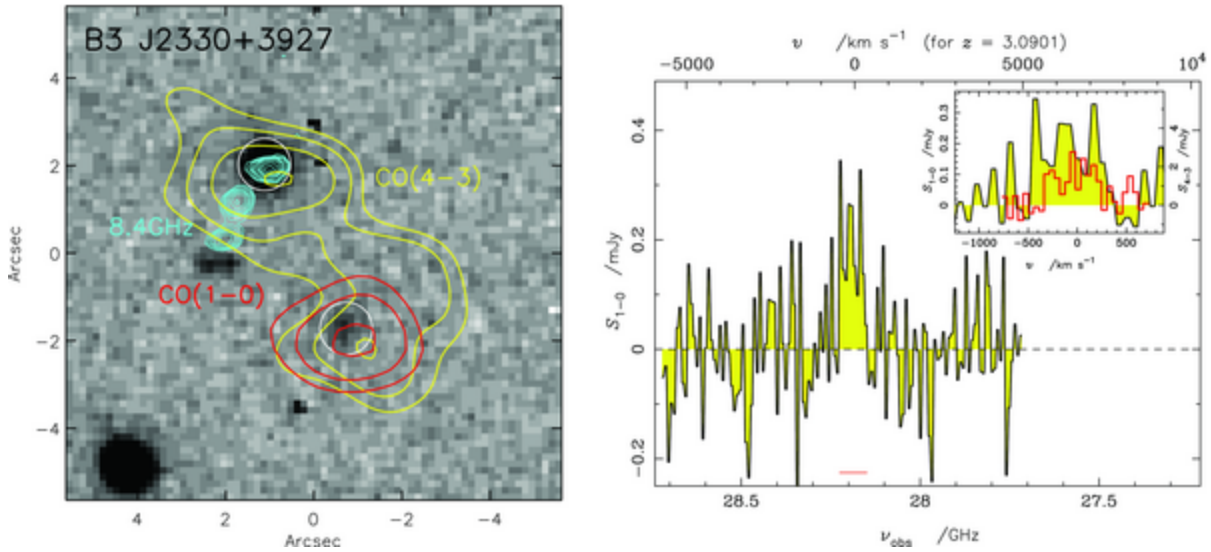




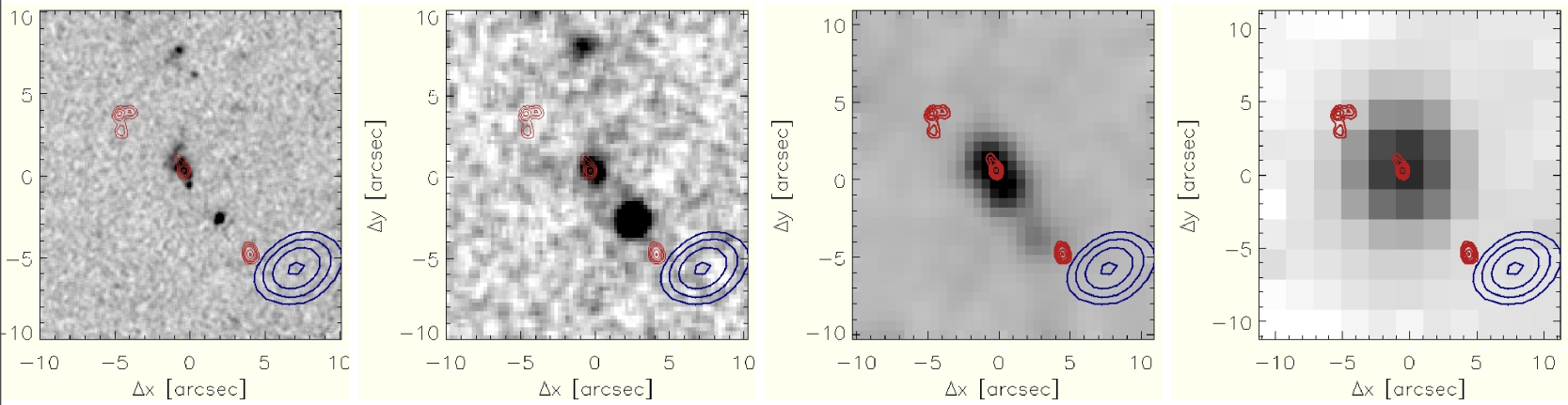
Venemans+ 2007

Dust obscured companion galaxies

- Dusty companions 10-50 kpc from the AGN are commonplace.
- Can be completely obscured in the optical.
- ALMA will be able to identify & spatially resolve these.



Ivison + 2012



Nesvadba + 2009

Summary

- AGN have been pointers to high redshift galaxies for as long as ESO has been around.
- AGN host galaxies are found at the top end of the mass scale.
- The role of the AGN in Galaxy formation is now recognised.
- Feedback from powerful radio jets may end the formation epoch.

ESO past and future role

- NTT and VLT played a major role in finding and studying AGN.
- 3D studies of AGN and their environments are essential to study feedback. KMOS and MUSE will provide the first wide-field view.
- Many AGN hosts and their companions are dust obscured. Redshift determinations will require ALMA 3mm band scans.
- The combination of ALMA + VLT is unique to obtain a complete view of AGN and the interaction with their environments to study the role of merger events.