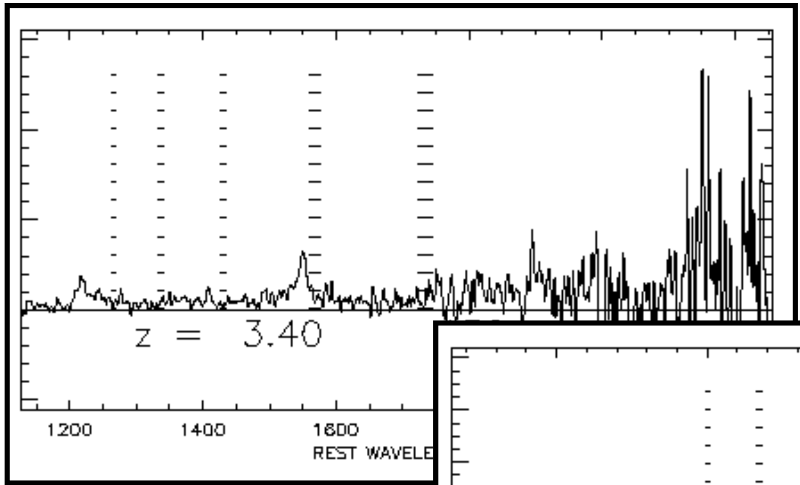
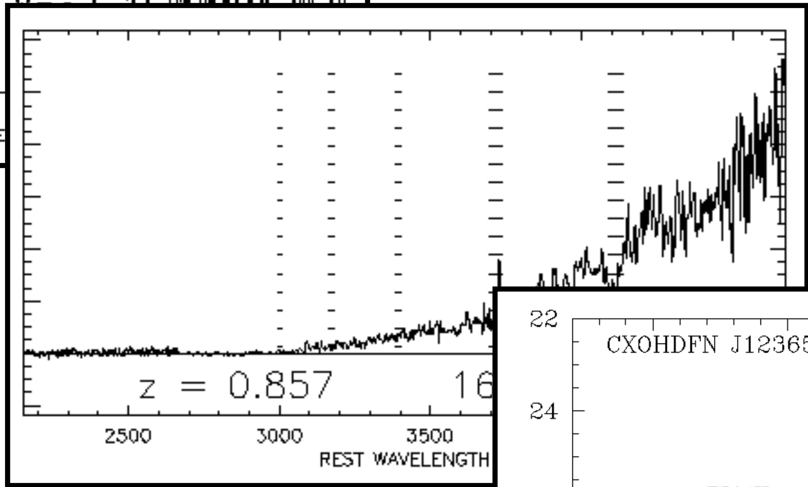
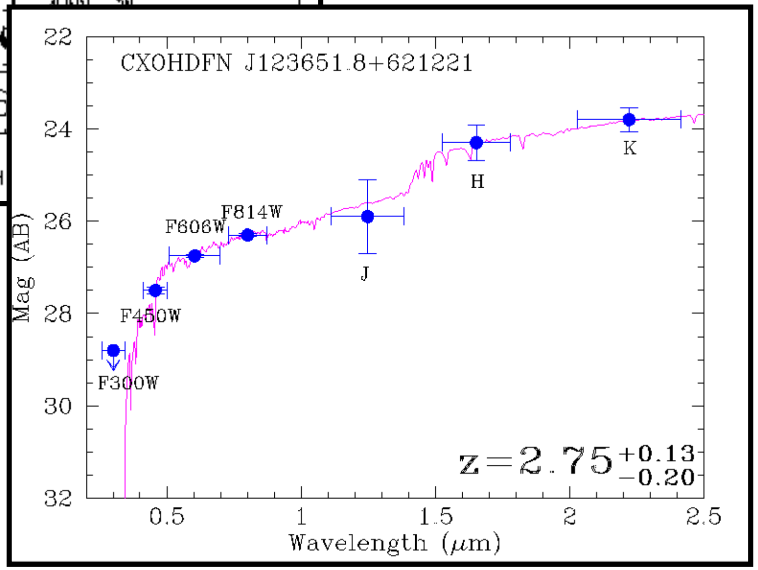
AGN in the Distant Galaxy Population

David M Alexander (Durham)

Poorer quality spectra and statistics than local studies

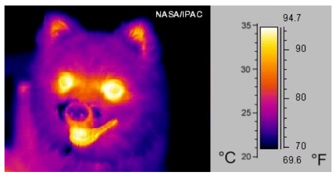






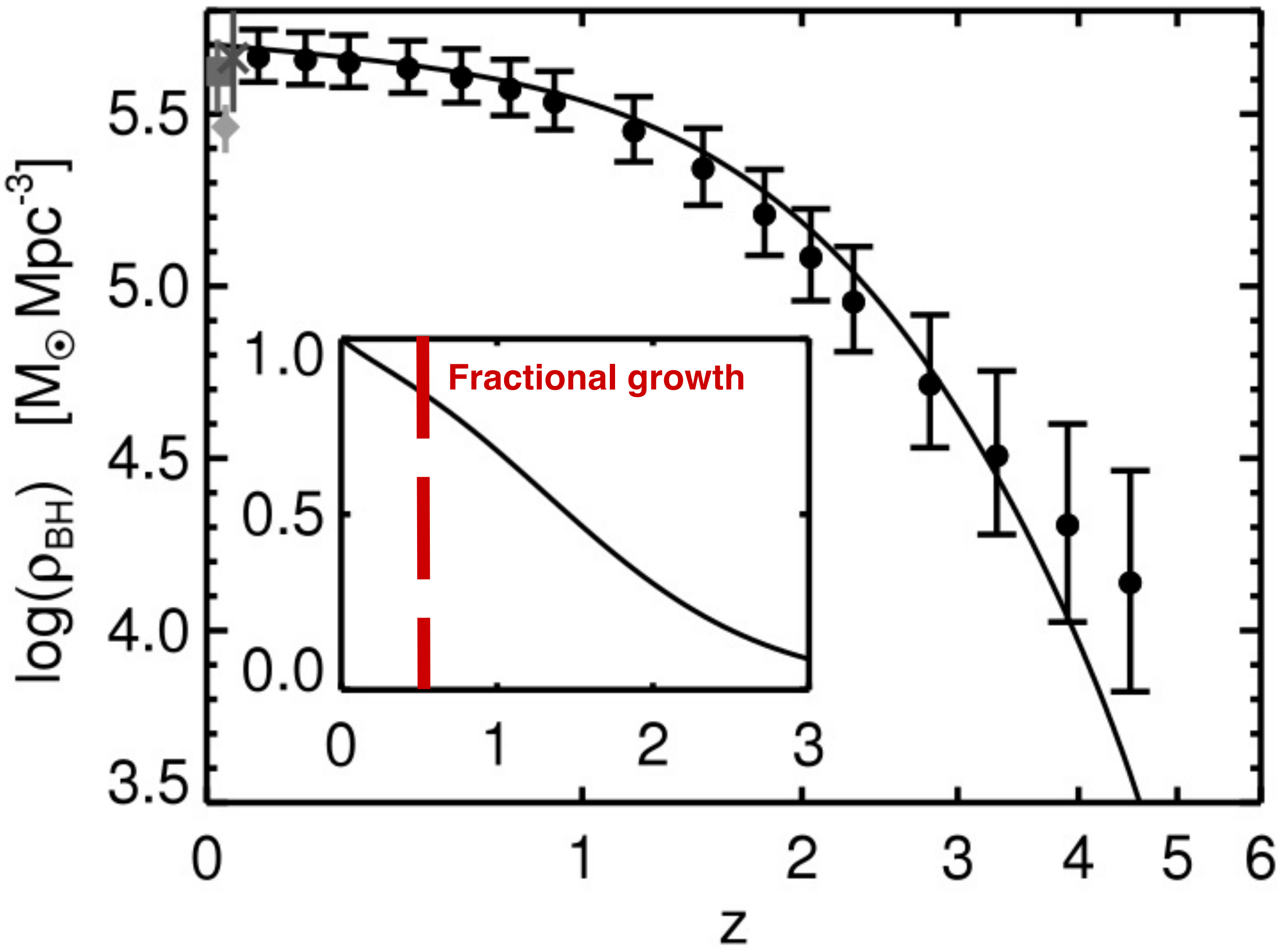
X-rays

Infrared



Majority of the growth of black holes: z~0.5-3

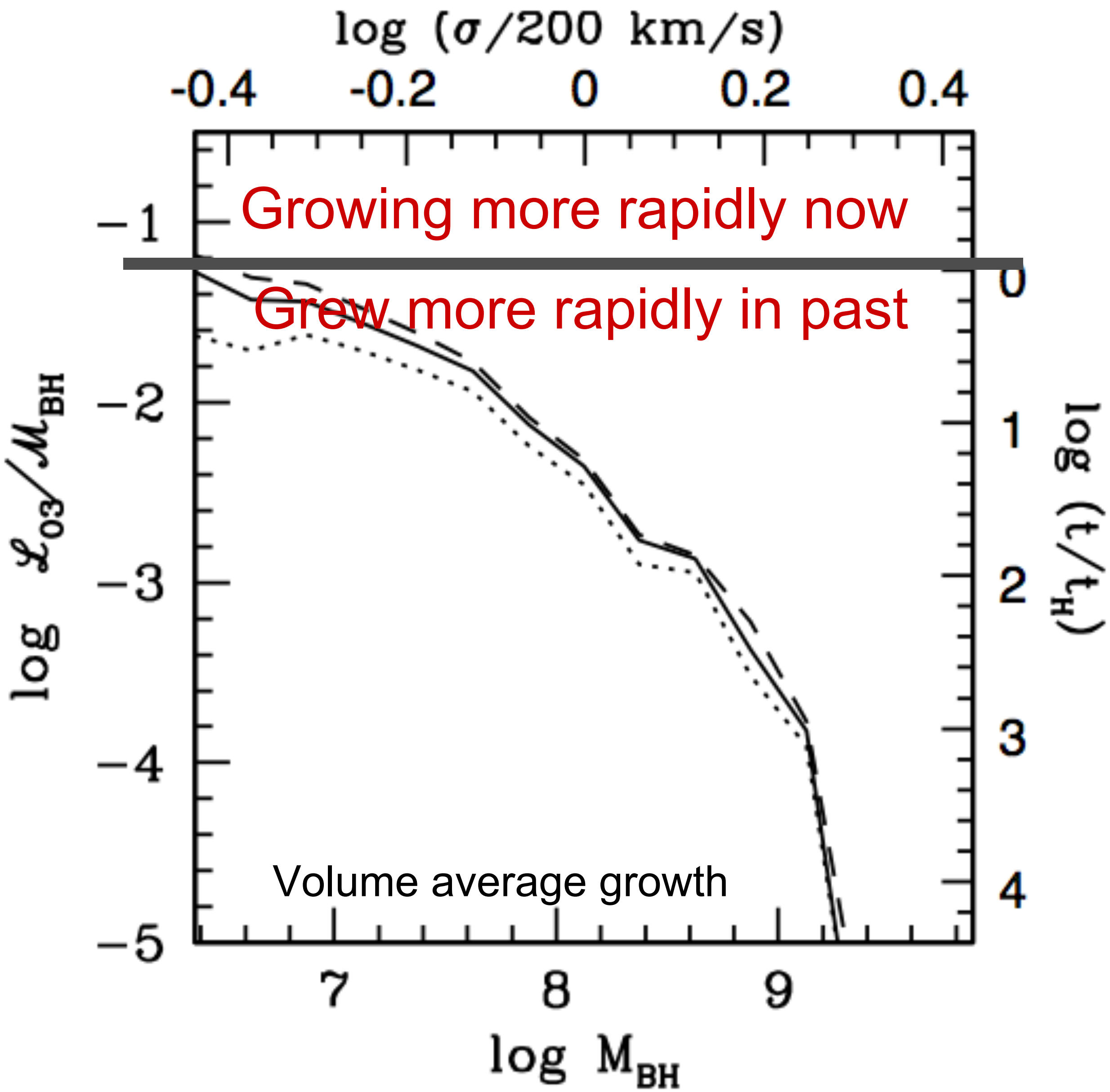
Build up of the black-hole mass density



Hopkins et al. (2007)

See also, for example, Barger et al. (2001, 2005); Ueda et al. (2003); Hasinger et al. (2005); Silverman et al. (2005, 2008); Aird et al. (2008, 2010)

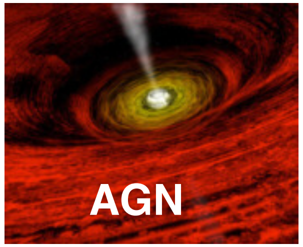
Rapid growth epoch of massive black holes



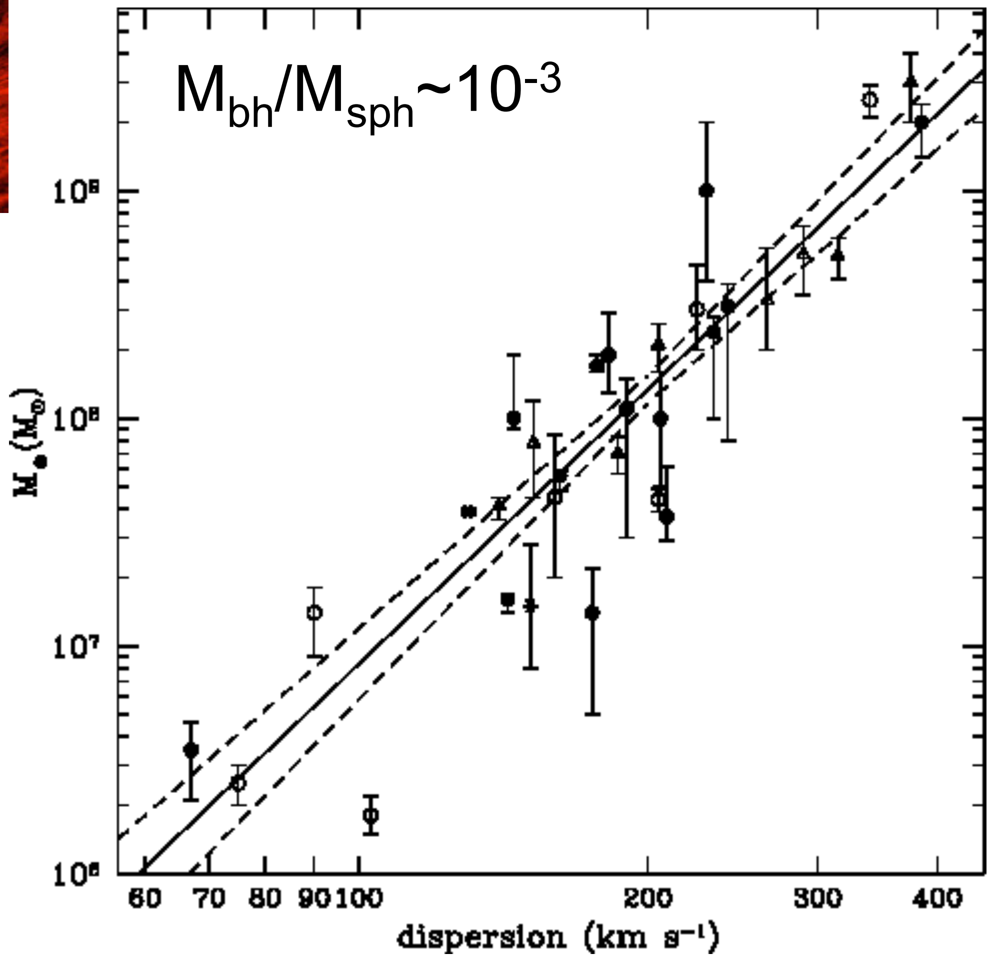
Heckman et al. (2004)

See Goulding et al. (2010) amongst others for lower black-hole mass constraints

Connection to the growth of massive spheroids



Driver: AGN activity



Driver: Star formation (gas accretion/mergers)

Tremaine et al. (2002)

See also, for example, Magorrian et al. (1998); Ferrarese & Merritt (2000); Gebhardt et al. (2000); Marconi & Hunt (2003); Haring & Rix (2004); Gultekin et al. (2009)

Key Questions

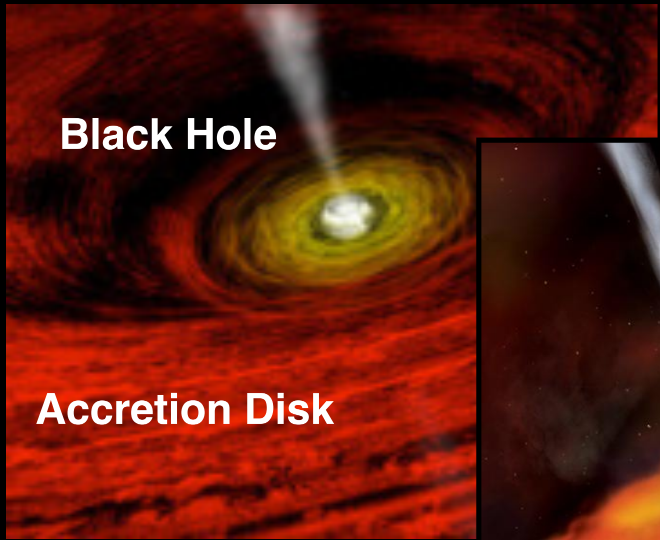
When and where did today's massive black holes grow?

How was the black-hole growth initiated?

What is the connection between AGN activity and star formation?

Have we found all of the sites of black-hole growth?

Finding the AGN: a multi-scale, multi-component, multi-wavelength challenge



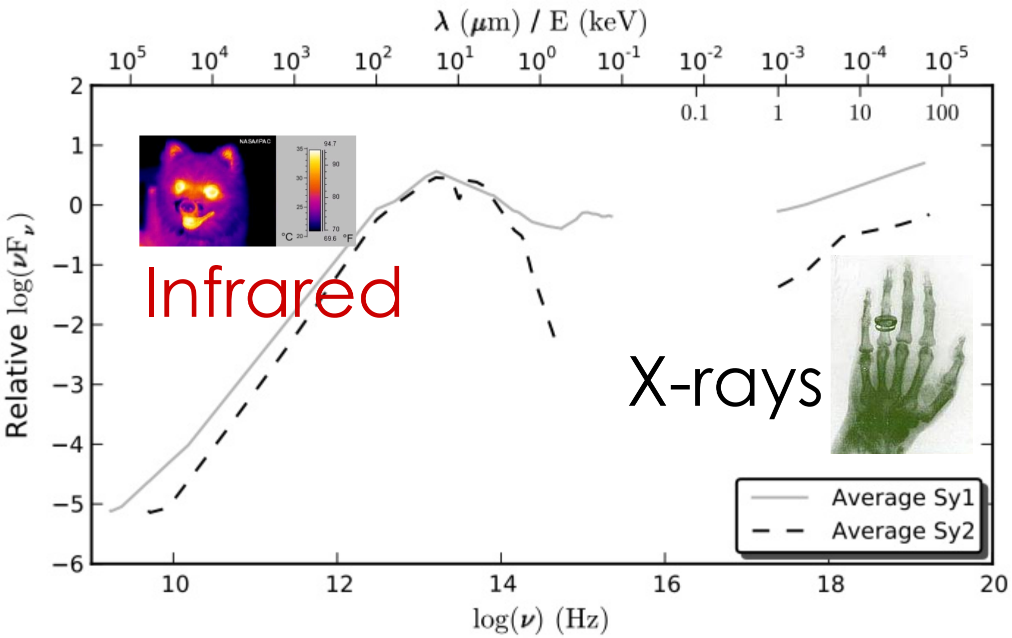
Problem: accretion disk is spatially unresolved

Problem: obscuration changes the observed AGN signatures

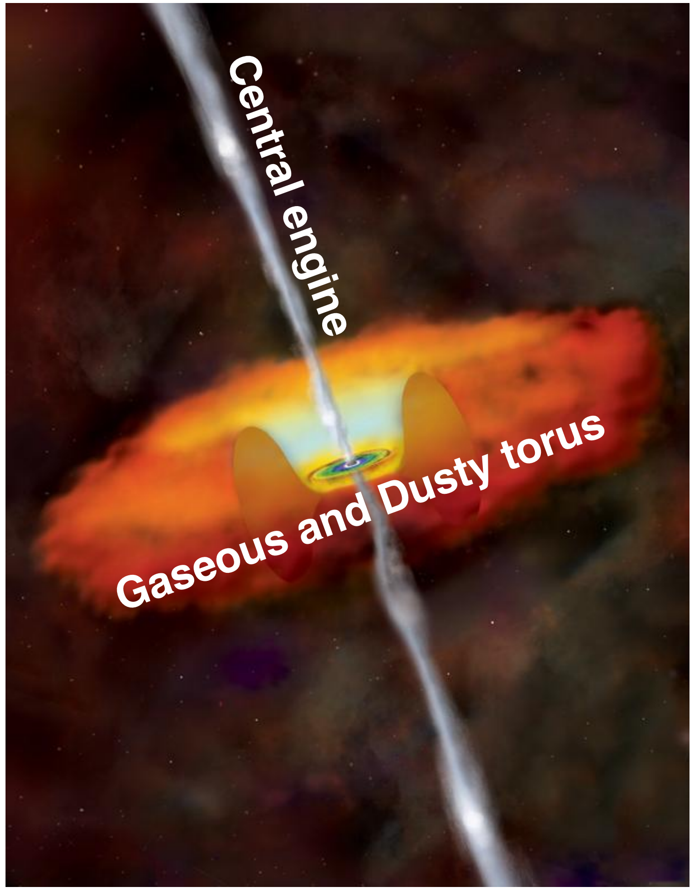
Problem: host galaxy can dilute/extinguish AGN signatures

Huge difference in size scale (from galaxy to black hole)

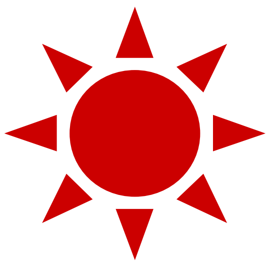
Method of AGN selection is important

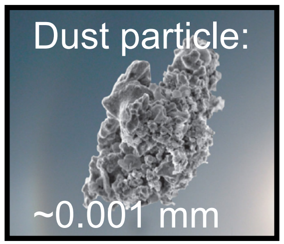


- Similar average SEDs - infrared due to dust emission; optical-X-ray differences due to absorption by dust and gas
- Host galaxy also produces strong infrared emission (star formation; Elbaz talk) but weak X-rays



Primary source (X-ray-optical)





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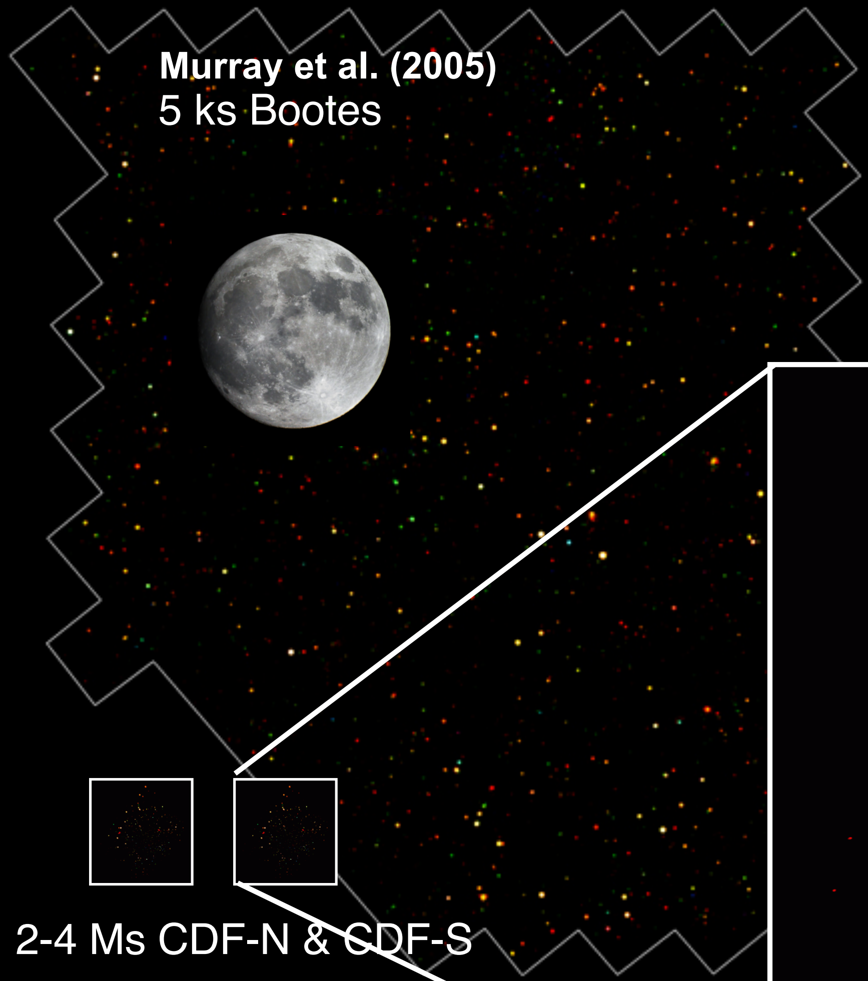
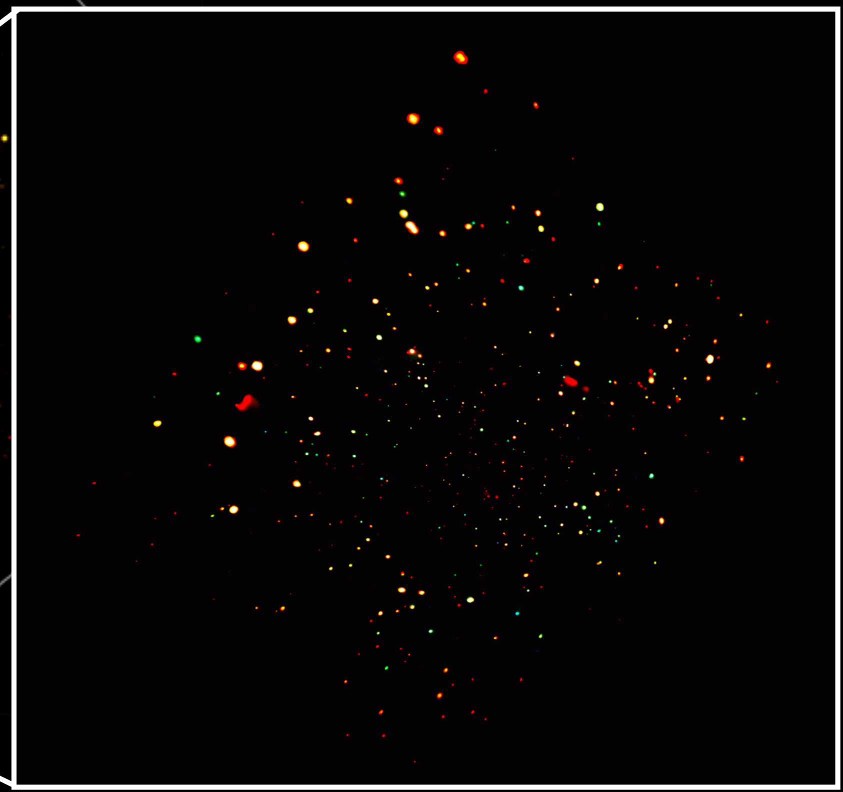
Reprocessed emission (infrared/submm)

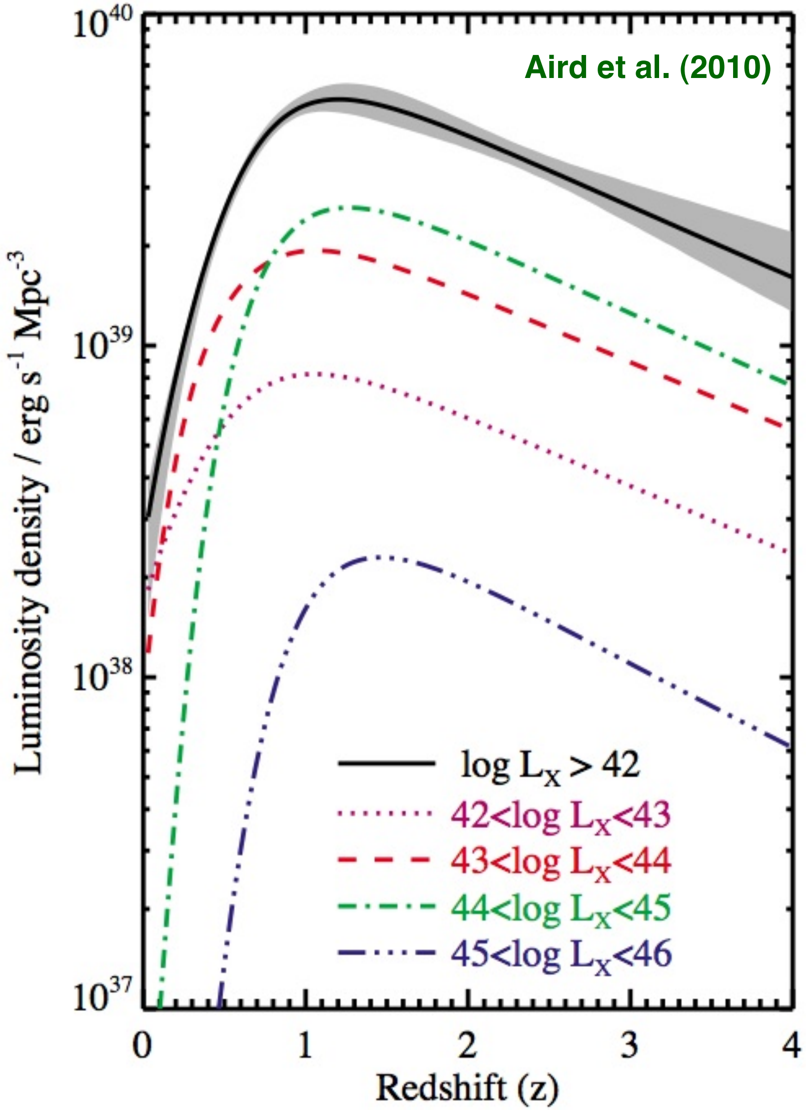
X-ray Surveys: Penetrating Probe of AGN activity



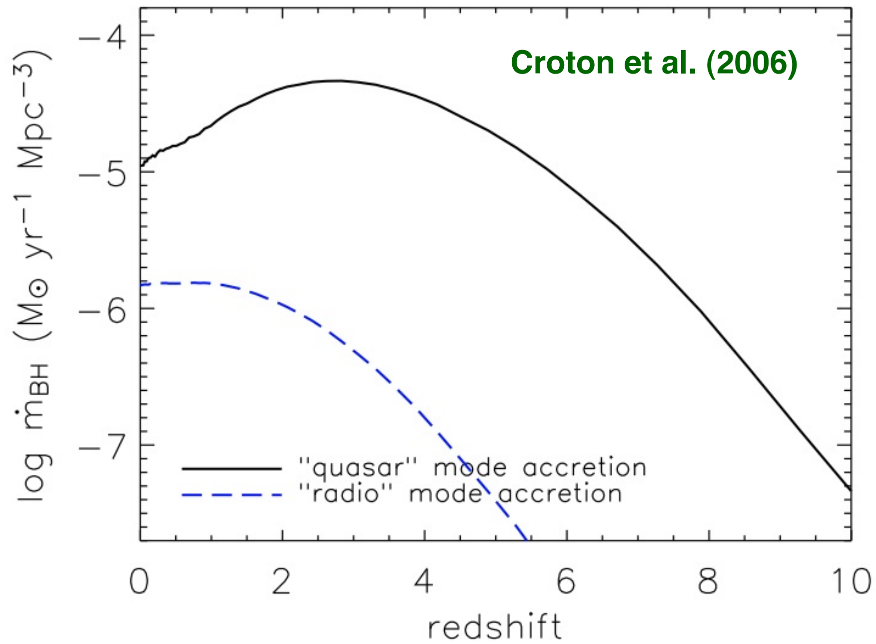


Observational constraints on the growth of distant black holes

Accretion density of black holes



- Moderate to high luminosity AGNs (L_X~10^{43}-10^{45} erg/s) dominate (~80%) black-hole growth
- Most luminous AGNs peaked at high-z, contrary to lower-luminosity AGNs

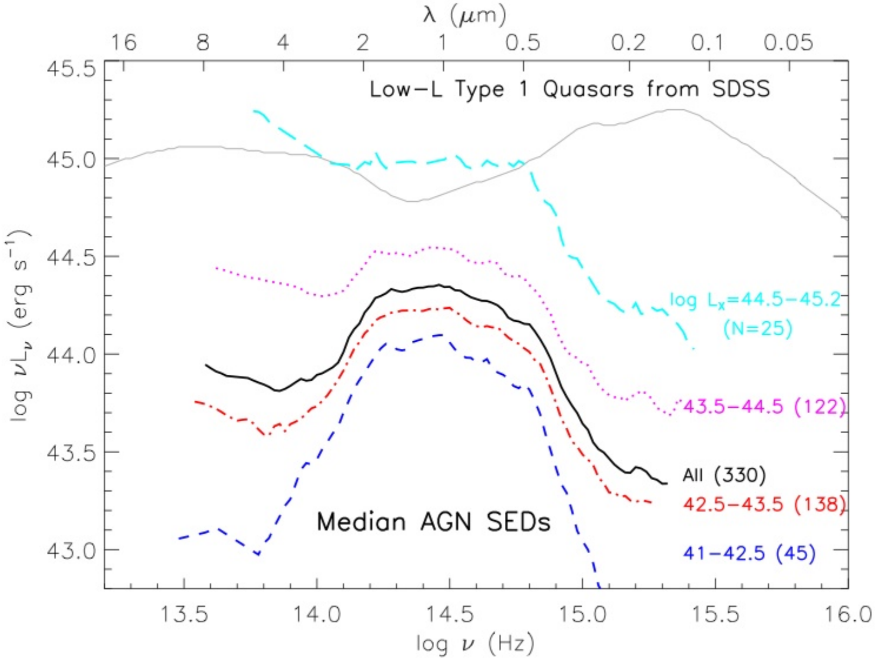


Radio-quiet AGN dominate the black-hole growth at all redshifts

HIGHER-Z TALKS: Mortlock; Schawinski

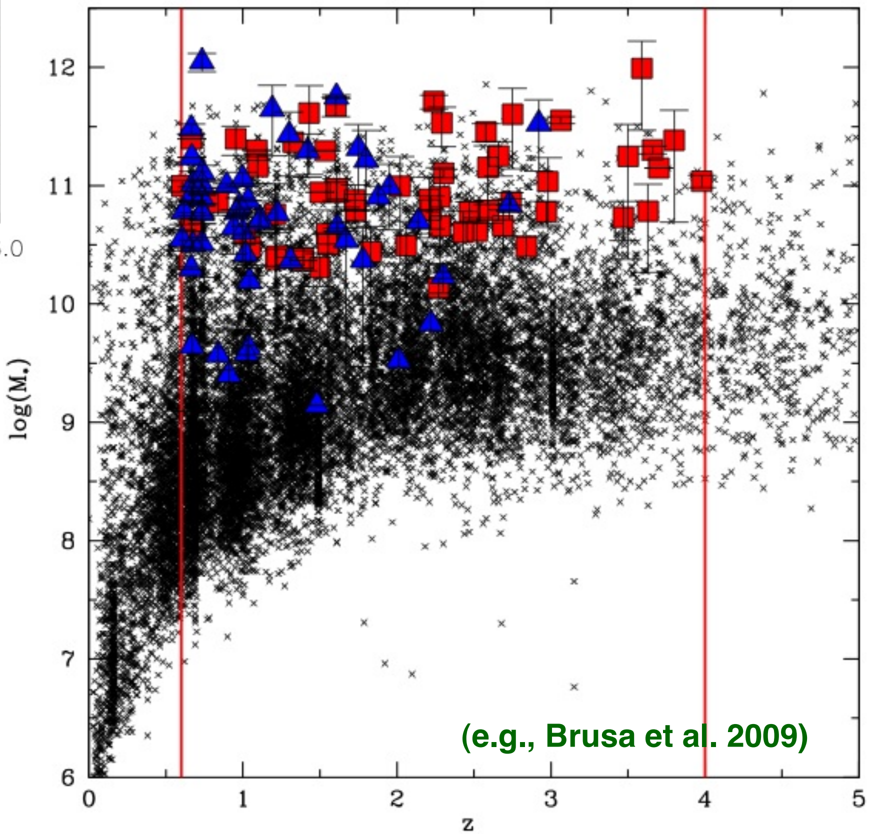
See also, for example, Barger et al. (2001, 2005); Ueda et al. (2003); Hasinger et al. (2005); Silverman et al. (2005, 2008); Hopkins et al. (2007); Aird et al. (2008)

What about the host galaxies?



(e.g., Luo et al. 2010)

Optical-near-IR emission typically dominated by the host galaxy - AGN becomes more prominent at higher X-ray luminosities

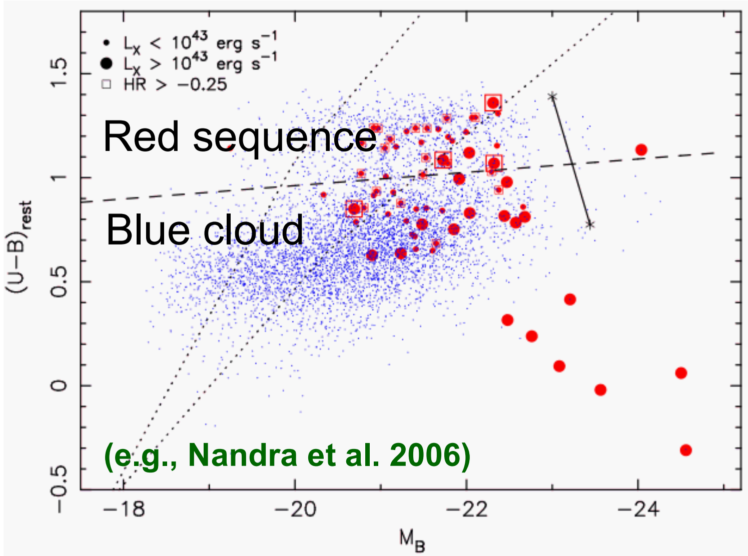


(e.g., Brusa et al. 2009)

Host galaxies are typically luminous (~L*) and massive (>3x10^{10} solar masses)

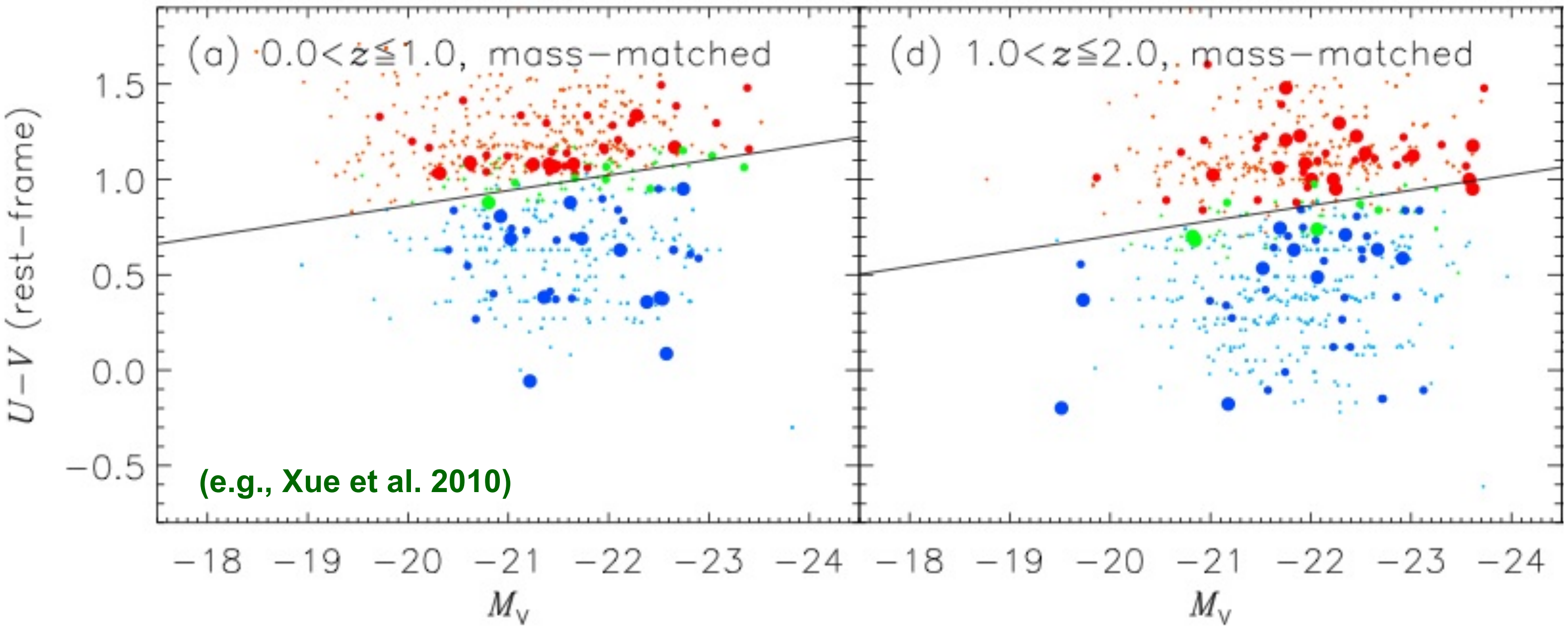
AGNs in low-mass black holes can be particularly challenging to identify: low X-ray luminosities, difficult to distinguish from starbursts (e.g., Shi et al. 2008)

Colour-magnitude relation consistent with that of massive galaxies



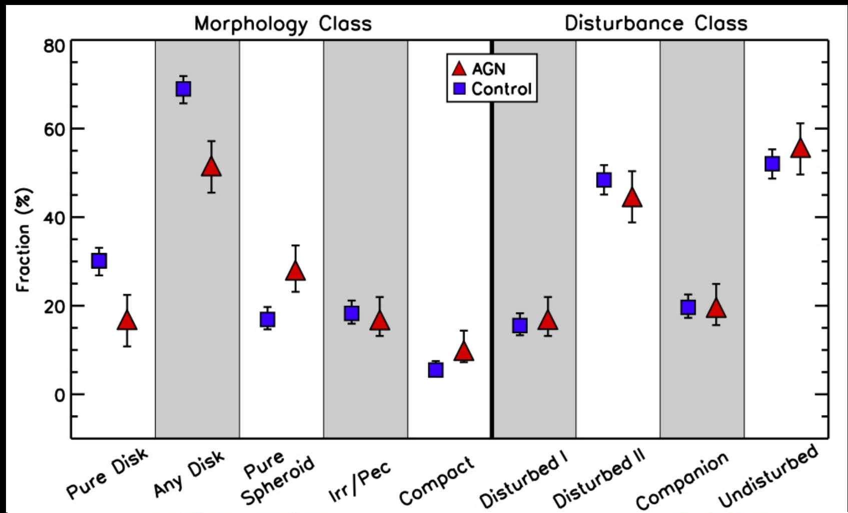
Original suggestion that AGNs lie in special region in the "green valley" have shown to be due to a mismatched selection of non-AGN galaxies

When consider non-AGN galaxies of the same mass there are no significant differences in the location of AGNs and non-AGNs in the colour-magnitude diagram

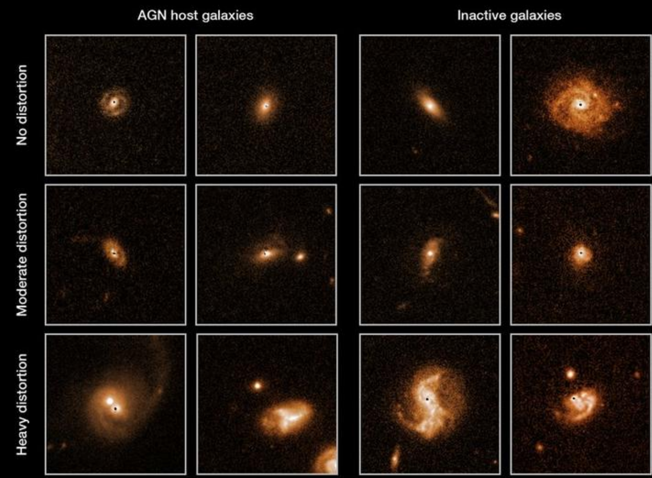


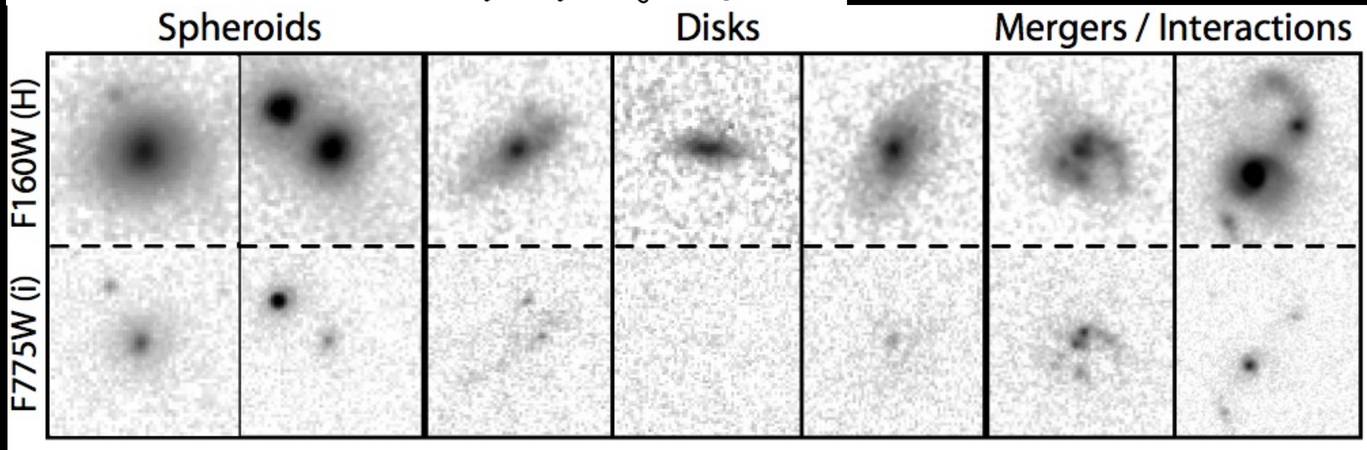
Host-galaxy morphologies?

z~2-3: HST-WFC3 (Kocevski et al. in prep)



z<1: HST-ACS (Cisternas et al. 2010)





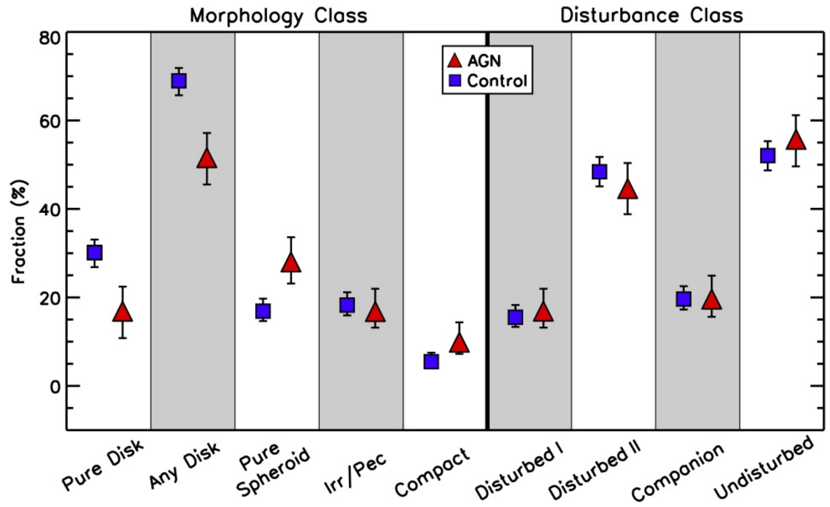
TALKS:
Kocevski
Schawinski

Broad range of morphologies but big differences between massive galaxies with or without AGN activity

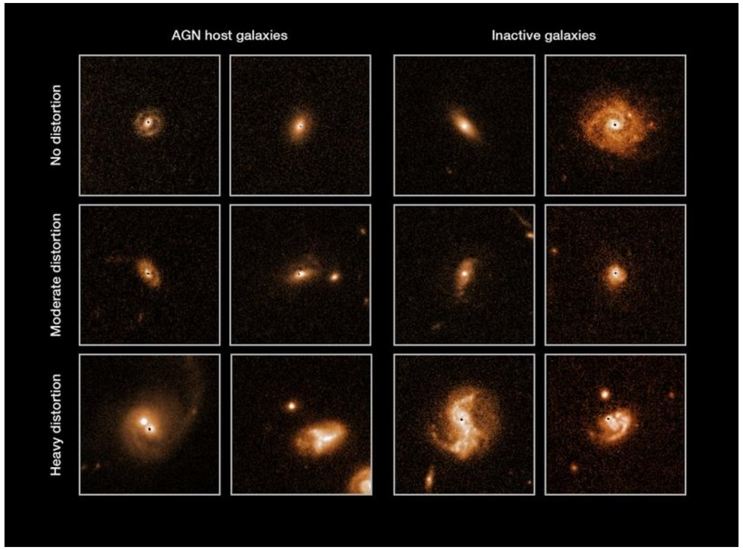
See also, e.g., Grogin et al. (2005), Pierce et al. (2007, 2010), Georgakakis et al. (2009), Cisternas et al. (2010), Schawinksi et al. (2011)

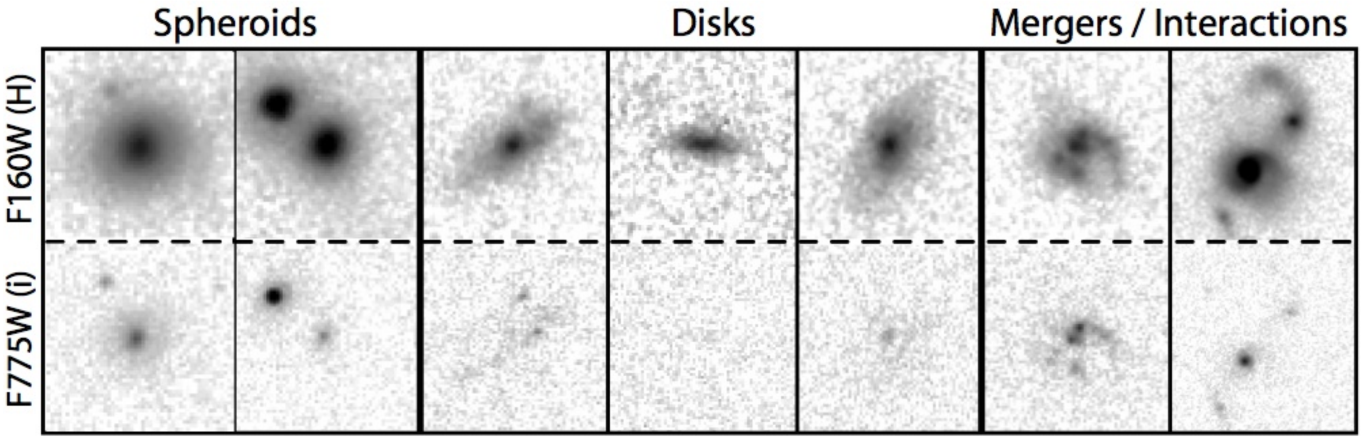
AGN triggering mechanism?

z~2-3: HST-WFC3 (Kocevski et al. in prep)



z<1: HST-ACS (Cisternas et al. 2010)



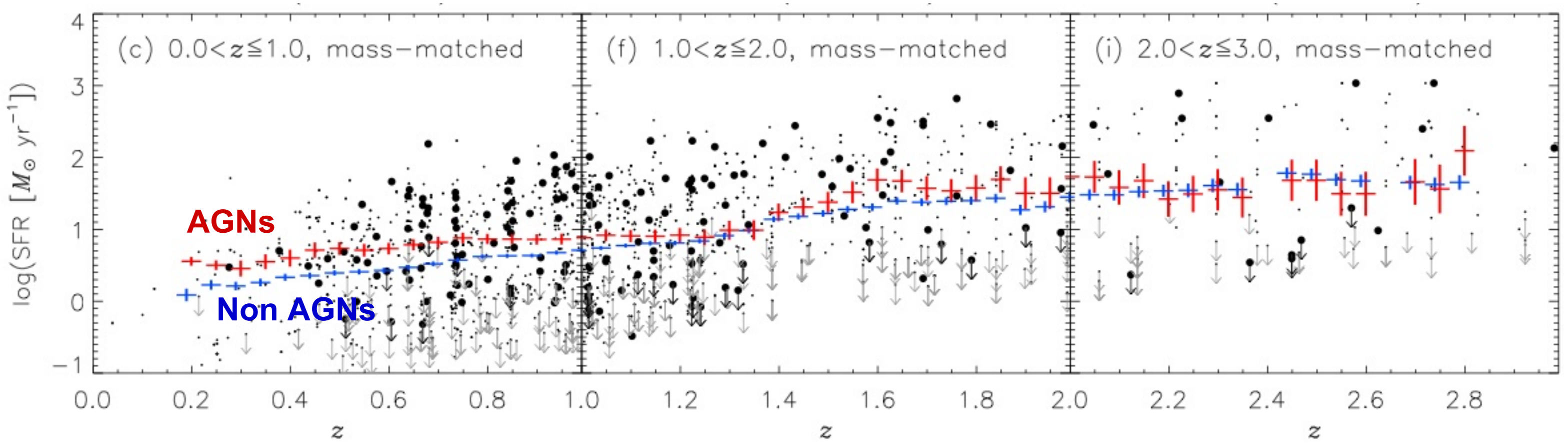


TALKS:
Ellison
Kocevski
Schawinski

Only ~15% are clearly mergers but difficult to determine clear merger signatures from morphologies, could be as much as ~50%: no clear difference between AGNs and non AGNs

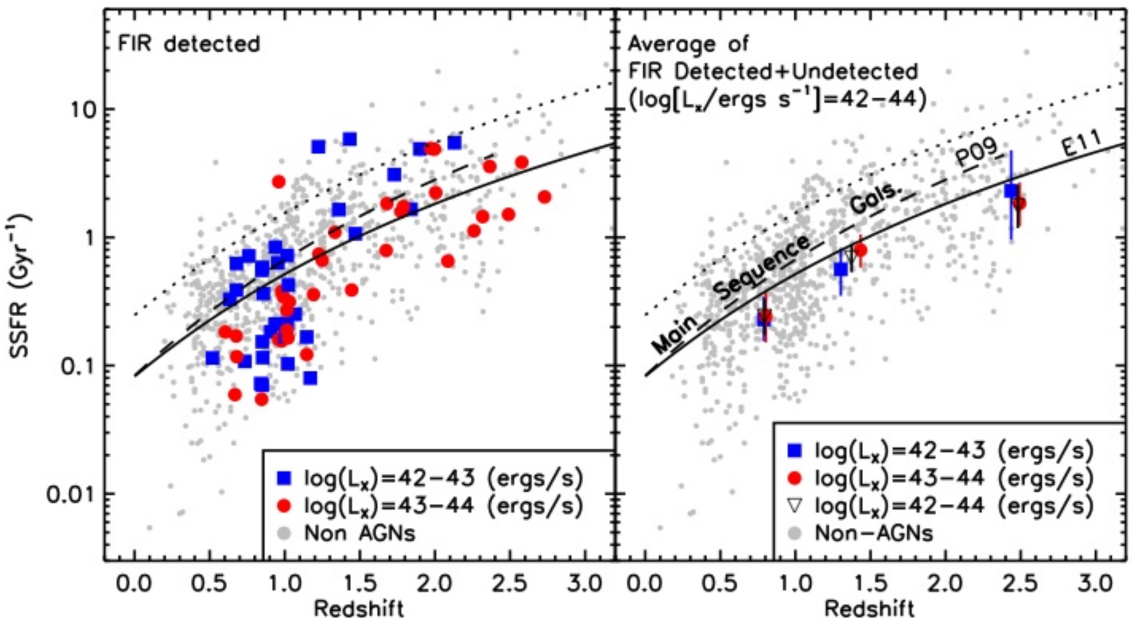
See also, e.g., Grogin et al. (2005), Pierce et al. (2007, 2010), Georgakakis et al. (2009), Cisternas et al. (2010), Schawinksi et al. (2011)

Star-formation rates typical of massive galaxies



Xue et al. (2010)

GOODS Herschel: Mullaney et al. (2011)



Specific star-formation rates (stellar mass/star formation rate) track those seen in non AGNs

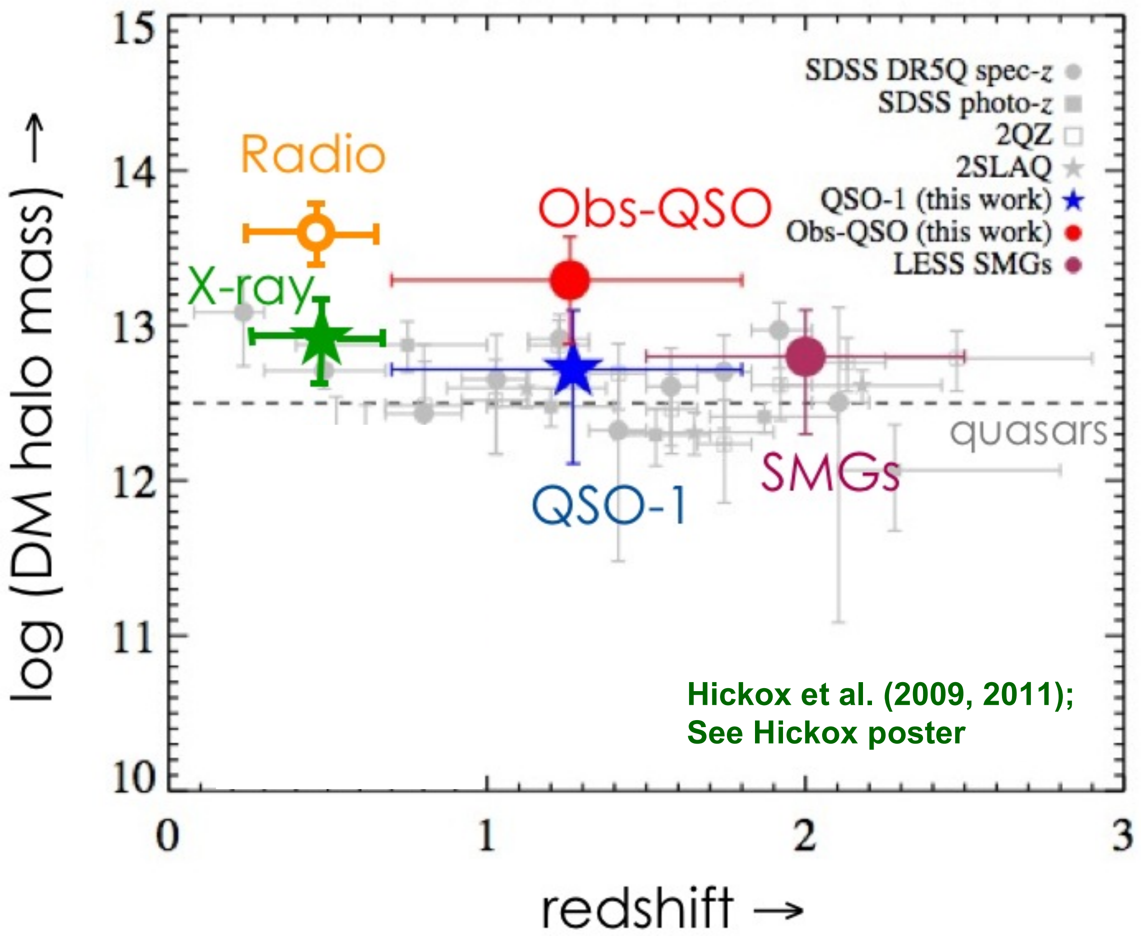
Driven by same processes

TALKS: Elbaz; Genzel; Mullaney; Tacconi

See also, for example, Lutz et al. (2010), Mullaney et al. (2010); Shao et al. (2010)

Dark-matter halo masses and environment

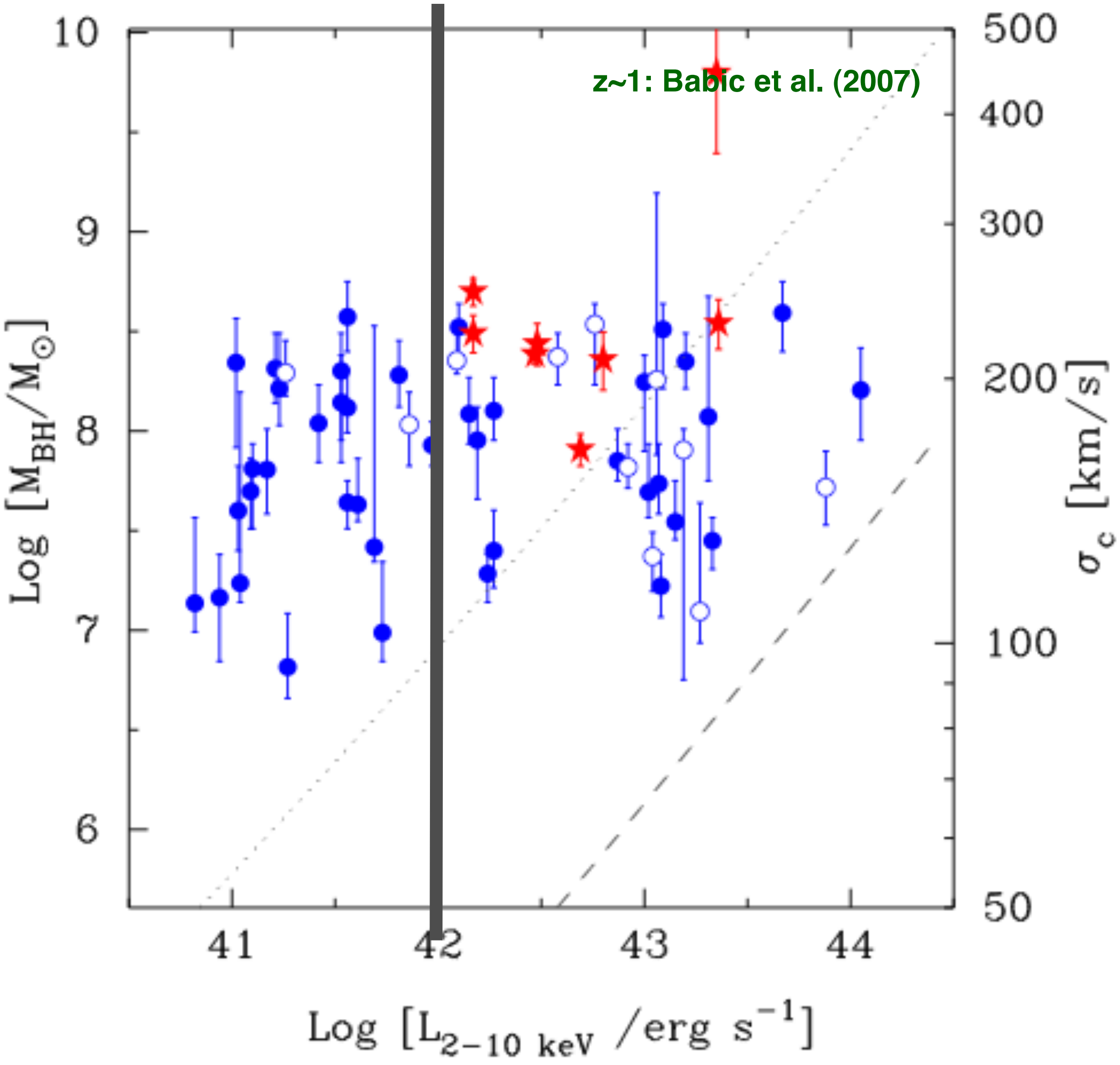
Cross correlation derived halo masses



Typical "active halo mass" ~(3-10)x10^{12} solar masses (e.g., Croton et al. 2006).
Radio galaxies have more massive halos - quenched fuel?

AGN evolution was earlier and more rapid in overdense regions
(e.g., Lehmer et al. 2009a,b): environment plays a key role

Typically modest black-hole growth rates



Typical black-hole mass ~10^8 solar masses

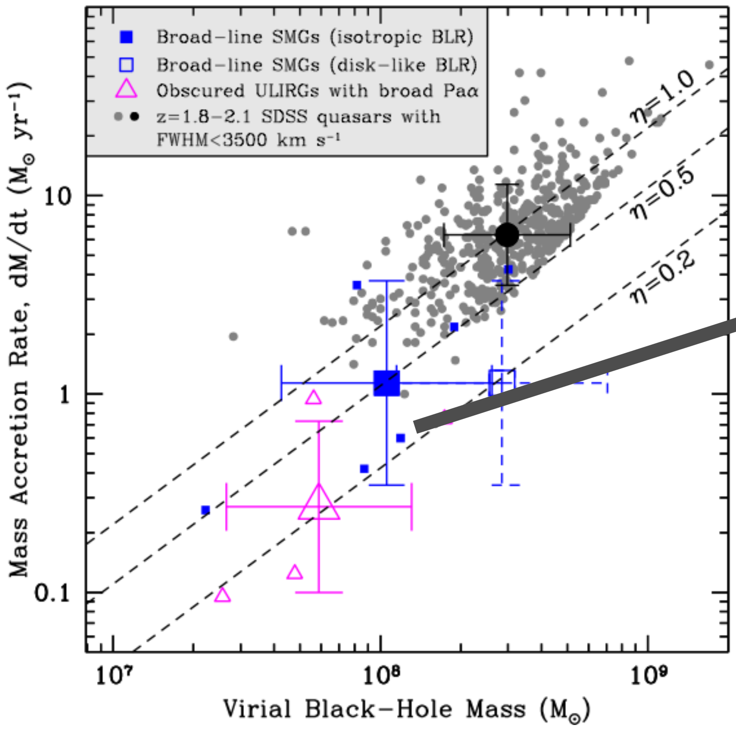
Median Eddington ratio of ~0.01 (for $L_X > 10^{42}$ erg/s): divide between optically thin and thick accretion discs (bolometric corrections?)

z~1 black holes growing more rapidly than ~10^8 solar-mass black holes locally but growth times still typically the age of the Universe

Poorer constraints for typical AGNs at higher redshift

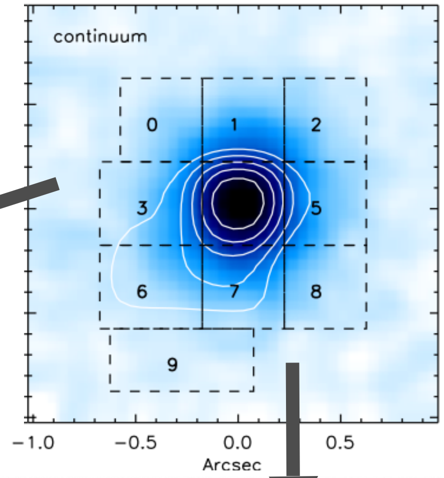
See also, for example, Ballo et al. (2007), Alonso-Herrero et al. (2008), Hickox et al. (2009); Simmons et al. (2011)

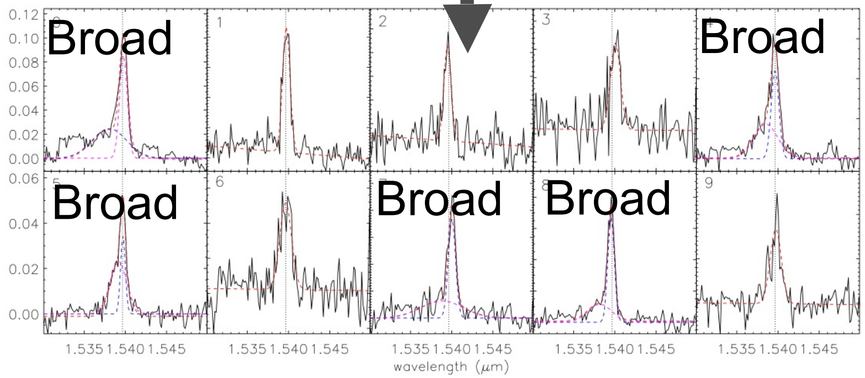
An example of a more rapidly growing z~2 black hole



Alexander et al. (2008, 2010)

An energetic superwind?





Harrison et al. (in prep); see poster 6.26 for more objects

TALKS: Martin; Steidel
POSTER: Collet

See also, for example, Nesvadba et al. (2006, 2007, 2008, 2011)

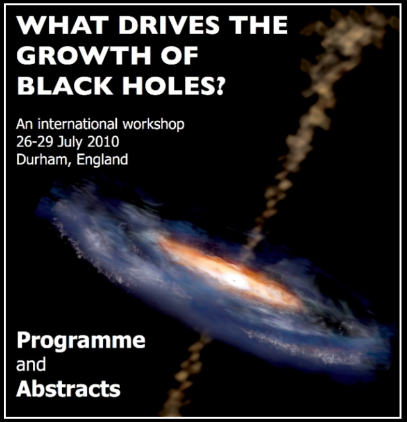
What drives the growth of distant black holes?

No discernable unique signatures of AGN activity on average - whatever drives the growth of massive galaxies drives the growth of black holes

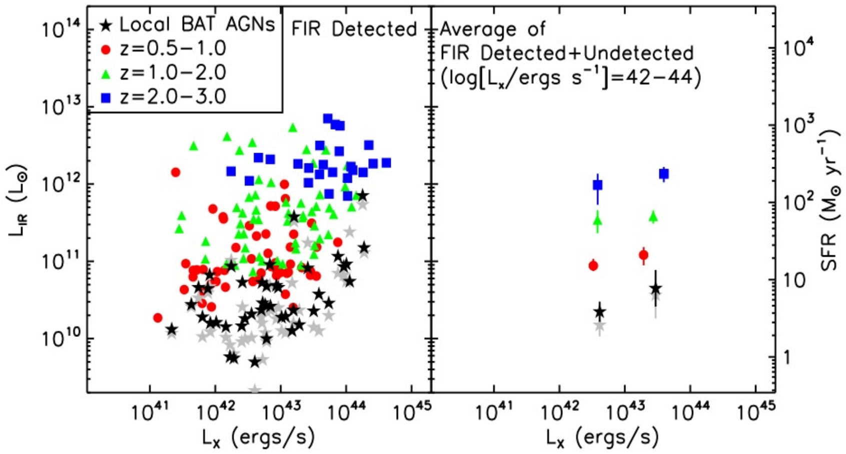
~10% of massive galaxies host a moderate-luminosity AGN (e.g., Bundy et al. 2008; Xue et al. 2010) so ~10% of the time the gas reaches the black hole

The triggers of gas onto the black hole are spatially unresolved and/or occurred a long time ago (initial signature will be lost)

Dark-matter halo seems important



Conundrum: increasing L_{IR}/L_X with redshift



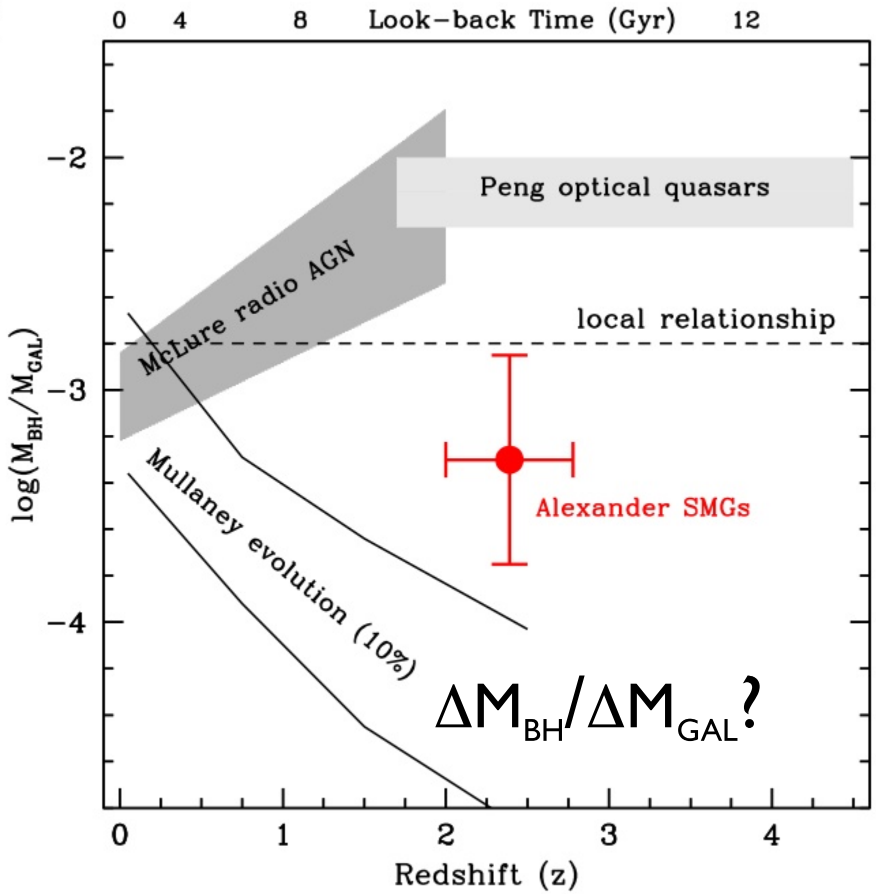
Mullaney et al. (2011)

Significant caveats:

Changing bulge vs disc star formation?
Changing AGN fraction?
Missing AGNs?
Changing IMF?

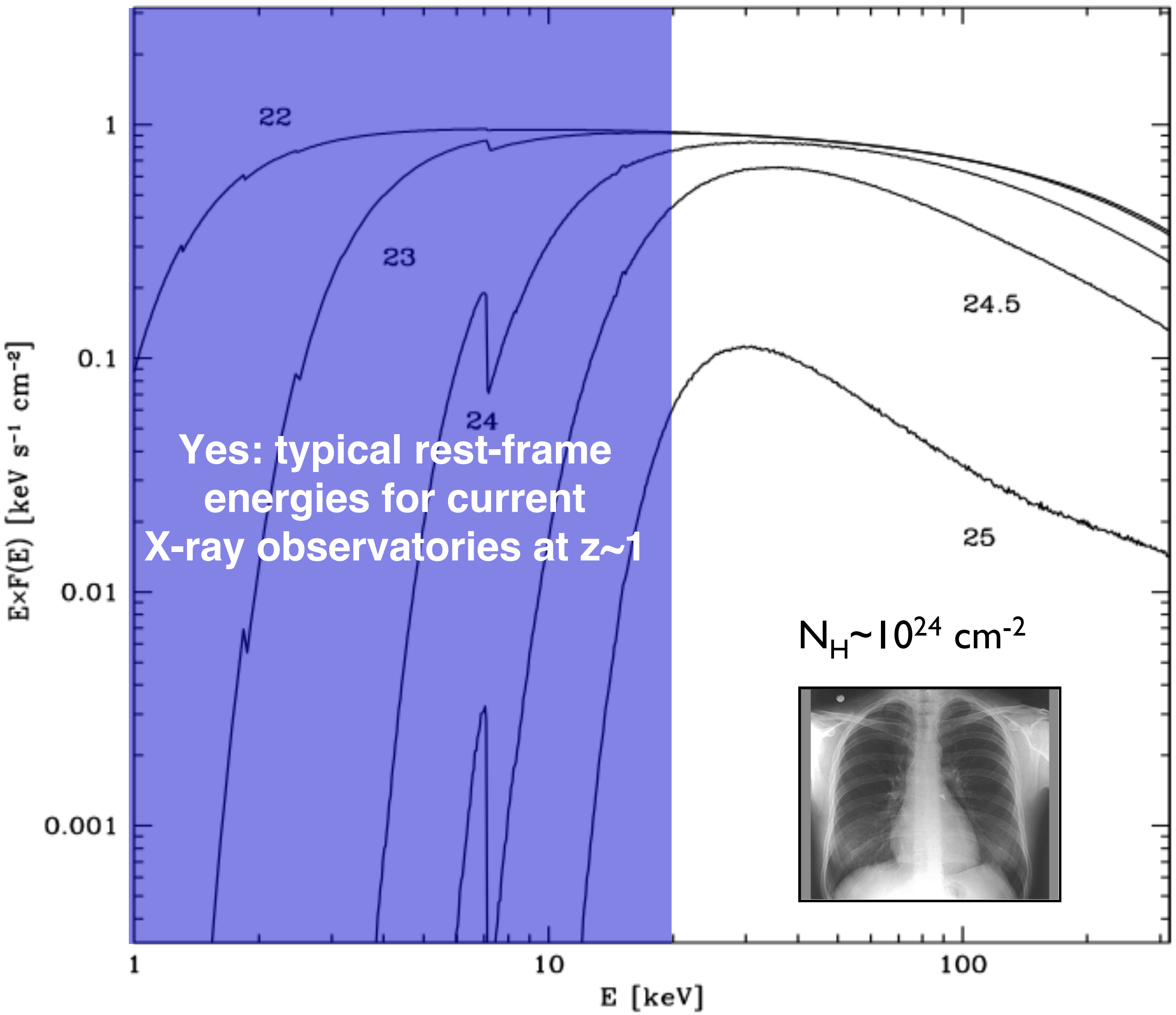
TALK: Bennert; Mullaney

Increase in L_{IR}/L_X with redshift implies more star formation without more black-hole growth



Missing AGNs?

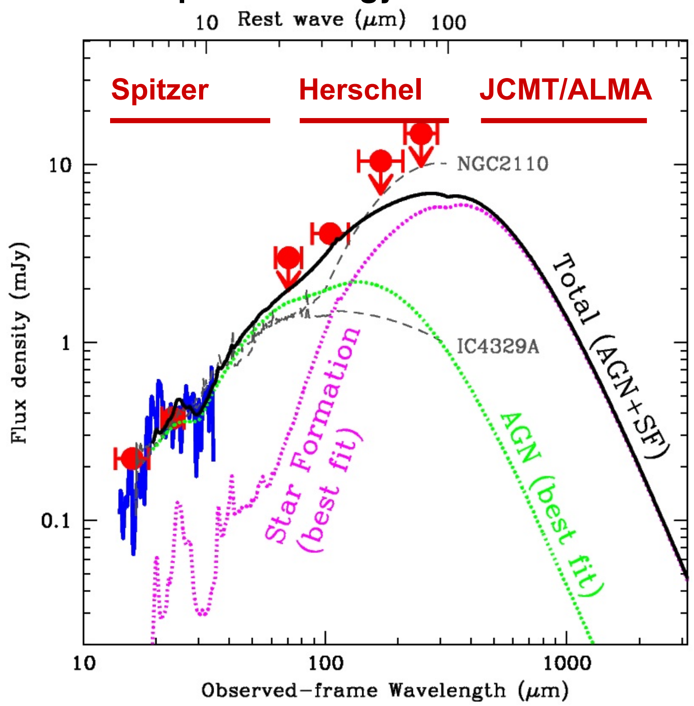
Have we missed any distant luminous AGNs?

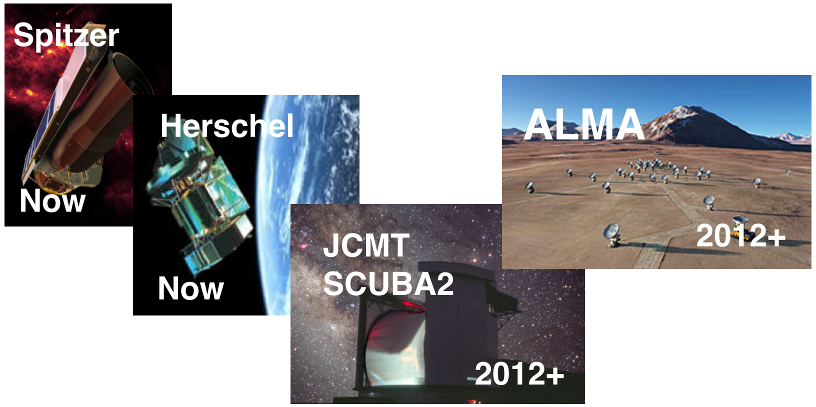


See, for example, Daddi et al. (2007), Fiore et al. (2008, 2009), Alexander et al. (2008, 2011), Treister et al. (2010), Luo et al. (2011)

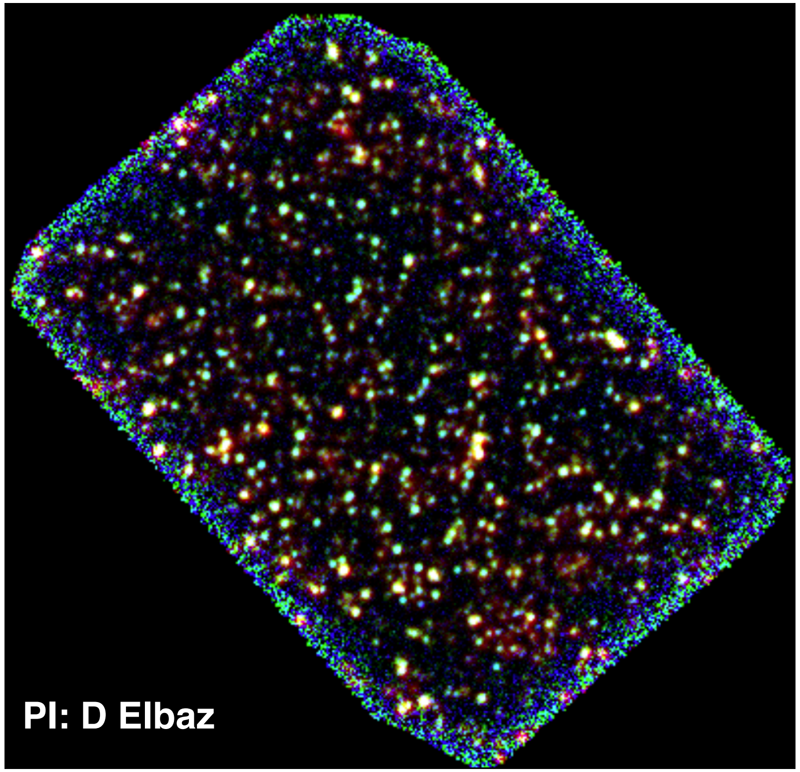
New opportunities: revealing the AGN-heated dust

z=2 spectral energy distribution





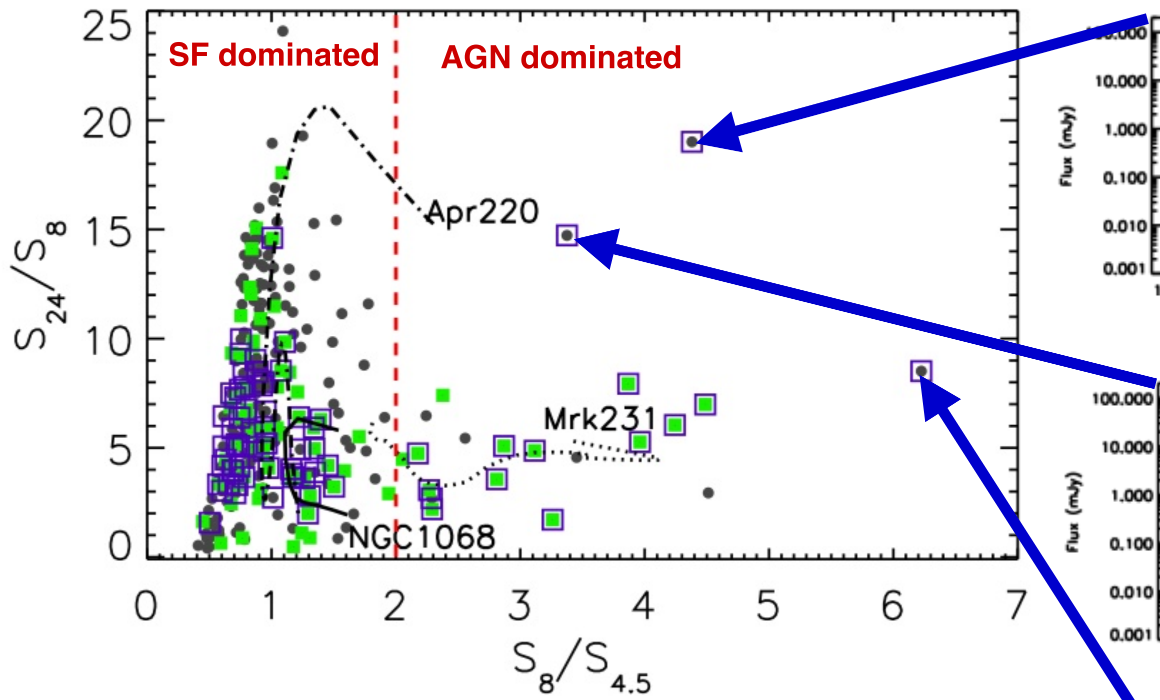
Herschel key project in GOODS fields: 100+160um (250+350+500um)

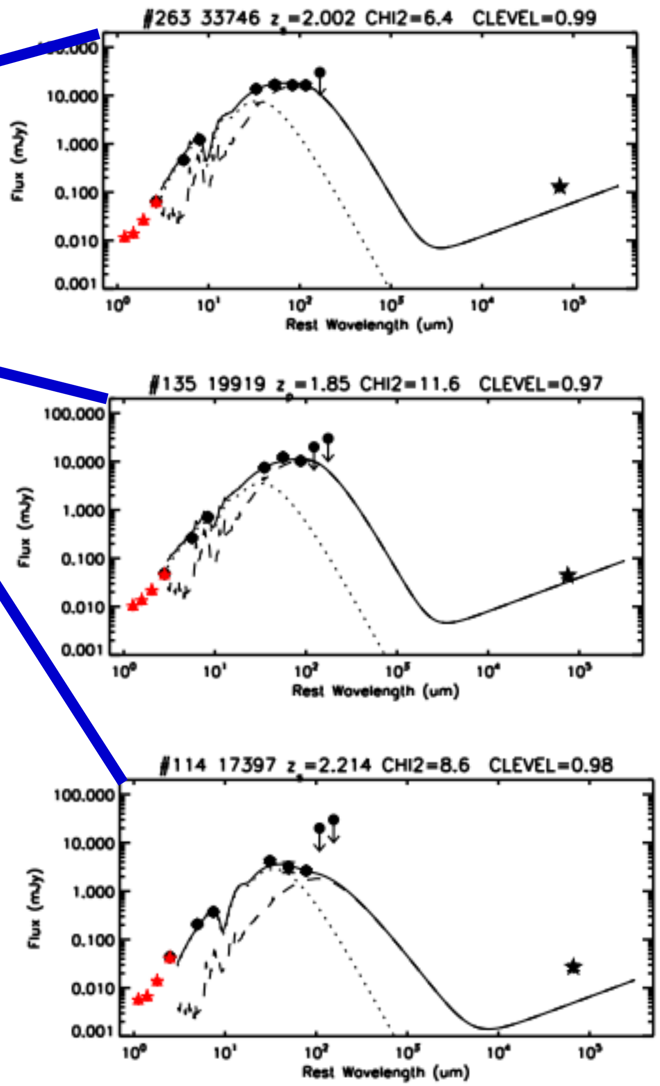


Herschel+Spitzer: infrared SEDs (3-500um) to identify AGN and star formation

Efficient and effective method of identifying heavily obscured AGNs

Comparison of AGN identification techniques (X-ray AGN=green; IR AGN=square)





- Better than simple colour selection - finds X-ray undetected AGNs (~40% of IR AGN are X-ray undetected in deepest X-ray surveys)
- Suggests a large number of likely luminous Compton-thick quasars at z~2 not revealed in X-ray surveys

Del Moro et al. (in prep)

Summary

Majority of the distant black-hole growth appears to have occurred in massive galaxies - the host galaxies of AGNs and non AGNs appear very similar. No clear unique AGN trigger signatures (size resolution, time resolution?). Issues with identifying AGNs in lower-mass galaxies?

The X-ray surveys generally identify massive (>10^8 solar mass) black holes, which are growing with a ~10% duty cycle. Growth rates are modest but more rapid than similar mass black holes locally: evidence for black-hole downsizing? Possible energetic outflows in some sources.

More star formation per unit AGN activity at higher redshift than seen today: a conundrum? Significant caveats: amount of spheroid star formation, changing AGN fraction, hidden AGNs

Hidden AGN missed by X-ray surveys can be found from detailed infrared SED modelling: ~40% of the luminous X-ray AGNs are undetected in X-rays. A population of heavily obscured (possibly Compton thick) AGNs?