Cosmological evolution of SMBH:

Clues about AGN feedback from multiwavelength surveys

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The theoretical necessity of AGN feedback for galaxy evolution: a history of failures

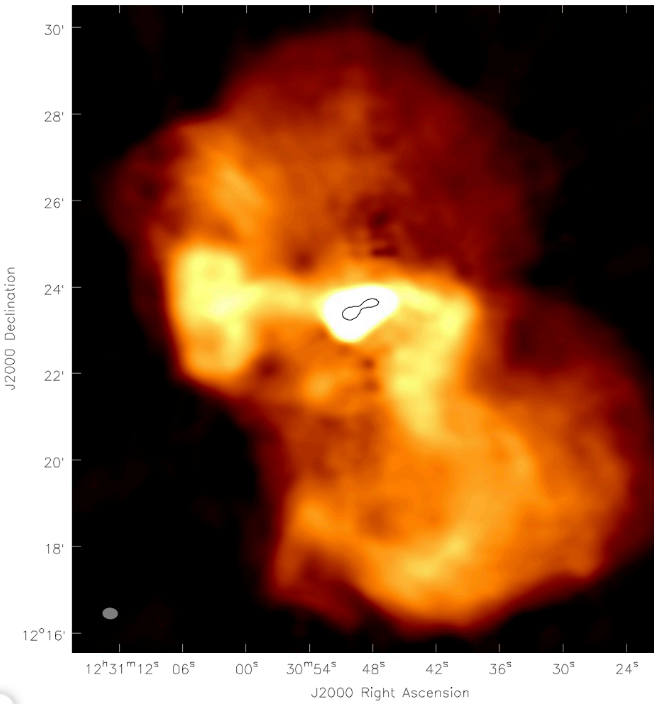
1. Maintain the observed close connection between the growth of SMBH and the growth of galaxies
2. Ensure a tight relation between black hole mass and galaxy mass/velocity dispersion
3. Help establishing the color-bimodality of galaxies
4. Prevent too massive galaxies from forming
5. Solve the cooling flow problem in clusters of galaxies

Feedback for real

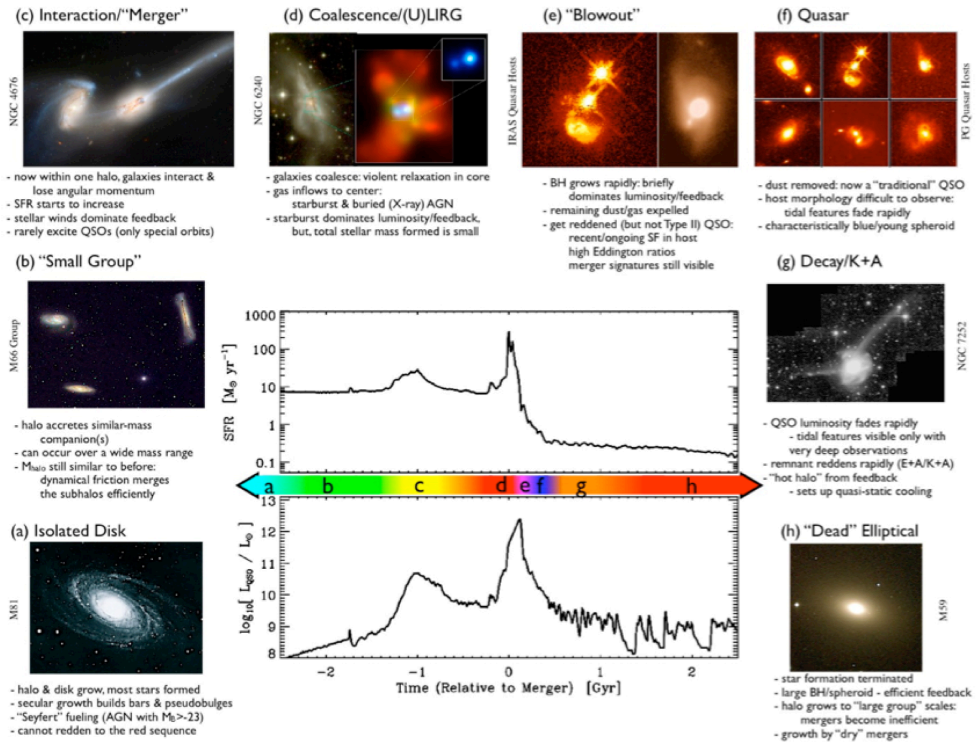
We need to classify AGN output according to:

1) Global energetics (mechanical power in Eddington units)
2) Covering factor/duty cycle
3) Impact on the gaseous phase of their host galaxies/structures
4) Redshift and mass distribution of the liberated energy

De Gasperin et al. 2012



LOFAR M87 map @ 150 MHz



Di Matteo, Hernquist, Hopkins+, 2005

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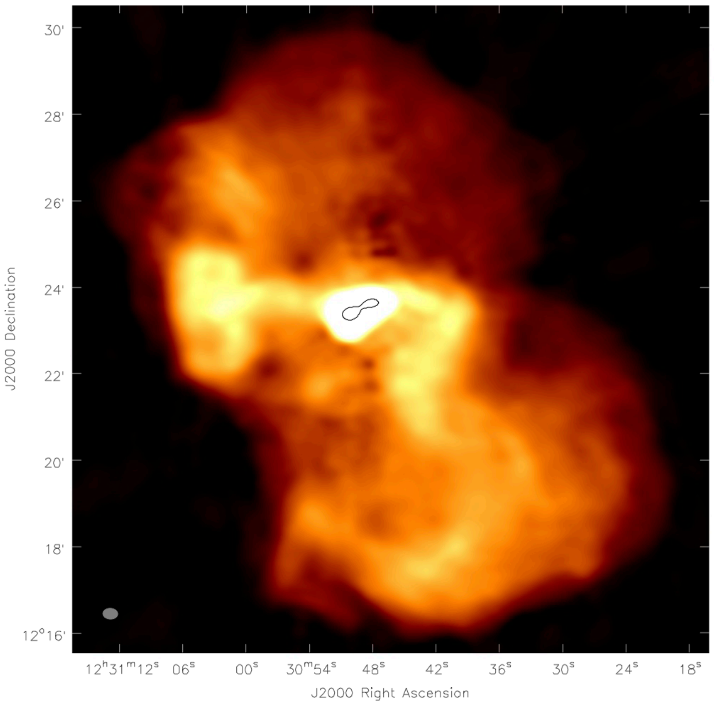

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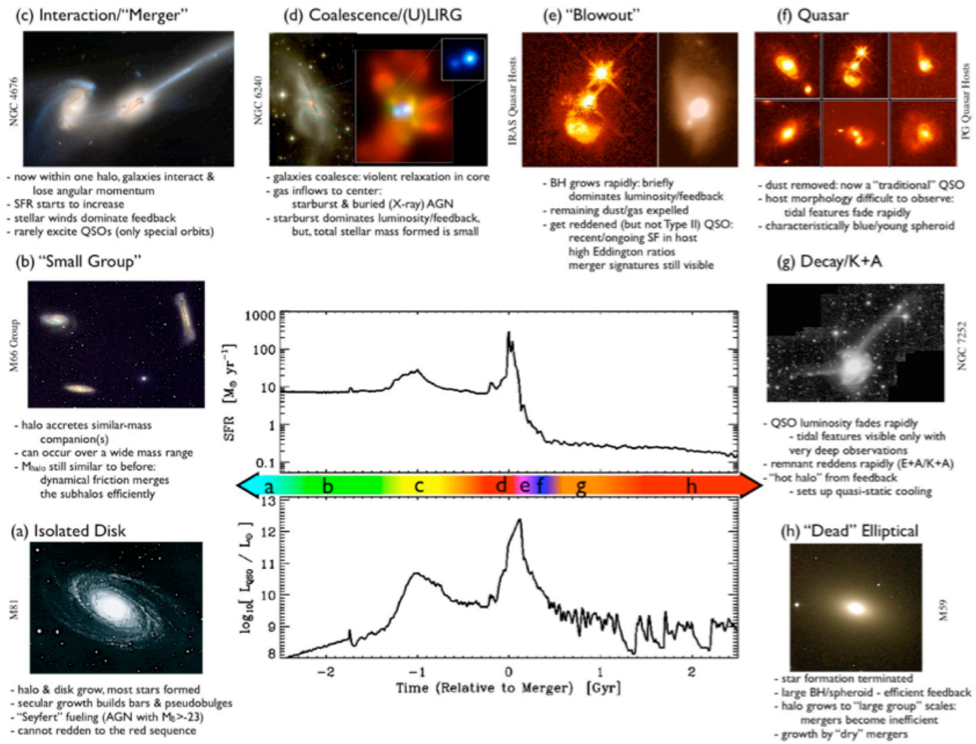


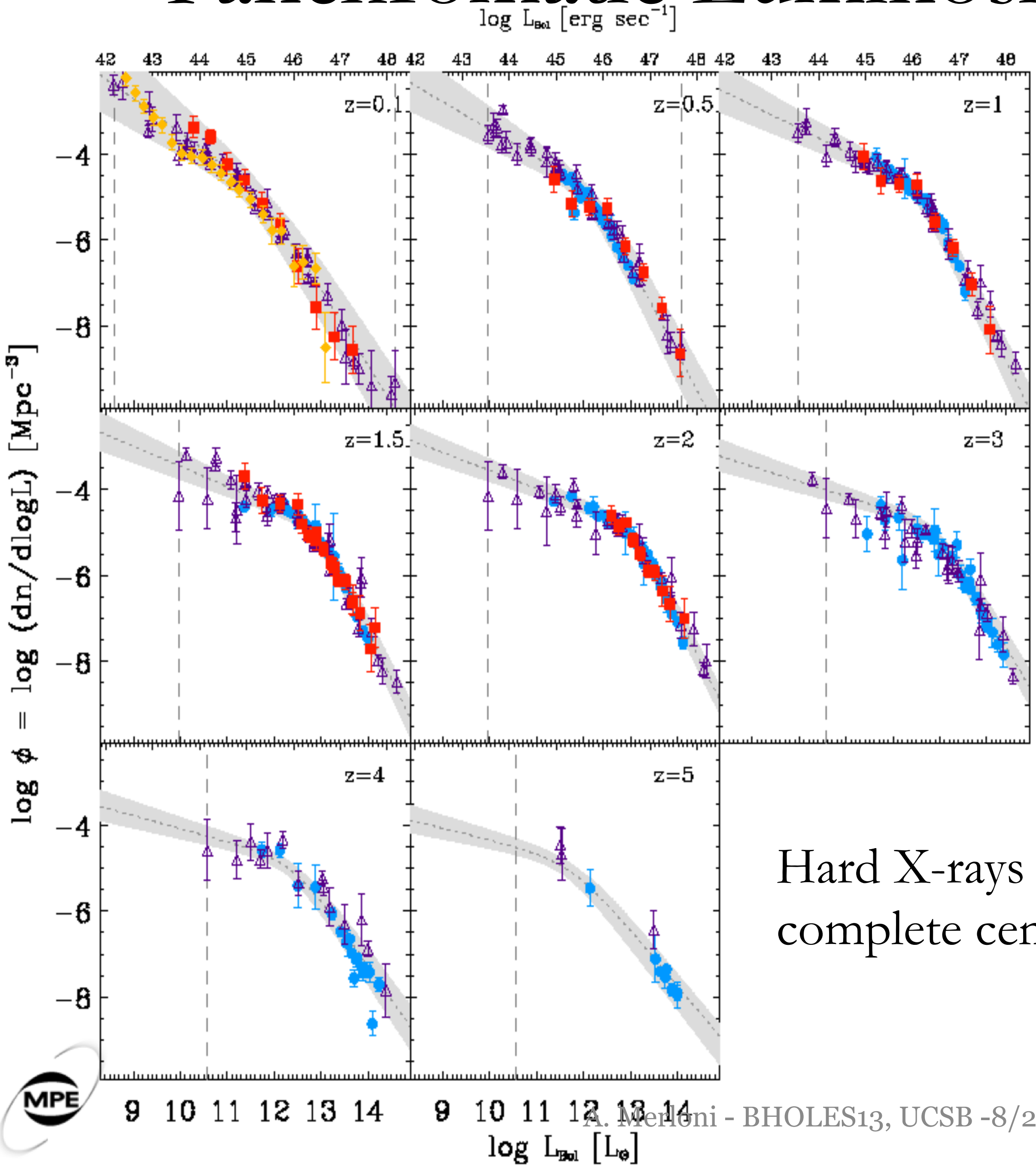
Di Matteo, Hernquist, Hopkins+, 2005

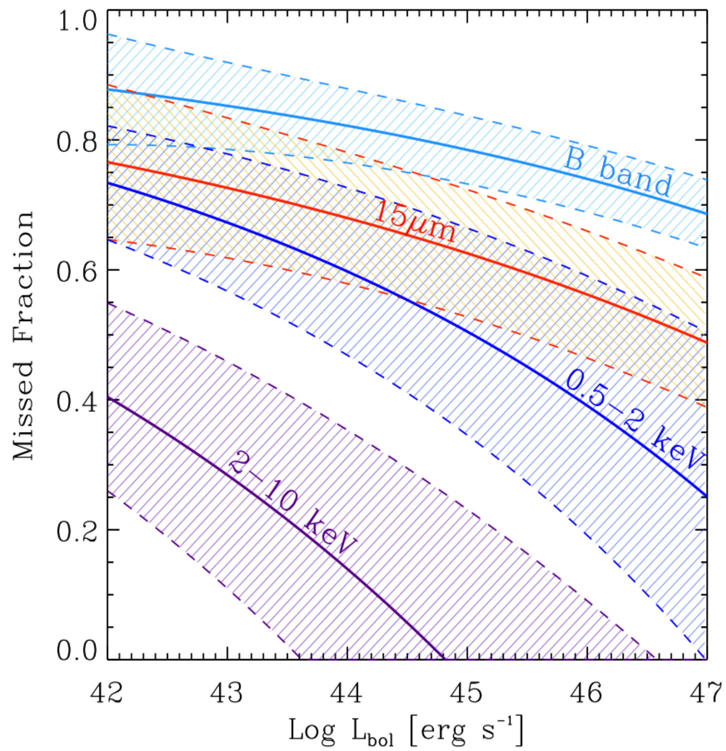
Outline of this talk

A. From multi-wavelength surveys to the history of accretion
B. The properties of AGN host galaxies in COSMOS
C. The incidence of obscuration in AGN

From multi-wavelength surveys to the history of accretion

Panchromatic Luminosity Functions





Hard X-rays provide by far the most complete census of AGN activity

See Hopkins et al. (2007); Marconi et al. (2004); Merloni & Heinz (2013)

Cosmological evolution: Integral constraints

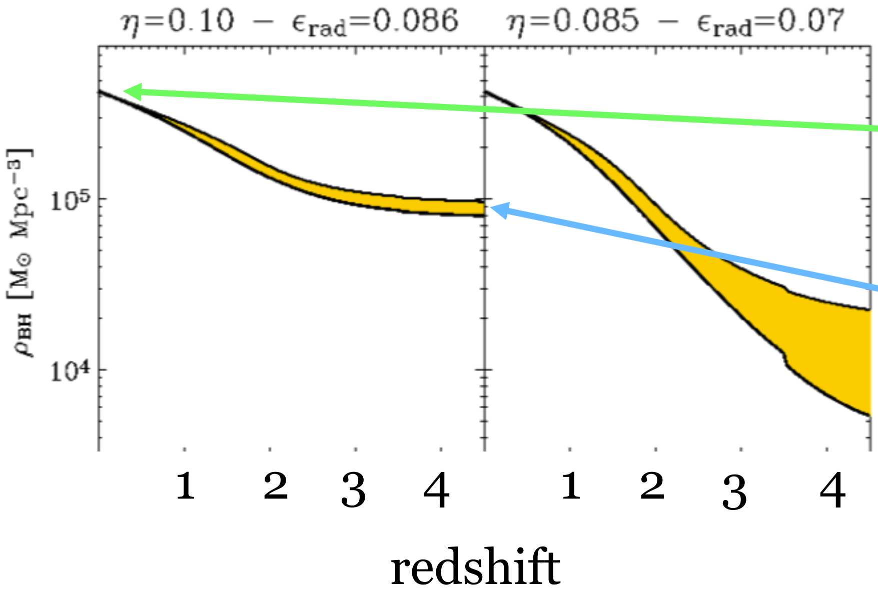
- **Soltan (1982)** first proposed that the mass in black holes today is simply related to the AGN population integrated over luminosity and redshift

$$\mathrm{BHAR}(z) \equiv \Psi_{\mathrm{BH}} = \int_0^{\infty} \frac{(1-\epsilon_{\mathrm{rad}})L_{\mathrm{bol}}}{\epsilon_{\mathrm{rad}} c^2} \phi(L_{\mathrm{bol}}, z) dL_{\mathrm{bol}}$$

$$\frac{\rho_{\mathrm{BH}}(z)}{\rho_{\mathrm{BH},0}} = 1 - \int_0^{z} \frac{\Psi_{\mathrm{BH}}(z')}{\rho_{\mathrm{BH},0}} \frac{dt}{dz'} dz'$$

Fabian and Iwasawa (1999) $\varepsilon \sim 0.1$; Elvis, Risaliti and Zamorani (2002) $\varepsilon > 0.15$;
Yu and Tremaine (2002) $\varepsilon > 0.1$; Marconi et al. (2004) $0.16 > \varepsilon > 0.04$;
Merloni, Rudnick, Di Matteo (2004) $0.12 > \varepsilon > 0.04$; Shankar et al. (2007) $\varepsilon \sim 0.07$

Constraints on radiative efficiency $\langle \varepsilon_{rad} \rangle$



$\xi_o = \rho_{BH,o}/(4.2\times10^5)$

$\xi_i = \rho_{BH}(z=z_i)/\rho_{BH,o}$

(Input from seed BH formation models needed!)

$\xi_{CT} = \rho_{BH,CT}/\rho_{BH,o}$

(Fractional Mass density of SMBH grown in a Compton Thick, heavily obscured phase)

$\xi_{lost} = \rho_{BH,lost}/\rho_{BH,o}$

(Mass density of SMBH ejected from galactic nuclei due to GW recoil after mergers)

$$\langle \varepsilon_{rad} \rangle / (1 - \langle \varepsilon_{rad} \rangle) \approx 0.075/[\xi_o\,(1 - \xi_{CT} - \xi_i + \xi_{lost})]$$

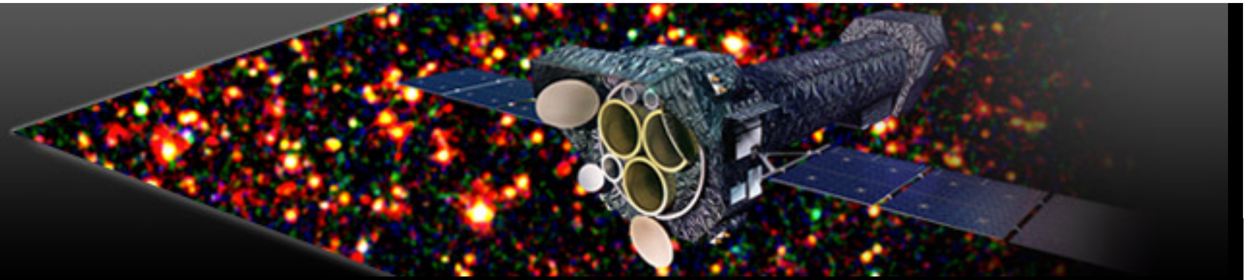
Merloni and Heinz 2008

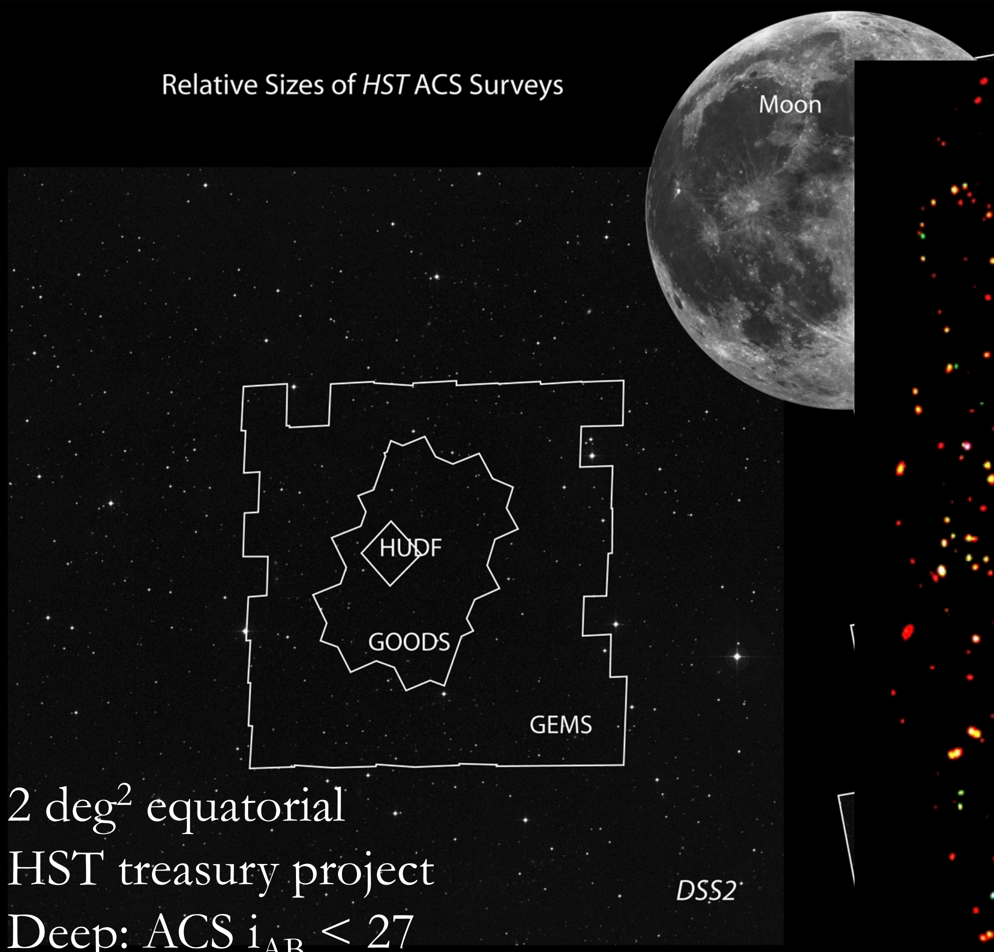
Volonteri et al. 2013

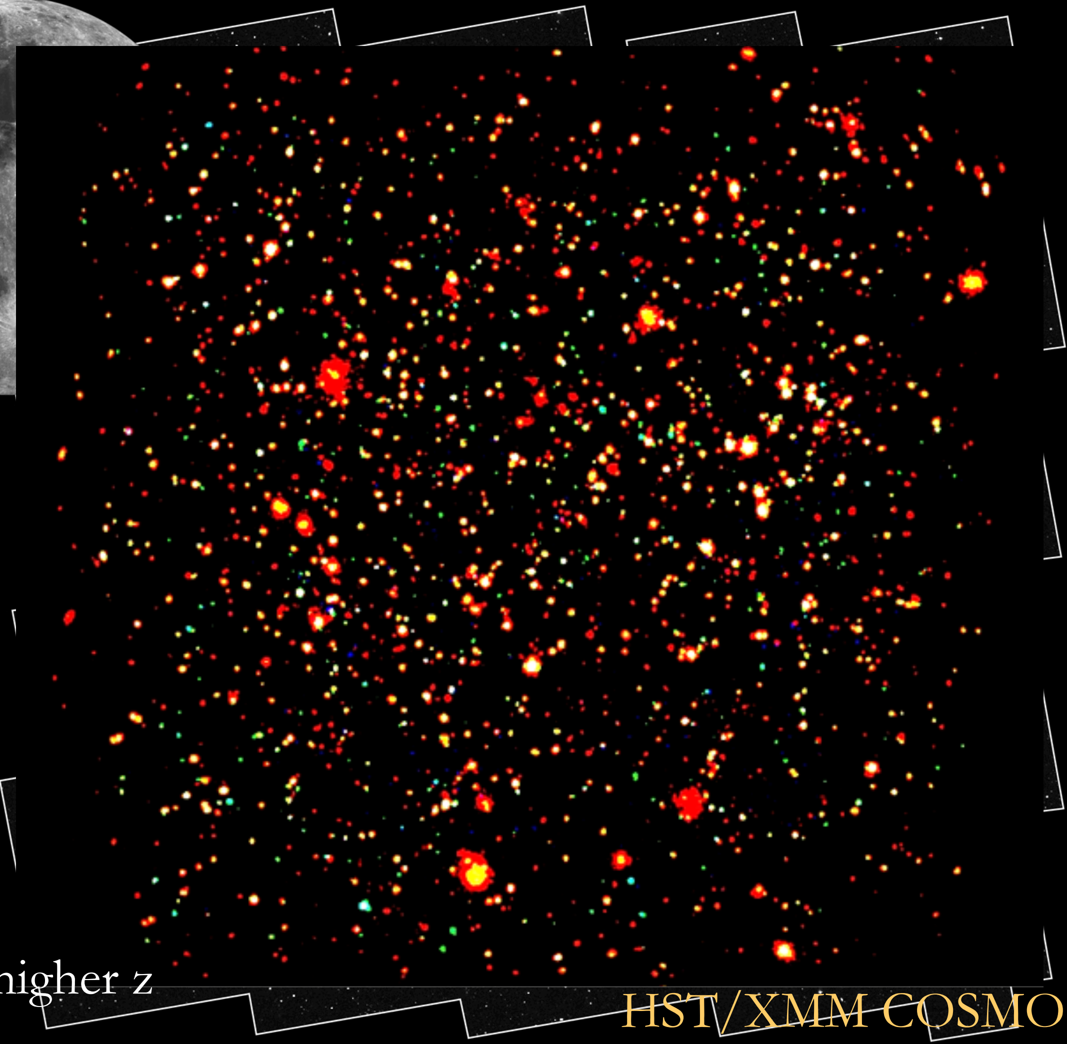
The properties of AGN host galaxies in COSMOS

Bongiorno et al. 2012, MNRAS, 427, 3103

COSMOS





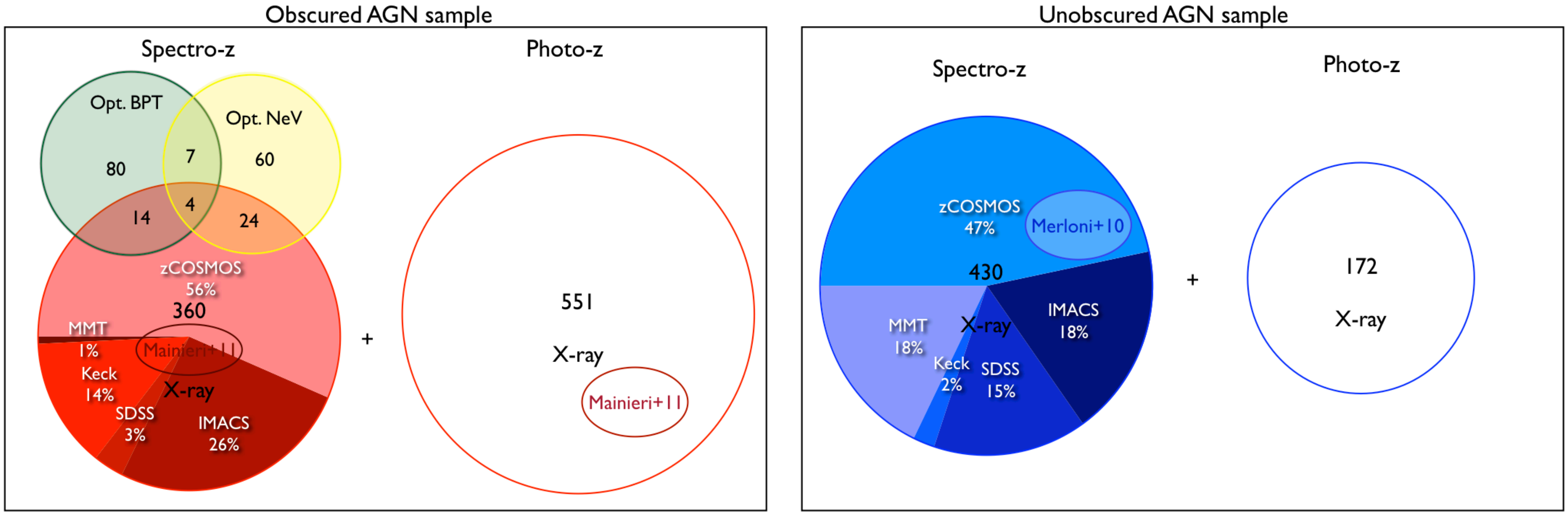


2 deg^2 equatorial
HST treasury project
Deep: ACS $i_{AB} < 27$
Similar volume ~~as SDSS, but fainter~~ and higher z
Extensive multi- λ coverage

~~HST/XMM COSMOS~~
[Scoville, Hasinger]

A complete, X-ray selected, AGN sample

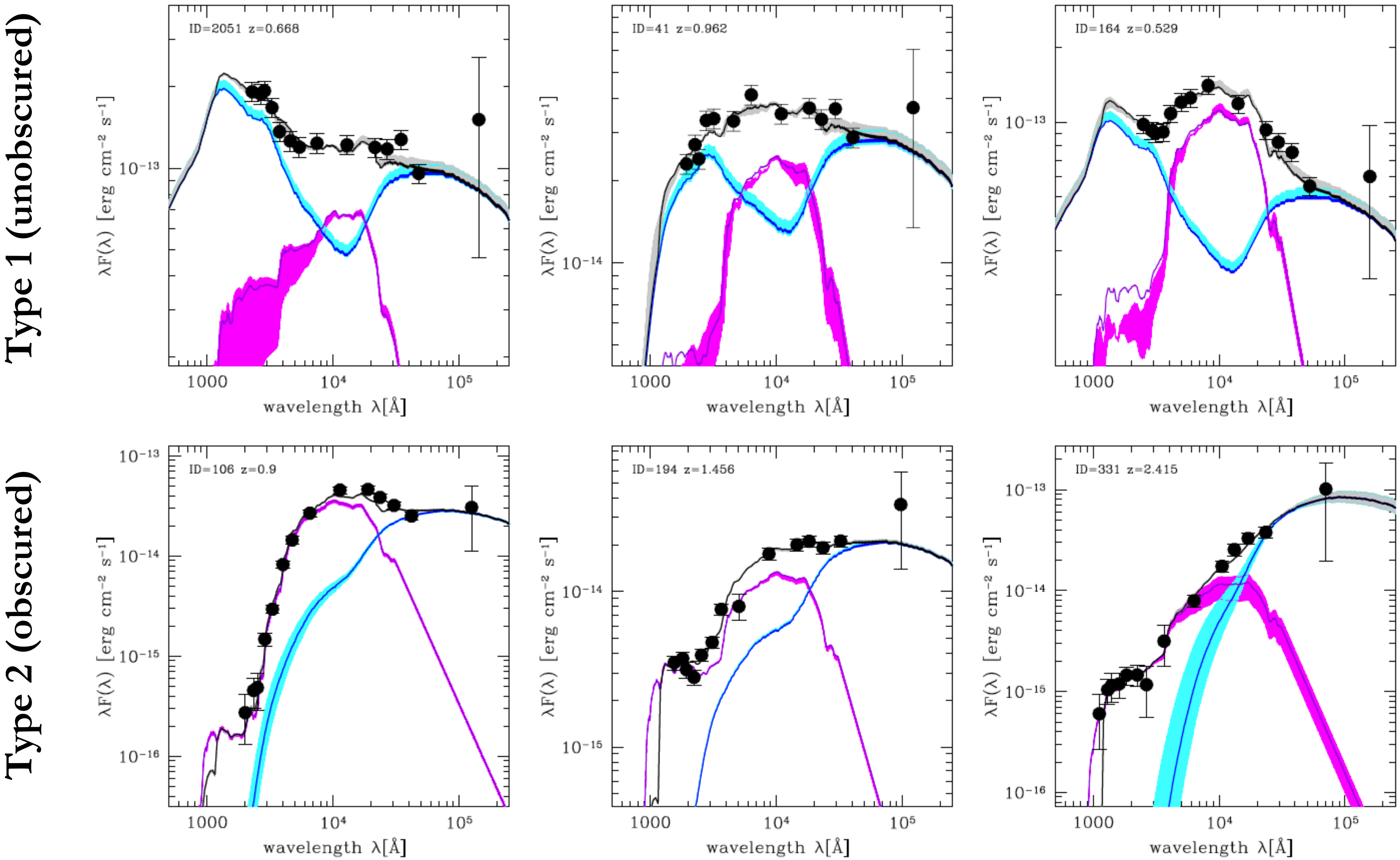
- 1555 X-ray selected AGN (XMM; $f_{lim} \sim$ **5×10^{-16}**[0.5-2]; **3×10^{-15}**[2-10])
- **100% redshift complete** (54% specz; 46% photoz)
- 602 Unobscured (71% specz; 29% photoz)
- 953 Obscured (42% specz; 58% photoz)
- **Parent sample** of ~200k IRAC galaxies (photoz, M_*; Ilbert et al. 2010)



Bongiorno et al. 2012

See also Brusa et al. 2010; Salvato et al. 2009; Lusso et al. 2011, 2012

AGN/Galaxy SED decomposition

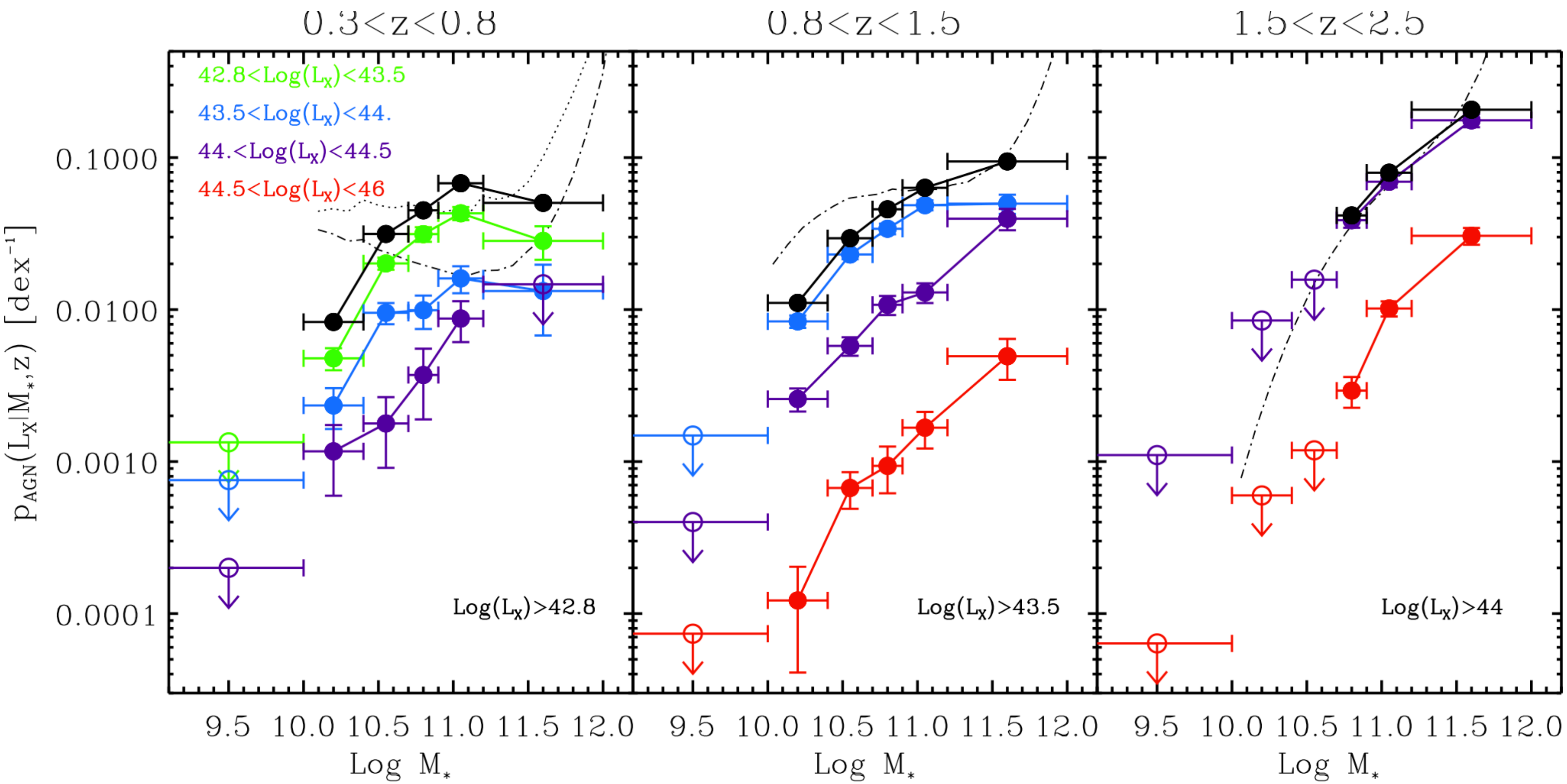


Scientific Questions

- Statistically robust assessment of AGN demographics:
  - Which galaxies host (which) AGN?
  - AGN triggering: under which conditions do SMBH grow?
- Does AGN activity affect galaxies' properties (at the population level)
  - Location of AGN in color-magnitude plots, etc.
  - Smoking guns of AGN feedback?

See e.g. Nandra et al. 2008; Silverman et al. 2009; Brusa et al. 2010; Xue et al. 2011; Schavinski et al. 2011; Rosario et al. 2012; Alexander & Hickox 2012; Mullaney et al. 2012; Santini et al. 2012; Page et al. 2012; Rovilos et al. 2012; Harrison et al. 2012; etc.

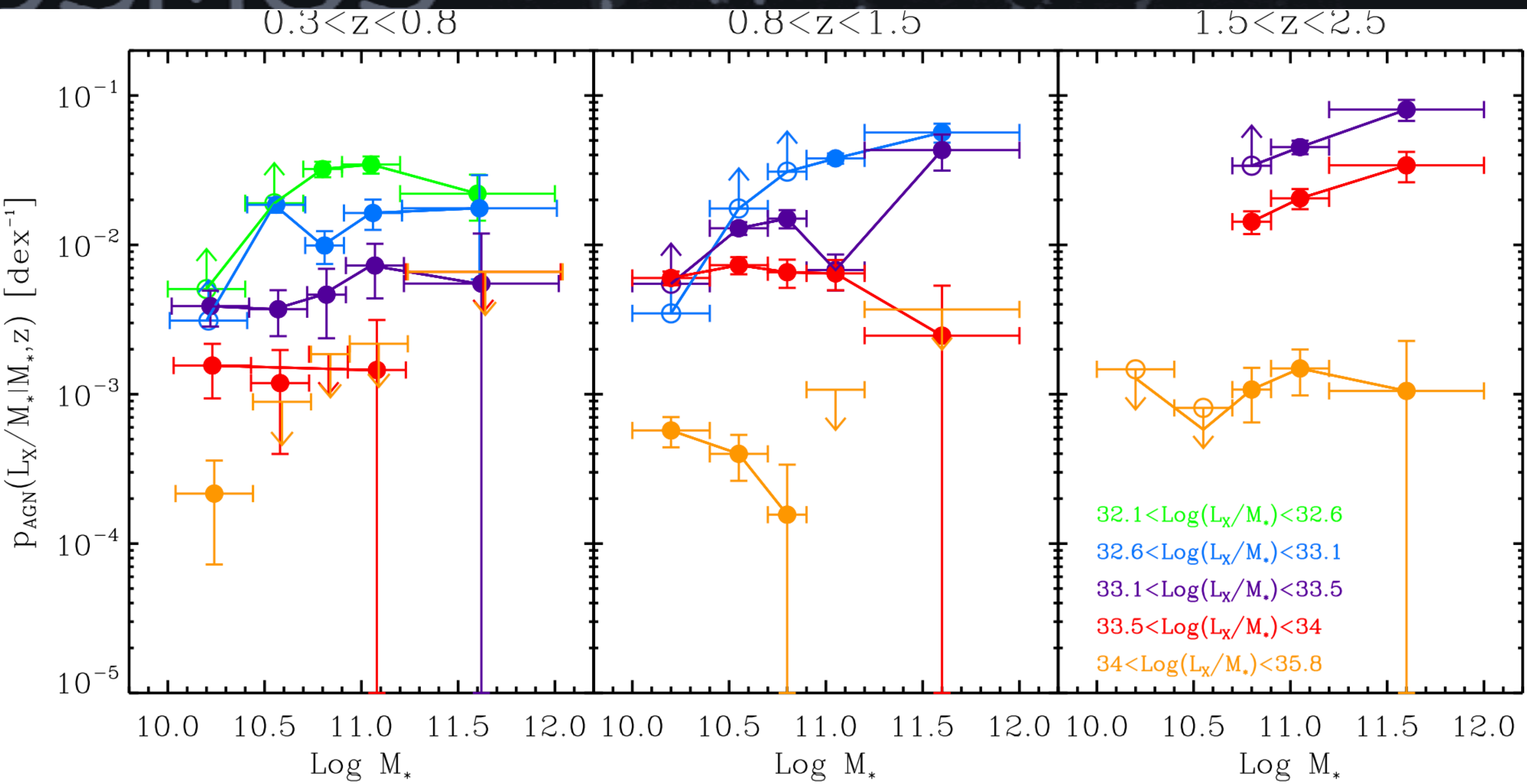
AGN fractions (M_*, L_X)



Bongiorno et al. 2012

1: The probability of a galaxy to host an AGN growing at a given L_X **strongly depends on stellar mass.** Similar at all luminosities! Narrow range of L_X/M_* clearly ruled out (Merloni & Heinz 2008)

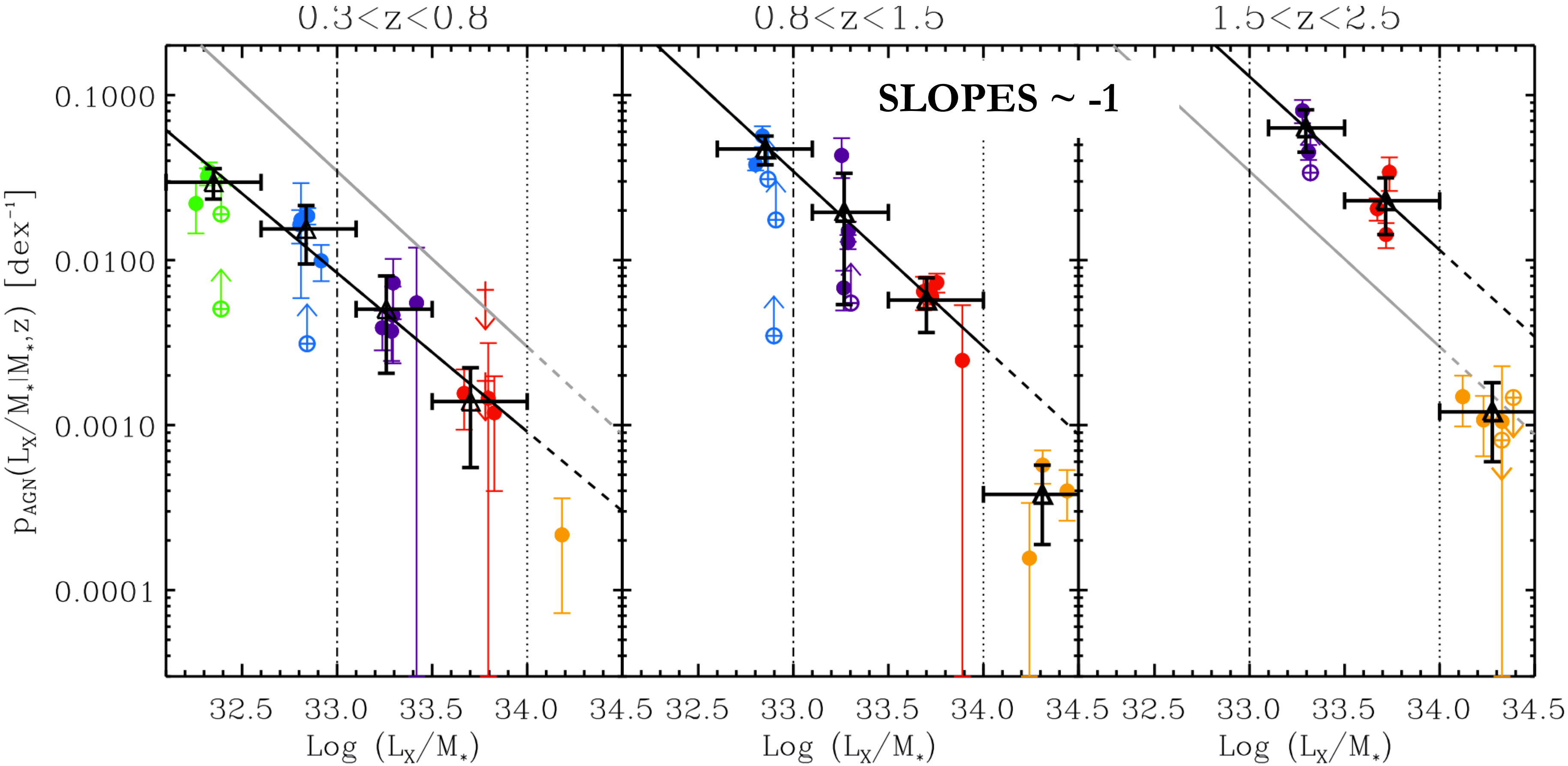
AGN fractions (M_*, L_X)



Bongiorno et al. 2012

2: AGN fraction at fixed L_X/M_* ~independent on galaxy mass!

Specific accretion rate distributions



Bongiorno et al. 2012

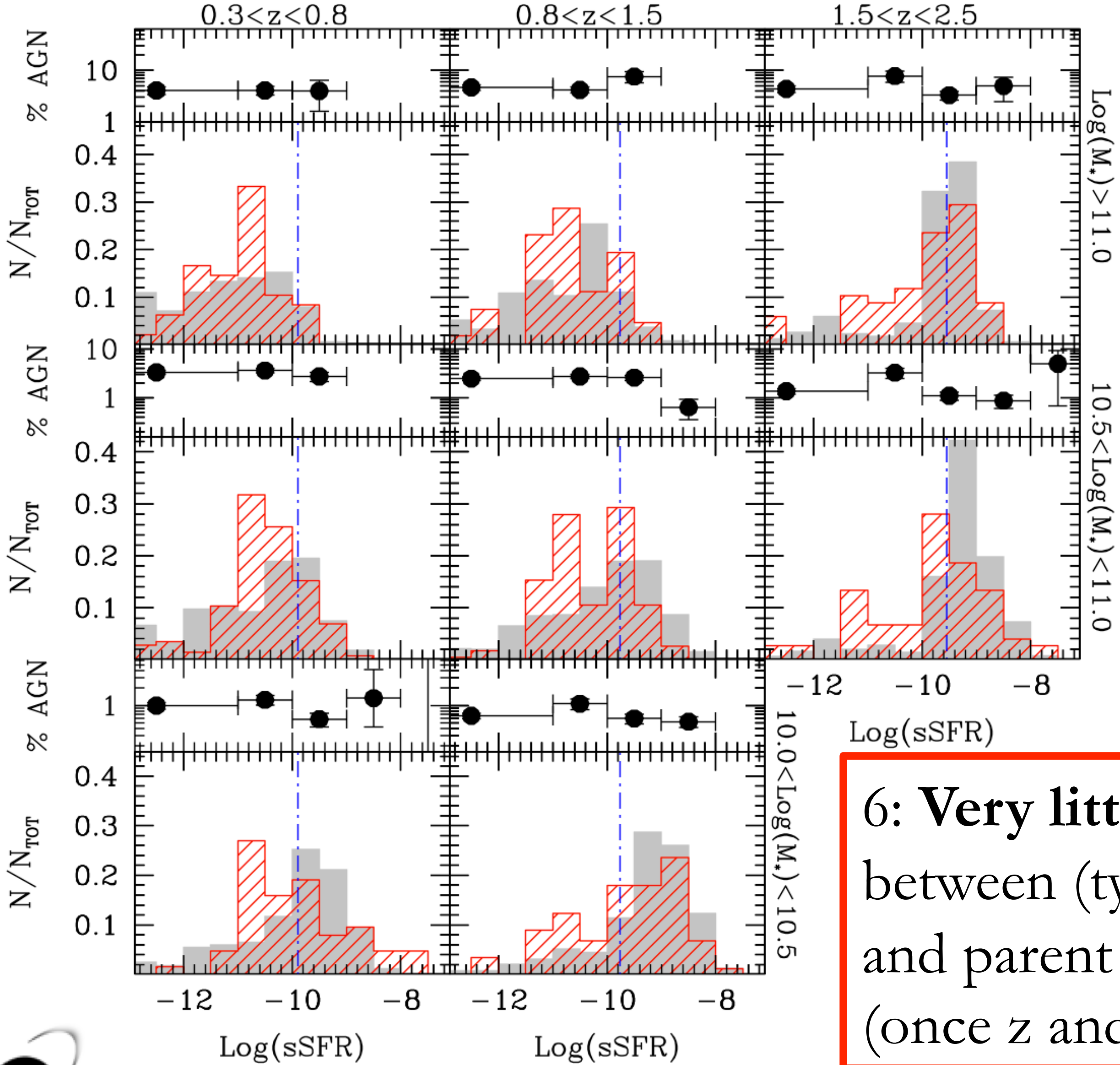
"Specific Accretion rate" (Aird et al. 2012)

3: AGN fraction at fixed L/M ~independent on galaxy mass!

4: Its normalization increases as **~(1+z)^4** [cfr. sSFR density]

5: There appears to be a break consistent with **~Eddington limit**

Obscured AGN in sSFR-Mass plane



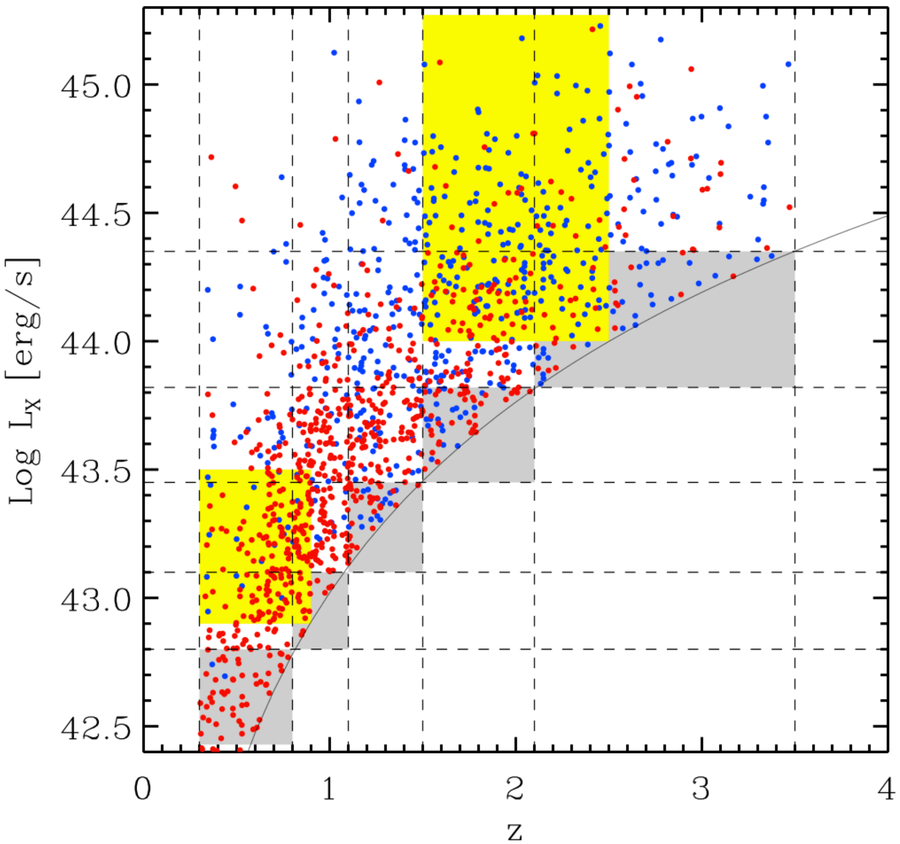
Bongiorno et al. 2012

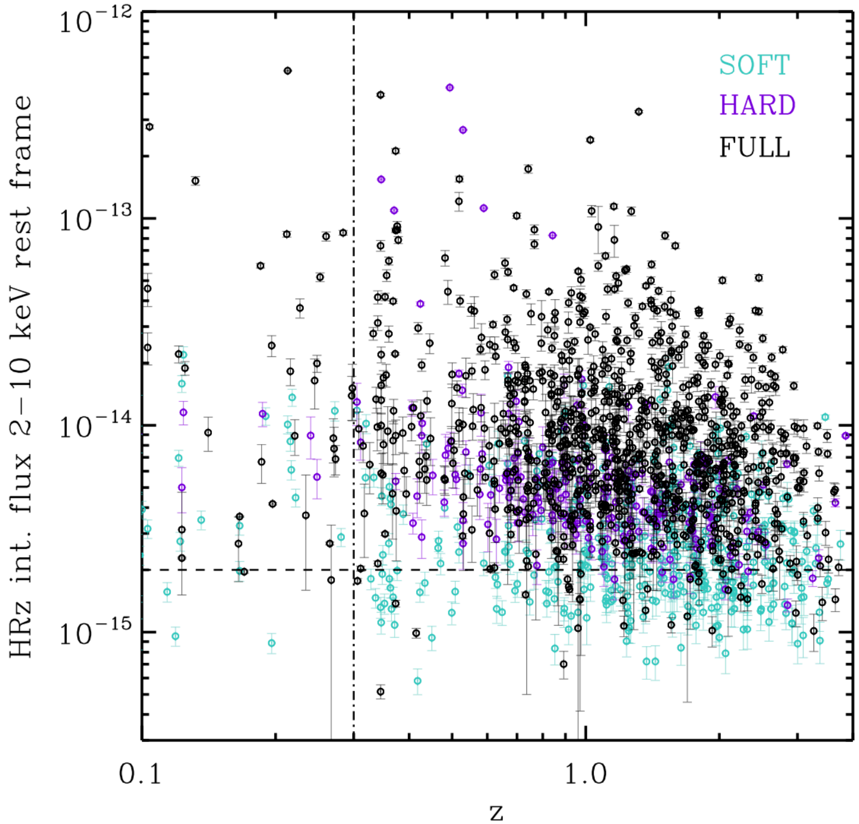
6: **Very little difference** between (type 2) AGN hosts and parent sample in sSFR (once z and M_* factored out)

The incidence of obscuration in AGN

Merloni et al. 2013, MNRAS, submitted

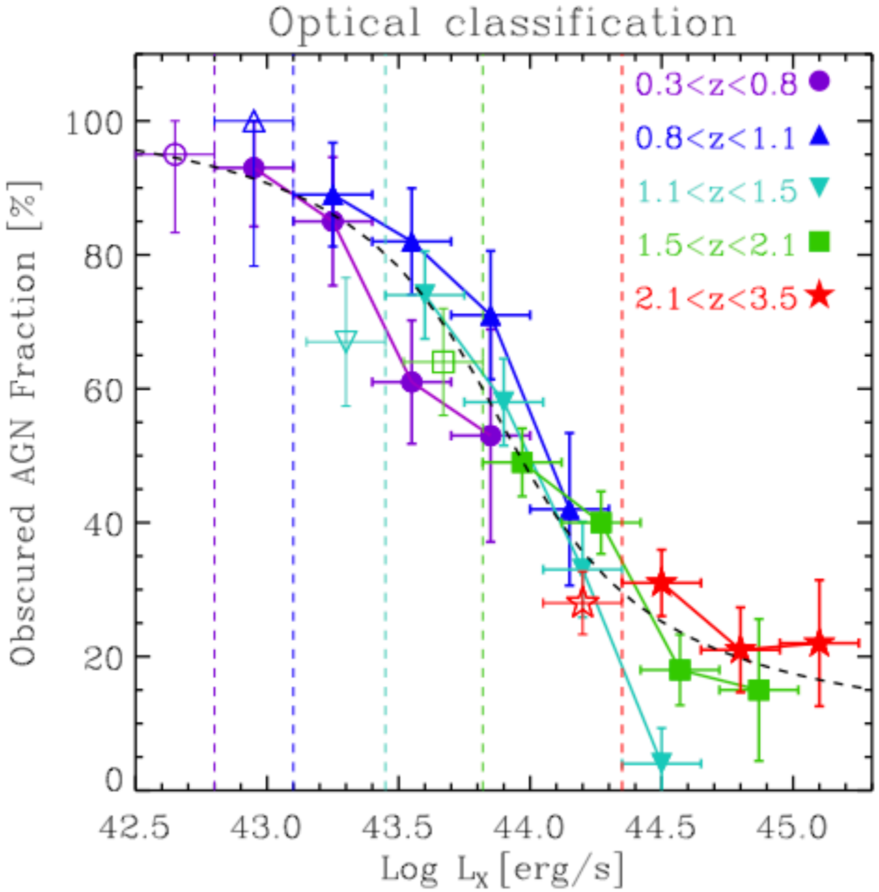
A 2-10 keV rest-frame selected sample

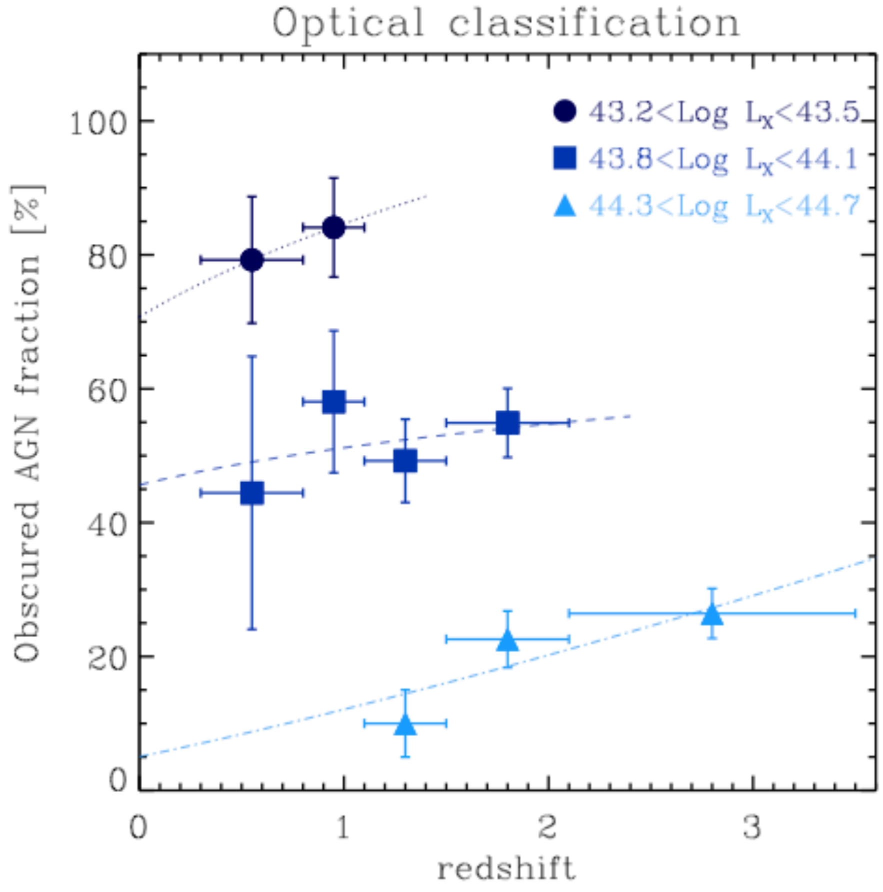




- 1310 X-ray selected AGN ($f_{lim} \sim$ **2×10^{-15}** erg/s/cm^2 [2-10 keV])
- Redshift information allows a 'clean' rest-frame selection based on the intrinsic (absorption corrected) X-ray flux

Optical Obscuration



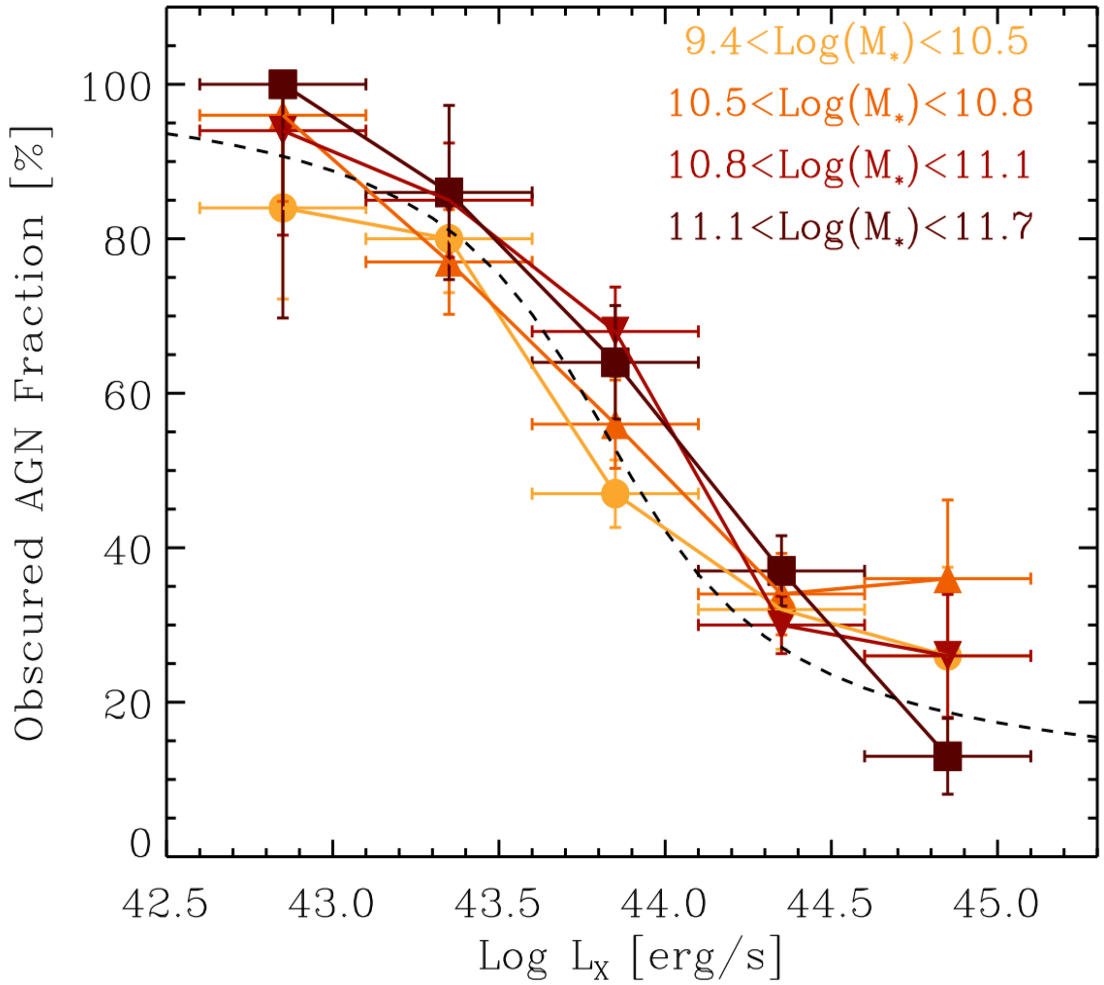


Merloni et al. 2013

7: The fraction of Optically obscured AGN depends on the nuclear luminosity, and on redshift only for the most luminous

Ueda+'03; Simpson'05; Maioliono'07

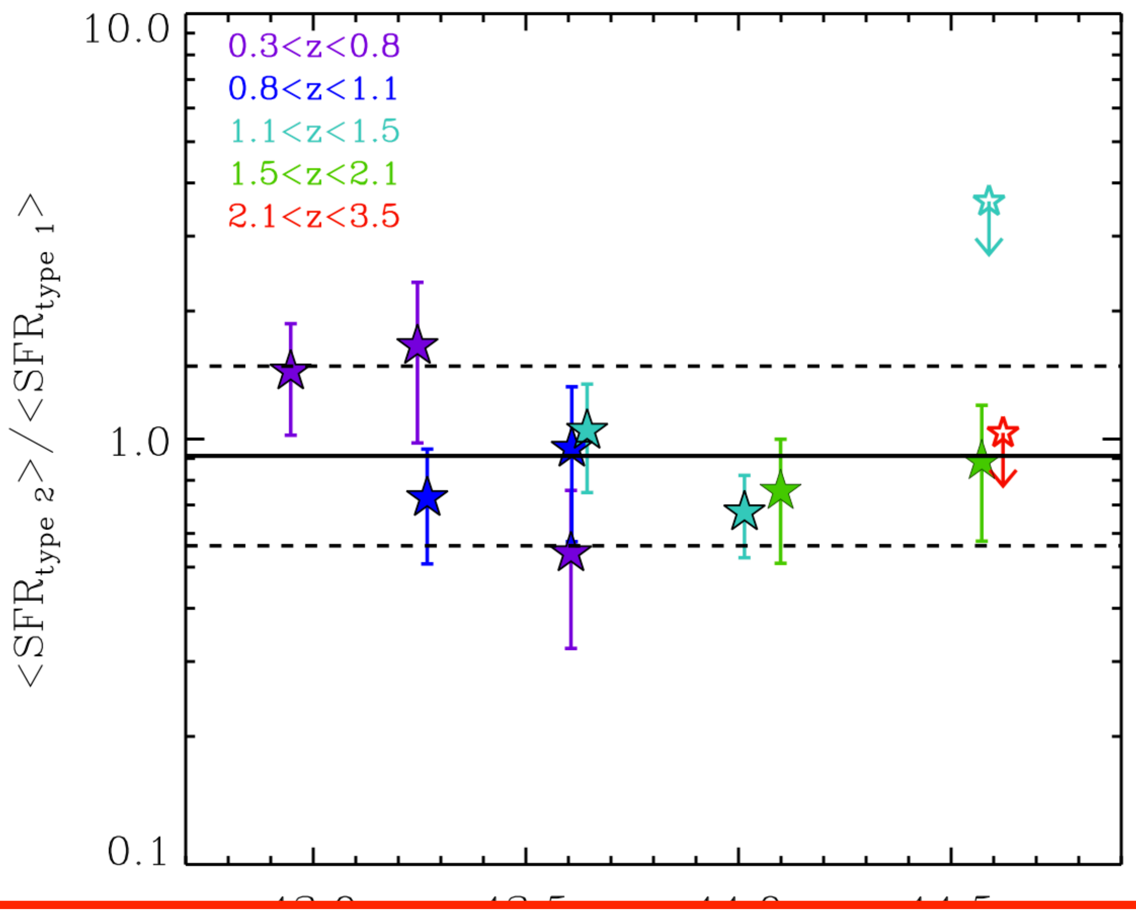
Optical Obscuration: no M_*-dependence



Merloni et al. 2013

8: The fraction of Optically obscured AGN does NOT depend on the host stellar mass

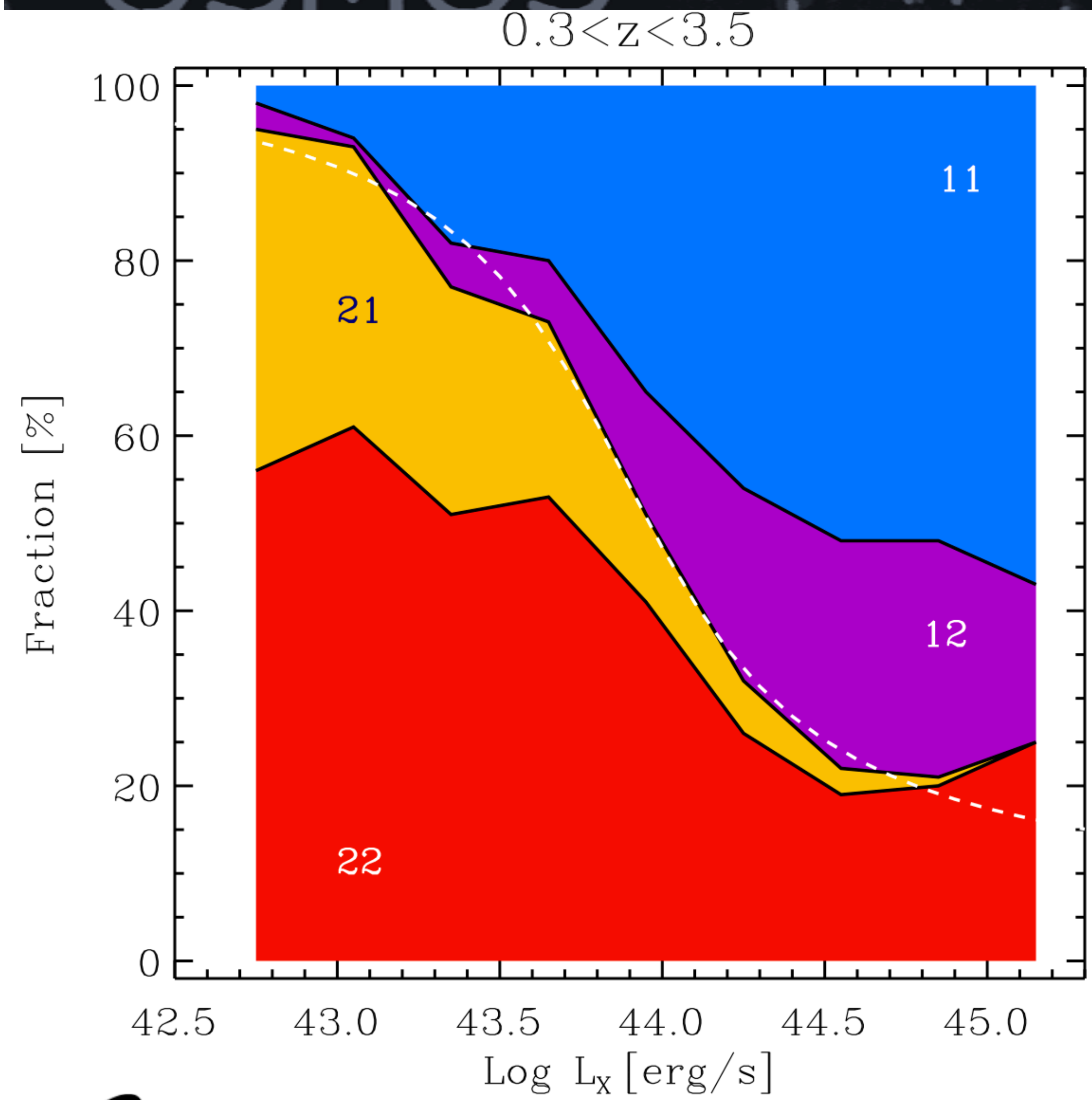
No link of AGN obscuration with SFR



9: The Galaxy-wide SFR of AGN hosts does not correlate with the properties of the obscuring medium Merloni et al. 2013

Lutz, Rosario, Santini, Magnelli, Berta, …

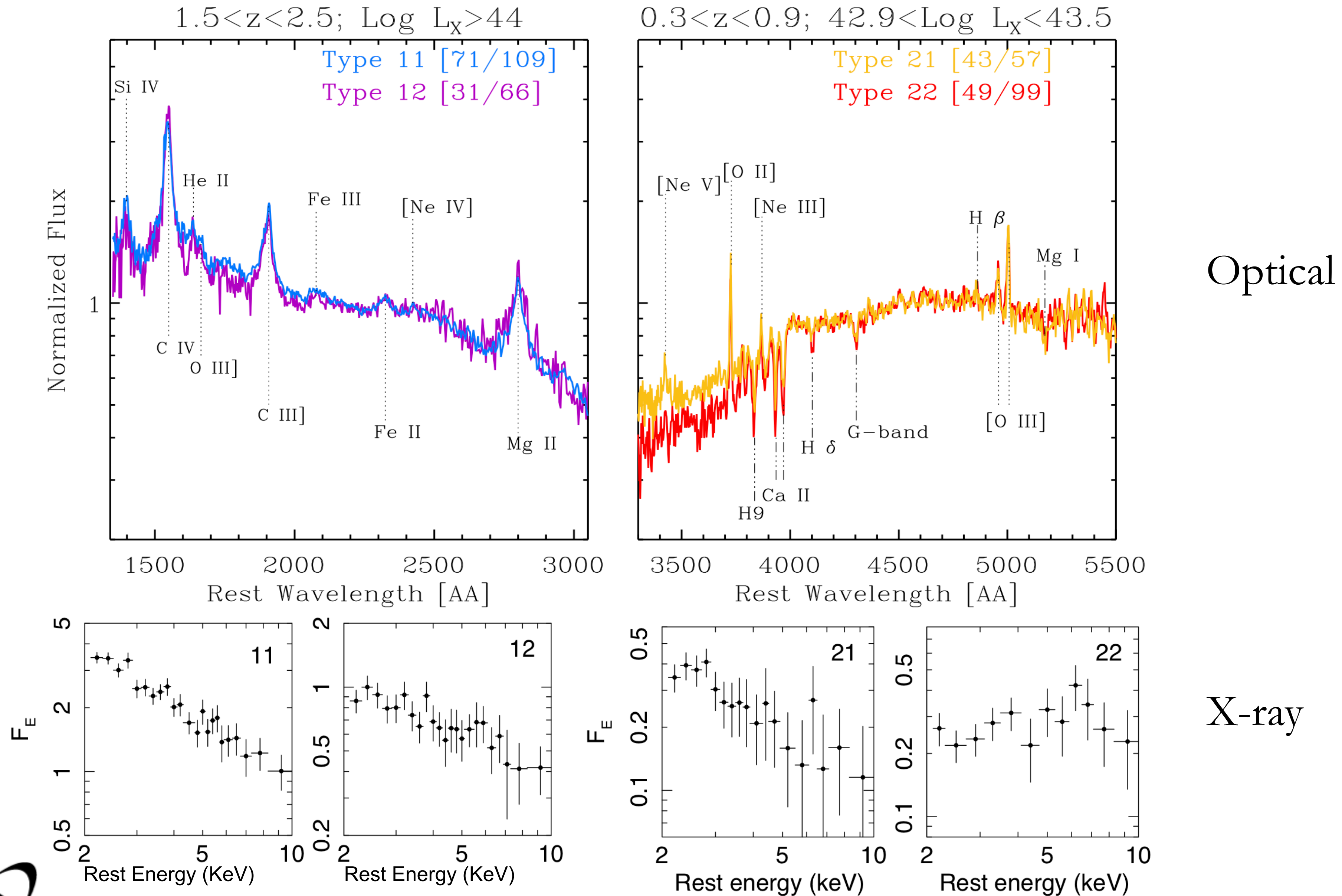
X-ray vs. Optical obscuration



Blue: X-ray & Optical type 1
Red: X-ray & Optical type 2
Yellow: X-ray type1, no BL
Purple: BLAGN, X-ray obscured

Merloni et al. 2013

Stacked rest-frame spectra



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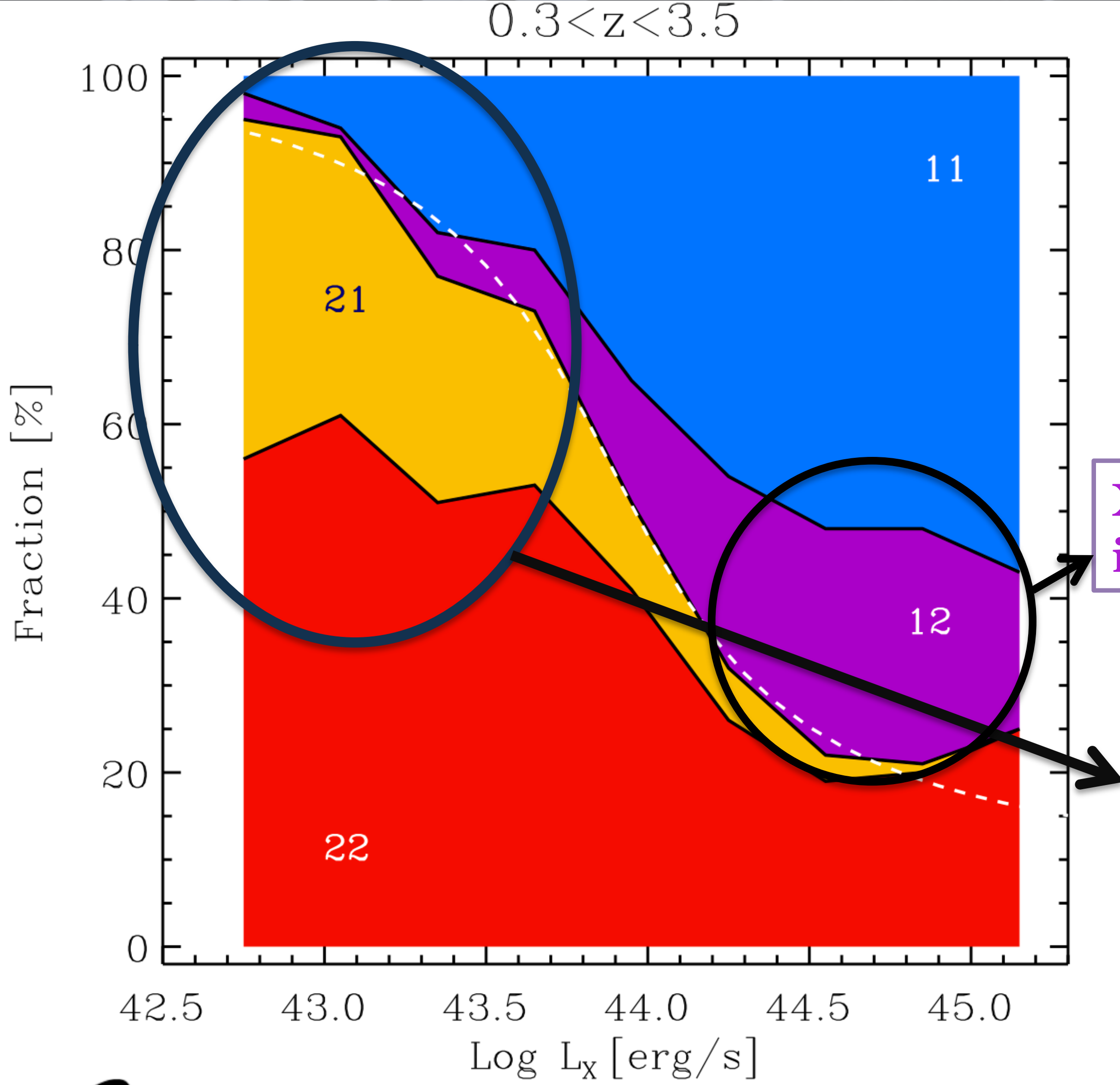

Blue: X-ray & Optical type 1
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Purple: BLAGN, X-ray obscured

X-ray absorber within, or inside BLR

Naked type 2 and/or BL diluted by galaxy light

Merloni et al. 2013

Summary

1. The probability of a galaxy to host an AGN growing at a given specific accretion rate is (almost) **independent of stellar mass**
2. Power-law distribution of Eddington ratios ➔ stochasticity of accretion
3. AGN fraction normalization increases **$\sim(1+z)^4$** [~sSFR density]
4. The AGN fraction distribution shows a break consistent with **Eddington limit**
5. Very little difference between (type 2) AGN hosts and parent sample in sSFR (once z and M_* factored out). **Where is AGN feedback smoking gun? ($t_{AGN} \ngtr t_{quench}$)**
6. Nuclear obscuration (AGN-gas interaction on pc scale) is clearly complex, and affected by the **AGN radiative output**, but not on any measured galaxy property (stellar mass or star formation rate)

Thank you