Obscured AGN and galaxy evolution

Fabrizio Fiore

Many thanks to
HELLAS2XMM, GOODS, COSMOS teams and in particular to
M. Brusa, A. Comastri, N. Menci

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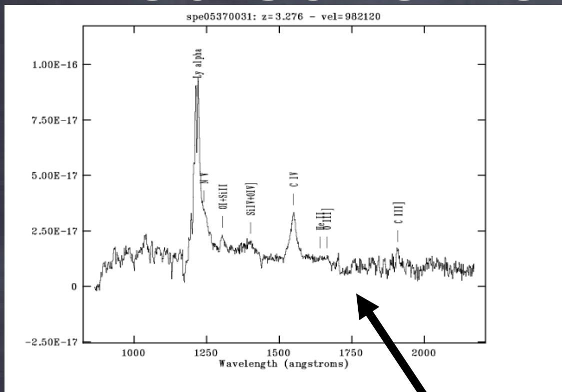
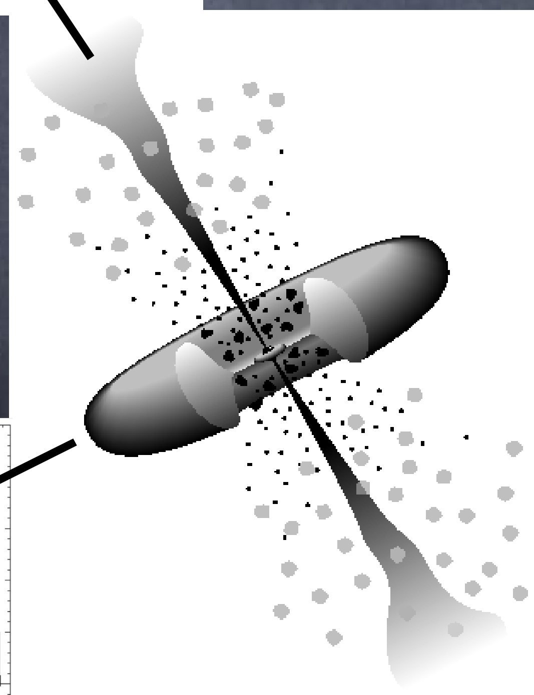
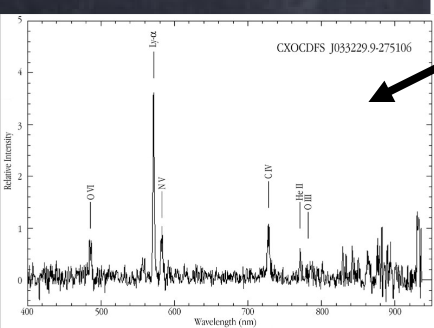
The two big scenarios

Unified schemes







Optical Spectrum of Distant Type II Quasar in Chandra Deep Field South (VLT ANTU + FORS1)

ESO PR Photo 09b/00 (13 March 2001)

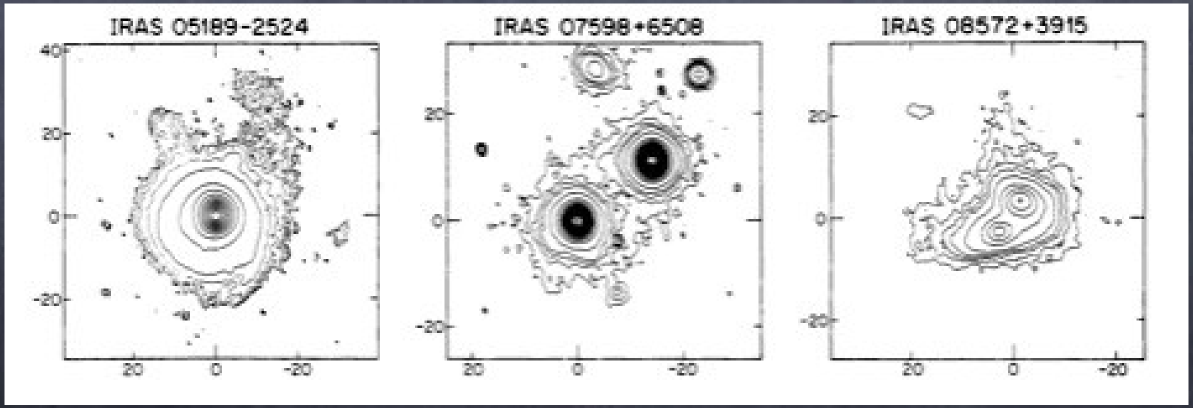
©European Southern Observatory

Evolutionary sequence

- **Early on**
- Strong galaxy interactions= violent star-bursts
- Heavily obscured QSOs
- **When galaxies coalesce**
- accretion peaks
- QSO becomes optically visible as AGN winds blow out gas.
- **Later times**
- SF & accretion quenched
- red spheroid, passive evolution

A (brief) history of obscured AGN

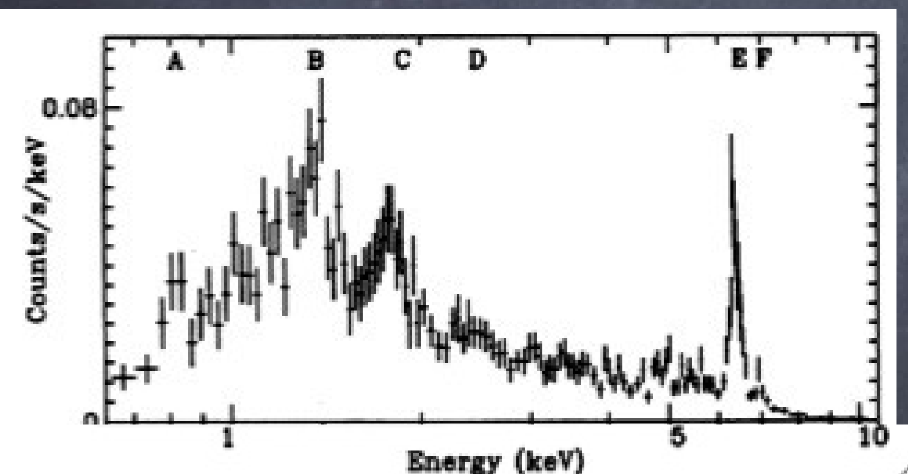
- Rowan-Robinson (1977) first unified scheme: “The distinction between type 1 and type 2 is caused by dust obscuration in the latter”.
- Antonucci, Miller + (mid 80’) spectropolarimetry of Seyfert and radio galaxies: geometrical unified schemes.
- Lawrence & Elvis (1982) Einstein. A first complication for unified schemes: obscuration is a function of AGN luminosity.
- Sanders + (end 80’) first ideas about an evolutionary sequence: “ULIRG: the transition from galaxy to quasar?”. First hints of a connection between galaxy activity and galaxy interaction (environment/nurture vs. nature).



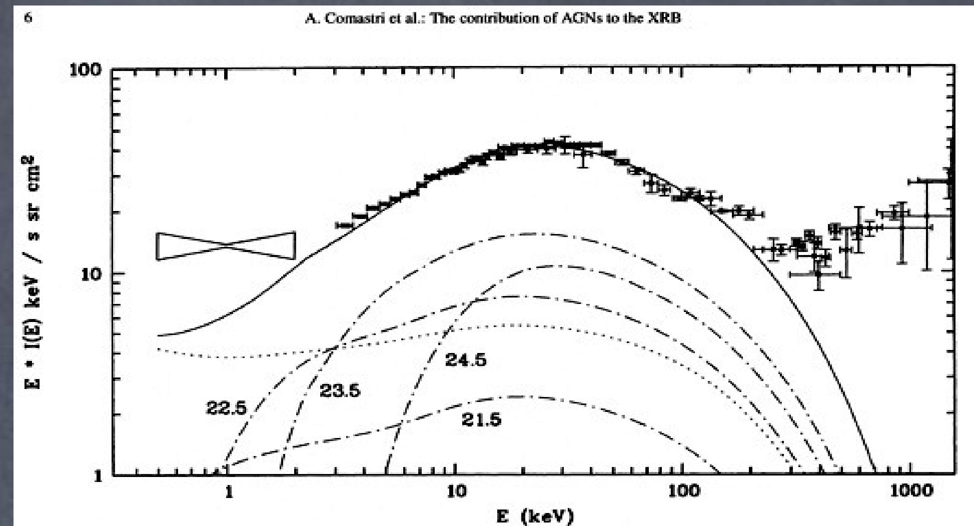
- Koyama, Awaki + (end 80’) Ginga. X-ray obscuration is common in Sy2 galaxies.
- Setti & Woltjer (1989) Use above results to explain CXB in terms of obscured AGN.
- Maiolino & Rieke (1995) Sy2/Sy1=4.

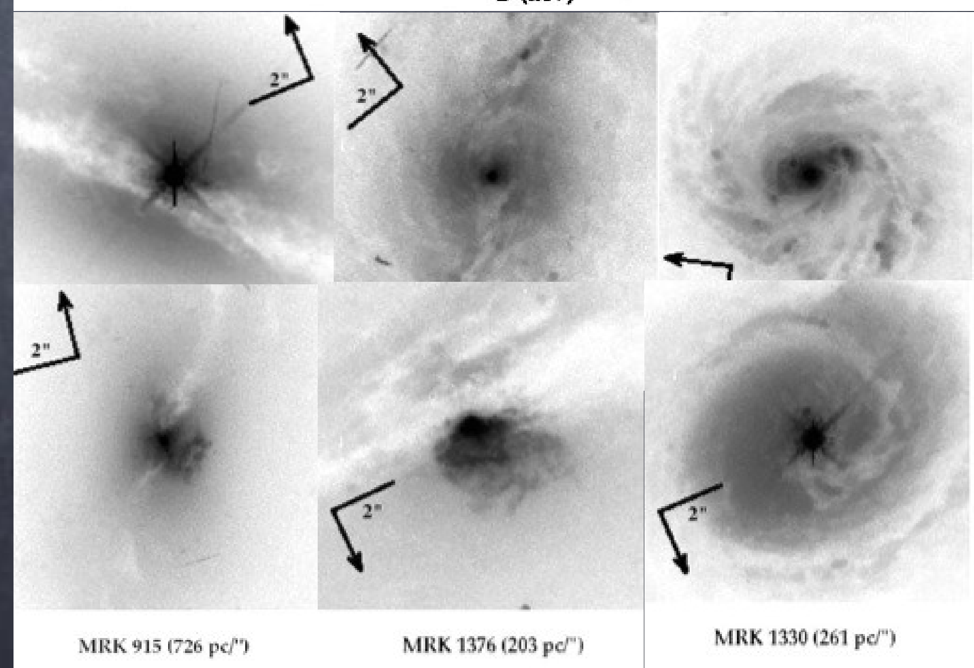
A (brief) history of obscured AGN

- Comastri + (1995) Use unified schemes + Sy2/Sy1=4 + ROSAT LF to make the first AGN synthesis models of the CXB
- Matt, FF + (1996) ASCA. Reflection spectrum from Circinus galaxy, I.e. Compton thick absorber.



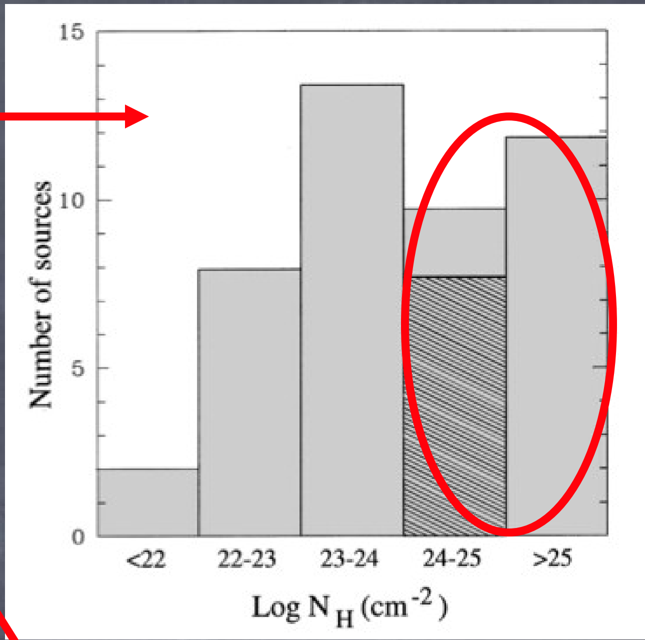
- Malkan + (1998) Dust lanes very common in galaxies. Matt (2000) these can be likely sites of obscuration.

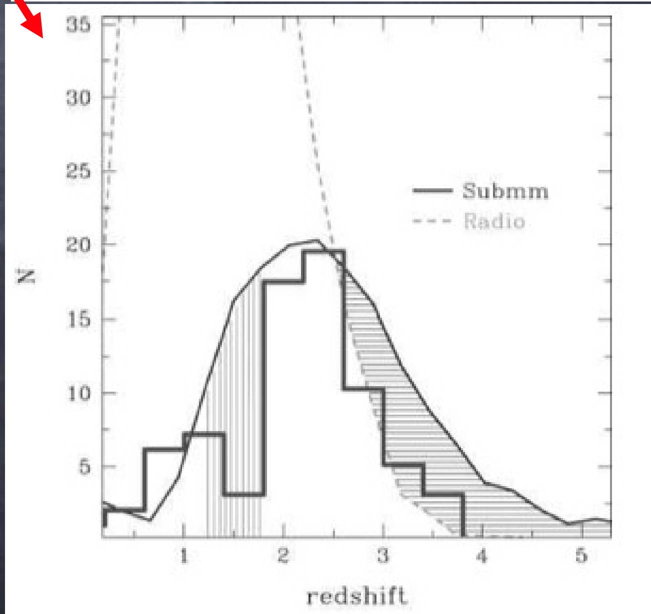




A (brief) history of obscured AGN

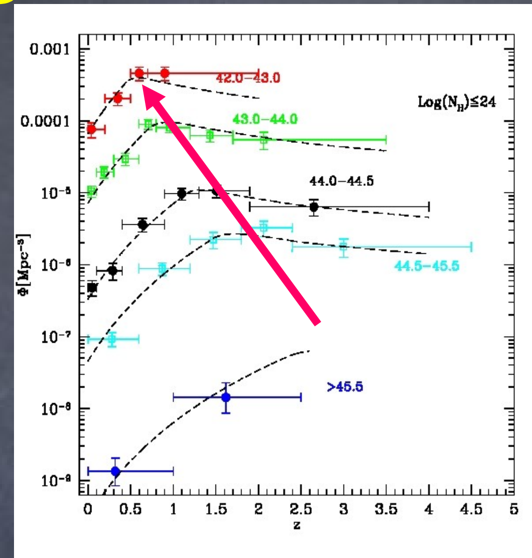
- Risaliti, Maiolino (1999) BSAX. NH distribution of Sy2 including Compton thick objects.
- Smail, Chapman + (end 90') discovery and identification of submm galaxies SMG: Dust enshrouded star-forming galaxies at z~2.
- Ferrarese+ Magorrian+ (end 90') BH in local bulges, tight correlations MBH-Bulge properties
- Silk & Rees (1998), Fabian (1999) first ideas/models for the formation of bulge+BH. Key ingredient is an AGN wind, which "terminates the growth of both BH and galaxy". "The BH obscured growth phase is a distinct phase (from "revived" Sy-like galaxies in the local Universe), not yet observed".
- FF+Akiyama+ (end 90') BSAX, ASCA. First identifications of large fraction of obscured AGN at z=0.2-1 in hard X-ray surveys.
- Giacconi+ Hasinger+ Brandt+ (2000-2003) Chandra/ XMM deep surveys. Large population of obscured AGN up to z=2-3.

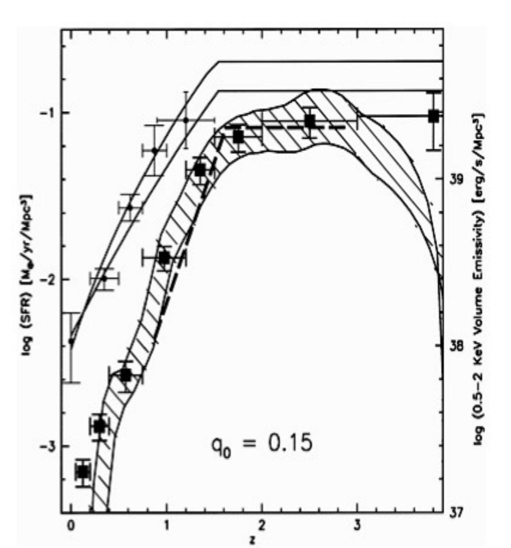


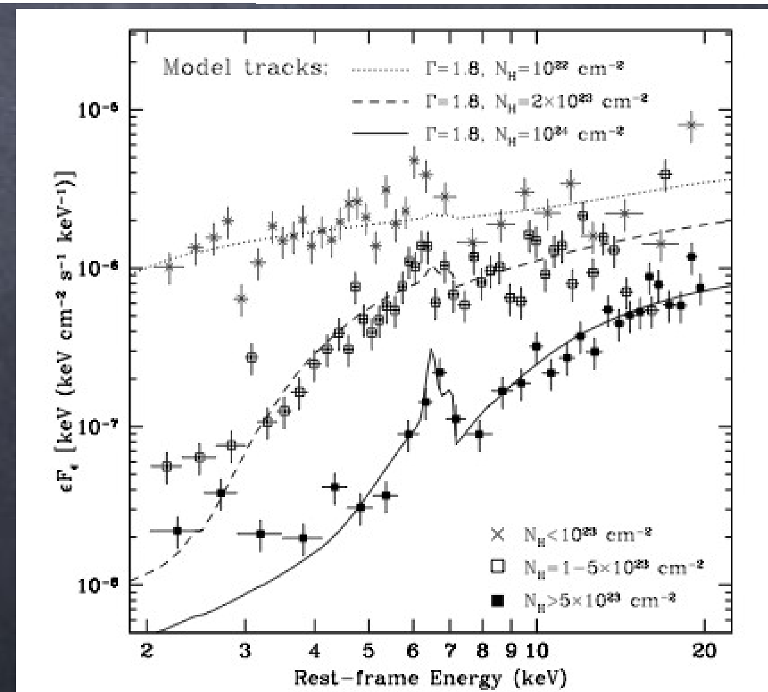


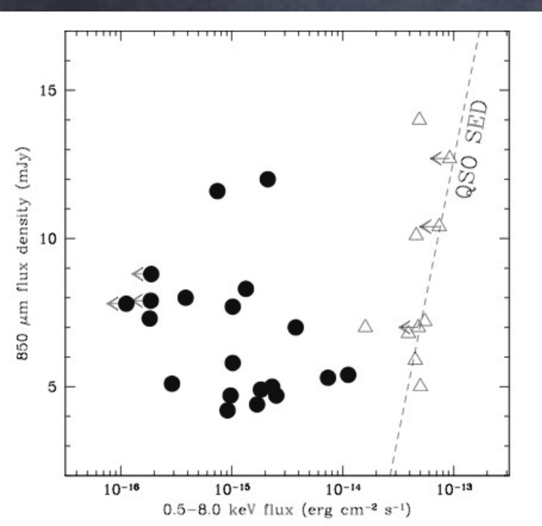
A (brief) history of obscured AGN

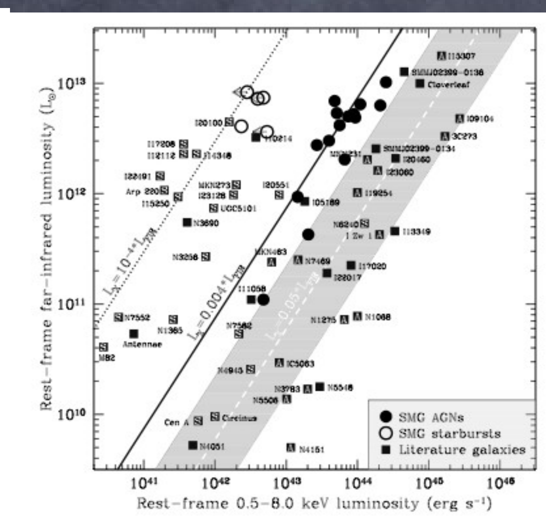
- Ueda+, FF+, Cowie+, LaFranca+ Hasinger+ (2003-2005) AGN X-ray "Downsizing" (Franceschini+ 1999). First luminosity functions of obscured AGN. Obscuration is a function of luminosity (and redshift).
- Alexander+ (2005) Most radio identified SMG host X-ray and optically obscured AGN. Their bolometric luminosity is dominated by star-formation. First strong observational link between AGN obscuration and starformation.





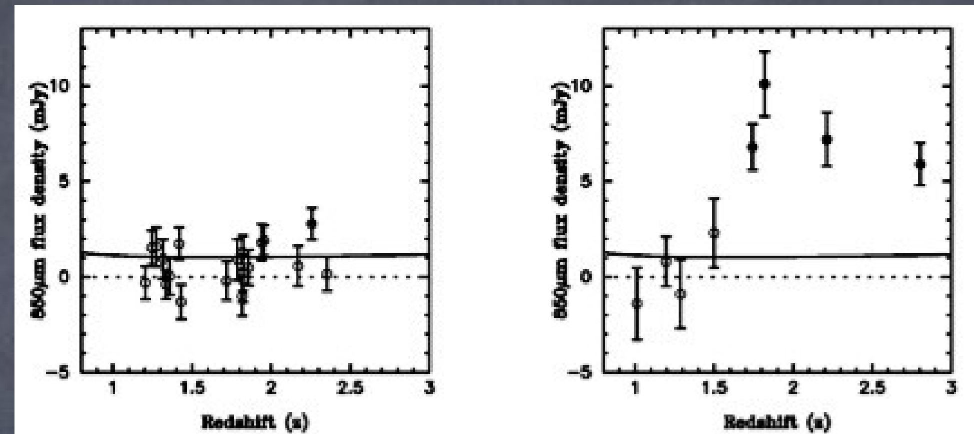


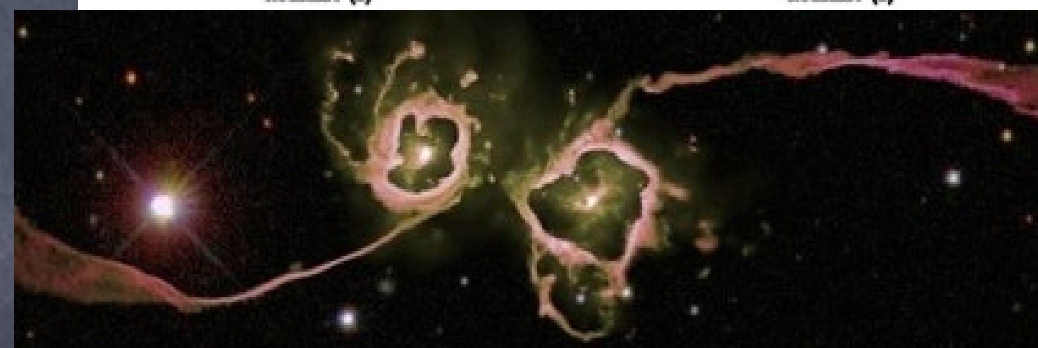


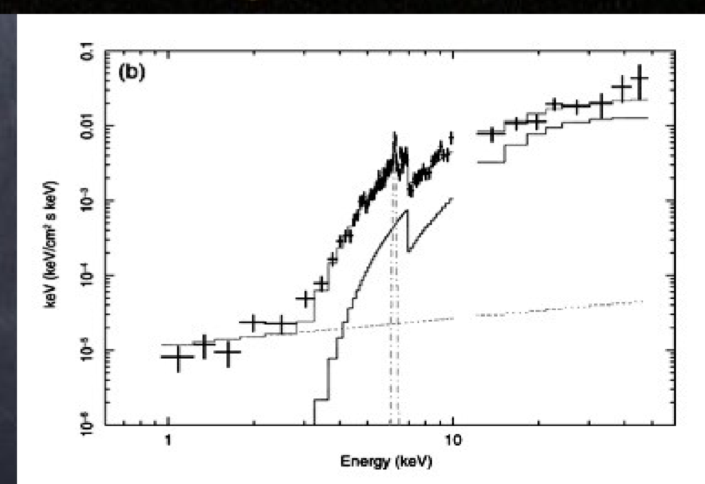


A (brief) history of obscured AGN

- Page+ (2000-2005) submm observations of AGN. Obscured AGN are systematically brighter than coeval unobscured AGN. “The evolutionary sequence of AGN and galaxy formation revealed”.
- Granato+, Menci+ Di Matteo+ (2004-2006) Physical models for the coevolution of AGNs and their host galaxies.
- Many (2004-) Spitzer. Selection and identification of large samples of highly obscured, Compton thick AGN using infrared photometry and infrared spectroscopy.
- Ueda+, de Rosa+ (2007,2008) Identification and spectroscopy of Swift BAT and INTEGRAL highly obscured AGN.



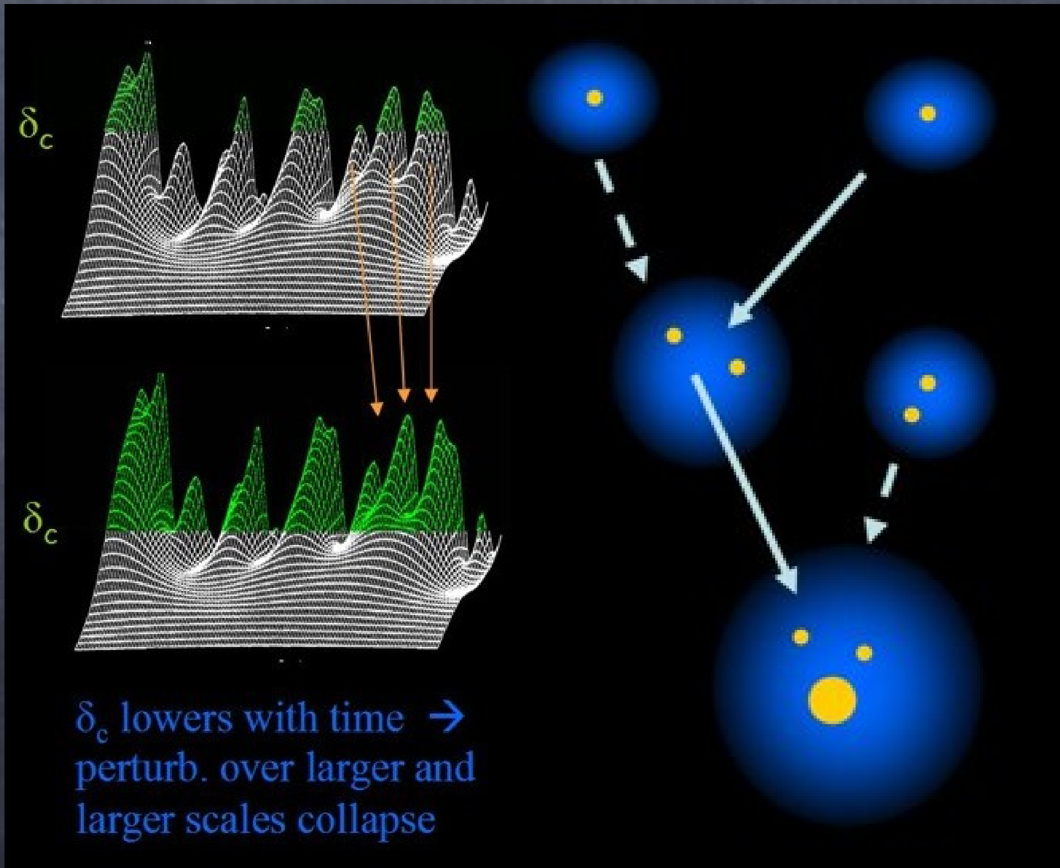




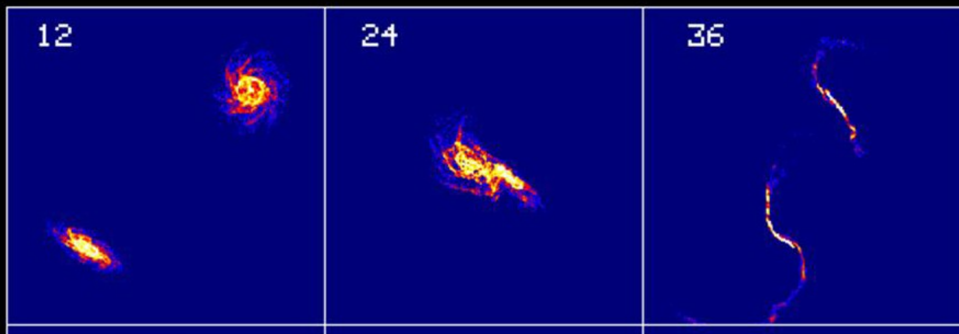
A semi-analytic model for the AGN-galaxy co-evolution

… which naturally leads to an evolutionary sequence

- Three main ingredients:
- § Hierarchical merging of DM haloes and of substructures: higher density perturbation collapse first, larger scale perturbation collapse later.
- § Galaxy interactions to fuel both Star-formation and AGN (Cavaliere & Vittorini 2000)
- § A physical model for AGN feedback (Cavaliere, Lapi, Menci 2005)



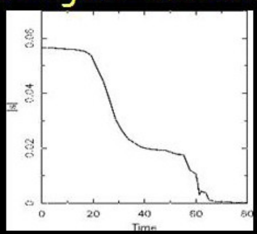
Galaxy encounters



Mihos & Hernquist 1996
See also Noguchi 1987
Barnes & Hernquist 1991

"'tidal forces during encounters cause otherwise stable disks to develop bars, and the gas in such barred disks, subjected to strong gravitational torques, flows toward the central regions "

Gas Angular Momentum



Part of the available galactic cold gas is detabilized and funnelled toward the centre

$$f(v,V) = \frac{1}{2}\left|\frac{\Delta j}{j}\right| \approx \frac{1}{2}\left\langle\frac{m' r_d v_d}{mbV}\right\rangle$$

Cavaliere Vittorini 2000

(Sanders & Mirabel 96)

This occurs at a rate:

$$\tau^{-1}_{FlyBy} \propto n\,(\pi\, r^2_{tidal})\,V_{rel}$$

It is averaged over all merging partners (m') in the same group/cluster (with relat. velocity V) at impact param. b. These quantities + the cold available gas mcold are obtained from the SAM (NM et al. 2002)

1/4 feeds the central BH

QSO Properties

$$\dot{m}_{acc}(v,t) = \frac{1}{4}\left\langle\frac{f\, m_{cold}}{\tau_r}\right\rangle$$

$$L(v,t) = \frac{\eta c^2 \Delta m_{acc}}{\tau}$$

$$m_{BH} = (1-\eta)\int_0^t \dot{m}_{acc}(v,t')\,dt'$$

3/4 feeds circumnuclear starbursts

Starbursts Properties

$$\Delta\dot{m}_*(v,t) = \frac{3}{4}\left\langle\frac{f\, m_{cold}}{\tau_r}\right\rangle$$

$$\Delta S_\lambda = \int_0^t \Delta\dot{m}_*(t-t')\,\Phi_\lambda(t')\,dt'$$

The rapid decrease at z<2.5 is due to 3 concurring factors

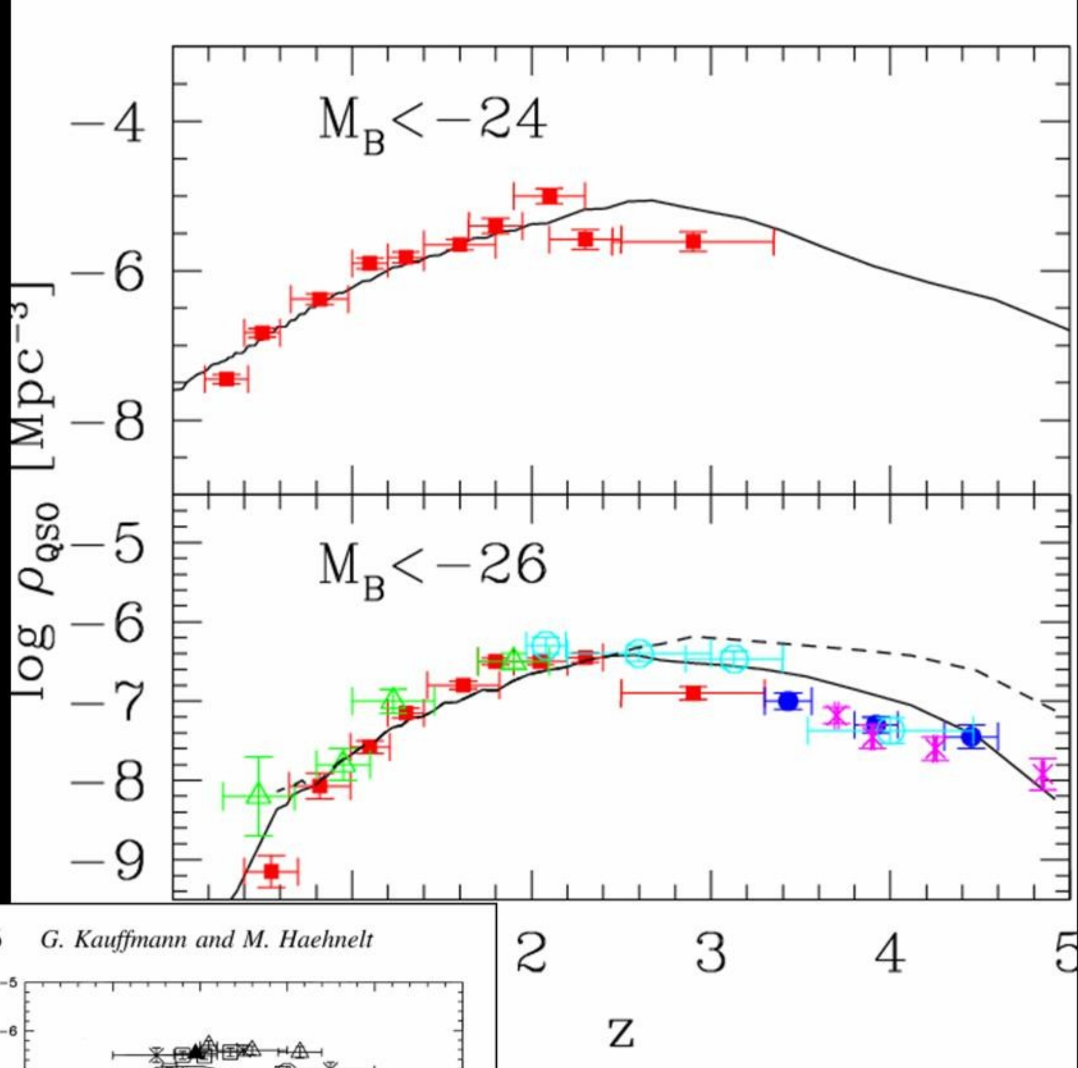
1) The decrease with time of the merging rate of galaxies

2) The decrease with time of the galactic cold gas left available for accretion

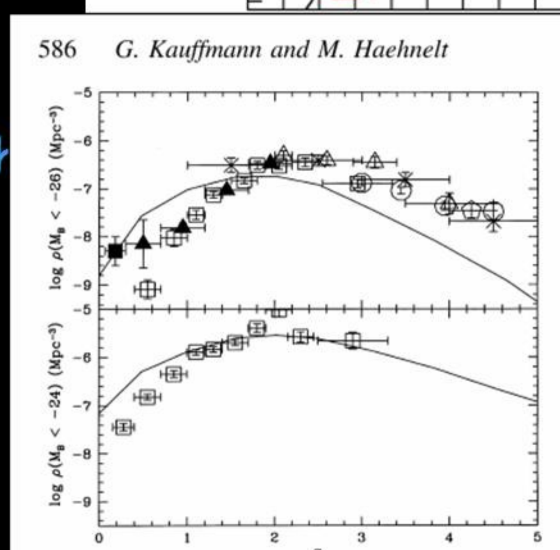
3) The decrease with time of the encounter rate stimulating the cold gas funneling toward the nucleus

Previous works adopting SAMs treated the accreted fraction f as a free parameter constant wit[h]

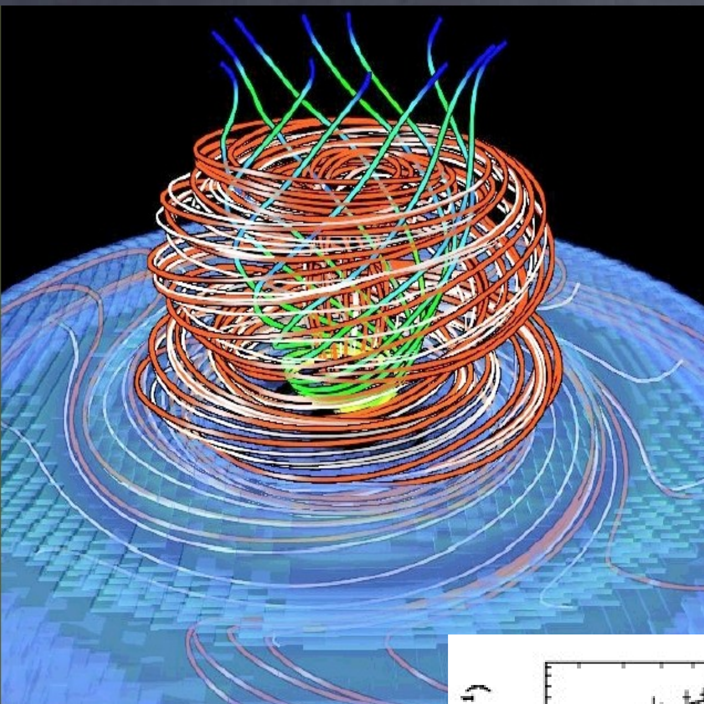
Missed process #3

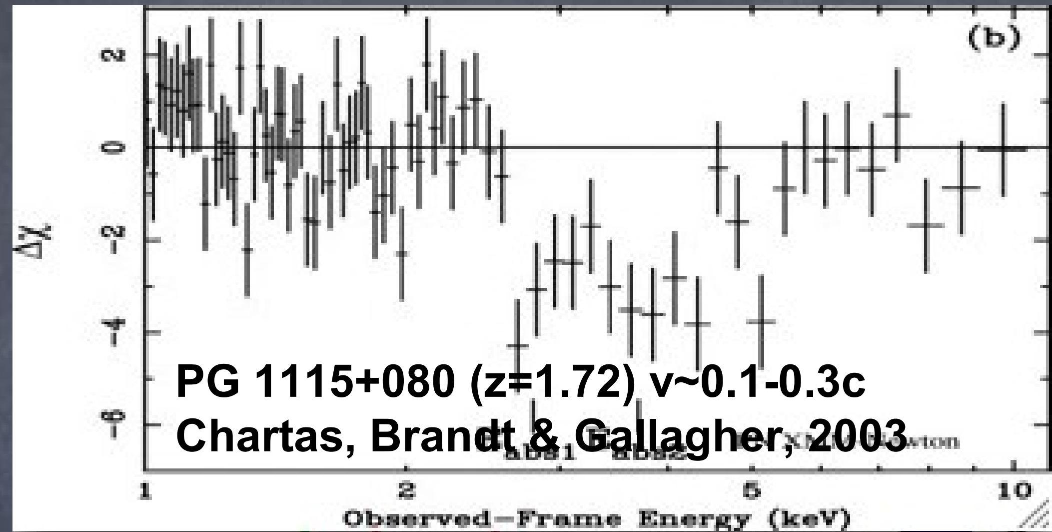


[1]990, Warren, Hewitt, Osmer 1994,
[Ki]yle et al 2000, Fan et al 2001

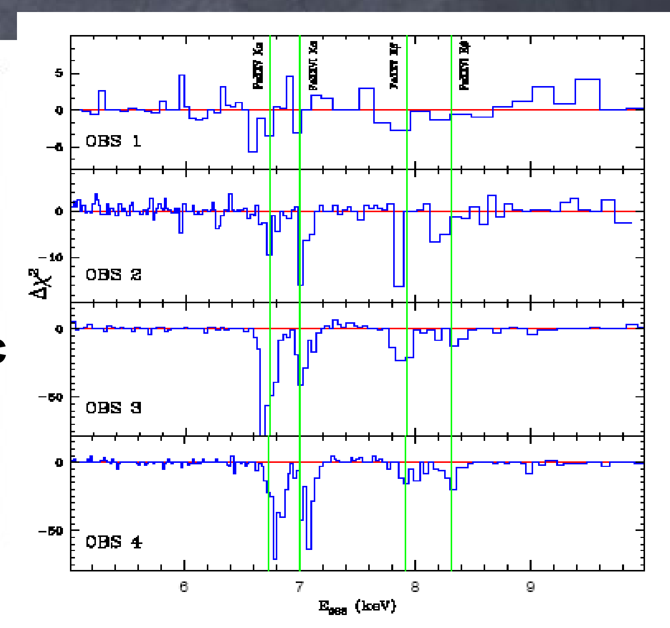


AGN feedback





NGC1365 Risaliti et al. 2005



Fast winds with ve
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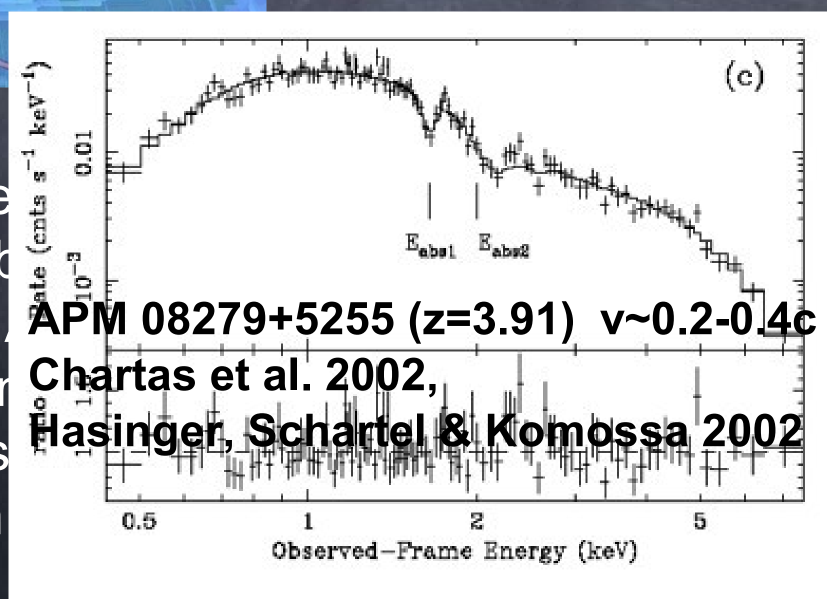
central regions of
likely originate fro
acceleration of dis
the AGN radiation



AGN Feedback & AGN accretion mode

- Quasar mode
  - Major mergers
  - Minor mergers
  - Galaxy encounters
  - Activity periods are strong, short and recurrent
- AGN density decrease at $z<2$ is due to:
  - decrease with time of galaxy merging rate
  - Decrease with time of encounters rate
  - Decrease with time of galactic cold gas left available for accretion
- Feedback is driven by AGN radiation

Menci et al. 2003 2004 2006 2008

- Radio mode
- Low accretion-rate systems tend to be radiatively inefficient and jet-dominated
- Feedback from low luminosity AGN dominated by kinetic energy
- Low level activity can be ~continuous

Croton 2006

AGN feedback & AGN obscuration

Lapi Cavaliere & Menci 2005 ***Blast wave model:*** a way to solve the problem of the transport of energy: central highly supersonic outflows compress the gas into a blast wave terminated by a shock front, which moves outwards at supersonic speed and sweeps out the surrounding medium

Measure of AGN obscuration can be an observational constraint of feedback models "in action"

$$R_S(t) \propto Mt \propto \left(\frac{\Delta E}{E}\right)^{1/2} t$$

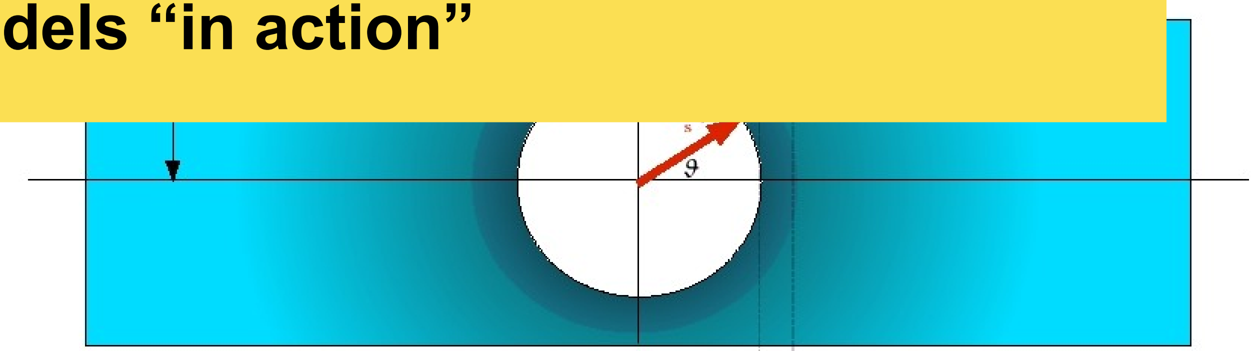
$$M \sim \left(\frac{\Delta E}{E}\right)^{1/2}$$

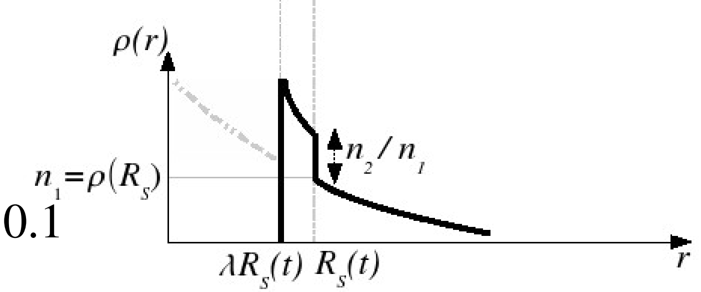
$$\Delta E = \varepsilon L \tau$$

$$\varepsilon \sim \frac{v_w}{2c} \sim 0.05 \text{ if } v_w \sim 0.1$$

$$\tau = \text{ timescale of AGN activity } = \frac{\mathrm{r_d}}{\mathrm{v_d}} = 10^7 - 10^8\, yr$$

$$L = \frac{\eta c^2 \Delta m_{acc}}{\tau} \quad \eta = \text{efficiency of conv. of mass in rad. } \sim 0.1$$

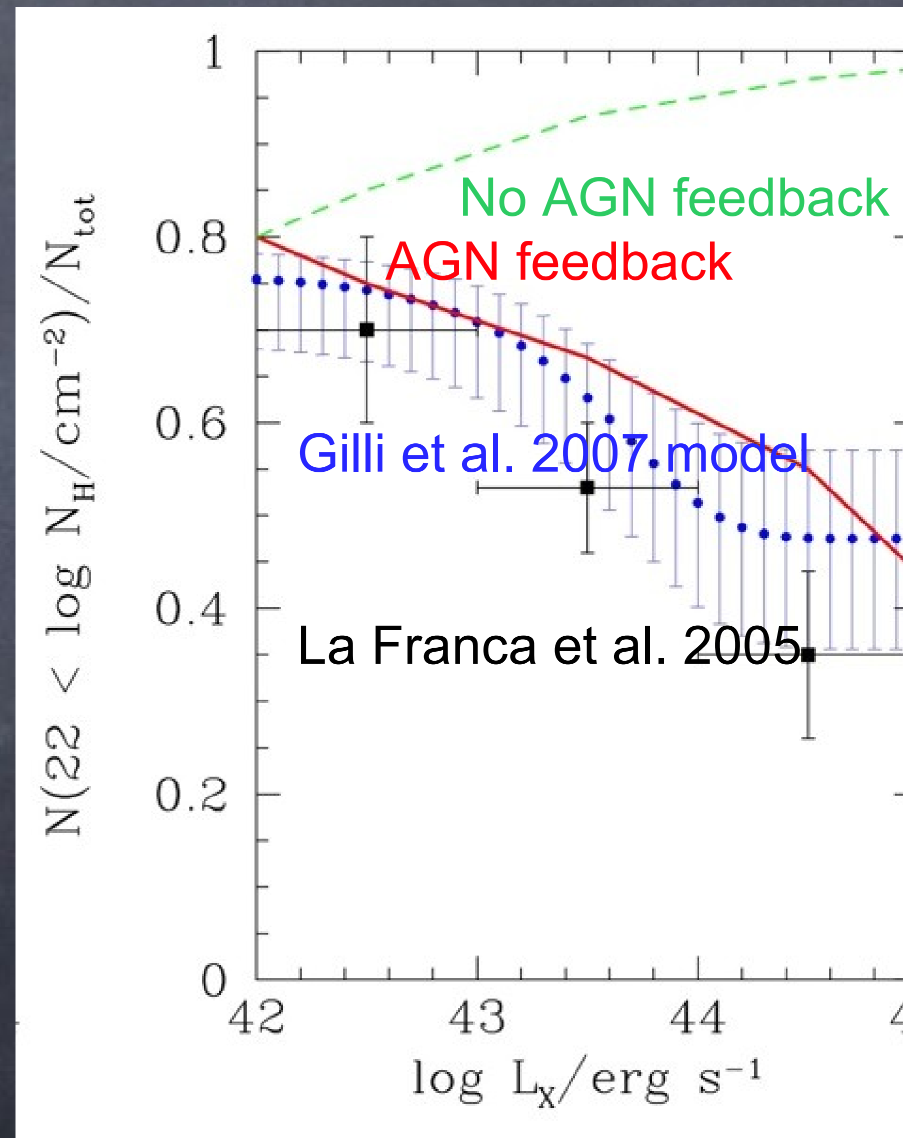


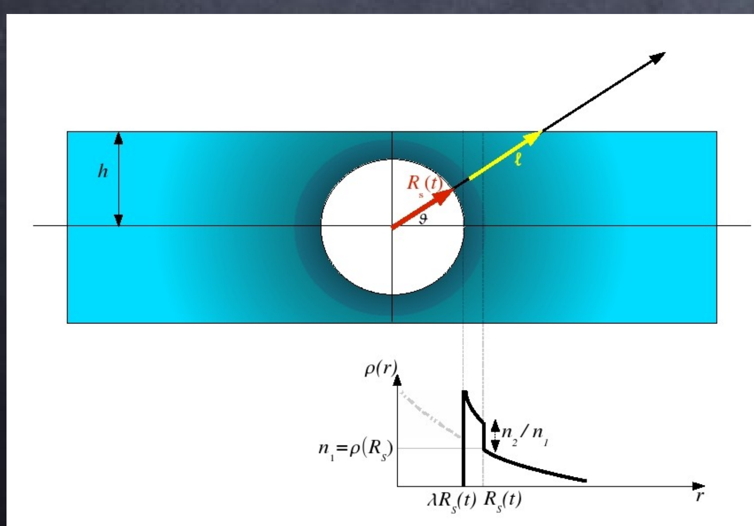


Fraction of obscured AGN

Powerful AGN clean their sight-lines more rapidly than low luminosity AGN, and therefore the fraction of obscured AGN can be viewed as a ***measure of the timescale over which the nuclear feedback is at work.***

Menci, FF et al. 2008



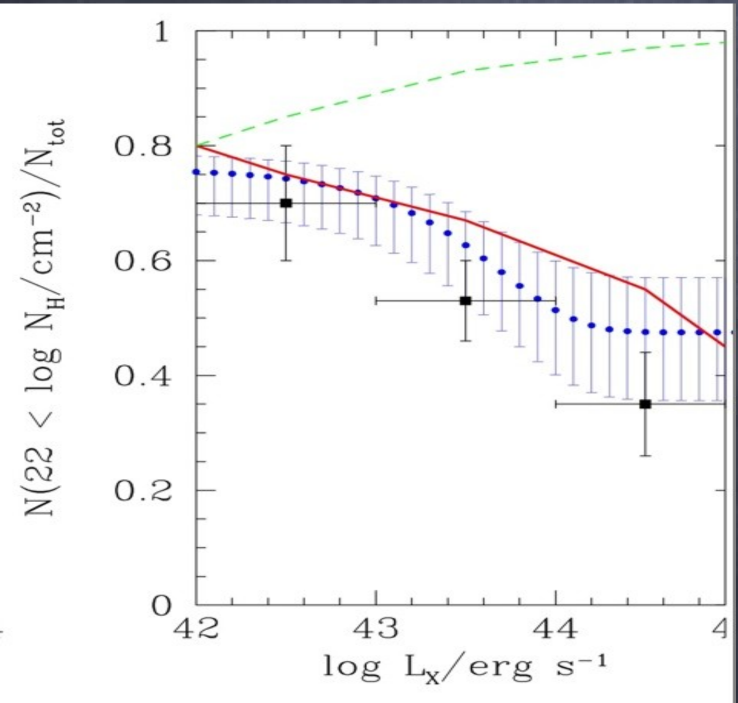


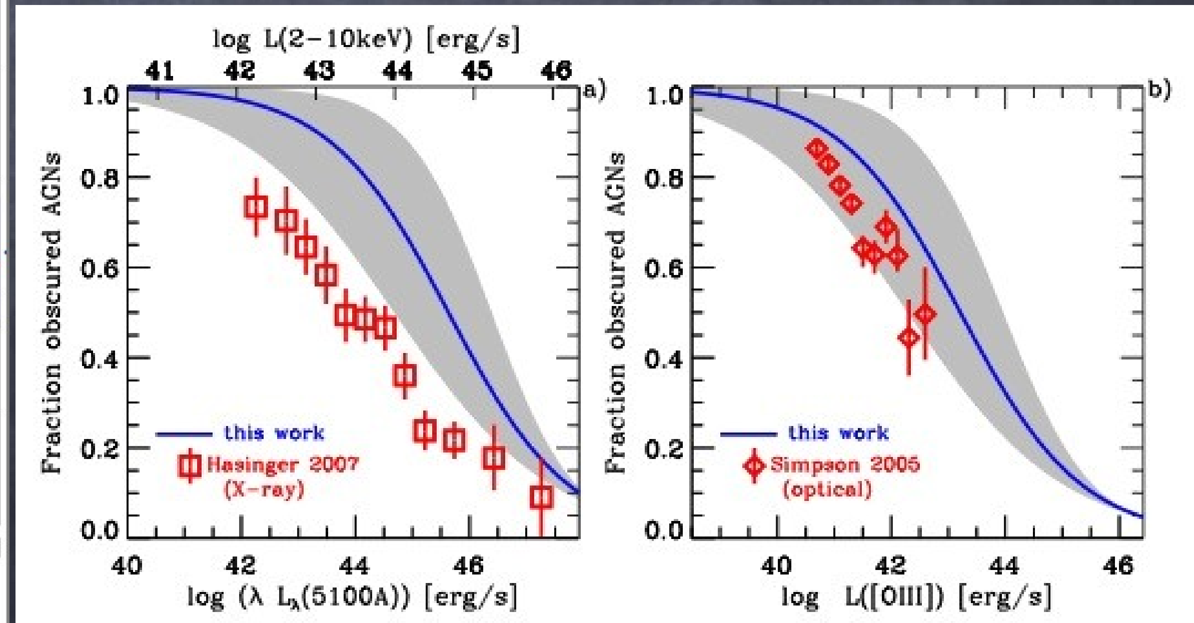
Fraction of obscured AGN

- **Consistent with:**
  - **La Franca+ 2005, Hasinger 2008 (X-ray selected AGN)**
  - **Maiolino+ 2007 (luminosity dependent covering factor in unobscured AGN**

Previous "geometrical" explanations:
- The receding torus (Lawrence 1991)
- BH potential (Lamastra+ 2006)

Menci+ 08 SAM already includes orientation effects. BH potential effect to be included soon.

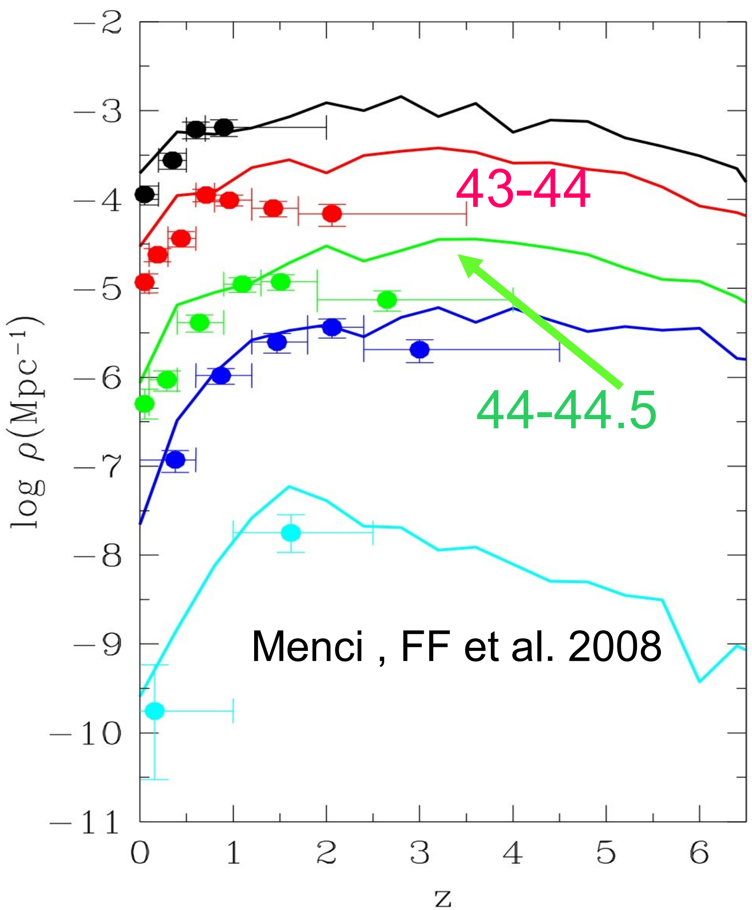




SAM Prediction:

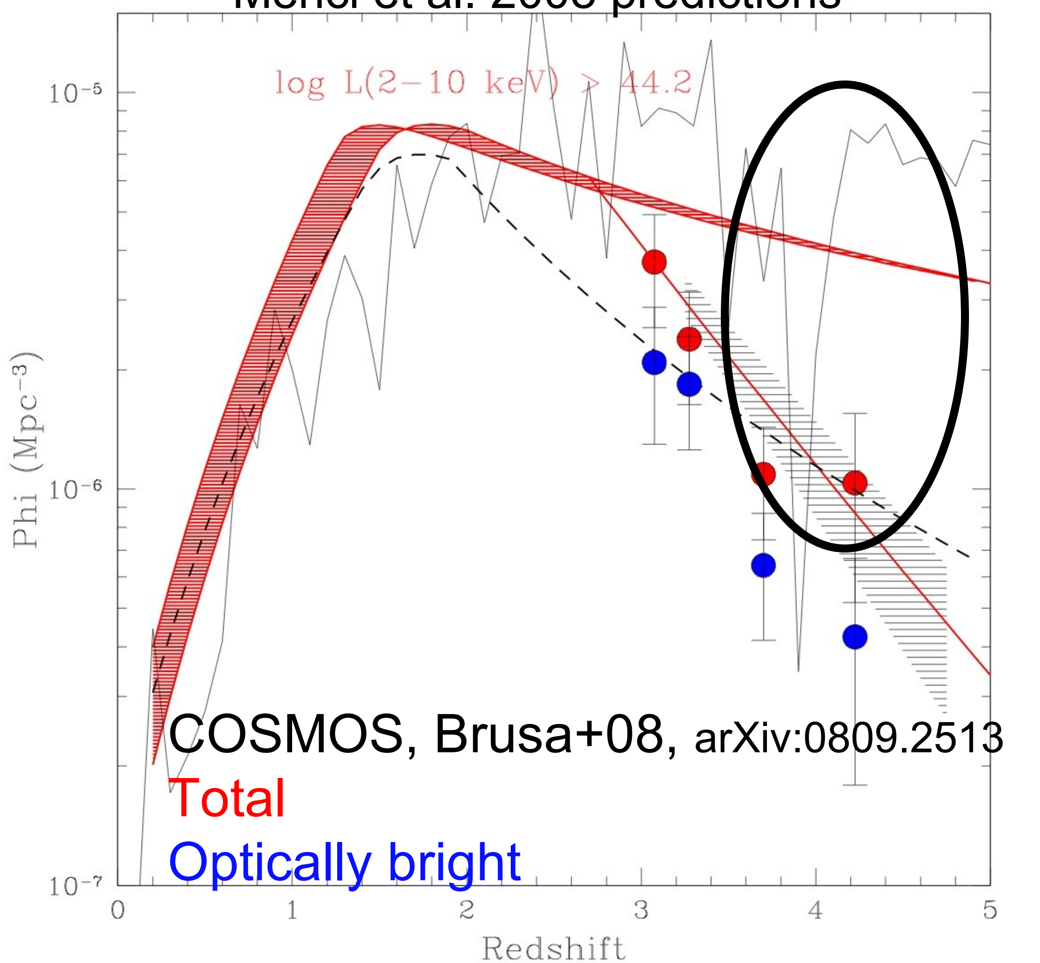
Flat number density of AGN with z.

Lots of LX=43-45 AGN at z>3. Are they Compton thick?



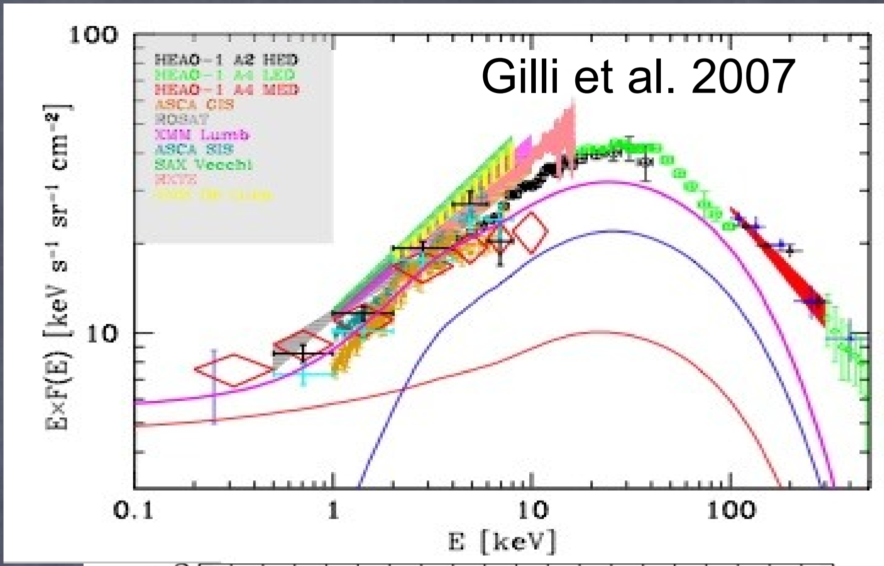
Adapted from La Franca et al. 2005

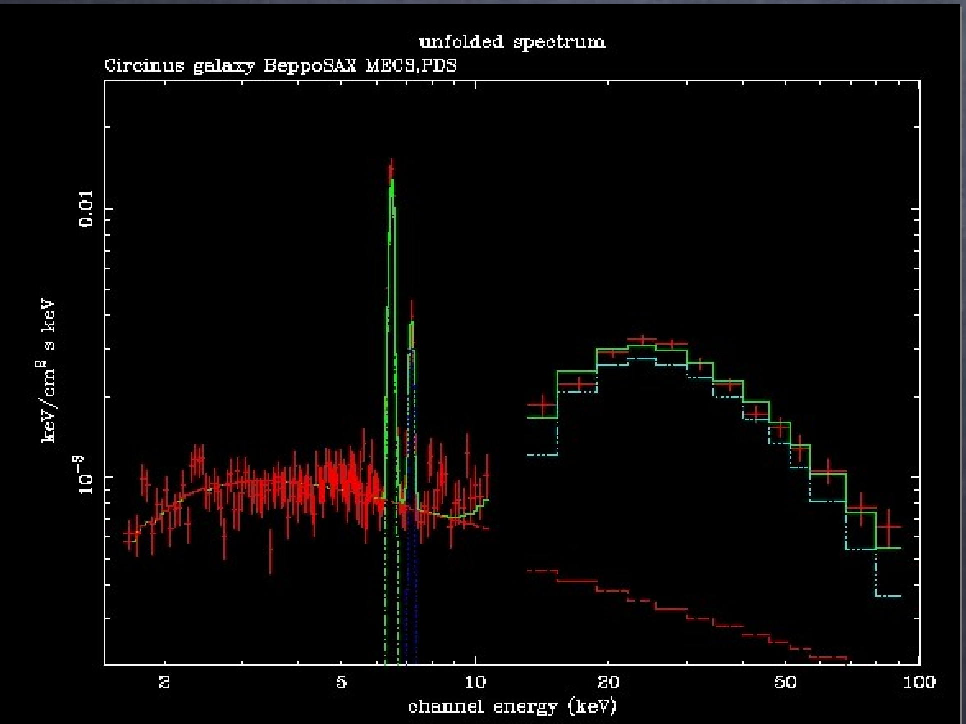
Menci et al. 2008 predictions

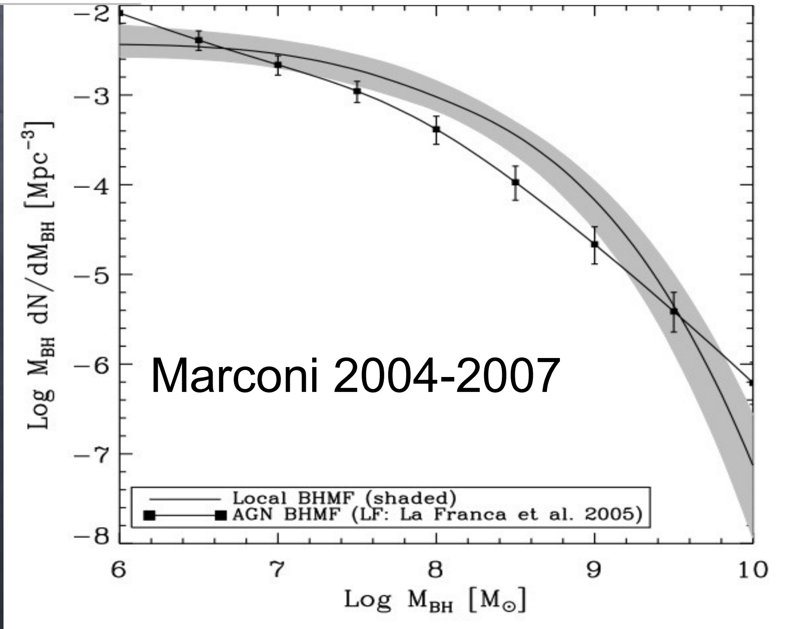


Missing BH

- Other strong evidences for missing SMBH
- Complete SMBH census needed, including CT AGN

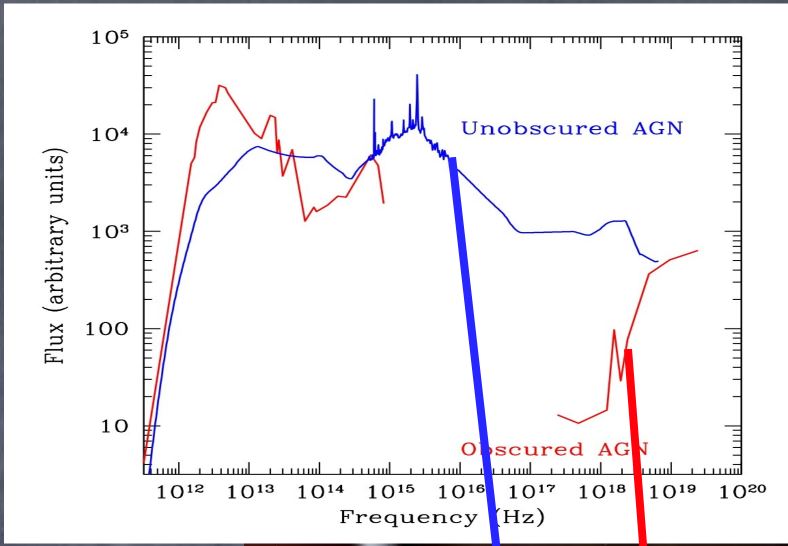


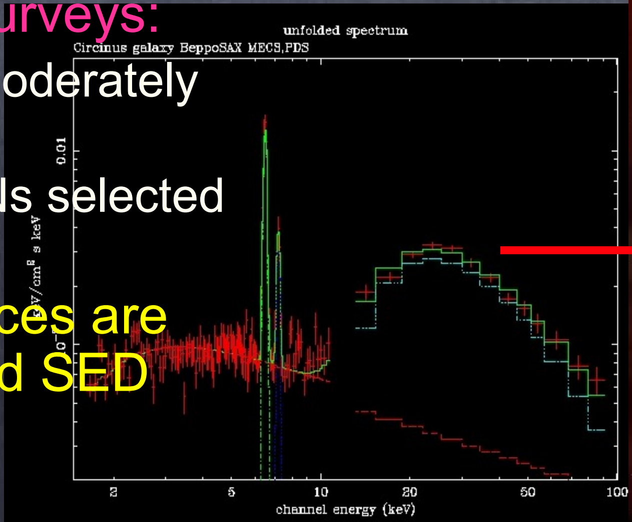


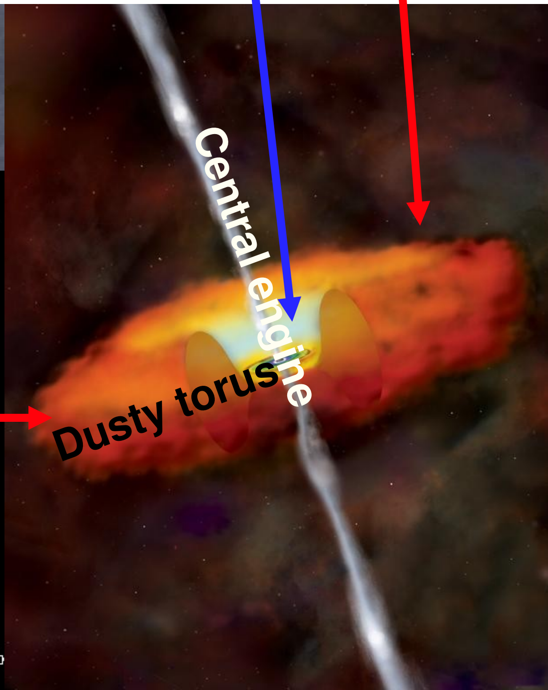


Completing the census of SMBH

- X-ray surveys:
  - very efficient in selecting unobscured and moderately obscured AGN
  - Miss most highly obscured AGN
- IR surveys:
  - AGNs highly obscured at optical and X-ray wavelengths shine in the MIR thanks to the reprocessing of the nuclear radiation by dust
- Use both X-ray and MIR surveys:
  - Select unobscured and moderately obscured AGN in X-rays
  - Add highly obscured AGNs selected in the MIR
- Simple approach: Differences are emphasized in a wide-band SED analysis

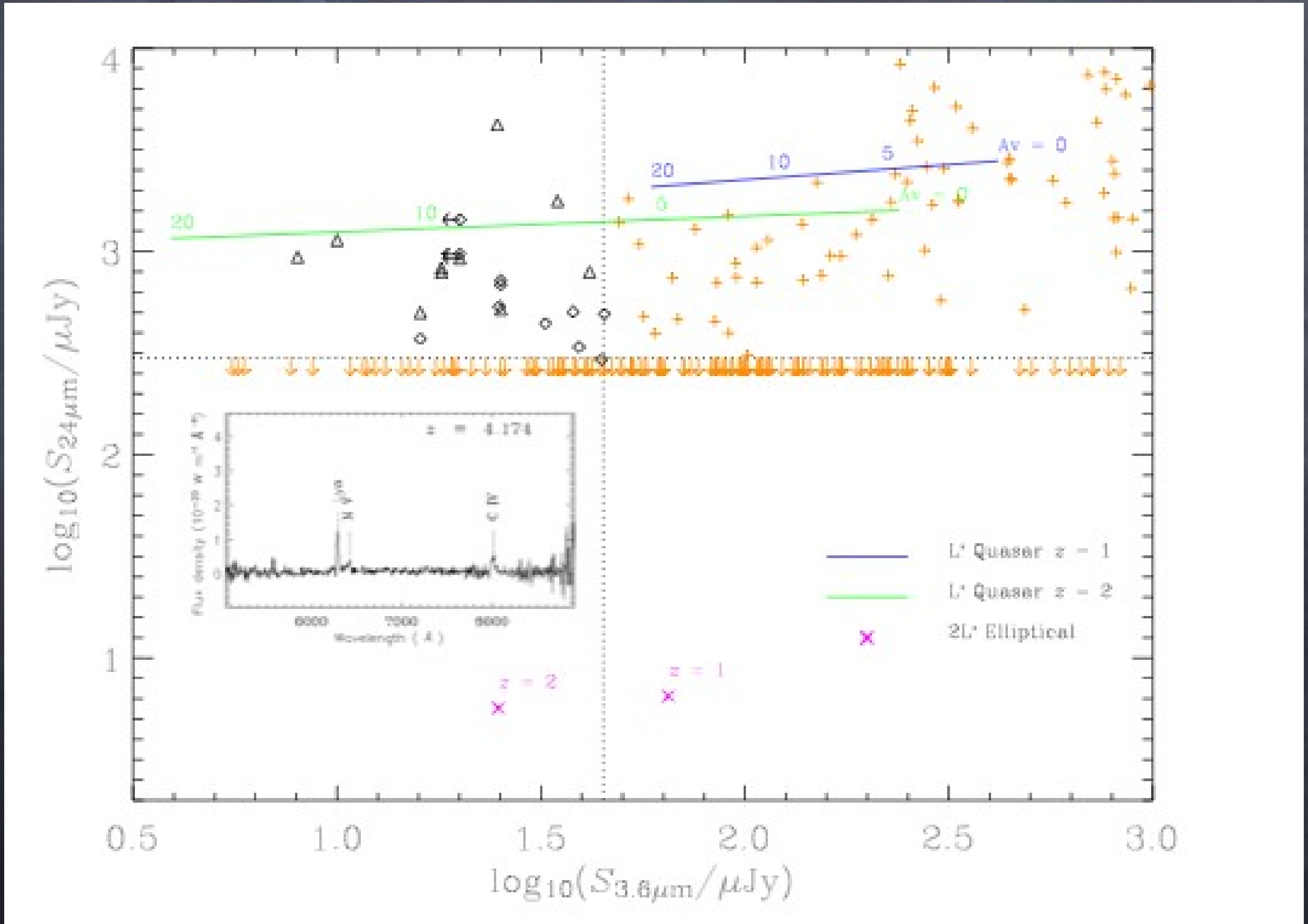




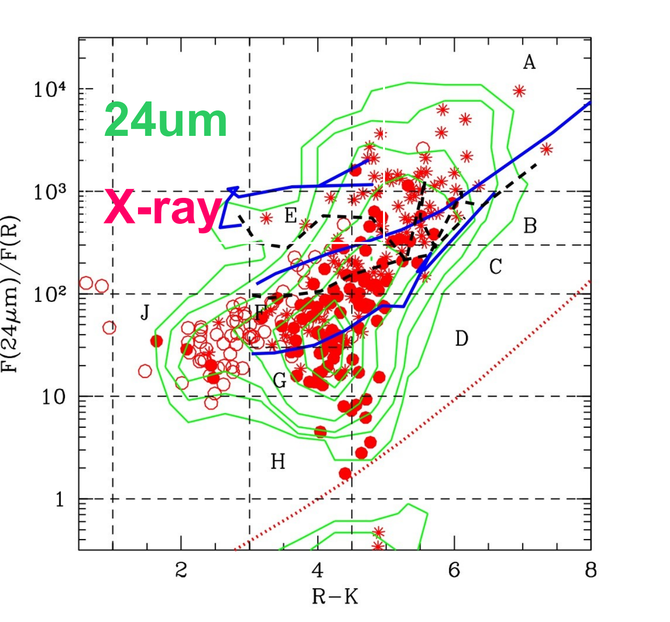


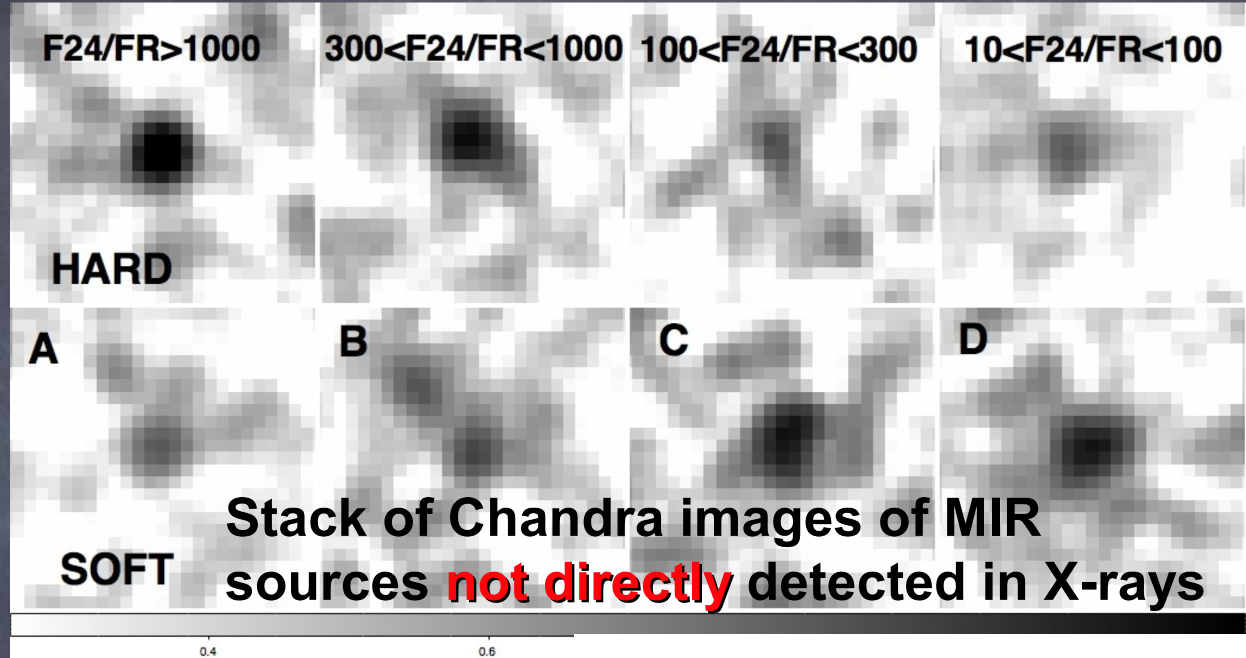
IR selected CT AGN

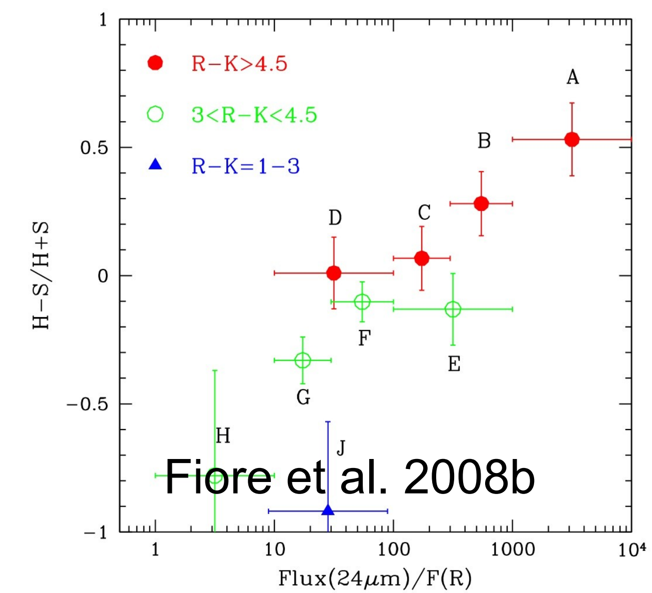
Efficient strategy: target sources with AGN luminosity in the MIR but faint (and red) optical counterparts.
First used by Martinez-Sansigre (2005)

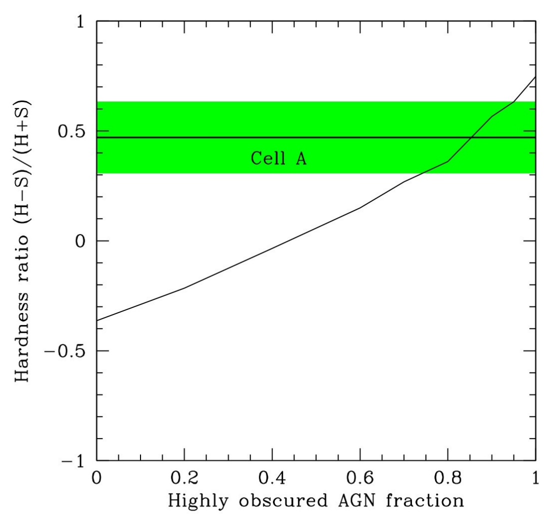


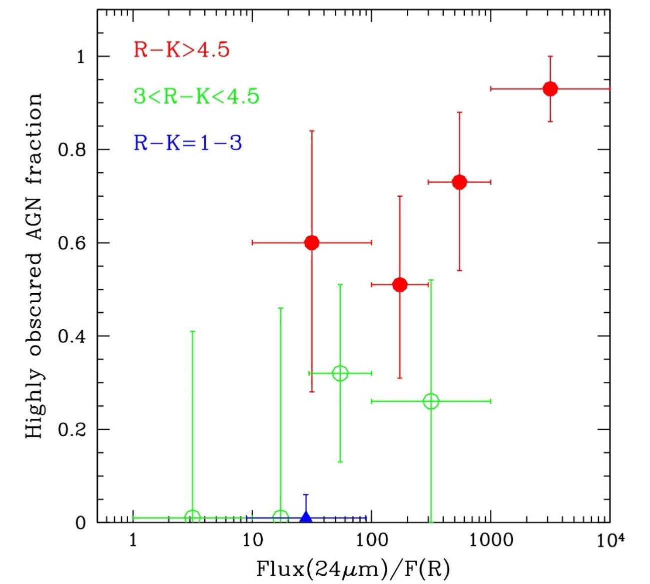
COSMOS MIR AGN



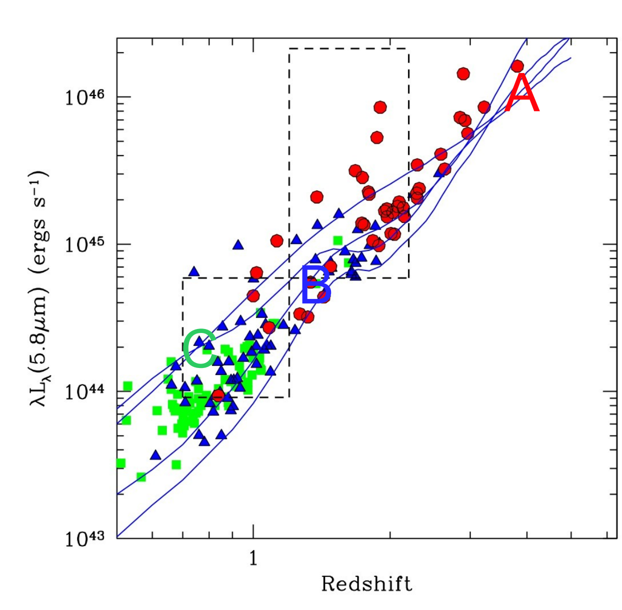


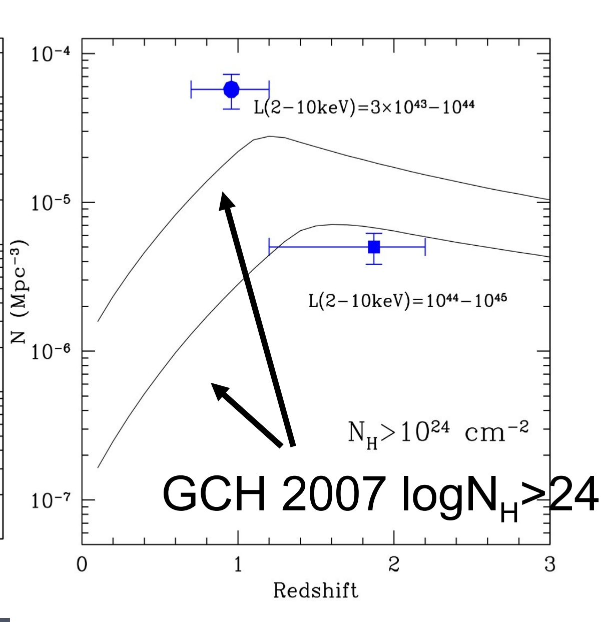


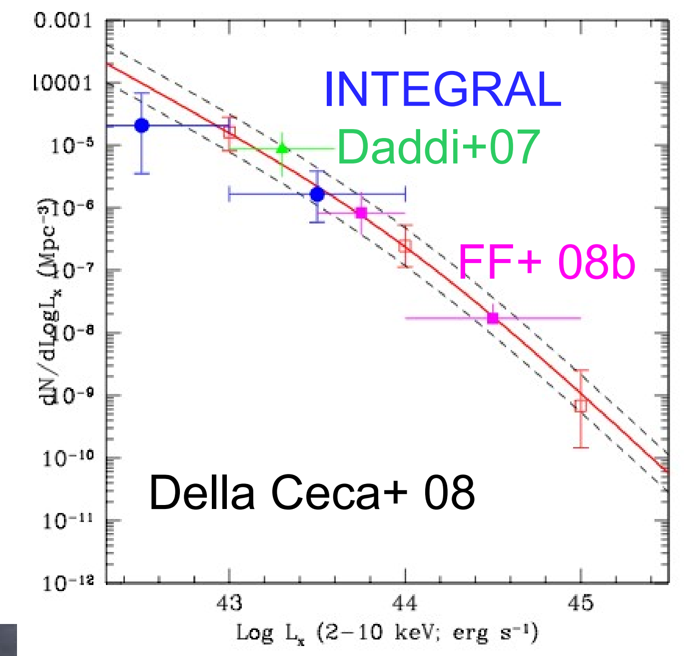




CT AGN volume density





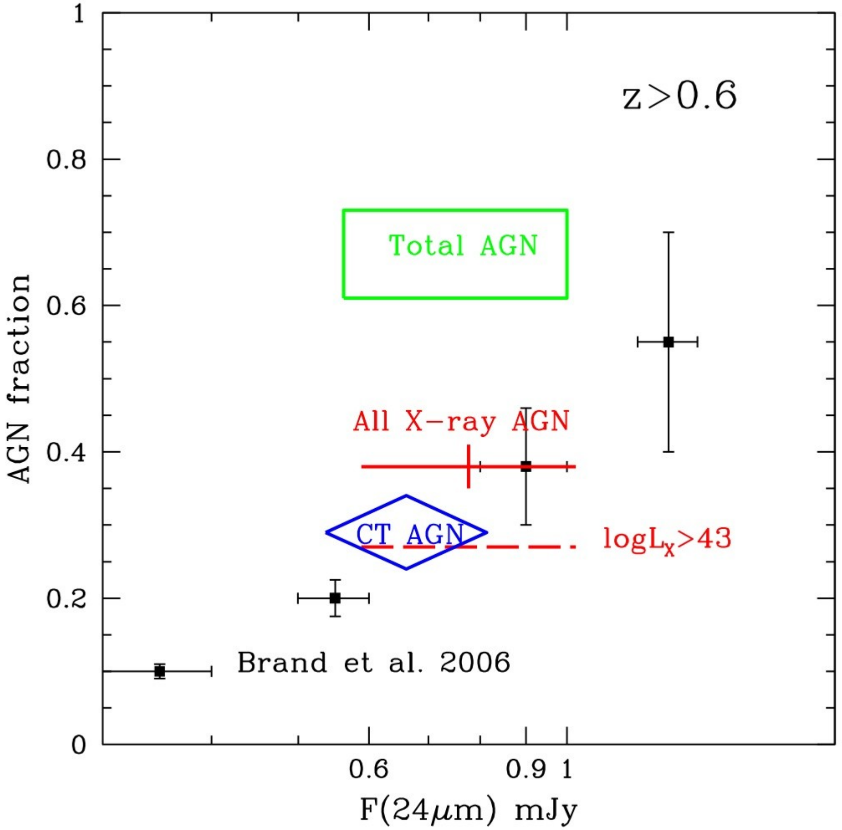


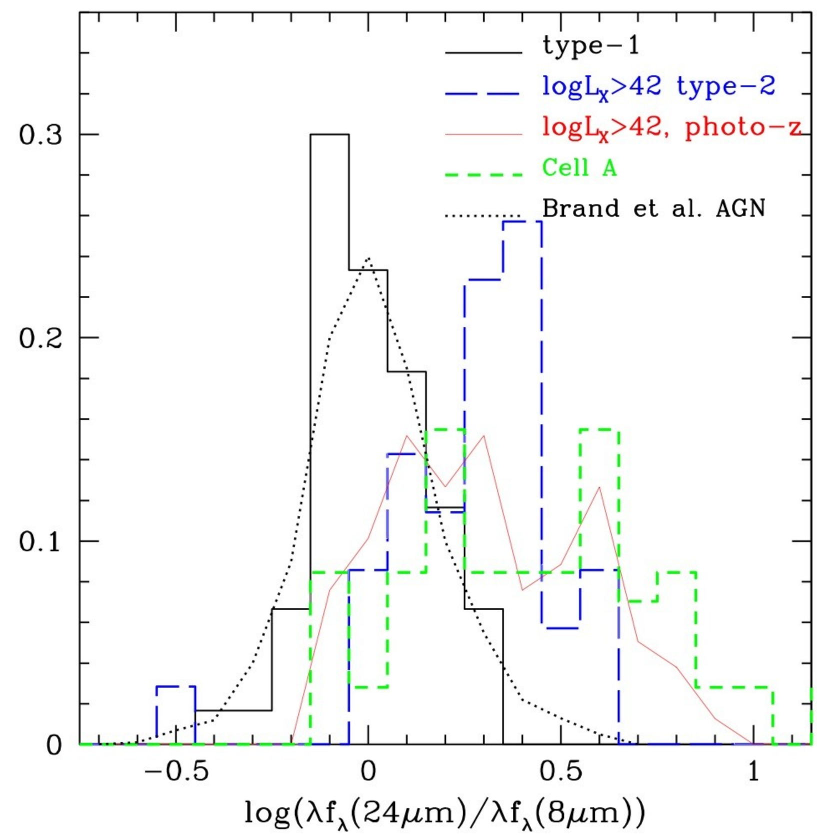
z=1.2-2.2: density IR-CT AGN ~ 45% density X-ray selected AGN, ~90% of unobscured or moderately obscured AGN

z=0.7-1.2: density IR-CT AGN ~ 100% density X-ray selected AGN, ~200% of unobscured or moderately obscured AGN

The correlation between the fraction of obscured AGN and their luminosity holds including CT AGN, and it is in place by z~2

AGN fraction





Chandra survey of the Bootes field (5ks effective exposure)
Brand et al. 2006 assume that AGN populate the peak at F24um/F8um~0 only. They miss a large population of obscured AGN, not detected at the bright limits of their survey.

AGN obscuration, AGN feedback and star-formation

- CT absorbers can be naturally included in the Menci et al. feedback scenario as an extension toward smaller distances to the nucleus where gas density can be high.
- If the fundamental correlation between the fraction of obscured AGN and L is due to different timescales over which nuclear feedback is at work

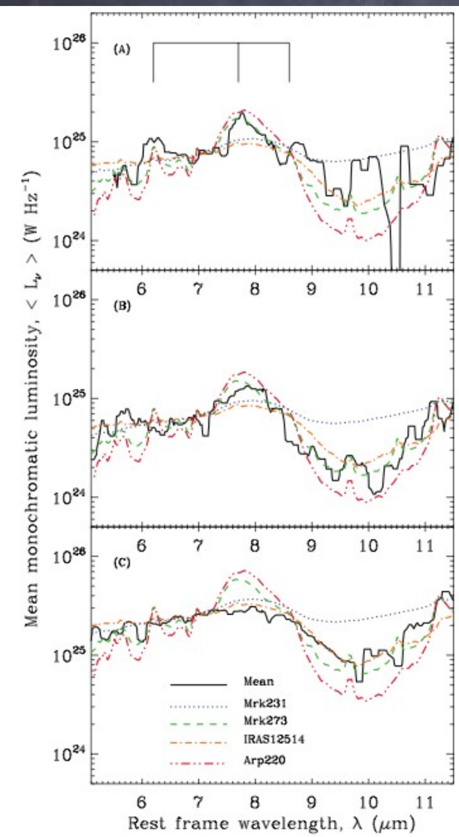
↓

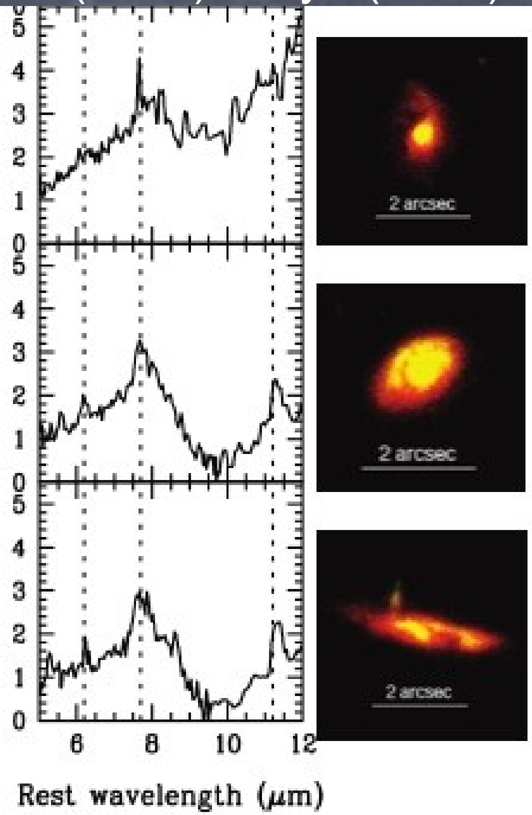
- Evolutionary star-formation sequence:

- CT → moderately obscured → unobscured
- Strong → moderate → small

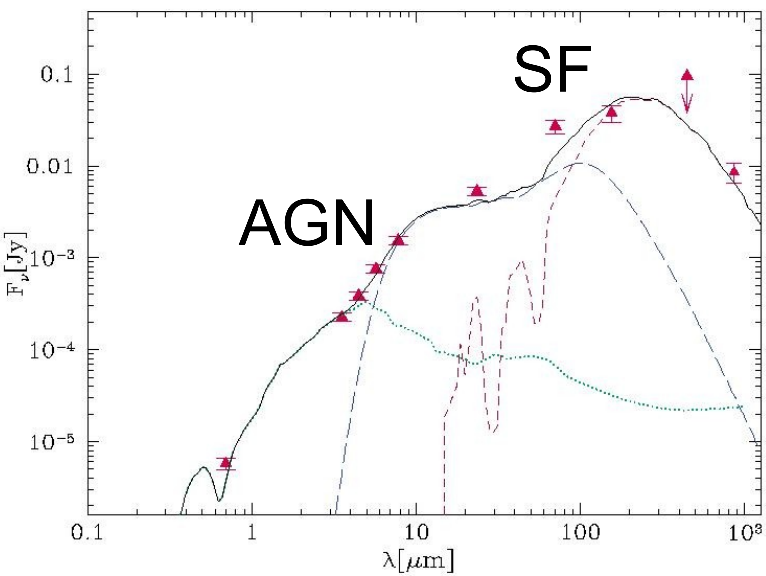
AGN obscuration, AGN feedback and star-formation

- Most SMG host obscured AGN (Alexander+ 2005)
- X-ray selected, type-2 QSO have higher sub-mm detection rate than unobscured QSO (Page+ 2004, Stevens+ 2004)
- Dust obscured star-formation revealed by Spitzer IRS in type 2 QSOs
- Martinez-Sansigre+ (2008) Lacy+ (2007)



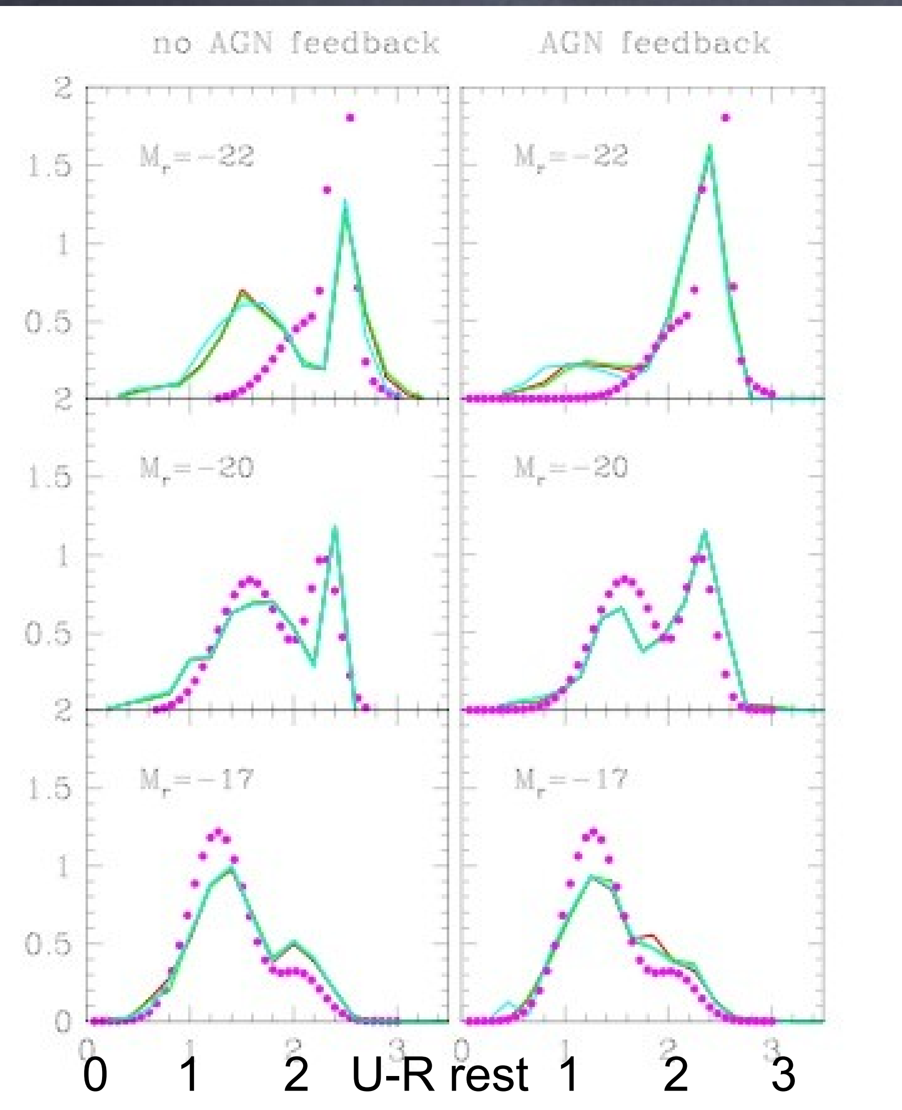


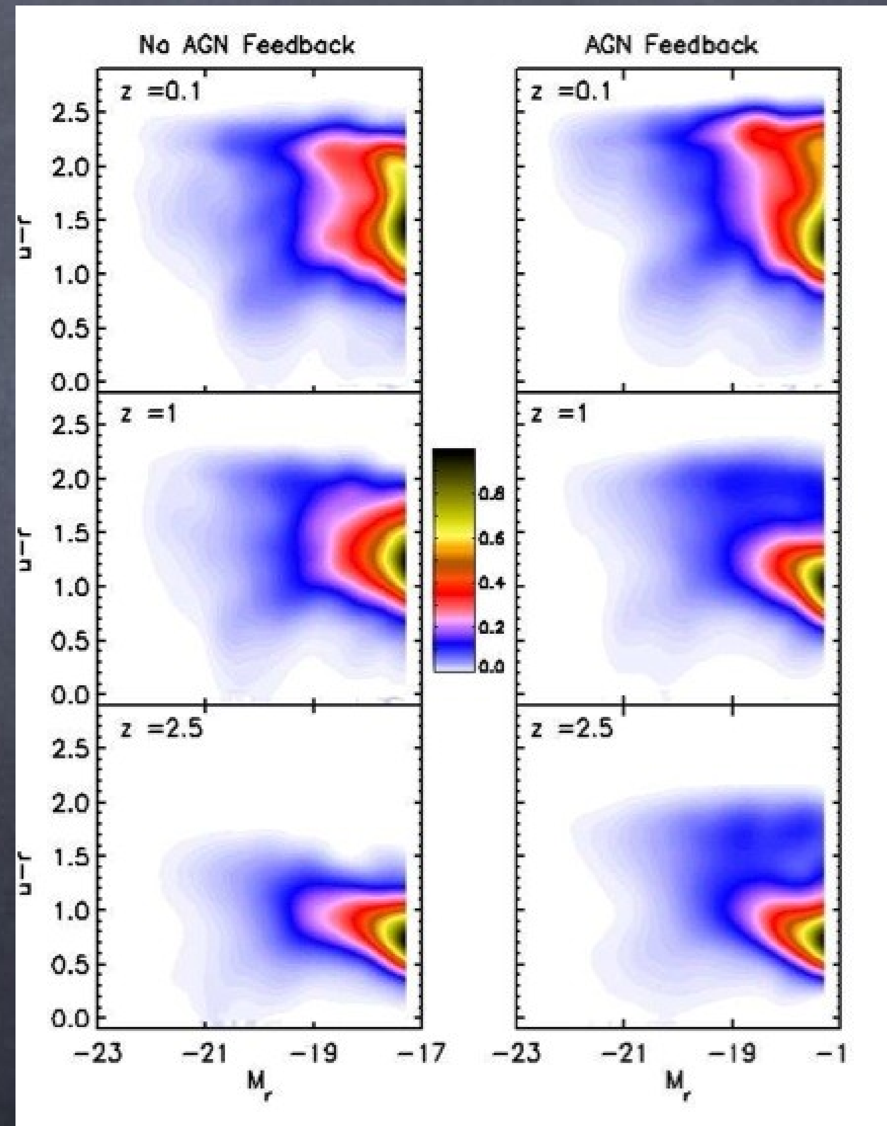
HELLAS2XMM QSO2, Vignali+ 08



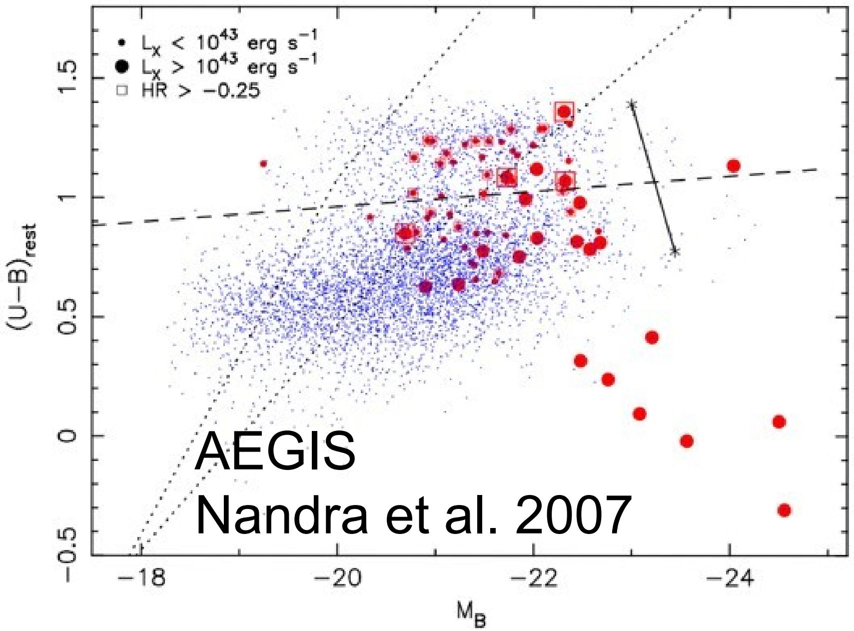
AGN feedback & galaxy colors

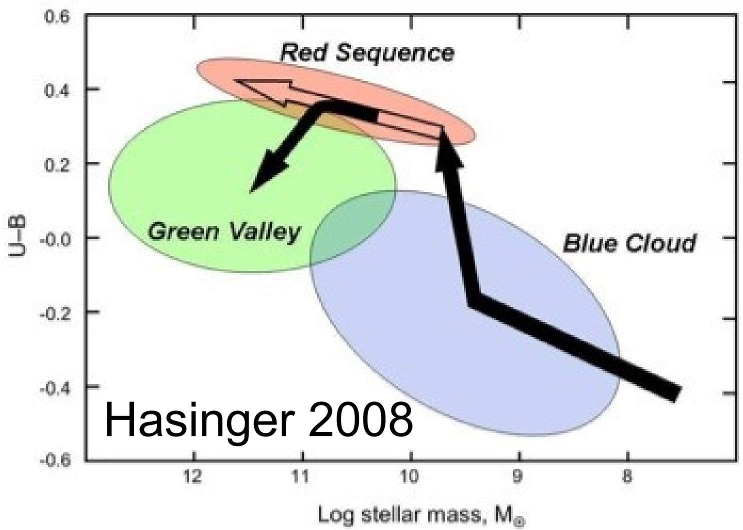
Menci et al. 2006

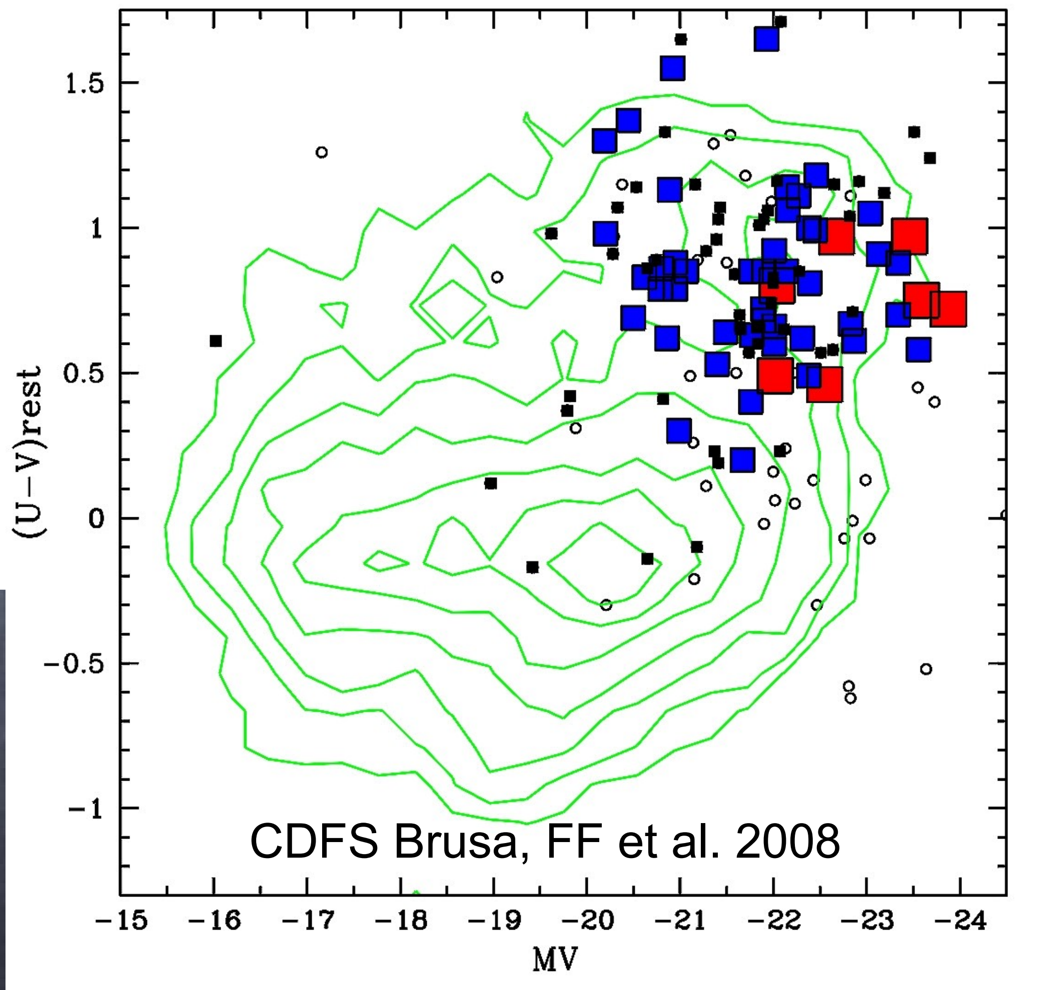




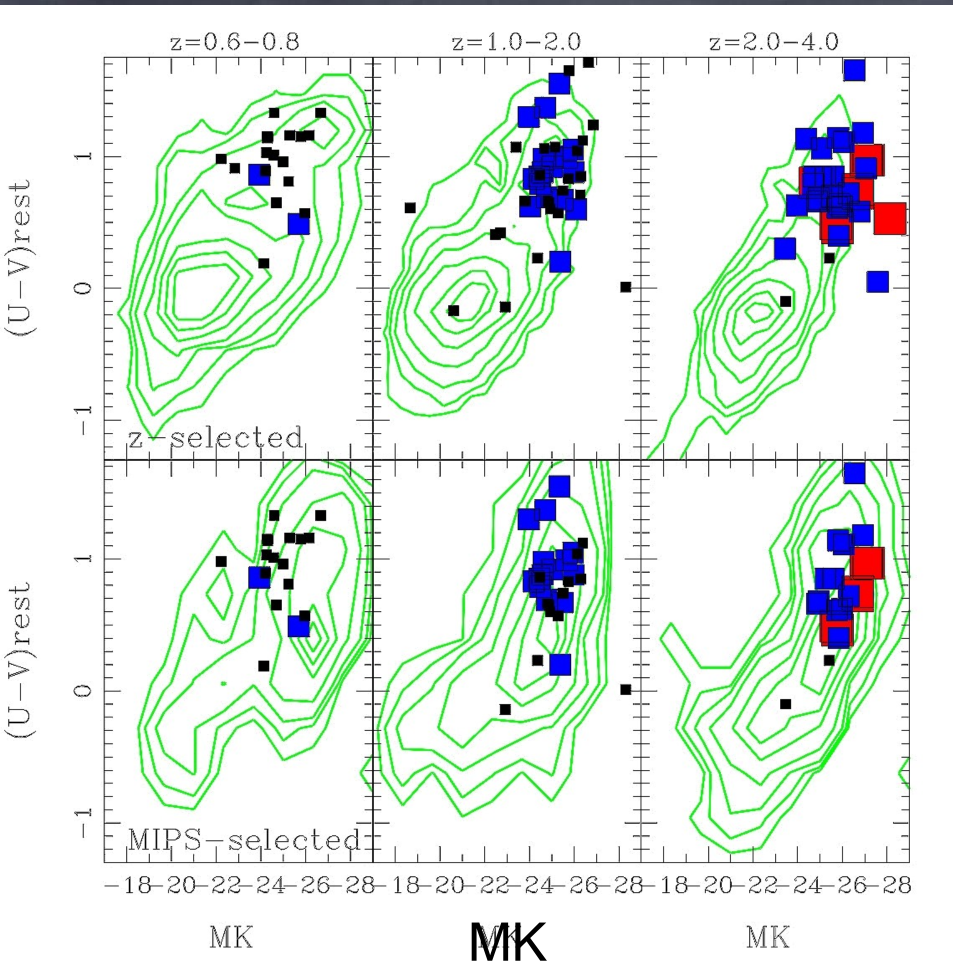
AGN host galaxies

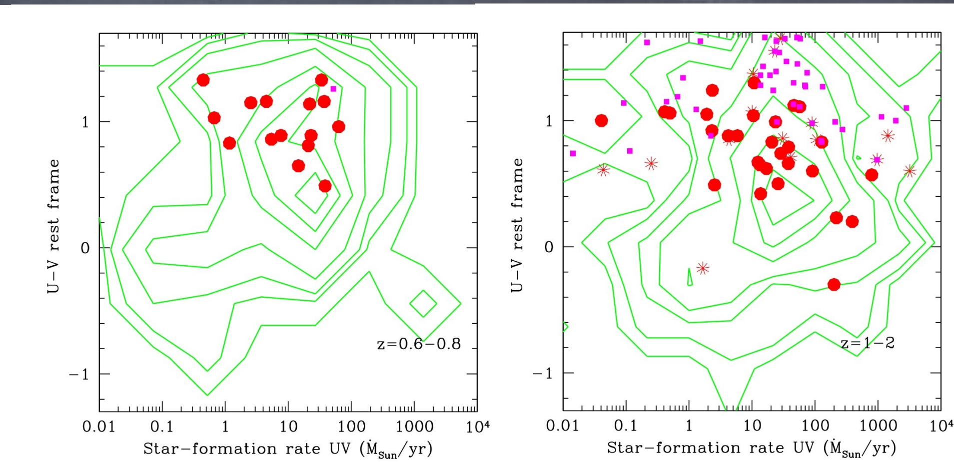


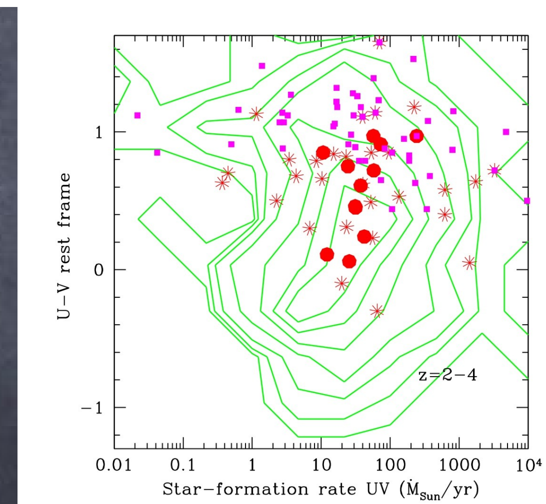




AGN host galaxies





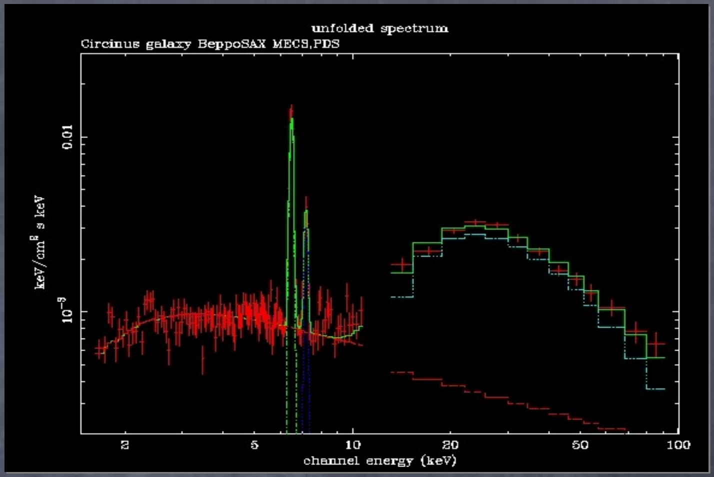


- Most X-ray selected (and IR selected), obscured AGN live in massive star-forming galaxies. ~1/3 live in galaxies with SFR<10M_{Sun}/yr.

Brusa, FF et al. (2008)

What is left?

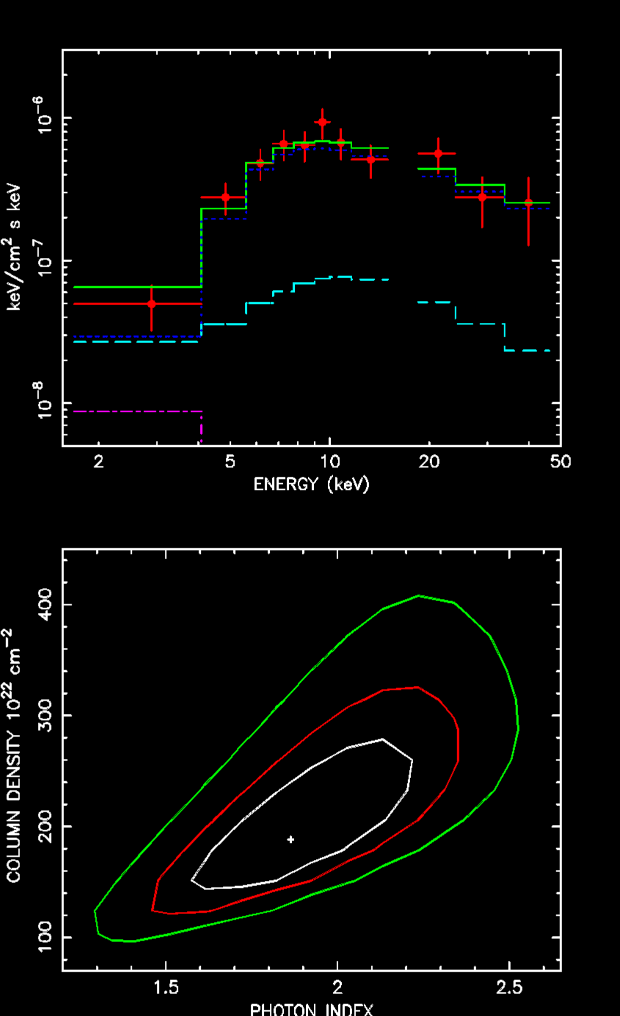
- **The "smocking gun" of CT AGN is the X-ray spectrum.**



- Today we can get:
  - X-ray spectra of CT Sy2 galaxies in the local universe (and little more at higher z).
  - X-ray colors of CT AGN up to z=2
  - Spitzer IRS spectra of Sy2 and of the most luminous type 2 QSO at z~2 (but we cannot tell if they are truly CT, only X-rays can tell)

- We badly need X-ray spectroscopy of CT AGN at z>0.5!!!
- Simbol-X will provide the first results at z=0.5-2

Simbol-X



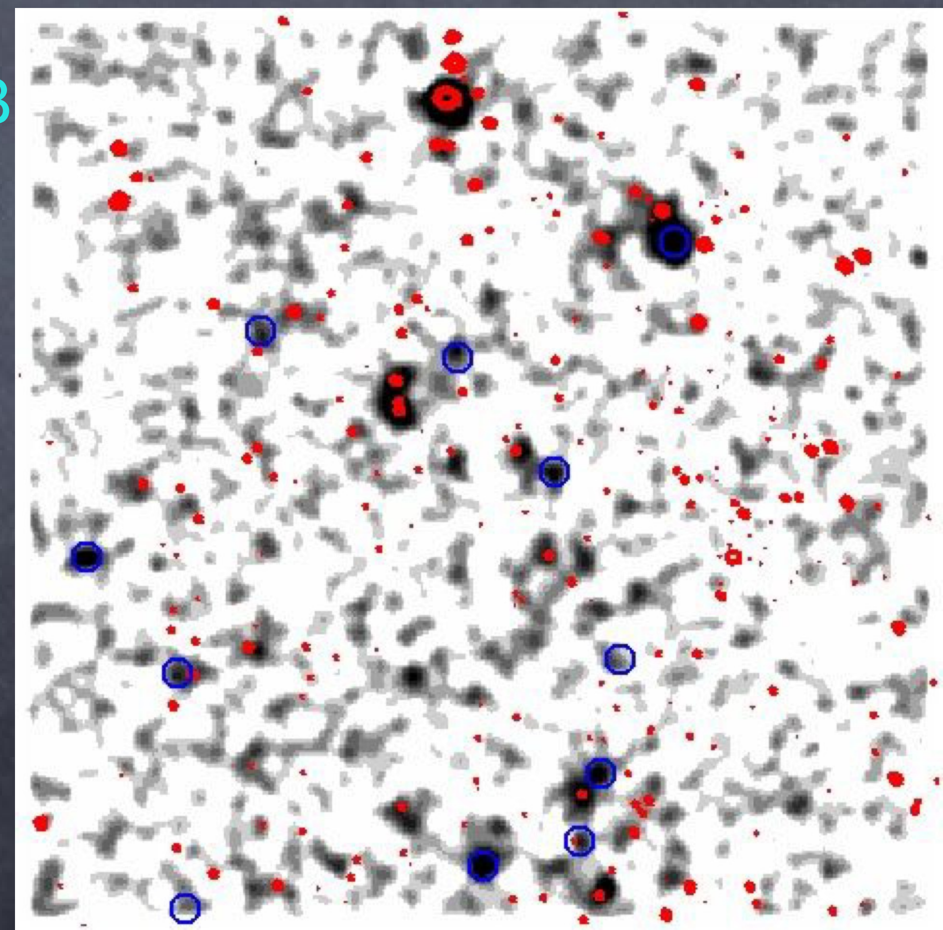
CDFS 1 Msec simulations 10-40 keV

- Chandra sources (red contours)

-IR selected CT AGN at z=0.5-2 (blue circles) assuming NH=10^{24} cm^{-2} and a reasonable IR/X-ray luminosity ratio

HEW<20”

>50% CXB Resolved @30keV



Intermediate luminosity, SWIRE AGN

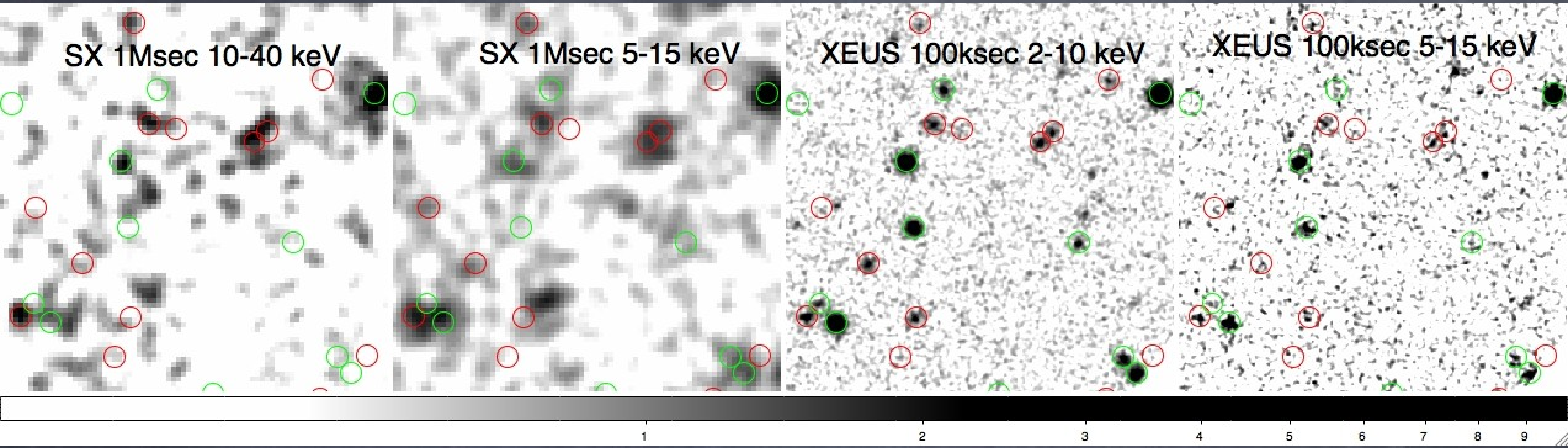
Z=1, N_H = 2 10^{24} cm^{-2}

L(2-10 keV) = 1.1 10^{44} cgs

F(2-10 keV) = 7.1 10^{-15} cgs

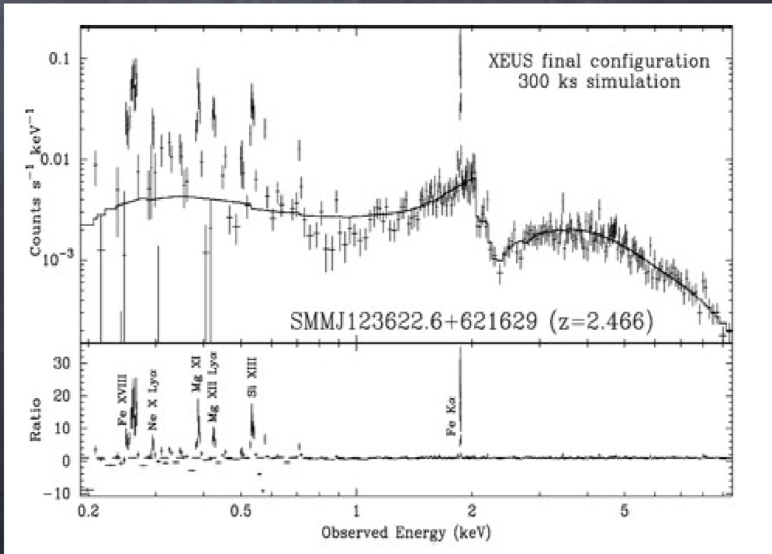
F(20-40 keV)=1.7 $^{-14}$ cgs

IXO



- Detection and colors of highly obscured AGN at z>4
- Spectra of the brightest at z=2-4

JWST will certainly get spectra of obscured AGN at any z but X-ray are *mandatory* to identify them as CT, and therefore to count them to complete the AGN census over the cosmic epoch.



CDFS2Msec