AGN evolution in multi-wavelength surveys

Crete Summer School 2008

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Outline

- AGN evolution from multi-wavelength surveys
- Optical surveys and QSO evolution
- X-ray surveys
- The X-ray background
  - Obscured accretion
  - Evolution of obscuration with luminosity and redshift
- Resolved AGN population
  - Luminosity and density AGN evolution
  - The role of obscuration
  - The IR view of obscured AGNs
- AGN/host galaxy connections
- The future: next generation surveys

References

- Textbook:
  - Peterson, "An Introduction to Actrive Galactic Nuclei", Chapters 10 & 11
- Recent Review
  - Osmer, astro-ph/0304150 (QSO evolution)
  - Wolf, 2005, Mem.SAIt, 76, 21 (optical surveys)
  - Brandt and Hasinger, 2005, ARAA, 43, 827 (X-ray surveys)
- Soltan argument
  - Yu and Tremaine 2002, MRNAS, 335, 965

Unified model

(Antonucci 1993, Urry e Padovani 1995)

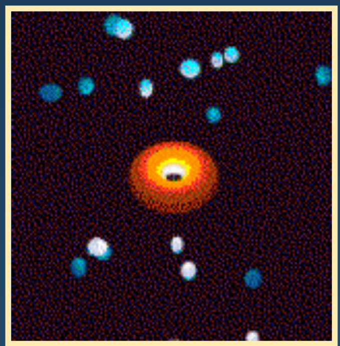
What we actually see depends on the viewing angle!

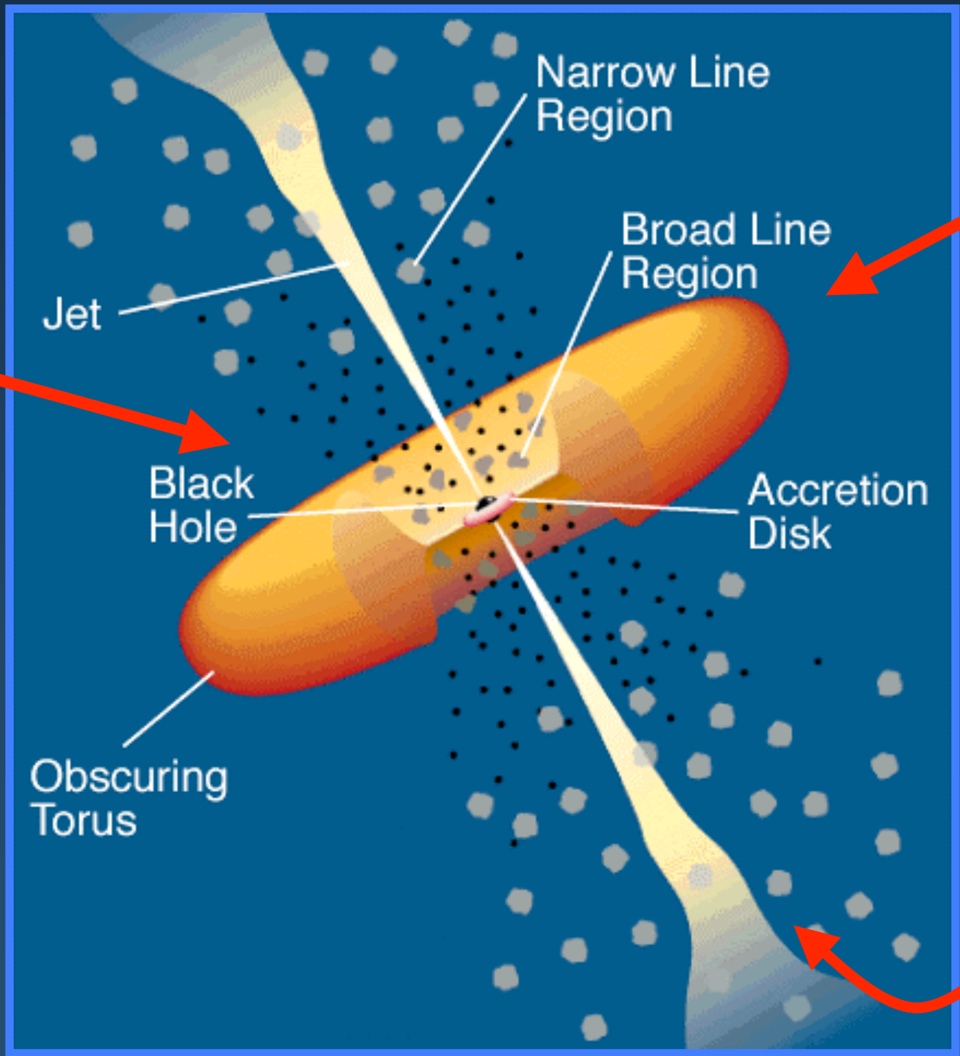
Type 1 objects:

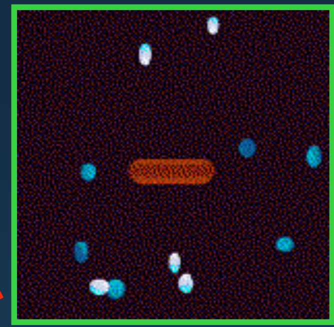
-Seyfert 1s

-Broad Line Radio Galaxies

-Type 1 Quasars





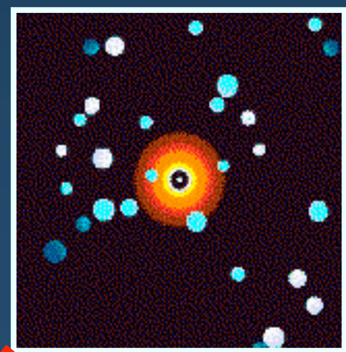


Type 2 objects:

-Seyfert 2s

-Narrow Line Radio Galaxies

-Type 2 Quasars



Blazars:

-BL Lac Objects

-OVVs

Why Extragalactic surveys

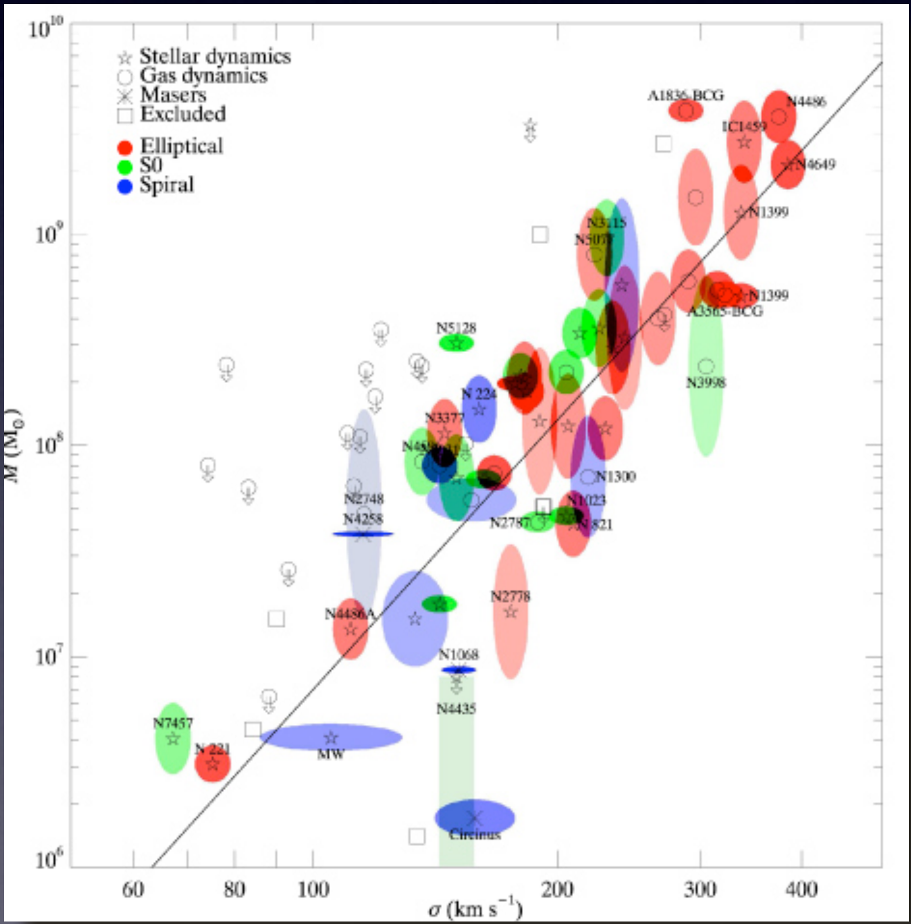
Deep extragalactic surveys are extremely important to understand the physics and evolution of Massive BH in the Universe:

- (Should) provide a fair census of massive Black Holes in the Universe
- Allow to detect rare and extreme phenomena (limits on the underlying physics)
- Provide statistical samples to investigate global properties
- Act as "time-machines" allowing to understand BH evolution with lookback time.

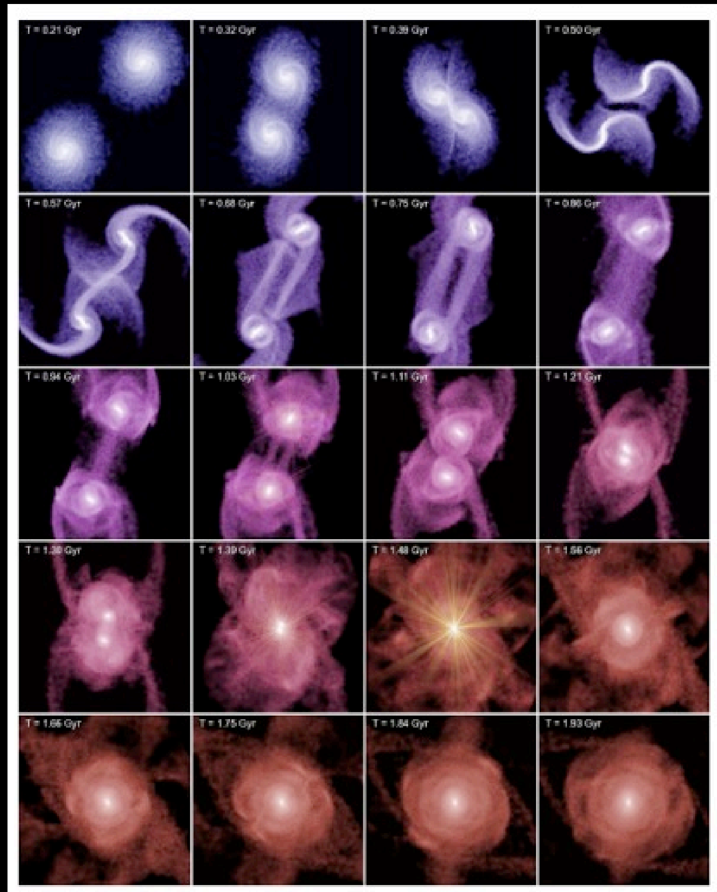
Are thus fully complementary to detailed studies of nearby, well resolved objects.

AGNs are strictly connected to galaxy evolution

We cannot understand cosmological evolution of barions without including a strong contribution from BH feedback.

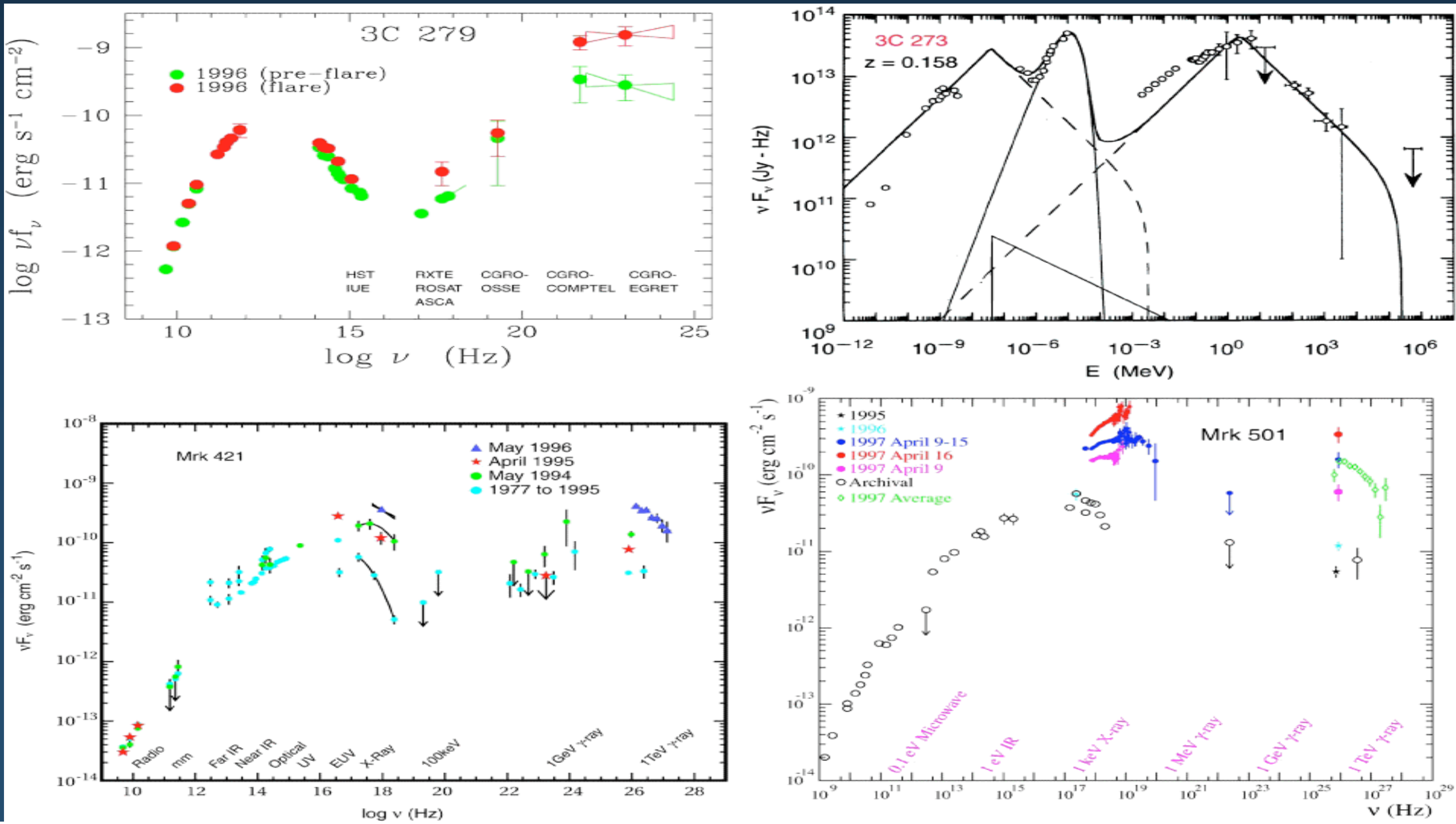


Merging galaxies trigger BH growth. AGN feedback drives out galaxy gas (Hopkins et al 2006).



Why multy-wavelength surveys

AGNs are an extremely complex phenomena (unification paradigm) and emit over the entire electromagnetic spectrum!



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AGNs are an extremely complex phenomena (unification paradigm) and emit over the entire electromagnetic spectrum!

Multi-wavelength studies allow to:

- Study different physical processes related to BH physics: thermal BB emission, compton scattering, syncrotron emission, ionization and de-excitation, Thomson scattering etc.
- Sample different spatial regions: accretion disk, hot coronae, relativistic jets, emitting clouds…
- Detect AGNs removing selection effects and observational biases
- Investigate different types of sources: Type 1/Type 2, obscured AGNs, radio-loud sources etc.

Are thus required to fully understand the AGN phenomena

Astronomers cannot be "narrow-sighted" anymore

Optical/Radio surveys

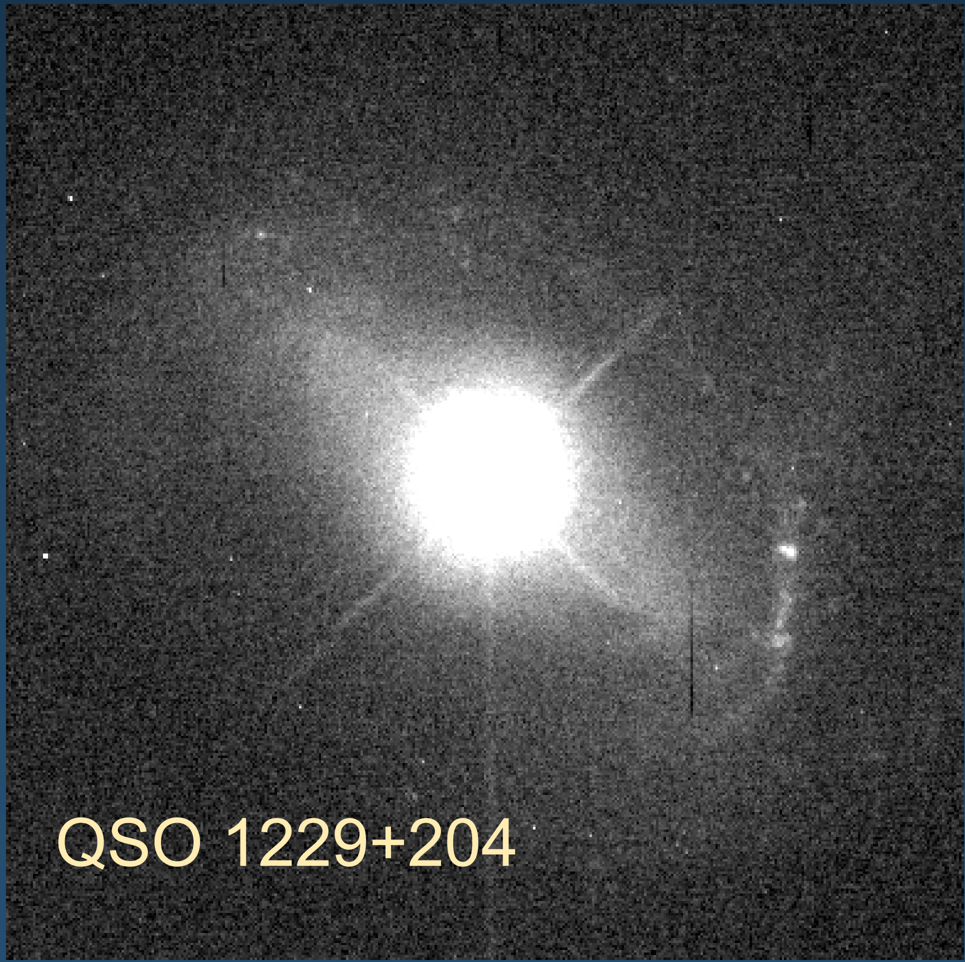
Traditionally AGN were discovered at different wavelengths independently: optical and radio surveys mainly

This lead to complex taxonomy:

- *QSOs/Quasars*
- *Seyfert galaxies*
- *BLRG (broad line radio galaxies)*
- *NLRG (narrow line radio galaxies)*
- *NLS1 (narrow line Seyfert 1)*
- *etc...*

We haven't stopped yet:

- *XBONG (X-ray bright/optically normal galaxies)*
- *EXO (Extreme X-ray objects)*



(some) Recent optical surveys
(C. Wolf, 2005)

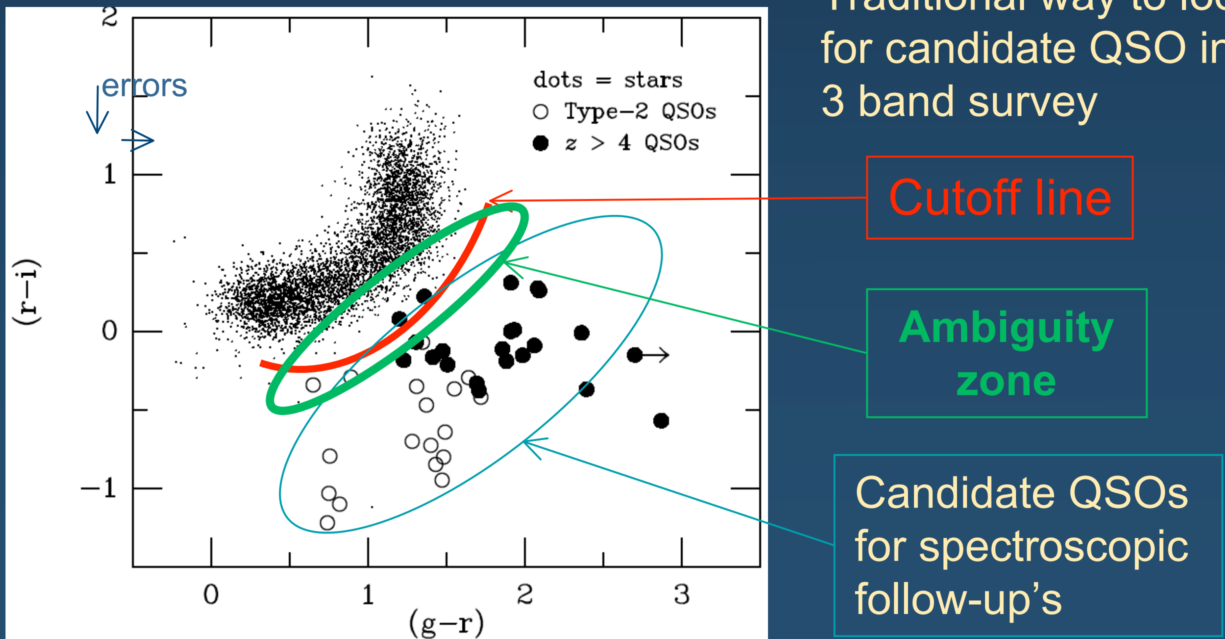
- the brightest (~ 400) objects were observed in the wide-area objective-prism *Hamburg- ESO-Survey* (HES, Wisotzki 2000) at $B < 17$, $z = [0.0, 3.2]$
- the *2dF Quasar Redshift Survey* (2QZ, Boyle et al. 2000, Croom et al. 2004) found large numbers (~ 23, 000) of QSOs at $z = [0.3, 2.2]$ and $B < 21$.
- the *Sloan Digital Sky Survey* (SDSS, York et al. 2000) collects the largest QSO sample to date (>100.000) with important complete subsamples at $z > 3.6$, $i < 20$ (Fan et al. 2001)
- the *COMBO-17* survey (Wolf et al., 2003) selected QSOs reliably at $z = [1, 5]$ with detailed SEDs from 17 filters, providing the deepest large sample
- the *BTC-40* survey (Monier et al. 2001) targeted specifically the very high-z end at $z > 4.8$, confirming just two of these rare QSOs to date
- *Lyman-break-selected galaxy* sample (Steidel et al. 2002) providing a small but the deepest probe into nuclear activity at $z \sim 3$ (Hunt et al. 2004)

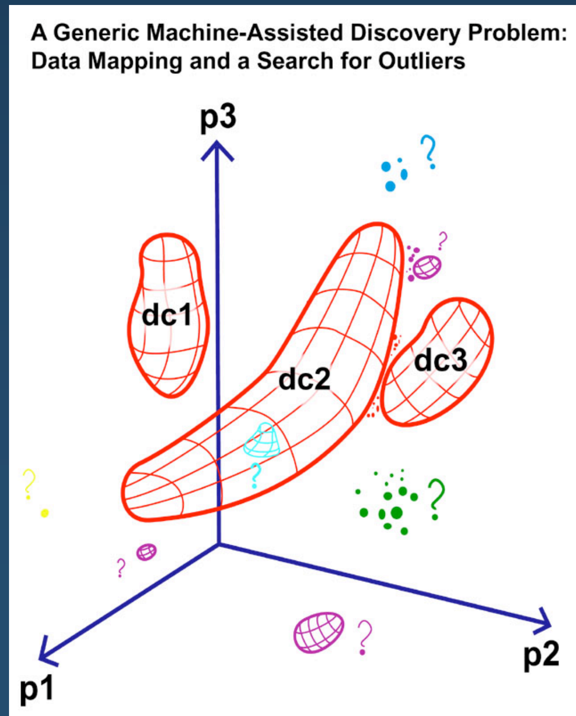
Photometric selection of candidate QSO's in optical surveys

Several algorithms for "general purpose" photometric identification of candidate QSOs select sources according to different techniques exist.

- *Optical surveys*: looking for counterparts of strong radio sources (but only ~ 10% of QSO are radio-loud).
- *Ultraviolet and optical surveys*: looking for star-like sources bluer than stars.
- *Multi-colour optical surveys*: looking for unresolved objects in colour parameter space lying outside compact regions ("star locus") occupied by stars.

Traditional way to look for candidate QSO in 3 band survey

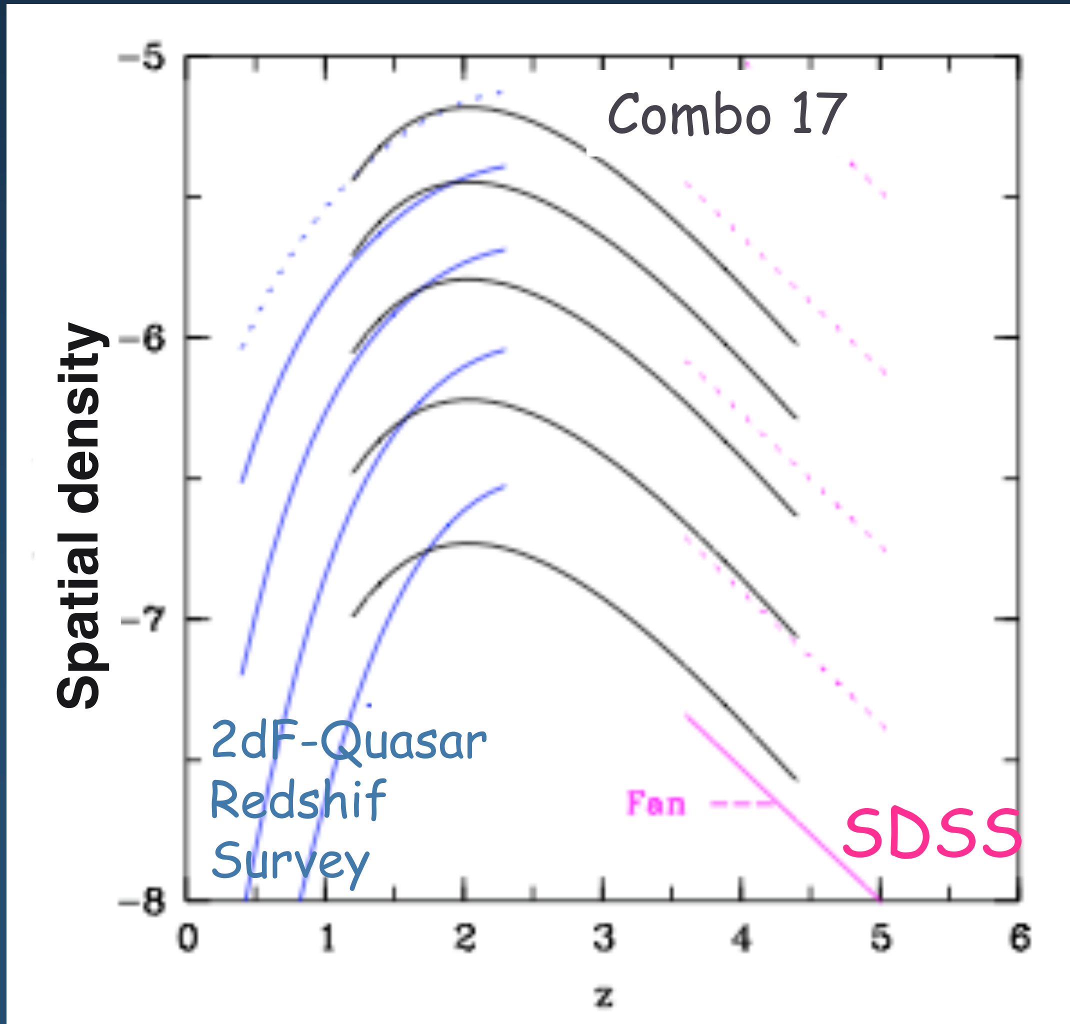




QSO number density evolution

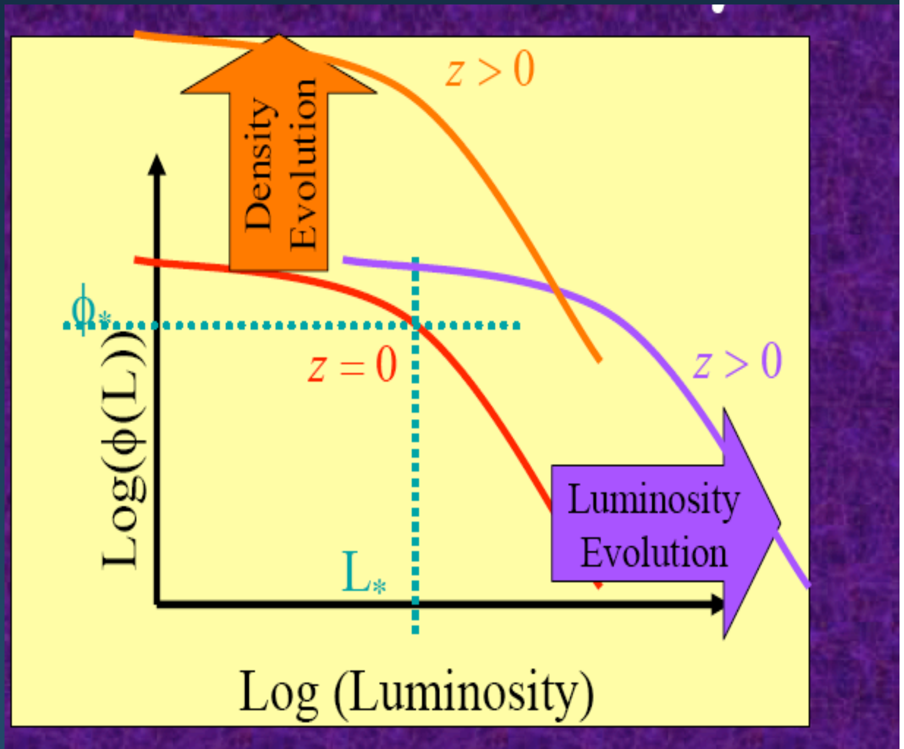
At high z optical surveys sample the population of bright unabsorbed QSOs

- Since the discovery it was evident that the QSO density decreased dramatically with redshift by a factor of > 100!
- Evolution is so strong that it was already evident in samples of ~20 objects
- The QSO space density peaks at z=2, close to the peak of star formation in galaxies.



Luminosity Functions

- Luminosity functions describe the number density of AGNs as a function of luminosity
- They represent a low-order statistical indicator of the global properties of the AGN population, and hold clues to understand their formation and evolution (e.g dependence on redshift, host-galaxy properties, etc.)
- To pinpoint the LF properties we need to use both wide (to sample rare bright objects) and deep (to trace the low-luminosity and high-z population) surveys

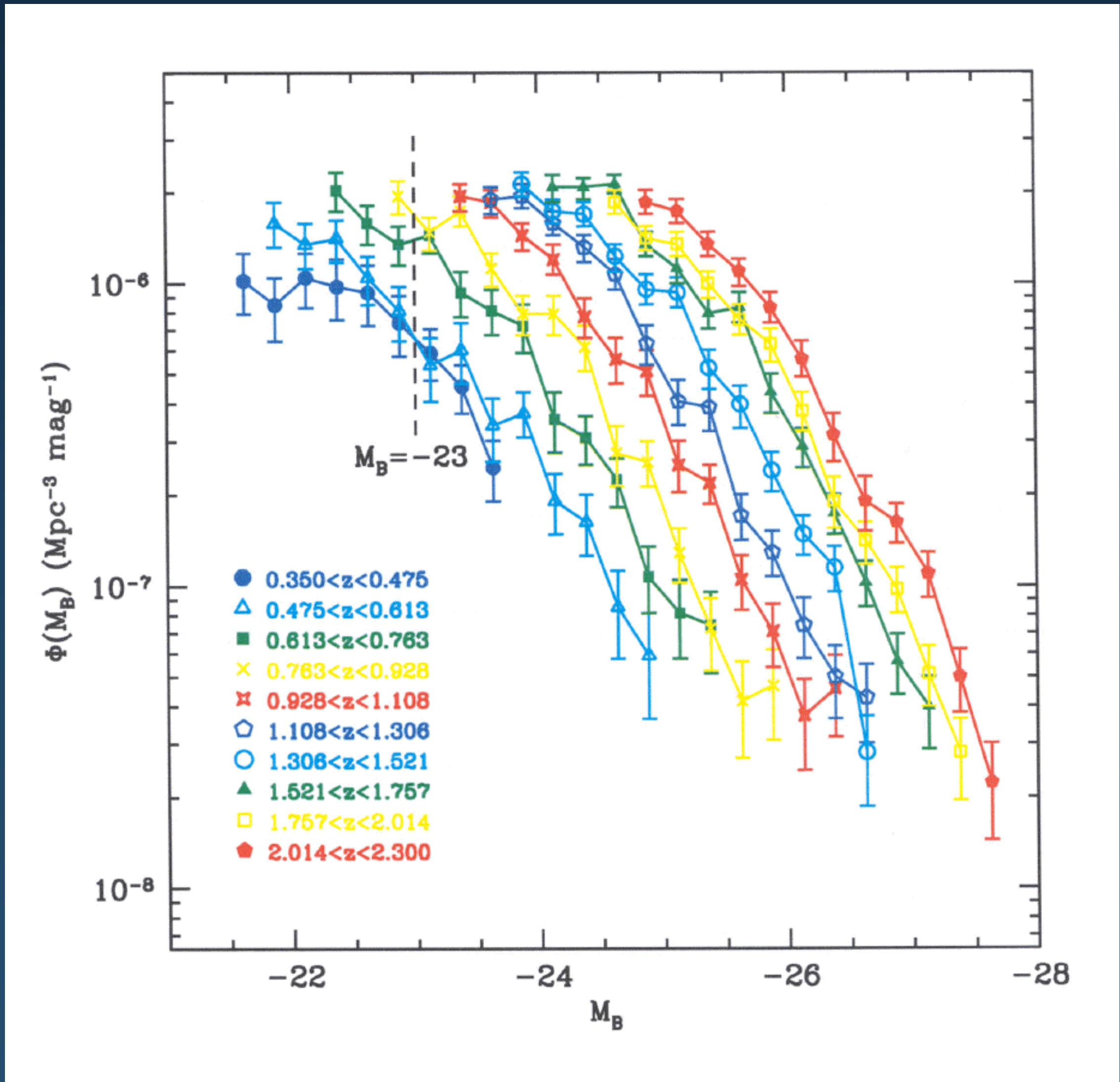


Courtesy of Xiaohui Fan

Note:

- pure power-law LF does not allow to distinguish PLE from PDE!
- However the LF must turn-over at low luminosities otherwise the luminosity density of AGNs would diverge

Luminosity Function from 2dF Quasar Survey



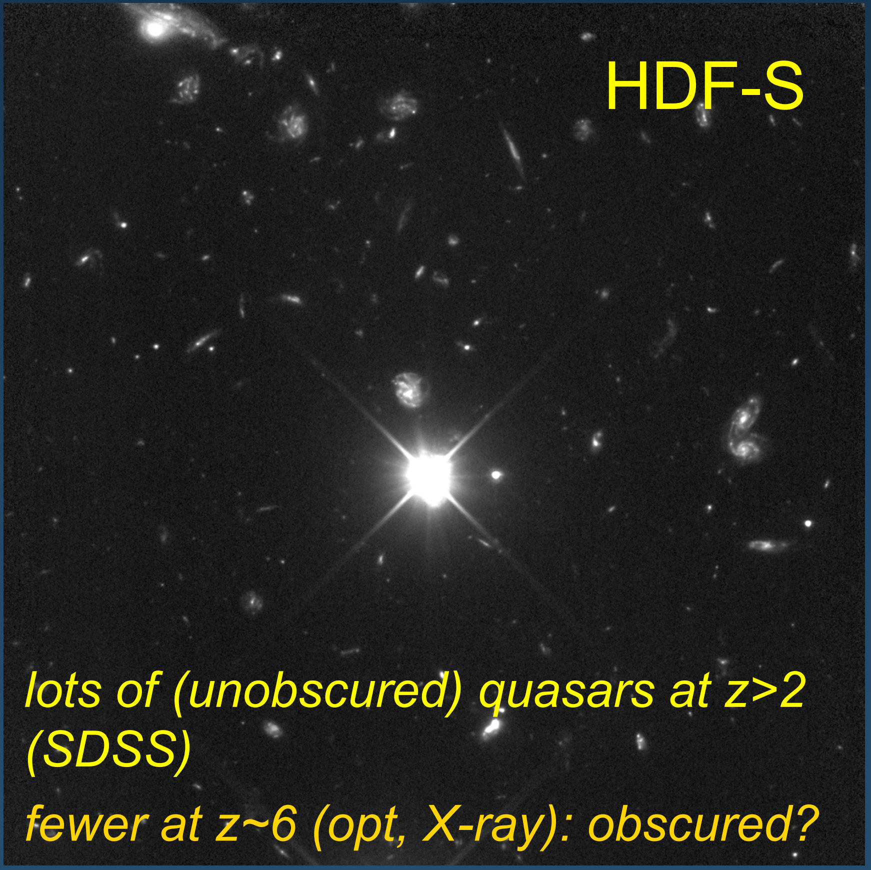
Boyle et al. 2001
Faint end poorly constrained: cannot discriminate evolutionary models

Also see Croom et al. 2004, Richards et al. 2006

Selection effects in optical/radio galaxies

Optical and Radio surveys (e.g. QSOs) were here first but:

- Optical wavelength are strongly affected by selection effects: obscuration, host galaxy contamination, spectroscopic incompleteness
- Radio-loud AGNs represent a minority (~10%) of all sources



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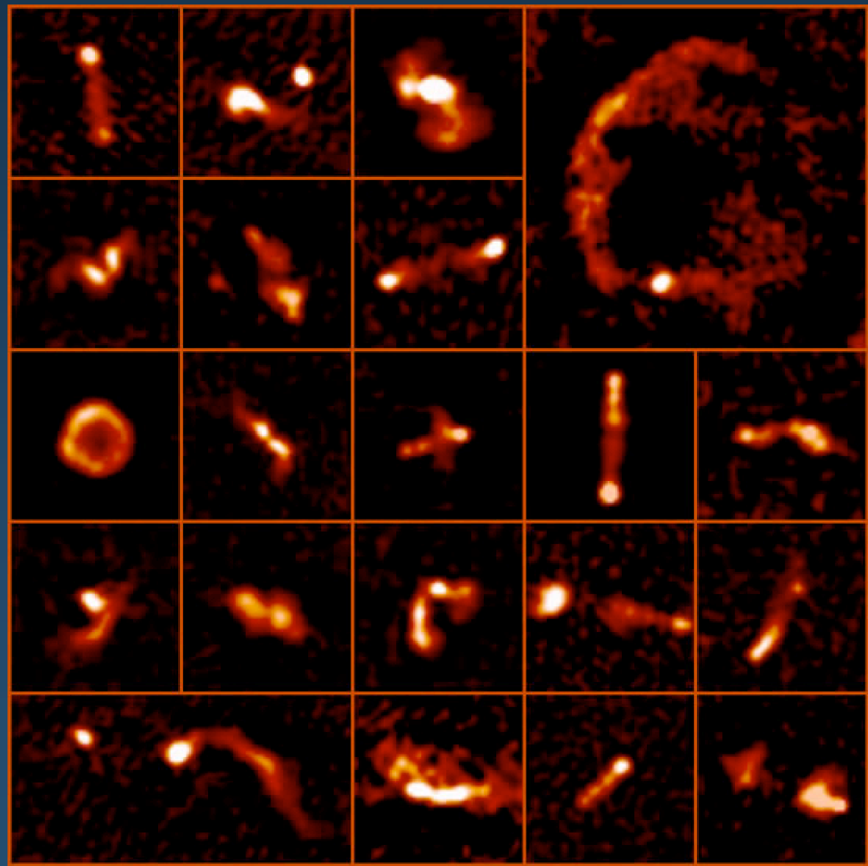
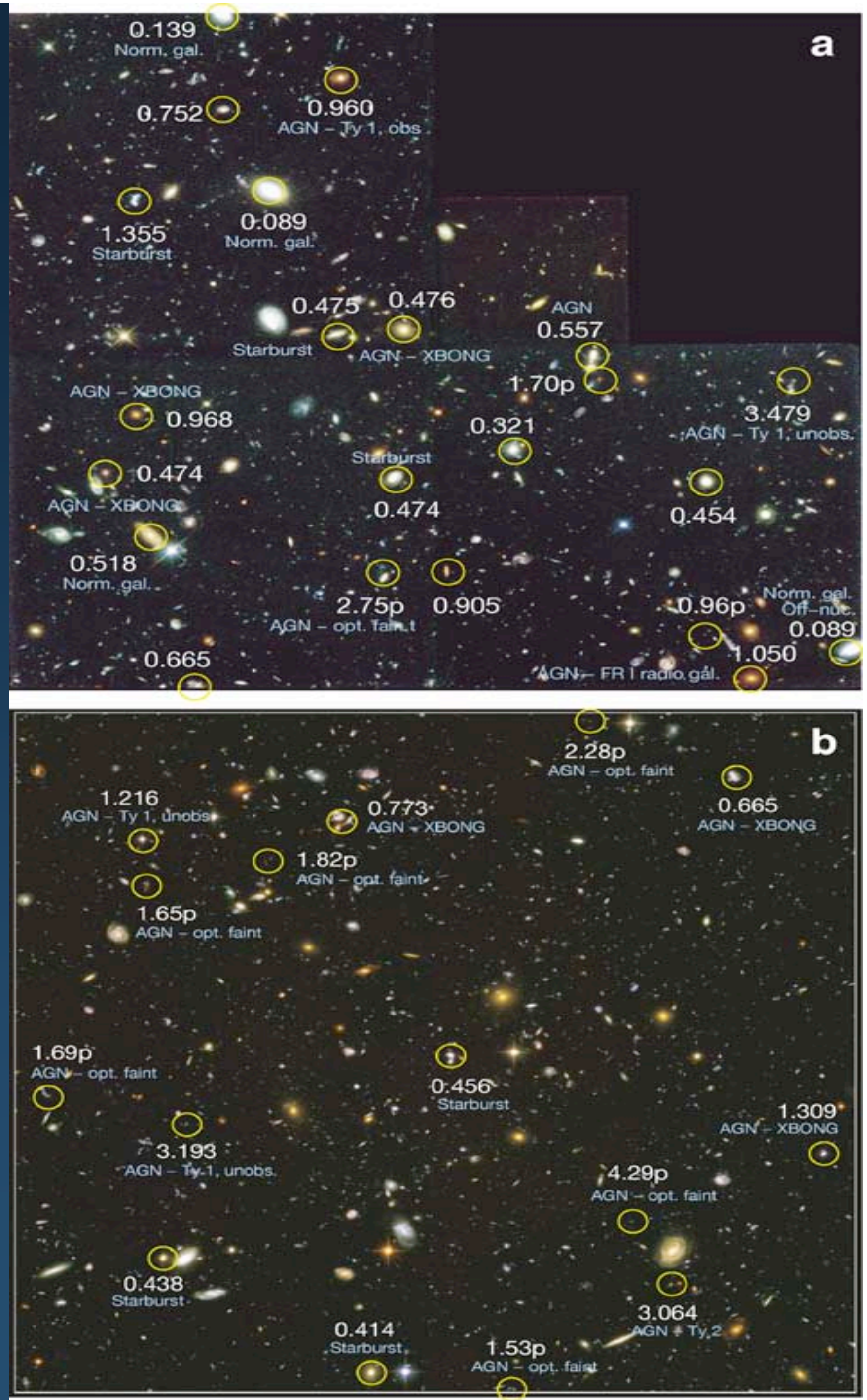


Optical vs X-ray surveys

- Even extremely well studied fields such as the Hubble Deep Field North or the Hubble Ultra Deep Field reveal additional (optically) hidden AGNs if observed in X-rays



Brandt, WN and Hasinger, G. 2005
Annu. Rev. Astron. Astrophys. 43: 827–59

X-ray surveys represent the most effective way to detect AGNs!

- X-rays are less obscured than optical/UV radiation
- X-rays are produced in non-stellar accretion processes: scarcely affected by host galaxy contamination

How do X-rays probe the AGNs content of the Universe:

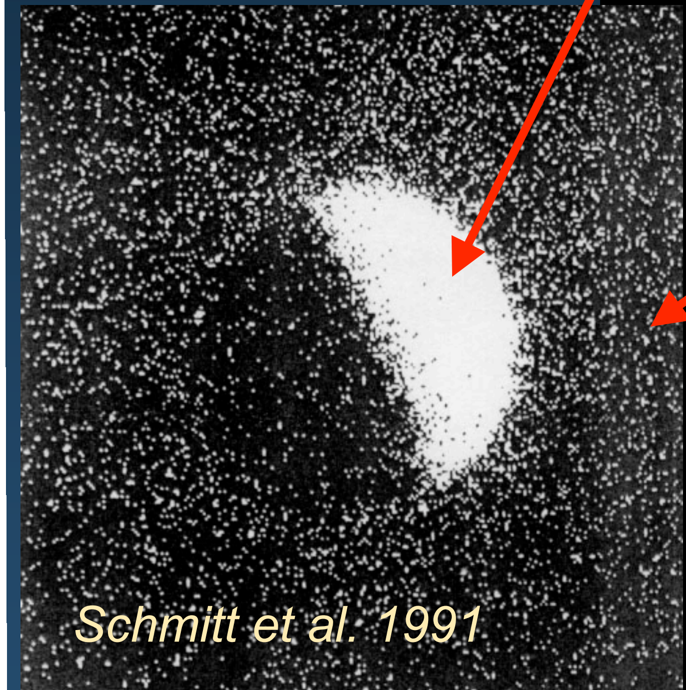
1. X-ray background
2. Individually detected sources

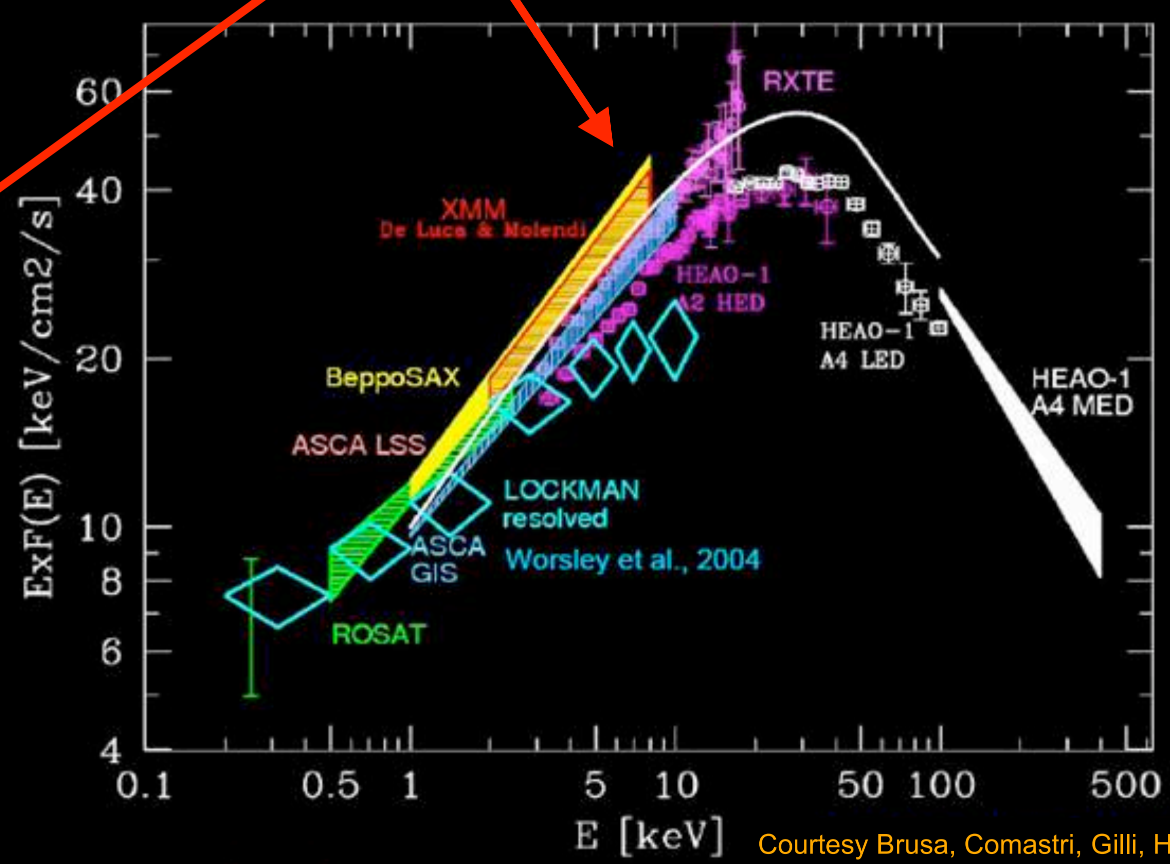
They require however multi-wavelength support as we shall see.

X-ray background (Giacconi 1962)

- Superposition of unresolved AGNs is very "hard"

The X-ray moon and the X-ray background





Courtesy Brusa, Comastri, Gilli, Hasinger

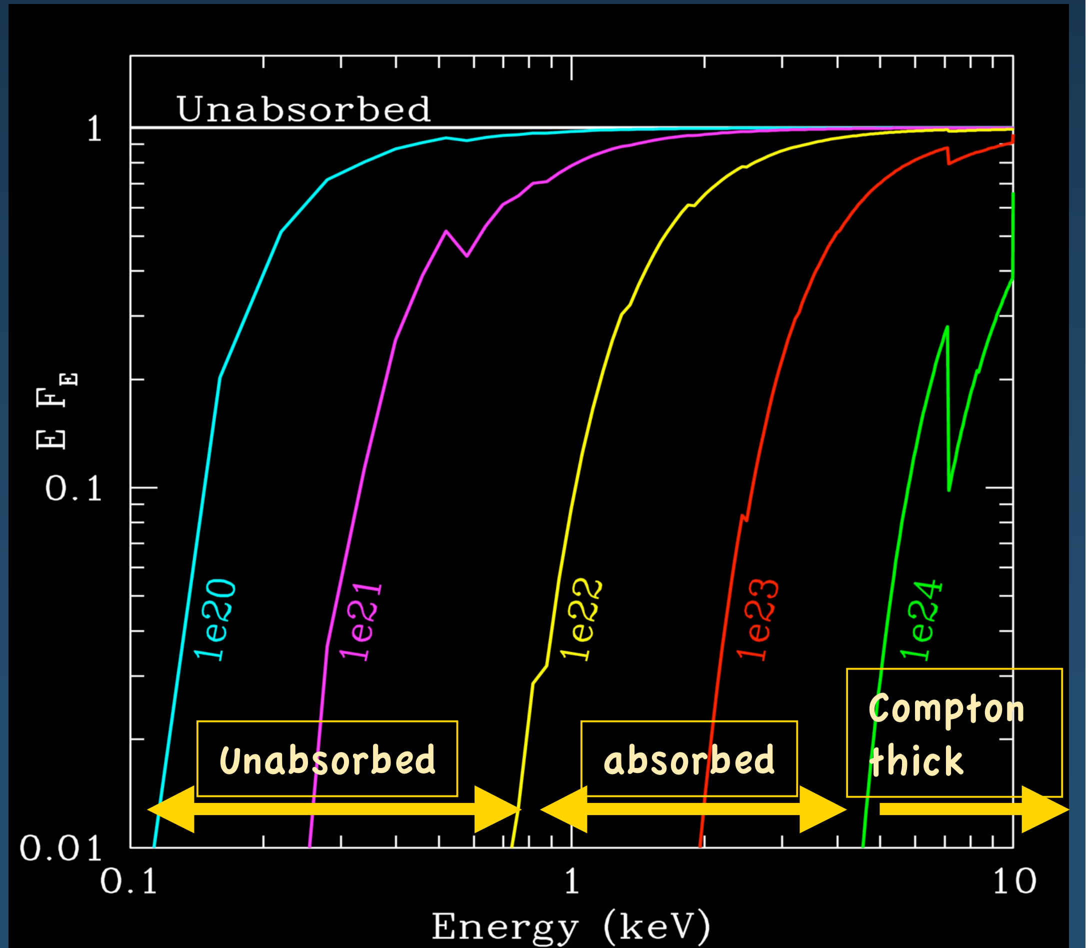
XRBG

- The existence of XRBG indicate the presence of a large population of unresolved X-ray emitters
- The shape of the XRBG indicates that X-ray radiation is mostly produced by accretion processes-> **AGNs**

Why are they undetected?

- Intrinsic low-luminosity
- Distant (high redshift)
- Obscuration: Photoelectric absorption/Compton scattering

  (parametrized by N_H column density)



XRBG

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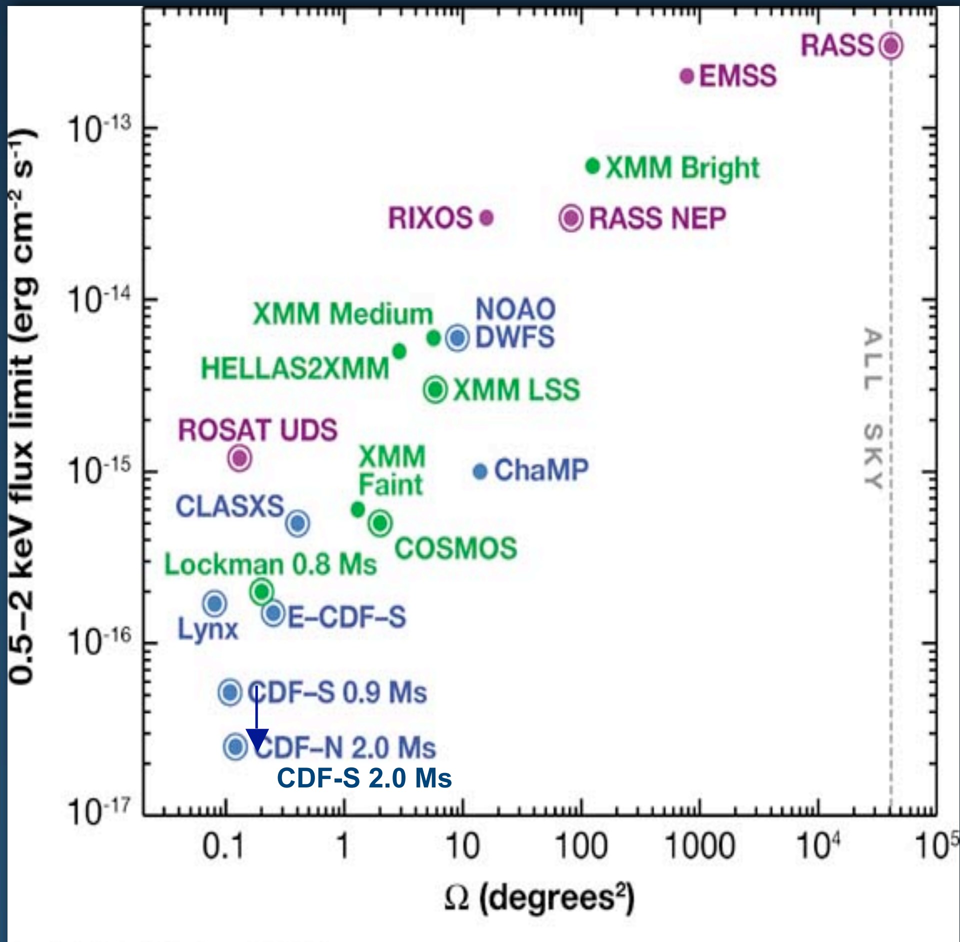
- The shape of the XRBG indicates that X-ray radiation is mostly produced by accretion processes-> **AGNs**

In fact X-ray surveys have been increasingly successful in resolving the XRBG into individual sources:

- *Einstein*: 25% of the 1-3 keV XRBG (Tanabaum et al. 1979)
- ROSAT: 75% of the 0.5-2 keV XRBG (Hasinger et al. 1993,1998)
- *ASCA*: 35% of XRBG in 2-10 keV (Gendereau et al. 1998)
- *Beppo-SAX*: 30% of 5-20 keV XRBG (Comastri et al. 2001)

Deep extragalactic X-ray surveys with Chandra and XMM-Newton

Survey name	Max. eff. exp. (ks)	**Solid angle (arcmin2)**	Representative reference or note
Chandra			
Chandra Deep Field-North	1950	448	
Chandra Deep Field-South	940	391	
HRC Lockman Hole	300	900	
Extended CDF-S	250	900	
Extended Groth Strip	200	1800	
Lynx	185	286	
LALA Cetus	174	428	
LALA Boötes	172	346	
SSA13	101	357	
Abell 370	94	357	
3C 295	92	274	
SSA22 “protocluster”	78	428	
ELAIS N1+N2	75	586	
XMM-Newton			
Lockman Hole	770	1556	
Chandra Deep Field-South	370	802	
Chandra Deep Field-North	180	752	
13 hr Field	130	665	
Subaru *XMM-Newton* Deep	100	4104	
ELAIS S1	100	1620	
Groth-Westphal	81	727	
Marano Field	79	2140	
COSMOS	75	7200	



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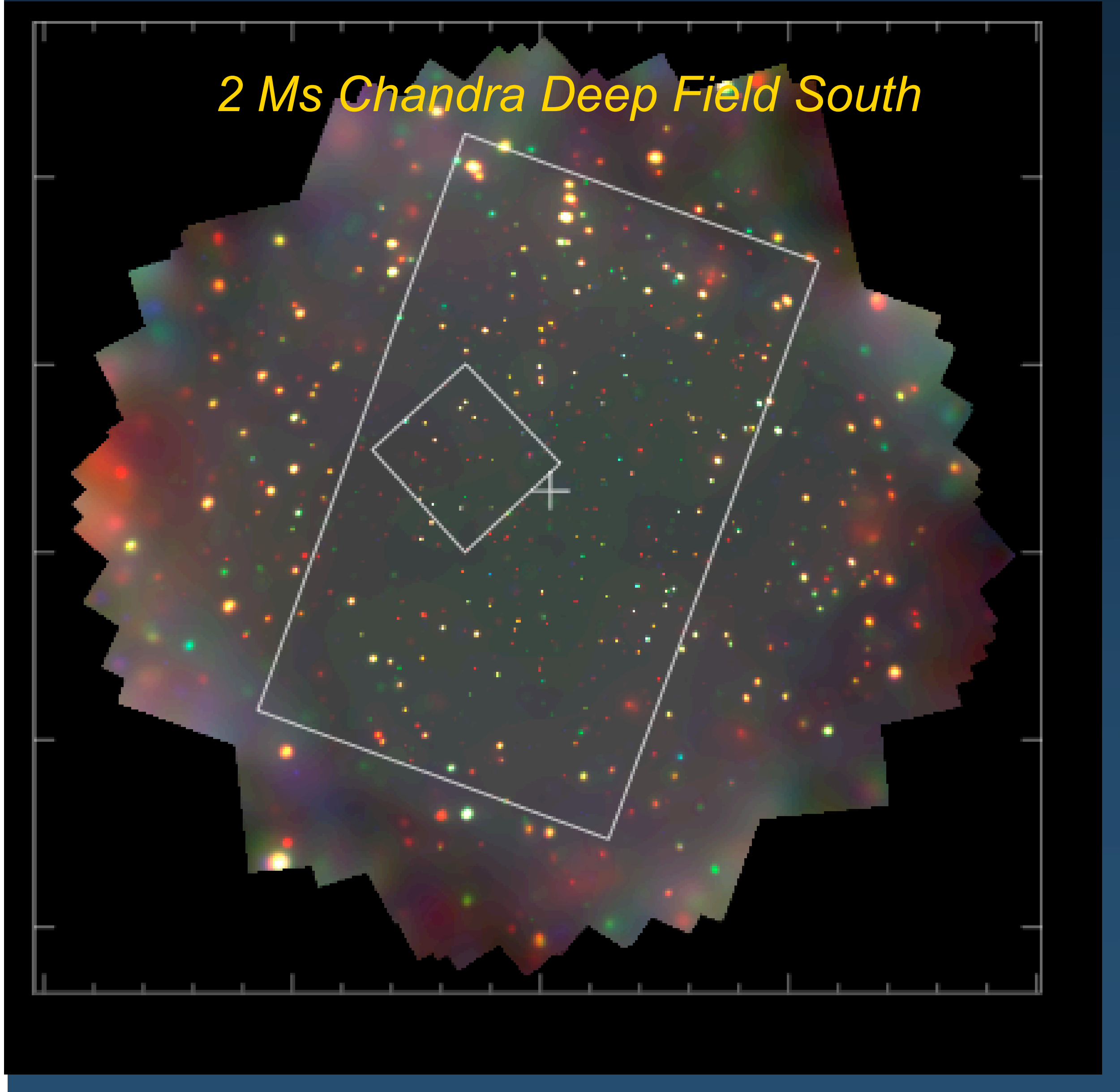
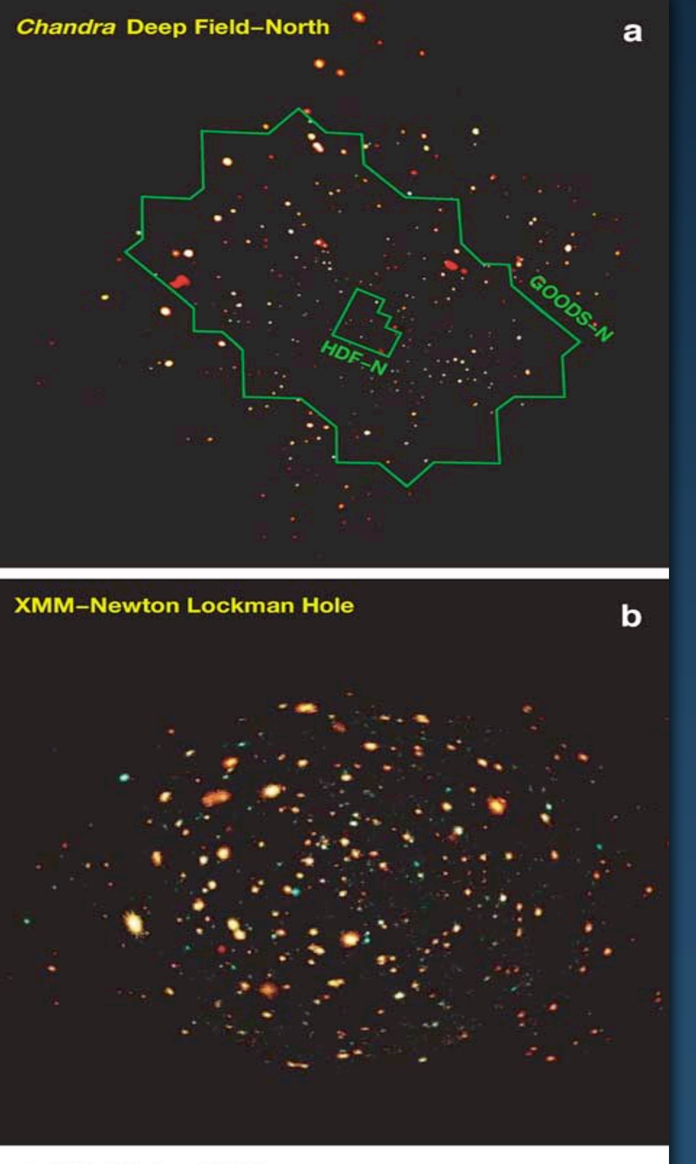
The deepest X-ray surveys





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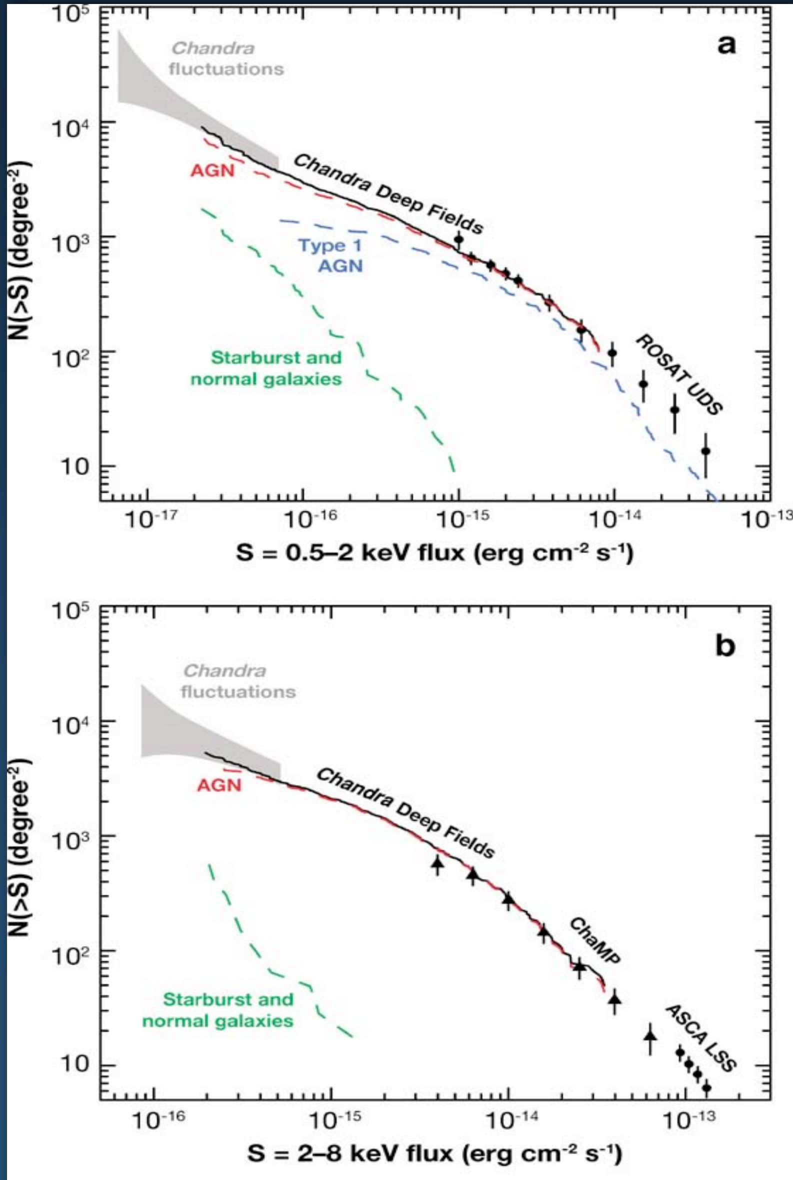
X-ray sources number counts

- In the soft band the number counts are dominated by AGNs at the bright end, but starburst and normal galaxies represent an increasing contribution at low flux levels
- In the hard band galaxies are minor contributors: a significant number of absorbed AGNs are required to match the observed counts.



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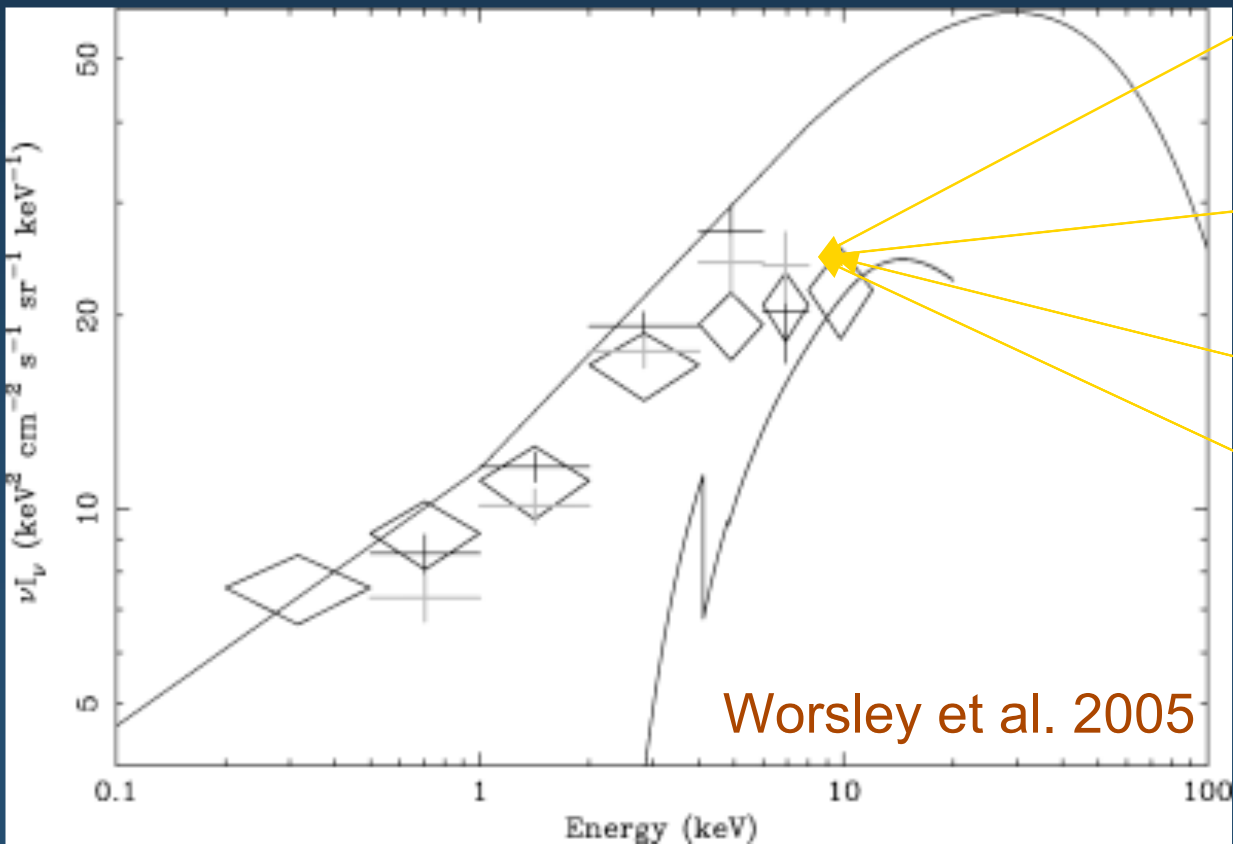
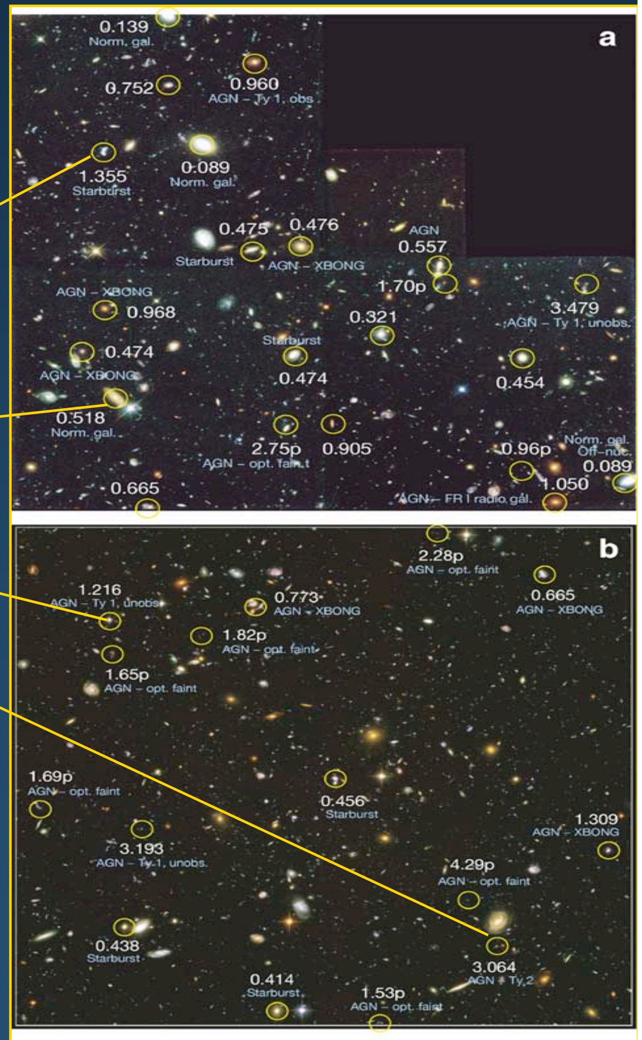
How much XRB can current deep X-ray surveys resolve?

- Almost all XRB resolved at low energies.
- Only ~50% X-Ray Background resolved at E>6 keV
- The missing fraction can be revealed "stacking" the X-ray undetected sources





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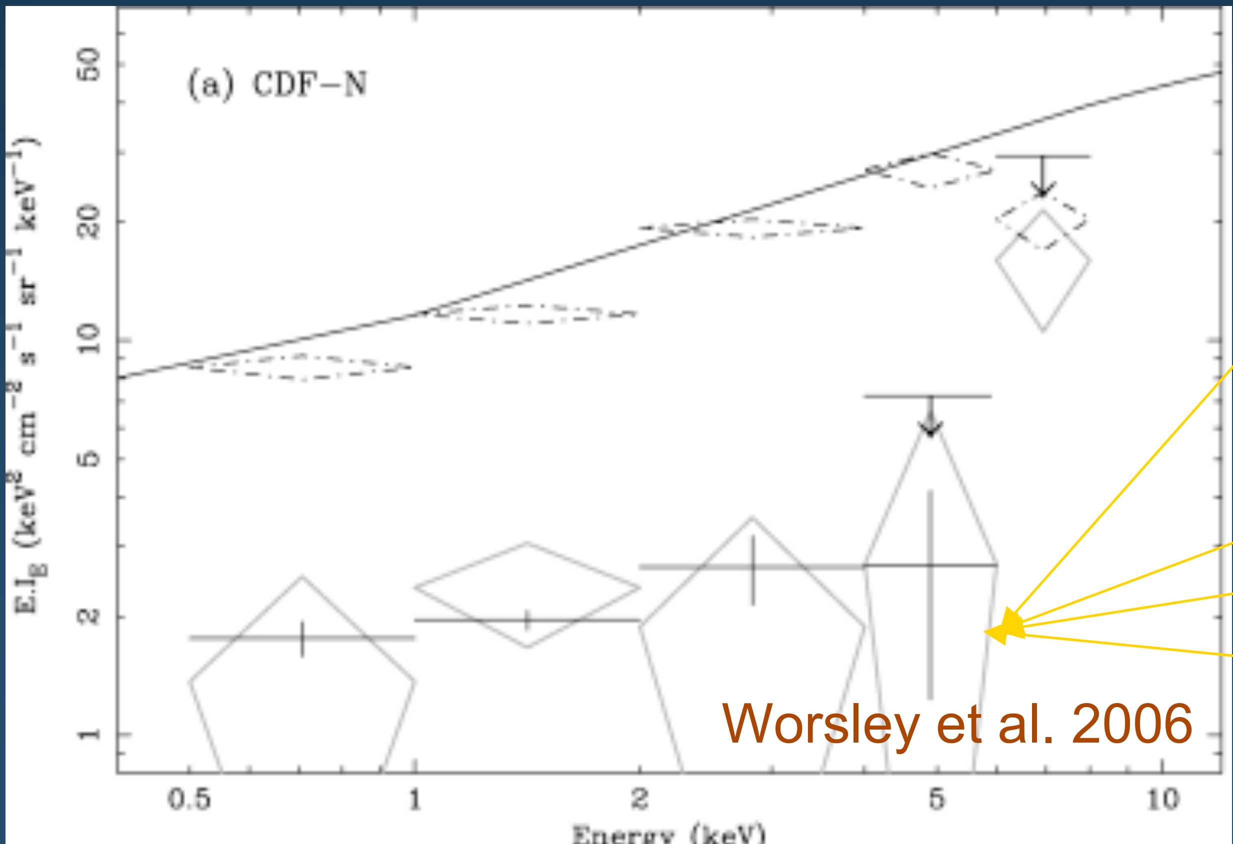

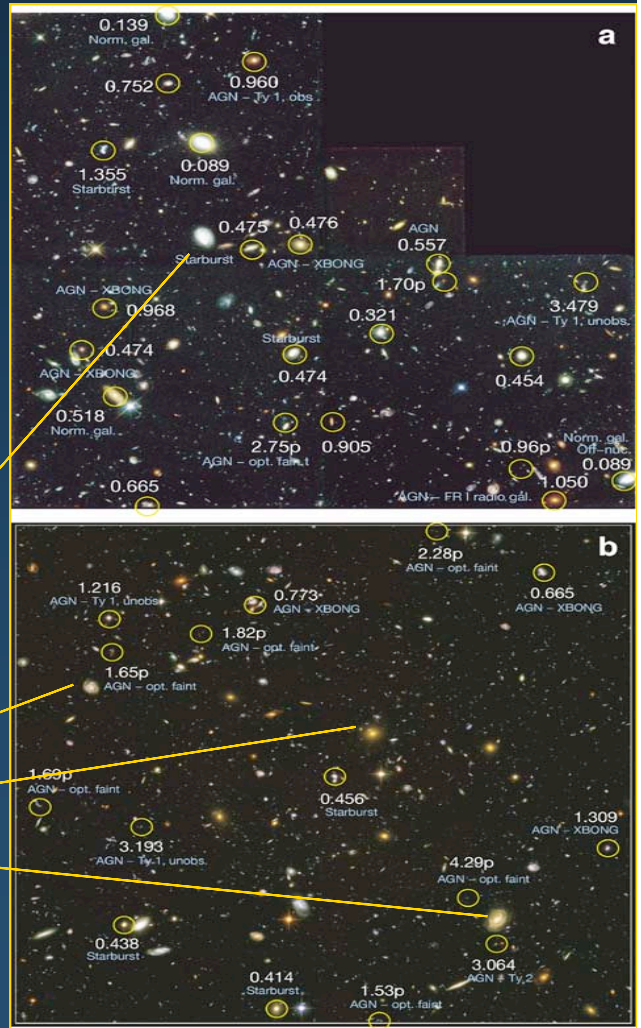

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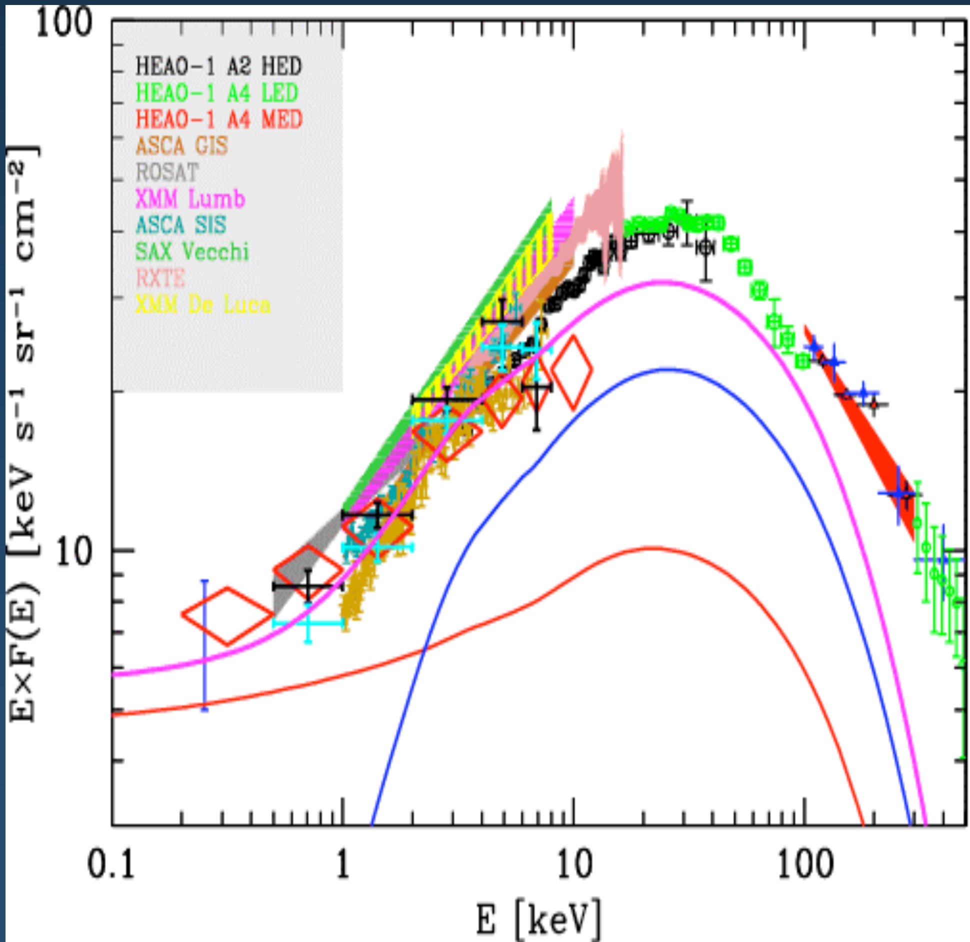
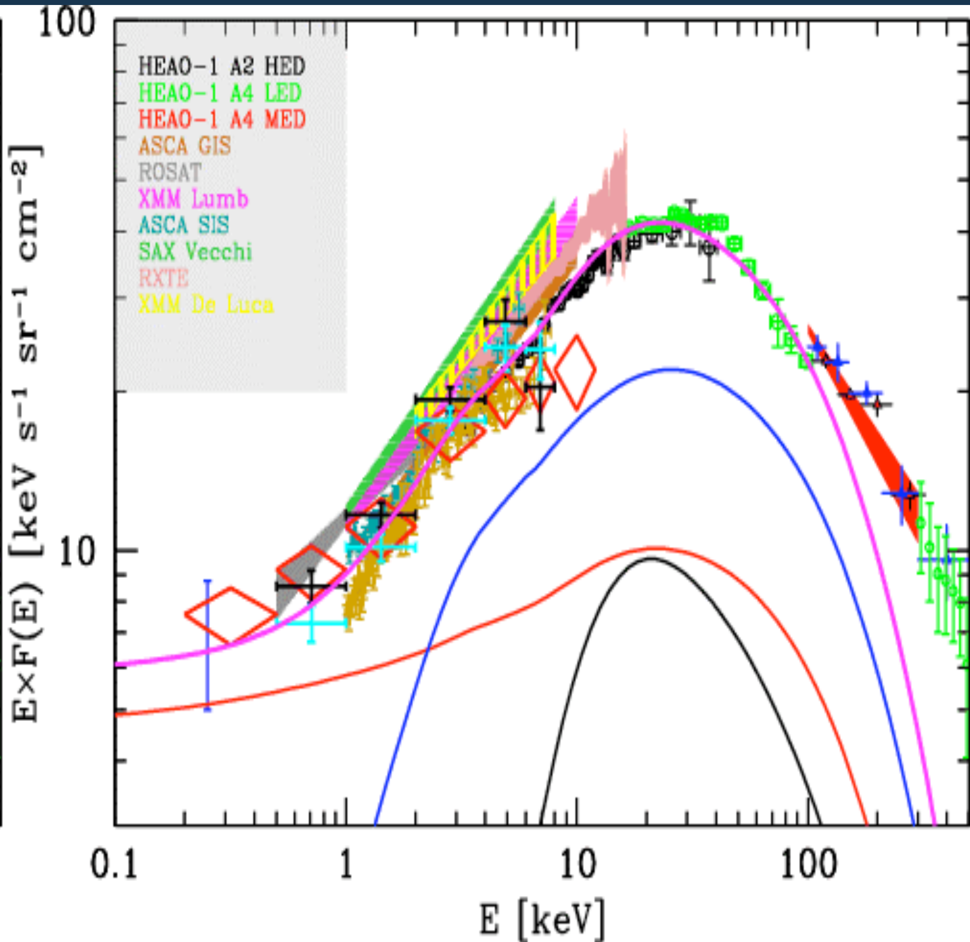
Oscured accretion

Unobscured / Obscured / Compton thick

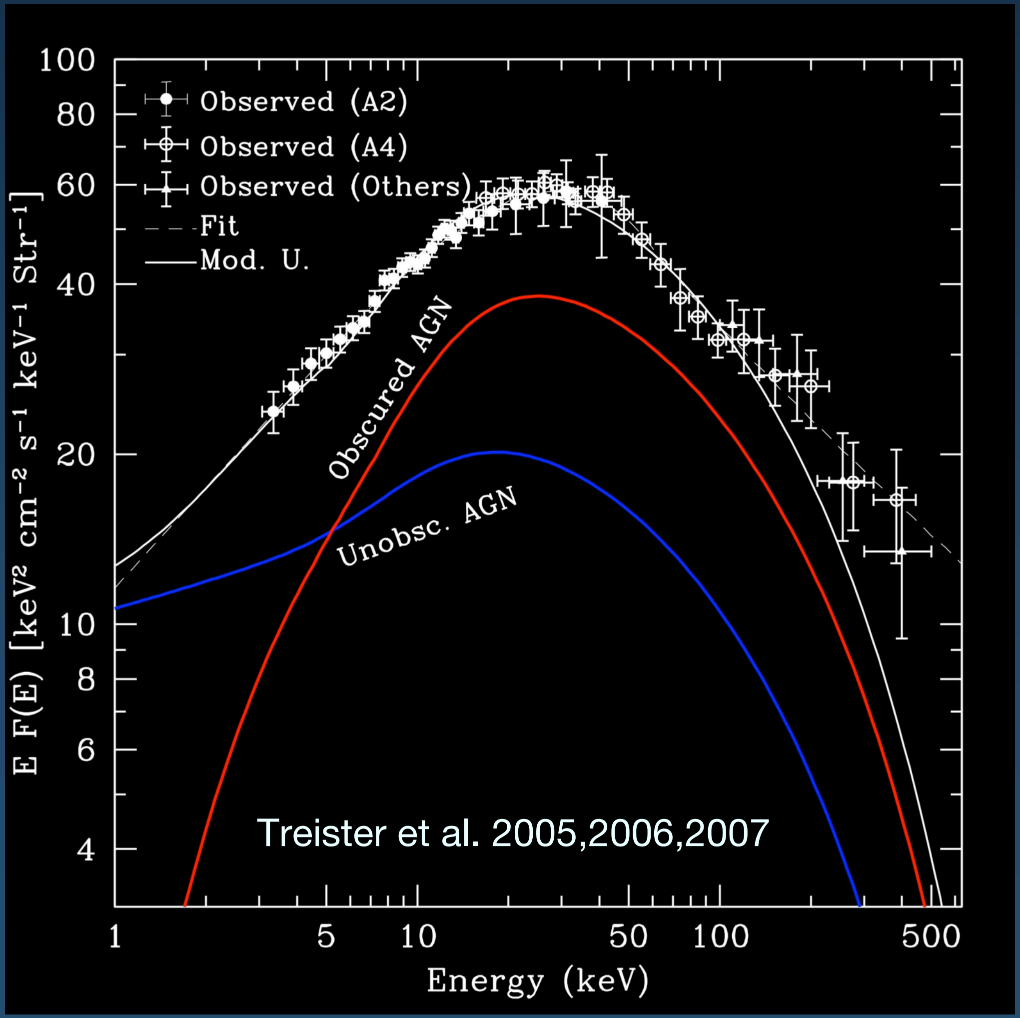
(Gilli et al. 2007)





Obscured vs unobscured accretion

- To reproduce the XRBG we need a mixture of absorbed and un-absorbed AGNs
- Obscured AGNs may represent >50% of the population
- The bulk of the BG is due to moderate luminosity AGNs
- Most undetected AGNs lie at moderate redshift (z~0.5).



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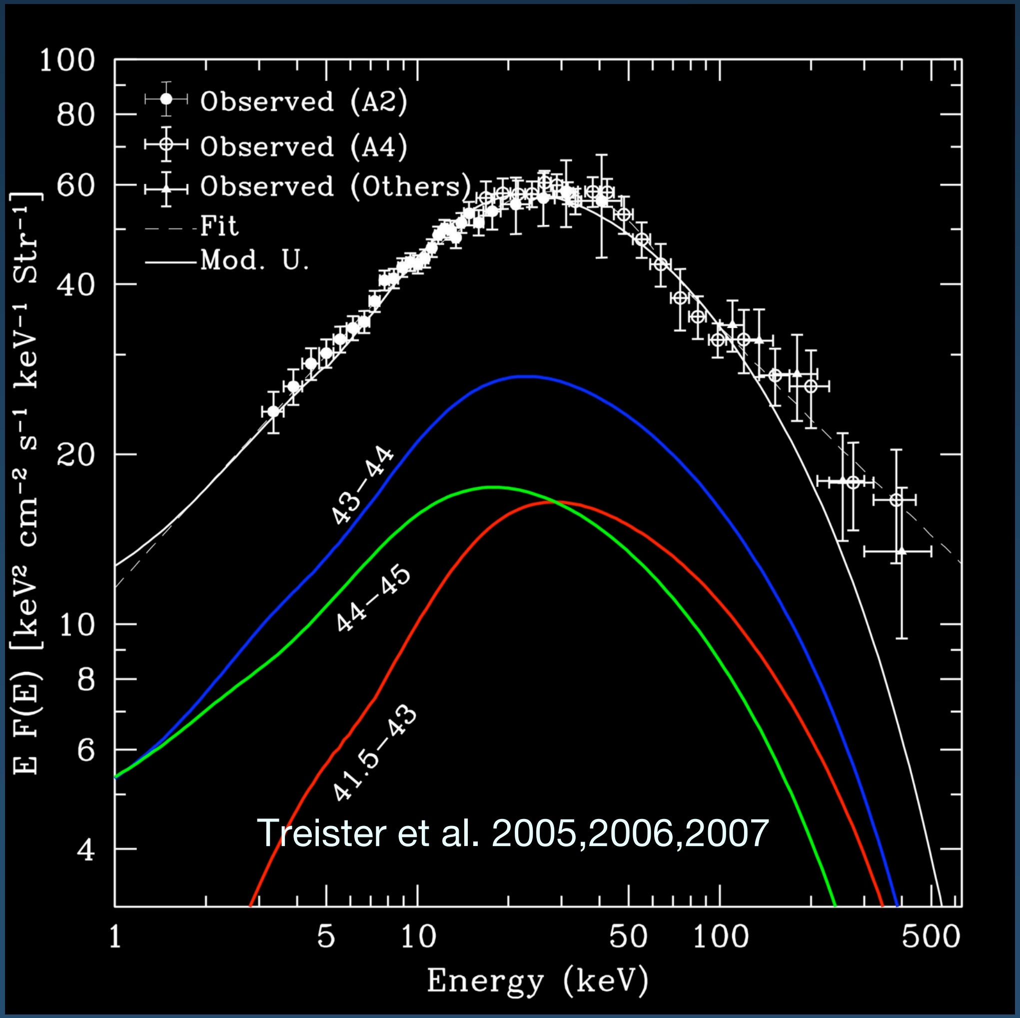

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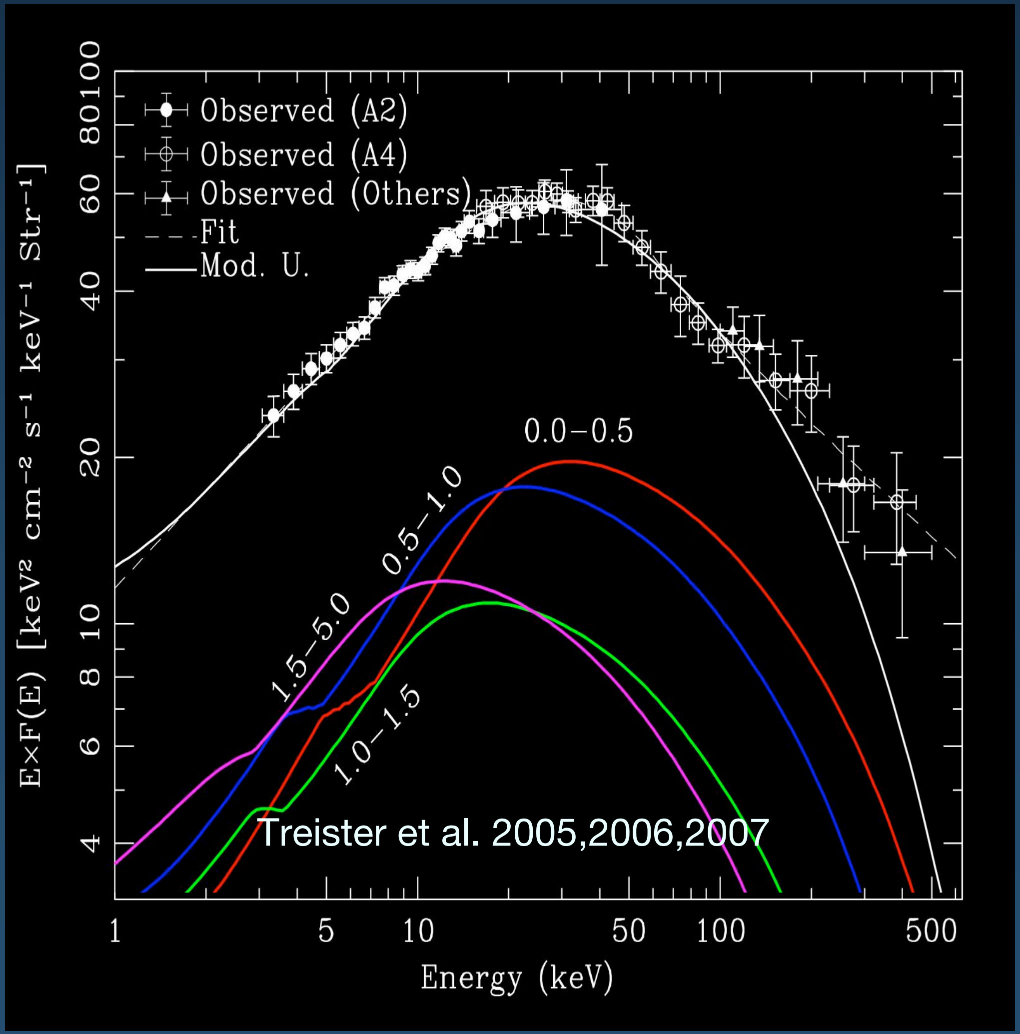

X-ray Luminosity Functions

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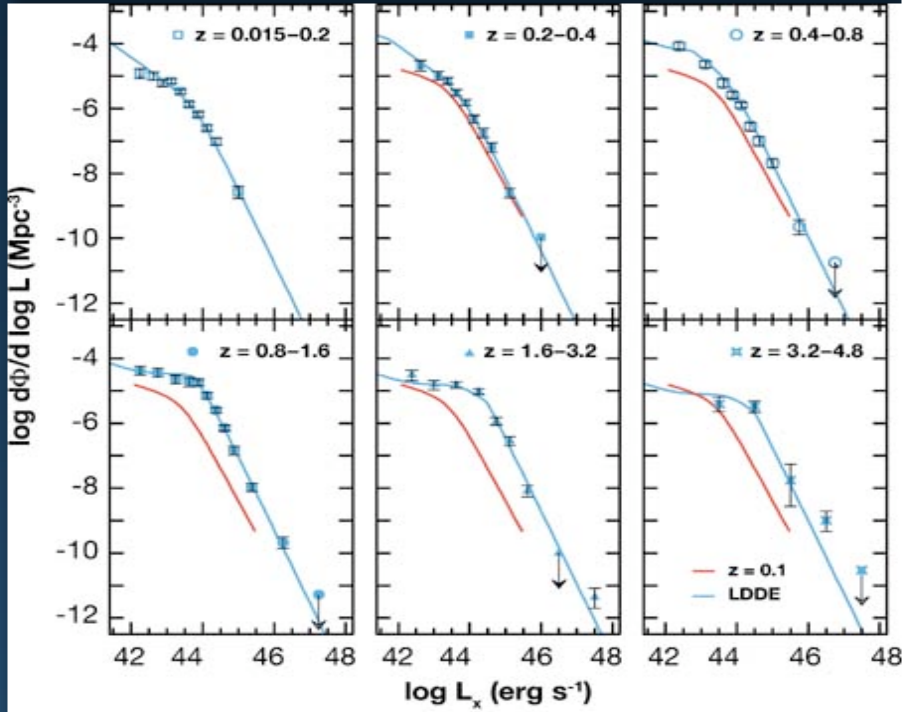
- They represent a low-order statistical indicator of the global properties of the AGN population, and hold clues to understand their formation and evolution (e.g dependence on redshift, host-galaxy properties, etc.)
- However to pinpoint the LF properties we need to use both wide (to sample rare bright objects) and deep (to trace the low-luminosity and high-z population) surveys
- Optical QSO LFs favored pure luminosity evolution



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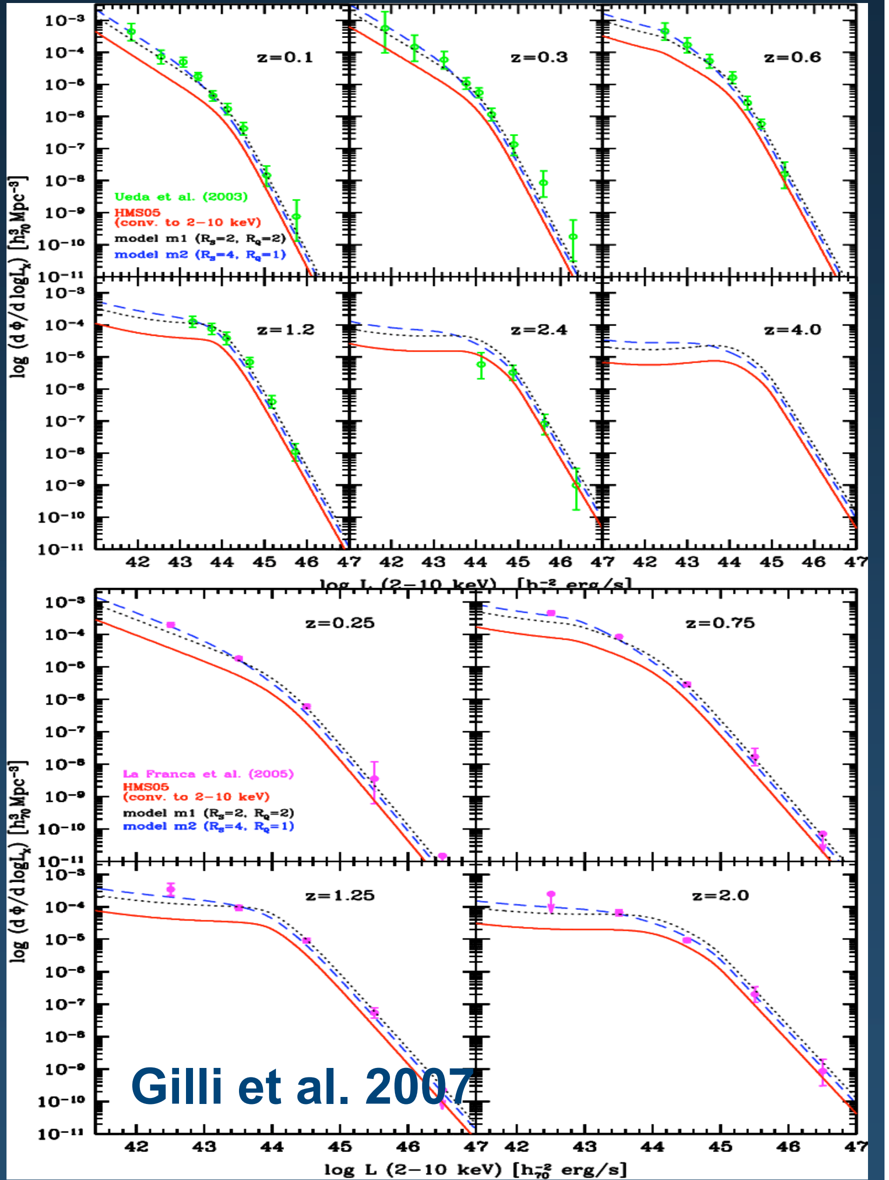
X-ray surveys now convincingly indicate a Luminosity-dependent density evolution

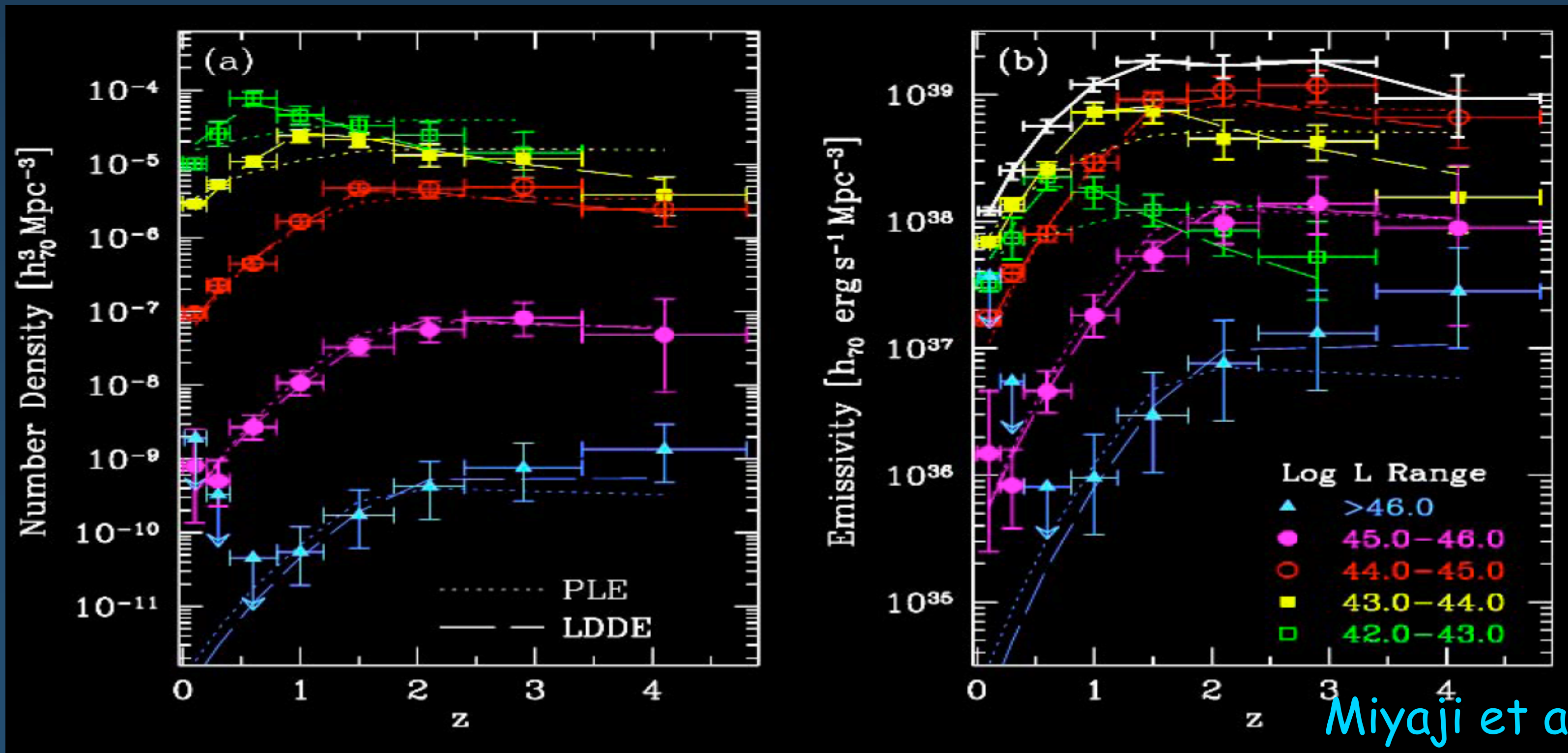
X-ray Luminosity Functions

- More recent result support this scenario:



Luminosity Dependent Density Evolution

- AGN populations of different intrinsic luminosities peak at different redshift
- "Downsizing" i.e. the bulk of accretion shifts from high-luminosity sources to low/intermediate-luminosity ones
- The AGN evolution is similar to the Star Formation History of the Universe
- PLE doesn't work; need luminosity-dependent density evolution to characterize evolution of the entire LF

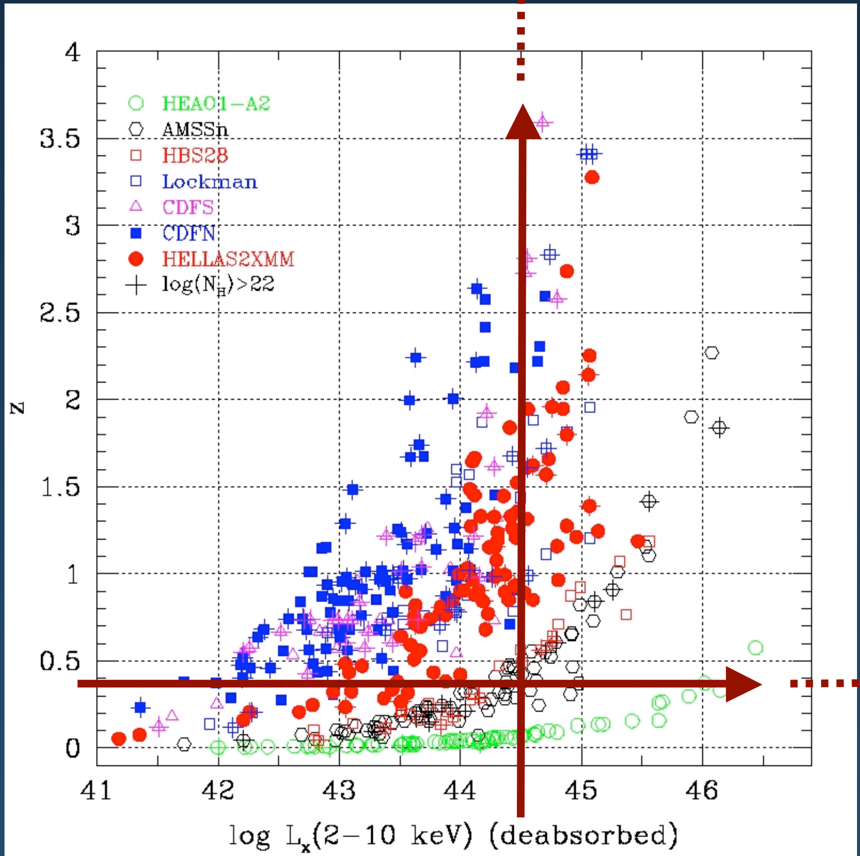


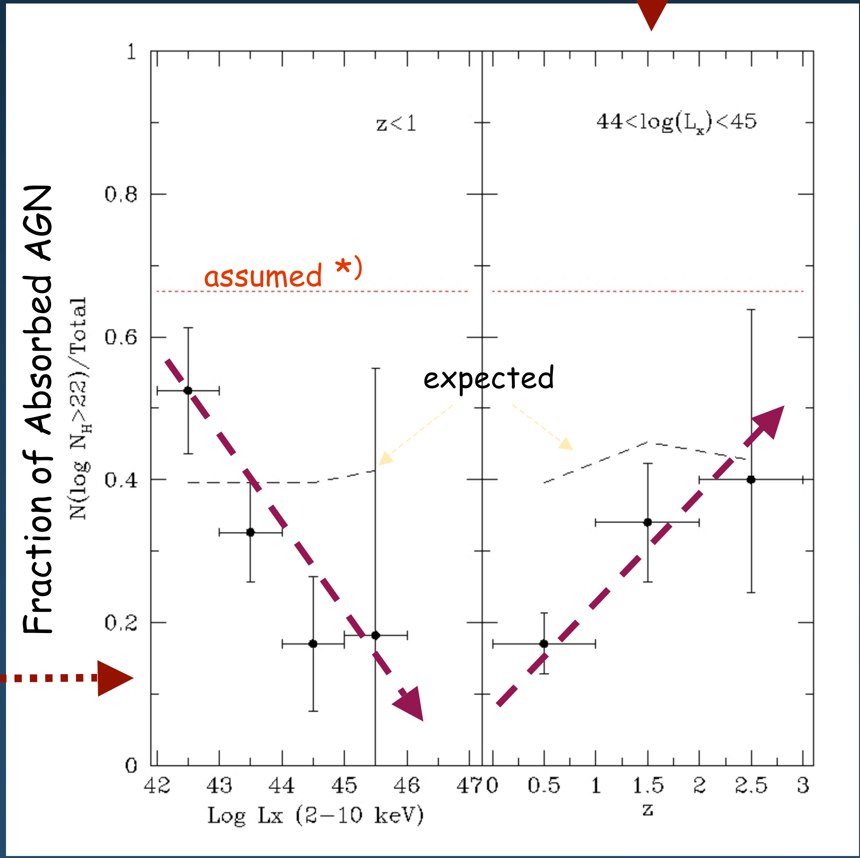
Miyaji et al. 2006

What do we know about the AGN evolution?

The fraction of absorbed AGN depends on L_X and z
(note the need of complete samples!)

INCREASE WITH REDSHIFT





*) Assuming no luminosity and redshift dependences

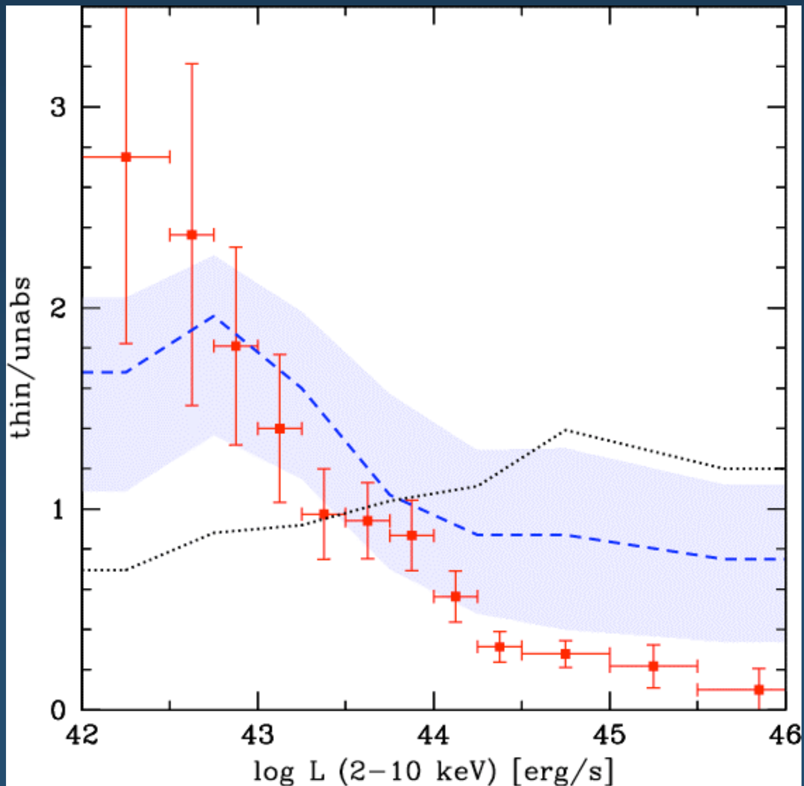
DECREASE WITH LUMINOSITY

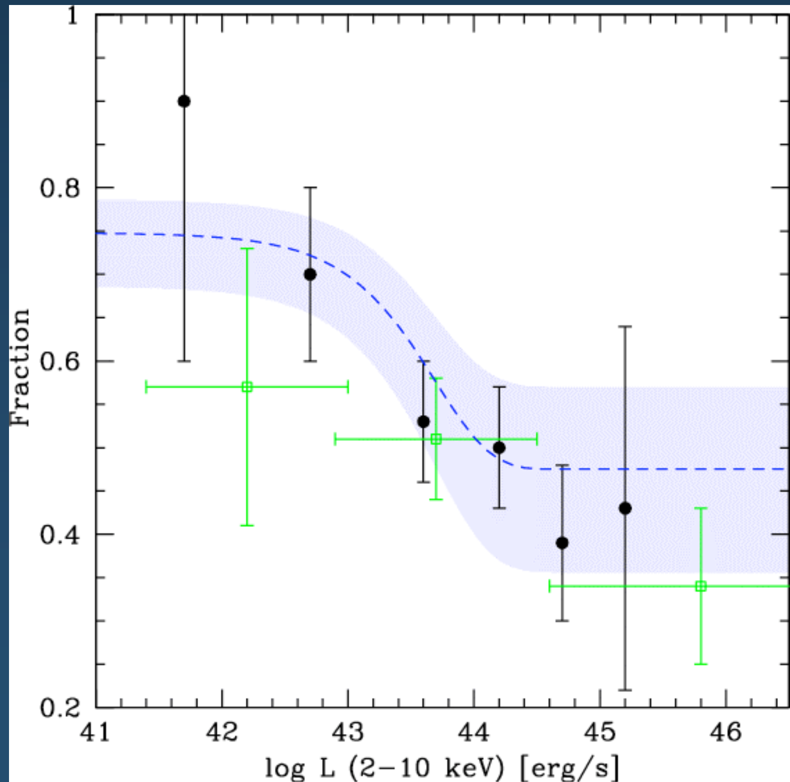
Earlier evidences of a decrease of the fraction of absorbed AGN with luminosity from Lawrence & Elvis (1982), confirmed by Ueda et al. (2003).

Courtesy of laFranca '07

Obscured fraction evolution

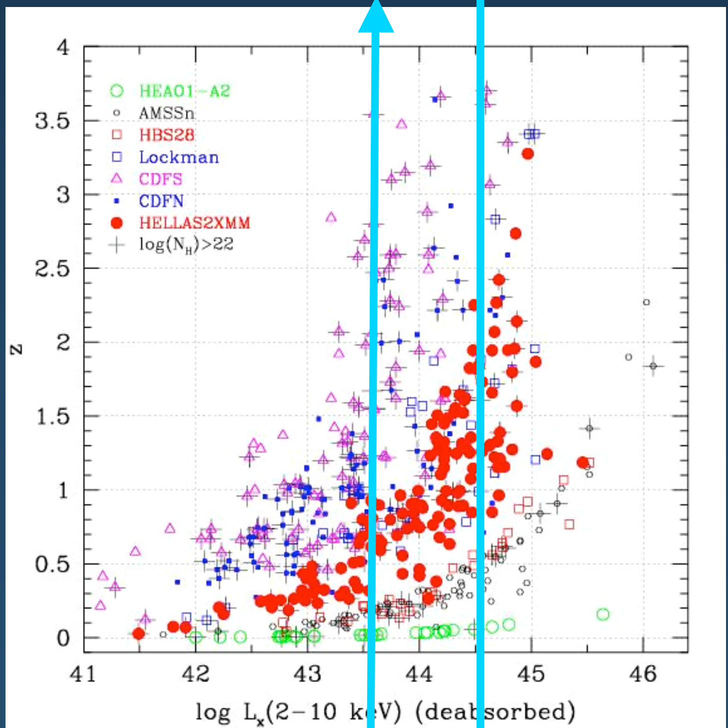
- Type I/type II (left panel) or low/high N_H ratio (right panel) are consistent and suggest that this ratio depends on intrinsic luminosity (Gilli et al. 2007, Akyla et al. 2006, Ueda et al. 2003, Hasinger et al. 2005) => AGN feedback on host galaxy?

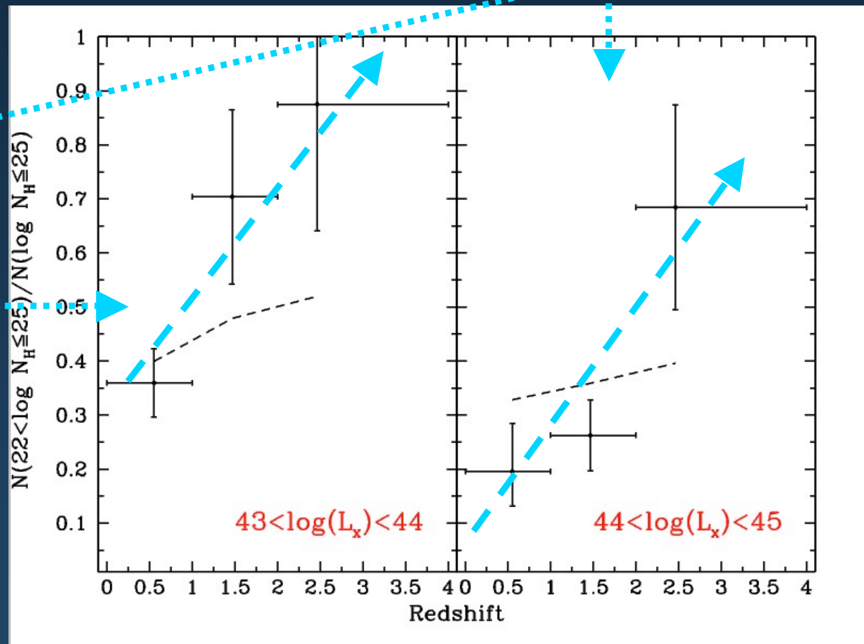




Fraction of absorbed AGN as function of z

The increase with z is confirmed using X-ray spectral fits only from CDFS-H2XMM-HBS28-Lockmann-Piccinotti samples (see also talk of Treister)





The z dependence is evident at any luminosity

The luminosity dependence is evident at any z

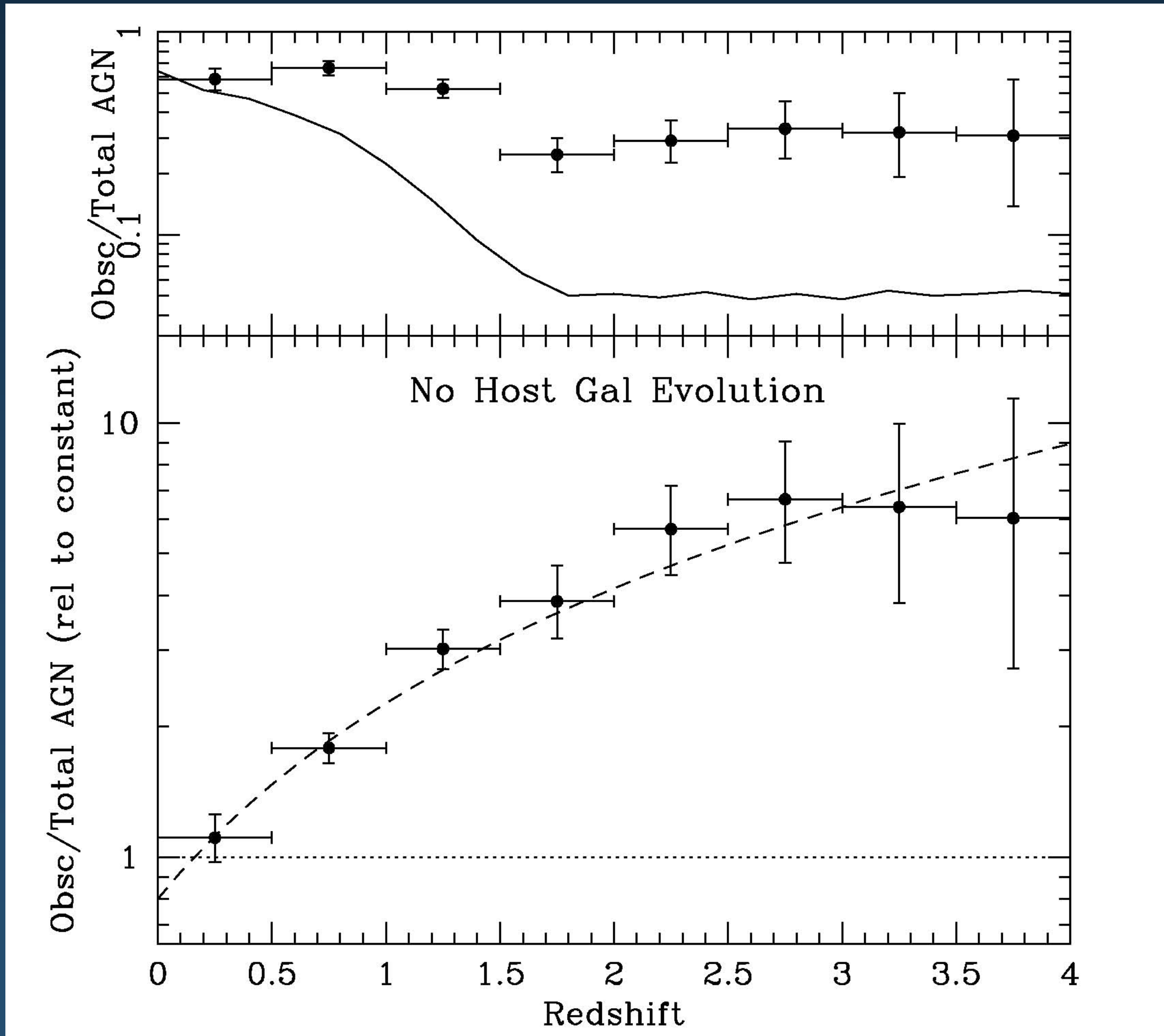
Courtesy of laFranca '07

Evolution with redshift is still debated!

Observed ratio

Relative to constant

Treister et al. 2007



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Observed ratio

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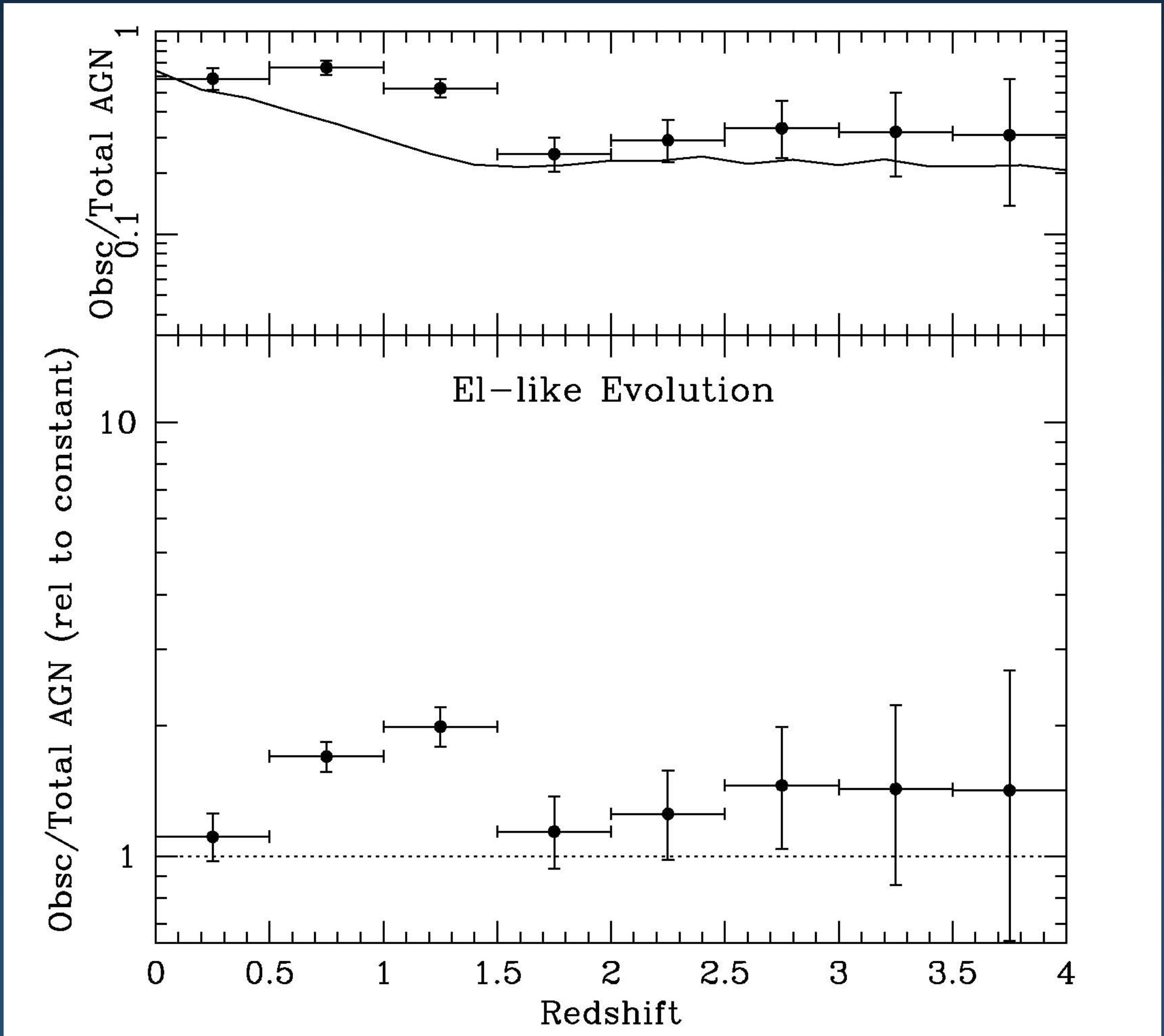
Treister et al. 2007



Local constrains on AGN accretion

- Soltan (1982) first proposed that the mass in black holes today is simply related to the emissivity of the Quasar population integrated over luminosity and redshift (if QSO are powered by accretion!)

$$L_{bol} = \epsilon \dot{M}_{acc} c^2 = \epsilon \dot{M}_{\bullet} c^2 / (1 - \epsilon)$$

$\dot{M}_{acc}$: mass accretion rate $\qquad \epsilon$: efficiency factor, ~ 0.1

$\dot{M}_{\bullet}$: BH accretion rate

The BH mass density at redshift z is thus given by integrating over the AGN bolometric LF

$$\rho_{BH,acc}(z) = \int_z^\infty \frac{dt}{dz'} dz' \int_0^\infty \frac{(1-\epsilon) L_i k_i}{\epsilon c^2} \Phi(L_i, z) dL_i$$

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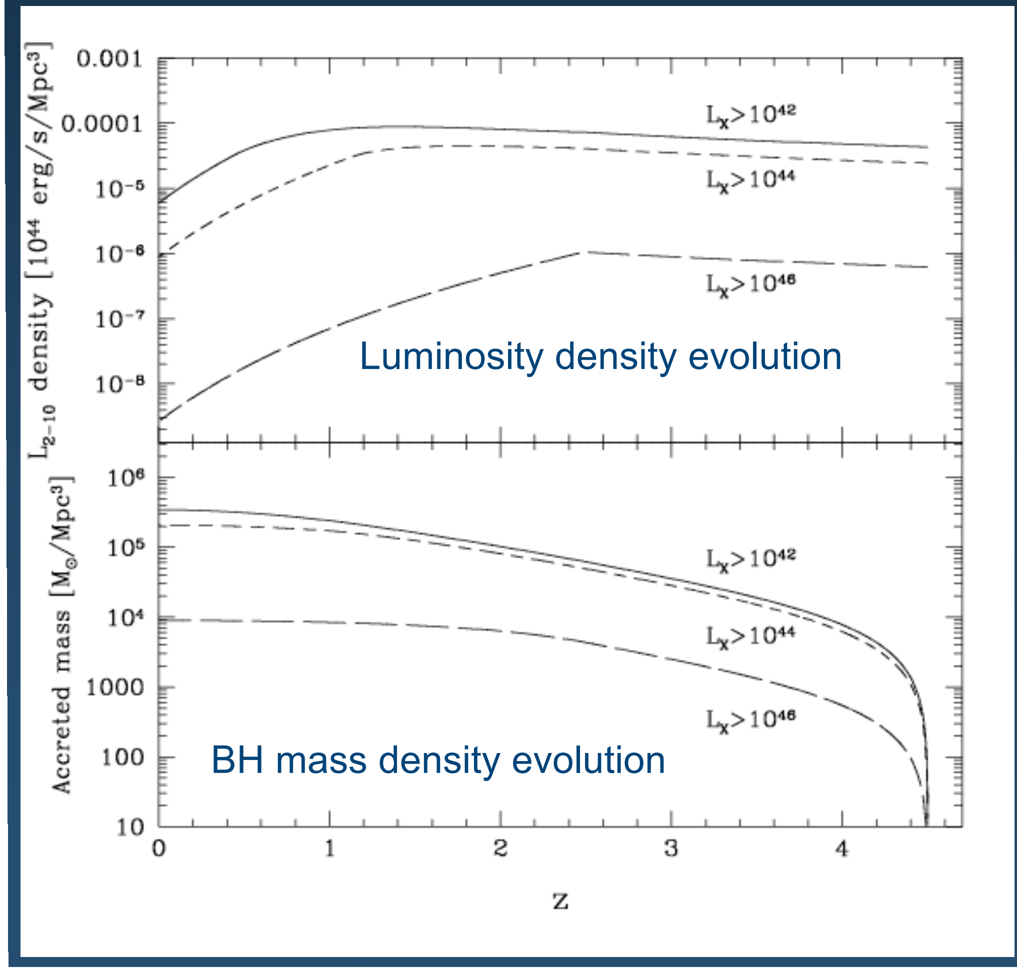
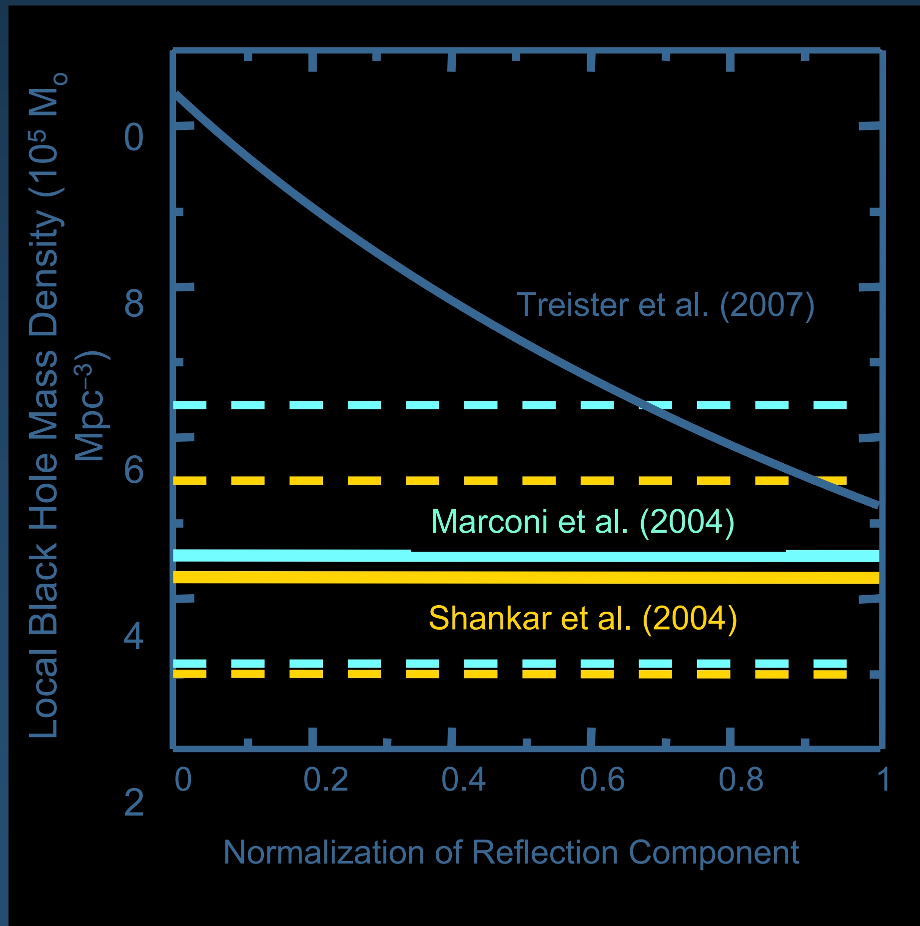
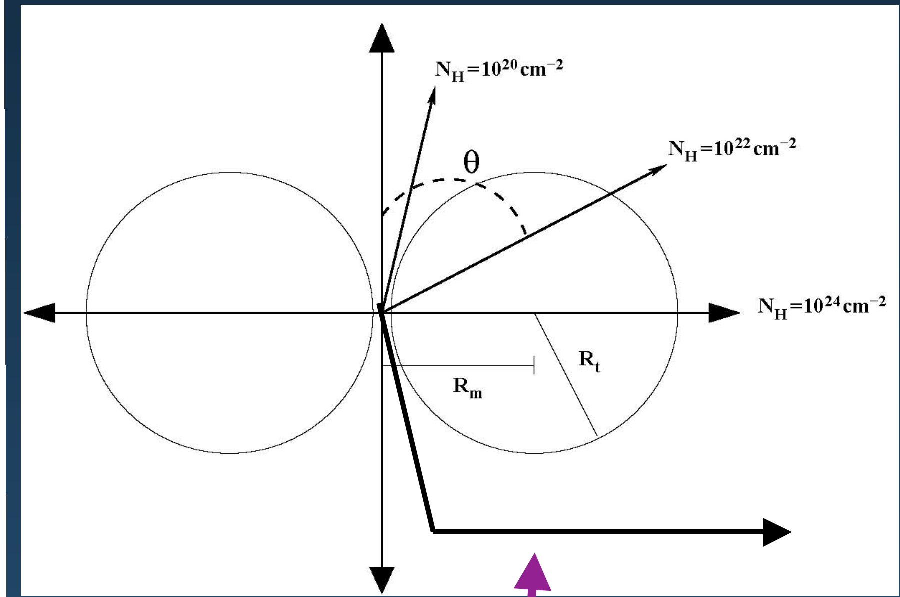
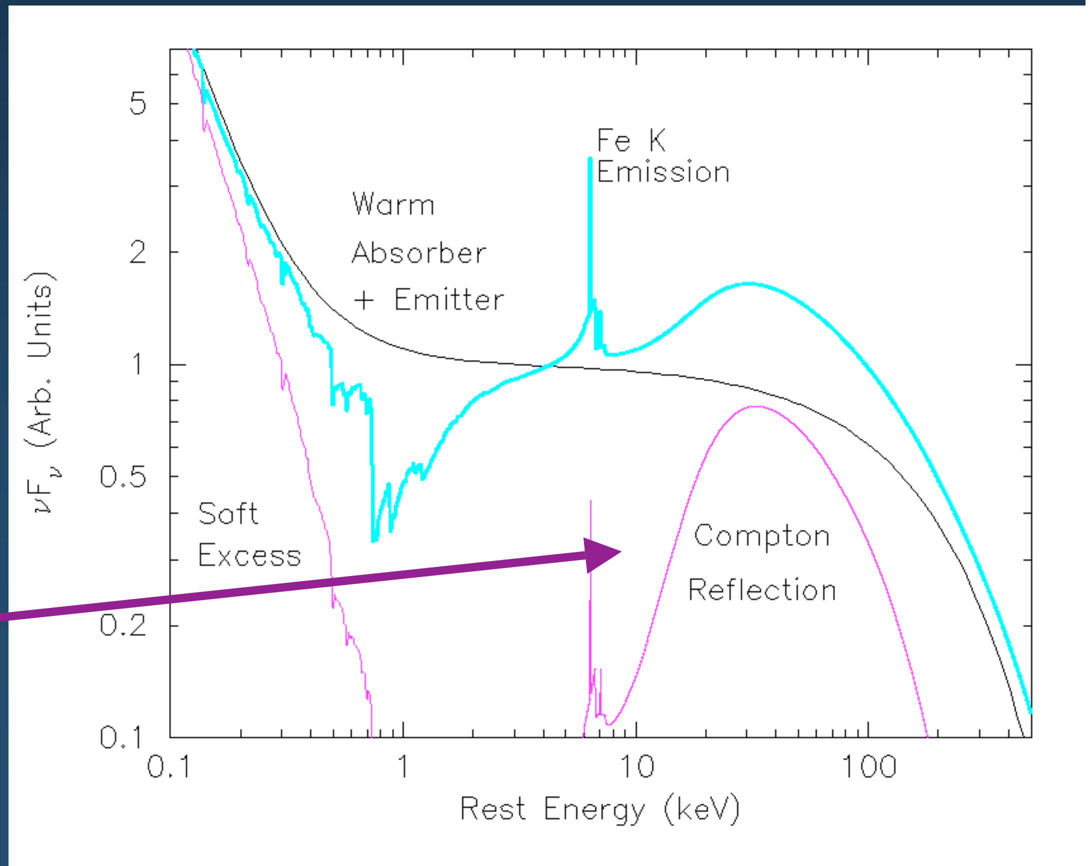




Were to look for hidden AGNs?

- Soft X-rays (<10 keV)





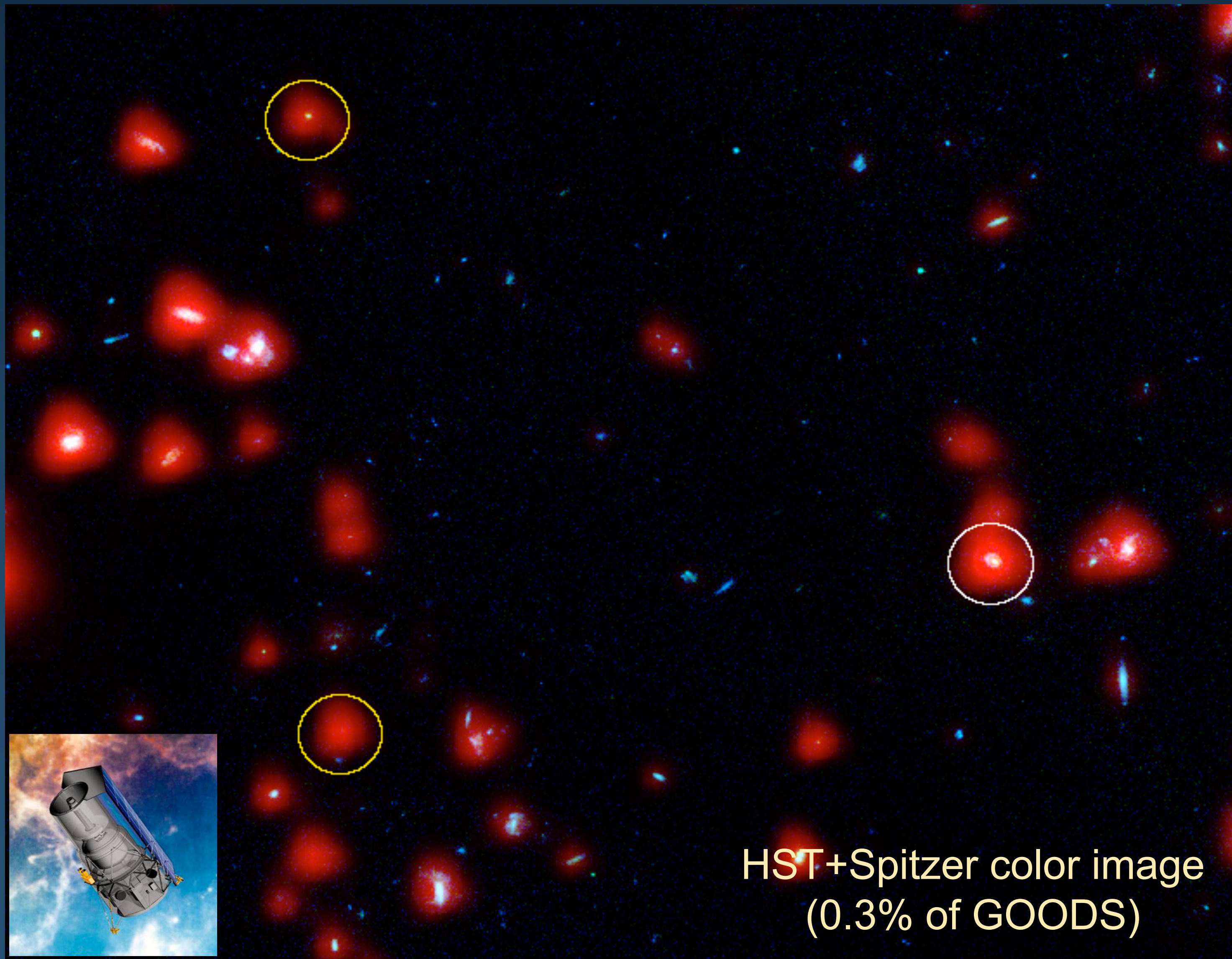
Compton reflection

Were to look for hidden AGNs?

- Infrared

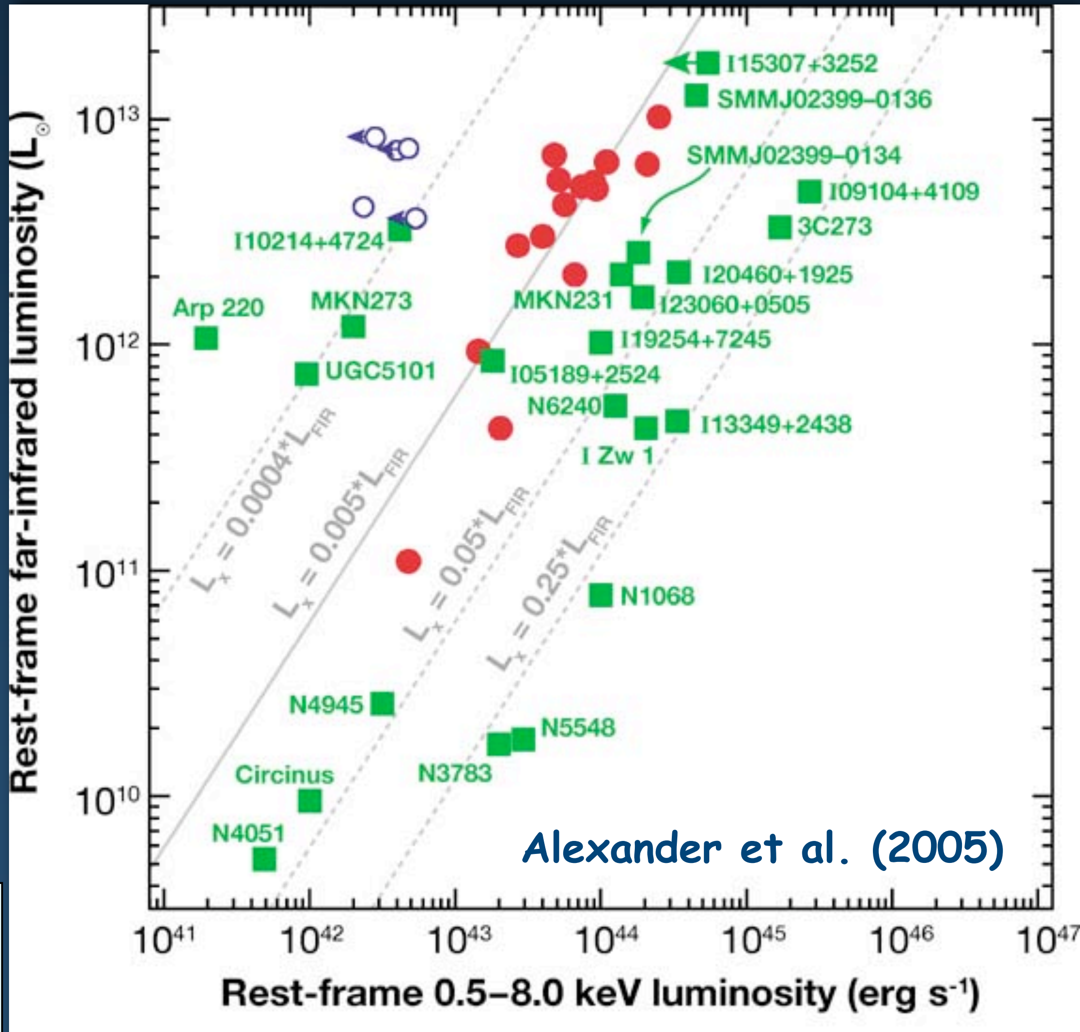
Were to look for hidden AGNs?

- Infrared



AGN content of submillimeter galaxies

- A large fraction of X-ray detected sub-mm (850 μm) galaxies contain AGNs (Alexander et al. 2005)
- SMBH are continuously growing during major star-forming episodes
- The duty cycle can be as high as 50% (Daddi et al. 2007)

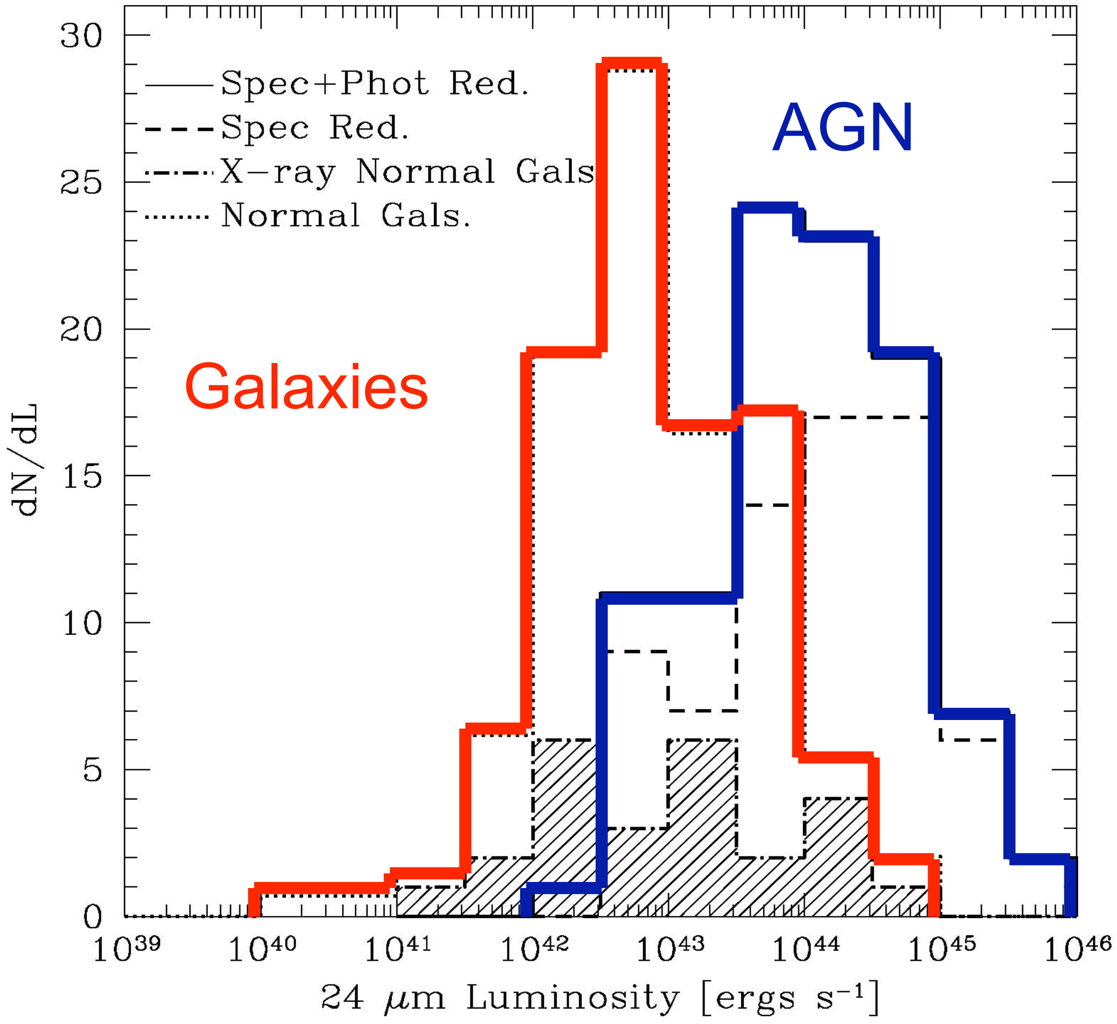


Brandt, WN and Hasinger, G. 2005
Annu. Rev. Astron. Astrophys. 43: 827–59

- AGN/Starburst dominated gals
- Sub-mm gals. Containing AGNs
- Possibly pure starbursts

Total 24 μm luminosities

- AGNs represent only a minor fraction of the IR background (<10%) but dominate at bright luminosities



IR excess in mid-infrared galaxies

- Gilli et al. (2007) find excess X-ray emission in mid-IR detected galaxies, compared to expectations from UV star-formation rates.
- The excess emission is likely due to obscured AGNs

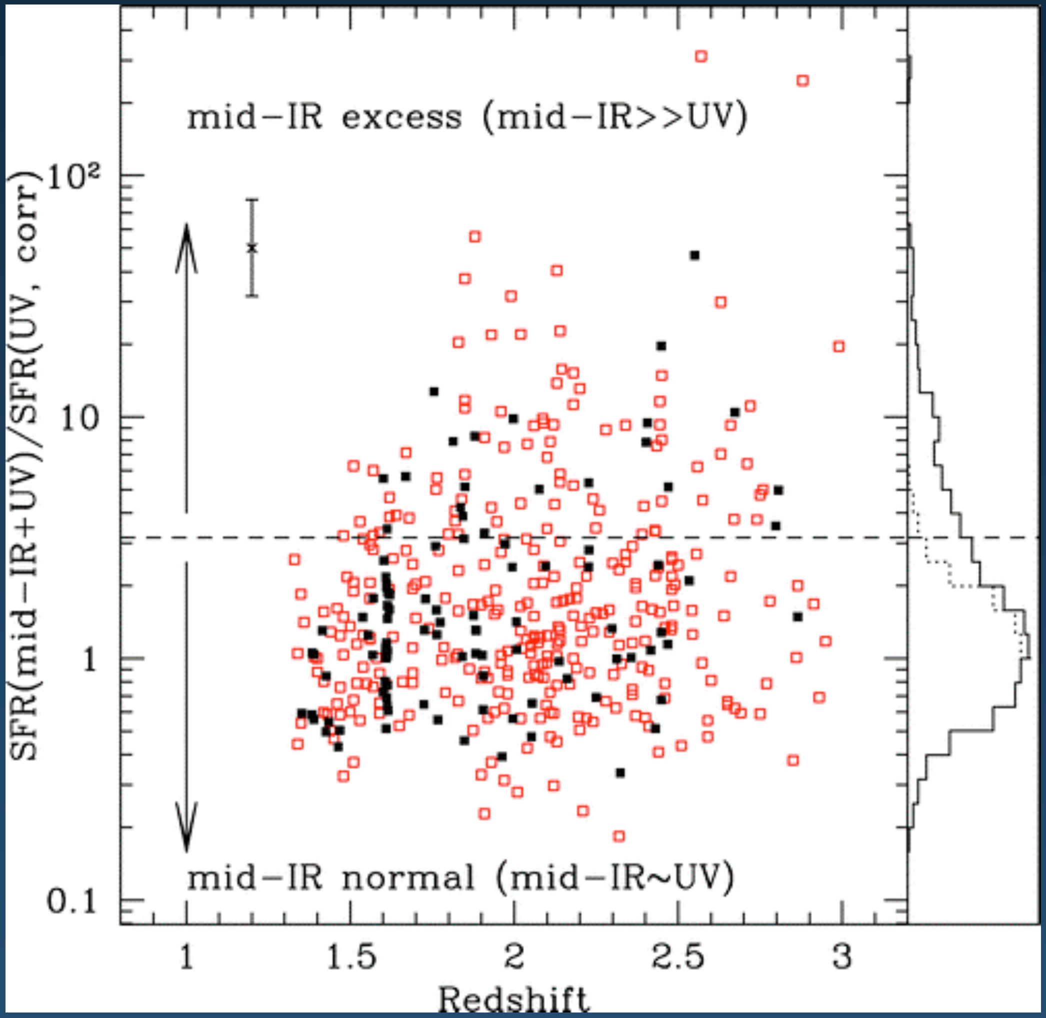


Fig. 1.— Ratio of mid-IR–based to UV-based SFR plotted as a function of the redshift. Here and in several of the figures in this paper, we plot only the GOODS-S portion of the galaxy sample, being deeper and extending to . Filled squares indicate spectroscopic redshifts, while open squares indicate photometric redshifts. The horizontal line defines the separation between mid-IR excess and normal galaxies, as given by eq. (1). The rightmost panel shows the distribution of sources as a function of mid-IR excess ratio. The dotted line is the reflection of the bottom part of the histogram around a ratio of 1. The error bar in the top left part of the figure shows the typical error in the SFR ratio, inferred from the spread of the histogram around a ratio of 1.

X-ray stacking of IR-excess gals

- Stacking the X-ray emission of normal and mid-IR excess galaxies we find an excess of hard photons in mid-IR excess galaxies.
- Note that the galaxies are selected based on UV and IR data, so **the difference is intrinsic** and not due to selection effects!

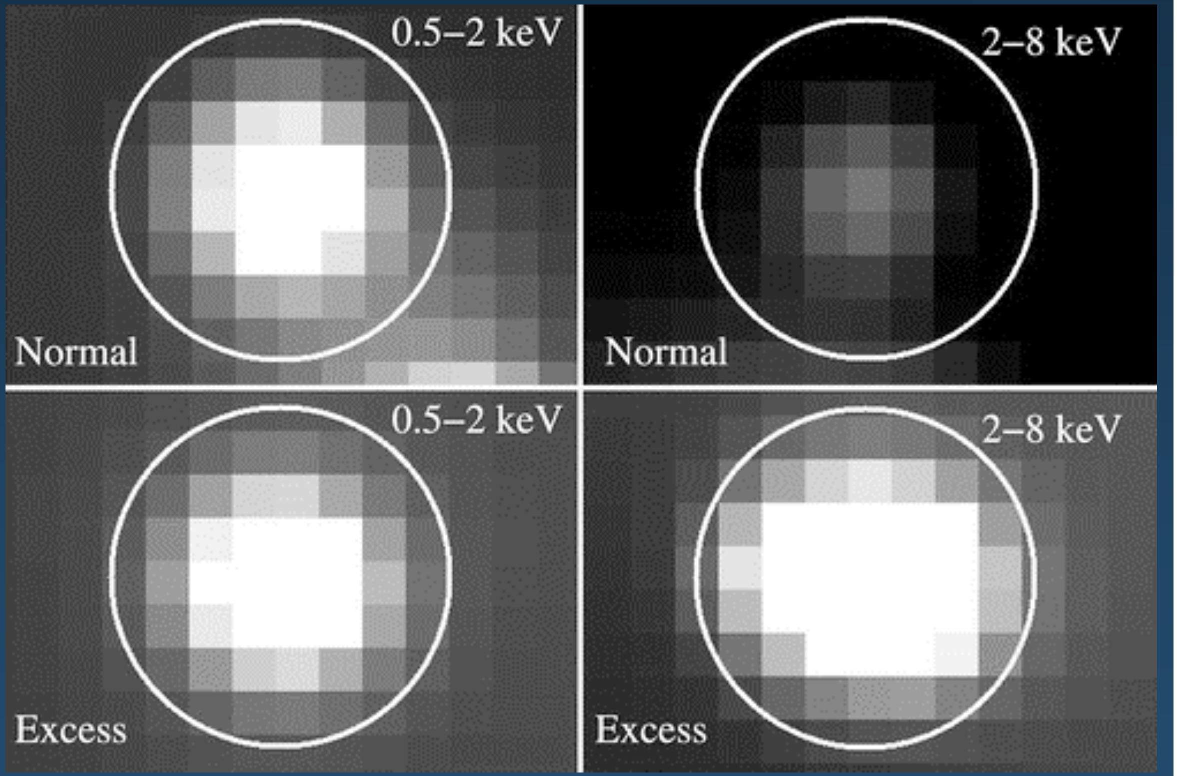


Fig. 6.— Soft and hard X-ray Chandra stacked images of normal and mid-IR excess objects in GOODS-S. Left panels show the soft (0.5–2 keV) bands, while the right panels are for hard (2–8 keV) bands. The top two images are for normal galaxies, while the bottom two are mid-IR excess objects. It is evident that similar soft X-ray fluxes are detected in the two samples, but much stronger hard emission is detected for the mid-IR excess galaxies. Images have been smoothed by a Gaussian with the size of the point-spread function. The circles (4 diameter) show the expected location of the signal.

Hard X-ray emission of IR-excess gals

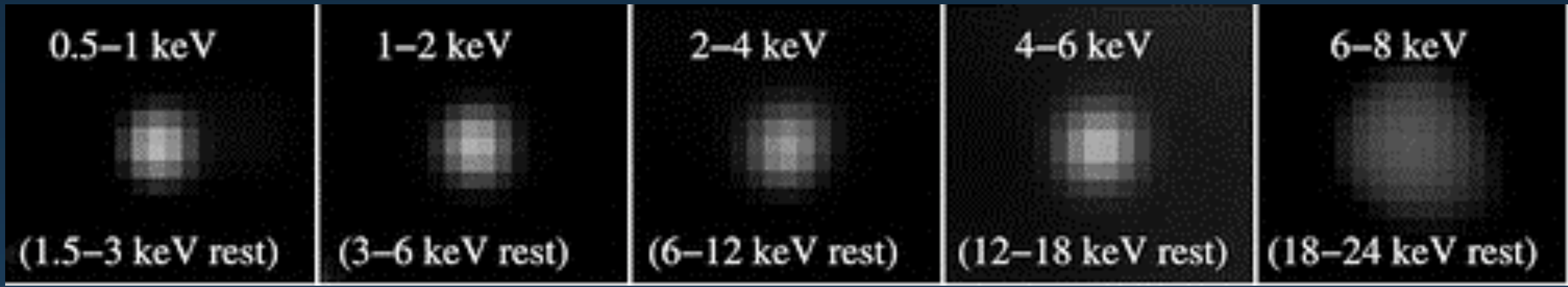
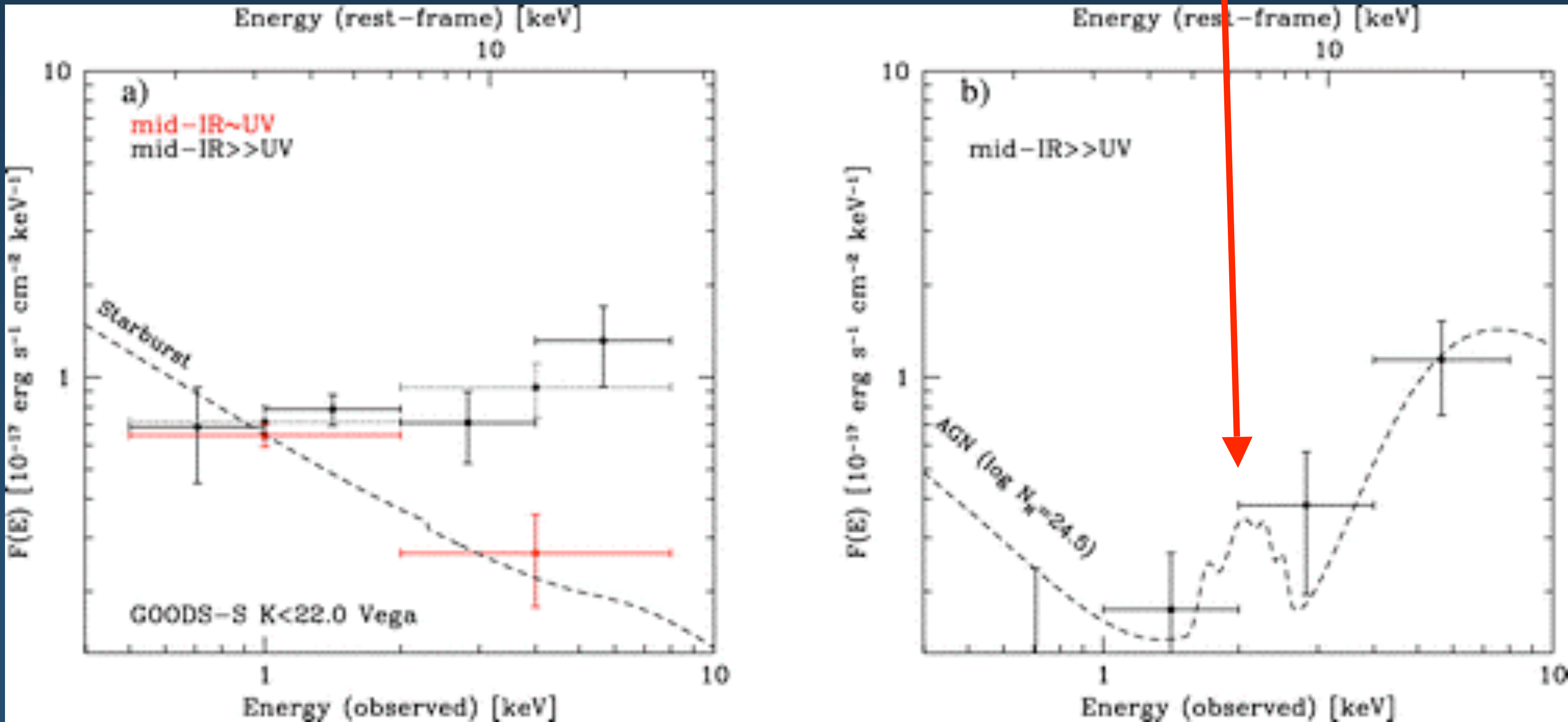


Fig. 8.—Chandra sub-band stacking detections of mid-IR excess galaxies. The images have been smoothed with the point-spread function of the band, to enhance the signal visibility. Each panel size is 12 .

- In this case **redshift plays in our favor**: in high-z galaxies we sample much harder energy ranges than we do for local sources!
- We are thus sensitive to the wavelength range where the bulk of X-ray emission from obscured and Compton-thick AGNs is detectable.

Hard X-ray emission of IR-excess gals

- The hard X-ray emission in excess to a pure starburst is well modeled by an AGN model with cm– 2 (Gilli et al. 2007) convolved with the redshift distribution of the sample.
- The bump in the models near 2 keV (in the observed frame) is due to the strong Fe emission line expected to be prominent in obscured AGNs



Density evolution of Compton-thick AGNs

- IR wavelength are best suited to detect the bulk of the Compton-thick AGN population

IR selected

X-ray selected

Radio selected

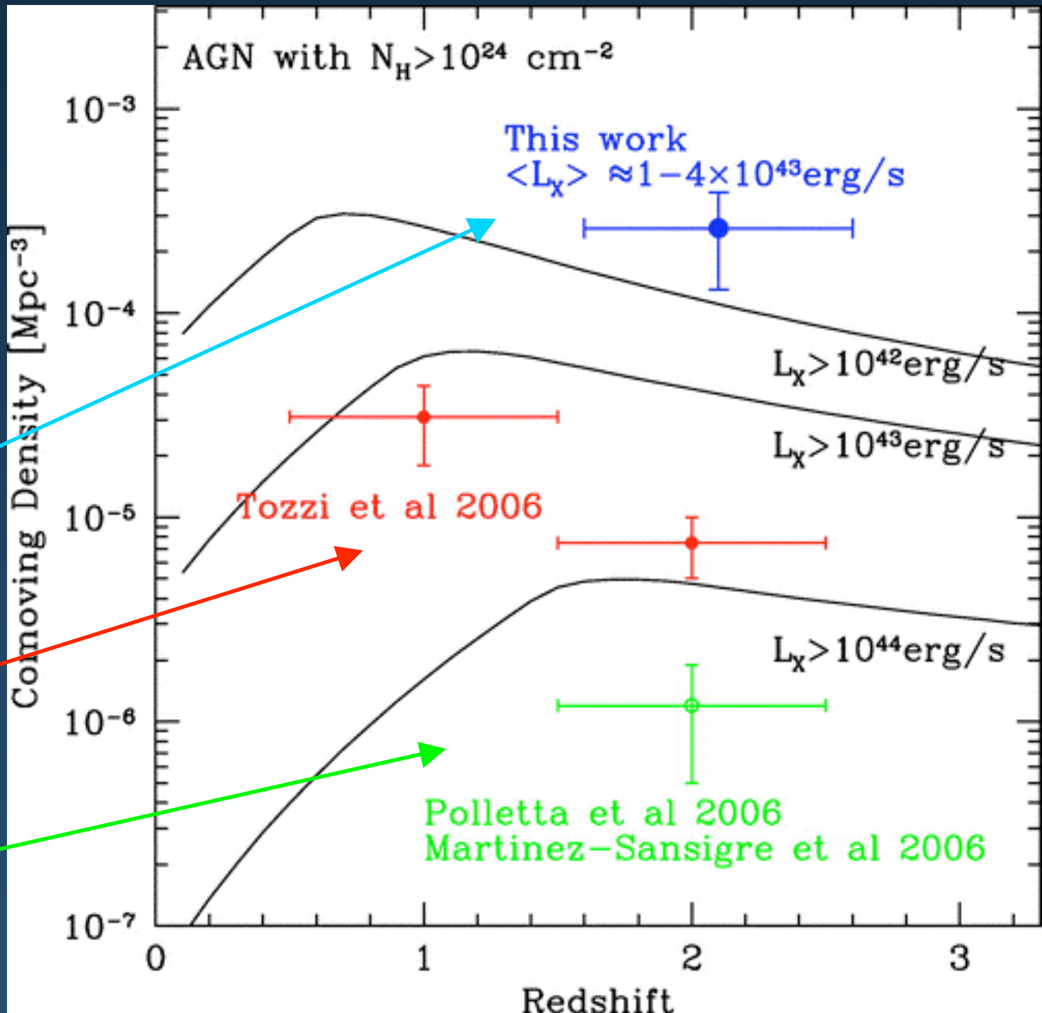
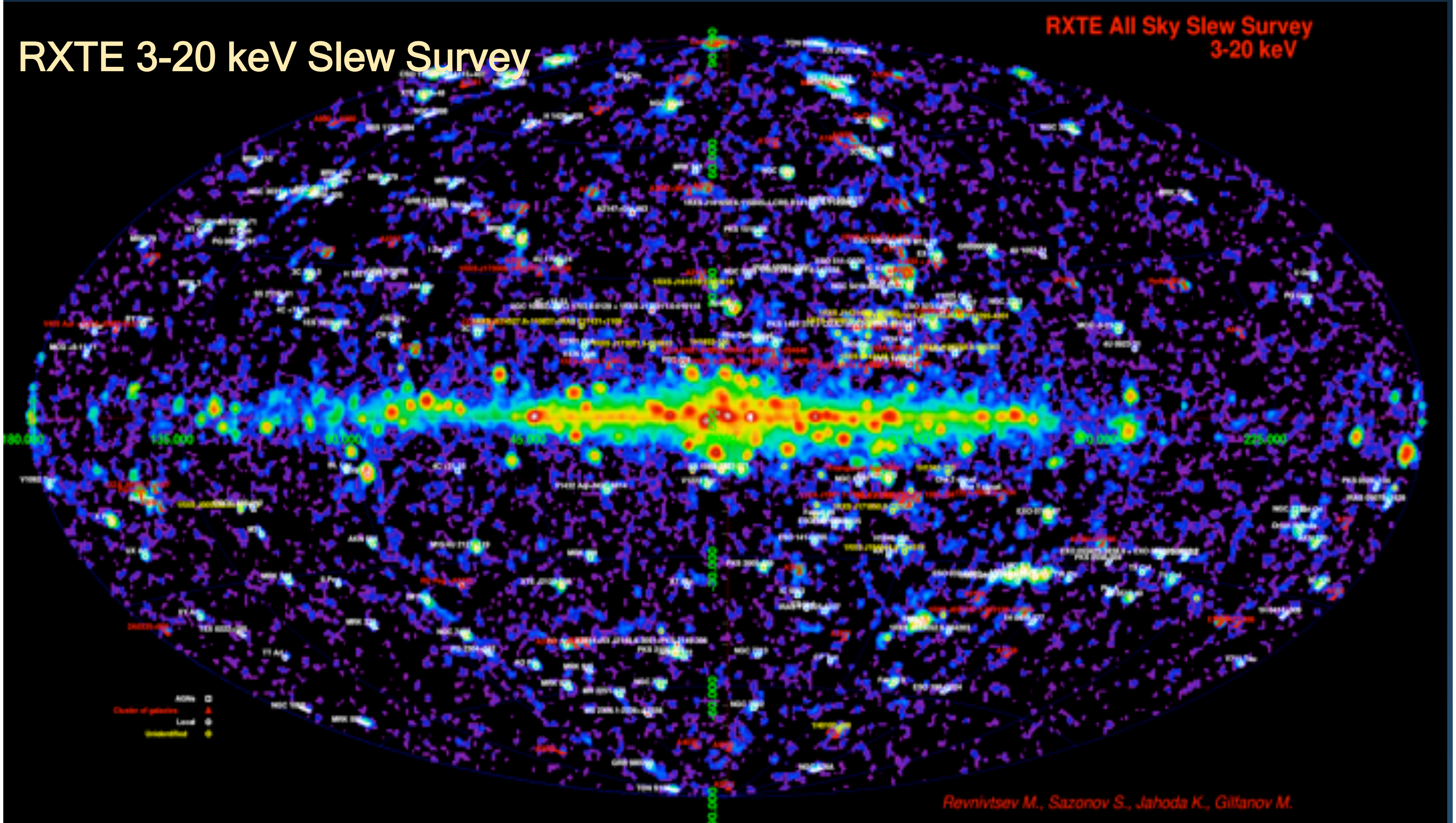


Fig. 10.— Space density of Compton-thick AGNs. The blue circle is our estimate, where we allow for a factor of 2 uncertainty. The red circles are taken from Tozzi et al. (2006), based on direct Chandra detections in GOODS-S. The green circles show the density that we crudely estimate for the survey of Polletta et al. (2006) and Martínez-Sansigre et al. (2006), accounting in the latter case for completeness correction due to their radio preselection. The lines show the predictions of the background synthesis model of Gilli et al. (2007), as a function of the limiting X-ray luminosity.

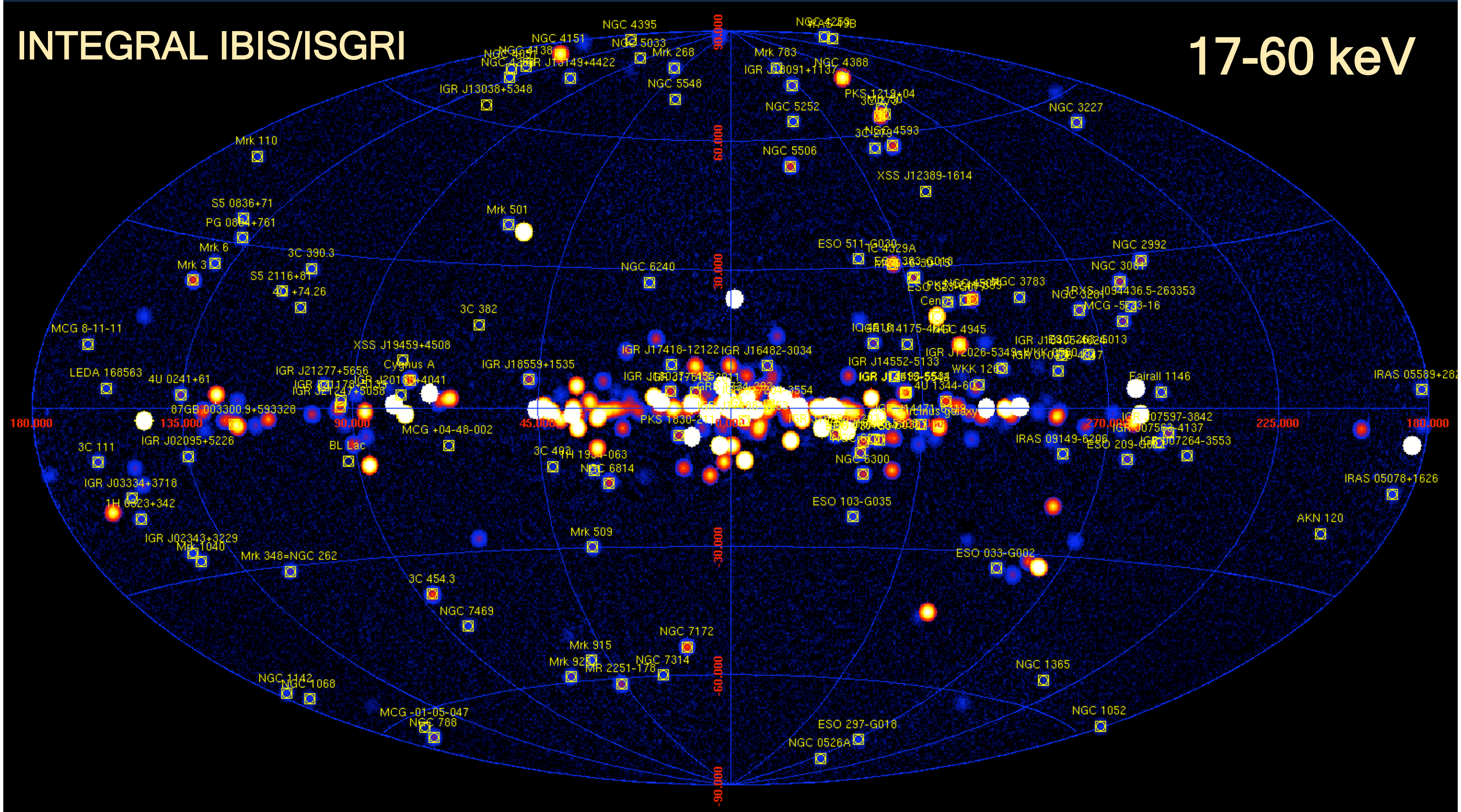
The hard X-ray perspective (3-20 keV)



294 sources at |b|>10°,
including 103 AGN and 16
unidentified

Revnivtsev et al. 2004
Sazonov, Revnivtsev 2004
Update to be published

The hard X-ray perspective (>10 keV)

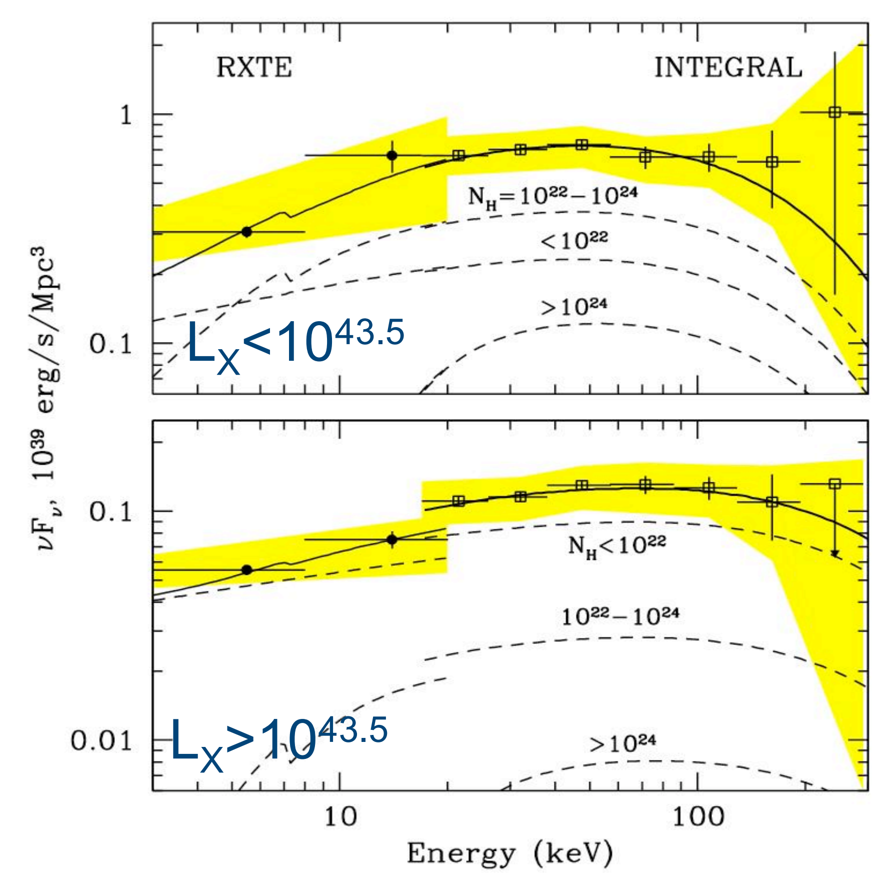


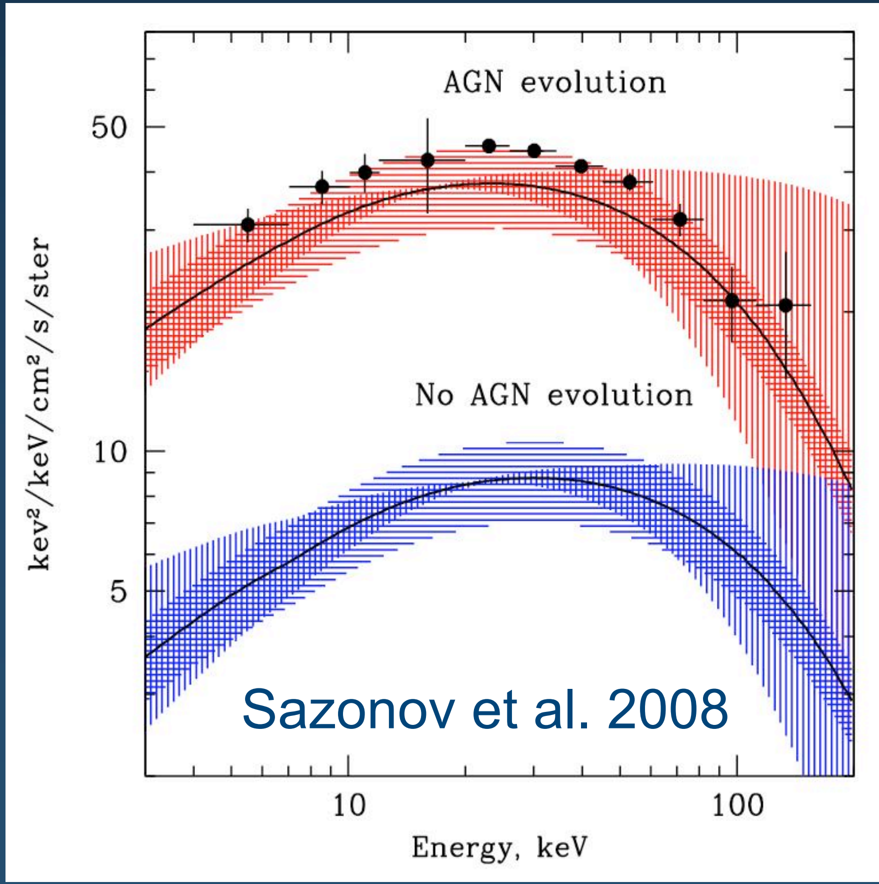
> 400 sources (as of August 2006)

Krivonos et al. 2007, Sazonov et al. 2007

The hard X-ray perspective (>10 keV)

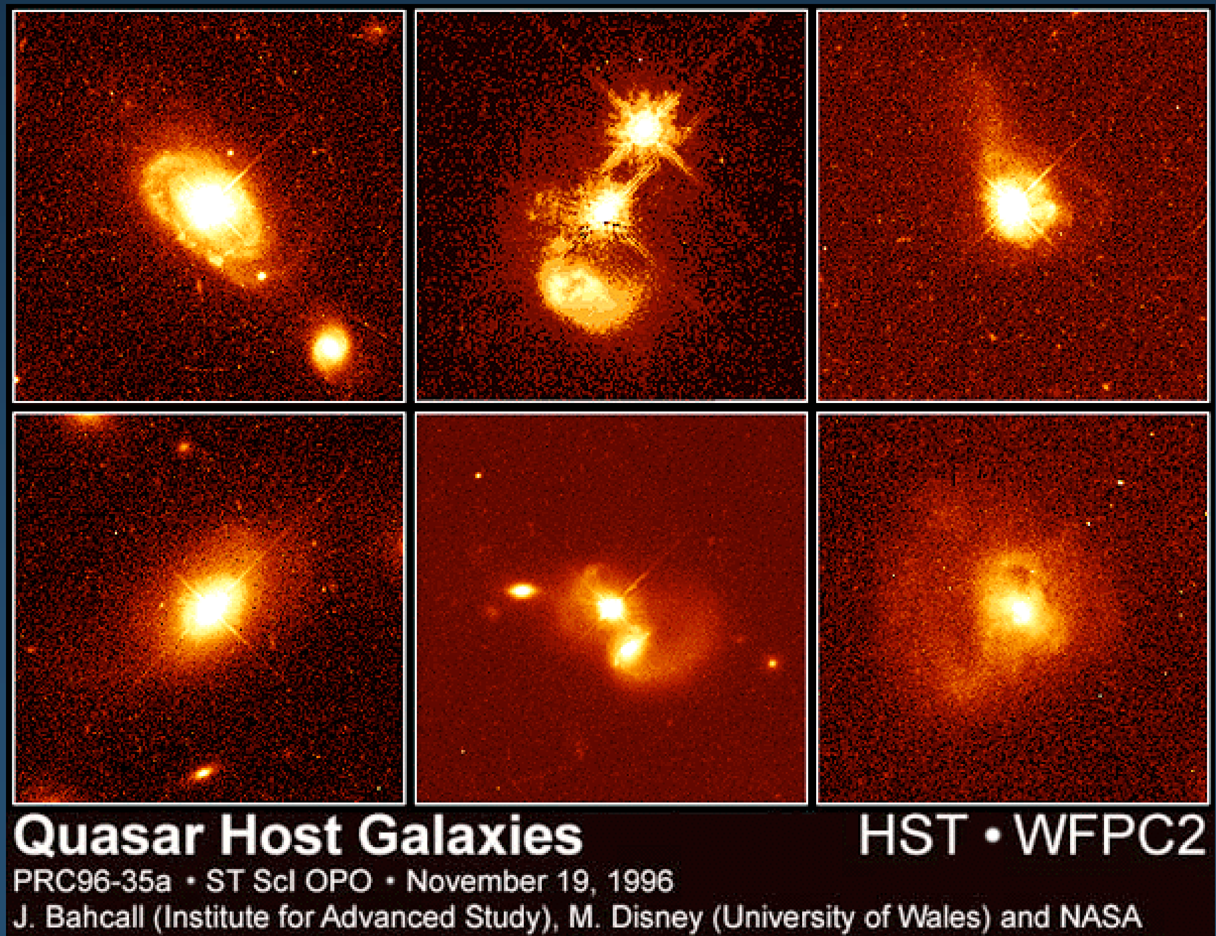
- RXTE and Integral AGN spectra confirm that a significant fraction of low-lum. AGNs is absorbed.
- Luminosity density (but not spectral or absorption) evolution is required to account for the hard XRBG





Triggering AGN activity

- QSO host galaxies often have disturbed morphologies and close neigbours, suggesting that galaxy interactions are triggering the nuclear activity.



AGN host galaxies at high redshift

- CAS indexes of AGN host galaxies represent rough morphological classificators.
- Concentration scales with the ratio of radii containing 80% and 20% of a source's total flux, and increases toward bulge-dominated systems:

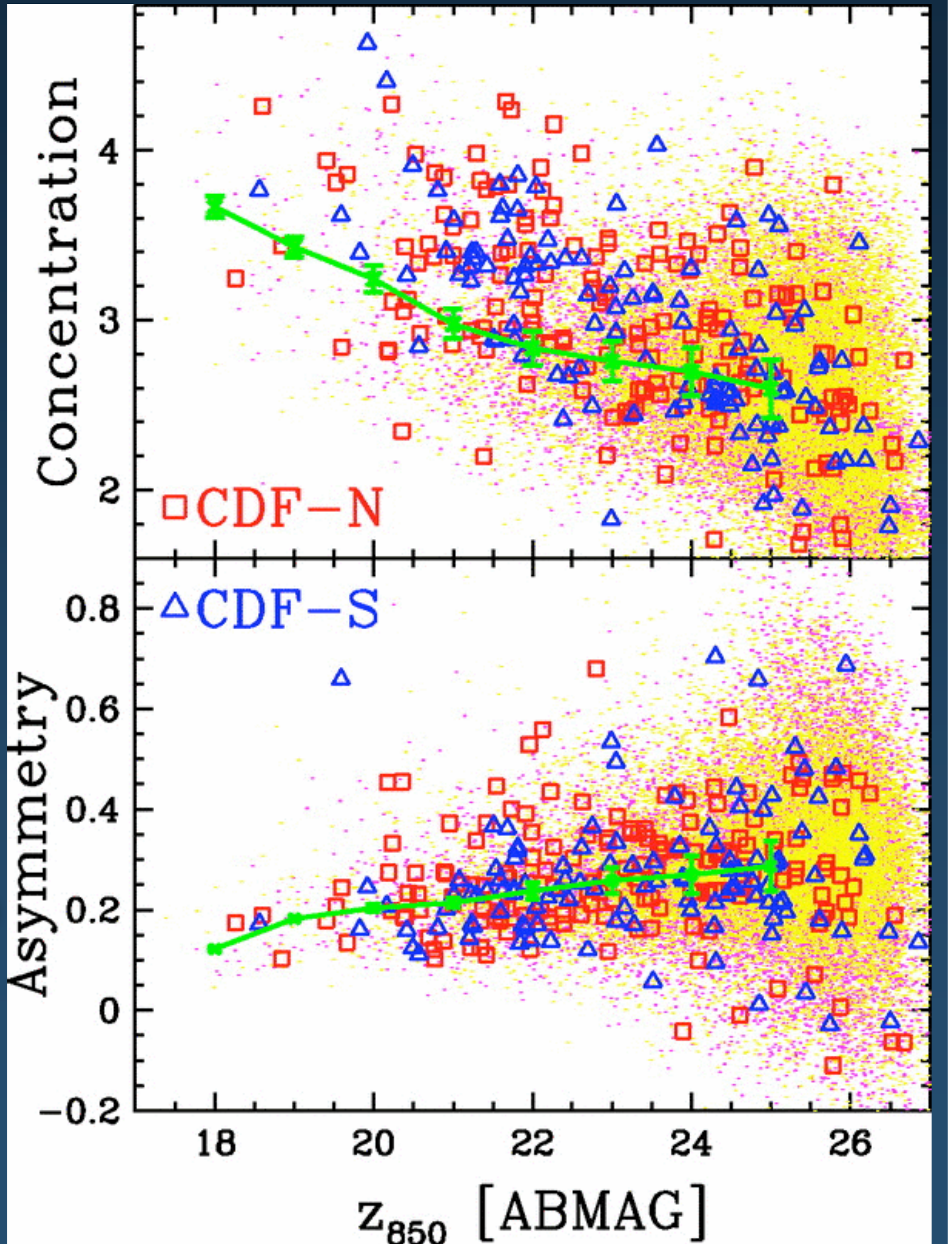
$$C \equiv 5\log\left(r_{0.8}/r_{0.2}\right)$$

- Asymmetry is the flux-normalized residual of the source pixels *S* differenced with their 180–-rotated counterpart:

$$A \equiv \min\left(\sum_{\rm pix}|S - S_{180}|/\sum_{\rm pix}|S|\right) - A_0$$

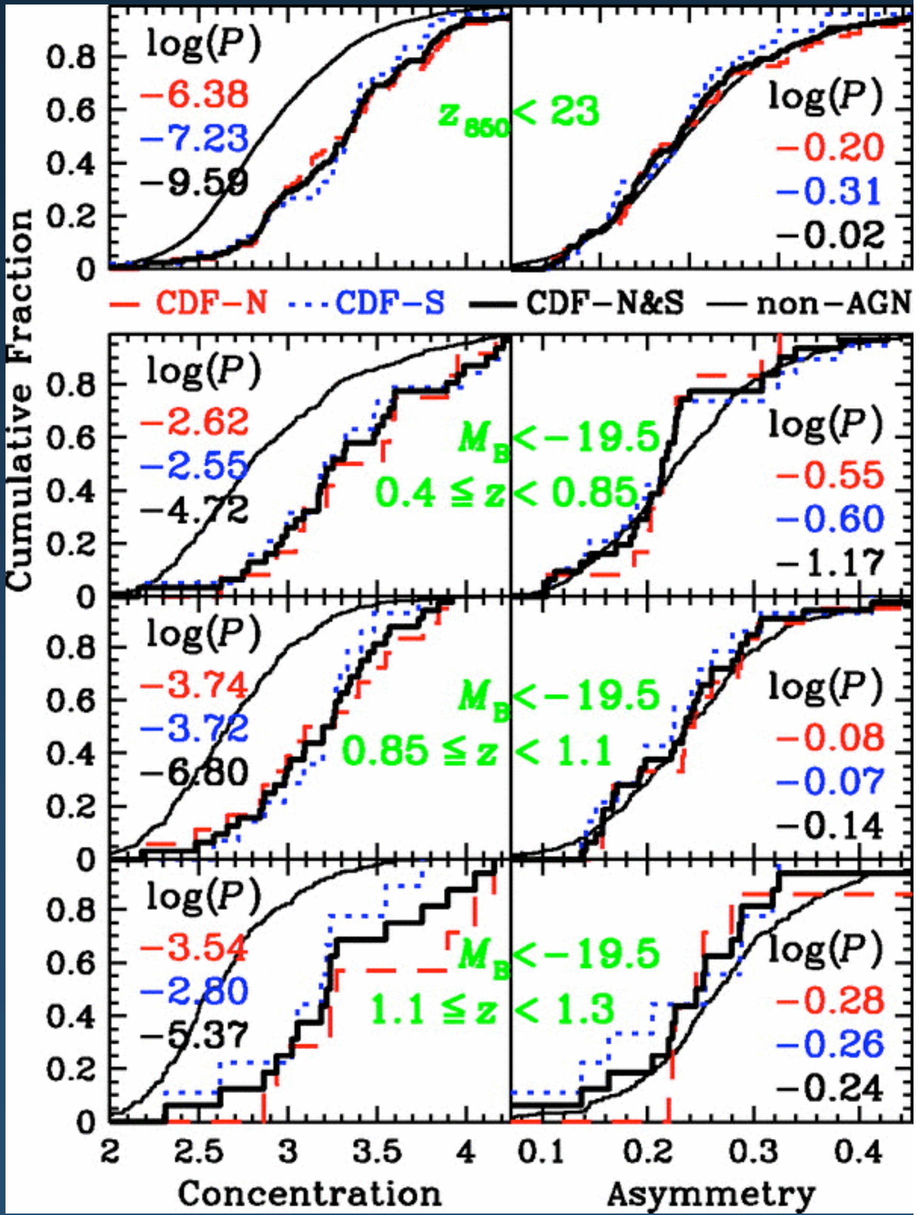
While *A* moderately increases toward disk-dominated systems, it is driven to large values by recent or ongoing interaction.

- Useful in deep surveys but to sample high-z we need HST superb spatial resolution.

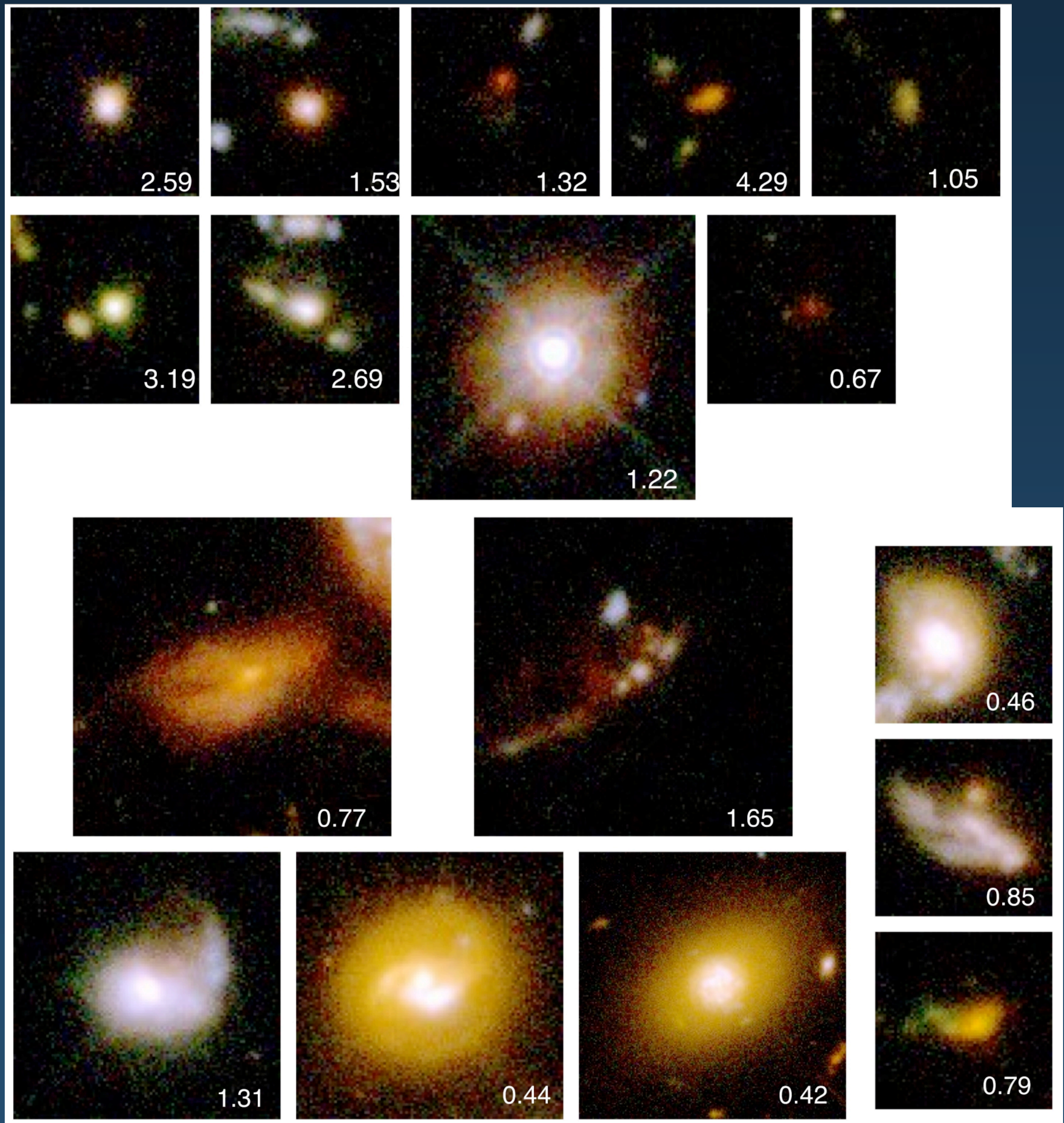


AGN host galaxies at high redshift

- AGNs have higher concentration indexes than the overall galaxy population. AGN activity is mainly associated to galaxy bulges out to z=1.3 (tracing the Magorrian relation?).
- No difference is found in the Asymmetry index, or in the nearest neighbour fraction.
- *HST* imaging of quasars (e.g. Bahcall et al. 1997) suggests that galaxy mergers/interactions are relatively common among the highest luminosity AGNs ($10^{44.5}$ ergs s^{-1}). However this study indicates that local environment, like host asymmetry, is not well correlated with moderate-luminosity AGN activity out to z=1.3.
- This can be explained only if merger signatures are erased rapidly (few hundred of Myrs).



However…HUDF X-RAY SOURCE HOSTS



Compact
Symmetric
Smooth
<z>=1.53

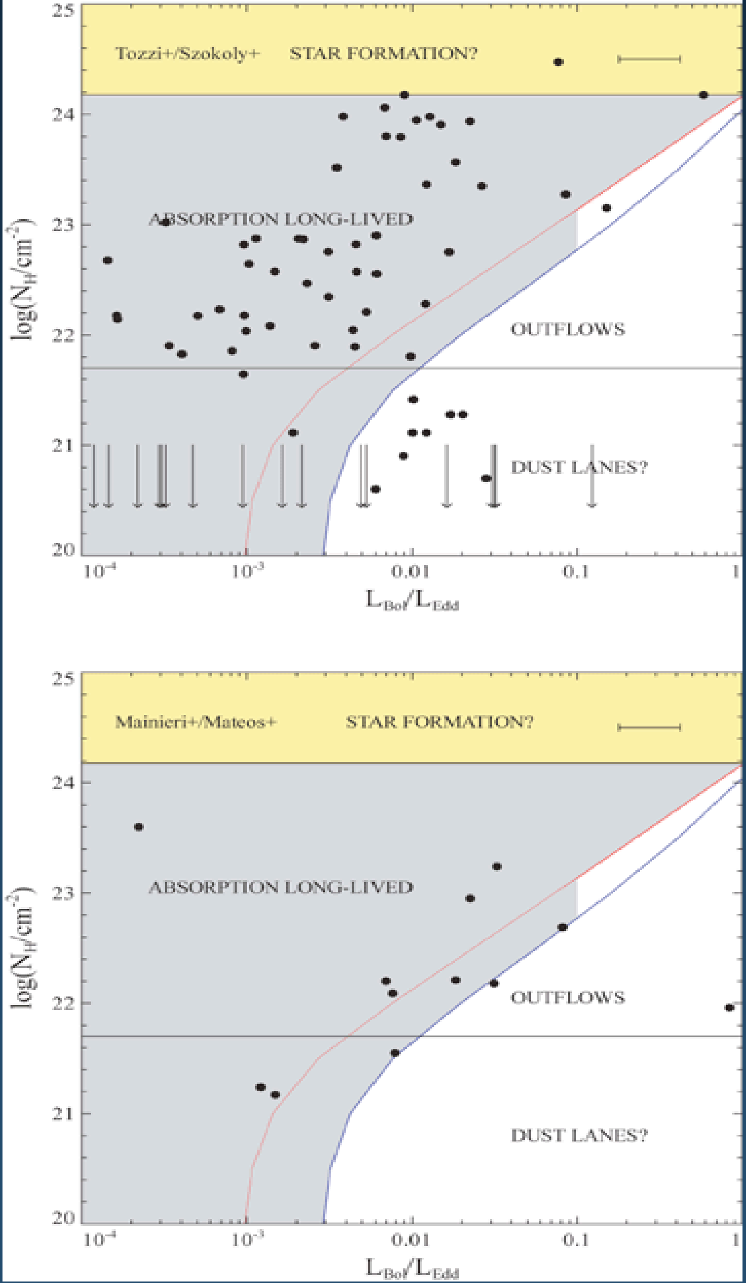
Extended
Asymmetric
Lumpy
<z>=0.79

+many companions
(Laird et al., in prep)

AGN feedback on host galaxies: building the Kormendy relation

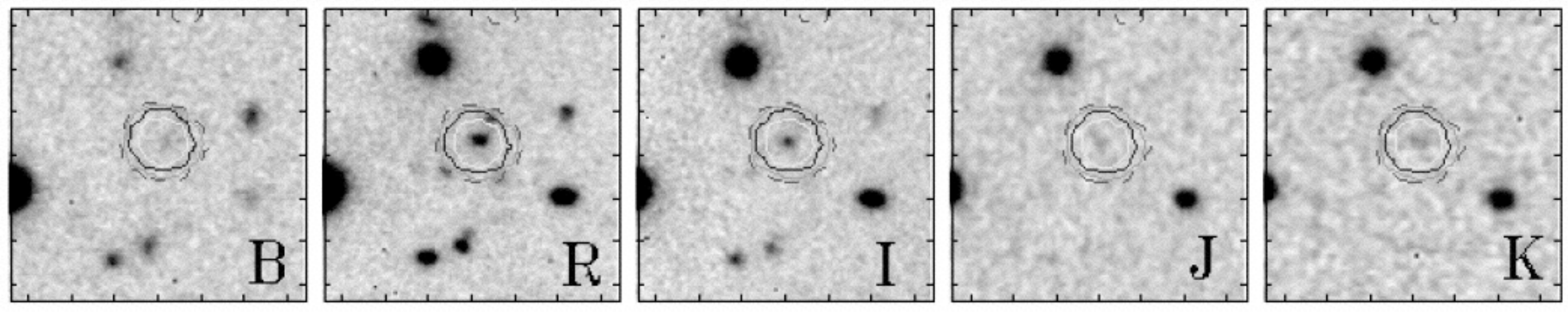
For an active AGN the limit when radiation pressure ejects mass is an effective Eddington limit relying on absorption of radiation by dust, not just electron scattering. The radiation pressure is amplified or boosted by a factor A which is the ratio of the effective, frequency-weighted, absorption cross-section for dusty gas, σ_d to that for electrons alone: σ_T.

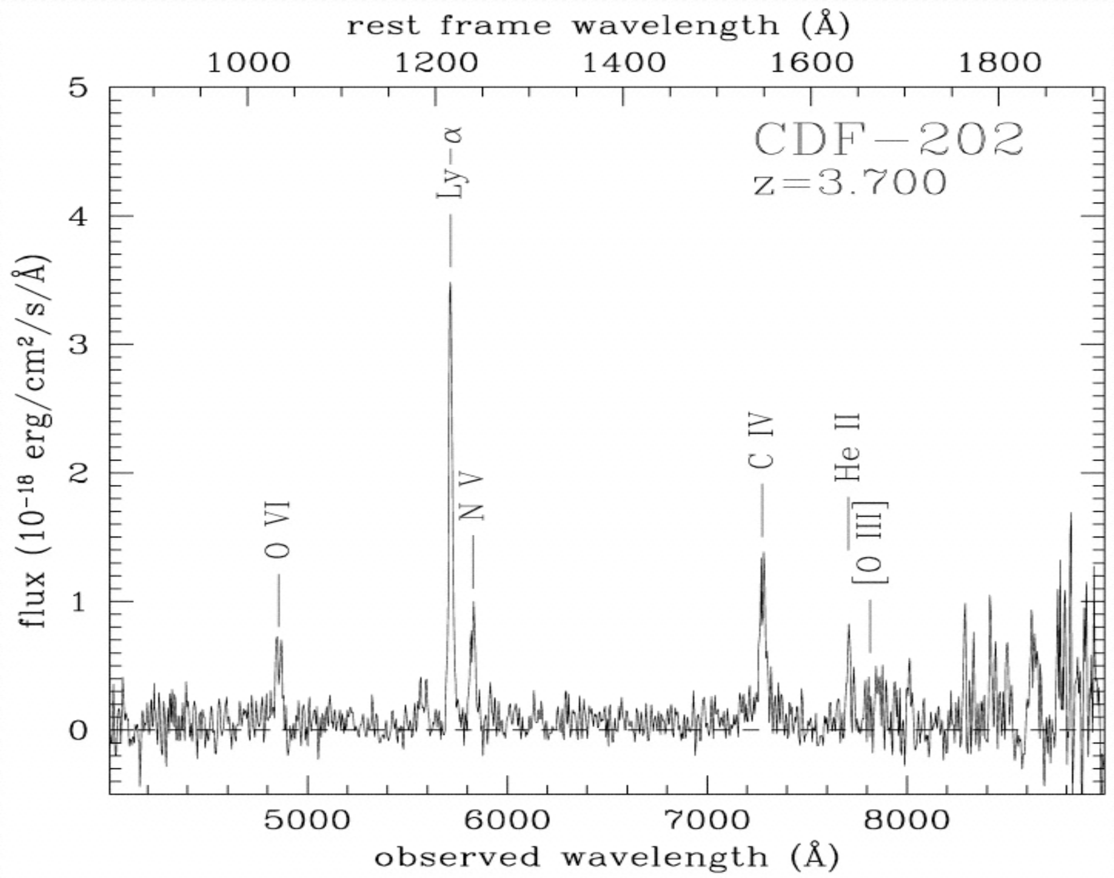
$$A(N_H)^{-1} = \frac{\sigma_{Thomp}}{\sigma_{dust}} = \frac{L_{Bol}}{L_{Edd}}$$



Deep survey data seem to agree that most AGN lie in the stability region where absorption is long-lived.
Any AGN in the outflow region would effectively deplete the host bulge of the gas and dust it feeds on, thus also suppressing star formation.

A typical type 2 QSO

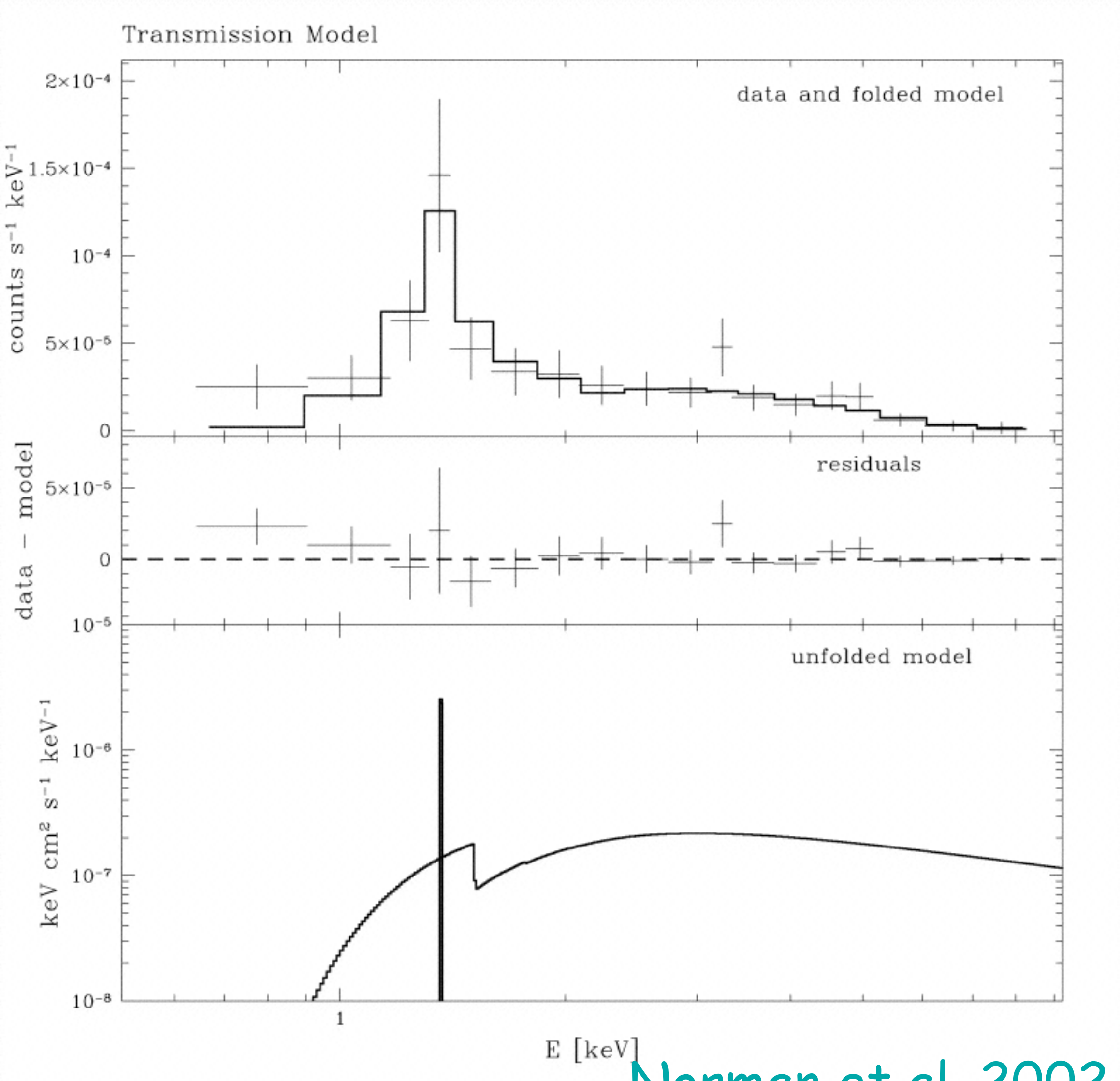




Norman et al. 2002

A typical type 2 QSO

- X-ray spectrum reveals a Fe line: ISM is already enriched at high z!
- The intrinsic luminosity is in the range 10^{44-45} erg/s depending on whether we assume a transmission or reflection model



Norman et al. 2002

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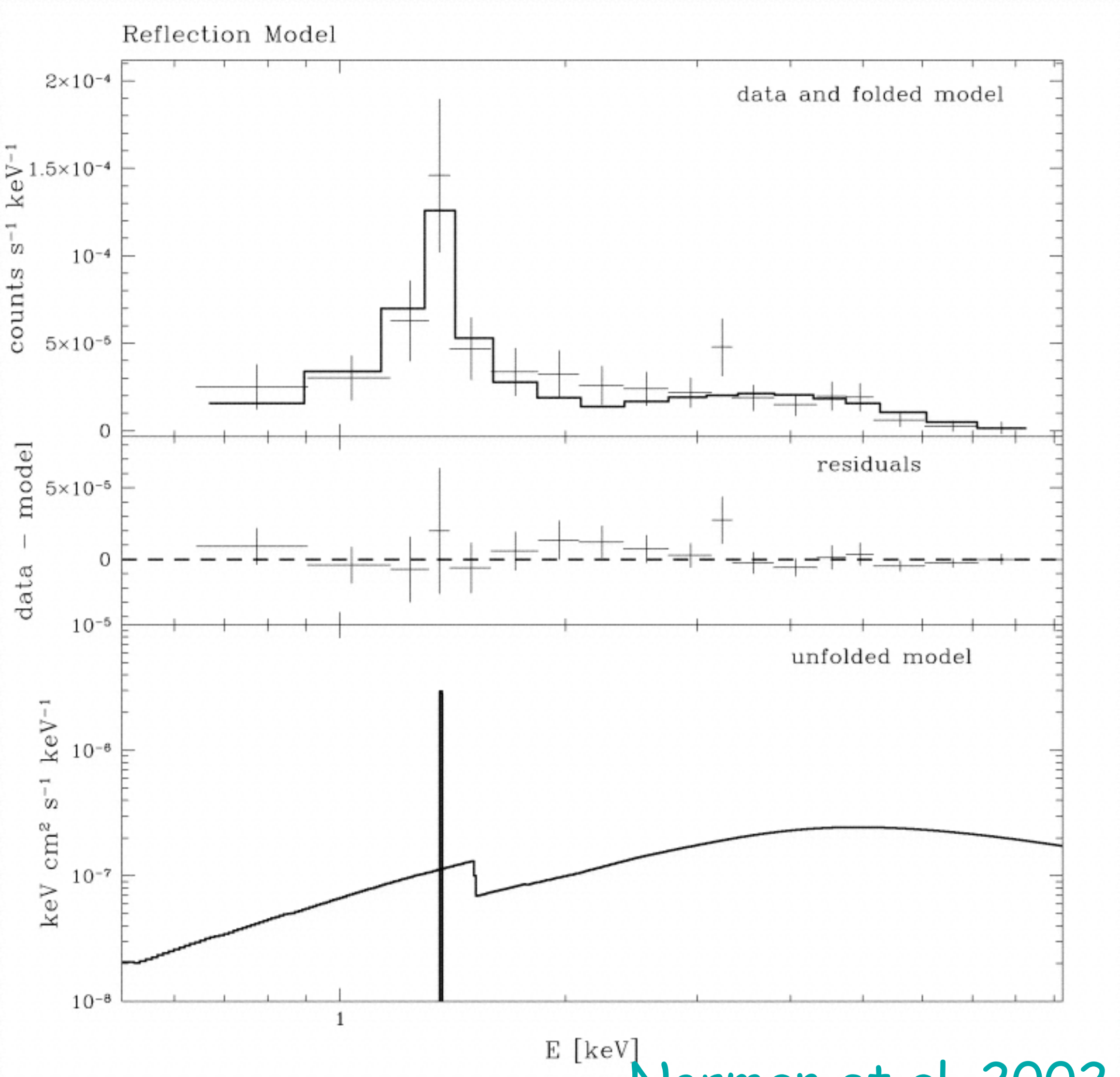
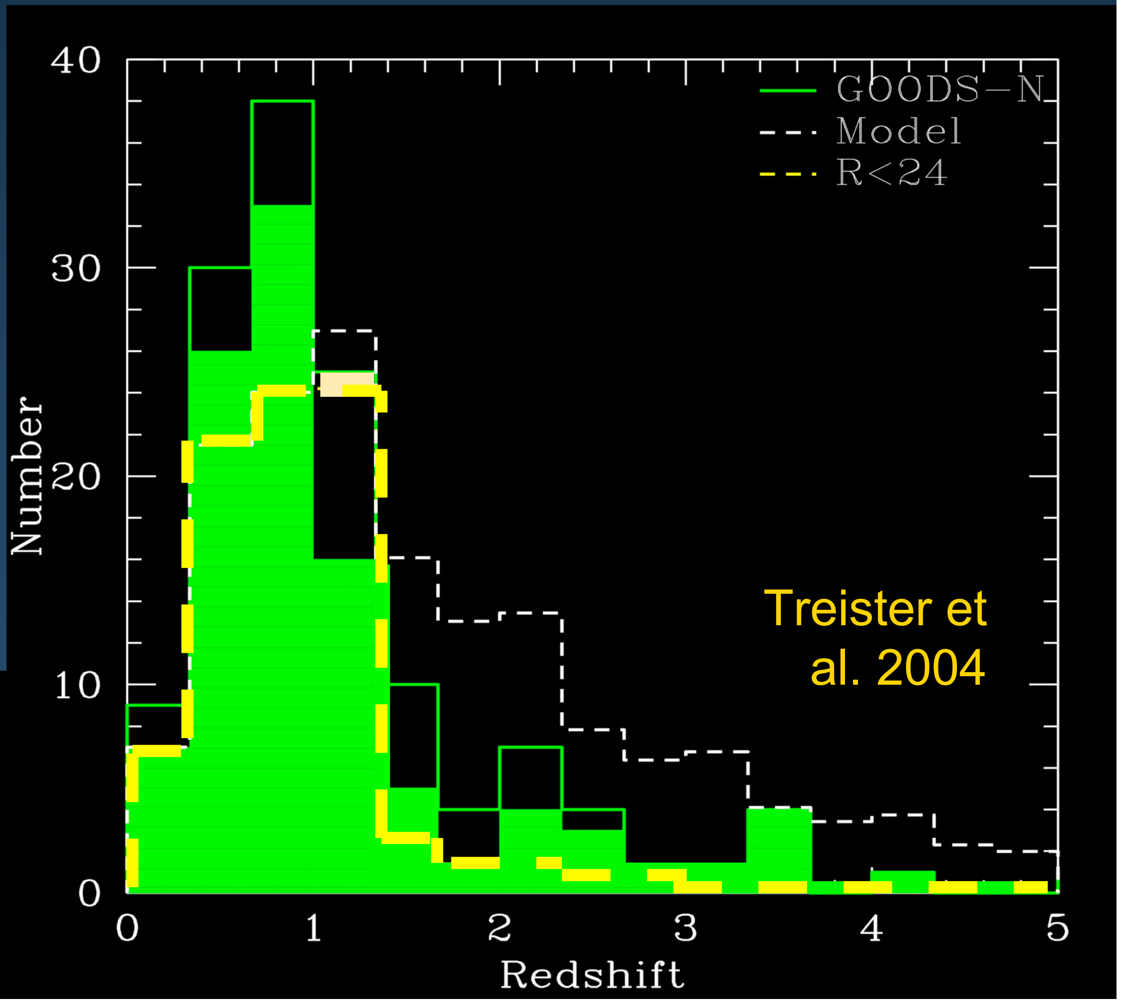


Norman et al. 2002

Selection effects

Selection effects play a crucial role in shaping our knowledge of AGN evolution:

- Optical samples are incomplete with respect to Type 2 AGNs
- Spectroscopic completeness must be accounted for to explain the observed distributions



redshifts of Chandra deep X-ray sources

Barger et al. 2002,3, Hasinger et al. 2002, Szokoly et al. 2004

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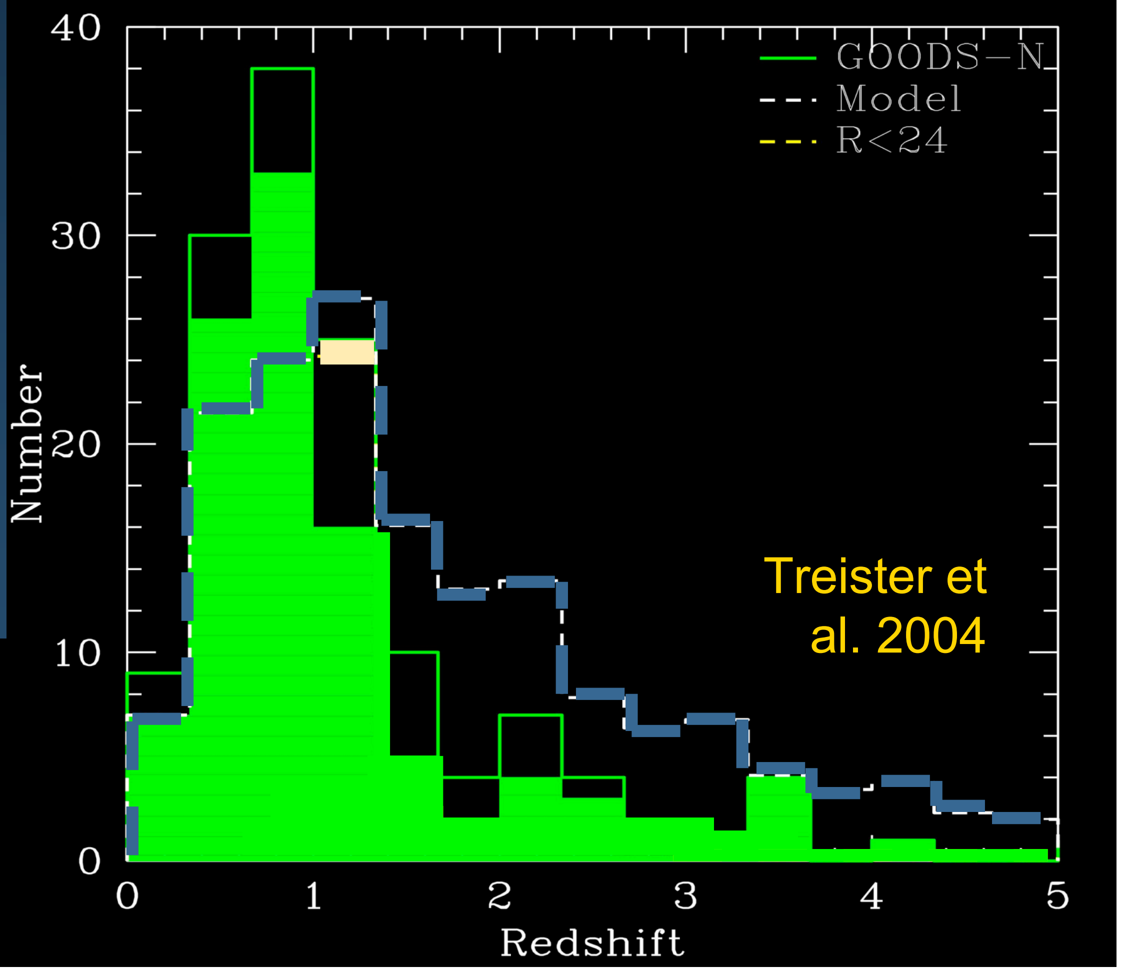
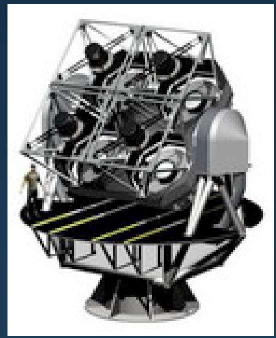


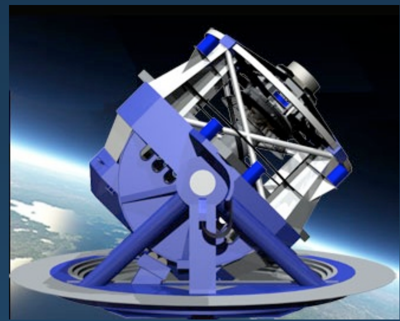
Future optical surveys

- VST/VISTA (e.g. KISD) - 2009
  - 2.5/4 m class, 1~2 deg. FOV

- Pan-STAR - 20??
  - 4x1.8m class, 3 deg FOV



- LSST - 2013 ?
  - 8m class, 10 deg FOV, 30 Tb/night



What to expect:

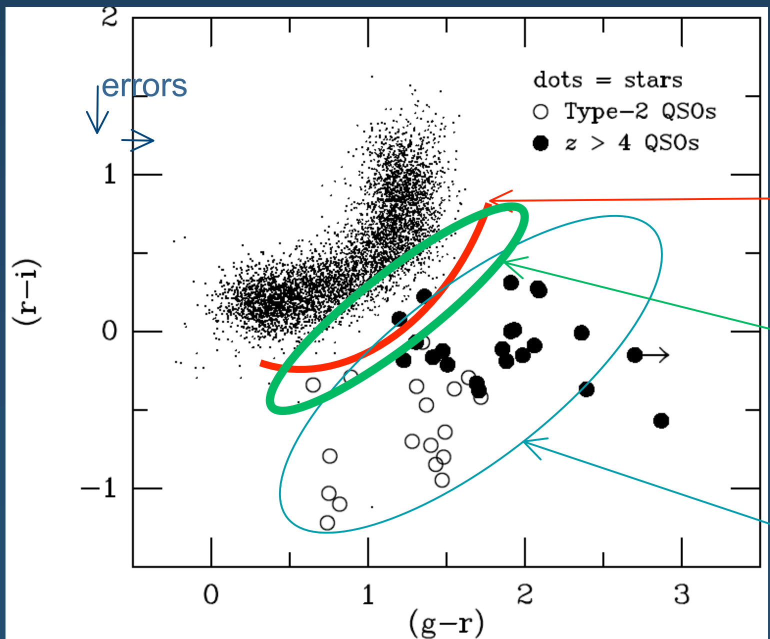
1. Will provide huge amounts of data over large areas of the sky.
2. Will open the time domain to the “average” astronomer: no need of dedicated surveys anymore.
3. Current generation of astronomical softwares/methodologies not suited yet to deal with such large amount of data.

Need for new approaches
(Data Mining)

Photometric selection of candidate QSO's in optical surveys

Several algorithms for "general purpose" photometric identification of candidate QSOs select sources according to different techniques exist.

- *Optical surveys*: looking for counterparts of strong radio sources (but only ~ 10% of QSO are radio-loud).
- *Ultraviolet and optical surveys*: looking for star-like sources bluer than stars.
- *Multi-colour optical surveys*: looking for unresolved objects in colour parameter space lying outside compact regions ("star locus") occupied by stars.

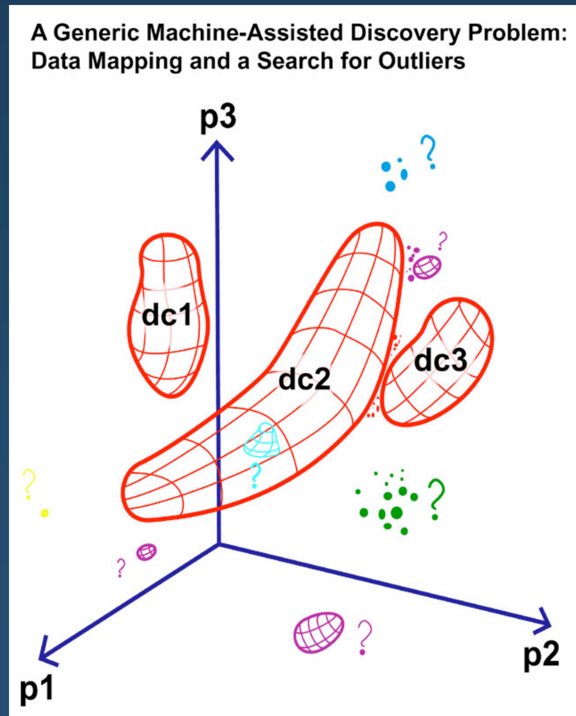


Traditional way to look for candidate QSO in 3 band survey

Cutoff line

Ambiguity zone

Candidate QSOs for spectroscopic follow-up's



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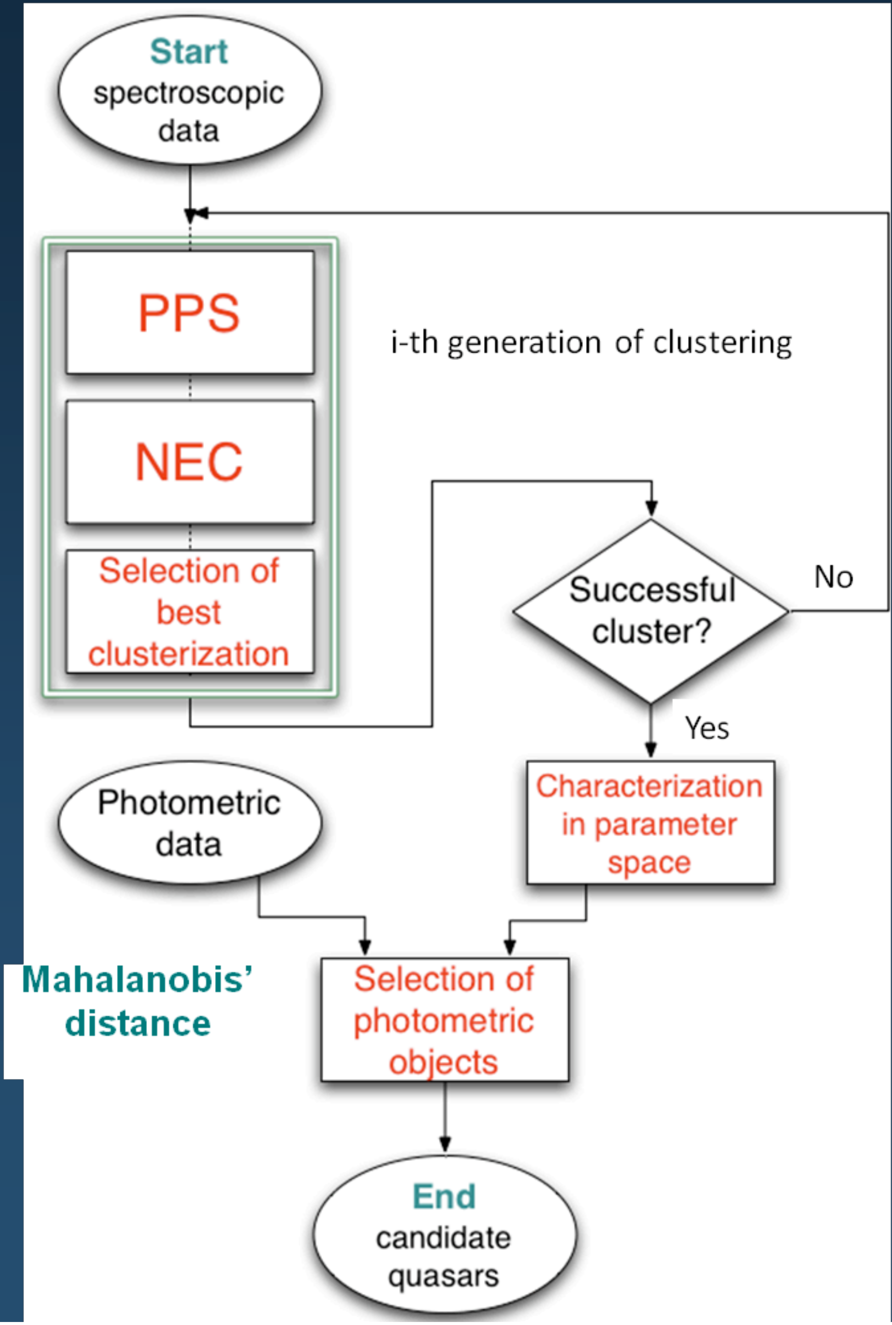
Overall performances of a generic targeting algorithm are usually expressed by two parameters:

Completeness $$c = \frac{\text{candidate quasars identified by the algorithm}}{\text{a priori known quasars}}$$

Efficiency $$e = \frac{\text{confirmed quasars identified by the algorithm}}{\text{candidate quasars selected by the algorithm}}$$

Improved selection of new candidates



Different methods to extract QSOs candidates

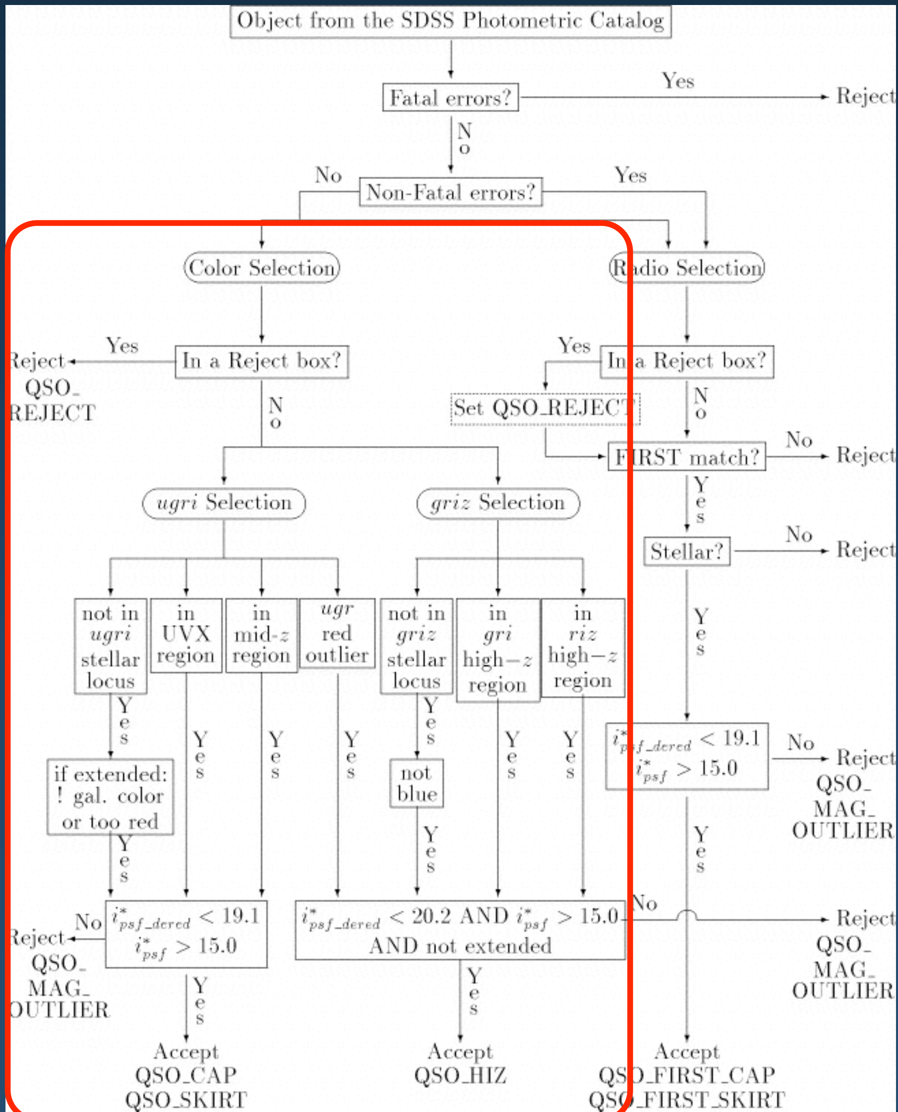
- **"Re-labelling"**: both spectroscopic and photometric objects put into the same clustering process: candidate QSOs are selected as those objects belonging to clusters where spectroscopic confirmed QSOs ("tracers") are found.

- **"Photometric cuts"**: "goal-successful" clusters are described in terms of their colours distribution; associated cuts are applied to photometric sample for candidate selection.

- **"Mahalanobis' distance"**: it is used to measure the distances of a given photometric object from each cluster; the object is assigned to the nearest "goal-successful cluster" or rejected.

SDSS QSOs targeting algorithm (I)

SDSS QSO candidate selection algorithm (Richards et al, 2002) targets star-like objects as QSO candidate according to their position in the SDSS colours space (u-g,g-r,r-i,i-z), if one of these requirements is satisfied:



- **QSOs are supposed to be placed >4σ far from a cylindrical region containing the "stellar locus"** (S.L.), where σ depends on photometric errors.

OR

- **QSOs are supposed to be placed inside the inclusion regions**, even if not meeting the previous requirement.

c = 95%, e = 65%
locally less

Data and experiments

Data samples:

1. **Optical**: sample derived from SDSS database table "Target" queried for QSO candidates, containing ~ $1.11 \cdot 10^5$ records and ~ $5.8 \cdot 10^4$ confirmed QSO ('specClass == 3 OR specClass == 4').
2. **Optical + NIR**: sample derived from positional matching ('best') between SDSS-DR3 database view "Star" queried for all objects with spectroscopic follow-up available and detection in all 5 bands (u,g,r,i,z) with high reliability for redshift estimation and line-fitting classification ('specClass') and high S/N photometry, and UKIDSS-DR1 star-like ('mergedClass == -1') objects fully detected in each of the four lasSurvey bands (Y,J,H,K) and clean photometry. **This sample is formed by 2192 objects**.

Experiments:

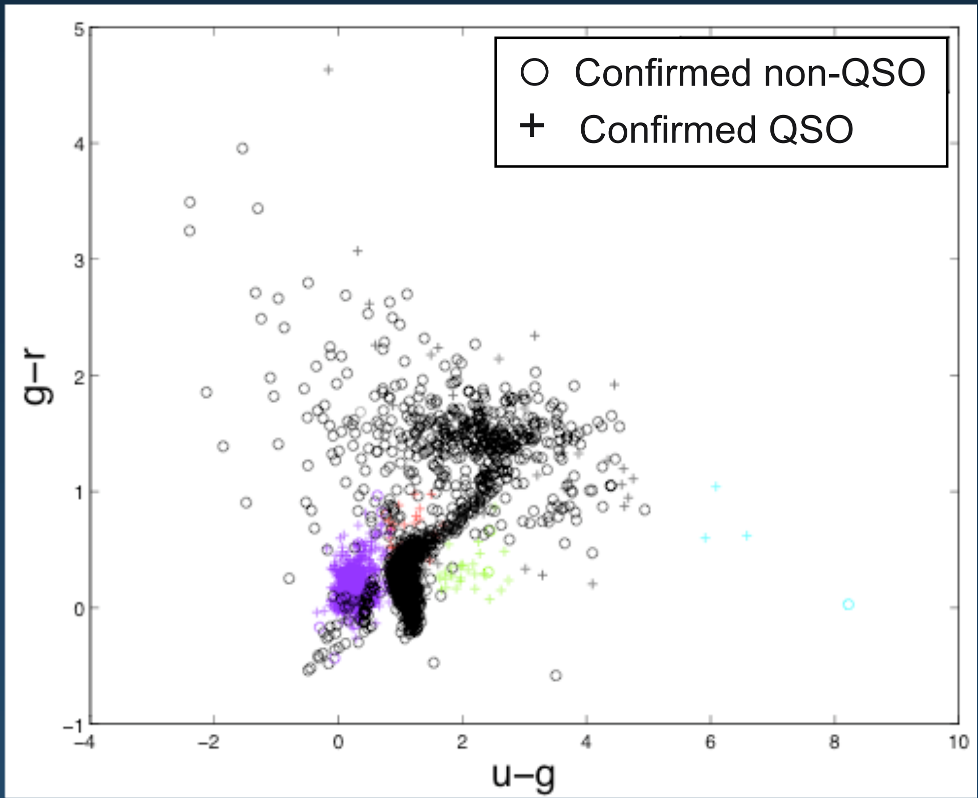
Optical (1)
candidate QSO
4 colours

Optical+NIR (2)
star-like objects
4 + 3 colours

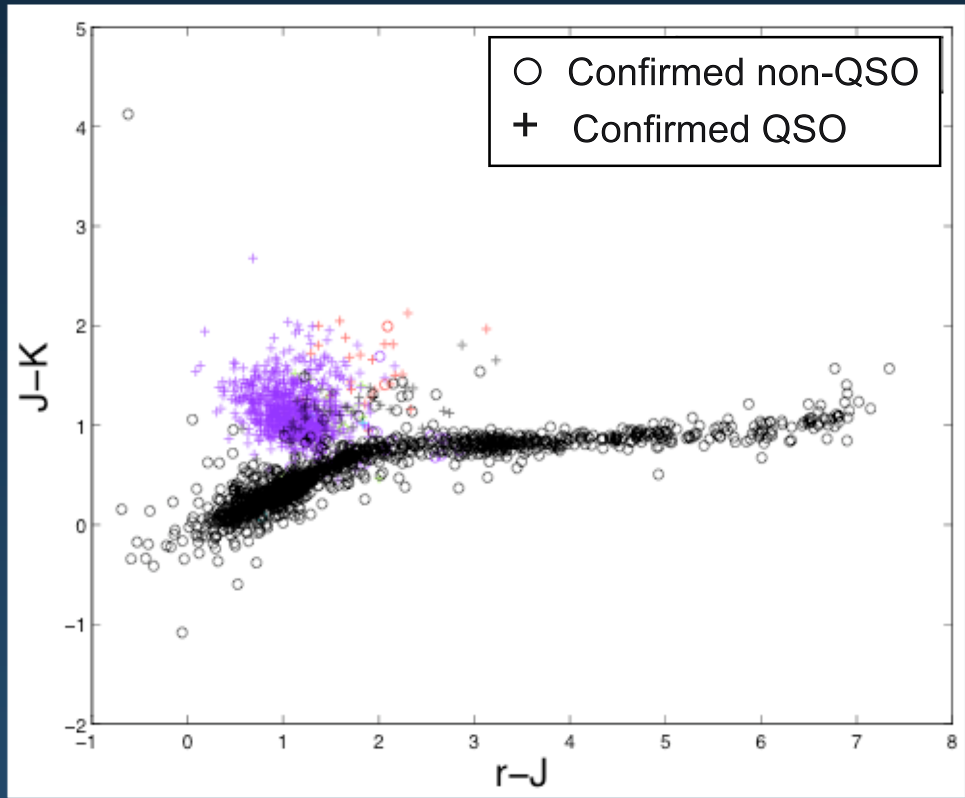
Optical (3)
star-like objects
4 colours

Applying the method: SDSS ∩ UKIDSS

u - g vs g - r



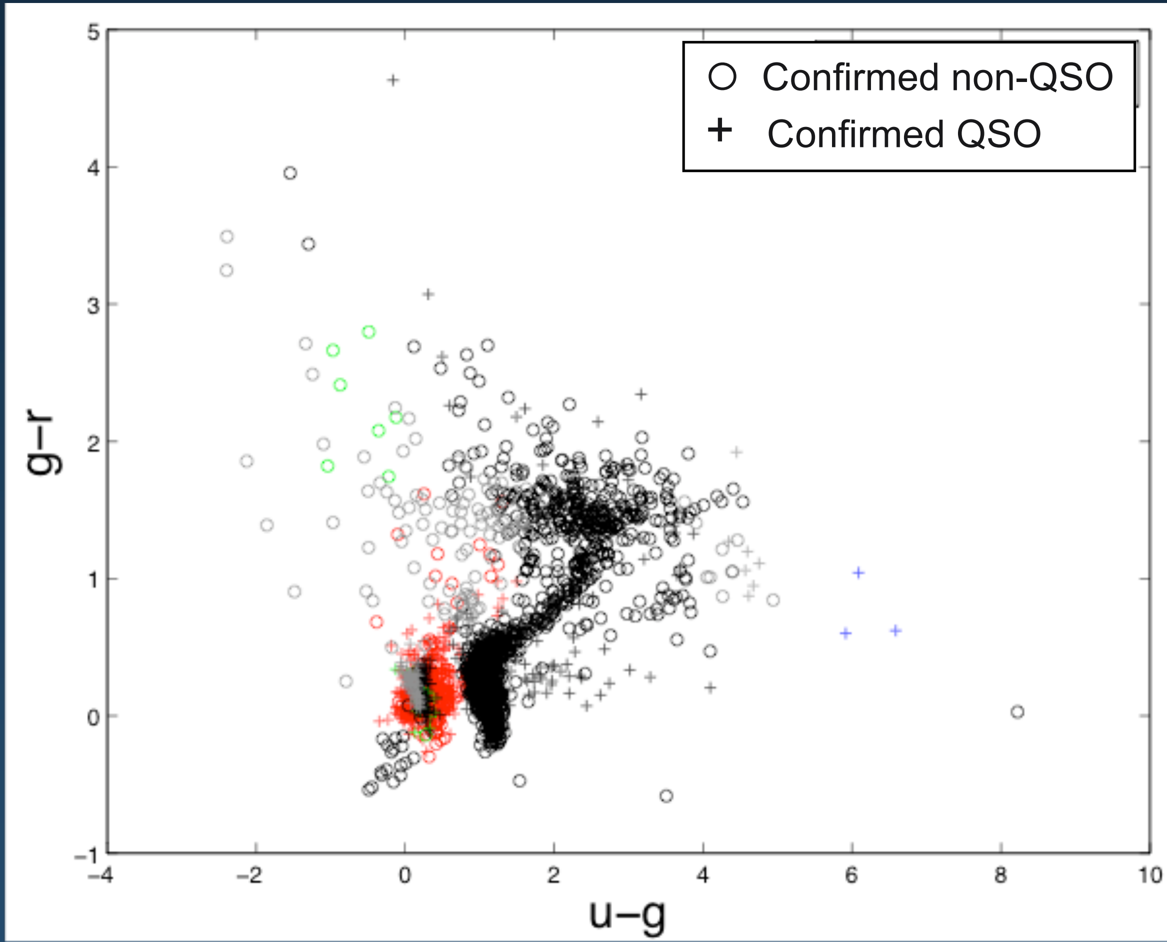
r - J vs J - K



Only a fraction (43%) of these objects have been selected as candidate QSO's by SDSS targeting algorithm in first instance: the remaining sources have been included in the spectroscopic program because they have been selected in other spectroscopic programmes (mainly stars). Method yields > 90% completeness and efficiency!

Applying the method: Optical colours

u - g vs g - r



In this experiment the clustering has been performed on the same sample of the previous experiment, using only optical colours.

Results

Sample	Parameters	Labels	e_{tot}	c_{tot}	n_{gen}	n_{suc_clus}
Optical QSO candidates (1)	SDSS colours	'specClass'	83.4 % (± 0.3 %)	89.6 % (± 0.6 %)	2	(3,0)
Optical + NIR star-like objects (2)	SDSS colours + UKIDSS colours	'specClass'	91.3 % (± 0.5 %)	90.8 % (± 0.5 %)	3	(3,1,0)
Optical + NIR star-like objects (3)	SDSS colours	'specClass'	92.6 % (± 0.4 %)	91.4 % (± 0.6 %)	3	(3,0,1)

AGN classification techniques

The BoK is formed by objects residing in different regions of the BPT plot (Baldwin, Phillips and Tellevich 1981).

I. AGN's catalogue (Sorrentino et al, 2006)

- $0.05 < z < 0.095$
- $M_r < -20.0$
- AGN's selected according to Kewley's empirical method (Kewley et al. 2001):

Seyfert I: galaxies for which these relations are satisfied:

(FWHM(H_α) > 1.5*FWHM([OIII] λ5007)

OR

FWHM(H_α) > 1200 Km s^{-1})

AND

FWHM([OIII] λ5007) < 800 Km s^{-1}

Seyfert II: all remaining galaxies.

II. Emission lines ratio catalogue (Kauffman et al, 2003)

Kewley's line

$$\log\frac{[\mathrm{OIII}]\lambda 5007}{H_\beta} = \frac{0.61}{\log\frac{[\mathrm{NII}]\lambda 6583}{H_\alpha} - 0.47} + 1.19$$

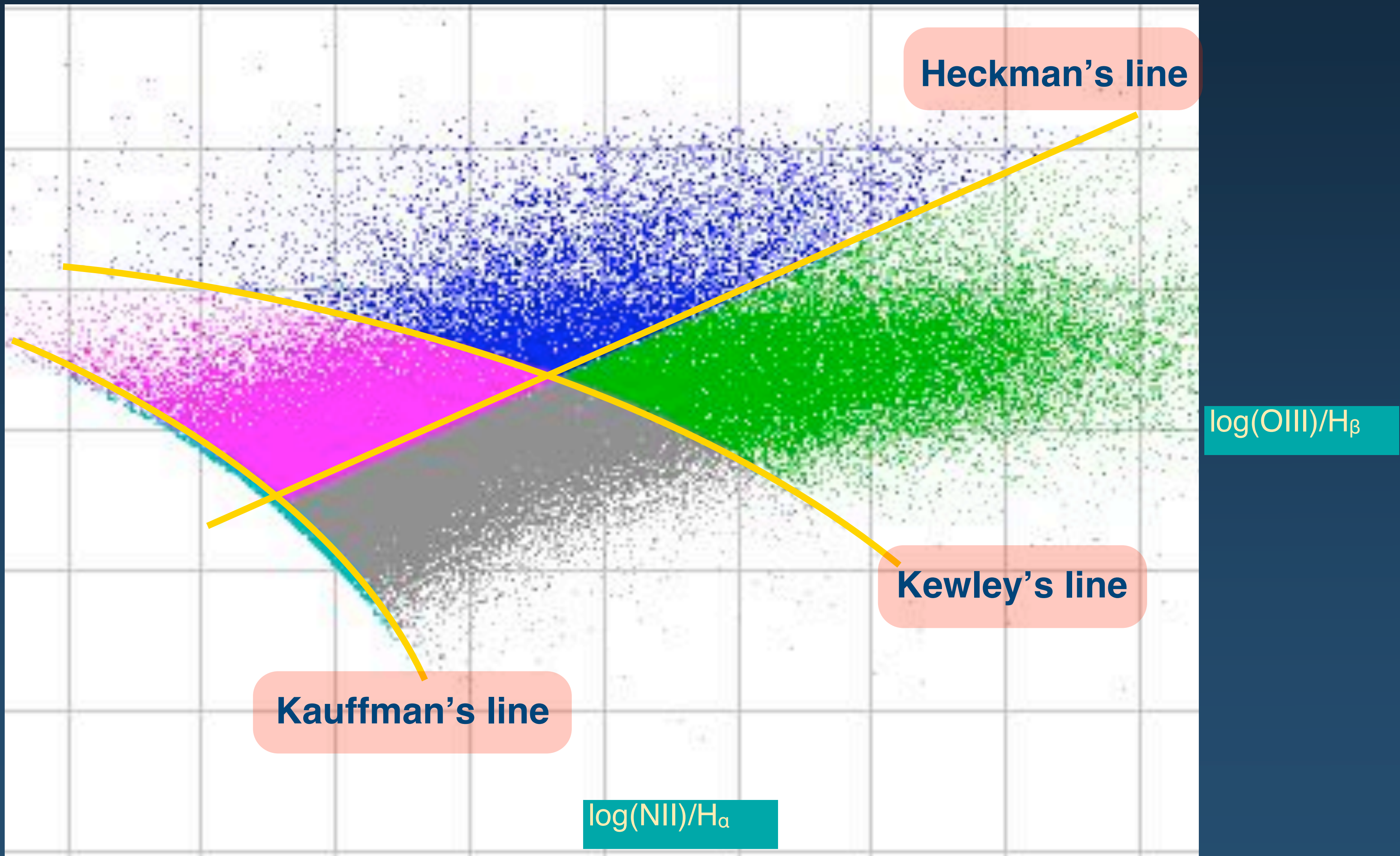
Kauffman's line

$$\log\frac{[\mathrm{OIII}]\lambda 5007}{H_\beta} = \frac{0.61}{\log\frac{[\mathrm{NII}]\lambda 6583}{H_\alpha} - 0.05} + 1.3$$

Heckman's line

$$\log\frac{[\mathrm{OIII}]\lambda 5007}{H_\beta} = \log\frac{[\mathrm{NII}]\lambda 6583}{H_\alpha} + 0.465$$

Classification criteria

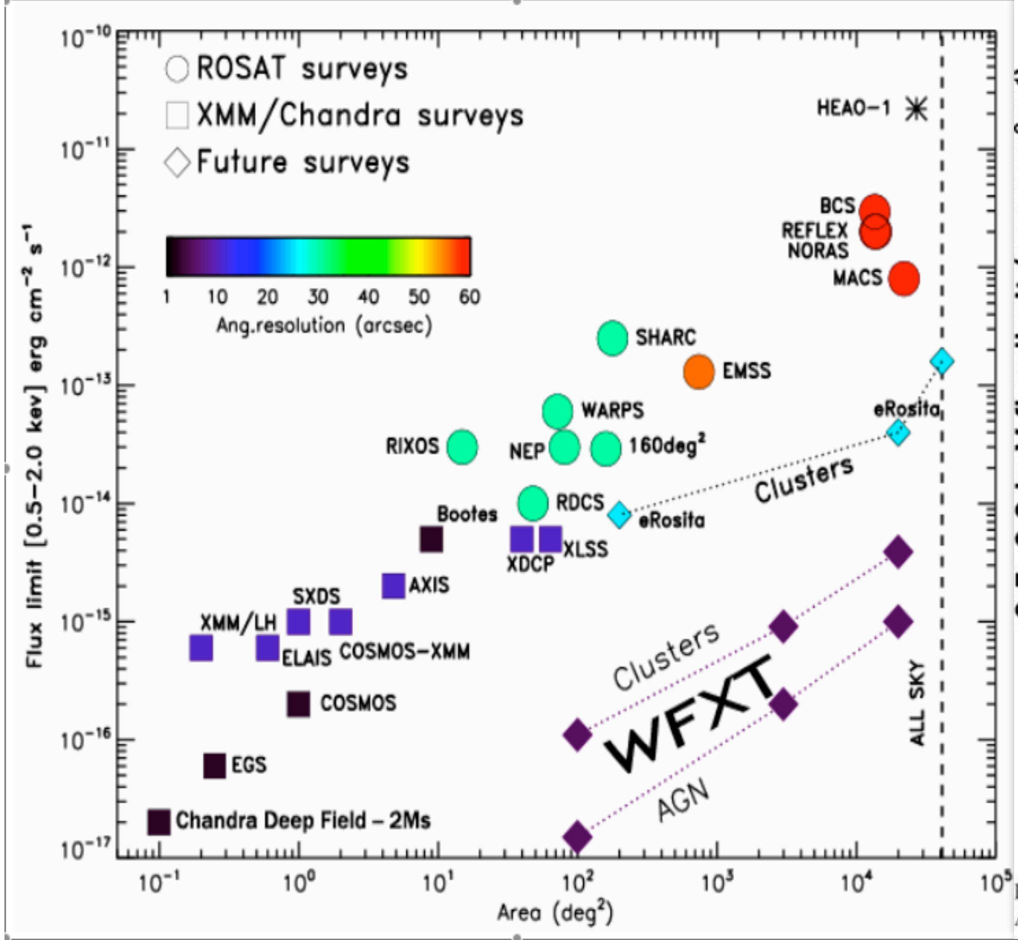


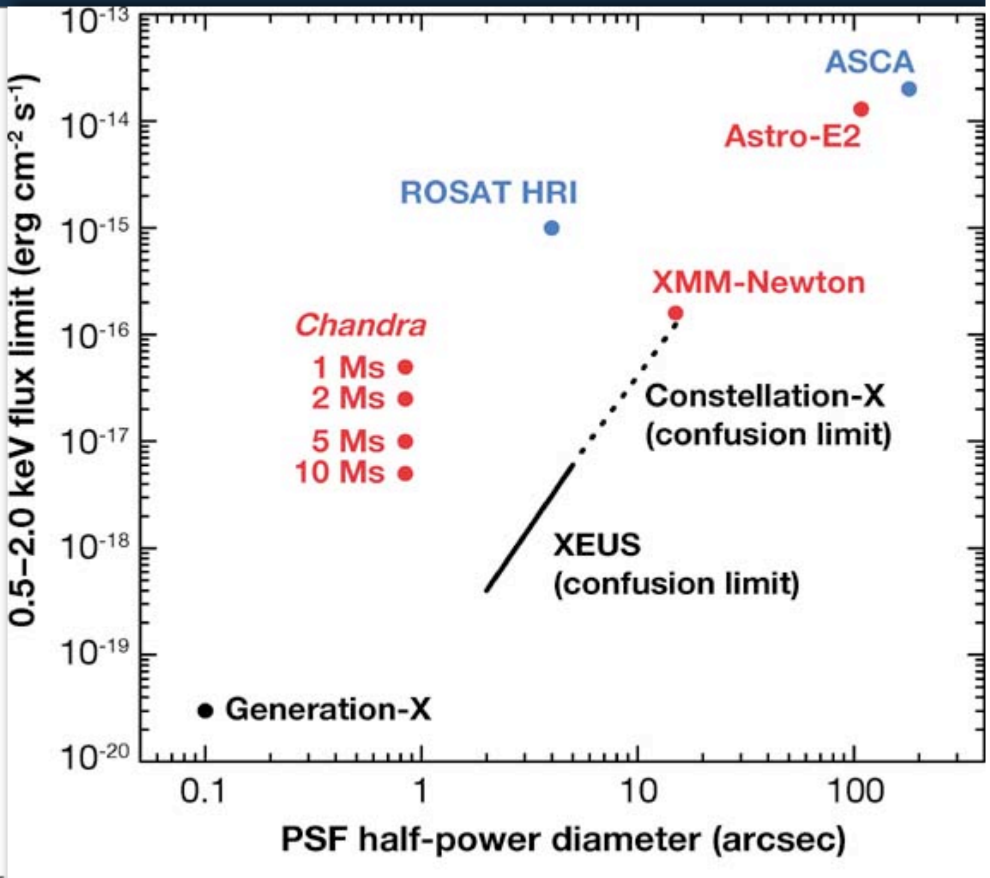
Results (II)

Sample	Parameters	BoK	Algorithm	e_{tot}	c_{tot}
Experiment (1)	SDSS photometric parameters + photo redshift	BPT plot +Kewley's line	SVM / MLP	SVM: ~74% / MLP: ~76%	SVM: ~55% / MLP: ~54%
Experiment (2)	SDSS photometric parameters + photo redshift	BPT plot+ Kewley's line	SVM / MLP	SVM: e_{typ1}~82%, e_{typ2}~86% / MLP: e_{typ2}~98%, e_{typ1}~95%	SVM: ~98% / MLP: ~100%
Experiment (3)	SDSS photometric parameters + photo redshift	BPT plot+ Heckman's+ Kewley's lines	SVM / MLP	SVM: ~78% / MLP: ~80%	SVM: ~89% / MLP: ~92%

Cavuoti, D'A., Longo, 2008, in preparation.

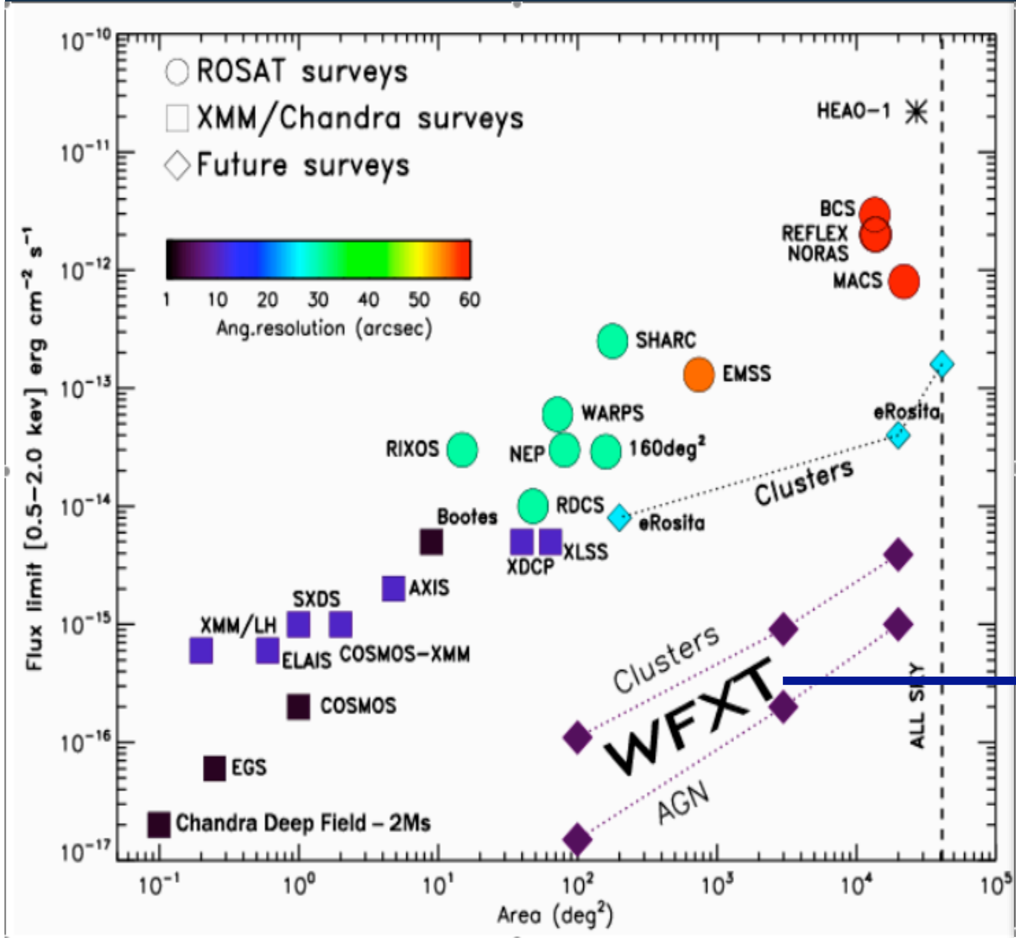
Future X-ray surveys

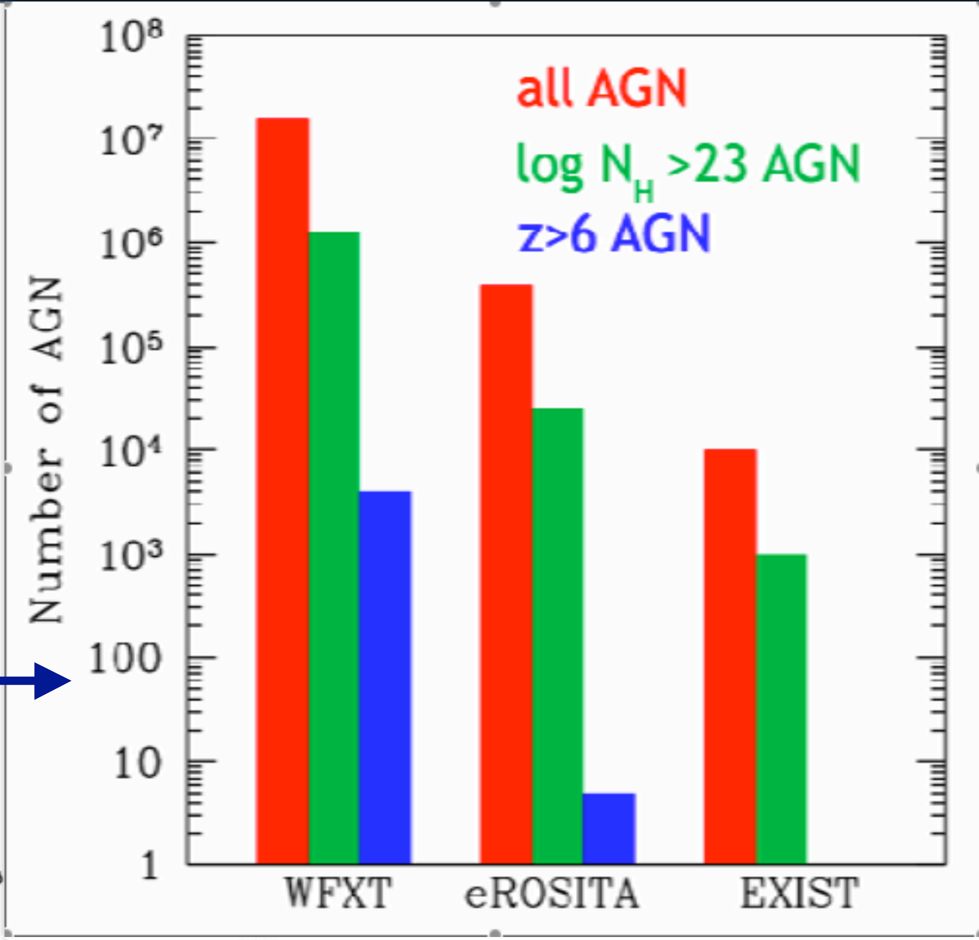


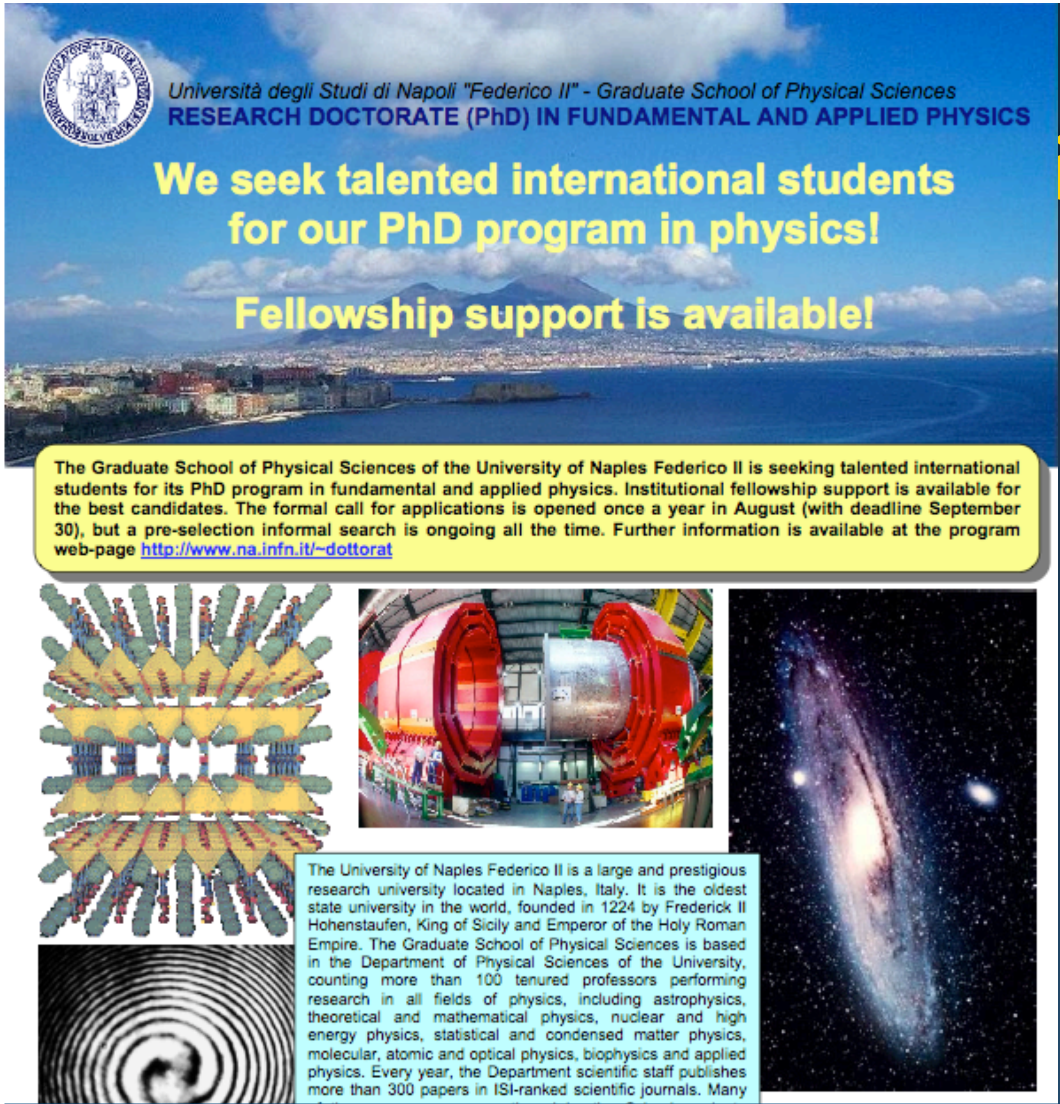


Brandt, WN and Hasinger, G. 2005
Annu. Rev. Astron. Astrophys. 43: 827–59

Future X-ray surveys







Research topics include:

- Observational astronomy: cosmology, distance scale, large scale structure, clusters of galaxies, galaxy dynamics, Active Galactic Nuclei, variable stars and cataclismatic variables, ...
- Theoretical astrophysics: plasma physics, alternative theories of gravity
- Computational astronomy: data mining for large surveys, Neural Networks applied to astrophysics,..