The History of Active Galaxies

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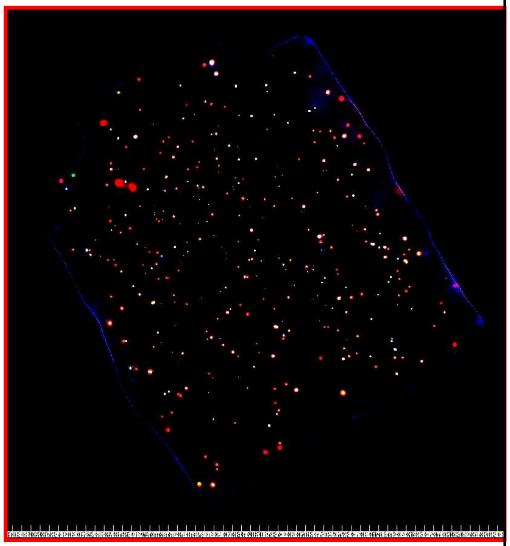
- Active Galaxies (AKA quasars, Seyfert galaxies etc) are radiating massive black holes with $L \sim 10^{8}$-$10^{14} L_{sun}$
- The change in the luminosity and number of AGN with time are fundamental to understanding the origin and nature of massive black holes and the creation and evolution of galaxies
- ~20% of all energy radiated over the life of the universe comes from AGN- a strong influence on the formation of all structure.
- **Chandra and XMM data have revolutionized our understanding of the number, luminosity and evolution of active galaxies from 0<z<4**



X-ray Color Image (1deg) of the Chandra Large Area X-ray Survey- CLASXS

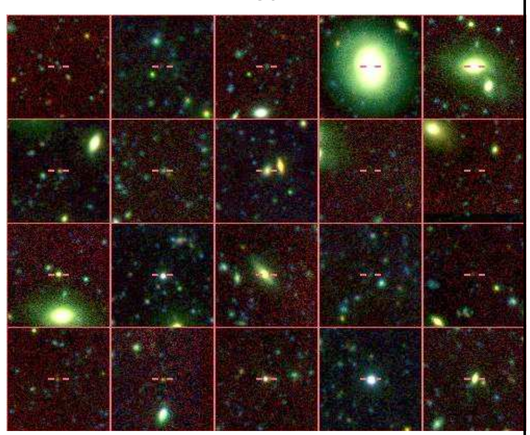
- GSFC
  - Yuxuan Yang Univ of MD graduate student
  - Richard Mushotzky
- University of Hawaii
  - Peter Capak - graduated student
  - W-H Wang
  - Prof. Len Cowie
- University of Wisconsin
  - Aaron Steffen - graduated student
  - Prof. Amy Barger

Table 1. Typical L_{bol} and M_{bh} for QSOs and local AGN

Type of AGN (1)	L_{bol}[a] (ergs s^{-1}) (2)	Typical L_{bol} (ergs s^{-1}) (3)	Typical M_{bh}[b] ($M_\odot$ yr^{-1}) (4)
QSOs	10^{46}–10^{48}	10^{47}–10^{48}	10–100
Seyferts	10^{40}–10^{45}	10^{43}-10^{44}	10^{-3}–10^{-2}
LINERs	10^{39}–$10^{43.5}$	10^{41}–10^{42}	10^{-5}–10^{-4}

Notes to Table – a. The full range in bolometric luminosity (L_{bol}) for Seyfert

Team



Optical counterparts of Chandra x-ray selected AGN

~400ks of Chandra time
Many nights of Keck and Subaru time
+deepest ISO 90,170μ data+SCUBA

Conclusion

- XMM/Chandra results on AGN have shown that
  - The number of AGN
  - The evolution of AGN
  - The nature of the hosts of AGN
  - The total energy radiated by AGN
  - The correlation function of AGN

Were all incorrectly estimated by optical and radio* surveys.

- **Since all theories on the origin, evolution and nature of AGN were based on optical surveys a massive re-think is necessary**

***Radio survey results depended on optical follow-up; in reality most radio sources have properties like the x-ray selected objects**

Because most the sources are optically "dim" **only** high quality x-ray spectral and timing data can

•determine the nature of these "new" objects

•set the basis for theories of the origin and evolution of massive black holes in the universe

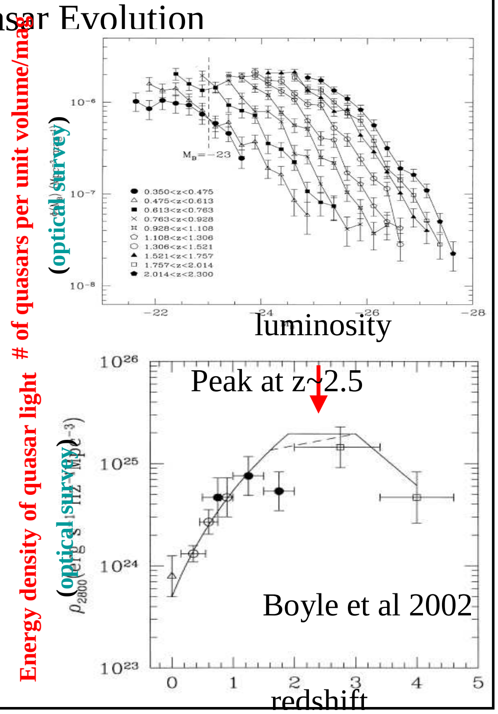
Optical Quasar Evolution

- Historically AGN were found in the optical band by a variety of techniques
  - Presence of strong very broad (1-10,000km/sec) optical and UV emission lines (Broad line objects)
  - The presence of a bright, semi-stellar nucleus (Quasar)
  - Variability of the nucleus
  - "Unusual" colors of the nucleus
  - Optical counterparts to radio source
- Large numbers were found out to z~6
- Since the late 1960's (Schmidt)

  "well known" that quasars were much more numerous and luminous in the past.

Thus quasars were thought to be created in the early universe.

Many theories were developed to explain this.

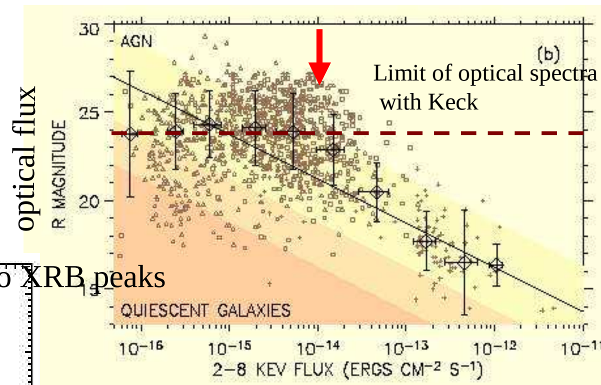


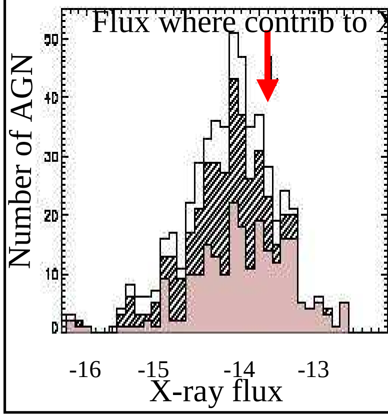
Chandra AGN samples

- large samples of AGN have been obtained by Chandra (~1500 with optical data so far, **525 in CLASX field**, over the redshift range to ~0.1-5)

Yang et al 2004

Steffen et al 2004





Faintness of Chandra/XMM sources makes optical redshifts difficult

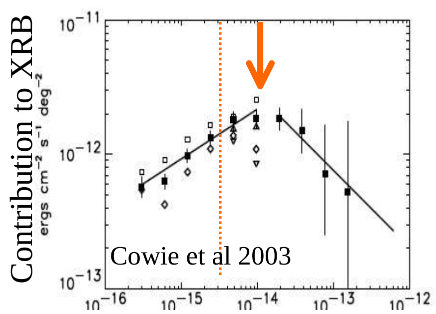
Objects with redshifts

Spectra -no redshift

Where Does the X-ray Background Come From

- The contribution of point sources to the XRB peaks at f(x)~10^{-14} ergs/cm^2/sec ~80% of the 2-8 Kev XRB originating at f(x)>3 10^{-15}

~80% of the sources have redshifts at f(x)>10^{-14} and 60% of the x-ray background light has spectroscopic redshifts



4 data sets used in analysis-1406 objects

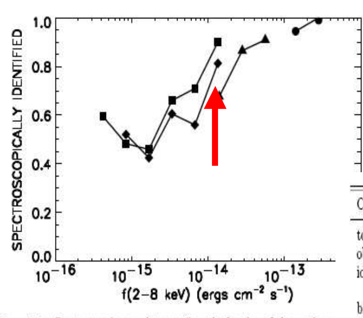
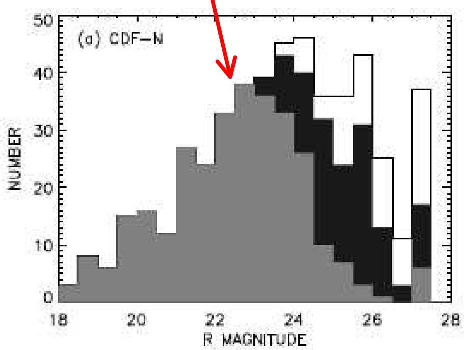


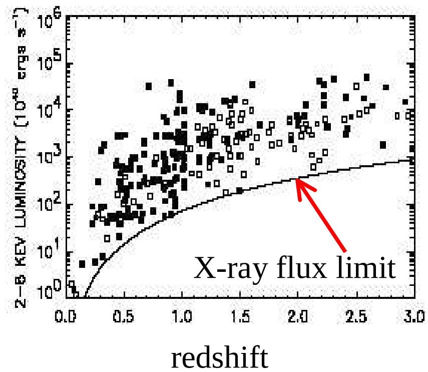
Figure 9.2. Spectroscopic completeness (i.e., the fraction of observed sou[rces] spectroscopically identified) of the 2 – 8 keV samples (*solid squares*—CD[F-N] et al. 2003; *diamonds*—CDF-S, Szokoly et al. 2004; *triangles*—LHNW, S[…] 2004; *circles*—*ASCA*, Akiyama et al. 2003). Sources are grouped in flu[x …] increase by a multiplicative factor of 2. Only flux bins containing more tha[n …] are plotted to illustrate the useful flux ranges of the various samples.

Category	CDF-N	CDF-S	CLASXS	ASCA
total	503	346	525	32
observed	451	247	467	32
identified	306	137	272	31
broad-line	43	32	106	30
high-excitation	39	23	45	0
star formers	148	55	73	0
absorbers	58	20	28	0
stars	14	7	20	1

Completeness vs Z

- Samples are highly complete at z<1.2
- Photometric redshifts extend low sample by δz~0.4
- Light Shaded - objects with spectroscopic z's; dark shade photometric in CDFN- open no z estimate

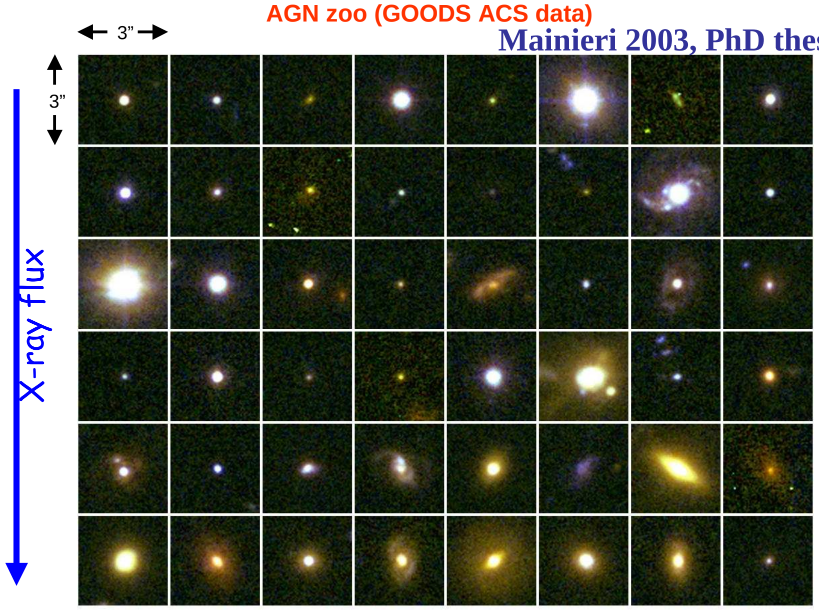




CDFN and CDFS- ground, HST data
CLASX Subaru imaging to ~27th mag (BVRIz) and Keck spectra

AGN zoo (GOODS ACS data)

Mainieri 2003, PhD thesis

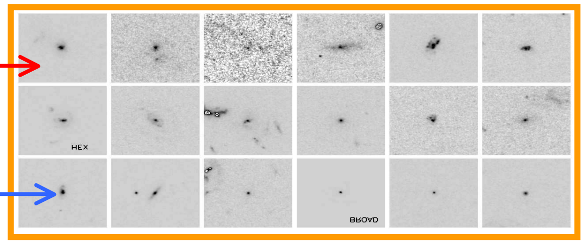


B V i z

Notice absence of bright nuclei
Prevalence of 'spheroidal' galaxies

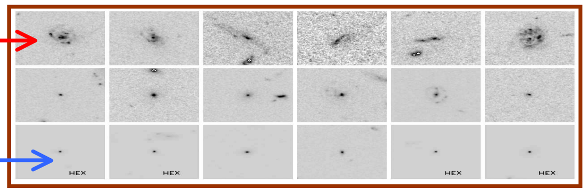
HST ACS Images of Optical Counterparts to Chandra Sources

- Z=0.5
- No Pt like nucleus
- Pt like nucleus

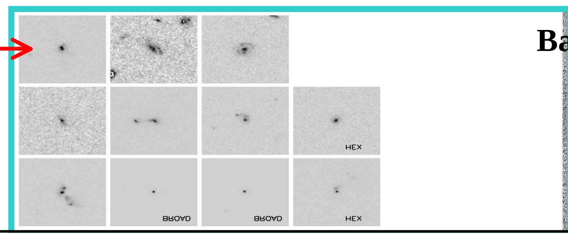


- Z=1

Pt like nucleus



- Z=1.5



Barger et al 2004

Pt like nucleus

What are the optical properties of the AGN

HST GOODs survey allows first estimate of nuclear optical fluxes (from the ground the objects are too blurry)

- For the **broad line objects** x-ray and UV flux are strongly correlated
- For the "narrow" line objects optical and x-ray fluxes are uncorrelated and many of the optical nuclei are invisible with deep HST observations.

Relative nucleus vs galaxy

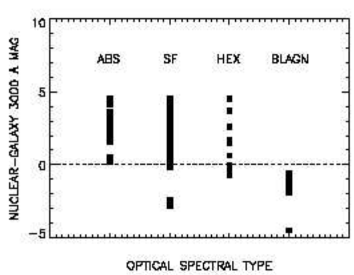
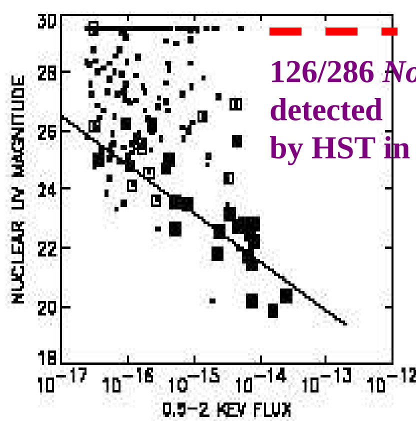


Fig. 16.— Rest-frame (nuclear – galaxy) 3000 Å magnitude computed by interpolating between the GOODS bandpasses vs. optical

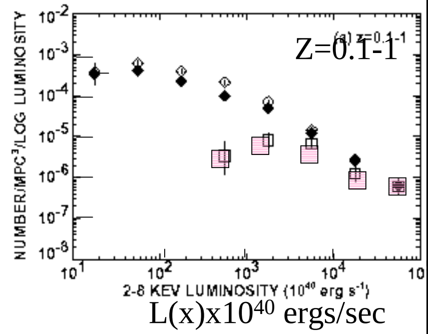
Negative values mean nuclear dominated



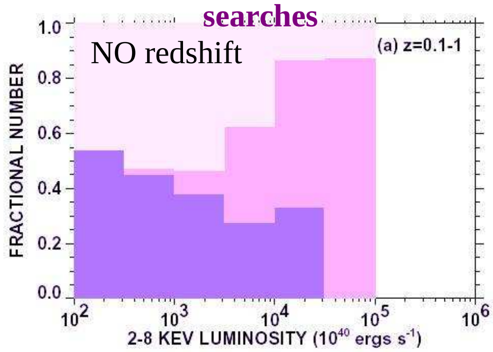
Nucleus is often 5 mags fainter than expected; at 3000A this corresponds to N(H)~10^{22} atm/cm^2 for MW dust to gas ratio

Chandra/XMM Change Everything

- Chandra/XMM observations show that number of x-ray selected AGN **exceeds optically selected ones by ~7:1**
- X-ray selected objects have very different properties than "optically" selected AGN
- most luminous AGN have broad optical lines, most lower luminosity AGN do not have obvious optical AGN signatures- Steffen effect- violation of unified model



Most AGN are "invisible" to optical searches



Objects with broad optical lines ("optical AGN")

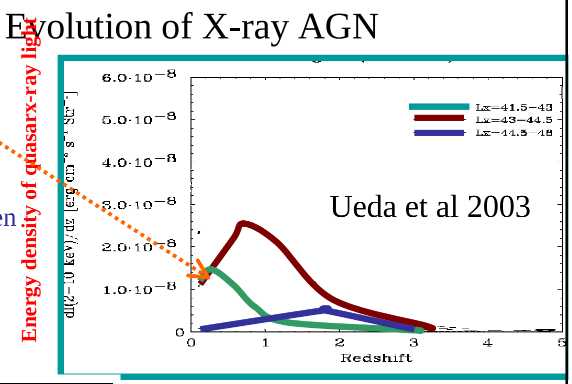
X-ray selected objects

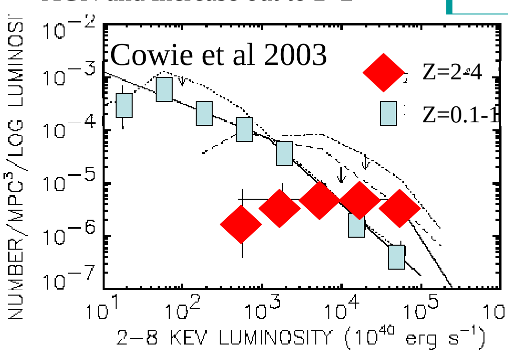
AGN without strong lines

Steffen et al 2003

"Backwards" Evolution of X-ray AGN

- In x-ray samples the low luminosity objects decrease in number at higher redshift
- The medium luminosity objects increase from z~0 to z~1 and then decrease at higher redshift
- The high luminosity objects behave like optically selected AGN and increase out to z~2



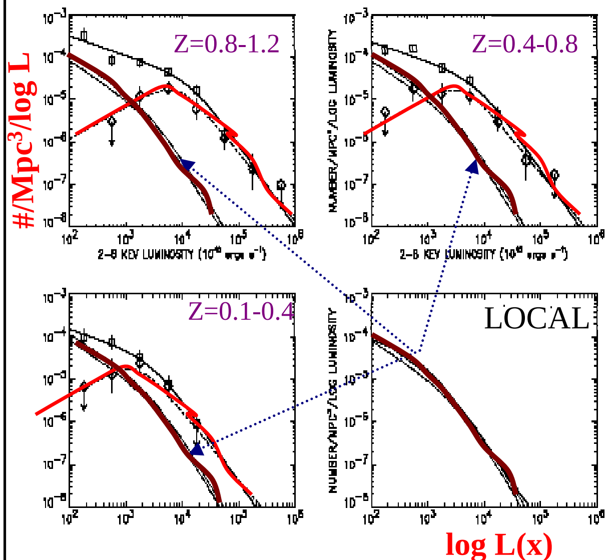


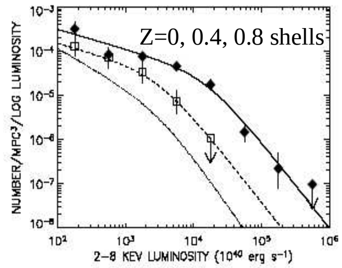
The x-ray sources represent **almost all of the AGN in the universe**

- all broad line AGN in CDF-N and COMBO-17 are x-ray detected

The Evolution of the 2-8 keV Luminosity Function for z<1

Barger et al 2004





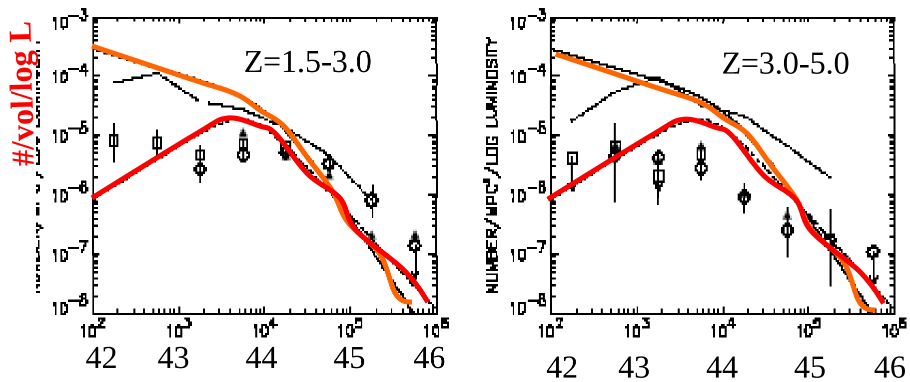
Red= broad line objects only
Black= all objects

At z<1 the evolution of the total AGN population is consistent with pure luminosity evolution $L(x) \sim (1+z)^{3.5}$

At z>1 the evolution radically changes

Z>1 Details

- **Orange line is the z=1 luminosity function *all objects***
- **Red is broad line z=1 f(L)**
- No matter how the upper limits are placed the space density of AGN

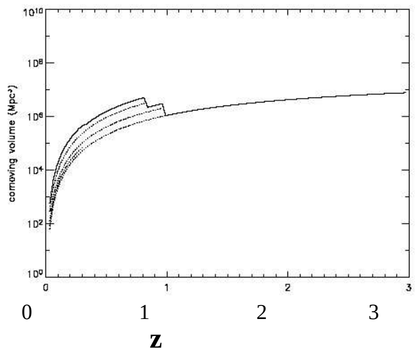


2-8 keV x-ray luminosity

Triangles all objects, diamonds broad line objects

Volume Surveyed by Sample

- For a 'minimal' luminosity object 1042 ergs/sec the volume surveyed is large



Best Fit Evolution Parameters at z<1

- Luminosity function can be parameterized by a broken power law
- And pure luminosity evolution (a,g1,g2 remain constant with z)

$$\frac{d\Phi(L_X, z)}{d\log L_X} = \frac{a}{(L/L_*)^{g1} + (L/L_*)^{g2}} .$$

Parameterizing the redshift evolution as

$$L_* = L_0\left(\frac{1+z}{2}\right)^A$$

and

$$a = a_0\left(\frac{1+z}{2}\right)^B ,$$

MAXIMUM LIKELIHOOD FIT PARAMETERS FOR ALL SPECTRAL TYPES AND FOR BROAD-LINE AGNS

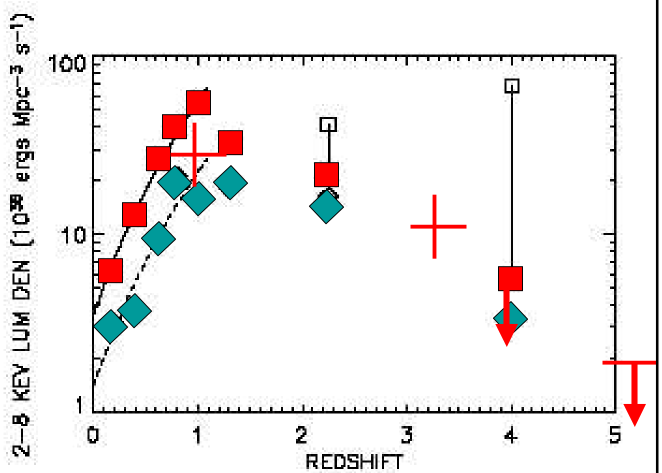
Parameter		All	Broad-line
$\log L_0$	Characteristic L	44.11 ± 0.08	43.81 ± 0.12
$\log a_0$		-4.42 ± 0.07	-4.44 ± 0.14
g_1	low L slope	0.42 ± 0.06	-0.9 ± 0.5
g_2	high L slope	2.2 ± 0.5	1.6 ± 0.3
A	Evolution parameter	3.2 ± 0.8	3.0 ± 1.0
B		-0.1 ± 0.7	-0.1 ± 0.6

The X-ray Luminosity density drops at z>1

- Even including upper limits there is less energy emitting per unit volume at z>1

Barger et al 2004
Similar results from Ueda et al 2003, Marconi et al 2004 Hasinger et al 2003 Fiore et al 2004

Upper limit at z~5.8 Moustakas and Immler 2004; points at z~3 and z~1 Nandra et al Also Lehman et al 2004

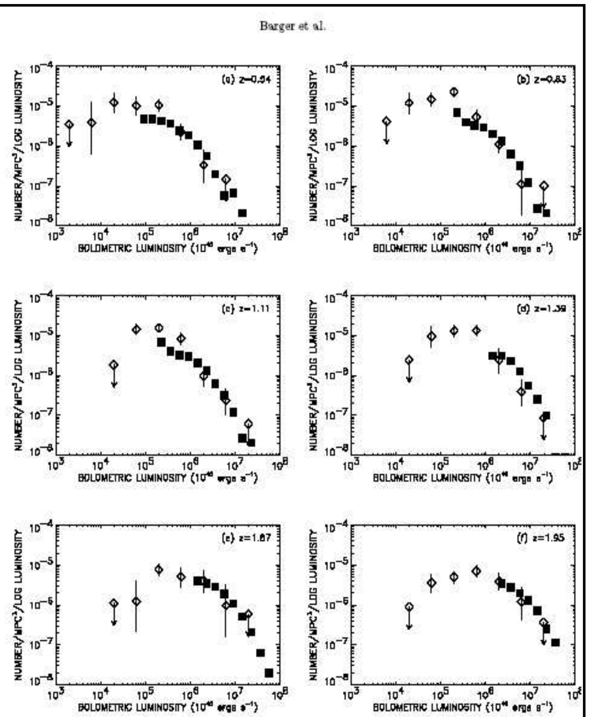


type I AGN, all objects
Open box- assigning all objects without a redshift to to redshift bin

Does this all make sense??

- The Chandra broad line objects reproduce the 2dF luminosity function of AGN as a function of z (Croom et al 2003) when both have been converted to bolometric luminosities using B band and x-ray conversion factors
- Notice the "turn down" of the luminosity function at low L- possibly due to new physics (Nicastro 2003, Laor 2003)

Direct comparison of broad line selected AGN from x-ray and optical surveys



Form of Broad Line Object luminosity function

- The turn-down of F(L) for broad line objects is present at all redshifts but increases in luminosity at higher z- not present in narrow line objects
- Suggests that lack of broad line objects at lower L is due to a physical cause- models developed by Laor and Nicastro suggest that this may be a Eddington ratio effect- objects at low L_{Edd} may not have broad lines

Luminosity function at z~1

compared to z~2 data

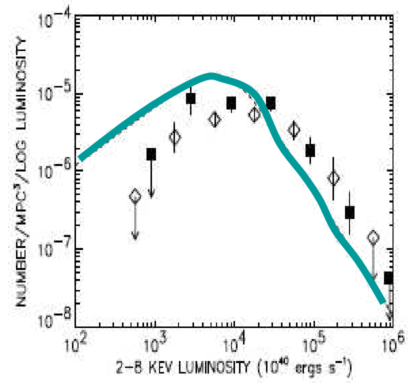


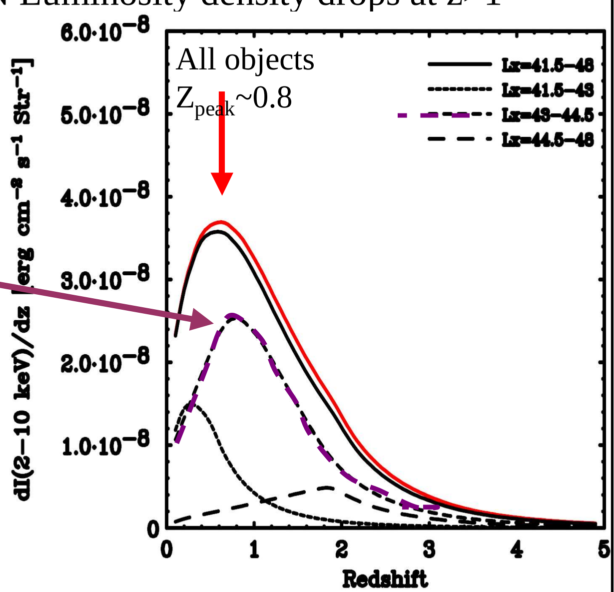
FIG. 21.— HXLF for BLAGNs at $z = 1.5 - 3$ computed from the observed-frame 0.5–2 keV *(diamonds)* and observed-frame 2–8 keV *(squares)* samples. Dashed curve denotes the MLF to the $z = 0-1.2$ HXLF for BLAGNs computed at $z = 1$.

The X-ray AGN Luminosity density drops at z>1

- Cosmic downsizing- low luminosity objects peak at lower redshifts

Objects producing most of the AGN energy

AGN are "creatures" of the moderate age universe ~5 Gyr ago

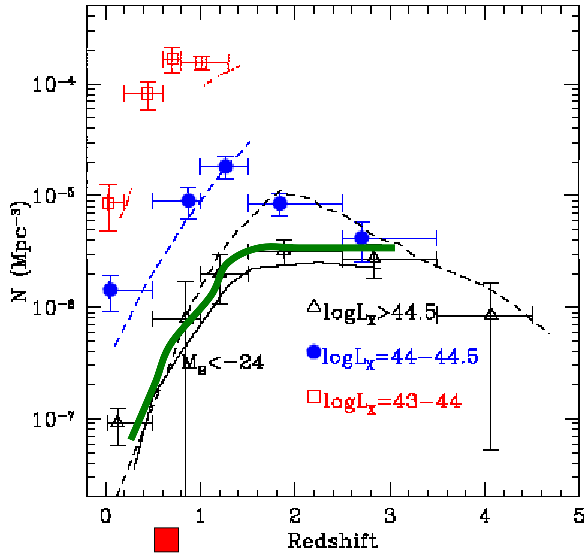


Barger et al 2004
Similar results from Ueda et al 2003, Fiore et al 2003
Marconi et al 2004
Hasinger et al 2003

Ueda et al 2003

The X-ray Luminosity density drops at z>1

- Independent analysis and samples (XMM data Fiore et al 2004) show the same results

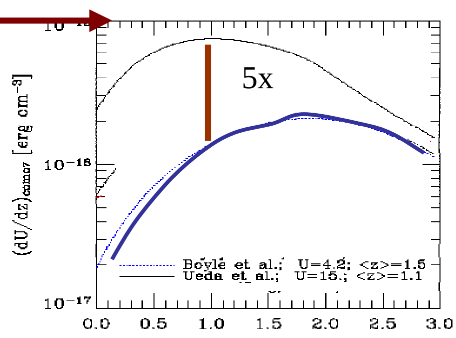


Barger et al 2004
Similar results from
Ueda et al 2003,
Marconi et al 2004
Hasinger et al 2003

Optical surveys

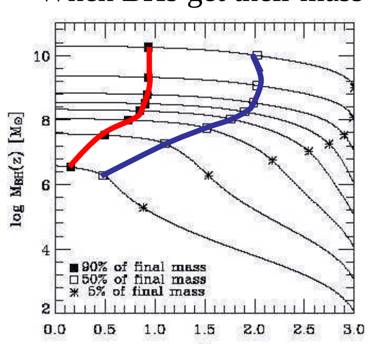
Comparison of Energy Densities and Evolution

- **Optical samples miss most of the energy radiated by BHs at z< 2**
- Most of the AGN luminosity is due to M~10 $^{7+/-1}$ M objects
- The x-ray data show that lower mass black holes evolve later and grow more than more massive objects.



Marconi et al 2004

When BHs get their mass



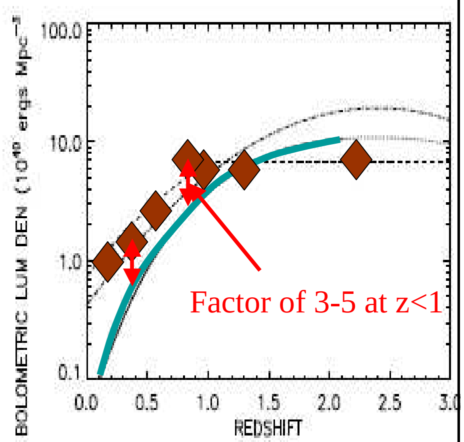
Accretion rate per unit time

Energy densities from AGN from Optical (---) x-ray (-------) surveys

Each line is the growth of a Massive BH vs z

Comparison of Energy Densities and Evolution

- **Barger et al gets similar result**
- **x-ray evolution of $(1+z)^3$ is somewhat steeper than $(1+z)^{1.7}$ for UV luminosity - consistent with $(1+z)^{3.7}$ for luminous IR sources (Cowie et al 2004)**
- **Peak of energy density is at z=0.8-1.2; 1/3 in broad line AGN and 1/2 in objects of luminosity <8x10^{43} ergs/sec which are mostly narrow or no-line objects.**



Barger et al 2004

Energy densities from AGN from Optical (—) x-ray (◆) surveys

How did black holes get their mass

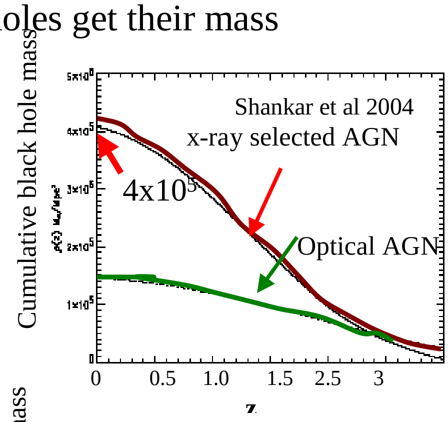
- The integral of the accretion rate of black holes (Soltan 1980) over all time must be ≤ total mass of black holes at z=0
- Recent estimates (Yu and Tremaine 2003) local mass density of SMBH~ (2.1 ± 1.1) $(C_{B,B}/11.8)\times 10^5 M_\odot/\mathrm{Mpc}^3$,

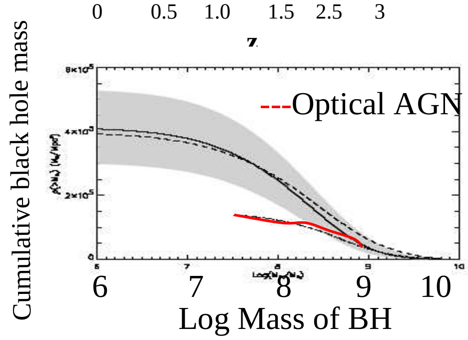
~ 25% in the bulges of late type galaxies.

- **optical surveys only account for ~1/4 of the z=0 mass density** (Shankar et al 2004)
- Our results (Barger et al 2004) give a mass density of **4×10^5** $(C_{B,X}/85)$ $M_\odot/\mathrm{Mpc}^{-3}$ for all x-ray AGN and

$1\times10^5\ 0.1(1-\varepsilon)/\varepsilon)M_\odot/\mathrm{Mpc}^{-3}$ for BLAGN-

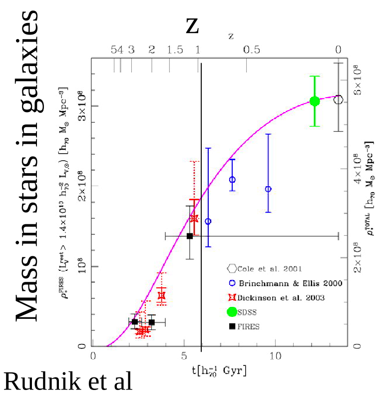
Half of the SMBH mass density has formed at z<1 and there is little or no room for further obscured or low efficiency accretion



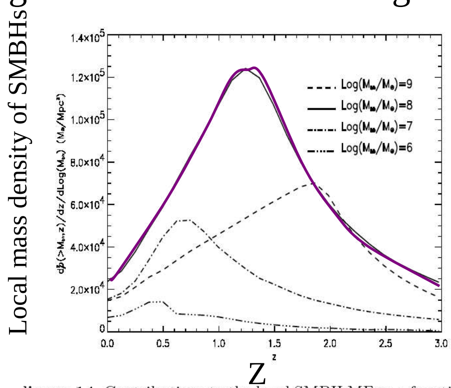


When did the black holes grow?- cosmic downsizing

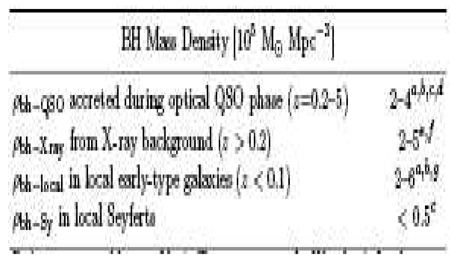
- Most black hole growth occurs at z~1 and is dominated by M~10^8 M objects
  Marconi et al and Shankar et al.
- The most massive objects M>10^9 grow most at earlier times
- **The peak of AGN growth is also the peak of galaxy growth.**



Rudnik et al 2003



'igure 14. Contributions to the local SMBH MF as a function of



BH Mass Density $[10^5\ M_\odot\ Mpc^{-3}]$	
ρ_{bh-QSO} accreted during optical QSO phase (z=0.2-5)	2-$4^{a,b,c,d}$
$\rho_{bh-Xray}$ from X-ray background (z > 0.2)	2-$5^{e,f}$
$\rho_{bh-local}$ in local early-type galaxies (z < 0.1)	2-$6^{a,b,g}$
ρ_{bh-Sy} in local Seyferts	$< 0.5^{c}$

How Does this Match to galaxy Formation ?

- Apparently the peak in AGN rate at z~1 is when massive galaxies

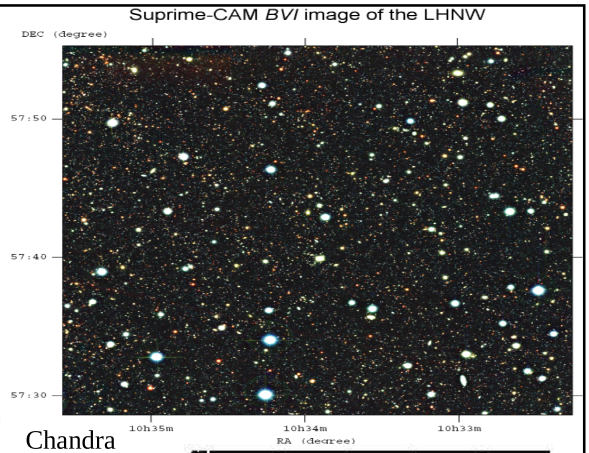
Heavens et al 2004

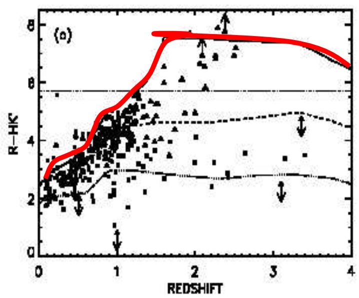
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Optical Image of CLASS Field (Steffen et al 2004)

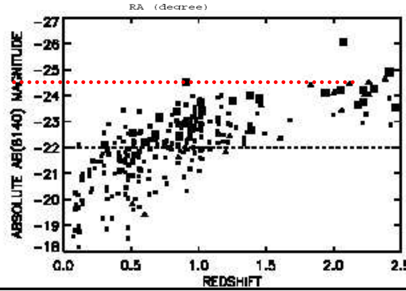
Chandra moderate luminosity AGN lie in luminous galaxies

- Of the sources with $L_X > 10^{42}$ ergs s-1, 82% lie in galaxies with $M_{(8000\ \text{Å})} < -21$ in the redshift range z = 0-1.2, where lower optical luminosity sources would still be seen. (Cowie et al 2004)





Chandra sources have the ~color and luminosity of massive galaxies

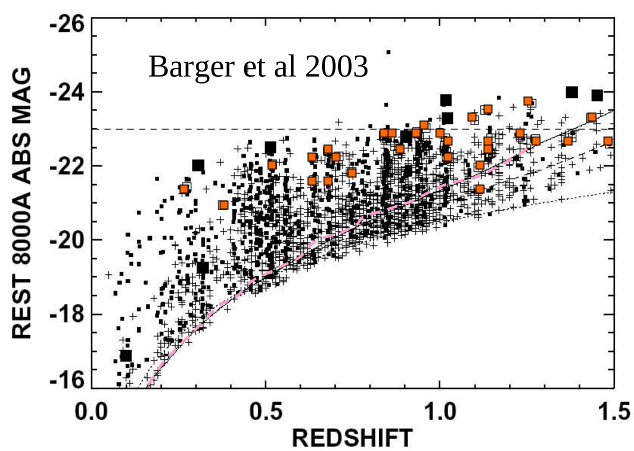


What sort of galaxies do the Chandra/XMM sources reside in?

- ~15% of luminous galaxies host Chandra AGN

80% of Chandra sources lie in luminous galaxies

At each z the x-ray sources are in the most luminous galaxies



Chandra data show that x-ray samples can trace large scale structure to high z- x-ray selected AGN are tracers of high overdensities

Nature of Host Galaxies

- Chandra sources are in luminous galaxies
- At low z there is an absence of very luminous galaxies- e.g. the nature of the host galaxies is changing with z (? !)

Such that lower mass galaxies become more prominent

(there is a selection effect due to the volume surveyed of an absence of high luminosity objects at low z in GOODs data- CLASX data support claim)

This type of analysis is only possible with HST data at moderate to high z and isconsistent with the CLASX and SDSS data at low z.

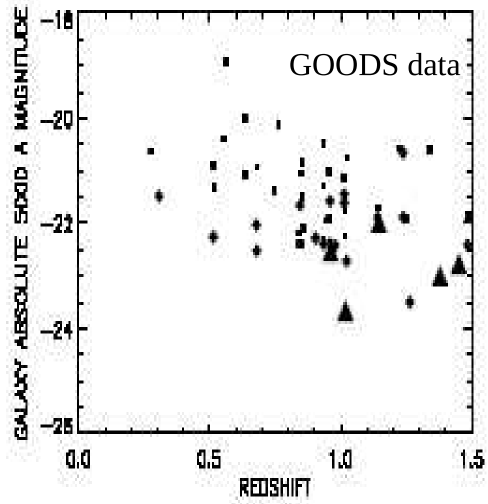


FIG. 19.— Host galaxy luminosity at rest-frame 5000 Å vs. redshift for sources in the GOODS region of the CDF-N shown for hree X-ray luminosity intervals (*triangles*—$L_X > 10^{44}$ ergs s^{-1}; *diamonds*—$L_X = 10^{43} - 10^{44}$ ergs s^{-1}; *squares*—$L_X = 10^{42} - 10^{43}$ ergs s^{-1}).

•Broad line objects (black) are systematically at higher z at a fixed optical magnitude than the non-BLAGN (red)

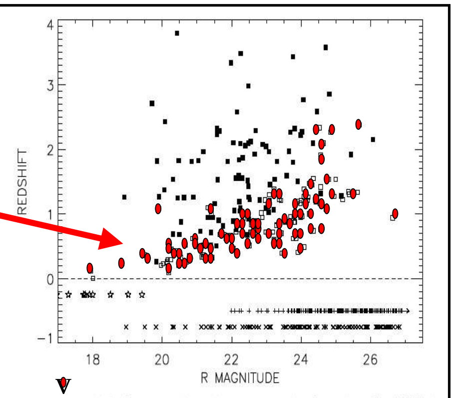
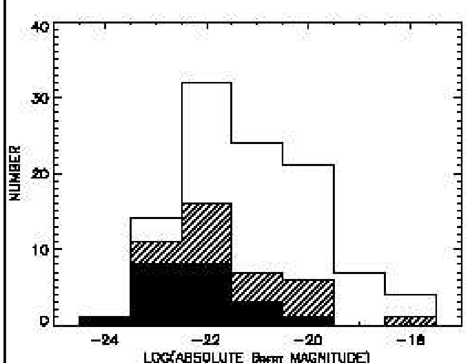


FIG. 7.— Redshift vs *R*-band magnitude for the CLASS ha

CLASX objects redshift vs R mag



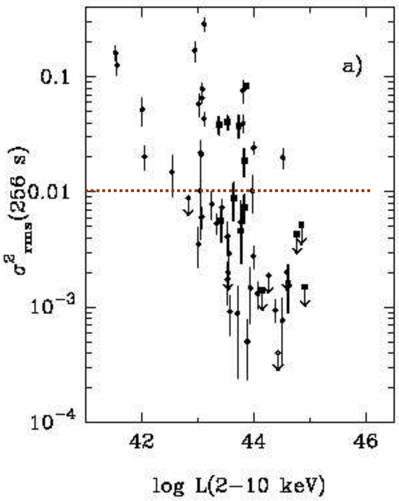
. 9.— Distribution of rest-frame absolute *B*-magnitud e CLASS X-ray sources with measured redshifts less 7 (open histogram). BLAGNs (other AGNs) are shown (hatched) histogram.

Absolute B_{mag} distribution of “no line” objects (open histogram) peaks at M_B~-22

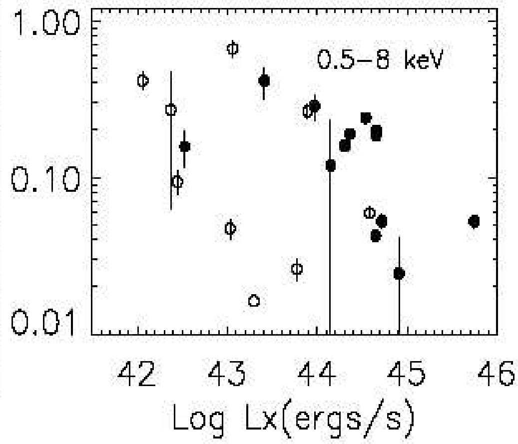
What is the nature of the Chandra sources?

- The Chandra sources show a variability pattern very similar to the x-ray bright sources studied by ASCA

Yang et al 2004
Open circles weak no lines
Closed circles broad lines

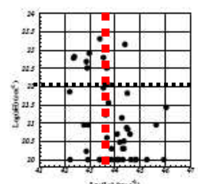


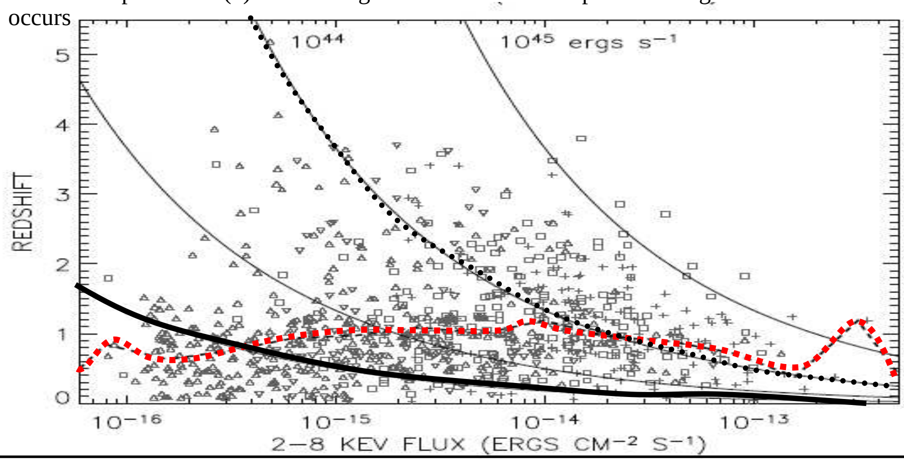
George et al 2000



Origin of the Observed Spectral Hardening
(Steffen et al 2004)

- The median redshift of x-ray selected objects with optical redshifts is ~constant (-----)
- Thus at lower fluxes one gets systematically lower luminosity objects
- At z~0 there is a "transition" such that at log L(x)>43.5 the fraction of objects that are absorbed increases rapidly (Shinozaki et al 2004)
- This corresponds to F(x)~5x10^{-15} ergs/cm^2/sec where the spectral change occurs

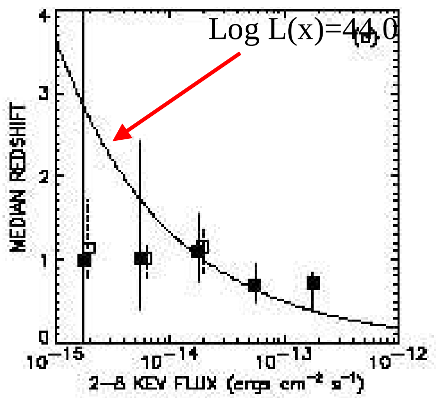


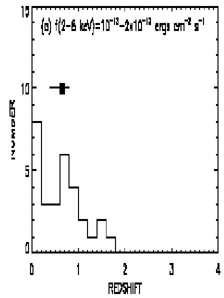


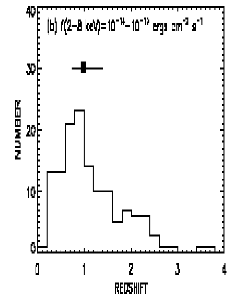
Median redshift vs X-ray flux

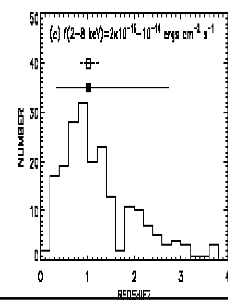
Redshift distribution in 3 x-ray flux bins.

Notice that the median and range do not change much with x-ray flux



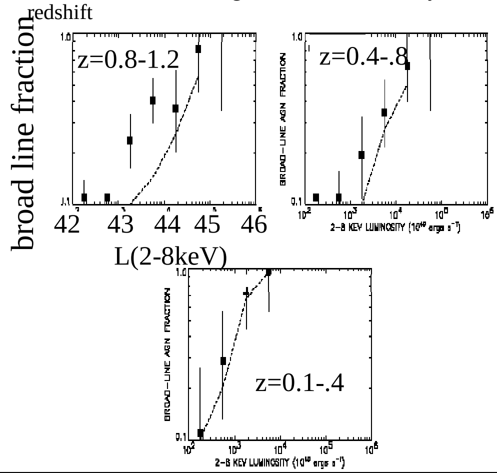


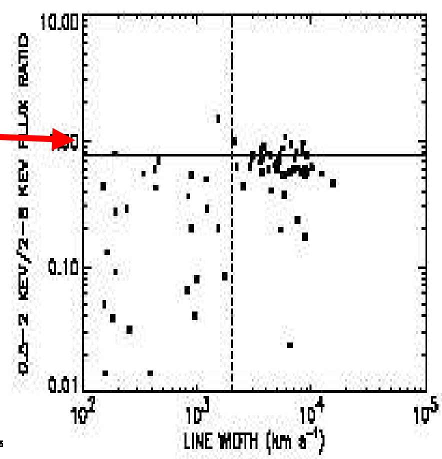




What are these objects?

- Most of the optically broad line objects show little x-ray absorption
- Most of the "narrow" line objects are very hard- probably high column density
- This change in properties occurs at ~2000km/sec.
- The fraction of objects that show broad optical emission lines is a strong function of luminosity and redshift

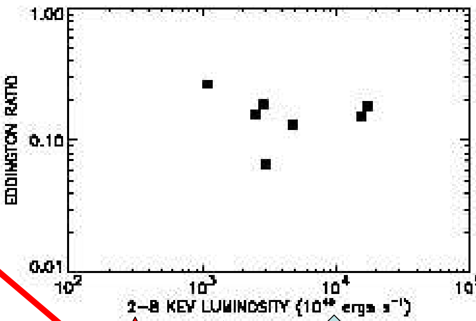




Barger et al 2004

Eddington ratio

- Using a broad optical emission line (MgII) to estimate the mass of the black hole one finds that many of the objects are radiating at ~15% of Eddington limit
- There is a weak relation between galaxy luminosity and bolometric luminosity which does not change with redshift
- Thus the “loss” of luminous AGN at low redshift is a result of cosmic downsizing - e.g. the big black holes at low z are not radiating (much)
- At low z hard x-ray emission is a good predictor of black hole mass



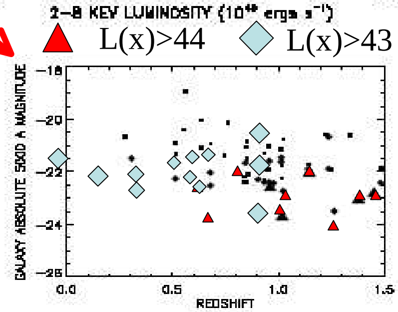
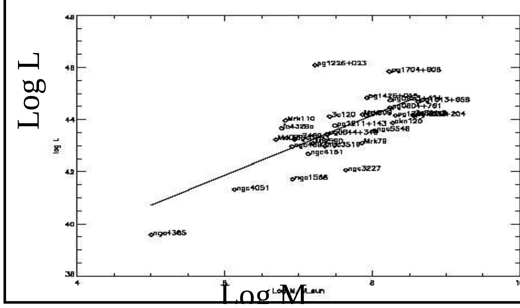


FIG. 25.— Host galaxy luminosity at rest-frame 5000 Å vs. redshift for sources in the GOODS region of the CDF-N shown for three X-ray luminosity intervals (*triangles*—$L_X > 10^{44}$ ergs s^{-1}; *diamonds*—$L_X = 10^{43} - 10^{44}$ ergs s^{-1}; *squares*—$L_X = 10^{42}$ – 10^{43} ergs s^{-1}).



Bolometric Corrections

- Of the sample 3/4 of the brightest sources are detected by ISO at 90μ and none at 170μ.
- There are systematic differences in the SEDS of the 3 classes of optical spectral and there is much scatter in the SEDs for the high excitation and “no-line” objects

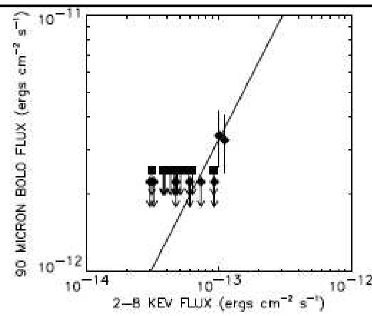


FIG. 32.— νf_ν at 90μm vs. $f_{2-8\ \mathrm{keV}}$ flux for the 23 CLASXS sources in the ISOPHOT field with $f_{2-8\ \mathrm{keV}} > 3 \times 10^{-14}$ ergs cm^{-2} s^{-1} and $L_X \geq 10^{42}$ ergs s^{-1}. Only the two brightest X-ray sources have been detected at 90μm. All of the

SEDS normalized to 2-8 kev flux

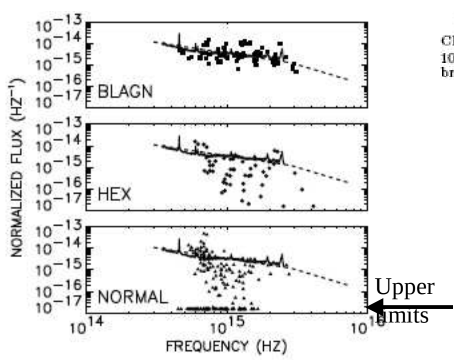


FIG. 34.— Composite SEDs of the nuclear light over the UV/optical range (1000 – 10000 Å) normalized to the 2 – 8 keV flux for three spectral classes. Solid (dashed) curve is the composite

The mean 2-8 kev bolometric correction is ~35 for broad line objects and 85 for the weak/no-line objects with major differences in the UV and FIR. It seems as if the best “optical” normalization pt is > 1μ.

How do the sources differ?

- The spectral energy distribution (SED) of the broad line and narrow line objects are very different and so is their ratio of x-ray to total luminosity
- This also changes with x-ray luminosity - lower luminosity sources are "redder"
- Using our best estimates of AGN bolometric corrections and evolution broad line objects contribute ~1/3 of today's rest mass of black holes

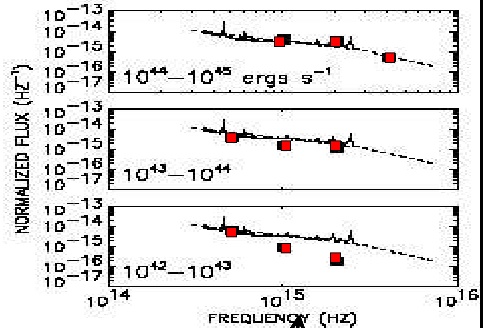
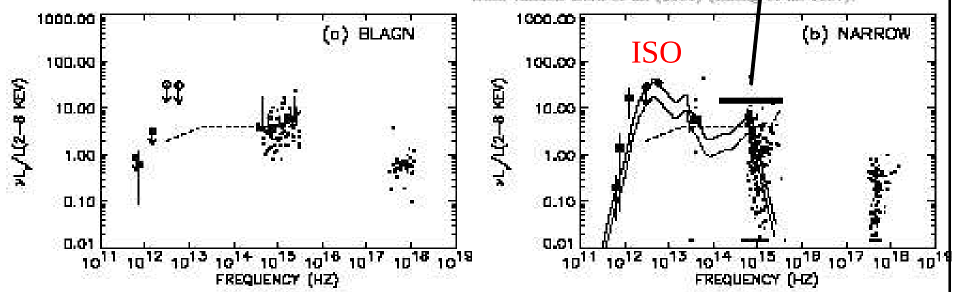


FIG. 33.— Mean composite SEDs of the nuclear light over UV/optical range (1000 − 10000 Å) for three hard X-ray lumino intervals. Solid (dashed) curve is the composite quasar spectr from vanden Berk et al. (2001) (Zheng et al. 1997).



CDFS-263 SCUBA data

- Detailed properties of one of the objects (Mainieri et al 2004)

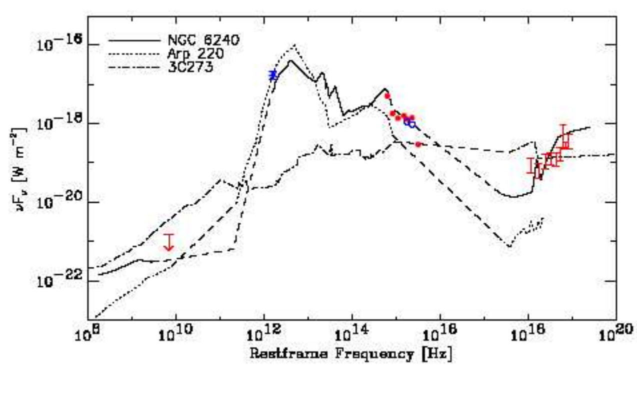


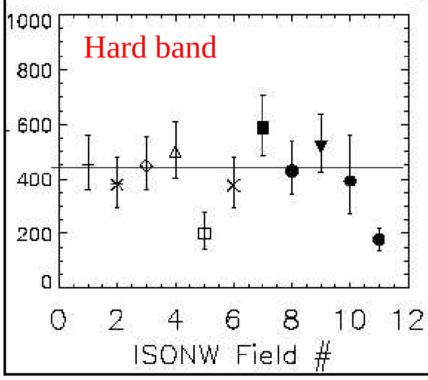
Figure 4. Detections and upper limits for CDFS-263 plotted over the SED of NGC 6240 (*solid*), Arp 220 (*dotted*) and 3C273

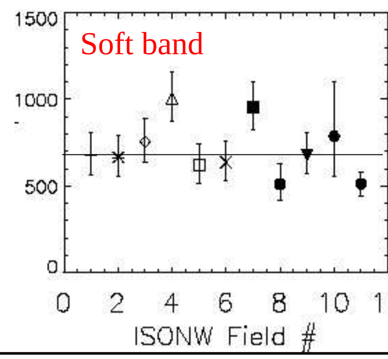
Large Scale Structure with X-ray Sources

There are ~11 fields with Chandra (so far published) that go deeper than 10^{-14} ergs/cm^2/sec in the hard band (9 from our data)

•In the soft band there is little variance in source numbers from field to field

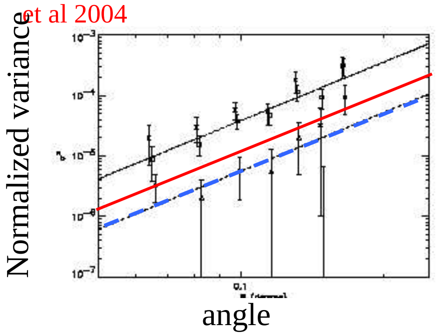
•In the hard band there is a factor of >3, on a scale of 1 ACIS-I field (17x17')





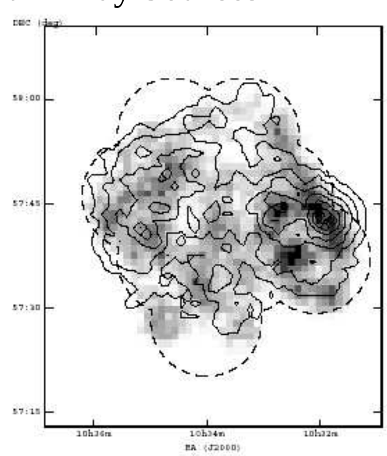
Large Scale Structure with X-ray Sources

- Optical surveys (Boyle et al) have found that AGN are distributed just like "normal" galaxies
- Chandra/XMM surveys find that "hard x-ray" selected AGN are highly clustered (Yang et al 2003, Basilikos et al 2004



--- hard sources

---- soft sources



Density of Chandra sources -notice large concentration to west, void to north

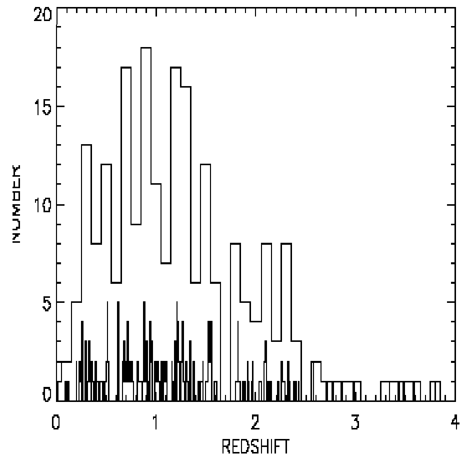
Yang et al 2003

Large Scale Structure with X-ray Sources

In the Chandra deep fields a very large fraction of the sources are grouped in small redshift ranges

Not seen in CLASX survey- due to larger solid angle??

Redshift Distribution in CLASS



Redshift Distribution in CDFS

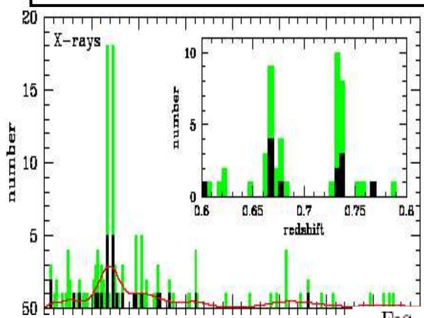


FIG. 5.— Redshift distribution for the spectroscopically ide
CLASS sources. All stars and sources without measured re
have been excluded. Two different bin sizes ($\Delta z = 0.1$ and
0.01) are shown.

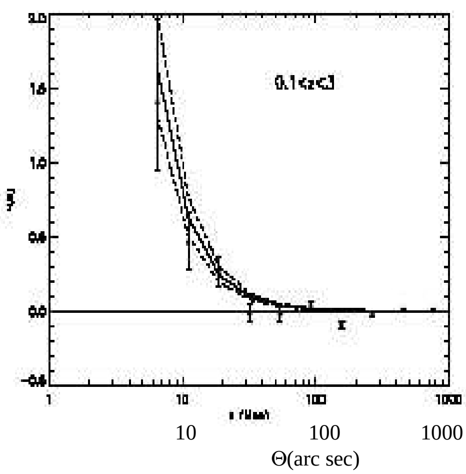
How are X-Ray sources Clustered- All X-ray selected

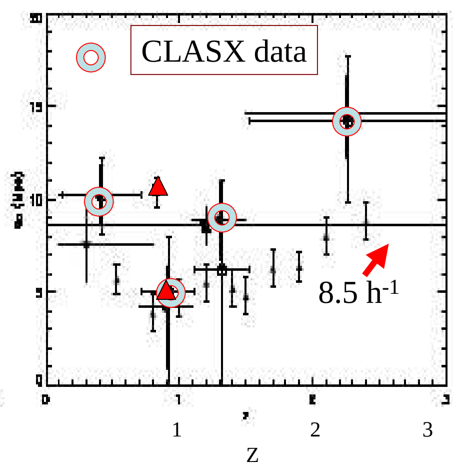
3-D Correlation function-

▲ 2dF data

▲ CDF-N,S data

Angular correlation function





Summary

- Majority of AGN in the universe are not like optically selected AGN
- Most of these sources are "optically dull" and radio quiet , obtaining optical redshifts is difficult
- z~1 is the peak epoch of AGN where the energy density peaks, consistent with the peak in the integral star formation
- AGN evolve very rapidly to z~1, consistent with pure luminosity evolution- at higher z the evolution changes ***sign***
- 1/2 of the nuclei are not detected by GOODS HST data - only x-ray spectral and timing data can determine the nature of most radiating black holes in the universe
- total energy radiated by AGN is ~3-5x larger than previously thought
- The Chandra objects can produce all of the mass of z~0 black holes via accretion
- Optically selected AGN (broad line objects) are a subset of x-ray selected objects
- The data are consistent with many of the non-broad line objects (the dominant population) having high column densities- but not a unique solution.
- Host galaxies of AGN tend to be the most luminous galaxies at each redshift-
- The data point to downsizing- massive luminous systems dominate at high z, low mass lower luminosity at lower z.
- Simple unified model is not correct- there are almost no low luminosity broad line objects (Steffen effect)

What's changed?

- Chandra/XMM results on AGN have shown that
  - The number of AGN
  - The evolution of AGN
  - The nature of the hosts of AGN
  - The total energy radiated by AGN
  - The correlation function of AGN
- **Were all incorrectly estimated by optical and radio surveys.**
- **Since all theories on the origin, evolution and nature of AGN were based on optical surveys a massive re-think is necessary**

Only high quality x-ray spectral and timing data can determine the nature of these objects and set the basis for theories of the origin and evolution of massive black holes in the universe

What's Next??

XMM data show that the objects which make up the 2-8 keV background contribute <60% to the 6-10 keV background.

Thus there are **even more** optically "invisible" AGN than Chandra and XMM have discovered- but may not make major contribution to accretion history of universe.

Evolution of Type I AGN

- Hasinger et al using a different sample have determined the evolution of 'type I' (e.g. broad line) AGN

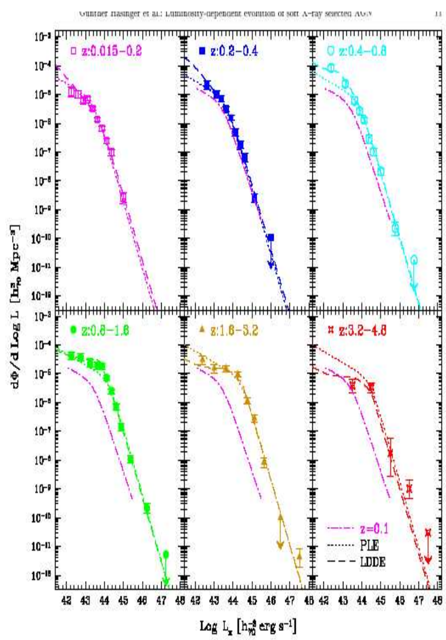
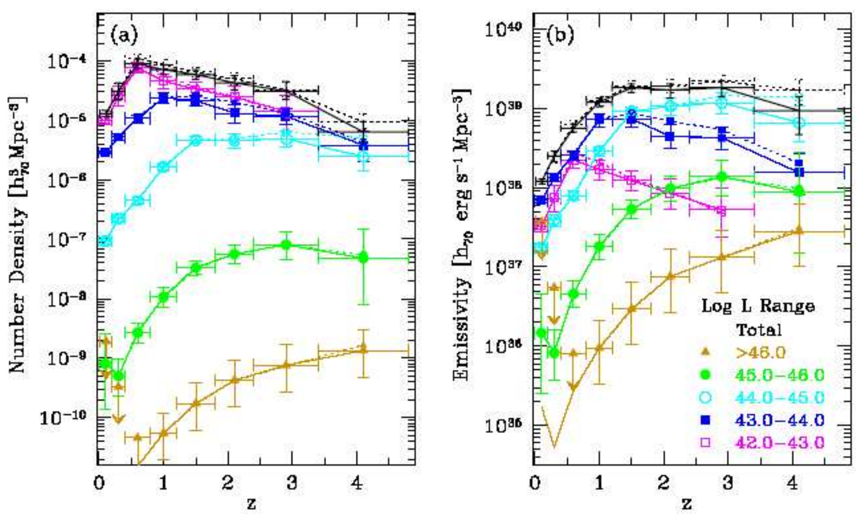


Fig. 4. The soft X-ray luminosity function of the type-1 AGN sample in different redshift shells for the nominal case as labelled.

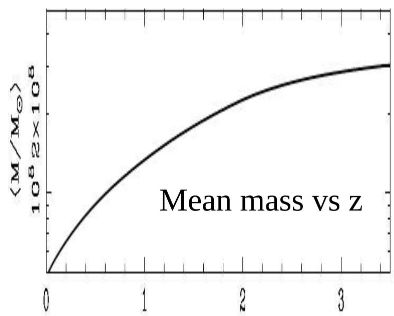
Evolution of Type I AGN

- Hasinger et al using a different sample have determined the evolution of 'type I' (e.g. broad line) AGN and also find luminosity dependent evolution.
- Low luminosity peak at lower redshifts
- Log L(x) ~43-44 erg/sec objects contribute most to the total luminosity density of AGN



Black hole mass function vs z

- With simple assumptions convert to BH mass function vs redshift (Merloni 2004) (e.g.
- L(x) → Lbol,
- Lbol- → mass.
- Growth of black holes is 'anti-hierarchical'



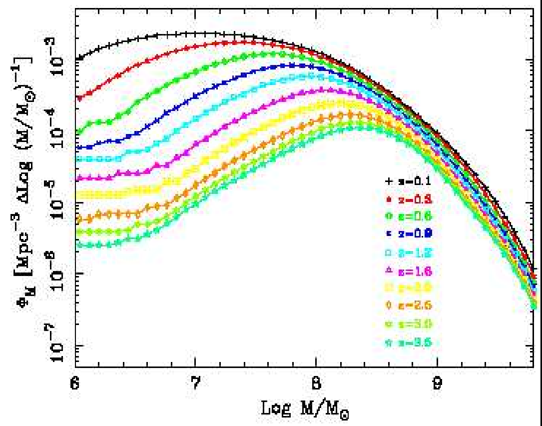


Figure 4. Redshift evolution of the SMBH mass function (BHMF), from redshift 3.5 till redshift 0.1. Different colors and symbols correspond to different redshift bins.

Beware of Non-standard redshift estimators

- Fiore et al have used the x-ray to optical ratio for non-BL objects as a measure of their luminosity.
- This is based, physically, on the lack of correlation of the x-ray and optical for these objects e.g the light comes from the galaxy, the x-ray flux comes from the AGN
- While this works well for R<24, it does not work for fainter objects and overestimates the luminosities by ~3 (and thus redshifts)- creating luminous, high z non-BL objects (Padovani et al 2004)

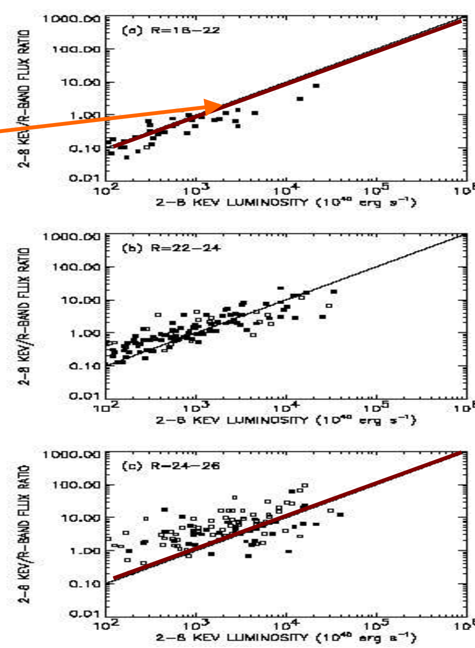


FIG. 8.— f_X/f_R vs. L_X for the non-BLAGN sample in CDF-N and CDF-S for R-magnitude ranges (a) $R = 18-22$, $R = 22-24$, and (c) $R = 24-26$. Spectroscopic (photometric) redshifts are shown as solid (open) squares. Solid line shows linear relation given by Fiore et al. (2004).