The History of Active Galaxies
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- Active Galaxies (AKA quasars, Seyfert galaxies etc) are radiating massive black holes with $L \sim 10^{8-10^{14}} L_{\text{sun}}$

- The change in the luminosity and number AGN with time are fundamental to understanding the origin and nature of 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 $0<z<4$
Optical counterparts of Chandra x-ray selected AGN

Team

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Conclusion

• 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

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

CON-X
Optical Quasar Evolution

- Historically AGN were found in the optical band by a variety of techniques
  - Presence of strong very broad (1-10,000 km/sec) optical and UV emission lines
  - The presence of a bright, semi-stellar nucleus
  - Variability of the nucleus
  - “Unusual” colors of the nucleus
- 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 (~1400 with optical data so far, 525 in our field, over the redshift range to ~0.1-5)

Steffen et al 2004

Faintness of Chandra sources makes optical redshifts difficult

Objects with redshifts

Spectra - no redshift

X-ray flux

Optical flux
AGN zoo (GOODS ACS data)

Mainieri 2003, PhD thesis
Chandra Changes Everything

- Deep Chandra 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
- While most luminous AGN have broad lines, most lower luminosity AGN do not have obvious optical AGN signatures

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 Chandra AGN

- In Chandra samples the low luminosity objects decrease in number at higher redshift.
- The medium luminosity objects increase from $z \sim 0$ to $z \sim 1$ and then decrease at higher redshift.
- The high luminosity objects behave like optically selected AGN and increase out to $z \sim 2$.

The Chandra sources represent almost all of the AGN in the universe:
- are often very optically faint and
- are hard to obtain optical redshifts for.
The Evolution of the 2-8 keV Luminosity Function for z<1
Barger et al 2004

At z<1 the evolution of the total AGN population is consistent with pure luminosity evolution \( L(x) \sim (1+z)^4 \)

At z>1 the evolution radically changes

Red= broad line objects only
Black= all objects
The Chandra AGN Luminosity density drops at z>1

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

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

\[ Z_{\text{peak}} \sim 0.8 \]
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.

When BHs get their mass

![Graph showing the growth of massive BHs vs. z](image)

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

Each line is the growth of a Massive BH vs z

Marconi et al 2004
The Chandra and deep optical data show that a large fraction of massive galaxies (giant ellipticals) at moderate redshift host Chandra moderate luminosity AGN.

Chandra sources have the color and luminosity of massive galaxies.
What sort of galaxies do the Chandra sources reside in?

- ~15% of luminous galaxies host Chandra AGN
- Chandra sources 80% of Chandra sources lie in luminous galaxies

This is radically different from the “old” ideas of the location of AGN.

Chandra data show that x-ray samples can trace large scale structure to high z- x-ray selected AGN are tracers of high overdensities.
Large Scale Structure with X-ray Sources

- Optical surveys (Boyle et al) have found that AGN are distributed just like “normal” galaxies.
- Chandra surveys find that “hard x-ray” selected AGN are much more highly clustered.

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

Yang et al 2003, also see poster by Yang et al.
What's changed?

- 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

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.

CON-X
Why Con-X?

- Chandra, XMM and HST data have shown that many of the AGN in the universe are “invisible” to optical techniques at $z>0.2$
- Even for “type I” sources the nuclear magnitudes are fainter than 27 for a large fraction of the objects and thus impossible to study optically.
- Thus to understand what these objects are is only possible with x-ray spectral and timing data.
- Only Con-X has the sensitivity to reach x-ray fluxes below $10^{-14}$ for detailed study.

HST Observations of Chandra sources (Grogin et al 2003)
Conclusions

- Optical surveys are very incomplete and miss ~75% of all the AGN energy radiated since z<3.
- The evolution of lower luminosity (lower mass) AGN is opposite in sign to that of more luminous objects.
- Hard x-ray sources are much more clustered than optical AGN and, even at z>1, lie in massive galaxies.
- The absence of “optical” signatures is more prevalent in lower luminosity objects and is not fully understood.
- These “very different” objects which produce most of the AGN energy in the universe can only be studied in detail with Con-X.

Chandra Contours on HST image

Ground based optical images of Chandra sources
Summary

• Most AGN in the universe are not like optically selected AGN
• There are major changes in the nature of the sources at F(x)<2x10^{-14} ergs/cm^2/sec
• Most of these sources are “optically dull” and radio quiet and obtaining optical redshifts is difficult

- Thus only X-ray spectral and timing data can determine the nature of most radiating black holes in the universe
- Only Con-X has the required sensitivity to study these sources individually, determine their redshifts and time variability characteristics

• Preliminary studies of composite spectra of these objects with XMM (Hasinger p.c.) shows that they may be rather different spectrally than brighter sources- are they radiating at a higher Eddington ratio?

- Strong evidence for AGN strongly influence their environment- strong winds (seen via x-ray absorption)- direct observation of the influence of AGN on galaxy formation (~2/3 of all stars form at 10^9 yr at z=1.2)
- Most of the mass of z=0 black holes is obtained via accretion rather than mergers
What is the nature of the Chandra sources?

- The spectra of sources harden significantly at fluxes below $10^{-13}$ consistent with luminosities of source below $10^{44}$ ergs/sec.

And including HRs from Chandra HDFN 1Ms...

**Graphs:**
- Fraction of absorbed sources
- Spectrum of X-ray background
  - Avg spectrum of bright sources

*References:*
- Yang et al. 2004
- Cappi 2003
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 $z \sim 0$ 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 $F(x) \sim 5 \times 10^{-15}$ ergs/cm$^2$/sec where the spectral change occurs
What are these objects?

- As the x-ray flux limit deceases there is a systematic reduction in the median x-ray luminosity $10^{43}$ at $10^{-15}$ ergs/cm$^2$/sec  
  $10^{44}$ at $10^{-14}$ ergs/cm$^2$/sec
- But there is no sharp change in the distribution of the absolute magnitude of the host galaxy as a function of apparent magnitude
- This change in median luminosity is consistent with the change in hardness ratio with flux.
- **Most of the luminosity density from AGN in the universe originates from moderate luminosity objects at z~1** - many of them have high column densities in the line of sight.
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
In the Chandra deep fields a very large fraction of the sources are grouped in small redshift ranges

Redshift Distribution in CDFS

Redshift Distribution in CLASS

Range
Majority of the sources lie at low-z; taking account of incompleteness is unlikely to significantly raise the z-peak
What are the differences in the objects

- The Chandra objects which have a broad optical line spectrum “classical AGN” have a very wide redshift distribution
- The weak-line/no line objects are at lower redshifts and lower luminosities
Miyaji et al 2004

- Dotted lines: upper bounds where unidentified XMM/Chandra sources are assigned central redshift of each bin at z>1.
- Number density peaks at z<1, a decline at z>1.
- Luminosity-dependent density evolution (>100 between z=0 to 2 at Log Lx>45, ≤10 at Lx<43)
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

![Graph]

- ▲ type I AGN,
- □ all objects

Open box- assigning all objects without a redshift to redshift bin
The X-ray Luminosity density drops at $z>1$

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Barger et al 2004
Similar results from Ueda et al 2003,
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$z=0.4-0.8$, $z=0.2-0.4$
Open box- assigning all objects without a redshift to to redshift bin