AGN and AGN Feedback

NASA/CXC/Columbia/Johnson et al


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Chandra: A giant leap forward for astronomy

Solved!

Giacconi +01;02; Vito +16; Luo +17
Chandra: A giant leap forward for astronomy

How do galaxies evolve?

Giacconi +01;02; Vito +16; Luo +17

Chandra Deep Field South (7 Ms)

Prof. Giorgio Palumbo

Prof. Riccardo Giacconi
How do galaxies evolve?

The unified model of AGN

AGN with Chandra ➔ Partially resolving point sources!

➔ Understand the fundamental role of winds
Imaging of the Narrow Line Region

Correlation optical-UV X-ray lines

\( \rightarrow \) Photo-ionised plasma (primarily)

Likely outflowing & stratified

Multi-phase \( \rightarrow \) shock heated?

See also: Young+01; Kinkhabwala+02; Ogle+03; Schurch+04; Bianchi+06,+07; Levenson+06; Paggi+12; Kallmann+14; Kraemer+15; Maksym+19
Warm absorbers: A multi-phase wind!

NGC 3783
Chandra HETG

\[ v_{\text{out}} \sim 10^{2-3} \text{ km s}^{-1} \]
\[ N_H \sim 2 \times 10^{21-23} \text{ cm}^{-2} \]
\[ f_c \sim 0.5 \]
\[ \log(\xi) \sim 1-3 \]
How do galaxies evolve?

The fundamental role of winds in AGN

Fundamental role of disc winds
Ubiquitous in accreting system

Old scheme

Winds!

New view

No Absorbers

Bal

NAL

v=1000 km/s
\( \Delta v=200 \) km/s

v=10,000-60,000 km/s
\( \Delta v=10,000-60,000 \) km/s

NH~10(24)

UV/X-ray luminosity source

Massive Black Hole

r~10^16 cm

v(\text{vertical}) = v(\text{radial})

Does the AGN torus exists?

Log radial scale

Elvis 2000
Is a torus present in AGN?

See also Jaffe +04; Suganuma +06; Meisenheimer +07; Burtscher +09; Kishimoto +07; +11a,b; Koshida +14; Netzer 15

Hot dust (sublimation) radius

Distributed (sub-pc to $10^{1-2}$ pc)

Certainly not a donut (clumpy & porous), maybe outflowing?

See also Jaffe +04; Suganuma +06; Meisenheimer +07; Burtscher +09; Kishimoto +07; +11a,b; Koshida +14; Netzer 15

NGC 4945 Chandra

NGC 5643 Chandra

Fabbiano +18
Is a torus present at the Milky Way center?

L_{SgrA^*} \sim 10^{43-44} \text{ erg s}^{-1} (10^6 \text{ yr ago})

Relic torus of past AGN?

Molinari +10; Ponti +13
Variable absorption: Crossing of BLR cloud?

NGC 1365

Compton thin (Type I)

Compton thick (Type II)

X-ray source

cometary cloud A

θ < 1.2°

$N_H \sim 10^{23} \text{ cm}^{-2}$

$N_H \sim 3 \times 10^{22} \text{ cm}^{-2}$

See also Elvis +04; Risaliti +07; +09a,b; +11; Puccetti +07; Turner +09; Markowitz +14; Torricelli-Ciamponi +14;

NGC 5548

Clouds BLR $\rightarrow$ X-ray absorption

Simultaneous with broad UV absorption $\rightarrow$ BAL QSO

Arav +15
Extreme winds $\rightarrow$ Feedback

$z = 3.91$ - Lensed $\rightarrow$ magnification $10x$

$v_{\text{out}} \sim 0.2-0.4\ c \rightarrow \dot{M}_{\text{wind}} \sim 16-60\ M_{\odot}\ \text{yr}^{-1} \rightarrow \epsilon \sim 0.2-2$

$\rightarrow$ Feedback!

See also Pounds +03; Reeves +03; +09; Tombesi +10a,b; +11; +12; +13; +14; +15; Cappi 06; +09; Gofford +13; +15; Nardini +15; Fukumura +14; +15;
Feedback: Jets

X-ray: Chandra
Optical: HST
Radio: VLA

Cygnus A

→ See Sera Markoff’s talk

Perseus Cluster

20 kpc

NASA/CXC/Columbia/Johnson et al.; NASA/STScI; NSF/NRAO/AUI/
Discovery of double AGN

NGC 6240

MRK 463

Necessary byproduct of structure formation in a hierarchical Universe!

Progenitor population of low frequency (LISA) GW sources
Central engine → Test of strong gravity

Broad lines → Powerful probe of strong gravity

Athena → exploit their full potential!
AGN \textit{(weird)} variability: Recurrent outbursts?

- Mrk 590:
  - Switched off
  - But currently awakening

GSN 069:
- 240 times brighter ($L_x \approx 10^{43}$ erg s$^{-1}$) than ROSAT in 2010 (TDE?)
- Exponential decay $\rightarrow$ 8 years after weird variability

- Quasi periodic eruptions

Denney +14
- But currently awakening

Mathur +18
- Exponential decay $\rightarrow$ 8 years after weird variability
Conclusions: What have we learned?

- Direct imaging
- Intermittent AGN activity
- Double AGN (precursors of GW)
- Broad lines (test of GR)
- Winds! (warm absorber, BLR clouds, obscurers)
- Powerful winds! (Ultra-fast)

→ Feedback
Sgr A*: A quiescent AGN?

$L_{\text{Sgr A}^*} \sim 10^{-9} L_{\text{Edd}}$

That’s faint!

Was Sgr A* brighter in the past?

NASA/CXC/MIT/Baganoff et al
Flows of hot Baryons at the Galactic center

Red: 0.5-2 keV
Green: 2-4.5 keV
Blue: 4.5-12 keV

Flow molecular matter

Hot plasma flow

1 deg – 140 pc

ESA News/XMM-Newton/G. Ponti 2015a
The Galactic center Chimney


Hot plasma flow

Galactic longitude

Galactic latitude

Latitudinal distance in pc from Sgr A*

Counts s$^{-1}$ (keV$^{-1}$ cm$^{-2}$ arcmin$^{-2}$)

Energy (keV)

Surface brightness

Pressure (keV cm$^{-3}$)

Density (cm$^{-3}$)

Ponti +2019, Nature

Hot plasma properties

Conical outflow

$\mathbf{b} = 0^\circ$

$\mathbf{b} = -1.5^\circ$

$10^3$

$10^4$

$10^{-3}$

$10^{-4}$

$0.1$

$0.5$

$1$

$0.1$

$0.5$

$1$

$10^6$

$10^7$

$10^8$

$10^{-5}$

$10^{-6}$

$10^{-7}$

$10^{-8}$
The radio counterparts of the Chimneys

Heywood +19, Nature 573, 235

Confined bubbles or Galactic outflow?


MeerKAT
Map the flows of hot Galactic Baryons

The ROSAT soft X-ray all sky survey (1990-1997)

Global outflow?

Fermi bubbles

Fountains?

XMM GC scan

Inner outflow

Outer inflow?

Chaotic flow?

Flows of hot Baryons connecting the Milky Way center to the corona, halo and beyond

(And a bit of advertisement....)

Watch out for PhD and Post Doc adverts
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Winds!

Powerful winds!

Double AGN (precursors of GW)

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