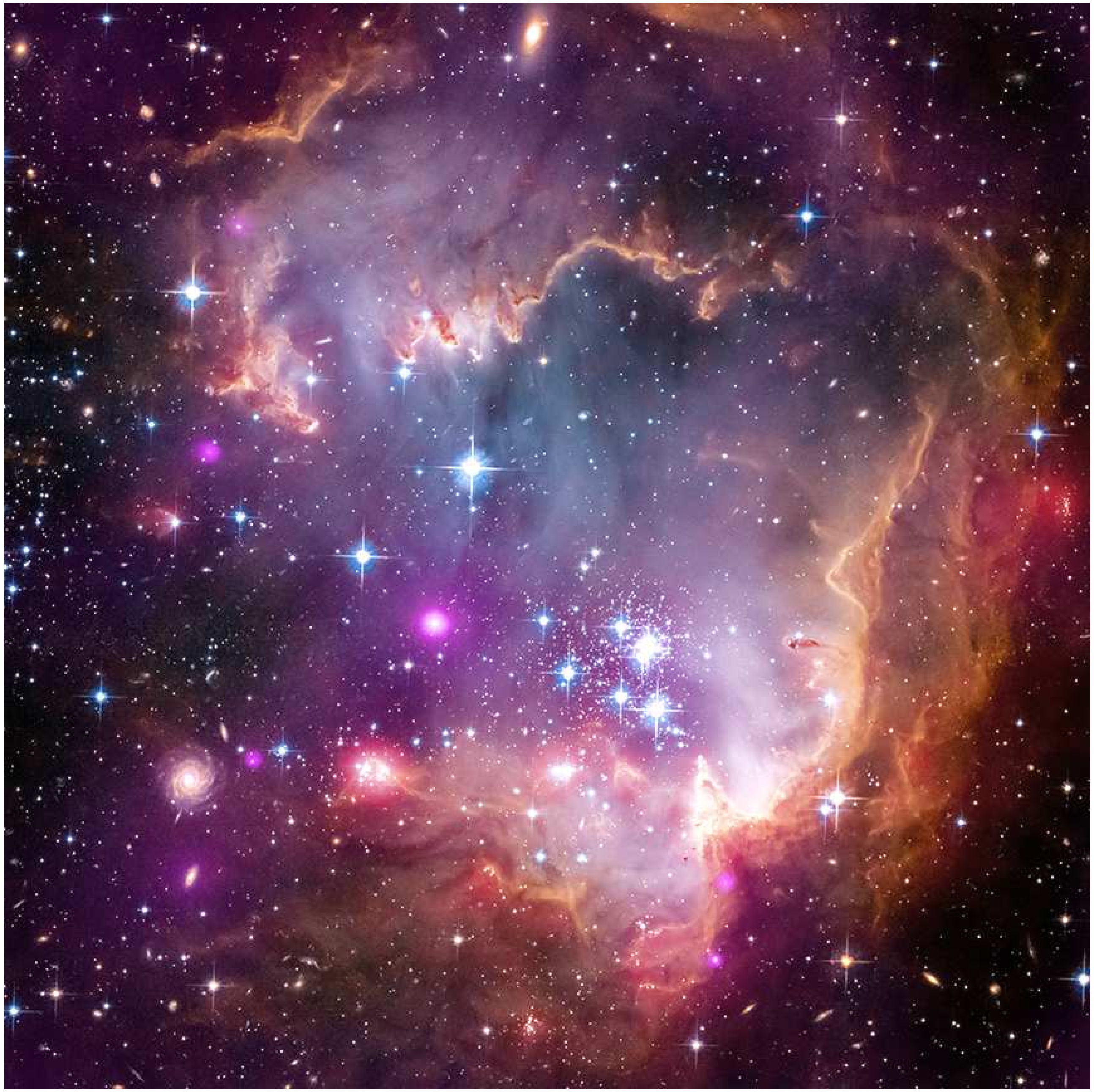
The X-Ray Universe



Potsdam University

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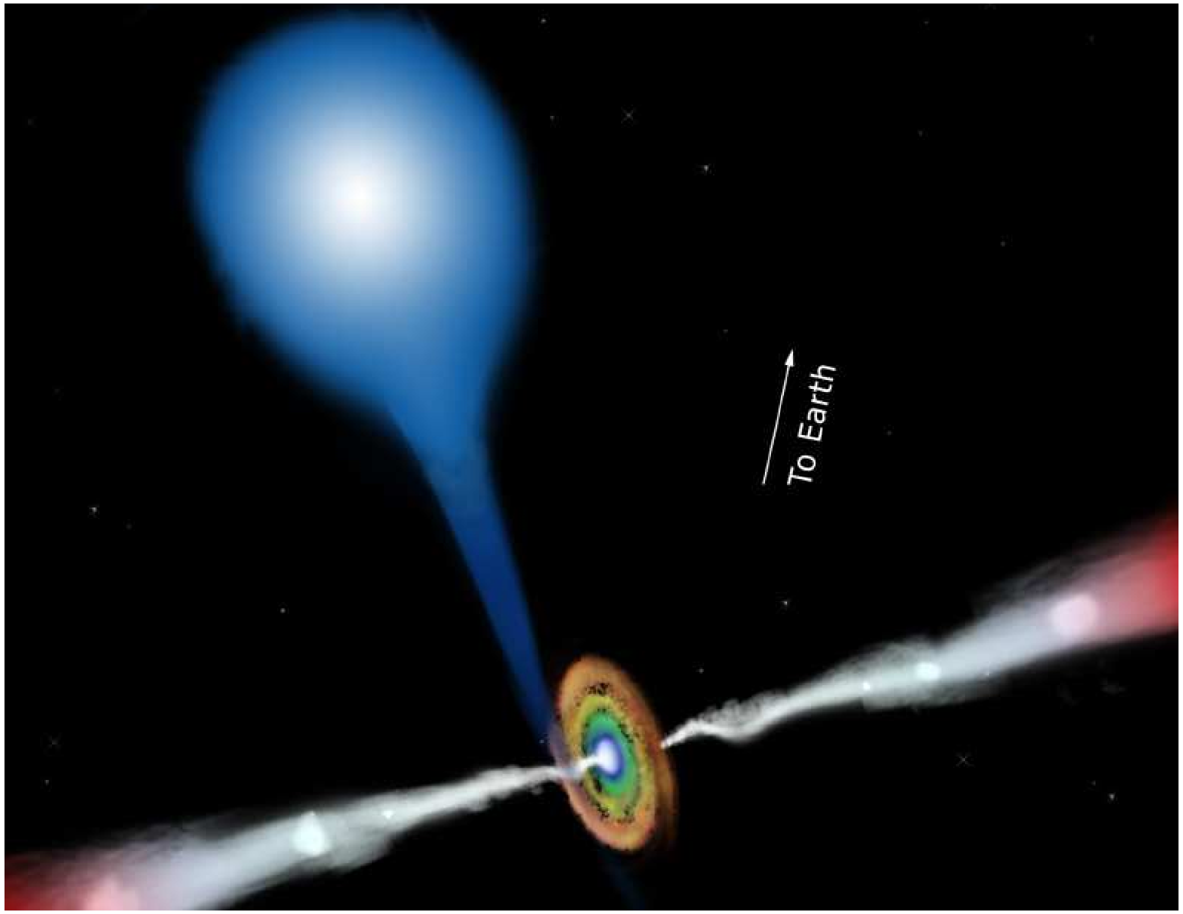
Chandra X-ray, HST optical, Spitzer IR
NGC602 in the SMC
d=60pc

From μQSO to QSO



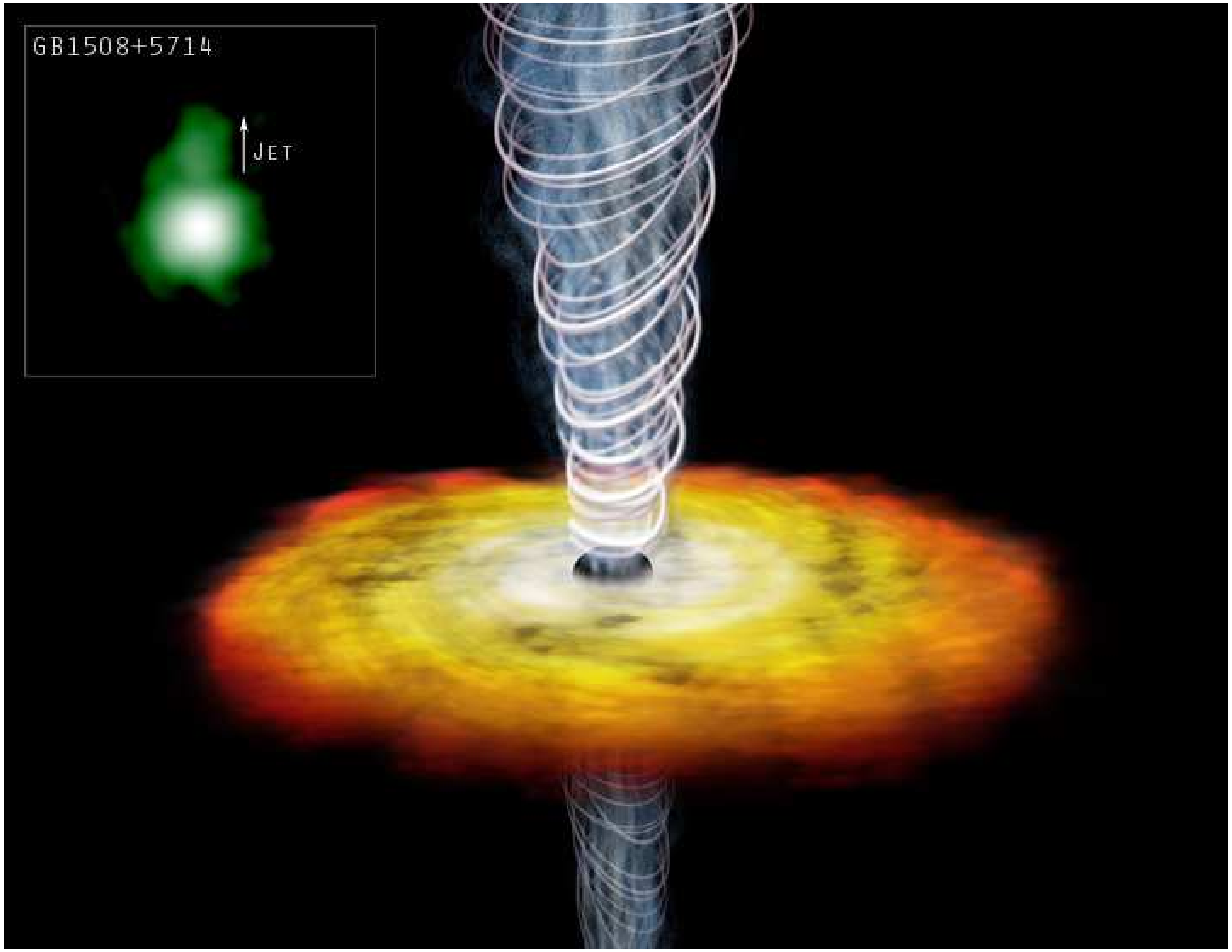
μQSO SS433:

- Strong emission from radio wave to X-ray
- Rapid strong variability in X-rays
- Radio jets where matter is accelerated to relativisitc velocities
- Fast-spinning accretion disk

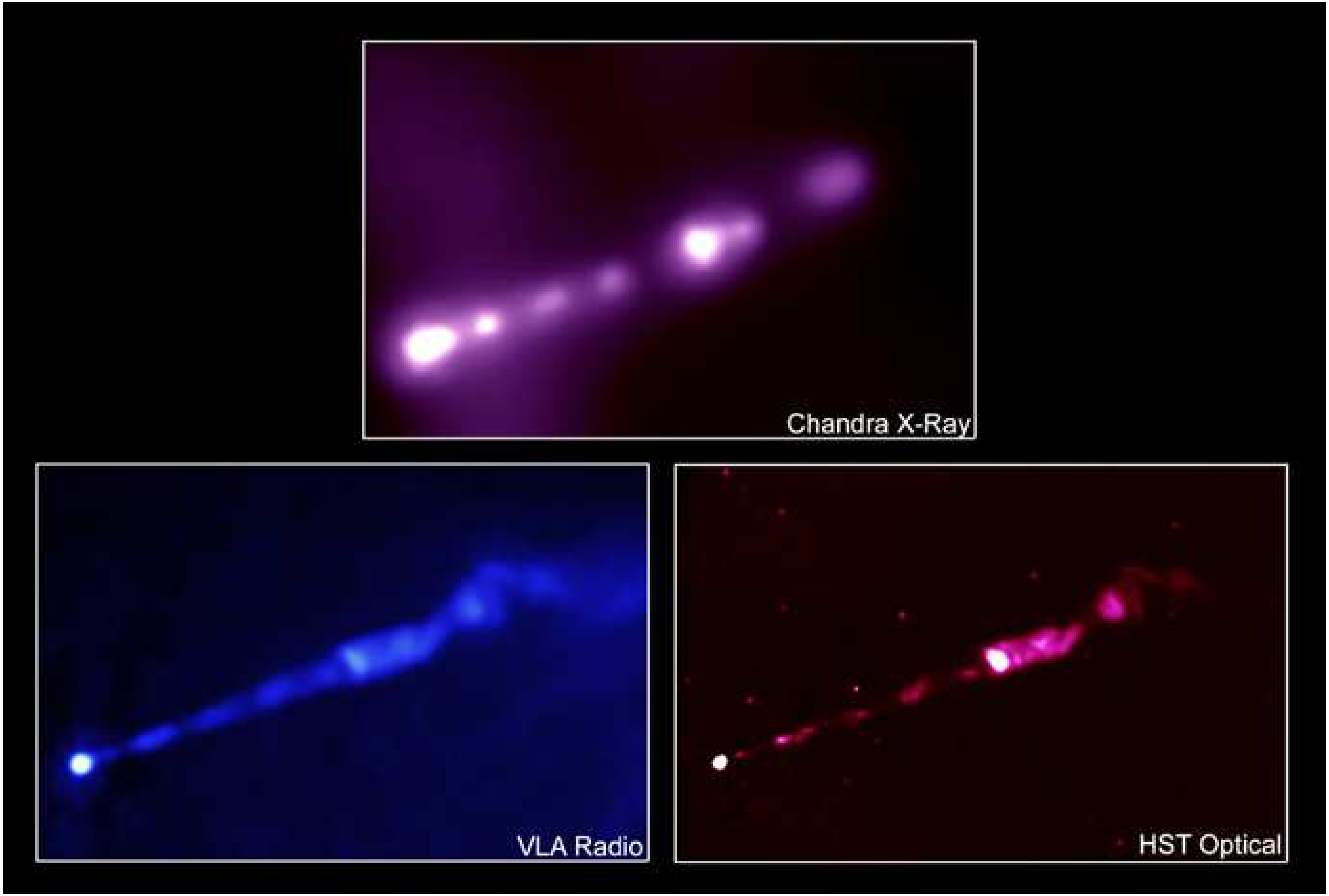
Typical properties of a QSO but contains a NS or a stellar mass BH

Object	XRB	Normal galaxy	Emission Line galaxy	Seyfert galaxy	BL Lac galaxy	QSO
$L_X\ [\frac{erg}{s}]$	$10^{34}-10^{36}$	$10^{37}-10^{39}$	$10^{40}-10^{43}$	$10^{43}-10^{45}$	$10^{44}-10^{46}$	$10^{45}-10^{47}$

Active Galactic Nuclei

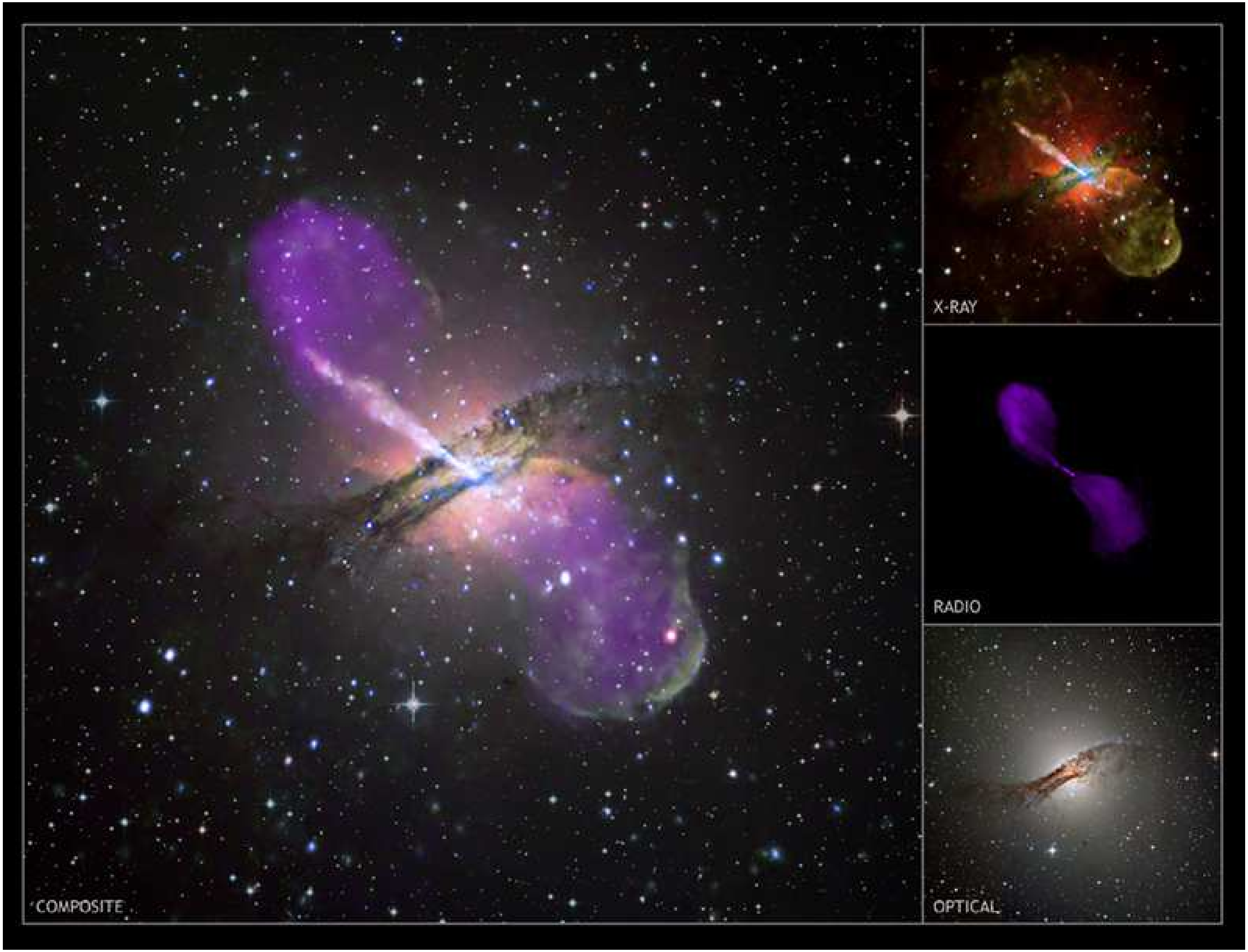


http://chandra.harvard.edu/



Credit: X-ray: NASA/CXC/MIT/H.Marshall et al. Radio: F. Zhou, F.Owen (NRAO), J.Biretta (STScI) Opt

04 The nearest active galaxy: Centaurus A



05 AGNs are scaled up XRBs

$$L_X = \eta \frac{GM\dot{M}}{R} \Rightarrow$$

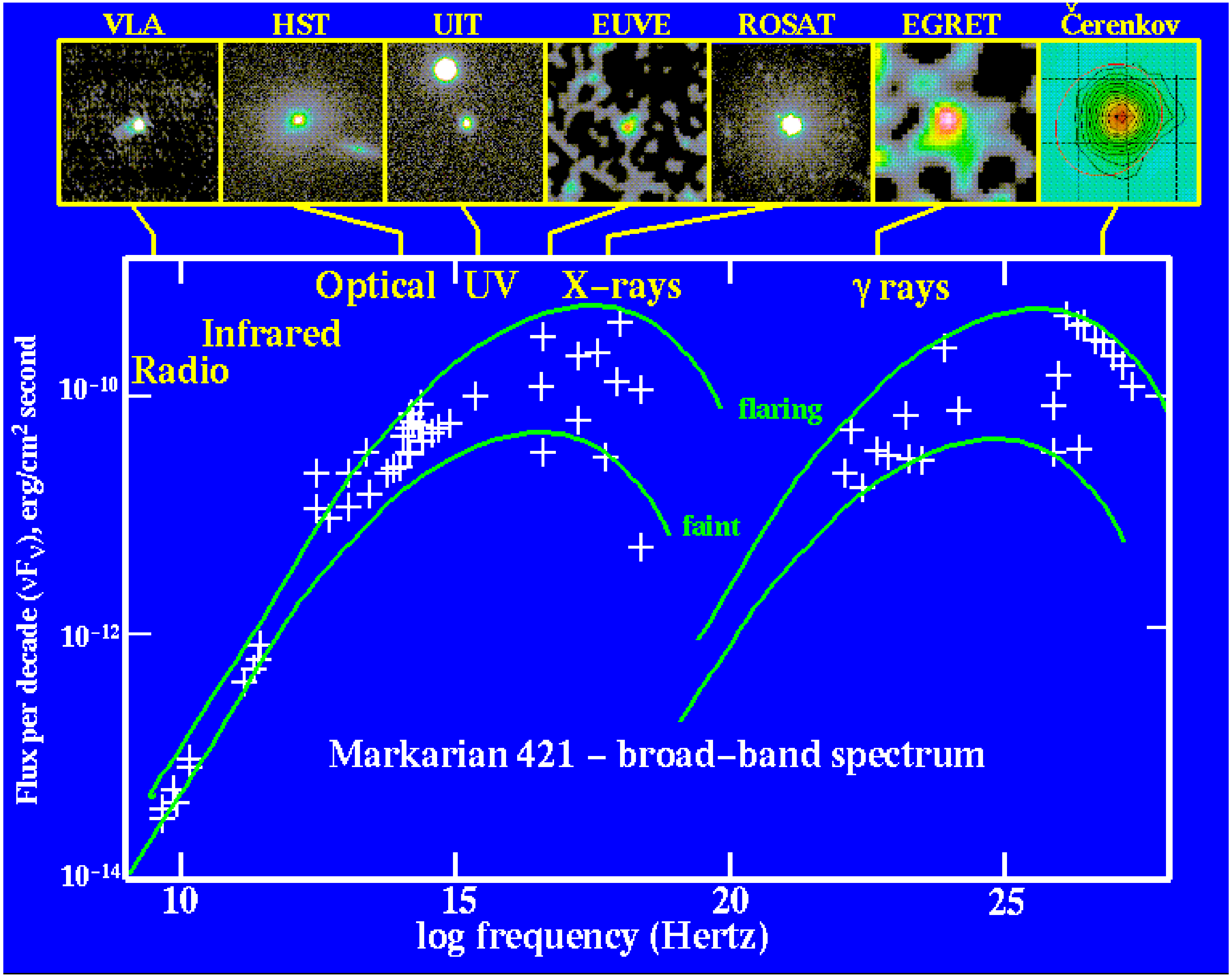
X-ray luminosity of QSO is 10 orders of magnitude higher than XRB

Eddington luminosity $L_{\rm Edd} \approx 1.3 \times 10^{38} \frac{M}{M_\odot}$ erg/s. The mass of central object should be orders of magnitude higher

XRB: M_{BH}~$10M_\odot$ → AGN: M_{BH}~$10^{6..8}M_\odot$

06 Observed properties of AGN

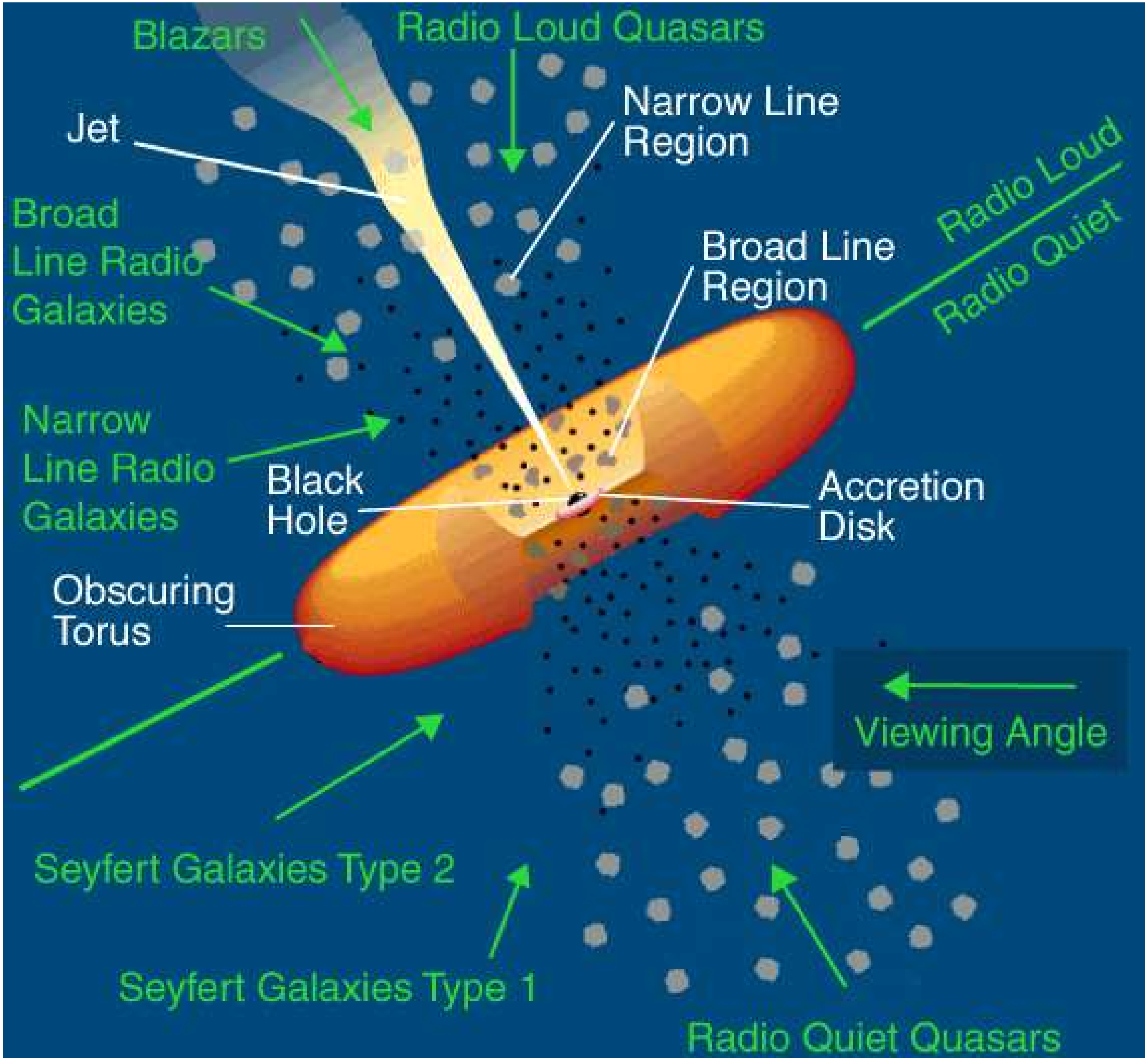
High luminosity $L_{bol}=10^{42}-10^{48}$; Size << 1pc; Variabilty; Emission & Absorption lines



http://www.astr.ua.edu/keel/agn/mkn421.html, see Dan Schwartz heasarc.gsfc.nasa.gov/docs/xrayschool/

07 AGN is common name for:

- Quasars (quasi-stars)
- QSOs (quasi-stellar objects)
- QSRSs (quasi-stellar radio sources)
- BL Lac objects
- Blazars (BL Lac type quasars)
- OVV (Optically Violent Variables)
- Seyfert Galaxies (which may be Type 1, Type 2, Type 1.x, Narrow line type 1)
- Narrow Emission Line galaxies
- LINER s (Low ionization nuclear emission region)
- LLAGN (Low Luminosity AGN)



Urry & Padovani 1995 PASP 107, 803

AGN with

$10^8 M_\odot$ BH

R_G $3\text{x}10^{13}$ cm

Accretion disk

$10^{13..14}$ cm

BLR $10^{16..17}$ cm

Torus 10^{17} cm ??

NLR $10^{18..20}$ cm

Jets $10^{17..24}$ cm

09 X-ray observations

Time Variability

- Size of emitting region, and regions where radiation is reprocessed.
- QPOs → relativisitc effects

X-ray Spectra:

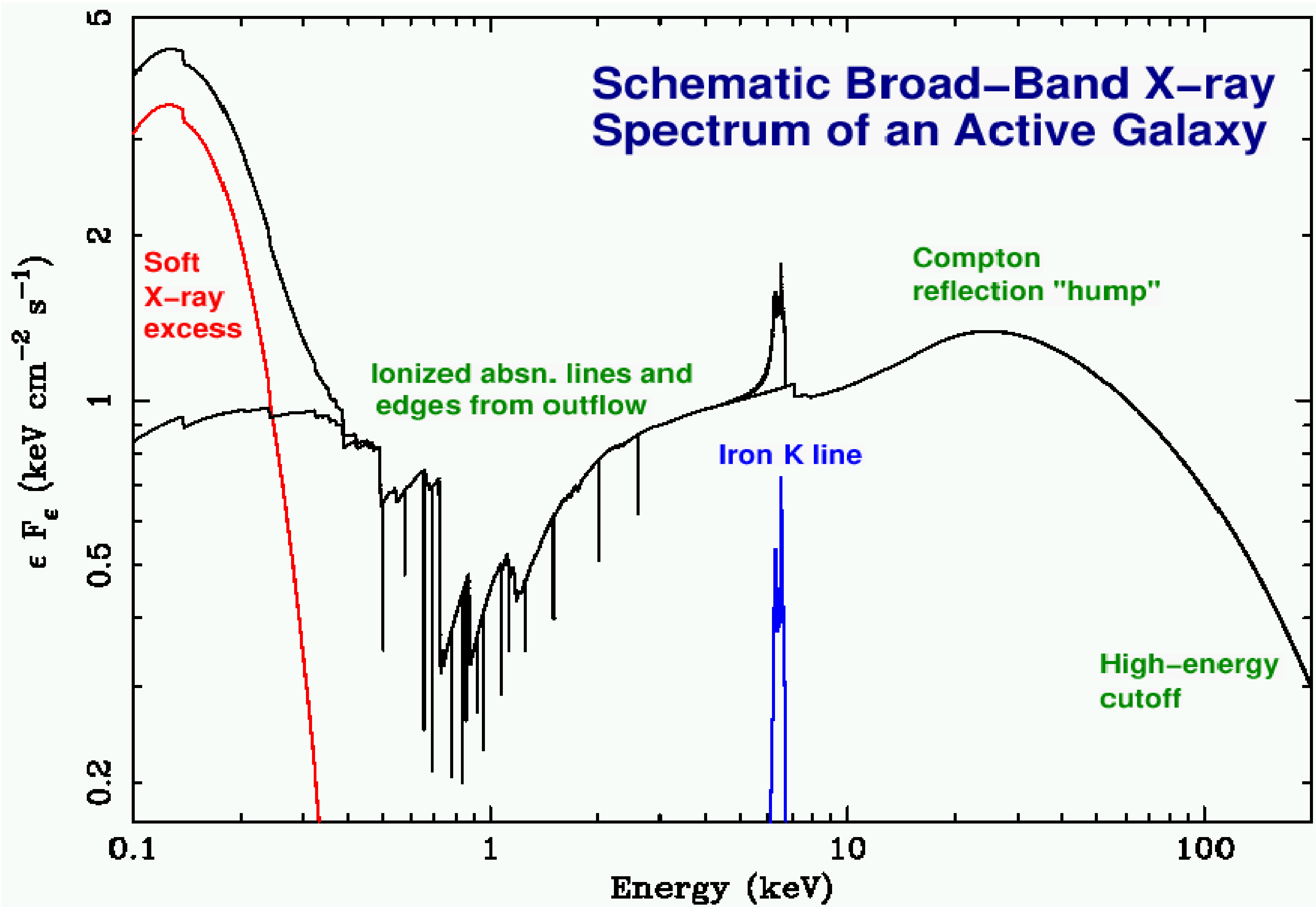
- Absorption: amount of absorbing material; velocity field (inflow/outflow); cold/warm absorbers; ionization state
- Thermal emission: from hot gas, accretion physics
- Non-thermal emission: synchrotron, Comptonisation, relativisitc effects, acceleration, magnetic fields
- Emission lines: relativistic effects

X-ray Images:

- Nucleus
- Extended emission on scale of 1 pc to 100 kpc
- Jets and radiolobes
- Correlstion between different components.

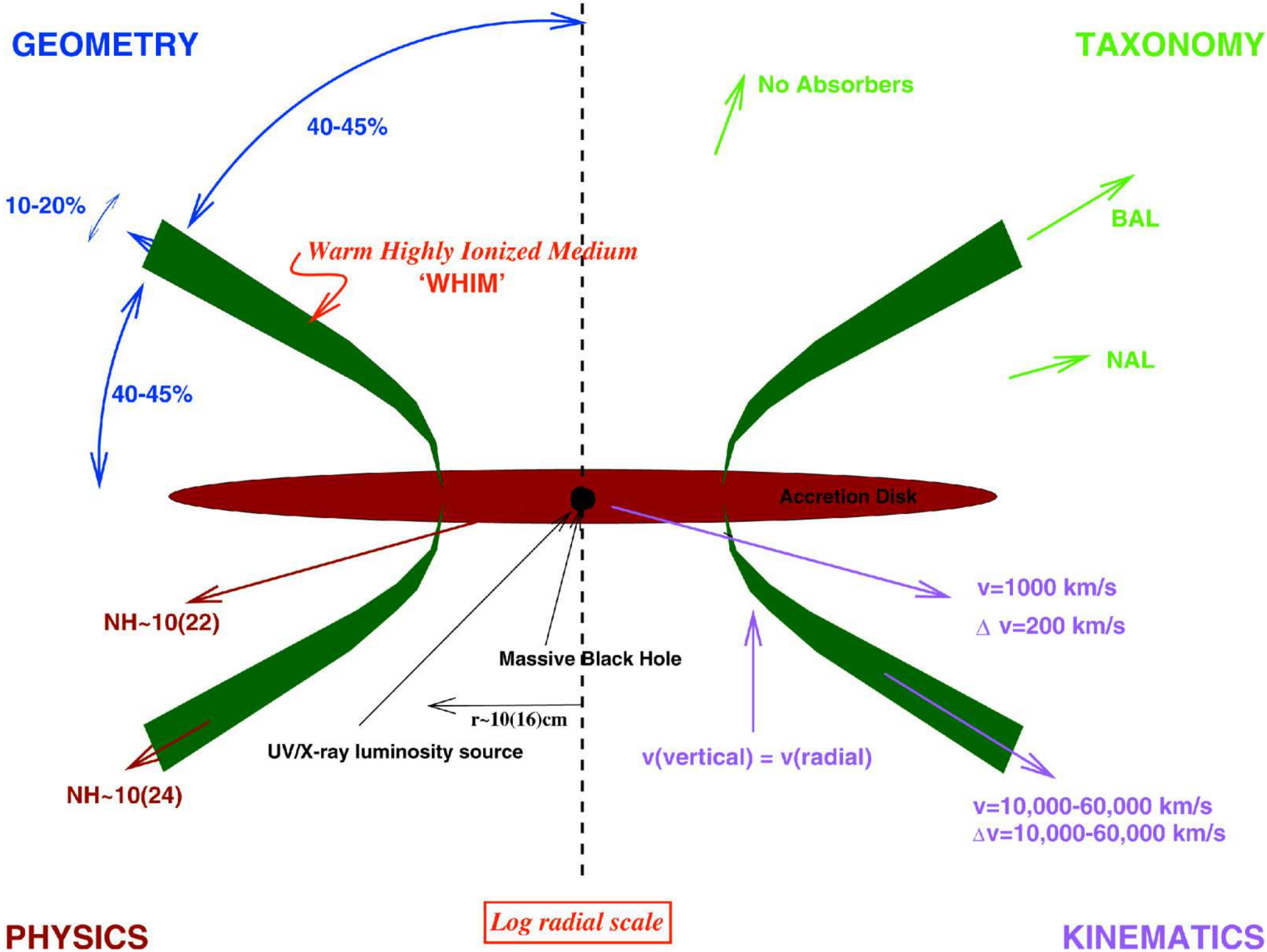
10 Schematic X-ray spectrum of AGN

From W.N.Brandt "X-raying Active Galaxies" AAS'04



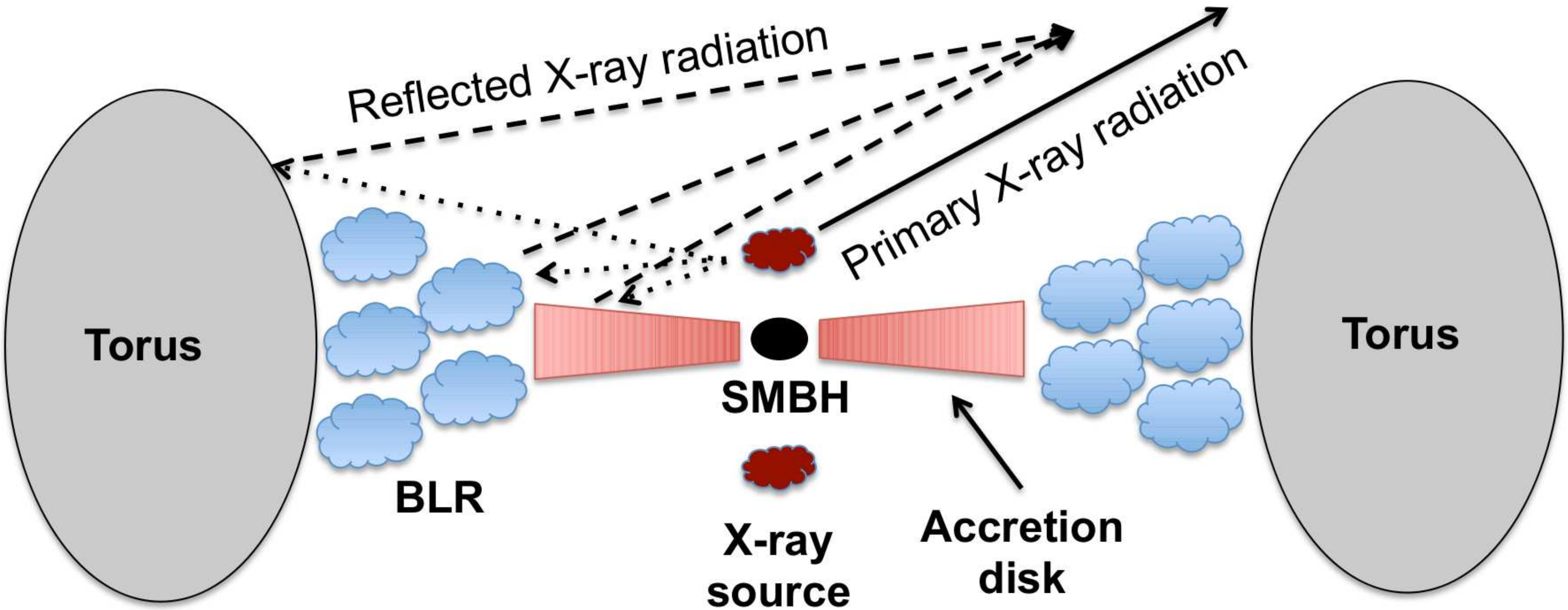
http://www.astro.psu.edu/users/niel/papers/

11 A Structure for Quasars



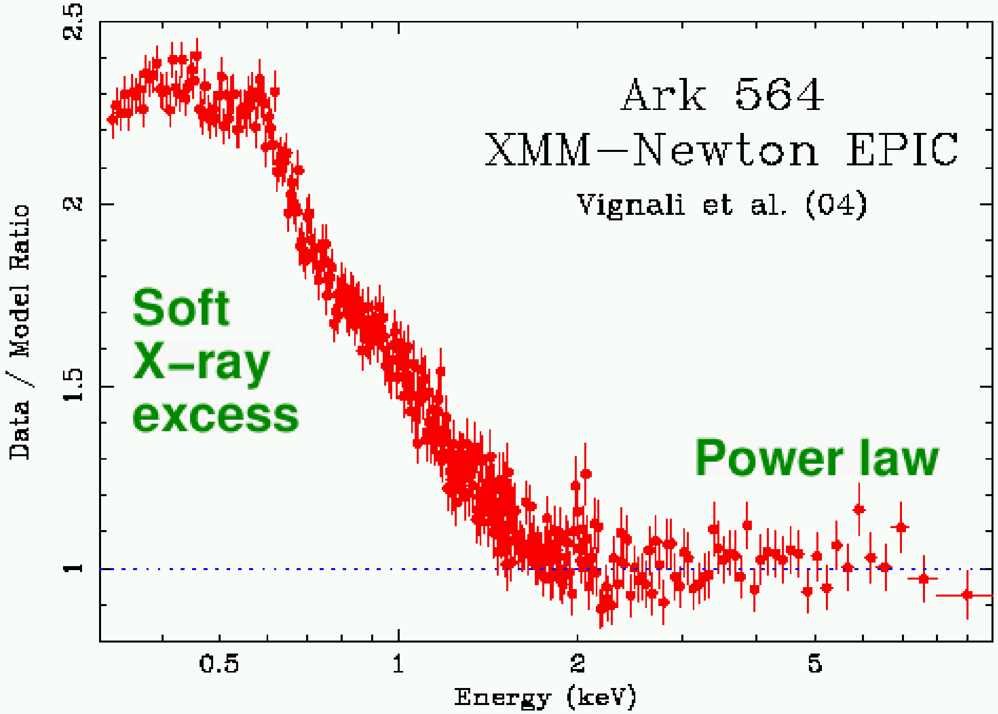
Elvis ApJ 545,63

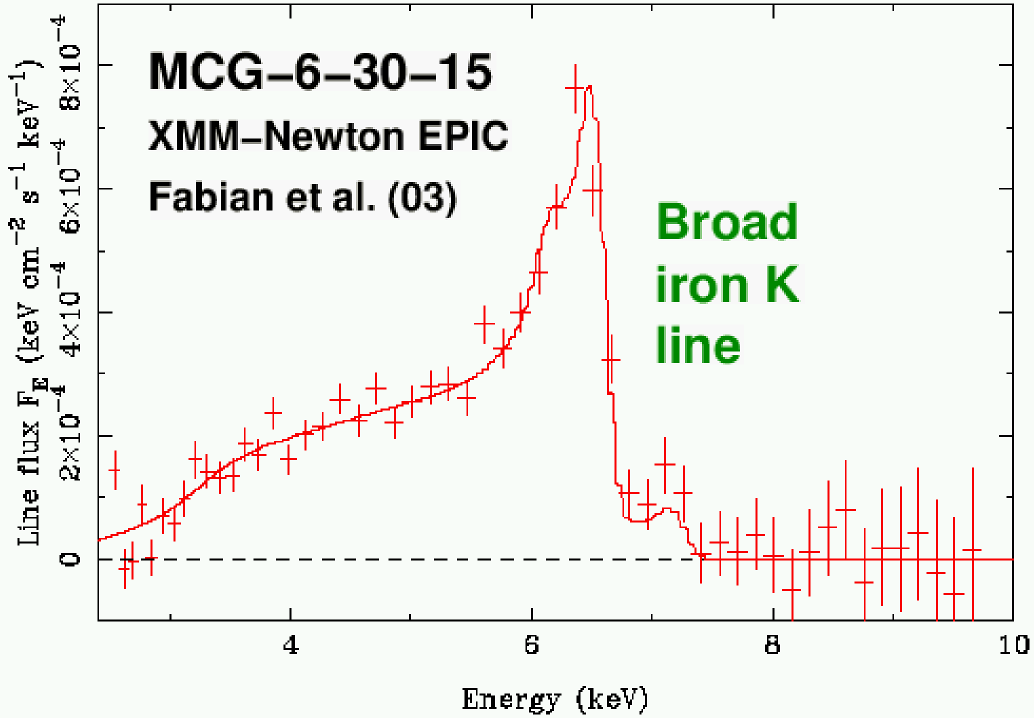
Direct and reprocessed component of AGN spectra

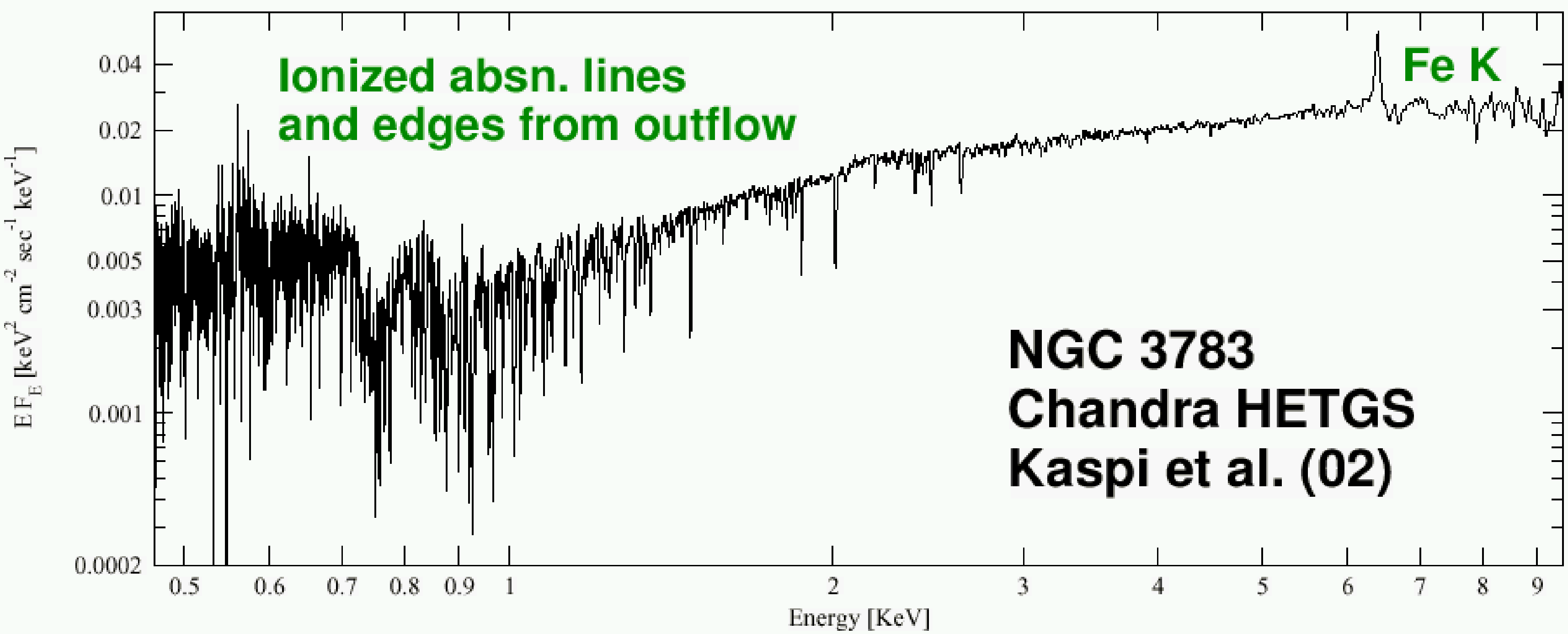


www.isdc.unige.ch/~ricci/Website/AGN_in_the_X-ray_band.html

12 Examples of obsevred AGN X-ray spectra





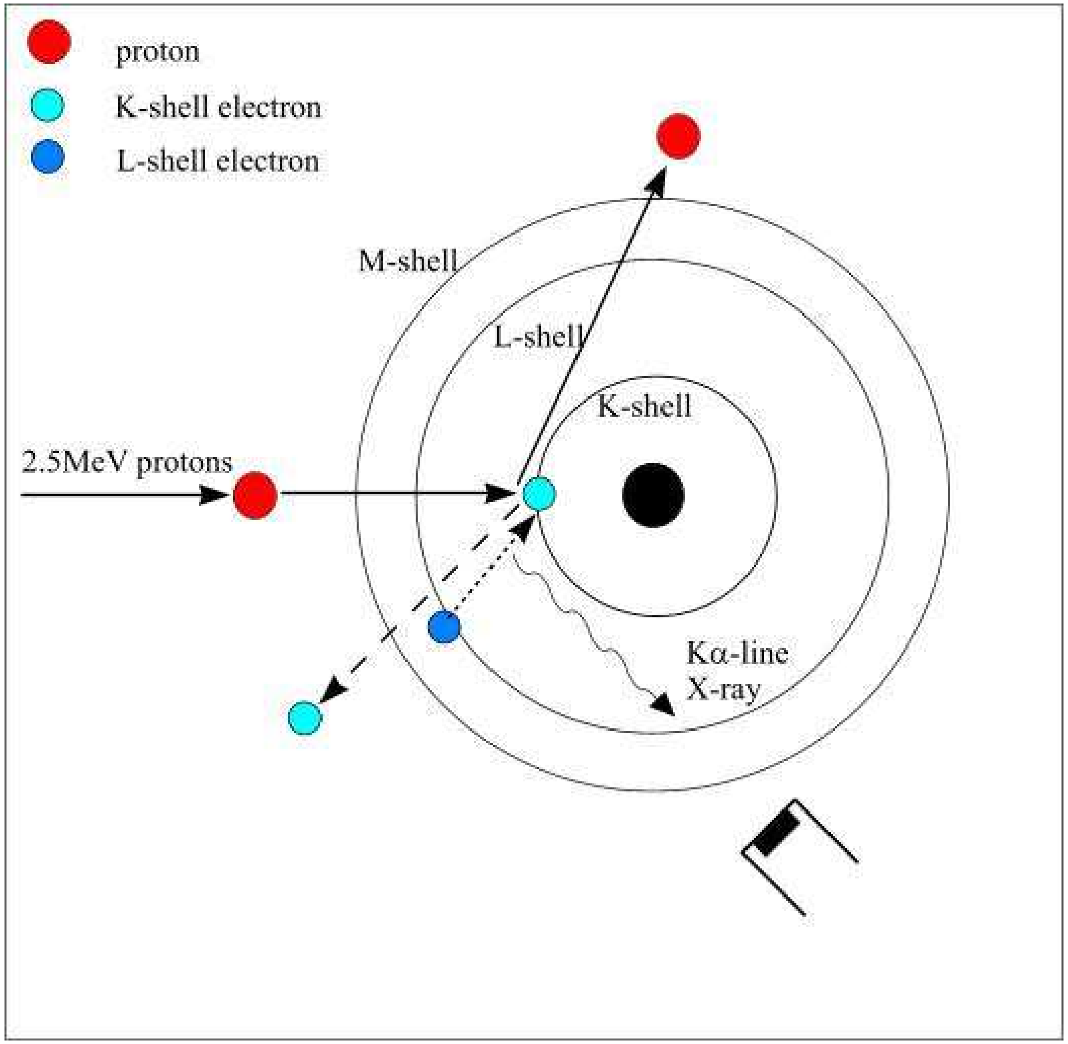


Also unidentified features

Also substantial jet–linked X–rays in radio–loud AGN

http://www.astro.psu.edu/users/niel/papers/ From W.N.Brandt "X-raying Active Galaxies" AAS'04

Inner Shell Processes



X-ray fluorescence An electron can be removed from inner K-shell (how many electornes are there?)

The vacancy is filled by a L-shell electron Kα-line. If the vacancy is filled by M-shell electron Kβ-line.

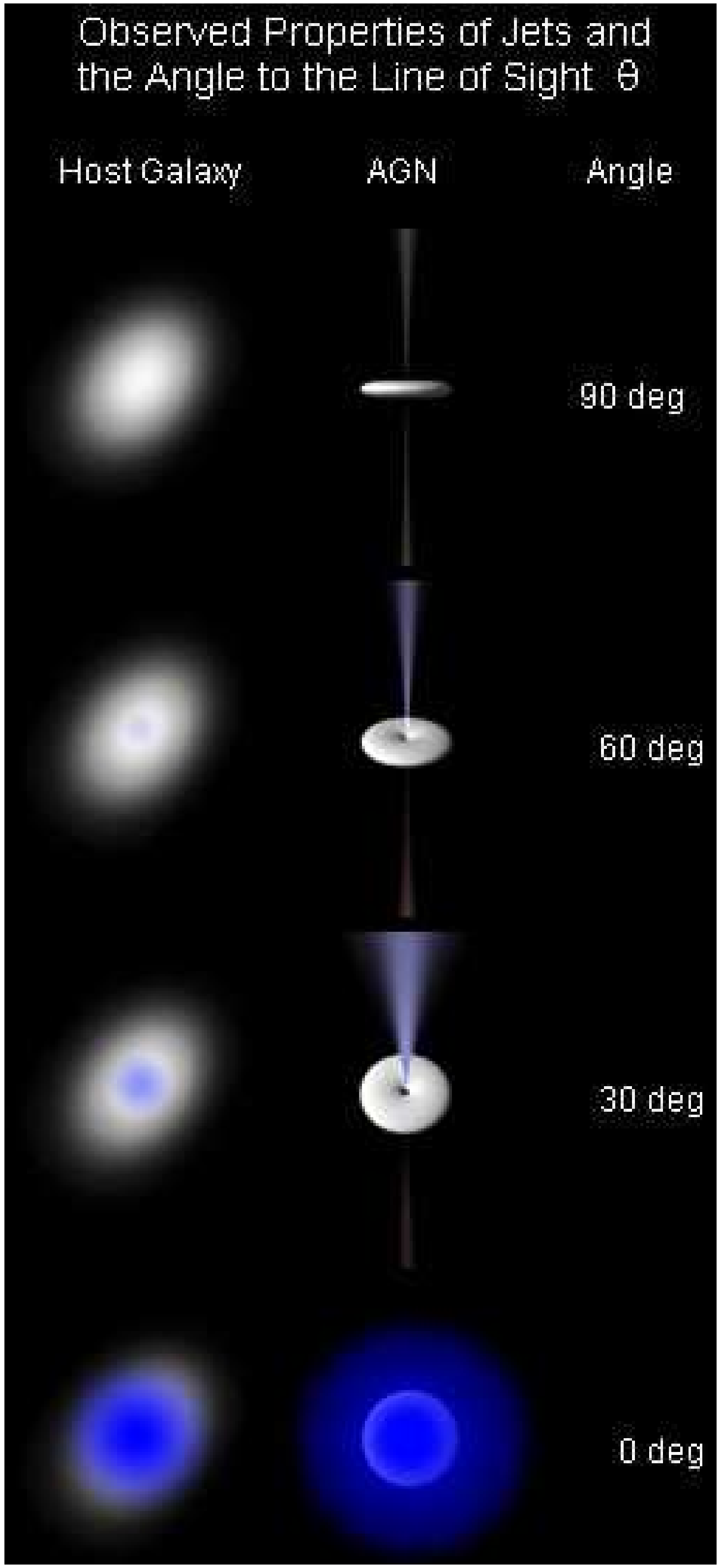
Iron is abundnat element with relatively large cross-section for K-shell ionization: Kα line at 6.4 keV is commonly observed from astrophysical objects

See Grotrian diagrmans in Kallman+ 04, ApJSS 155, 675

• The speed of matter within the jets is large fraction of c. SR's effects must be taken into accout: relativistic beaming, relativistic Doppler effect, superluminal motion

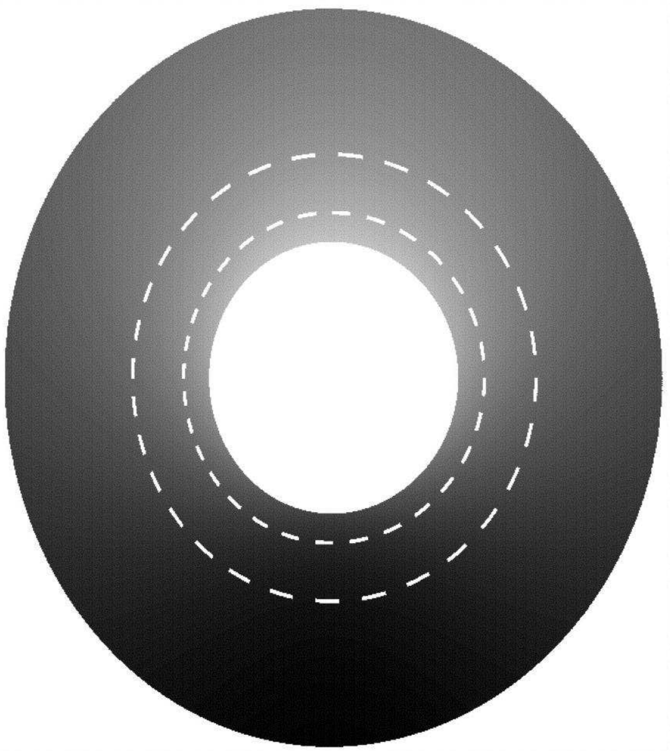
• The inner parts of the discs are close to the BH. GR effects must be taken into account: gravitational red-shift.

• The emitted radiation interacts with the discs and the surrounding matter



Wikipedia

15 Relativisitc broadening Fe-line



Newtonian

Special relativity

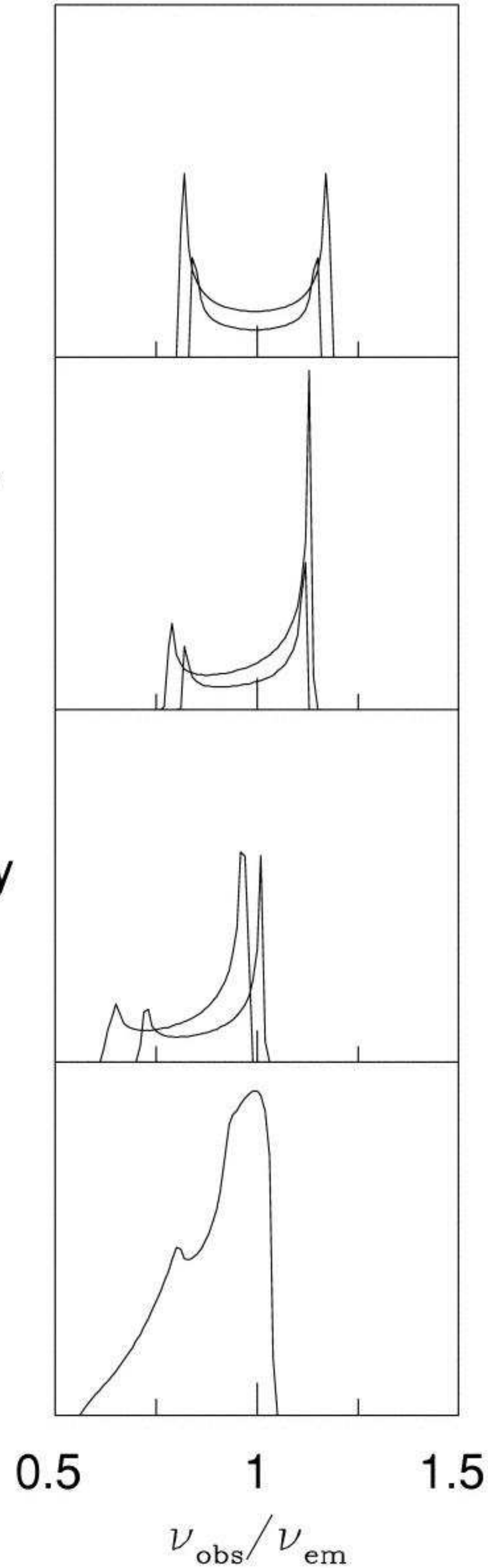
Transverse Doppler shift

Beaming

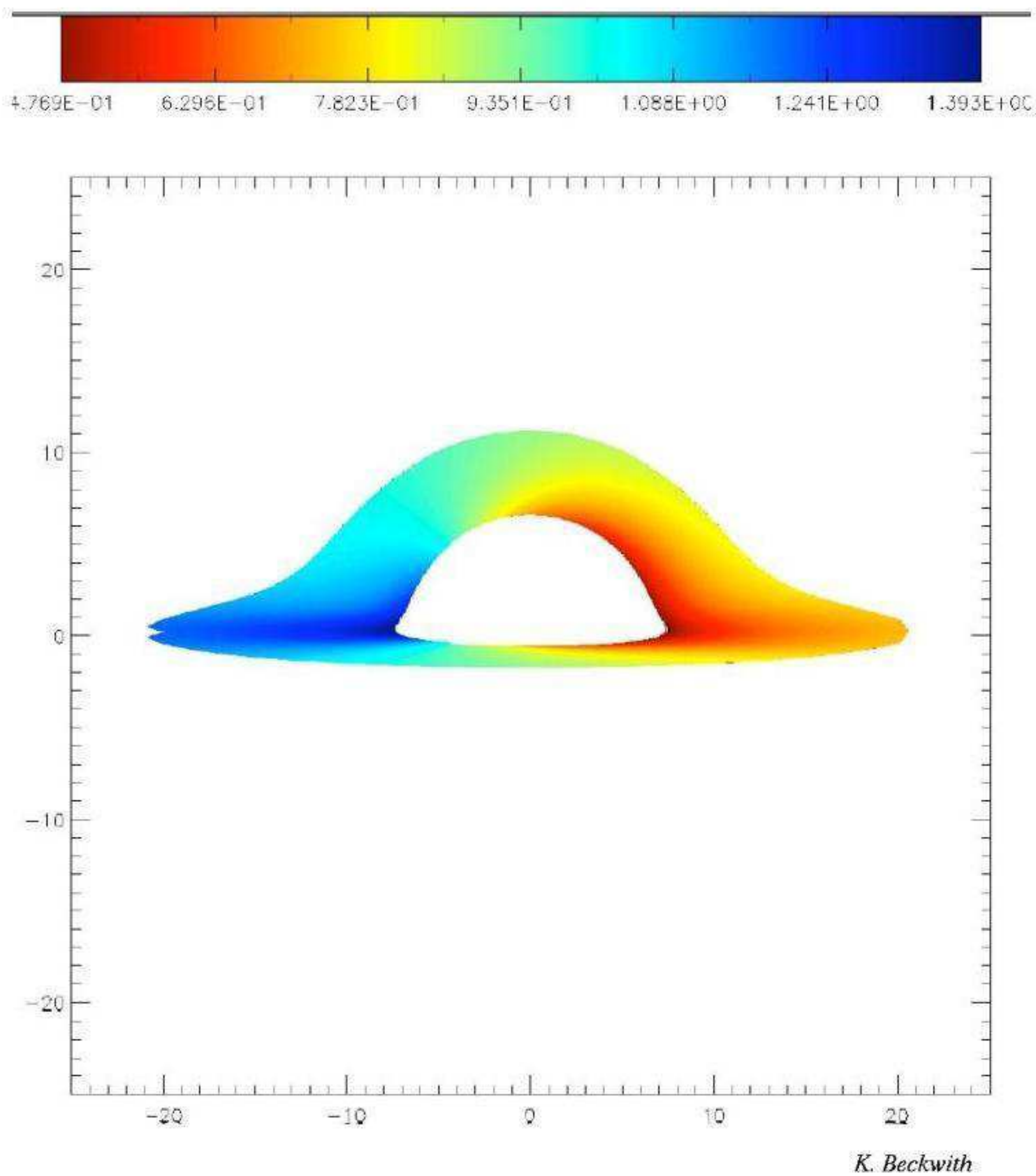
General relativity

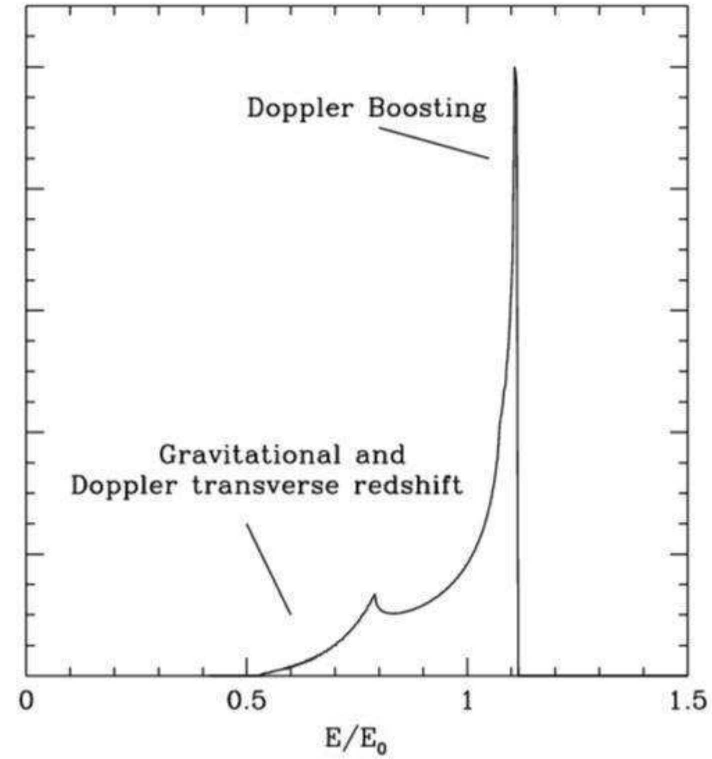
Gravitational redshift

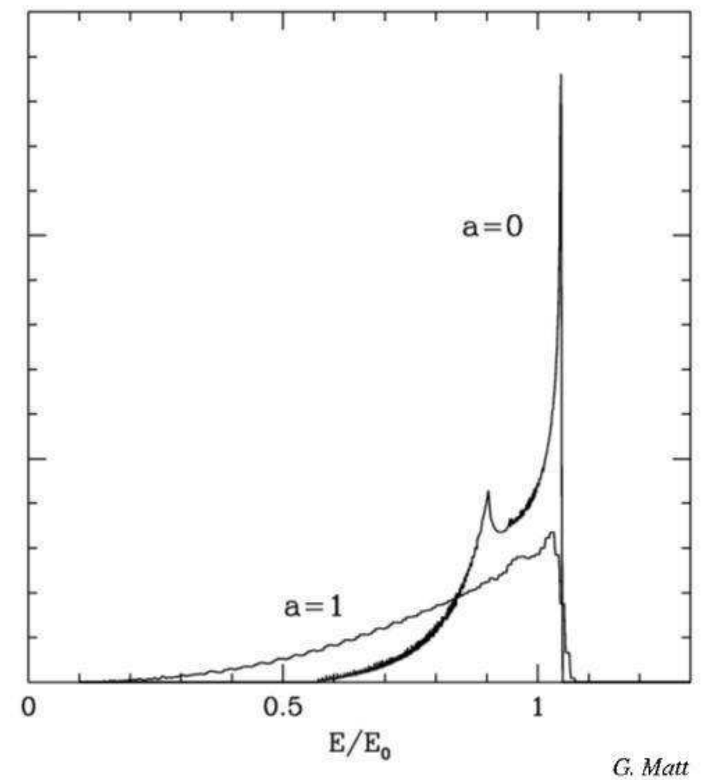
Line profile



Fabian et al. 2002 PASP 112, 1145





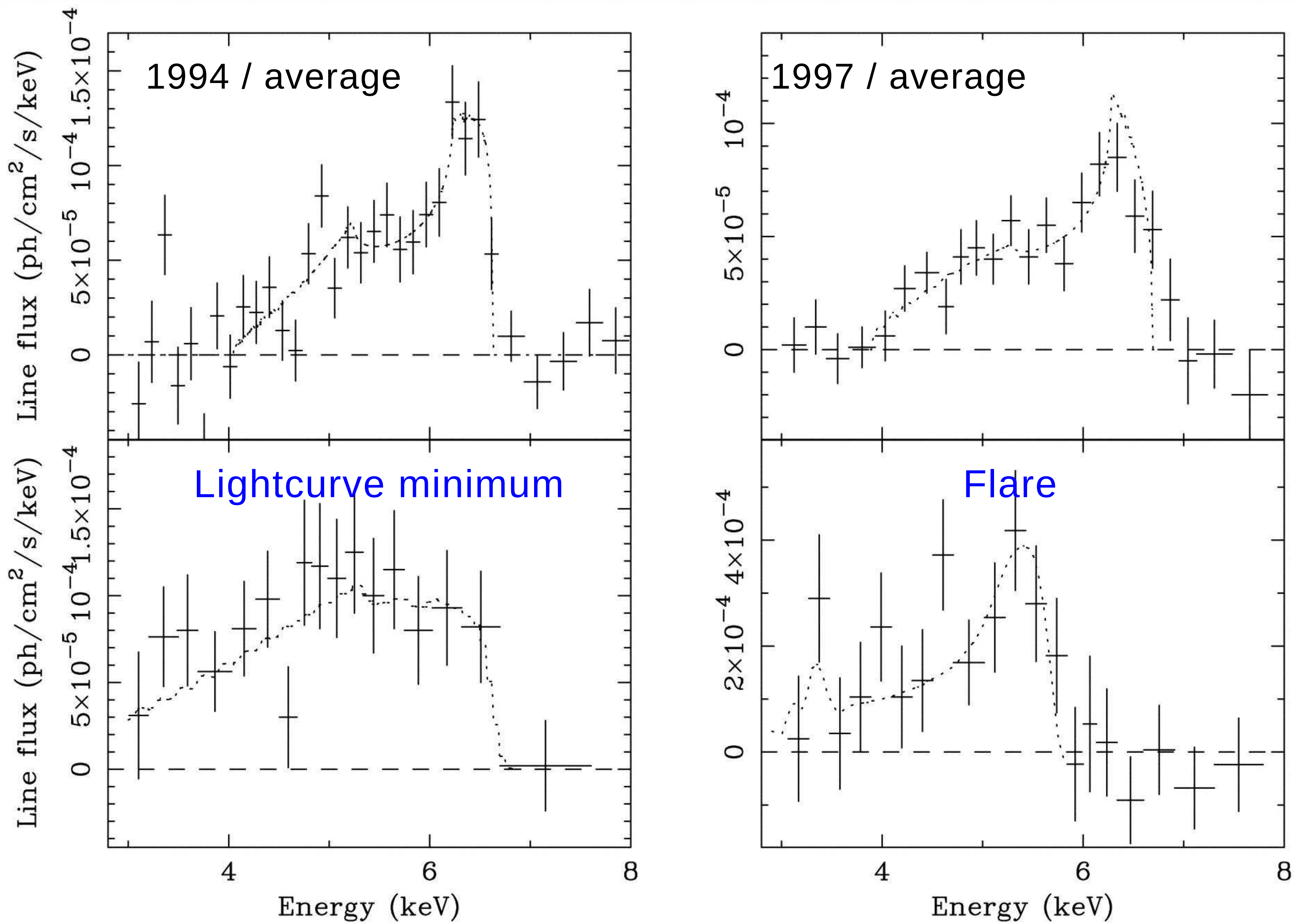


relativistic lines from accretion disks around black holes

Image courtesy of G. Matt, Universita degli Studi Roma Tre, Italy, and K. Beckwith, Universityof Durham, UK,

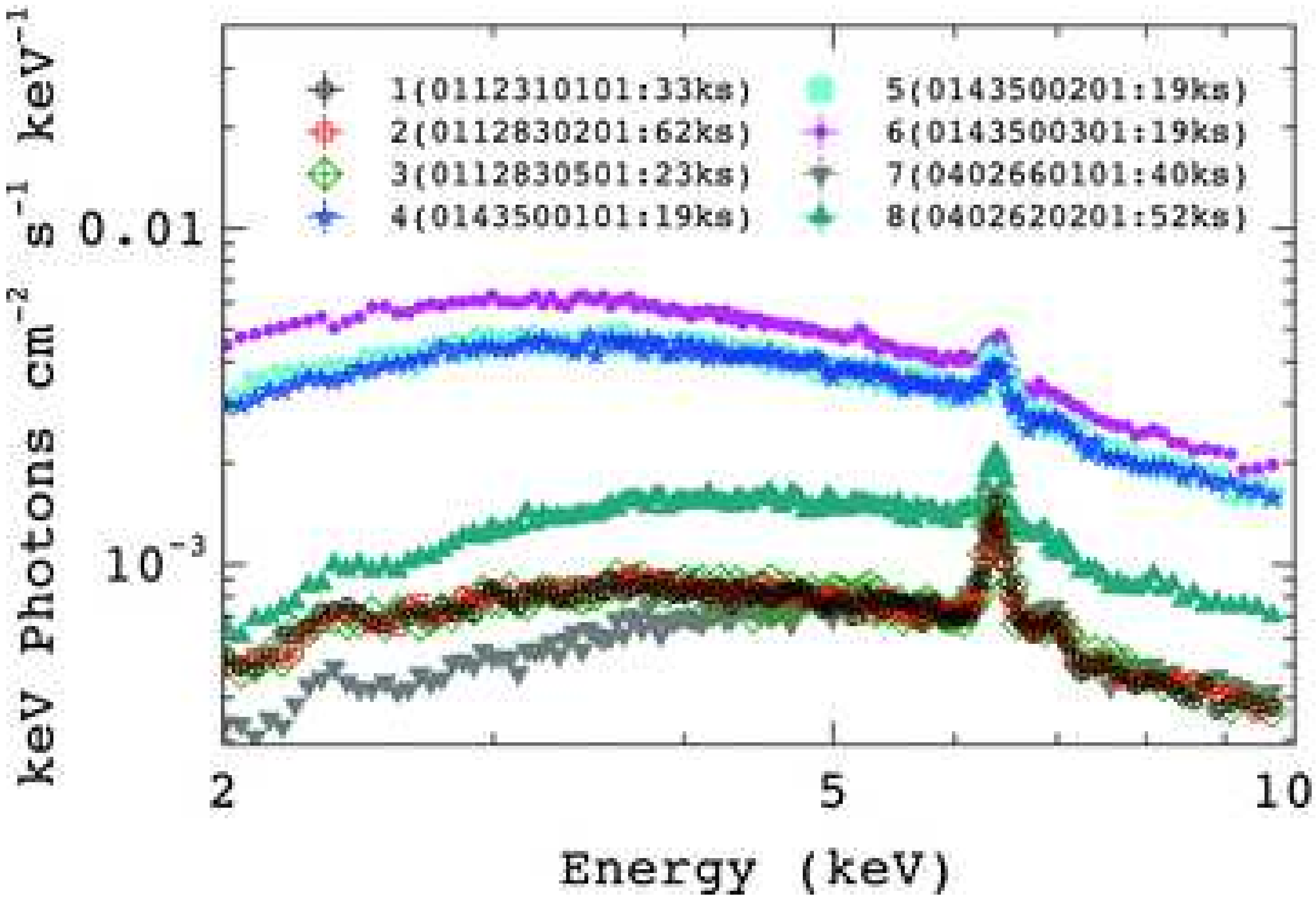
European Space Agency

17 Time average (ASCA) observations of AGN MGC6-30-15



Fabian et al. 2002 PASP 112, 1145

Relativistic iron K X-ray reverberation in NGC 4151



Zoghbi et al. 2012

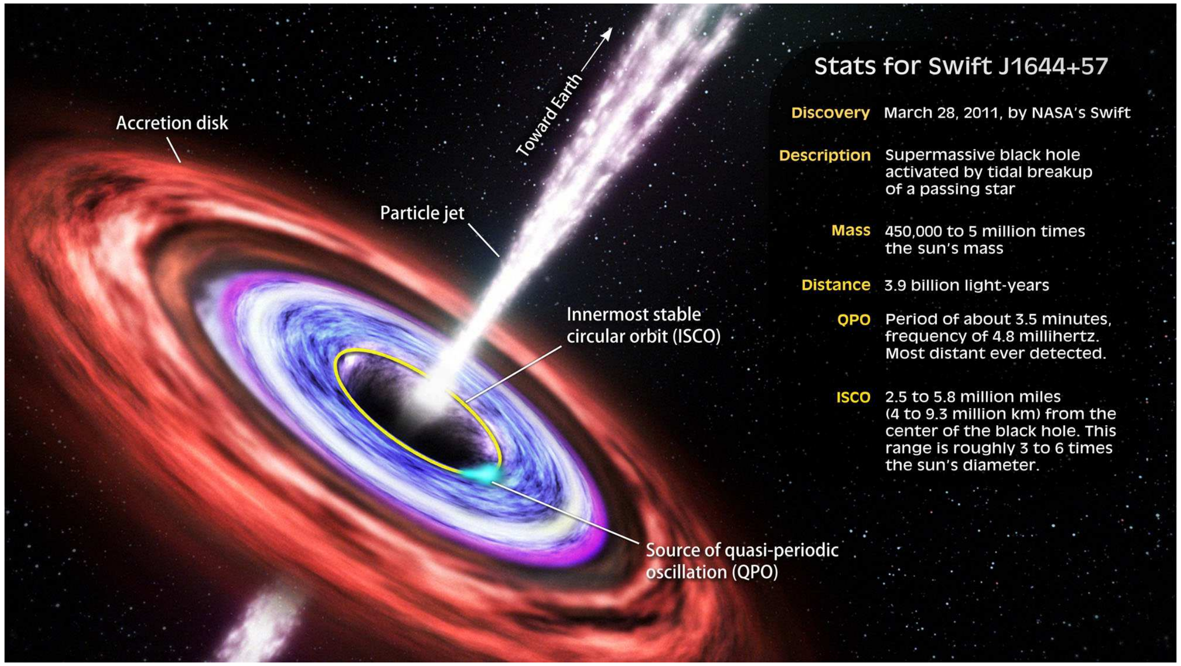
Lag between hard (13keV) direct continuum and the soft excess (0.51keV)

Lag profile resembling a relativistically broadened iron line

Red wing of the line: reflection off the inner accretion disc

Accreting Black Holes

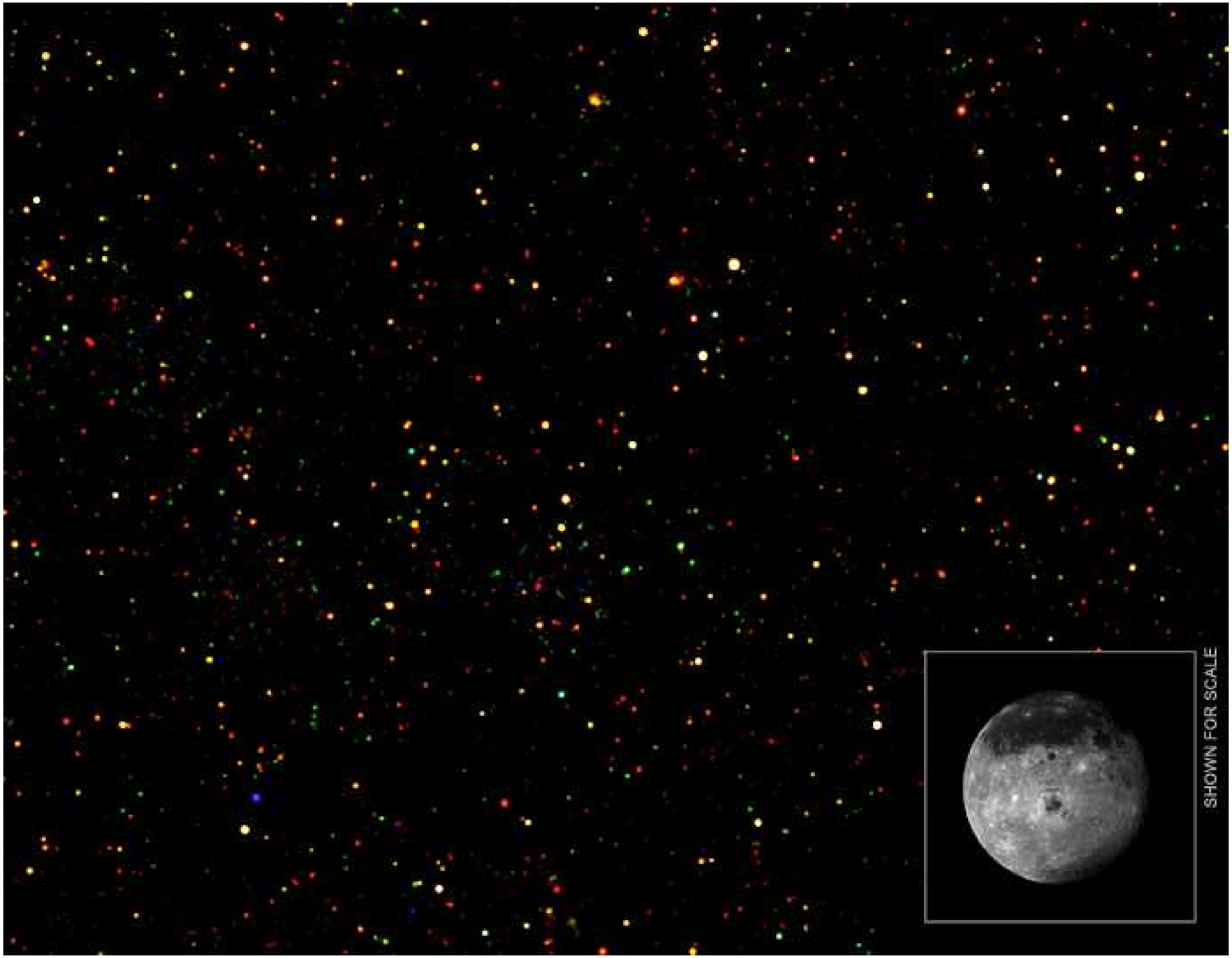
Oppenheimer & Snyder (1939): formation of a black hole.



- http://svs.gsfc.nasa.gov/10545
- A BH is specified by M (scale) and spin a=J/c M (geometry), where J is angular momentum. Or $a^*=a/R_G$. Schwarzschild BH: $a^*=0$; Kerr BH: $a^*=1$.
- Event horizon of a Schwarzschild BH $R_S=2R_G=30\text{km}\,(M/10M_\odot)$, the ISCO lies at $R_{ISCO}=6R_G$, and the maximum orbital frequency is $\nu_{ISCO}=220\text{Hz}(M/10M)^{-1}$. For Kerr BH (a* = 1), the $R_S=R_{ISCO}$ and $\nu_{ISCO}=1615\text{Hz}(M/10M)^{-1}$.
- Radiating gas orbiting a compact object is the steady-state, thin accretion disk model (Shakura & Sunyaev 1973) → $T(R) \propto R^{-3/4}$. Luminosity of an annulus $L_X \propto R dR \sigma_{sb} T^4 \propto R^{-2}$. X-rays are the best window to the horizon of a BH.

20 Cosmic X-ray background and AGN

Black holes in centra of galaxies $M=10^5$-10^{10} powered by accretion.



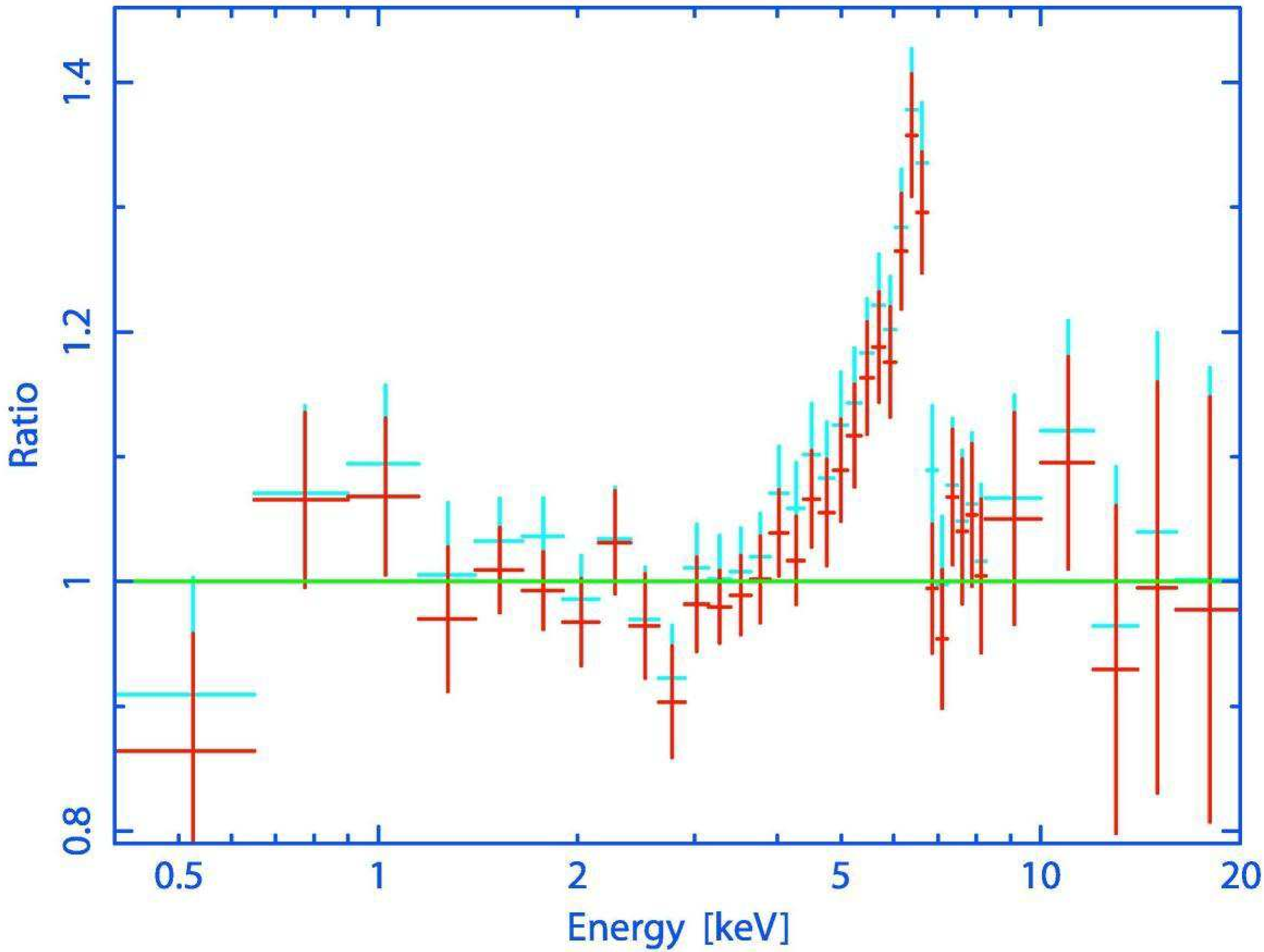
http://chandra.harvard.edu/photo/2007/

600 obscured and
700 unobscured AGN
agree with
standard scheme

X-ray surveys
deep or wide

many ongoing
automatic
selection

21 XMM spectra of the X-ray background with a relativistic iron line

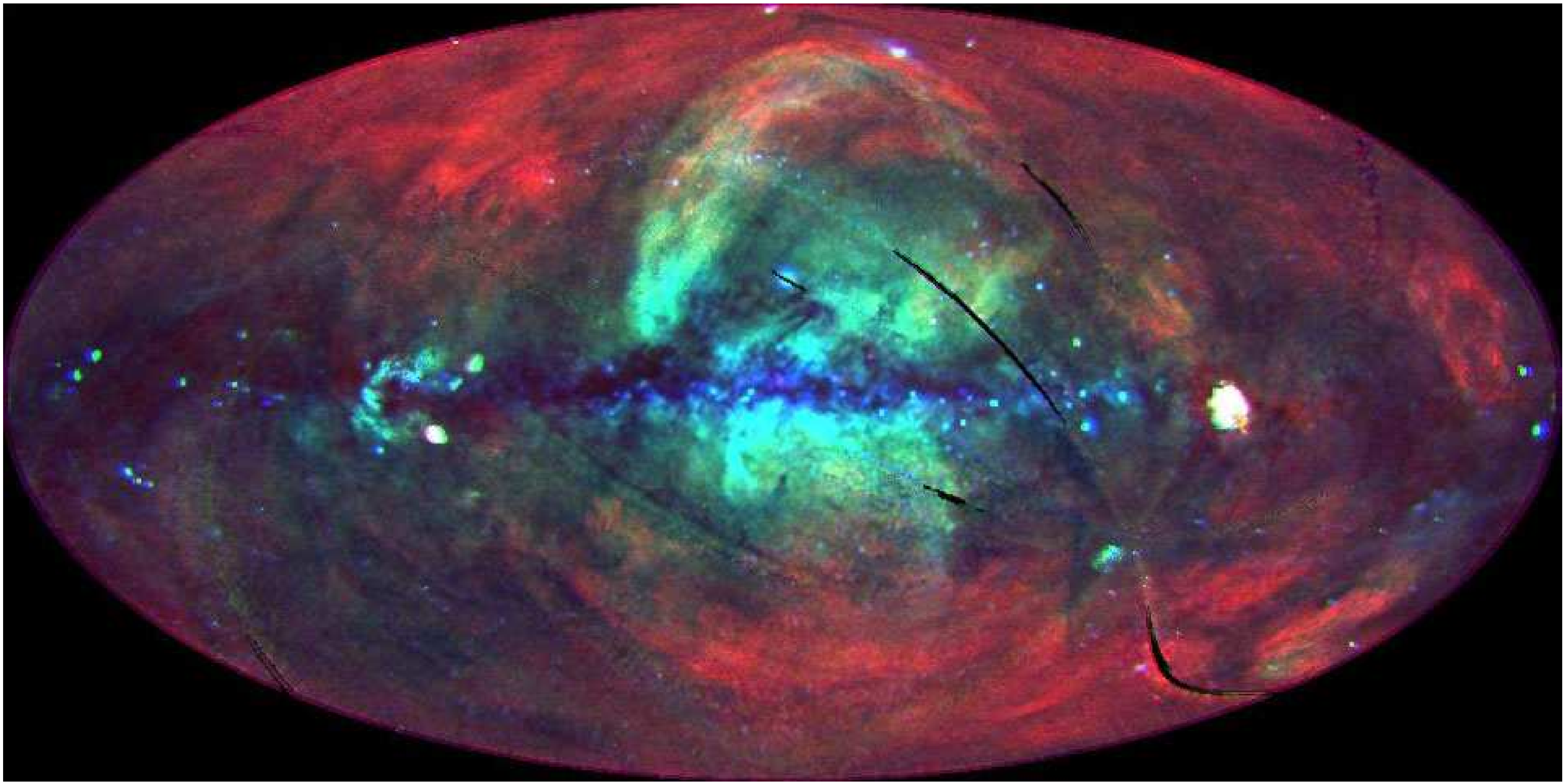


XMM-Newton spectrum of the X-ray background, showing a relativistic iron line

Image courtesy of Alina Streblyanska (Max-Planck-Institut fuer Extraterrestrische Physik)

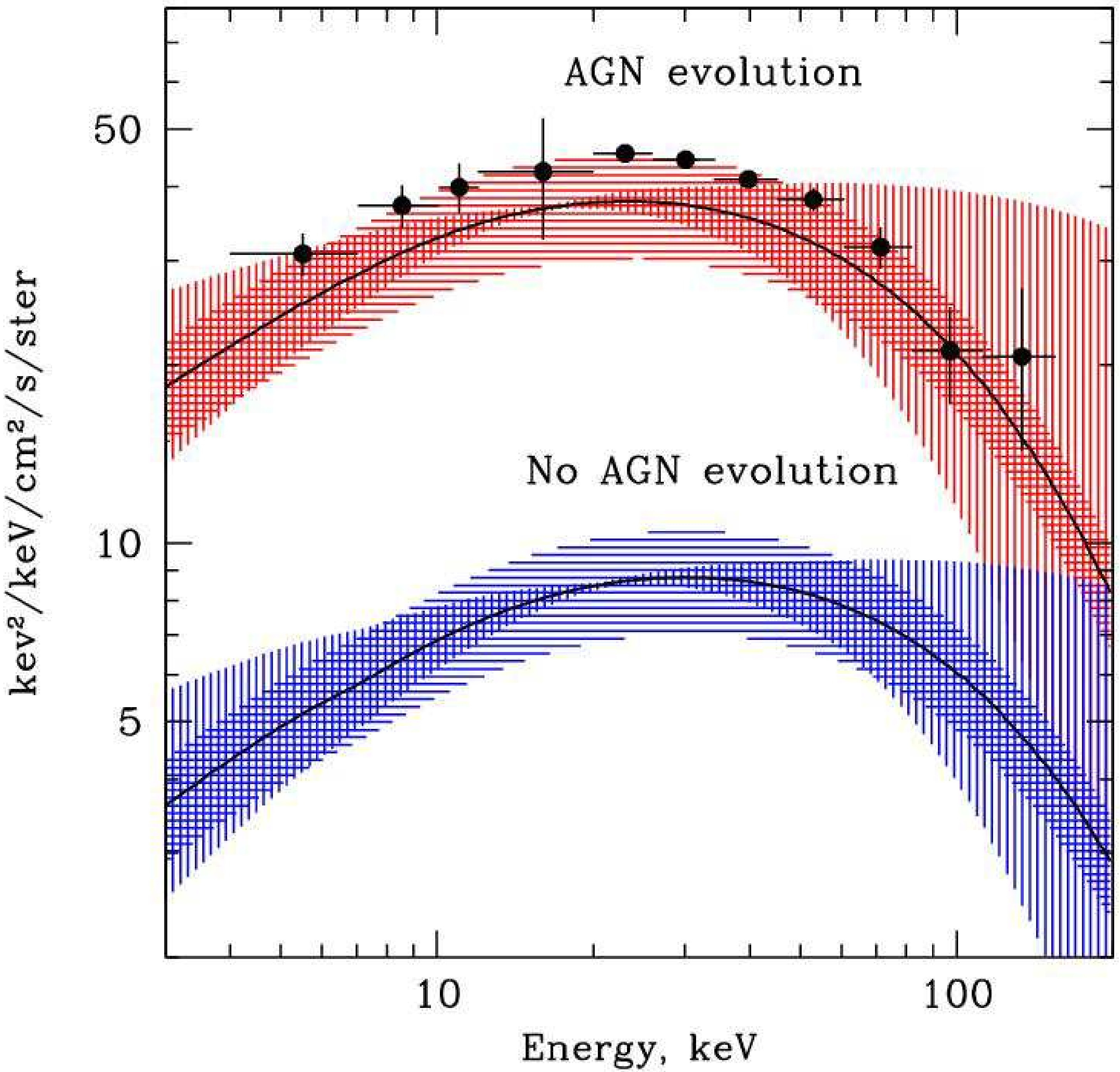
European Space Agency

22 RASS



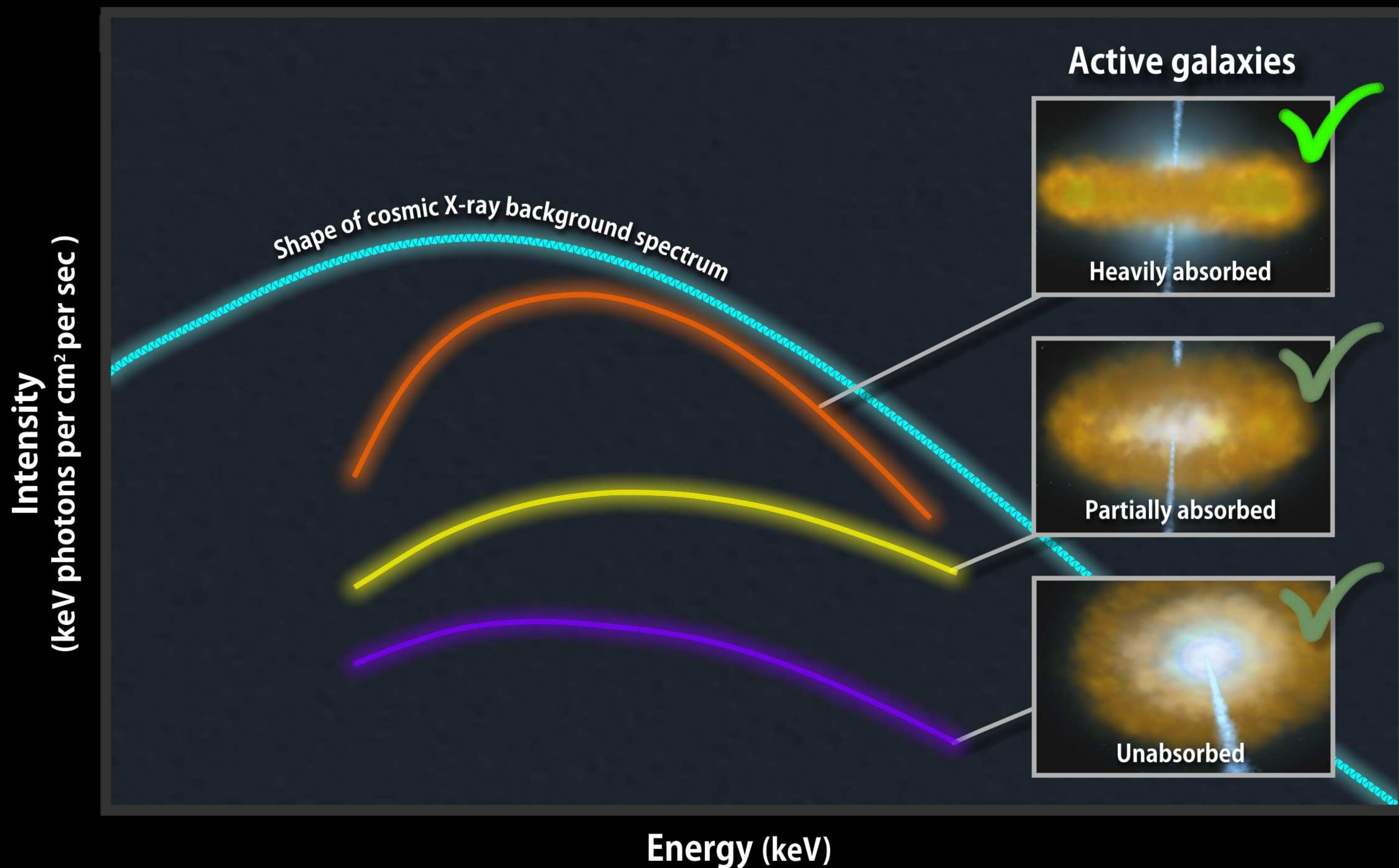
Spectrum of Cosmic X-ray Background

- The first direct comparison between the collective hard X-ray SED of local AGN and the CXB spectrum.
- The CXB is likely a superposition of AGNs.
- The data are consistent with cosmic evolution of AGNs.

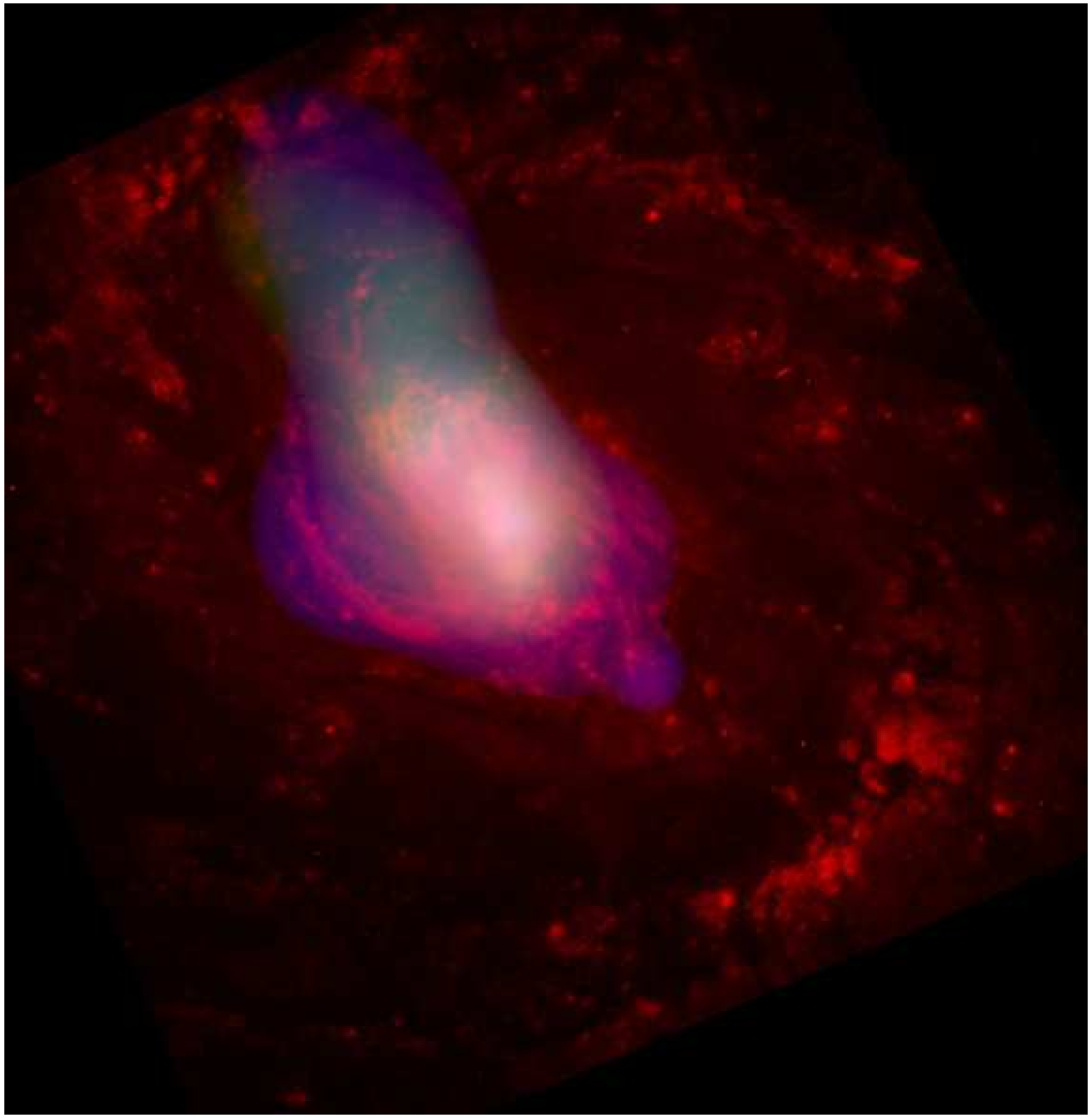


Sazonov etal. 2008

What makes up the cosmic X-ray background?



25 Summary



http://chandra.harvard.edu/ngc1068

- SMBH in center of galaxies are scaled up stellar mass BH
- AGN luminous accros the EM spectrum
- Responsible for CXB
- Unification model seems to explain obsevraitions
- X-rays spectra: contribution from a varaiety of processes
- Absorption → complex geometry
- Emission → accretion, reprocessing
- Relativisitc line broadening
- Imaging: multiwavelength approach