The X-Ray Universe

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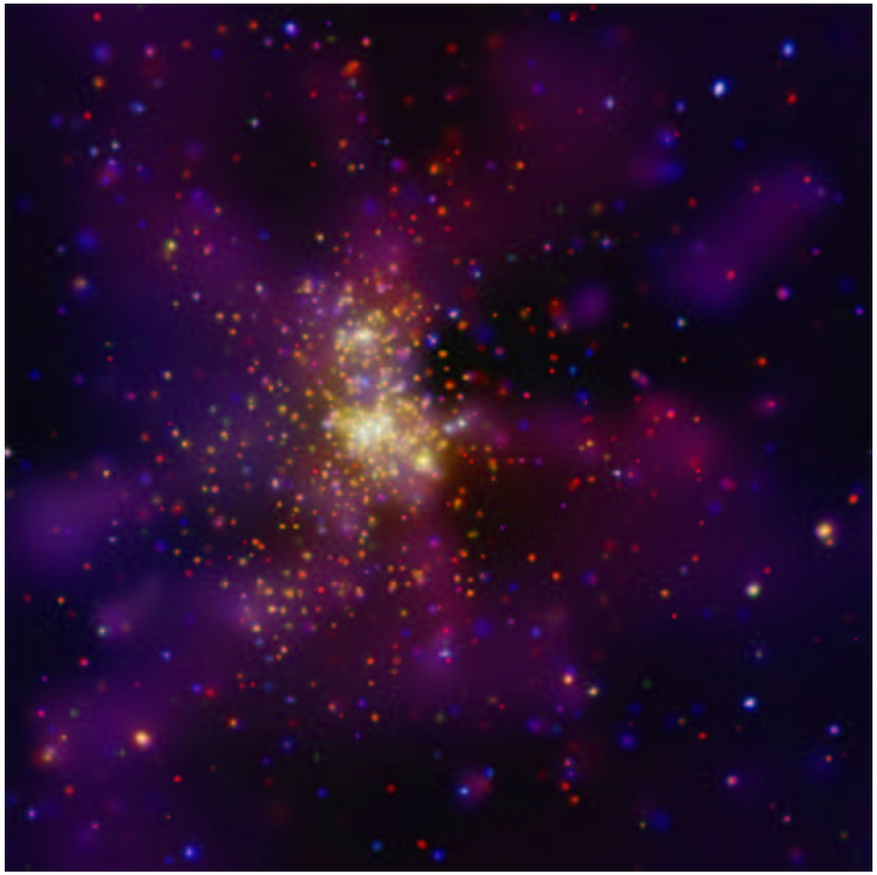
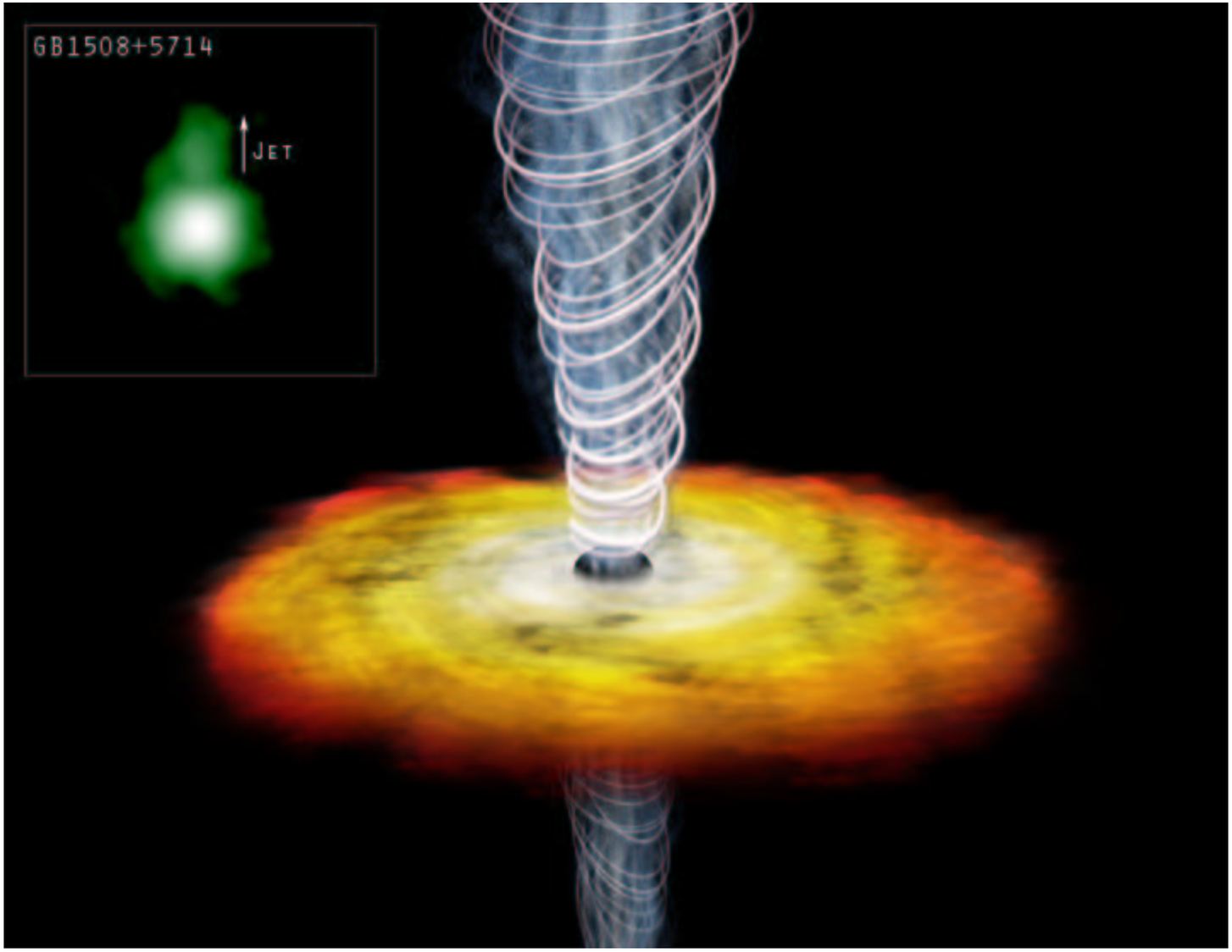


Chandra X-ray Observatory
Westerlund 2 - a young star cluster
d=2×10^4ly

IX. Active Galactic Nuclei

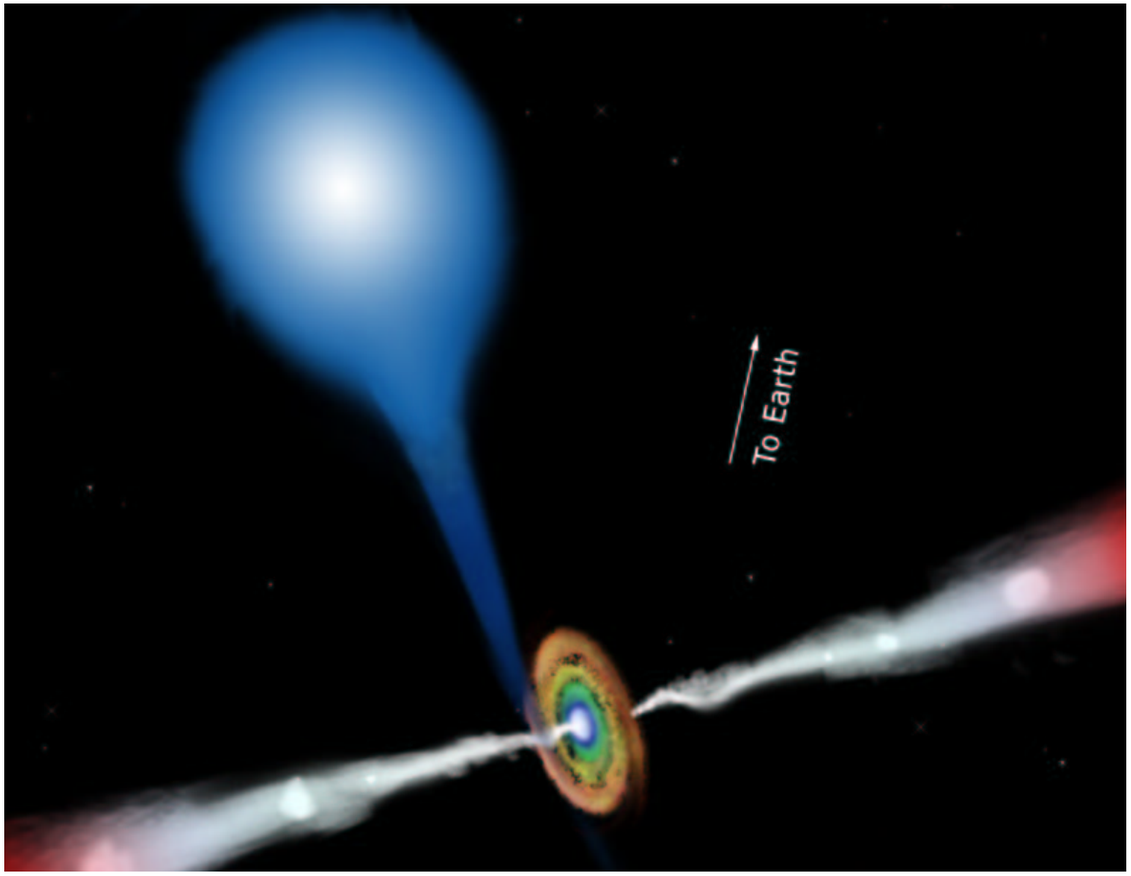


http://chandra.harvard.edu/

02 Summary: X-ray binaries

- Binary star where one companion is a neutron star or a black hole. Second companion is Pop II or Pop I star → HMXB or LMXB.
- Gravitational and kinetic energy of matter falling onto the central object is converted by dissipation to heat: spheriClaly symmetric accretion (Bondi) or accretion disk.
- Accretion disk: ISCO orbits below of R_{ISCO} are unstable. Kerr black holes $R_{ISCO} = R_G$ → HFQPOs are best probe of physics close to the BH
- Neutron stars: X-ray pulsars. Can measure mass of the NS (about 1.4Msun)
- Black holes: About 20 have known masses. All below 20Msun

03 From μQSO to QSO



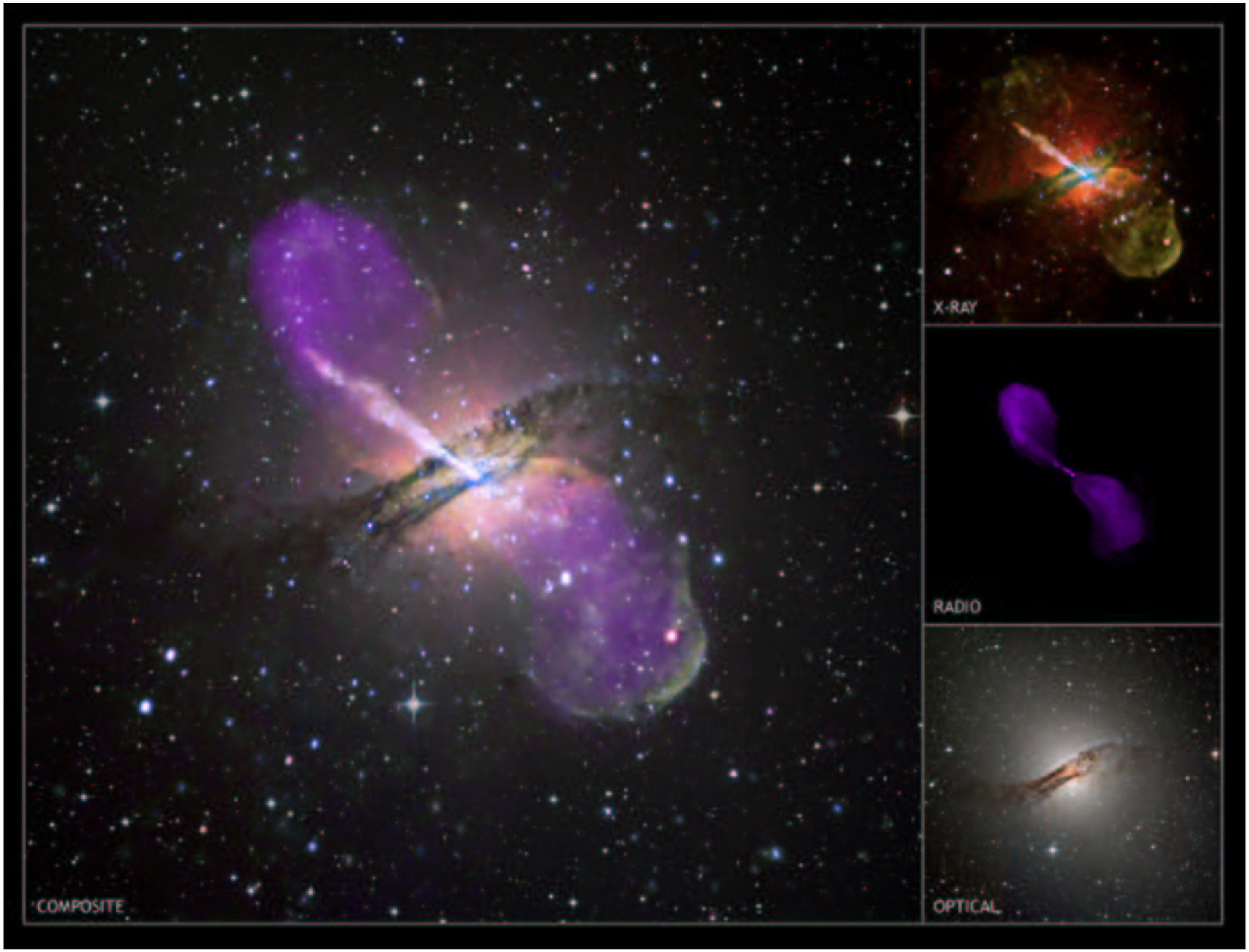
μQSO SS433:

- 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
$L_X\,[\frac{erg}{s}]$	$10^{34} - 10^{36}$	$10^{37} - 10^{39}$	$10^{40} - 10^{43}$	$10^{43} - 10^{45}$	$10^{44} - 10^{46}$	$10^{45} - 10^{47}$

04 The nearest active galaxy: Centaurus A



05 AGNs are scaled up XRBs

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

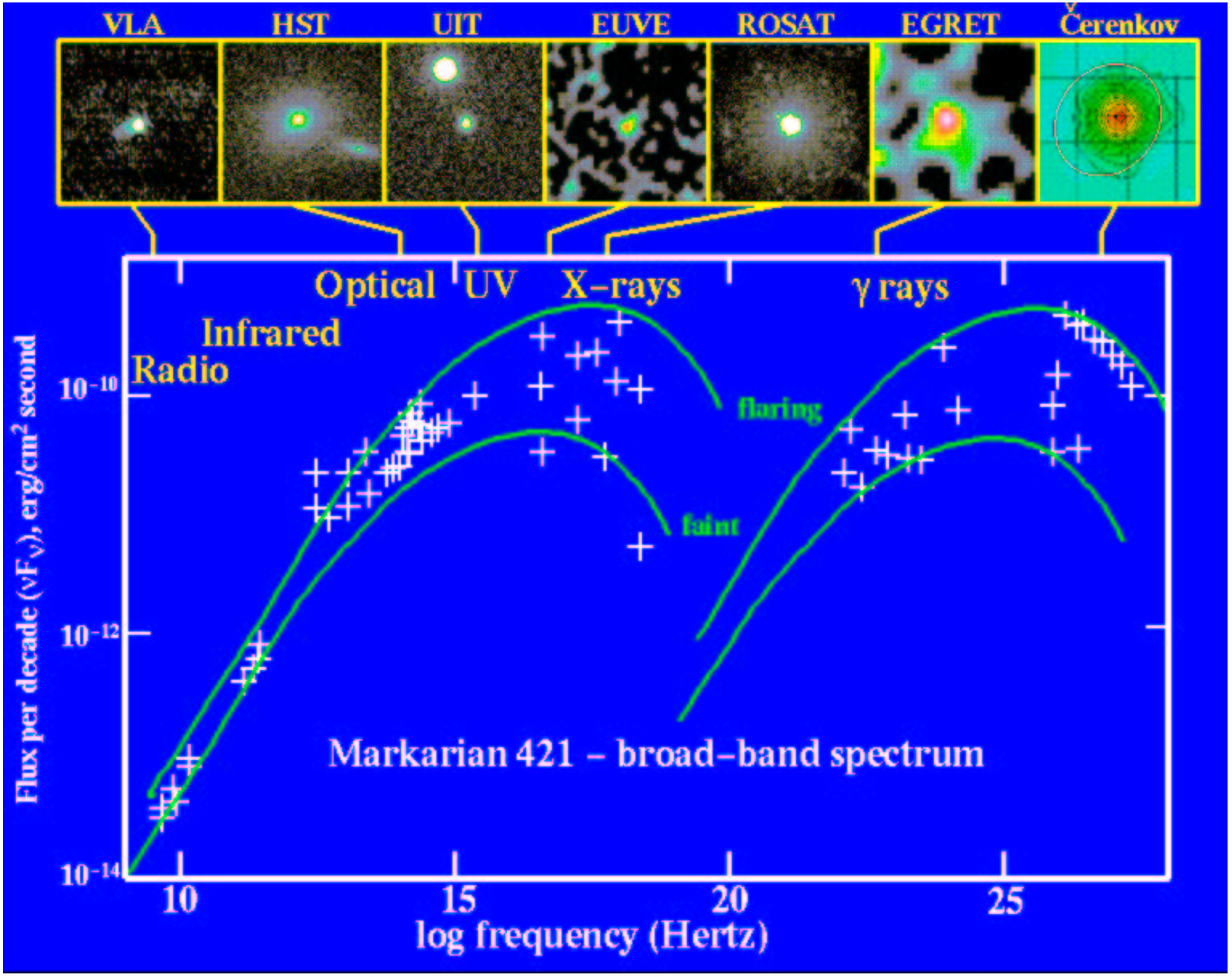
X-ray luminosity of QSO is 10 orders of magnitude higher than XRB

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

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

06 Observed properties of AGN

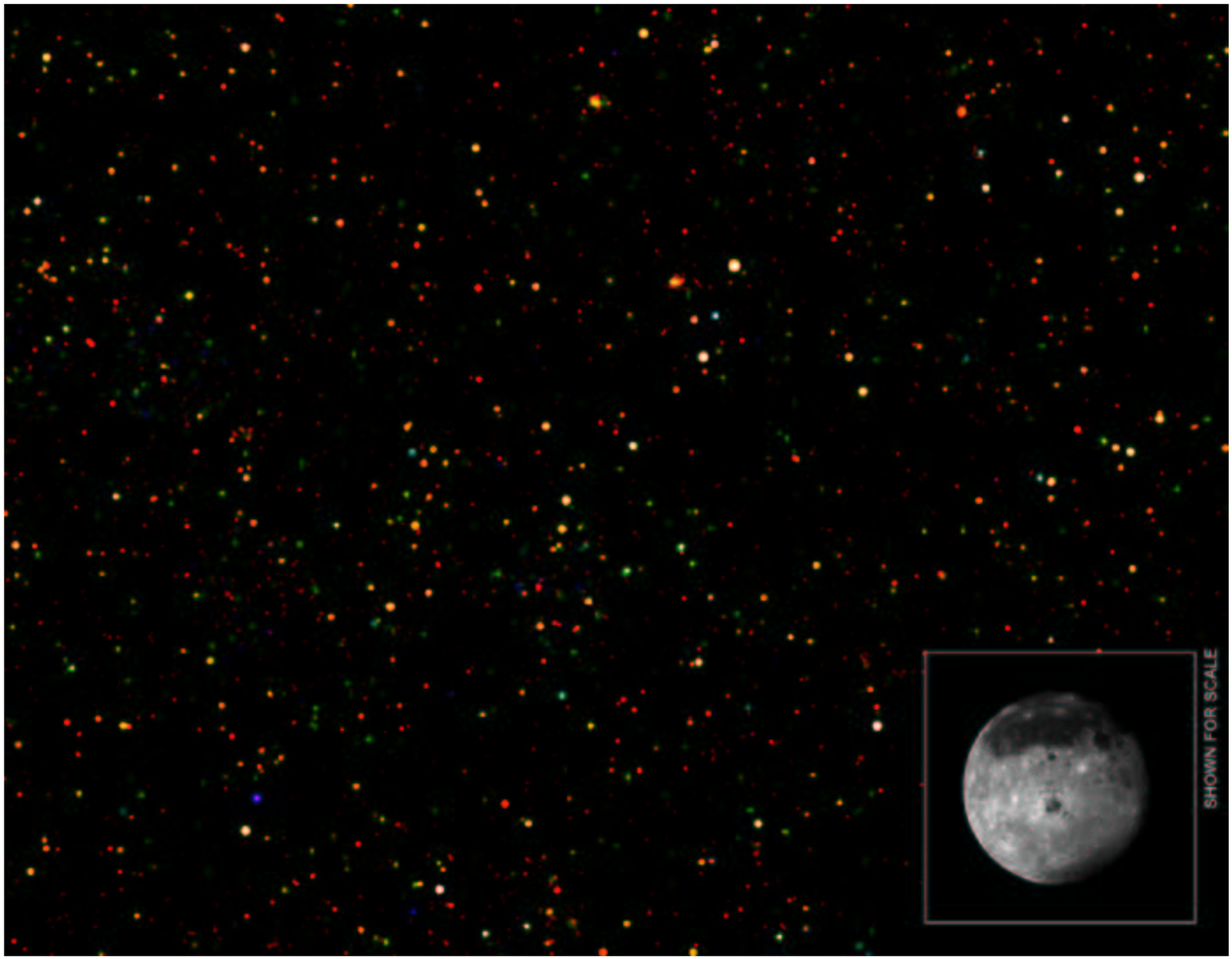
High luminosity $L_{bol}=10^{42}$-10^{48}; Size << 1pc; Variabilty; Emission & Absorption lines



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

07 Cosmic X-ray background and AGN

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



600 obscured and
700 unobscured AGN
agree with
standard scheme

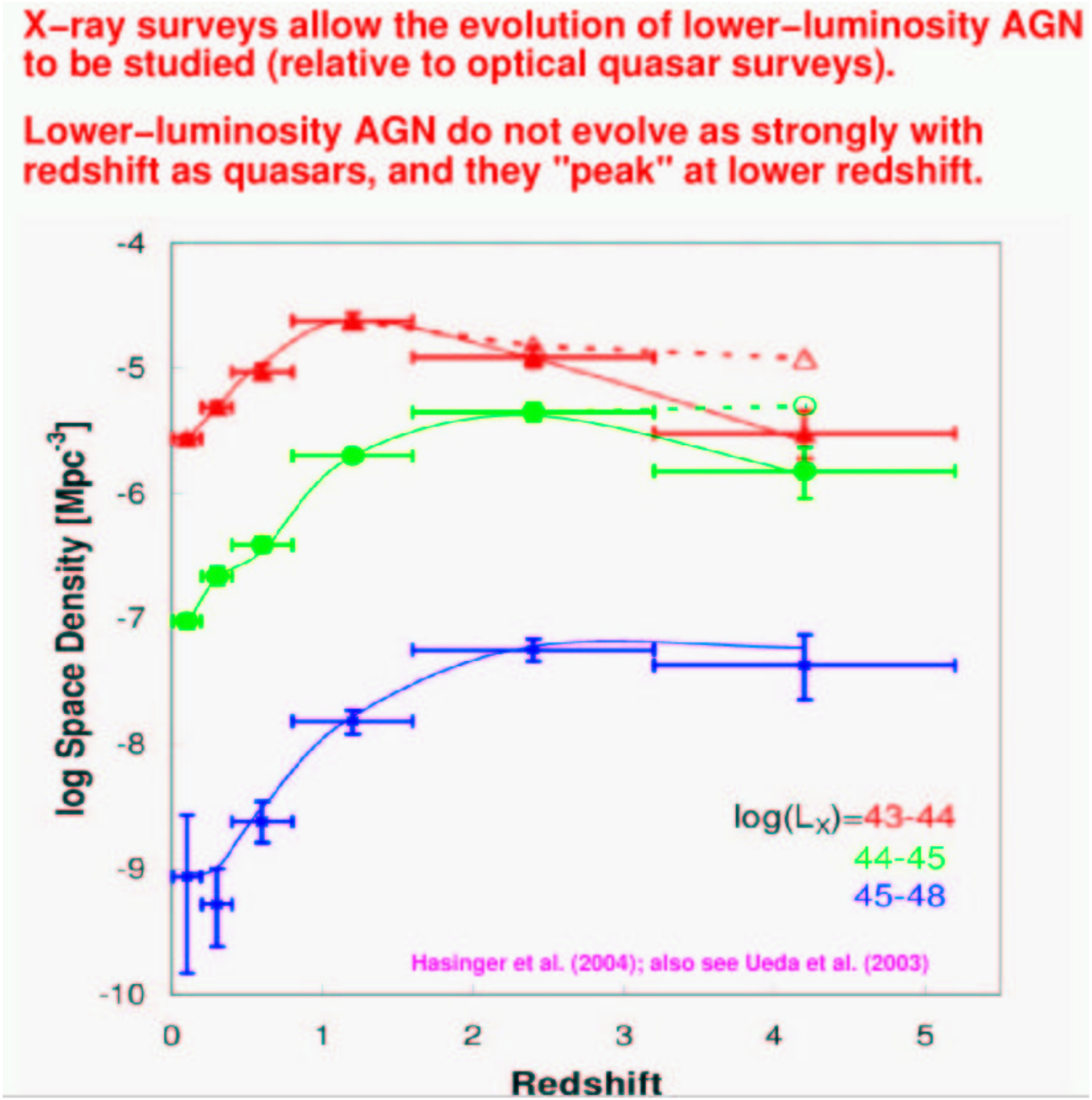
X-ray surveys
deep or wide

many ongoing
automatic
selection

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

07a Cosmic evolution of AGN ?

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



from W.N.Brandt 2004

600 obscured and

$10^{9..10}$ $M_\odot$ BH

early Universe

negative

feedback?

smaller BH

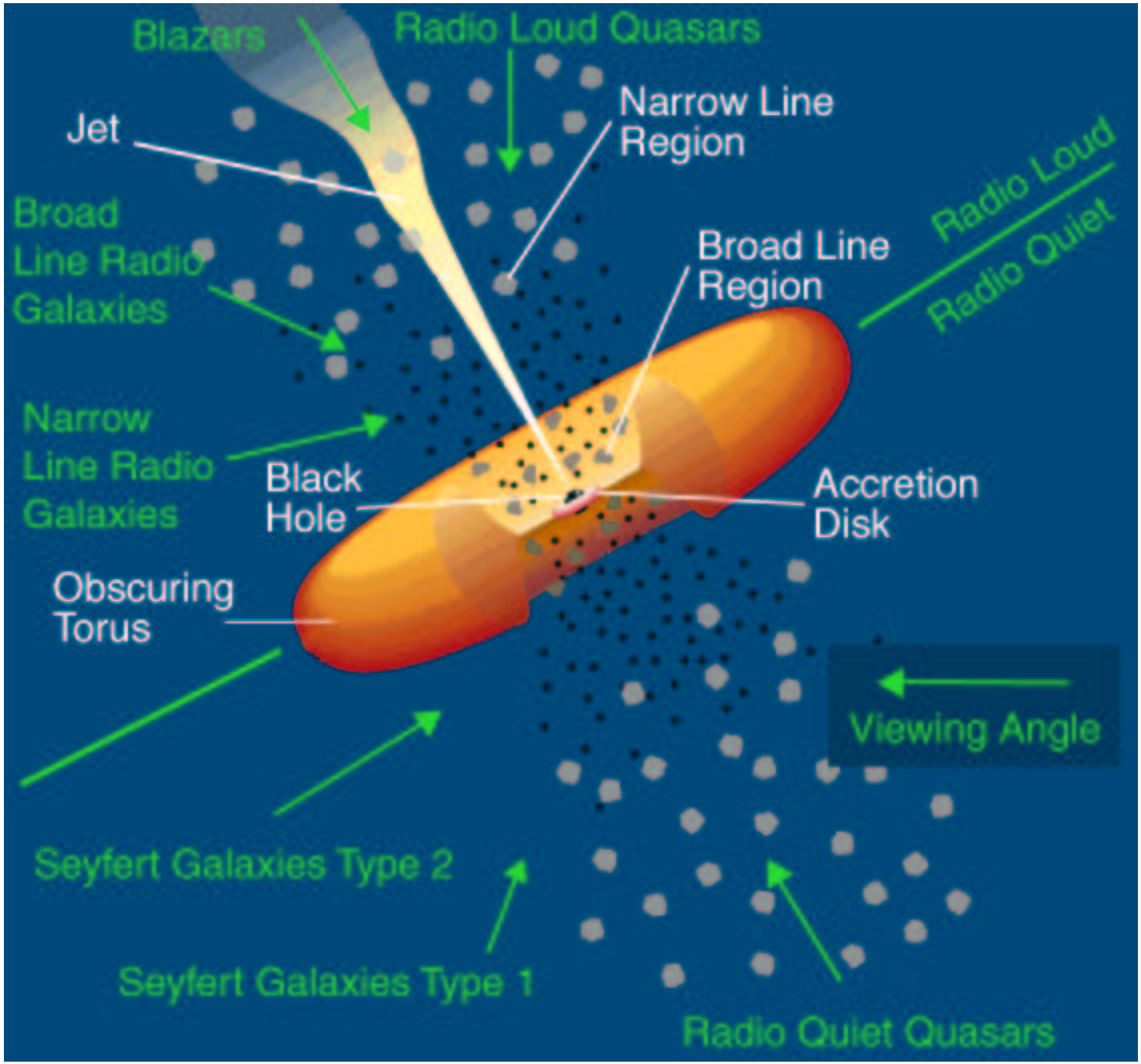
everywhere

continous growth?

08 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)

09 Famous sketch (unification model)



Urry & Padovani 1995 PASP 107, 803

AGN with $10^8 M_\odot$ BH

R_G 3×10^{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

10 X-ray observations

Time Variability

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

X-ray Spectra:

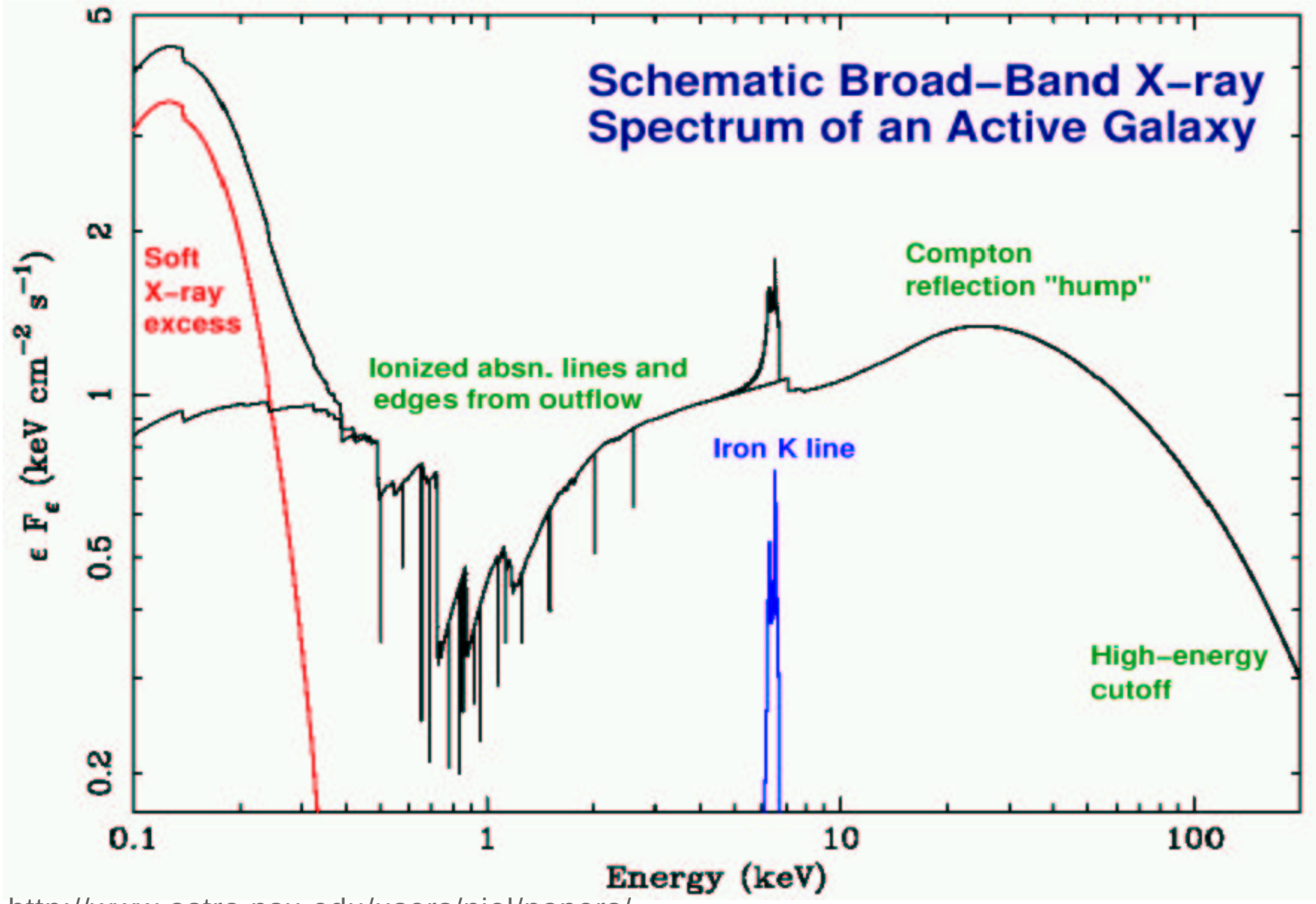
- Absorption: amount of absorbing material; velocity field (inflow/outflow); cold/warm absorbers; ionization state
- Thermal emission: from hot gas, accretion physics
- Non-thermal emission: synchrotron, Comptonisation, relativisitc effects, acceleration, magnetic fields
- Emission lines: relativistic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

X-ray Images:

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

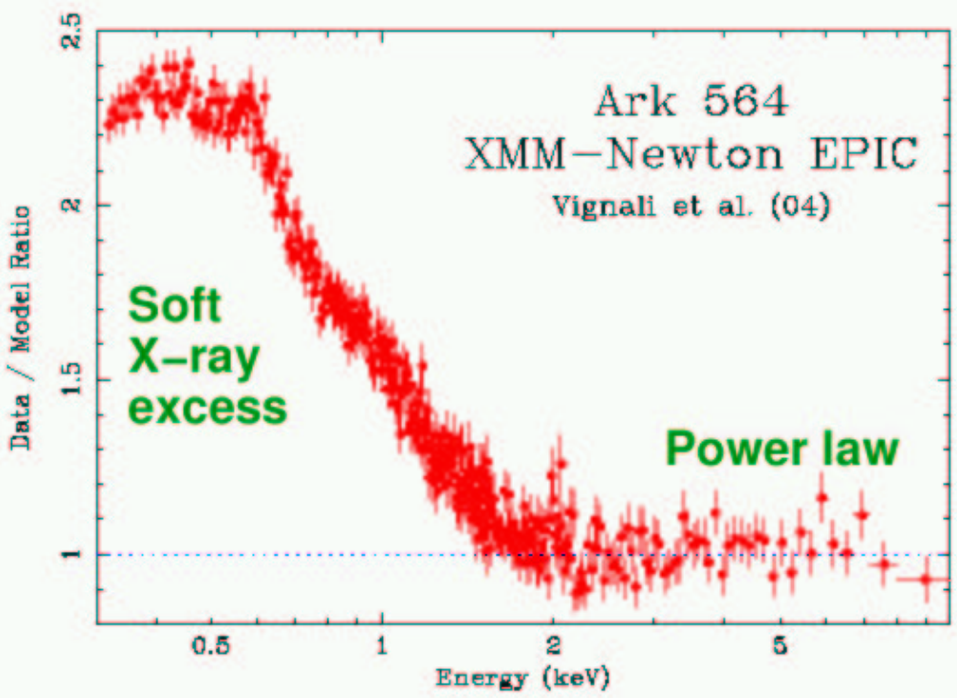
10a Schematic X-ray spectrum of AGN

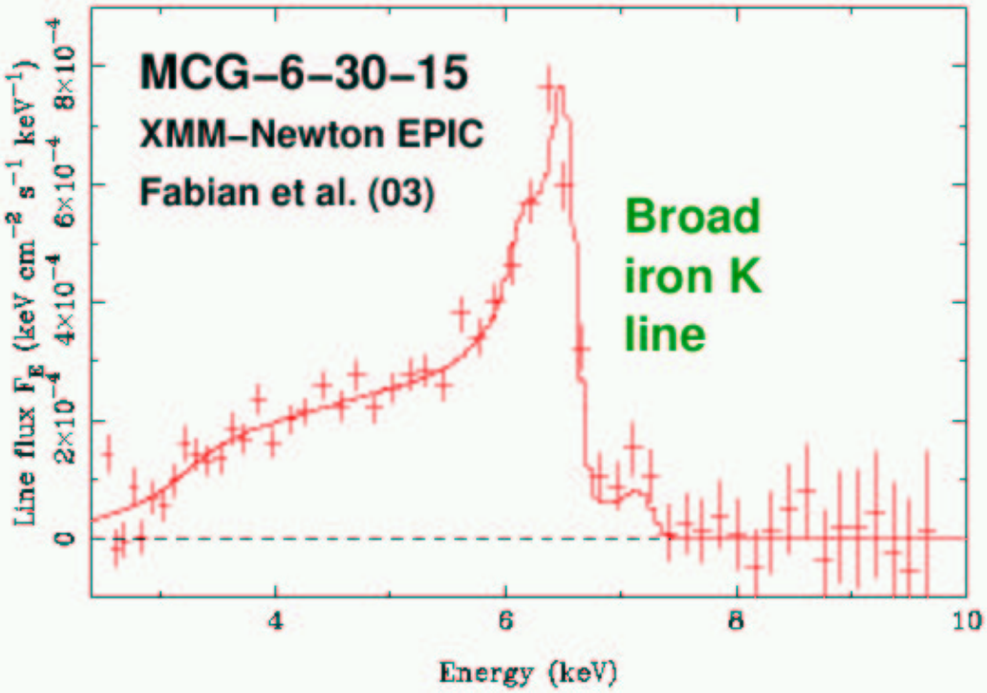
From W.N.Brandt "X-raying Active Galaxies" AAS'04

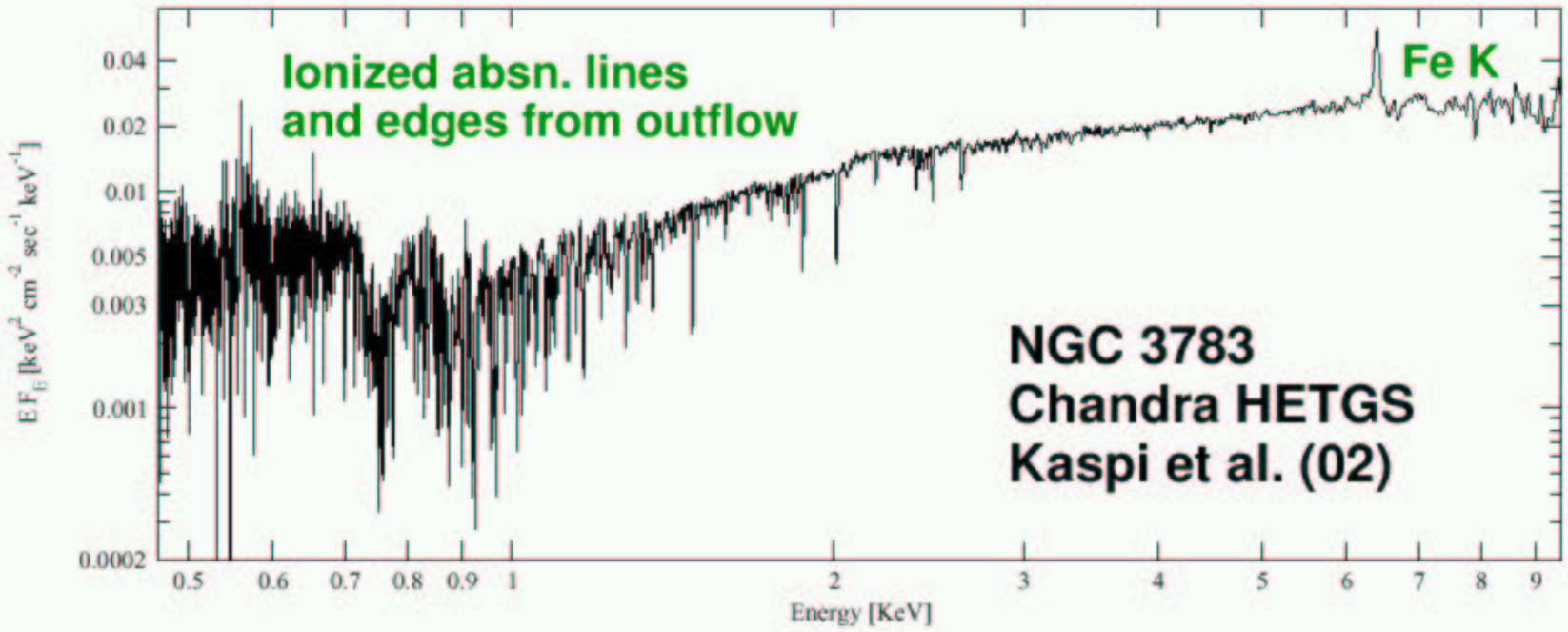


http://www.astro.psu.edu/users/niel/papers/

10b Examples of obsevred AGN X-ray spectra







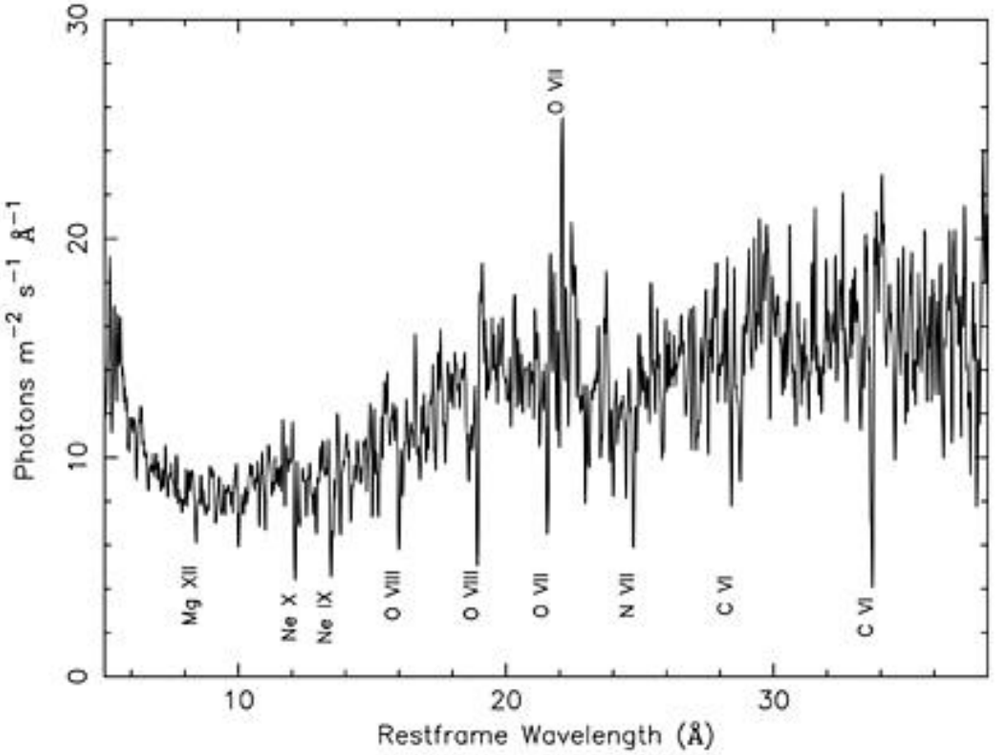
Also unidentified features

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

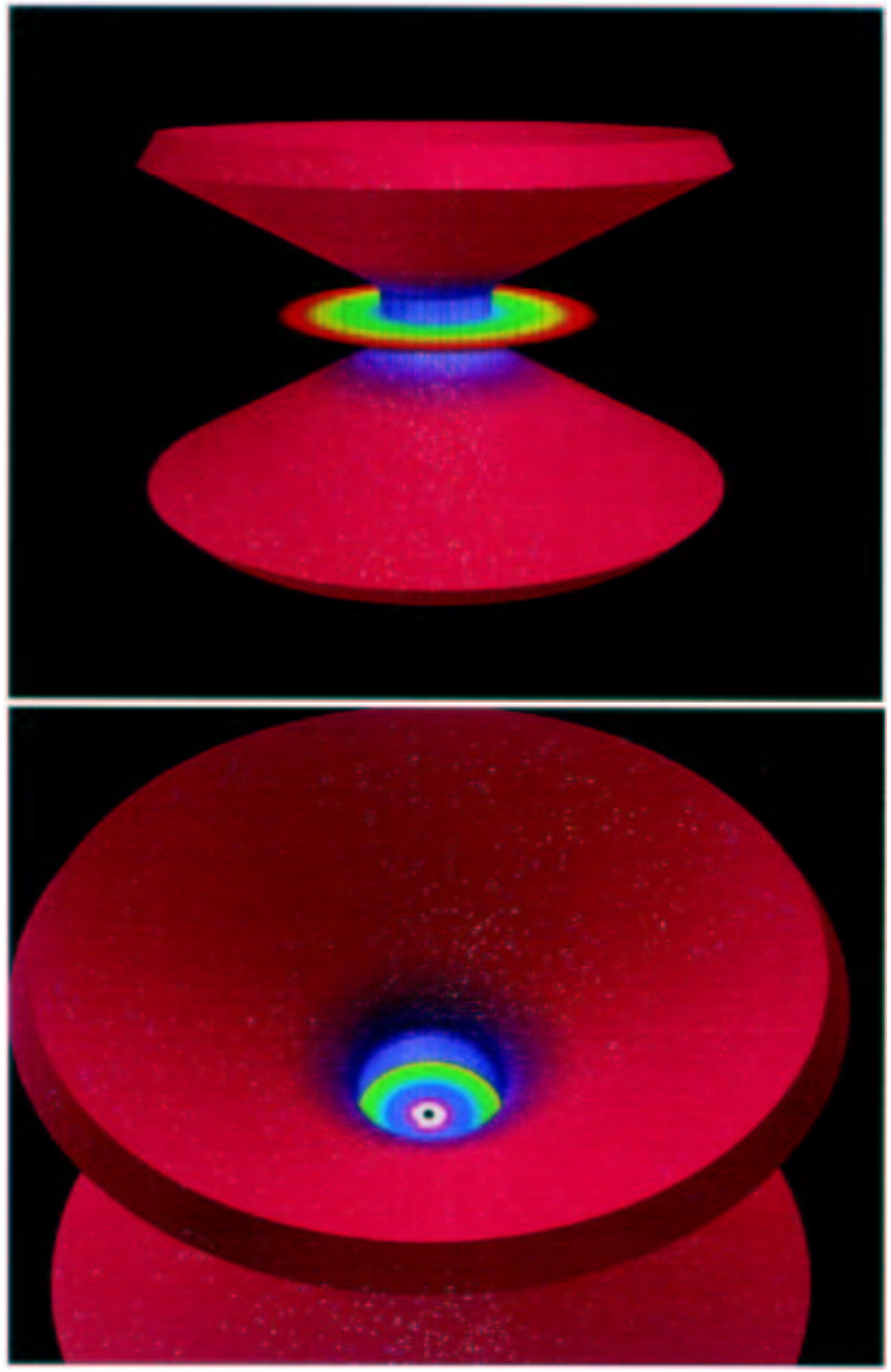
http://www.astro.psu.edu/users/niel/papers/ From W.N.Brandt "X-raying Active Galaxies" AAS'04

11 Absorption signatuers in QSO X-ray spectra

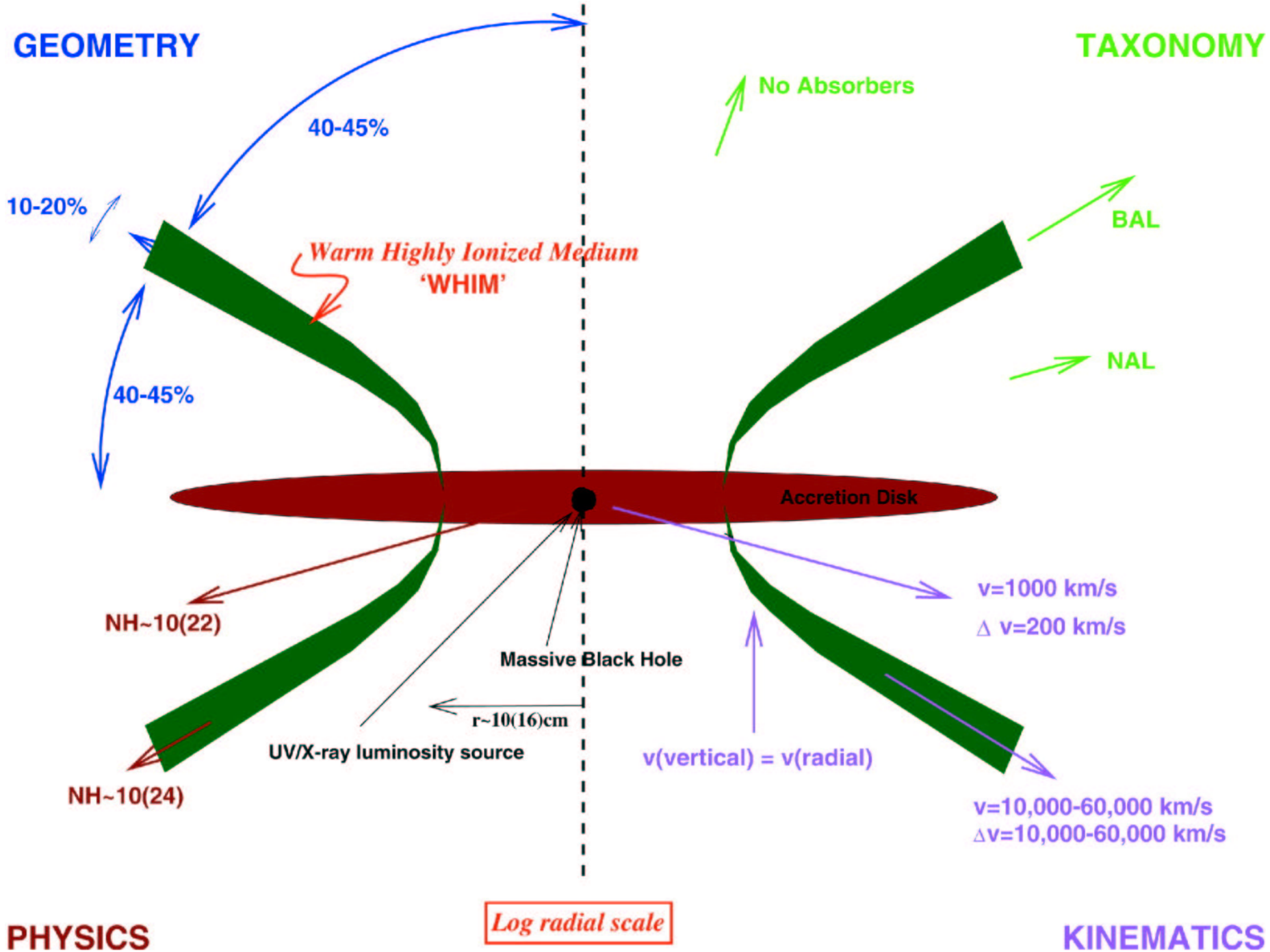
” A simple, empirically derived, unifying structure for the inner regions of quasars. This structure is constructed to explain the BALRs and NALs, and is also found to explain the BELRs and several scattering features, including a substantial fraction of the broad X-ray Fe-K emission line and the biconical



NGC 5548 LETGS spectrum

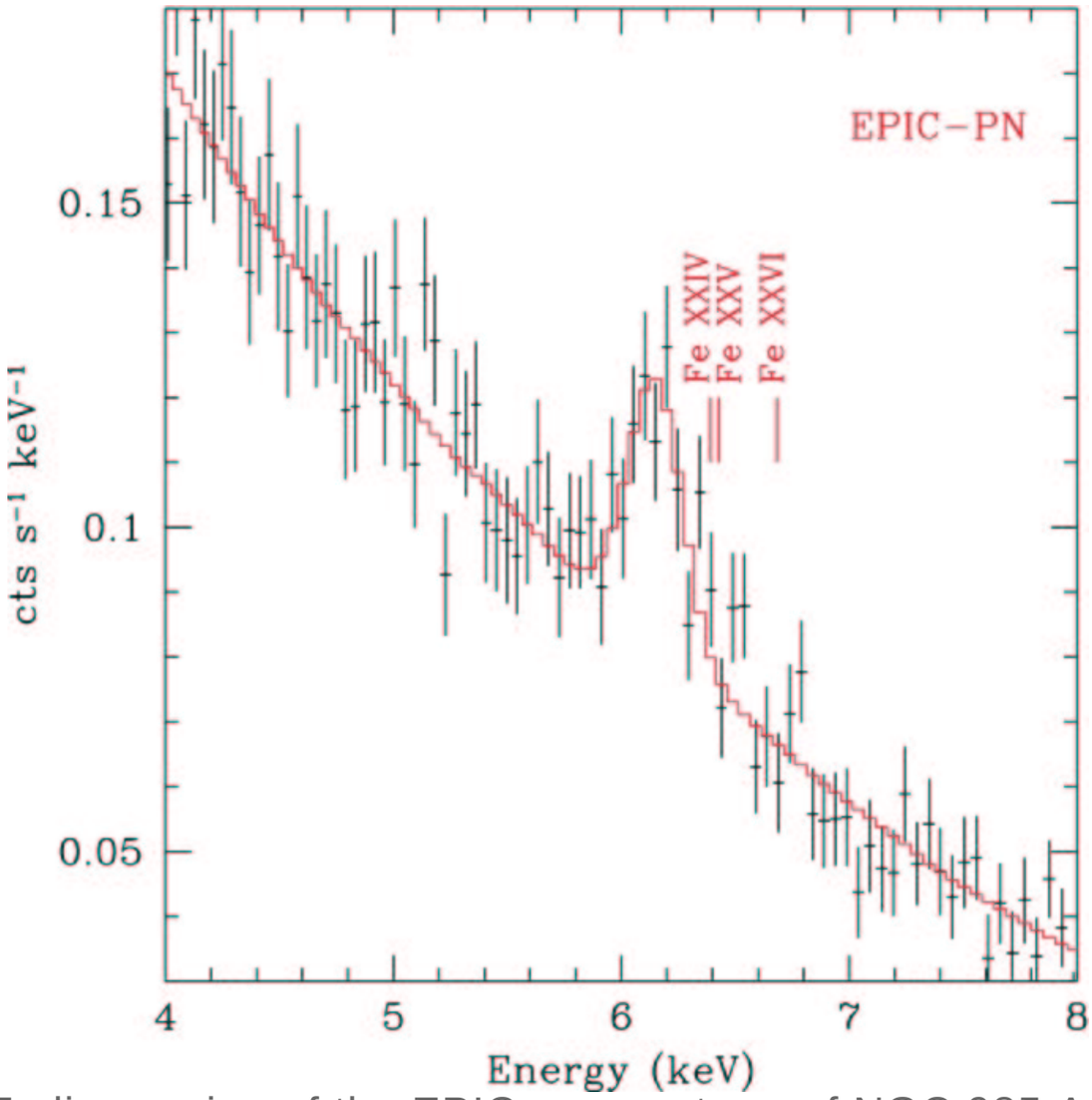


12 A Structure for Quasars



Elvis ApJ 545,63

13 Emission lines in AGN X-ray spectra



Fe line region of the EPIC-pn spectrum of NGC 985 ApJ 291, 873

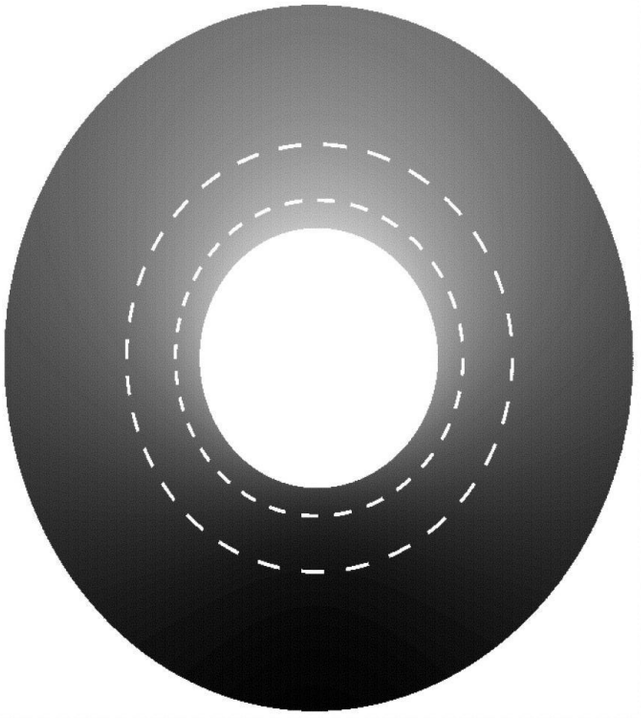
Emission Lines from Nucleus

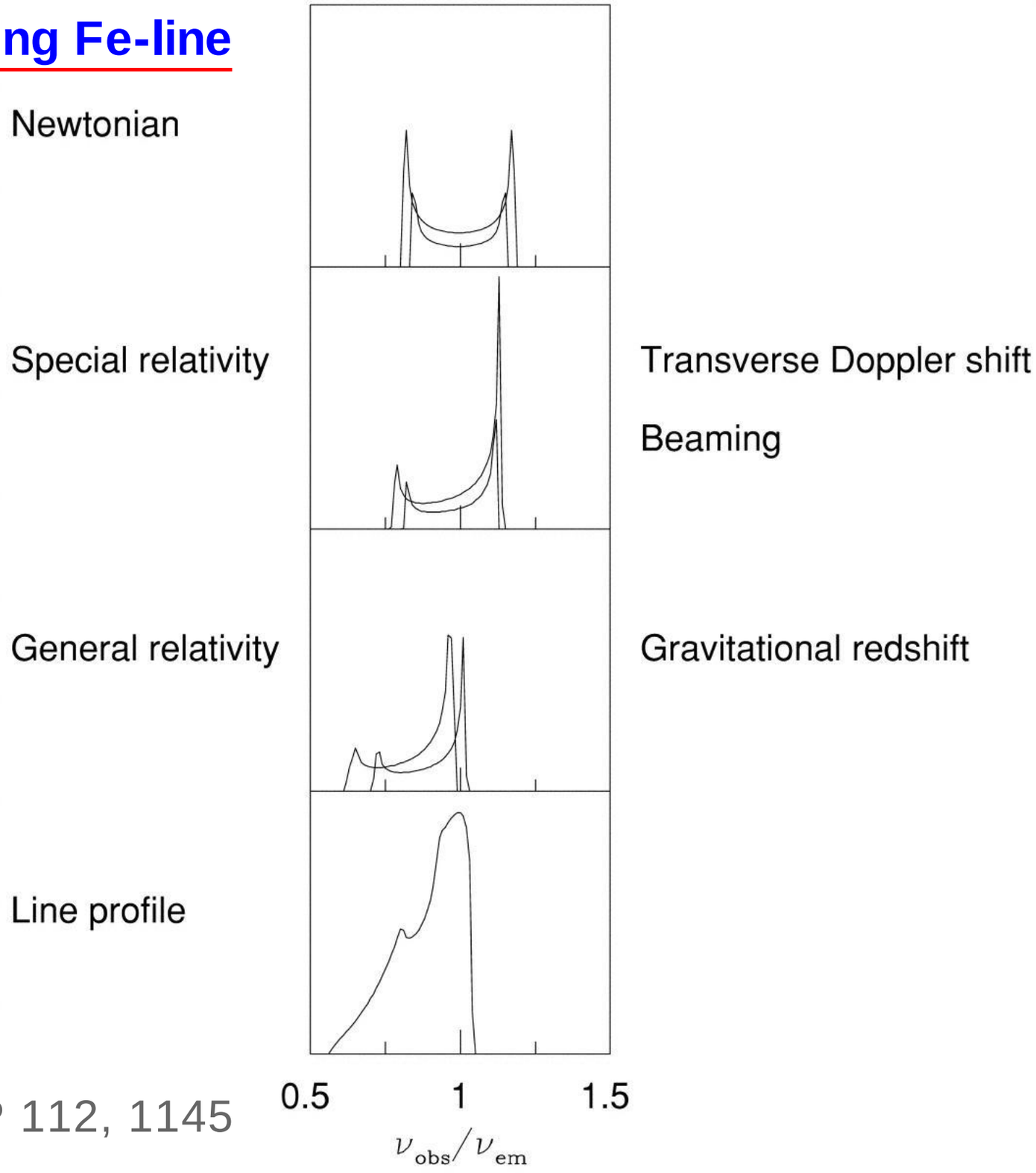
- Accreting matter
- Relativisitc broadening Fe-line
- BLR clouds

Emission lines away from the BH

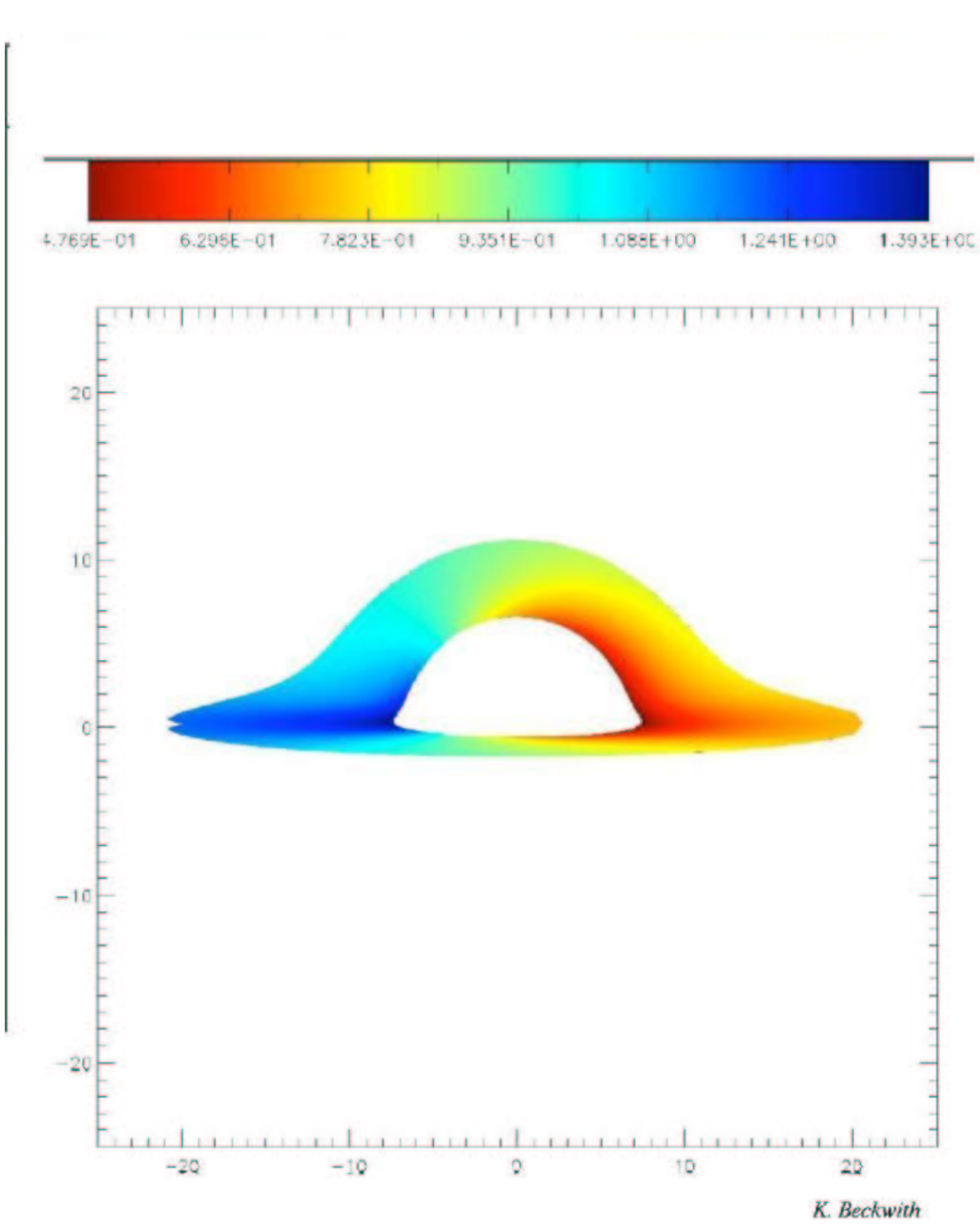
NLR in Seyfert 2

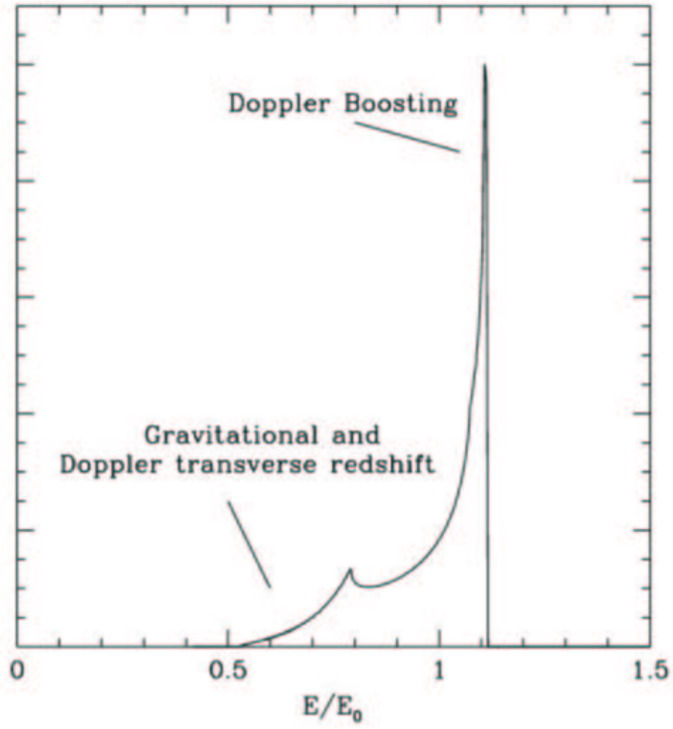
14 Relativisitc broadening Fe-line

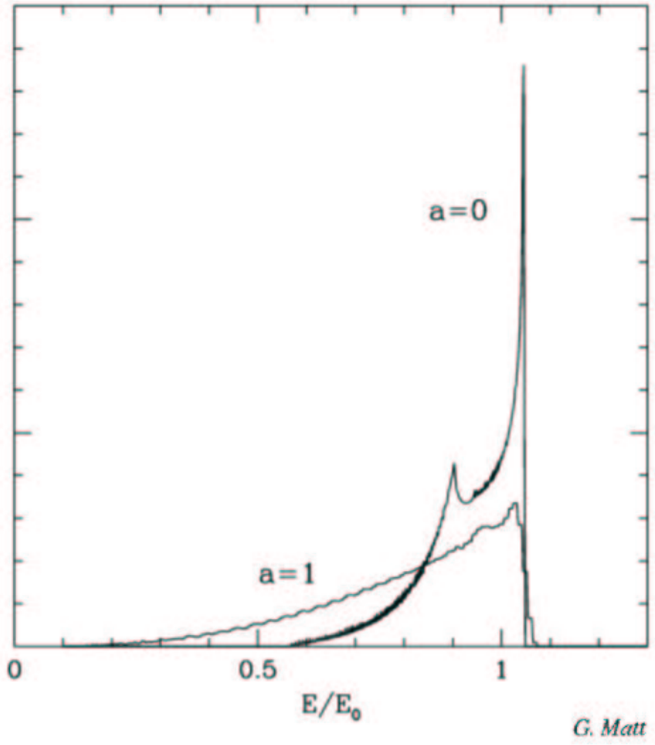




Fabian et al. 2002 PASP 112, 1145



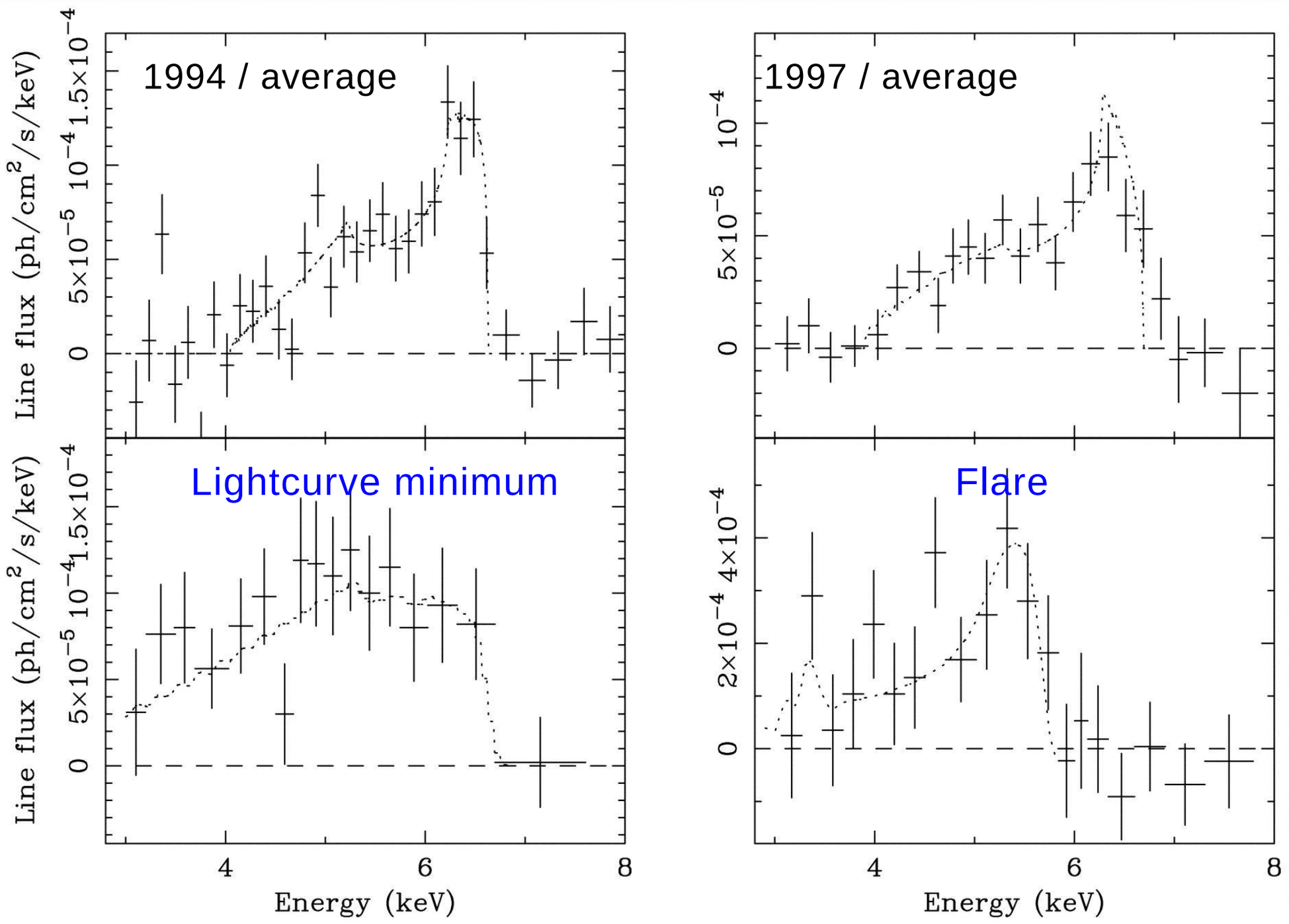




relativistic lines from accretion disks around black holes

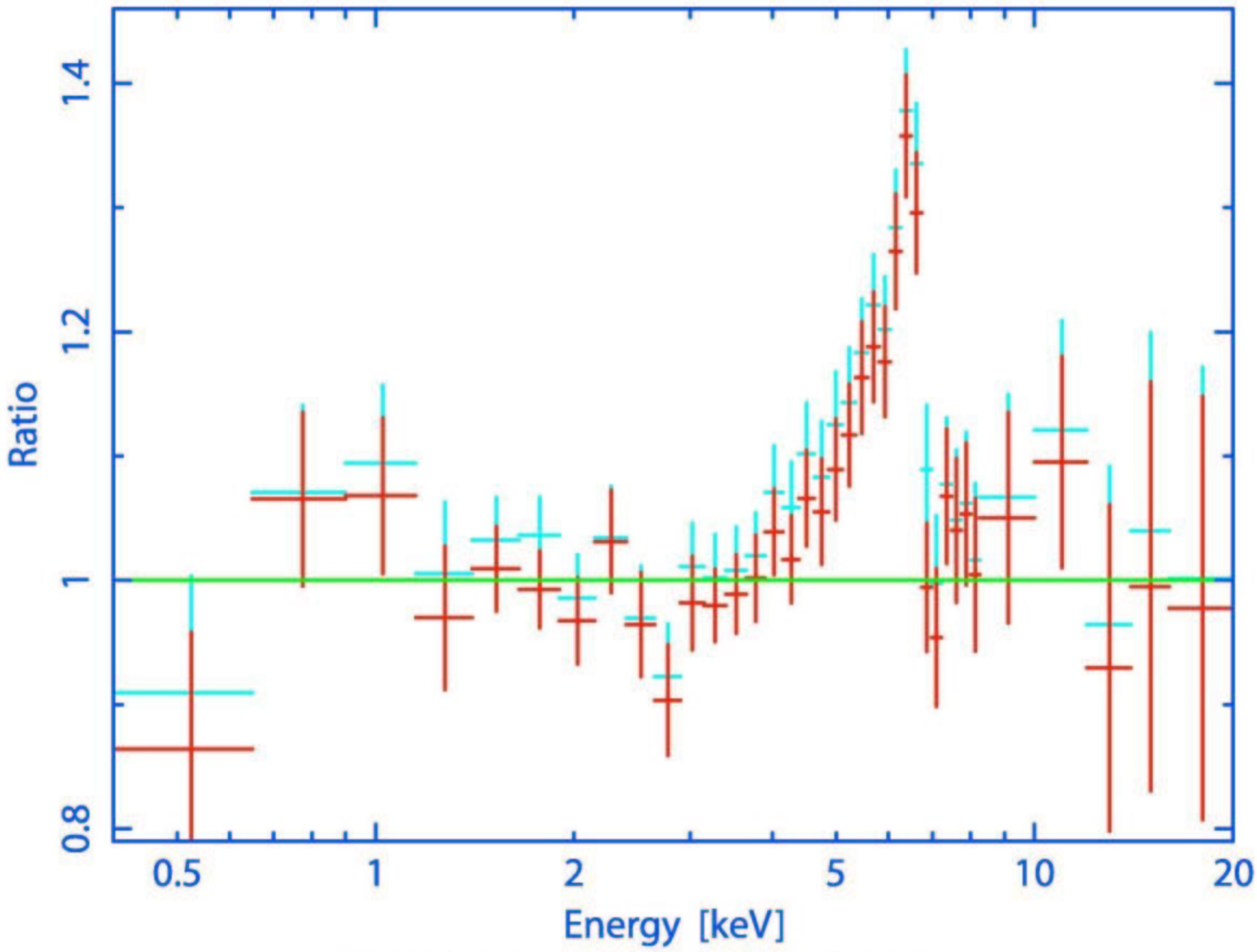
Image courtesy of G. Matt, Universita degli Studi Roma Tre, Italy, and K. Beckwith, Universityof Durham, UK,

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



Fabian et al. 2002 PASP 112, 1145

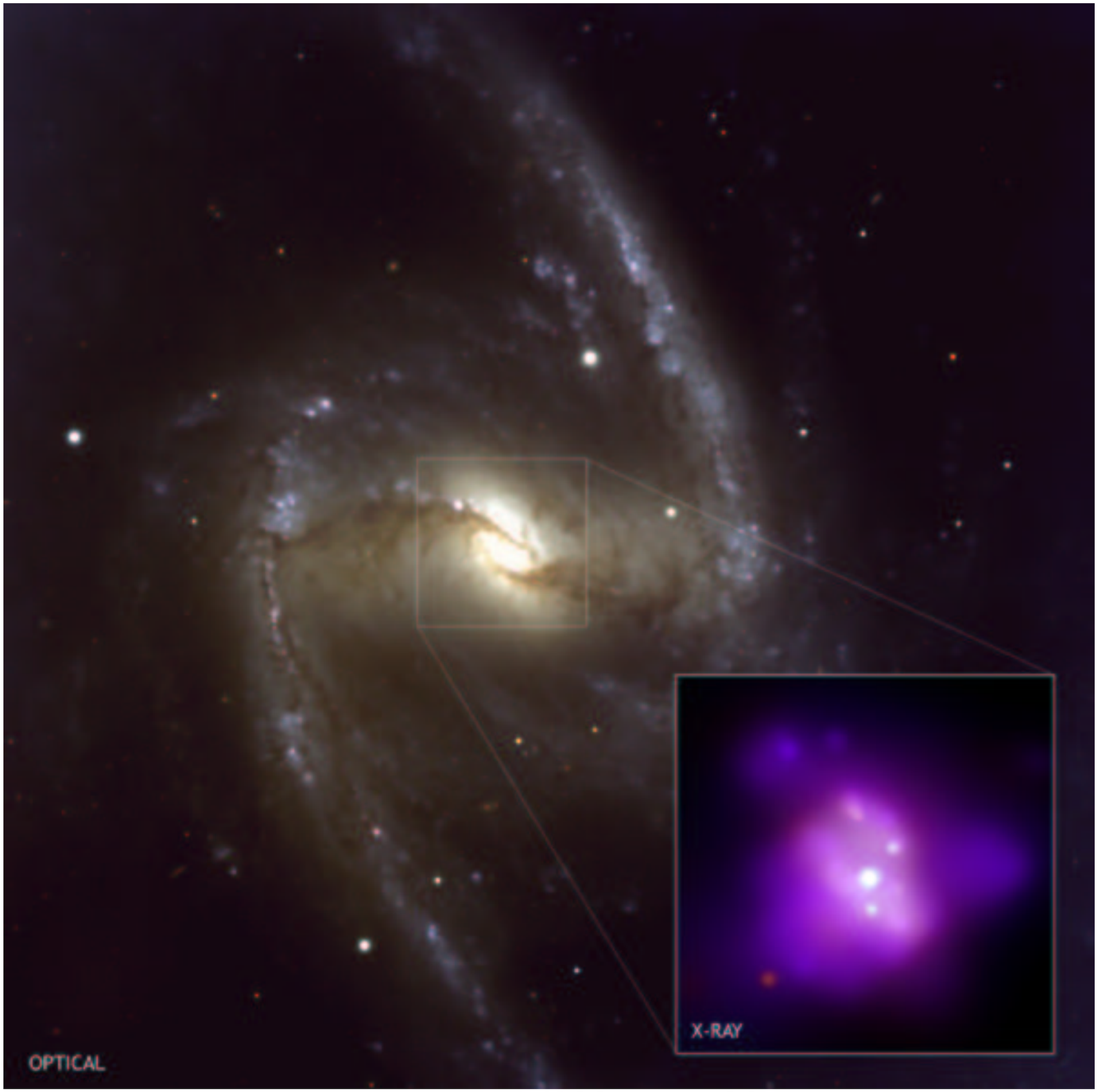
17 XMM spectra of the X-ray background with a relativistic iron line



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

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

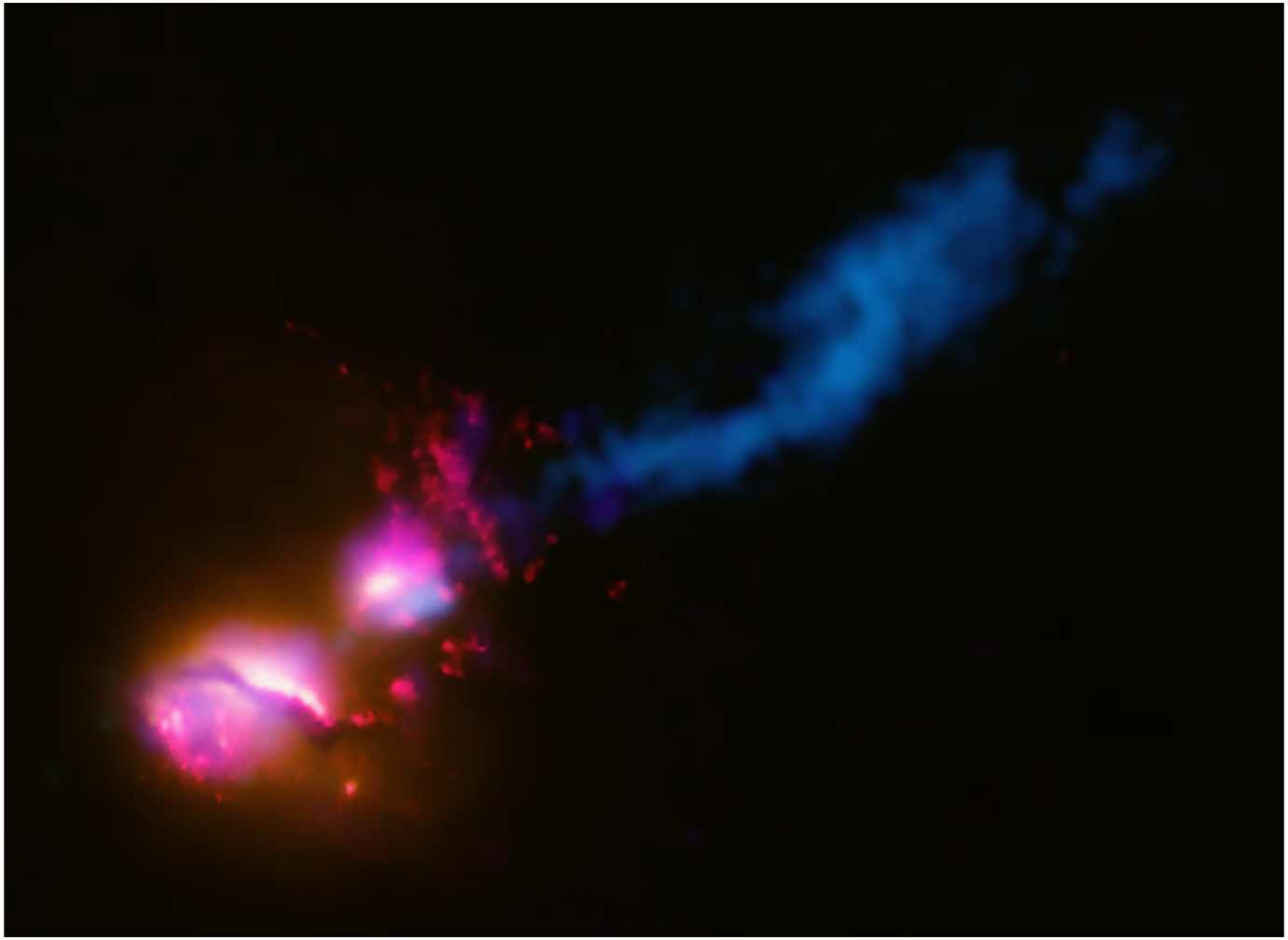
18 X-Ray imaging



Chandra observations of NGC 1365: eclipse of the supermassive black hole at its center. A dense cloud of gas passed in front of the black hole blocking X-rays. ”This serendipitous alignment allowed astronomers to measure the size of the disk of material around the black hole, a relatively tiny structure on galactic scales.”

http://chandra.harvard.edu/photo/2007/ngc1365

19 X-Ray imaging: interaction between galaxies



http://chandra.harvard.edu/

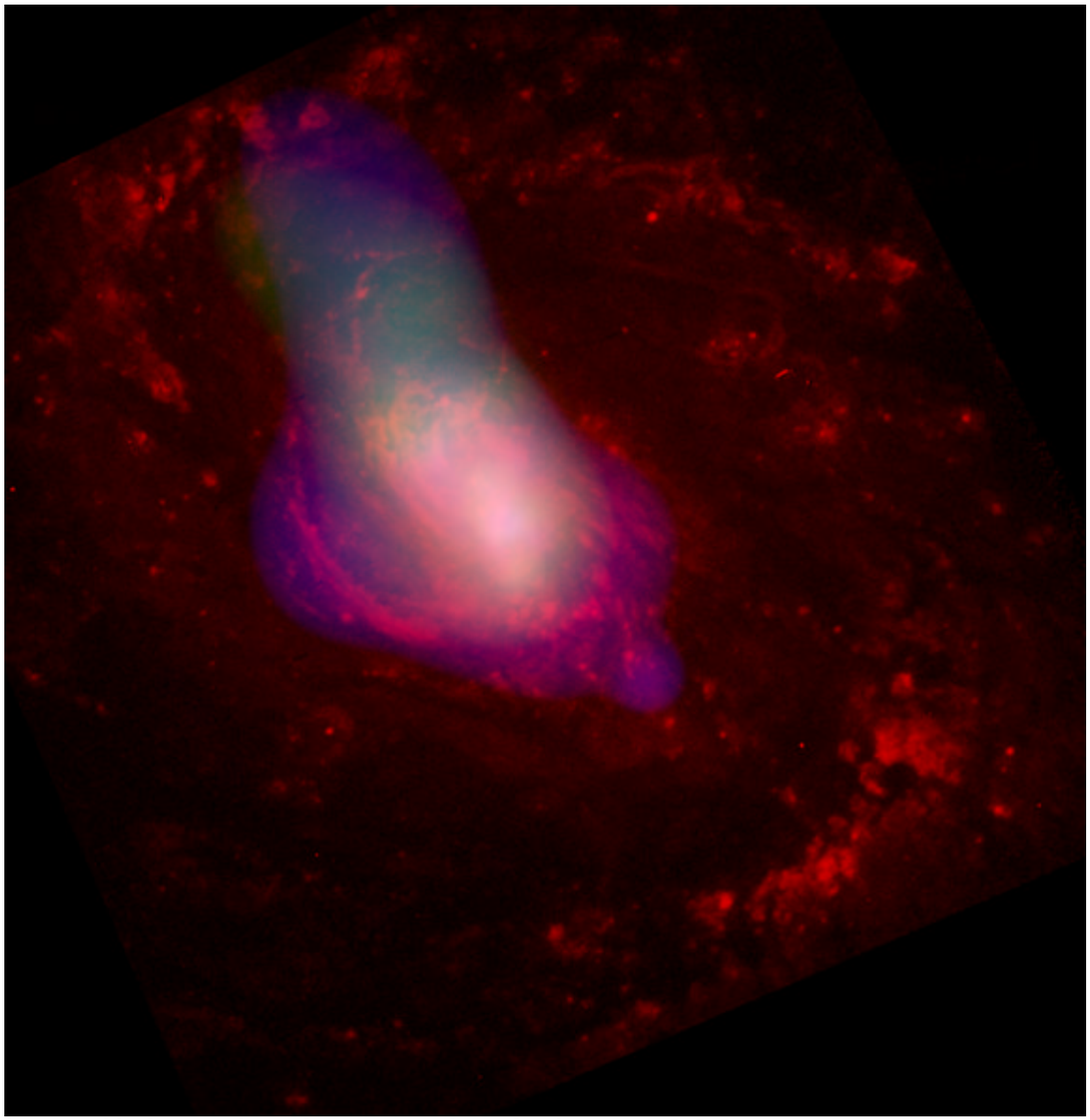
” X-rays (CXO), optical (HST), radio (VLA). Jet from the main galaxy on the lower left is striking its companion galaxy to the upper right. The jet impacts the companion galaxy at its edge and is then disrupted and deflected, much like how a stream of water from a hose will splay out after hitting a wall at an angle.”

20 X-Ray imaging: Jets

http://chandra.harvard.edu/photo

X-rays, optical, radio. M87: largest galaxy in the Virgo. Bright jets moving at close to the speed of light . Strong radio source, Virgo A. X-ray emitting cloud that extends over much of the Virgo cluster. Evidence for a series of outbursts from the BH. The loops and bubbles in the X-ray emitting gas are relics of small outbursts from close to the black hole. X-ray fillaments emission hot gas trapped by magnetic fields.

21 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