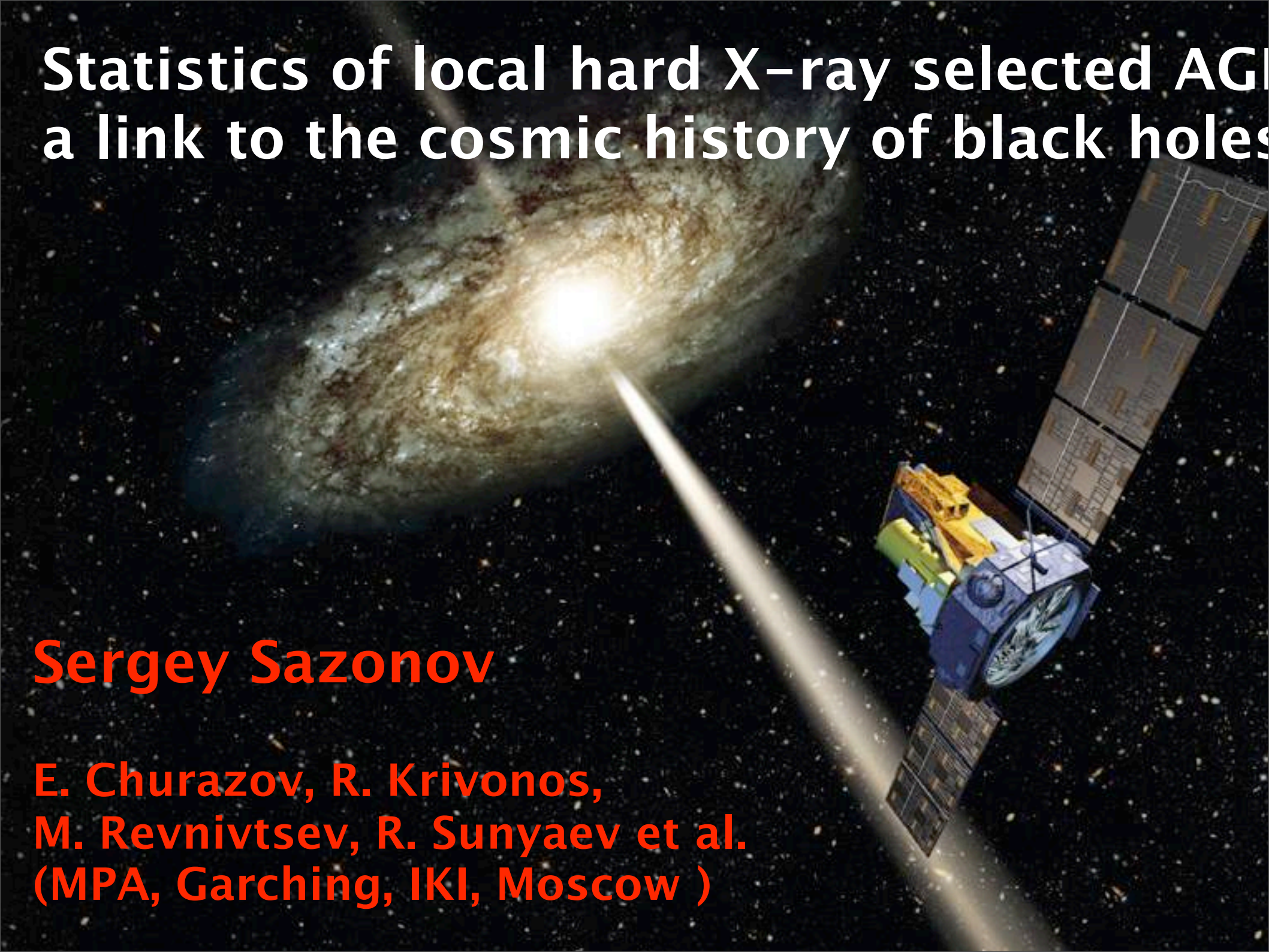
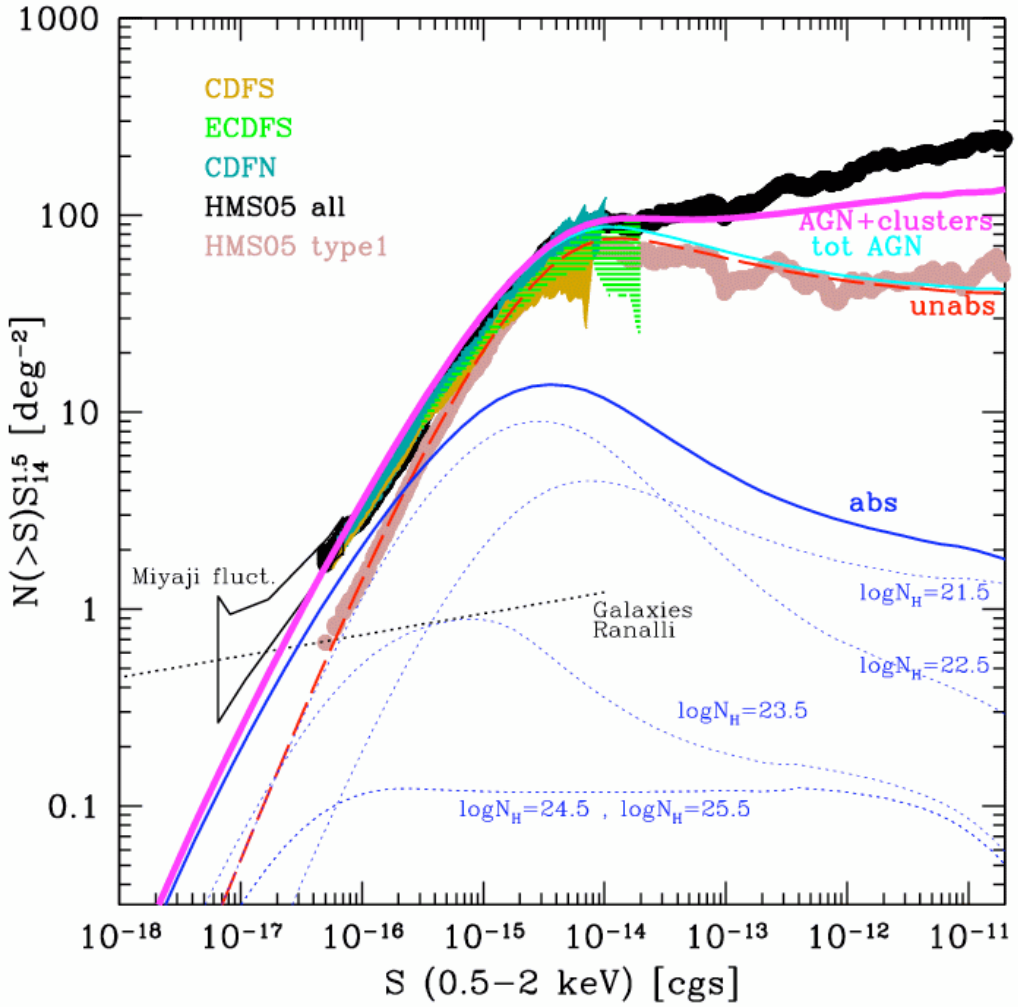
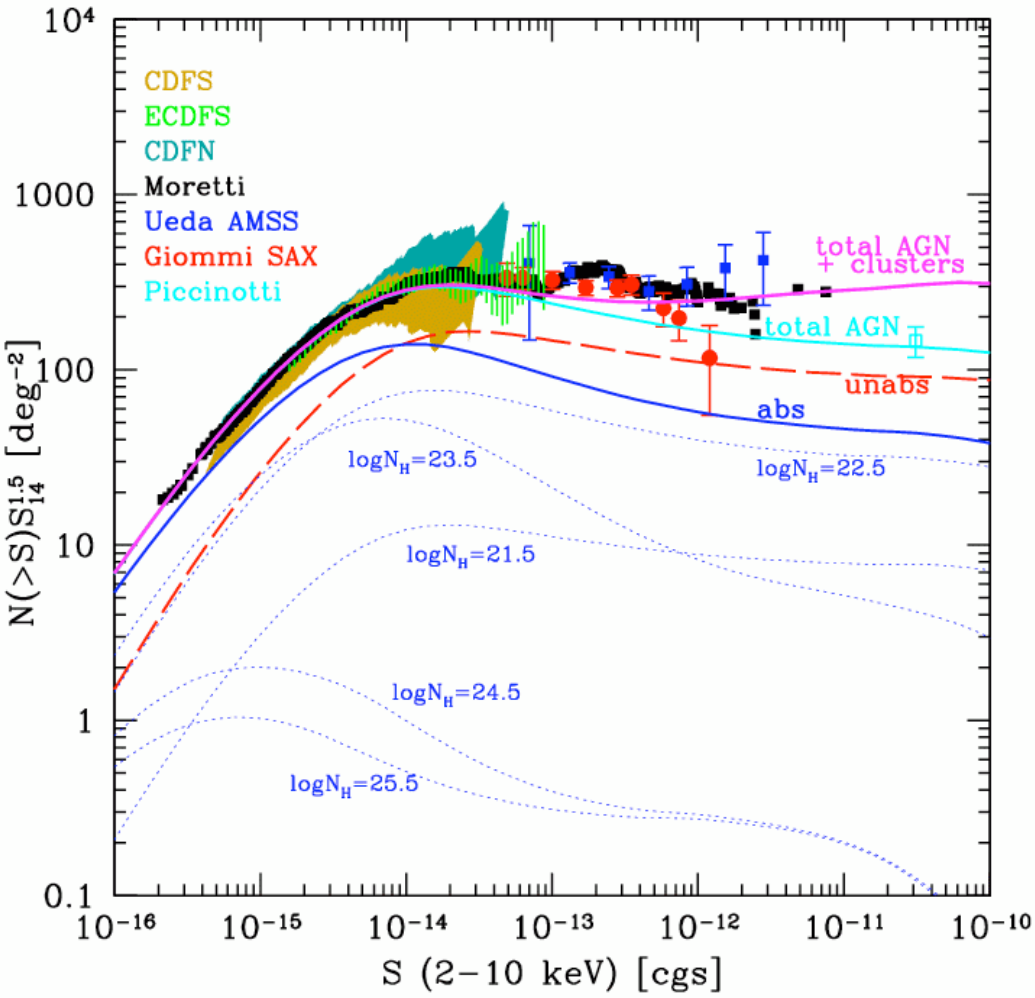
Statistics of local hard X-ray selected AG
a link to the cosmic history of black holes



Sergey Sazonov

E. Churazov, R. Krivonos,
M. Revnivtsev, R. Sunyaev et al.
(MPA, Garching, IKI, Moscow)



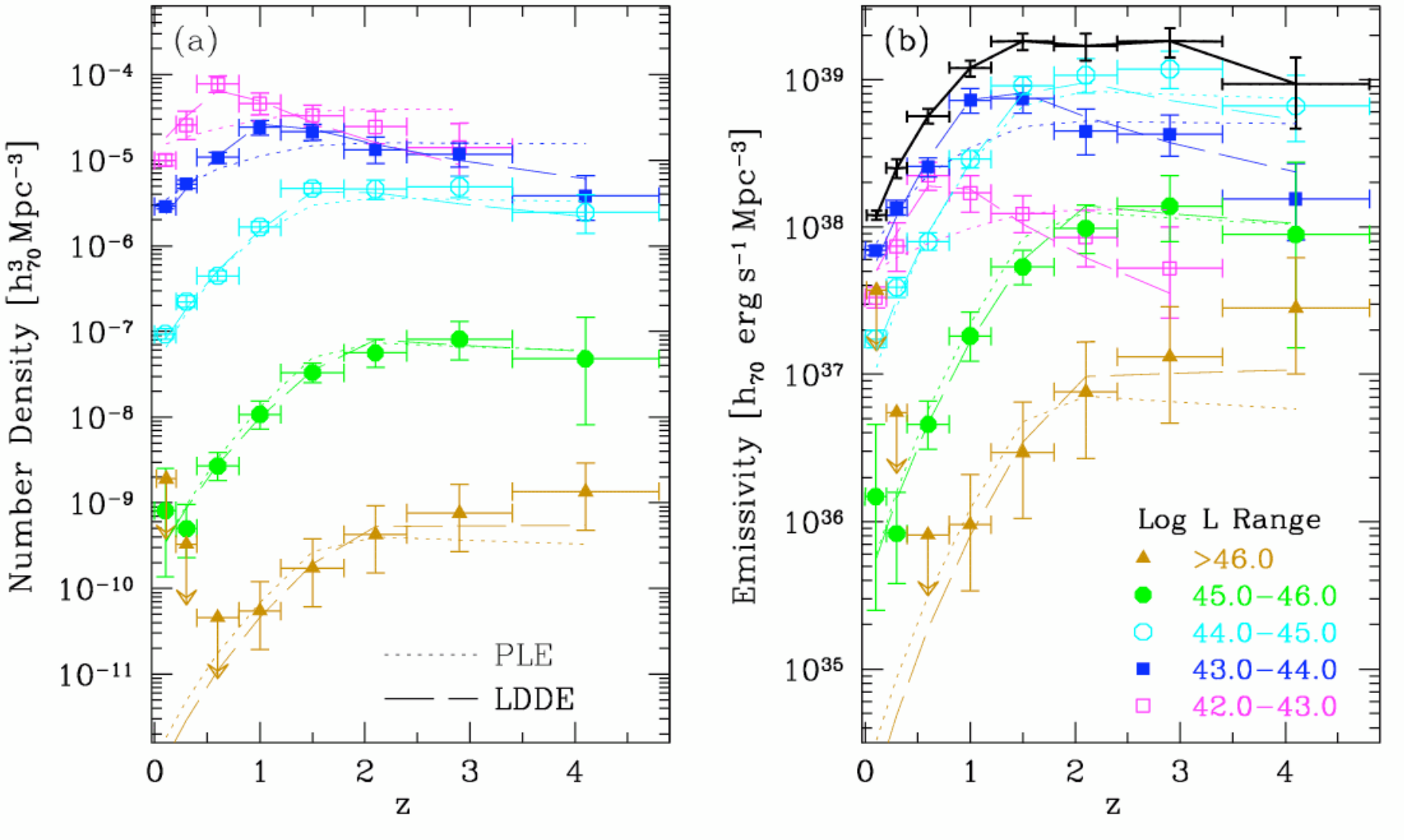


Gilli, Comastri & Hasinger 2007

The bulk of the cosmic X-ray background below 10 keV has been resolved:

0.5–2 keV: 94±7%, 2–10 keV: 89±7% (Moretti et al. 2003)
1–2 keV: 77±3%, 2–8 keV: 80±8% (Hickox & Markevitch 2006)

History of MBH growth: first the big, then the small

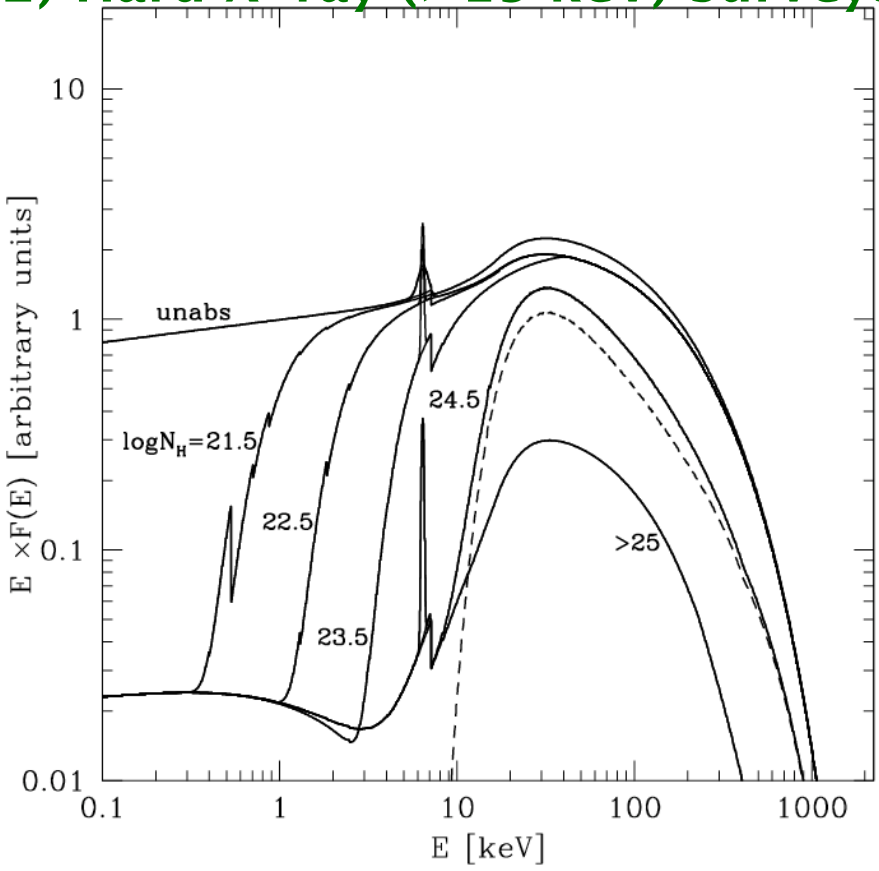


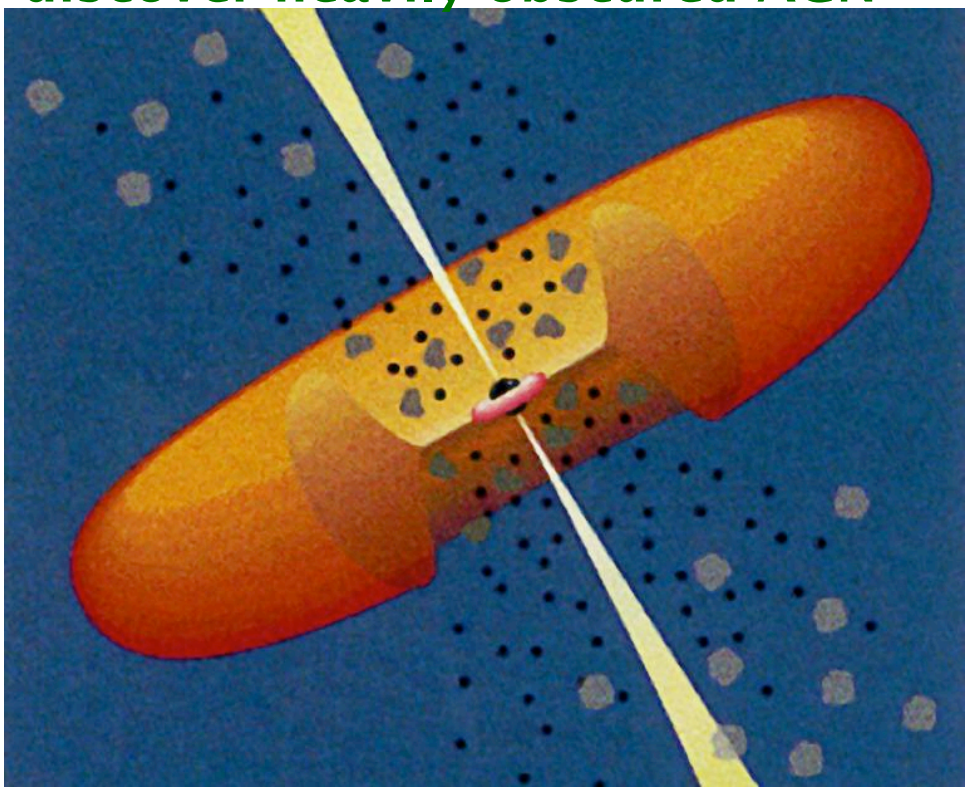
AGN-1, 0.5-2 keV Hasinger et al.

Deep X-ray surveys have taught us a lot, but we need complementary surveys of two kinds:

1) Large area shallow surveys to have a census of AGN at low redshift and of most luminous quasars at all redshifts

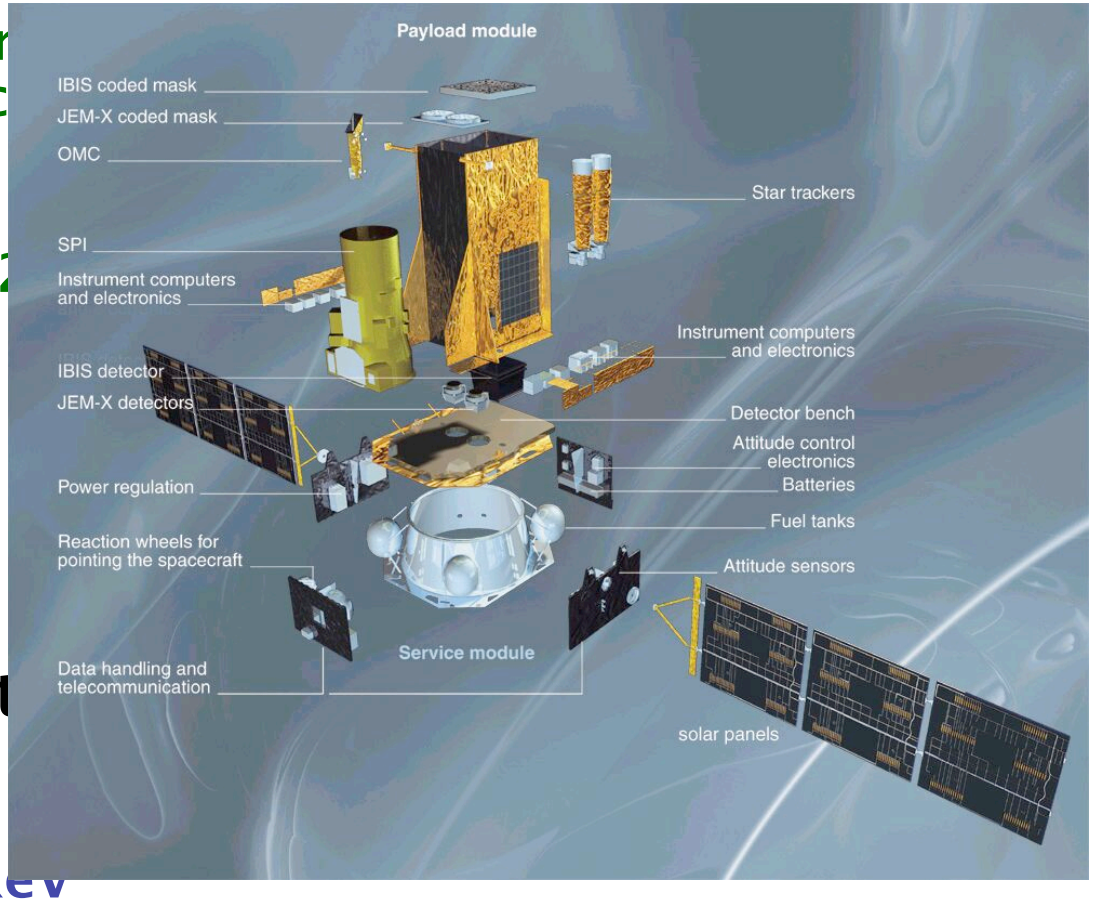
2) Hard X-ray (>15 keV) surveys to discover heavily obscured AGN





INTErnational Gamma-Ray Laboratory

- Launched October 17, 2002 fro
  Baikonur by Russia's Proton roc
- In a high 72-hour orbit
- ESA payload
- Extended till December 31, 201



Coded mask imager IBIS wit
the ISGRI detector

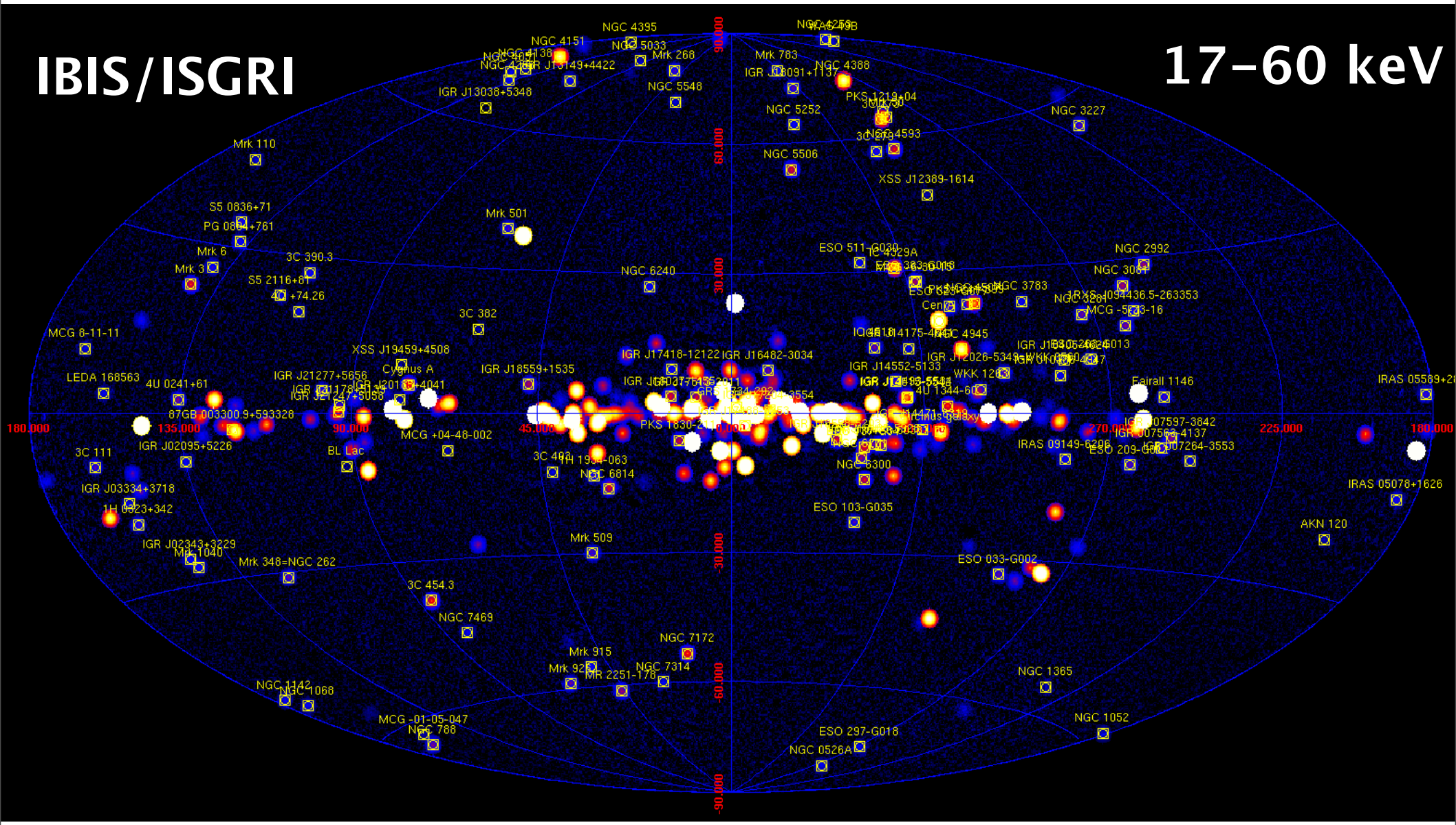
- Effective energy band: 15-300 kev
- Detector area: 2,600 cm^2
- Field of view: 28°x28°, 9°x9° fully coded
- Angular resolution: 12 arcmin
- Localization accuracy: 2-3 arcmin for weak sources, <1 arcmin for bright ones

INTEGRAL All-Sky Survey (Dec 2002 – June 2006)

Mostly serendipitous + a program of “empty field” observations

12% sky – 1 mCrab, 80% – 5 mCrab in 17–60 keV

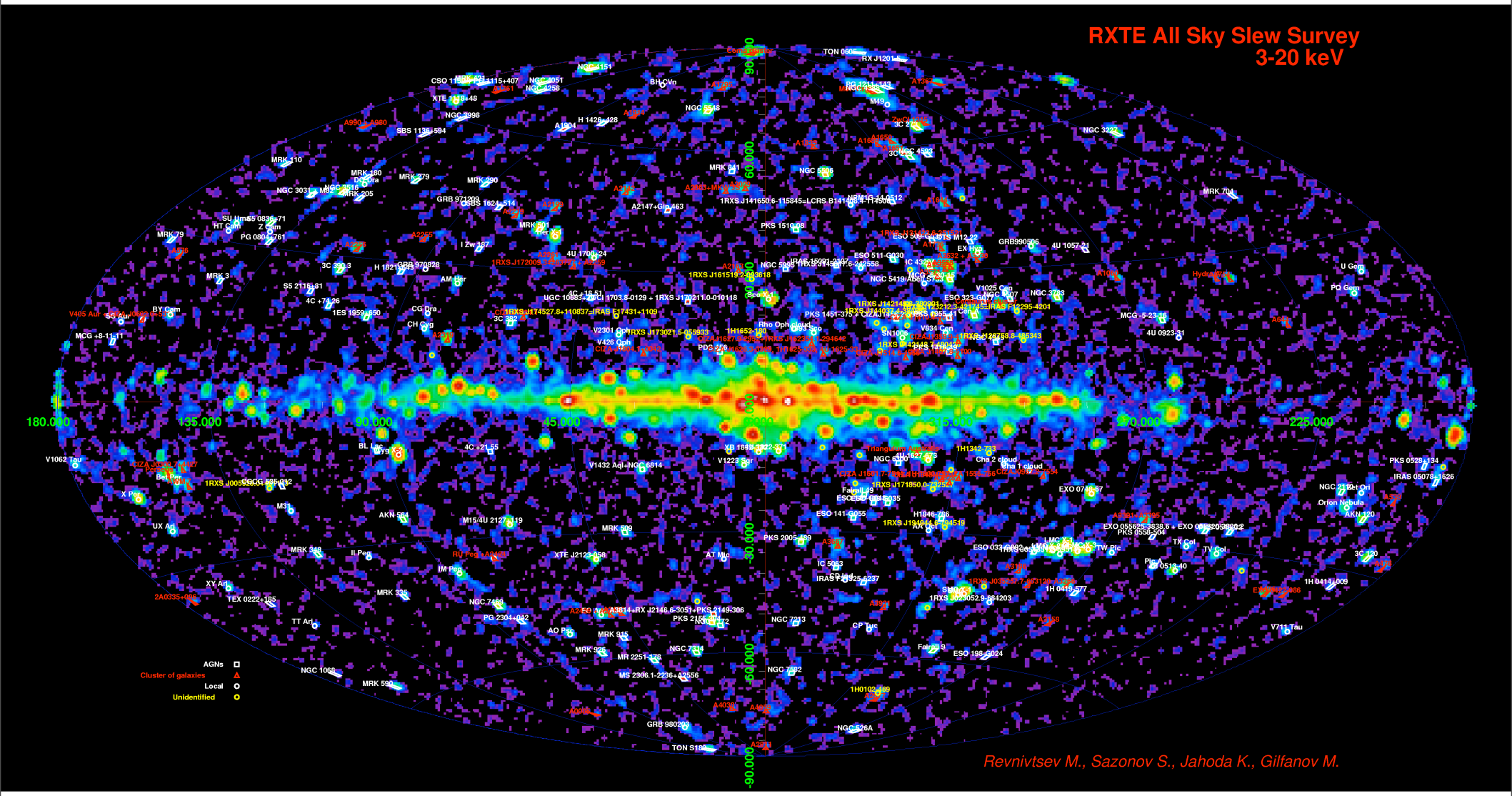
All-sky map



403 sources, including 131 confirmed AGN
(as of mid-2006)

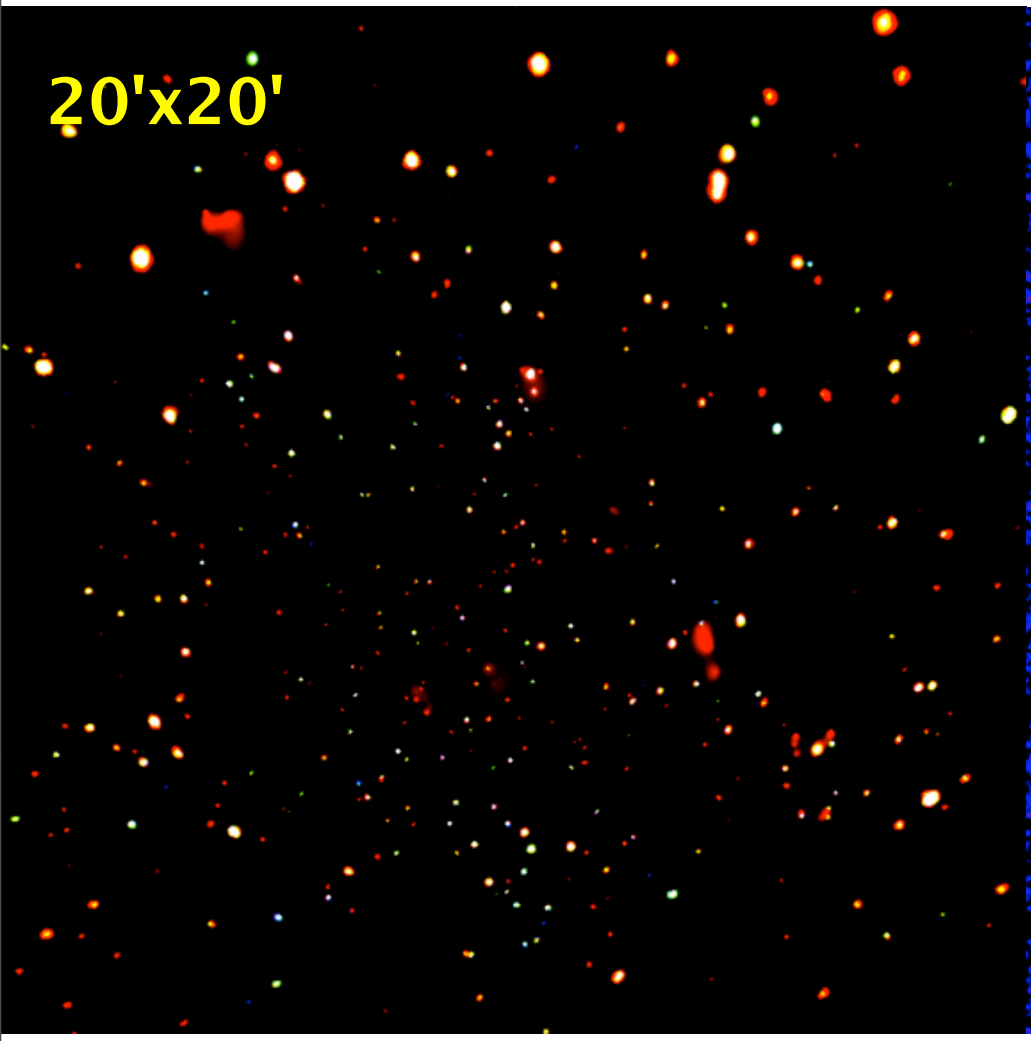
Krivonos et al.
2007

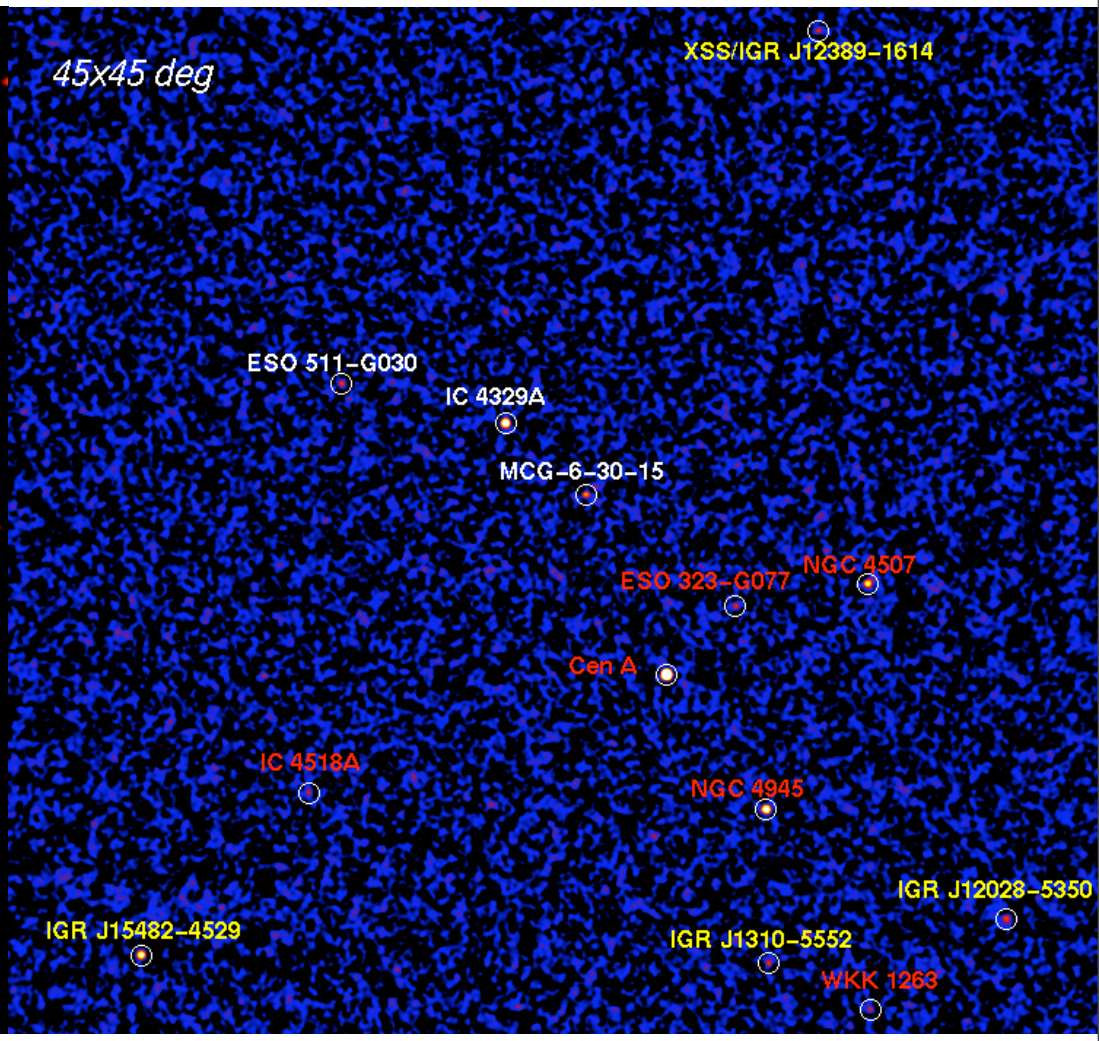
RXTE 3–20 keV Slew Survey



294 sources at |b|>10°, including 103 confirmed AGN

Revnivtsev et al. 2004
Sazonov, Revnivtsev 2004





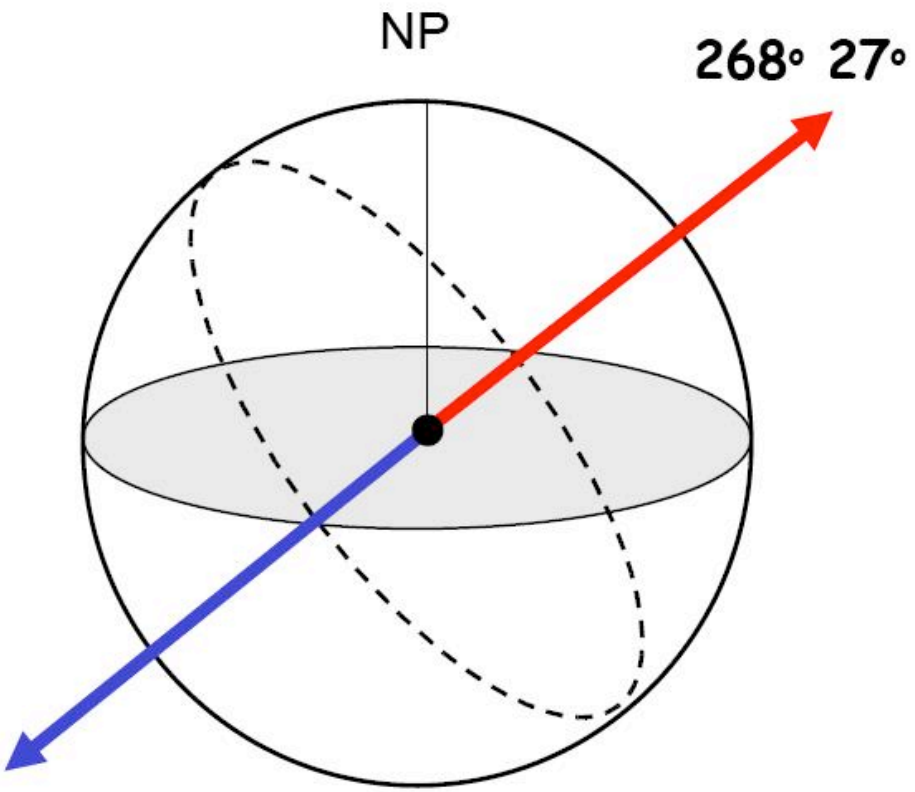
Chandra Deep Field North

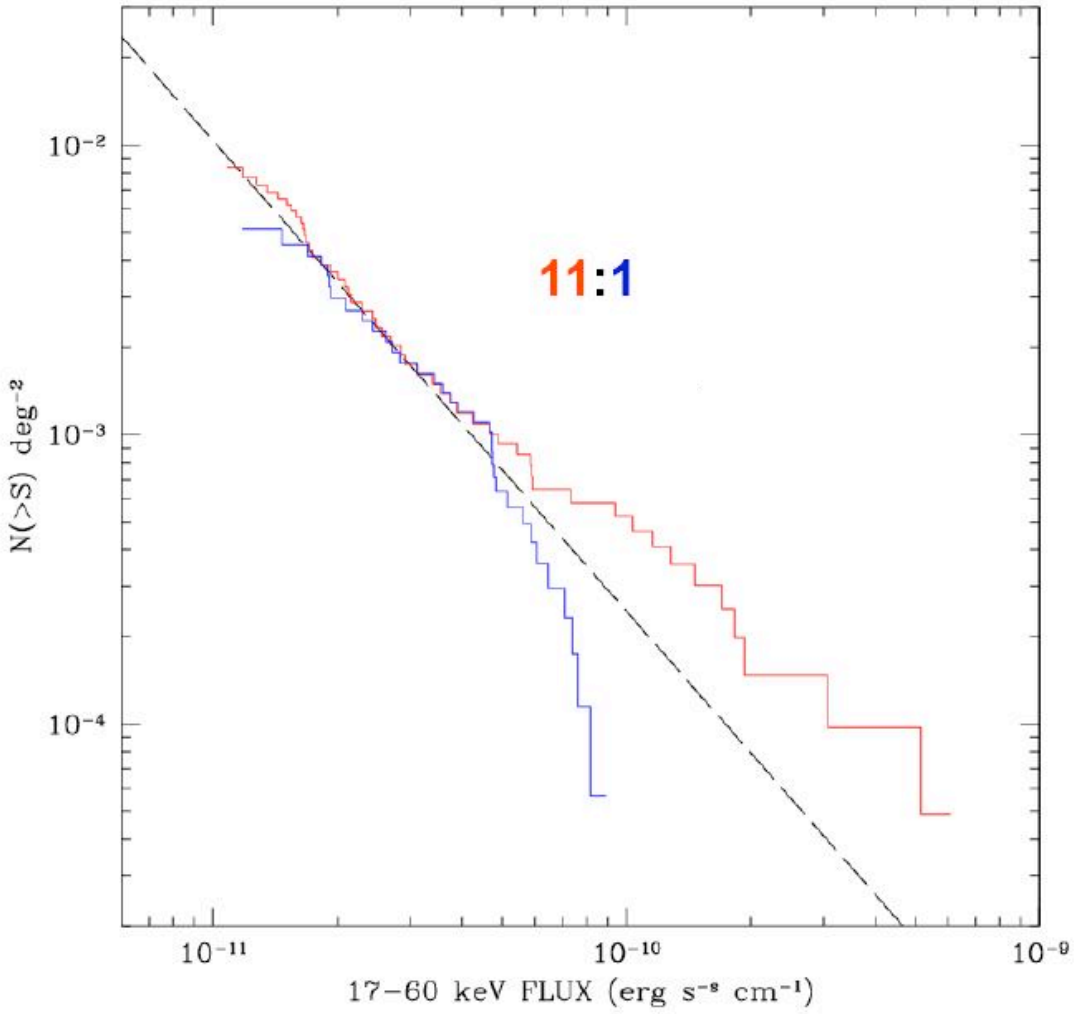
>80% of the CXB below few keV is resolved into distant AGN

INTEGRAL Cen-Shapley region

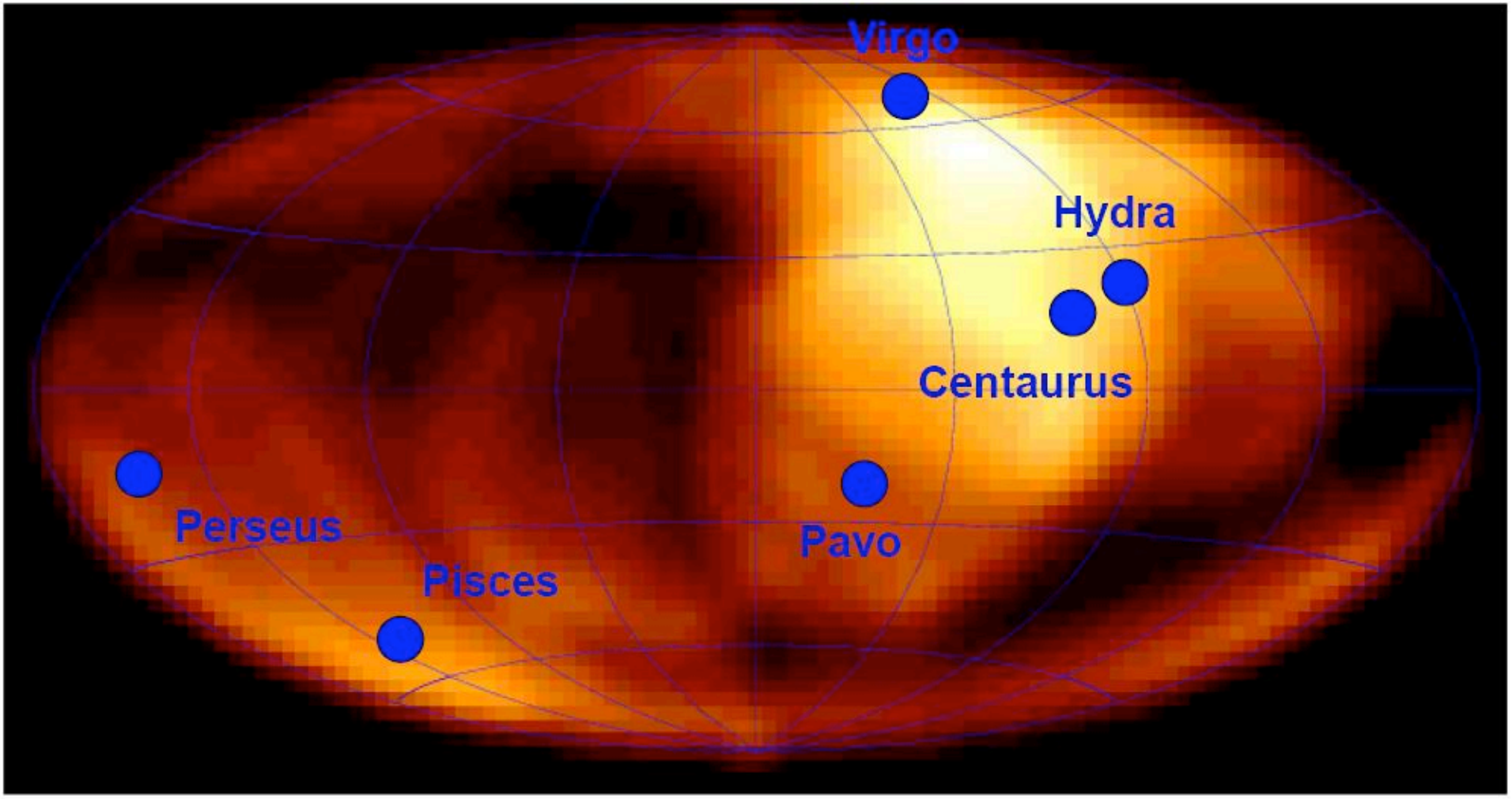
1-2% of the CXB at 17-60 keV is resolved into nearby AGN

log N – log S of extragalactic sources (AGN)





AGN space density (D<70 Mpc) reveals local



40 AGNs

$n = 1.4 \times 10^{-3}$ / Mpc^3 , $L > 10^{41}$ erg/s

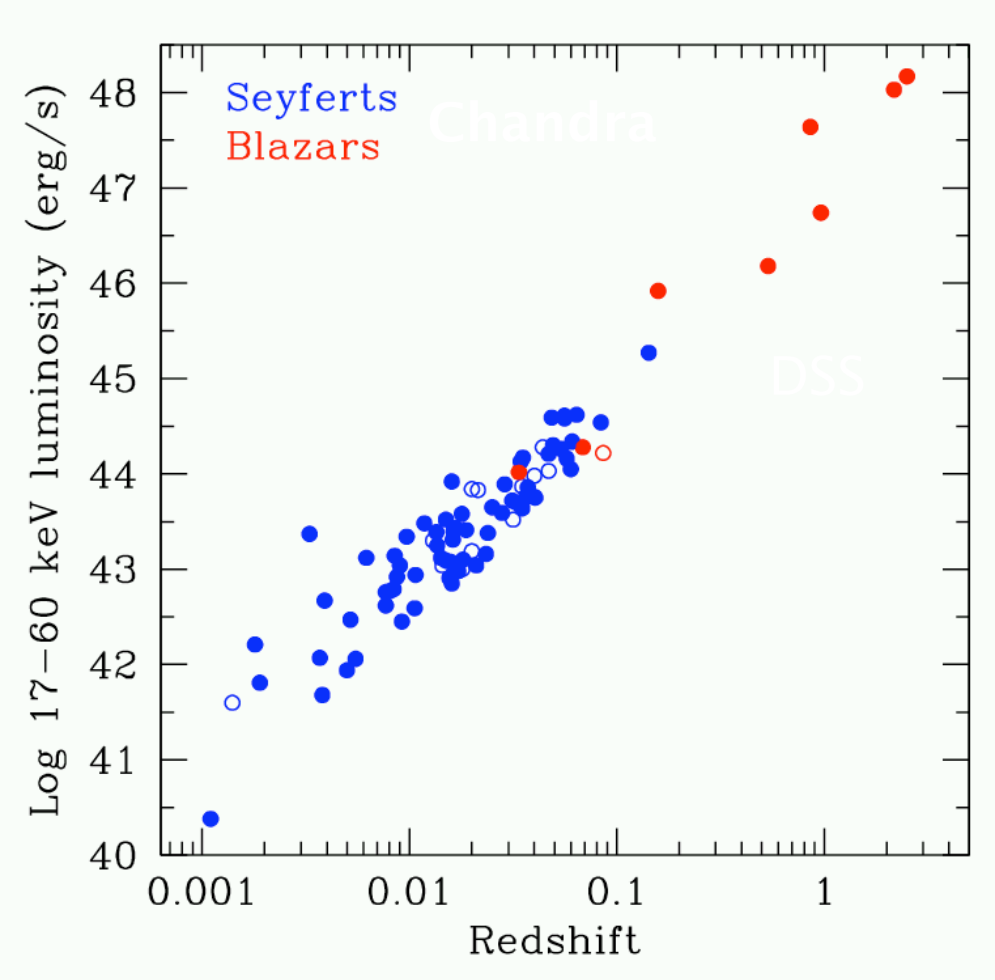
INTEGRAL AGN catalog

All sky:

94 AGN (86 Seyferts, 8 blazars)
+37 AGN temporarily detected
+40 unidentified sources

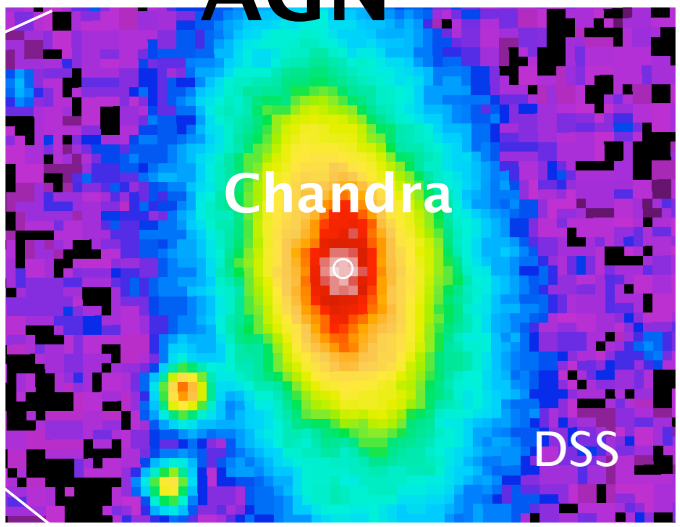
|b|>5°:

76 AGN (68 Seyferts, 8 blazars)
+7 unidentified sources

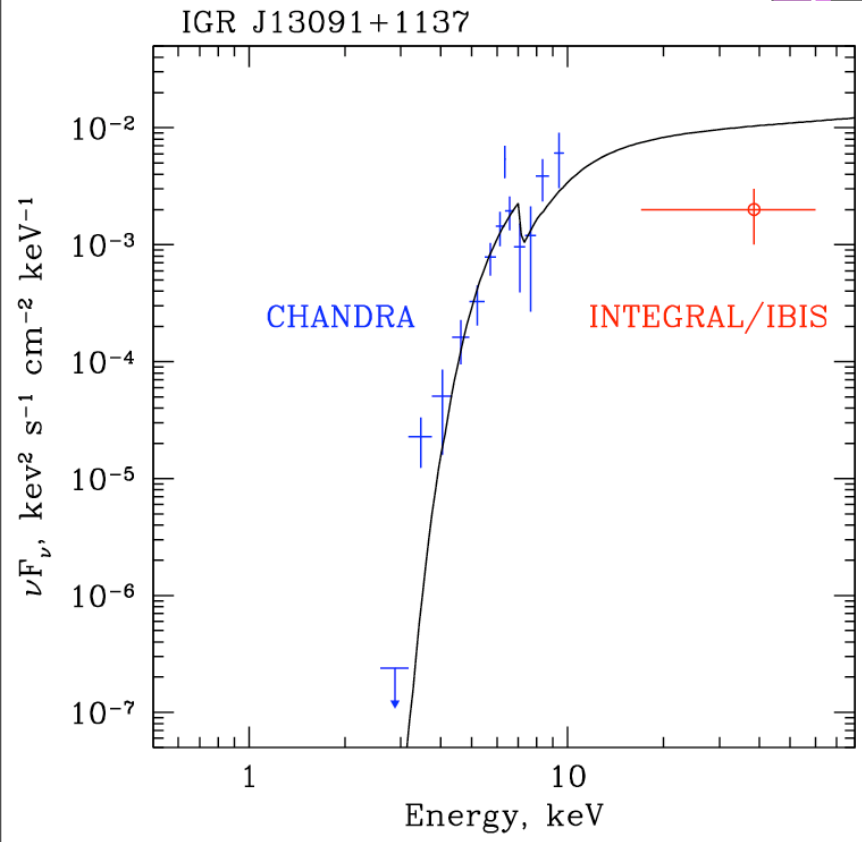


Identification program: discovery of obscured AGN

R=3'



NGC 4992
Sa galaxy at
z=0.0251



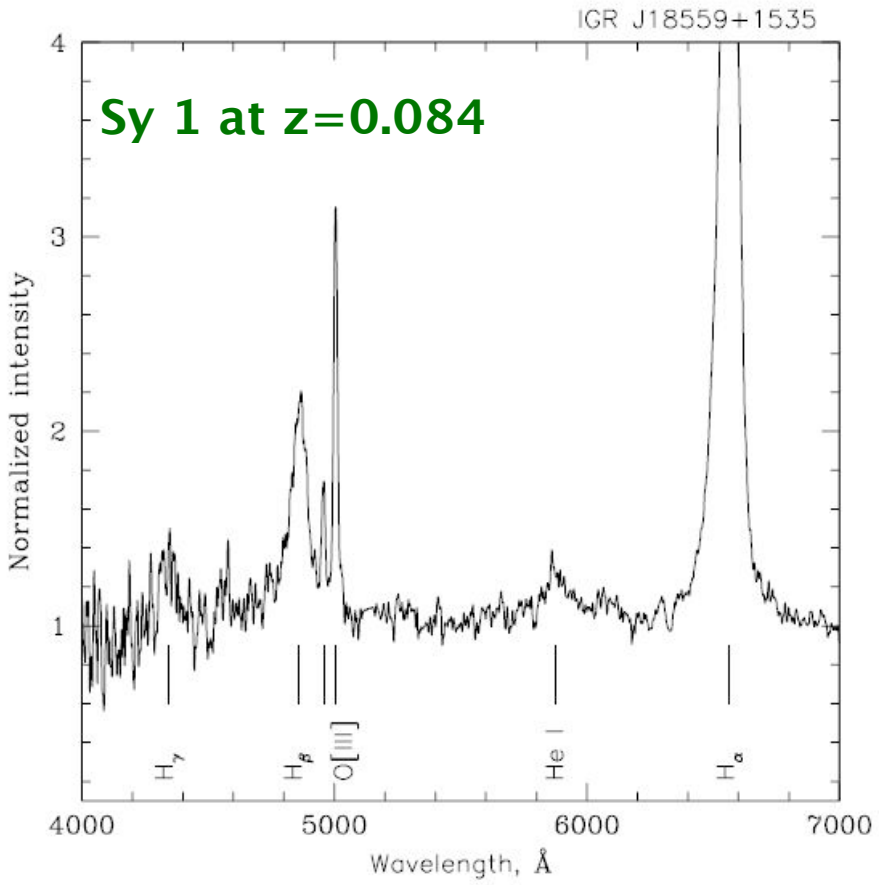
$N_H=(9\pm1)\ 10^{23}$ см$^{-2}$ (Sazonov et al. 2005)

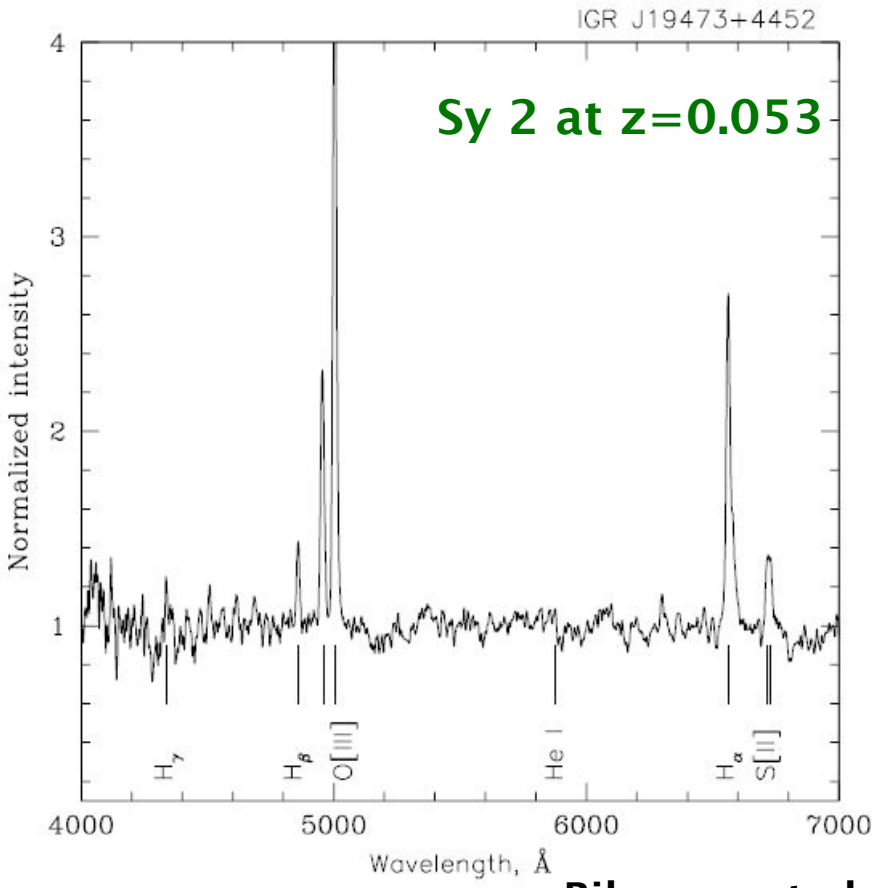
⇨ nearly Compton thick AGN

No optical emission lines (Masetti et al. 2007)

⇨ nearest X-ray bright, optically normal galaxy!

Optical follow-up

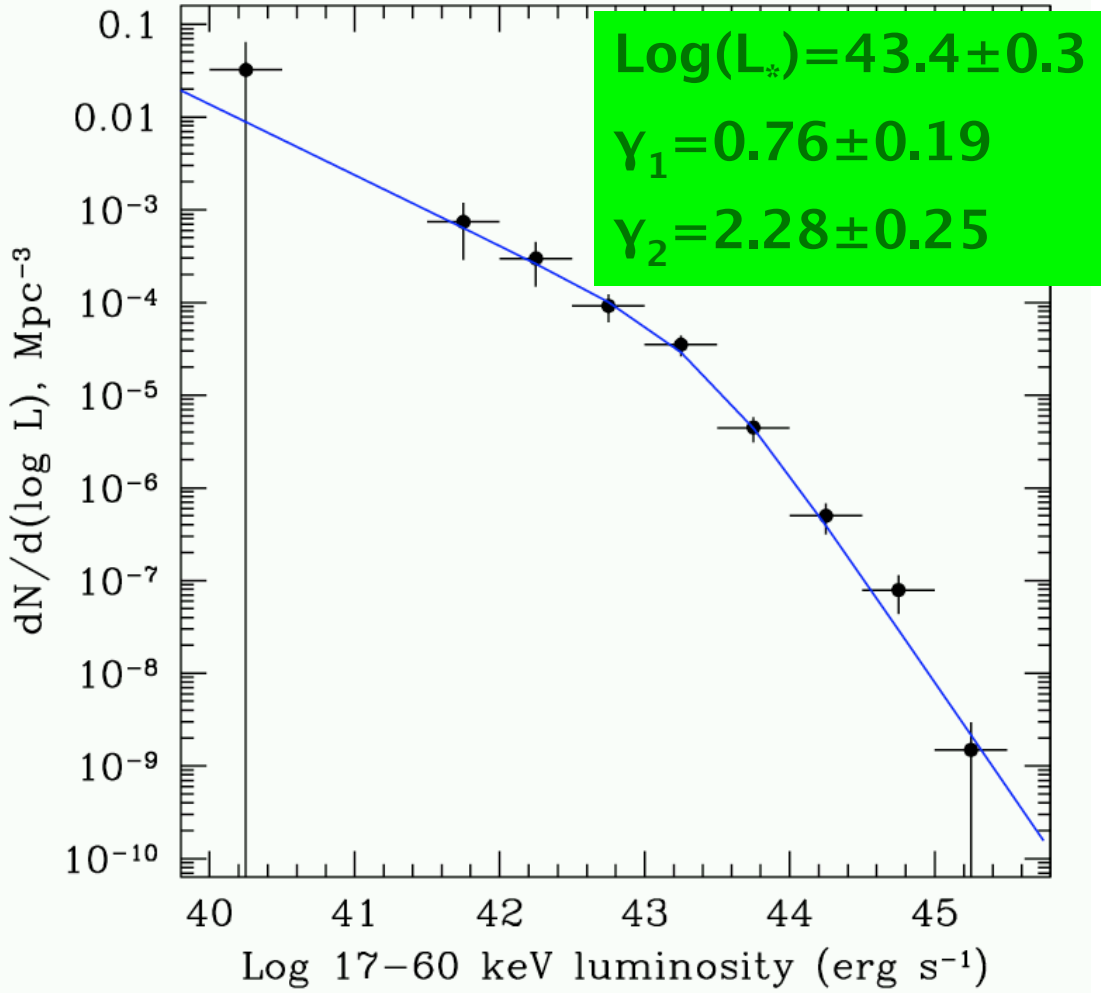




Bikmaev et al. 2005

Identification and classification usually straightforward with a 1.5-m class telescope
(e.g. Russian-Turkish Telescope, Antalya), once the localization is improved with
Chandra or Swift/XRT but often even without that

Hard X-ray luminosity function



Sazonov et al. 2007

AGN number density:

$n(L>10^{41})=$
$(1.4\pm0.6)\ 10^{-3}\ \mathrm{Mpc}^{-3}$

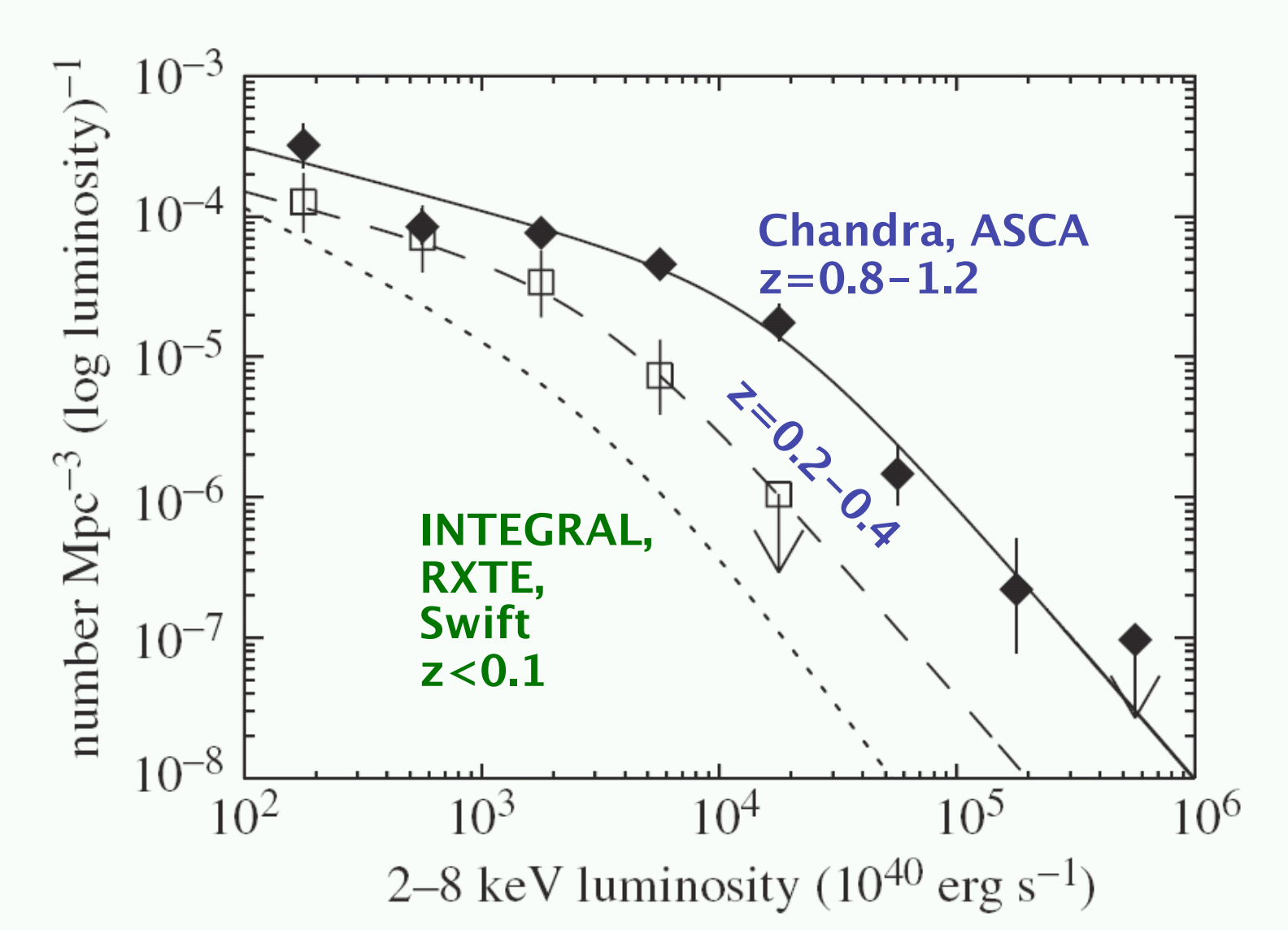
AGN luminosity density:

$\epsilon_{17\text{-}60\ \mathrm{keV}}\ (L>10^{41})=$
$(12.4\pm1.5)\ 10^{38}\ \mathrm{erg/s/Mpc}^3$

In good agreement with:

- Beckmann et al. 2006 (smaller INTEGRAL sample)
- RXTE Slew Survey 3-20 keV LF (Sazonov & Revnivtsev 2004)
- HEAO-1 2-10 keV LF (Shinozaki et al. 2006)
- Swift (Tueller et al. 2007)

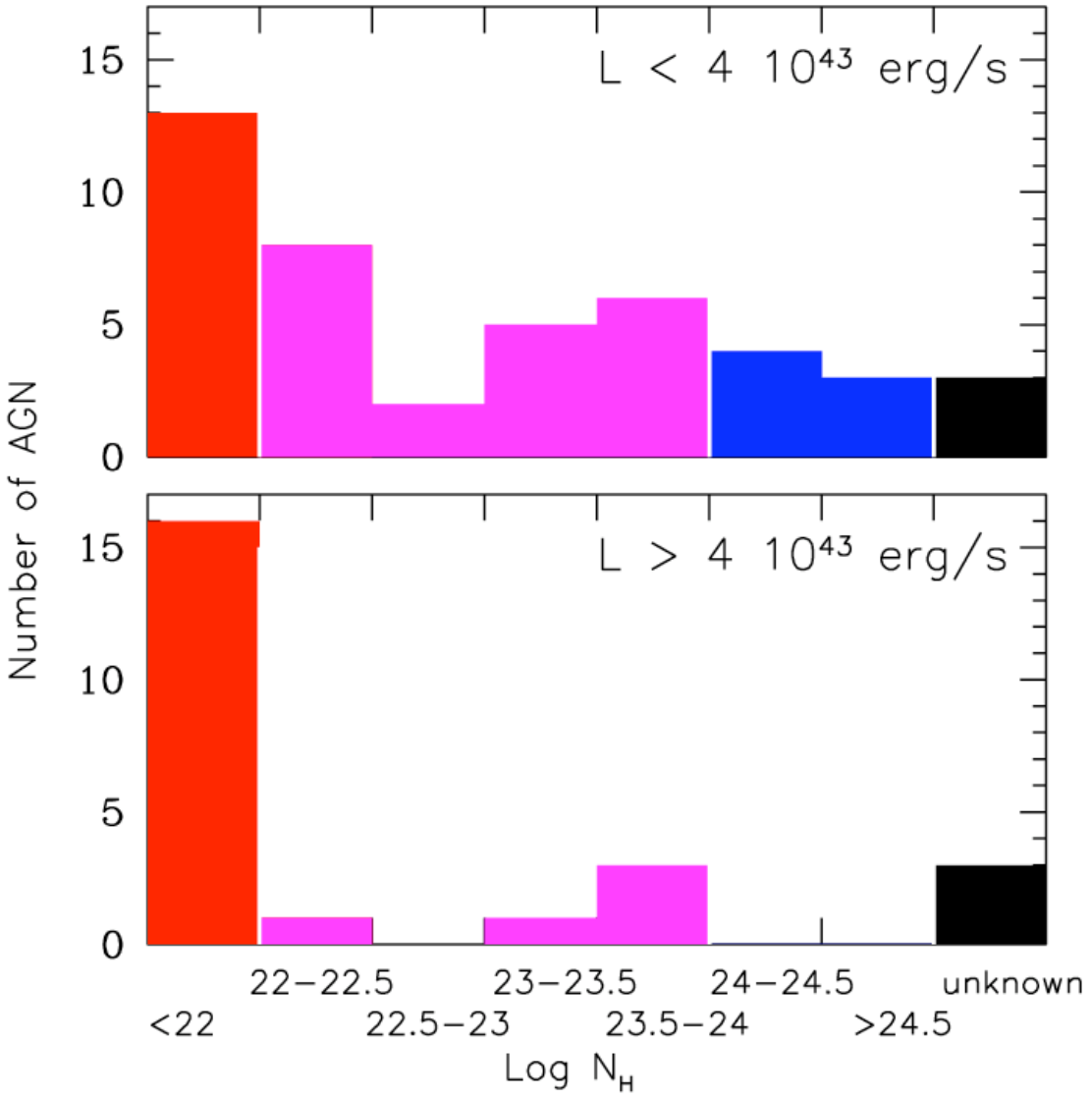
AGN downsizing continues at z~0



Barger et al. 2005

$L_* \sim (1+z)^3$ $(z<1)$

Obscured vs. unobscured AGN

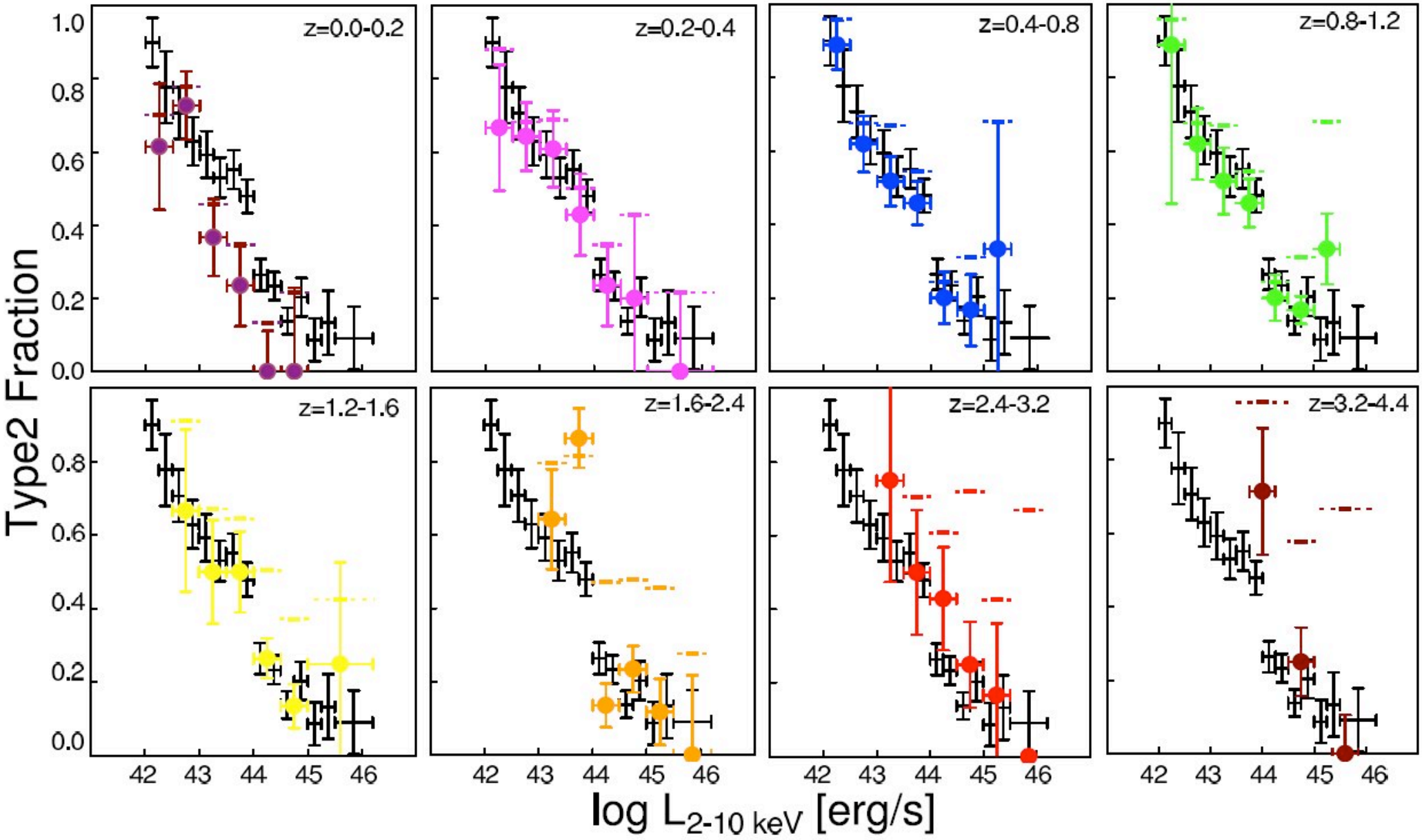


- Fraction of obscured AGN decreases from 65–70% at low L to 20–30% at high L
- Only 10–15% of AGN are Compton thick – all at low L

Same luminosity trend was seen by RXTE (Sazonov & Revnivtsev 2004) and is being observed by Swift (Tueller et al. 2007)

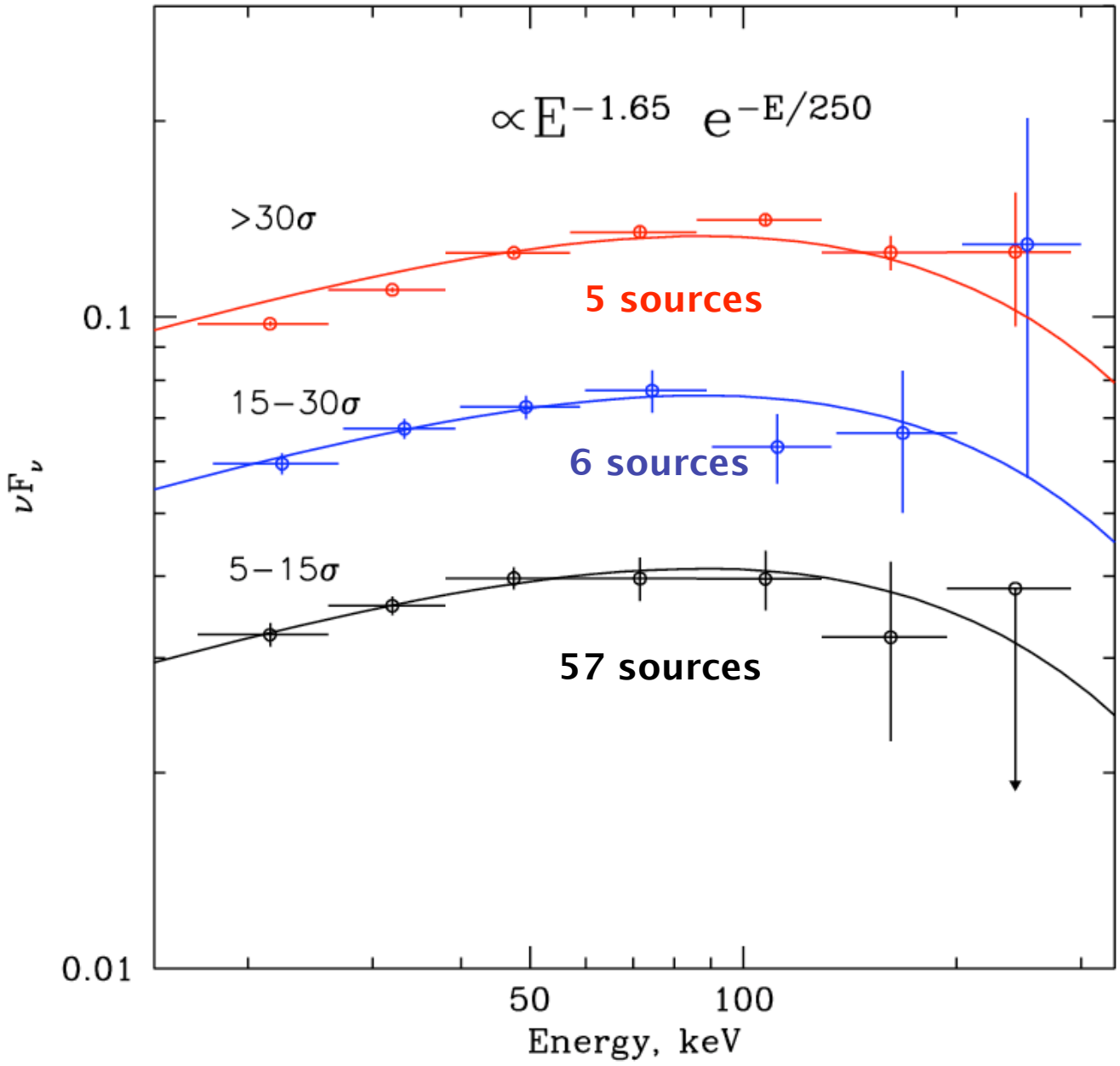
Simplest AGN unification doesn't work!

Similar trends are seen at higher redshifts



Mueller & Hasinger 2007

Average hard X-ray SED of local AGN



Simple stacking:

$S=\Sigma f_i$

Space density weighted sum: $S=\Sigma L_i / V_{max,i}$

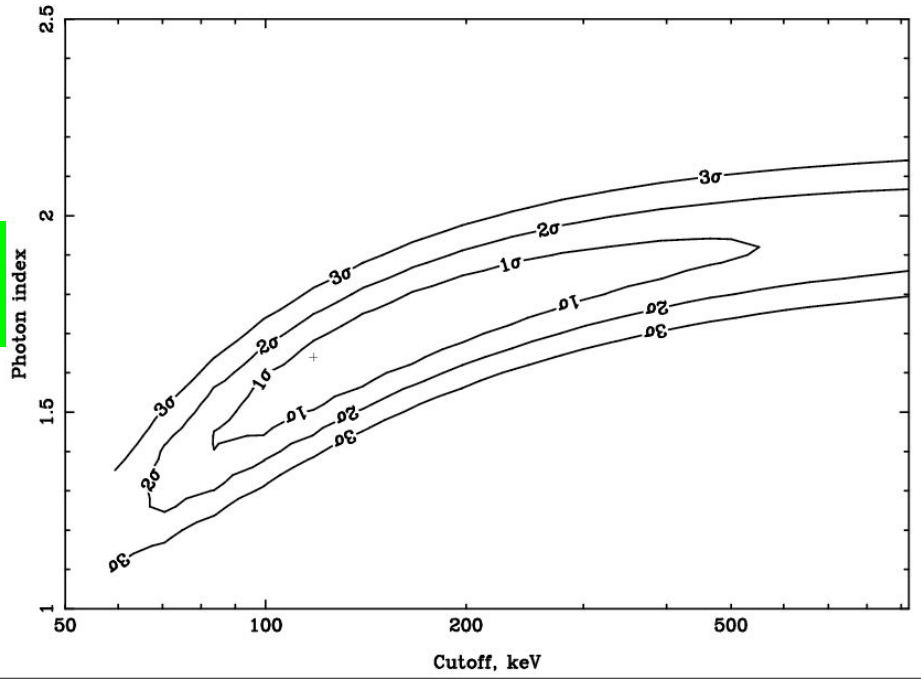
$L<10^{43.5}$ erg/s

νF_ν, 10^{39} erg/s/Mpc^3

10 100

Energy, keV

Model: $\Sigma f(N_H) E^{-\Gamma} e^{-E/Ecut}$



zonov et al., submitted to A&A

Space density weighted sum: $S=\Sigma L_i / V_{max,i}$

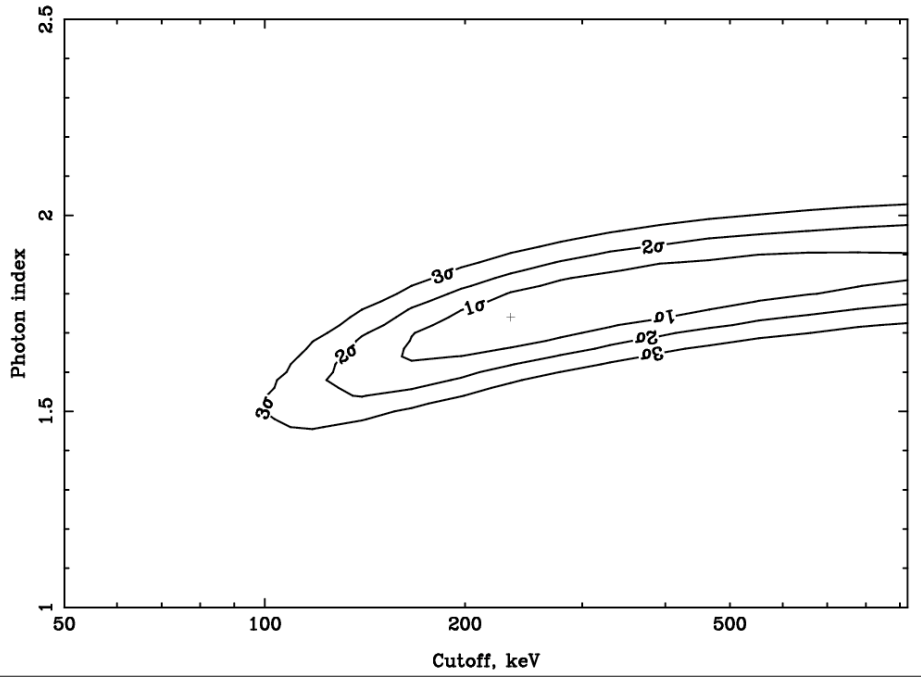
$L>10^{43.5}$ erg/s

νF_ν, 10^{39} erg/s/Mpc^3

10 100

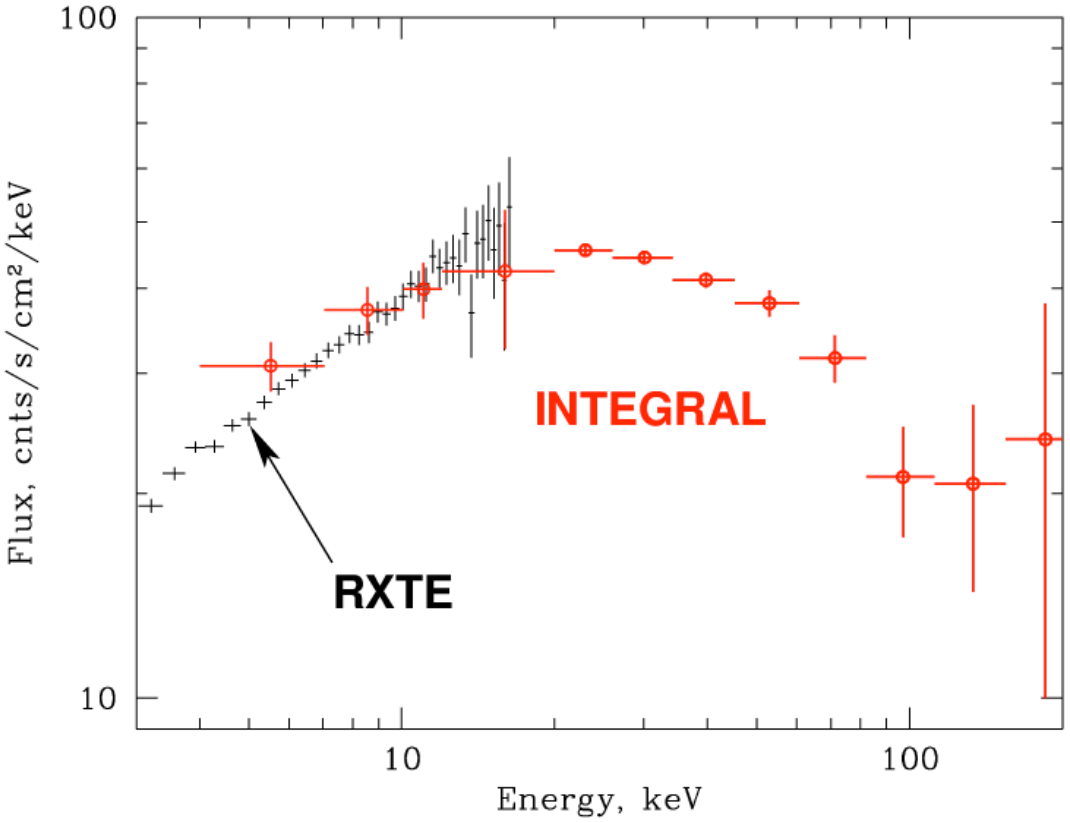
Energy, keV

Model: $\Sigma f(N_H) E^{-\Gamma} e^{-E/Ecut}$

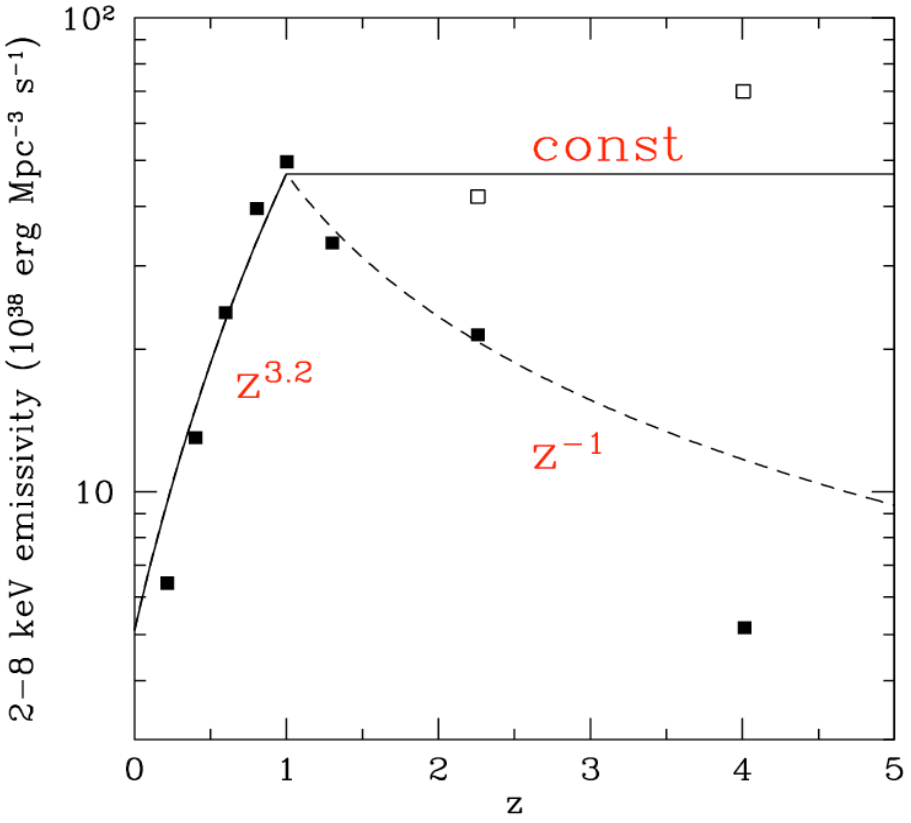


zonov et al., submitted to A&A

Spectrum of Cosmic X-ray background



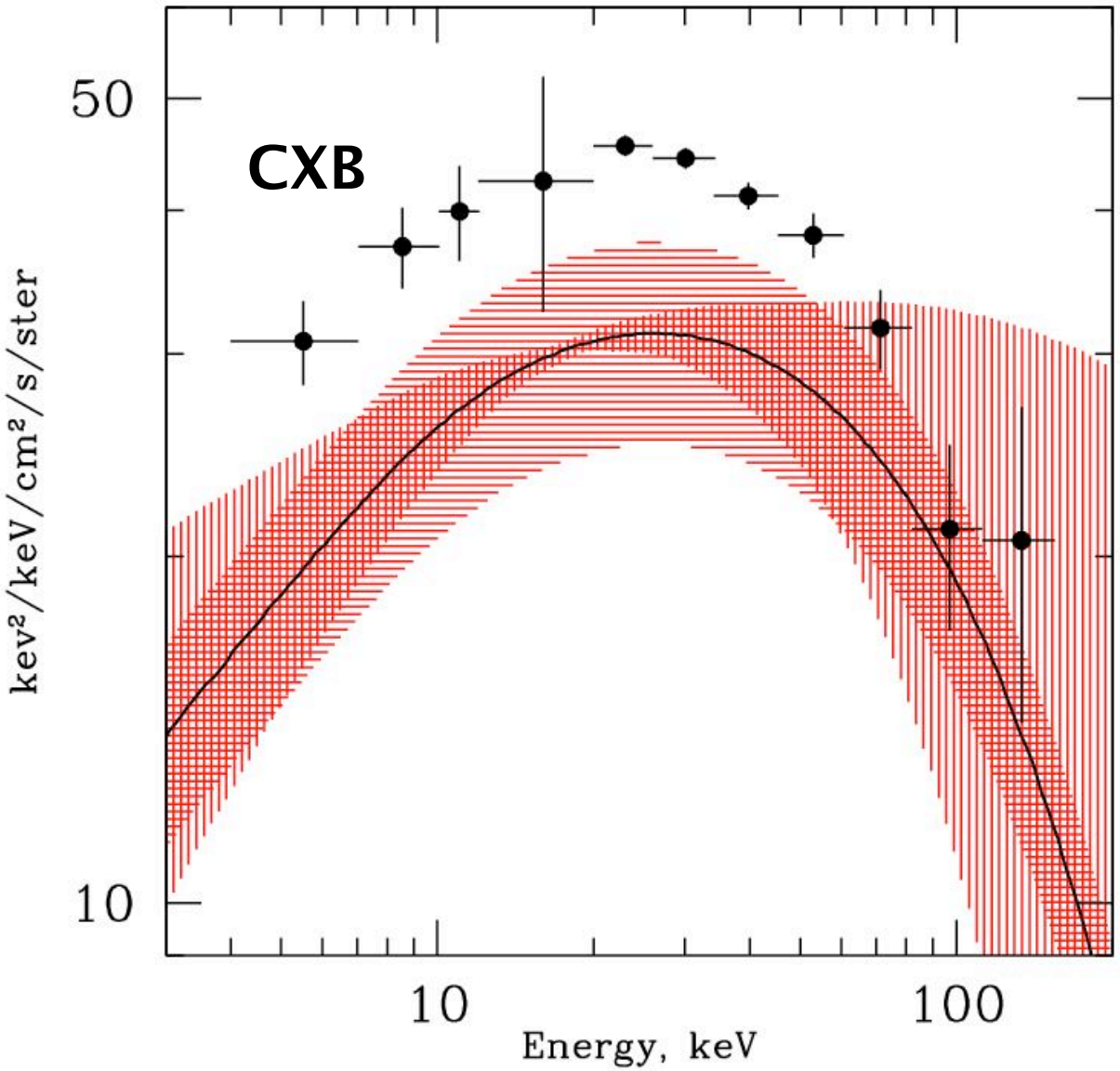
Evolution of AGN X-ray luminosity density



Barger et al. 2005

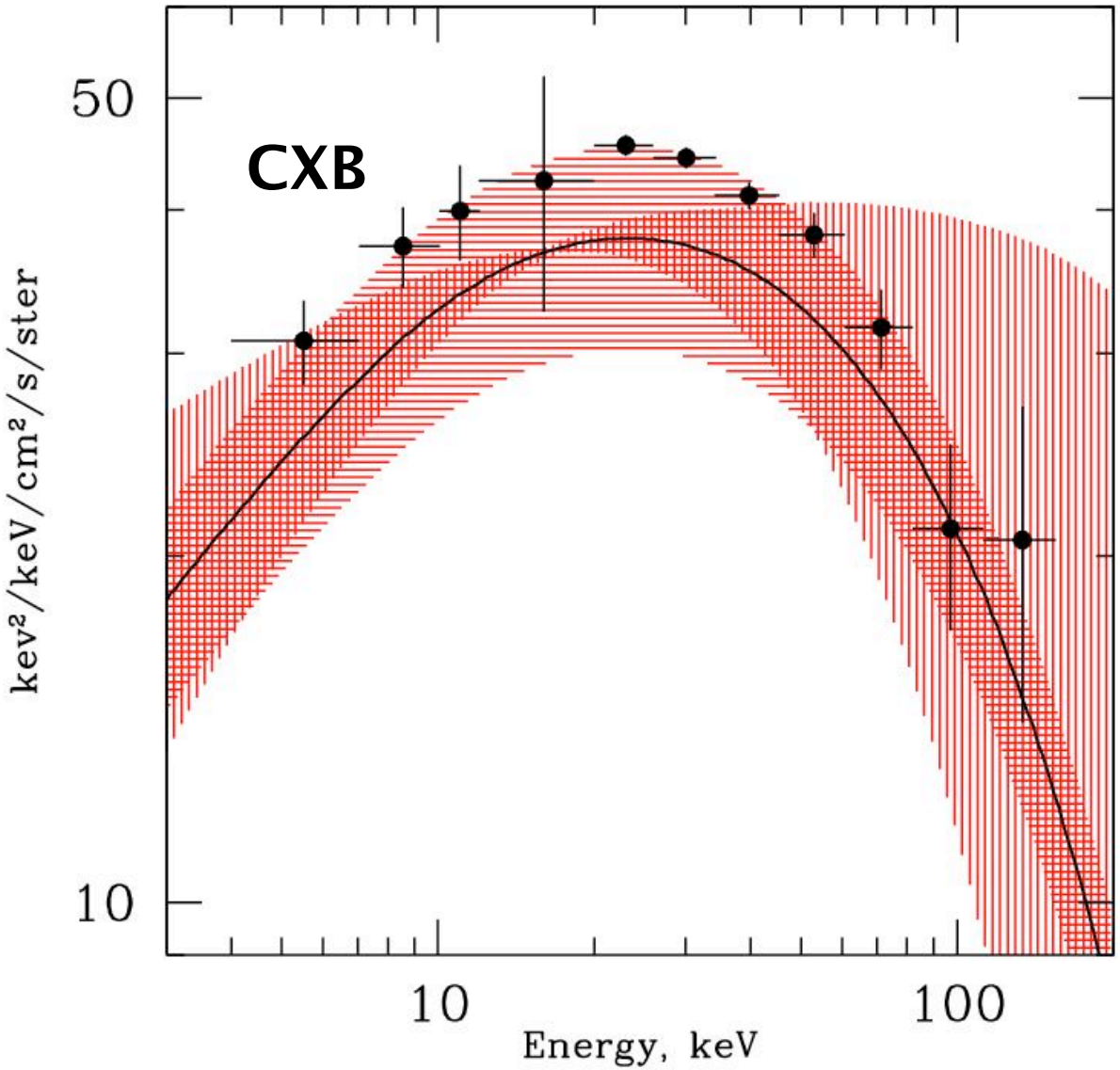
Let's convolve average local AGN SED with z-dependence

$\epsilon \sim 1/z$ at $z>1$



Let's convolve average local AGN SED with z-dependence

ϵ = const at z>1



Consistent with the CXB spectrum! (within large uncertainties)

Main results from the INTEGRAL survey so far

- Local ratio of obscured to unabscured AGN drops from 2:1 at low luminosities to 1:3 at high luminosities. The same trend is seen in deep surveys at higher redshifts. Does this mean that AGN feedback on the dusty torus is important or something else?

- Observed fraction of Compton-thick AGN is significant (~15%), but not as large as some early expectations. But we do not know yet the space density of extremely thick objects ($N_H > 10^{24.5}$ cm^{-2}) – infrared surveys could help.

- Average properties of local AGN – hard X-ray luminosity density, column density distribution, and high-energy cutoff – are all consistent (within large uncertainties) with the CXB spectral shape and flux if the local AGN population is just a downsized version of that at z=1-2.

Future work

- Complete identification of INTEGRAL sources near the Galactic plane and around the Galactic Center – unique possibility of studying LSS in the Zone of avoidance. In combination with Swift at high Gal. latitudes, <1 mCrab hard X-ray coverage of the whole sky will soon be achieved.

- Using the increased INTEGRAL AGN sample, re-derive the hard X-ray luminosity function, absorption column distribution and improve the average 3-300 keV AGN SED – better constraints on the high-energy spectral cutoff.

- Observe the whole local AGN sample in the infrared with Spitzer (proposal submitted). Study IR – hard X-ray correlations – use for diagnostics of weak sources detected in deep surveys. Construct a representative infrared to hard X-ray SED of local AGN.