Simbol-X and the violent Universe

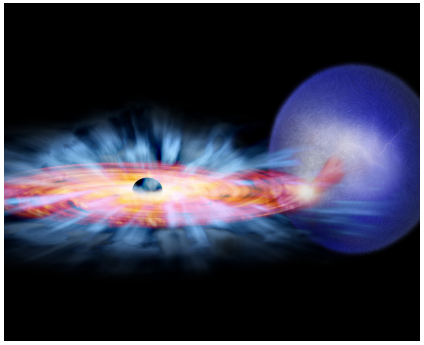
Fabrizio Fiore

on behalf of the Simbol-X JSMG

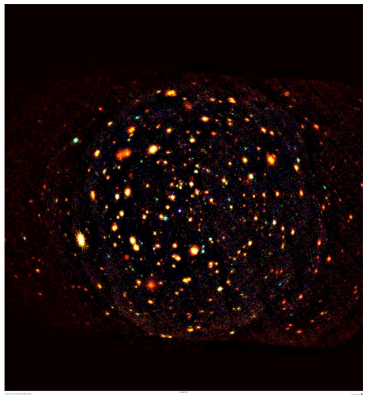
and Core science/observing plan SPST

Importance of the hard X–ray domain

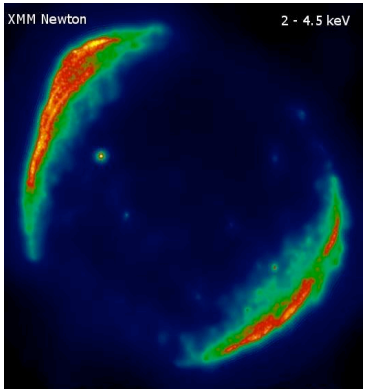
Emissions probing matter under extreme conditions particularly around Black Holes



Domain in which the emission of the Universe is dominated by that of Super Massive Black Holes

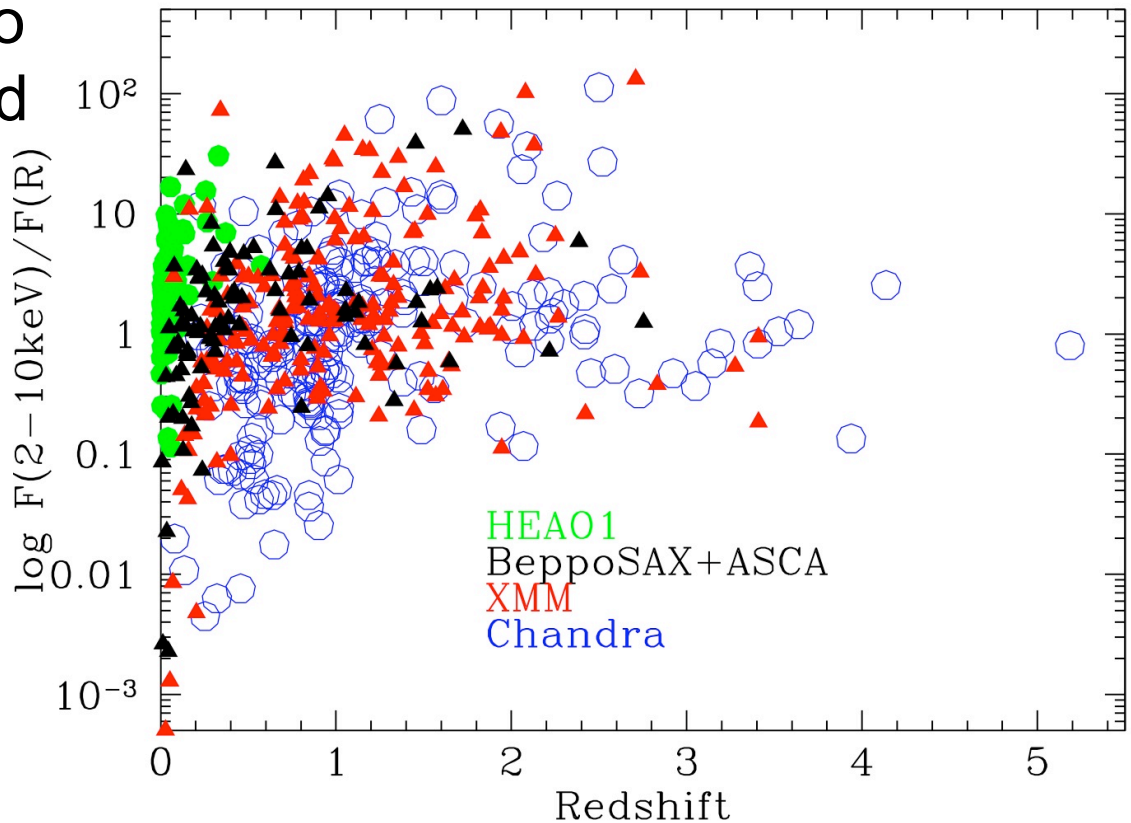


Domain where non-thermal emissions are dominating, directly tracing particle acceleration mechanisms



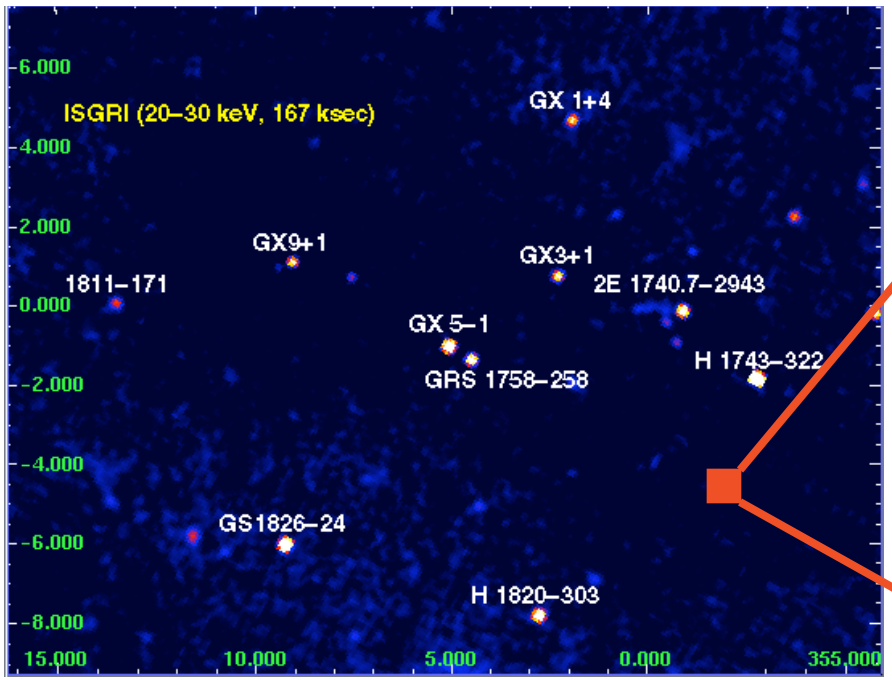
Increasing by 3 orders of magnitude the discovery space at E=10-70 keV

X-ray imaging observations by Einstein and ROSAT at E< 2-3 keV and by ASCA, BeppoSAX, XMM and Chandra up to 10 keV increased by many orders of magnitude the discovery space with respect to collimated and coded mask instruments. They discovered thousands of X-ray sources and resolved ~80% of the CXB below 5-7 keV.

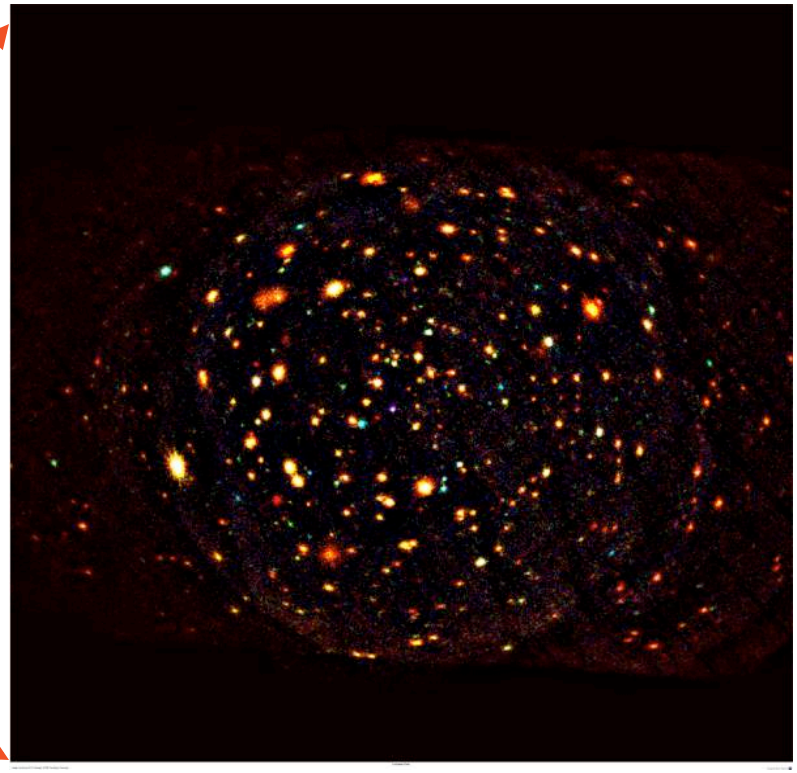


Opening up a new window in X-ray astronomy

Above 10 keV only a few hundred sources known, thanks mainly to the BeppoSAX PDS INTEGRAL and Swift, a situation recalling the pre-Einstein era.



20 degrees

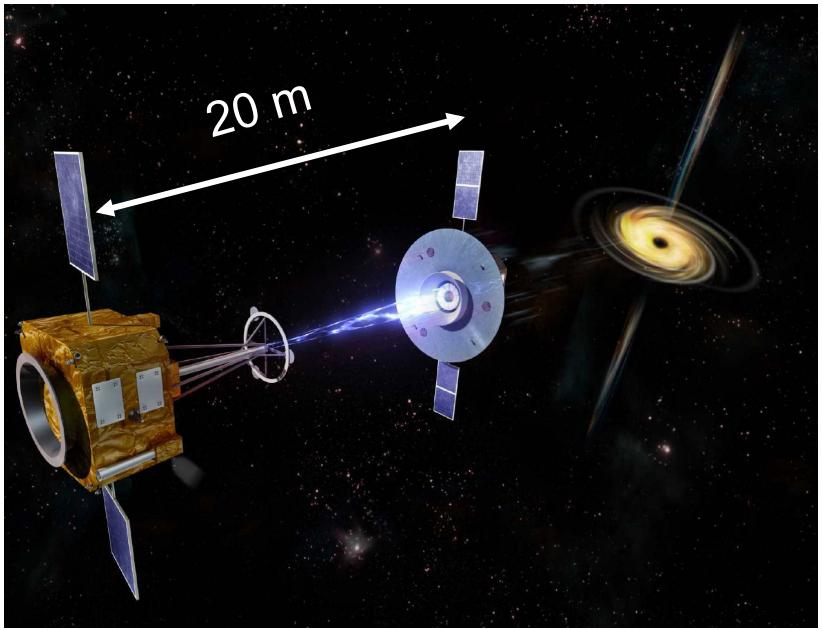


30 arcmin

Simbol-X concept

- Large effective area
- excellent angular resolution
- very low background

} ⇒ focusing



How ?

Extend to the hard X-rays the successful focusing technics based on grazing incidence angle mirrors by using a very long focal length (possible thanks to formation flight) and multi-layer coatings.

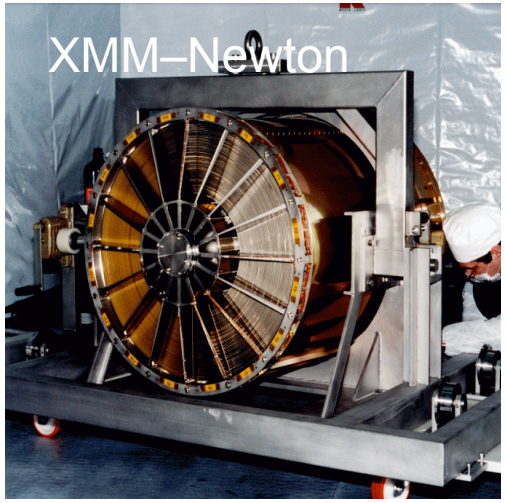
Grazing incidence : Emax ~ 1/θ ~ Focal Length

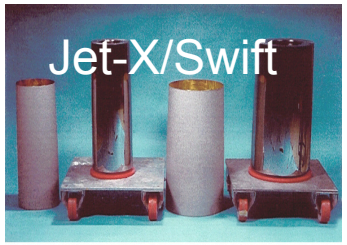
Optics (INAF/O.A. Brera)

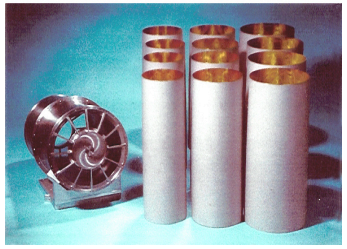
Build on the italian experience in electroforming mirror shells. Media-Lario facilities, upgraded for Simbol-X.

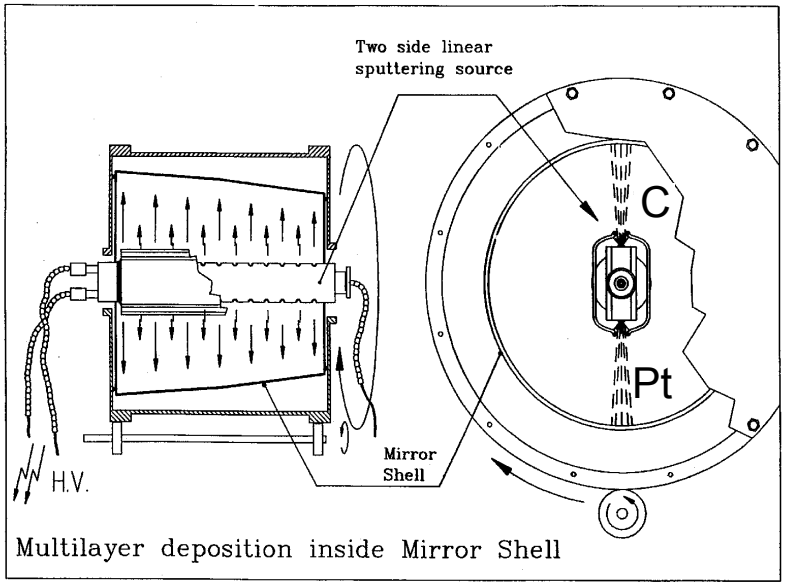
Use reduced thickness for shells, along a demonstrated trend.

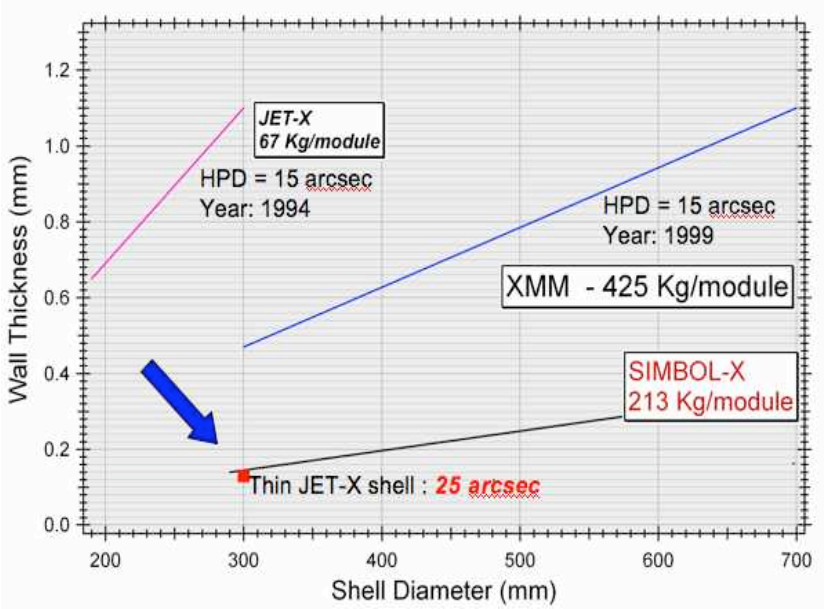
Use multi-layer coating building on experience of OAB/CfA.



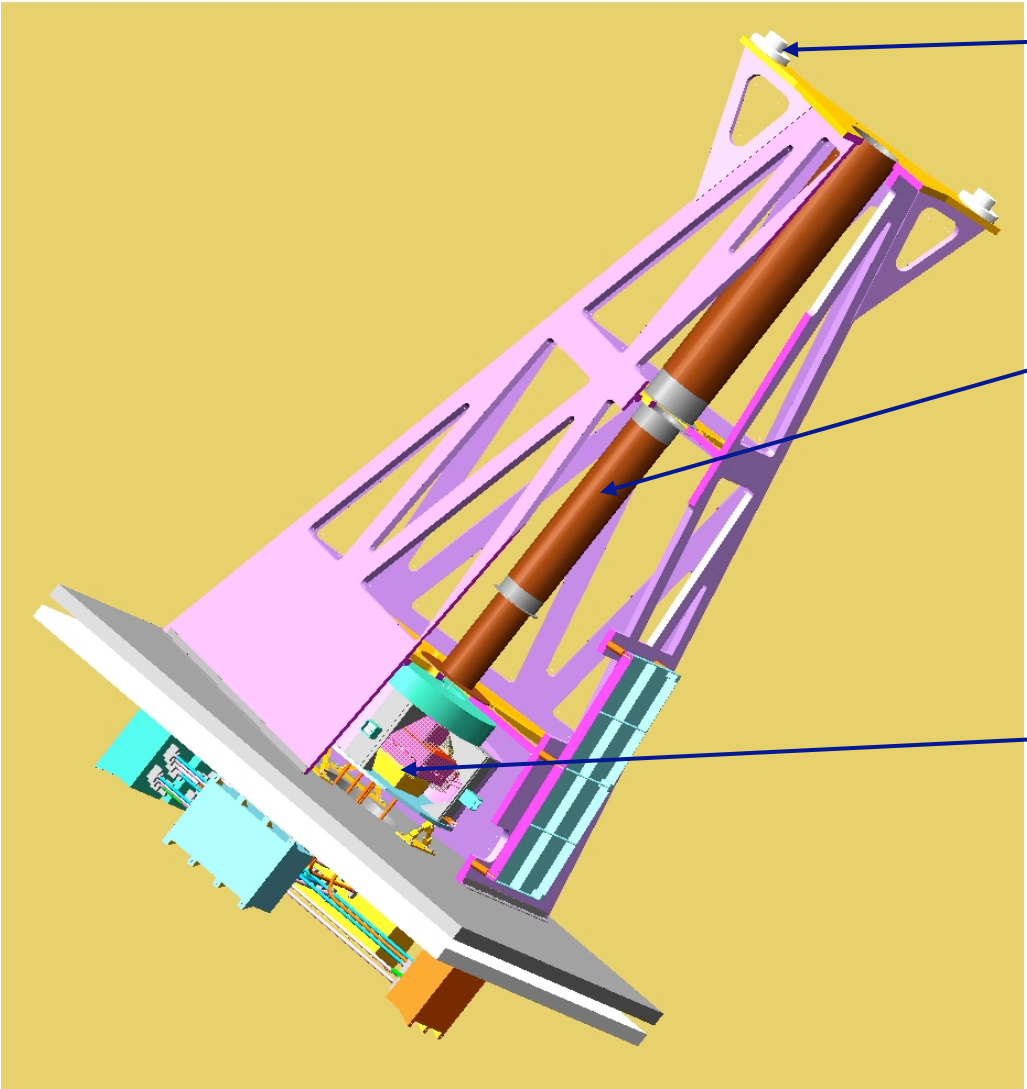








The detector payload



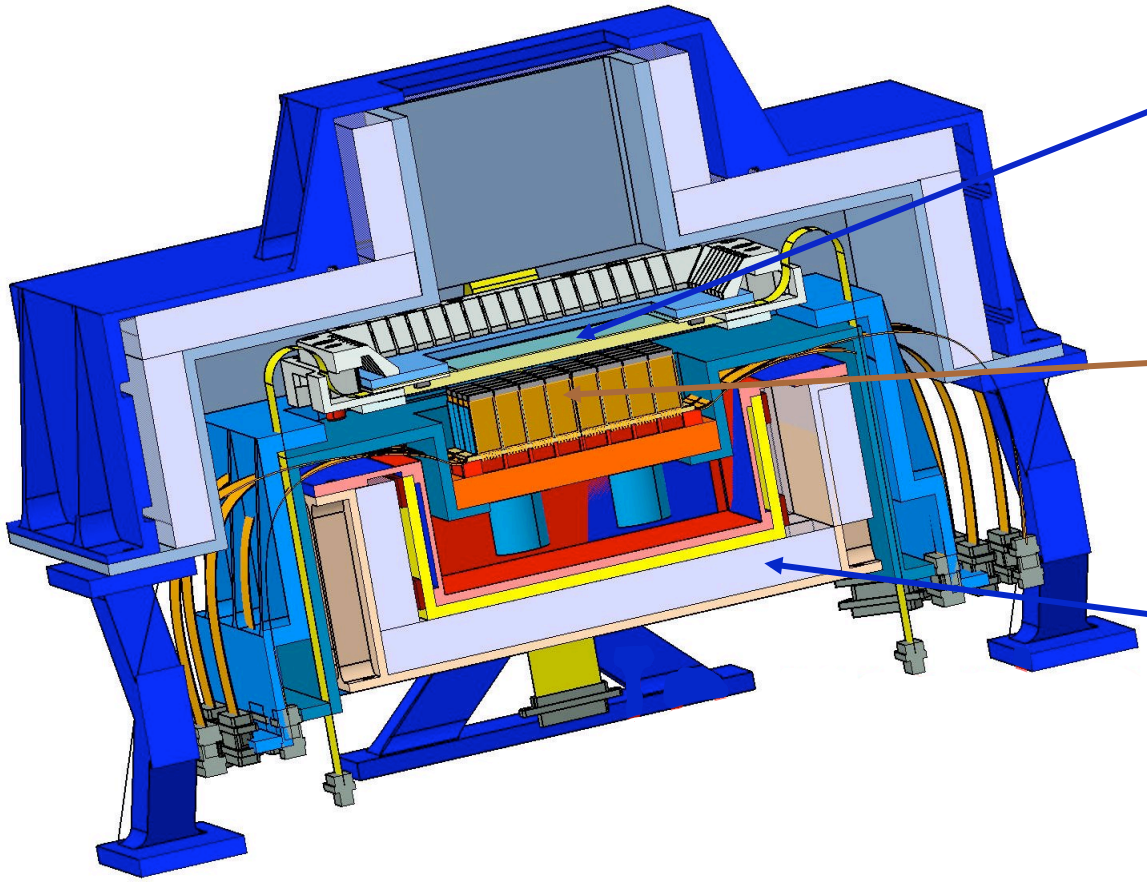
Antennas for formation flight

Collimator :

~ 2 m long graded shield. Full out of FOV sky closed with associated sky-shield on mirror S/C.

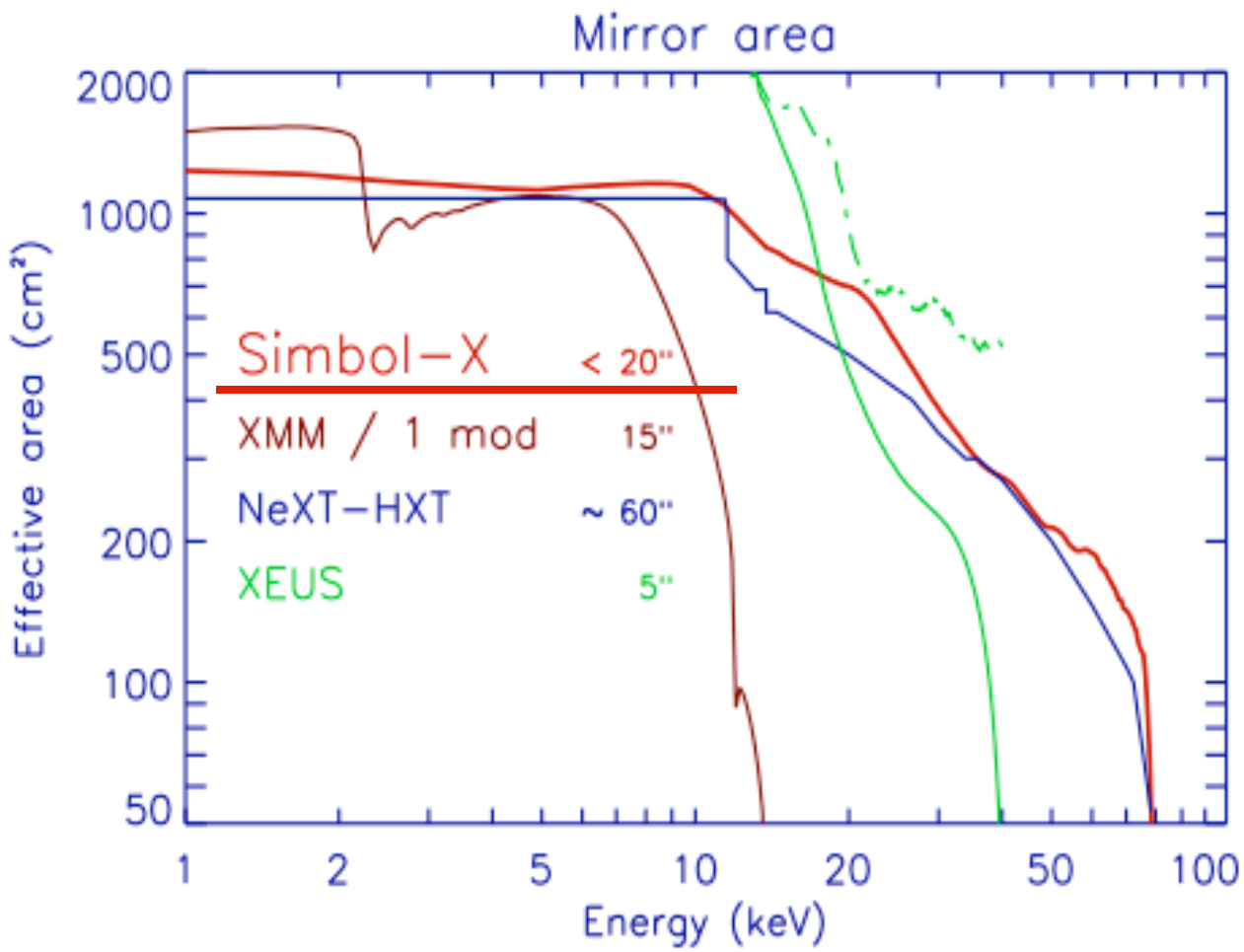
Focal plane assembly

The focal plane assembly



- Spectro-imaging system 0.5-100 keV, fast reading ==> low background using active anti-coincidences (+passive shields)
- Full size : 8x8 cm2, 128x128 pixels of 625 mm
- Operation at ~ -40°C

Effective area

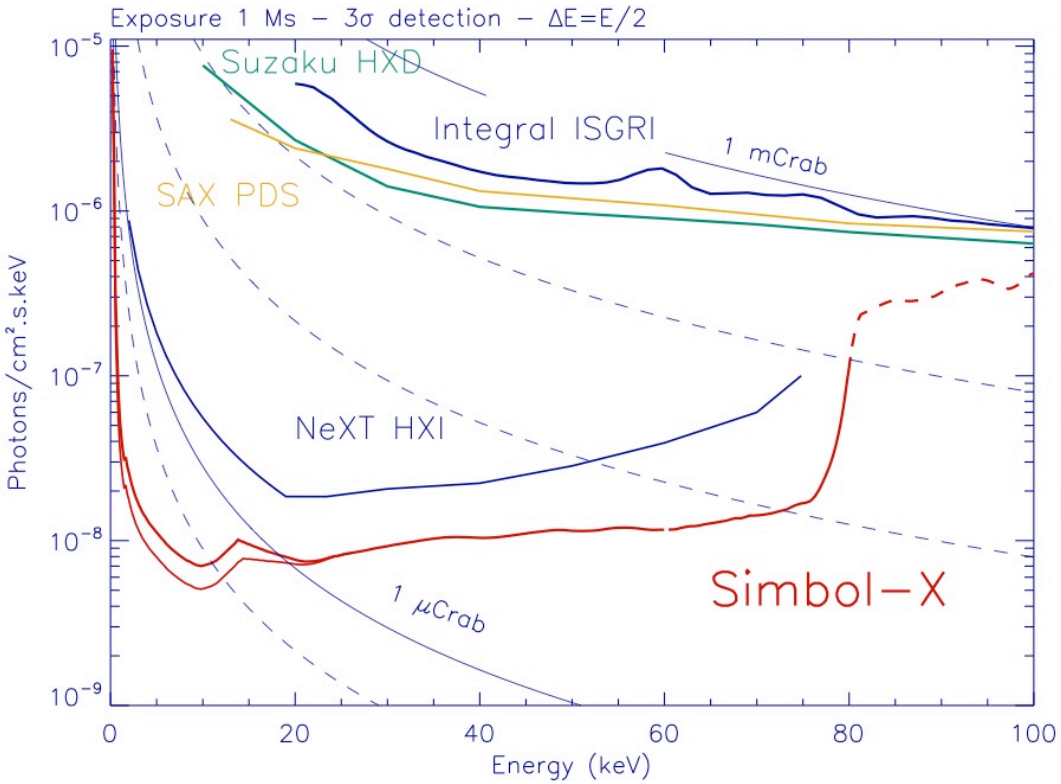


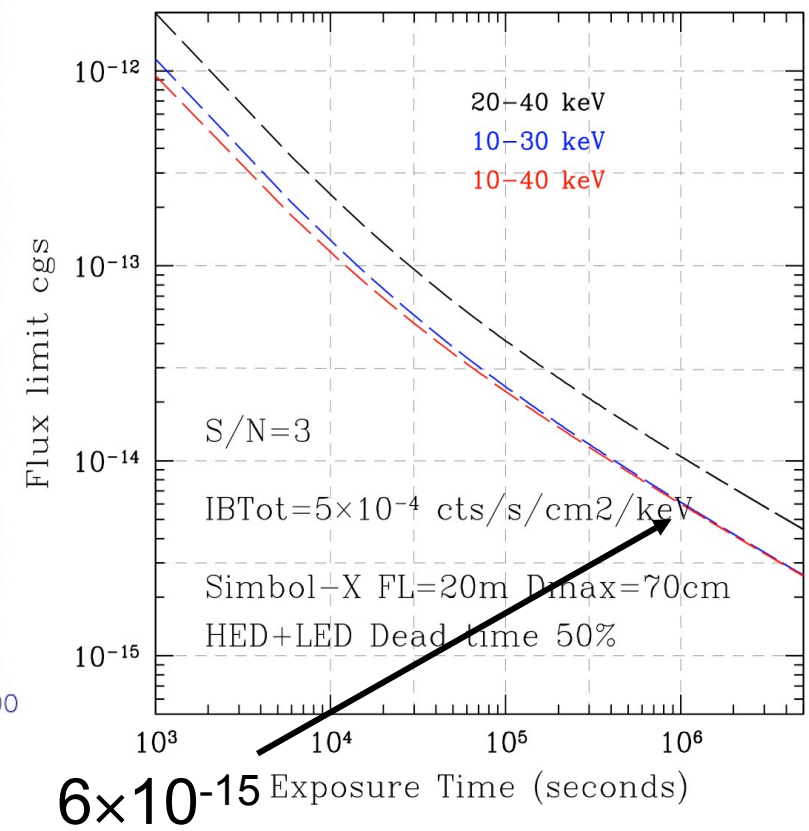
100 shells
Pt/C coating
Max diam. 65 cm
Min diam. 29 cm

Will have both sides covered with thermal blankets

Implementation of a proton diverter

Performances - Sensitivity





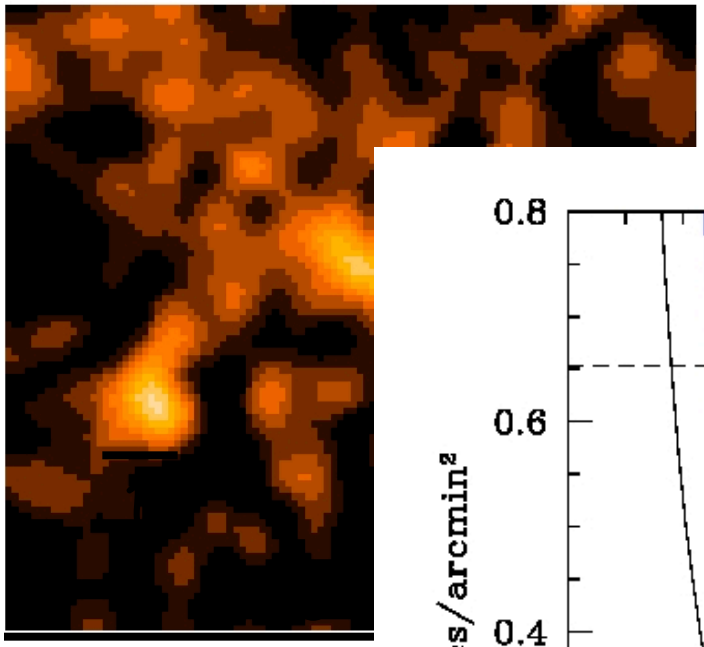
With background levels of 2×10^{-4} and 3×10^{-4} cts/cm^2/s/keV achievable with full anti-coincidence scheme

In a 1 Ms observation :

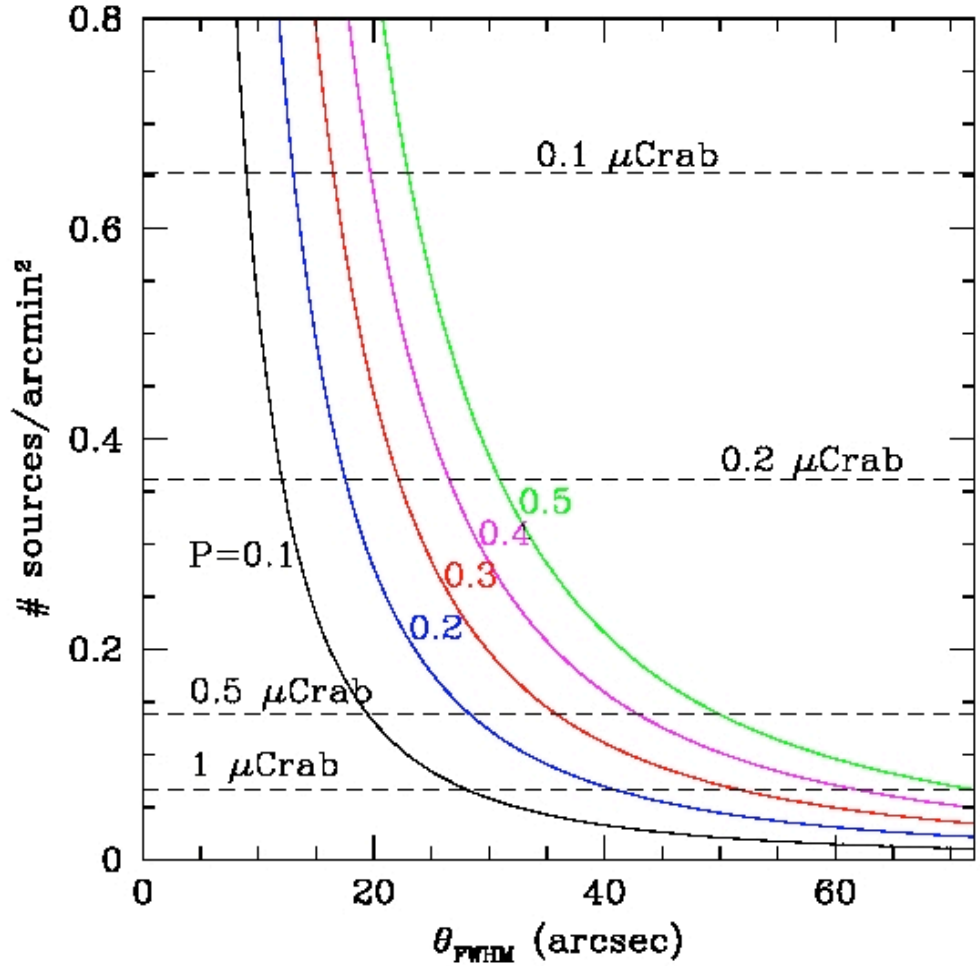
~ 20 sources / field

~ 10 highly obscured (logNH> 23.5)

(1) Image quality: which PSF do we need?

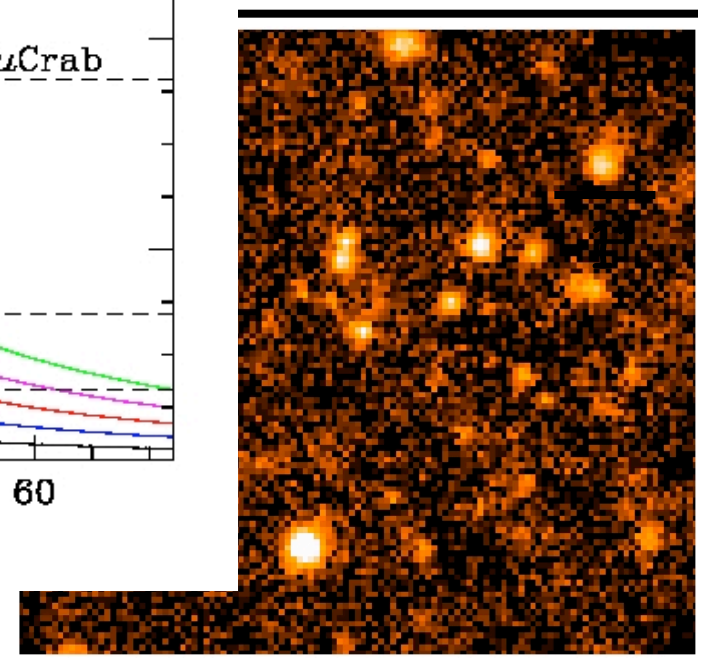


50”HPD; eq. 2mCrab

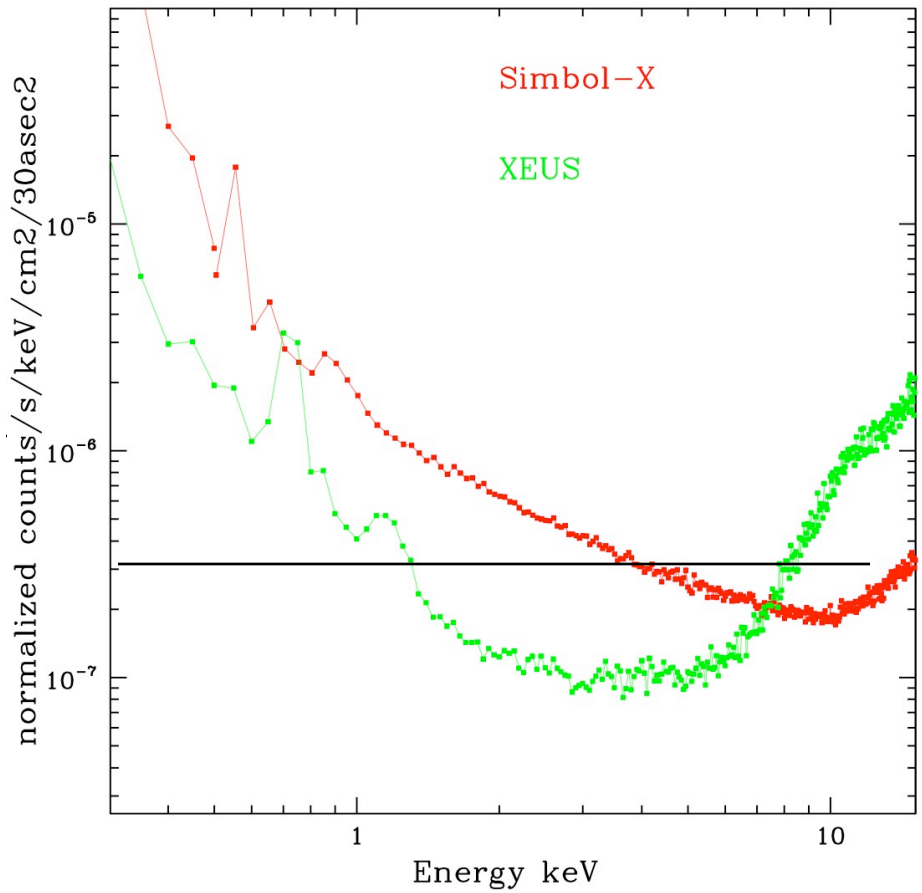


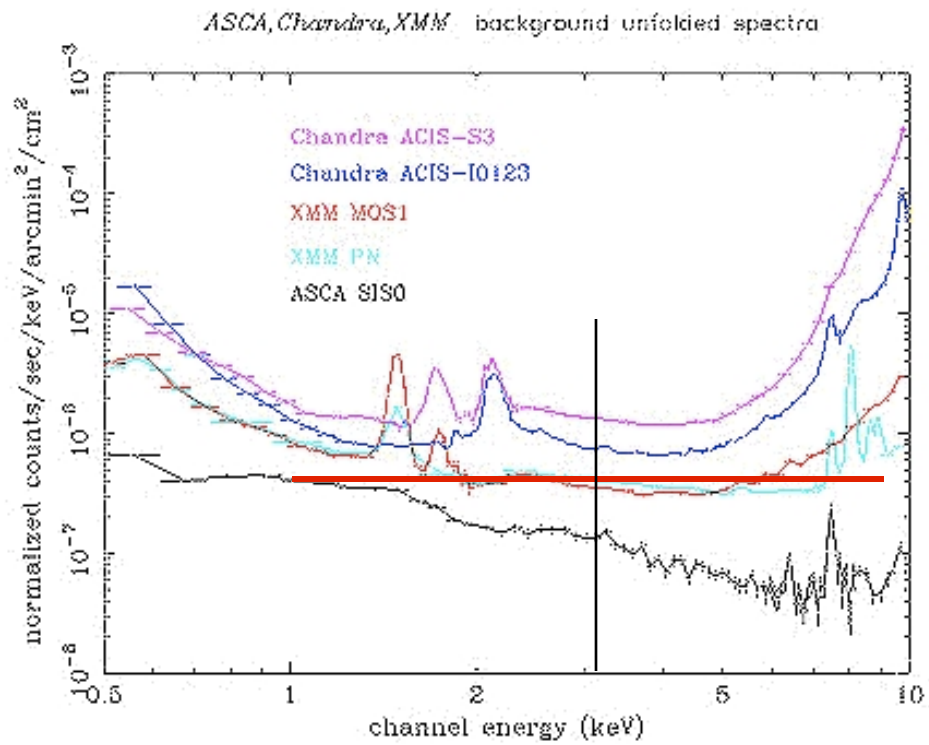
30
Eq.2

10′

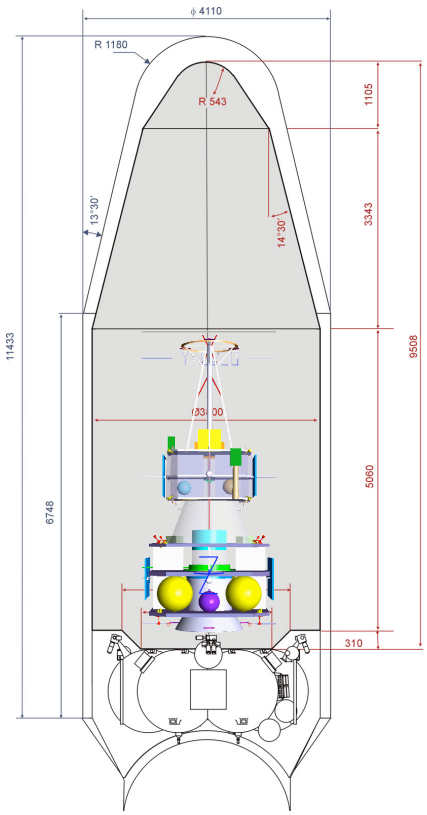


Performances

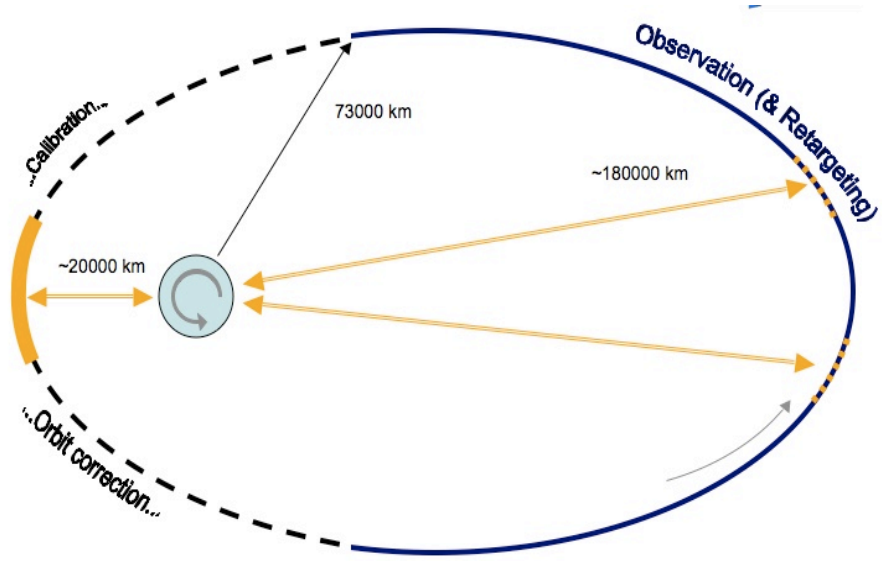




Orbit and operations



- Single launch of 2 spacecrafts, by Soyuz from Kourou, with overall mass within launcher performances (2.3 tons, 5 deg. incl.)



- 4 days orbit, 20,000–180,000 km, with 83 % of the time above 73,000 km (Science time)
- One station (Malindi), with contact at perigee for downlink of data and at change of target
- Formation flight (within ~ 1 cm^3) ensured with cold gas thrusters

Increasing by 3 orders of magnitude the discovery space at E=10-70 keV

The wide discovery space that Simbol-X will uncover is particularly significant for the advancement of two large and crucial areas in high-energy astrophysics and cosmology

- Accreting Black holes
- Non-thermal emission, particle acceleration mechanisms

These two broad topics define the core scientific objectives of Simbol-X.

Accreting black holes

1. ***resolve > 50% of the CXB*** in the energy range where it peaks, thus determining the fraction and evolution of obscured sources and providing a more ***complete census of SMBH***
2. solve the puzzle on the ***origin of the hard X–ray emission from the Galactic centre***, which harbors the closest SMBH
3. constrain the ***physics of the accretion flow onto both SMBH and solar mass BH***

Non-thermal emission, particle acceleration mechanisms

1. Acceleration processes in the ***relativistic Jets of blazars and GRB*** and in ***RG lobes and hot spots***
2. acceleration mechanisms in the strong electromagnetic and gravitational fields of ***pulsars***
3. measure the maximum energy of ***e^- acceleration in SNRs shocks***, and search for ***hadron acceleration***
4. map the controversial ***non-thermal emission in clusters of galaxies***

Simbol-X core scientific topics

A difficulty in building the science cases is that it is not sufficient to evaluate the timeliness of Simbol-X with respect to today's hot topics and instrumentation only.

Extrapolations must be done, taking into account the progresses that in the next few years will be possible thanks to the present and future instrumentation.

This exercise has to be multi-disciplinary, because new ambitious projects today in preparation (e.g. Planck, Herschel, GLAST, Cherenkov telescopes, etc..) may also major produce progresses, and therefore offer synergies, on problems related to the SX core science.

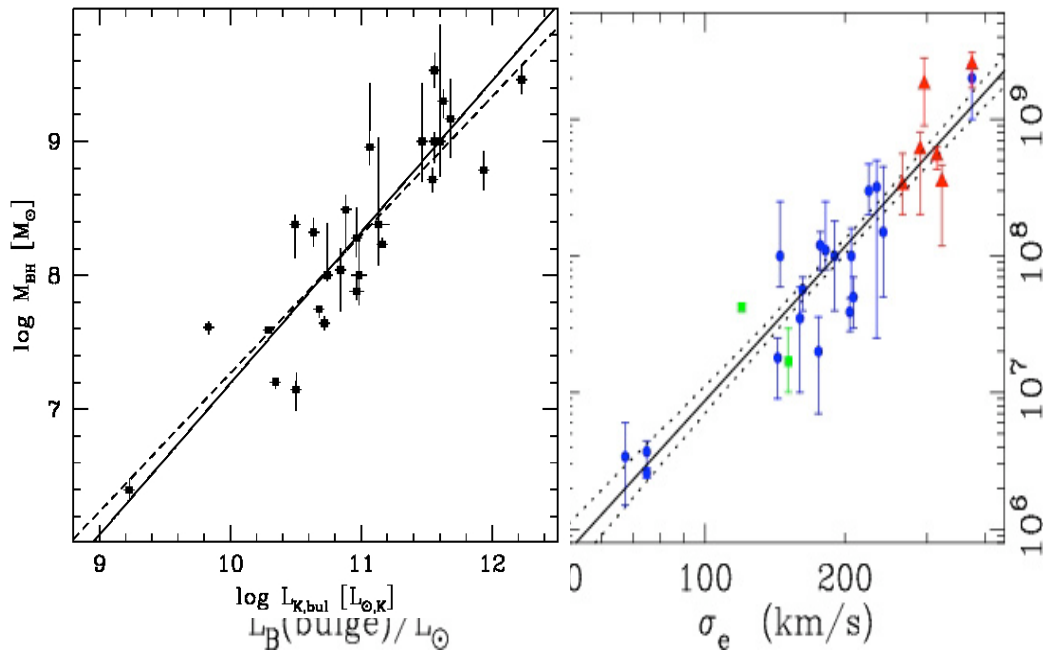
Simbol-X in a context

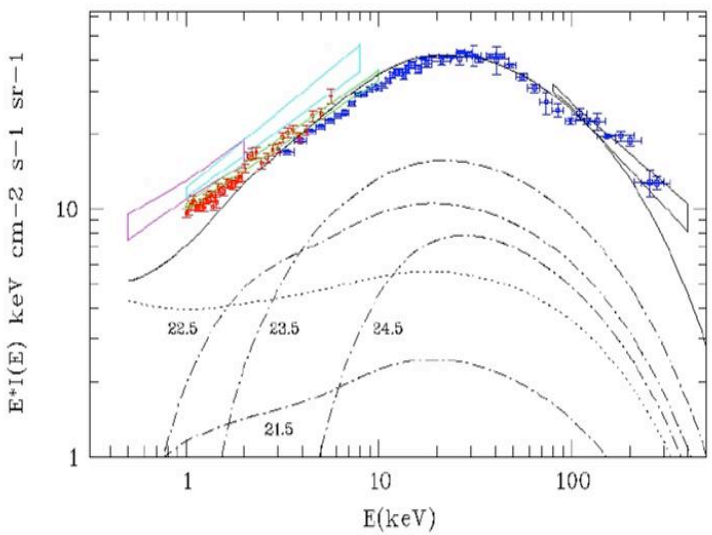
	2009	2010	2011	2012	2013	2014	2015
Simbol-X							
Chandra					?	?	
XMM					?		
INTEGRAL					?		
eROSITA			?				
NeXT				?	?	?	?
GLAST							
Cherenkov telescopes	HESS/ MAGIC		HESS2/ MAGIC2			CTA?	
JWST					?		
Herschel					?		
Planck					?		
ALMA							
LOFAR							
ELTs							?

CXB and SMBH census

Two seminal results:

1. The discovery of SMBH in the most local bulges; **tight correlation** between M_{BH} and bulge properties.
2. The BH mass density obtained integrating the AGN L.-F. and the CXB ≈ that obtained from local bulges



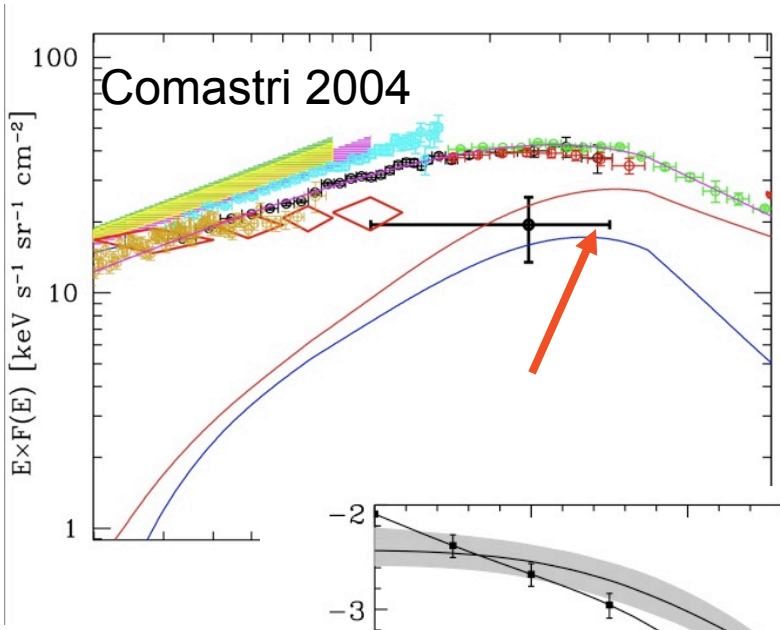


⇒ most BH mass accreted during luminous AGN phases!

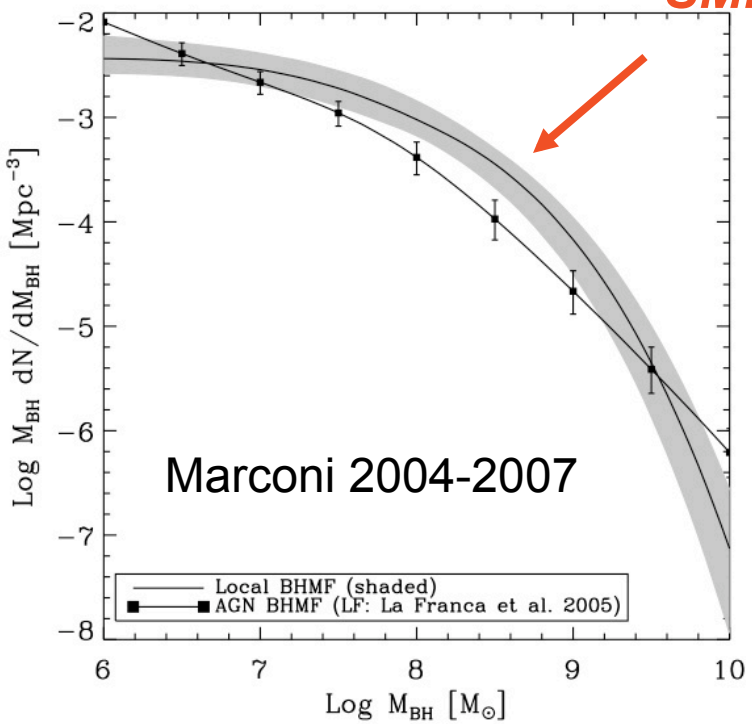
Most bulges passed a phase of activity:

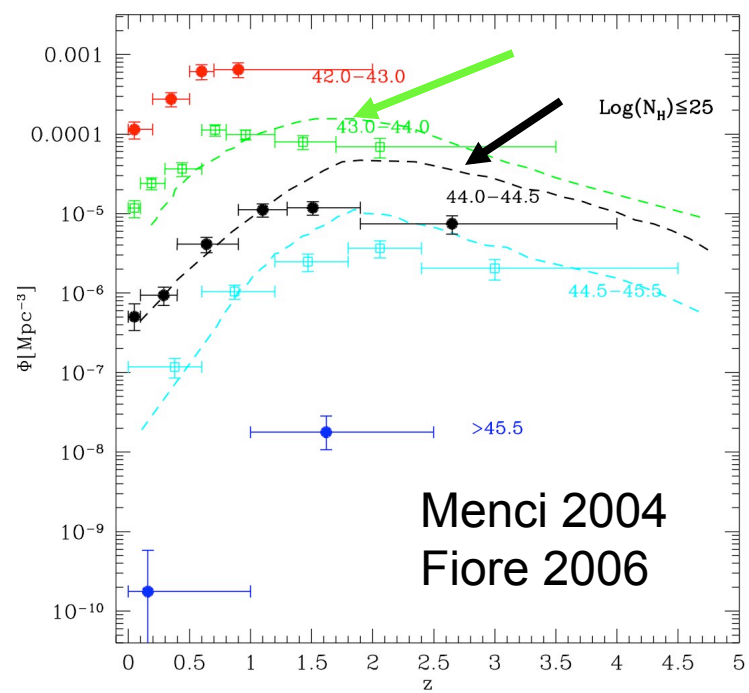
Complete SMBH census, full understanding of AGN evolution and AGN feedback are key ingredients to understand galaxy evolution

Evidences for missing SMBH



While the CXB energy density provides a statistical estimate of SMBH growth, the lack, so far, of focusing instrument above 10 keV (where the CXB energy density peaks), frustrates our effort to obtain a ***comprehensive picture of the SMBH evolutionary properties***.



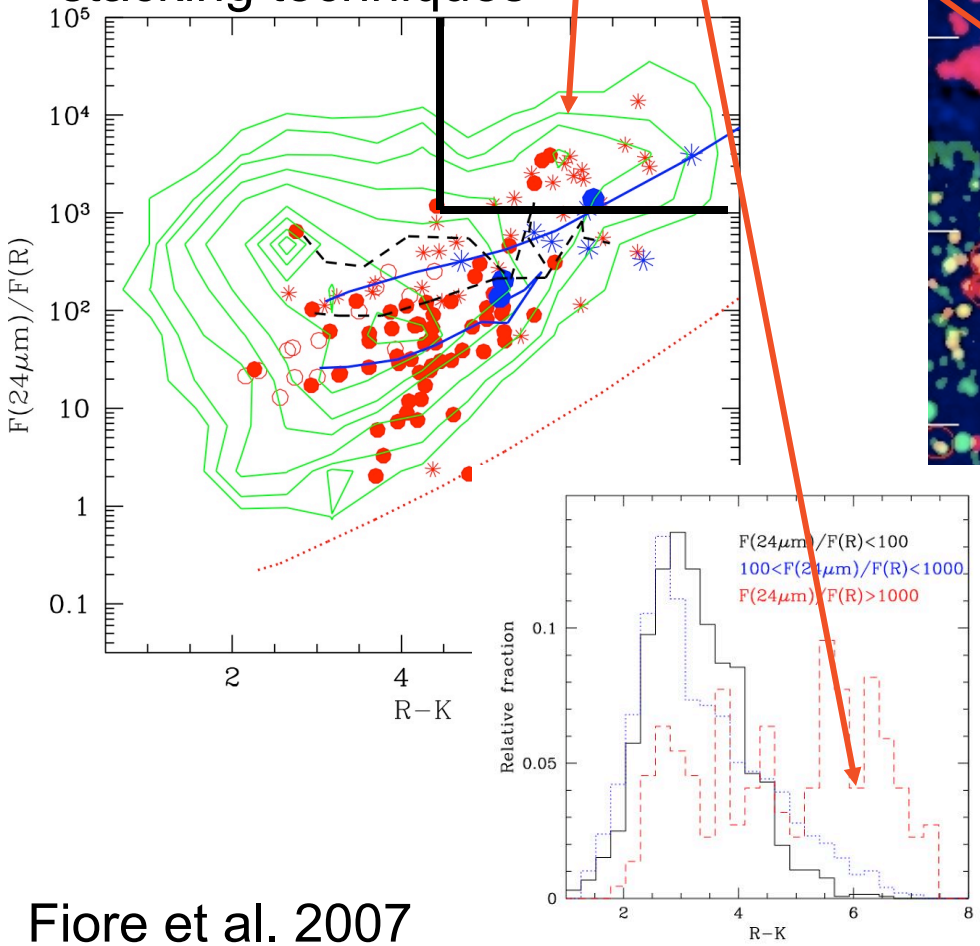


The quest for obscured accretion: the IR perspective

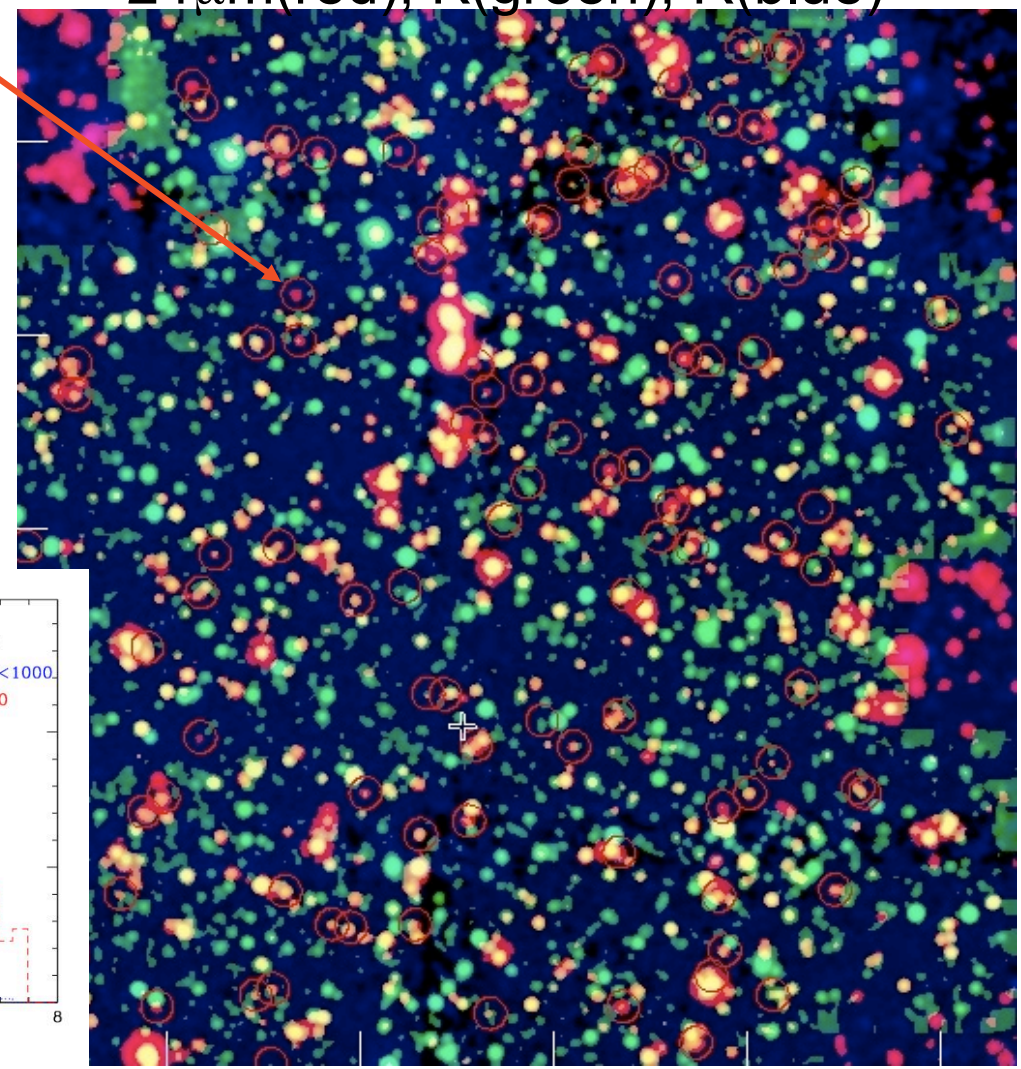
High F(24μm)/F(O), high R-K sources

A new population of CT AGN!!

Detected in the CDFS through stacking techniques



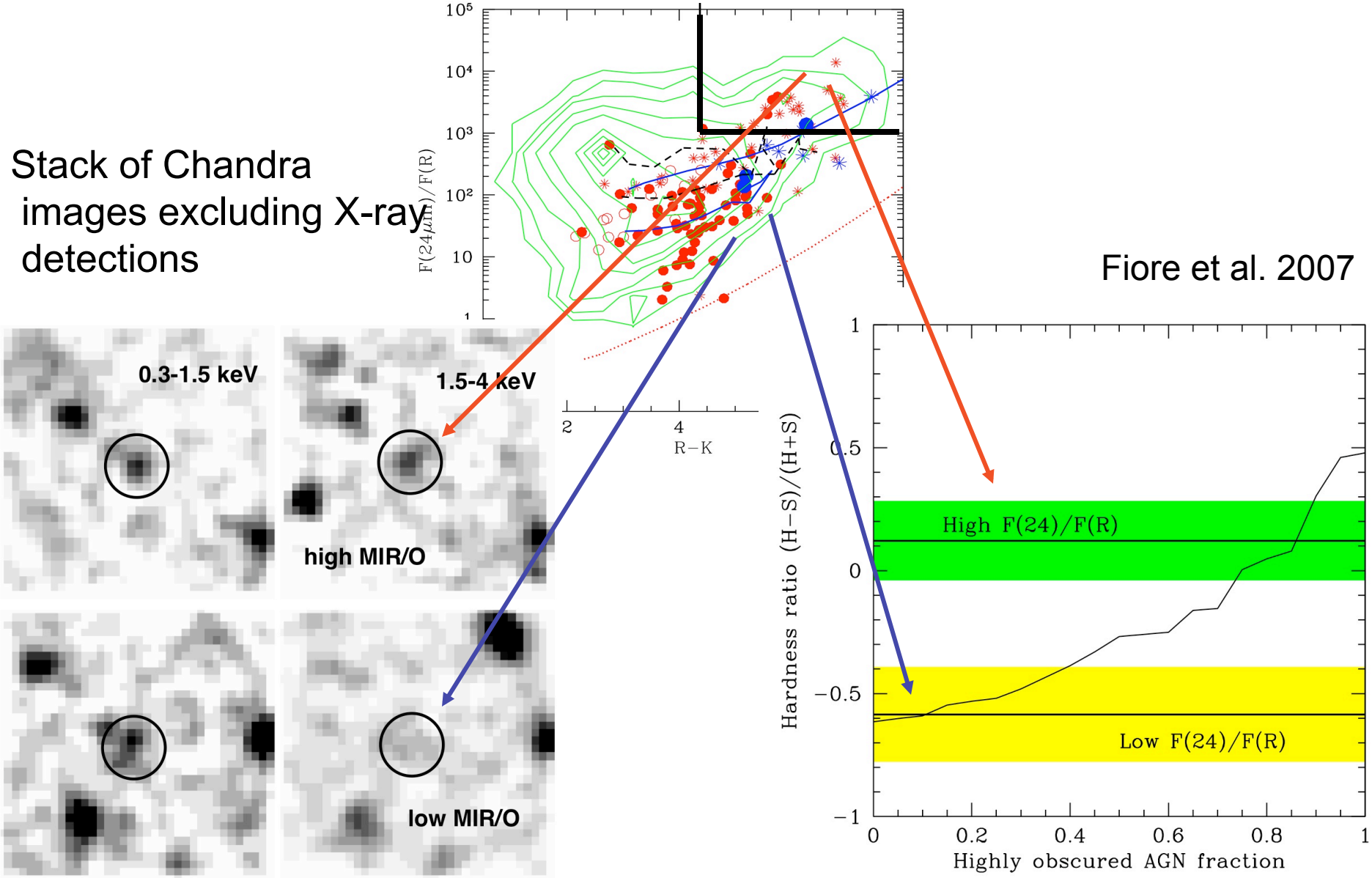
CDFS truecolor
24μm(red), K(green), R(blue)



Fiore et al. 2007

A new population of CT AGN

Stack of Chandra images excluding X-ray detections

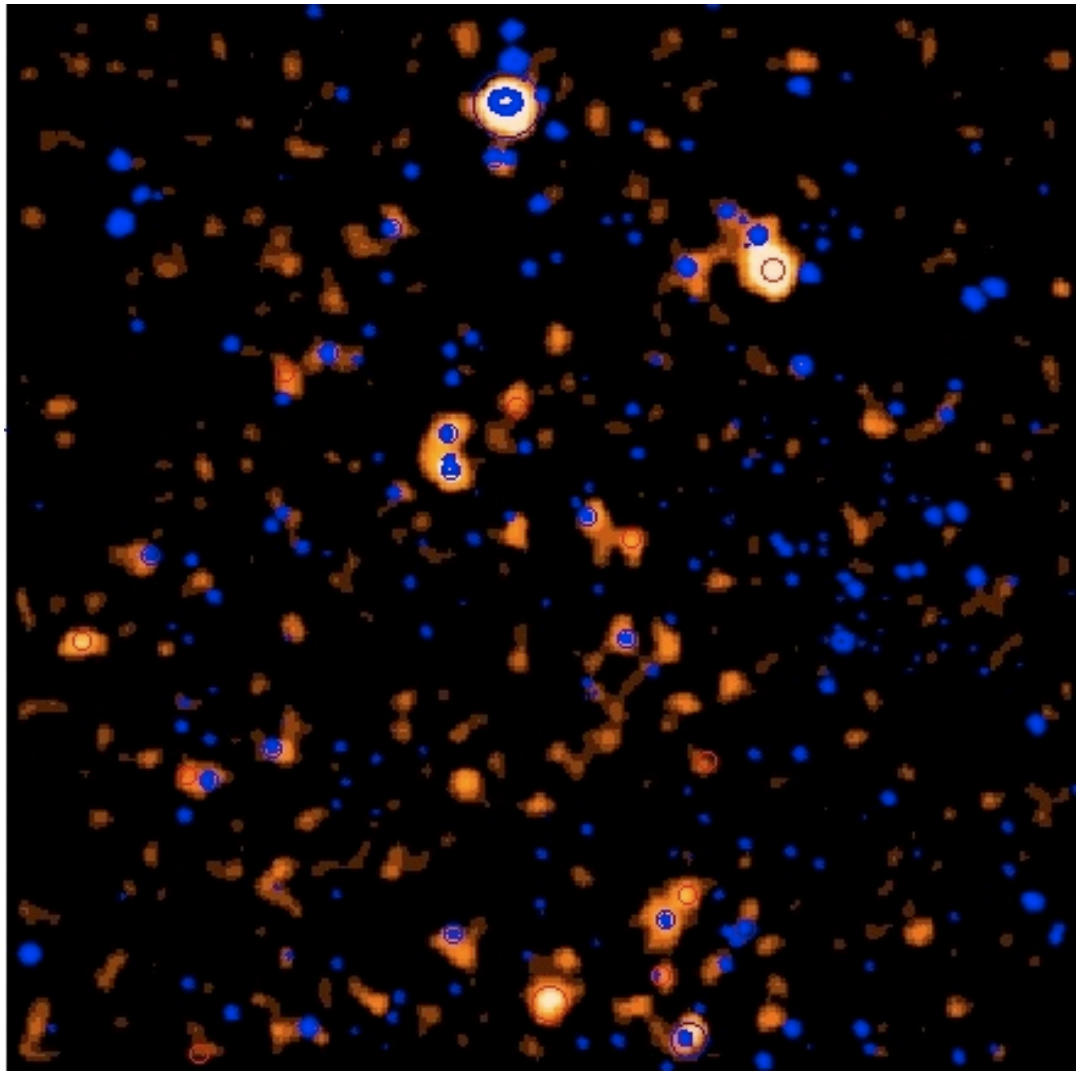


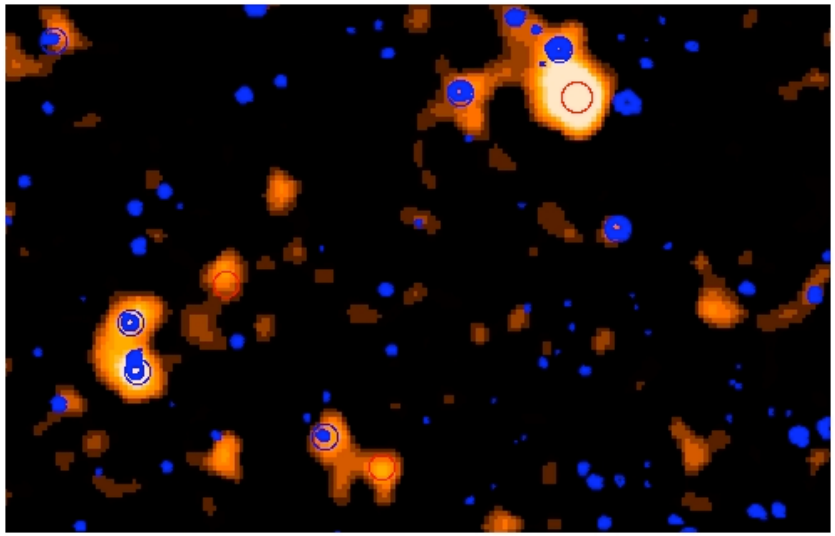
Fiore et al. 2007

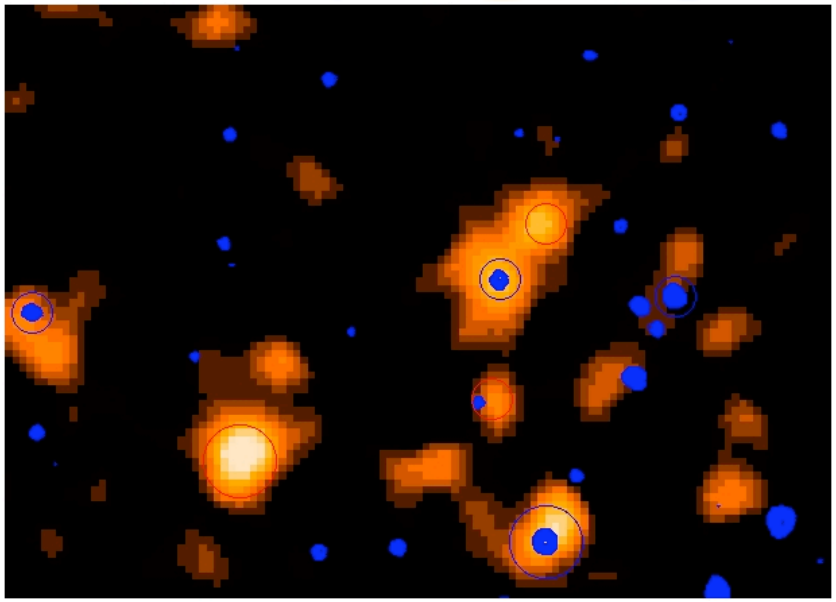
CDFS simulation 10-40 keV

1Msec CZT+ 0.5Msec SDD. **Chandra sources + MIPS selected CT AGNs**
Blue contours = Chandra 0.3-8 keV

12 arcmin

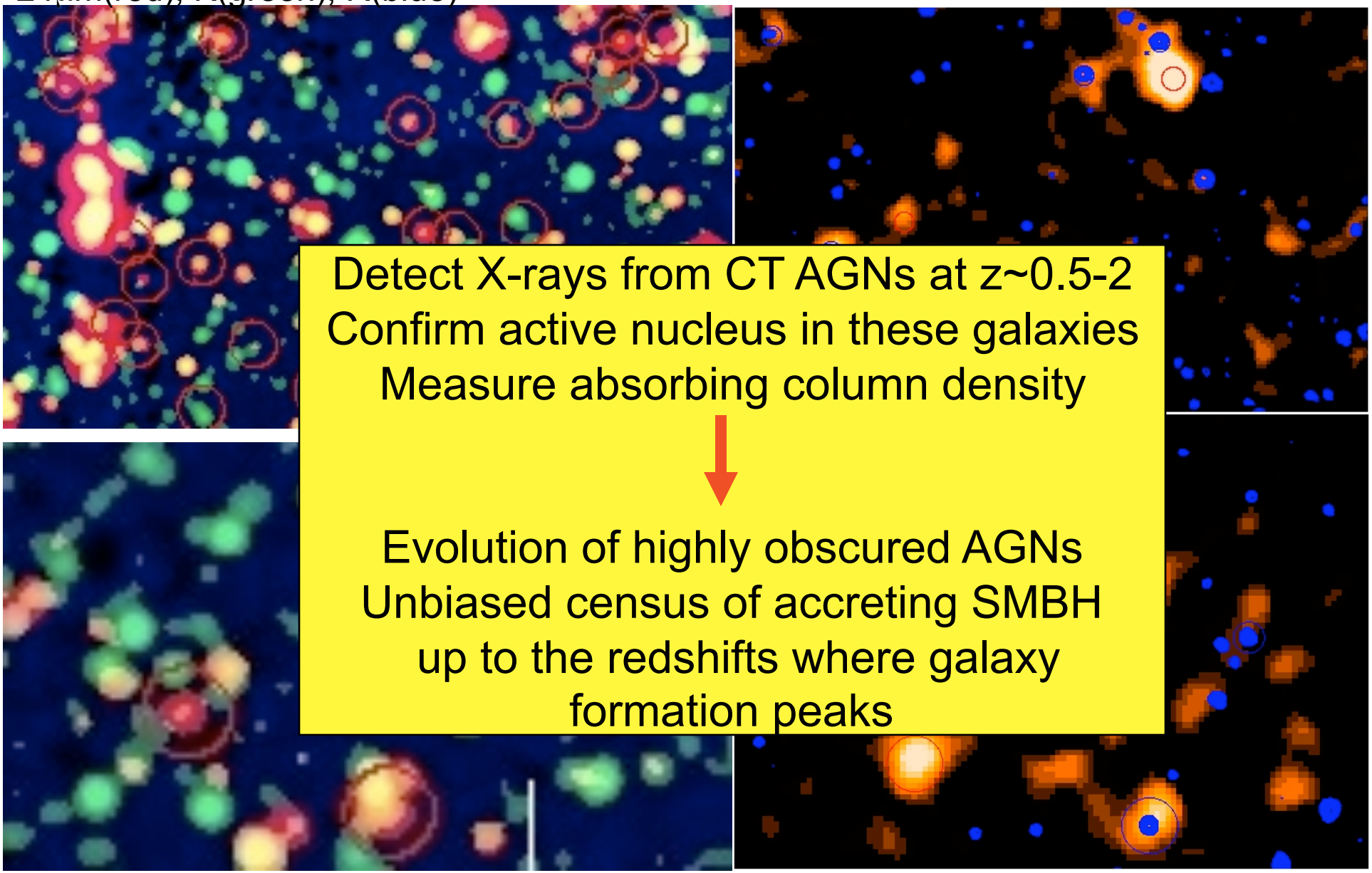






Unveiling obscured accretion in the CDFS

24μm(red), K(green), R(blue)

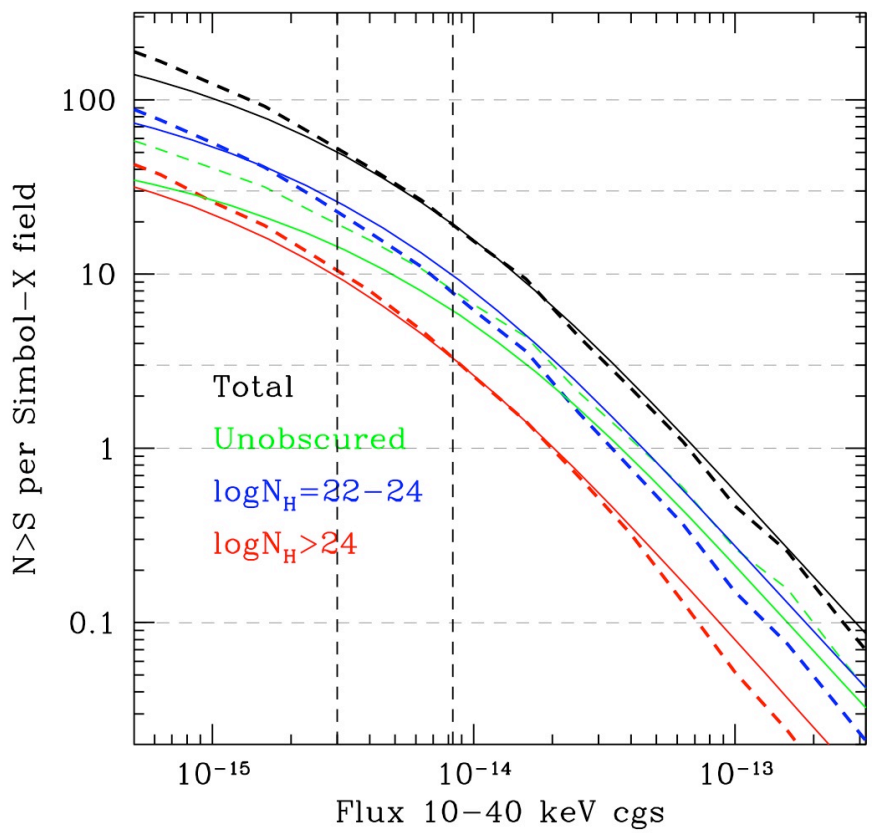


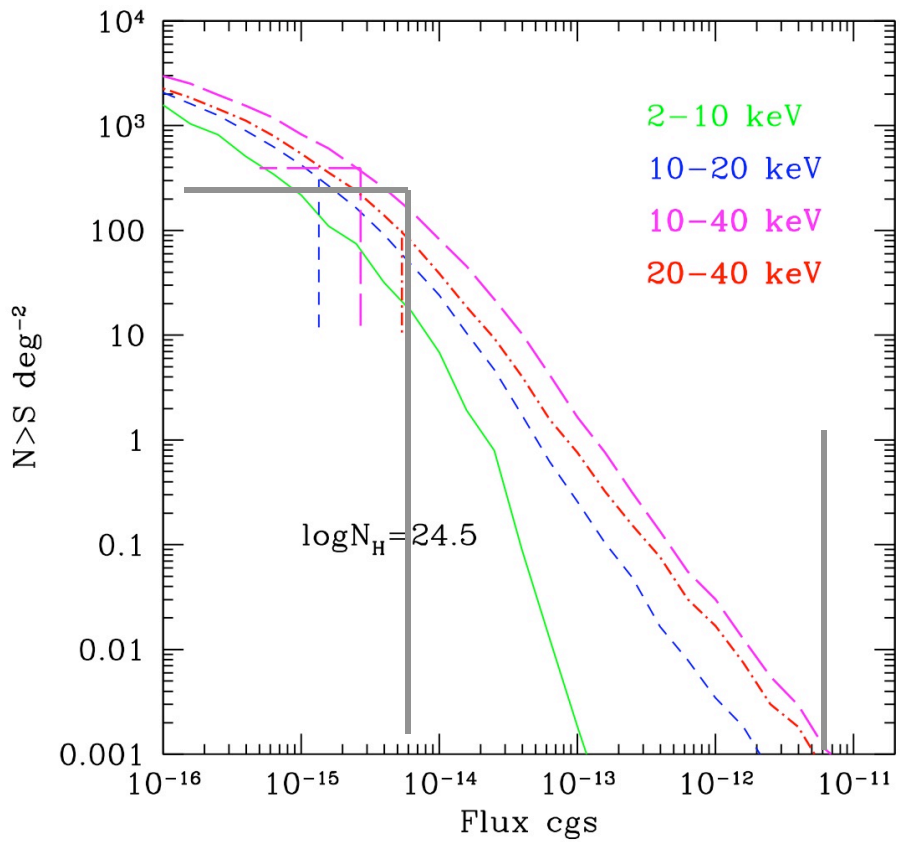
Detect X-rays from CT AGNs at z~0.5-2
Confirm active nucleus in these galaxies
Measure absorbing column density

↓

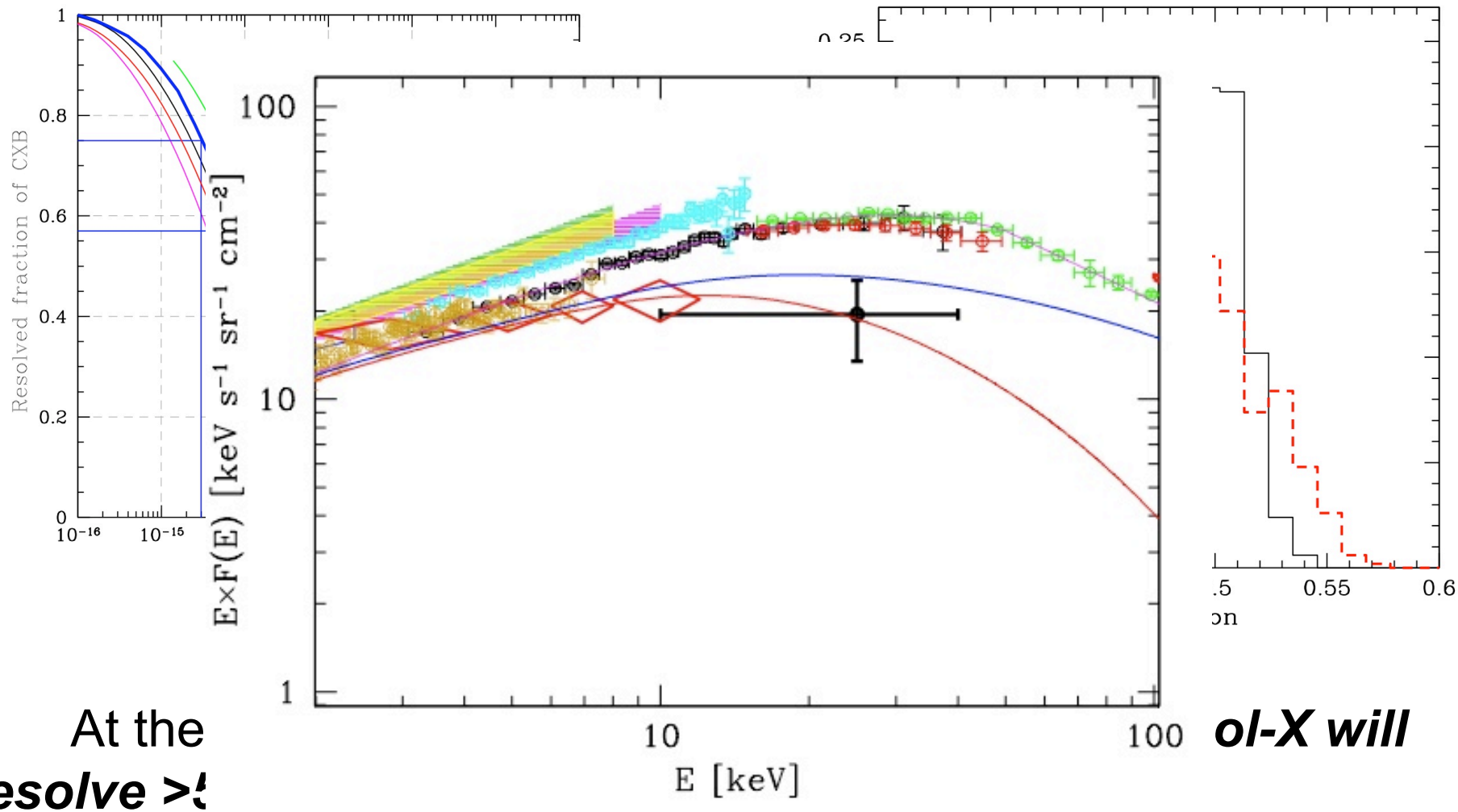
Evolution of highly obscured AGNs
Unbiased census of accreting SMBH
up to the redshifts where galaxy
formation peaks

Number counts





CXB resolved fraction



At the

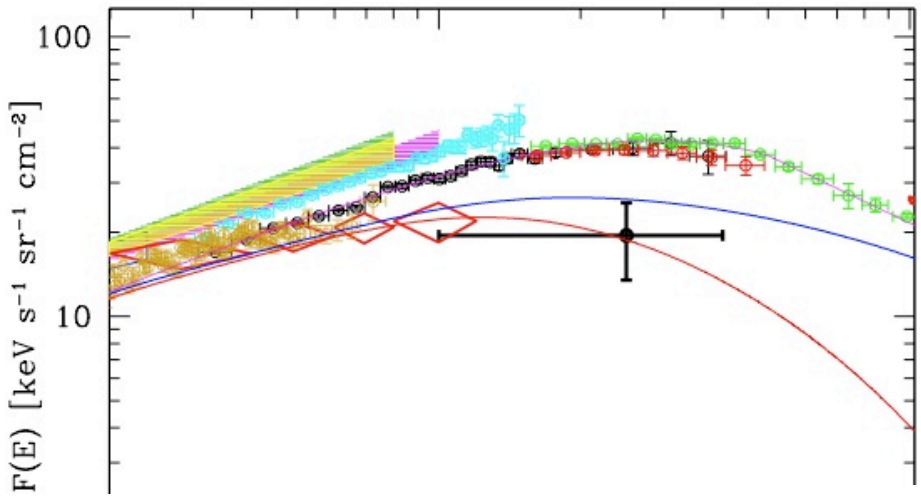
resolve >

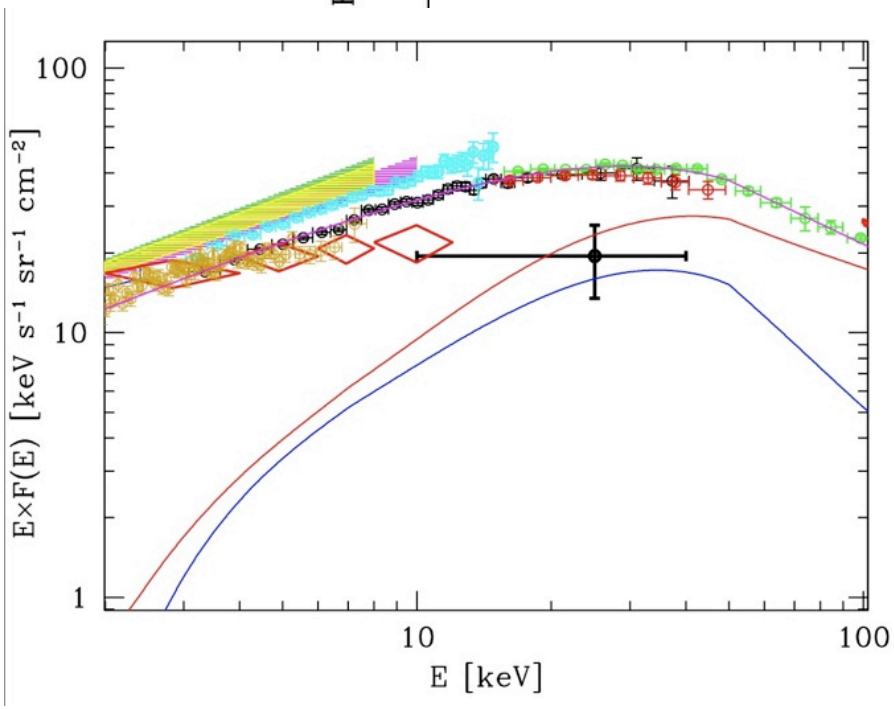
ol-X will

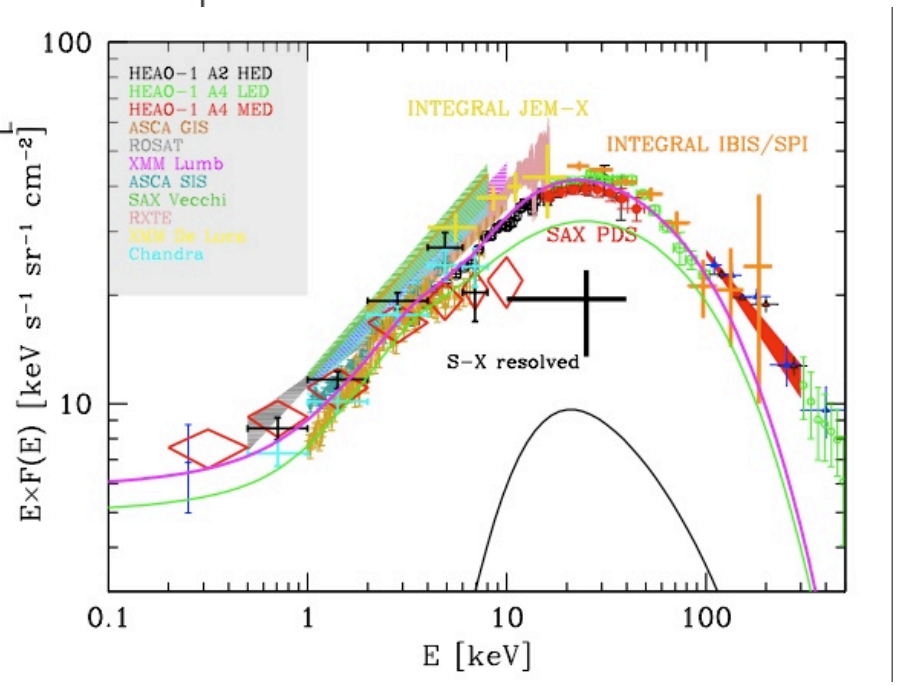
Key issues: sharp PSF, low background, wide FOV

Synergies with Spitzer, ALMA, Herschel

CXB resolved fraction



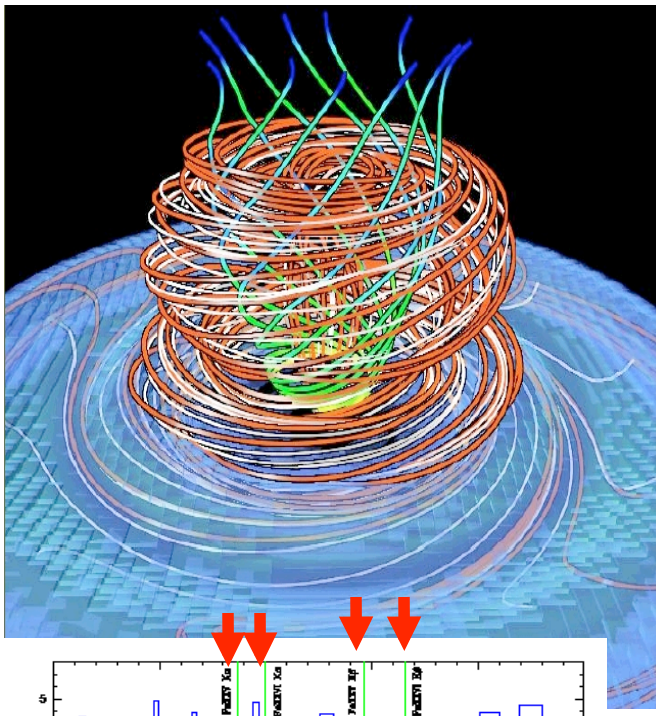




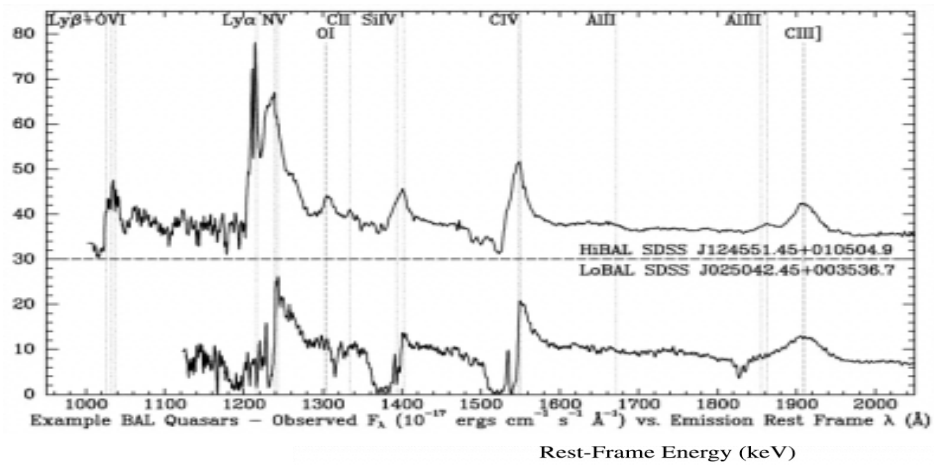
Obscured AGN and SMBH census: 4 observation strategies

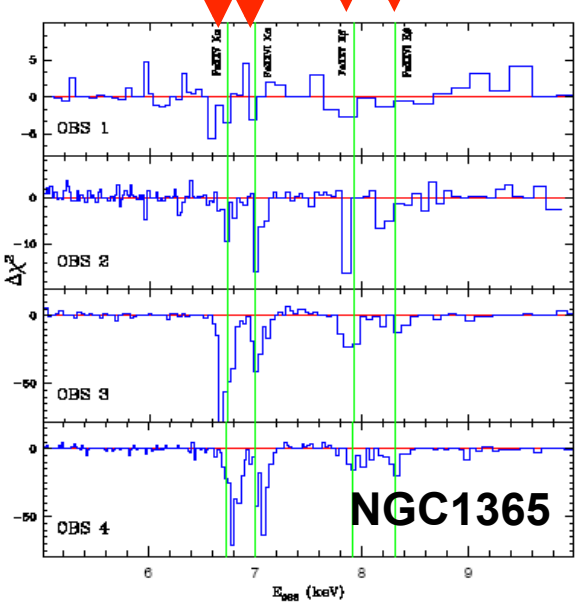
1. A spectral survey of local CT Seyfert 2 galaxies previously discovered by BeppoSAX, INTEGRAL and Suzaku. This may be accompanied by a volume limited survey of infrared bright galaxies which have not shown strong X-ray emission below 10 keV, to search for highly CT objects.
2. A spectral survey of moderately obscured QSOs discovered by XMM, Chandra and previous satellite up to z~1
   - obtaining information on the density, geometry and physics of the absorbers
   - Obtaining statistically meaningful N_H distributions (one of the key ingredient of AGN synthesis models of CXB)
3. Deep observations to search for faint CT AGN + serendipitous survey
4. A survey of candidate CT AGN selected using their infrared emission (Spitzer/Hershel).

Outflows & winds

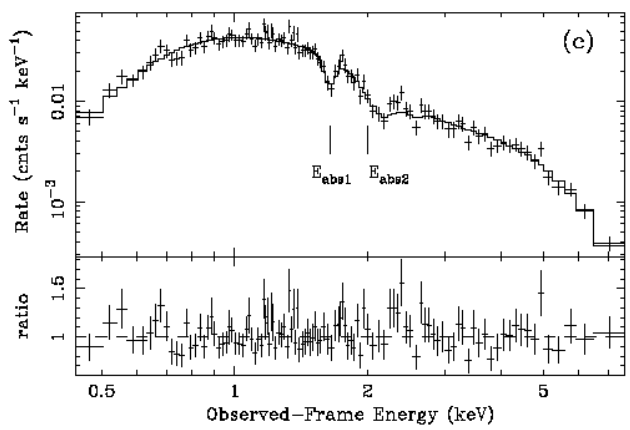


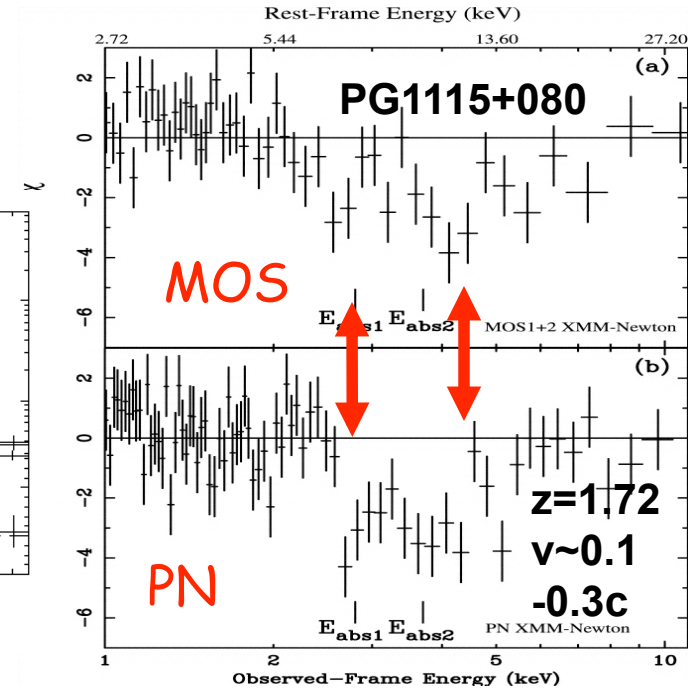
Fast (v up to ~ 50000 km/s) winds in BAL QSOs (10-20% of all QSOs)





APM 08279+5255
z=3.91 v~0.2-0.4c

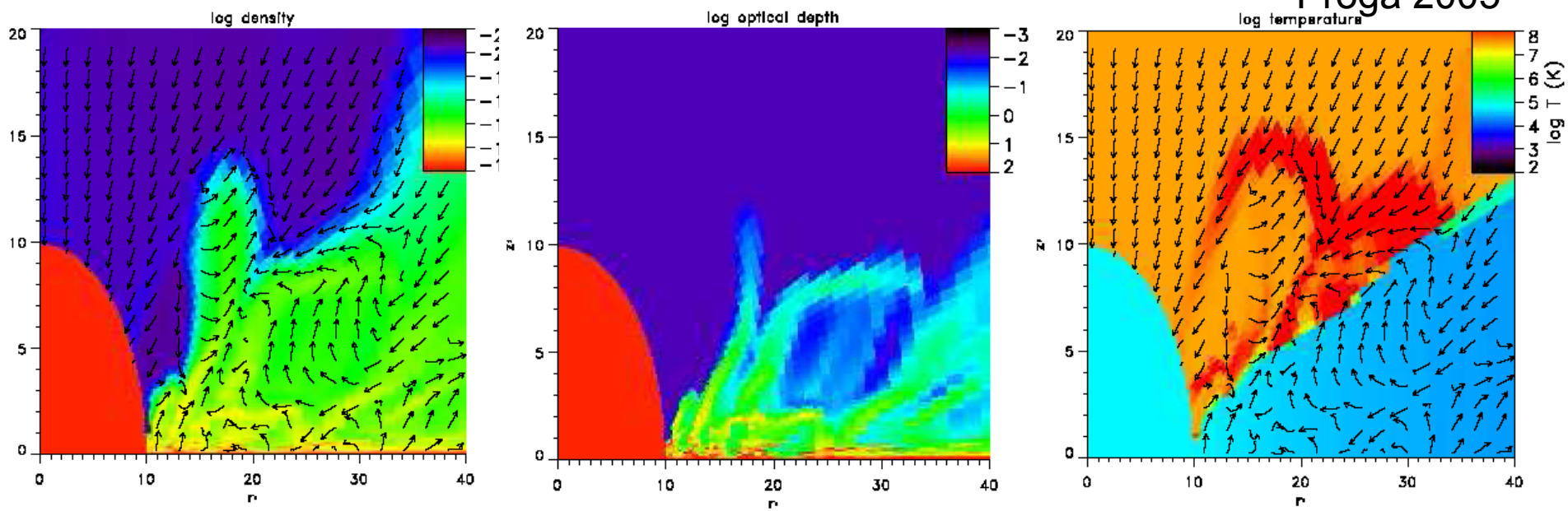




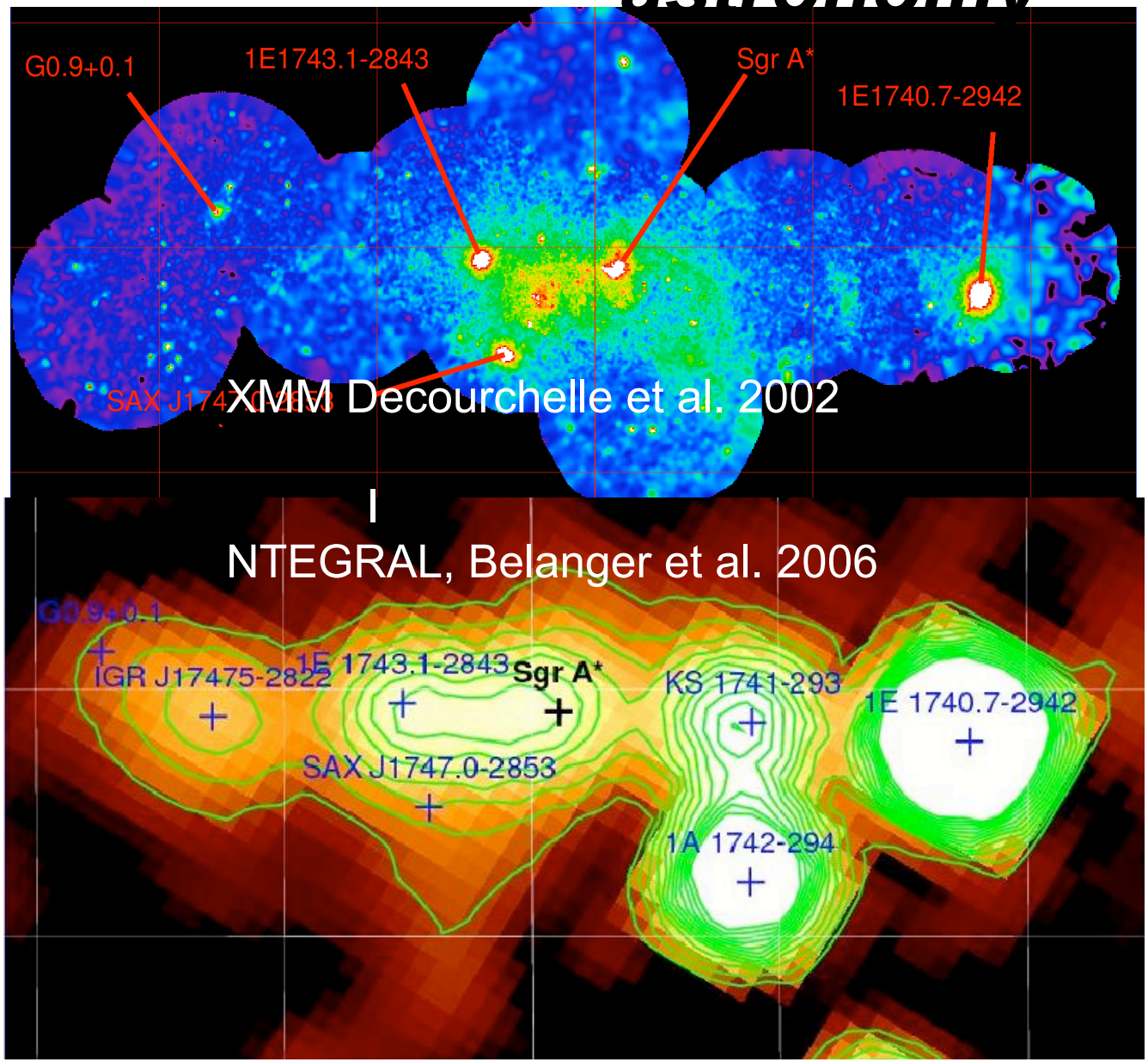
Outflows & winds

- Feedback in the co-evolution of AGN and galaxies:
  - Total mass in the outflows; Kinetic energy; Dynamics (velocity structure, acceleration)
- Simbol-X key issues:
  - Remove observational bias against high velocity flows and high ionization gas: high sensitivity in the 8-30 keV band: probe the highest velocities (v>0.3c)
  - Probe dynamics (measure Δv in addition to v)

Proga 2005



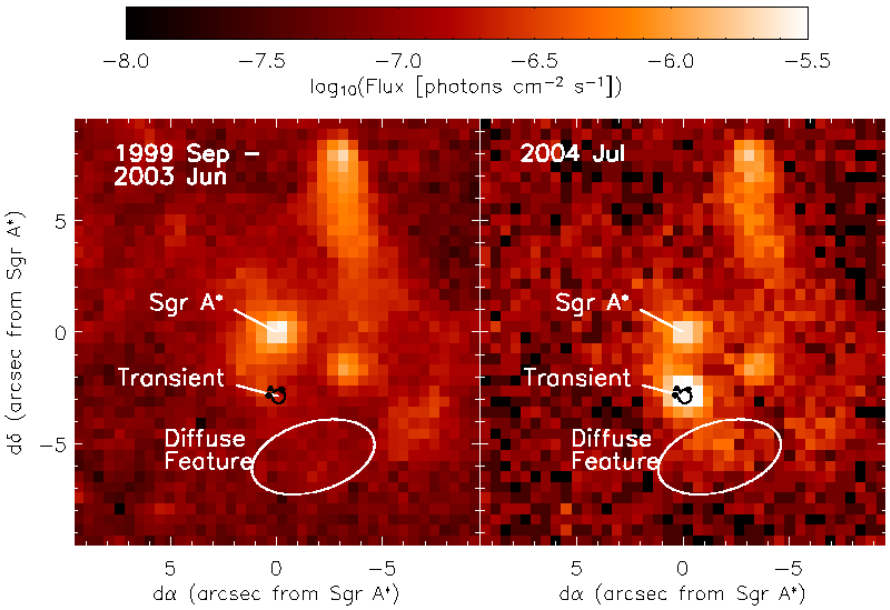
Opening up a new window in X-ray astronomy

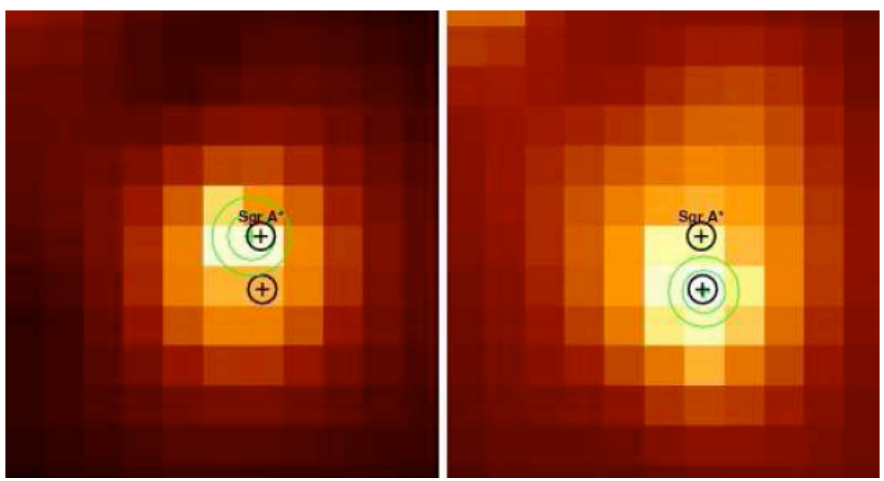


Galactic centre

- Accretion physics and GR test in the closest SMBH: ***spectrum and variability of Sgr A* flares in hard X-rays***
- Particle acceleration from SMBH: ***Identify and reveal the nature of the central INTEGRAL (and HESS) source***
- ***The nature of the hot diffuse X-ray emission***

Galactic centre





Transient at ~ 2.5” from Sgr A* in 2004 (Chandra)

With XMM-Newton it was possible to ***localize the flare*** of 31st August 04 with ***1” accuracy and identify it with Sgr A**** (Belanger et al. 2005)

Same will be possible with Simbol-X below 30-40 keV.

Key issue: sharp PSF!, wide band, wide FOV

Acceleration processes in SNR

What is the maximum energy of accelerated particles ?

Electrons are a few % of cosmic rays but can reveal a lot on the mechanism of diffusive shock acceleration

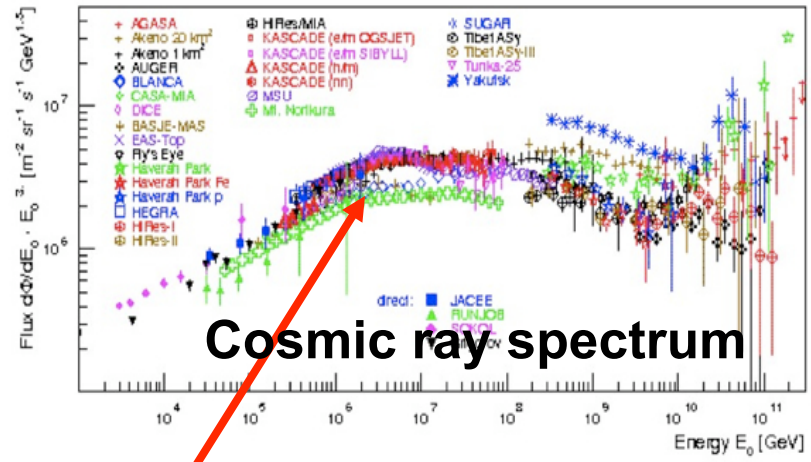
X-ray synchrotron emission

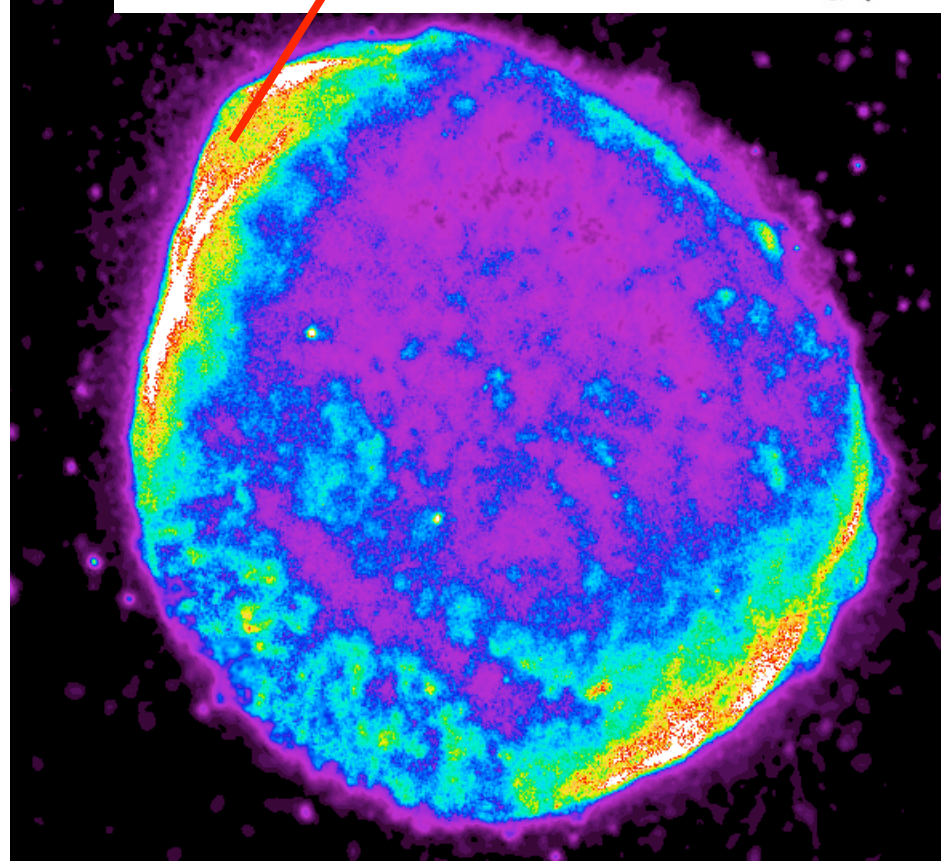
- Maximum energy of accelerated e^- obtained through the measurement of the **cut-off frequency of the synchrotron emission**, observable in X-rays (if the magnetic field is known)

=> e^- energy on the order of 10-100 TeV!

- Azimuthal variation of E_{max} along the SNR shock

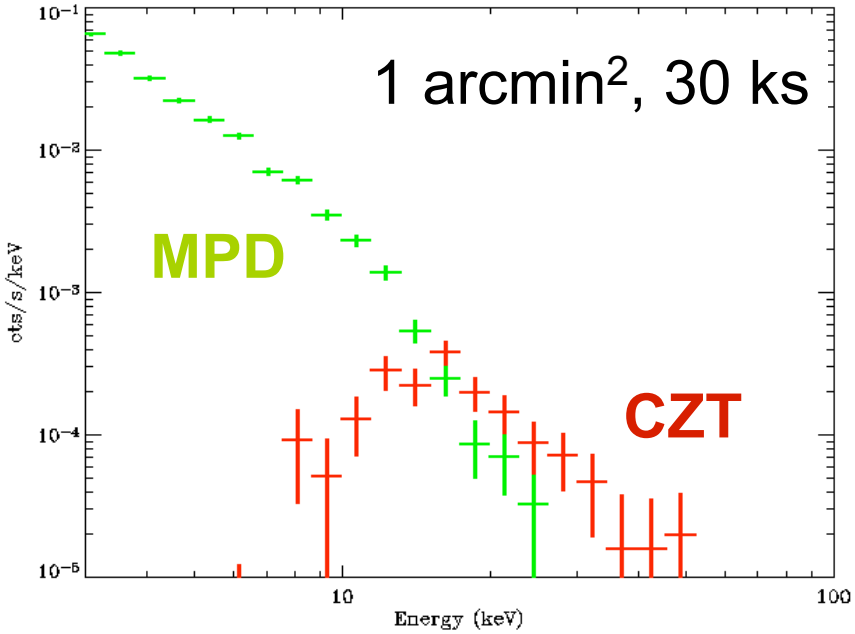
spatially resolved spectroscopy required

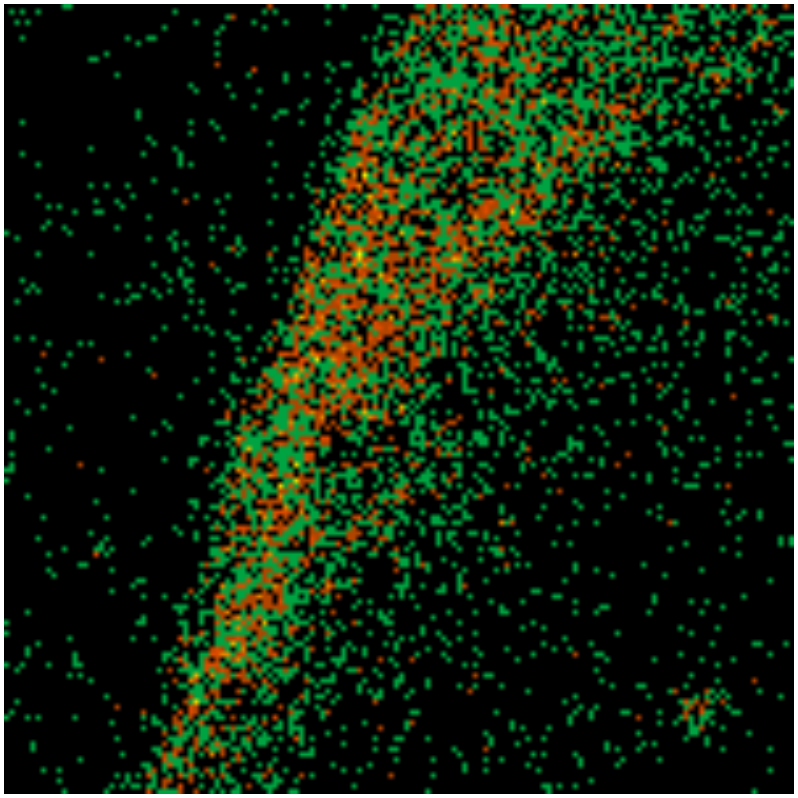




SN 1006

Spectrum and maximum energy of the electrons accelerated at parallel

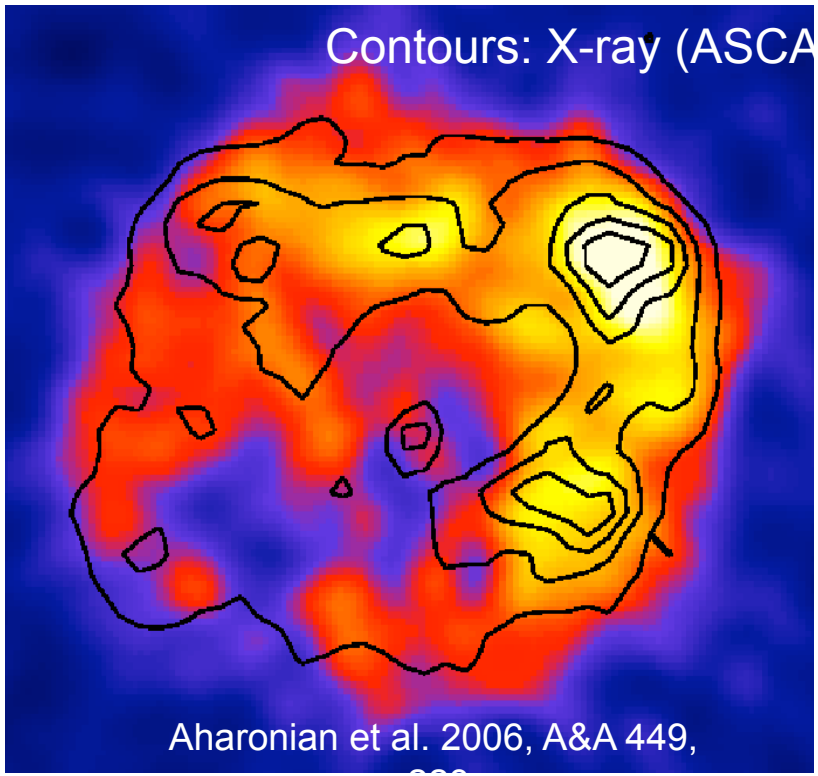


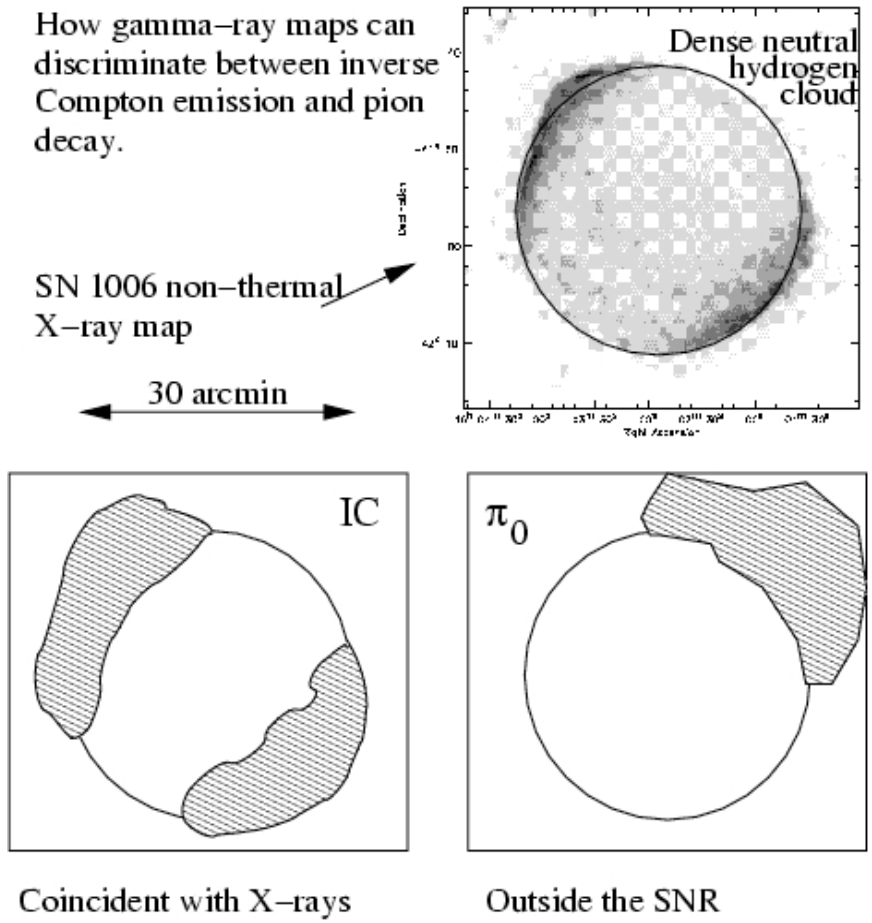


Simulation with SIMBOL–X
NE region of SN 1006 with bright and relatively hard emission

Simulation with SIMBOL–X > 10 keV
Field of 10 x 10 arcmin^2
Total exposure time = 30 ks

Particle acceleration in SNRs





HESS/ASCA view of RXJ1713.7-3946

Regions with similar TeV and X-ray morphology are probably sites of e^- acceleration. Strong GeV-TeV emission in regions with little hard X-ray emission are probably site of hadron acceleration, through detection of π_0 decay

Key issues: wide band, wide FOV Strong synergies with GLAST and Cherenkov telescopes.

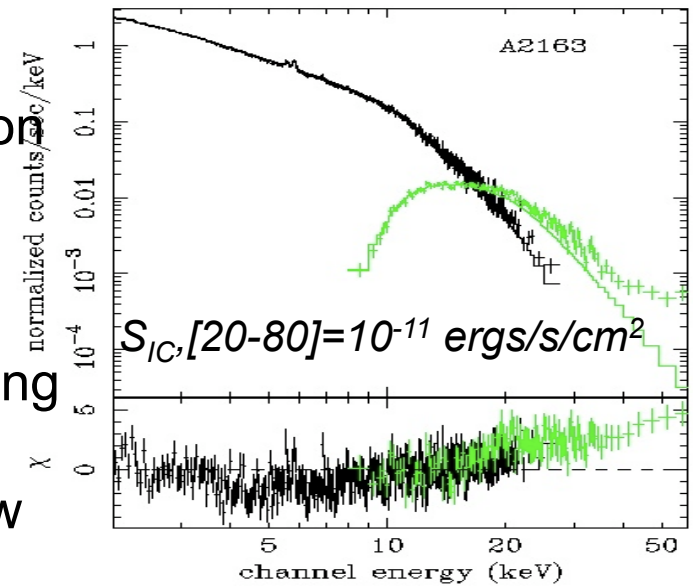
NT emission of clusters of galaxies

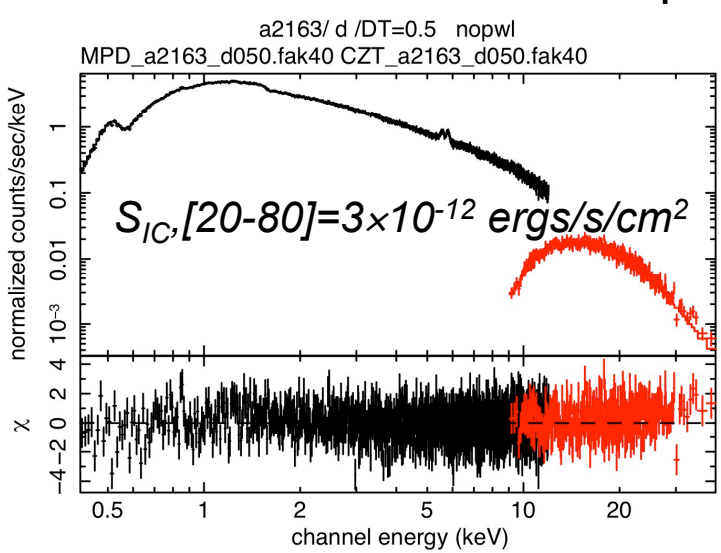
Diffuse radio emission = synchrotron from **relativistic e$^-$, B=0.1-1μG** Inverse Compton of e$^-$ on CMB ==> **NT X-ray emission**

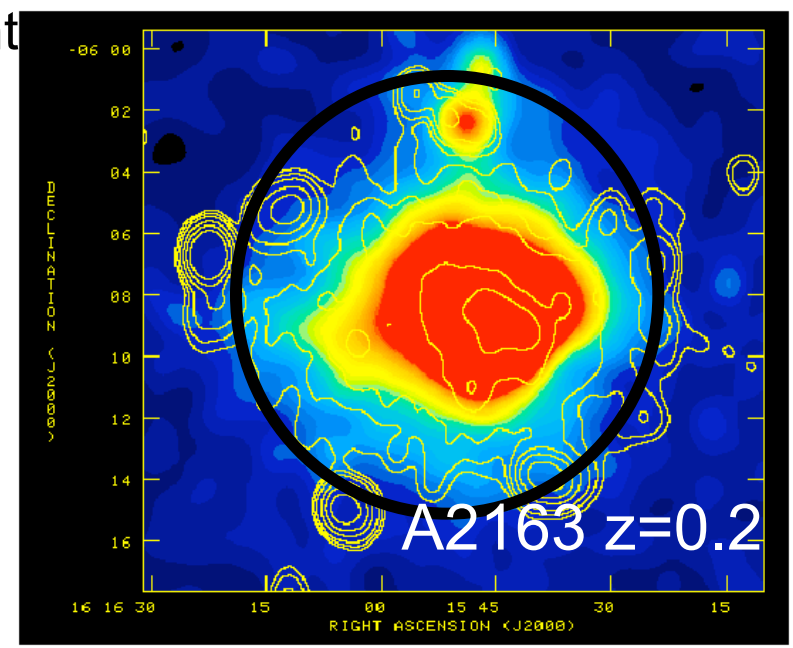
Break the degeneracy between B and e$^-$

Origin and acceleration mechanisms. Connection with cluster formation, redistribution of energy during mergers.

A few BSAX, RXTE, INTEGRAL detections with low S/N. Simbol-X will probe NT emission at a level 10-20 times fainter than all previous instrument

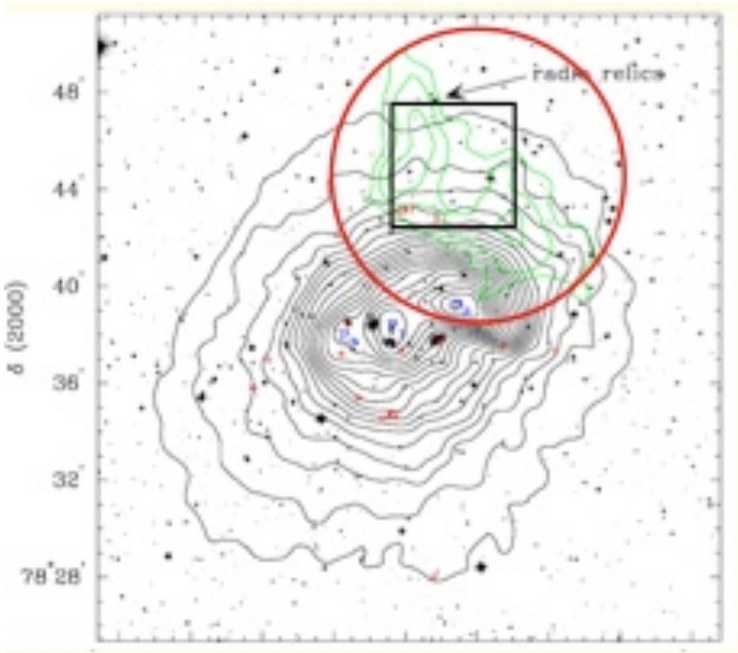


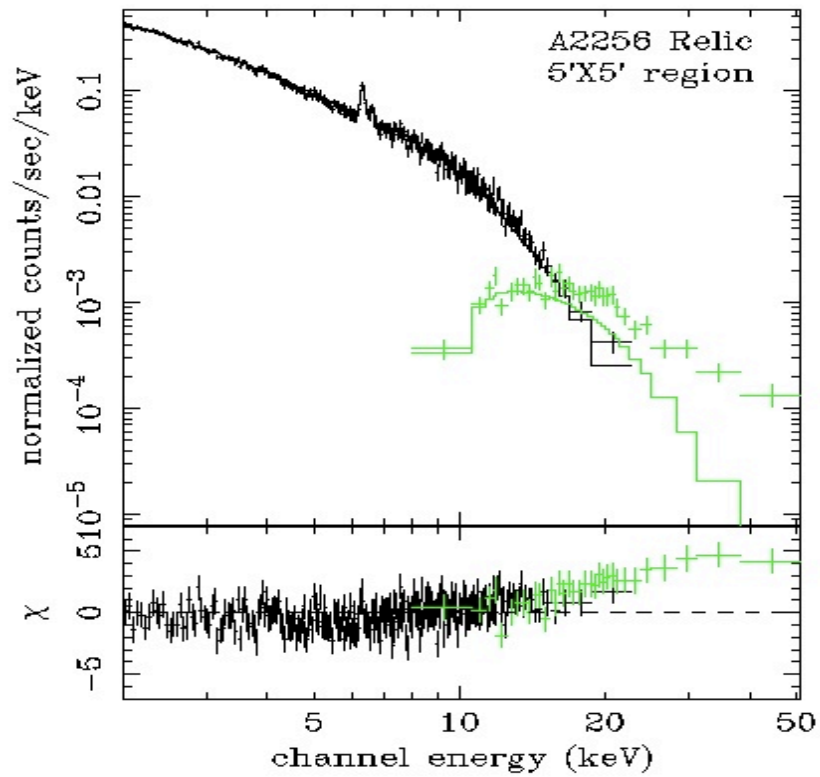




NT emission from clusters of galaxies

SX FOV





S_{IC},*[20-80] keV=5×10^{-12} ergs/s/cm^2*

Key issues: low background, wide band, wide FOV

Strong synergies with:

LOFAR: 1000 radio halos detections (25% z>0.3); spectral index maps; B measurements in polarized relics

GLAST: first detection >100 MeV? π_0 decay and/or IC

Top level scientific requirements

- Sensitivity
  - to discover sizable samples of highly obscured AGN and make a fundamental step forward with respect to the Chandra and XMM-Newton results, we need to resolve ~50% of the CXB in the 10-40 keV band. This goals imply a flux limit of ~10^{-14} cgs in the 10-40 keV band (3σ 1Ms).
- Background
  - To reach the goal sensitivity it is critical to keep both the internal background and the CXB coming from outside the Field of View as small as possible, I.e. below 2×10^{-4} cts cm^{-2} s^{-1} keV^{-1} at 20-60 keV, and below 3×10^{-4} cts cm^{-2} s^{-1} keV^{-1} at 2-20 keV.
- Angular resolution
  - A good image quality is necessary to reach the required sensitivity to avoid source confusion and to study the structure of extended sources. A PSF with Half Power Diameter (HPD) <20 arcsec would allow to reach the flux limit given above on exposures of the order of 1 Ms and to keep the probability of having two sources at the flux limit closer than the beam size, at <10%.
- Field of view
  - A reasonably large FOV would allow the collection of a statistically meaningful sample of hard X–ray selected sources and to study acceleration sites in extended sources like SNRs, radio-galaxies and cluster of galaxies. A reasonable compromise is a FOV of ~12' diameter (vignetting of 50% at 30 keV).

Top level scientific requirements

- Energy band:
  - **A broad-band,** extending at ≥80 keV and down to ~1 keV **is necessary to constrain and cleanly separate different continuum and absorption spectral components. Extending the band at ≥80 keV is important also to cover the ^{44}Ti line for nucleosynthesis studies.**
- Spectral resolution:
  - **The separation of different absorption and emission spectral components and the study of narrow features like emission and absorption lines and edges require a spectral resolution** $E/\Delta E$ better than 20 at 30 keV and 40-50 at 6-10 keV and at 68 keV**.**
- line sensitivity
  - **A limiting line sensitivity of** 3×10^{-7} **ph/cm^2/s (3σ 1Ms) at 68 keV is necessary to achieve the mapping of the ^{44}Ti line in Cas-A, SN1987A and other Galactic young SNRs**
- Absolute timing accuracy and time resolution
  - **The need to perform absolute phase determination of e.g. ms pulsars, and compare with radio data, an absolute timing accuracy of at least** 50 μs **is needed. This implies a time resolution of at least this order of magnitude.**

Conclusions

- **Simbol-X will increase by 3 orders of magnitude the discovery space at E=10-70 keV**
- **This will allow spectacular breakthroughs in BH physics, BH census, plasma physics and acceleration mechanisms in many astrophysical environments**
- **Synergies with major future astrophysical infrastructures will further increase the discovery space**
- **Observation strategies, fully exploiting these synergies, are under studies**

Simbol-X schedule

- Simbol-X is beginning phase B, conducted jointly by CNES & ASI, with the participation of MPE-IAAT
- Launch date: mid 2014
- Operations for three years, with a provision for a 2 years extention
- Observation program will be composed of :

  - *a "core program", with main priority science targets*

  - and a guest observer program open to the community

The Simbol-X collaboration

F : CEA/Saclay, CESR/Toulouse, APC/Paris, LAOG/Grenoble, Obs.Paris/Meudon, Obs.Astr.Strasbourg

It : INAF: OABrera, Bologna, Roma, Palermo, IASF: Milano, Bologna, Roma, Palermo

ASI: ASDC, Frascati

D : MPE Garching, I.A.A.Tübingen, T.U. Darmstadt, Univ. Erlangen-Nürnberg