Wide Field X-ray Telescope
(A Moderate Class Mission)

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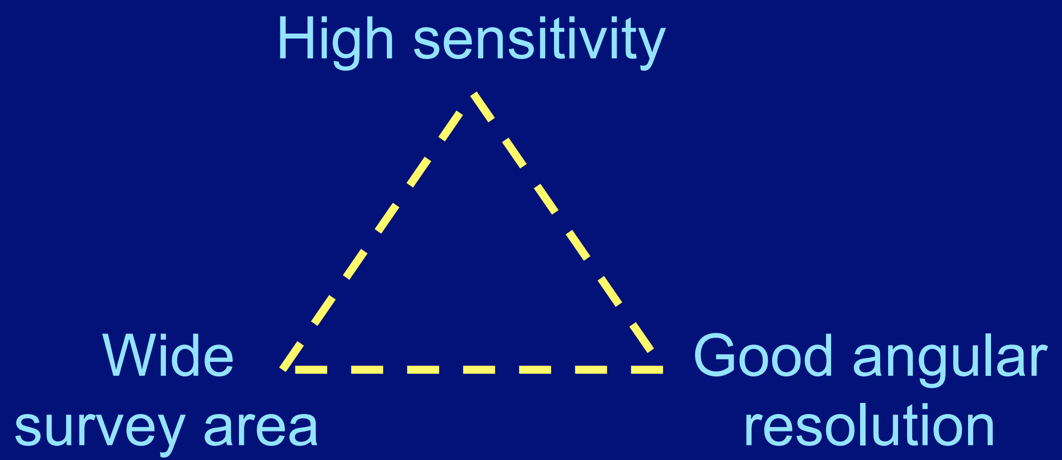
The Future of X-ray Surveys

All outstanding issues - structure formation, precision cosmology, cosmic cycle of baryons, first SMBHs, galaxy/AGN co-evolution, feedback mechanisms -
all require:



Can be done with a specific X-ray optical design and modest technological development

Wide Field X-ray Telescope
(an old idea…)

OPTIMAL GRAZING INCIDENCE OPTICS AND ITS APPLICATION TO WIDE-FIELD X-RAY IMAGING

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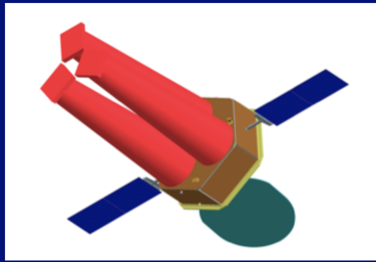
Received 1990 April 16; accepted 1991 November 4

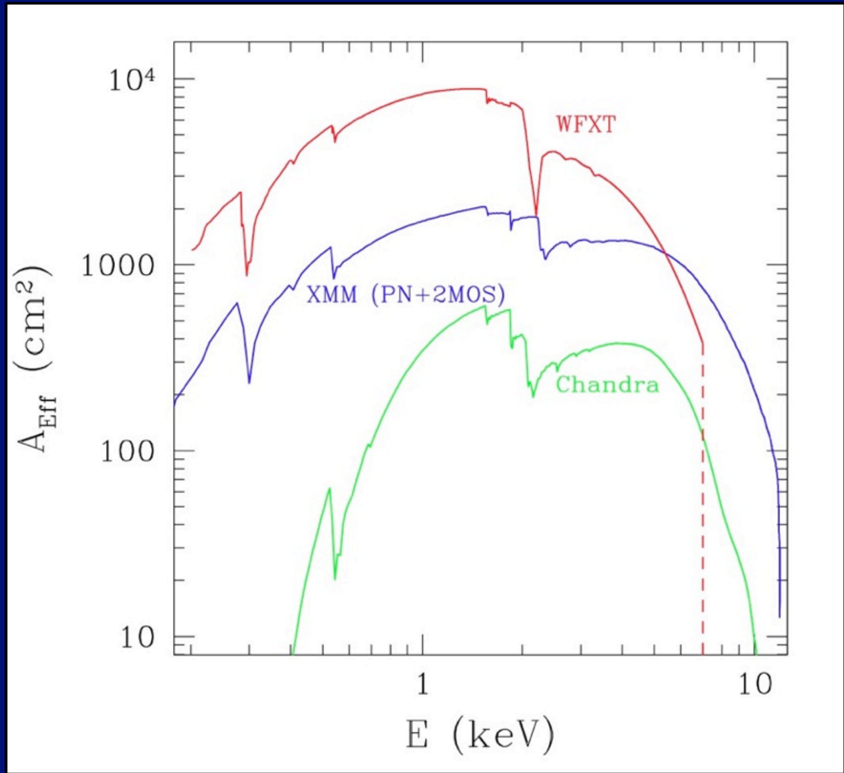
- First idea: Burrows, Burg, Giacconi 1992 (ApJ, 392, 760)
  - ⇒ Polynomial optics design to ensure 1 deg^2 with a flat ~5” PSF, with the specific goal of a “cluster survey out to z>1”
- NASA-Explorer Proposal in 1995 (Pis: Giacconi, Burg)
  - ⇒ Scientific case built around a large Cluster Survey (Evolution, LSS, Cosmology)
  - ⇒ Basically turned down on the basis of a prejudice which dominated the the theoretical and observational community in the early-mid 90s…
- Other attempts with ESA/ASI/NASA until 2002 not successful
- Currently under review of Decadal Survey (US+Italian collaboration). X-ray optics design in Milan funded by ASI.

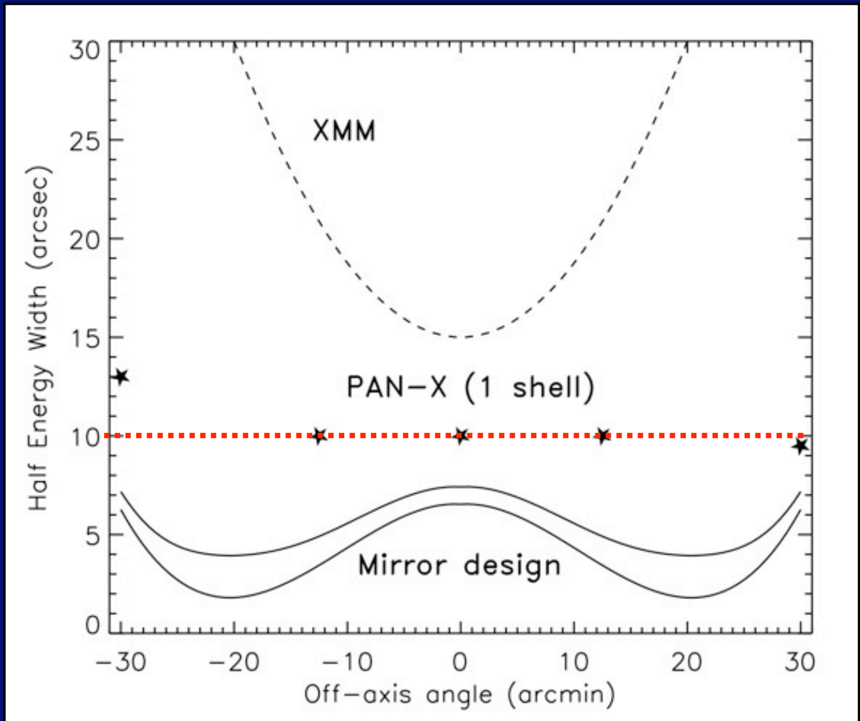
Key mission concept components



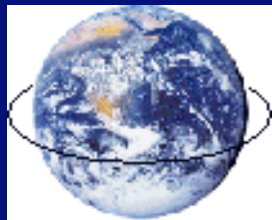
Three co-aligned telescopes with wide field optics and CCDs with ΔE/E~20 resolution

Large effective area: ~1 m^2 @ 1 keV (10x Chandra) from 78 shells in 3 telescopes. Excellent effective area to 6 keV .





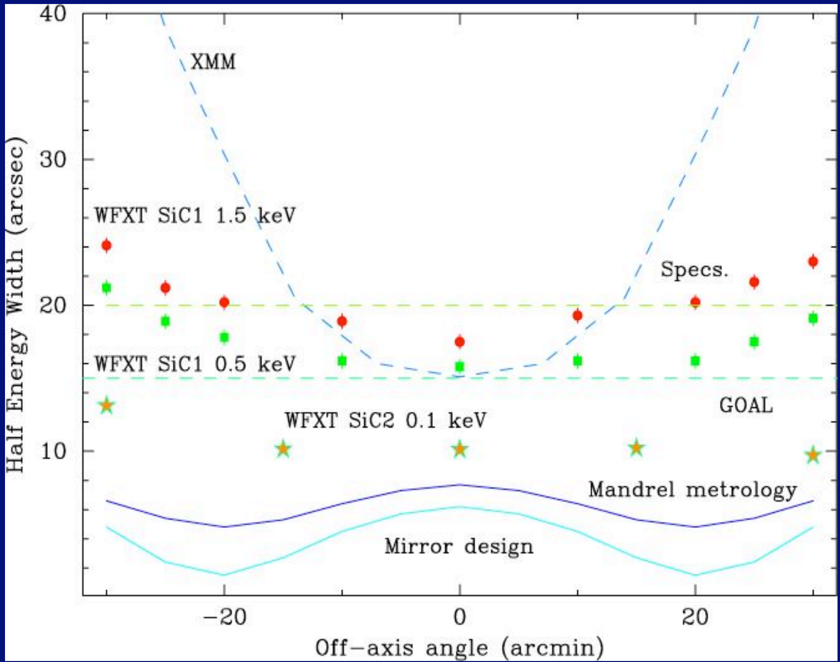
Wide field optics ensure ~constant PSF over 1 sq. degree (HEW=5” goal)

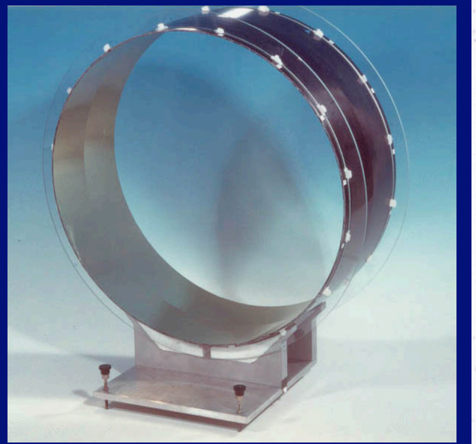


Low-earth orbit (550 km @ 6 deg) to minimize particle background

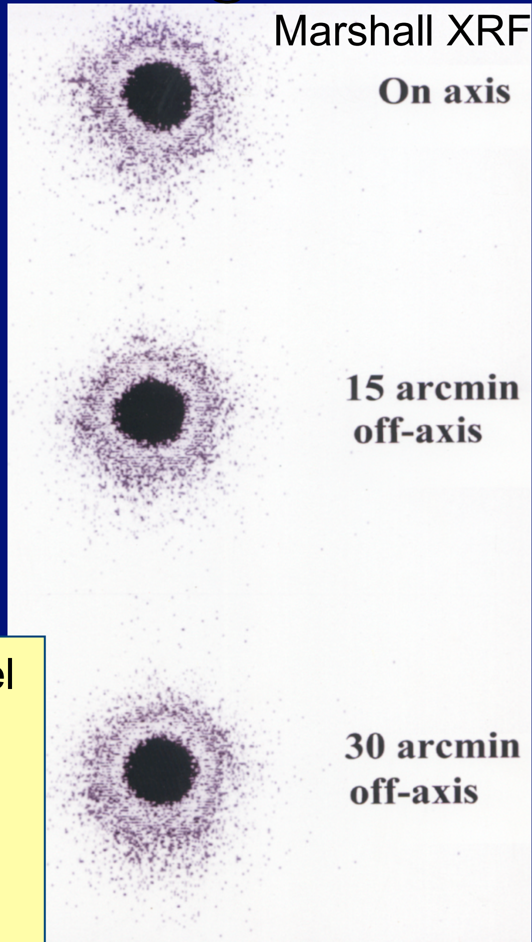
WFXT heritage (SiC by epoxy replication)

see O. Citterio, et al., ", SPIE Proc., 3766, 198 (1999) Ghigo et al., SPIE Proc., 3766, 209 (1999)





Tests @ Panter-MPE & Marshall XRF



WFXT (epoxy replication on SiC)
Ø = 60 cm

Height = 20 cm

F. L. = 300 cm

HEW = 10 arcsec @ 0.1 keV

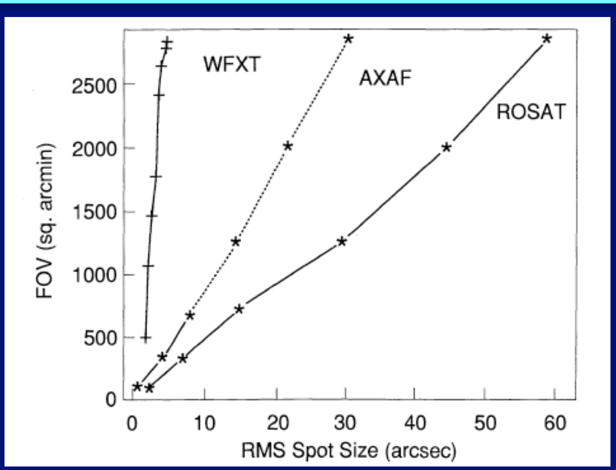
Ni replication with same mandrel
Ø = 60 cm

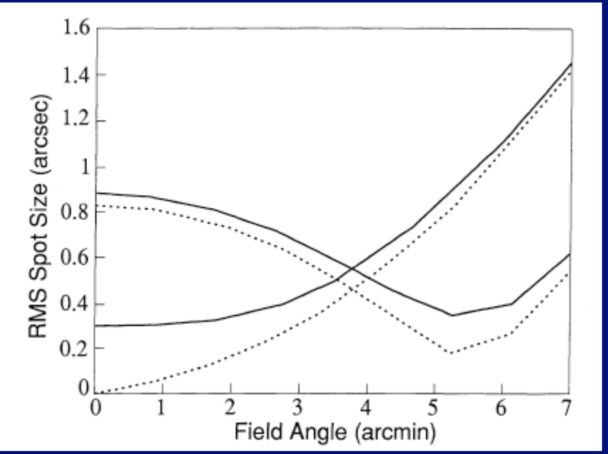
Height = 20 cm

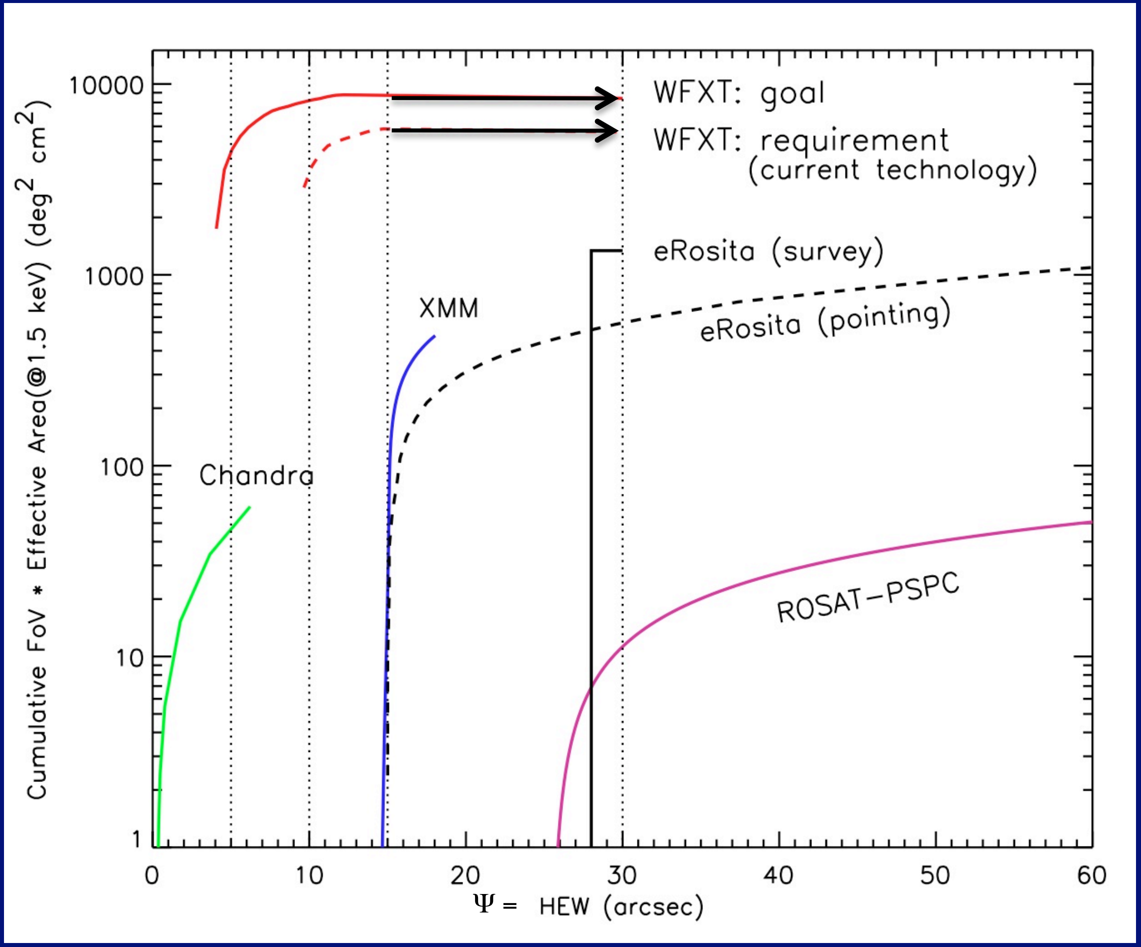
F. L. = 300 cm

HEW = 35 arcsec @ 0.28 keV

Unique combination of FoV - Collecting Area - PSF





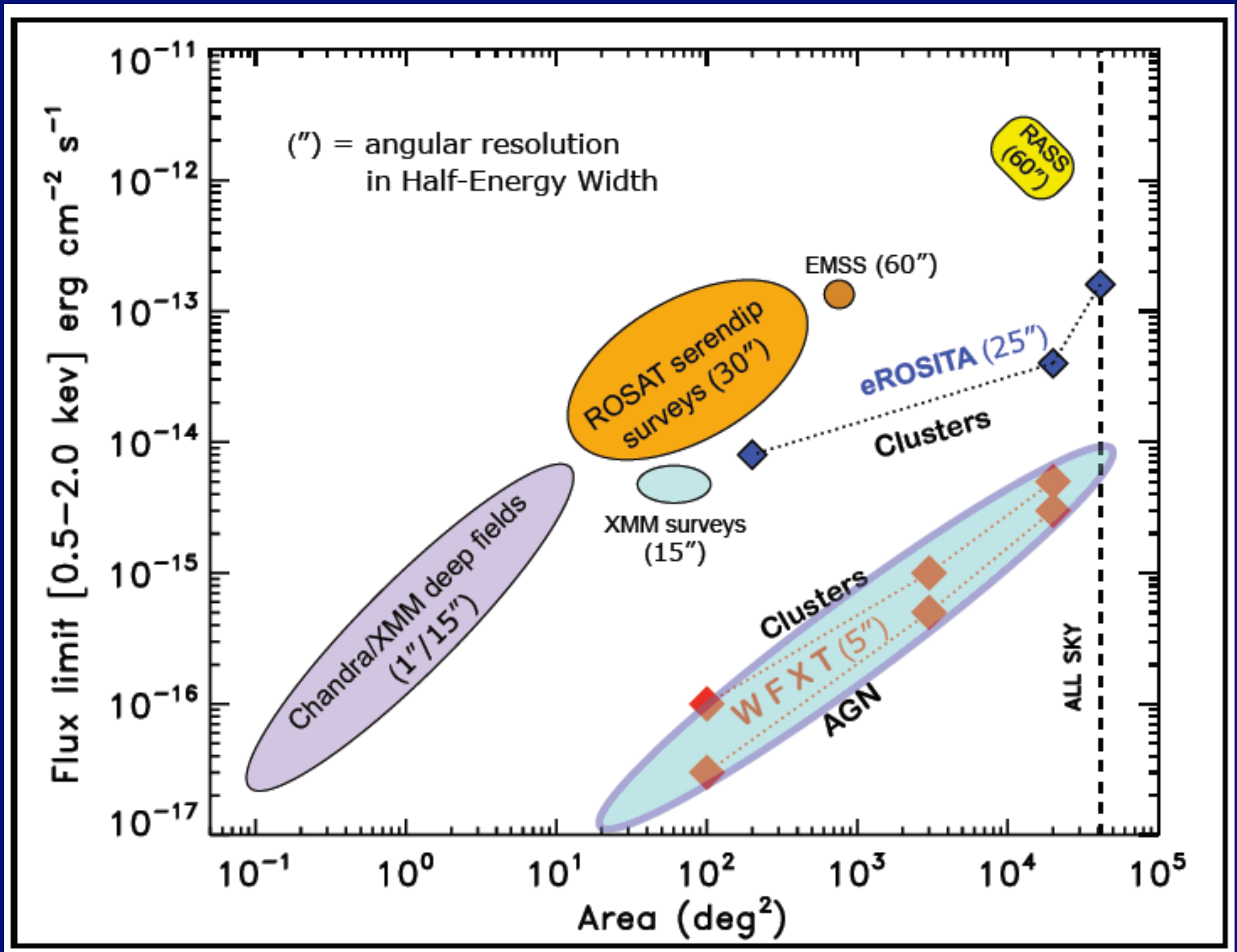


WFXT Team - 2010

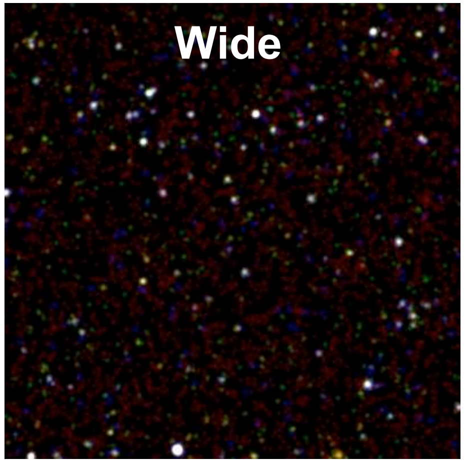
Burrows, Burg, Giacconi 1992

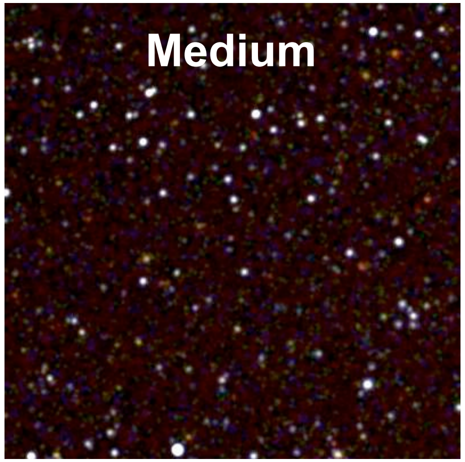
Wide & Deep

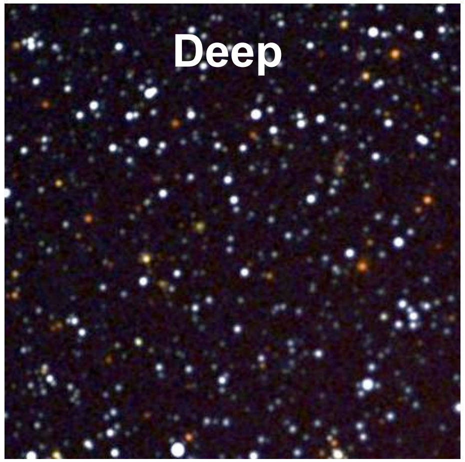
- <u>to dramatically increase survey volume</u> ($\Phi(M,L_x)$), i.e. large number of sources, over a wide L_x/Mass and z range
- <u>to enable physical source characterization</u> with a large number of high S/N spectra



Dramatic advance over existing/planned missions in combined solid angle/ sensitivity







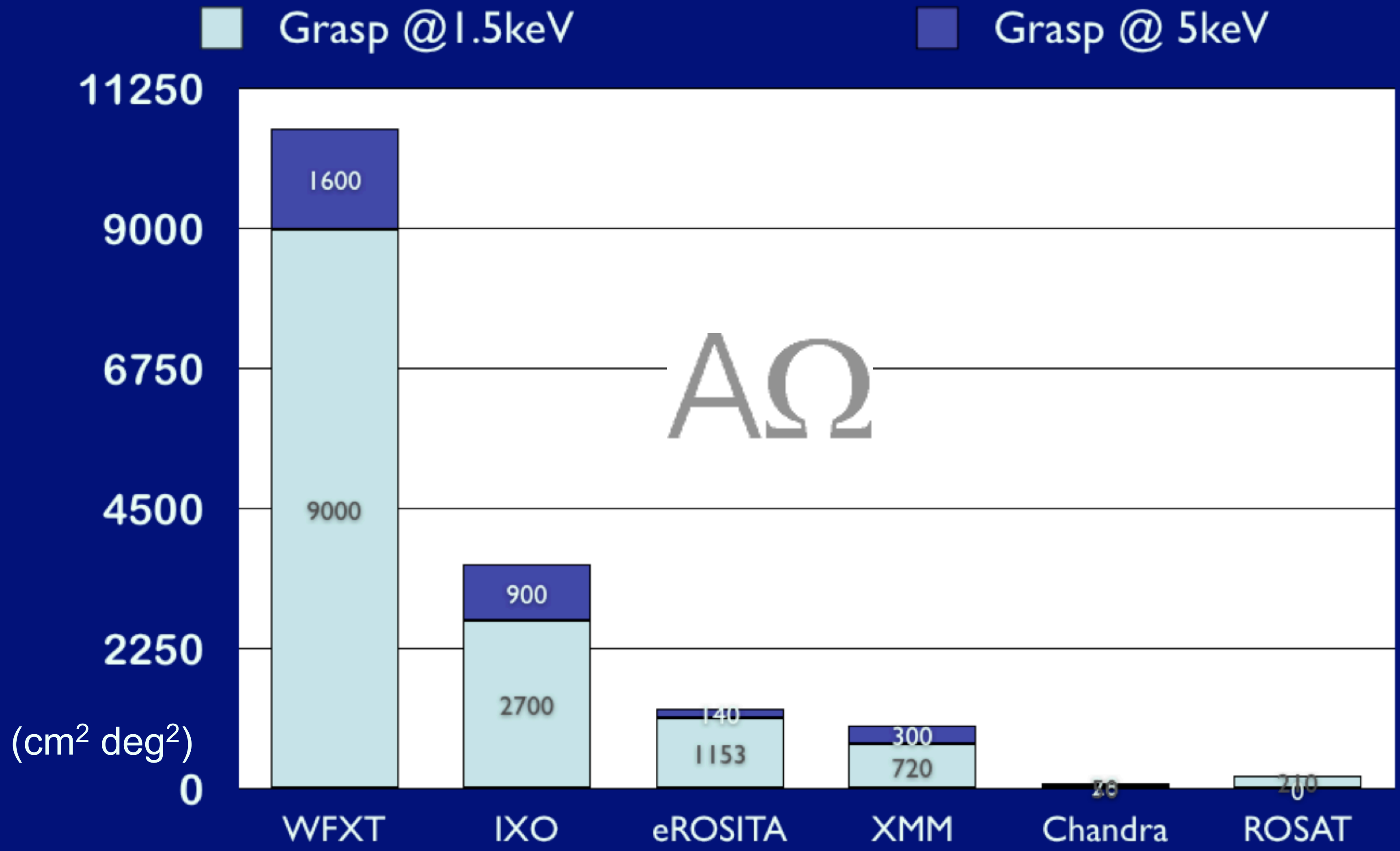
“SDSS-like” X-ray survey and beyond

- Lifetime: 5 years - 3 main surveys:
  - Wide: 20,000 deg^2 (2 ksec) to 3×10^{-15} erg/cm^2/s, 500× more sensitive than RASS (but 5” PSF instead of 60”)
  - Medium: 3,000 deg^2 (13 ksec) to deep Chandra/XMM sens.
  - Deep: 100 deg^2 (400 ksec): CDF depth over 800x area!

Quantity	Survey		
	Wide	Medium	Deep
Ω (deg^2)	20,000	3000	100
Exposure time	2 ks	13 ks	400 ks
Total time	1.67 yr	1.66 yr	1.67 yr
S_{min} (point-like) $^{(*)}$	3×10^{-15}	5×10^{-16}	3×10^{-17}
Total AGN detected	1×10^{7}	4×10^{6}	5×10^{5}
S_{min} (extended) $^{(*)}$	5×10^{-15}	1×10^{-15}	1×10^{-16}
Total clusters/groups	3×10^{5}	2×10^{5}	3×10^{4}

$^{(*)}$ Flux limit in erg cm^2 s^{-1} (0.5-2 keV band) at 5σ detection
$^{(**)}$[2-7 keV] flux limits ~10× higher

Discovery potential: Grasp = $A \cdot \Omega$



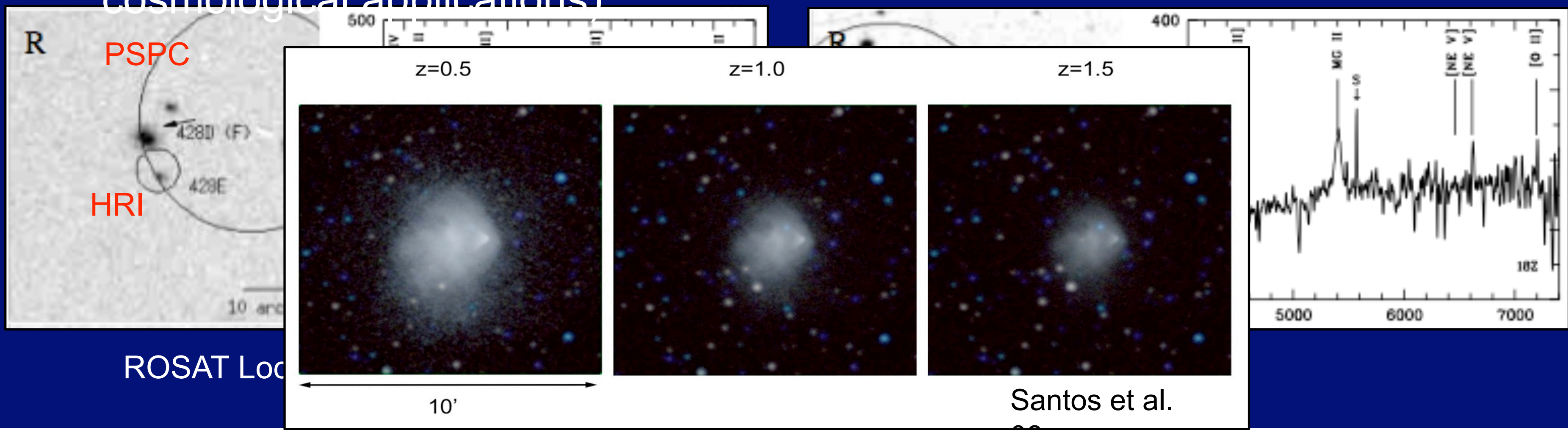
Discovery speed (ability of discovering and identifying sources) = $A \cdot \Omega \cdot \Psi^{-2}$
2-3 times order of magnitude higher than previous or planned missions

ω: Angular Resolution (sensitivity, confusion, identification efficiency)

Angular resolution

HEW=10” requirement, 5” goal <u>over the entire FoV</u>

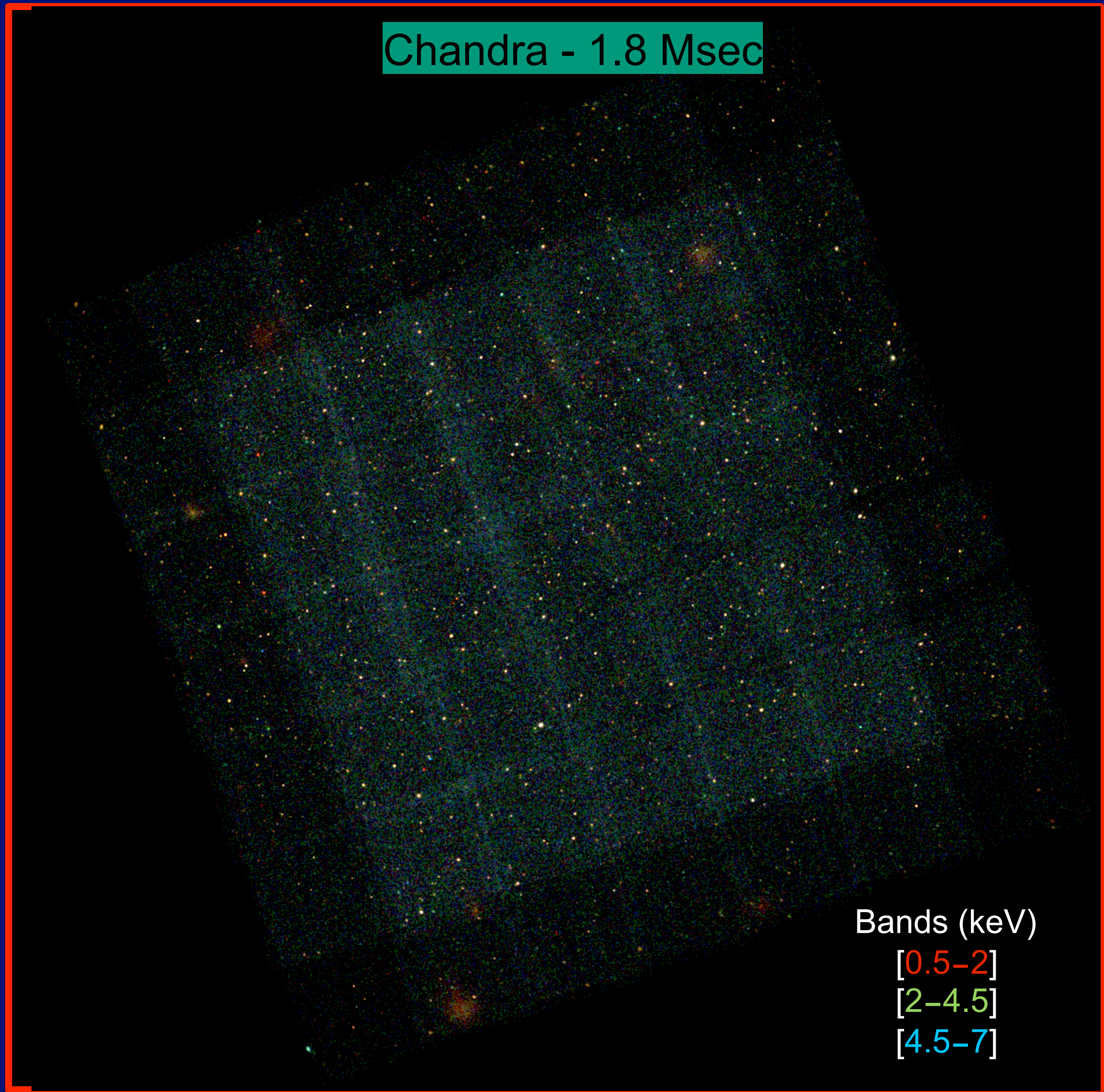
- Improve sensitivity for point and extended sources
- Minimize source confusion
- Efficient identification of optical counterparts, 1.5” positional accuracy (essential for 10^7 AGN and 5×10^5 clusters!)
- 5” HEW goal (vs 10”) will enable:
  - confusion free Deep survey
  - AGN / cluster discernment at any redshift
  - Chandra-like id accuracy (<1” radius error circle, >90% right IDs)
  - detect sharp features of the ICM (shocks, cold fronts, cavities)
  - resolve cool cores of z>~1 clusters (reliable mass proxies for cosmological applications)



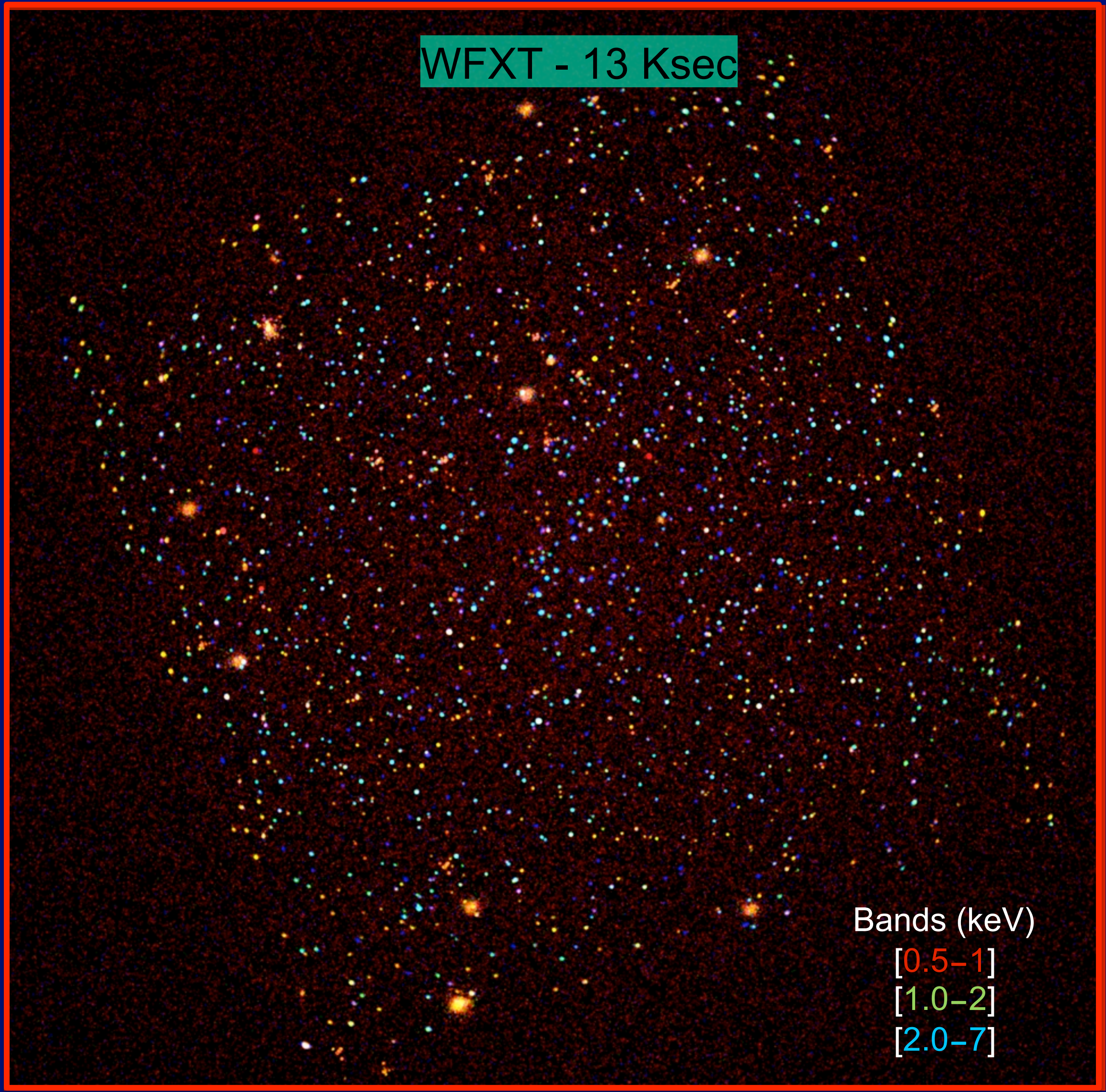
ROSAT Loc

Santos et al. 08

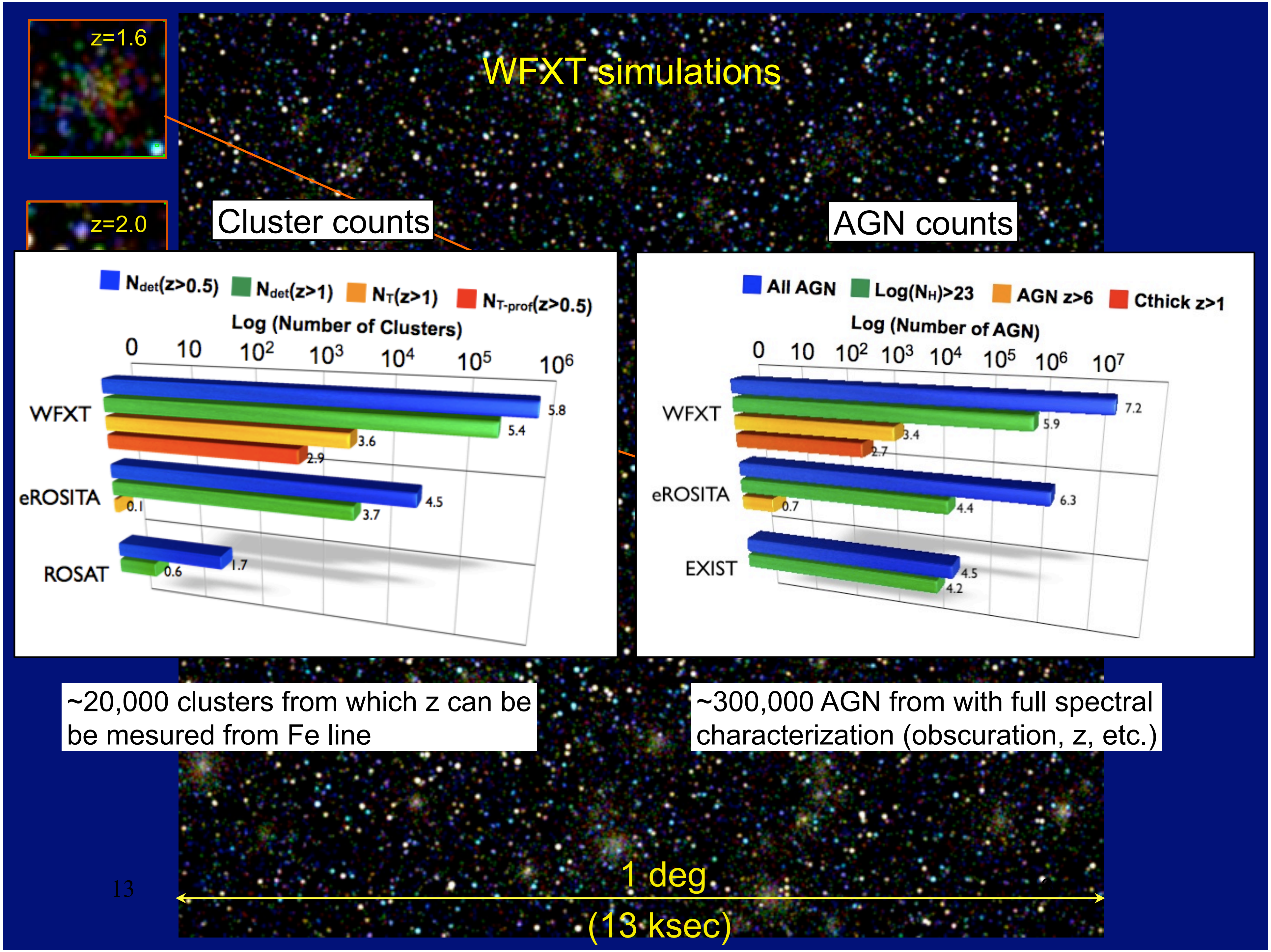
Chandra COSMOS survey (1 deg^2) (Elvis et al. 2009)

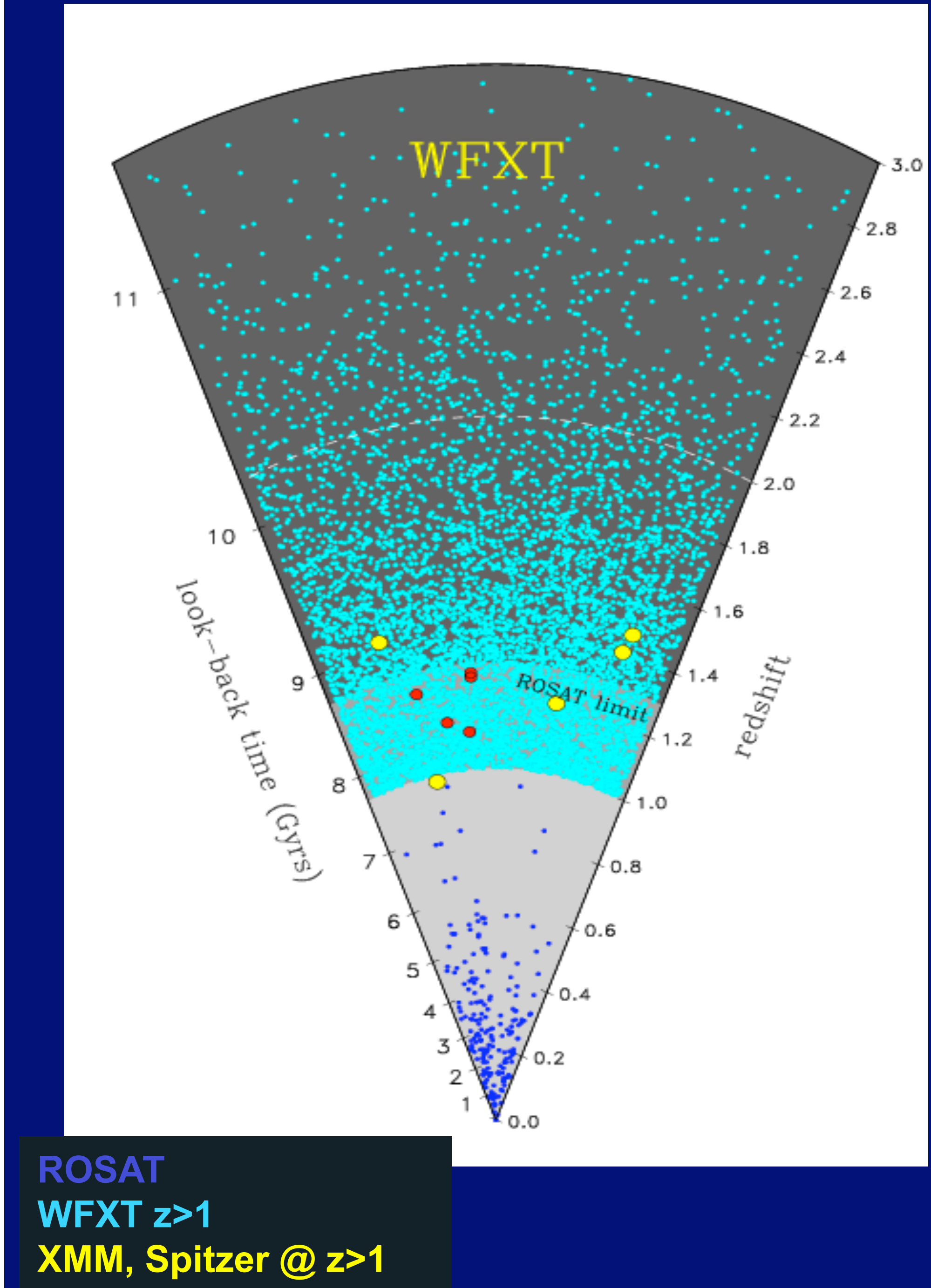


WFXT simulation (one tile from the medium survey) using the Chandra COSMOS catalog (Tozzi, Bignamini, Santos and the WFXT team)



>100 times faster than Chandra


z=1.6
z=2.0
WFXT simulations
Cluster counts
AGN counts
N_det(z>0.5) N_det(z>1) N_T(z>1) N_T-prof(z>0.5)
Log (Number of Clusters)
0 10 10^2 10^3 10^4 10^5 10^6
WFXT 5.8 5.4 3.6 2.9
eROSITA 4.5 3.7 0.1
ROSAT 1.7 0.6
All AGN Log(N_H)>23 AGN z>6 Cthick z>1
Log (Number of AGN)
0 10 10^2 10^3 10^4 10^5 10^6 10^7
WFXT 7.2 5.9 3.4 2.7
eROSITA 6.3 4.4 0.7
EXIST 4.5 4.2
~20,000 clusters from which z can be be mesured from Fe line
~300,000 AGN from with full spectral characterization (obscuration, z, etc.)
1 deg
(13 ksec)

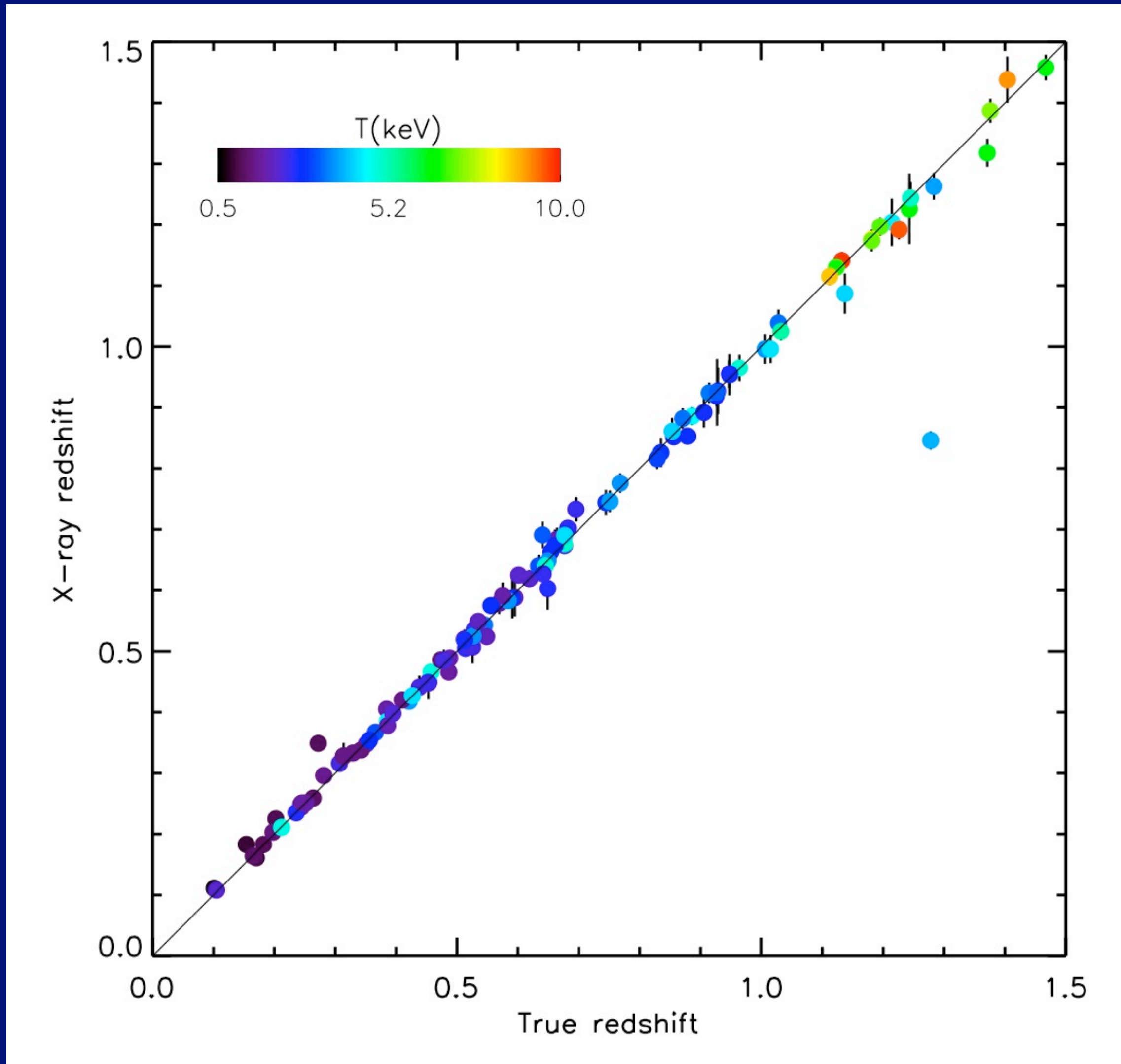


Not just a cluster counting machine:

- Characterize ICM properties and measure mass proxies for thousands of clusters at z>1.
- Trace the epoch of entropy injection and metal enrichment of the ICM.
- Study proto-cluster assembly to z~2.
- Multi-λ synergies: a vast scientific legacy for decades to come
- Path finder for follow-up studies with ELTs, IXO, ALMA,...

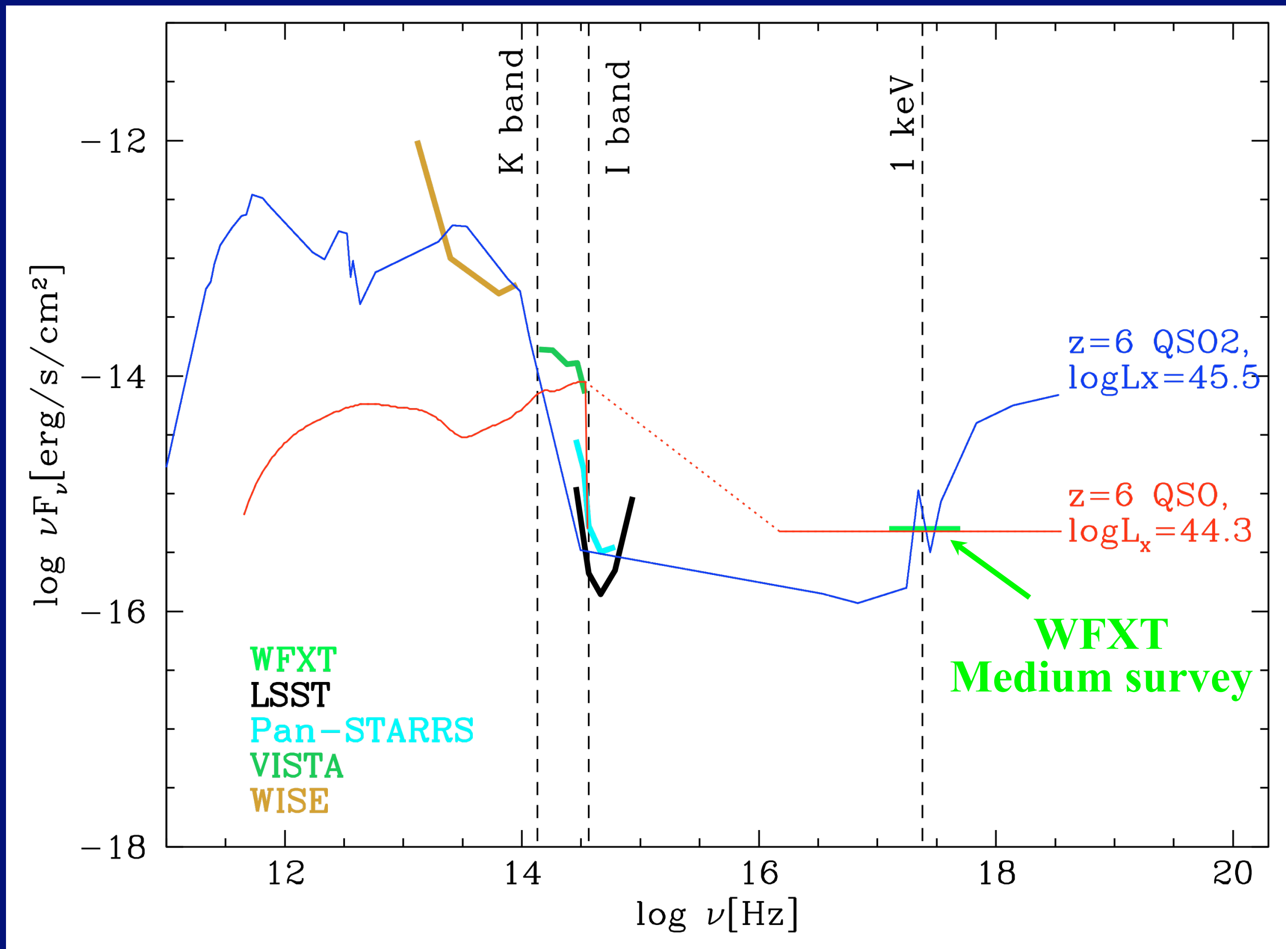
Completely X-ray based cluster redshift survey

Example: Redshift measured for ~100 clusters with >1500 counts in 10 sq.deg medium survey (13 ks) field (Yu Heng, Tozzi et al)



Synergies with other wide area surveys

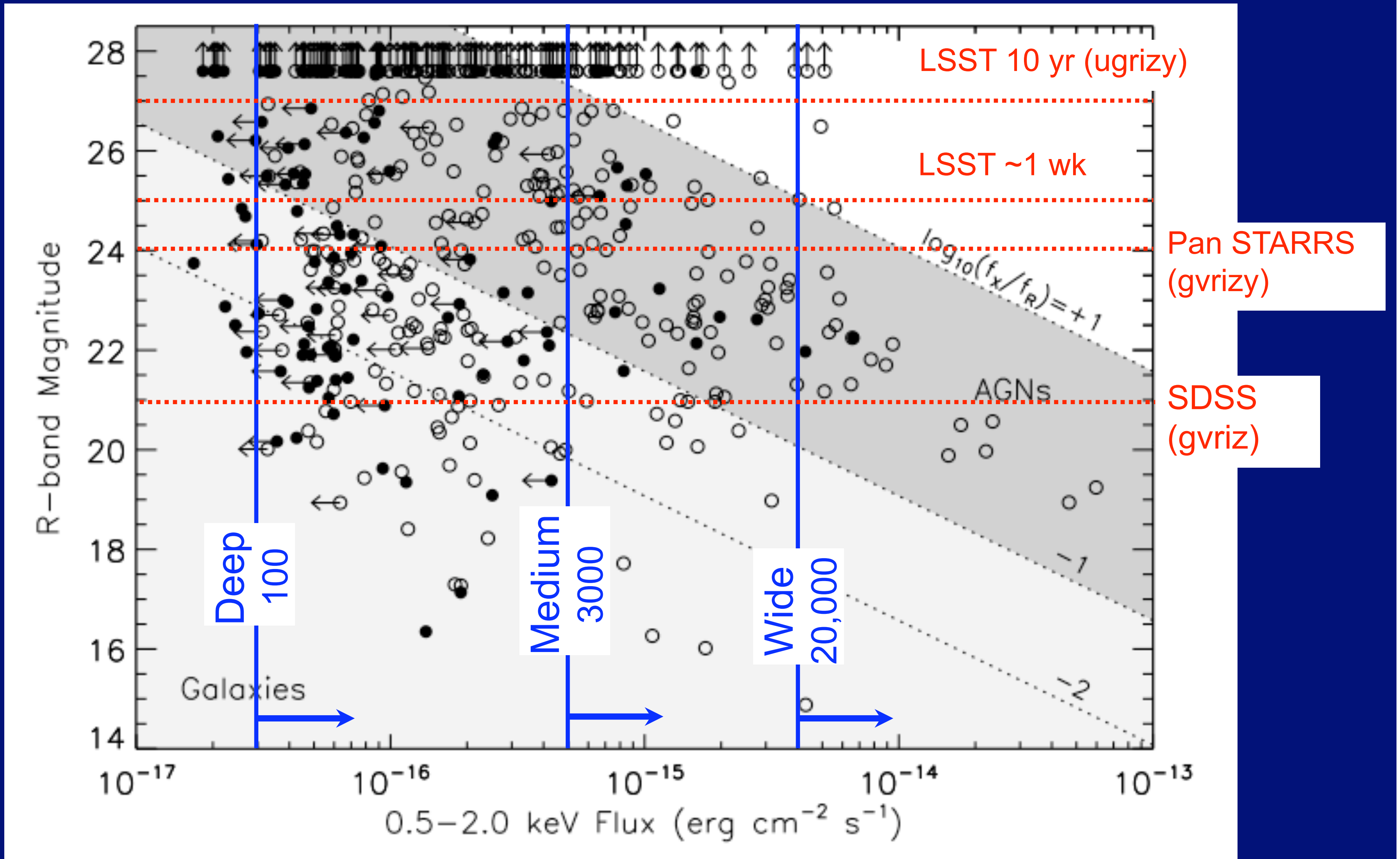
WFXT is the only X-ray mission that will match, in area and sensitivity, the next generation of wide-area O/IR and radio surveys



Courtesy of R.Gillli

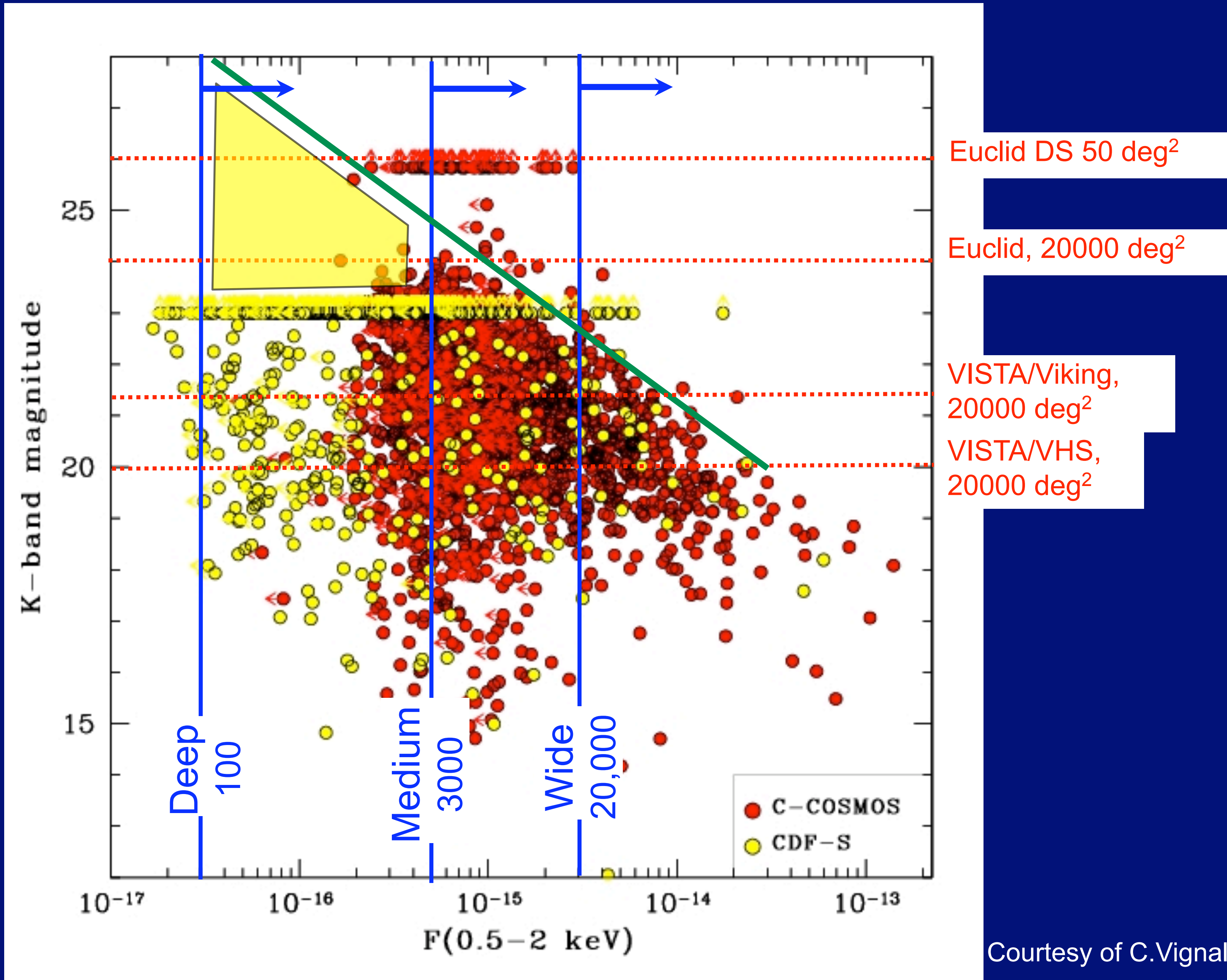
How will we identify 500,000 clusters and 100 million AGN ???

Source identification (optical)



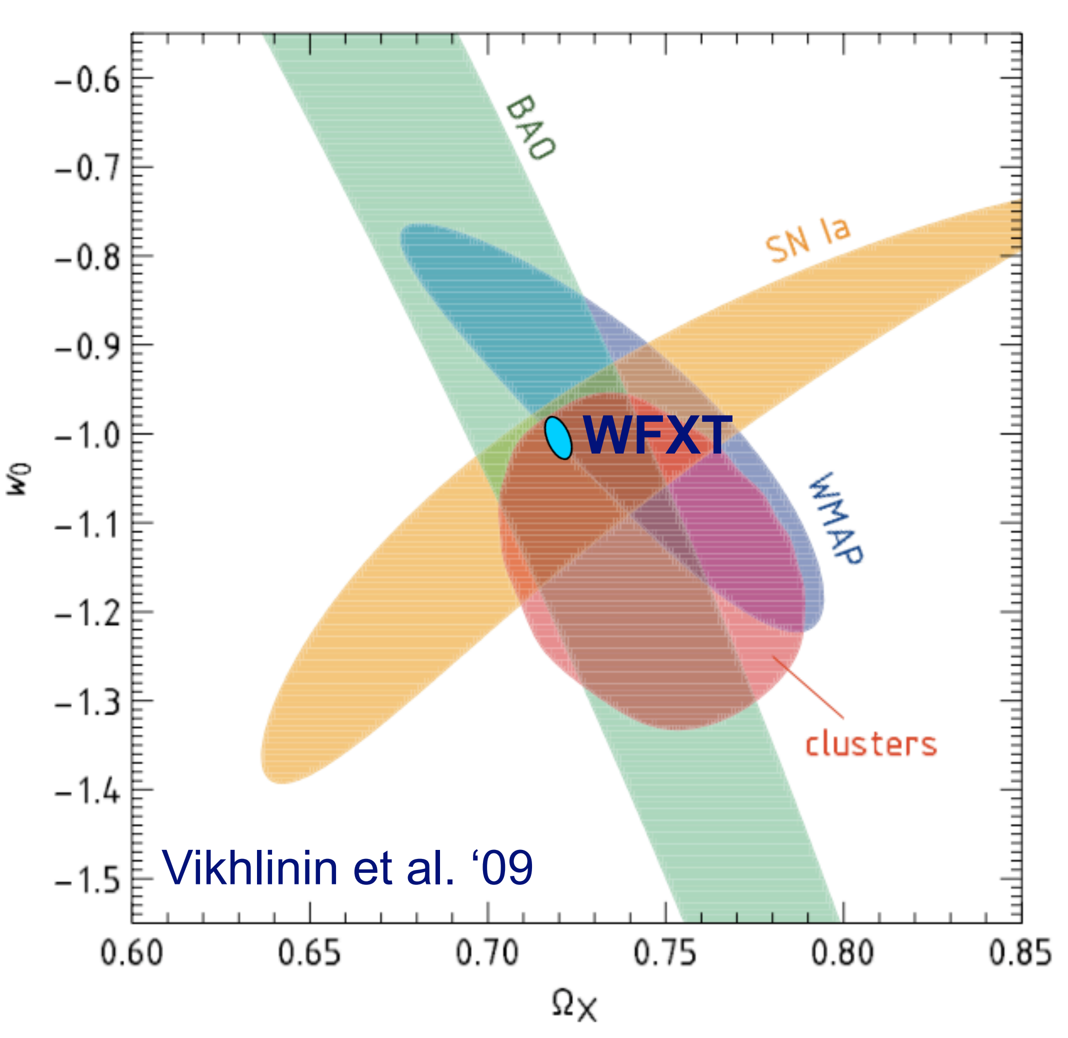
CDFS 2 Msec IDs (Luo et al. 2008)

Source identification (near IR)



Courtesy of C.Vignali

Forecasting WFXT DE constraints



Current constraints:
<100 ROSAT clusters at <z>~0.5 followed-up with Chandra (Vikhlinin et al. 09)

WFXT: ~2x10^4 clusters expected to be observed with quality comparable to Chandra observations (same assumptions as in V09) (Sartoris, Borgani et al. 10)

Wide Field X-ray Telescope

A broad range of science

- WFXT surveys will generate a legacy data set of
  - ~>5×10^5 clusters of galaxies to z~2
  - >10^7 AGN to z > 6
  - ~10^5 normal and starburst galaxies.
- The WFXT mission will have a strong impact on a wide range of disciplines, from which the entire astronomical community will benefit (SDSS effect)
  - provide a description of the cosmic evolution and cycle of baryons
  - map the large scale structure of the Universe
  - constrain and test cosmological models and fundamental physics (e.g. the nature of Dark Matter, Dark Energy and gravity)
  - determine the black hole accretion history to early epochs and its intimate link with galaxy formation and environment
  - provide an unprecedented view of nearby galaxies including our own
- WFXT is not only a path finder for other missions (IXO, ELTs, ALMA), its large A_{eff} allows direct physical characterization of >2×10^4 Clusters and ~3×10^5 AGN with no need of follow-up observations. Synergy with other missions further enhances its scientific potential and breadth.
- Like the Sloan Digital Sky Survey, all WFXT data will become public through a series of annual data releases that will constitute a vast scientific legacy for decades.

Programmatics and Schedule

Cost:

- Construction+5 yr operation (total life cycle exclusive of launch) $526M (3 independent estimates - PHASE A-E)
- Atlas V launch services $190M, Falcon 9 launch services $90M
- Potential European contribution to operations and e2e systems ($20M?)
- Potential Italian contribution for mirrors (up to $50M?)

Timeline:

Launch early in the next 10 years
(66 Month development schedule)