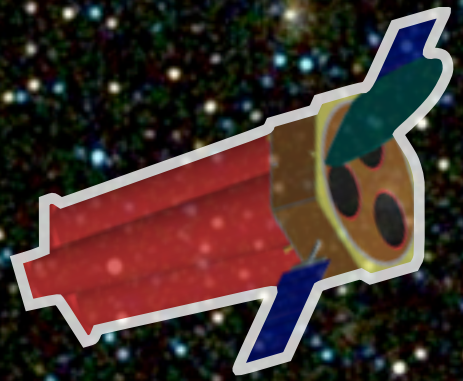
Wide Field X-ray Telescope

The ultimate X-ray survey

Science Overview



Piero Rosati

(ESO- European Southern Observatory)

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WFXT Workshop, Bologna, 25 Nov 2009

WFXT/Decadal Survey Team

Center for Astrophysics: Stephen S. Murray (PI), Alexey Vikhlinin, William Forman, Christine Jones, Ryan Hickox, Paul Reid, Andreas Zezas, Pepi Fabbiano

Johns Hopkins University: Riccardo Giacconi, Andrew Ptak, Kip Kuntz, Suvi Gezari, Hal Weaver (APL), Neil Miller, Ed Reynolds (APL), Michael (APL), Cheryl Reed (APL), Danielle Marsh (APL)

Marshall Space Flight Center: Martin Weisskopf, Brian Ramsey, Ron Elsner, Steve O'Dell

Massachusetts Institute of Technology: Mark Bautz

ESO: Piero Rosati

Trieste - Univ.: Stefano Borgani, **INAF**: Paolo Tozzi, Joana Santos, Andrea Bignamini

Milano - **INAF:** Giovanni Pareschi, Gianpiero Tagliaferri, Sergio Campana, Ginevra Trinchieri, Vincenzo Cotroneo, Alberto Moretti

Bologna - INAF: Roberto Gilli

Napoli - Univ.: Maurizio Paolillo , **INAF:** Domitilla di Martino

ASI Science Data Center: Paolo Giommi

Penn State University: Neil Brandt, Eric Feigleson, Don Schneider

Stanford University: Steve Allen

University of Illinois: You-Hua Chu

University of Durham: David Alexander

Michigan State Unversity: Meg Donahue, Mark Voit

University of Michigan: Gus Evrard

Space Telescope Science Center: Kathryn Flanagan

University of Chicago: Andrey Kravtsov

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Wide Field X-ray Telescope
(a brief history…)

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

CHRISTOPHER J. BURROWS,[1] RICHARD BURG,[2] AND RICCARDO GIACCONI
Space Telescope Science Institute,[3] 3700 San Martin Drive, Baltimore, MD 21218
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 + Science assessment study in TS, BO, NA funded by ASI.

Wide Field X-ray Telescope
(...history)

Regarding your point that WFXT could provide an unbiased survey for clusters of galaxies, to help understand the development of structure in the early universe, the peer panel felt that the proposal did not adequately address the possibility that cluster evolution may be significant at z = 0.3 and more so out to z = 0.5. Estimates in the proposal of the number of sources were based upon the absence of evolution, despite recent publications (including one by some of the Co-Investigators) that suggest the presence of evolution at most redshifts. In the opinion of the reviewers, few clusters would be seen at z greater than 0.5 to 0.75 if evolution is, in fact, important. The result could be a mean spacing between detected galaxies too large to permit the determination of large scale structure at high redshift, but the proposal ignored this possibility.

NASA source, Oct 95

Top science case drivers
(see corresponding DS white papers)

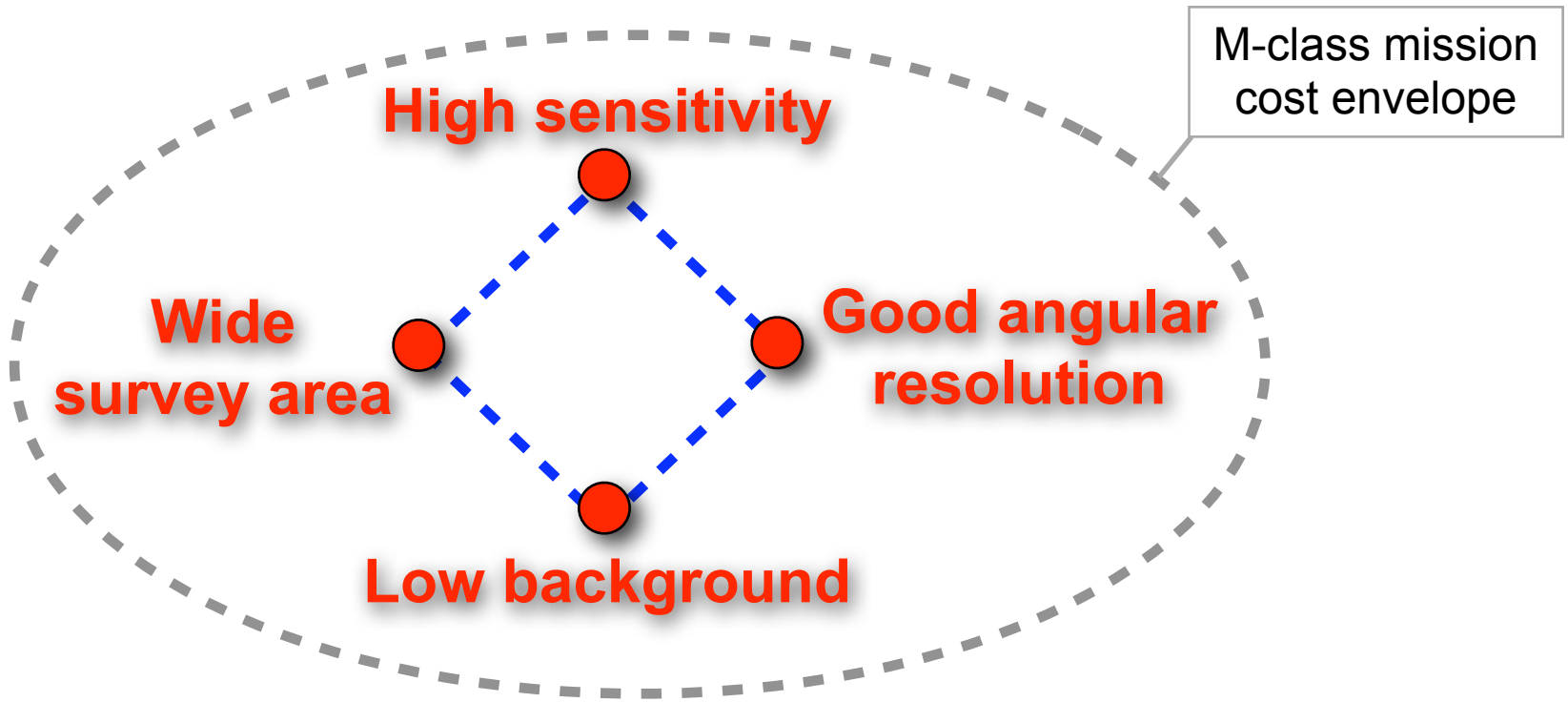
- The growth and evolution of SMBHs (Murray, Gilli et al. 09)
  - Measure volume density and Φ(L) of obscured and unobscured AGN vs z and mass, accretion rate, host galaxy SFR
  - Unveil primordial population of AGN at z>6

- Trace cosmic evolution and cycle of baryons with clusters (Giacconi, Borgani, Rosati et al. 09)
  - Understand entropy and metallicity injection into ICM from galaxies and SMBHs
  - Map ICM physical properties out to R_{vir}
  - Precision cosmology (i.e. competitive Dark Energy FoM) with evolution of cluster mass function (Vikhlinin et al. 09, Borgani et al. 09) + test of non-GR theories on large scales
  - Detect protoclusters at z~>2 at the peak of SF and BH accretion

- Studies of local Universe (Ptak et al. 09)
  - Hot gas distribution in MW halo, feedback from SF regions, SNRs, compact objects
  - Magellanic clouds survey, Virgo
  - X-ray determined SF histories of >~10^4 galaxies at z<1

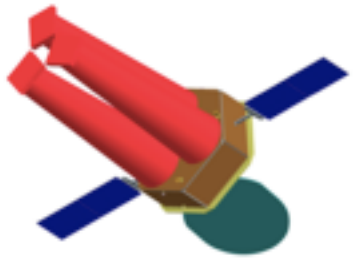
Mission parameter requirements

All outstanding issues - *first SMBHs, galaxy/AGN co-evolution, cosmic cycle of baryons, structure formation, precision cosmology, galactic studies (SF regions, hot ISM, compact objects)* - require:

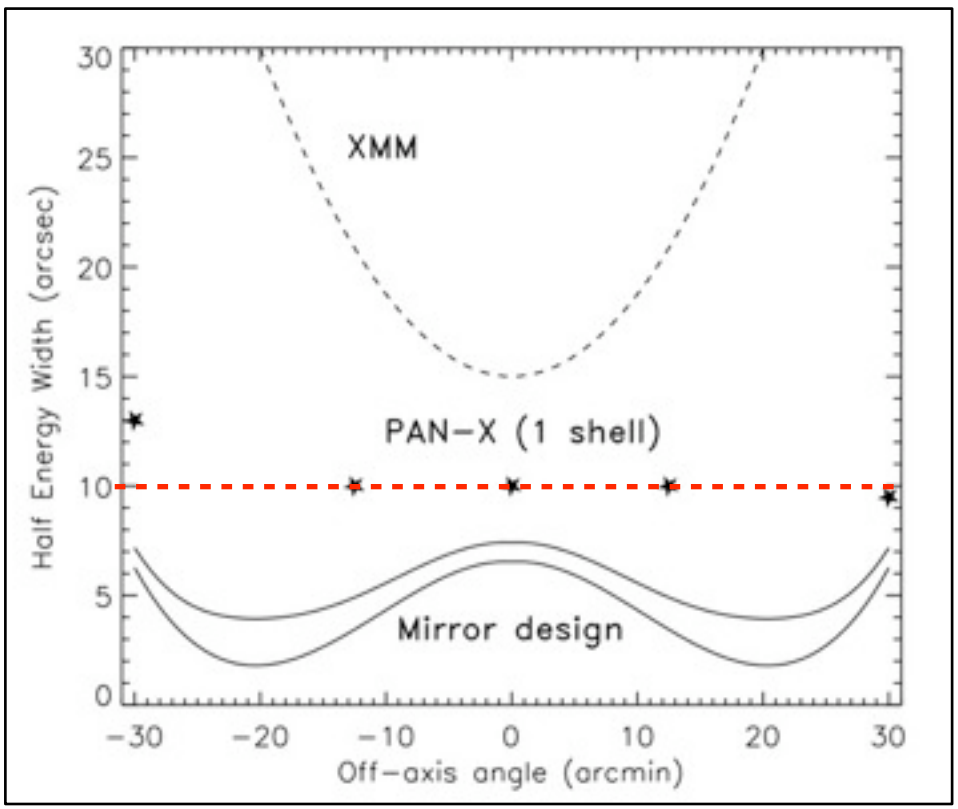


Can be done with a specific X-ray optical design and affordable technological development

Key mission concept components

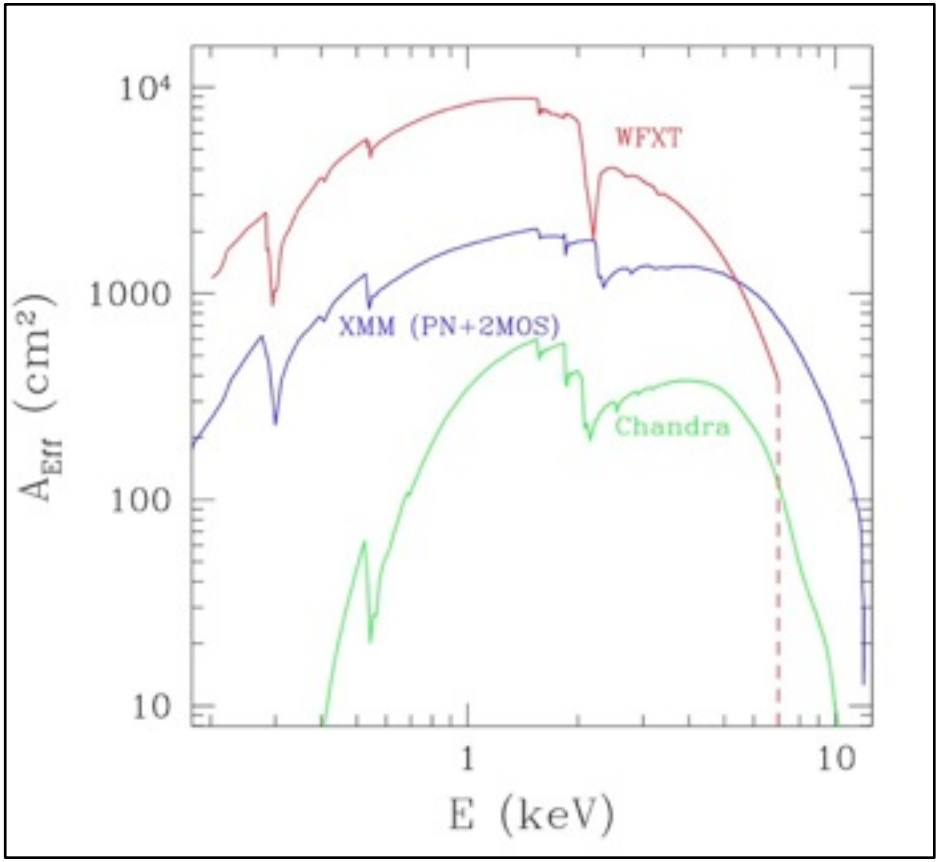


Three co-aligned telescopes with wide field optics and CCDs with ΔE/E~20 resolution



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

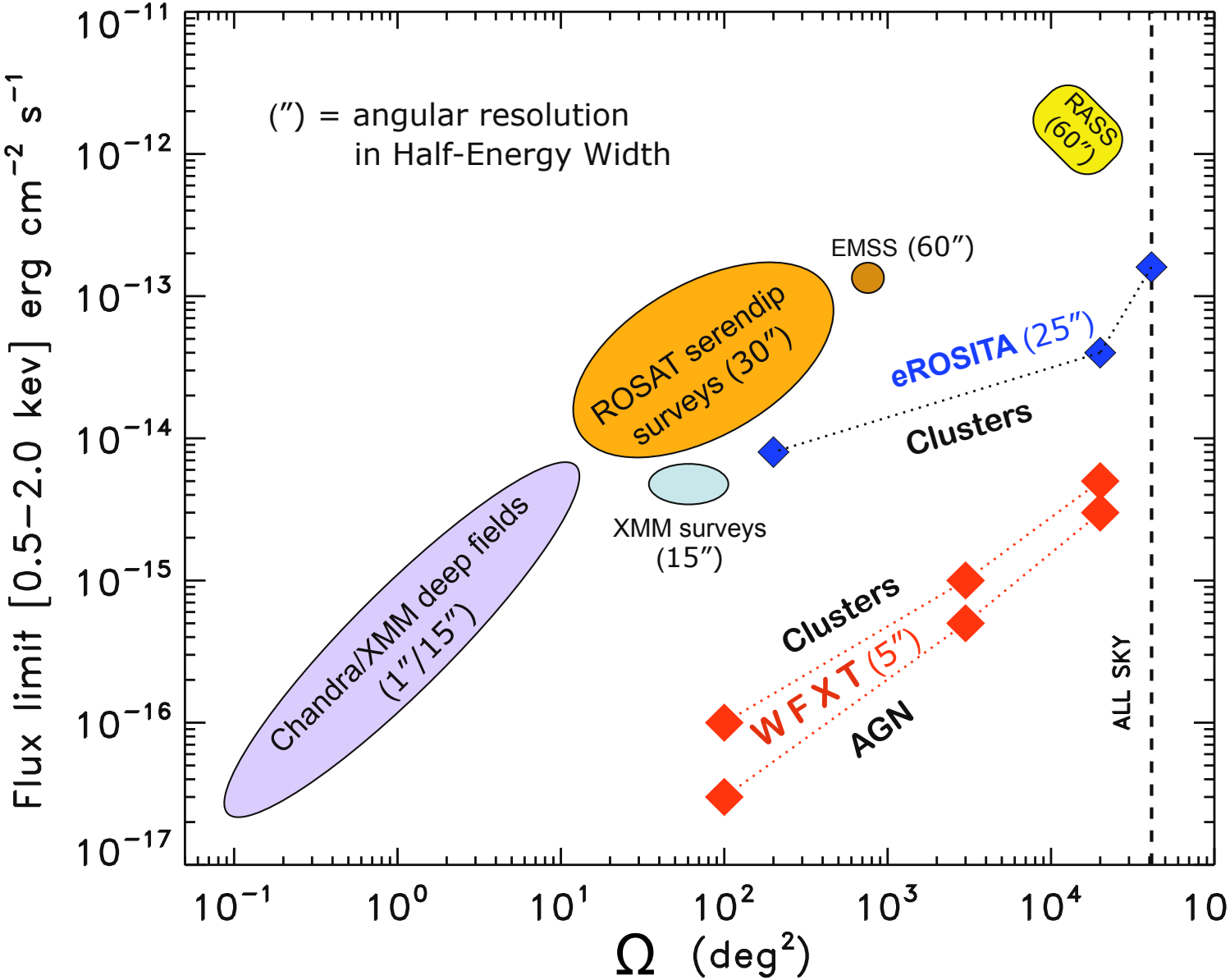
Large effective area: ~1 m^2 @ 1 keV (10x Chandra) from 78 shells in 3 telescopes. Excellent effective area to 6 keV .



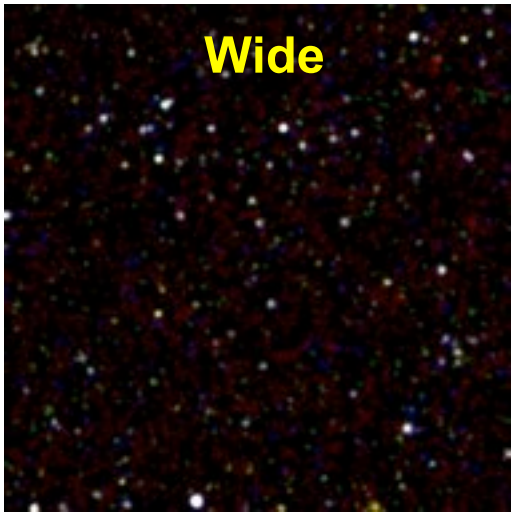
Low-earth orbit (550 km @ 6 deg) to minimize particle background

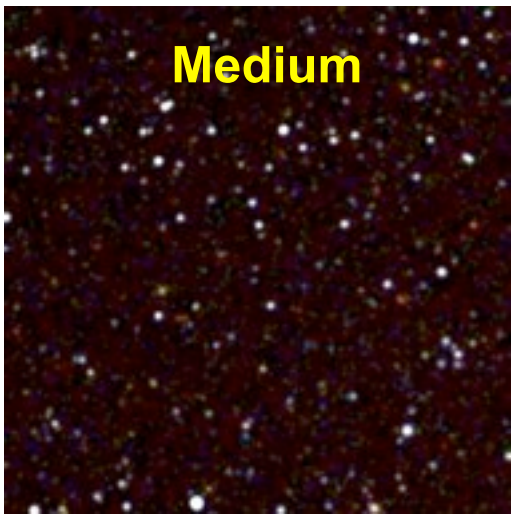
Wide & Deep

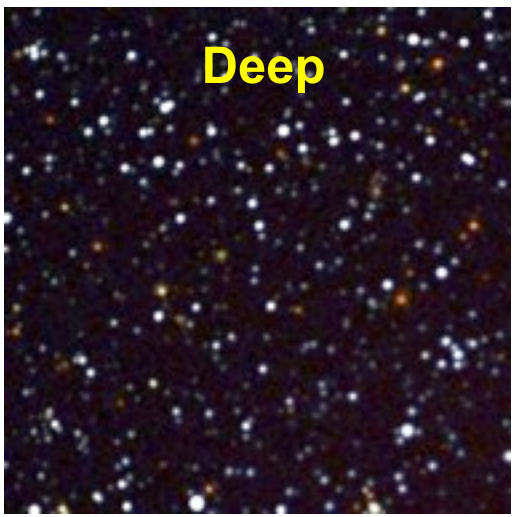
- to dramatically increase survey volume ($\Phi(M,L_x)$), i.e. large number of sources, over a wide L_x/Mass and z range
- to enable physical source characterization with a large number of high S/N spectra



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







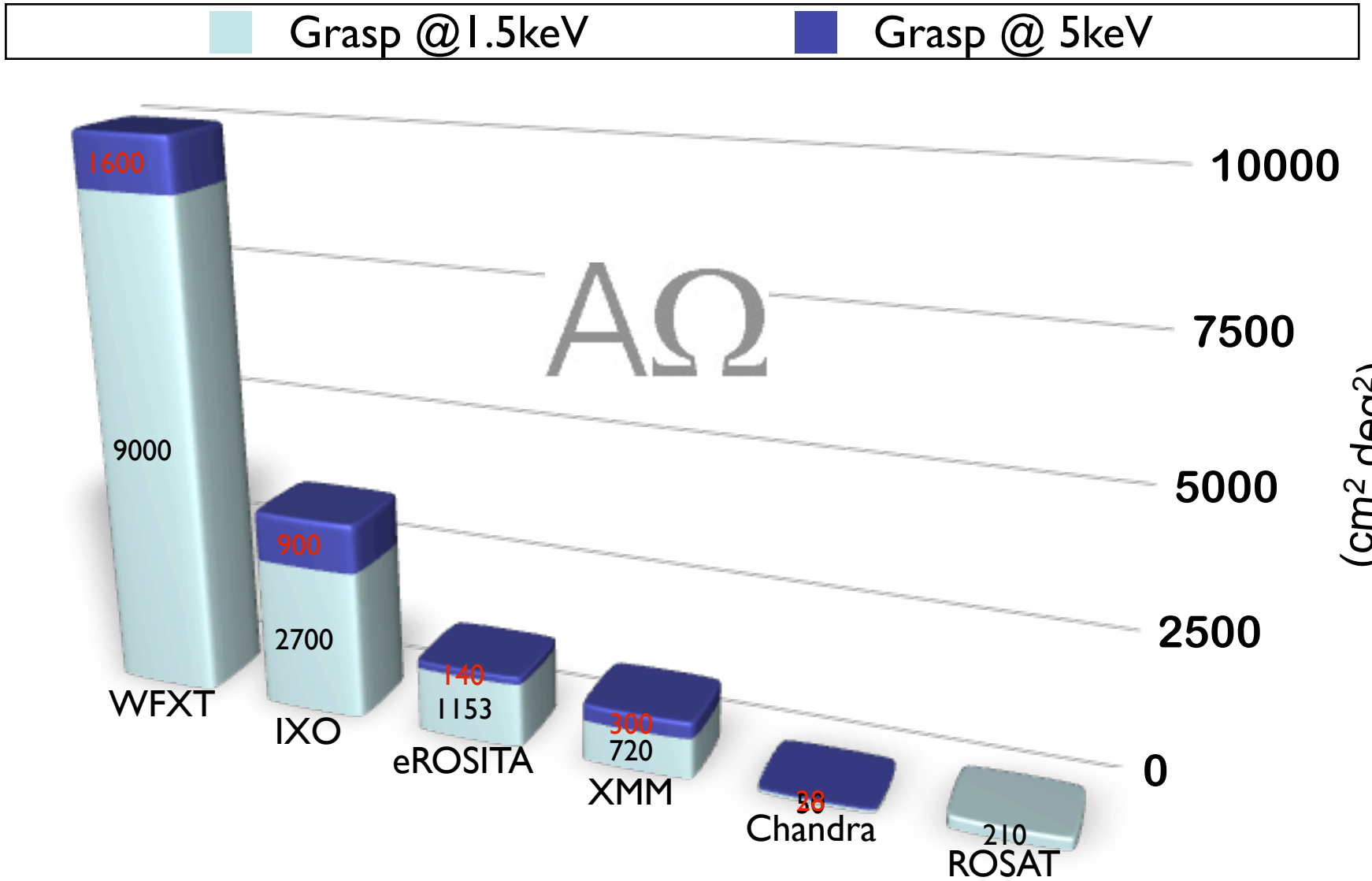
WFXT Surveys

"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 1000x 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·Ω



Discovery speed (ability of discovering and identifying sources) = $A \cdot \Omega \cdot \omega^{-2}$

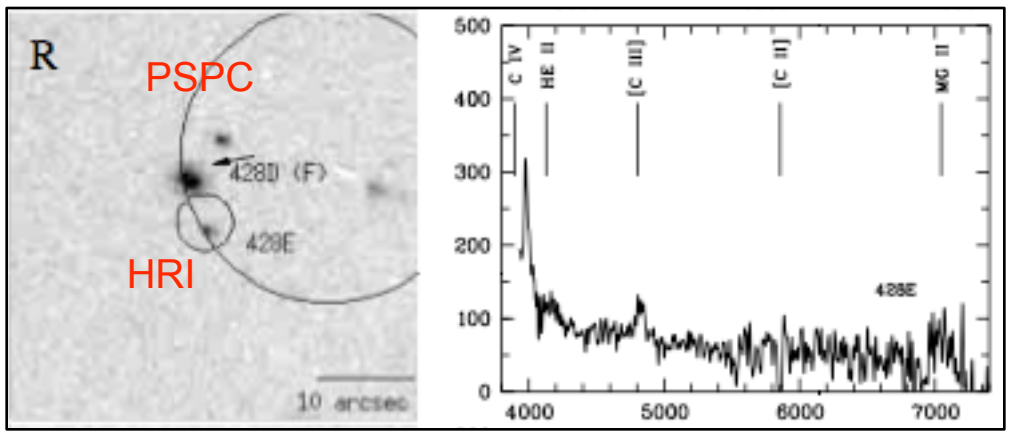
2-3 times order of magnitude higher than previous or planned missions

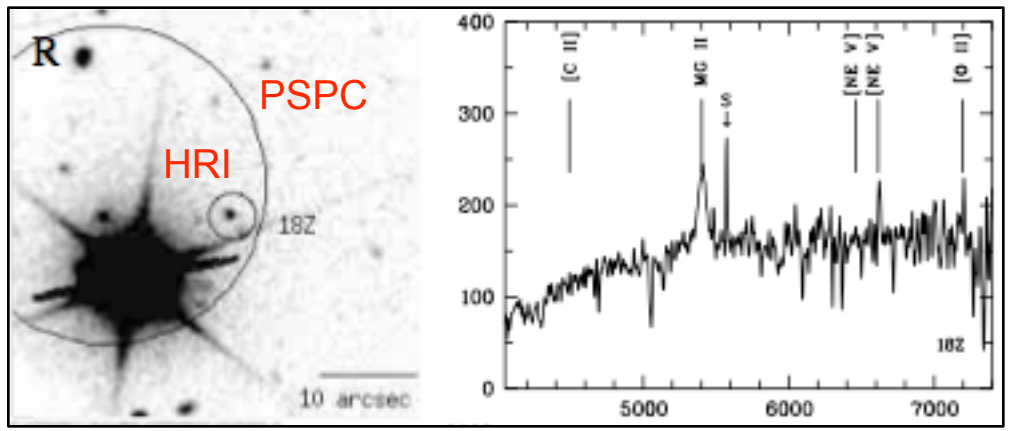
ω: Angular Resolution (sensitivity, confusion, identification efficiency)

Angular resolution

HEW=10” requirement, 5” goal over the entire FoV

- 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)





ROSAT Lockman Hole survey (25” vs 5” resolution) (Lehmann et al. 2001)

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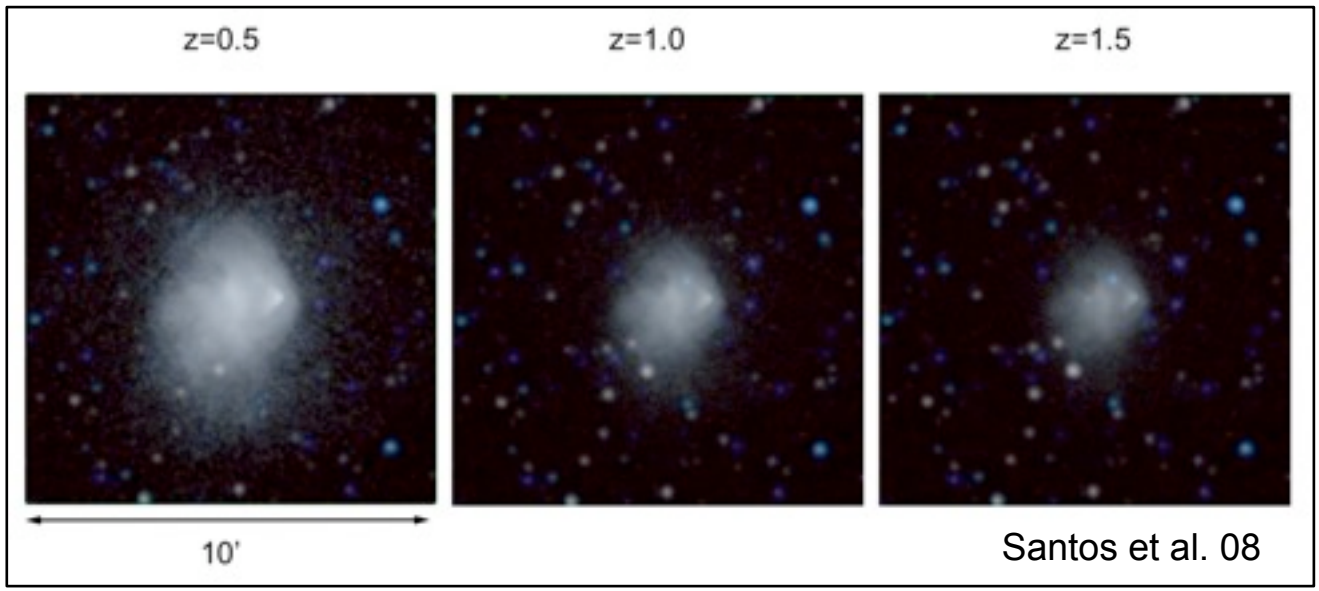

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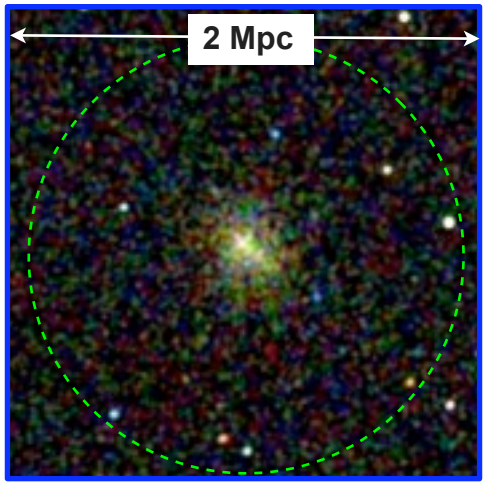
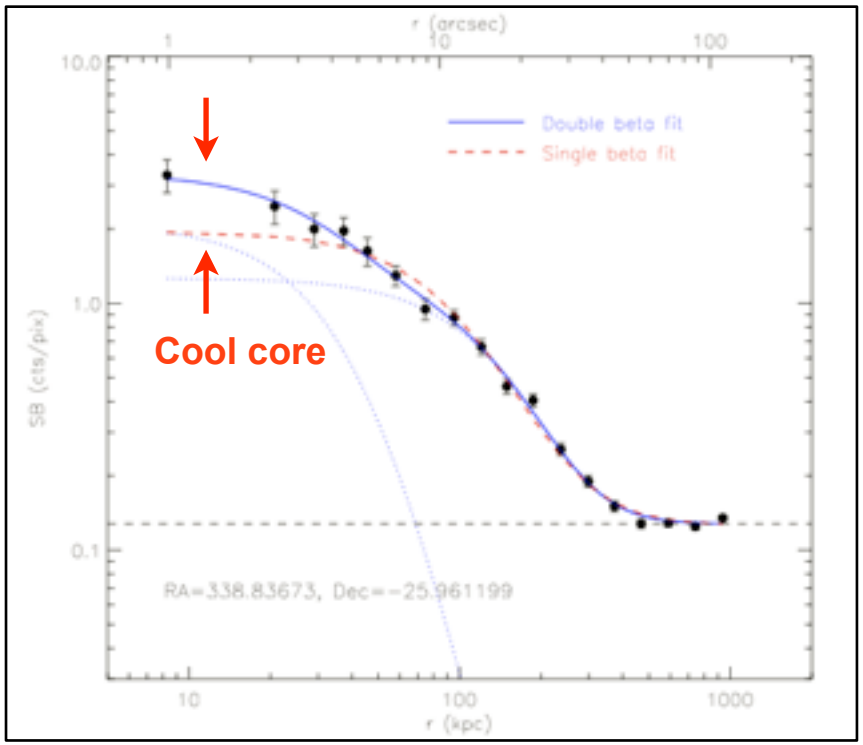
  - detect sharp features of the ICM (shocks, cold fronts, cavities)
  - resolve cool cores of z>~1 clusters (essential for cosmological applications, reliable mass proxy)

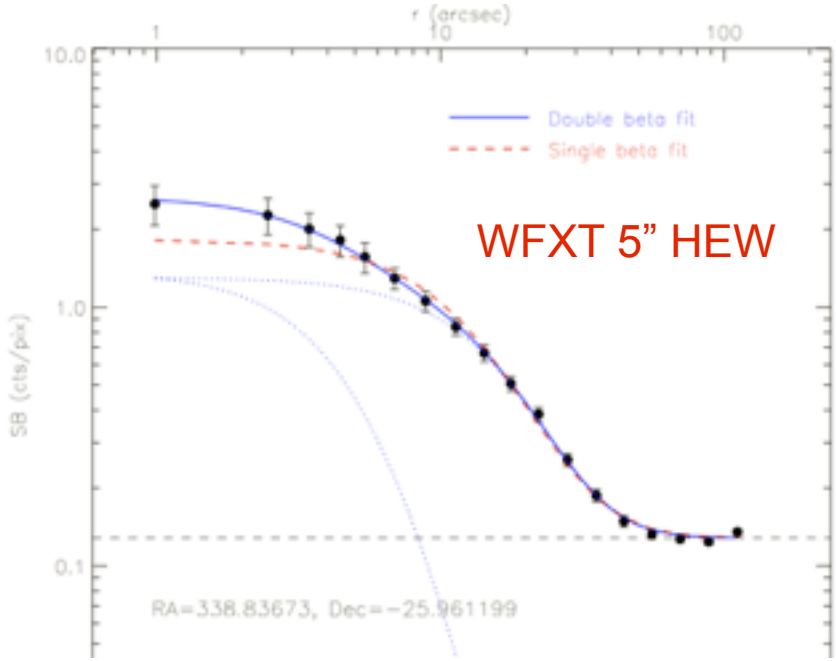
Massive z=1.39 cluster with Chandra (190 ks) (Rosati et al. 09)

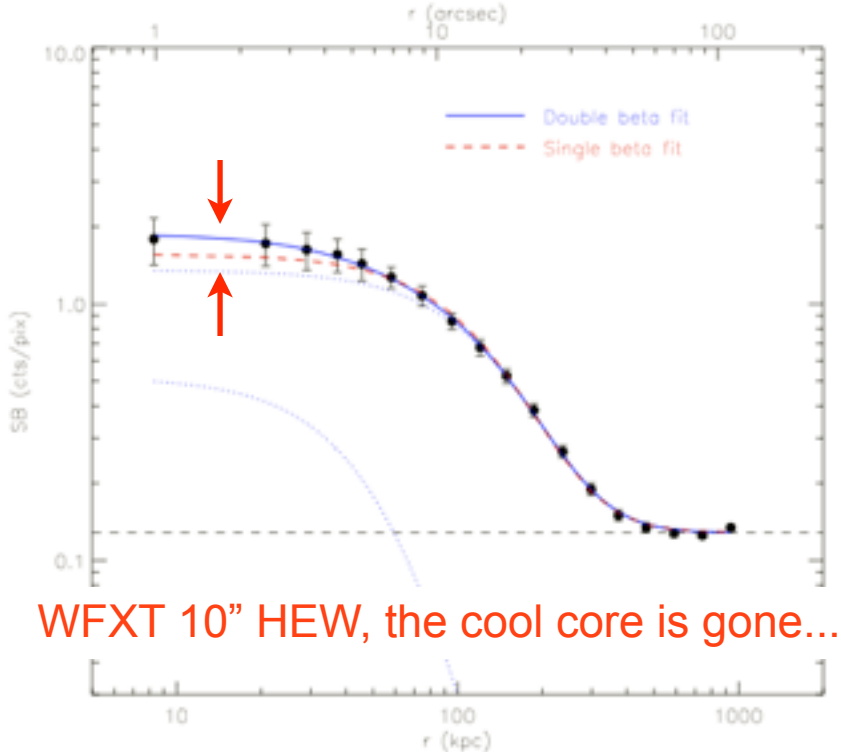
(10”=80 kpc at z=1)





Chandra observations

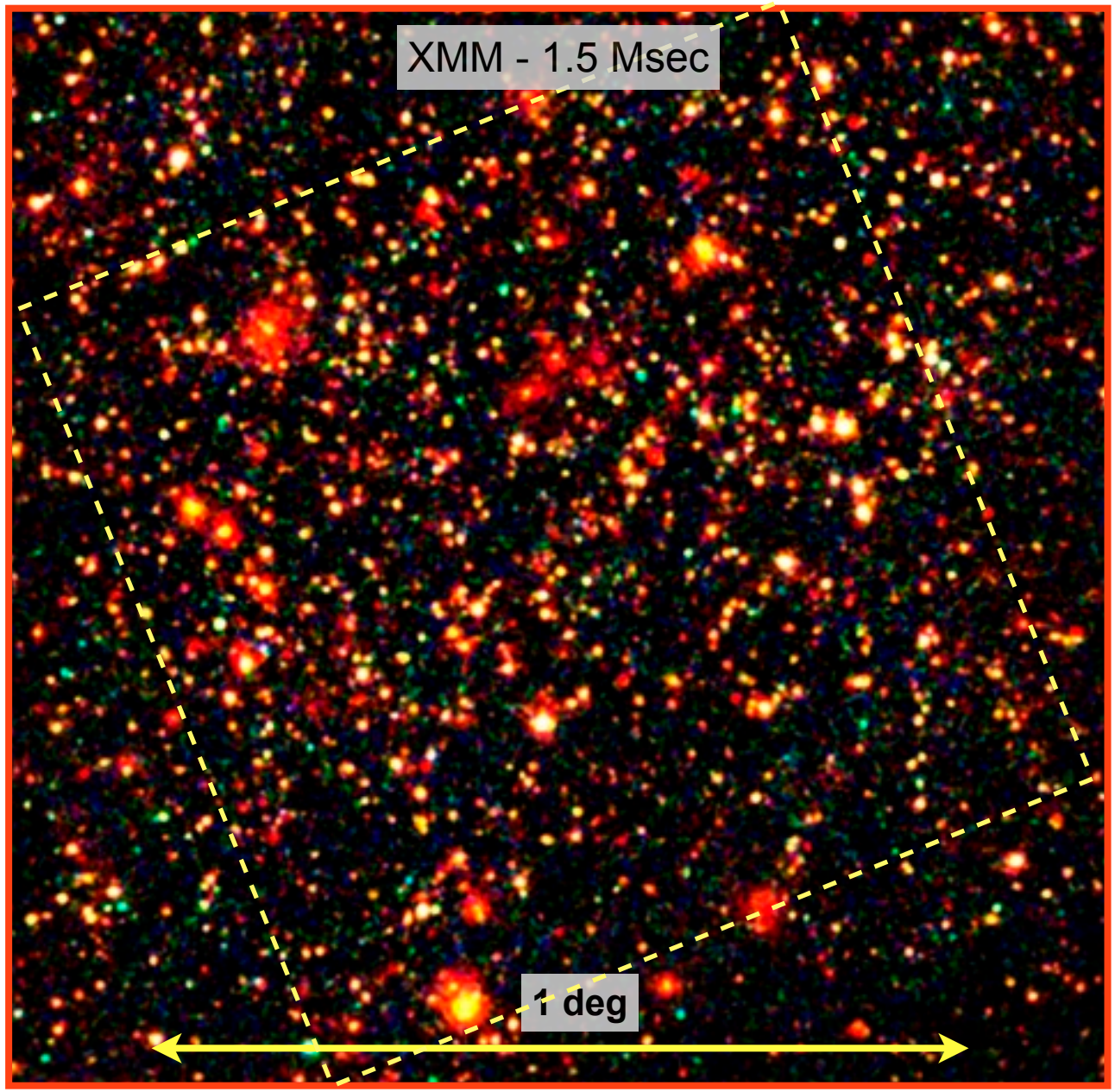




WFXT 10” HEW, the cool core is gone...

XMM COSMOS field (2 deg^2)

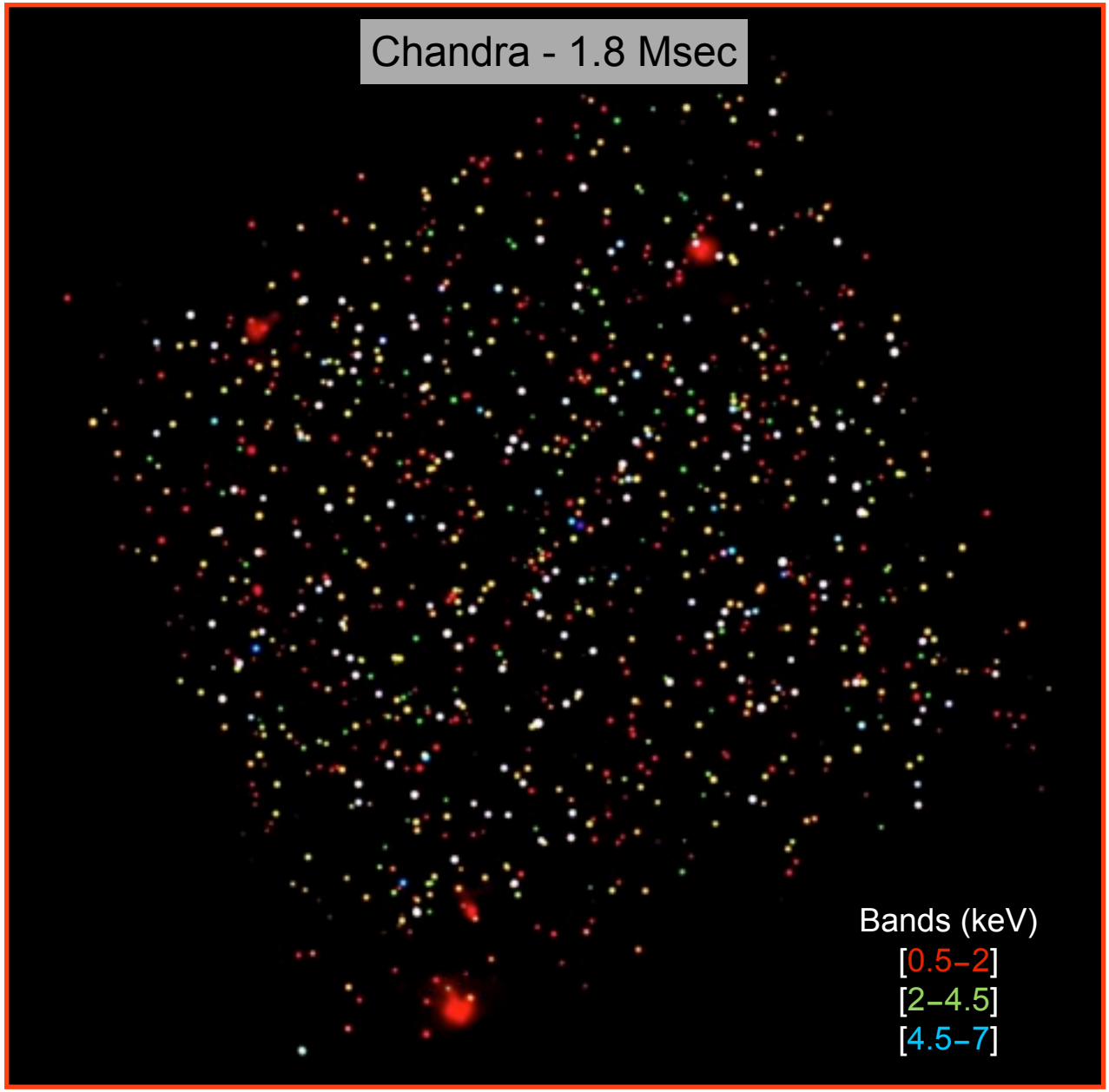
Cappelluti et al. 09



F_{lim} [0.5-2]≈ 7×10^{-16} erg cm^{-2} s^{-1} (confusion limited)

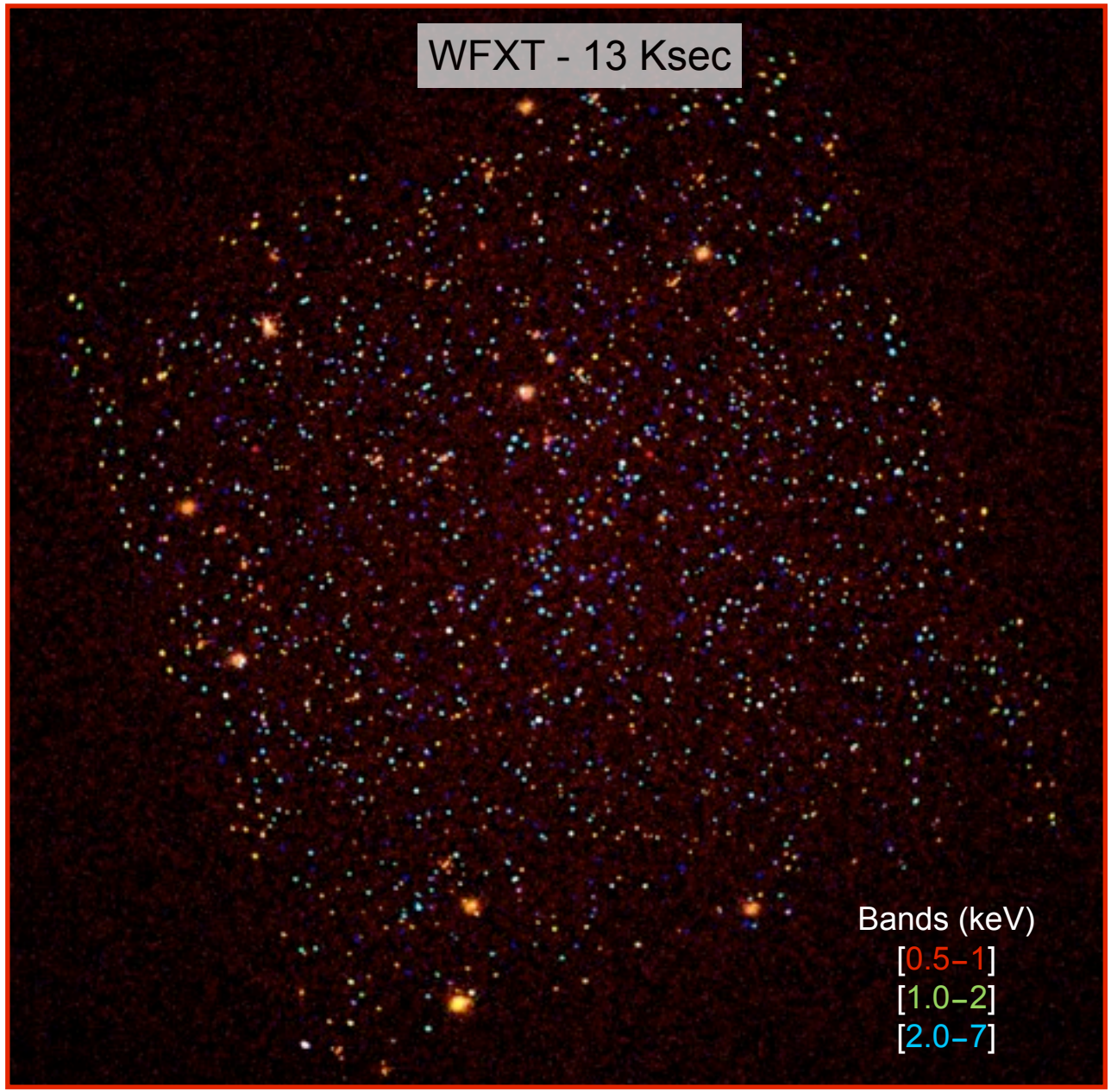
C-COSMOS field (1 deg^2)

Elvis et al. 09



F_{lim} [0.5-2] ≈ 5×10^{-16} erg cm^{-2} s^{-1}

WFXT COSMOS field
(one Medium survey tile only)



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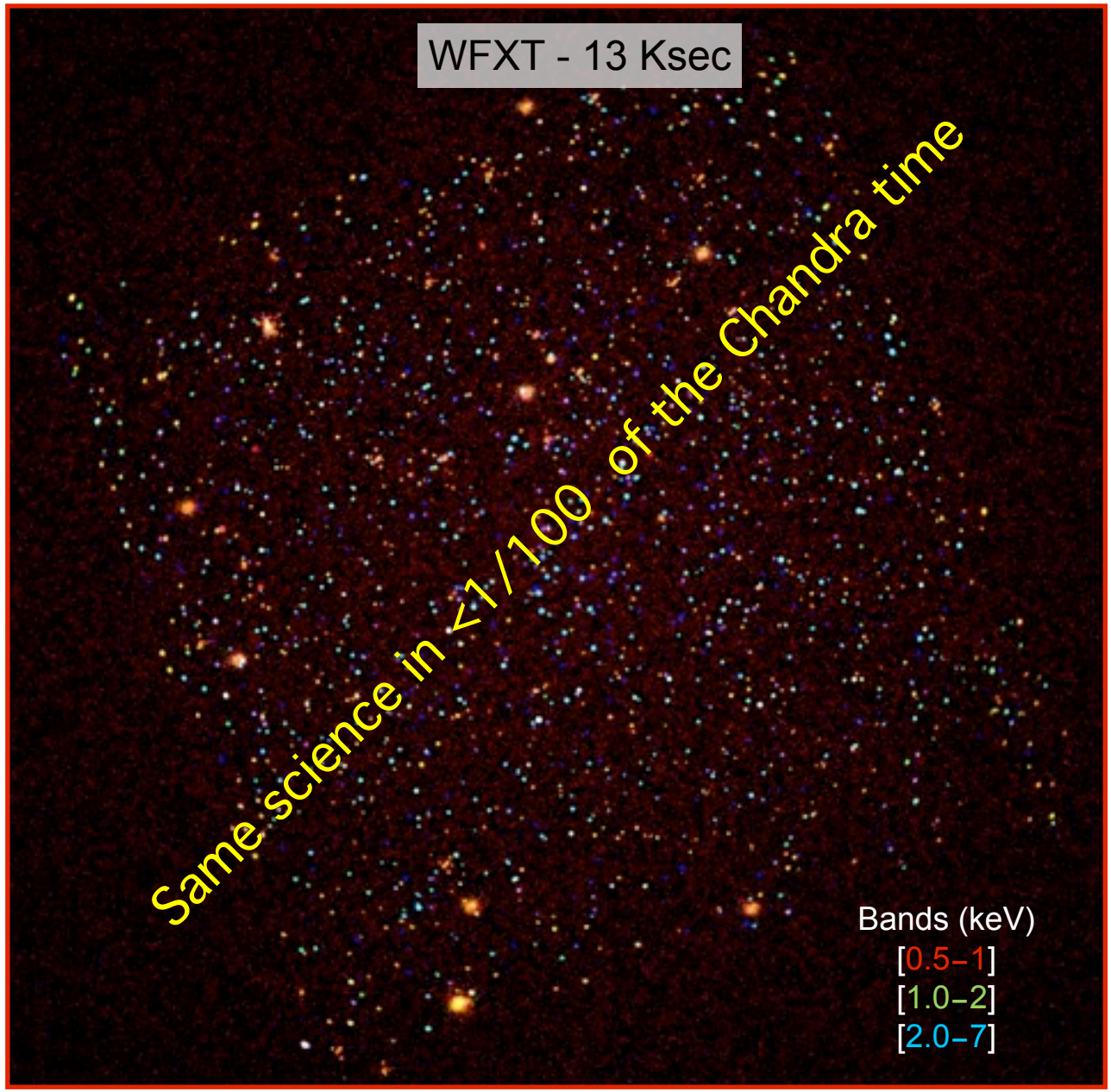

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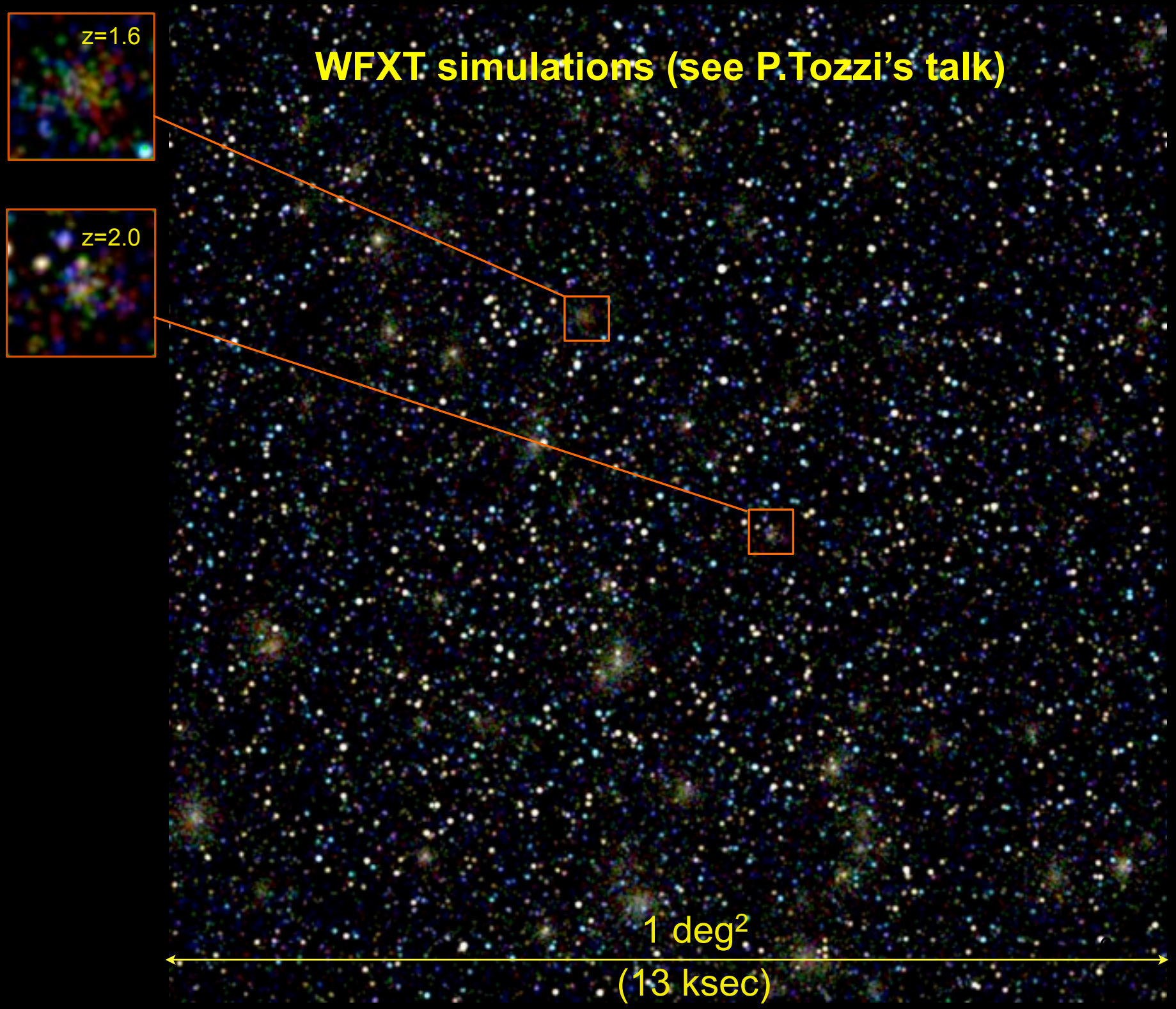
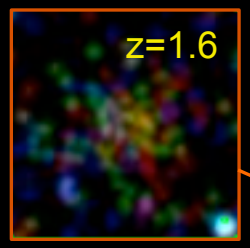
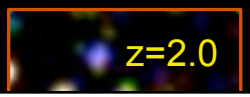
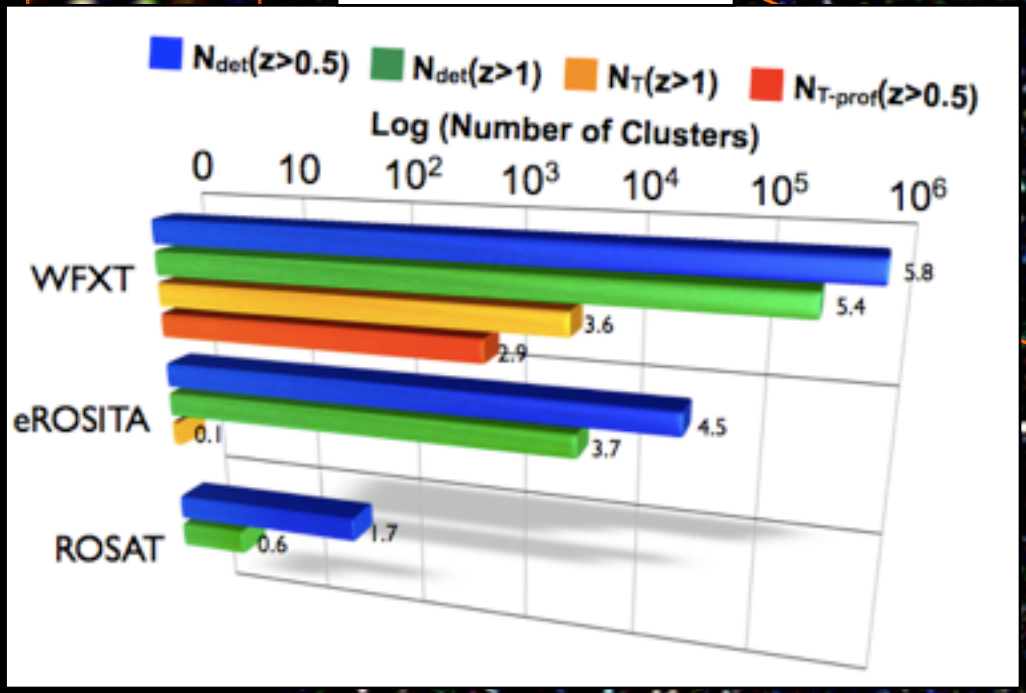

z=1.6
z=2.0
WFXT simulations (see P.Tozzi's talk)
1 deg²
(13 ksec)

WFXT simulations (see P.Tozzi's talk)

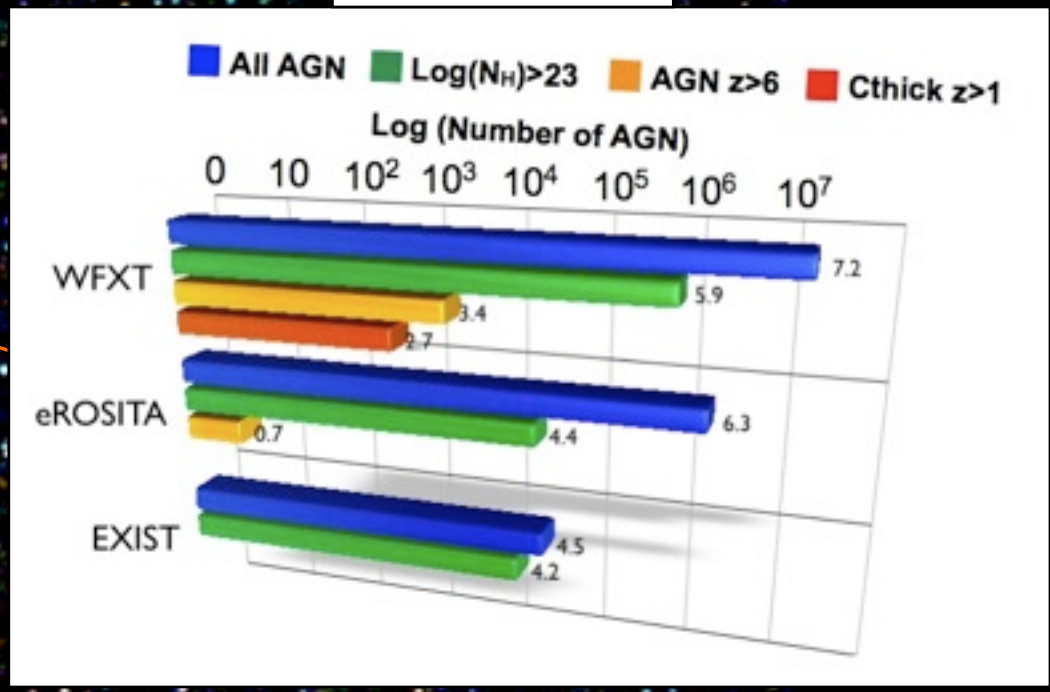




Cluster counts



AGN counts



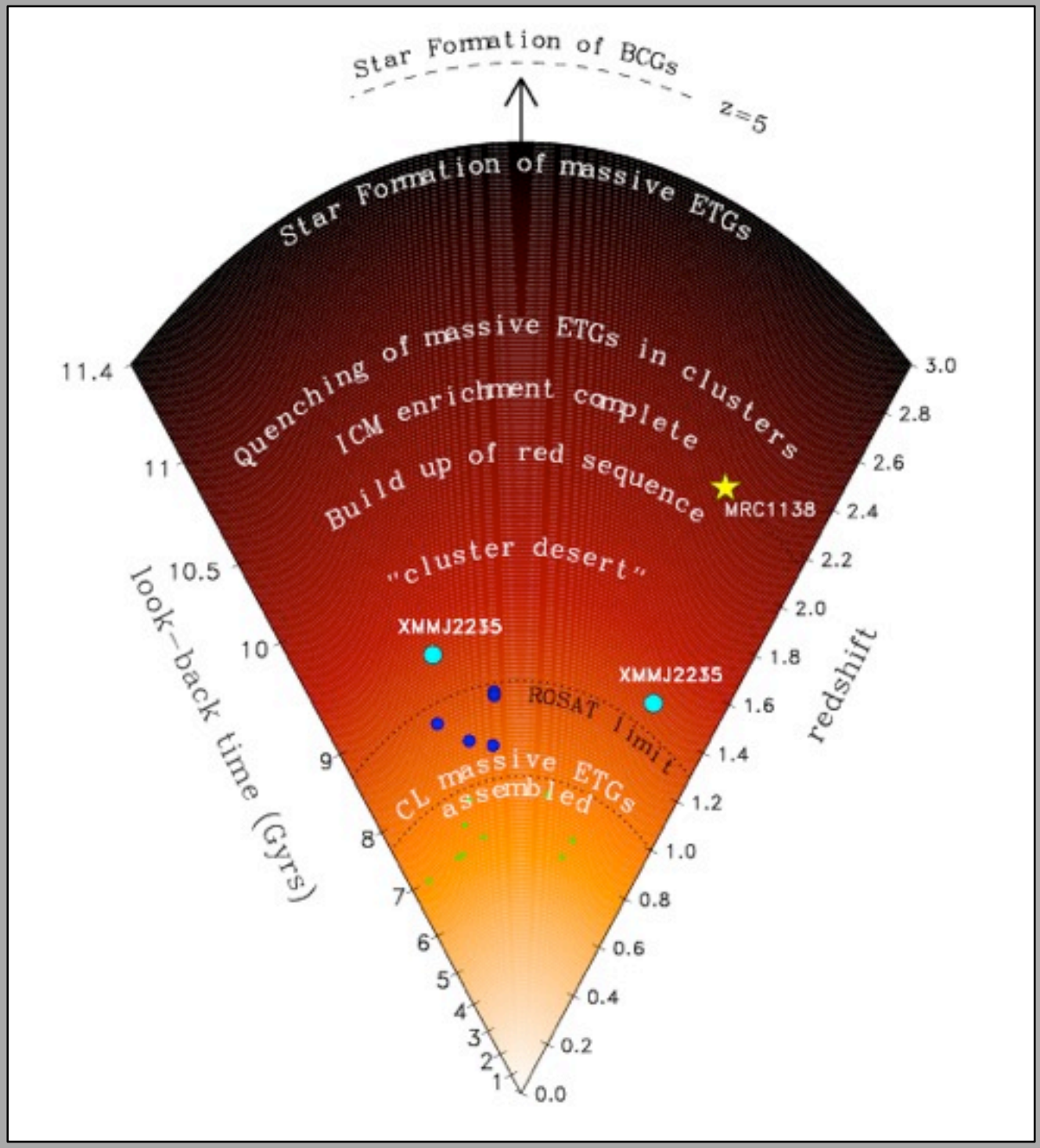
~20,000 clusters from which z can be be mesured form Fe line

~300,000 AGN from with full spectral characterization (obscuration, z, etc.)

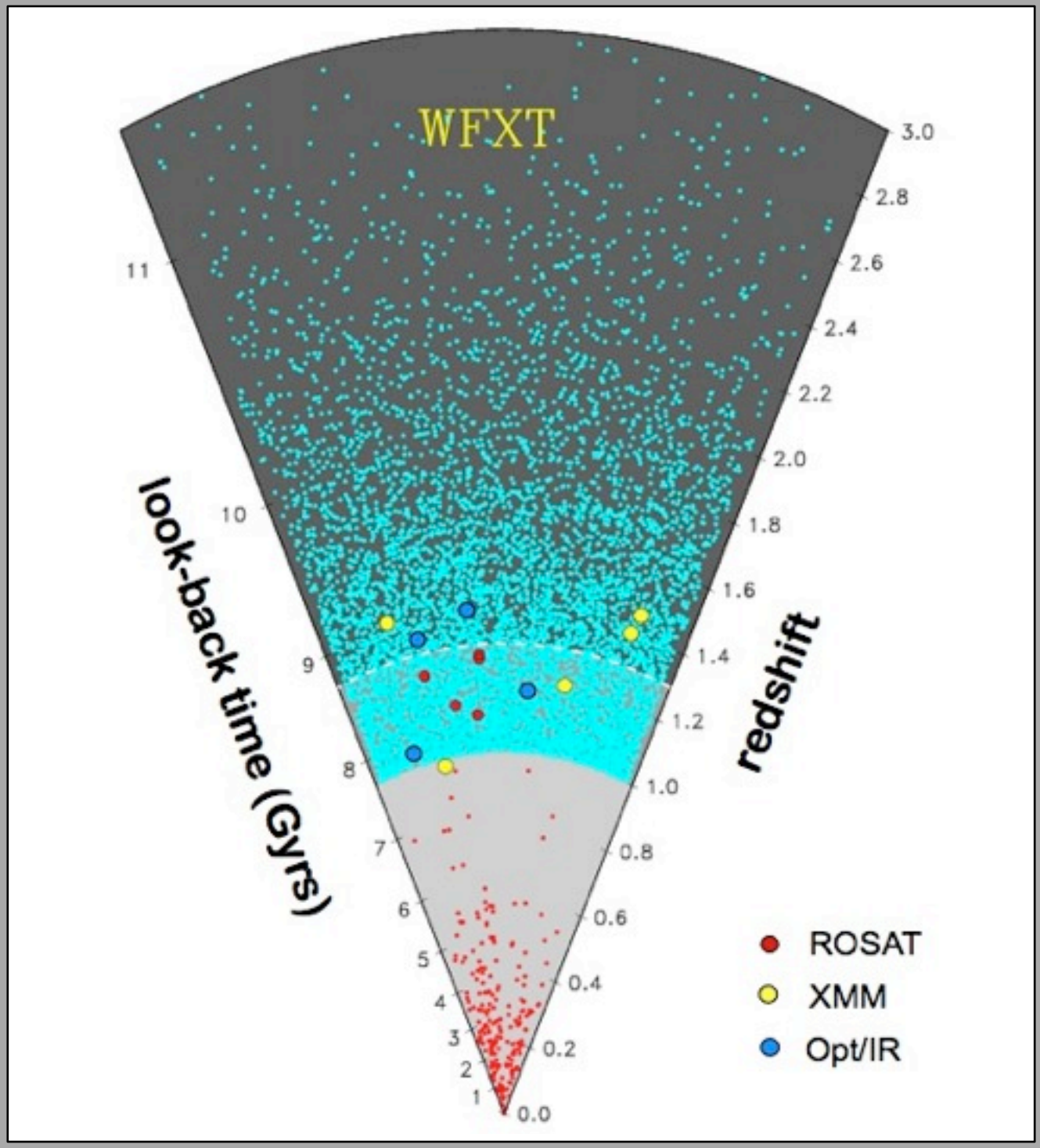
1 deg^2

(13 ksec)

Cluster mass assembly history



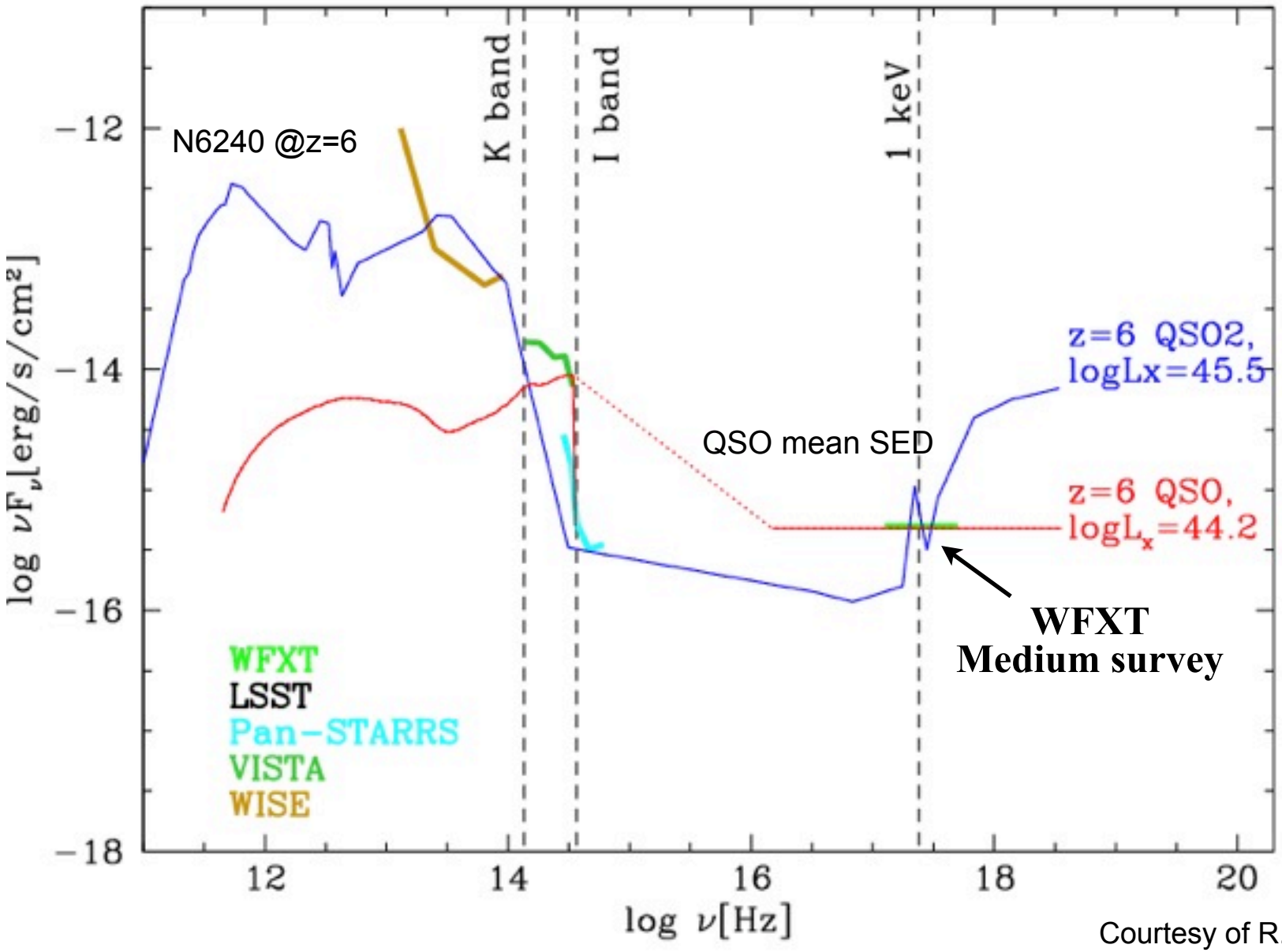
Cluster mass assembly history



Synergies with other wide area surveys

(See tomorrow's talks)

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

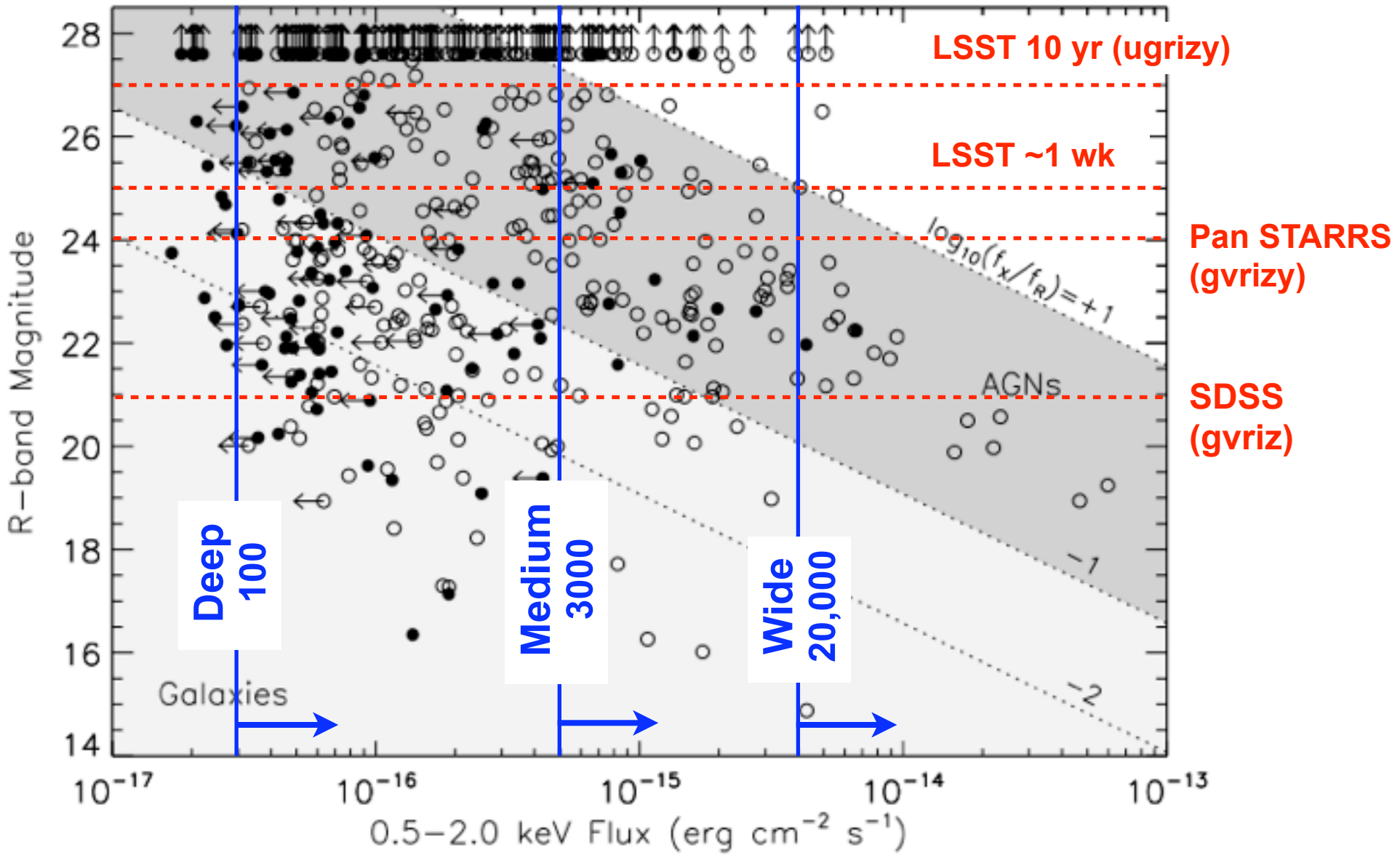


Courtesy of R.Gillli

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

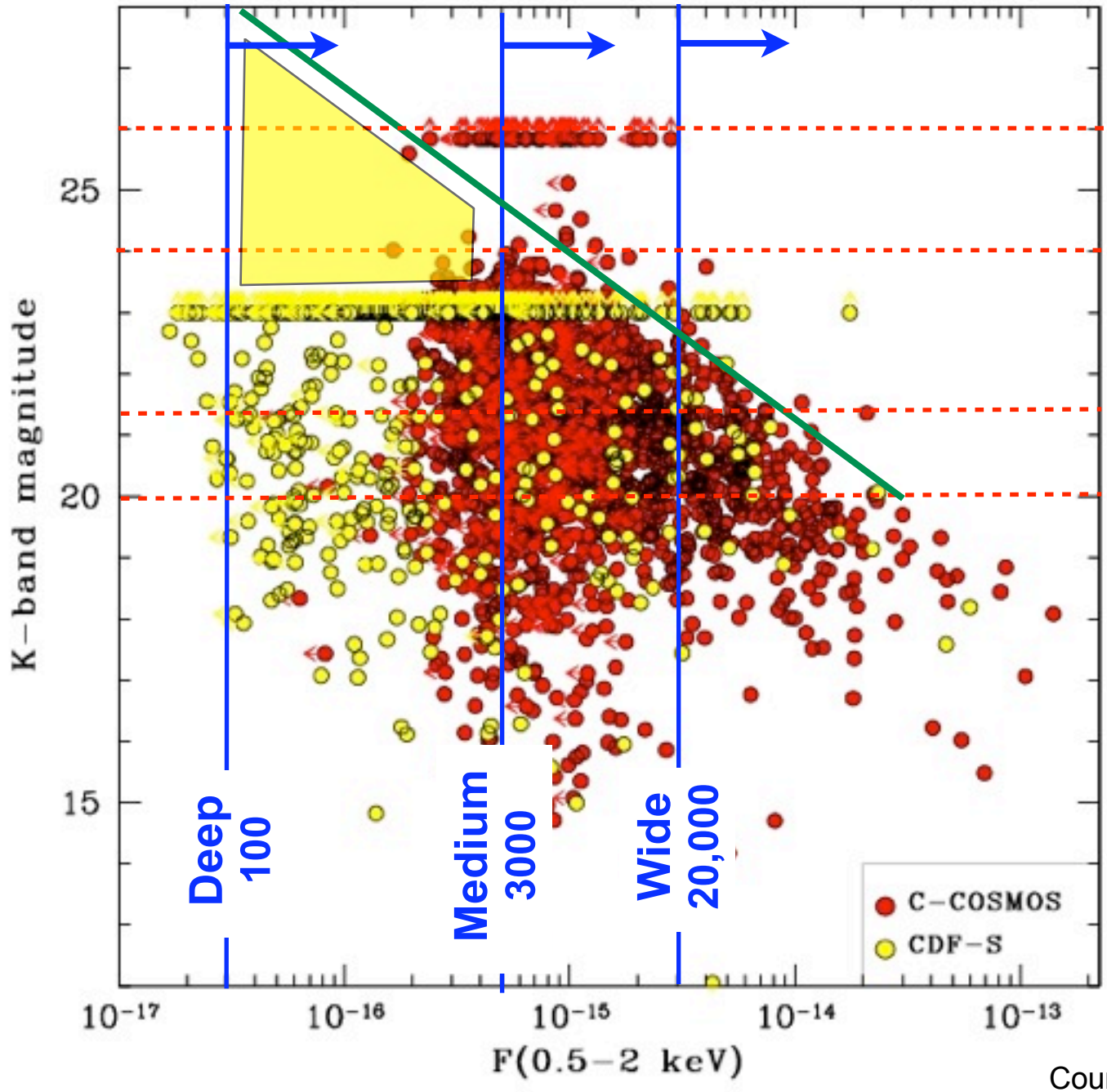
(See Marcella's talk)

Source identification (optical)



CDFS 2 Msec IDs (Luo et al. 2008)

Source identification (near IR)



Courtesy of C.Vignali

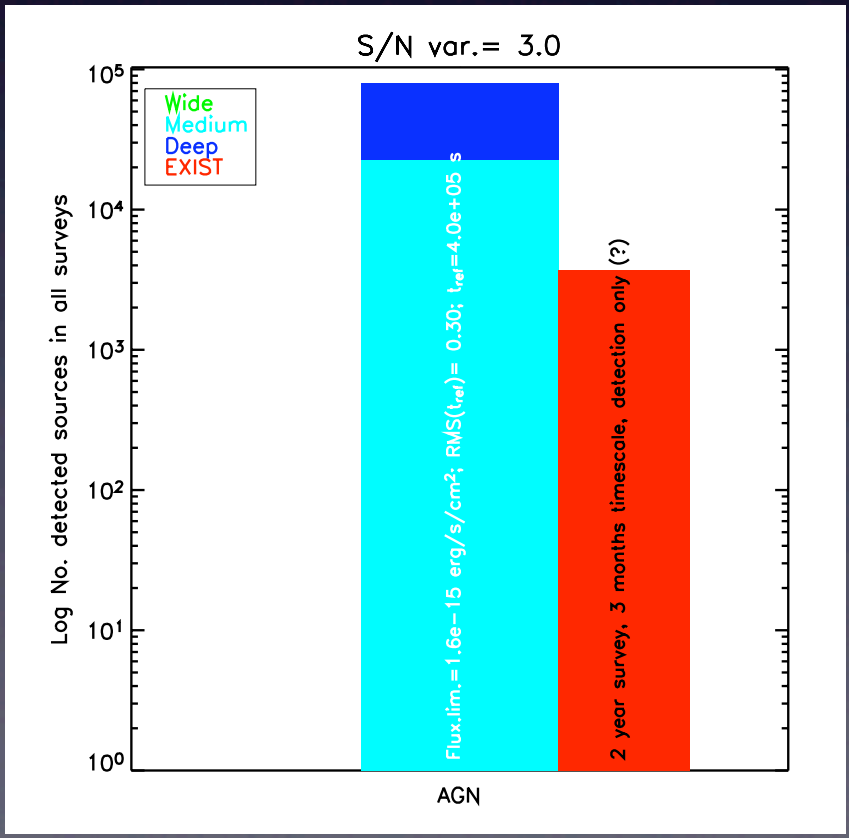
Variability with WFXT

(see M.Paolillo's talk)

WFTX strengths:

- **Large collecting area**: short temporal sampling independently of time devoted to targets.
- **Ang. resolution**: mitigate crowding and cross-id problems, increasing the number of targets suited for variability studies
- **Field of View**: simultaneous monitoring of large areas

AGNs (probe mass and accretion properties of SMBHs, see G.Risaliti's talk)

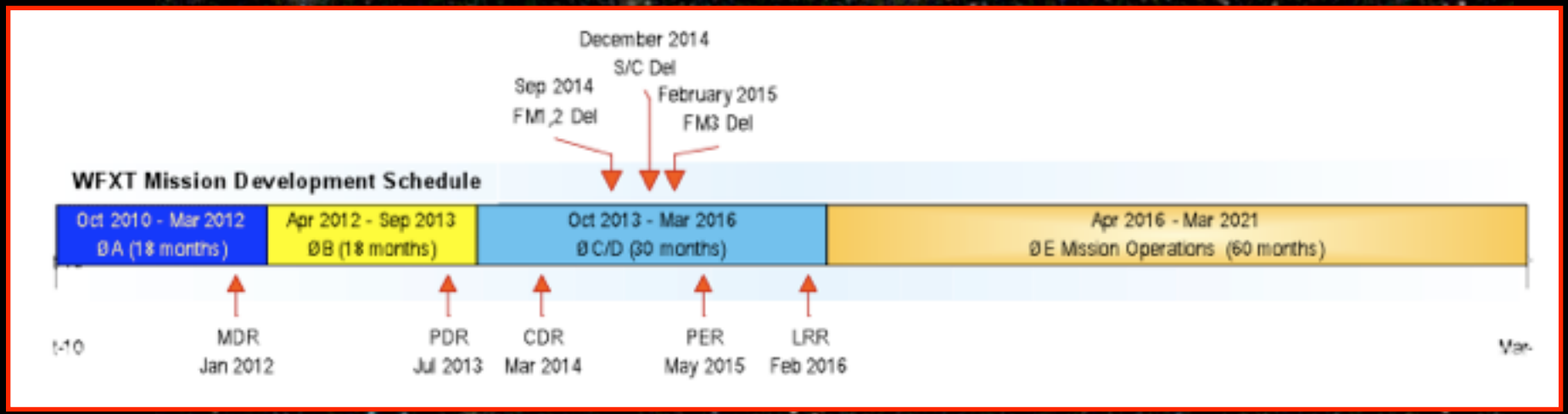


Also large number of transients
(see M.Paolillo, M.Della Valle)

Programmatics and Schedule

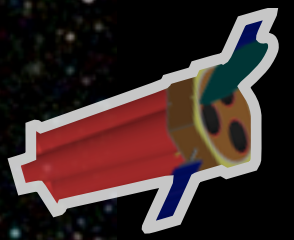
Cost:
- construction+launch (excl. Phase A and Operations) $690M (3 independent estimates)
- total life cycle mission: 750-800M$
- envisaged Italian contribution for mirrors (up to $50M)

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



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 at z>1

- The WFXT mission will have a strong impact on a wide range of disciplines, from which the entire italian 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 >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.