Synergies between (AGN) X-rays (surveys) and Multi Objects Spectrographs

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Marcella Brusa

"Science with MOS", Milano, 13 December 2018

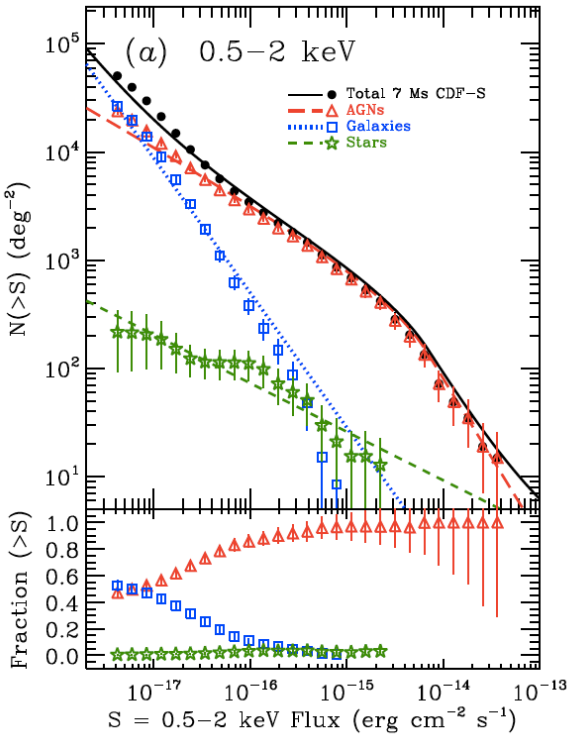
The X-ray Sky

The X-ray sky is populated by different classes of sources

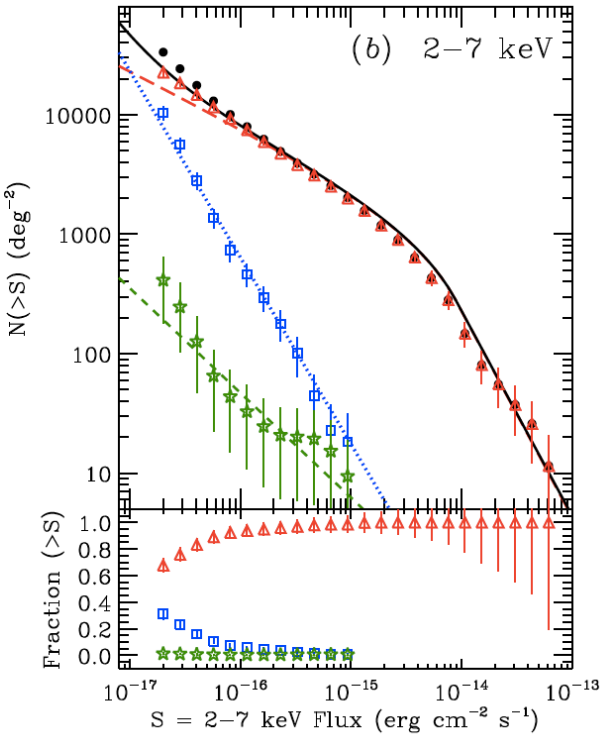
Luo et al. 2017 (CDFS 7Ms)

POINTLIKE SOURCES:
***Active Galactic Nuclei**
***Galaxies (unresolved)**
***Stars/LMXB/HMXB**

Relative contribution of sources in different classes depends on
- X-ray limiting flux
- X-ray band



SOFT



HARD

The X-ray Sky

The X-ray sky is populated by different classes of sources

POINTLIKE SOURCES:

***Active Galactic Nuclei**

***Galaxies (unresolved)**

***Stars/LMXB/HMXB**

first X-ray source detected: Scorpius X-1 (Riccardo Giacconi, 1962)

Relative contribution of sources in different classes depends on
- X-ray limiting flux
- X-ray band

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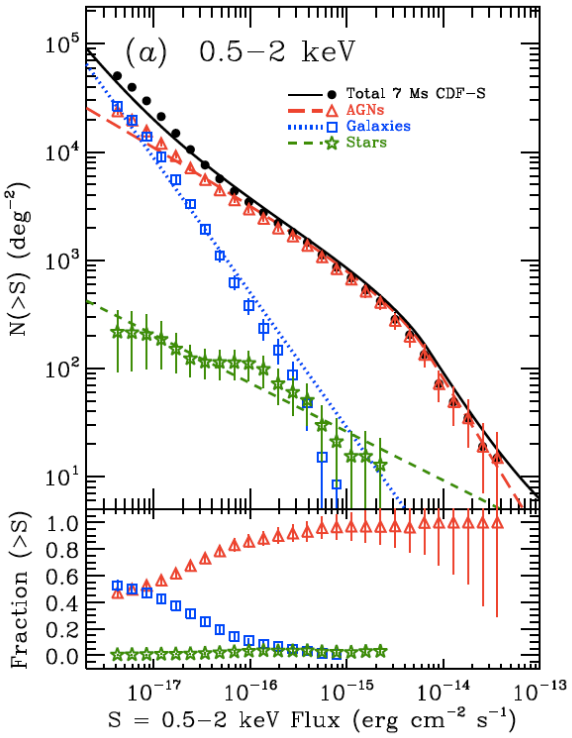

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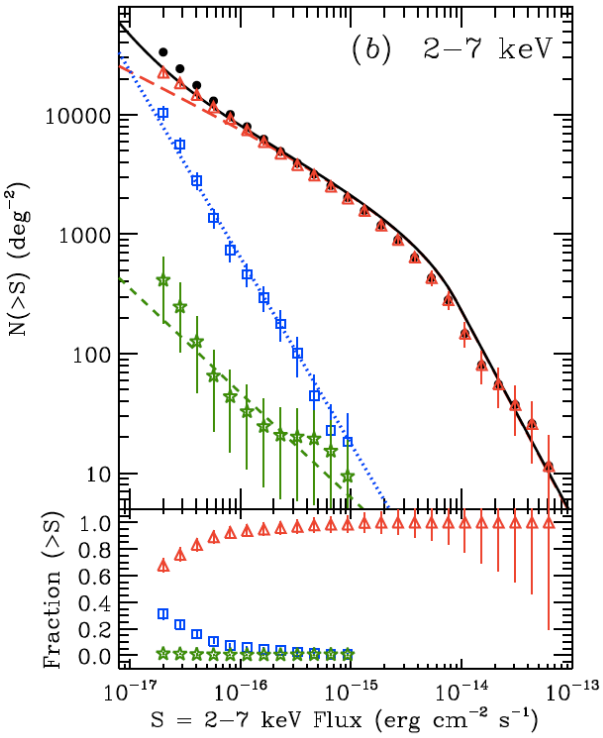
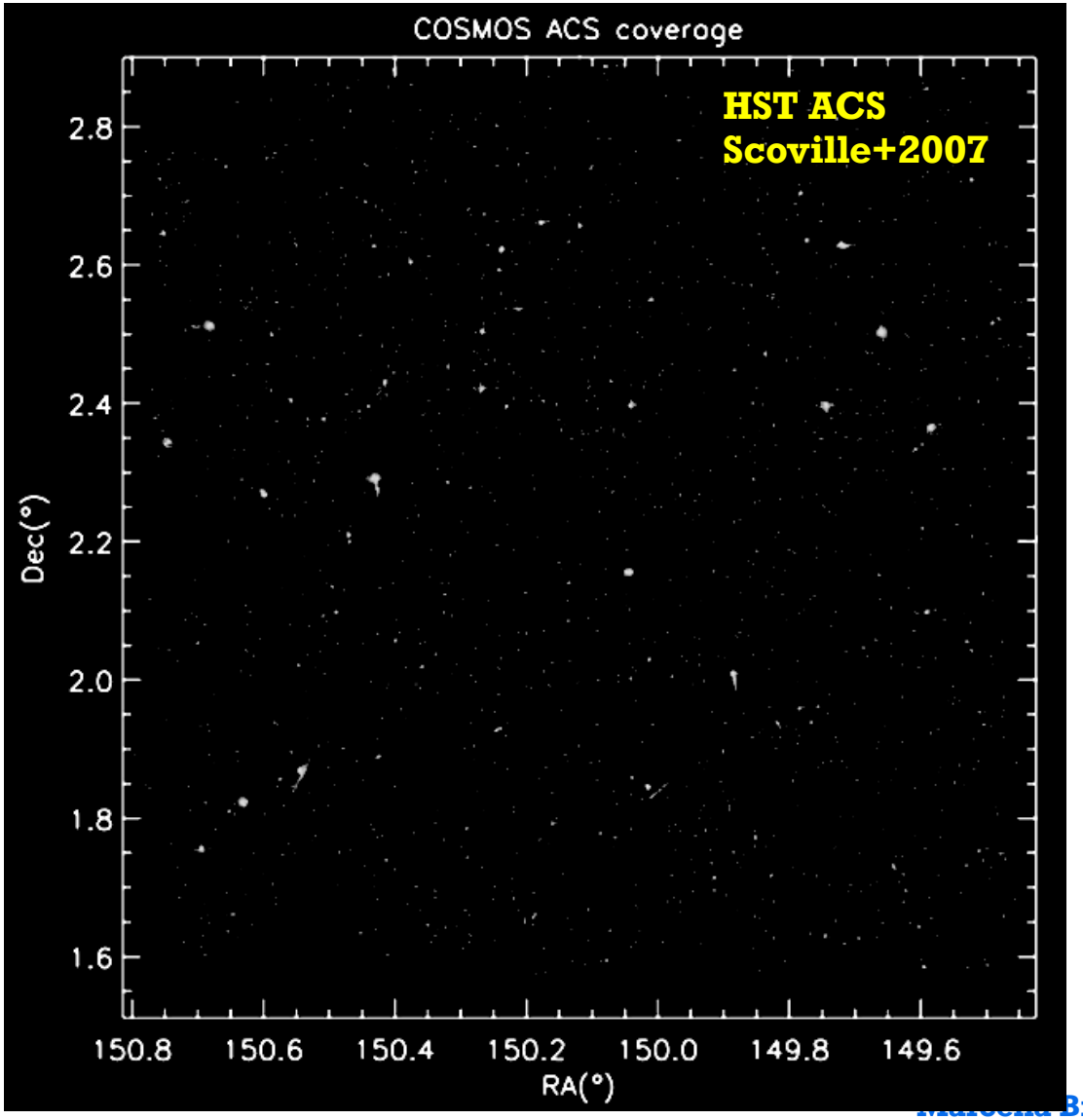


HARD

The X-ray Sky

COSMOS field
2 deg²

The Moon
30' diameter

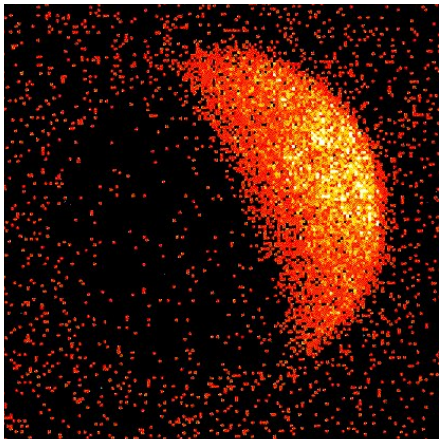


The X-ray Sky

COSMOS field
2 deg²

XMM-Newton
Hasinger+2007
Cappelluti+2009

mostly AGN
(pointlike)



The Moon
30' diameter
ROSAT observation

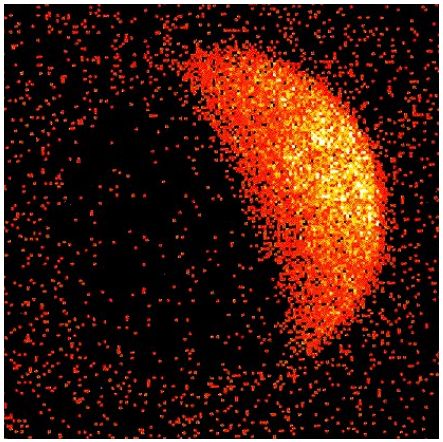
RA(°)

The X-ray Sky

COSMOS field
2 deg²

Clusters (diffuse)

mostly AGN
(pointlike)



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30' diameter

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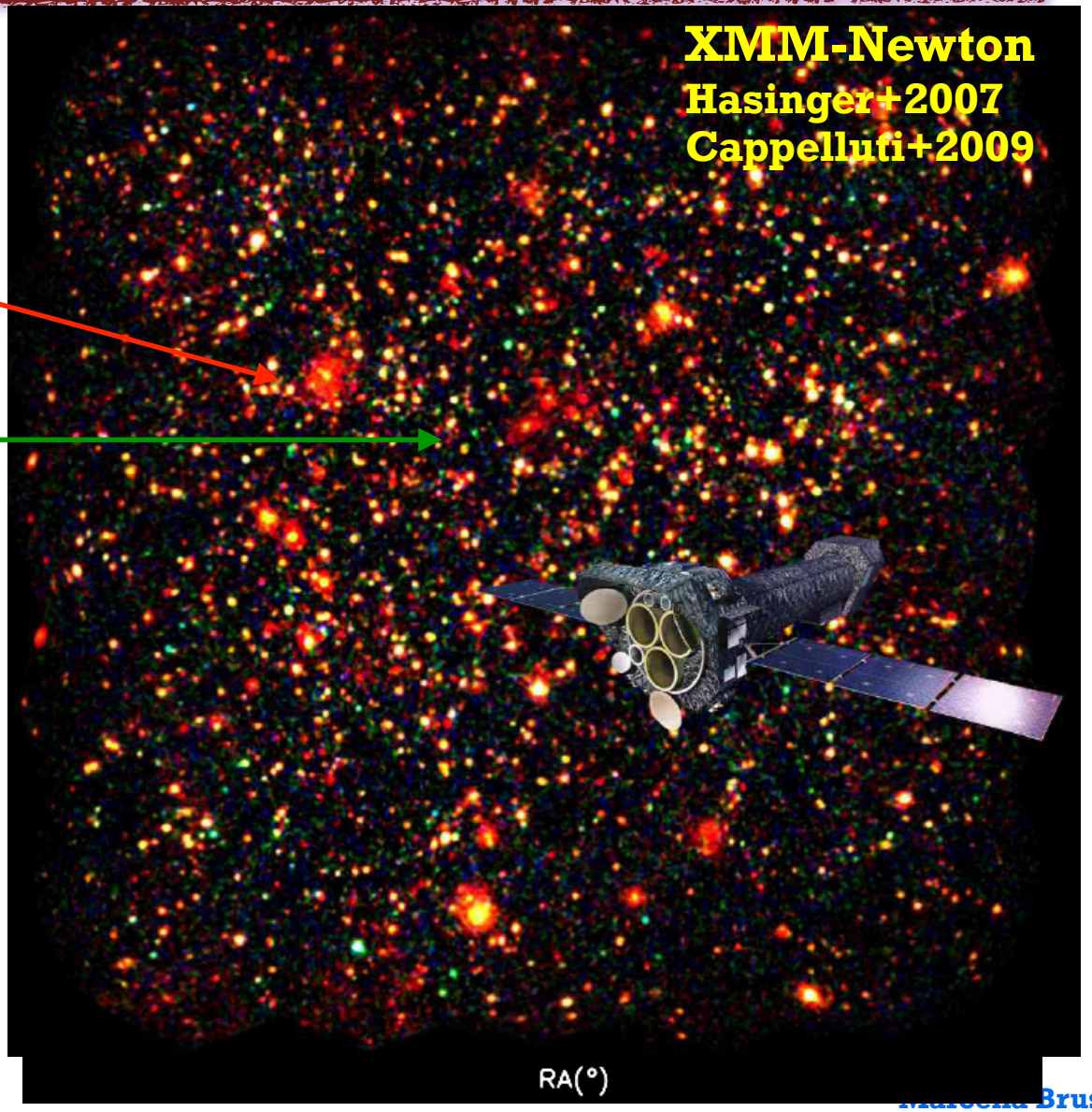
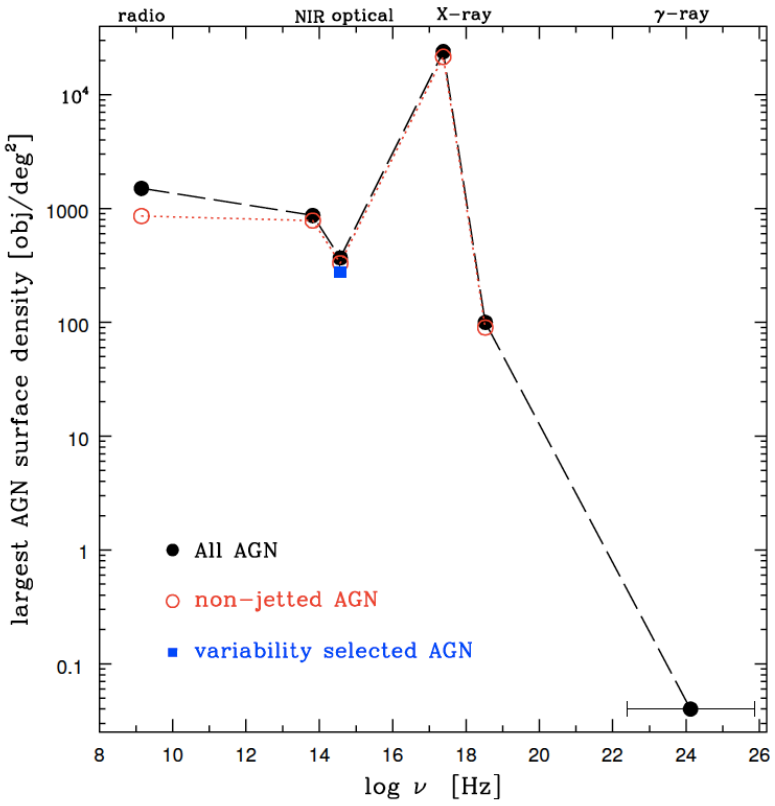


The cleanest selection

AGN and clusters are best selected from the X-rays

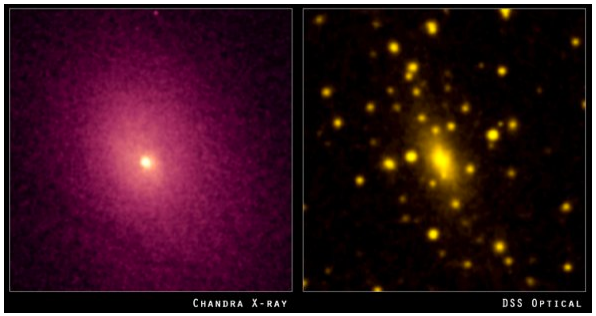
(Hard) X-ray surveys: AGN

Padovani+2017

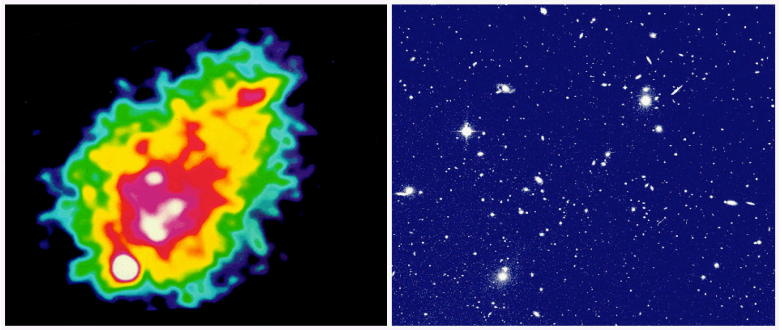


Soft X-ray surveys: Clusters

A2029 cluster



A1367 cluster



examples of synergies: CLASH-VLT program (PI: Rosati)
Balestra+2016 (800 members in 1 cluster!)

CODEX/SEQUELS RASS+SDSS3-4 (Clerc+2016)

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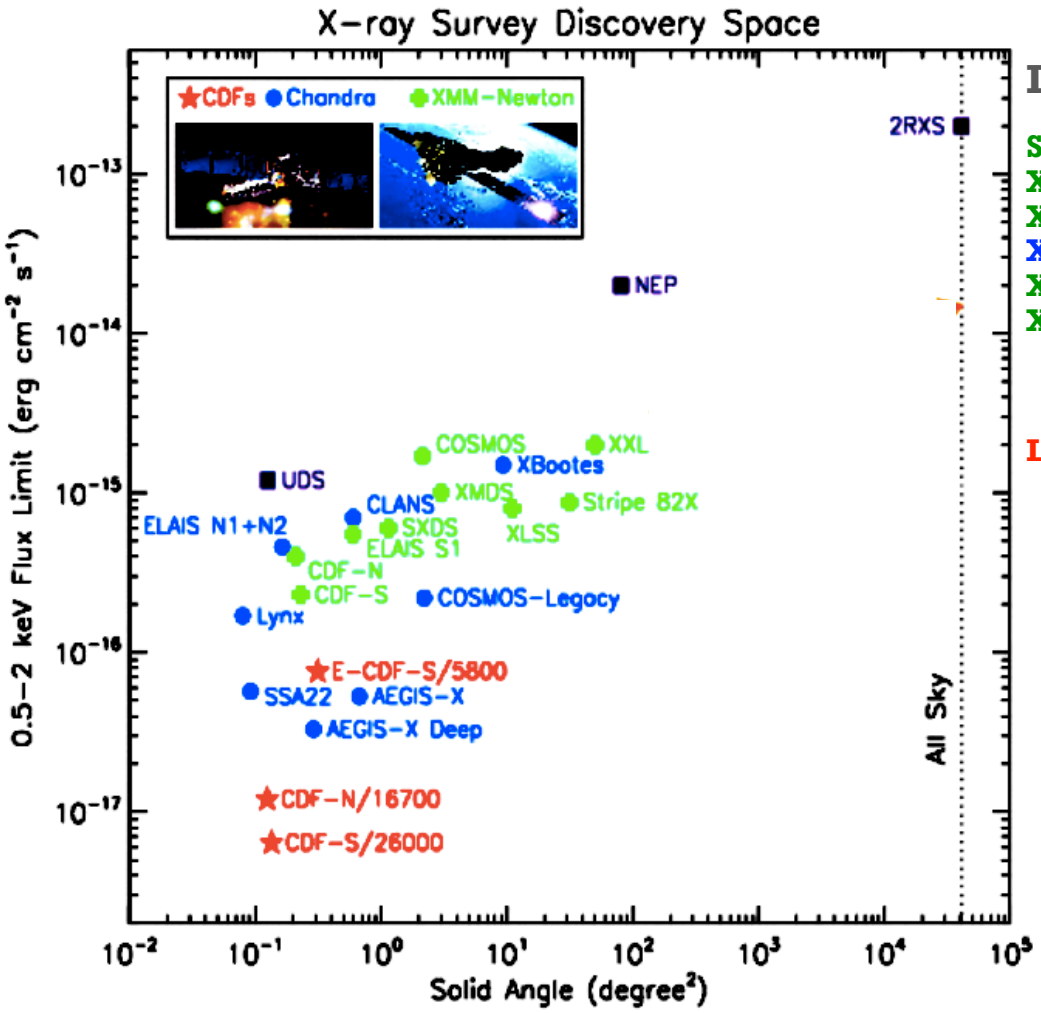
The era of AGN X-ray surveys (2000-2018+)

Brandt&Alexander 2015



Many (~50) XMM, Chandra +++ surveys in russian-doll style

Largest contiguous surveys:

Stripe82X 31 deg² (LaMassa+13,16a,16b)
XXL 2x25 deg² (Pierre+16, Fotopoulou+16,Chiappetti+18)
XXL-North 18 deg² (Liu+16, Menzel+16)
XBöotes ~10 deg² (Murray+05,Kochanek+12)
XMM-LSS 5-10 deg²(Chiappetti+13,Melnyk+13,Chen+18)
XMM-COSMOS 2 deg² (Cappelluti+09, Brusa+10)

LARGE TIME INVESTMENT IN X-RAYS OBSERVATIONS

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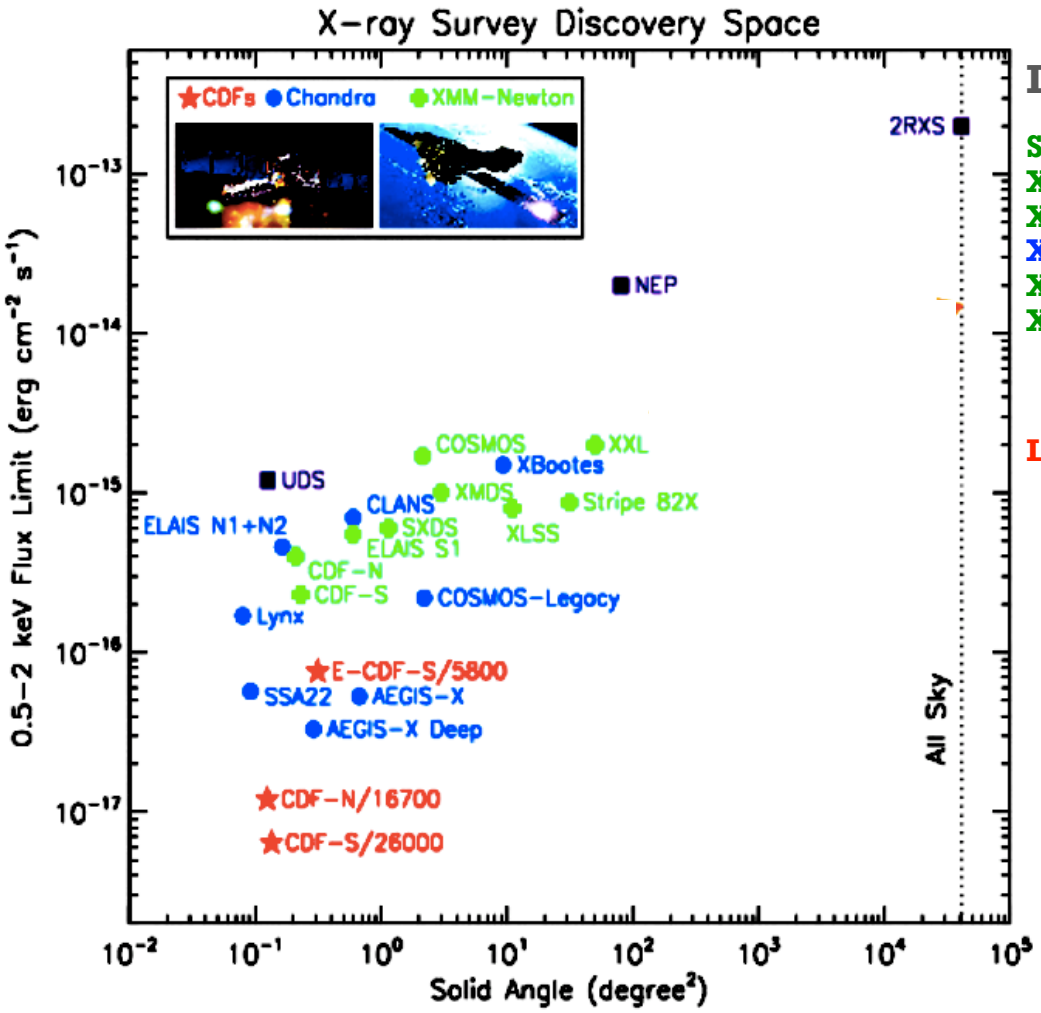

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Deep and large area X-rays (+ multi-λ surveys) so far have benefited by synergies with spectroscopic surveys and in particular with spectroscopic identification campaigns with MOS !

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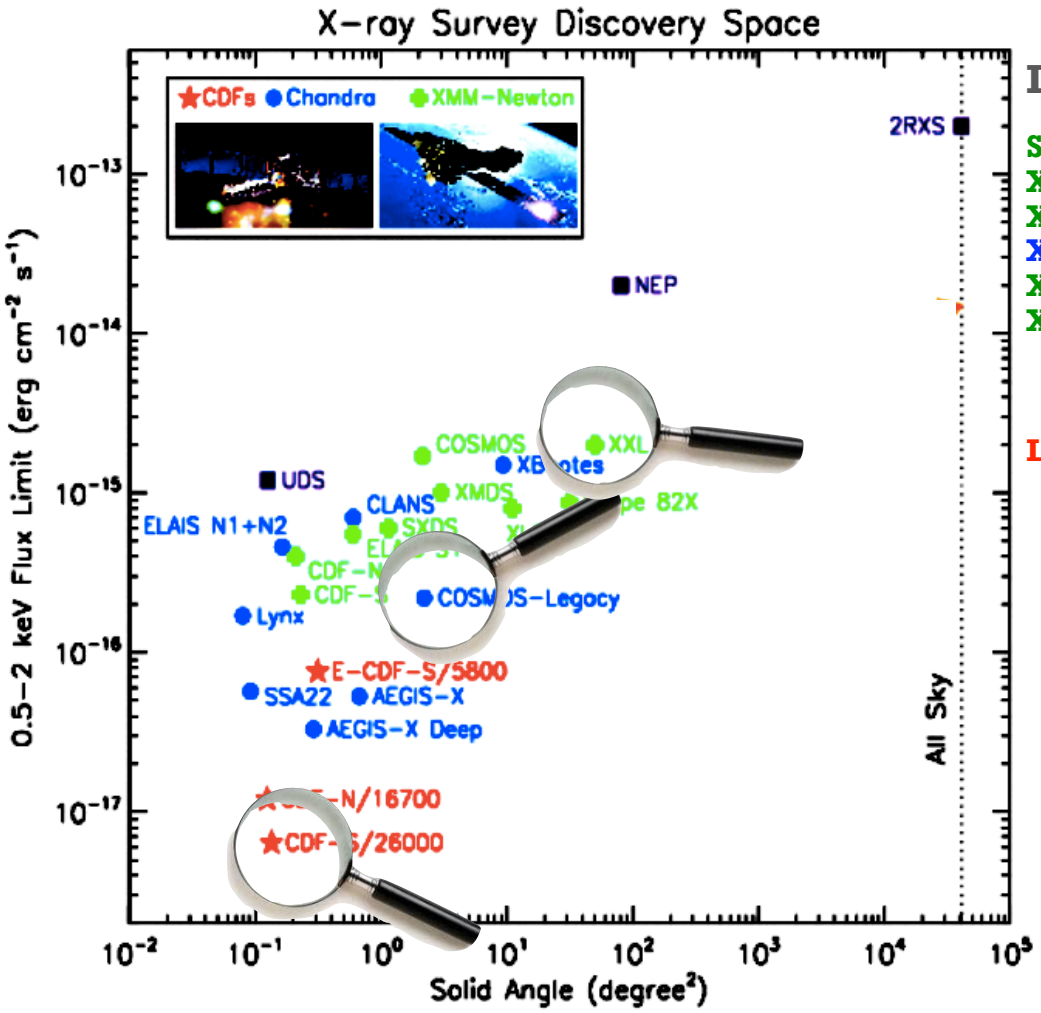

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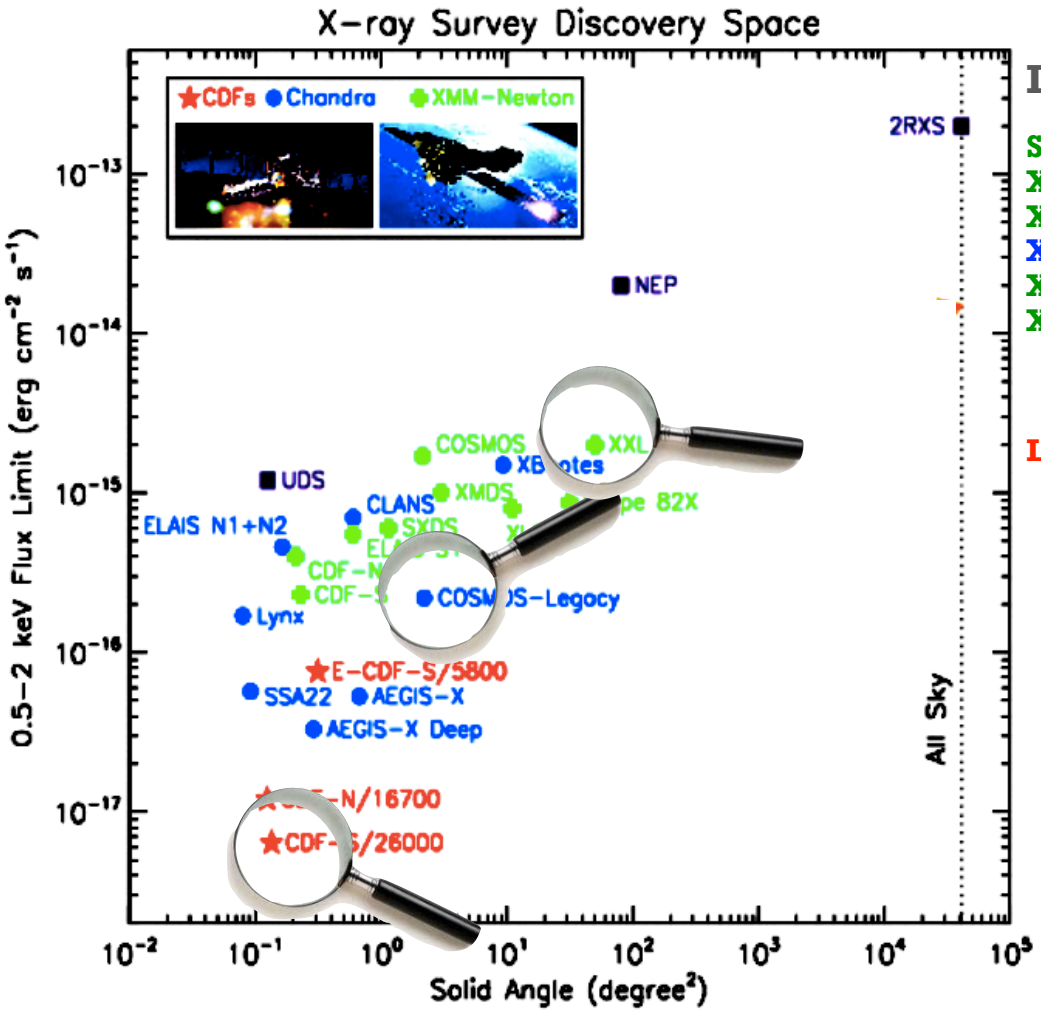

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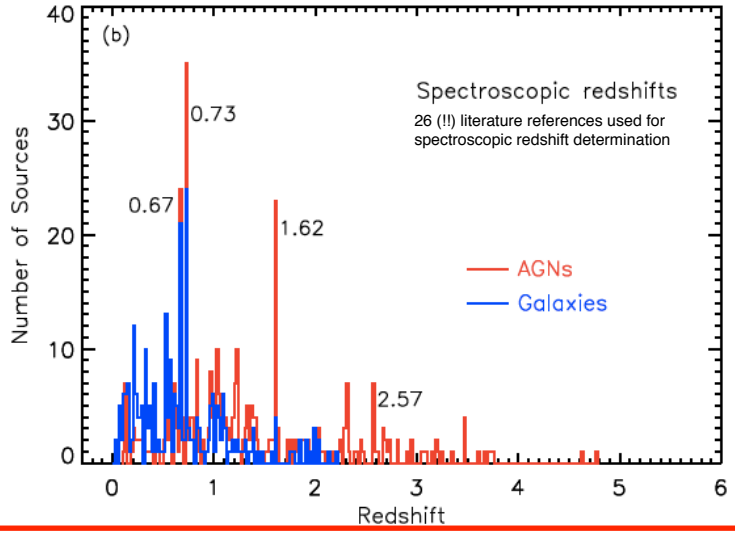
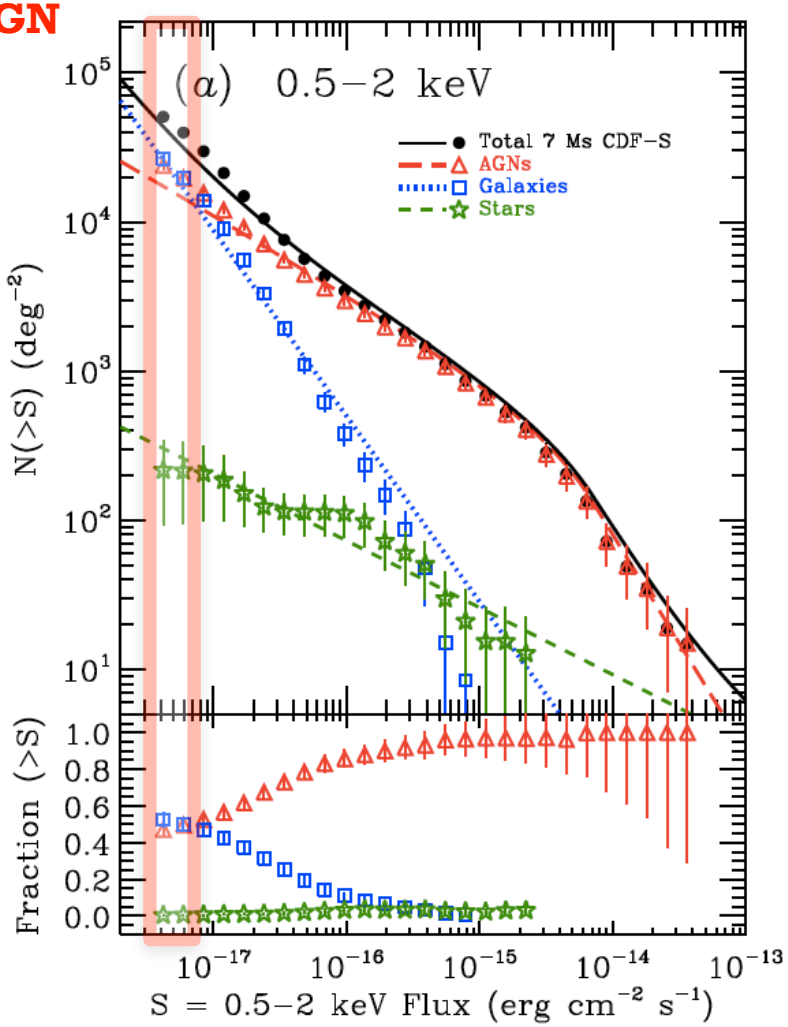
MOS in the deepest X-ray field (CDFS)

- **Limit 5e-18 erg/cm2/s**
  key role: RESOLVING XRB, FAINTEST/HIGHEST z AGN

Xue et al. 2017

AGN ~20.000 sources/deg2
Galaxies ~25.000 sources/deg2





1) average R~24 (many undetected at R=27.5!)
   ➜ faint population

2) at most 12 sources/arcmin², need long exposures (8m, NIR)
   ➜ **VIMOS, FORS** (+ synergies with gal. surveys)

3) area covered very small (max 0.13 deg2)
   ➜ IFU surveys may be even more efficient (MUSE; Urrutia+18)

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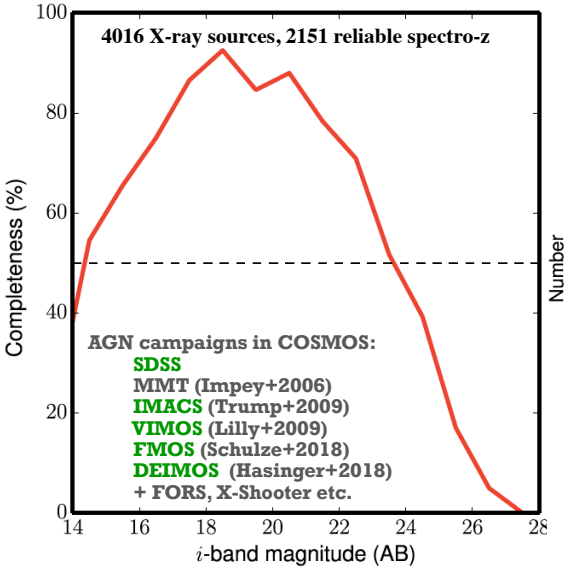
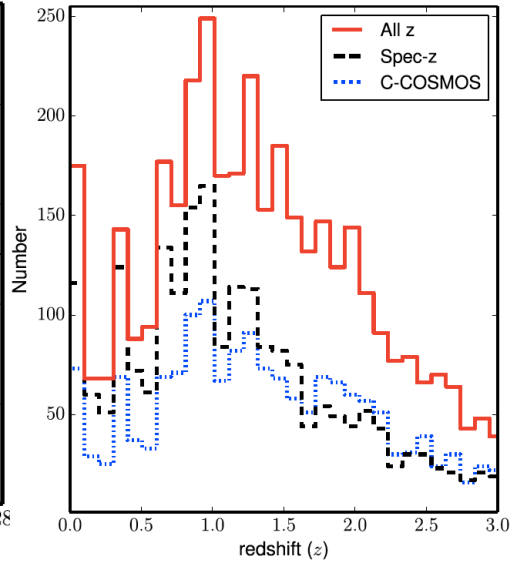
MOS in a medium-deep field (COSMOS)

- **Limit 2e-16 erg/cm2/s**
  key role: OBS QUASARS, ENVIRONMENT & CLUSTERING

AGN ~3.000 sources/deg2
Galaxies ~100 sources/deg2



Marchesi+2016



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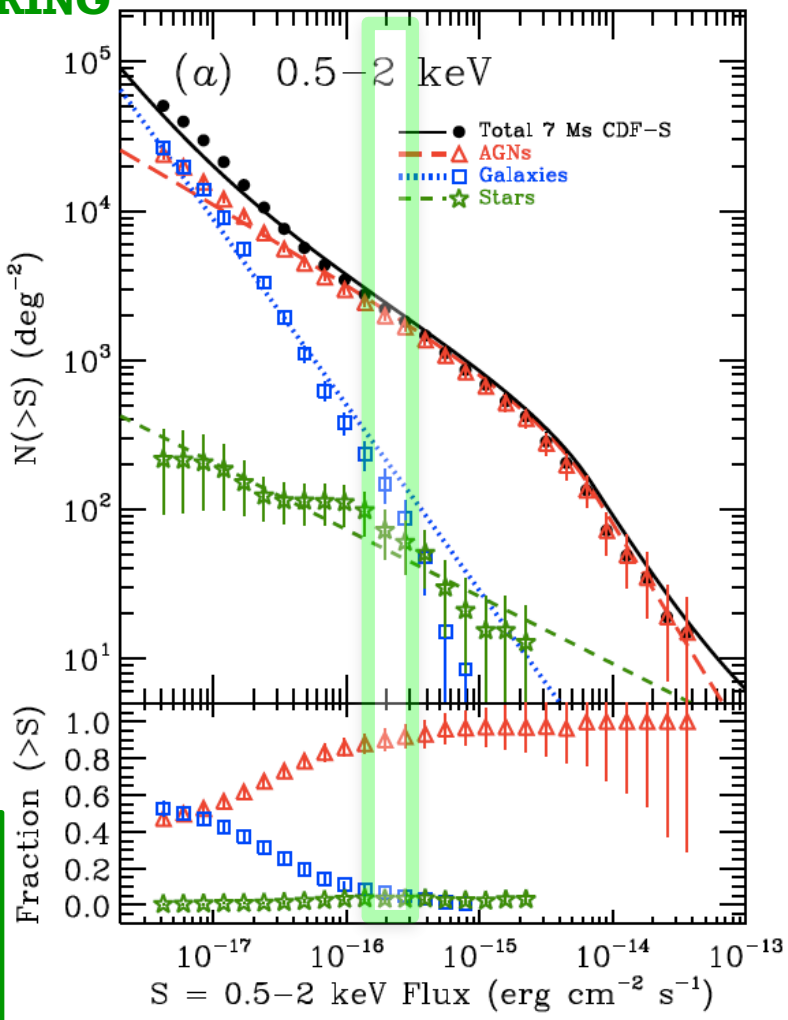

1) 1 sources/arcmin^2,
   ➜ need synergies with gal. surveys

2) average i~22.5 (few undetected)
   ➜mostly optical MOS (**zCOSMOS** Bright)
   NIR follow-up for selected targets and/or science goals

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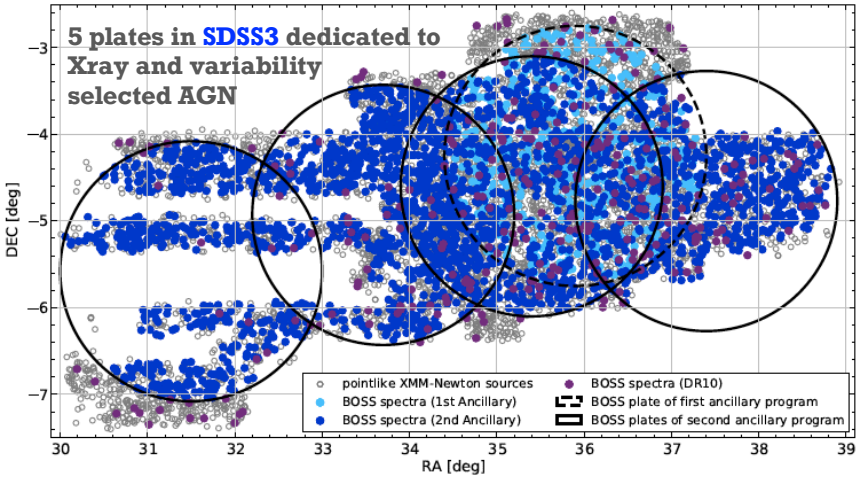
MOS in a large area surveys (XMM-XXL-North)

- **Limit 1e-14 erg/cm2/s**
  First dedicated spectro-z follow-up of a LARGE area
  key role: HIGH RES STACKED SPECTRA, OUTFLOWS
  AGN ~60 sources/deg2
  Galaxies (negligible)

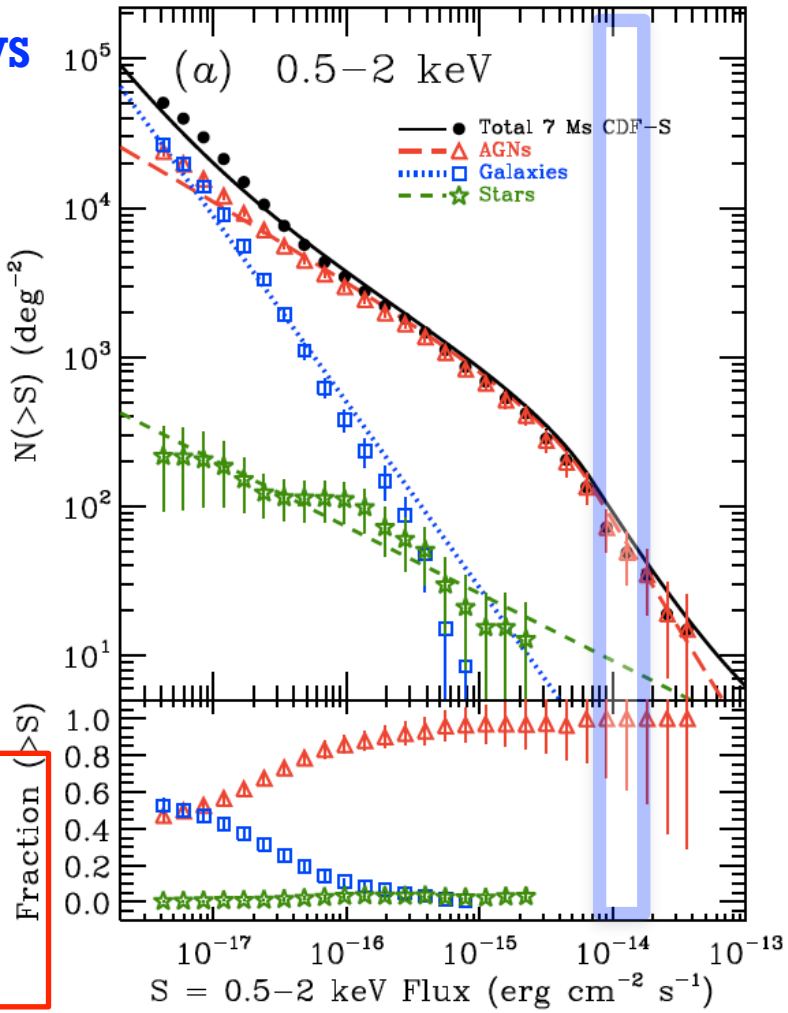
Menzel+2016 (see also Perna+2017a,b Xray-SDSS samples)



1) average i~18-19
   ➜ shallow exposures, large FoV MOS (SDSS-3 / BOSS)

2) still low surface density with respect to available fibers
   ➜ team up with other science goals
   (e.g. variability selected AGN, eBOSS)

Xue et al. 2017

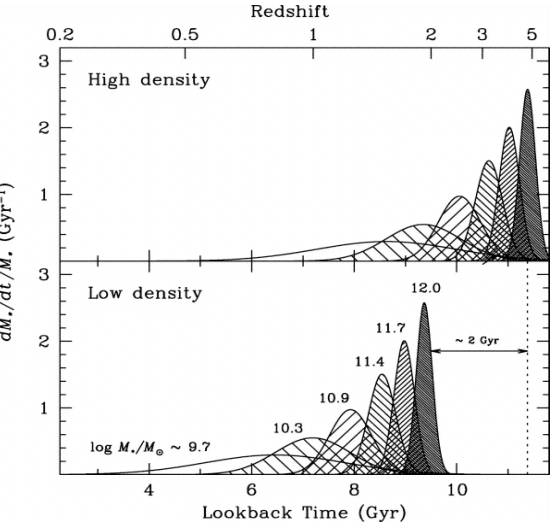


The revolution of AGN X-ray surveys

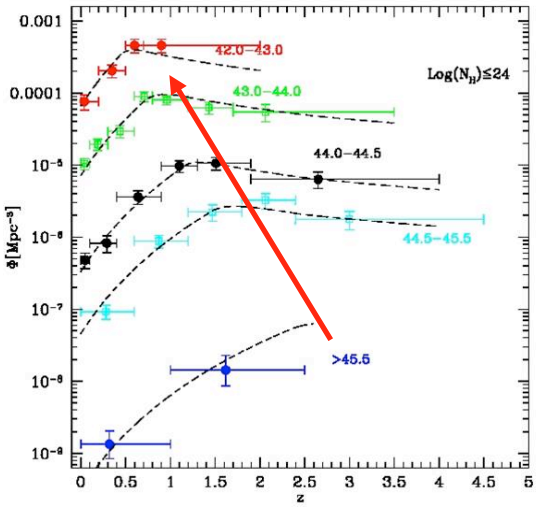
Several breakthroughs in AGN demographics in the past 20 years

- **downsizing in AGN evolution** (e.g. Miyaji+2015)
- high-z decline in XLF and paucity of X-ray selected QSOs (e.g. Vito+2017)
- AGN clustering properties and relation with environments (e.g. Gilli+2009, Silverman+2009, Allevato+2016, Mountrichas+2017)
- BH accretion rate vs. SFR (also via stacking; e.g. Rodighiero+15, Delvecchio+15)
- X-ray obscured AGN as signposts for feedback (e.g. Brusa+2015)

Thomas+2005



La Franca+2005
few x100 AGN



the larger the faster (Cowie et al. 1996):
".. galaxy formation took place in "downsizing", with more massive galaxies forming at higher redshift.."

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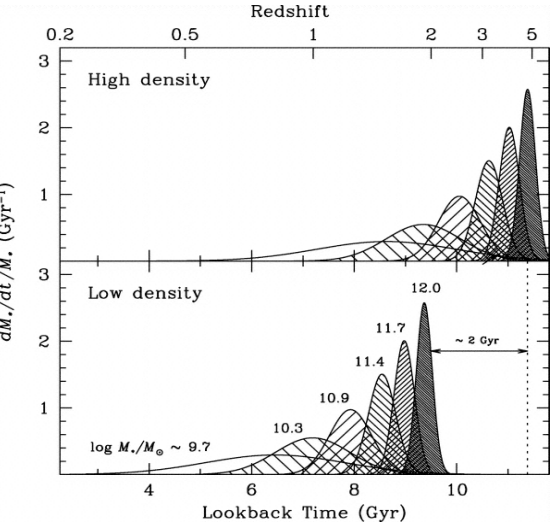

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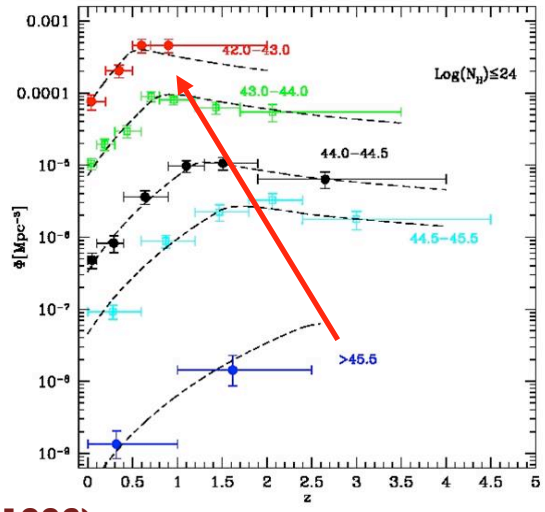
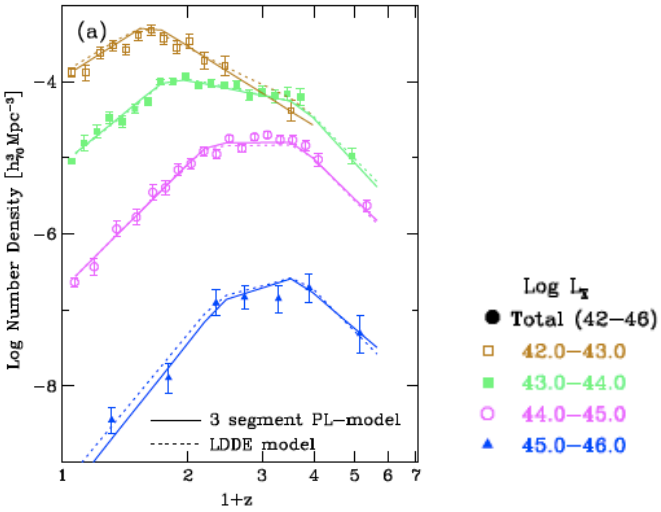


....Miyaji+2015
few x 1000 AGN



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Main limitations:

- small FoV of Chandra and XMM (not survey instruments!)
- only 3500-12000 sources in the **largest contiguous fields** (with 30-65% spec-ID)

➜ Our understanding of BH growth across cosmic time, environments and LSS lags significantly behind galaxy evolution investigations

➜ Our understanding of the accretion properties of first BH (AGN at z>6) is basically unconstrained (no sensitivity to probe low-L AGN)

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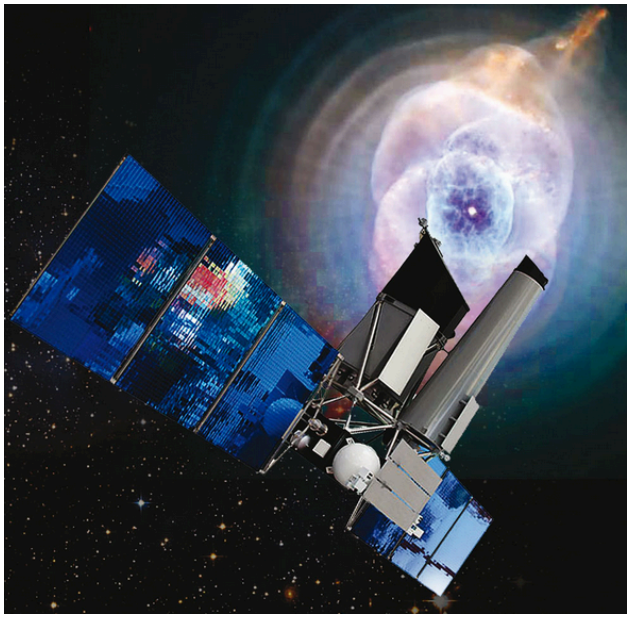
Future missions and Global Landscape

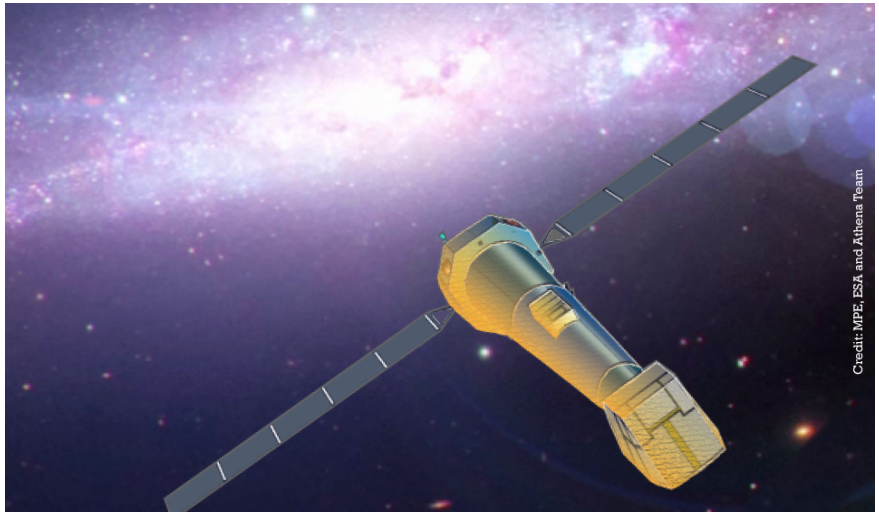
eROSITA



The Structure of the Energetic Universe

ALL-SKY
Cluster cosmology & AGN

ATHENA



The Hot and Energetic Universe

Deep AGN surveys (WFI) +
Clusters physics (XIFU)

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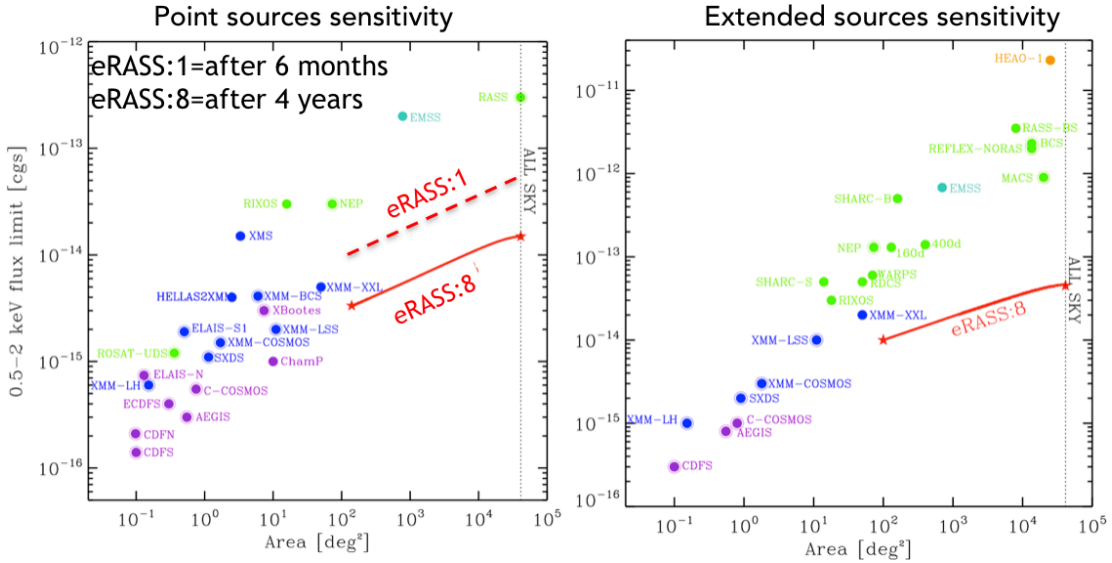
The eROSITA revolution

eROSITA: extended ROentgen Survey with an Imaging Telescope Array

Next Generation All-sky X-ray survey telescope
4 years Survey phase (8 all-sky surveys) + pointed phase (GO)

Built by consortium led by MPE, to be launched in April 2019
on the Spectrum Röntgen Gamma (SRG) mission along with ART-XC
Final all-sky survey: Q4/2023



eROSITA sensitivity:

0.5-2 keV: 30× deeper than ROSAT
1.2×10^{-14} cgs (AGN)
3.4×10^{-14} cgs (clusters)
2-10 keV: 100× deeper than HEAO-1
2×10^{-13} cgs (AGN)

Driving science:

1) detect **>100.000 clusters** (cluster cosmology) - **Merloni+2012, Pillepich+2018**
2) detect **>2.5Million AGN**, including most luminous, obscured ones - **Merloni+2012**
BONUS: 500.000 stars (!!!), SNR, planets, etc.

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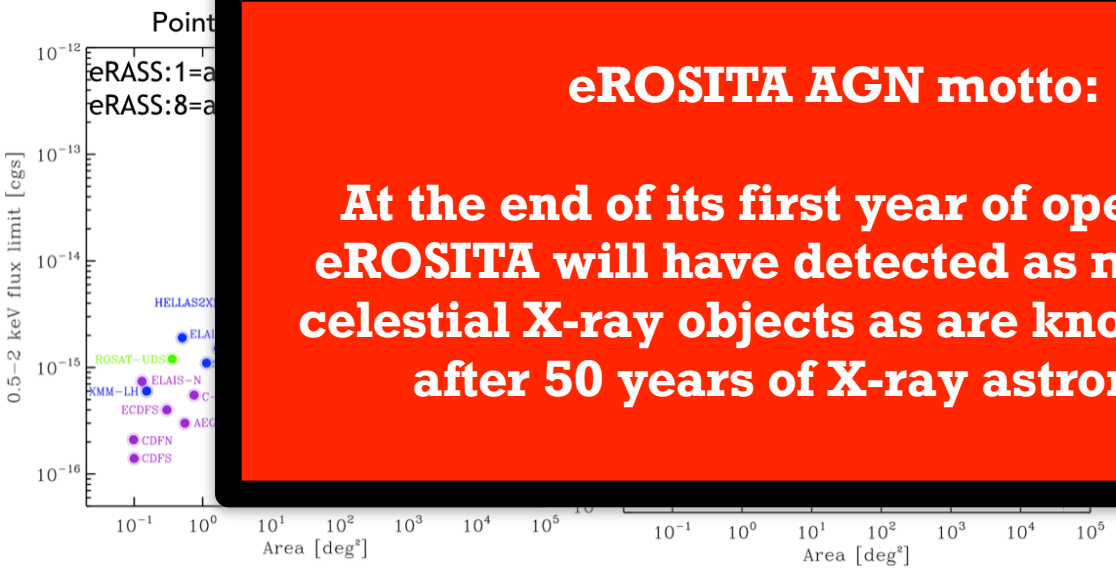
Marcella Brusa
"Science with MOS", Milano, 13 December 2018

The eROSITA revolution

eROSITA: extended ROentgen Survey with an Imaging Telescope Array

Next Generation All-sky X-ray survey telescope
4 years Survey phase (8 all-sky surveys) + pointed phase (GO)

Built by consortium led by MPE, to be launched in April 2019
on the Spectrum Röntgen Gamma (SRG) mission along with ART-XC
Final all-sky survey: Q4/2023



eROSITA AGN motto:

At the end of its first year of operations, eROSITA will have detected as many new celestial X-ray objects as are known today, after 50 years of X-ray astronomy

…itivity:
…eeper than ROSAT
…10^{-14} cgs (AGN)
…10^{-14} cgs (clusters)
…eeper than HEAO-1
…^{13} cgs (AGN)

Driving science:

1) detect **>100.000 clusters** (cluster cosmology) - **Merloni+2012, Pillepich+2018**
2) detect **>2.5Million AGN**, including most luminous, obscured ones - **Merloni+2012**
BONUS: 500.000 stars (!!!), SNR, planets, etc.

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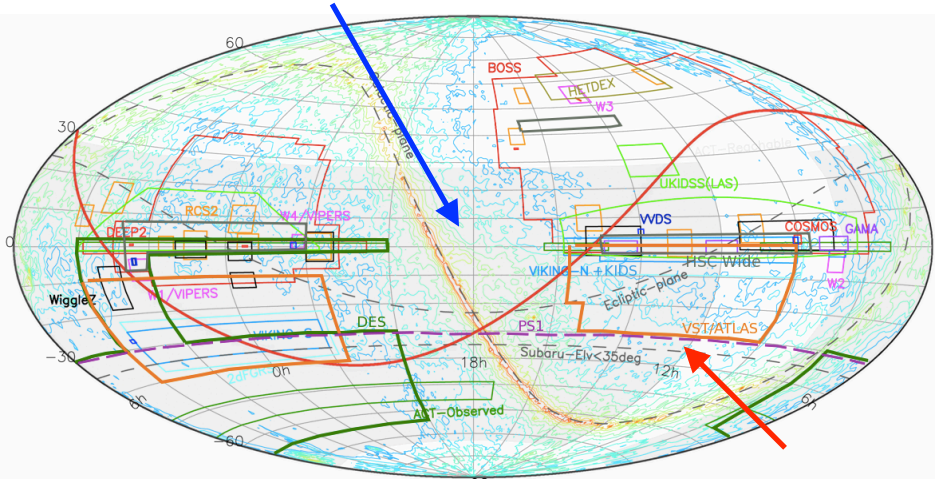
The eROSITA revolution / German sky

eROSITA: extended ROentgen Survey with an Imaging Telescope Array

German/Russian collaboration, 50% of the sky each;
eROSITA_DE data releases: 2021-2023-2025 (final)

eROSITA_DE welcomes External Collaborators

eROSITA_RU

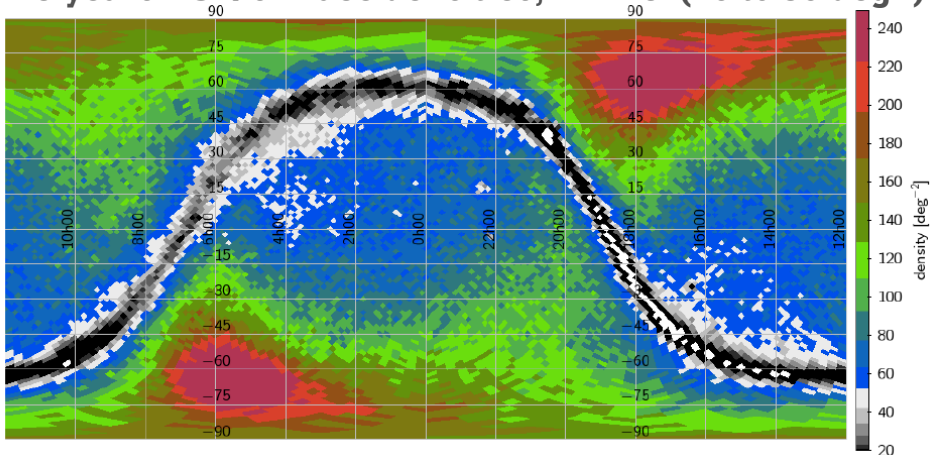


eROSITA_DE
12.800 deg2 of extragalactic sky (|b|>15°)

Merloni et al. 2012
eROSITA Science Book

4 years AGN surface densities, all: 60 to 240 deg^{-2}

1.5 years AGN surface densities, I<21.5: (20 to 30 deg^{-2})



Comparat et al., to be sub

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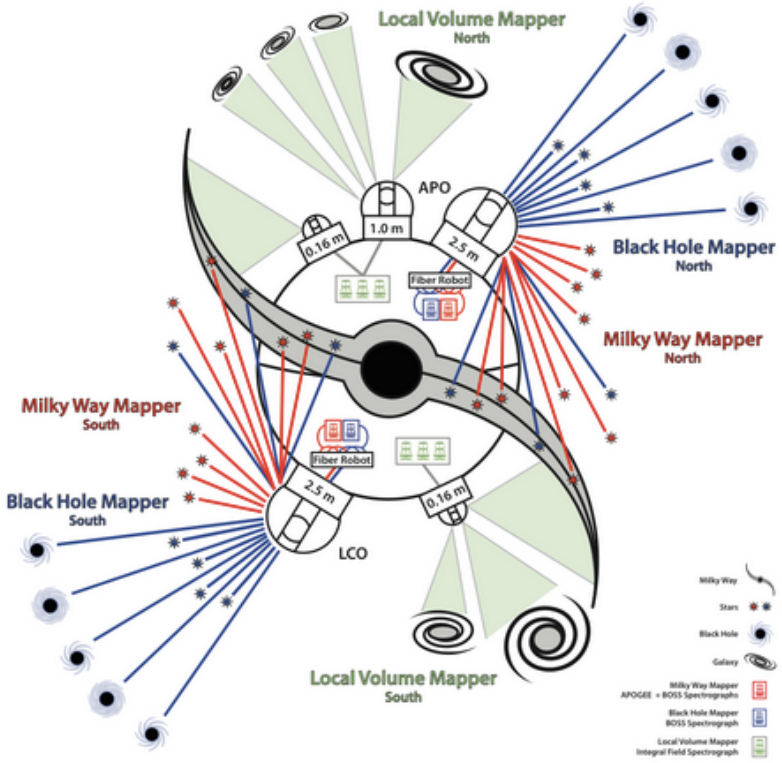
eROSITA spectroscopic follow-up

- **SDSS-V (2020-2024) www.sdss.org/future/**

  access to all sky

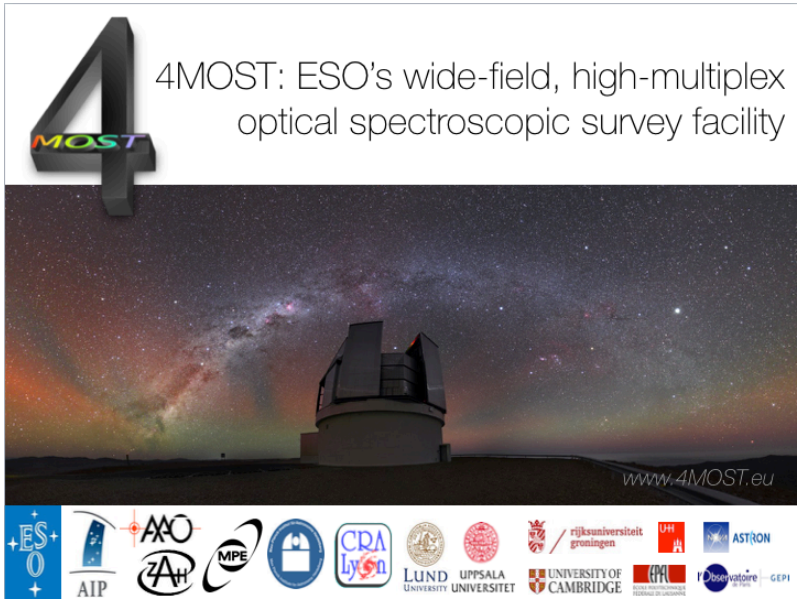
  (eROSITA_DE area: 12.800 deg²)



- **4MOST (2023-2027) www.4most.eu**

  access to Southern emisphere

  (eROSITA_DE area: ~10.000 deg²)



DESI: limited overlap with eROSITA_DE and DESI-BAO

WEAVE: northern hemisphere

Euclid: 15.000 deg² / ~7500 overlap with eROSITA_DE

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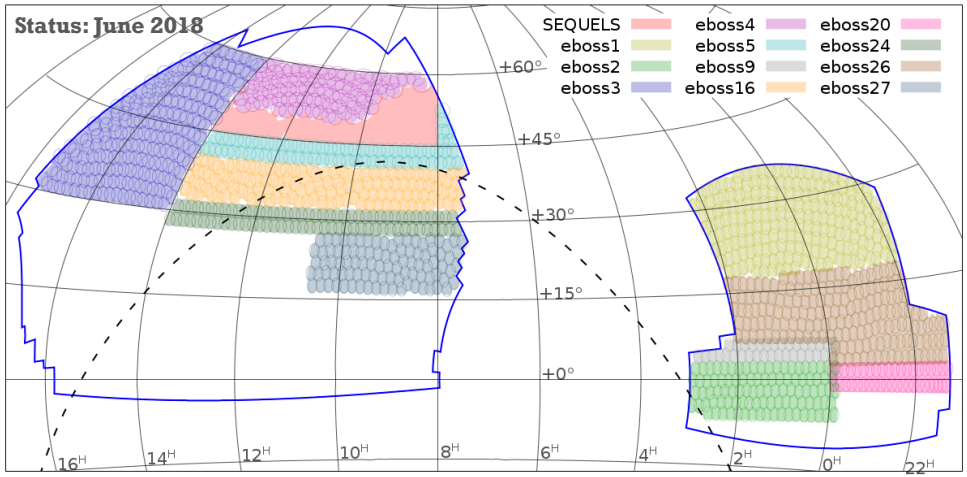
SPIDERS: The largest area covered (so far)

SPIDERS: SPectroscopic IDentifications of ERosita Sources

SDSS 2.5mt telescope
FoV=7deg², BOSS optical spectrograph (1000 fibers)
SDSS-IV project (share fibers with eBOSS)

Follow-up of X-ray sources selected from Rosat and XMM-Newton

- Clusters of Galaxies:
  using ROSAT+XMM+redMapper ~(0.8+0.08)/deg²;
  ~7-8 (new) targets per cluster
- Pointlike (mainly) AGN:
  using ROSAT+XMM ~(1.8+0.2)/deg²



Dwelly+2017, Salvato+2018, Coffey+in prep

eROSITA

- About 600 deg² of eROSITA_DE sky will be covered by eBOSS/SPIDERS in Spring 2020
- Target eRASS:1
  (~6000 AGN and ~500 clusters)

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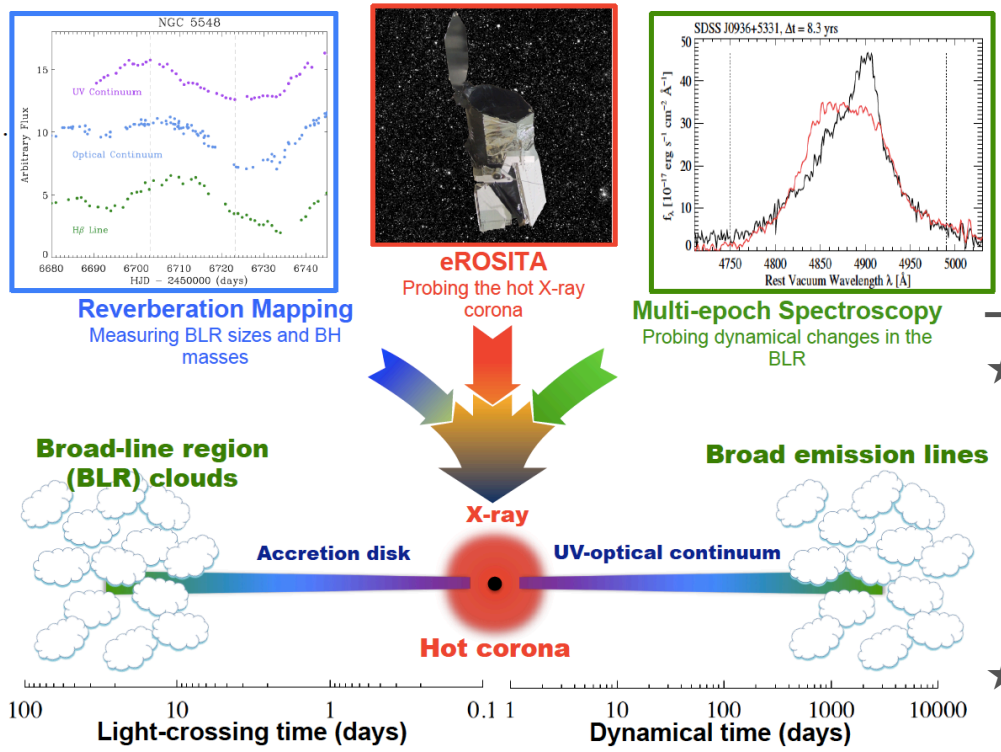
SDSSV (Black Hole Mapper) and eROSITA

Kollmeier et al. 2017,
SDSS-V: Pioneering Panoptic Spectroscopy
Appendix K



★ **Redshifts and spectral identifications for >300,000 X-ray selected AGN, from the first 1.5 years of eROSITA_DE scans, r<21.5 [requirement: ~10.000 deg² in 4 years]**

- ➜ first ever highly unbiased mapping of quasar clustering
- ➜ 10x deeper than ROSAT
- ➜ 10x larger than the total number of X-ray AGN with spec-z available in 2020!

★ **Time domain (repeated) optical spectra of known quasars**

- ➜ Reverberation Mapping to measure BLR sizes and BH masses
- ➜ dynamical changes in BLR to study accretion and outflows astrophysics

★ **A closely related spectral survey of >10,000 eROSITA clusters**

- ➜ to understand cluster physics
- ➜ constrain the cosmological model

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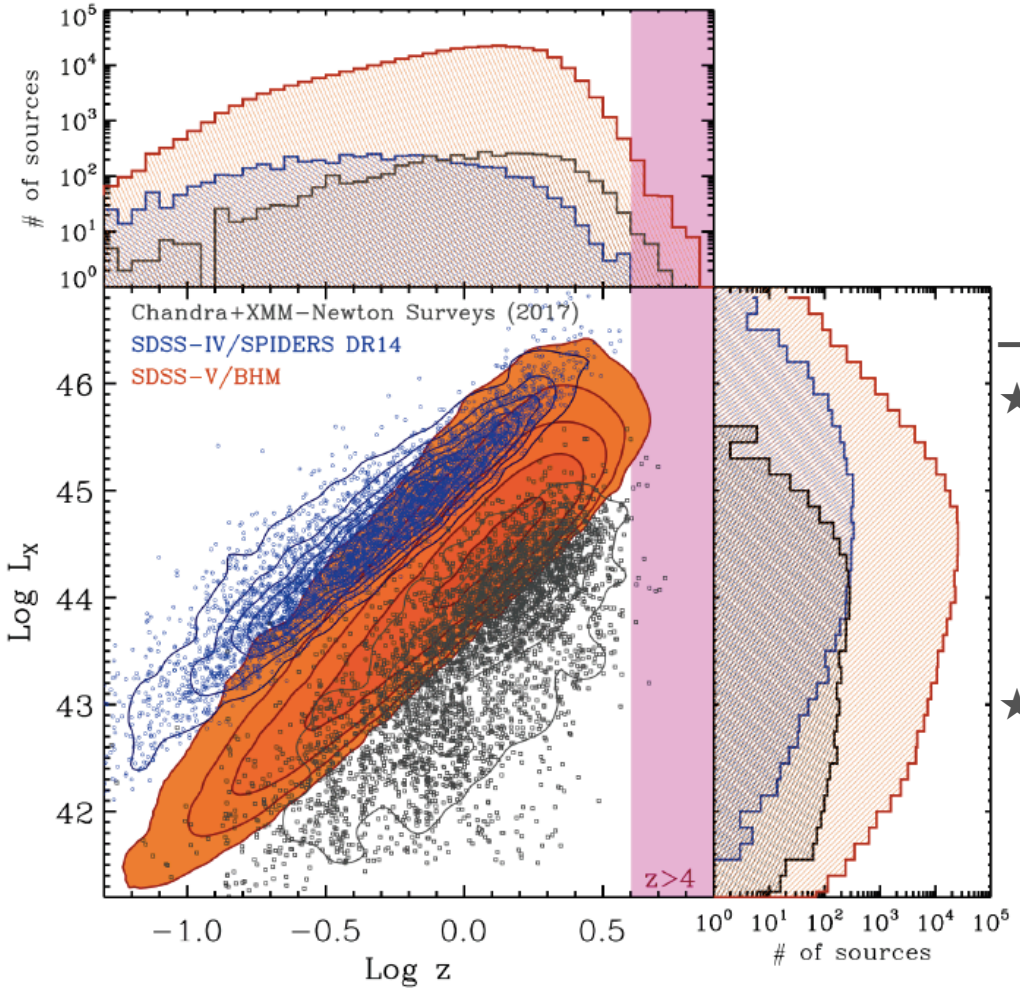

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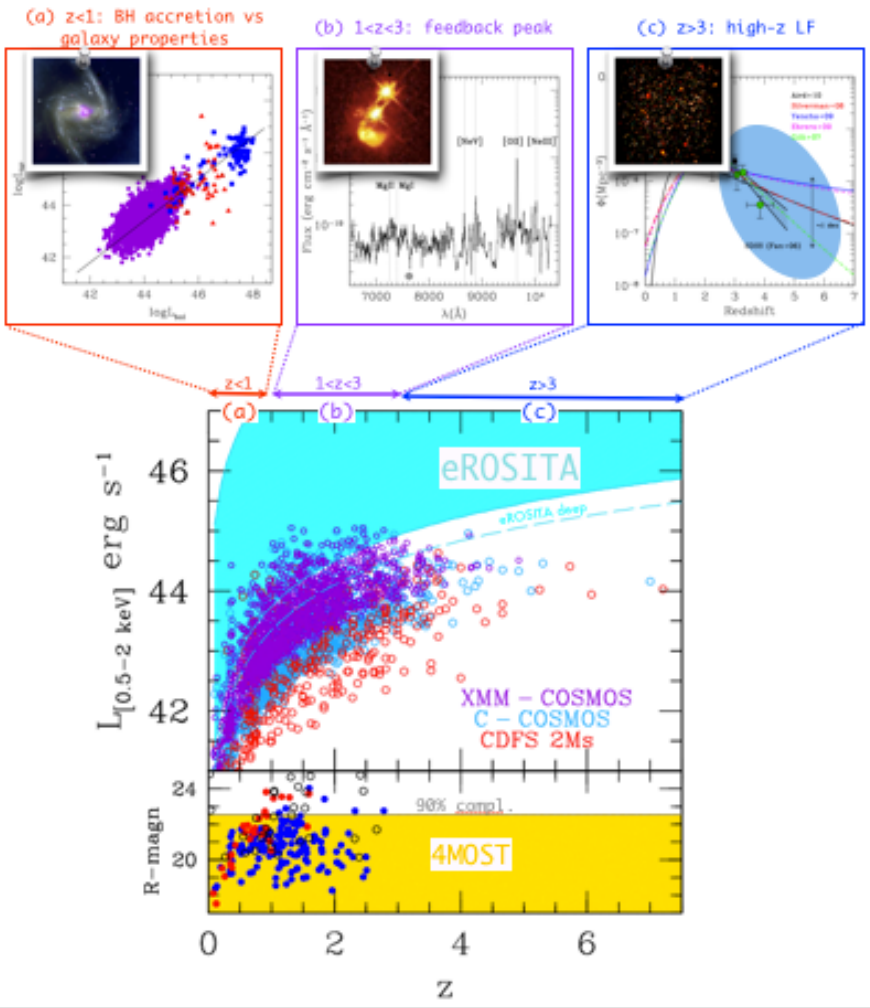
4MOST and eROSITA



★**Redshifts and spectral identifications for ~800,000 X-ray selected AGN, from the 4 years survey of eROSITA_DE scans, r~22.8 [~10.000 deg²- including full DES area]**

- ➜ obscuration-unbiased demographics of BH growth and evolution
- ➜ highly unbiased mapping of quasar clustering up to z=3 and beyond
- ➜ BH accretion vs. galaxy properties
- ➜ feedback probes
- ➜ XLF of z>3 QSOs
- ➜ 30 times deeper than ROSAT

★**A closely related spectral survey of 1Mio galaxies in 50,000 eROSITA clusters**

- ➜ to understand cluster physics
- ➜ constrain the cosmological model first stage IV experiment in the DETF

For both AGN and clusters: a uniform selection function

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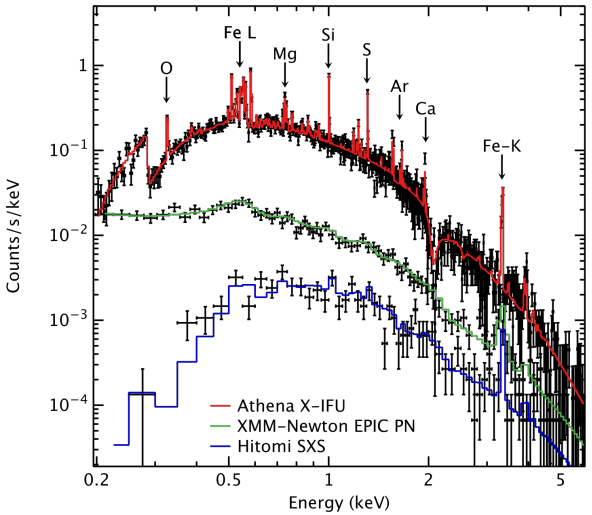
Advanced Telescope for High-Energy Astrophysics

- **Second Large (L2) mission of ESA Cosmic Vision, launch early 2030s**
  Lifetime: 4 yr +Possible extensions

http://www.the-athena-x-ray-observatory.eu/

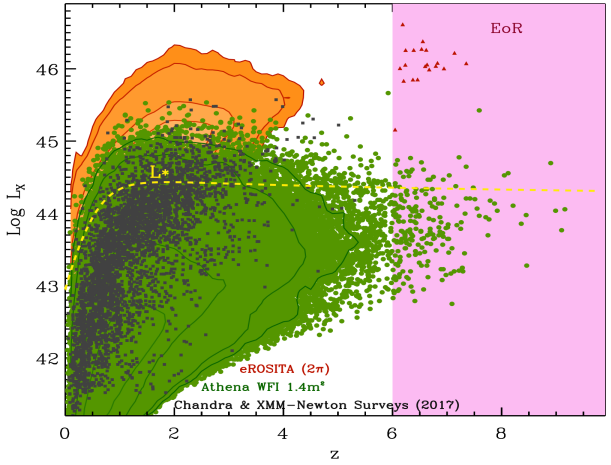
- **Science themes:**
  - **How does ordinary matter assemble into the LSS we see today?**
    groups at z>1, chemical evolution of cluster gas
  - **How do black holes grow and shape the Universe? High-z (z>6) census**

Barret+16 (SPIE)

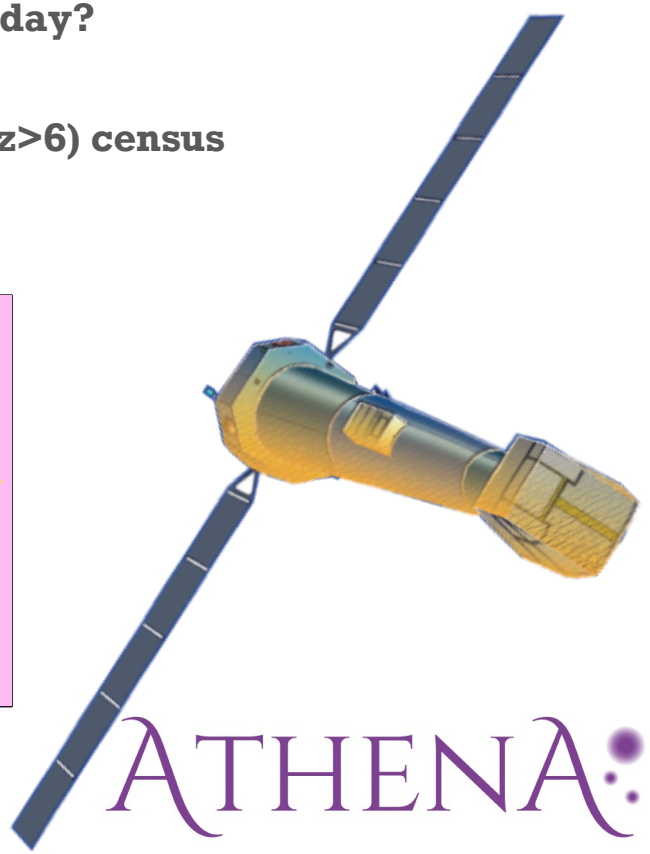


- **X-IFU spatially resolved high-resolution spectroscopy pixel size 5”**

adap. Aird, Comastri, MB+13



- **WFI sensitive imaging limiting flux ~1e-17 cos**



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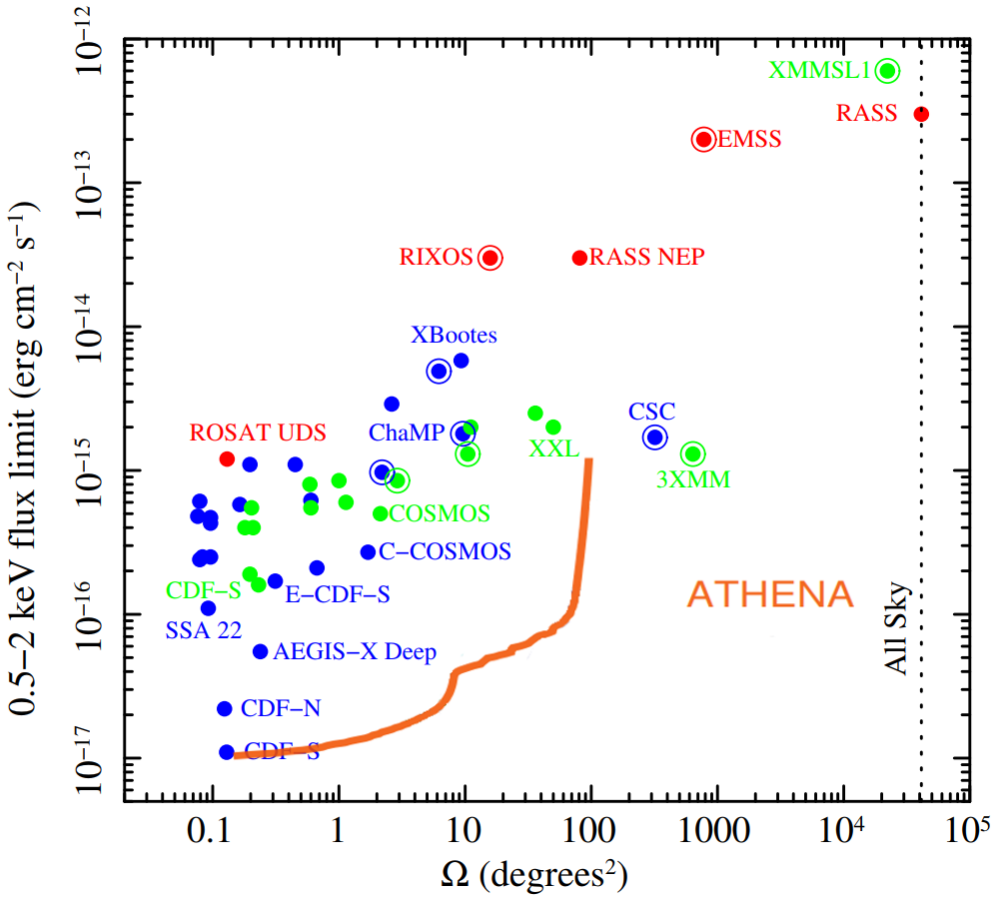
AGN Surveys in the Athena era



★**Multi-tier AGN survey with WFI**
>10,000 X-ray selected AGN in 2 deg^2

★**I-band mag ~24 (average), many faint**

➜ needs an efficient, large FoV, NIR MOS:

MOONS
(right spectral coverage and sensitivity)

➜ NIR crucial for high-z confirmation and/or galaxy/AGN classification

➜ first XLF at z>6 (BH seeds models constrain)

★**Synergies with JWST, SKA**

Euclid Deep survey:
40 deg2 —> 10.000 AGN

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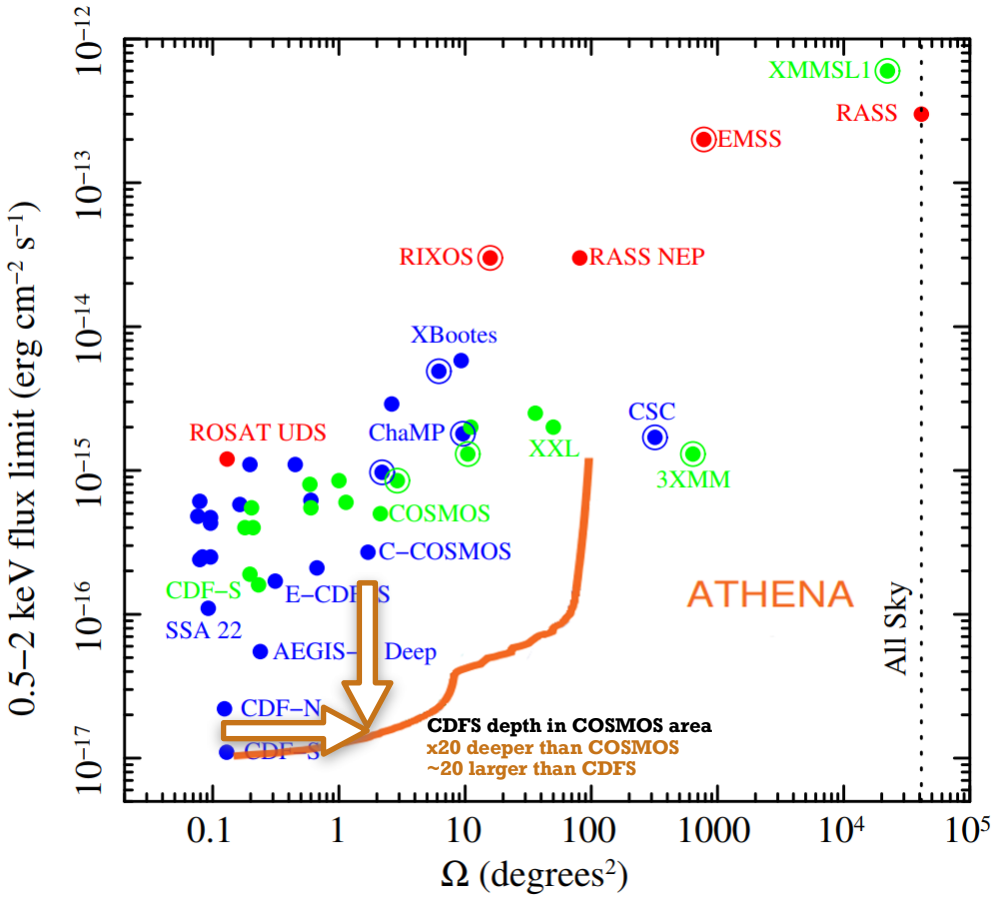

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Take home message

The results obtained in the past 20 years on AGN evolution, clustering and AGN-galaxy coevolution would have not been possible without coordination with spectroscopic campaigns with MOS instruments

➜ Excellent examples of Synergies (always worked very well/efficiently)
➜ Italian X-ray/AGN community has been at the forefront in all the achievements

Future synergies foreseen:

2020-2025: eROSITA_DE (12800 deg²)
+ SDSSV and 4MOST (~10.000 deg²) + (Euclid 7.500 deg²)
(AGN/clusters samples of SDSS size;
definitive QSO evolution; clustering and AGN environments)

2030+: Athena
+ MOONS (+ JWST)
(first accreting AGN and constrain BH seeds models;
strong involvement of italian community in both instrument and science teams)

BACKUP SLIDES

Italian involvement in Athena

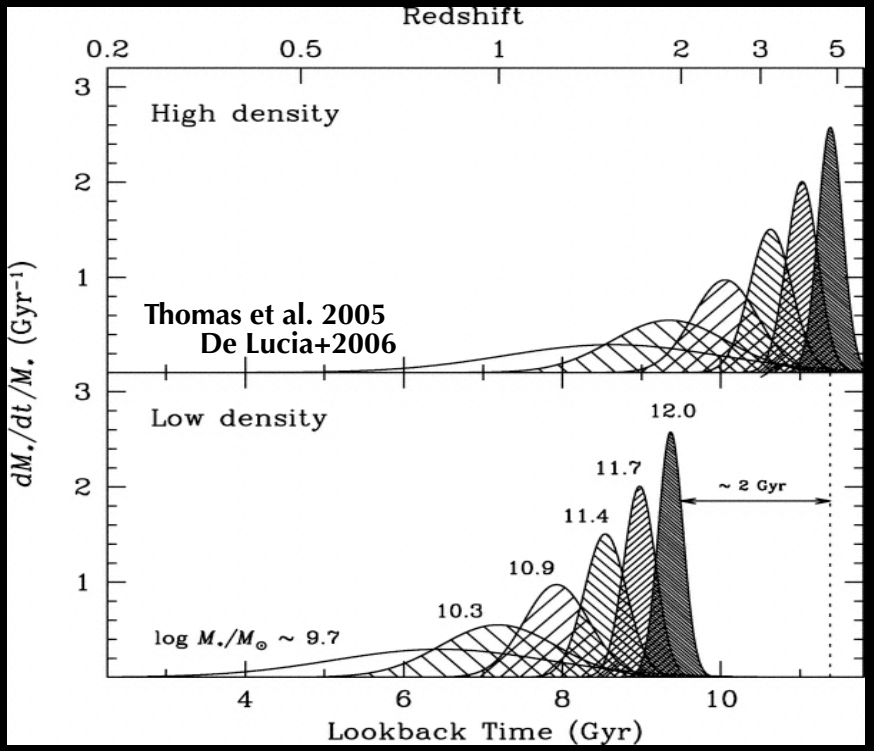
ESA Athena Science Study Team (ASST)

M. Guainazzi (Chair), K. Nandra (Science Lead & WFI), D. Barret (X-IFU), A. Decourchelle, J.W. den Herder, A.C. Fabian, H. Matsumoto (JAXA), L. Piro, R. Smith (NASA), R. Willingale.

SWG1	SWG2	SWG3	TWG4	MWG5
Hot Universe	**Energetic Universe**	**Observatory**	**Telescope**	**Mission Performance**
Fabian, Reiprich, Ohashi	Nandra, Cappi, Brenneman	Decourchelle, Matsumoto, Smith	Willingale, Pareschi	den Herder, Piro, Rau
SWG1.1 Evolution of galaxy group and clusters *Allen, Ota, Pointecouteau*	**SWG2.1** Formation and growth of earliest SMBH *Aird, Comastri*	**SWG3.1** Solar System & exoplanets *Branduardi-Raymont, Güdel*		**MWG5.1** Science ground segment *Watson, Webb*
SWG1.2 Astrophysics of galaxy group and clusters *Ettori, Pratt, Eckert*	**SWG2.2** Understanding the build-up of SMBH and galaxies *Georgakakis, Carrera, Ueda*	**SWG3.2** Star formation and evolution *Rauw, Sciortino*		**MWG5.2** Background *Laurent, Molendi*
SWG1.3 AGN feedback in galaxy group and clusters *Croston, Sanders, McNamara*	**SWG2.3** Feedback in local AGN and star forming galaxies *Ponti, Ptak, Terashima*	**SWG3.3** End points of stellar evolution *Bozzo, Schwope*		**MWG5.3** Inter-calibration *Burwitz, Pajot, Sembay*
SWG1.4 Missing baryons and warm-hot intergalactic medium *Kaastra, Finoguenov*	**SWG2.4** Close environments of SMBH *Dovciak, Matt, Miniutti*	**SWG3.4** Supernova remnants & Interstellar medium *Bamba, Costantini*		**MWG5.4** End-to-end simulations *Peille, Wilms*
				MWG5.5 Advanced analysis tools *Fiore, Haberl*

Observational evidences of a mutual relationship (3)

SF downsizing

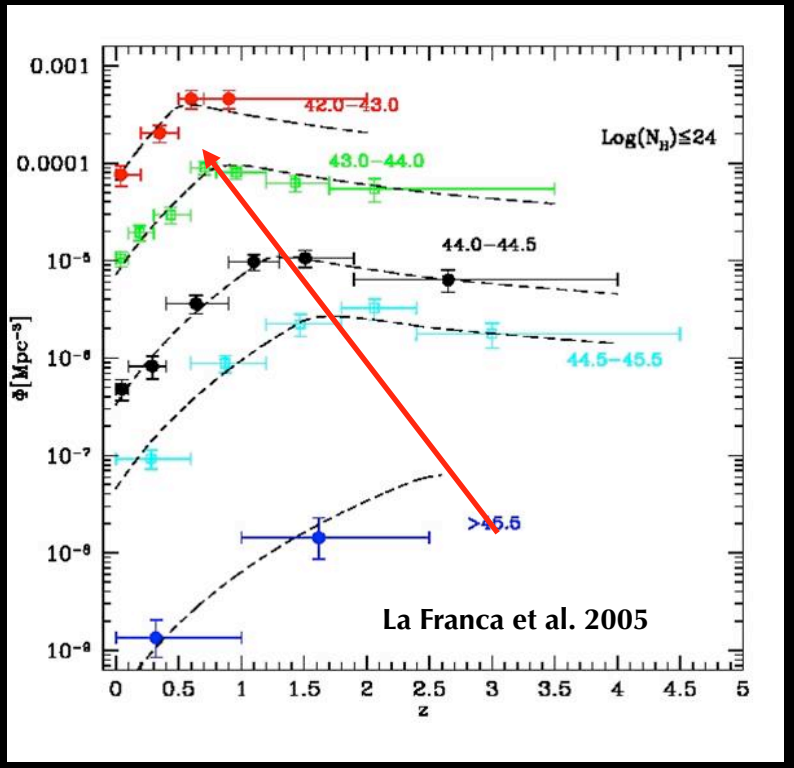


Cosmic "downsizing"

the larger the faster (Cowie et al. 1996):

".. galaxy formation took place in "downsizing", with more massive galaxies forming at higher redshift.."

AGN downsizing



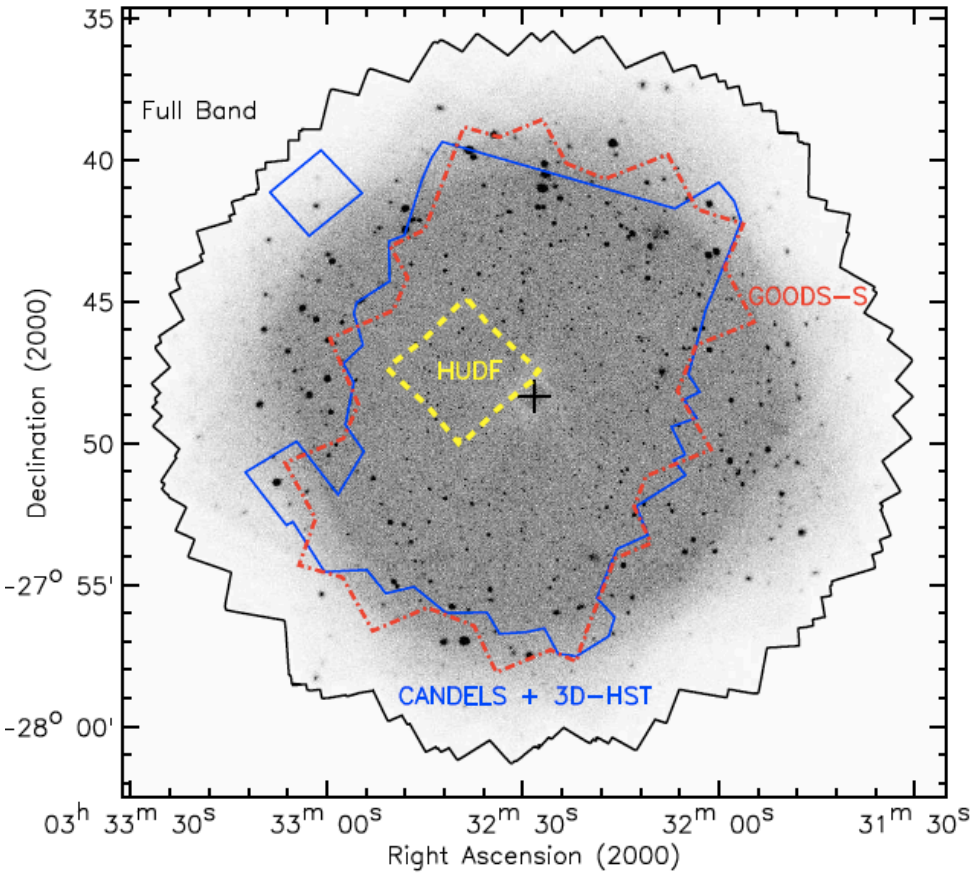
Fiore,Brusa+2003 (HELLAS2XMM)

Ueda+03; Barger+05; Hasinger+05; Silverman+05, Bongiorno+07, Della Ceca+08, Ebrero+09 etc. - but see Aird et al. 2010

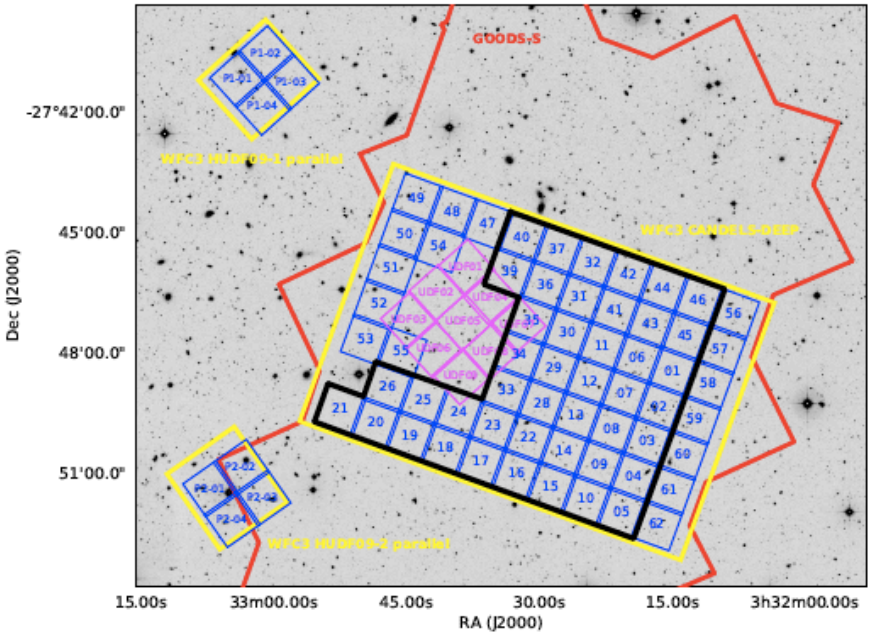
more luminous AGN had the peak of activity at earlier redshifts

How many sources per deg2? (1 - CDFS)

Luo et al. 2017



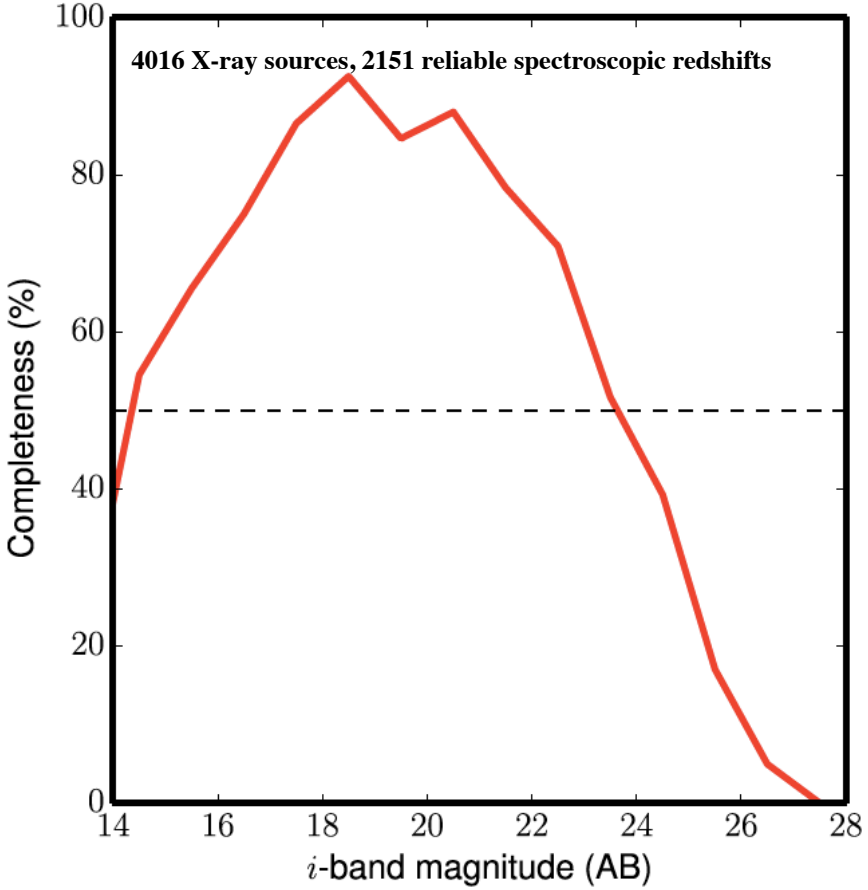
Urrutia et al. 2018
MUSE-Wide survey of CDFS

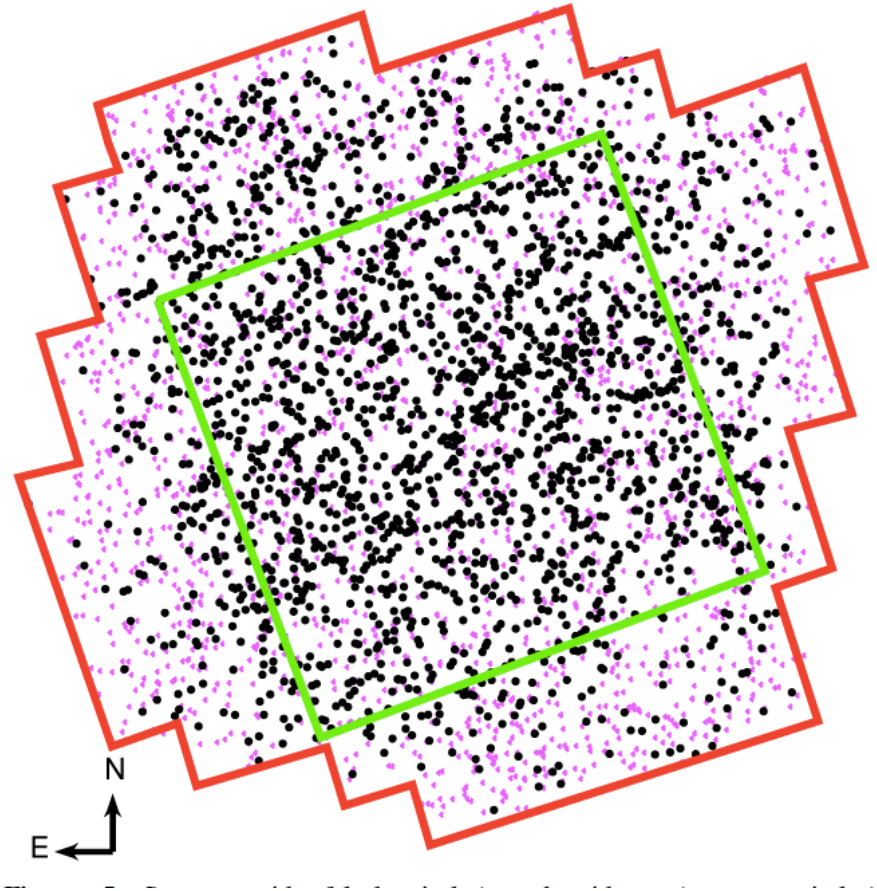


26 literature references
used for spectroscopic redshift determination),

MOS in a medium-deep field (COSMOS)

Marchesi+2016





"COSMOS" contribution

COSMOS field, 2 deg² (Scoville+07)

http://cosmos.astro.caltech.edu/

XMM-Newton 1.55 Ms
~1800 objects, down to ~1e-15 cgs
(Hasinger+07, Cappelluti+09, Brusa+10)

Chandra coverage available on the entire field
(Elvis+2009, Civano+2016; 2.7 Ms)
Nustar data too
(Civano+2015)

Complete and deep **multiwavelength coverage from radio to UV**: identification, SED studies, host galaxy properties, and alternative AGN selection (e.g. Compton Thick census)

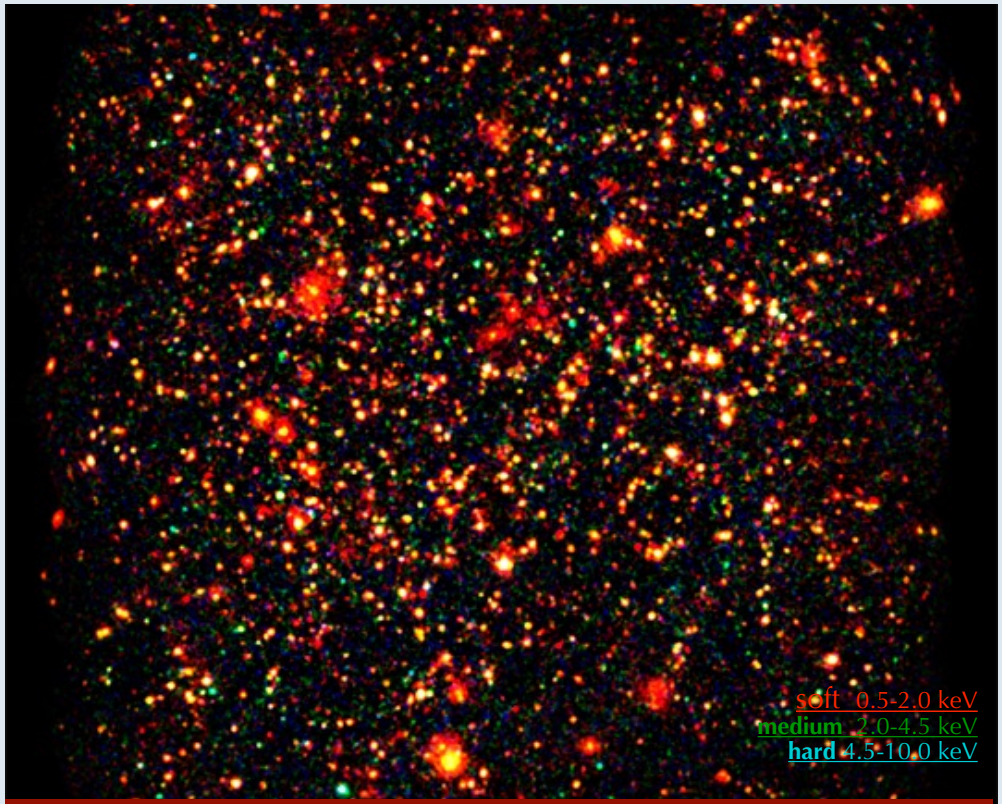
Essential AGN photometric redshifts
Salvato+2009, Salvato+2011

Large spectroscopic programs:

VIMOS/VLT (zCOSMOS survey, Lilly+07,09)

IMACS/Magellan (AGN targets, Trump+07,09)

DEIMOS/Keck+FMOS/Subaru+++(Hasinger+18)



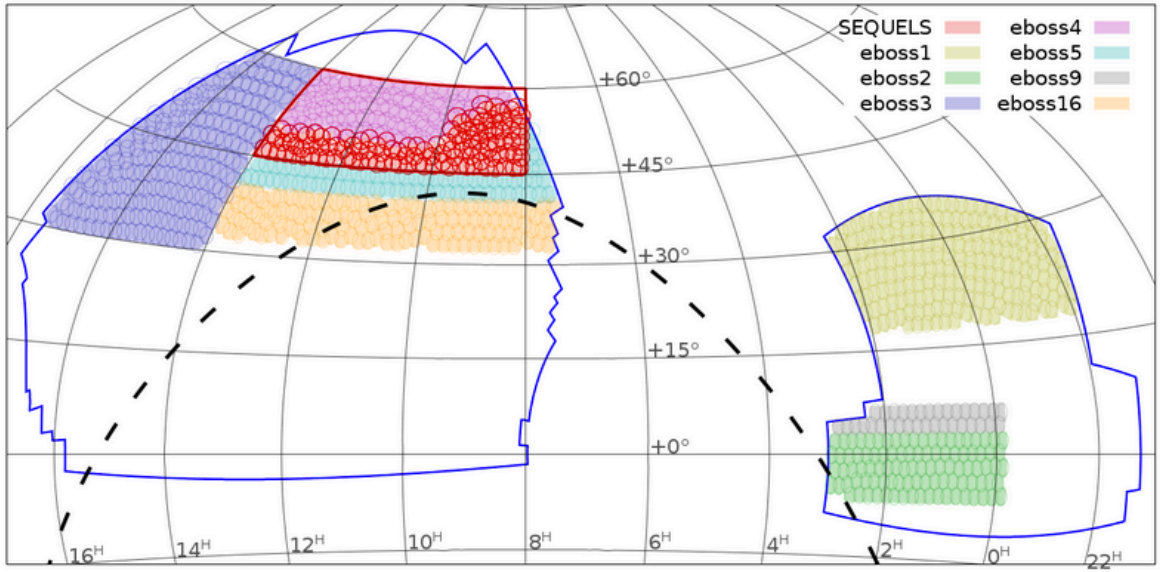
Only one among the many (~50) XMM, Chandra +++ surveys in russian-doll style

All wavelengths, very deep coverage available

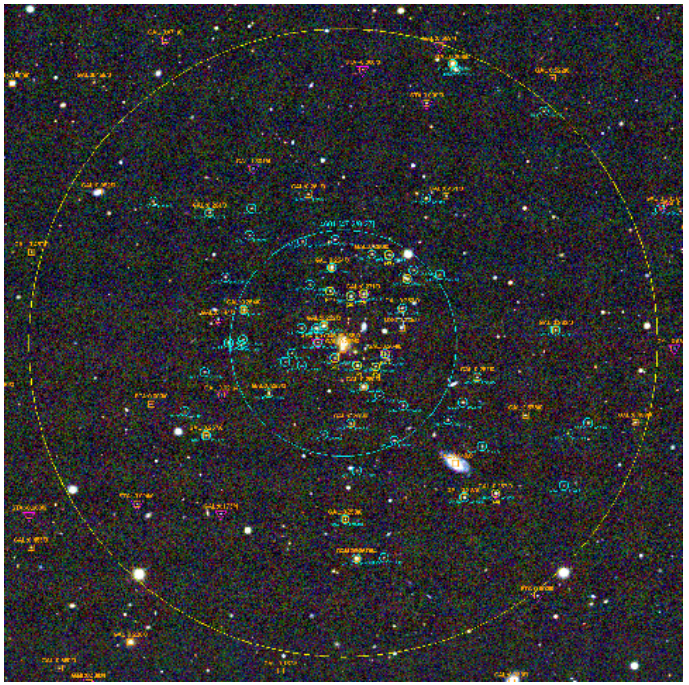
X-rays-MOS synergies (Clusters)

- **Ideal case for synergies**
  X-rays = cleanest cluster selection
  MOS = identification of clusters members simultaneously

Clerc+2016



12x12 arcmin CODEX 1_4601



ROSAT Selected Clusters (CODEX sample; 918 clusters)
+ SDSS-IV/EBOSS Follow-up

230 fully observed in DR12 + ~700 to come

eROSITA FAQs

What is the launch date?	March 29 – April 12, 2019
How are data shared btw Ru/D?	50:50 in galactic coordinates
Science (D)	12 Working Groups >135 Scientists + External Collaborators
When gets data public?	D: Survey after 2 years D: Pointed after 1 year, as usual
Alerting transient detections?	Yes, of course. But...
What is the sensitivity?	Point sources: 3 - 12 x 10^{-15} erg/s/cm^2 Ext. sources: 1 - 4 x 10^{-14} erg/s/cm^2

Working with eROSITA

- **eROSITA is a PI instrument**
  - All-sky data reduced and calibrated at MPE with own pipeline
  - Scientific exploitation of data shared between the partners: 50% MPE and 50% IKI, West/East (gal. coord.)
  - German data public after 2 yrs, 3 releases (**'21, '23, '25;** TBC)
  - Proprietary access via **eROSITA_DE (/RU) consortium**
  - In DE, Projects/papers regulated by working groups. Currently counting about 120 members + 20 EC
- **Working Groups:**
  - Clusters/Cosmology, AGN, Galaxies, Compact objects, Diffuse emission/ SNR, Stars, Solar System, Time Domain Astrophysics
- **Collaboration policy (German Consortium):**
  - Individual External Collaborations (proposal to WGs)
  - Group External Collaborations (team-to-team MoUs)
    - CAASTRO->AAL (Australian Community)
    - HSC SSP
    - SDSS-IV -> SDSS-V
    - J-PAS

RASS vs. eROSITA vs. XMM

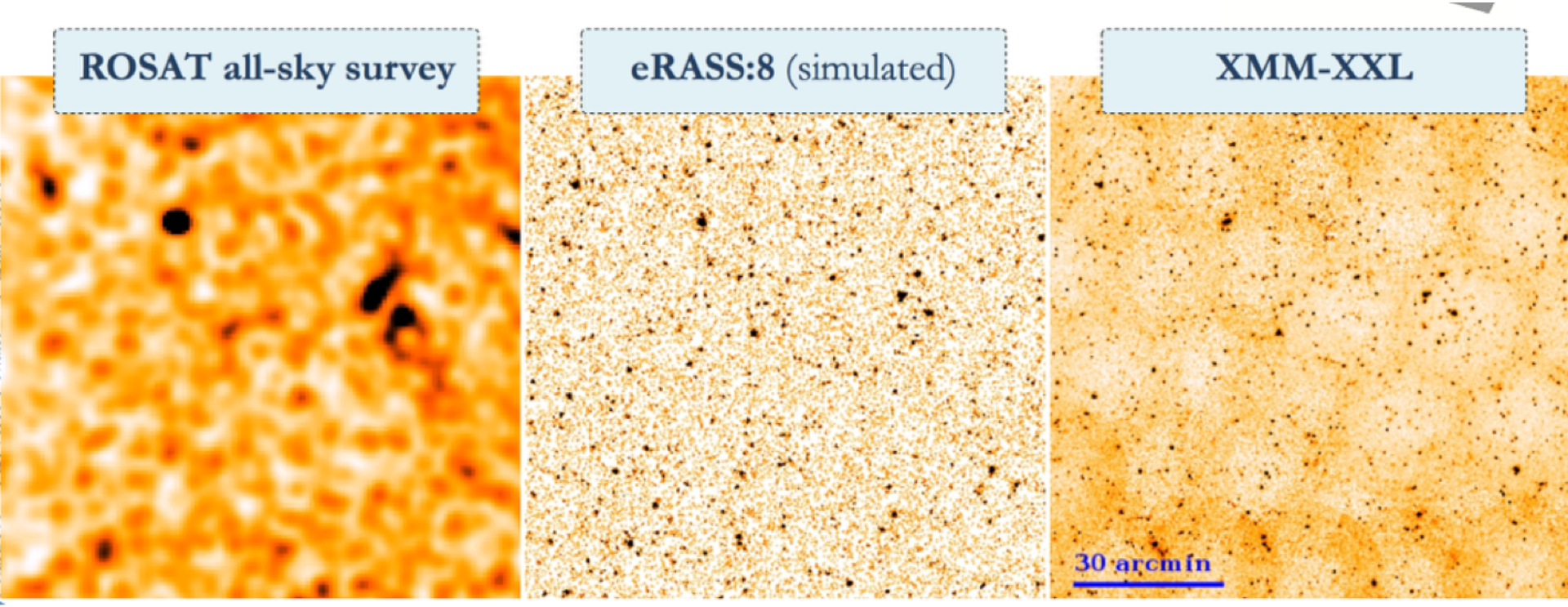
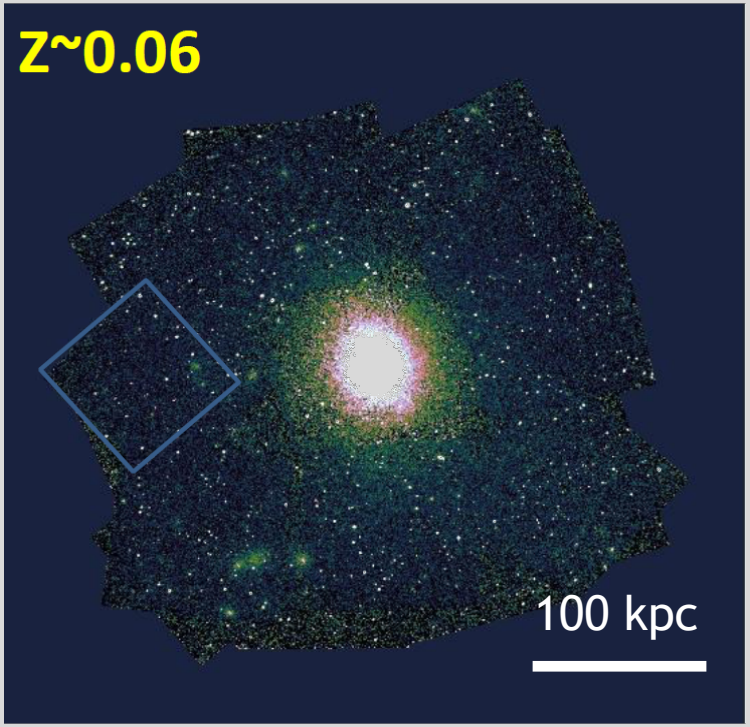


Image credits: MPE, eRosita_DE consortium, XMM-XXL

Fast Survey Machine

Chandra

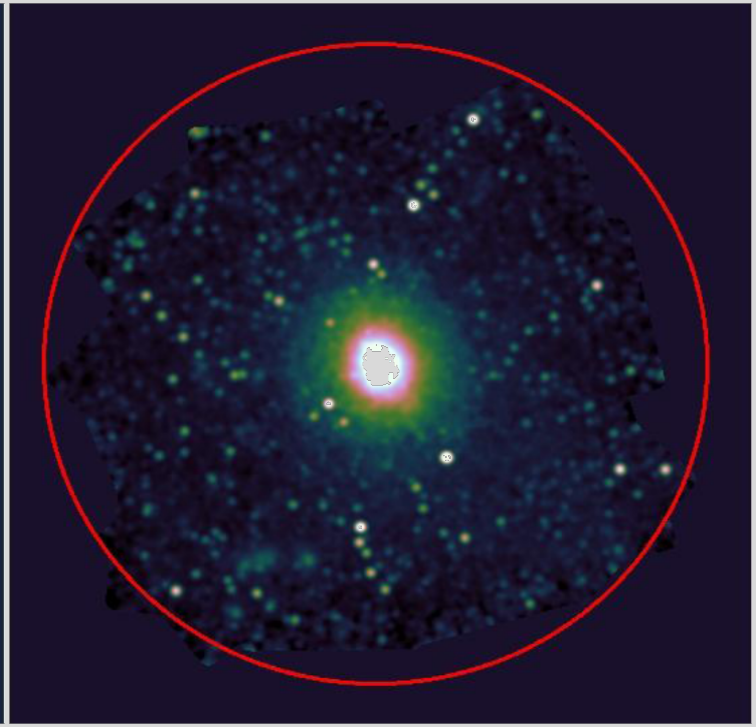


~30 pointings

~2 Msec

[0.5” HEW]

eRosita

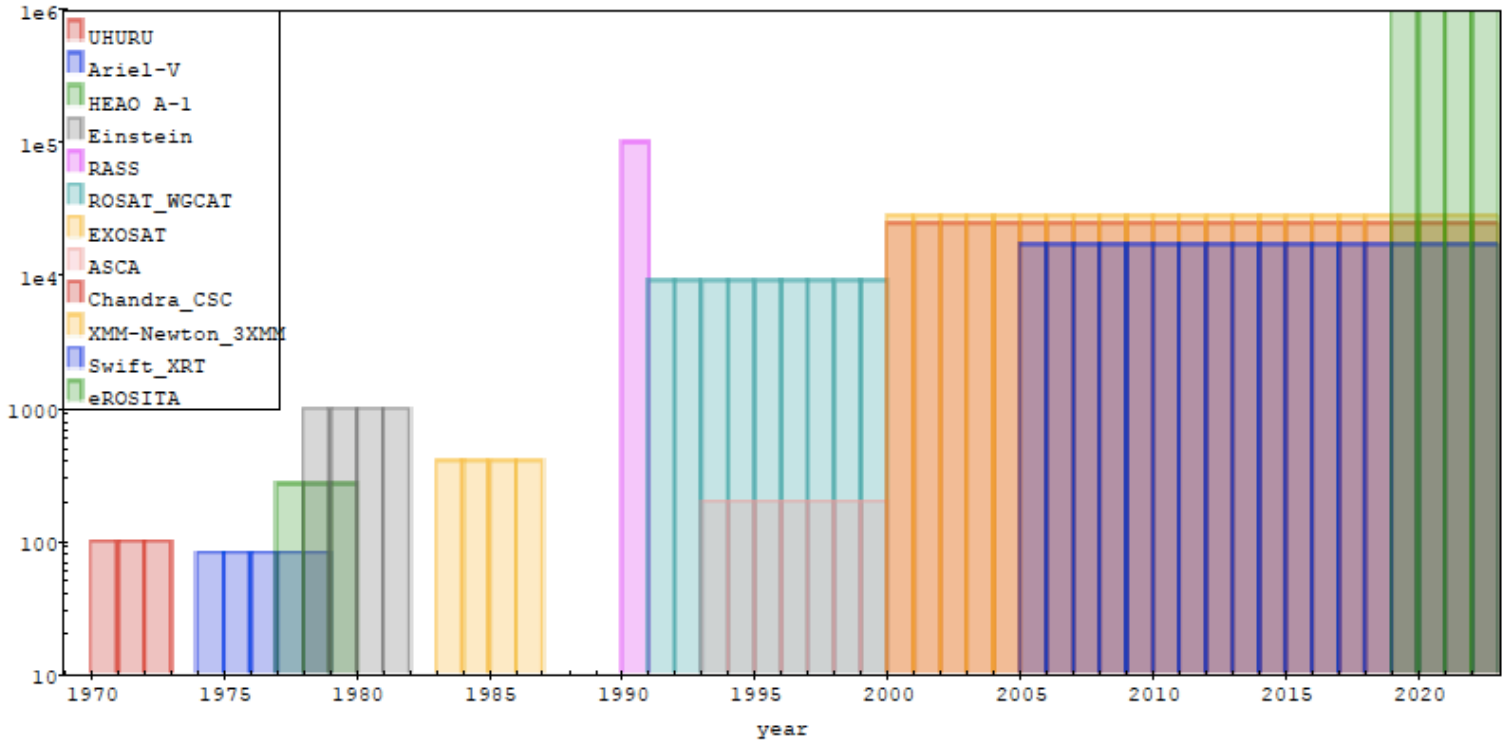


~1 pointing

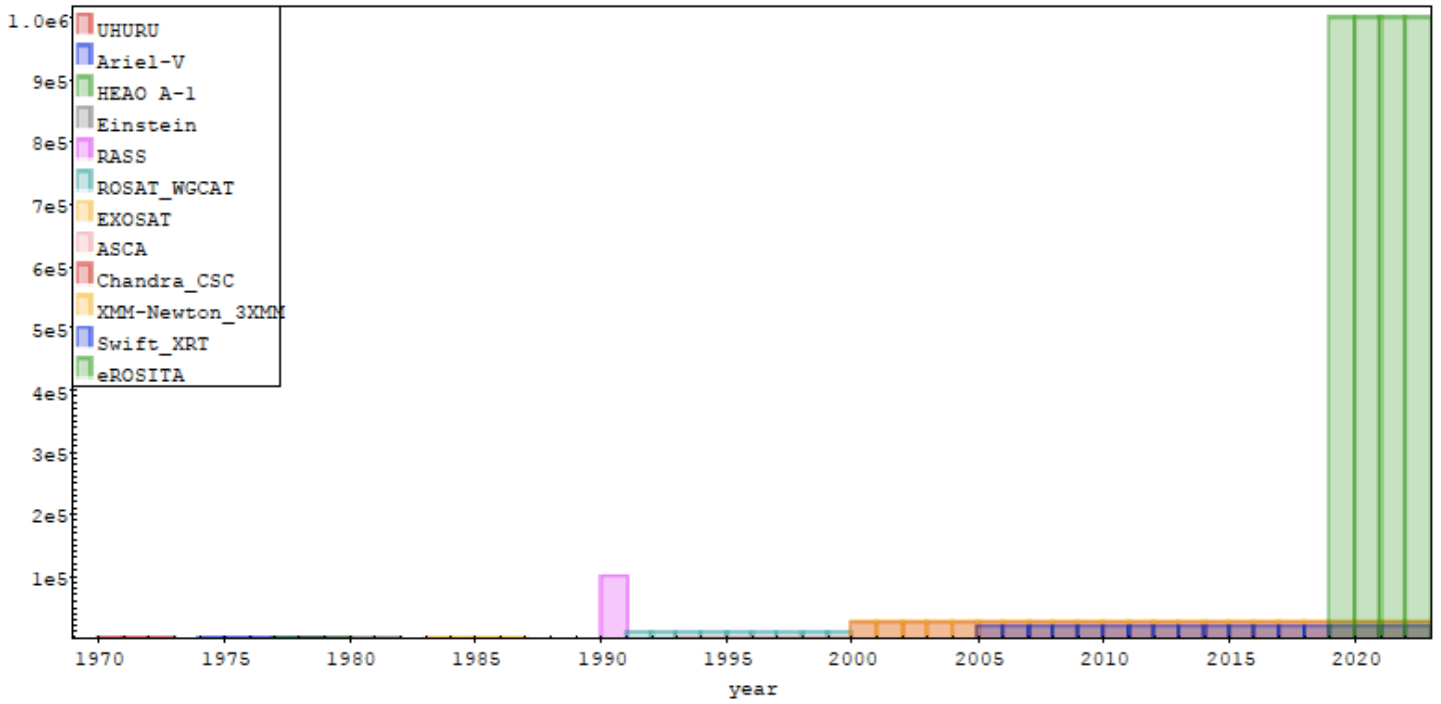
~80 ksec

[26” HEW (FoV avg)]

Churazov, IKI, MPA

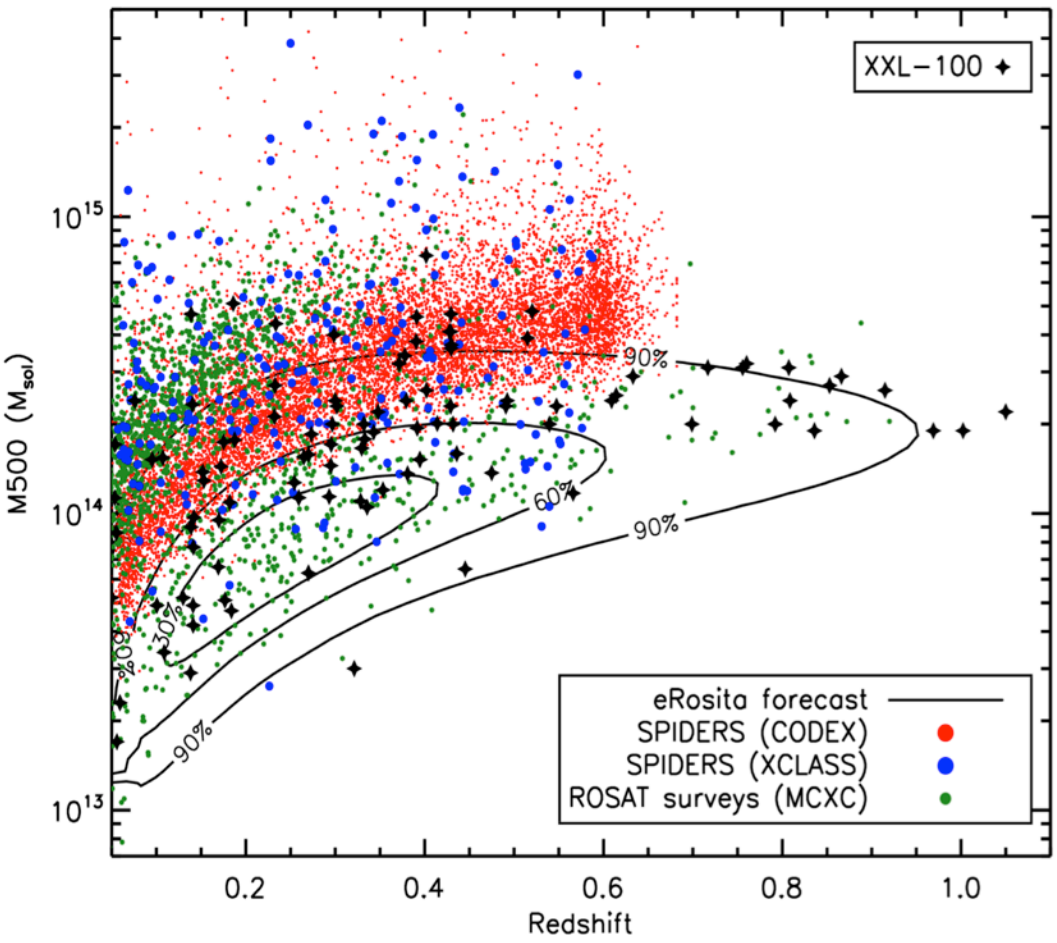


Approx. Number of X-ray sources detected per year



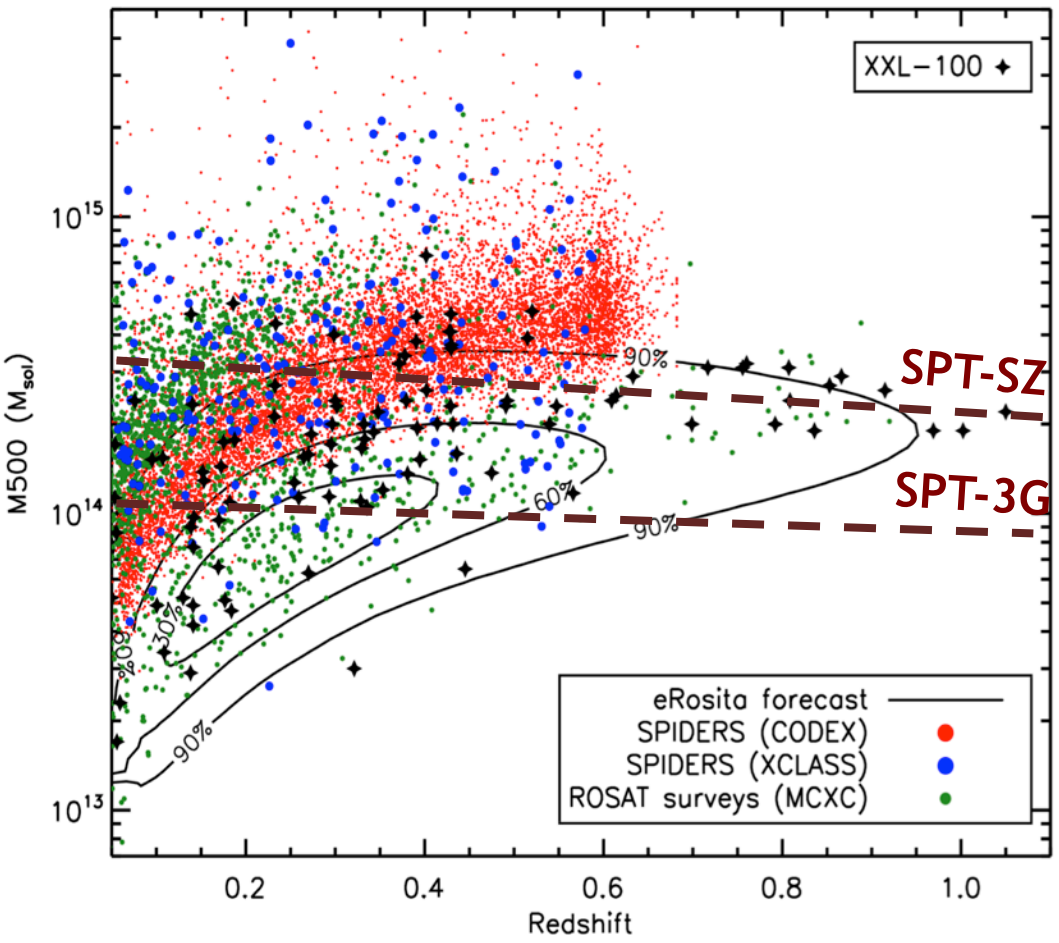
Approx. Number of X-ray sources detected per year

ALL Massive Clusters



- eROSITA will detect ~110k clusters with more than 50 net counts; 2k with more than 1000 counts
- ~20k clusters with good redshift determination, up to z~0.45
- ~2k clusters with precise Temperature (to <10%)
- eROSITA PSF is good enough to resolve ~0.3R_{500} regions at z=1 for $10^{14}M_{\odot}$ clusters
- For cosmology, M_{gas} and core-excised L_X are excellent mass proxies with very low scatter (~10%)

ALL Massive Clusters



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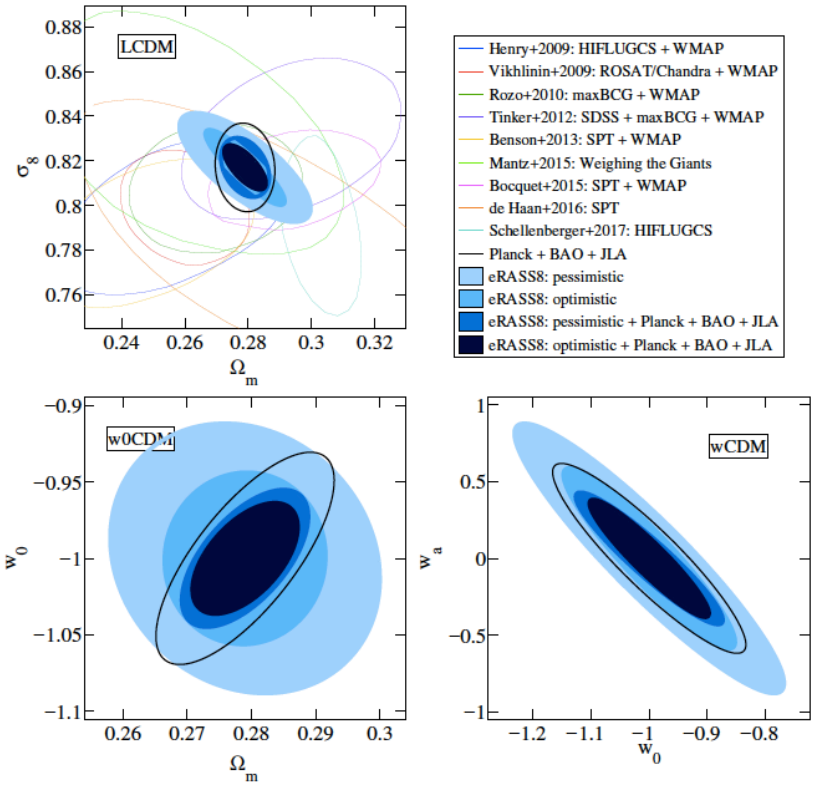
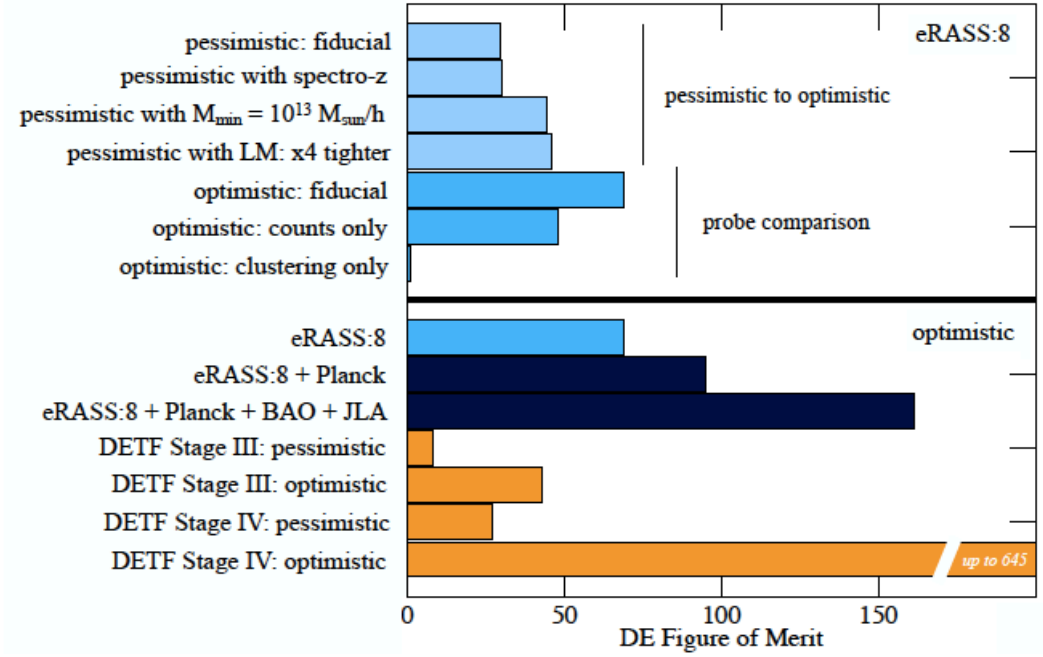
eROSITA as a StageIV experiment

Pillepich+2018

forecast using **number density** and **spatial clustering** of a photon-count-limited sample of clusters of galaxies up to z~2
Tested against:
(i) X-ray follow-up observations, (ii) photo and spectroz, (iii) accurate knowledge of the observable – mass relation down to the scale of galaxy groups





dark energy figure of merit
DE FoM ~116-162

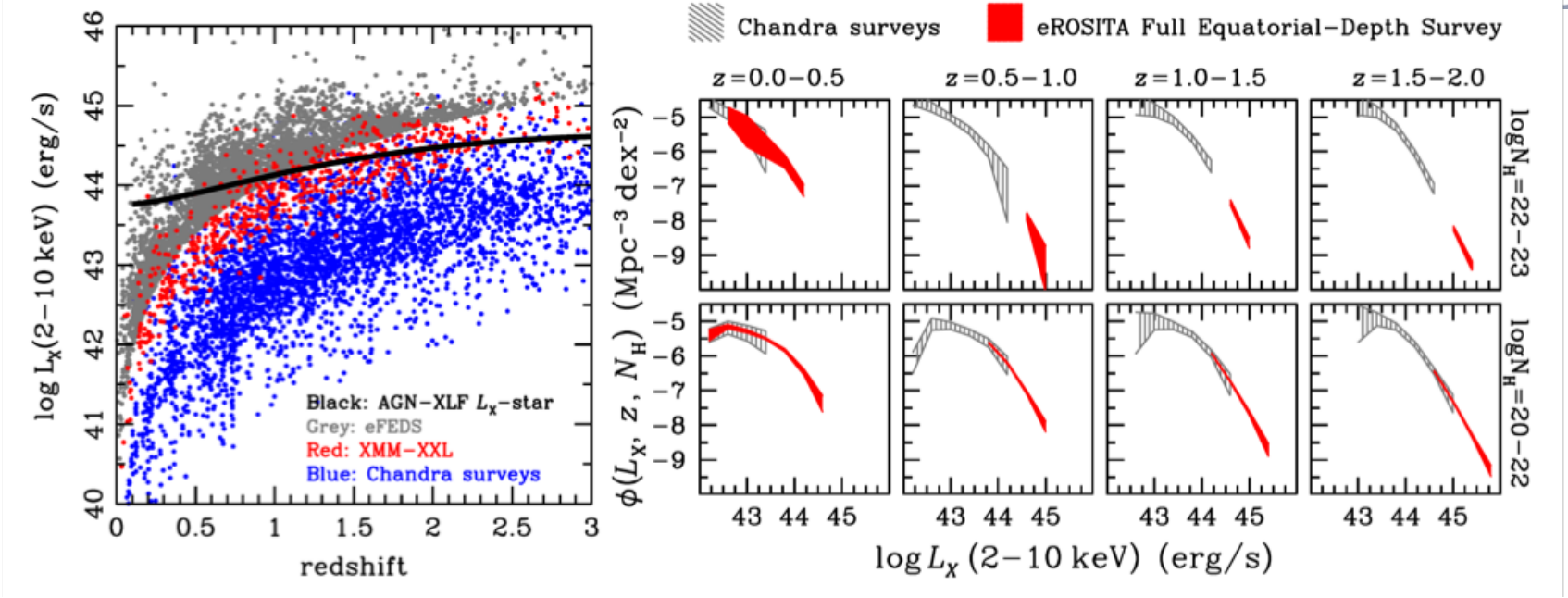
eROSITA one of the first Stage IV experiments to come on line according to the classification of the Dark Energy Task Force.

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
DIPARTIMENTO DI FISICA E ASTRONOMIA

INAF ISTITUTO NAZIONALE DI ASTROFISICA
OSSERVATORIO DI ASTROFISICA E SCIENZA DELLO SPAZIO DI BOLOGNA

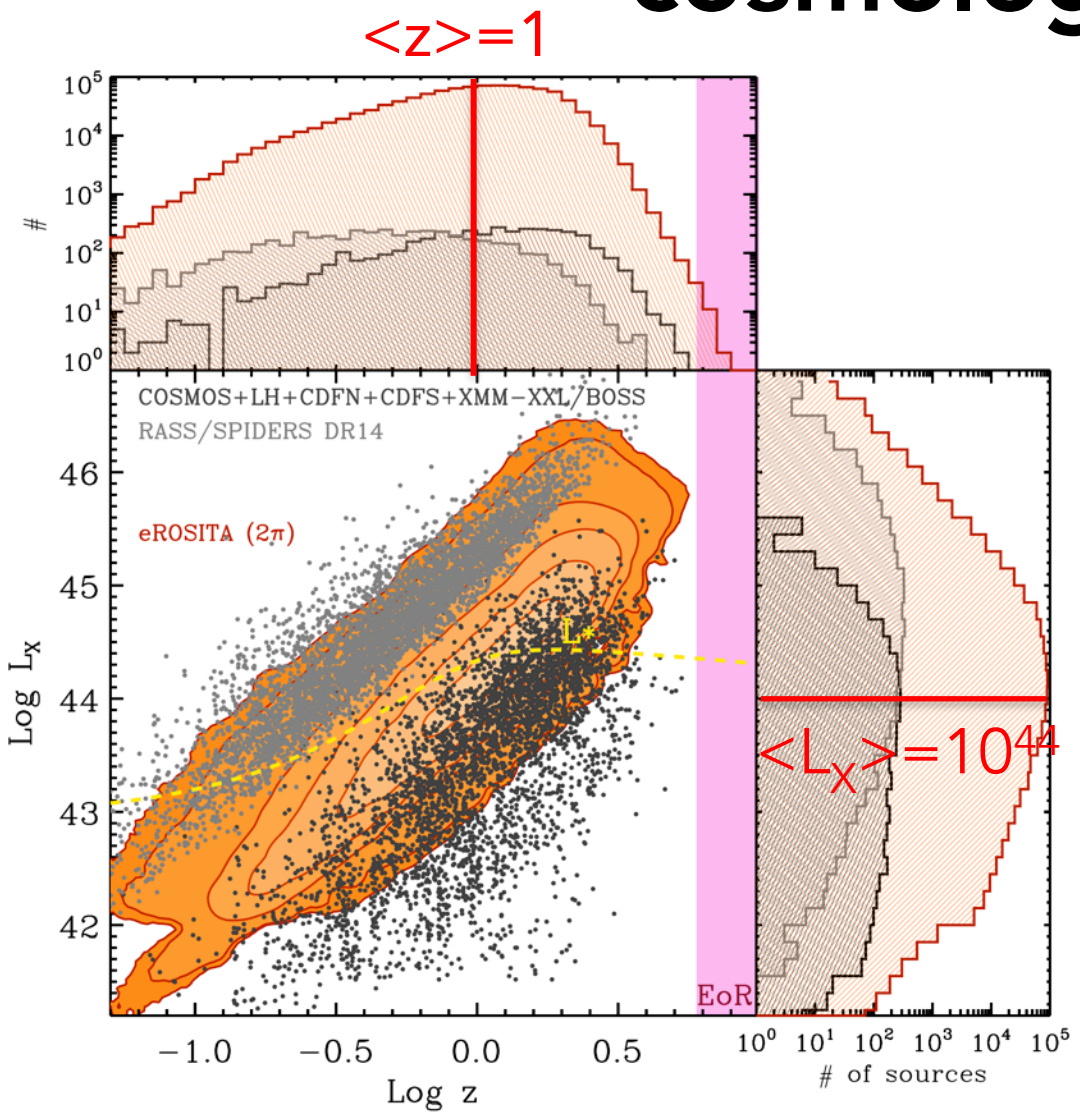
Marcella Brusa
"Science with MOS", Milano, 13 December 2018

AGN synergies



- Incidence/ of accreting SMBH (and BH growth rate itself) in:
  - The (z<1) galaxy population overall
  - Merging galaxies and other morphological freaks
  - AGN in Voids, filaments, groups, clusters
  - High-z X-ray population

3 Million AGN: physics and cosmology



- The most luminous AGN, tracers of large scale structure: the "quasar" mode of AGN feedback
- (Obscured and Un-obscured) accretion history
- High-z AGN
- SED vs. L, L/L_{EDD}
- All-sky reference
- **>95% identified to i~24** (~80% at i~22)
- High complete spectroscopy with SDSS-V (r~21.5) and 4MOST (r~23)
- All-sky reference for LSS tomography via clustering redshift

Relationship between AGN and LSS governed by:

- redshift (optical spectroscopy)
- dark matter halo mass (clustering)
- host galaxy mass (SED and spectral fitting)
- star formation in the host (optical spectroscopy)
- black hole mass (optical spectroscopy)
- level of accretion on black hole (X-ray luminosity)

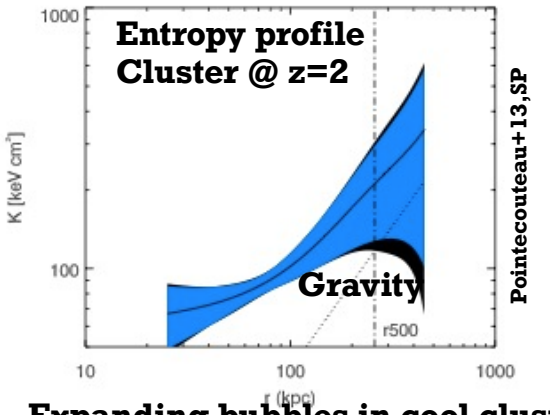
If we want to be able to probe with good statistics this entire multi-dimensional parameter space, with 20 objects per bin and 5 bins per parameter, we need at least

$10 \times 4^6 = 312{,}000$ objects

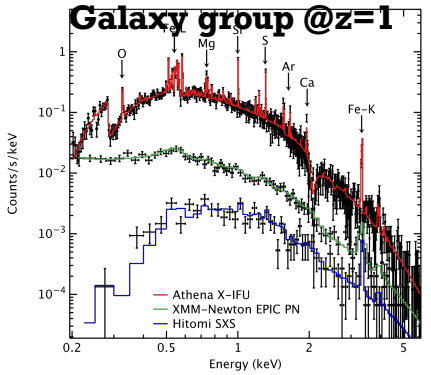
Only the combination of SDSS-V and eROSITA, in the near future, will be up to this task.

The Hot Universe

- **How does ordinary matter assemble into the large-scale structures that we see today?**
  - **Thermal history of hot baryons in clusters up to z~2**
  - **The quest for early galaxy groups @ z>2**
  - **Chemical evolution of cluster gas**
  - **AGN feedback on cluster scales**
  - **Missing baryons in the Warm & Hot Intergalactic Medium**

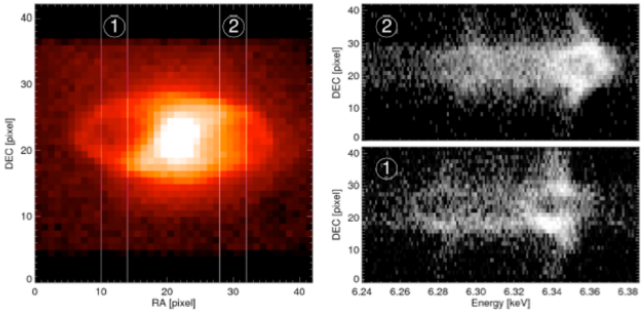


Pointecouteau+13,SP



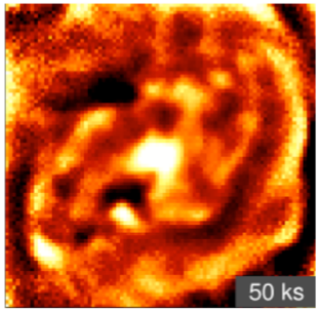
Barret+16, SPIE

Expanding bubbles in cool cluster cores

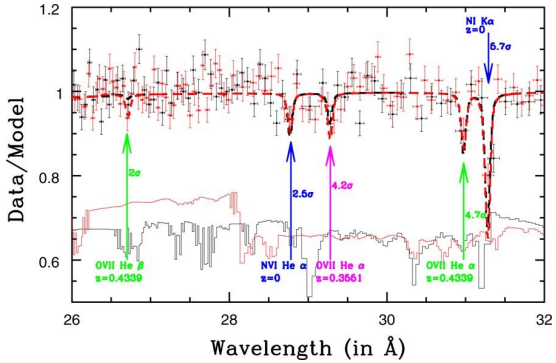


S. Heinz

AGN-produced ripples



Croston+13 , SP



XMM-Newton finds missing baryons observing a QSO at z > 0.4 !

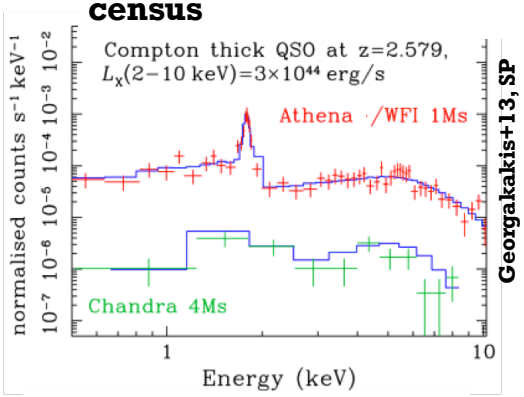
Nicastro+18

The Energetic Universe

- How do black holes grow and influence the Universe?
  - The history of SMBH growth
  - Obscured AGN census z~1-3
  - AGN winds and outflows z~0-3
  - SMBH growth: accretion vs. mergers
  - BH & SMBH physics
  - Luminous extragalactic transients

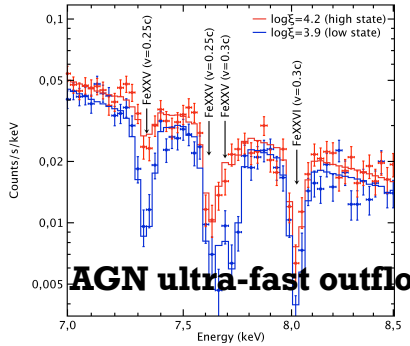
Typical AGN z~6-8

Compton-tick AGN census



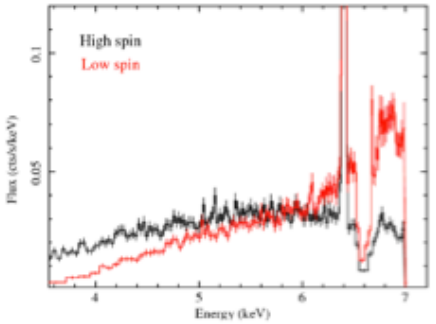
Comastri+13, SP

Georgakakis+13, SP

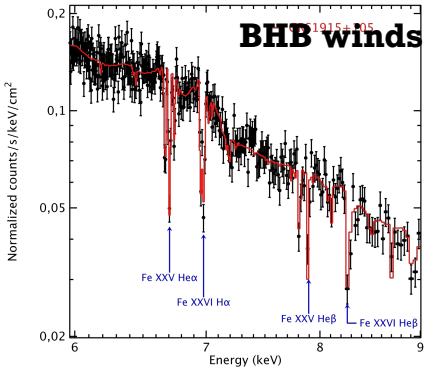


AGN ultra-fast outflows

Cappi+13, SP

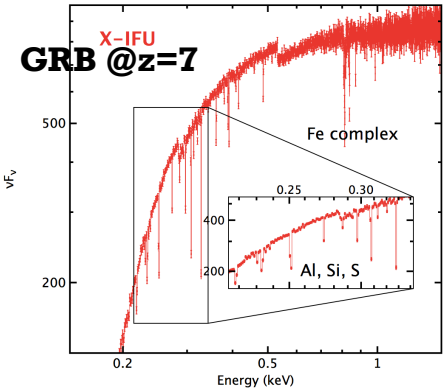


Dovciak+13, SP



BHB winds

J.M. Miller+16



Jonker,+13, SP

Add your own logos here, height=0.9cm

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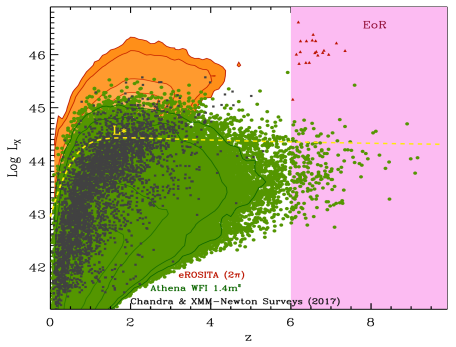
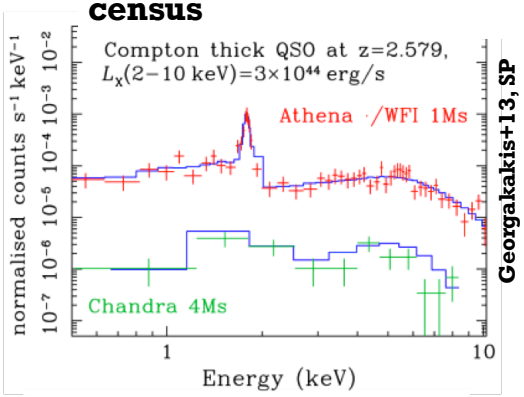
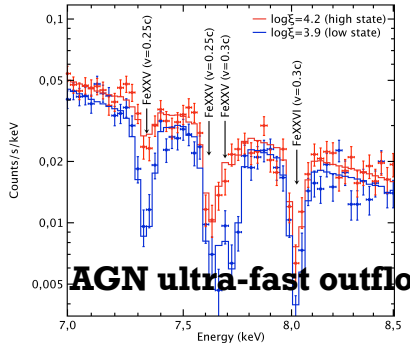


Comastri+13, SP

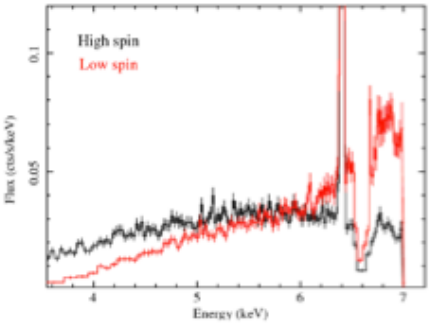
Compton-tick AGN census



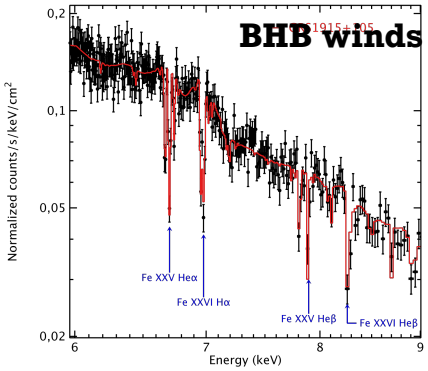
Georgakakis+13, SP



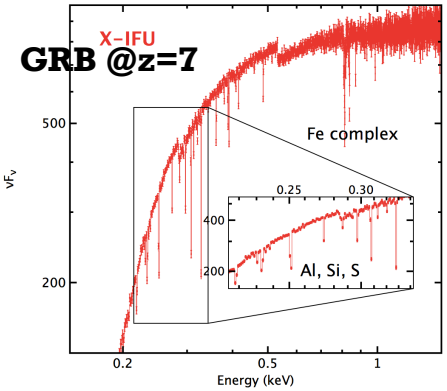
Cappi+13, SP



Dovciak+13, SP



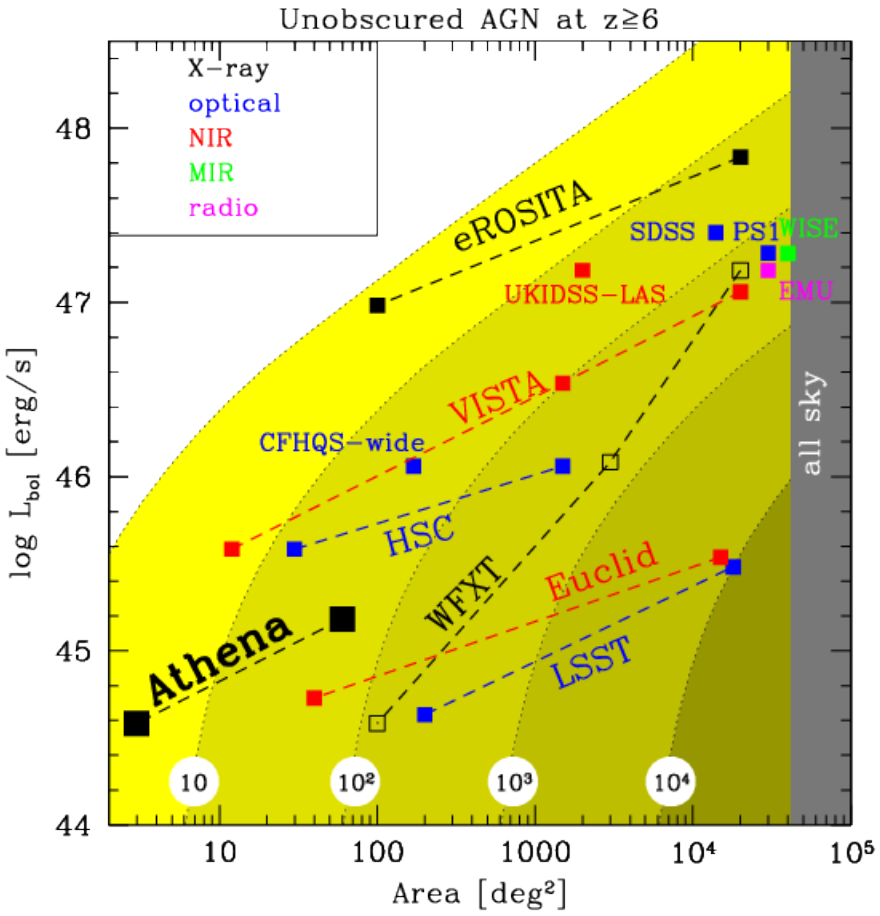
J.M. Miller+16

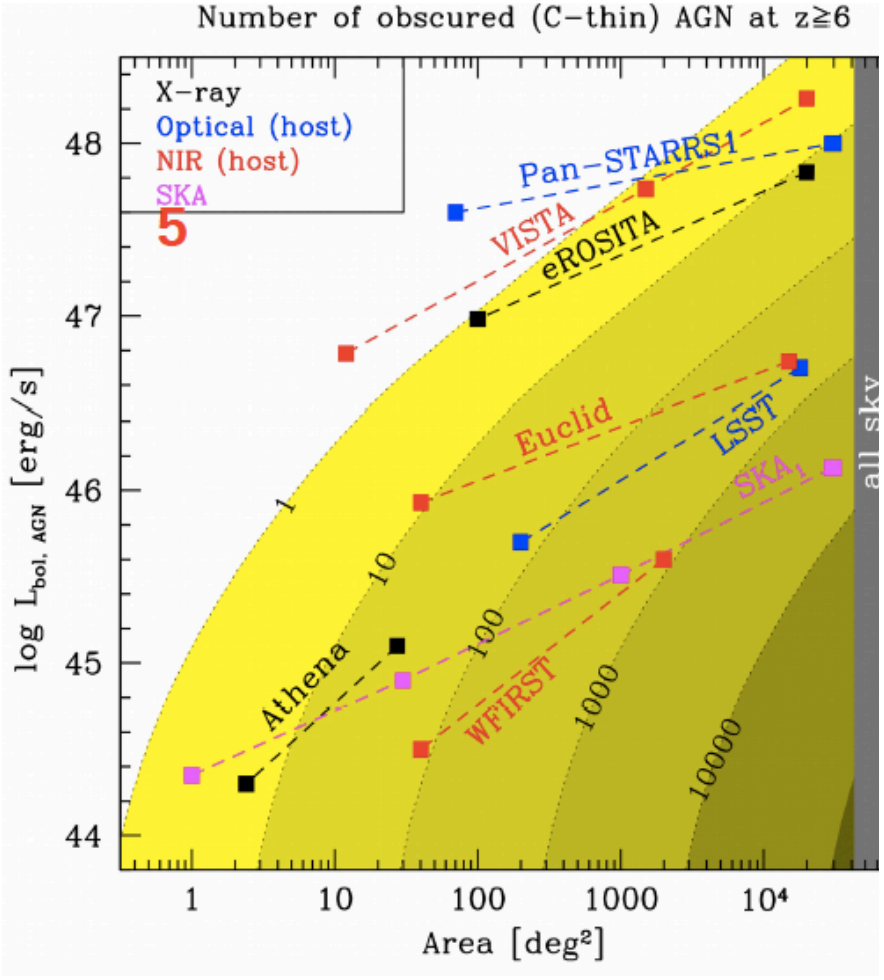


Jonker,+13, SP

Add your own logos here, height=0.9cm

z>6 AGN in large area surveys





courtesy R. Gilli