Prospects for Future X-ray Deep Surveys

1. Active Galactic Nuclei (2. Clusters of Galaxies)

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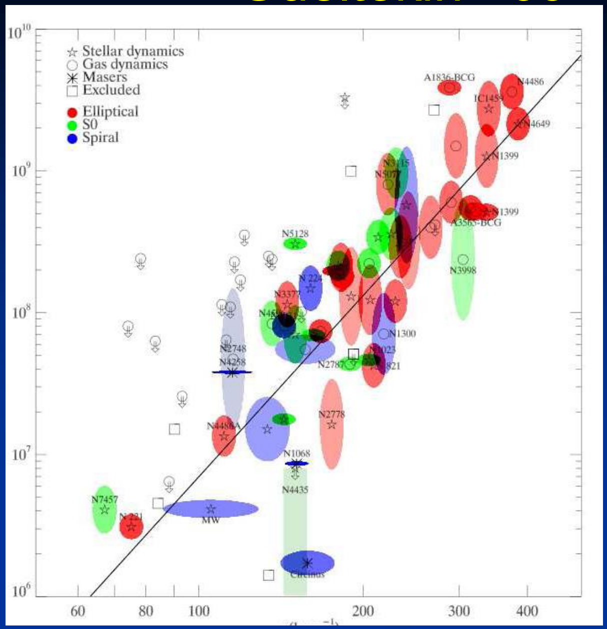
Introduction

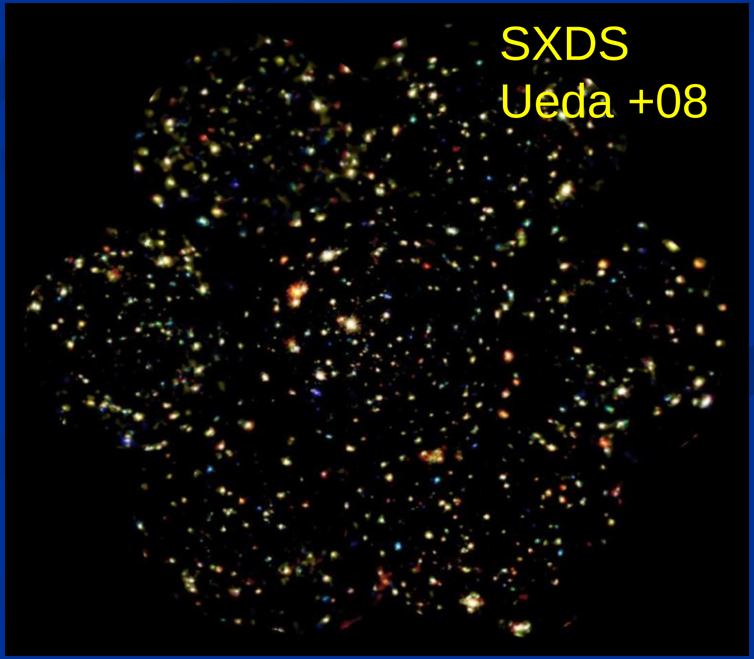
- Importance of SMBHs in cosmic history
  - Galaxy-BH coevolution is a key issue to be addressed in modern astronomy
- AGN = SMBH growth
- To fully understand the growth history of SMBHs, *Complete* detection of AGNs with all types (type 1 and type 2) is required over a wide *L-z* range
- The integration of X-ray emission from all AGNs is observed as the “X-ray background”
  - >80% of the XRB below 8 keV has been resolved into AGNs with ~10^4 deg^{-2} in Chandra deep surveys

Gueltekin +09

Mass of SMBHs



Velocity Dispersion



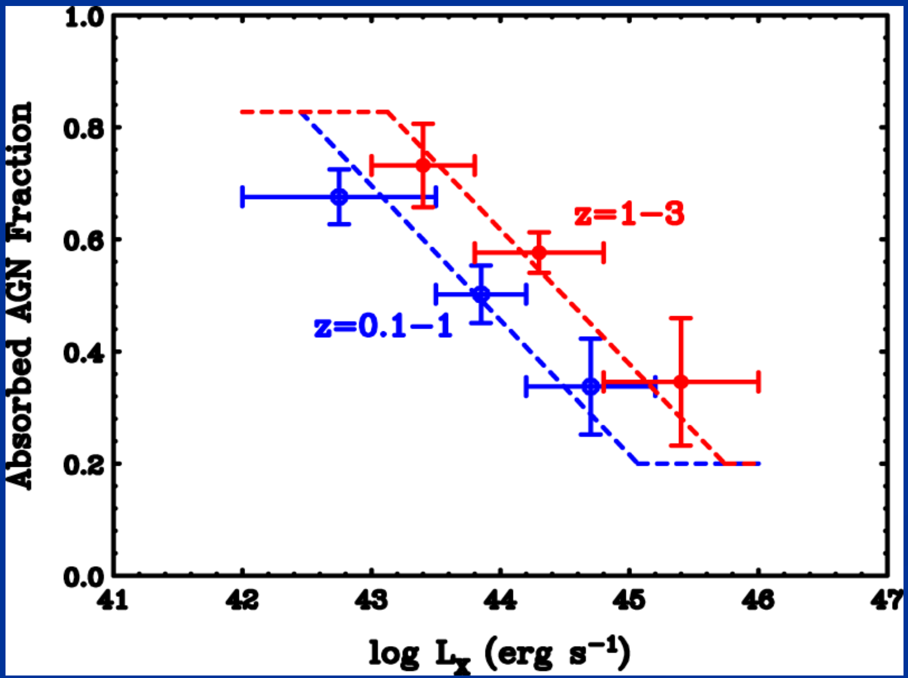
Why do we need X-rays?

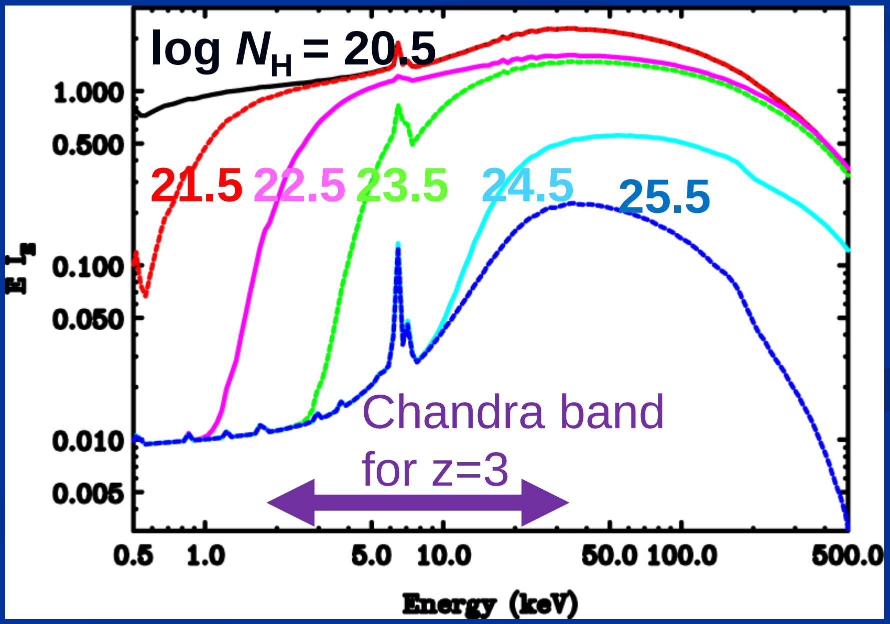
X-ray surveys provide the most complete and clean AGN sample

Majority of AGNs are obscured by gas and dust

- The fraction of absorbed AGN increases at low luminosity and high z
- Hard X-rays (>2 keV) have strong penetrating power against absorption and little contamination from stars
- In optical/infrared bands, contamination from host galaxies become significant, particularly for low luminosity AGNs
- Chandra deep surveys are the most sensitive among those at any wavelengths even for unabsorbed AGNs

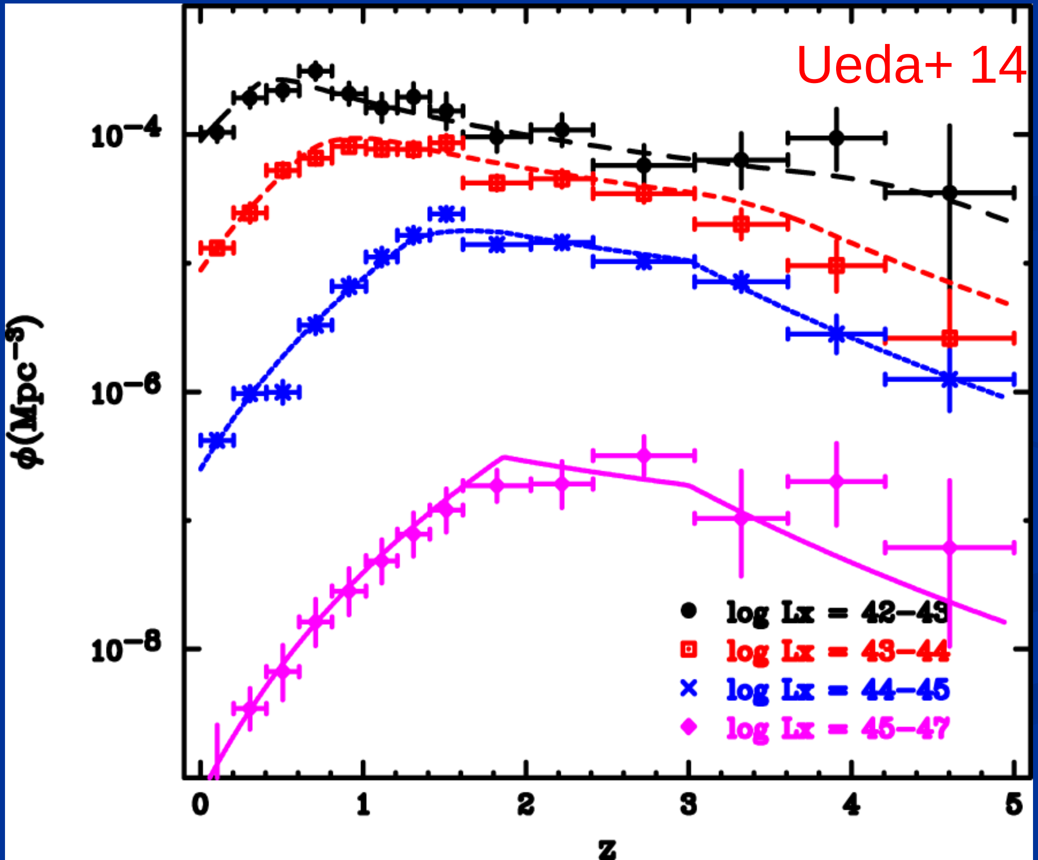
Ueda+ 14





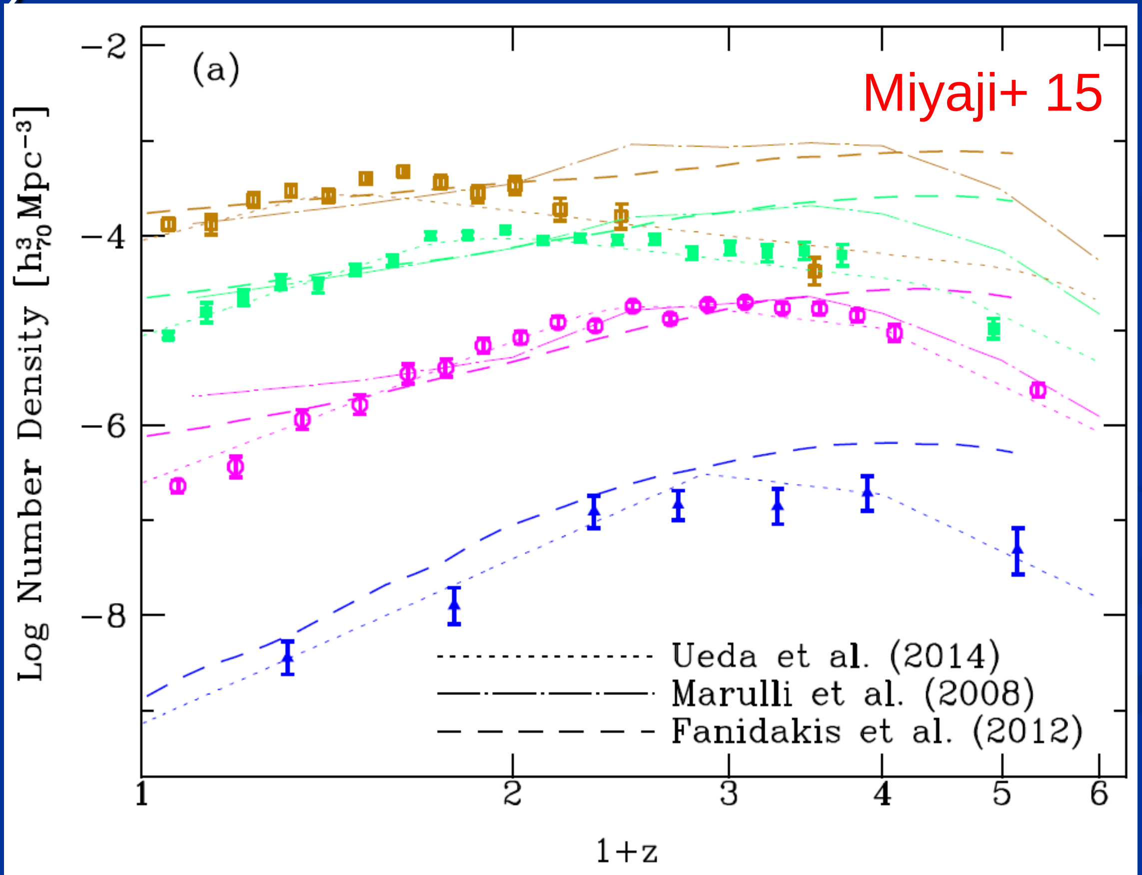
Number density evolution

- AGNs with lower Lx have the number density peak at lower redshift (“Downsizing” or “anti-hierarchical evolution”)
- 2 different modes in AGN fueling? (major merger for trigger luminous AGNs + another process for less luminous ones?)



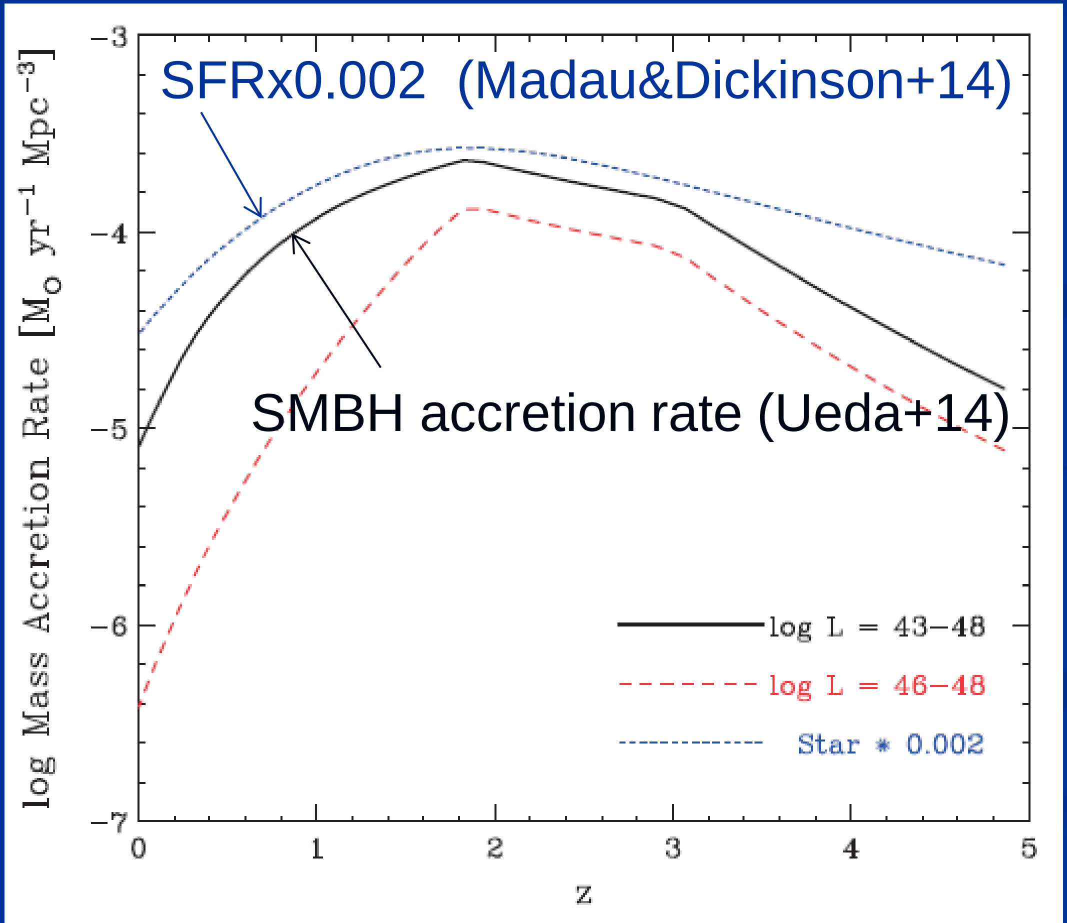
Number density evolution

- AGNs with lower Lx have the number density peak at lower redshift (“Downsizing” or “anti-hierarchical evolution”)
- 2 different modes in AGN fueling? (major merger for trigger luminous AGNs + another process for less luminous ones?)
- Theoretical models overpredict the space density at high z and low L_x than observed (or many heavily obscured AGN missing?)



Accretion vs Star Formation History

- The overall history of mass accretion rate onto SMBHs and of star forming rate is similar (with a factor of ~500)
- ~74% of total mass was produced by “obscured” accretion
- Discrepancy at z>3 ? (due to heavily obscured AGNs??)



Ueda (2015) PJAB 91, 5

Current Status of X-ray AGN Surveys

1. Chandra deep survey is limited in survey area (because Chandra's angular resolution rapidly degrades toward outer field-of-view)
   - Little is known about evolution at z>5 of whole AGN population including obscured ones
   - We need advanced X-ray observatories that enable "deep" and "wide" surveys
2. The identification of X-ray sources is not complete (~95% in CDFS). Also, a significant fraction of X-ray AGNs (30-40%) rely on photometric redshifts.
   - These cause uncertainties in AGN evolution at z>3: whether/when "upsizing" occurred?
3. Sensitivities above >8 keV are poor to unveil the evolution of Compton-thick AGN populations

Future X-ray missions

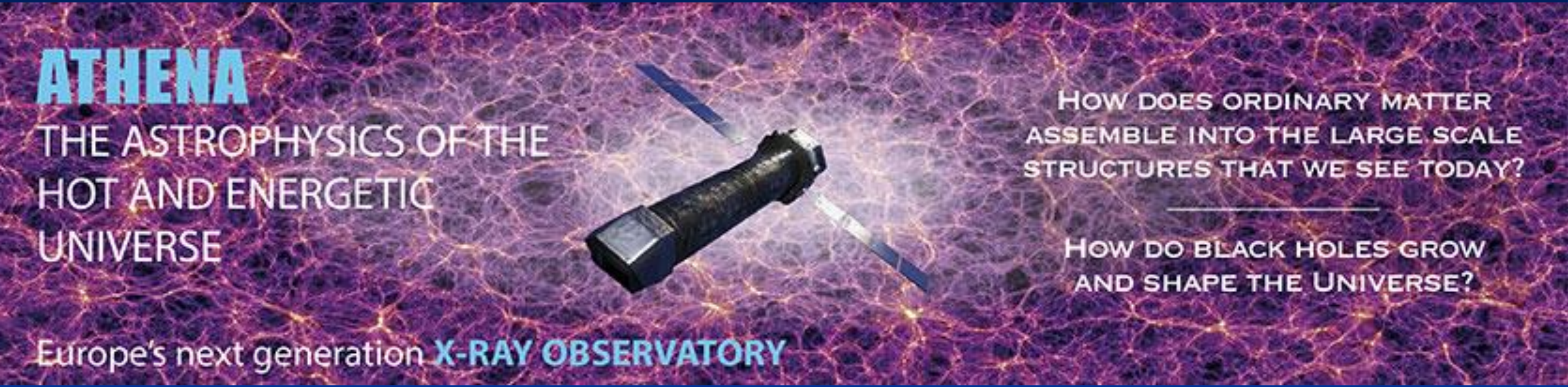
		Area	F.o.V.	Ang. Res.
		S (m^2)	Ω (deg^2)	HPD (on-offset)
NASA	Chandra	0.04	0.07	0.5”-16”
ESA	Athena	2	0.44	5”-10”
NASA	STAR-X*	0.18	1	5”-5”
NASA	XRS*	2	0.13	0.5”-2.5”

(JAXA FORCE* covering *E*>10 keV)

*still mission of concept

Athena

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

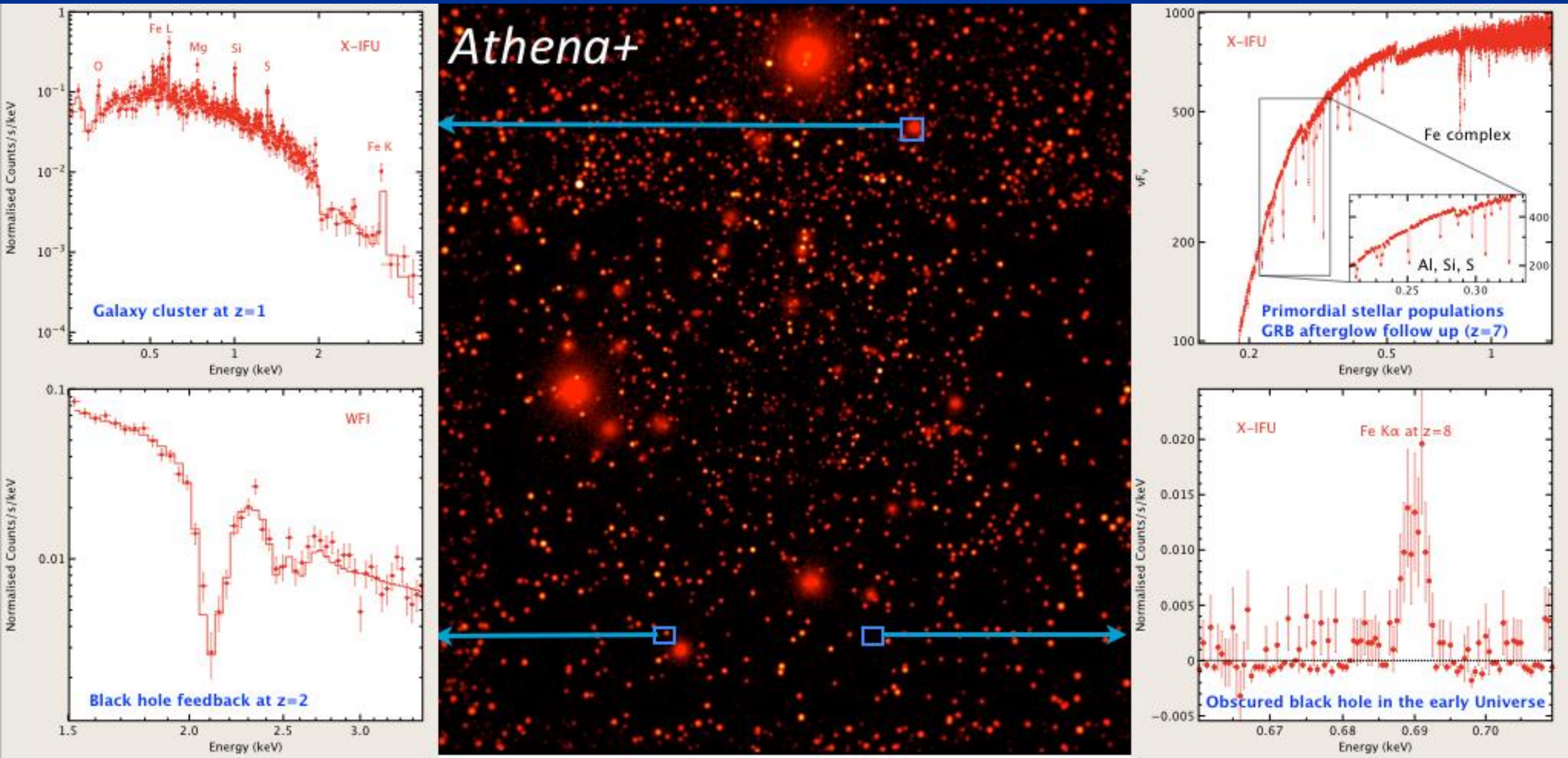


- Selected as ESA L2 mission (2028-)
- Japan’s participation decided

「これでエックスはあと30年は戦える」

Athena

- Large colleting area (2 m^2) and wide FoV (40') imaging
  ~300 times larger grasp ($S\Omega$) than Chandra
- Measurement of AGN XLF at z=4-10 down to L_x~10^{43}
- High resolution spectroscopy with microcalorimeter

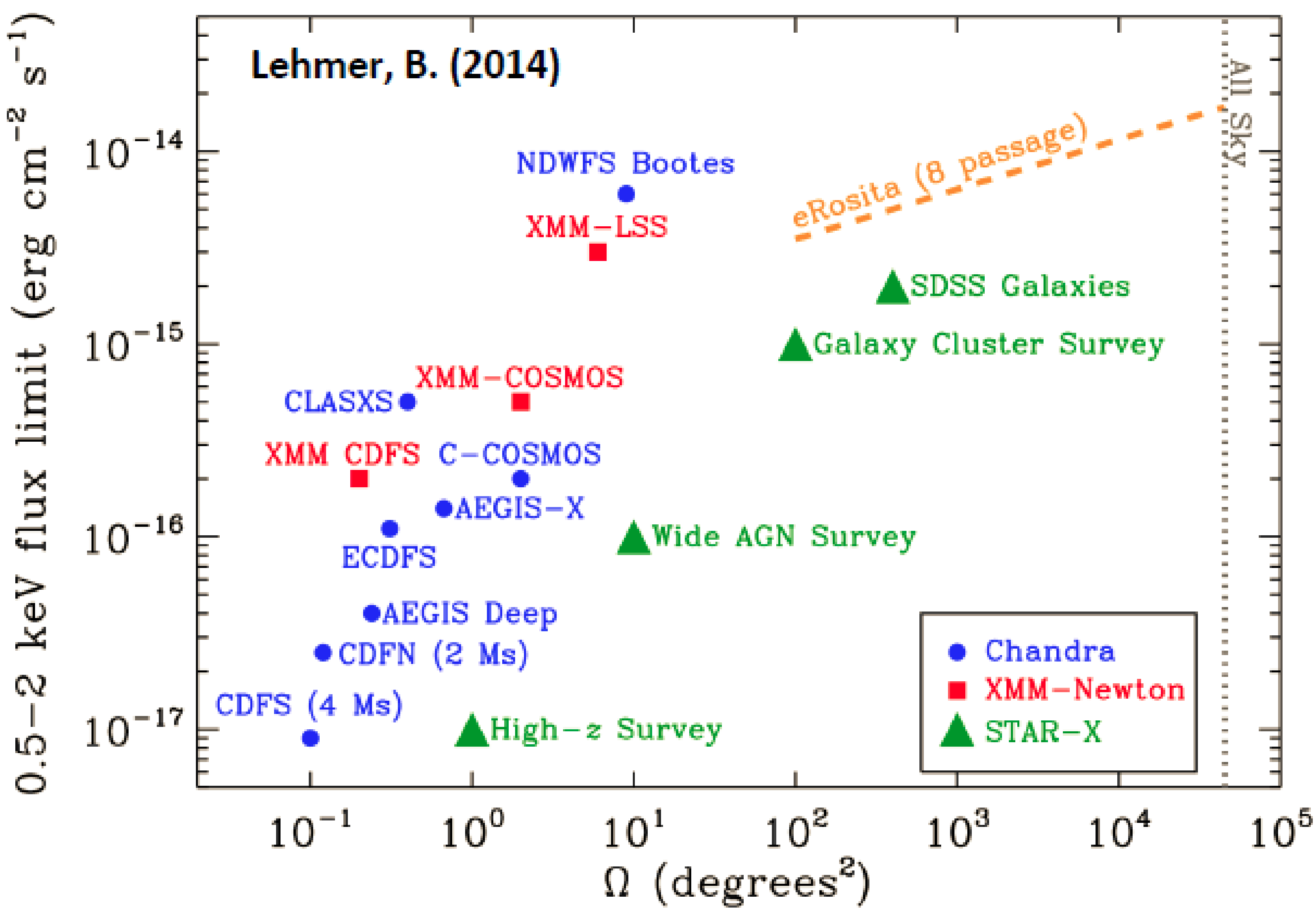


Survey and Time-domain Astronomical Research eXplorer (STAR-X)

- US mission led by NASA/Goddard (PI: Will Zhang)
  - Scientific participation by IPMU and Kyoto U
- To be proposed to MIDEX programs in 2016 (start observation from 2022/23)

- Wide Field of View (1 deg^2)
- Large collecting area
- Good point spread function (uniform 5” in FOV)
- >30 times faster survey than Chandra at E<2 keV

STAR-X Survey Design (TBD)

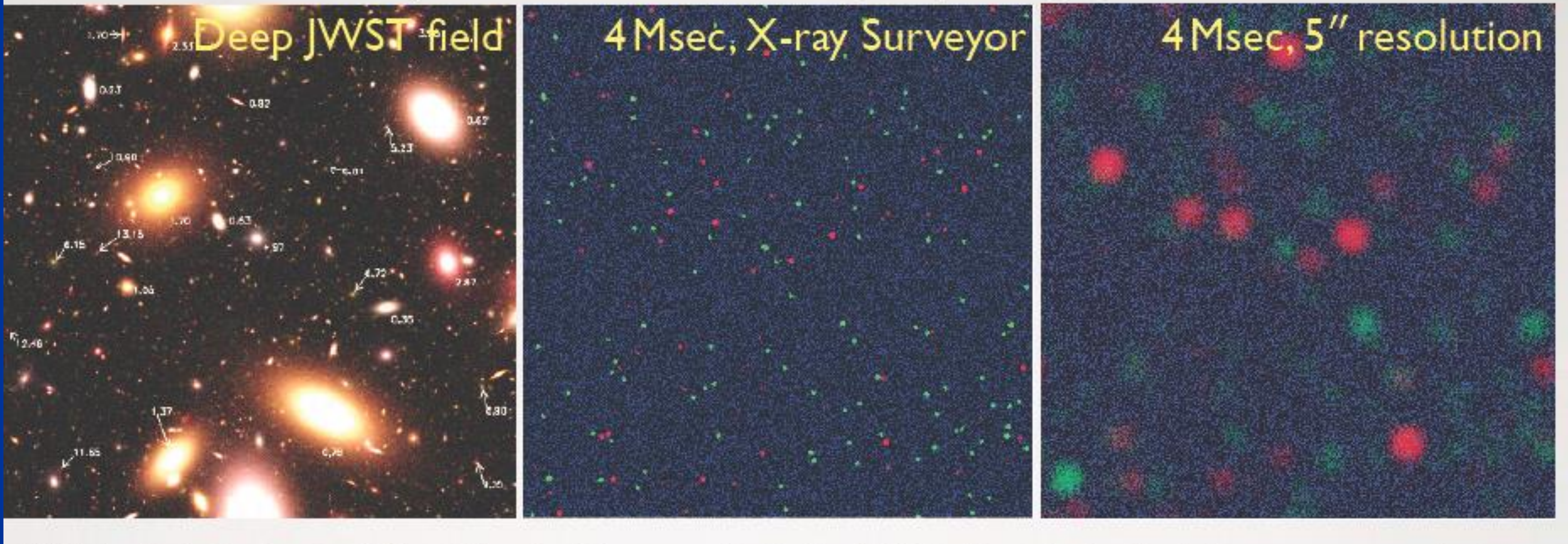


X-Ray Surveyor (XRS)

http://wwwastro.msfc.nasa.gov/xrs/

- One of 4 candidates of NASA's next flagship mission submitted to 2020's decadal survey (>2030 ?)
- Sensitivity $F_{0.5\text{-}2}$~10^{-19} cgs (>10 times better than Chandra 4 Ms survey)
- First BHs of 10^4 $M_\odot$ at z=10 detectable

Simulated 2x2 arcmin deep fields observed with JWST, X-ray Surveyor, and ATHENA

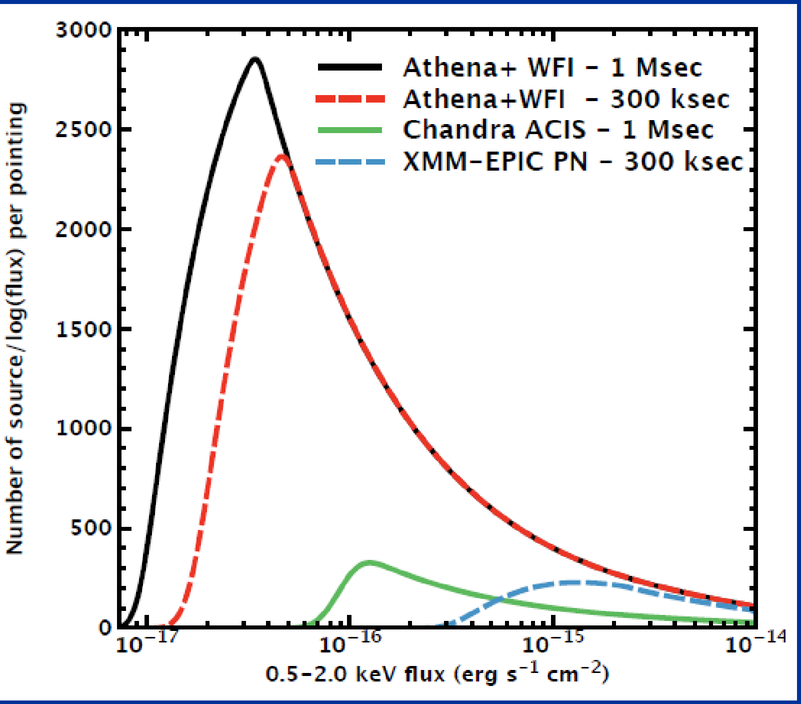


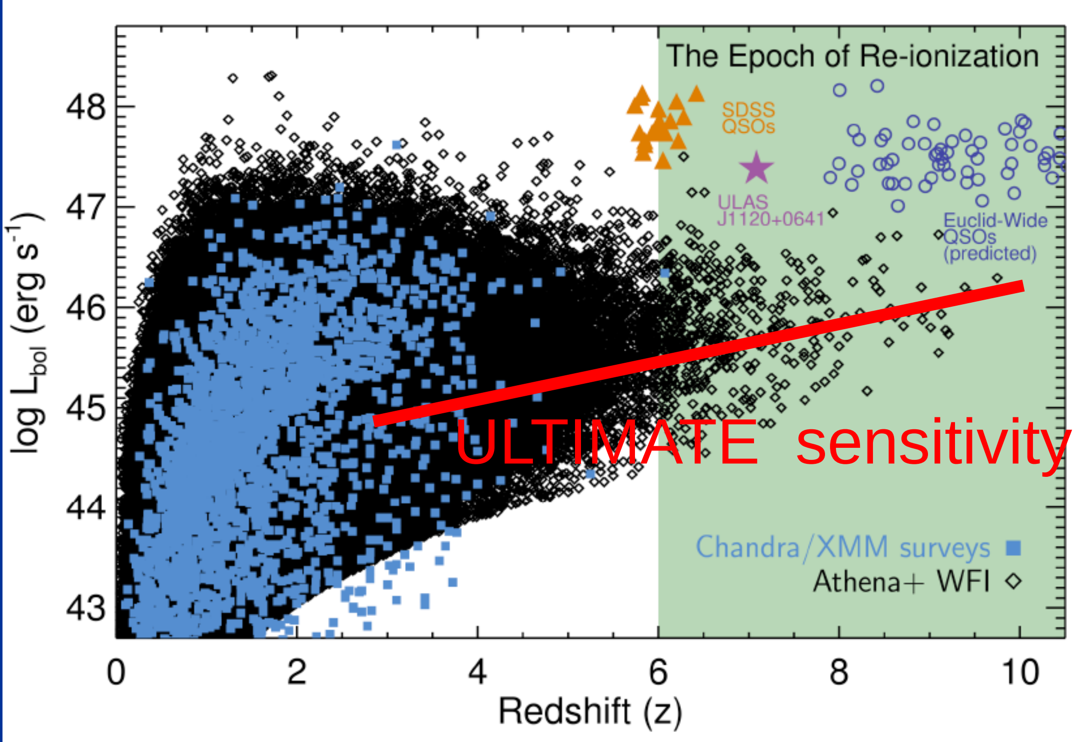
Synergy with ULTIMATE

- Spectroscopic follow-up with MOS (0.8-2.5 μm)
  - To obtain spec-z as much as possible including z>5 AGNs
  - BH mass measurements (Matsuoka-san's talk)
- N_{obj} ~ 1500-10000 deg^{-2} of MOS well matches AGN number density in X-ray deep fields
- Examples of strong emission lines in type-2 AGNs
  - Hα (z=0.22-2.8)
  - [O III] λ5007 (z=0.6-4)
  - C III] λ1909 (z=3.2-12)
  - C IV λ1549 (z=4.2-10)
  - Lyα (z=5.6-19)
- Assuming the line luminosity is ~1/100 L_X, the GLAO-MOS sensitivity (~3×10^{-18}) corresponds to
  - $L_X > 2 \times 10^{43}$ at z=3, $L_X > 8 \times 10^{43}$ at z=5, $L_X > 2 \times 10^{44}$ at z=7

Athena

- A large fraction of Athena AGN sample can be spectroscopically identified with ULTIMATE/MOS *very quickly*





Answers to the 4 Questions

Q1. Key Science

Spectroscopic Identification of z>5 obscured AGNs detectable only with X-rays

Q2. Which instrument?

MOS

Q3. GLAO+MOIRCS science at early 2020s

Yes. Observations of current X-ray samples (e.g., Chandra survey of SXDF)

Q4. Survey Design

Plan D (complete mass-limited survey including AGNs) but deep K-band imaging should be also useful to improve photo-z accuracy

Please select fields with deep X-ray data (e.g., SXDF, CDFS)