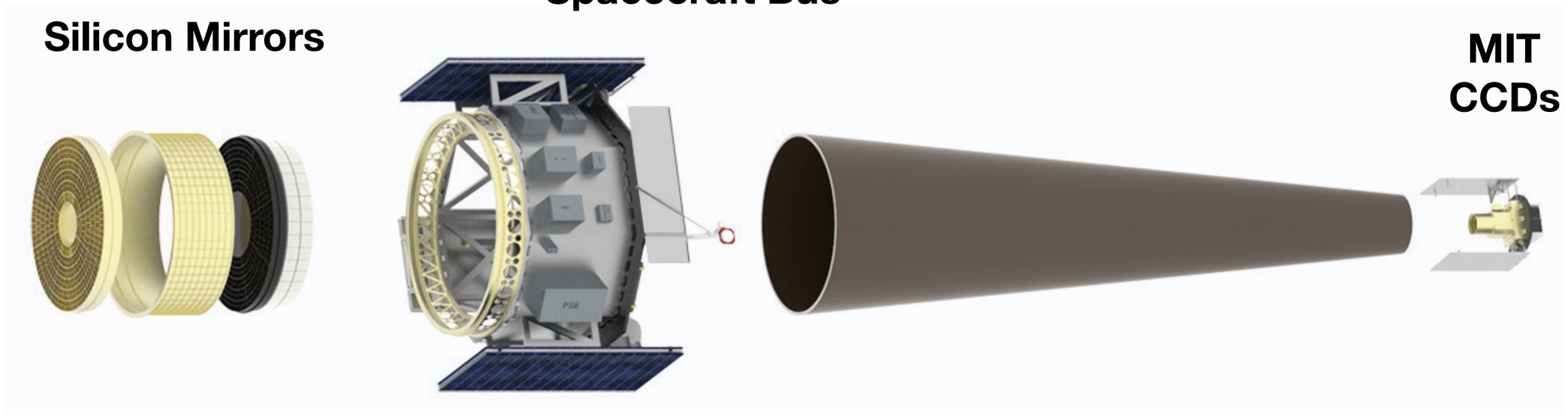
Characterizing the First Galaxy Clusters at the Epoch of their Formation with *STAR-X*

Daniel R. Wik (NASA GSFC/JHU/University of Utah)
on behalf of the *STAR-X* MidEx proposal team

Science Team

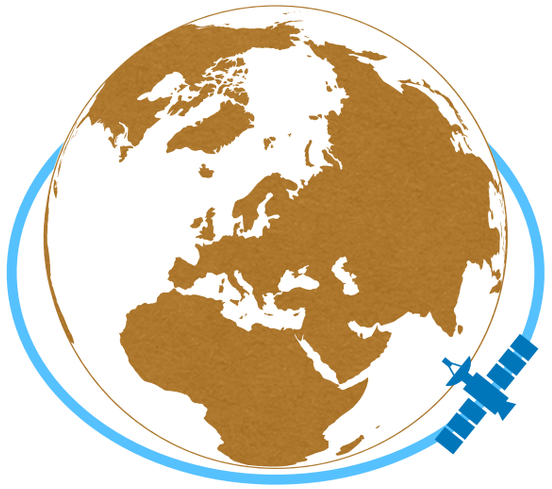
- PI: Will Zhang
- Deputy PI: Ann Hornschemeier
- Project Scientist: Andy Ptak
- Science Leads: Goal 1: Brad Cenko; Goal 2: Ann Hornschemeier; Goal 3: Dan Wik
- Cluster-interested Co-Is: Maxim Markevitch, Mike McDonald, Dan Wik, Piero Rosati, Mark Bautz, Eric Miller, Stefano Borgani, Paolo Tozzi, Alexey Vikhlinin, ++++

The Telescope

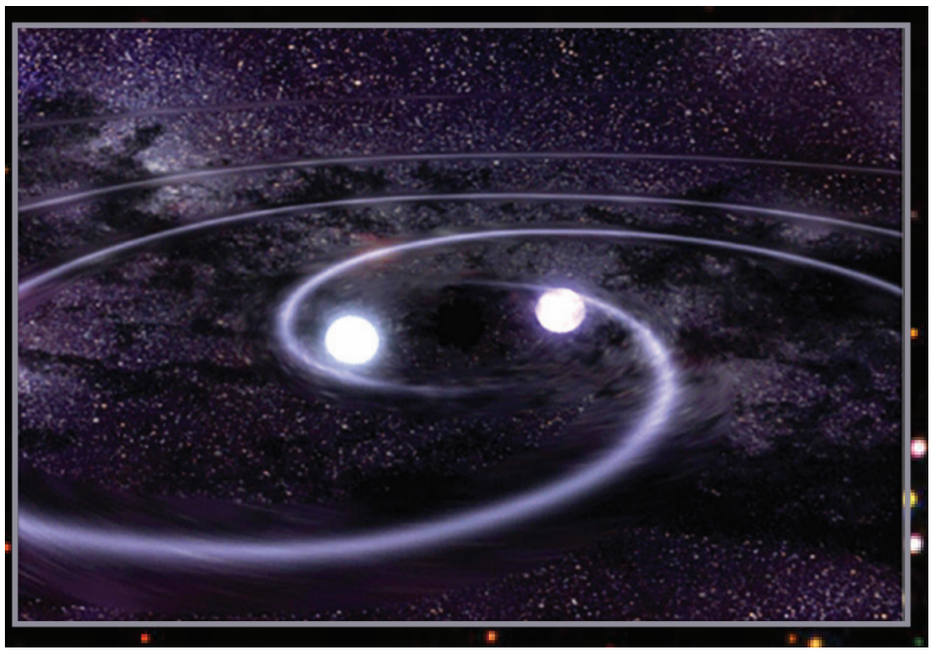


- Large FOV: 1 deg^2
- Large effective area: >1,800 cm^2
- Excellent PSF over entire FOV: 5 arcsec
- Low background (LEO)
- Soft X-ray response: <0.5 keV
- Fast slew, f = 5.5m

Equatorial LEO

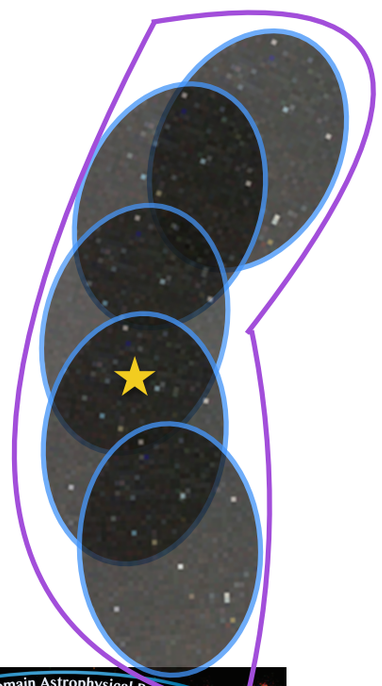


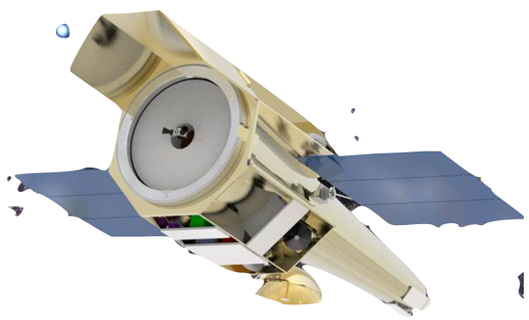
Science Goal 1



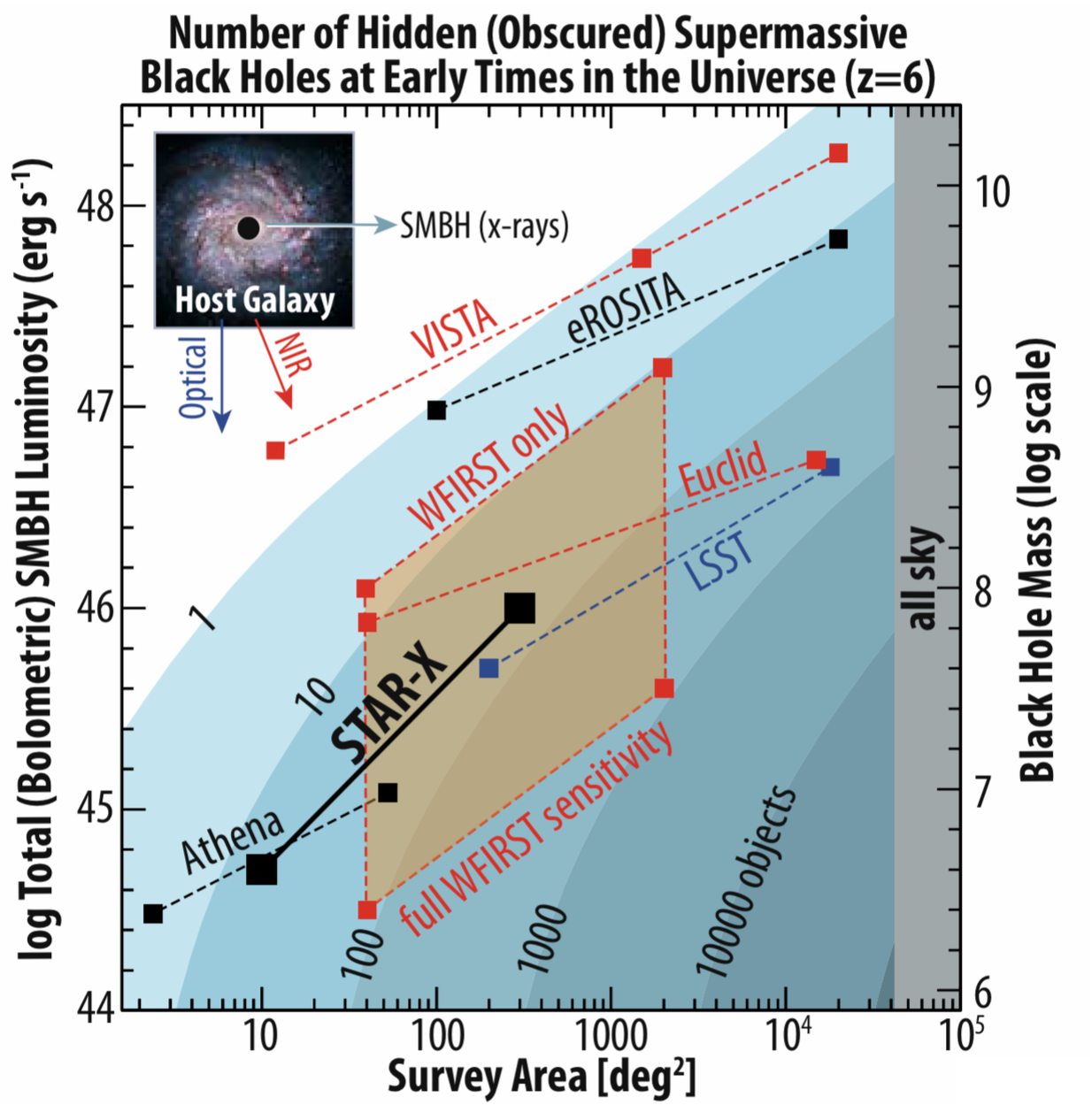
Discover what powers the most violent explosions in the Universe

- Characterize the X-ray counterparts to gravitational wave sources due to compact binary mergers
- Identify the progenitors of Hydrogen-poor (Type I) supernovae
- Constrain the central engine powering the ultra-relativistic ejecta in long-duration Gamma Ray Bursts





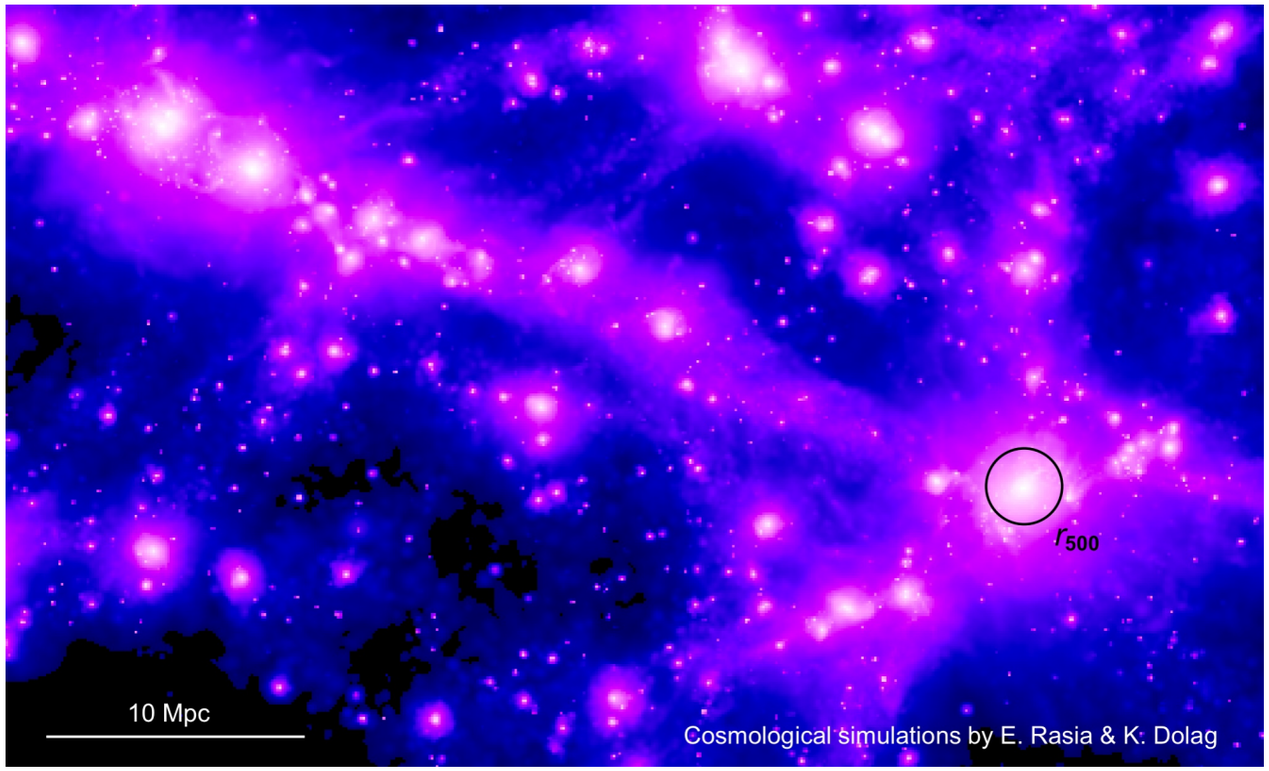
Science Goal 2



Understand how black holes grow across cosmic time and mass scale

- Find the elusive population of obscured and faint supermassive black holes at z>6.
- Measure the fraction of dwarf galaxies with intermediate-mass black holes via the discovery of tidal disruption flares.
- Search for the expected population of short-period Neutron Star and Black Hole binaries via their predicted subluminous and short-duration X-ray outbursts

Science Goal 3

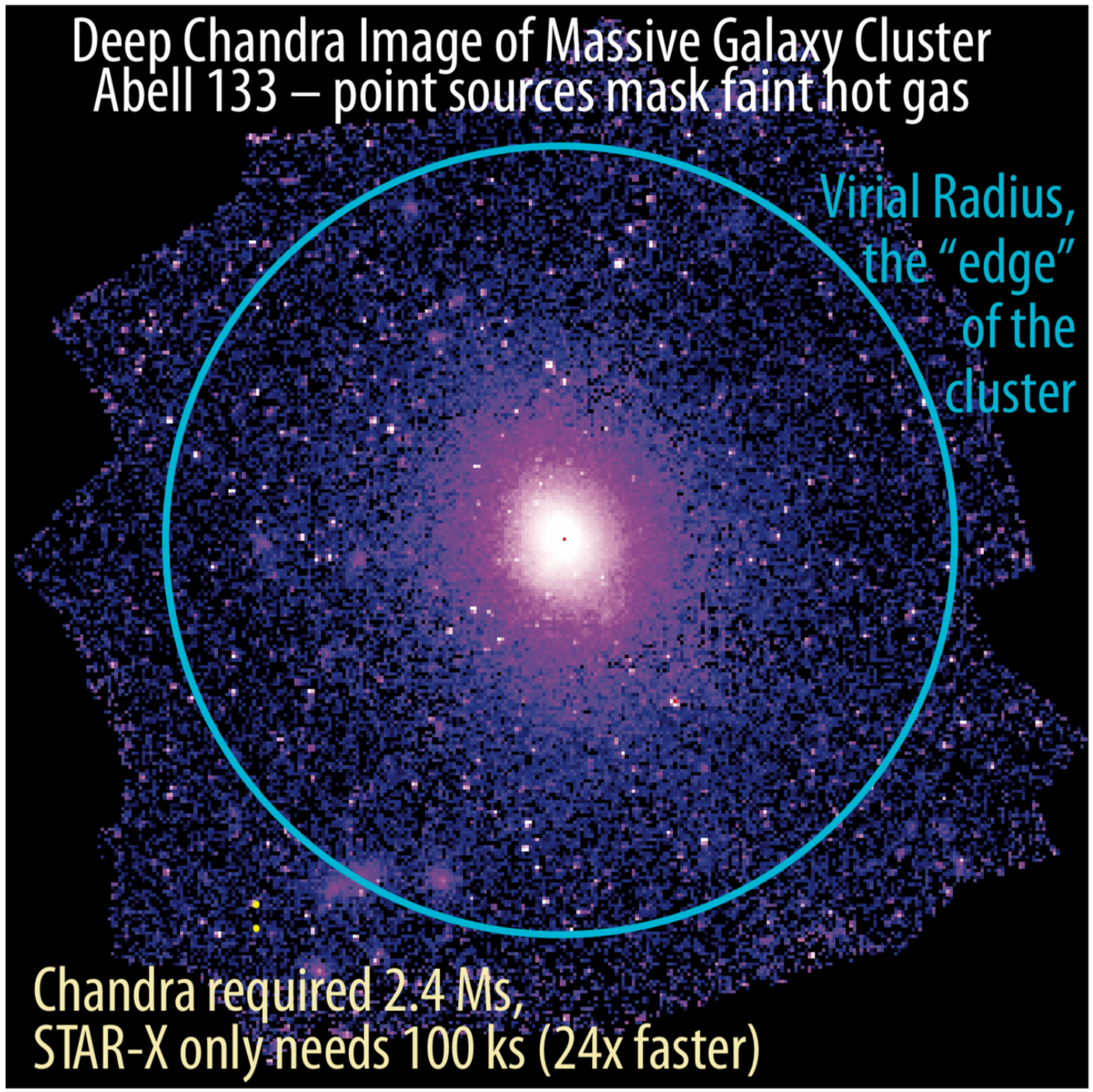


Measure how structure formation heats the majority of baryons in the Universe

- Determine how filaments of the Cosmic Web feed the intracluster medium (ICM) at the outskirts of galaxy clusters.

- Witness the initial collapse of galaxy clusters at z=2-3; calibrate the X-ray emission from clusters for precision cosmology

Objective 1: Exploit STAR-X's low background to study cluster outskirts



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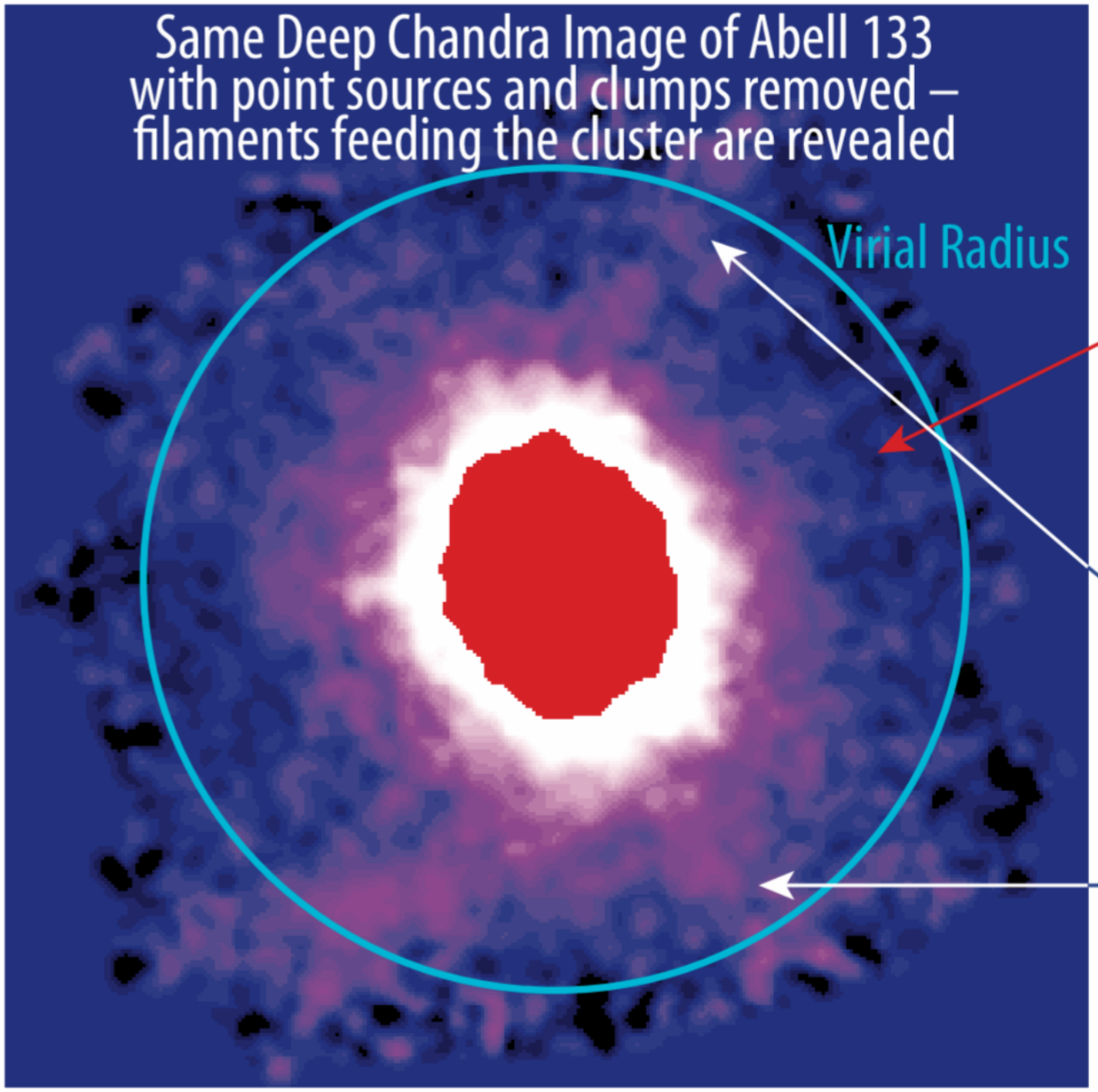
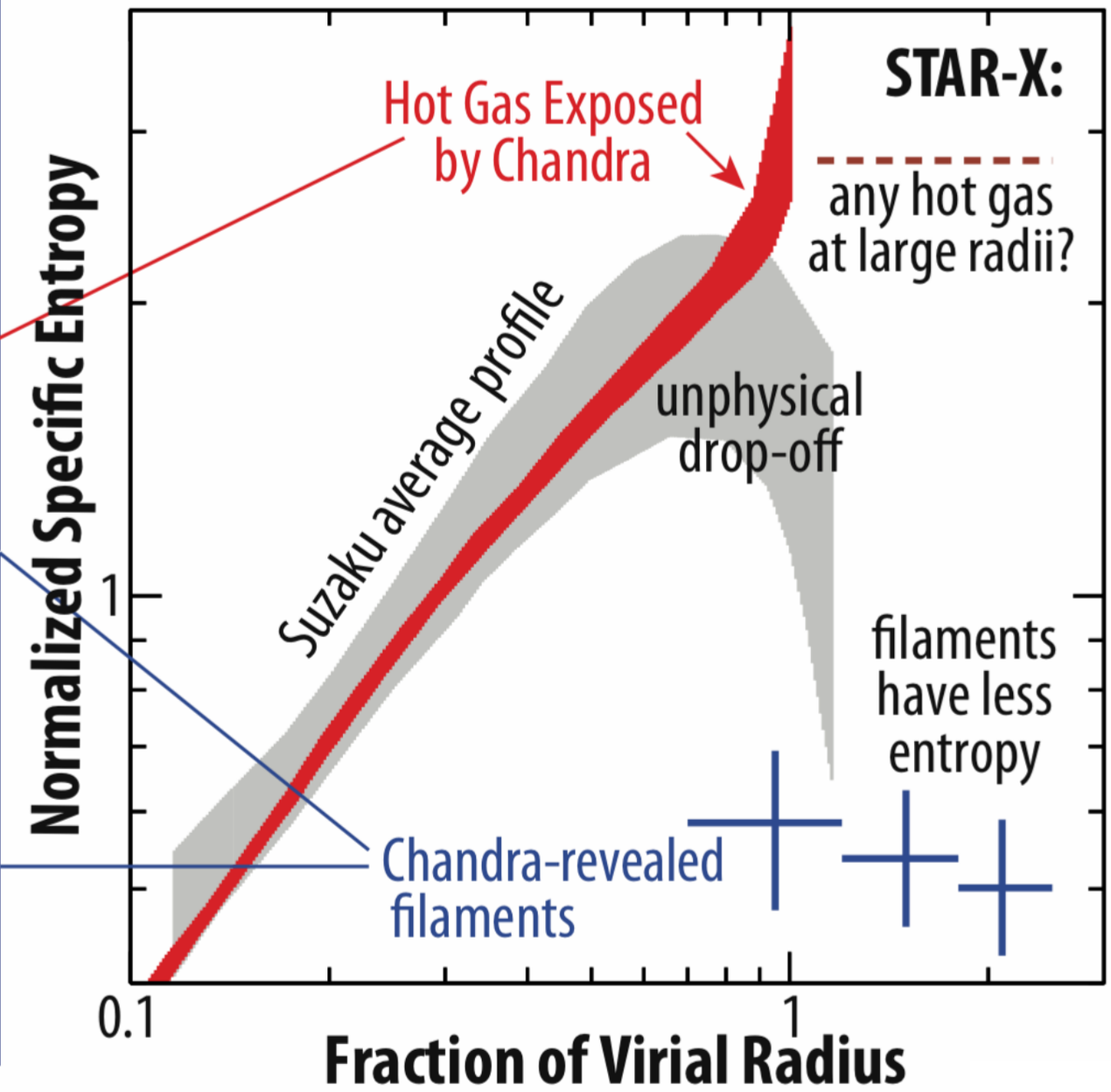


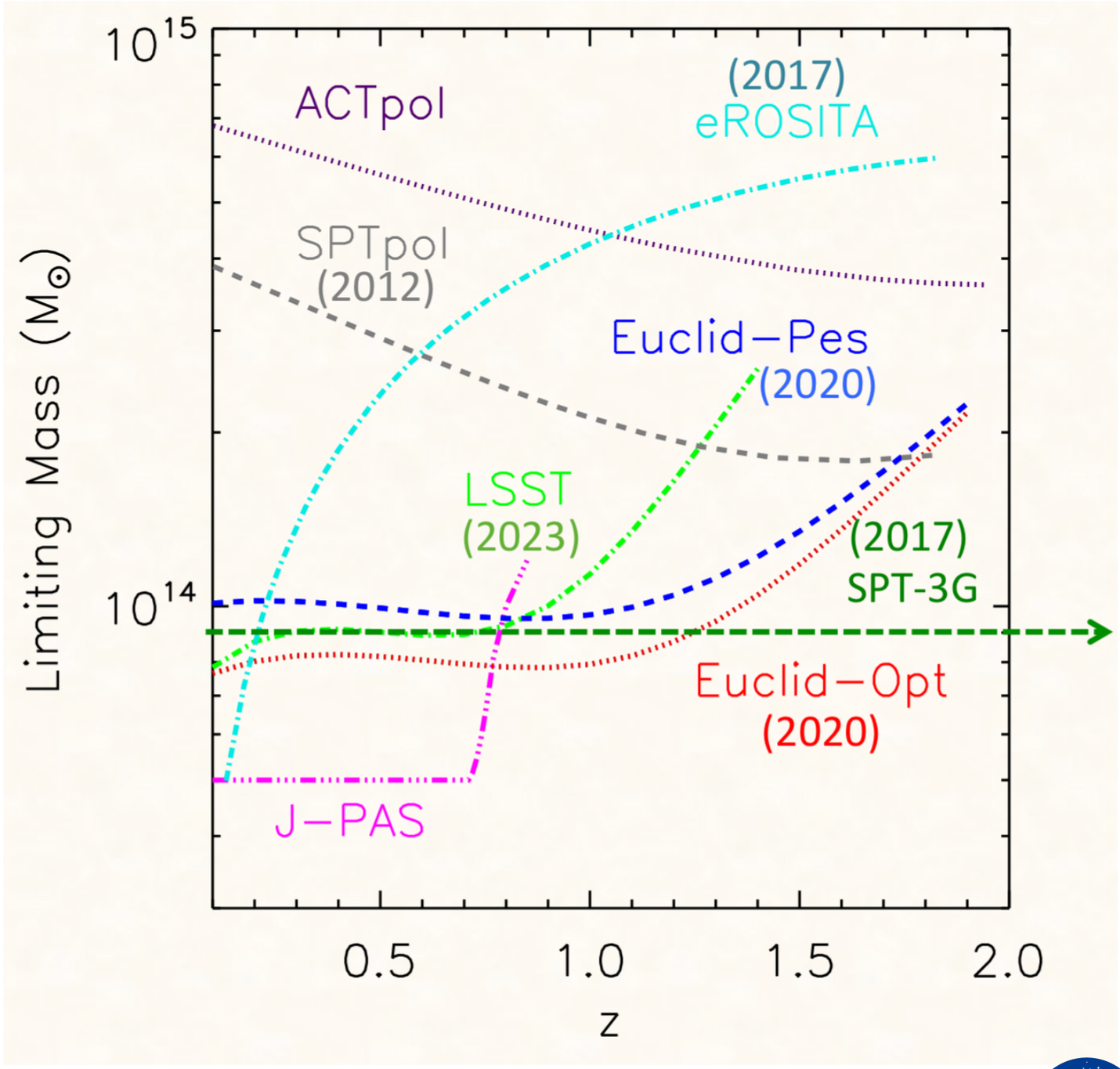


Objective 2: Efficiently follow-up high redshift SZ-discovered clusters

~2020s will be the era of N > 10,000 cluster samples

- **Euclid (N~10^5)**
- **LSST (N~10^4)**
- **SPT-3G (N~10^4)**
- **eROSITA (N~10^5)**

Currently, there is no X-ray mission planned which can follow up the thousands of clusters discovered at z>1



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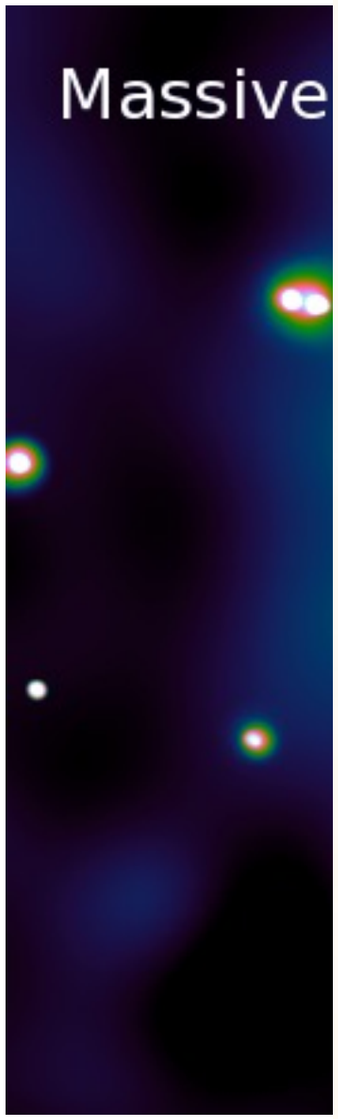

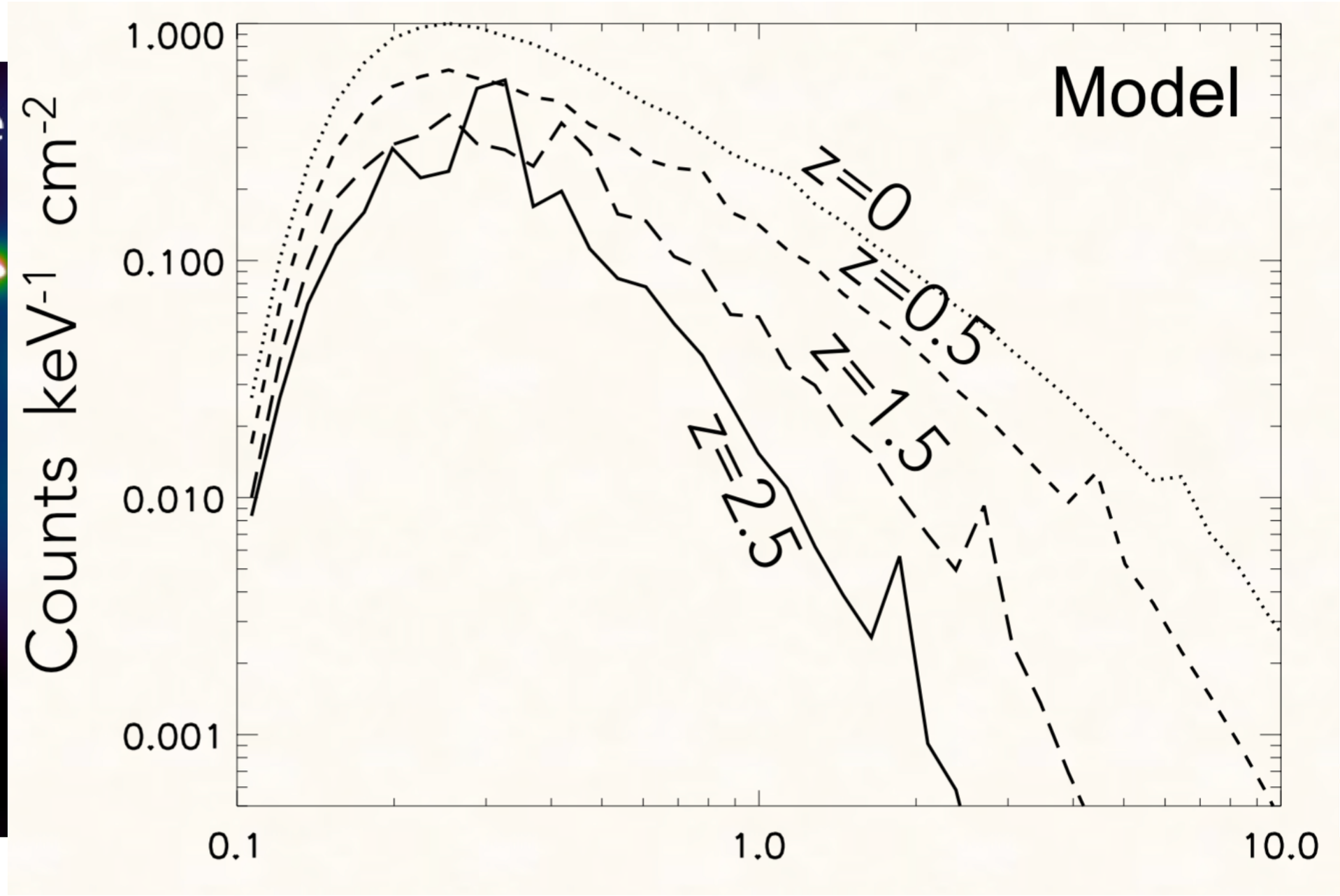

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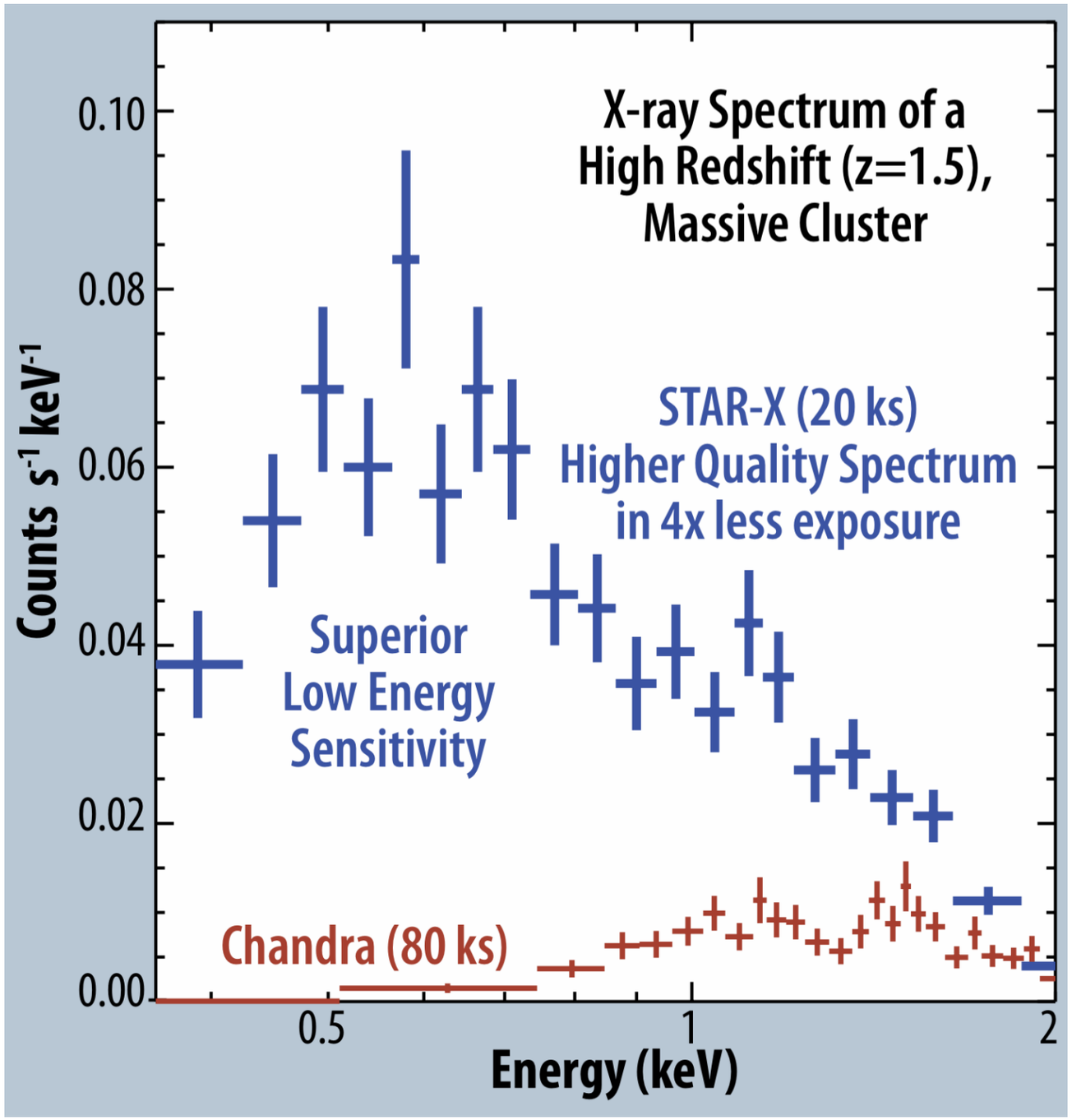

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Options

Baseline

Survey Strategy	Area [deg^2]	No. of clusters*	No. @ $z > 1.5$	No. @ $z > 2$
Max clusters per square degree	500	3478	242	33
$z > 1.5$ complete	576	2351	576	79
Survey†	500	1657	115	16
Current (CXO)	7.7	100	~2	~0

The Voyages of STAR-X; Its 2 Year Mission…

- GW Counterparts Follow-up 3 Ms
- Medium Survey (300 deg^2) 16.5 Ms
  - High-z Clusters (100 deg^2) 50 ks each
- GRB Afterglow Follow-up 700 ks
- Deep Survey (10 deg^2) 6 Ms
- TDE Follow-up 400 ks
- MW Bulge Survey (50 deg^2) 1 Ms
- Mapping Nearby Clusters 2 Ms
  - Coma Cluster Mosaic 1 Ms
  - 10 Others 100 ks each
- High-z Clusters (150) 3 Ms (20 ks each)
- Community ToOs 4 Ms
- Local Group (4 galaxies) 1 Ms
- Nearby Galaxies (10) 700 ks
- Supernova Remnants 400 ks

~40 Ms (+calibration) requiring only 66% efficiency

Phase A decision imminent

If selected, would launch ~2022-3

Technology largely proven

Flexible, Observatory-class telescope on a MidEx budget

GO program after prime mission (if renewed for another season)