A detailed 3D rendering of the STAR-X satellite in space. The satellite features a large, circular, segmented primary mirror at the front, with various instruments and structural components visible behind it. The background is a dark field of stars, with some stars appearing as bright, multi-colored points of light. An orange horizontal bar is located in the top left corner of the slide.

# STAR-X: Survey and Time-domain Astrophysical Research Explorer

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# Survey and Time-domain Astrophysical Research eXplorer



EXPLORING THE FAST, FURIOUS, AND FORMING UNIVERSE

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Ann Hornschemeier, Deputy Principal Investigator

In response to NASA's Astrophysics Explorers Program 2021 Medium Explorer (MIDEX)  
Announcement of Opportunity – NNH21ZDA0180 - December 9, 2021

## *Science*

**GSFC:** Brad Cenko, Edmund Hodges-Kluck, Ann Hornschemeier, Craig Markwardt, Kim Weaver, William Zhang, **JHU:** Mihoko Yukita, **UMBC:** Antaras Basu-Zych, Kai-Wing Chan, **CFA:** Francesca Civano, **Howard:** Joel Coley, **INAF-Bologna:** Roberto Gilli, **McGill:** Daryl Haggard, **MIT:** Mark Bautz, Erin Kara, Michael McDonald, Eric Miller, **Northwestern Univ.:** Maya Fishbach, Wen-fai Fong, Vickey Kalogera, **Penn State Univ.:** Niel Brandt, **UCB:** Raffaella Margutti, **UCSC:** Ryan Foley, **Univ. of Colorado:** Brian Fleming, Kevin France, Sebastian Pineda, **Univ. of Utah:** Daniel Wik, **Univ. of Crete:** Andreas Zezas

## *X-ray Telescope*

**GSFC:** Michael Biskach, Kai-Wing Chan, Ryan McClelland, Raul Riveros, Peter Solly, Timo Saha, William Zhang  
**MIT:** Mark Bautz, Mark Egan, Robert Goetze, Eric Miller

## *UV Telescope*

**Univ. of Colorado:** Brian Fleming, Carl Gelderloos, Kevin France, Thomas Patton  
Jerry Jason (mission operations)

## *Spacecraft and Observatory*

**Ball Aerospace:** Daniel Miller, Michael Veto, Brian Woods  
**GSFC:** Henock Legesse, Matthew Marcus, Ryan McClelland

## *Science and Mission Operations*

**GSFC:** Craig Markwardt, **Univ. of Colorado:** Jerry Jason

# Exploring the Fast, Furious, and Forming Universe

## *The STAR-X Science Story*

**The FAST:** Locally rare, brief events have an outsized impact on the Universe.



The heavy elements needed for life are synthesized in and dispersed by supernovae and neutron star mergers. Similarly, a single stellar superflare can evaporate an ocean or catalyze prebiotic pathways. The STAR-X wide field UV/X-ray design and fast and flexible operations captures these events.

**The FURIOUS:** Black holes grow extremely rapidly at early times in the Universe and are critical to galaxy evolution.



STAR-X will uniquely probe the physics of rapid accretion that allowed massive black holes to grow so quickly in the early Universe. STAR-X will catch transient, extreme black hole feeding events, such as TDEs, where entire stars are disrupted.

**The FORMING:** Distant galaxy clusters provide maximal leverage in evolutionary studies of structure formation and chemical enrichment.

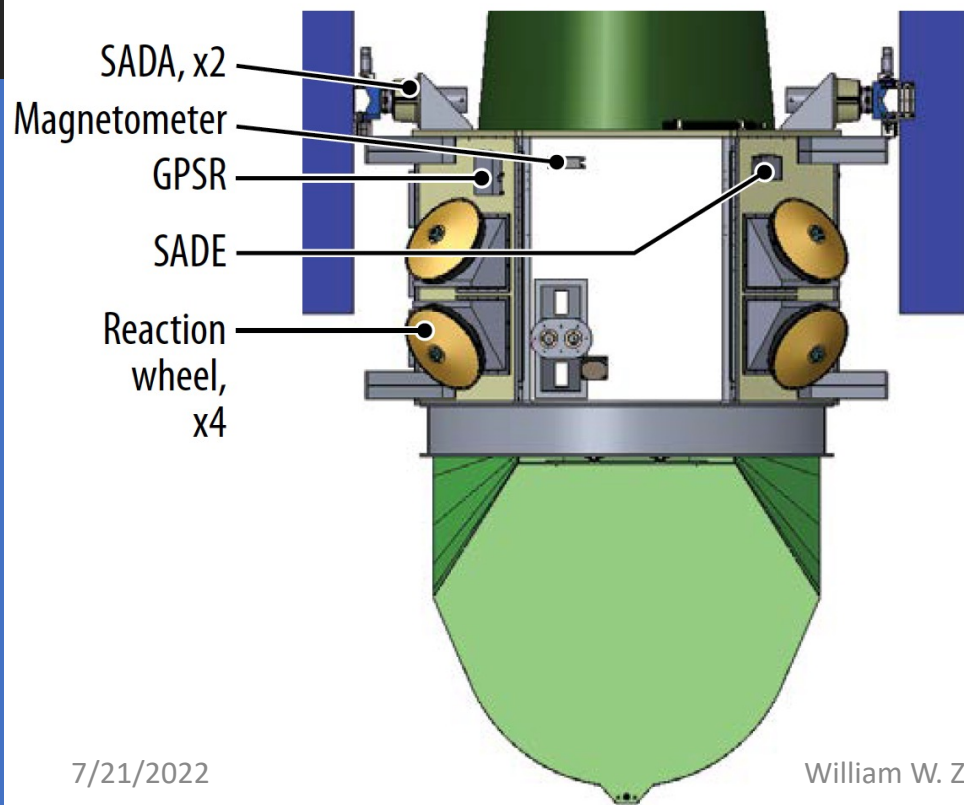


STAR-X will conduct deep surveys and discover the elusive diffuse emission from the largest bound objects in the Universe (clusters of galaxies), shortly after their birth. STAR-X's combination of excellent imaging and low particle background (due to orbit choice) makes this possible in a way that no other mission can.

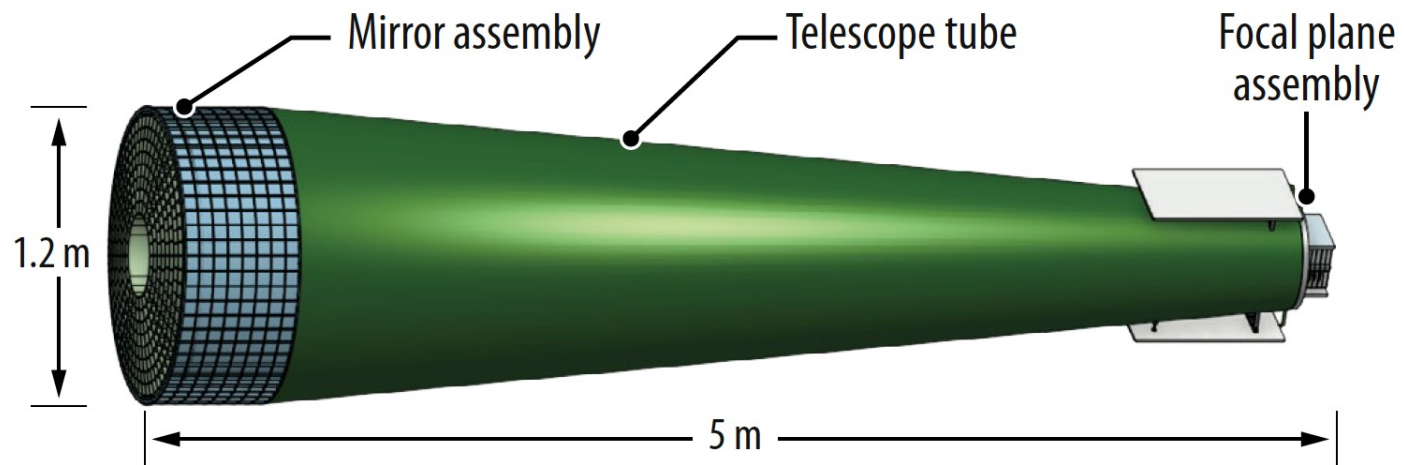


# What's STAR-X?

## Spacecraft (SC)



## X-ray Telescope (XRT)

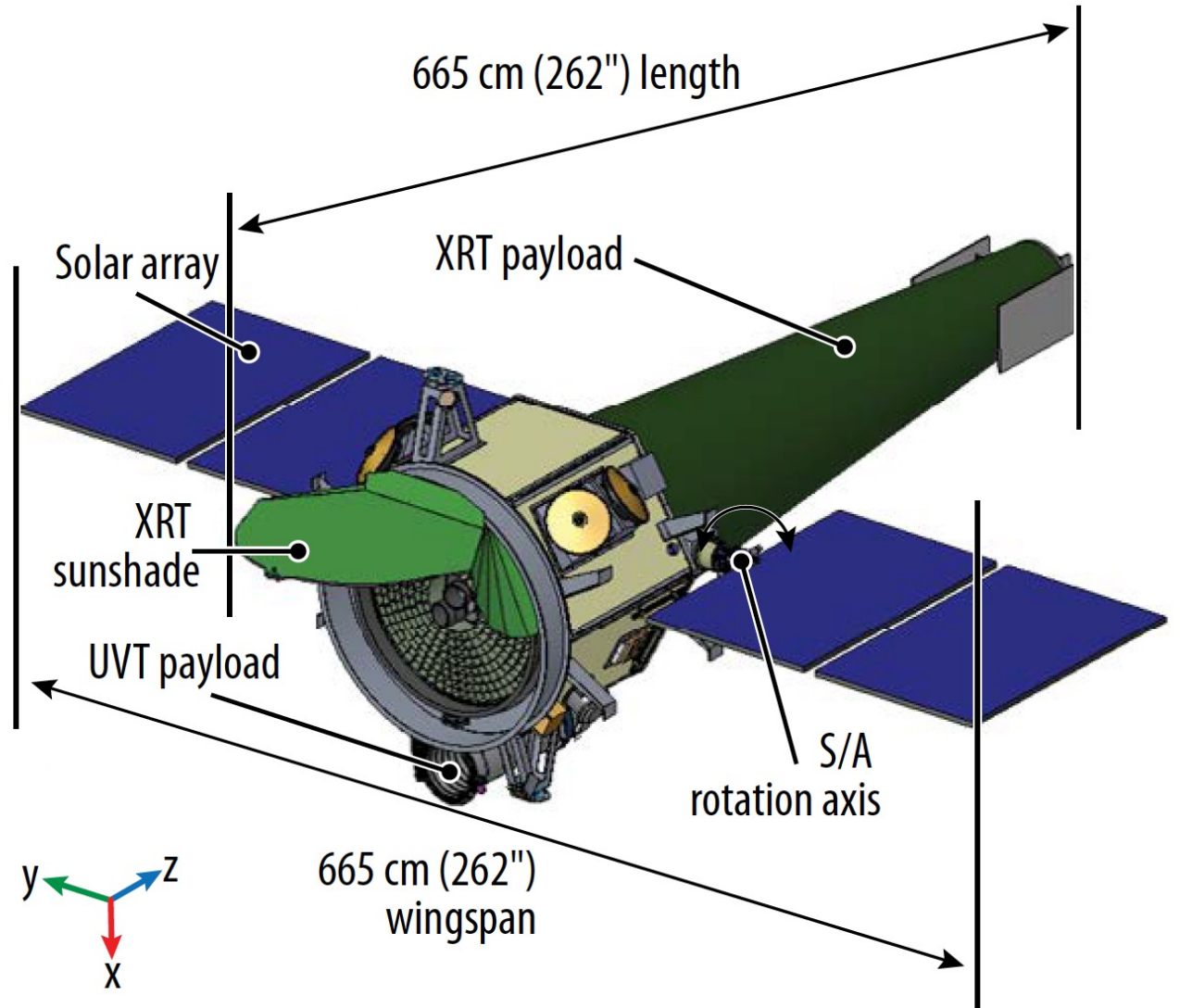


## UV Telescope (UVT)



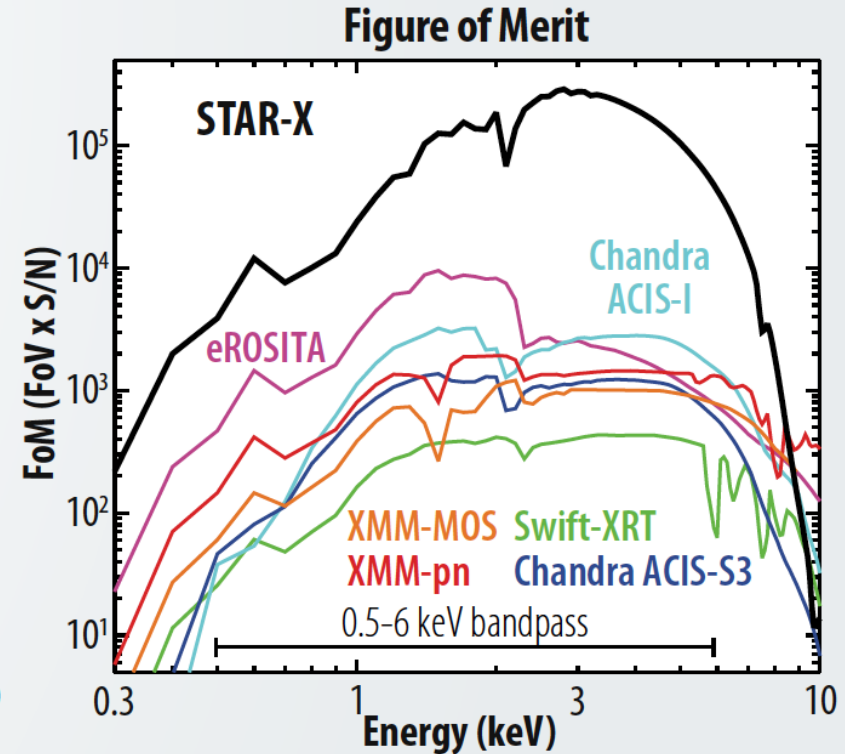
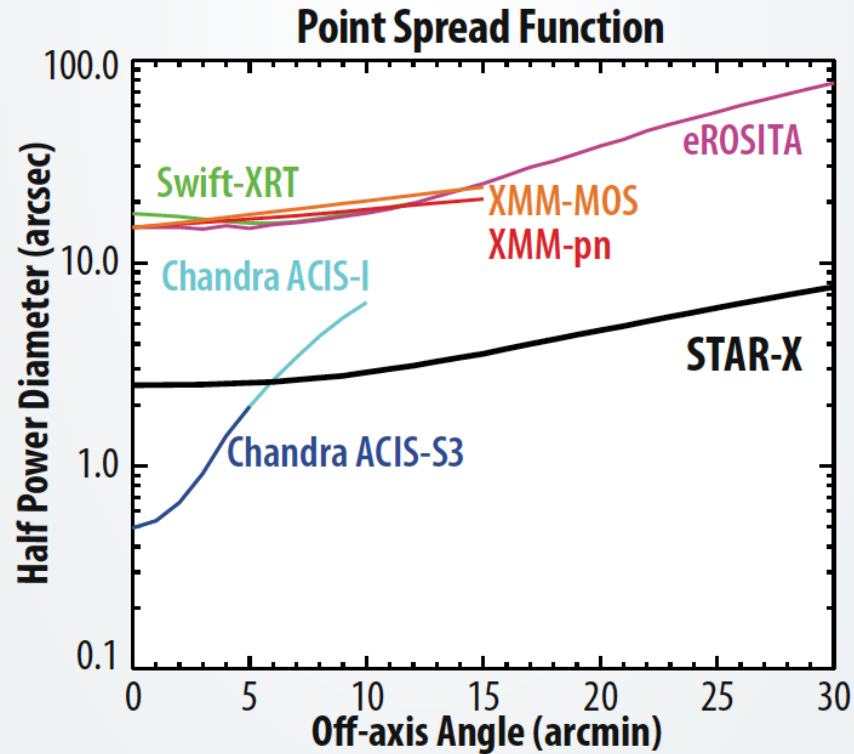
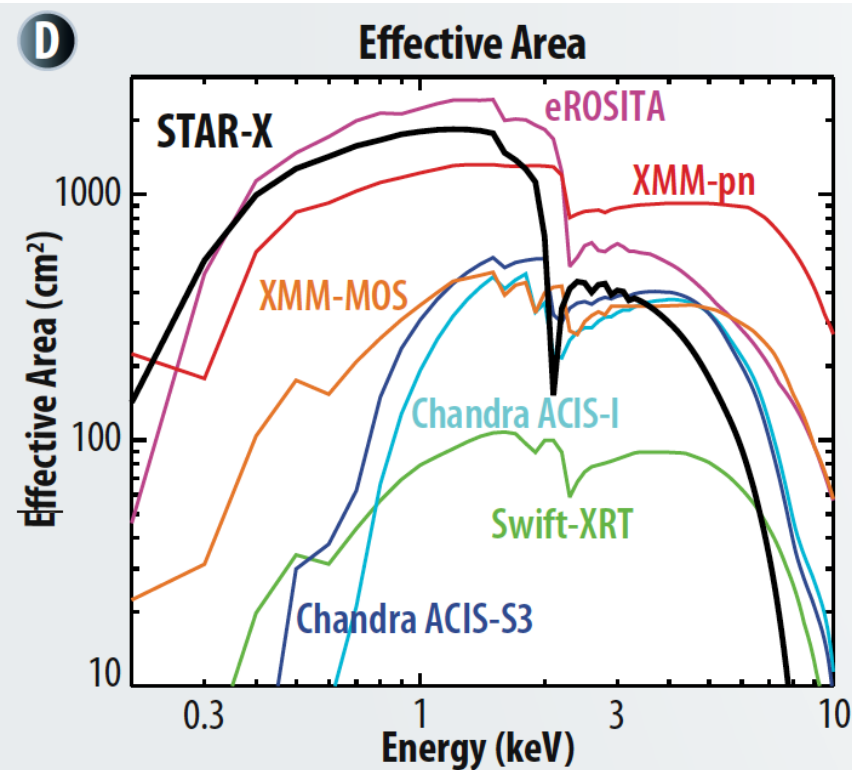
# Key Features of the STAR-X Observatory

- Three largely independent subsystems: XRT, UVT, and SC
- Each independently built and qualified
  - XRT by GSFC+MIT
  - UVT by Univ. of Colorado
  - SC by Ball Aerospace
- Easy integration and testing: “plug and play”
  - Obs. Integration and testing by Ball Aerospace

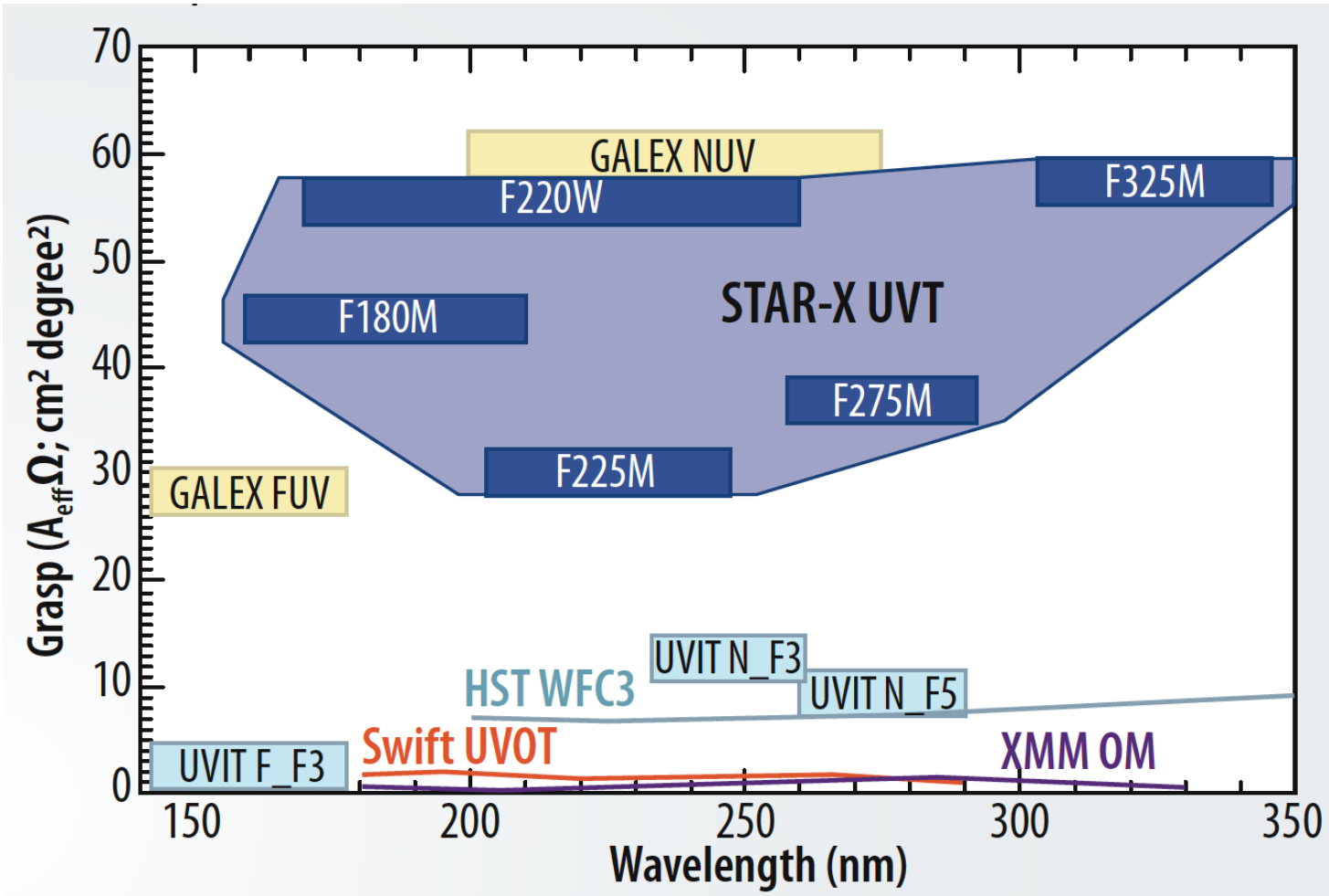


# Key Features of the X-ray Telescope

- Excellent PSF: 2.5" on-axis, 8" 0.5-deg off-axis.
- Large FOV: 1 deg<sup>2</sup>.
- Large effective area: >1,800 cm<sup>2</sup> at 1 keV.
- Low particle background.



# Key Features of the UV Telescope



- Excellent PSF:  
4" on- and off-axis.
- Large FOV:  $1.0 \text{ deg}^2$ .
- Good effective area:  
 $25 - 55 \text{ cm}^2$ .
- Five filters
  - 180 nm
  - 220 nm
  - 225 nm
  - 275 nm
  - 325 nm

# Key Features of the Spacecraft

- **Three-axis Stability and Short Settle Time**

- Supports the excellent PSF of XRT and UVT
- Enables efficient raster scans

- **High Degree of Autonomy**

- Can protect itself and instruments
- Enables efficient operations

- **Fast Slew**

- Fast response to ToO
- High observing efficiency

- **Fast And Real-time Communication To Ground**

- Uplinks triggers from other observatories
- Downlinks information of new transients

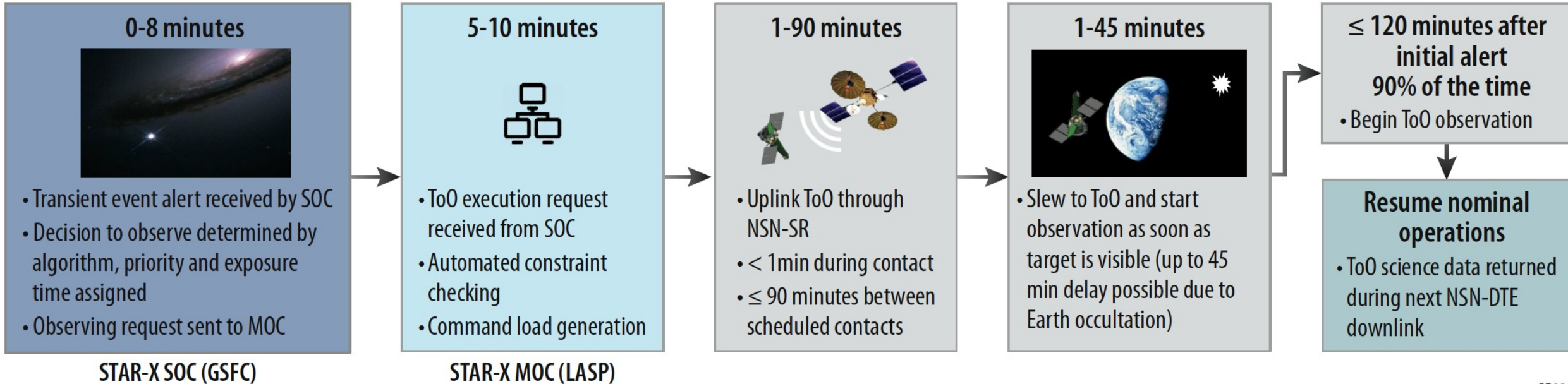
- **Large Data Storage**

- Enables observation of bright sources

- **No Consumables**

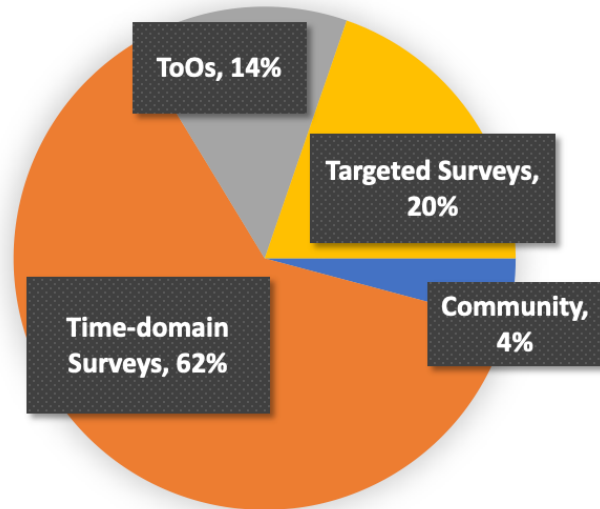
- Mission can last far beyond the two year prime mission

# Fast Response to TOO: <120 mins, 90% of the time



- Algorithmic selection of ToO for STAR-X to respond to.
- Scheduled command uplink windows to minimize response time.
- Near real-time downlink information of transients detected by STAR-X

# Science Program for the Two Year Prime Mission



## • Time Domain Surveys

- Deep survey: Rubin deep drilling fields
  - 12 deg<sup>2</sup>, **Daily Cadence**
  - $1 \times 10^{-14}$  cgs (X-ray) and 22.5 mag (UV)
- Medium survey: Stripe 82 + Subaru fields, & Rubin deep drilling fields
  - 300 deg<sup>2</sup>, **Weekly Cadence**
  - $3 \times 10^{-14}$  cgs (X-ray) and 22.3 mag (UV)

## • Targets of Opportunity

- Young supernovae
- GW X-ray/UV counterparts
- GW source late-time follow-up
- Tidal-disruption events

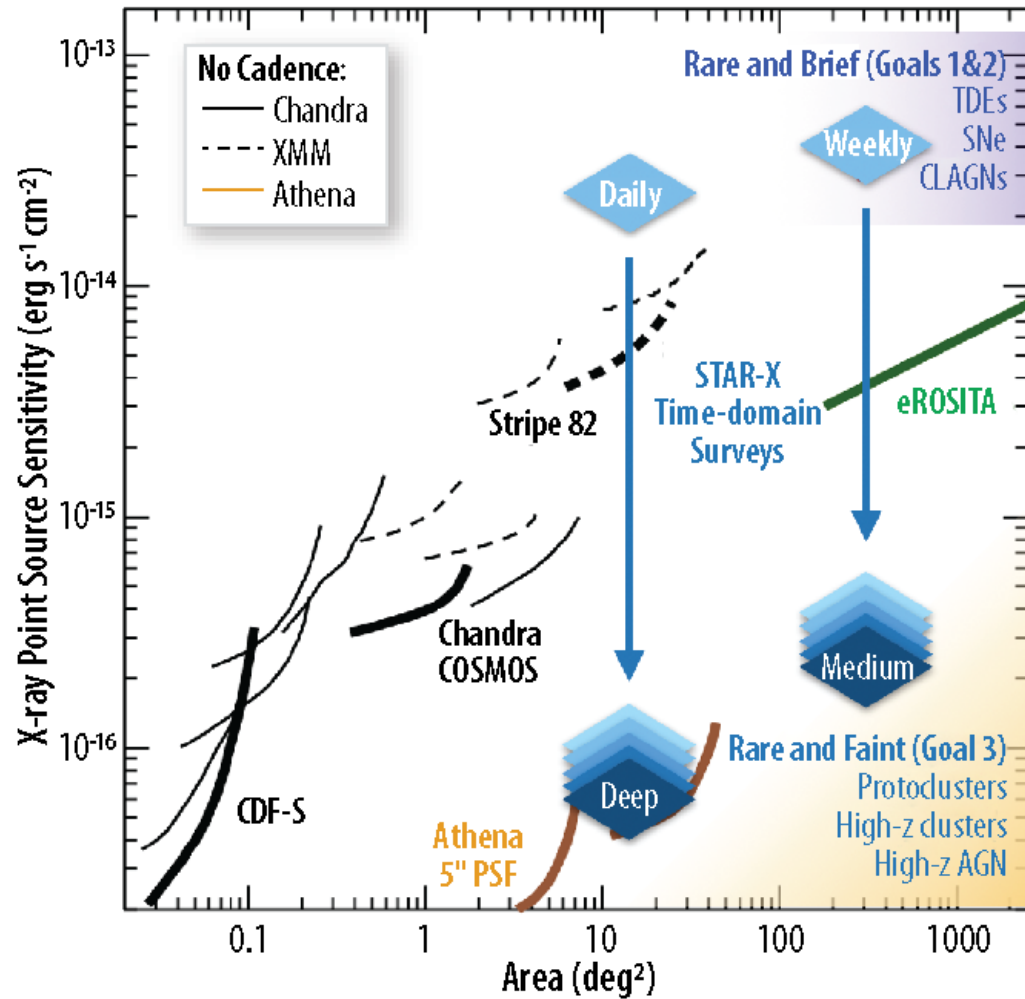
## • Targeted Surveys

- 10 nearby galaxies
- 9 low-mass, planet-bearing stars
- 20 high-z SZ-detected clusters
- 20 nearby clusters

## • Community Program

- Impromptu requests from the broad community

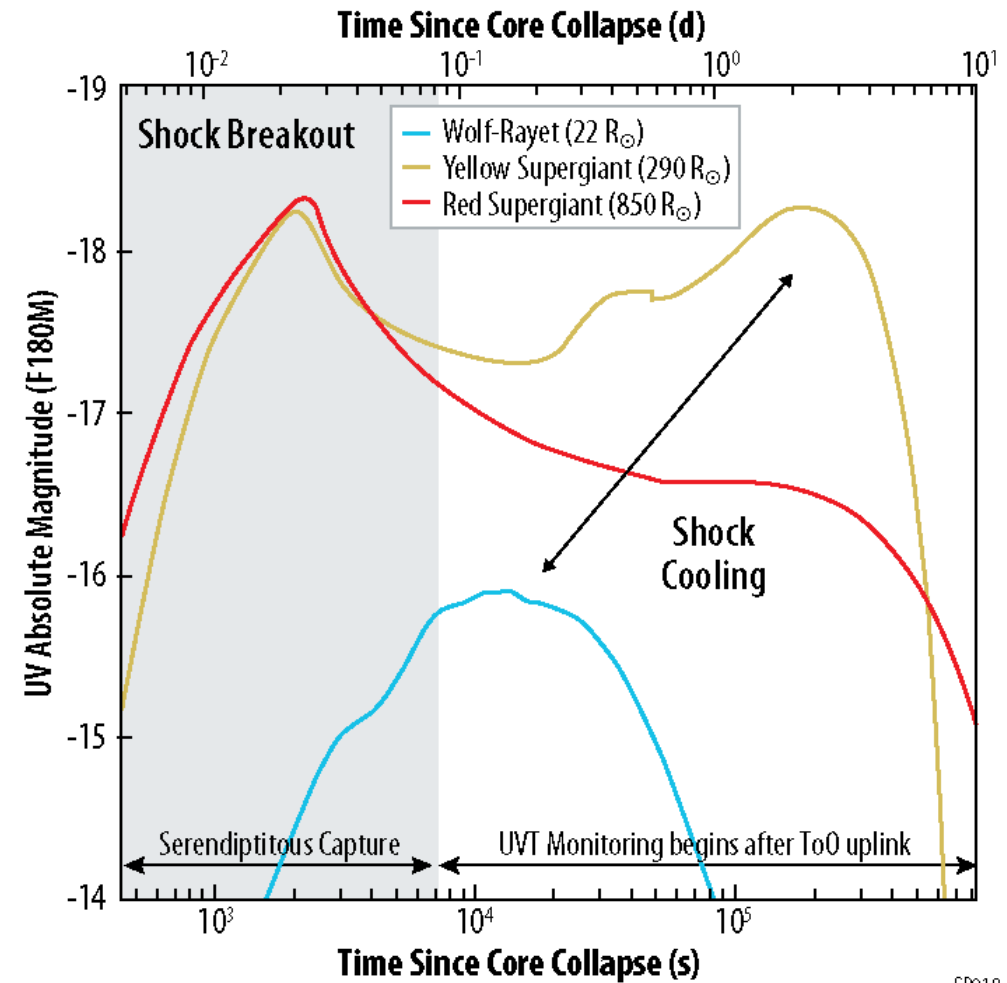
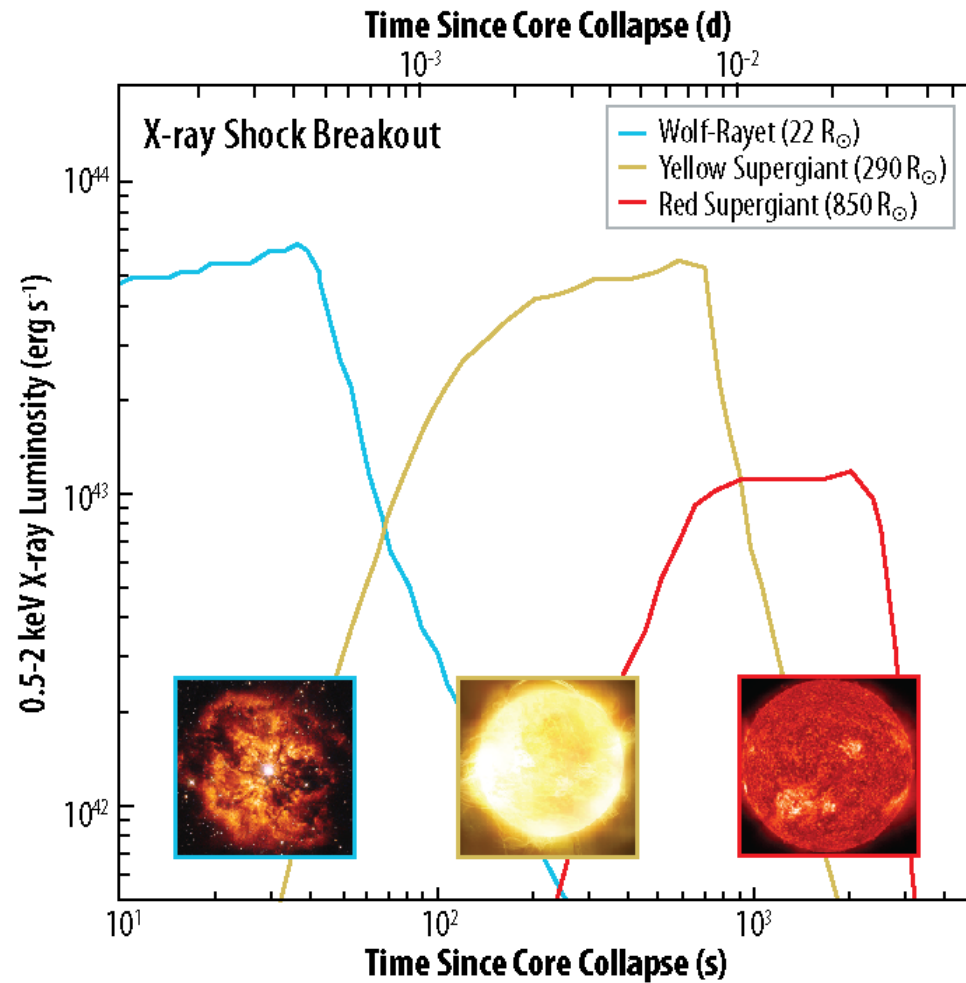
# Time-domain Surveys



<p><b>1-1 Supernovae</b></p> <p>XRT discovers a shock breakout and triggers a ToO to catch cooling in the UV</p>	<p><b>2-1 Tidal Disruption</b></p> <p>Weekly X-ray/UV monitoring rapidly reveals hundreds of new TDEs</p>	<p><b>2-2 AGN Accretion Flows</b></p> <p>Daily X-ray/UV monitoring probes accretion disk structure via time lags</p>
<p><b>3-1 Protoclusters</b></p> <p>STAR-X will witness the birth of galaxy clusters at <math>z &gt; 3</math> via AGN clustering and early intracluster medium</p>	<p><b>3-2 High-z Clusters</b></p> <p>STAR-X will discover hundreds of high-z clusters to trace cluster growth over cosmic time</p>	<p><b>Survey Science: <math>z &gt; 6</math> AGNs</b></p> <p>STAR-X surveys high-z AGNs 64x faster than Chandra with a better FOV-averaged PSF</p>

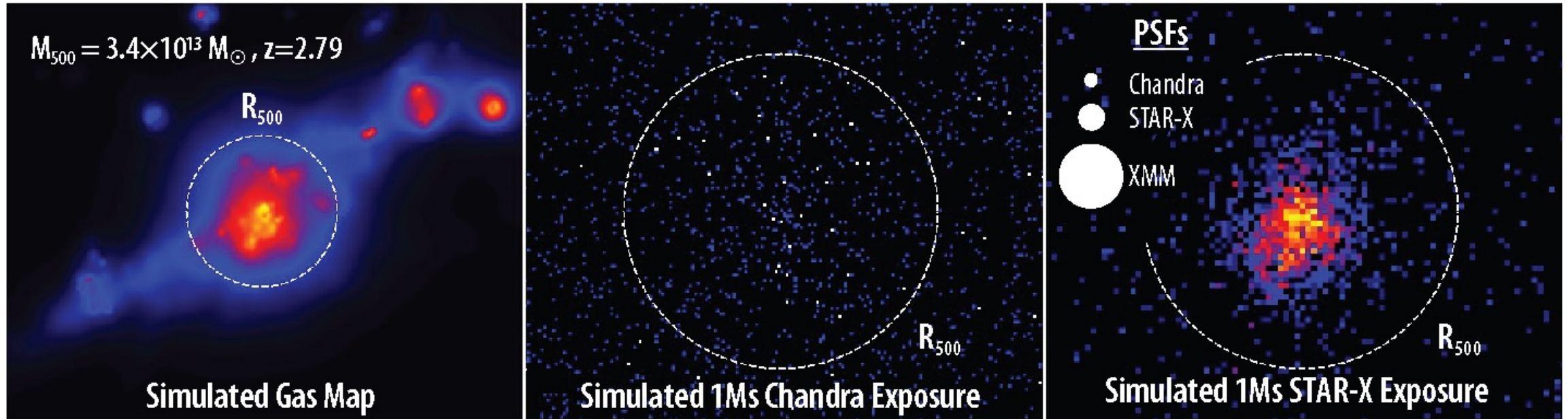
SR024

# Study of Core Collapse Supernovae



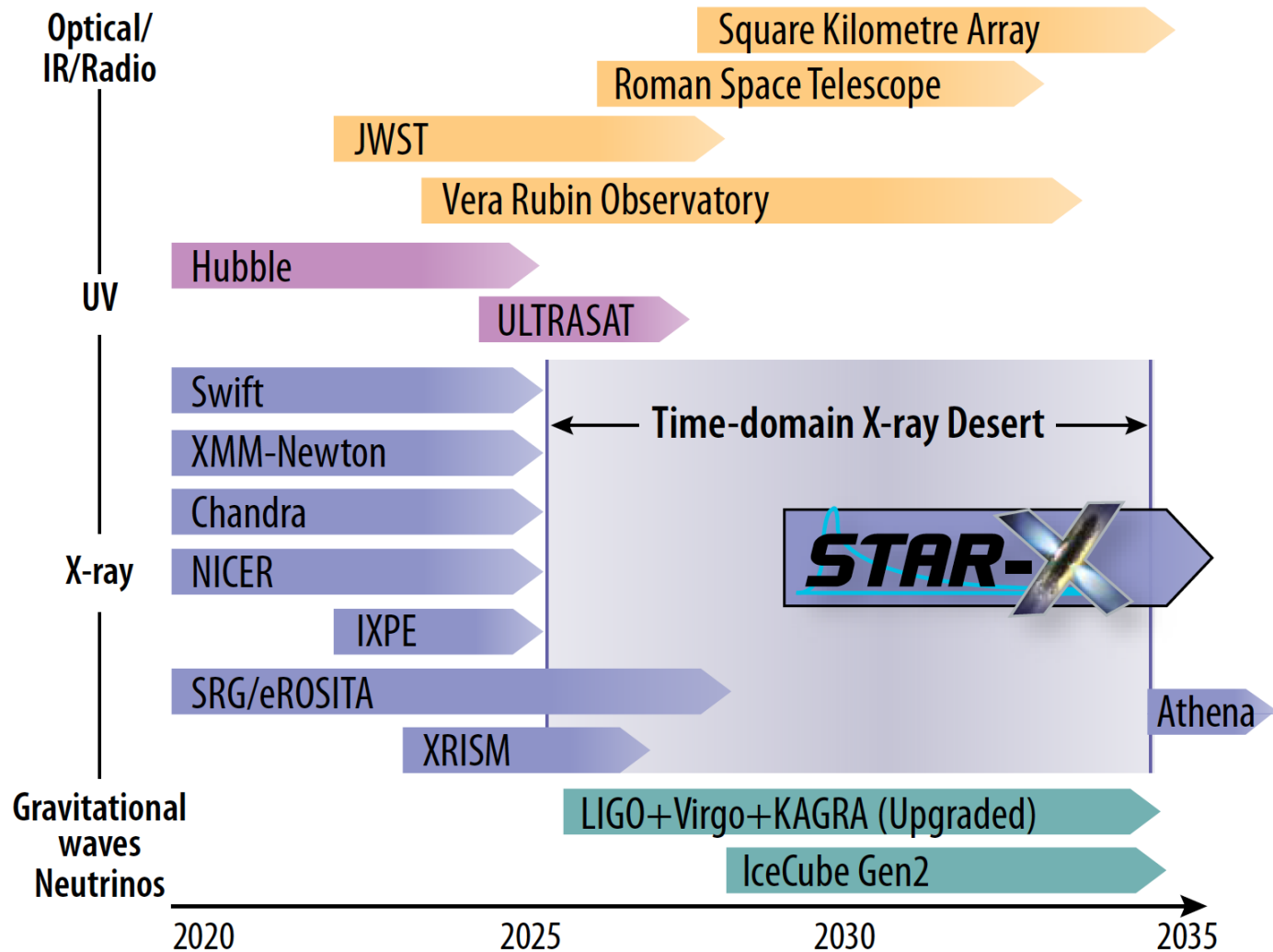
SR018

# Study of High-z Galaxy Clusters



SR026

# Why STAR-X and Why Now?



STAR-X fills the gap in X-ray and UV time-domain coverage in the late 2020s, providing simultaneous X-ray and UV observations that complement optical, infrared, and gravitational wave facilities.

# Summary

- STAR-X represents a revolutionary jump in capability.
- STAR-X does great and timely science on its own.
- STAR-X complements and enhances other great observatories such as JWST, Rubin LSST, Roman WFIRST, SKA, and Athena.
- STAR-X is a timely response to Astro2020's recommendation for "a space-based, sustaining time-domain and multi-messenger program."