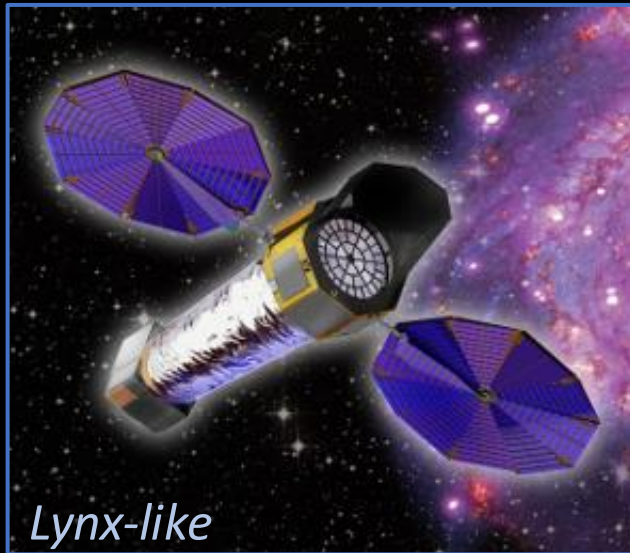


An X-ray Extremely wide-field Spectroscopic Surveyor (XESS or “chess”)



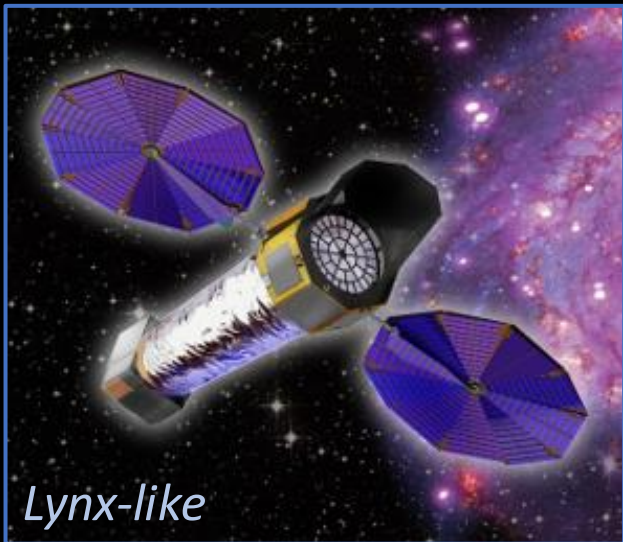
Or: *A Strategic Approach to the New X-ray Landscape*
W. Peter Maksym, NASA/MSFC



Left: Lynx , NASA

Right: NewAthena, ESA/IRAP/CNRS/UT3/CNES/Fab&Fab. Composition: ACO.

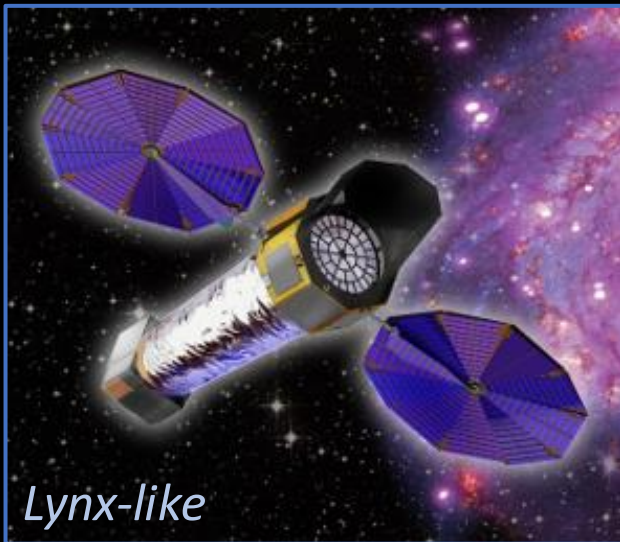
What *will* such Flagships be able to do?



- 0.2-12 keV, ~9" HPD, 0.6 m², 4 eV, 4 arcmin FOV (X-IFU)
- Spectroscopically constrain the mechanics of **AGN feedback** ([E]NLR, UFOs)
- **Galaxy clusters**: plasma state, pressure, kinematics
- **X-ray binaries**: accretion dynamics, plasma, winds, NS physics
- **Supernova Remnants**: composition, kinematics, origins
- **Time domain**: sensitive high-res spectroscopy & follow-up: wind mechanisms & geometry of **TDEs, XRBs and more**
- 0.2-7 keV, ~0.5" HPD, 2.1 m², >3 eV, >5 arcmin FOV
- Spatially resolved **AGN** imaging spectroscopy on **sub-kpc scales**
- Cleanly resolved **cavities, shocks, filaments** for clusters, SNRs
- Rich, high-throughput **grating** spectro. Incl. bright sources.
- Greatly enhanced sensitivity imaging spectroscopy **sensitivity**
- Deep measurements of faint BH's in the **early universe**
- Alterations: **Polarimetry**? Expanded **bandwidth**? More?

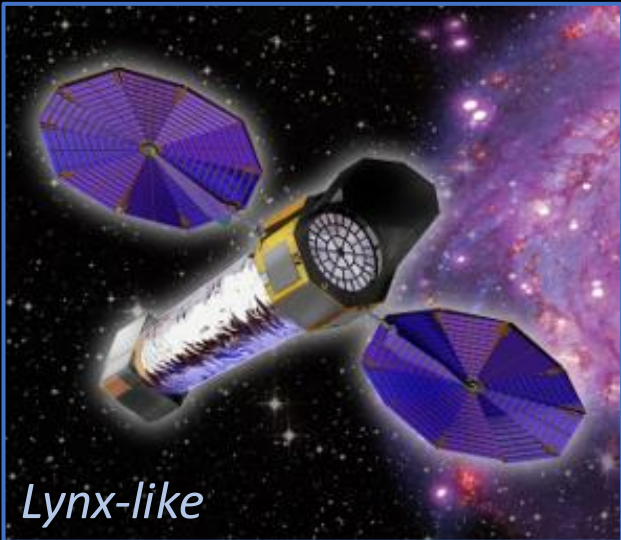
Peter Maksym - An X-ray Extremely wide-field Spectroscopic
Surveyor (XESS or "Chess") - Community Science (Ad ASTRA)
Workshop, Pasadena, CA

What *won't* such Flagships be able to do?



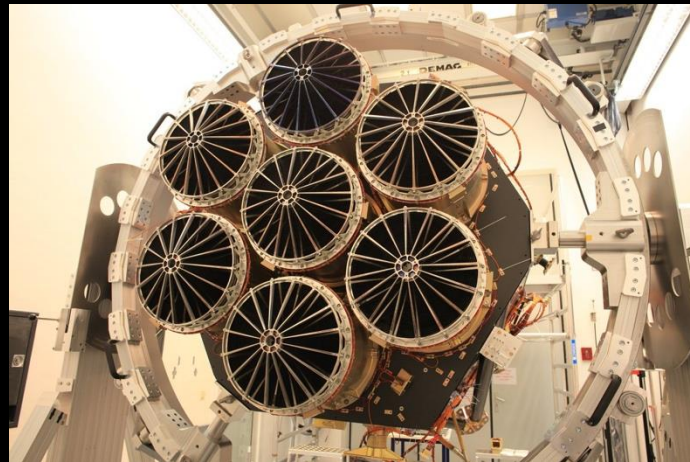
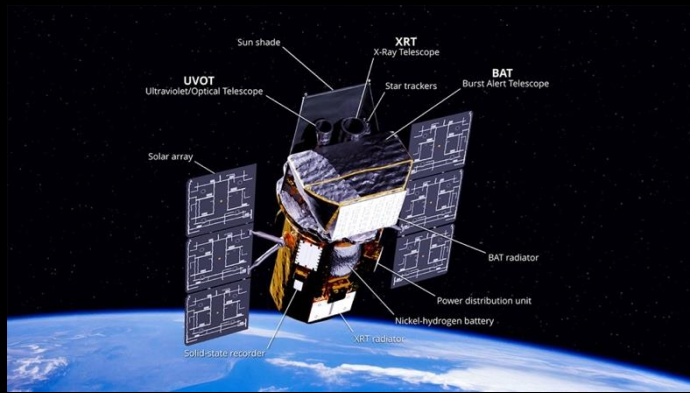
- Extremely **high angular resolution** ($\sim 0.5''$ for *Lynx*)
 - *Chandra* like; *HST/JWST*-like is a serious challenge at $\sim m^2$
- **Broadband!** ($>> 10$ keV) See other talks this session...
- Time domain **discovery**: limited survey capability at $\Omega \sim 20$ arcmin 2 for MC's, ~ 0.1 deg 2 for imagers
 - These will predominantly be **follow-up** machines
 - Limited exceptions: deep fields, imaging surveys
- Beat down selection-driven spectroscopic **systematics**
 - **Blind selection**: limited by FOV. Typically informed by other wavelengths.
 - **Time domain systematics**: seriously limited by selection
 - Duty cycle of transient accretion/outflow states (**UFO, QPE, CLAGN, TDE**)
 - X-rays: often part of an **evolving** multi-wavelength picture
 - **Survey selection** of non-TDAMM phenomena
 - **AGN feedback**, states & energetics
 - Faint & extended: Baryons in the **WHIM** & cosmic filaments
 - The largest, closest extended phenomena: **Fermi Bubbles, SNRs, local bubble, MW, LMC, SMC**

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What *is* the state of Wide-Field X-ray Astronomy in the Golden Age of Wide Fields?



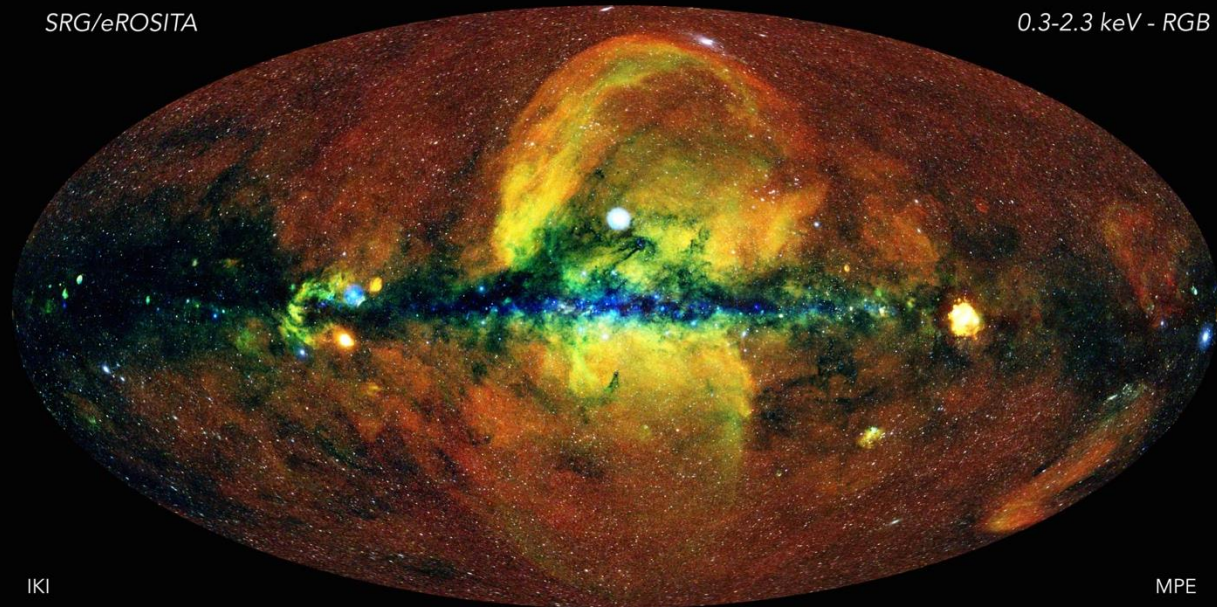
Top: Swift, NASA

Bottom: eROSITA, J. Buchner (CC BY-SA 4.0)

eRASS, J. Buchner (CC BY-SA 4.0)

SRG/eROSITA

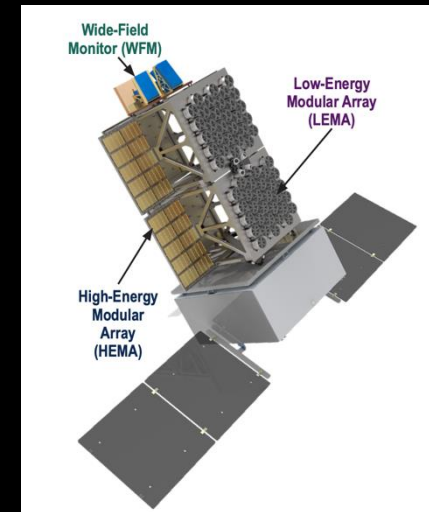
0.3-2.3 keV - RGB



- **Non-imaging:** CA (*Swift*, *SVOM*, *Integral*, *MAXI*)
- **Focusing:** Lobster (*Einstein Probe*), Spektrum-Roentgen-Gamma (*eROSITA*/ART-XC)
- Trade-offs: Ω vs $\Delta\theta$, A_{eff} , F_{lim}
- Spectral resolution: thus far limited to $\sim\text{Si}$ ($\sim 50\text{-}150$ eV, $R \sim 20\text{-}40$)

What *ought* a wide-field X-ray mission do?

- **Optimally complement** planned *X-ray* missions
 - Fill in *gaps and weaknesses* (incl. systematics, statistics)
 - Inform observing choices by *more capable* instruments
 - Take advantage of *new capabilities*
- **Optimally complement** wide-field instruments in *other bands*
- **Supersede** the capabilities of *previous missions*. But where?
 - Solid Angle? → Fast transients
 - Effective area? → Variability, sensitivity, spectroscopy
 - Dynamic range? → Surveys, timing, versatility
 - Timing precision? → NS's, XRBs, other fast transients
 - Angular resolution? → Sensitivity, confusion, structure
 - Sensitivity? → Variability, spectroscopy, volume, dy. range
 - Throughput? → Variability, timing, spectroscopy
 - Survey speed (grasp)? → Transients, variability, spectroscopy, volume
 - Energy resolution? → Plasmas, winds, shocks, temperature, density, **PHYSICS!**

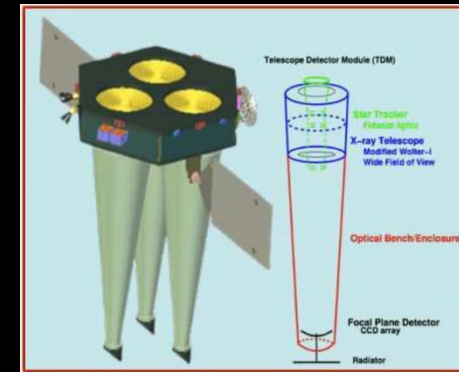


STROBE-X top left:
Ray et al, 2024

WFXT bottom left:
Murray et al, 2013

See also: LEM:
Kraft et al, 2022

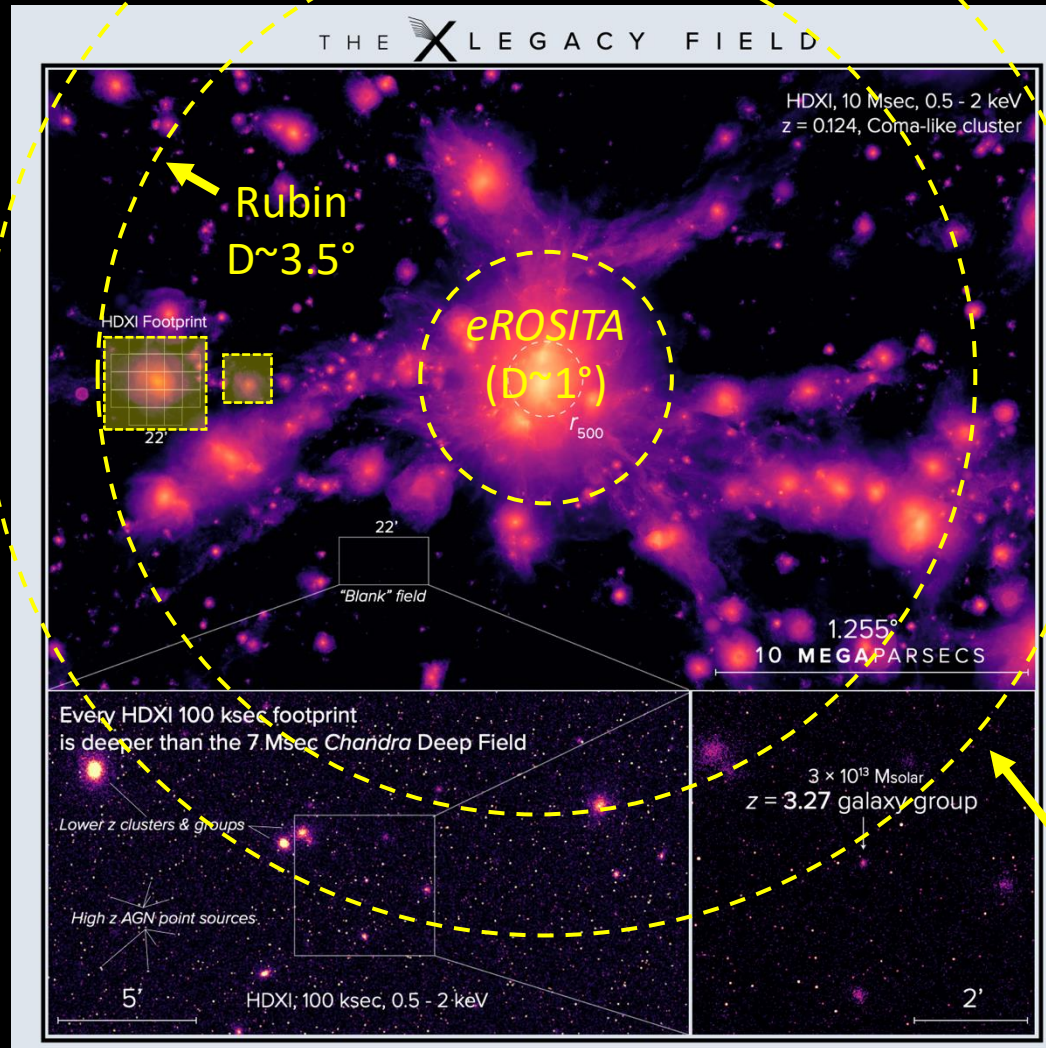
WFXIS: Ulmer et al,
1995



Ray, P. S., et al. (2024). "Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays." *Journal of Astronomical Telescopes, Instruments, and Systems*, 10(4), 042504. doi:10.1117/1.JATIS.10.4.042504

Murray, S. S., et al. (2013). "Wide Field X-ray Telescope (WFXT)". *Mem. S.A.It. Vol. 84*, 790.

What *ought* a wide-field X-ray mission do?



Lynx X-ray Observatory Concept Study Report

Vikhlinin, Özel, Gaskin, et al. 2019, NASA Marshall Space Flight Center

LXM: $\sim 20\%$ of HDXI Ω , but needs $>30\times$ the counts!
(~ 100 eV vs. 3 eV)

Needed:

Survey-scale coverage of extended plasmas
(WHIM, Fermi Bubbles, SNRs, local galaxies)

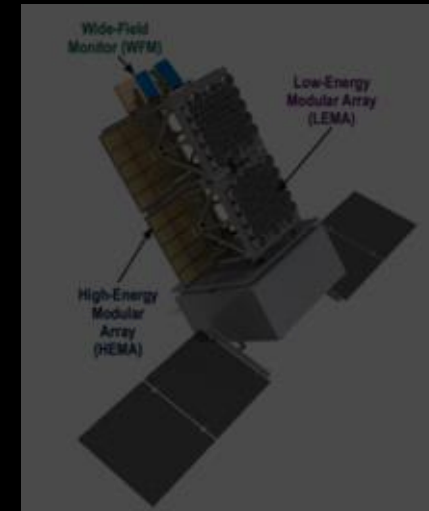
Time domain multiplexing (AGN, XRBs, TDEs, etc)

Spectroscopic survey multiplexing (galaxies, AGN, XRBs)

LISA inspiral
 ~ 1 month before
 $D \sim 4.5^\circ$

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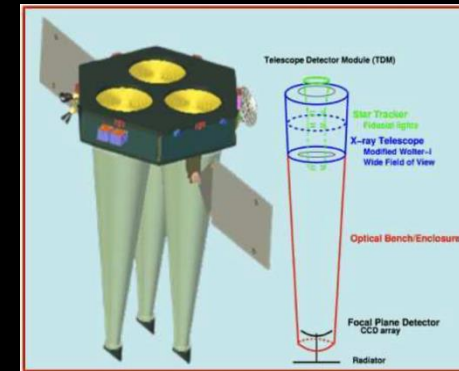


STROBE-X top left:
Ray et al, 2024

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See also: **LEM:**
Kraft et al, 2022

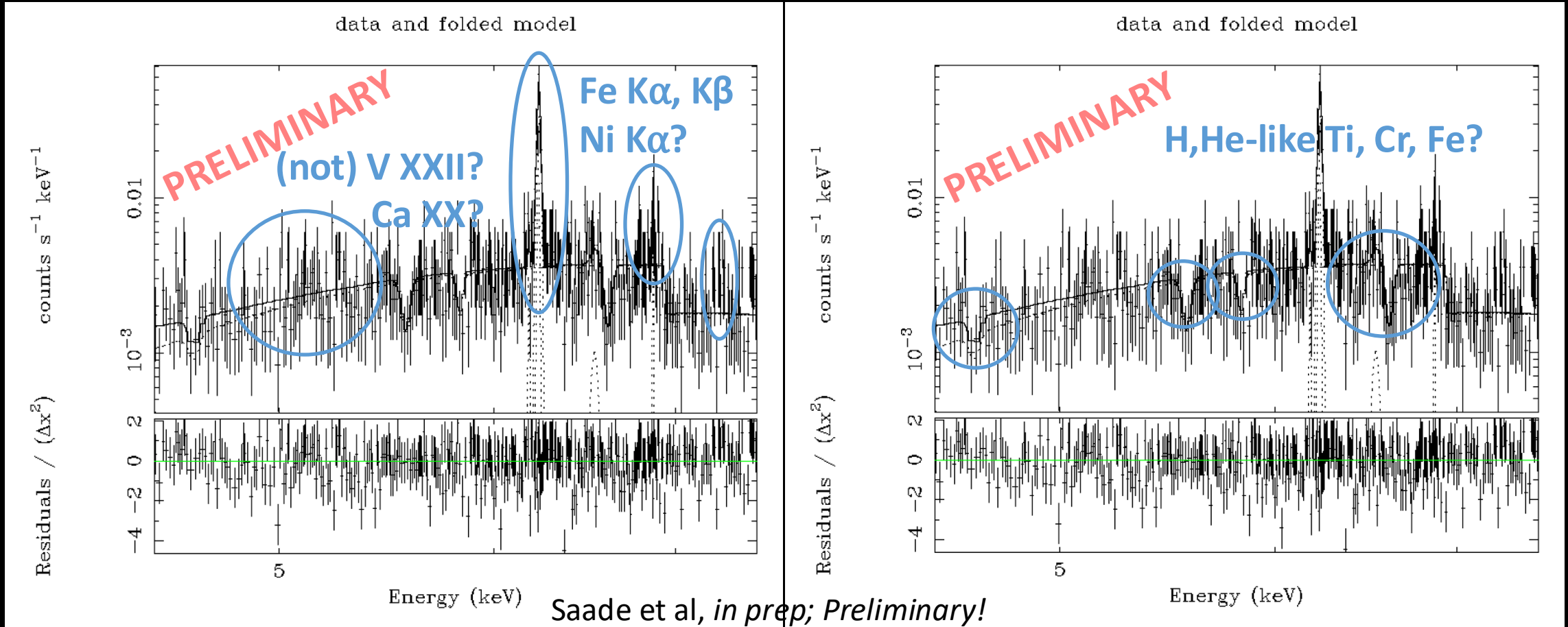
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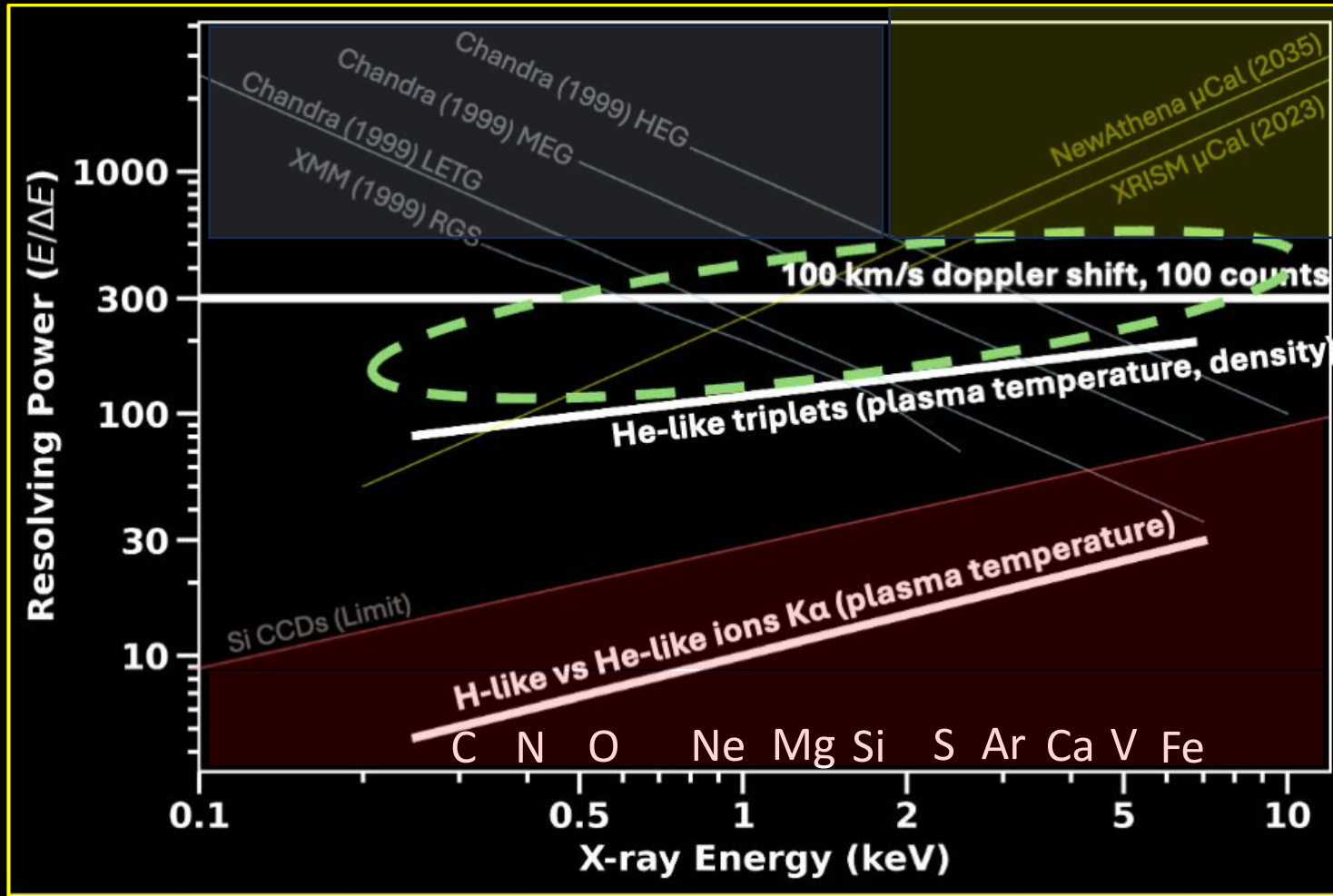
Murray, S. S., et al. (2013). "Wide Field X-ray Telescope (WFXT)". *Mem. S.A.It. Vol. 84*, 790.

NGC 7212 – Faint-ish *Swift*-BAT/*ROSAT* AGN ($7e-13$ erg/s/cm²) 220 ks *XRISM*/Resolve, binned to larger ΔE



Imagine ~ 7 deg² of the NEP at 220ks, but deeper! Or the LMC!

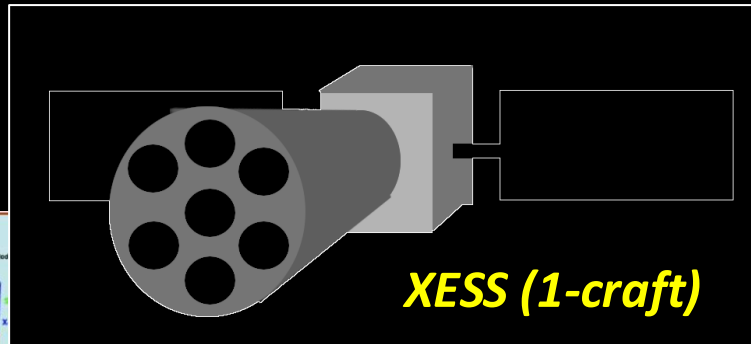
What $E/\Delta E$ is *Enough*? What does it *cost*?



- **H-like, He-like transitions:** Cover $\sim 10^5$ - 10^9 K over a range of metals (C through Fe and beyond)
- **Microcalorimeters:** powerful & power-hungry ($T \sim 0.05$ K!).
-> Monolithic optics
- **Gratings:** non-imaging
-> Not for surveyors
- **Silicon:** cheap, imaging, large
-> Can we do better?
- **Other?** Good $E/\Delta E$ (100s of km/s), imaging, well-matched to replicated optics.

Replicated optics can allow you to scale Ω^2 , A_{eff} , F_{lim} massively at good ($< 10''$) $\Delta\theta$, but what *detector* replication gives you the most science/\$???

Scalability for a Next Generation Super-eROSITA



Survey @ 1 keV	$\sim A_{\text{eff}}$ (cm ²)	Ω (deg ²)	Grasp (cm ² deg ²)	ΔE (eV)	$\Delta\theta_{\text{HPD}}$ (arcsec)
XESS	2000	7.000	14,000	10	10
eROSITA	1300	1.000	1300	70	30
Einstein Probe	3	3600.000	10,800	170	300
LEM	1500	0.250	375	2	15
Athena X-IFU	6000	0.004	21	4	10
Lynx LXM	20000	0.007	139	3	0.5

- **Good A_{eff} , ΔE :** Essential for spectroscopy. *Doesn't have to be flagship-grade*
- **Large Ω :** A good match for essential near-field targets & optical/GW
- **Good $\Delta\theta$:** Source identification, confusion, structure, sensitivity (background reduction)
- **Monster Grasp:** Survey throughput, discovery, completeness.
- **The Tall Pole:** Can you beat Si ΔE & still scale *detectors* with the *mirrors*?
 ➔ **Superconducting Tunnel Junctions at ~ 0.3 K: in development!**

**For mission architecture & strategy,
see my poster!**

Constellation images: Murray, S. S., et al. (2013).

"Wide Field X-ray Telescope (WFXT)". *Mem. S.A.It. Vol. 84*, 790.

Peter Maksym - An X-ray Extremely wide-field Spectroscopic
Surveyor (XESS or "Chess") - Community Science (Ad ASTRA)
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XESS (constellation)