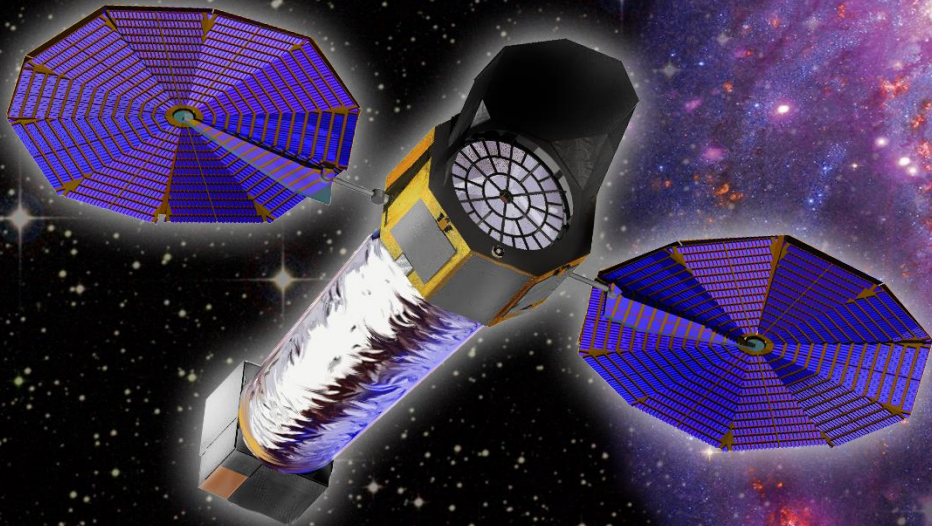
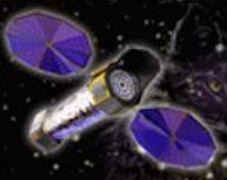


# The *Lynx* X-ray Observatory: Concept Study Overview and Status

X-RAY OBSERVATORY  
**LYNX**  
Revealing the Invisible Universe

Jessica A. Gaskin (Lynx Study Scientist, NASA MSFC)



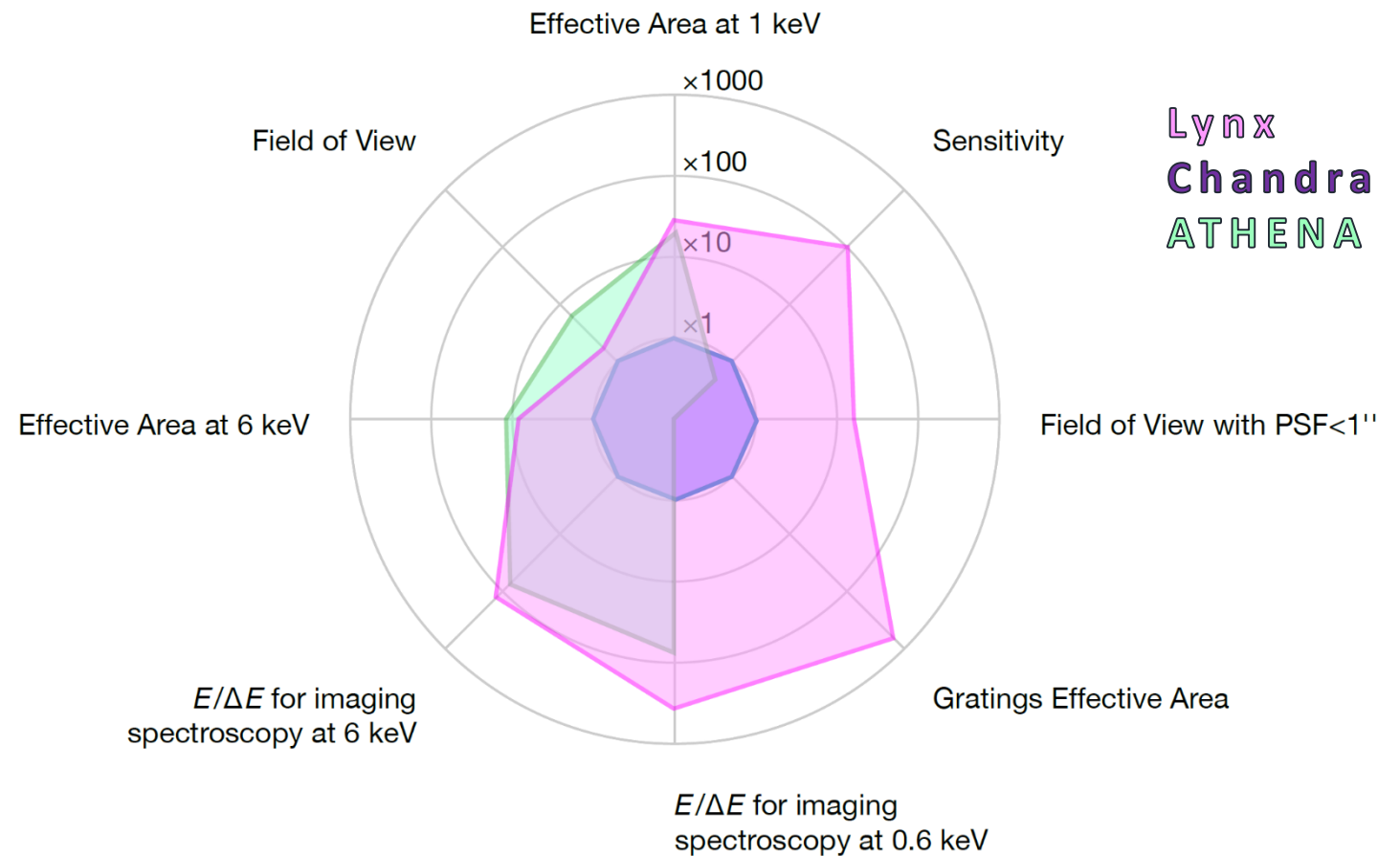


# Meet Lynx!

One of 4 large missions under study for the 2020 Astrophysics Decadal, Lynx is the only observatory that will be capable of directly observing the high-energy events that drive the formation and evolution of our Universe.

Lynx will provide unprecedented X-ray vision into the “Invisible” Universe with leaps in capability over *Chandra* and *ATHENA*:

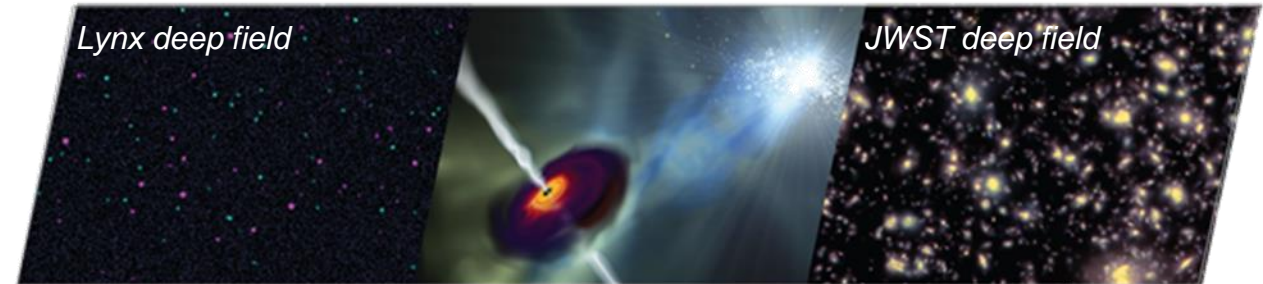
- 100× gain in sensitivity via high throughput with high angular resolution
- 16× field of view for arcsecond or better imaging
- 10–20× higher spectral resolution for point-like and extended sources



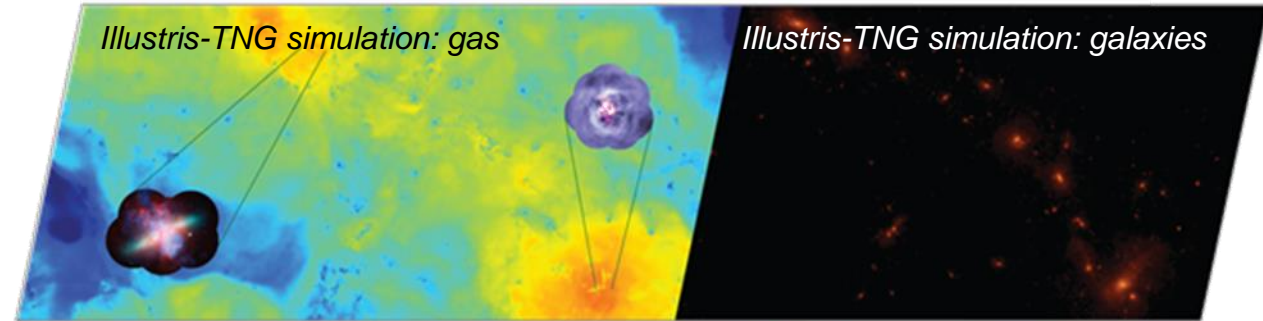
# The Science of Lynx

Through a GO Program, Lynx will contribute to nearly every area of astrophysics and provide synergistic observations with future-generation ground-based and space-based observatories, including gravitational wave detectors.

## *The Dawn of Black Holes*



## *The Invisible Drivers of Galaxy and Structure Formation*



## *The Energetic Side of Stellar Evolution and Stellar Ecosystems*

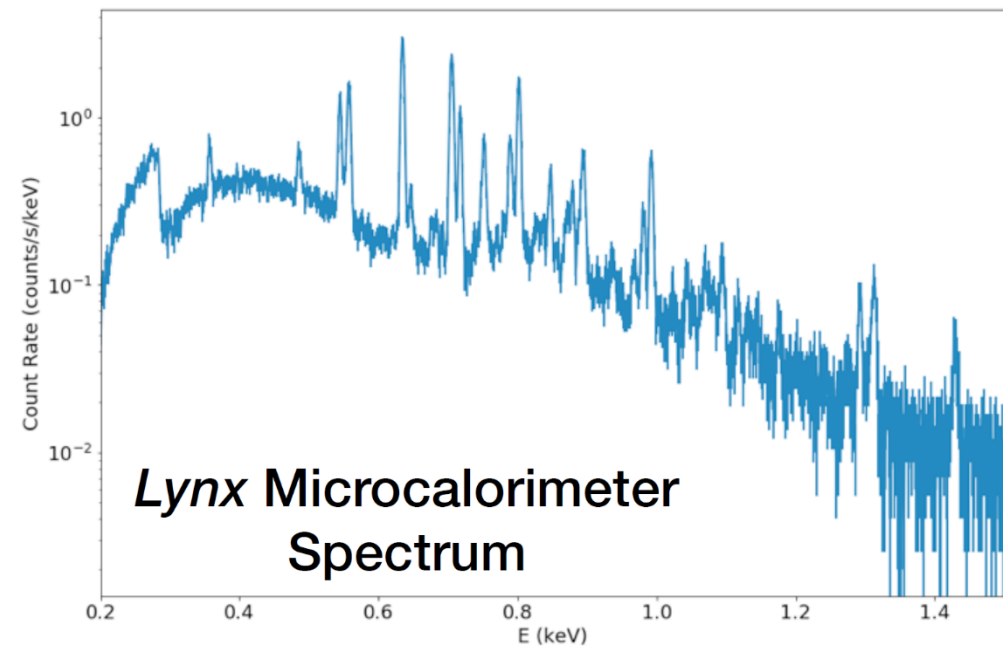
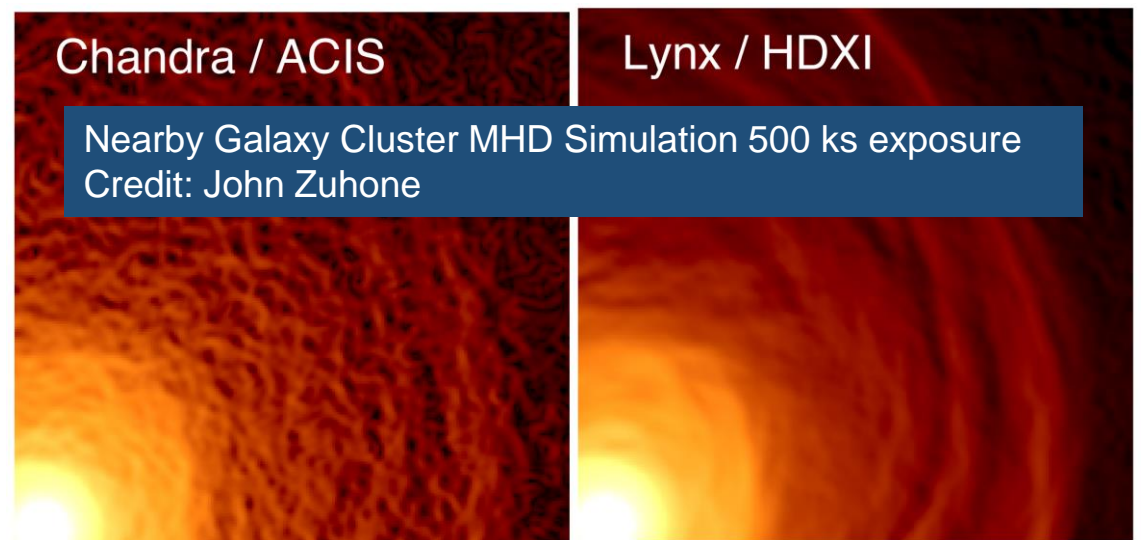
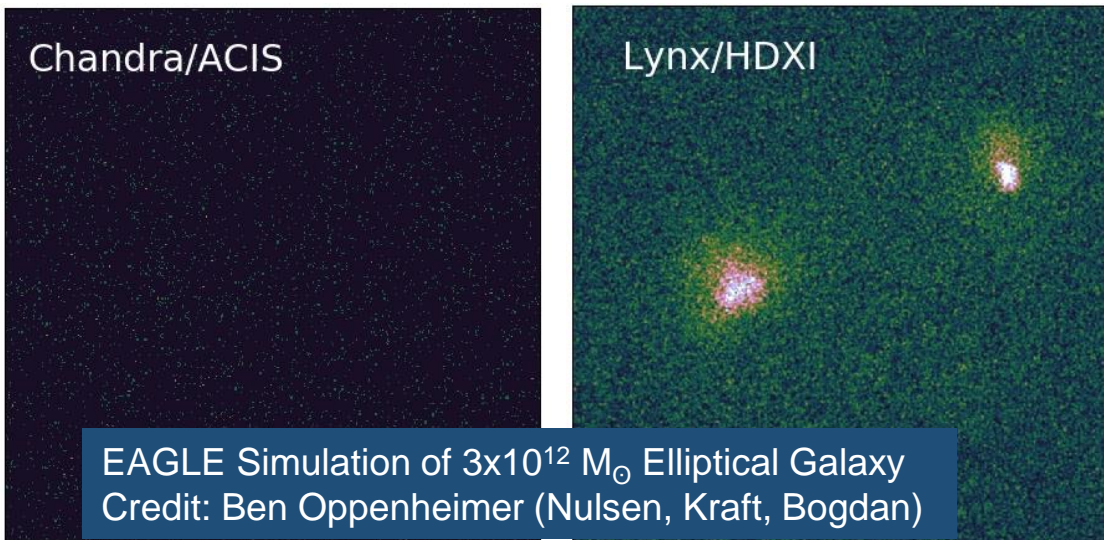


*Endpoints of stellar evolution*

*Stellar birth, coronal physics, feedback*

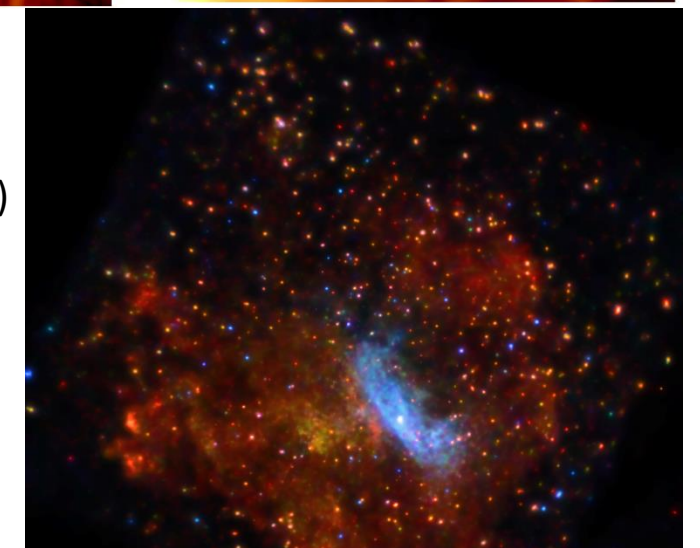
*Impact of stellar activity on habitability of planets*

# Revealing the Unknown – Chandra to Lynx

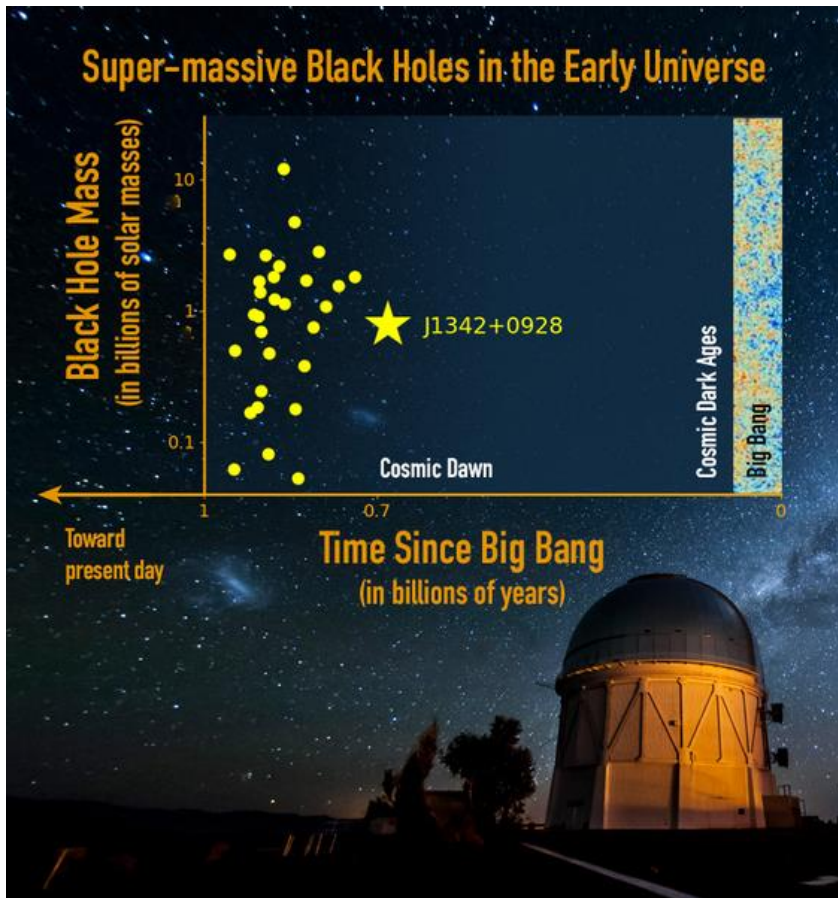


## Lynx Distinguishing Features:

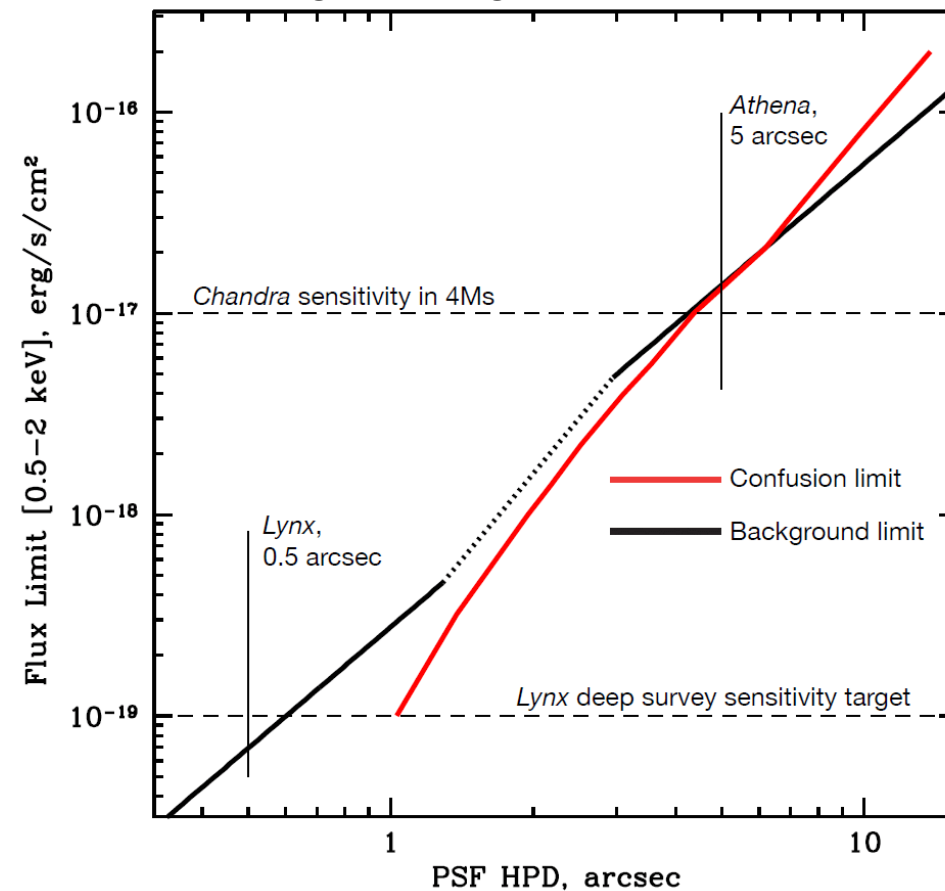
- Wide-Field Imaging with  $< 1''$  PSF (HPD)
- Large Effective Area
- X-Ray Microcalorimeter - Imaging Spectrometer
- Higher resolution X-ray grating spectrometer



# Revealing the Unknown – ATHENA to Lynx

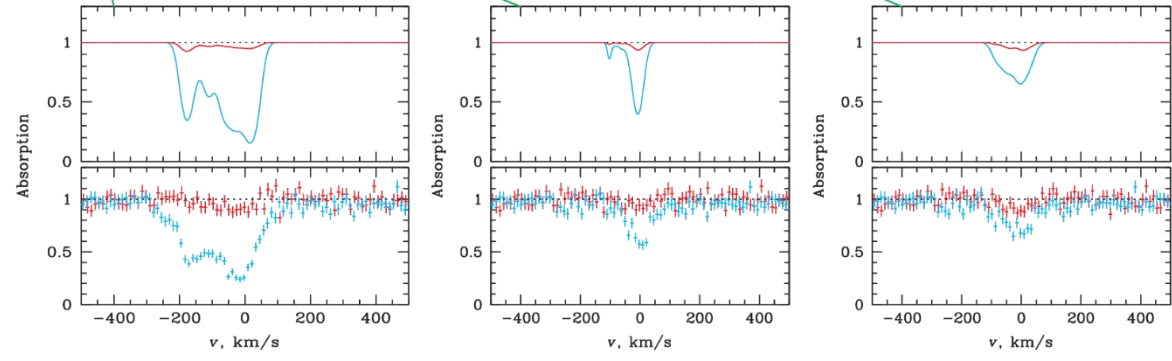
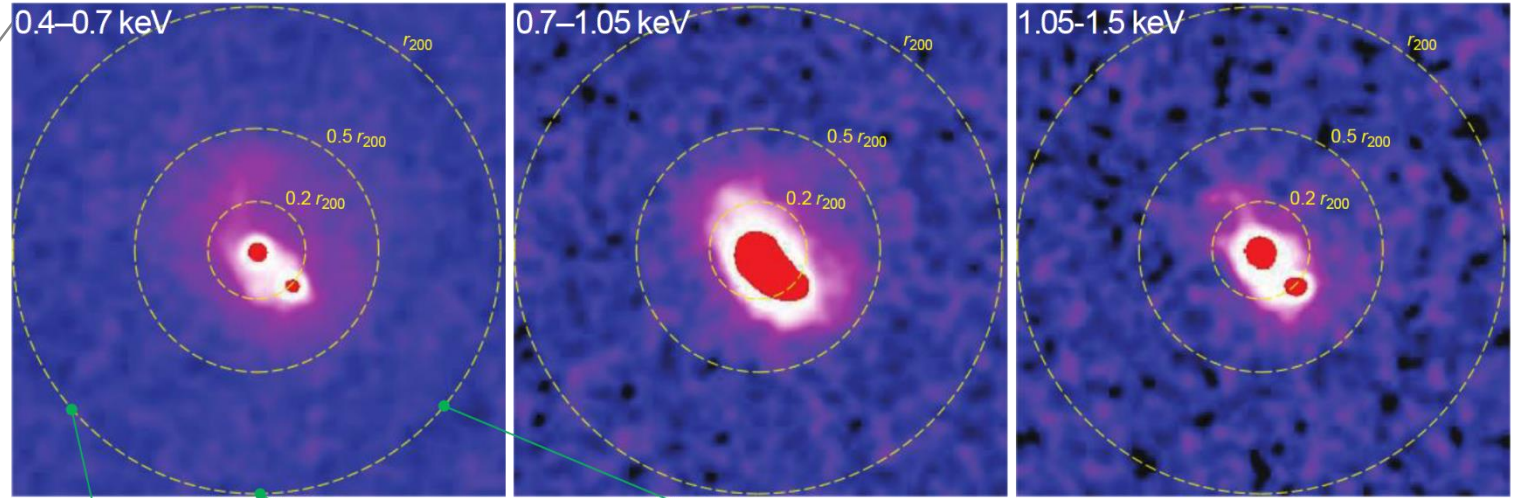
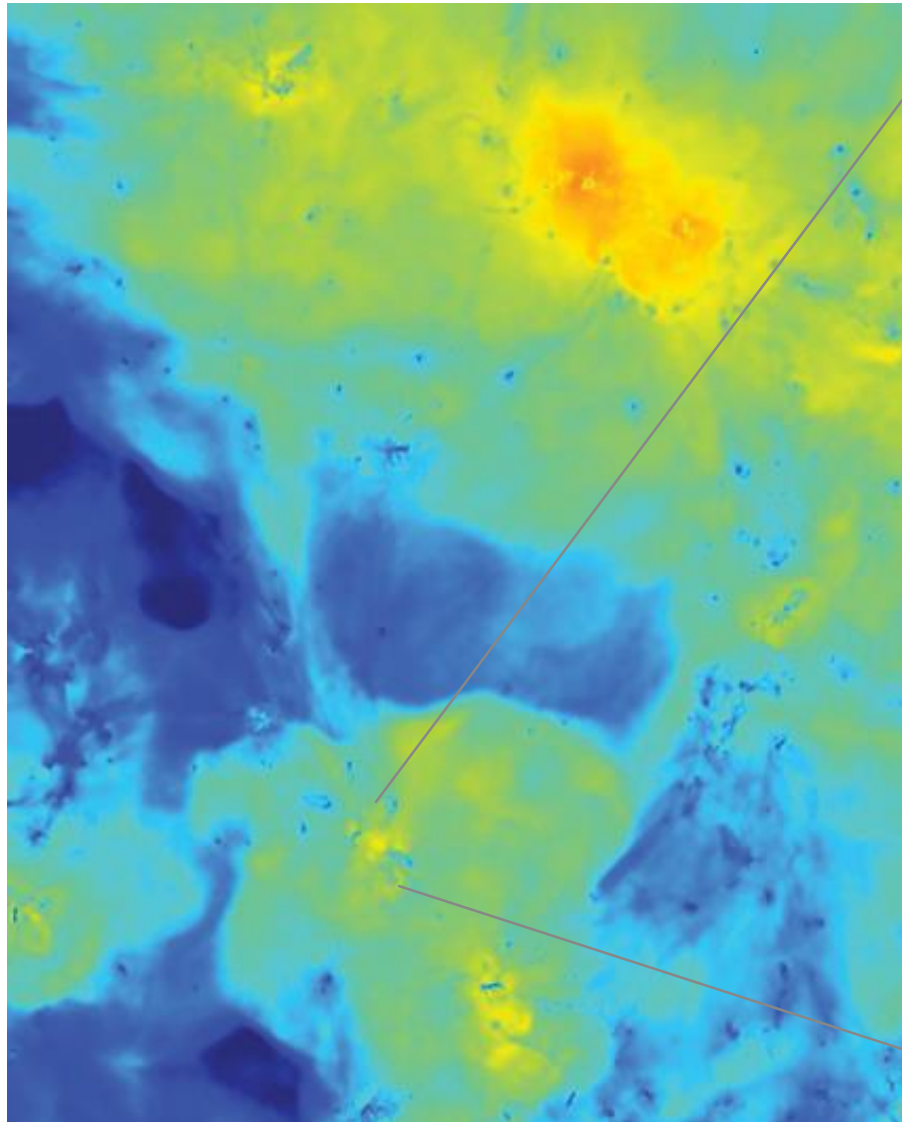


Sensitivity vs. angular resolution for high-throughput telescopes



- A flux limit of  $3 \times 10^{-19}$  erg/s/cm<sup>2</sup> in 0.5-2 keV band corresponds to a 10-photon detection limit
- $< 1''$  HPD desired to resolve majority of galaxies
- Extended sources require  $< 1''$  HPD to resolve key features

# Revealing the Unknown – ATHENA to Lynx



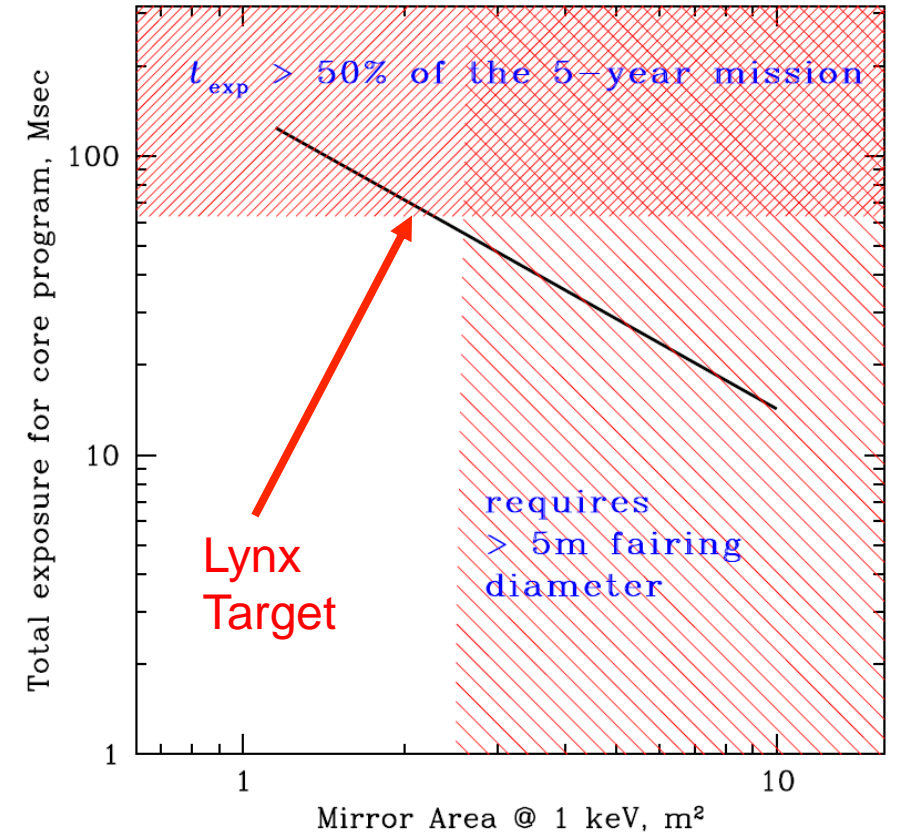
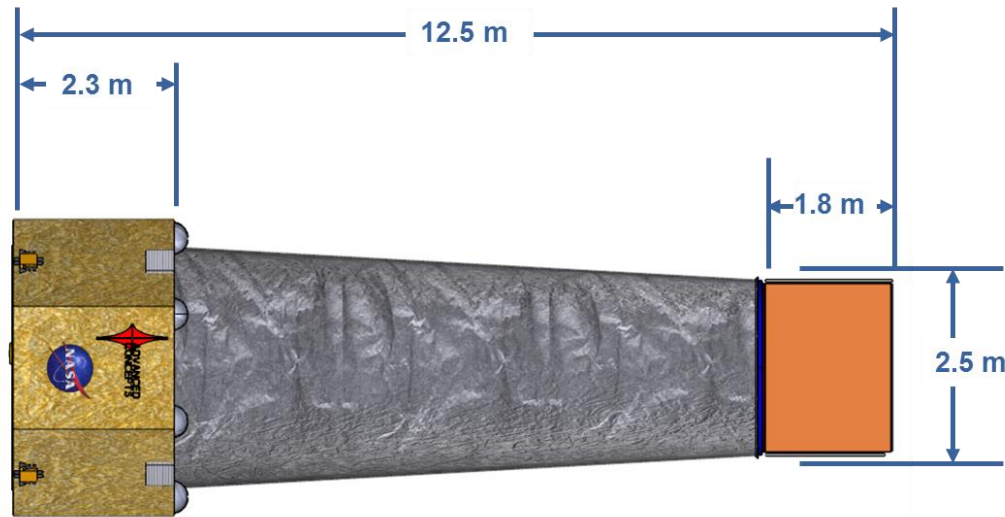
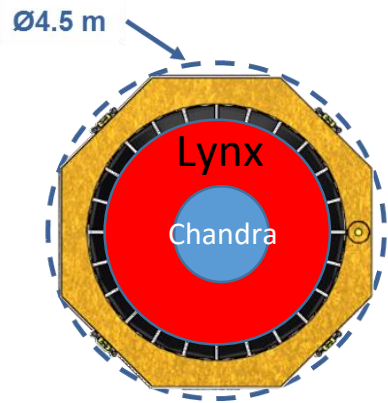
OVII  
OVIII  
 $f_{\text{AGN}} = 10^{-11} \text{ erg/s/cm}^2$

Simulated Lynx 500 ks images and 300 ks spectra revealing detailed halo density, temperature, metallicity, and velocity structures for a  $3 \times 10^{12} M_{\odot}$  galaxy at  $z = 0.03$ .

# Lynx Science Traceability Matrix

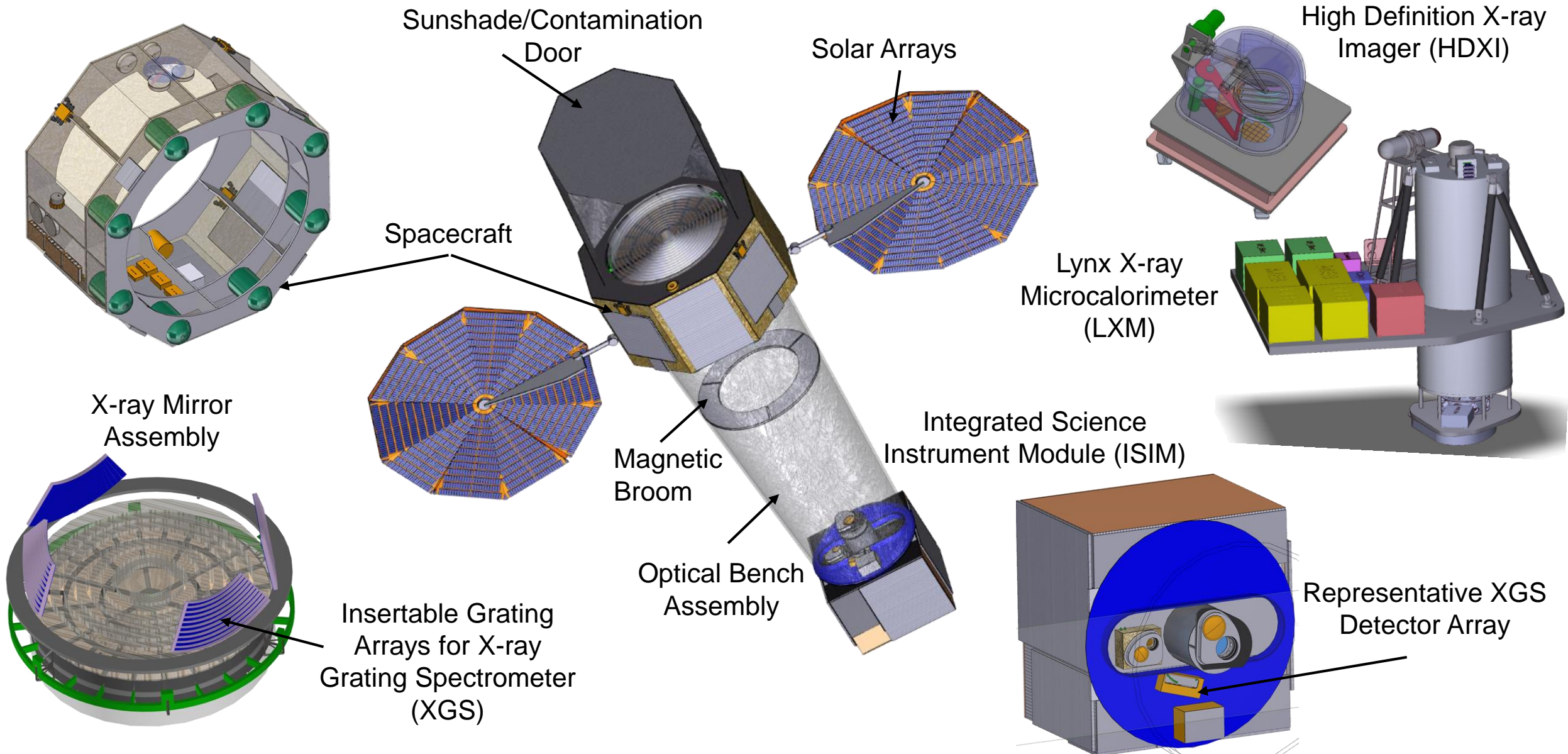
Science Theme/Goal	Performance Driver	Key observations, physical parameters, and measurement requirements		Mirror and Instrument Requirements			Also required by Core Science Objectives
				Instrument	Property	Value	
Observe the Dawn of Black Holes	Observe progenitors of supermassive black holes at their seed stage or soon after	Detection of black holes in $z=6-10$ galaxies down to a mass limit of $M_{\text{lim}}=10,000 M_{\text{sun}}$ over a volume with $10^3-10^7$ potential host galaxies	Surveys with flux limits [0.5–2 keV]: <ul style="list-style-type: none"> <li><math>1.6 \times 10^{-19}</math> erg/s/cm<sup>2</sup> over 1 deg<sup>2</sup></li> <li><math>7 \times 10^{-20}</math> erg/s/cm<sup>2</sup> over 400 arcminutes<sup>2</sup></li> </ul>	Mirror+ HDXI	Angular Resolution	<1 arcsecond (HPD) across the field, 0.5 arcseconds on-axis	<ul style="list-style-type: none"> <li>Trace how growth of SMBHs proceeds from cosmic dawn to <math>z \sim 3</math>, and how these SMBHs are connected to their host galaxies</li> <li>Response to LISA triggers of SMBH mergers</li> <li>Mapping diffuse baryons in Cosmic Web in emission</li> <li>Post-merger evolution of GW sources</li> </ul>
Reveal the Invisible Drivers of Galaxy and Structure formation	Observe the state of diffuse baryons in galactic halos	Direct imaging of hot gas in galactic halos in continuum and line emission	Image 15 low- $z$ galaxies with $M \sim 3 \times 10^{12} M_{\text{sun}}$ to reach 10% accuracy for derived thermodynamic parameters of gas in halos at $0.5 r_{200}$	Mirror+ HDXI	Effective Area @1 keV	2 m <sup>2</sup>	<ul style="list-style-type: none"> <li>Characterization of first galaxy groups at <math>z=3-4</math></li> <li>Detect entire mass spectrum of stars in active star forming regions to <math>d=5</math> kpc</li> <li>Obtain complete census of the diffuse, hot gas in star forming regions out to <math>d \sim 1</math> Mpc</li> <li>Protoplanetary disk dissipation time scales</li> <li>Statistics of X-ray binary populations in nearby galaxies to constrain binary evolution models and evolutionary paths to LIGO sources</li> </ul>
					Angular Resolution	1 arcsecond (HPD) across the FOV, 0.5 arcseconds on-axis	
	Field of view	10 arcminute radius					
	Spectral Energy Resolution @ 1 keV	60 eV					
Understand the Energetics, Physics, and the Impact of Energy Feedback	Absorption line spectroscopy of galactic halos near virial radius	Observe 80 sight lines to reach the sensitivity of 1 m Å for OVII and OVIII absorption lines, to characterize galactic halos near virial radius 60 galaxies with mass $10^{12}-10^{13} M_{\text{sun}}$		XGS	Spectral Resolving Power	5,000	<ul style="list-style-type: none"> <li>Energetics of AGN feedback</li> <li>State of gas in the Milky Way halo</li> <li>Impact of X-ray flares on protoplanetary disks, exoplanet conditions</li> <li>Physics of accretion on young stars</li> <li>Dynamics in pre-main sequence and young main sequence stars</li> <li>Stellar coronal mass ejections</li> </ul>
					Mirror + gratings effective area at OVII and OVIII lines	4,000 cm <sup>2</sup>	
Understand the Energetics, Physics, and the Impact of Energy Feedback	Spatially and spectrally resolve the structure of starburst-driven winds in low-redshift galaxies	Measure the outflow velocity profile with 100 km/s accuracy, and momentum & energy flux with TBD% accuracy		LXM	Spectrometer pixel size	1 arcsecond	<ul style="list-style-type: none"> <li>Energetics and statistics of AGN feedback</li> <li>Impact of X-ray flares on protoplanetary disks, exoplanet conditions</li> <li>Transit spectroscopy down of superearths around M-dwarfs</li> <li>Pre-explosion evolution of SN progenitors of recent core-collapse SNe within 10 Mpc</li> </ul>
					Energy resolution at $E < 1$ keV	0.3 eV	
Understand the Energetics, Physics, and the Impact of Energy Feedback	Determine the effects of AGN energy feedback on ISIM, and determine the physical state of gas near the SMBH sphere of influence in nearby galaxies	Resolve extended emission line regions, AGN inflated bubbles, and characterize the thermodynamic state of gas with 10% precision at or close to the Bondi radius from the central black hole		Mirror + LXM	On-axis angular resolution	0.5 arcseconds (HPD)	<ul style="list-style-type: none"> <li>Stellar spectroscopy in crowded regions</li> <li>Non-thermal physics in Galactic SNRs and PWNs</li> </ul>
					Spectrometer pixel size	0.5 arcseconds	
Understand the Energetics, Physics, and the Impact of Energy Feedback				LXM	Energy resolution @ 0.6-7 keV	<5 eV	
					Spectrometer subarray size	1 arcminute x 1 arcminute	
Unveil the Energetic Side of Stellar Evolution and Stellar Ecosystems	Observations of SNRs in Local Group galaxies to constrain explosion physics, origin of elements, and a relation between SN activity and local environment	Survey of young SNR in the Local Group galaxies	Measure spatial structure of SNRs in spectral lines of individual elements, and in non-thermal emission	LXM	Spectrometer pixel size	1 arcsecond	<ul style="list-style-type: none"> <li>Use metallicity in galaxy clusters to <math>z=3</math> as a probe of galaxy formation processes near the peak of cosmic star formation</li> <li>Study plasma physics effects related to dissipation of energy from AGN outflows</li> <li>State of hot gas, and feedback measurements in high-<math>z</math> galaxy clusters and groups</li> <li>Studies of hot ISIM and stellar feedback in active star forming regions in the Milky Way</li> <li>Identifications of young SN in Galactic SNRs</li> </ul>
					Spectrometer field of view	5 arcminutes x 5 arcminutes	
					Energy resolution @ 0.6-7 keV	<5 eV	
					Effective area @ 6 keV	1,000 cm <sup>2</sup>	

# Science Driven Telescope Configuration



**2 m<sup>2</sup> of effective area at  $E = 1$  keV is required to execute the science required by the three pillars in under 50% of the 5-year mission time. Implies outer diameter  $\phi = 3$ m and  $f = 10$ m**

# Lynx Observatory



# Lynx Mission Design

- Launch Vehicle:

Heavy class 5-m fairing

SLS co-manifested payload feasibility study underway

- Mission Life: 5 years, extendable to 20 years

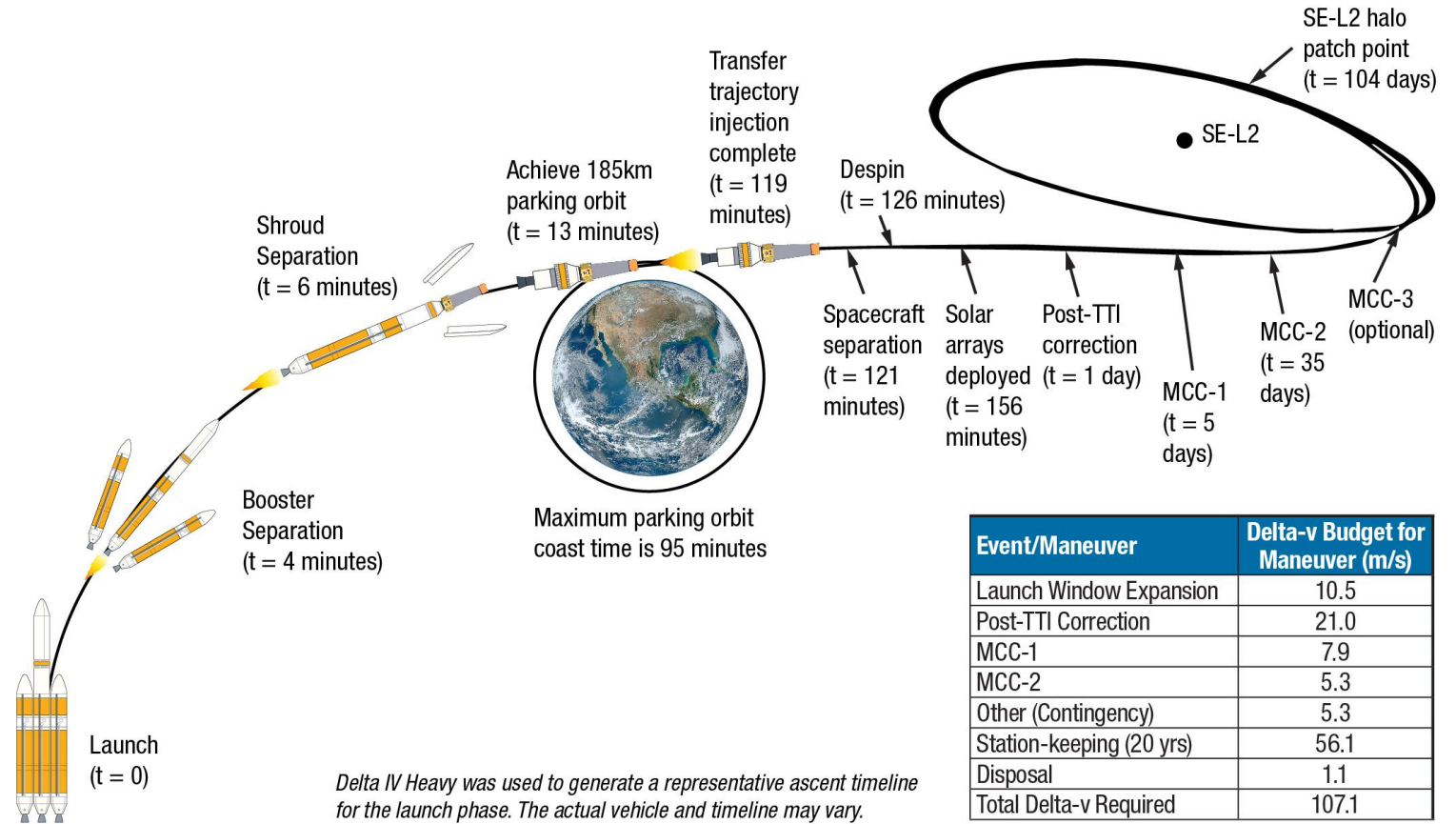
- Orbit: halo around SE-L2

- Communication: up to 3 x per day via DSN

- Mission Operations:

*Chandra*-like

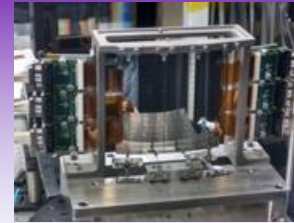
Primarily General Observer Program



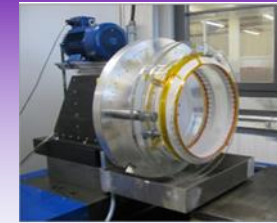
**Ascent timeline provided by NASA LSP for a Delta-IV Heavy and a target C3 of  $-0.7 \text{ km}^2/\text{s}^2$ .**

# Lynx Optics Technology Trade

- 3 actively funded Optics Technologies
- Kepner-Tregoe Trade Study chartered by Lynx STDT Chairs
- Recommendation to STDT on 8/8/18



Adjustable Segmented (SAO)  
**10699-24**



Full Shell (Brera / MSFC)  
**10699-36**



Silicon Meta-Shell (GSFC)  
**10699-22**

Decision Statement									
Description		Option 1		Option 2		Option 3			
Feature 1									
Feature 2									
Feature 3									
<b>Musts</b>									
M1		✓		✓		✓			
M2		✓		?		?			
M3		✓		✓		✗			
<b>Wants</b>									
Weights									
W1	w1%	Rel score		Rel score		Rel score			
W2	w2%	Rel score		Rel score		Rel score			
W3	w3%	Rel score		Rel score		Rel score			
100%		Wt sum =>		Score 1		Score 2		Score 3	
<b>Risks</b>		C   L		C   L		C   L			
Risk 1		M   L		M   L					
Risk 2		H   H		M   M					
<b>Final Decision, Accounting for Risks</b>									
C = Consequence, L = Likelihood									

## Process Overview

- Agree on **Evaluation Criteria** and **Weights**
- Document **Options** and **Description**
- **Evaluate** Options vs Criteria
- Reach **Consensus** on Evaluation
- Document **Risks, Opportunities**
- **Recommendation** accounting for Risks, Opportunities

# Lynx Optics Technology Trade

## Musts (Y/N?)

## Wants

<u>Science</u>	
M1	Optical performance will meet requirements flowing down from Science Trace Matrix
<u>Technical</u>	
M2	Credible roadmap from today's status to predict flight on-orbit performance
M3	Performance modeling tools related to current results are demonstrated to be credible
M4	Repeatable fabrication process based on current status
M5	Credible error budget that flows down to each mirror element
M6	Expected to survive launch
<u>Programmatic</u>	
M7	Show a credible plan to meet TRL 4-6
M8	Produce the mirror assembly within the Program schedule allocation

		Weight
<u>Technical</u>		
W1	Highest predicted technology readiness at Astro2020 by March 2020	12
W2	Relative demonstrated performance	12
W3	Relative credibility of roadmaps from today's status to predict flight on-orbit performance	12
W4	Relative simplicity of mirror assembly production process and test	10
W5	Relative contamination control (cost, complexity)	1
W6	Relative ease of implementing stray light control	3
W7	Relative ease of implementing thermal control and baffling	4
W8	Relative ease of creating a system option for charged particle mitigation	1
W10	Relative confidence in launch survivability	3
W11	Relative complexity and accuracy of ground calibration of mirror assembly	6
W13	Relative impact of technical accommodation	10
<u>Programmatic</u>		
W14	Lowest relative cost to reach TRL5 and 6	3
W12	Relative cost and credibility of grass-roots cost estimate of the mirror assembly through delivery	10
W16	Best assessment of the cost of ground calibration of mirror assembly	3
W17	Earliest date to reach TRL5 and 6	4
W18	Best assessment of the schedule to mirror assembly delivery	6
Total Weights		100

# Lynx Optics Technology Trade - Team

## Consensus Group

### Member at Large

1. Mark Schattenburg MIT

### Advocates

- |                      |             |                      |
|----------------------|-------------|----------------------|
| 2. Kiranmayee Kilaru | USRA / MSFC | Full Shell           |
| 3. Giovanni Pareschi | INAF / OAB  | Full Shell           |
| 4. William Zhang     | NASA GSFC   | Silicon Meta-shell   |
| 5. Peter Solly       | NASA GSFC   | Silicon Meta-shell   |
| 6. Paul Reid         | Harvard SAO | Adjustable Segmented |
| 7. Eric Schwartz     | Harvard SAO | Adjustable Segmented |

### Science Evaluation Team (SET)

- |                  |                |                 |
|------------------|----------------|-----------------|
| 8. Frits Paerels | Columbia Univ. | <b>SET Lead</b> |
| 9. Daniel Stern  | NASA JPL       |                 |
| 10. Ryan Hickox  | Dartmouth      |                 |

### Technical Evaluation Team (TET)

- |                              |                         |                 |
|------------------------------|-------------------------|-----------------|
| 11. Gabe Karpati             | NASA GSFC               | <b>TET Lead</b> |
| 12. Ryan McClelland          | NASA GSFC               |                 |
| 13. Lester Cohen             | Harvard SAO             |                 |
| 14. Gary Matthews            | ATA Aerospace, LLC      |                 |
| 15. Mark Freeman             | Harvard SAO             |                 |
| 16. David Broadway           | NASA MSFC               |                 |
| 17. David Windt              | Reflective X-ray Optics |                 |
| 18. Marta Civitani           | INAF / OAB              |                 |
| 19. Paul Glenn               | Bauer Associates, Inc.  |                 |
| 20. Ted Mooney               | Harris                  |                 |
| 21. Jon Arenberg             | NGAS                    |                 |
| 22. Chip Barnes/Bill Purcell | Ball                    |                 |

### Programmatic Evaluation Team (PET)

- |                      |            |                 |
|----------------------|------------|-----------------|
| 22. Jaya Bajpayee    | NASA ARC   | <b>PET Lead</b> |
| 23. John Nousek      | Penn State |                 |
| 24. Karen Gelmis     | NASA MSFC  |                 |
| 25. Steve Jordan     | Ball       |                 |
| 26. Charlie Atkinson | NGAS       |                 |

## Subject Matter Experts, Observers and Guests

- |                         |                              |
|-------------------------|------------------------------|
| Denise Podolski         | NASA STMD                    |
| Rita Sambruna/Dan Evans | NASA HQ                      |
| Terri Brandt            | NASA PCOS                    |
| Vadim Burwitz           | MPE                          |
| Susan Trolier-McKinstry | Penn State                   |
| Casey DeRoo             | U. Iowa                      |
| Kurt Ponsor             | Mindrum/Optics Working Group |
| Dan Schwartz            | SAO/Optics Working Group     |
| Steve Bongiorno         | MSFC                         |

## Steering Group

- |                   |                       |
|-------------------|-----------------------|
| Feryal Özel       | University of Arizona |
| Alexey Vikhlinin  | Harvard SAO           |
| Jessica Gaskin    | NASA MSFC             |
| Robert Petre      | NASA GSFC             |
| Doug Swartz       | NASA MSFC             |
| Jon Arenberg      | NGAS                  |
| Bill Purcell      | Ball                  |
| Lynn Allen        | Harris                |
| Jaya Bajpayee     | NASA ARC              |
| Gabe Karpati      | NASA GSFC             |
| Frits Paerels     | Columbia University   |
| Mark Schattenburg | MIT                   |

## Facilitator

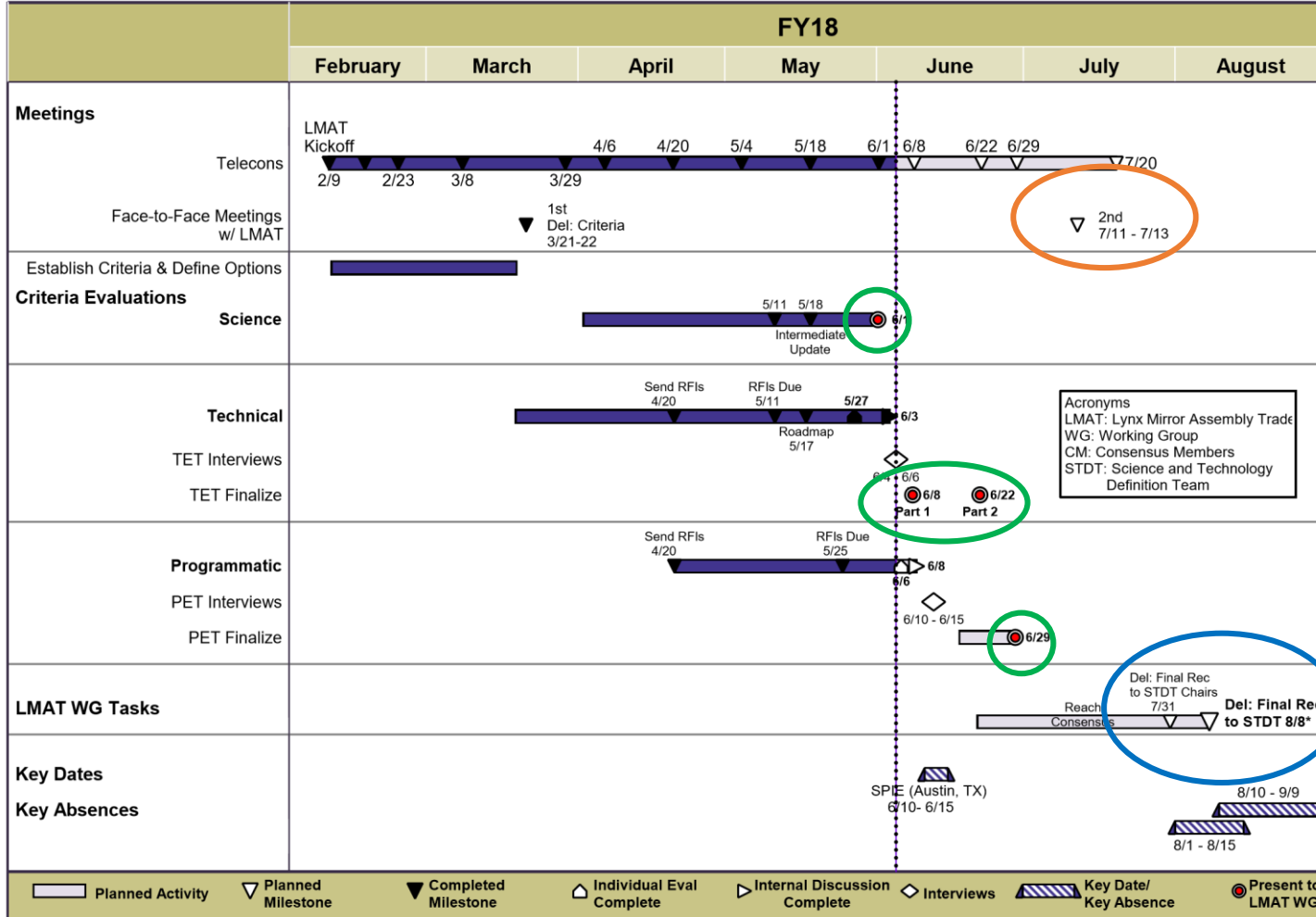
- |                |                |
|----------------|----------------|
| Gary Blackwood | NASA ExEP/ JPL |
|----------------|----------------|

# Lynx Optics Technology Trade

## LMAT Top Level

\* Tentative Dates

Rev. 2018 Jun 04



### LMAT Process:

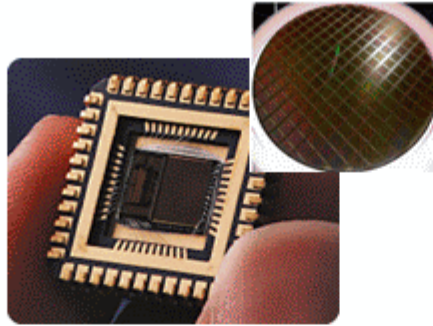
- ✓ Kickoff Telecon with Steering Group
- ✓ Kickoff Telecon with the LMAT Working Group
- ✓ Establish consensus criteria for a successful trade outcome
- ✓ Description of options for evaluation
- ➔ Subgroup evaluation of Science, Technical, and Programmatic criteria
  - Reach consensus by LMAT Consensus Members on evaluation criteria, risks, and opportunities
  - Reach consensus on LMAT Consensus Member recommendation
  - LMAT delivery recommendation to the STDT Chairs

➔ Recommendation to STDT (8/8/18)

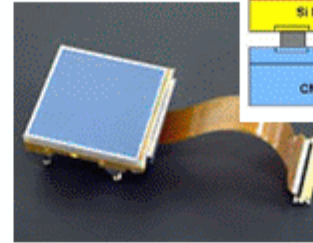
Planned Activity  
  Planned Milestone  
  Completed Milestone  
  Individual Eval Complete  
  Internal Discussion Complete  
  Interviews  
  Key Date/Key Absence  
  Present to LMAT WG

# Lynx Instrument Suite

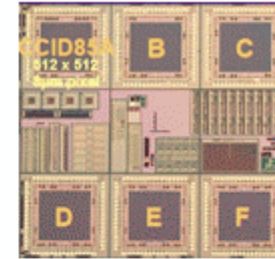
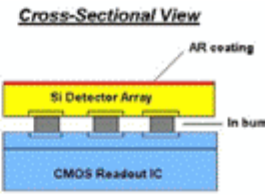
High Definition X-ray  
Imager (HDXI)



Monolithic  
CMOS



Hybrid CMOS

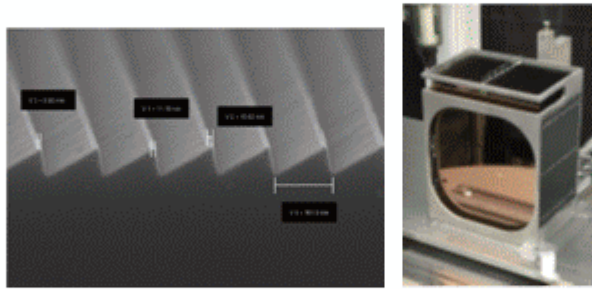


Digital CCD  
with CMOS  
readout

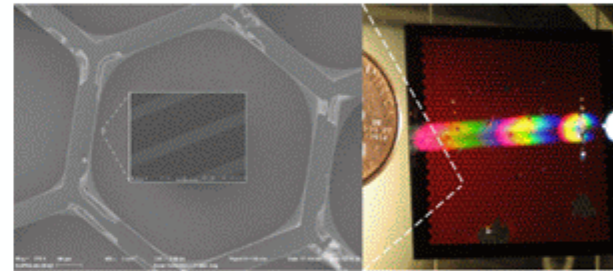
## STATUS

IDS (MSFC)  
IDL (GSFC)  
**10699-37**  
**10699-42**  
**10709-14**

X-Ray Grating  
Spectrometer  
(XGS)



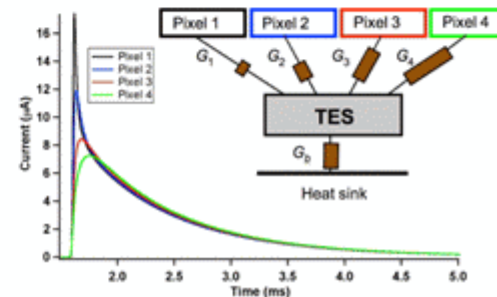
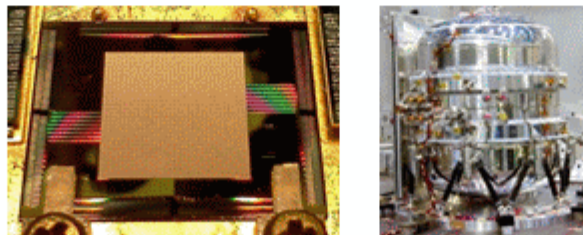
Off-Plane Grating  
Array



Critical Angle Transmission Grating  
Array

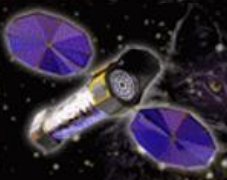
IDS (MSFC)  
**10699-39**  
**10699-40**

Lynx X-ray  
Microcalorimeter (LXM)



IDL (GSFC)  
**10699-38**

**Session 9: Lynx**  
**Tuesday: 1:30 PM - 3:30 PM**  
**Location: CC Level 3, Room 5A/C**



# *It's Time for Lynx!*

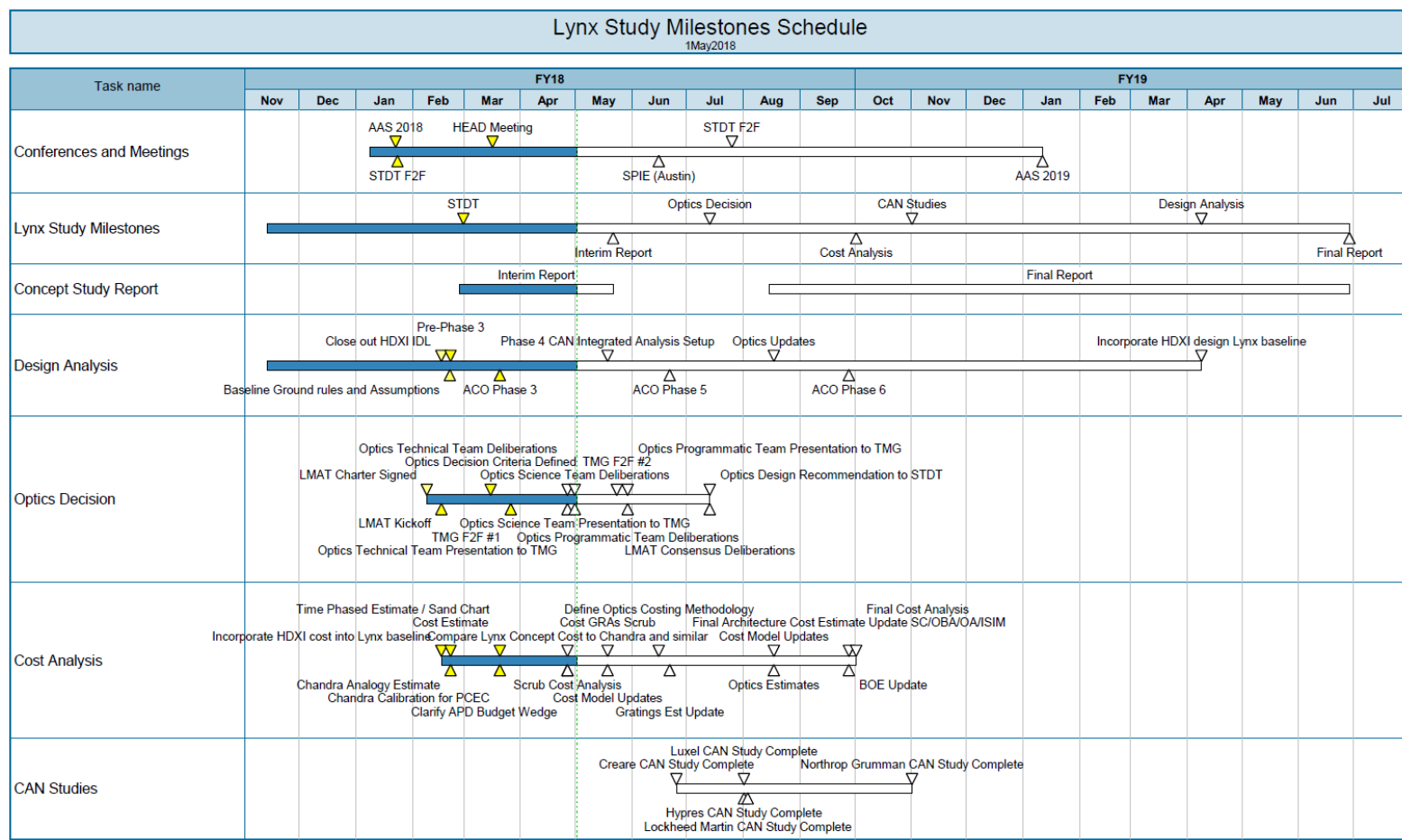
## Enabling Technologies TRL Assessment Summary

At DSMT request, the ExE, PCOS, and COR Program Offices and the Aerospace Corp assessed the TRL of tech gaps submitted by the teams as of Dec. 2016. Assessment was presented June 2017.

ID	Technology Gap	TRL	
1	High-Resolution 'Lightweight' Optics	2	<b>Multiple Technologies 3-4 by mid-2020</b>
2	Non-deforming X-ray Reflecting Coatings	3	
3	Megapixel X-ray Imaging Detectors (HDXI)	3	<b>Multiple Technologies</b>
4	Large-Format, High Spectral Resolution X-ray Detectors (LXM)	3	<b>Subsystem Heritage</b>
5	X-ray Grating Arrays (XGS)	4	<b>Multiple Technologies</b>

# Forward Work

- Complete Optics Technology Study: 8/8/18
- Continue Instrument Design Studies, observatory & mission concept design: on-going through end of 10/18
- Complete Technology Roadmap for Optics and Instruments: on-going through 12/18
- Complete Risk Assessment and Independent Costing for Lynx: 10/15/18 (TBS)
- Freeze point design: 1/14/19
- Initiate Final Report: 1/14/19
- Deliver Final Report to HQ: 6/28/19



# Partnerships & Lynx Team

## Partnerships

Orgs.	Effort
GSFC	HDXI IDL runs LXM IDL & costing contributed effort!
JPL + Community	Optics Trade Study facilitation & Evaluation Contributed effort!
Interim Report Red Team	Chair: C. Kouveliotou (GWU) Contributed effort!
CAN Study Partners	<u>Creare</u> : LXM cryocooler study <u>Hypres</u> : superconducting ADC study <u>Luxel</u> : blocking filter fab. & test <u>Lockheed Martin</u> : LXM cryo-system design <u>Northrop Grumman (w/Ball &amp; Harris)</u> : Observatory design & analysis >50% overall contributed contract value!
UAH	MBSE modeling of interfaces, requirements & Observatory error budget



Over 275 total members!

- **22 STDT Members**
- **8 Science Working Groups**
- **Optics Working Group**
- **Calibration Working Group**
- **Communications Working Group**
- **Instrument Working Group**
- **Ex-officio International Members**

# JATIS Special Section on Lynx

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## Scope

The Lynx X-Ray Observatory will radically change the way we see the universe by answering some of the most persistent questions of our time: How and when did the first supermassive black holes form, and how do they co-evolve with their host galaxies? What processes drive the formation and evolution of the largest structures in the universe? What high-energy processes play critical roles in the birth and death of stars, and how do they influence planet habitability?

The ability to answer these questions is made possible through the Lynx payload design. Currently in concept phase, Lynx is designed to have leaps in capability over NASA's existing flagship Chandra and the European Space Agency's (ESA) planned Athena mission. More specifically, Lynx will have a 50-fold increase in sensitivity via the coupling of superb angular resolution with high throughput, 16× larger field of view with arcsecond or better imaging, and 10 to 20 times higher spectral resolution for both point-like and extended sources. The primary purpose of this special section is to present details of the Lynx observatory and expected on-orbit performance. Related topics of interest include, but are not limited to:

- instrument and x-ray optics descriptions (system and subsystems)
- structural, thermal, and optical performance
- in-flight performance predictions and modeling
- data analysis algorithms
- instrument-related software systems
- spacecraft systems critical to in-flight performance
- systems engineering practices
- applied lessons learned from previous missions
- planning for the 2030s.

This special section focuses on technical aspects of the Lynx mission and instrumentation. Purely science discussions are to be published elsewhere. All submissions will be peer reviewed. Peer review will commence immediately upon manuscript submission, with a goal of making a first decision within 6 weeks of manuscript submission. Special sections are opened online once a minimum of four papers have been accepted. Each paper is published as soon as the copyedited and typeset proofs are approved by the author. Submissions should follow the **guidelines of JATIS**. Manuscripts should be submitted online at <http://JATIS.msubmit.net>. A cover letter indicating that the submission is intended for this special section should be included.



X-RAY OBSERVATORY  
**LYNX**

## THE LYNX X-RAY OBSERVATORY

### Publication Date

Special section papers are published as soon as the copyedited and typeset proofs are approved by the author.

### Submission Deadline

Submissions are due 1 October 2018.

[Submit a Manuscript](#)

[Author Guidelines](#)

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## Important Information:

- **Papers due October 1, 2018**
- **Published in Spring 2019**
- <http://JATIS.msubmit.net>



**Thank you!**

<https://wwwastro.msfc.nasa.gov/lynx/>

**MSFC X-ray Astrophysics Group is hiring!**  
Announcement coming soon [<https://www.usajobs.gov/>]

<https://www.worldscientific.com/worldscinet/jai>

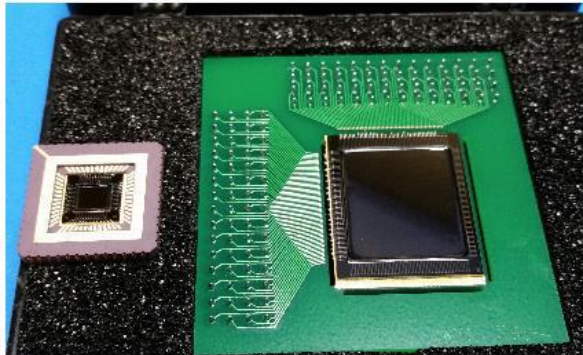
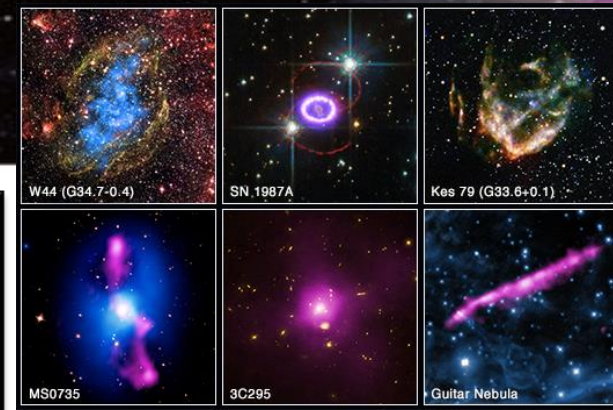


# Backup Slides

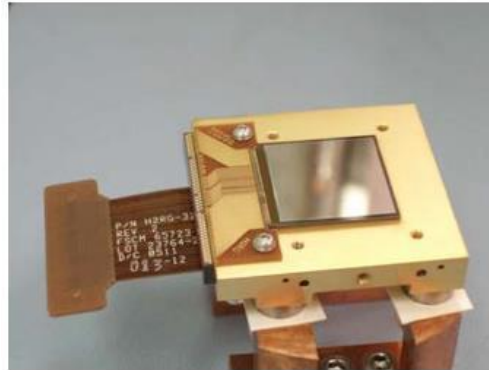
# High Definition X-ray Imager (HDXI)

Every X-ray observatory launched in the past 20 years has flown CCDs. Lynx will use Active Pixel Sensors.

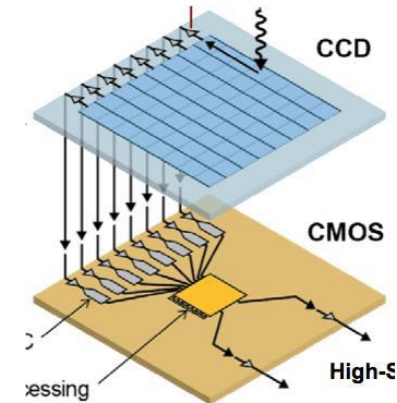
\*CMOS (Complementary metal oxide semiconductor)



Monolithic CMOS  
(Sarnoff/SAO, and MPE)



Hybrid CMOS (TBE/PSU)



Digital CCDs w/  
CMOS readout (LL/MIT)

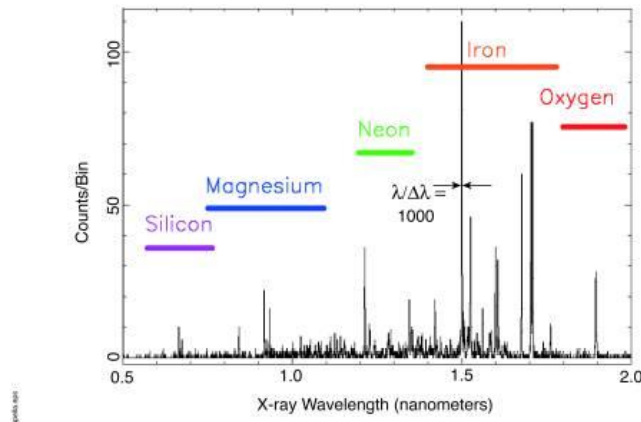
## Key improvements over CCDs

- Orders of magnitude higher frame rates
- Significantly improved radiation hardness
- Fully addressable
- Lower power
- Near room temperature operation
- Large format (up to 4Kx4K) abuttable devices
- Near Fano-limited resolution over entire bandpass

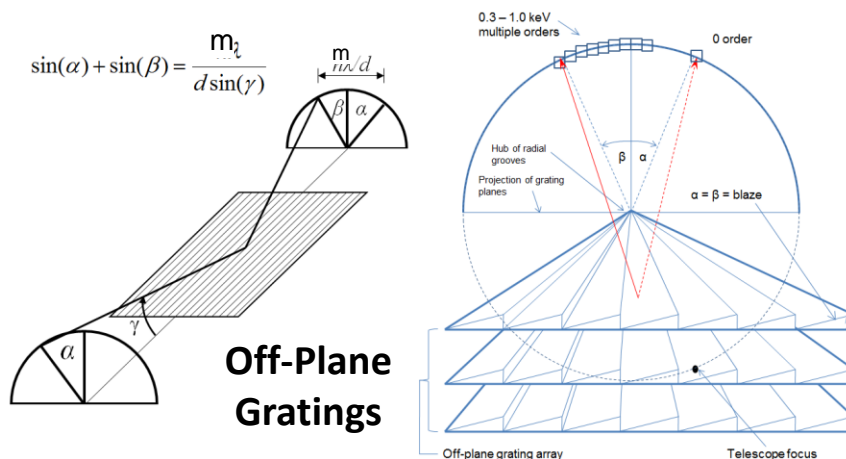
# X-Ray Grating Spectrometer (XGS)

When there is a need to separate light of different wavelengths with high resolution, in the soft X-ray band (0.3-1.0 keV) then a diffraction grating is the tool of choice!

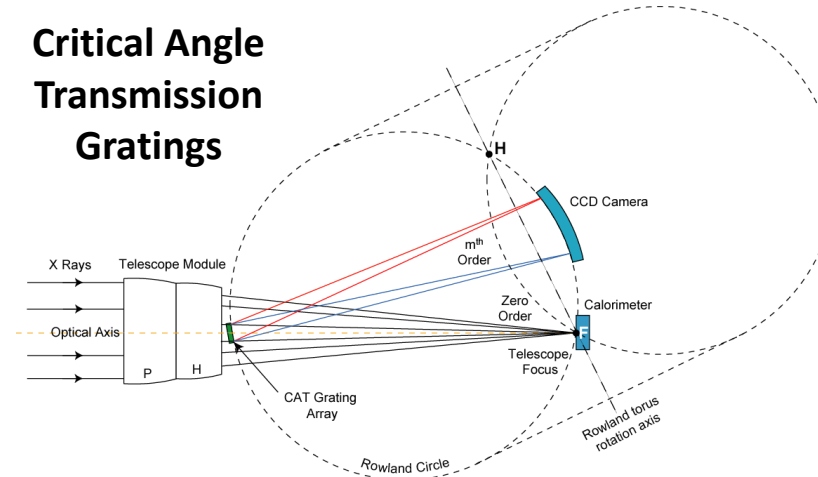
Chandra Observatory X-ray Spectrum of Binary Star Capella



Lynx XGS will provide high spectral resolution ( $R > 5000$ ) and high effective area ( $\sim 4000 \text{ cm}^2$ ) at low energies (0.3-1.0 keV)

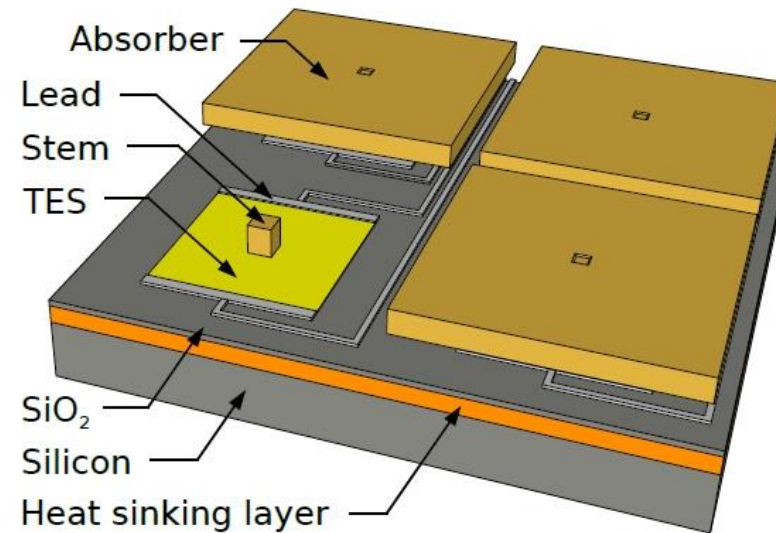
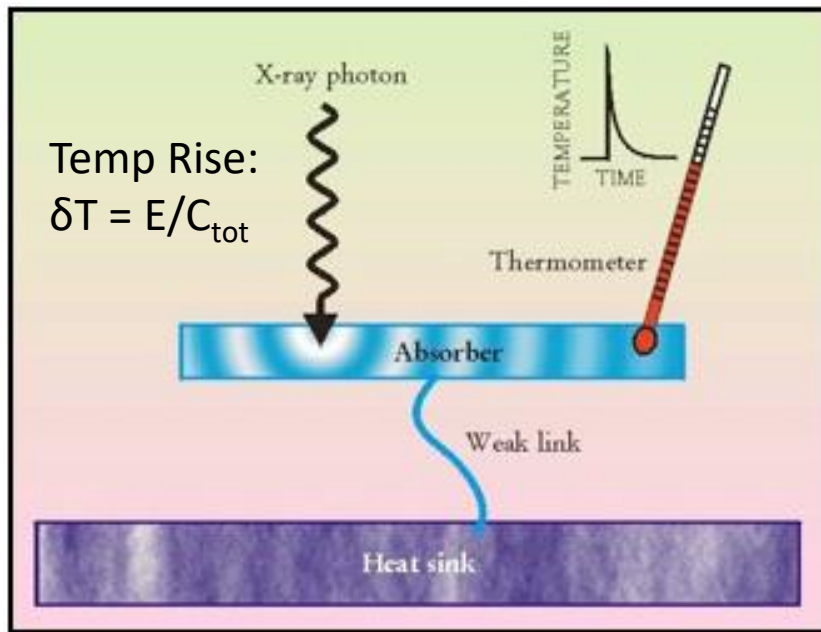


## Critical Angle Transmission Gratings



# Lynx X-ray Microcalorimeter (LXM)

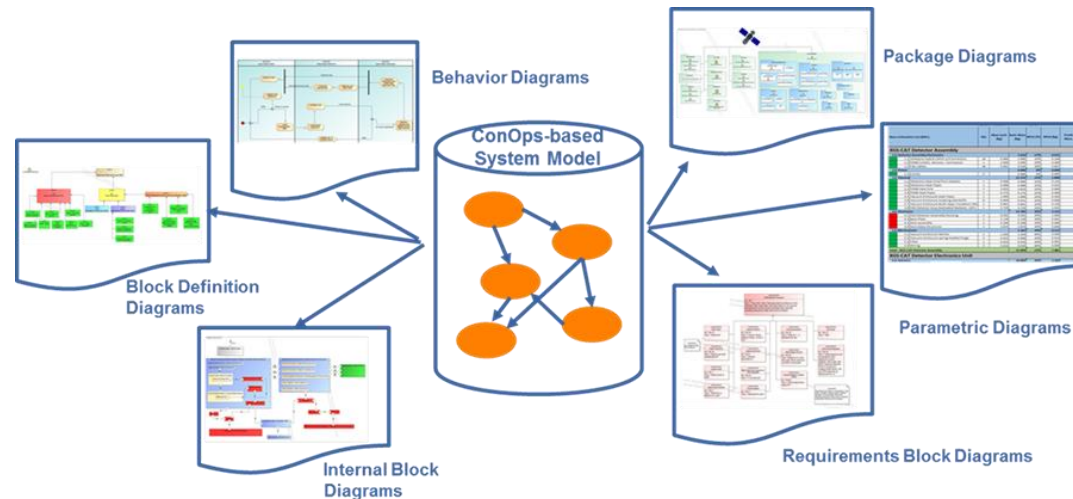
Converts individual incident X-ray photons (0.2-7 keV) into heat pulses and measure their energy via precise thermometry. Must operate at cold temps of ~50 mK.



- Mapping hot gas in nearby galaxies
- Determining the state of the gas in high-z groups and clusters
- Supernova feedback studies
- Observing spatially-resolved plasma outflow velocities (O VII lines)

# MBSE Modeling

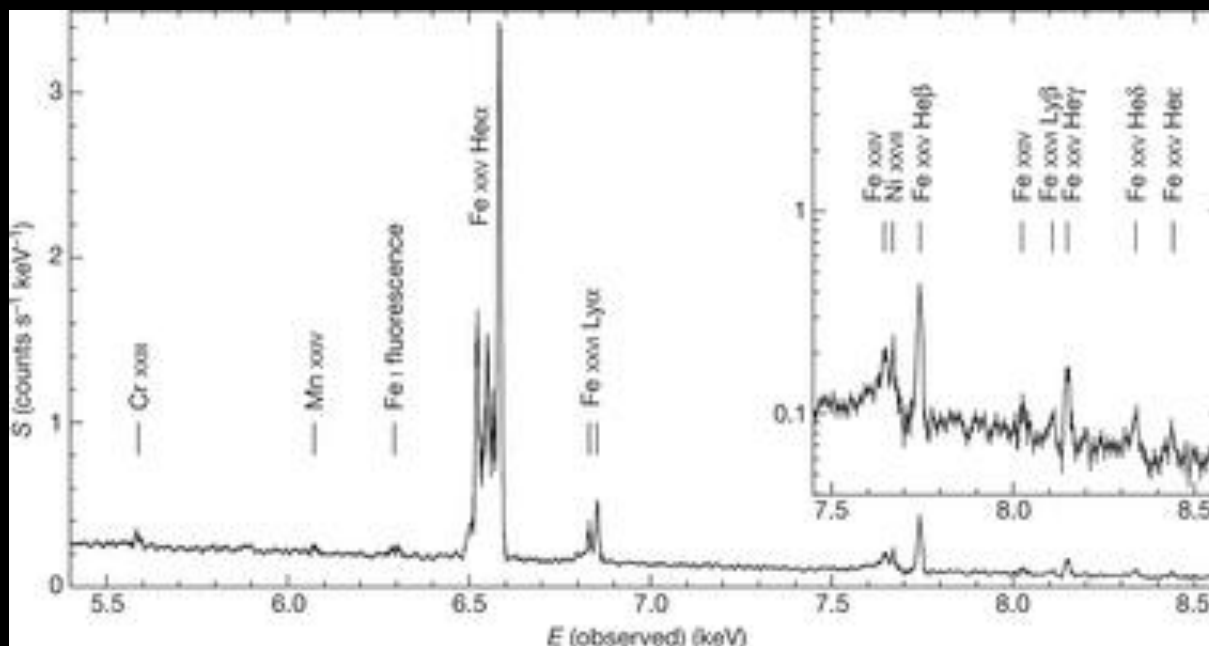
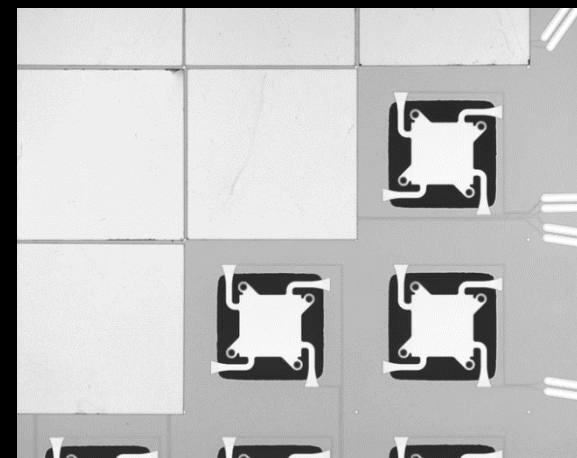
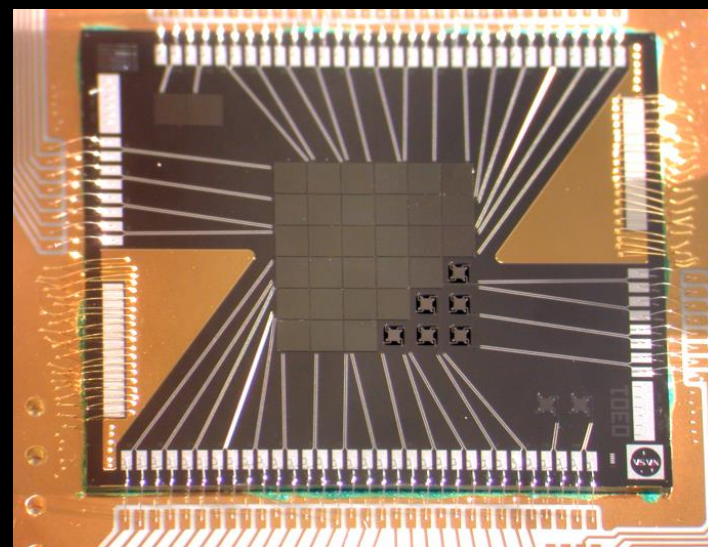
- Partnering with UAH School of Industrial and Systems Engineering to utilize MBSE / SysML modeling to strengthen SE approach to the Study
- Early model efforts focused on development of ConOps-type content
  - Early stage of study consistent with ConOps development
  - Identifies interface issues early
  - Focusing effort on cost, schedule, and requirements drivers
- Working with Integrated Design Analysis team to develop error budget and observatory stability models



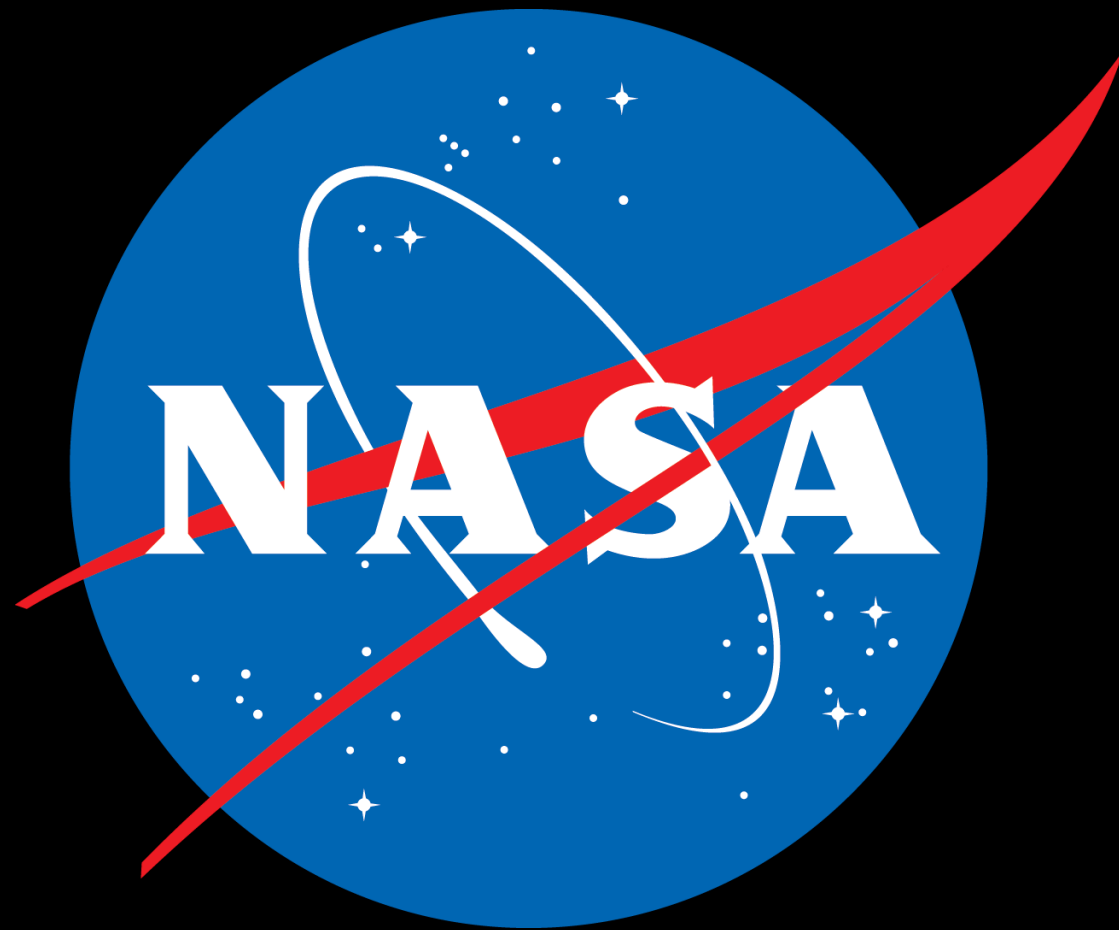
# The X-ray Astronomy Recovery Mission

- XARM (launch 2021)
- Unfortunate loss of Hitomi, March 2017
- 4<sup>th</sup> time lucky?

- 4 eV resolution at 6 keV.
- 6 x 6 array of 820  $\mu\text{m}$  pixels (30" pixe 3' FOV)
- Ion-implanted thermistors; manually attached absorbers
- Technology (eg. JFET amplifiers) limits number of pixels



- Spectrum of Perseus cluster core
- Discovered remarkably quiescent atmosphere
  - Gas has velocity dispersion of  $\sim 164 \pm 10$  km/s in the region 30–60 kiloparsecs from central nucleus.



# Lynx Concept Study Interim Report



## Interim Report delivered to HQ: 3/30/18

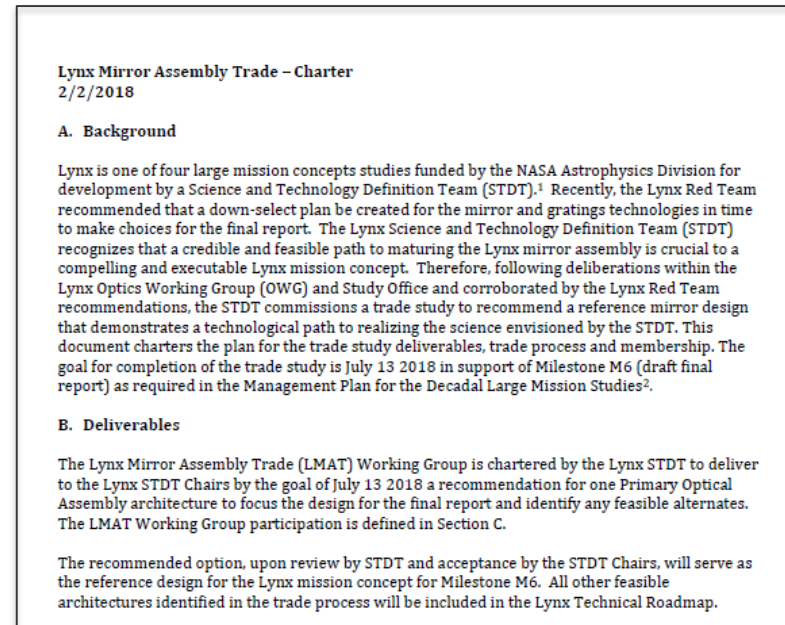
- Delivery included:
  - Interim report
    - Reviewed by Independent Red Team
    - Chair: C. Kouveliotou
  - Concept Maturity Level (CML) concordance matrix
  - List of supplemental documents for use by HQ review team
  - Preliminary costing not included
- Link to report and contents here:  
<https://drive.google.com/drive/folders/1jf46nZLqDdrG4Xdi8xOn5sfC-cQN7hgA>
- Currently in Review by HQ-appointed team
- Comments due ~early June
- Edited document for public release due ~early July



# Lynx Mirror Architecture Trade

## Why Conduct this Trade, and Why Now?

- Charter from STDT chairs calls for a recommendation for “**one DRM Mirror Optical Assembly architecture to focus the design for the final report and identify any feasible alternates.**”
- The Lynx Mirror Architecture Trade (LMAT) Working Group represents scientific and technical leadership across academia, NASA, and industry
- Full signed charter: [Lynx Optics Trade Study](#)



\* \* \*

