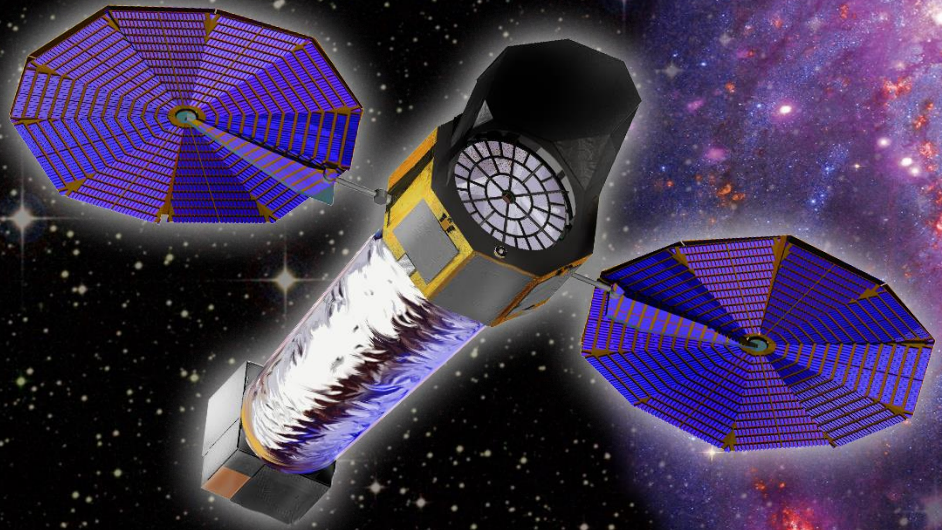
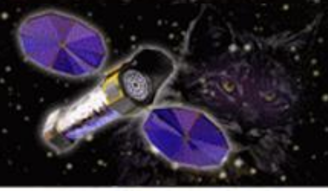
The Lynx X-ray Observatory: Concept Study Overview and Status

X-RAY OBSERVATORY
LYNX
Revealing the Invisible Universe

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



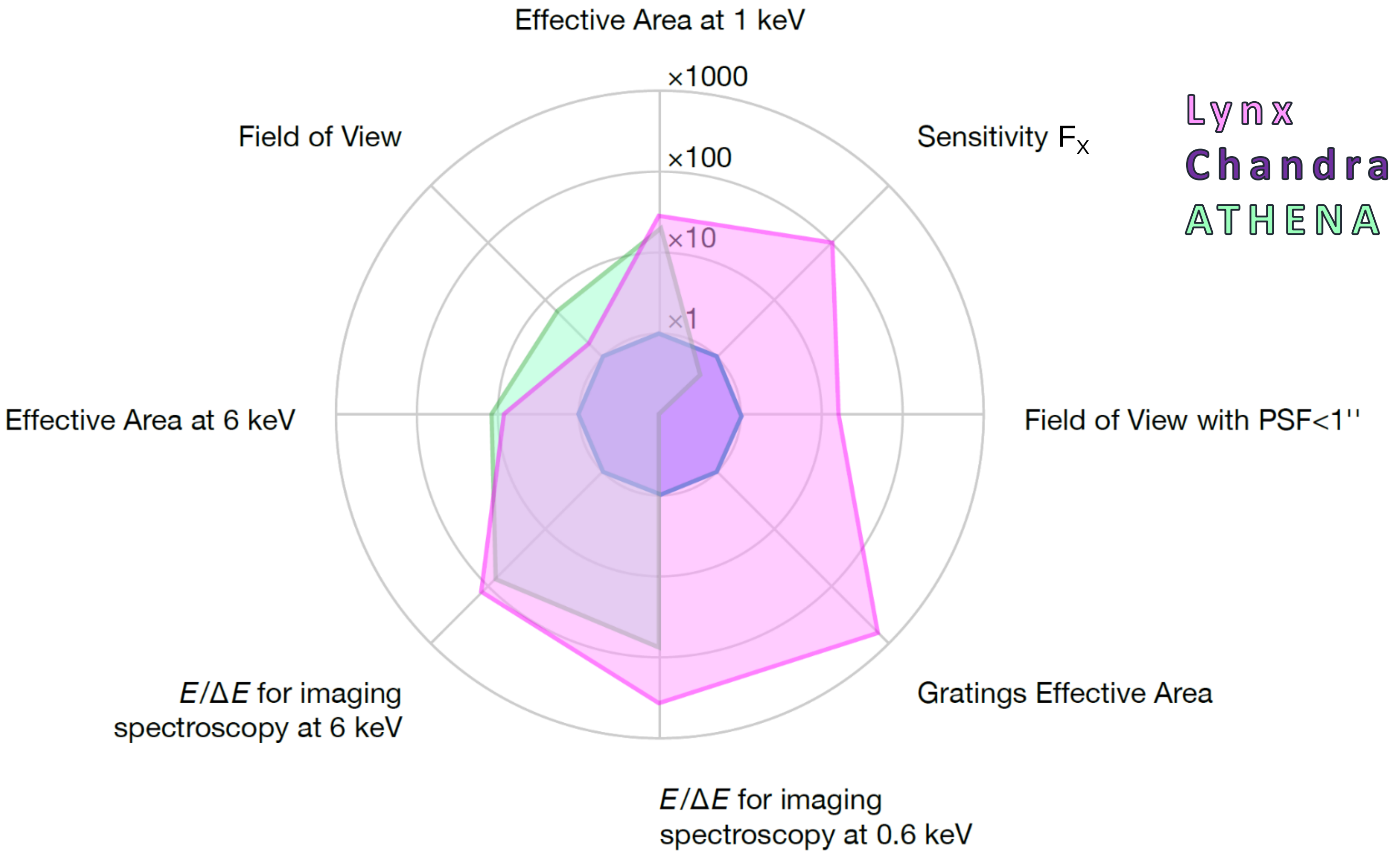


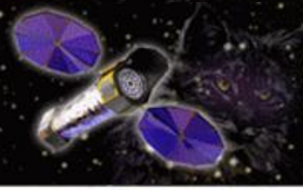
Meet Lynx!

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:

- 50x gain in sensitivity over Chandra and 100x gain over Athena, 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

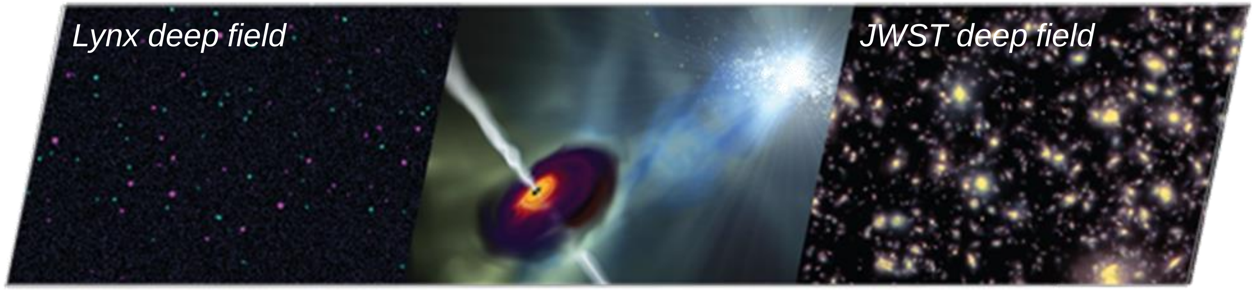




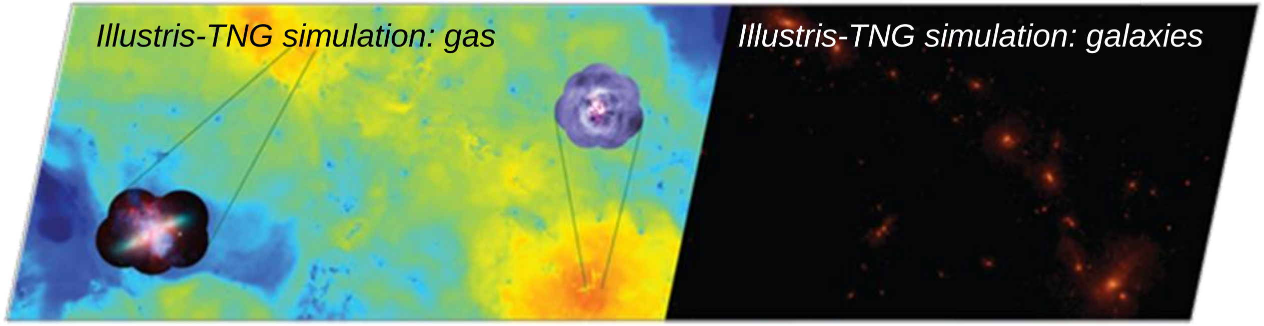
The Science of Lynx

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



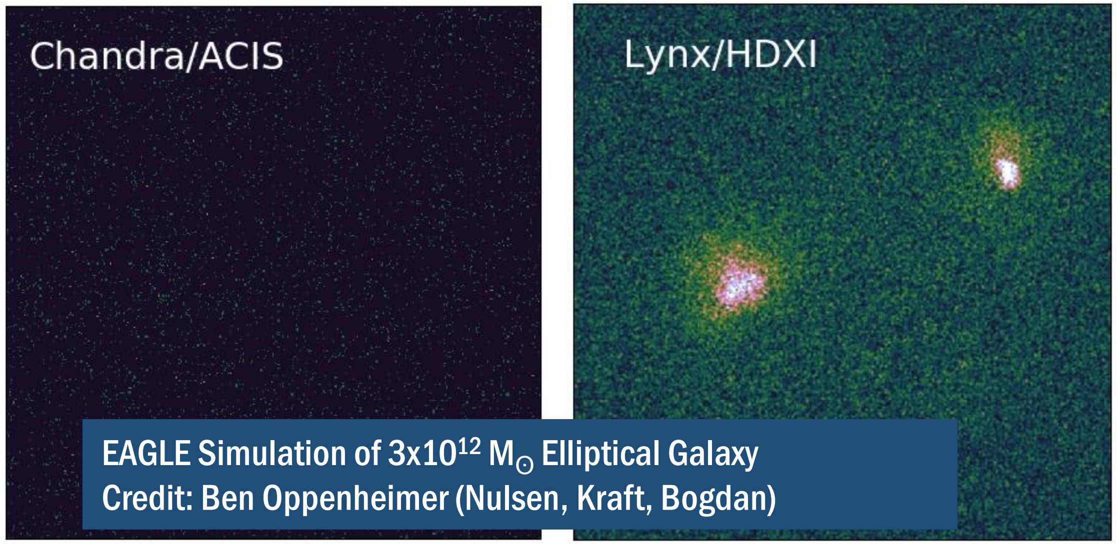
The Energetic Side of Stellar Evolution and Stellar Ecosystems

Endpoints of stellar evolution

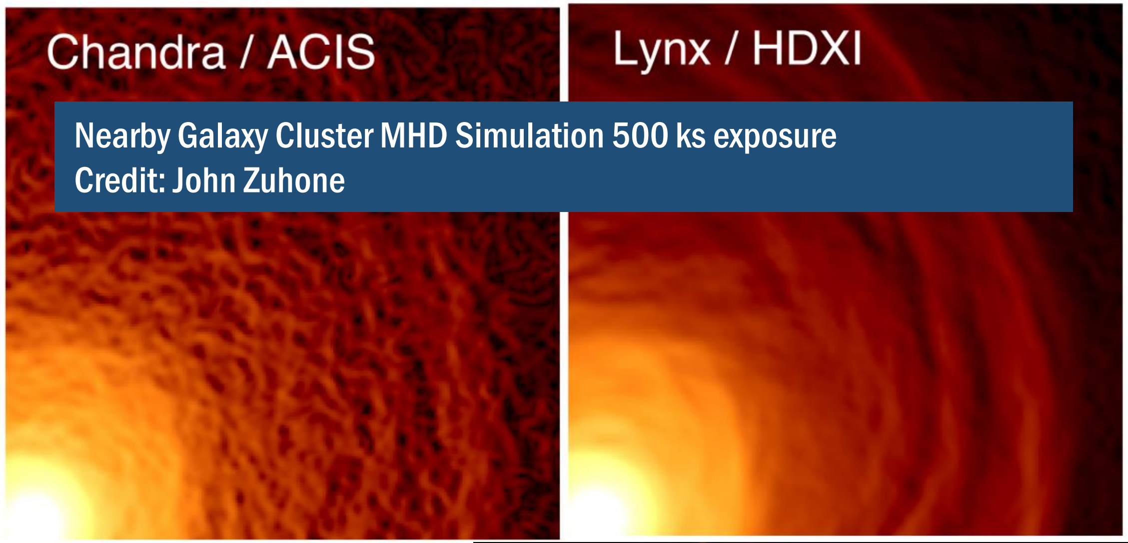
Stellar birth, coronal physics, feedback

Impact of stellar activity on habitability of planets

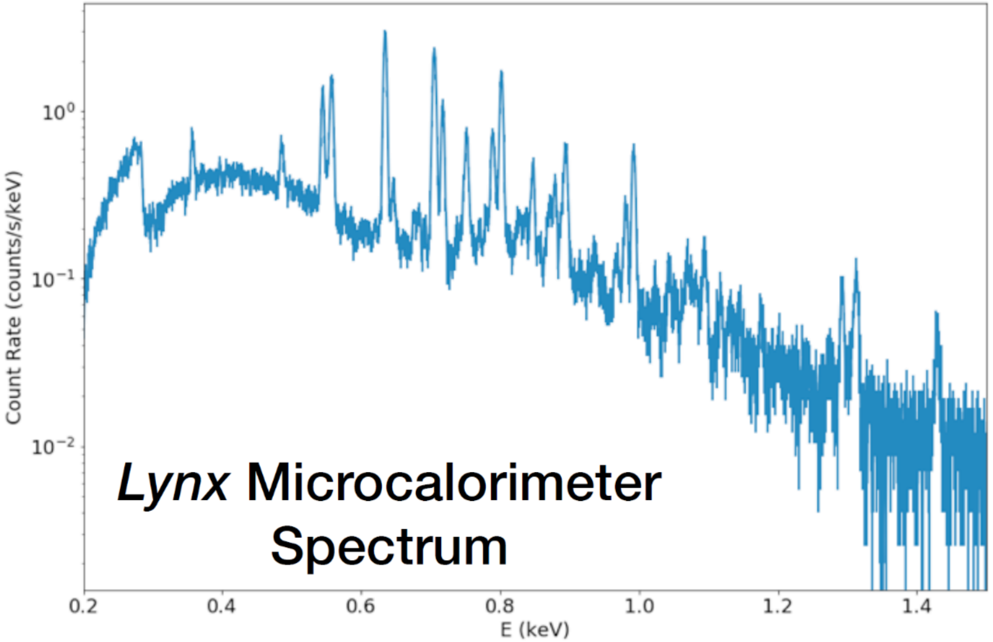
Revealing the Unknown – Chandra to Lynx



EAGLE Simulation of $3\text{x}10^{12}$ $M_{\odot}$ Elliptical Galaxy
Credit: Ben Oppenheimer (Nulsen, Kraft, Bogdan)

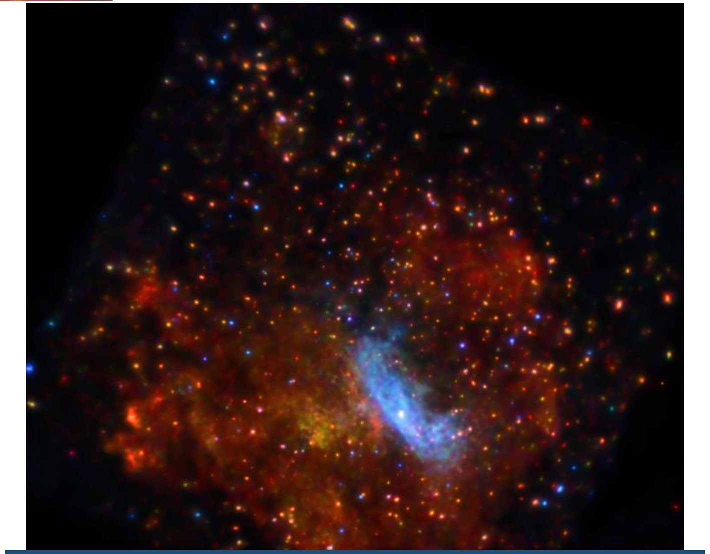


Nearby Galaxy Cluster MHD Simulation 500 ks exposure
Credit: John Zuhone



Lynx Distinguishing Features:

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



SNR MSH 11-62
Credit: NASA/CXC/SAO/P. Slane et al.

Revealing the Unknown – ATHENA to Lynx

J1342+0928; z=7.54; 800 million Msun!

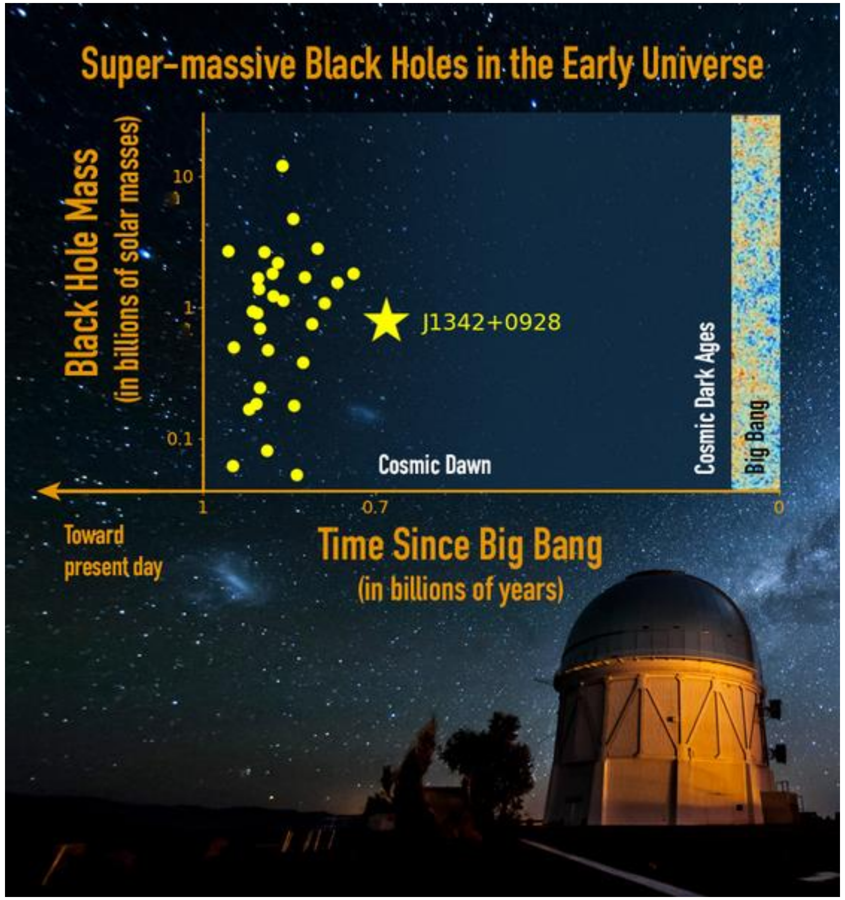
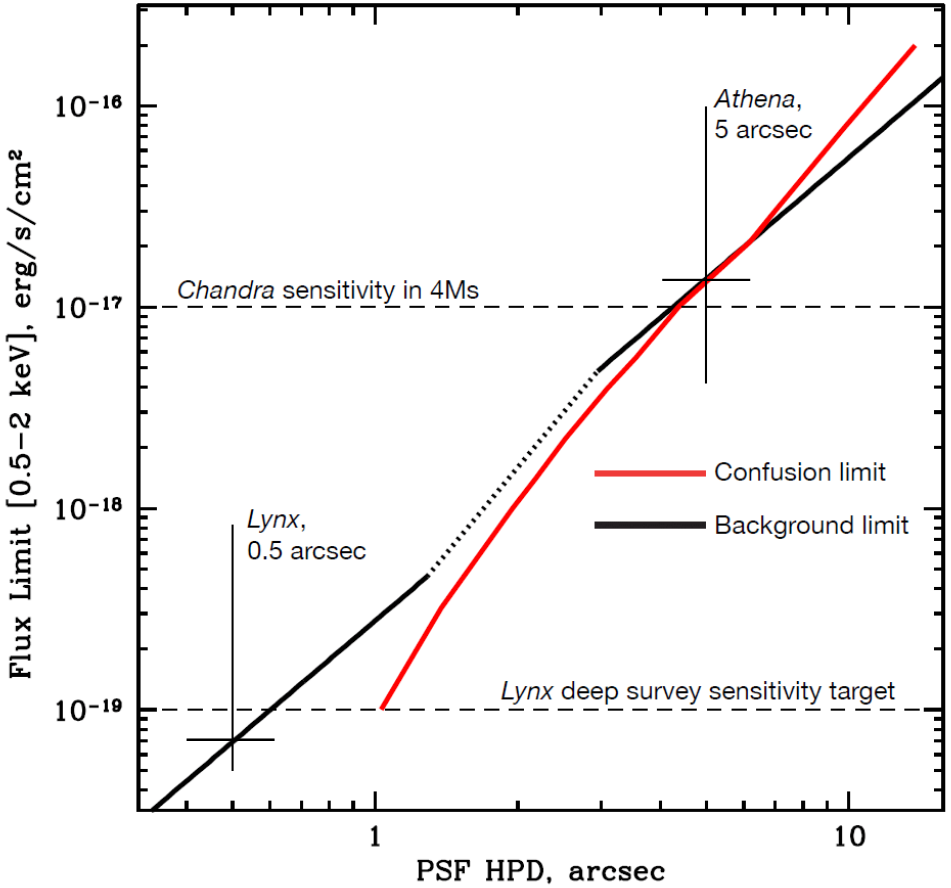


Image credit: Jinyi Yang/UA; Reidar Hahn/Fermilab; M. Newhouse/NOAO/AURA/NSF

Illustris simulated deep fields

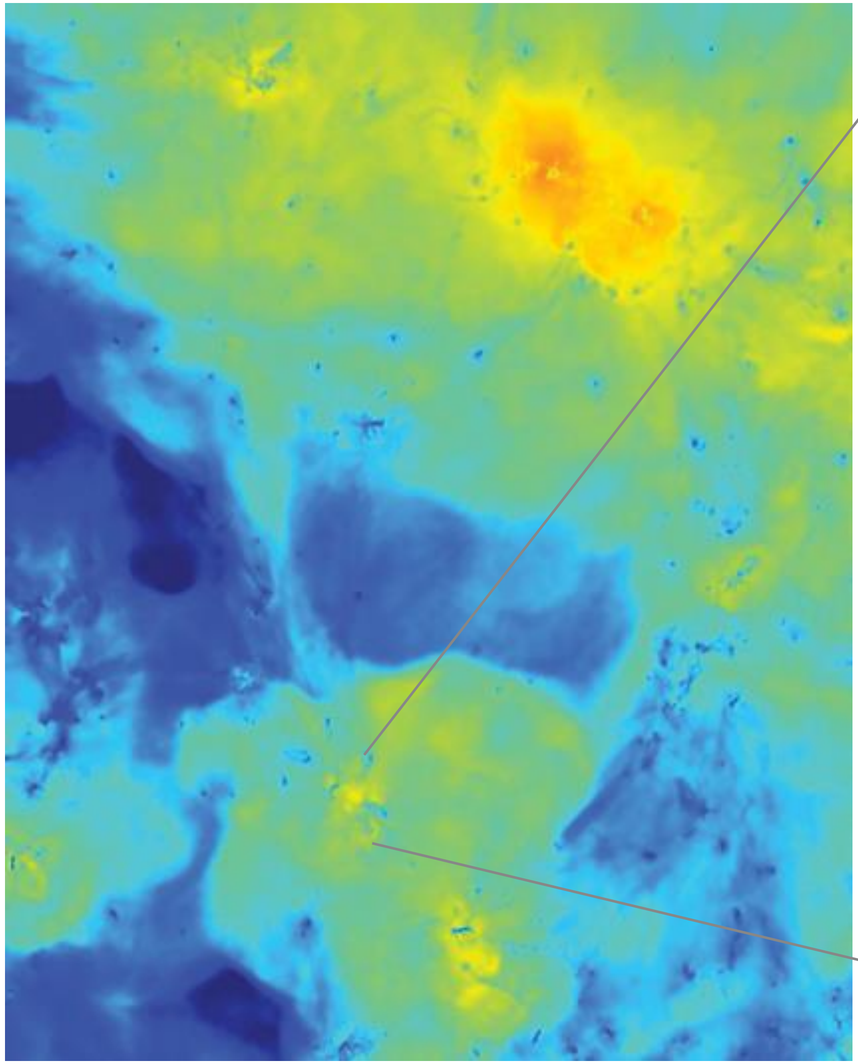
purple = AGNs, green=galaxies

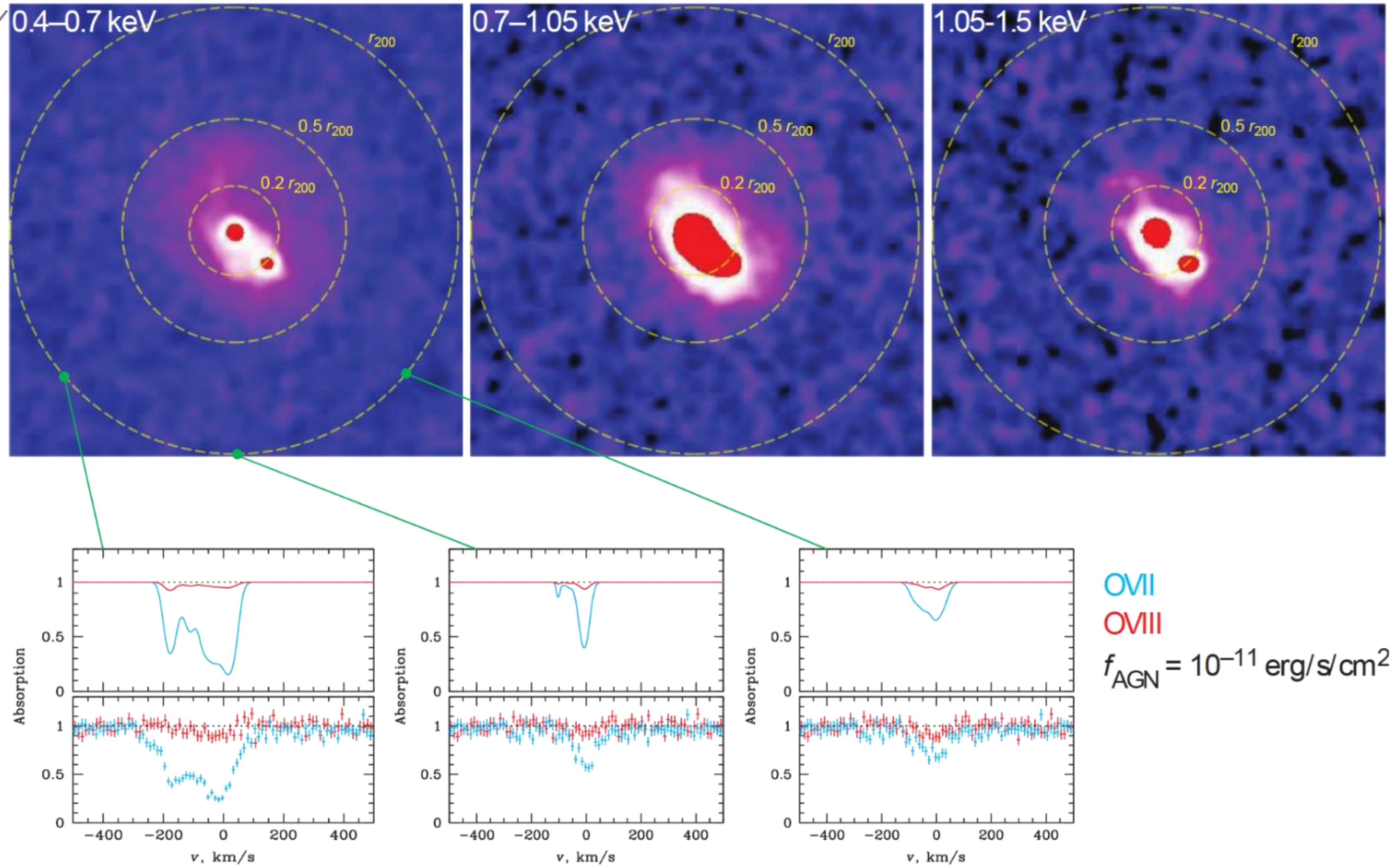
Sensitivity vs. angular resolution for high-throughput telescopes



Revealing the Unknown – ATHENA to Lynx

Detecting and characterizing CGM near the virial radius of MW type galaxies requires a grating spectrometer with R ≥ 5000 and effective area ~4000 cm^2 over 0.25-0.7 keV band.





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

Presented by F. Ozel (AAS HEAD 2018)

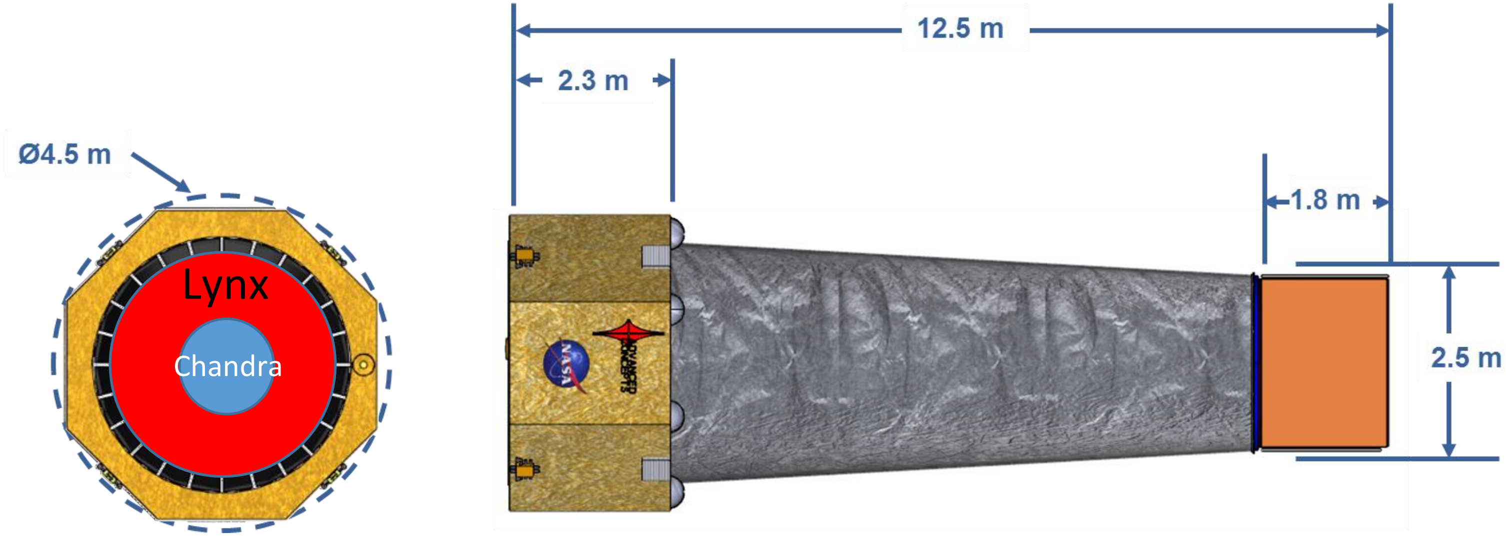
Lynx Science Traceability Matrix

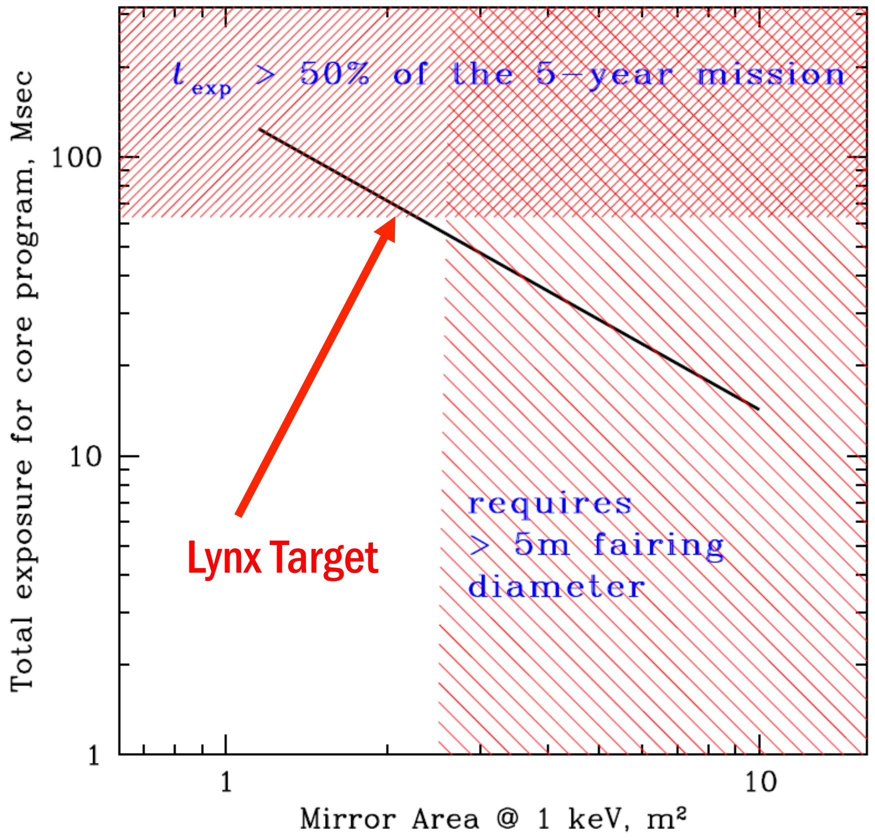
Science Theme/Goal	Performance Driver	Key observations, physical parameters, and measurement requirements		Mirror and Instrument Requirements: Instrument	Property	Value	Also required by Core Science Objectives
Observe the Dawn of Black Holes	Observe progenitors of supermassive black holes at their seed stage or soon after	Detection of black holes in z=6–10 galaxies down to a mass limit of Mlim=10,000 Msun over a volume with 10^3–10^7 potential host galaxies	Surveys with flux limits [0.5–2 keV]: • 1.6×10^{-19} erg/s/cm² over 1 deg² • 7×10^{-20} erg/s/cm² over 400 arcminutes²	Mirror+ HDXI	Angular Resolution	<1 arcsecond (HPD) across the field, 0.5 arcseconds on-axis	■ Trace how growth of SMBHs proceeds from cosmic dawn to z ~ 3, and how these SMBHs are connected to their host galaxies ■ Response to LISA triggers of SMBH mergers ■ Mapping diffuse baryons in Cosmic Web in emission ■ Post-merger evolution of GW sources
					Grasp	~600 m² arcminutes²	
					Imager pixel size	0.33 arcseconds	
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 $M\sim3\times10^{12}$ Msun to reach 10% accuracy for derived thermodynamic parameters of gas in halos at 0.5 r_{200}	Mirror+ HDXI	Effective Area @1 keV	2 m²	■ Characterization of first galaxy groups at z=3–4 ■ Detect entire mass spectrum of stars in active star forming regions to d=5 kpc ■ Obtain complete census of the diffuse, hot gas in star forming regions out to d~1 Mpc ■ Protoplanetary disk dissipation time scales ■ Statistics of X-ray binary populations in nearby galaxies to constrain binary evolution models and evolutionary paths to LIGO sources
					Angular Resolution	1 aresecond (HPD) across the FOV, 0.5 arcseconds on-axis	
					Field of view	10 arcminute radius	
					Spectral Energy Resolution @ 1 keV	60 eV	
		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} Msun	XGS	Spectral Resolving Power	5,000	■ Energetics of AGN feedback ■ State of gas in the Milky Way halo ■ Impact of X-ray flares on protoplanetary disks, exoplanet conditions ■ Physics of accretion on young stars ■ Dynamos in pre-main sequence and young main sequence stars ■ Stellar coronal mass ejections
					Mirror + gratings effective area at OVII and OVIII lines	4,000 cm²	
	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	■ Energetics and statistics of AGN feedback ■ Impact of X-ray flares on protoplanetary disks, exoplanet conditions ■ Transit spectroscopy down of superearths around M-dwarfs ■ Pre-explosion evolution of SN progenitors of recent core-collapse SNs within 10 Mpc
					Energy resolution at E<1 keV	0.3 eV	
					Spectrometer subarray size	1 arcminute ×1 arcminute	
		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)	■ Stellar spectroscopy in crowded regions ■ Non-thermal physics in Galactic SNRs and PWNs
					Spectrometer pixel size	0.5 arcseconds	
					Energy resolution @ 0.6-7 keV	<5 eV	
					Spectrometer subarray size	1 arcminute ×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	■ Use metallicity in galaxy clusters to z=3 as a probe of galaxy formation processes near the peak of cosmic star formation ■ Study plasma physics effects related to dissipation of energy from AGN outflows ■ State of hot gas, and feedback measurements in high-z galaxy clusters and groups ■ Studies of hot ISIM and stellar feedback in active star forming regions in the Milky Way ■ Identifications of young SN in Galactic SNRs
					Spectrometer field of view	5 arcminutes ×5 arcminutes	
					Energy resolution @ 0.6-7 keV	<5 eV	
					Effective area @ 6 keV	1,000 cm²	

Science Driven Telescope Configuration

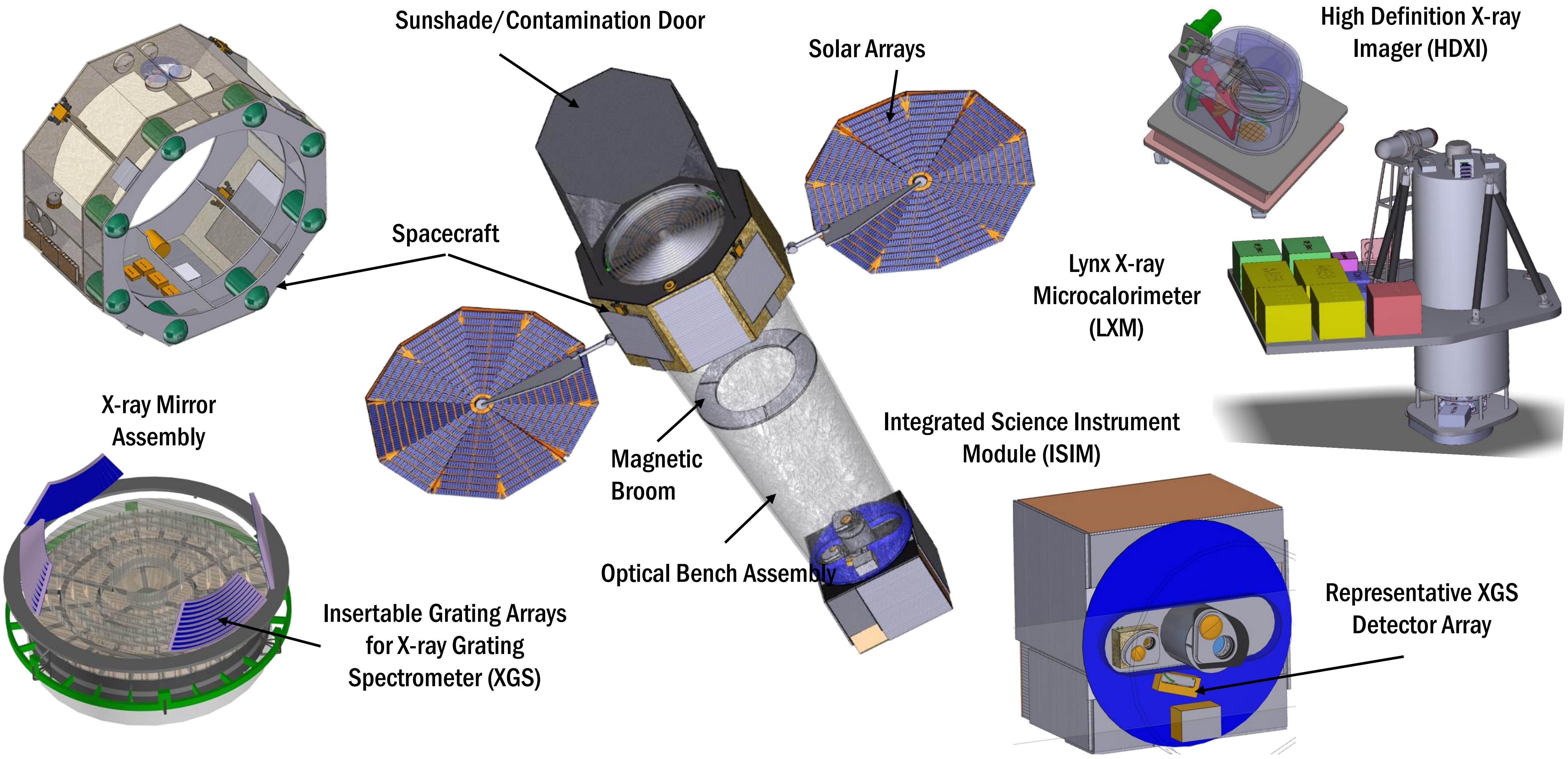
- 2 m^2 of effective area at E = 1 keV is required to execute the science required by the three pillars in under 50% of the 5-yr mission timeline.

- This implies an outer diameter of 3-m with a focal length of 10-m.





Lynx Observatory Configuration



Lynx Mission Design

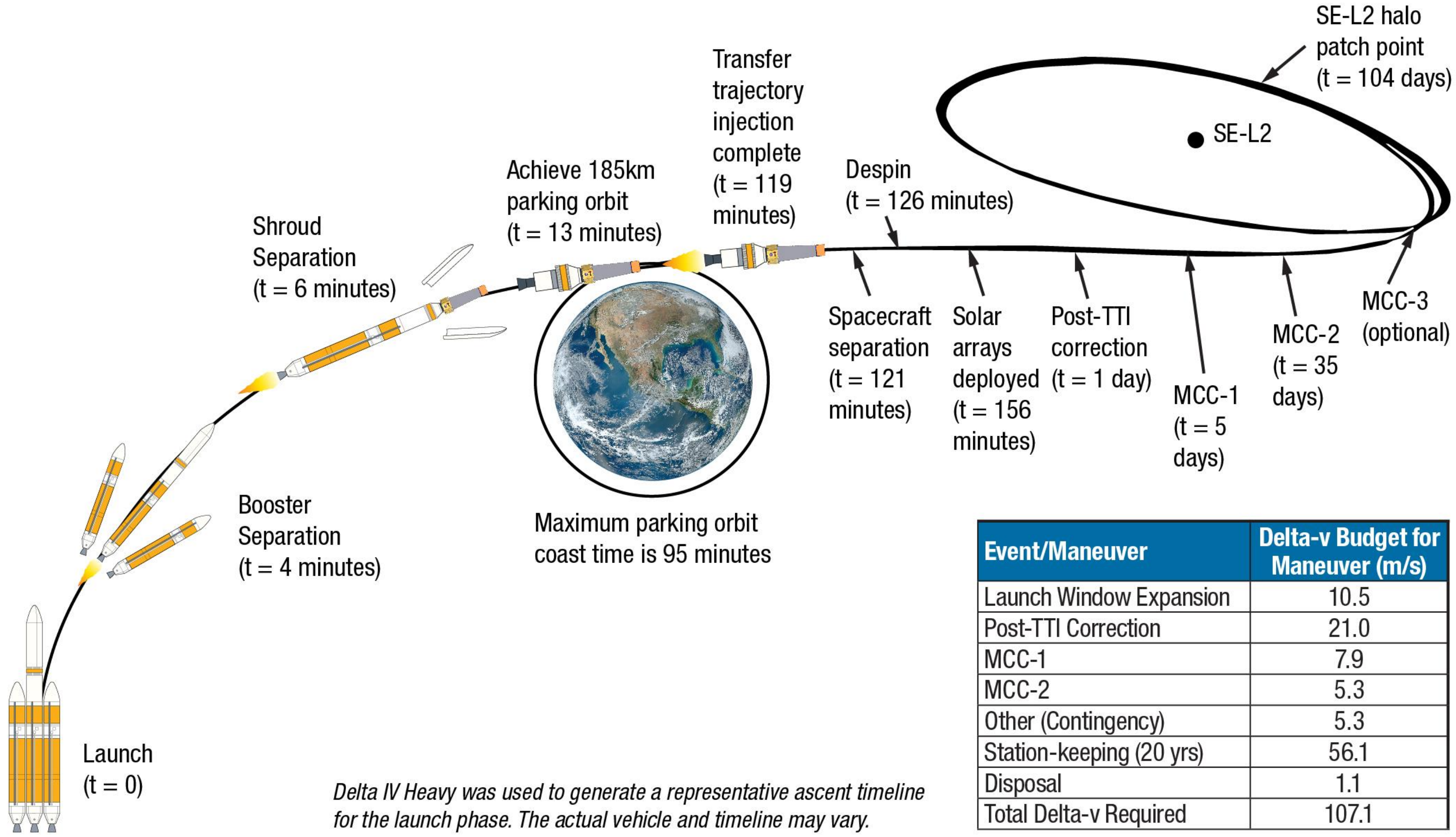
Launch Vehicle:
- Heavy class, 5-m fairing
- SLS co-manifested payload study underway

Mission Life:
- 5 years, extendable to 20 years

Orbit:
- Halo around SE-L2

Communication:
- Up to 3 x per day via DSN

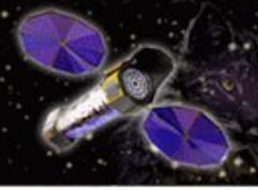
Mission Operations:
- Chandra-like
- Primarily General Observer Program



Event/Maneuver	Delta-v Budget for Maneuver (m/s)
Launch Window Expansion	10.5
Post-TTI Correction	21.0
MCC-1	7.9
MCC-2	5.3
Other (Contingency)	5.3
Station-keeping (20 yrs)	56.1
Disposal	1.1
Total Delta-v Required	107.1

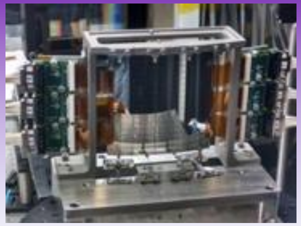
Delta IV Heavy was used to generate a representative ascent timeline for the launch phase. The actual vehicle and timeline may vary.

Ascent timeline provided by NASA LSP for a Delta-IV Heavy.



Lynx Optics Trade Study

- 3 actively funded Optics Technologies
- Kepner-Tregoe Trade Study chartered by Lynx STDT
- Facilitated by G. Blackwood (NASA JPL)
- 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					
Evaluation	**Musts**					
	M1			✔	✔	✔
	M2			✔	?	?
	M3			✔	✔	✗
	Wants	*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*
	Risks			C | L	C | L	C | L
	Risk 1			M | L	M | L	
	Risk 2			H | H	M | M	
Final Decision, Accounting for Risks						

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** and **Opportunities**
- **Recommendation** to STDT

Lynx Optics Trade Study - Musts

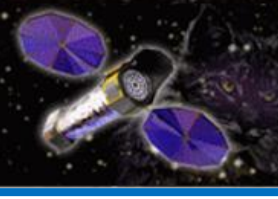
Musts are binary, either a technology passes or does not pass.

	Science
M1	Optical performance will meet requirements flowing down from Science Trace Matrix
	Technical
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
	Programmatic
M7	Show a credible plan to meet TRL 4-6
M8	Produce the mirror assembly within the Program schedule allocation

Lynx Optics Trade Study - Wants

Wants are weighted and evaluated on a comparative basis.

		Weight
	Technical	
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
	Programmatic	
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 Trade Study - 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.	**SET Lead**
9. Daniel Stern	NASA JPL	
10. Ryan Hickox	Dartmouth	
Technical Evaluation Team (TET)		
11. Gabe Karpati	NASA GSFC	**TET Lead**
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	**PET Lead**
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

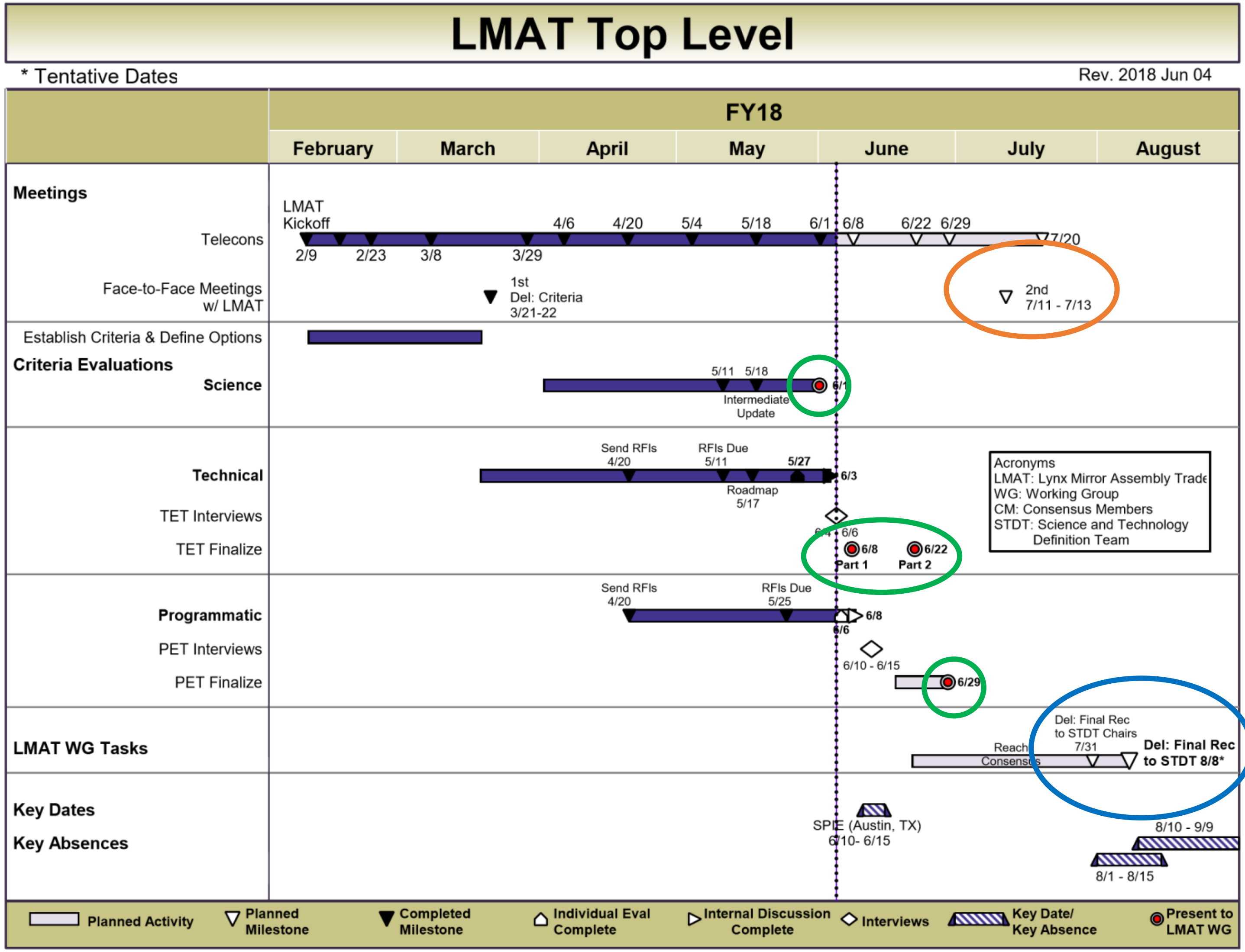
Steering Group

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 Trade Study Schedule



LMAT Process:

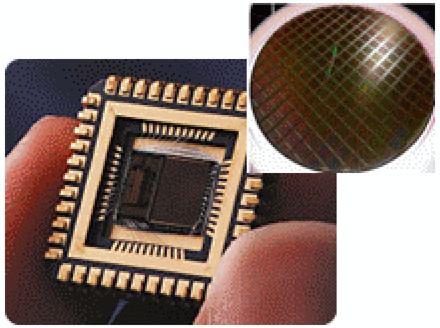
- ✓ Kickoff Telecon with Steering Group
- ✓ Kickoff Telecon with the LMAT Working Group
- ✓ Establish consensus criteria for a successful trade outcome
- ✓ Description of options for evaluation
- ➡ Subgroup evaluation of Science, Technical, and Programmatic criteria
- Reach consensus by LMAT Consensus 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)

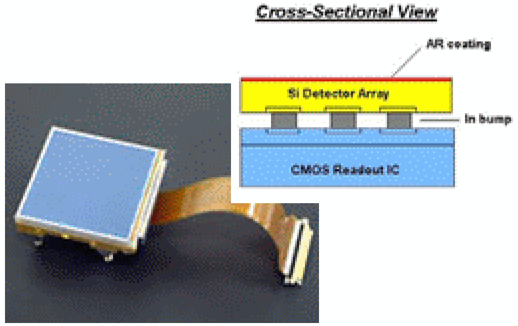
Lynx Instrument Suite Status

STATUS

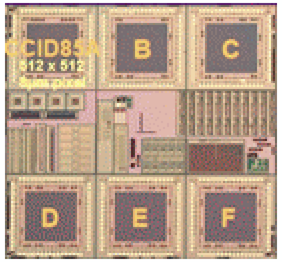
High Definition X-ray Imager (HDXI)



Monolithic CMOS



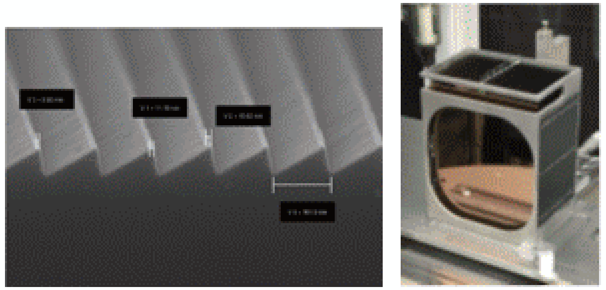
Hybrid CMOS



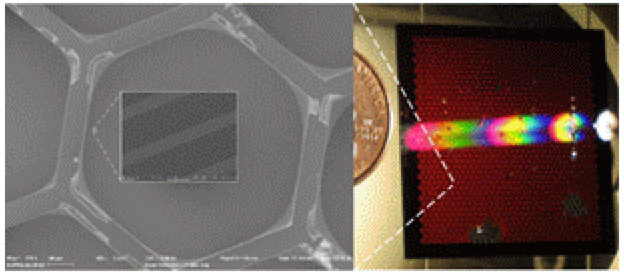
Digital CCD with CMOS readout

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

X-Ray Grating Spectrometer (XGS)



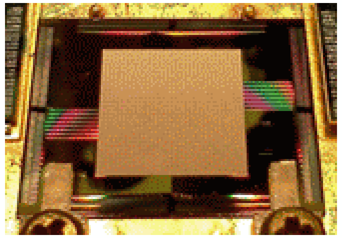
Off-Plane Grating Array

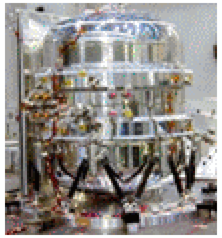


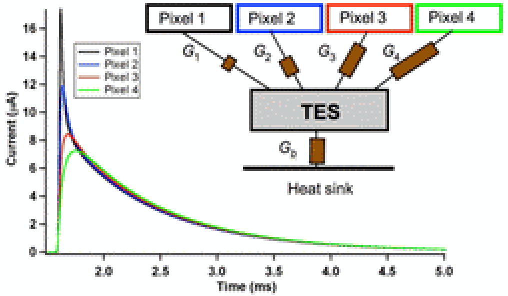
Critical Angle Transmission Grating Array

IDS (MSFC)
10699-39
10699-40

Lynx X-ray Microcalorimeter (LXM)







IDL (GSFC)
10699-38

The Time for Lynx is Now!

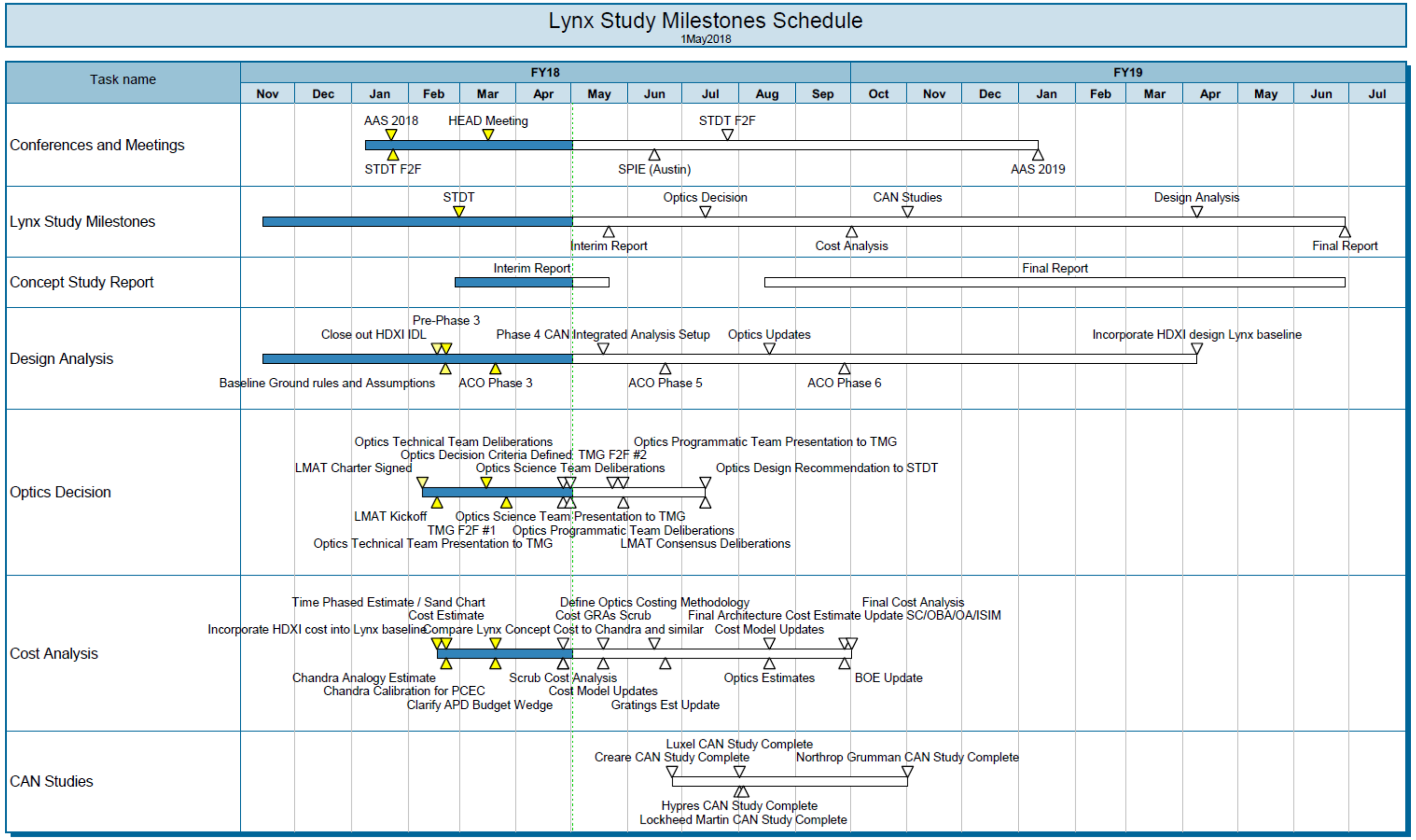
Enabling Technologies TRL Assessment Summary

At Decadal Studies Management Team 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~~ 3	**Multiple Technologies 3-4 by mid-2020**
2	Non-deforming X-ray Reflecting Coatings	3	
3	Megapixel X-ray Imaging Detectors (HDXI)	3	**Multiple Technologies**
4	X-ray Grating Arrays (XGS)	4	**Multiple Technologies**
5	Large-Format, High Spectral Resolution X-ray Detectors (LXM)	3	**Subsystem Heritage**

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 & 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 & 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**
- **Instrument Working Group**
- **Calibration Working Group**
- **Communications Working Group**
- **Ex-officio International Members**

JATIS Special Section on Lynx

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.

Important Information:

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

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

Guest Editors

Alexey Vikhlinin
Smithsonian Astrophysical Observatory
Cambridge, Massachusetts, United States
avikhlinin@cfa.harvard.edu

Feryal Özel
University of Arizona
Tucson, Arizona, United States
fozel@email.arizona.edu

Jessica Gaskin
NASA Marshall Space Flight Center
Huntsville, Alabama, United States
jessica.gaskin@nasa.gov

Douglas Swartz
Universities Space Research Association
Marshall Space Flight Center,
Huntsville, Alabama, United States
doug.swartz@nasa.gov

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

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

Posters: Lynx
Wednesday 13 June 2018
6:00 PM - 8:00 PM
Location: CC Level 1, Exhibit Hall 2

Lynx Talks:

Observatory Design Considerations
10699-41

Optics
Full Shell: 10699-36
Silicon Meta-Shell: 10699-22, 10699-23, 10699-141
Adjustable: 10699-24
Ion Figuring & Coatings: 10699-28, 10699-143
Alignment & Mounting: 10699-144
Ray-Trace Software: 10699-133

Instruments
HDXI: 10699-37, 10699-42, 10709-14
XGS: 10699-39, 10699-40, 10699-25, 10699-26
LXM: 10699-38

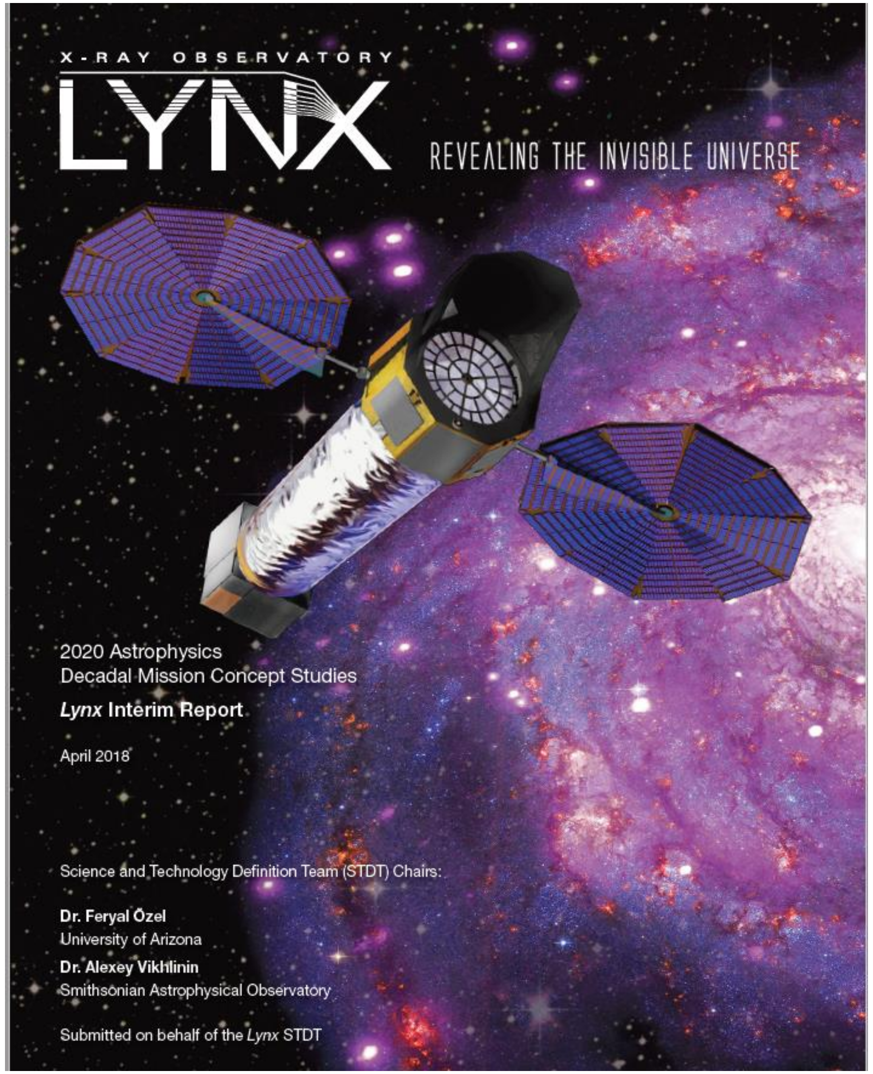
NASA

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]

Lynx Mirror Assembly Trade – Charter
2/2/2018

A. Background

Lynx is one of four large mission concepts studies funded by the NASA Astrophysics Division for development by a Science and Technology Definition Team (STDT).[1] Recently, the Lynx Red Team recommended that a down-select plan be created for the mirror and gratings technologies in time to make choices for the final report. The Lynx Science and Technology Definition Team (STDT) recognizes that a credible and feasible path to maturing the Lynx mirror assembly is crucial to a compelling and executable Lynx mission concept. Therefore, following deliberations within the Lynx Optics Working Group (OWG) and Study Office and corroborated by the Lynx Red Team recommendations, the STDT commissions a trade study to recommend a reference mirror design that demonstrates a technological path to realizing the science envisioned by the STDT. This document charters the plan for the trade study deliverables, trade process and membership. The goal for completion of the trade study is July 13 2018 in support of Milestone M6 (draft final report) as required in the Management Plan for the Decadal Large Mission Studies[2].

B. Deliverables

The Lynx Mirror Assembly Trade (LMAT) Working Group is chartered by the Lynx STDT to deliver to the Lynx STDT Chairs by the goal of July 13 2018 a recommendation for one Primary Optical Assembly architecture to focus the design for the final report and identify any feasible alternates. The LMAT Working Group participation is defined in Section C.

The recommended option, upon review by STDT and acceptance by the STDT Chairs, will serve as the reference design for the Lynx mission concept for Milestone M6. All other feasible architectures identified in the trade process will be included in the Lynx Technical Roadmap.

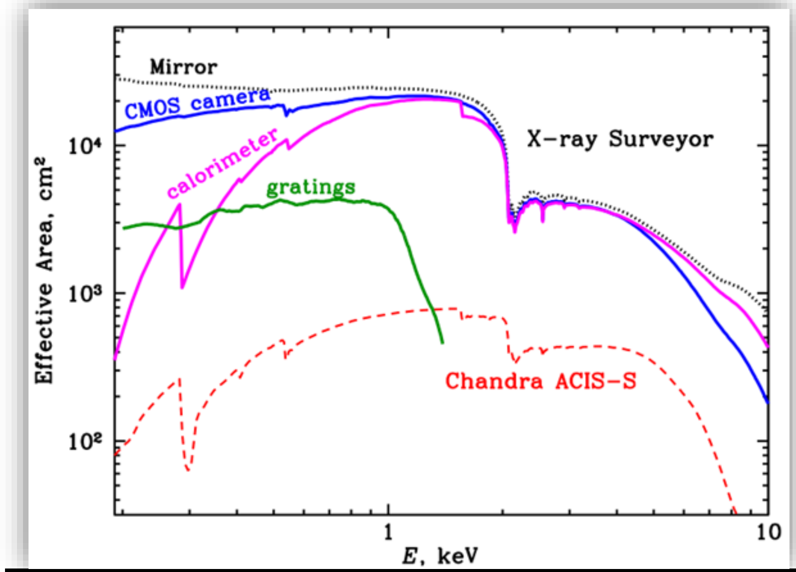
* * *

Feryal Ozel
Feryal Ozel
STDT Chair, Lynx
Professor of Astronomy
University of Arizona

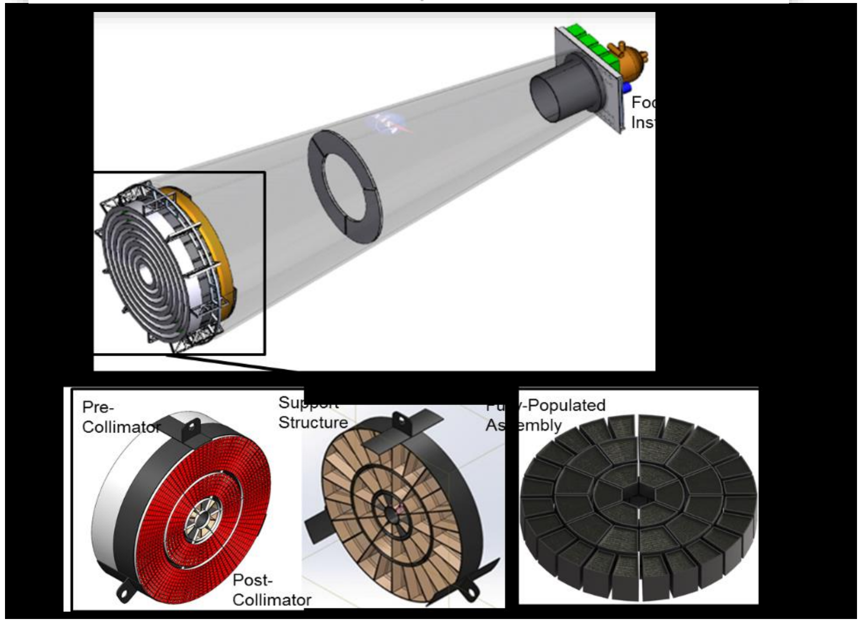
A. Vikhlinin
Digitally signed by Alexey Vikhlinin
Date: 2018.02.05 15:42:32 -05'00'

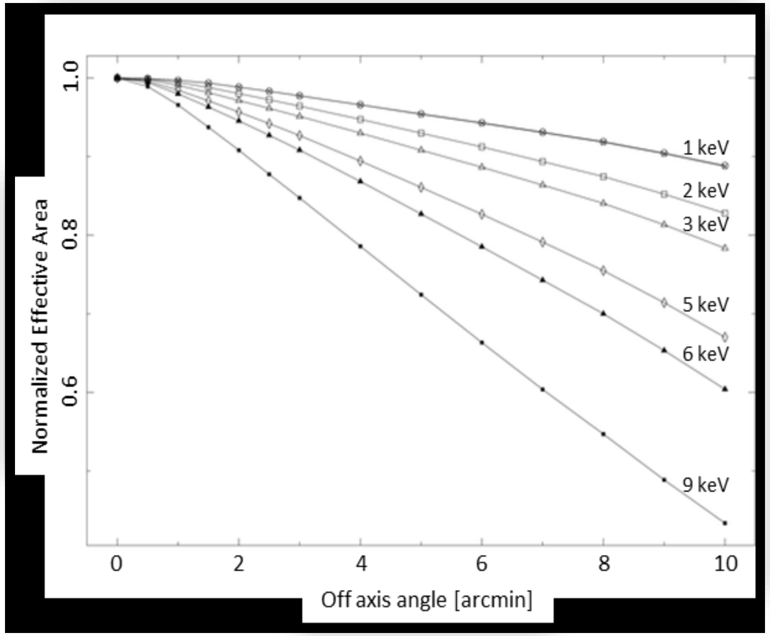
Alexey Vikhlinin
STDT Chair, Lynx
Deputy Associate Director, High Energy Astrophysics Division
Harvard-Smithsonian Center for Astrophysics

Optics – Specifications & Performance



- Wolter-Schwarzschild optical scheme
- 292 nested shells, segmented design
- 3m outer diameter
- 30x more effective area than Chandra HRMA
  - (2.3 m^2 @ 1 keV)
- 16x larger solid angle for sub- arcsecond imaging
- 800x higher survey speed at the CDFS limit





Angular Resolution Versus Off-axis Angle

E < 2 keV

Short segments and Wolter-Schwarzschild design yields excellent wide-field performance.

- 16x larger solid angle for sub- arcsecond imaging
- 800x higher survey speed at the CDFS limit