The *Lynx* Mission Concept

2017 Accomplishments and 2018 Goals

Dr. Jessica A. Gaskin (Study Scientist, MSFC)

- Presented On behalf of the *Lynx* Team
Meet *Lynx*!

One of 4 large missions under study for the 2020 Astrophysics Decadal, *Lynx* is an X-ray observatory that will directly observe the dawn of supermassive black holes, reveal the invisible drivers of galaxy and structure formation, and trace the energetic side of stellar evolution and stellar ecosystems.

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

- 50–100× 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

*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.
Study Deliverables

M1 Comments on Study Requirements and Deliverables
- Accept the study requirements/deliverables and submit plan--- or
- Provide rationale for modifying requirements/deliverables

O1 Optional: Initial Technology Gap Assessment
- To impact PCOS/COR/ExEP 2016 technology cycle

O2 Optional: Update Technology Gap Assessments

M4 Interim Report
- Provide science case and mission concept (use CML 3 as a guide)
- Deliver initial technology roadmaps; estimate technology development cost/schedule
- CML 4 tailored approach (optional)

O3 Update Technology Gap Assessments

M6 Draft Final Report at Concept Maturity Level 4 Audit / Freeze Point Design
- Provide science case and mission concept (use CML4 as a guide)
- Support independent cost estimation/validation process
- Submit to HQ for CATE

M6’ CATE report returned by HQ to STDTs for incorporation into M7

M7 Final Report / incorporate CATE report + final changes
- As described in study success criteria chart 15

M8 HQ Submits final report to Decadal

*Note: Schedule relaxed from original by ~4 months due to decadal committee schedule delay
New Members!

**STDT Members**

- Zoltan Haiman, Columbia
- Andrey Kravtsov, Chicago
- Terri Brandt, PCOS Program Office Acting Chief Scientist

**Ex-Officio**

- Peter Jonker, SRON-Appointed
- Giovanni Pareschi INAF-Appointed

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

Over 275 total members!
Science of Lynx

The Dawn of Black Holes

The Invisible Drivers of Galaxy and Structure Formation

The Energetic Side of Stellar Evolution and Stellar Ecosystems

- Lynx deep field
- JWST deep field
- Illustris-TNG simulation: gas
- Illustris-TNG simulation: galaxies

Endpoints of stellar evolution
Stellar birth, coronal physics, feedback
Impact of stellar activity on habitability of planets
AAS Lynx Science Talks

- Monday, 9:45AM-10:05AM, Grav. Wave SIG, Lynx and LISA, R. Petre
- Tuesday, 10:00AM-11:30AM, 103.04: Lynx Mission Concept Study, A. Vikhlinin
- Wednesday, 2:00PM-3:30PM, 223.08, Future prospects with the Chandra and XMM source catalogs: Setting the stage for Lynx, R. Hickox
- Thursday, 2:00PM-3:30PM, 332.01: Implications from XMM and Chandra Source Catalogs for Future Studies with Lynx, A. Ptak
- Thursday, 5:30PM-6:00PM, 350.01: Looking for Dust Scattering Light Echoes, B. Mills

Hyperwall
Tuesday & Thursday, 9:10AM-9:35AM NASA’s Decadal Mission Concept Studies: HabEx, LUVOIR, Lynx, OST, D. Pooley & A. Vikhlinin (Lynx)

Wednesday, 9:10AM-9:20AM Revealing the Dawn of Black Holes with the Lynx X-ray Observatory, R. Hickox

Friday, 9:20AM-9:30AM Revealing the Invisible Drivers of Galaxy and Structure Formation and Evolution, J. Kollmeier
Science Driven Instrument Requirements

**High-Definition X-ray Imager**

Optimized for deep survey science

- Silicon sensors with ~ 0.3” pixels
- FOV ≥ 20’×20’
- ΔE ~ 100 eV over 0.1–10 keV band
- High frame rates to minimize pile-up.

**X-ray Grating Spectrometer**

Detail outflow velocities and mass loss rates to provide information on matter and energy feedback in accreting galaxies.

Map the unobserved, large fraction of baryons that likely exists in the hot phase of the intergalactic medium.

- Resolving power λ/Δλ > 5000
- Effective area > 4000 cm² covering X-ray emission and absorption lines of C, O, Mg, Ne, and Fe-L.
**Lynx X-ray Microcalorimeter**

- **Main Array** provides non-dispersive spectroscopy with $\Delta E < 3$ eV over the 0.2–7 keV band and imaging with 1” pixels over a 5’×5’ FOV.
- Several subarrays are optimized for sub-arcsec imaging, 0.3 eV energy resolution, and coverage of 20’×20’ FOV.

**Enhancement Main Array:** Optimized to allow for higher count-rates, such as from AGN.

**High-Res Inner Array:** Optimized to allow for higher count-rates, such as from AGN.

**Ultra-High-Res Array:** Enables the study of turbulent line broadening around individual galaxies through the study of the highly ionized oxygen lines.

**Extended Array:** Surveys over large regions of the sky for observations of the soft diffuse emission from extended galaxies, the outer regions of galaxy groups and clusters and also cosmic filaments.
MSFC Advanced Concept Office performed a comprehensive Design Study for HDXI and XGS (for both Off-Plane and Critical Angle Transmission Grating readouts)

- Configuration
- Structures
- Mechanisms
- Thermal
- Power
- Electronics
- Cost

GSFC contributed an Instrument Design Lab for LXM, including baseline and updated cost modeling
Optical Assembly Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular resolution (on-axis)</td>
<td>0.5 arcsec HPD (or better)</td>
</tr>
<tr>
<td>Effective area @ 1 keV</td>
<td>~2 m² (met with 3-m OD)</td>
</tr>
<tr>
<td>Grasp, A* (FOV for HPD &lt; 1 arcsec)</td>
<td>~600 m² arcmin²</td>
</tr>
<tr>
<td>Wide FOV sub-arcsec Imaging</td>
<td>10 arcmin radius</td>
</tr>
</tbody>
</table>

**Science Traceability:**

*Lynx* will find the first supermassive black holes in the first galaxies detected by *JWST*, trace their growth from the seed phase, and shed light on how they subsequently co-evolve with the host galaxies. Needed sensitivities, $10^{-19}$ erg/s/cm², are $\sim 200\times$ below *ATHENA* confusion limit.

- Angular resolution < 1” (50% power diameter) will avoid source confusion and limit background

- An Effective area > 2m² and FOV > 10’ in radius with arcsecond or better imaging will survey sufficient volume at $z=10$ in less than 25 Msec.
Lynx will use the Kepner-Tregoe trade process to select an optics technology for the Lynx Design Reference Mission and to establish feasibility for alternate viable technologies. – Supported by G. Blackwood, NASA Exoplanet Exploration Program

Study has been initiated for 3 Viable Optics Technologies

- Adjustable Optics (Study Lead: P. Reid/SAO)
- Si Meta-Shell Optics (Study Lead: W. Zhang/GSFC)
- Full Shell Optics (Study Leads: K. Kilaru/USRA/MSFC, G. Pareschi/INAF/OAB)

Selection will be based on Science, Technical and Programmatic criteria (TBD)

The Lynx Optics Working Group will make a formal recommendation to STDT in Summer 2018!
Mission Design Study

**Launch Vehicle**
Most likely will need a Heavy-class launch vehicle (TBC)

**Orbit**
Sun-Earth L2

**Mission Lifetime**: Baseline mission is 5 years, extendable for an additional 20 years based on consumables (still need to complete analysis on L2 radiation environment)

**Mission Operations**: Chandra-like. Lynx will have a primary science program combined with a general observer program
Lynx Observatory

Under Refinement!
2017 Additional Accomplishments

- Awarded 5 Cooperative Agreement Notices (CANs) to industry partners to support payload design and programatics.
- Science Traceability Matrix was developed.
- Interim Report first draft completed and reviewed by Red Team.
- Major improvements to the Lynx simulation package (http://hea-www.cfa.harvard.edu/~jzuhone/soxs/)
  - Astrophysical backgrounds now include resolved point sources.
  - A module to generate an X-ray light cone from a cosmological situation was added.
  - Instrument specifications were added for imaging observations of ACIS-I and ACIS-S, Cycles 0 and 19, Hitomi/SXS, and AXIS.
  - The ability to generate gratings spectra for Lynx and Chandra ACIS-S/HETG was added.
- Model Based Systems Engineering implemented.
Updated Website

LYNX SCIENCE

REVEALING THE HIDDEN UNIVERSE
2018 Key Tasks

- Submit Interim Report to HQ (due 03/2018)
- Continue to strengthen science case and traceability to observatory architecture
- Improve fidelity of instruments, observatory, and mission concept design (MSFC and GSFC)
- Complete Optics Technology Study
- Complete Technology Roadmap for Optics and Instruments
- Complete Risk Assessment and Independent Costing for Lynx
- Carry out Informal CATE with Aerospace
- Initiate Final Report

*Next STDT F2F is 01/25/18-01/26/18 in Houston, TX*
Thank you!

- Please visit the Lynx Display next to the Chandra Table and the Decadal Studies Table for more information.

- Participation is open and welcome at any level. For more information and to sign-up to our News Distribution, visit our website at: https://www.astro.msfc.nasa.gov/lynx/