Decadal survey 2020: X-Ray Surveyor – *Lynx*

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The *X-ray Surveyor – "Lynx"* is a large astrophysics mission concepts that is studied by NASA in preparation for the 2020 U.S. Decadal Survey. The goals for the observatory are:
- Sub-arcsec (Chandra like) angular resolution imaging, with a factor of 30-100 higher throughput;
- Larger field of view than Chandra,

The high-resolution optics are complimented by high-resolution gratings and instruments located at a focal length of 10 m.
- microcalorimeter [XMIS]
- High Definition Imager and [HDXI]
- high-efficiency gratings [XGS]

Critical Angle Transmission (CAT) gratings can be inserted and retracted into and out of the X-ray beam. XMIS and HDXI are mounted on a translation table that allows them to be swapped with each other at the telescope focus. The CAT-XGS readout is mounted in a fixed location at the focal plane.
As with the optics, none of these instruments currently exist in a form that can meet all of *Lynx's* requirements, but there is significant activity and substantial progress towards their development.
Lynx will be able to detect and characterize extremely faint objects and study physical processes in a very wide range of astrophysical settings.

The *X-ray Surveyor – "Lynx"* は、
2020 U.S. Decadal Surveyのために、NASAで検討されているミッションのひとつ。このミッションの特徴は、
- Chandra(*1)と同様の秒角を切る角度分解能と桁で上回る有効面積
- Chandraを上回る視野

この光学系と組み合わされる検出器は、
- X線マイクロカロリメータ [XMIS]
- 高精度撮像器 [HDXI]
- 高効率分散分光器 [XGS]

XMIS と HDXI は、焦点面のテーブルに搭載され、切り替えて使用する。光学系、検出器ともに現状でLynxの要求を完全に満たす物はないが、開発は進められている。
高精度の画像と大きな有効面積に、Lynx は、これまで観測されてこなかった単独の中性子星など、非常に暗いX線源も観測できるようになり、宇宙物理学の地平を大きく広げることが期待される。

*1) 1999年に打ち上げられ、現在稼働中の米国の大型X線天文衛星

Lynx--Native American Mythology

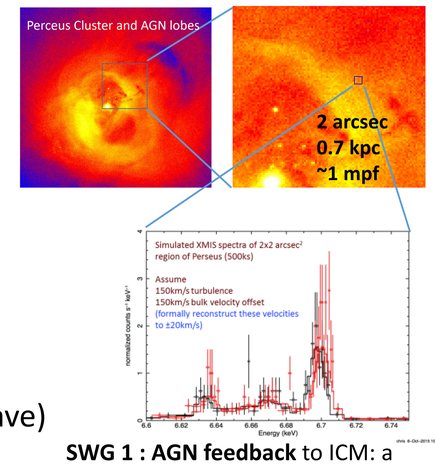
In the Pawnee tribe, Wildcat is a more mythologically important character associated with the stars. Pawnee parents used to wrap their babies in wildcat furs to bring them celestial blessings.

Known in some American Indian traditions as a 'Keeper of Secrets'. It is also believed to have supernatural eyesight, capable of seeing even through solid objects.

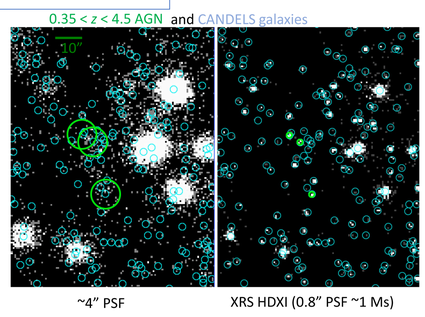
As a result, it often symbolizes the unraveling of hidden truths, and the psychic power of clairvoyance.

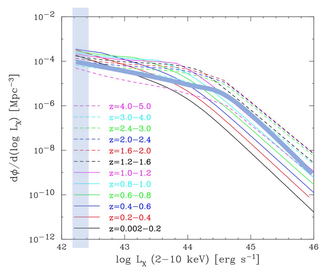
Science requirement drivers -- by 7 Science Working Groups

1. Feedback (AGN, stars and ICM/ISM)
2. First accretion light
3. Baryon cycle
4. Evolution of structures and AGN
5. Extreme physics (black hole outflows, neutron star equation fo state…)
6. Stellar lifecycle
7. Synergies (w/ radio to gravitational wave)

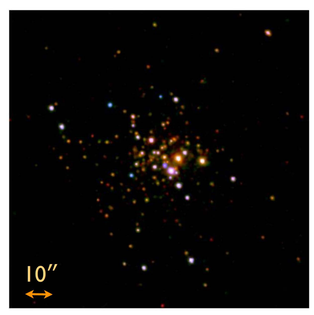


SWG 1 : AGN feedback to ICM: a demonstration of *Lynx* high resolution imaging spectroscopy (C. Reynolds+)





SWG 4: Blackhole growth: *Full* population of growing black holes evolve at the peak epoch of activity and beyond. With *Lynx* (XRS HDXI), we detect obscured AGN and *identify counterparts* to *z*~4 to ~2 orders of magnitude below the "knee" in the XLF (right).



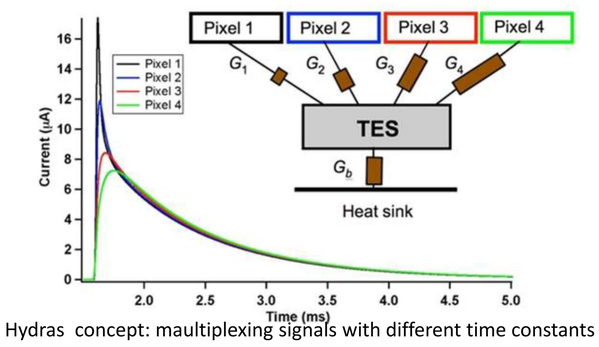
47 Tuc/ *Chandra*; Heinke *et al.*, 2005

SWG 5 : EoS of NS: Measure T_{eff}, log *g*: calculate *R*. Differentiate between pure H, pure He composition: collect 10^6 counts in 10^5 s; with with wide bandpass, down to .2 keV measure log g (broadband curvature)

X-ray Microcalorimeter Imaging Spectrometer (XMIS)

The XMIS instrument provides very high energy resolution covering the entire band of Lynx with imaging capability. It utilizes "transition-edge sensor (TES)" or "magnetically coupled calorimeters (MCC)" in 100 kilo-pixels.

Key technology on readout: To reduce the number of sensors read out, an example approach is *"Hydras"*. Hydras consist of a single TES coupled to multiple absorber pixel elements. Each pixel has a different thermal coupling, which allows for identification via pulse shape discrimination. Multiple Hydras can be arrayed to read out the full detector. Recent results from a 3 x 3 absorber pixel array, where all 9 pixels were read out with a single TES gave 2.4 eV FWHM-resolution at 6 keV. Pixels were 65 µm square and had a thickness of 5 µm and TES pitch was 75 µm. This implies the potential for reading out larger, 10^5 pixel arrays.
Alternative readout approaches also exist that utilize microwave Superconducting QUantum Interference Devices (SQUIDs) coupled to each sensor in resonator circuits in the GHz frequency range.

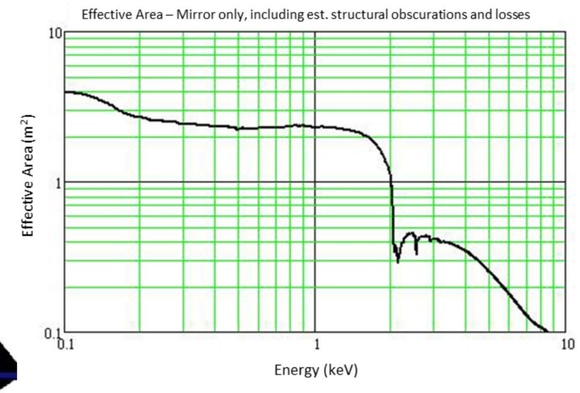


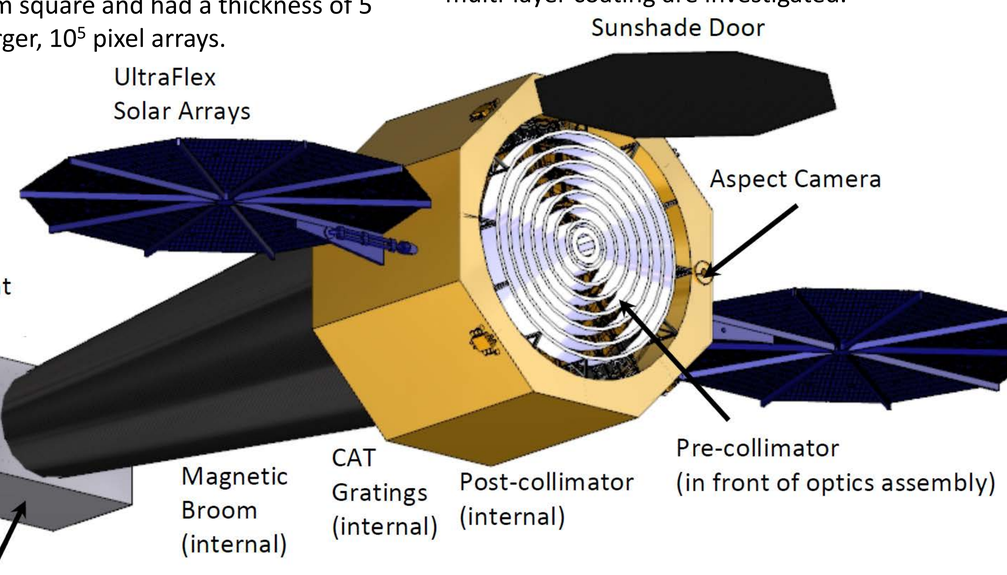
Hydras concept: maultiplexing signals with different time constants

Parameter	Goal
Energy Range	0.2 – 10 keV
Field of View	5 arcmin x 5 arcmin (minimum)
Energy Resolution	< 5 eV
Pixel Size / array size (10-m focal length)	50 µm pitch (1 arcsec) / 300 x 300 pixel array
Count Rate Capability	1 c/s per pixel

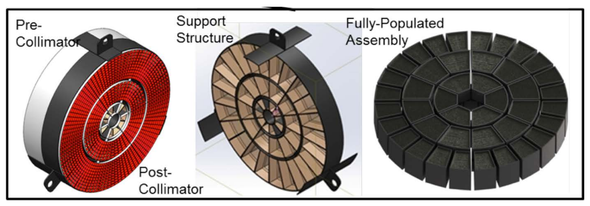
Optics:

An initial optical design for the *Lynx* mirror system incorporates a segmented system with a 3 m diameter, a 10 m focal length and a 0.5 arcsec Half Power Diameter (HPD) at 1 keV.
A Wolter-Schwarzschild (W-S) prescription is used, which provides superior off-axis imaging to a Wolter-I. The result is a ~15 arcmin diameter field-of-view with 1 arcsec or better HPD. When convolved with nominal as built mirror performance and the 'curved' focal plane, off-axis imaging (mirror + aberrations) at 1 keV is less than 1 arcsec (HPD) over a ~20 arcmin diameter field-of-view.
Large mirror effective area is accomplished by nesting 292-segmented shells into 42 individual mirror modules, which are then assembled into a larger structure with a 3 m outer diameter.
The calculated effective area (below) includes structural obscuration, misalignments, particulate contamination, scatter and raytraced vignetting as a function of energy and field position. The on-axis effective area is 2.3 m^2 at 1 keV. Possibility of larger effective area and/or higher energy extend by multi-layer coating are investigated.





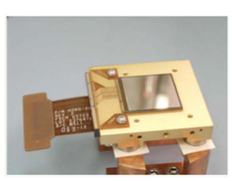
X-ray Microcalorimeter Imaging Spectrometer (XMIS)
High Definition X-ray Imager (HDXI)
CAT X-ray Grating Spectrometer (XGS) Readout

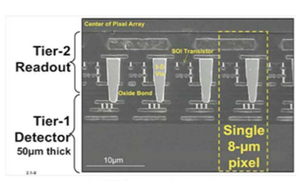


High-Definition X-Ray Imager (HDXI)

The HDXI focal plane instrument for *Lynx* will provide a large field of view while simultaneously providing fine pixel resolution and high readout rate. To satisfy these requirements, multiple active pixel sensor technologies are under consideration, including
A) hybrid Complementary Metal Oxide Semiconductor or CMOS (PSU/Teledyne),
B) monolithic CMOS (SAO/Sarnoff), and
C) 3-D tiered/layered bonded Si (MIT/Lincoln Labs).
to support *Lynx's* large field of view, one could use a single 4096 x 4096 pixel device with 16 µm pixels.
However, in order to accommodate the curvature of the focal surface, a preferred design is to use multiple abuttable detectors with a bowl-shaped tilt, as was done for the *Chandra* ACIS instrument. A possible configuration would be to tile 1024 x 1024 pixel devices using 21 detectors arranged in a 5x5 grid pattern with the 4 corners removed. A detector design with 15 µm pixels would then cover a 26 arcmin x 26 arcmin field of view when arranged in this way, thus exceeding the 22 arcmin x 22 arcmin goal.


SAO/Sarnoff


PSU/Teledyne

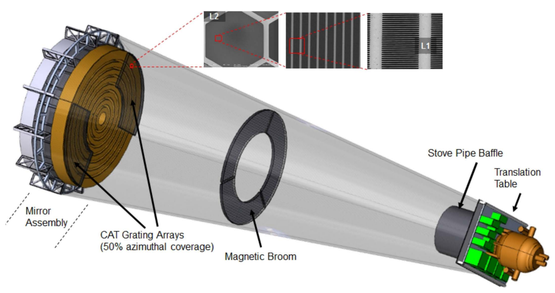


MIT/Lincoln Labs

Parameter	Goal
Energy Range	0.2 – 10 keV
Field of View	22 arcmin x 22 arcmin
Energy Resolution	37 eV @ 0.3 keV, 120 eV @ 6 keV (FWHM)
Pixel Size / array size (10-m focal length)	< 16 µm (< 0.33 arcsec) / 4096 x 4096 (or equiv.)
Frame Rate	> 100 frames/s (full), 10000 frames/s (window)
Read Noise	< 4 e^- rms

X-ray Grating Spectrometer (XGS)

A) Critical-Angle Transmission (CAT) and
B) Off-Plane Reflection Gratings (OPG)
are two candidate technologies for *Lynx*.
With the combination with square-meter collecting-area optics, it will provide unprecedented performance below ~ 2 keV; complementing the XMIS performance in the harder X-ray band.



Ex. effective area on the order of 4,000 cm^2,
R= λ/Δλ of up to 5,000,
is achieved by covering less than 50% of the optics aperture with retractable grating arrays.

References

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