The X-Ray Imaging and Spectroscopy Mission

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Memorial Symposium to Honor
Riccardo Giacconi

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Chandra image
Hitomi/SXS spectrum
X-ray emission from clusters of galaxies was first detected by Gursky et al., 1971 in the Uhuru X-ray sky survey.

- Extended (~45 arcmin) source found associated with the Coma cluster.

Similar extended cluster X-ray sources were later discovered (e.g. Perseus, Virgo), but the spectra at the time were insufficient to distinguish between power law and thermal bremsstrahlung spectra.

Two possible mechanisms were proposed:

- Inverse Compton radiation from 3 K microwave background photons interacting with a relativistic electron population in the cluster (Brecher and Burbidge, 1972).

- Thermal bremsstrahlung from a hot isothermal gas (Lea et al., 1973).
Expected X-ray spectrum of intra-cluster medium

normalized counts s⁻¹ keV⁻¹

Energy (keV)

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10

0 5 10 15

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X-Ray Calorimeter (1982)

Bolometric X-Ray Spectrometer
H. Moseley and R. Mushotzky

- Theory and current experiments suggest sensitive bolometers can be used as x-ray detectors with the efficiency of imaging detectors and energy resolution exceeding that of current crystal spectrometers.

- We propose to produce and test such detectors to prove their utility as practical x-ray detectors.

Energy resolution of ~ 1 eV theoretically possible
The **AXAF X-Ray Spectrometer (XRS)**

**A PROPOSAL FOR AN X-RAY SPECTROSCOPY INVESTIGATION FOR THE AXAF OBSERVATORY**

**VOLUME 1: TECHNICAL PROPOSAL**

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**Fig. 1. overall experiment layout**

**≈ 140 eV resolution**

**Counts vs. Time (ms)**

**Pulse Height (keV)**
The “XRS” is History!

AXAF

AXAF-I  AXAF-S

AXAF

Chandra

1993

Astro-E

Astro-E2

Astro-H

XRISM

2000

2005

2016

2022

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NASA Hardware Contributions to Astro-H

**Soft X-Ray Telescope**

- 5.6 m focal length – fixed optical bench
- 203 concentric shells (1624 individual reflectors)
- Outer Diameter: 45 cm
- Mass: CBE = 46 kg.
- Half-Power Diameter of better than 1.2 arcmin

**Soft X-Ray Spectrometer**

- SXS – energy resolution better than 4.9 eV at system level
- 6 x 6 array of 30” x 30” pixels (3 arcmin FOV)
1st Astro-H target – Perseus Cluster
(Chandra image, Fabian et al.)
1st Astro-H target – Perseus Cluster (Chandra image, Fabian et al.)
Astro-H (Hitomi) SXS Spectrum of Perseus cluster

BLACK: Hitomi SXS (energy resolution 4.9 eV, FWHM)
BLUE: Best previous spectrum (Suzaku CCD; FWHM 140 eV)

Hitomi Collaboration, Nature 2016
Astro-H (Hitomi) SXS Spectrum of Perseus: He-like Fe

\[ \sigma_{\text{turb}} = 164 \pm 12 \, \text{km s}^{-1} \]

\[ P_{\text{turb}} < 0.04 \times P_{\text{thermal}} \]

Notice how the high spectral resolution of Hitomi/SXS allows easy detection of the turbulent velocity broadening. This capability was eagerly anticipated for all nearby clusters.
The X-Ray Imaging and Spectroscopy Mission

X-Ray Mirror Assemblies (2)

- Coming in 2022
- Incorporates many lessons learned from Astro-H
US Access to XRISM

NASA to have access to ~ 44% of observing time and all data from Resolve and Xtend once in US archive (+1 year). JAXA and ESA have separate agreement on remainder.

NASA responsible for data pipeline and dissemination.

NASA Participating Scientists selected by NASA (science advisors):

- Lia Corrales/U. Michigan
- Erin Kara/MIT
- Jon Miller/U. Michigan
- Paul Plucinsky/SAO
- Irina Zhuravleva/U. Chicago

Additional target Collaborating Scientists to be selected to support performance/verification phase (6 months duration following commissioning)

- It is anticipated that ~ 60 scientists will be selected to join target teams.

- AO for Collaborating Scientists to be released in late 2020.

- Negotiating early release data from a few targets shortly after commissioning.

- AO-1 released after commissioning (~ late Spring, 2022).
Giant leap: ATHENA will push capability all the way out to $z \sim 1$

- Contains very large fraction of all x-ray clusters
- 3168-pixel array, 2.5 eV resolution

Figure 2. Left: Reconstructed bulk motion induced velocity field (in km/s) of the hot intra-cluster gas for a 50-kiloseconds X-IFU observation of the central parts of a Perseus like cluster from the numerical simulations in Ref. 20. The cluster has the luminosity of Perseus but is considered at a redshift of 0.1. Right: Simulated X-IFU spectrum of a $z = 1$ galaxy group with $kT = 3$ keV and $L_X = 1 \times 10^{44}$ erg s$^{-1}$ for 50 ks. Emission lines from elements which are key to understand chemical evolution can be clearly seen.