The ASTRO-H Mission

1. Why we need new X-ray Missions
2. Current Status of ASTRO-H

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Why we need new X-ray Missions

Violent mergers

1E0657-56 at z=0.30  (Bullet cluster)

Color:  X-ray (collisional gas)
Contours:  weak lensing
(Clowe;  Mastropietro & Burkert 08)

Projected $T_e$
Chandra 0.5-7.0 keV
500 ksec
(Markevitch & Vikhlinin 07)

$\beta_3 = 3.0$
$V_{preshock} \sim 4700 \text{ km/s}$
$V_{postshock} \sim 1600 \text{ km/s}$

Rankine-Hugoniot relation:

$$\frac{T_2}{T_1} = \frac{[2\gamma M^2 - \gamma + 1][\gamma - 1]M^2 + 2}{(\gamma + 1)^2 M^2}$$

Mach number $\sim 3.0$
Impacts on the mass determination of galaxy clusters

**Why we need new X-ray Missions**

**Mass bias for X-rays:**
\[ \sim -12\% \pm 12\% \]

Numerical simulations show, that this discrepancy can be accounted for by about 10 – 20% extra turbulent pressure.

**X-ray mass vs Weak Lensing mass**

Hydrostatic equilibrium

\[
\frac{d(P_{\text{thermal}} + P_{\text{nonthermal}})}{dr} = -\frac{GM(<r)}{r^2}\rho_{\text{gas}}
\]

\[
\frac{P_{\text{turb}}}{P_{\text{therm}}} = 0.11 \left( \frac{V_{\text{turb}}}{300 \text{km/s}} \right)^2 \left( \frac{kT_e}{5 \text{keV}} \right)^{-1}
\]

**Measurement of non-thermal pressure support** (gas motions, high energy particles, etc.) by high-resolution or hard X-ray spectroscopy is VERY important.
There should be sufficient number of type-2 Compton thin/thick AGN above 10 keV, but have not been resolved yet, directly.

Gilli, Comastri & Hasinger, 2006
Why we need new X-ray Missions

Hard X-ray Observations plays a key role

a flux level of $1.1 \times 10^{-11}$ ergs sec$^{-1}$ cm$^{-2}$ over 50% of the sky and $1.48 \times 10^{-11}$ ergs sec$^{-1}$ cm$^{-2}$ over 90% of the sky.

Swift did a great Job, but still only a few % of Cosmic X-ray Background have been resolved in hard X-rays.

New type of AGNs discovered by followup observations by Suzaku

<Deeply buried in dense tori of gas that they show little emission in soft X-ray and visible light.>
Radiative and mechanical heating and pressure from black holes have a profound influence on the evolution of all galaxies whether or not they are in clusters.

**Cosmic Feedback from AGN**

**Why we need new X-ray Missions**

How does Cosmic Feedback work and influence galaxy formation?
ASTRO-H is an international X-ray observatory, which is the 6th in the series of the X-ray observatories from Japan. It is currently planned to be launched in 2014 with an H-IIA rocket from the Tanegashima Space Center, Kagoshima, Japan.

<table>
<thead>
<tr>
<th>Launch site</th>
<th>Tanegashima Space Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch vehicle</td>
<td>JAXA HII-A rocket</td>
</tr>
<tr>
<td>Orbit Altitude</td>
<td>550 km</td>
</tr>
<tr>
<td>Orbit Type</td>
<td>Approximate circular orbit</td>
</tr>
<tr>
<td>Orbit Inclination</td>
<td>&lt; 31 degrees</td>
</tr>
<tr>
<td>Orbit Period</td>
<td>96 minutes</td>
</tr>
<tr>
<td>Total Length</td>
<td>14 m</td>
</tr>
<tr>
<td>Mass</td>
<td>&lt; 2.7 metric ton</td>
</tr>
<tr>
<td>Mission life</td>
<td>&gt; 3 years</td>
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</table>

ASTRO-H (formerly called NeXT) is now in Phase-C (Detail Design Phase)

CDR : 2011 June-July
Launch Year : 2014
ASTRO-H as an X-ray Observatory (0.3 - 600 keV)

1. Micro-calorimeter + XRT
   0.3-12 keV, \( \Delta E = 5 \text{eV} \), \( \text{FOV}=3' \), \( \Delta \theta = 1.3' \)
2. Soft X-ray CCD + XRT
   0.4-12 keV, \( \Delta E = 150 \text{eV} \), \( \text{FOV}=38' \), \( \Delta \theta = 1.3' \)
3. Hard X-ray imager + Hard XRT
   5-80 keV \( \Delta E < 2 \text{keV} \), \( \text{FOV}=9' \), \( \Delta \theta = 1.7' \)
4. Soft Gamma-ray detector
   100-600 keV no imaging capability

ASTRO-H
14 m
2.7 t
Launch 2014

Suzaku (ASTRO-E2)
(6m, 1.7t)
Launch 2005
ASTRO-H Configuration

HXI (Hard X-ray Imager)

SGD (Soft Gamma-ray Detector)

SXS (Micro Calorimeter)

SXI (X-ray CCD)

9.2 m

14 m
ASTRO-H  Hard X-ray Telescope (HXT)

- Pt/C depth-graded multilayer X-ray telescope, original to Japan.
- Large photon collecting area above 10 keV.
- Light-weight design as a heritage of Suzaku.
- Proven technology by balloon experiments.

**Bragg Reflection**

\[ n\lambda = 2d \sin \theta \]

- Heavy Material (Pt)
- Light Material (C)
- gap (d)

300 cm² (@30 keV)

- Newton
- Suzaku

HXT

SXT

1. Forming foil
2. Spray epoxy
3. ML coating
4. Curing
5. Removing
6. Finished ref.

Nagoya/Ehime/ISAS/Kobe/Chuo and more

At Nagoya U.
ASTRO-H  Hard X-ray Imager (HXI)

4 Layers of Si
1 Layer of CdTe

50 kg

Engineering Model

Shadow image is obtained with a Tungsten slit at 60 keV (241Am) source.
Power of Hard X-ray Telescope
improve sensitivity by ~100x over non-imaging missions
Large Collection Area by Mirrors+Small Focal Plane Detector
ASTRO-H Soft X-ray Spectroscopy (SXS)

- High Resolution Spectroscopy by a micro calorimeter array

<table>
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<th>Requirements (/Goal)</th>
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<tbody>
<tr>
<td><strong>Energy resolution</strong></td>
</tr>
<tr>
<td>7 eV (FWHM)</td>
</tr>
<tr>
<td>(4 eV (FWHM) Goal)</td>
</tr>
<tr>
<td><strong>Energy range</strong></td>
</tr>
<tr>
<td>0.3 - 12 keV</td>
</tr>
<tr>
<td><strong>Field of view</strong></td>
</tr>
<tr>
<td>2.9 x 2.9 arcmin</td>
</tr>
<tr>
<td><strong>Detector array</strong></td>
</tr>
<tr>
<td>6 x 6</td>
</tr>
<tr>
<td><strong>Absorber size</strong></td>
</tr>
<tr>
<td>800 μm</td>
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<tr>
<td><strong>Effective area</strong></td>
</tr>
<tr>
<td>160 / 210 cm² (at 1 / 6 keV)</td>
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ASTRO-H Coolers/Dewar

Detector to be Operated at 50 mK
EM Detector System (Detector Assembly + Detector Array + Anti-co Detector)
Very Recent Results based on the Engineering Model of ASTRO-H

ADR control is very good
FWHM = 0.72 μK

Resolution is superb

Measured: 0.3 μK RMS, Requirement: 2.5 μK RMS

Gain is extremely stable

Measured: ~1eV over 18 hr, Requirement: ~3eV per 10 min

Detectors are very uniform

NASA/GSFC
ASTRO-H Soft X-ray Telescope for SXS & SXI

Soft X-ray Telescope (SXT) will be an upgraded version of the Suzaku X-ray telescope (XRT). The diameter and focal length is larger, thus number of the nesting shells are increased.

(1) thicker aluminum substrate for the larger radii,
(2) more forming mandrels for better substrate shaping
(3) precise alignment bars
(4) glue to fix reflectors on the alignment bars
(5) stronger housing.
Simulated spectra: the Tycho SNR <5-7 eV Energy Resolution>

Simulated spectra of the iron K-shell complex from the inner region of the Tycho SNR with an exposure of 100 ks with SXS/ASTRO-H.

The ion temperature is assumed to be 30 billion degrees (black) or negligible (green). Red- and blue-shifted lines from the fast moving gas can be readily resolved with SXS.
Merging Cluster

A2256

(z = 0.058)

Perseus cluster (r<2’, 100ks)
vapec 3T (0.6keV, 2.6keV, 6.1keV)

1000 km/s
80 ksec x 2

ASTRO-H Micro calorimeter + Hard X-ray Science
ASTRO-H Summary

• As the international X-ray observatory in 2010’s, ASTRO-H will investigate the physics of the high-energy universe using high-resolution, high-throughput imaging and spectroscopy from 0.3 to 600 keV.

• ASTRO-H will push on X-ray astronomy to a new exciting phase by showing dynamical motions with a micro-calorimeter. Direct measurement of velocity field.

ASTRO-H is now in Phase C.

Next major step is the CDR (critical design review) in June/July 2011 for the planned launch year of 2014.

Simulation Tools are available from

http://astro-h.isas.jaxa.jp
The ISAS Space Science Committee approves that the IXO team in Japan can join the study activity on IXO during the definition phase, if the IXO mission is approved to proceed to the next phase in the down selection process of the Cosmic Vision.

The Japanese X-ray community regards the IXO mission as the next major X-ray program in Japan, following ASTRO-H.