The ASTRO-H Mission

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On behalf of the ASTRO-H team

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Science: White papers in 16 categories.
Many PV targets will be selected from them.

- Stars -- Accretion, Shocks, Charge Exchanges and Magnetic Phenomena
- White Dwarf
- Low-mass X-ray Binaries
- Accreting Pulsars, Magnetars, and Related Sources
- Stellar-Mass Black Holes
- Young Supernova Remnants
- Older Supernova Remnants and Pulsar Wind Nebulae
- Plasma Diagnostic and Dynamics of the Galactic Center Region
- High Resolution Spectroscopy of Interstellar and Circumgalactic Gas in the Milky Way and Other Galaxies
- Clusters of Galaxies and Related Science
- AGN Reflection
- AGN Winds
- New Spectral Features
- Shock and Acceleration
- Broad-band Spectroscopy and Polarimetry
- Chemical Evolution in High-z Universe
Introduction

ASTRO-H is the 6th in the series of the X-ray observatories from Japan, with more than 160 scientists from Japan/US/Europe/Canada contributing. Launched in early 2016.

NASA
- Micro Calorimeter Array/ADR
- Two soft X-ray Telescopes
- Eight Science Advisors
- Pipeline Analysis

SRON & U. of Geneva
- Filter Wheel/MXS for SXS

CEA/DSM/IRFU
- Cont. to BGO Shield/ASIC test

ESA
- Three Science Advisors
- Cont. to mission instruments
- User support in Europe

CSA
- Metrology System

Length: 14 m (in orbit)
Weight: 2.5 t

Orbit Alt./inclination: 550 km/31 deg
Launch: Early 2016 by H-IIA
4-types of science instruments onboard ASTRO-H

- **Soft X-ray Spectrometer**
  Hi-reso. Spec. 0.3-12 keV

- **Hard X-ray Imager**
  5-80 keV imaging

- **Soft X-ray Imager**
  30’x30’ wide CCD

- **Soft Gamma-ray Detector**
  60-600 keV with polarimetry

- **High resolution non-dispersive spectroscopy @ 0.3-12 keV**
  \( \Delta E < 7 \text{ eV} @ 6.4 \text{ keV} \), even for diffuse sources. Can easily resolve < 300 km/s.
  → Access to **sub-sonic motion** (bulk + turbulent) of hot plasma
4-types of science instruments onboard ASTRO-H

- Wide-band spectroscopy from 0.3 keV to 600 keV with good sensitivity
  - Hard X-ray imaging spectroscopy up to 80 keV with high sensitivity (~ NuSTAR)
  - Soft Gamma-ray coverage up to 600 keV with good sensitivity, with moderate polarimetry.

![Graph showing limiting flux and energy bands for different instruments]
4-types of science instruments onboard ASTRO-H

- **Field of view**

  - SXS: 3.05' x 3.05' (1.3' HPD) 0.3-12 keV
  - SXI: 37.8' x 37.8' (1.3' HPD) 0.5-12 keV
  - HXI: 9.2' x 9.2' (1.7' HPD) 5-80 keV

- **Effective area**

  - SXS: 210 cm² @ 6 keV
  - SXI: 360 cm² @ 6 keV
  - HXI: 300 cm² @ 30 keV (2 HXTs)
  - SGD: >20 cm² @ 100 keV
High Energy Resolution Performance (SXS)

- Imaging instrument (Not grating instrument)
  ⇒ Can observe extended sources.
- Better energy resolution at higher energy band
  ⇒ Best performance around Fe-K lines ($\Delta E < 7$ eV).

![Collecting area and Energy resolution graphs](image-url)
Science case-1: Intra-Cluster Matter Dynamics

ASTRO-H can determine:
- Ion kinetic temperature + motion (bulk + turbulence)
- Ionization temperature
- Electron temperature
- Resolve overlaid components with is broadband

From ASTRO-H White Paper (Cluster related science) S. Allen, T. Kitayama, M. Markevitch et al.
Wide-band & High-timing Capability

- 4 instruments covers from 0.3 to 600 keV.
- Events are processed one by one: SXS, HXI, SGD
  ⇒ Their timing resolutions: several – several 10 μs.
  (SXS frame exposure time: 0.1 – 4 s + window mode.)

❖ Effective area

❖ Pulsation / Burst

Crab with Suzaku-HXD (Kouzu+2013)
Science case-2: materials around AGNs

Unified model

CCD era: **detect** reflection
A-H era: **identify where** the reflection occurs (Doppler & Ionization)

+ Compton shoulder (surroundings info.)
+ Cut-off/reflection ident. (emission info.)

From ASTRO-H White Paper (AGN reflection related science) Raynolds, Ueda, Awaki, Gallo et al.
The Hard X-ray Imager

HXI Camera

- Height: 65 cm
- Weight: 43 kg

Active shields
- 9 units of BGO + APD (21.6 kg in total)

4 Si double-sided strip detectors (0.5 mm thick)

CdTe double-sided strip detector (0.75 mm thick)

250 μm strip pitch x 128 ch (each side)

ASIC with low-noise readout & ADC (JAXA/GM-Ideas)
Spectra during Thermal Vac. Test

**HXI1-S spectra**
- P-side (DSSD)
- Al-side (CdTe-DSD)

All events
- non-cal, non-fast BGO events
- & non-hit pattern events

- $^{241}$Am calibration sources < 60 keV/ Bi-K lines of 77&87 keV (from BGO)
- Energy resolution: ~1.0 keV (Si), ~2.0 keV (CdTe)@60 keV.
- All strips are working good. => Uniform image
- $^{241}$Am source locates one side (with only tagged calibration events).
The Soft Gamma-ray detector

Height: 50 cm
Weight: 150 kg

3 Compton Cameras

Active BGO shields
25 units of BGO + APD (80 kg in total)
+ Passive fine collimator

Si: 32 layers
CdTe (bottom): 8 layers
CdTe (Side): 2 layers x 4

Compton kinematics

\[ \cos \theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2} \]

Narrow Field-of-View Compton Camera
Removing background outside FOV efficiently
Performance of Compton Camera (SGD)

Energy resolution: < 2 keV @ 60 keV
- to reject line backgrounds effectively
- to achieve better angular resolution for Compton reconstruction.

$^{241}$Am Si spectrum

Energy: 59.5 keV
$\Delta E$: 1.9 keV (FWHM)

$^{22}$Na Compton event spectrum

Energy: 511 keV
$\Delta E$: 7.6 keV (FWHM)
SGD Polarization Capability

- Using Compton events, SGD measures polarization (e.g., IBIS/SPI).

  Polarized photons tend to scatter perpendicular to polarized vector.

  1 Compton Camera has 13,312 pixels, measuring scattering angle accurately.

- Detail performance will be verified with synchrotron beam at SPring-8 in Nov. 2015 using Engineering Model.

  (Beam energies: ~120 & 250 keV).
- Each SGD has 25 BGO units covering ~2 pi (2 SGDs: ~4 pi) and 150-5000 keV.
- Data are used for GRB/Transient sciences (e.g., Suzaku/WAM).
Thermal & Mechanical Verification @ Tsukuba (2015)

⇒ Almost ready to deliver to launch site, Tanegashima.
**ASTRO-H observation/operation framework**

Phase 0: 3 Months: Satellite/Instruments Check out (including Calibration)

Phase 1: 6 Months: SWG 90 % (PV Phase) Observatory 10 %

Phase 2: 12 Months: SWG Carry Over 15 %, GO 75 %, Observatory 10 %

Phase 3: Rest of the mission: KeyProject 15 % (TBD), GO 75 %, Observatory 10 %

Observatory 10 % = Calibration + TOO + Director's Time

<table>
<thead>
<tr>
<th>Check</th>
<th>Sci. WG</th>
<th>Key Project?</th>
</tr>
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<tbody>
<tr>
<td>0</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>GO</td>
<td>GO</td>
</tr>
<tr>
<td>21 month</td>
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</table>

Data policy among J/Europe/US in the GO time, would be similar to the Suzaku case. But we are planning to introduce key-project type and/or early-data-released type observations from early phase of the mission.
ASTRO-H is coming in Early 2016

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# ASTRO-H science specifications

## TABLE 2. Key parameters of the ASTRO-H payload

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hard X-ray Imager (HXI)</th>
<th>Soft X-ray Spectrometer (SXS)</th>
<th>Soft X-ray Imager (SXI)</th>
<th>Soft γ-ray Detector (SGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector technology</td>
<td>Si/CdTe cross-strips</td>
<td>micro calorimeter</td>
<td>X-ray CCD</td>
<td>Si/CdTe Compton Camera</td>
</tr>
<tr>
<td>Focal length</td>
<td>12 m</td>
<td>5.6 m</td>
<td>5.6 m</td>
<td>--</td>
</tr>
<tr>
<td>Effective area</td>
<td>300 cm² @ 30 keV</td>
<td>210 cm² @ 6 keV</td>
<td>360 cm² @ 6 keV</td>
<td>&gt;20 cm² @ 100 keV Compton Mode</td>
</tr>
<tr>
<td>Energy range</td>
<td>5 – 80 keV</td>
<td>0.3 – 12 keV</td>
<td>0.5 – 12 keV</td>
<td>40 – 600 keV</td>
</tr>
<tr>
<td>Energy resolution (FWHM)</td>
<td>2 keV</td>
<td>&lt; 7 eV</td>
<td>150 eV</td>
<td>4 keV</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>&lt;1.7 arcmin</td>
<td>&lt;1.3 arcmin</td>
<td>&lt;1.3 arcmin</td>
<td>--</td>
</tr>
<tr>
<td>Effective Field of View</td>
<td>~ 9 × 9 arcm²</td>
<td>~ 3 × 3 arcm²</td>
<td>~ 35 × 35 arcm²</td>
<td>0.6 × 0.6 deg² (&lt; 150 keV)</td>
</tr>
<tr>
<td>Time resolution</td>
<td>several 10 μs</td>
<td>several 10 μs</td>
<td>4 sec</td>
<td>several 10 μs</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>−20°C</td>
<td>50 mK</td>
<td>−120°C</td>
<td>−20°C</td>
</tr>
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