Athena → Athena+
Towards a European
Large X-ray Observatory

Mike Watson
University of Leicester
Topics

- Brief history and context
- New ESA approach to L-class selection
- The Athena+ concept

- Credits: Athena & Athena+ teams
The road to a next generation X-ray observatory

- **ATHENA concept** 2011
  - ESA (+ JAXA, NASA ?)
- **IXO concept** 2008
  - ESA + JAXA + NASA
- **XEUS CV proposal** 2007
  - ESA + JAXA
- **XEUS concept 1996**
  - ESA
- **Constellation-X concept 1995-6**
  - NASA
The road to a next generation X-ray observatory

- **XEUS concept 1996** (ESA)
- **Constellation-X concept 1995-6** (NASA)
- **IXO concept 2008** (ESA + JAXA + NASA)
- **XEUS CV proposal 2007** (ESA + JAXA)
- **ATHENA concept 2011** (ESA + JAXA, NASA ?)
- **ATHENA+ 2013** (ESA + JAXA, NASA ?)
- **ATHENA+ concept 2013** (ESA + JAXA, NASA ?)
**ESA L2/L3 missions: new approach**

- **Science themes** for L2 and L3 chosen this year
- Return to “cornerstone” approach for large missions (cf H2000)
- Budget ~€1bn ESA cost (plus ~€200M ESA MS)
- ESA-led, max. ~20% “non-critical” international contributions OK
- New process defined and has already started

**Themes proposed “white papers”**
- March – May 2013

**Theme selection for L2 and for L3**
- May – Oct 2013
- Senior Review Committee
- Nov 2013

**Call for L2 missions for selected theme**
- Early 2014

**L2 launch 2028**

**NB L3 call 2020**
Athena mission was not fundamentally flawed

- *Came very close to being selected for L1*
- *Cost, technical readiness, schedule all OK (c.f. NGO)*
- *Issues: conservative design, TRL of some elements …*

Plan: Athena+

- **White Paper: Revealing the Hot and Energetic Universe** - *From Large scale structures to accreting Black Holes*
- **Strawman mission: Athena+ concept**
- *… and hope to be selected*
Revealing the Hot and Energetic Universe: From Large Scale Structure to accreting Black Holes

- Where are the hot baryons and how do they evolve?
- How do black holes grow and how do they shape the Universe?
- The Astrophysics of the hot, energetic Universe

*slide courtesy K Nandra*
Athena in 2012

Ariane V launch to L2, 5yr nominal mission

Payload

- Wide Field Imager (WFI)
- X-ray Microcalorimeter Spectrometer (XMS)

ESA Silicon Pore X-ray Optics
5 - 10” resolution

Focal plane
Service Module
Fixed Metering Structure 12m long
Mirror Assembly

Payload slide courtesy K Nandra
MISSION, SPACECRAFT
• no major change (L2 orbit, 12 m focal length, SPO optics)
• but single telescope, 2 focal plane instruments with interchange mechanism

OPTICS
• increased effective area (x2 approx)
  – 500→1000 modules, 3m outer diameter
• 5” PSF requirement (3” goal)
  – ambitious but plausible

INSTRUMENTS
• no major change
• increased FOVs
• improved energy resolution for XMS (now XIFU)
# Athena+: Science Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement</th>
<th>Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Area</td>
<td>2m² @ 1 keV (goal 2.5m²)</td>
<td>Black hole evolution</td>
</tr>
<tr>
<td></td>
<td>0.25 m² @ 6 keV (goal 0.3m²)</td>
<td>Large scale structure</td>
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<td></td>
<td></td>
<td>Strong gravity</td>
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<tr>
<td>Angular Resolution</td>
<td>5” (goal of 3”)</td>
<td>Black Hole Evolution</td>
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<tr>
<td></td>
<td></td>
<td>Large Scale structure</td>
</tr>
<tr>
<td>Fields of view</td>
<td>WFI: 40’ diameter (goal 50’)</td>
<td>Black Hole Evolution</td>
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<tr>
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<td>XMS: 5’ x 5’ (goal 7’ x 7’)</td>
<td>Large Scale structure</td>
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<tr>
<td>Spectral resolution</td>
<td>150 eV @ 6 keV (WFI)</td>
<td>Black Hole Evolution</td>
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<tr>
<td></td>
<td>2.5 eV (XMS) (goal 1 eV central)</td>
<td>Large Scale Structure</td>
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<tr>
<td>Count rate capability</td>
<td>&gt;1 Crab</td>
<td>Strong Gravity</td>
</tr>
<tr>
<td>Timing resolution</td>
<td>50 µs</td>
<td>Strong Gravity</td>
</tr>
<tr>
<td>TOO response</td>
<td>8 hours (2 hours goal)</td>
<td>Large Scale Structure</td>
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</tbody>
</table>
Effective areas

![Graph showing effective areas for different instruments vs energy in keV. The x-axis represents energy in keV, and the y-axis represents area in m^2. Different instruments are represented by different colors: red for ATHENA+ WFI, teal for ATHENA+ XIFU, pink for ATHENA WFI, blue for ATHENA XMS, and yellow for IXO WFI.](image)
Effective areas

- ATHENA+ WFI
- ATHENA+ XIFU
- Astro-H SXS
- XMM pn

Area (m^2)

Energy (keV)
Angular resolution

Athena

Athena+

FWHM=10 arcsec

requirement

FWHM=5 arcsec

goal

requirement

FWHM=3 arcsec

goal
FOV sizes

XMS (XIFU)

ATHENA+ 5.7x5.7arcmin

ATHENA 2.3x2.3'

WFI

ATHENA+ 40 X 40 arcmin

ATHENA 24 X 24arcmin
## X-ray IFU design options (geometry TBC)

<table>
<thead>
<tr>
<th>region</th>
<th>area / format</th>
<th>pixel size</th>
<th>ΔE</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>central</td>
<td>10”x10” 10x10</td>
<td>~1” 50µm</td>
<td>1.5 eV</td>
<td>(E_{\text{max}} \approx 2.5) keV lower count rate limit</td>
</tr>
<tr>
<td>inner</td>
<td>1.4’x1.4’ 20x20</td>
<td>~4” 250µm</td>
<td>2.5 eV</td>
<td>(E_{\text{max}} \approx 6) keV</td>
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<tr>
<td>outer</td>
<td>5.7’x5.7’ 40x40</td>
<td>~9” 500µm</td>
<td>8 eV</td>
<td>(E_{\text{max}} \approx 6) keV (40x40) array with 10x10 ‘hole’</td>
</tr>
</tbody>
</table>
ATHENA+ Coordination Group
Kirpal Nandra, chair (MPE, D)
Xavier Barcons (IFCA, ES)
Didier Barret (IRAP, F)
Andy C. Fabian, (Cambridge, UK)
Jan-Willem den Herder (SRON, NL)
Luigi Piro (IASF, I)
Mike Watson (Leicester, UK)

X-TASAT (X-ray Technology Activities Science Advisory Team, ESA committee)

+ Telescope Working Group (Dick Willingale)
+ 11 Science Working Groups

Website: http://the-athena-x-ray-observatory.eu
preliminary response matrices available
X-ray Observatories: Timeline

1995

Chandra

2000

NuSTAR

2005

Suzaku

2010

Spektr-RG

2015

Astro-H

2020

Athena+

2025

Uncertain Future?

2030

+ASTROSAT (India), HXMT (China)

slide courtesy K Nandra
end