The XENIA mission

Cosmic chemical evolution of baryons

Dieter H. Hartmann

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and the Xenia team:
consortium of Institutes from US, Eu, Japan
Xenia will trace structure formation

**Gamma-Ray Bursts**
- Evolution of massive star formation using GRBs to trace their explosions back to $z > 8$
- Measure the metals in the host galaxies of GRBs and the explosive enrichment in their close environment out to $z > 8$

**Clusters of Galaxies**
- Trace the evolution and physics of clusters out to their formation epoch ($z > 1$)
- Measure the thermodynamical and chemical properties of a fair sample out to the virial radius

**Cosmic Web**
- Detect the largest reservoir of baryons from $z \sim 1$ to the present time by measuring densities $\sim 30$ times smaller than previously done
Xenia mission profile
Xenia instruments
CRIS
Cryogenic Imaging Spectrometer

Area $1000 \text{cm}^2@0.5\text{keV}$
Energy range: 0.1-3 keV
Resolution: 2.5eV (1eV goal)
Field of view=1.0°
ang.res=3’

TES microcalorimeters
Xenia instruments
HARI
High Angular Resolution Imager

Area = 1000 cm$^2$ @ 1 keV
Range: 0.3-8 keV
Field of view = 1.4°
ang.res = 10” constant
CCD
Xenia instruments
TED
Transient Event Detector

Eff area = 1500 cm²
8-200 keV (goal <5 keV)
3 sr (¼ of the sky)
3’ localization

2 CZT based coded mask detectors
GRBs as cosmological probes

• TED: 150 GRB localized per year, 80 GRB with Fluence(15-150keV) > 10^{-6} erg cm^{-2} s^{-1}

• GRB @ z>6: 7-14 (goal) per year

• Mid-bright GRB afterglow with a fast (t<60s) pointing CRIS yields 10^{5-6} X-ray photons, and 10^{3} cts in 1 eV resolution bin

• In 5 years: Golden sample of >250 afterglows with high resolution X-ray spectra: redshift, metals in host-galaxy and close environment from local to high-z universe

• Platinum sample of 150 afterglows for WHIM studies
Exploring a new region of the Cosmic web

Cluster @ Virial r.

Hot (clusters)

Cold Diffuse

Star forming

Branchini et al 2009
Tomography of the Universe: the X-ray forest from the Cosmic Web with GRBs

~200s OVII-OVIII filaments in 5 years

OVII triplet
z=0.069

OVIII
z=0.069
3D mapping of the Cosmic Web

Model, $\Delta z=0.01$

Detected, O\text{VII}+O\text{VIII} in emission, 5 $\sigma$, 1 Ms

Down to overdensities of 100
GRBs as cosmological probes

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• Platinum sample of 150 afterglows for WHIM studies
Xenia X-ray spectrum of a GRB

MCG-6-30-15, Lee et al, Chandra HEGT 120 ksec
Tracing the metal enrichment in the GRB local environment

X-ray metal edges from a GRB nearby environment at z=7
ISM of the host galaxies

Chemical c., ionization, kinematics (outflows) in galaxies up to z>7

Resonant absorption lines from GRB host galaxy at z=1
Summary

• Medium class mission proposed to the 2010 Decadal Survey
• Xenia Unique capabilities: large grasp, fast reaction, high spectral resolution)
• Core science: GRB as probes, WHIM, clusters
• + Auxiliary science
• Brings in a large community outside GRBs
Cosmic Chemical Evolution Workshop
June 2-4, 2010 St. Michael’s Maryland
(http://sms.msfc.nasa.gov/xenia/workshop.html)

INVITED SPEAKERS:

Shirley Ho
Alex Heger
Jason Tumlinson
Serena Bertone
Takaya Ohashi
Grant Matthews
Art Champagne
Jelle Kaastra
Kyoko Matsushita
Neil Gehrels
Friedel Thielemann
David Burrows
Renyue Chen
Yoh Takei
Jochen Greiner
Volker Bromm
Andreas Burkert
Anna Frebel
Kazuhisa Mitsuda
Josh Grindlay

Eli Dwek
Thorsten Naab
Nobu Kawai
Christoph Pfrommer
J.-W. den Herder
Avionics: Communication Strategy

3 - Ground stations

WSGT
White Sands

GSFC
Goddard M

GRGT
Guam

Xenia
600 km orbit

Science data
3.8 Mbps orbital average
Ku-band

GRB alerts, TOO

Engineering data
4 kbps, S-band

7 - TDRSS at GEO (35888 km)

Supports:
Ka-band 27.5-22.2 GHz
25 Mbps up, 800 Mbps dw
Ku-band 15.0-13.7 GHz
25 Mbps up, 300 Mbps dw
S-band 2.3-2.0 GHz
300 kbps up, 6 Mbps dw

Notes:
This communication strategy is similar to FERMI (formerly GLAST), and suggested in EDGE.
Spectroscopy: fast reaction and wide field

- Line spectroscopy merit factor for variable sources = S/N for EW=1eV for a typical GRB afterglow
X-ray Narrow abs lines from ISM in our own ‘host galaxy’

• Bright galactic binary (1820-303) observed with Chandra grating (Yao and Wand 2006)
Fast repointing

Requirement: < 65 sec for 80% GRB)

• Suggest using Ball Aerospace M-95 CMG 4 wheel pyramid configuration for all slews, station keeping, and observations.

• Provides up to 6.1 Nm torque (~4.0 Nm required for Xenia)
CRIS

Table 5: CRIS Instrument Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution at 0.5 keV</td>
<td>2.5 eV</td>
<td>1 eV</td>
</tr>
<tr>
<td>Field of View</td>
<td>0.9°×0.9°</td>
<td>1°×1°</td>
</tr>
<tr>
<td>Array size [pixels]</td>
<td>2000</td>
<td>2176</td>
</tr>
<tr>
<td>Energy range [keV]</td>
<td>0.2 – 2.2</td>
<td>0.1 – 3.0</td>
</tr>
<tr>
<td>Effective area @ 0.6 keV</td>
<td>1000 cm²</td>
<td>1300 cm²</td>
</tr>
<tr>
<td>grasp@0.6 keV [cm²·deg²]</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Angular resolution (HPD)</td>
<td>4 arcmin</td>
<td>2.5 arcmin</td>
</tr>
<tr>
<td>Peak count rate [c/s]</td>
<td>10,000</td>
<td>15,000</td>
</tr>
</tbody>
</table>

- Mirror: 2/4 reflection
- TES microcalorimeter
Transient Event Detector

2 Coded Mask / CZT detectors

Table 3: TED Instrument Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution at 100 keV</td>
<td>5 keV</td>
<td>3 keV</td>
</tr>
<tr>
<td>Field of View</td>
<td>2.8 sr</td>
<td>3 sr</td>
</tr>
<tr>
<td>Array size (pixels, one camera)</td>
<td>24,576</td>
<td>98,304</td>
</tr>
<tr>
<td>Energy range (keV)</td>
<td>8–200</td>
<td>5–300</td>
</tr>
<tr>
<td>Effective area, 20-50 keV ( cm²)</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Angular resolution (FWHM)</td>
<td>34°</td>
<td>17°</td>
</tr>
<tr>
<td>Source location accuracy (10σ)</td>
<td>4°</td>
<td>2°</td>
</tr>
<tr>
<td>Min. count rate (background) [c/s]</td>
<td>2500</td>
<td>2500</td>
</tr>
<tr>
<td>Peak count rate [c/s]</td>
<td>7000</td>
<td>7000</td>
</tr>
<tr>
<td>S/W processing time</td>
<td>20 s</td>
<td>10 s</td>
</tr>
<tr>
<td>Continuum sensitivity (1s, 15-150 keV; ph/cm²/s)</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>
NGC4051
Krongold et al 2009
Back up slides
Observing programme

<table>
<thead>
<tr>
<th>CORE PROGRAM</th>
<th>Fields</th>
<th>ks/target</th>
<th>Total [ks]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRBs</td>
<td>400</td>
<td>50</td>
<td>20,000</td>
</tr>
<tr>
<td>Cluster Formation (10° x 10°)</td>
<td>100</td>
<td>50</td>
<td>5,000</td>
</tr>
<tr>
<td>Clusters (1Ms on source + 1Ms bg)</td>
<td>10</td>
<td>2000</td>
<td>20,000</td>
</tr>
<tr>
<td>WHIM 4.5° x 4.5°</td>
<td>25</td>
<td>1000</td>
<td>25,000</td>
</tr>
<tr>
<td>Auxiliary Science</td>
<td></td>
<td></td>
<td>40,000</td>
</tr>
<tr>
<td>Total (5 years)</td>
<td></td>
<td></td>
<td>110,000</td>
</tr>
</tbody>
</table>
**HARI**

**Table 7: HARI instrument requirements**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution at 0.5 keV</td>
<td>80 eV</td>
<td>70 eV</td>
</tr>
<tr>
<td>Resolution at 5.9 keV</td>
<td>150 eV</td>
<td>130 eV</td>
</tr>
<tr>
<td>Field of View (diameter)</td>
<td>1.4°</td>
<td>1.5°</td>
</tr>
<tr>
<td>Energy range [keV]</td>
<td>0.3 – 5.0</td>
<td>0.2 – 10.0</td>
</tr>
<tr>
<td>Effective area @ 1 keV</td>
<td>530 cm²</td>
<td>1000 cm²</td>
</tr>
<tr>
<td>Effective area @ 6 keV</td>
<td>25 cm²</td>
<td>100 cm²</td>
</tr>
<tr>
<td>Angular resolution (HPD)</td>
<td>15 arcsec</td>
<td>10 arcsec</td>
</tr>
<tr>
<td>Time resolution</td>
<td>0.5 s</td>
<td>0.1 s</td>
</tr>
<tr>
<td>Peak count rate [c/s]</td>
<td>10,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Instrumental background @ 1 keV [cts/cm²/s/keV]</td>
<td>1.5 x 10⁻³</td>
<td>6 x 10⁻⁴</td>
</tr>
</tbody>
</table>

- **Mirror: Polynomial profile with constant PSF**
- **CCD**

**Figure 8: Wide-field X-ray optics design.**
Satellite and payload

- HARI
- Bulkhead scope support
- Scope support
Back to the Future

• Future X-ray missions based on new generation of Transition Edge Sensor microcalorimeters (<2 eV resolution)
• International X-ray Observatory (IXO) - Xenia
• Exciting drivers addressing cosmology in X-rays
Tracing clusters at virial radius
Configuration: Falcon Shroud
Configuration
Evolution of the Universe

Past
- Reionization
- Stars

Small scale
- GRBs
- SNRs

Starburst galaxies/AGNs

Clusters
- Feedback & Enrichment
- Clusters

Large scale
- WHIM

Structure formation

Present
- WHIM

Feedback & Enrichment

XENIA
- First metal creation at z>5
- Metal creation/injection by supernovae
- Cluster temperature/mass study to virial radius
- Cluster abundance to virial radius
- Missing baryons at low redshift
EDGE/XENIA

Cosmic chemical evolution of baryons

L. Piro

on behalf of the EDGE/XENIA collaboration
Table 1: Estimated number of absorption systems detected at $>5\sigma$ per year by Xenia [4]

<table>
<thead>
<tr>
<th>Fluoence 0.3-10 keV [erg cm$^{-2}$]</th>
<th># GRBs [yr$^{-1}$]</th>
<th>EW$_{\text{min}}$ [eV]</th>
<th>EW$_{\text{min}}$ [eV]</th>
<th>O VII/VIII [yr$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt;1 \times 10^5$</td>
<td>6</td>
<td>0.12</td>
<td>0.08</td>
<td>19</td>
</tr>
<tr>
<td>$&gt;5 \times 10^5$</td>
<td>13</td>
<td>0.18</td>
<td>0.12</td>
<td>29</td>
</tr>
<tr>
<td>$&gt;2 \times 10^6$</td>
<td>33</td>
<td>0.28</td>
<td>0.19</td>
<td>37</td>
</tr>
</tbody>
</table>
Cluster evolution

<table>
<thead>
<tr>
<th>Survey</th>
<th>Wide</th>
<th>Deep-1</th>
<th>Deep-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure</td>
<td>50 ks</td>
<td>1 Ms</td>
<td>2 Ms</td>
</tr>
<tr>
<td>Total area (deg$^2$)</td>
<td>340</td>
<td>11.5</td>
<td>8</td>
</tr>
<tr>
<td>Clusters @ z&gt;1</td>
<td>1800</td>
<td>510</td>
<td>600</td>
</tr>
<tr>
<td>Clusters, $T_X$ @ z&gt;1</td>
<td>450</td>
<td>140</td>
<td>170</td>
</tr>
</tbody>
</table>

Diagram showing the evolution of clusters with redshift, exposure times, and total areas for different surveys.
WFImager: polynomial optics

WFXT (epoxy replication su carrier in SiC) – Ø = 60 cm
F. L. = 300 cm

HEW = 10 arcsec

Test @ Panter-MPE
Auxiliary Science

- Cosmological parameters (Clusters & GRBs)
- Feedback processes
- AGN
- Physics and Progenitors of GRBs
- The densest matter
- Violent accretion on compact objects
- Stars
- Solar system
- Search for light Dark Matter (sterile neutrinos)
- Gravitational waves from SMBH mergers
Metal and ISM evolution with GRB

Metal enrichment in the environment of massive stars upto $z > 6$

ISM of the host galaxy, kinematical studies of the outflows

X-ray metal edges from a GRB nearby environment at $z = 7$

Resonant absorption lines from GRB host galaxy at $z = 1$
Payload I

- **WFM** → coded mask, CZT detector

- **GRBD**
  2 scintillators (NaI)
Payload II

- **WFS**
  2/4 fold →
  TES calorimeter

- **WFI →**
  polynomial, CCD

---

WFXT (epoxy replication su carrier in SiC) – $\varnothing = 60$ cm
F. L. = 300 cm

$HEW = 10$ arcsec

Test @ Panter-MPE
Most of the baryon of the Universe are locked in large scale, low density structures visible only in X-rays.

High resolution spectroscopy and spatial resolution, wide field in emission.

GRB as cosmological beacons: fast reaction, high res. absorption spectroscopy.

HOW?

Structure Formation

Structure size

Stars
Galaxies
Clusters
Filaments
XENIA: Mission and Payload

**HARI: High Angular Resolution Imager**
- 1000cm\(^2\)@1keV 0.3-8 keV CCD
- Field=1.4°  ang.res=10” constant

**CRIS: Cryogenic Imaging Spectrometer**
- 1000cm\(^2\)@0.5keV
- 0.1-3 keV TES DE<2.5eV
- Field=1.0°  ang.res=3’

**TED: Transient Event Detector**
- ¼ of the sky, 3’ localization
- 8-200 keV

- Low bkg: LEO equatorial
- Autonomous fast pointing in 60 s
- 2 tons
- TRL≥4
- Decadal Survey
- medium size