IXPE: Imaging X-Ray Polarimetry Explorer Mission

2017 IEEE Aerospace Conference
Yellowstone Conference Center, Big Sky, MT • USA
March 4-11, 2017

Session 2.01
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Ball Aerospace

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Introduction
Overview of science
Project partners and roles
Technical summary
Schedule and milestones
Conclusions
IXPE

Quick Summary of IXPE

- NASA Explorer Mission, cost capped at $175M (FY15)
- PI: Martin Weisskopf, MSFC
- Class D Mission managed by MSFC
- LEO observatory that measures spatial, spectral, timing, and polarization state of X-rays from 49 known astrophysical targets
- Ball Roles: Spacecraft, Payload mechanical, AI&T, and Mission Ops (with LASP)
- MSFC: Management, X-ray optics, SOC
- ASI (Italian Space Agency): Detectors Units, Ground station
- Phase B starts now; launch Nov 2020
X-ray emission from energetic processes: In-fall of matter into Neutron Star or Black Hole, synchrotron or shock emission, or very hot regions

Can originate both from point and extended sources; *Imaging* separates these sources

*Polarization* of X-rays if there is anisotropy in emission geometry or mag field, plasma reflections, or general relativistic effects

*Imaging* separates regions with different emission mechanisms

*Polarization* probes the source geometry and mag field strength
Active galaxies are powered by supermassive Black Holes with jets
- Radio polarization implies the magnetic field is aligned with jet
- But other models also consistent with current observations

**IXPE** can image the Cen A jet and separate from other sources in the field (e.g., Ultra Luminous X-ray source)
IXPE SCIENTIFIC OBJECTIVES

- **Science Objectives:**
  - Enhance our understanding of the physical processes that produce X-rays from and near compact objects such as neutron stars and black holes.
  - Explore the physics of the effects of gravity, energy, and electric and magnetic fields at their extreme limits.

- **IXPE addresses key questions in High Energy Astrophysics**
  - What is the spin of a black hole?
  - What are the geometry and magnetic-field strength in magnetars?
  - Was our Galactic Center an Active Galactic Nucleus in the recent past?
  - What is the magnetic field structure in synchrotron X-ray sources?
  - What are the geometries and origins of X-rays from pulsars?

Polarimetry of X-ray sources largely unmeasured
Opens a new window on the X-ray Universe
PRINCIPAL TEAM MEMBERS

- Principal Investigator
- Project Management
- Systems Engineering & SMA
- Mirror Module Design, Fabrication, & Calibration
- Science Operations Center (SOC)
- Science Data Analysis and Archiving
- Detector System Funding
- Ground Station (Malindi)
- Mission Assurance (Italian contribution)
- Spacecraft
- SE and SMA Support
- Payload Structure
- S/C, Payload, Observatory I&T
- Italian PI (IPI)
- Mission Ops Management
- Mission Operations Center
- Polarization-Sensitive Detector System
- Payload Computer
INTERNATIONAL RELATIONSHIPS

CLEAR INSTITUTIONAL ROLES, WITH WELL-DEFINED INTERFACES
Science Team

- Martin Weisskopf, PI
- Brian Ramsey, Deputy PI
- Paolo Soffitta, Italian PI
- Ronaldo Bellazzini, Italian Co-PI
- Enrico Costa, Senior Co-I
- Steve O’Dell, Project Scientist
- Allyn Tennant, Co-I
- Fabio Muleri, Co-I
- Jeffrey Kolodziejczak, Co-I
- Roger Romani, Co-I
- Giorgio Matt, Co-I
- Vicky Kaspi, Co-I
- Ronald Elsner, Co-I
- Luca Baldini, Co-I
- Luca Latronico, Co-I
IXPE has a Straight Forward Mission Concept

- IXPE Observatory is a single flight element
- Observatory launched to a 540 km, 0° orbit
- Pegasus XL launch vehicle is baselined
- 3 critical events occur within ground or TDRSS contact
  - Separation from launch vehicle (TDRSS) – free flying S/C
  - Solar array deployment (TDRSS) – full power available
  - Payload boom deployment (Malindi) – ready for payload commissioning
- Observatory comm via S-band link
  - Half of available Malindi contacts meet data download requirements for high data rate targets (e.g. The Crab)
    - Most targets require only 2 (of 15 available) contacts per day
Set of three mirror module assemblies (MMA) focus X-rays onto three corresponding focal plane detector units.

Mirror modules provide imaging and background reduction.

Detectors provide position, energy and polarization information, photon by photon, plus time stamp.
**Mirror Module Design**

**Heritage Design Approach**
- Electroformed Ni shells use a proven fab process
- Mounting combs provide shell attachment points
- A single rigid spider supports the 24 nested shells and attach module to structure

**IXPE Mirror Module Assembly**

- Paraboloid Surfaces
- Hyperboloid Surfaces
- X-rays
- Focal Point
- Shell Mounting Comb
- Rigid Support Spider
Detector A Contribution from ASI

- Detection uses photoelectric effect
- X-rays absorbed in detector fill gas
- Photoelectron emission aligned with X-ray polarization vector
- Electron multiplier with pixelated detector

Gas Pixel Detector (GPD)

TRL 6 Prototype same form/function as FM

- Flexible cables
- Ti frame
- Be window
- Gas cell
- GEM
- Miniboard
- Al flange

Laboratory DAQ
END-TO-END FLOW FROM DETECTED PHOTON TO SCIENTIFIC DATA PRODUCTS
**IXPE has substantial timeline and technical margins**

- Design Reference Mission (DRM) targets studied in detail during Year 1
  - Year 2 is available for follow up observations, targets of opportunity, survey of additional sources
- **IXPE also has high technical margins**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Requirement</th>
<th>Capability</th>
<th>Margin</th>
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<tbody>
<tr>
<td>Launch Mass</td>
<td>291.7 kg</td>
<td>380.0 kg</td>
<td>30.3%</td>
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<tr>
<td>Science Data Storage</td>
<td>4 GB</td>
<td>6 GB</td>
<td>50%</td>
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<tr>
<td>EOL Science Mode Power Generation w/30° offset</td>
<td>188 W</td>
<td>257 W</td>
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<td>LOS Pointing Accuracy</td>
<td>53.1 arcsec (3σ)</td>
<td>25.2 arcsec (3σ)</td>
<td>110%</td>
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<td>LOS Co-alignment Accuracy, X-axis</td>
<td>19.8 arcsec (3σ)</td>
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<td>Link Margins</td>
<td>&gt;3 dB</td>
<td>&gt;3.9 dB</td>
<td>&gt;3 dB</td>
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IXPE USES HERITAGE GROUND DATA SYSTEM
# IXPE Integrated Master Schedule

## Mission Phases

<table>
<thead>
<tr>
<th>Phase A (11 mos)</th>
<th>Phase B (13 mos)</th>
<th>Phase C (15 mos)</th>
<th>Phase D (17 mos)</th>
<th>Phase E (19 mos)</th>
<th>Phase F (21 mos)</th>
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<td>6/1/19</td>
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<td>Submit CDR</td>
<td>Flight Select</td>
<td>SSR/MMR</td>
<td>BIR</td>
<td>OBR</td>
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<td>1/1/18</td>
<td>4/3/19</td>
<td>7/1/20</td>
<td>10/1/21</td>
<td>1/2/22</td>
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## Major Milestones/Reviews

- **PSR A Select**
- **Submit CDR**
- **Flight Select**
- **SSR/MMR**
- **BIR**
- **OBR**
- **Launch 11/20**
- **PSR 11/30**
- **FLAP/MMR E 12/15**
- **KSP E 12/22**

## Master Schedule

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## Payload

- **Optics Assembly Design**
- **EM Manufacturing and Test**
- **Flight Mirror Mod Assy Test**

## Payload Harness

- **Detector System**
- **Detector Units**

## Payload Computer

- **Payload Computer Design**
- **Contracts**
- **EM Unit**

## Spacecraft (Ball)

- **Spacecraft Program Management**
- **Spacecraft Mission Assurance**
- **Spacecraft System Engineering**

## Flight Software

- **RF and Communications**
- **EPPOs**
- **Spacecraft Harness**
- **Spacecraft Structure and Mech**
- **Spacecraft Thermal Control**

## Mission Operations (LAPSI)

- **Mission Operations**
- **Mission Operations Development**
- **Commissioning**

## Launch Vehicle

- **Launch Site Operations**
- **Launch Site Site Planning**

## Education and Public Outreach

- **EPO Planning**
- **Track Analysis**
- **Algorithms for X-ray Data Analysis**
- **Training**

## IXPE Key Events

- **Launch Vehicle**
- **Mission Operations Development**
- **Commissioning**
- **Launch Site Site Planning**

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**Critical Path Margin (work days/months):**
- Phase: 109
- SR to IR: 51
- PSR to Launch: 15
- Total Critical: 175
- Path Margin: 83

**Notes:**
- 1 month = 21 work days

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**Funded Schedule Margin**
- **Schedule Slack**
- **Primary Critical Path**
- **Secondary Critical Path**

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**IXPE**

**Integrated X-ray Polarimetry Explorer**

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**NASA**

**Marshall Space Flight Center**

**AGI**

**Rita Space Operations**

**IXPE Collaboration**

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**Rita Space Operations**

**IXPE Collaboration**
IXPE Project Phase B Kicked off in February 2017

SRR planned mid-September 2017

PDR planned February 2018

Observatory built up from heritage elements

X-ray optics build starts at MSFC 2017

Gas-pixel detector fabrication starts 2017

Launch planned November 2020
The Ball Aerospace IXPE Project Team would like to thank NASA Marshall Space Flight Center for their support of this work under contract number NNM16581489R. We are grateful for the support.

The work described in this presentation is a culmination of efforts from teams at NASA MSFC, Ball Aerospace, ASI, INFN, IAPS, LASP, Stanford, McGill, Roma TRE