Neutron star Interior Composition ExploreR, to be deployed on ISS in August, 2016

Ron Remillard, on behalf of NICER Team

XRSIG Meeting Jan 4, 2016
Outline

Instrument Summary
• Instrument Components & Capabilities
• Status & Remaining Milestones
• Target Accessibility

NICER Science Goals
• Primary Goals: Physical Properties of Neutron Stars
• Additional Goals for Neutron Stars
• Other Types of X-ray Sources & Guest Observer Program
• Comparisons RXTE & XMM
• Science Time Line
Payload

- Sunshades and X-Ray Concentrators (56)
- Possible TMD Locations
- Detector Radiator
- Focal Plane Modules (MIT/Amptek/GSFC) with SDD Shields (56)
- DAPS – Az/El/Deploy/Latching Actuators (Moog)
- Contamination Shield
- AFRAM
- Adapter Plate
- Frangibolt Launch Lock Mounts (x4, 3-2-2-1 constraints)
- HiPoS Box
- Gimbal Bracket
- Star Tracker (DTU)
- Electronics (MBR, MIT, DTU)
- Electronics Radiator (not shown)
- GPS Antenna Bracket
- XTI (structure is IOB)
Instrument & Capabilities

PI: Keith Gendreau (NASA/GSFC)

GSFC: Optics; I&T; Cal. GSE; Project
MIT/Amptek: Detectors & Electronics
Moog: Pointing System

• 56 cameras for X-ray spectra/timing
  (concentrator optics + Si drift detectors)

• 0.2-12 keV bandwidth

• Area peak 1400 cm² @ 1 keV

• 140 eV FWHM at 6 keV

• Unique combination:
  Sensitivity to sub-mCrab sources;
  timing to 100 ns (barycenter);
  1% deadtime @ 3 Crab intensity
Instrument Status & Schedule

- Ground Calibration Jan-Aug 2015
- Instrument Components Integrated Aug 2015
- Instrument Thermal Vac. Cycles Sep 2015
- Payload Integration Nov 2015
- Pre-Environmental Review Dec 2015
- EMI Testing Jan 2016
- Payload Thermal Vac. Cycles Feb 2016
- Payload Ship to Kennedy Jun 2016
- Launch to ISS (SpaceX-11 re-supply) Aug 2016
1. ISS Rotation (1 RPO): Track targets for half of ISS orbit → 2 ks exposure quanta

2. SolarExclusion Zone of 45°

Primary targets in Ecliptic coordinates
Primary Science: physical properties of neutron stars

Primary Targets: non-accreting pulsars

(5 Baseline Science Requirements)

1. \textit{msec pulsars}: Measure pulse-folded light curves to infer the radii of 4 neutron stars to accuracy \(\pm 5\% \, (1\sigma)\).

2. \textit{msec pulsars}: Measure Shapiro delays to determine the masses of 4 neutron stars to accuracy \(\pm 10\% \, (1\sigma)\).

3. \textit{magnetars, selected pulsars, and pulsar candidates}: Monitor 20 cases to study distribution to 1.4 ms, and to track changes versus “glitches” and other disruptions.

4. \textit{msec pulsars}: Measure rotational stability of 4 cases, to accuracy of 1 part in \(10^{14}\) (track pulse arrival to \(\leq 1 \, \mu s\) RMS, monthly, for 18 months).

5. \textit{msec pulsars}: Measure phase offsets between pulsed thermal and non-thermal components to determine the absolute phases of particle acceleration regions in neutron star magnetospheres to \(\pm 100 \, \mu s \, (1\sigma)\).
Neutron Star M/R via Light Curves

Non-Accreting msec Pulsars

Lightcurve modeling constrains the compactness (M/R) and viewing geometry of a non-accreting millisecond pulsar through the depth of modulation and harmonic content of emission from rotating hot-spots, thanks to gravitational light-bending…!
Demonstration of X-ray-Based GPS using the same msec pulsars
(Station Explorer for X-ray Timing & Navigation Technology: “SEXTANT”)

Science Goals for other classes of neutron stars

- accreting msec pulsars:
  - transient pulsations / B-supression
- X-ray Bursters:
  - model burst oscillations, constrain M/R kHz and other types of QPOs
- low-mass X-ray binaries:

Science Enhancement & Guest Observer Program

- accreting black holes:
  - physics of hot corona / Comptonization
- ULXs in nearby galaxies:
  - multi-technique approach to BH spin QPOs & power continuum vs. BH Mass
- active galactic nuclei:
  - Absorption components in soft X-ray
- magnetic cataclysmic variables:
  - detailed magnetic accretion models
- stars with active coronae:
  - line diagnostics of temps., abundances
NICER Effective Area higher at $E < 2$ keV

Bright sources (> 50 mCrab): NICER throughput is 50x higher than XMM in fast-readout mode;

Very bright (0.5-3 Crab): NICER 100% throughput immune to pileup.
Comparison with RXTE

Crab Nebula: NICER XTI ; RXTE with 3 PCUs

If \(N_H\) were 5e+20

- NICER simulation (2013)
  - 10.8 M cts in 1000 s

- RXTE: 7.7 M cts in 1000 s, 3 PCUs

Background in 1000 s:
- 200 NICER cts 0.2-12 keV
- 96,000 RXTE (3 PCUs) cts 2-60 keV
Science Time-Line

- **In-Flight Calibration**  
  Sep 2016

- **Begin Science Mission**  
  Oct 2016
  - **Primary targets**  
    pursue science requirements
  - **Non-NS Targets**  
    fill schedule; bright sources*

- **Begin Guest Observer Observations**  
  Oct 2017

- **Compete in 2018 Senior Review**  
  Mar 2018

- **Complete prime + enhanced Mission**  
  Sep 2018
  (18 months + 6 month, interspersed)

*Reap science of TOOs & transients
Showcase Instrument capabilities
Rapid publication
Less dependence on systematics
Groundwork for Senior Review
Science Data Analysis

34 Science Team Members plus TBD affiliated members (not funded)

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Agreements with NASA: Data public (HEASARC) 7 months after obs. Complete set of analysis tools in HEAsoft
NICER is a versatile X-ray timing/spectroscopy Instrument

- Bandpass: a direct view of thermal processes, e.g. pulsar hot spots, hot NS surfaces, NS bursts, accretion disks
- Spectral Resolution: typical Si FWHMs; 10x better than RXTE
- Time Resolution: Timing knowledge (100 ns in barycenter) without parallel in X-ray astronomy
- Faint Sources: Sensitivity of an Imager (low background)
- Bright Sources: Higher count rates & less deadtime than RXTE
- Discovery space for timing signatures in soft X-rays
Spare Slides
Comptonization and seed photons in hard state.

Disk in hard state?
Truncation?
Constrain spin?
Illumination vs. state?
Observing Cyg X-1

NICER: Cyg X-1 in soft/int state

- Comptonization model?
- Seed photons?
- Constrain spin?
- Disk in Int state?
- Leverage on Comptonization?
- Need hard X-ray partner?