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

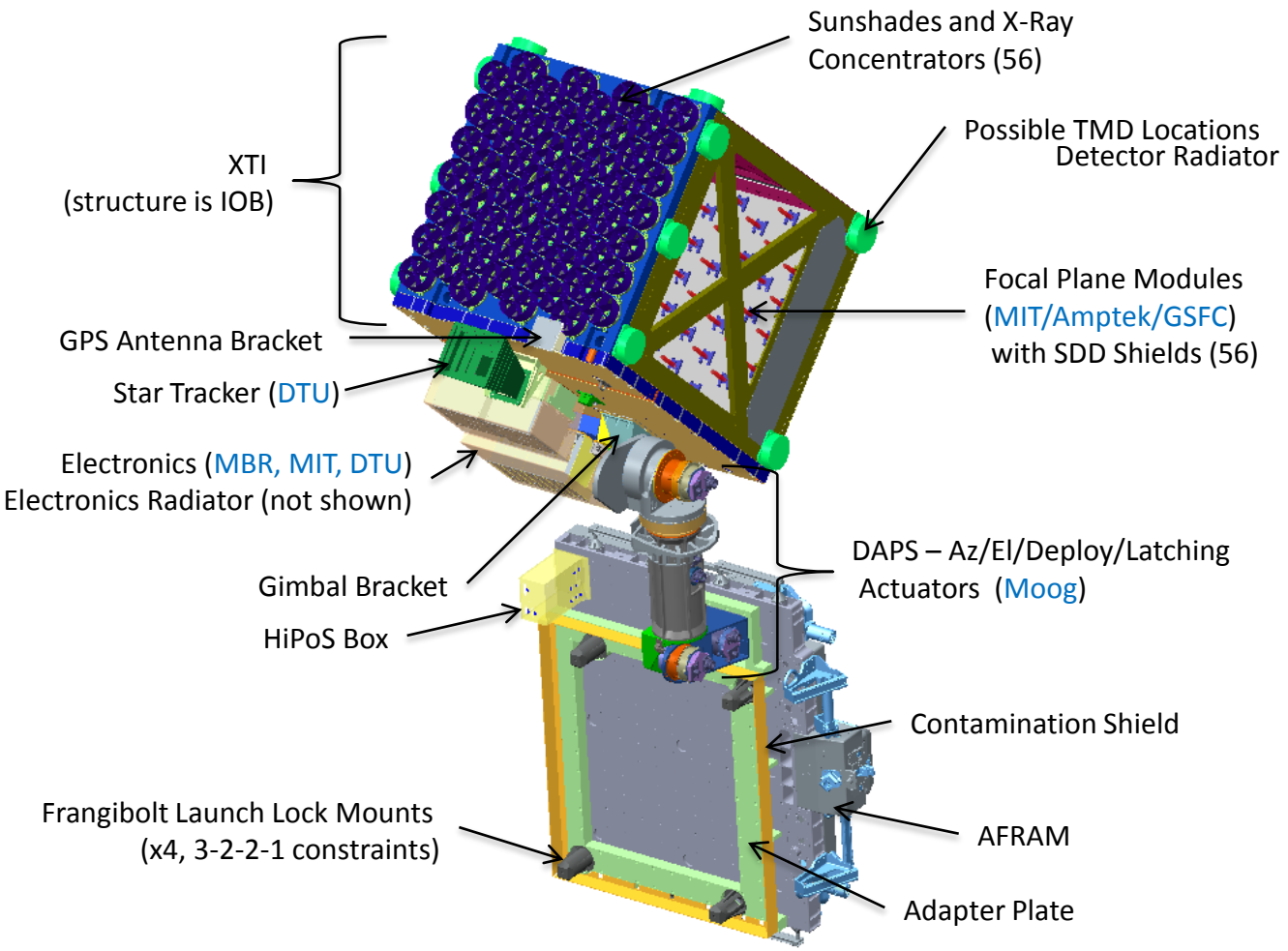
Instrument Summary

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

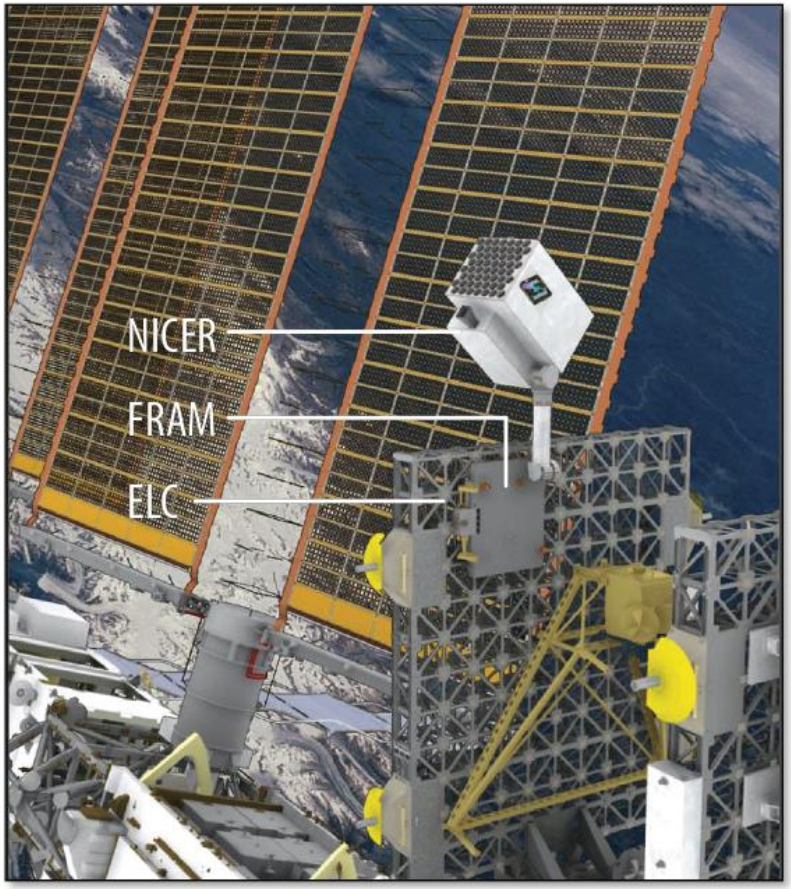
Instrument & Capabilities

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 cm^2 @ 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

Illustration of Deployment on ISS



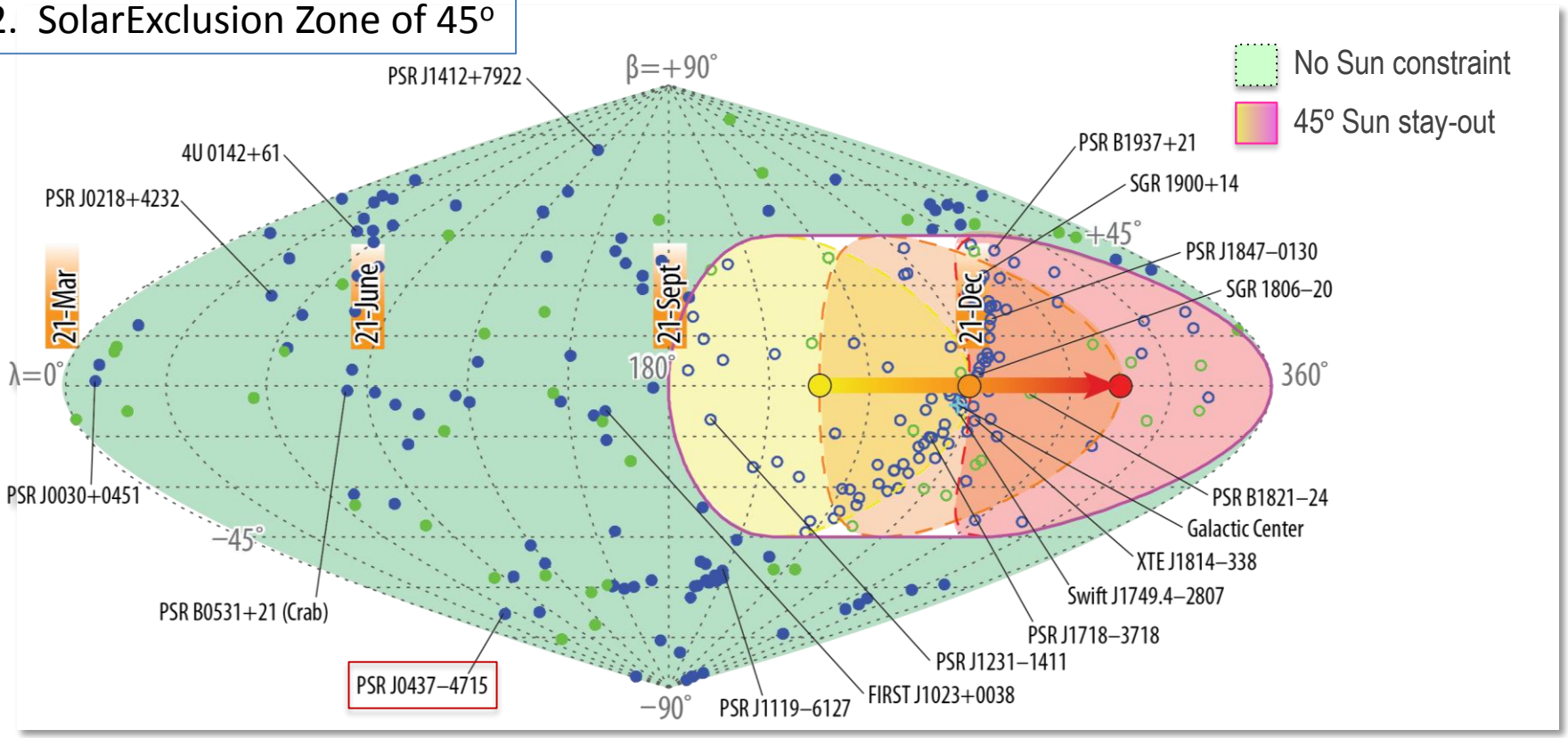
Instrument Status & Schedule

• 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*

Target Visibility Constraints

1. ISS Rotation (1 RPO): Track targets for half of ISS orbit → 2 ks exposure quanta

2. SolarExclusion Zone of 45°

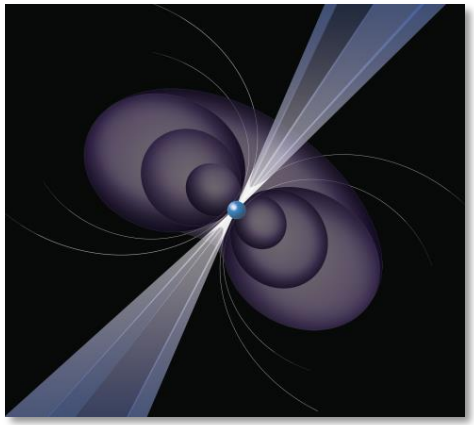


Primary targets in Ecliptic coordinates

Science Targets - 1

Primary Science: physical properties of neutron stars

Primary Targets: non-accreting pulsars



(5 Baseline Science Requirements)

1 ***msec pulsars:*** Measure pulse-folded light curves to infer the radii of 4 neutron stars to accuracy ±5% (1σ).

2 ***msec pulsars:*** Measure Shapiro delays to determine the masses of 4 neutron stars to accuracy ±10% (1σ).

3 ***magnetars, selected pulsars, and pulsar candidates:*** Monitor 20 case to study distribution to 1.4 ms, and to track changes versus "glitches" and other disruptions.

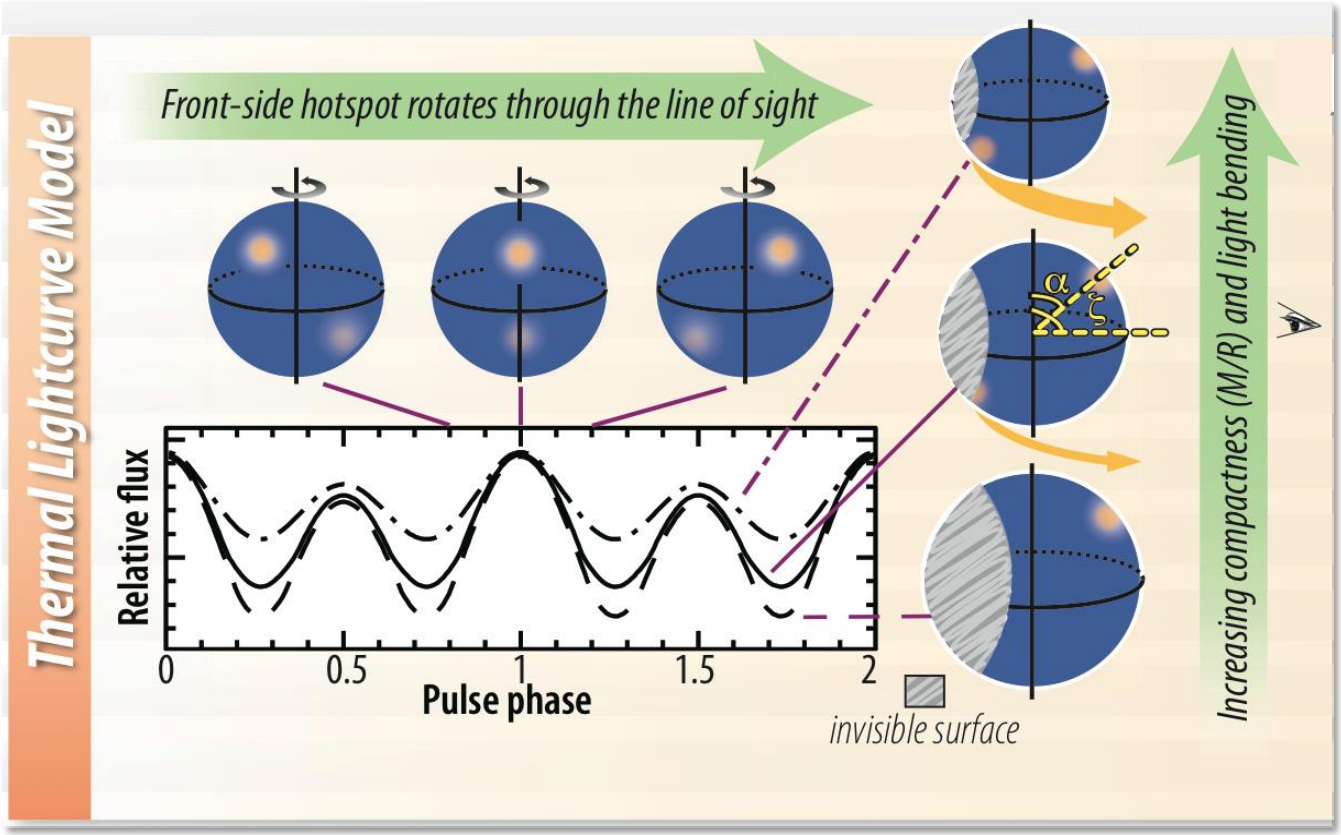
4 ***msec pulsars:*** Measure rotational stability of 4 cases, to accuracy of 1 part in 10^{14} (track pulse arrival to ≤ 1 μs RMS, monthly, for 18 months).

5 ***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 ±100 μs (1σ).

Neutron Star M/R via Light Curves

NICER

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… !

Science Targets - 2

Demonstration of X-ray-Based GPS using the same msec pulsars

(Station Explorer for X-ray Timing & Navigation Technology: "SEXTANT")

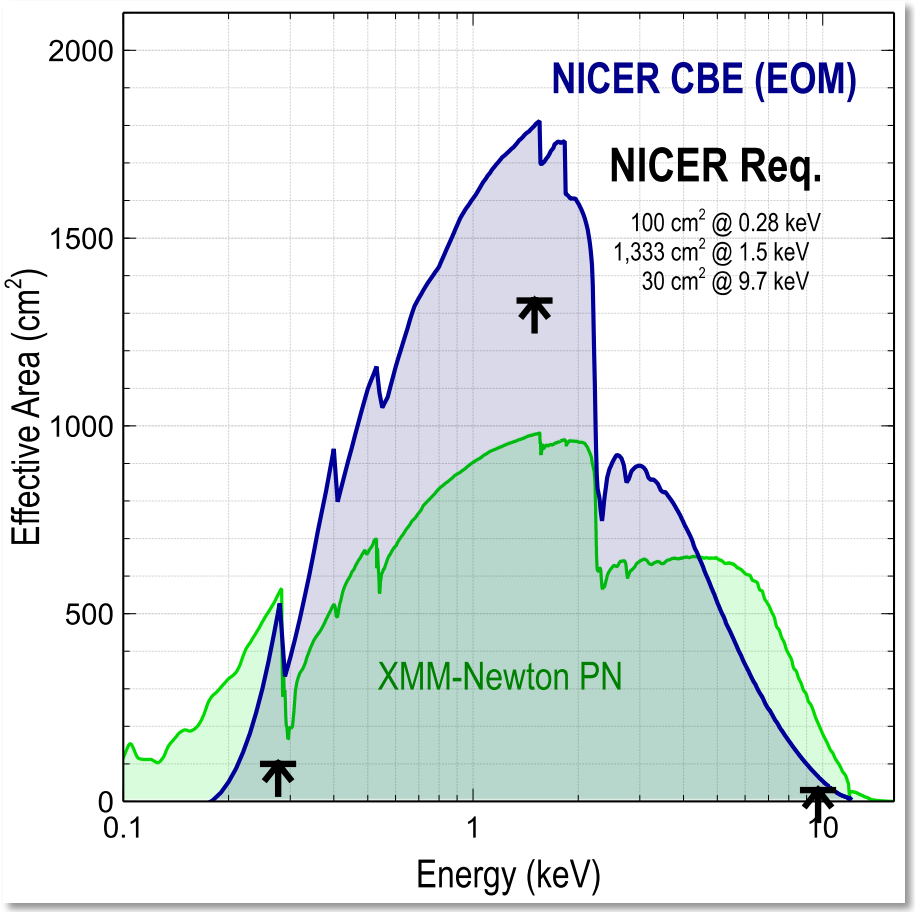
Science Goals for other classes of neutron stars

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

Science Enhancement & Guest Observer Program

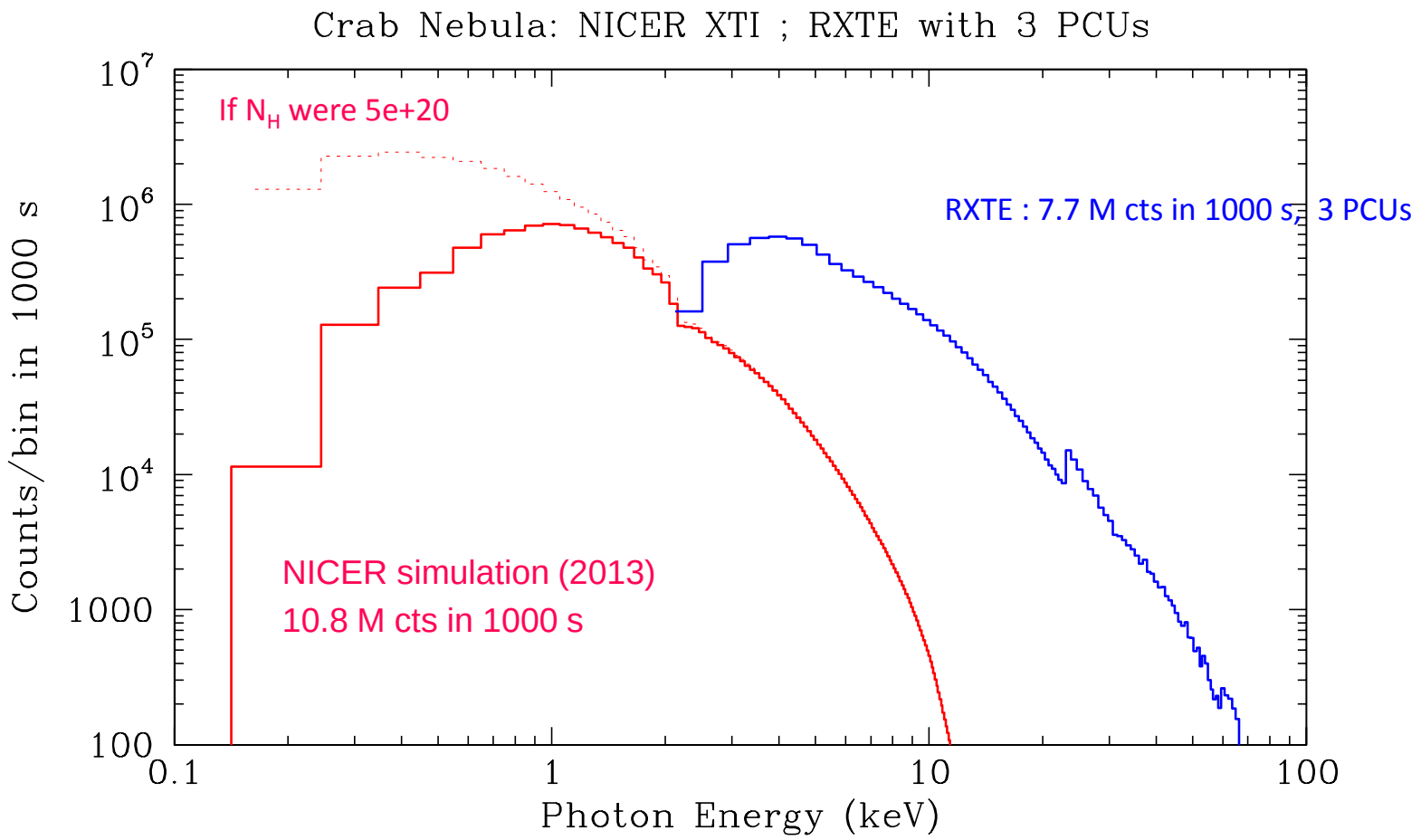
accreting black holes :	physics of hot corona / Comptonization multi-technique approach to BH spin
ULXs in nearby galaxies :	QPOs & power continuum vs. BH Mass
active galactic nuclei :	Absorption components in soft X-ray
magnetic cataclysmic variables :	detailed magnetic accretion models
stars with active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

Comparison with XMM-Newton



- 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 ith RXTE



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)

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*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)

Working Group Theme	Chair
Calibration	— C. Markwardt
Lightcurve Modeling	— S. Bogdanov
X-ray Burst Phenomena	— F. Ozel
Pulsar Searches & Multi-λ Observations	— P. Ray
Long-term High-precision Timing	— A. Lommen
Magnetars & Young Pulsars	— V. Kaspi
Theory	— C. Miller
Non-Neutron Star Sources	— R. Remillard
Target Prioritization & Planning	— Z. Arzoumanian

Agreements with NASA: **Data public (HEASARC) 7 months after obs.**
Complete set of analysis tools in HEAsoft

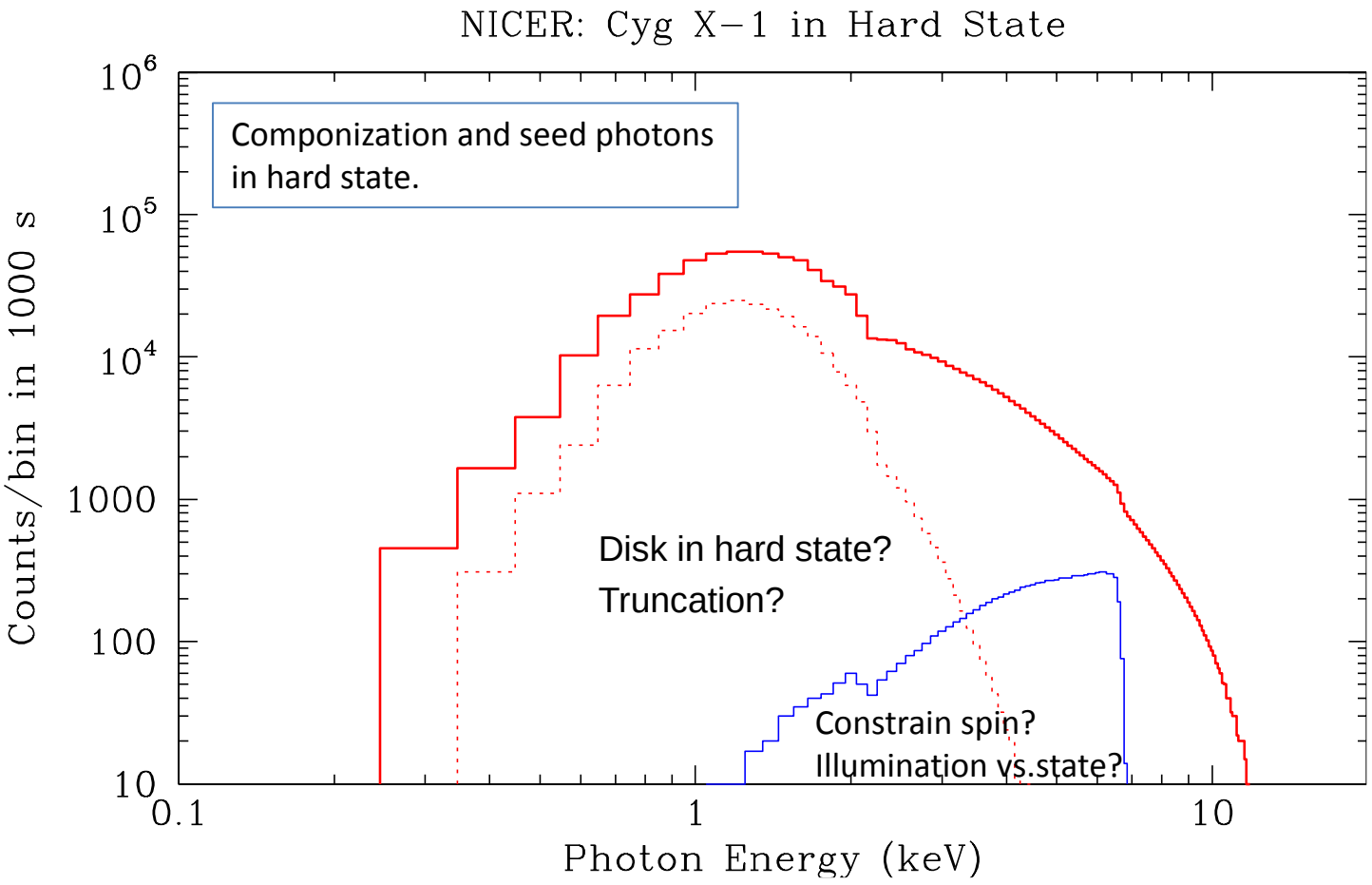
Summary

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

Observing Cyg X-1



Observing Cyg X-1