
NICER
Neutron star Interior Composition ExploreR
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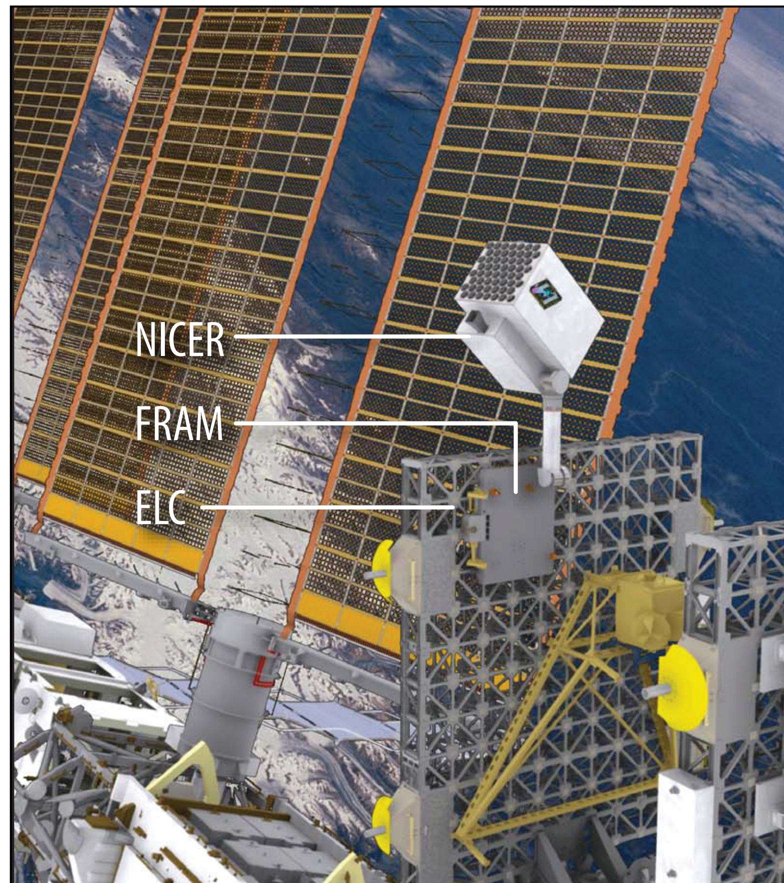
Mission Overview

NICER

Astrophysics on the International Space Station —
Understanding ultra-dense matter through soft X-ray timing

- ***Science:*** A proposed International Space Station (ISS) payload dedicated to the study of *neutron stars*. A fundamental investigation of extremes in gravity, material density, and electromagnetic fields
- ***Launch***: Late 2016, JAXA *HII-B* or U.S. commercial (e.g., SpaceX)
- ***Duration:*** 18 (minimum 12) months, with an optional Guest Observer program
- ***Platform:*** ISS ExPRESS Logistics Carrier (ELC), with active pointing over 2π steradians
- ***Instrument:*** X-ray (0.2–12 keV) "concentrator" optics and silicon-drift detectors. GPS position and absolute time reference to better than 300 ns.



ISS Accomodations

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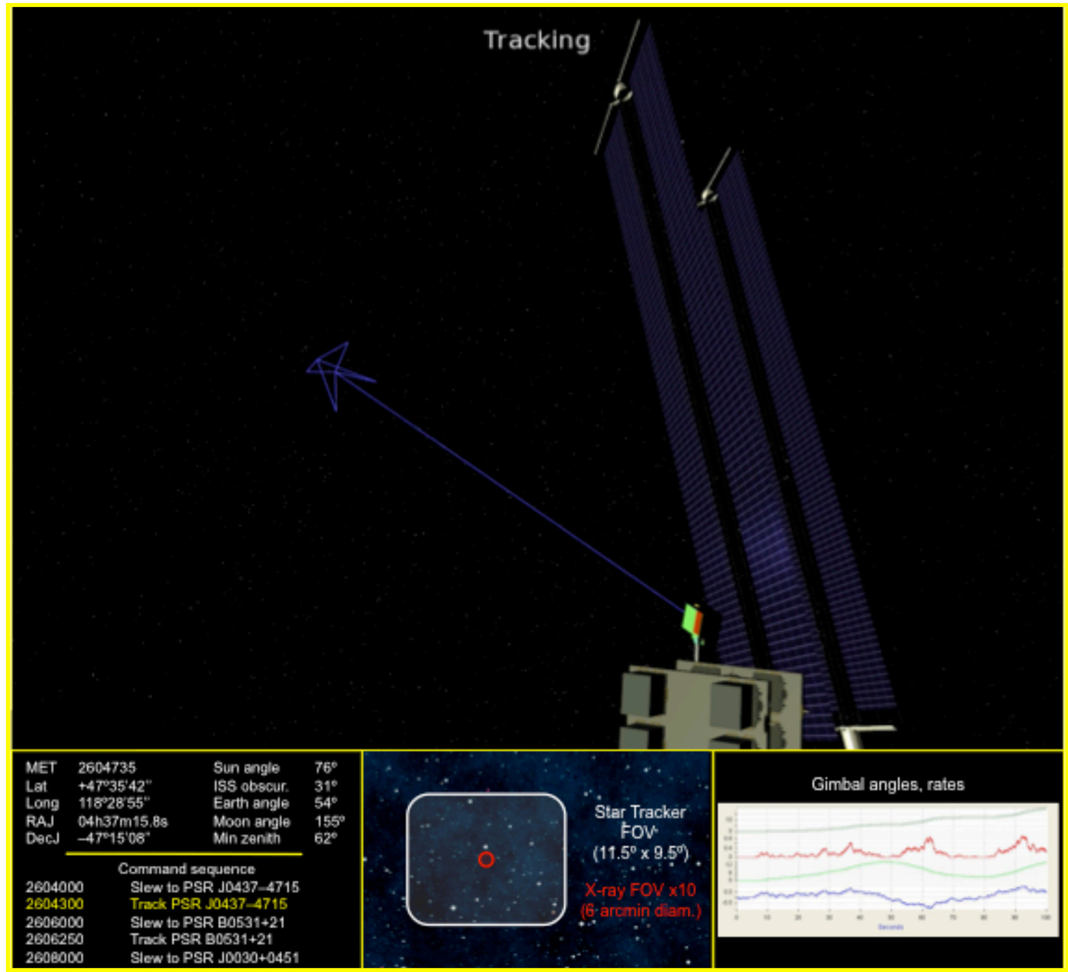
An established platform and a benign environment

The ISS offers:

- Established infrastructure (transport, power, comm, etc.) that reduces risk
- Generous resources that simplify design and reduce cost.
- A stable platform for arcminute astronomy

NICER's design:

- Is tolerant of ISS vibrations
- Is insensitive to the ISS contamination and radiation environments, with safe-stow capability
- Provides high (> 65%) observing efficiency.



Science Objectives

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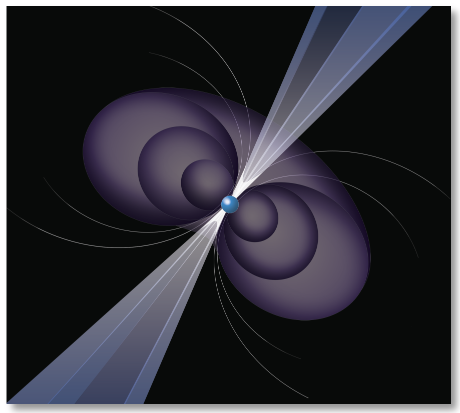
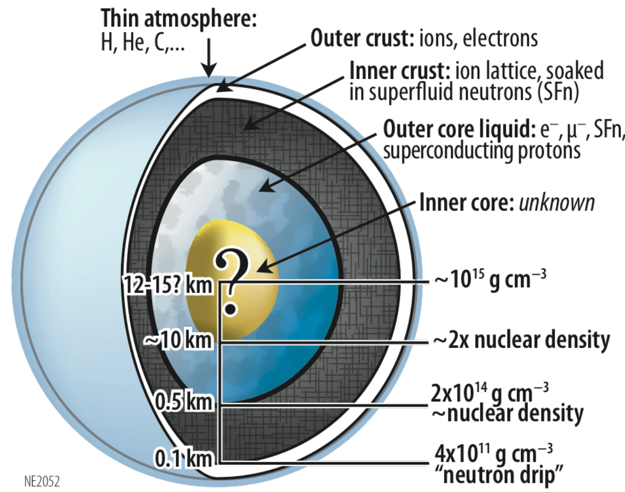
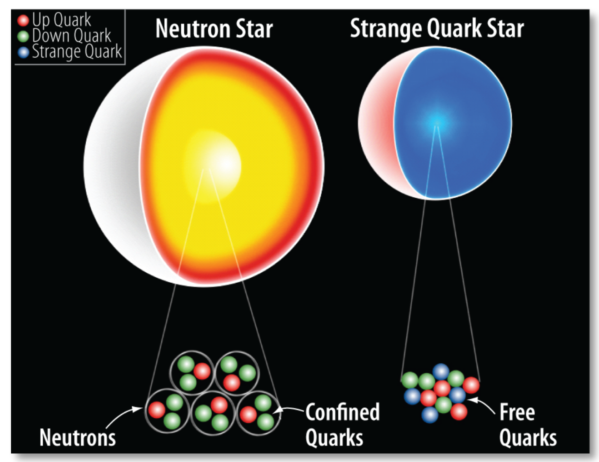
Neutron stars — Unique environments in which all four fundamental forces of Nature are simultaneously important.

- To address NASA and National Academy of Sciences strategic questions
- To resolve the nature of ultradense matter at the threshold of collapse to a black hole
- To reveal interior composition, dynamic processes, and radiation mechanisms of neutron stars.



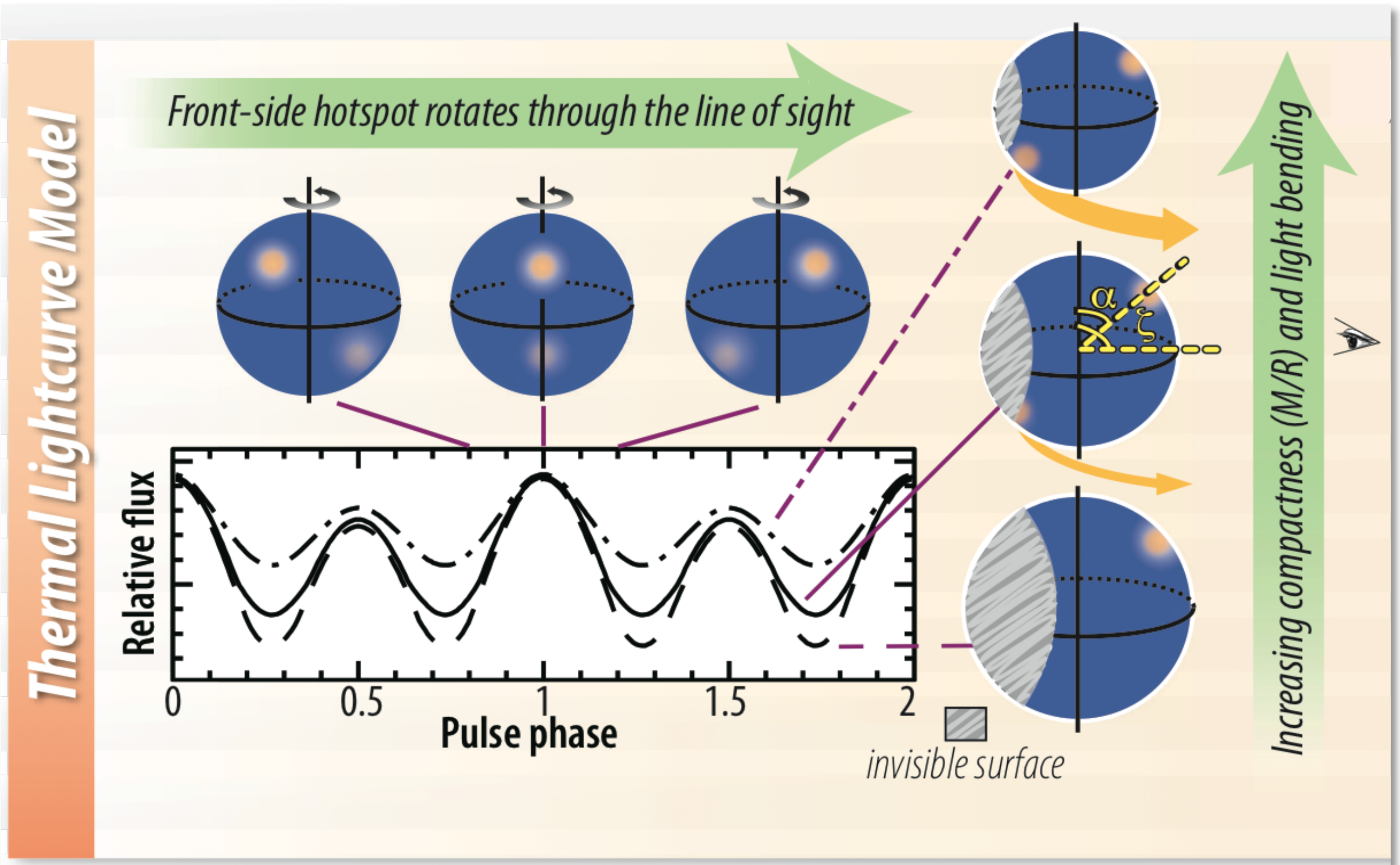


Objective	Measurements
Structure — Reveal the nature of matter in the interiors of neutron stars	Neutron star radii to ±5%. Cooling timescales
Dynamics — Uncover the physics of dynamic phenomena associated with neutron stars	Stability of pulsars as clocks. Properties of outbursts, oscillations, and precession
Energetics — Determine how energy is extracted from neutron stars.	Intrinsic radiation patterns, spectra, and luminosities.



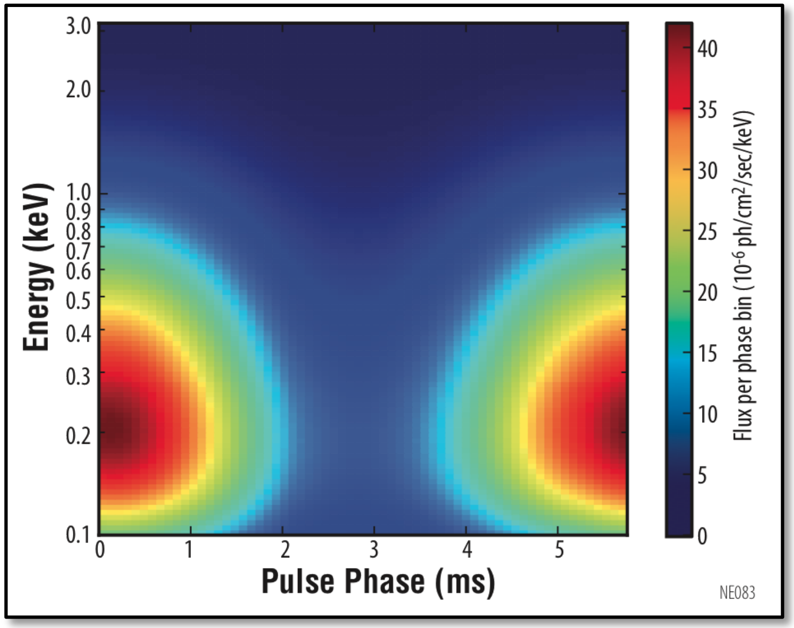
Science Measurements

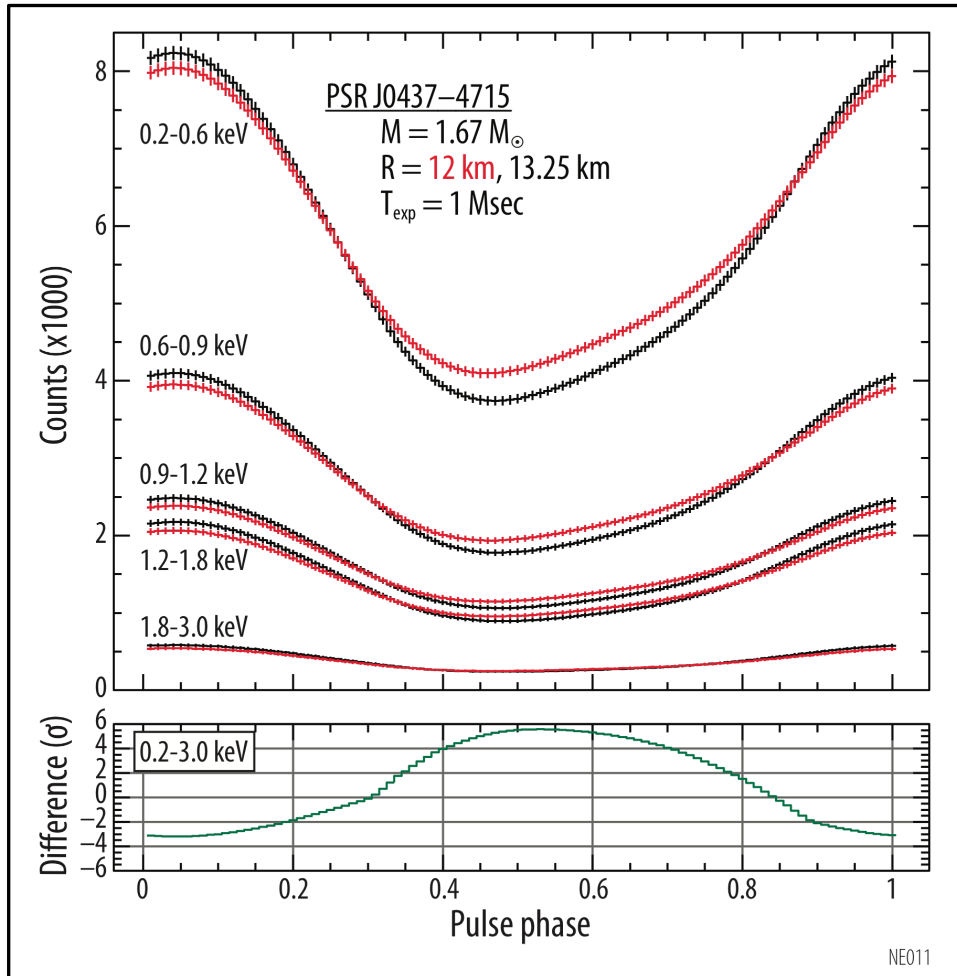
Reveal stellar structure through lightcurve modeling, long-term timing, and pulsation searches



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 Measurements (cont.)



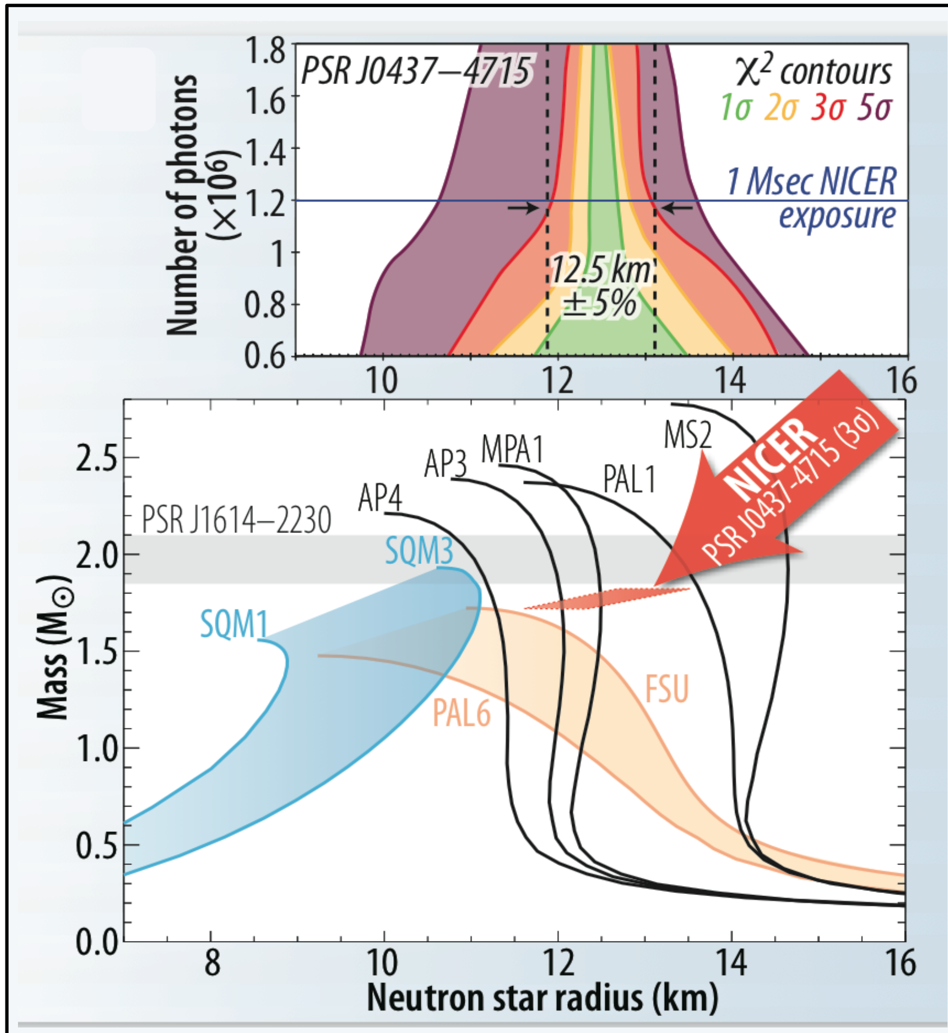


… while phase-resolved spectroscopy promises a direct constraint of radius *R*.

Science Measurements (cont.)

Simulations demonstrate how well an assumed neutron star radius can be recovered. The ±5% (3σ) measurement goal is attained in less than 1 Msec.

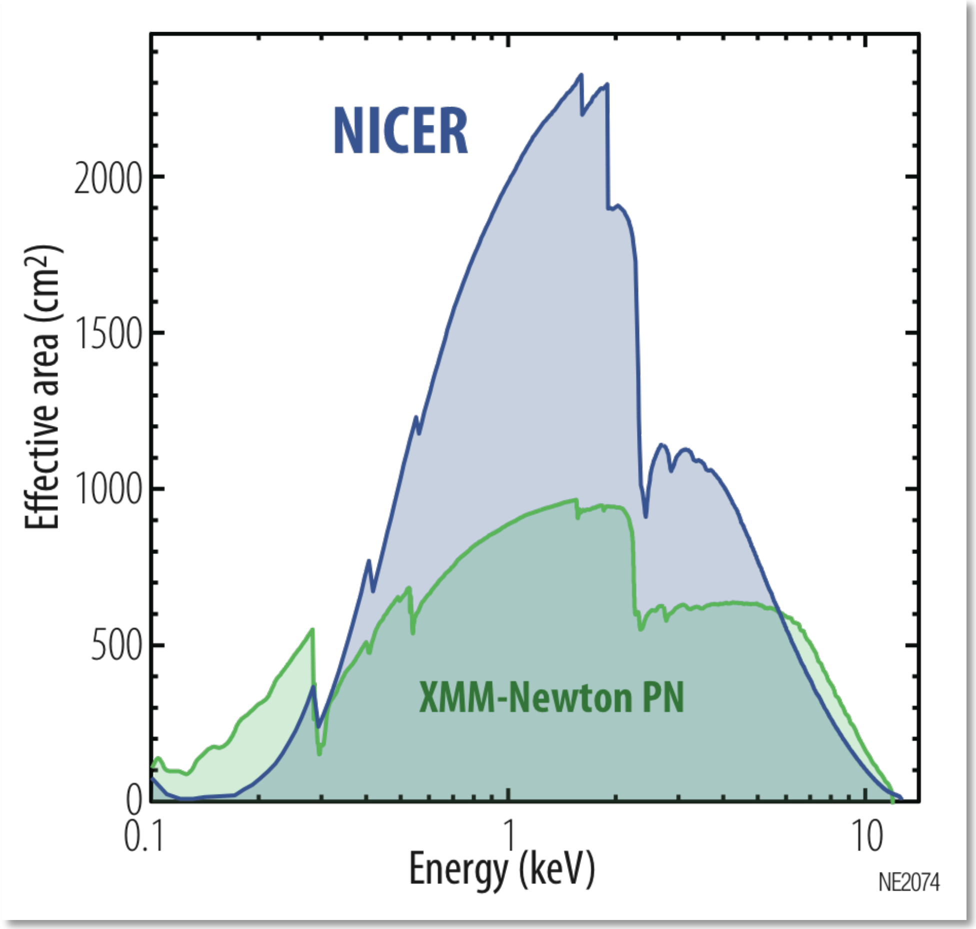
The resulting allowed regions in the *M-R* plane rule out proposed families of neutron star equations of state. The best mass measurements alone can't distinguish among competing models.



Instrument Performance

High-throughput, low-background soft X-ray timing and spectroscopy

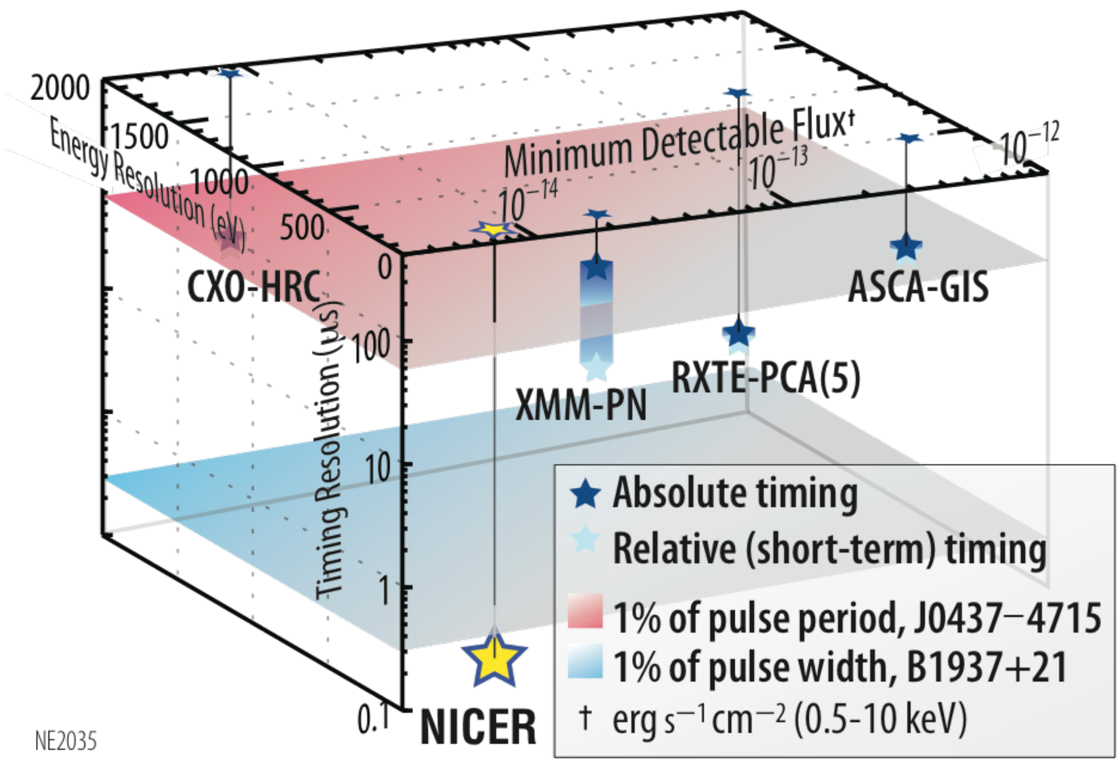
- ***Bandpass:*** 0.2–12 keV
- ***Effective area:***
  > 2000 cm^2 @ 1.5 keV,
  600 cm^2 @ 6 keV
  2x XMM-Newton for soft X-ray timing
- ***Energy resolution:***
  85 eV @ 1 keV,
  137 eV @ 6 keV
  Similar to XMM and Chandra
- ***Time-tagging resolution:***
  < 300 nsec (absolute)
  ~25x better than RXTE
  ~100–1000x better than XMM
- ***Spatial resolution:*** 5 arcmin diam.
  non-imaging FOV
- ***Background:*** Dominated by diffuse
  cosmic XRB (soft)
- ***Sensitivity:*** 3 x 10^{-14} ergs s^{-1} cm^{-2}
  (0.5–10 keV, 5σ in 10 ksec)
  ~30x better than RXTE,
  ~4x better than XMM



Instrument Performance (cont.)

High-throughput, low-background soft X-ray timing and spectroscopy

NICER offers a combination of capabilities not available in any existing mission.



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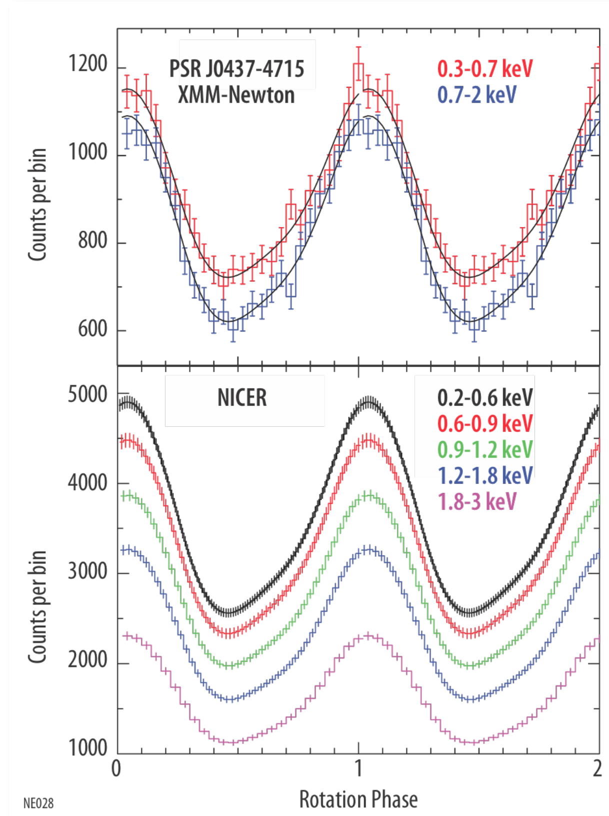
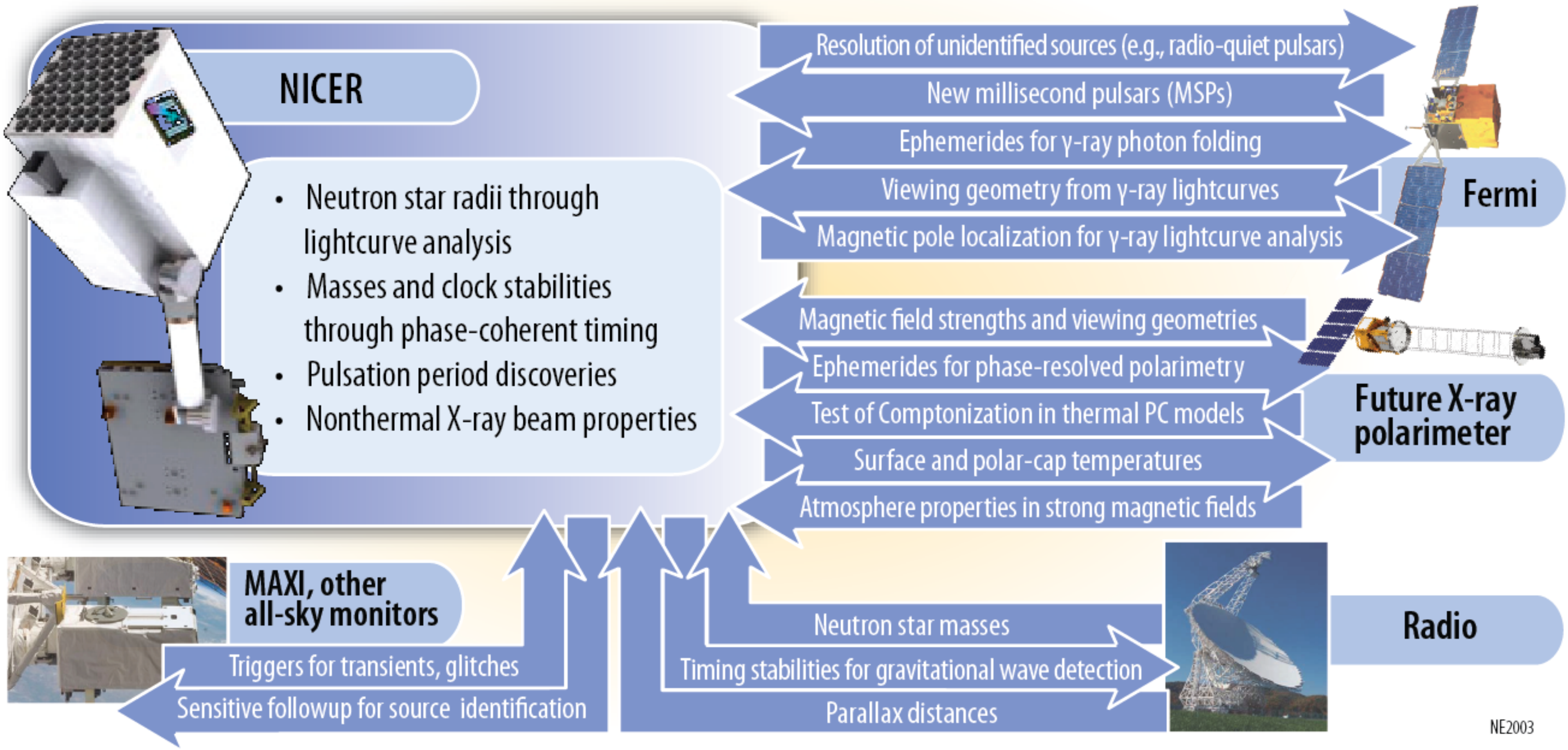


"Best effort" XMM and NICER lightcurves for key target PSR J0437–4715.

Neutron Star Science Synergies

Interplay between multiwavelength capabilities amplifies scientific returns from all



Proposed Guest Investigator/Guest Observer Program

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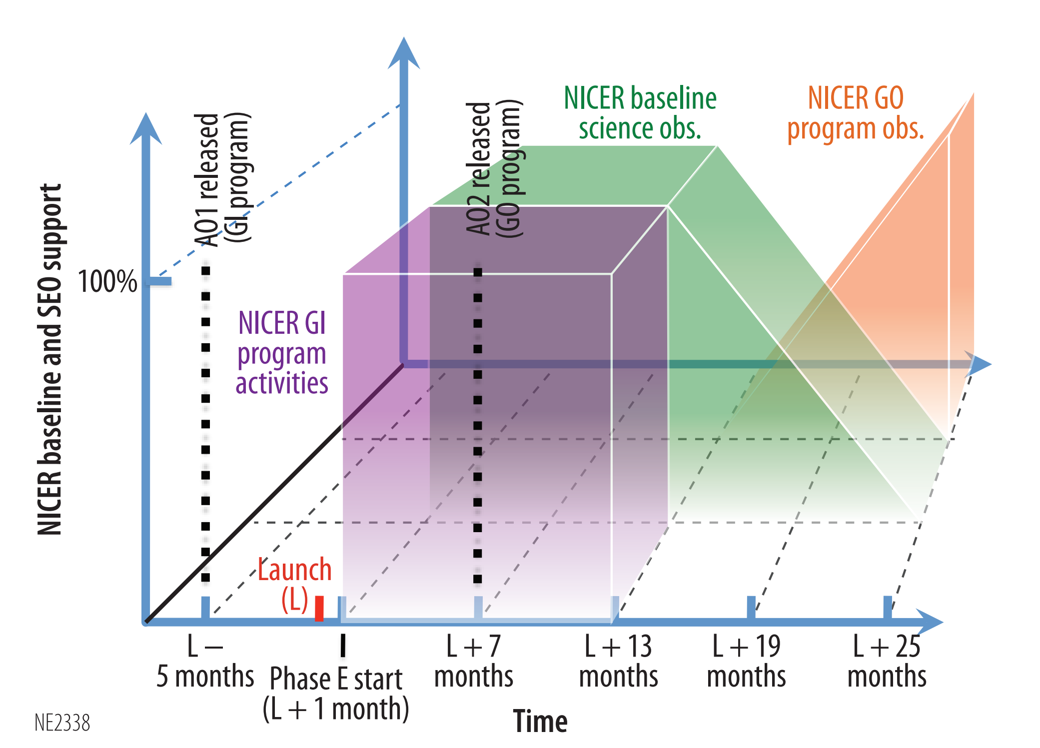
X-ray astrophysics beyond neutron stars, continuity of RXTE timing science

A proposed two-part Guest Investigator/Observer program, modeled after *Swift*:

- In Year 1, support for corollary neutron star research: theory & complementary multiwavelength observations
- In Year 2, solicitation of proposals for guest observations with NICER, not necessarily targeting neutron stars.



Proposed Guest Investigator/Guest Observer Program (cont.)

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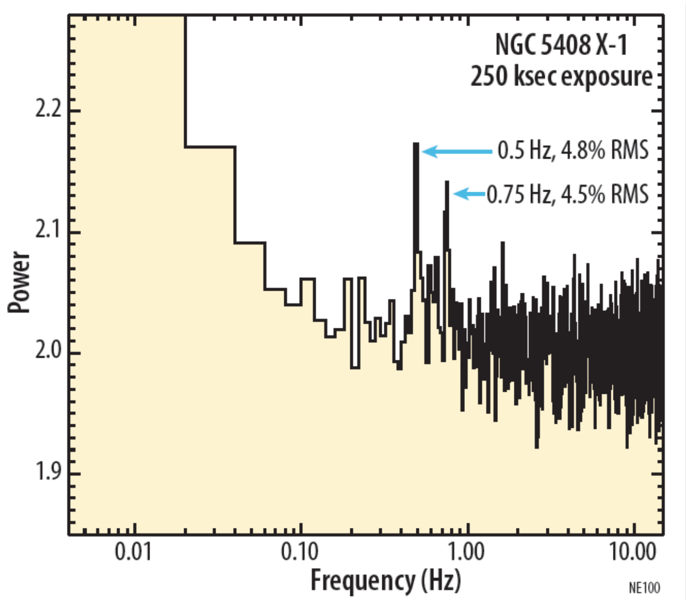
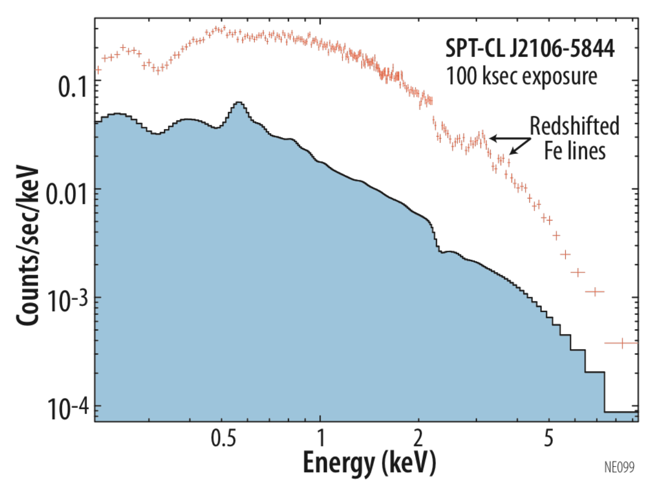
Sample science enabled by the NICER GO program

Black holes of all sizes are probed through soft continuum spectroscopy to constrain spins in stellar-mass binaries, power spectra of QPOs to definitely establish *ultraluminous X-ray sources* as intermediate-mass black holes, and relativistic reflection lines to discriminate among AGN models.





Redshifted Fe lines from ***galaxy clusters*** reveal star-formation history and poorly understood feedback processes that drive galaxy evolution. (*Left*) A z = 1.18 line is seen well above the diffuse X-ray back-ground (*blue*).

Plus…

- Temporal and spectral variability studies of ***bright coronal stars*** can be conducted on much shorter timescales than previously possible
- The interplay of accretion processes and gravitational radiation in ***double-degenerate systems*** can be studied through QPOs in "polars" and long-term timing of SN Ia progenitors
- Emission lines and soft excesses in ***high-mass X-ray binaries*** probe field strengths, accretion geometry, and long-term spin evolution.