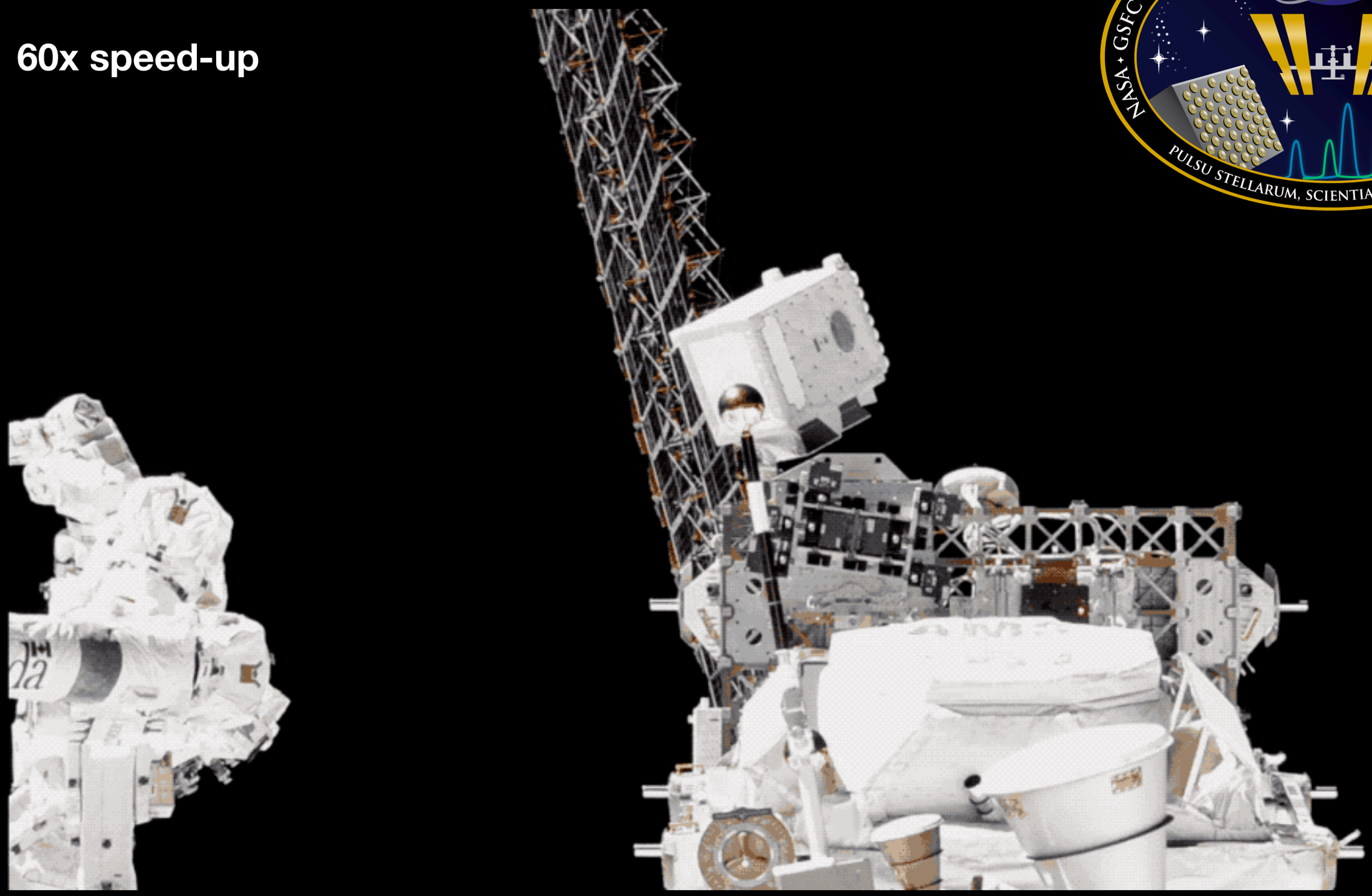
NICER Science Highlights

Erin Kara

on behalf of NICER Science Team

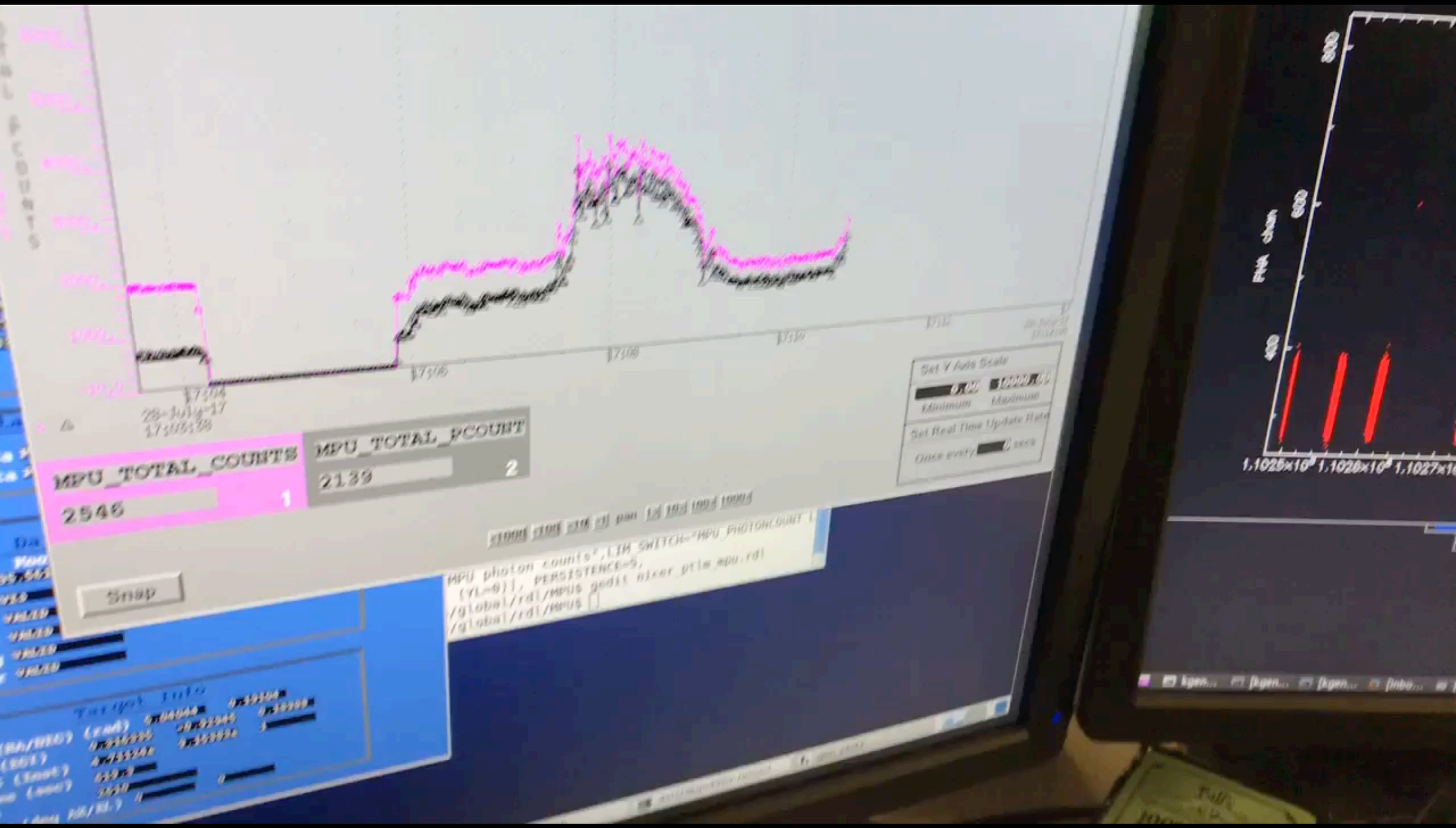
X-ray SIG
Virtual AAS Meeting
13 January 2021

60x speed-up



Launch: June 3, 2017
PI: Keith Gendreau (NASA GSFC)
Deputy PI: Zaven Arzoumanian (NASA GSFC)

Live ISS contact ~85% of the time

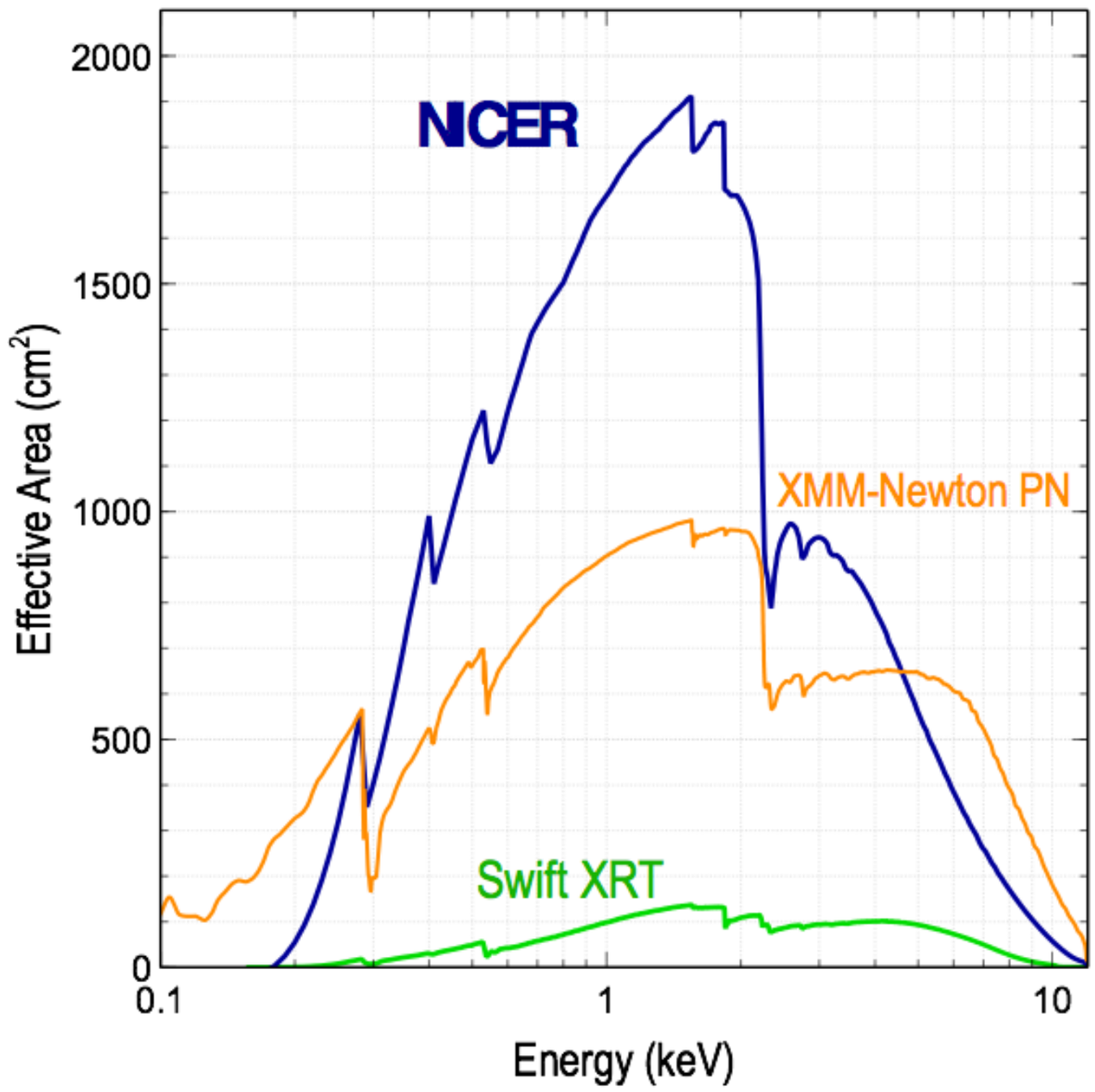


GRS 1915 heart-beat in real time

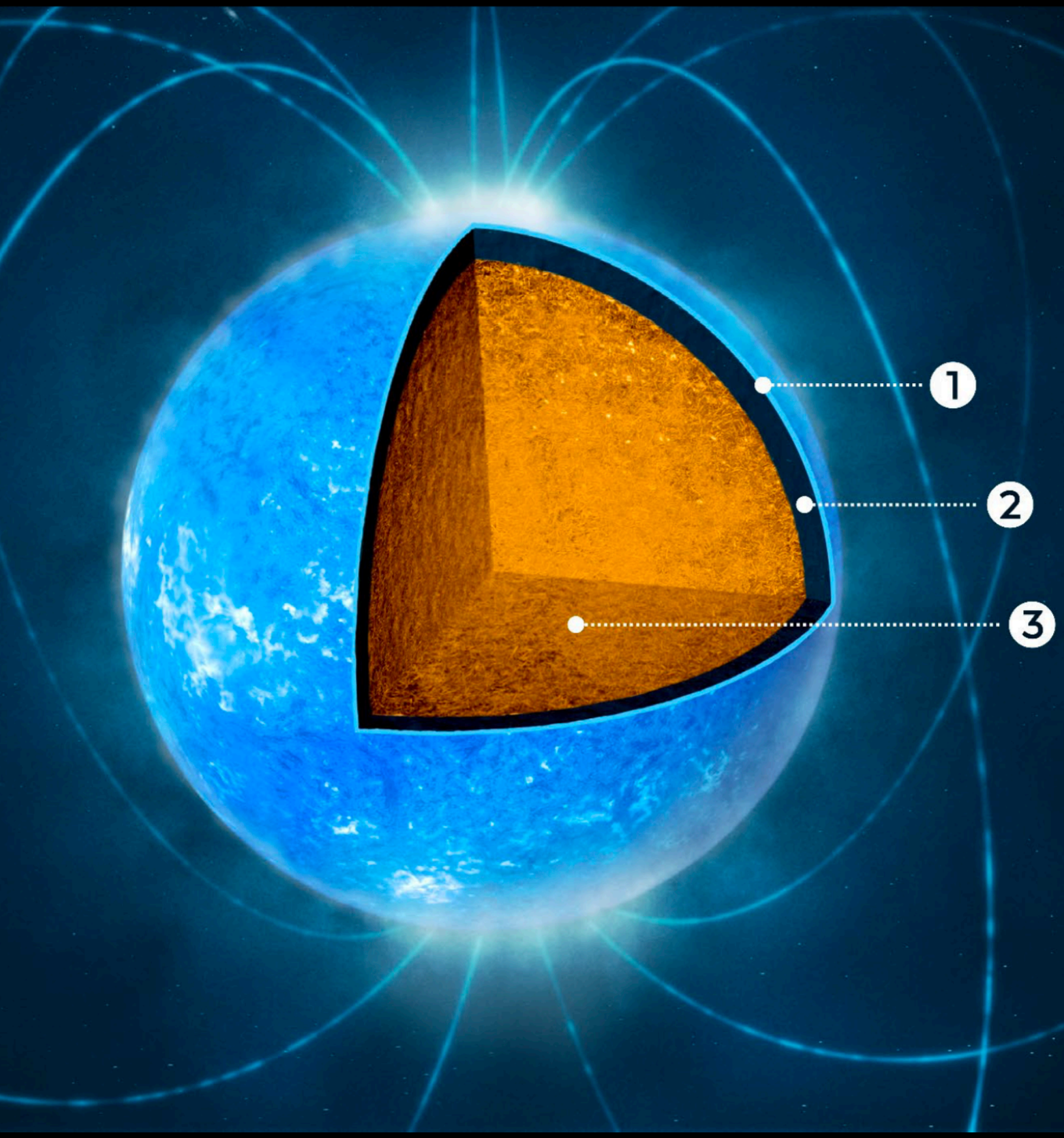
Science-enabling capabilities

A unique combination of time resolution, energy resolution, sensitivity, and throughput

- Spectral band: 0.2–12 keV
  - Well matched to WDs, NSs, and BH accretion disks
- Timing resolution: < 100 ns RMS absolute
  - 50x better than RXTE
  - > 100x better than XMM-*Newton*
- Energy resolution: 2.5% @ 6 keV
  - 10x better than RXTE
- Throughput: > 3.5 Crab with no pile-up
  - ~100x better than CCD instruments
- Angular resolution: 6 arcmin (non-imaging)
  - 10x better than RXTE
- Sensitivity (10 ks, 5σ): < 1×10^{-13} erg/s/cm^2
  - 20x better than RXTE
  - 3x better than fast timing with XMM
- ToO response: 1°/sec slew
  - hours to command (but improving!)



The neutron star interior



1 | OUTER CRUST

NUCLEI
ELECTRONS

2 | INNER CRUST

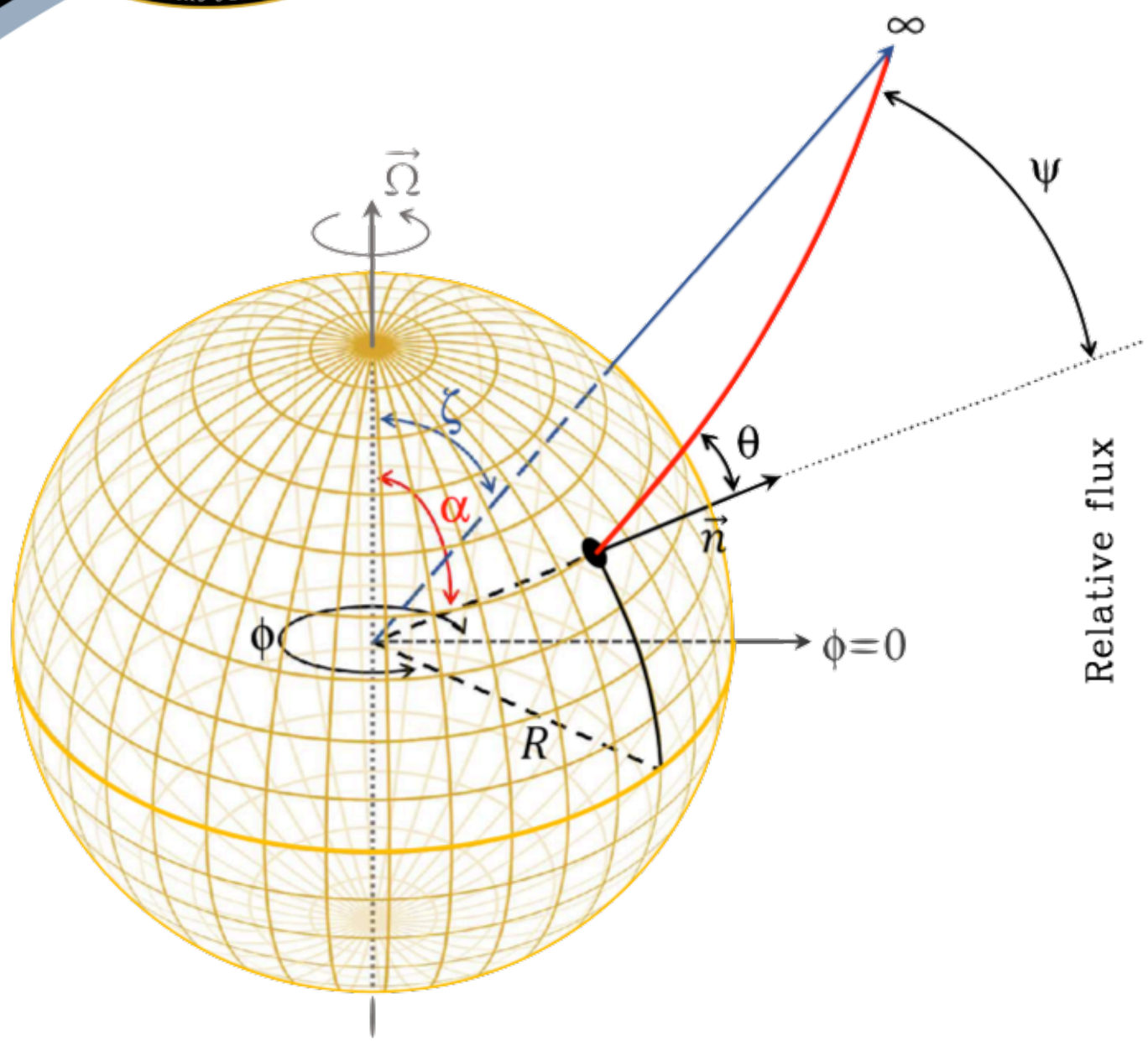
NUCLEI
ELECTRONS
SUPERFLUID NEUTRONS

3 | CORE

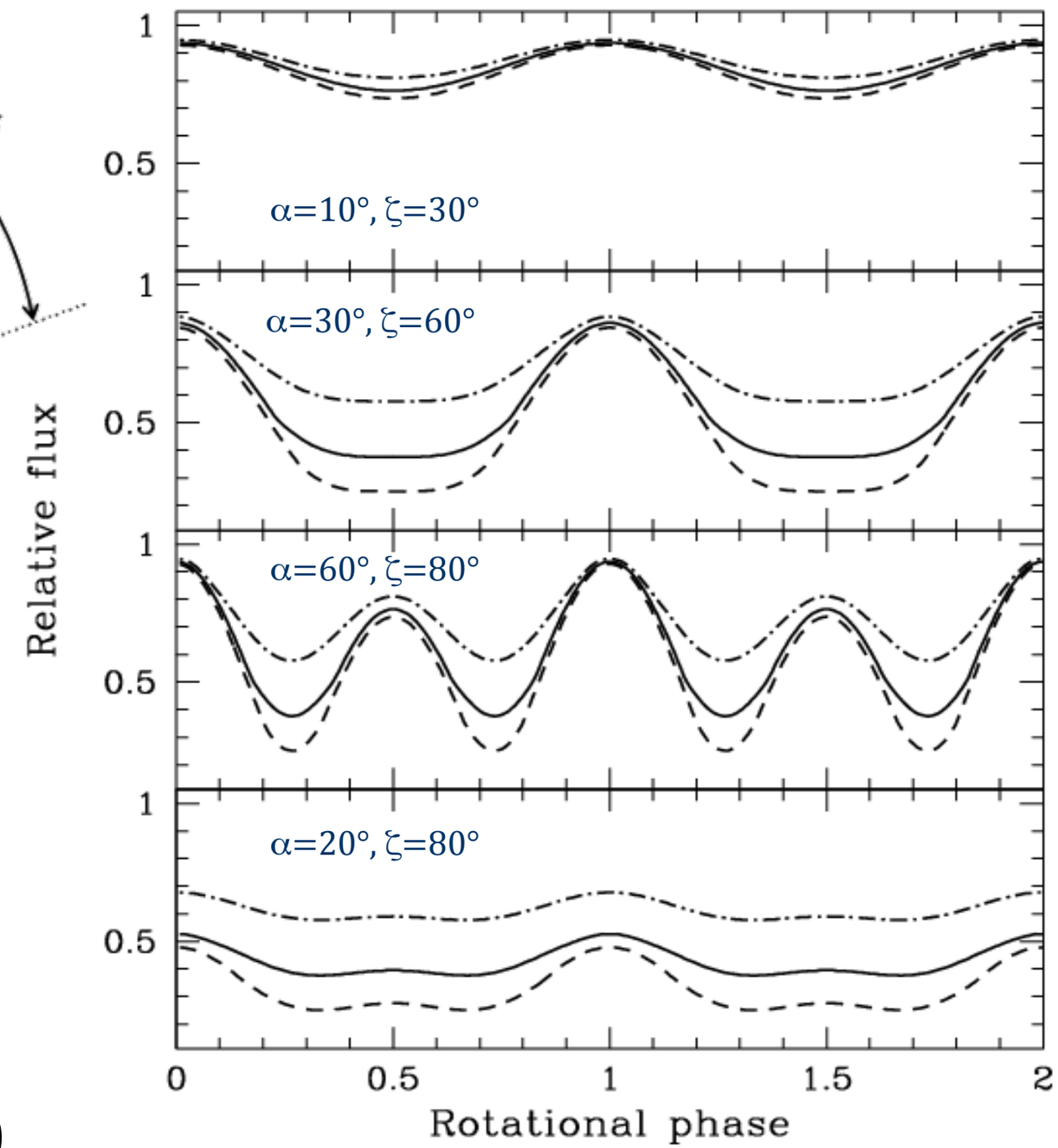
SUPERFLUID NEUTRONS
SUPERCONDUCTING PROTONS
HYPERONS?
DECONFINED QUARKS?
COLOR SUPERCONDUCTOR?

Figure: Watts et al. 2016

Inferring M,R through lightcurve modeling of rotation-powered MSPs



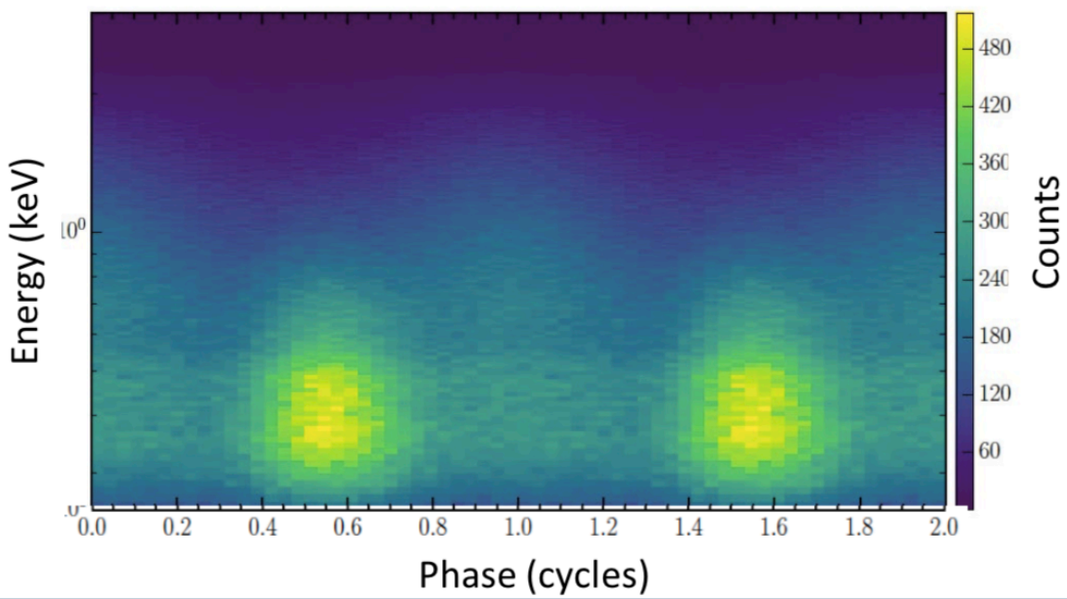
Bogdanov, Rybicki, & Grindlay, *ApJ*, 670, 668 (2007)



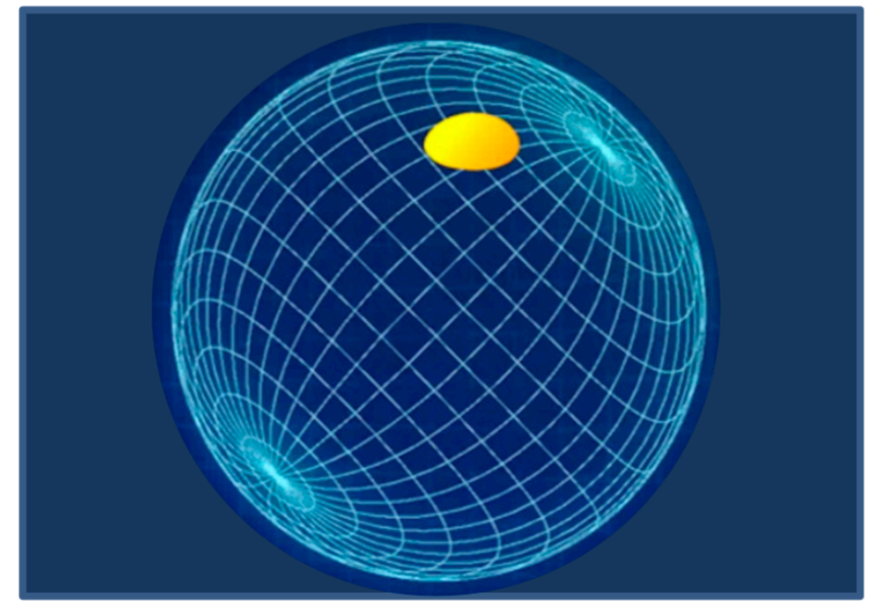
9 km
12 km
16 km
} for M = 1.4 $M_\odot$

Pulse Profile Modeling

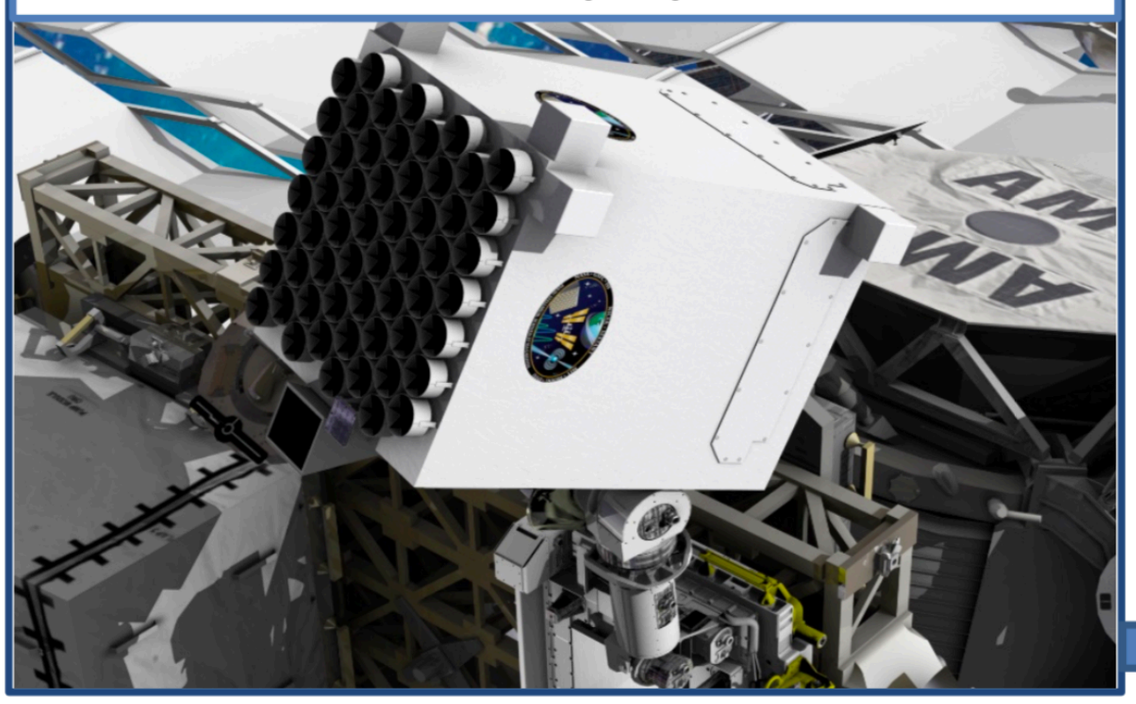
Pulse profile data: Phase, Energy



Lightcurve model:
Atmosphere, Relativistic ray-tracing



Instrument properties

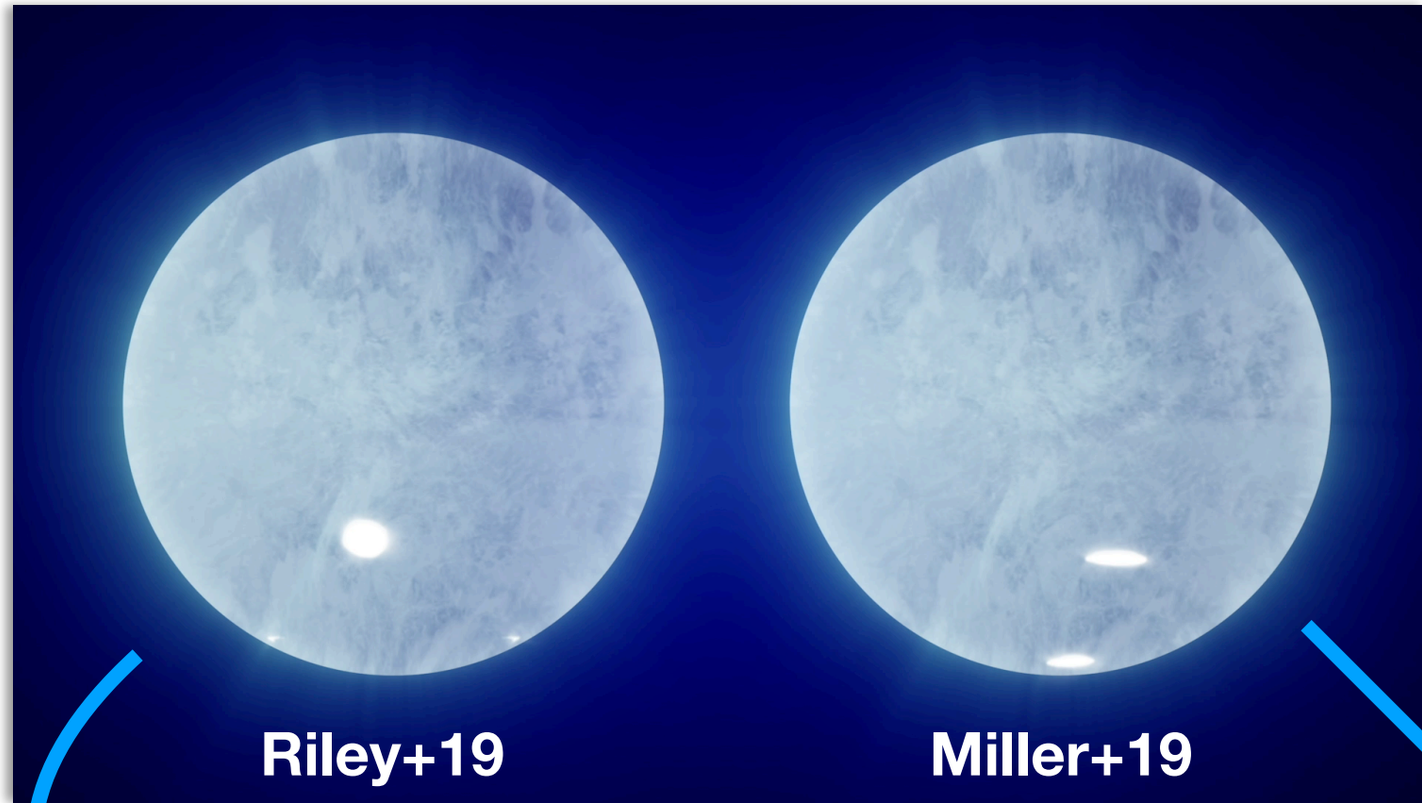


Inference code:
Likelihood calculation,
statistical sampling

Mass-radius
EOS (nuclear physics)

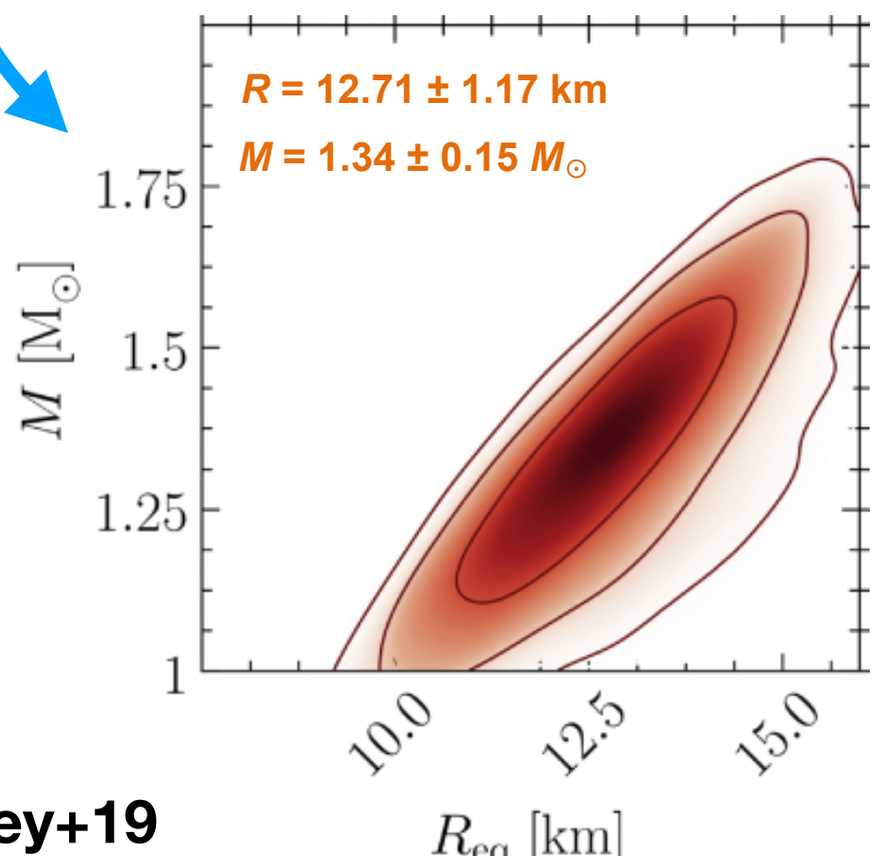
Slide from Slavko Bogdanov

Mass-Radius Measurements for J0030



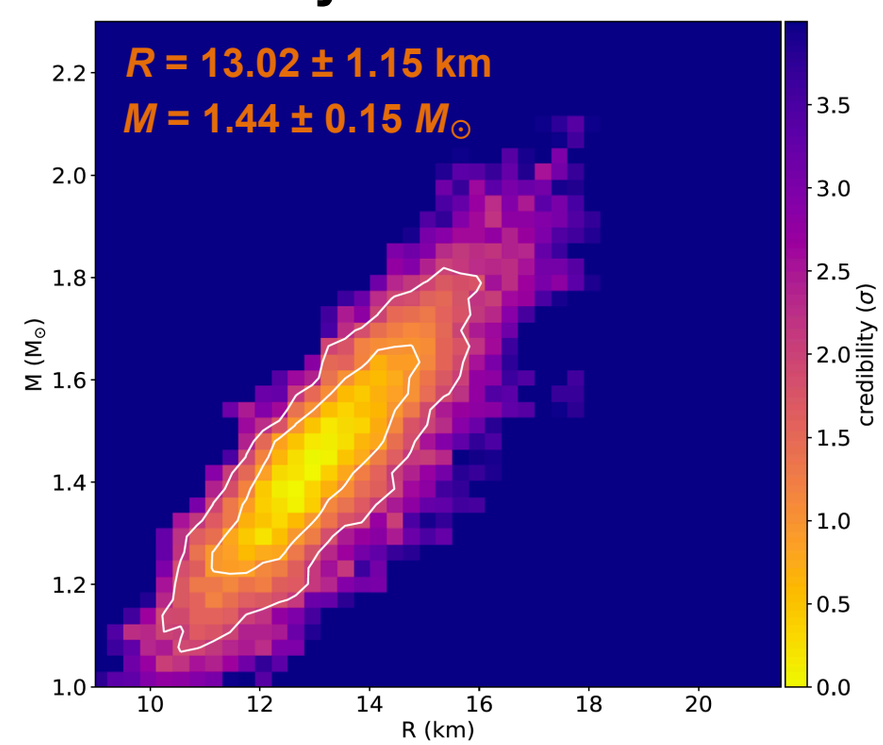
- First precise mass *and* radius measurements for the same star (±10%, 1σ)
  - First mass of an isolated (i.e., non-binary) pulsar
- First map of surface "hot spot" locations, shapes, sizes, and temperatures
  - Robust demonstration of non-dipolar magnetic field geometry
- New constraint on the equation of state of ultra-dense matter
  - Tightened uncertain pressure-density range by 30%

Amsterdam inference code (X-PSI)



Riley+19

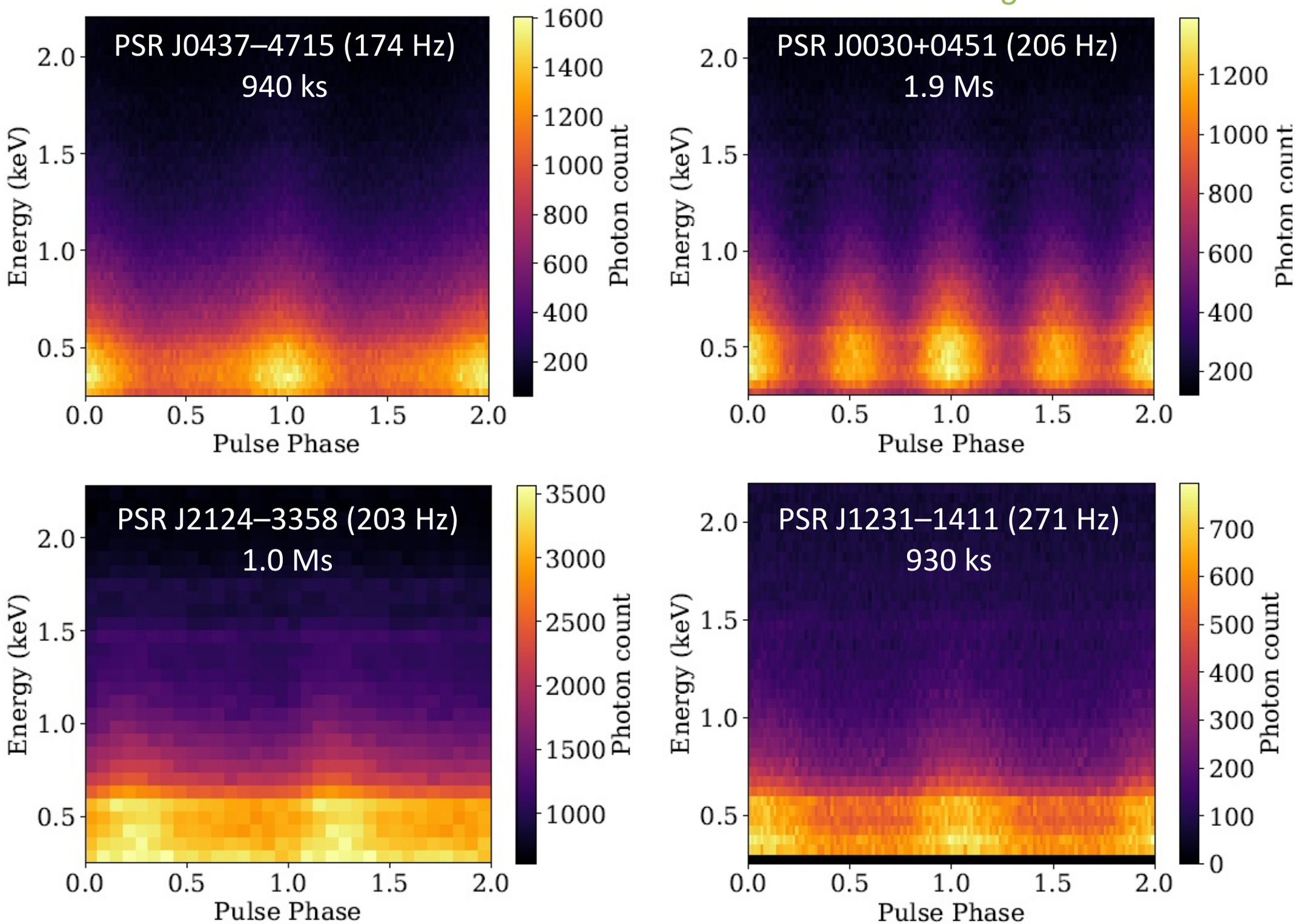
Illinois-Maryland inference code



Miller+19

Additional pulsars to come…watch this space!

Bogdanov et al. 2019



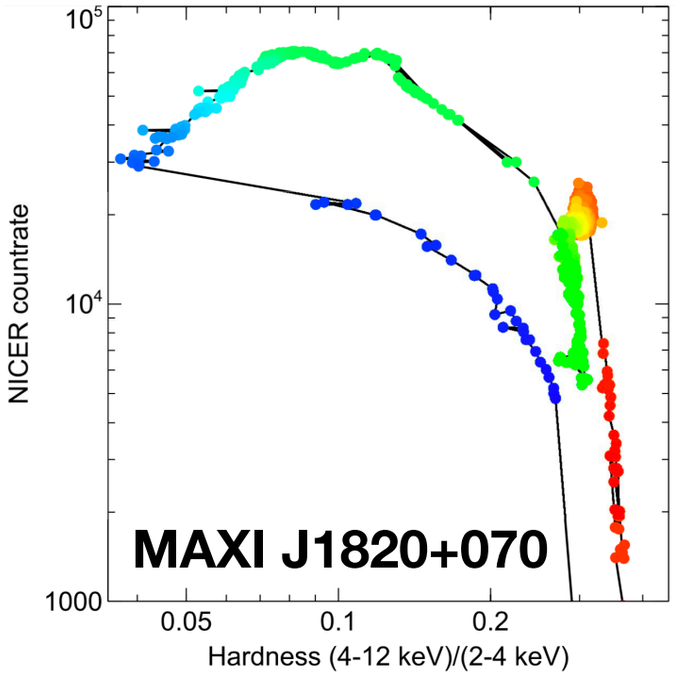
- **Previously unknown X-ray pulsations have been detected from a handful of additional rotation-powered pulsars**
  - **Too dim for 5–10% goal, but sample a wide range of masses. (Guillot et al., 2019)**

NICER is a time domain *observatory*

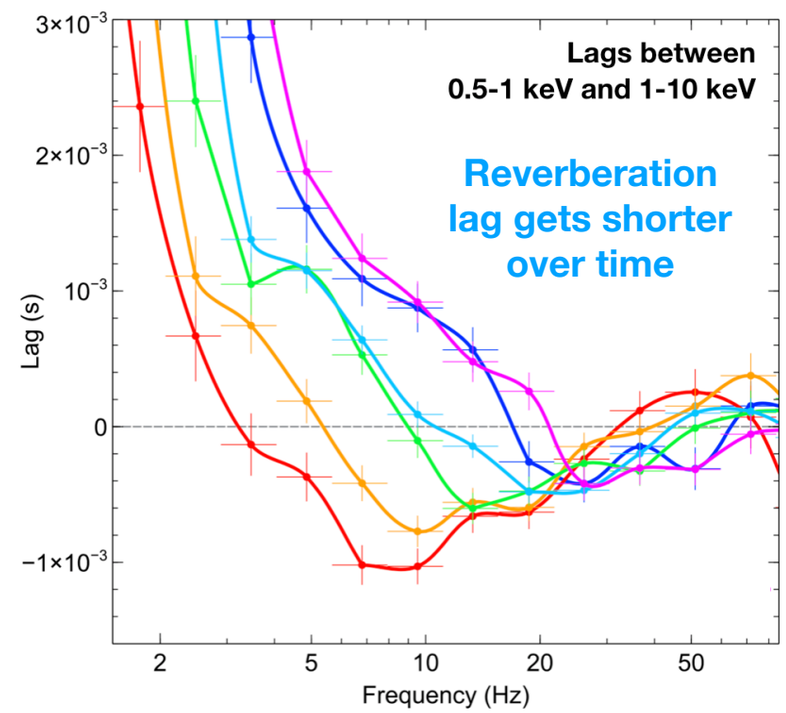
Rapid slew and rapid ToO response

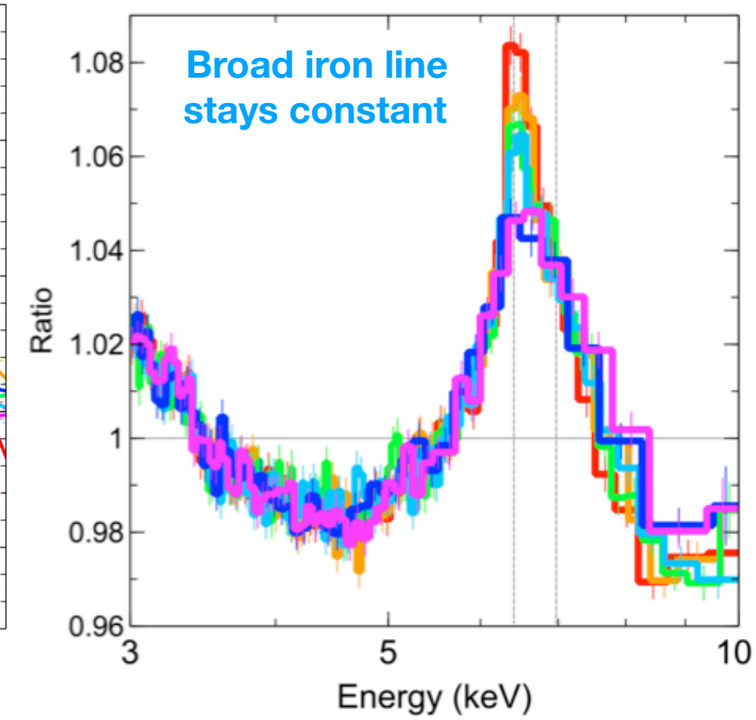
Providing high-quality, high-cadence spectral and timing products

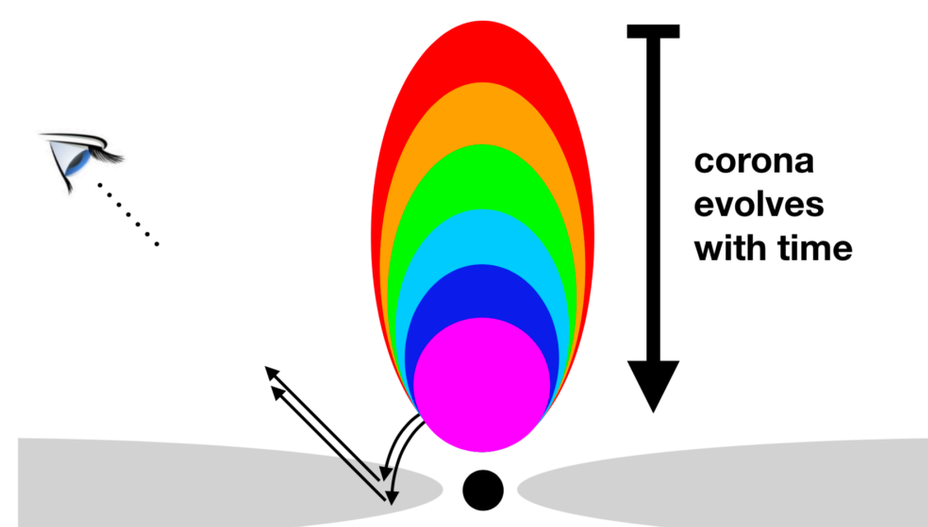
X-ray reverberation in stellar mass black holes



Kara et al., 2019



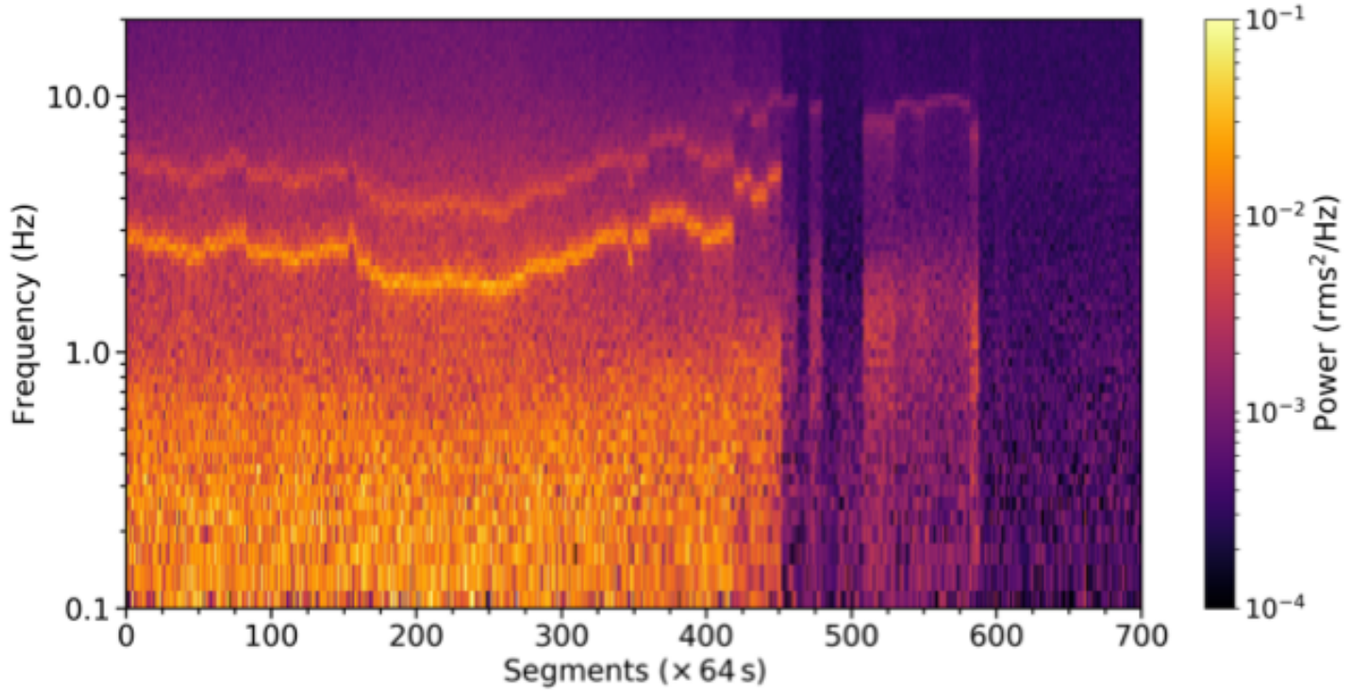


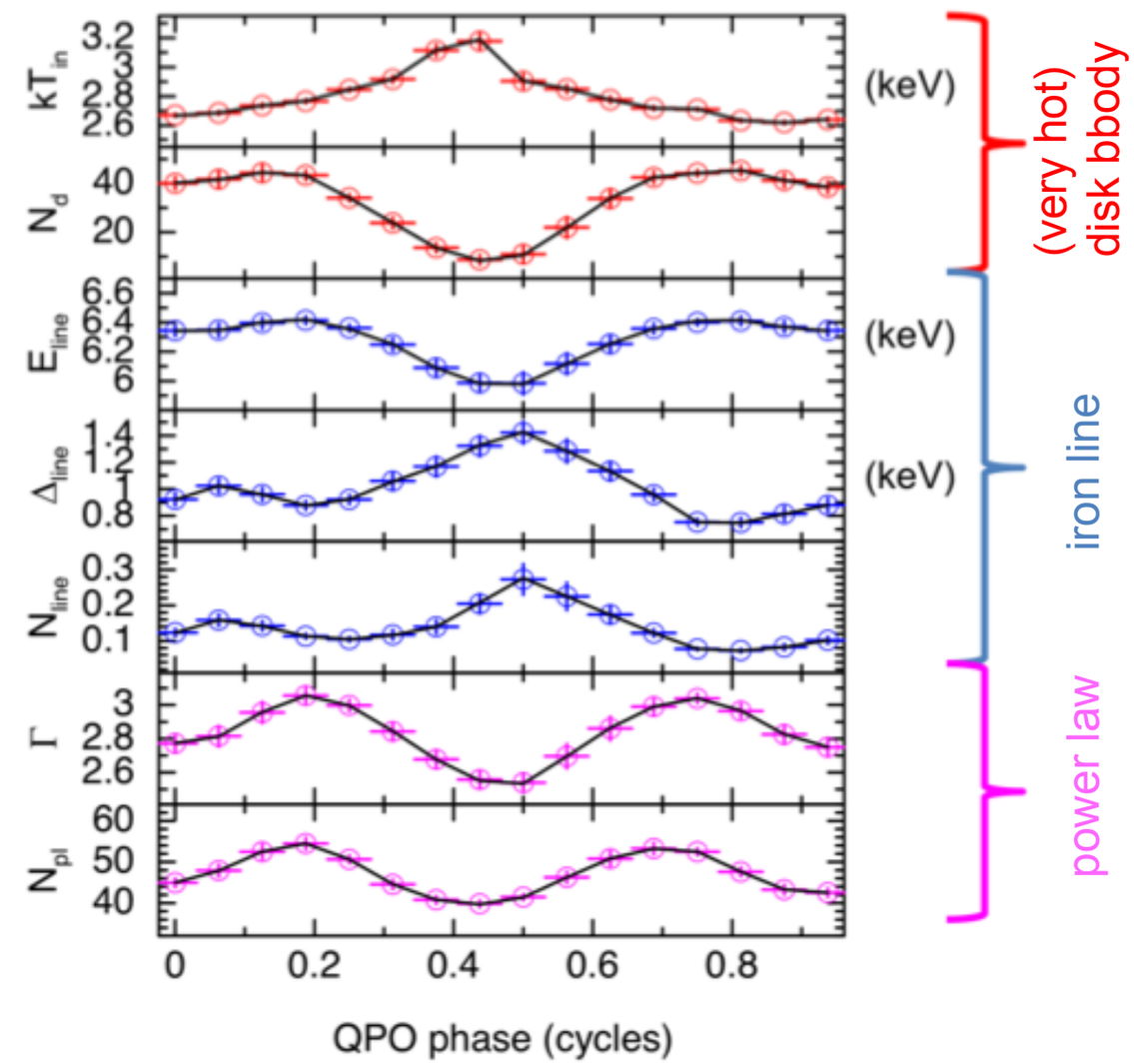


Spectral-timing QPO studies

Crown jewels of NICER data archives — MAXI J1535–571

Abbie Stevens
Adam Ingram



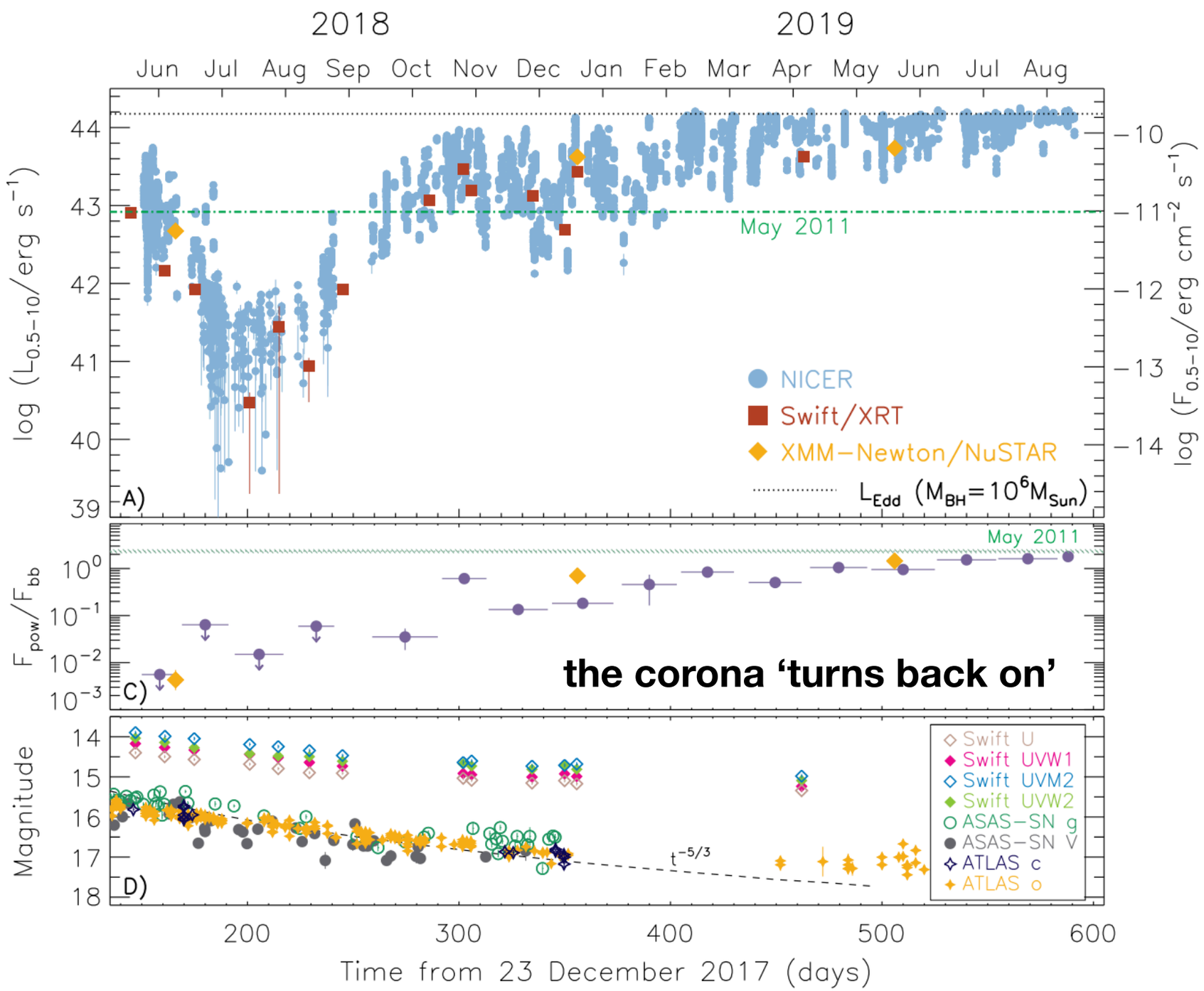


Large QPO amplitudes suggest origin deep in the gravitational potential.

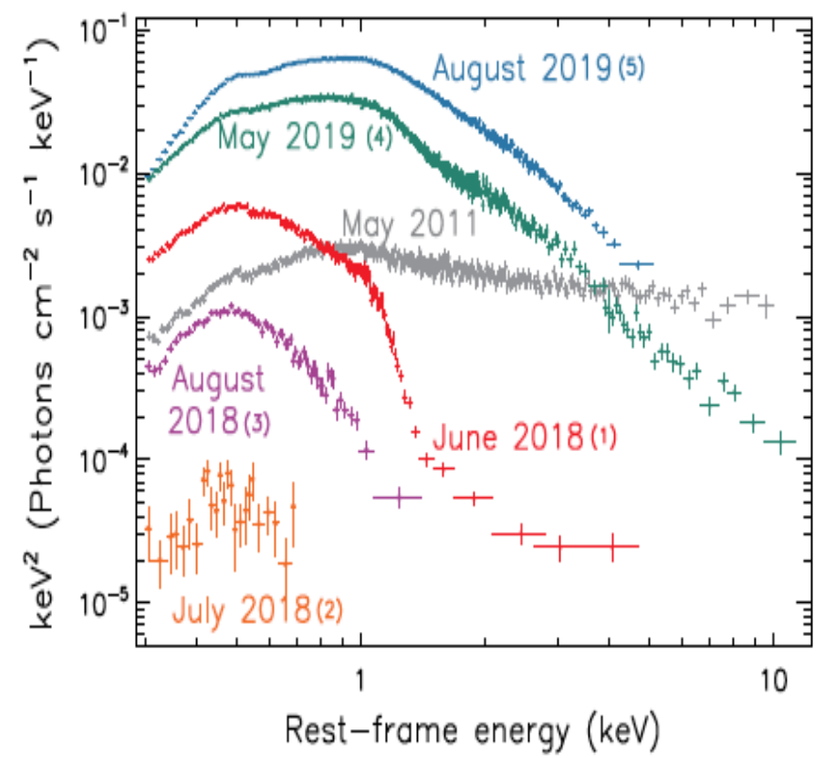
Disk emission varies out of phase with the coronal emission, suggesting the QPO is generated by precession of the inner corona, possibly due to general-relativistic frame-dragging.

Destruction and recreation of a supermassive BH's X-ray corona

Ricci et al. 2020, ApJ 898, L1



Changing-Look Quasar 1ES1927+564

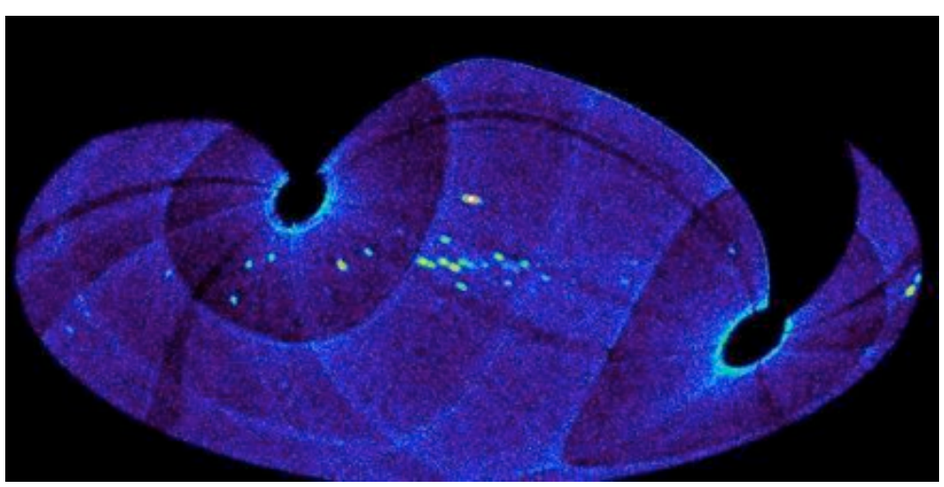


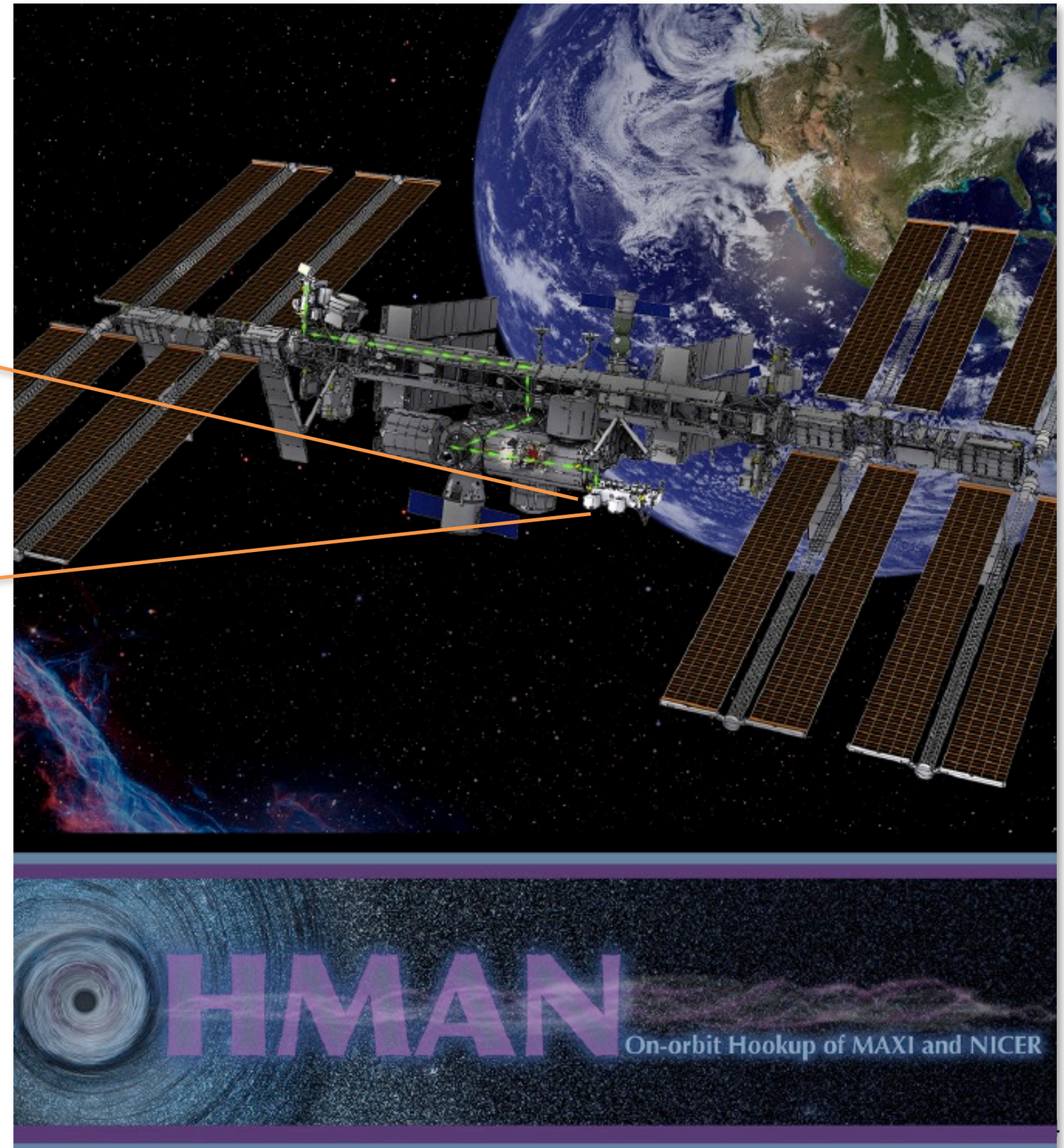
What's next? OHMAN!

Connecting two ISS payloads (not originally designed to work together) using ISS infrastructure to enable fast-transient science that would otherwise be inaccessible

JAXA's Monitor of All-sky X-ray Image (MAXI):

- > 900 deg^2 instantaneous FOV
- > 95% of the sky each orbit





Want to get involved?

NICER Spectral Fitting Workshop

Schedule

Three 3-hr blocks: Tues. Feb 2 – Thurs. Feb 4, 9am – noon EST

Topics

1. NICER Calibration: Status & Future (Gain and Response Files)
2. Data Preparation: GTI Selection and Background Subtraction
3. Fitting Mechanics (Energy Range; Channel Binning; Systematic Error)
4. Calibration sources: Crab and E0102

5. Fitting Broadband Spectra : BHBs, NSBs, AGN, etc.
6. Joint spectral fits : NICER/NuSTAR, NICER/XMM, etc.

7. Spectral Line Features
8. Fitting Soft Sources : TDEs, soft AGN, WDs, etc.
9. NICER Deadtime

email Ron Remillard (ronrem4@gmail.com) for more info

1st NICER Science Meeting

Virtual meeting in April 2021
Look out for HEAD announcement