NICER

Neutron star Interior Composition ExploreR

NICER Users Group Kickoff Meeting 2022

Keith Gendreau, Zaven Arzoumanian, Elizabeth Ferrara, Craig Markwardt
(NASA/GSFC)

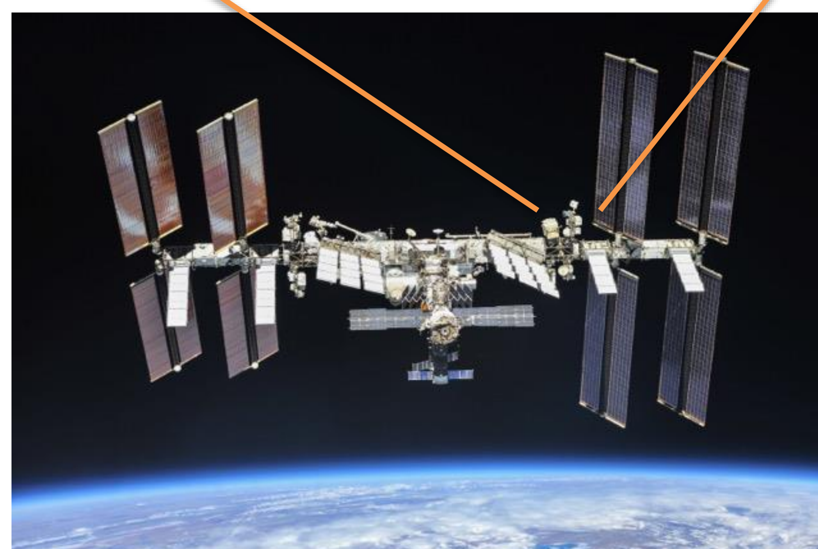
NASA GSFC MIT KAVLI INSTITUTE DTU BROAD REACH MOOG

Outline

- Welcome and Introductions
- Mission overview – Keith Gendreau
  - Introduction
  - Team
  - Operations and Interactions with HQ/ISS
  - Collaborations
  - Senior Review Results and Status
  - NUG timeline
- Science Program – Zaven Arzoumanian
- Instrument Performance and Calibration – Crag Markwardt
  - See presentation sent by Craig and video
- Guest Observer Program – Elizabeth Ferrara
- NUG Chair Discussion – Ed Cackett
- Questions and Discussion

An X-ray Astrophysics Observatory on the International Space Station

- ***Key science:*** Understanding ultra-dense matter via observations of neutron stars in the soft X-ray band
- ***Launch:*** June 3, 2017, SpaceX-11 ISS resupply
- ***Platform:*** ISS ExPRESS Logistics Carrier (ELC), with active pointing over nearly a full hemisphere
- ***Instrument:*** X-ray (0.2–12 keV) "concentrator" optics and silicon-drift detectors; GPS position & absolute time reference
- ***Enhancements:***
  - Guest Observer program
  - Demonstration of pulsar-based spacecraft navigation
- ***Status:***
  - Payload performing very well
  - Successful demo of pulsar-based navigation
  - Rich archive of public data
  - Second mission extension approved
  - GO Cycle 4 in progress; Cycle 5 proposal deadline in September



NICER is the largest producer of peer reviewed papers of any experiment on International Space Station

- Currently yielding 1-2 peer-reviewed papers per week based on NICER data or results
- Astronomer's Telegram (ATel) rate is now roughly 1 per week
- In 2021, NICER produced ~50% of all the Earth and Space Science papers from ISS payloads

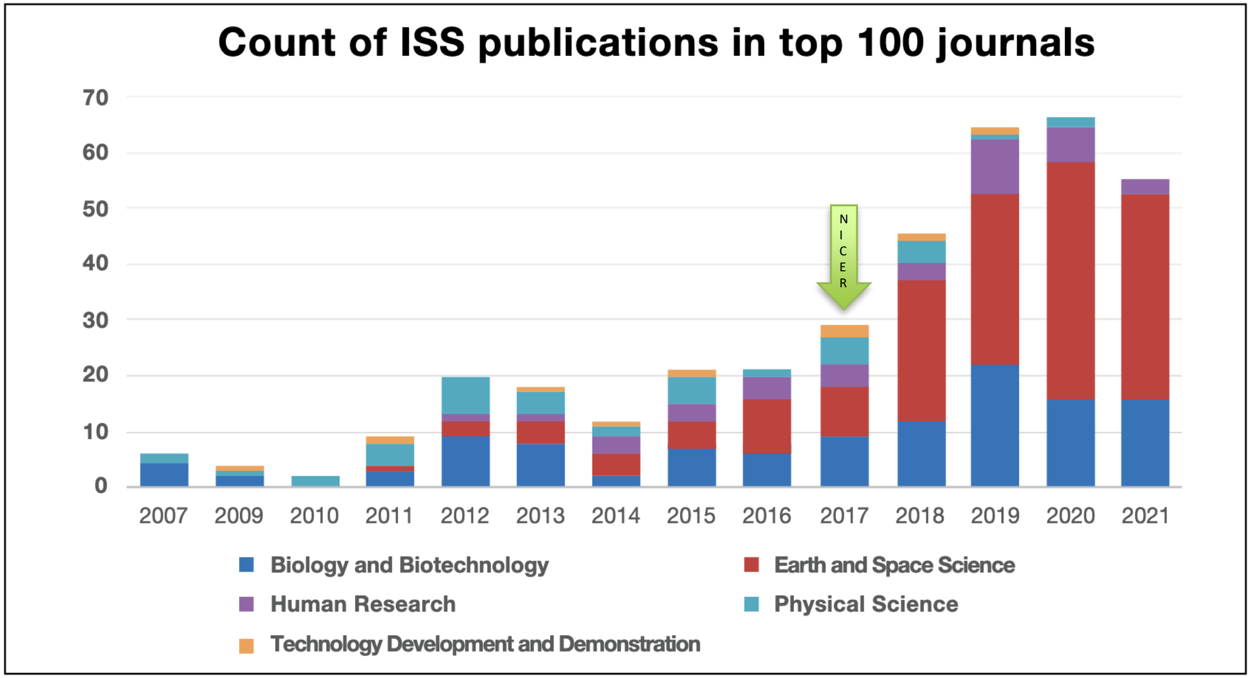


Figure 2. ISS articles published in Top 100 journals according to Clarivate's Eigenfactor ranking. Data are displayed by year, space agency, ISS research category, and ranking. Larger dots represent more distinguished journals based on Eigenfactor score.

- From "Annual Highlights of Results from the International Space Station: October 1, 2020–October 1, 2021"
- Shows all ISS publications in "top 100 journals"
- Note that "Astrophysical Journal" and "Astrophysical Journal Letters" are NOT considered one of the top 100 journals in this report
- NICER science return is clearly visible after its 2017 installation on ISS

NICER Team awarded the 2022 Bruno Rossi Prize

NICER Team was awarded the 2022 Bruno Rossi Prize

This is the highest prize in the High Energy Astrophysics Division of the American Astronomical Society

Prize Lecture during January 2023 AAS meeting in Seattle.

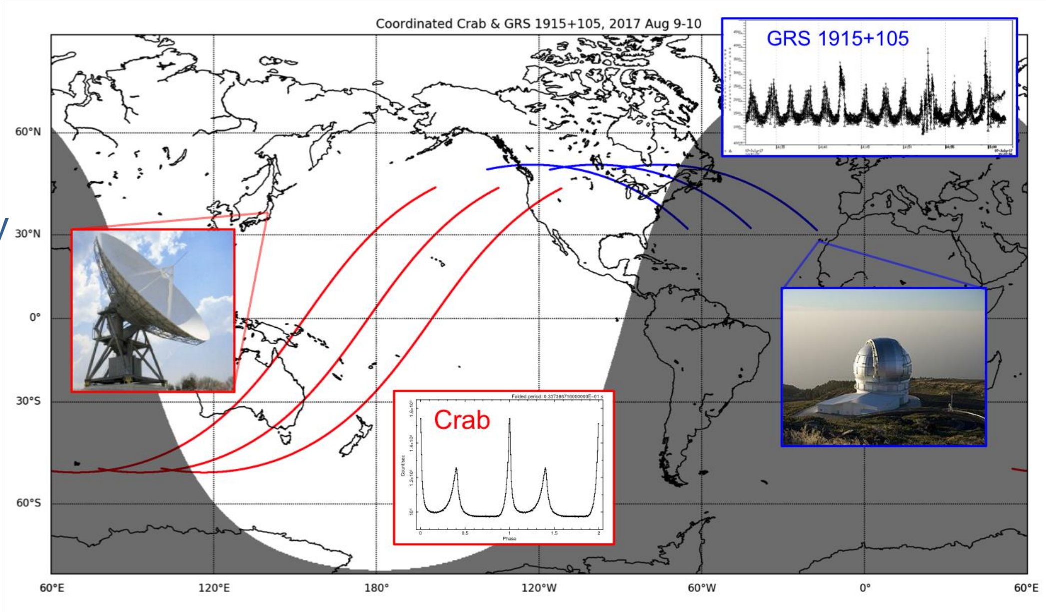
"To Keith Gendreau, Zaven Arzoumanian and the NICER team for development of the Neutron Star Interior Composition Explorer (NICER) and the revolutionary insights it is providing about the extreme environments of neutron stars and black holes, including the first precise and reliable measurement of a pulsar's mass and radius from detailed modeling of its pulsed waveform."

Photograph courtesy of the MIT Museum

NICER on the ISS

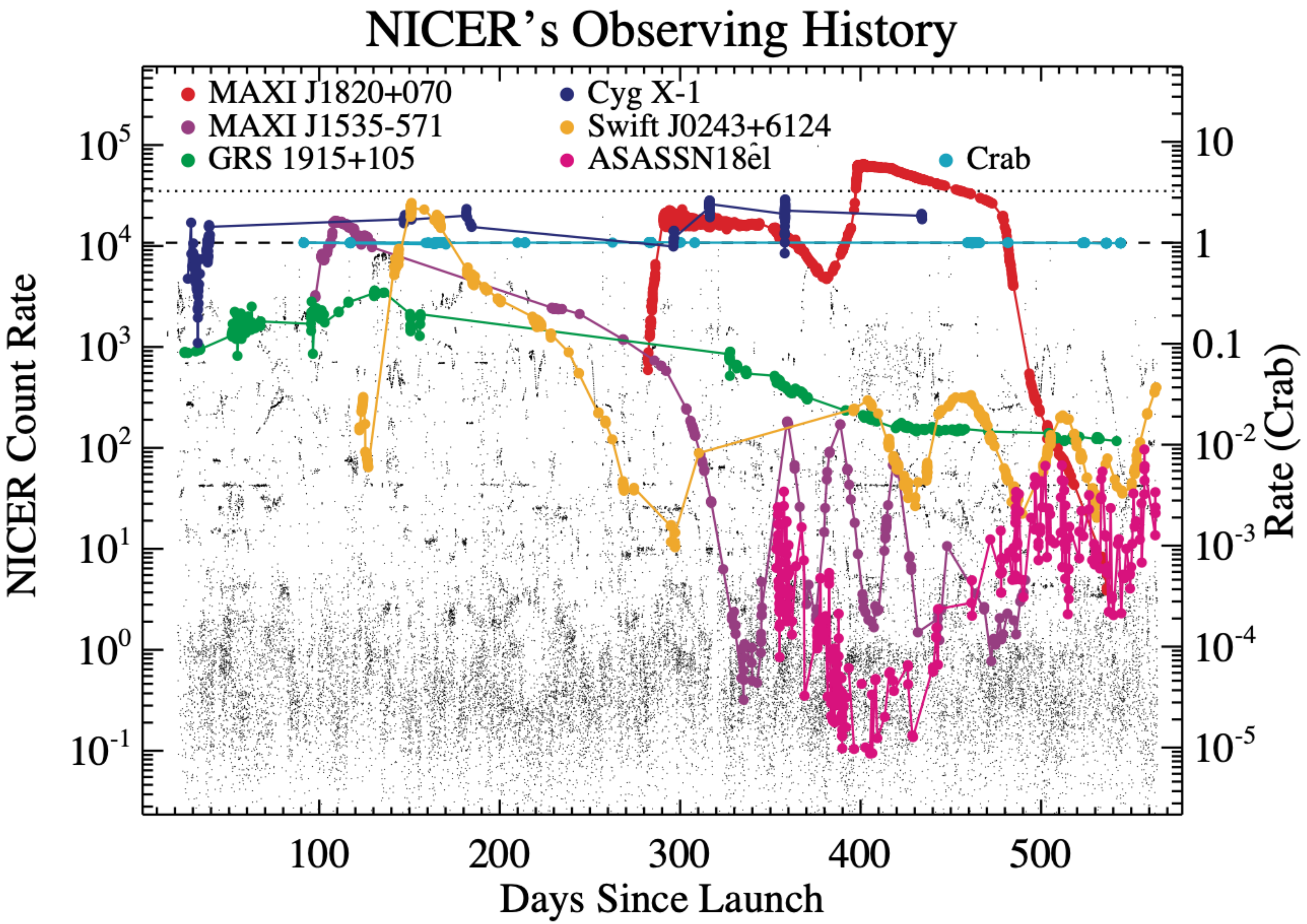
Flexibility to Coordinate Enables Powerful Multiwavelength Science

- NICER scheduling agility allows it to be a major part of multiwavelength campaigns, sometimes executing multiple coordinated observations in each ISS orbit.
- NICER makes its schedule and detailed visibility tools publicly available to enable this type of science and service to the community.
- As of January 2022, NICER has participated in over 415 coordinated campaigns with observatories around the world and in space.
- NICER has already begun coordinated observations with IXPE, and GOs have requested JWST coordination.



Waveband	Facilities	# of Campaigns
Radio	ALMA, AMI, ATA, Arecibo, CHIME, DSN, EHT, JVLA, Green Bank, Effelsberg, FAST, GMRT, Nancay, Jodrell Bank, Parkes, VLBI, eVLBI, MeerKat, MWA, GMVA, DSA, plus many telescopes in Japan & Korea	102
Infrared/ Optical	HST, TESS, Gemini, Palomar, Liverpool, SALT, VLT, Apache Point, Lowell, La Palma, La Silla, Las Campanas, Las Cumbres, Faulkes, GTC, plus numerous telescopes in Chile, Japan and elsewhere	133
UV/X-ray	Chandra, XMM-Newton, Hisaki, Swift, Halosat, DXL	65
X-ray/γ-ray	NuSTAR, ASTROSAT, HXMT, INTEGRAL, Fermi, MAGIC, X-Calibur	115

NICER expands the dynamic range of X-ray astrophysics



NICER Team: Most play multiple roles!

- Operations/Planning/Pipeline
  - Operations: J. Pope, M. Saylor, B. Kozon, IT staff: ~2 FTE
  - Planning: K. Gendreau, Z. Arzoumanian, E. Ferrara, K. Hamaguchi: ~2.75 FTE
    - Beginning to bring on a "Pathways Intern" (Isiah Holt)
  - Data pipeline: C. Markwardt, K. Rutkowski: ~1.5 FTE
- GOF
  - E. Ferrara (Lead)
  - K. Hamaguchi, M. Corcoran, M. Loewenstein, S. Sturner, T. Strohmayer, J. Coley
    - Bringing on Isiah Holt
- Instrument Team
  - C. Markwardt (Calibration Lead)
    - Craig is transitioning to ½ time on Swift; interviewing for a deputy now
    - Senior Review request for additional calibration scientist not received well
  - T. Okajima (optics)
  - R. Remillard, G. Prigozhin, B. LaMarr, D. Pasham, J. Steiner (detectors)
  - B. Trout, J. Pope (FSW, OHMAN)
- Science Team

NICER Science Team

- Led by Zaven Arzoumanian
- Organized into 6 Working Groups
  - Light Curve Modeling
  - Searches & Multiwavelength Coordination
  - Bursts & Accretion Physics
  - High-Precision Timing
  - Magnetars & Magnetospheres
  - Observatory Science (everything *not* neutron stars)
- Membership (76 members, plus ~17 students)
  - Instrument Team
  - Original mission proposal science Co-Is and Collaborators
  - Affiliated Scientists (post-doc & higher seniority)
  - Students (pre- & post-graduate)

NICER Operations

- Ground System led by John Pope, supported by Maxine Saylor
- Three weekly tag-ups
  - Planning
  - ISS product status
  - Hot issues (e.g., ISS operations)
  - Pipeline status
  - GO status
- Two regular command loads a week
  - Tuesdays and Fridays
  - plus, as needed
- TOO planning and commanding
  - ARK submission
  - Scientist planning
  - Commanding by engineers or scientists
  - One silver lining of COVID

NICER Programmatic Scheduling

- Weekly tag-ups with NASA HQ
  - Program Executive: Rachele Cocks -> Janet Letchworth
  - Program Scientist: Roopesh Ojha
  - Thursday mornings
  - Covers instrument status, ISS issues, key science results, GO status, program issues and concerns
- Monthly GSFC Astro Comms (outreach) tag-up
- ISS processes next slide….

NICER ISS Interactions

- All commands go through established ISS infrastructure
  - Payload Operations Integration Center (POIC) at MSFC is the hub for all payload commanding
  - Voice Loops for command enabling
- Multiple email exploders communicate ISS operations to payloads
  - Not reliable for some critical information (examples coming)
  - Recent progress for External payloads
- Twice a year ISS-wide Payload Operations Integration Working Group (POIWG) meeting
  - Tend to be “crew-centric"
- ISS manifesting is completely independent of the SMD Senior Review cycle and requires constant attention
  - ISS may decide to replace NICER with another payload
  - MiPROM meetings every few months
- OHMAN
  - Weekly Payload Integration Manager (PIM) meetings
  - Regular interactions with JAXA and MAXI team
  - Requirement verifications and ISS processes
- Weekly ISS “Science Nuggets”
  - High-level timely science result sent to ISS program
  - Typically, an ATel, recent peer-reviewed publication, or exciting TOO
  - Read by ISS management, engineers, and astronauts
  - NICER’s “soft power” on ISS program
  - https://heasarc.gsfc.nasa.gov/docs/nicer/science_nuggets/

Example ISS Science Nugget

- One ISS Science Nugget sent in each week
- Read by many people in ISS program, including astronauts
- NICER really stands out in these inputs compared to most all payloads
- Useful tool to keep track of highlights for NICER

NICER / ISS Science Nugget for June 16, 2022

NICER discovers millisecond pulsations from the new transient MAXI J1816-195

On June 7th, JAXA's Monitor of All-sky X-ray Image (MAXI) payload discovered a new transient X-ray source, which was named MAXI J1816-195. The NICER team was quickly informed of this discovery through the OHMAN collaboration, and responded within 2 hours of the first detection. NICER initially scanned a region around the nominal coordinates reported by MAXI to localize the exact position of the source (Figure 1). Once the best source coordinates were determined, NICER began monitoring this new X-ray source using pointed observations. The NICER team quickly discovered that MAXI J1816-195 showed coherent X-ray pulsations at a period of 1.9 ms (Figure 2), and promptly reported it to the community on June 8th in Astronomer's Telegram #15425.

Since the discovery that MAXI J1816-195 is a new accreting millisecond pulsar, NICER has conducted a regular monitoring campaign of this object. We have already found that the apparent pulse frequency is oscillating sinusoidally with time, revealing the 4.8 hr binary orbit of this neutron star, as reported in ATel #15431. Further, we discovered that MAXI J1816-195 shows thermonuclear X-ray bursts, with three such events detected so far. The detailed analysis of these data by P. Bult (NASA GSFC) and collaborators is ongoing, and will continue while NICER conducts additional observations for the duration of this new target's outburst.

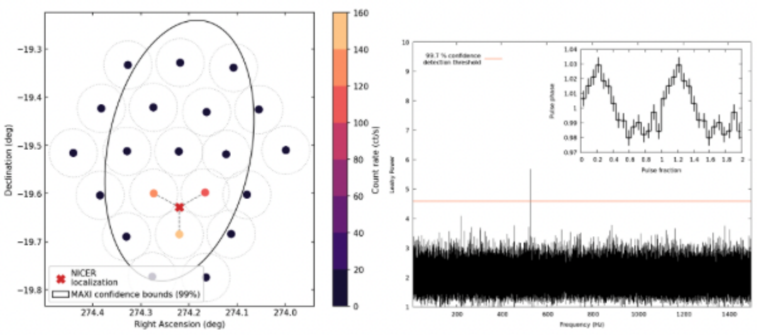


Figure: Left: NICER raster scan around the nominal MAXI localization: 21 pointed observations lasting 60 sec each were carried out in a grid covering the full uncertainty region of the nominal MAXI coordinates. A bright X-ray source was clearly detected in this field, which, by interpolation, could be localized to Right Ascension 274.2205 deg and Declination -19.627 deg. Right: Power spectrum of the initial 2300 sec observation collected with NICER. The narrow peak rising well above the noise level is the 528 Hz (or 1.9 ms) pulse signal. After correcting for the orbital motion of the neutron star and folding the photon arrival times on this period we obtain the slightly asymmetrical pulsar waveform shown in the inset.

NICER on the ISS: Pros and Cons

- Pros
  - Nearly continual contact enables rapid TOO response and feedback
  - High data-volume capacity and power availability
  - Low-cost operations
  - Integration possibilities (e.g., OHMAN)
- Cons
  - Accommodating other payloads (e.g., MISSE)
    - "Science" has a broad definition on ISS, which hosts payloads by SMD, NASA STMD/HEOMD, DoD, Commercial, International
  - EVAs and EVRs
    - Rarely impact NICER at ELC2
  - ISS structure avoidance
    - Reduces the length of continuous observations of targets
  - High-inclination orbit
    - Results in highly variable & unpredictable radiation background
  - Occasional poor communication from ISS program to payloads
    - MISSE operations
    - iROSA solar panels

NICER on the ISS: Pros and Cons

- iROSA Solar Panels
  - Attempt to make up for aging solar arrays
  - Will be installed beginning as soon as this summer (port side)
  - NICER team was not informed until after we found an article in a public magazine
  - Will affect planning
  - Will slightly reduce availability of sky to NICER at low beta angles
- This incident is unlike other ISS upgrades where NICER (and other payloads) were consulted/informed well in advance
- Led to an "Externals" payload forum after NICER team talked with HQ and some in ISS program.

iROSA Solar Panels

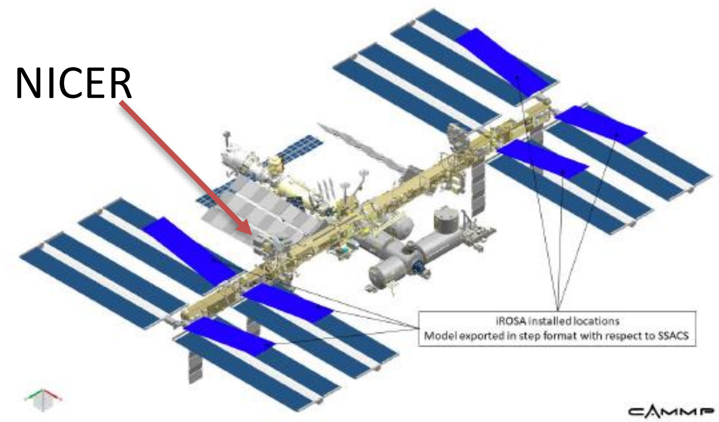


Figure 1. iROSA installed locations

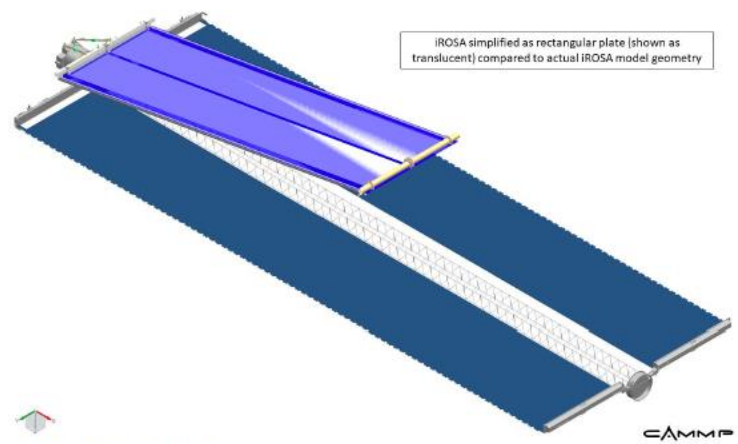
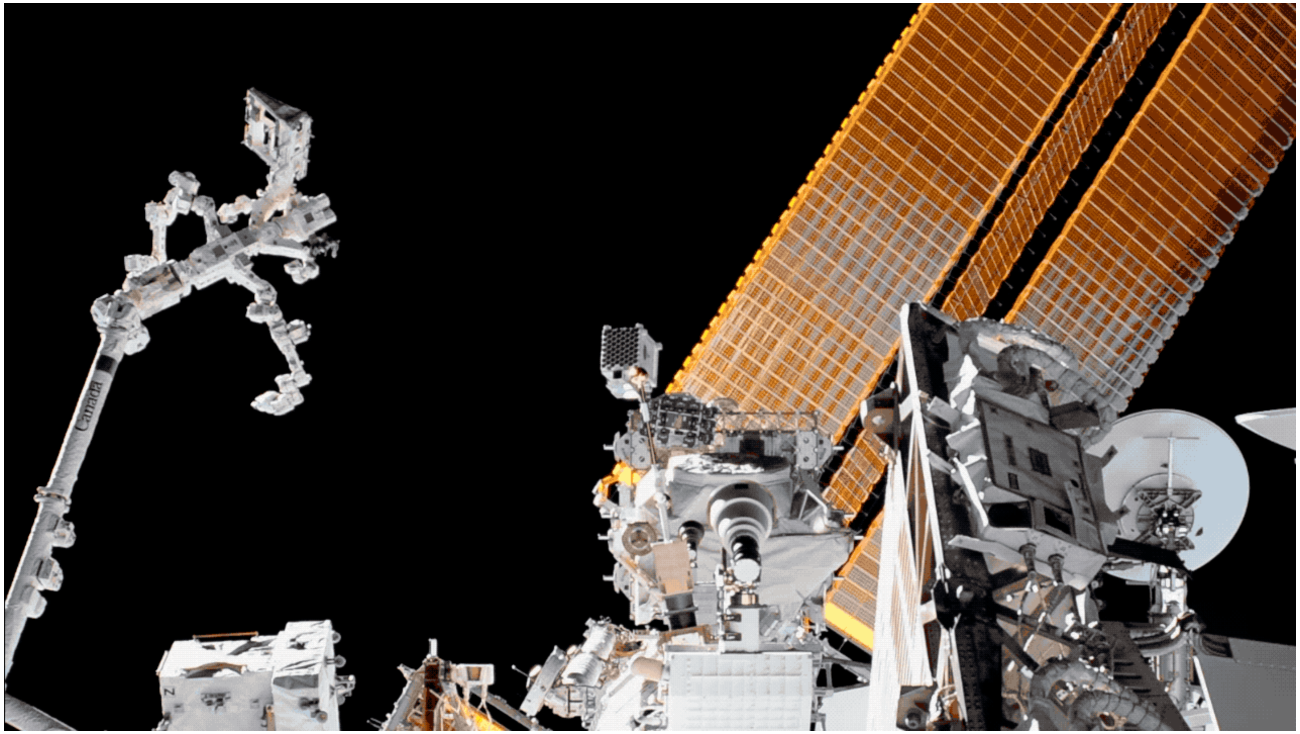


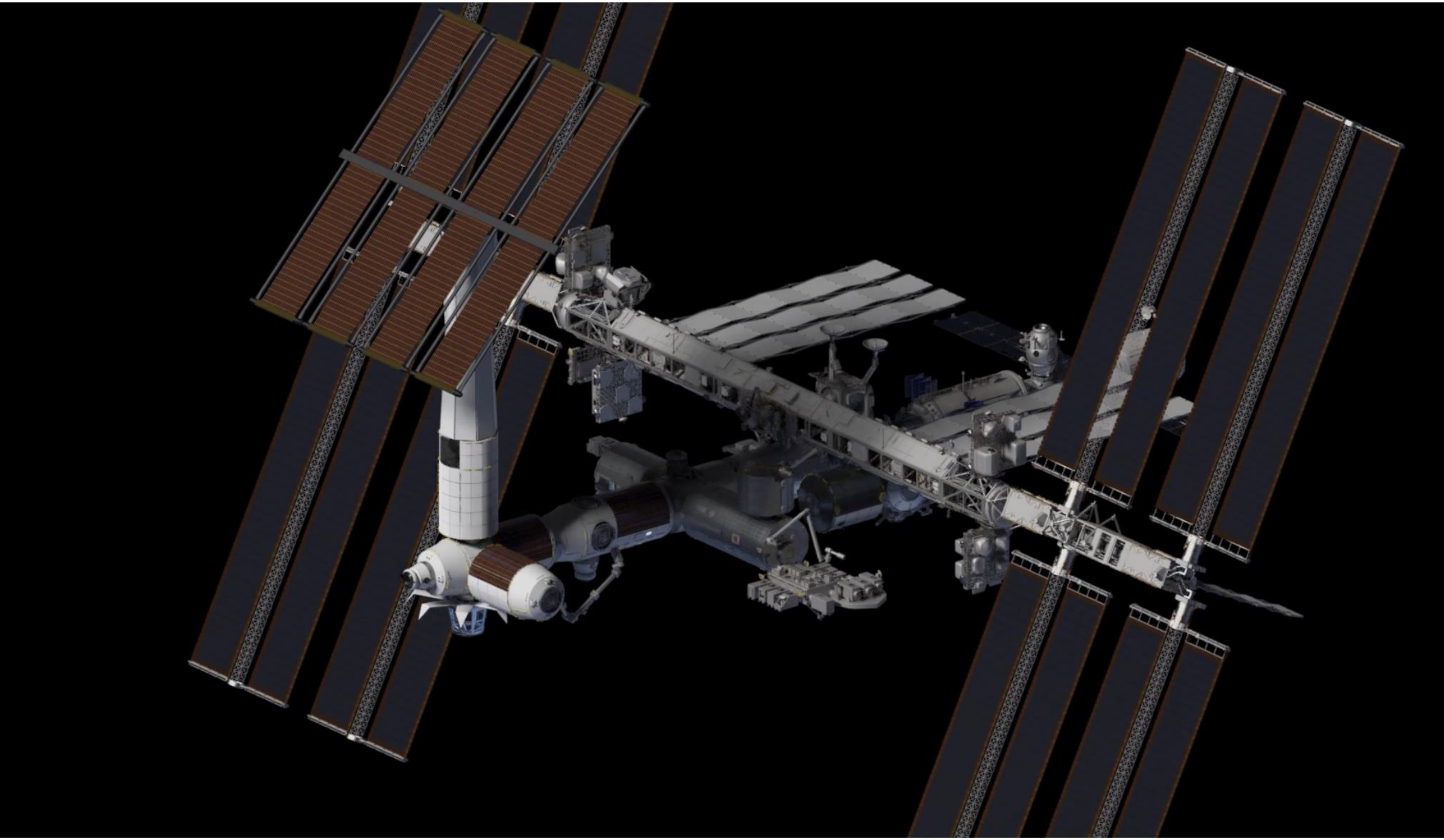
Figure 2. iROSA simplified model

NICER on the ISS: Pros and Cons

- Down in front!
- ISS obstructions do happen, but are relatively rare
- During ISS day, NICER star tracker can be blinded by glint off structures in unexpected places
- During ISS night, NICER star tracker may function fine, but XTI is blocked, leading to false eclipses



AXIOM Private Space Station “Power Tower” will severely affect NICER science… expected ~2025-2026



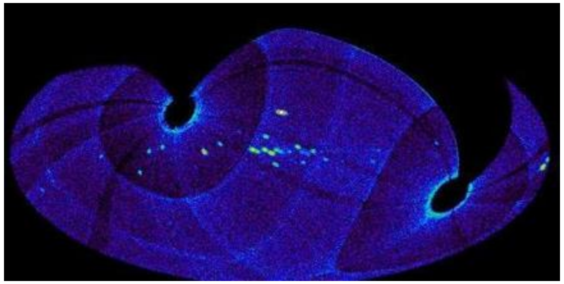
OHMAN TOO capability

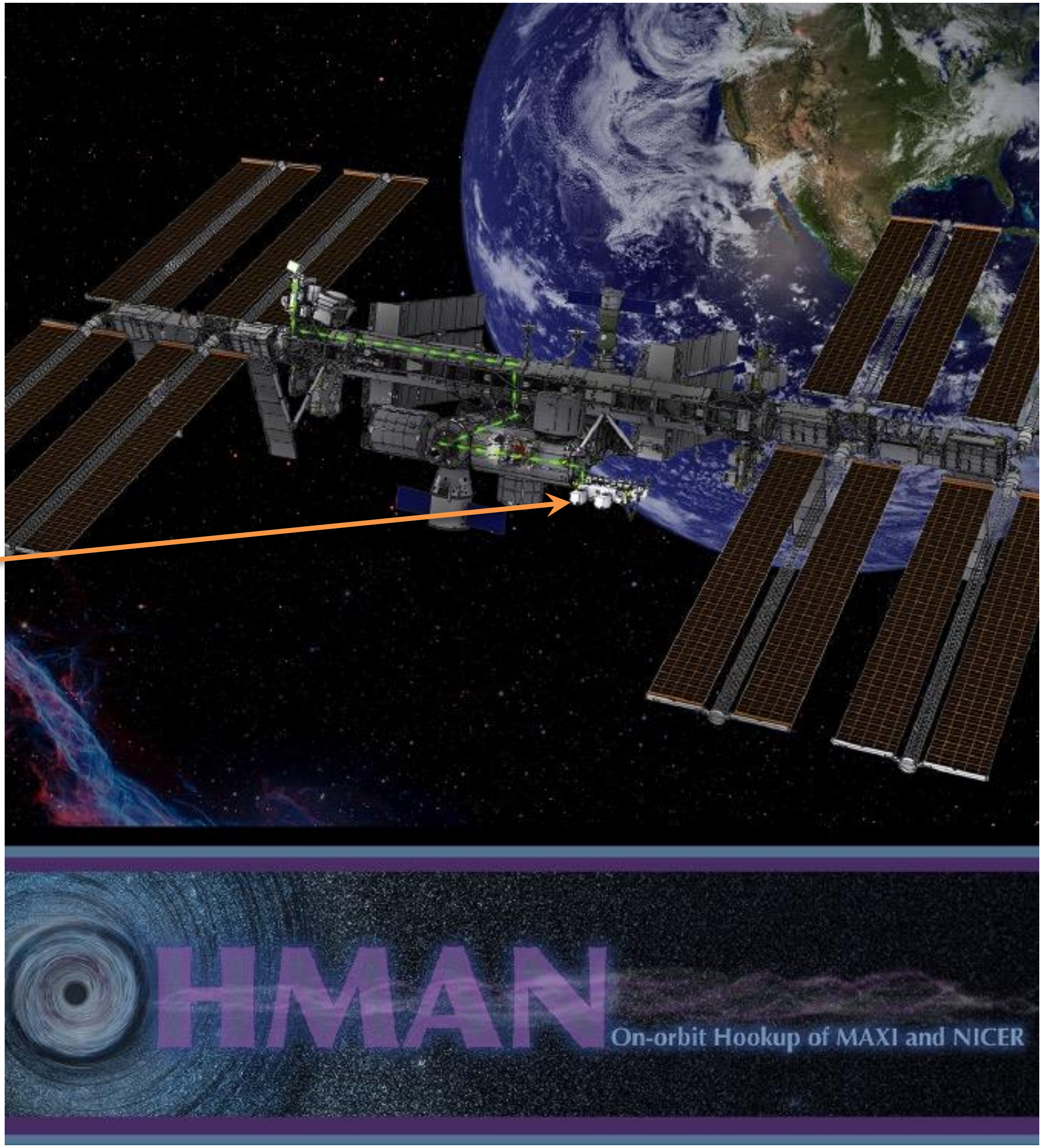
OHMAN: Connecting two ISS payloads using ISS infra-structure to enable science of fast transients that would otherwise be inaccessible.

© NASA

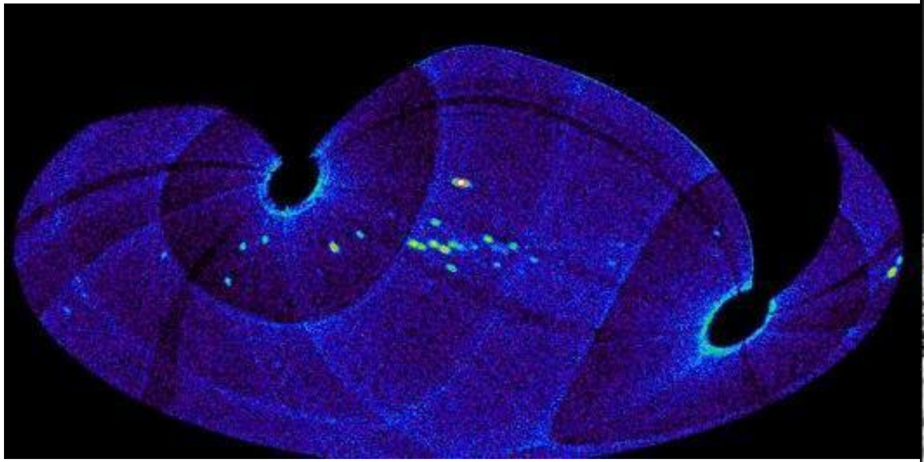
JAXA's Monitor of All-sky X-ray Image (MAXI)

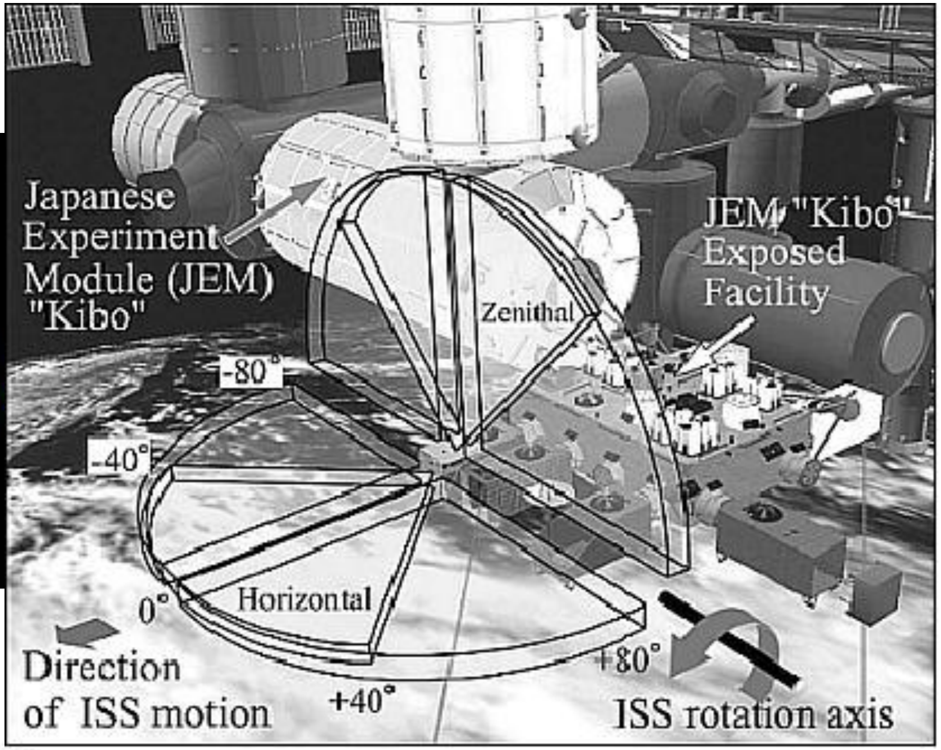
- > 900 deg^2 instantaneous
- *> 95% of the sky each orbit*

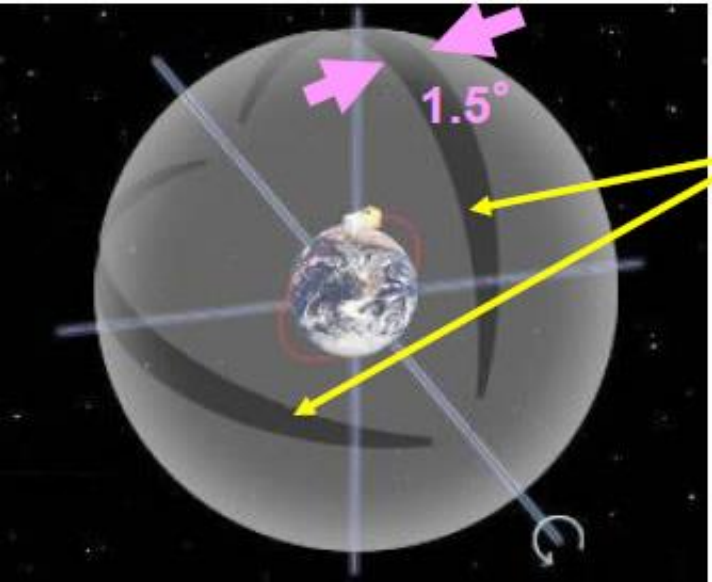




MAXI Sky Coverage







View of GSC
(1.5°X 160° arch)

Observations in two directions; in the moving direction of the ISS and toward the zenith

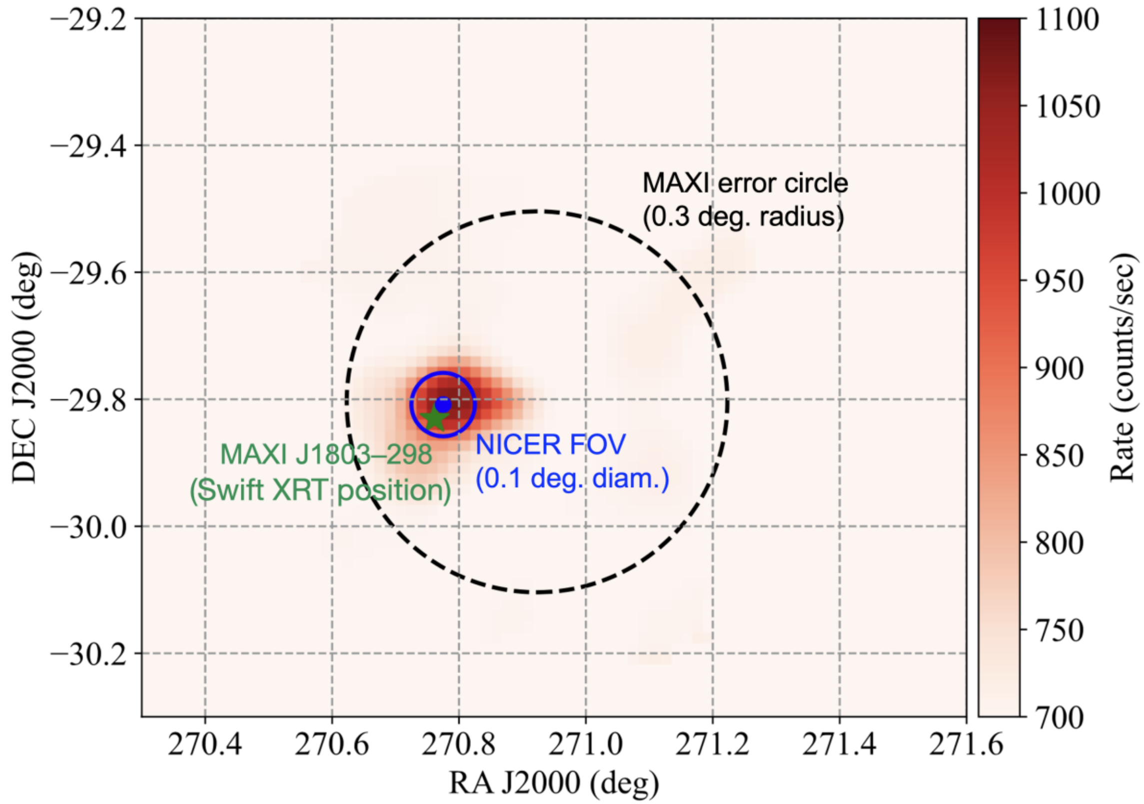
- Instantaneous coverage of 960 deg^2 of sky (2%)
- 95% of entire sky each orbit
- 80 mCrab sensitivity

OHMAN Concept

- Use a laptop to monitor live data from the MAXI instrument, running existing software for rapid data analysis and visibility checking
- Communicate location of transient (~80 mCrab threshold) to NICER
- Exploit NICER's rapid slewing capability to bring > 15x the collecting area of *Swift* XRT to bear on the transient.

OHMAN fully exploits all existing infra-structure on ISS as well as in the NICER and MAXI ground systems and data processing pipelines.

New — NICER can now localize targets by scanning MAXI error circles.



OHMAN Status

- OHMAN was significantly delayed by lack of action by ISS program to get in place a Payload Integration Agreement (PIA) and to have a Payload Integration Manager (PIM) assigned
- OHMAN operations began ~2 weeks ago
- Spending time understanding triggers
  - About 1 trigger every 5 days or so
  - Several are poor triggers (common RA/DEC/SAT_LON/SAT_LAT)
  - Some are real
- There are a few knobs to adjust
  - Thresholds on individual sources
  - Overall S/N
  - Possibility to control relative priority to planned GO targets
- If we do future software updates, much easier to do so on the NICER side and not the OHMAN laptop side
- Looking at possibility to use the OHMAN infrastructure to enable automated triggers from the ground
  - Likely a programmatic hurdle.

NICER Instrument Performance and Calibration

- Instrument has suffered very minor degradation since launch
  - Radiation damage has led to dark-current growth in SDDs
  - Radiation damage has made inoperable nearly every SDD cold-side temperature sensor
    - This was caught recently in the mission and confused with expected radiation damage of SDDs
    - For past ~2 years, NICER has been running SDDs at max TEC current, and dark current has been substantially reduced with no significant loss of calibration
- Overall performance (gain, energy resolution, timing performance) remains within specifications and is captured in calibration
  - Optical loading is more difficult to account for, but calibration is improving
    - Leads to gain shifts (calibrated) and energy resolution degradation
    - Leads to extra noise in lowest channels (< 400 eV, typically)
    - Standard processing can yield “0” events, while there may be plenty of useful data
- Calibration effort lead by Craig Markwardt
  - **Please see Craig’s talk**

Established NICER Collaborations

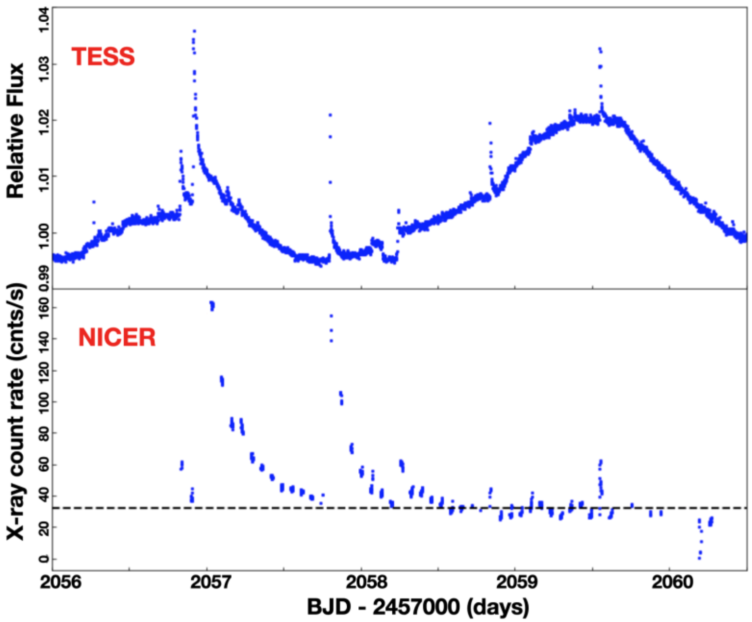
- NICER has an agreement to offer NICER time to NuSTAR GO program in exchange for NuSTAR time in the NICER GO program
  - NICER can plan to use 400 ksec of NuSTAR time each cycle
  - NuSTAR can plan to use 200 ksec of NICER time each cycle
  - Excellent synergy between NICER and NuSTAR yields great science!
- NICER and MAXI are collaborating as part of OHMAN
  - OHMAN email exploder has already resulted in many fruitful science returns (e.g., MAXI J1820+070)
  - On-orbit operations should yield ~minute reaction times to new transients
  - MAXI on-orbit time possibly extended due to this arrangement
- Sellers Exoplanet Environment Collaboration (SEEC)
  - NICER works in conjunction with TESS and other observatories to provide multiwavelength studies on stellar flares in exoplanet systems to understand impacts on habitability
- Radio Collaborations
  - DSN and others for a variety of pulsar science
- IACHEC (International Astronomical Consortium for High Energy Calibration)
  - NICER participates in coordinated calibration programs with nearly all existing high-energy missions to maintain cross-calibration.

New NICER Collaborations

- NICER/Swift
  - Joint GO/GI program similar to the NICER/NuSTAR program
  - Joint TOO program – Not clear if budget will be approved as overguide
    - NICER and Swift would share a scientist to better coordinate NICER and Swift TOO capabilities
- NICER/TESS
  - Joint GO/GI Program
    - NICER will provide 300 ksec to TESS proposers
    - NICER proposers will be able to propose many high-cadence target windows from TESS
- JINA-CeNAM Collaboration
  - Center for Nuclear Astrophysics Across Messengers (CeNAM))
    - A proposed Department of Energy research center to foster research at the intersection of astrophysics and nuclear physics. CeNAM is a multi-institutional, interdisciplinary collaboration that builds on a decade of research within the Joint Institute for Nuclear Astrophysics–Center for the Evolution of the Elements (JINA-CEE) and its JINA predecessor, both National Science Foundation Physics Frontiers Centers.
    - If approved, CeNAM will begin Sept 1, 2022.

TESS/NICER and Swift/NICER GO/GI Collaborations

- Over the years, there have been many joint TESS/NICER and Swift /NICER observations
- The new collaborations proposed will enhance this relationship
  - Beginning TESS GI Cycle 5, NICER is offering up to 300 ksec of NICER time for TESS proposers and for the upcoming NICER GO Cycle 5, TESS is offering high-cadence windows for NICER proposers
  - Similarly, NICER will offer 200 ksec for Swift GI proposers and Swift will offer 200 ksec to NICER GO proposers in September 2022
- Novel science return:
  - Flaring stars — Joint observations will place our Sun in the context of other stars, provide insight into habitability of exoplanets around active stars
  - Long-term monitoring of sources where NICER handles bright sources and Swift handles background-dominated or confused sources
  - Investigations in which Swift's sky-tiling capability will help localize a source with poor position knowledge that NICER can then follow up
  - AGN studies



Multiple stellar flares from exoplanet host AU Mic are captured simultaneously by TESS and NICER, probing flare energetics and implications for habitability.

Joint Swift-NICER TOO

- Approximate and (very) conservative timeline for joint NICER-Swift TOO coordination effort (if approved)
  - Fall 2022:
    - Exchange planning details between projects and prepare the “nudge” options on NICER's and Swift's individual TOO request pages
    - Prepare a call for the hiring of a TOO-planning scientist shared between NICER and Swift
  - Spring/Summer 2023:
    - Bring online the nudge options
    - Hold public workshop on the shared Soft X-ray TOO effort
    - Hire shared planning scientist
  - Fall 2024: Begin preparing a single joint Soft X-ray TOO interface
  - Spring 2025: Bring online a single joint Soft X-ray TOO interface
- Note that the joint TOO program is an over-guide request for both NICER and Swift, while the joint GO/GI program fits within NICER's in-guide budget.

Diversity, Equity, Inclusion, and Accessibility are core NICER values

- NICER is pooling its resources with other astrophysics missions within GSFC for a comprehensive approach to DEIA.
- In addition to being a full partner in this combined DEIA effort, NICER is making available 50–100 ks of its discretionary time (DDT) for hands-on experience in proposal writing, observation planning, and data analysis as part of a workshop for underrepresented groups.
- We would like to add to the NUG charter an annual evaluation of NICER's DEIA efforts

2022 Senior Review Results

- NICER has been extended, but budget is not clear
- Many overguide requests are likely to not be accepted per Senior Review report recommendations
  - Likely, extra calibration scientist advocated by NUG was not recommended by Senior Review
  - Likely, GO budget will remain flat
  - Likely, shared Swift NICER scientists for TOO coordination will not be approved.
- The Reports of the Senior Review Subcommittee and the three Senior Review panels are available at

https://science.nasa.gov/researchers/nac/science-advisory-committees/apac#meetingdocs

NICER User Group Timeline

- Kickoff meeting – 20 June 2022
- NICER's 2nd public workshop – targeting early September
- NUG Summer meeting (tomorrow?)
- NUG Fall Meeting

NICER Science Program

Science Themes — Responsive to Sky and Community

NICER pursues science within three broad, not mutually exclusive, themes:

- ***Legacy.*** Investigations of neutron stars in all their manifestations. Goals:
  - Structure — M-R, dense-matter EOS, implications for GW emission
  - Dynamics — bursts, glitches, clock stability
  - Energetics — powered by rotation, accretion, or magnetic fields.
- ***Observatory.*** Targeting all cosmic sources of X-rays, from comets to blazars. Includes Guest Observer and ToO/DT programs.
- ***OHMAN.*** Most rapid-response capability, highly anticipated for GRB, stellar flare, NS and BH outburst investigations, and more.

All are highly responsive to Astro2020 Decadal Survey priorities, especially TDAMM astrophysics.

All hold tremendous promise for many additional years of productivity: discoveries of new phenomena and key insights facilitated by time-domain responsiveness and multi-wavelength/multi-messenger coordinations at which NICER excels.

"At the vanguard" of neutron star science

- March 2020 Nature feature article spotlights NICER: "the golden age of neutron star physics has arrived… NICER is at the vanguard…"
- Since 2019 SR, NICER has released blockbuster M-R and surface thermal map results (with hundreds of citations!) for two neutron stars; several more to come.
- Radius and mass reveal interior composition, with broader impacts — e.g.,
  - BH-NS threshold in mass; demographics
  - strong-gravity parity violation test improved by *7 orders of magnitude*
  - independent "standard siren" measurement of the Hubble constant.

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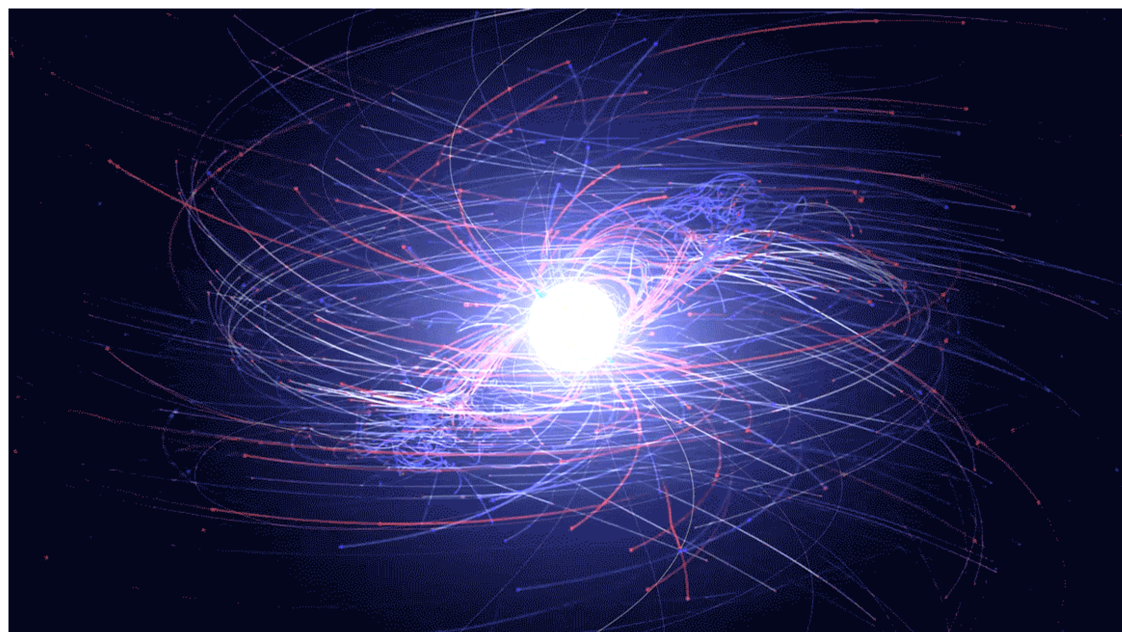
NEWS FEATURE | 04 March 2020

The golden age of neutron-star physics has arrived

These stellar remnants are some of the Universe's most enigmatic objects – and they are finally starting to give up their secrets.

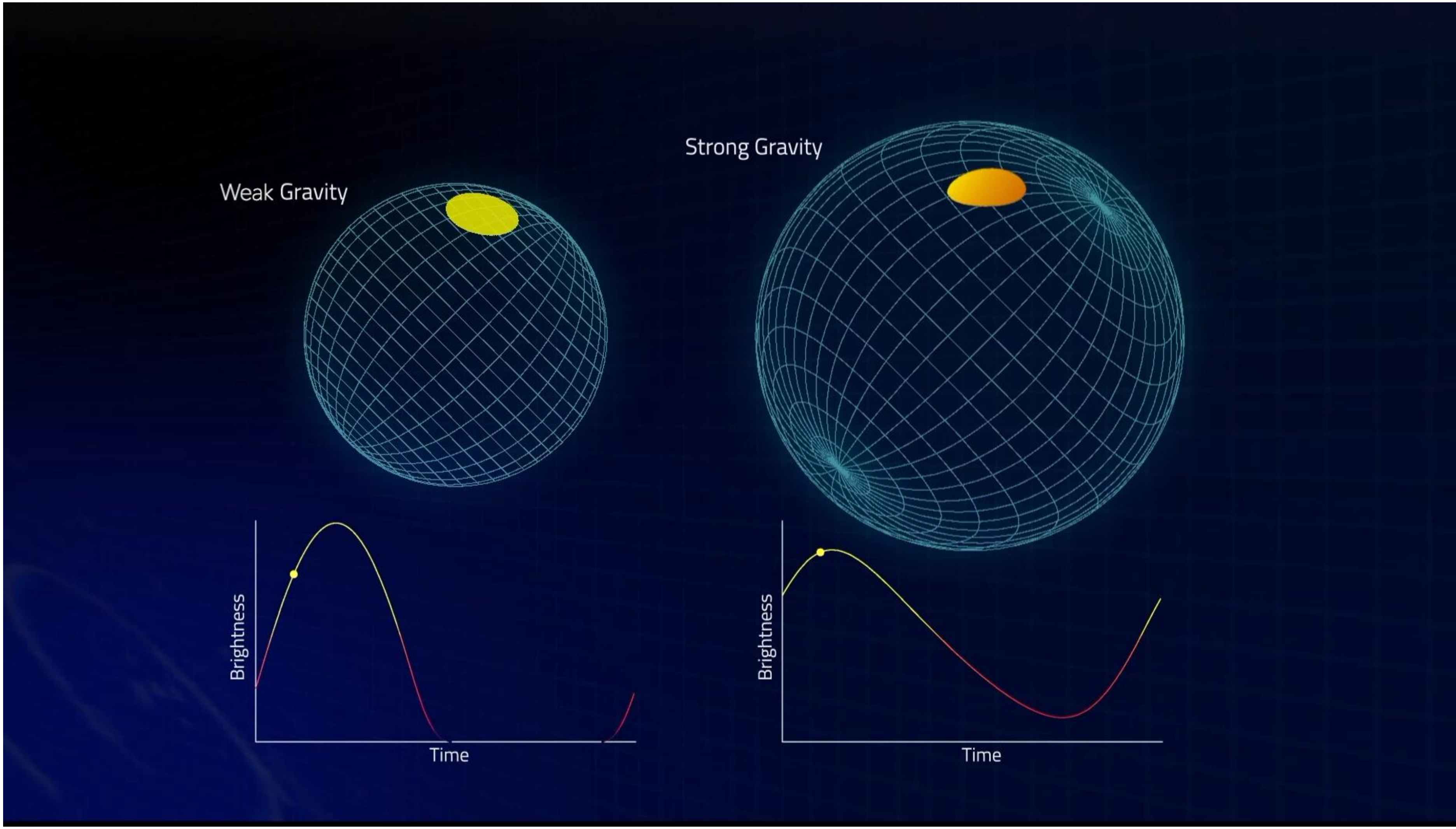
Adam Mann



Powerful magnetic and electric fields whip charged particles around, in a computer simulation of a spinning neutron star. Credit: NASA's Goddard Space Flight Center

How do you infer mass and radius?

Pulsation profiles are altered by gravitational light-bending

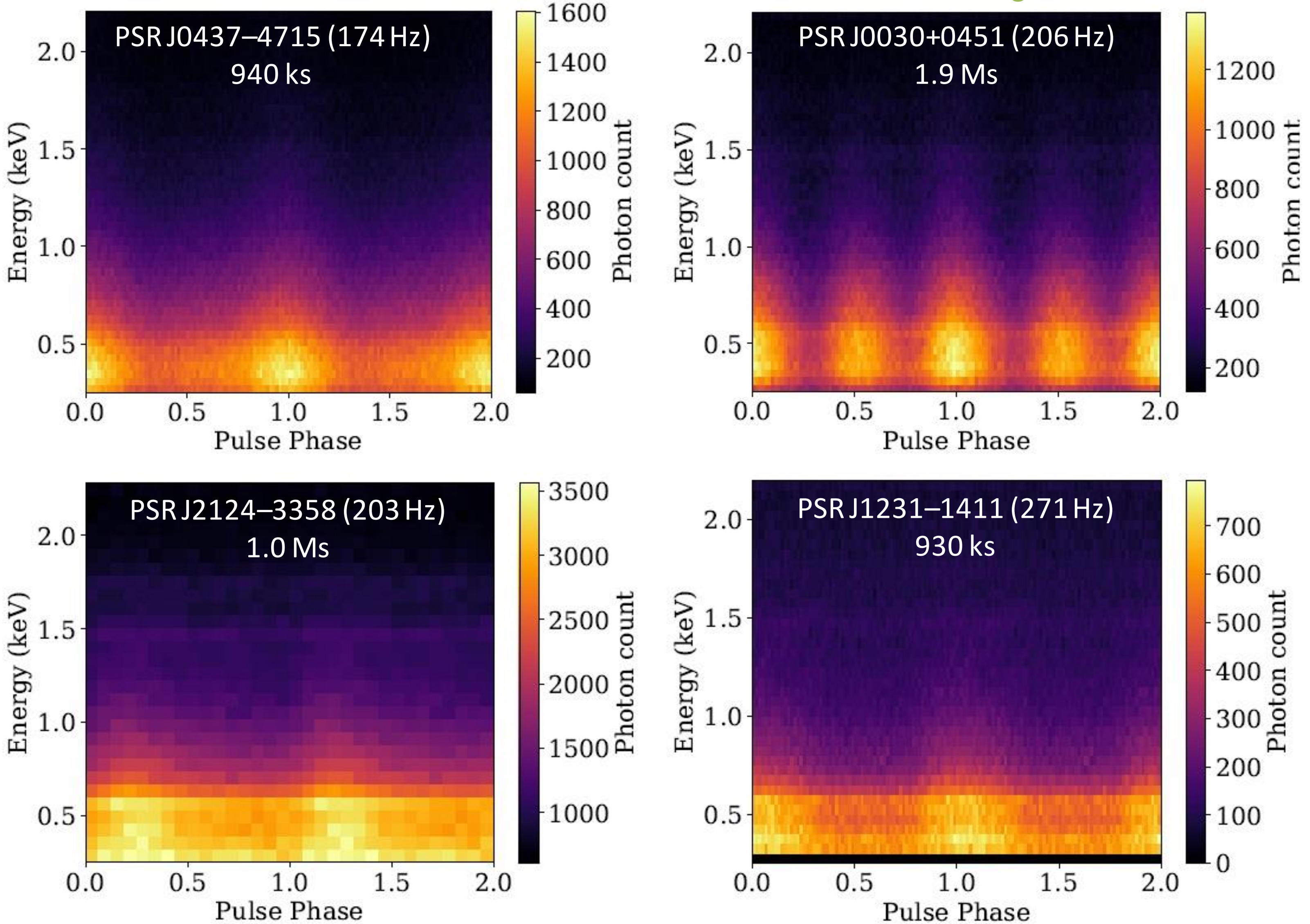


Credit: S. Morsink & NASA

Uniquely deep NICER pulse profiles

Additional pulsars to come...

Bogdanov et al. 2019



NICER sizes up its first neutron stars

PSR J0030+0451

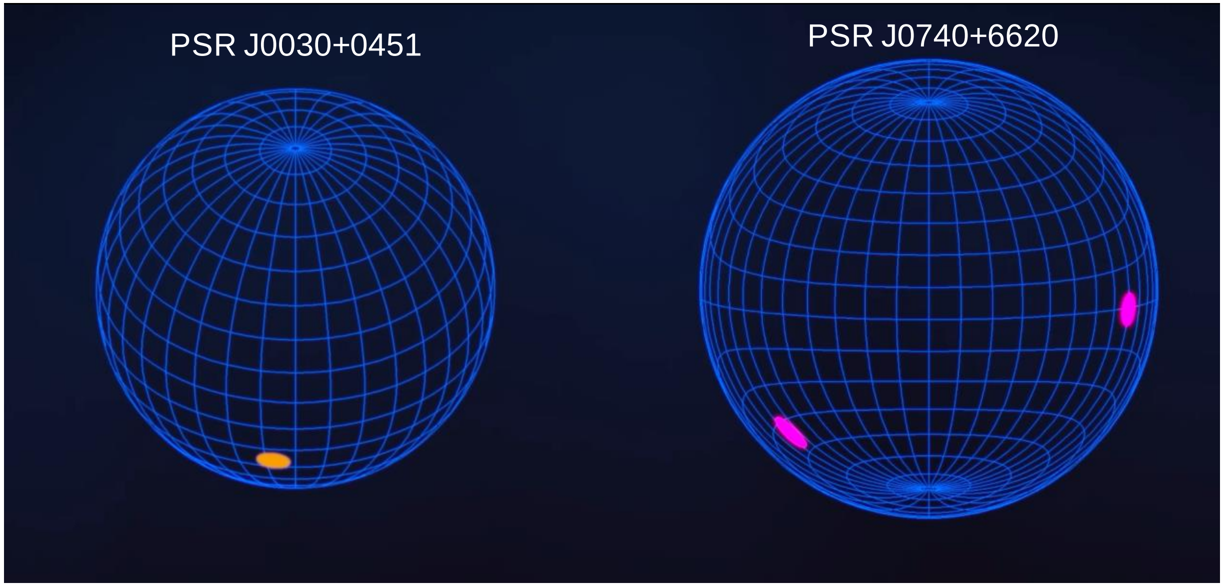
$M = 1.34 \pm 0.15\, M_{\odot}$ $R = 12.71 \pm 1.17$ km

- First precise mass *and* radius measurements for the same star ($\pm$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 pressure-density uncertainty by 30%

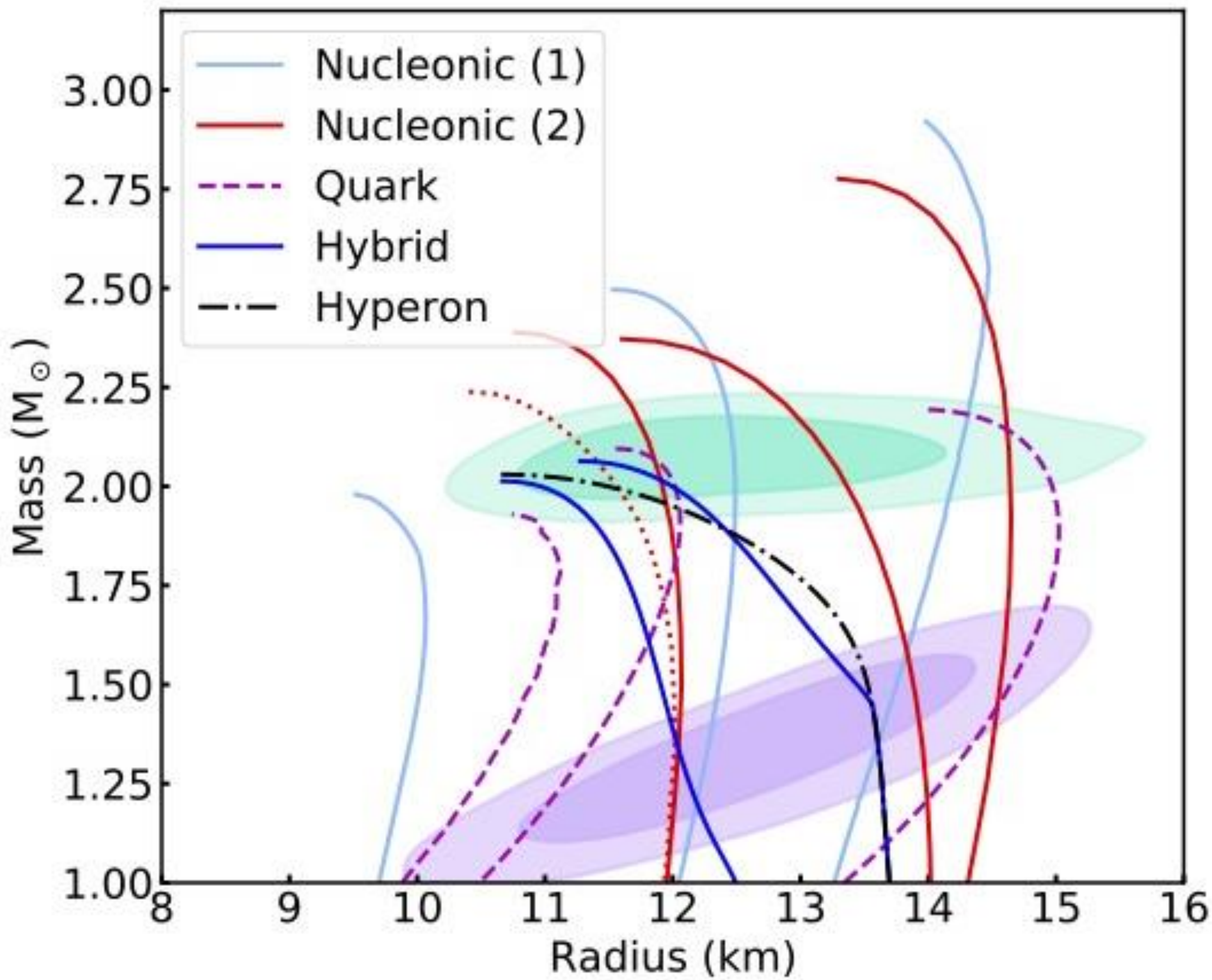
PSR J0740+6620

$M = 2.11 \pm 0.09\, M_{\odot}$ $R = 13.7^{+2.4}_{-1.5}$ km

- Most massive (reliably measured; radio timing) NS known
  - Existence alone begins to constrain EOS
- Hot spots in opposite hemispheres, more nearly dipolar
  - Data consistent with small, circular spots
- Radius surprisingly large, very similar to J0030+0451
  - Strong support for "stiff" equation of state!



Together, EOS constraints



68% and 95% uncertainty contours

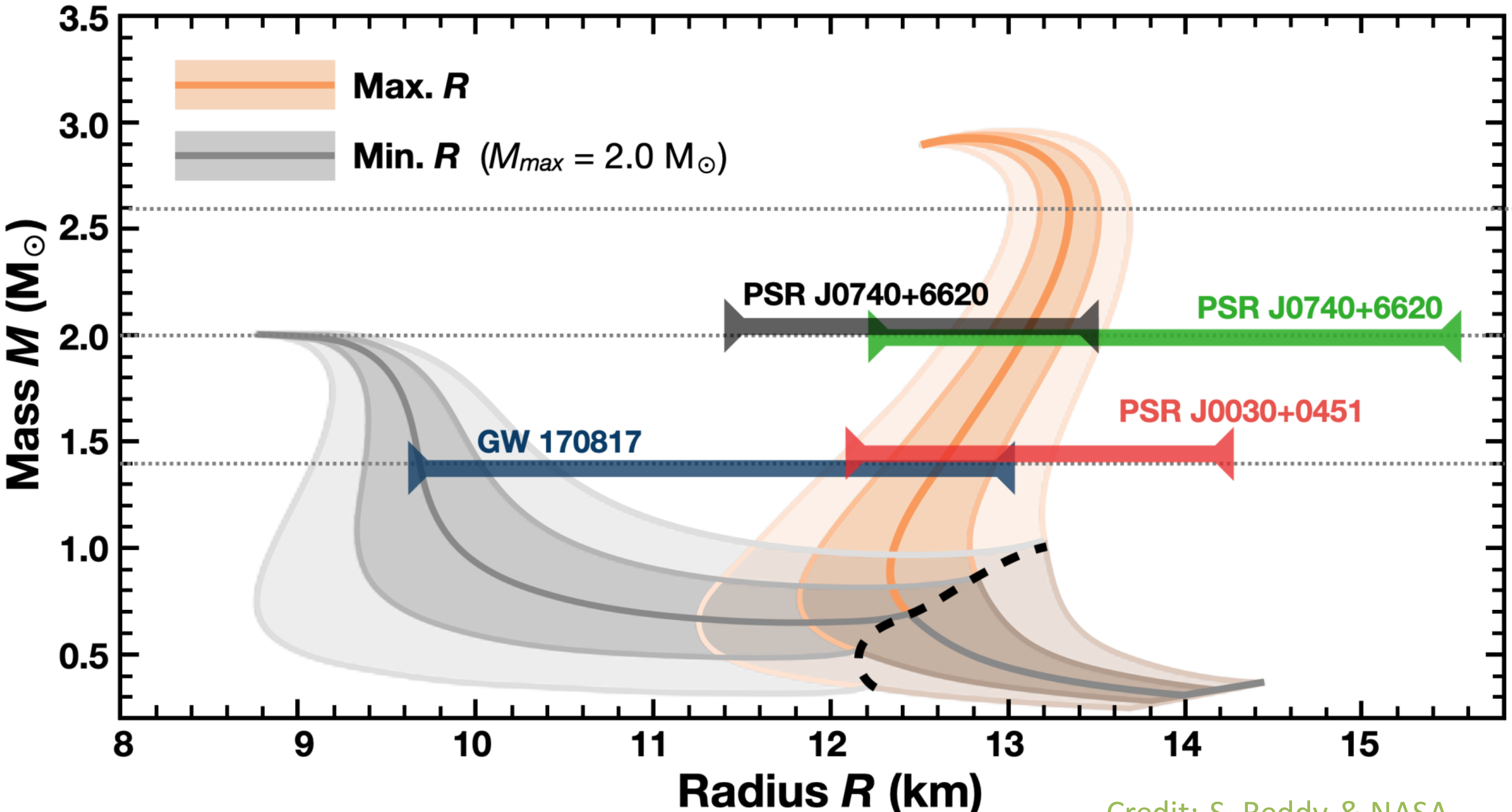
PSR J0740+6620

PSR J0030+0451

Credit: A. Watts & NASA

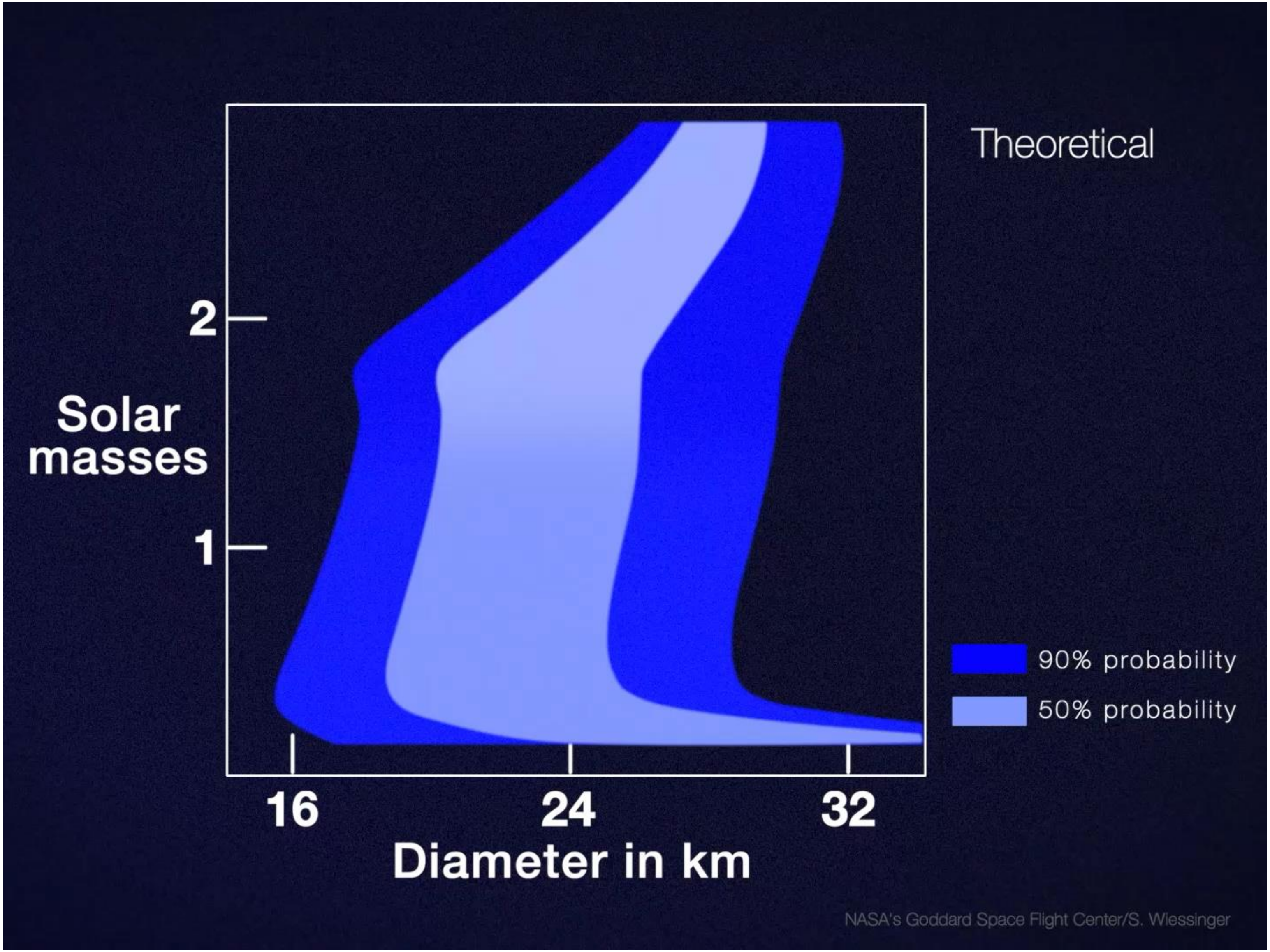
Evidence for a stiff dense-matter EOS

When combined, M-R for the two pulsars rule out "soft" and exotic models for dense matter.



Credit: S. Reddy & NASA

Inferred NS mass-radius relationship



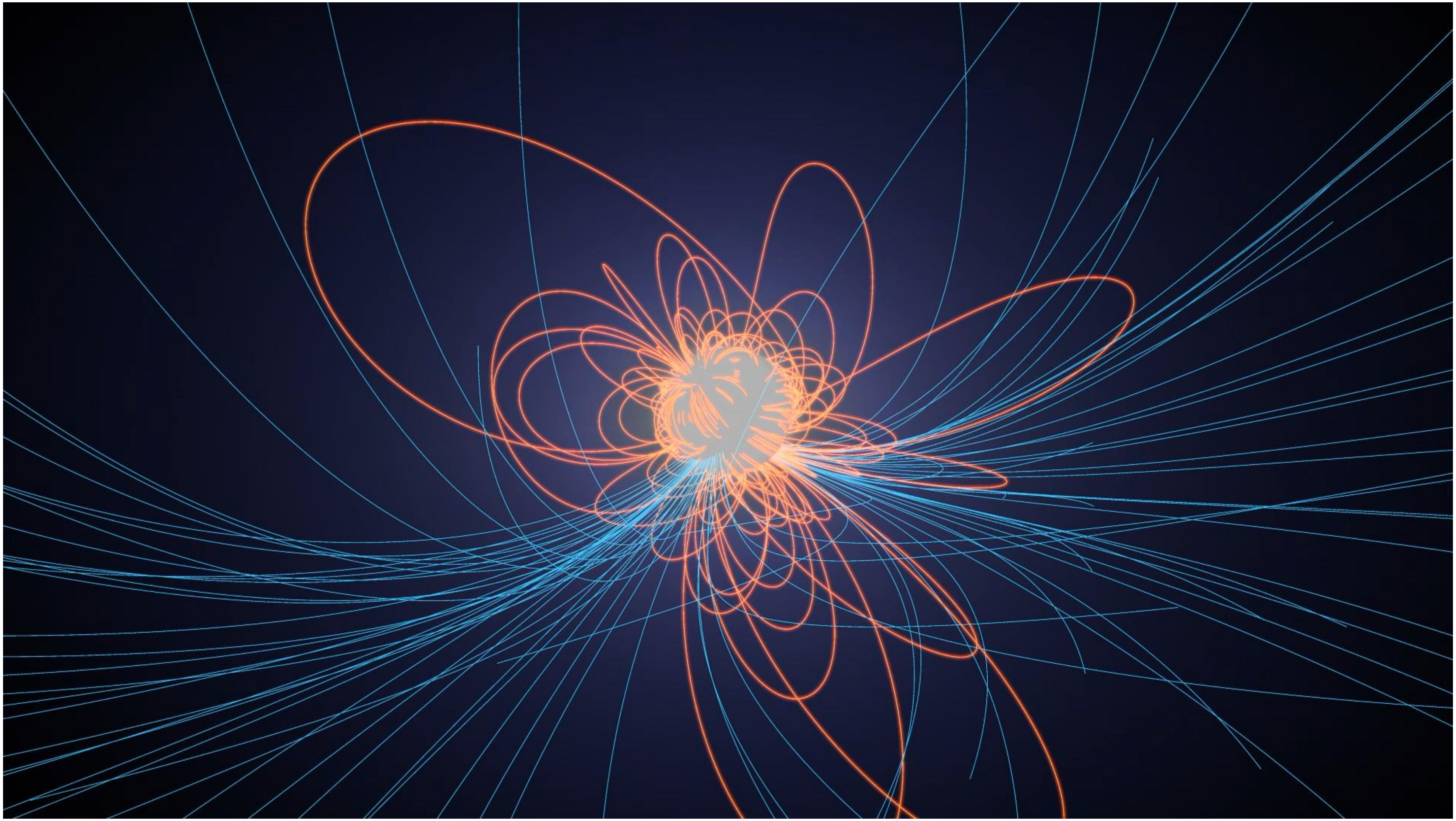
Credit: C. Miller & NASA

The best is yet to come!

- New M-R constraints, at the 2–10% level, for *at least 4 new sources*
- Steady reduction in statistical M-R uncertainties, confirmed to scale with number of photons — as NICER continues to accumulate data, anticipate tighter M-R bounds and EOS constraints
- Further tightening of constraints through higher-fidelity background models and instrument calibration.
  - Generous allowance is already made in existing M-R inference for limitations in background and instrument-response knowledge, so published results will improve as this knowledge is refined.
  - Background models are improving steadily, and with an extended mission we have time to fully constrain "interloper" sources in the pulsar fields. Recent reanalysis of the PSR J0740+6620 dataset using new background models and limits is extremely promising, but additional exposure is needed.
  - Improved characterization of the instrument response, with observations of soft calibration sources, is also improving our M-R models.
- Exploration of extended physical models & testing predictions: exotic B-field configurations (e.g., "quadrudipolar"), He atmospheres, magnetized atmospheres, even alternatives to GR…

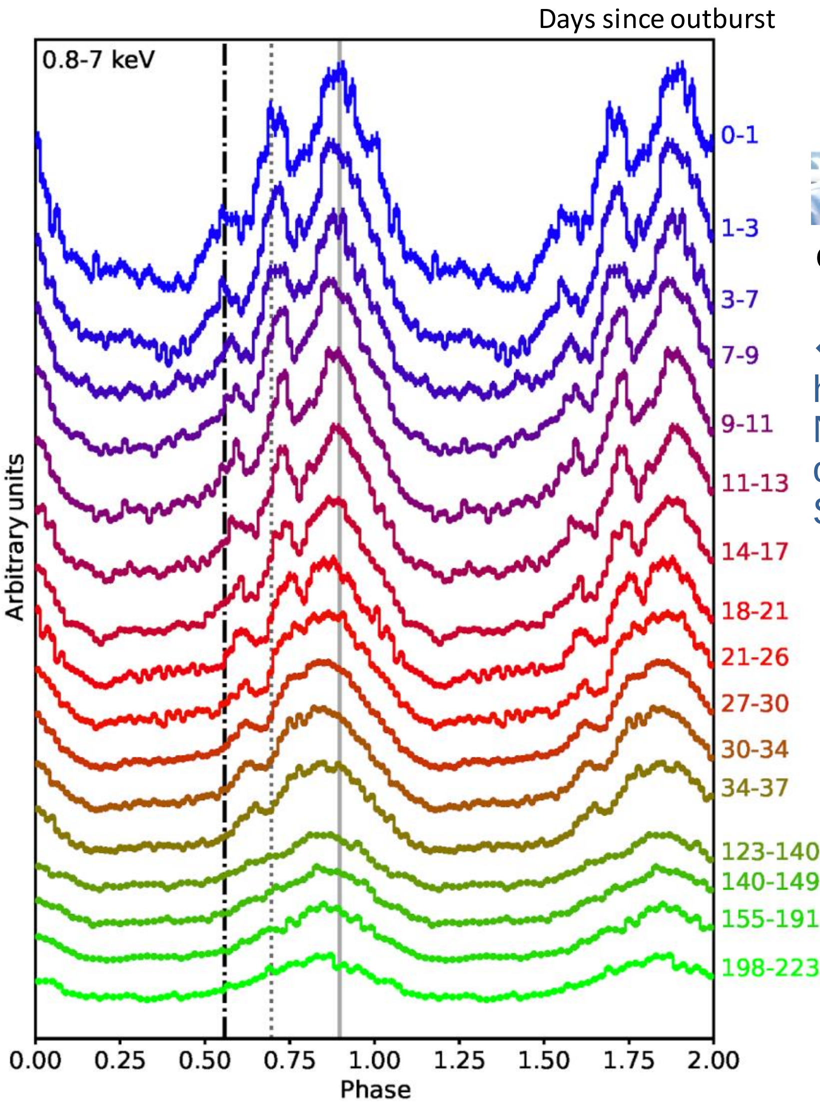
Redrawing ”textbook” pulsar magnetic fields

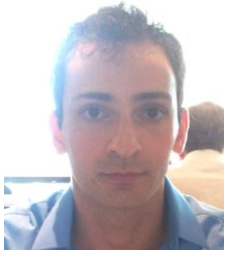
More complex than a simple dipole!



Novel probes of magnetars & extreme magnetospheres

…with implications for the origin of fast radio bursts (FRBs)





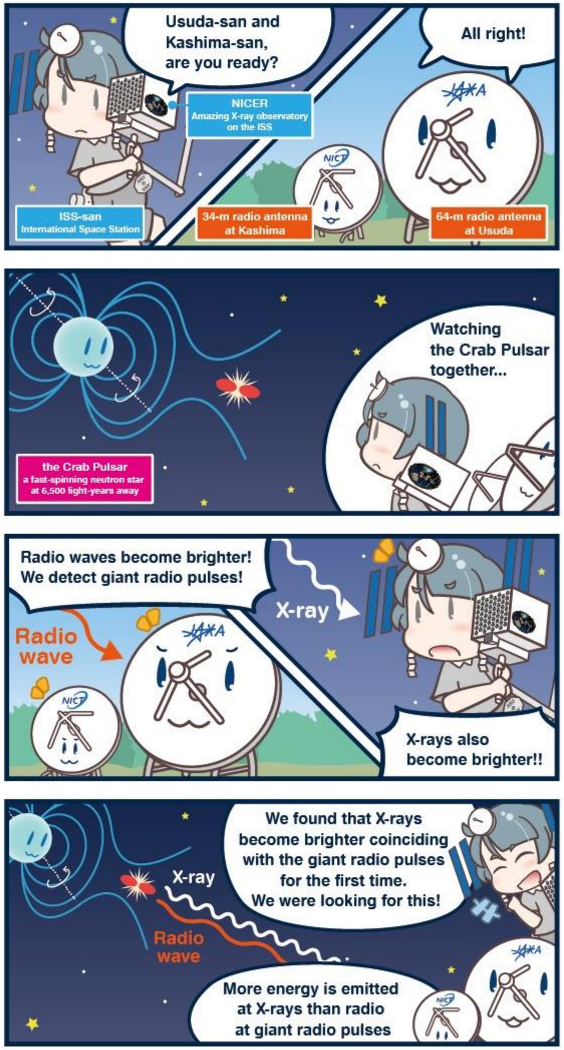
George Younes (NASA/GWU)

← First detailed view of hot-spot evolution on a NS surface, during outburst of magnetar SGR 1830–06

Discovery of X-ray enhancement during giant radio pulses from Crab pulsar →

Teruaki Enoto (Riken)

NICER on the ISS, Usuda, and Kashima antennas are watching the Crab Pulsar



A Pulsation Discovery Machine

A new accreting MSP in an ultracompact binary

NICER detection of 376 Hz X-ray pulsations from IGR J17494-3030

ATel #14124; *M. Ng (MIT), P. S. Ray (NRL), T. E. Strohmayer (NASA/GSFC), P. M. Bult (NASA/GSFC), D. Chakrabarty (MIT), D. Altamirano (Southampton), G. K. Jaisawal (DTU Space), C. Malacaria (NASA-MSFC/USRA), S. Bogdanov (Columbia), K. C. Gendreau (NASA/GSFC), Z. Arzoumanian (NASA/GSFC), on behalf of the NICER team*
on 27 Oct 2020; 23:42 UT
Credential Certification: Deepto Chakrabarty (deepto@space.mit.edu)

Subjects: X-ray, Neutron Star, Transient, Pulsar

Tweet

In response to the recent report of renewed activity from the faint X-ray transient IGR J17494-3030 in INTEGRAL data (ATel #14119), NICER began monitoring observations of this source. We collected 4.1 ks of data between 2020 October 27 00:38 and 17:51 UTC, finding that the source is detected with an initial 1-10 keV count rate of about 16 c/s (including a background of < 1 c/s), with a slow decline to about 14 c/s.

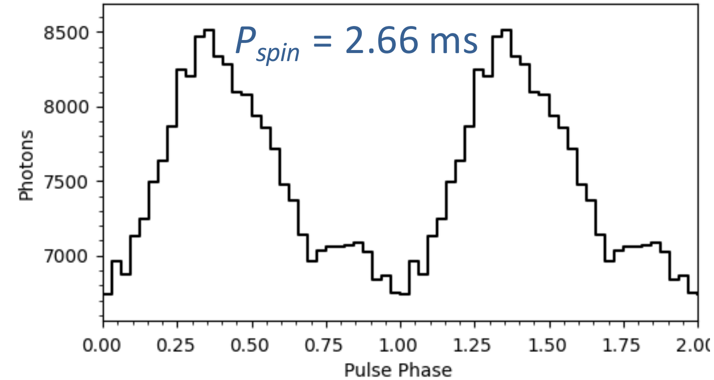
We detect highly significant coherent pulsations with a barycentric frequency of 376.05 Hz (2.66 ms period). The pulse frequency is modulated by a circular orbit having a period of 4509 s (75 minutes), and a projected semi-major axis of 0.0164 lt-s. Hence, this system is an ultracompact binary accreting millisecond X-ray pulsar with a minimum companion mass of 0.015 Msun. We find that the pulse profile has a 10% fractional sinusoidal amplitude in the 1-10 keV energy range, with a 2% second harmonic.

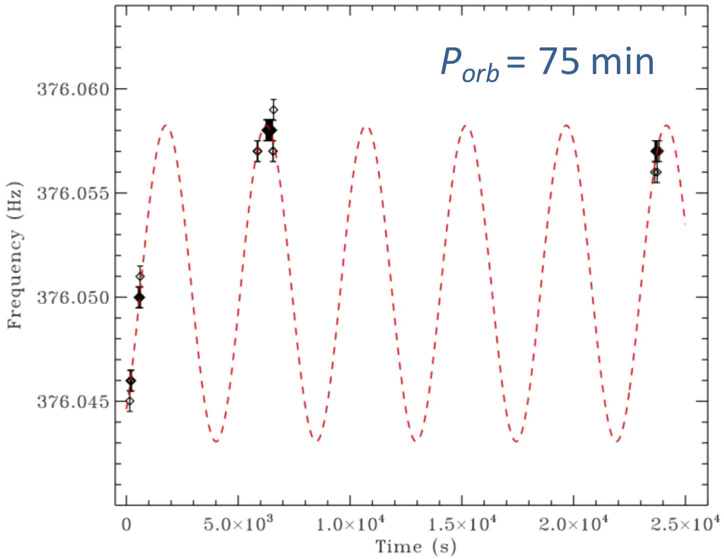
We extracted the energy spectrum in the 0.5-10 keV range, finding that the continuum emission is well described by an absorbed power-law model. A preliminary fit provides a photon index of 1.84+/-0.04 and an absorption column density of (2.05+/-0.05)x10^{22} cm^{-2}. The 0.5-10 keV unabsorbed flux is 1.68x10^{-10} erg cm^{-2} s^{-1}.

The NICER team is continuing the monitoring and analysis of this source.

NICER is a 0.2-12 keV X-ray telescope operating on the International Space Station. The NICER mission and portions of the NICER science team activities are funded by NASA.

Mason Ng
(MIT)





Enabling searches for GW emission from rapidly rotating pulsars

…from rotation-powered and accreting NSs

Wynn Ho
(Haverford)

arXiv > astro-ph > arXiv:2012.12926

Search...
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Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 23 Dec 2020 (v1), last revised 10 Jun 2021 (this version, v2)]

Diving below the spin-down limit: Constraints on gravitational waves from the energetic young pulsar PSR J0537-6910

The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: R. Abbott, T. D. Abbott, S. Abraham, F.

[Submitted on 29 Apr 2021 (v1), last revised 7 Jan 2022 (this version, v2)]

Constraints from LIGO O3 data on gravitational-wave emission due to r-modes in the glitching pulsar PSR J0537-6910

The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: R. Abbott, T. D. Abbott, S. Abraham, F.

[Submitted on 20 Sep 2021 (v1), last revised 21 Jan 2022 (this version, v2)]

Search for continuous gravitational waves from 20 accreting millisecond X-ray pulsars in O3 LIGO data

The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: R. Abbott, T. D. Abbott, F. Acernese, K.

[Submitted on 25 Nov 2021]

Searches for Gravitational Waves from Known Pulsars at Two Harmonics in the Second and Third LIGO-Virgo Observing Runs

The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: R. Abbott, H. Abe, F. Acernese, K. Ackley,

[Submitted on 21 Dec 2021]

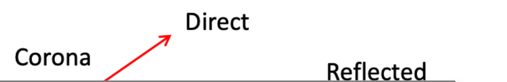
Narrowband searches for continuous and long-duration transient gravitational waves from known pulsars in the LIGO-Virgo third observing run

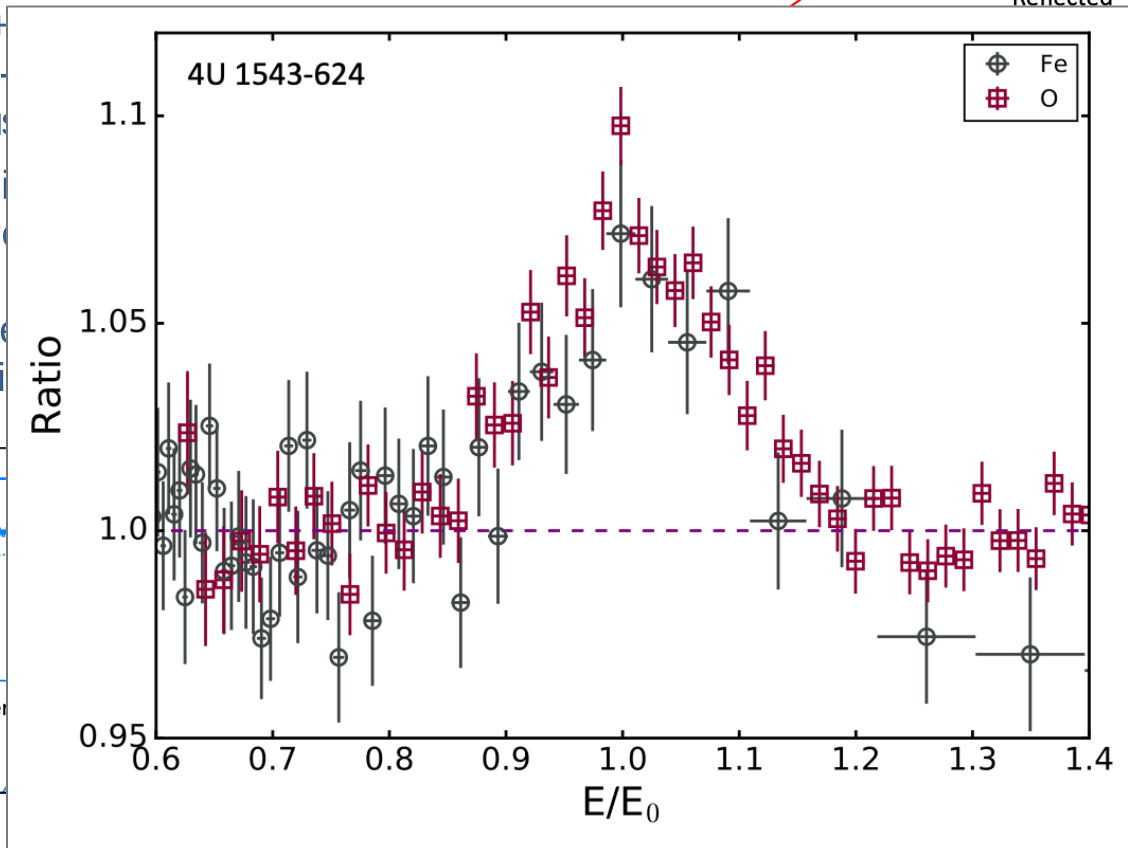
The LIGO Scientific Collaboration, the Virgo Collaboration, the KAGRA Collaboration: R. Abbott, T. D. Abbott, F. Acernese, K.

Reflection spectroscopy

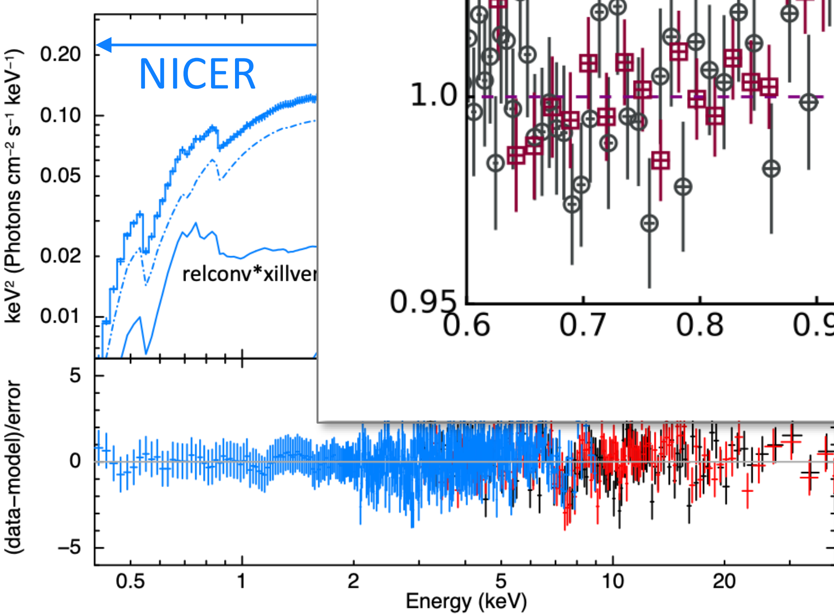
Constraining NS radii and accretion geometry

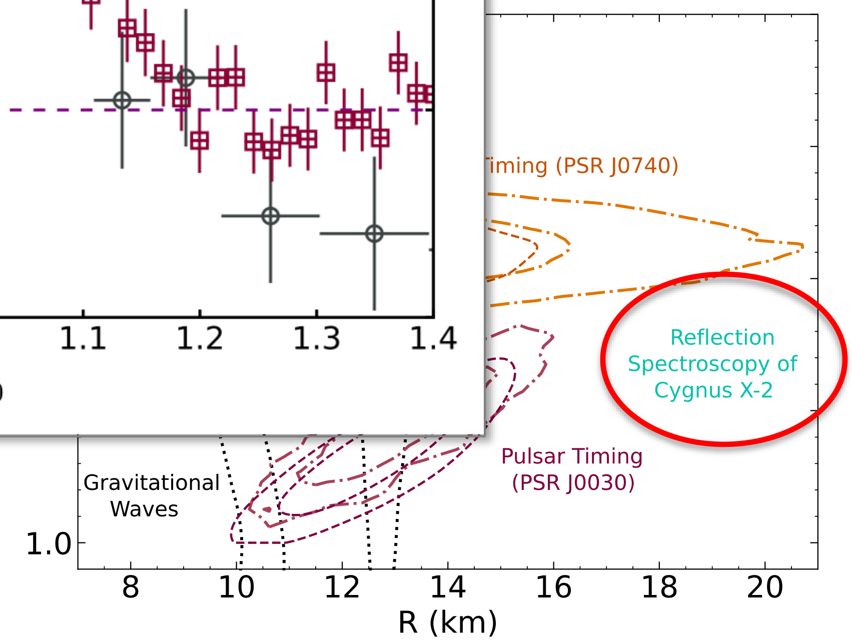
- In ultracompact systems (4U 1543–624, 4U 0614+ LMXBs (Ser X- disk radius mus
- Choice of conti models — incr and motivated band capabilitie radius constrai



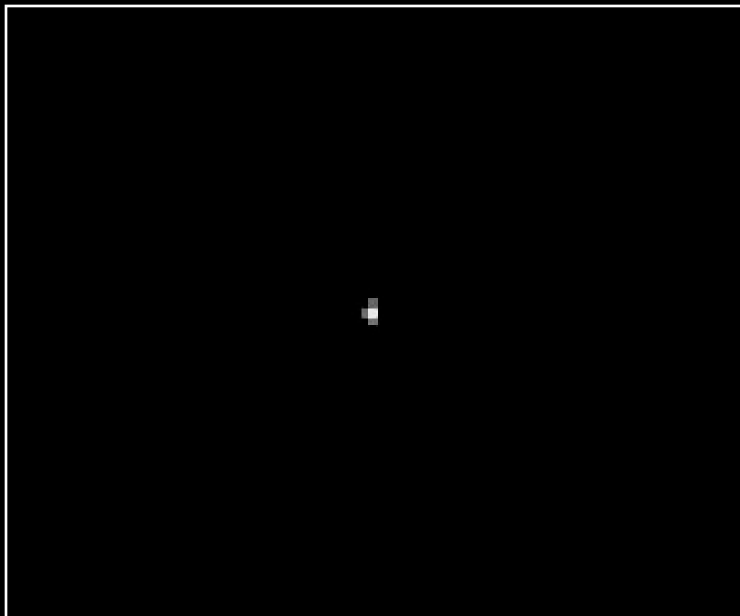


Renee Ludlam (Caltech)





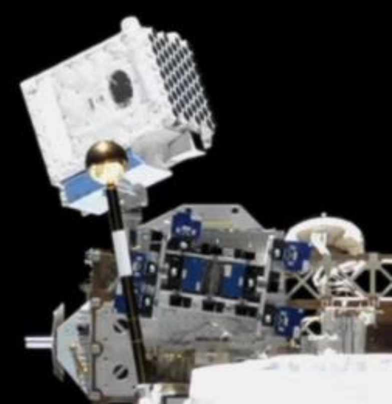
Goal of Reverberation Mapping



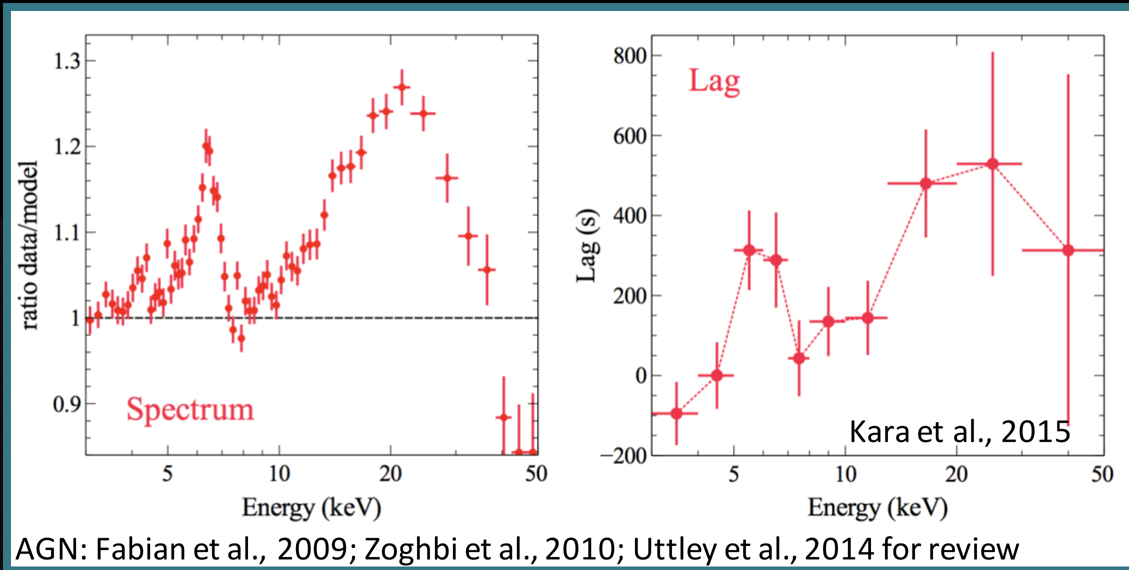
Actual Data

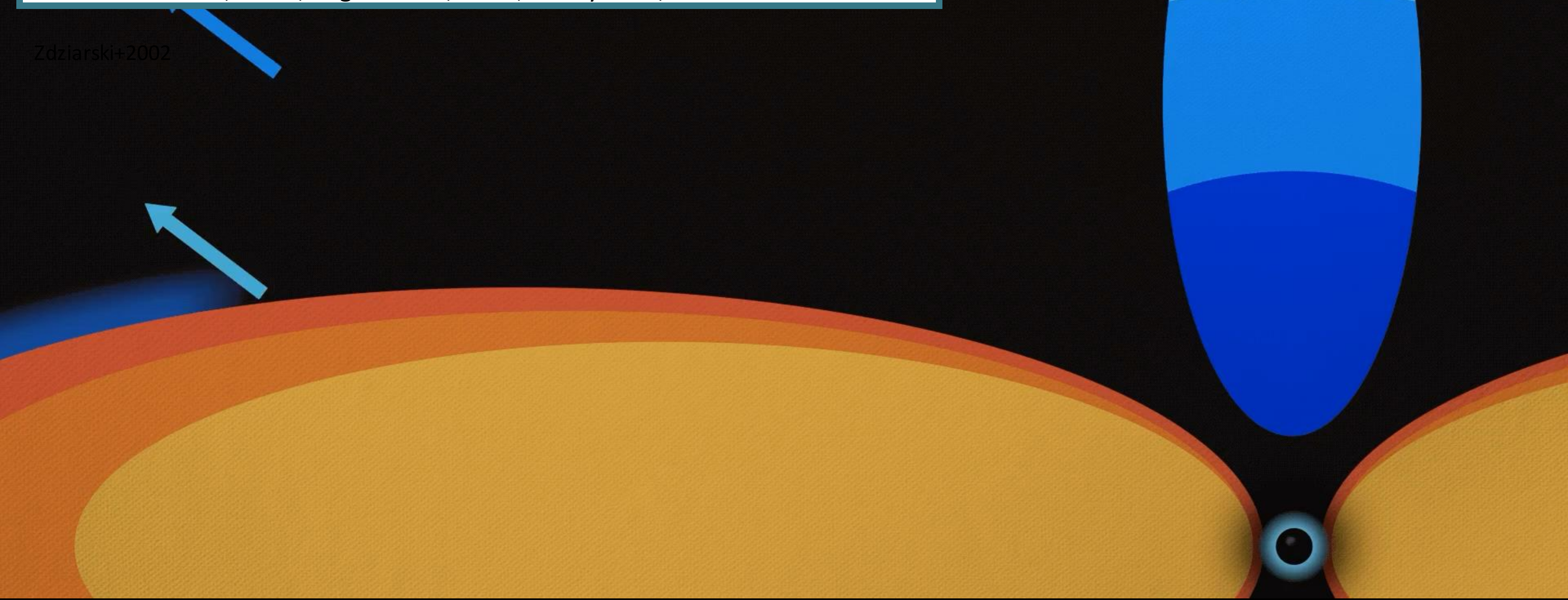
Black hole Gargantua
from *Interstellar*

**“Swap spatial resolution
for time resolution”**



Reverberation Mapping





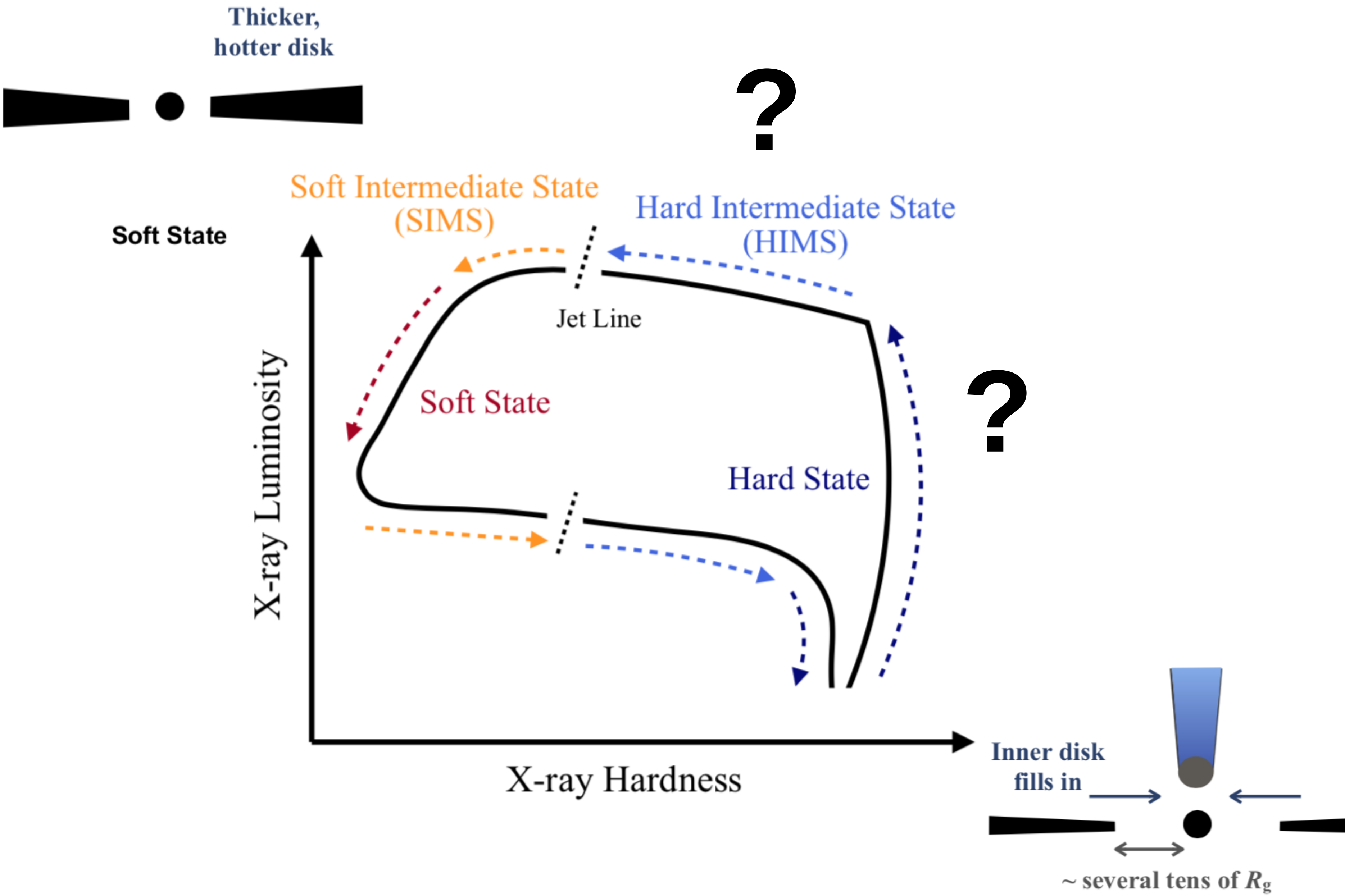
Take Home:
NICER is revolutionizing Reverberation Mapping across mass and accretion rate scale

Kara et al., 2019
(see 2019 Senior Review)

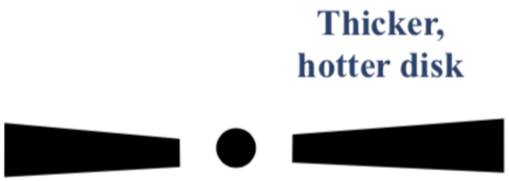
NEW

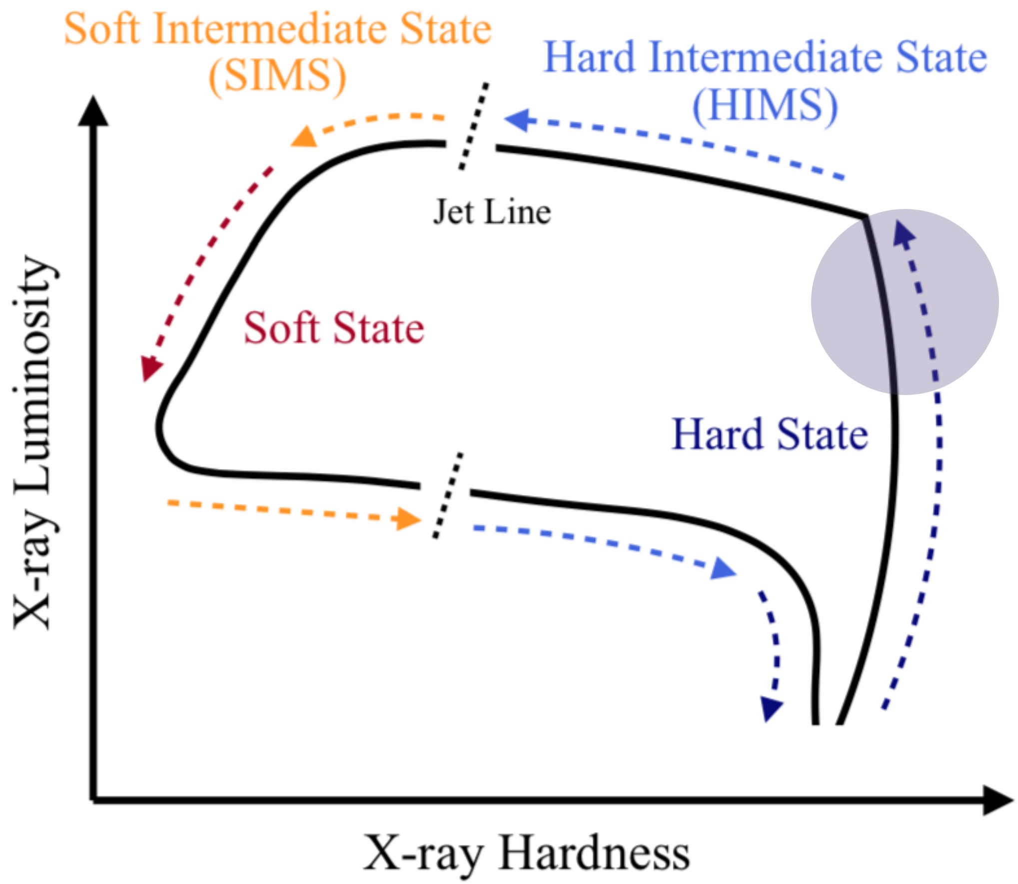
1) **Black hole X-ray Binaries:**
   From 2 to 11 sources
   (& over many accretion states!)

2) **AGN STORM 2 Reverberation Campaign**
   NICER & HST track accretion disk winds

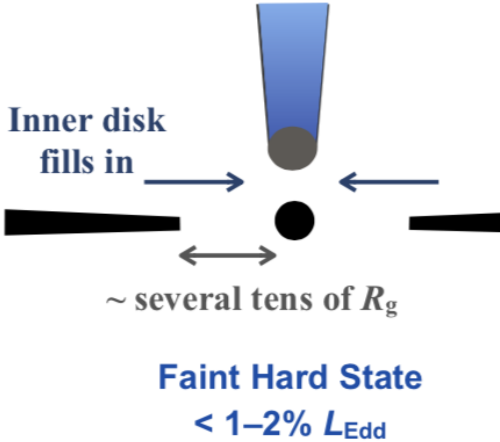


Black Hole Transients





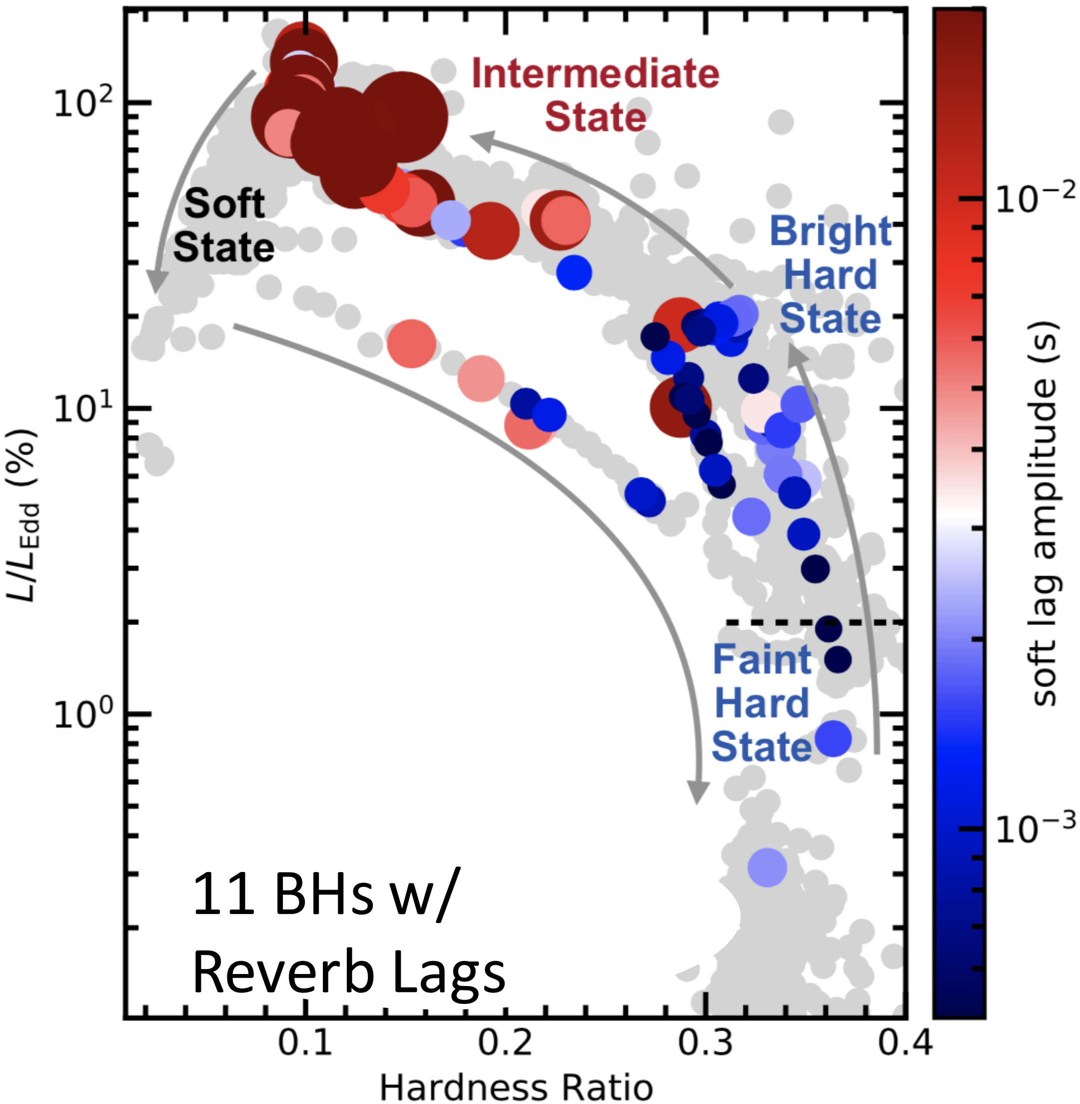
Kara+19

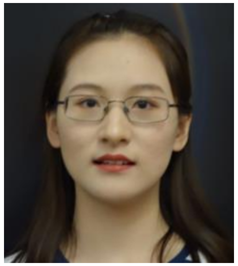


Black Hole Transients

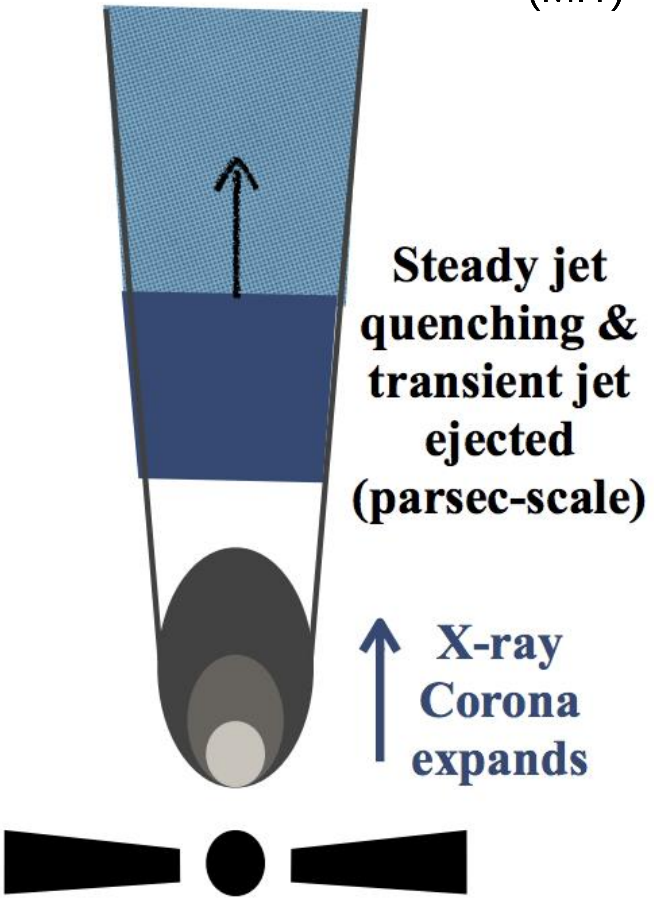
The NICER "Reverb Machine"

Wang, Kara et al., ApJ accepted

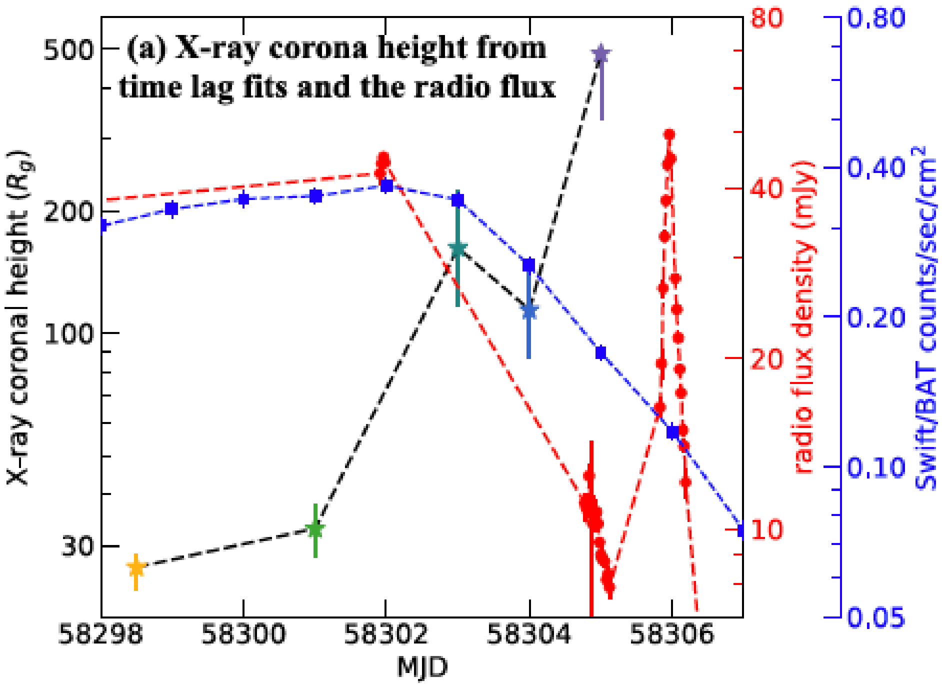




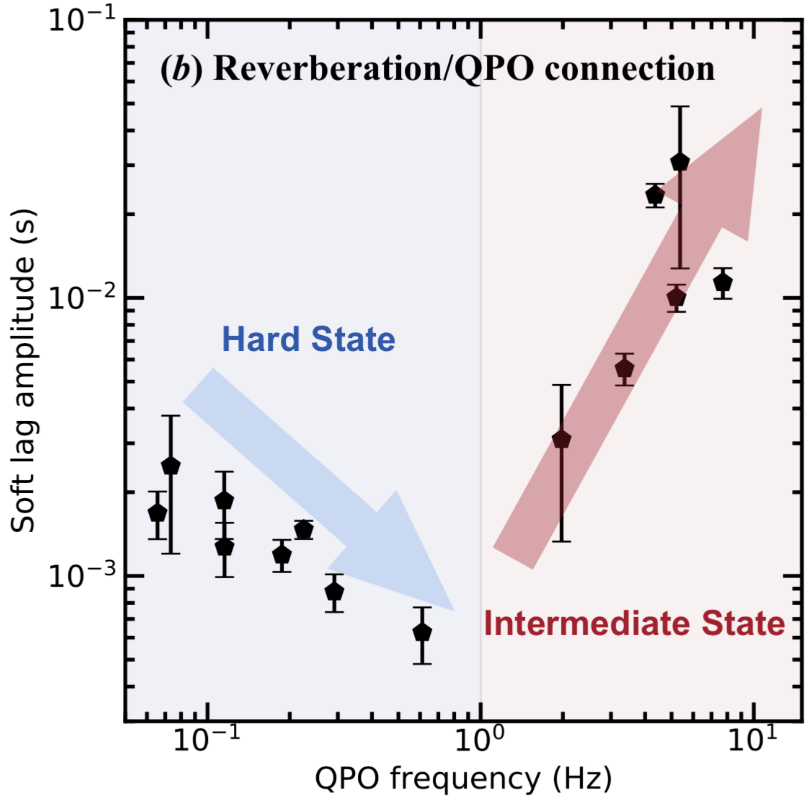
Jingyi Wang (MIT)



The Future



Wang+21



Wang+22

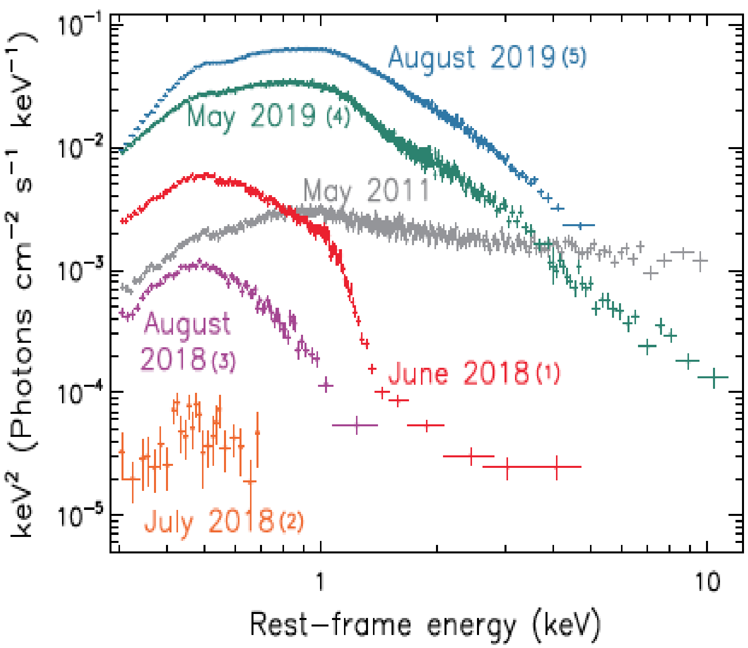
- **NICER should "reverberation map" 2–3 outbursts per year**
- **Next: Track disk-corona-jet connection with NICER-IR-Radio monitoring**
- **Next: Finally figure out what causes QPOs!**
- **Next: X-ray timing/spectral/polarimetry measurements of black-hole spin**

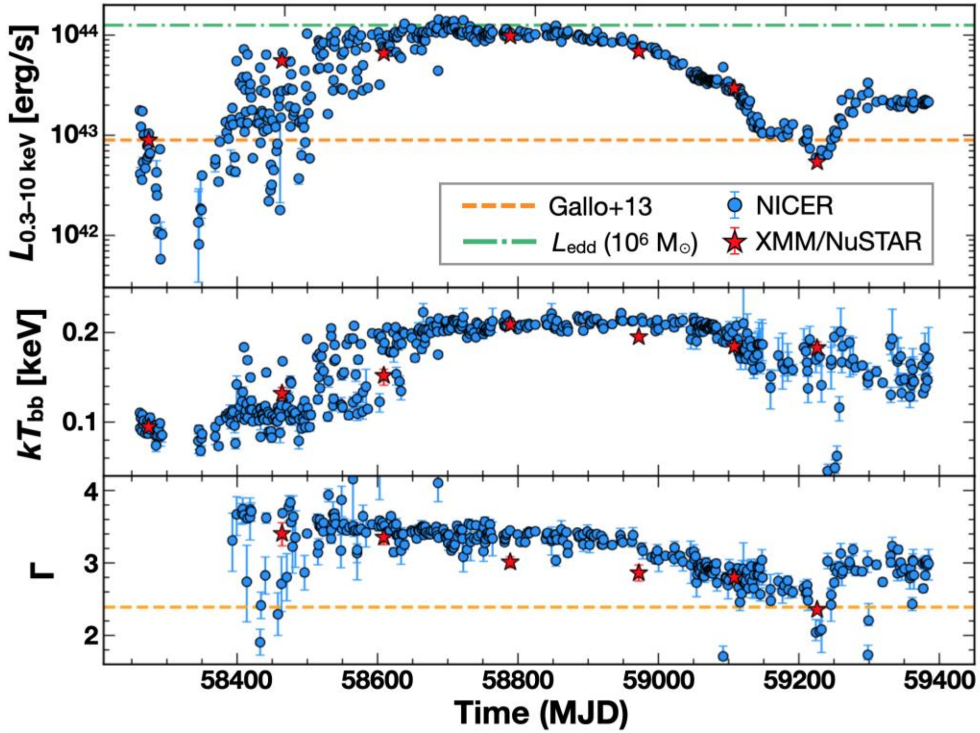
Extragalactic transients — Changing-look AGN 1ES 1927+654

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

- Drastic transformation of X-ray properties following optical/UV outburst
- Power-law component from corona disappeared, blackbody dominates instead; implies the corona was destroyed
- Dense NICER monitoring for 1,400+ days — deep luminosity dip, then increase to pre-outburst level
- X-ray corona is recreated — power-law reappears & dominates after 300 days
- Interpretation: likely interaction between accretion flow and a tidally disrupted star.

Megan Masterson (MIT)



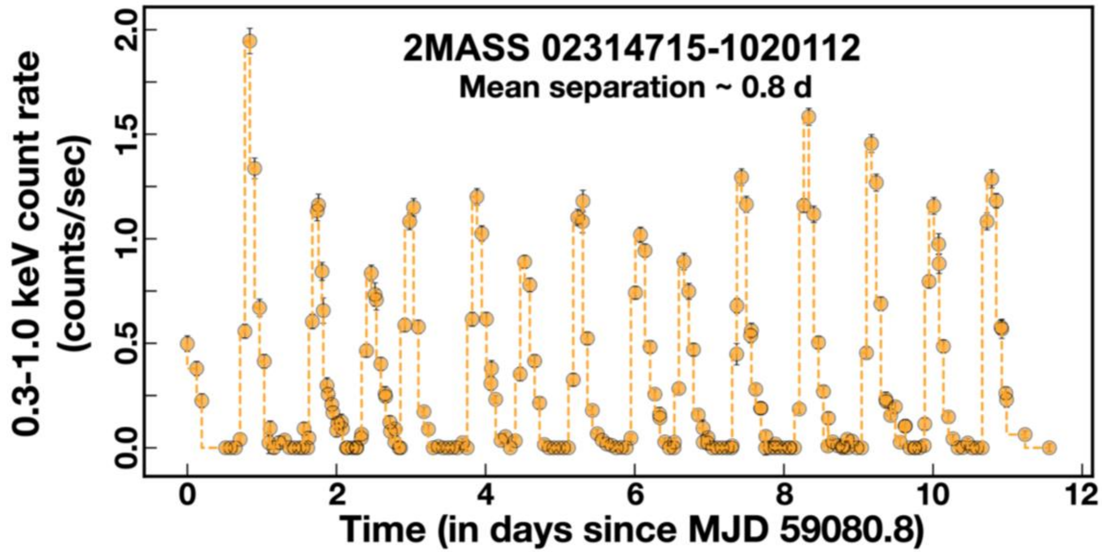


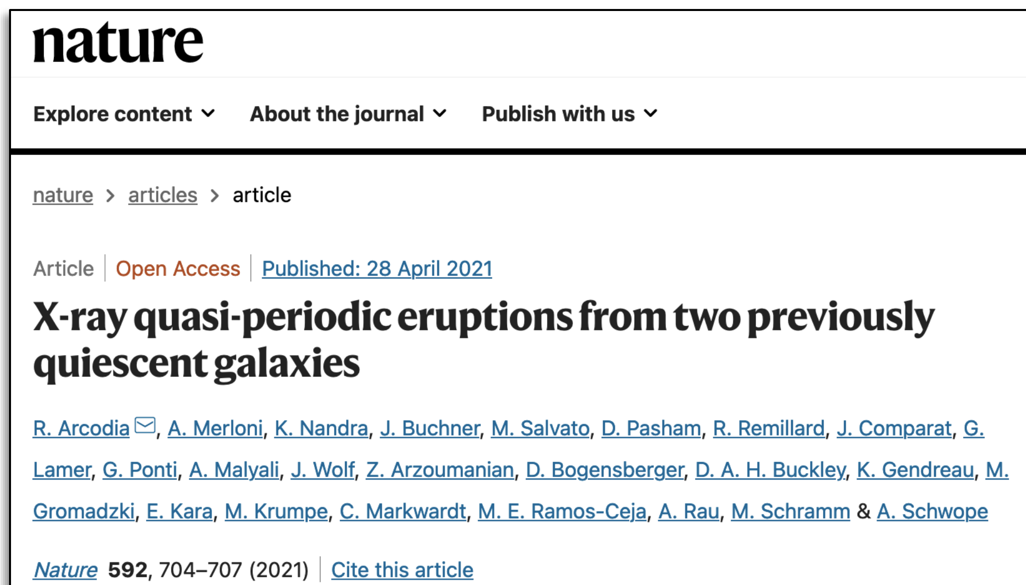
Ricci et al. 2020, ApJ 898, L1

Extragalactic transients — QPEs

Ricardo Arcodia
(Max Planck)

- NICER followup of eROSITA X-ray transient results in discovery of quasi-periodic eruptions in an otherwise quiescent galaxy
- Leading explanation is EM counterpart to extreme mass-ratio inspiral (EMRI) event, of the type anticipated as GW source class for LISA.

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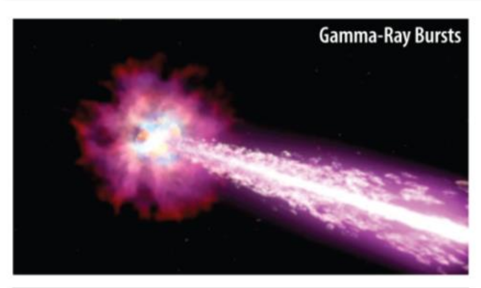
Article | Open Access | Published: 28 April 2021

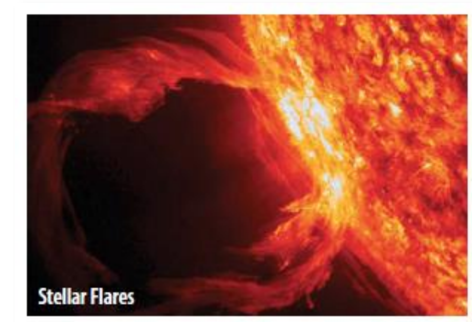
X-ray quasi-periodic eruptions from two previously quiescent galaxies

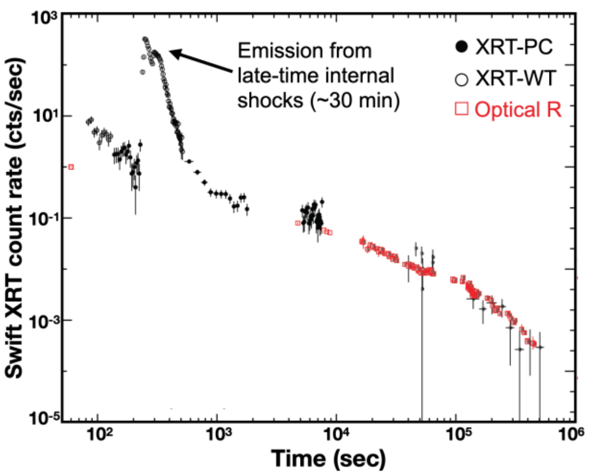
R. Arcodia, A. Merloni, K. Nandra, J. Buchner, M. Salvato, D. Pasham, R. Remillard, J. Comparat, G. Lamer, G. Ponti, A. Malyali, J. Wolf, Z. Arzoumanian, D. Bogensberger, D. A. H. Buckley, K. Gendreau, M. Gromadzki, E. Kara, M. Krumpe, C. Markwardt, M. E. Ramos-Ceja, A. Rau, M. Schramm & A. Schwope

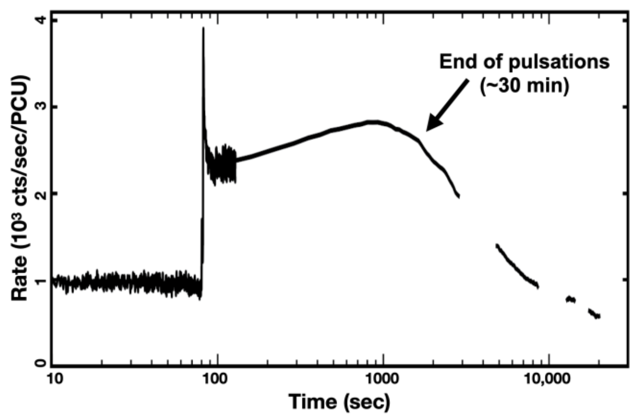
Nature **592**, 704–707 (2021) | Cite this article

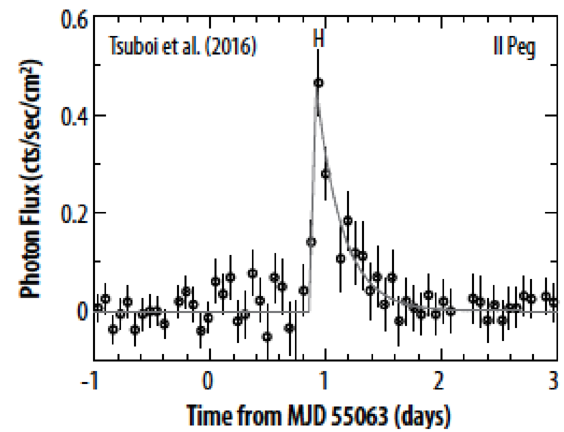
Sample OHMAN science investigations











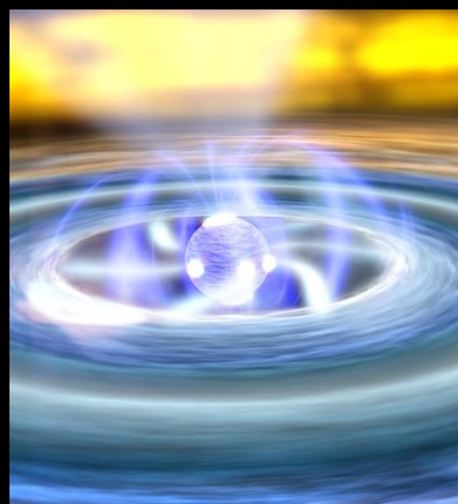
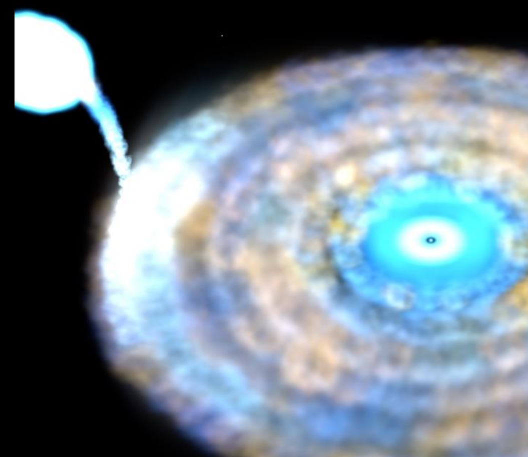
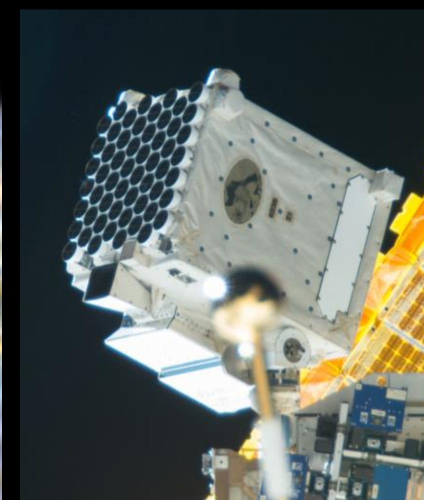
Putting unprecedented spectroscopic and timing capability (sensitivity, through-put) on prompt emission and shock re-brightening.
~ 1 trigger per month

For long-duration thermo-nuclear bursts, crucial early variability enables detection of pulsations and gravitationally redshifted absorption lines from burning ashes. ~ 2 per year

For stellar flares, a novel probe of heating due to magnetic reconnection.
~ 1 trigger per month

NICER: NASA's Neutron Star Interior Composition Explorer

NICER General Observer Facility Overview and Status

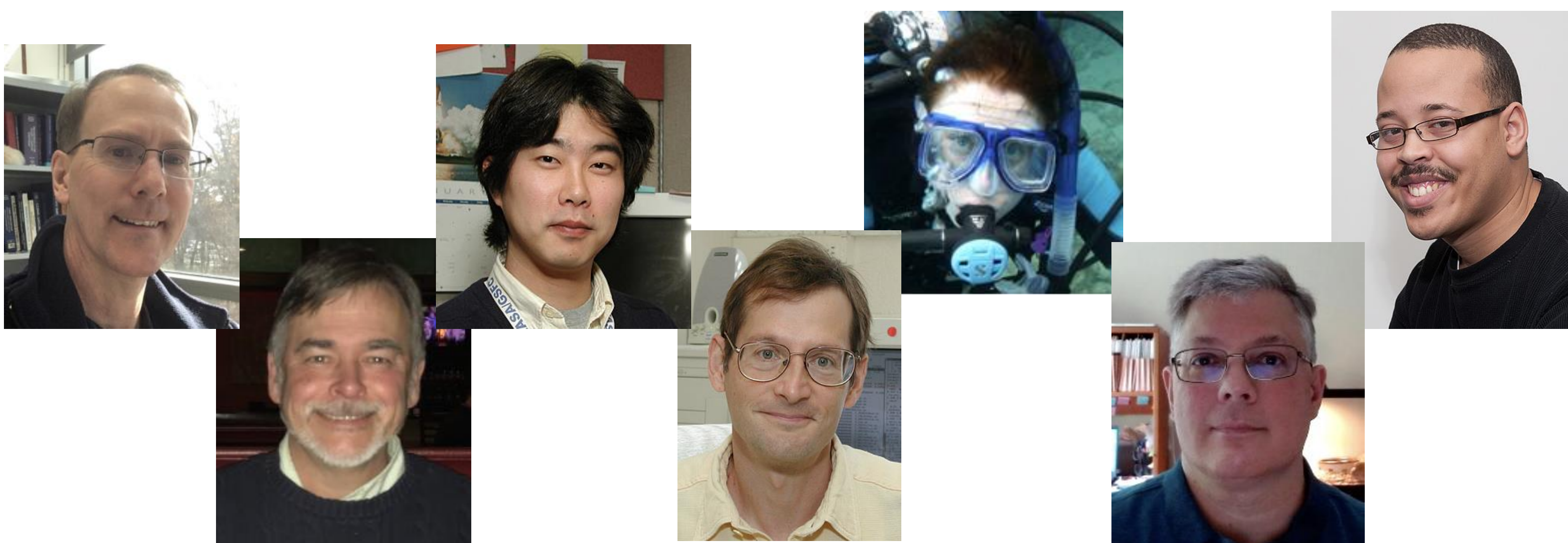





Elizabeth Ferrara
Lead Scientist
NICER Guest Observer Facility
Elizabeth.C.Ferrara@nasa.gov

NICER User's Group Meeting
June 20, 2022

NICER GOF Personnel & Responsibilities

- General Observer Facility (7 scientists)
  - Elizabeth Ferrara, GOF Lead Scientist, GO Program, Science Planning
  - Mike Corcoran, Archive Scientist, Software & Webpage
  - Mike Loewenstein, Data Analysis & Software
  - Kenji Hamaguchi, Data Analysis & Science Planning
  - Steve Sturner, Data Analysis
  - Tod Strohmayer, Data Analysis
  - Joel Coley, Science Support
- GOF meetings every 2 weeks, weekly during proposal/review season.
- Level of Effort for all GOF-specific tasks is ~2.25 FTE.



NICER Science Timeline Planning

- NICER Long-term plan is generated at the start of each GO cycle
  - Designed to meet the science needs of the non-TOO GO programs
  - Based on long-term ISS data products that lack many details that can affect visibilities
  - Implemented in a Google Calendar visible to the planning team

- NICER Planning Document
  - Google doc communicates on-going investigations (both GO and TOO/DDT) in 10-day increments by DOY
  - Used as input to the science command scheduling software

Keith Gendreau Zaven Arzoumanian

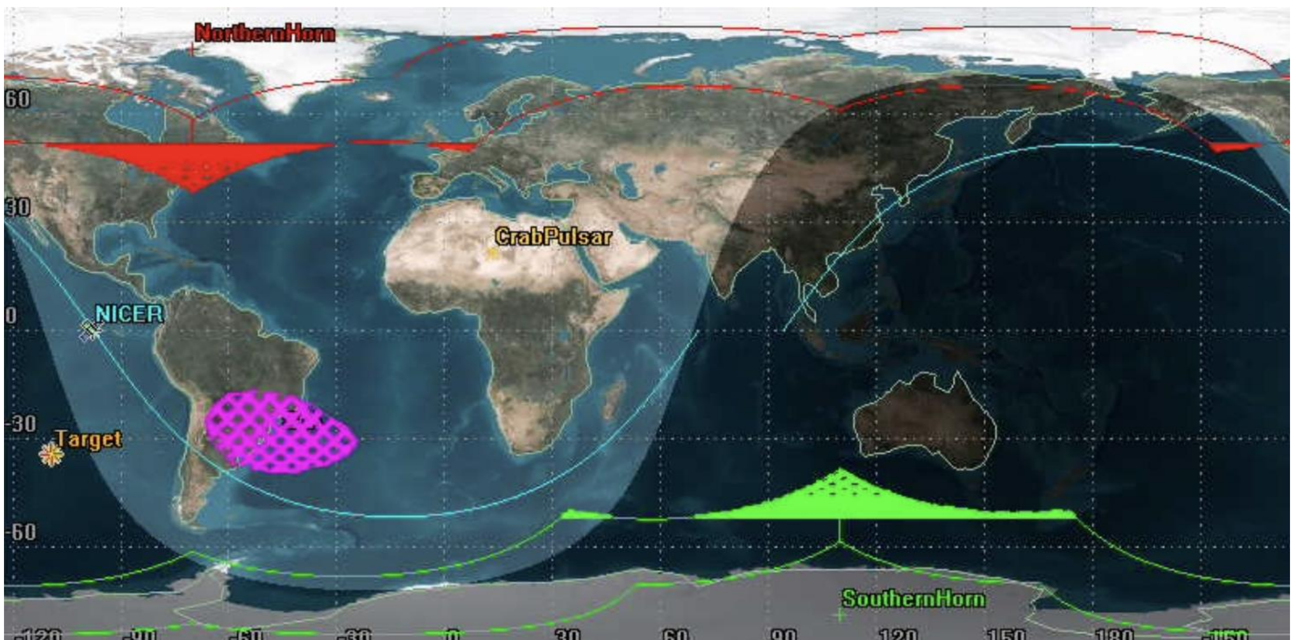
Kenji Hamaguchi

Elizabeth Ferrara

- NICER science plans are nominally generated on a biweekly schedule:
  - Plans usually extend ~10 days into the future
  - Time-sensitive requests cause frequent re-plans
  - Changes to the ISS products (crew arrivals/departures, launch slips, EVAs, etc.) also necessitate replans
  - 4-person planning team to ensure coverage

Background Estimation Software

- Currently two background models available to users:
  - 3C50 - empirical measurements (unaffected by target X-rays) at the time of observation.
    - Developed at MIT, implemented by Mike Loewenstein.
  - Environmental - uses concurrent space weather, orbital and target postions at the time of observation.
    - Developed by Keith Gendreau, implemented by Mike Corcoran



Keith Gendreau

Mike Loewenstein

Mike Corcoran

- Currently investigating atmospheric oxygen line possibly resulting from solar activity.
- Next steps: Add these estimation tools into the standard NICER analysis software

Publicly Available Tools


Mike Corcoran


Steve Sturner

- In addition to Data and Software, NICER's website also provides:
  - A **visualization tool** showing where the mission is in its orbit. This tool also models the ISS structures that may affect the current observation.
  - The **current observing schedule** which allows for unplanned coordination opportunities.
  - A **TOO table** containing all TOOs and their observing status.
  - An **enhanced visibility tool** that utilizes the most recent ISS predicts to provide the same fidelity used in our planning process.
  - **Analysis threads** - step-by-step details for hov common analysis tasks.
  - Recordings from last year's **Analysis workshop** - information about the instrument, software, and calibration, plus a detailed question-and-answer session with the participants.
  - The most current information regarding the **next GO cycle**.
  - Weekly "**Science Nuggets**" that provide high-level information about the current science being performed by the mission.


Elizabeth Ferrara


Kenji Hamaguchi

NICER Science Nuggets

Each week, the NICER team summarizes important scientific activities or results utilizing data from the NICER mission.

Here are past Science Nuggets listed in reverse chronological order. A list by topic is also available.

2022

- *May*
  - 05 May 2022: NICER Feeds a Reverberation Machine
- April
  - 28 April 2022: Assessing the stability of Nature's best clocks
  - 21 April 2022: An X-ray outburst from a radio-loud magnetar after 13 years of quiescence
  - 14 April 2022: NICER's Cosmic Calibration
  - 7 April 2022: NICER Confirms X-ray "Heartbeats" from IGR J17091-3642
- March
  - 31 March 2022: NICER engages in global supermassive black-hole campaign
  - 24 March 2022: Anticipating an X-ray heartbeat
  - 17 March 2022: The NICER Team Wins the Rossi Prize
  - 10 March 2022: Attentive to Accretion Echoes
  - 03 March 2022: An Exceptionally Deep Cyclotron Resonance in the X-ray Binary GRO J1750-27
- February
  - 17 February 2022: NICER Helps Solve a Hot Neutron Star Puzzle
  - 10 February 2022: Accreting on the edge: Witnessing accretion regime transitions on a magnetized neutron star
  - 03 February 2022: Using reflection to constrain the radius of a neutron star
- January
  - 27 January 2022: NICER homes in on a new MAXI source discovery
  - 20 January 2022: Last Gasp of an Unfortunate Star?
  - 13 January 2022: NICER Probes the Accretion Flow near a Black Hole
  - 06 January 2022: NICER Detects Neutral or Nearly Neutral Oxygen Line From Earth's Atmosphere

Science User Support & Outreach

- **Data Analysis Support**
  - Analysis thread creation, documentation, and maintenance
  - Analysis workshops
- **Direct User Support**
  - GOF members rotate helpdesk shifts via a current “hotseater”
  - User support mailing list maintenance and announcements
- **Outreach and Communications**
  - Conference staffing and other outreach activities (Hyperwall, etc.)
- **Other mission support as needed**
  - Includes Senior Review proposal development

Craig Markwardt

Mike Loewenstein

Mike Corcoran

Tod Strohmayer

Joel Coley

Steve Sturner

Kenji Hamaguchi

Keith Gendreau

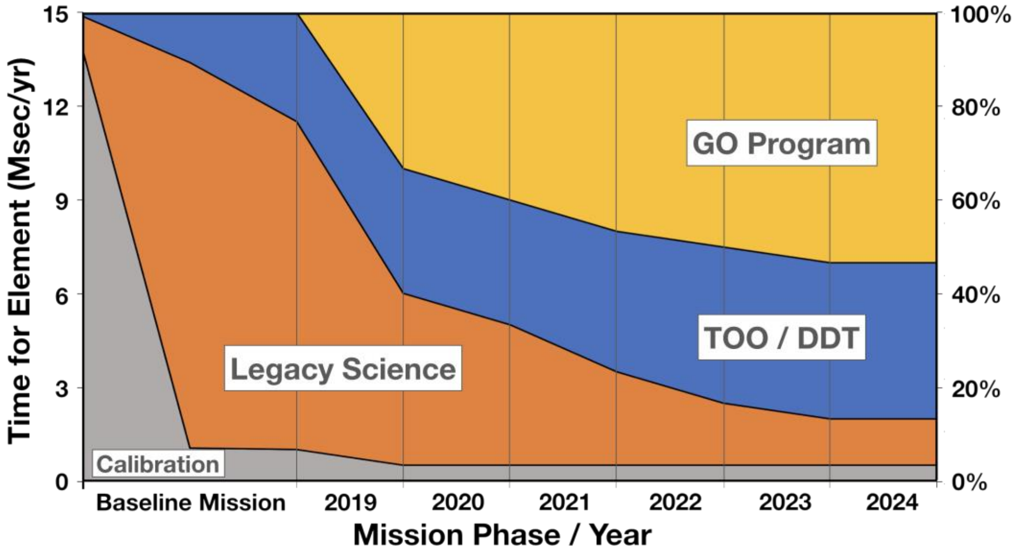
Zaven Arzoumanian

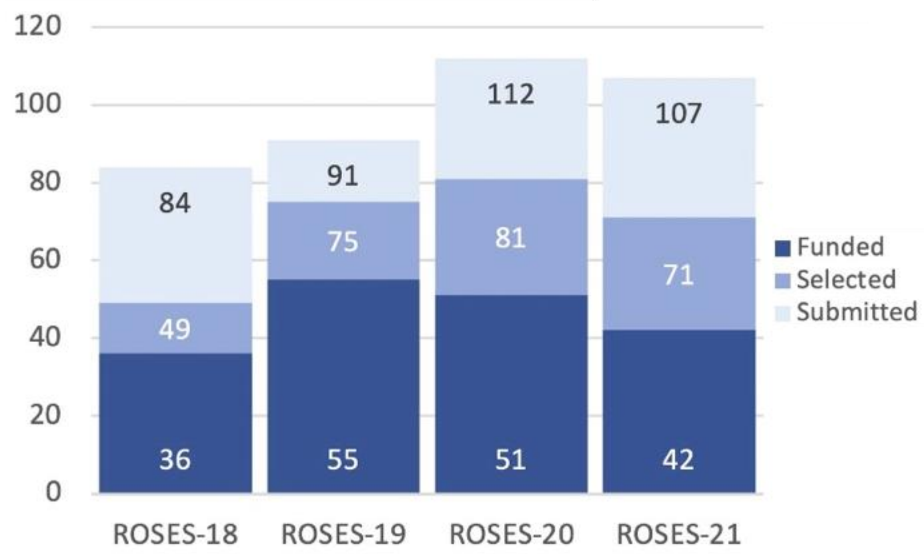
Elizabeth Ferrara

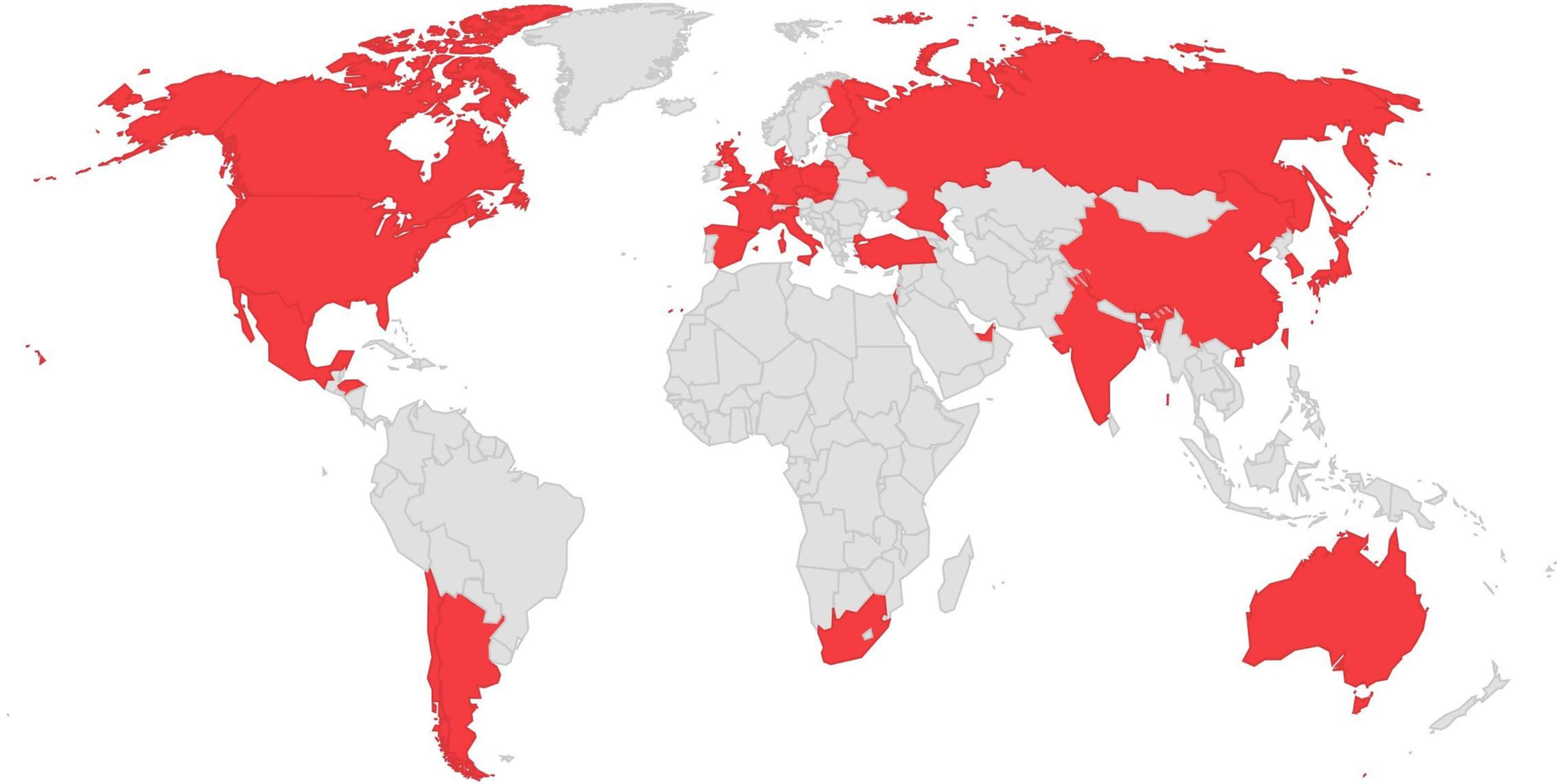
NICER's General Observer Program

Guest Observer (now General Observer) program began in 2019. Provides small grants for data analysis and publication.

- Joint program with NuSTAR also started in 2019.
- Adding joint **Swift and TESS programs** in next GO cycle (cycle 5).
- Time available to broader science community has **increased to ~80%** of the time available on the observatory.
- NuSTAR joint time has stayed constant at **400 ksec** NuSTAR time offered by NICER, and **250 ksec** of NICER time offered by NuSTAR.
- Since Cycle 3, NICER reviews have been held fully virtually and follow a **Dual-Anonymous Review** process.
- Since Cycle 3, NICER has offered **multi-cycle** investigations (up to two years) to proposers.







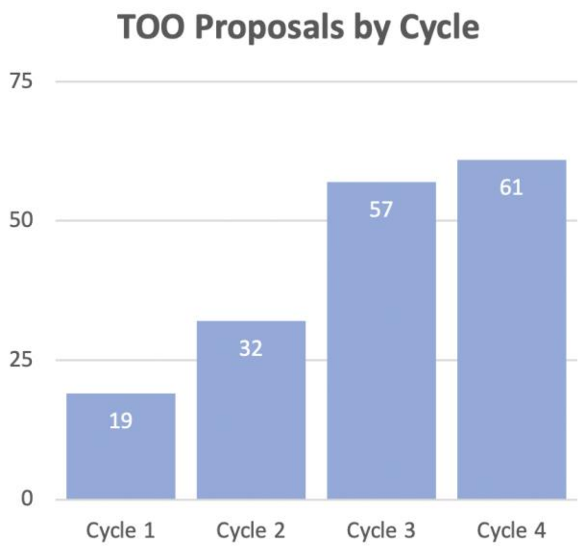
NICER Cycles 1–4 have resulted in:

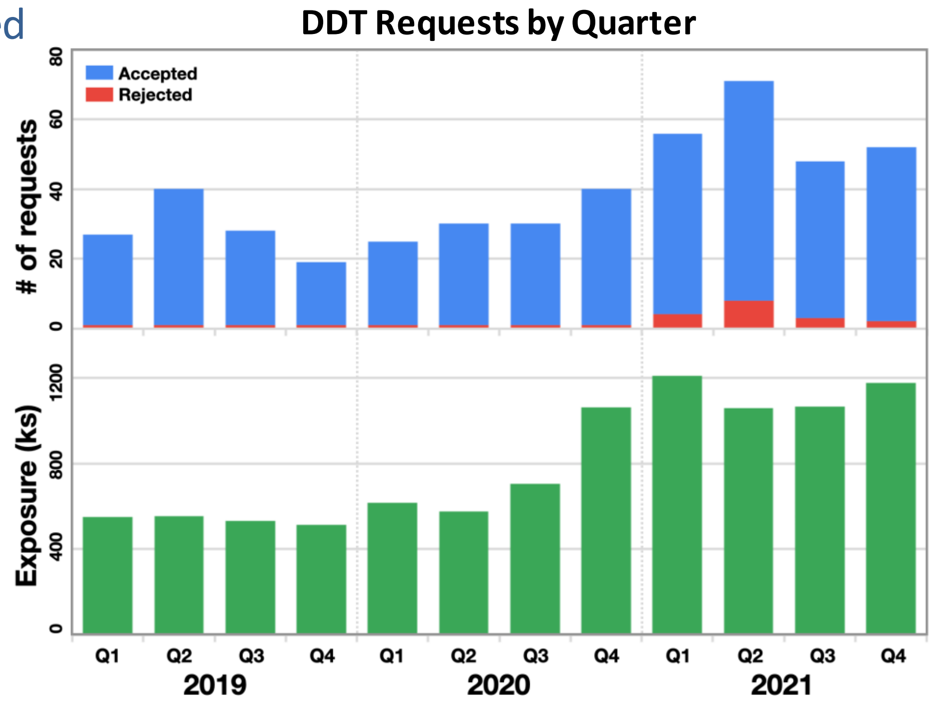
- Submission of **394** proposals
- By **759** unique proposers
- From **33** countries
- Requesting **47.6 Msec** of exposure
- Time oversubscription factor ~ **1.9x**
- Funding oversubscription ~ **2.2x**

Note that only US-based PIs are eligible for funding under the NICER GO program.

General Observer Science

- Accepted proposals are used to generate a long-term timeline each cycle, into which Legacy, Calibration, and Opportunistic Science activities are inserted.
- **Rapid response** science requests (GO TOO proposals + DDT requests) have been **increasing each year**.
  - Adding observations requires replan and re-upload of science timeline.
  - Replans in response to ISS ephemeris changes are relatively frequent.
- Observing timeline uploads are performed by the operations team, or by specially trained science staff to help cover nights/weekends/vacations.





NICER GO Program – Proposal Review

Proposal Review:
- Typically, 5-6 panels with 6 members each.
- Minimize conflicts within each panel. Dual anonymous helps.
- Work to create diverse review panels, inclusive in several ways:
  - Working at a variety of career levels and institution types
  - Of various ethnicities and backgrounds
  - Gender-inclusive (at least one female reviewer in each panel, at least one female panel chair each year)
- Virtual reviews help us meet these goals.

Develop skills in our reviewers:
- Usually, 1-2 panels each year are chaired by a first-time panel chairs
- Pair with experienced reviewers (prior chairs) as deputy chairs to provide assistance and build confidence.

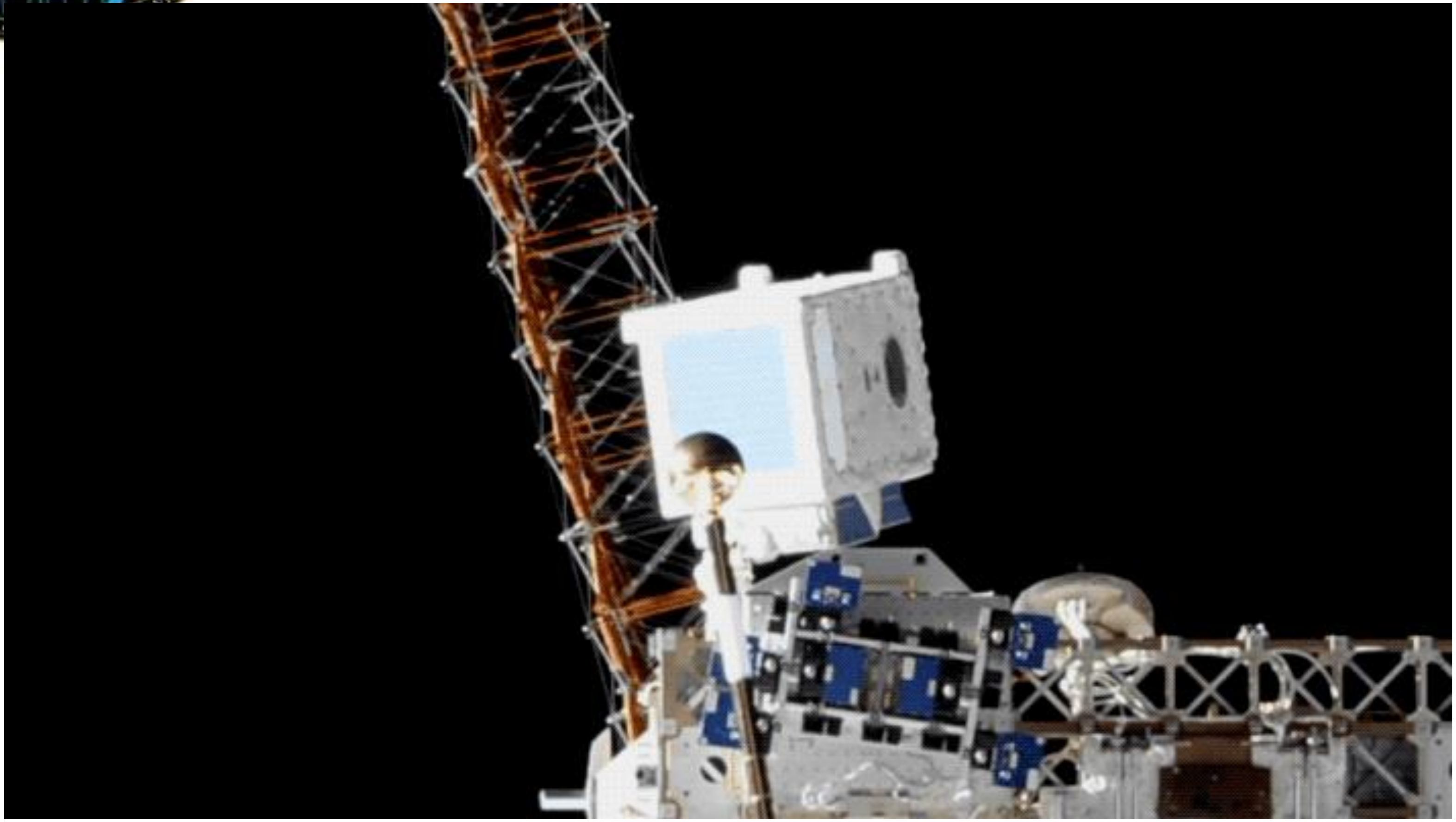
In addition, HQ has requested that we minimize participation from scientists at non-US institutions.
  - Greatly complicates the task of finding reviewers

NICER GO Program – Selections

<u>Selection process:</u>

- Panels provide rank-ordered list from each panel
  - Chairs defined 4 ranges: important, worthy, average, unselectable
- Feedback from panels considered: NuSTAR allocation, Exclusive Use, Target Prioritization, etc.
- Proposals that are meritorious and provide for a balanced science program are recommended for time allocation **by rank** from each panel until a) proposals begin to be unselectable, in which case selection continue from other panels, or b) the full GO time allocation is used
  - Guarantees a broad science program
  - Mitigates against “tough grader” panels
- NuSTAR time is allocated to selected proposals that request it, until all has been used.
  - Overages are sometimes negotiated with the NuSTAR team.
- US PIs will be invited to submit budget requests. Fair share allocation based on total number of US-led proposals selected.

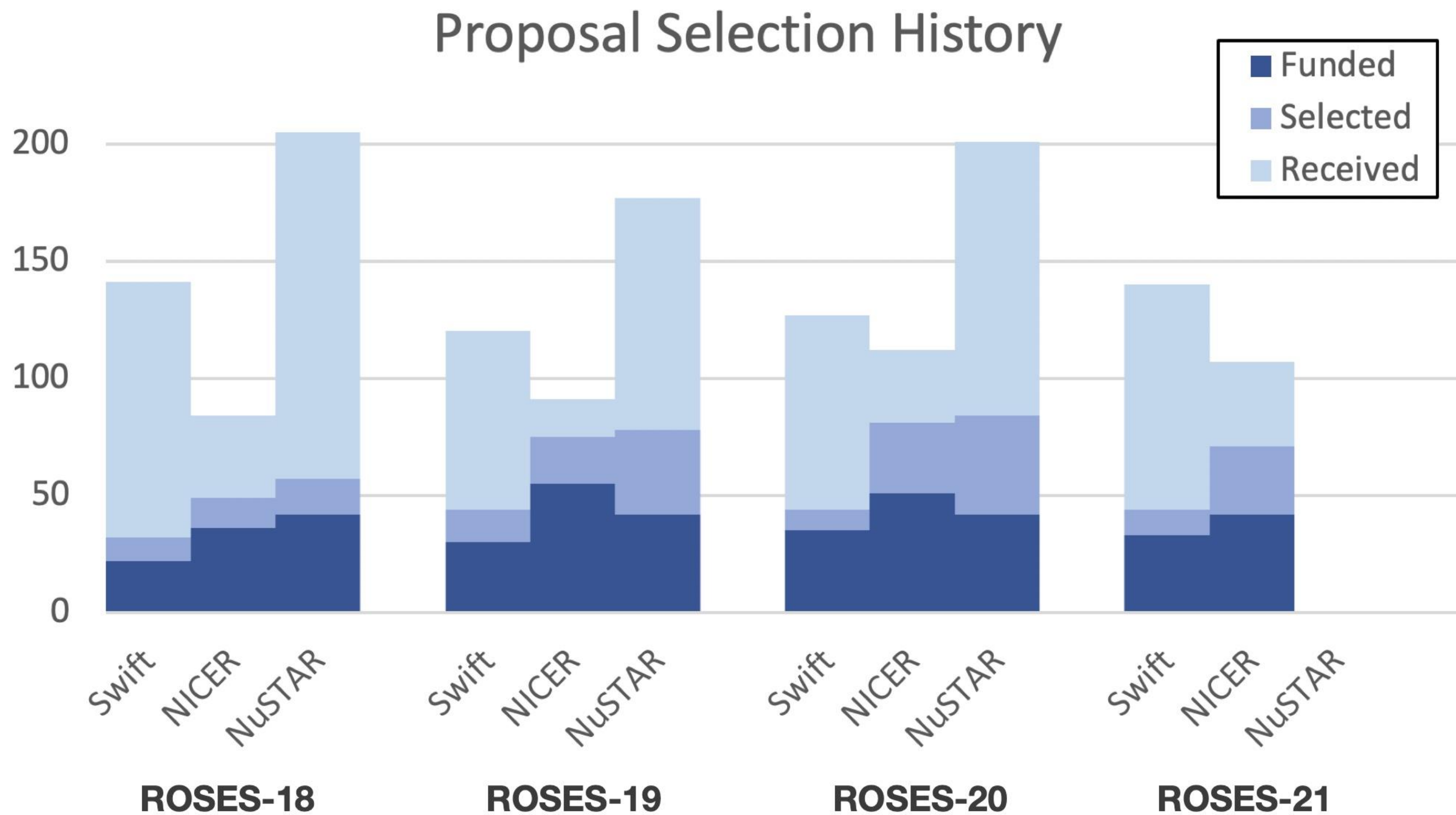
Extremely Agile Observing



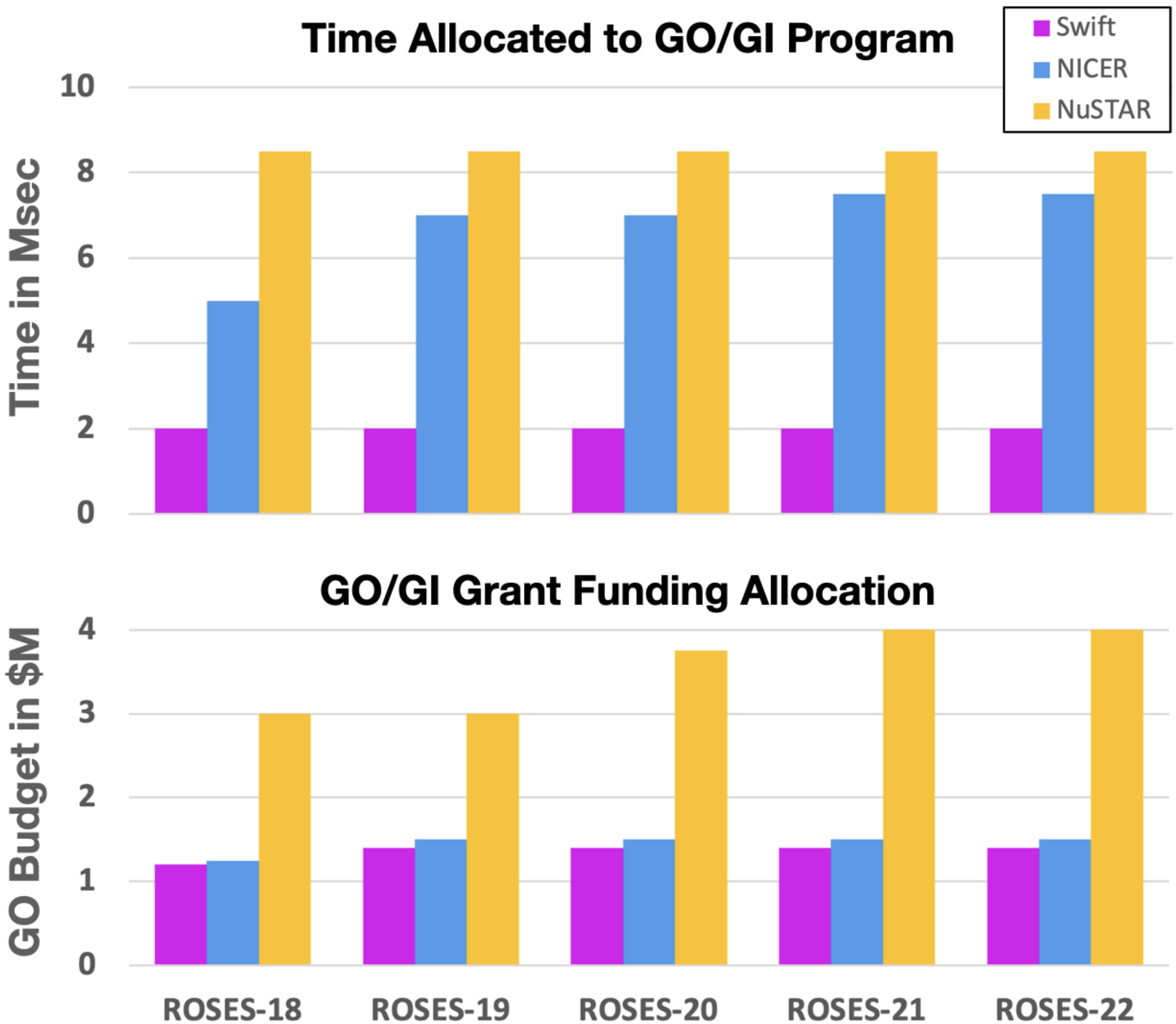
- NICER typically observes 3-6 targets per orbit with snapshots ranging from 200 sec to a maximum of 2.5 ks for the most optimal geometries.

NICER GO Program – Senior Review Feedback

"The panel finds that further work is needed to continue to grow NICER's scientific community and increase the GO AO response rate and publications/citations in areas outside of the key neutron star science. The NICER team has not done as much as other missions in terms of organizing scientific meetings, data analysis workshops, and community organization." (Astro2020 - ROM Report)



GO Program Comparisons – Allocations



- NuSTAR minimum snapshot is 20 ks
- NICER minimum snapshot is 200s

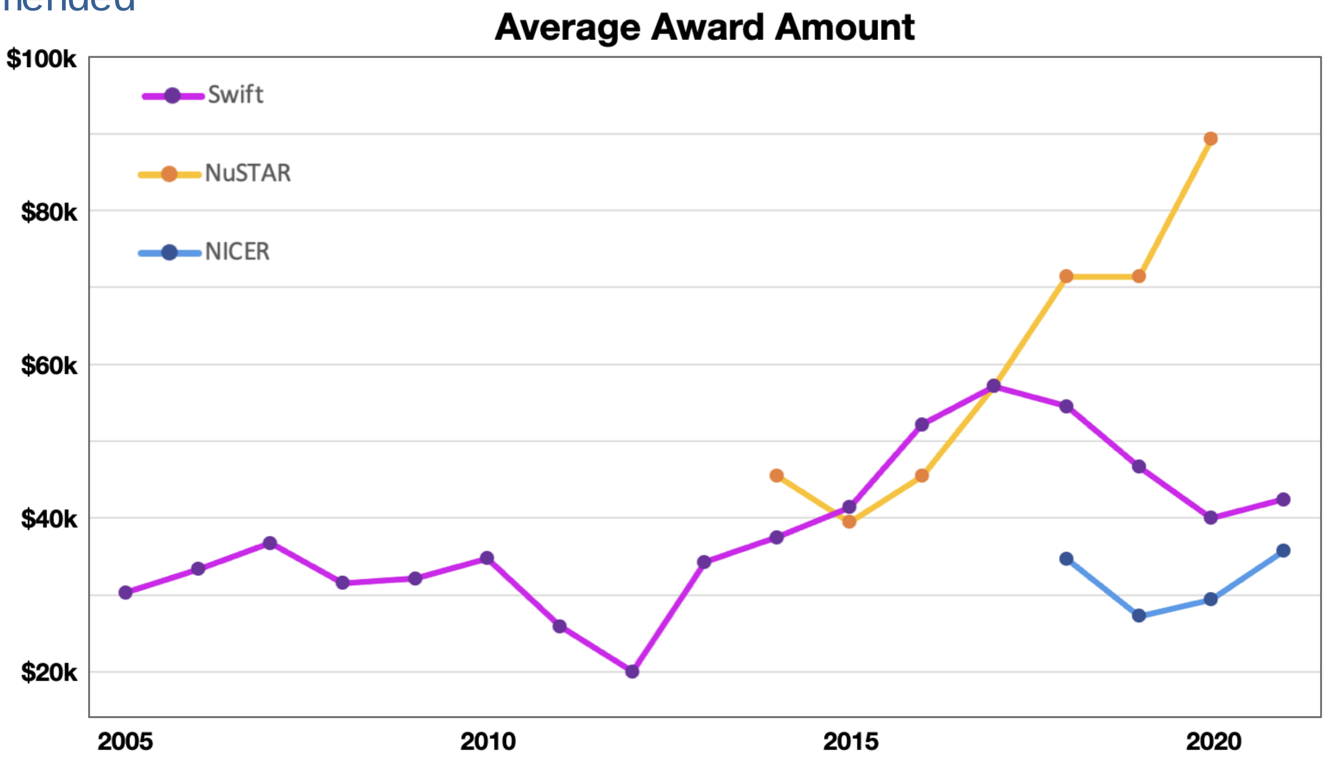
- NICER's GO time allocation results in many more targets being observed.
- ⇒ Many more programs are selected.

- GO time allocation is in line with NuSTAR, but grant funding closer to Swift.

GO Grants Comparisons

NICER requested an Over-guide 20% increase ($300k/year) to the NICER GO grants budget

- NICER GO grants budget fixed by NASA HQ at $1.5M per year since launch.
  - ***Has not grown with inflation or the increasing amount of time NICER has made available to GOs (~2x)***
- Likely not recommended



Options to Address Senior Review Feedback

Increase community involvement with NICER:

- Analysis Workshop:
  - In the planning stage for another analysis workshop, this time with a more "hands-on" approach
  - Goal is to get participants comfortable with using NICER data by exercising those skills in real time
- Add internships to get students more involved (budget-restricted)
- Organize NICER-focused scientific meetings (budget-restricted)
- Other ideas?

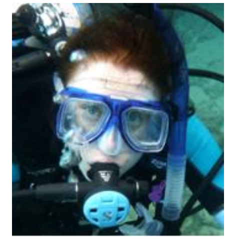
Increase oversubscription:

- Greater advertising of AO and submission deadlines
- Reduce number of selections
  - Add stricter selection criteria?
    - Place constraints on GO time for heavily-utilized regions of the sky
  - Reduce time available per cycle?
    - Add key projects that utilize large time allocations
    - Decrease overall GO Allocation to address significant increase in TOO utilization
- Proposal writing workshops
- Other options?

GO Program Timeline (changed for Cycle 5)

- **Year 0:**
  - Early Nov: Provide initial ROSES element to HQ & iterate until complete.

- **Year 1:**
  - 14-Feb: ROSES Announcement including initial NICER AO
  - **Jun 1: AO Amendment Released.** NICER website updated to reflect new cycle timeline and guidelines
  - Early Aug: Get NRESS task for this cycle put in place. Define proposal review timing and location. Start scouting in-person proposal review locations. Send initial solicitation for reviewers.
  - **Early Sep: Proposal deadline.**
  - Mid Sep: Complete sorting proposals into panels and start assigning reviewers based on conflicts. Identify gaps in coverage and solicit non-conflicted scientists to fill the gaps.
  - Mid/late Sep: Sign contract for in-person review location
  - Early Oct: Finalize panels and notify reviewers of their assignments and review timeline. Begin technical review process within the NICER team.
  - Mid/late Oct: Deliver proposal packages and technical reviews to panels
  - **Mid Nov: Proposal review (ALL HANDS ON DECK)**
  - Thanksgiving
  - Early Dec: Present science program to HQ for approval
  - Mid Dec: Work with NRESS to develop selection letters for PIs and get them signed by HQ. (This often isn't complete until well after selections are announced.)
  - Upon approval: Announce selections to the community, post on website.
  - Christmas



Elizabeth Ferrara

Keith Gendreau   Zaven Arzoumanian

- **Year 2:**
  - New Year's / Winter AAS
  - **Mid/late Jan: Phase 2 budget deadline** (must be at least 6 weeks after selection announcement, 8 is better)
  - Early Feb: Present budgets to HQ for review. (If there are any questions, iterate until budgets are approved.)
  - Mid Feb: Work with NRESS to develop budget award letters and get them signed by HQ.
  - Late Feb: Develop funding packages (one for each budget). Once award letters are approved by HQ, send these to GSFC RA for implementation with the NSSC.
  - End Feb: Complete long-term observing timeline for the full cycle
  - **1-Mar: Start of GO Cycle observations**

- **Year 3:**
  - 28-Feb: End of GO observations for this cycle.

Tell your friends/colleagues that they should submit NICER proposals in September.

THANKS!

Backup

NICER Policy for Target of Opportunity Requests

NICER is committed to maximizing science yield in time-domain X-ray astrophysics. Building on real-time data acquisition and commanding capabilities, pointing agility, and increasing automation, NICER's dynamic operations enable rapid response to transient and otherwise unpredictable phenomena.

The NICER operations team aims to react promptly to all time-sensitive requests for "target of opportunity" (ToO) observations, such as for unfolding astrophysical events or coordination with dynamically scheduled observations at other facilities. ToO requests, which must be submitted via the online form, may originate from within the NICER team, from a Guest Observer (GO) with an approved peer-reviewed proposal, or from the general community.

In keeping with the goal of maximum science return – in particular, to avoid missed opportunities – the NICER operations team evaluates, and may choose to act on, all ToO requests as they are received, whatever their origin. NICER staff also endeavor to deliver "quick look" data to ToO requesters, on a best-effort basis; in any case, all non-GO data enter the public NICER archive within two weeks of acquisition.

There are special implications of this policy for GO ToO investigations. It is the GO investigator's responsibility to notify NICER, via the online form, that ToO triggering criteria have been satisfied and to request that observations be scheduled. *It is possible, however, that an independent ToO request for the same target will have already been received, approved, and executed,* or that an existing monitoring program for the same target will have resulted in a recent set of observations. In such cases, implementation of the GO trigger will take place at the next reasonable observation scheduling opportunity. Data acquired from any observations scheduled prior to implementation of the GO trigger will be considered "public" – i.e., will enter the public archive within two weeks, but *with quick-look data likely available to any initial ToO requester.* Data acquired subsequent to a GO trigger notification will be assigned to the GO project and will be subject to any exclusive-use period granted to that project.

Occasionally, an independent ToO request received after a GO trigger notification will offer enhanced science return – e.g., through coordination with another observatory or because prompt analysis of the data suggests a modified observing strategy not anticipated by the GO effort. In such cases, NICER will consider this information in planning additional observations of the ToO, and will reach out to both the GO investigator and the independent ToO requester to foster collaboration where possible.

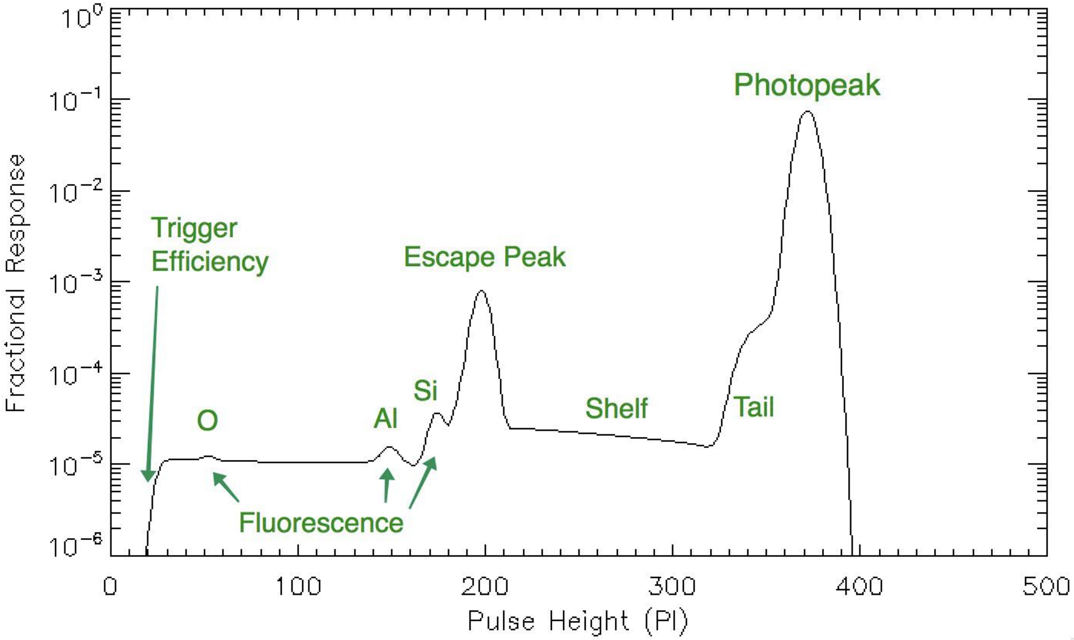
Instrument Calibration

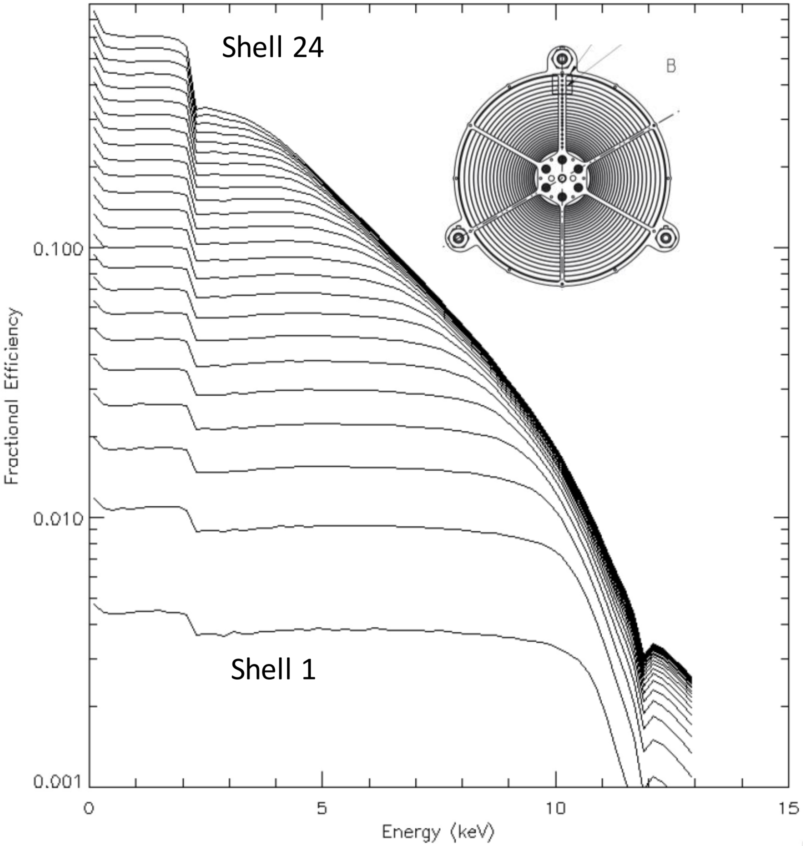
- Currently, NICER instrument calibration activities are being performed by Craig Markwardt.
  - Modeling, fititng, delivering updates
  - Released to user community via CALDB

Craig Markwardt

Mike Corcoran

- We are now looking for another calibration scientist to help reduce Craig's workload





Software & Data Pipeline

- NICER analysis software development and maintenance work is done by Craig Markwardt.
  - Regular deliveries into HEASoft to maintain/improve performance, fix bugs, and add new functionality.

- Also developed the NICER Data Pipeline, now maintained by Kristin Rutkowski
  - Standard data checks to verify full data set has been received from the observatry
  - Performs standard data processing
  - Generates metadata for Browse, and delivers to the HEASARC at the end of the validation period.
  - Applies encryption for GO datasets with approved Exclusive Use periods
  - Sends notification emails to PIs

NICER Archive

NICER Archive Access

The NICER archive can be accessed via the following interfaces:

HEASARC Browse interface	Allow searches via the observatory log nicermastr database
Anonymous FTP via HTTPS or wget or script	Do direct data retrieval without browsing the observation logs via HTTPS/FTP or via wget or via a script.

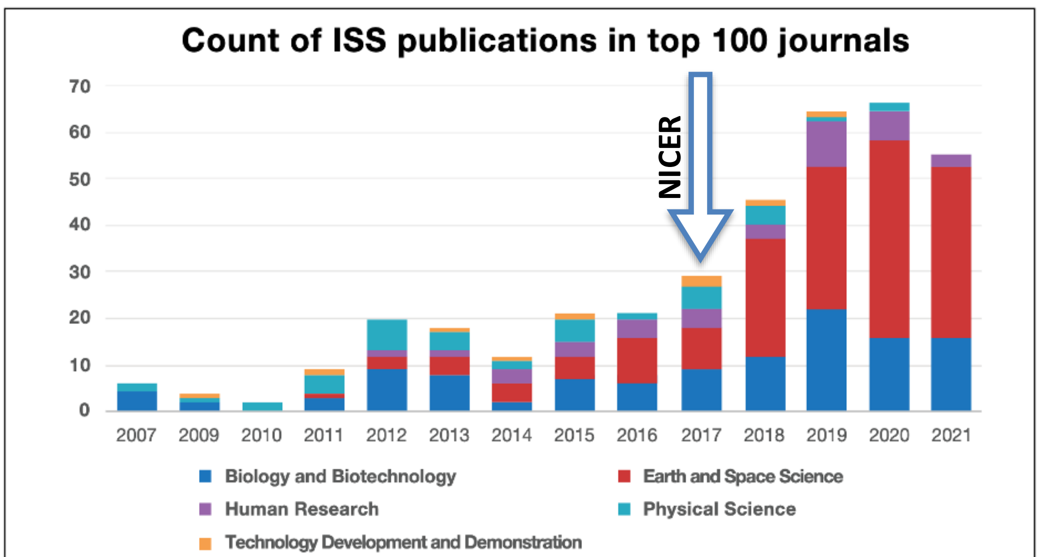
Craig Markwardt

Kristin Rutkowski

NICER Science Publications

- The number of peer-reviewed articles using NICER data continues to grow, along with citation counts.

- NICER is the most prolific generator of peer-reviewed science on the ISS.



RED = Earth & Space Science