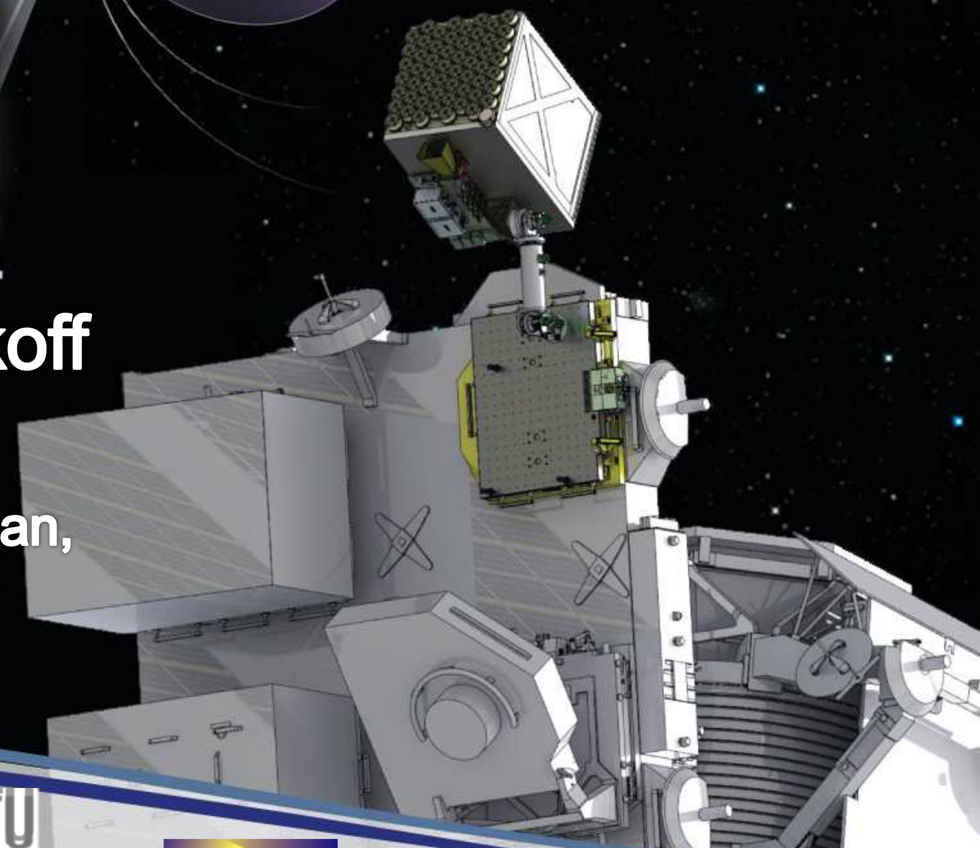
NICER

Neutron star Interior Composition ExploreR

NICER Users Group Kickoff Meeting 2021

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



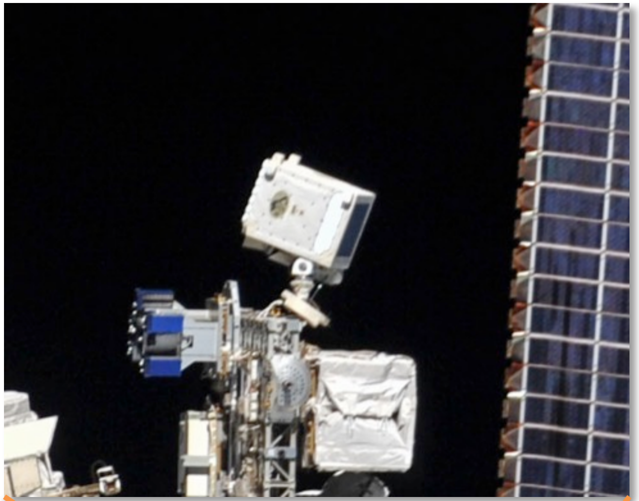
NASA GSFC MIT KAVLI INSTITUTE DTU BROAD REACH MOOG

Outline

- Welcome and Introductions
- Mission overview –Keith Gendreau
  - Introduction
  - Team
  - Science Program
  - Operations and Interactions with HQ/ISS
  - Instrument Performance and Calibration
  - Collaborations
  - Plans for Upcoming Senior Review
  - NUG timeline
- NUG Chair Discussion- Ed Cackett
  - NUG Charter
  - Logistics
- Questions and Discussion

An X-ray Astrophysics Observatory on the International Space Station

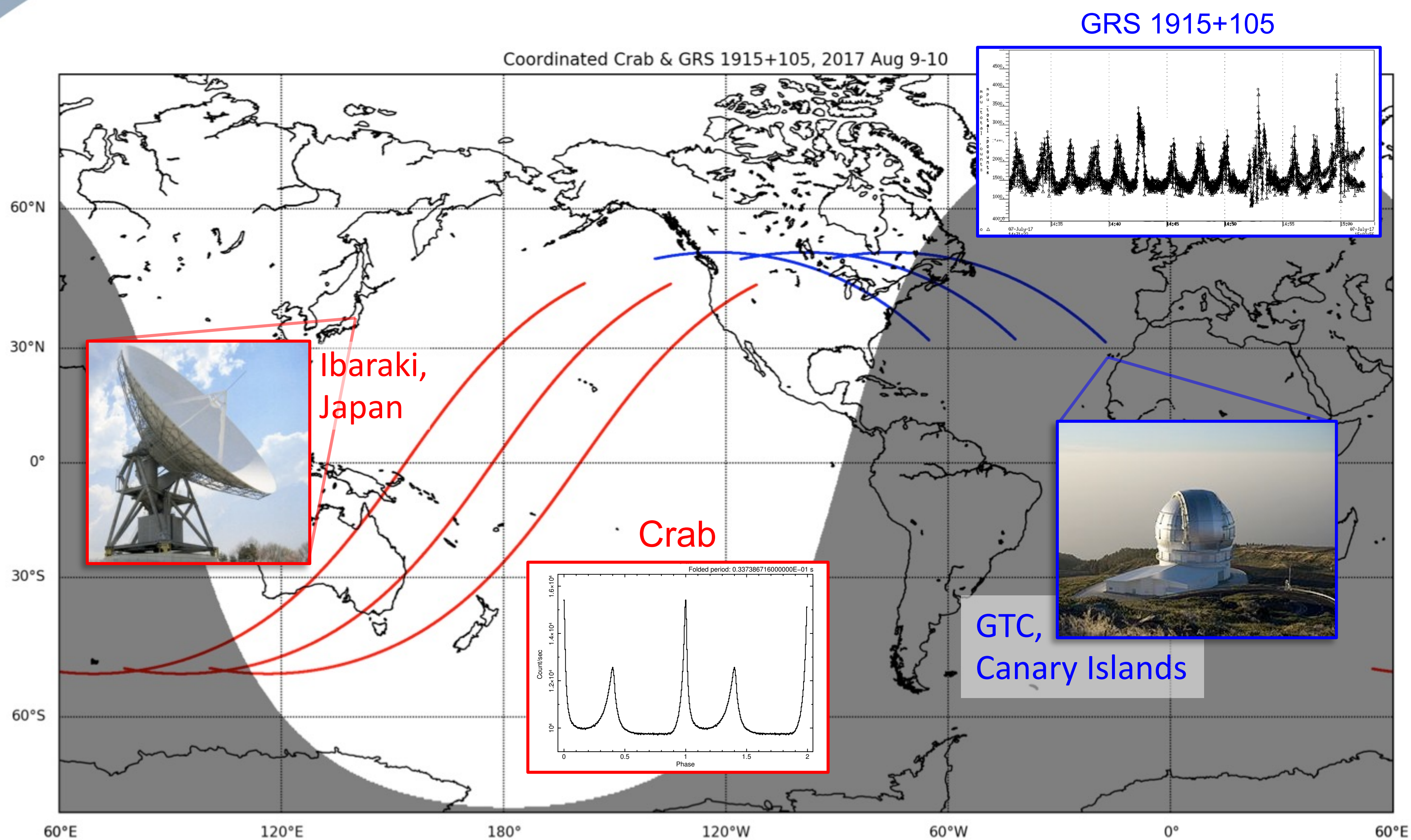
- ***Key science:*** Understanding ultra-dense matter via observations of neutron stars in the soft X-ray band
- ***Launch:*** June 3, 2017, SpaceX-11 ISS resupply
- ***Platform:*** ISS ExPRESS Logistics Carrier (ELC), with active pointing over nearly a full hemisphere
- ***Instrument:*** X-ray (0.2–12 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
  - Extended mission approved
  - GO Cycle 3 in progress



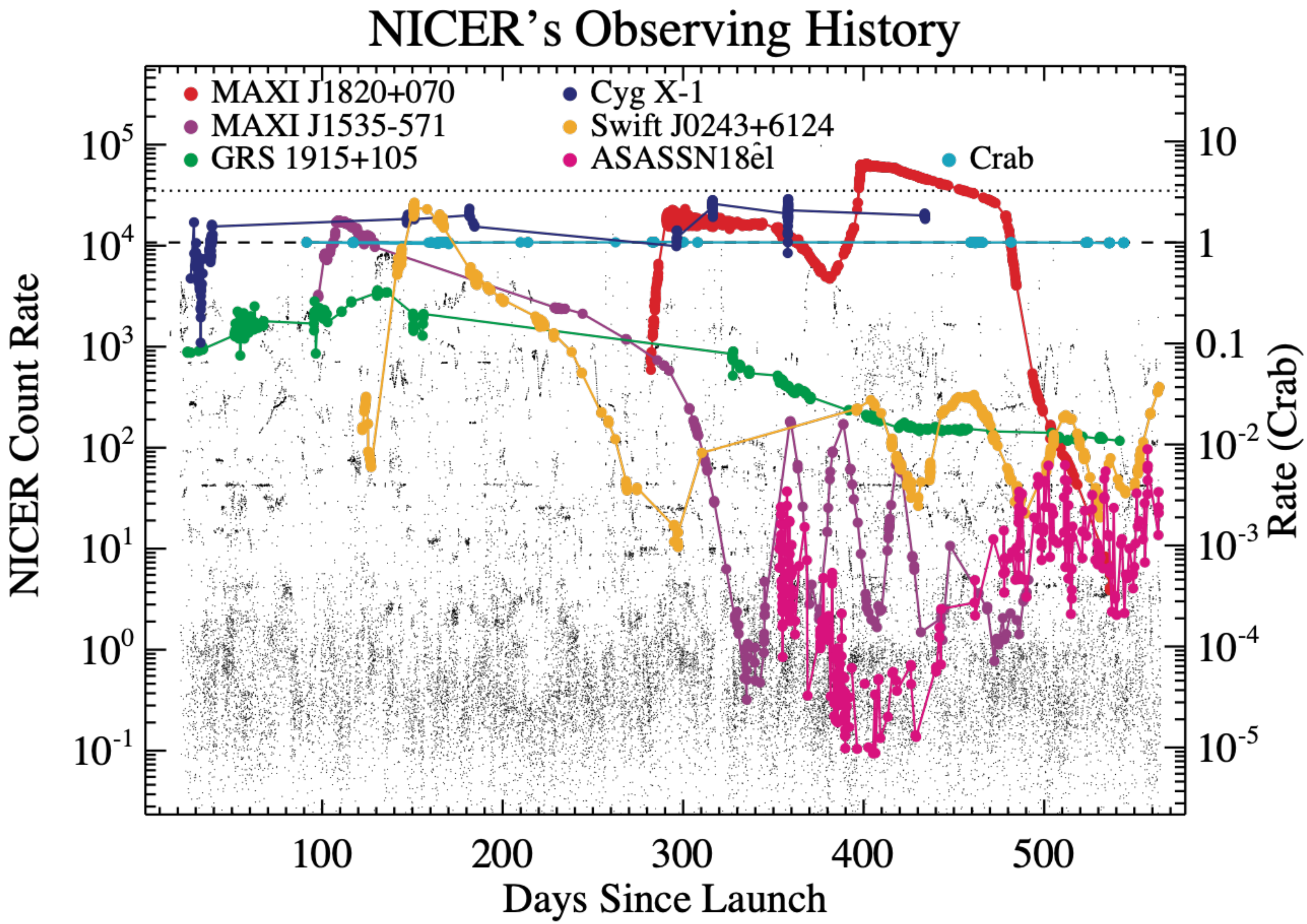
NICER on the ISS

Coordination across wavelengths and facilities

Two targets, two ground-based telescopes, three successive ISS orbits



NICER expands the dynamic range of X-ray astrophysics



NICER Team: Most play multiple roles!

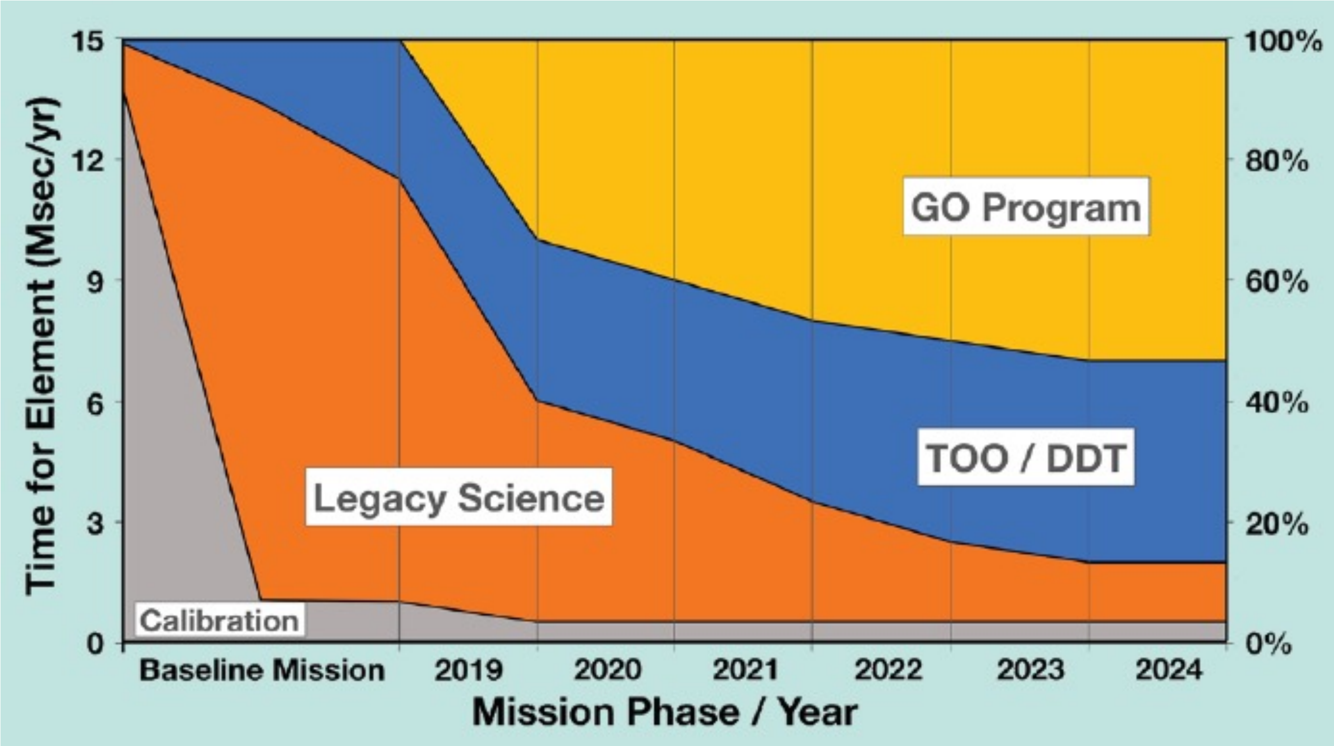
- Operations/Planning/Pipeline
  - Operations: J. Pope, M. Saylor, B. Kozon, IT staff: ~2 FTE
  - Planning: K. Gendreau, Z. Arzoumanian, E. Ferrara, K. Hamaguchi: ~2.75 FTE
  - Pipeline: C. Markwardt, K. Rutkowski: ~1.5 FTE
- GOF
  - E. Ferrara (Lead)
  - K. Hamaguchi, M. Corcoran, M. Loewenstein, S. Sturner, T. Strohmayer
- Instrument Team
  - C. Markwardt (calibration lead)
  - 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
  - Lightcurve Modeling
  - Searches & Multiwavelength Coordination
  - Bursts & Accretion Physics
  - High-Precision Timing
  - Magnetars & Magnetospheres
  - Observatory Science
- Membership (76 members, plus ~17 students)
  - Instrument Team
  - Original mission proposal science Co-Is and Collaborators
  - Affiliated Scientists (post-doc & higher seniority)
  - Students (under- & post-graduate)

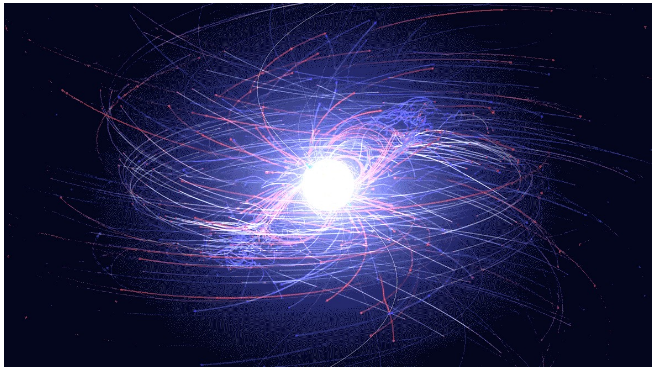
NICER Science Program

- Legacy Science and Observatory Science
- Guest Observer (GO) Science Program
- Target of Opportunity (TOO) Enhancements



Legacy Science Program

- Neutron Star Interior Composition Explorer
- Deeper (and more) neutron star mass and radius measurement
    - 2019 papers on PSR J0030 mass and radius
    - Upcoming PSR J0740 radius (2 Msun)
    - Upcoming PSR J0437, and more
    - => better constrain nuclear theory
- Finding new neutron stars with pulsation searches
    - TOO follow-ups from eROSITA, INTEGRAL, MAXI, and others
    - Fermi sources
- Bursting neutron star LMXBs
    - Based on TOO triggers, including OHMAN
- Magnetars
    - Connection to FRBs?
- Long term monitoring of “stable” pulsars



The golden age of neutron-star physics has arrived
Nature feature article
4 March 2020

NICER Observatory Science

- During baseline mission, it became possible to schedule more targets than just neutron star targets
- HQ approved NICER to expand target base to include a variety of other targets and form an “Observatory Science” working group (OSWG)
- OSWG lead by Ron Remillard @ MIT
- Has led to a combination of great science results as well as a fertile working ground for calibration and broader community interactions
- The core of NICER’s first public workshop coming this May.

- *Nature* cover story (Jan 2019) on NICER results from the black hole MAXI J1820+070

NICER Guest Observer Program

GO Cycle 3 Overview:

- 7 Msec of NICER time
- Multi-cycle and carryover time from Cycle 2 = 1 Msec
- 400 ksec of NuSTAR time (>3x oversubscribed)
- Up to $1.5 M to help support US scientists using NICER for investigations through the GO program.

- Timeline:
  - 14-Feb-2020 : ROSES Announcement
  - 17-Aug-2020 : AO Amendment released
  - 17-Nov-2020 : Proposal deadline
  - 23-Jan-2021 : Proposal review completed
  - 1-Mar-2021 : Start of GO Cycle 3 observations
  - 20-Apr-2021 : Phase 2 deadline (Budget)
  - 28-Feb-2022 : End of GO Cycle 3

NICER-Cycle 3 Science Highlights – 1

X-ray Pulsars, Magnetars, and Neutron Star Binaries:

- Several studies of ultraluminous X-ray sources and other candidate pulsars, to determine pulsation periods and track accretion evolution
- TOO observations of magnetar outbursts and fast radio bursts (FRBs), many with coordinated observations
- Long-term timing of pulsars that are candidates for detection with LIGO of continuous gravitational-wave emission (continuation of Cycle 2 multi-cycle investigation)
- Investigating the changing spin behavior of PSR B0540-69 in the LMC.
- Intensive campaigns to further probe spectral lines in Type I (thermonuclear) bursts from 4U 1820–30 (coordinated with Chandra) and other well known systems
- High-precision timing of accreting and transitional millisecond pulsars in outburst, to track long-term spin and orbital evolution.

White Dwarfs and Cataclysmic Variables (CVs):

- Joint optical/X-ray timing of polar-like CVs to constrain accretion physics through quasi-periodic oscillations
- Studies of X-ray eclipses in several objects to determine their physical properties.

NICER-Cycle 3 Science Highlights – 2

Active Galaxies and Quasars:

- Pathbreaking studies of the newly identified "quasiperiodic eruption" (QPE) phenomenon in AGN
- Multiple investigations of tidal-disruption events and "changing look" AGN — objects with mysterious faster-than-expected evolution — using dense spectroscopic monitoring and reverberation mapping
- Monitoring of AGN coordinated with 1) TESS continuous viewing to study the source of accretion disk variability, and 2) Hubble for reverberation mapping.

Black Holes:

- Multiple TOO efforts to track Galactic black-hole binary outbursts, to improve understanding of outburst onset, state transitions, and strong-gravity accretion
- Coordinated observations for many of these with a variety of observatories, both space- and ground-based, including IXPE for polarization and high-speed optical cameras for simultaneous variability studies and to probe jet ejection.

Non-compact Stellar Objects:

- Observations of planet-hosting stars, coordinated with TESS, to determine impact of stellar flares on habitability
- Understanding the physics of massive-star, colliding-wind binaries.

Target of Opportunity (TOO)

- Currently, NICER can take up to 4 hours on weekdays and 72 hours over holidays/weekends to respond to a TOO request
    - This is limited by the need to have ISS-certified operators issue commands to NICER from the NICER SMOC at GSFC.

- For our current mission extension, we are dramatically improving this in three steps
    1. Train/qualify NICER Science Team members to issue TOO follow-up commands to NICER directly, and schedule on-call duty scientists 24 hours
    2. Automate NICER TOO follow-up command generation and execution on the ground to eliminate the need for scientists and operators to travel to the NICER SMOC
    3. Make use of ISS infrastructure to allow NICER to automatically follow up on transient events detected by the MAXI wide-FOV X-ray monitor on the ISS.

Steps 1 and 2: Improving Ground Operations to Decrease TOO Response Time

- "Step 1" increases the role of local NICER team scientists to issue the commands
  - Currently, TOO reaction time is limited by the need to have a qualified operator on-line and enabled by POIC to issue commands
  - Our primary ISS qualified operators normally work 8 hour shifts, 5 days a week
  - This reduces the need to call in an operator and coordinate a response
- "Step 2" involves automating the command generation to react to a TOO.
  - NICER's 1st flight software (FSW) update was made in late 2020 which significantly streamlines TOOs and also allows for "rasterscans" of large error boxes
    - Significantly improves efficiency of ground generated TOOs
    - Done in anticipation of OHMAN ("Step 3")

COVID has improved remote access for commanding

Step 3: Using the ISS as a multitool laboratory

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

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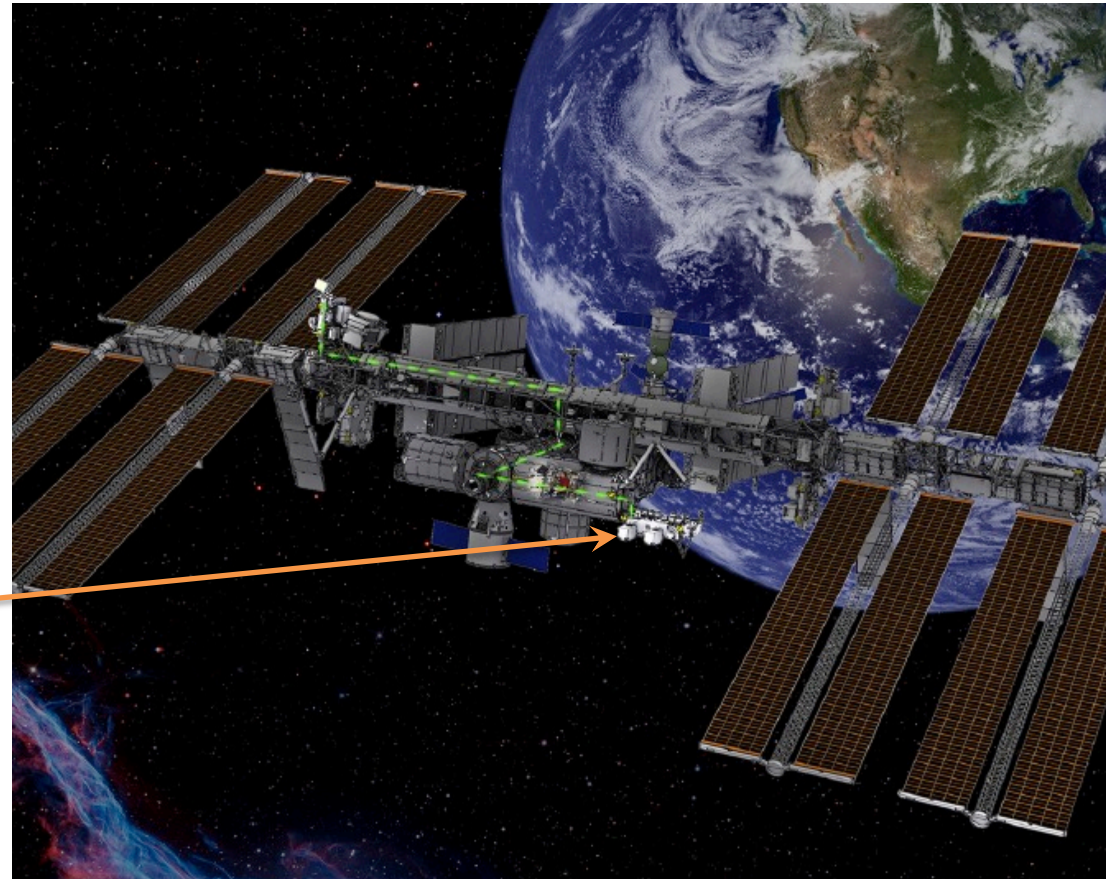
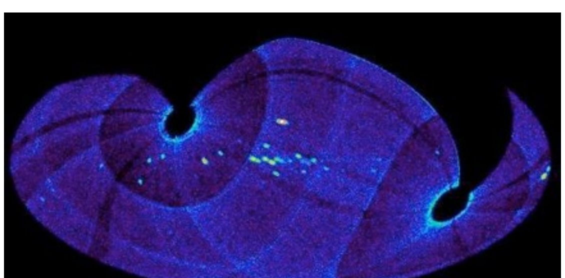
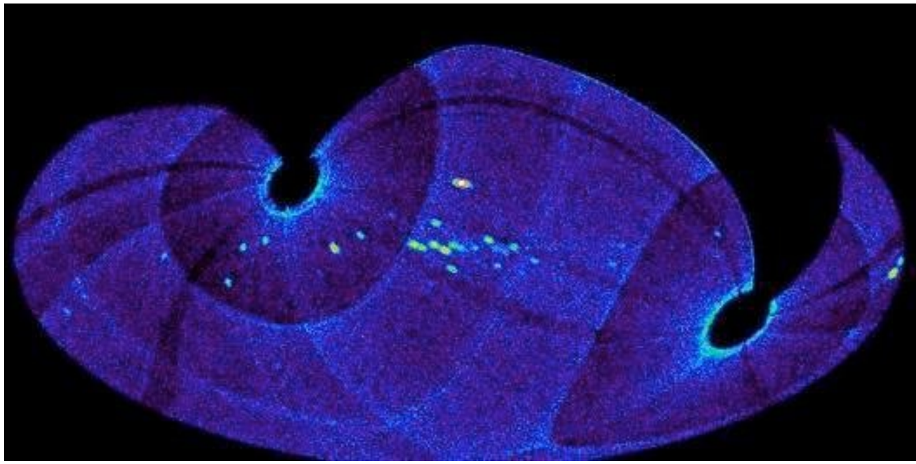


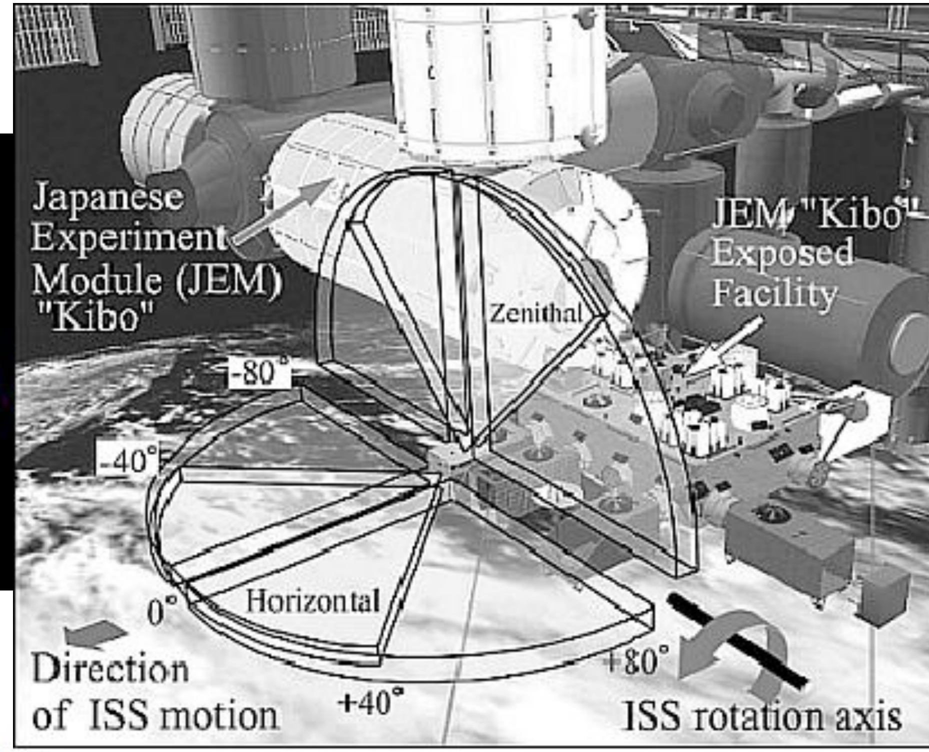
JAXA's Monitor of All-sky X-ray Image (MAXI)

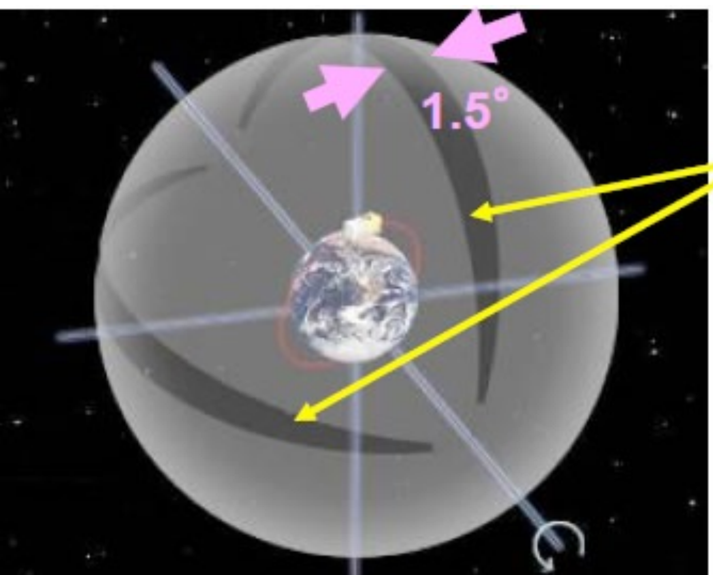
- > 900 deg^2 instantaneous
- *> 95% of the sky each orbit*



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 Basic Concept

- Use an existing laptop computer already on ISS to monitor live data from the MAXI instrument
- Communicate to NICER information about transients worth following up
- Use NICER's rapid slewing capability to bring 15 times the collecting area of Swift XRT onto the transient within minutes of the MAXI trigger
- Make full use of all existing infrastructure on ISS as well as in the NICER and MAXI ground systems and data processing pipelines.

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: Edwin Griego
  - Program Scientist: Roopesh Ojha
  - Thursday mornings
  - Covers: instrument status, ISS issues, key science results, GO status, program issues and concerns
- Monthly Communications tag-up
- ISS processes later on….

NICER GOF Activities

- GO Program lead by Elizabeth Ferrara
- Bi-weekly GOF meeting
  - Updates on observatory status, observation planning, pipeline, software development, helpdesk, and webpage development
- Annual GO proposal cycle preparation
  - Revise AO as needed, send solicitations and reminders
- Annual GO proposal review
  - GOF lead defines panels, recruits and assigns reviewers
  - GOF members provide mission expertise for each panel
- NICER HEASARC web content - documentation, tools, etc.
  - Recent addition: Analysis threads
  - Next development: TOO reporting table
- NICER Helpdesk

NICER ISS Interactions

- All commands go through established ISS infrastructure
  - Payload Operations Integration Center (POIC) at MSFC is the hub for all payloads to command through
  - 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 schedule is completely independent to the SMD Senior Review Cycle and requires constant attention
  - ISS may decide to replace NICER with another payload
  - MiPROM meeting 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

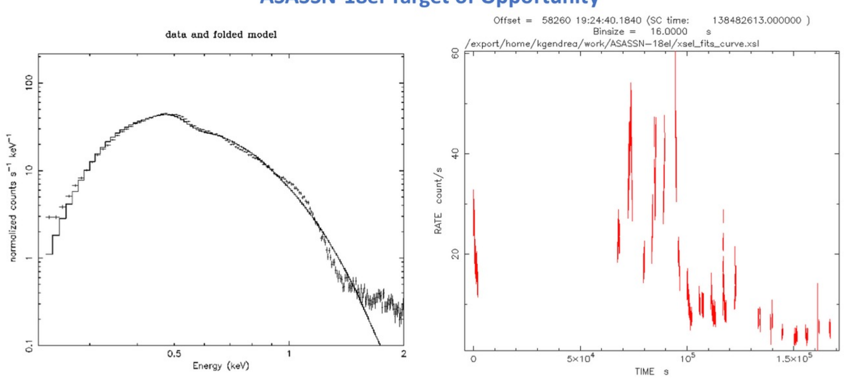
NICER / ISS Science Nugget for May 24, 2018

Target of Opportunity observations of new transient ASASSN-18el

This week, NICER responded to an extreme nuclear transient associated with a known active galaxy (of the "Seyfert 2" class). This extreme accretion event may be due to a "tidal disruption event" (TDE), where a star has ventured too close to the galaxy's central black hole. TDEs are near-pristine laboratories of relativistic accretion.

NICER observed the target ASASSN-18el, discovered by the All Sky Automated Survey for SuperNovae (ASAS-SN) collection of telescopes distributed around the world. NICER investigations can help us understand the nature of this extreme accretion event, and can yield black hole masses, spins, and inclinations from TDEs, together with the structure of the extreme gravitational field just outside the event horizon of a black hole that was previously unobservable.

ASASSN-18el Target of Opportunity



Spectrum with 150 eV blackbody model — X-ray Light Curve

Figure: *The X-ray spectrum (left) and light curve (right) of ASASSN-18el as observed by NICER. Both are consistent with a 150 eV blackbody.*

NICER will continue to observe this object and the science team is analyzing the data to determine the nature of this unusual X-ray activity.

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
  - 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

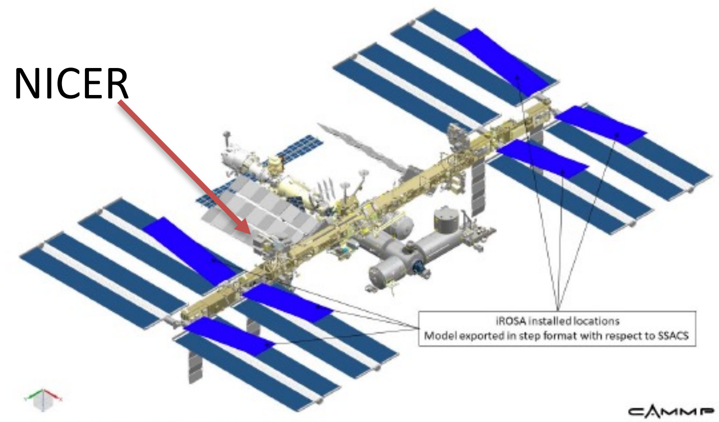


Figure 1. iROSA installed locations

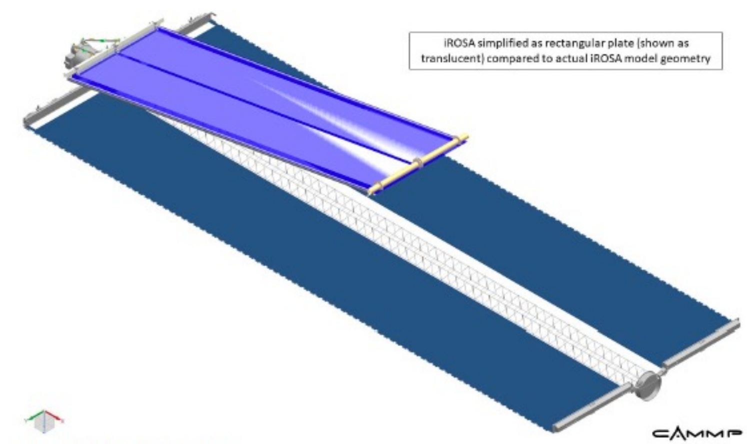
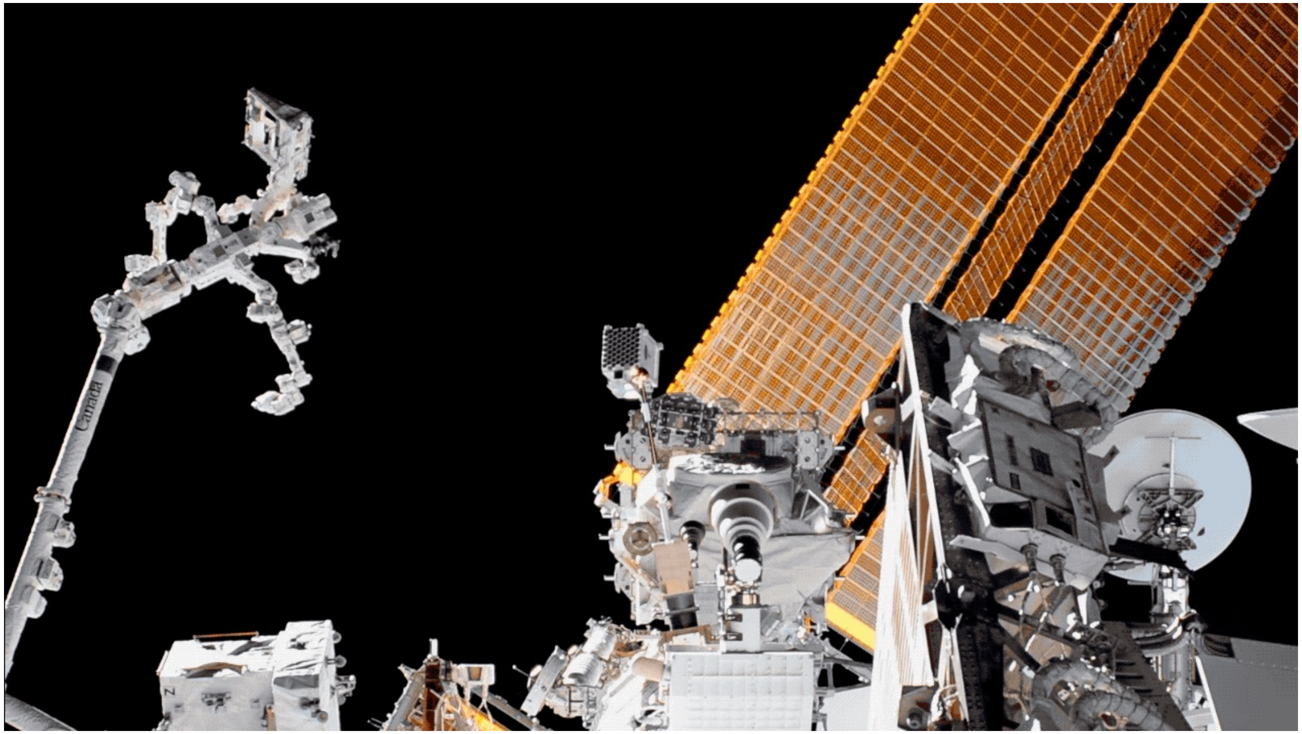


Figure 2. iROSA simplified model

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



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
- PIM became active with NICER team in winter 2020/2021
- NICER team provide Payload Data Library (PDL) input to ISS program in February 2021
- Regular PIM tagups (every Thursday afternoon) began in March 2021
- NICER team was informed that our intent to be active with OHMAN in October 2021 would not be possible due to an unadvertised schedule not being met.
  - OHMAN is an unusual payload in that it has no hardware, involves a computer in the pressure chamber as well as two external payloads, and it crosses international boundaries
  - Next ISS programmatic readiness date in April 2022
- NICER and MAXI team will be technically prepared for installation before October 2021

NICER Instrument Performance and Calibration

- Instrument has suffered very minor degradation since on orbit
  - Radiation damage has lead 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
    - In past 2 months, NICER has been running SDDs at max TEC current and dark current has been significantly reduced with no noticeable loss of calibration
- Overall performance (gain, energy resolution, timing performance) has been within specifications and captured in calibration
  - Optical loading is more difficult to account for, but calibration improving
    - Leads to gain shifts (calibrated) and energy resolution degradation
    - Leads to extra noise at lowest < 400 eV (typical) channels
    - Standard processing can yield "0" events, while there may be plenty of useful data
- Calibration effort lead by Craig Markwardt
  - Listen to Craig's talk on May 10 at NICER's 1st public workshop

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 J 1820)
  - 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 a broad bandpass on exoplanet systems to understand 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 most all existing high energy missions to maintain cross calibration

Next NICER Senior Review Plans

- Waiting for Senior Review call to come out, but expecting a proposal due date in Fall/Winter 2021
- Considering the following new initiatives:
  - Collaboration with GBT
  - Collaboration/Coordination with IXPE (to be confirmed with IXPE team)
  - Multi Messenger Science (LIGO, etc…)
  - QPE/ Long term monitoring of Optical Transients
  - TDEs
  - ULTRASAT Coordination
- We would like to hear thoughts from the NUG on what initiatives to work on

NICER User Group Timeline

- Kickoff meeting - 8 April 2021
- NICER's 1st public workshop- Week of 10 May 2021
- NUG Spring meeting
- NUG Fall Meeting
- NICER Senior Review- Fall/Winter

Backup

Key-science summary

- NICER has accumulated > 6 Msec of data on four key-science targets
  - Achieved first mass-radius constraints at the 10% level (including first mass measurement of a non-binary pulsar), with two independent analyses producing consistent results
  - Remaining calibration uncertainties are accounted for, will improve with time
  - Expect publication of additional results, on PSR J0437–4715 and others, in 2021.
- 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.
- Data demonstrate robustly that canonical assumptions for surface “hot spots” — small & single temp, antipodal & dipole B field — are not viable
  - First surface temperature maps of a neutron star, with sizes, shapes, locations of heated regions
  - Complex parameterizations reduce statistical precision, but Bayesian evidence isolates the needed level of complexity.

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.

NICER GO Cycle 3 – Proposal Responses

The NICER Cycle 3 announcement of opportunity resulted in:

- Submission of **112** proposals (+21 over Cycle 2)
- By **370** unique proposers (+8)
- From **27** countries (-1)

Oversubscription:

- NICER time requested: **12.7** Msec = factor of **2.1** oversubscription
- NuSTAR time requested **1.325** Msec = factor of **3.3** oversubscription

Global interest in NICER:

- **40** proposals were submitted by principal investigators affiliated with non-US institutions (35%)

NICER GO Cycle 3 – Response Statistics

Number of submitted proposals = 112
Number of submitted proposals with likely female PIs = 25 (22%)

Submissions by topic:

- Rotation Powered Pulsars & Magnetars = 17 proposals
- White Dwarfs = 5 proposals
- X-ray Binaries = 58 proposals
- Active Galaxies and Quasars = 23 proposals
- Other = 9 proposals (ULXs, FRBs, comets, transients, etc.)

Percentage of proposals requesting:

- TOO = 57 = 50.8% Average Trigger Probability = 0.59
- Exclusive-use period = 33 = 29.4%
- NuSTAR observations = 18 = 16% (13 are TOOs)
- Coordinated with other facilities = 49 = 43.7% (29 are TOOs)
- Multi-cycle observations = 6 (2x Cycle 2 req.)

NICER GO Cycle 3 – Proposal Review

Cycle 3 was NICER's first dual-anonymous proposal review. It was also the first virtual review for the mission.

34 panel members across 5 panels
- 6 or 7 members per panel
- 22-24 proposals per panel
- 2 non-voting members to provide technical and logistical support

Diversity
- 13 minority voting panelists (38%)
  - 2 middle eastern, 4 asian, 2 hispanic, 5 indian
  - 1 non-voting minority panelist
- 10 female voting panelists (29%)
  - 2 non-voting female panelists

Panel Leadership
- Effort was made to recruit younger reviewers and female reviewers
- 2 "first-time" chairs
- No ethnic minority chairs
- 1 female chair

NICER GO Cycle 3 – Proposal Recommendations

Selection process:

- One proposal eliminated because of non-compliance with ROSES
- Panels provide rank-ordered list from each panel
- Chairs defined 3 ranges: important, worthy, average
- Feedback from panels considered: NuSTAR allocation, Exclusive Use, Target Prioritization, etc.
  - 12 Exclusive Use and 1 NuSTAR request deemed “Not Justified”
- Proposals that are meritorious and provide for a balanced science program are recommended for time allocation

After reviewing the recommendations and evaluations by the review panels, the NICER Mission recommended **81** proposals for inclusion in NICER’s Cycle 3 Guest Observer Science Program:

- **51** are from PIs affiliated with US-based institutions
- **45** are TOO proposals, with a maximum of **4.1 Msec** (2.8 Msec when scaled by prob)
  - Based on prior cycles, this is likely an overestimate
- In order to maximize science, low-priority target time allocations have been zeroed out

- Expected NICER time in program is **7.1 Msec** (not including carryover)
  - Priority A time = 6570 ksec
  - Priority B time = 570 ksec
  - Priority C time = 0 ksec (was 800 ks)

Here, priority indicates the importance of the target to the success of the proposed investigation.

- Allocated NuSTAR time in program is **393 ksec** (7 programs)

NICER GO Cycle 3 – Statistics

Number of recommended proposals = 81

Number of unique targets in program = 122 known, up to 82 unknown

Number of recommended proposals with female PIs = 20 (24.6%)

- Female PI submissions = 22%

Recommended proposals by topic:

- Rotation Powered Pulsars & Magnetars = 12 proposals
- White Dwarfs = 3 proposals
- X-ray Binaries = 40 proposals
- Active Galaxies and Quasars = 18 proposals
- Other = 8 proposals (ULXs, FRBS, comets, transients, etc.)

Percentage of recommended proposals with these attributes:

- TOO = 45 (55%)
- Exclusive Use period requested = 21 (26%), 15 deemed “justified”
- NuSTAR observations = 7 (9%), 6 are TOOs
- Coordinated with other facilities = 28 (34%), 18 are TOOs
- Multi-Cycle observations = 4
  - Will carry over 570 ksec into Cycle 4

NICER GO Cycle 3 – Fair Share

Budget for GO support = $1.5M

- Desire is for awards to be sufficient to provide meaningful support
- Also desire success to have financial benefit

Rely on past experience:

- In Cycle 2, only 15 of 34 (44%) of the selected TOO proposals have triggered so far.
- Funds were allocated for all selected proposals with US-based PIs, but for TOO proposals funds are only sent once the program has triggered observations.
- Result is that funds have been reserved, but are never sent to the PI
- We want to avoid this situation going forward

For Cycle 3:

- Of 51 proposals with US-based PIs, 29 are standard proposals, and 22 are TOOs
- If we anticipate a 50% trigger rate, then 40 awards should be planned (29+11)
- Implies average award of $37.5k
  - At $38k, total of $1.52M
- If all 22 triggers happen, over-obligated by $412k
  - Should additional funds be needed, underrun from Cycle 2 TOOs can mitigate this concern.
- Plan to award $38k to each successful proposal once observations have begun

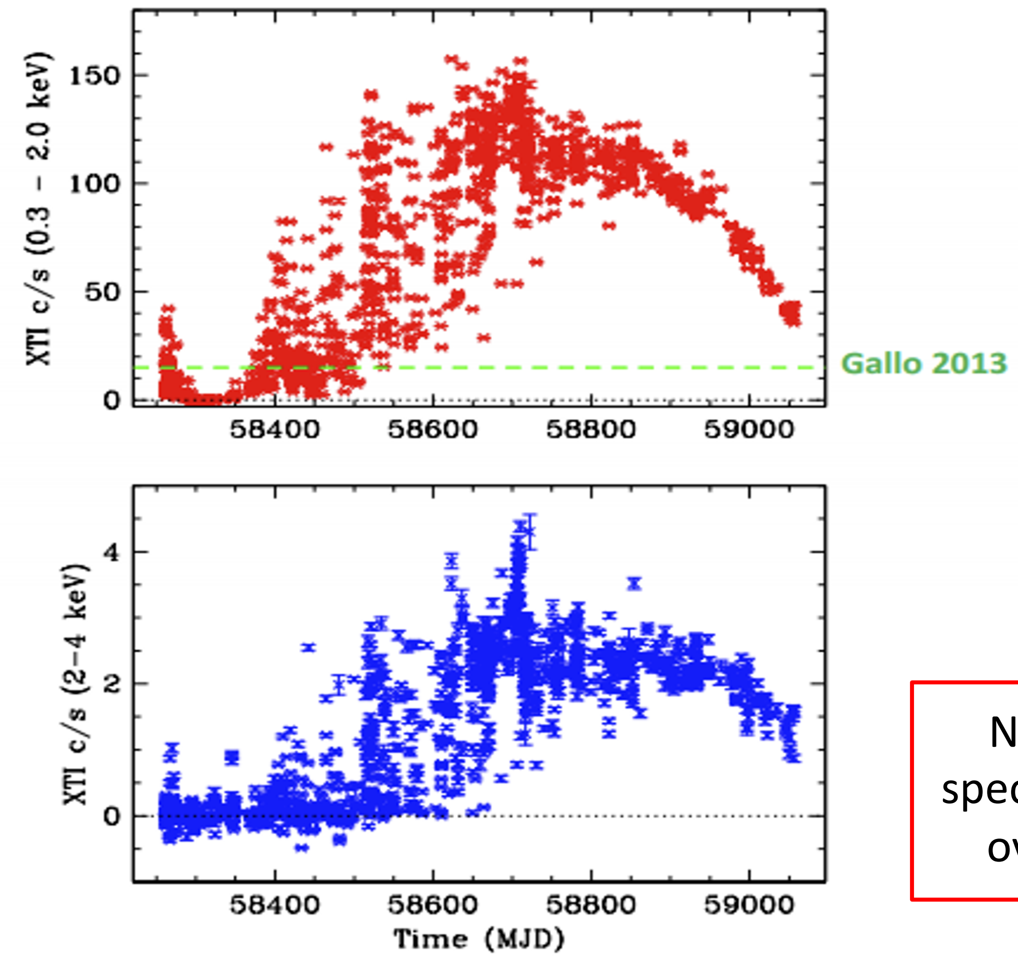
NICER Follow up of Optical Transients

- NICER has a large effective area like XMM-Newton/EPIC with very flexible maneuvering capabilities like Swift
  - Rapid response
  - Long-term monitoring of transients (months to years)
  - High-cadence monitoring of transients (several exposures per day)
  - Best timing accuracy in soft X-rays
  - Ability to handle a huge dynamic range in flux
- These give NICER a great vantage point to chase X-ray transients
- Roughly 2 Msec of NICER time observing ~20 optical transients
  - Mostly TDE events
- ZTF targets in the northern hemisphere typically have good visibility and plenty of unconflicted availability

NICER Optical Transient Observations

Target Name	Type	Notes	NICER Detection?	Total Exposure (seconds)
ASASSN-18el	Changing-look AGN/TDE?	> 2 year campaign; Ricci et al.	Yes	1000000
ASASSN-18ul	TDE	> 2 year campaign	Yes	315000
AT2020ocn	TDE candidate	Ongoing active monitoring	Yes	140000
AT2020nov	TDE candidate	Detects something but not sure what? (definitely not diffuse emission)	Yes	14000
AT2018jcp	AGN in outburst		Yes	8300
AT2018cow	SN	Evidence of compact object	Yes	40000
ASASSN-18fv	Nova	V906 Carinae, Nova Carinae 2018 detected only at high energies (NuSTAR, Fermi)	No	18000
ASASSN-18pg	TDE	Large optical/X-ray	Yes	12000
ASASSN-19yt	CV?	Evidence of lines in X-ray spectrum	Yes	30000
ASASSN-20hx	TDE	GO Cycle 2 target	Yes	
AT2018dyk	Changing-look LINER?	Soft x-ray source	Yes	21000
AT2019ebq	Unknown	Possible LIGO counterpart	No	5000
ZTF19aassfws	Unknown	This is a LIGO target??	No	10000
AT2019dsg	Unknown	Coincident with IceCube neutrino alert; Soft Source that decayed with time	Yes	29000
AT2019ehz	TDE Candidate	Can see decay in X-rays	Yes	6000
AT2019osy	Unknown	Possible LIGO counterpart	No	2500
AT2019pev	AGN flare	Initial flare and then settled to steady flux and spectrum, large X-ray/optical	Yes	91000
AT2019qiz	TDE Candidate	Closest TDE	No	19000
SN2019qyl	SN Candidate		No	18000
AT2019azh	TDE	Caught late-time X-ray brightening	Yes	173000
AT2020neh	IMBH TDE candidate	Prompt follow-up after optical discovery	No	21000

Changing-look AGN ASASSN-18el (z=0.017)



1200+ NICER exposures over the last **22 months** (Note: initially wrongly classified as SN II)

Dedicated NICER monitoring revealed the most compelling evidence (spectrally) to-date of the disappearance and the reappearance of an X-ray corona in an AGN

NICER can provide high SNR X-ray spectra over a long period of time and over a wide dynamic range in flux

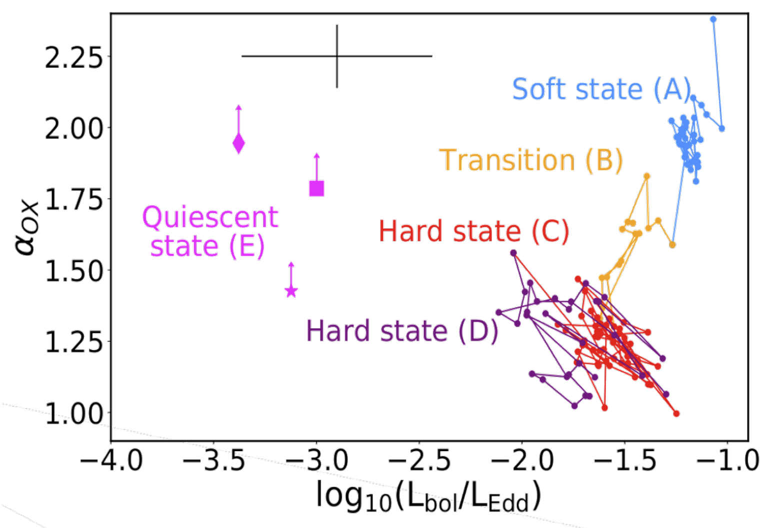
Ricci, + NICER team members 2020, ApJL

ASASSN-18ul

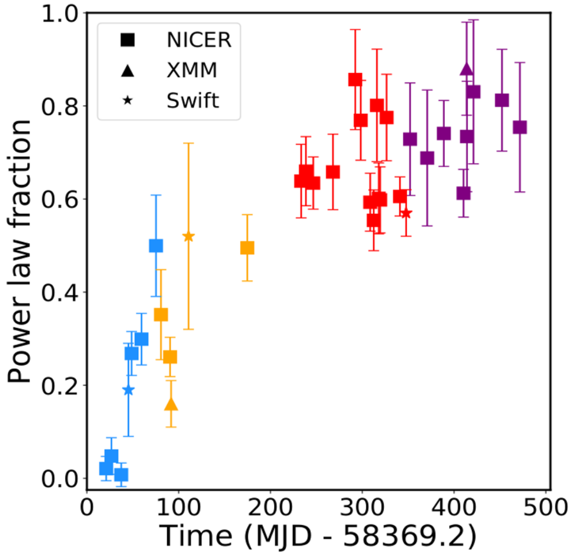
Tidal Disruption Event ASASSN-18ul: Multiple accretion state transitions analogous to stellar-mass black hole X-ray binaries

NICER monitored ASASSN-18ul for 500 days

Equivalent to hardness-intensity diagram of X-ray binaries: α_{ox} tracks the relative strengths of disk and the corona



NICER spectral monitoring shows independently that the X-ray corona is getting energized at late times

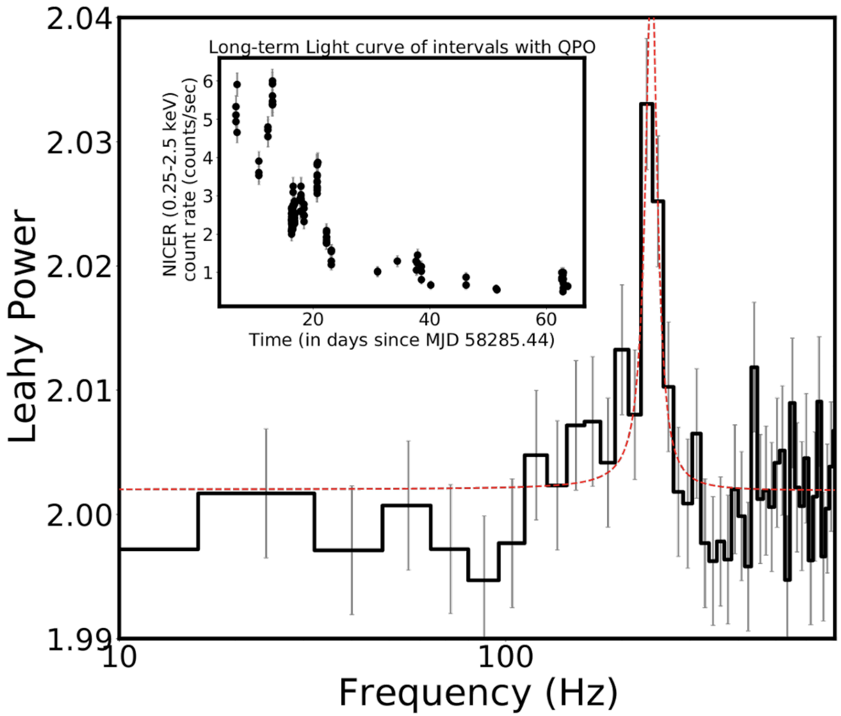


NICER data can work in-conjunction with other wavelengths to maximize the science output

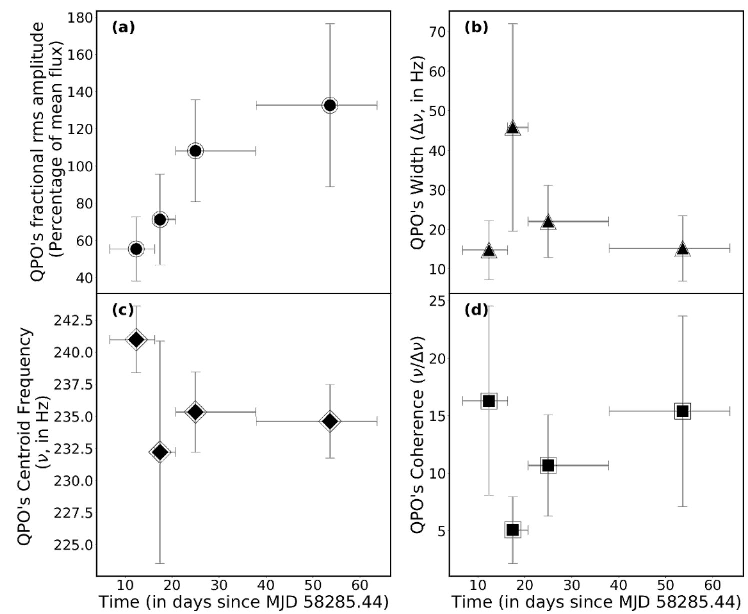
Wevers + NICER team members 2021, ApJ

The "Wow in the Cow" AT2018cow

A high-amplitude quasi-periodic oscillation (QPO) in soft X-rays



Fractional rms amplitude appears to increase as the source fades

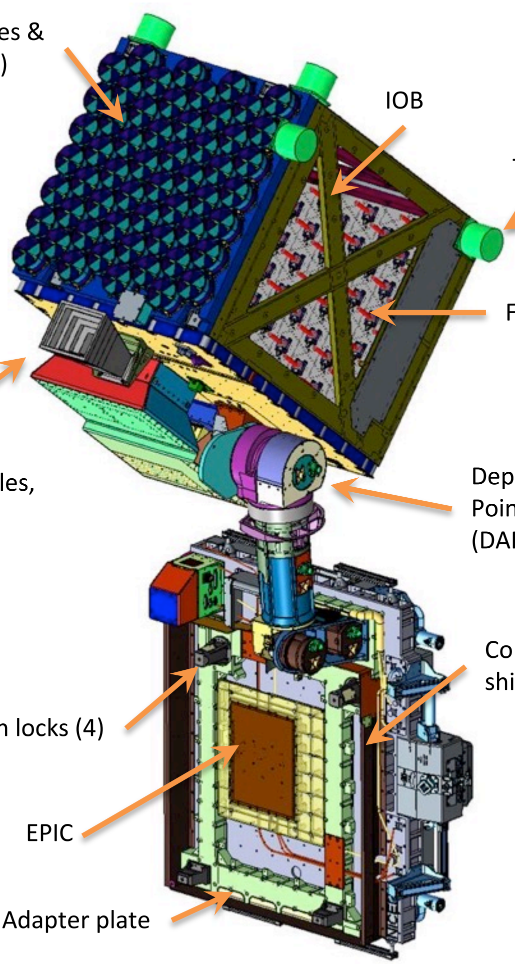


Affirms that AT2018cow was powered by a compact object

Pasham + NICER team members, in prep.

The NICER Payload

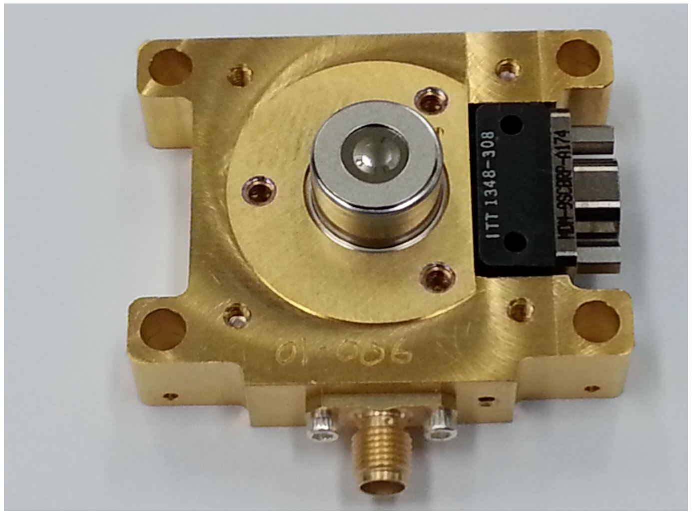
An innovative combination of high-heritage components



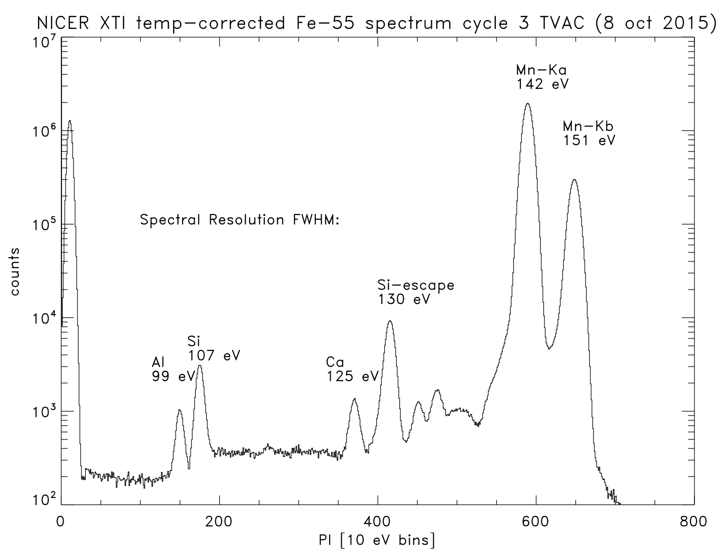
- **X-ray Timing Instrument (XTI)**
  - Assembly of 56 X-ray concentrators (XRCs) and Focal Plane Module detectors (FPMs)
  - Detects individual X-ray photons, returns energy and time of arrival
  - Held together in the Instrument Optical Bench (IOB)
- **Thermal system**
  - Maintains thermal-mechanical alignment
- **Pointing System**
  - Composed of high-heritage components
  - Enables XTI tracking of targets, and slewing between them
  - Stabilized by tuned mass dampers (TMDs)
- **C&DH**
  - Digital interface to ISS for commands, data
  - Supports pointing system
- **Flight Releasable Attachment Mechanism**
  - Electrical & mechanical interface to ISS and transfer vehicle
  - Provided by ISS program

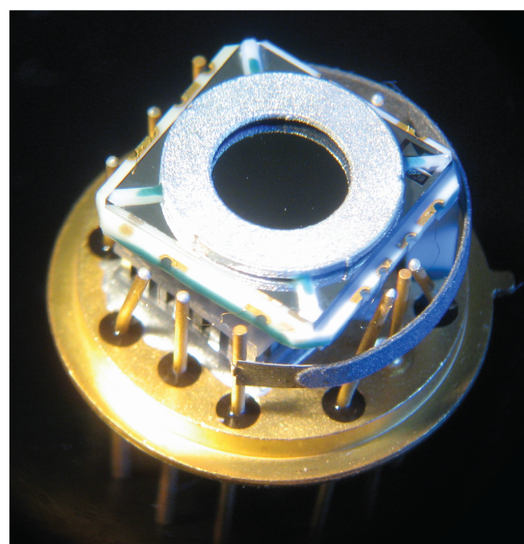
Focal Plane Module (FPM)

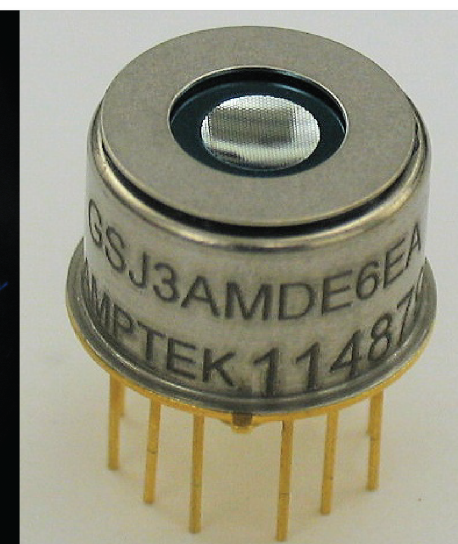
Flight-lot detector in flight housing



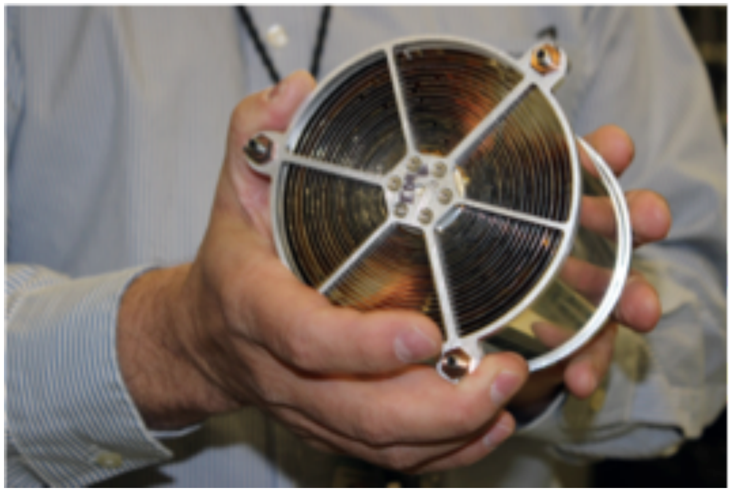
- Commercial silicon drift detectors (SDD) from Amptek Inc. provide CCD-like energy resolution and < 100 ns time resolution with built-in thermo-electric cooling
- Detector window consists of 40 nm of Si_3N_4 and 30 nm of Al. Transmits very low energy X-rays (better than 200 eV) while maintaining a hermetic seal.

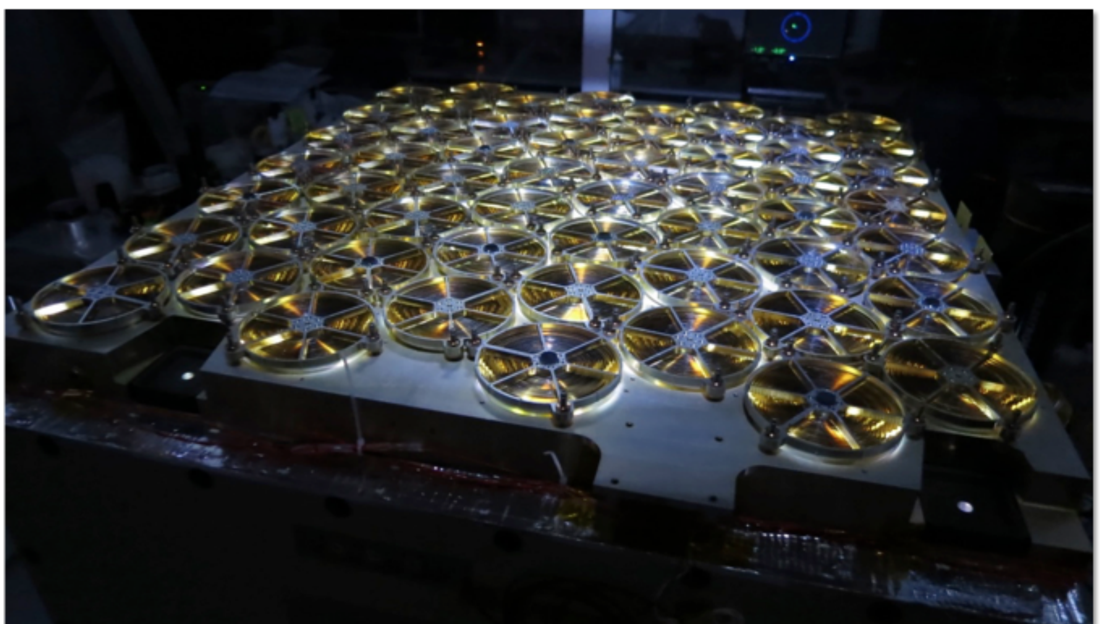






Concentrator optics





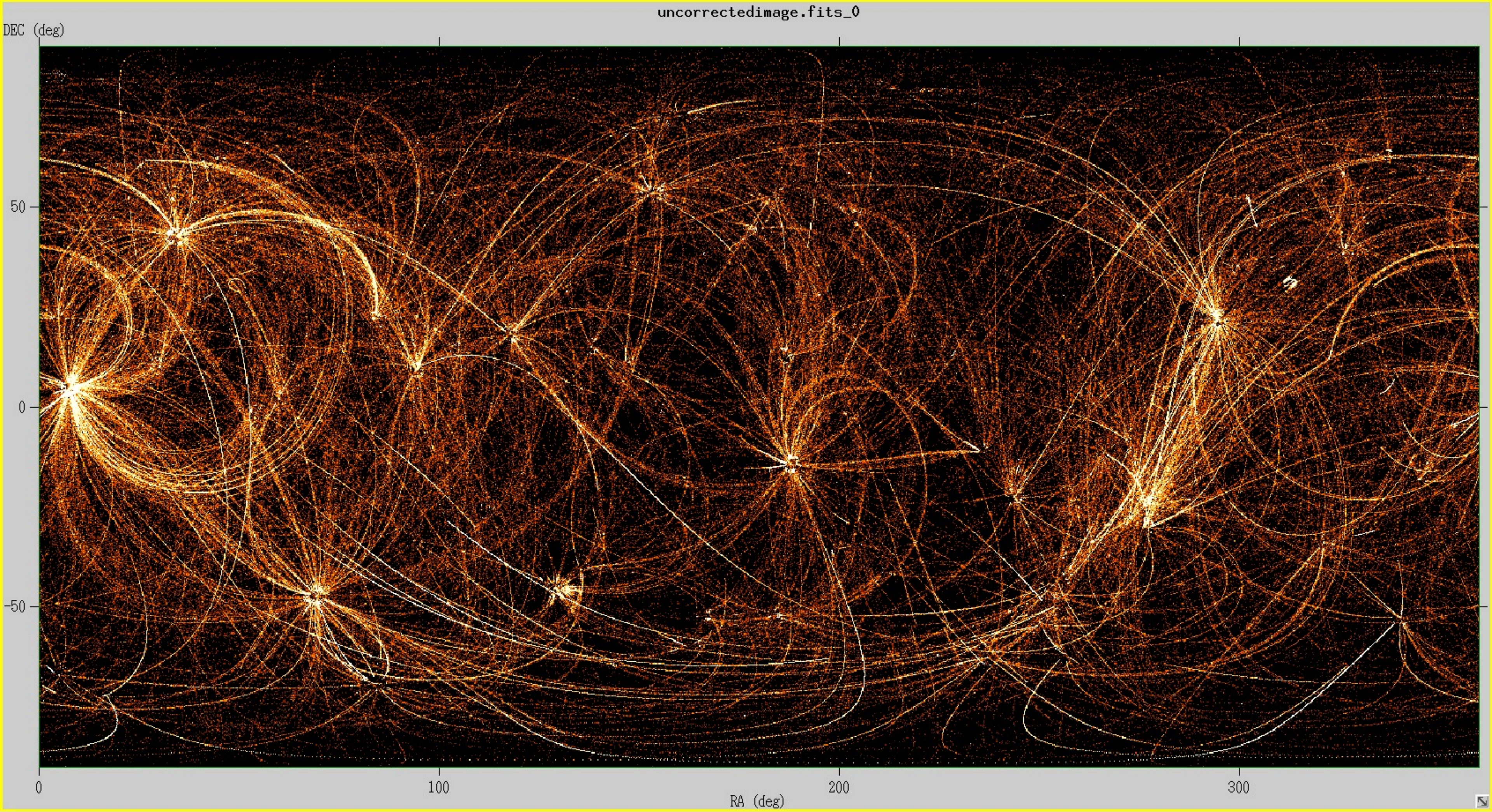
- Thin-foil optics with heritage from *ASCA*, *Suzaku*, and *Astro-H*
- Single-reflection optic to maximize throughput, with limited mass, for isolated point-like sources
- Advances compared to previous GSFC optics:
  - Single shell, not quadrants
  - Parabolic shape, not conical approximation
  - Improved replication and alignment techniques

Publications

- Through FY19, ISS has produced ~1500 peer-reviewed publications
- NICER has published 56 peer-reviewed papers — and counting, at about one per week — as well as 47 Astronomer's Telegrams
- NICER is already a significant contributor, will have a ***major*** impact on the science productivity of ISS as a national laboratory!

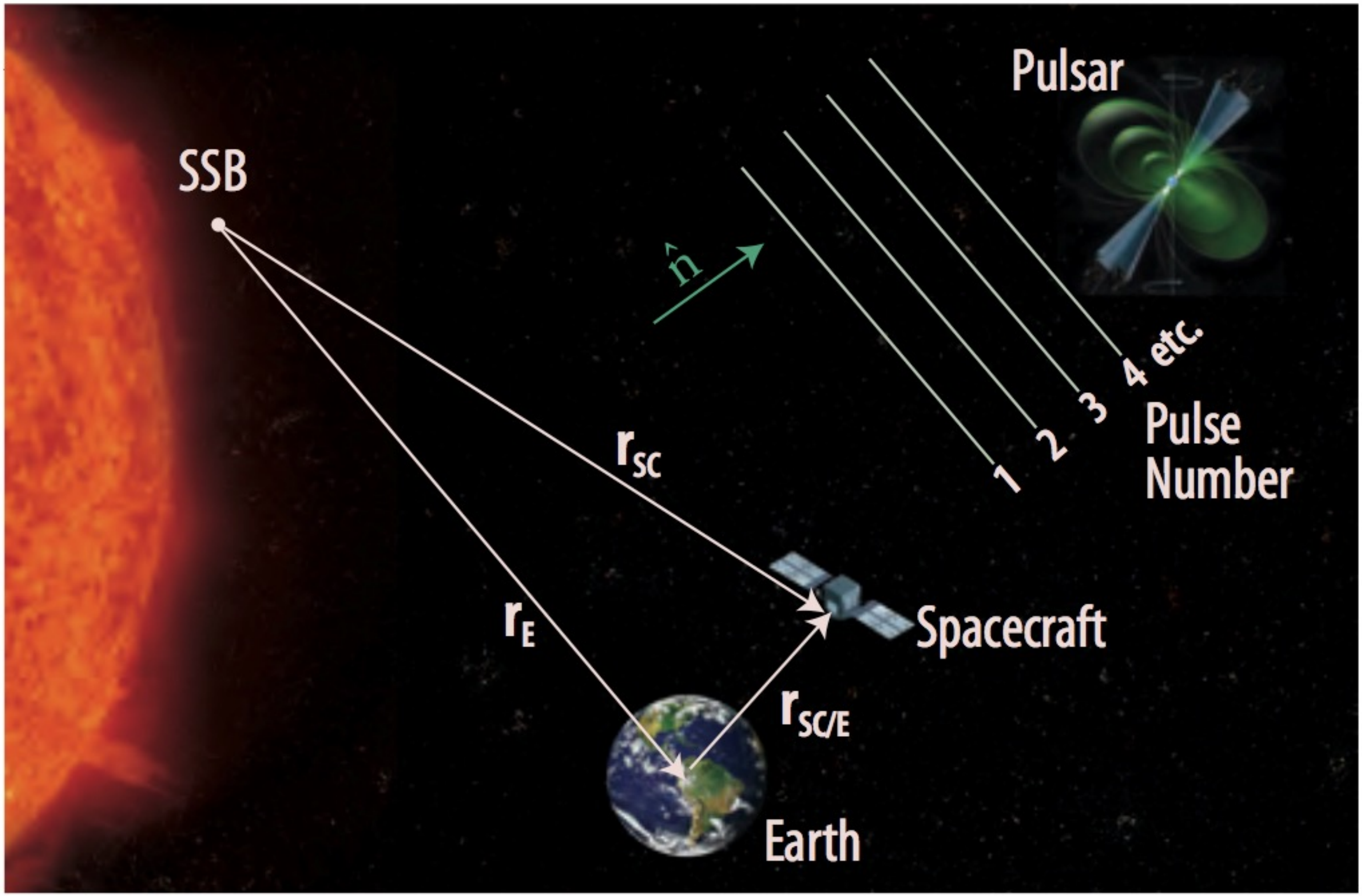
Word cloud of keywords identified in ISS results publications collected from October 1, 2018 - October 1, 2019.

Initial NICER Slew Survey



SEXTANT — Method

Inverting traditional pulsar-timing techniques



SEXTANT success!

First demonstration of autonomous pulsar-based navigation