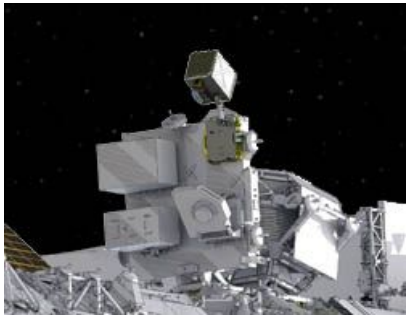
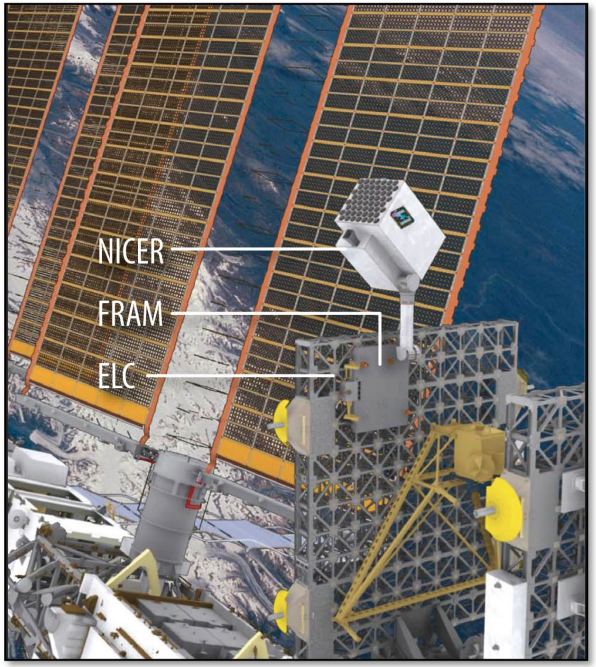
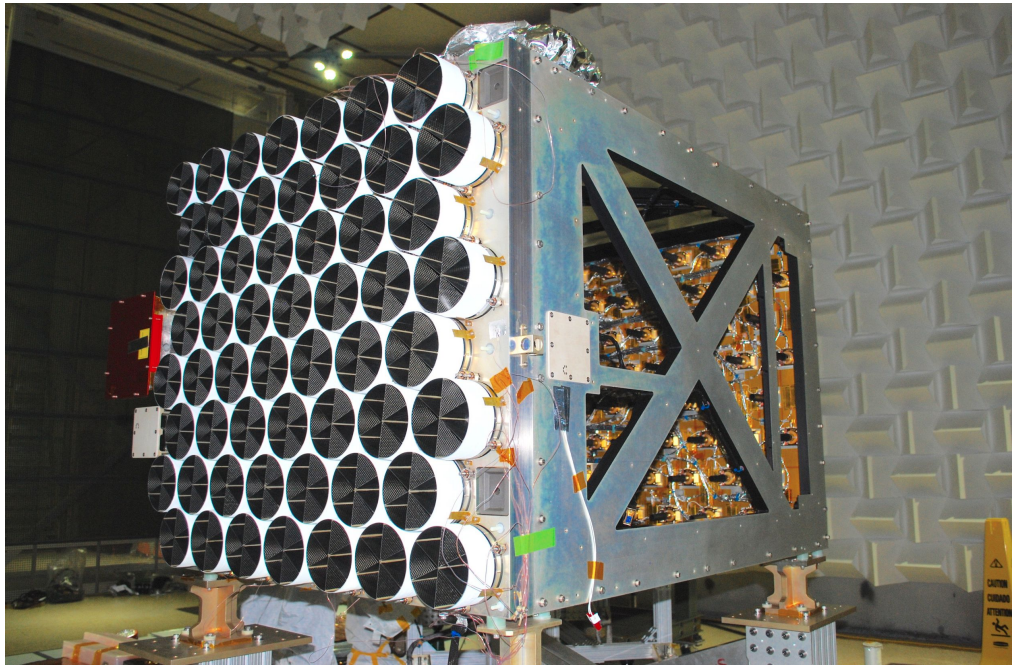
NICER Overview







By Yashvi Sharma

Mission Overview

- ISS Mission of Opportunity, first mission for dedicated study of Neutron stars
- Operating since 13 June 2017
- Celebrated 3 years in space, has observed 577 distinct targets
- Mission officially extended to 2022
    - will continue its flagship science goal of constraining NS equation of state through millisecond pulsar studies
    - will continue Guest Observer (GOs) program
    - will speed up TOO follow-up (specially automated follow up of MAXI targets through On-orbit Hookup of MAXI and NICER or "OHMAN")

Technical Specifications

- Energy range in soft X-rays (0.2 - 12 keV)
- 56 pairs of X-ray concentrators (XRCs) and Focus plane modules (FPMs), each with a roughly 30 arcmin2 FOV.
- Each XRC has 24 single-bounce grazing-incidence reflective parabolic shells with a focal length of 1.085 m.
- FPM (2 mm aperture) consists of Silicon Drift Detector that precisely tags each X-ray photon (2% precision in energy, 100 ns precision in timing)
- Tracking accuracy ~ 66 arcsec more than 99% of the time
- Max effective area ~1900 cm2 at 1.5 keV
- Typically observes 3-6 targets during one ISS orbit
- Moderate spectral resolution (6 to 80 for 0.5 to 8 keV)

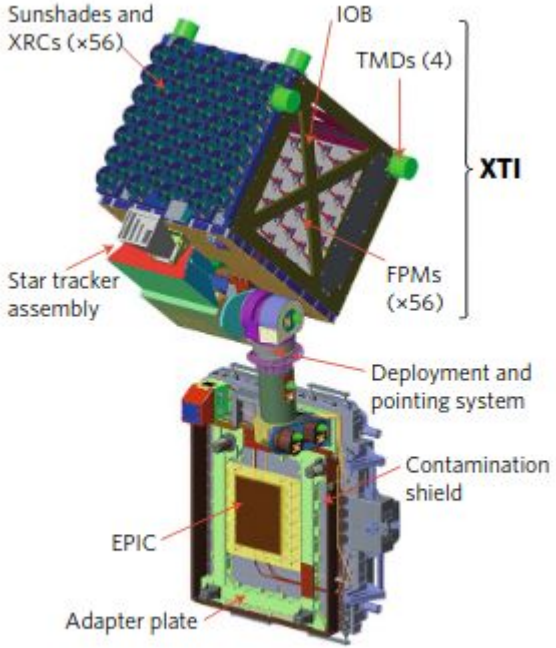
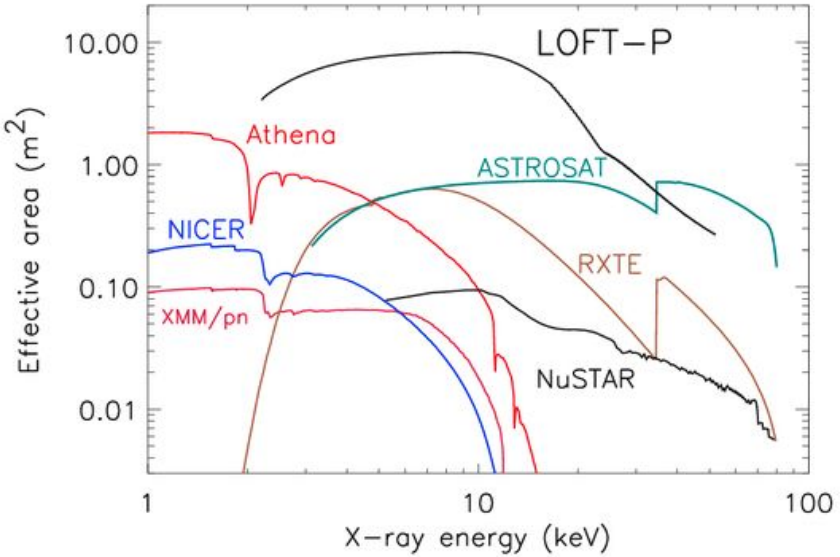


Fig. 1 | Illustration of the NICER payload without thermal blankets installed. Credit: NASA

Concentrators vs Collimators

- Focusing optics : High quality imaging and high SNR but narrow FOV
- Collimators : Uses coded aperture masks, larger FOV and effective area but low sensitivity
- NICER takes the middle ground!
- Order of magnitude improvement in timing resolution, spectral resolution and sensitivity compared to RXTE



Science Goals

- Constrain NS equation of state : Lightcurve modeling group
- High precision timing of MSPs
- Bursts & Accretion physics
- Magnetars and magnetospheres
- Periodicity searches
- Guest Observer Program (GO)
    - Accreting BHs
    - X-ray binaries
    - Stellar flares
- TOO follow-up

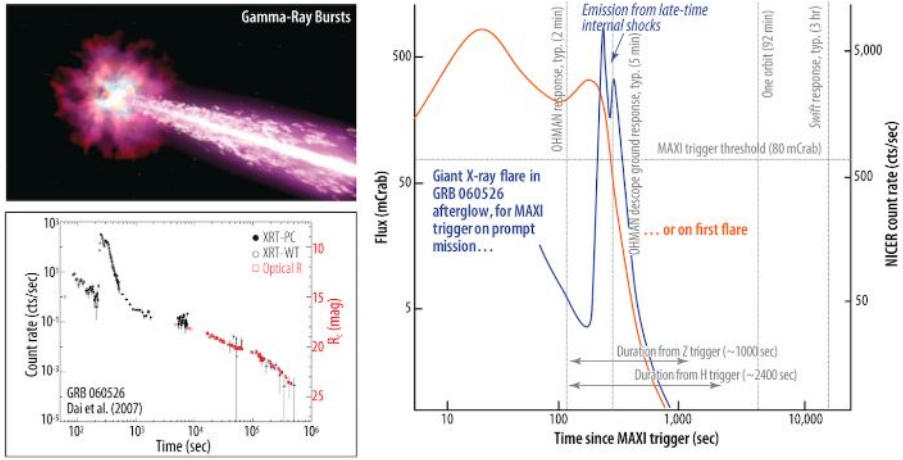
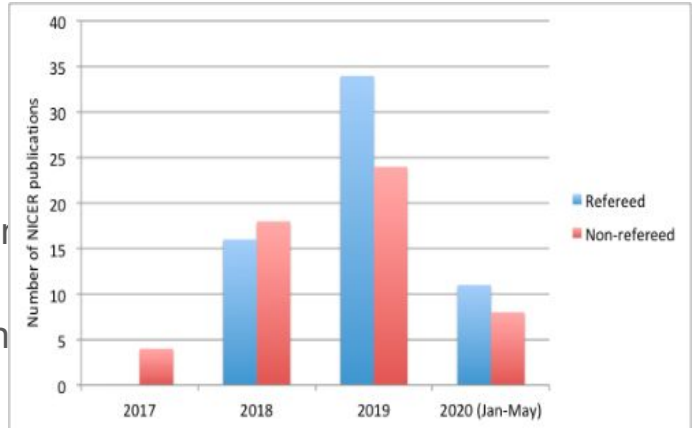
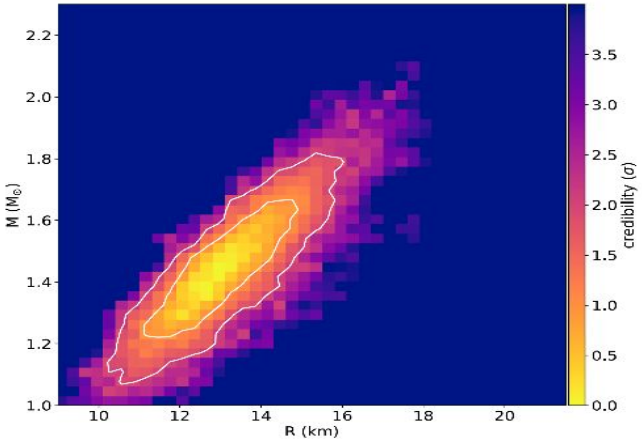


Figure: *With automated OHMAN triggering, NICER's response time for gamma-ray bursts (GRBs) is comparable to NASA's Swift mission, but with 15x the collecting area of Swift's X-ray Telescope (XRT). NICER's large collecting area will enable a new probe of the central engines of these mysterious explosions and the environments in which they occur, through time-resolved spectroscopy of early X-ray afterglows and flares. Swift's lightcurve for GRB 060526 (a gamma-ray flash detected on May 26, 2006) is shown at left and reproduced in the sketch (right): a MAXI detection of the prompt emission (blue) would trigger an OHMAN alert so that NICER observes the initial afterglow and both flare peaks. If instead OHMAN triggers on the first flare (orange), NICER would still observe the second. Swift's response to MAXI triggers is typically 3-6 hours.*

Key Science Results

- Analysis of milli-second pulsar J0030+0451 resulted in
  - first precise (±10%, 1σ) mass and radius measurements for the same star
  - first map of surface "hot spot" locations (1 million Kelvi regions), found both magnetic poles to be in southern hemisphere (one small round shape and other crescen shaped)
  - a new constraint on NS equation of state





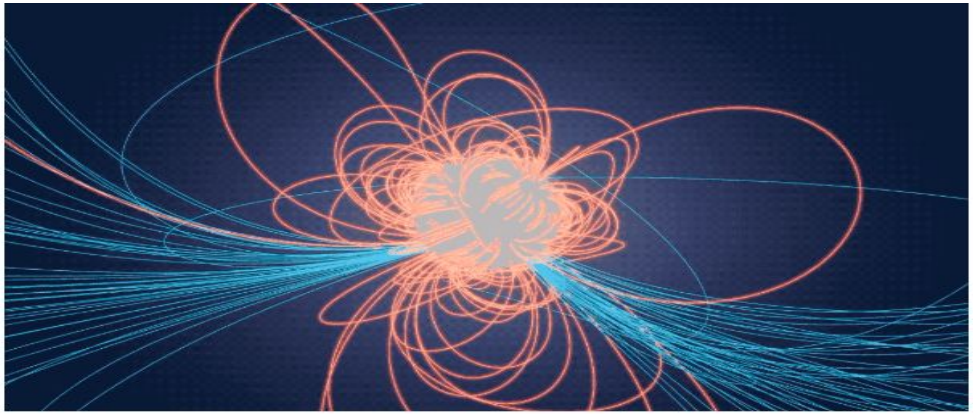


Figure: *Notional magnetic field geometry of PSR J0030+0451 based on the locations and shapes of the magnetic polar caps derived from NICER X-ray measurements. Where the "open" (blue) and "closed" (orange) field lines intersect with the surface is a function of the combined dipolar and quadrupolar field geometries. This image is one frame from an animation viewable here.*

NICER Observations of ZTF TDE

- TOO request to investigate the optical and X-ray transient AT2020ocn at core of a bright galaxy at 0.07 redshift, discovered by ZTF on April 29, 2020 was carried out on 11 July 2020
- Prior Swift X-ray observations showed an X-ray flare at AT2020ocn location suggesting it was a likely Tidal Disruption Event (TDE),
- Time-resolved X-ray spectroscopy by NICER during the rising part of the X-ray emission shows a surprisingly rapid change in the accretion disk formed around the black hole by the stellar debris.

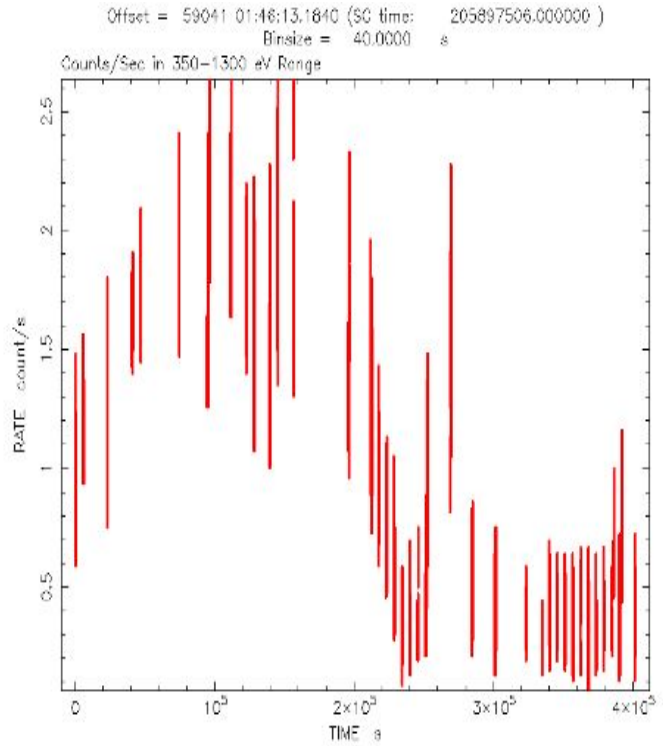


***Figure**: The measured brightness of AT2020ocn as a function of time for X-rays in the energy range 350-1300 eV.*