Time Domain X-ray Astrophysics: ISS-TAO

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ISS - TAO
Transient Astrophysics Observer

• TAO has been proposed to fly to the International Space Station with
  - Wide Field X-ray Imager (GSFC, Leicester, MIT)
  - Gamma-ray Transient Monitor (Technion)

• Primary mission science is X, γ - ray transients from the mergers of Black
  Holes and Neutron Stars and as followup of Gravitational Wave events
  - Also, supernovae, Tidal Disruption Events, Gamma-Ray Bursts

• ISS-TAO and COSI-X are finalists for NASA’s MoO program
  - Concept Study Report submitted May 2018
  - Site Visit in September 2018
  - Final selection any day now
EM Counterparts to GWs

- GWs give masses and possibly spins of merging compact objects
- LIGO localization limited to ~1000 sq. deg. (< 100 with Virgo)
- Coincident EM coincident counterparts increase GW sensitivity
- EM counterparts can be imaged, localizing the host galaxy of the GW source and provide astrophysical context
  - Gamma-, X-ray burst, afterglow
  - Host galaxy, Redshift
  - Gas dynamics, accretion disk, jet?
  - Ejecta after the merger, kilonova
Most Sensitive All-Sky X-Ray Survey

With a 12-fold improvement in sensitivity beyond previous all-sky soft X-ray imagers, ISS-TAO will dramatically extend the discovery space for transient X-ray sources involving black holes and neutron stars. The near continuous ISS-to-ground communications link will allow transient alerts to be rapidly delivered to ground and space observatory networks.

Supernova Shock Breakouts are the elusive short bright X-ray flashes signaling SNe explosions. ISS-TAO will detect them at a rate of ~0.3 per year.

Binary neutron-star mergers produce short-lived strong gravitational waves followed by electromagnetic signals. ISS-TAO will detect these counterparts and provide insight into both their progenitor systems and the dynamics of strong gravity.

Tidal Disruption Events signal the demise of a star when it wanders too close to a supermassive black hole in the center of a galaxy. ISS-TAO will detect >80 per year, elucidating stellar dynamics, and providing supermassive black hole demographics.

Classical and Recurrent Novae are the results of thermonuclear burning on the surface of a white dwarf. ISS-TAO will detect X-rays from their runaway phases.

170 Active Galactic Nuclei will be monitored weekly by ISS-TAO, to search efficiently for modulated X-ray flux associated with the circumbinary disk of inspiraling supermassive black hole binaries.

2-4 high redshift GRB locations per year will be passed from ISS-TAO to ground-based telescopes to JWST, for early universe investigations.
Gamma-Ray Transient Monitor
10 keV to 1 MeV
Scintillator + PMT
Technion Israel

Wide Field Imager (GSFC)
FoV: 18.6x18.6 sq deg
Fast Slew: 4 deg / s
Localization: 1.5'
Energy: 0.4 - 4 keV
Eff. area 2.3 cm²
2 ks sensitivity: $2 \times 10^{-11}$ erg cm⁻² s⁻¹

Micro-channel optics (U. Leicester)
CCDs (MIT/LL)
International Space Station

ELC ESP Berthing Locations on ISS

- PAS-1 (ULF3), STS-129
- PAS-2 (ULF6), ELC2, AMS
- PAS-3 (13A.1), STS-118
- ELC4 (ULF5), STS-133
- PAS-4
- ELC1 (ULF3), STS-129
- UCCAS-2
- STS-134
- ELC3
- UCCAS-1

(on port side of Quest)

(on port side of Destiny)
ISS-TAO Fast on Target

- GW170817 LIGO/VIRGO error circle was about 30 sq. deg.
- GBM error circle was ~ 1000 sq. deg.
- Host galaxy identified only ~11 hours later

- WFI on ISS-TAO can localize GW source within minutes
- Trigger by LIGO (minutes) or by GTM on board (seconds)
Lobster-Eye geometry provides simultaneous large FoV, high position resolution and high sensitivity \( \rightarrow \) Time Domain Astronomy
GTM Requirements

• Gamma-ray bursts
  – Detect as many as possible
  – Detect them as weak as possible
  – Identify direction aiming at WFI FoV of 350 sq. deg.

• Coincidence
  – On board - between detectors
  – With gravitational wave events (LIGO)

• Triggering
  – Notify WFI for quick slewing
  – Report to global astronomical community
Concept - Segmented Detector

- Uniform all sky coverage
Concept - Segmented Detector (2)

- Localization based on count ratios
Adding Central (5th) detector
Summary

• Followup of GW events will significantly improve our understanding of NS and BH mergers
• The transient X-ray sky has never been studied at high sensitivity and with a wide field instrument
• The combination of a wide-field X-ray imager and an all-sky GRB detector are key to being fast on target
• ISS-TAO is ready to meet these challenges of modern high-energy transient astronomy
Thank You for Your Attention
Laboratory Measurements
(with Cs 662 keV source)