

Time Domain and Multi-Messenger Astronomy: NASA Updates Since TDAMM Workshop

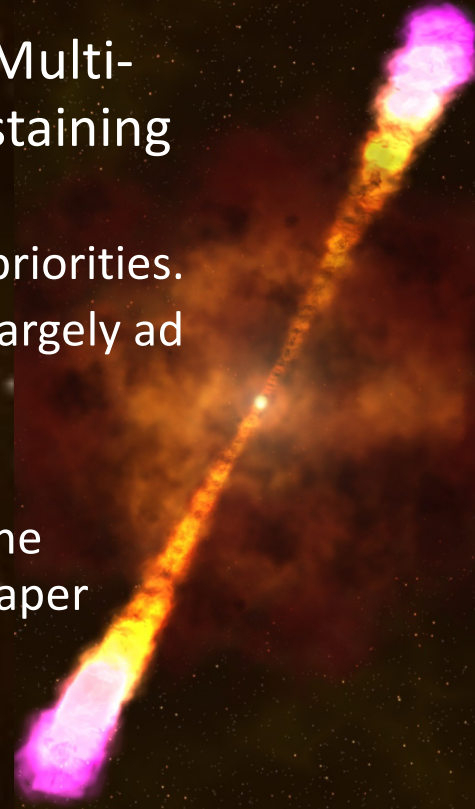
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AAAC mtg, September 19, 2023

Motivation

- The Astro 2020 Decadal Survey identified Time Domain and Multi-Messenger (TDAMM) Astrophysics as the highest-priority sustaining activity in space.
 - ❖ Presently, there is no community-validated set of TDAMM science priorities.
 - ❖ Space-based follow-up observations of Targets of Opportunity are largely ad hoc.
- ❖ NASA Astrophysics Division response:
 - ❖ Hosted a workshop in Annapolis in August 2022 to bring together the community to discuss science opportunities and produce a white paper summarizing science and infrastructure needs.
 - ❖ Asked the Physics of the Cosmos Program office to study implementation options for a TDAMM-focused General Observer Facility.



Outline

- NASA TDAMM Workshop: Recap of the White Paper Findings
- PhysCOS TDAMM Study & Astrophysics Cross-Observatory Science Support (ACROSS) pilot initiative
- PhysPAG initiatives
- NASA attendance at Gravitational-Wave Agencies Correspondents (GWAC)



TDAMM Workshop White Paper: Science

Source Class	EM	ν	Lo-f GW	Hi-f GW	CR	Phenomena
White Dwarfs	★		★			Type Ia SNe, WD+WD mergers, detached WD binaries, novae, accreting WD LISA sources, accretion induced collapse, WD+NS/BH binaries
NS / BH	★	★		★		X-ray binaries, NS+NS mergers, NS+BH mergers, gamma-ray bursts, core-collapse SNe, common envelope events, stellar mergers, fast and blue optical transients
SMBH	★	★	★		★	blazars, tidal disruption events, extreme-mass ratio inspirals, binaries, coalescences, and recoiling systems, compact-object mergers in AGN disks
Unknowns	★				★	fast radio bursts, fast X-ray transients, pevatrons, “unknown unknowns”
Interdisc.	★	★	★	★		fundamental physics, cosmology, dense matter

TDAMM Workshop WP



<https://pcos.gsfc.nasa.gov/TDAMM/>

White Paper: Findings (1/2)

- Real-Time Cyberinfrastructure:
 - ❖ Real-time transient detections.
 - ❖ Sw to do joint data analysis.
 - ❖ Archive coordination.
- Theory Funding:
 - ❖ Specific urgent topics.
 - ❖ Interdisciplinary aspects w/ physics, lab Astro, cosmology.
 - ❖ Precursor/preparatory science.
 - ❖ High Computing simulations.
- TDAMM General Observer Facility
 - ❖ To streamline transient follow-up with NASA facilities.
 - ❖ Reduce coordination burden for observers.
 - ❖ Provide scheduling options.
 - ❖ Assist with proposal preparation and submission.
 - ❖ Manage funding.

TDAMM Workshop WP



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White Paper: Findings (2/2)

- Training a diverse workforce:
 - ❖ Capitalize on TDAMM science to inspire STEM.
 - ❖ Build on core value of Inclusion from the start.
 - ❖ Ensure diversity of PIs.
- Crediting hidden figures:
 - ❖ Data scientists, Sw/Hw developers, managers.
 - ❖ Ensure appropriate rewards and recognition are in place.
- NASA-NSF-international coordination:
 - ❖ Optimize observing schedules.
 - ❖ Archives and alerts standardization.
 - ❖ Joint proposal opportunities.
- Continuity of capabilities across the EM spectrum:
 - ❖ Timely replacement of aging telescopes.

TDAMM Workshop WP



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White Paper: Ongoing Engagement with Community

- White paper will be revised and published as a review article in a special issue of *Frontiers of Astronomy and Space Sciences*:

“The Dynamic Universe: Realizing the Potential of Time Domain and Multimessenger Astrophysics”

- Solicited additional contributions from community with focus on the potential for the variable source to be a Multi-Messenger source, i.e., the likelihood of being detected in the future with Gravitational Wave detectors (e.g., LVK, LISA) and/or neutrinos. Papers focusing on mission concepts are NOT allowed.

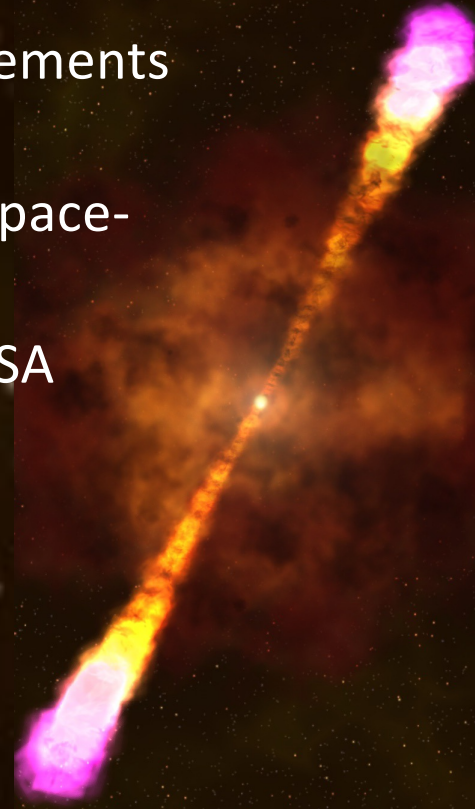
- ❖ 36 proposed topics submitted.
- ❖ Papers due January 2024.
- ❖ Editors: Rita Sambruna & Francesca Civano.

Link to the call:



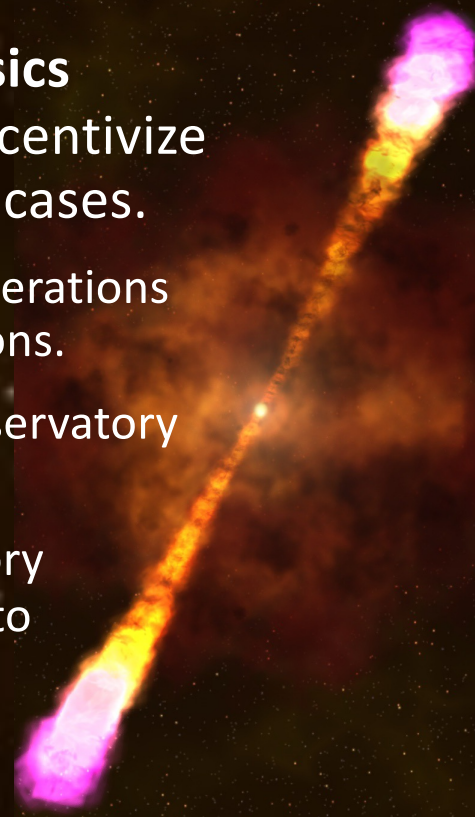
PhysCOS TDAMM Study

- In October 2022, PhysCOS initiated a study to identify requirements and formulate implementation options for a TDAMM GOF.
- Phase 1 of the study investigated the coordination of NASA space-based missions.
- Phases 2-3 of the study (2024-25) will address aspects of NASA space-based mission coordination with ground-based and international facilities.



Summary of Initial Findings: ACROSS

- NASA HQ authorized a two-year pilot phase of the **Astrophysics Cross-Observatory Science Support (ACROSS)** initiative to incentivize and facilitate the planning and execution of TDAMM science cases.
 - ❖ Emphasizing development of cross-observatory science-support operations concepts, tools, and infrastructure to facilitate follow-up observations.
 - ❖ Primary users of ACROSS capabilities are general observers and observatory (mission) science teams.
 - ❖ To incentivize community development of TDAMM cross-observatory science cases, ACROSS is collaborating with mission science teams to develop a general observing competitive research grant solicitation and program, targeting an inaugural call for proposals for 2026.



ACROSS Activities

➤ We focus initial development on the following technical capabilities:

- ❖ Procurement and configuration of collaboration IT services that work across NASA IT boundaries to facilitate/improve cross-mission follow-up planning and execution.
 - X-Ray missions GW follow-up planning meeting and **coordination led by Brad Cenko (GSFC)**.
- ❖ A multi-messenger web portal, with content curated by **Dan Kocevski (MSFC)**.
 - Includes links to existing mission resources, community tools, and information targeted for TDAMM General Observers.
- ❖ Development of ToO toolkit capabilities led by **Jamie Kennea (Penn State)**.
 - Minimum viable product is a webform; embedded science feasibility and constraint calculators make the ToO page “smart.”
 - APIs with existing missions (or migration of their ToO pages) allow global situational awareness through the web portal.

ACROSS Timeline

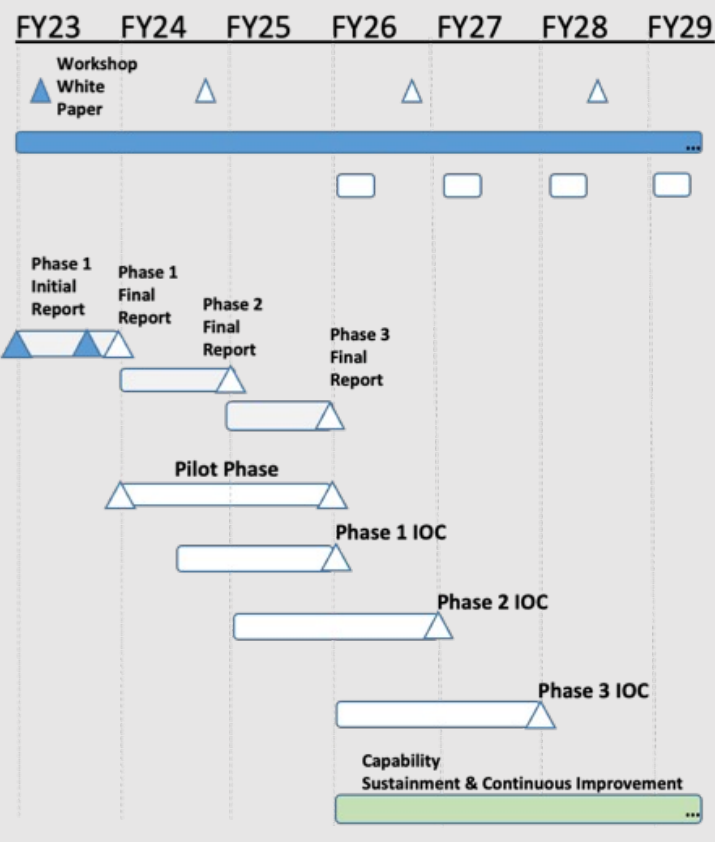
Science Community Engagement

- Series of TDAMM Workshops
- PhysPAG/TDAMM SIG Coordination
- Annual Call for Proposals

System Development

- Study Phase
 - Top Level Requirements, Concepts and Implementation Strategy
- Definition/Development
 - Pilot & prototypes for NASA assets
 - Phase 1 TDAMM Follow Up Capability for NASA Assets
 - Phase 2 TDAMM Follow Up Capability for US Gov Assets (NSF etc.)
 - Phase 3 TDAMM Follow Up Capability for International Assets

Operations



- Phases 2-3 of the study (2024-25) will address aspects of NASA space-based mission coordination with ground-based and international facilities.

TDAMM Science Interest Group



- Chaired by Eric Burns (Phys), Rebekah Hounsell (Phys), Brad Cenko (CO), Ian Crossfield (EXO).
 - ❖ Representing all Physics Analysis Groups: Physics of the Cosmos, Cosmic Origins, Exoplanet Exploration.
- Objectives:
 - ❖ **Provide analysis and feedback to NASA** on the impact of the Astronomy & Astrophysics Decadal Survey on the subfield.
 - ❖ **Identify and articulate “science gaps”**: gaps between the current state of knowledge in the subfield and the goals outlined by the Decadal Survey that require new data in order to fully define new missions (precursor gaps), prepare for approved missions that are in development (preparatory gaps), and maximize the science return from current missions (follow-up gaps).
 - ❖ **Serve as ambassadors to facilitate communications between NASA and the science community**. In particular, act as the interface to relevant TDAMM communities outside NASA’s immediate sphere e.g., ground-based observers, physics facilities.
 - ❖ **Engage in scientific discussions and exchange of ideas** through meetings and seminars to make best use of NASA assets for current research and to assist NASA in strategic planning in TDAMM activities.
 - ❖ **Propose and organize TDAMM sessions at conferences and arrange other public meetings** as appropriate.
 - ❖ **Establish and disseminate best practices for conducting TDAMM science**, for missions both in development and in operations, and for observers and investigators, including in regards to sharing and citing data in an era of open data.
- Kick-off session at the 243rd AAS (January 2024).

Gamma-ray Transient Network Science Analysis Group

- Co-chairs: Eric Burns, Michael Coughlin. 50+ SAG members.
- 70+ pages report delivered to NASA HQ.
- Report Findings:
 - ❖ Multidisciplinary TDAMM science enabled by observations of magnetars, compact mergers, collapsars across electromagnetic, gravitational wave, and neutrino spectra.
 - Implications for gamma-ray bursts, supernovae, fast radio bursts, multimessenger sources, etc.
 - ❖ Focused section on how instrumental capabilities flow to specific scientific outcomes.
 - ❖ Actionable items for improving TDAMM return from current/forthcoming/future NASA missions.
 - E.g. “Immediately enacting the additional data downlinks requested by Swift during Senior Review would provide strong scientific return for low operational cost, with potential groundbreaking discovery given LIGO is now observing.”
 - ❖ Holistic exploration on enhancements to the InterPlanetary Network (IPN) operations to maximize TDAMM science return with existing facilities.
 - E.g. treating all gamma-ray burst monitors as a single effective telescope (within existing international agreements) would vastly improve sensitivity without launching new hardware.

GTN SAG Report



TDAMM Space Communications Science Analysis Group

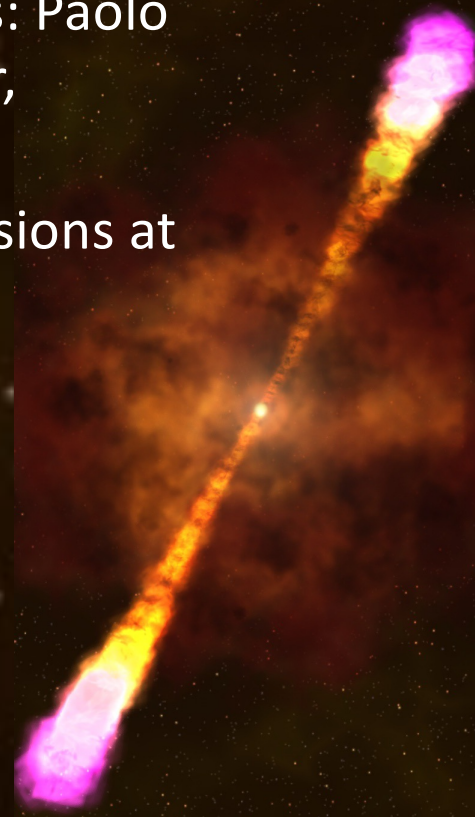


- Co-chairs: Jamie Kennea, Judy Racusin. 20 SAG members.
- Objectives:
 - ❖ NASA's Tracking and Data Relay System (TDRSS) will be replaced circa 2030 by a commercial service.
 - ❖ SAG will explore requirements of a future communication system based on TDAMM science drivers.
 - ❖ Addressing science drivers, non-LEO orbits, bandwidth requirements, latency and coverage, cost, availability and scheduling, future capability, impacts of not meeting requirements.
- Aim to deliver report by end of calendar year.

Drivers of Future Gamma-ray Astrophysics SAG

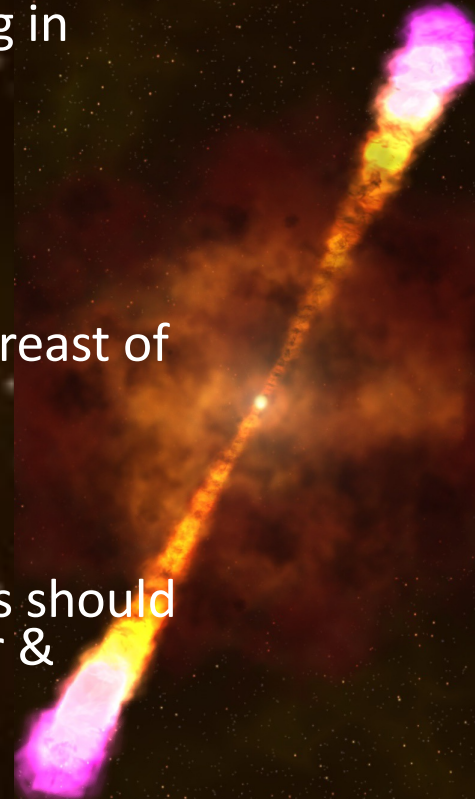
- Lead co-chairs: Chris Fryer, Michelle Hui. Additional co-chairs: Paolo Coppi, Milena Crnogorčević, Tiffany Lewis, Marcos Santander, Zorawar Wadiasingh.
- Objective: to study science drivers for future gamma-ray missions at all size scales over 5-20 year time horizon.
 - ❖ Including TDAMM science cases.
- Terms of Reference in formulation.
- Kick-off session at the 243rd AAS (January 2024).

Gamma-ray SIG



NASA Attendance at GWAC

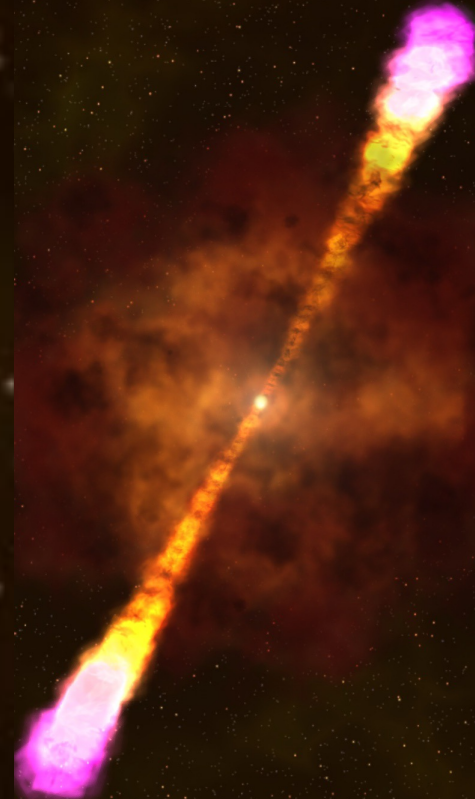
- Gravitational-Wave Agencies Correspondents – NSF-led committee involving representatives from international facilities participating in Gravitational-Wave science.
<https://www.nsf.gov/mps/phy/gwac.jsp>
- To date NASA's participation has been LISA-centered.
- V. Connaughton attended the telecon in March as TDAMM lead.
- Main focus of APD interest from TDAMM perspective: keeping abreast of developments in ground-based GW experiments & activities.
 - ❖ Timing and duration of Science Runs.
 - ❖ Any changes to configurations and/or schedules that could impact NASA counterpart observations.
- One of Astro 2020 recommendations for NASA: future capabilities should be planned taking into account the landscape of multi-messenger & international facilities.
 - ❖ Seat at GWAC table facilitates this planning.
 - ❖ ACROSS pilot activities are motivated in part as a response to O4.



Summary

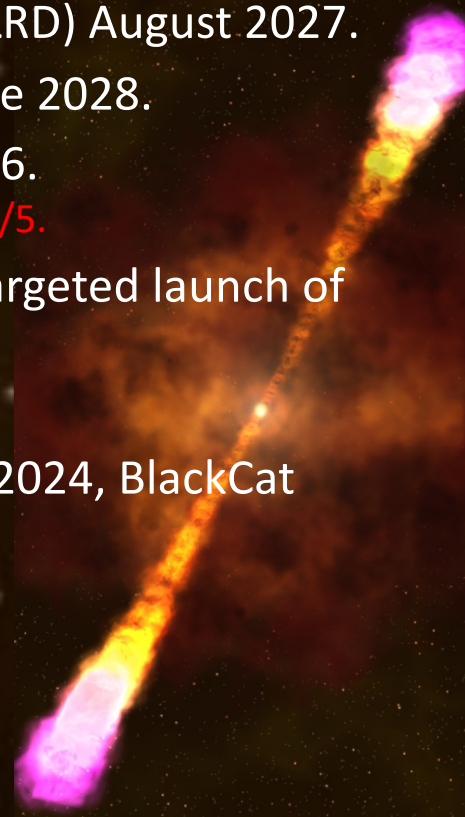
- Throughout Astro 2020 examples of TDAMM science display the breadth of science that comes under the TDAMM umbrella.
- TDAMM science is broad but the recommendations for NASA are narrow:
 - ❖ Space-based counterparts to potential multi-messenger phenomena.
 - ❖ Maintenance and replacement of “workhorse” missions that have contributed so much to TDAMM science.
 - Workhorses can be monitors (counterpart or trigger for observations) or follow-up telescopes.
 - ❖ Planning TDAMM workhorses within a changing international & interagency landscape.
 - Astro 2020 mentioned need for sensitive gamma-ray & X-ray monitors & UV follow-up capability.
- NASA is concentrating on the infrastructure aspect:
 - ❖ Updated alert system for the Rubin era of 10M transients per night.
 - ❖ More efficient use of existing resources – PhysCOS study & ACROSS pilot: existing mission responses & recommendations for efficiencies for both missions and investigators.
 - ❖ Development of multi-mission software tools to enable TDAMM science.
- Workhorse question to be answered within program of record and new missions within fiscal constraints. TDAMM White Paper & follow-up volume & SAGs to lay out open science questions these workhorses need to consider most urgently.
- Anticipating 2nd NASA TDAMM workshop to be held Fall 2024; planning to begin after the NSF WOU workshop in October.

Backup



Upcoming TDAMM Missions

- Compton Spectrometer and Imager (COSI) Launch Readiness Date (LRD) August 2027.
- NEO Surveyor – TDAMM aspect of Planetary IR mission LRD NET June 2028.
- NASA Participation in Israeli Space Agency's ULTRASAT LRD June 2026.
 - ❖ 14 US-based scientist selected through ROSES-22 D.19 to join Science Team 6/5.
- Downselect of Explorers in 2024: Star-X and UVEX (Mid-EX) with a targeted launch of FY '29, MoonBeam and LEAP (MoO) targeted launch of FY '28.
- Pioneers: StarBurst LRD 2026, PUEO 2024, TIGERISS 2026.
- SmallSats & ISS: GlowBug launched to ISS 3/15/23, BurstCube early 2024, BlackCat LRD 2024.
- Roman – Julie McEnery update.
 - ❖ TDAMM news in this presentation.
- LISA – NASA contribution to ESA mission.
- APRA: suborbitals & technology development.
 - ❖ The Lobster-eye X-ray Telescope (LXT) sounding rocket mission (PI Galeazzi) selected APRA 22.



Nancy Grace Roman Space Telescope as a TDAMM Mission

- Roman will conduct at least two significant time-domain astronomy surveys defined by Astro2010:
 - ❖ Galactic Bulge – 15min cadence, ~2 sq. deg., timescales up to 5 years: stars & planets.
 - ❖ High Latitude – ~5-day cadence, ~20 sq. deg., timescales up to 2 years: SNe, active galaxies, TDEs.
- Roman has adjusted its science planning to elevate the level of support for time-domain astronomy in response to Astro2020 starting in FY24.
- Roman's Project Infrastructure Teams associated with time-domain astronomy are planning on:
 - ❖ Enabling rapid image differencing.
 - ❖ Providing prompt variable/transient alerts to brokers within ~24hrs of processing.
 - ❖ Supporting light curves, photometry, moving object identification, catalog production.
 - ❖ Developing tools to classify various transient phenomena.
 - ❖ Developing tools to enable time series Roman photometry from external triggers.