ACROSS: Enabling Time Domain and Multi-Messenger Astrophysics

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Abstract. The U.S. Astro2020 Decadal Survey recommended an investment in Time Domain and Multi-Messenger Astrophysics (TDAMM) as the top-priority sustaining activity in space for the coming decade. One aspect of NASA's response to this recommendation is a pilot project, the Astrophysics Cross-Observatory Science Support (ACROSS) Initiative, designed to provide support to both missions and observers as they pursue TDAMM science. In this talk, we present our observations of needs in the community and initial plans for ACROSS activities, including services to facilitate and improve cross-mission follow-up planning and execution; a multi-messenger web portal with links to existing mission resources, community tools, and information targeted for TDAMM General Observers; development of "Smart Target of Opportunity submission page" proof-of-concepts; and ongoing development of a potential TDAMM general observing competitive grant solicitation. While the initial focus has been to enhance coordination between NASA missions, we are eager to work with ground-based and international partners as well. We invite discussion with both missions and observers to better understand their needs and concerns as ACROSS progresses. Here we present our efforts on the web-portal and API, along with our development to support NASA's BurstCube mission.

1. Introduction

The year 2017 provided two remarkable firsts – the first coincidence of a gravitational wave (GW) event, GW170817, with a short gamma-ray burst (GRB), kilonova, and off-axis jet (Abbott et al. 2017) and the first strong indication of an association between an astrophysical neutrino, IceCube-170922, and an active galactic nucleus (AGN), TXS 0506+056 (IceCube Collaboration et al. 2018) – which motivated the Astro2020 Decadal Survey (National Academies of Sciences, Engineering, and Medicine 2023) to highlight the new capabilities encompassed by Time-Domain and Multimessenger Astrophysics (TDAMM) as the "highest priority sustaining activity" in space for the

coming decade. Astro2020 recognized that to "advance this science, it is essential to maintain and expand space-based time-domain and follow up facilities." In the coming years, exploration of the broad range of science accessible via multimessenger observations will be enabled by NASA's fleet in synergy with ground-based observatories spanning all messengers.

NASA has recognized that in order to meet the vision outlined in the Astro2020 Decadal Survey it must invest in the infrastructure needed to enable multimessenger and time-domain astronomy discoveries. NASA's Physics of the Cosmos Time-Domain and Multimessenger (TDAMM) Initiative forms a portion of NASA's response to the Astro2020 Decadal Survey and has been tasked with (1) organizing or supporting TDAMM workshops; (2) conducting a three-year TDAMM Study investigating policy, processes and technical coordination mechanisms to enable TDAMM science; and (3) recommending one or more potential implementations for enabling TDAMM science support. The Astrophysics Cross-Observatory Science Support (ACROSS) pilot project is an outcome of the first year of the TDAMM study, which identified needs for: (1) software and data systems to facilitate TDAMM science workflows; (2) a TDAMM help desk to provide expertise and facilitate coordination; and (3) a TDAMM community grant program to incentivize scientific innovation.

ACROSS fits in between observers and mission science teams to assist with handling complex, multi-observatory follow-up observations, as indicated by Figure 1. In the following sections, we describe plans for the implementation of the software tools and data systems during the pilot phase of ACROSS, with a target of releasing an initial set of tools and web portal in the fall of 2025. A more complete description of the results of the first year of NASA's TDAMM study and plans for ACROSS can be found in Humensky et al. (2024).
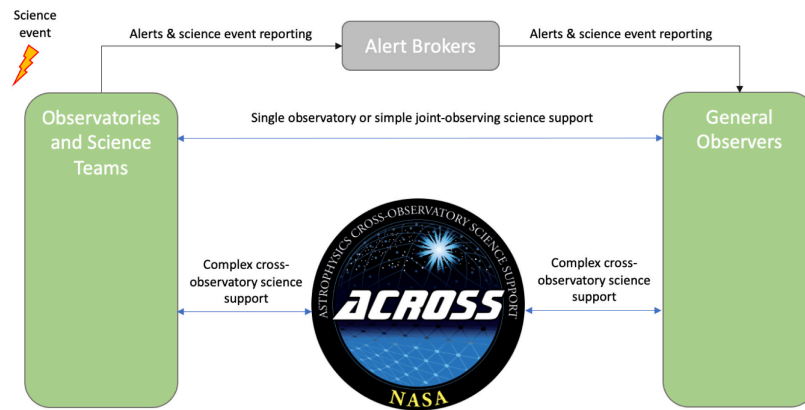

Figure 1.   Schematic of the transient follow-up ecosystem, illustrating the role played by ACROSS as a facilitator of complex multi-observatory follow-up programs. Green: clients/users. Gray: science support infrastructure.

2.   TDAMM Workflow Status Dashboard, Web Services, and Toolkit

One of the critical objectives of ACROSS is to expose mission science status and planning information in a way that is easy to find and digest for both observers and missions. ACROSS plans to build a collection of open-source software products that can

be instantiated to streamline, standardize, and automate TDAMM planning workflows. ACROSS will develop live dashboards of NASA observatory status parameters relevant for TDAMM science planning and execution, including observing plans for recent past and near future. REST API access will also be available to easily incorporate these information streams into observer and operations team planning and execution tools, in both JSON and Virtual Observatory (VO) compliant formats.

All ACROSS web services will be available through a web portal that is currently under development. The services will be hosted in the cloud, with both human and machine interfaces, providing: (1) multi-observatory science situational awareness, follow-up planning, and feasibility analysis tools; (2) a follow-up hub collating information about recent interesting events and providing easy access to submission portals for target-of-opportunity observation requests; and (3) tools providing follow-up decision support and recommendations, such as guidance on the most suitable observatories to meet the goals of an observation.

3. ACROSS and BurstCube

BurstCube (Myers et al. 2024) is a 6U cubesat designed to detect gamma-ray bursts and other high-energy transients. Its onboard storage is a ring buffer designed with a depth of roughly 2 days, but the mission did not have the bandwidth to download all of its data to the ground. BurstCube can self-trigger on bright transients and prioritize the data recorded around the time of the transient for download. To enable BurstCube to also prioritize for download the data associated with events triggering other ground- and space-based telescopes, including gravitational-wave detectors, ACROSS worked with the BurstCube team to build a burst-alert API and dashboard. A snapshot of the dashboard is shown in Figure 2. For each event, the trigger time and the fraction of the event's localization region that fell within BurstCube's field of view at the time of the trigger are shown, and additional information is available under the "Show Trigger Info" button. The BurstCube team used these tools during the mission's ~5-month lifetime to prioritize data for download.

trigger_time	trigger_info	too_info
2024-05-07 04:16:32.362000	Show Trigger Info	Probability inside FOV: 70.86%.
2024-05-07 04:16:32.352000	Show Trigger Info	Probability inside FOV: 25.74%.
2024-05-06 10:20:29.884000	Show Trigger Info	Probability inside FOV: 81.18%.
2024-05-04 13:31:47.236000	Show Trigger Info	Probability inside FOV: 92.41%.

Figure 2. Example snapshot of the burst alert dashboard created for BurstCube.

4.   ACROSS and Virtual Observatory

ACROSS aims to make cross coordination of observations easier for NASA missions and beyond, to enable TDAMM science; building on existing standards and tools already in use by the community is a key part of the ACROSS strategy. Therefore, ACROSS software tools are being built with support for VO standards. Implementations of Observation Locator Table Access Protocol (ObsLocTAP) and Object Observability Simple Access Protocol (ObjObsSAP) will be provided by ACROSS's tools for all supported NASA astrophysics missions. ACROSS also leverages existing VO infrastructure; for missions that already provide ObsLocTAP and ObjObsSAP services, the ACROSS API will use those in favor of local implementations. However, for missions or observatories that have not adopted VO protocols, ACROSS can partner with them to accommodate whatever formats are available in order to ingest their status data. In this way, ACROSS will be broadening the availability of certain VO protocols for missions that do not have the resources to implement them themselves.

5.   Summary and Conclusions

The ACROSS pilot initiative, instituted as an outcome of the first phase of NASA Astrophysics' TDAMM study, intends to provide support to both missions (observatories) and observers as they pursue time-domain and multimessenger science. It is doing so by developing tools and relationships that will allow the exposure and easy discoverability of observatory state and status information and support for decision-making, planning, and requesting of follow-up observations. ACROSS tools will be open-source and provided to all future missions, enabling small, low cost missions (e.g. cubesats) to implement these interfaces without overly burdening the teams, leading to more missions having available implementations of virtual observatory protocols. As a pilot initiative, ACROSS is eager to talk with observers and mission science team members to get feedback on what tools and features are most urgently needed by the community.

6.   References

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