

## DIVISION B / WORKING GROUP TIME DOMAIN ASTRONOMY

### CHAIR BOARD

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### TRIENNIAL REPORT 2016-2018

#### 1. Motivation for the Working Group on Time Domain Astronomy

The IAU Working Group on Time Domain Astronomy promotes the study of variability - transient, periodic, secular, or aperiodic - across all disciplines of astronomy from the solar system to cosmological distances. In keeping with the broad scope of activities, WG members represent a diversity of topics including synoptic surveys in all bandpasses, multi-messenger follow-up, stellar variability, moving objects, heritage data, instrumentation, robotic telescopes, communication, analysis, and education. Thus we provide a forum to bring together specialists who may not interact very frequently, if at all, providing a basis for exploring commonality in data analysis tools, simulations, standards, observing strategies, transient alert infrastructure, telescope scheduling, etc. In particular, we support meetings such as IAU Symposium 339, *Southern Horizons in Time Domain Astronomy* and the ongoing workshop series, *Hot-wiring the Transient Universe*.

#### 2. History

The first discussions of forming an IAU working group on the astronomical time domain occurred during the highly successful symposium *New Horizons in Time Domain Astronomy*, IAUS 285<sup>†</sup> that was held in 2011 at the University of Oxford. This resulted in a proposal to form a new IAU Commission on the Time Domain that was submitted as part of the IAU's major effort leading up to the last General Assembly to restructure its several commissions. Though widely supported, this proposal was not among those adopted, at least partially due to the extremely broad nature of time domain astronomy that created difficulty in finding the right home among the IAU's divisional structure.

It was thought best to focus on converting the proposal from a commission to the working group level, and Commission 5 seemed a good home. Commission 5, nominally "Data and Documentation", but also the home of software efforts such as the International Virtual Observatory Alliance and FITS, was already the venue for many time domain activities. We are grateful for the generous support the TDA Working Group received from Commission 5 and then from its successor, Commission B2, during the several months of the Working Group's existence at the Commission level.

Shortly following the 2015 General Assembly we proposed restructuring the Working Group at the divisional level under Div-B which broadened its reach to "Facilities, Technologies and Data Science". Approval from the Executive Committee was secured by

<sup>†</sup> <https://www.iau.org/science/meetings/past/symposia/998/>

November 18, 2015, and further activities such as the proposal for what became IAU Symposium 339 have been pursued as a divisional working group.

The time domain reaches into almost all corners of astronomy, so the ultimate goal for this group likely still remains a cross-division commission to be proposed again at a future General Assembly, but for 2018 we propose that the Division B Working Group on Time Domain Astronomy continue for the next triennium. However the group is organized, we welcome collaboration from all institutions and individuals on both the science and infrastructure of time-varying phenomena of all kinds.

The Chair of the Working Group especially thanks Vice-chair R. Elizabeth Griffin, who has worked tirelessly to bring all of this to fruition.

### 3. Activities, 2015-2018

Working Group activities during this three year period included organizing two Time Domain Astronomy (TDA) meetings with international participation. The working group also provides a mailing list for announcements and discussions pertinent to TDA.† Membership of the TDA WG currently numbers 127, with several members taking the opportunity to join the IAU at the same time. Several WG members were also involved in organizing the *Science of Time* symposium ‡ at Harvard University in 2016 which placed the astronomical time domain in a broader context.

#### 3.1. *Hot-wiring the Transient Universe V*

The first *Hot-wiring the Transient Universe* meeting was organized as a joint workshop of the Virtual Observatory and of the Heterogeneous Telescope Networks consortium and was held in 2007 at the University of Arizona. Meeting roughly every two years, scientists and engineers involved in projects carrying out time domain astronomical observations have the opportunity to wrestle with the complex and intertwined requirements of synoptic science.

The fifth *Hotwired* workshop benefited from being organized for the first time by members of the IAU Time Domain Astronomy Working Group, bringing together the efforts of several prominent time domain projects¶ in October 2016 at Villanova University, Philadelphia, USA with the mission:

Hot-wiring the Transient Universe 5 will explore opportunities and challenges of massively parallel time domain surveys coupled with rapid coordinated multi-wavelength follow-up observations. The interdisciplinary agenda include future and ongoing science investigations, information infrastructure for publishing observations in real time, novel data science to classify events, and robotic systems to optimize follow-up campaigns. Time domain astronomy is at the fore of modern astrophysics and crosses fields from solar physics and solar system objects, through stellar variability, to explosive phenomena at galactic and cosmological distances. Recent rapid progress by instruments in space and on the ground has been toward a continuous record of the electromagnetic sky with ever increasing coverage, sensitivity, and temporal resolution. With the advent of gravitational wave and neutrino observatories, we are witnessing the birth of multi-messenger astronomy.

Given the success of *Hotwired V* under the umbrella of the TDA Working Group, we are currently organizing *Hotwired VI* to be hosted in 2019 by Northwestern University.

† [https://pairlist10.pair.net/mailman/listinfo/tda\\_wg](https://pairlist10.pair.net/mailman/listinfo/tda_wg)

‡ <https://www.springer.com/us/book/9783319599083>

¶ <http://hotwired5.villanova.edu>

### 3.2. IAUS 339: *Southern Horizons in Time Domain Astronomy*

IAU Symposium 339, *Southern Horizons in Time-Domain Astronomy*<sup>||</sup>, was held at the University of Stellenbosch, near Cape Town, South Africa, from 2017 November 13–17. Morning plenary sessions addressed many different aspects of time-domain astronomy; the objective being to examine the similarities of the underlying physics rather than to rehearse the characteristics of a particular group of objects. Afternoons were dedicated to workshops, 14 in total, targeting diverse TDA topics or concerns, and organized by participants. Some 160 participants attended representing 33 countries.

IAUS 339 was a successor to 2011’s Symposium 285 (*New Horizons in Time-Domain Astronomy*) which had tackled the subject of variability by focusing on different manifestations, such as periodic, explosive, recurrent or transient, and sought explanations through commonalities that could be identified across the cosmos rather than through studying groups of like objects. IAUS 285 was likely the first meeting of its kind and brought together as diverse a cross-section of participants as ever seen. The TDA Working Group has continued and extended this broad conversation on time domain topics through IAUS 339 and its other activities.

Scheduling for the Symposium was coordinated with *Astroinformatics 2017*<sup>†</sup>, an explicit recognition that future advances in both the time domain and in informatics applied to astronomy are tied together intimately.

Many of the scientific topics described in S339 were not new: searches for elusive objects such as supernovae, classical novae, cataclysmic variables, flare stars, extrasolar planets and the many ramifications thereof have been key research areas for several sometimes a great many years. What was new was the means, the aspect, the scope, the scale and (of course) the technology which is now being enlisted to revolutionize the research. The LIGO discovery of GW170817, and the scientific and engineering infrastructure that made it possible was only one of the dramatic new TDA trends that were discussed.

The program this time had a particularly strong radio emphasis, and a strong accent was also placed on automated surveys, both in space and on the ground, and both targeted and triggered. Aspects of long-term variability are being stretched and enhanced through new and novel technologies, and even objects once believed to be rather quiescent are proving to harbour variabilities previously unimagined and certainly undetected; some are challenging core theories about aspects such as stellar pulsations.

## 4. The future, 2018-2021

Moving forward, planning is advancing for the *Hot-wiring the Transient Universe VI* workshop to be held in the first six months of 2019 at Northwestern University, Illinois, USA. A Hotwired VII workshop may also fall during the next triennium. A pace of 2–3 workshops with attendance up to about one hundred, versus 1–2 larger symposia seems about right for the TDA Working Group each Triennium. We will also continue discussions with the American Astronomical Society’s WG-TDA to identify and develop opportunities for collaboration. An example of this is a current investigation of adding features in support of moving objects and other transient phenomena to the AAS’s World Wide Telescope. It appears there are no significant road blocks to such a project aside from resources.

The next few years is likely to be the triennium of the event broker, with projects

<sup>||</sup> <http://iaus339.ast.uct.ac.za>

<sup>†</sup> <http://www.astroinformatics2017.ska.ac.za>

like ANTARES‡ for stationary transients and NEOfixer¶ for moving objects in the solar system defining key infrastructure for their respective communities in support of large surveys like the Zwicky Transient Factory, the Large Synoptic Survey Telescope, Pan-STARRS, and the Catalina Sky Survey, as well as similar functionality for investigator driven time domain projects of all descriptions. These projects must be tied together by community-adopted standards and protocols such as VOEvent||, JSON††, and ADES‡‡. The TDA Working Group can (one is tempted to say, must) engage with the community to ensure wide adoption of core standards in pursuit of closing the event loop between celestial transient events and robotic follow-up.

One aspect of the astronomical time domain that often receives too little attention is the infrastructure needed to ensure precise and accurate timekeeping at the telescope and in data archives. This is a particular interest of the current Chair, who will be speaking on the topic at the 2018 SPIE Astronomical Telescopes and Instrumentation meeting. As with many diverse issues of astronomical standards and engineering, the IAU serves a critical role in defining and promulgating time standards.

During the next triennium the Working Group will hold elections for Chair and Organizing Committee members.

The Working Group on Time Domain Astronomy proposes to continue as a Division B WG for the next triennium. As a division level WG we will be well-positioned to coordinate activities with diverse commissions, for example C.B2 (Data and Documentation) and C.B3 (Astroinformatics and Astrostatistics).

Robert L. Seaman, Chair

*For the Division B Time Domain Astronomy Working Group*

‡ <https://www.noao.edu/ANTARES/>

¶ <http://neofixer.net>

|| <http://wiki.ivoa.net/twiki/bin/view/IVOA/IvoaVOEvent>

†† <http://wiki.ivoa.net/internal/IVOA/InterOpMay2017-TD/patterson-alert-filter-ivoa.pdf>

‡‡ <https://minorplanetcenter.net/iau/info/ADES.html>