Transients in New Surveys: the Undiscovered Country

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Over the past decade, optical transient surveys have transformed transient science. New classes of transients have been found, enriched and puzzled our knowledge of how stars evolve and die. Next generation surveys will take this effort to the next level, increasing the variety of transients and producing statistical samples for even the rarest phenomena. However, these advances come with their own unique challenges: upcoming surveys will routinely discover millions of transients and identifying outlier events in real-time will require specific observing strategies together with innovative algorithms and techniques.

In particular, the first day of our meeting, focused on transients of supernova luminosities (<-14mag) that rise to maximum light in less than a week and decline in 1-2 weeks, including objects showing a high ratio of Ca/O in their nebular spectra roughly 50 days after maximum (i.e. Ca-rich objects). We established that the main survey mode within the Large Synoptic Survey Telescope (LSST) is not ideal for fast transient discovery due to the proposed cadence but dedicated mini-surveys within LSST might serve the purpose. The Zwicky Transient Facility (ZTF) in the northern hemisphere and BlackGEM in the southern hemisphere are more suited to this task but do not provide multi-band colour information. We designed a strategy to maximise our desired output, focusing on targeting transients in faint and low-luminosity hosts. All of the workshop participants agreed that progress can only result from dense sampling of the early time evolution (<1 day cadence) of these transients.

Superluminous supernovae (SLSNe) were the main topic of the second day. We agreed that the current definition and terminology needs revision, and that using a simplistic luminosity criteria to define these events is not ideal. Ideally, we need a classification scheme related to the physical mechanism driving these events, but this is currently not possible as most events only have limited spectral information and light-curve coverage. To achieve this, we require medium to late time observations of nearby SLSNe with facilities such as ZTF and BlackGEM together with UV data from telescopes such as the Hubble Space Telescope and the James Webb Space Telescope (JWST) and X-ray observatories such as eROSITA. Understanding the physics of SLSNe is pivotal to use them as cosmological probes. LSST, the ESA Euclid satellite, as well as NASA Wide Field Infrared Survey Telescope (WFIRST) will find hundreds of SLSNe up to z~4, so their use in cosmology is a timely topic prior to the commencement of next-generation surveys.

The third day of our meeting focussed on transients that are spatially consistent with the nucleus of their host (a.k.a.: nuclear transients). We concluded that a clear distinction between extreme Active Galactic Nuclei (AGNs) activity and Tidal Disruption Events (TDEs) still eludes us. Multi-wavelength observations at all phases can allow us to distinguish between these events. X-ray observations will be crucial since only a small fraction of supernova are visible at these frequencies, compared to TDE/AGN. Studying how emission lines in the optical part of the electromagnetic spectrum behave with respect to light-curve morphology will improve AGN science. We established that more statistical studies of temporal variability in AGNs are needed. This requires data from Stripe-82, LSST and ZTF-style monitoring (i.e. high cadence observations). The existence of tori can be determined through detections of light echoes in the infrared. This is critical to highlight the difference between AGN and TDE.

The application of machine learning techniques, radio and gamma-ray transients, such as Fast Radio Bursts (FRBs), as well as next-generation facilities and the coordination between them were the focus of days four and five of the workshop. We concluded that the inaccurate localisation of FRBs is the main issue hindering our understanding of their origin. The Square Kilometer Array (SKA) will have improved

localisation for discovered events, while an order of magnitude more events will be discovered by SKA-survey. Maximising our survey and follow-up resources, as well as avoiding data duplication requires coordination between facilities, even when they have limited real-time overlap (e.g. LSST and Euclid). Coordination between surveys requires tools, similar to those offered by existing transient brokers, but must be organised in the near term. Applying machine learning techniques to transient astronomy, in particular transient classification has made tremendous progress recently, and will be further advanced byl challenges promoted by the LSST consortium (e.g. the Photometric LSST Astronomical Time-series Classification Challenge - PLAsTiCC). Transient forecasting is critical to identify events at early phases, but requires a good understanding of the transient landscape and the models underlying each subclass.

Some additional remarks from the scientists who attended the meeting were:

1. There is still a large interest in the local Universe, but the LSST wide survey is not ideal to explore the local Universe due to the proposed cadence and the fact that observations will saturate at relatively faint magnitudes
2. Real-time filters (e.g. light-curve and electromagnetic spectral properties) are required to find interesting events from ongoing surveys. Discovering peculiar events now is critical as training samples for near-future projects (such as LSST)
3. Transients are often discovered, rapidly classified but then discarded due to their similarity to prototypical events, before showing anomalies at late times. An obvious example of this is iPTF14hls. Regular monitoring and visual follow-up of classified events is important to uncover peculiarities in the transient population.

Participants breakdown: we had a slightly smaller attendance than originally proposed. However, we were able to secure speakers and participants from 4 out of 5 continents. The workshop gender balance of 20% female participants is in line with the astronomy picture, but it fell short of our initial goal due to a series of unforeseen circumstances; many of the female invited speakers were unable to attend the final dates of the meeting. As the focus of the meeting was on future transient surveys, our goal was to have more junior researchers (Senior research fellows, Postdocs, PhDs) with respect to senior academics (permanent staff). We achieved a 65% (junior) to 35% (senior) ratio as planned.

The meeting was well received in terms of topic, format and timeliness. All participants were in favour of turning this workshop into a regular series (or to be the starting point of a series of seminars with similar formats) on a biannual basis. As a result of this, and the scientific output, we consider the workshop a success.

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