Astrophysics in the Era of Massive Time-Domain Surveys

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Abstract

Synoptic sky surveys are now the largest data producers in astronomy, entering the Petascale regime, opening the time domain for a systematic exploration. A great variety of interesting phenomena, spanning essentially all subfields of astronomy, can only be studied in the time domain, and these new surveys are producing large statistical samples of the known types of objects and events for further studies (e.g., SNe, AGN, variable stars of many kinds), and have already uncovered previously unknown subtypes of these (e.g., rare or peculiar types of SNe). These surveys are generating a new science, and paving the way for even larger surveys to come, e.g., the LSST; our ability to fully exploit such forthcoming facilities depends critically on the science, methodology, and experience that are being accumulated now. Among the outstanding challenges, the foremost is our ability to conduct an effective follow-up of the interesting events discovered by the surveys in any wavelength regime. The follow-up resources, especially spectroscopy, are already and, for the predictable future, will be severely limited, thus requiring an intelligent down-selection of the most astrophysically interesting events to follow. The first step in that process is an automated, real-time, iterative classification of events, that incorporates heterogeneous data from the surveys themselves, archival and contextual information (spatial, temporal, and multiwavelength), and the incoming follow-up observations. The second step is an optimal automated event prioritization and allocation of the available follow-up resources that also change in time. Both of these challenges are highly non-trivial, and require a strong cyber-infrastructure based on the Virtual Observatory data grid, and the various astroinformatics efforts. Time domain astronomy is inherently an astronomy of telescope-computational systems, and will increasingly depend on novel machine learning and artificial intelligence tools. Another arena with a strong potential for discovery is a purely archival, non-time-critical exploration of the time domain, with the time dimension adding the complexity to an already challenging problem of data mining of highly-dimensional parameter spaces produced by sky surveys.