Transients and Variables with LSST

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The first half of the twentieth century was dominated by the discovery of explosions (supernovae), eruptions (novae) and variable stars (Cepheid variables). As we go into this century, LSST, thanks to its large etendue, can be expected to contribute tremendously to the area of transients and variables. Are there events between novae and supernovae? Are there new types of (rare) supernovae? What do coalescences of stars (combination of main sequence, planets, white dwarfs, neutron stars, black holes) result? Are these connected to short hard gamma-ray bursts and LIGO events? LSST is in a position to address these questions.

The LSST project clearly recognizes the importance of transients and variables. To this end, a specific Science Working Group has been formed. Through this poster we wish to inform the community of the vision and stated goals of this group (see panel on right). The working group is seeking members to join this effort. In addition to astronomers working at member institutions we are seeking astronomers with great depth in variable stars.

Perhaps the best evidence of the vibrancy of the transient and variable star field are provided by the findings in 2006: the Halloween transient (likely a nearby micromoving event), the Perseus transient (the brightest supernova recorded to date), the Conca mystery object, the M85 transient (the brightest member of an emerging class of transients), a new class of GRBs and the GALEX transient (a star being swallowed by a nuclear black hole).

There are a number of transients noted in the past but whose nature still remains uncertain or controversial. Examples include V838 Mon and the peculiar supernova SN 1961V. In almost all cases, prompt identification and follow up would most certainly have led to better understanding. This lesson has not been lost on our working group.

The study of variable stars is an extremely interesting area in itself. However, the proper identification of Galactic variables is absolutely essential prior to identification of extragalactic transients (Becker et al. 2004; see below). One of the recent dramatic flares is from il Pegasi (a well known active binary system located 42 pc away). The energy in non-thermal spikes exceeded 10^13 erg (Dalen et al. 2006).

The Transients Working Group addresses the science arising from the discovery of light from astronomical objects. As such we plan to focus on the astrophysics of sources which show regular, irregular and dramatic variations. Examples of dramatic events include explosive supernovae (GRBs), cataclysmic novae (e.g. dwarf novae, novae), luminous blue variables and accreting sources (X-ray binaries, cataclysmic variables, RS CVn). Examples of regular variations include eclipsing binaries, pulsators and rotators. Next, the large etendue of LSST should result in discovery of new cosmic phenomena (microlensing, micromovements). Finally, the extensive sky coverage of LSST should help in identifying transients found at other wavelengths (X-ray, radio).

It is our hope that LSST will discover new classes of transients apart from increasing our understanding of the currently known transients.

Program

We see a three phase program. The first phase is (1) "becoming familiar with known classes of transients and variables; (2) developing a plan for classifying transients (archival data); and (3) conducting the experiment, and (4) scoping out and developing the followup plans.

The next phase will be to develop an annual all-sky rates of variables and transients. This may require analysis of on-going survey (e.g. supernova searches) or conducting experiments expressly designed for such purposes.

The Working Group expects to have a document which captures all of the above work in the form of a Collaboration Report (by December 2010). The third phase will be to develop specific plans to optimize (at least some part of time) LSST for transient research.

Systematic studies of variables:

Fundamental Astronomy

LSST will enable the systematic studies of a large number of Galactic variables. Consider, as an example, astro-seismology of white dwarfs. White dwarfs crystallize with age which affects the observed power spectrum. Metcalfe, Montgomery and Kanaan (2004) infer 90% of BPM 37039 is crystallized. Such a study expanded to a large number of white dwarfs can sharpen the use of white dwarfs as Galactic chronometers.

Vision

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Halloween 2006 Transient in Cassiopeia

Japanese amateurs (Tago and Nakano, CBET 711), observing with a 70-mm f/3.2 lens and a Canon EOS digital camera, reported the discovery a brightening star in Cassiopeia on Halloween -- October 31, 2006. It appeared that a "perfectly respectable" A star (GSC 666-1339) at a distance of 1 kpc from Earth brightened from 11 mag to 7 mag and decayed on a timescale of a week (CBET 711, 716, ATEL 1031, 942, 943). The object was followed up by professional and amateur telescopes (including the Center for Backyard Astrophotography). Several authors argue that the wave was a microlensing event. The probability of such a strongly amplified event is 10^-7.

A CONCA Transient

An intriguing 5th magnitude flash seen by the CONCA all-sky camera located in Cerro Pachon and La Palma (marked by circle; see below). Since a third CONCA, located at Cerro Paranal, did not detect the flash, the authors suggest that the flash was perhaps a series of cosmic ray hits, meteors or satellites (Sharma & Nemiroff 2006).

Paracelsus 2006 Transient, SN 2006gy

Quinty (CBET 844) discovered a bright transient, designated SN 2006gy, towards NGC 1260 in the Perseus Cluster. It is now the brightest supernova known, having peaked at an absolute magnitude of -22 mag. Spectroscopic observations revealed that the event is a member of the emerging class of “type IIb” supernovae (Ofek et al. 2006) or a type supernova (Smith et al. 2006). It is possible that SN 2006gy could be the first example of a pair instability supernova (postulated several decades ago and expected to be prevalent in the early Universe).

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Transients in the local Universe: The peak-magnitude versus timescale of transients in the local Universe. This well known family tree for short bursts (including supernovae and luminous blue variables (LBV). Supernovae without massive envelopes (type Ia; also include Ib/Ic) are defined by the amount of synthesized radioactive Nickel. Novae shine by reprocessing of light from a central star. LBVs are hiccups of the brightest stars. An emerging new class is the red luminous novae. (Figure from Kulkarni et al. 2006.)

V383 Mon

The Galactic transient V383 Mon, discovered by Brown (2002), had a peak outburst amplitude of ~10 mag, reaching 6.7 mag during its multi-peaked, two month-long eruption. Soon after the eruption, spectropolarimetric light echoes were detected, the evolution of which has been imaged with the Hubble Space Telescope (Figure, Bond et al. 2003) and also recently with Spitzer (Bennert et al. 2006). Possible scenarii include a binary merger (Bok et Tylenda 2003) or a star swallowing a planet (Retter & Marom 2003).

Red Luminous Nova in M51 (2006)

GRB 060614. A new type of GRB

Until recently only two classes of GRBs were known short (< 2 s) and long. GRB 060614 is neither. This long (1232; Gehrels et al. 2006) had an afterglow, but no associated supernova (Gal-Yam et al. 2006; Fenyo et al. 2006; Deol Vala et al. 2006). It also resided in a galaxy that appears to be atypical when compared to hosts of previously studied long GRBs. This GRB may well require a new process to explain it: either a massive star that is very different from those that make either short GRBs (and which does not end up as a supernova), or a compact binary merger that can produce long-lived radiation (contrary to theoretical models and all previous examples of short, less-bright) or something totally new.

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