Transients and Variables with LSST

S.R. Kulkarni (Caltech), A. Becker (UW), J. S. Bloom (UCB), K. H. Cook (LLNL/NOAO), S. Kahn (SLAC), P. Szkody (UW), J.A. Tyson (UCD), W.T. Vestrand (LANL) and the LSST Transient Object Science Collaboration

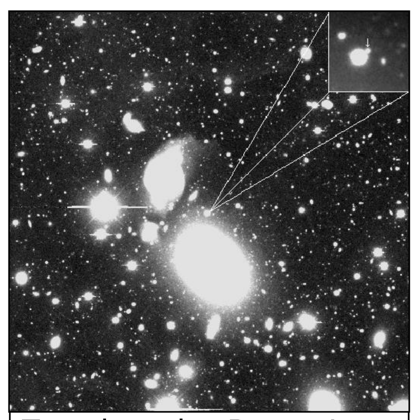
The first half of the twentieth century was dominated by the discovery of explosions (supernovae), eruptions (novae) and variable stars (Cepheid variables). As we go into this century, LSST, thanks to its large etendue, can be expected to contribute tremendously to the area of transients and variables. Are there events between novae and supernovae? Are there new types of (rare) supernovae? What do coalescence 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 microlensing event), the Perseus transient (the brightest supernova recorded to date), the Concam 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 pseudo 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 entirely 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 II Pegasi (a well known active binary system located 42 pc away). The energy in non-thermal electrons exceeded 10^{40} erg (Osten et al. 2006).



Transient in Deep Lens Survey turns out to be an M dwarf!

Vision

The Transients Working Group addresses the science returns arising from temporal variation of 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), eruptive (flares, dwarf novae), ejective (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 kinematic transients (microlensing, mesolensing). 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 entirely 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 real time detection of transients,
[3] understanding the systematics in the detector and other artifacts especially in regard to very fast transients and
[4] scoping out and developing the followup plans.

The next phase will be to develop 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 purpose(s).

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.

GRB 060614: A new type of GRB

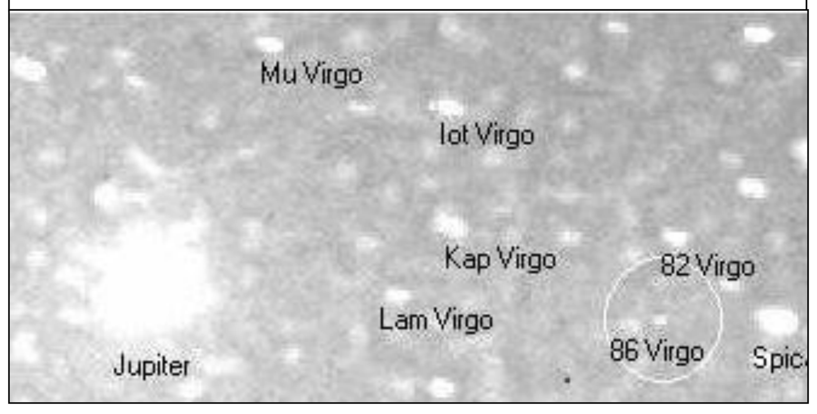
Until recently only two classes of GRBs were known: short (< 2s) and long. GRB 060614 is neither. This long (102s; Gehrels et al. 2006) had an afterglow, but no associated supernova (Gal-Yam et al. 2006; Fynbo et al. 2006; Della Valle et al. 2006). It also resided in a galaxy that appears to be atypical 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 long 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, SN-less bursts) or something totally new.

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 3656-1328) 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, 718; ATEL 931, 942, 943). The object was followed up by professional and amateur telescopes (including the Center for Backyard Astrophysics). Several authors argue that the event was a microlensing event. The probability of such a strongly amplified event is 10^{-7}.

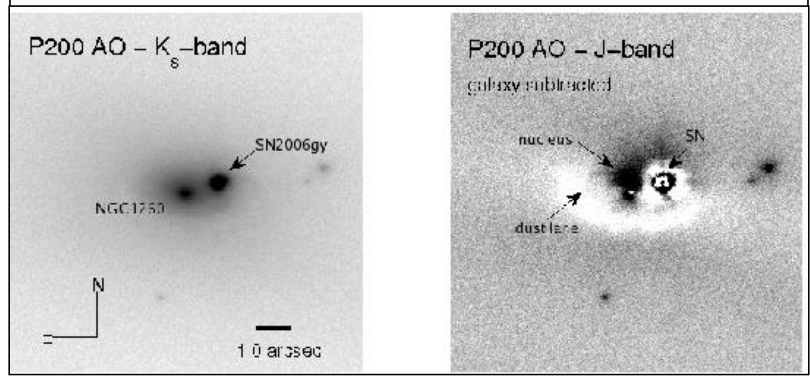
A CONCAM Transient

An intriguing 5th magnitude flash seen by the CONCAM all-sky camera located in Cerro Pachon and La Palma (marked by circle; see below). Since a third CONCAM, 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 satellite glints (Shamir & Nemiroff 2006).



Perseus 2006 Transient, SN 2006gy

Quimby (CBET 644) 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 IIa'' supernovae (Ofek et al. 2006) or a IIn 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).



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 37093 is crystallized. Such a study expanded to a large number of white dwarfs can sharpen the use of white dwarfs as Galactic chronometers.

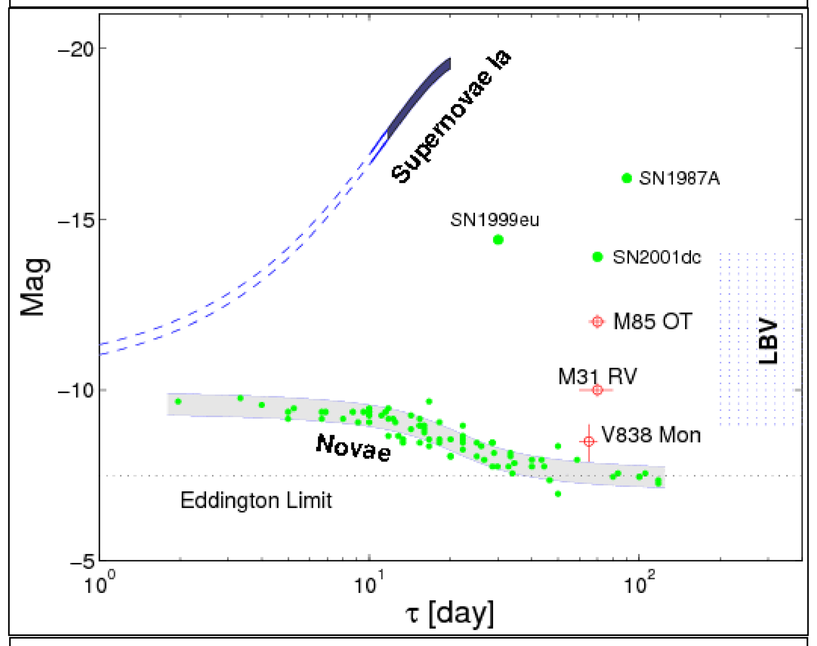
SN 1961V

SN 1961V was either a giant eruption of a luminous blue variable (LBV) between the main sequence and Wolf-Rayet phases, or a peculiar sort of Type II supernova (Zwicky's ``Type~V'' SN). Its progenitor is an extremely luminous (M_{pg} ~ -12) and massive (M ~ 100 Msun) star (Goodrich et al. 1989) in NGC 1058. SN 1961V has an atypical light curve - a peak absolute magnitude of -18 (!), It has a few contentious candidates for survivors of the explosion - an Of/WN star (Goodrich et al. 1989), K-type supergiant (Fillipenko et al 1995) or a yellow supergiant (Chu et al 2004), suggesting it is an LBV.

V838 Mon

The Galactic transient V838~Mon, discovered by Brown (2002), had a peak outburst amplitude of ~10 mag, reaching V of 6.7 mag during its multi-peaked, two month-long eruption. Soon after the eruption, spectacular expanding 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 (Banerjee et al 2006). Possible scenarios include a binary merger (Soker & Tylenda 2003) or a star swallowing a planet (Retter & Marom 2003).

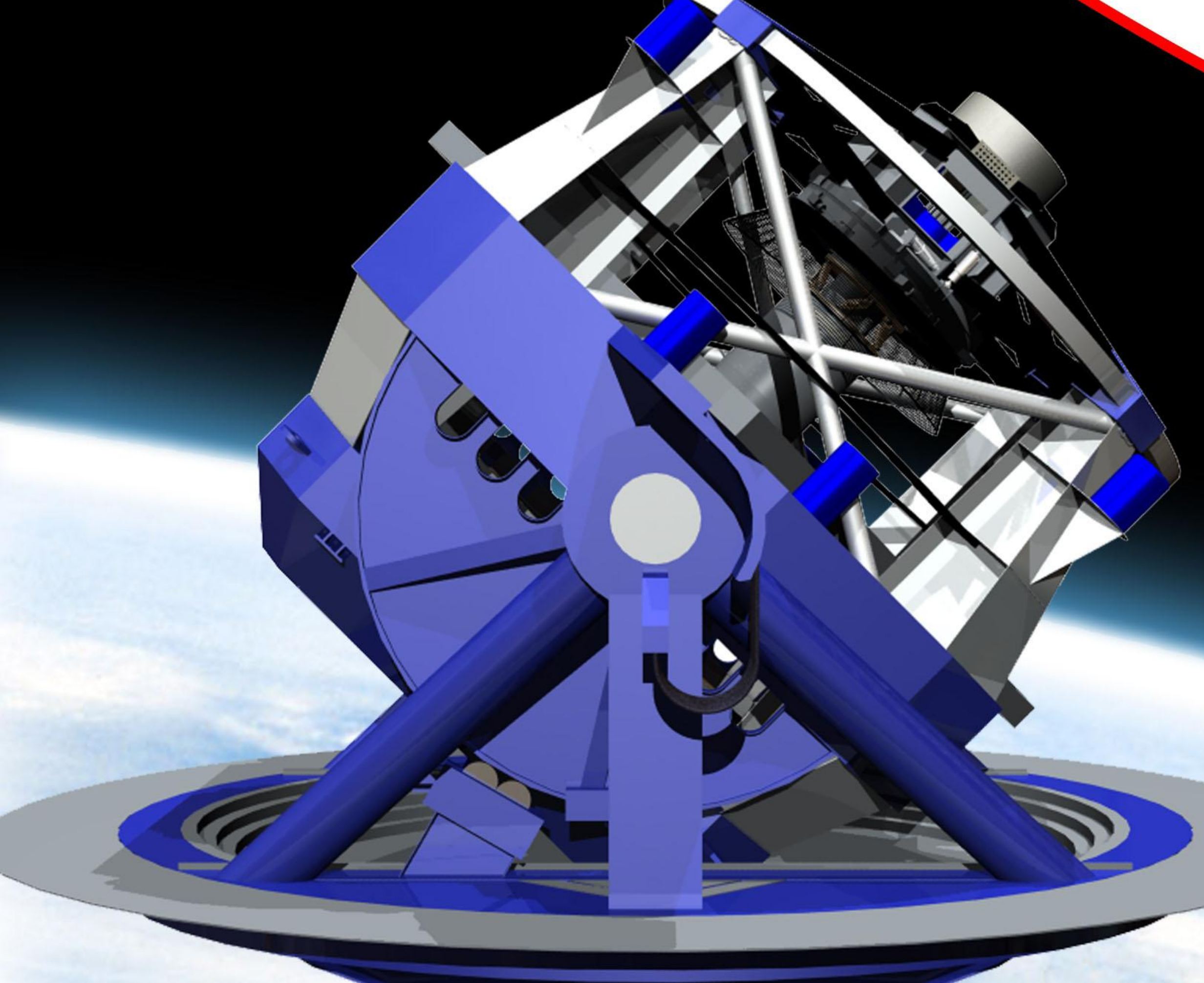
Red Luminous Nova in M85 (2006)



Transients in the local Universe: The peak-magnitude versus timescale of transients in the local Universe. The well known families are supernovae, novae and luminous blue variables (LBV). Supernovae without massive envelopes (typified by 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.)

GALEX Transient

Gezari et al. (2006) report a luminous flare coincident with a z=0.37 elliptical galaxy which does not have an active nucleus. They provide a compelling interpretation that the flare result from tidal disruption of a star in the vicinity of the (expected) central black hole of the host galaxy .This example demonstrates an entirely new and efficient way to study the statistics (and spin) of nuclear black holes.



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