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SNAP Type Ia Supernova Trigger

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Abstract

In a high-cadence search for Type Ia supernovae, a large number of other transient objects will be discovered. In order for efficient targeted spectroscopic observations to ensue, the Type Ia events must be identified and tagged for further study. In this note, we discuss the cuts with which we expect to produce a pure sample of SNe Ia.

1 SNAP Triggers

SNAP will tailor its observational strategy to fulfill its science objective of measuring cosmological parameters. This means discovering more than 2000 Type Ia SNe and following them up with regular photometric B and V observations in the SN rest-frame and a spectrum at maximum light. For a few SNe, more detailed information will be collected to form reference data for further calibration. The strategy includes several trigger and filter stages.

1. Early Detection: 20 degrees square will be observed with a cadence of 4 days. Differences between new images and reference images will be used to detect new or brighter point sources with a signal-to-noise (S/N) greater than 10. (Note: a more sophisticated detection strategy that uses time-series information, such as those used by the microlensing searches, will allow even fainter and earlier detections for SNAP.)

2. High-frequency variation and proper motion cuts: Each SNAP image is built from a series of dithered exposures taken in sequence. After the initial trigger, the primary images can be used to identify asteroids and Gamma-Ray Bursters (GRB's) because of their spatial and temporal variation. (Note: Cosmic-ray rejection is performed during the coadding of the dithered images; cosmics should not contribute a significant background.)

   A series of other statistics has been identified and used by the Supernova Cosmology Project in selecting supernova candidates. These include percentage increase, source shape, location, and host galaxy size and brightness. These statistics help identify spurious candidates produced by missubtractions or CCD glitches.

3. Type Ia Trigger: Host-galaxy redshifts and the time-series of multi-band photometric data around the trigger will be used after early detection to distinguish SNe Ia from the AGNs, supernovae of other types, and variable stars that have passed the previous cuts.

4. Type Ia Signatures: Spectra at maximum brightness will be taken to identify the SiII line that defines the Type Ia class.

2 Type Ia Candidate Selection

In this note we discuss the third trigger stage: namely the Type Ia candidate selection. As can be inferred from the above list of triggers, this cut feeds the target list for spectroscopic observations. Since we are targeting spectroscopy for the supernova near maximum light, only pre-maximum data will be available for the trigger and a quick turnaround time is necessary.

Spectroscopy of the highest-redshift supernovae dominates the observational time for SNAP; an efficient filter with low incidence of false triggers is essential for the success of the experiment. Core-collapse SN are believed to be 4X more frequent than Type Ia SNe for our magnitude limited sample. Therefore, with a S/N ≥ 10, a reduction in background rate by a factor of forty is required while maintaining near perfect efficiency for signal. Ground-searches have not needed the third stage trigger since their long cadences and lower magnitudes triggered much fewer Type II events.

A time-series of wide-field images in approximately 12 pass-bands between 0.35 and 1.7 microns will provide the data for the cut. The first few data sets will be combined to produce photometric redshifts to $< 5\%$ accuracy for the field galaxies. Type Ia SNe photometrically differ from other Type I and Type II SNe in a number of ways: color, brightness, and in the rise time. The twelve light curves near the trigger epoch will be checked for consistency with Type Ia's.

The rise-time, dm/dt, of the supernova-frame B-band light curve will provide a simple and powerful discriminant of supernova type; core-collapse supernovae generally reach maximum almost 2 times faster than the SNe Ia. The B-band is singled out because of its availability in current rise-time data and its spanning the wavelength region of peak SN flux-emission. Limitations of the rise-time cut arise from the following factors. Although Type Ia light curves are very homogeneous, they do exhibit some variation that can be described by a stretching of the time axis. This variation modifies the rise time of SNe Ia by about $\pm 20\%$. The observed light-curve time evolution of objects at high redshift also changes due to time dilation. A $1 + z$ correction to convert the observed dm/dt to the rest-frame rise time adds error due to uncertainty in z. Finally, examples of core-collapse supernova with rise-times similar to SNe Ia have been observed and will constitute an unwanted background.

Type Ia supernovae have a strong UV deficit caused by iron-line blanketing whereas most core-collapse supernovae resemble blackbodies. Eleven color measurements will be available for each candidate and will be used to provide additional cuts. Type II SNe are on average intrinsically fainter that their SN Ia counterparts by two magnitudes; the probability of measuring the observed brightness for a Type II at the appropriate redshift can also be used as a cut. The brightness and color of SNe Ia do vary slightly as a function of their light-curve shape. Extinction by dust can also cause variations in the brightness, but do not affect the observed risetime. And again outlier Type II's are expected to pollute the sample.

We are building a simulation that will aid in determining optimal filter cuts; an optimized selection of Type Ia supernova with minimal Type II and Type Ib/Ic SN contamination is sought. Light curves of all SN types are generated covering their range of shapes, colors, brightness, and foreground extinction. The phase space in the above parameters spanned by each supernova type will be compared to set efficient cuts. Other parameters such as three-point statistics in the rise of the light curve will be studied for their use in cuts.

Since SNAP is still in the design phase, we will also explore the pass-bands and observational strategy to see if there is an optimal configuration for triggering. We feel it is important to measure the Type Ia efficiency and the background fractions passed:

1. as a function of the number of days (currently 4) between wide-field observations of a particular 1 degree sky patch.
2. as a function of the number and width of various bandpass filters
3. as a function of exposure times.