Ultraviolet SN observations with Swift

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Why Study SNe in *Ultraviolet*

- **Metallicity**: for the higher sensitivity to the ejecta metal content, UV is a powerful probe of the progenitor structure and explosion mechanism;

- **CSM interaction**: SN environment structure through UV excess and spectral features (accompanied by X-ray emission);

- **High-z Ia SN survey**: local UV template light curve to compare against higher redshift SNe;

- **SN Spectral Energy Distribution**: UV combined with optical and IR data will improve actual knowledge about it;

- …

**UV is a powerful tool to improve our knowledge on SNe!!**
Why Study SNe with *Swift*

*Swift* has imaging and spectral capabilities perfectly suited to study SNe:

- **Extended λ coverage** from Opt to X-rays:  
  - *UVOT telescope*: wavelength range 1700 -- 6000 Å,  
    - 3 optical UBV + 3 UV (W1,M2,W2) filters  
    - 2 grism (UV,V)  
  - *XRT telescope* (0.3 -- 10 KeV);

- **Rapid response and flexible scheduling**: observations can be scheduled within less than one day from SN discovery mapping the rising phase of the supernova light curve;

- **Ability to revised targets frequently**: more detailed light curves and great spectroscopic follow-up (spectral time evolution).

For details see P. Roming talk
Selection Criteria

- **Young**: several days before maximum in optical wavelengths;

- **Nearby**: only local events at $z < 0.01$ ($\approx < 50$ Mpc), to enable X-ray detections;

- **Low extinction**: $Av < 0.5$ mag;

- **Good location**: distant $>8''$ from the host galaxy nucleus or bright field star;

- **SN brightness for Grism observations**: $V < \approx 16$ mag.
# Swift Observations of Supernovae

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43 SNe total — 19 (12) type Ia — 12 (2) type Ib/c — 12 (3) type II
UVOT Lightcurves of SNe

Brown et al.
SN 2006jc - Type I b/c

13.8 mag in unfiltered image at the discovery epoch (Nakano et al, CBET 666)
23.6 Mpc (z=0.00557, H₀=71 km s⁻¹ Mpc⁻¹)
48 epochs with Swift+UVOT (photometry both in Optical and UV filters)
3 UV grism + 3 V grism spectra
SN 2006jc is the result of LBV, whose outburst was observed two years before SN
Independent evidence of interaction: SN 2006jc detections in X-rays with Chandra and XRT (Immler et al. 2007, in prep).

In Optical strong HeI emission lines with a narrow P-Cygni profile and a very blue continuum confirm dense CSM. (Foley et al. 2007, Pastorello et al. 2007)
The UV light curves have similar shapes.
The UV light curves appear more homogenous than the opt light curves.
Light curves were shifted in time and magnitude to fit template.
• **Excess ultraviolet emission** detected for SN 2005ke
• Caused by the interaction of the supernova shock with dense CSM?
• Evidence for a single degenerate binary system?
SN 2005ke

No Spectral Evidence: Only pre-maximum Spectra

SN 2005ke is a sub-luminous Type Ia
SNe Type Ia UV spectra

SN2005df  
Line blanketing

SN2005cf  
Detailed Spectral Follow-up
Future SN Observations with Swift

Due to the **fast response**, **flexible scheduling** and **multi-λ coverage** (opt+UV+X-rays, both photometry and spectroscopy), **Swift** is perfectly suited to study SNe.

Results obtained so far demonstrate the high potential of **Swift**:

- UV and X-rays as probes for **CSM interaction and SN progenitor** (UV excess, UV grism, early X-ray detections, etc);
- **SNe Ia UV light curve templates** are being created and efforts are being made to establish **SNe Ia as UV standard candles** with large implications for cosmology and future missions.

A continuation of this program (with slight adjustments as needed, e.g., more use of grism) will have strong positive impact on the general field of SN research.
Thank you for your attention..!
First detection of a type Ia SN in X-rays from CSM interaction?
Mass-loss rate of the progenitor’s companion $3 \times 10^{-6} \, M_\odot \, \text{yr}^{-1}$
CSM density $4 \times 10^7 \, \text{cm}^{-3}$ at a distance of $3 \times 10^{15} \, \text{cm}$

Immler et al. 2006
UV Template

- Light curves are fitted to the UVW1 template.
- This improves the peak date and magnitude determination.
- The UV template rises quicker and fades slightly slower than the U-band template.

Milne et al, 2007 (in preparation)
• SNe that are opt bright are also bright in the UV
• Correlation between peak brightness and $\Delta m_{B15}$

Brown et al.
A **thermonuclear (Type Ia) supernova** is a white dwarf that accretes matter from a companion star and explodes as it reaches the Chandrasekhar mass (1.4x Sun).

Unsolved question: **What is the companion star?**

Two scenarios how thermonuclear SN (Type Ia) systems could look like