Importance of UV/optical observations for transients and ULTRASAT & LAST

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Talk Layout

- Focus: why around-the-globe UV-optical wide-field are important
- Goal: comparing observations with theory
  - UV-optical surveys
  - High cadence
- Our facilities

Why multi-wavelength?

- Goal: compare theory and observations (robust!)
- Bolometric LC & T evolution (less uncertainty)
- Examples - for what can we do:

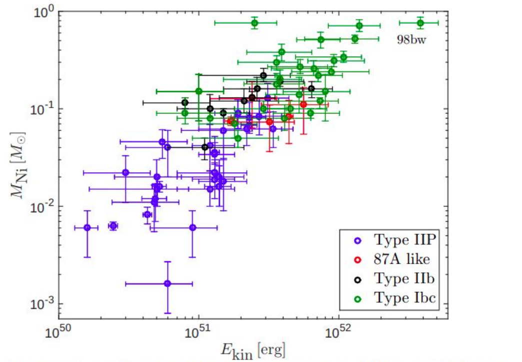
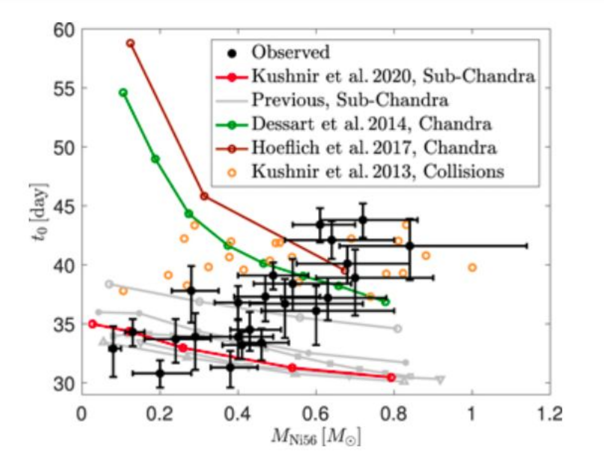


Figure 3. Estimates of $E_{\rm kin}$ and $M_{\rm Ni}$ from the literature for 70 observed supernovae (see Table 2). This is the same compilation of Kushnir (2015) with a few more events. In the case that $E_{\rm kin}$ or $M_{\rm Ni}$ lack an error estimate, an error of 50% was assumed (10% for SN 1987A). The estimates of $E_{\rm kin}$ from observations involve complicated light-curve modeling (which can include large systematic uncertainties). However, unlike the situation in Figure 2, in this case the sample is large and it spans more than two orders of magnitude in $M_{\rm Ni}$ and $E_{\rm kin}$, such that the large systematic uncertainties are less important.

Kushnir 18



Sharon+Kushnir, 20

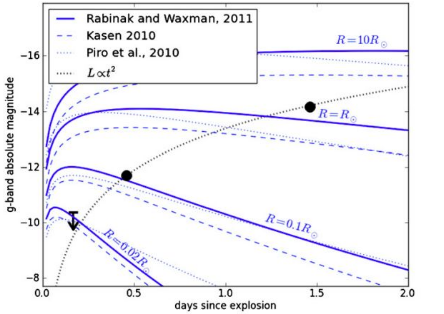


Figure 2. Absolute g-band magnitude vs. time since explosion in three theoretical models for the early-time shock-heated evolution of Type Ia SNe. Shown is 4 hr, 5σ non-detection discussed in Section 2.2 and the first two detections from PTF (Nugent et al. 2011). The black line shows the $L \propto t^2$ radioactive-heating behavior seen in later-time PTF data, consistent with the non-detection. For the Kasen (2010) companion interaction model, R denotes the separation distance between the two stars, and the light curve is shown for an observer aligned with the collision axis, which produces the brightest observed luminosity.

Bloom+2012, Nugent+2011

Why UV? Transients

- Transients (explosions) starts:
    - Optically thick
    - Hot
- A robust way to compare theory with observations:
    - Bolometric LC [UV important at early time]
    - Temperature evolution [UV important when T>20,000K]
- UV observations (and search) are important

Why UV? NS mergers

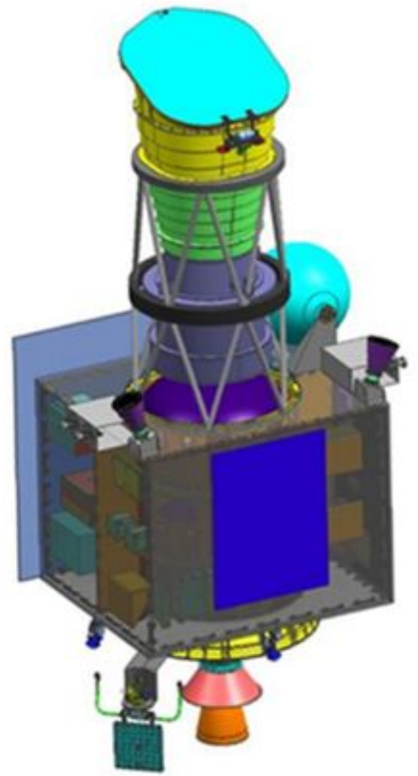
- UV bright at early times (<1 day)
- Bol. LC not consistent with a single velocity components - solutions:
    - Add more components with different opacities
    - Use ejecta with velocity distribution (e.g., Waxman+18)
-

What is needed?

- Surveys with high grasp
- IR to UV
- UV evolves fast
- High cadence(!)
  - Unexplored
  - Followup limited
- Sky accessibility (space and/or around the globe)

Space observatories solutions: ULTRASAT, UVEX, STAR-X

- ULTRASAT (PI: Waxman)
- Launch: 2025
- 33 cm, 200 deg^2 UV telescope
- Geo orbit
  - Continuous obs + download
  - 50% of sky at any time + fast response
- ~8” PSF, 22.4 mag in 900s
- Additional missions:
  - UVEX (2028) - 2 band + UV spectroscopy



The Grasp

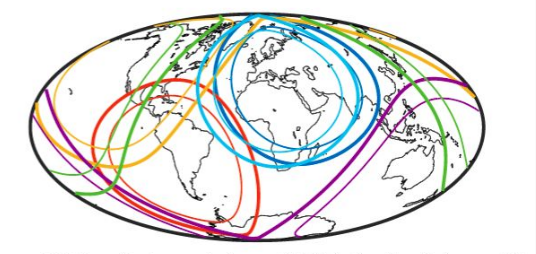
$$\mathcal{G} \propto \overset{\text{FoV}}{\Omega} \left(\frac{S}{N}\right)^{-3/2} \overset{\text{Area}}{A_{\rm eff}^{3/4}} \underset{\text{Background}}{B^{-3/4}} \overset{\text{Seeing}}{\sigma^{-3/2}} \frac{\overset{\text{Exp. Time}}{t_{\rm E}^{3/4}}}{t_{\rm E}+\underset{\text{Dead Time}}{t_{\rm D}}}$$

Ofek & Ben-Ami 2020

- Have a maximum a $t_{\rm E} = 3t_{\rm D}$
- Cost (van Belle+2004): $\$ \propto A^{1.2}$
- Multiple telescopes - more cost effective
- Optimize the seeing: D>20 cm
- For small telescopes -> small pixels: < 4 microns

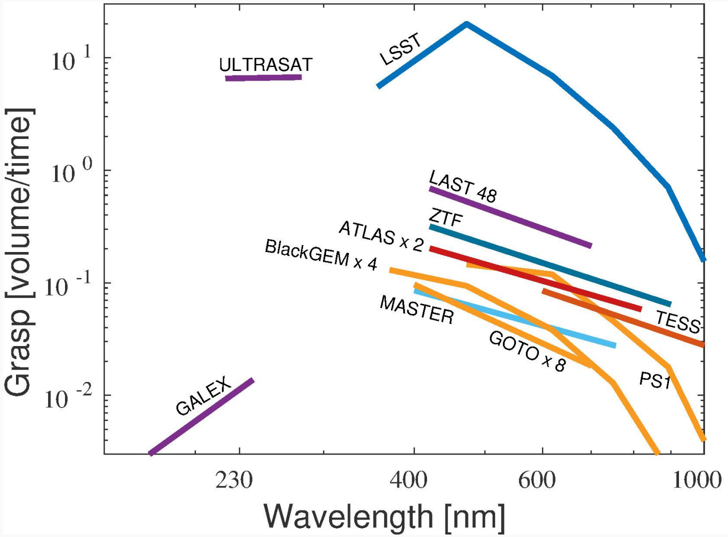
Observatories solution: The Large Array Survey Telescope (LAST)

- LAST (PI: Ofek & Ben-Ami)
- Cost effective!
- 48, 28-cm tel.
- Flexible operations
- 355 deg^2 FoV
- 21.0 mag in 400s
- Under construction
- 48 tel. (end 2022)



Summary

- UV is missing and important
- Models: robust predictions regarding early UV emission
- Impact: NS mergers, SNe, CSM SN, AGNs, TDE, stars
- Observatories to fill the [UV + high cadence] gaps:
  - ULTRASAT (2025)
  - LAST (2022)
  - MAST (2024) PIs: Ben-Ami & Ofek



End

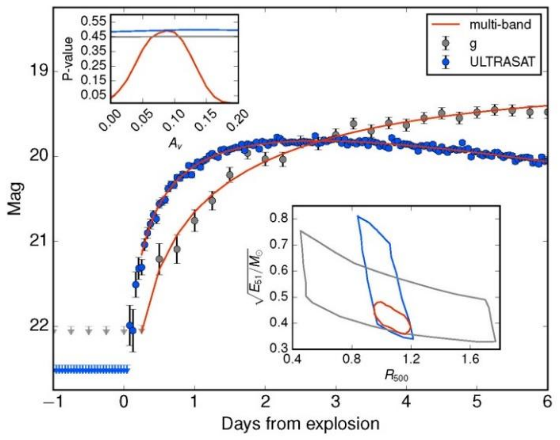
- End

End

- Backup

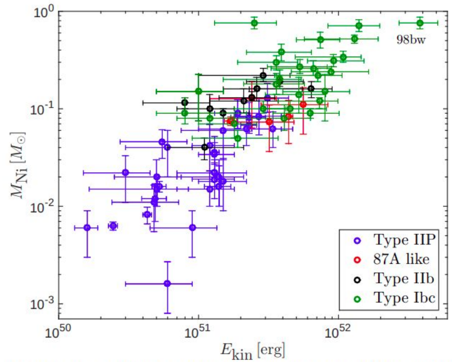
Why UV? More

- CC SN shock cooling [see AGY talk]
  - R*, E/M -> The nature of progenitors
  - CSM (wind breakout)
- AGN
  - Var. higher in UV
  - Look for power spectra break / mass of BH
- ...



Open Questions I

- How transients explodes - details are not clear:
    - Ia explosion scenario?
    - CC: Neutrino mechanism has difficulties



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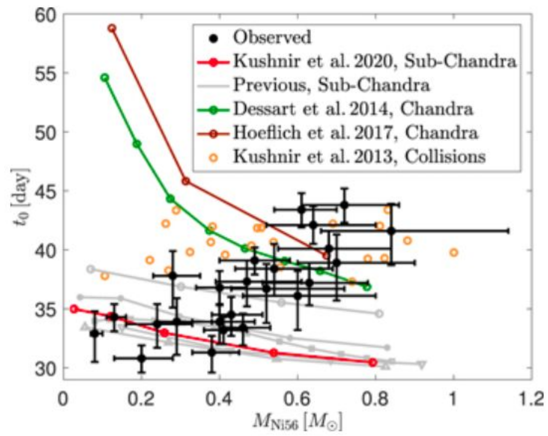

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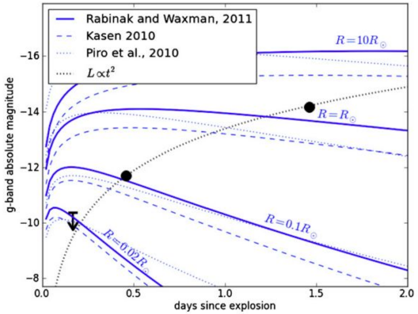

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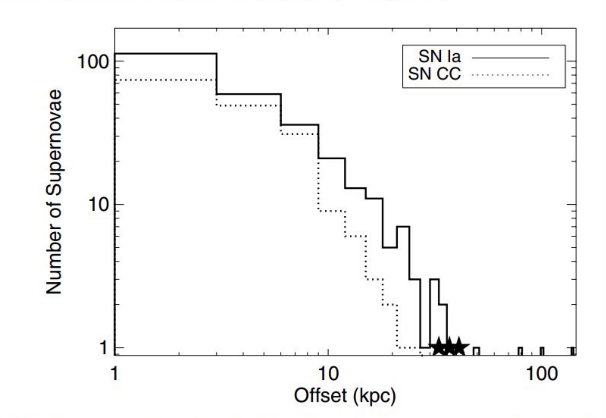
Bloom+2012, Nugent+2011

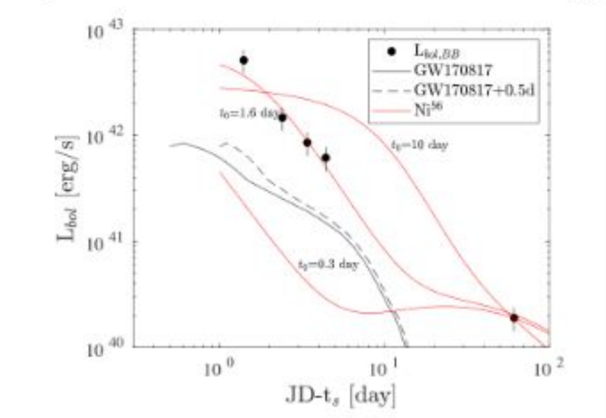
Open Questions II

- Enigmatic transients
  - Ca rich SNe
  - SLSN
  - Some FBOTs
- The formation of heavy elements

Kasliwal+12



Ofek+21



LAST data rate challenge

- LAST node: 2.9 Gpix camera
- w/20x20s exposures: data rate: 2.2 Gbit/s (x1.5 LSST rate)
- A new efficient pipeline is required (Mostly done)
- Efficiency (high-level) examples:
  - Sources find/measure: x30 faster than SExtractor
  - FITS writing: x3 faster than CFITSIO
  - Astrometry: x300 faster
  - …

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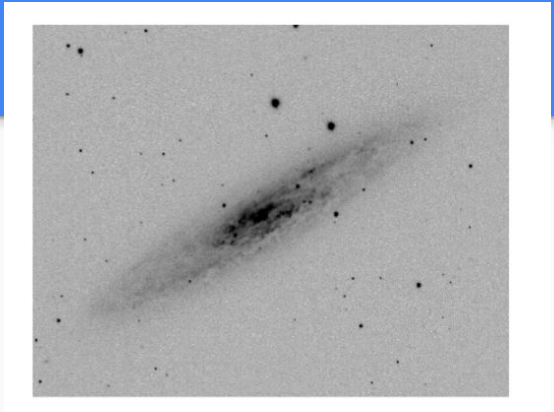
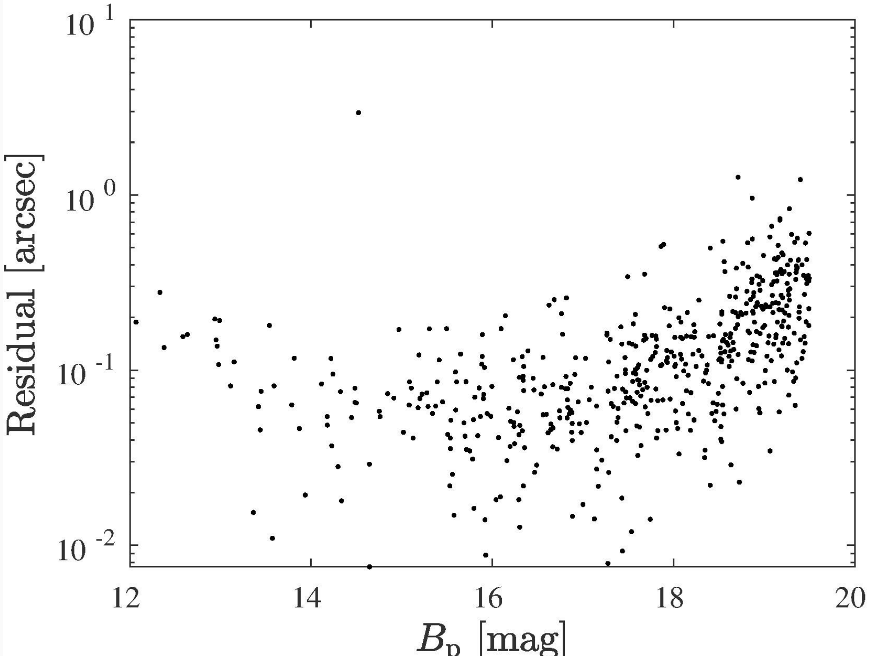
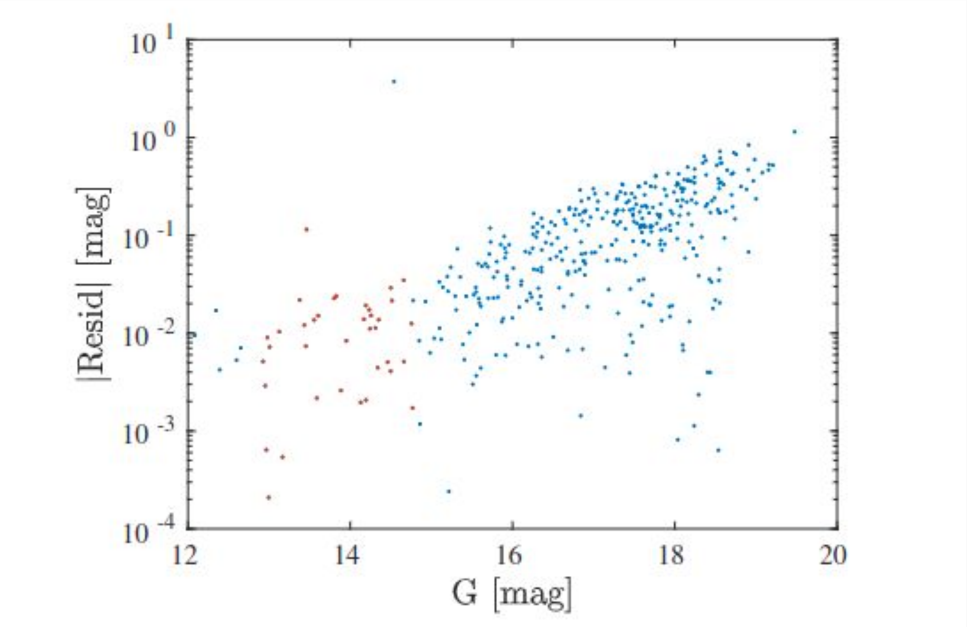
- Main data products:
  - Individual calib. Images, masks, cat
  - Merged visits catalogs
  - Coadd images, masks, cat, PSF
  - Solar system products
  - Subtraction, Reference, translient

LAST performances



- Astrometric precision: 30 (60) mas in 400 (20)s
- Cal. phot. ~1%





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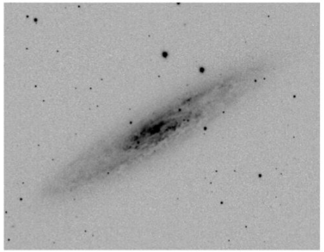

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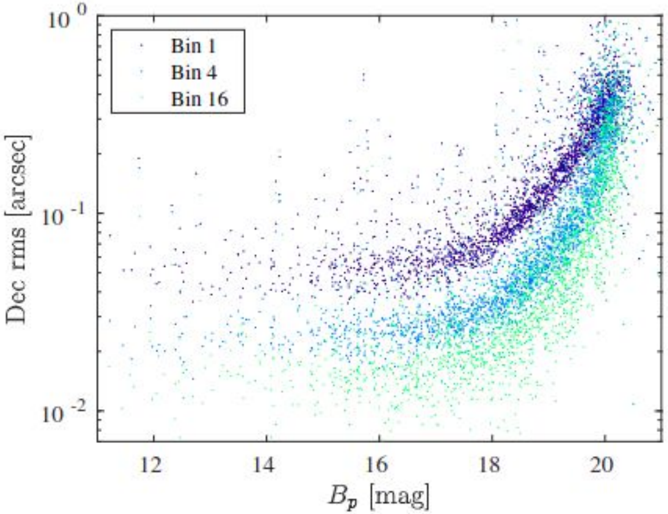

FIG. 7.— The one-axis Declination rms of the relative astrometry solution, measured over the 100 epochs of 20 s exposures, vs. the GAIA $B_{\rm p}$ magnitude. The color represents single epochs (dark blue; Bin1), average over 4 epochs (blue; Bin4), and average over 16 epochs (green; Bin16).

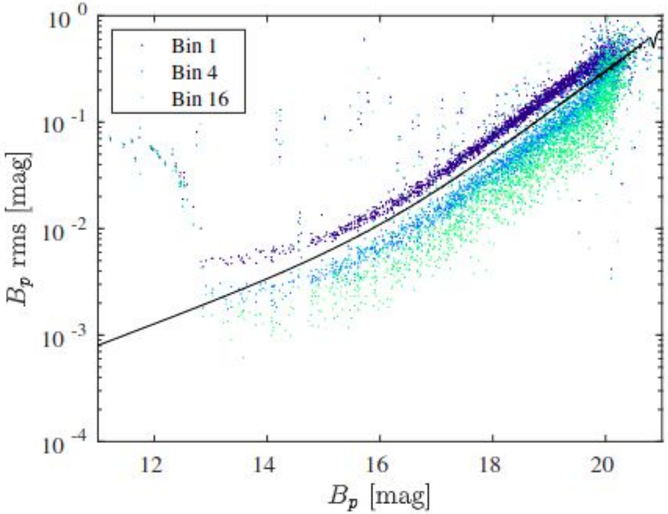

FIG. 9.— The rms of the relative photometry solution, measured over 100 epochs, vs. the GAIA $B_{\rm p}$ magnitude. The color represents single epochs (dark blue; Bin1), average over 4 epochs (blue; Bin4), and average over 16 epochs (green; Bin16). A 6 pixels radius aperture photometry was used. The Black line shows the theoretical noise curve for Bin1, assuming no systematic.