Normal or Transitional?

The evolution and properties of two type Ia supernovae in the Virgo cluster

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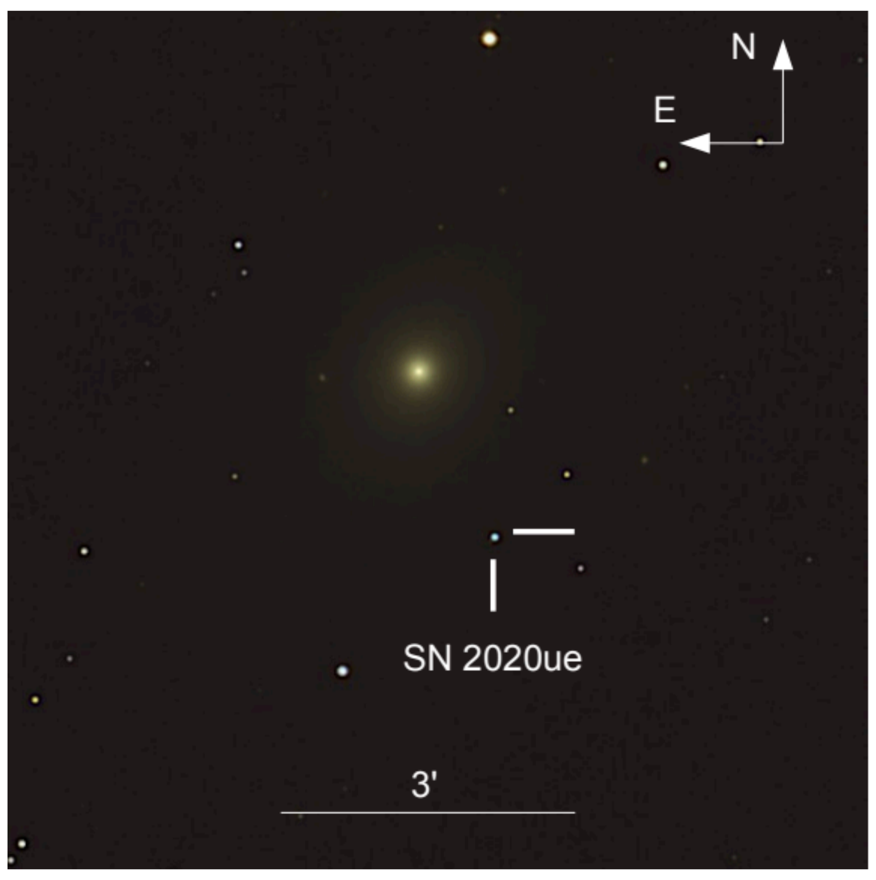
Introduction

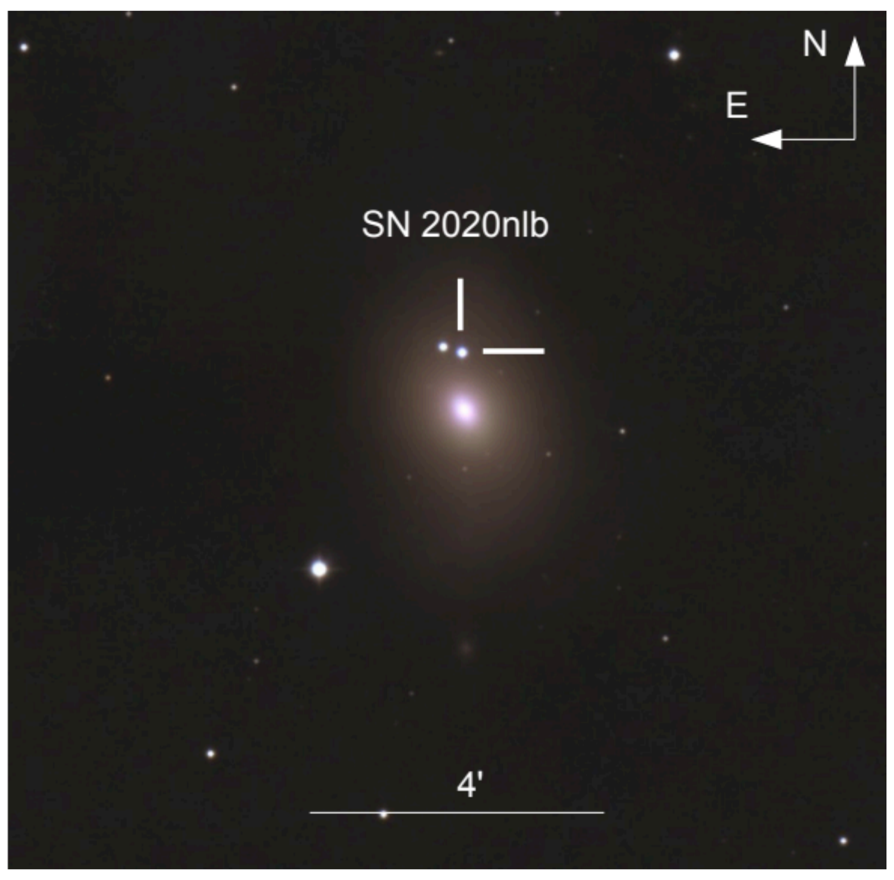
In early 2020, two significant Type Ia supernovae were discovered within the Virgo cluster, providing a unique comparative study.

SN 2020ue was detected in the elliptical galaxy NGC 4636 just days after its explosion; its location in an older stellar environment offers vital clues about the nature of white dwarf progenitors.

SN 2020nlb was found in the grand-design spiral galaxy M100, allowing for high-cadence monitoring of its early evolution.

Because both events occurred in the same cluster, researchers were able to bypass typical distance uncertainties. This turned the Virgo cluster into a "controlled laboratory," enabling a direct comparison of their peak luminosities and chemical signatures to better understand the differences between "normal" and "transitional" Type Ia events.



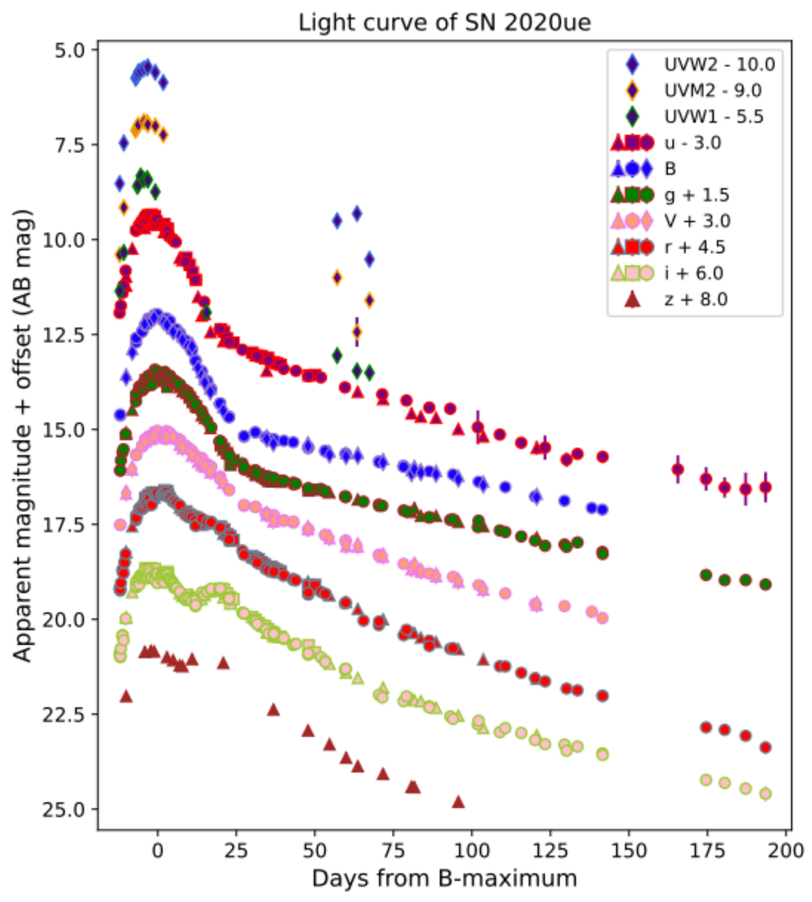


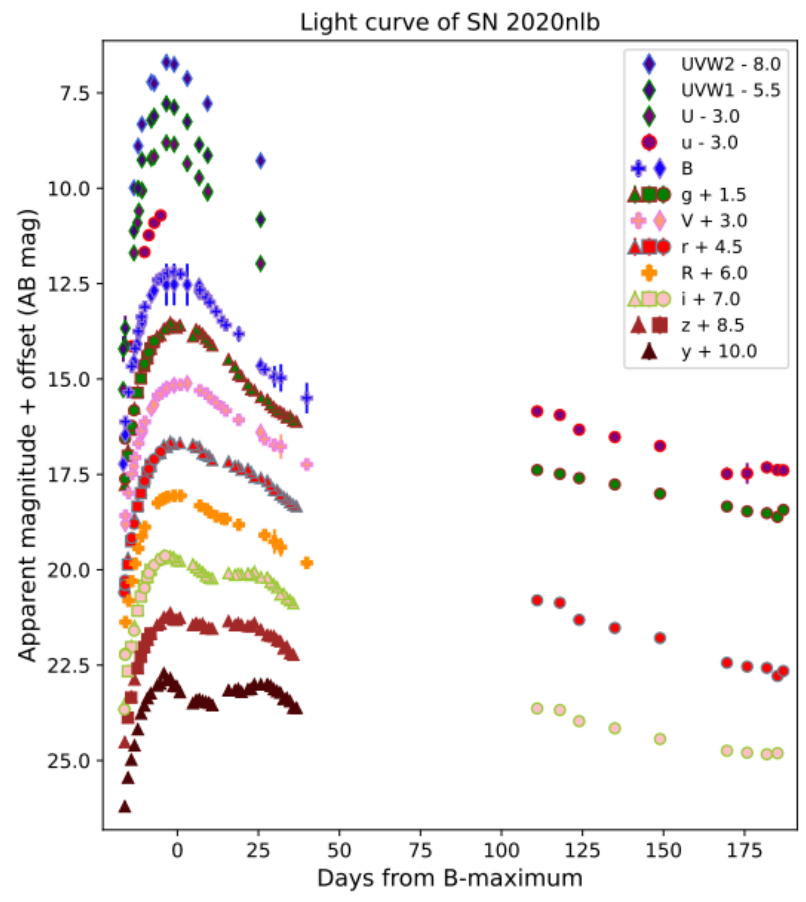
SN 2020nlb: Insights into Color Diversity

- Showed an unusually red color during its initial phases, not caused by interstellar dust, but likely from variations of the photospheric temperatures in the early ejecta.
- This provides evidence that the color variations seen in "normal" Type Ia supernovae can have a purely physical basis.

SN 2020ue: The "Hybrid" Case

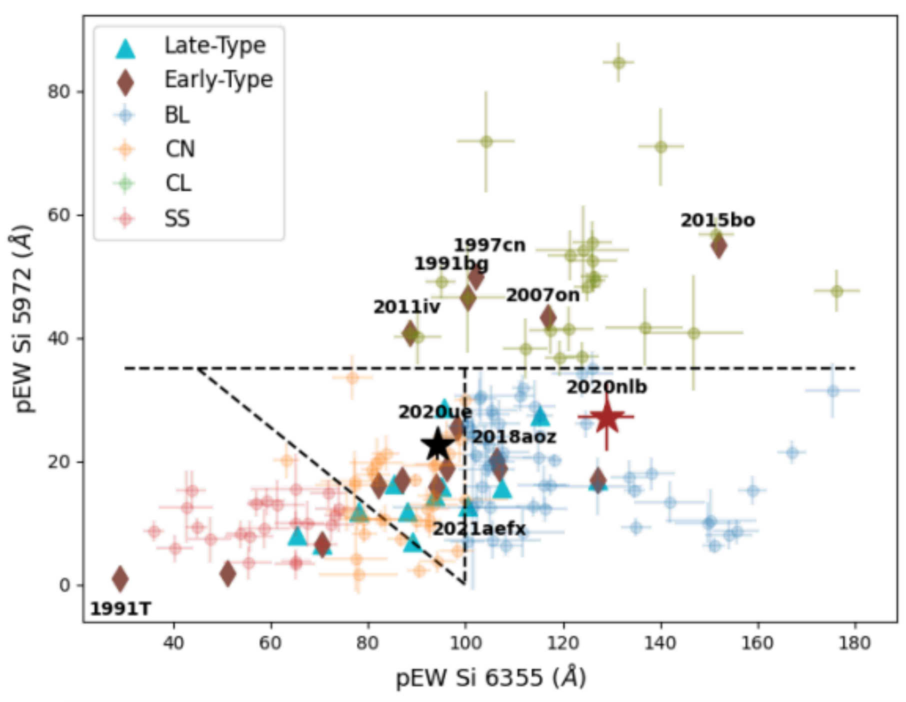
- Its light-curve decay and color evolution place it in the transitional regime between normal and subluminous (91bg-like) events.
- Despite its transitional photometric traits, it remains spectroscopically aligned with the normal supernova population.
- This hybrid profile suggests that similar "edge-case" events may be frequently misclassified or overlooked in large cosmological samples.

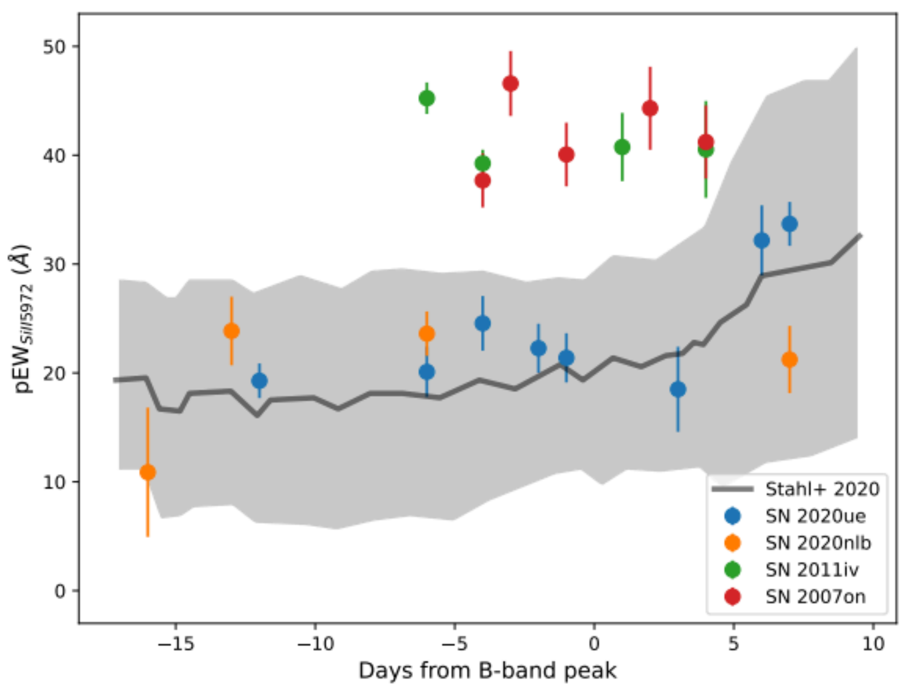




The Photometric vs. Spectroscopic Discrepancy in SN 2020ue

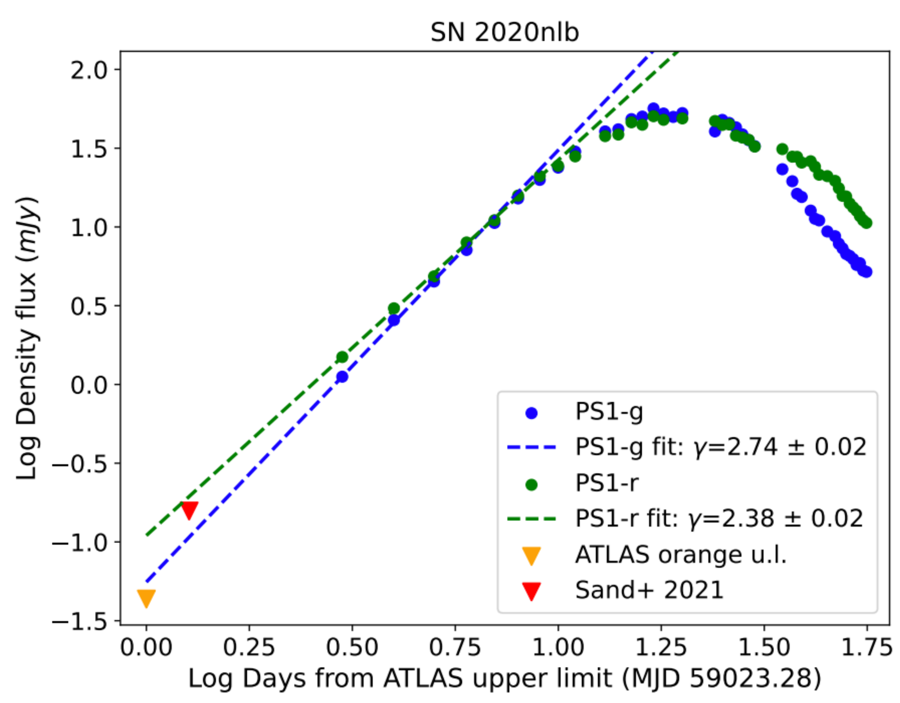
- Despite the light-curve data, spectroscopic indicators like pseudo-equivalent widths of Si II lines, align the event firmly with the **normal Type Ia population**.
- At peak brightness, the supernova lacked the cool temperatures and low ionization levels typical of transitional objects, showing a physical state consistent with standard-luminosity explosions.
- SN 2020ue is at the "extreme photometric edge" of the normal range. Without spectroscopy, such events are easily misclassified in cosmological samples that rely solely on light-curve fitting
- This case suggests that high-quality spectroscopy is essential to build physically homogeneous samples for high-precision cosmology.

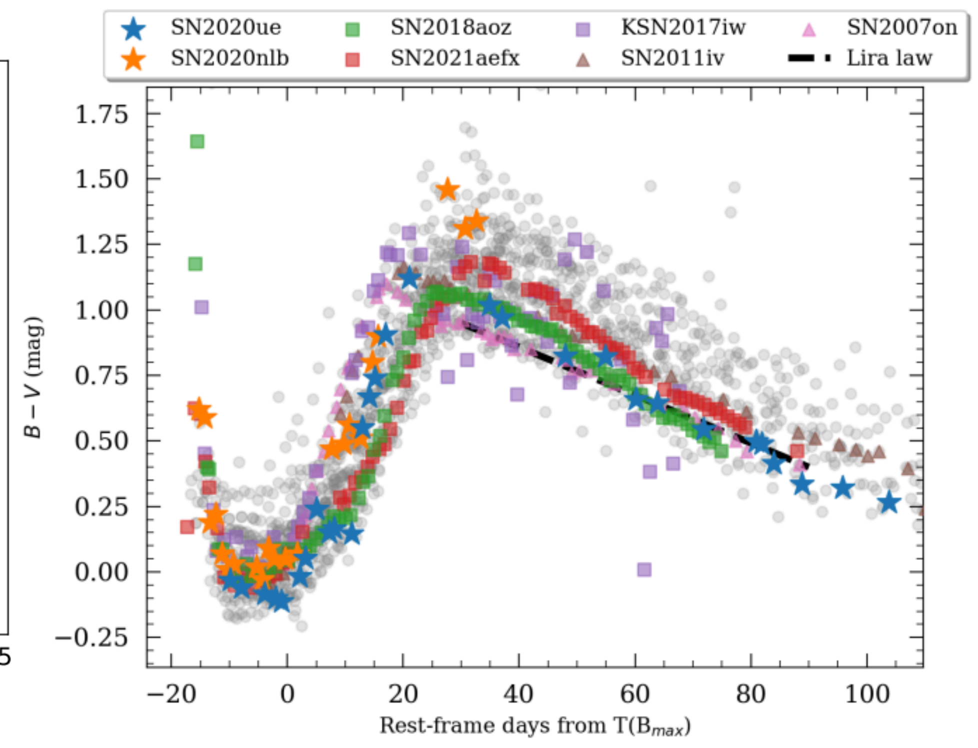




The "Color" Problem and Systematic Bias (SN 2020nlb)

- SN 2020nlb proves that early red colors can stem from intrinsic temperature variations rather than interstellar dust.
- Color variation was initially found from departure from the “fireball law” of γ = 2 for early rising SN light curves
- Several eplxanations proposed in literature for this behavior, including enhanced CSM density near the WD progenitor.
- Standard extinction correction methods, such as the "Lira Law," may be over-correcting for dust that isn't actually there.
- If intrinsic color diversity is widespread, it introduces systematic biases into distance measurements, potentially affecting the precision of the Hubble constant (H_0).





Take-home messages

This study underscores the necessity of high-cadence, early-time observations for understanding the inherent physical diversity of Type Ia supernovae. By examining two events within the Virgo cluster, the research demonstrates that traditional photometric classifications can be misleading. Specifically, the discovery that SN 2020nlb early redness is an intrinsic physical property, rather than an effect of host-galaxy dust, serves as a vital warning for future surveys. Without accounting for such temperature-driven variations, extinction corrections could be systematically biased, affecting the precision of the local Hubble constant (H0).

Similarly, the case of SN 2020ue reveals the limitations of relying solely on light-curve templates, as its spectroscopic “normality” contradicts its transitional photometric appearance. As next-generation facilities like the Vera C. Rubin Observatory begin to discover thousands of supernovae, the focus must shift toward obtaining comprehensive datasets that break the degeneracies between intrinsic and extrinsic factors. Ultimately, this work advocates for a "spectroscopic standardized candle" approach to better calibrate the cosmic distance ladder and minimize uncertainties in our understanding of the expansion of the Universe.

[1] Williams et al., MNRAS 527, 4702 (2024) [2] Sand et al., ApJ 922, 21 (2021) [3] Phillips, ApJL 413, L105 (1993) [4] Phillips et al., AJ 118, 1766 (1999) [5] Branch et al., PASP 118, 560 (2006) [6] Filippenko et al., AJ 104, 1543 (1992) [7] Blondin & Tonry, ApJ 666, 1024 (2007) [8] de Vaucouleurs et al., RC3 (1991) [9] Burke et al., ApJ 937, 62 (2022) [10] Zheng et al., ApJL 778, L15 (2013) [11] Livio & Mazzali, Phys. Rep. 736, 1 (2018) [142 Mazzali et al., Science 315, 822 (2007) [13] Hillebrandt & Niemeyer, ARA&A 38, 191 (2000)