Pushing the Limits

Studying SN 2025zi and the Nature of Type Iax Supernovae

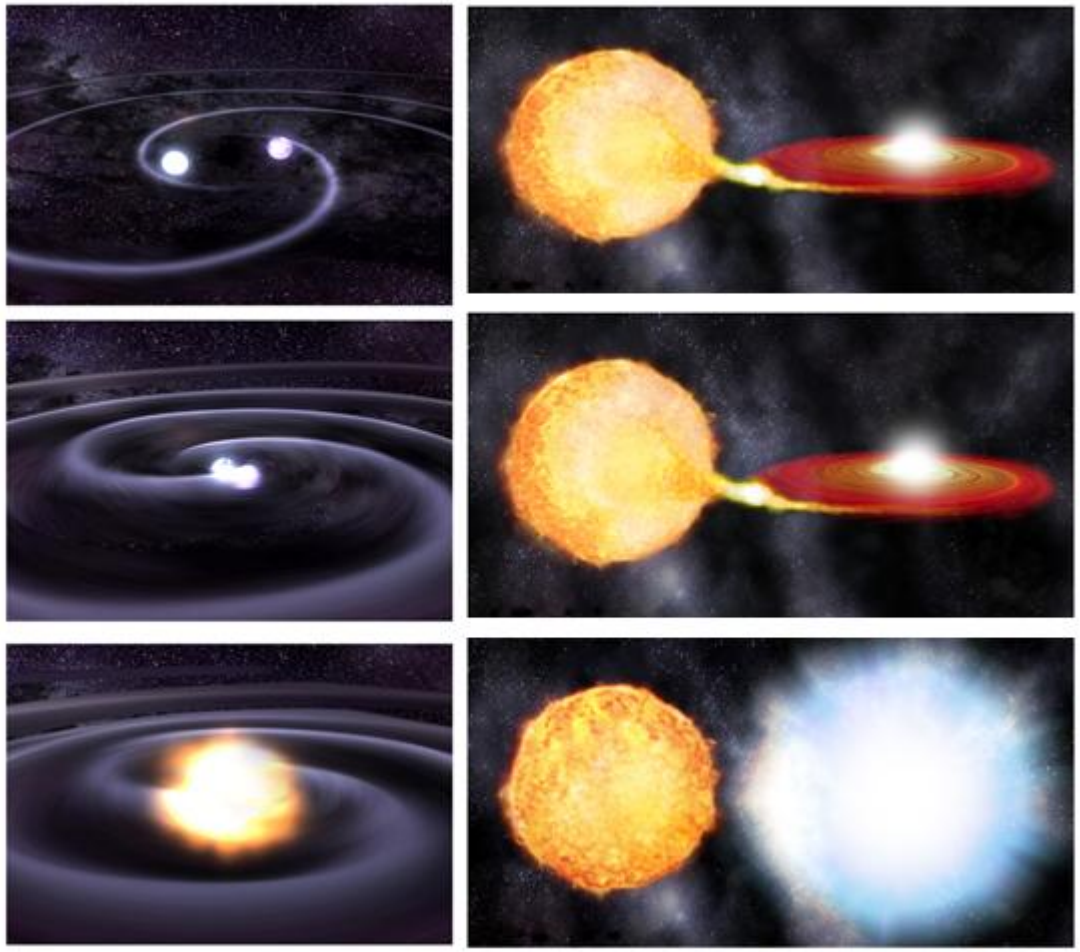
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PhD student

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Department of
experimental physics

Type Ia supernovae

- Thermonuclear stellar explosions
- Their origin is still under debate
- Normal Type Ia SNe used for distance measurements



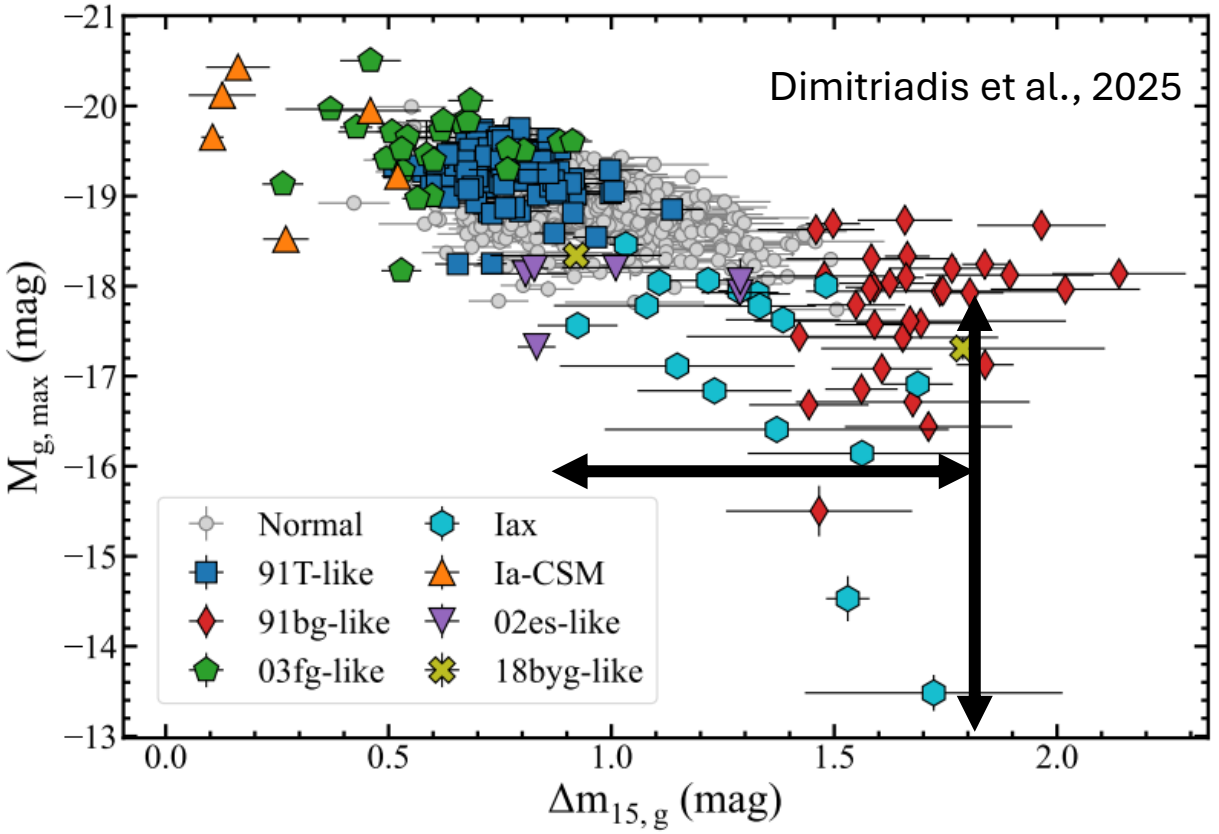
Source: https://astrobites.org/wp-content/uploads/2015/04/two_sne.png

Type Iax supernovae

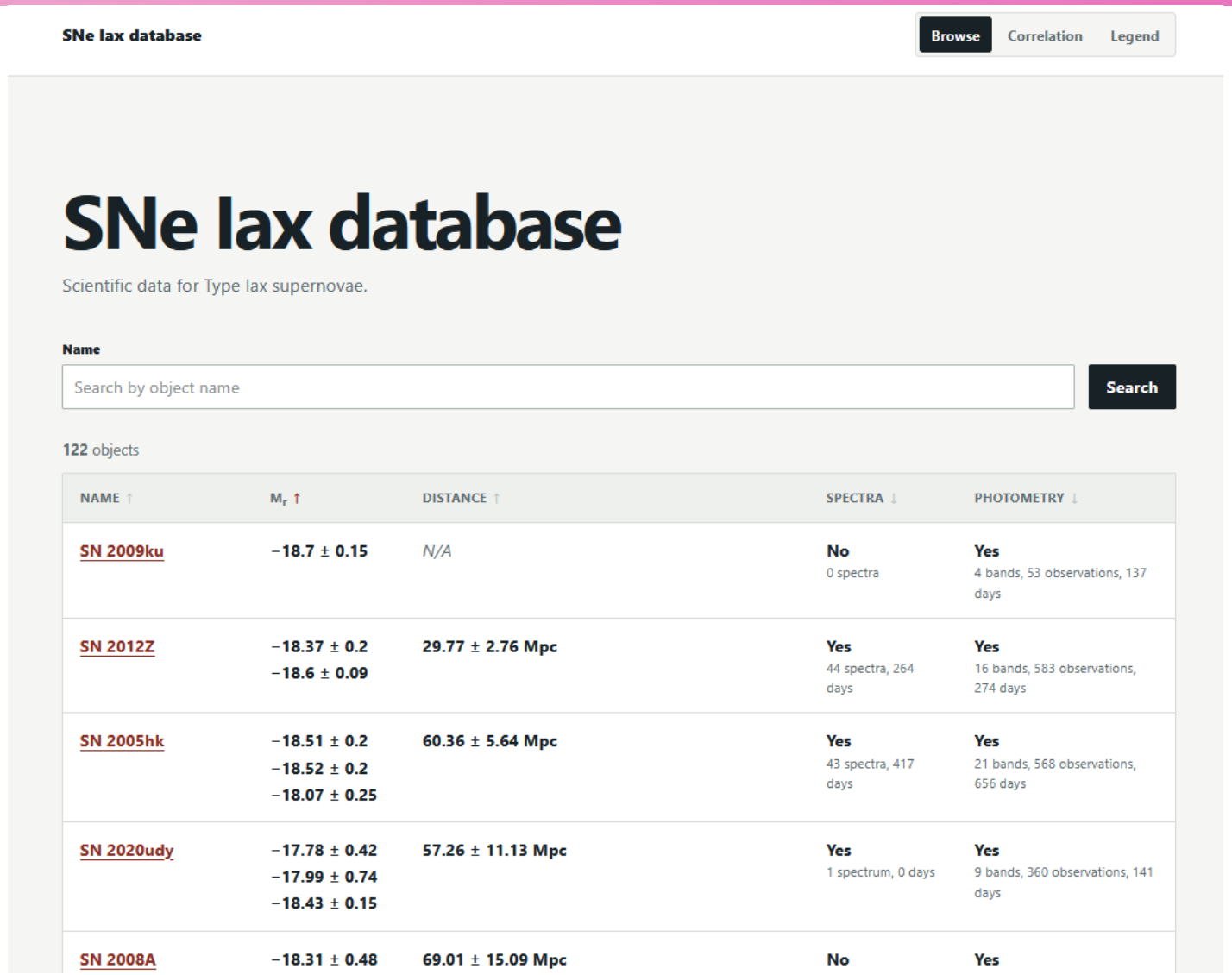
A subclass of Type Ia supernovae (SNe Ia)

Key features:

- Much fainter than normal SNe Ia
  (Ia: $M_{V,max} \sim -19$ mag [1])
  $-18{,}5\ \text{mag} \lesssim M_{V,max} \lesssim -13\ \text{mag}$
- Much lower photospheric velocity
  (Ia: 10.000 – 15.000 km/s [2])
  $2500\ \text{km/s} < v_{phot} < 9000\ \text{km/s}$
- Great diversity in every physical property



SNe Iax database



- 122 SNe Iax
- 7229 photometry
- 660 spectra

The lax rate



The lax rate

The main limiting factor are extremely low-luminosity SNe lax!

The faintest SNe lax: **SN 2021fcg** (Karambelkar et al, 2021)

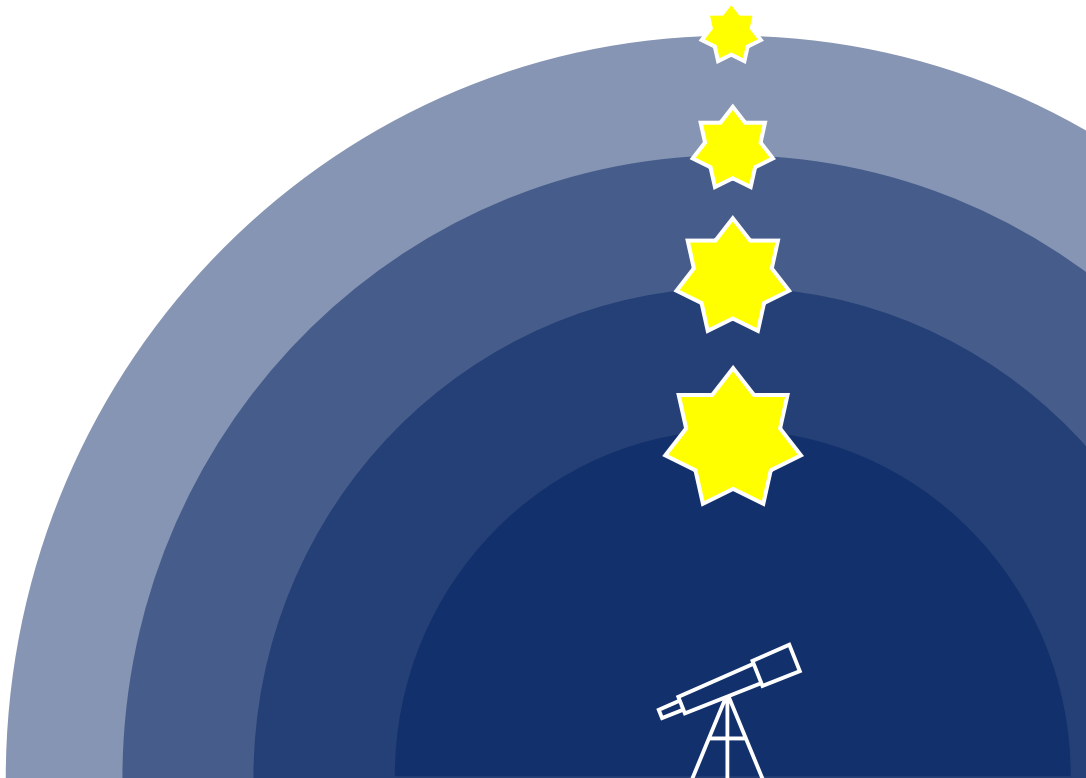
$$M_g^{peak} = -11.6 \pm 0.42 \text{ and } m_g^{peak} = 20.16 \pm 0.24$$

The discovering survey: ZTF

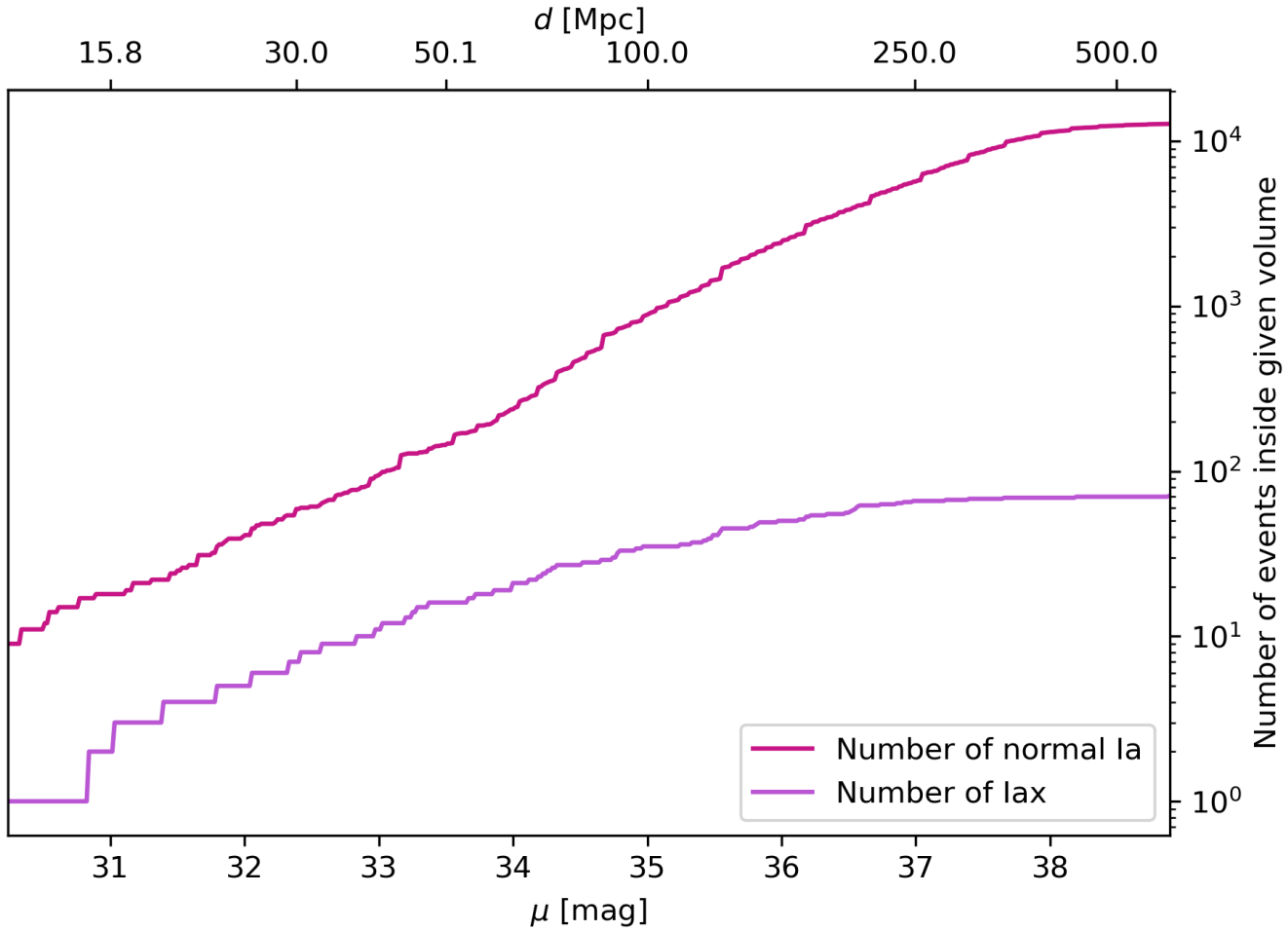
$$m_g^{lim} = 20.8$$

Discovery limit:

$$\mu_{lim} = 32.46 \leftrightarrow d_{lim} = 31.05 \text{ Mpc}$$

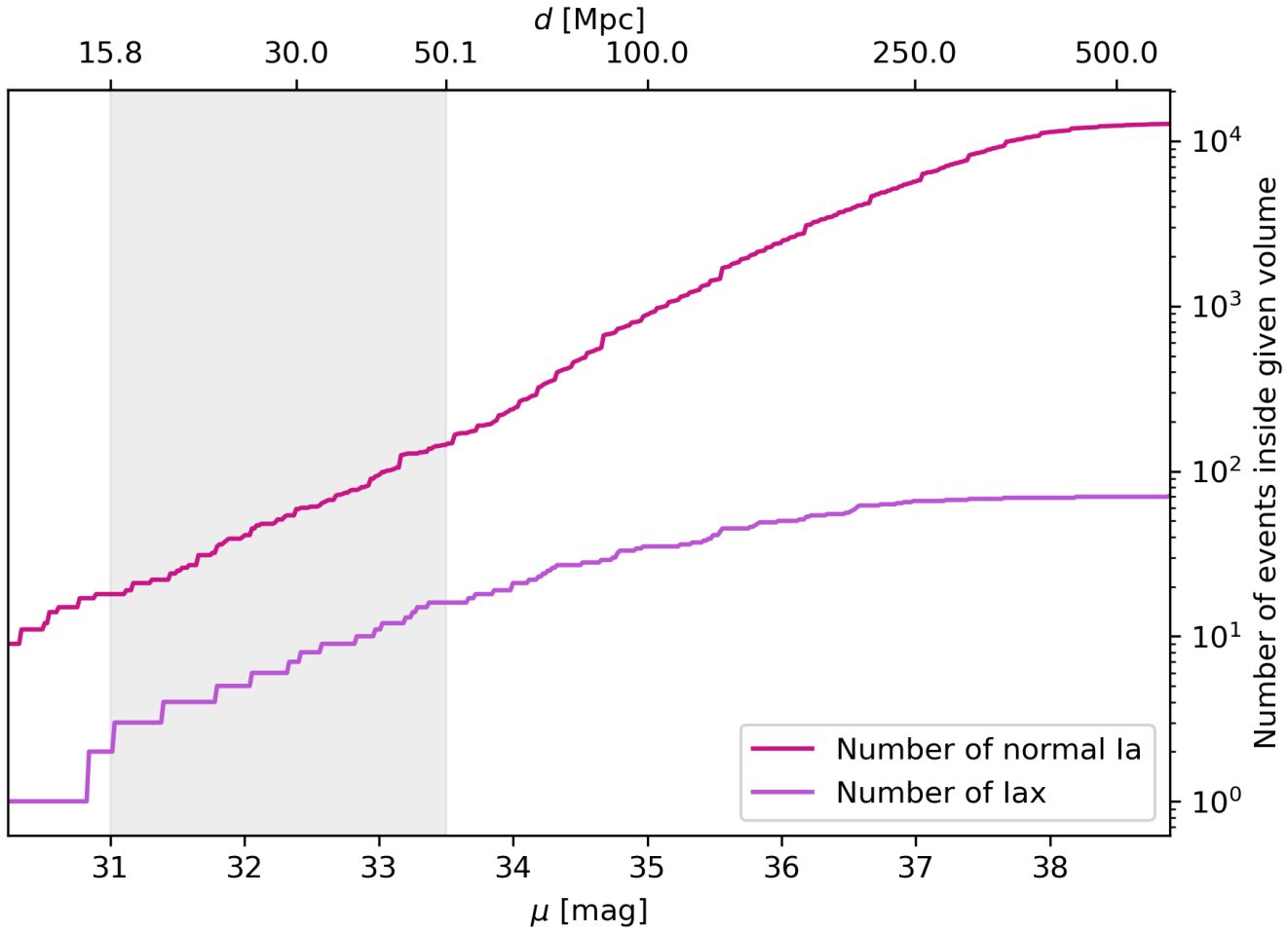


Finding the right volume



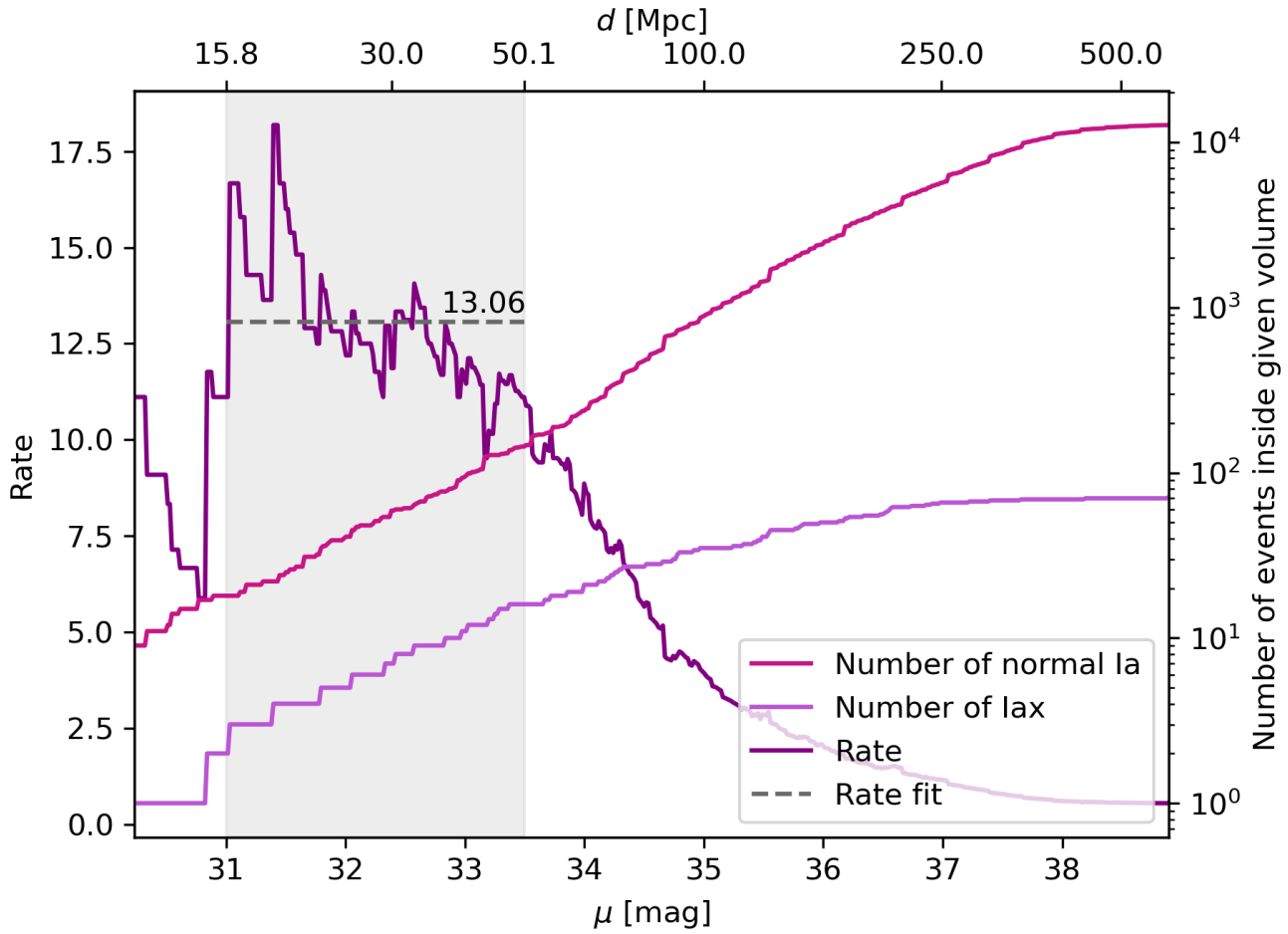
Finding the right volume

$$31.0 \text{ mag} < \mu < 33.5 \text{ mag} \Leftrightarrow 15.84 \text{ Mpc} < \text{d} < 50.12 \text{ Mpc}$$



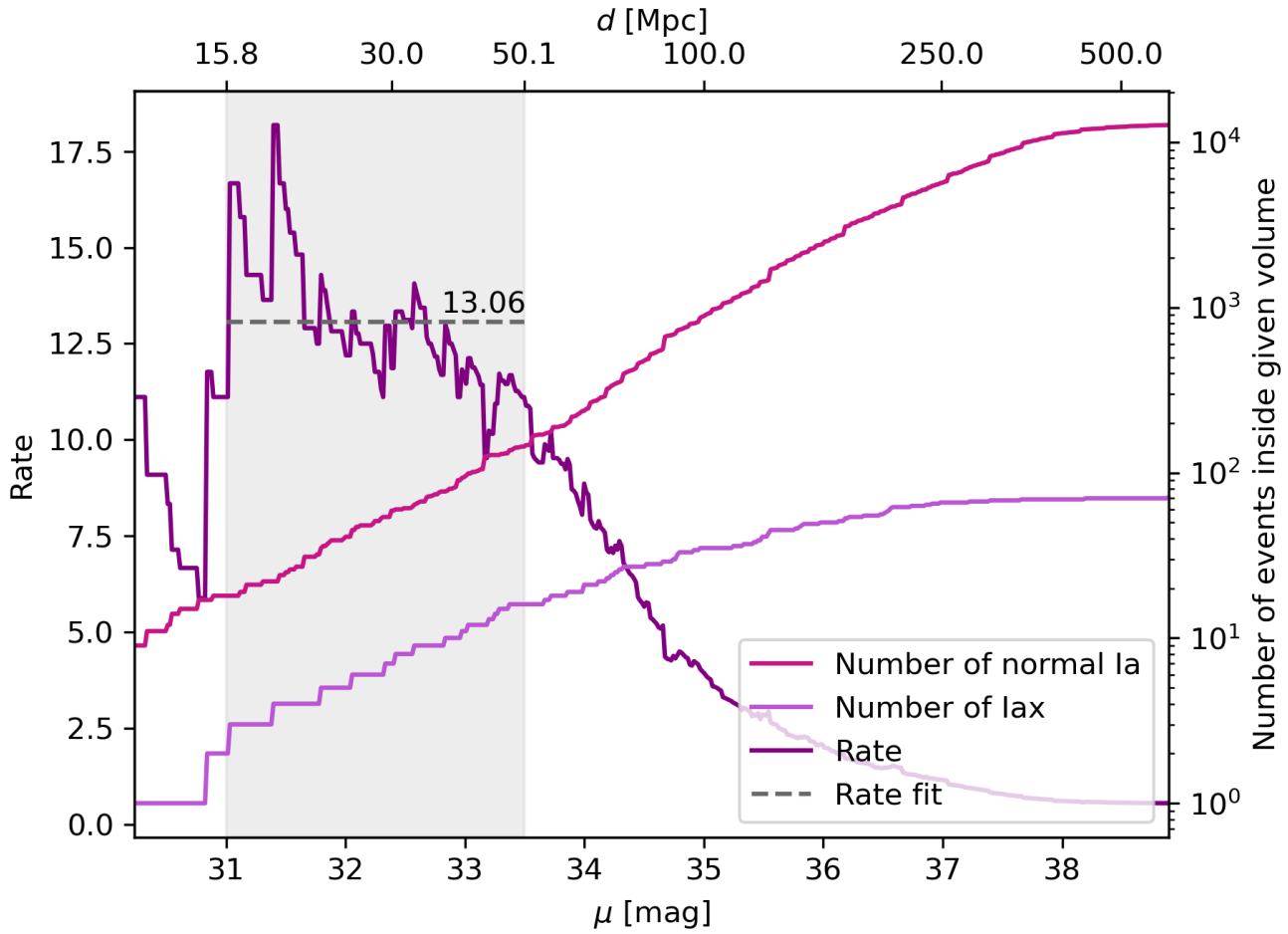
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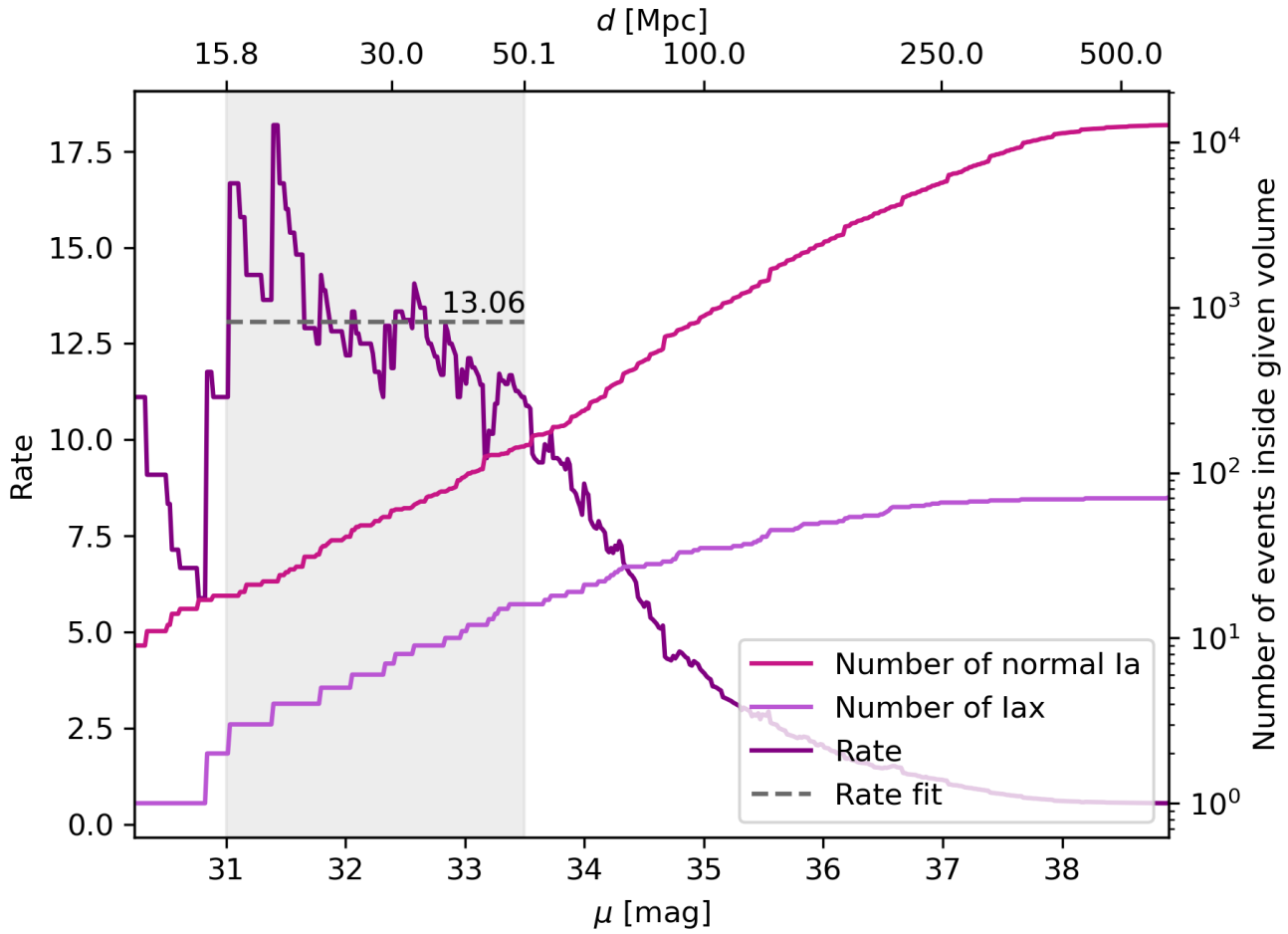
$$31\ \text{mag} < \mu < 33{,}5\ \text{mag} \Leftrightarrow 15{,}84\ \text{Mpc} < \text{d} < 50{,}12\ \text{Mpc}$$



$$\text{Rate} = \frac{\text{N}_{\text{Iax}}}{\text{N}_{\text{Ia}}} \cdot 100$$

Finding the right volume

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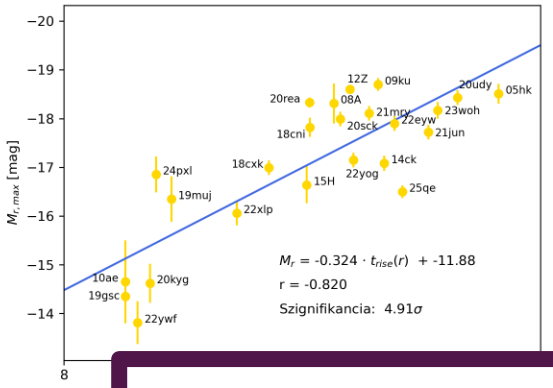
$$\text{Rate} = \frac{N_{Iax}}{N_{Ia}} \cdot 100$$

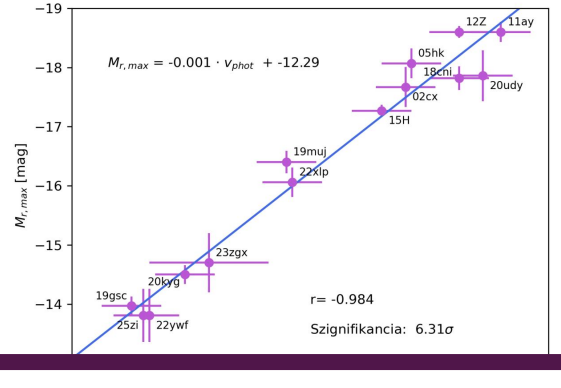
$$13.06^{+9.25}_{-6.09}$$

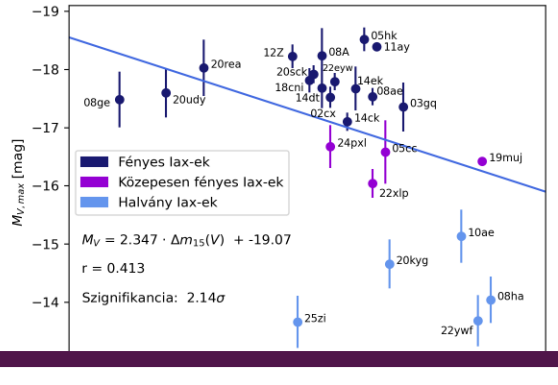
(In prep., Barna and Mochnács)

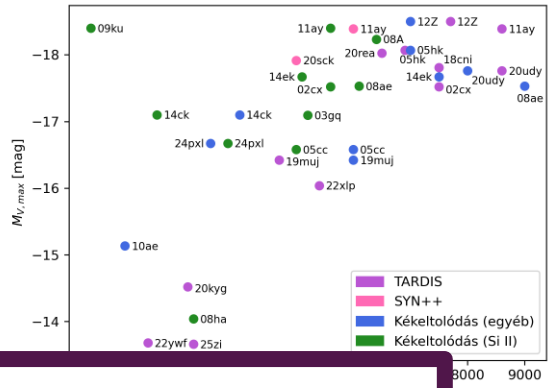
There is about 13 SNe Iax for every 100 normal SNe Ia!

Investigating correlations

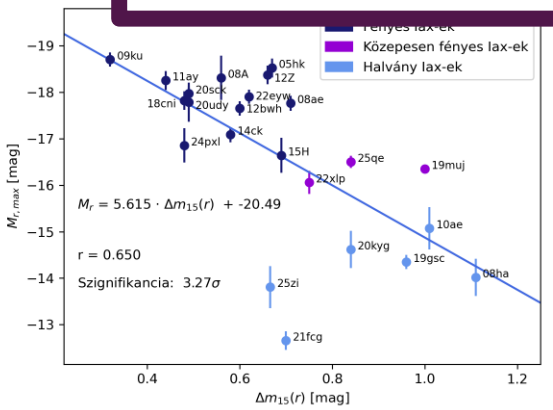


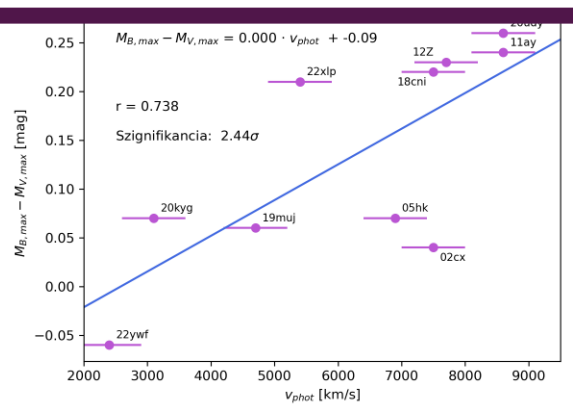


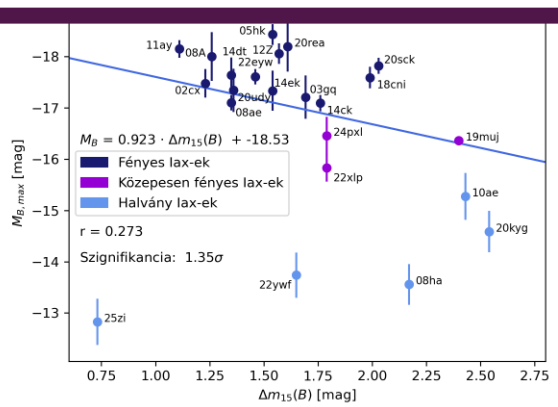


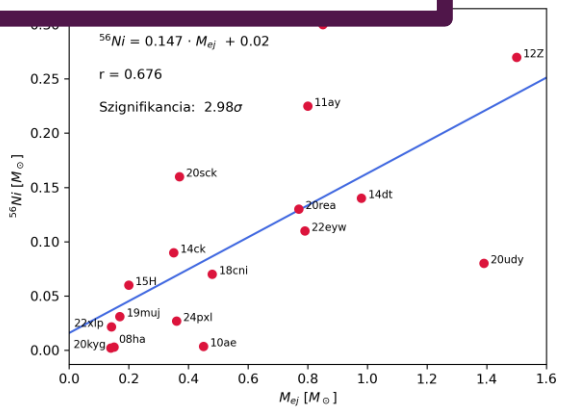


Continuous distribution! → Common origin



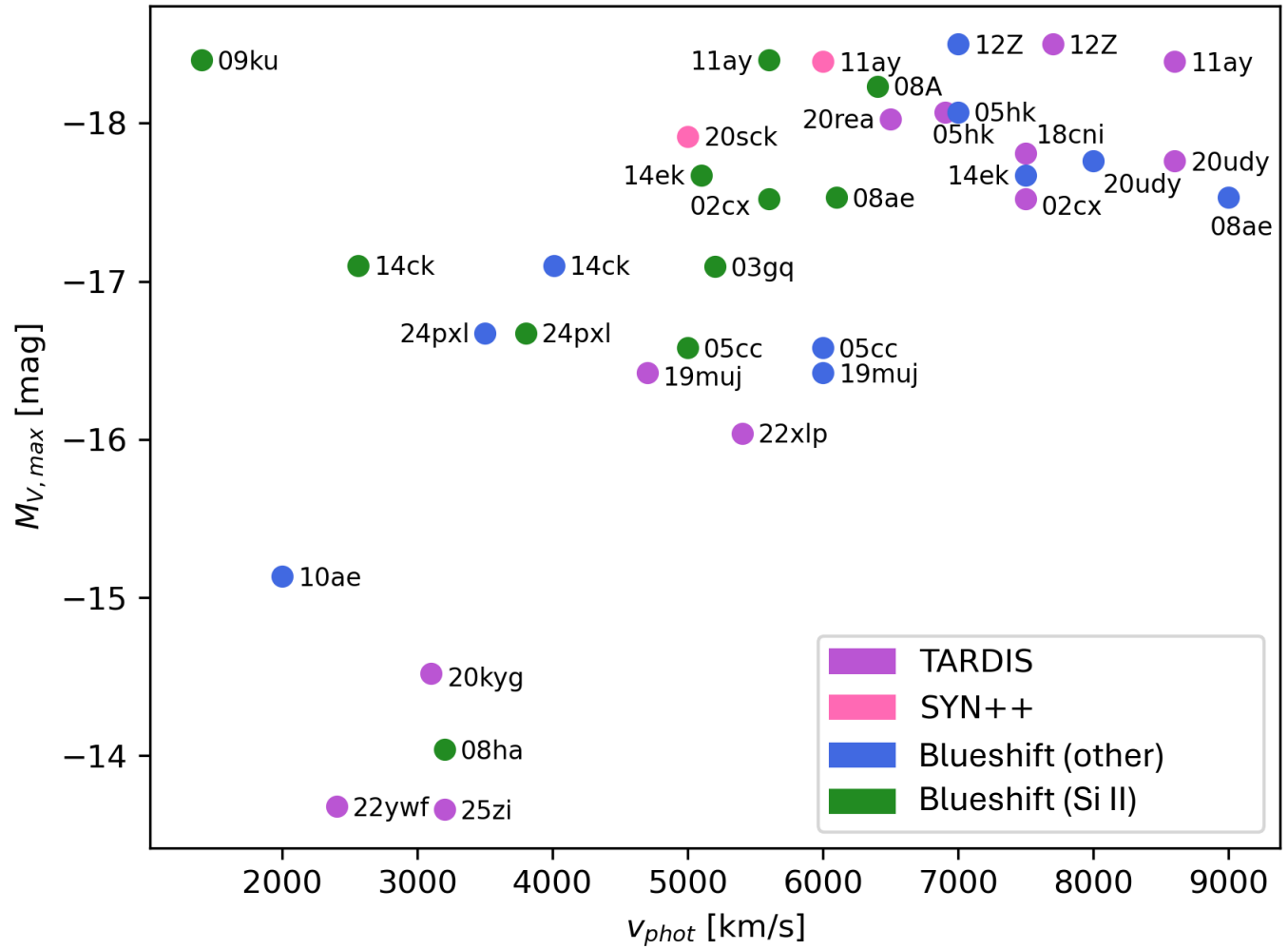






The most interesting of all

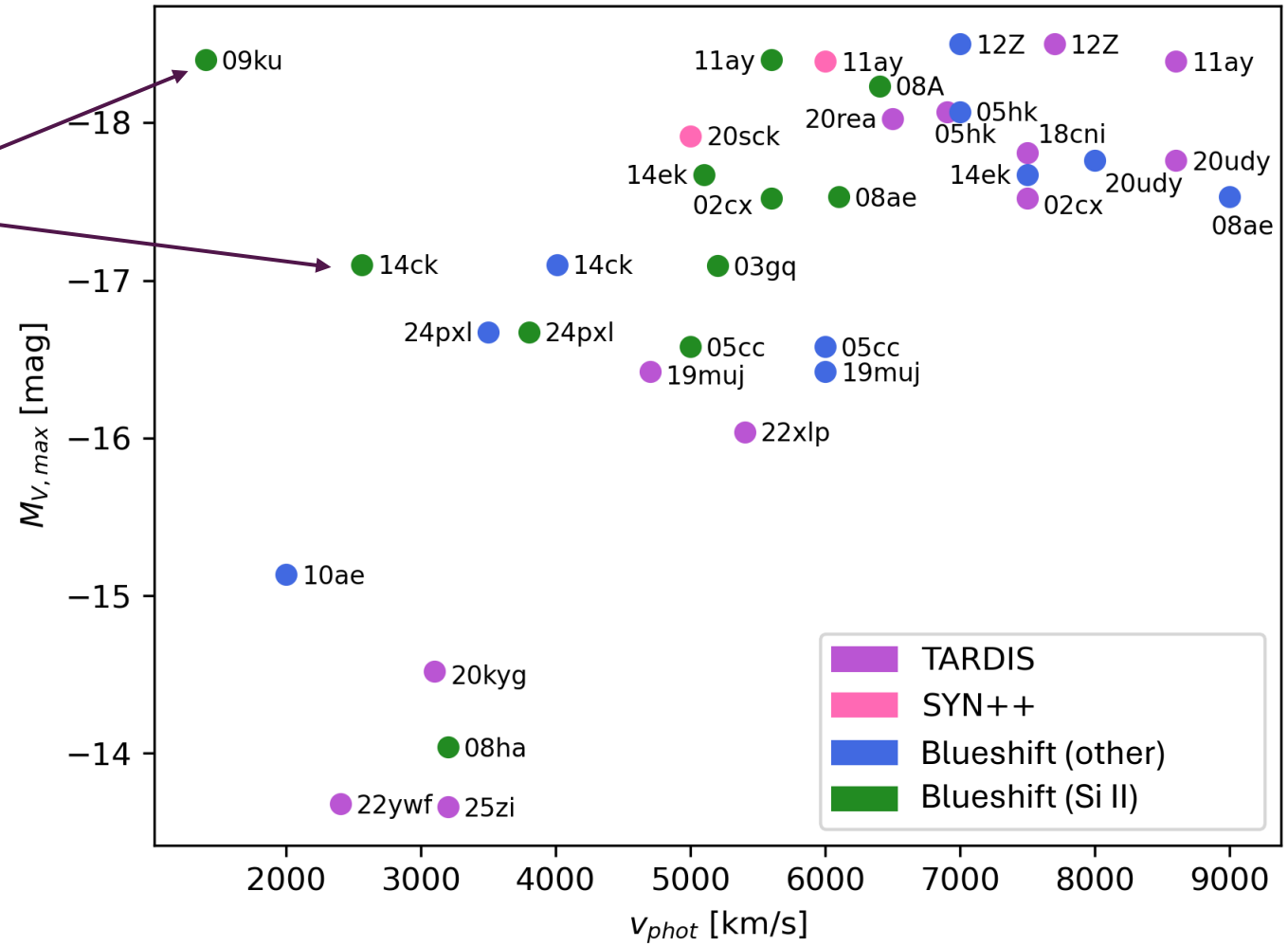
Photospheric velocity (v_{phot}) – Peak brightness ($M_{V,peak}$)



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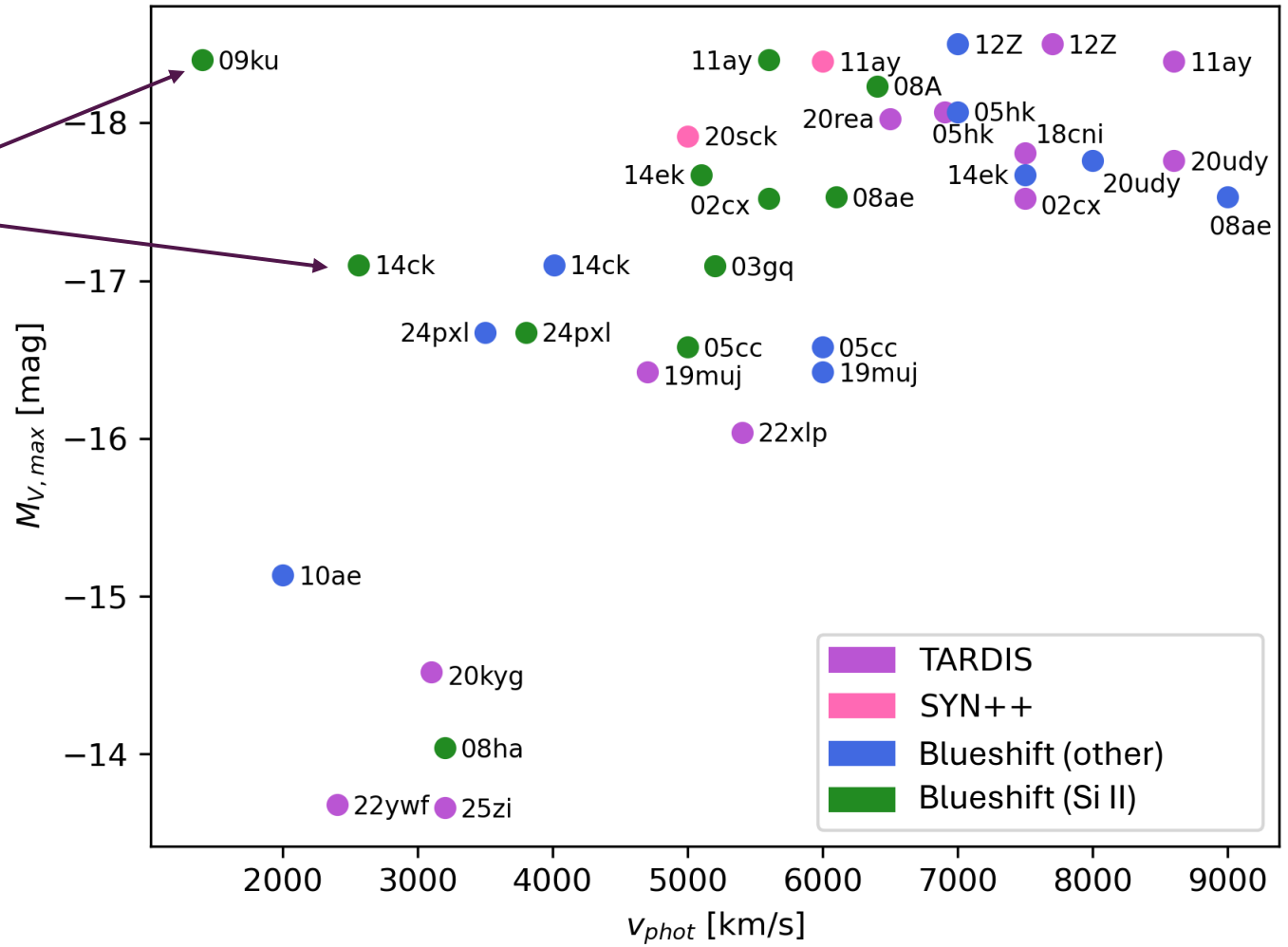
Obvious outliers

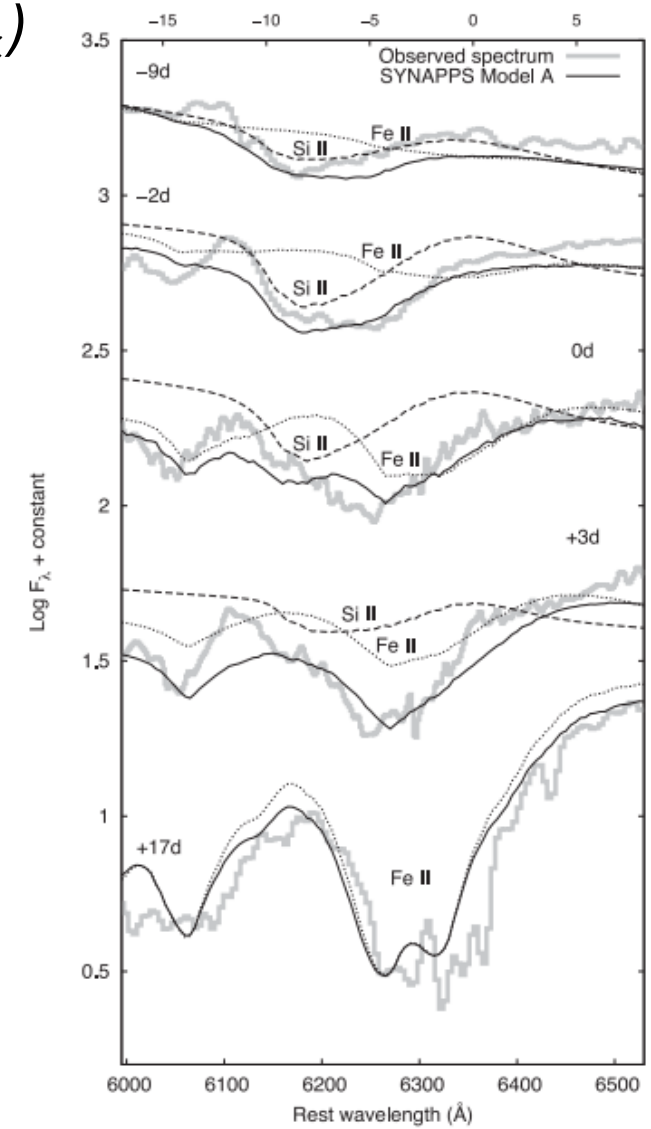


The most interesting of all

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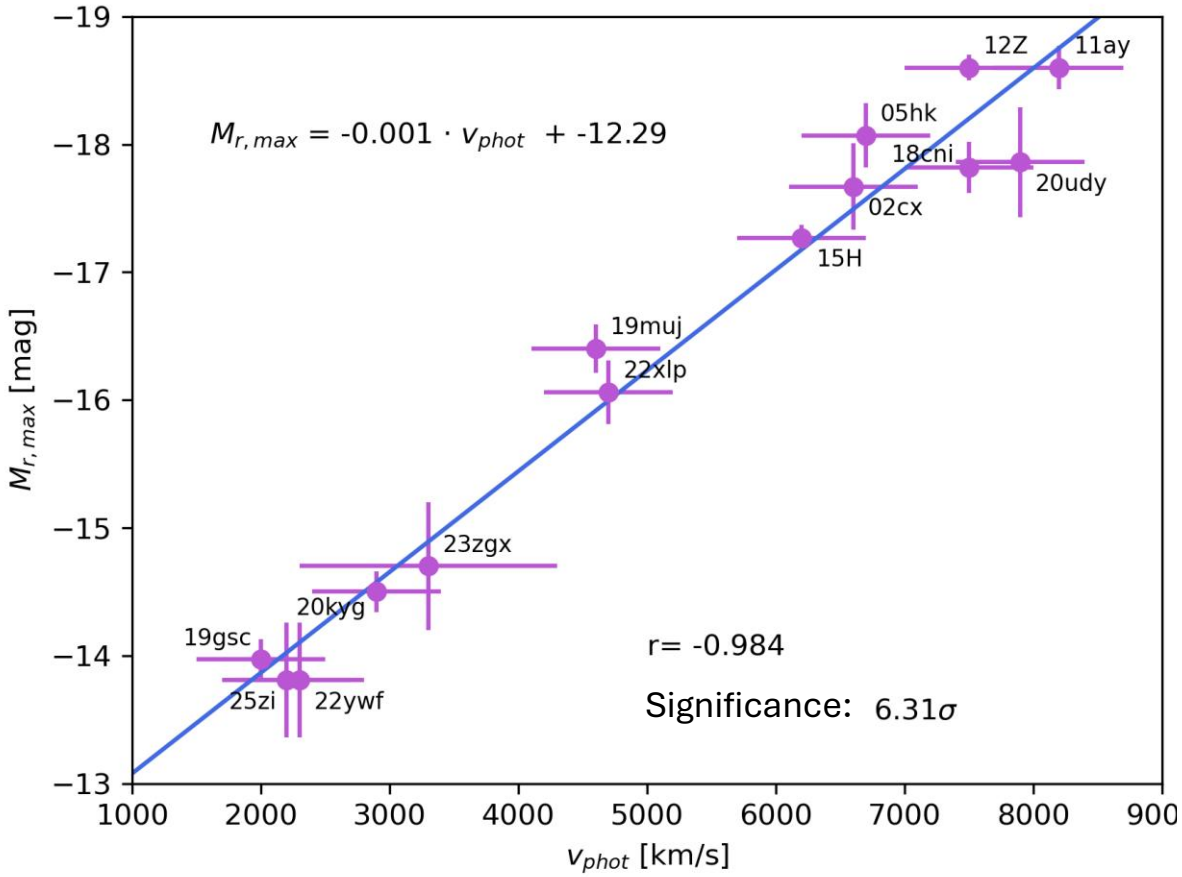


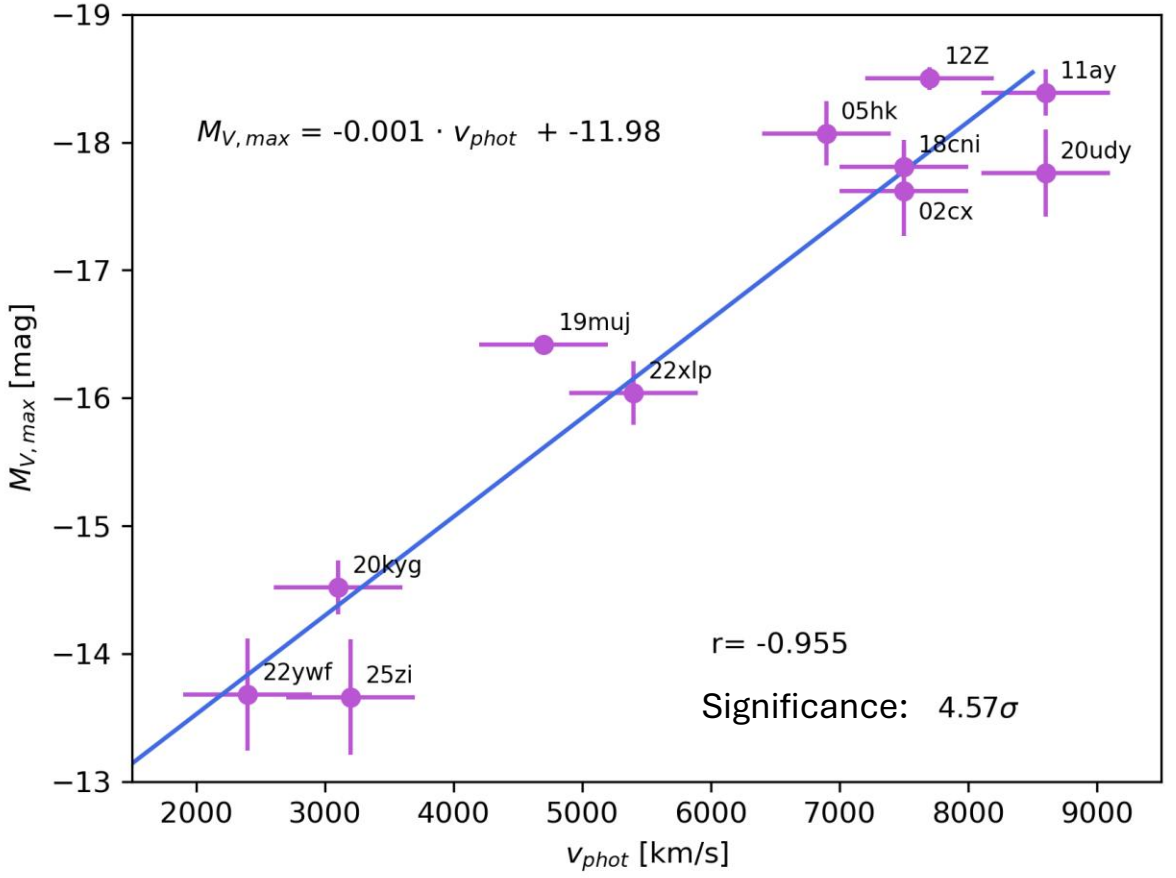


Szalai et al, 2015

The most interesting of all

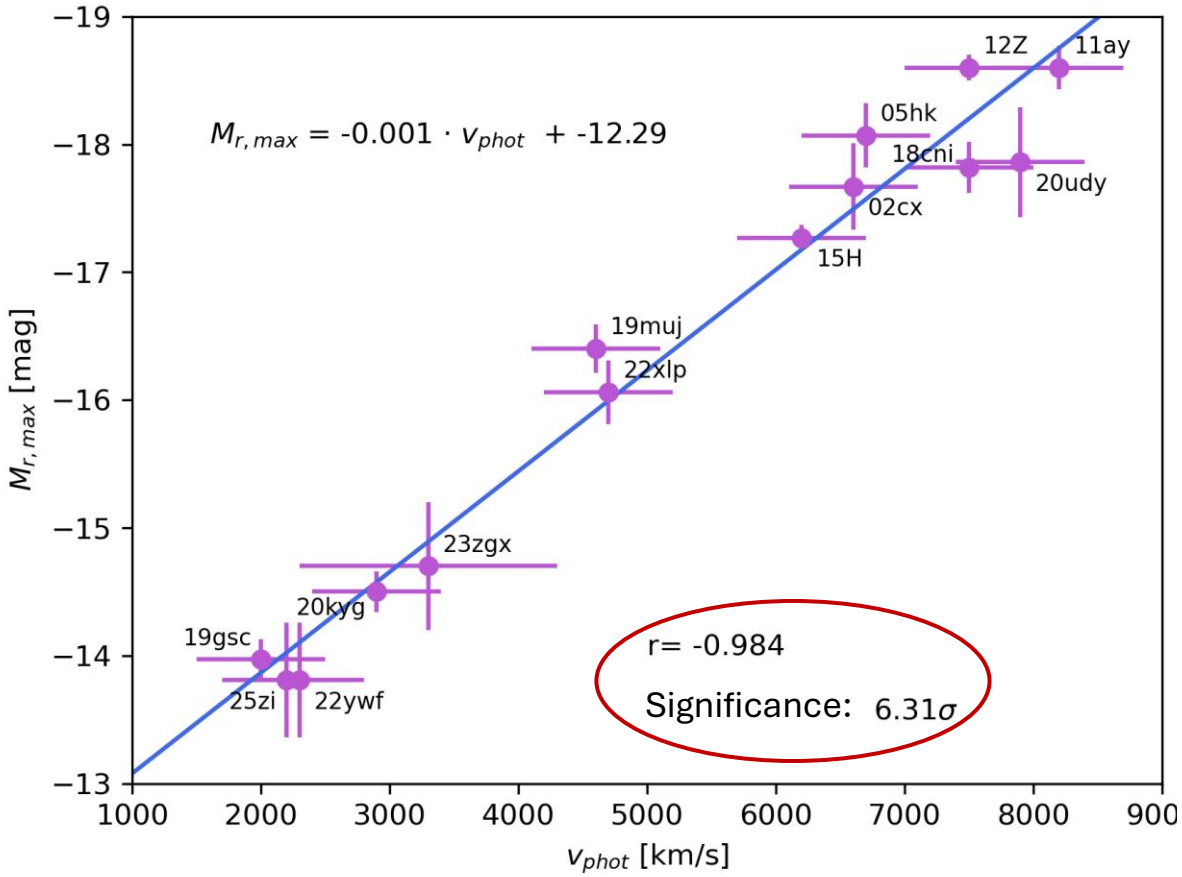
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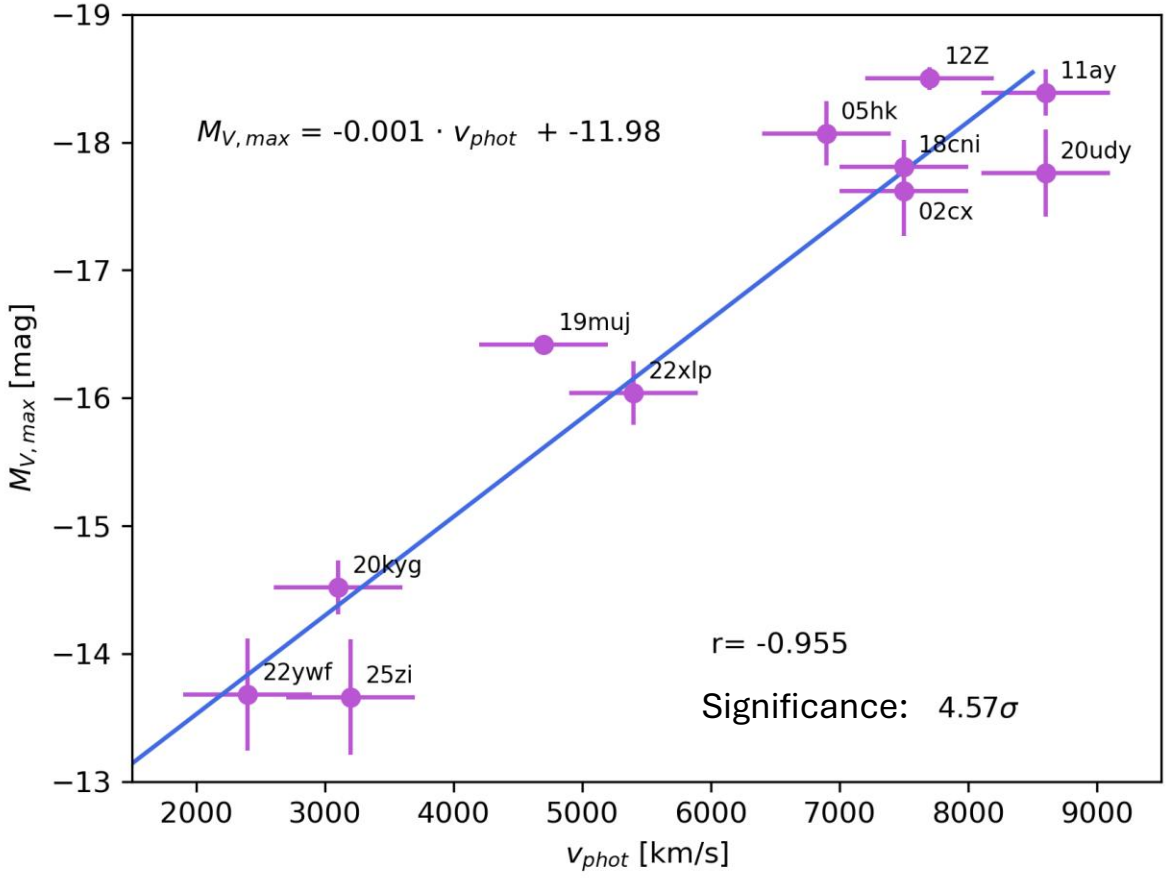




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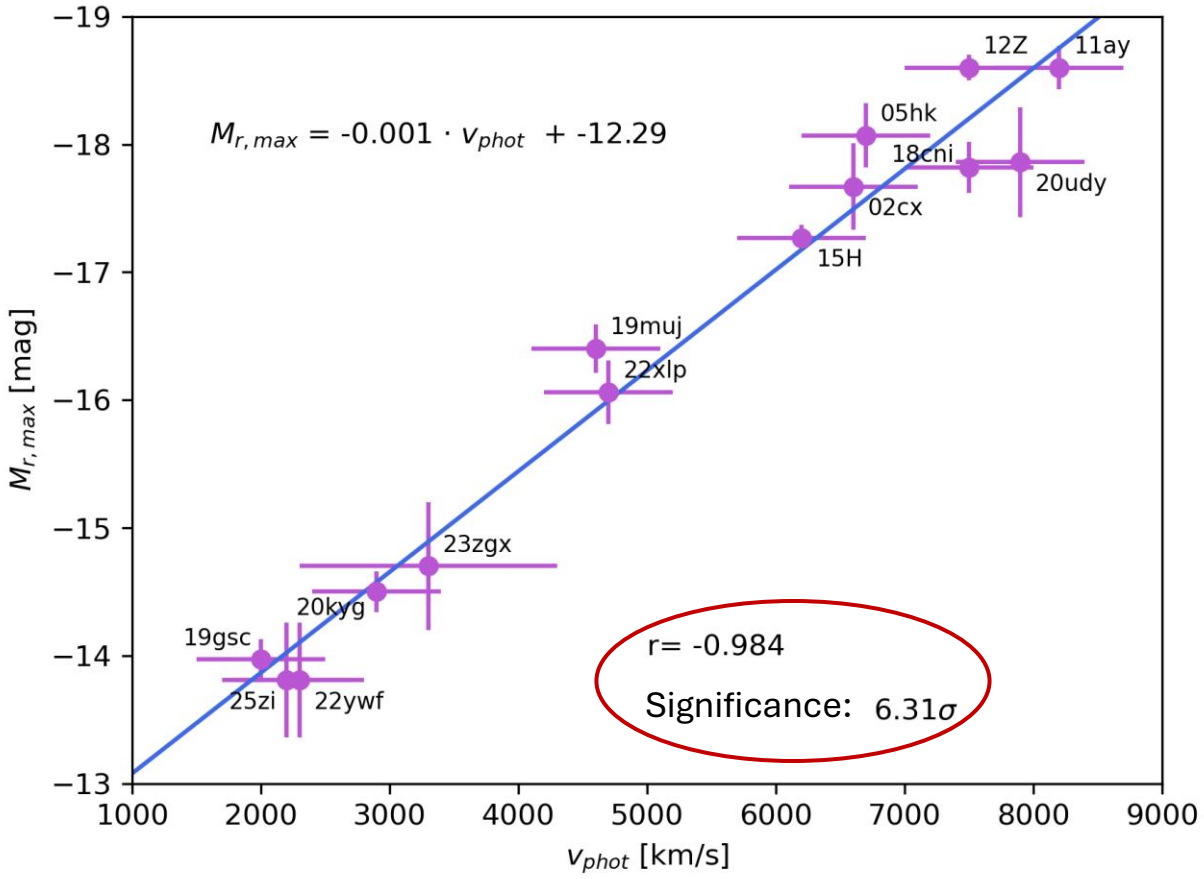
Photospheric velocity (v_{phot}) – Peak brightness ($M_{V,peak}$)





The most interesting of all

Photospheric velocity (v_{phot}) – Peak brightness ($M_{V,peak}$)



May be possible to use it for distance measurements!

The Phillips-relation

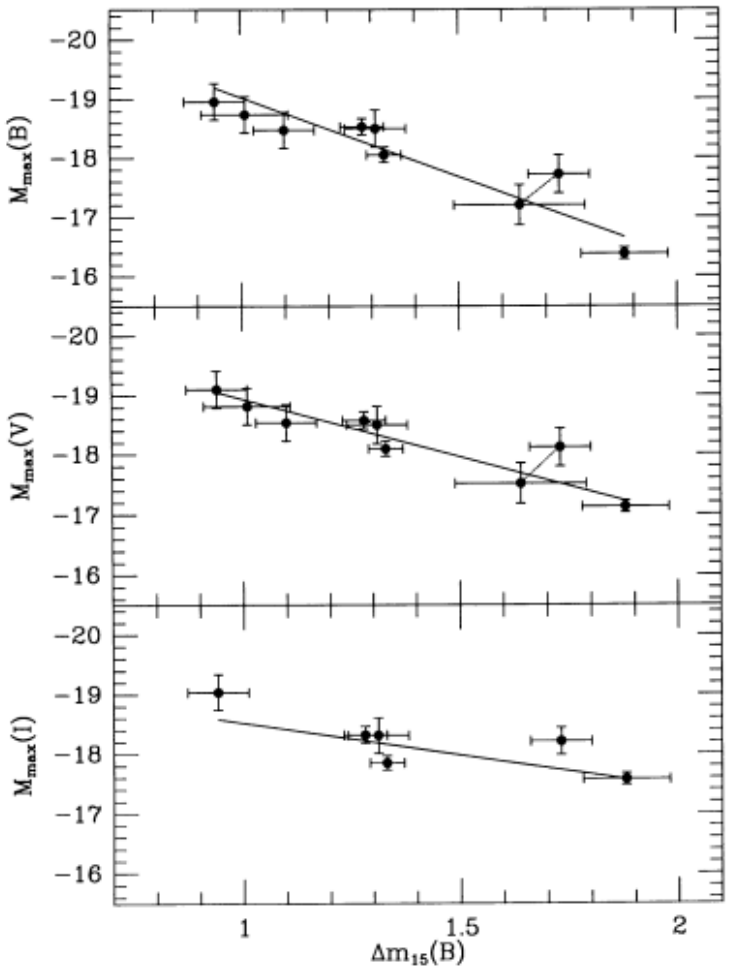


FIG. 1.—Decline rate–peak luminosity relation for the nine best-observed SN Ia's. Absolute magnitudes in *B*, *V*, and *I* are plotted vs. $\Delta m_{15}(B)$, which measures the amount in magnitudes that the *B* light curve drops during the first 15 days following maximum.

Phillips, 1993

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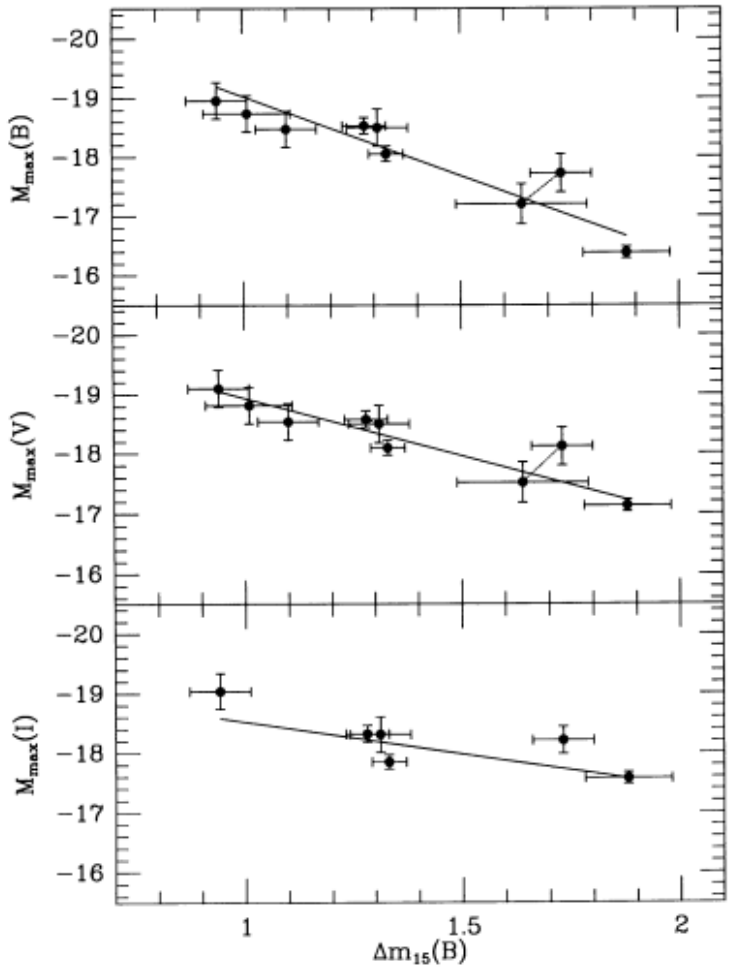
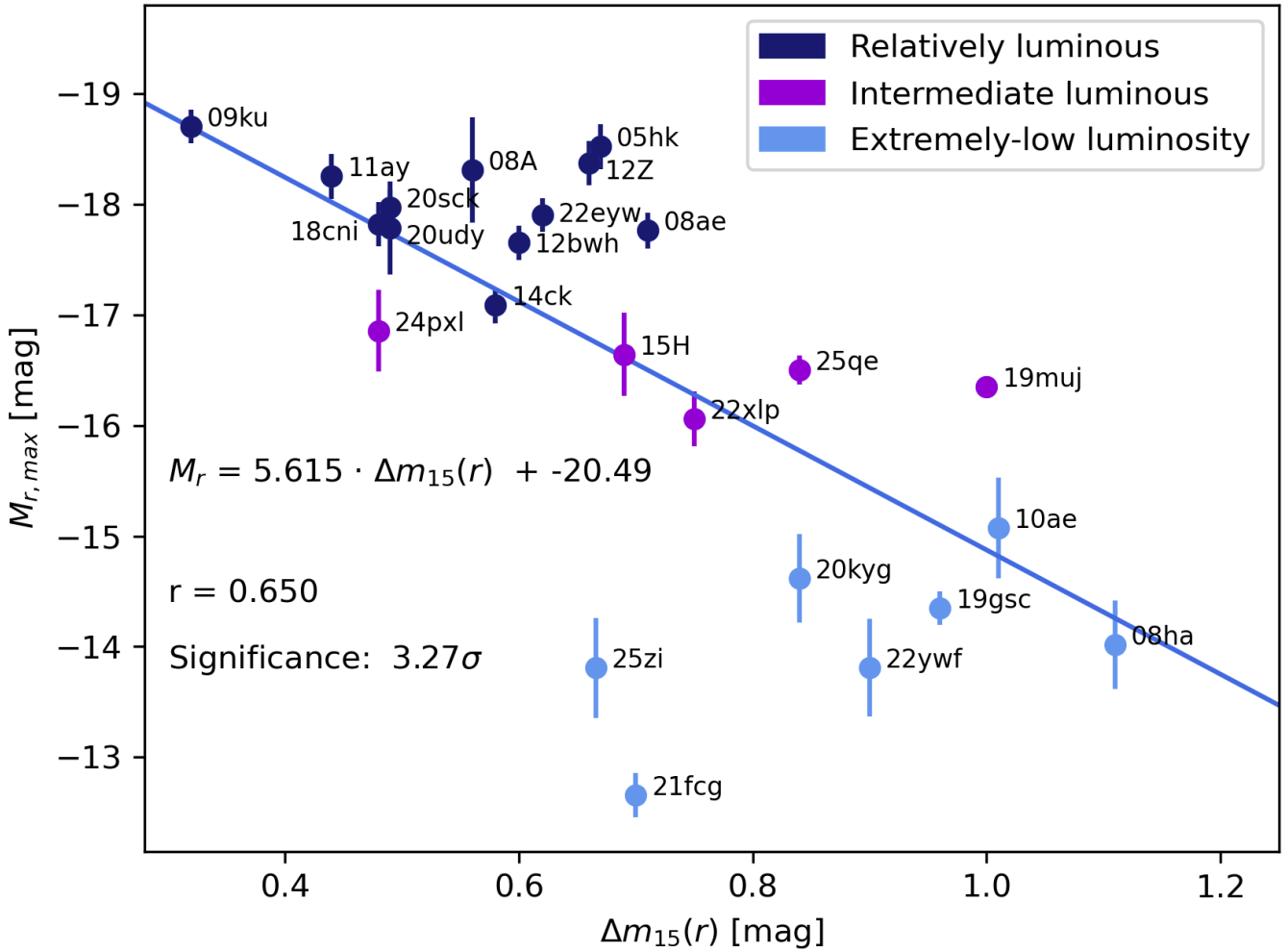


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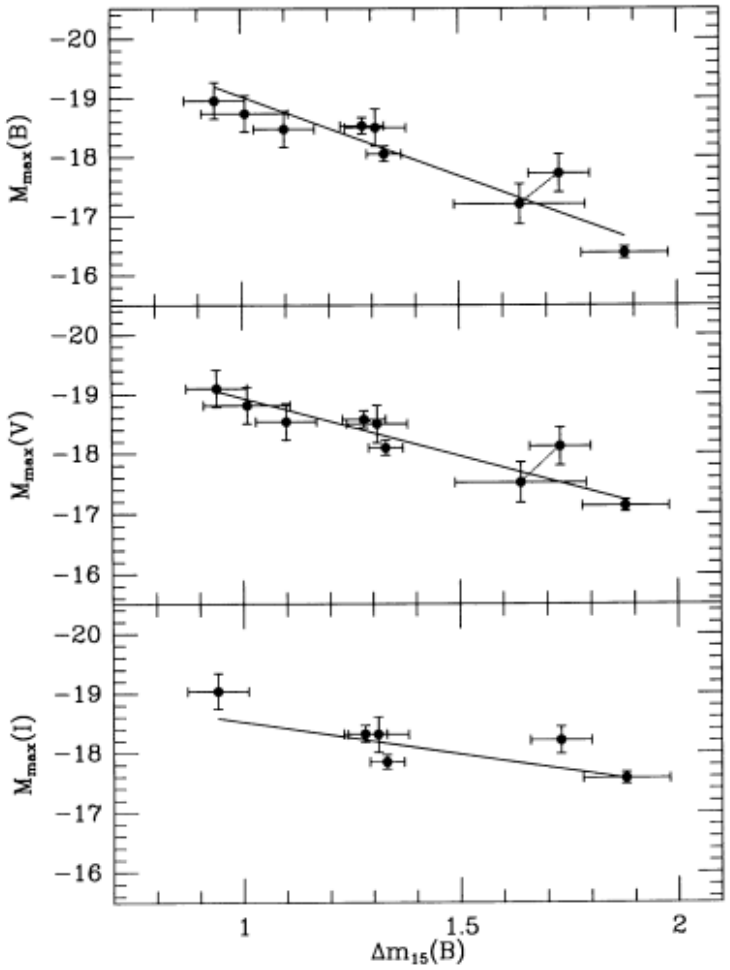
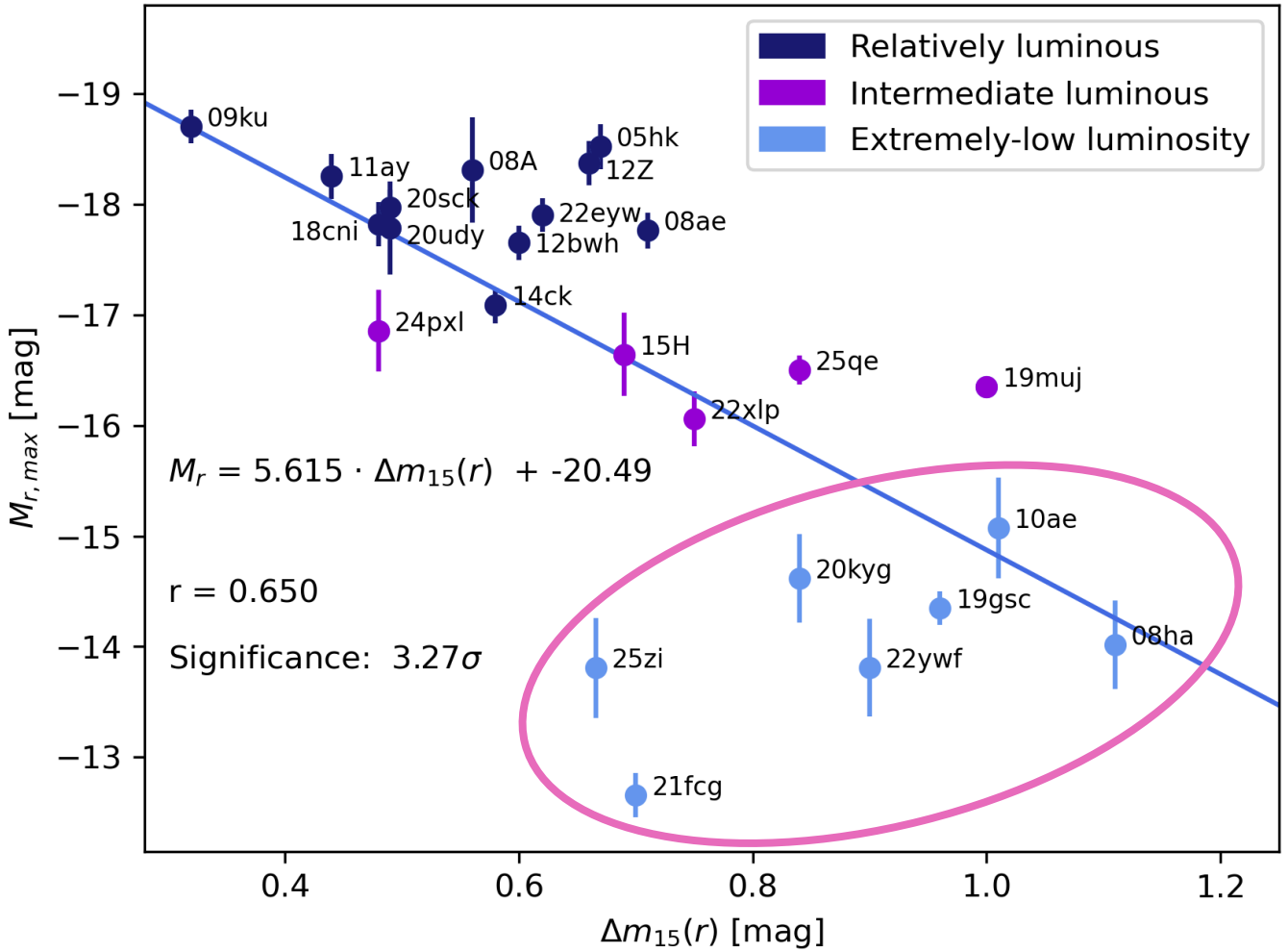


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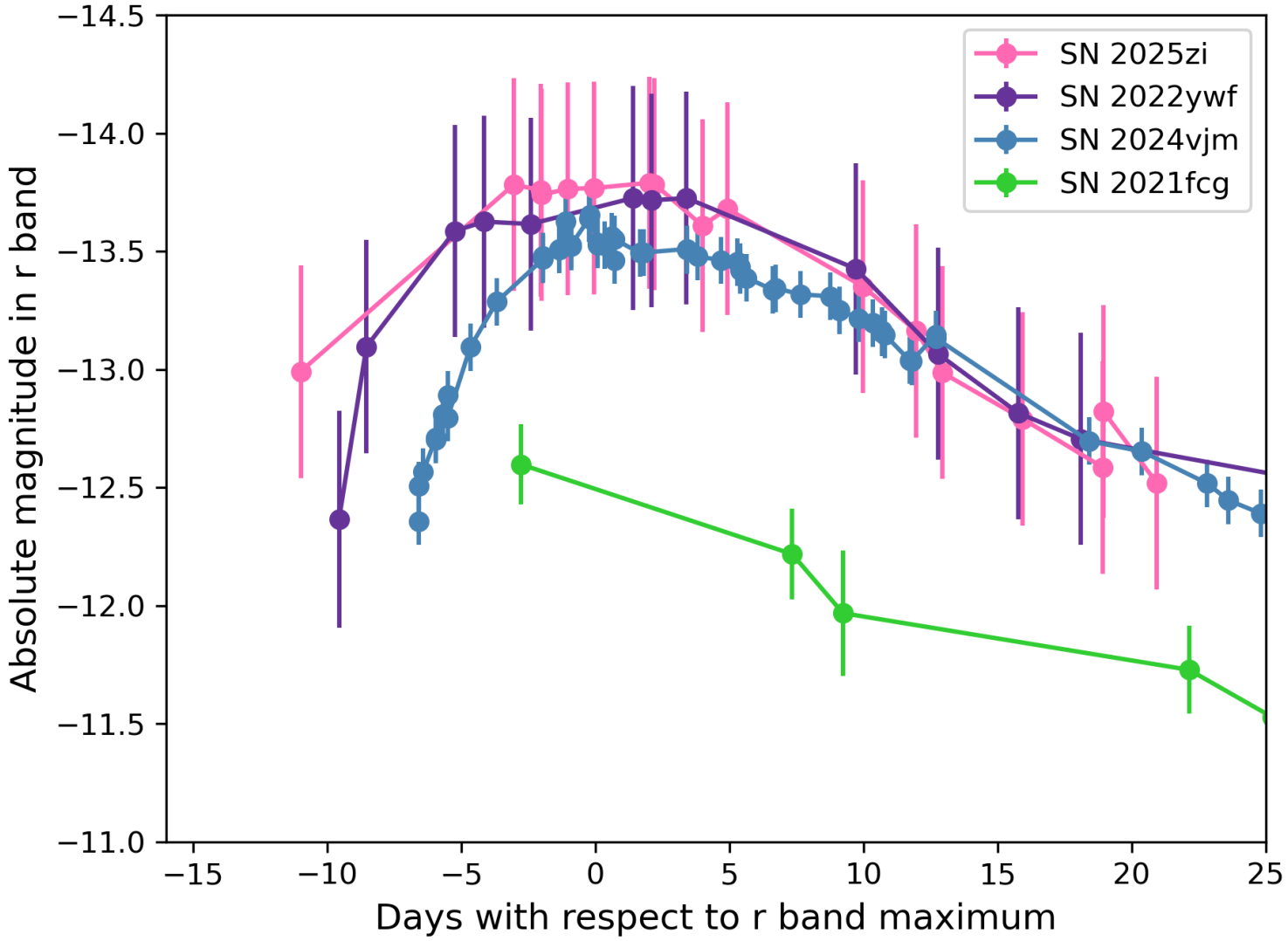
SN 2025zi

Peak magnitude:

$$M_r^{peak} = -13.78 \pm 0.45$$

Very similar light-curve to other low luminosity SNe Iax events

(Submitted, Mochnács et al., 2026)



SN 2025zi

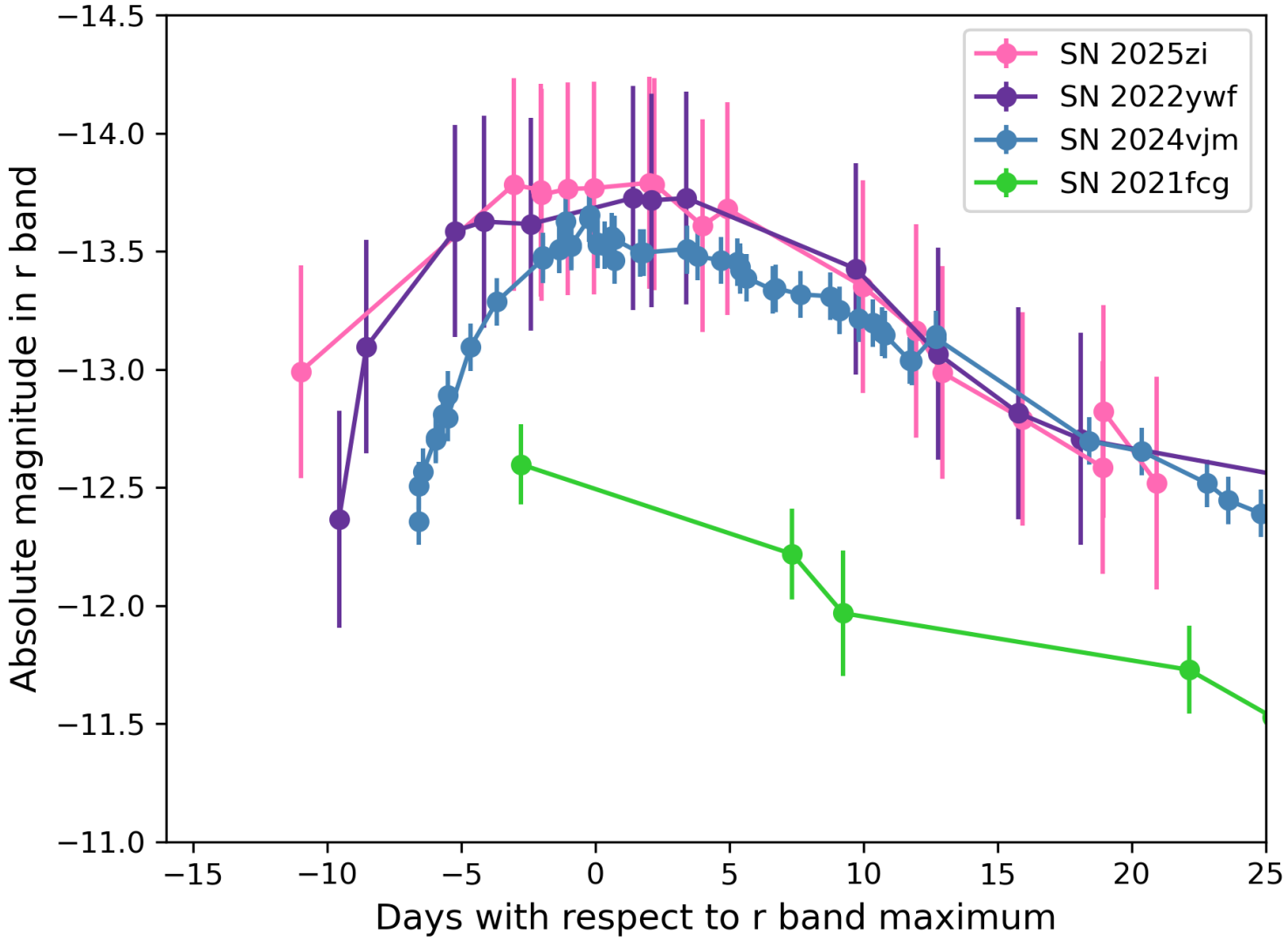
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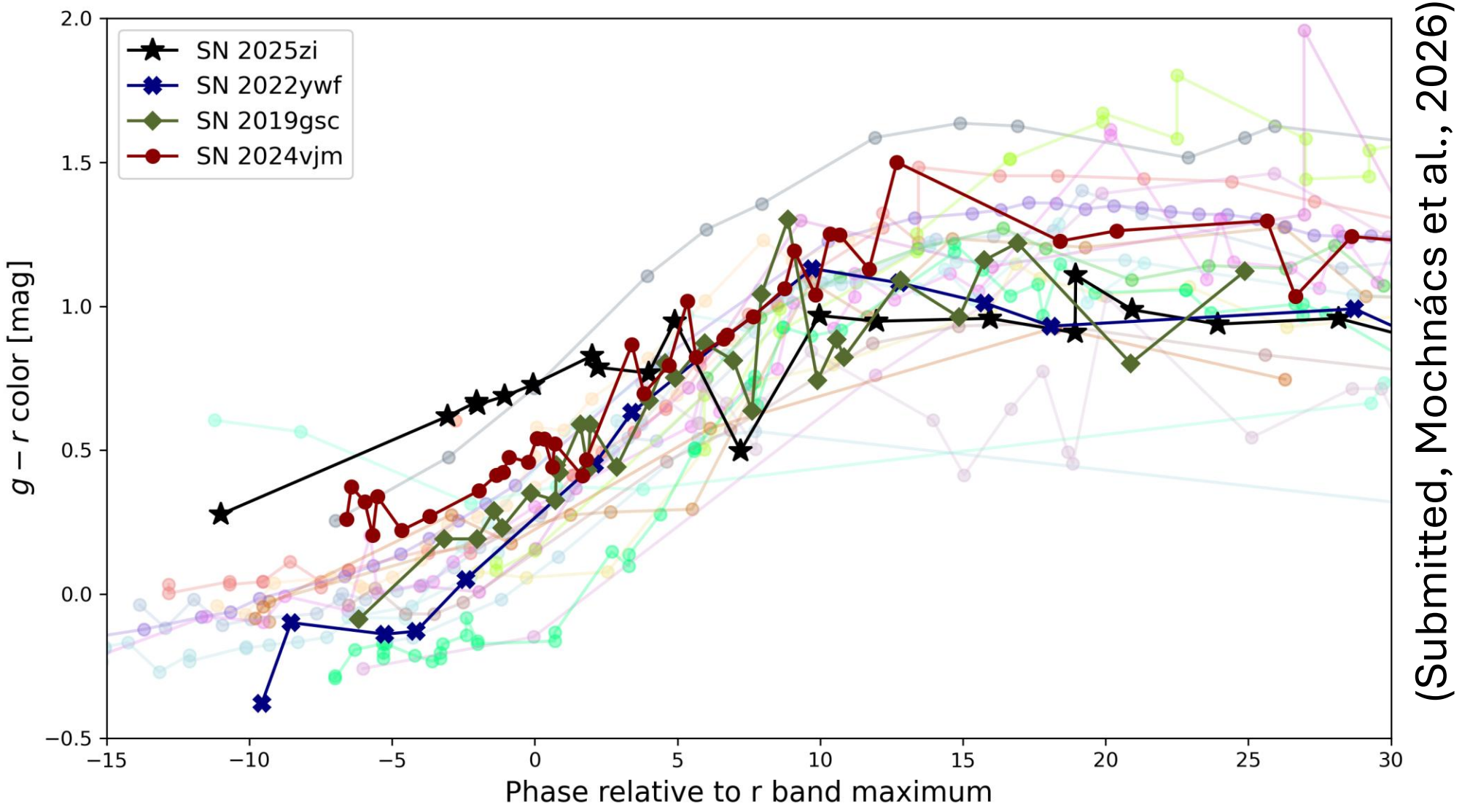
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(Submitted, Mochnács et al., 2026)

BUT!



SN 2025zi



(Submitted, Mochnács et al., 2026)

In summary

- Online available database
- Re-estimated Type Iax rate: $13.06^{+9.25}_{-6.09}$
- Investigated their possible use to distance measurements

Publications and appearances in the subject:

- First author:
  SN 2025zi: a very faint and red member of the Type Iax supernova subclass (submitted to MNRAS)
- Co-authorship:
  Barna and Mochnács (in prep.): *Supernova Iax Database - investigating the parameter correlations of the diverse subclass of thermonuclear supernovae*
  Barna et al., 2026: *Tomography analysis of the intermediate-luminosity Type Iax SN 2024pxl, A&A*
  Barna et al., 2026: *The extremely low-luminosity Type Iax SNe 2022ywf and 2023zgx, A&A*
- Conference – Poster presentation:
  IAUS 406: Future Landscape of astrophysical transients - Finland, Turku, 2026

Thank you for your attention!

The database is available here:

Further references:

[1] Phillips, Mark M. et al., 1999: *THE REDDENING-FREE DECLINE RATE VERSUS LUMINOSITY RELATIONSHIP FOR TYPE Ia SUPERNOVAE*, DOI: 10.1086/301032

[2] Barna, Barnabás et al., 2021: *SN 2019muj - a well-observed Type Iax supernova that bridges the luminosity gap of the class*, DOI: 10.1093/mnras/staa3543

