Early NIR signatures of supernovae dust formation with RATs

Shifting Landscapes in Astrophysics: New Frontiers to Explore with Roman

July 15th 2026

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With the WINTER and ZTF collaborations

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Why study astronomical dust formation?

Star formation is dust obscured!

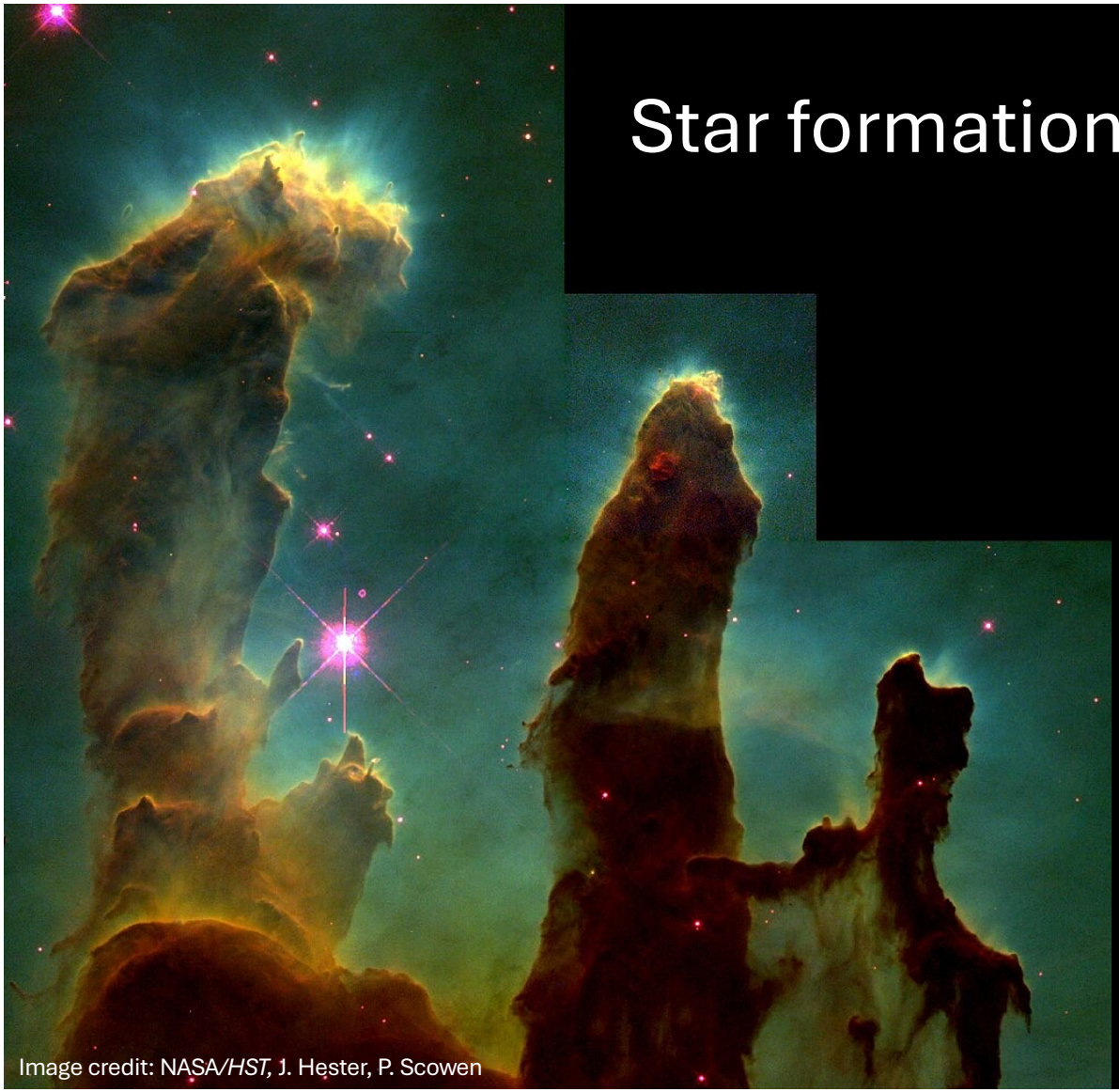
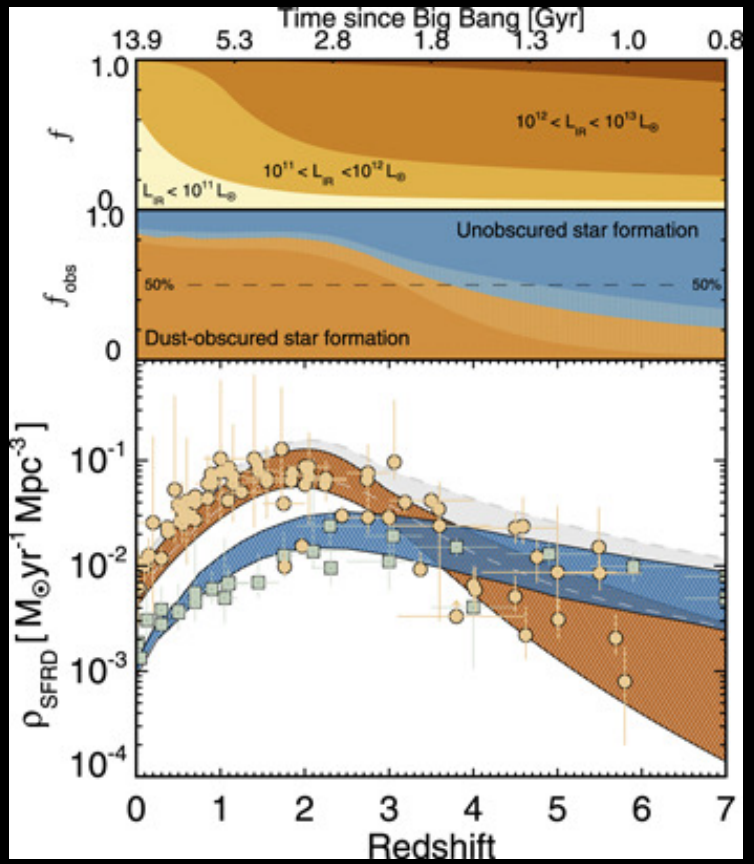


Image credit: NASA/*HST*, J. Hester, P. Scowen



Zavala+ 2021

Dust rocks!

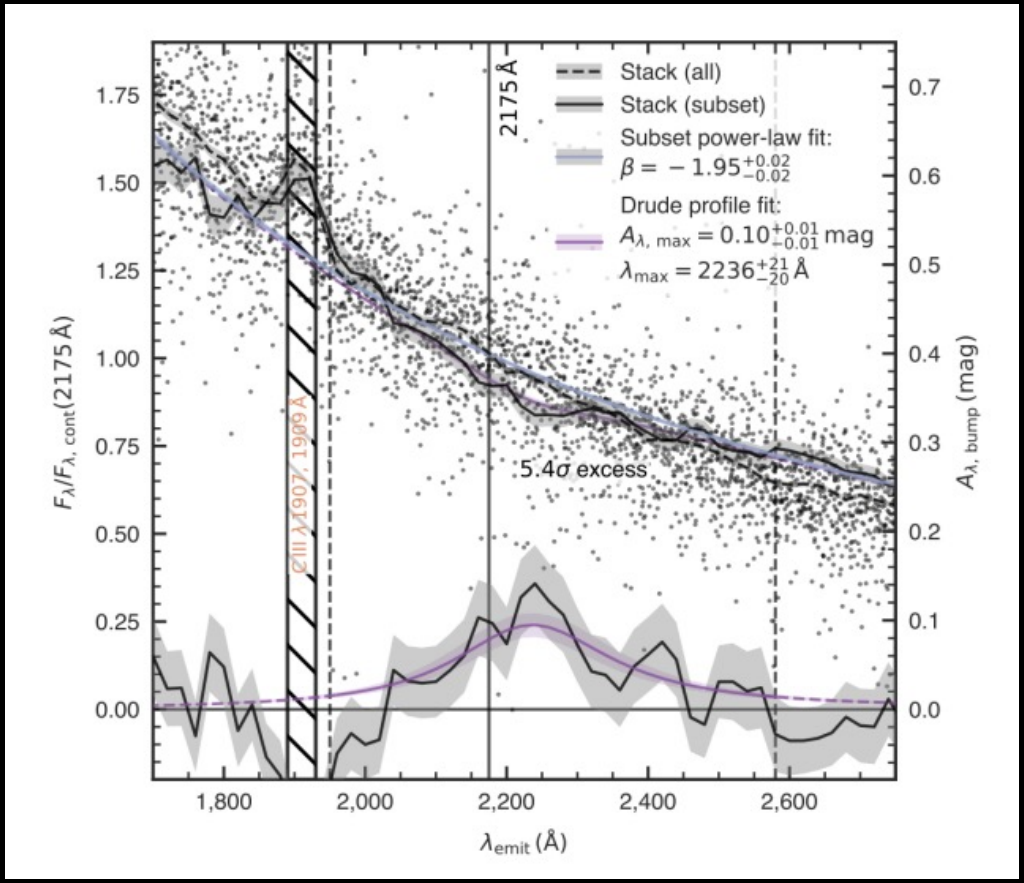
Image credit: NASA/Apollo 17

Image credit: NASA

Image credit: NASA

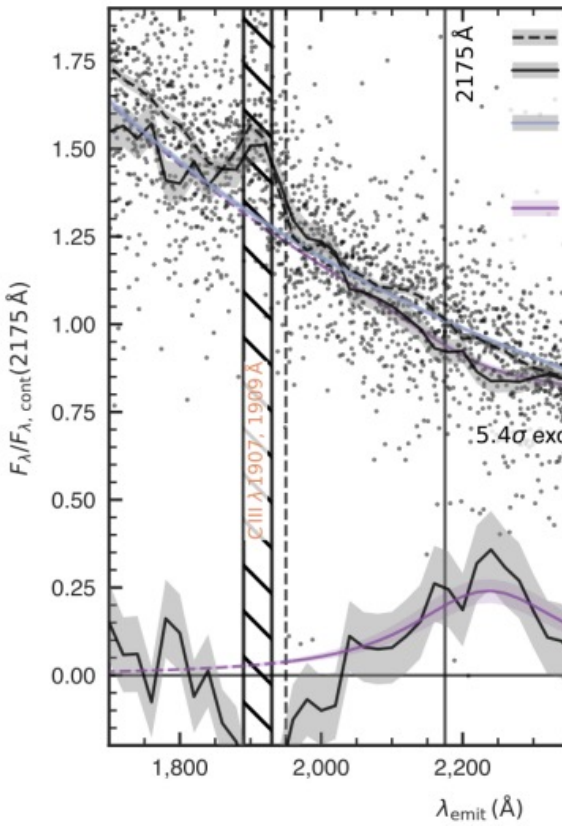
Image credit: S. Rose

Dust forms early in the Universe

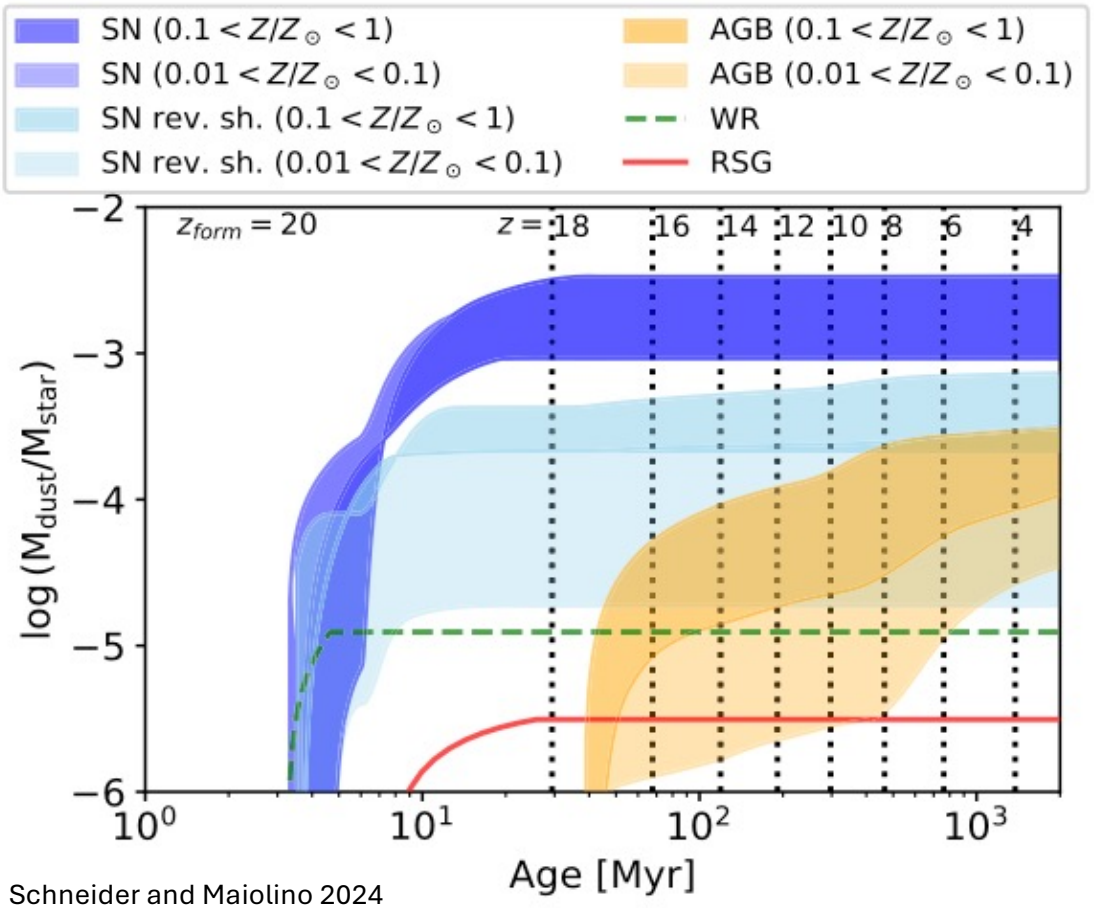


Witstok + 2023

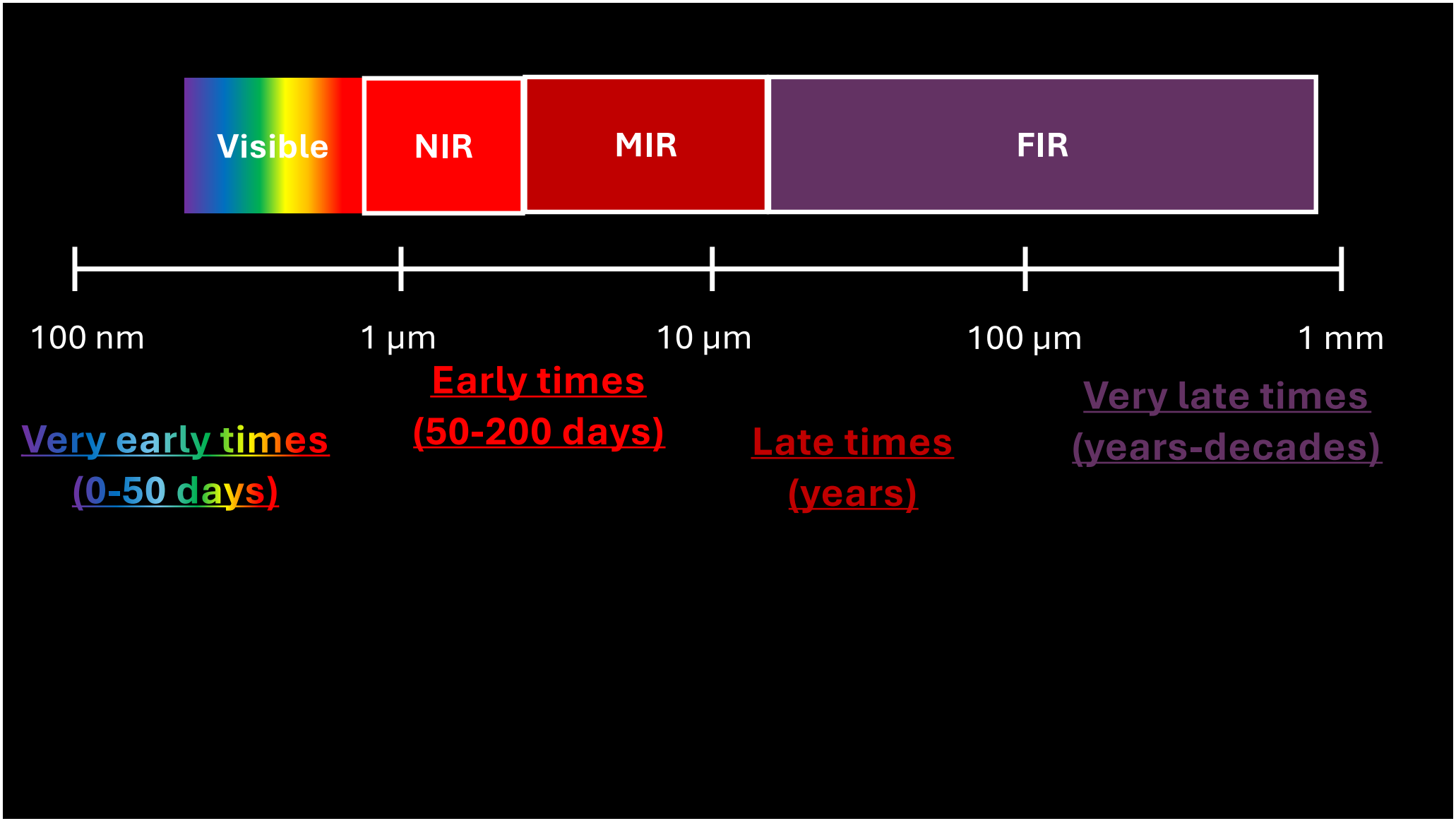
Supernovae produce dust early



Witstok + 2023



Schneider and Maiolino 2024


Visible
NIR
MIR
FIR
100 nm
1 μm
10 μm
100 μm
1 mm
Very early times
(0-50 days)
Early times
(50-200 days)
Late times
(years)
Very late times
(years-decades)

Very early times (0-50 days)

Early times (50-200 days)

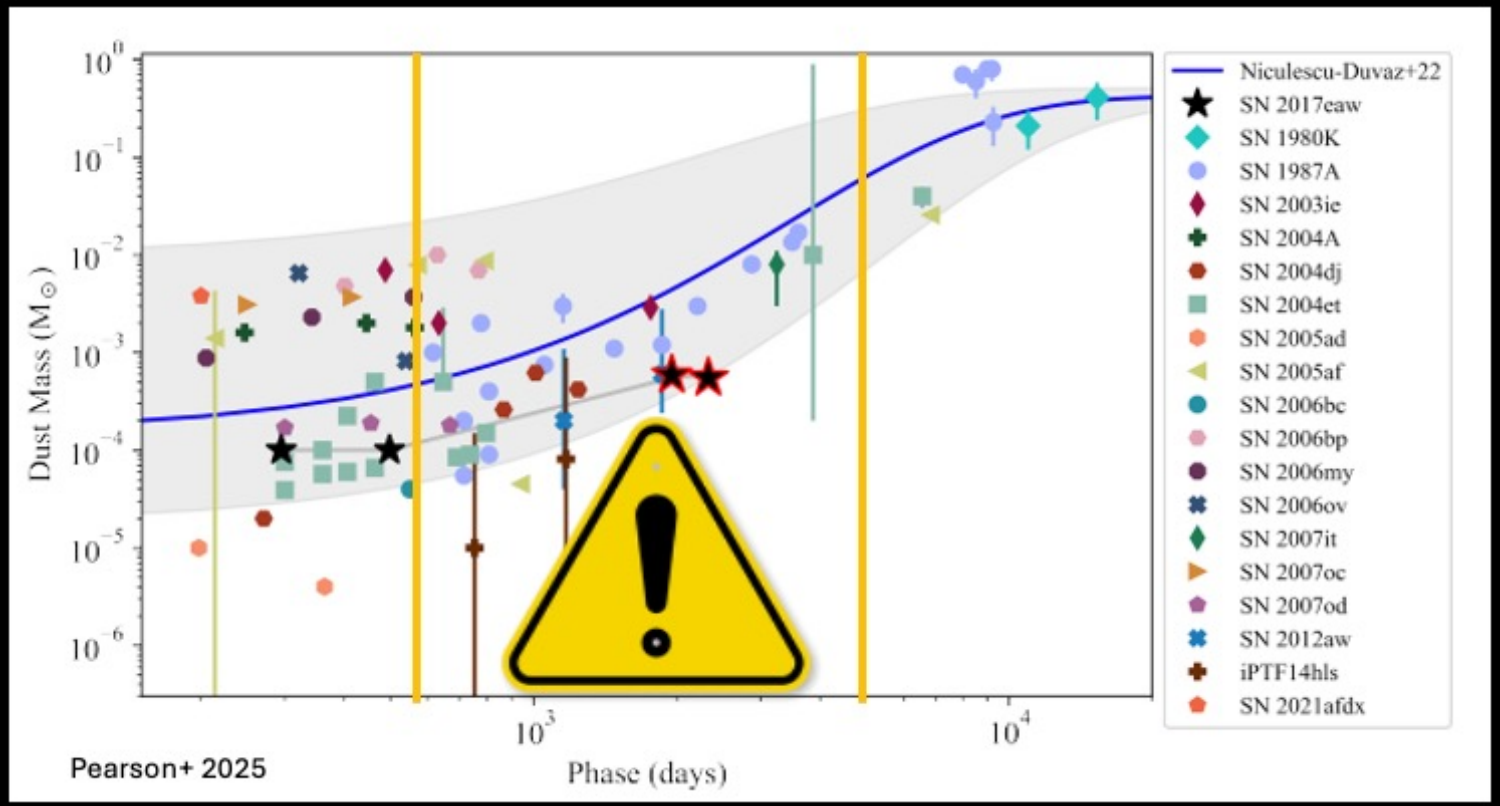
Late times (years)

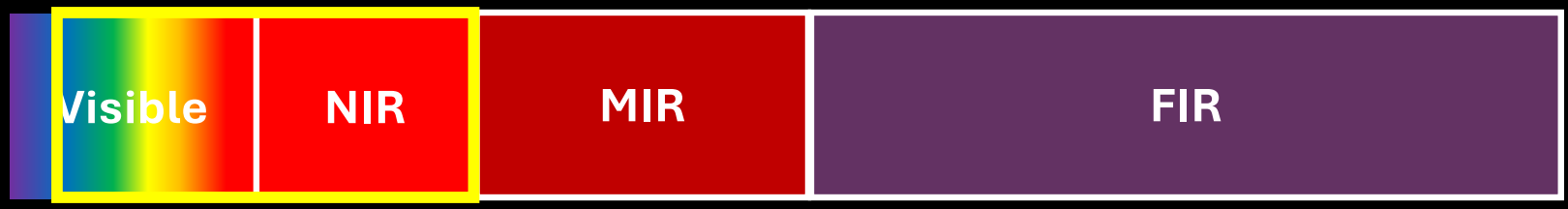
Very late times (years-decades)

Easy! Bright! Can get large samples! Can distinguish between new and old dust!

Hard! Dim! Limited objects! Limited observing resources! Multi-epoch observations are rare!

Single-epoch MIR observations do not easily distinguish between newly formed ejecta dust and pre-existing CSM dust





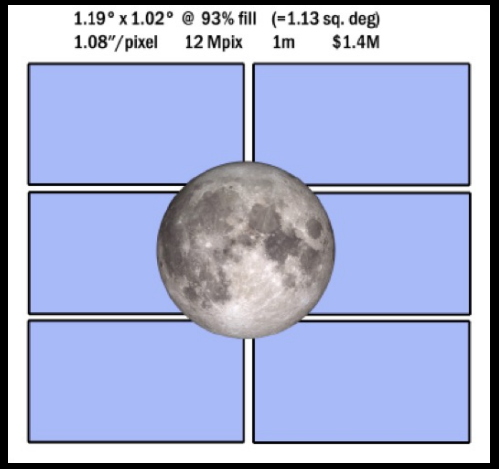
The Red Astronomical Transient (RAT) survey: A systematic NIR study of ZTF supernovae


Image credit: J. Lomberg

WINTER

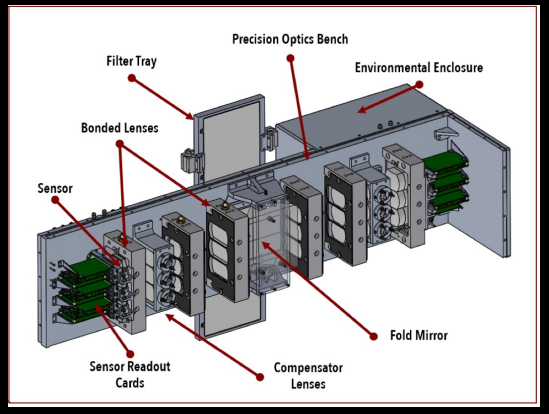
A NIR time-domain survey at Palomar Observatory

Dedicated 1 m. robotic telescope



1.2 x 1.0 sq. deg. FOV

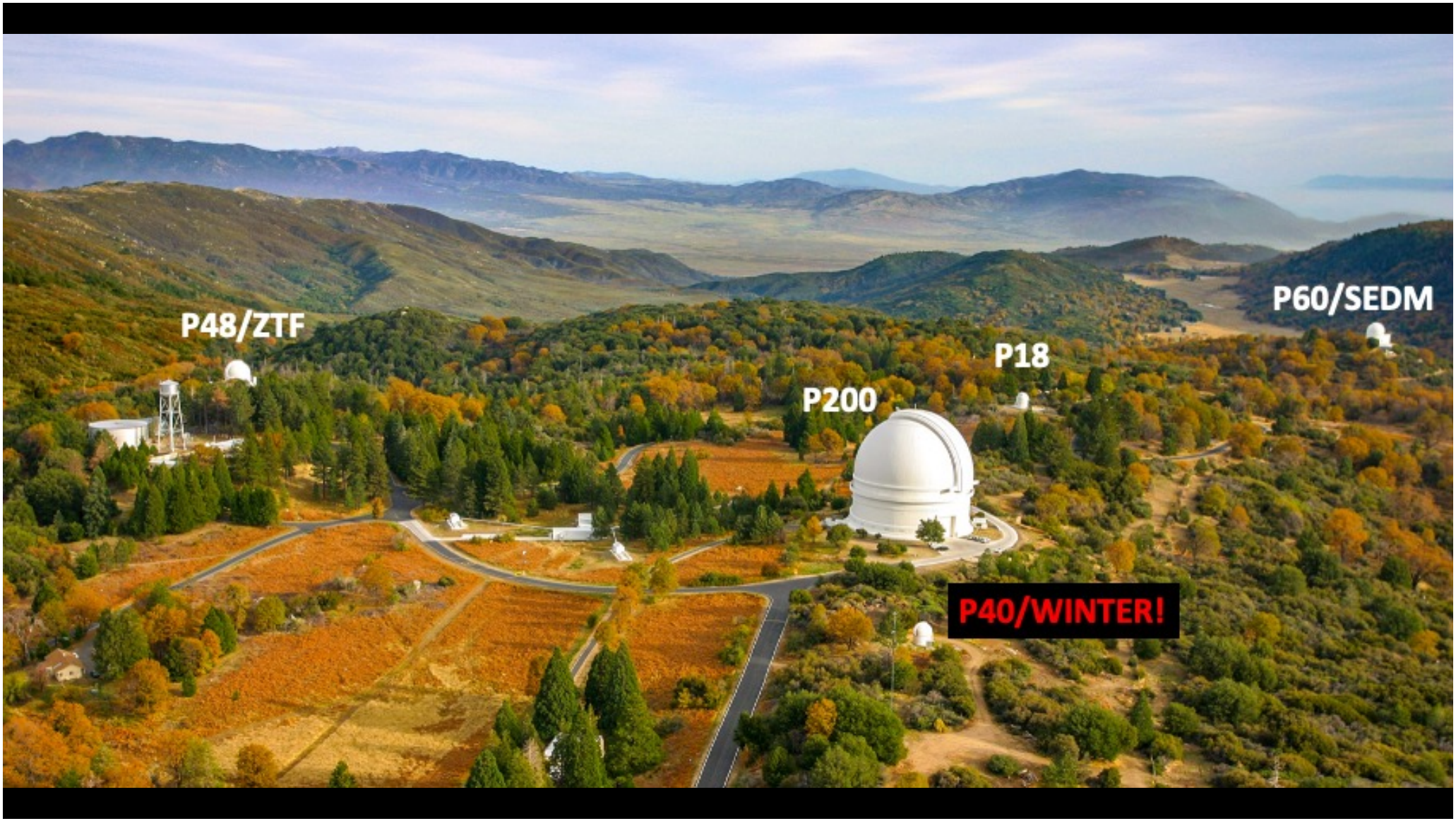
Lourie+ 2019



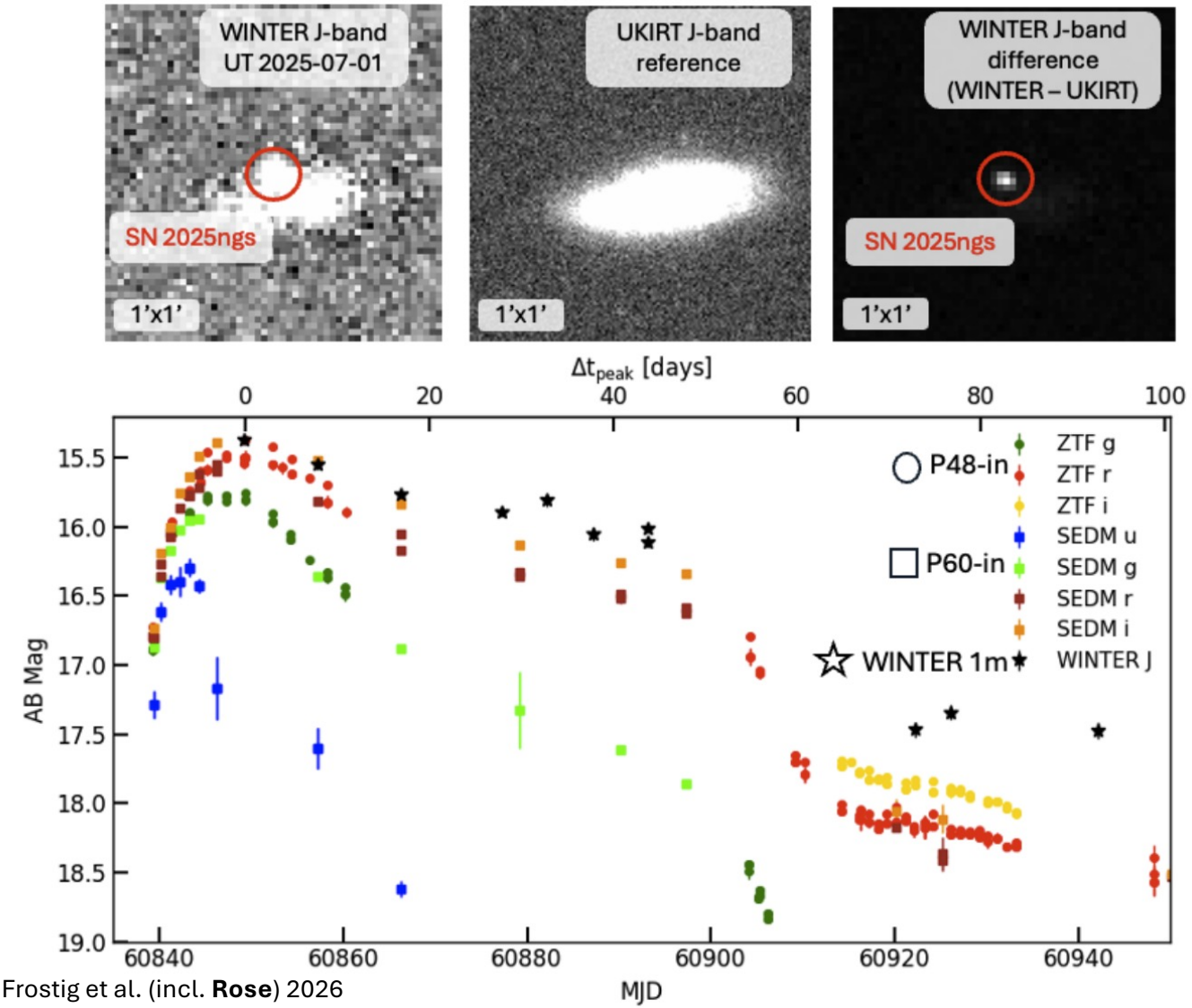
Novel InGaAs sensors
0.9 – 1.7 um

NIR Y, J, Hs bands

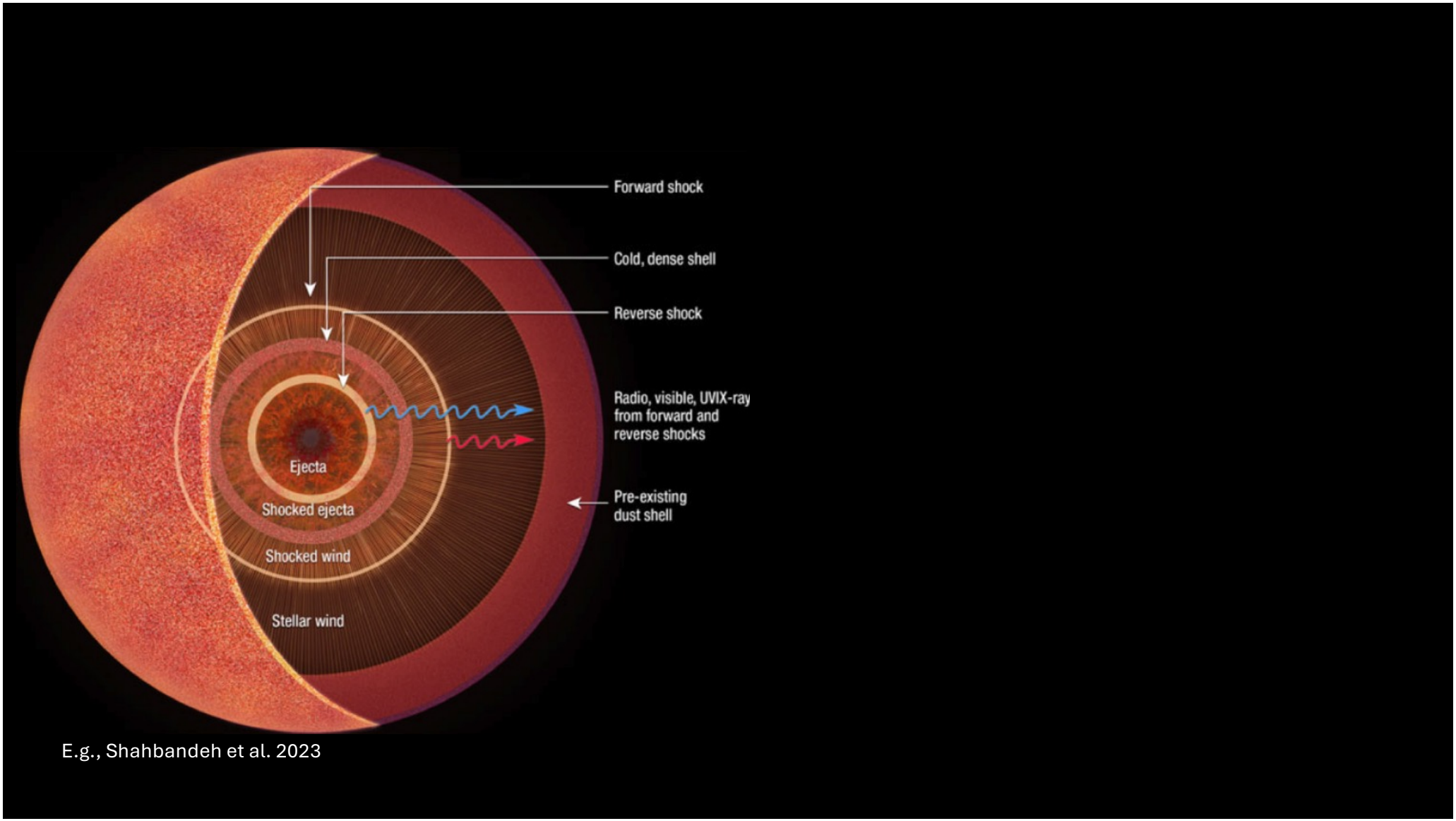
Survey to J >= 18.5 mag (AB)


P48/ZTF
P60/SEDM
P18
P200
P40/WINTER!

NIR light curves with WINTER probe the appearance of warm dust continuum emission

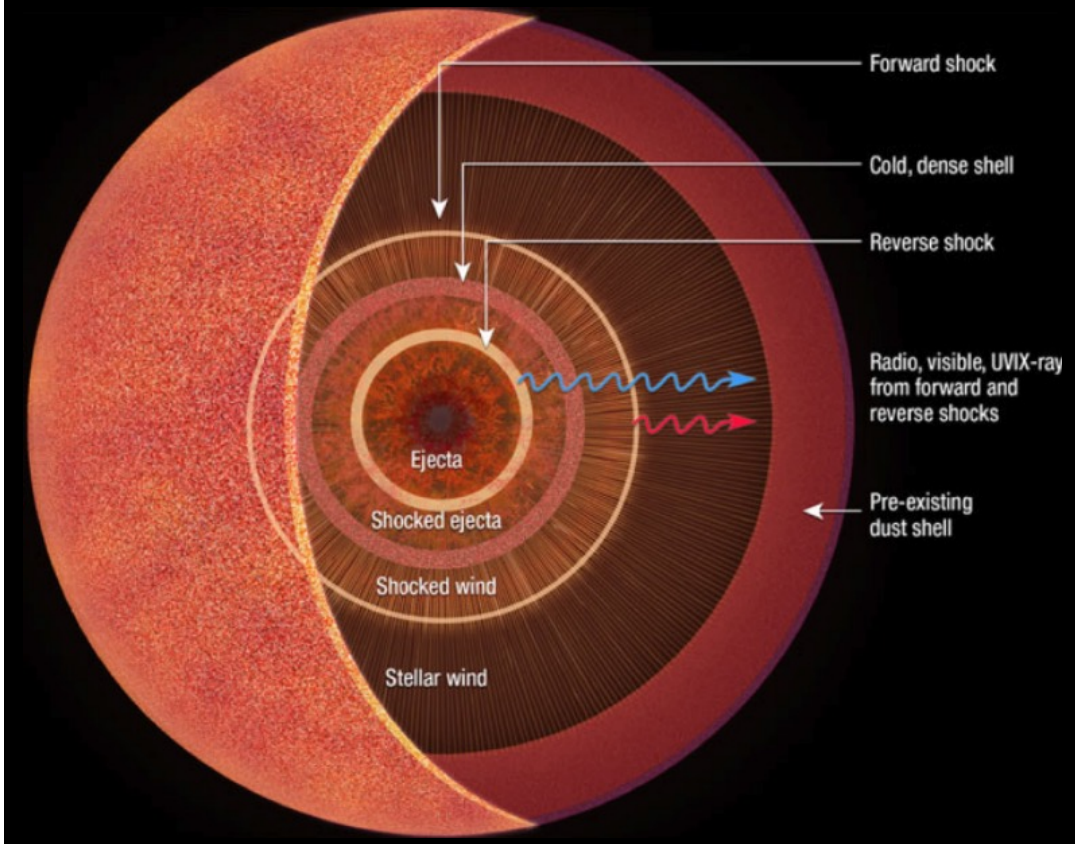


Frostig et al. (incl. **Rose**) 2026

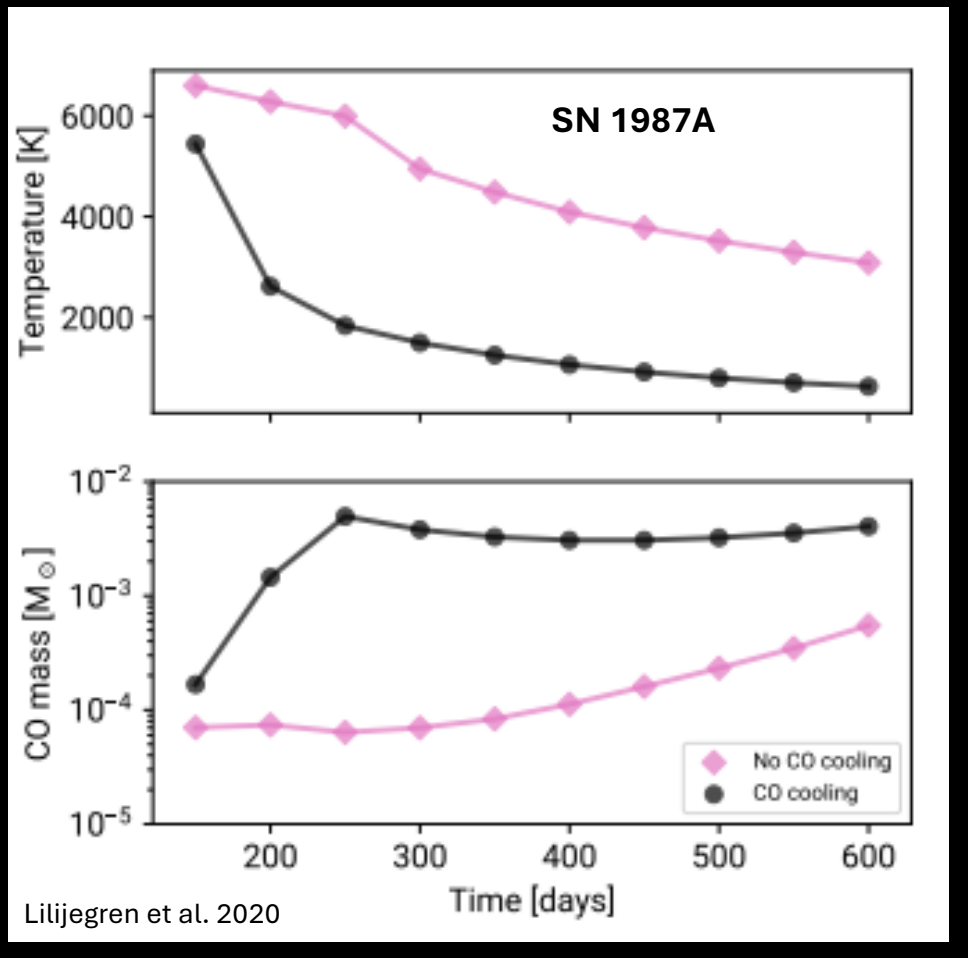


E.g., Shahbandeh et al. 2023

Carbon monoxide traces cooling ejecta

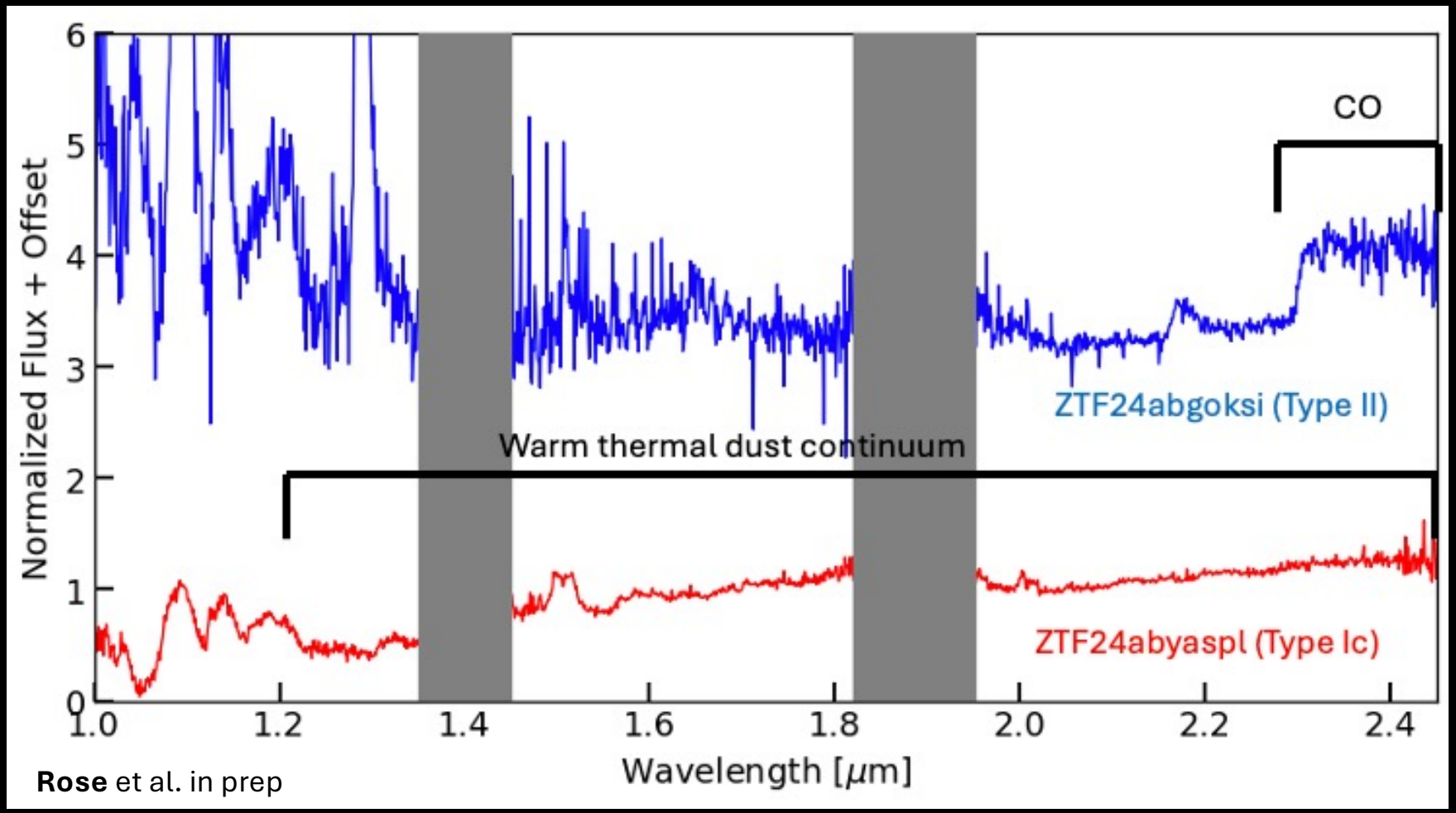


E.g., Shahbandeh et al. 2023



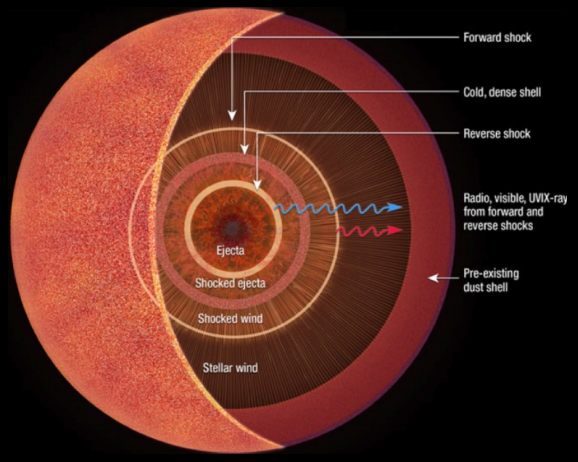
Lilijegren et al. 2020

Keck-II/NIRES observations of RATs detect CO!

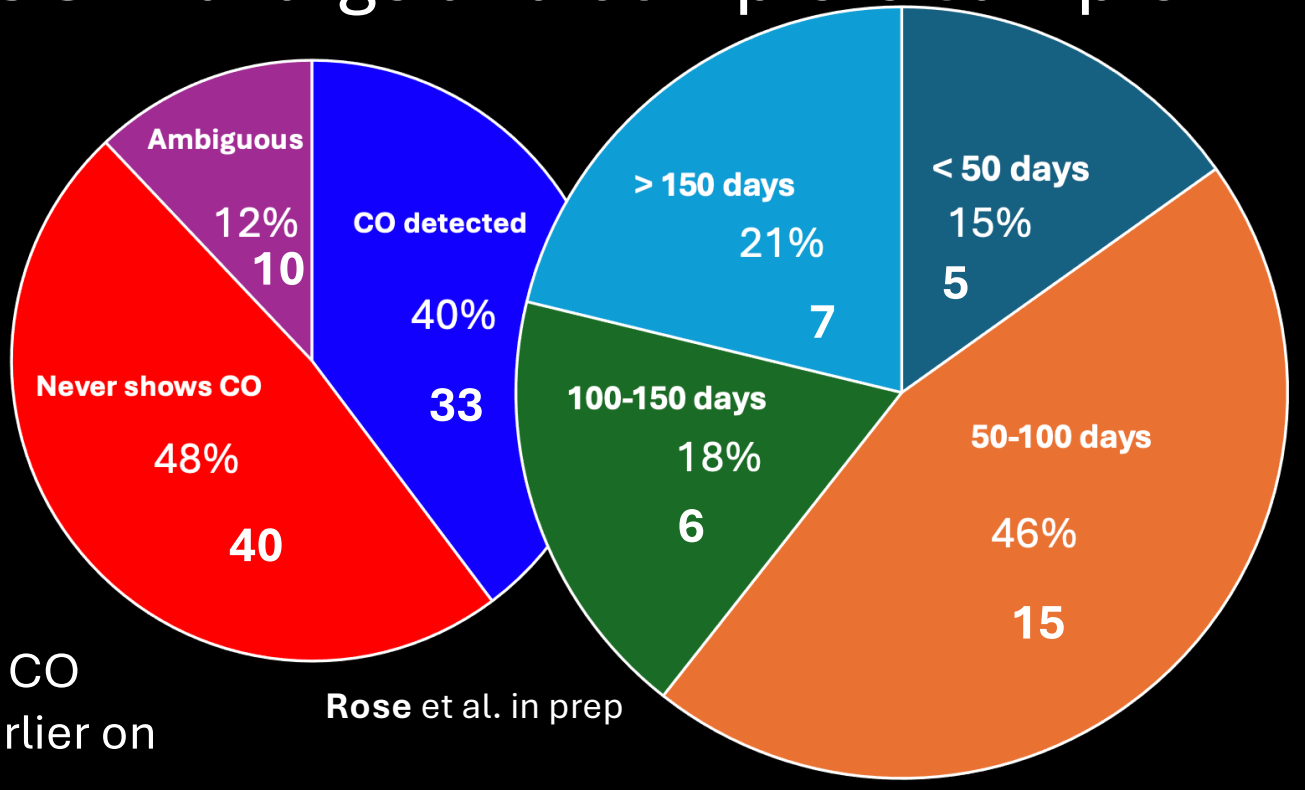


Rose et al. in prep

RATs is providing the first constraints on the appearance of CO in a large and complete sample of CCSNe



E.g., Shahbandeh et al. 2023



Rose et al. in prep

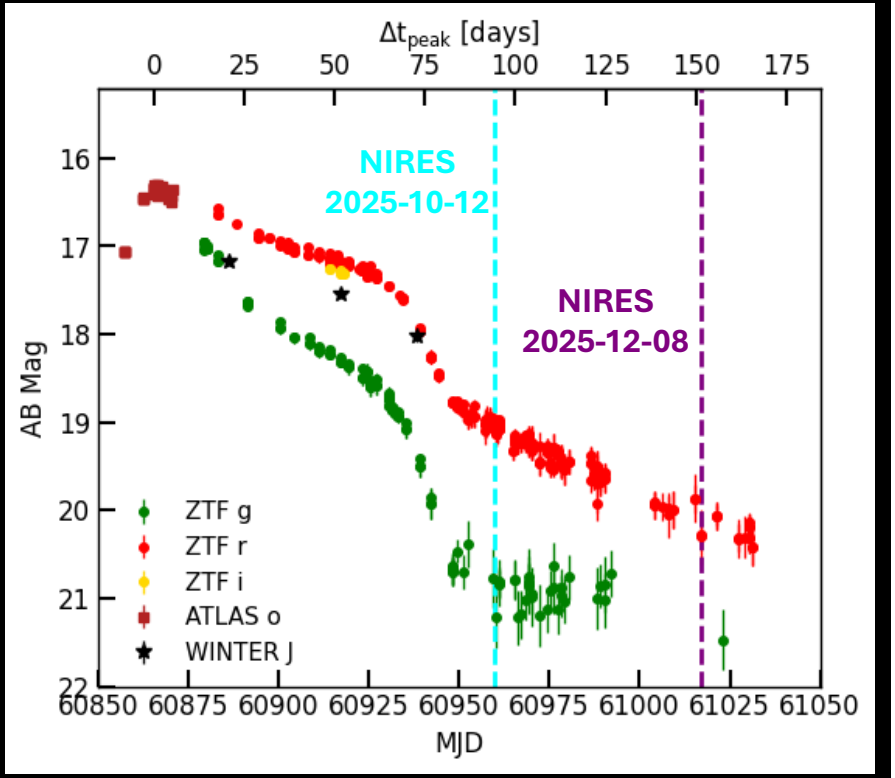
Interacting SNe show CO emission ~20 days earlier on average

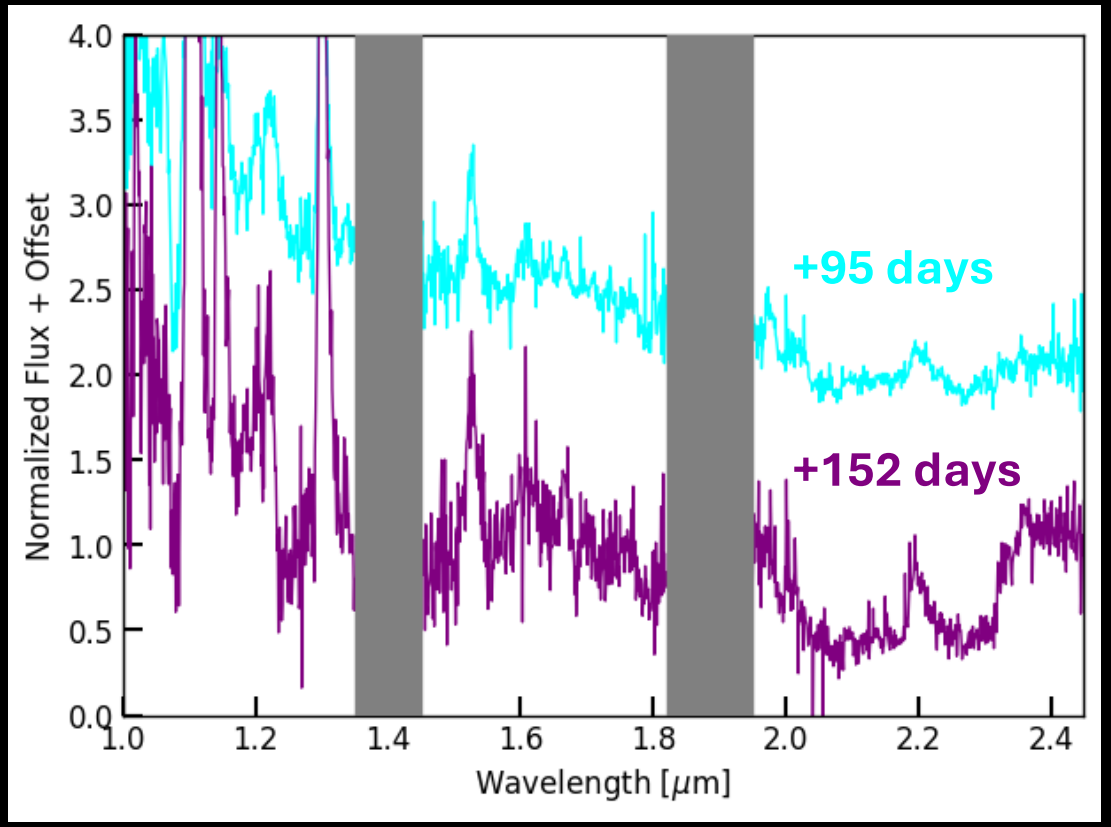
From the cold dense shell?

33 objects with CO detections including stripped envelope supernovae!

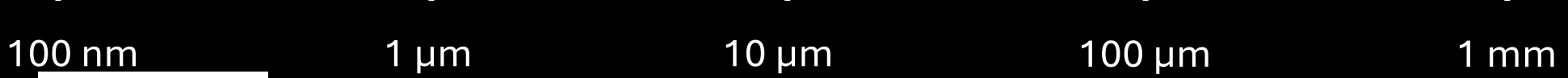
CO strength evolves with time

E.g., Type II SN 2025pjx





Rose et al. in prep



ZTF

HERSCHEL
Exploring the Cold Universe

WINTER
Wide-field INfrared Transient ExploreR

100 nm 1 μm 10 μm 100 μm 1 mm

ZTF

ROMAN SPACE TELESCOPE

HERSCHEL Exploring the Cold Universe

VERA C. RUBIN OBSERVATORY

WINTER Wide-field INfrared Transient ExploreR

PRIMA

Roman will provide sensitive NIR observations of supernovae at late times

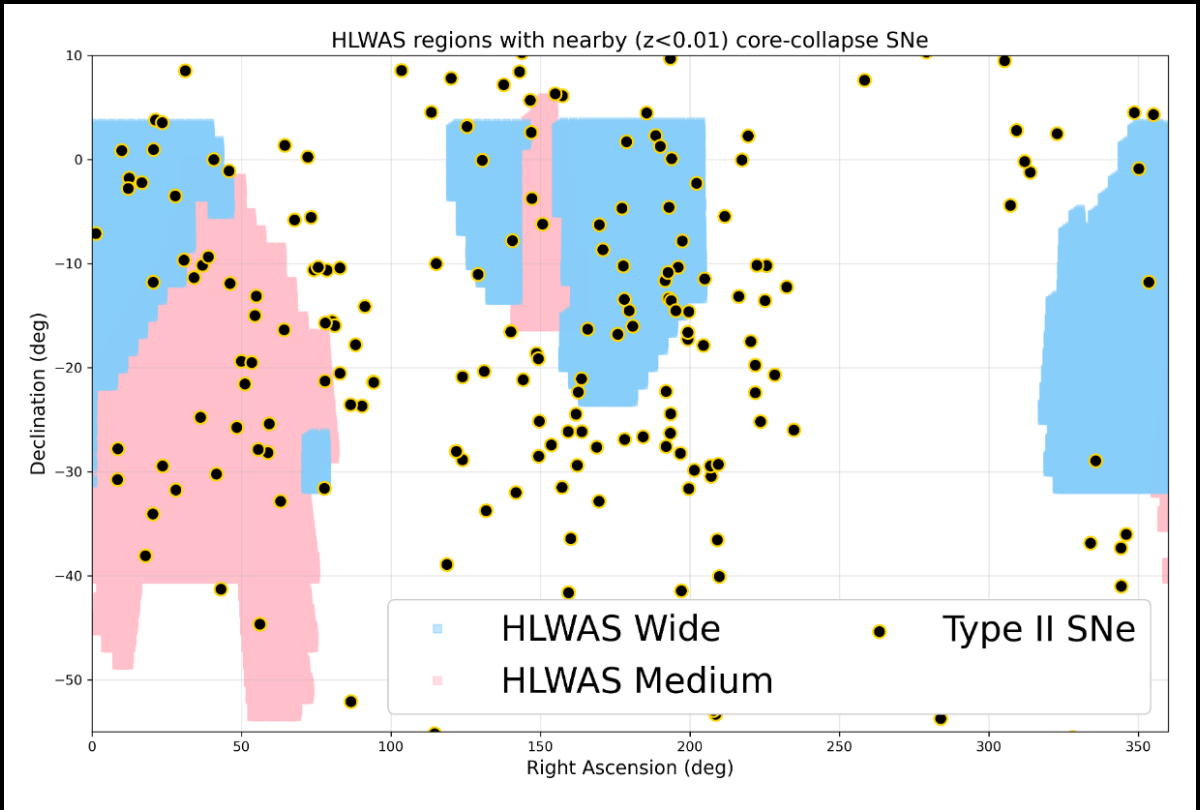
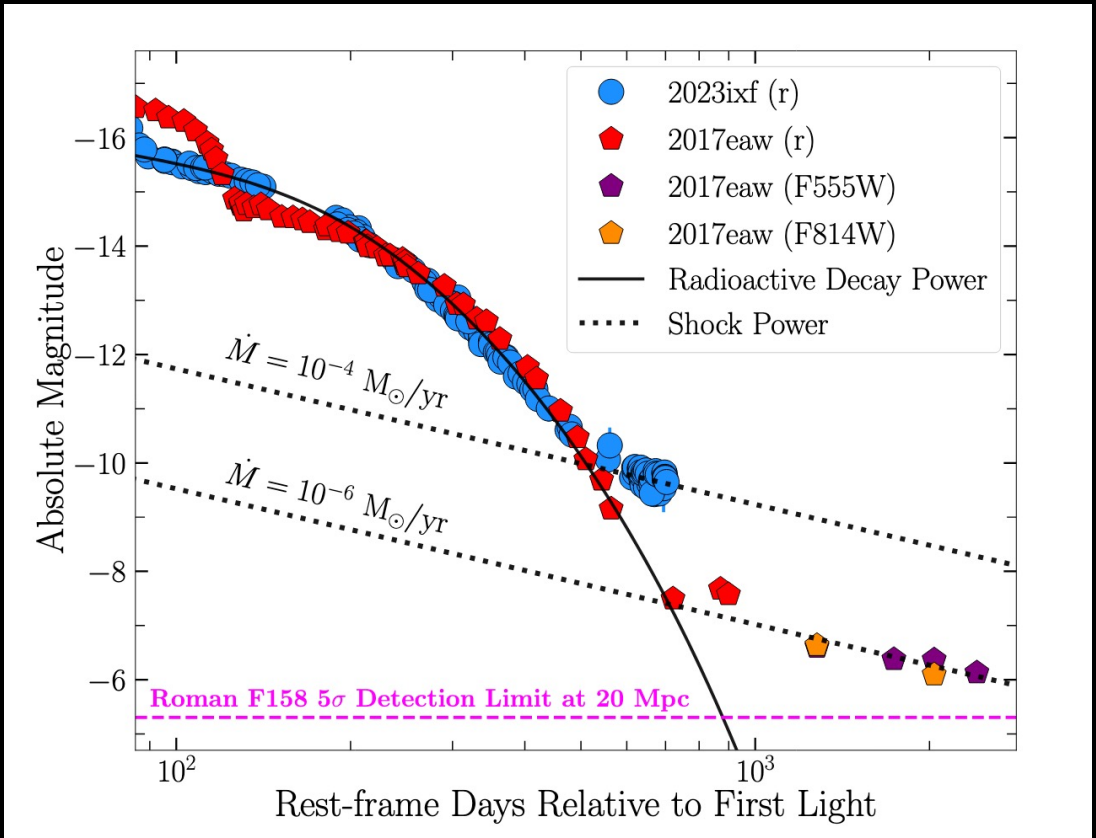


Image credit: Jacobson-Galán

Approved Cycle 1 analysis program PI Jacobson-Galán

Roman will provide sensitive NIR observations of supernovae at late times



Approved Cycle 1 analysis program PI Jacobson-Galán

Image credit: Jacobson-Galán

Conclusions

- Dust is an essential component of galaxies and forms early in the Universe
- Supernovae explosions, which come from fast evolving massive star progenitors are likely an important contributor of dust at early times
- Long wavelength observations with *JWST* probe dust properties, but only for a limited number of objects. Ground based NIR observations probe SNe dust formation at early times and can be obtained for a large and complete sample of objects
- Roman observations will provide sensitive constraints on the percentage of CCSNe which have interaction heated dust at late times (e.g., 17eaw)

Like dust? Email me! srose@caltech.edu