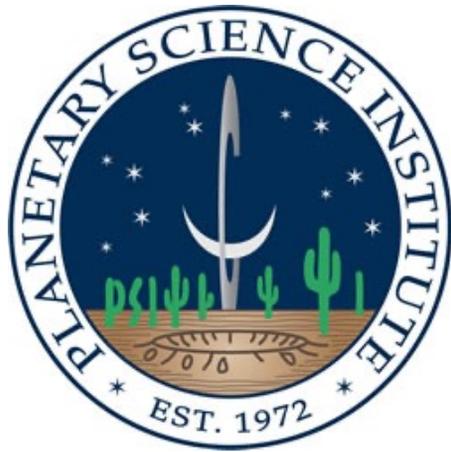


Eddie Baron



# JWST Insights into the dim Type Ia SN 2024vjm

# MIRSNAC Collaboration

- Chris Ashall
- Peter Hoeflich
- EB
- Melissa Shahbandeh
- James DerKacy
- Kyle Medler
- Sagiv Shiber
- Tyco Mera
- Elham Fereidoui
- Cameron Pfeffer

## JWST as tool to understanding SNe

We are using the advent of high-resolution observations in the NIR+MIR to advance our understanding of all Types of supernovae

## SNe Ia

SN 2021aefx: DerKacy+23, Ashall+24; SN 2022xkq: DerKacy+24

## SNe II

SN2023ixf: DerKacy+25, Medler+25; SN 2024ggi: Baron+25, Mera+25

## SNe Ibc

SN 2023dbc: Shahbandeh+, in prep; SN 2024ahv: Shahbandeh+, in prep

## SNe Iax

Baron+26 and this talk

# PHOENIX Collaboration

- Peter Hauschildt
- EB
- Travis Barman
- Jason Aufdenberg

## Generalized Stellar Atmospheres Code

Static and Moving Atmospheres

## Stars, Supernovae, Irradiated Planets

## Full NLTE

1-D and 3-D

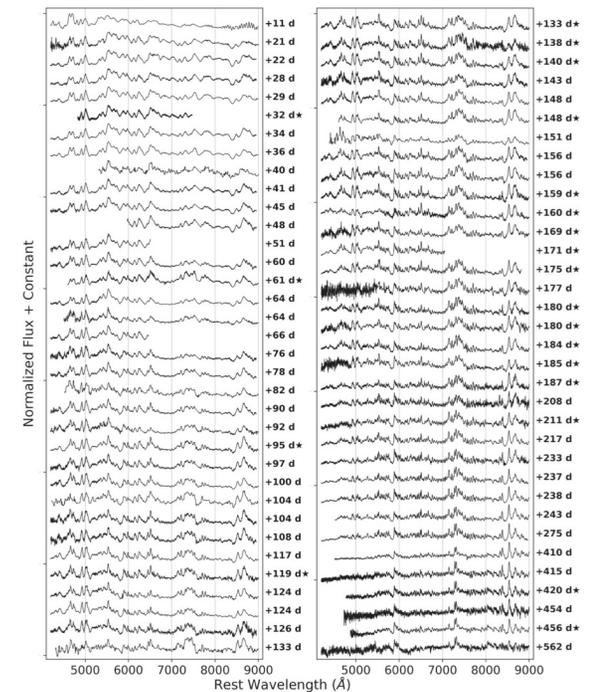
## Includes Ions and Molecules

## Over a TeraByte of Atomic Data

Hauschildt+25, Barman+26 (in prep)

# SNe Iax

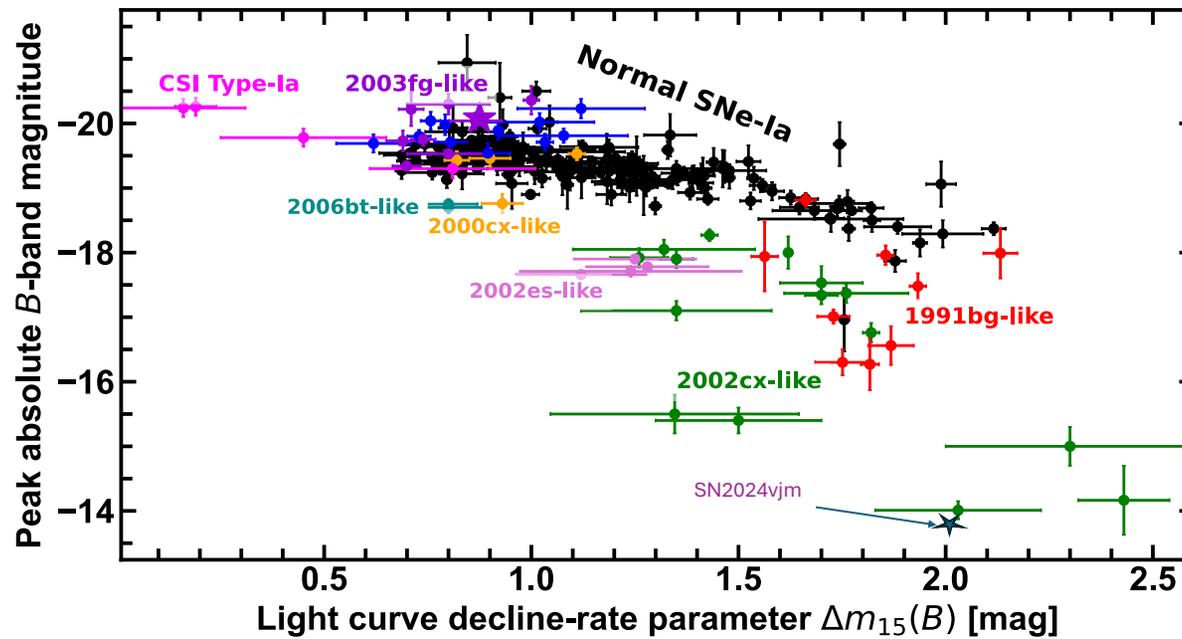
- SNe Iax defined spectroscopically: SN Ia features (Si II 6355 line, S II “W” feature) but low velocities.
- Tend to have “hot” spectra in sense of Nugent+95 (weak Si II, Fe III lines).
- NIR shows characteristic Co II fingerprint.
- Photometrically, dim, but can be almost as bright as Ia.
- Tend to have fast decline, but slower decline in red bands.
- Not rare, about 15-20% of SNe Ia rate.



SN 2014dt

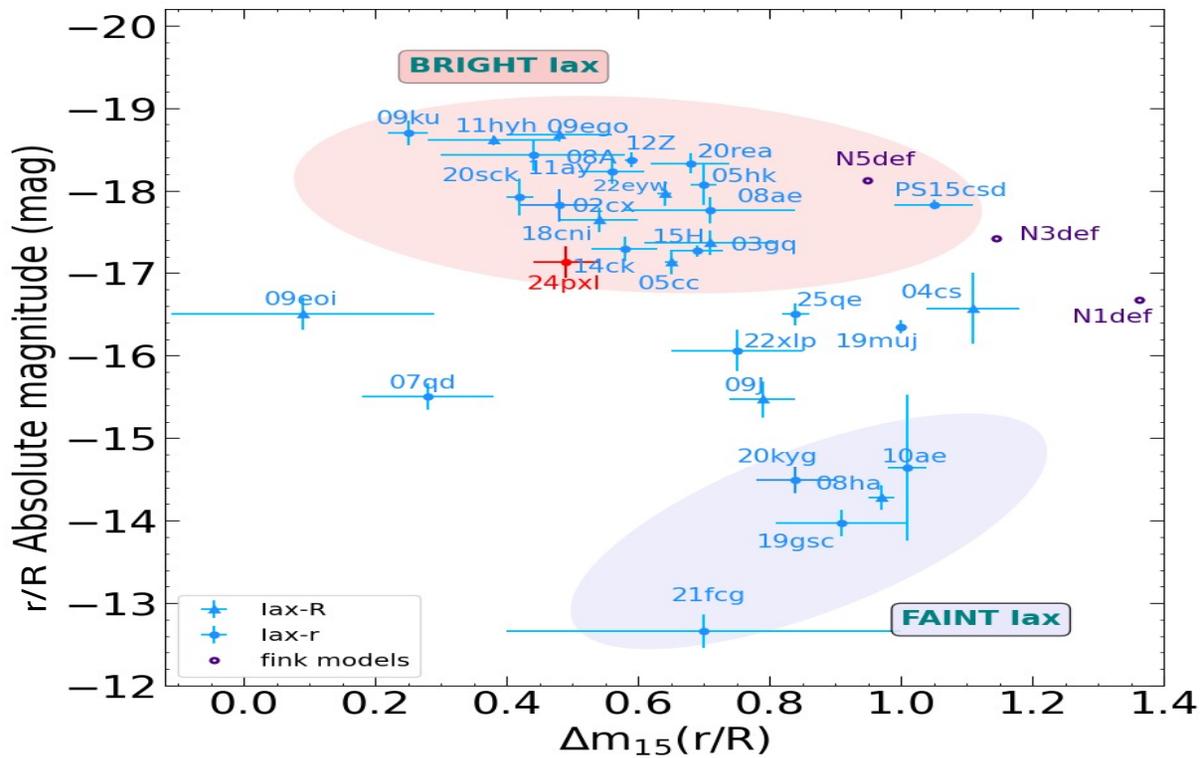
Camacho-Neves+23

# Abs Mag vs $\Delta m_{15}$ for the Ia Zoo



Stritzinger+15

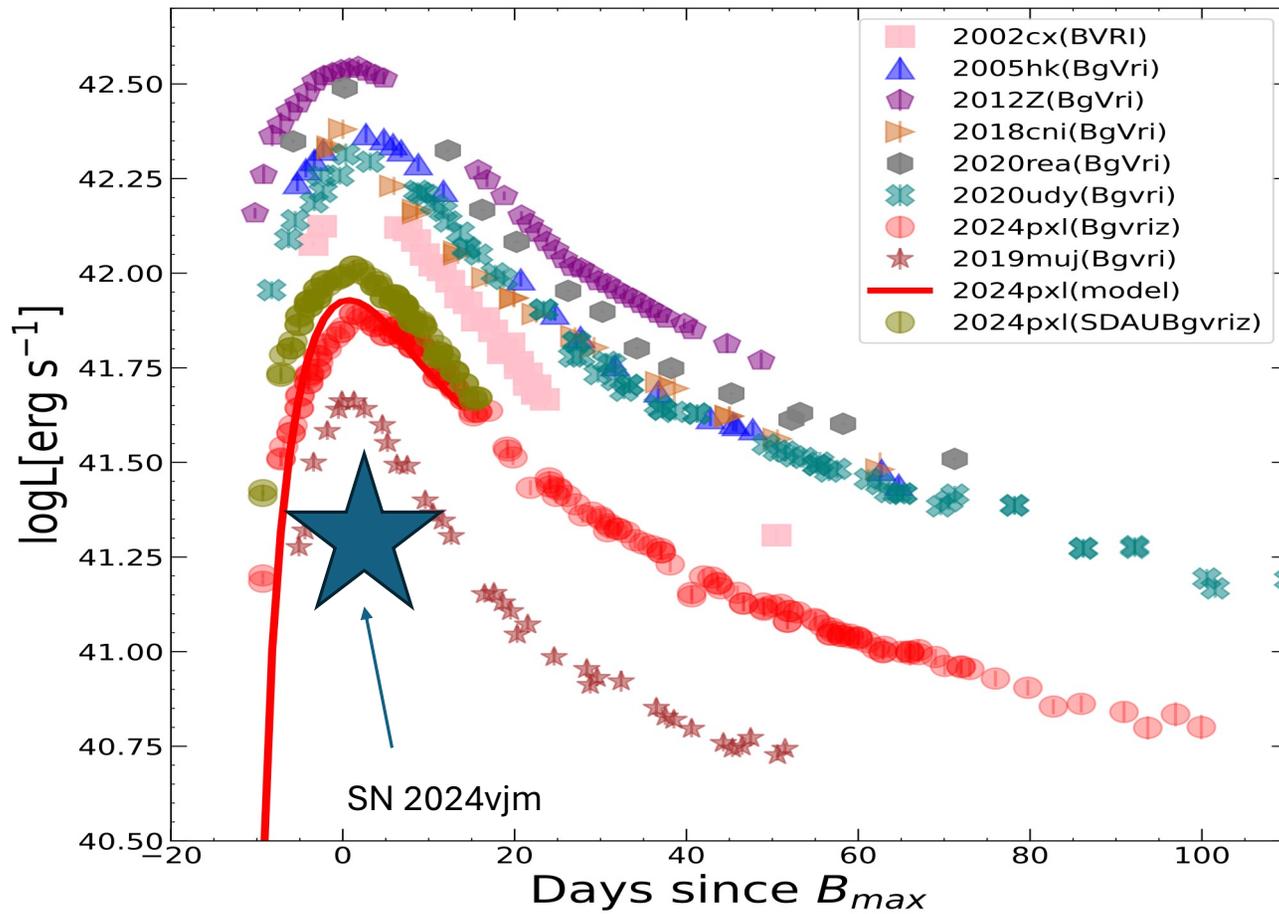
# SN Iax span a range of brightness with slower red band decline rates



# SN 2024vjm

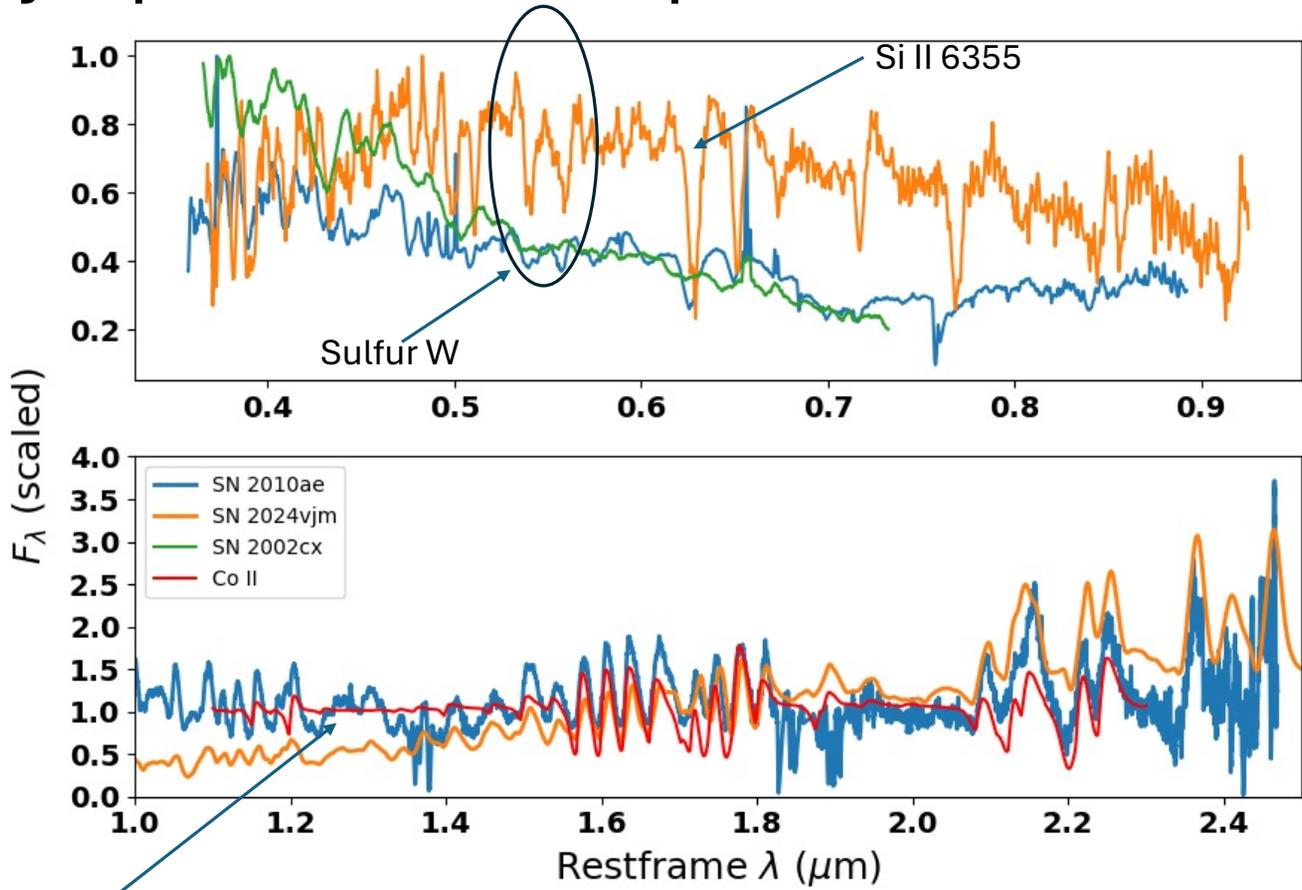
- Very dim SN Iax at 7.2 Mpc
- Observed by JWST at +12 day by Kwok+25 (ID: 6811, PI L. Kwok)
- Observed by JWST at +196 day (ID: 9231, PI E. Baron)

## Bolometric LCs of SNe Iax



Singh+26

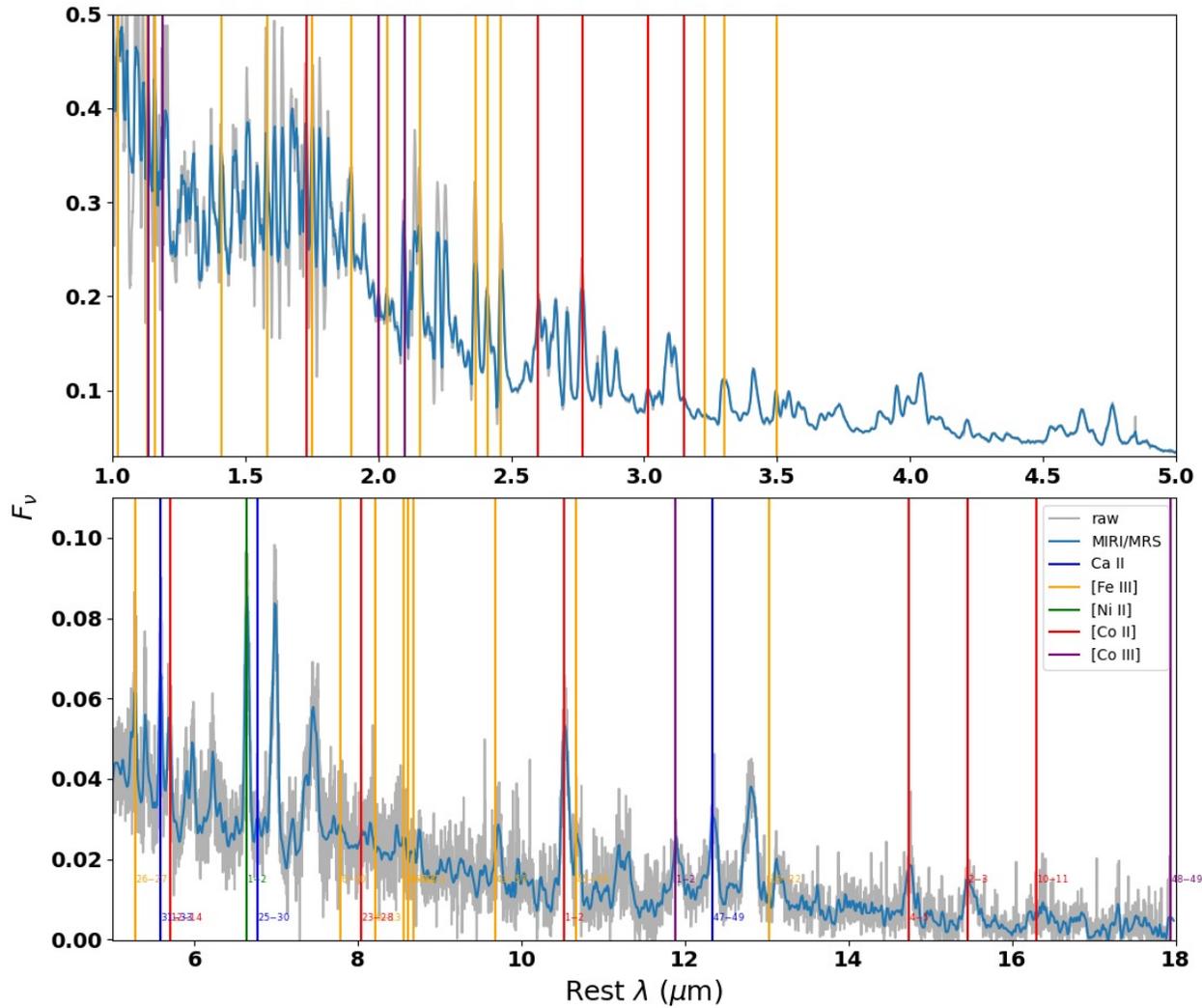
# Early Optical and NIR spectra



SYNAPPS fit

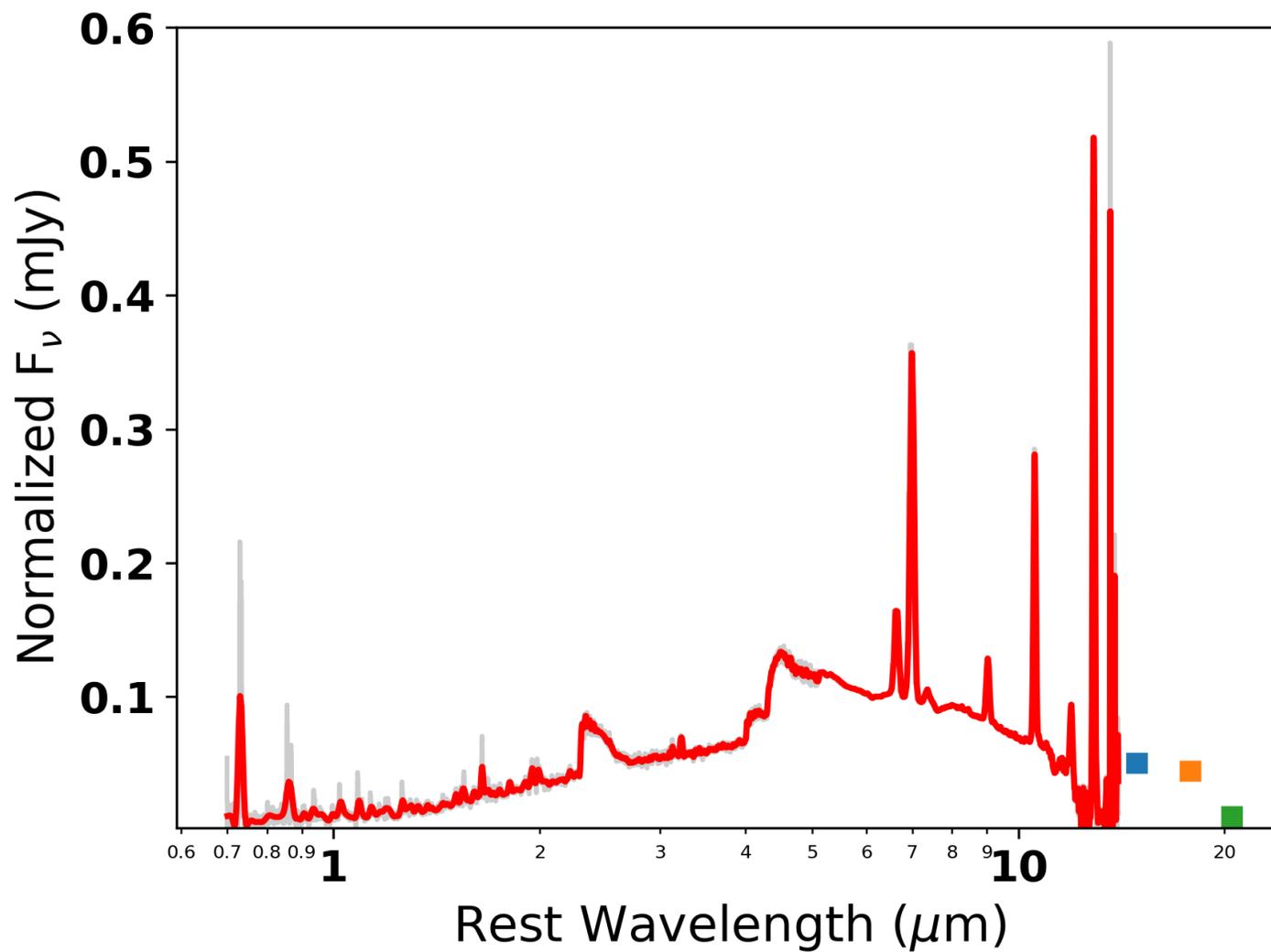
Data from: Kwok+25, Stritzinger+13, Li+03

Early time JWST  
spectrum  
of SN 2024vjm



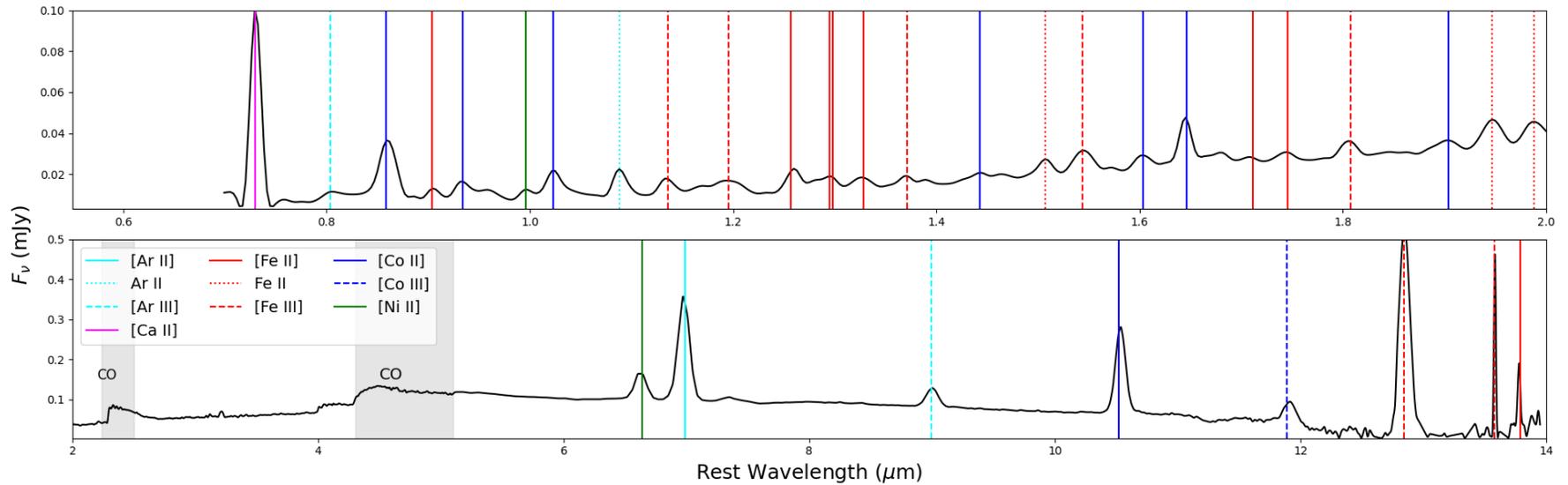
Kwok+25

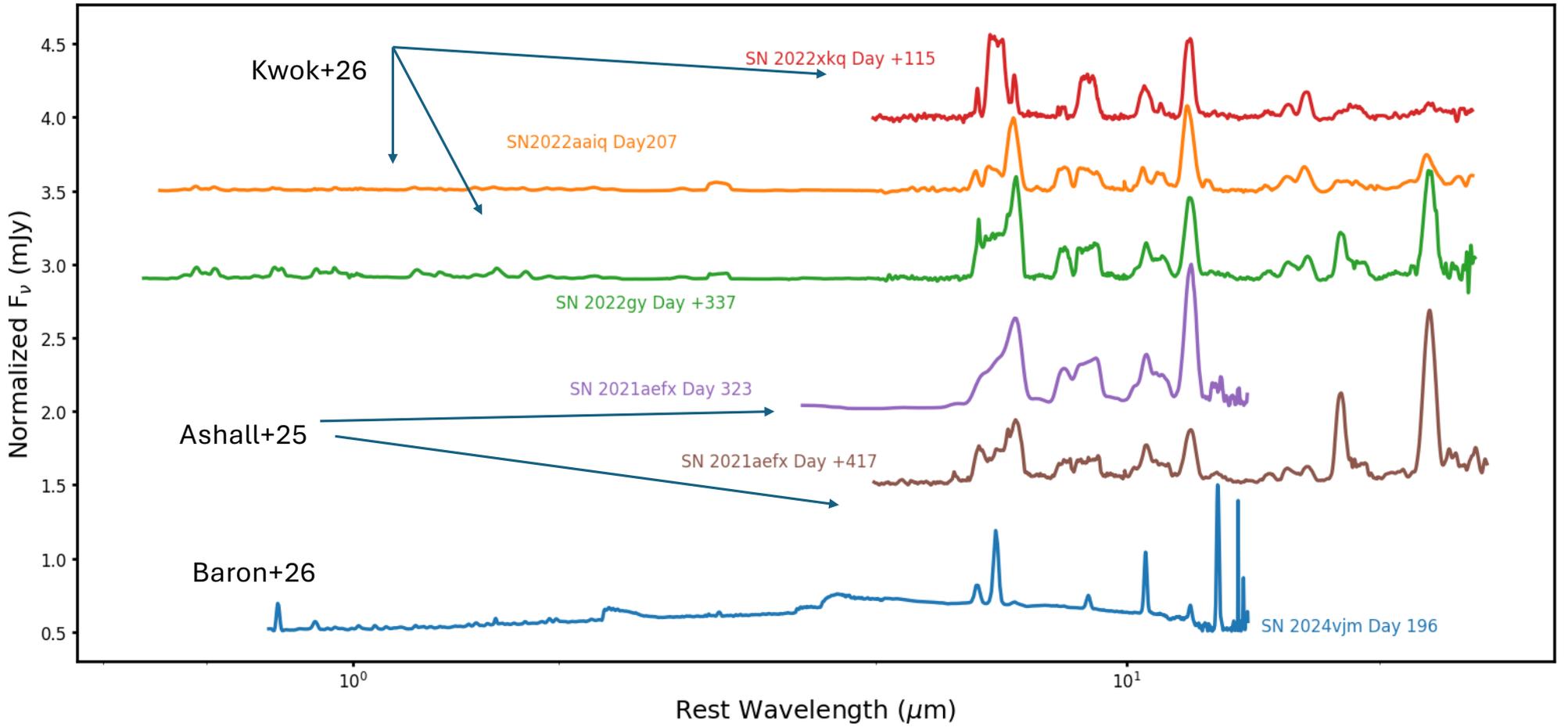
Day 196 SED  
of SN 2024vjm



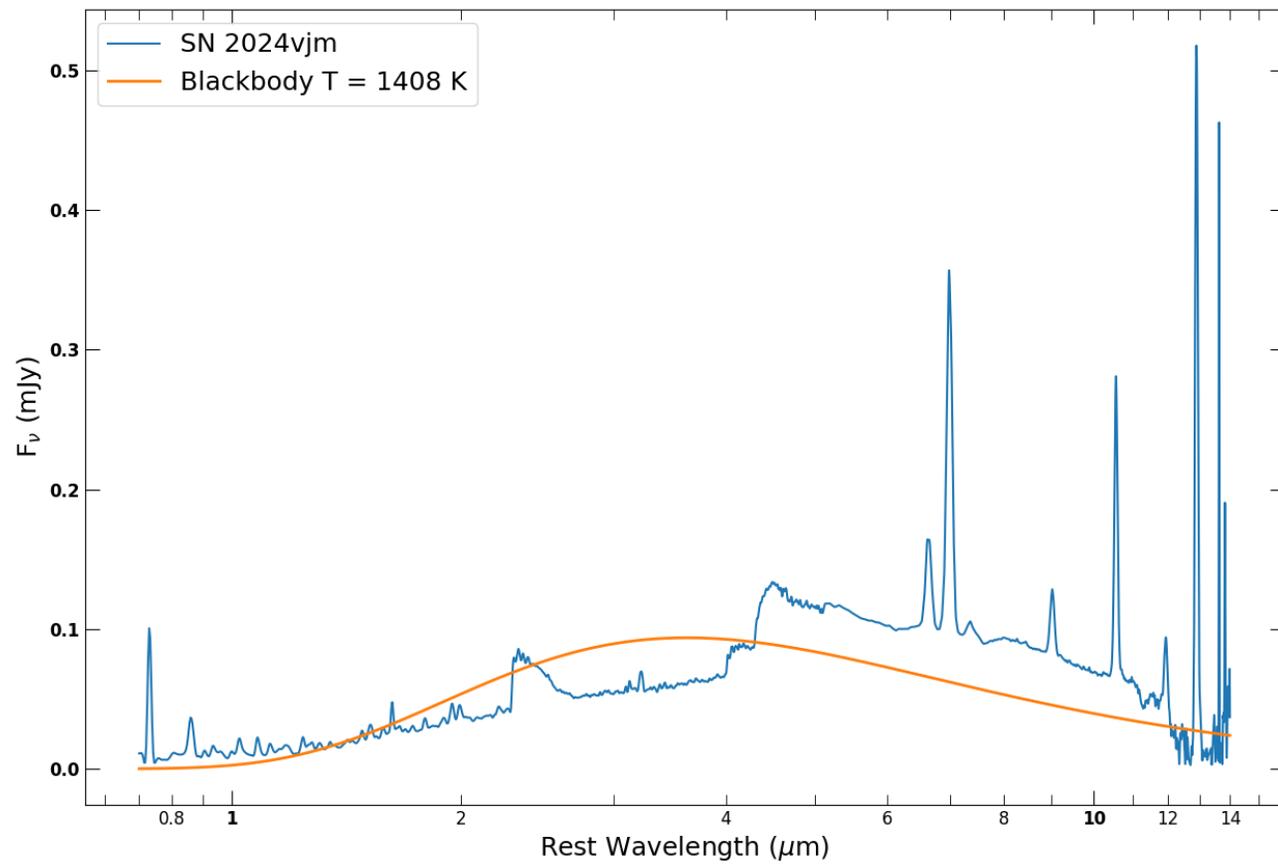
# Line IDs of SN 2024vjm

The prominent Co II feature near 1.6 microns has faded. Dominated by forbidden lines, with a few permitted Fe II lines

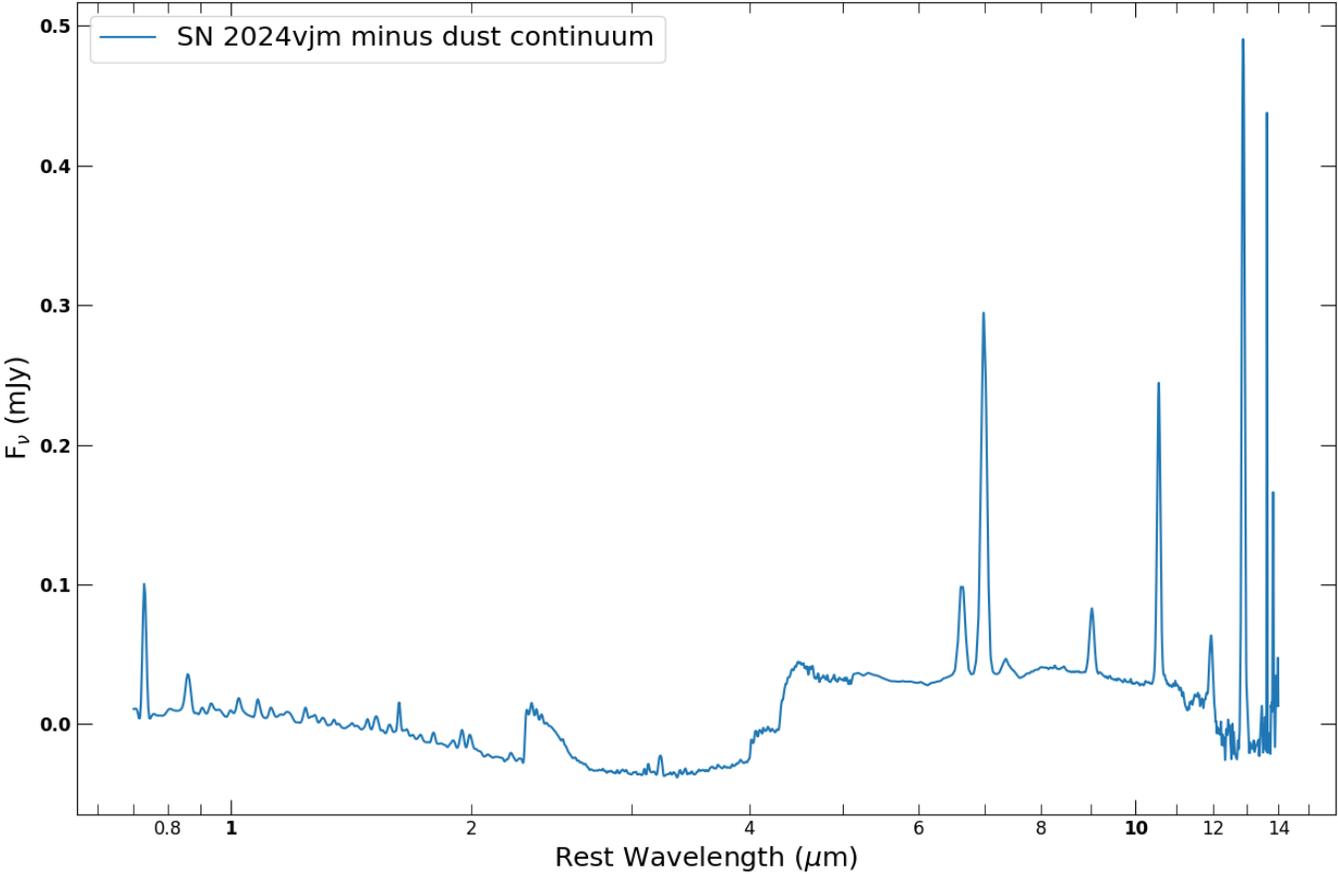




# Blackbody fit to SN 2024vjm SED day 196



SED with  
“dust continuum”  
removed



# Light Curve Models

Failed deflagration: C+O+Ne WD in binary with helium donor. Accretion ignites burning in primary, but it doesn't completely disrupt, leaving a bound remnant (Fink+14, Feldman+23)

Merger of C+O+Ne WD and C+O WD, leading to failed deflagration, enough  $Ni^{56}$  but light curves too fast and faint (Kashyap+18)

Mergers lead to highly magnetized, uniformly rotating WDs that contract and spin up, giving both DDT and failed deflagration (Neopane+22)

Maybe all single degenerate binary systems lead to SNe Iax (Michaelis & Perets 2026)

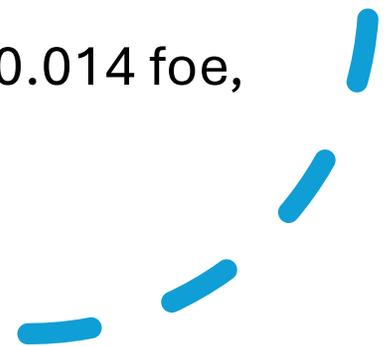
# Spectroscopy Models

Most popular model is failed deflagration, which leads to a bound remnant and low mass ejecta

Barna+18 found they could fit a range of luminosity SNe Iax with TARDIS by varying the density structure in analogy with the NXXdef series of Fink+14, where XX is the number of ignition spots and  $XX=100$  for SNe Ia. Found more shellular composition than predicted by pure deflagration.

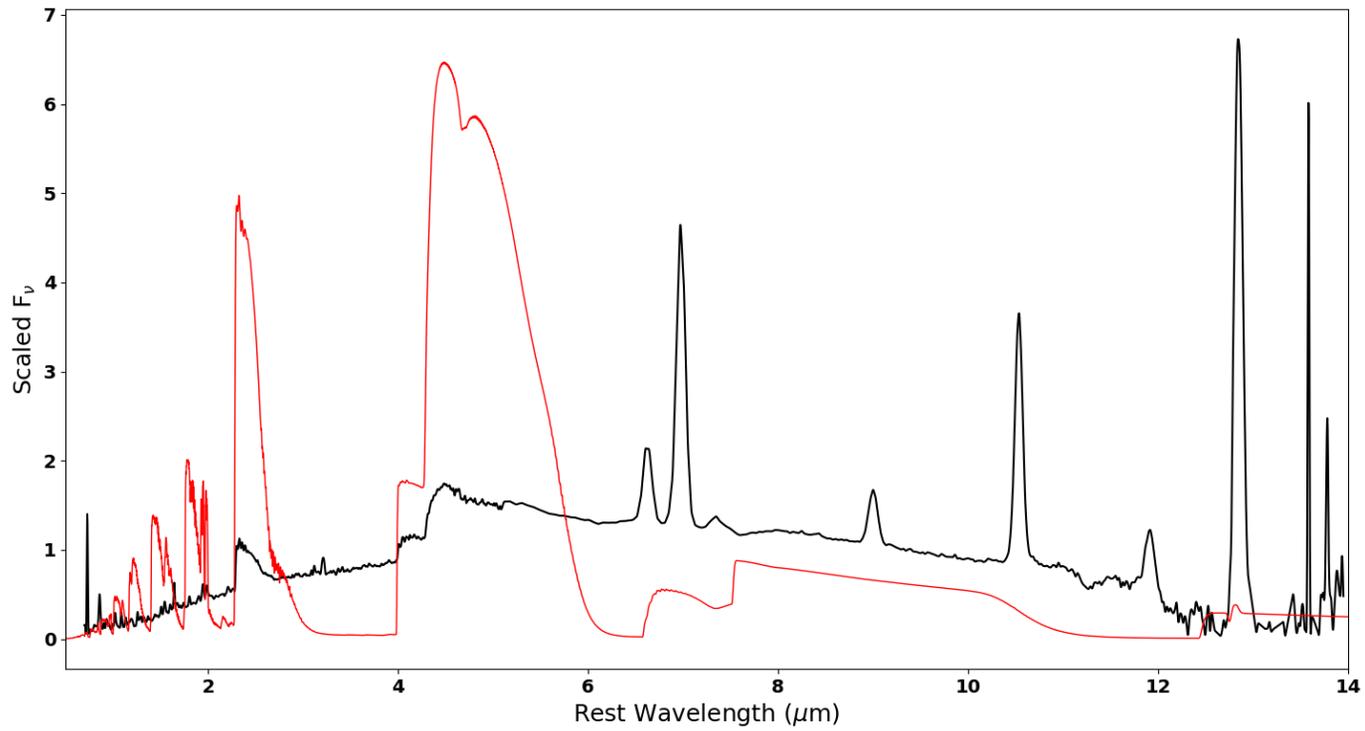
Choose some simple models to perform full NLTE synthetic spectral modeling and compare to data

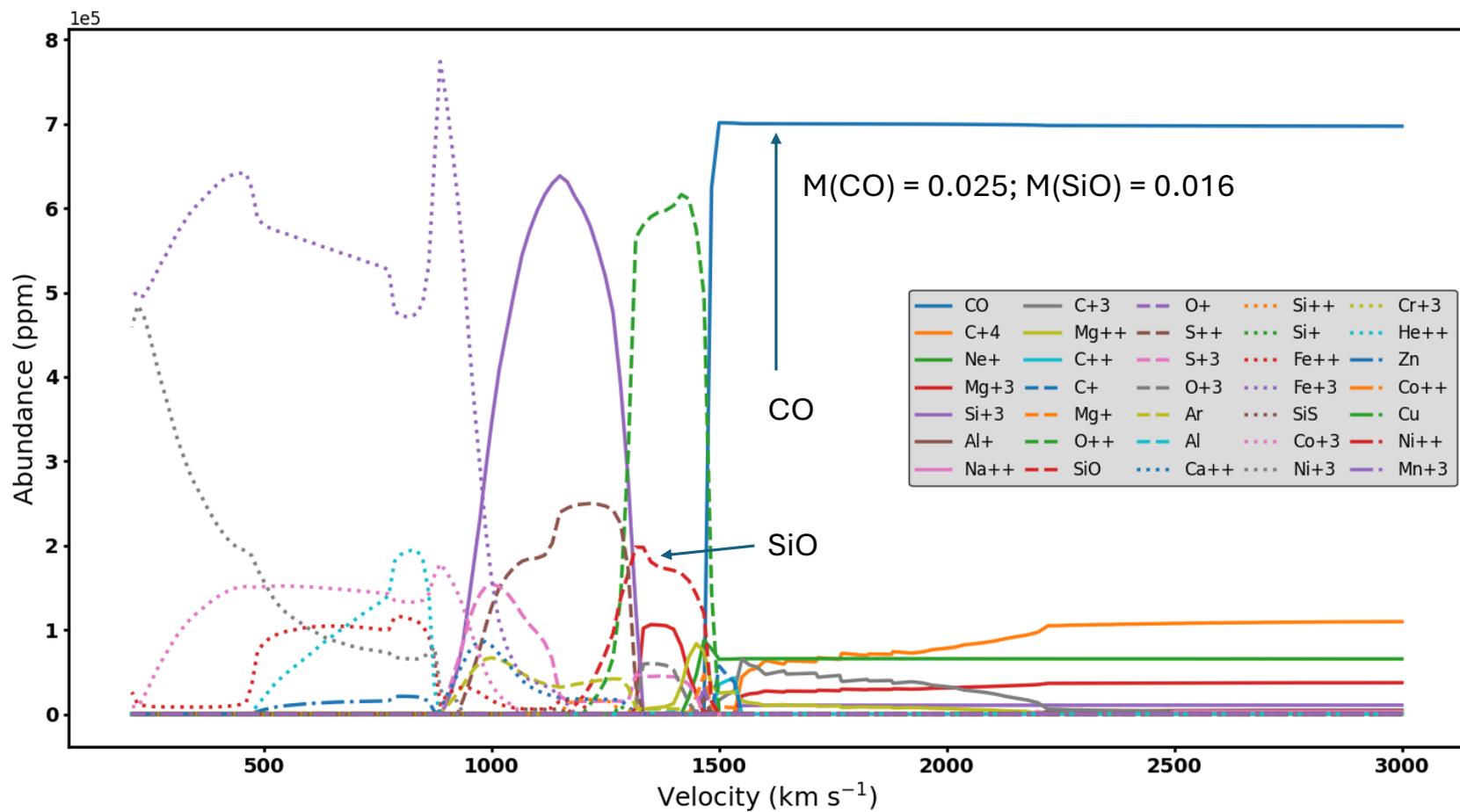
- Tool: PHOENIX Generalized stellar atmosphere code (Hauschildt & Baron, 1999)
- W7 is a (tuned) pure deflagration for normal SNe Ia. Happy 45th birthday!
- W7 too fast, but shellular, so modify W7: reduce density and velocity:  $M = 0.42 M_{\odot}$ ,  $E(\text{KE}) = 3.5 \times 10^{-3}$  foe,  $E/M = 0.008$
- N1def:  $M = 0.075 M_{\odot}$ ,  $E(\text{KE}) = 0.014$  foe,  $E/M = 0.018$



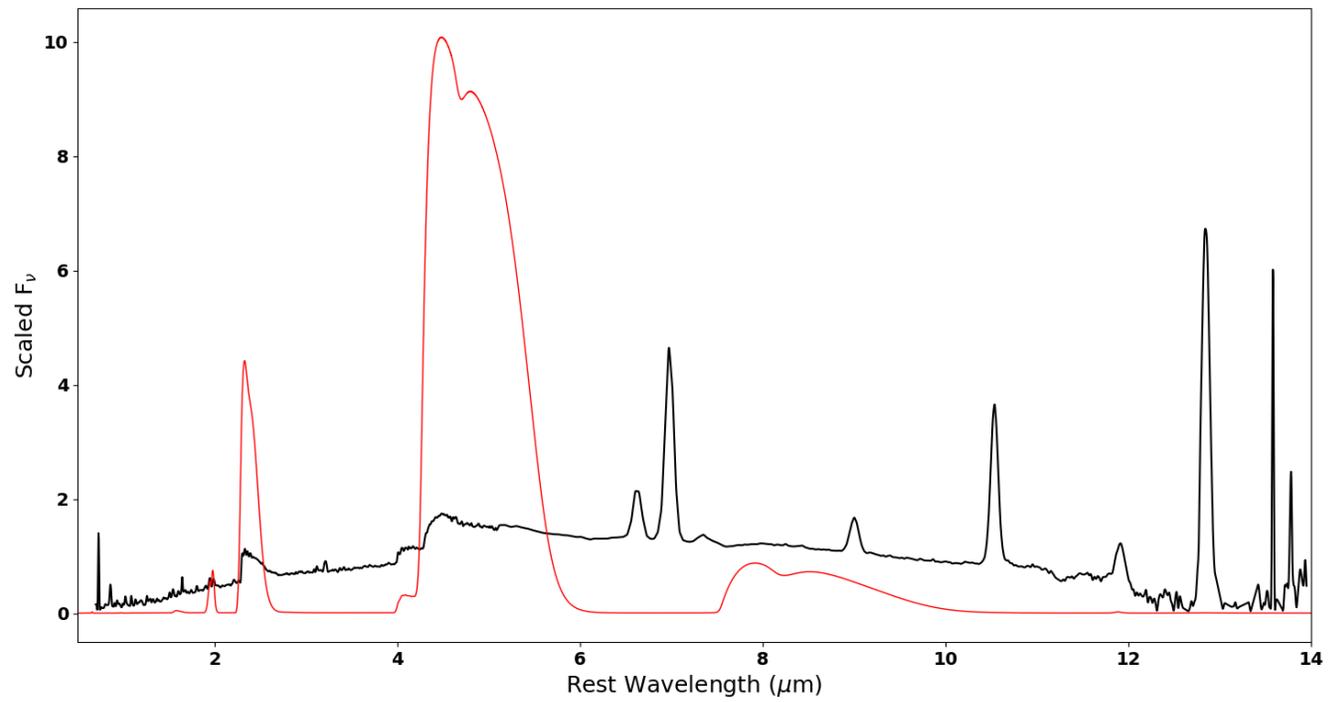
# Simple modified W7 model

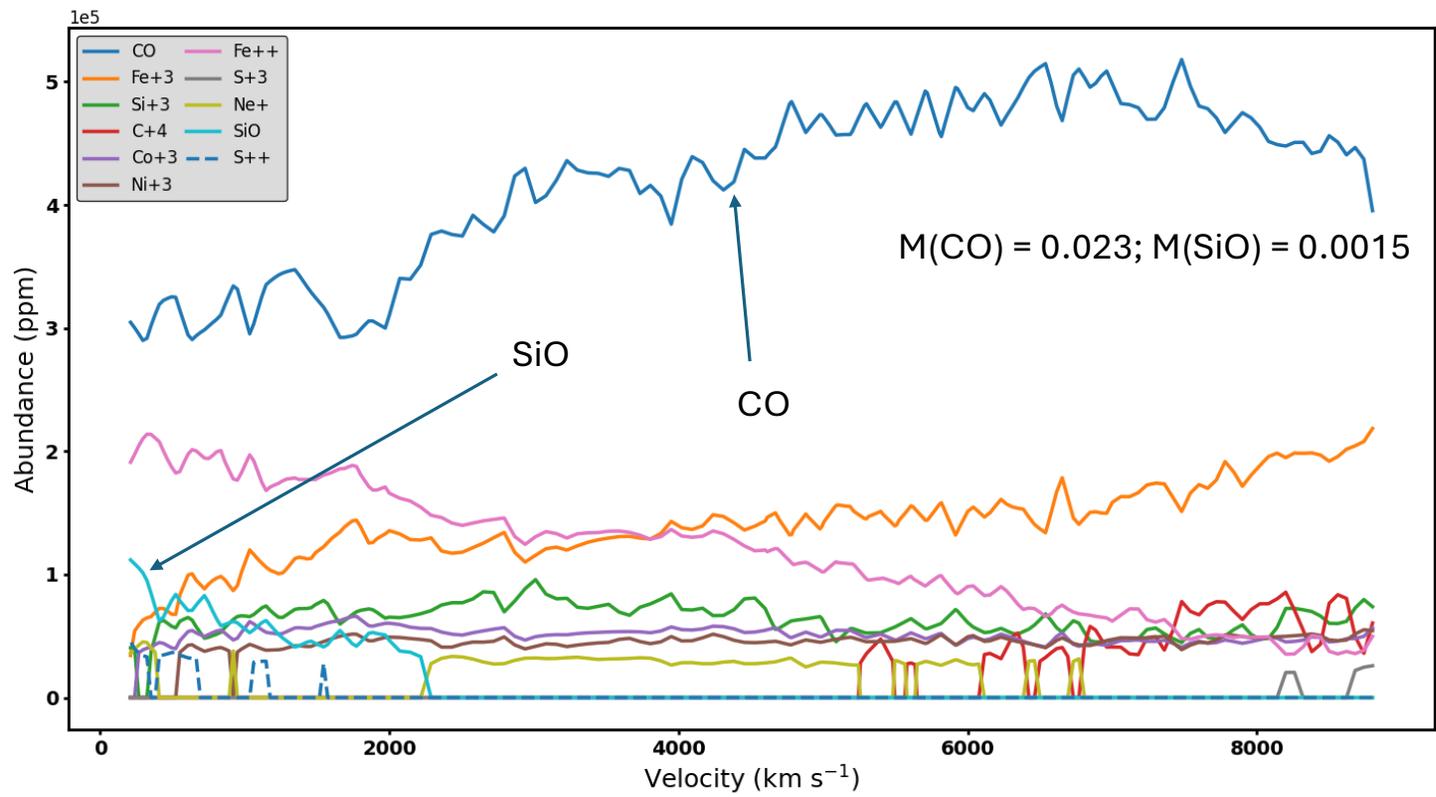
$V_{\max} \rightarrow 3000 \text{ km/s}$ ,  $M \rightarrow 0.42 M_{\odot}$



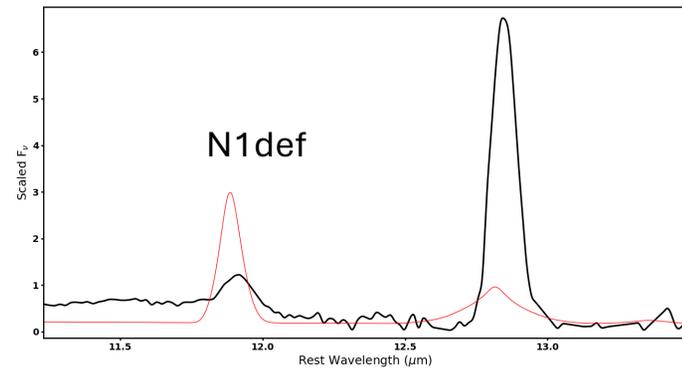
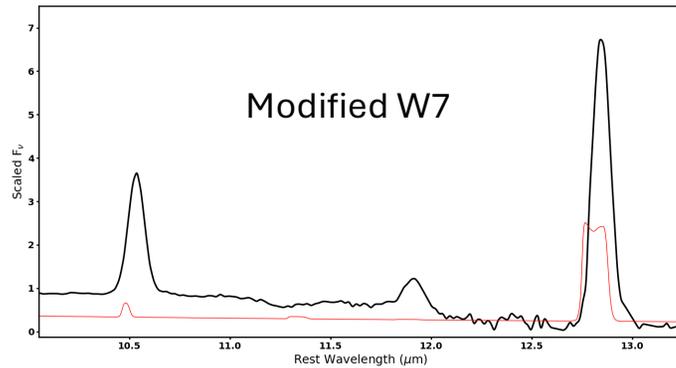


# N1def Model





Is feature at 12.8 microns [Ne II] or [Fe III]?



A bit hard to tell because [Co II] line is also redshifted compared to models

Neither model does particularly well

- M\_CO about ten times too large → M\_CO about 0.001
- M\_SiO at least ten times too large → M\_SiO about  $10^{-4}$  or less
- If 12.8 micron feature is [Ne II] 12.81 micron line, it is redshifted, if [Fe III] 12.84 micron line, not redshifted. Gives constraint on explosion.

# Summary

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JWST opens a new window in the NIR+MIR for all types of SNe

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Molecule formation and emission by resonance forbidden lines put strong constraints on the nature of SNe Ia explosions, implying that more SNe Ia should be followed in the NIR+MIR (with JWST).

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Questions?