Unraveling Cosmic Dust Origins: *JWST* Revelations from Supernovae

Melissa Shahbandeh, STScI

+ an amazing team including

O. Fox, C. Ashall, E. Baron, P. Hoeflich, J. DerKacy, T. Mera, A. Sarangi, T. Temim, T. Szalai, S. Tinyanont, E. Dwek, L. Dessart, A. Filippenko, T. Brink, R. Foley, J. Jencson, J. Pierel, S. Zsiros, A. Rest, W. Zheng, J. Andrews, G. Clayton, K. De, M. Engesser, S. Gezari, S. Gomez, S. Gonzaga, J. Johansson, M. Kasliwal, R. Lau, I. De Looze, A. Marston, D. Milisavljevic, R. O'Steen, M. Siebert, M. Skrutskie, N. Smith, L. Strolger, S. Van Dyk, Q. Wang, B. Williams, R. Williams, L. Xiao, Y. Yang

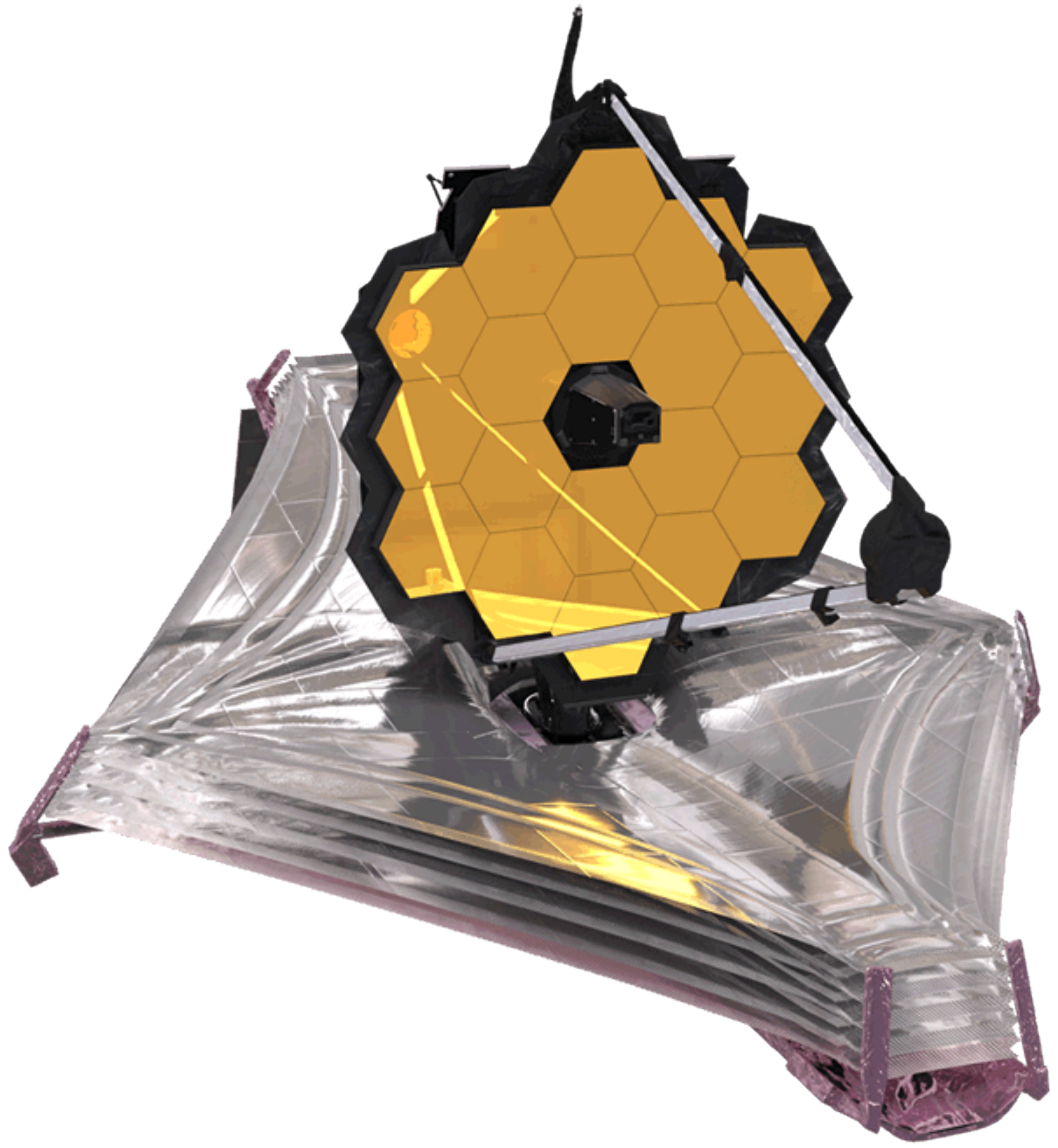
+ **many more**

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

SNR III, June 13th, 2024

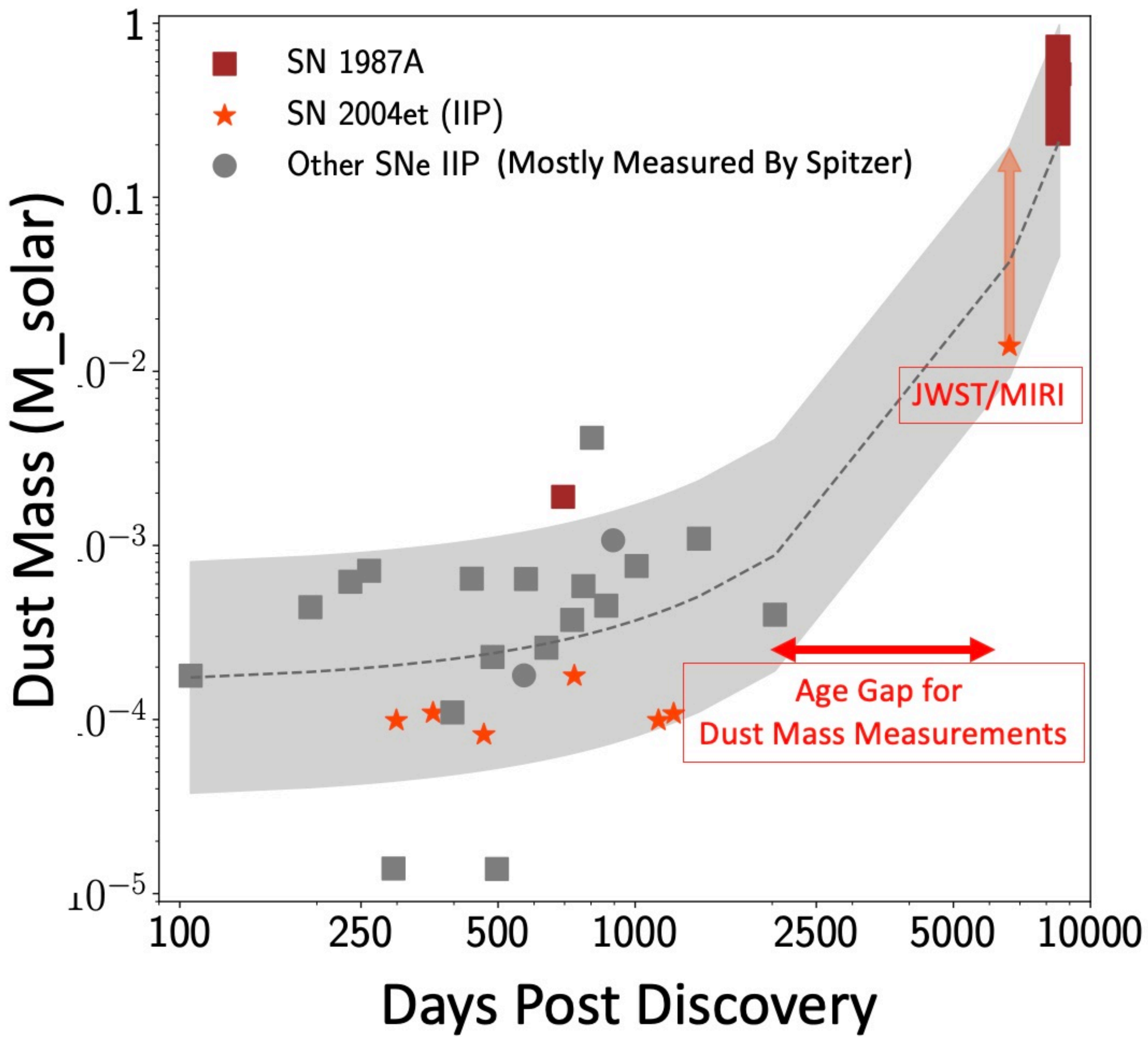
Goals

- Do SNe contribute to the total dust budget of the Universe?
- Do all SNe produce dust?
- Are dust properties different among SNe?



Disentangling dust formation and heating mechanism

- Formation/location
- Heating mechanism
- The amount of dust
- The evolution of dust



melissa.shahbandeh@gmail.com

melissa.shahbandeh@gmail.com

SNe II

melissa.shahbandeh@gmail.com

GO-2122 (PI: C. Ashall)

SN 2022acko

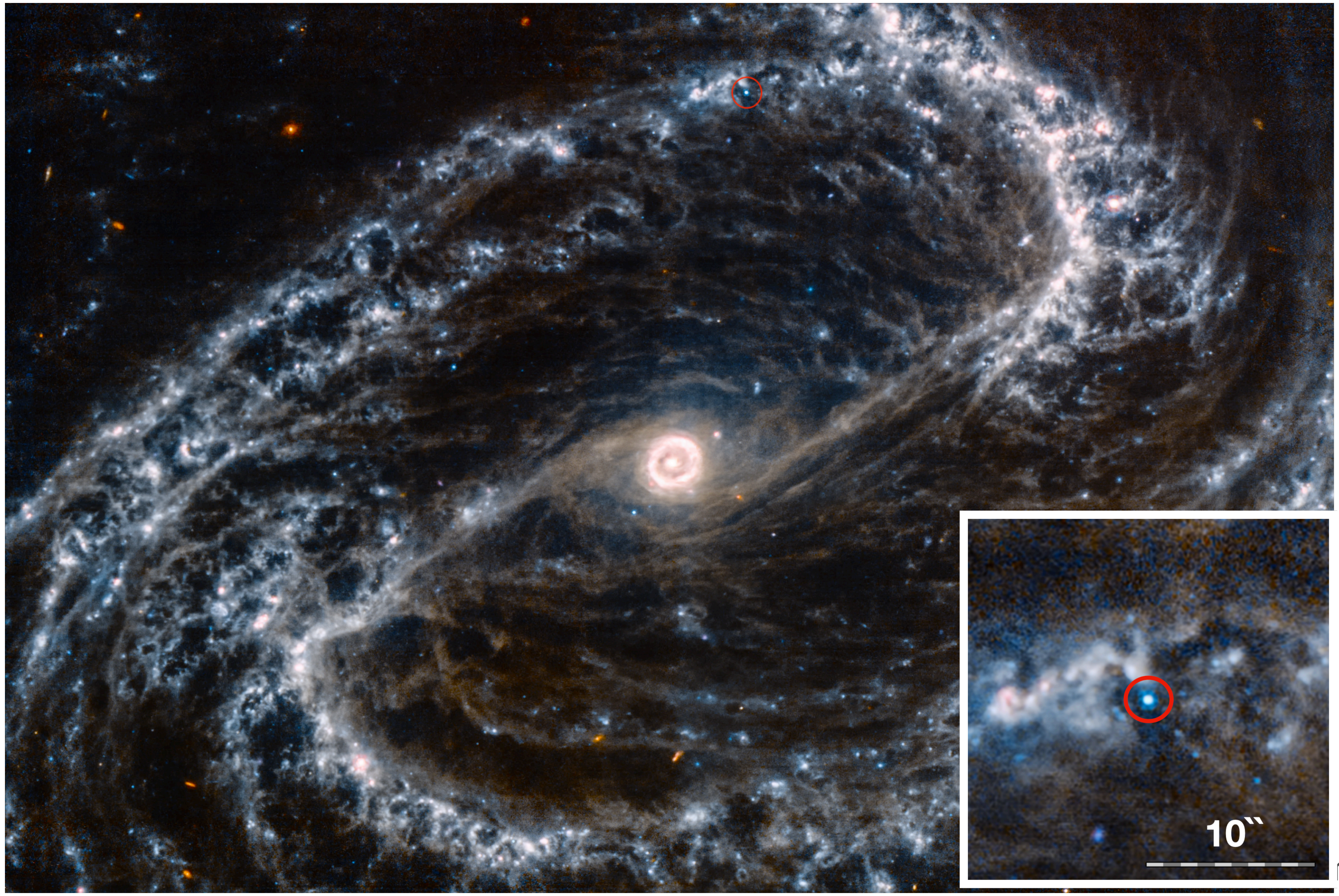




C. Ashall E. Baron P. Hoeflich J. DerKacy T. Evans

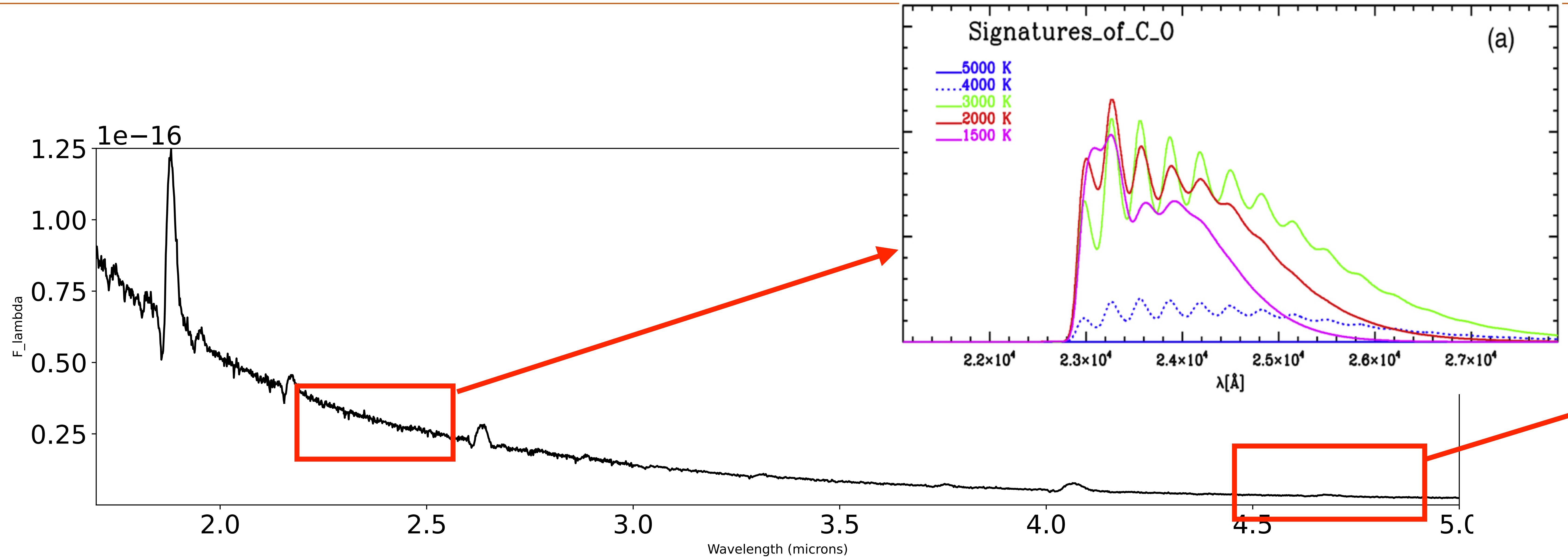
- Nearby SN IIP
- First ever SN II spectrum with *JWST*

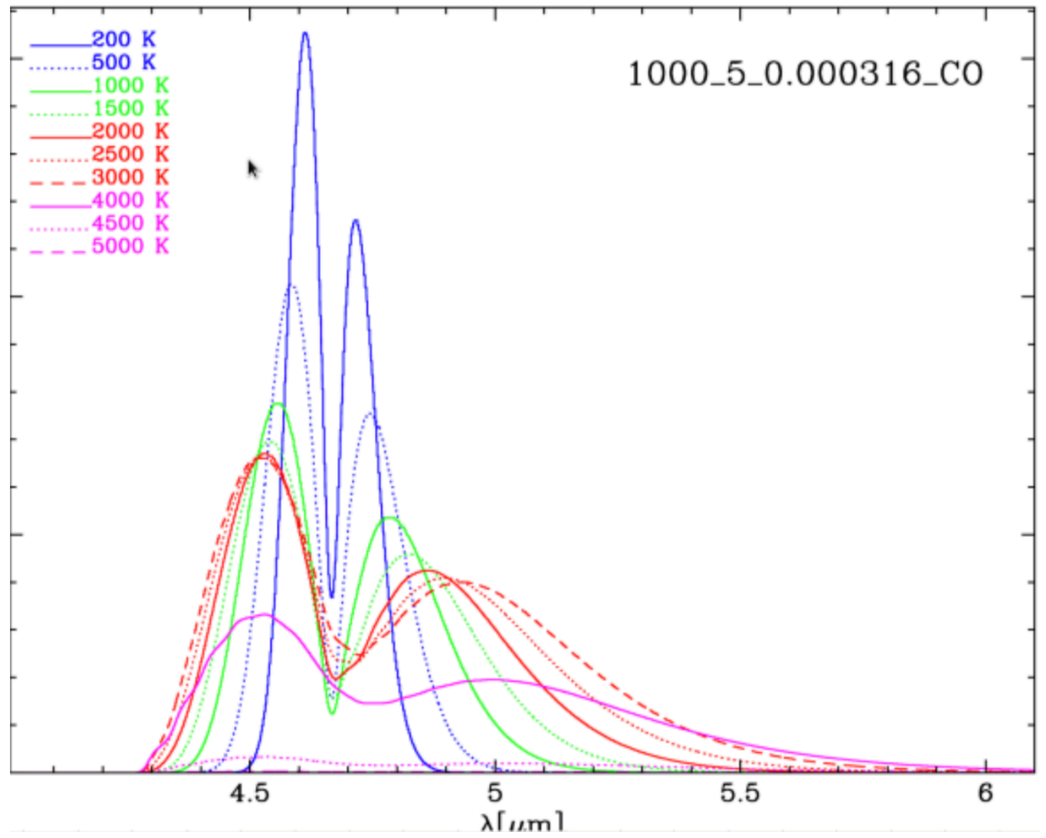
Shahbandeh+ 2024



Dust precursors not detected in *JWST* data of 2022acko

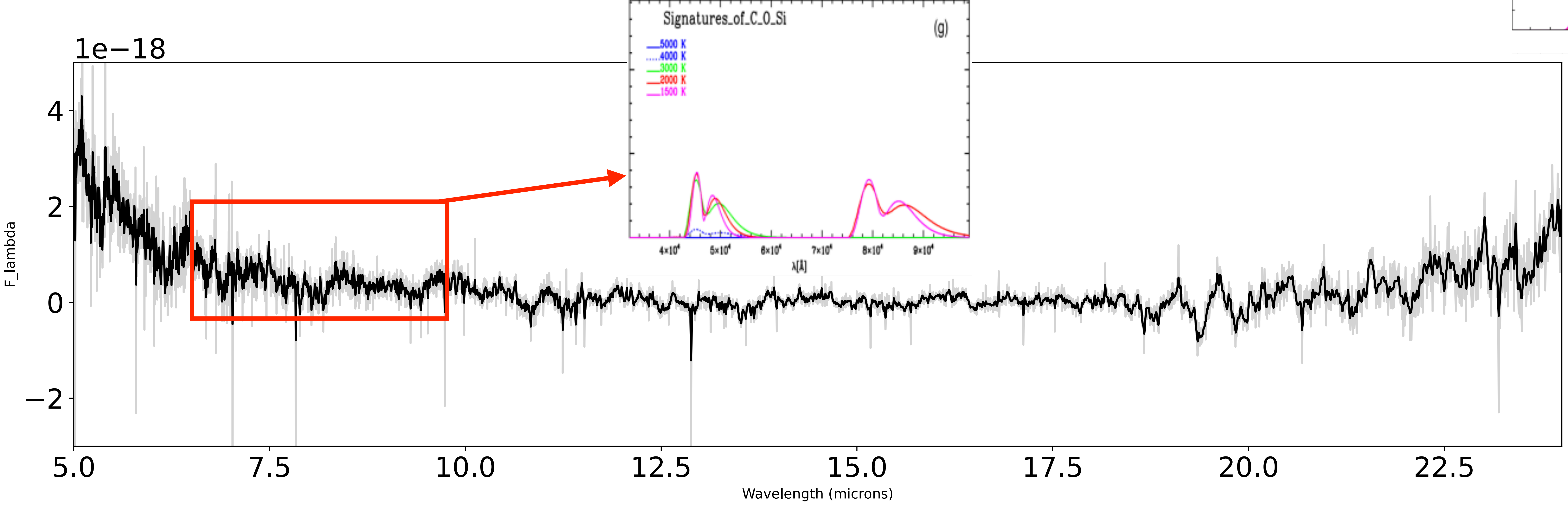
NIRSpec





C. Ashall

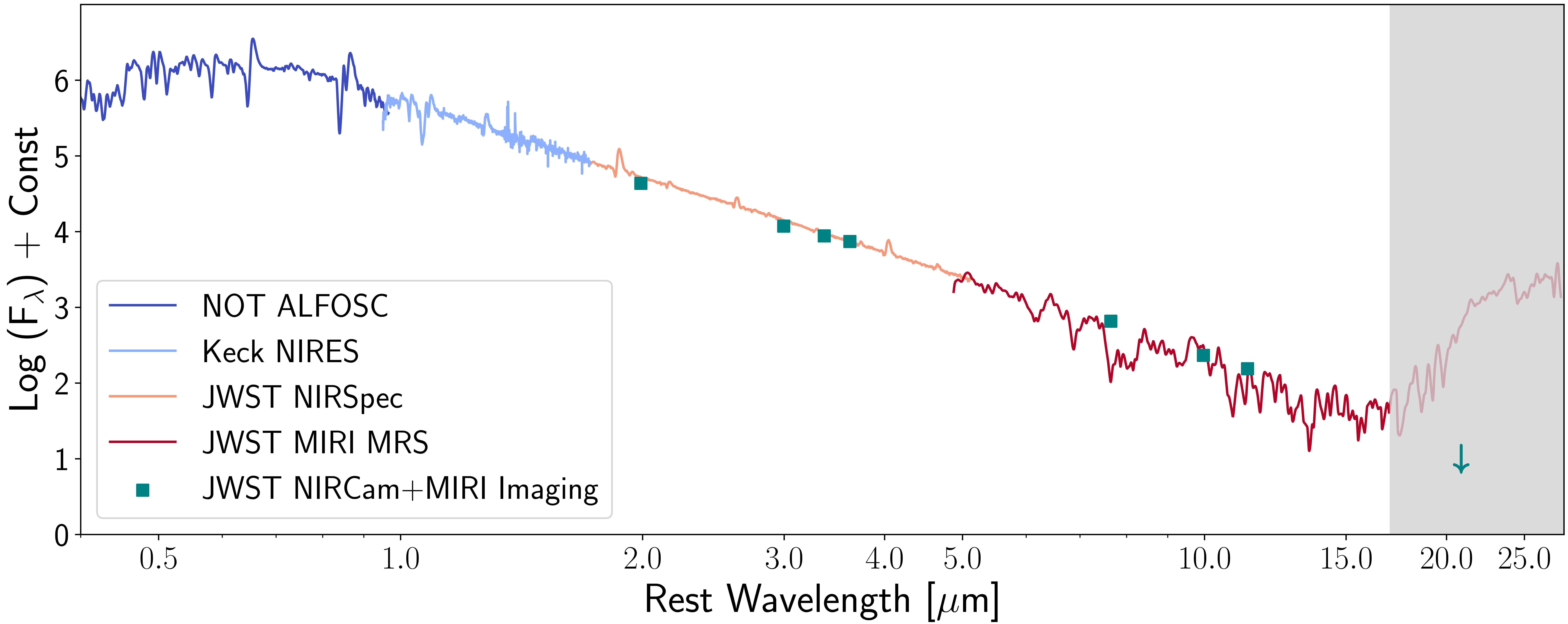
MIRI



Shahbandeh+ 2024

melissa.shahbandeh@gmail.com

First full SED of a core-collapse SN



Shahbandeh+ 2024

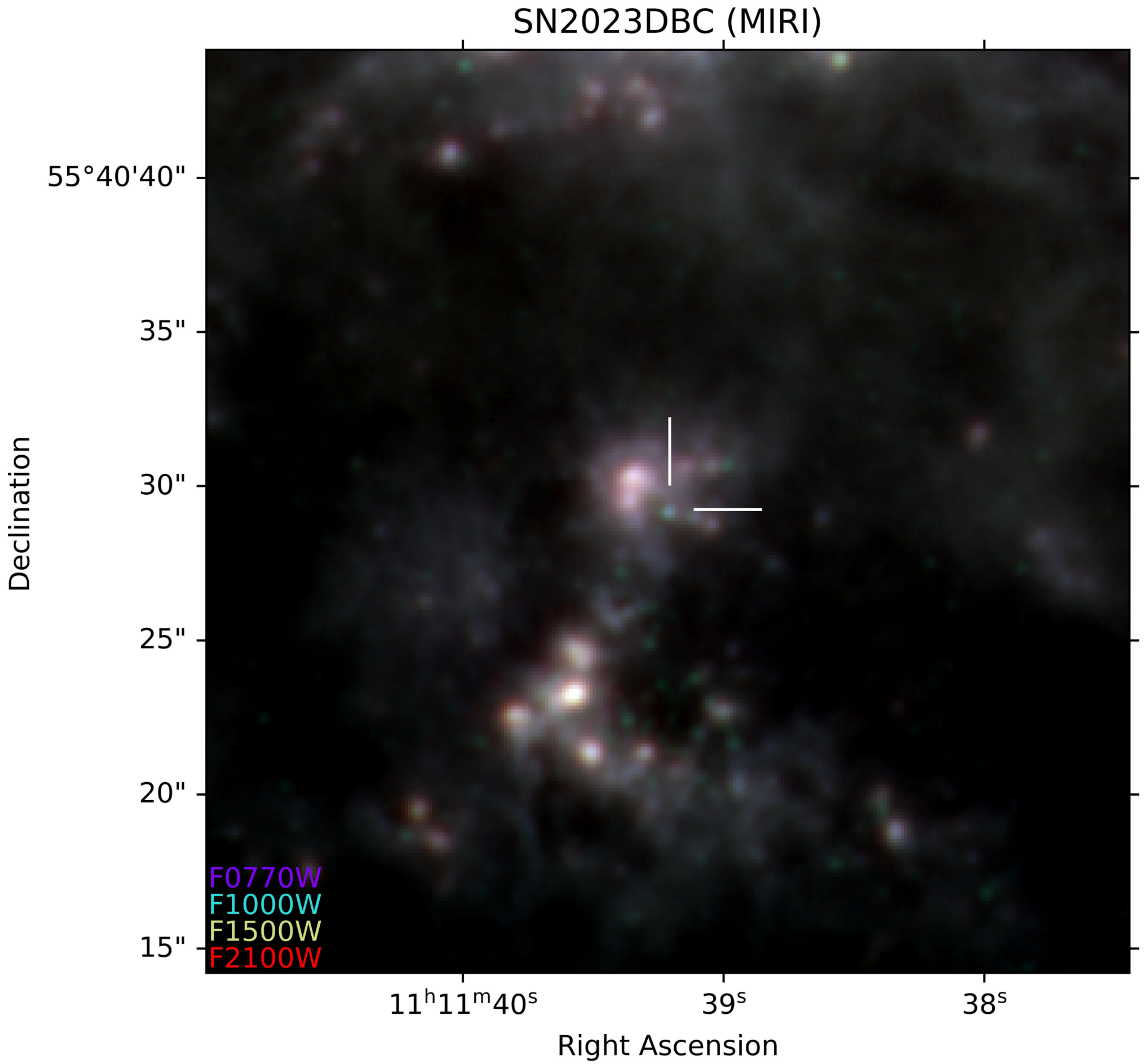
melissa.shahbandeh@gmail.com

What about SESNe?

melissa.shahbandeh@gmail.com

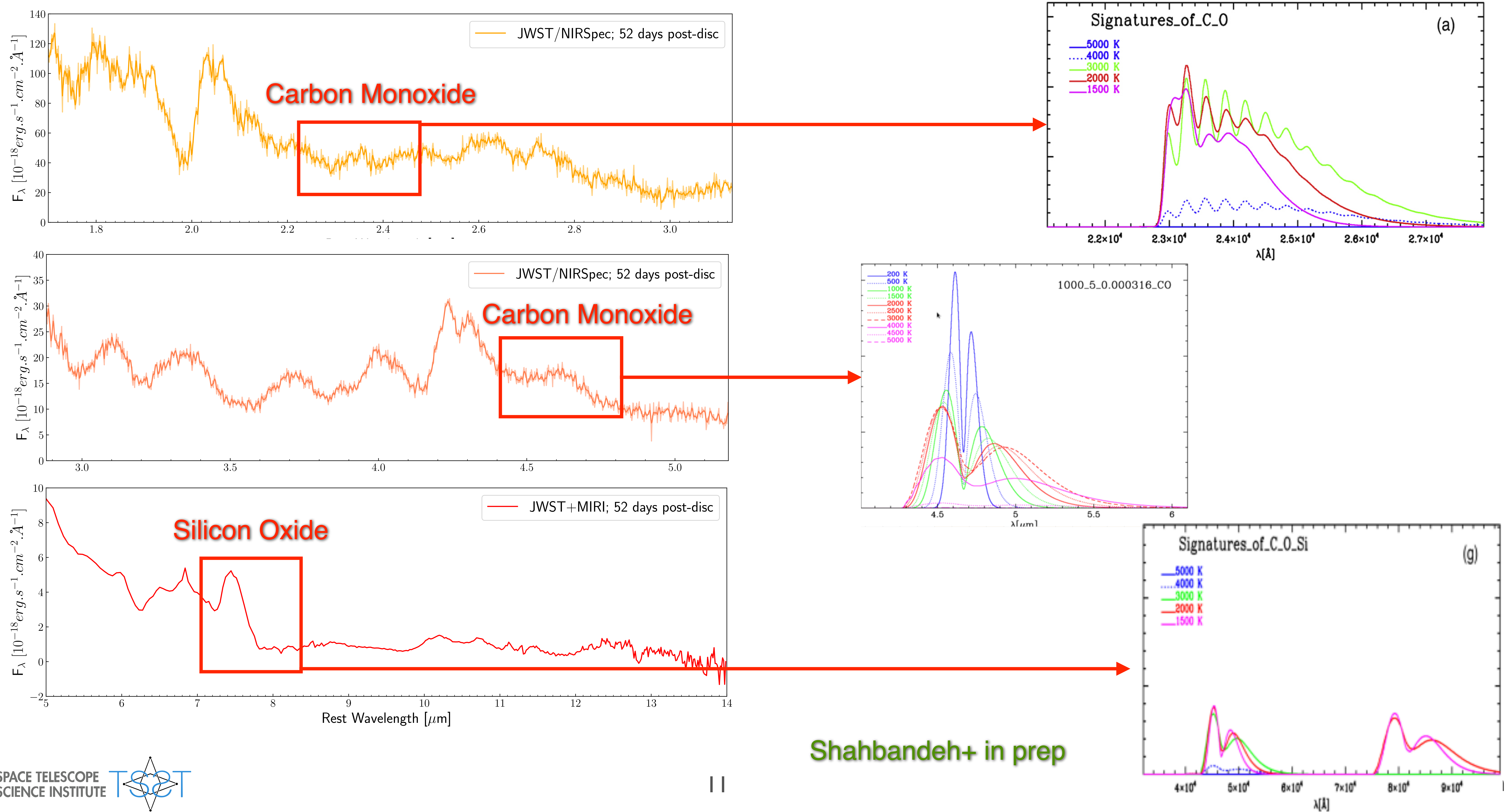
SN 2023dbc

- Nearby SN Ic (10 Mpc)
- First ever SESN spectrum with *JWST*
- Cycle 1, 2, 3



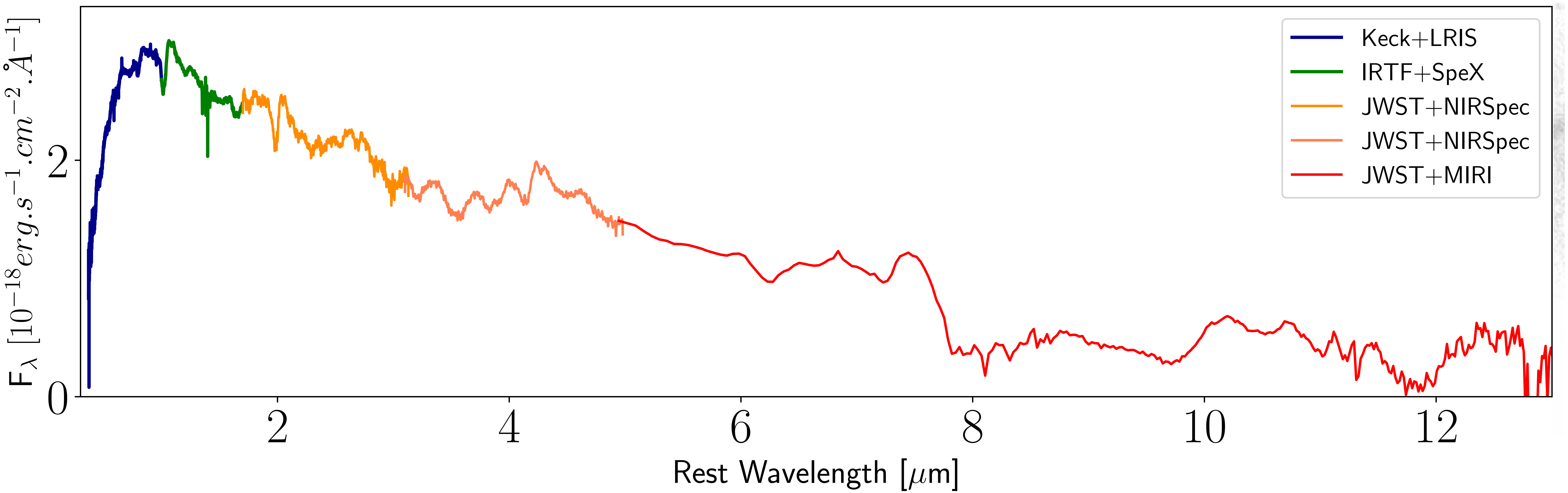
melissa.shahbandeh@gmail.com

Dust precursors detected in *JWST* observations of a SN Ic



Shahbandeh+ in prep

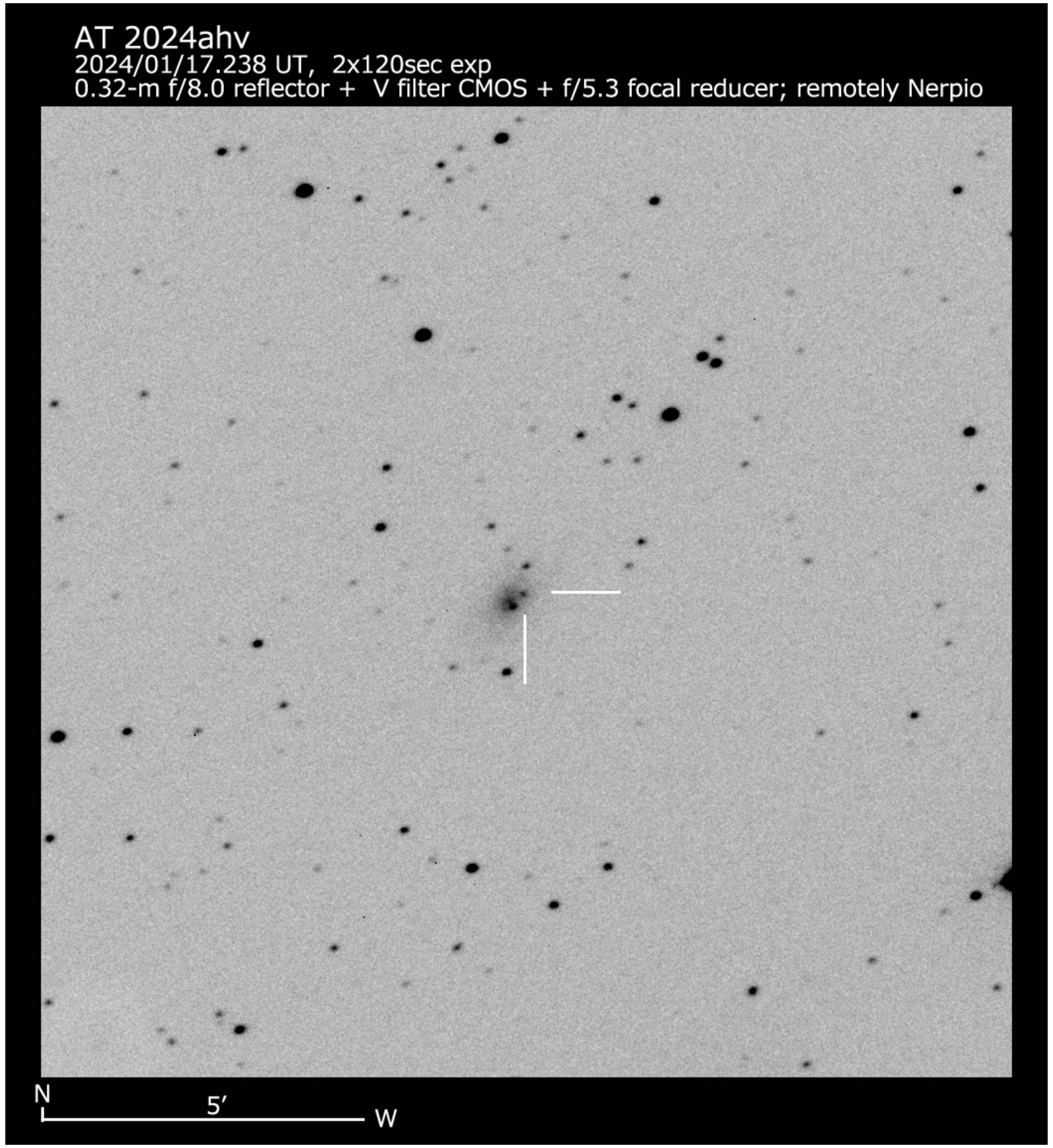
First full SED of a SESN



Shahbandeh+ in prep

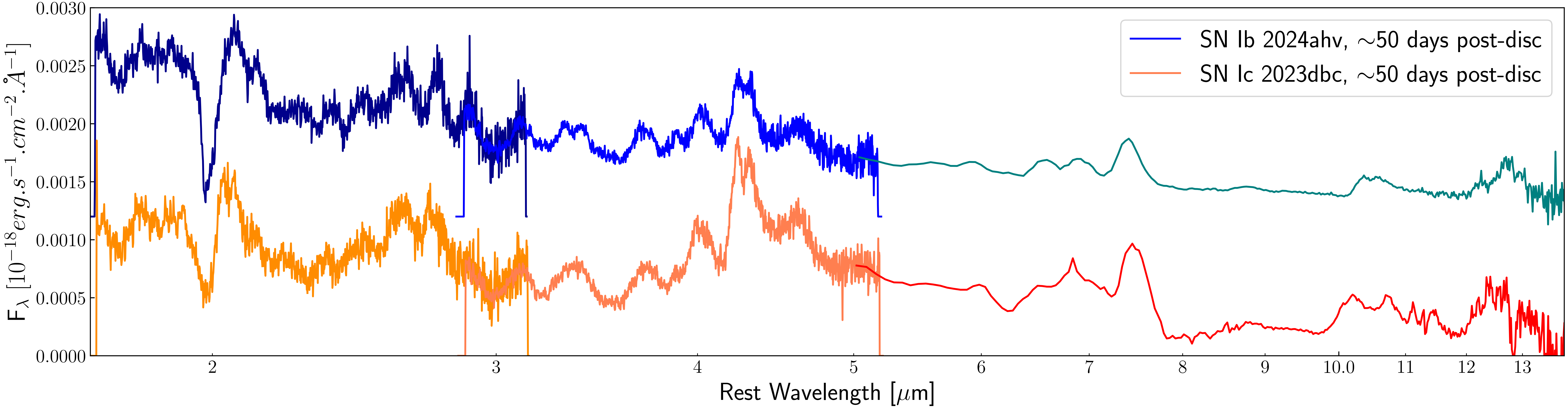
SN 2024ahv

- Nearby SN Ib (20 Mpc)
- 4 epochs



K. Yoshimoto

SN Ib vs SN Ic



Shahbandeh+ in prep

melissa.shahbandeh@gmail.com


Data to be acquired within 1-3 years
Logistical Phase
PHASE I
Dust precursors' formation
PHASE II
Dust precursors' evolution
PHASE III
Dust evolution and beyond
JWST programs
DD-4436: Type Ic SN 2023dbc
DD-4522: Type IIP SN 2023ixf
GO-2122: Type IIP SN 2022acko
GO-4217: Stripped-envelope SN
DD-4520: Type Ic SN 2023dbc
DD-4522: Type IIP SN 2023ixf
GO-2122: Type IIP SN 2022acko
GO-4217: Stripped envelope SN
GO-2666: 6 Type IIP SNe
GO-1860: 5 Type IIn SNe
SURVEY-3921: 44 Dusty SNe
Phenomenological Phase
Maximum Light
70 days
100 days
200 days
300 days
SN photospheric phase
Onset of CO formation
Onset of SiO formation, evolution of CO
Onset of dust formation, evolution of CO and SiO
Evolution of dust
SN explosion
Measurement Scheme
How dust forms
How much dust forms

melissa.shahbandeh@gmail.com

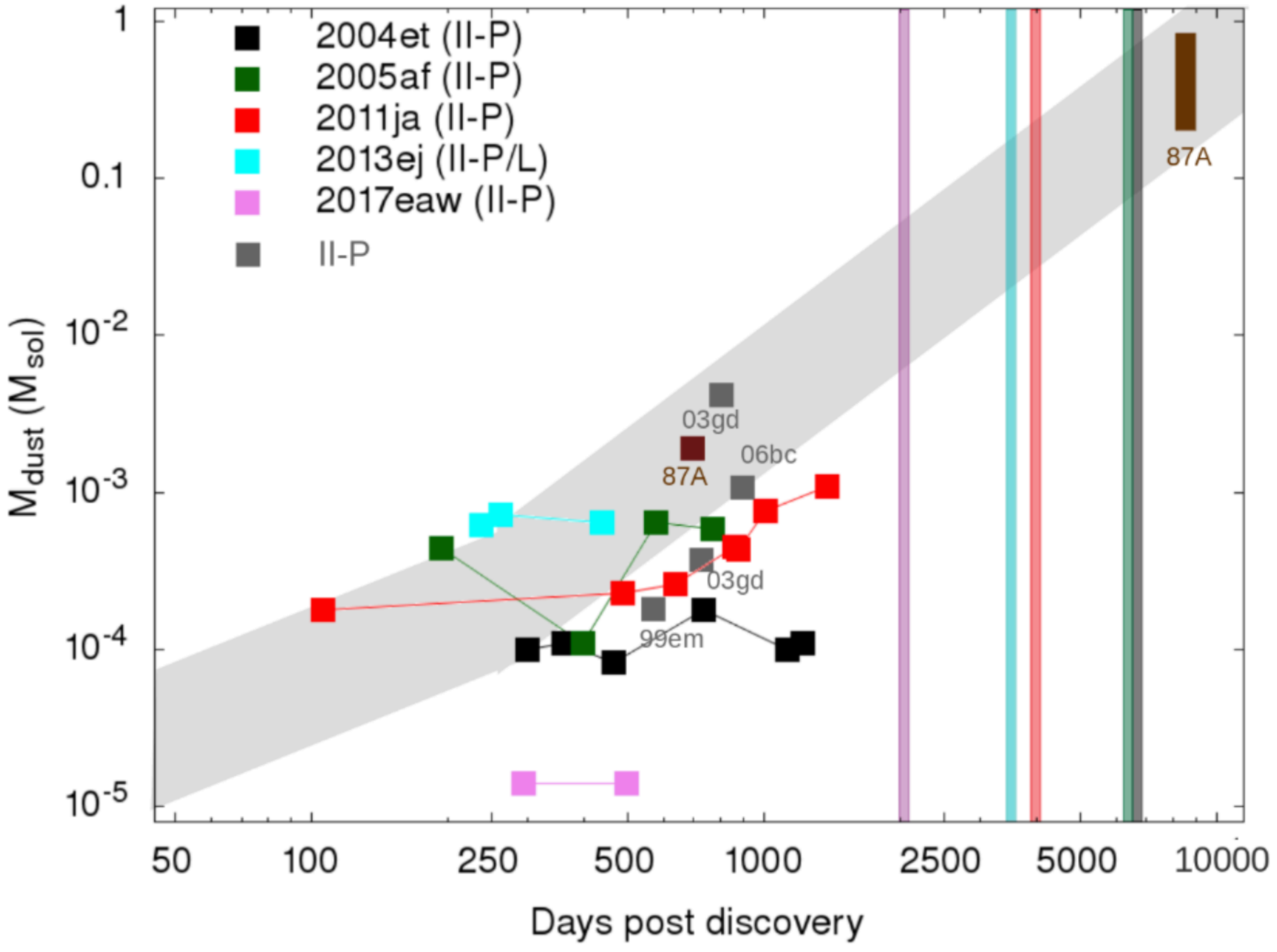
SNe IIP

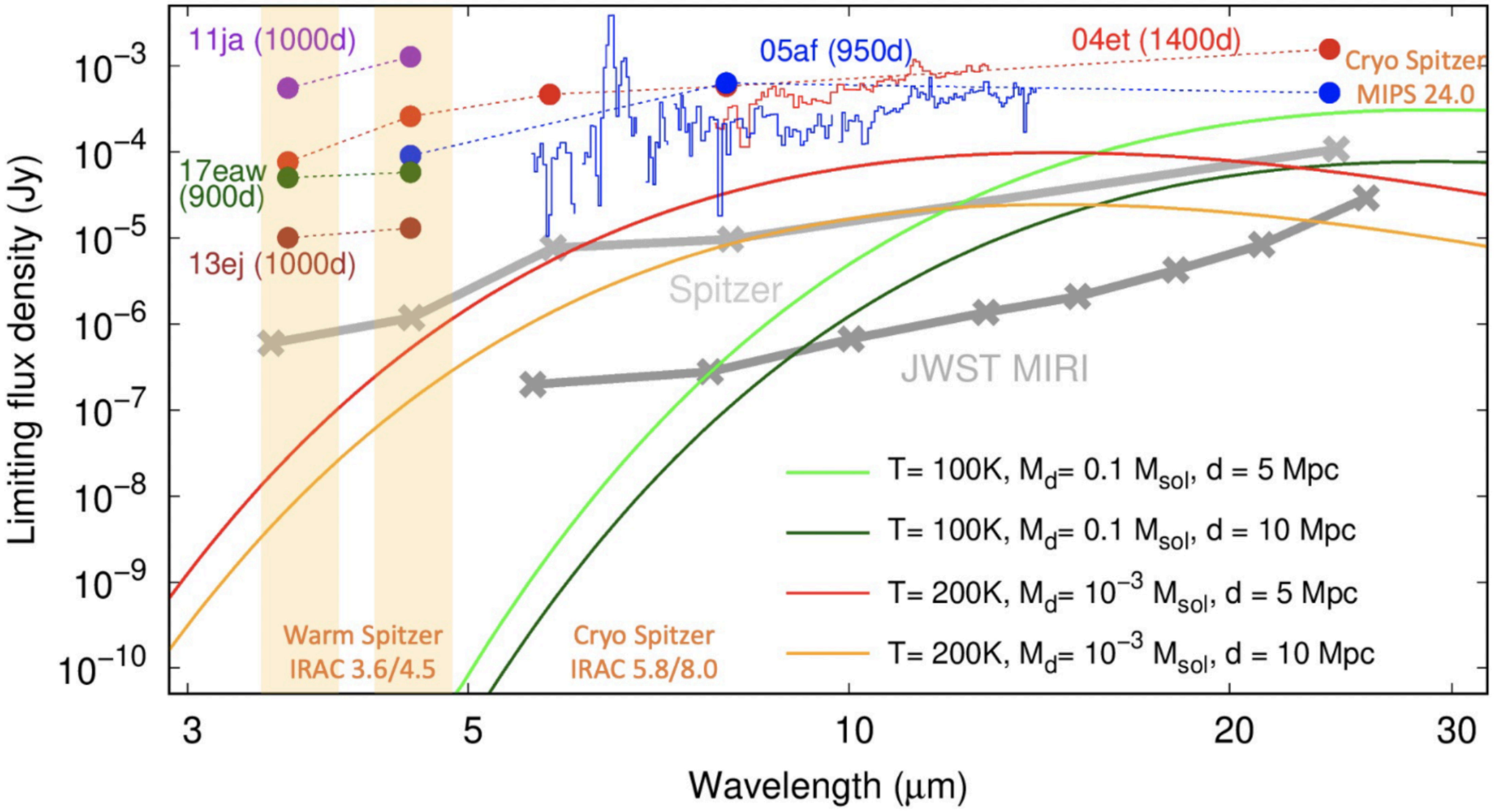
melissa.shahbandeh@gmail.com

GO-2666 (PI: O. Fox)

SN 2004et | SN 2017eaw | SN 1980K | SN 2005af | SN 2011ja | SN 2013ej

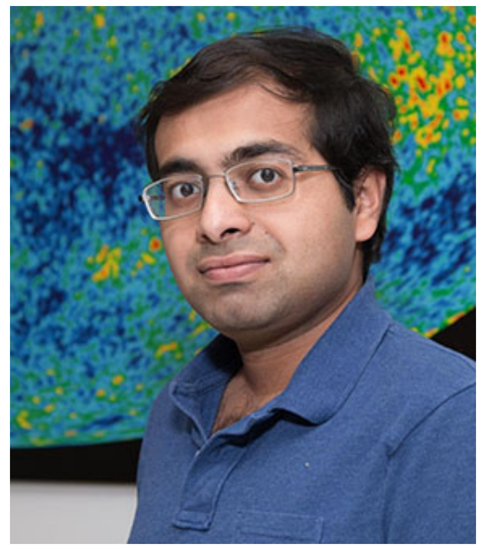
Target SN	Galaxy	Distance (Mpc)	Approx. Age[a] (yr)	Flux Density Estimate[b] (μJy)	Science/Total (hr)
2004et	NGC 6946	6.8	18	100	0.75/2.8
2005af	NGC 4945	3.5	17	325	0.25/2.2
2011ja	NGC 4945	3.5	11	325	0.25/2.2
2013ej	M74	9.0	9	60	1.7/3.9
2017eaw	NGC 6946	6.8	5	100	0.75/2.8



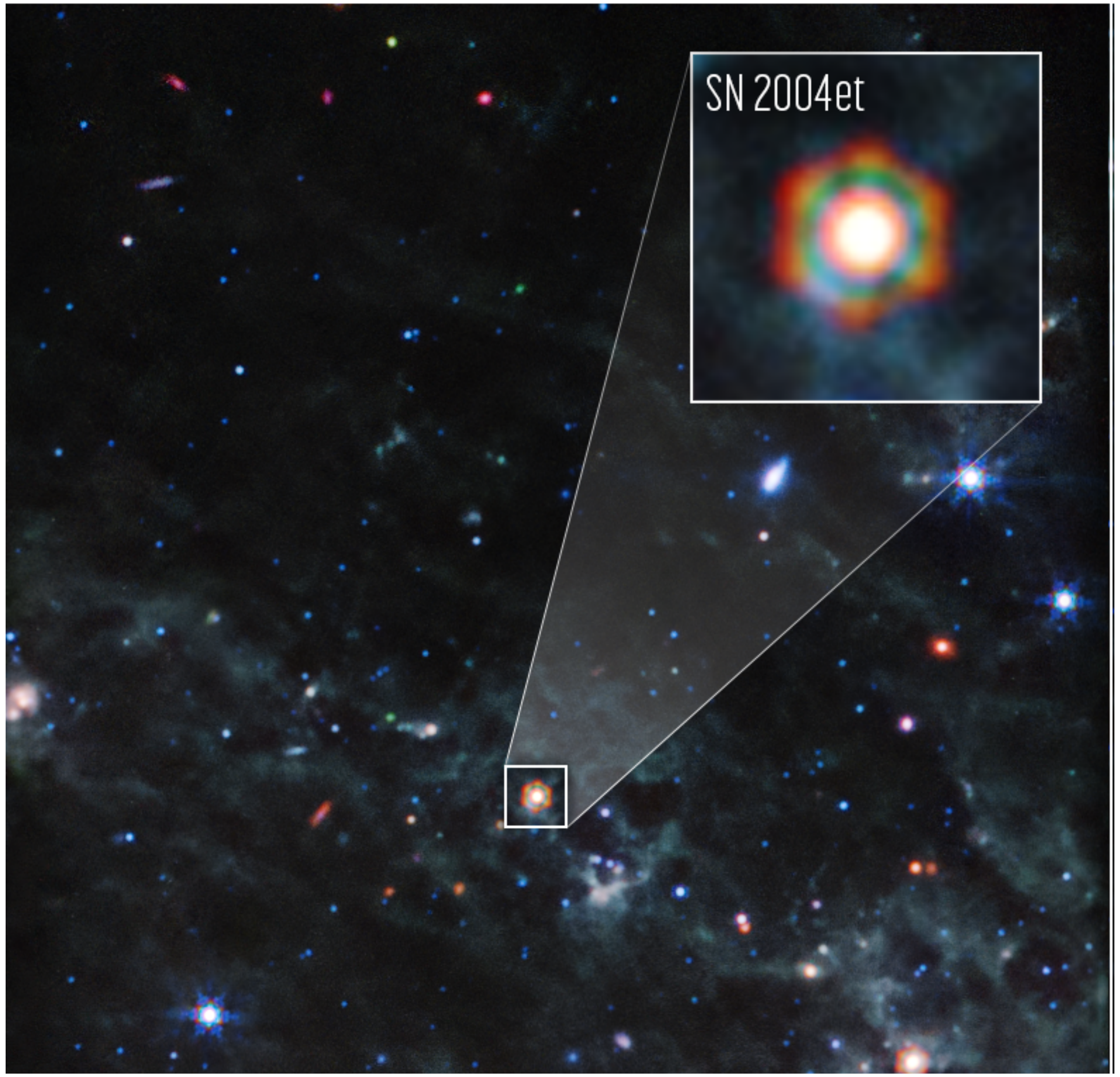


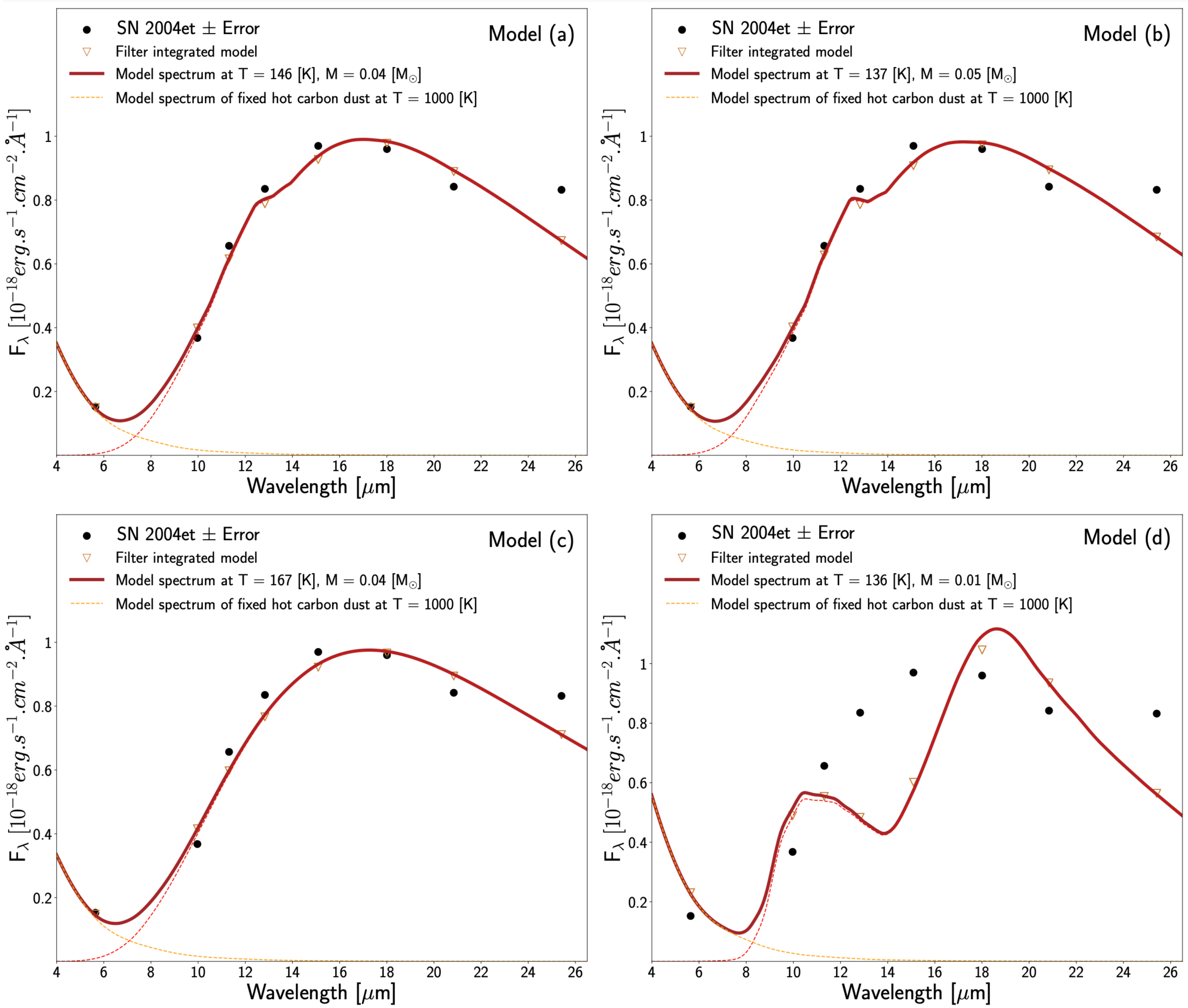

O. Fox


T. Temim


A. Sarangi

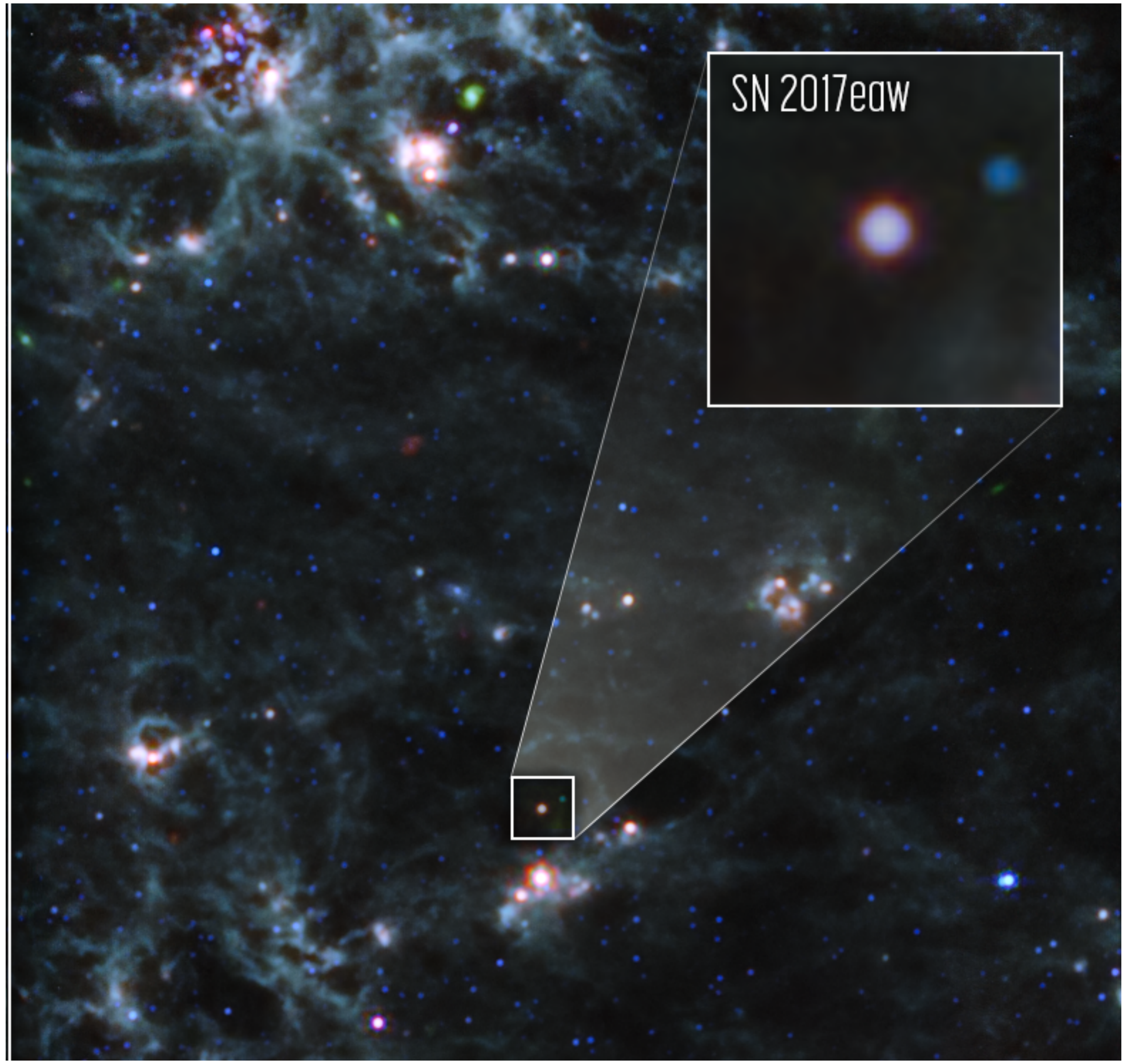

E. Dwek

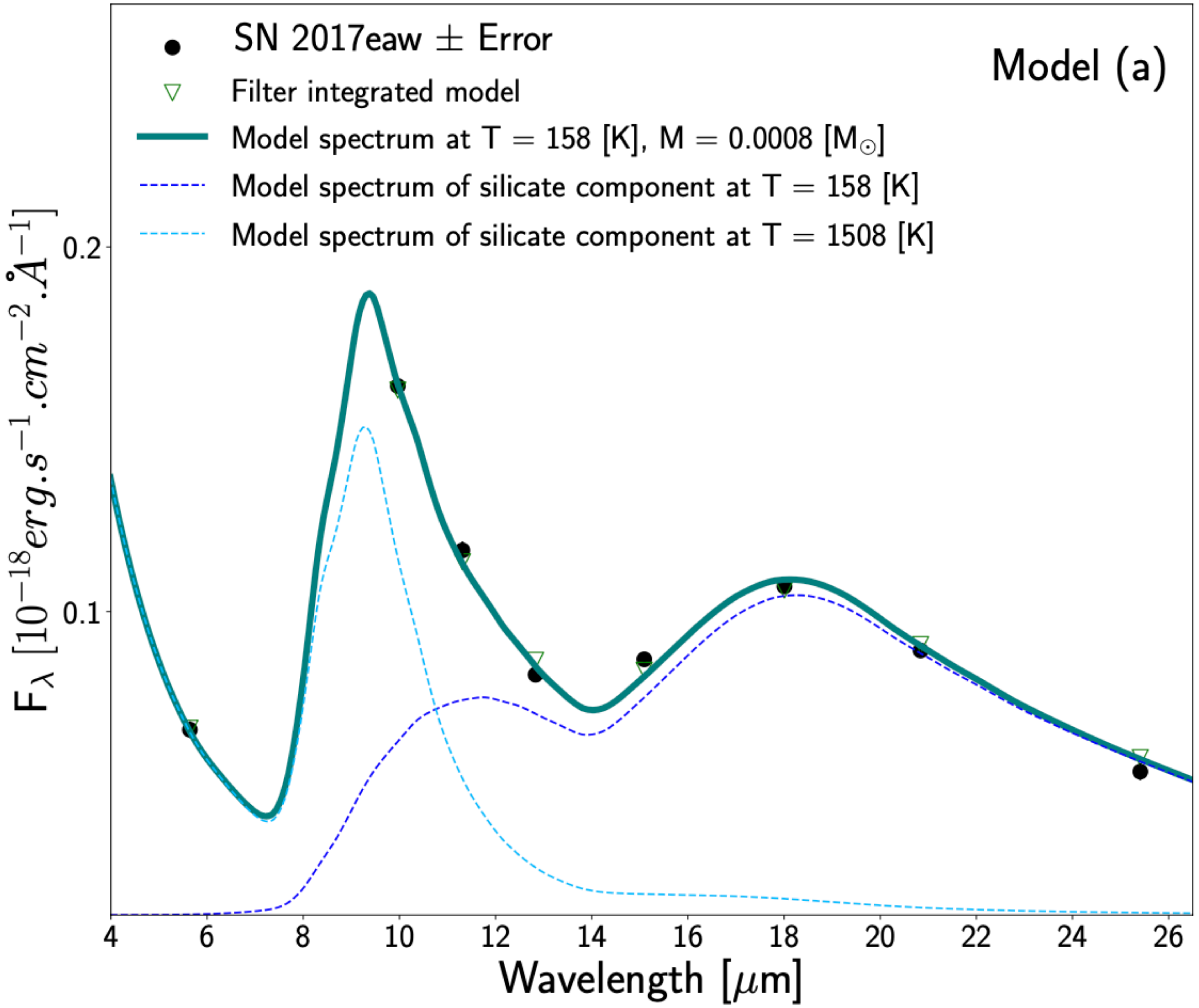




Shahbandeh+ 23

melissa.shahbandeh@gmail.com





Shahbandeh+ 23

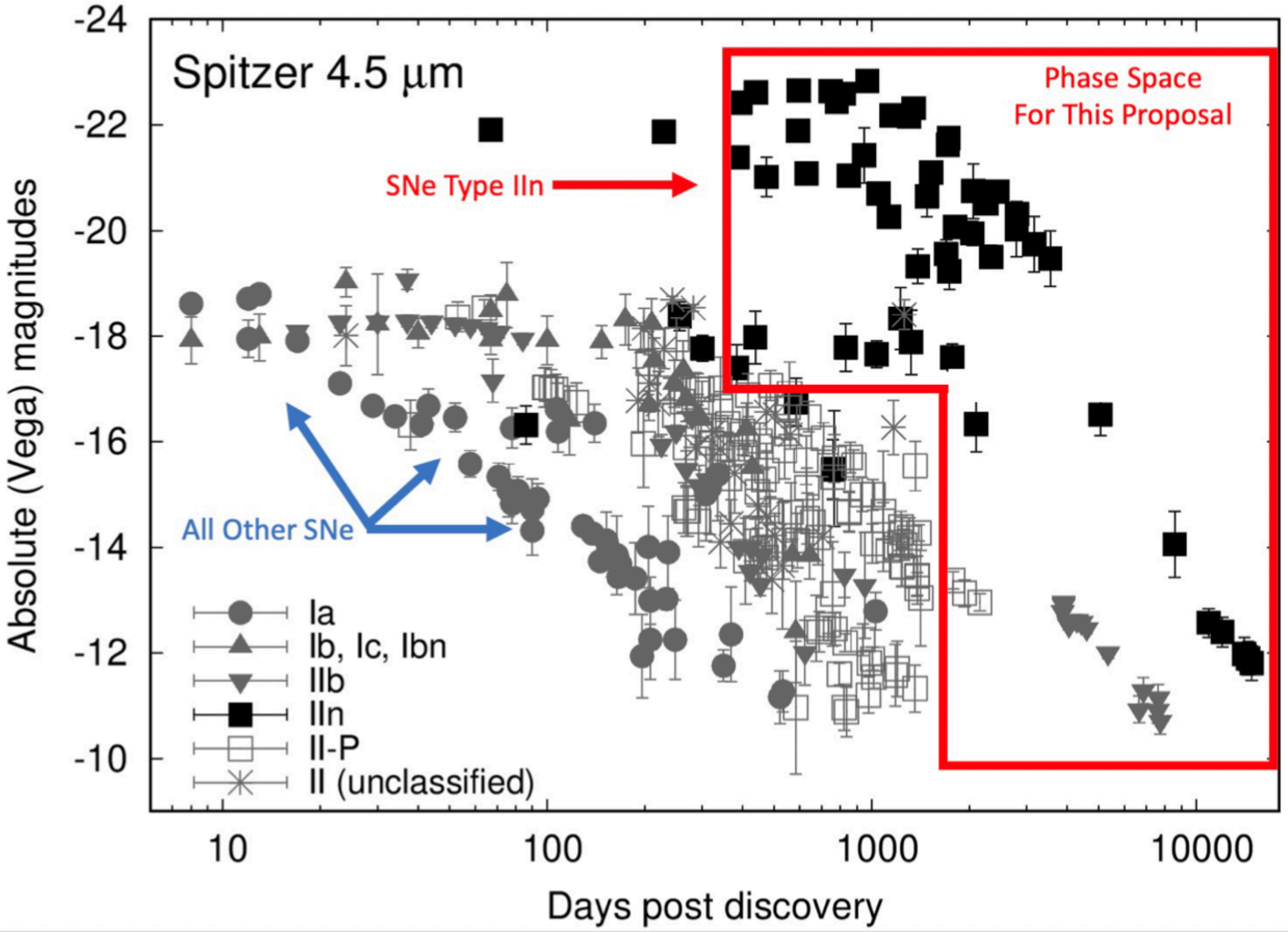
SNe IIn

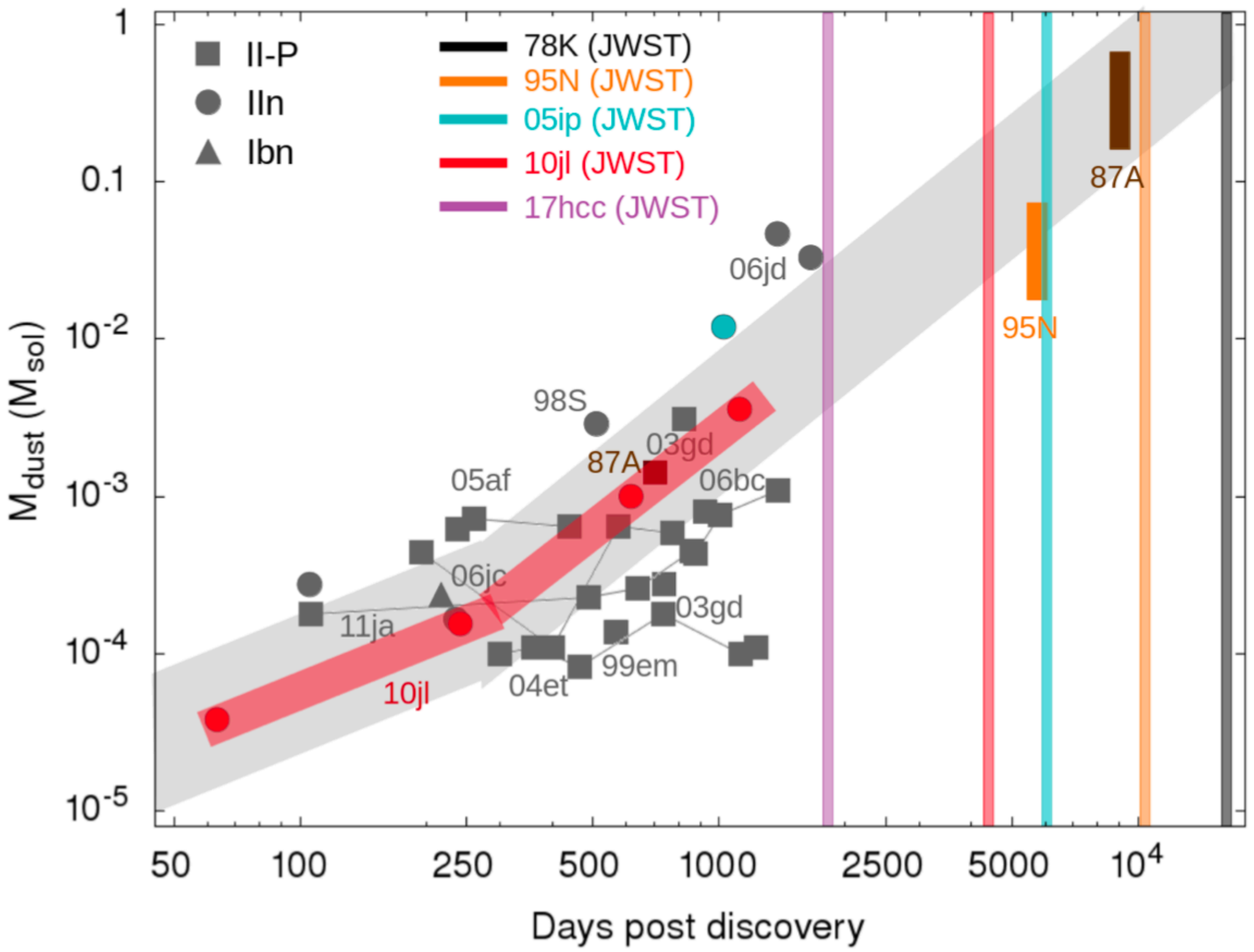
melissa.shahbandeh@gmail.com

GO-1860 (PI: O. Fox)

SN 1978K | SN 1995N | SN 2005ip | SN 2010jl | SN 2017hcc

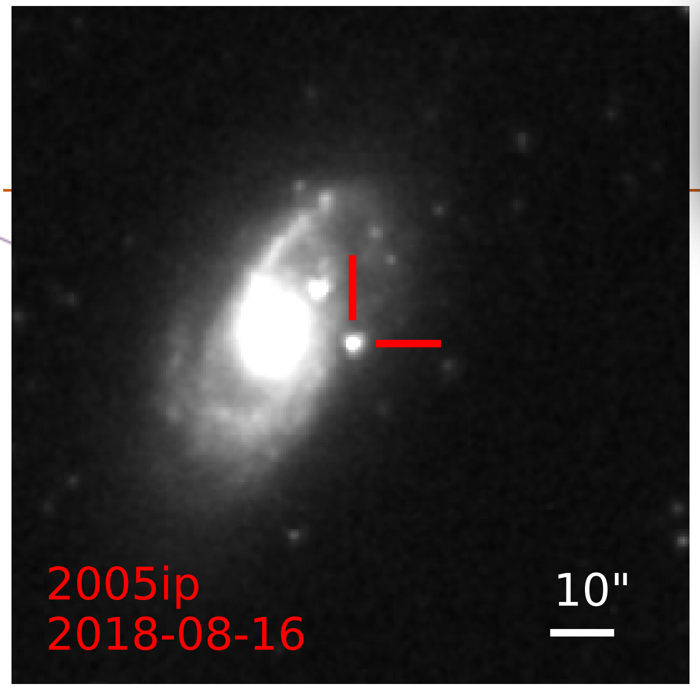
Target	Host Galaxy	Distance (Mpc)	4.5 μm Flux Estimate (Abs/App Mag_{Vega})	Science/Total (hr/epoch)
SN 1978K	NGC 1313	4.5	-11/17.3	0.19/1.5
SN 1995N	MCG-02-38-017	25	-13/19.0	0.9/2.3
SN 2005ip	NGC 2906	30	-18/15.3	0.9/2.3
SN 2010jl	UGC 5189A	50	-18/15.5	0.9/2.3
SN 2017hcc	Anon.	70	-19/15.3	0.9/2.3





O. Fox

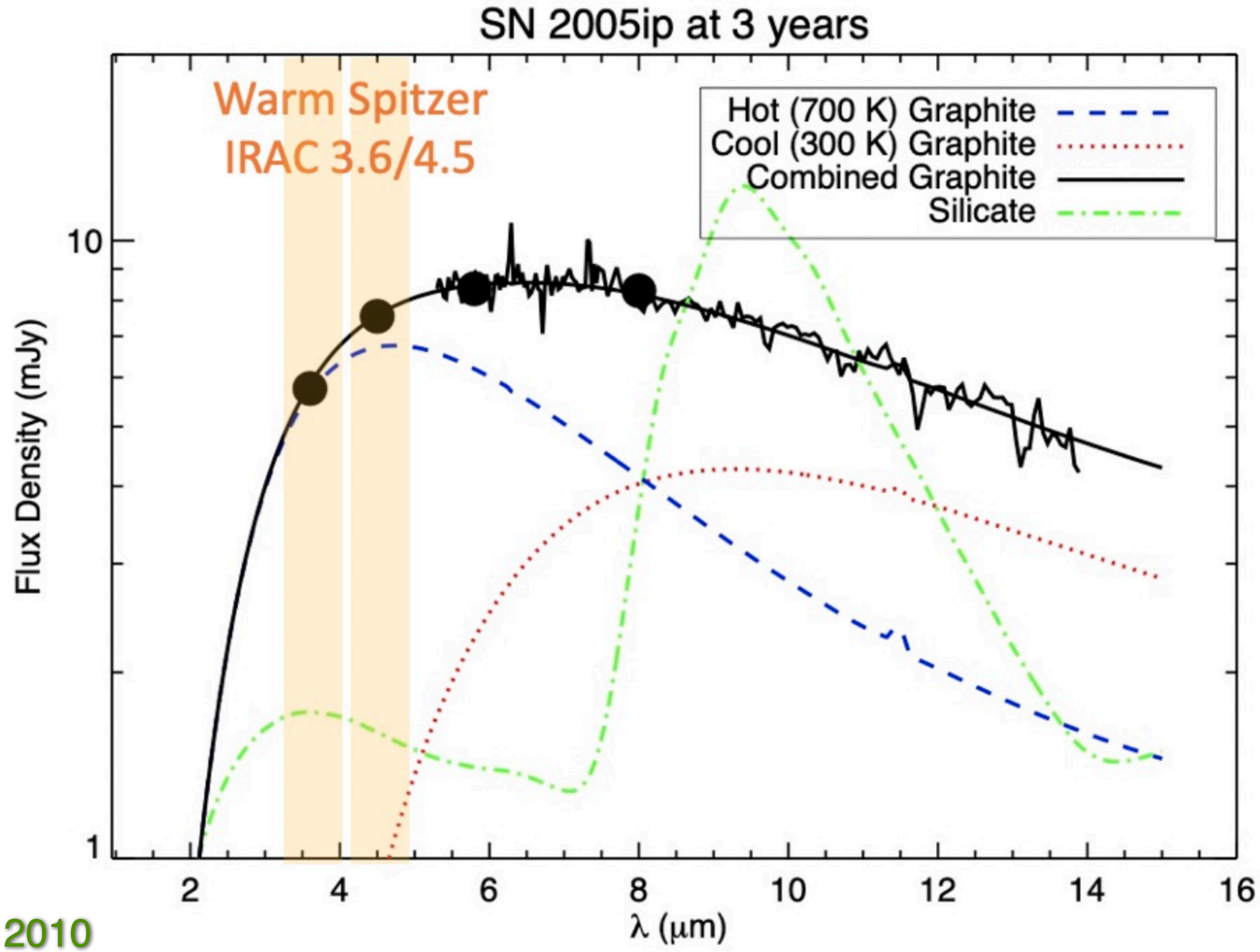
melissa.shahbandeh@gmail.com



- Spitzer MIR photometry and spectroscopy at ~3 years

- 2 carbon optically thin dust components

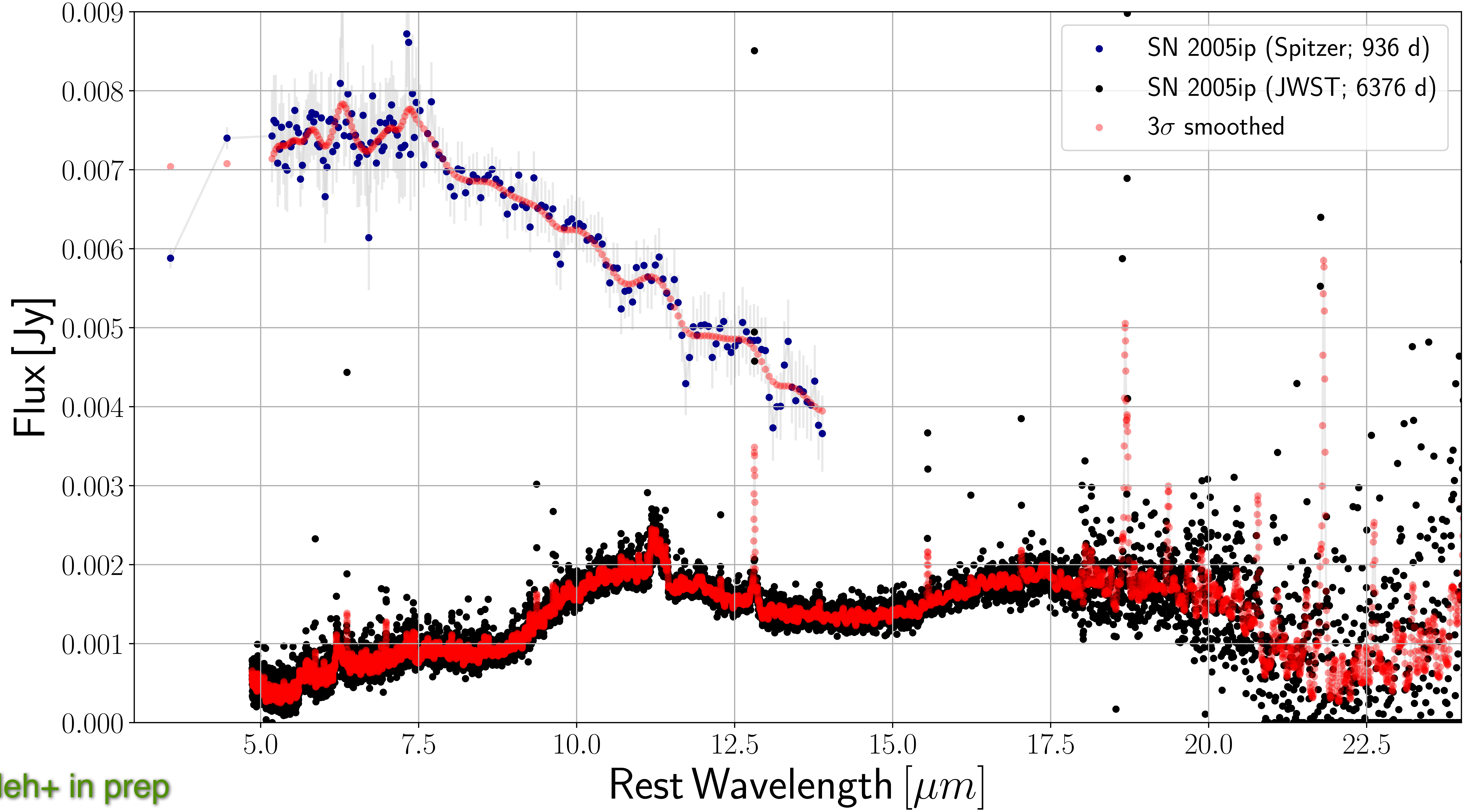
- Dust mass ~ 0.001 to 0.1 M_{sun}



Fox+ 2010

GO-1860 (PI: O. Fox)

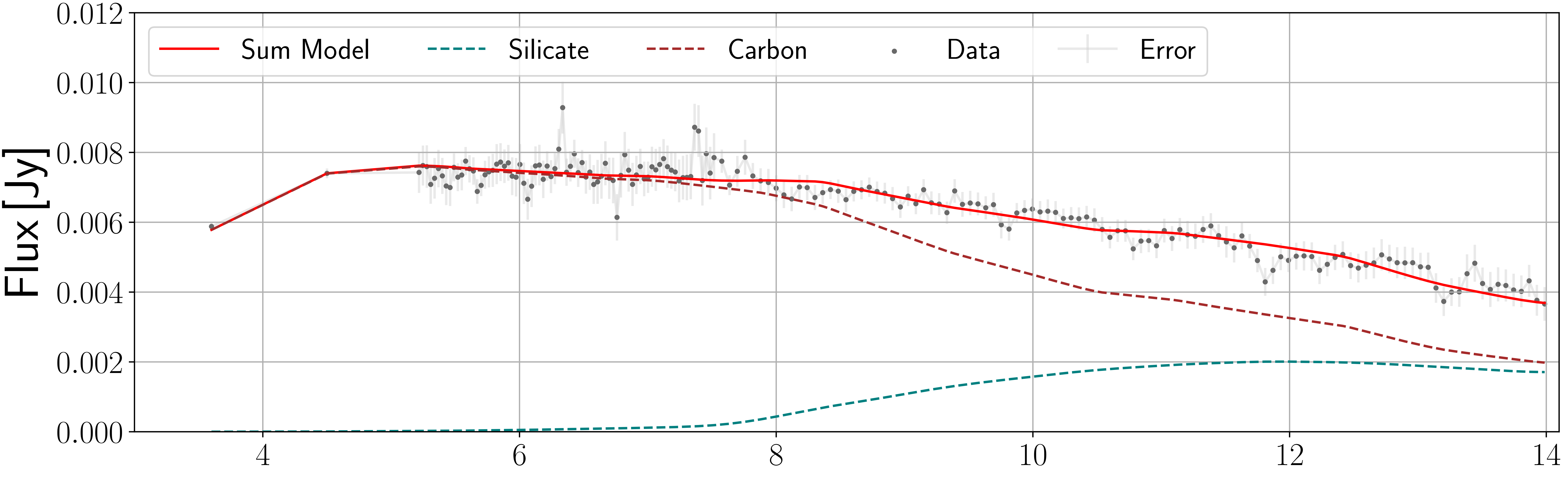
SN 1978K | SN 1995N | **SN 2005ip** | SN 2010jl | SN 2017hcc



Shahbandeh+ in prep

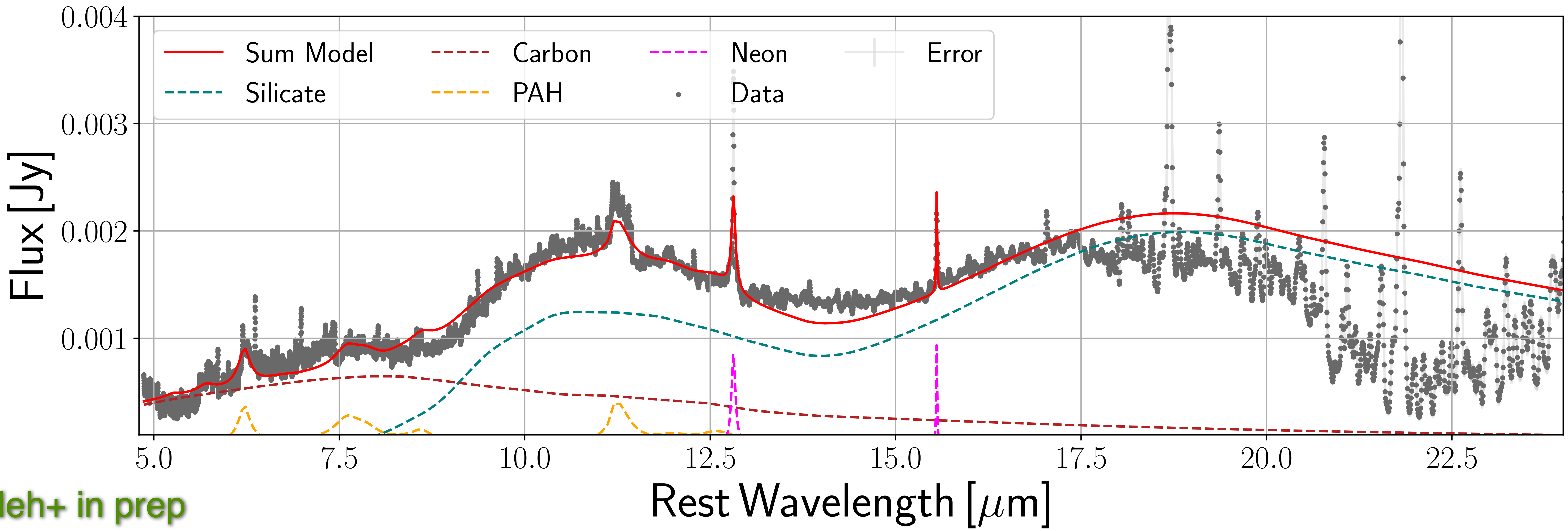
GO-1860 (PI: O. Fox)

SN 1978K | SN 1995N | **SN 2005ip** | SN 2010jl | SN 2017hcc



- Optically thick silicate and carbon
- Radii indicate Newly formed in CDS
- Dust mass ~ 0.07 M_{sun}

- Optically thin silicate and carbon
- Radii indicate Newly formed in CDS
- Dust mass ~ 0.1 M_{sun}

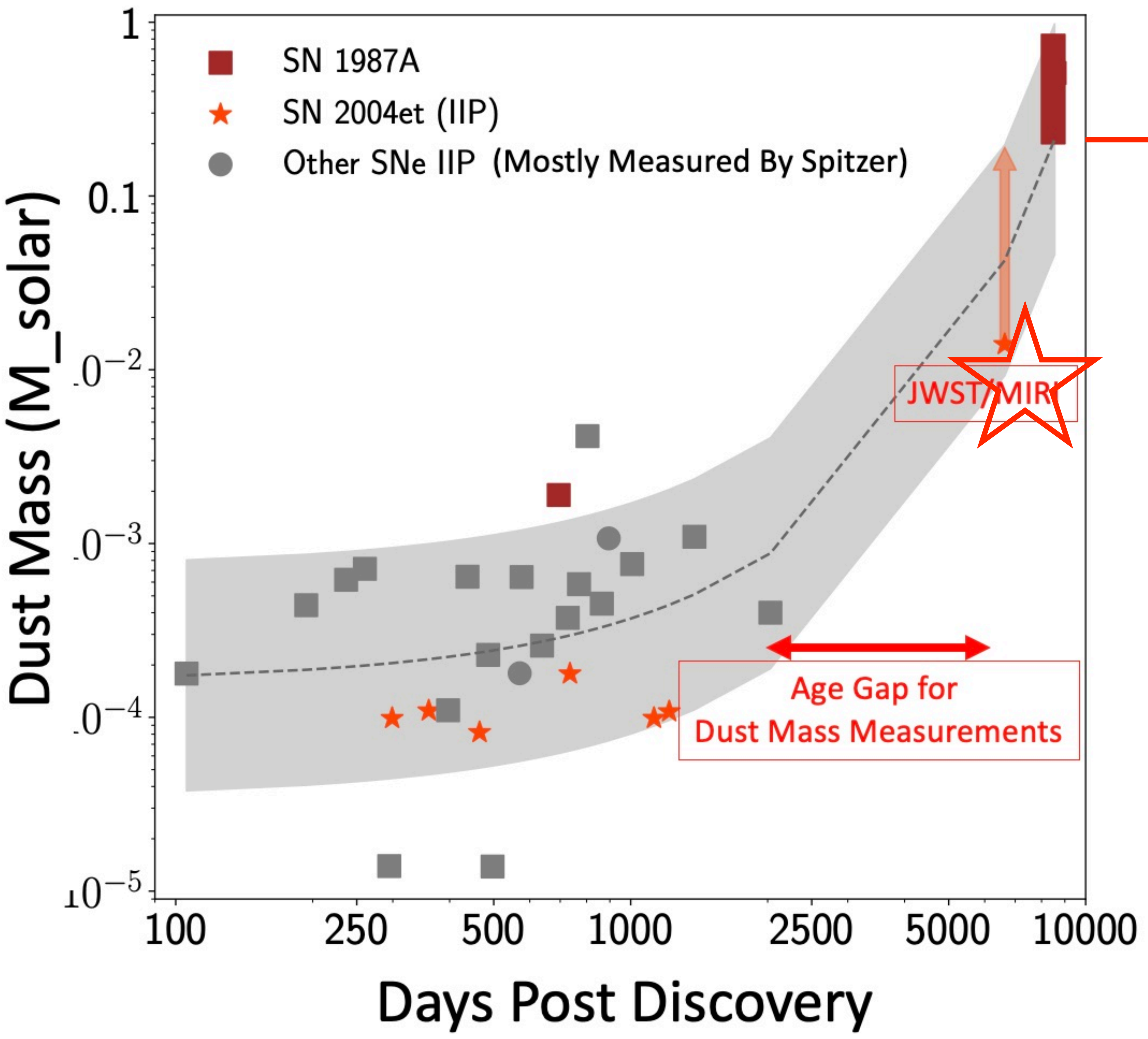


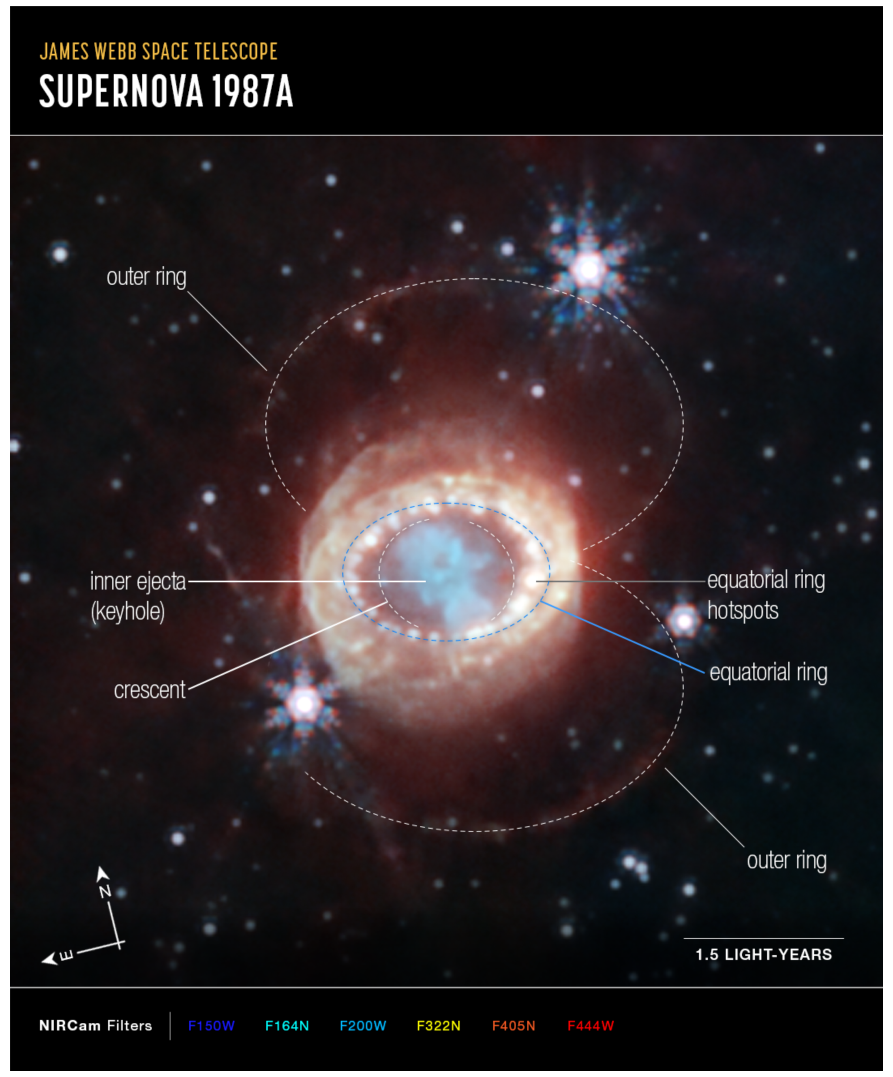
Shahbandeh+ in prep

Evolution of dust: Filling the dust growth gap

Highest dust mass observed in the MIR with *JWST*

Why do we need more than 1 SN?

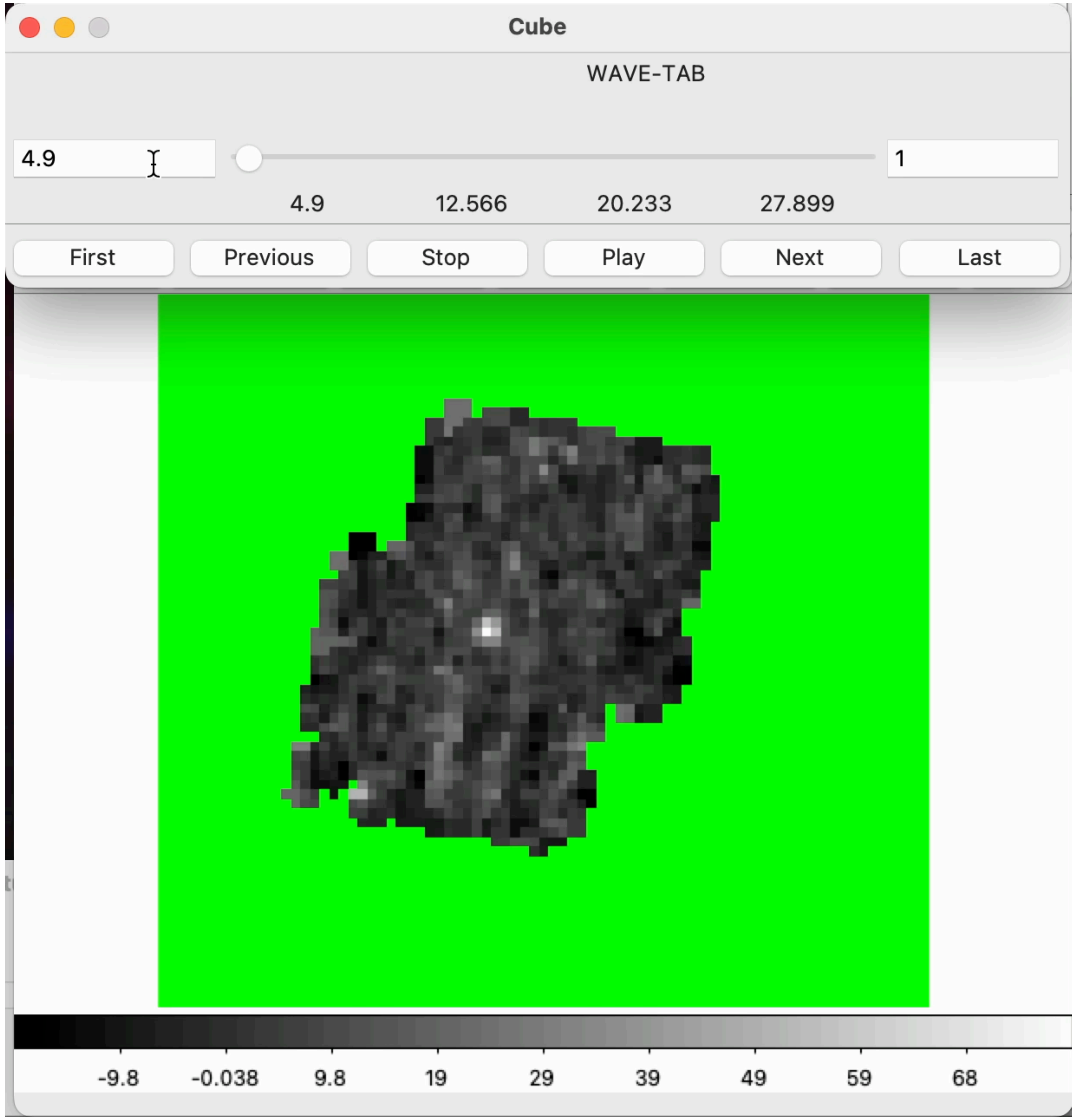




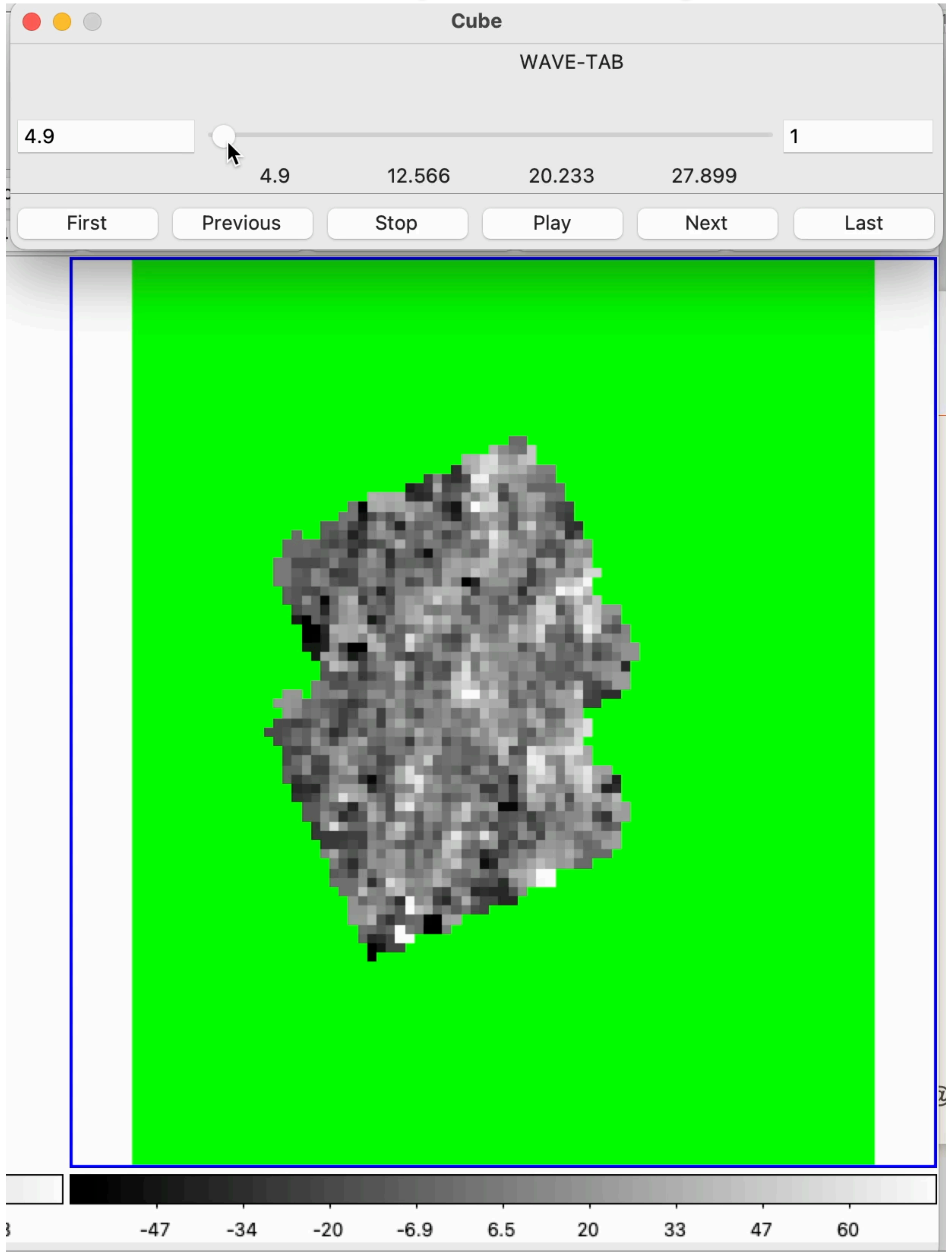
melissa.shahbandeh@gmail.com

Young SN vs. Dusty SN

SN 2022acko, ~50 days



SN 2005ip, ~6350 days



melissa.shahbandeh@gmail.com

Summary

SNe are key to probe cosmic dust.

Conneting early to late...

JWST is the only facility enabling it.

SESNe are dust producers as well!

We need more data!

melissa.shahbandeh@gmail.com