White Dwarf Supernovae: Astrophysics & Cosmology

Saurabh W. Jha

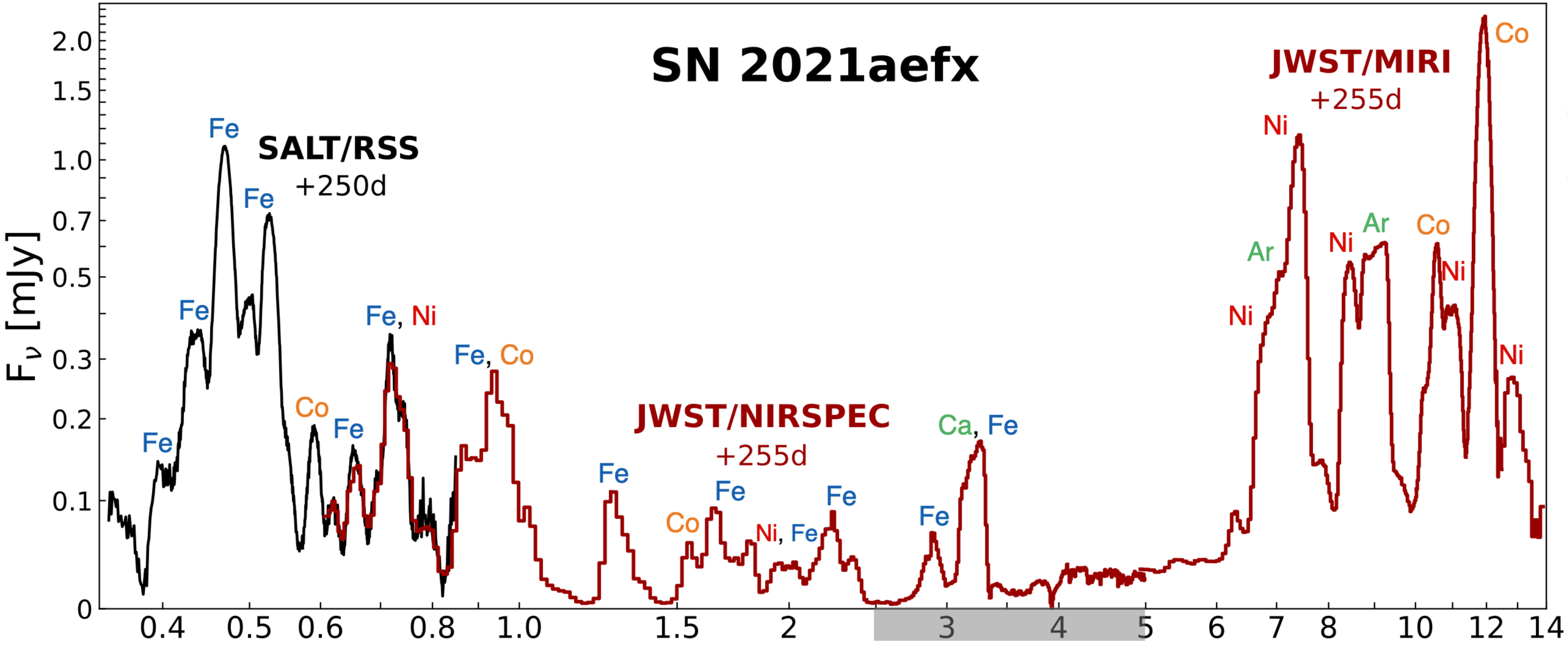
Multi-Messenger Astrophysics in the Dynamic Universe
February 20, 2026 Kyoto, Japan

JWST/MIRI image of NGC 1566
data via JWST GO 2107 (PI: Janice Lee), processing by Judy Schmidt

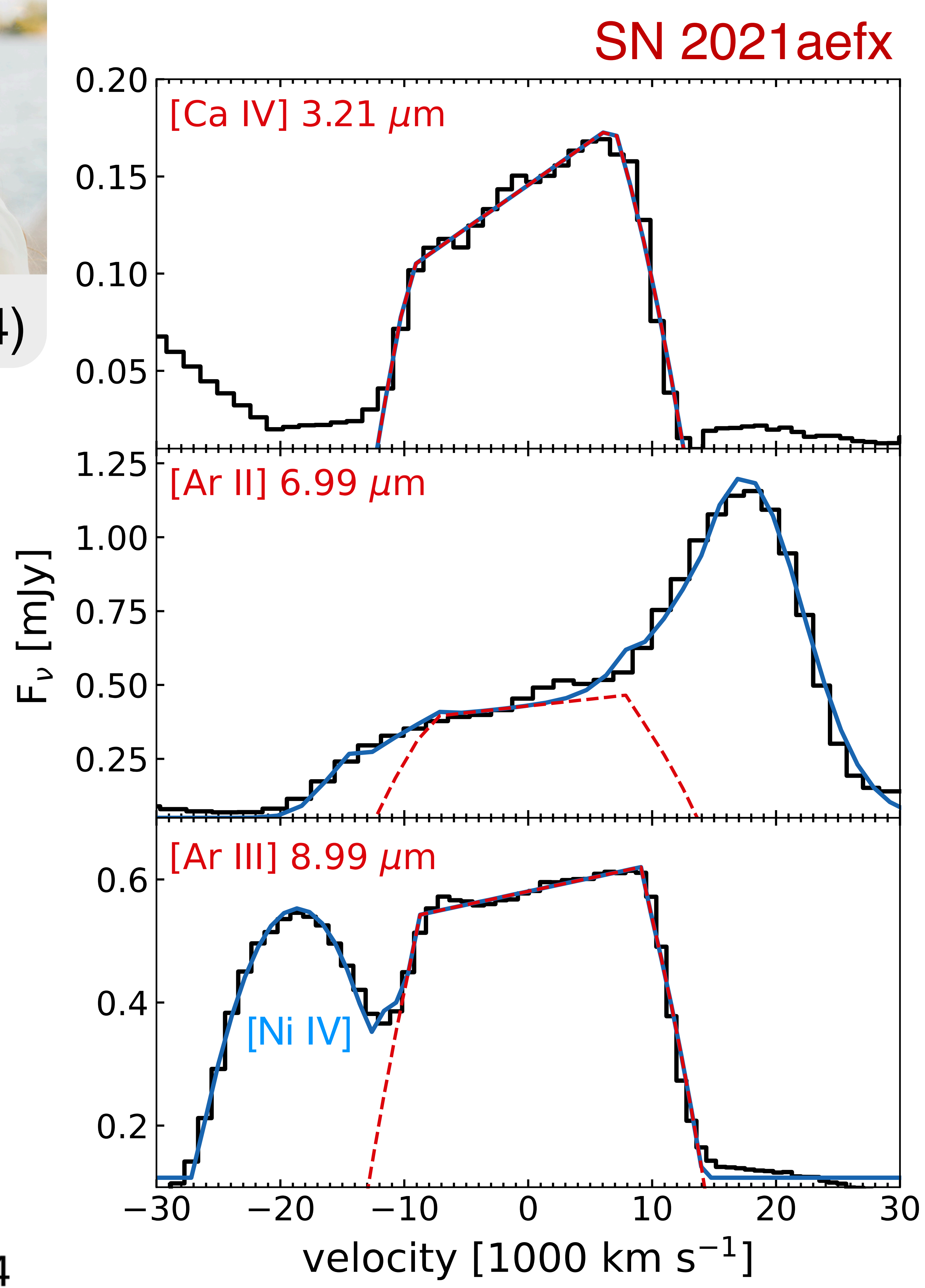
JWST observations of normal SN Ia 2021aefx

Strong, stable ^{58}Ni → **high-mass** white dwarf

Kwok et al. (2023); DerKacy et al. (2023, 2024); Mayker Chen et al. (2023); Ashall et al. (2024)

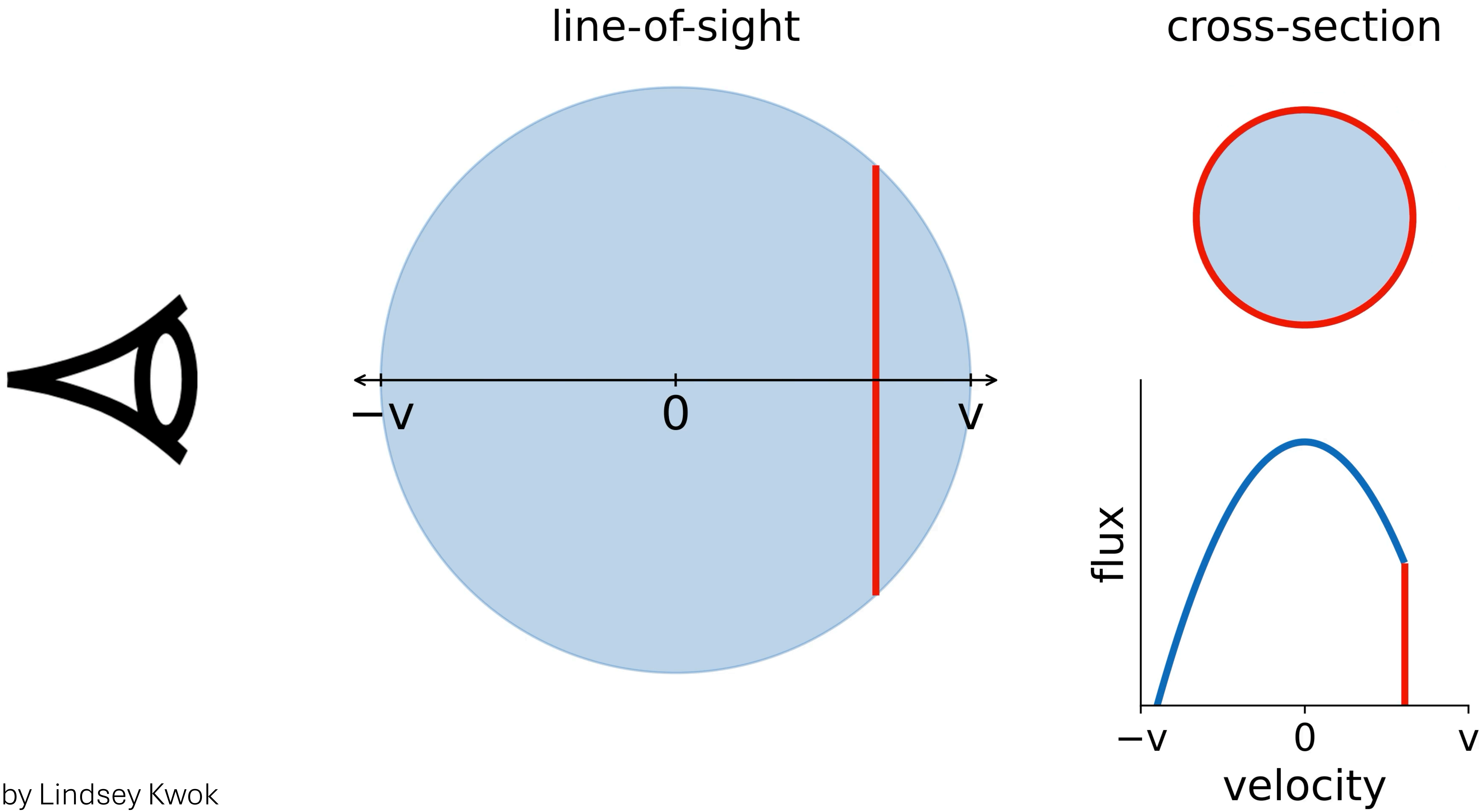


Kwok et al. (2023)



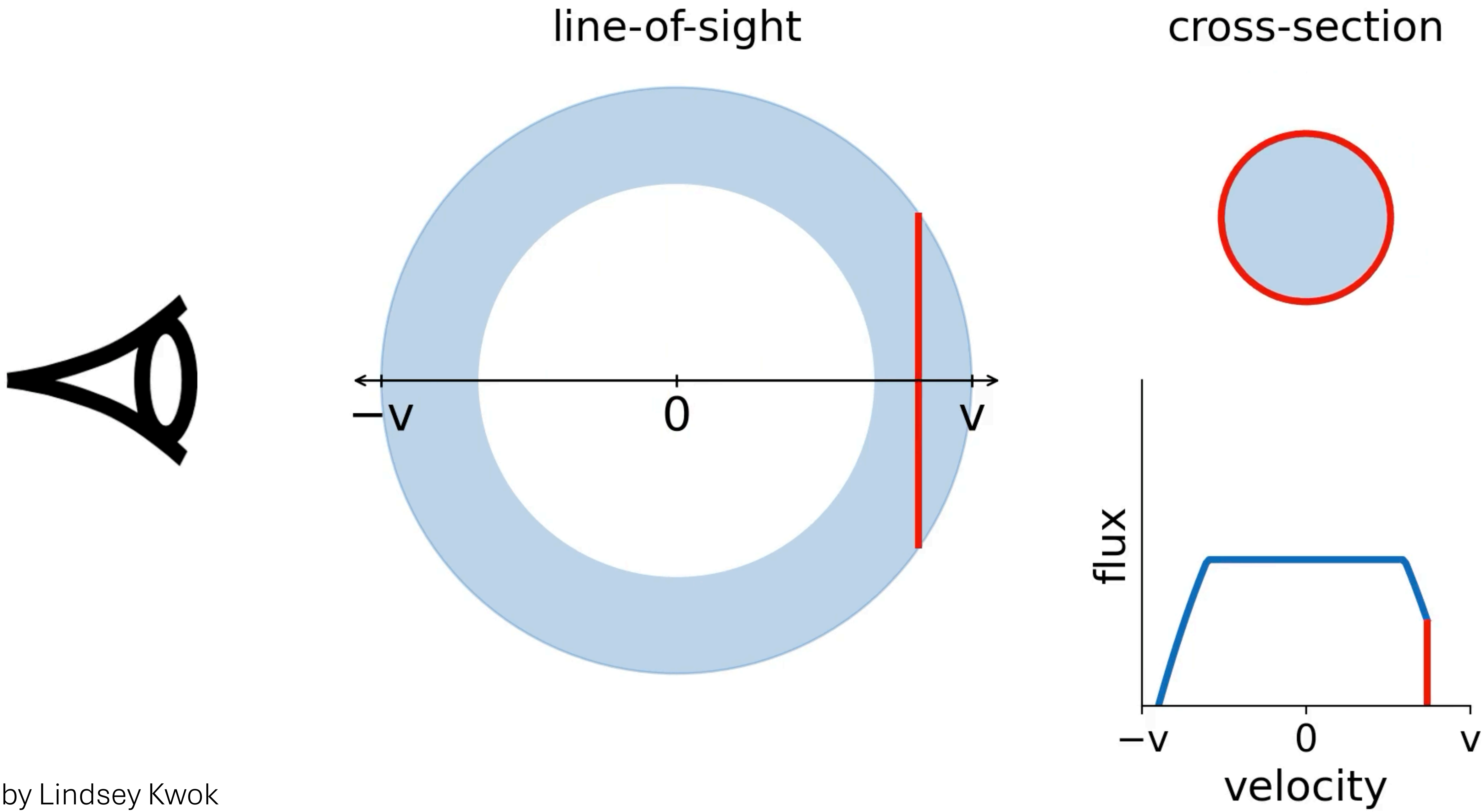
Kwok et al. (2023)

Ejecta Geometry from Emission Line Profiles



graphics by Lindsey Kwok

Ejecta Geometry from Emission Line Profiles



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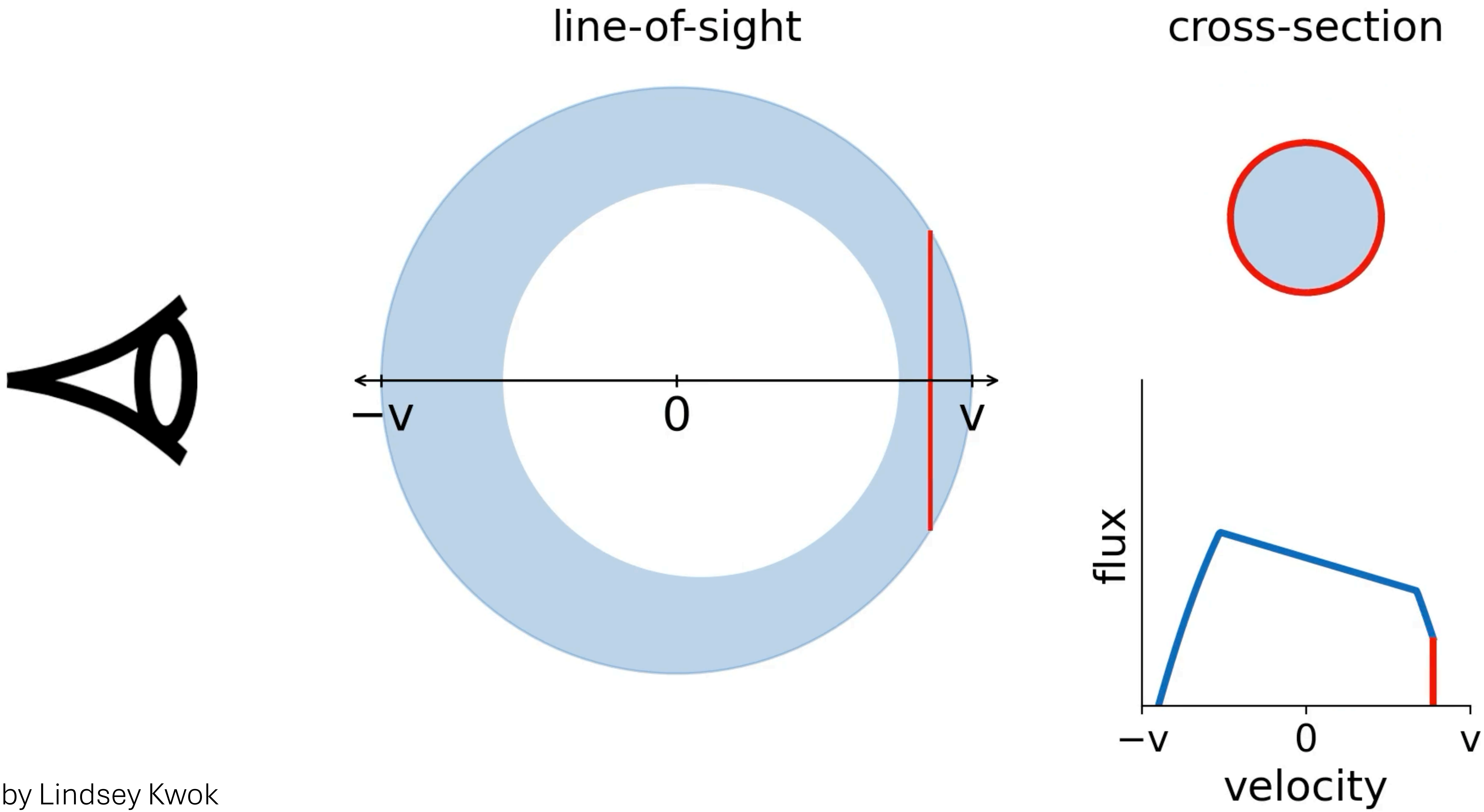
Ejecta Geometry from Emission Line Profiles



graphics by Lindsey Kwok

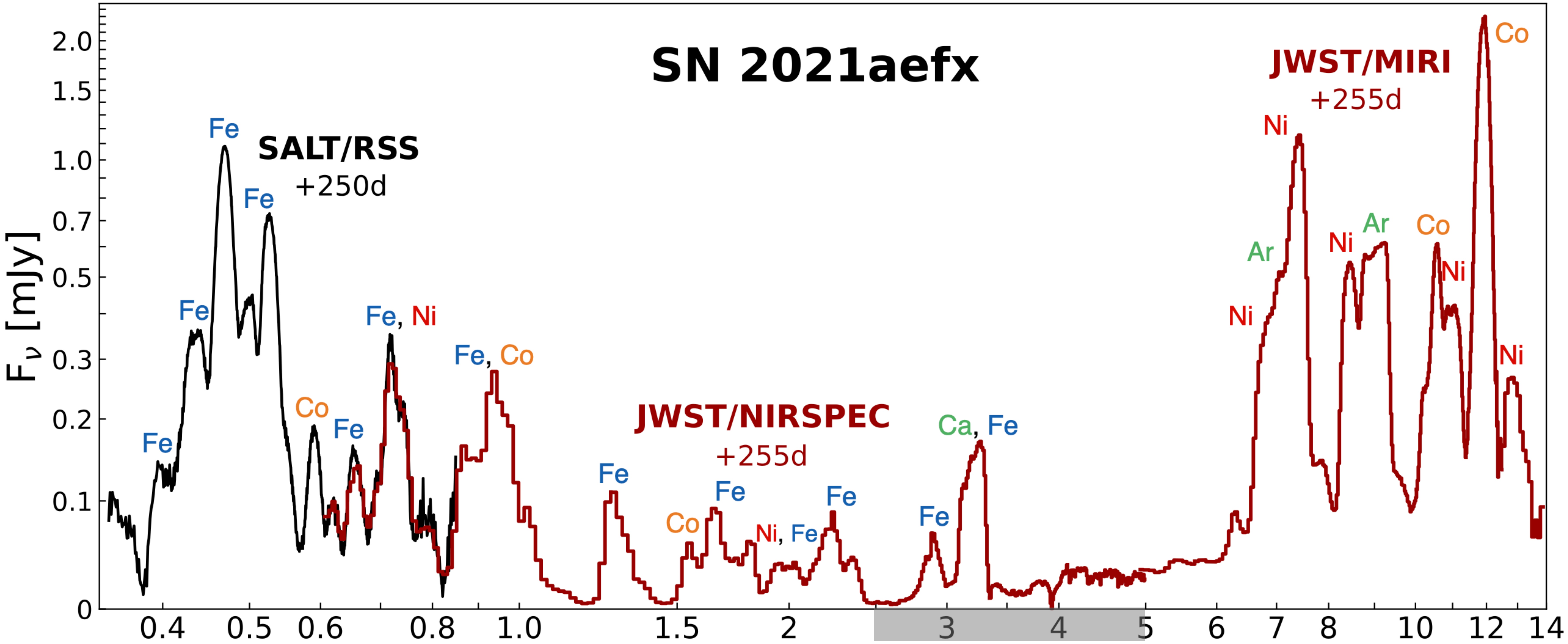
JWST observations of normal SN Ia 2021aefx

Strong, stable ^{58}Ni → **high-mass** white dwarf

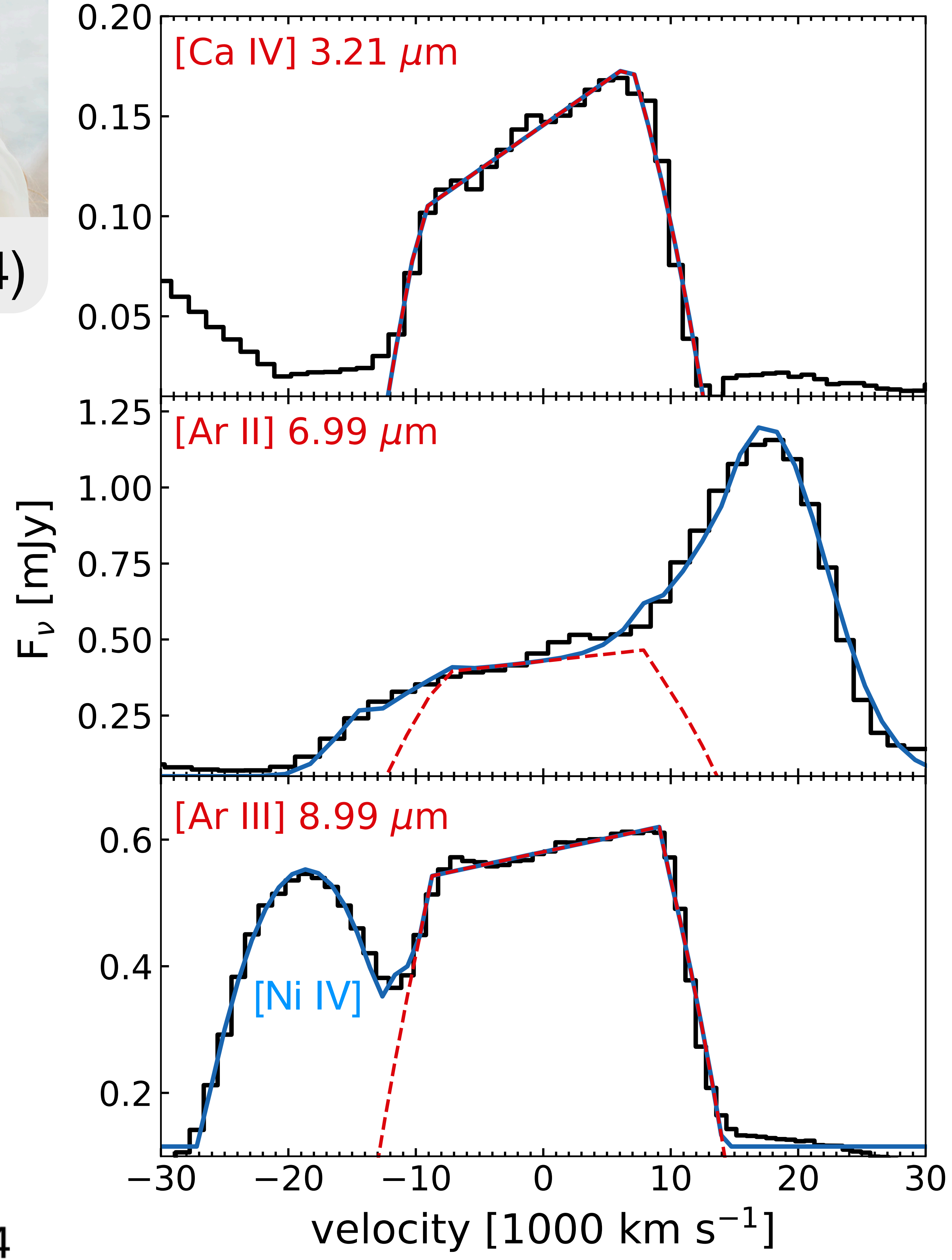
Broad, flat-topped Ar, Ca → layered ejecta structure

→ some type of **detonation** involved

Kwok et al. (2023); DerKacy et al. (2023, 2024); Mayker Chen et al. (2023); Ashall et al. (2024)



Kwok et al. (2023)

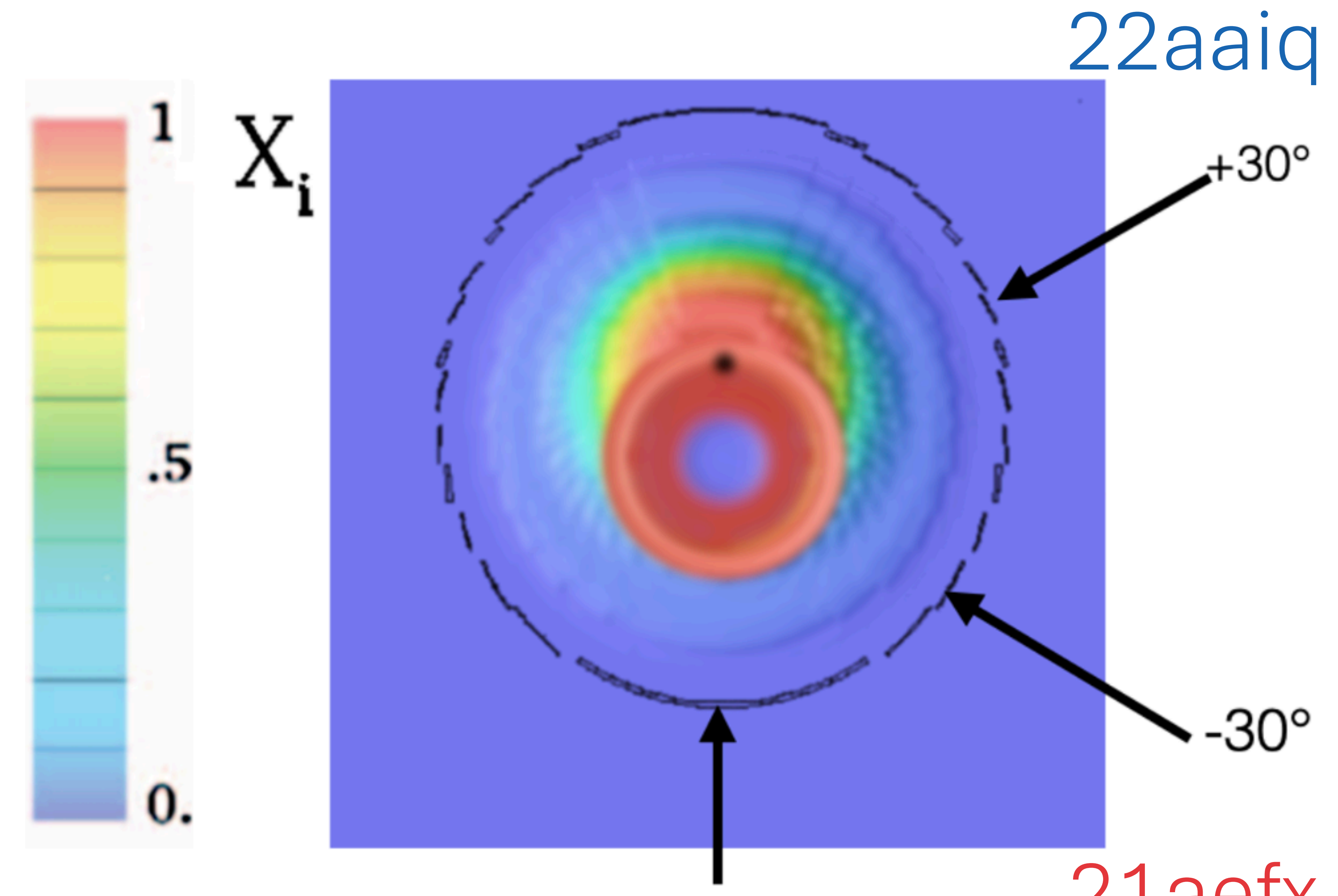


Kwok et al. (2023)

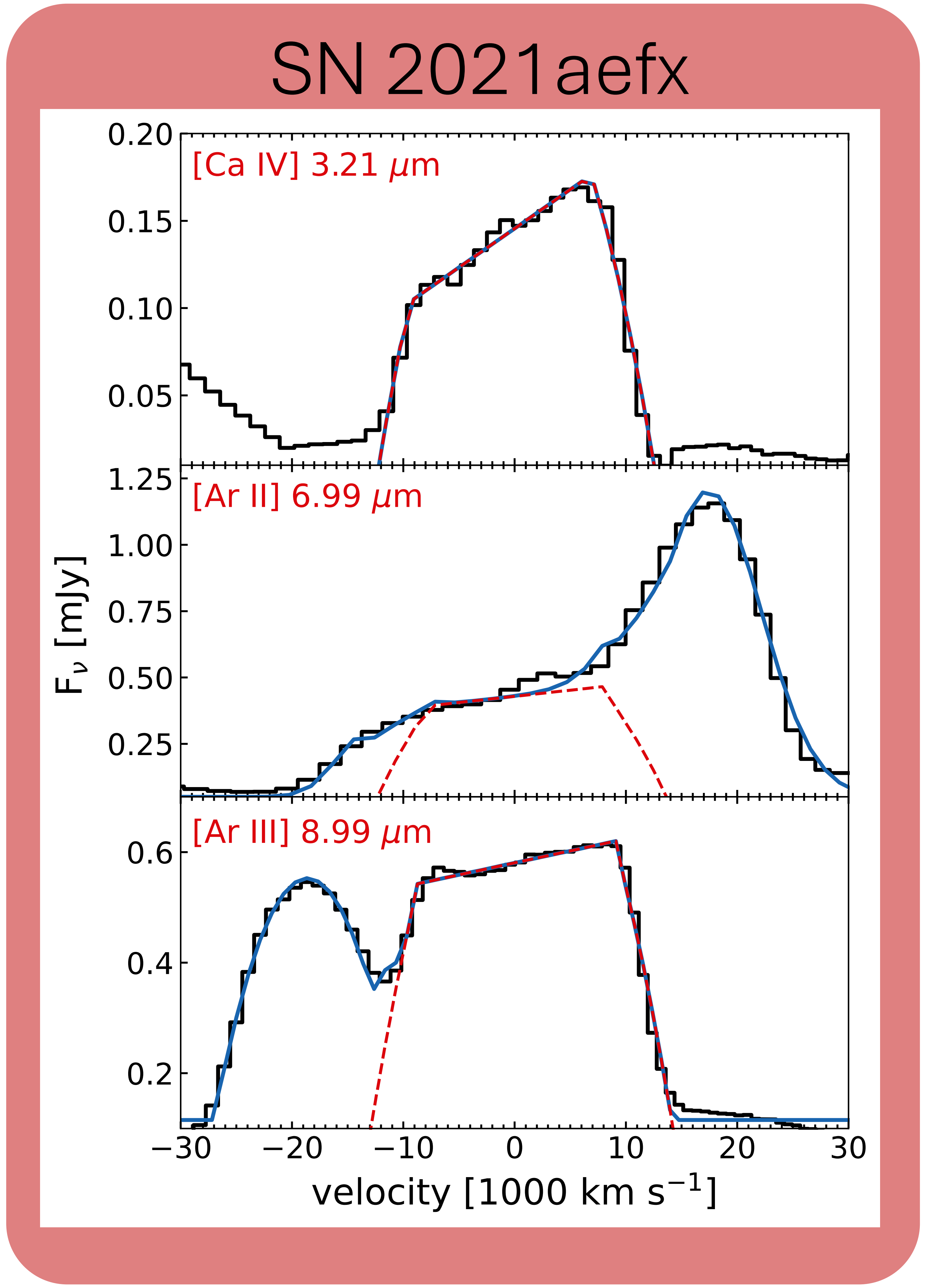
JWST observations of Normal SN Ia

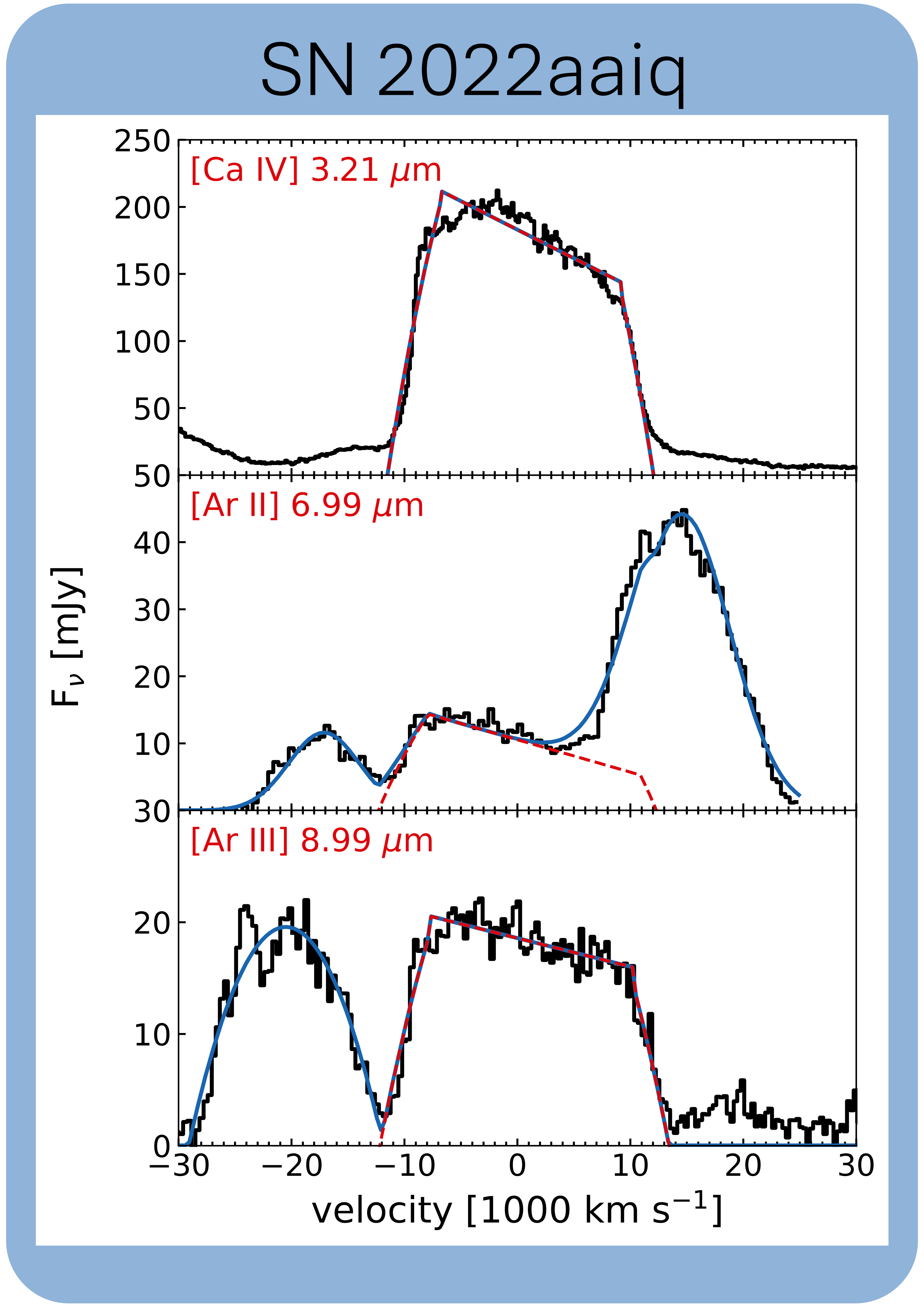
variations in viewing angle should produce different slopes for IME line profiles

as seen in JWST data!



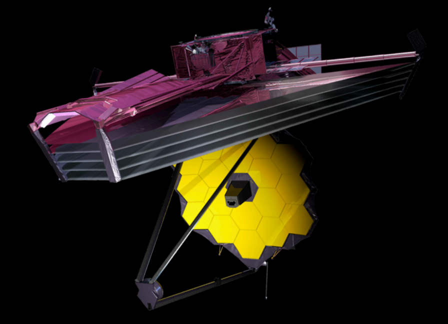
DerKacy et al. (2023)





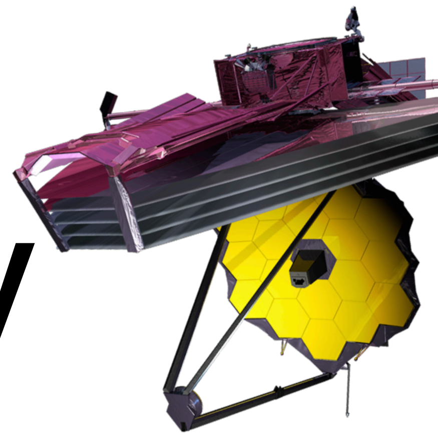
Kwok et al. (2025, submitted)

JWST observations of Normal SN Ia 2024gy

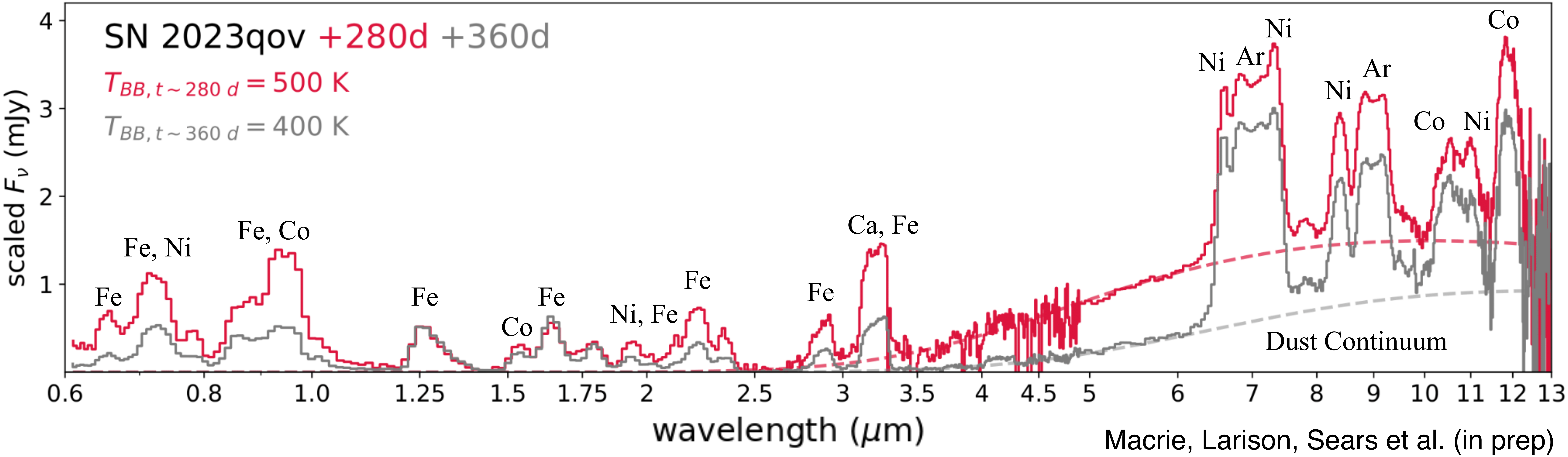


JWST observations of Normal SN Ia 2024gy

Cooling CSM dust in the normal SN Ia 2023qov



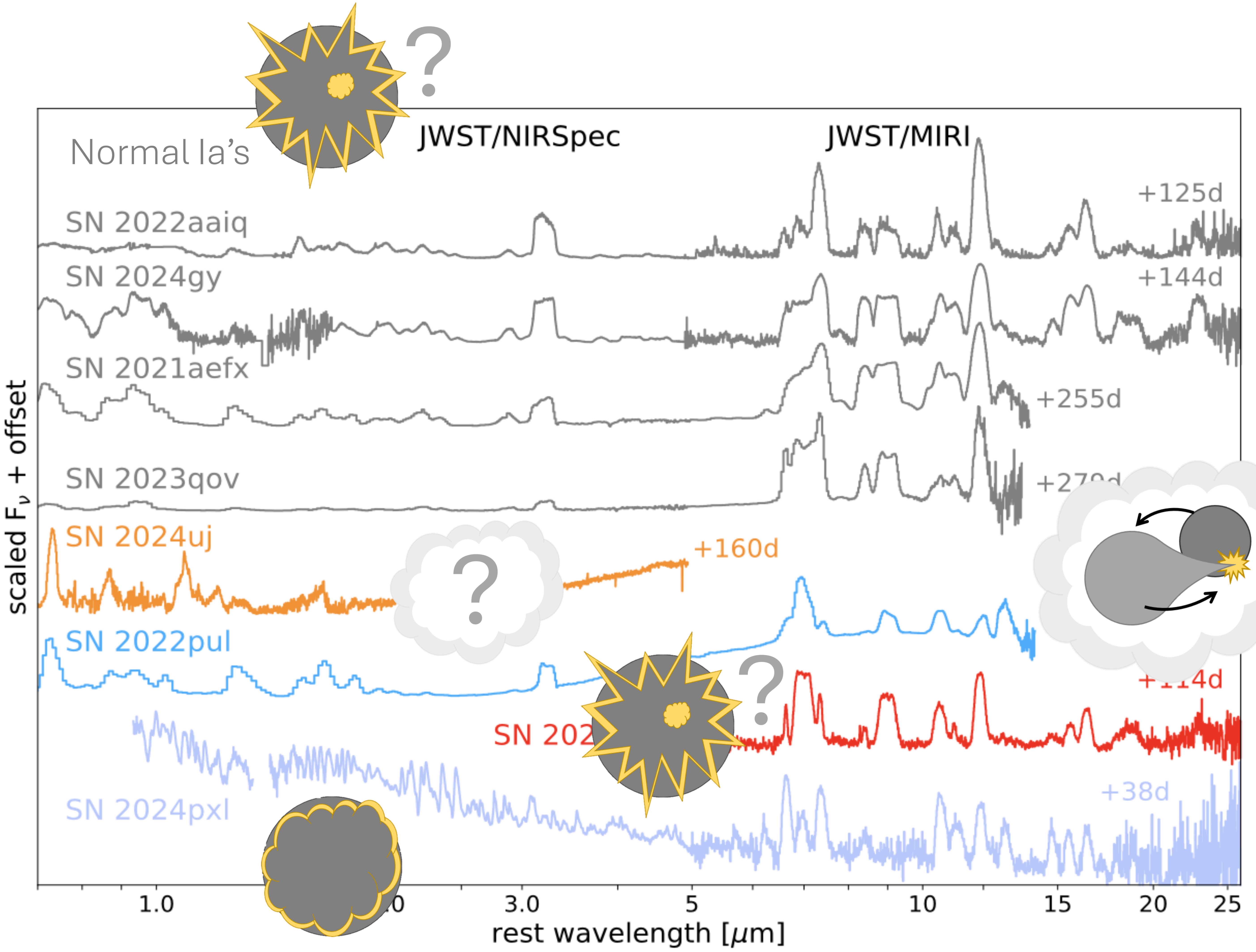
see also A. Singh talk from Thursday



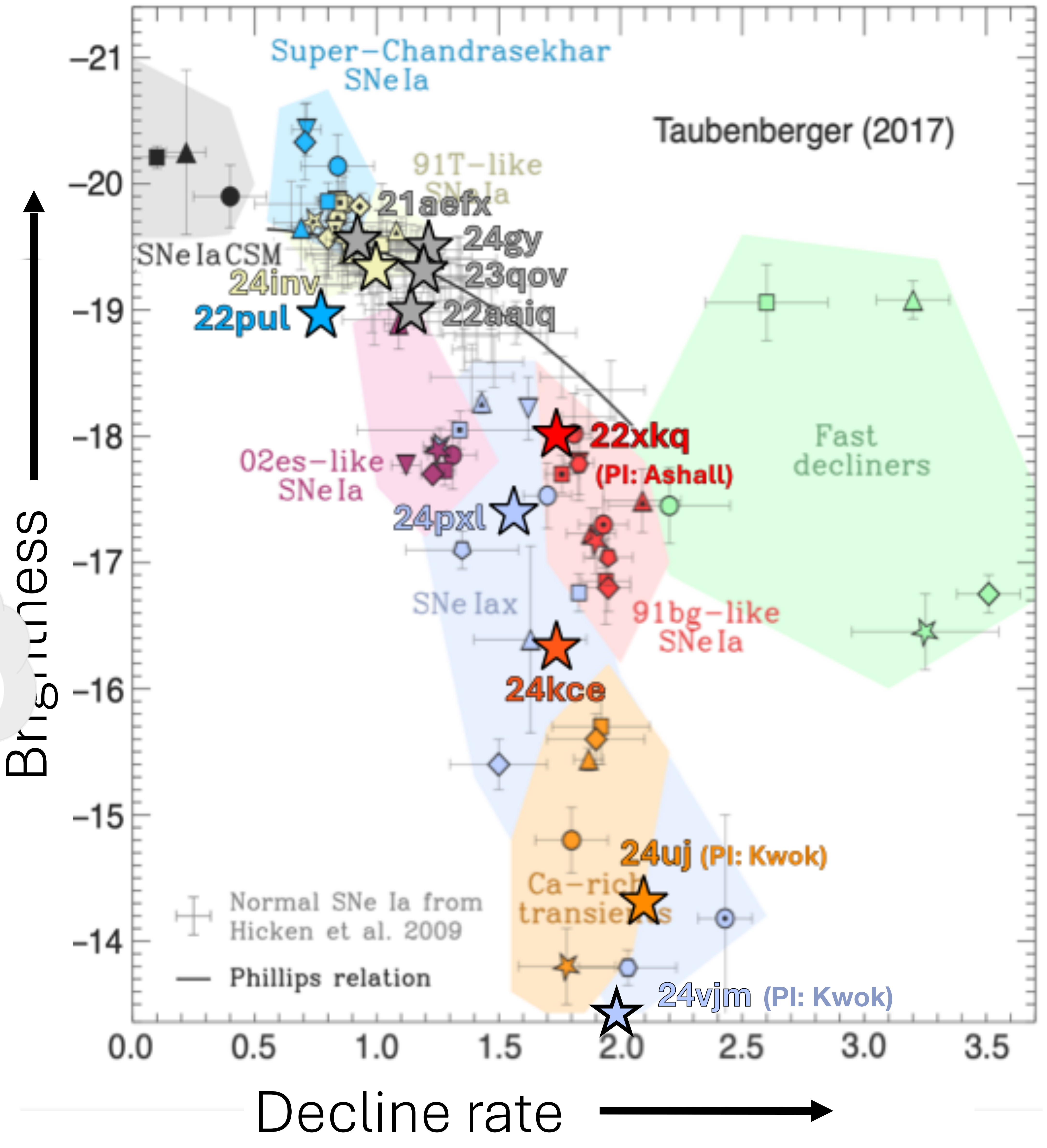
Macrie, Larison, Sears et al. (in prep)

JWST is revolutionizing our view of WD SN

IR spectra: a key to progenitors & explosion models



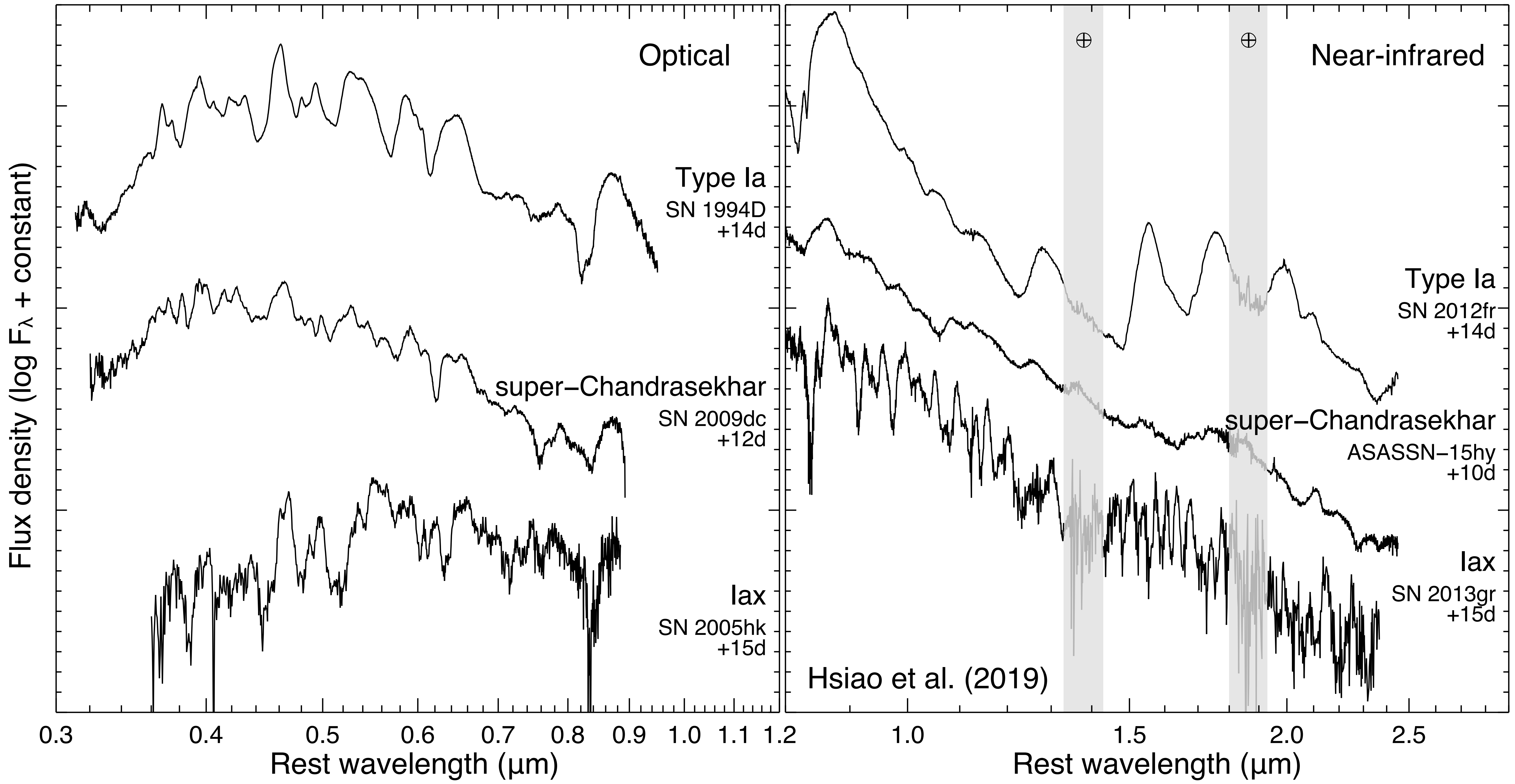
Kwok (2024) PhD thesis

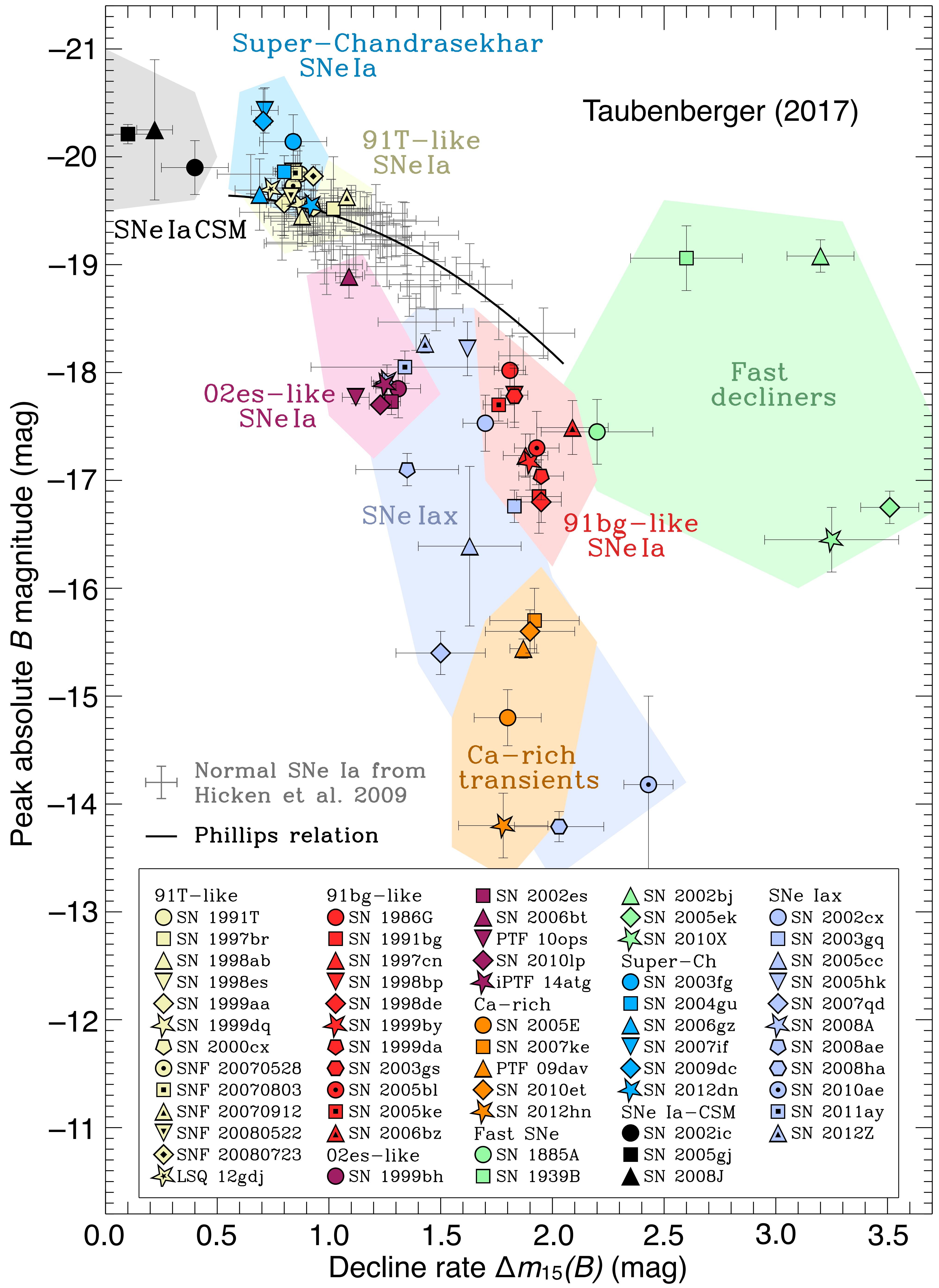


the thermonuclear supernova zoo

exploding white dwarfs:
much more than just normal SN Ia!

what can the outliers teach us?





SN 2022pul: a peculiar 03fg-like WDSN

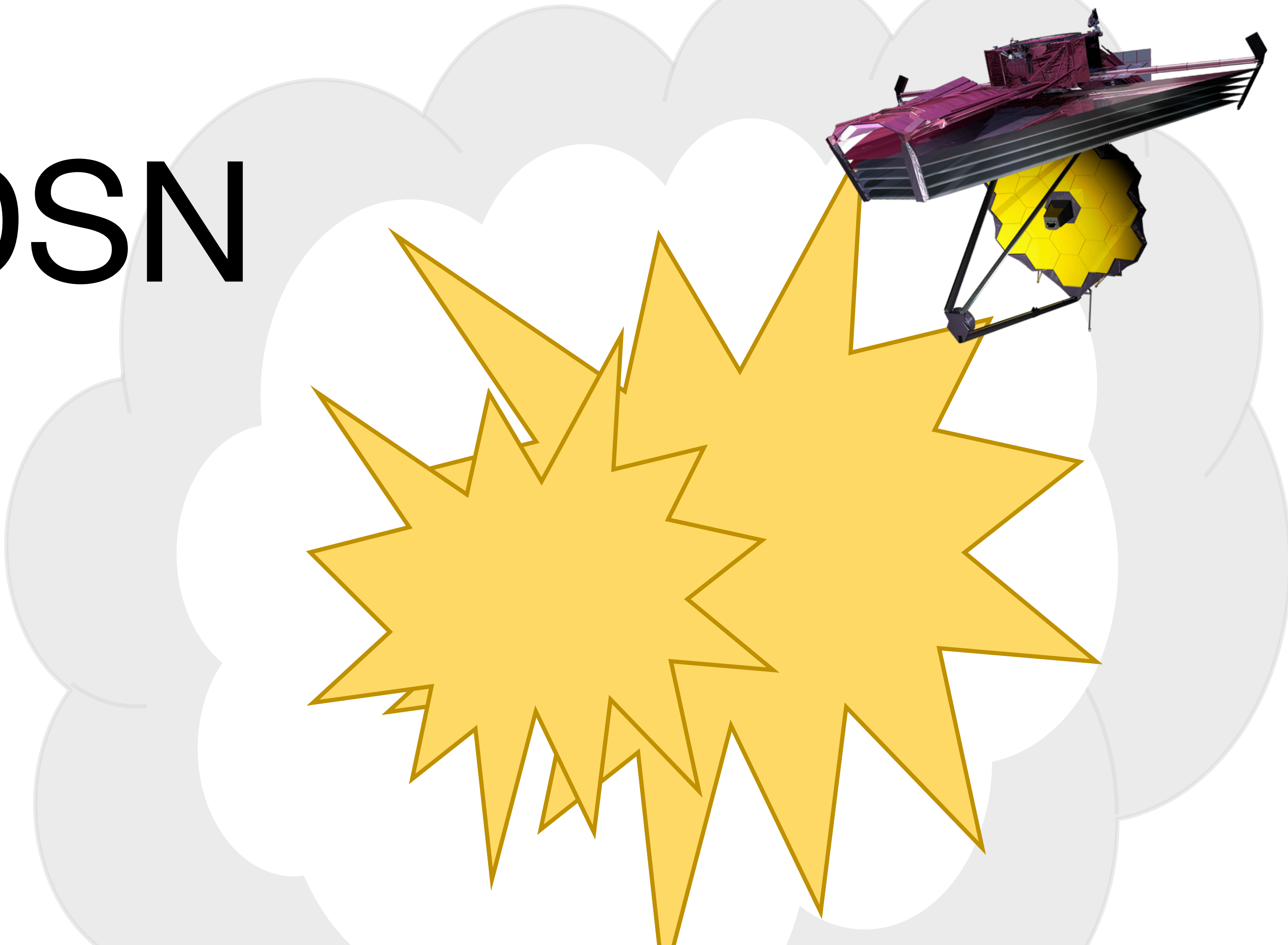
Dust!

Asymmetric line profiles

Central O, Ne

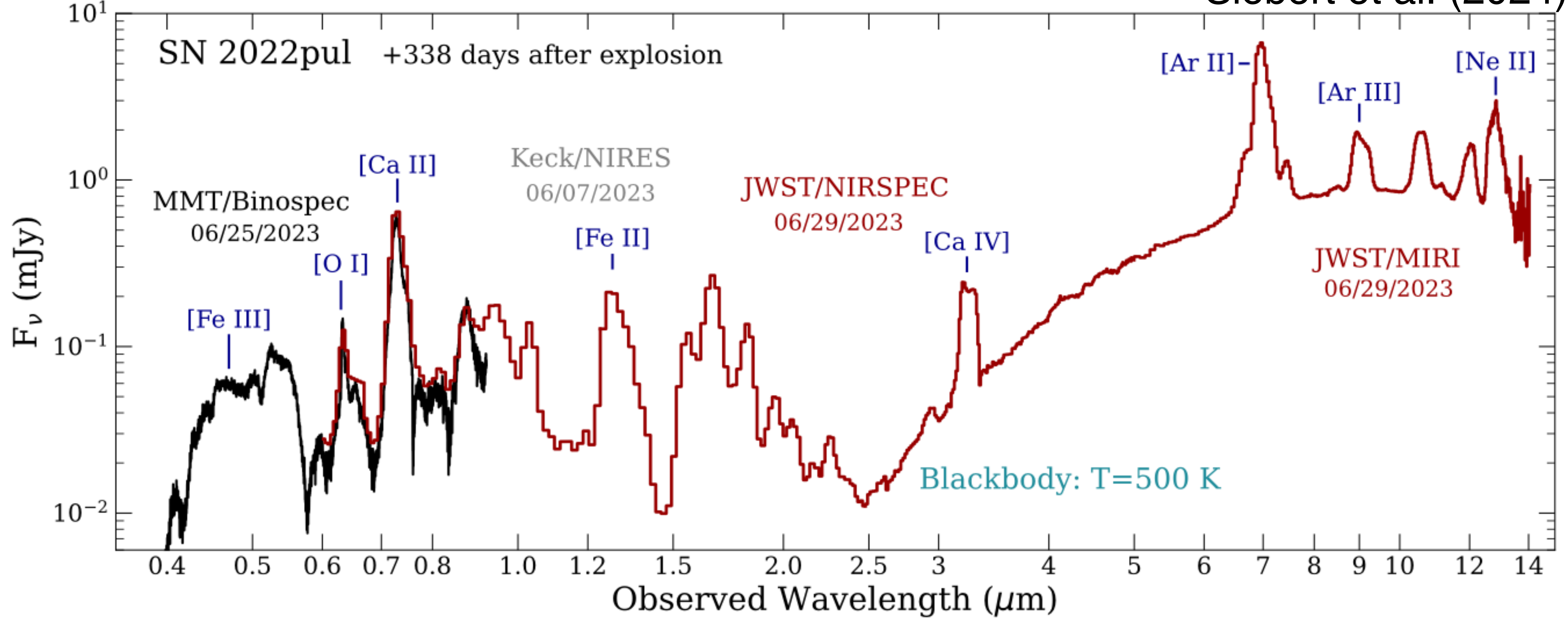
Strong Ar, Ca emission

Violent WD-WD merger within C/O CSM

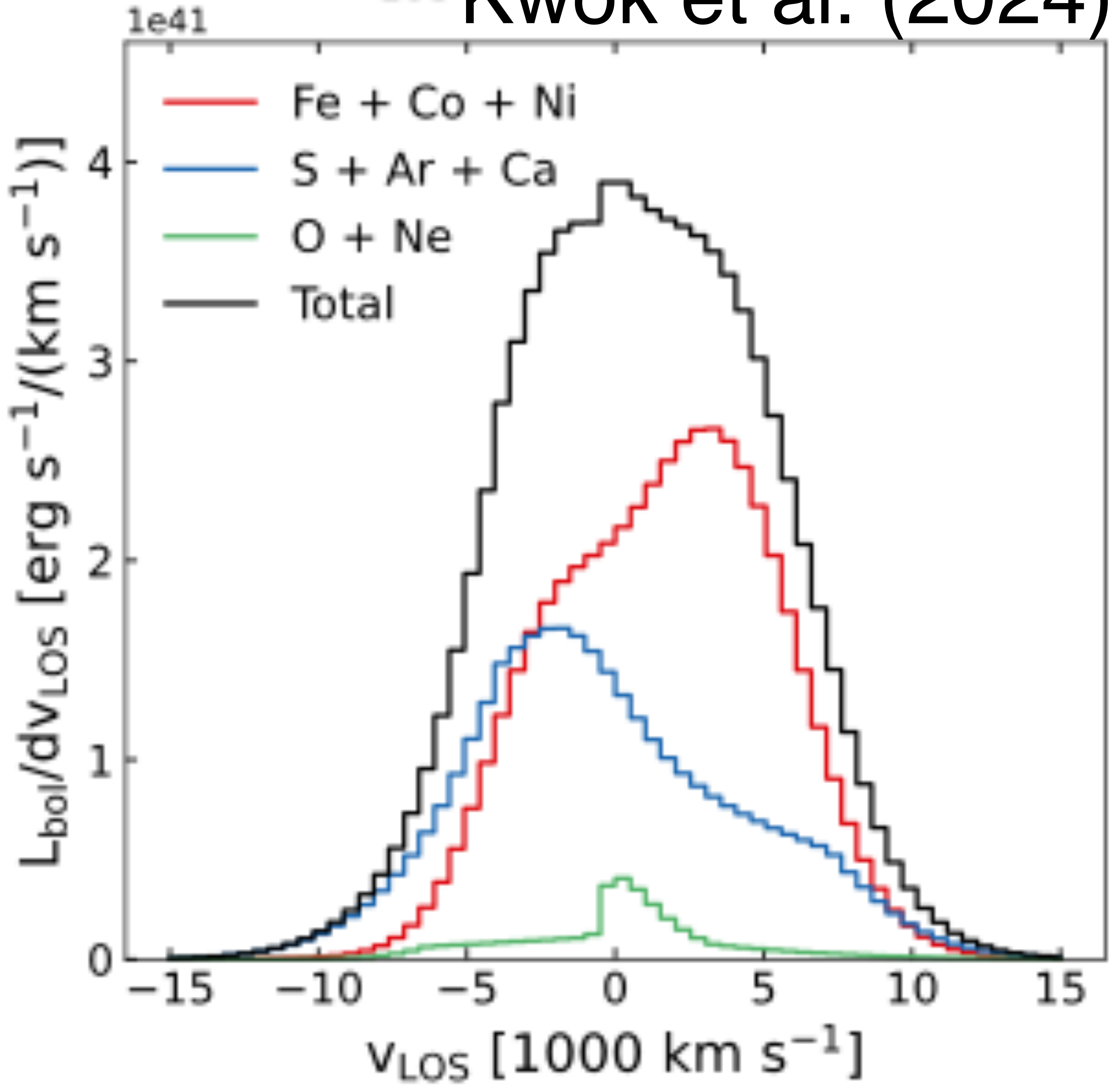


Blondin et al. (2023)

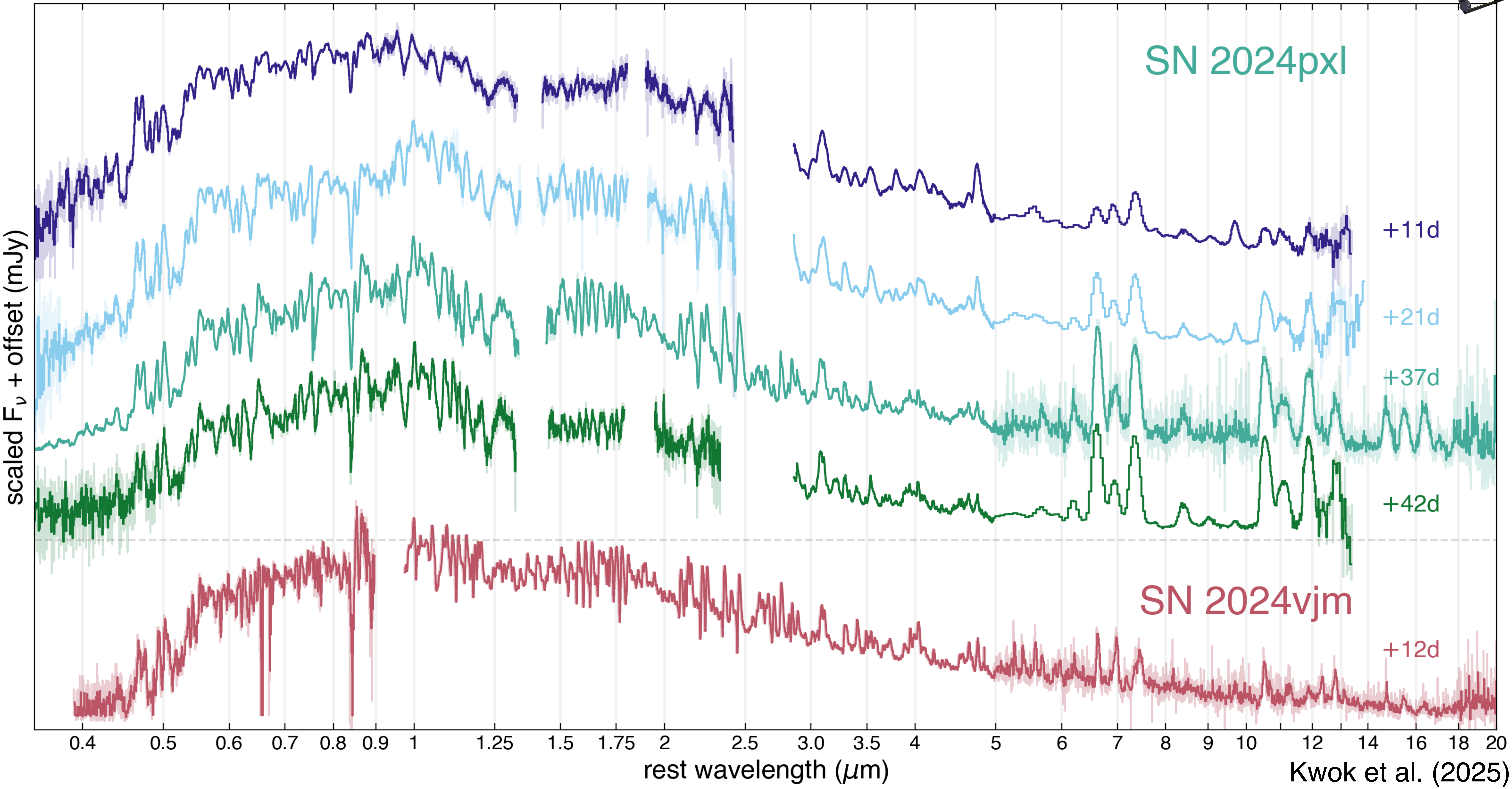
Siebert et al. (2024)



Kwok et al. (2024)



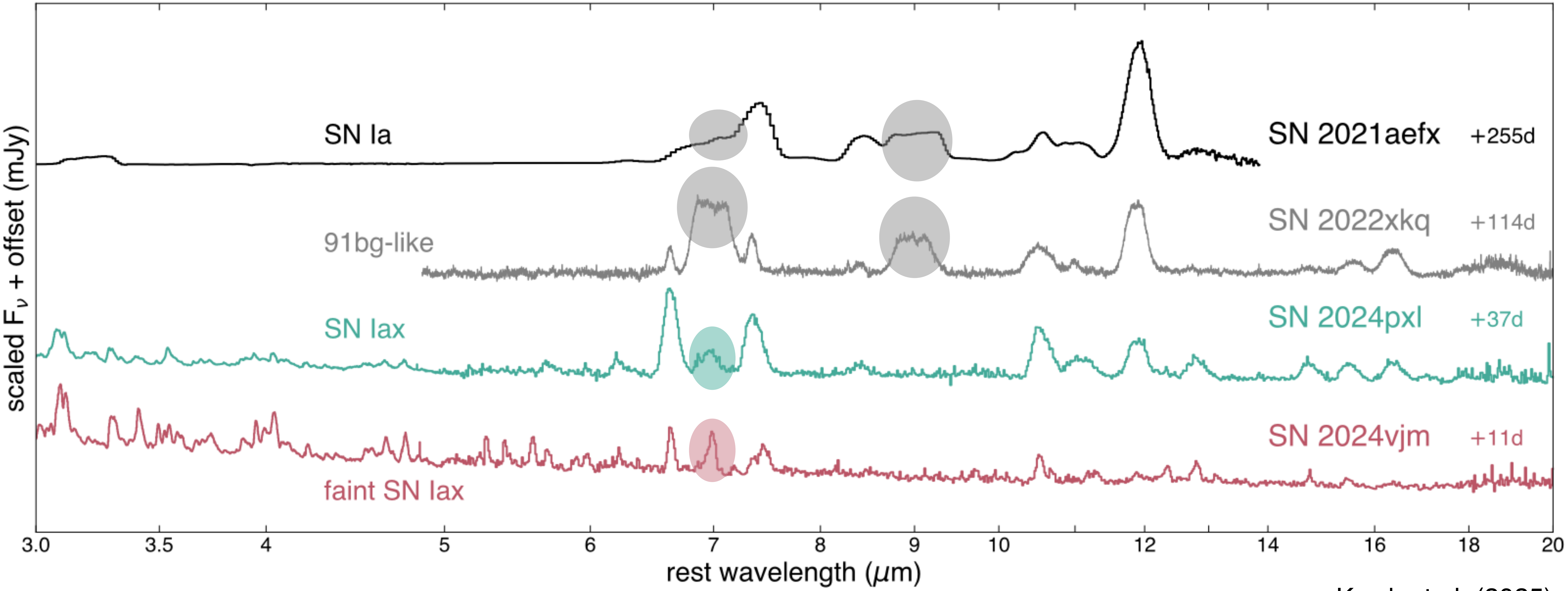
Getting Late Early: MIR Spectra of SN Iax



SN Ia vs. SN Iax in the MIR

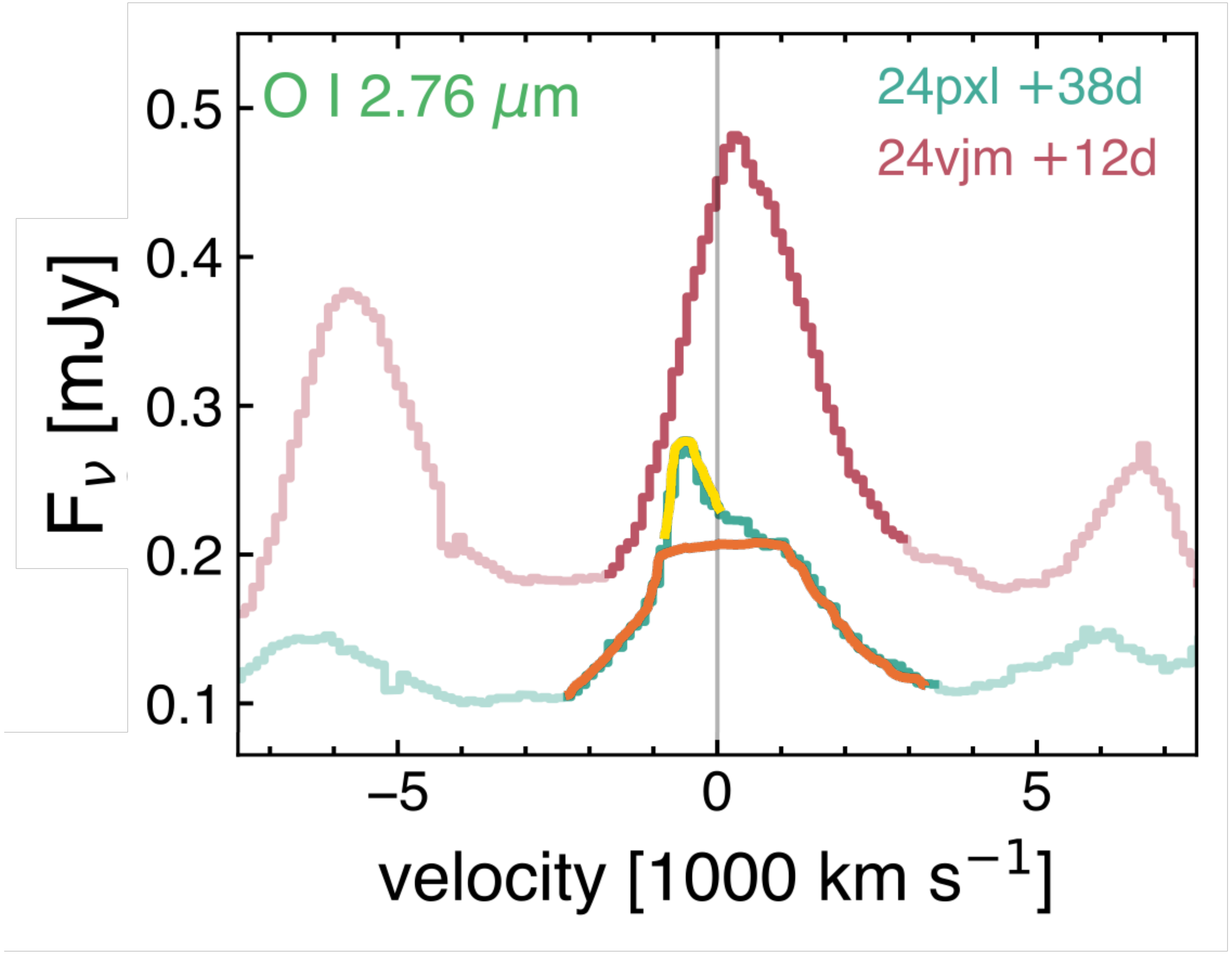
flat topped IME and peaked IGE profiles in normal/91bg-likes → stratified ejecta → detonation

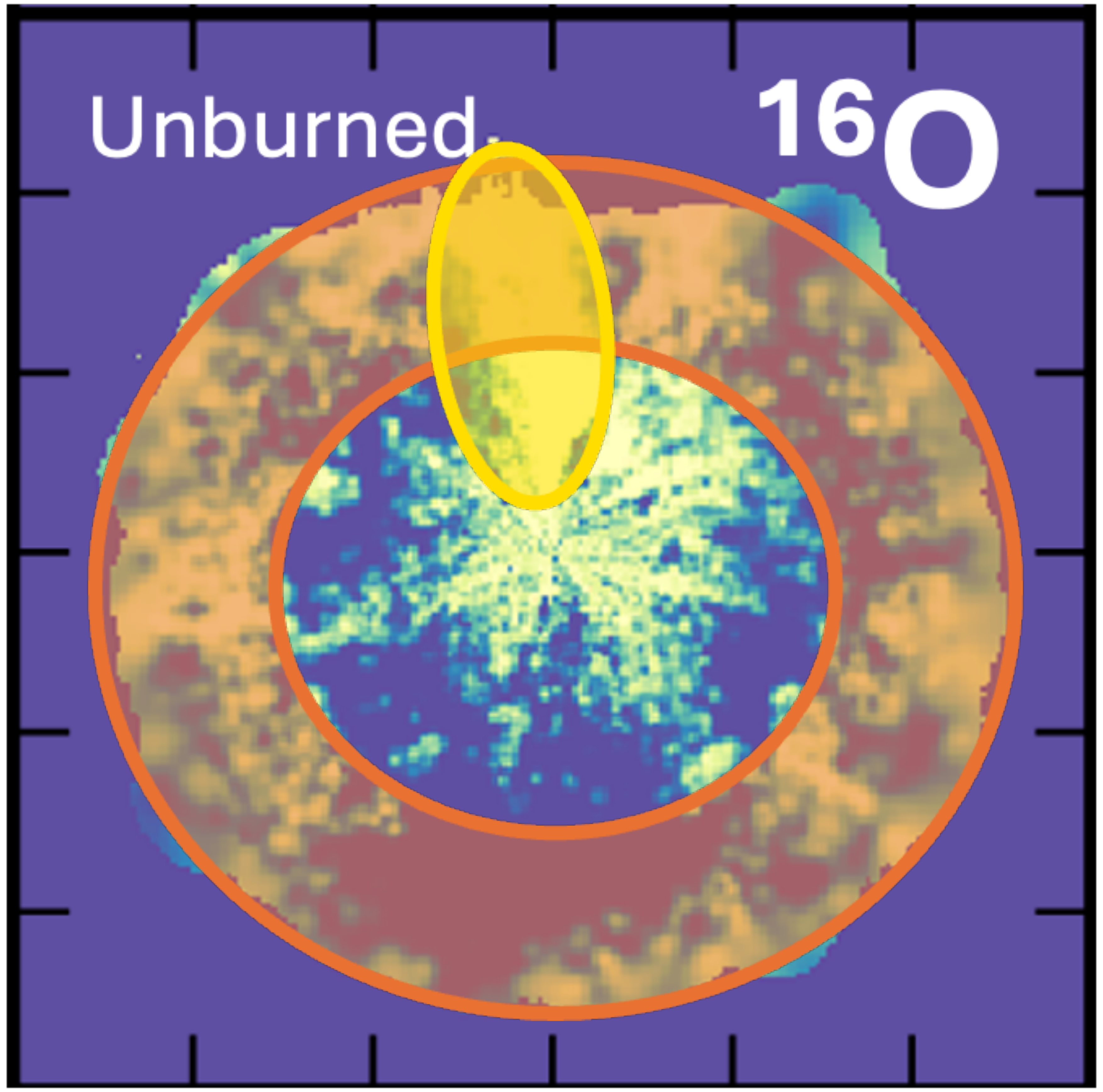
peaked IME and IGE profiles in SN Iax → mixed ejecta → deflagration?



Kwok et al. (2025)

Getting Late Early: SN Iax as Deflagrations





N20def model, Fink et al. 2014

Kwok et al. (2025)

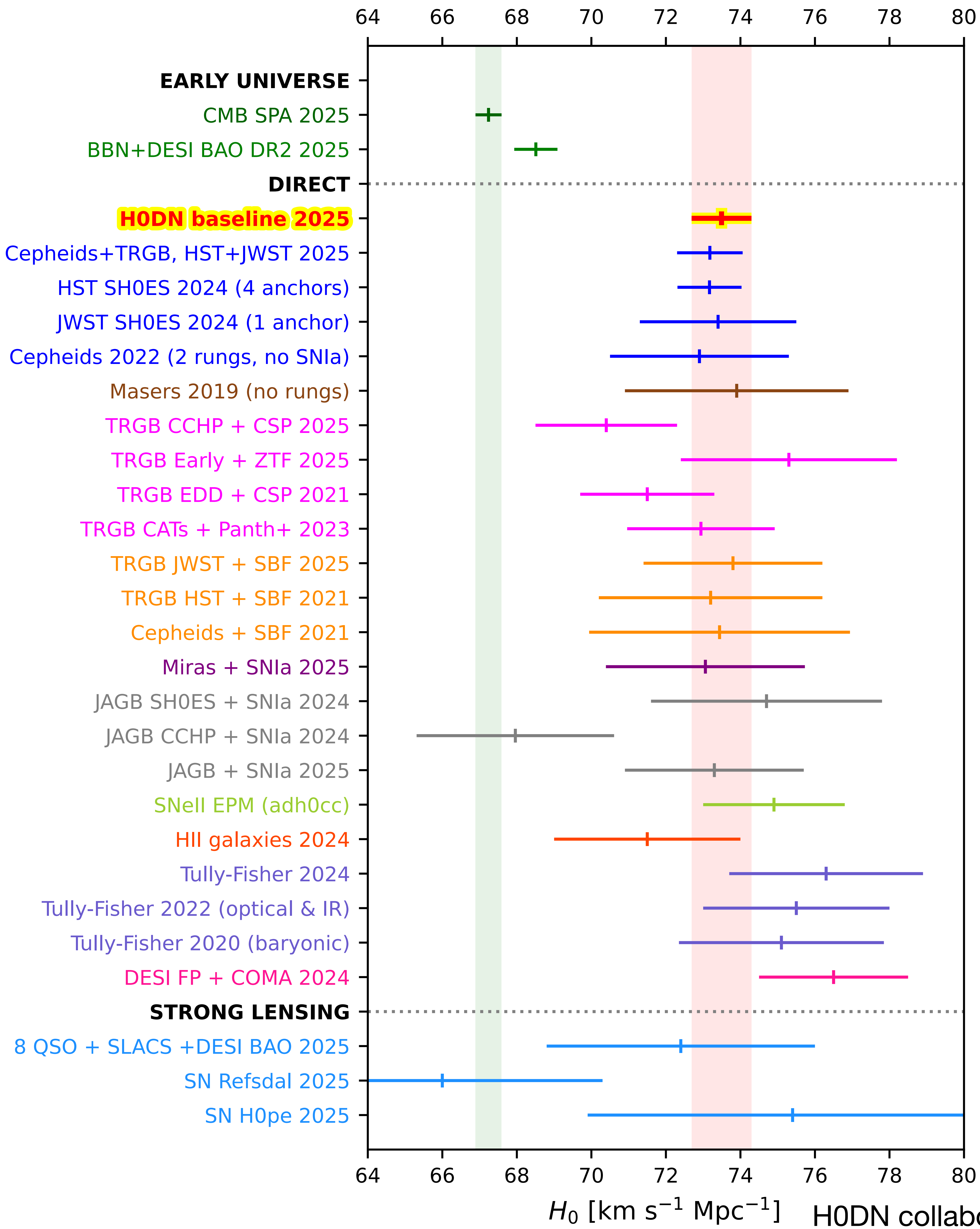
Hubble trouble

Geometric anchors + Cepheids + SN Ia show
~9% H_0 tension with Planck CMB + ΛCDM

a *differential* measurement between
Hubble-flow and local calibrator SN Ia

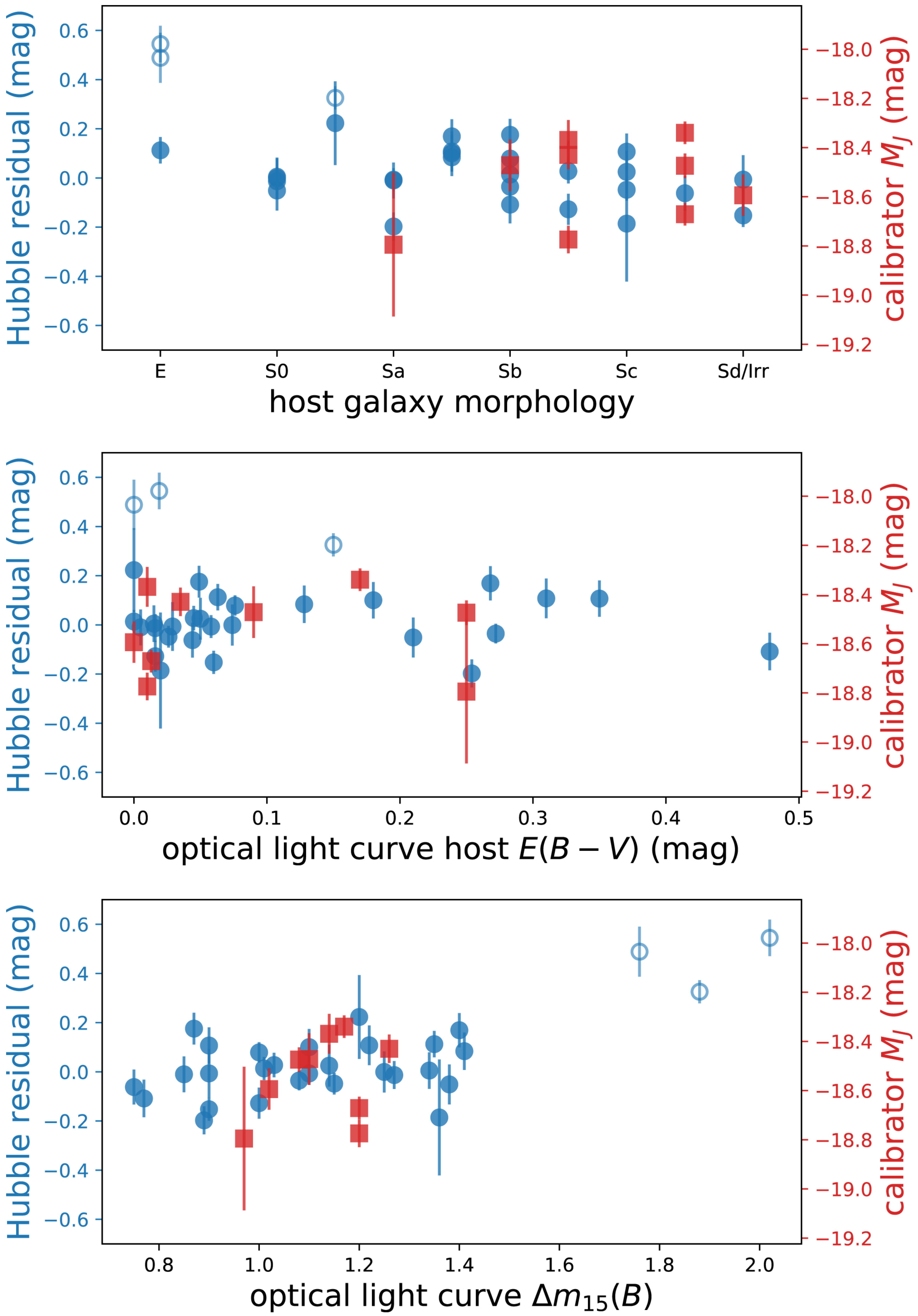
Calibrated SN Ia	Hubble-flow SN Ia
$d \sim 25\,\mathrm{Mpc},\ z \sim 0.006$	$d \sim 200\,\mathrm{Mpc},\ z \sim 0.05$
$\mu = m - M \sim 32$	$\mu = m - M \sim 36.5$
$\mathrm{lookback}\ t \sim 80\,\mathrm{Myr}$	$\mathrm{lookback}\ t \sim 650\,\mathrm{Myr}$

As long as these SN Ia samples are similar on average, there is no large SN Ia systematic. The Hubble flow SN Ia sample itself spans a wider range in distance, redshift, or lookback time than the difference with the calibrators, and it shows no evidence for large systematics.

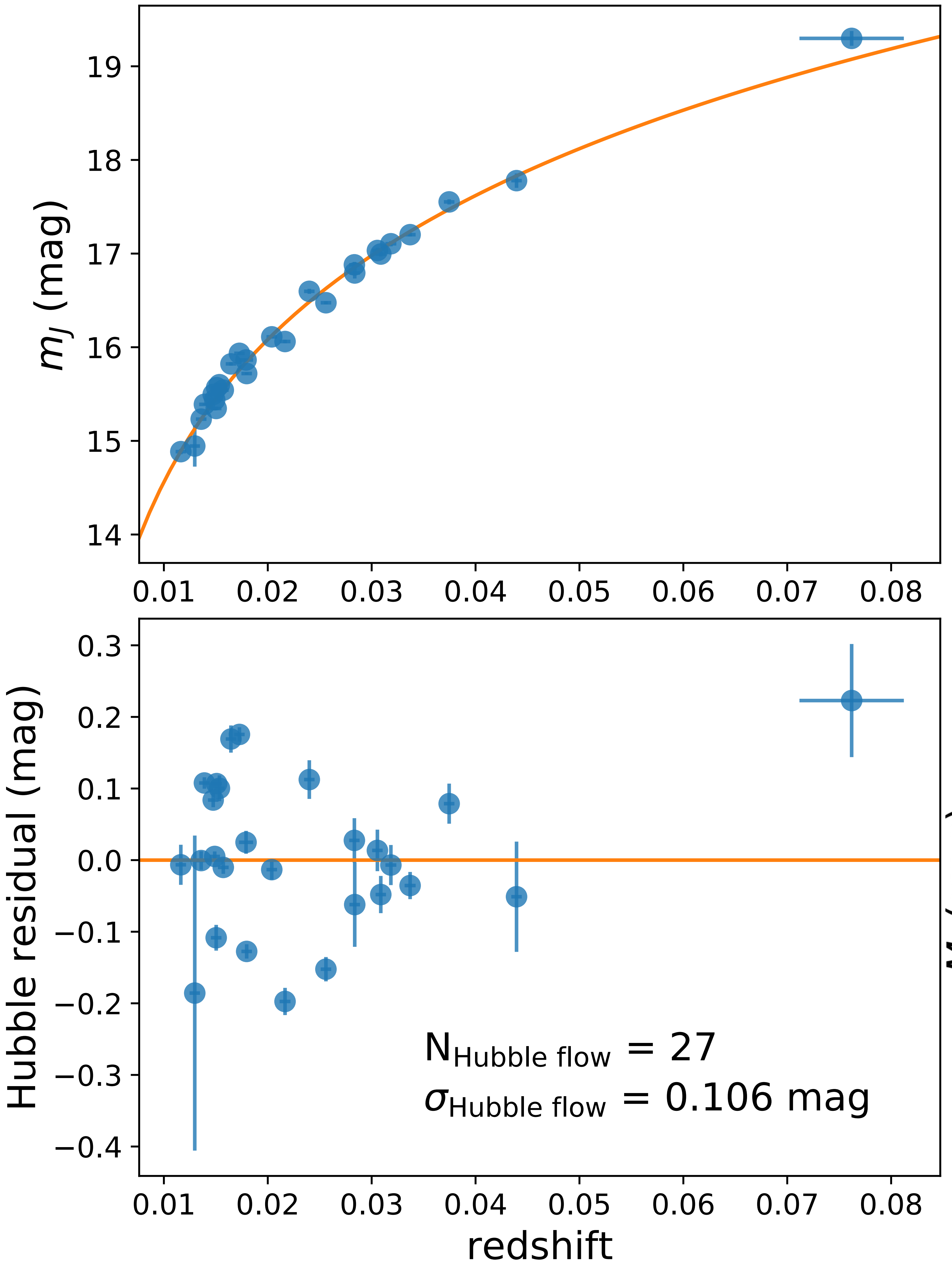


H0DN collaboration
Casertano et al. (2025)

SN Ia as NIR *standard* candles



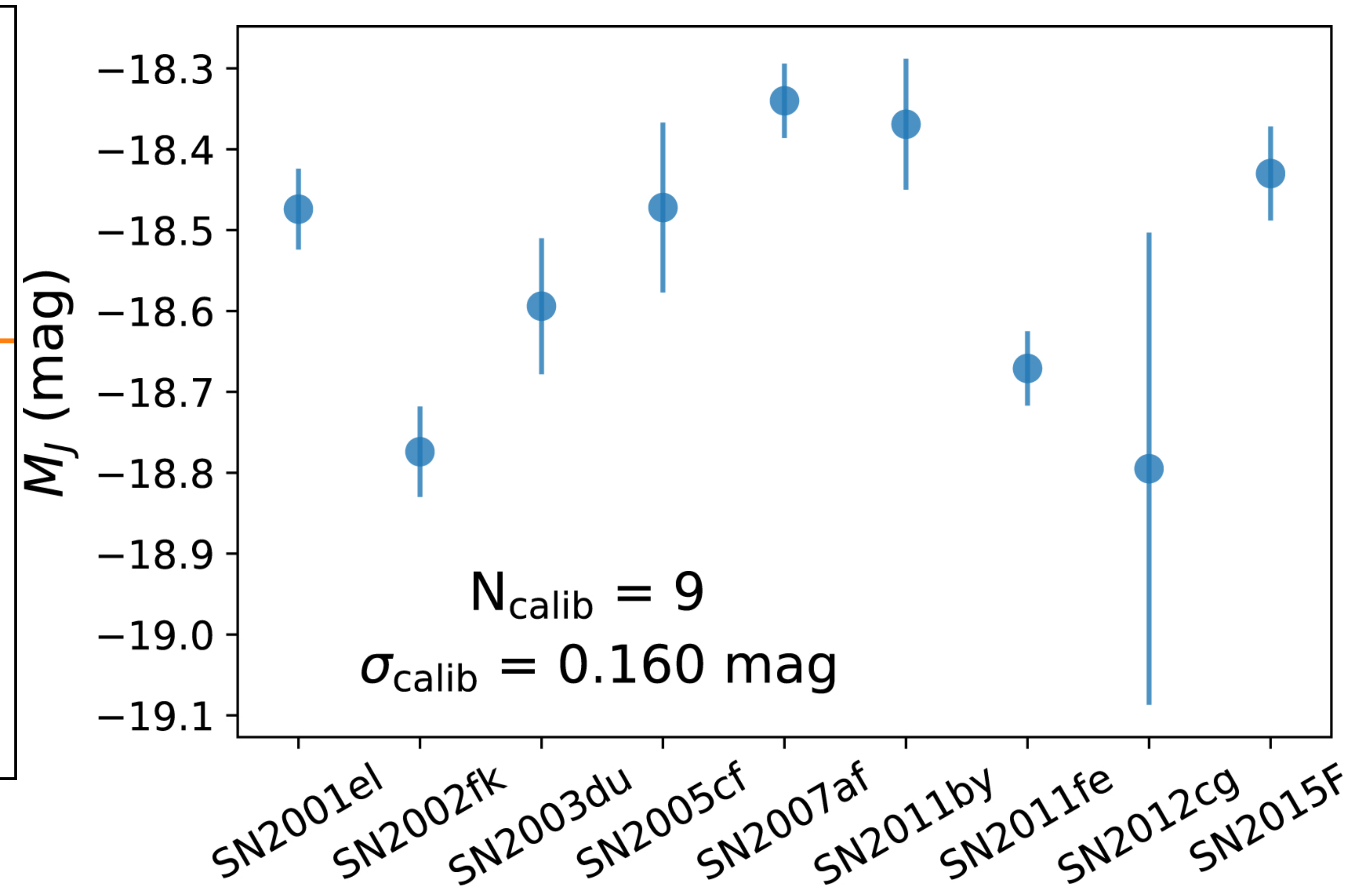
Dhawan, Jha, & Leibundgut (2018)



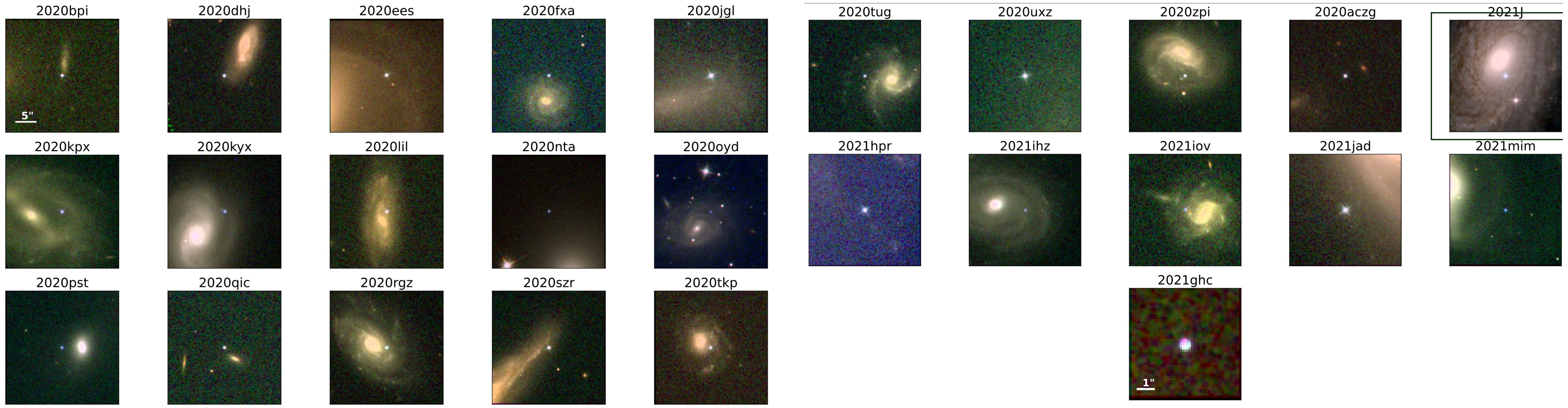
$H_0 = 72.8 \pm 3.1$ km s^{-1} Mpc^{-1}
consistent with SH0ES results
[using same HST Cepheid distances]

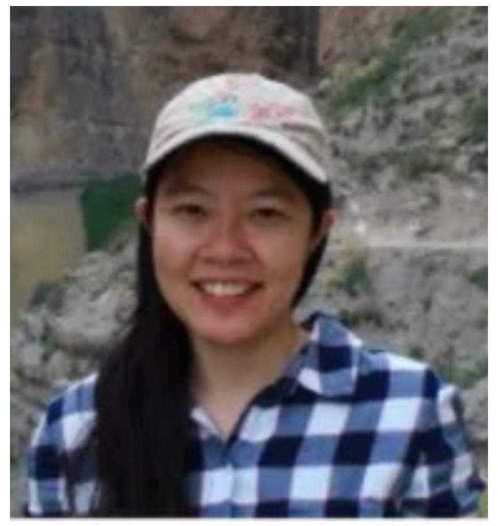
updated in Galbany et al. (2022):
$H_0 = 72.9 \pm 1.9$ km s^{-1} Mpc^{-1}
Dhawan et al. (2023) opt+NIR:
$H_0 = 74.8 \pm 1.3$ km s^{-1} Mpc^{-1}

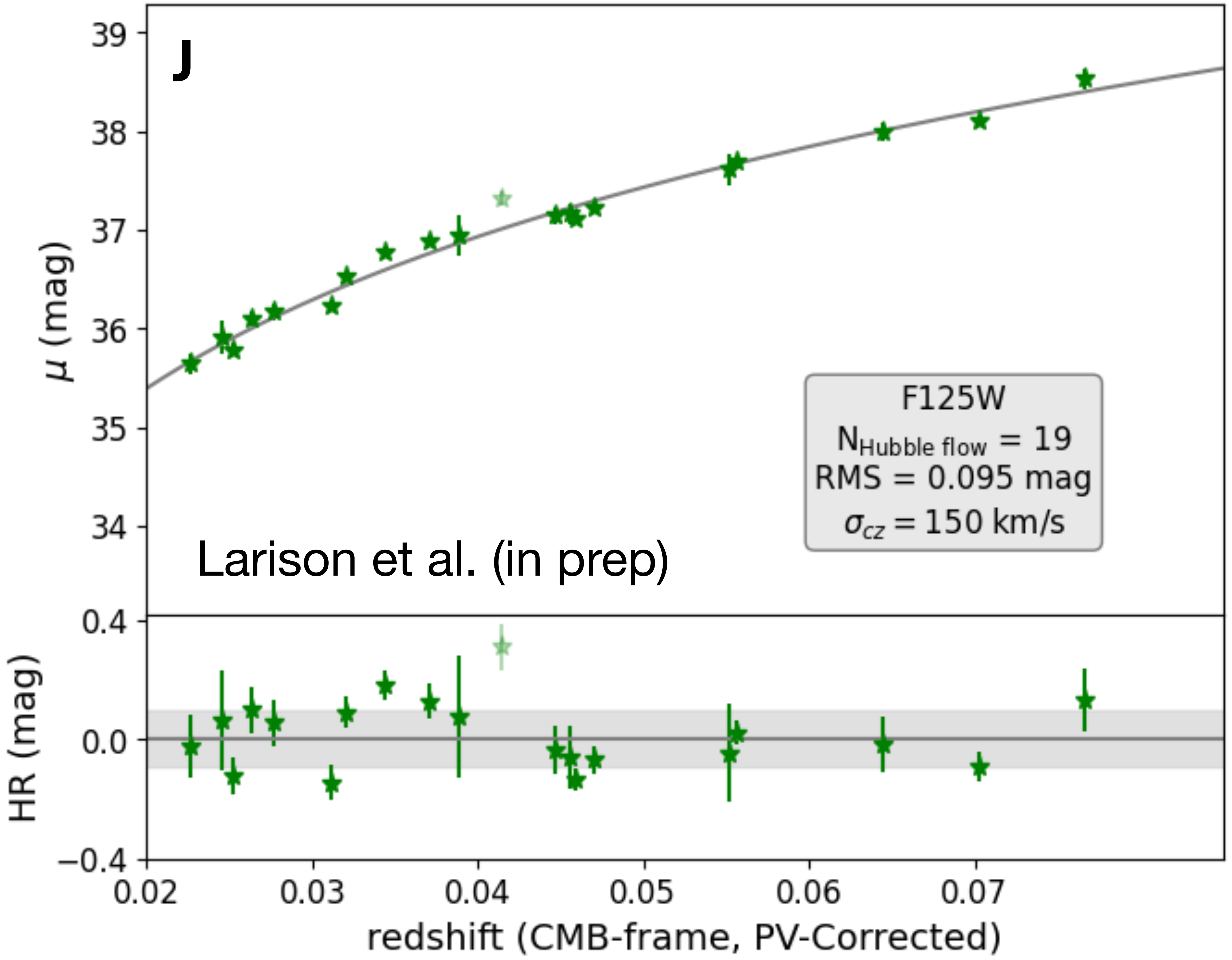
H_0 tension does not result from a wavelength-dependent systematic uncertainty in the SN Ia

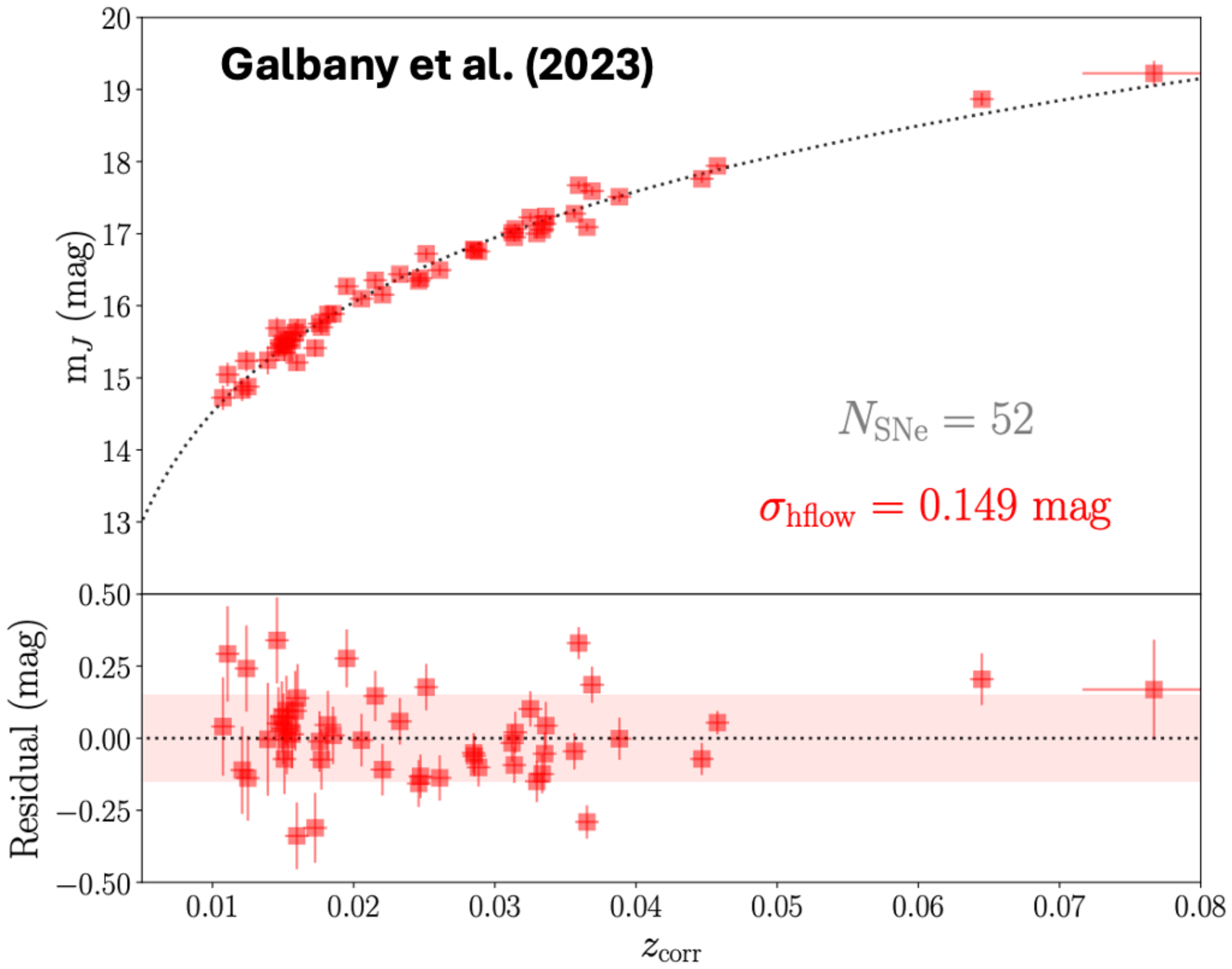


SIRAH







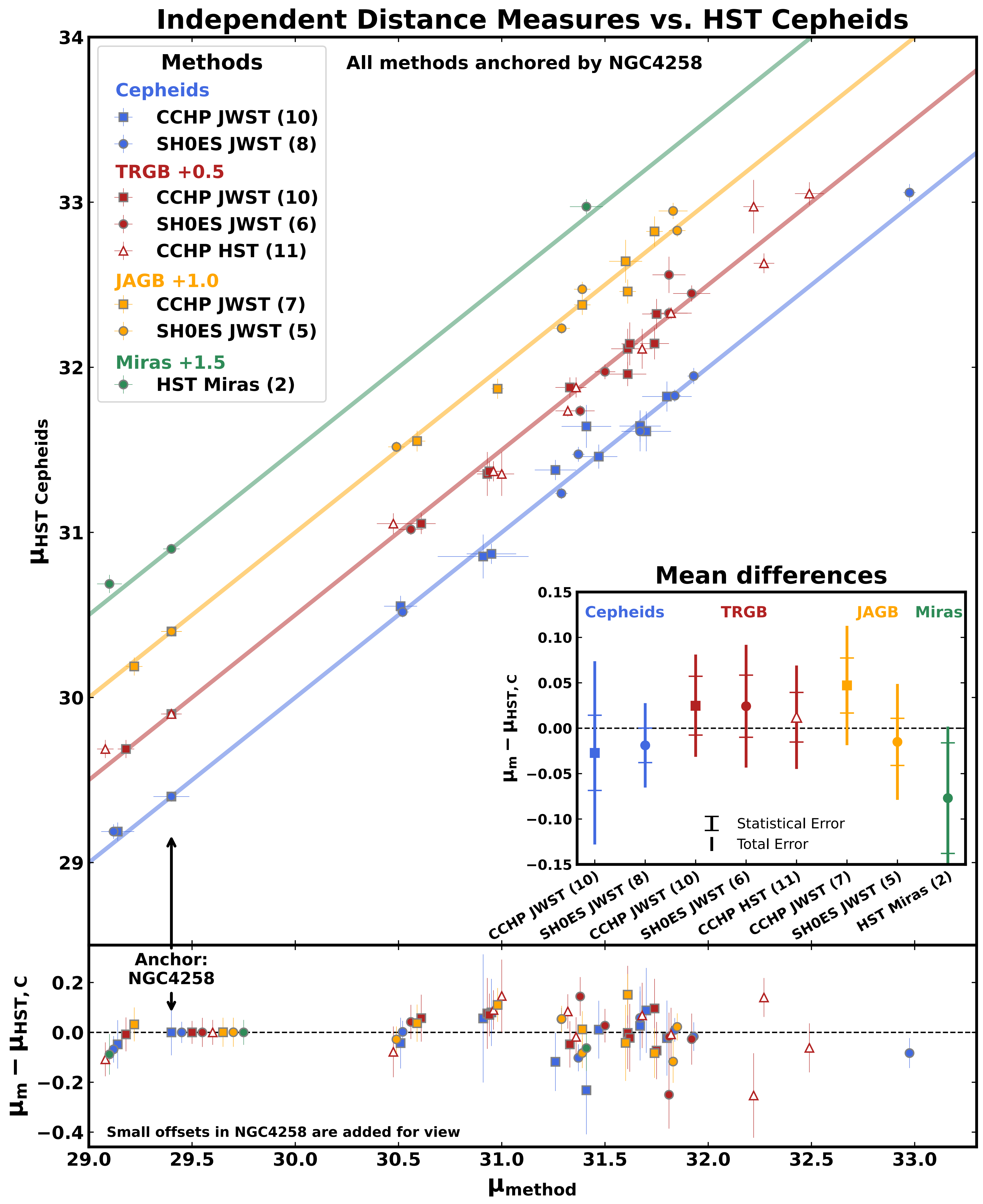


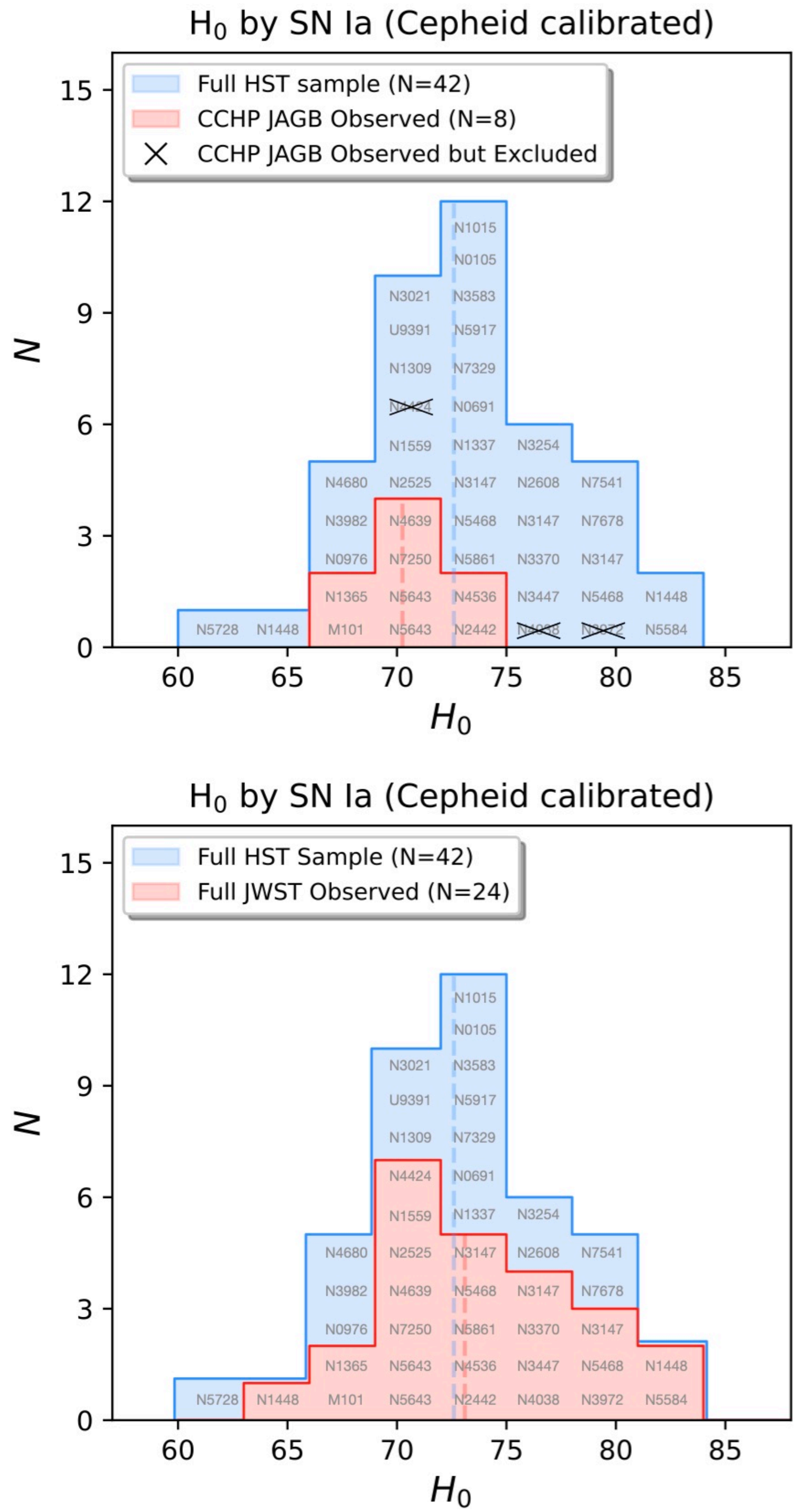
space-based calibration of NIR SN Ia

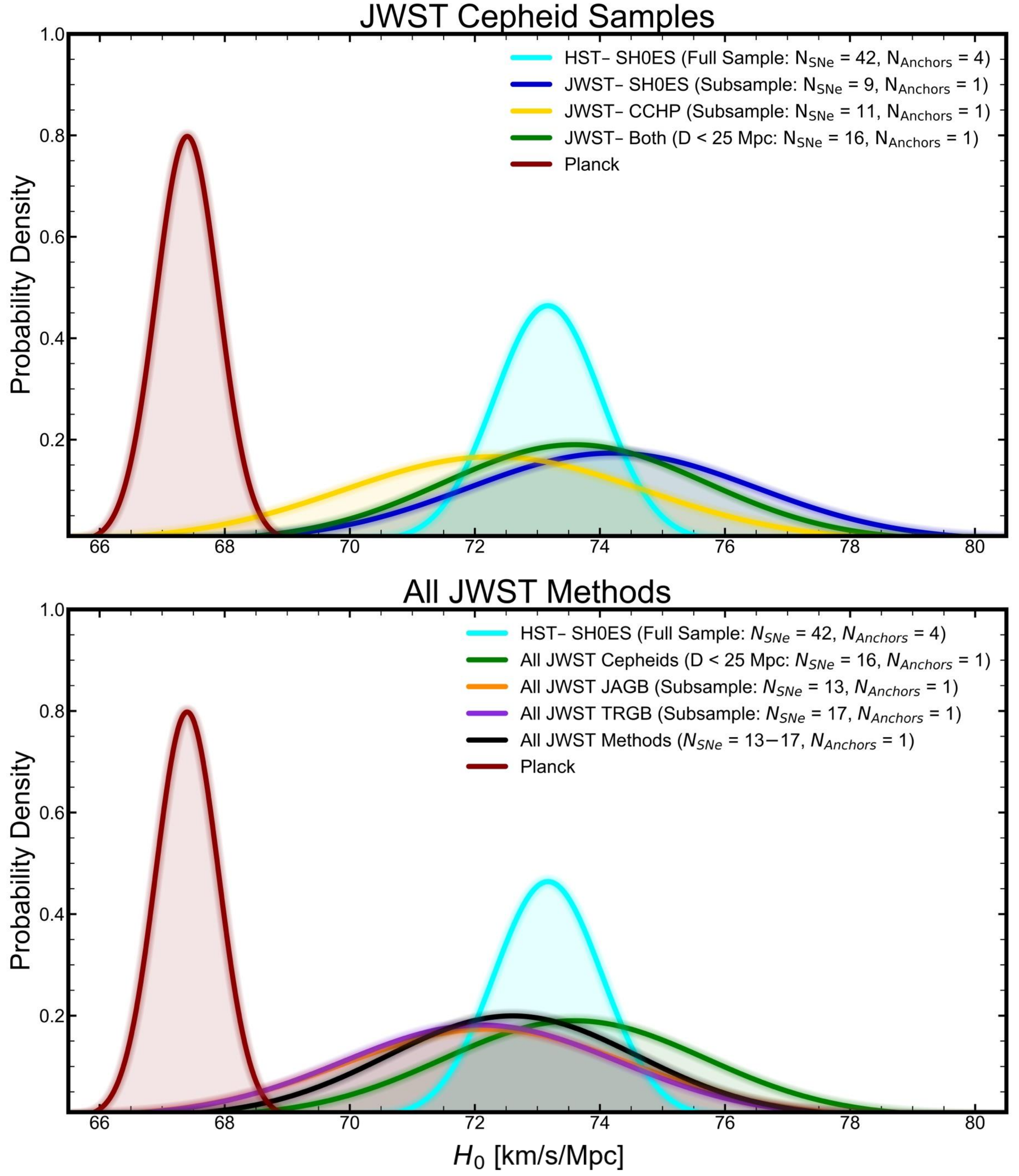
application to H_0, but also dark energy with, e.g., Roman

from Hubble to JWST

good consistency between JWST and HST distances
(independent of supernovae, testing 2nd rung)
JWST sample is smaller than HST: less precise H_0

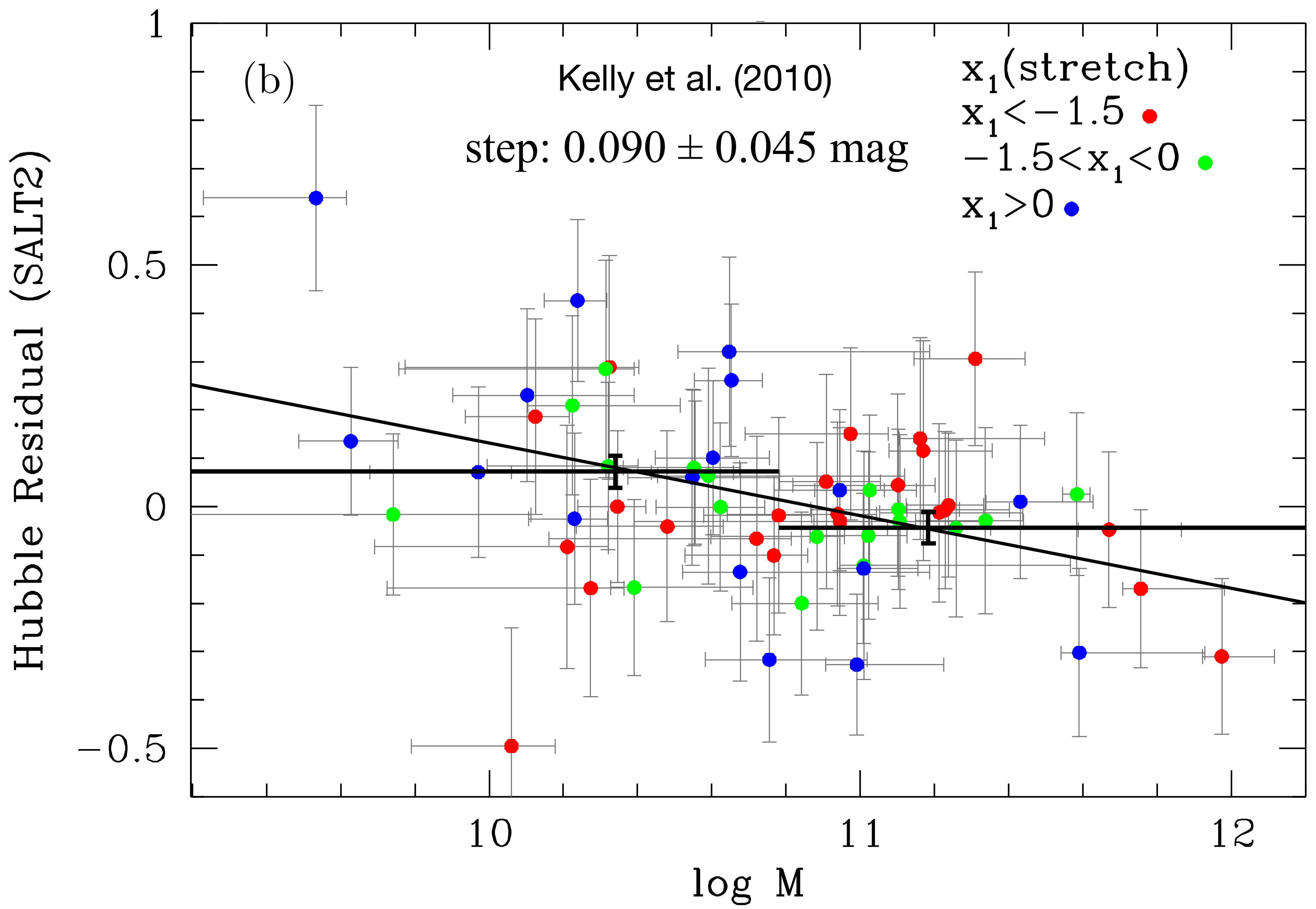






Riess et al. (2024)

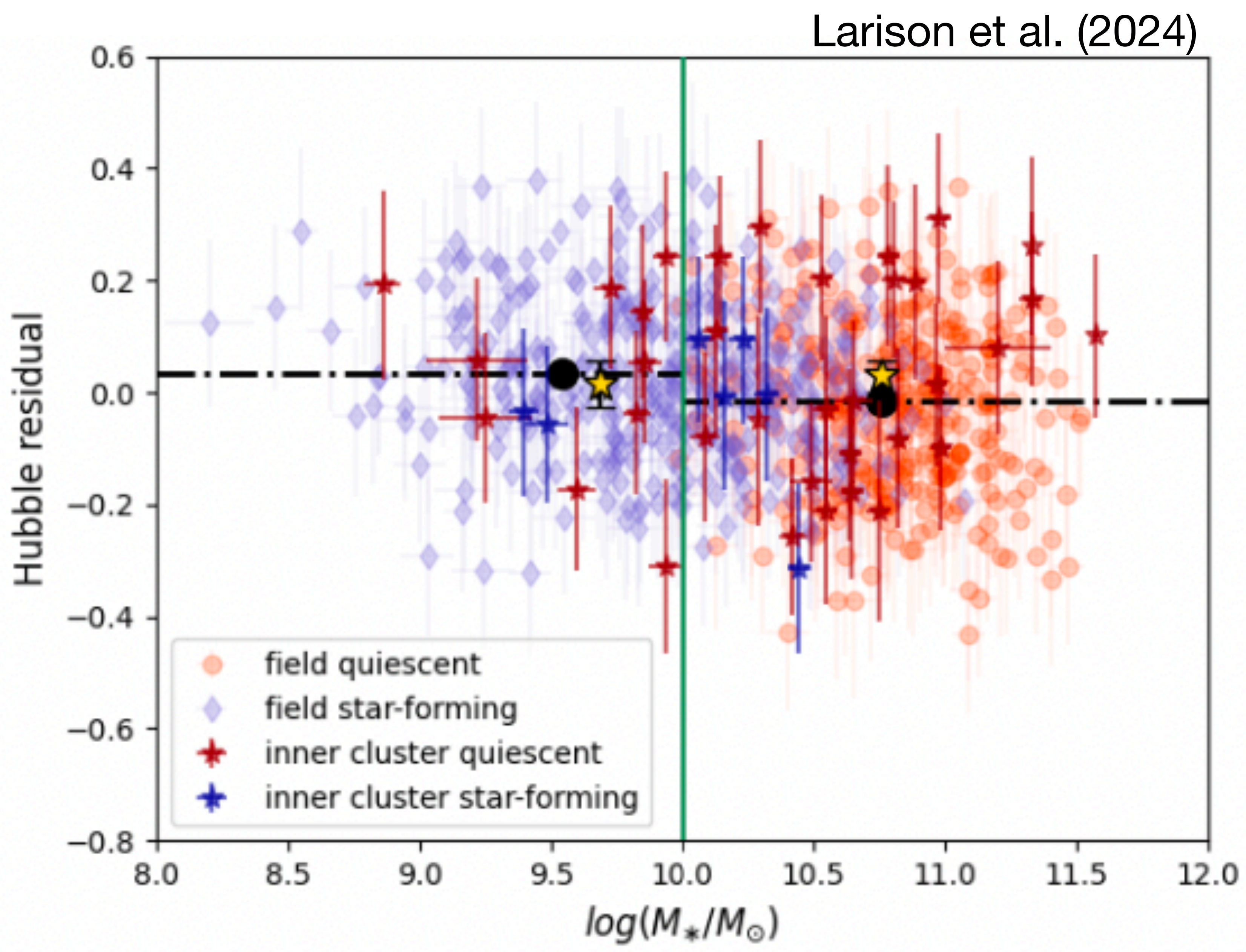
astrophysical systematics: SN Ia standardized luminosity & host galaxy

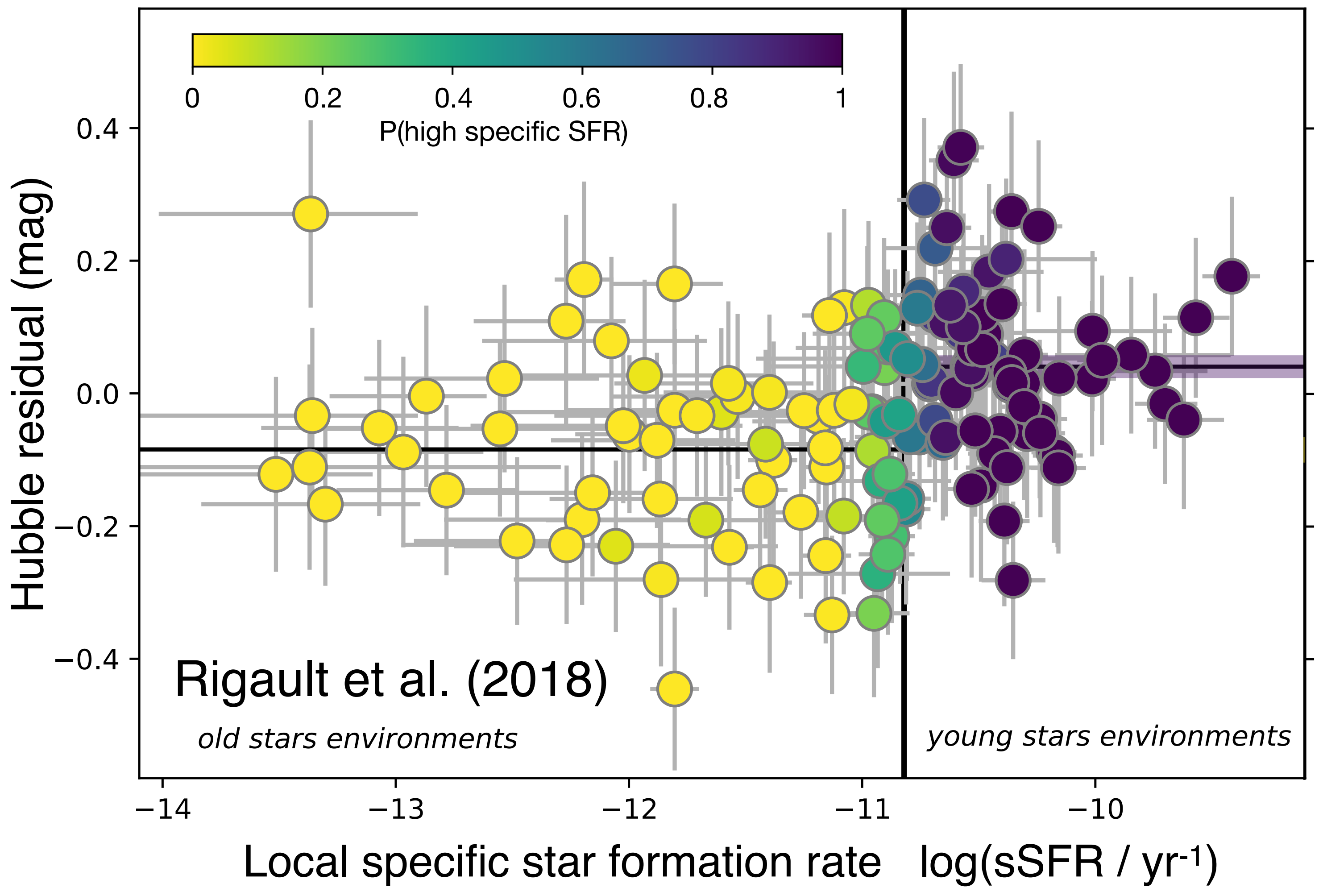


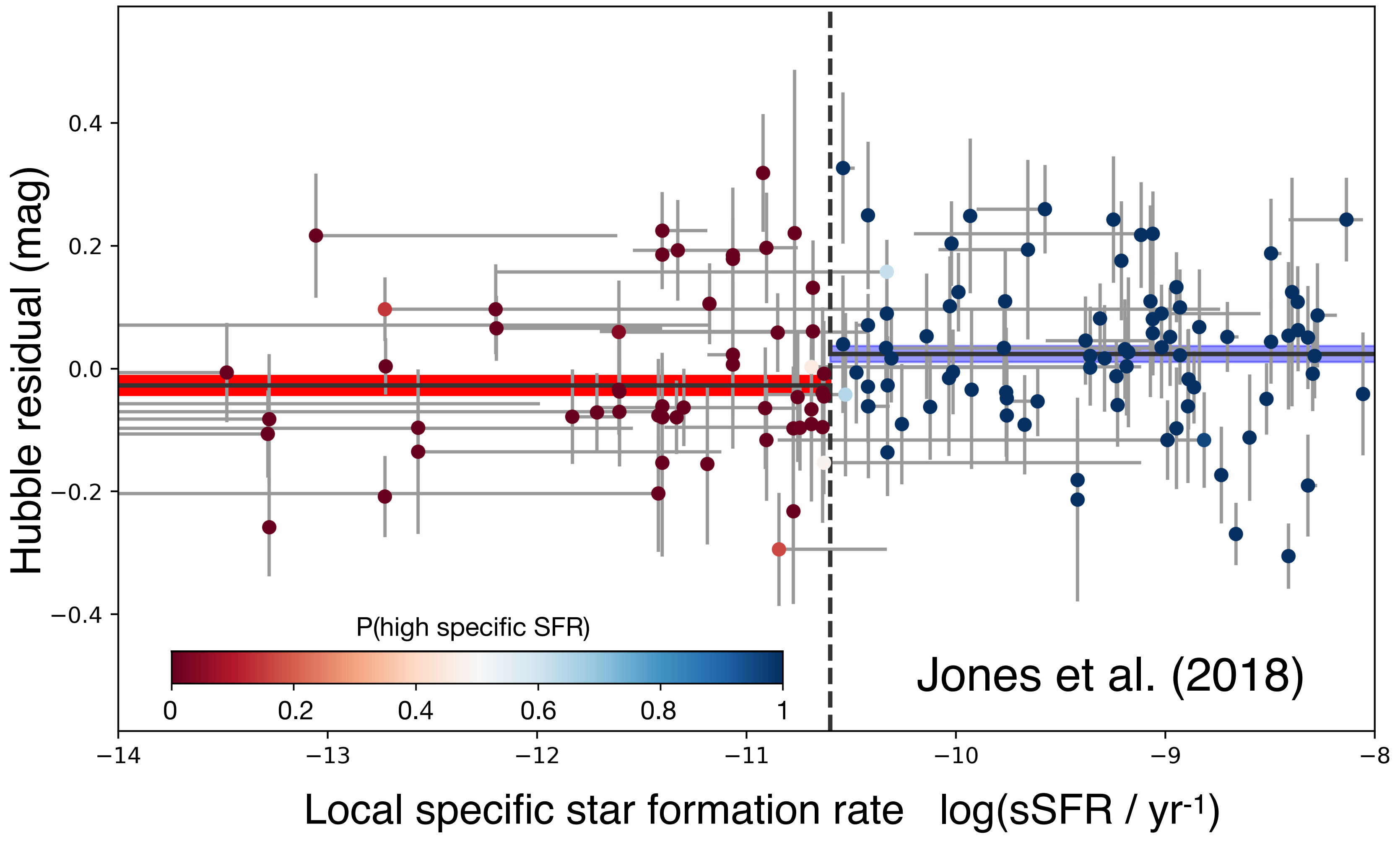
SN Ia luminosity and other properties vary systematically with host galaxy properties

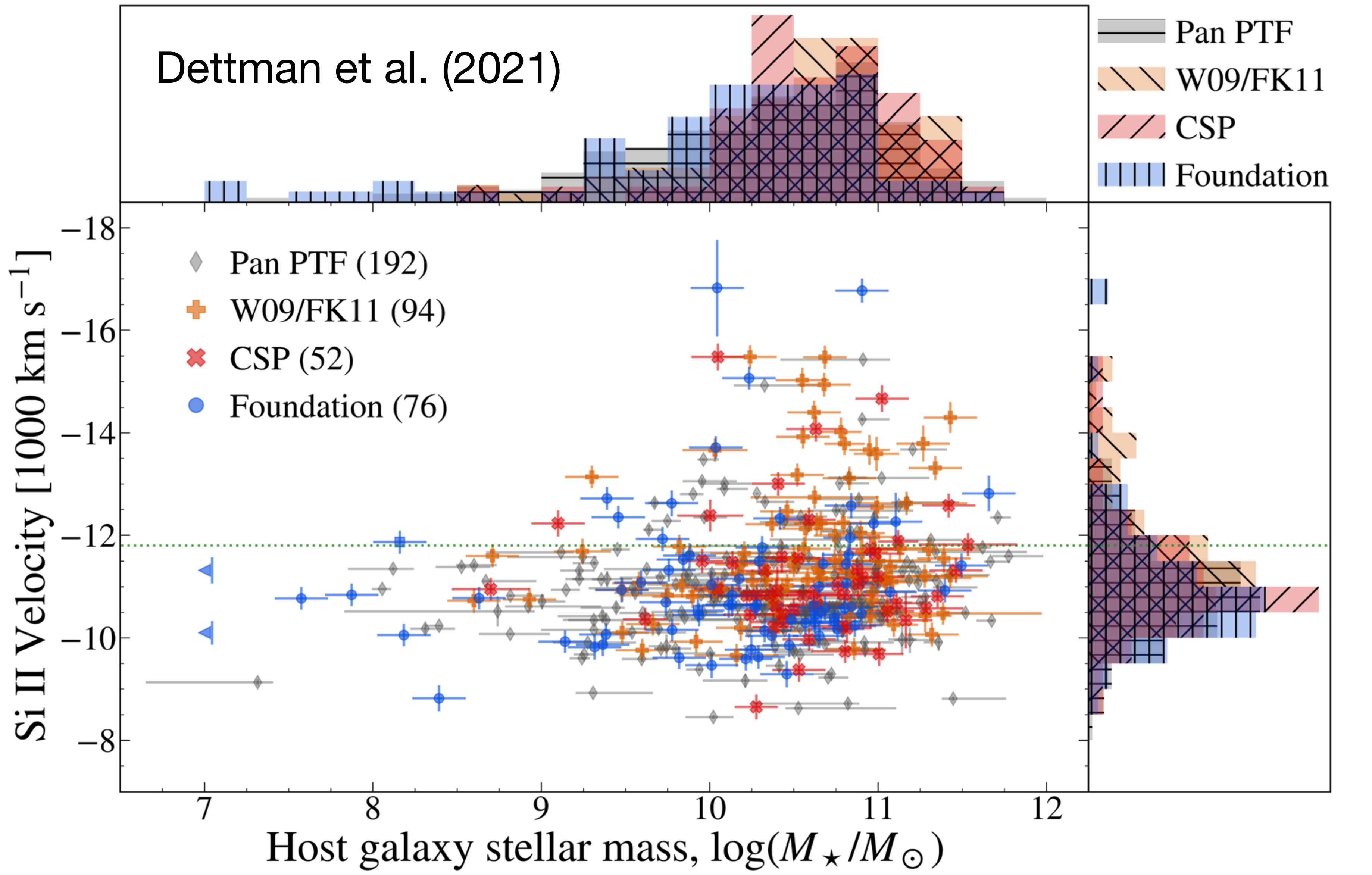
modest (< 1%) effect on H_0 but could be more substantial at high-redshift for dark energy

see also N. Sarin talk from Tuesday





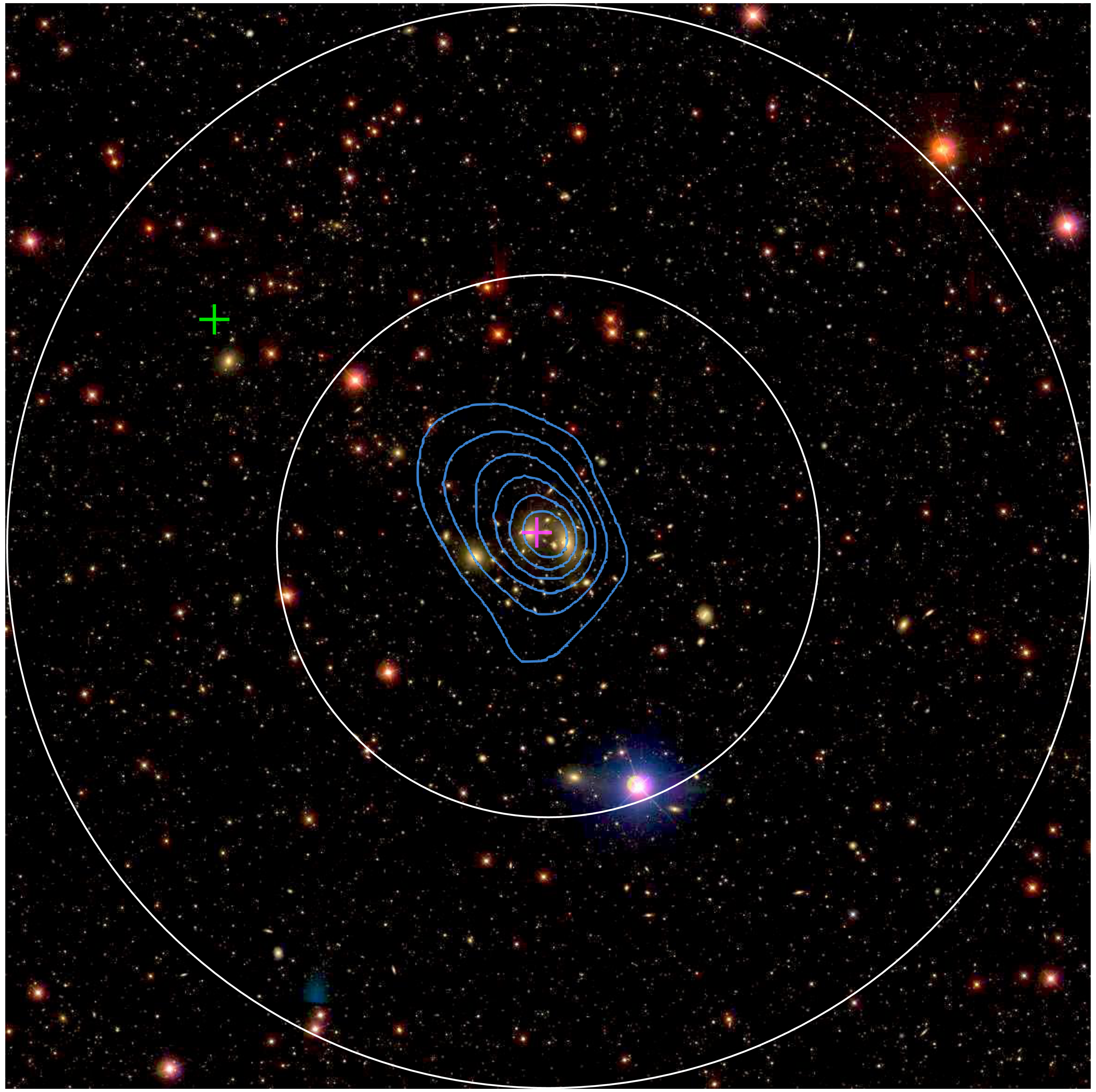


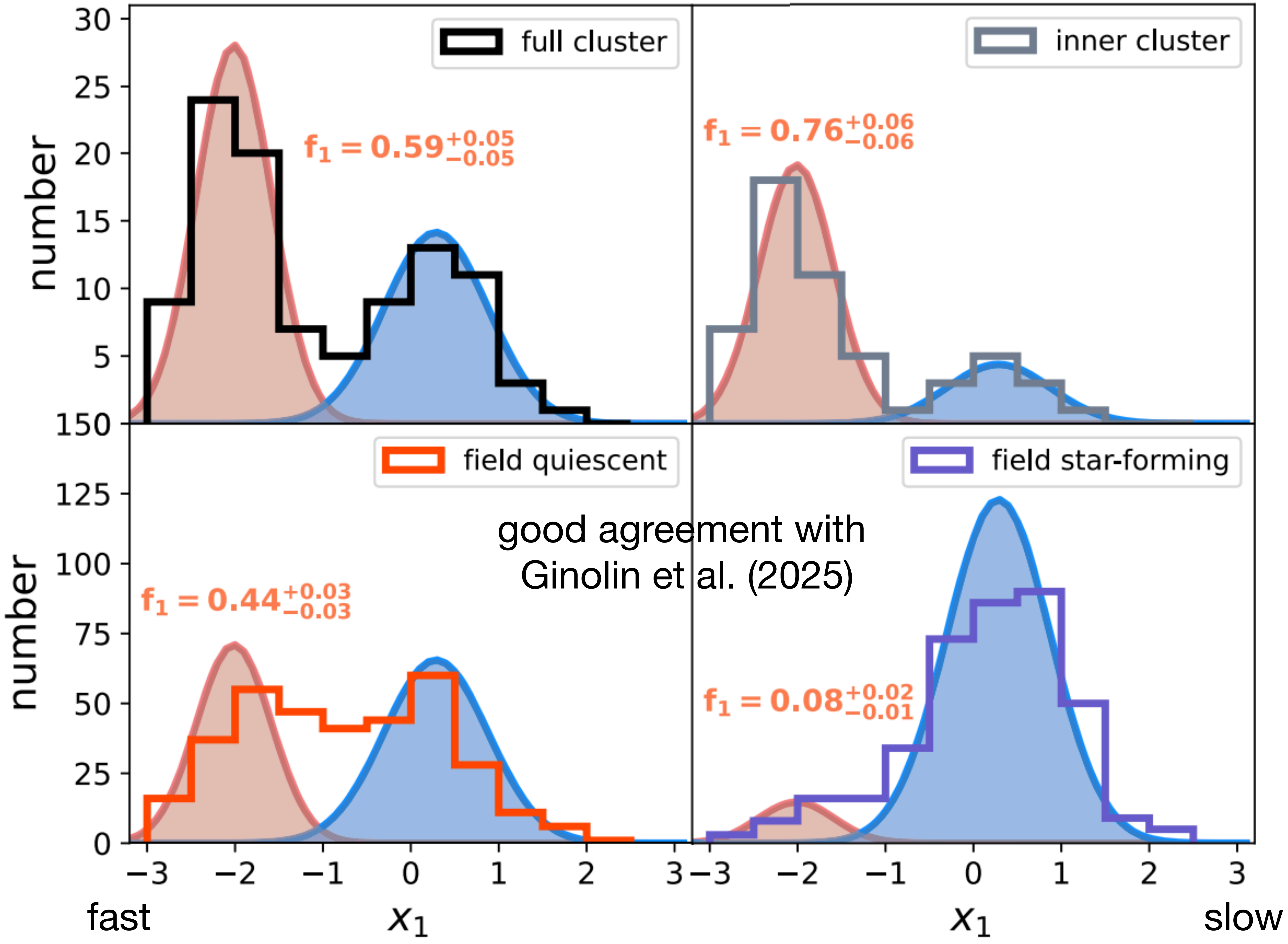


SN Ia properties: correlation with large-scale environment

a strong excess of fast-declining ZTF SN Ia in the center of low-redshift x-ray selected galaxy clusters
seen also in larger ZTF sample of Ruppin et al. (2025), but weaker at higher-redshift (Toy et al. 2023)
an age effect? cosmological implications (Rigault et al. 2020, Nicolas et al. 2021, Wotjak et al. 2023)

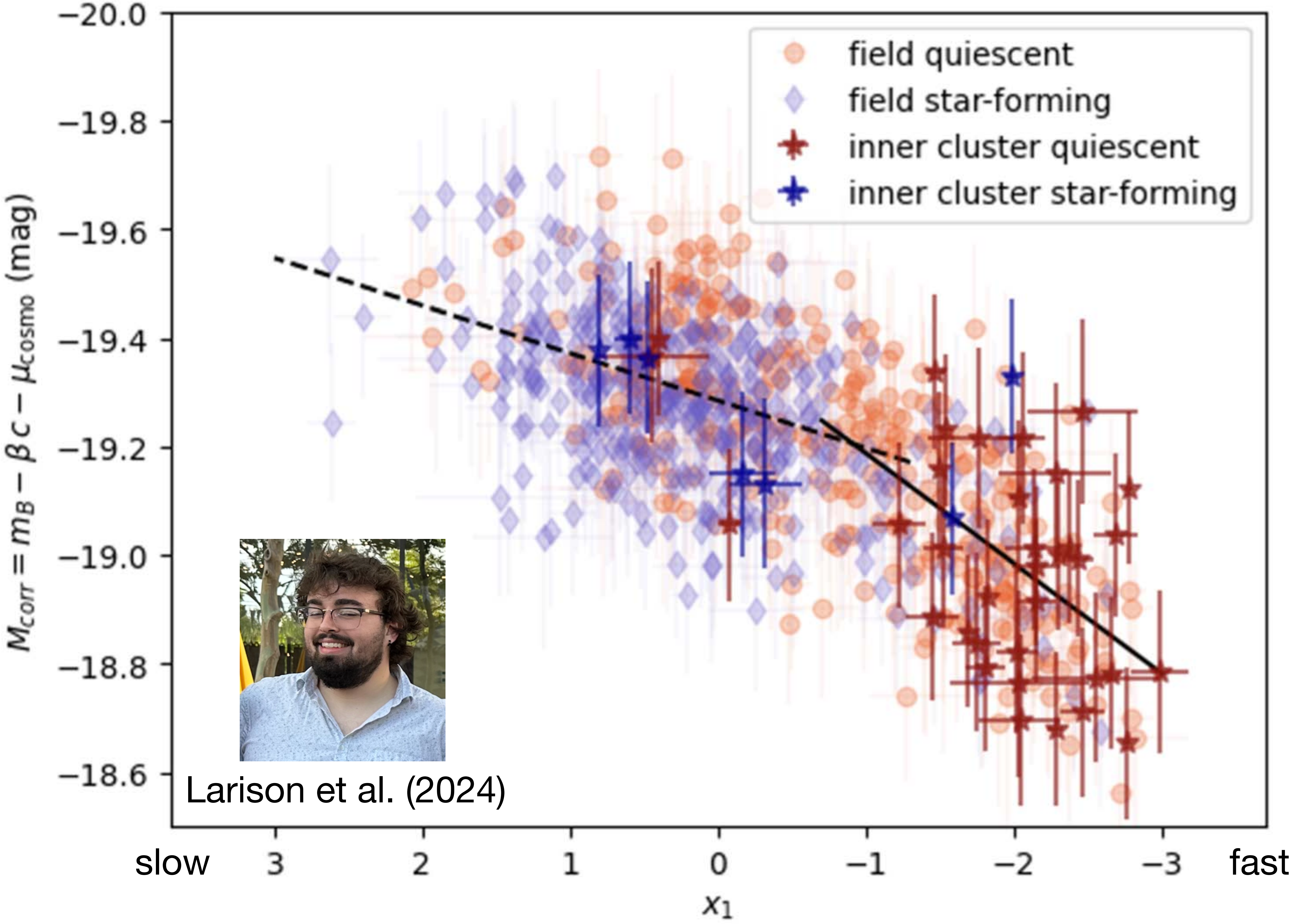
Larison et al. (2024)



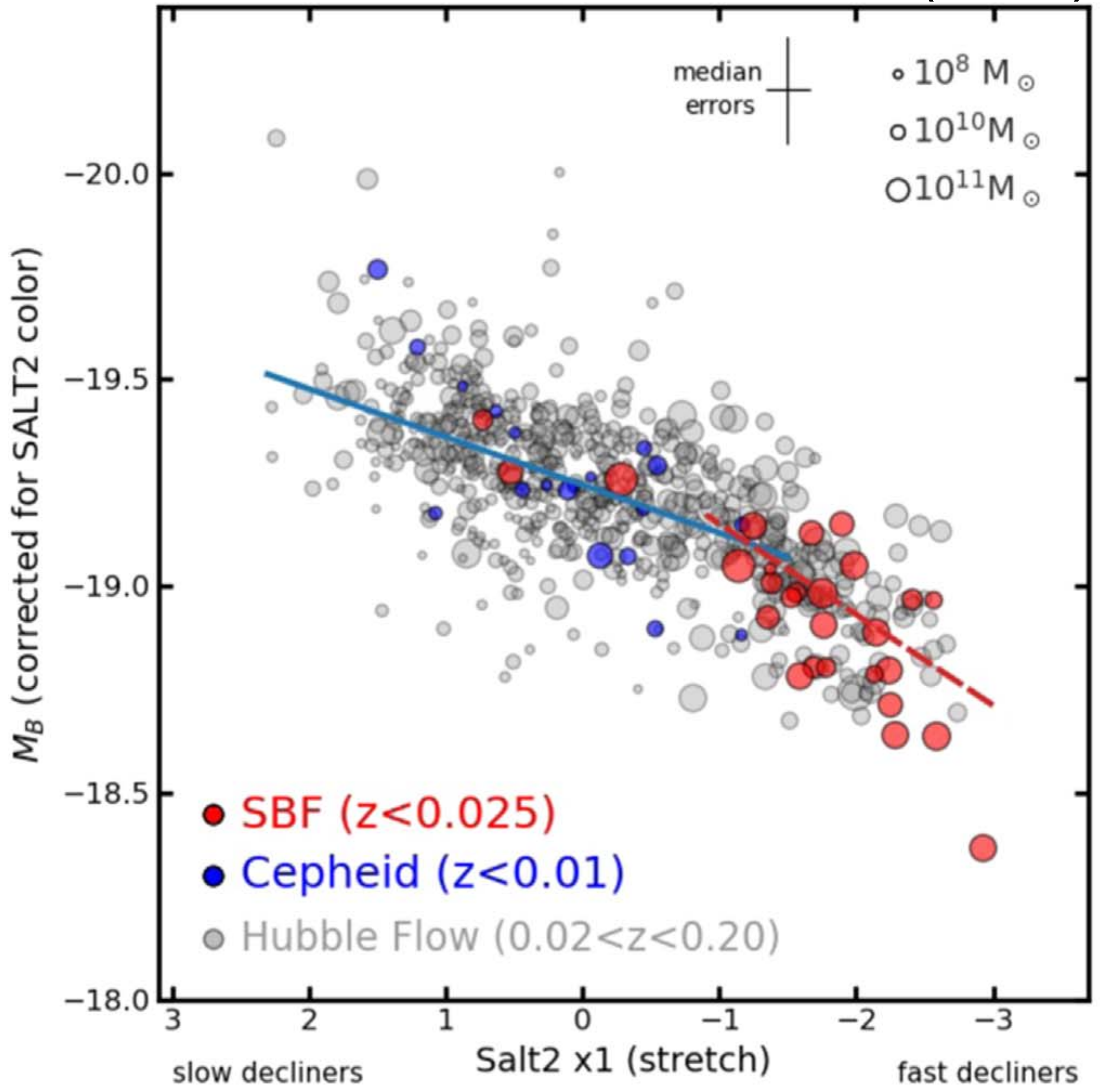


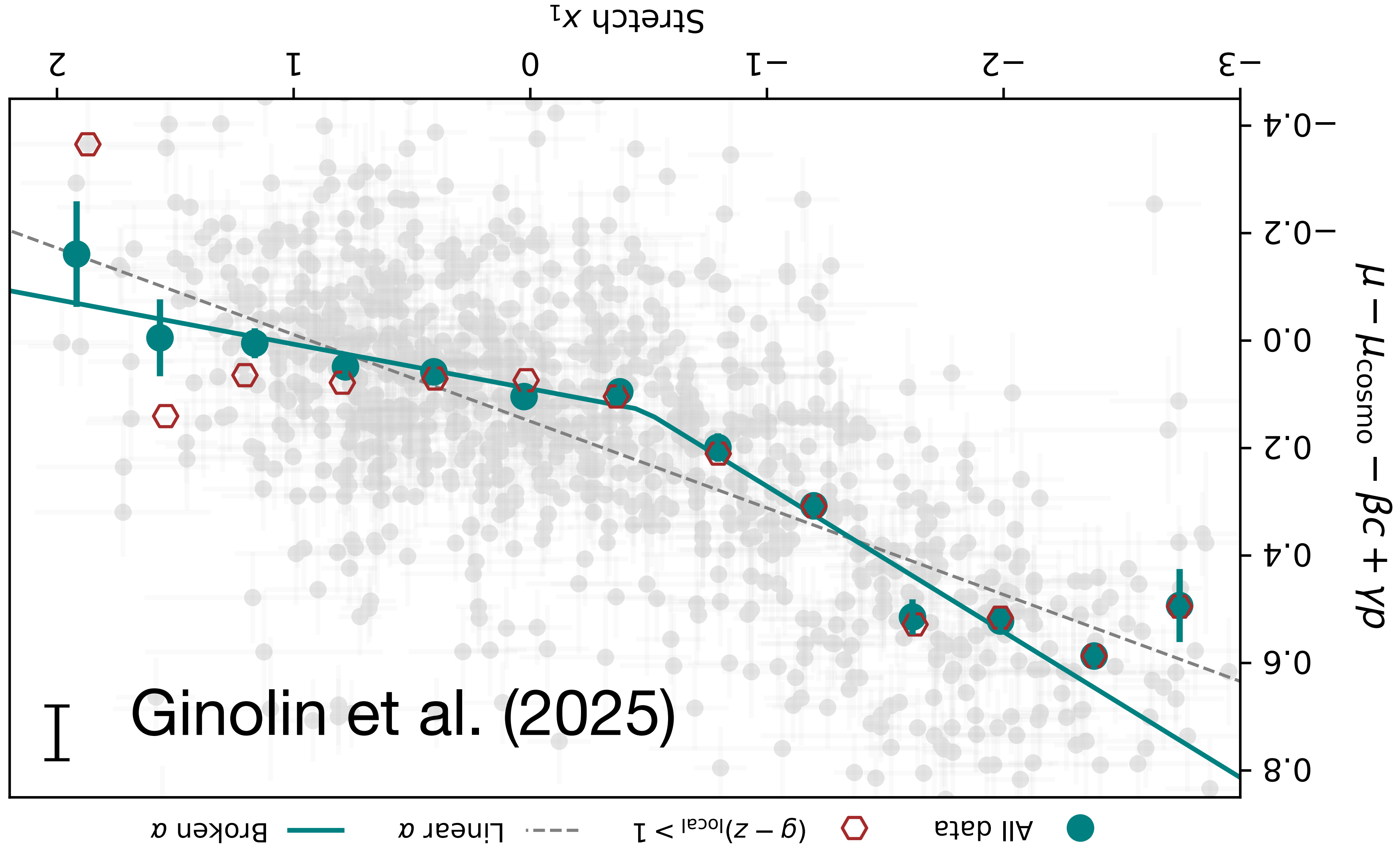
SN Ia standardization: non-linear x_1 correction

light-curve decline (also Si velocity) is an *intrinsic* property of the SN Ia so trends and environmental correlations point to progenitors+explosions



Garnavich et al. (2023)

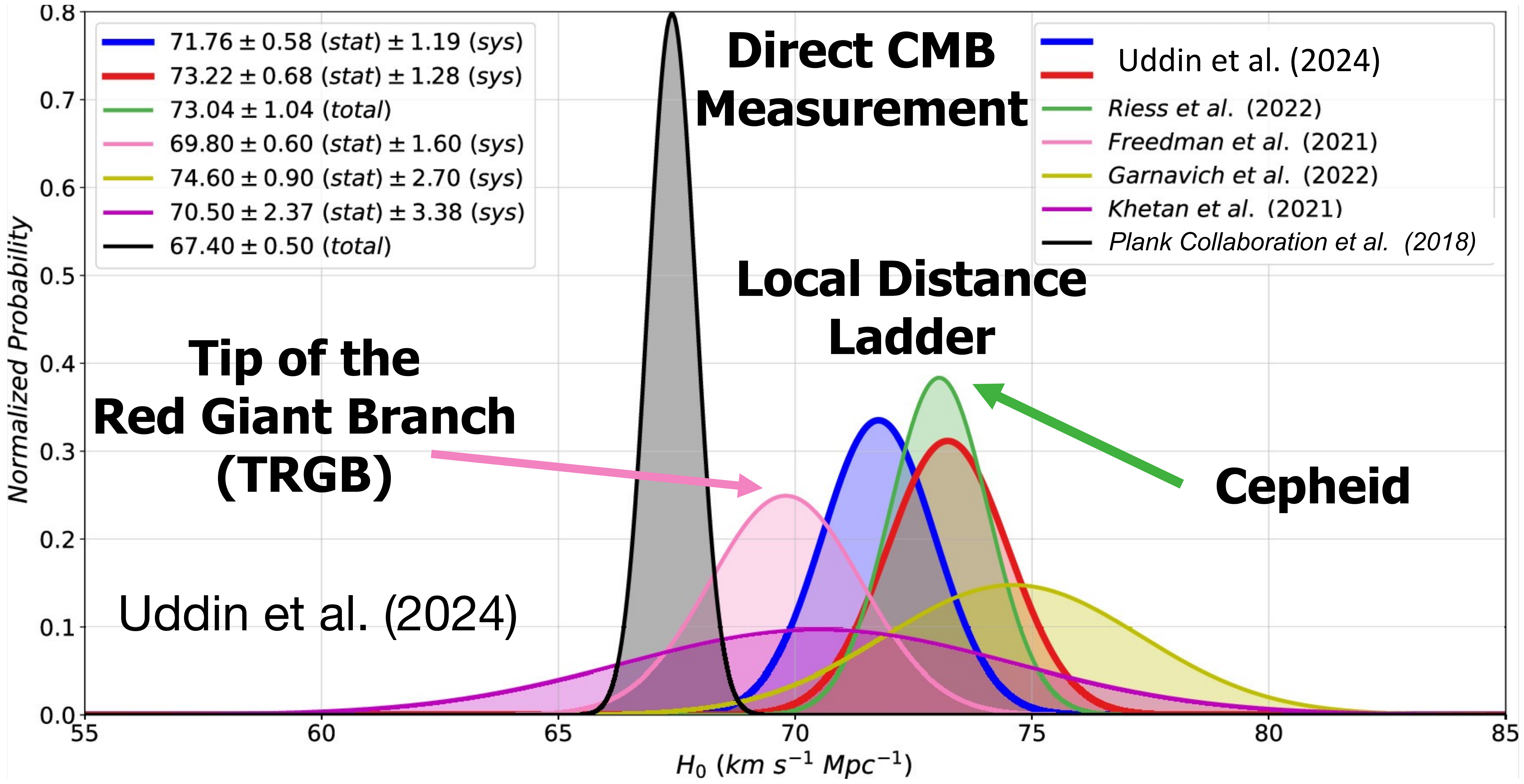


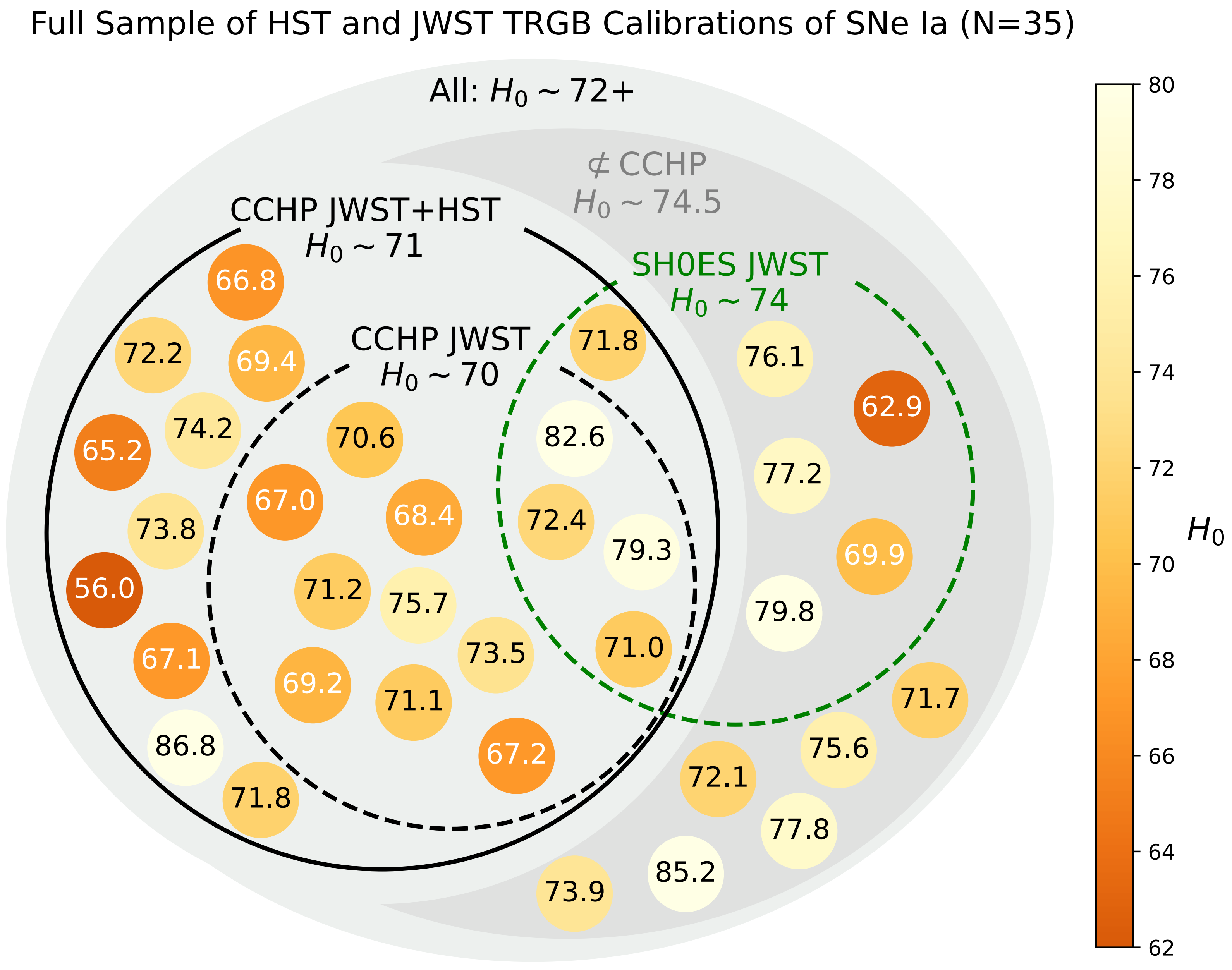


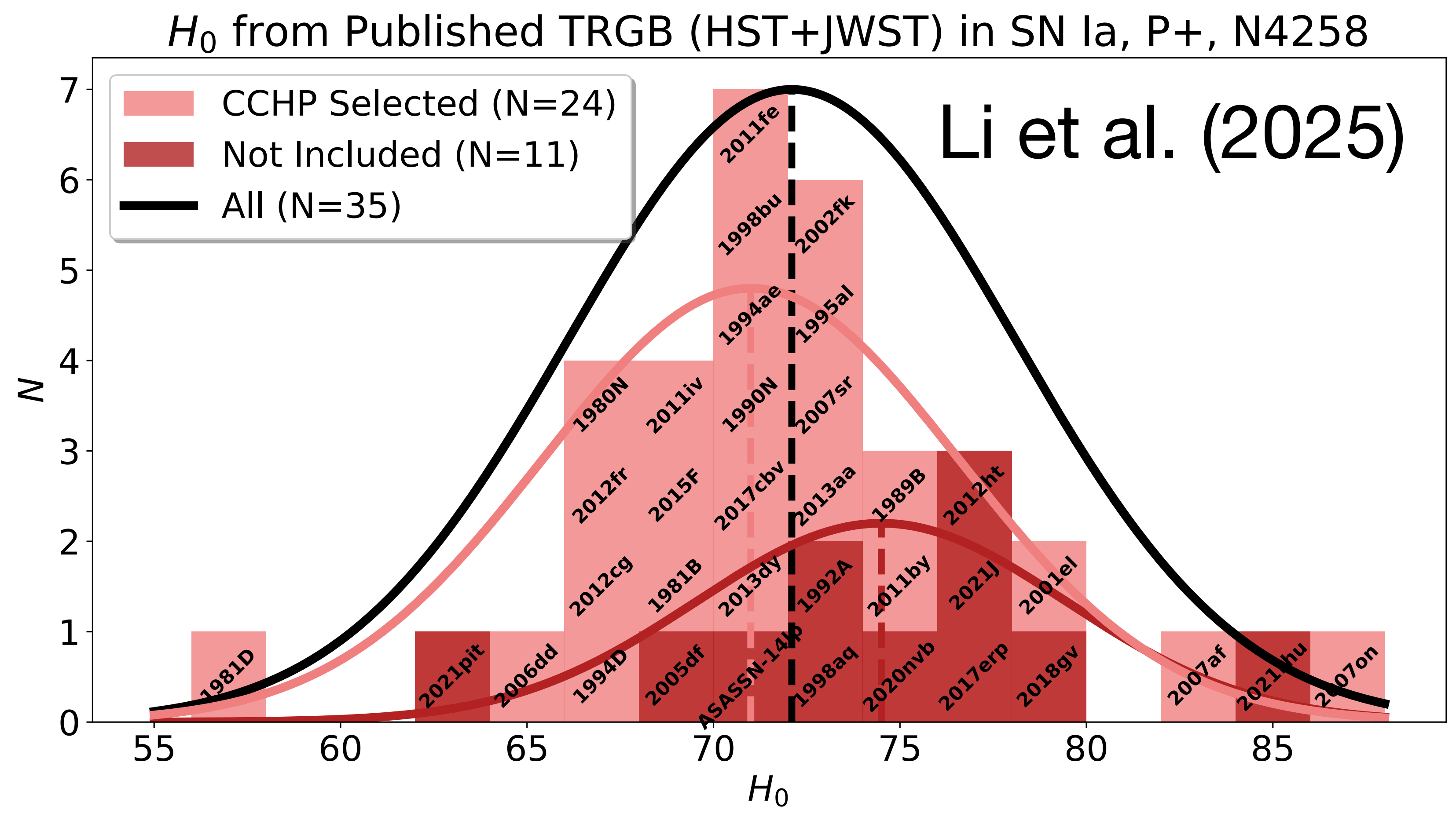
SN Ia: Cepheid vs. TRGB calibration

SN Ia sample choices can make a difference

Many SN Ia calibrator galaxies with both Cepheid and TRGB distances same supernova data means correlations in inferred Hubble constant

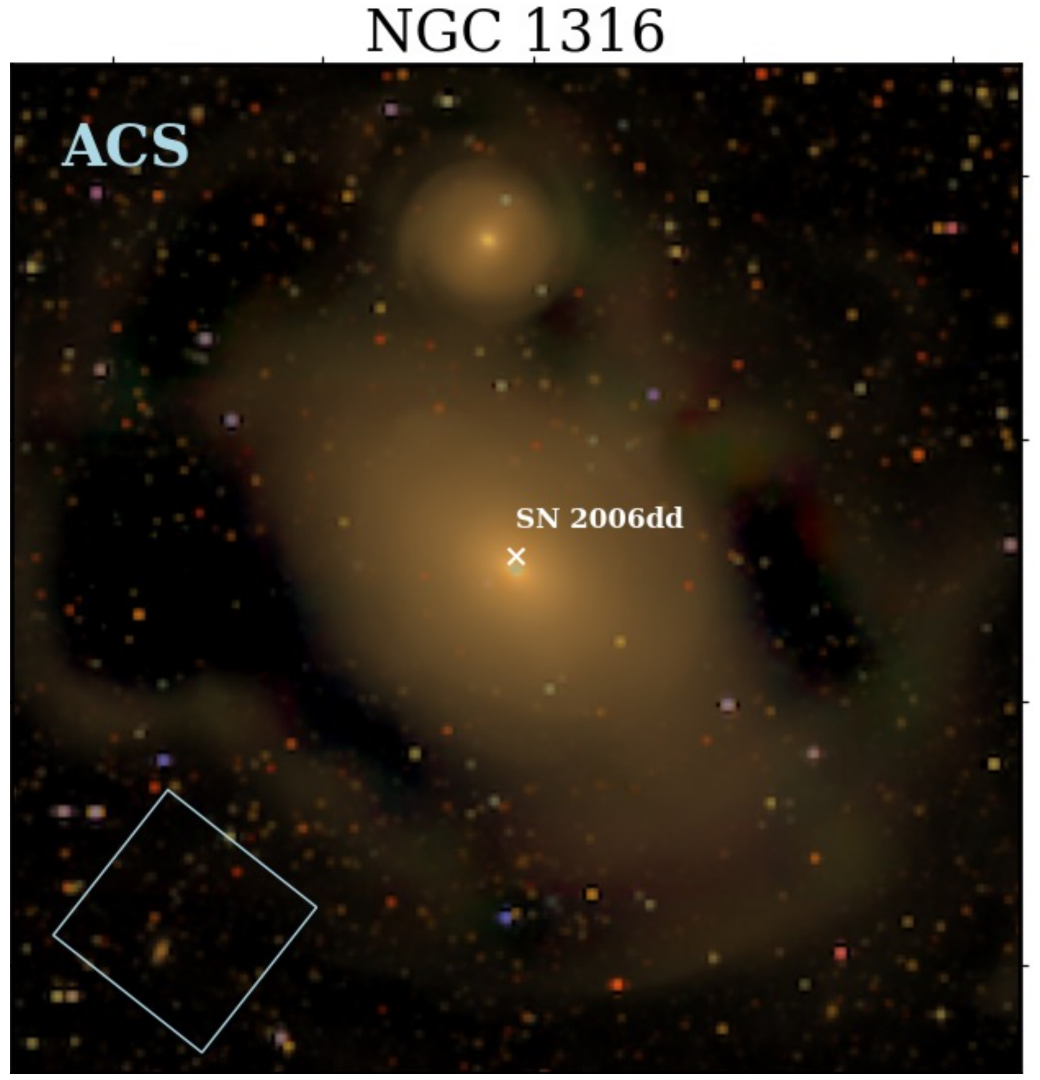


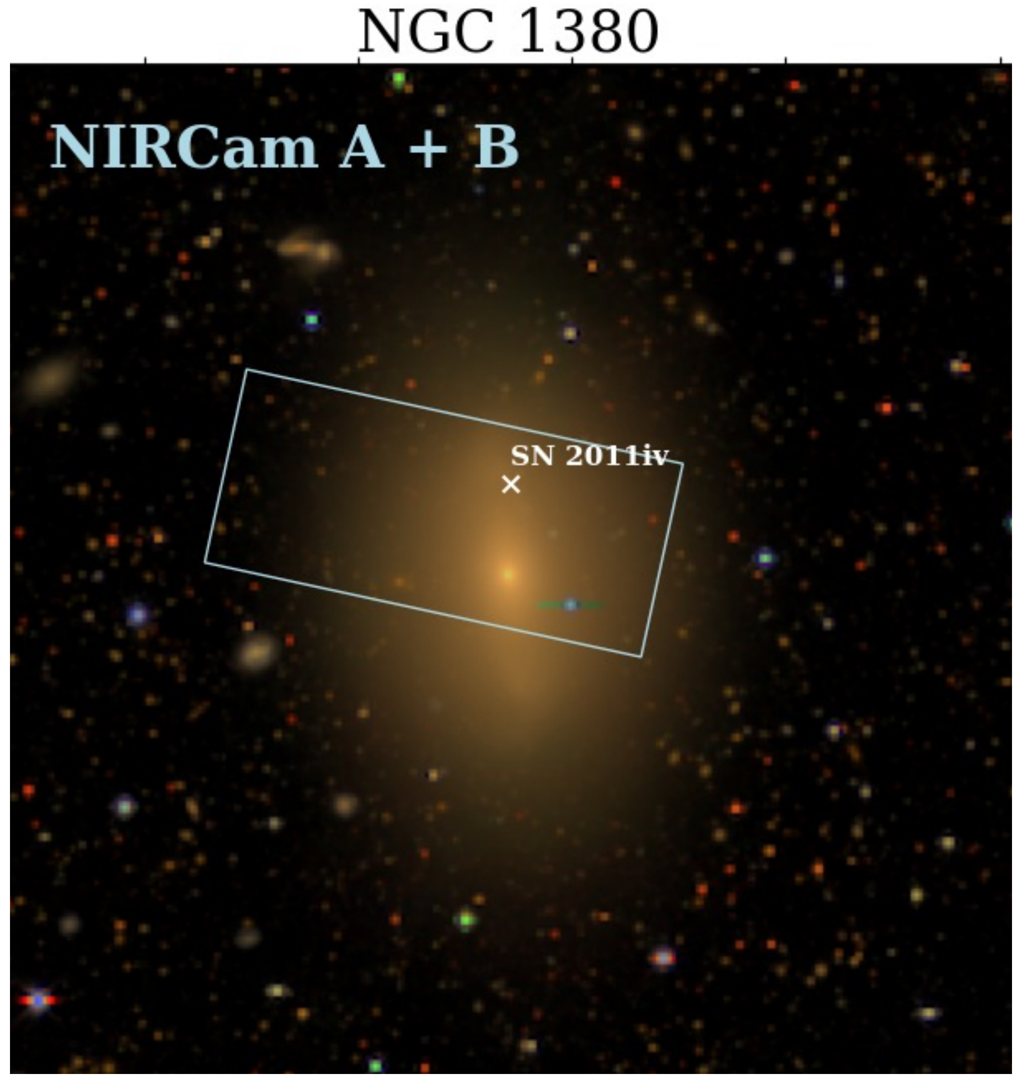


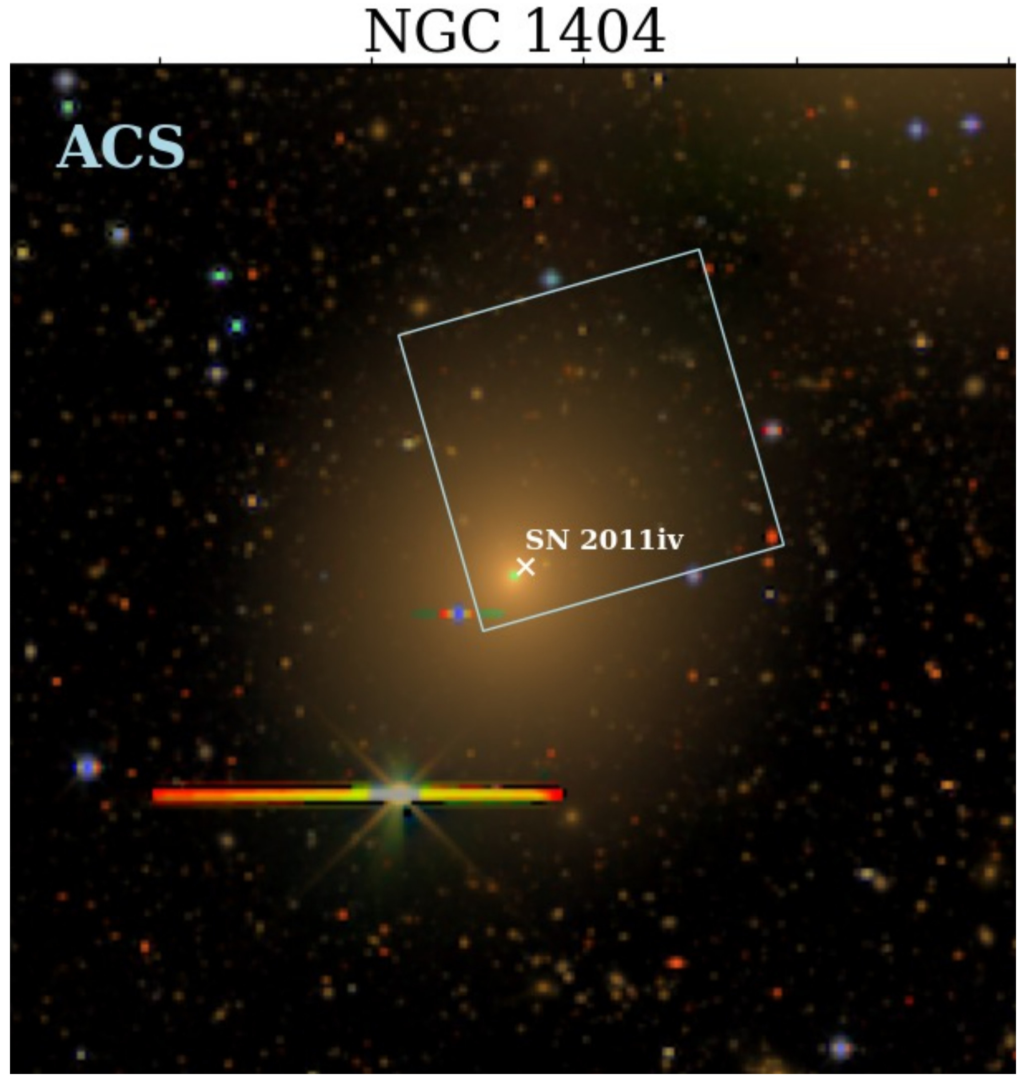


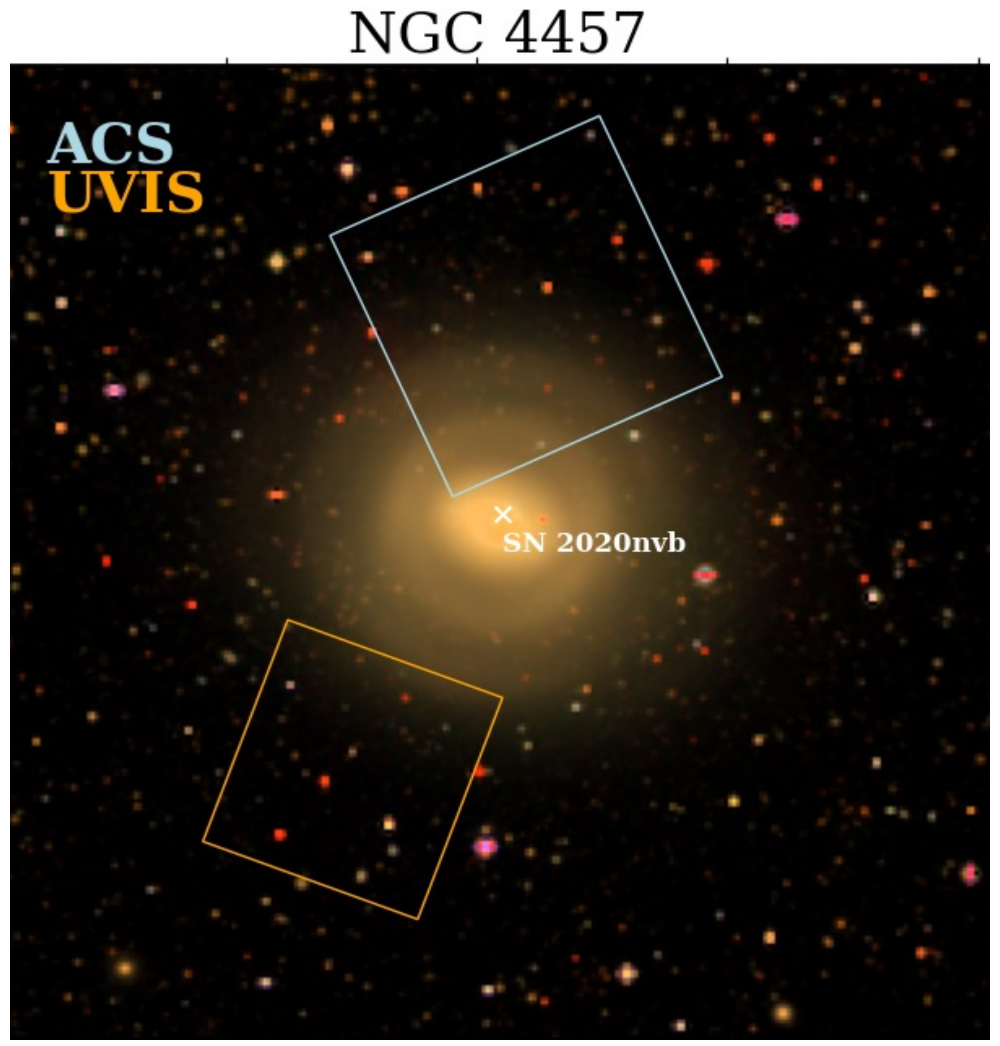
a more independent parallel distance ladder

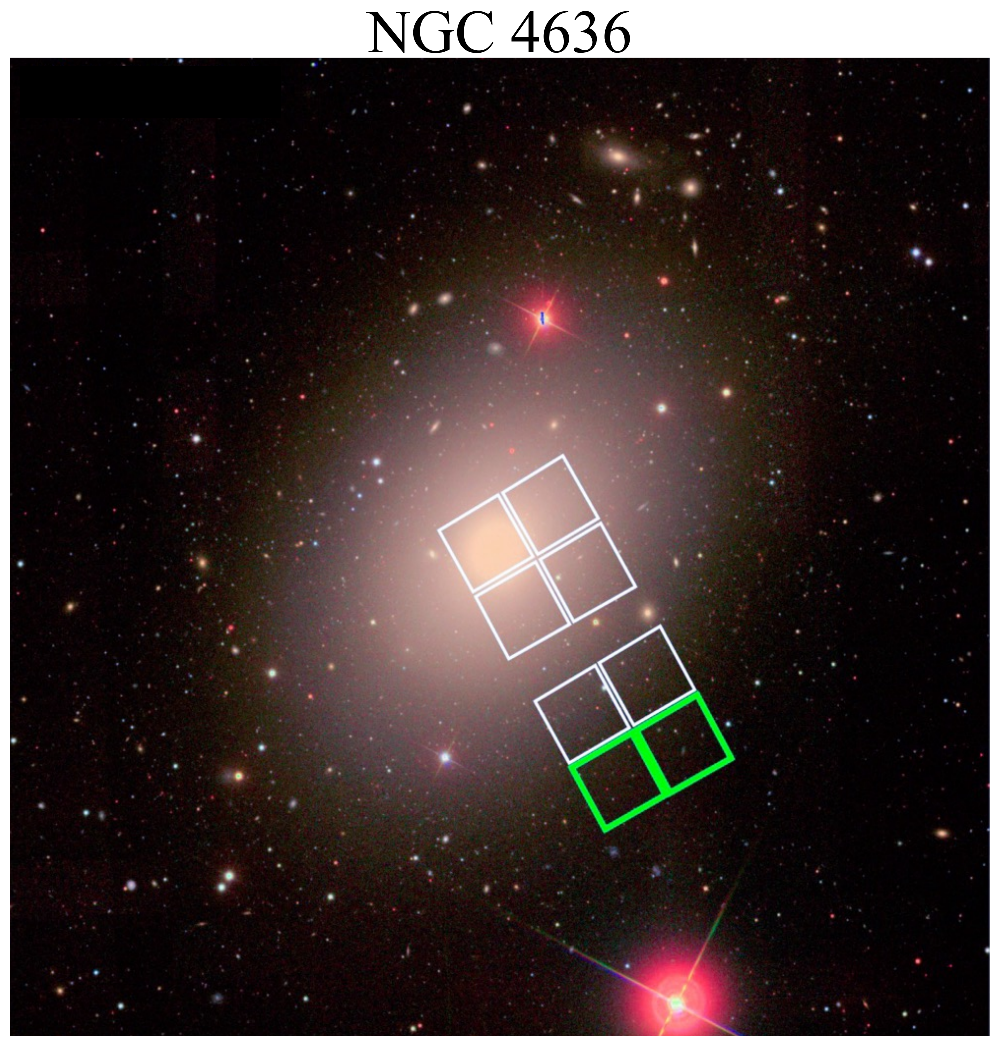
a pilot study: TRGB distances to massive/quiescent SN Ia hosts

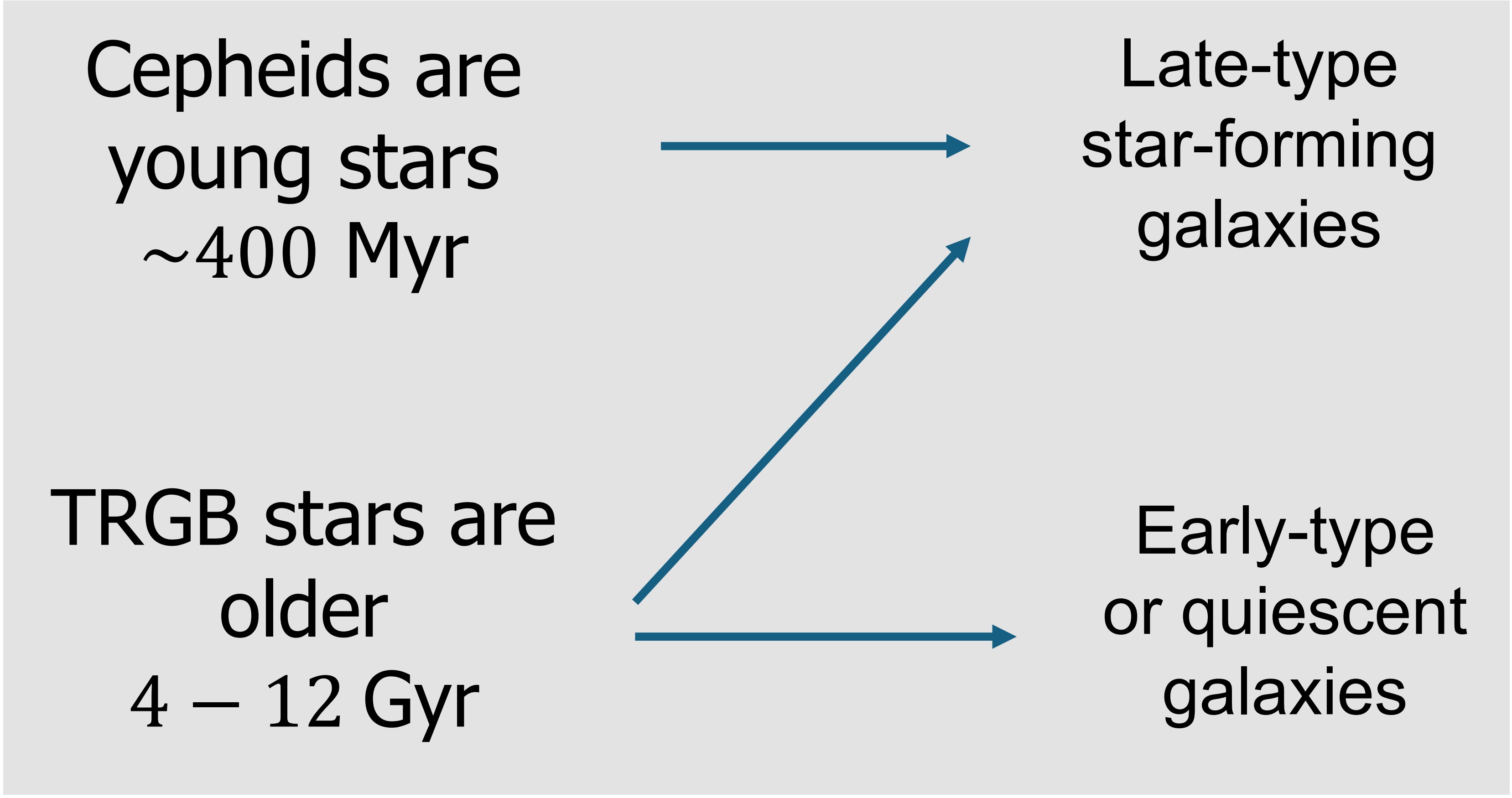






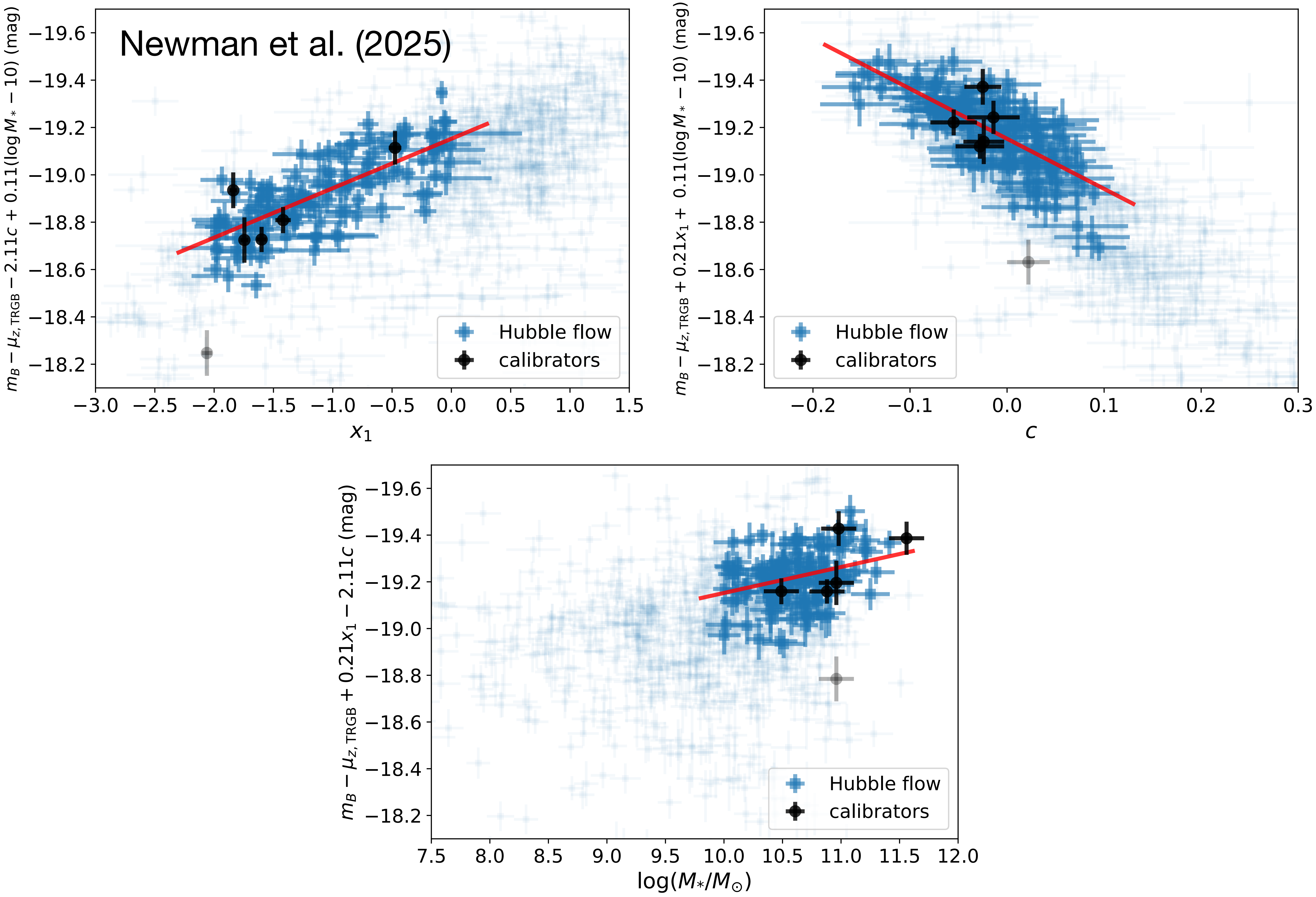


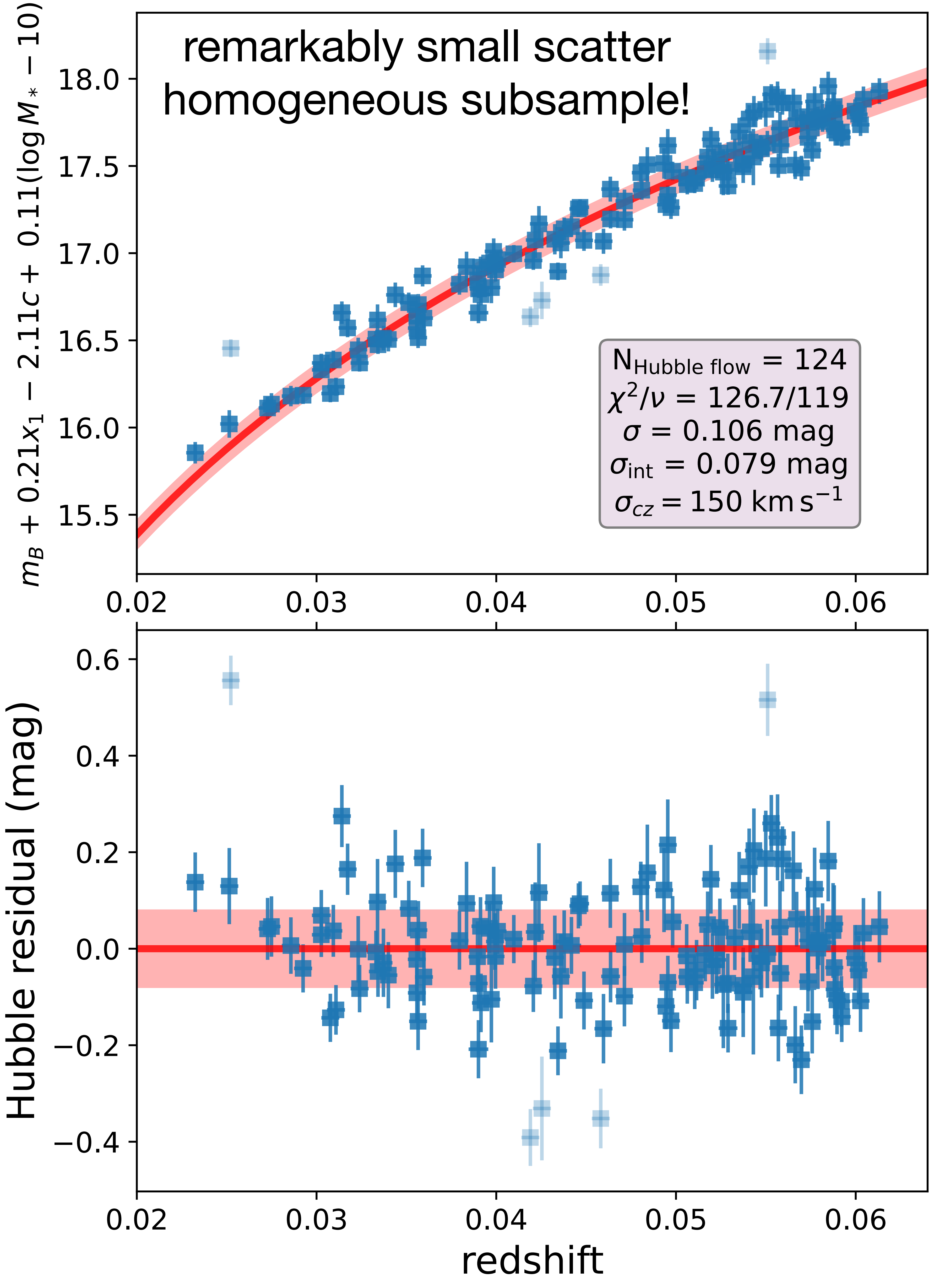




Newman et al. (2025),
Anand et al. (2025)

ZTF DR2 SN Ia Hubble flow sample to match calibrators



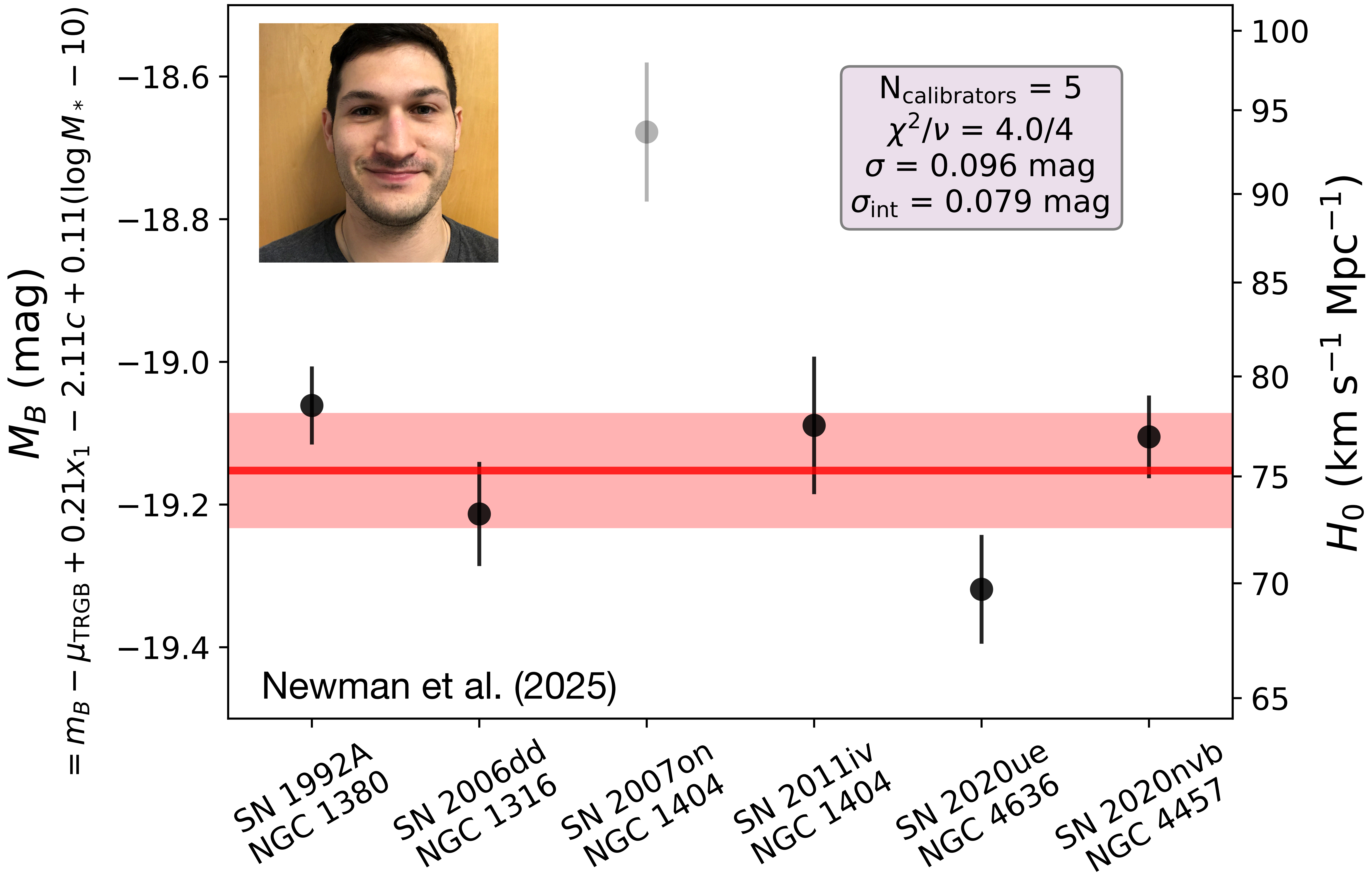


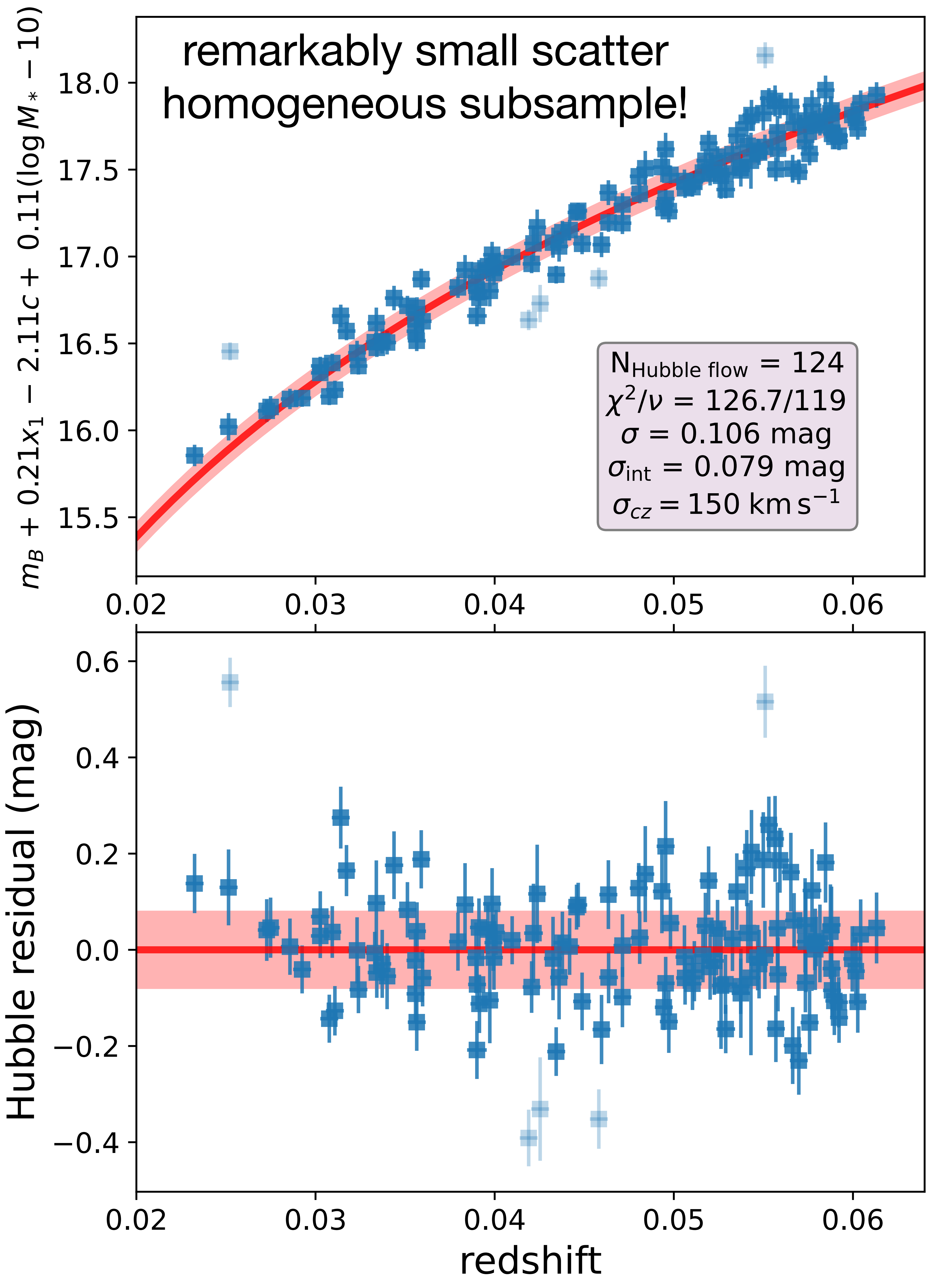
ZTF sample from Rigault et al. (2025)

sample selection: early-type massive hosts, cuts on x_1 and c to match calibrators

redo standardization for this subsample only

early-type TRGB calibrated SN Ia distance ladder





H_0 = 75.3 ± 2.9 km s^{-1} Mpc^{-1}

but note some systematic uncertainty from potential photometric offset between calibrator SN Ia and ZTF SN Ia (method proof of concept)

The Future is Now: Rubin Observatory

large surveys enable homogeneous subsamples and many systematic checks (hosts, age, etc.)

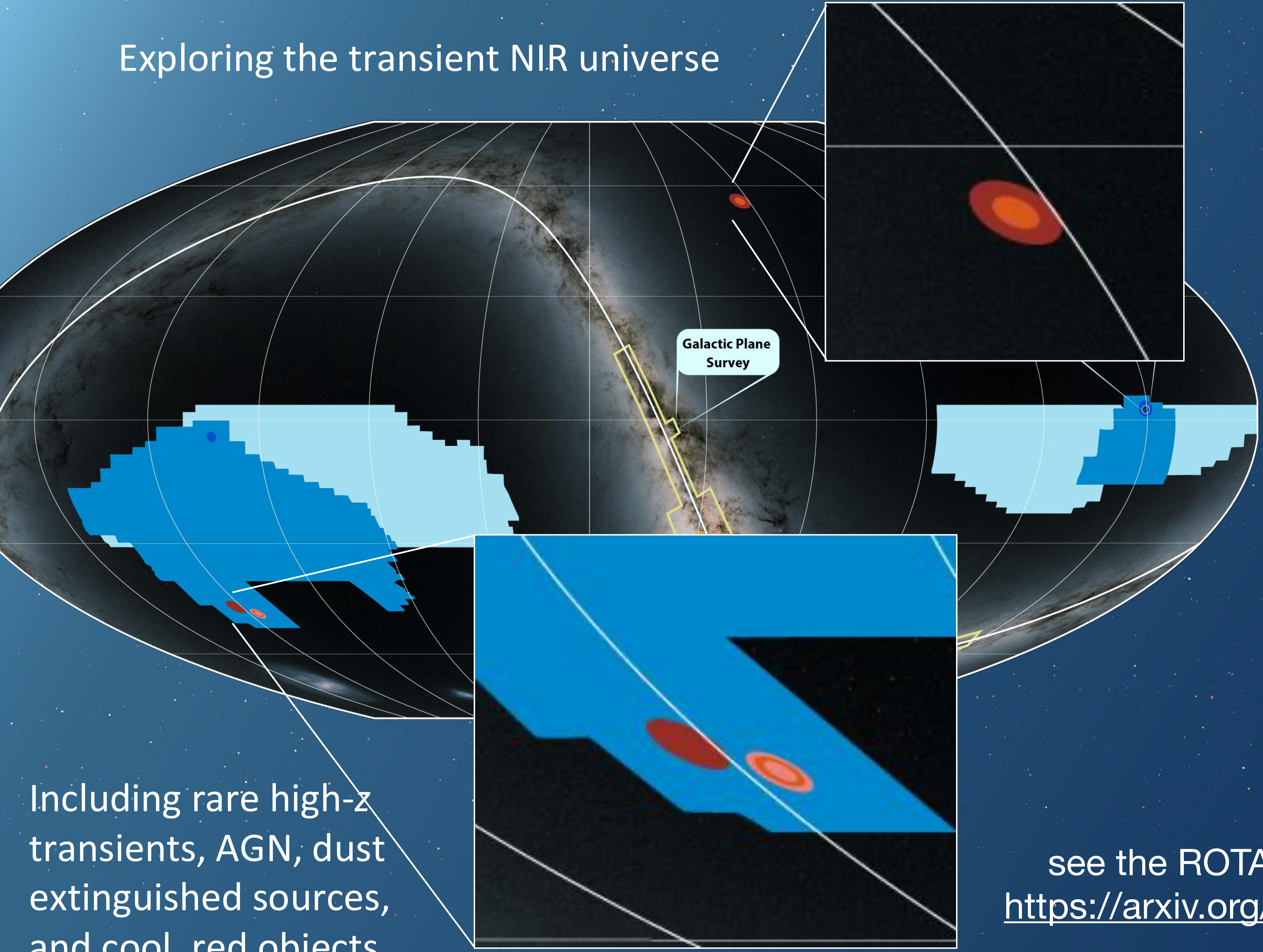
p.s. have a look at the Deep Drilling Fields & new “ocean” DDF observing strategy

The Future is Soon: Nancy Grace Roman Space Telescope

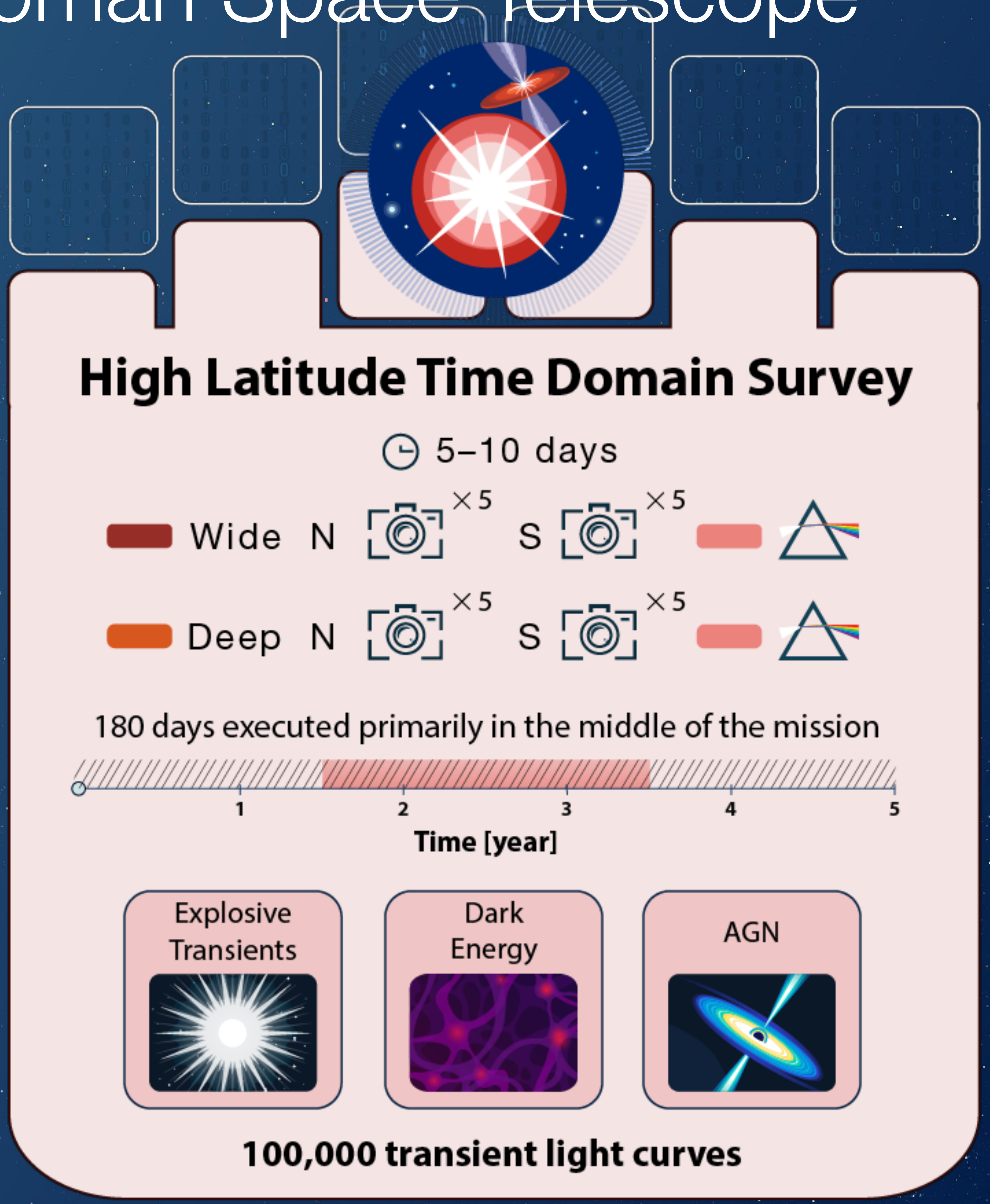
Science for All

ROMAN'S EXTENSIVE SURVEYS

Exploring the transient NIR universe



Including rare high-z transients, AGN, dust extinguished sources, and cool, red objects



see the ROTAC final report:
https://arxiv.org/abs/2505.10574

ROMAN SPACE TELESCOPE

slide from K. Gilbert https://outerspace.stsci.edu/display/AAS/STScI+Town+Hall+-+June+2025,+AAS+246

JWST/MIRI image of NGC 1566
data via JWST GO 2107 (PI: Janice Lee), processing by Judy Schmidt