

Cosmology and Neutrinos with Lensed Supernovae

Sherry Suyu

Technical University of Munich
Max Planck Institute for Astrophysics

Precision Cosmology with Strong Lensing Time Delays Conference

August 3, 2026 @ University of Tokyo

Key questions



Lensed
supernova



Cosmology

How fast is the Universe expanding?



Supernova

What is the rate of supernovae, and the formation rate of black holes?

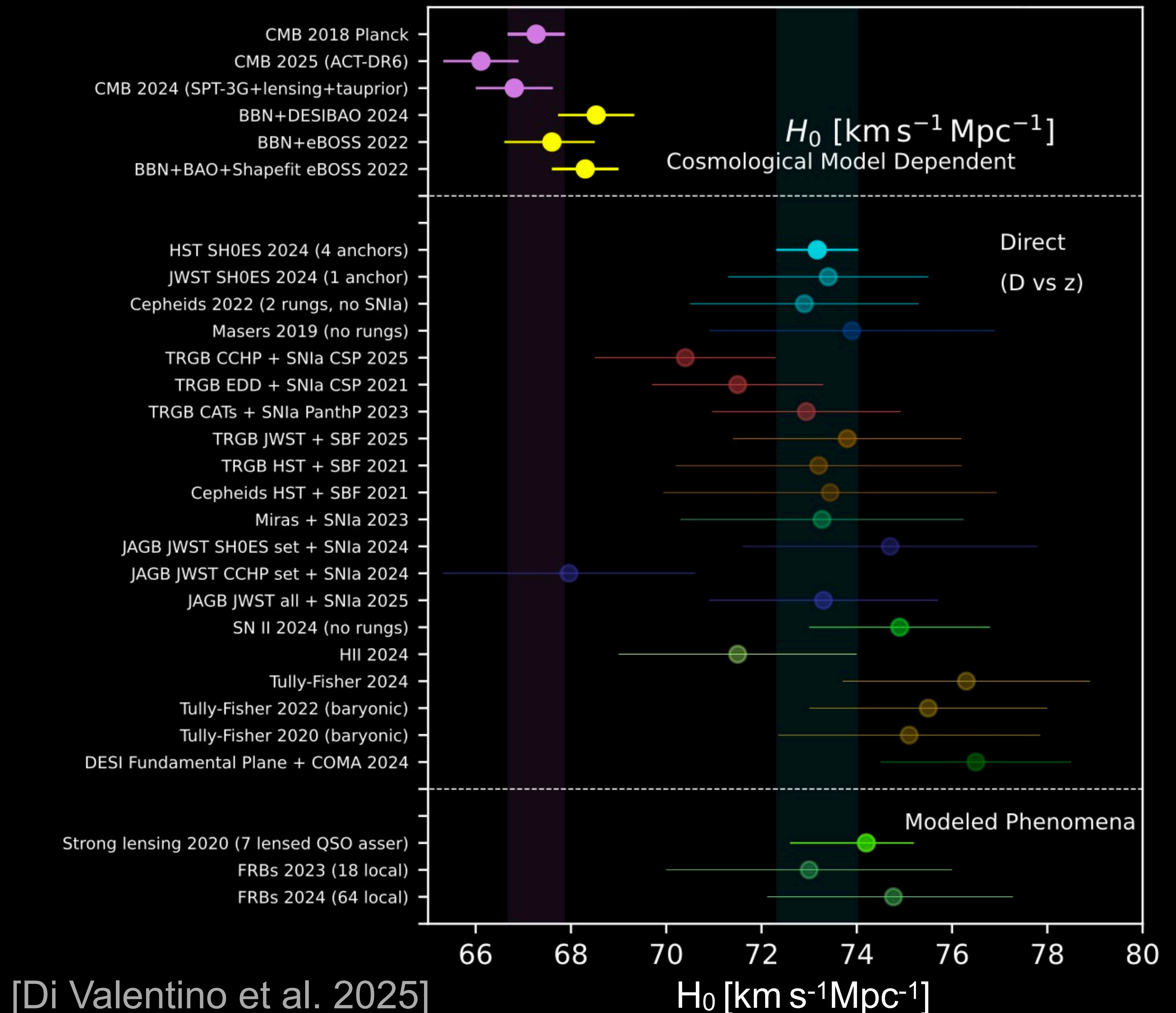
Strongly lensed supernova



Cosmology

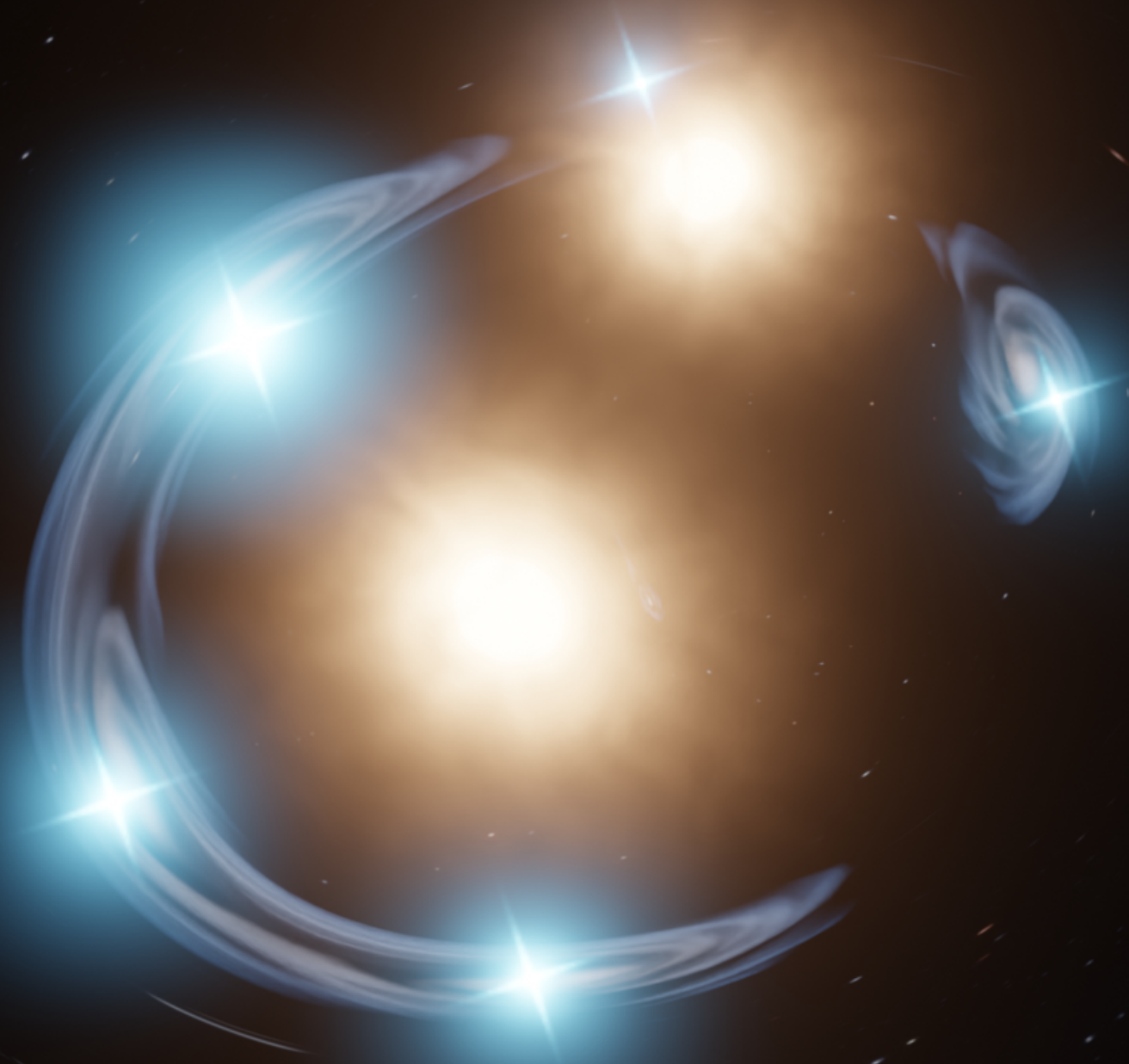
H_0 tension

- $\sim 6\sigma$ tension between Planck collaboration (2020) and SH0ES [Riess et al. 2025]
- New physics beyond the standard flat Λ CDM model?
- Need independent measurements of H_0



Cosmology with lensing delays

[Refsdal 1964]



[credit: E. Mamuzic]

Time delay:

$$t = \frac{1}{c} D_{\Delta t} \phi_{\text{lens}}$$

Time-delay
distance:

$$D_{\Delta t} \propto \frac{1}{H_0}$$

Obtain from
lens mass
model

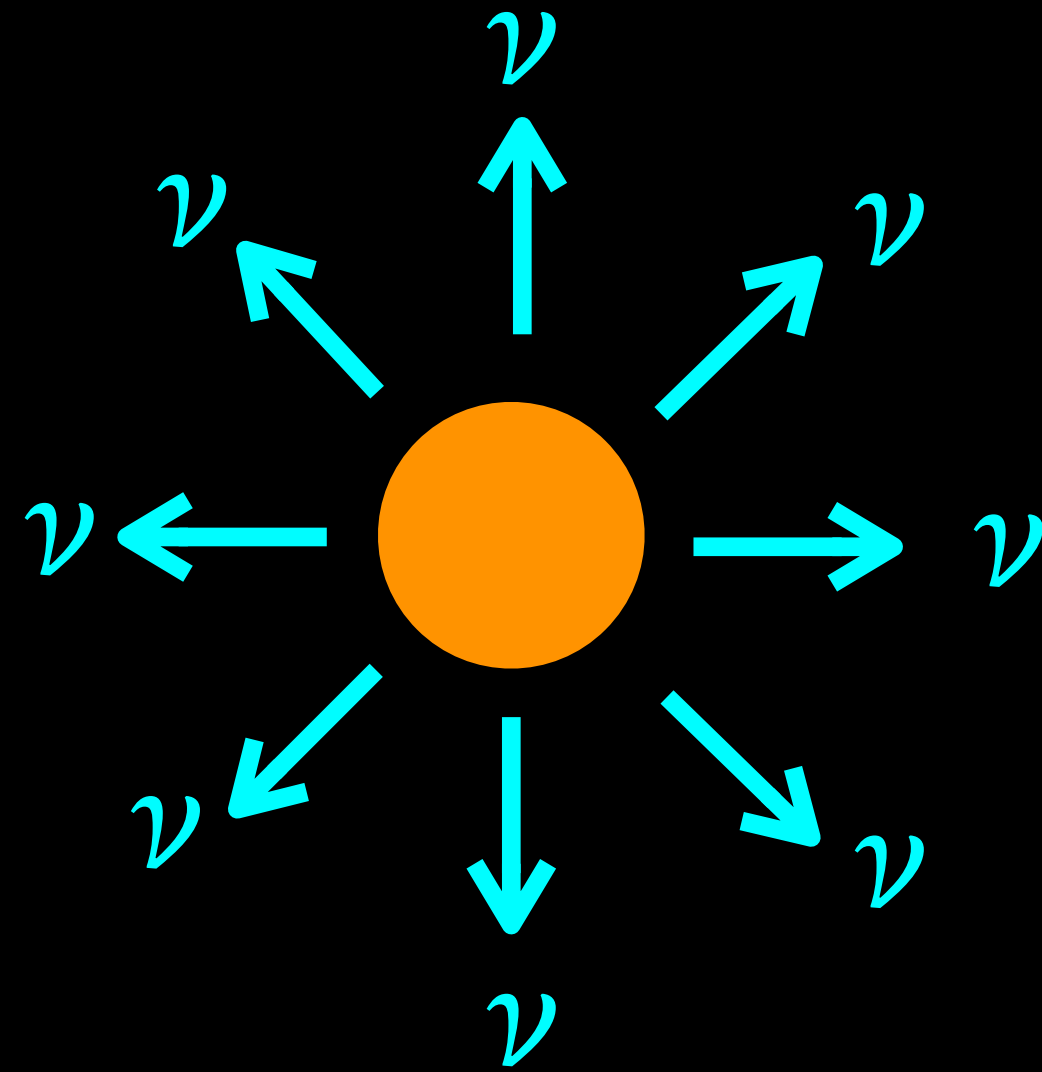
To measure $D_{\Delta t}$ and H_0 , need:

- (1) time delays
- (2) lens mass model
- (3) mass along line of sight

Supernova neutrinos

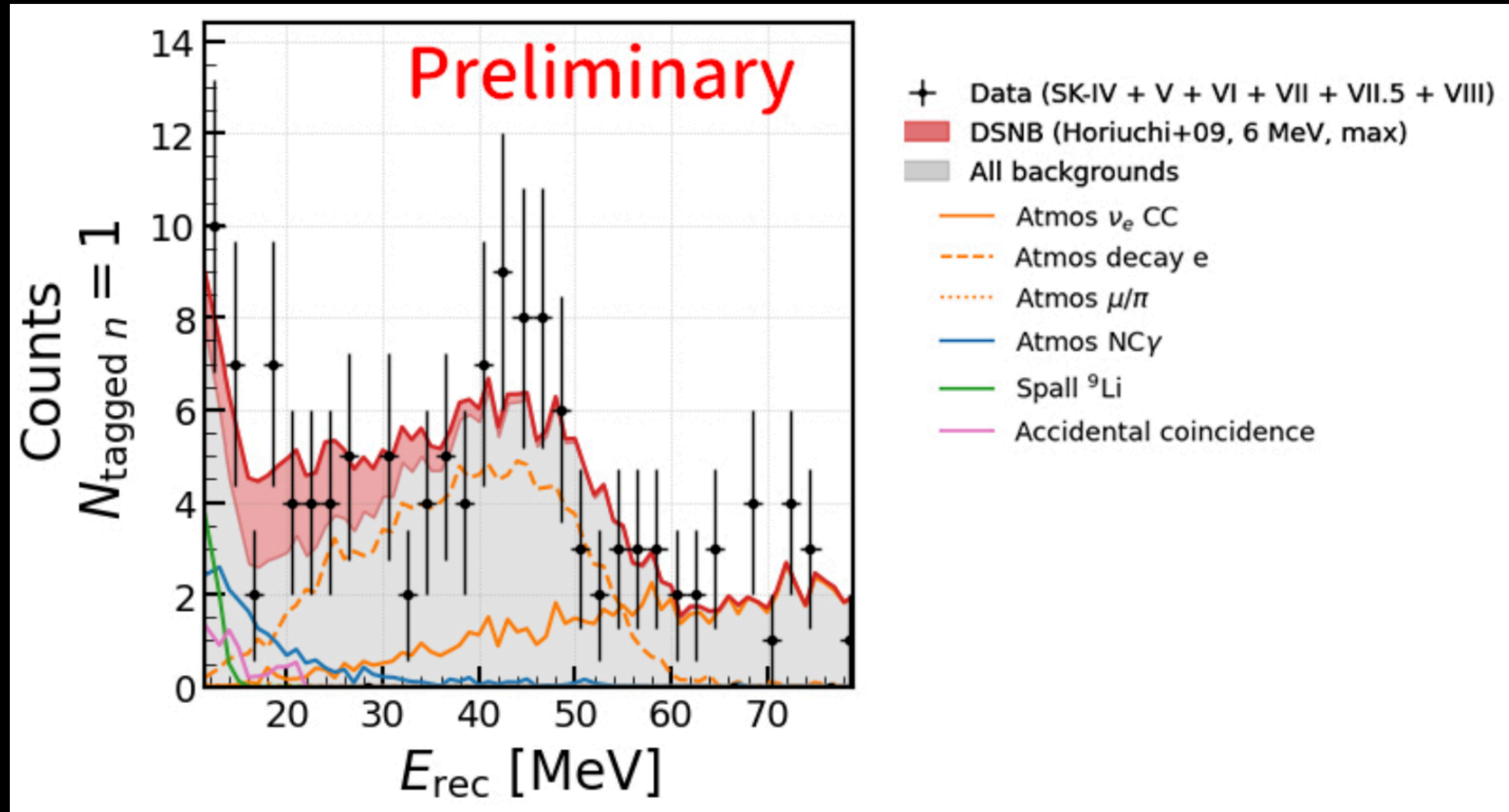
Diffuse Supernova Neutrino Background (DSNB)

Observations from Super-Kamiokande Collaboration



stellar core-collapse (CC)
produces neutrinos
→ supernova (SN), or
→ black hole

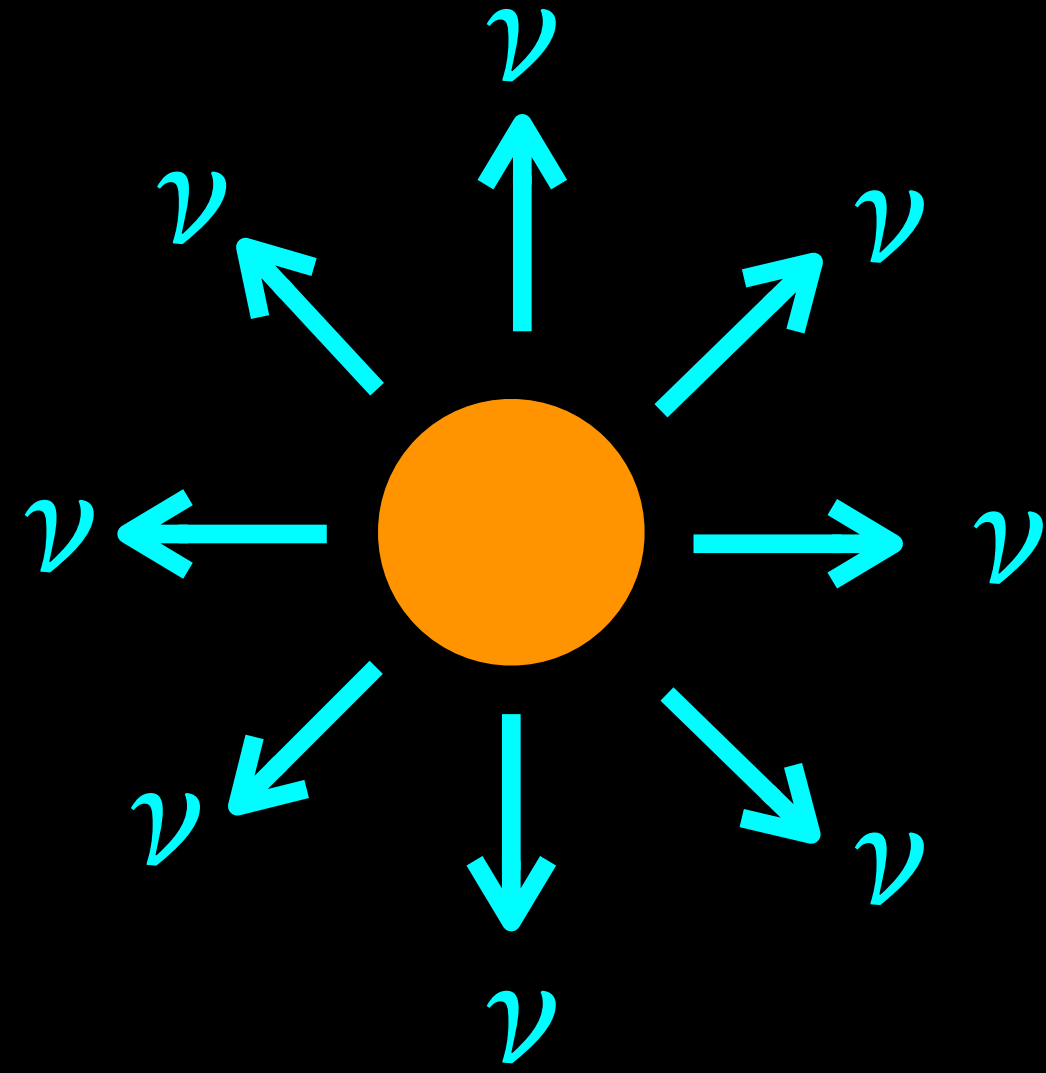
neutrinos from core-collapse
form a diffuse background:
DSNB



[source: Kamioka Observatory, ICRR, University of Tokyo website:
<https://www-sk.icrr.u-tokyo.ac.jp/en/news/detail/1258>]

- First Indication of DSNB from Super-Kamiokande
- 2.6σ significance

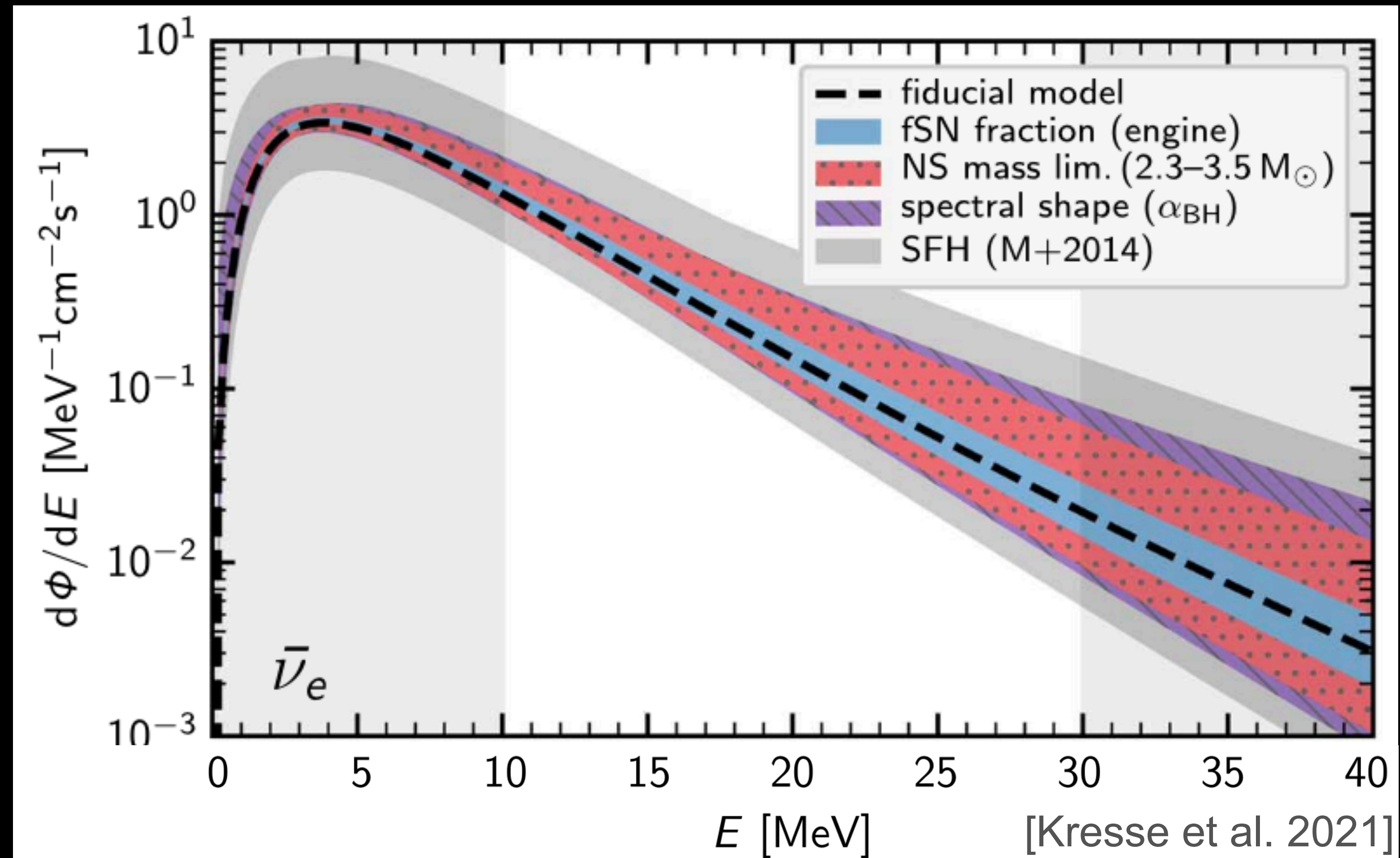
Diffuse Supernova Neutrino Background (DSNB)



stellar core-collapse (CC)
produces neutrinos
→ supernova (SN), or
→ black hole

neutrinos from core-collapse
form a diffuse background:
DSNB

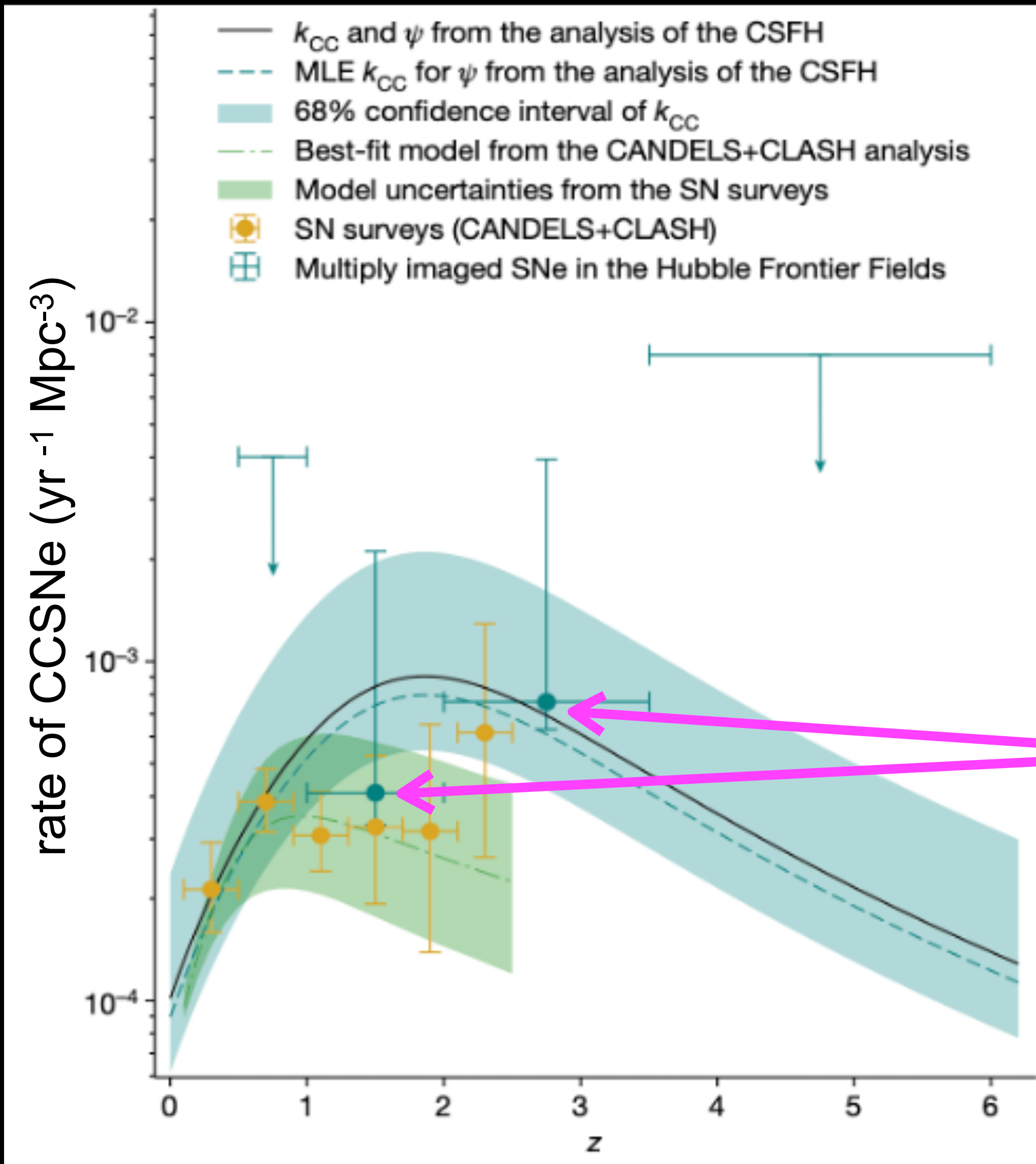
Theoretical model from core-collapse simulations



→ Rate of SNe: a dominant source of uncertainty

Rate of supernovae

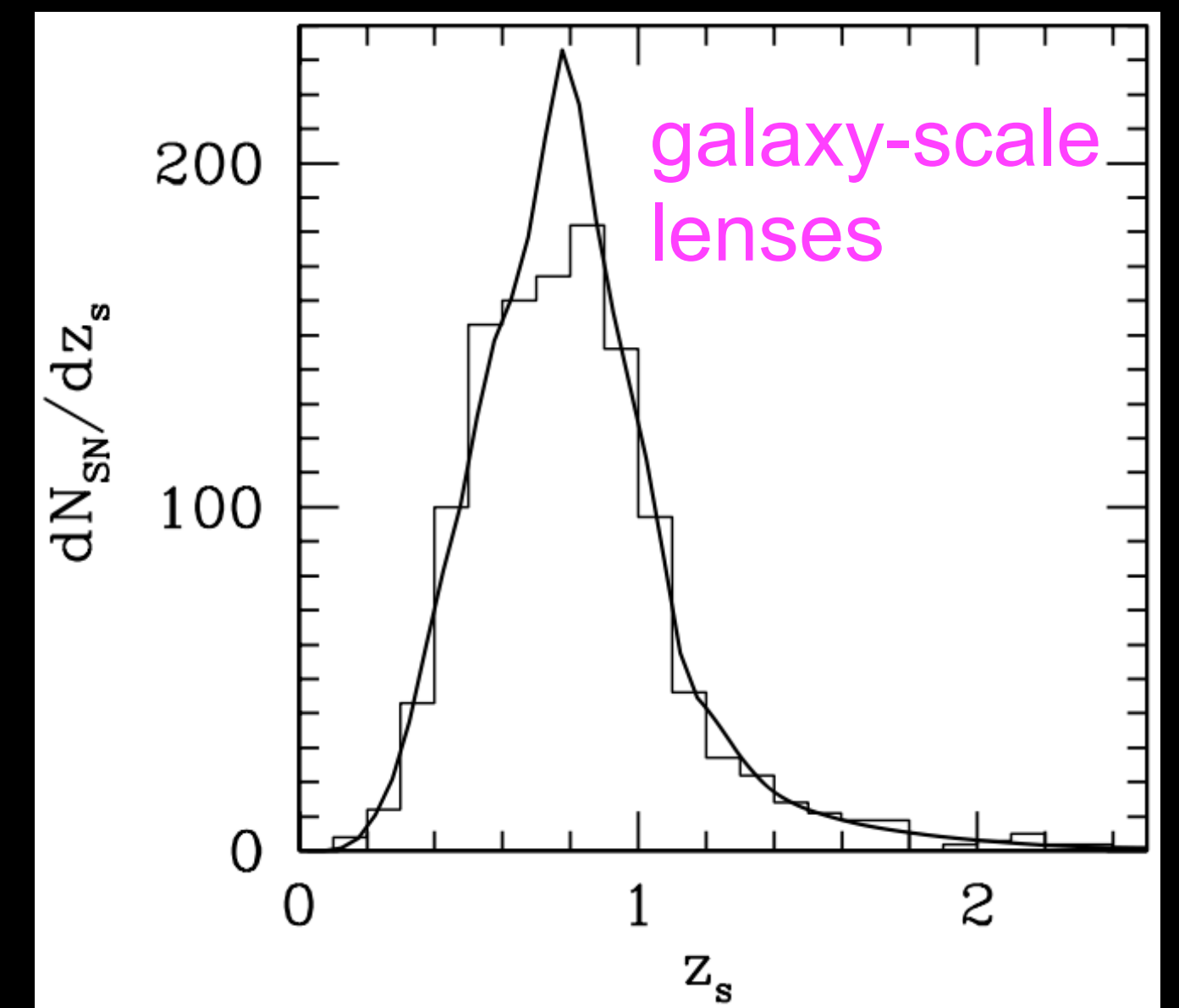
- Rate of SNe: a dominant source of uncertainty
- need better measurements of core-collapse SN rates between redshifts $z \sim 0.5$ to $z \sim 1.5$
- Rubin LSST expected to detect $\sim 10^4/\text{yr}$ core-collapse SNe up to redshift $z \sim 1$



[Chen et al. 2022]

strongly lensed
SNe extend
redshifts to
 $z \gtrsim 0.5$

JWST SNe also
extend to $z \gtrsim 1$

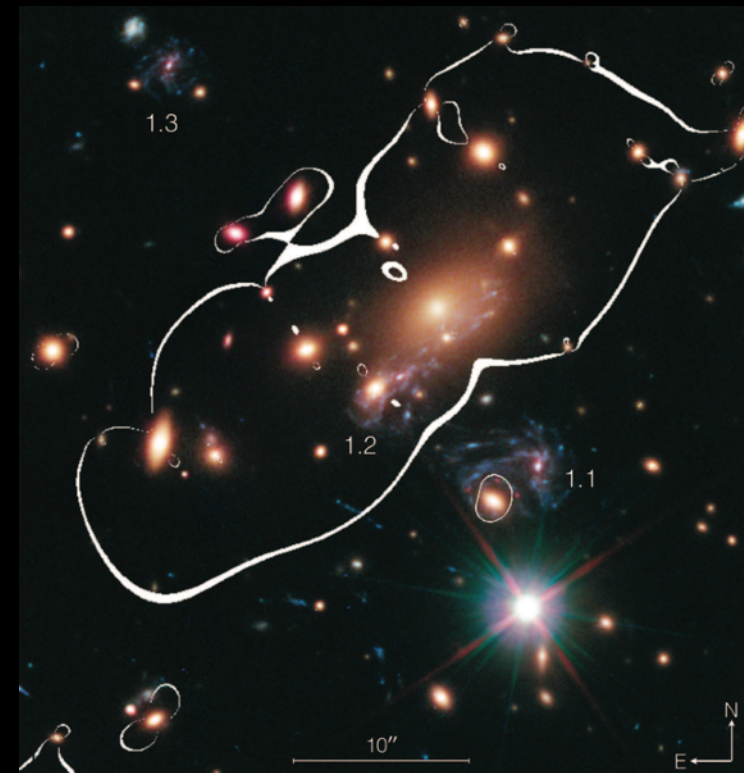


[Oguri & Marshall 2010] 10

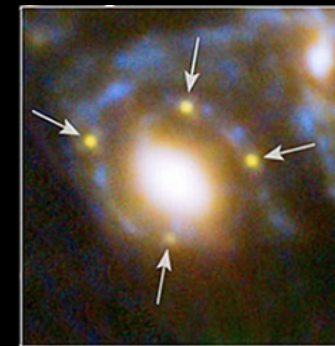
Strongly lensed SNe

Strongly lensed supernovae (SNe)

4 galaxy scale systems
6 cluster-scale systems



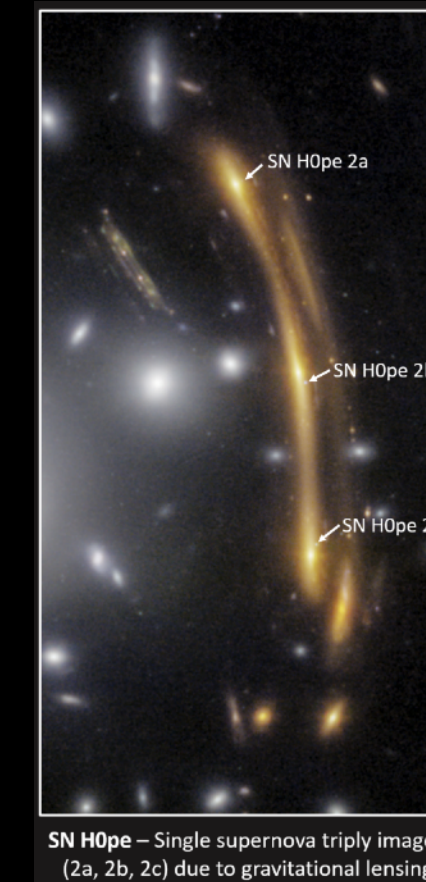
SN
Refsdal



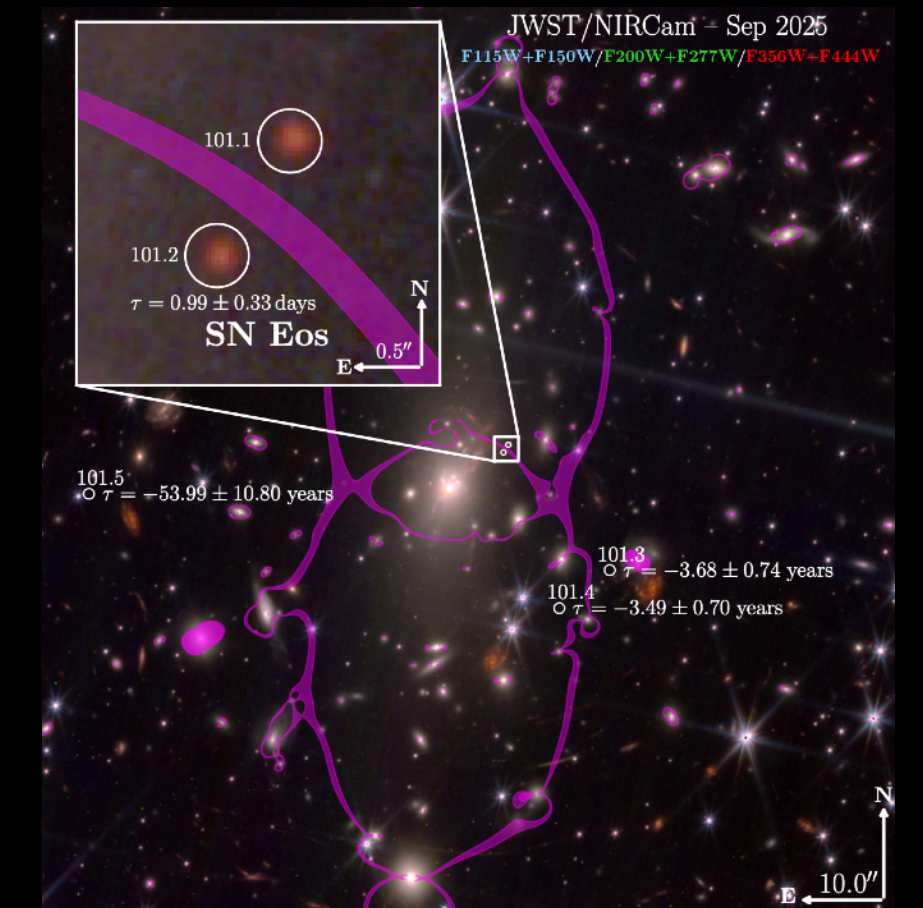
SN
Requiem



SN Zwicky



SN H0pe



SN Eos

1964

2016

2022

2025

2026

2014

2021

2023

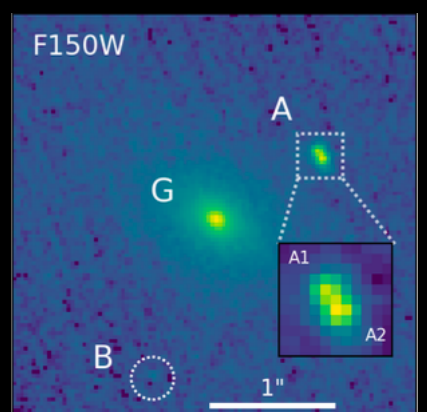
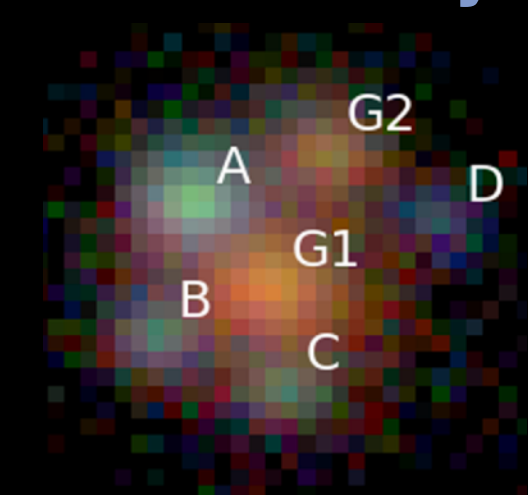
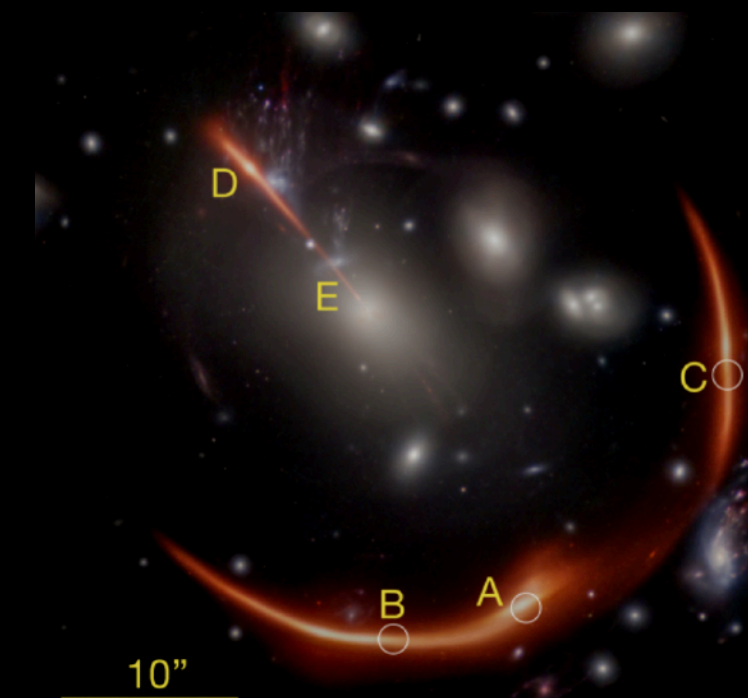
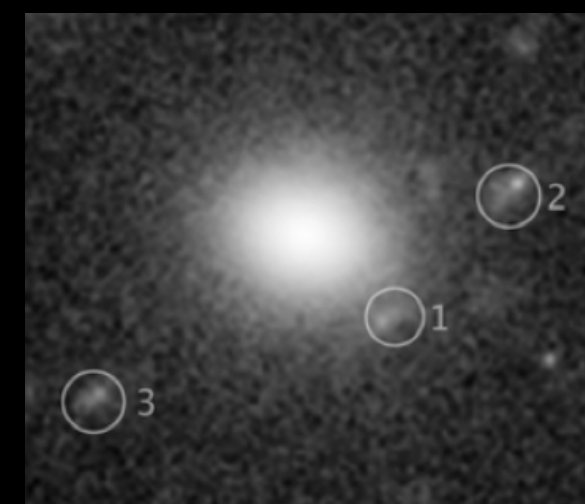
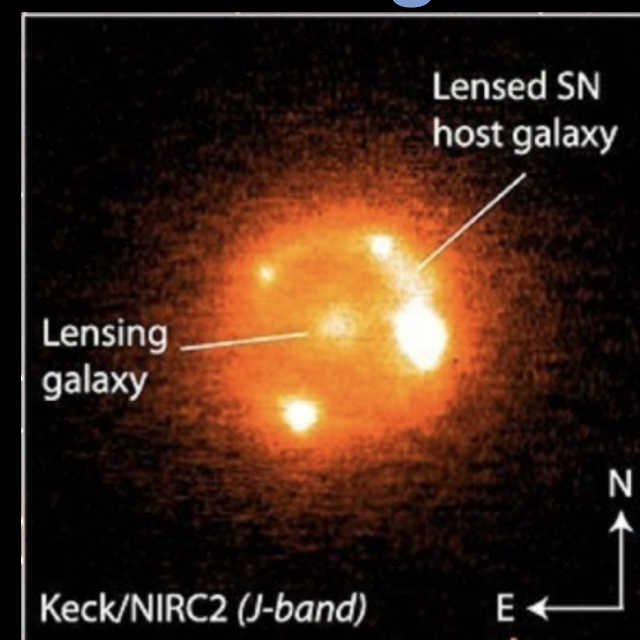
iPTF16geu

Abell 370

SN Encore

SN Winny

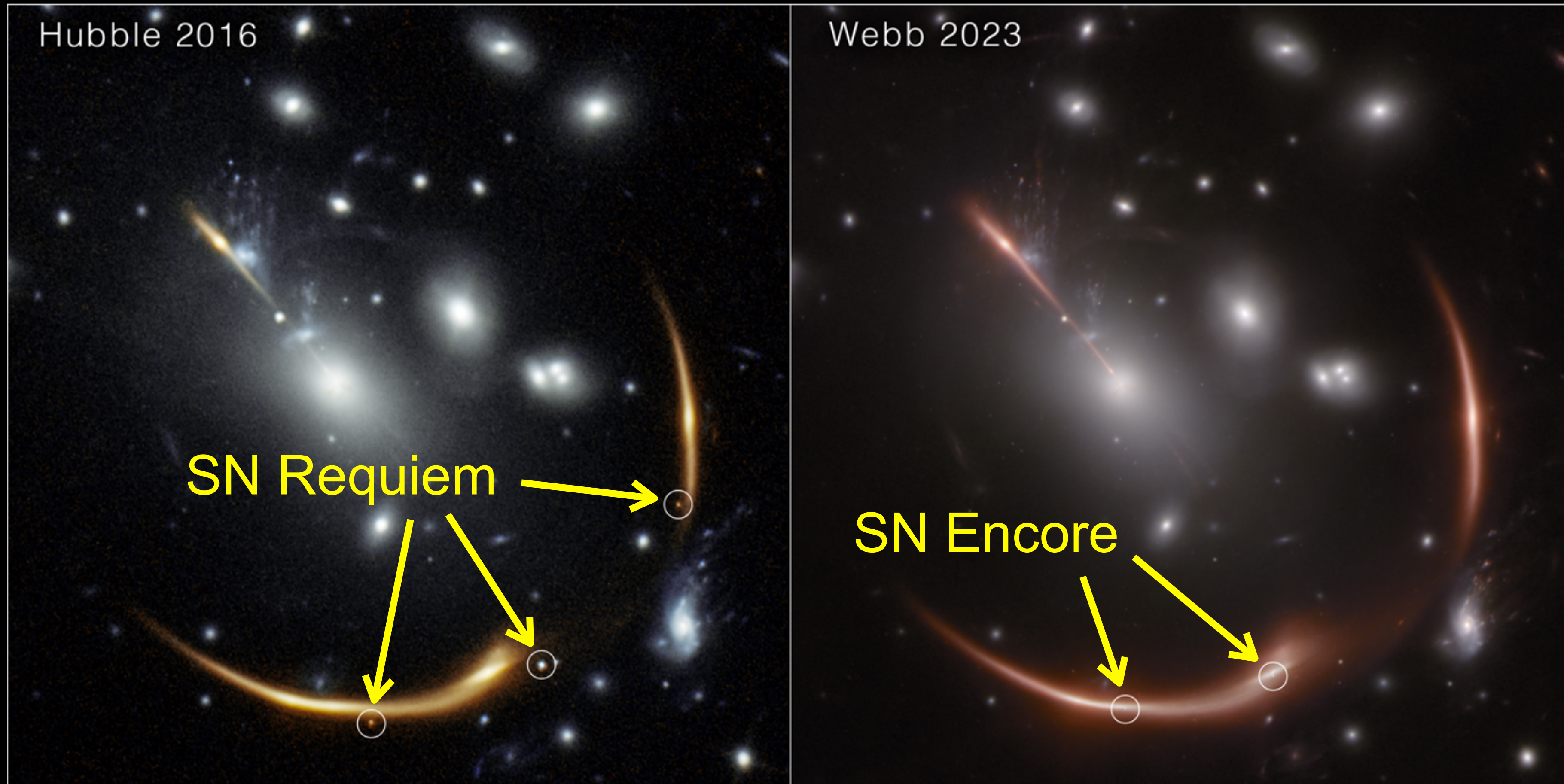
SN 2025mkn



Prediction
by
Refsdal

[Kelly et al. 2015; Goobar et al. 2017; Rodney et al. 2021; Chen et al. 2022; Goobar et al. 2023; Frye et al. 2024; Pierel et al. 2024; Taubenberger et al. 2025; Johansson et al. 2025; Coulter et al. 2026; Lemon et al. 2026]

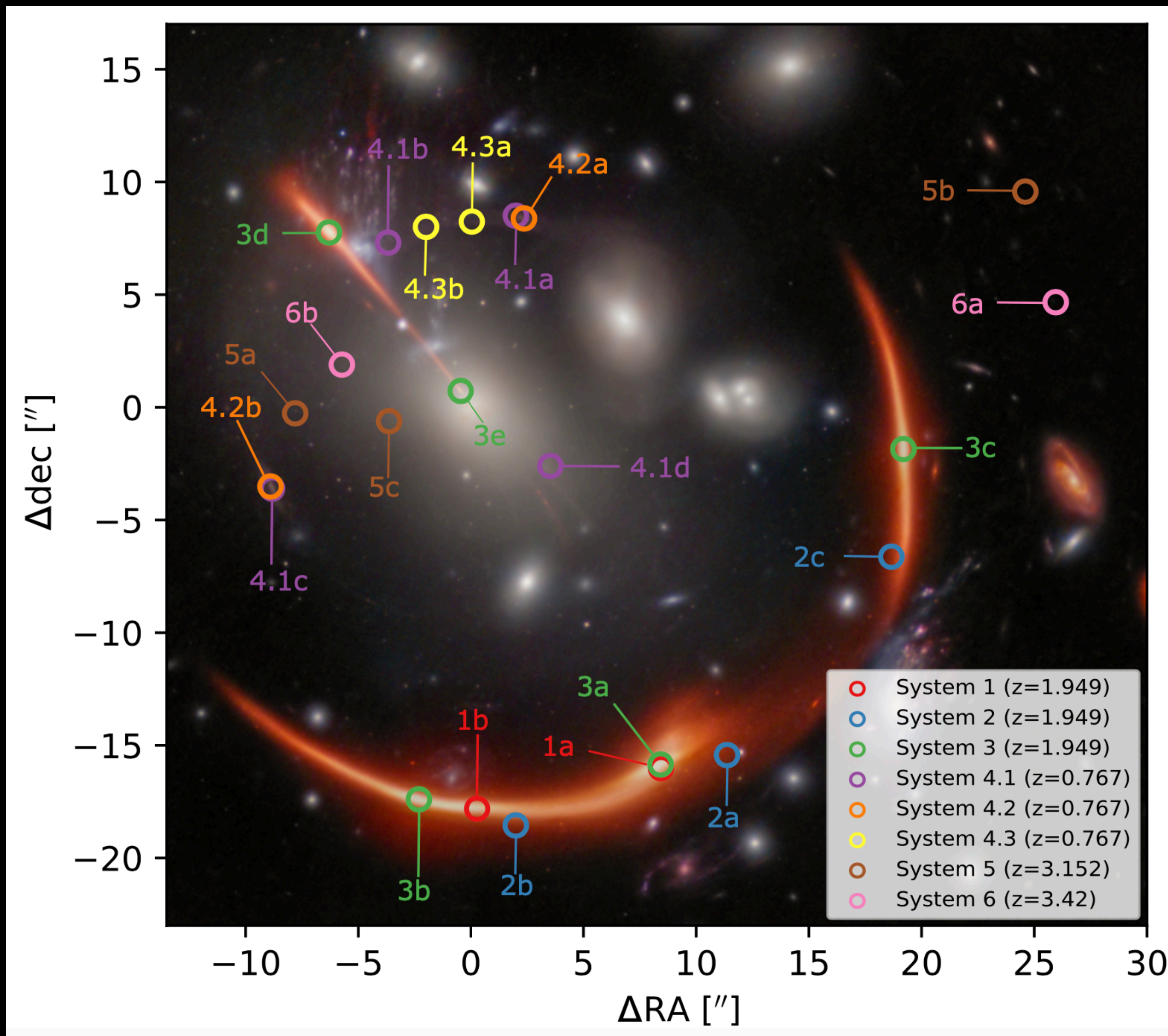
SN Requiem and Encore!



[Image credits: Hubble image: NASA, ESA, STScI, Steve A. Rodney (University of South Carolina) and Gabriel Brammer (Cosmic Dawn Center/Niels Bohr Institute/University of Copenhagen). JWST image: NASA, ESA, CSA, STScI, Justin Pierel (STScI) and Andrew Newman (Carnegie Institution for Science).]

[Pierel et al. 2024]

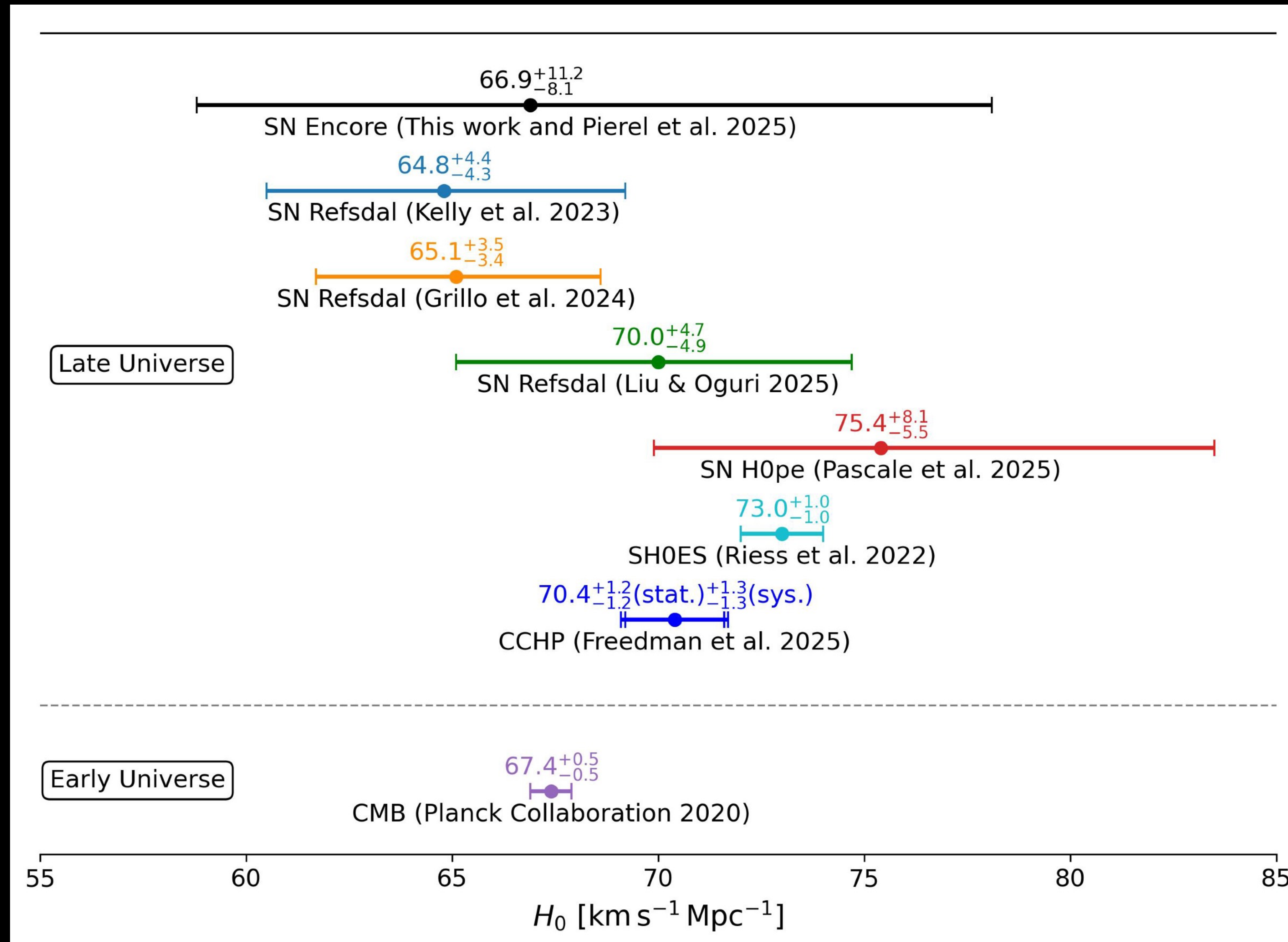
Lensed multiple images



7 independent modeling teams vetted JWST, HST and MUSE data, identifying:

- 84 galaxy cluster members
- 8 lensed image systems from 4 distinct redshifts

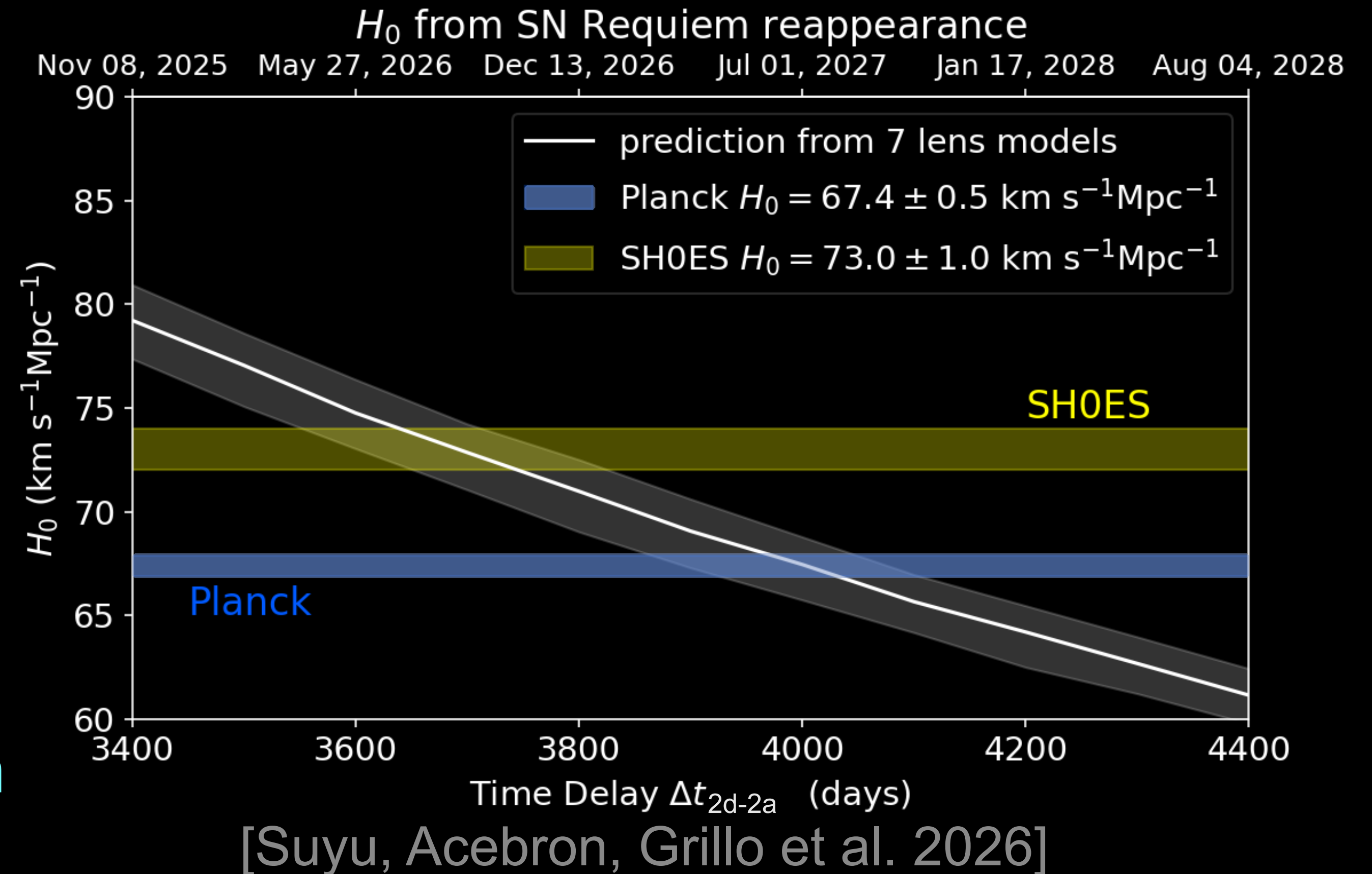
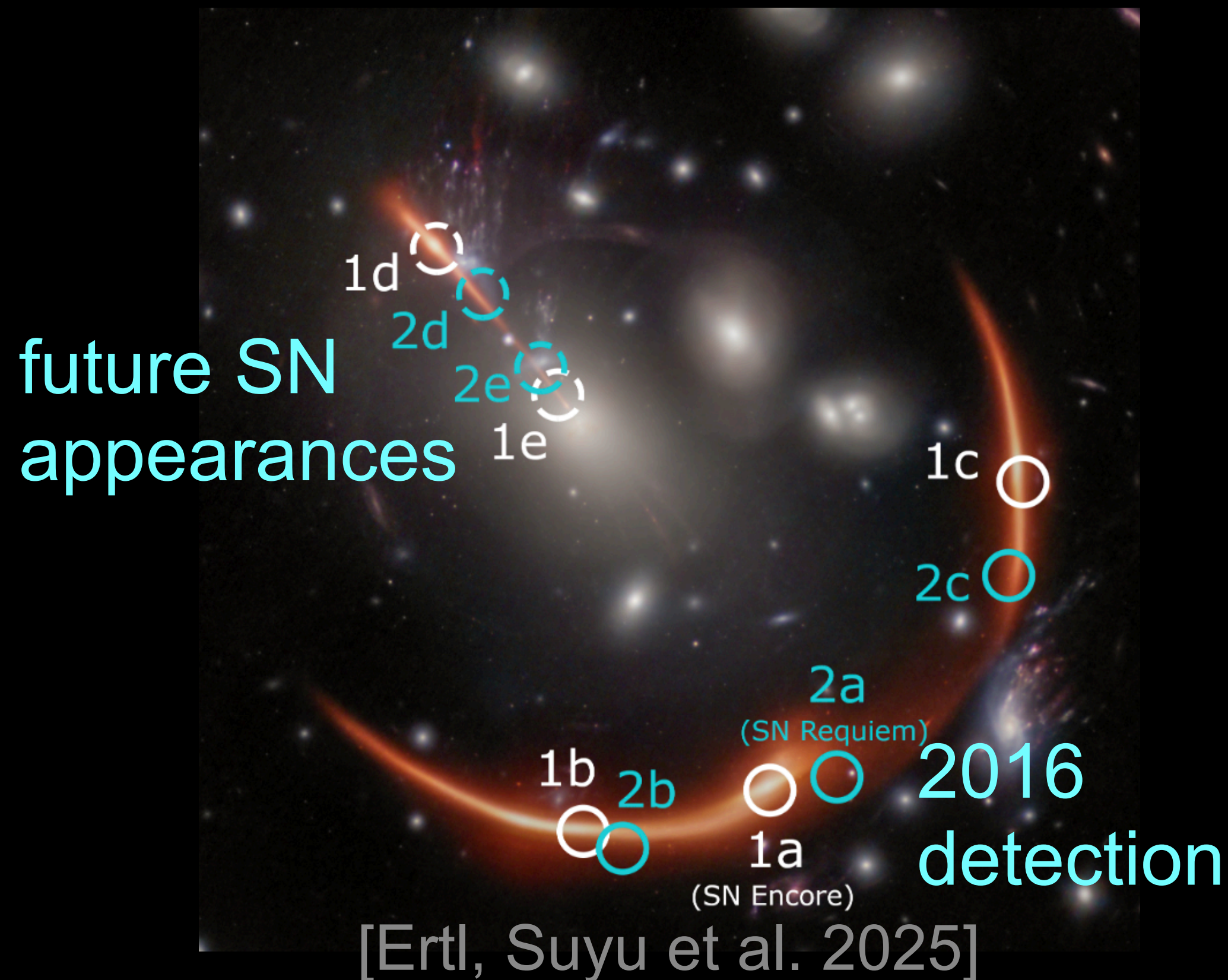
H_0 from SN Encore



[Suyu, Acebron, Grillo et al. 2026; Pierel, Hayes, Millon et al. 2026]

Strong-lensing time machine: H_0 to 2-3%

predict SN Requiem will reappear in ~2026-2027 after 10-year hiatus



- Approved JWST and HST programs to catch SN Requiem reappearance
- Detection of SN Requiem reappearance will yield H_0 with 2-3% uncertainty!

HOLISMOKES!

Highly **O**ptimised **L**ensing **I**nvestigations
of **S**upernovae, **M**icrolensing **O**bjects,
and **K**inematics of **E**llipticals and **S**pirals

HOLISMOKERS



Satadru
Bag



Stéphane
Blondin



Raoul
Cañameras



James
Chan



Janet
Chen



Frédéric
Courbin



Jana
Grupa



Simon
Huber



Elias
Mamuzić



Alejandra
Melo Melo



Stefan
Schuldt



Yiping
Shu



Stuart
Sim



Dominique
Sluse



Sherry
Suyu (PI)



Stefan
Taubenberger



Christian
Vogl

Lens Search

(Papers II, VI, VIII, XI, XIII,
XV, XVI, XVII, XIX, XXI)

Follow-up Observations

(Paper III)



Time Delays

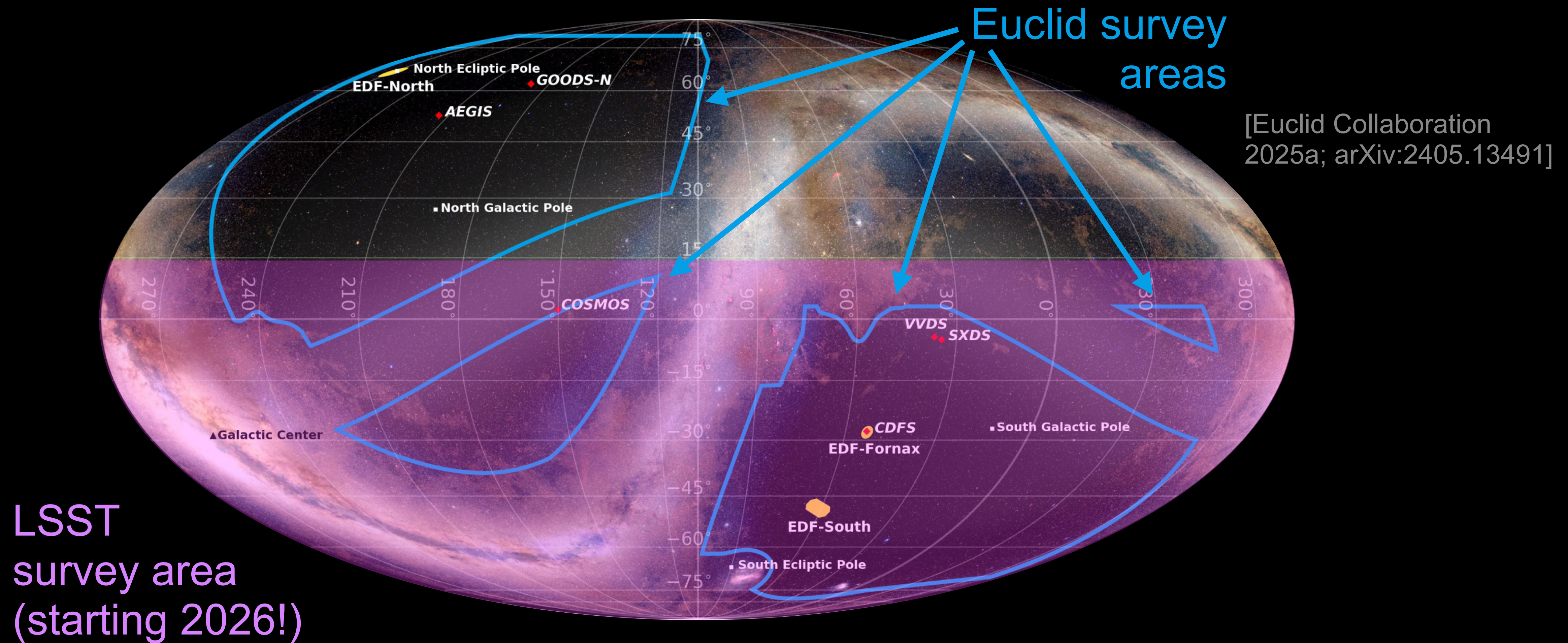
(Papers V, VII, XII,
XIV, XVIII)

Lens Modelling

(Papers IV, IX, X
XX)

- 1. measure H_0 with 1% uncertainty***
- 2. obtain unprecedented constraints on SN progenitors***

Euclid+LSST: treasure trove of lensed flares



Expect hundreds of lensed SNe in LSST survey → Golden era for lensed transients

[Oguri & Marshall 2010; Goldstein et al. 2017; Wojtak et al. 2019]

Summary

- Lensed supernovae are new and powerful probes of cosmology and supernova neutrino background
- Exciting time with the first lensed SNe being discovered
- SN Requiem expected to reappear in ~2026-2027
- HOLISMOKES program to study cosmology and SN progenitors through lensed SNe
- Upcoming cadenced surveys especially LSST will find at least dozens of lensed SNe - a bright future ahead!