

A Type Ia Supernova explosion, showing a bright, expanding shell of orange and yellow light against a dark, star-filled background. The explosion is centered in the upper half of the frame, with a bright, glowing core and a surrounding, diffuse, and irregular shell of light. The background is a deep black space filled with numerous small, white stars of varying brightness.

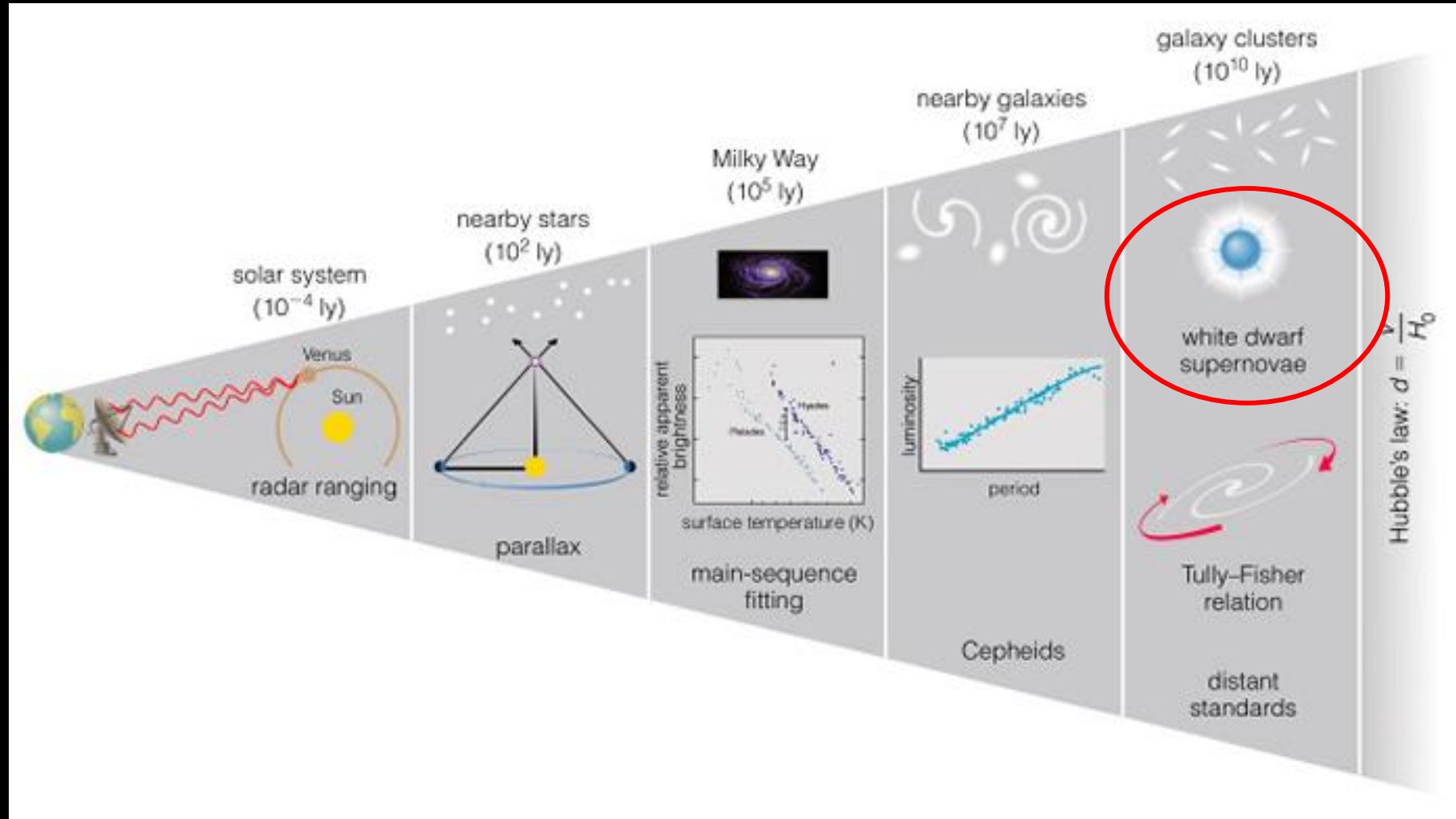
Type Ia Supernovae

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Cosmic Distance Ladder Context

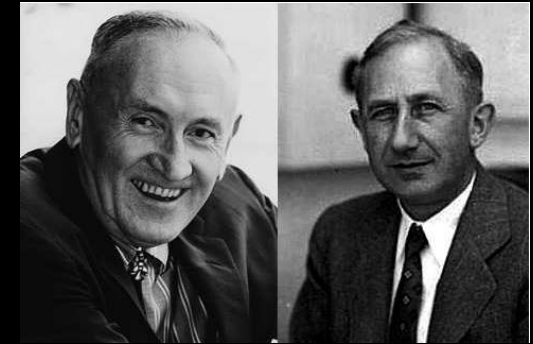


Credit: Darling [1]

Historical Context [2]

1930s – Fritz Zwicky and Walter Baade

- Discovered novae that were very bright and very distant (high energy)



1941 – Rudolph Minkowski

- Separated Type I (No H Lines) and Type II (Strong H Lines)



1993 – Mark Phillips

- Phillips Relation - Correlation between peak luminosity and decay rate

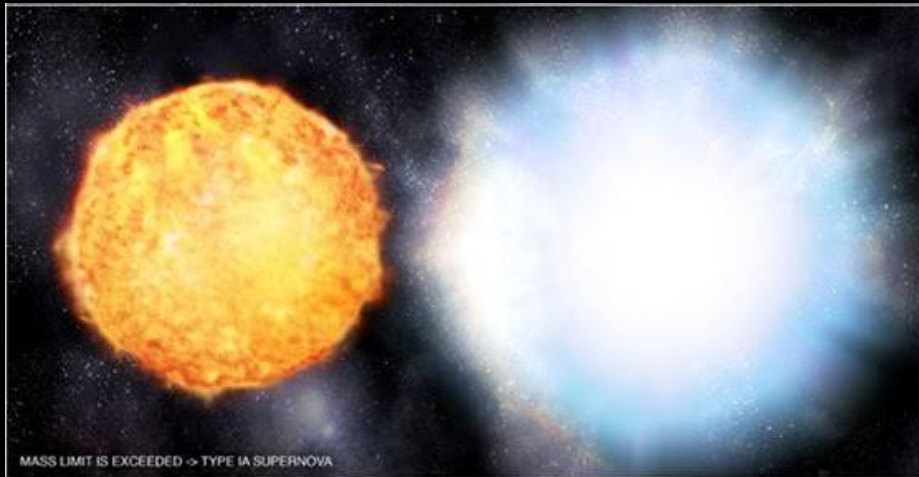
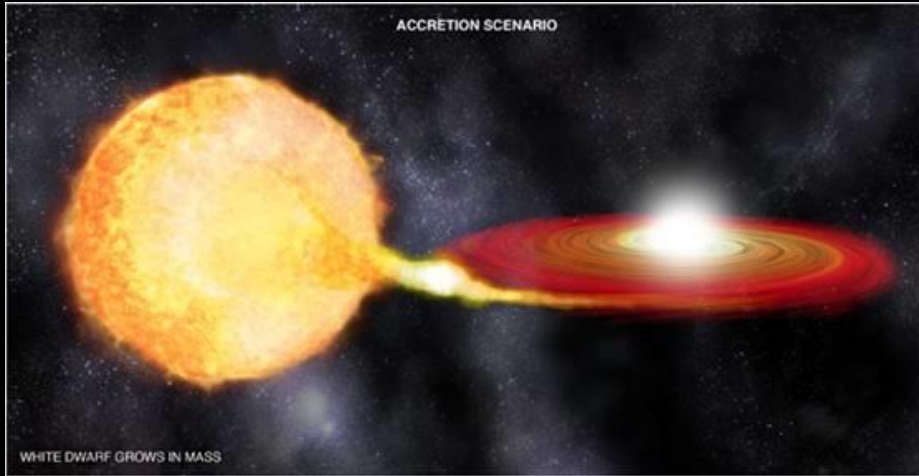


1998 - Supernova Cosmology Team

- Discovery of the accelerating expansion of the universe



What is a Type Ia Supernova

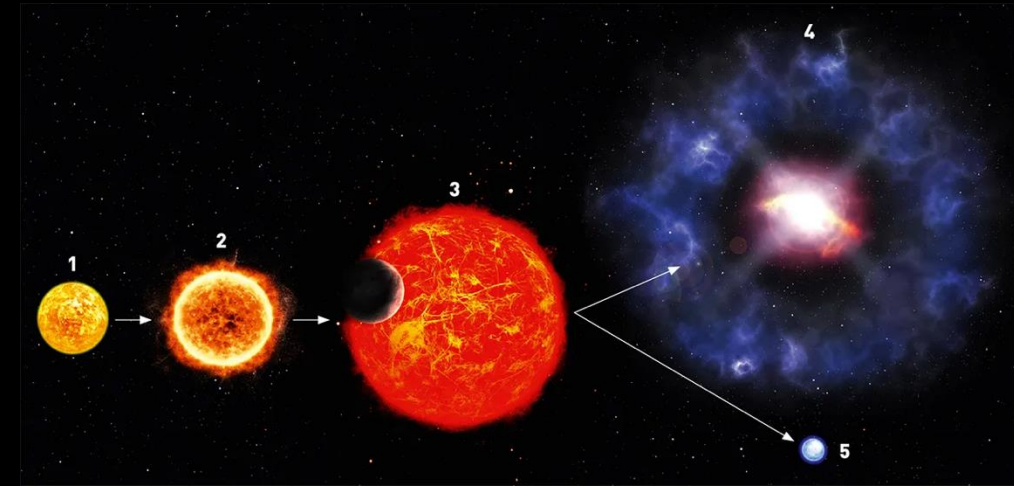


Credit: IAA (2014) [3]

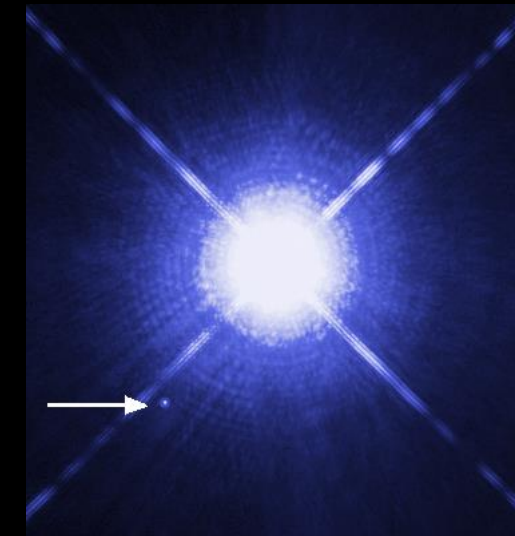
- Binary Star system containing a white dwarf
- Companion star accretes matter onto the white dwarf
- White dwarf gains mass from its companion until it hits mass limit
- Explosion produces very high consistent luminosity
 - No Hydrogen lines in spectrum (Type I)

Why a White Dwarf

- End state of low/intermediate mass stars
 - Dense stellar core left after outer layers shed
 - Core of Carbon and Oxygen
- Well defined maximum limit (~ 1.44 solar masses)
- Leads to similar explosion conditions
 - Identical masses at explosion \rightarrow Similar luminosities



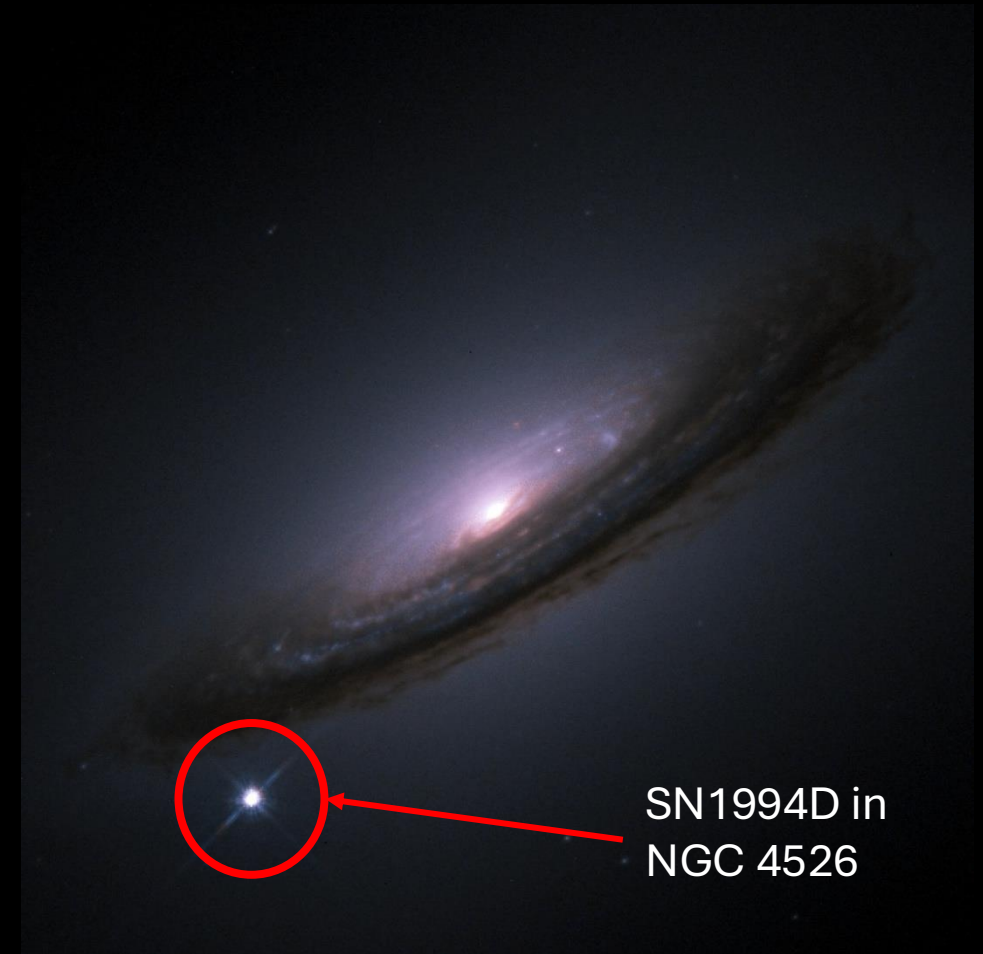
Credit: BBC (2022) [4]



Credit: ESA (2005) [5]

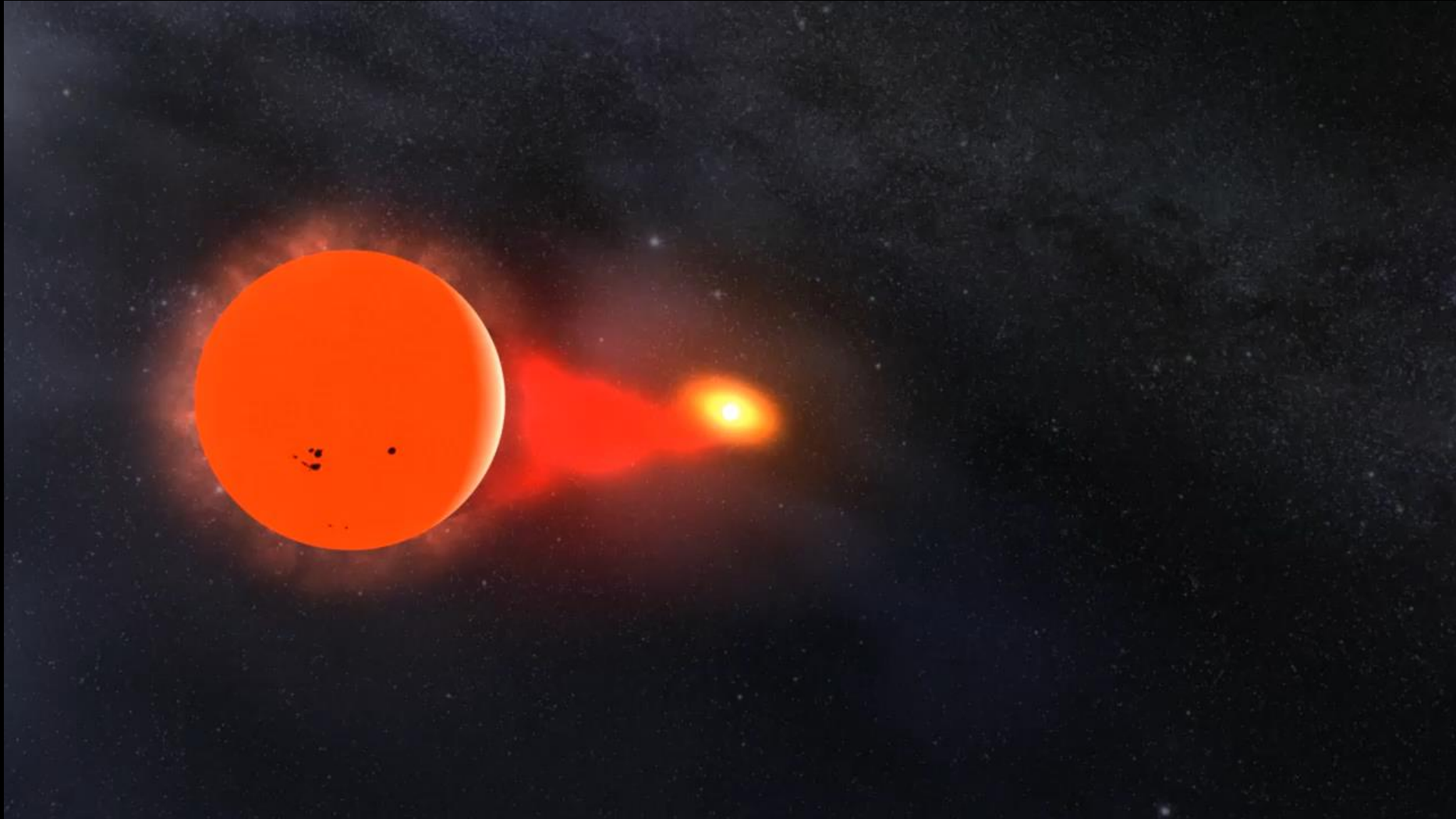
Explosion Mechanism

- White Dwarf supported by electron degeneracy
- Size shrinks as mass increases
- Temperature and pressure increase
- Mass approaches ~ 1.44 solar masses (Chandrasekhar Limit)
- Eventually, carbon fusion is triggered
 - Runaway reaction and explosion is triggered
 - No compact remnant is expected



Credit: NASA/ESA [6]

Type Ia Supernovae Visualized



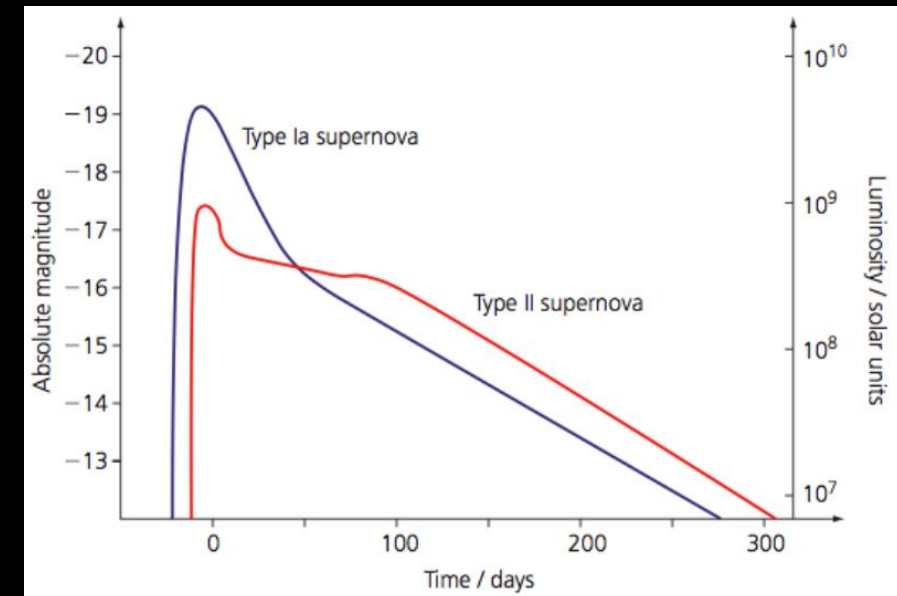
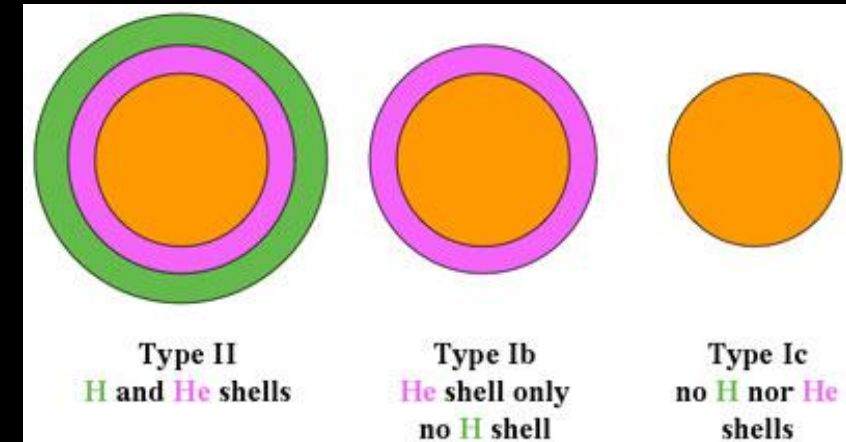
Credit: NASA's Goddard Space Flight Center/Walt Feimer [7]

Why Just Type Ia

- Type Ib
 - No Hydrogen but has Helium lines
- Type Ic
 - No Hydrogen or Helium Lines
- Type II
 - Contains hydrogen

Types Ib, Ic, and II
caused by core
collapse supernovae!
Variable mass &
Variable Brightness

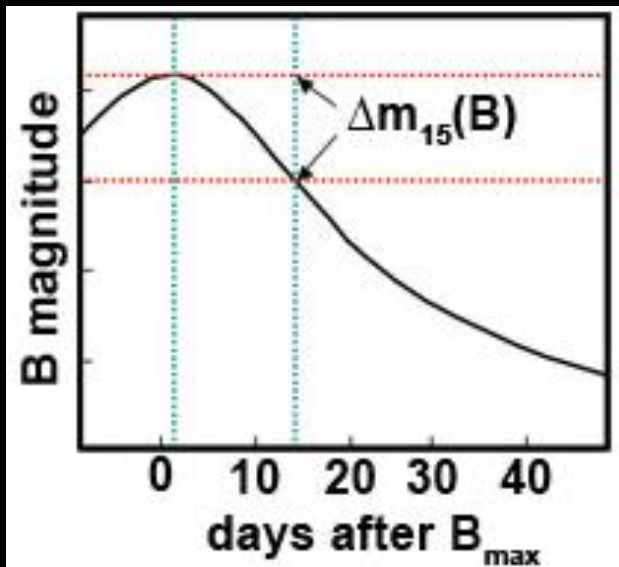
Credit: Swinburne University [8]



Credit: Swinburne University [8]

Why Standard Candle

- Roughly uniform mass at explosion time → Same peak luminosity?
 - WRONG! +/- ~1 magnitude difference in peak luminosity
- Phillips Relation – Brighter Type Ia Supernovae Fade more slowly (15 days in B)



Credit: Swinburne University [9]

Process Simplified:

1. Observe apparent brightness
2. Measure light curve and decline rate
3. Correct for intrinsic luminosity using Phillips Relation
4. Compare corrected luminosity to observed to get distance

Range and Limitations

Range (Riess et al, 1998) [10]

- Typically used beyond 10 Mpc
- Upper Limit: ~few thousand Mpc (~5 Gpc)

Accuracy (Kim et al, 2004) [11]

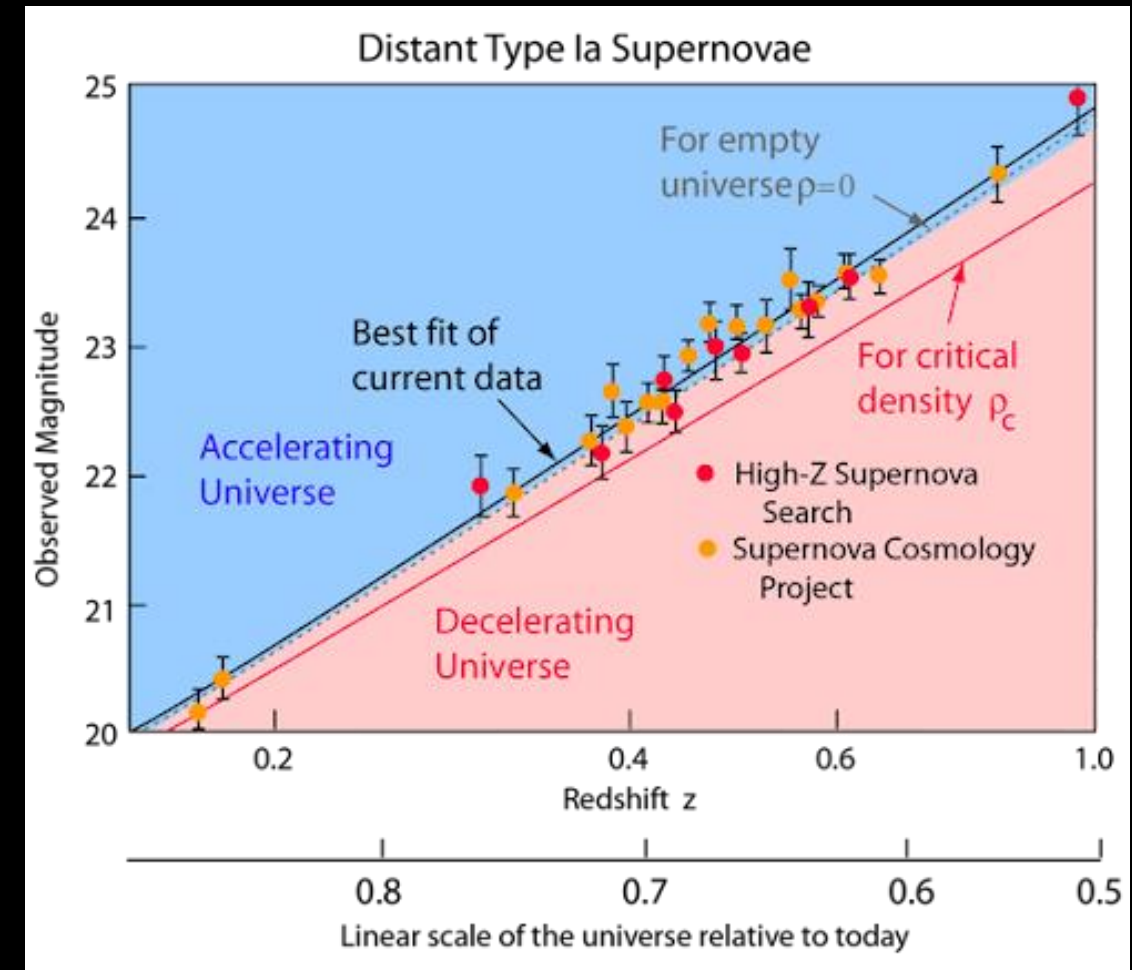
- Distances accurate to 5 – 10%

Limitations:

- White Dwarf Composition and Age
- Extinction of the ISM
- Reddening
- Difficulty Separating out Types of Supernovae
- Photometric Calibrations

Cosmological Impact

- Two Independent Projects in 1998 both studying Type Ia Supernovae
 - Supernova Cosmology Project (Perlmutter et al, 1998) [12]
 - High-Z Supernova Team (Riess et al, 1998) [10]
- Plot Distance vs Redshift
 - Distant Type Ia DIMMER than expected
 - Expansion of the universe is accelerating – Dark Energy!

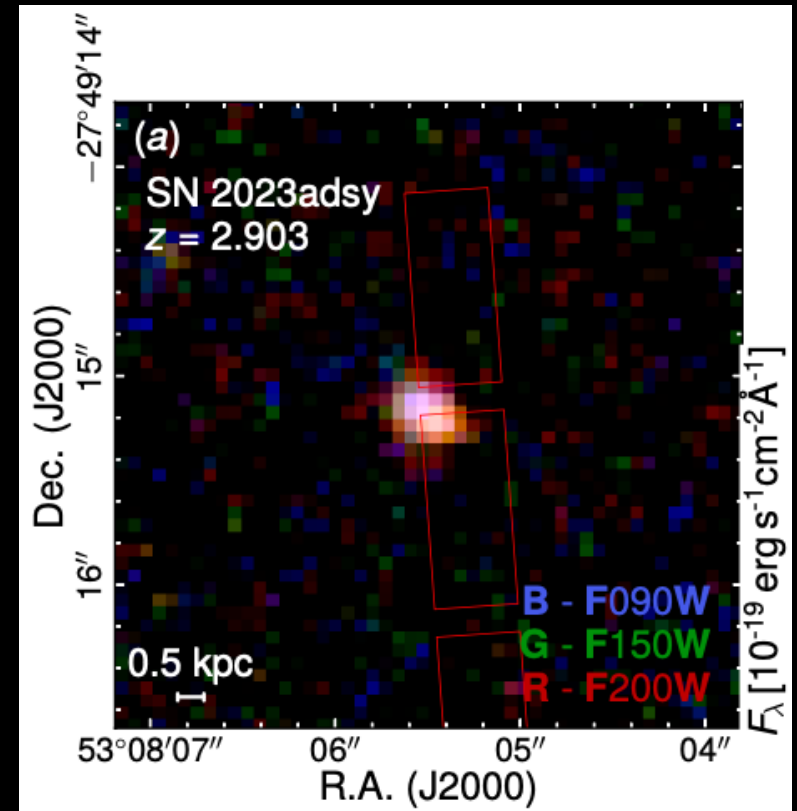


Credit: Hyperphysics GSU (2024) [13]

Recent Result – JWST

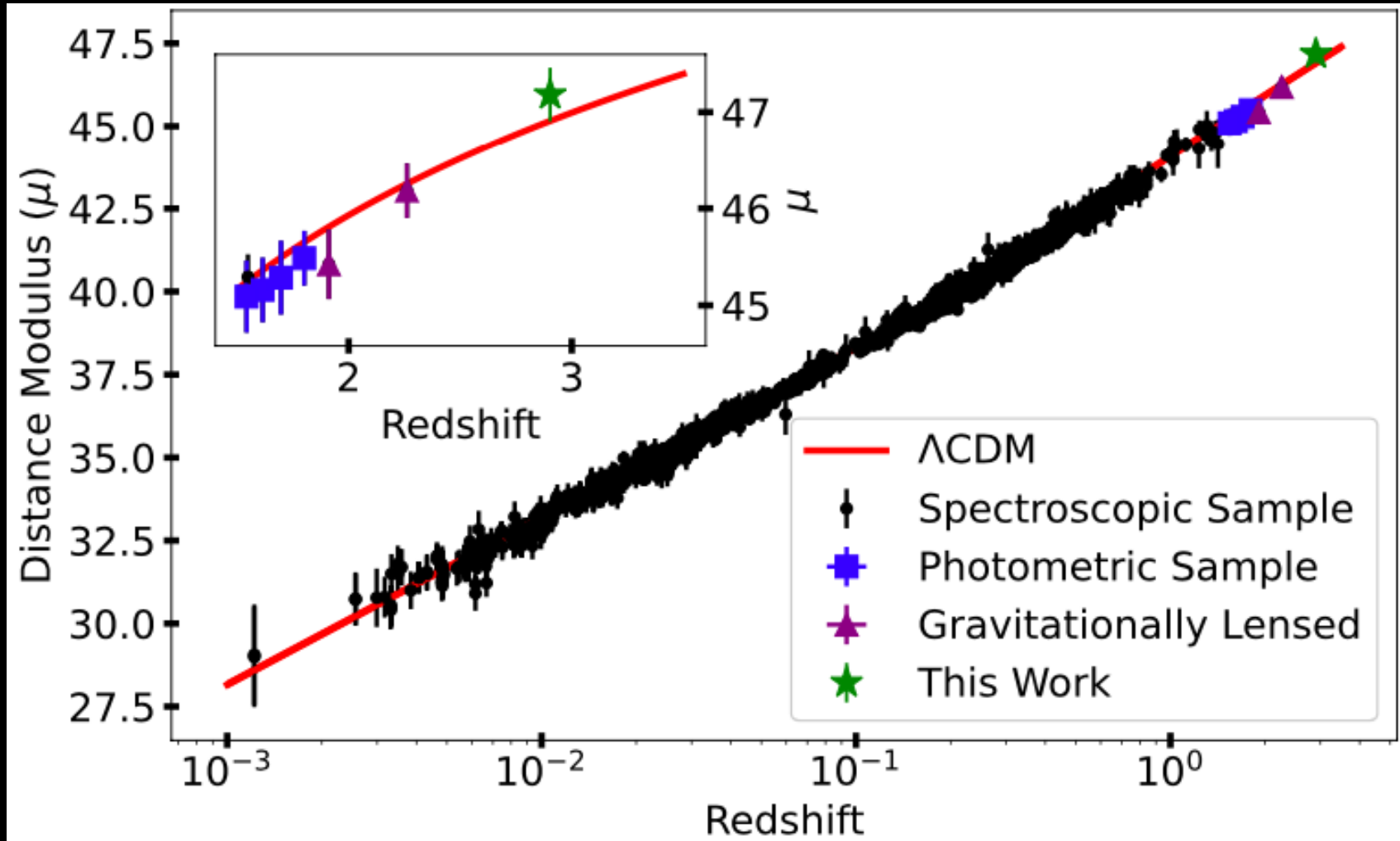
Discovery of An Apparent Red, High-Velocity Type Ia Supernova at $z = 2.9$ with JWST (Pierel et al) [14]

- Most distant type Ia discovered and spectroscopically confirmed
- Redshift of $z \sim 2.9$ (lookback time 11.3 Gyr)
- Luminosity distance measurement in excellent agreement with the standard Λ CDM model
- Standard candle remains consistent with Λ CDM into early universe



Credit: Pierel et al (2024) [14]

Recent Result – JWST



Credit: Pierel et al (2024) [14]

References

- [1] Darling, David. “Cosmic Distance Ladder.” *The Encyclopedia of Science*, www.daviddarling.info/encyclopedia/C/cosmic_distance_ladder.html. Accessed 10 Apr. 2026.
- [2] “Type Ia Supernovae.” NASA, science.nasa.gov/mission/roman-space-telescope/type-ia-supernovae/. Accessed 10 Apr. 2026.
- [3] “Type Ia Supernovae Stem from Explosion of White Dwarfs.” *Phys.org*, 2014, phys.org/news/2014-08-ia-supernovae-stem-explosion-white.html. Accessed 10 Apr. 2026.
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- [7] “Type Ia Supernovae Explained.” *YouTube*, www.youtube.com/watch?v=-yEBVm5o97E. Accessed 10 Apr. 2026.
- [8] “Type Ic Supernova.” *COSMOS*, Swinburne University of Technology, astronomy.swin.edu.au/cosmos/t/Type+Ic+Supernova. Accessed 10 Apr. 2026.
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- [10] Riess, Adam G., et al. “Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant.” *The Astronomical Journal*, vol. 116, no. 3, Sept. 1998, pp. 1009–1038. <https://doi.org/10.1086/300499>.
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- [13] “Redshift and the Expanding Universe.” *HyperPhysics*, Georgia State University, <http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/dareng.html>. Accessed 10 Apr. 2026.
- [14] Pierel, J. D. R., et al. “Discovery of an Apparent Red, High-Velocity Type Ia Supernova at $z = 2.9$ with JWST.” *arXiv*, 11 June 2024, arxiv.org/abs/2406.05089v2.