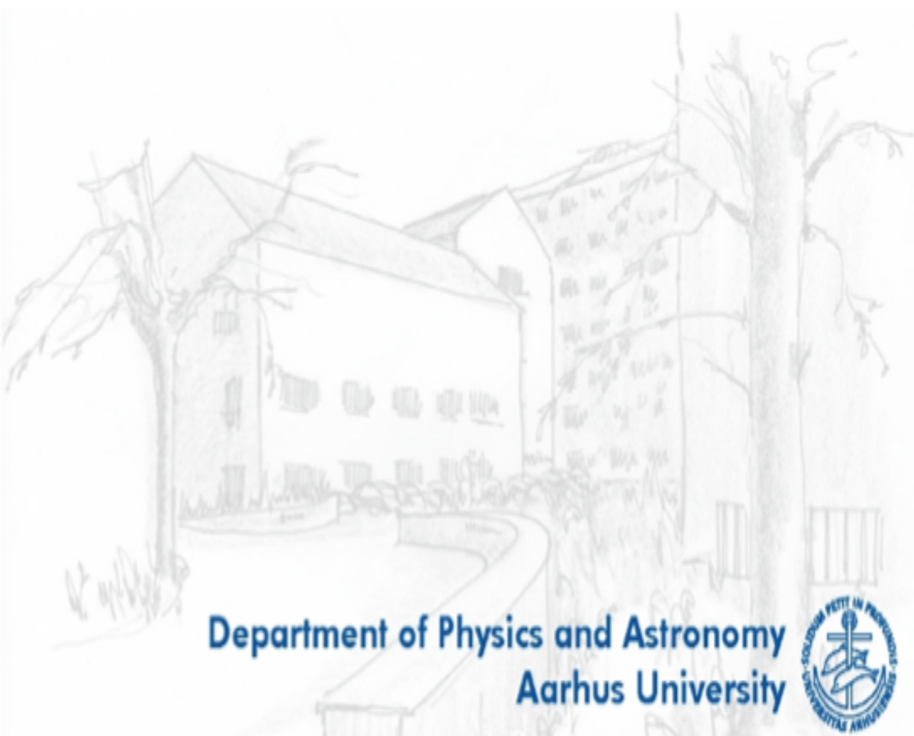
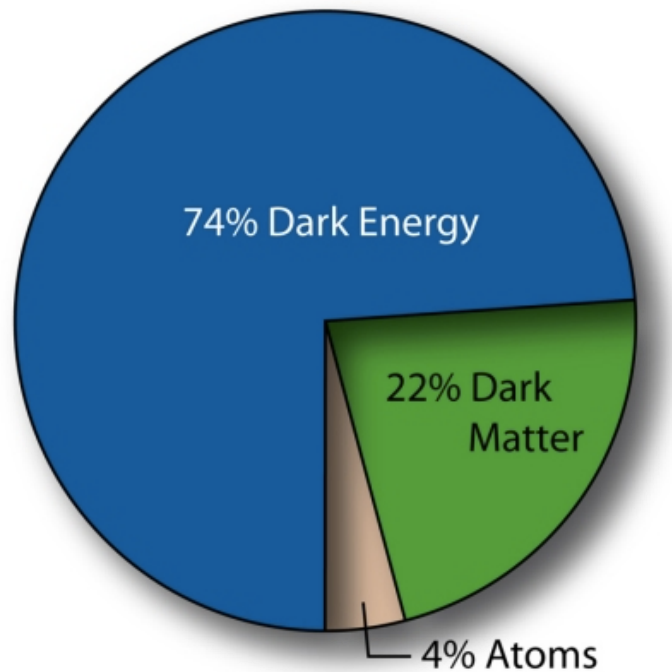
Type Ia supernovae and Dark Energy

Maximilian Stritzinger, IFA





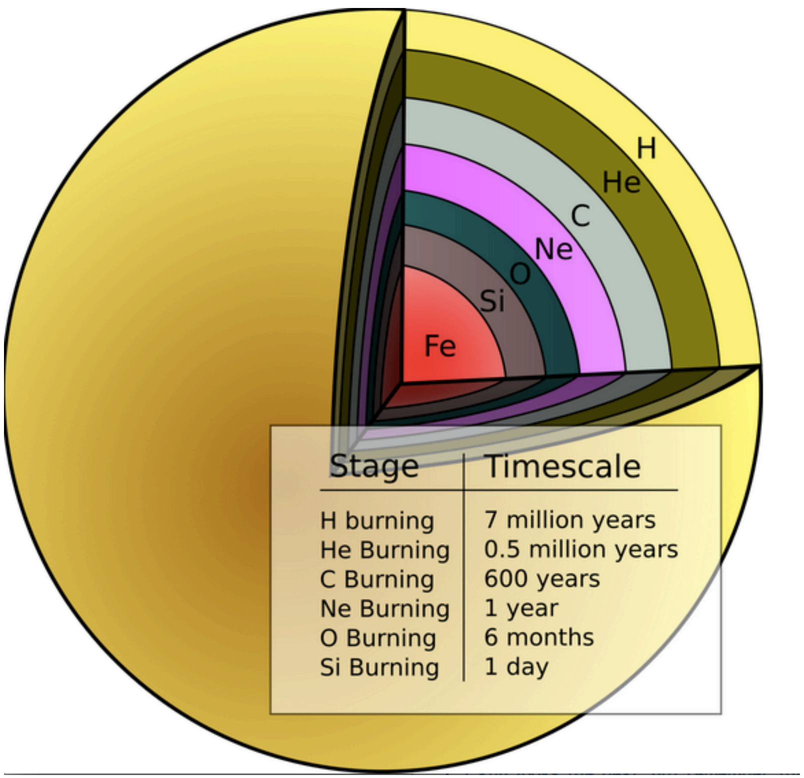
Going out with a Stellar....


Supernova!
25 years of SN 1987A
© Anglo-Australian Telescope

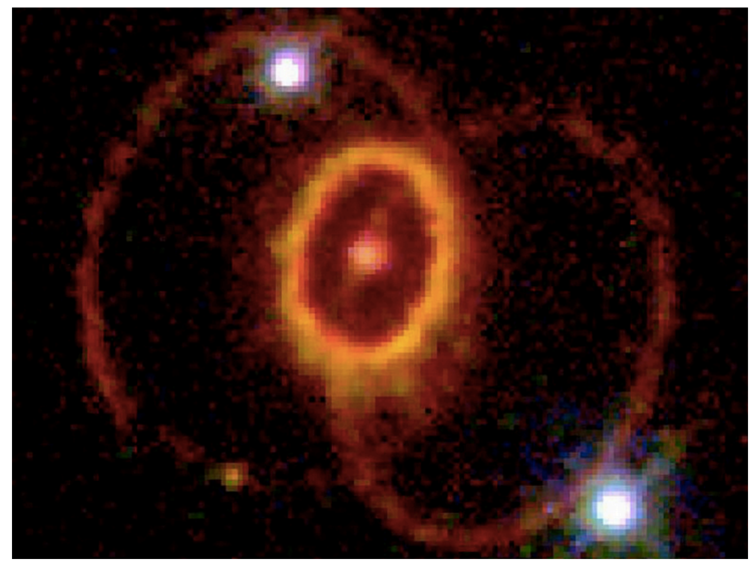
"Core-collapse" Supernovae

The death of massive stars > 8 $M_\odot$

"Stellar Onion Structure"



SN 1987A @ 20 yrs



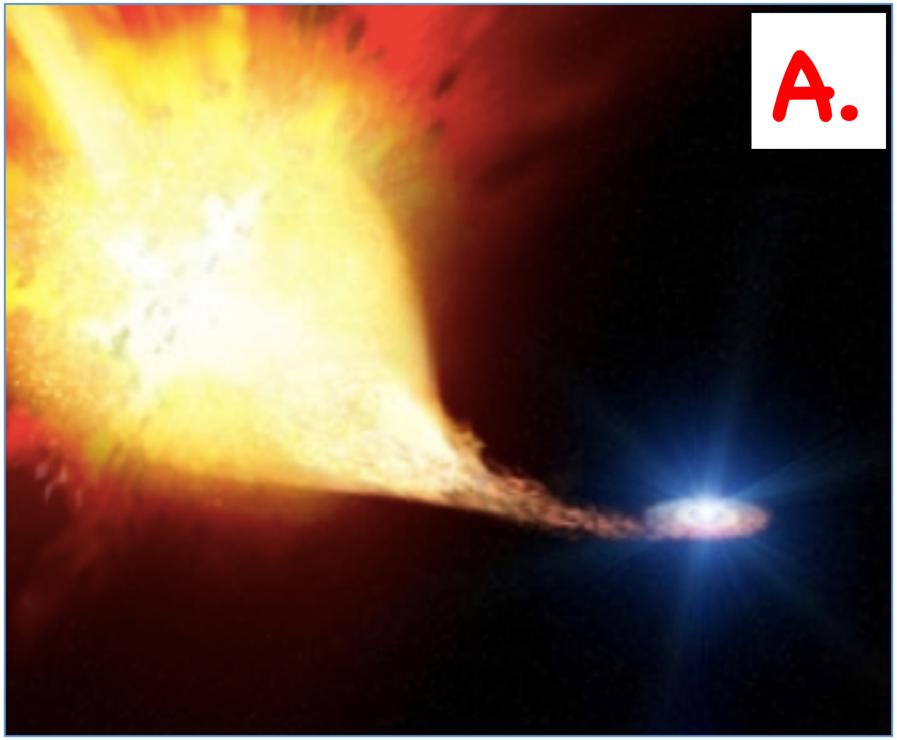
White Dwarf (Degenerate) Star

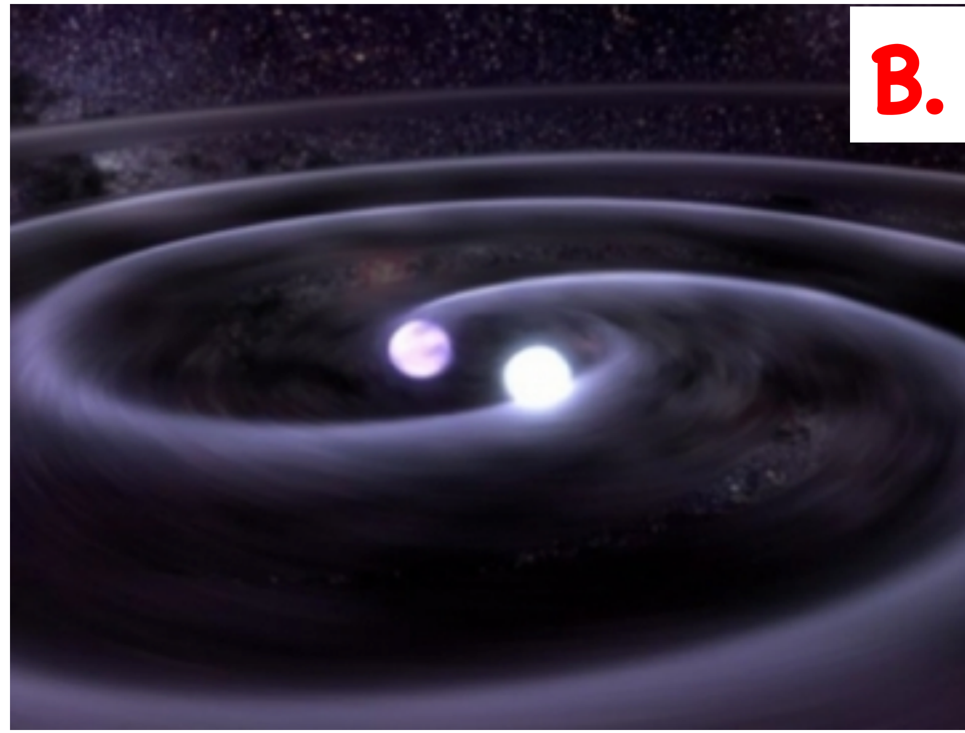
- Remnant of a < 8 $M_{\odot}$ star:
  Future for 97% of all stars in our Galaxy

- Mass of the Sun in a sphere the size of the Earth! → 1 ton per cm^3

- Gravitational attraction is balanced by pressure supported provided by electron degeneracy → "Pauli Exclusion Principle"

Type Ia Supernovae Progenitors ?



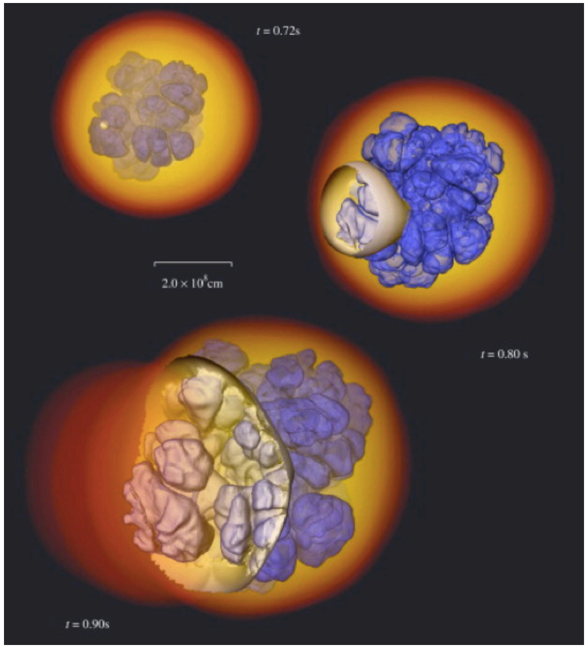


A: Carbon/Oxygen White Dwarf that explodes upon reaching the Chandrasekhar mass $\approx 1.4\ M_\odot$

B: Merger of two White Dwarfs

Several SNe Ia Explosion Models

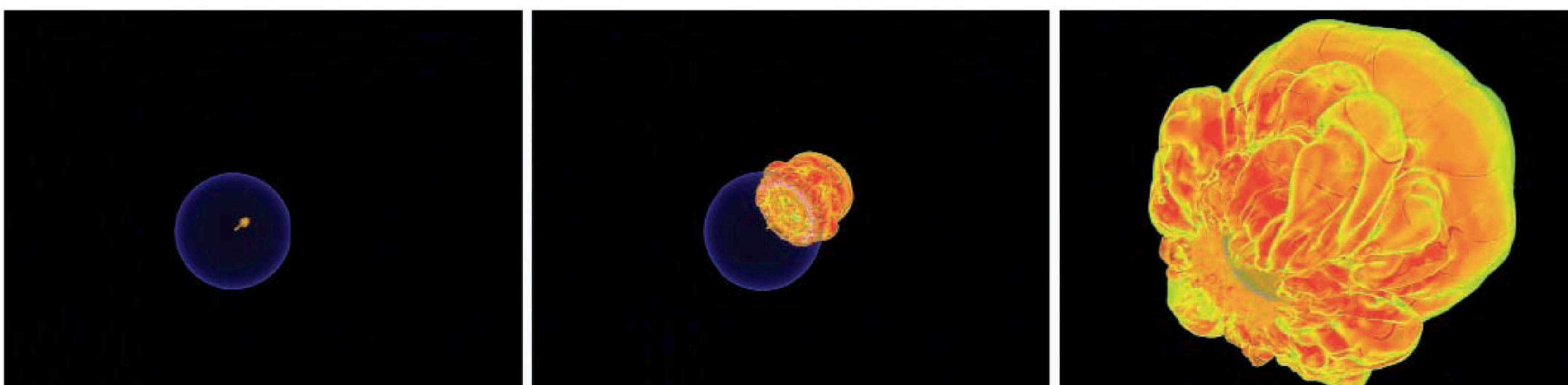
Delayed Detonation



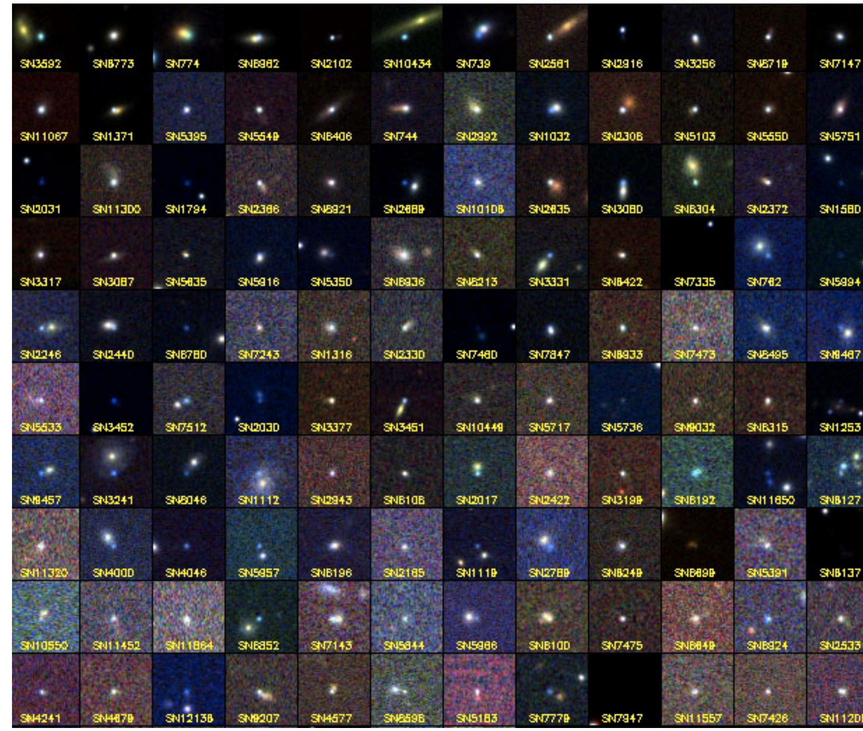
Fritz Röpke and MPA group

Gravitationally confined detonation

U. Chicago FLASH centre



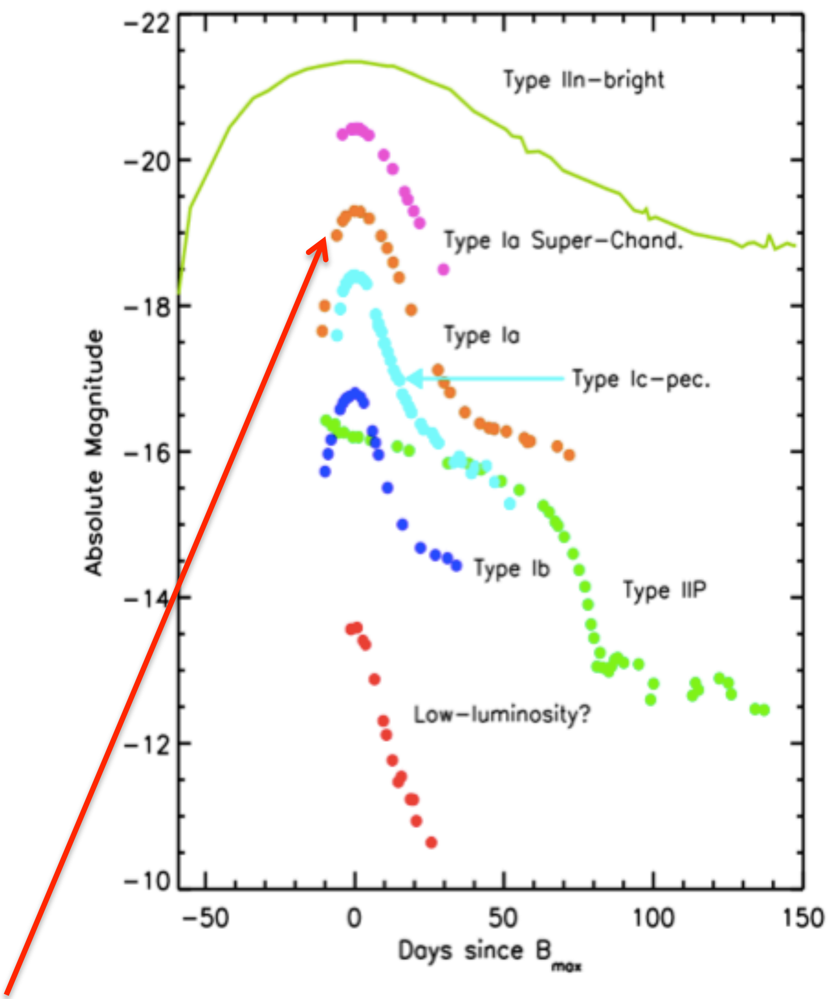
Type Ia Supernova Explosion

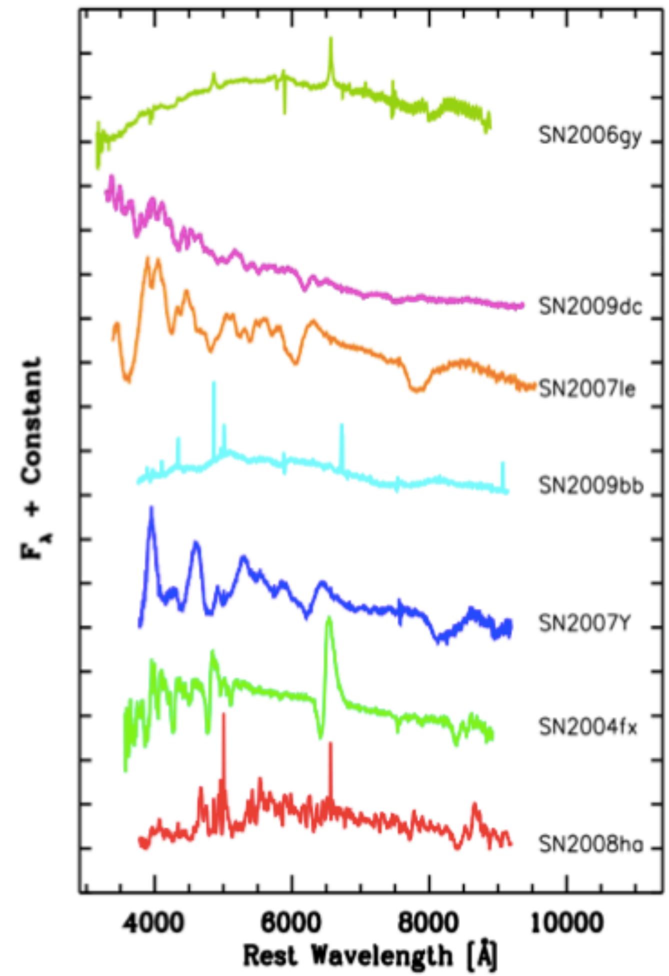


- SNe Ia occur in all types of galaxies and at all epochs of the Universe
- SN occur at a rate of 1 per second

  → 1 SNe Ia per galaxy per century!
- However much work involved to discover them young

Supernova Observations



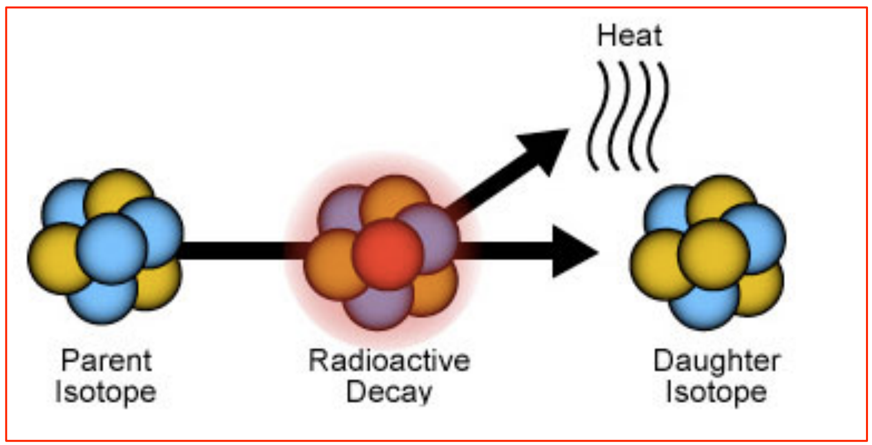


At maximum brightness the luminosity is several billion times brighter than our sun!

Supernovae Energetics

We (usually) do not observe the SN explosion, but rather a rise to maximum light.

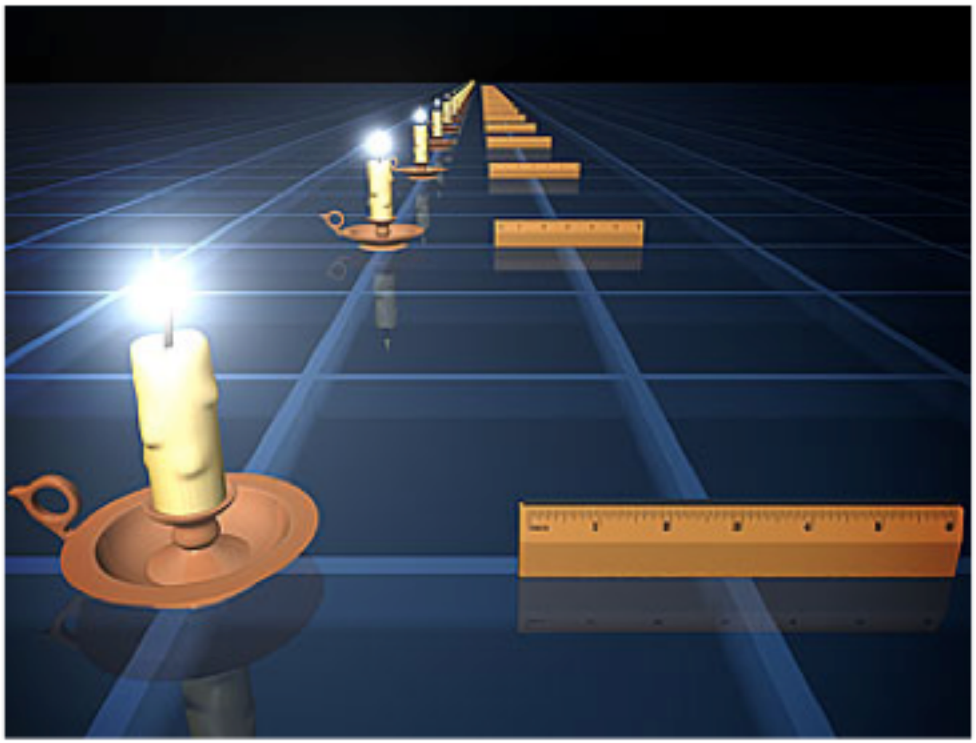
Energy that powers the "light curves" comes from radioactivity



In the case of supernova it is the decay of

$$^{56}\mathbf{Ni} \rightarrow {}^{56}\mathbf{Co} \rightarrow {}^{56}\mathbf{Fe}$$

SNe Ia as cosmological yardsticks



Luminosity Distance

$$D_L = \left(\frac{L}{4\pi F} \right)^{1/2}$$

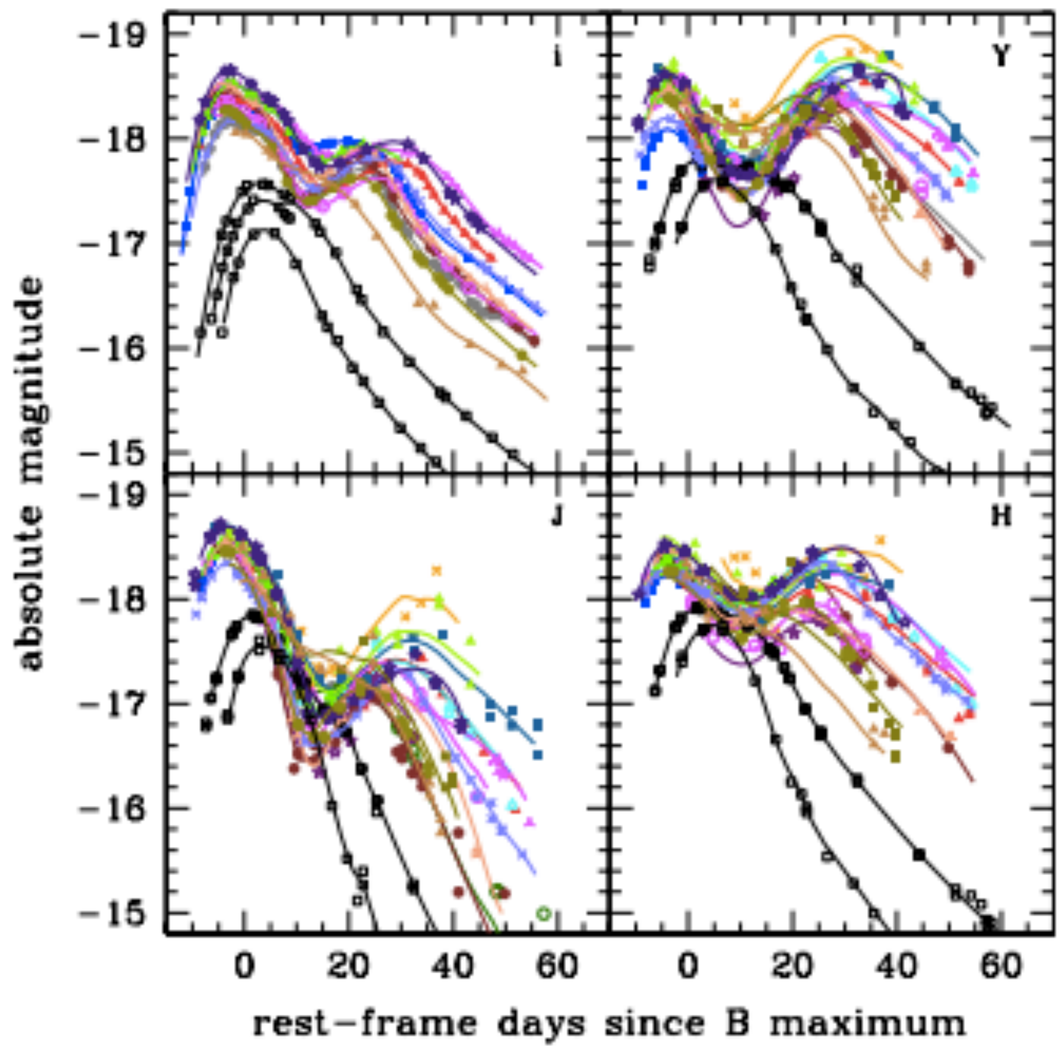
In FRW cosmology, D_L at a given redshift, z, is a function of the cosmological parameters: H_0, Ω_B, Ω_Λ:

$$D_L = cH_0^{-1}(1+z)\left|\Omega_k\right|^{1/2} \sin n\left\{\left|\Omega_k\right|^{1/2} x \int_0^z dz[\left\{(1+z)^2(1+\Omega_m z) - z(2+z)\Omega_\Lambda\right]^{-1/2}\right\},$$

Standardizable Candles at Optical Wavelengths

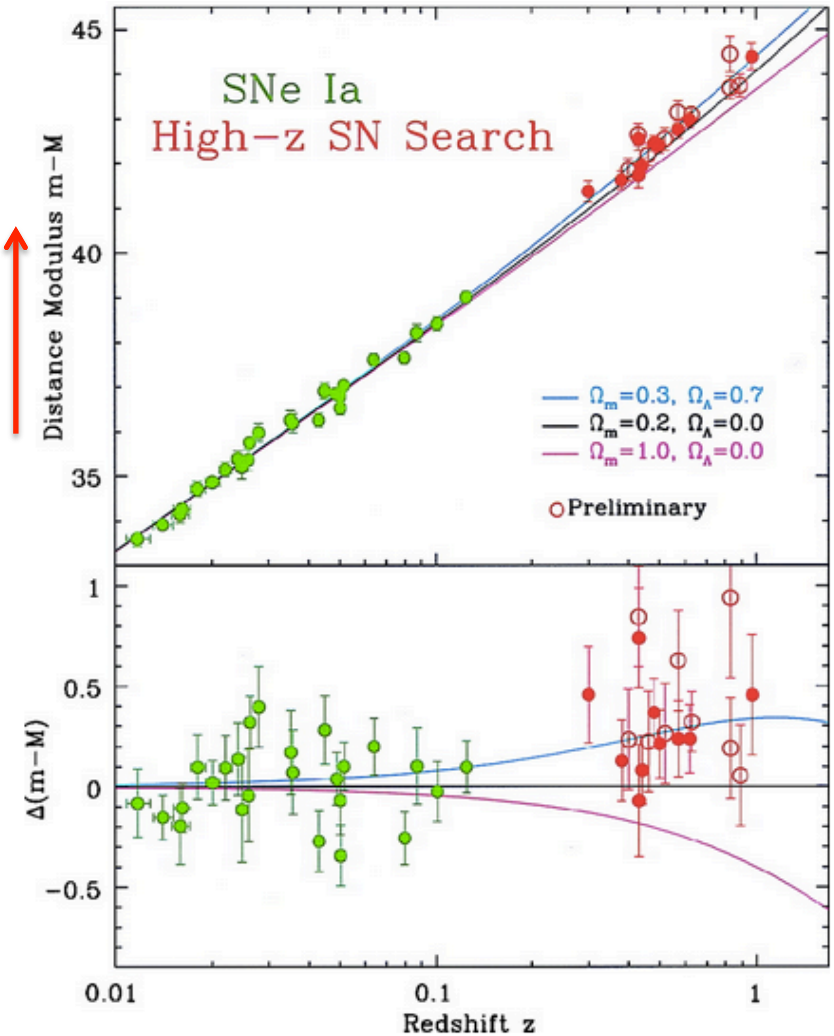
Peak luminosity spans a factor of 10 at optical wavelengths

However, near-IR wavelengths they are essentially true standard candles!

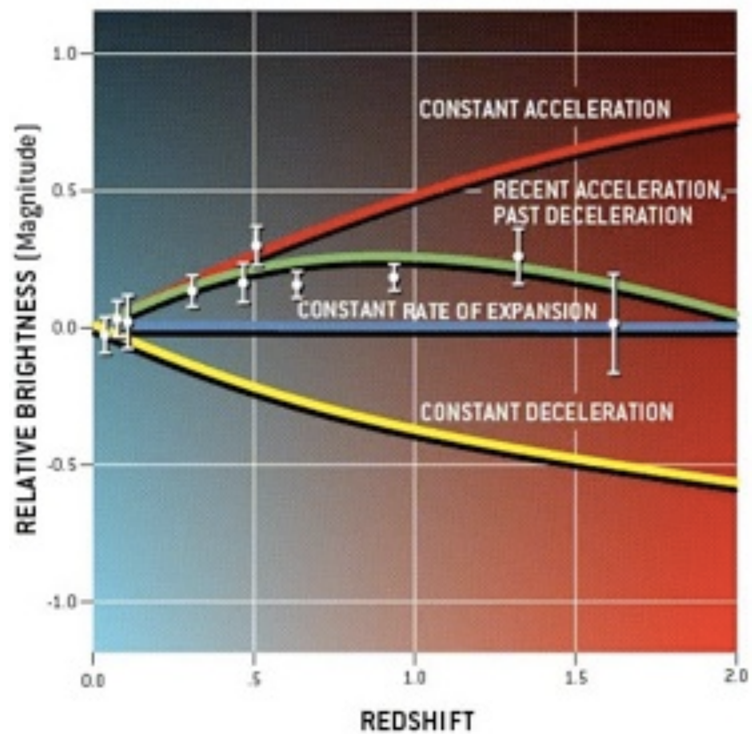


Hubble Diagram of SNe Ia

Fainter

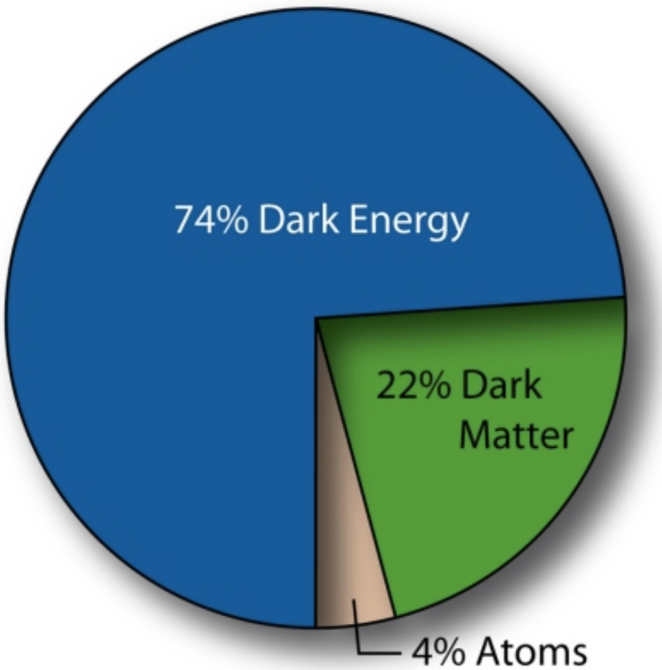


Data sample as of the late 90s



Hubble diagram of SNe Ia provided the first direct evidence for the accelerated expansion of the Universe!

→ We live in a Dark Universe!



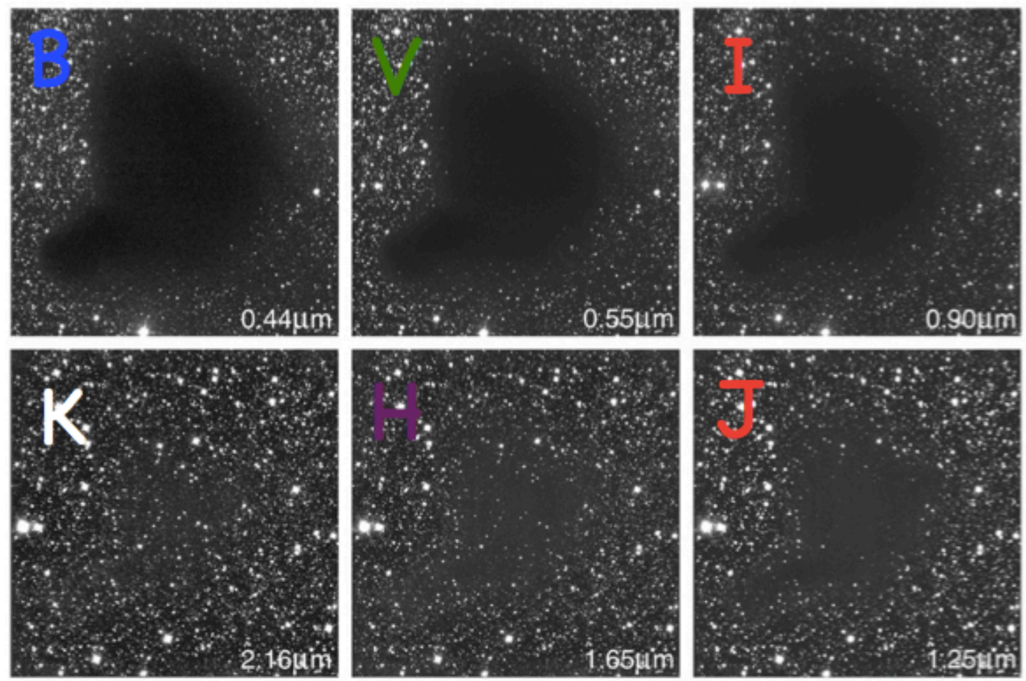
What is the origin of DE and how has it evolved over cosmic time?

What is Dark Energy?

Mapping out the time dependence of DE

Requires SNe Ia distance accuracy to improve from the 5% level down to the 1–2% level

→ Refine methods for estimating *dust extinction* and better *photometric calibration*



The Dark Cloud B68 at Different Wavelengths (NTT + SOFI)

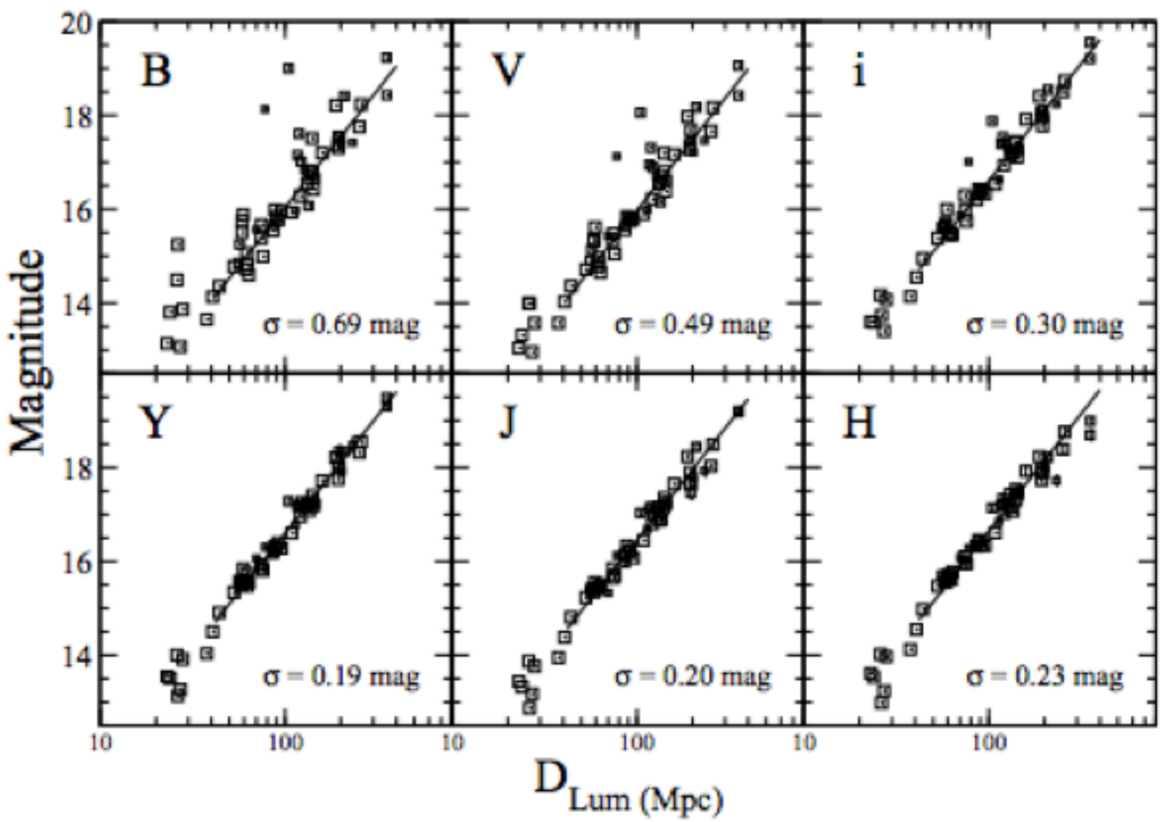
ESO PR Photo 29b/99 (2 July 1999)

Carnegie Supernova Project-II

- Construct a sample of ≈ 150 SNe Ia over 5 year period
- Special emphasis to observe in the near-IR

Improved Distance Accuracy

Near-IR observations do offer more precise distances. Can we make it to the 1-2% level? → Stay Tuned!



Thank You

Las Campanas Observatory