Type Ia Supernovae, and the High-Z Supernovae Search

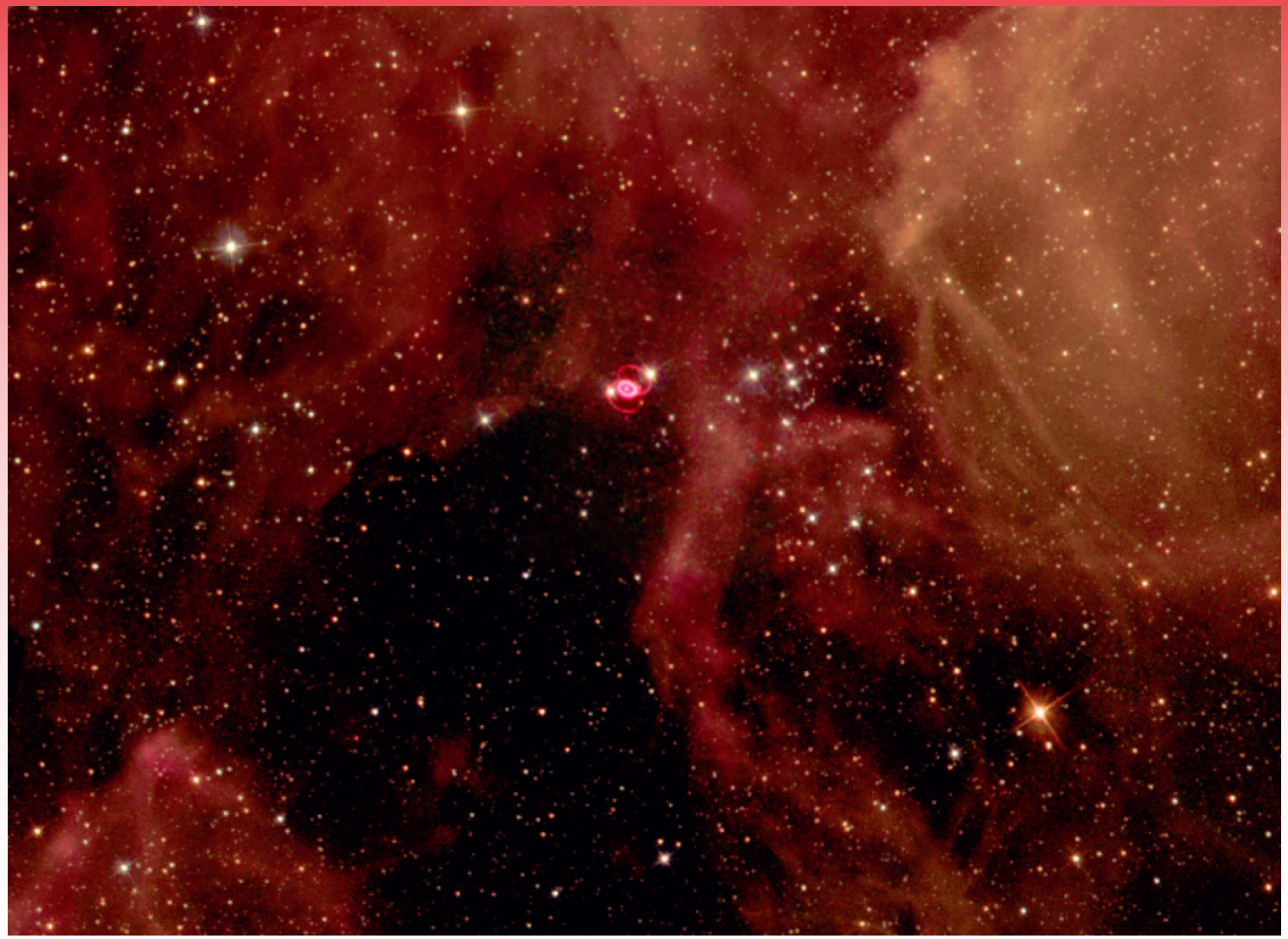
The Evidence for Dark Matter

Physics 090

2020-05-15

SAINT MARY'S COLLEGE of CALIFORNIA

Review Supernovae

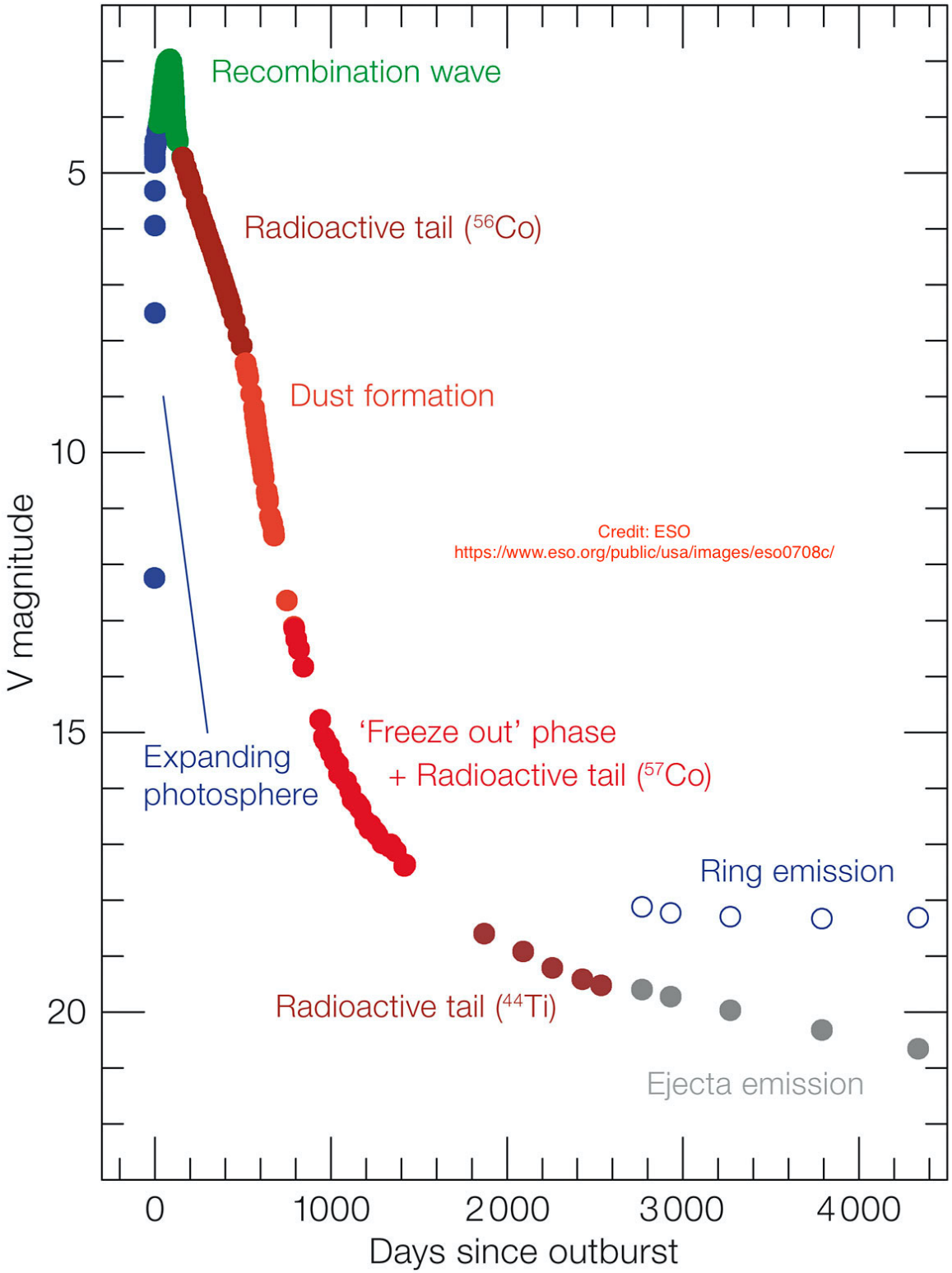


Hubble Space Telescope Image
Supernova 1987A in Large Magellanic Cloud

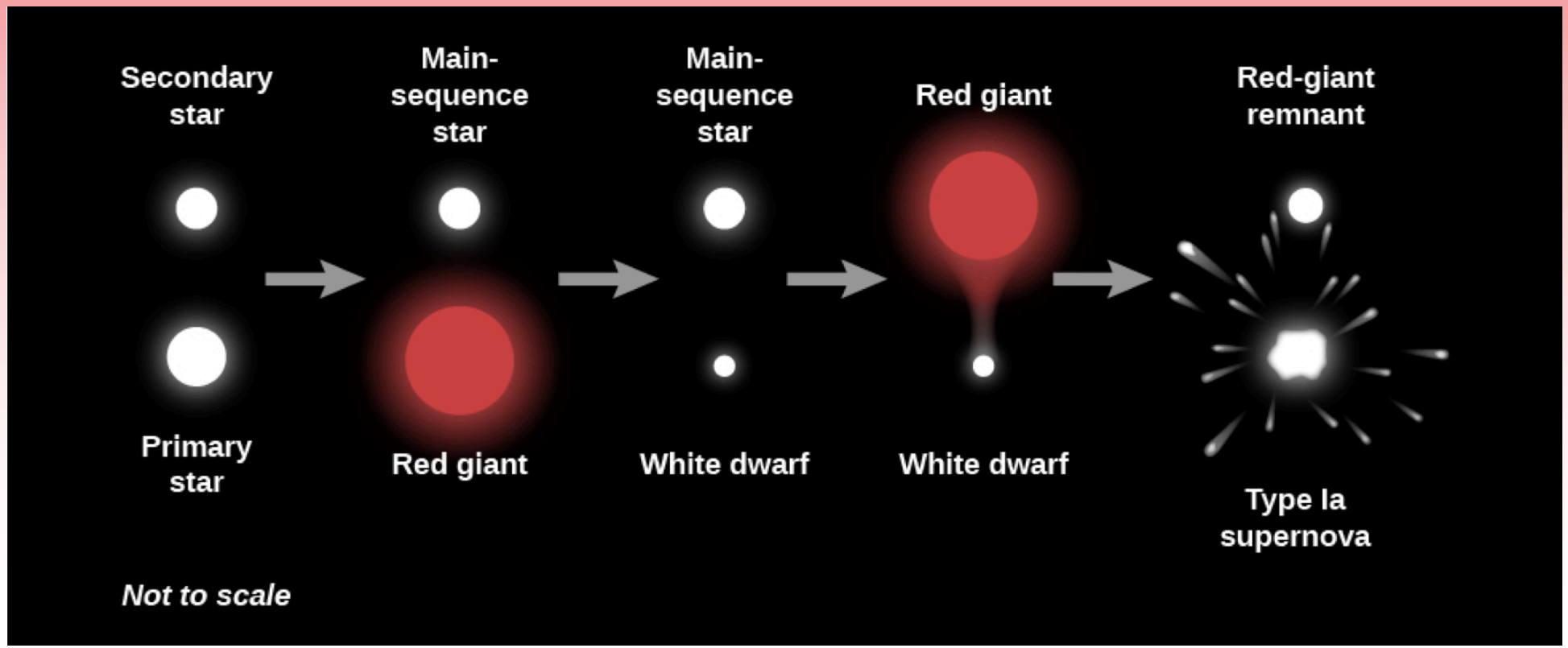
Light Curve

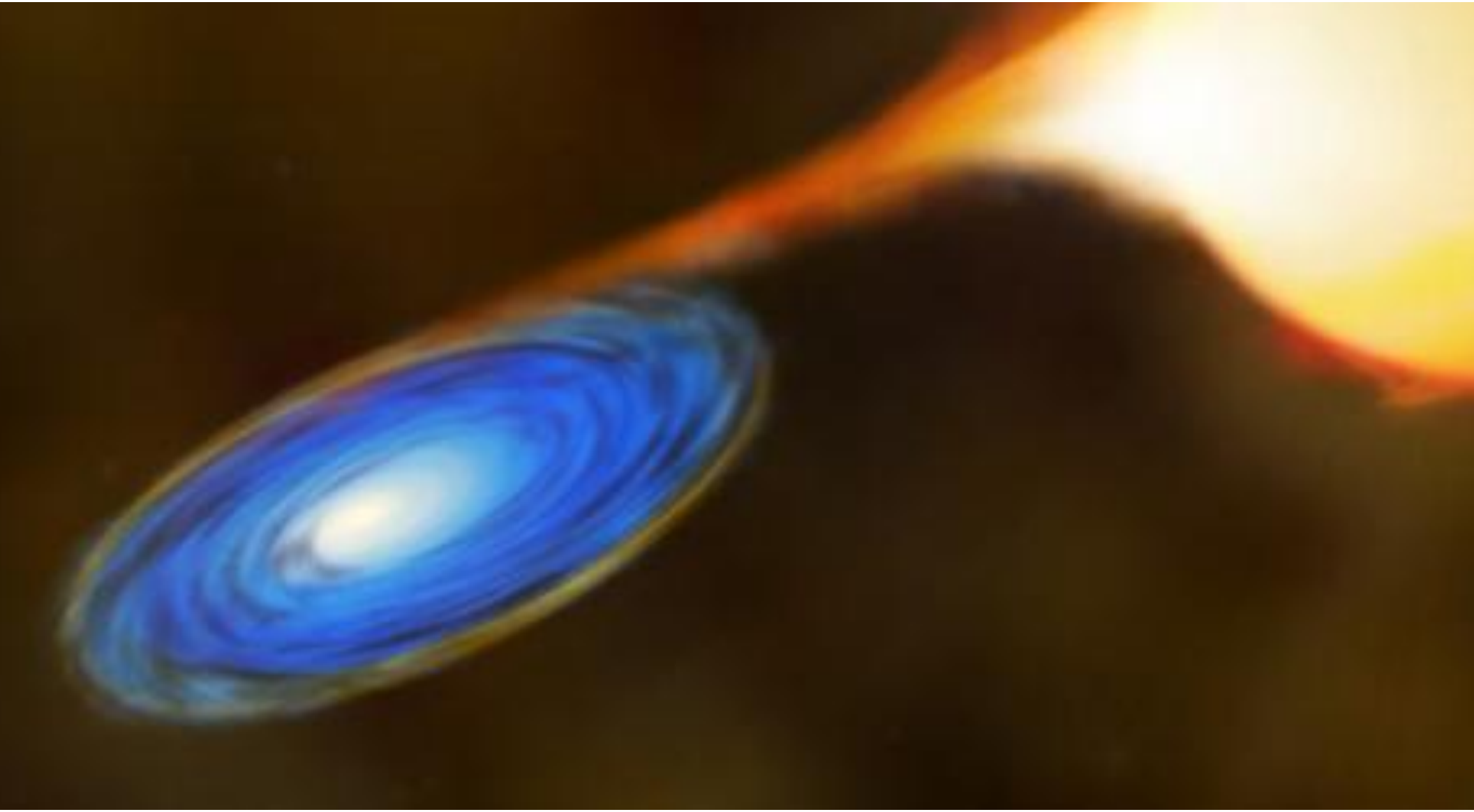
Supernova 1987A

European Southern Observatory



Another Kind of Supernova


Secondary star
Main-sequence star
Main-sequence star
Red giant
Red-giant remnant
Primary star
Red giant
White dwarf
White dwarf
Type Ia supernova
Not to scale



Red Giant "Feeding" a White Dwarf

Harvard Center for Astrophysics, https://www.cfa.harvard.edu/news/2011-04

Review Hubble Plot

Doppler Shift

λ=wavelength
f=frequency
o=observed
s=source
$\beta=v/c$
v=velocity of source
c=speed of light

z=fractional shift in wavelength

$$\frac{\lambda_o}{\lambda_s} = \frac{f_s}{f_o} = \sqrt{\frac{1+\beta}{1-\beta}},$$

and the resulting redshift

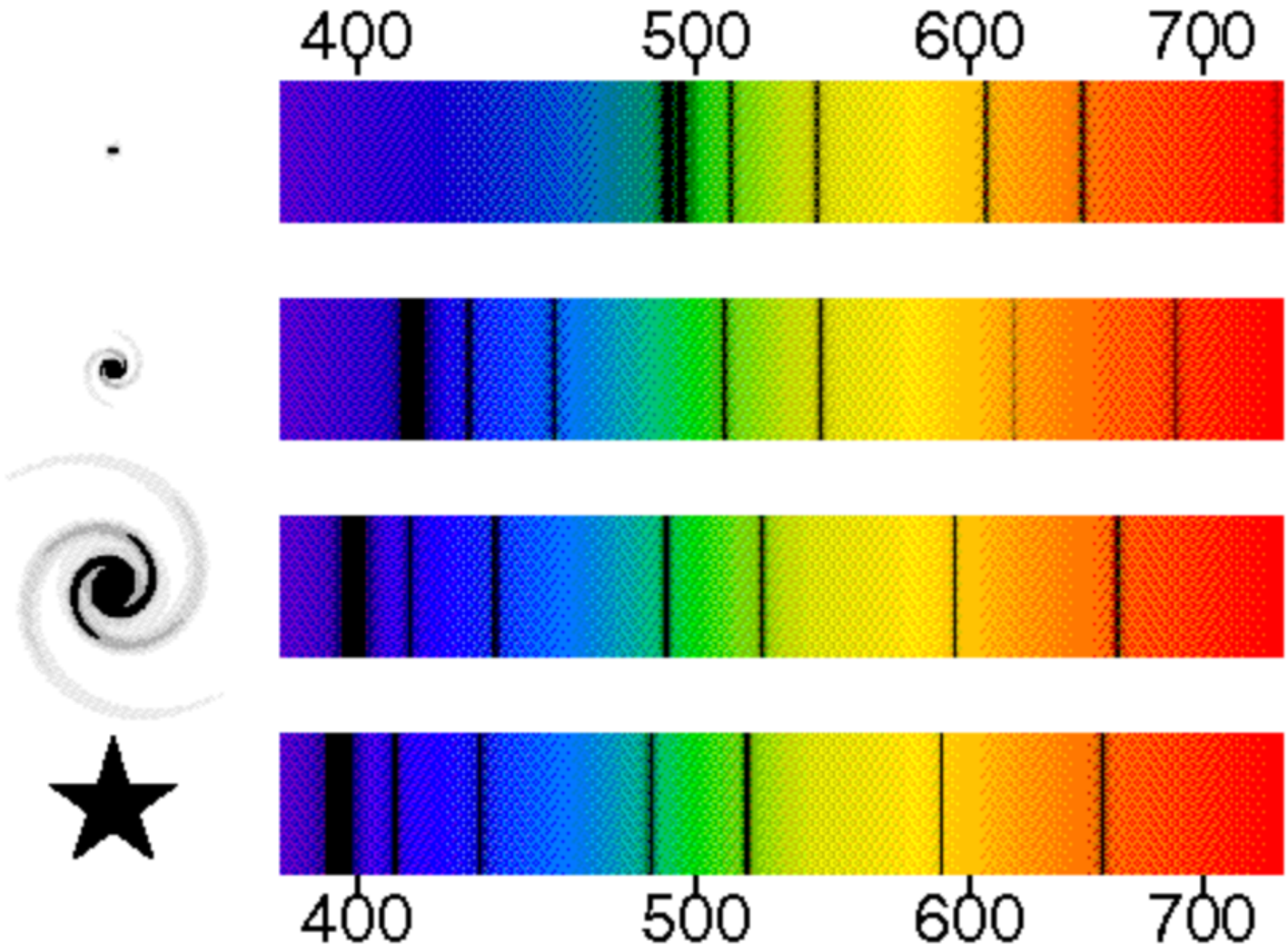
$$z = \frac{\lambda_o - \lambda_s}{\lambda_s} = \frac{f_s - f_o}{f_o}$$

can be written as

$$z = \sqrt{\frac{1+\beta}{1-\beta}} - 1.$$

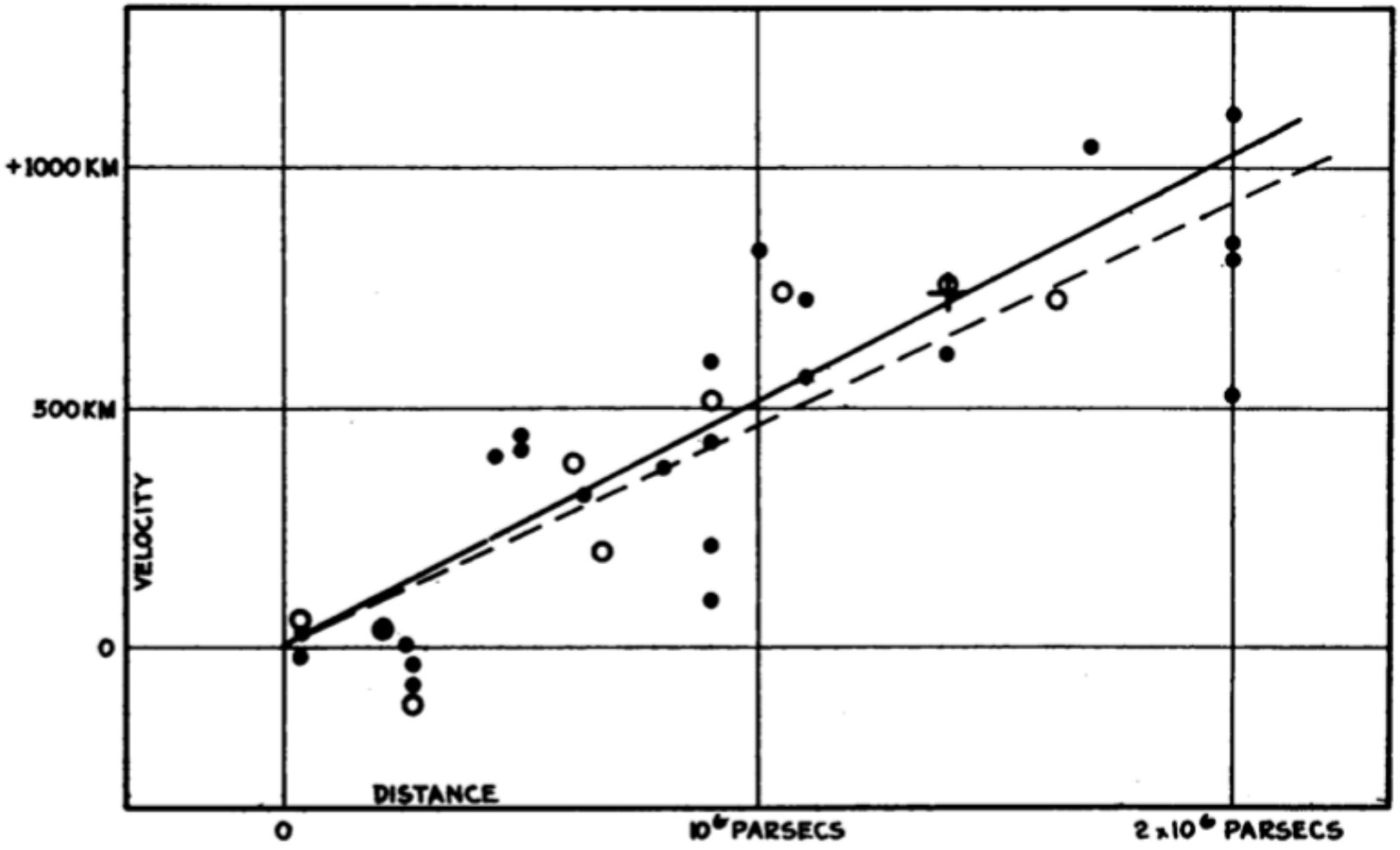
In the non-relativistic limit (when $v \ll c$)

$$z \simeq \beta = \frac{v}{c},$$


400
500
600
700
400
500
600
700

Doppler Shift is how Hubble Knew how Fast the Spiral Nebula were Moving Away

Cepheid Brightness is How he Knew How Far Away they Were

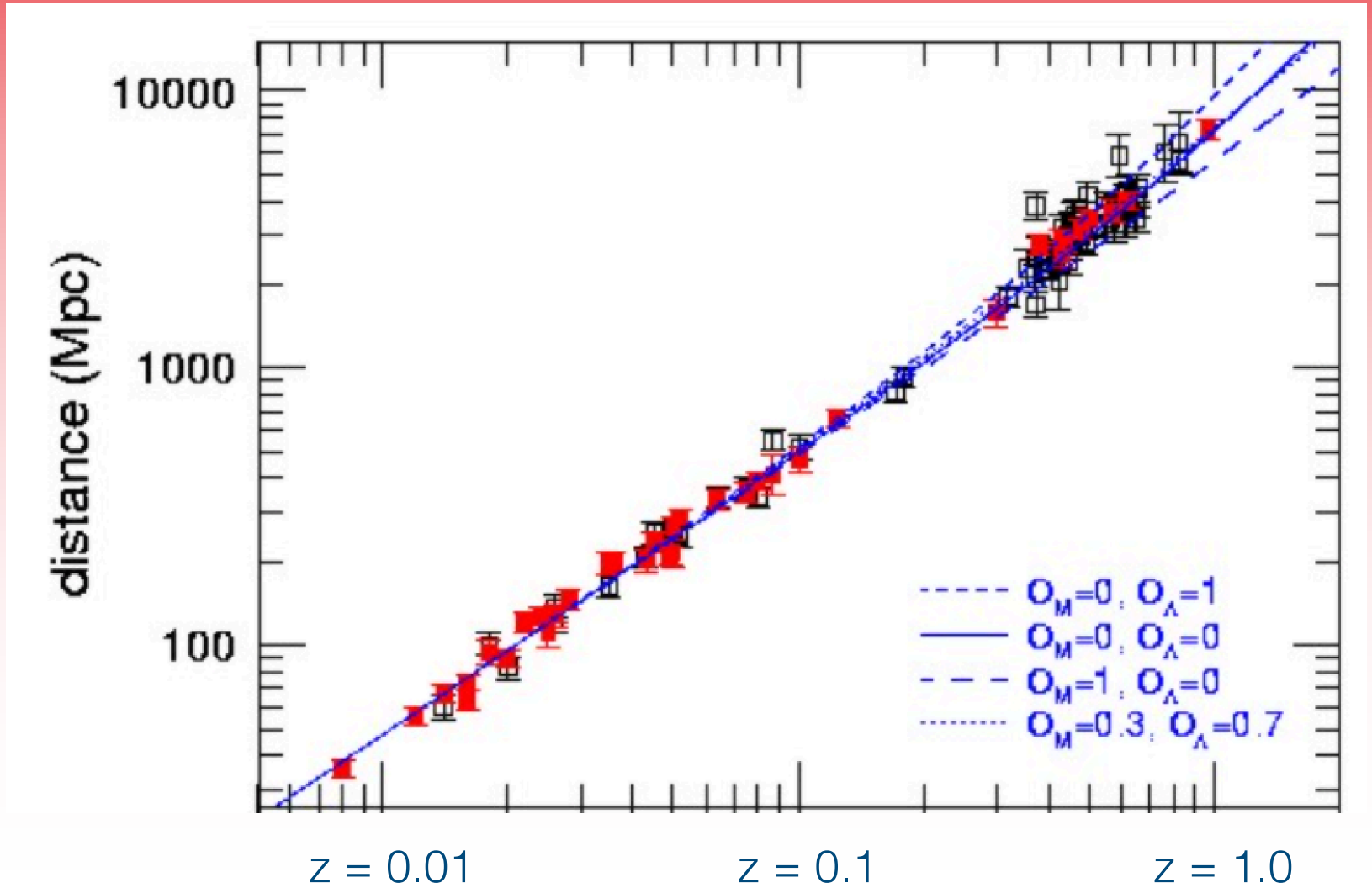


Hubble, 1929

Type Ia Supernovae

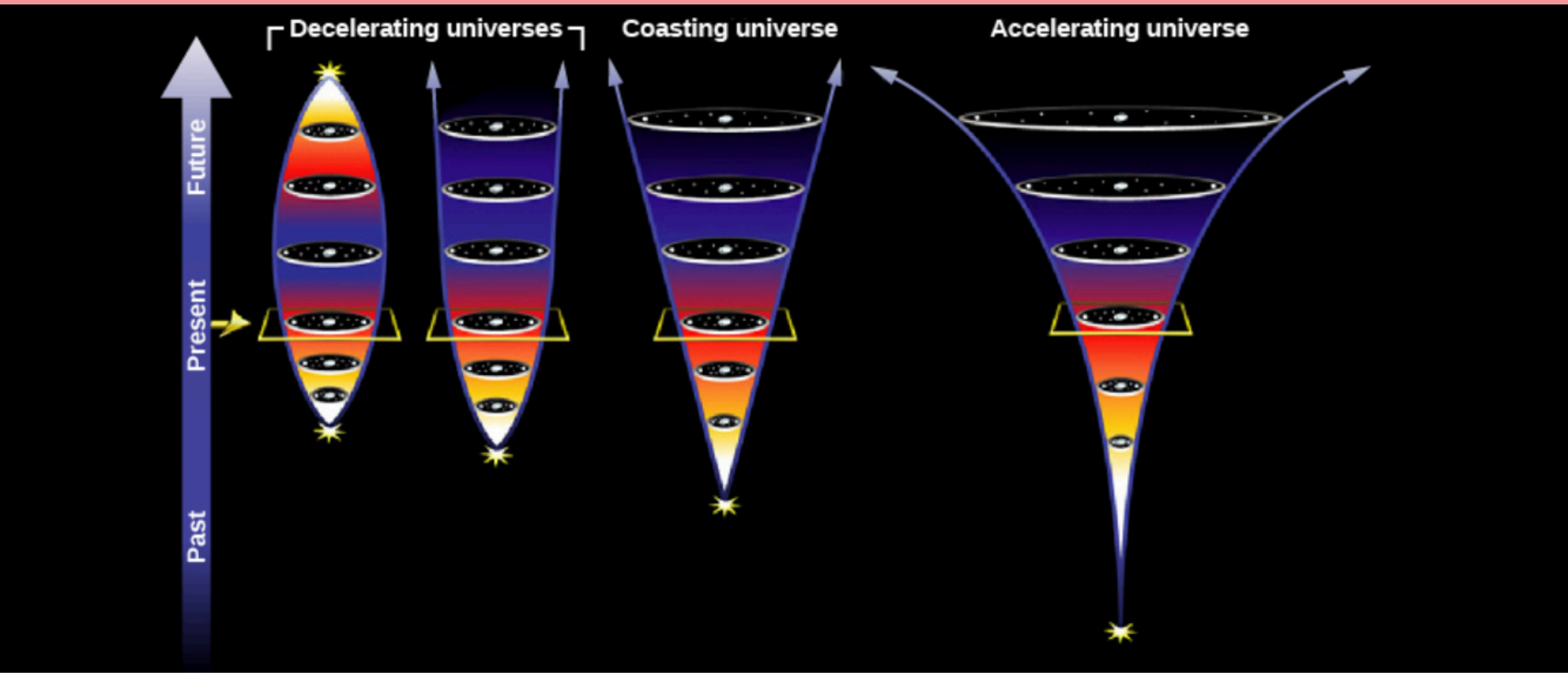
The New Standard Candle

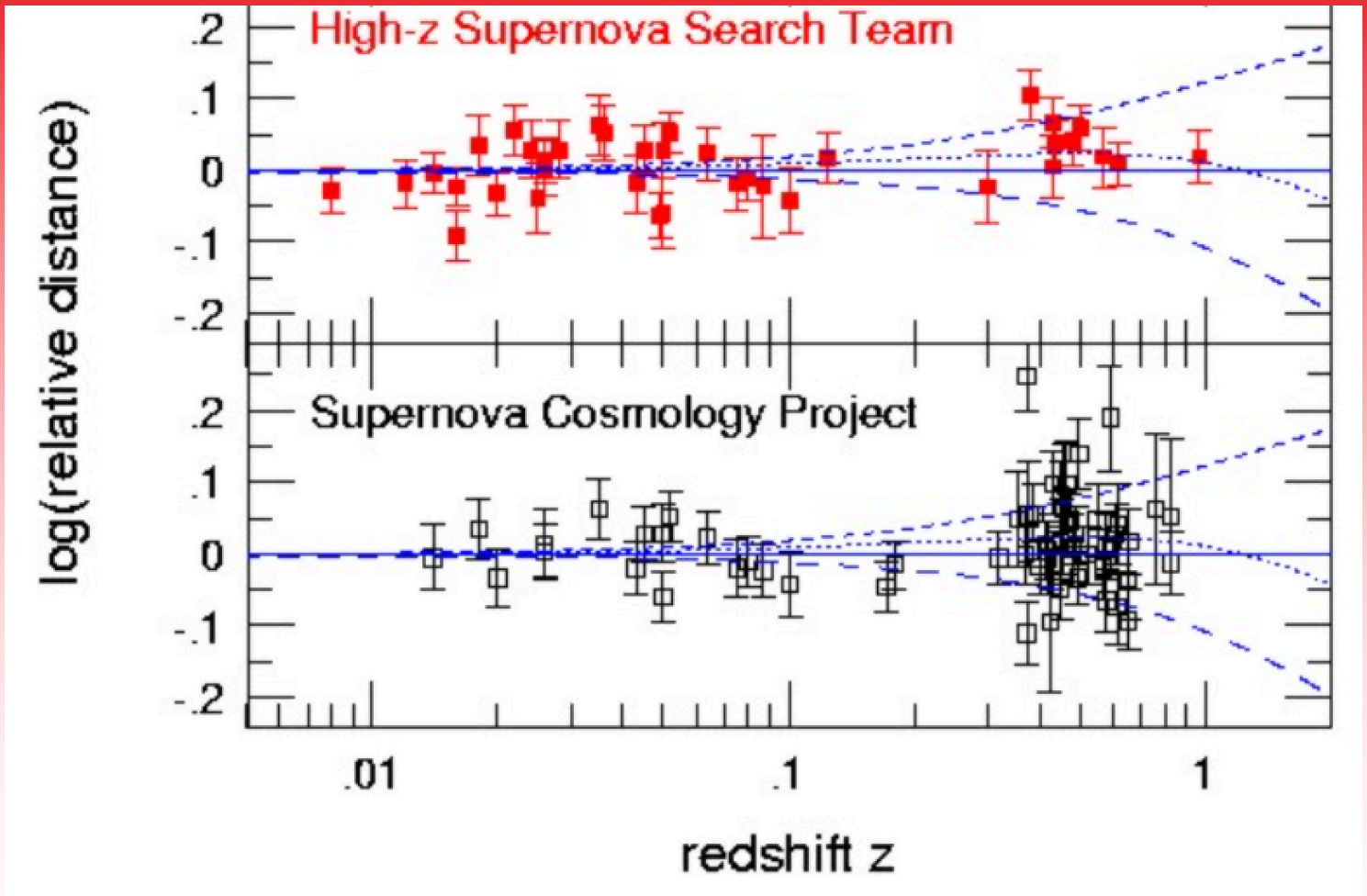
A New and Better Hubble Plot



Combined Results:
High-z Supernova Search Team (red)
Supernova Cosmology Project (black)

Models of Expansion





Best Fit to Data is the Dotted Line

Ordinary Matter + Dark Matter = 30%

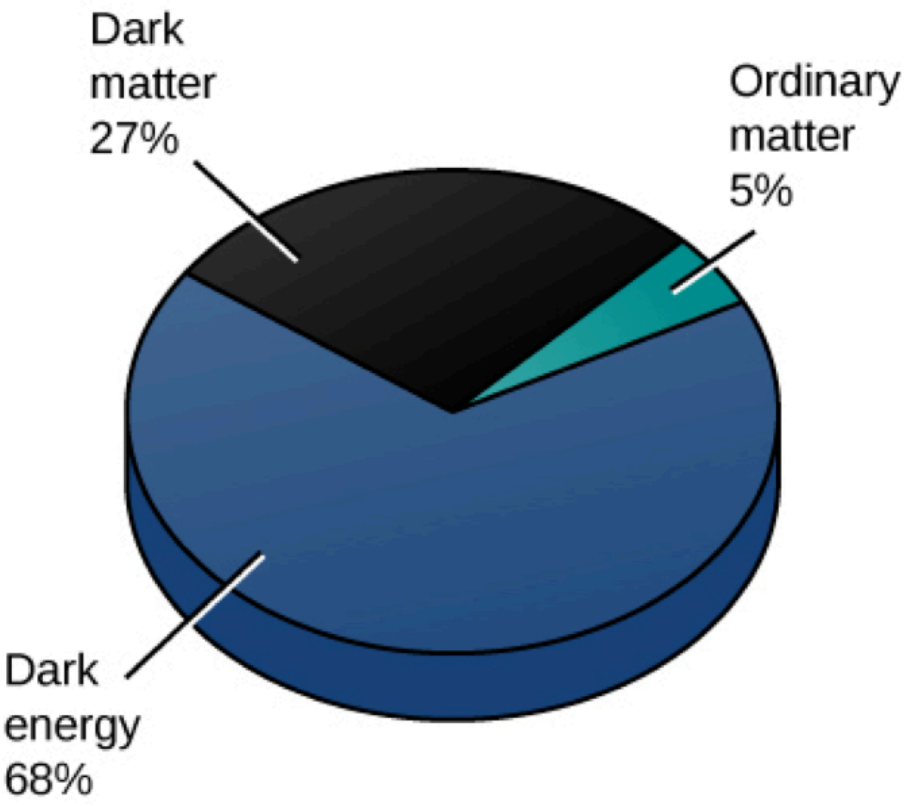
Dark Energy = 70%

2011 Nobel Prize, Perlmutter, Berkeley, Supernova Cosmology Project, Schmidt and Riess, High-z Supernova Search Team

Composition of the Universe

Dark matter
27%

Dark energy
68%



Ordinary matter
4% H and He
<1% Stars
<1% Other

Best Estimate today: 5% Matter we understand, 27% dark matter, 68% Dark Energy