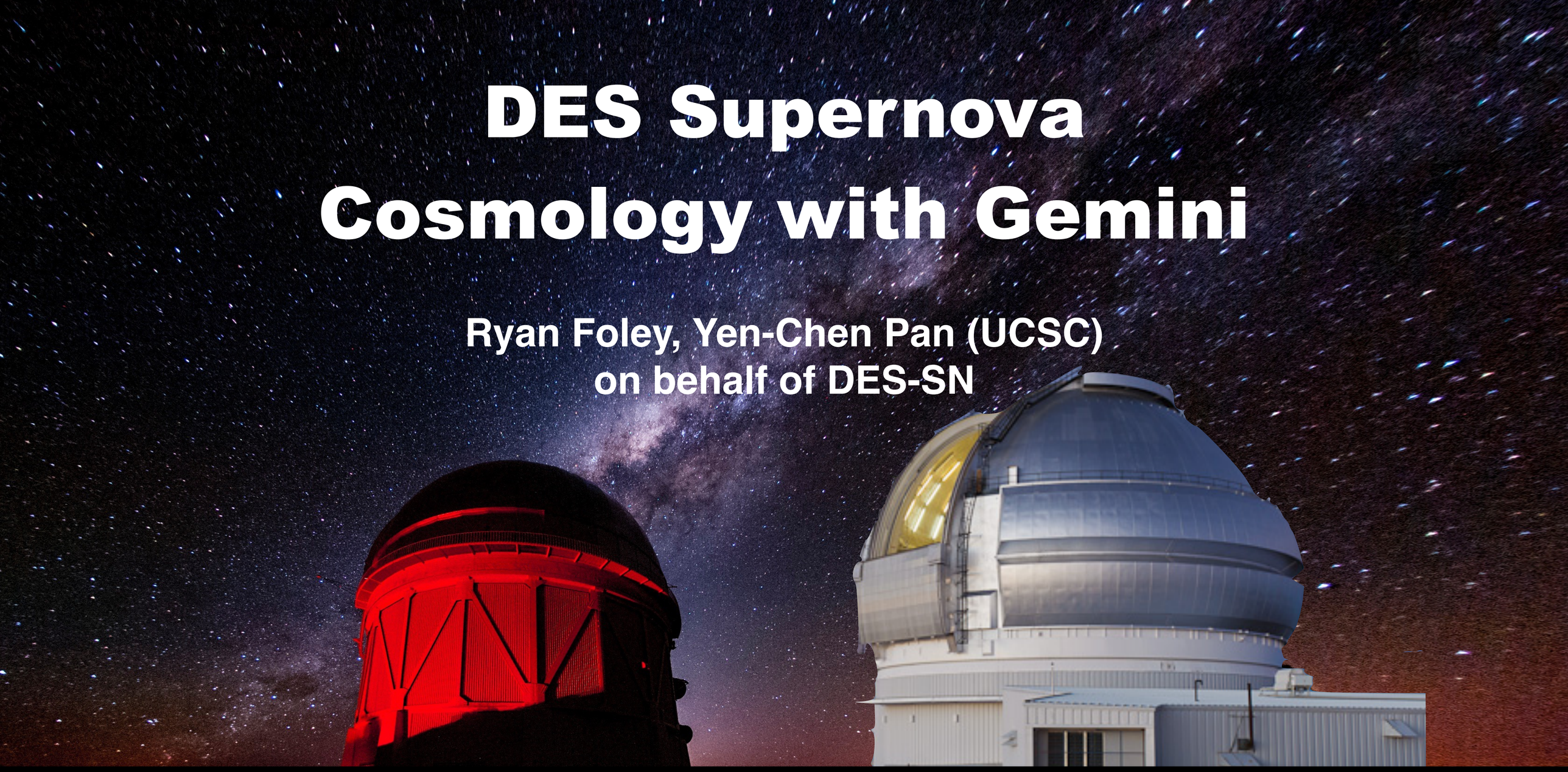
DES Supernova Cosmology with Gemini

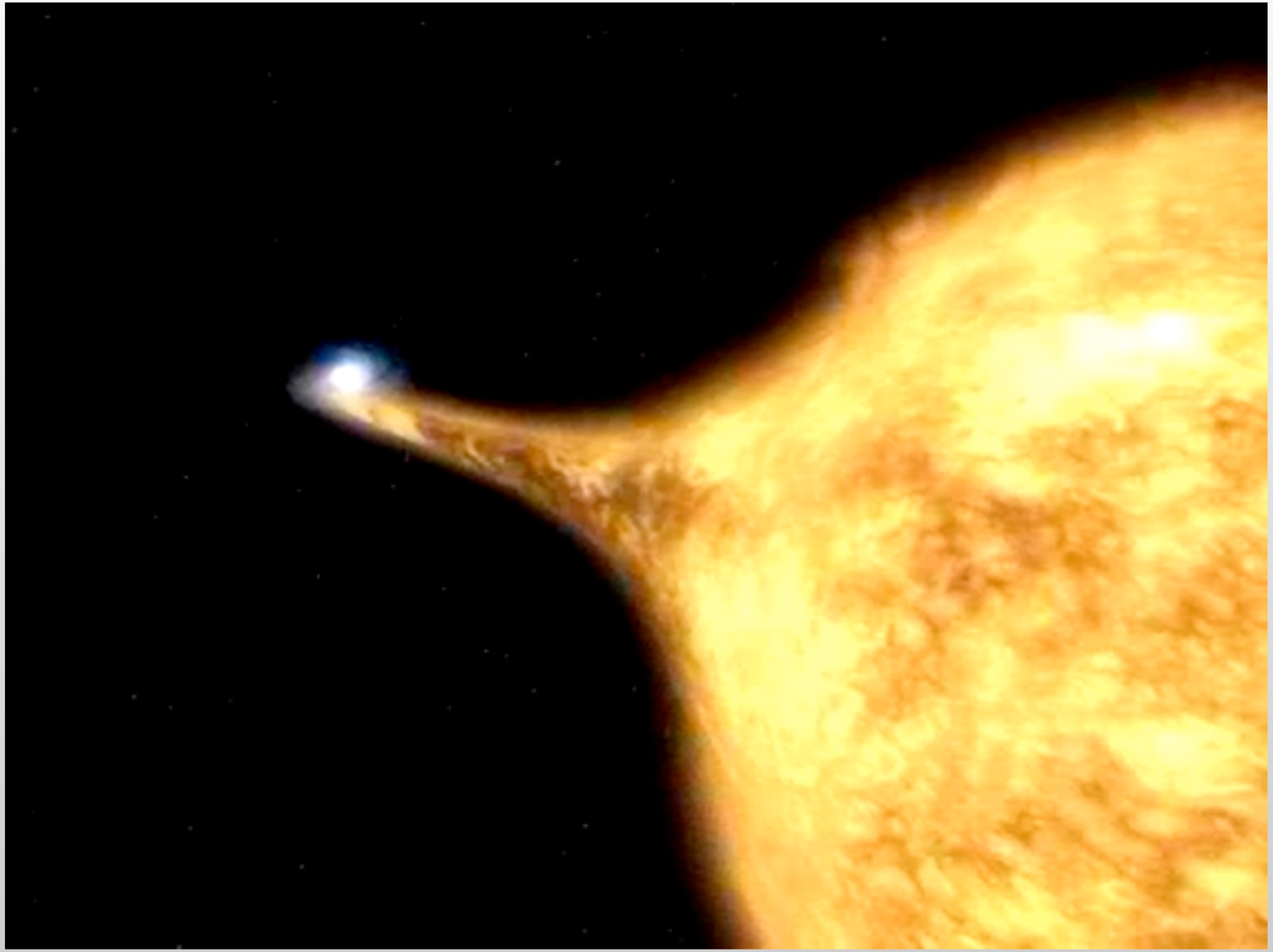
Ryan Foley, Yen-Chen Pan (UCSC)
on behalf of DES-SN



UC SANTA CRUZ

THE DARK ENERGY SURVEY

SNe Ia Are Exploding White Dwarfs

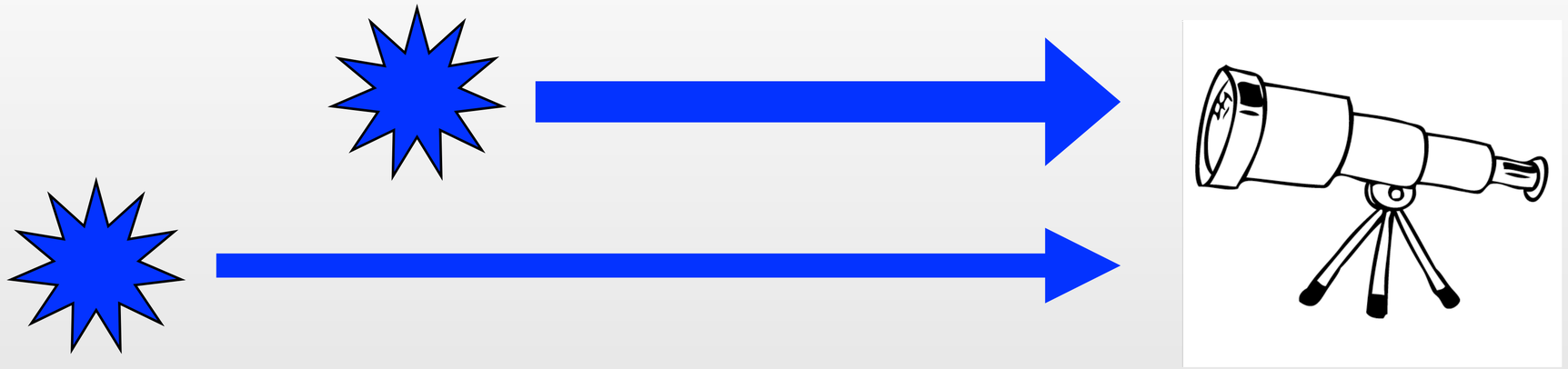


White Dwarf in Binary System

Accretes Matter Until ~1.4 times the Mass of the Sun

Explodes and is Very, Very Luminous

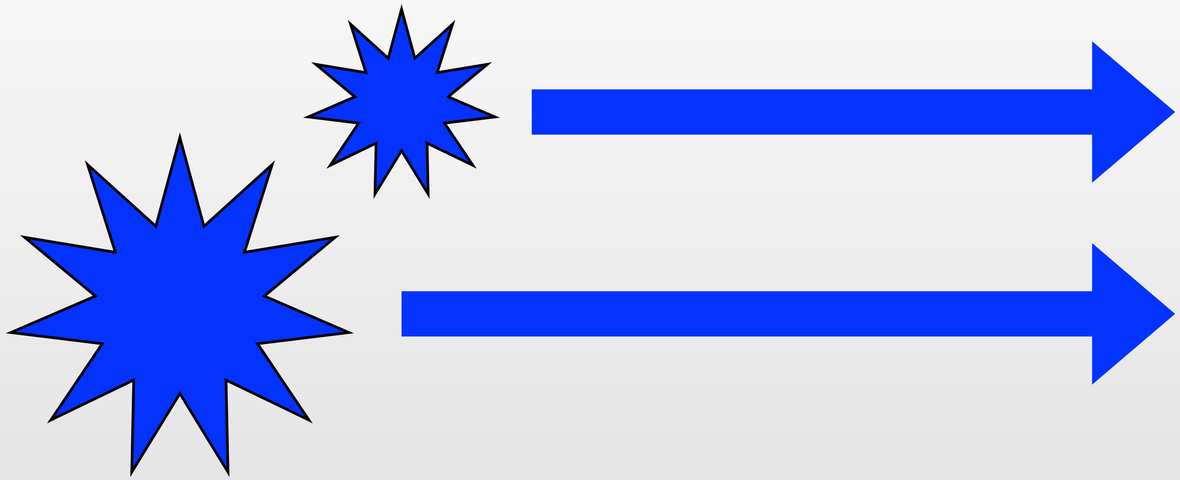
Standard Candles and Distances

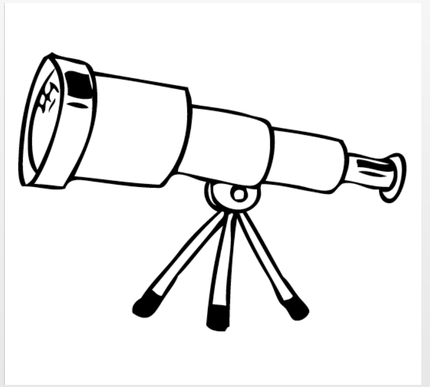


Obs: $D = (L/4\pi F)^{1/2}$

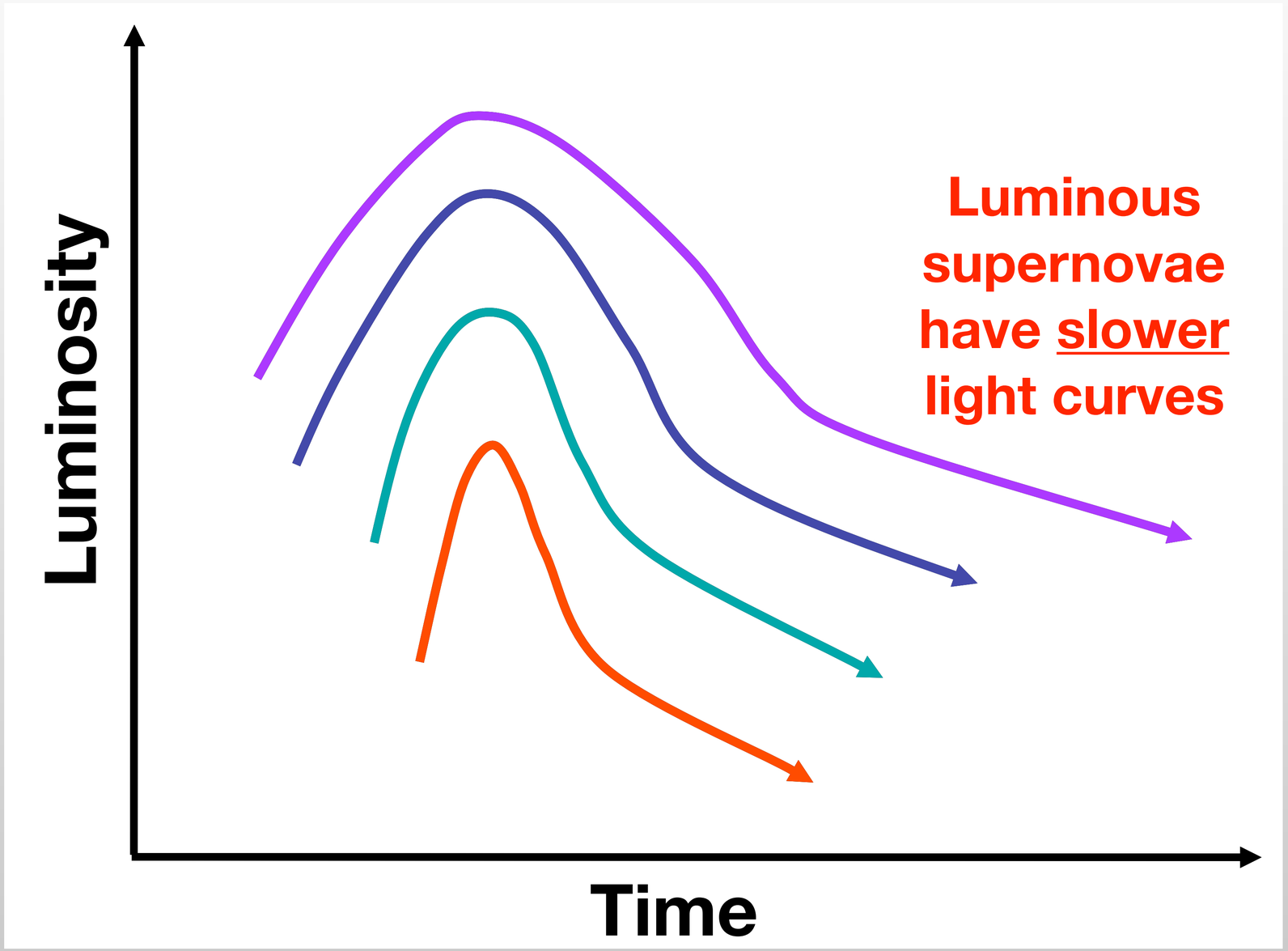
Theory: $D = f(z, \Omega, w(z), \text{etc})$

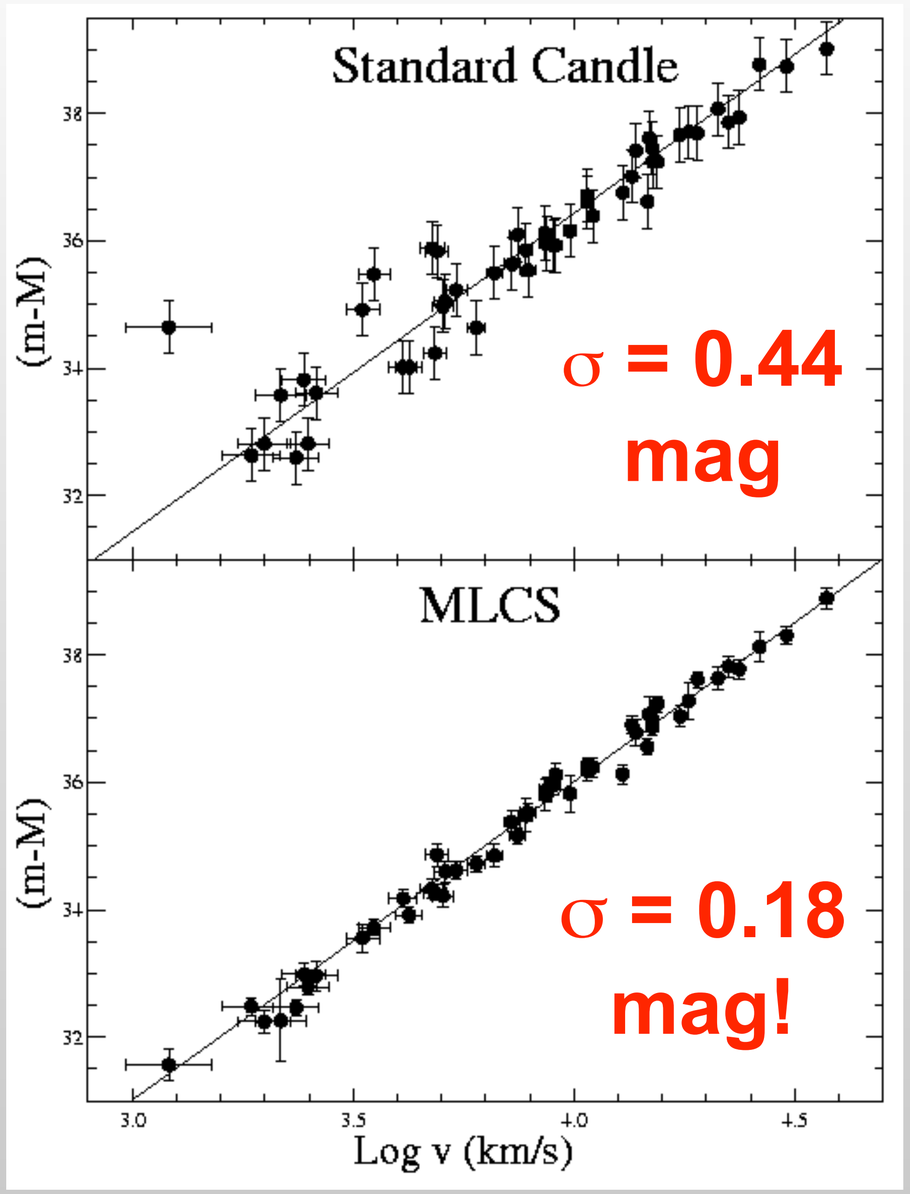
SNe Ia are NOT Standard Candles!



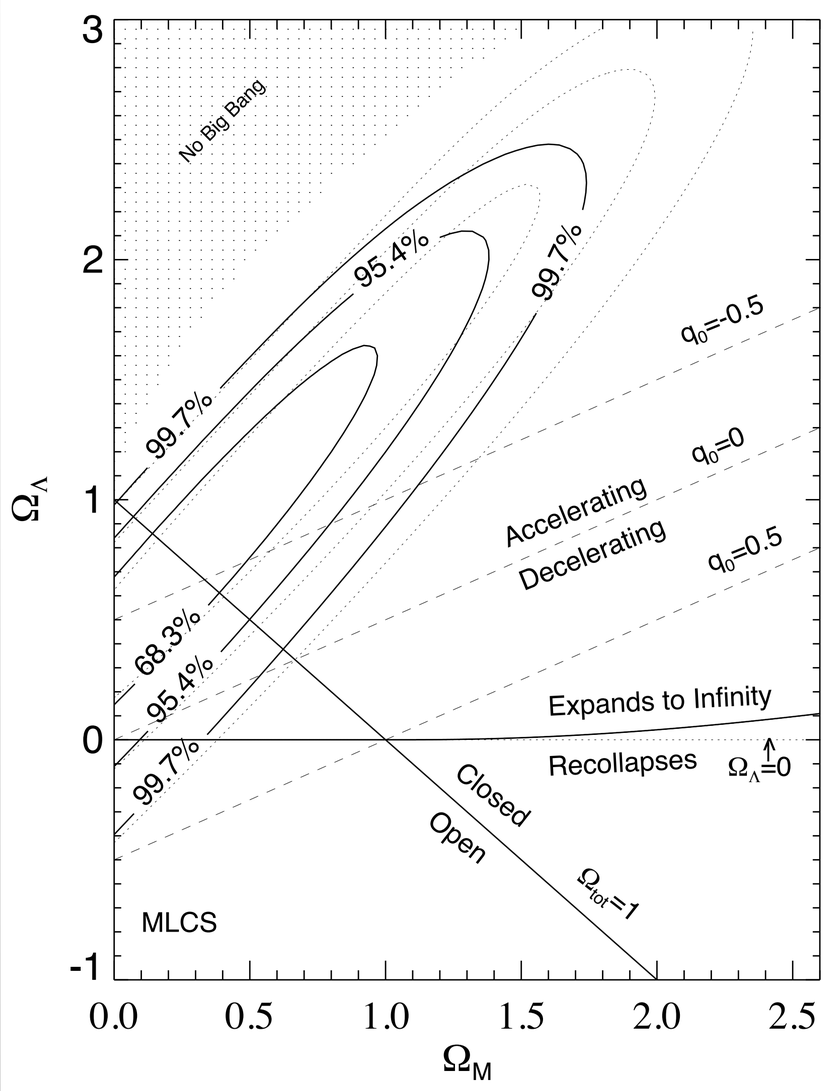


Calibrating the Nearly Standard Candle

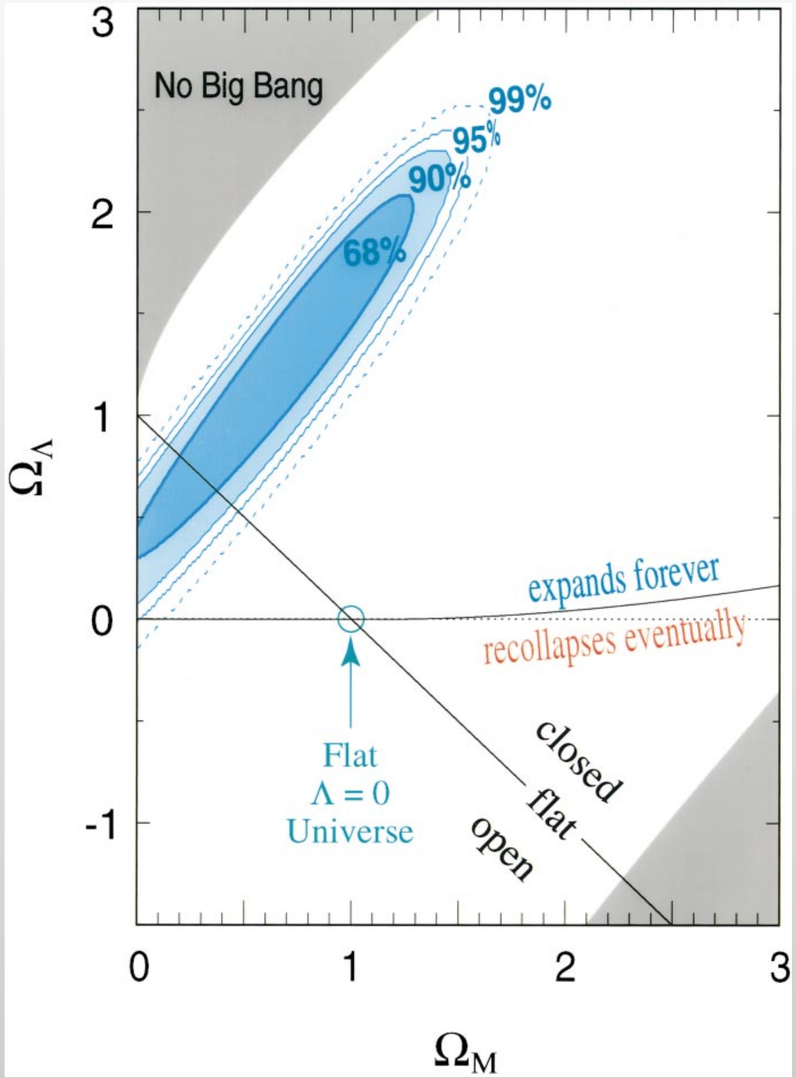




Accelerating Universe!



Riess et al. 1998



Perlmutter et al. 1999

What is Dark Energy?

Look at Equation of State: $w = P/(\rho c^2)$

Need $w \leq -1/3$ for acceleration

$w = -1$ for cosmological constant

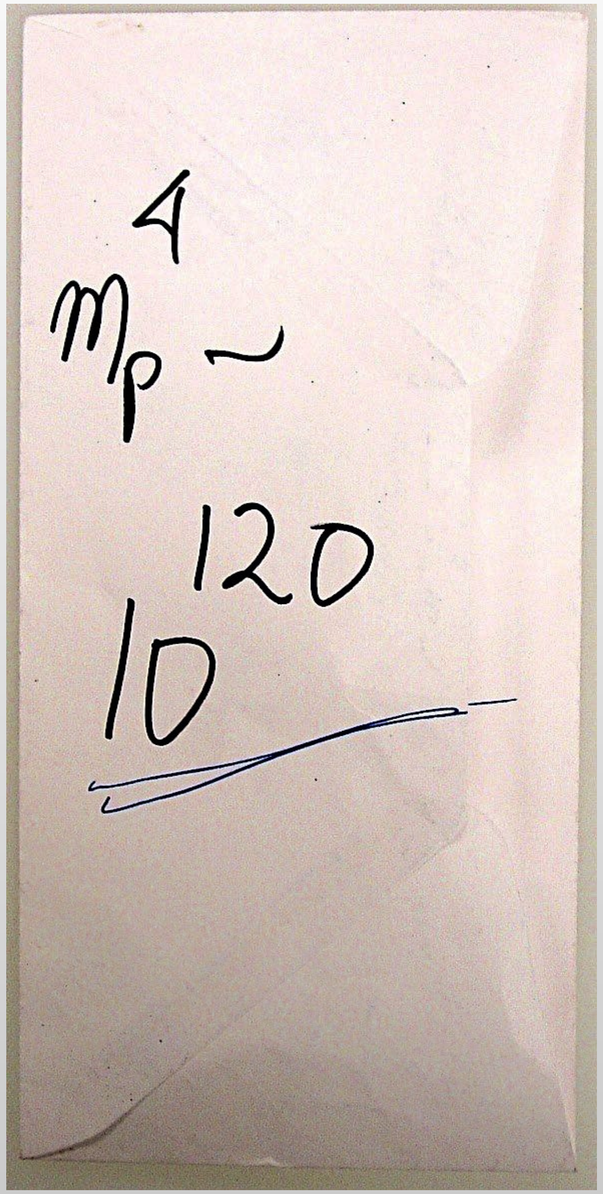
Several Problems with

Cosmological Constant:

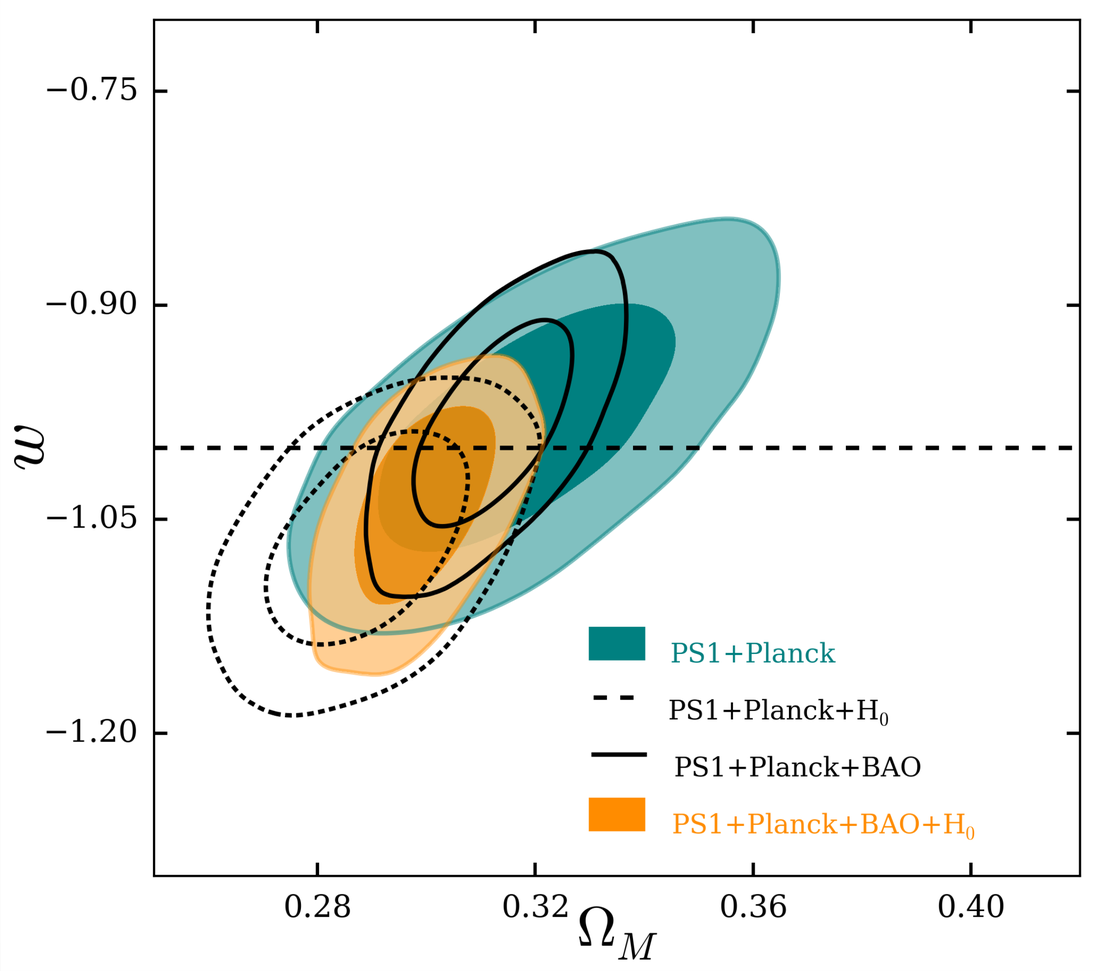
1. Simple theory suggests Λ should be much larger

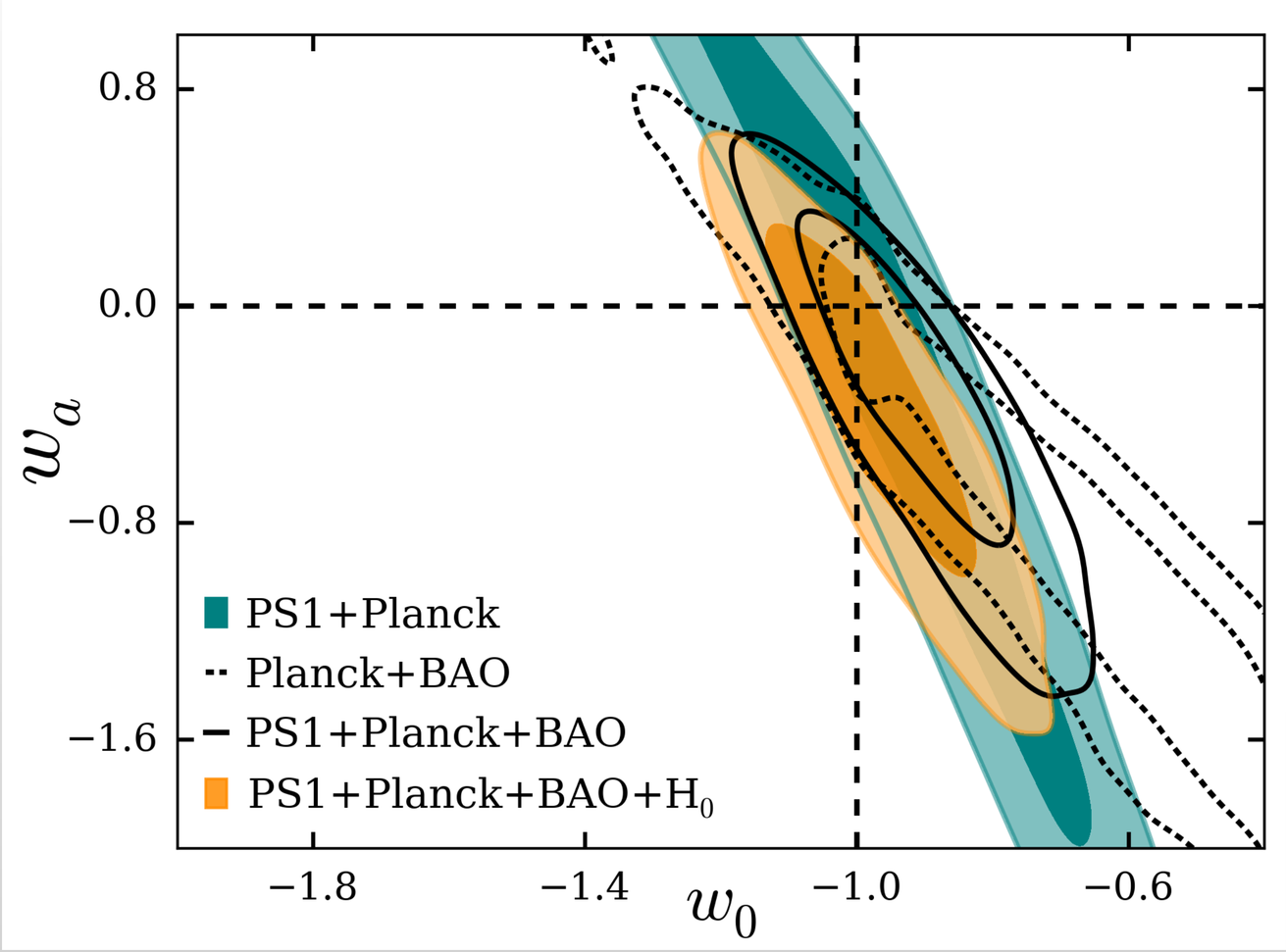
2. Why is $\Omega_\Lambda \approx \Omega_m$?

3. Already another period of accelerated expansion without cosmological constant (inflation)



$w = -1.040 \pm 0.046$ | $w_0 = -0.97 \pm 0.10$; $w_a = -0.38 \pm 0.45$



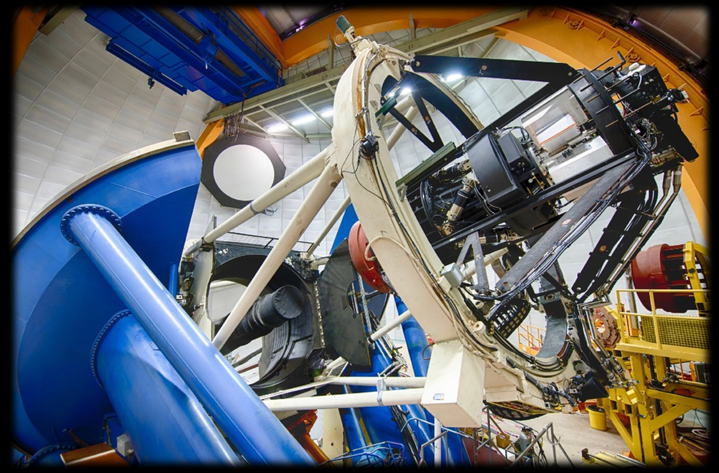


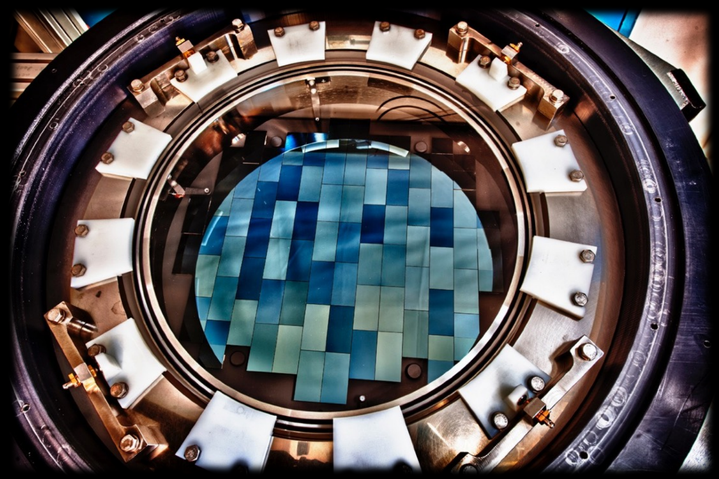
Jones et al., 2018

THE DARK ENERGY SURVEY

DES is a 5-year survey to probe the dark energy using galaxy clusters, weak lensing, large-scale structure, and type Ia supernovae.

Blanco 4-m telescope

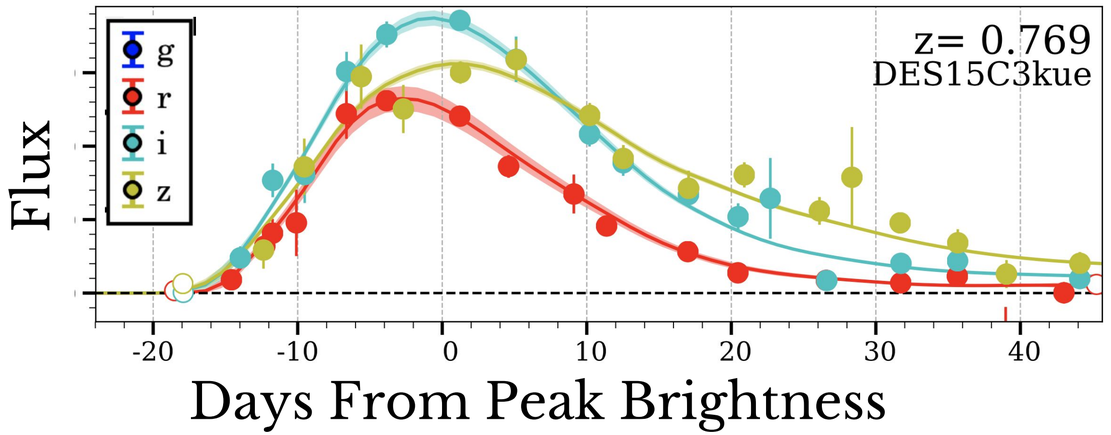




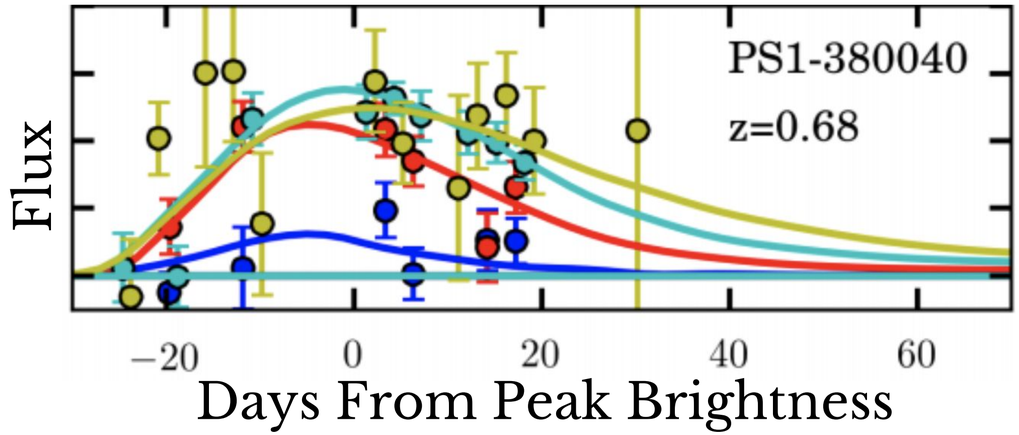
Dark Energy Camera

wErr (stat+sys)	#SNe	SURVEY
0.054	740	JLA-Spec (2014)
0.040	1049	PANTHEON-Spec (2018)
0.058	~1000	PS1-Phot (2017)
?	**334**	**DES3YR-Spec (2018)**

DESSN



Pan-STARRS1 (Scolnic et al. 2018)



The Ingredients for Supernova Cosmology

Difference Imaging	→ SNe Candidates
Spectra	→ Type & redshift
Photometry	→ Light Curves → Distances
Calibration	→ Relative Distance between all SNe
Simulations	→ Distance Bias Corrections
Systematics	→ Covariance Matrix
CosmoMC	→ wCDM fit with SNeIa + Planck 2015

The Ingredients for Supernova Cosmology

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BLINDED

(unblinded December 22nd, 2017)

Preliminary RESULTS! (flat wCDM)

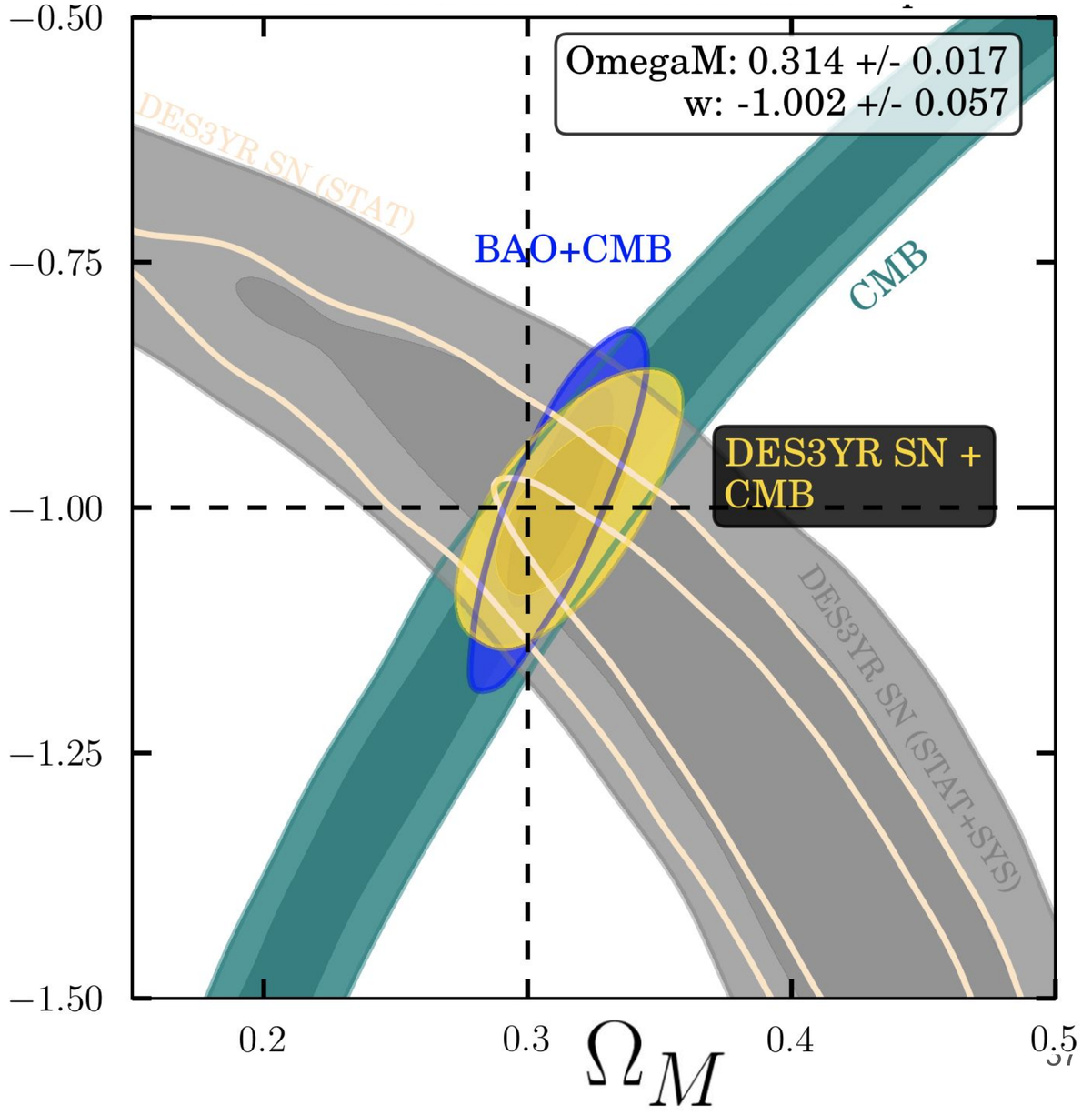
wErr (stat+sys)	#SNe	SURVEY
0.054	740	JLA-Spec (2014)
0.040	1049	PANTHEON-Spec (2018)
0.058	~1000	PS1-Phot (2017)
0.057*	**334**	**DES3YR-Spec (2018)**

*equally STAT and SYS dominated

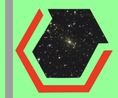
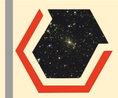
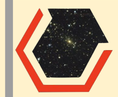
Preliminary RESULTS! (flat wCDM)

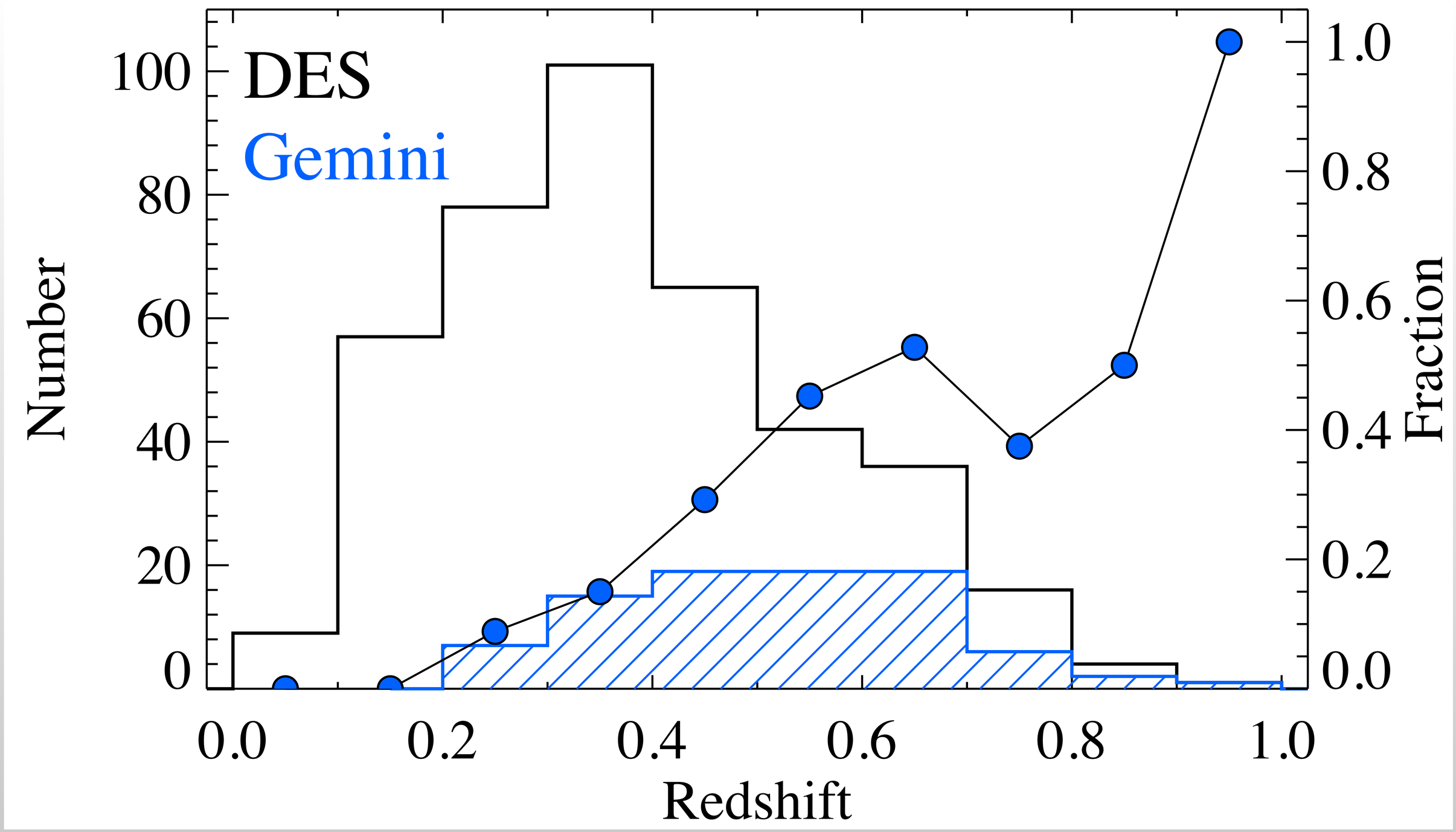
$$w = -1.002 \pm 0.057$$

$$\Omega_M = 0.314 \pm 0.017$$



Where do we go from here?

wErr (stat+sys)	#SNe	SURVEY
0.054	740	JLA-Spec (2014)
0.040	1049	PANTHEON-Spec (2018)
0.058	~1000	PS1-Phot (2017)
0.057	**334**	 **DES3YR-Spec (2018)**
?	**~500**	 **DES5YR-Spec (future)**
?	**~2000**	 **DES5YR-Phot (future)**

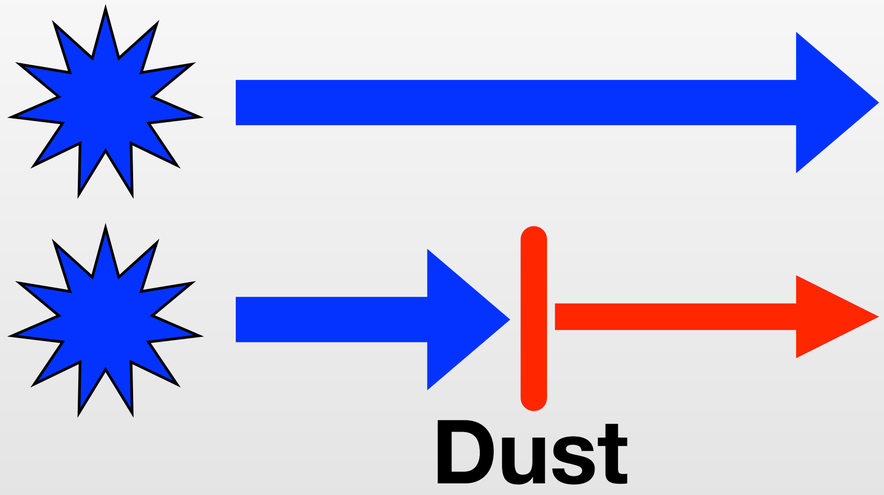

DES
Gemini
Number
Fraction
Redshift
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0

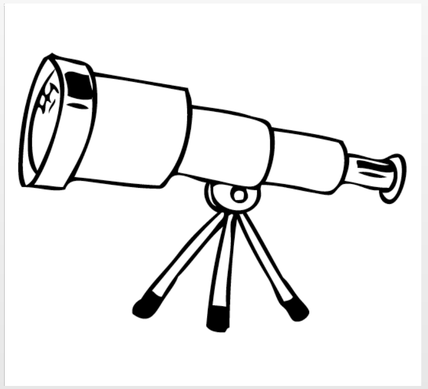
Systematics Dominate

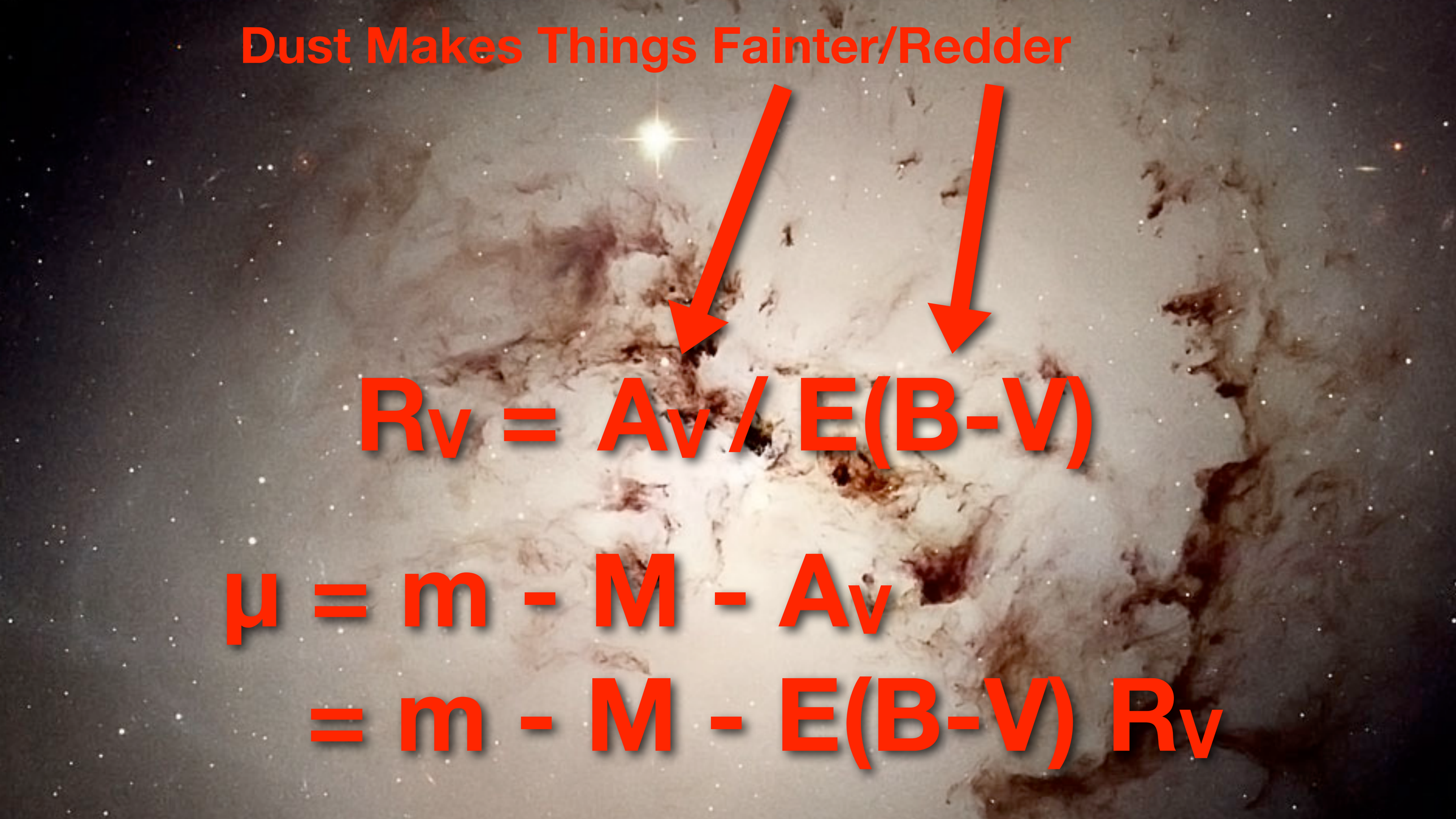
Source	dw
Total Uncertainty	**0.072**
Statistical Uncertainty	0.050
Systematic Uncertainty	**0.052**
Photometric calibration	**0.045**
SN color model	0.023
Host galaxy dependence	0.015
MW extinction	0.013
Selection Bias	0.012
Coherent Flows	0.007

Scolnic et al. 2014

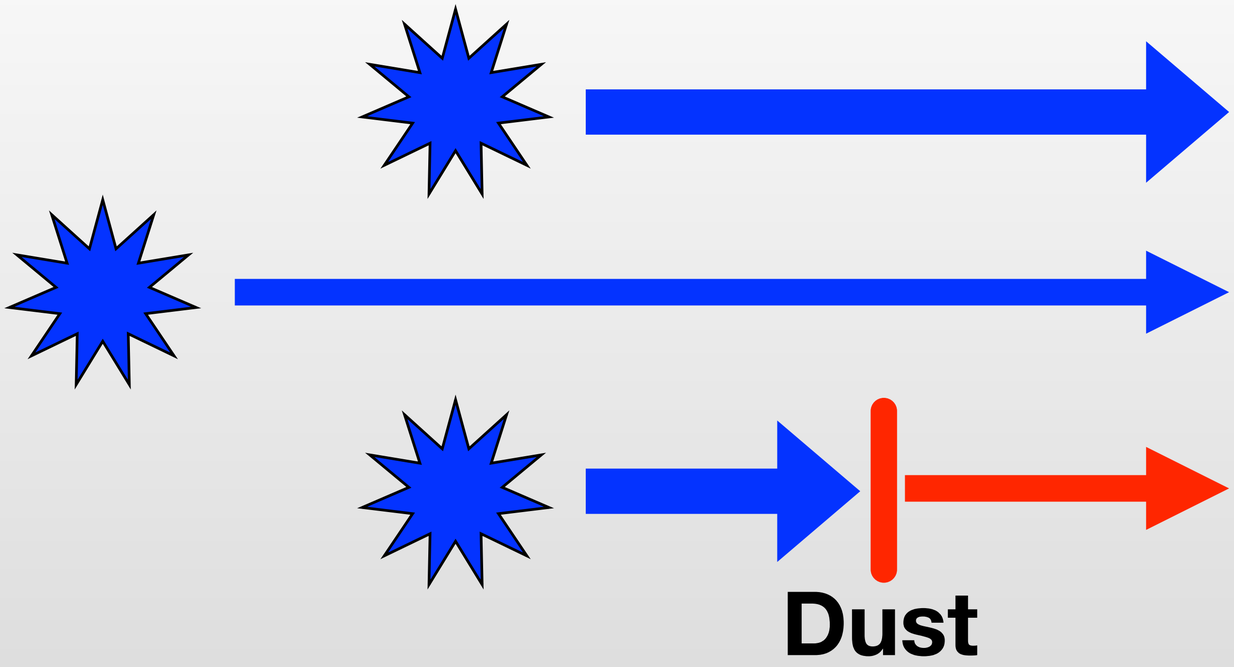
Dust Makes Things Fainter/Redder

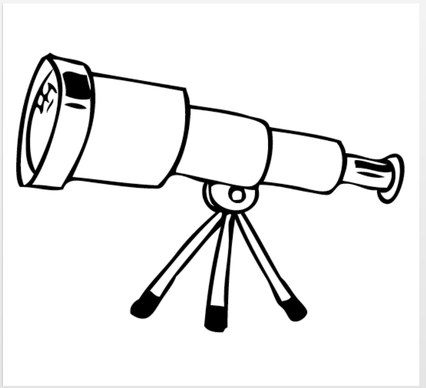





Dust Makes Things Fainter/Redder
Rv = Av / E(B-V)
μ = m - M - Av
= m - M - E(B-V) Rv

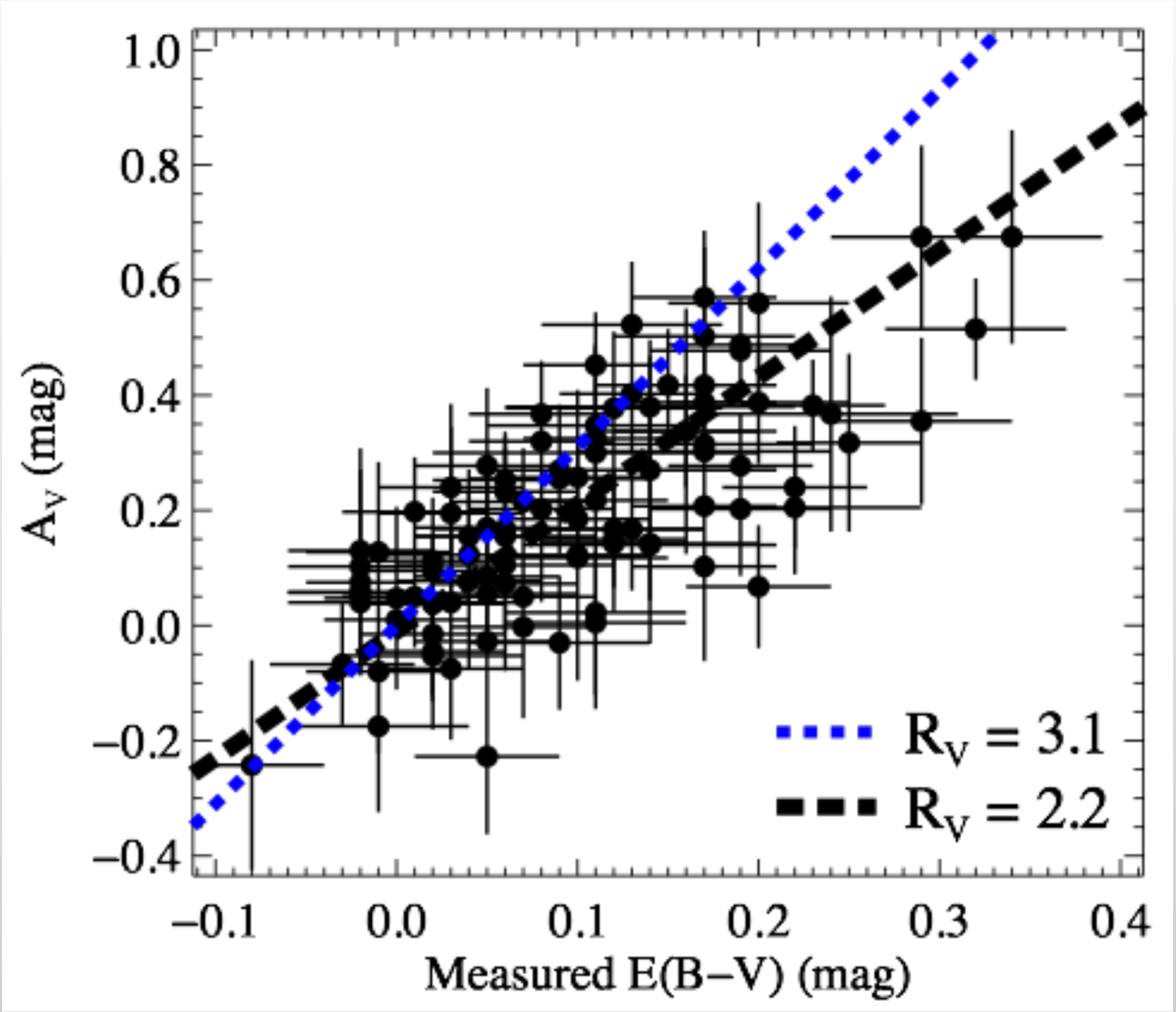
Dust Makes Things Fainter/Redder





$$A_V = E(B\text{-}V)\ R_V$$

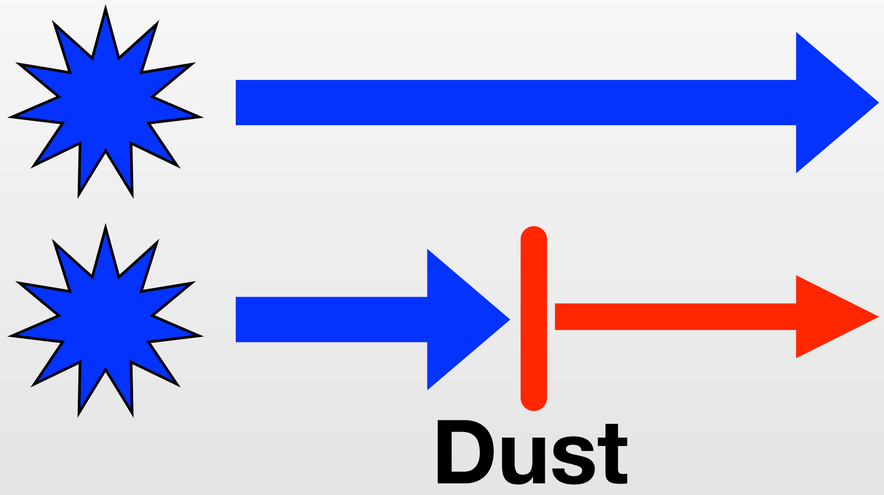
Samples of SNe Ia have Low R_V

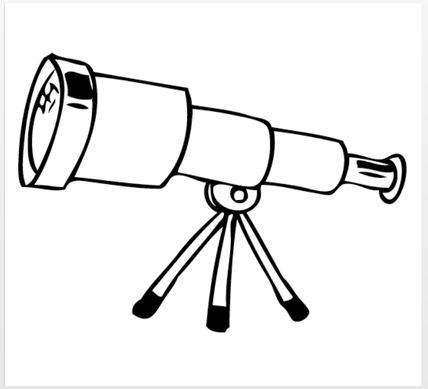


Foley & Kasen 2011

R_V = A_V/E(B-V)

Dust Makes Things Fainter/Redder





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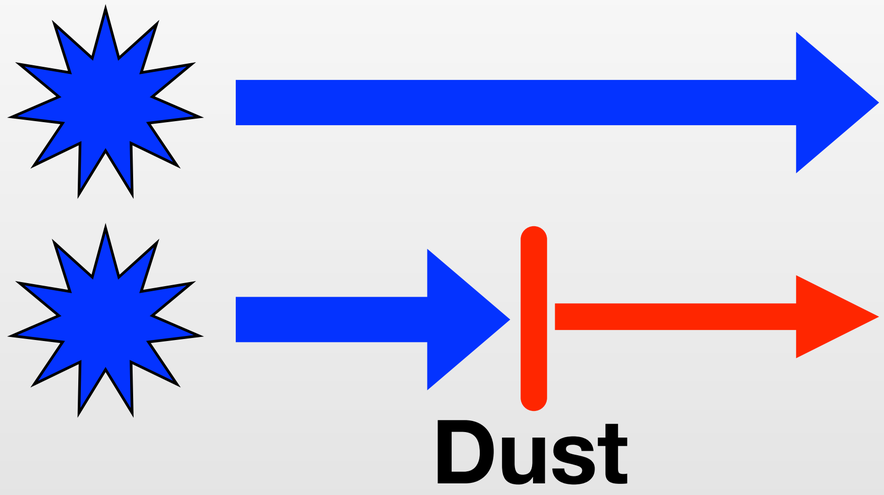
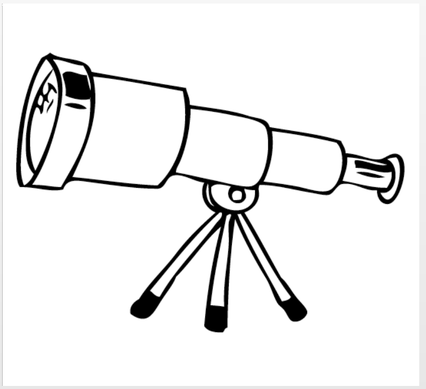
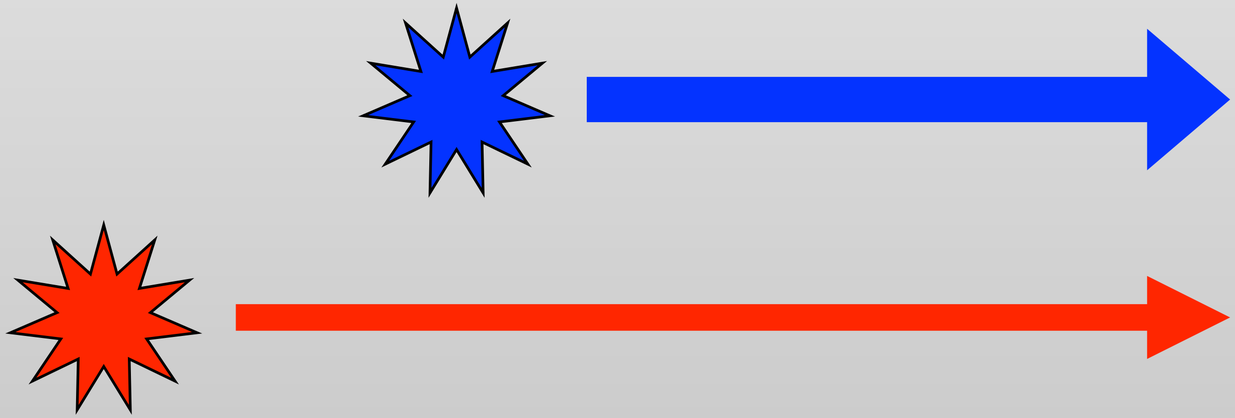
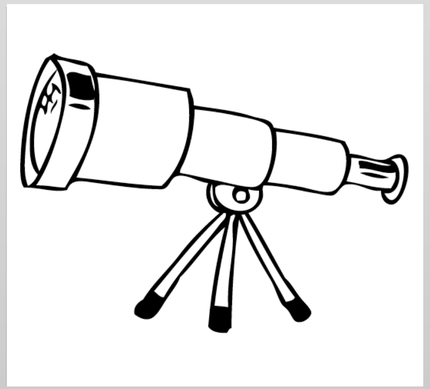


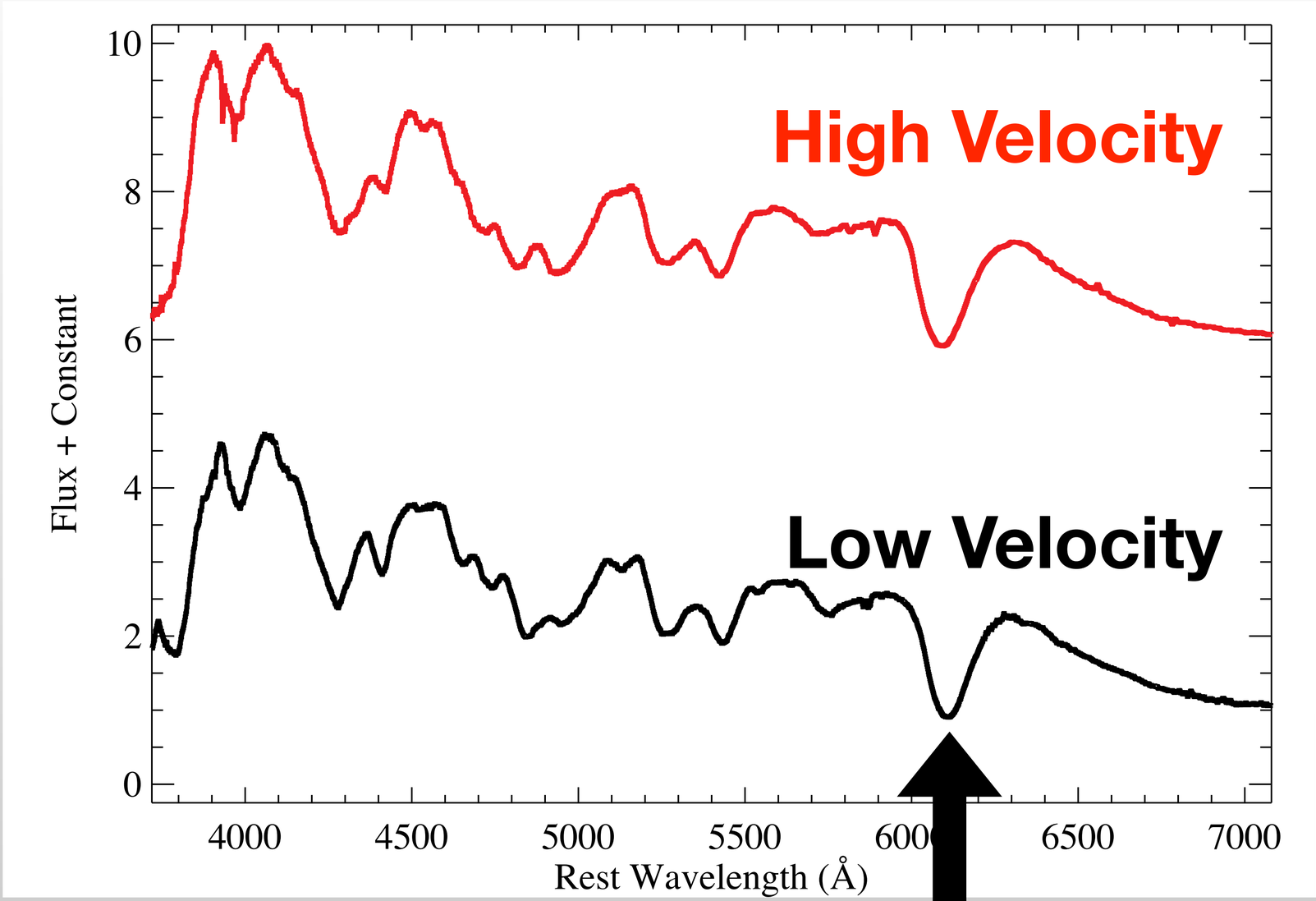


Different Intrinsic Colors

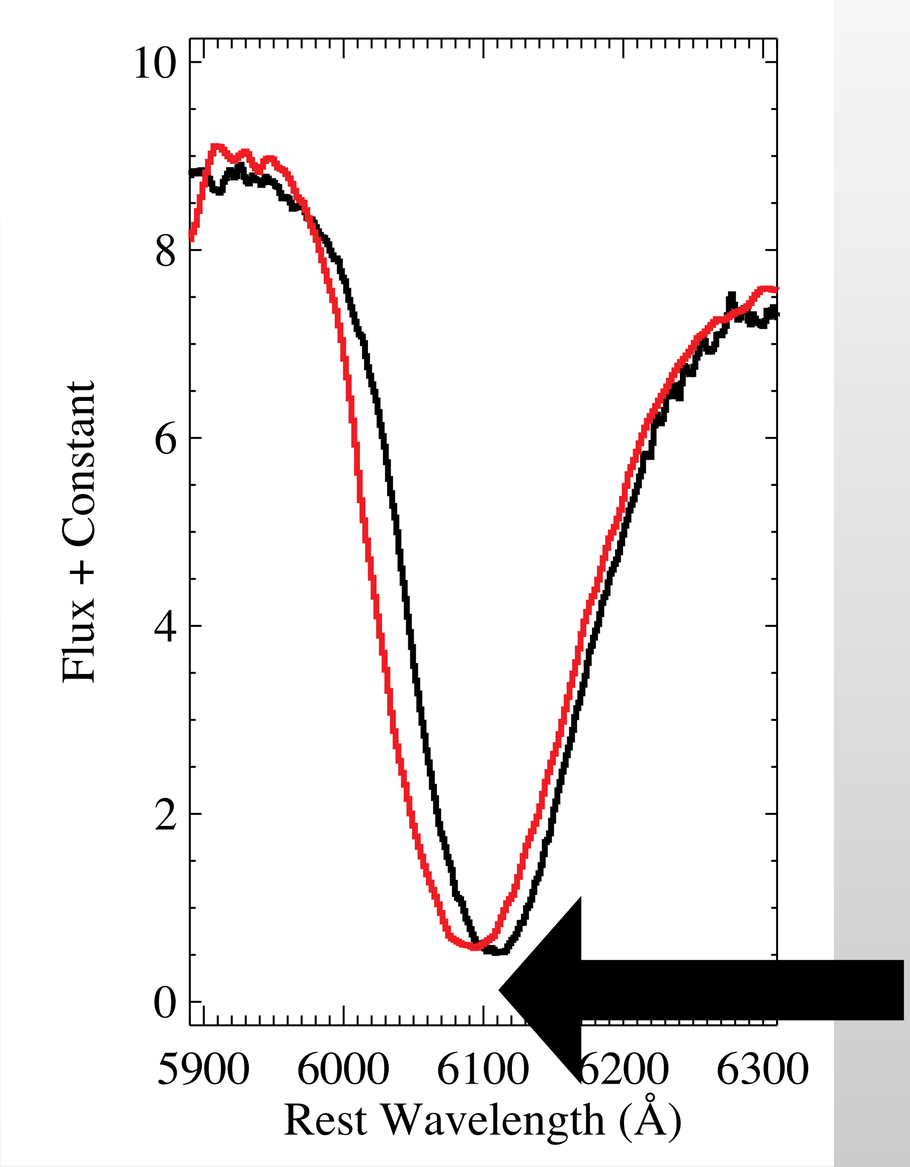




Optical Spectrum to Measure Velocity



Measuring Silicon Velocity

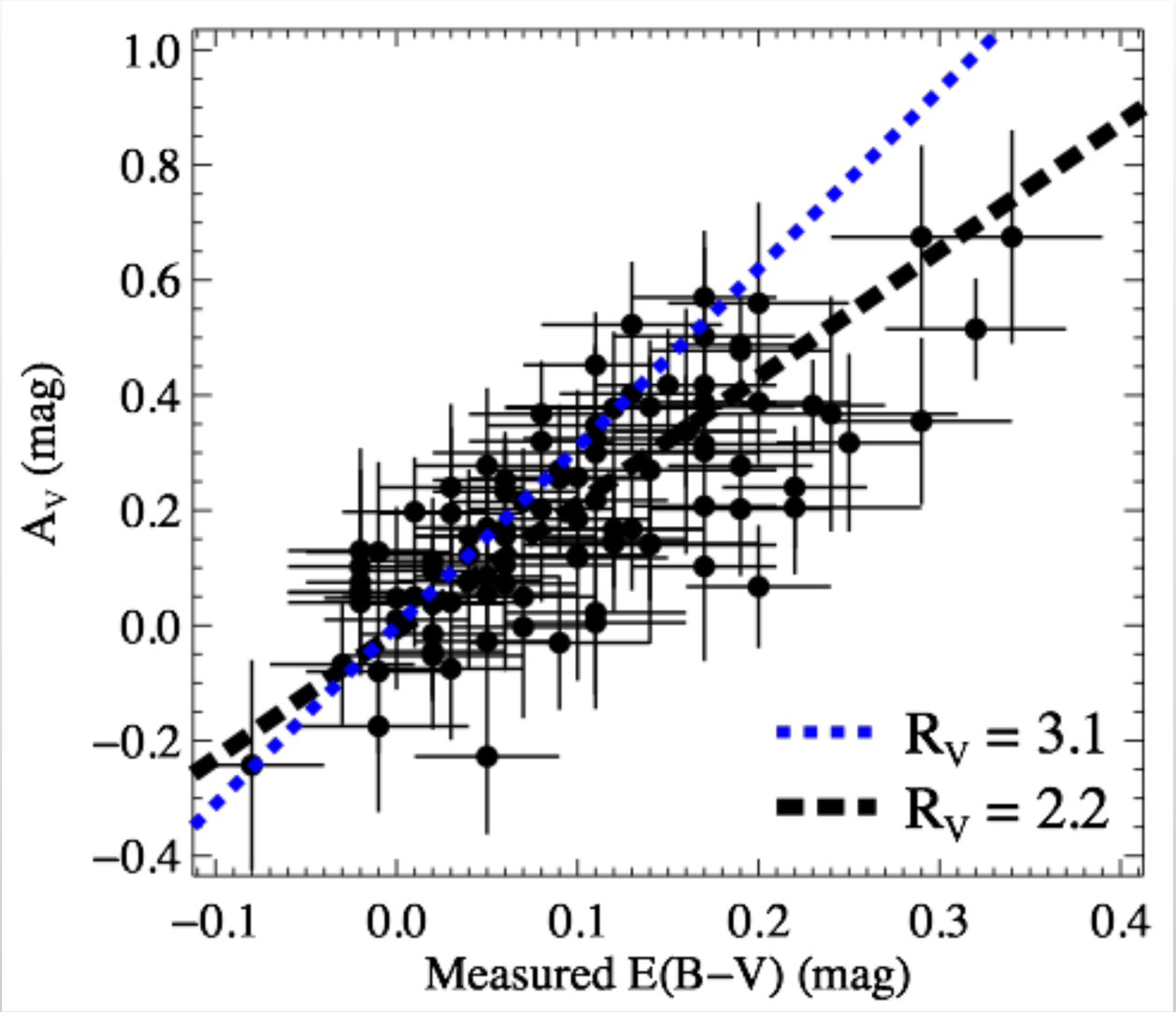


High Velocity:
~ -13,000 km s^{-1}

Low Velocity:
~ -10,000 km s^{-1}

Wider Lines With Higher Velocity

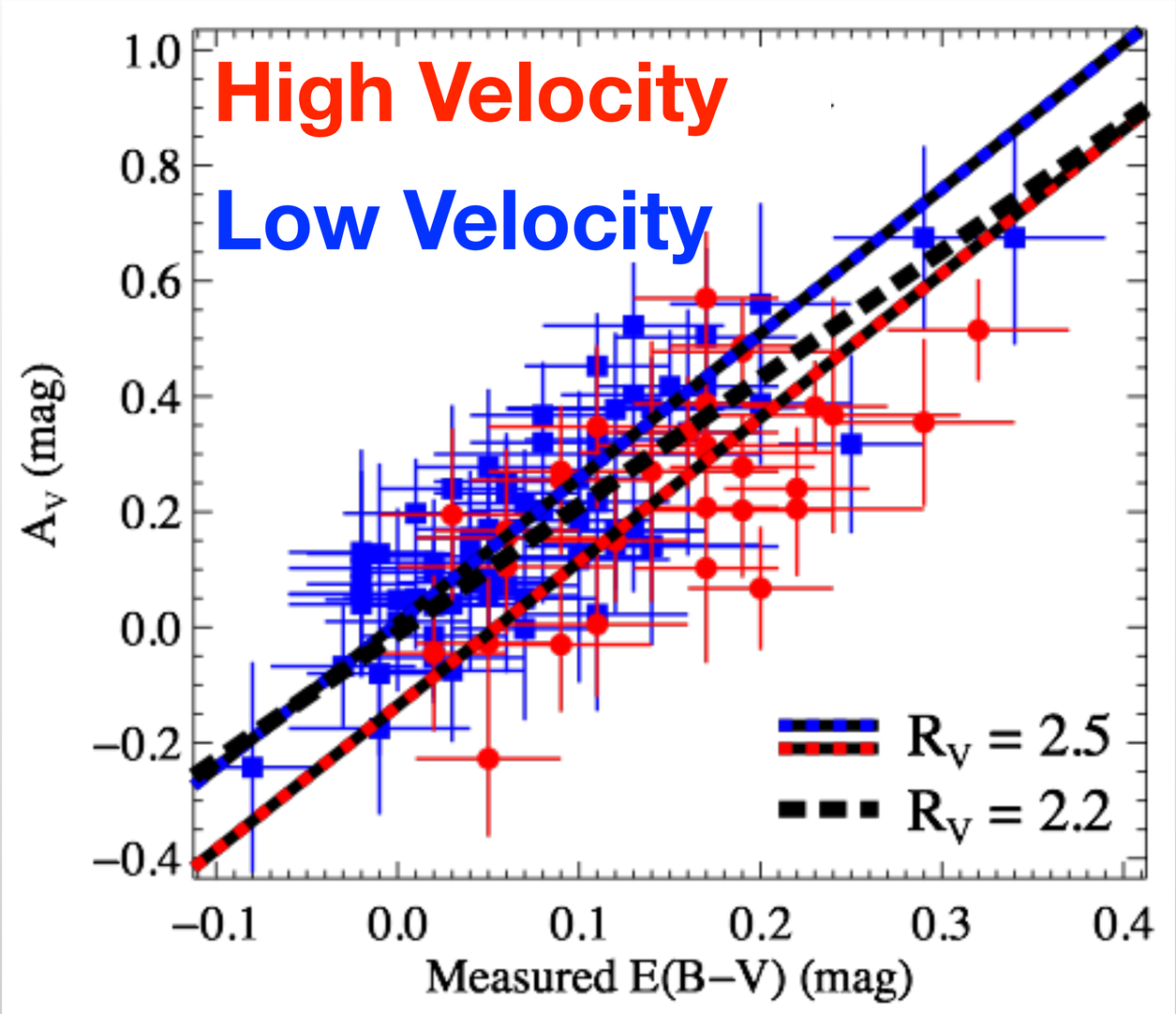
Samples of SNe Ia have Low R_V



Foley & Kasen 2011

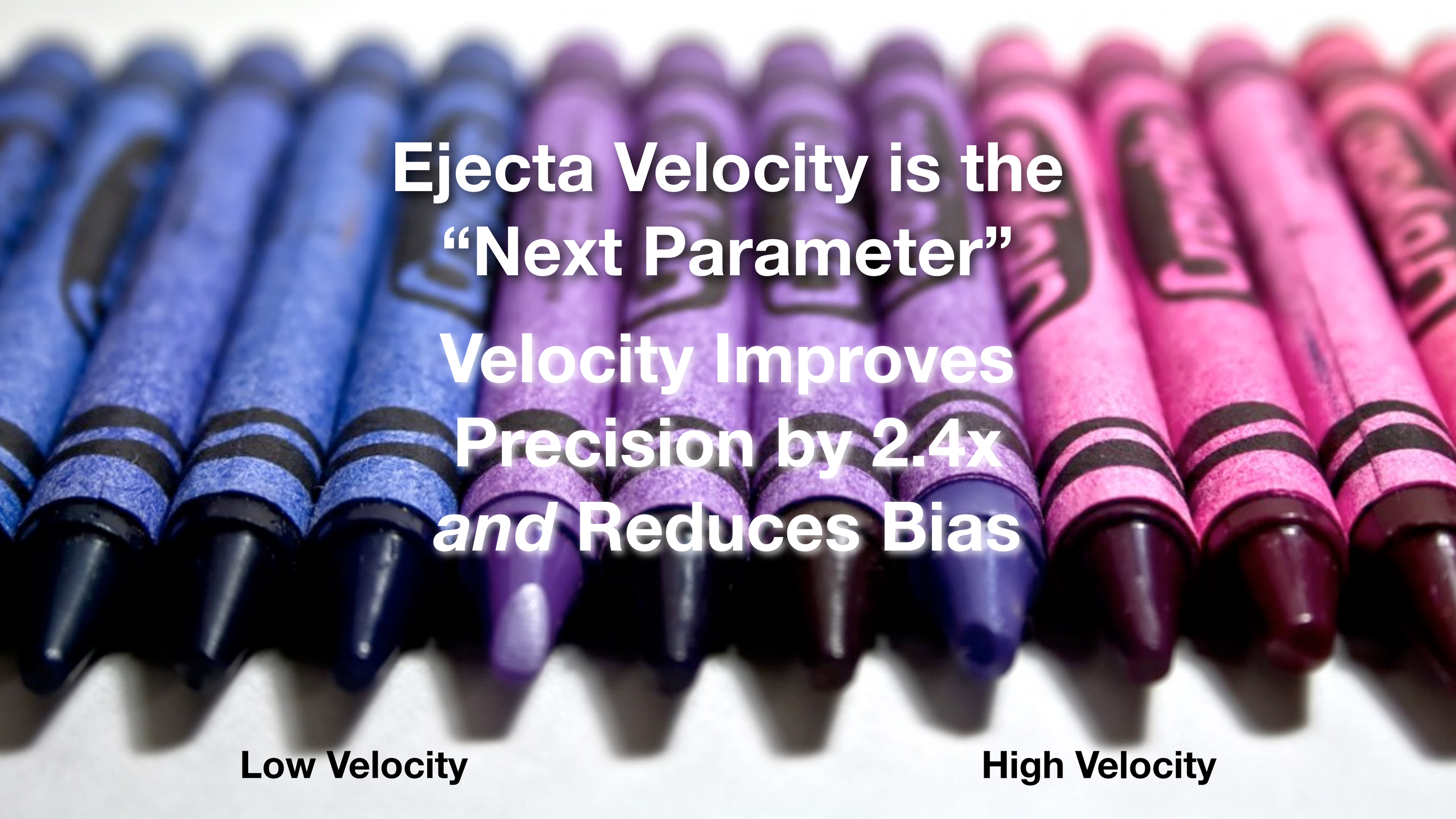
R_V = A_V/E(B-V)

Intrinsic Color Depends on SN Velocity

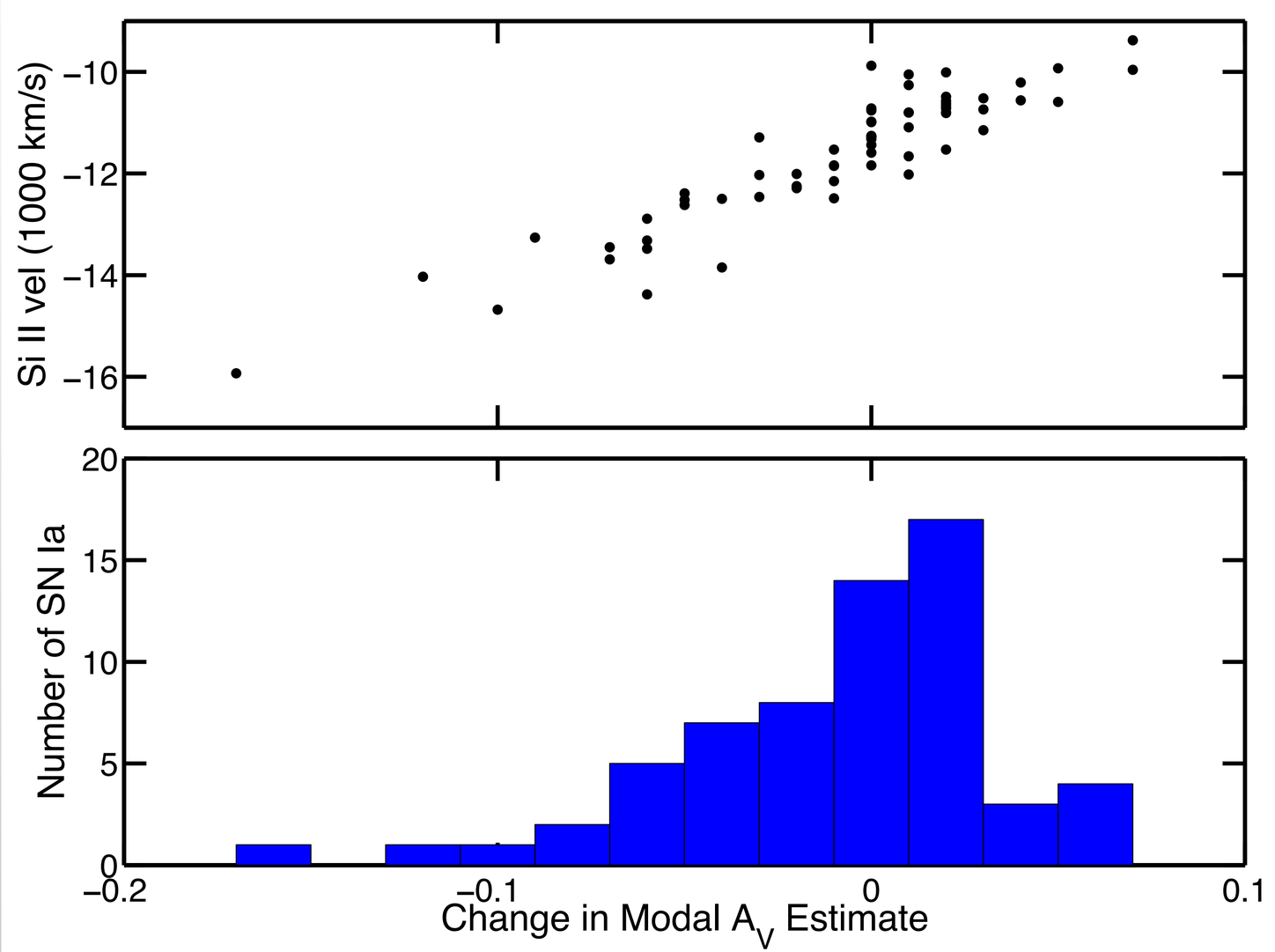


R_V = A_V/E(B-V)

Foley & Kasen 2011
also Foley 2012; Foley, Sanders, & Kirshner 2011; Mandel, Foley, & Kirshner 2014

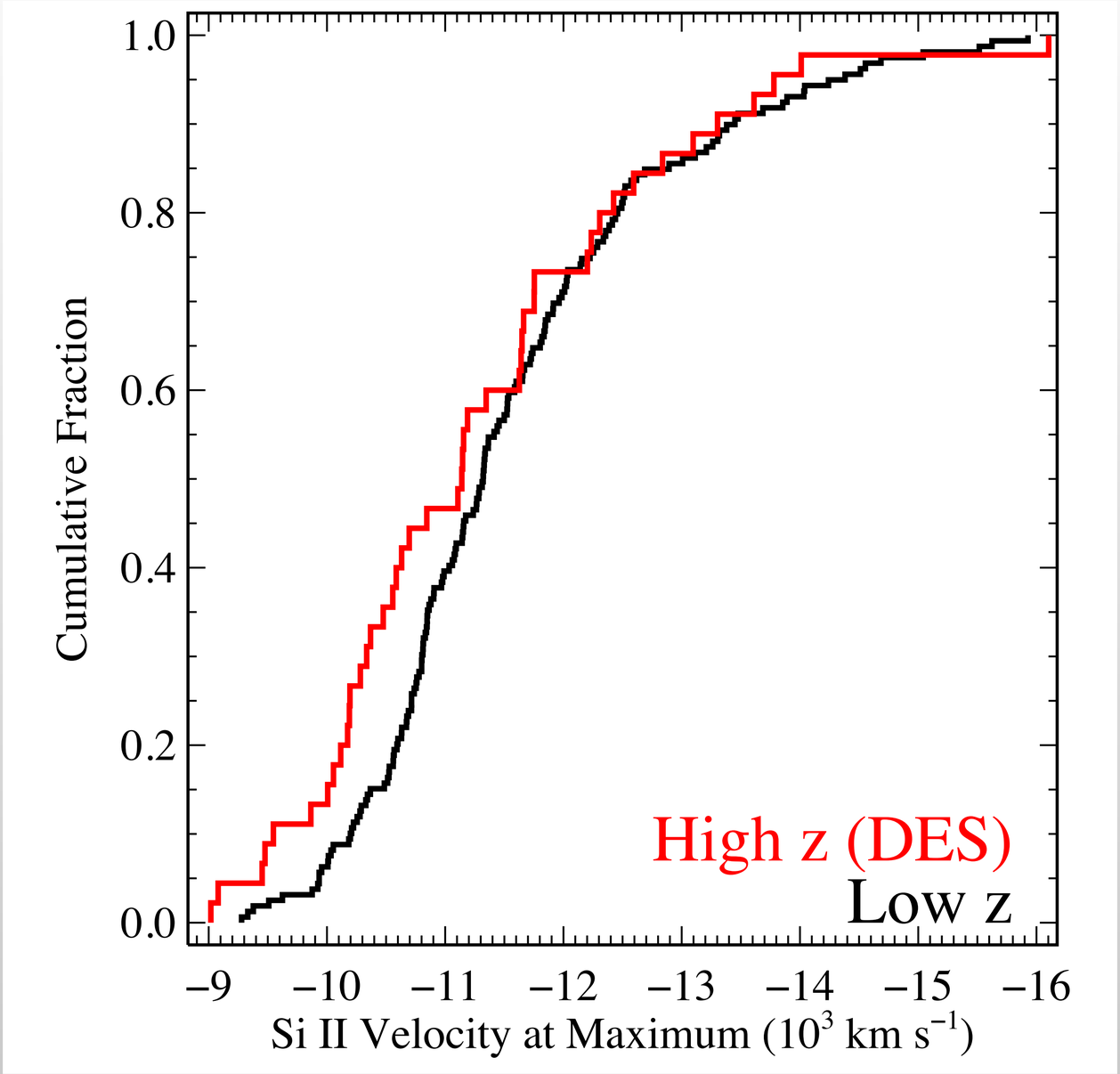

Ejecta Velocity is the
“Next Parameter”
Velocity Improves
Precision by 2.4x
and Reduces Bias
Low Velocity
High Velocity

Intrinsic Color Depends on SN Velocity



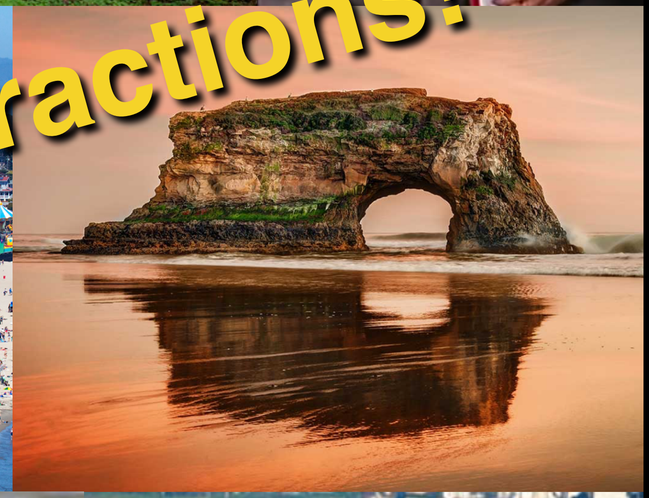
Mandel, Foley, & Kirshner 2014

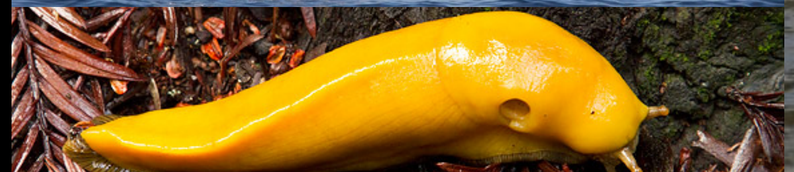
No Velocity Bias in Gemini Sample



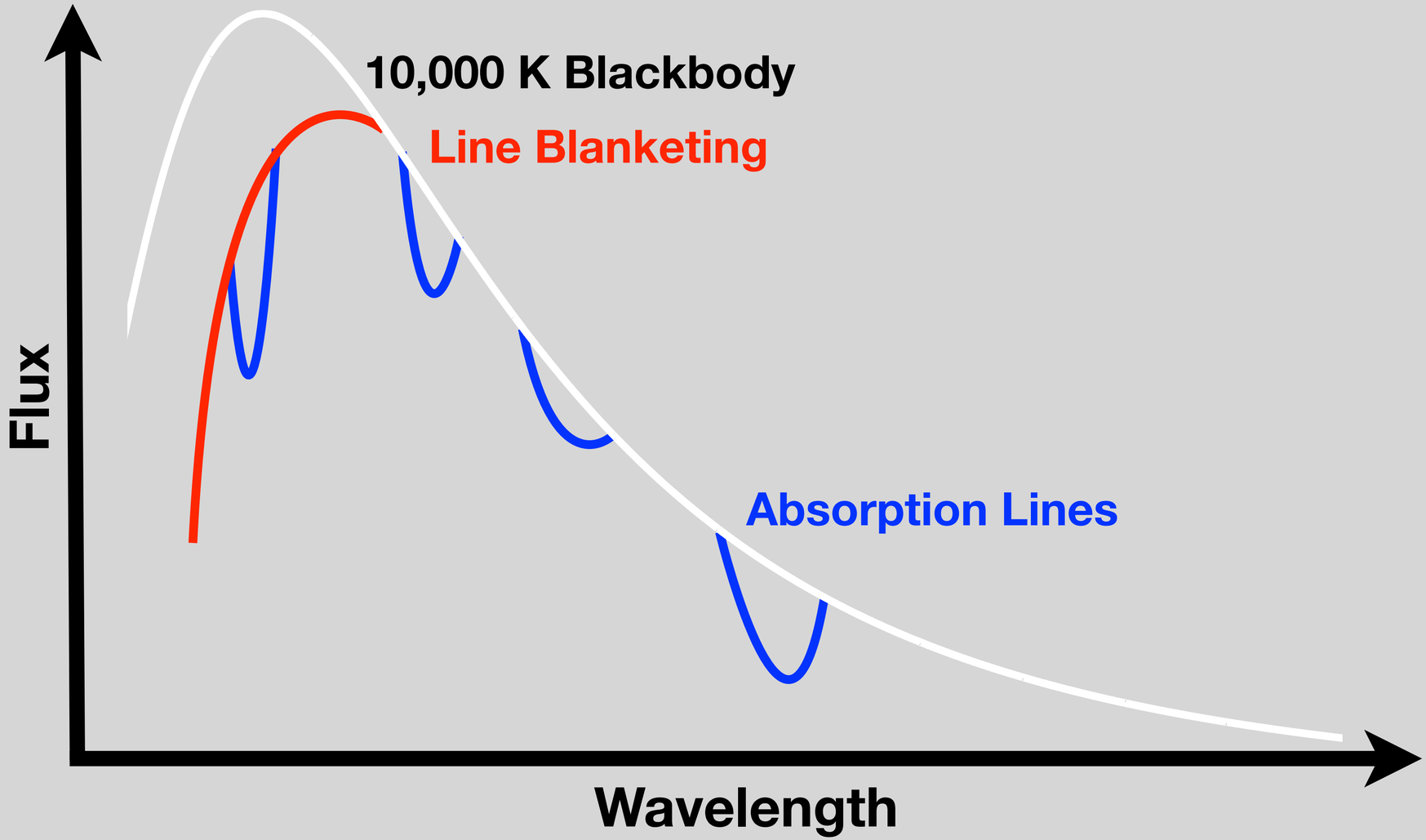
Visit Santa Cruz

Enjoy the Local Attractions!

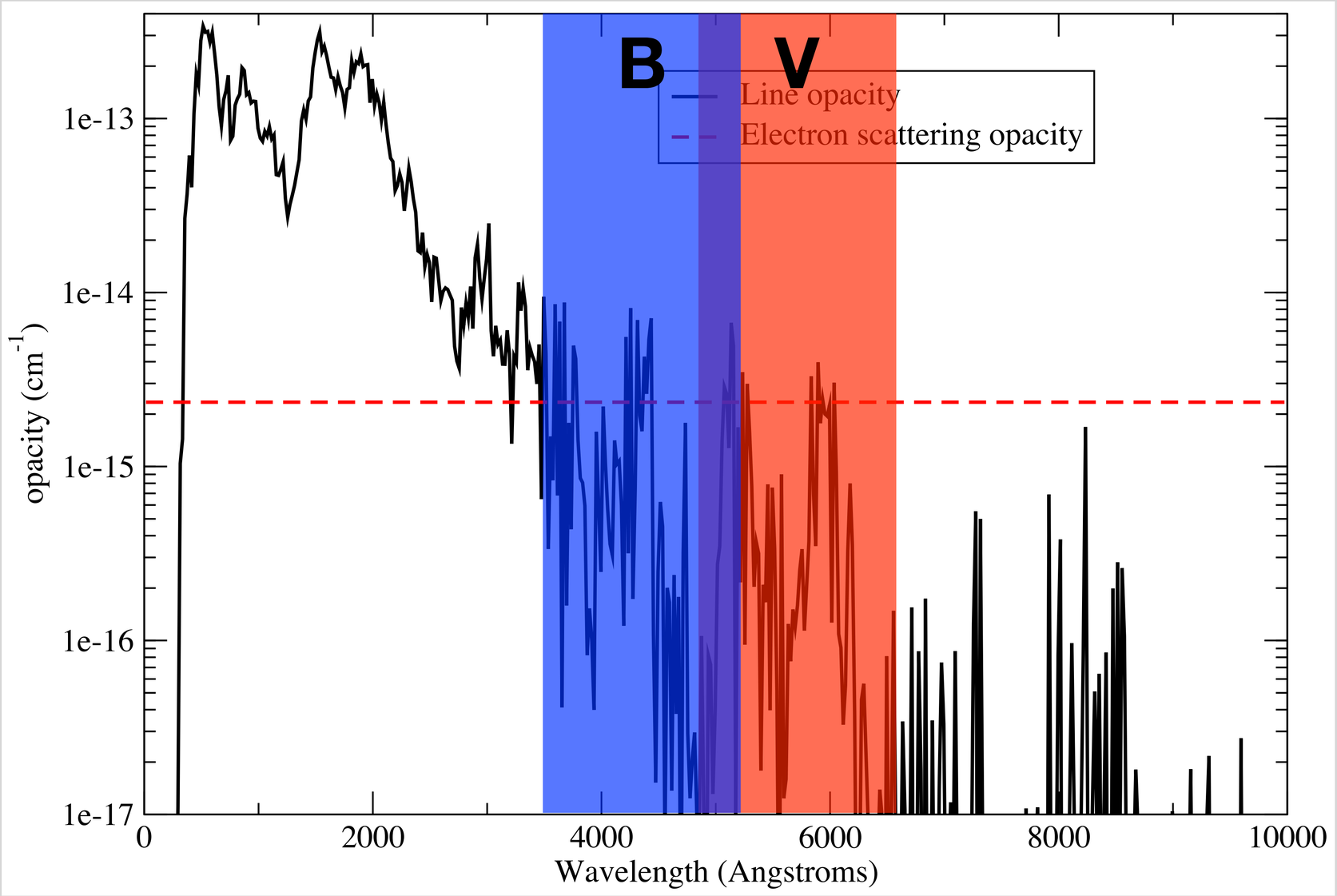




Supernova SED

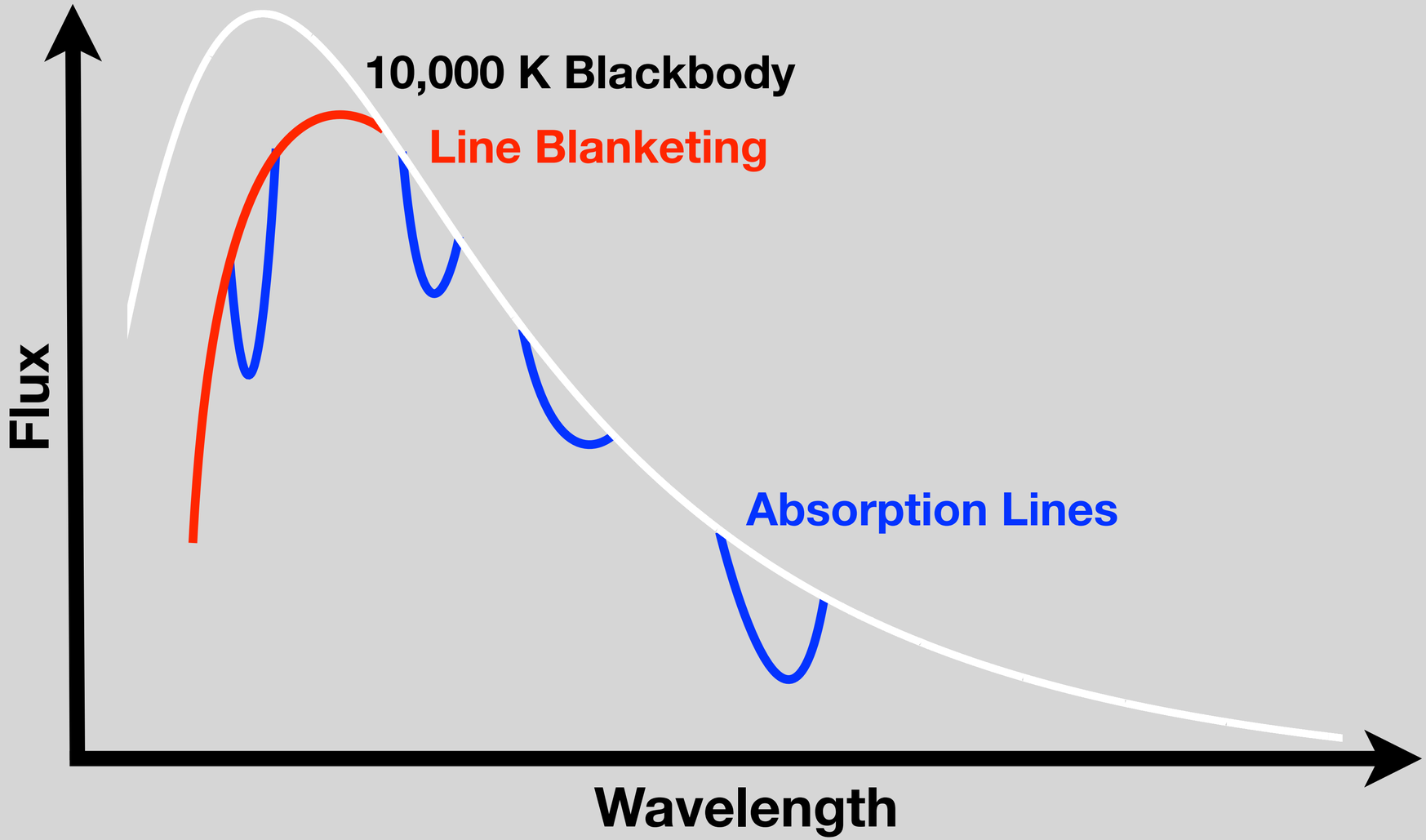


Opacity Depends on Velocity



Ellis et al. 2008

Supernova SED



Supernova SED