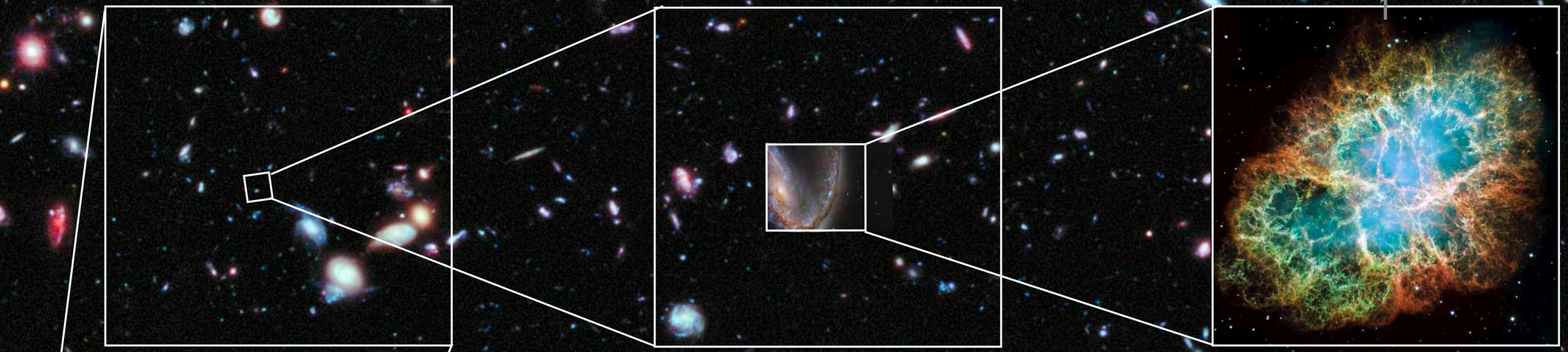


Supernova Cosmology & Science Communication:

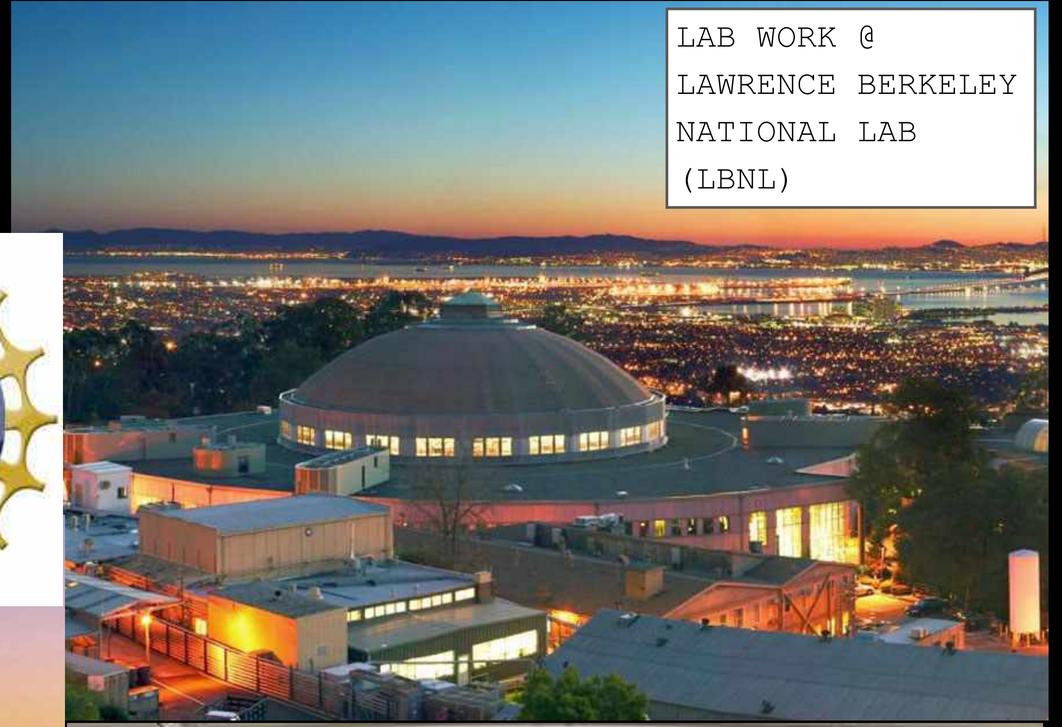
A Conscious Approach To Exploring The Cosmos

Sarafina Nance
Ph.D. Candidate
UC Berkeley / LBNL

@starstrickenSF

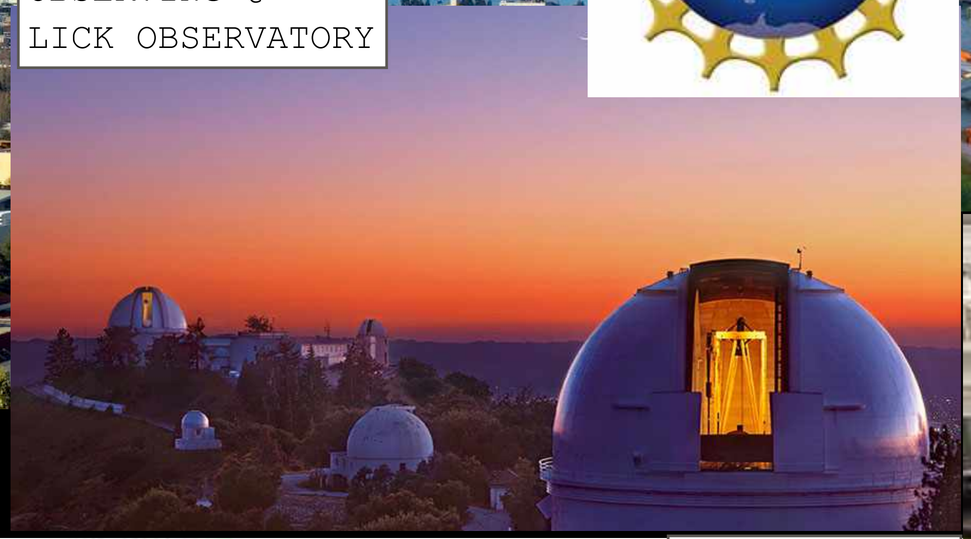
ABOUT ME

LAB WORK @ LAWRENCE BERKELEY NATIONAL LAB (LBNL)



GRAD SCHOOL @ UC BERKELEY

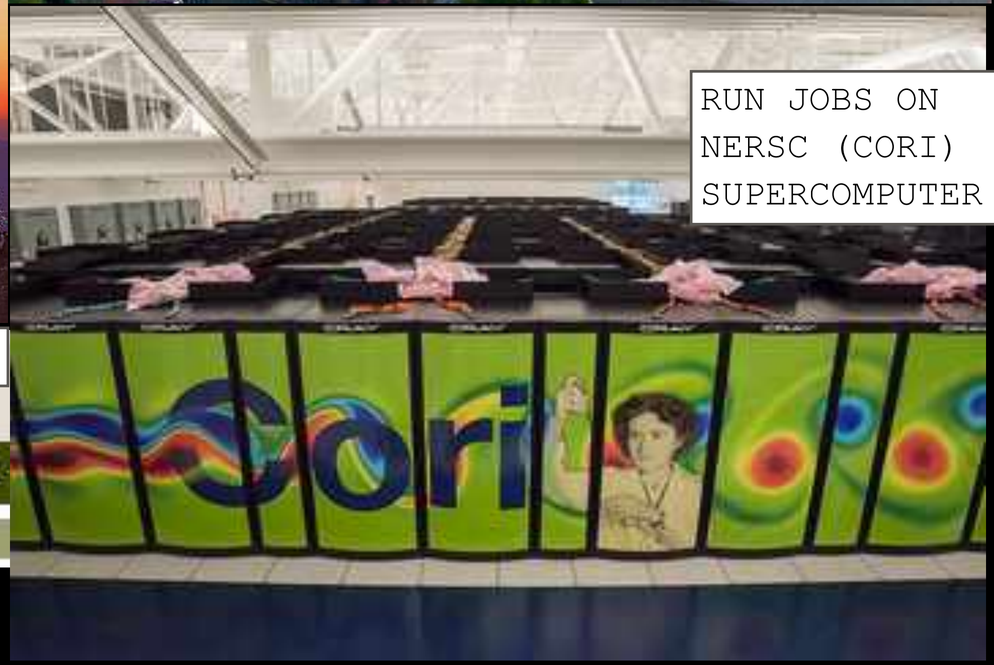
OBSERVING @ LICK OBSERVATORY



GRAD ADVISOR PETER NUGENT

MEMBER OF C3

RUN JOBS ON NERSC (CORI) SUPERCOMPUTER



SCI COMM

nature.com

SPACE.com

POPULAR MECHANICS

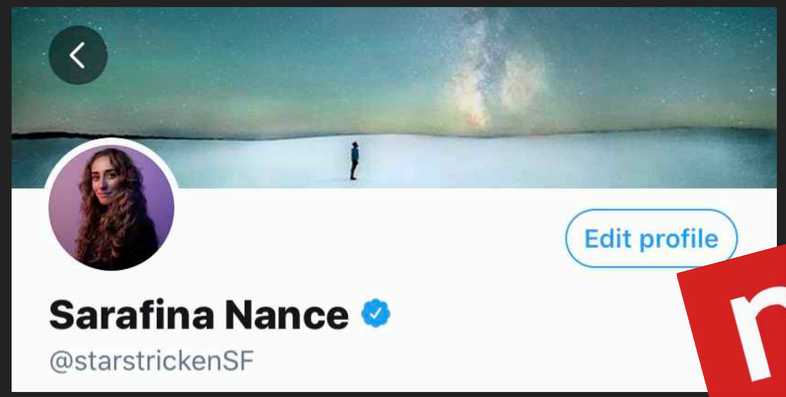
npr

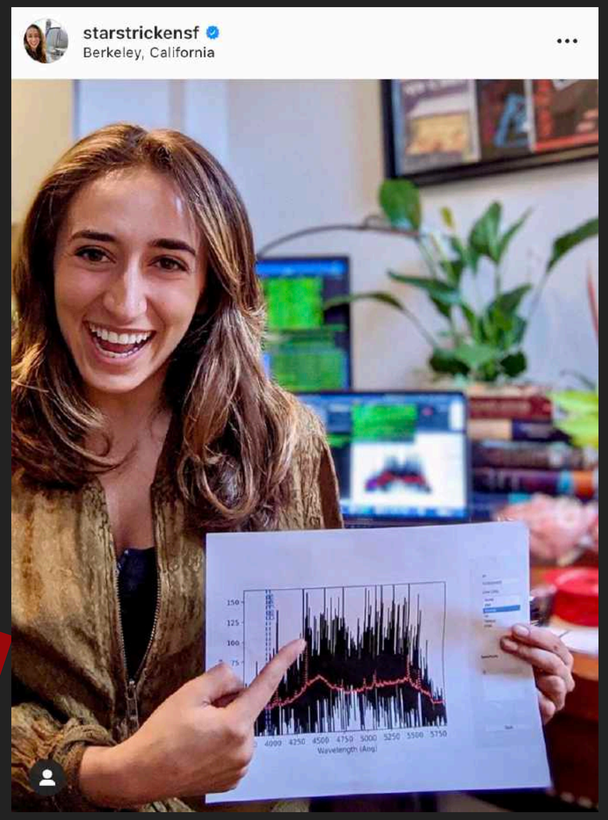
BBC NEWS

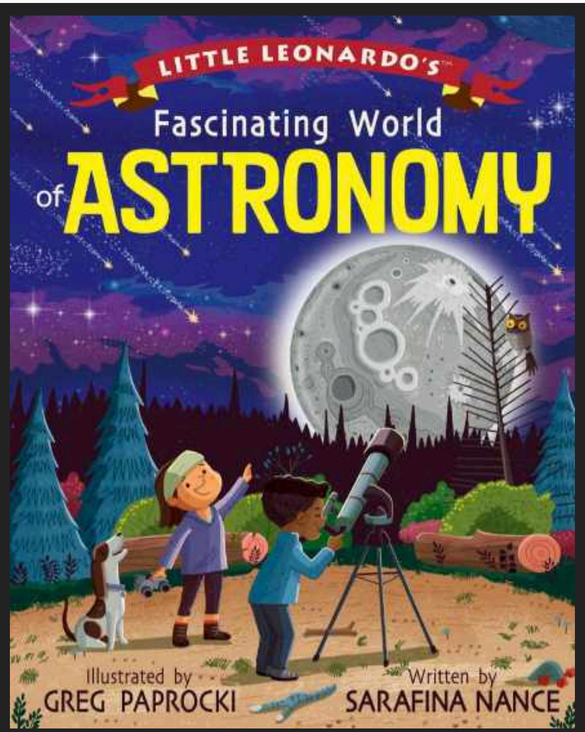
NATIONAL GEOGRAPHIC

BBC 100 WOMEN

LIVESCIENCE







OUTLINE OF THIS TALK

- PART I: THE SCIENCE
  - The Hubble Constant & Controversy
  - Supernovae (SNe) Classifications
  - Type IIP Supernova for Cosmology & SCM
  - A Case Study: ZTF19abqhobb

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- PART II: SCIENCE COMMUNICATION & ADVOCACY
  - Studies on representation in STEM
  - My personal journey
  - Scicomm I do
  - Scicomm strategies

A Brief History of the Hubble Constant Controversy

Hubble (1929) found evidence of the expansion of the Universe.

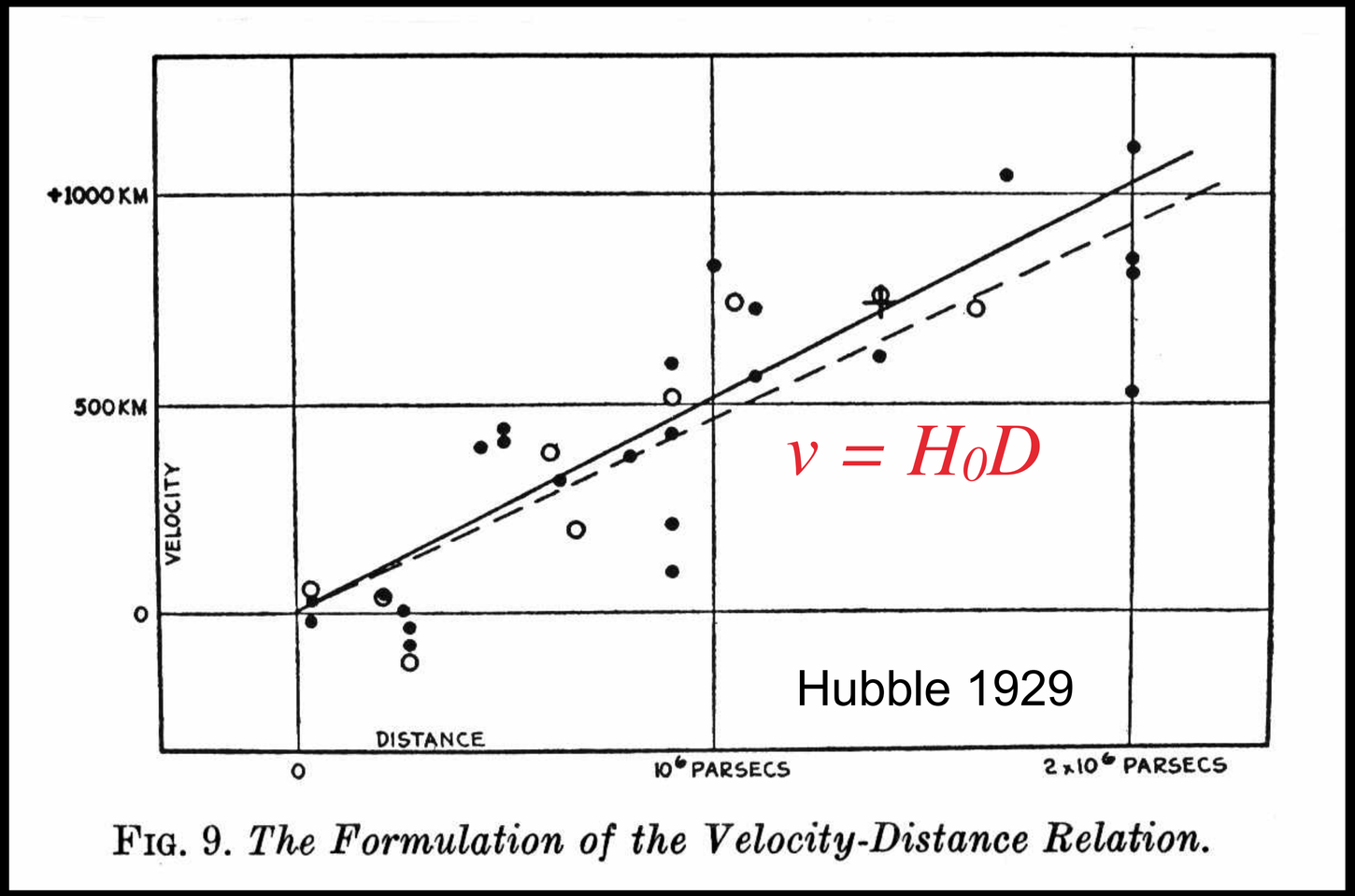


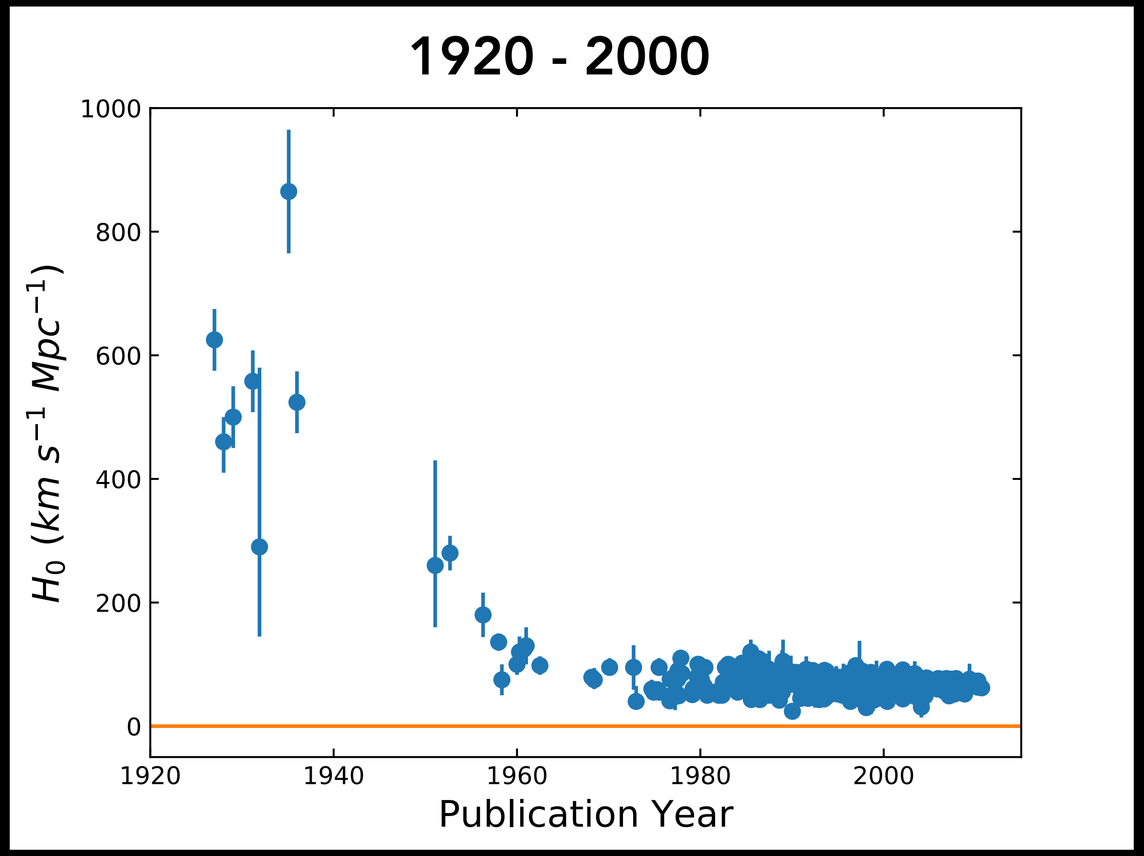
FIG. 9. *The Formulation of the Velocity-Distance Relation.*

Hubble Constant H_0:

- Sets size & age scale of the Universe
- Tells us how the Universe evolved
- But this value isn't well constrained…

The Evolution of our Knowledge of the Hubble Constant since the ‘20s…

Historic Look



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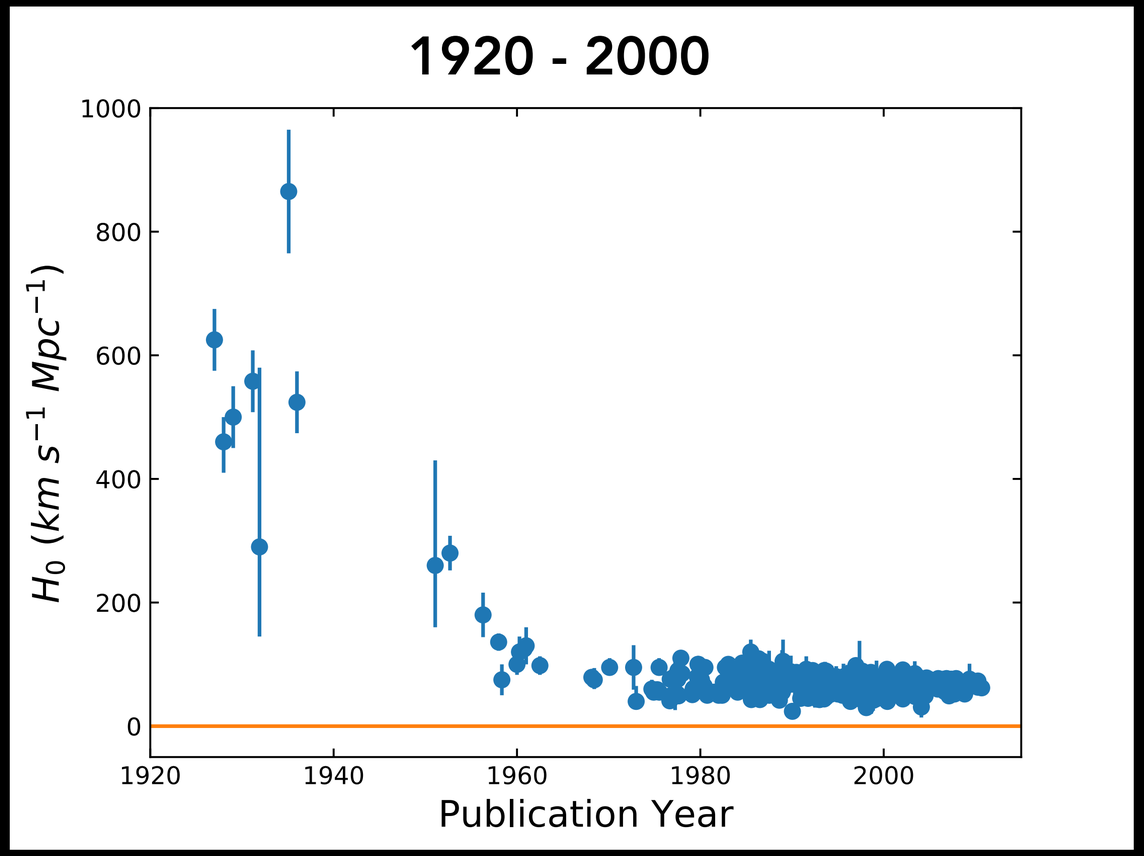
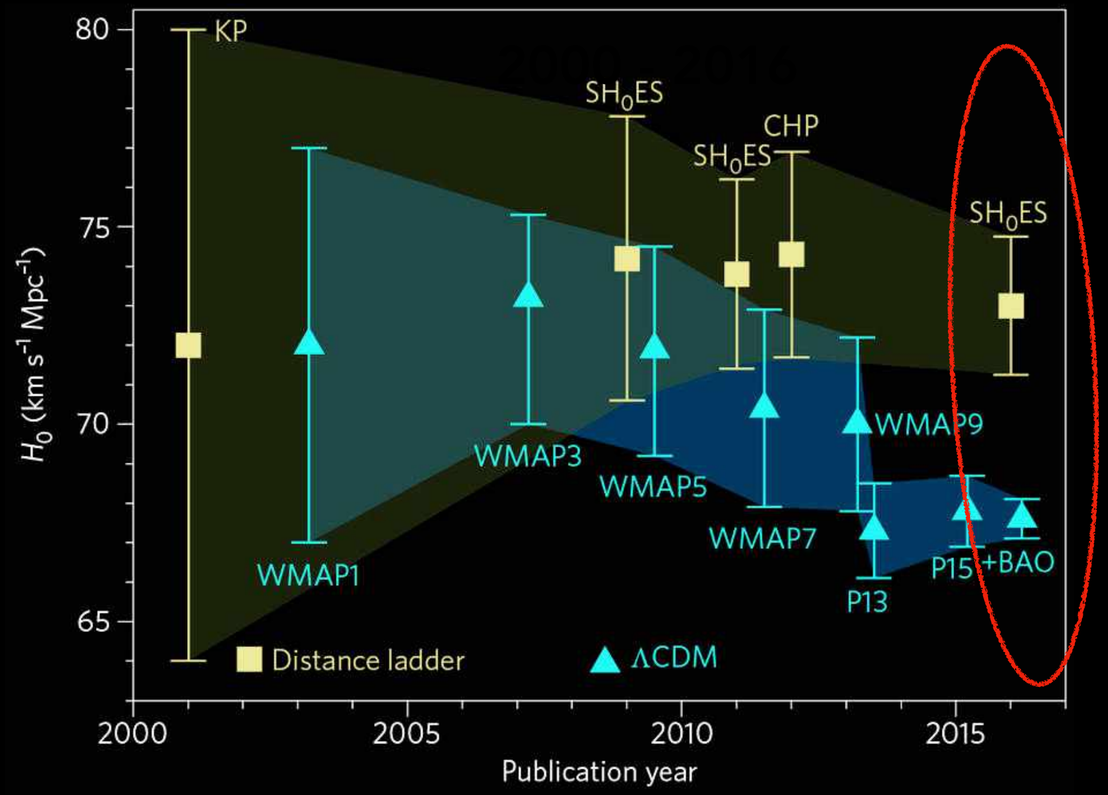


Modern Day



Freedman 2017 (Nature Astronomy)

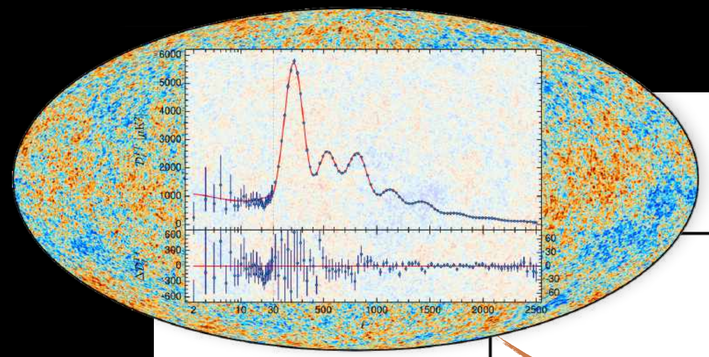
4.2σ

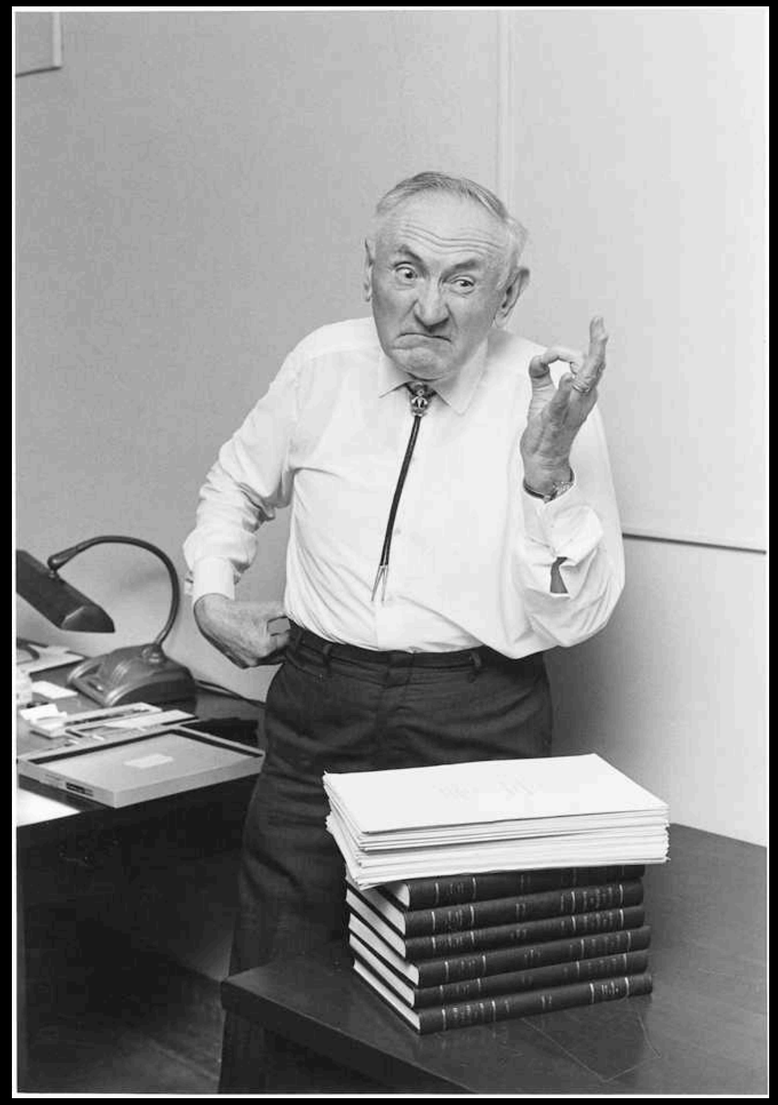
Need H_0 to <1% to resolve tension

Riess et al. 2021

Seems to converge around 65 km/s/Mpc, but clearly some variability

4.2σ Tension: New Physics or a Systematic Error?





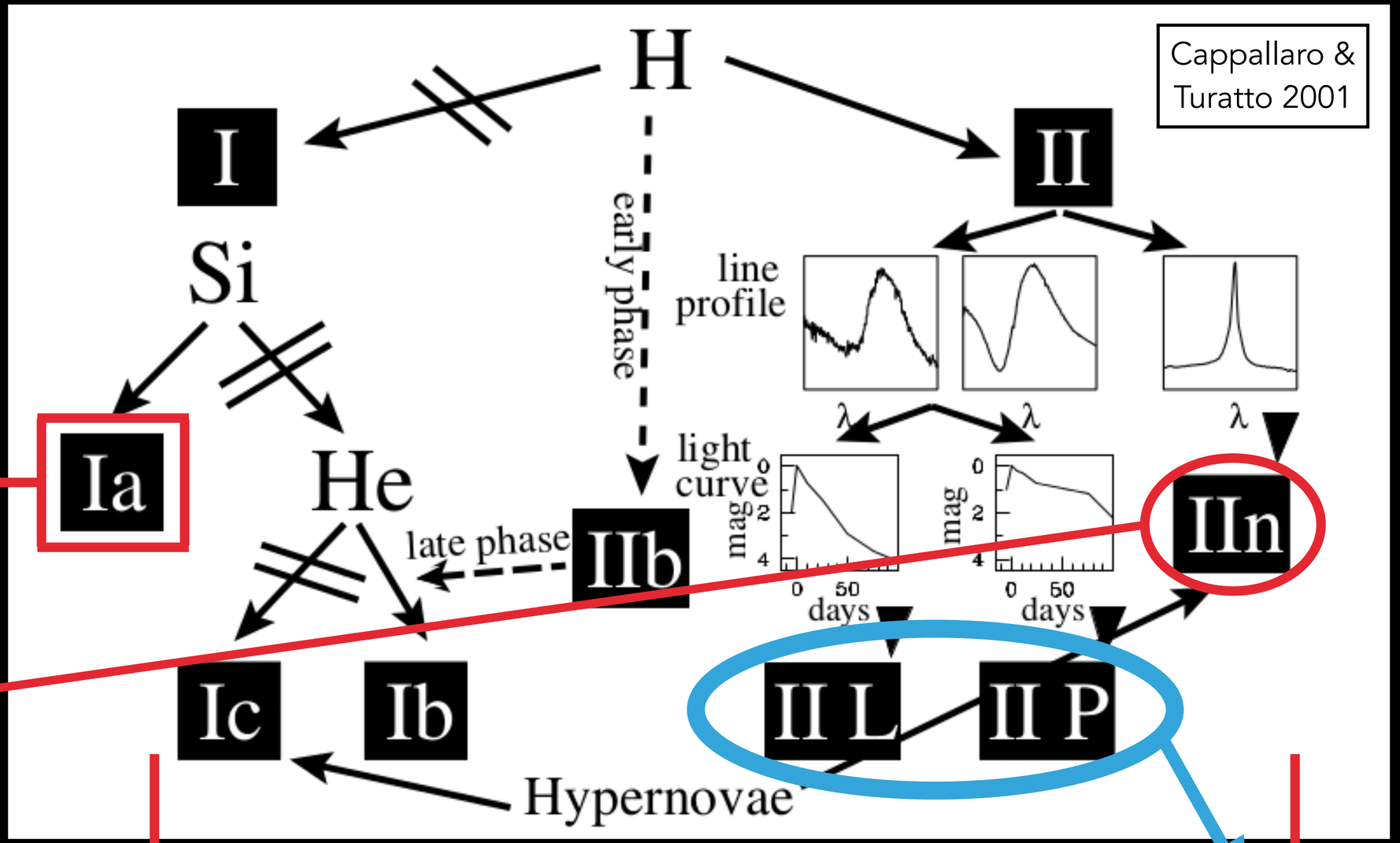
In the words of Fritz Zwicky,

“Don't believe in any of those methods. The only reliable way of determining extragalactic distances is through supernova investigations.”

😉

Supernova Taxonomy

A supernova (Zwicky 1931) is a stellar explosion that briefly outshines an entire galaxy (10^9 - 10^{11} $L_\odot$)



THERMONUCLEAR

SN Imposter? Definitive SN event unclear

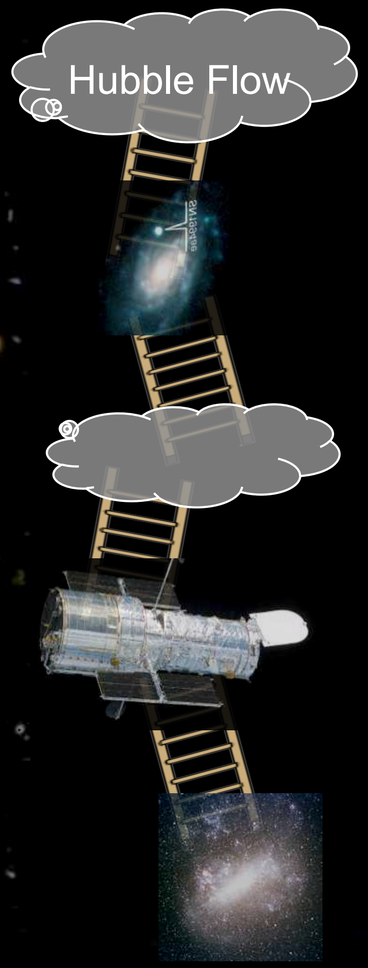
CORE-COLLAPSE

SNe II

SN Ia's are limited by systematics

PAST DISTANCE LADDER (100 Mpc)

11% error



1% # Modern, distant SNe Ia

3% # Modern, local hosts

3.5% SN Ia hosts,
Metallicity change

4% long to short Period Cepheids

4.5% Ground to HST

5% Anchor: LMC

NEW LADDER (100 Mpc)

4 % error

1%

2%

Calibrator

NA

3% Anchor:
NGC4258

Adam Riess

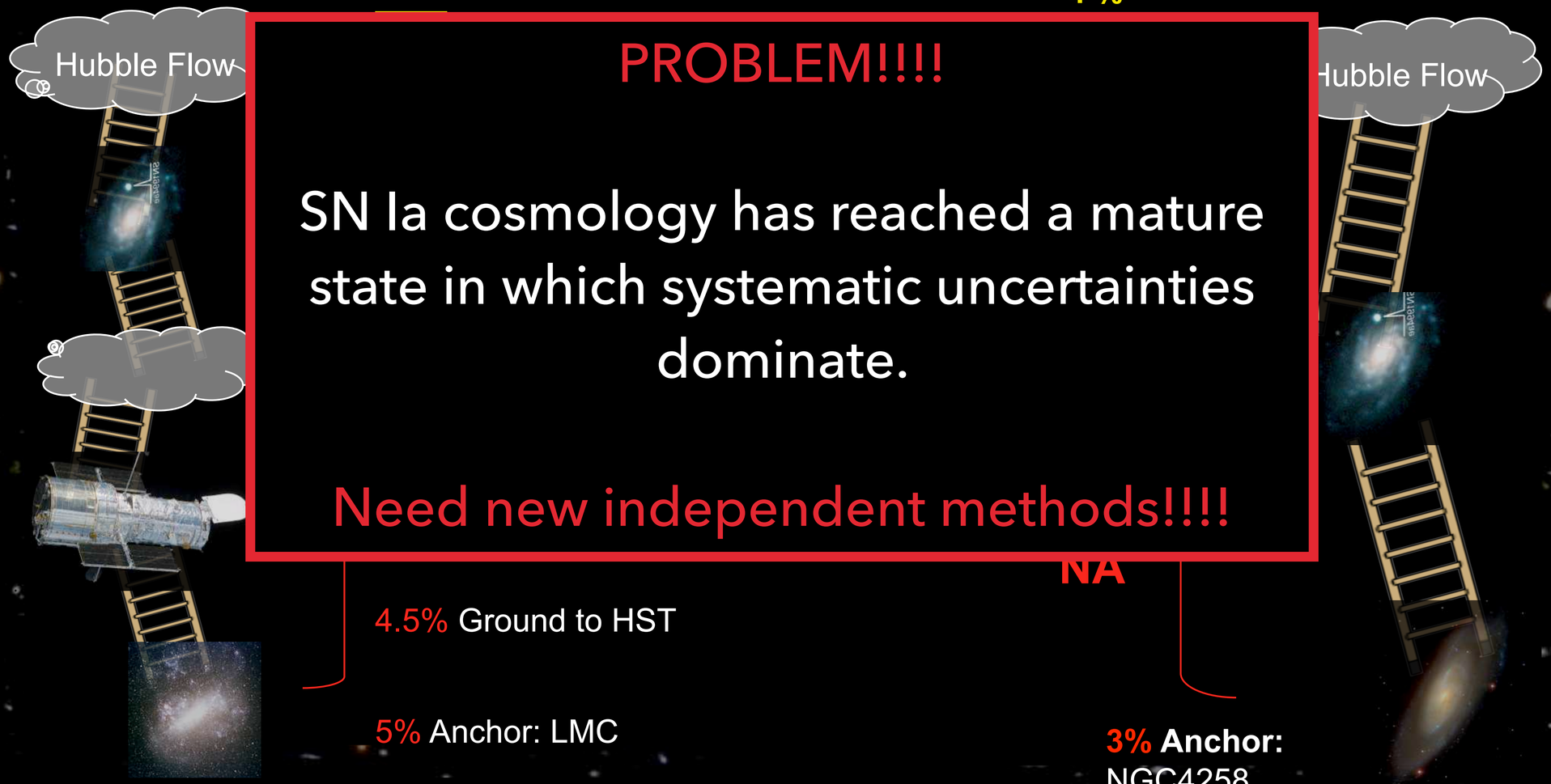
SN Ia's are limited by systematics

PAST DISTANCE LADDER (100 Mpc)

11% error

NEW LADDER (100 Mpc)

4 %



PROBLEM!!!!

SN Ia cosmology has reached a mature state in which systematic uncertainties dominate.

Need new independent methods!!!!

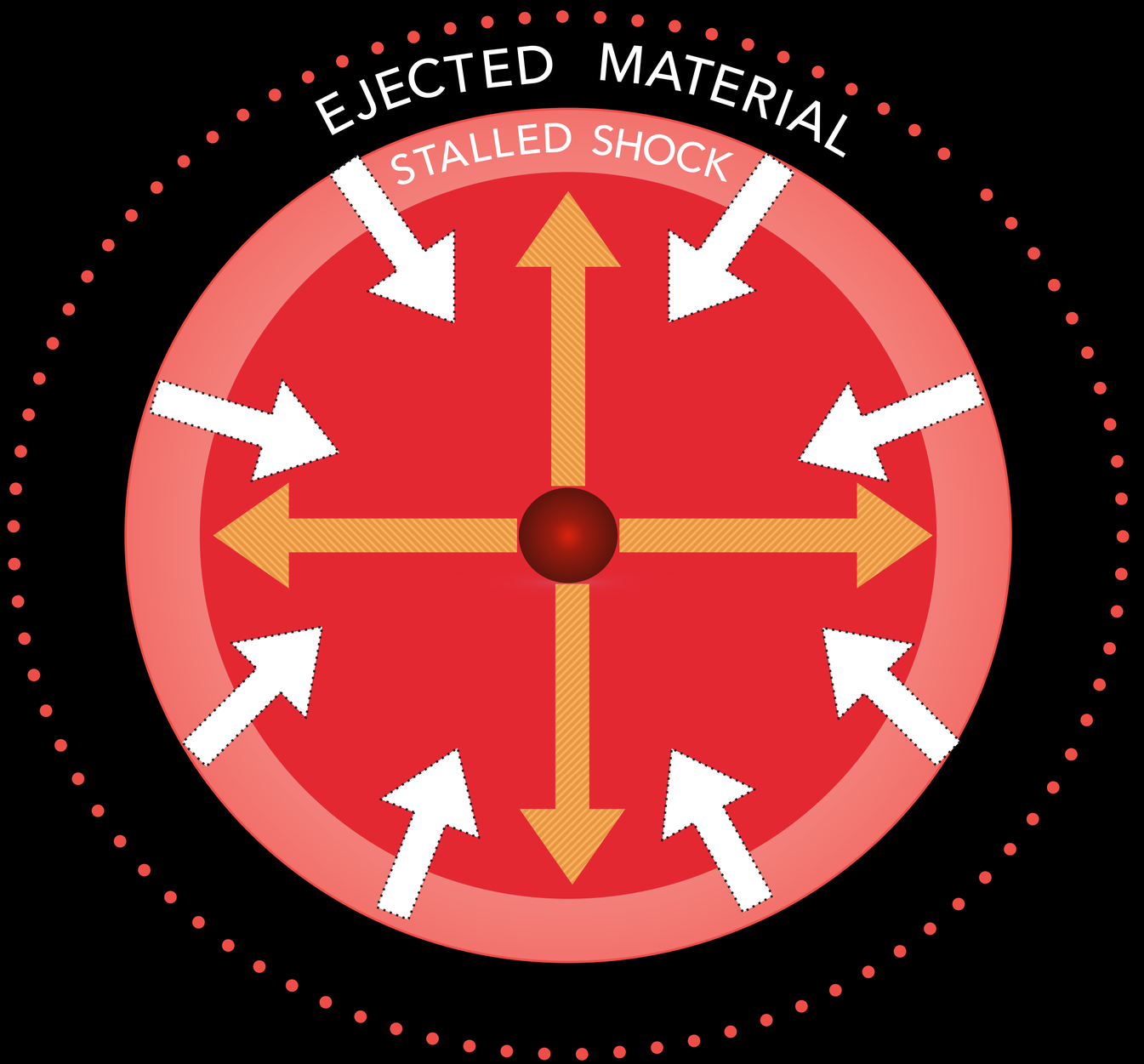
NA

4.5% Ground to HST

5% Anchor: LMC

3% **Anchor:** NGC4258

Type IIP SNe



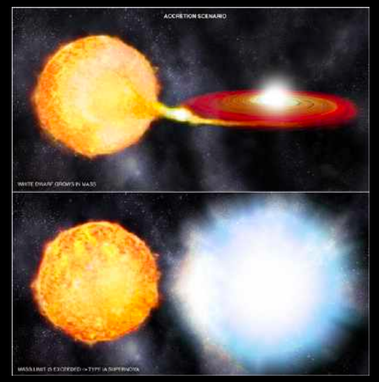
Pressure from *neutrinos* that drives the expansion & subsequent explosion

Proto-Neutron Star

In-falling material driven by gravity

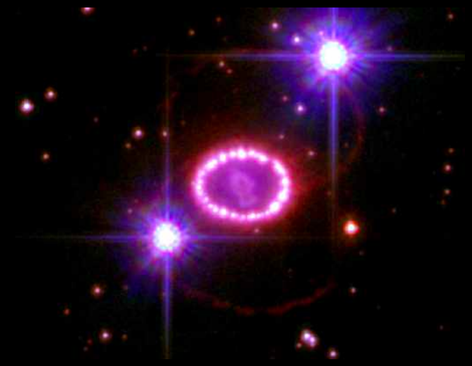
Core-collapse explosions of massive, H-rich stars

Ia vs. IIP's

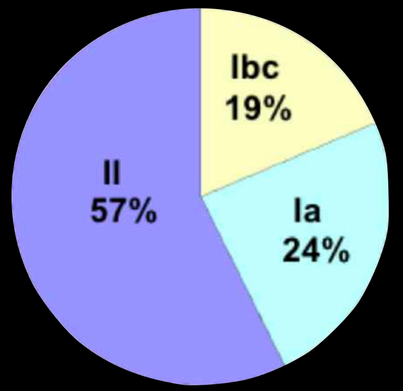


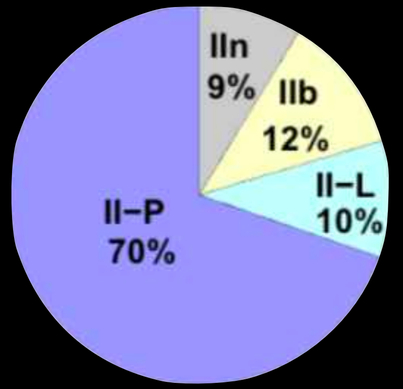
Ia's

IIP's



	Ia's	IIP's
LUMINOSITY:	Brighter	Dimmer
RATES:	Infrequent	At low *z*, 5x more abundant than Ia's
PROGENITOR SYSTEM & ENVIRONMENTS:	Not well-understood	Well-understood

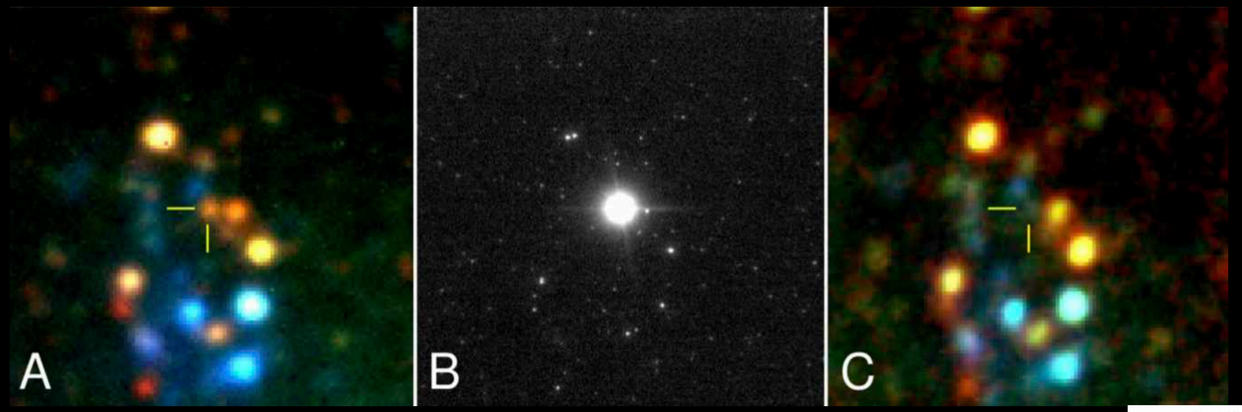




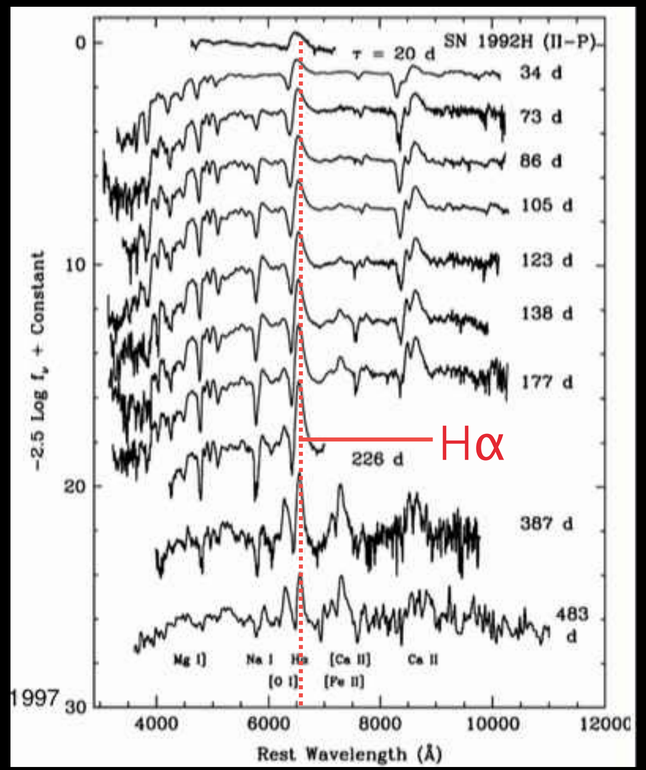
Li et al. 11

Type IIP SNe Characteristics

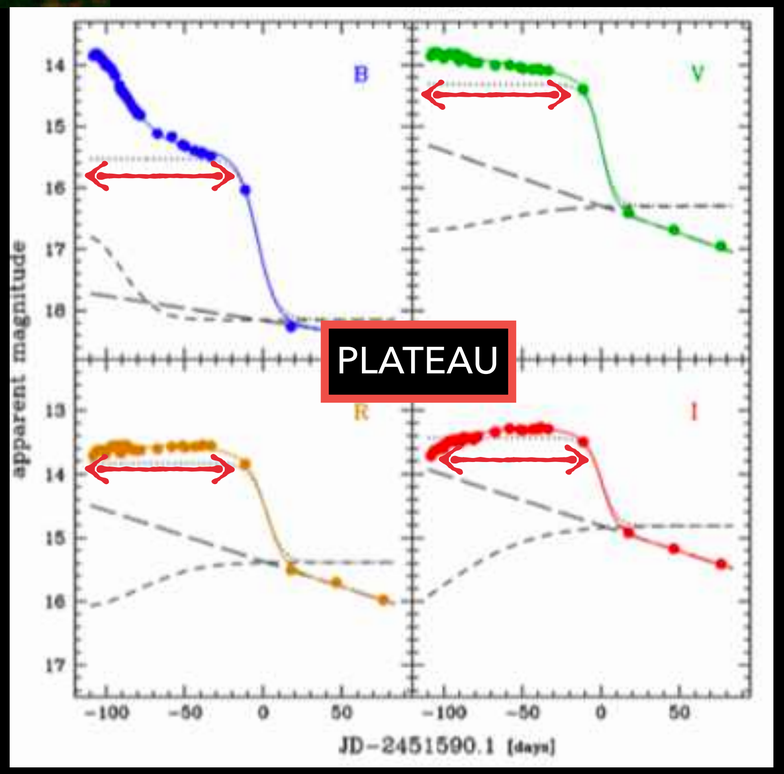
Mattila et al. 14



Filippenko 97



Olivares et al. 10



Progenitor detections: Red Supergiants w/ masses 8 - 17 $M_\odot$

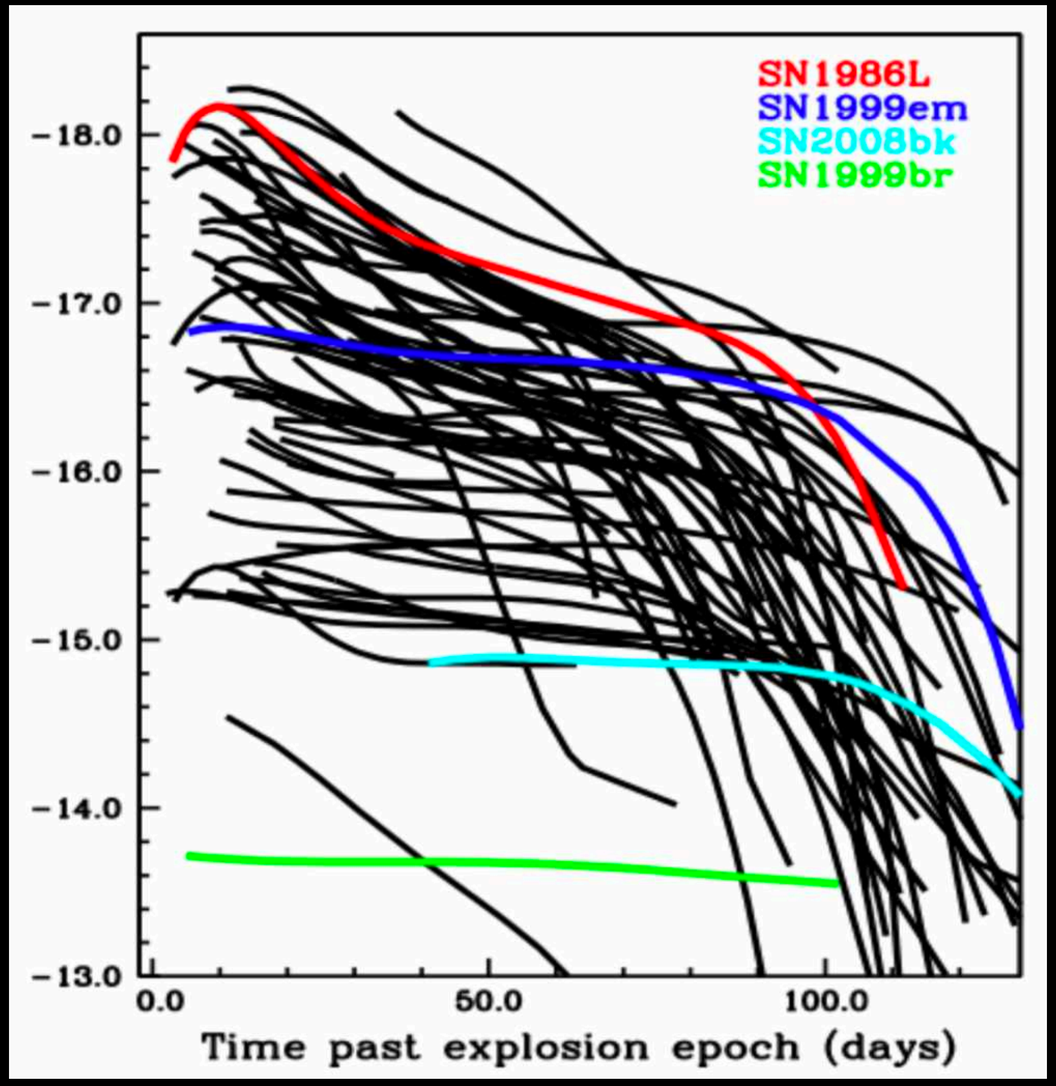
Smartt 09

Spectra with prominent H-lines

+

Plateau in lightcurve

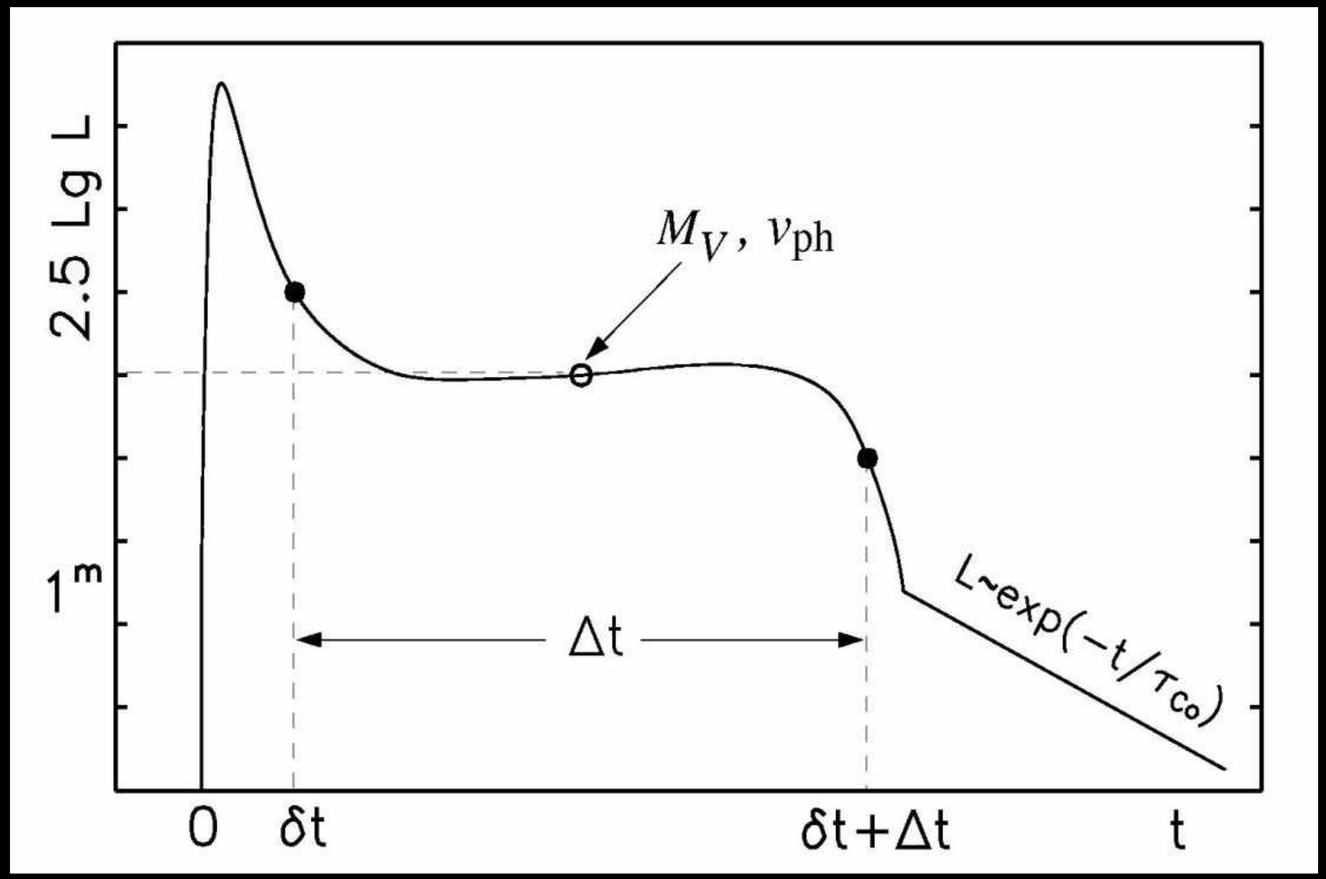
Type IIP Lightcurves Vary Widely



Anderson et al. 14

Type II SN Physical Parameters

Light curve shape + Velocity evolution (from spectrum) = $E_{tot},\ M,\ R_i$



Observables (Popov 93):

- Length of plateau phase Δt
- Luminosity of the plateau L_v
- Velocity of the ejecta v_{ph}

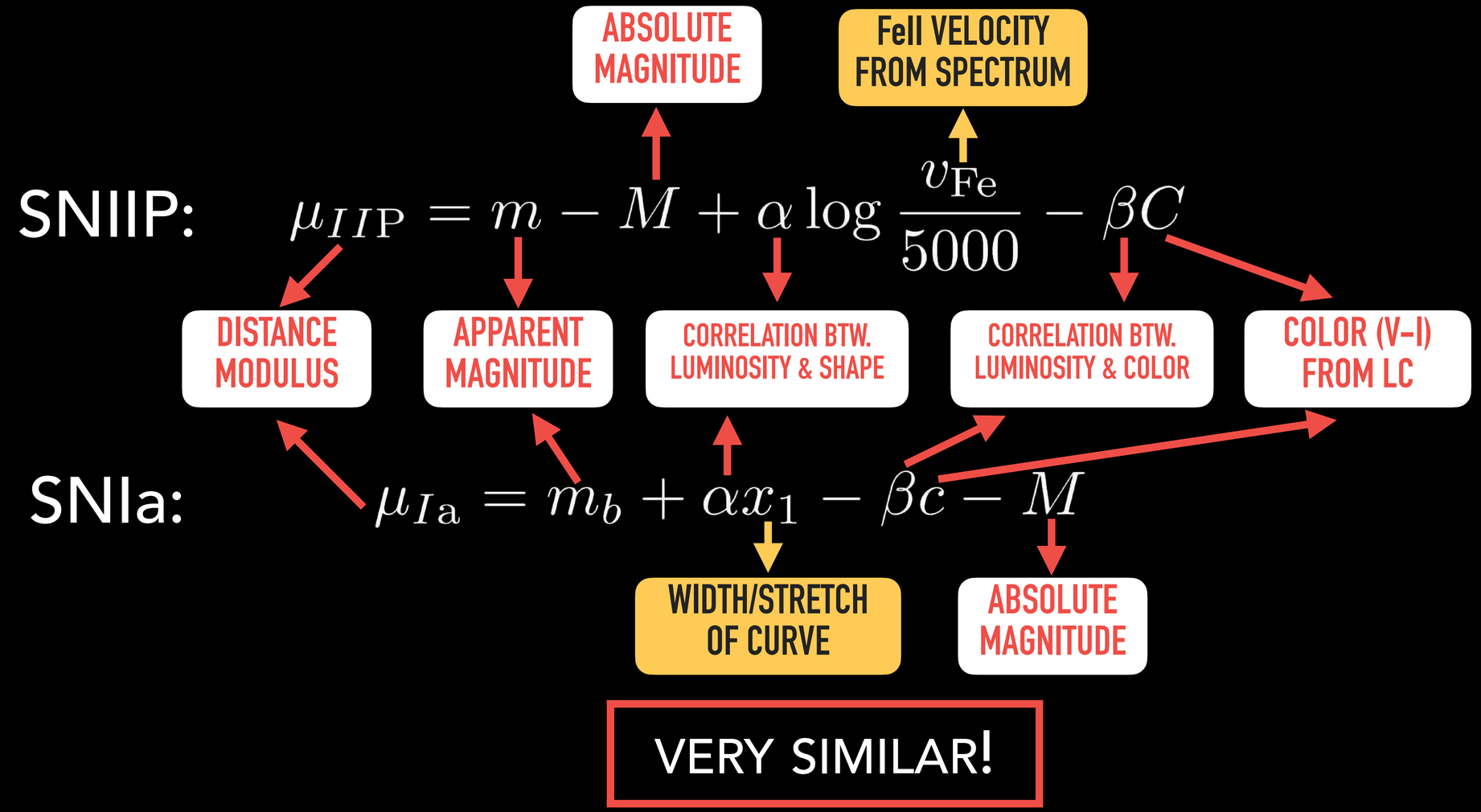
$$E \propto \Delta t^4 \cdot v_{ph}^5 \cdot L^{0.4}$$
$$M \propto \Delta t^4 \cdot v_{ph}^3 \cdot L^{0.4}$$
$$R \propto \Delta t^{-2} \cdot v_{ph}^{-4} \cdot L^{0.8}$$

Cosmology with SNe IIP:

STANDARD CANDLE METHOD: 2 variables correlate with the intrinsic luminosity

Expansion velocities of the ejecta:
More luminous SNe have faster ejecta

Color: Due to host galaxy extinction,
brighter SNe are bluer (similar to Ia's)



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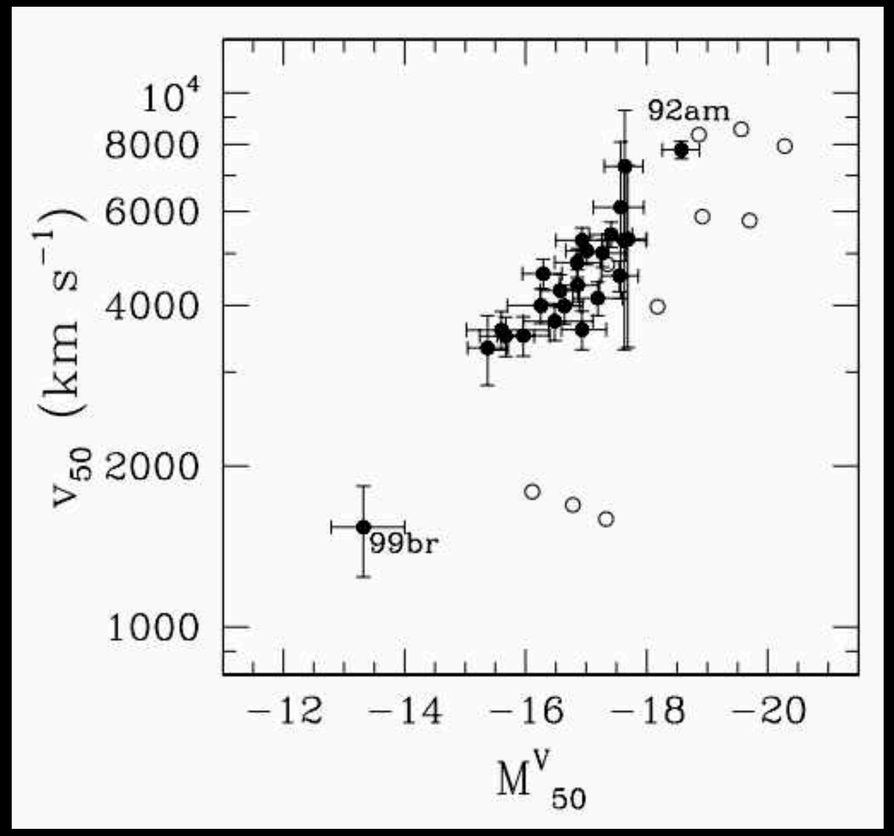
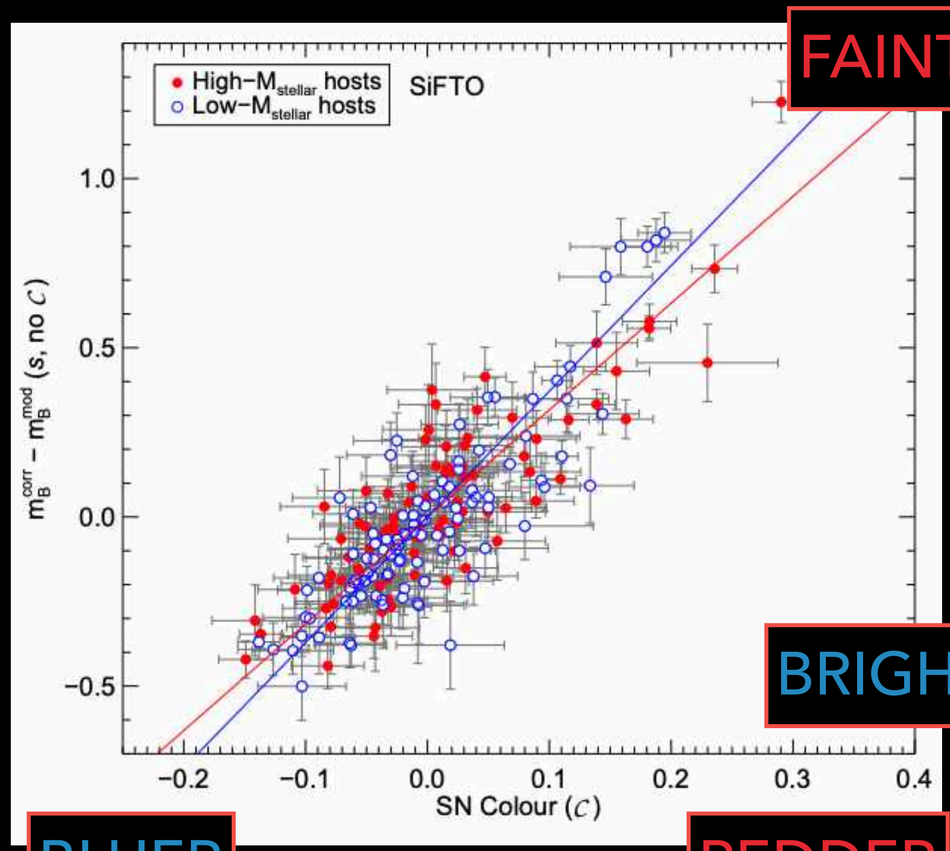
$$\mu_{IIP} = m - M + \alpha \log \frac{v_{\rm Fe}}{5000} - \beta C$$



Hamuy 03

Color: Due to host galaxy extinction, brighter SNe are bluer (similar to Ia's)

$$\mu_{Ia} = m_b + \alpha x_1 - \beta c - M$$



FAINTER

BRIGHTER

BLUER

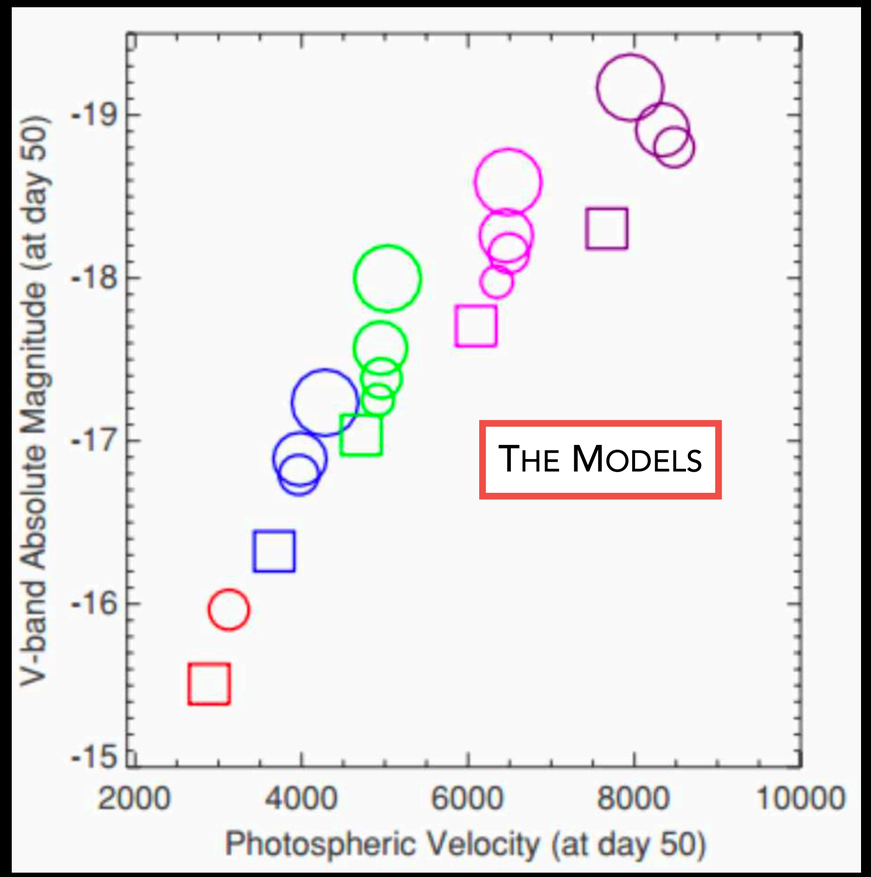
REDDER

Sullivan et al. 10

Cosmology with SNe IIP:

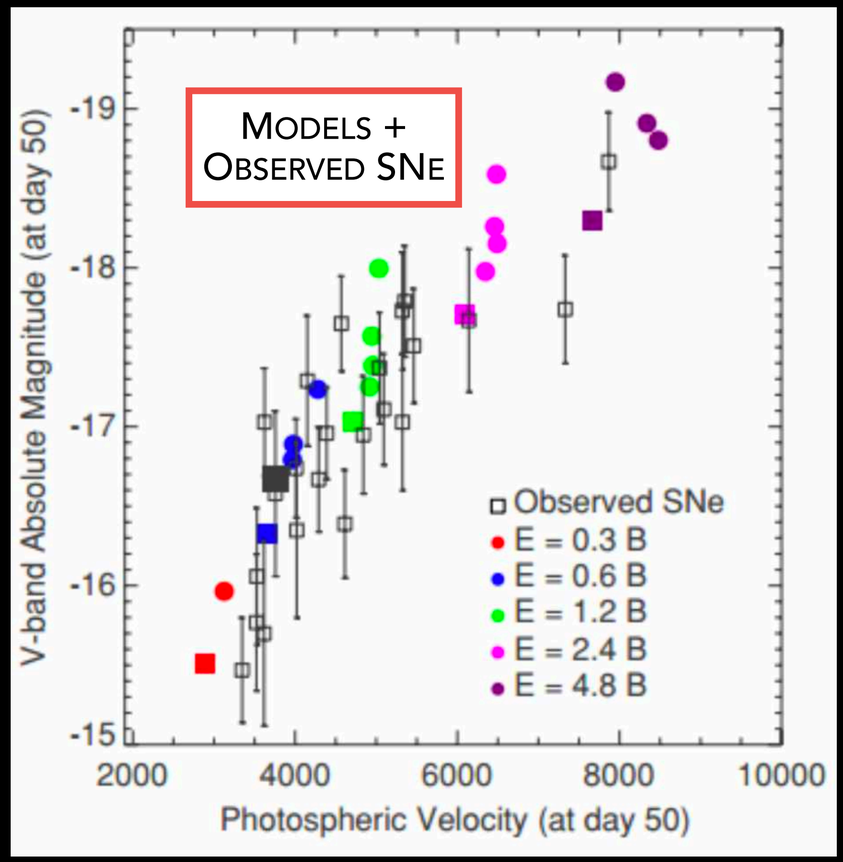
Standard Candle Method: Observations Match The Theory!

Empirical correlation between the mid-plateau velocity & luminosity.



More luminous → H recombination front at a larger radius → greater velocity*

*assuming homologous expansion



Kasen & Woosley 09

Standardizable Candle Method (SCM)

BENEFITS	DOWNFALLS
Straightforward method; only need a few observations	Need to know explosion date t_0, which is not always obvious (unless high cadence survey)
	Measurements needed during “faint” epoch (plateau, not max)
	Spectroscopy can be difficult: faint phase / faint lines

The Data: ZTF

Zwicky Transient Factory (ZTF)

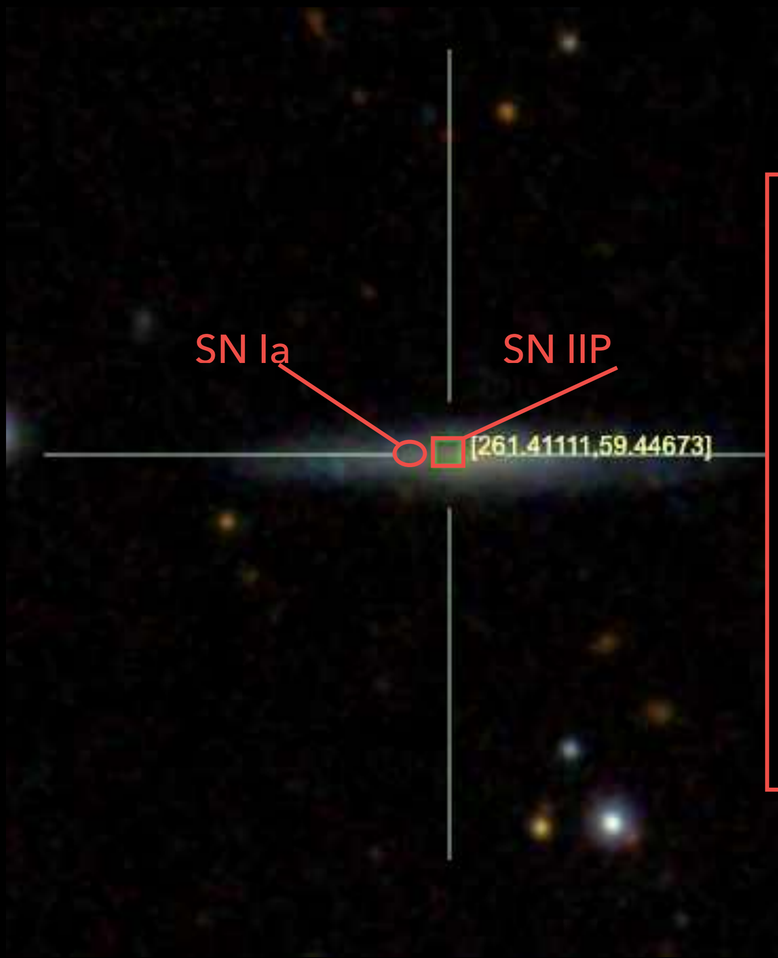
- 2018 —
- Optical Filters: g’, r’, i’
- Optical Spectroscopy
- 3750 sq. deg. per hour up to 20.5 mag

We find 475 SNe IIPs, 31of which are *excellent* candidates that have:

- Non-detection(s)
- 3 filters on plateau
- Detailed multi-epoch spectra
- $z < 0.05$

48-in (1.2-m) Samuel Oschin Schmidt Telescope

Candidate SN: ZTF19abqhobb (and its Ia sibling)

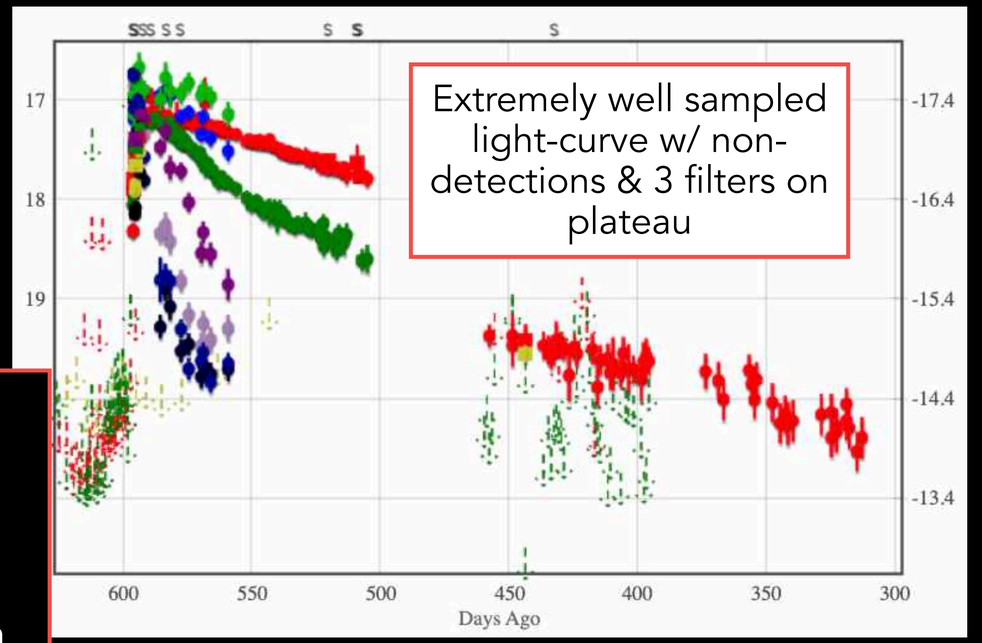


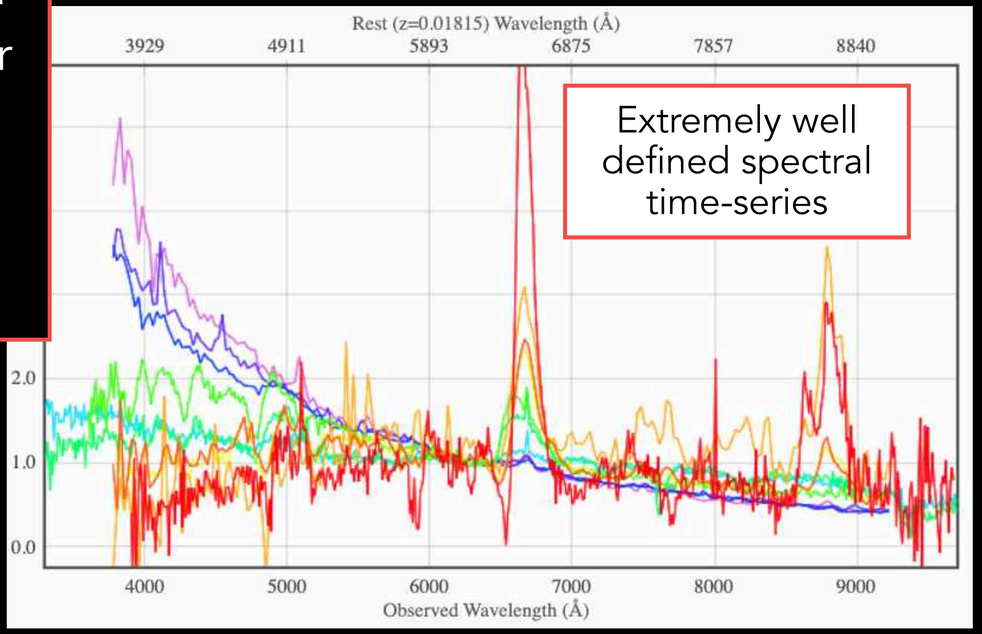
z = 0.01815

Discovered August 19 2019

It has a sibling SN Ia that we have a distance measurement to… do their distances agree?

Need t_0, v_{50}, & color C to get a distance measurement

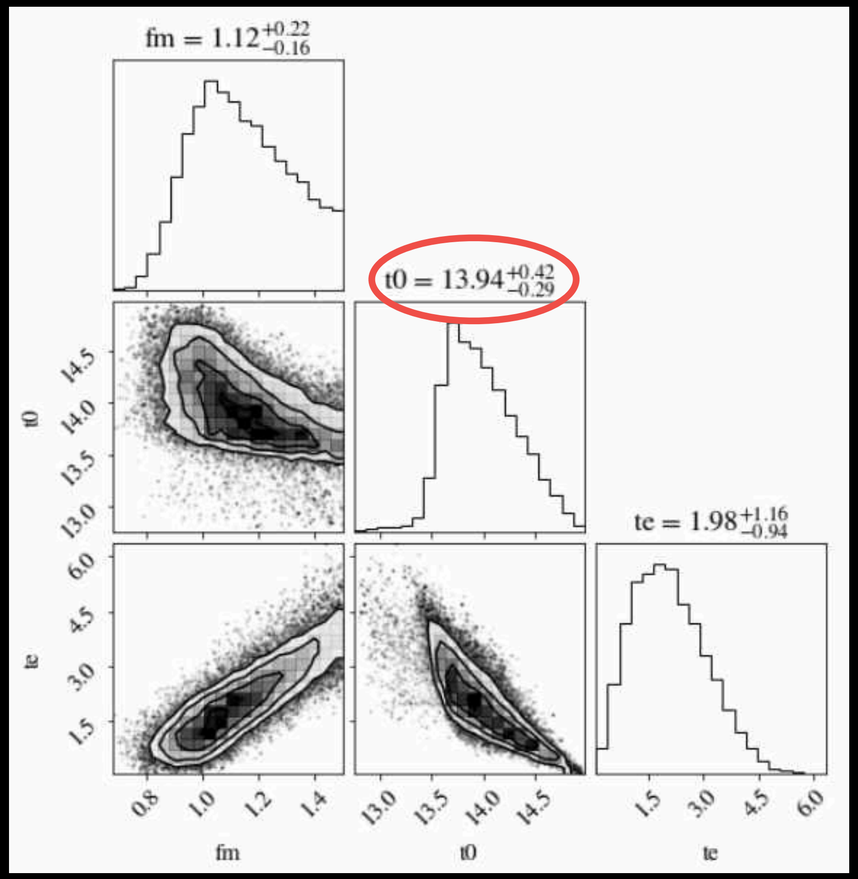


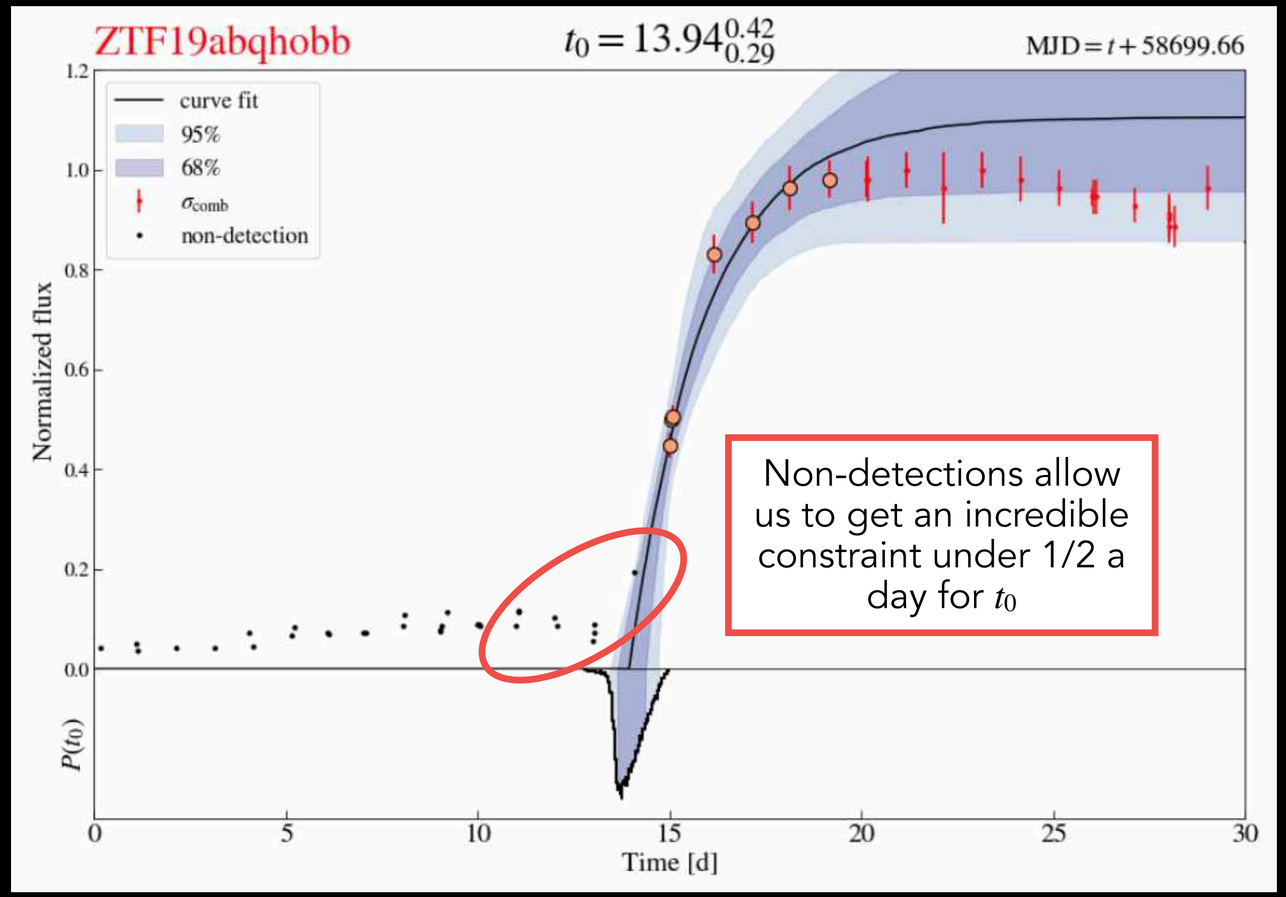


Bayesian Inference: A Novel Approach to Determining t_0:

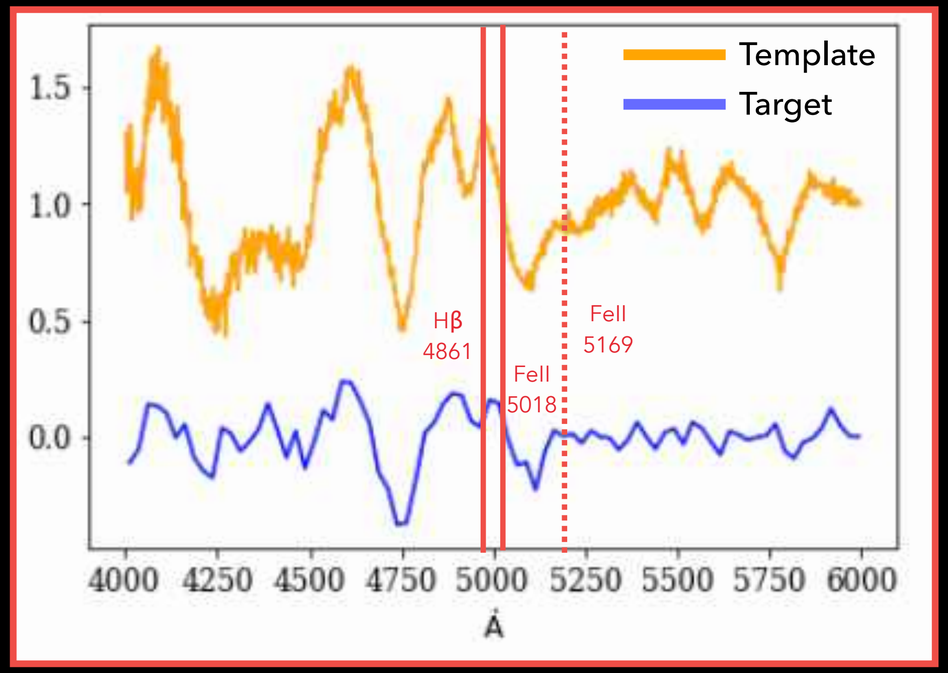
Following Vogl et al. 20

$$f(t) = f_m\left(1 - \exp\left(-\frac{t - t_0}{t_e}\right)\right)$$





Then we use t_0 to cross-correlate our spectra with templates to extract v_{50}



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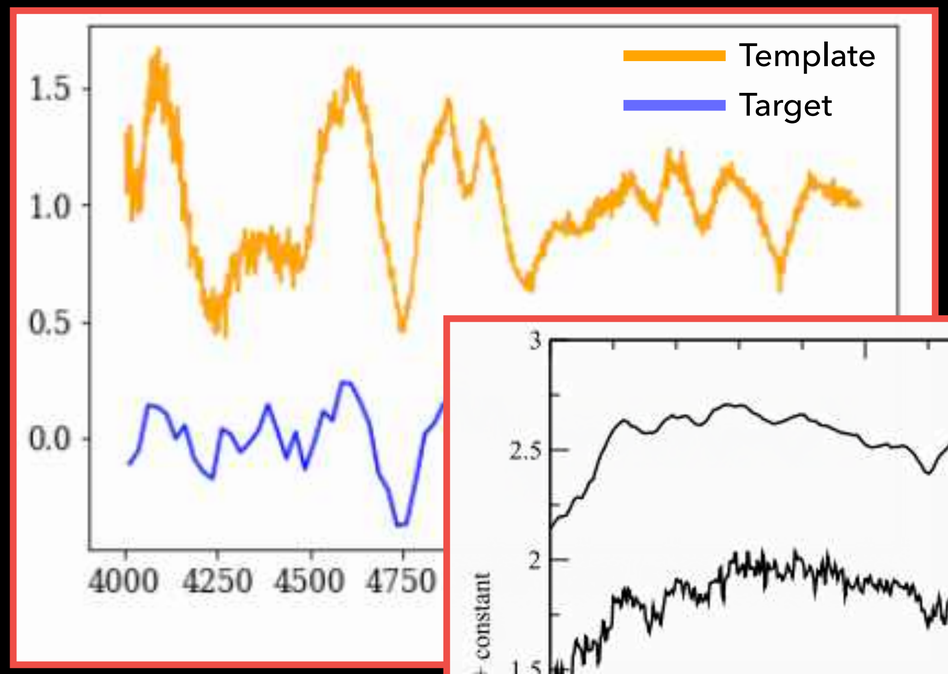
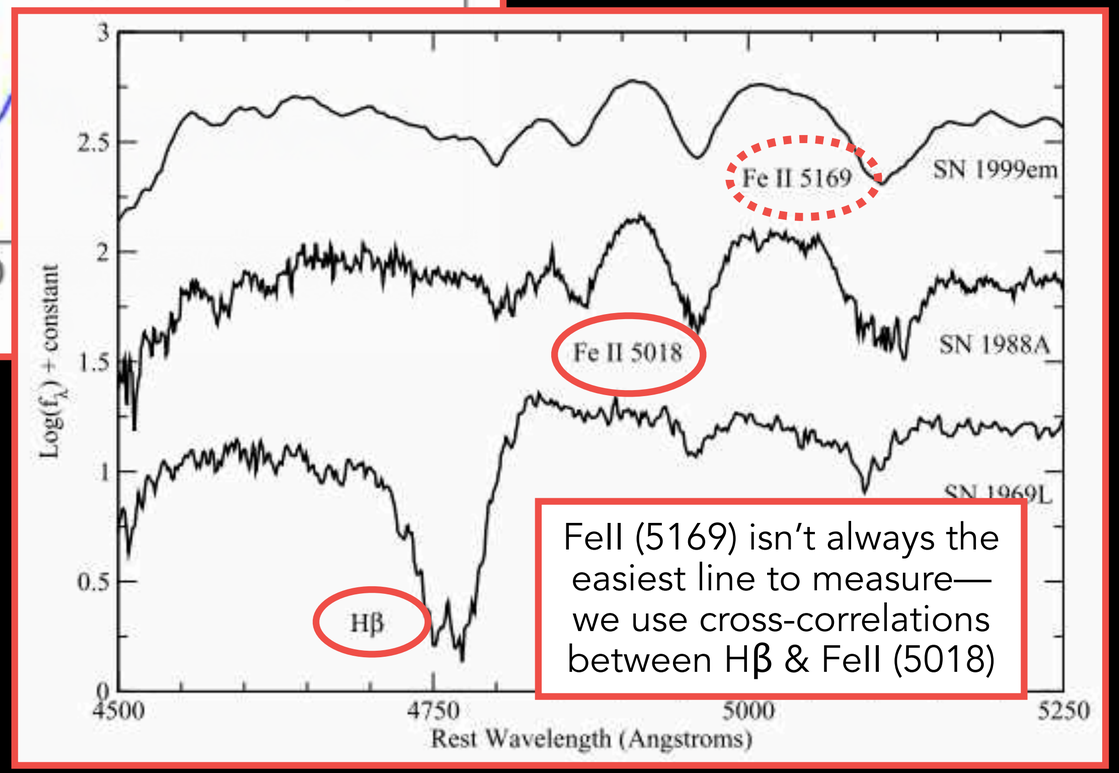
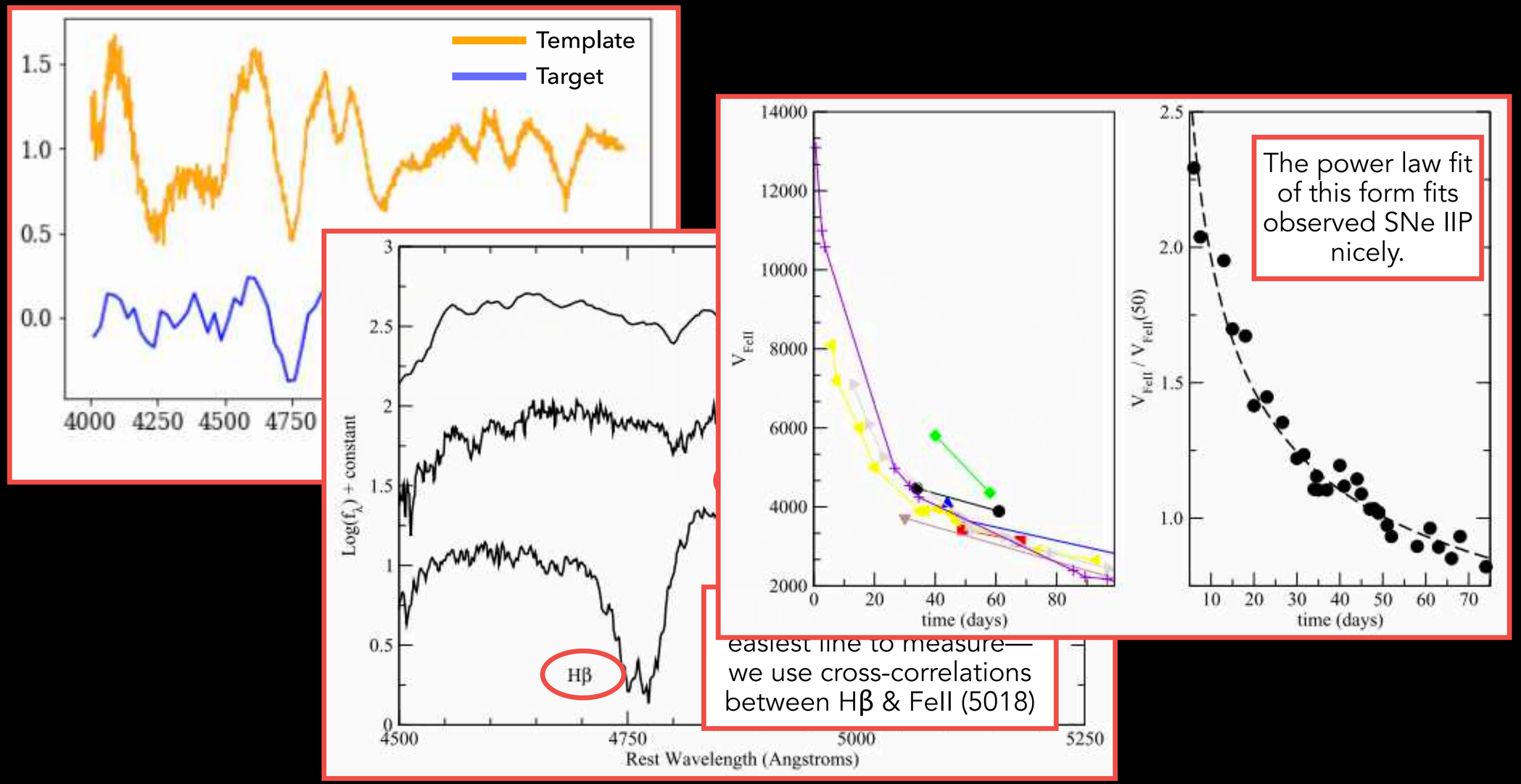


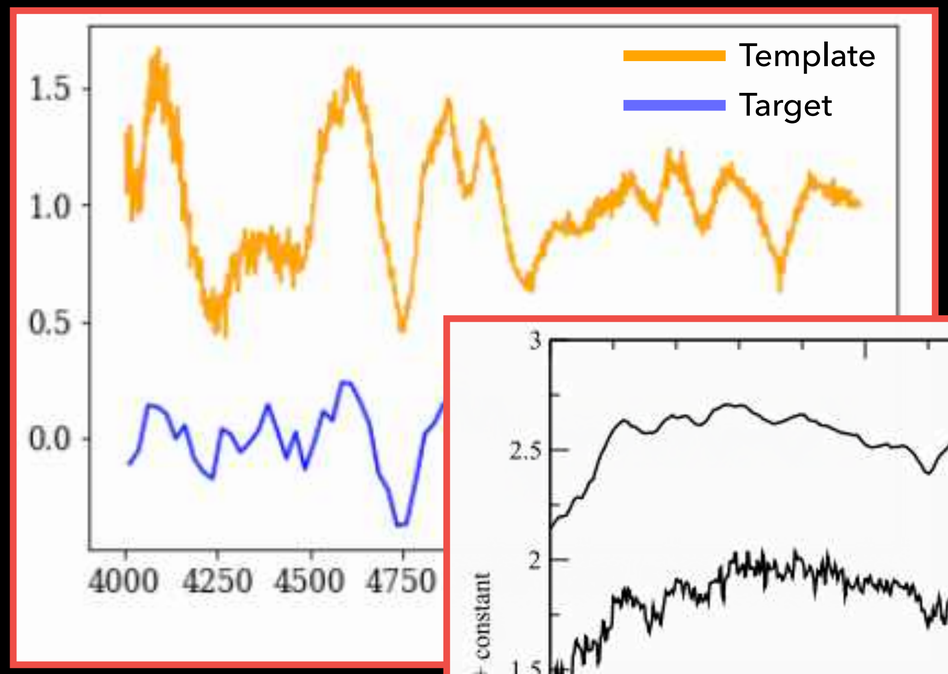


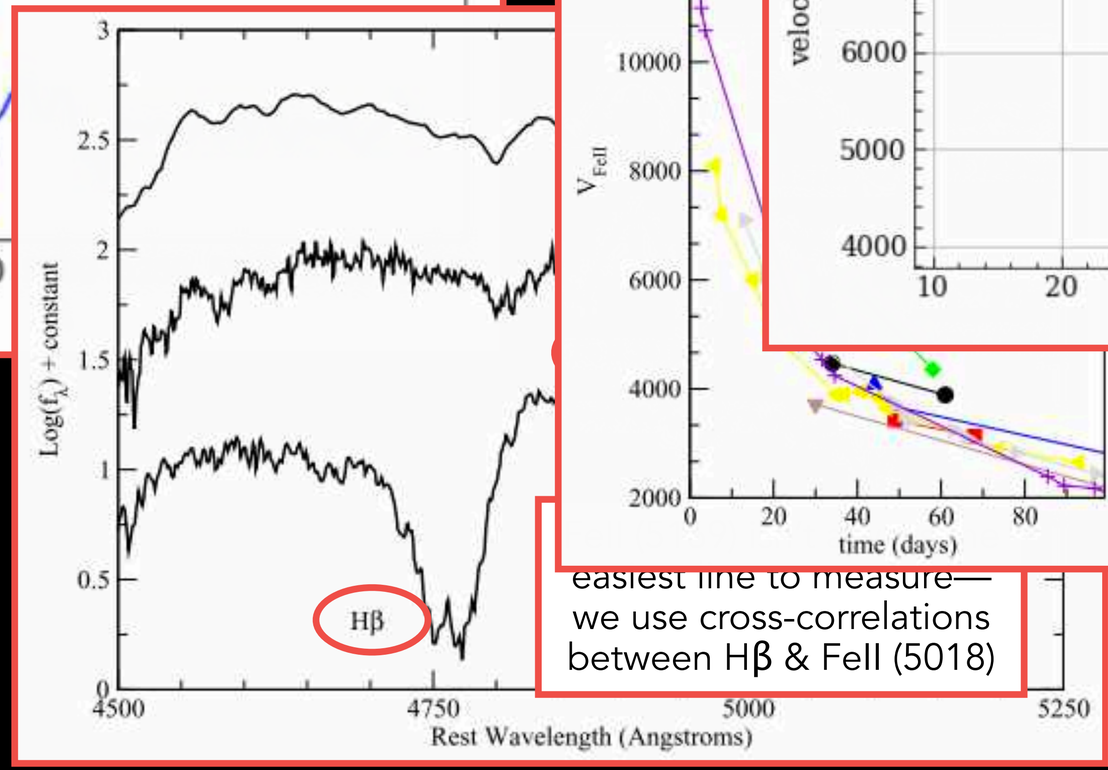
FeII (5169) isn't always the easiest line to measure—we use cross-correlations between Hβ & FeII (5018)

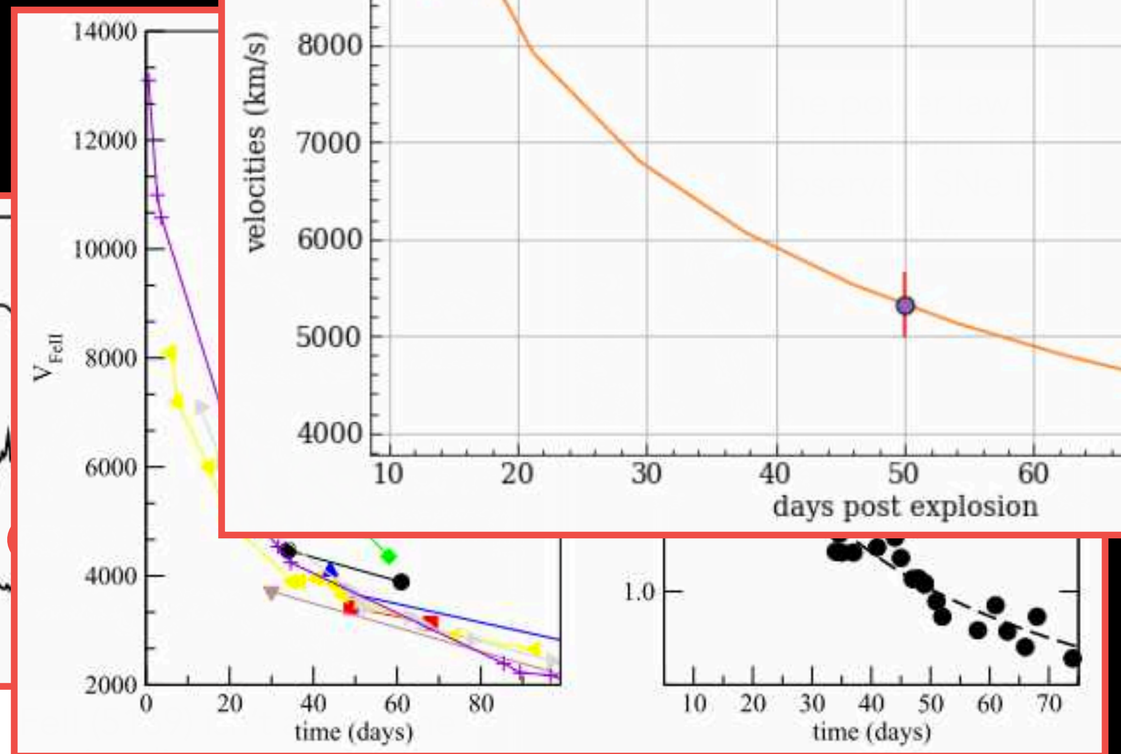
Then we use t_0 to cross-correlate our spectra with templates to extract v_{50} $\quad v = v_{50} \cdot (t/50)^{-0.464}$



Then we use t_0 to cross-correlate our spectra with templates to extract v_{50} $\quad v = v_{50} \cdot (t/50)^{-0.464}$

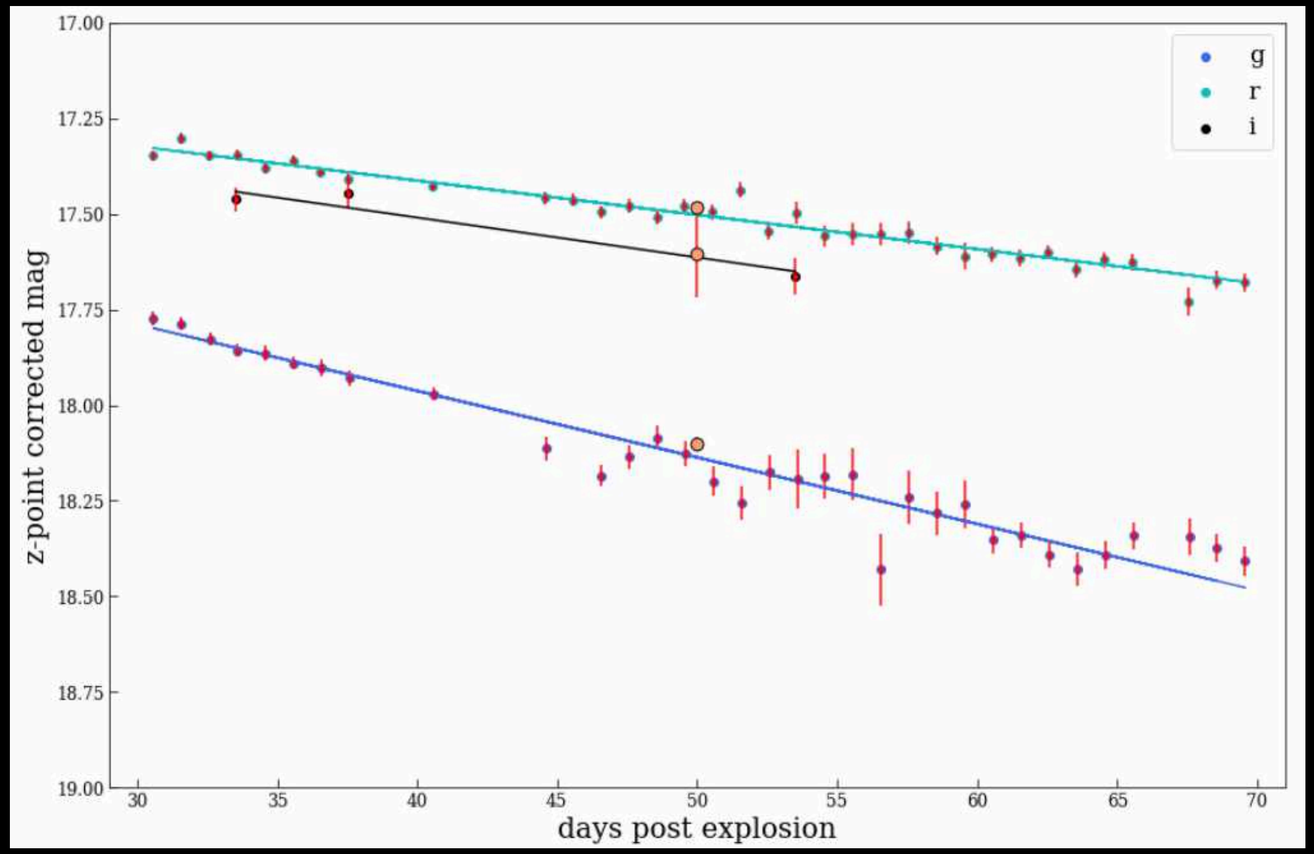






easiest line to measure—
we use cross-correlations
between Hβ & FeII (5018)

Finally use t_0 and v_{50} to extract colors at Day 50.



$$\mu = m - M + \alpha \log \frac{v_{Fe}}{5000} - \beta C$$

$$M_{I_{50}} = -\alpha \log_{10}\left(\frac{v_{50,FeII}}{5000}\right) - 1.36[(V-I)_{50} - (V-I)_0] + M_{I_0}$$

$$\mu_{IIP} = 34.95 \pm 0.26$$

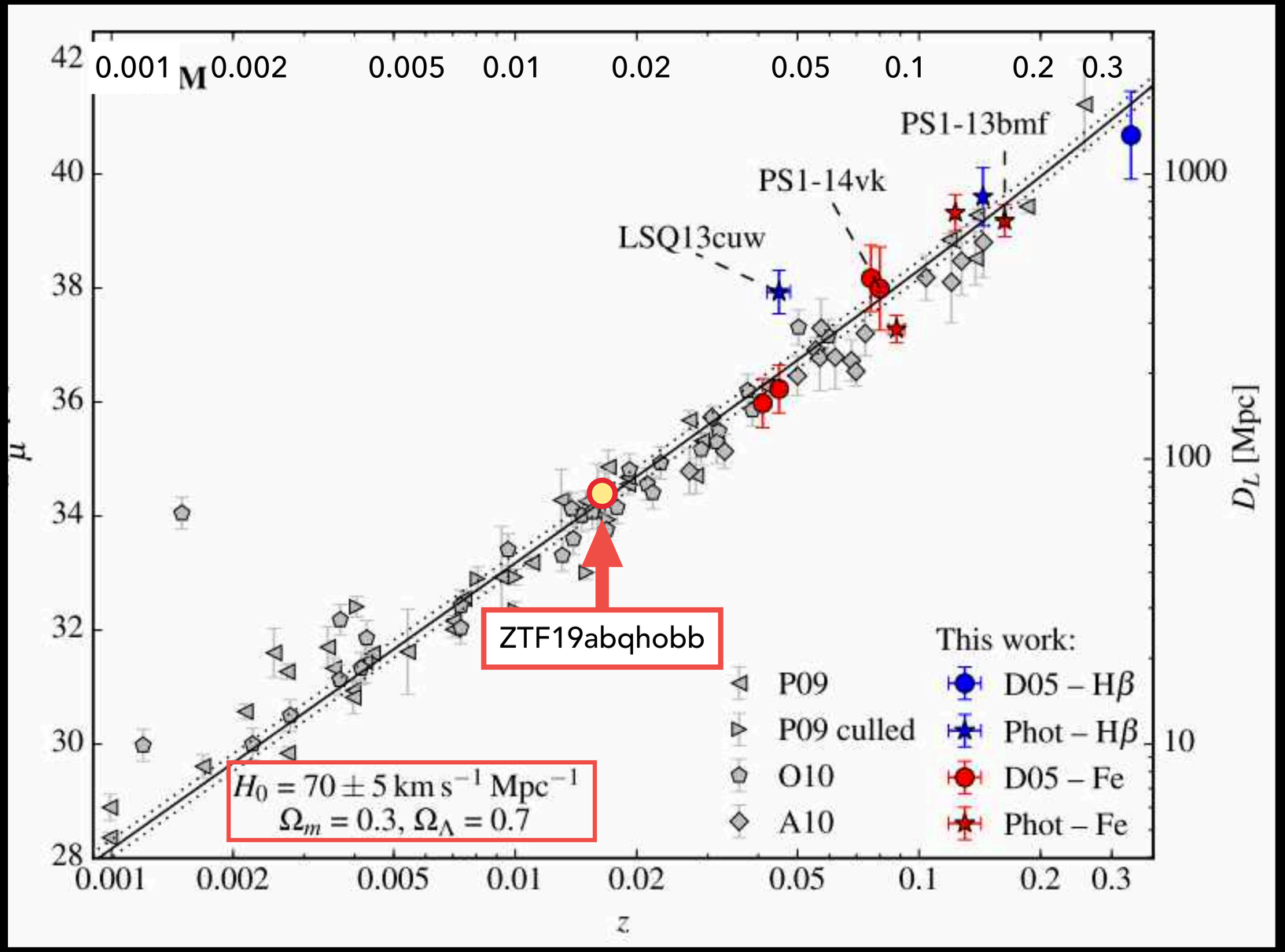
vs

$$\mu_{Ia} = 34.824 \pm 0.16$$

These agree within 0.4σ!!!!

D = 97.6 Mpc +/- 12 Mpc

Next Step: Hubble Diagram with all candidate 31 SNe IIP



Gall et al. 2016

Nance et al. 2021 *in prep*

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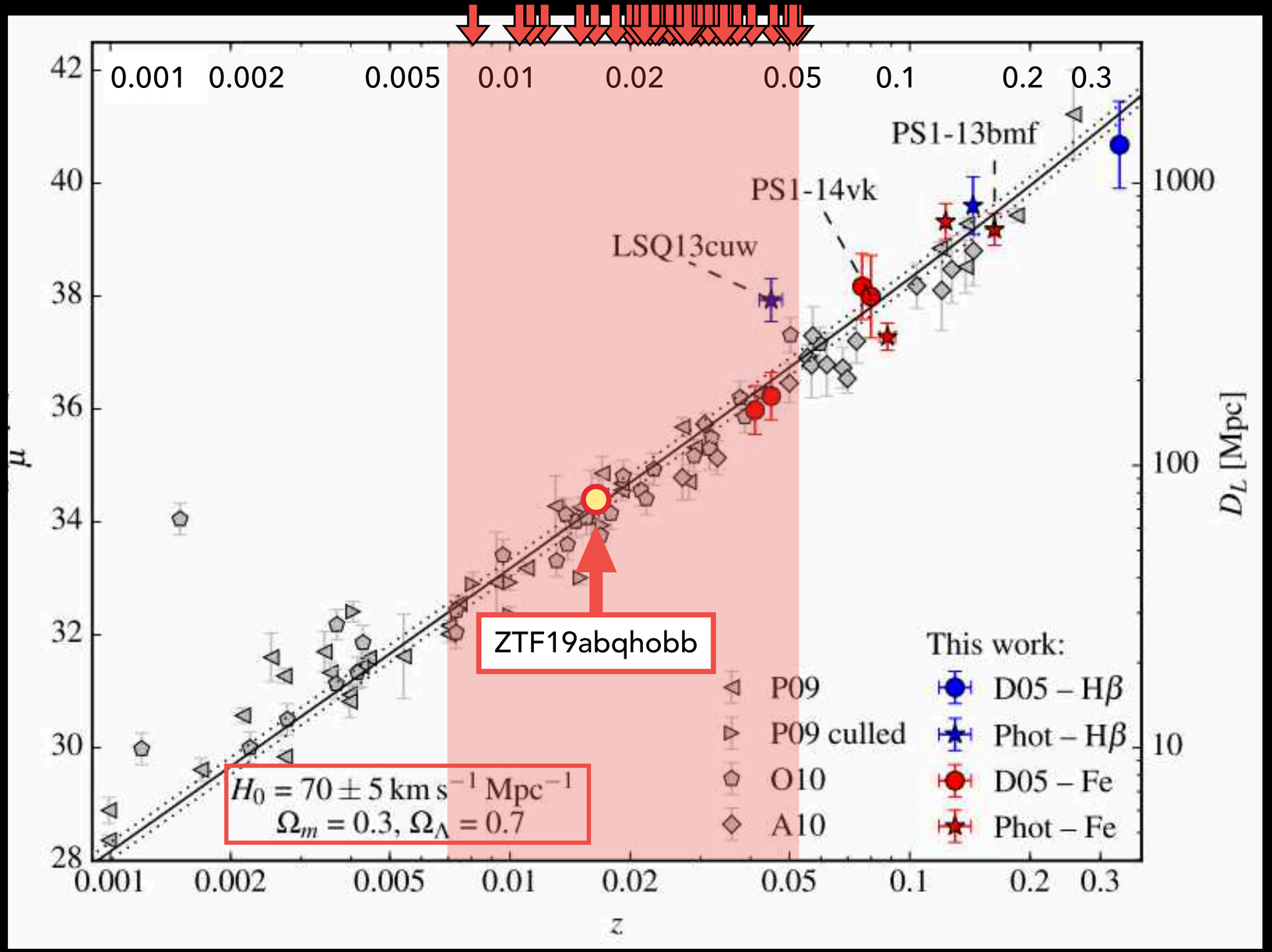

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SUMMARY.

H0 value is not well-constrained – we are missing something.

We can use Type IIP SNe to resolve this tension.

The Standardizable Candle Method (SCM) is a good strategy for determining distances to SNe/Host Galaxies.

ZTF19abqhobb fits nicely on the Hubble diagram with SCM, yielding a value of H0 = 70 km/s/Mpc.

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OUTLINE OF THIS TALK

- PART I: THE SCIENCE
  - The Hubble Constant & Controversy
  - Supernovae (SNe) Classifications
  - Type IIP Supernova for Cosmology & SCM
  - A Case Study: ZTF19abqhobb

- PART II: SCIENCE COMMUNICATION & ADVOCACY
  - Studies on representation in STEM
  - My personal journey
  - Scicomm I do
  - Scicomm strategies

Representation
Matters.

Stereotype threat, bias, and systemic barriers

THE PROBLEM

WOMEN MAKE UP JUST 28% OF THE CURRENT SCIENCE AND ENGINEERING WORKFORCE (NSB)

OF THIS 28%, WOMEN OF COLOR COMPRISE AN ABYSMAL 5%.

TedX x UCLA
Shawntel Okonkwo

Stereotype threat, bias, and systemic barriers

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Dweck & Leggett 98
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THE RESEARCH

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Steele et al 06

When children as young as 8 are asked to draw a mathematician or scientist, girls are 2x more likely to draw a man than a woman.

TedX x UCLA
Shawntel Okonkwo

Communication
Matters.

The Top 50 Science Stars of Twitter

Science, 2014

The Top 50 Science Stars of Twitter

Science, 2014

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Science, 2014

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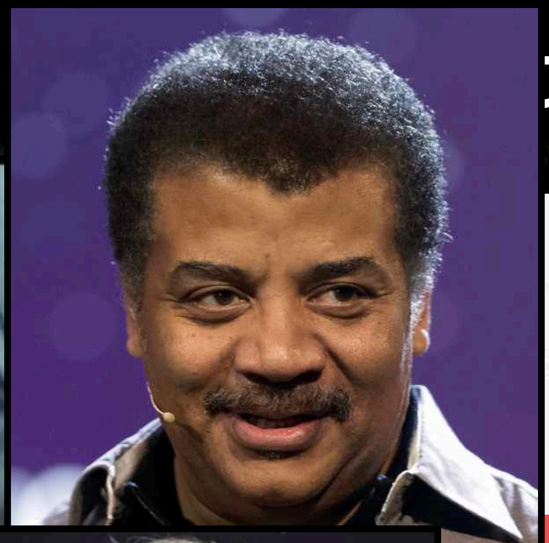

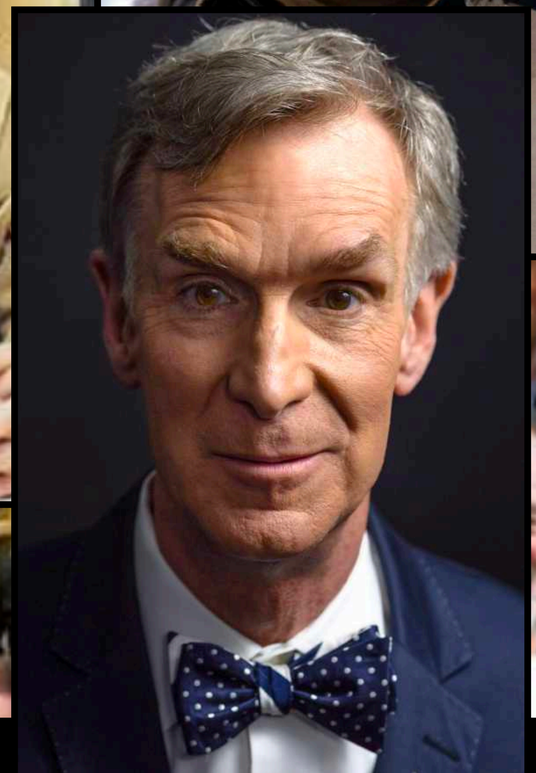

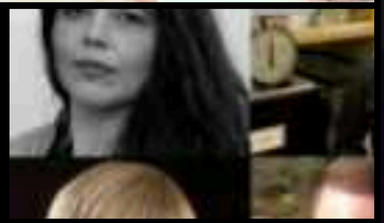

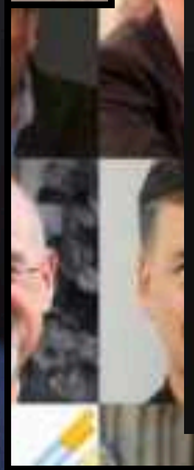

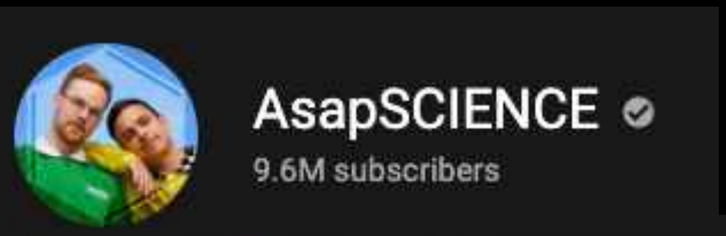

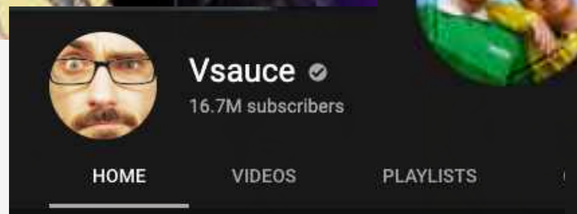

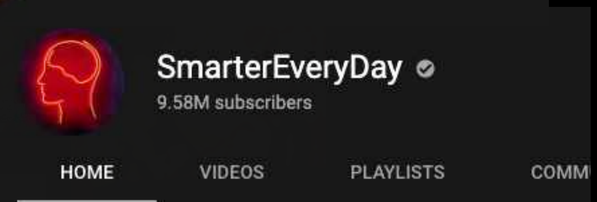

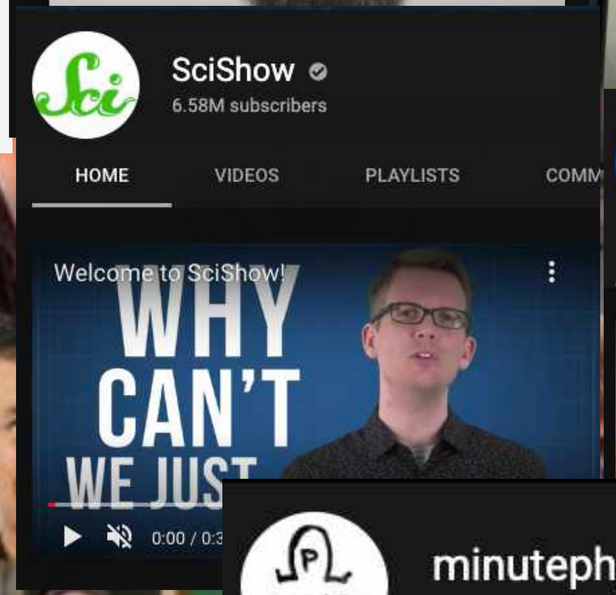

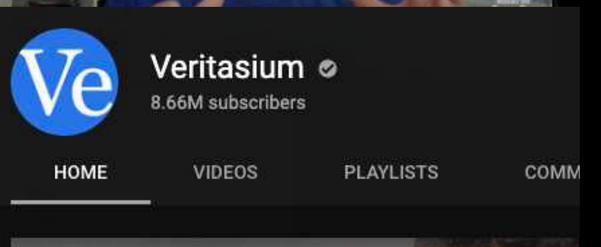

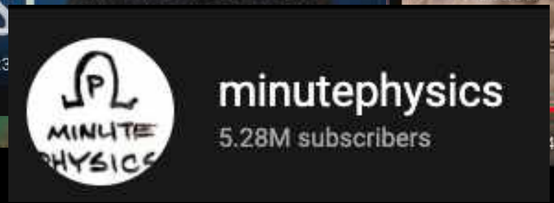

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I felt out of place in the halls of science: as a woman, as an Egyptian-American, as a student to whom physics/math didn't come particularly easily.

I've wanted to be an astrophysicist since I can remember, but for most of my life I simply didn't think a career in astronomy was possible.

My Mission: To change this for future generations.

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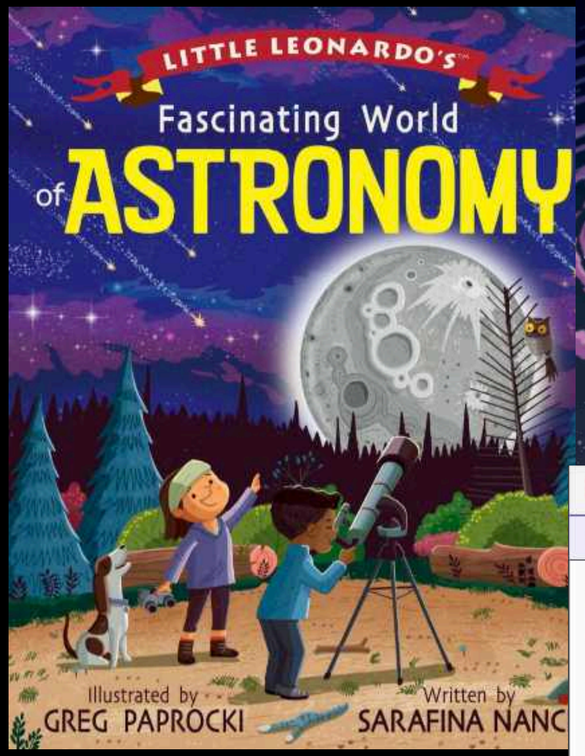
Some sci-comm I do

Books



PublishersMarketplace Deal Report

Non-fiction: Memoir — March 31, 2021

Egyptian-American astrophysicist, advocate, speaker, and science communicator **Sarafina Nance**'s ***STARSTRUCK***, a memoir and inspirational story about both the wonders of the universe and the more earthbound obstacles she's experienced here on earth as a woman of color in a predominantly white and male field, as well the beautiful, transformative, sometimes messy experience of pursuing one's passion through life's inevitable challenges, to **Jill Schwartzman** at **Dutton**, in a pre-empt, by **Melissa Danaczko** at **Stuart Krichevsky Agency** (world English).

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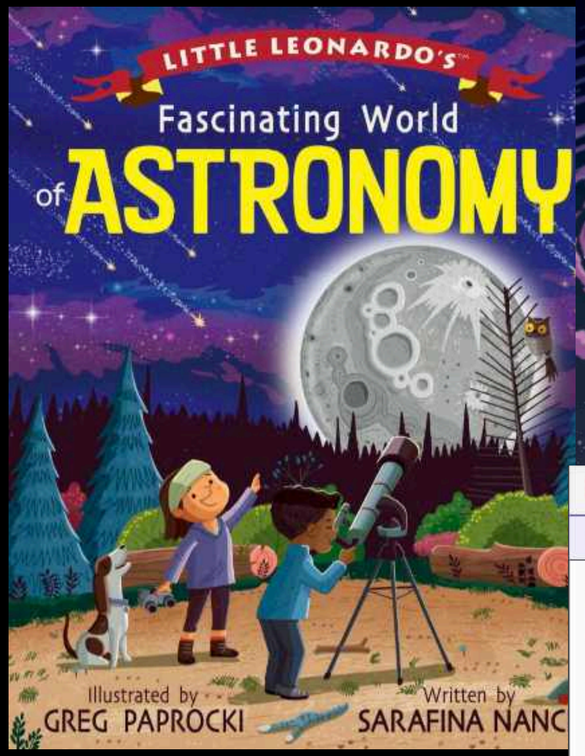

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Social media

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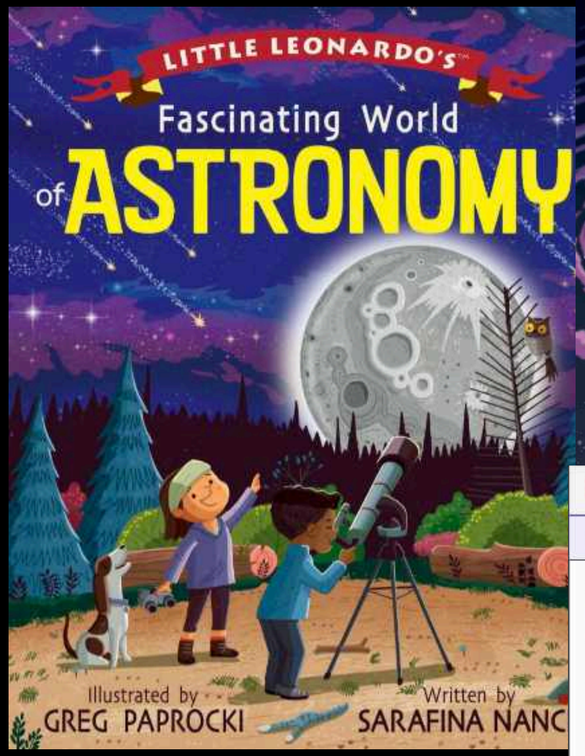

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Social media

TV

Conscious Science Communication is about Representation + Accessibility

STRATEGIES	REASONS
Remove technical language/ jargon	Increases accessibility
Use inclusive frameworks + language	Increases accessibility
Communicate with passion	Gets people excited about whatever you're talking about (+ increases accessibility ;))
Own up to your mistakes.	Fallability is OK. It's how we learn.
Intentionally uplift underrepresented folks	Because it's the right thing to do, and they have been left out of spaces like these.

OUTL TALK

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