Shifting Landscapes in Astrophysics:
New Frontiers to Explore with Roman
July 13 - 16, 2026 • Pasadena, CA

Cole Meldorf | July 13-16 | Masao Sako, Richard Kessler, James Lasker

Constraining Type Ia SNe Volumetric Rates and Progenitor Systems with the Roman Space Telescope

BIG QUESTION:

What is the nature of the Type Ia Progenitor System?

Single Degenerate?

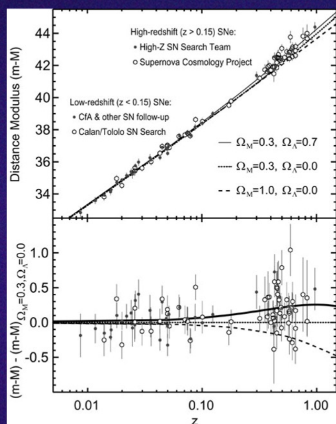
Double Degenerate?

A secret third thing?

I don't know, why should I care?

I'm glad you asked!

Cosmology:

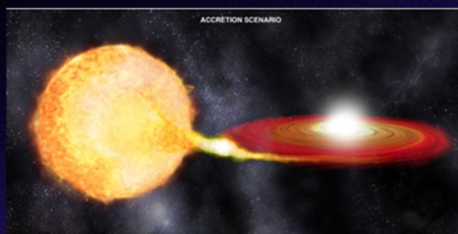


How standard are our standard candles?

Metallicity Enrichment in galaxies / the Universe.

SNe IA create intermediate mass and iron group elements, almost 70% of the iron!

Rough guidelines



In the Single Degenerate scenario, time to explosion is a few Gyr at most.

Double degenerate scenario, distribution of explosion times has a long tail.

Prompt SN = within a few hundred Myr

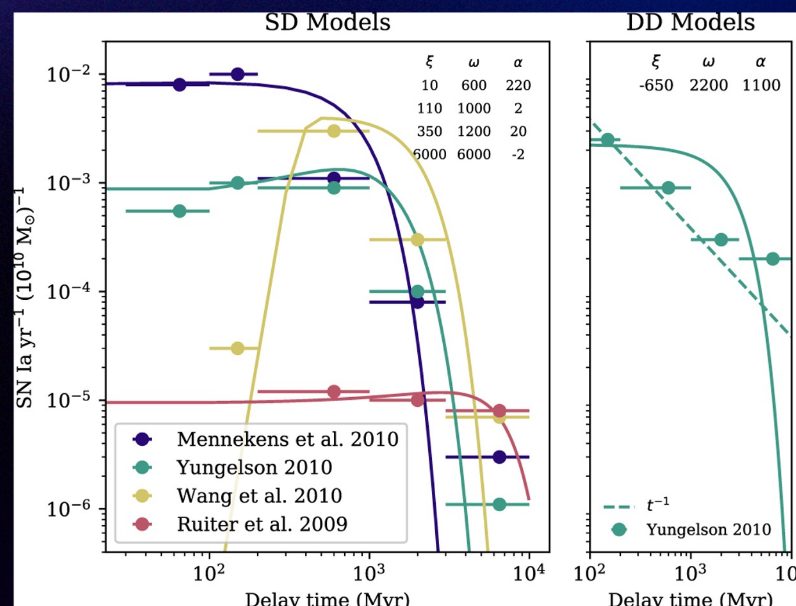
Delayed = Several Gyr.

How do we determine the progenitor?

In the absence of direct detections we are forced to get more creative.

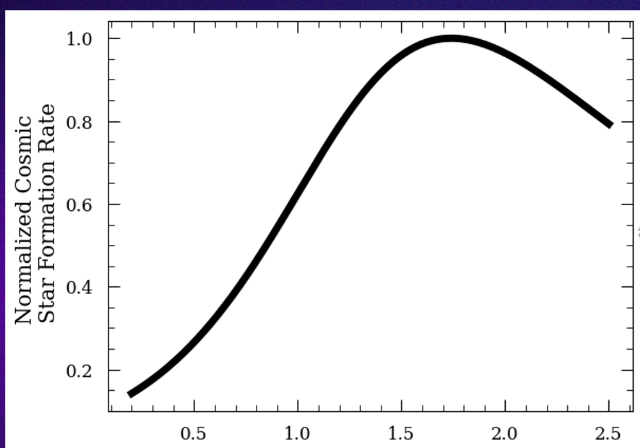
Enter: The Delay Time Distribution (DTD)

Unfortunately, we also cannot observe this directly, as typical delay times are just a little longer than a typical PhD tenure.

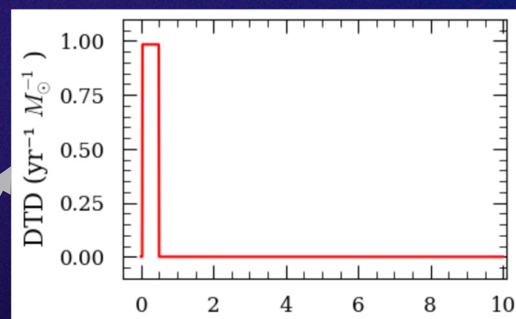


We will measure the DTD using the Volumetric Supernova Rate

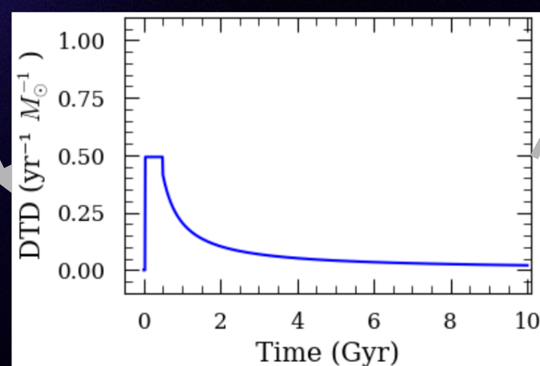
Say we live in a universe with the following Cosmic Star Formation Rate:



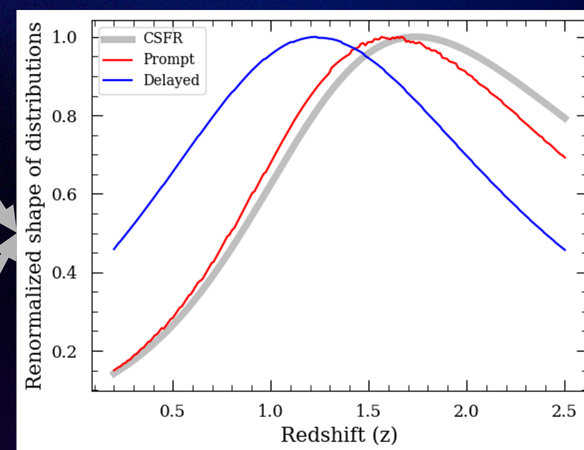
Scenario 1: DTD is short and sharp



Scenario 2: DTD has a long tail

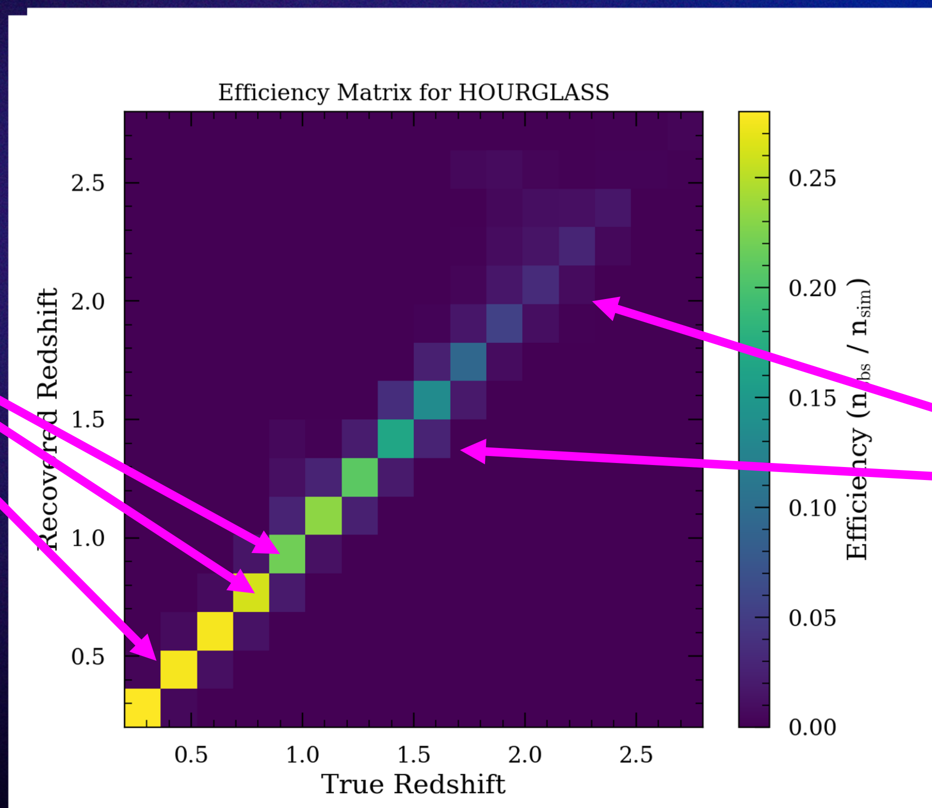


We get different Volumetric Supernova Rates!



Define a 2D efficiency matrix.

These SNe have a photo-z that is approximately correct. However, efficiency is < 1 because realistically not all SNe are detected.



These SNe have a measured photo-z outside of the redshift bin of their true redshift. By including off-diagonal terms in our efficiency matrix, we partially account for these biases.

Why Roman?

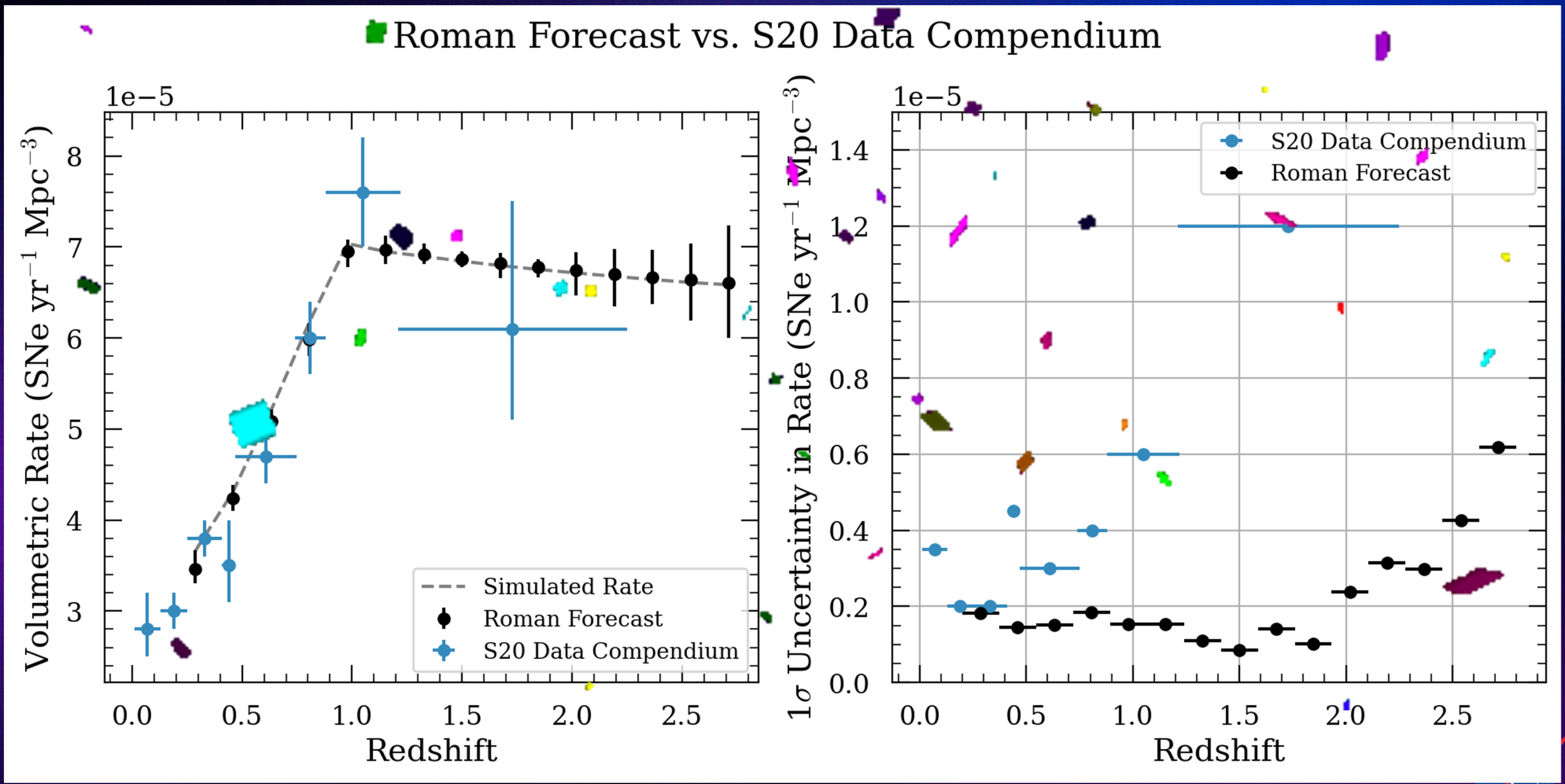
With Roman, SNe Ia will be:

- Abundant
- Detected at High Redshift
- Well-Sampled

RISE:
Will help us constrain very high z rate.

Certainly looks like a telescope to me!

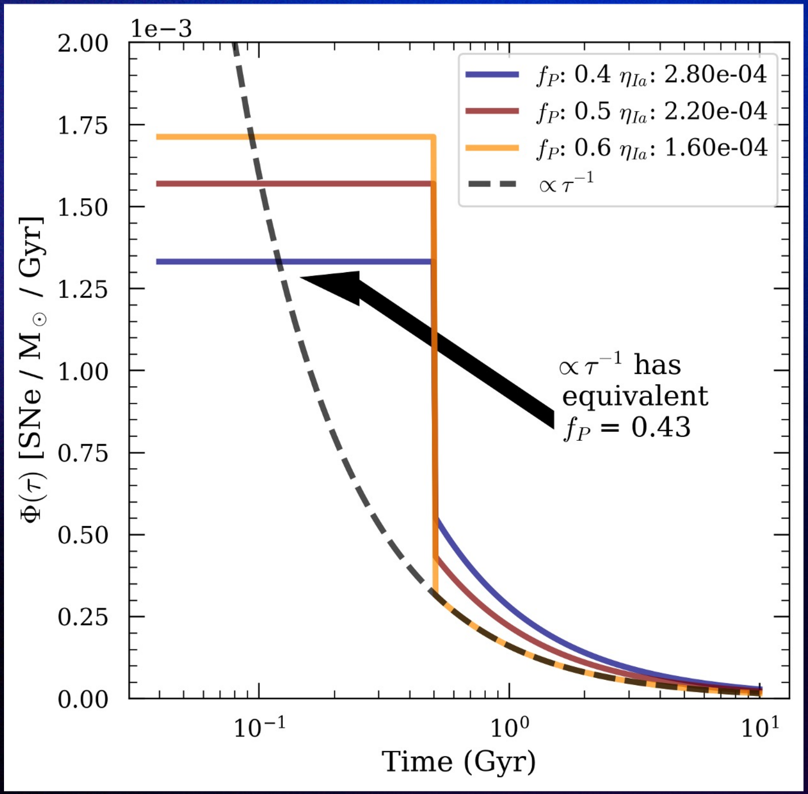
Results (Tentative)



Toy DTD Model

Courtesy of Rodney et. al. 2014

$$\mathrm{SNR}(t) = \begin{cases} 0 & \text{for } t < 0.04 \text{ Gyr}, \\ K\,\eta_{\mathrm{Ia}}\,\frac{f_P}{1-f_P} & \text{for } 0.04 < t < 0.5 \text{ Gyr}, \\ \eta_{\mathrm{Ia}}\,t^{-1} & \text{for } t > 0.5 \text{ Gyr}, \end{cases} \quad (4)$$



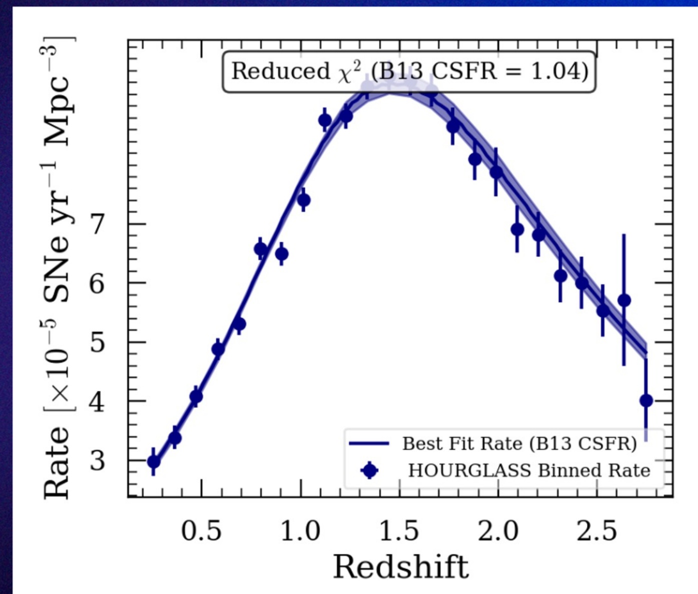
This model is a balance between physically motivated and intuitive to understand, but of course, one can get much more complicated....

Note that a pure t^{-1} power law is consistent with fP = 0.43

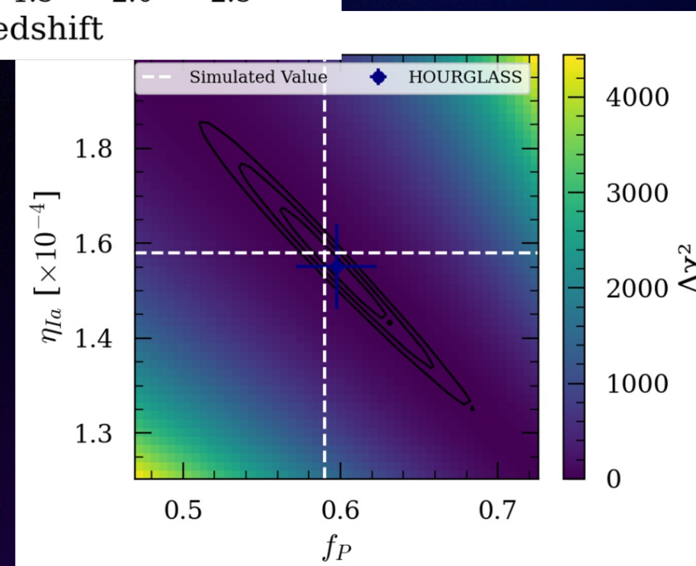
Results Part 2

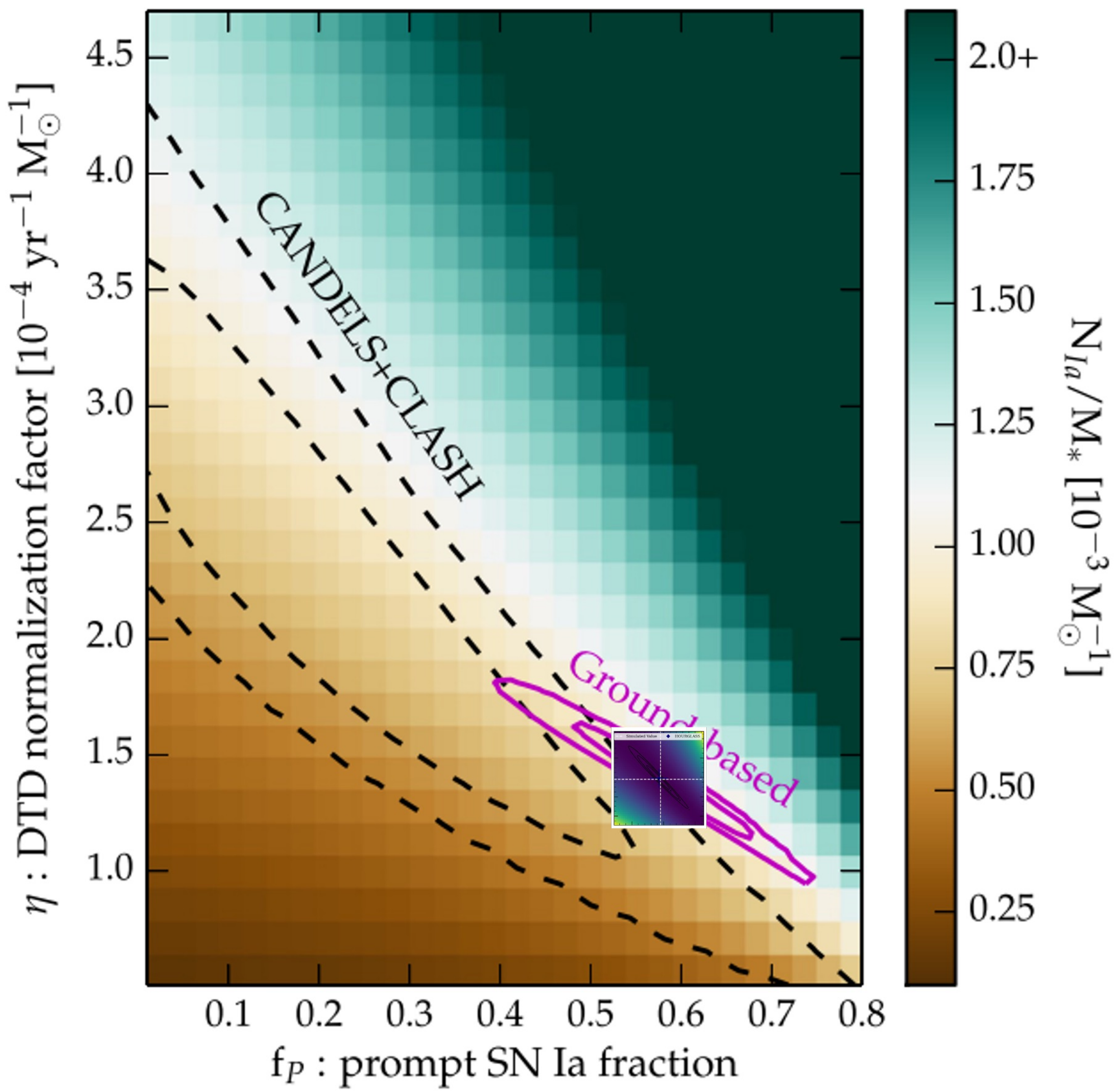
- Prompt fraction constrained to about 4-5%!
- Compared to R14 who measure to about ~30% (!).

$$f_P = 0.53^{\pm 0.09}_{\text{stat}0.10}{}^{\pm 0.10}_{\text{sys}0.26},$$



Nitpicky note, I simulate with fP = 0.59, as the value of 0.53 was combined from two measurements, one of which had much much larger error than the other. I decided to go with *just* the more accurate measurement than the combination. Regardless, the point is the constraint, not the value of fP. Also, why are you reading this?





CANDELS+CLASH
Ground-based
η : DTD normalization factor [10^{-4} yr^{-1} M$_\odot^{-1}$]
f_P : prompt SN Ia fraction
N_{Ia}/M_* [10^{-3} M$_\odot^{-1}$]
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.0+

Of course this makes some key assumptions...

- Uncertainty in the CSFR is certainly higher than 5% at high redshift right now....

CSFR introduces ~10% systematic uncertainty, which will certainly be lowered by Roman + Rubin!

- What if the toy model is not a good fit to real data...?

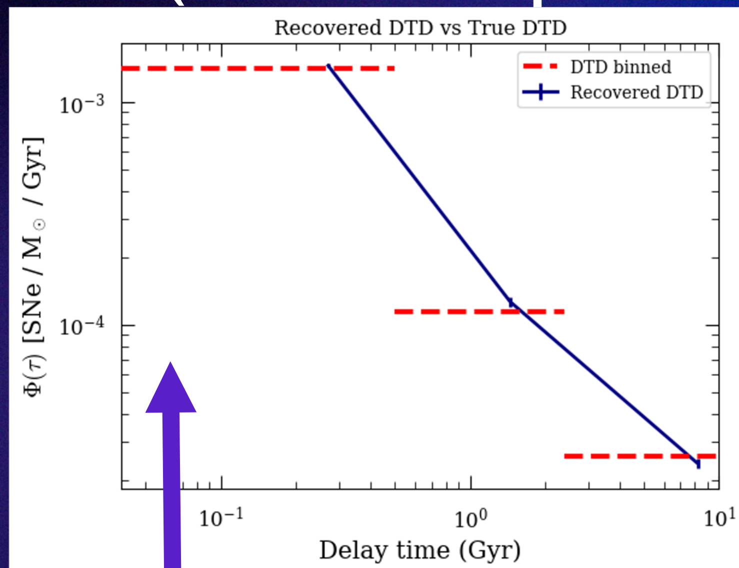
...we can compare DTD models with real data. Or look at non-parametric models...

...like right now! (Results part 3)

Recover the input DTD with error:

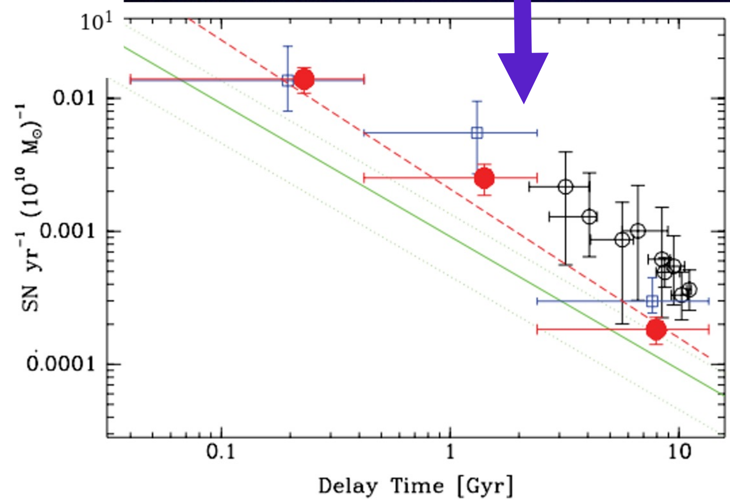
Prompt: 2%

Intermediate and Delayed: 5%



Roman Simulated Results

C.f., e.g., Maoz et. al. 2012
20-25% error in all bins.



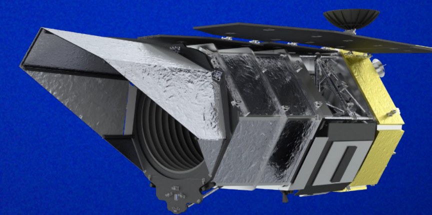
Conclusions

- Roman will give an unprecedentedly fine measurement of the VSNR with only photometric data! (Up to 10x smaller error and much finer binning.)
- We can expect to constrain the prompt fraction 6x better than currently, potentially refute a 1 channel universe?
- Unbinned DTD will be constrained 5-10x tighter.

Lingering Questions...

- Will the Simulations accurately model real roman data? (Can do fake SN injection if not)
- Will CSFR rate error decrease enough to make it subdominant to VSNR error?
- How on Earth will I finish this talk and study for my qualifying exam?

Questions?



Special thanks to:

- Prof. Rick Kessler, answering my inane questions about SNANA
- Prof. Lou Strolger, helping me track down an error in some of the DTD literature
- (Future Prof.) Jillian Paulin, whose simulations mine are largely based upon, and also answered my inane questions about SNANA.

Conclusions, again:

- Roman will give an unprecedentedly fine measurement of the VSNR with only photometric data! (Up to 10x smaller error and much finer binning.)
- We can expect to constrain the prompt fraction 6x better than currently, potentially refute a 1 channel universe?
- Unbinned DTD will be constrained 5-10x tighter.