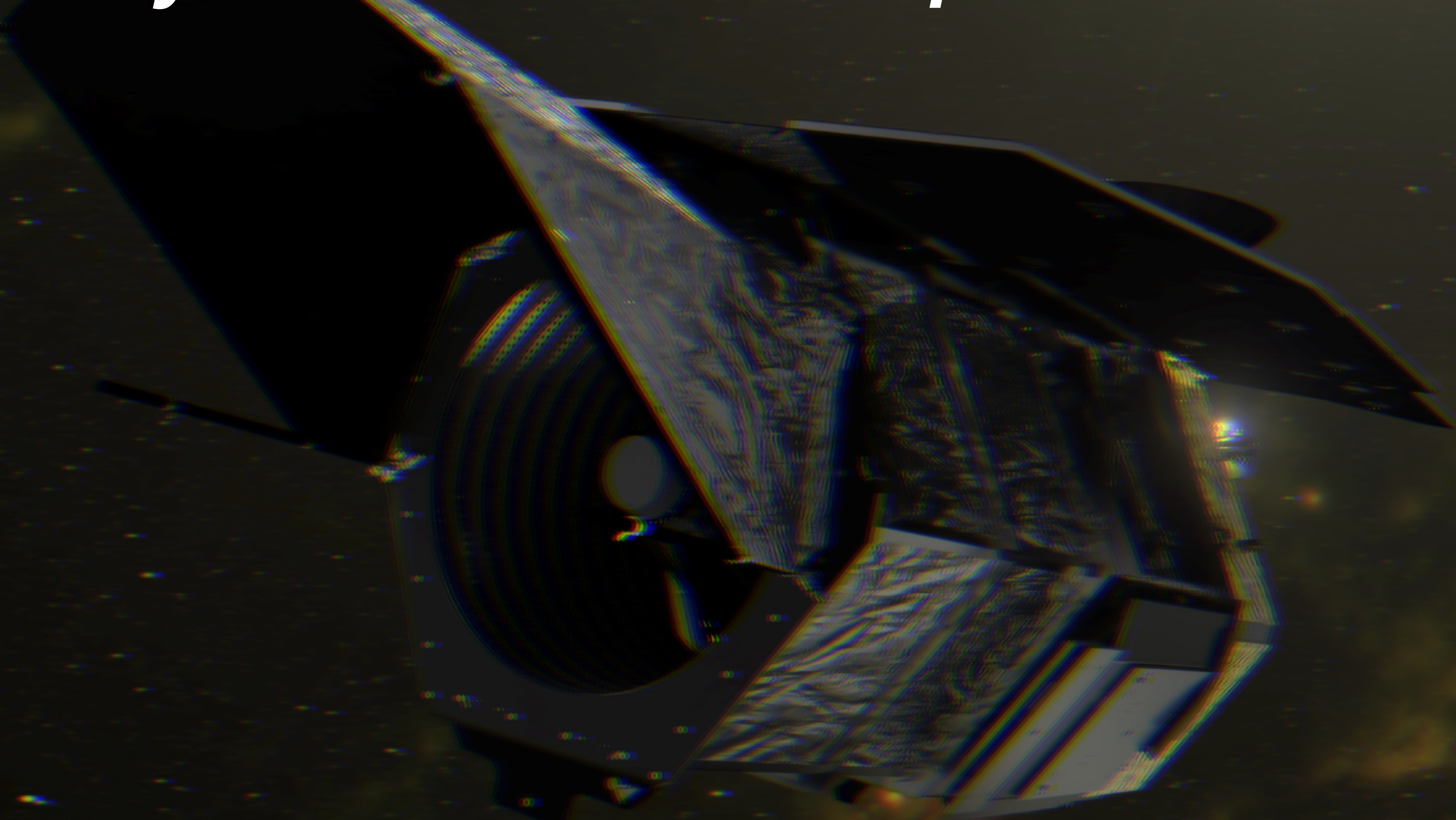
Prism SN Spectroscopy with the *Nancy Grace Roman Space Telescope*



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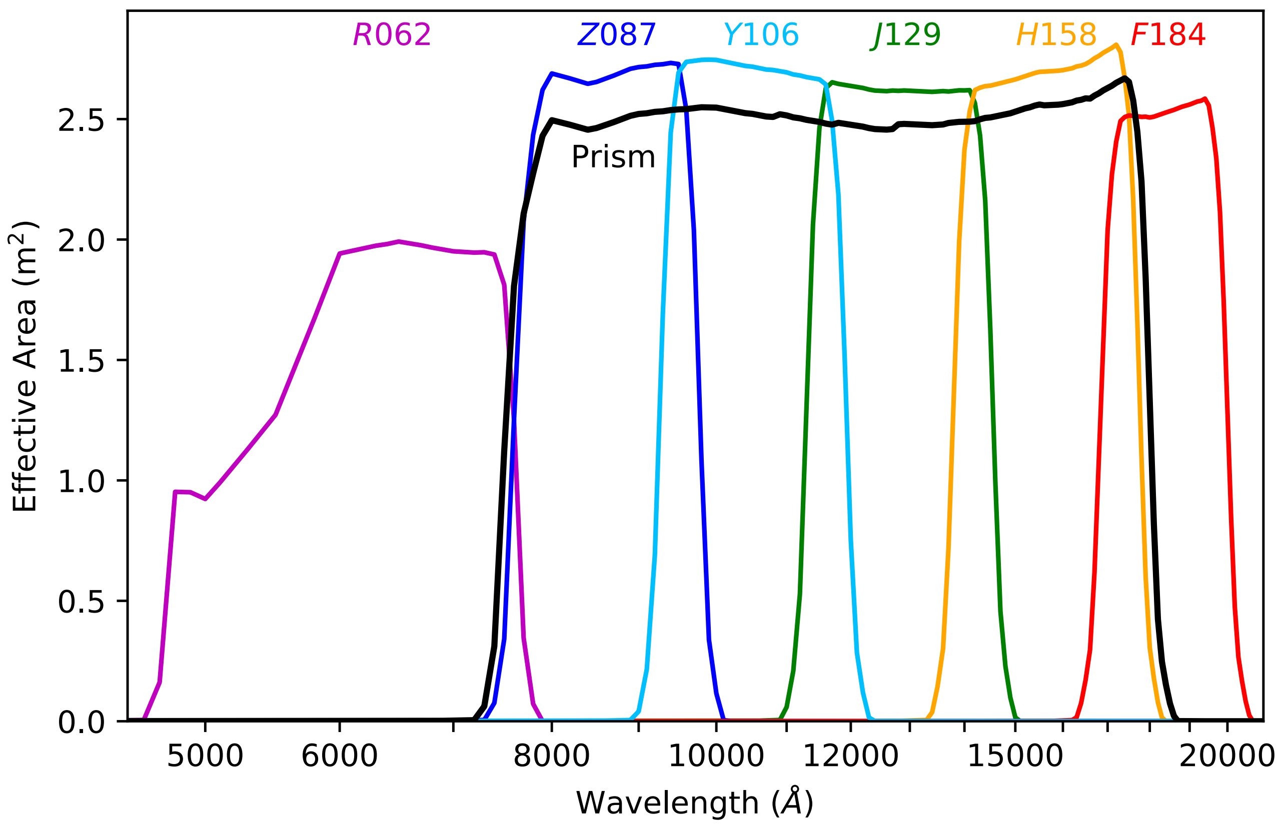
University of Hawai‘i at Mānoa
Feb 8th 2022

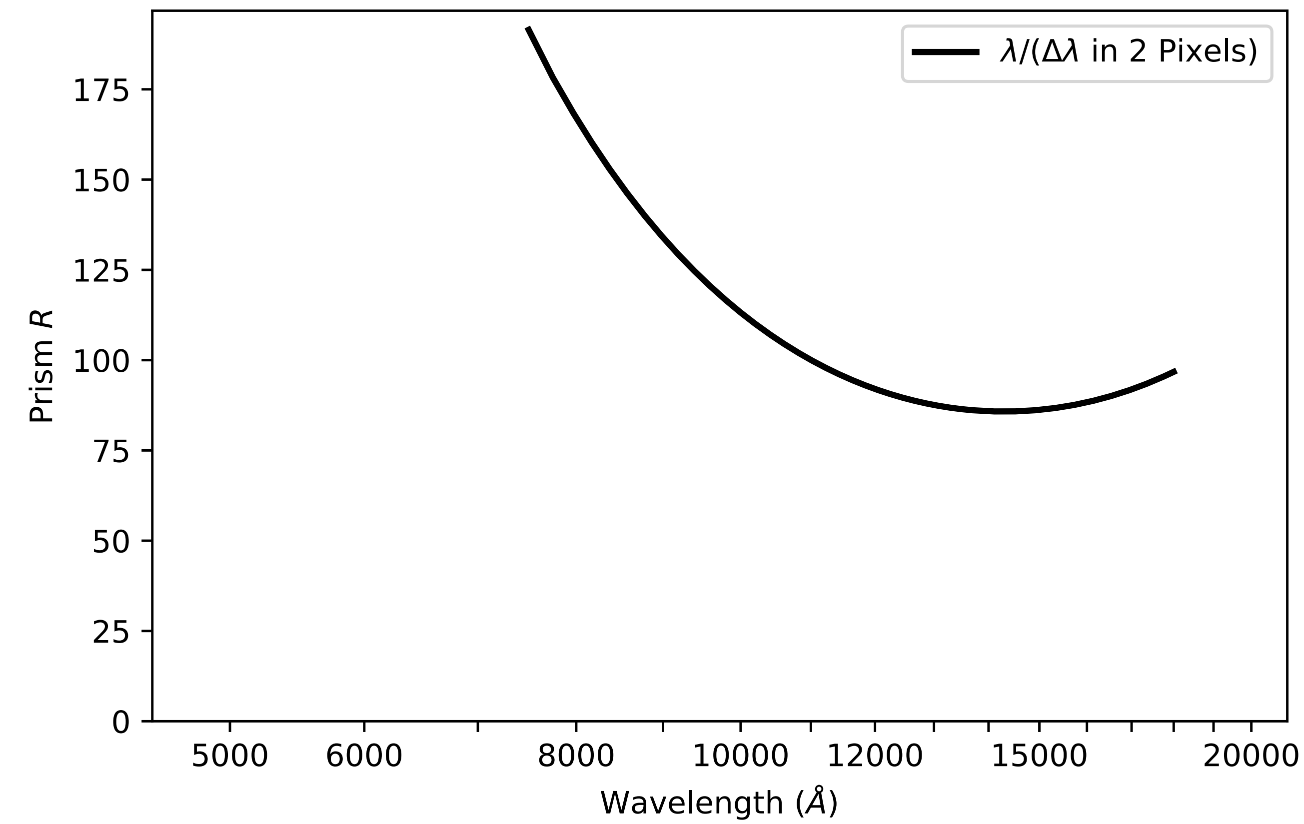
ROMAN SPACE TELESCOPE

Why SN Spectroscopy?

	Direct Value of Prism-Observed SNe	Value of Prism-Observed SNe to Imaging-Only SNe
SN Redshifts	Early, self-contained cosmology analysis (no waiting on host-galaxy redshifts)	Test/training host-galaxy association
SN Typing		Test/training photometric classification
SN Subclassifcation	Early, self-contained, higher-precision-per-object analysis	Training SN model, measuring any SN-population/extinction drift

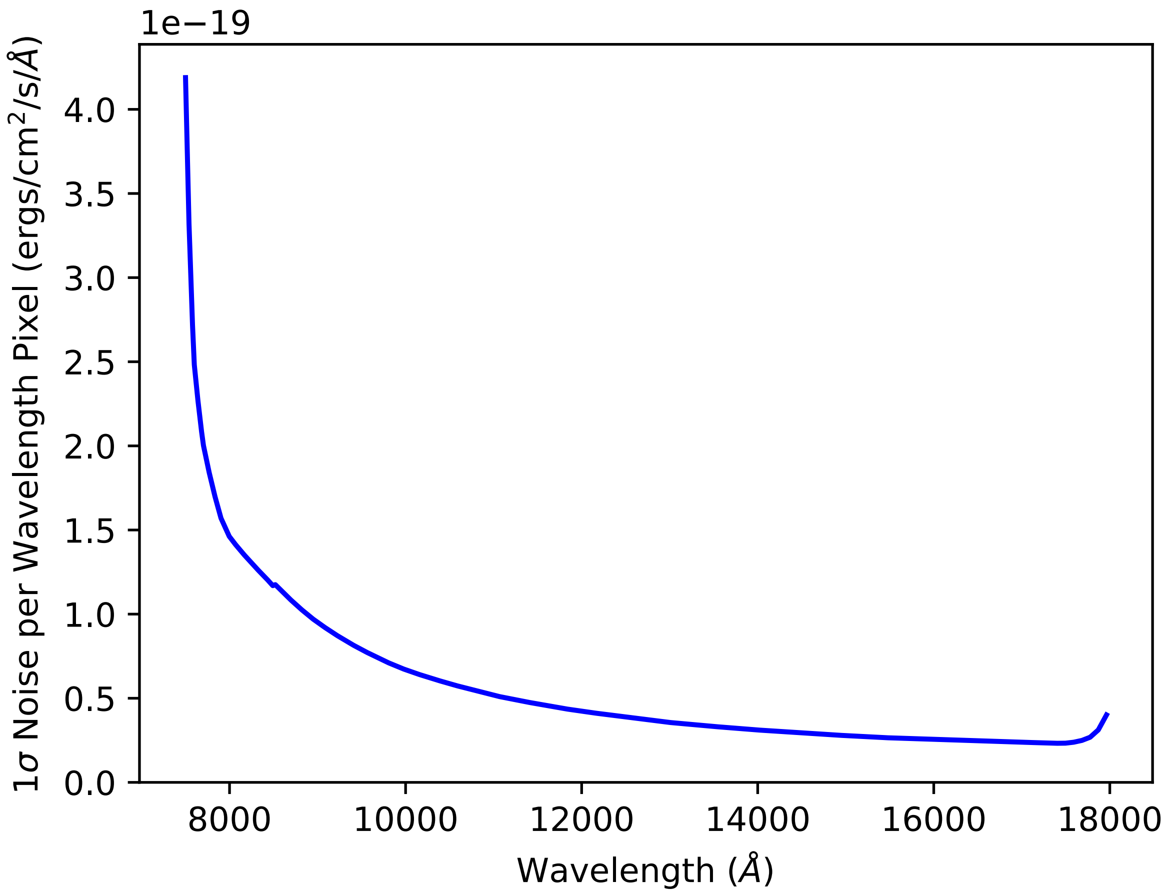
Prism Parameters

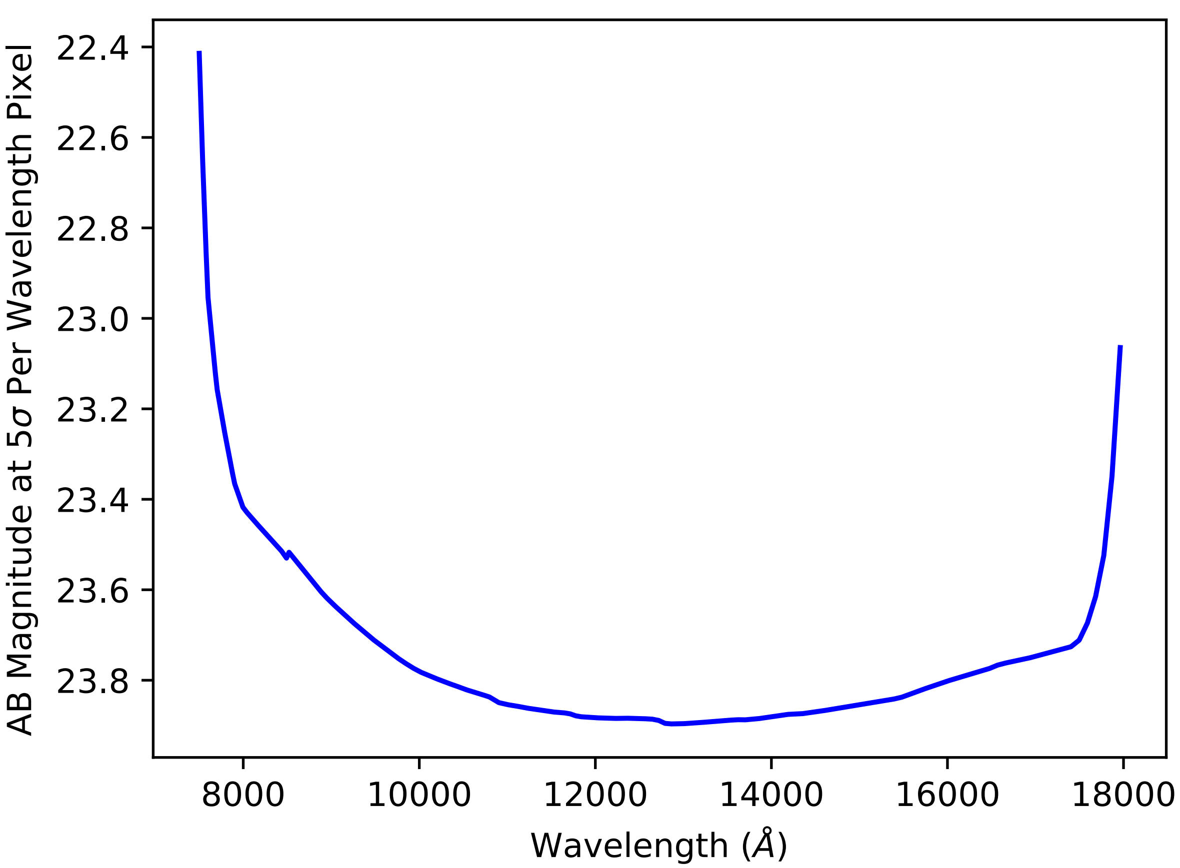




- The prism spans 0.75 μm to 1.8 μm with $R_{2\ \mathrm{pixels}} \sim 100$.
- The prism dispersion is much lower than the grism, so higher continuum sensitivity.

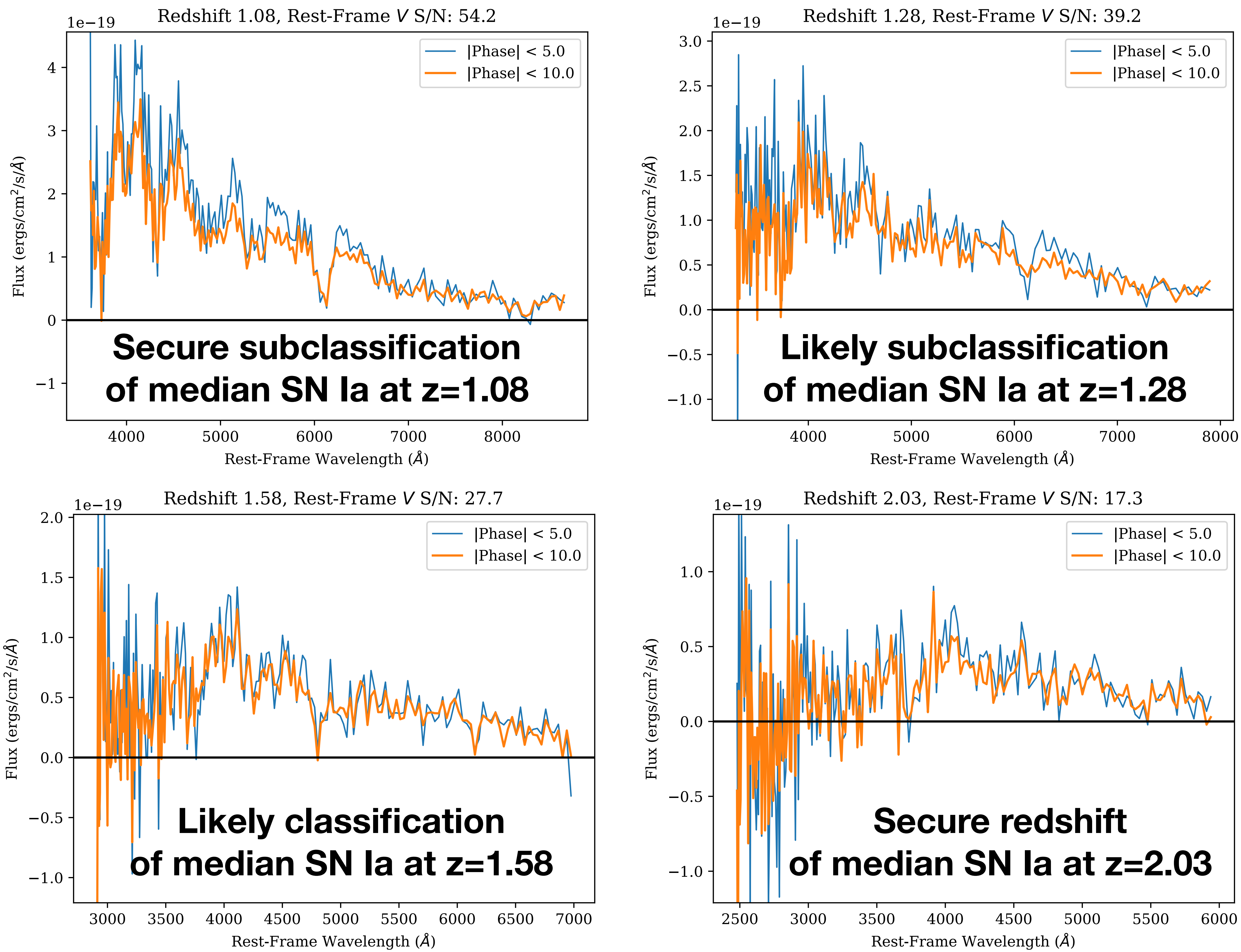
Prism Parameters



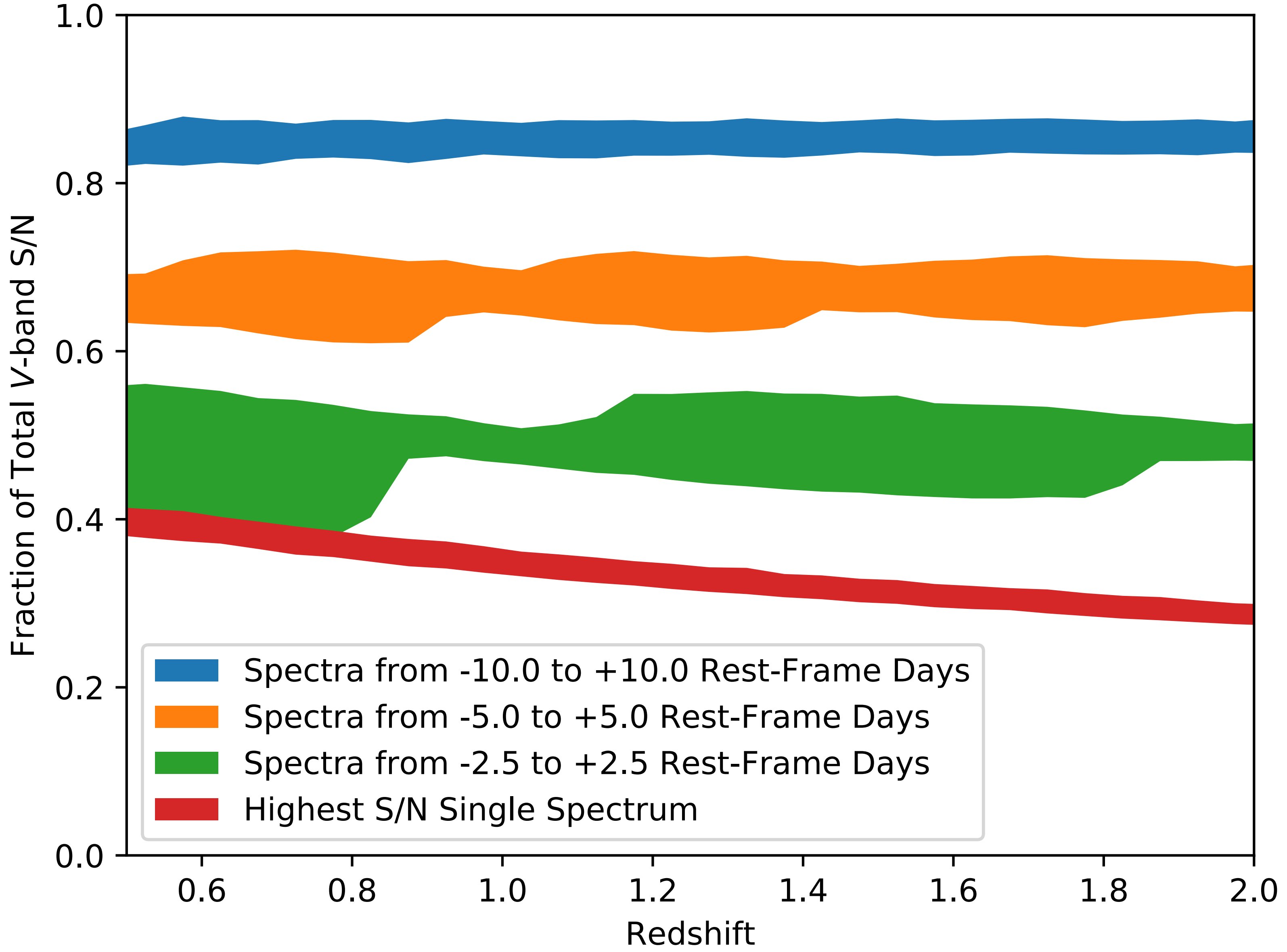


- The point-source sensitivity in one hour is about AB 23.8!
- As we have seen, the deep tier of the HLTDS has ~10 one-hour visits per SN in a time series.

Live SN Spectroscopy



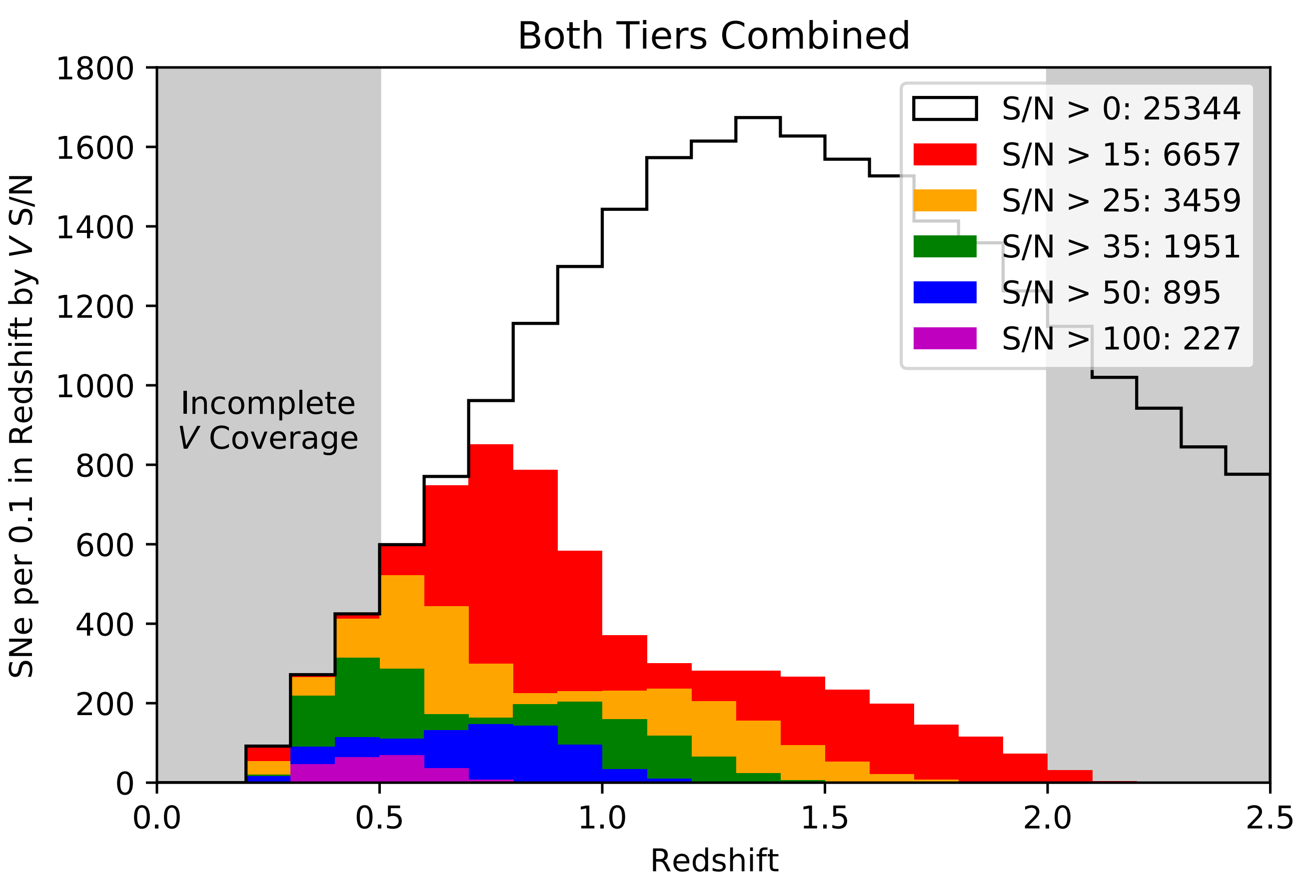
S/N in the Prism Timeseries



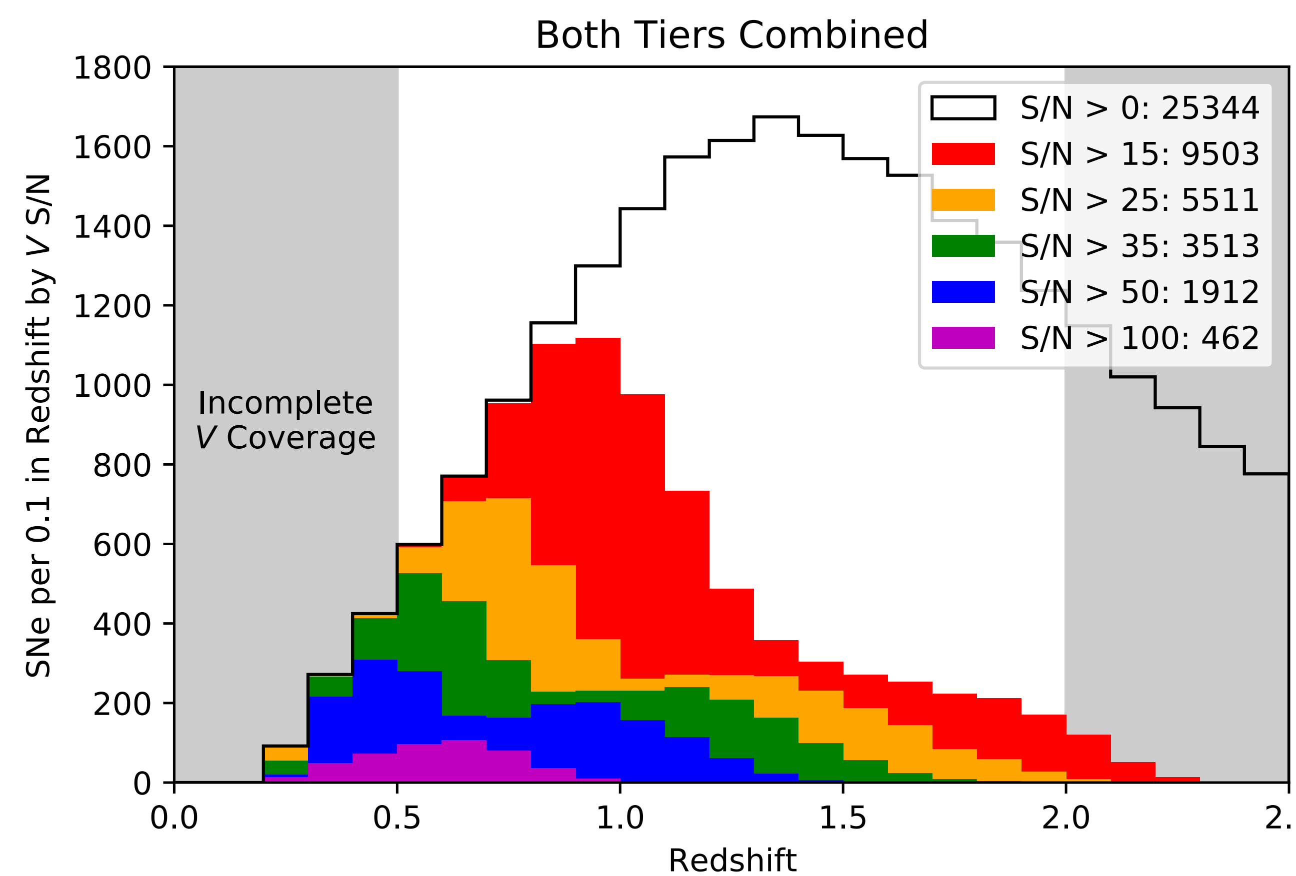
- A time-series analysis is key to extracting the smallest measurement uncertainties.
- This poses a problem for many current SN codes, which assume one spectrum (more time-series training data would also be useful here).

SN Ia Yields (100% prism)

2D Host-Galaxy Subtraction



3D Host-Galaxy Subtraction



- Ignoring edge effects, scale these numbers down to the fraction of time the prism will have.
- 3D host-galaxy subtraction (Astraatmadja in prep. and Joshi in prep.) is important.
- Thousands of live-SN measurements!

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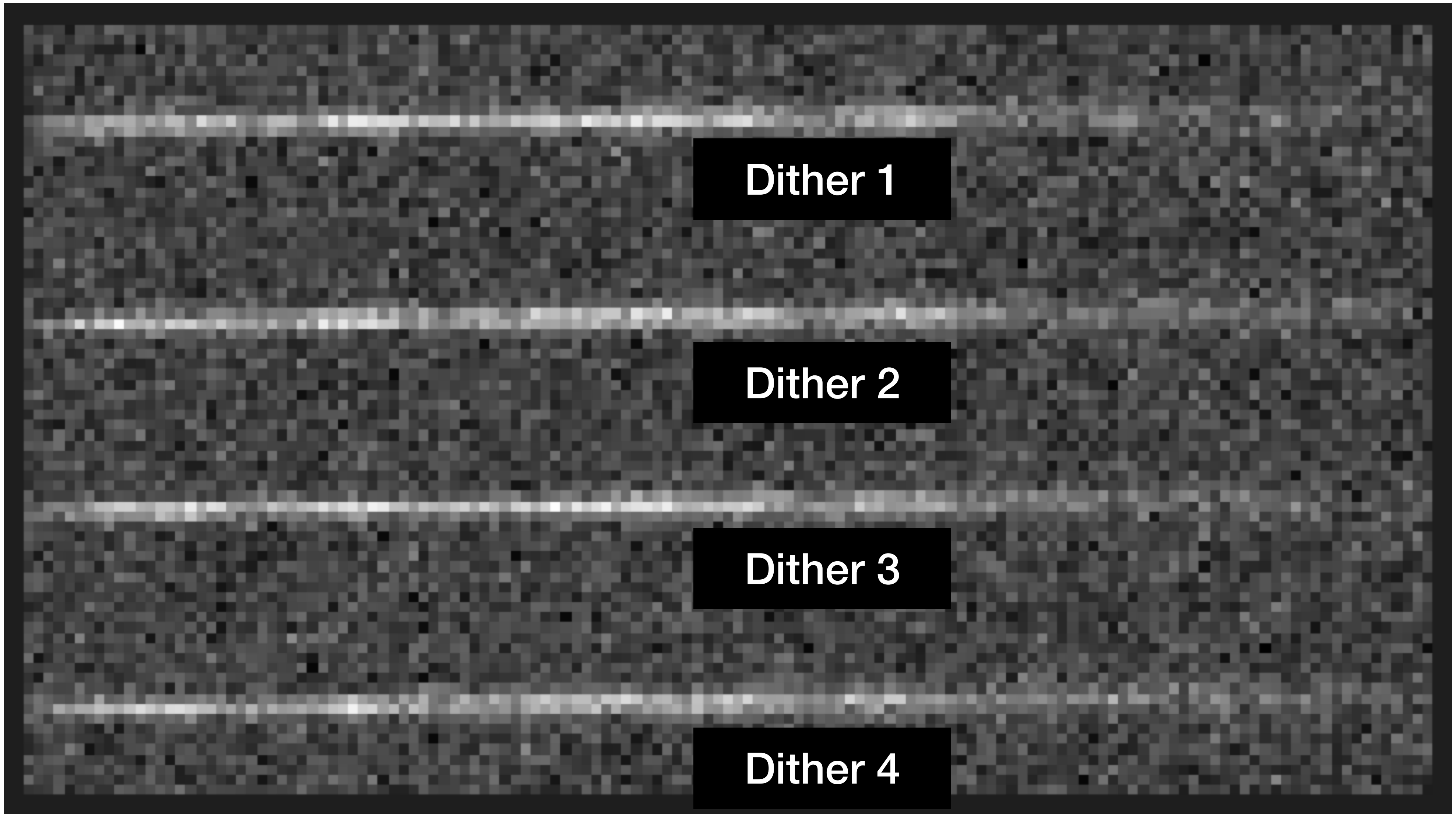
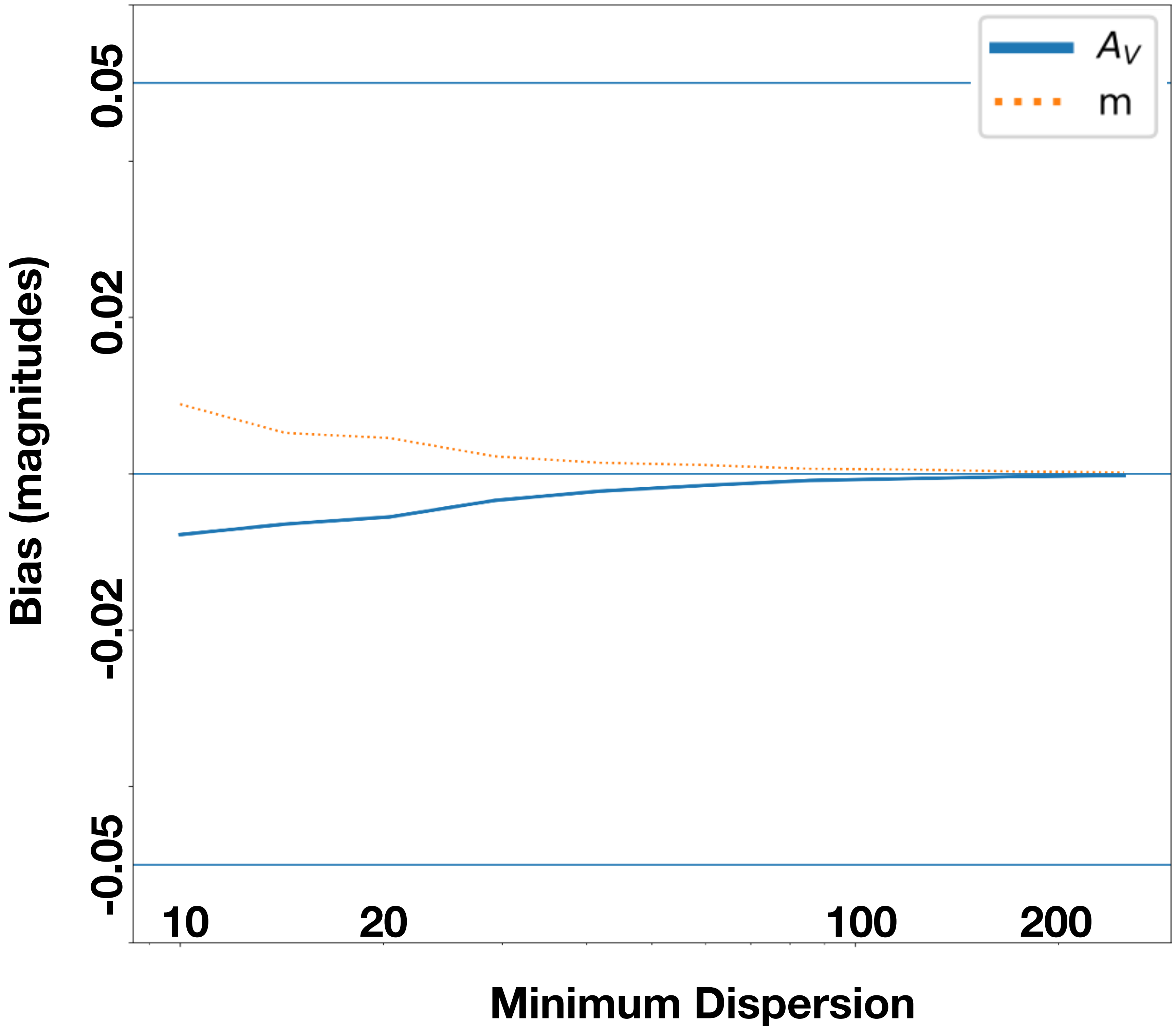
Prism Parameter Optimization



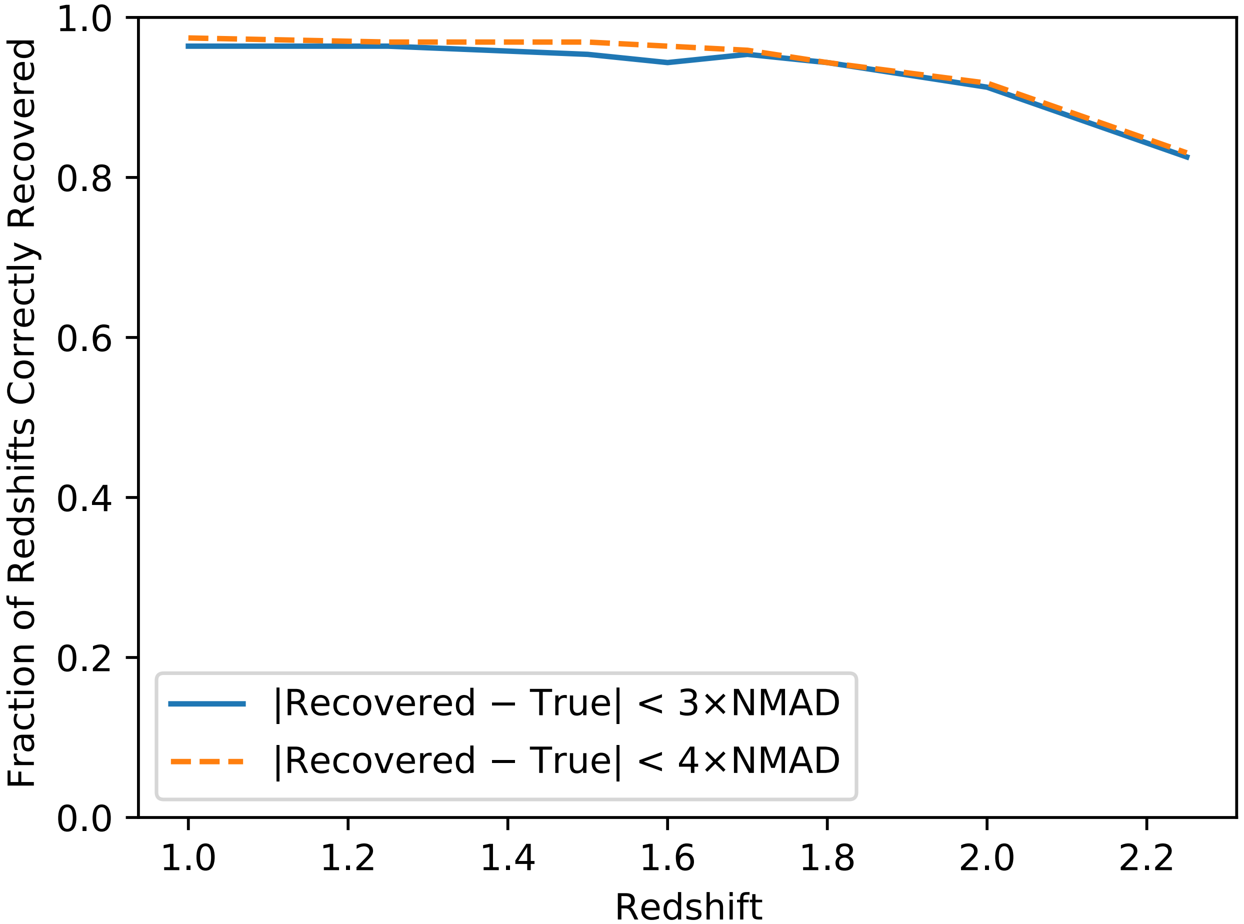
- The prism is background limited, so broader wavelength coverage trades greater spectral range for lower S/N.
- Higher spectral dispersion also trades against lower S/N, but results in lower systematic uncertainties from, e.g., imprecise line-spread function knowledge.
- We need a pixel-level forward-model code to investigate these trades. Exposure-time calculations are not good enough!

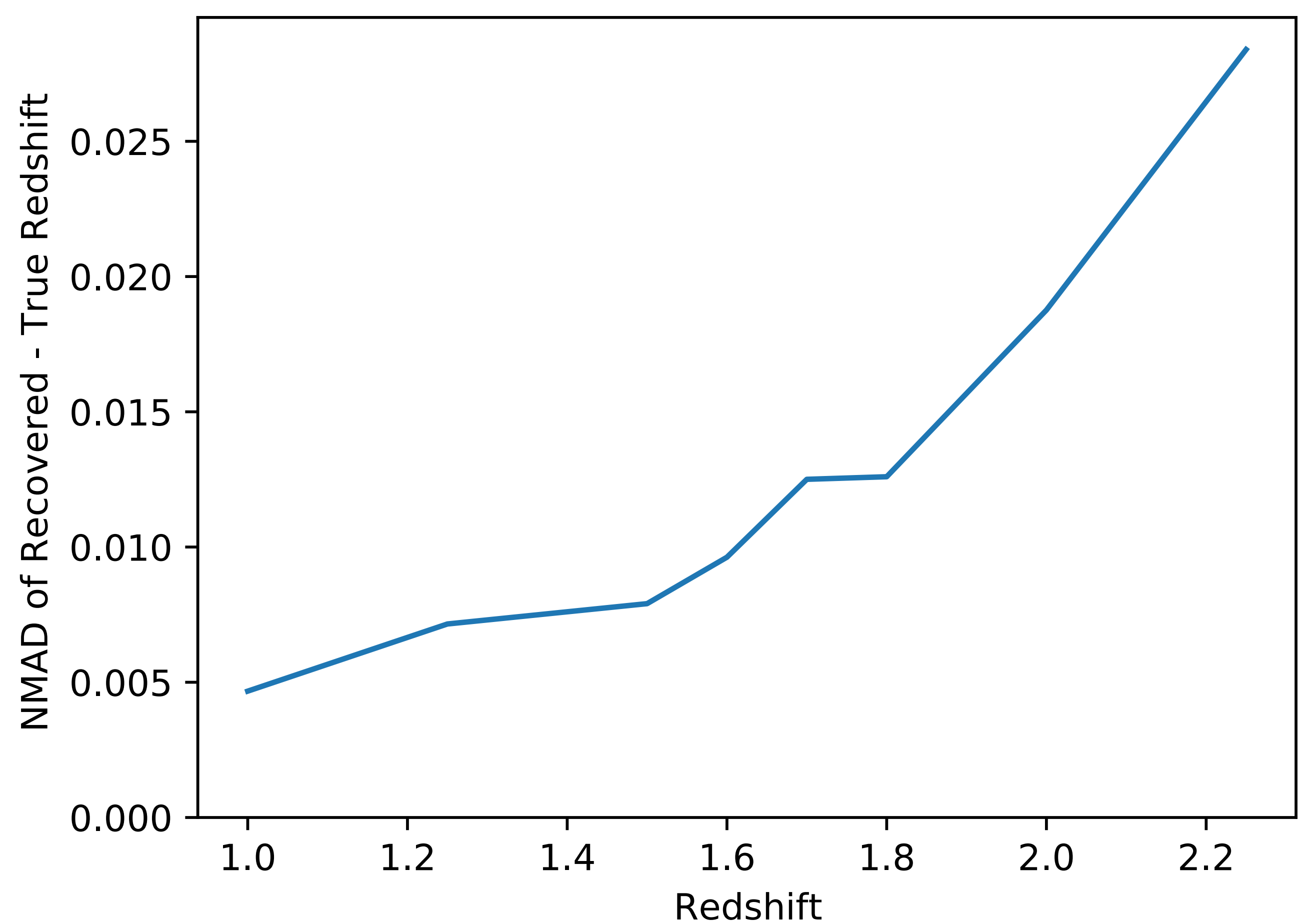
Prism Parameter Optimization



- Imposing an inaccurate line-spread function (by 5%) causes a bias (evaluated here with SNEMO15, Saunders+ 2018) which rapidly drops with dispersion.

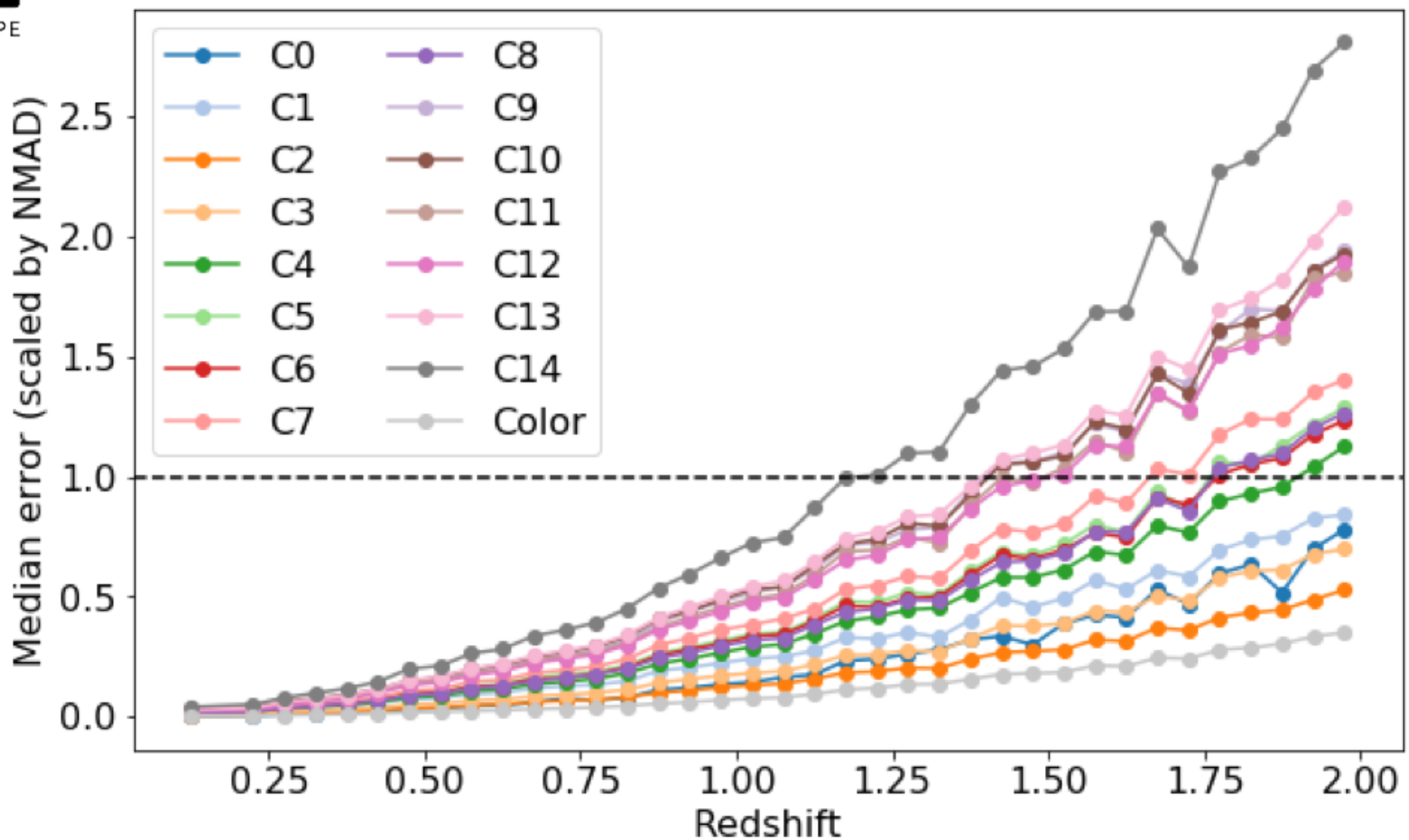
SN Redshifts





- Simulate by resampling real SN time series, fit with SALT2-Extended template.
- Redshift recovery above redshift 2!
- (The plateau at low redshift is due to a peculiar SN in the training set that is not well fit by SALT2.)

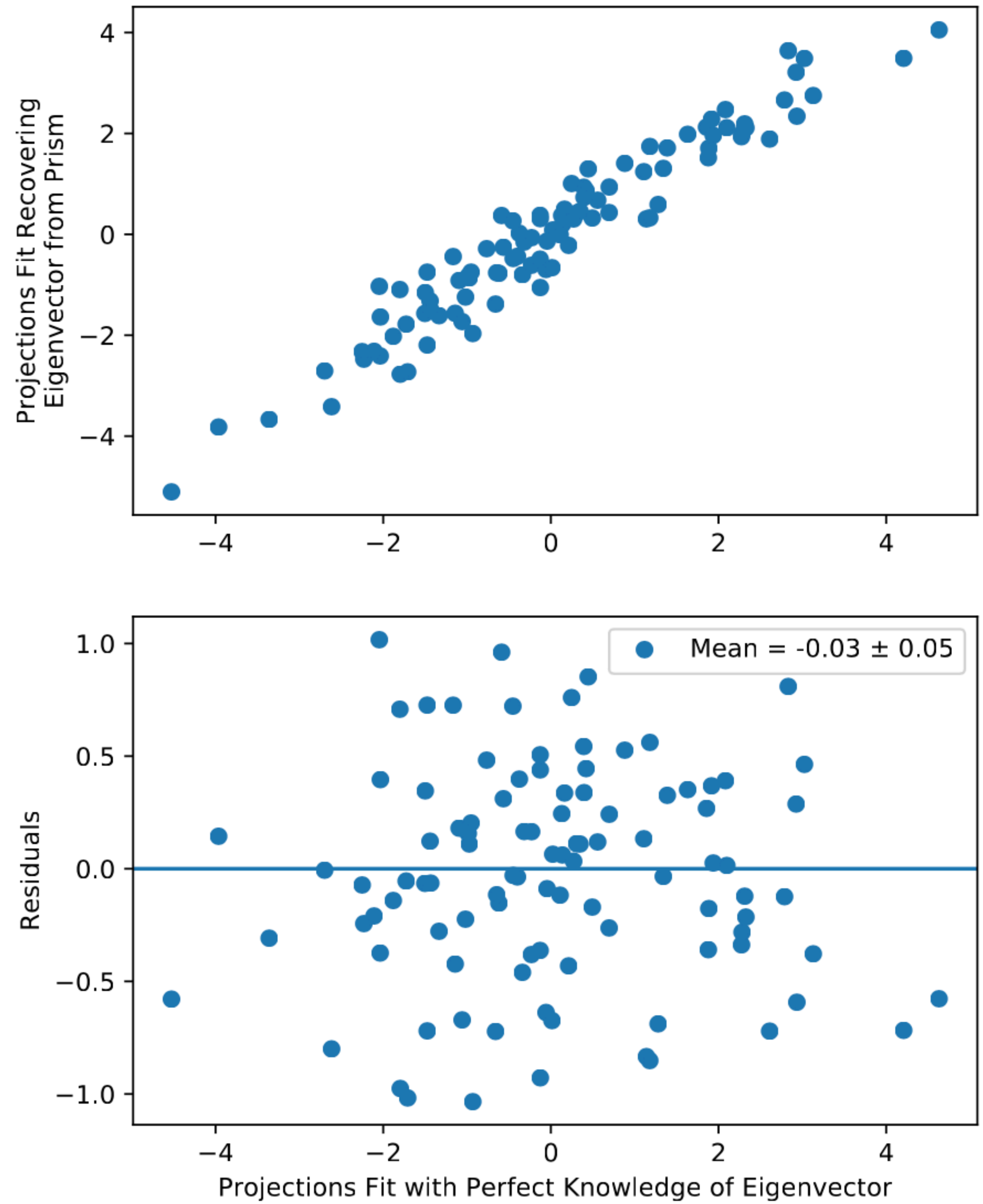
SN Subclassifcation



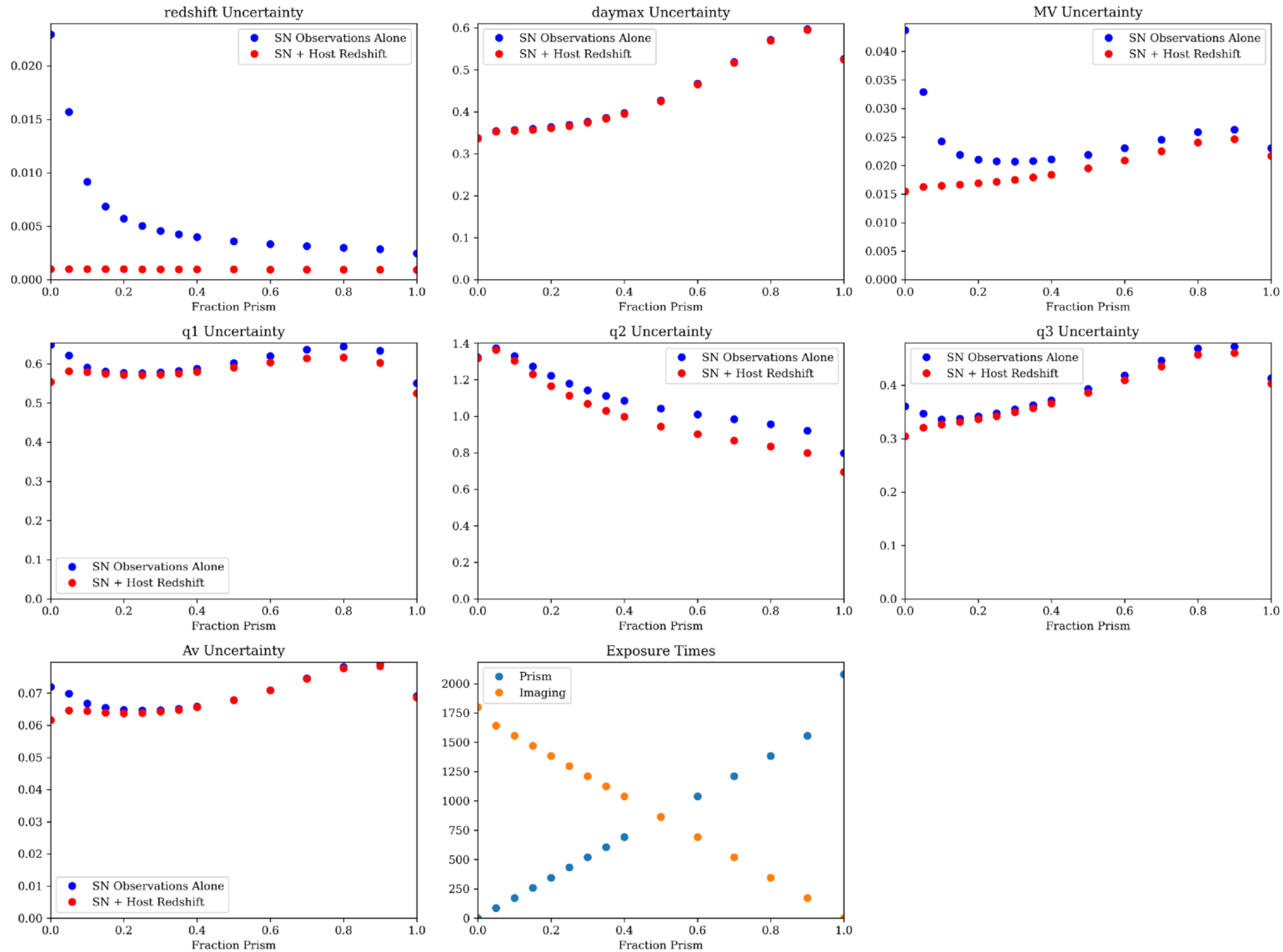
- The prism is capable of interesting subclassifcation measurements above redshift 1.

SED Model Training

- 100 $z \sim 1$ SNe observed with the prism using one-hour-per-visit epochs.
- Good recovery of unknown SNEMO15 (Saunders+ 2018) eigenvector to within a few percent of the population RMS (the statistical uncertainty is ~ 1/sqrt(100) = 0.1).



Prism/Imaging Trade at Fixed Total Time



- The details change with redshift (this is redshift 1.1), but using the prism ~ a fraction of the time generally lowers uncertainties (and never significantly raises them).

Survey Optimization

V S/N Target	HD RMS (Mag)	Wide Tier	Deep Tier	Statisical-Only FoM
25	0.15	5.2 deg^2, 581.95 s	1.3 3178.12	214
25	0.10	5.6 deg^2, 477.43 s	1.3 3178.12	362
35	0.10	4.8 deg^2, 666.70 s	0.7 6011.60	275
35	0.075	5.4 deg^2, 519.80 s	0.7 6011.60	381

- Here, all four surveys have been optimized assuming 25% prism time.
- The optimal prism survey is not very sensitive to assumptions!
- Statistical-only FoMs of 200—400 are possible using just prism-observed SNe!

Conclusions

- The prism is useful for obtaining SN redshifts, SN classifications, and SN subclassifications. The optimal tiers and exposure times for doing this do not vary much with assumptions!
- SNe observed in the prism provide a reasonably high FoM, 200—400 statistical, even without SNe observed in only imaging.
- The prism data allows one to find an “unknown unknown” in the spectral energy distributions of high redshift SNe.
- Possibly the prism should have ~ a fraction of the total time, but this needs better optimization using SED models with wide rest-frame wavelength coverage.
- Prism SN yields (above a given S/N cut) are 50%—100% higher if 3D host subtraction can be used.