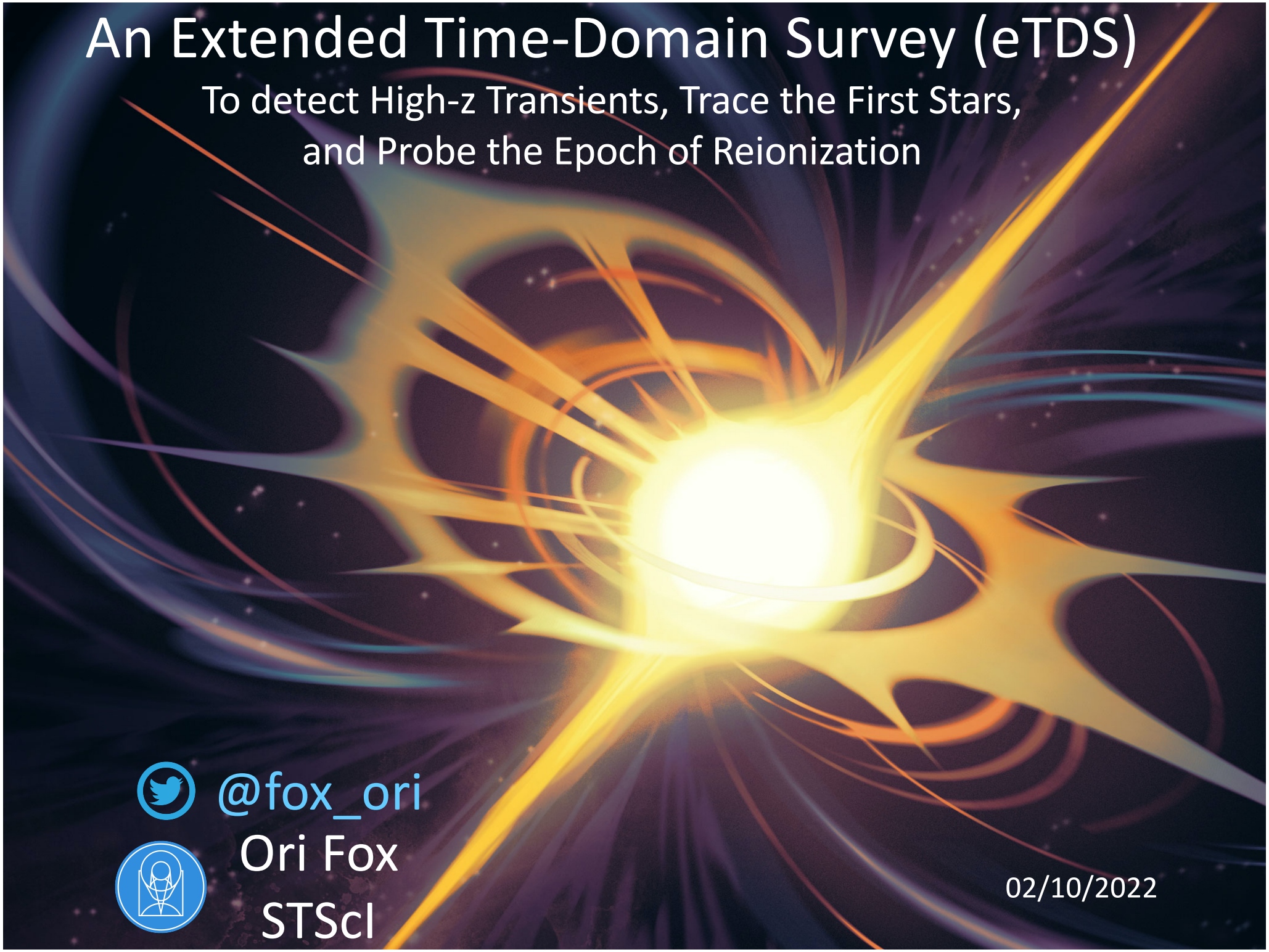
An Extended Time-Domain Survey (eTDS)

To detect High-z Transients, Trace the First Stars, and Probe the Epoch of Reionization



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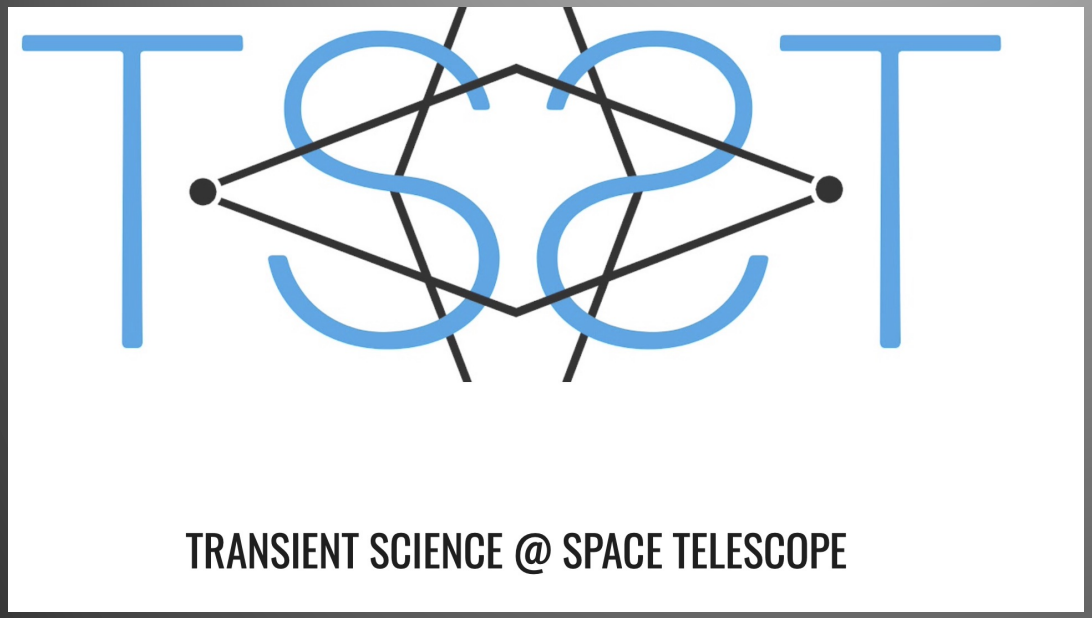
Ori Fox

STScI

02/10/2022

It Takes A Village



- https://sites.google.com/view/stsci-transients/home

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Previous Proposals and White Papers

Discovering Supernovae at Epoch of Reionization with *Nancy Grace Roman Space Telescope*

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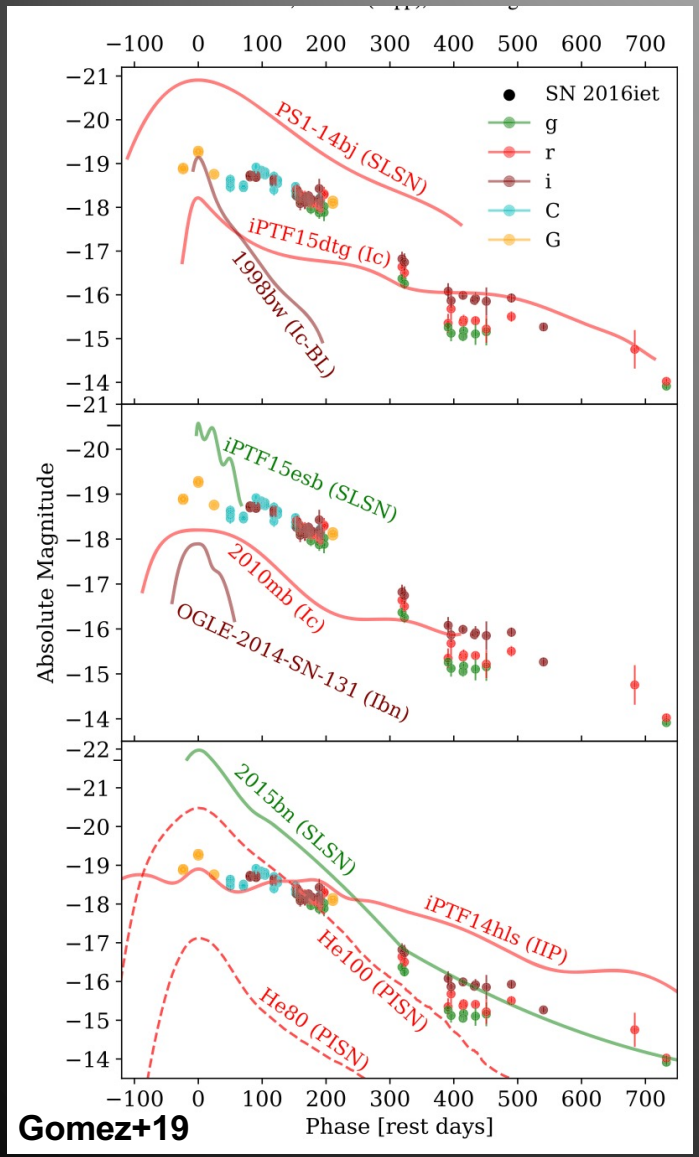
Survey Characteristics

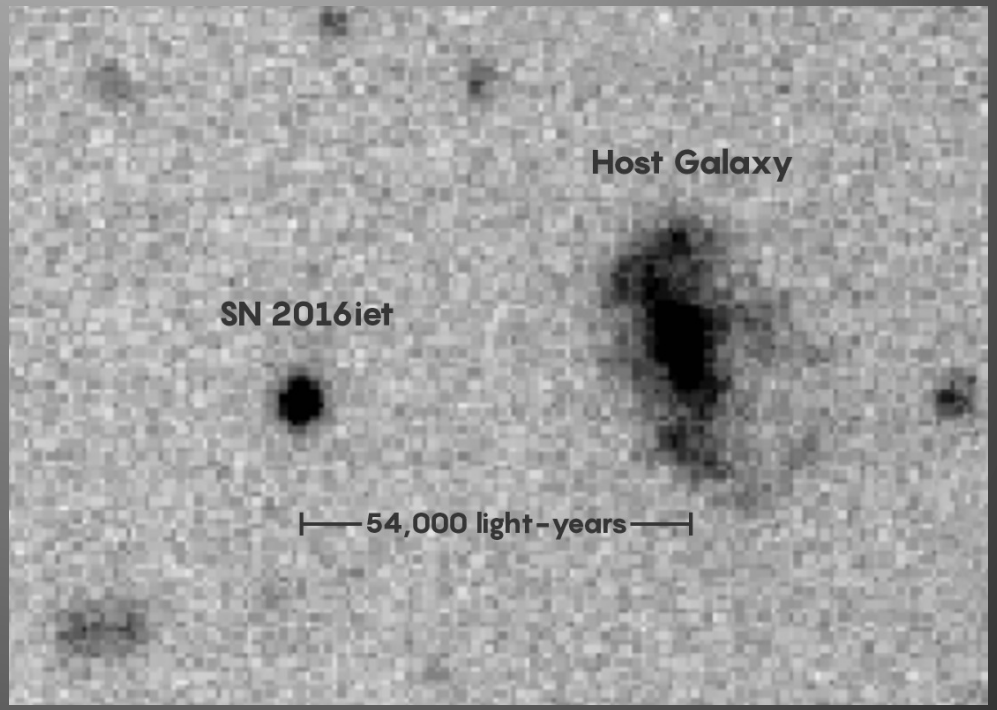
Table 1: Characteristics of Various Space Time-Domain Surveys[a]

Name	Near-IR Sensitivity[b,c] (mag)	SN z_{max} (M>-21) (z)	Area (deg^2)	Timescale (yr)
HLTDS	F158=27.5, F184=27.7	5.3	5	2
eTDS	F158=28.7, F213=26.6	8.5	5	> 4
COSMOS-Webb	F444W=27.7, F277W=28.1 F150W=27.6, F115W=27.4 F770W=23.9	5.5	0.6 0.6 0.2	1 1 1
HST-COSMOS[d]	F814W=26.2	–	1.7	2
CANDELS	F160W=25.4, F125W=25.8	2.3	0.25	3
GOODS[d]	F850lp=25.4	–	0.08	4

[a] All numbers are rough approximations since many numbers are case-dependent.
[b] 5σ detection in difference imaging.
[c] In roughly a month of stacked images, which we take to correspond to a single epoch.
[d] These surveys had no sensitivity in the near-IR, but found no transients at $z \gtrsim 2$.

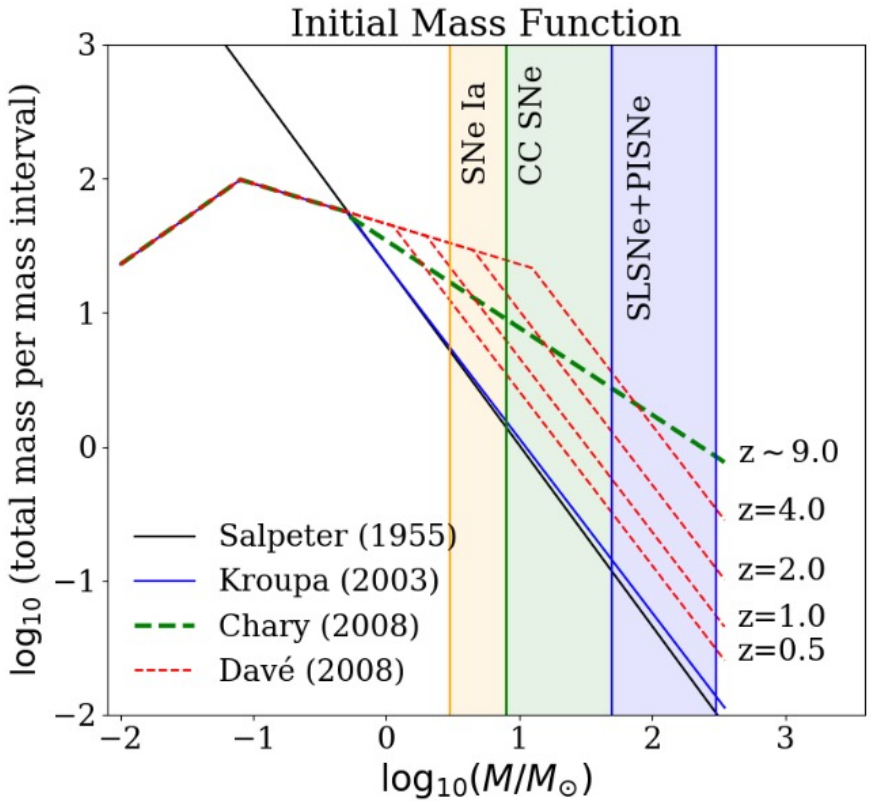
PISN 2016iet

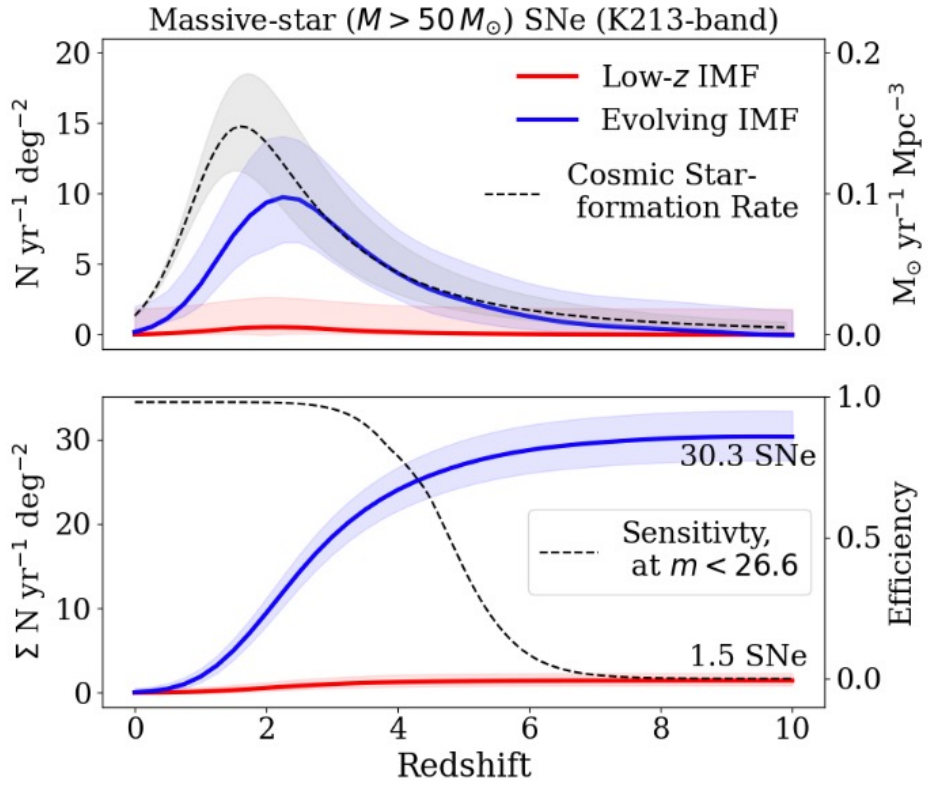




- Double Peak Light Curve
- Decline ~5 mag in ~650 days
- Intermediate-width emission lines
- Ca-rich transient spectrum
- Large offset from low-metallicity galaxy
- Inferred mass of progenitor (CO Core) ~55-120 M_sol
- ZAMS 12—260 M_solar

High-Mass IMF and EoR



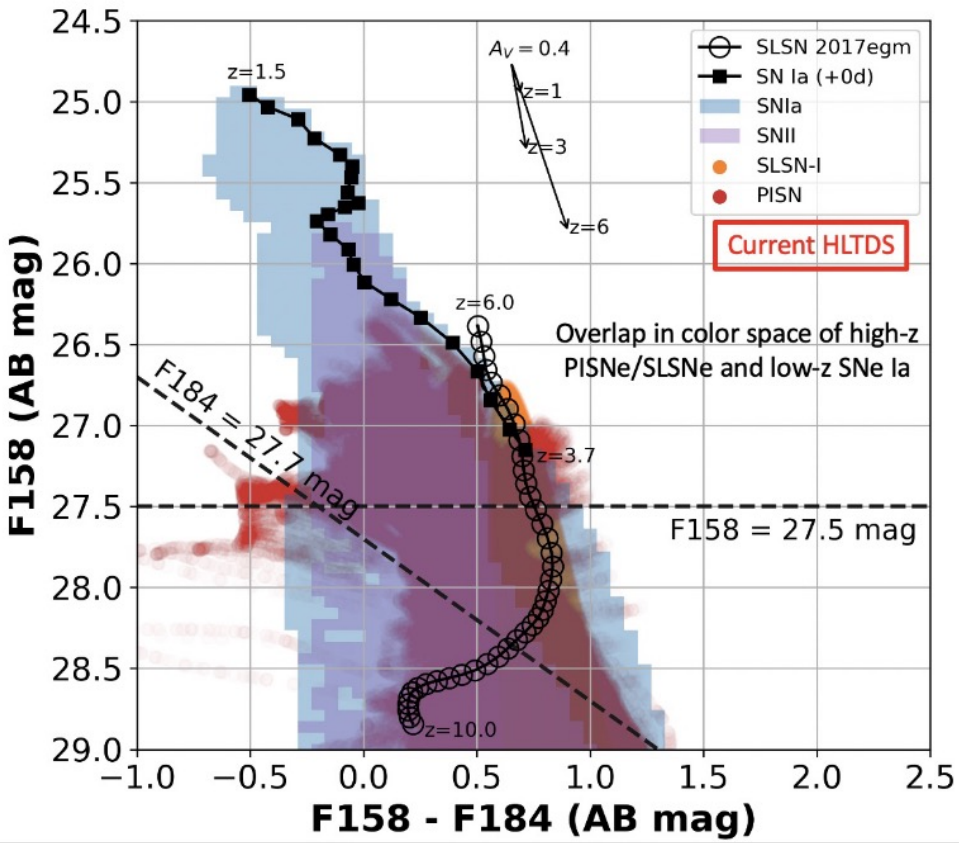


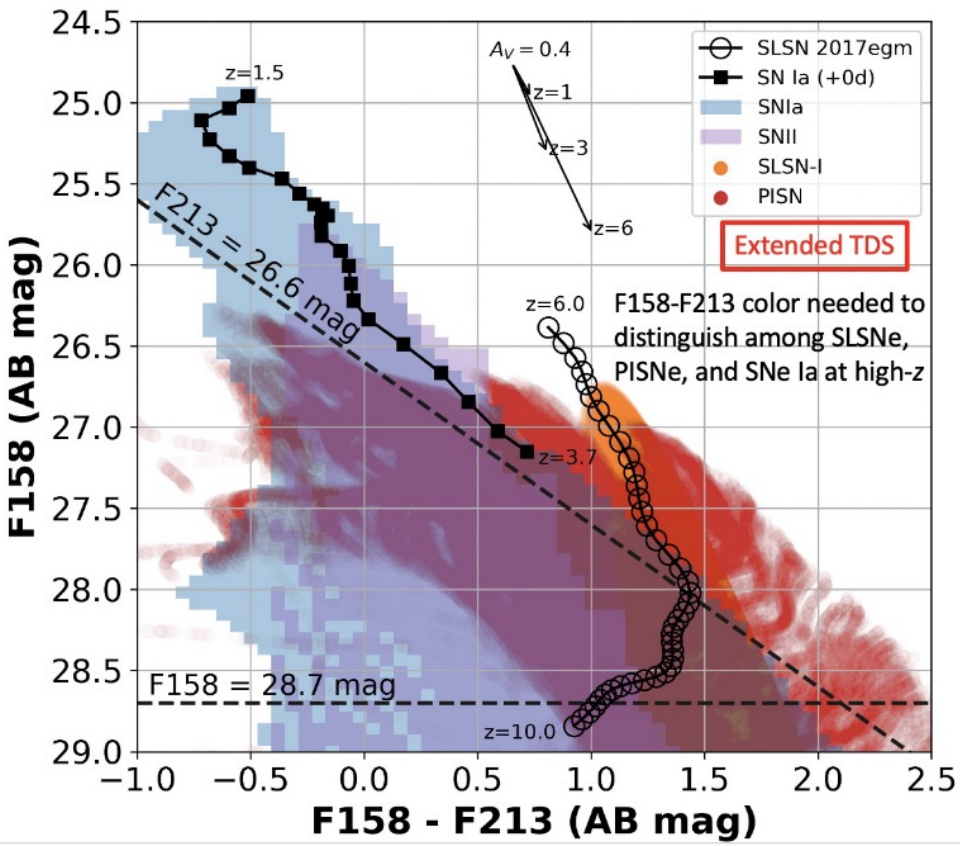
Can resolve open questions to understanding the impact of massive stars on reionization, the buildup of galaxy masses, and other aspects of both stellar/galaxy evolution.

Ancillary Science

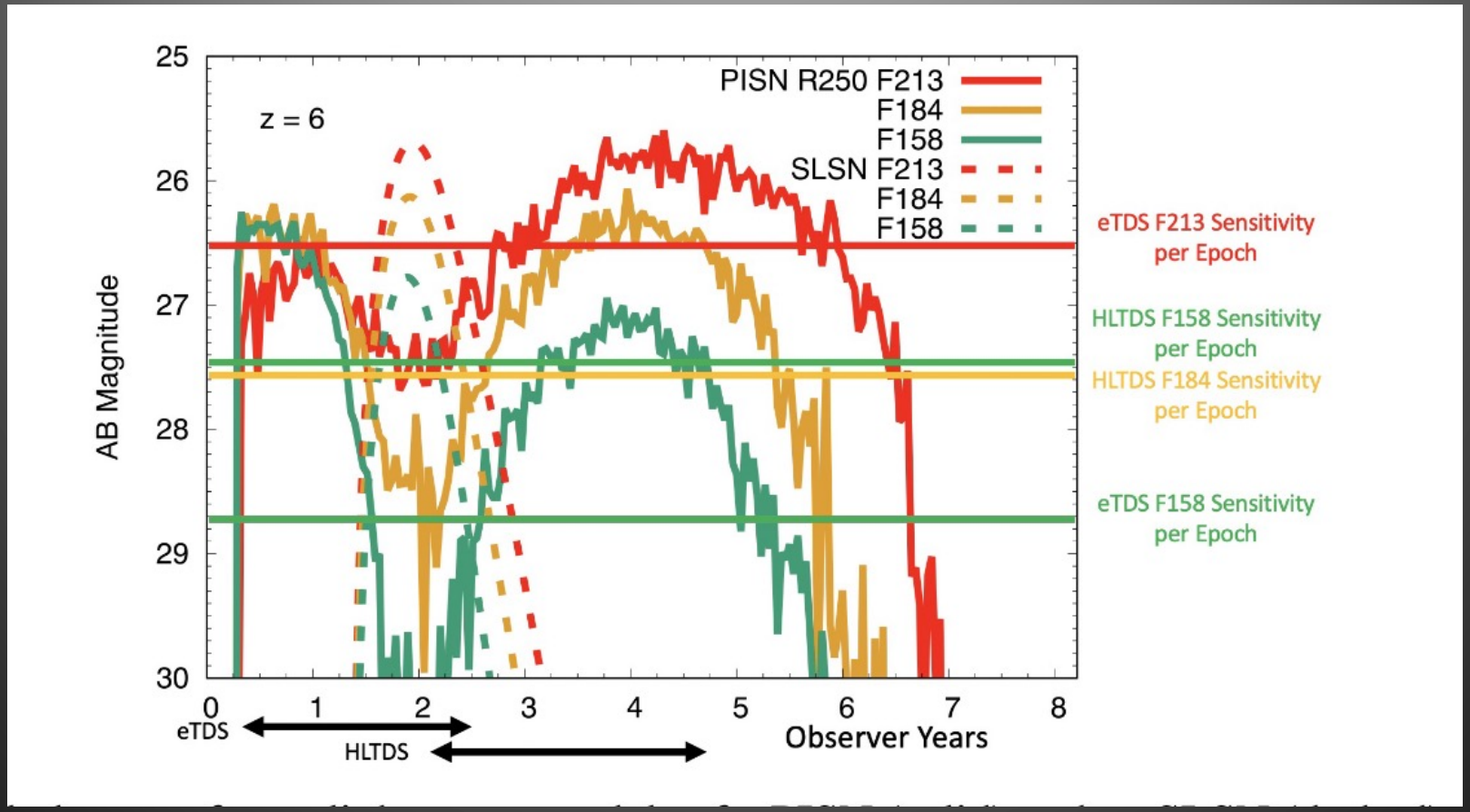
- Extending low-*z* time-domain science out to high *z*, where time-dilation effects dominate
- AGN reverberation mapping to measure black hole masses at $z \approx 6$ (Homayouni+20)
- Large SN sample extend CCSN rate studies beyond anything currently possible, including possibly the highest-*z* Ia ever discovered (Rodney+14)
- Dust obscured and/or nuclear SNe (Kool+18, Jencson+19, Fox+21)
- IR-bright transients (Kasliwal+17)
- Long-term monitoring of long-duration transients (i.e., SN 2005ip; Fox+20)
- Ultra-deep ~5 deg^2 field

Filter Choice





Cadence and Time Frame



Need for Early Definition

- Roman only a guaranteed 5 year mission.
- Only way to obtain a full light curve of high-z PISN and confirm it fades is to begin this survey in its first year.
- eTDS will serve as an excellent foundation for the planned HLTDS: deep F158 template, F213 important for photo-z's of host galaxies, filter out "contaminating" transients (AGN and variable stars).

Rates

Table 2: Simulated Number of Transients for eTDS[a]

model	z					
	(<6)	(6-7)	(7-8)	(8-9)	(9-10)	(>10)
CCSN	316355[b]	6766	3713	2075	1299	–
PISN	–[c]	11.2	7.0	3.1	2.0	3.0
SLSN	14.3	2.26	1.15	0.55	0.033	0.003

[a] (F158, F213) = (28.7, 26.6), 5 deg^2, 0.5 yr cadence for 2 years

[b] These rates are based on extrapolations of low-z observations. Actual numbers will vary based on evolving IMF and metallicities, as well as on final survey design.

[c] Although the extrapolated rates would seem to suggest a large number of PISNe at $z < 6$, we know this not to be true from current observations. These numbers do not account for metallicity, which limits the likelihood of any PISNe at low z. We therefore do not include any number here.

Survey Characteristics

- Survey characteristics driven by desired sensitivity to and rates of SLSNe and PISNe at high-*z* (Moriya+21)
- 18 pointings; 5 deg^2; 4 epochs spaced evenly over ~2 years (every ~6 months)
- ~2.5 hours of integration per filter, totaling ~90 hours/epoch, or 360 hours total
- Individual exposures would consist of shorter integrations spaced over a month to optimize sampling of low-*z*/faster-evolving transients
- Choice of field flexible, but recommend HLTDS to optimize existing survey

Conclusion

- Roman's wide FOV and near-IR sensitivity provide the only route for probing the IMF and stellar populations at high-*z* by finding intrinsically rare explosions.
- The eTDS is NOT just to extend low-*z* studies, but to probe Pop III stars and the Epoch of Reionization, including PISNe and SLSNe.
- A statistically significant sample of these massive-star explosions (>50 M_sol) uniquely traces the evolution of the high-mass end of the IMF.
- HLTDS provides powerful capability to detect transients, but eTDS provides the necessary time (Cycles 1 & 2) and wavelength (K-band) to more definitively color select high-z events.
- Unparalleled transient database in terms of combined SN redshift, reach, area, and timescale.
- eTDS will provide exceptionally deep and wide imaging compared to COSMOS-Webb in depth (F158 ≈ 29.5/F213 ≈ 27.5 mag), but 8x larger in area!
- Total cost ~360 hours, a small fraction of HLTDS.