The WFIRST SN Survey: What the Community Needs to Know

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SNe la 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:** $D = f(z, \Omega, w(z), etc)$

SNe la are NOT Standard Candles!



Calibrating the Nearly Standard Candle



Time

Systematics Dominate SN Cosmology

Source	$\mathrm{d}w$
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

Seeing Through The Dirt in the NIR



Neaptifrared

Smaller Extinction Errors in IR



Mandel et al., 2011

Theory Points to the IR for Cosmology



Kasen 2006

Smaller Light Curve Corrections in IR



Mandel et al., 2011

Smaller Total Errors in IR



IR is Hard! (From the Ground)

Rest frame IR measurements of z~1 supernovae are not possible from the ground

Go as far into the IR as technically feasible!

Sky is very bright in NIR: >100x brighter than in space Sky is not transparent in NIR: absorption due to water is very strong and extremely variable



WFIRST

ExopWayelengt	$h_{Z}(\mu_{n}) = 0.760-0.9$	977 20927-1 1 S 0	.192 1.131/ <u>a</u> 1.454 1.3	880-1 ₆ 7742 days 0914 2 0 ays	$4 - \frac{7}{7} + \frac{12}{12} + \frac{100}{12} + \frac{100}{13} + 1$
Apschaagpric	Y. J. H. F184	2 60is m (C	$1.28/1 \pm 1200^{2}$, J = 26.9	IFU (3.00 x	3.15 arcs/gc)
Capability	, , ,	1.35 – 1.95 μ	.ml, R2655,0 -800 = 26.2	0.6 – 2.0 μ	m, R = ~100
HLS	1.35 – 1.95 μm	2660 line	S 0:5x100harg/s/oristic	S	n/a
Survey	Bandpass	Area (deg ²)	Depth	Duration	Cadence
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Microlensingle	Y, J	27.44	Y = 27.1, J = 27.5	(in a 2-yr interval)	Z: 12 hrs
HLS Invægingm	Ү, Ј, Ј Ӊ Ҥ 184	2096	У <i>=</i> 26 <i>б</i> , н = 26.9		n/a
Deep	J, H	5.04	Н <u></u>		
HLS IFU Spec 71 of postures with S/N=29/pix, 1 near 5/eak ¹⁶ /with 9/s/N=10/pix, 1 post-SN reference with 9/s/N=6/pix Spectroscopy Parallel imaging during deep tige 1/ 1/25 per troscopy: Z. Y. J. H ~29.5. F184 ~29.0					
SN Survey WFIRST-2.4: What Every Astronomer Should Know arXiv:1305.5425 ^{days} Wide Y, J 21,44 years of the 25 year or an Signa 2-yr interval)					
Medium	J, H Z087	8.96¥10	6 J = 27.6j 1 ⊉⊊ 28.1	H158 F184	W149
2 Components: Imaging and Spectroscopy Imaging depth in 27.15 27.15 27.15 27.14 27.12 27.12 26.15 27.67 1000 Seconds (mas)					
3 f Triers of Imaging during deep tier IFU spectroscopy: Z, Y, J, H ~29.5, F184 ~29.0 180 (secs)					
	IFU Spe	1.4 years N=10 per R= Ctra Y10	s of the 5 year prime min ~ 600 element at AB=20 ~ 129 t _{exp} for $\sigma_{read} = \sigma_{sky}$	ssion 4 (1.45 μm) or 20.5 H158 F184 : 170 secs	(1.75 μm) W149
lfoggiegtdentho ggg0 seconds	j 0 0 27.15 (т _{АВ})	\$7N1=	³ 10 per R~ ² 1700 ⁴ element	at7AB=24.2 (1.39um)	27.67
Stevendesettle (secs)	time 200	chip gap ster	b: 13 sec, full¤field step: Coronagraph Capabilit	6 1%e c, 10 deg ste p: es	178 sec 90
Grism depth ineadition to files the per fination of the second of the se					
860d of view Appular region around star stithfor 240 01 Great 170 666 and outer redii					

	$h_{Z}(\mu_{m}) = 0.760-0.9$	977 20,927-1 1 S 0	.192 1.131 <u>-</u> 1.454 1.3	80-167742 1 683-2.0	4^{-7}
Algertrageric	Y. J. H. F184	2 60is m (0	$1.28/1 \pm 1000$	IFU (3.00 x	3.15 arqşeac)
Capability	, , ,	1.35 – 1.95 μ	.ml, R2655,0 -889 = 26.2	0.6 – 2.0 μ	m, R = ~100
HLS	1.35 – 1.95 μm	2000line	S 0:5x102harg/s/eristic	S	n/a
Survey	Bandpass	Area (deg ²)	Depth	Duration	Cadence
Exb Slanvety	Z, W	2.81	n/a	60x57 geetarys	W5 115a yrsin
Microlensimigle	Y, J	27.44	Y = 27.1, J = 27.5	(in a 2-yr interval)	Z: 12 hrs
HLS Invægingm	Y, J, J , J,F 184	<u>2096</u>	Y <i>=</i> 26.6, H = 28.9		n/a
Deep	J, H	5.04	Η ∃ -260.3,3, F 1+β4 2 92.6.2		
HLS IFU Spec 71 apposites with S/N=29/pix, 1 near 5/eak 16/01/01/01/01/01/01/01/01/01/01/01/01/01/					
SN Survey WFIRST-2.4: What Every Astronomer Should Know arXiv:1305.5425 ^{days} Wide Y, J 21.44 years of the 25 year Brand mission 2-yr interval)					
But Imaging Depths Did NOT include Overheads W149					
Imaging depth in 27.15 27.13 27.14 27.12 27.12 26.15 27.67					
All Surveys (Shogle Epochie and Stacked), Will 564 ~29.90					
Shallower with Currents Strategy ne mission Grism depth in 1000 S/N=10 per B=~600 element at AB=20.4 (1.45 µm) or 20.5 (1.75 µm)					
Sec	Z087	Y10	$6 J129 \\ t_{even} for \sigma_{read} = \sigma_{skv}$	H158 F184	W149
Lego seconds	Me Survey	, this is	Stop 7 5 2 60 Define To	atal 2Time 15	27.67
Uninkertigation here Will be a Wide Survey 618ec, 10 deg step: 178 sec 90					
Grism depth ive apply addition to \$1/205-1/2000 prover a solution in the rest of the stand of th					
Stad of view Appular region around star with for 2 to 27 meets add outer radii					

WFIRST SDT SN Fields



Figure 8-55: The footprint of served during the WFIRST-AFTA DRM. The red area indicates the high-latitude survey.

>30 deg from Galactic Plane

140

>55 deg from Ecliptic

Far Enough North for Ground-based Telescopes

WFIRST SDT SN Survey



Requires Real-time Decisions

Uses Imager to Discover. IFU to get Photometry Assumes **Systematic Error:**

 $\sigma_{\rm sys} = 0.01(1+z)/1.8 \text{ mag},$

Figure 2-4: An example WFIRST-AFTA observing sequence for discovering and studying SNe Ia across the range of

WFIRST SDT SN Survey



equence for discovering and studying SNe Ia across the range of observing plan that meets WFIRST-AFTA science objectives. The

Requires Real-time Decisions

Uses Imager to Discover, IFU to get Photometry

Assumes Systematic Error:

 $\sigma_{\rm sys} = 0.01(1+z)/1.8 \text{ mag},$

Exoplanetelengt	$h_{Z}(\mu m) = 0.760-0.9$	977 20,927-1 1 S 0	.192 1.131 _a 1.454 1.3	80-167742 1 683-2.0	$100 \sqrt{2.927} = 2.000$	
Algertrageric	Y. J. H. F184	2 60is m (0	1.2811 ± 1000^{2} , J = 26.9	IFU (3.00 x	3.15 arcsec)	
Capability	- , - , - ,	1.35 – 1.95 μ	nh, R2655,0 -800 = 26.2	0.6 – 2.0 μ	m, R = ~100	
HLS	1.35 – 1.95 μm	2660 line	S0:5x100harg/s/eristic	S	n/a	
Survey	Bandpass	Area (deg ²)	Depth	Duration	Cadence	
ExbSlanve ty	Z, W	2.81	n/a	60x572eeerss	W5 105 ysin	
Microlensimigle	Y, J	27.44	Y = 27.1, J = 27.5	(in a 2-yr interval)	Z: 12 hrs	
HLS Invægingm	Y, J, J , J,F 184	<u>2096</u>	Y <i>=2</i> ¢ <i>d</i> ,,⊌ = 28.9		n/a	
Deep	J, H	5.04	Н ј 26 3,3 , 184 2 926.2			
HLS IFU Spec Spectroscopy	HLS IFU Spec 71 35 postures with S/N 29/Pix, 1 near 5 eak with 95/N=10/pix, 1 post-SN reference with 97/N=6/pix Spectroscopy Parallel imaging during deep tige 17:05 per troscopy; Z. Y. J. H ~29.5. F184 ~29.0					
SN Survey WFIRST-2.4: What Every Astronomer Should Know arXiv:1305.5425 ^{days} Wide Y, J 21.44vears of the 25 vear brands mission 2-yr interval)						
Medium	J, H Z087	8.96 Y10	6 J = 27.6j 1 ⊉9 28.1	H158 F184	W149	
5- Gradence is Overkill for Deep Survey 6.15 27.67 1000 Seconds (map) seconds (map)						
Parallel imaging during deep tier IFU spectroscopy: Z, Y, J, H ~29.5, F184 ~29.0 180 180 180 240 90						
Will Likely Make Caderoberhongers						
Grism depth in sec	1000 Z087	/N=10 per R= /10	s of the 5 year prime min ~ 600 element at AB=20 $\int 129$ t_{exp} for $\sigma_{read} = \sigma_{sky}$	ssion 4 (1.45 μm) or 20.5 H158 F184 : 170 secs	(1.75 μm) W149	
lford giept deptho 1990 seconds	ј0 0 27.15 (т _{АВ})	\$7∩1	310 per R~217004element	at7AB=24.2 (1.39um)	27.67	
Stevendesettle	stime 200	chip gap ster	b: 13 sec, full¤field step:	6 1 %e c, 10 deg ste p: ies	178 sec 90	
Grism depth webplot addition to \$1/205-1/2000 Reparter about the rate of the r						
Bend of view Annular region around stor stitle for one of an it 170 eached outer region						

Full, Public Simulations Complete



Wednesday, November 11. 2015

Optimizing the WFIRST Type Ia Supernova Survey

The Wide Field InfraRed Survey Telescope (WFIRST), which is expected to launch in about a decade, will conduct a supernova (SN) program to discover and measure distances to highredshift SNe. Using open-source tools, including ones we have built and released, we have produced the first fully simulated realization of the survey. We made dramatically different strategic decisions and examined how the survey and its cosmological utility change with those choices. For these different strategies, we estimate how well the WFIRST SN survey can constrain the nature of dark energy.

This website presents the results of these strategies and makes suggestions for optimizing the survey.

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WFIRST SDT SN Survey



3 Tiered Imaging Survey (27, 9, 5 sq degrees)

Discover 24k SNe Ia and 14k CC SNe to z = 3

Simulated Background Galaxy Flux to Match CANDELS

Will Need to Re-run Simualtions and Re-evaluate Assumptions

Figure 2-4: An example WFIRST-AFTA observing sequence for discovering and studying SNe Ia across the range of

	$h_{Z}(\mu_{N}n) = 0.760-0.9$	977 20,927-1	.192 1.131 _a 1.454 1.3	$80 - 1_6 7_7 \frac{4}{72} days - 2.0$	4°
apectrosoppic	Y .I H F184	2 Gnis m (0	1.281 ± 1000^{2}	IFU (3.00 x	$3.15 \operatorname{arcsec}$
Capability	1, 0, 11, 1 101	1.35 – 1.95 μ	$r_{\rm H}$ = 2655, $r_{\rm 800}$ = 26.2	0.6 – 2.0 μ	m, R = ~100
HLS	1.35 – 1.95 μm	E666 line	S 0:5x100harg/s/aristic	S	n/a
Survey	Bandpass	Area (deg ²)	Depth	Duration	Cadence
Exb Slarvety	Z, W	2.81	n/a	60x57gedargs	W5 115 yrsin
Microlensimigle	Y, J	27.44	Y = 27.1, J = 27.5	(in a 2-yr interval)	Z: 12 hrs
HLS Invagingm	Y, J, J , J,F 184	2096	Y <i>=</i> 26∂, H = 28.9		n/a
Deep	J, H	5.04	Н <u></u>		
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SN Survey WFIRST-2.4: What Every Astronomer Should Know arXiv:1305.5425 ^{days} Wide Y, J 21,44years of the 25 year Brand mission 2-yr interval)					
IFU SYN Is Really per Resolution Element (not pixel)?					
maging depth in J, H 27,15 5.04, 7,13 J = 29.3, H = 29.4 Torease uniced demed SN1 har at kpeak whith NO Galaxy S/N=6/pix					
Background of ANY Template Errors ⁰ (secs)					
Grism depth in	ISN FIEX	/N=10 per P= With YTQ	s of the 5 year prime mi ~600 element at AB=20 MEANS I	ssion 4 (145 um) er 20.5 F OWER S7N	(1.75 μm) ₩149
Imagieptdepth	j o o 27.15	<u>8</u> 7∩1	$\frac{2}{3}$ 10 per R $\frac{2}{700}$ delement	at7AB=24.2 (1.39 futts)	27.67
Elow S/		te Mea chip gap ster	ins Lower S b: 13 sec, fullPfield step:	/N 61 sec, 10 deg step:	178 sec 90
Gnanteleas SNd SED/Means 6 beginetrates Standard (145 Rundard 12 Blondik Zishum)					
Bead of view Appular region around stor stithforms and around store it.					

WFIRST SDT SN Survey Spectroscopy



Three Kinds of IFU **Exposures:** Typical S/N **3.5 (really 1.4)** Classification S/N = 6 (really 4.0) Deep S/N = 10 (really 6.5)

Figure 2-4: An example WFIRST-AFTA observing sequence for discovering and studying SNe Ia across the range of

WFIRST SDT SN Survey Selection



Figure 2-4: An example WFIRST-AFTA observing sequence for discovering and studying SNe Ia across the range of













WFIRST Cosmology



WFIRST Systematics



Hounsell et al., in prep.

WFIRST Cosmology



Hounsell et al., in prep.

Other WFIRST Strategies

- 1. SDT
- 2. SDT + Higher S/N Galaxy Template
- 3. SDT Imaging Only (IFU breaks or can't calibrate)
- 4. **IFU Survey for** z < 0.8
- 5. Imaging Only (using 4 bands)
- 6. Imaging + High S/N IFU/grism at peak
- 7. Imaging Only for z < 0.8
- 8. SDT + LSST

Other WFIRST Strategies



Hounsell et al., in prep.

Other WFIRST Strategies



Hounsell et al., in prep.

All Simulations Public

WFIRST Supernova Simulation

OBSERVING STRATEGIES | SOFTWARE TOOLS

DATABASE

THE TEAM

Wednesday, November 11. 2015

Optimizing the WFIRST Type Ia Supernova Survey

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What You Should Know about the WFIRST SN Survey

- 1. Take SDT Survey with Grain of Salt
- 2. All Images Shallower than Expected
- 3. Unlikely to Have Wide Survey
- 4. Will Try to Move SN Fields North
- 5. Cadence for Deep Survey Likely to Increase
- 6. All Spectra Lower S/N than Expected
- 7. Simulating Alternatives
- 8. All Simulations Public
- 9. More Input Wanted!