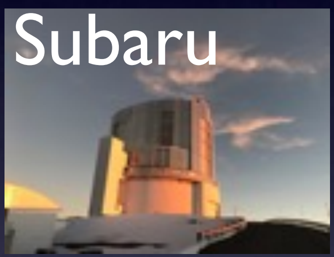
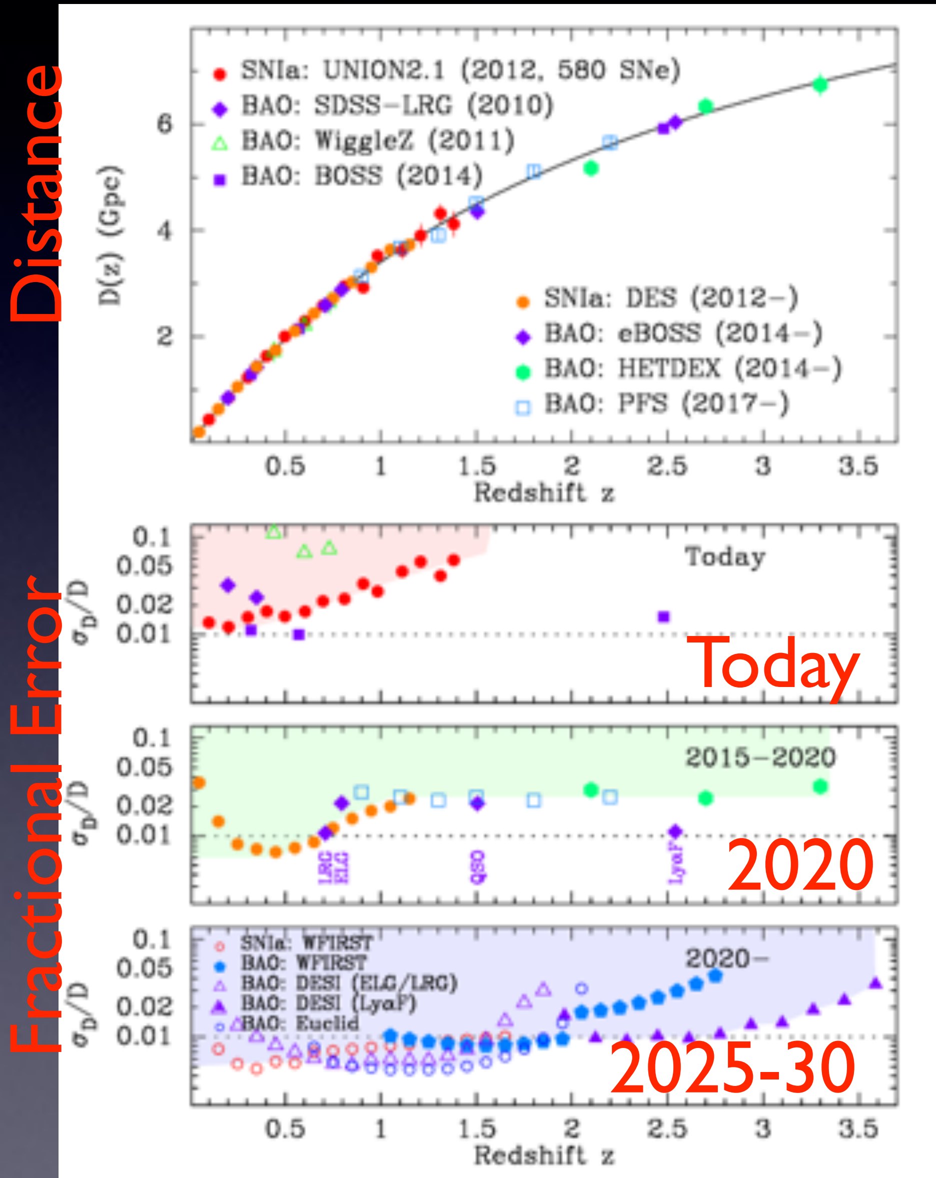
SN Cosmology with Subaru & WFIRST

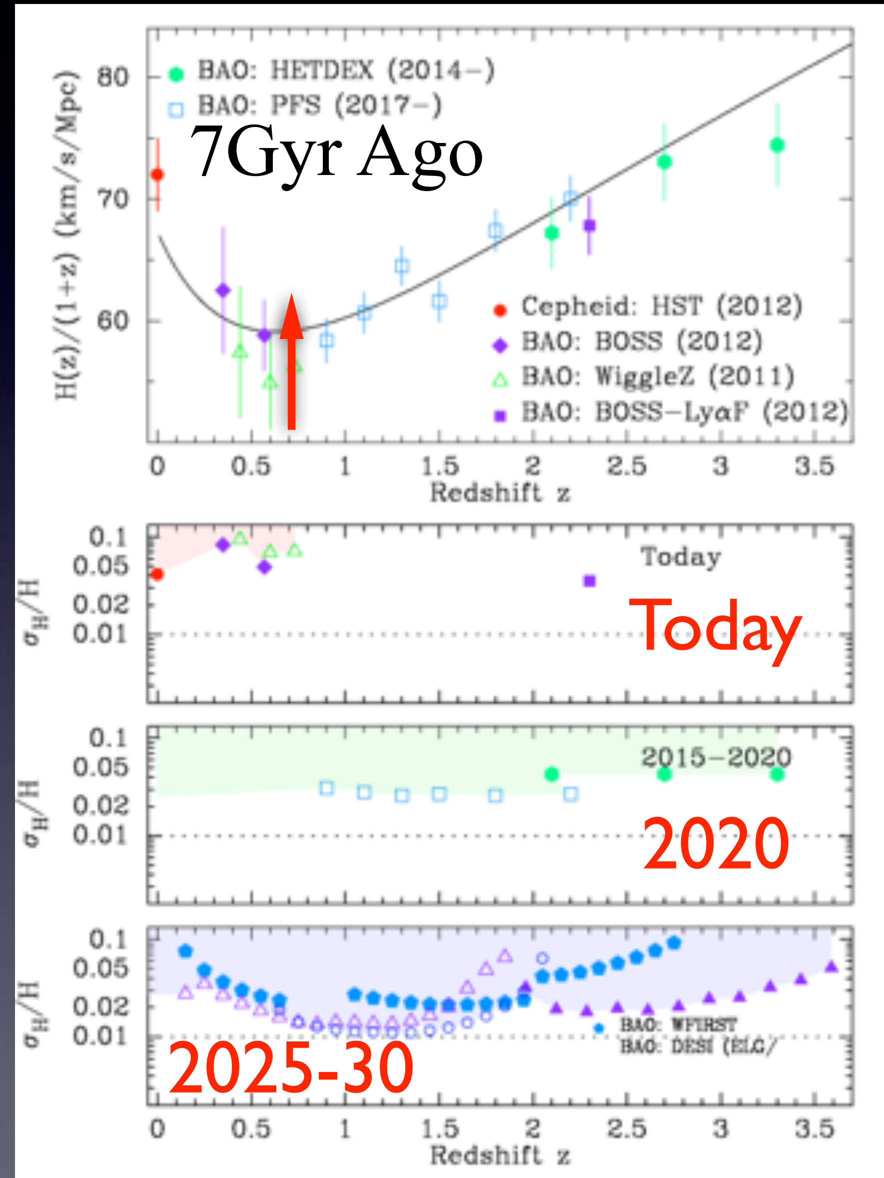
Nao Suzuki (Kavli IPMU)



1: SNIa Cosmology Today & Future
2: WFIRST SNIa Plan by Two Teams
3: Role of Subaru for Supernova Cosmolog
4: Need for IFC
5: North vs South

SNIa Cosmology Today and Future
Expansion History of the Universe

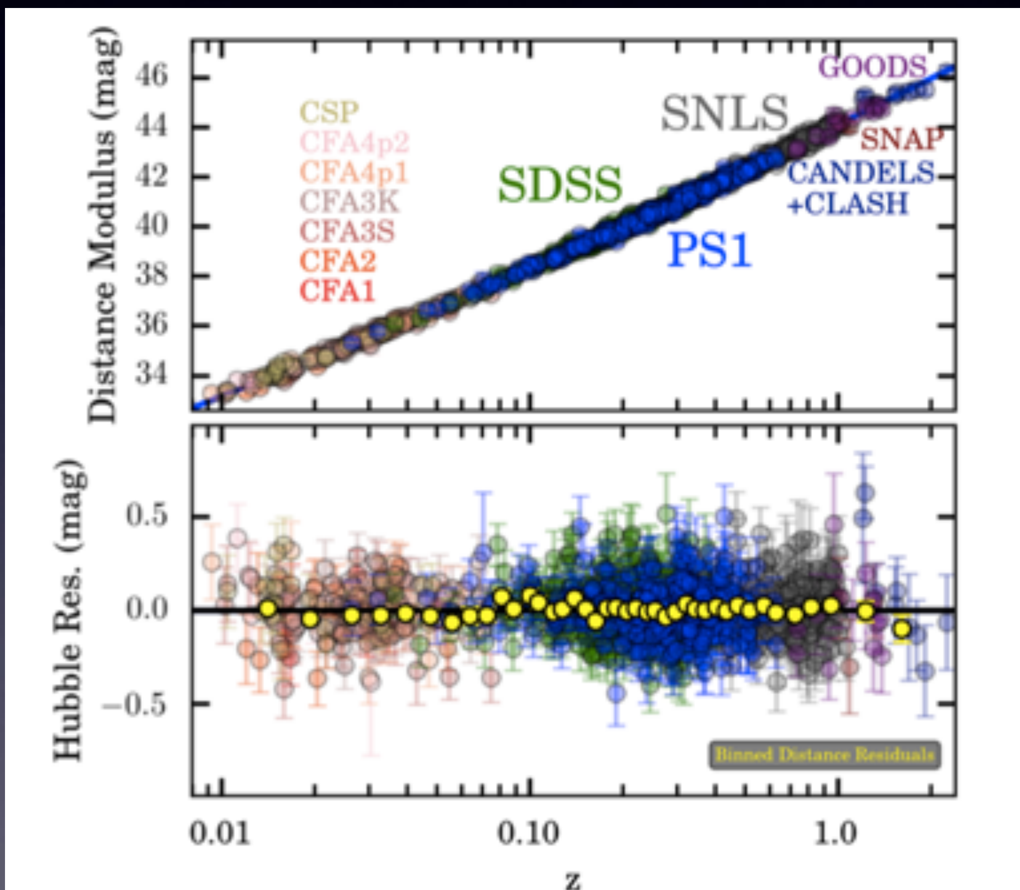




SNIa Cosmology Today

Stat = 3.2%
Sys = 2.4%

1049 SNeIa : w=-1.031 +/- 0.04 (stat + sys)



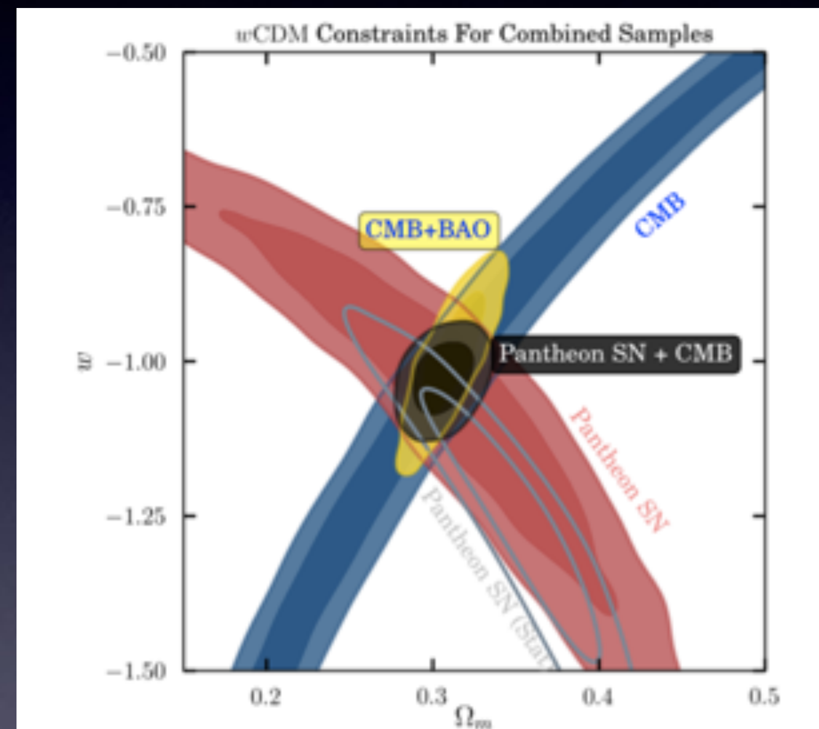


Figure 20. Confidence contours at 68% and 95% for the Ω_m and w cosmological parameters for the wCDM model. Constraints from CMB (blue), SN - with systematic uncertainties (red), SN - with only statistical uncertainties (gray-line), and SN+CMB (purple) are shown.

Scolnic et al. 2017

Foley Team arxiv : 1702.01747

Simulations of the *WFIRST* Supernova Survey and Forecasts of Cosmological Constraints

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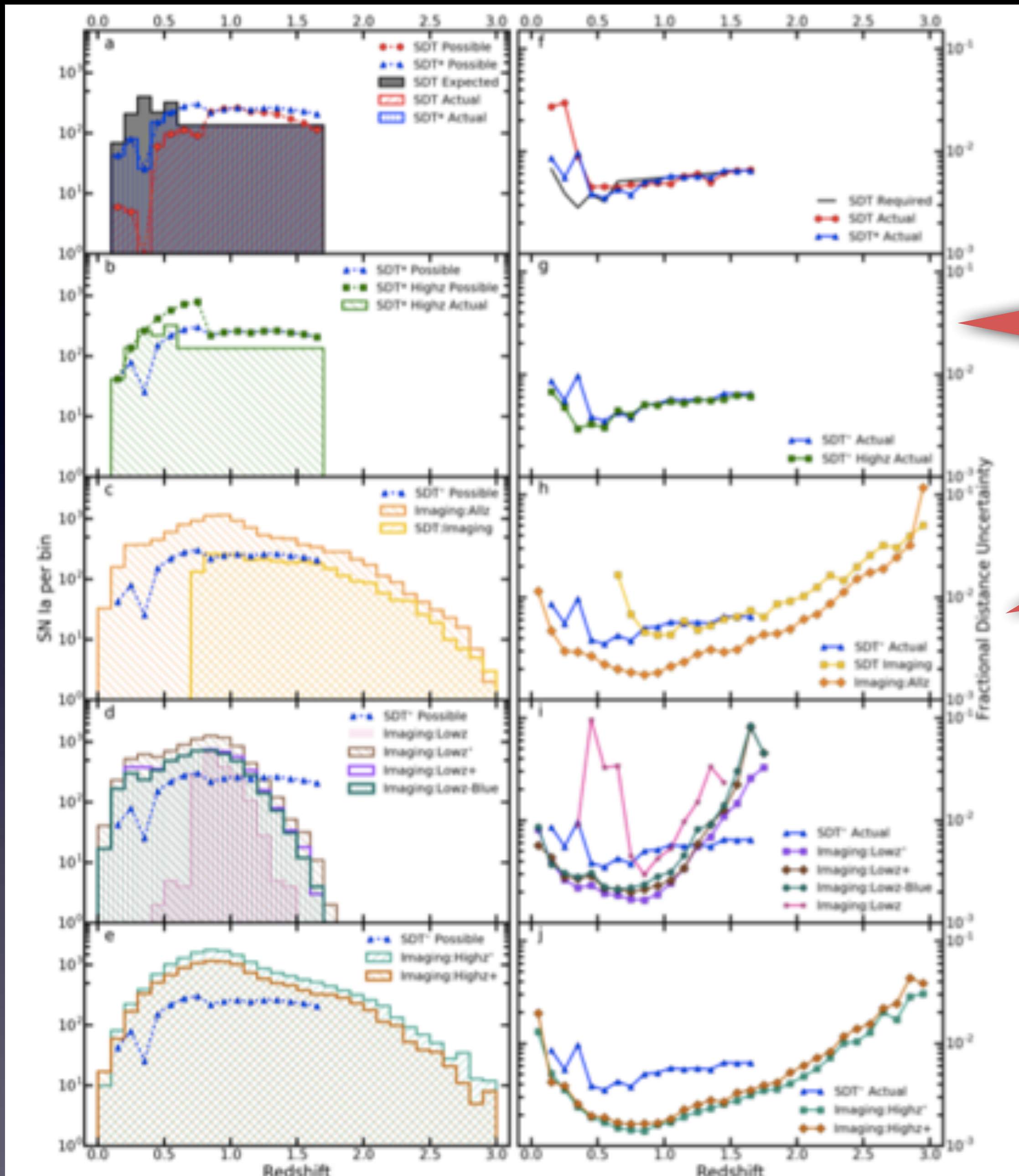
Table 8. Simulated strategies investigated for the *WFIRST* SN survey. This includes the strategy suggested within the SDT report.

	Redshift Range			Filter Set Used			Area (deg^2)			Number of SN Ia Selected		
Name	Shallow	Medium	Deep	Shallow	Medium	Deep	Shallow	Medium	Deep	Shallow	Medium	Deep
SDT	0.10–0.39	0.40–0.79	0.80–1.70	IFC-S, *YJ*	IFC-S, *JH*	IFC-S, *JH*	27.44	8.96	5.04	12	364	1204
SDT*	0.10–0.39	0.40–0.79	0.80–1.70	IFC-S, *YJ*	IFC-S, *JH*	IFC-S, *JH*	27.44	8.96	5.04	149	647	1224
SDT* Highz	···	0.10–0.79	0.80–1.70	···	IFC-S, *JH*	IFC-S, *JH*	···	22.80	5.04	···	1271	1224
SDT Imaging	0.01–2.99	0.01–2.99	0.01–2.99	*YJ*	*JH*	*JH*	27.44	8.96	5.04	0	221	2546
Imaging:Allz	0.01–2.99	0.01–2.99	0.01–2.99	*RZYJ*	*RZYJ*	*YJHF*	48.82	19.75	8.87	557	4807	5892
Imaging:Lowz	0.01–2.99	0.01–2.99	···	*YJ*	*JH*	···	142.30	66.91	···	0	1797	···
Imaging:Lowz*	0.01–2.99	0.01–2.99	···	*RZYJ*	*RZYJ*	···	73.57	32.24	···	822	8117	···
Imaging:Lowz+	0.01–2.99	0.01–2.99	···	*RZYJHF*	*RZYJHF*	···	50.66	20.68	···	588	5167	···
Imaging:Lowz-Blue	0.01–2.99	0.01–2.99	···	*BVRIYJ*	*BVRIYJ*	···	50.66	20.68	···	347	4894	···
Imaging:Highz*	···	0.01–2.99	0.01–2.99	···	*RZYJ*	*YJHF*	···	32.06	13.24	···	7990	8881
Imaging:Highz+	···	0.01–2.99	0.01–2.99	···	*RZYJHF*	*RZYJHF*	···	20.50	9.14	···	5211	6289

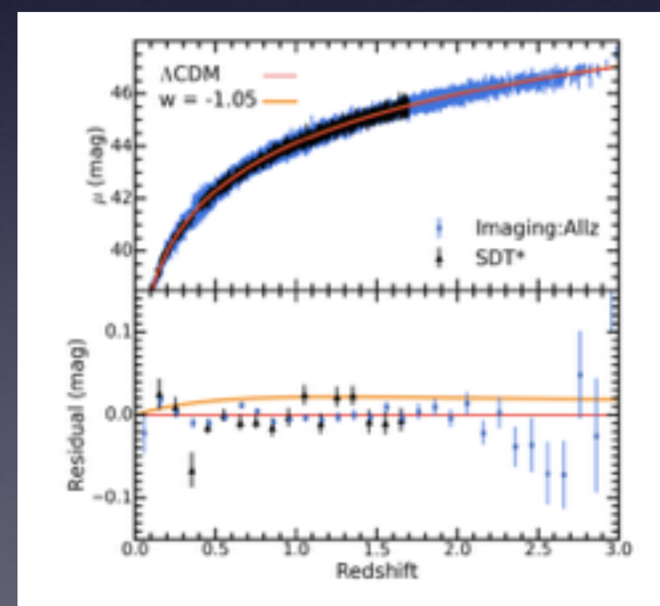
Foley Team

arxiv : 1702.0174f7



IFC Spec Follow-up

w/o IFC Spec



Perlmutter Team : Feb 2017 Meeting at Goddard

1 **Yield of WFC** photometry-only SNe in WFIRST IFC + WFC SN program. Rubin

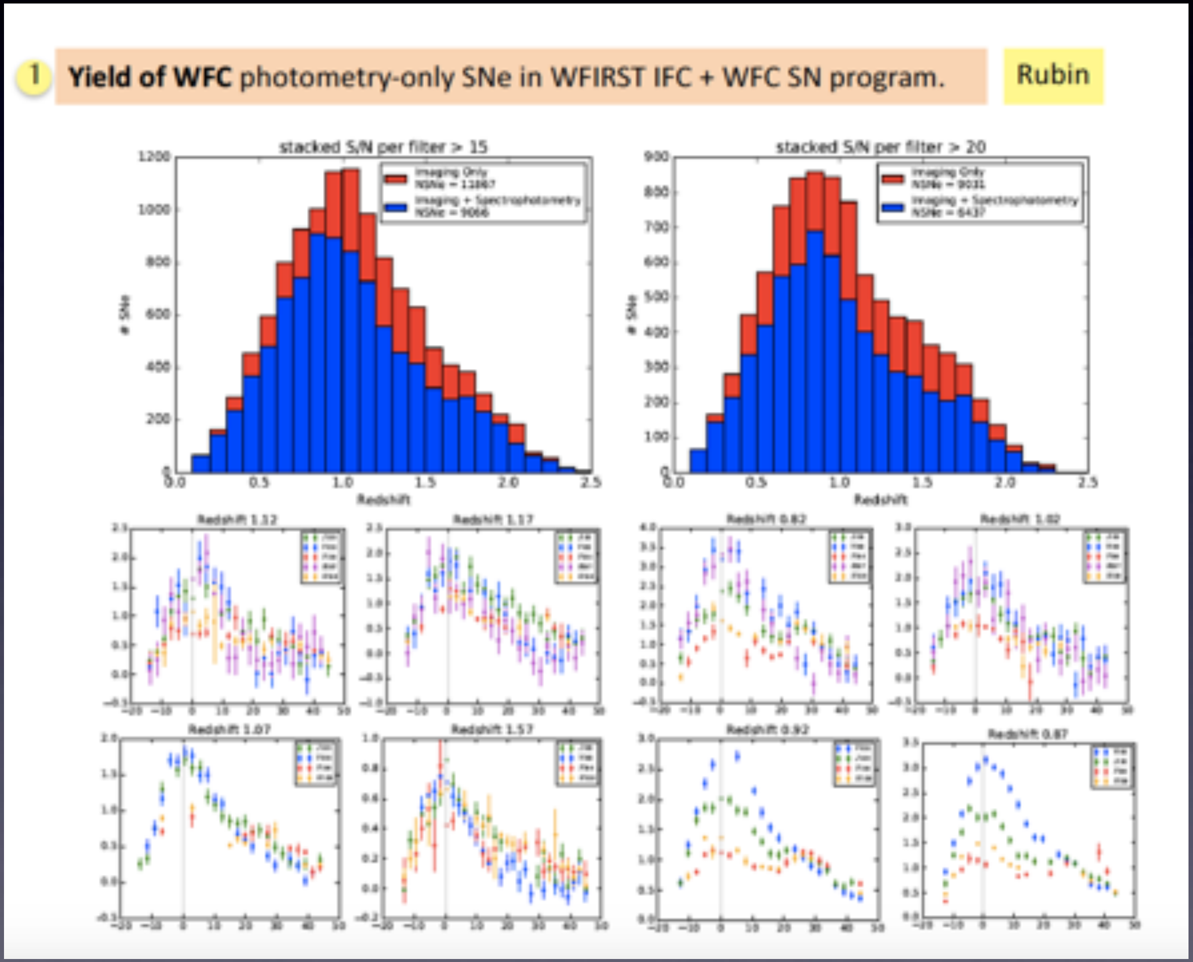
		Low-z (z<0.8) Tier	High-z (0.8<z<1.7) Tier	Total
IFC program and WFC program running in parallel	Number of spectrophotometrically-observed SNe:	2031	766	2797
	Number of photometry-only SNe:	3768	4615	8383
WFC program running alone	Number of photometry-only SNe:	4526	6158	10684

Dropping F184 observations for low-z tier increases the number of photometry-only SNe by ~28% (mostly at the lower z). Roughly the same (~75%) fraction are still found parallel to IFC.

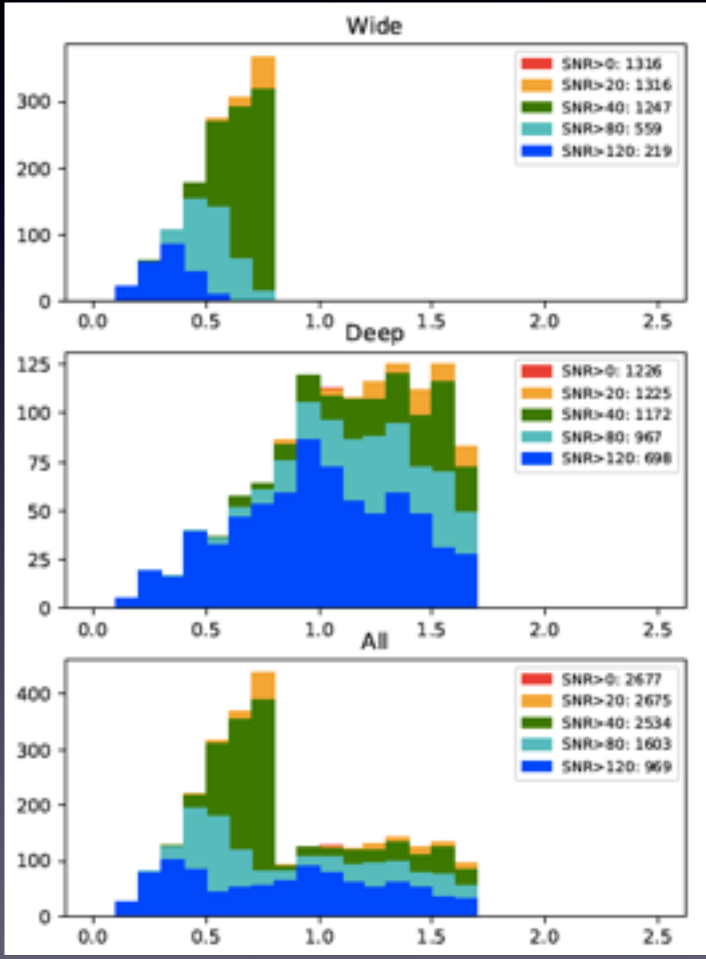
If one significantly reduces S/N for photometry on each SN to increase the photometry-only numbers further, then the systematics control approaches of, e.g., BEAMS doesn't work.

Note: Less than ½ of the higher-redshift photometry-only SNe will have a redshift measured.

Perlmutter Team : Feb 2017 Meeting at Goddard



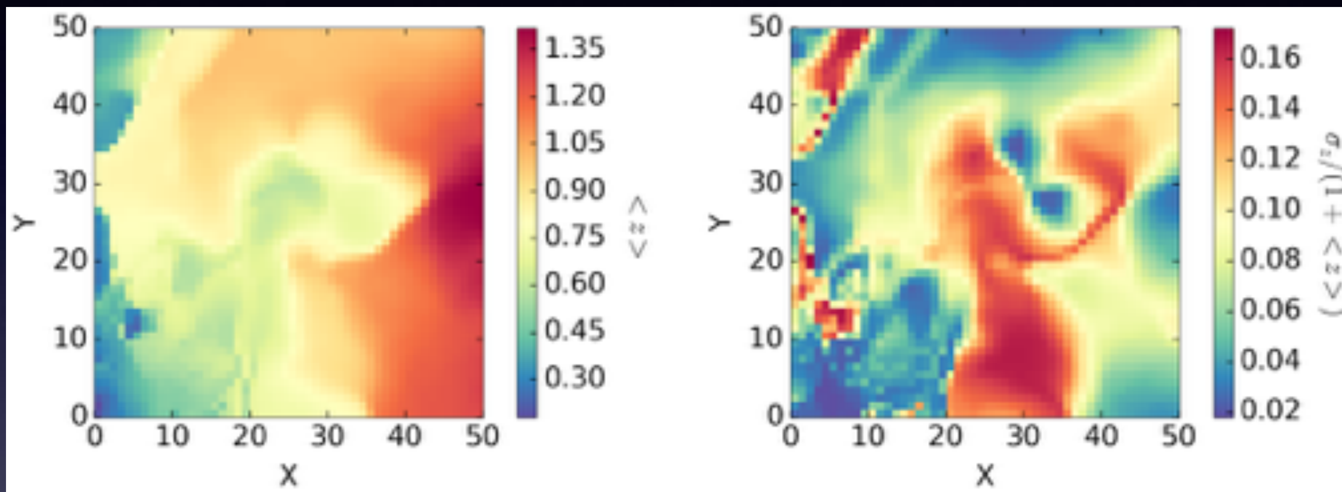
Wide/Deep SNe by Rubin

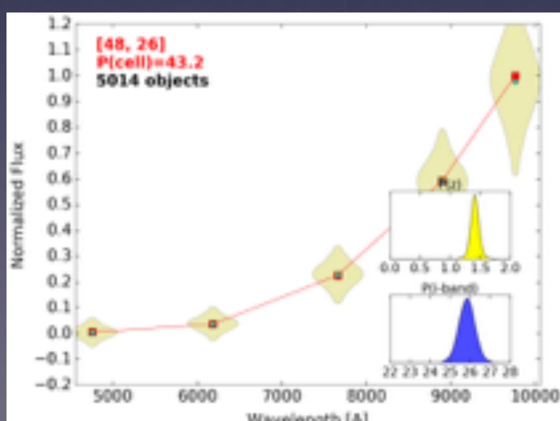


Supernova Classification in 2020s

SNIa Self Organizing Map (SOM)

Photometric SED Classification w/o Light Curve





HSC 5-band data (1 epoch)
We have a good guess of
Redshift and Identification

Credit : Josh Speagle & SOM Team

Machine Learning Classifying Supernova Types : IPMU+NTT

Simulated SN Datasets

HSC image Data + Sim. SN info. Light curve Redshift(z) Host Galaxy

training

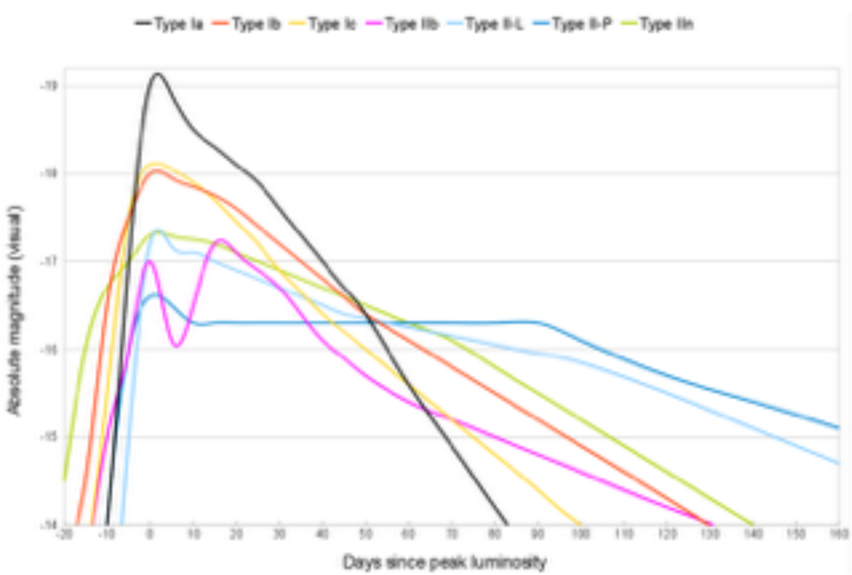
test

Classifier using DNN

Band-wise CNNs
Estimating SN flux

Joint network

Fully connected NN
SN classification

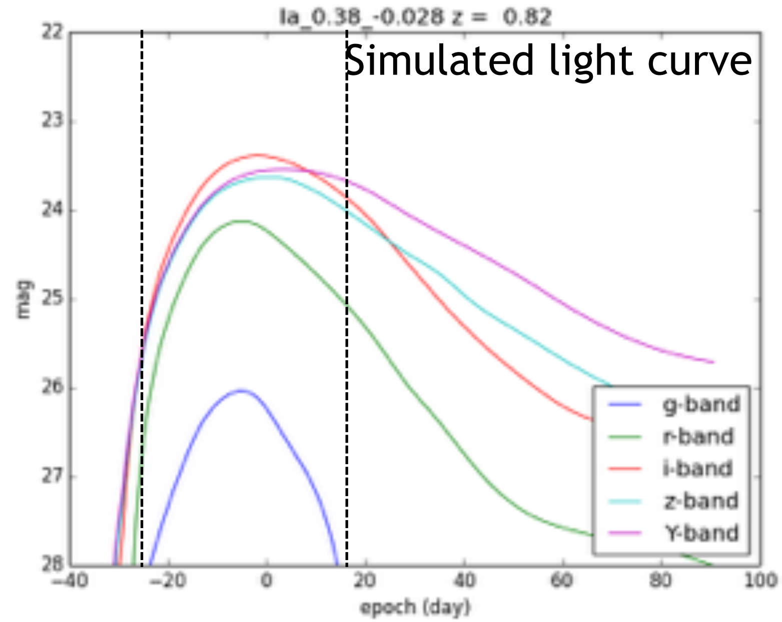


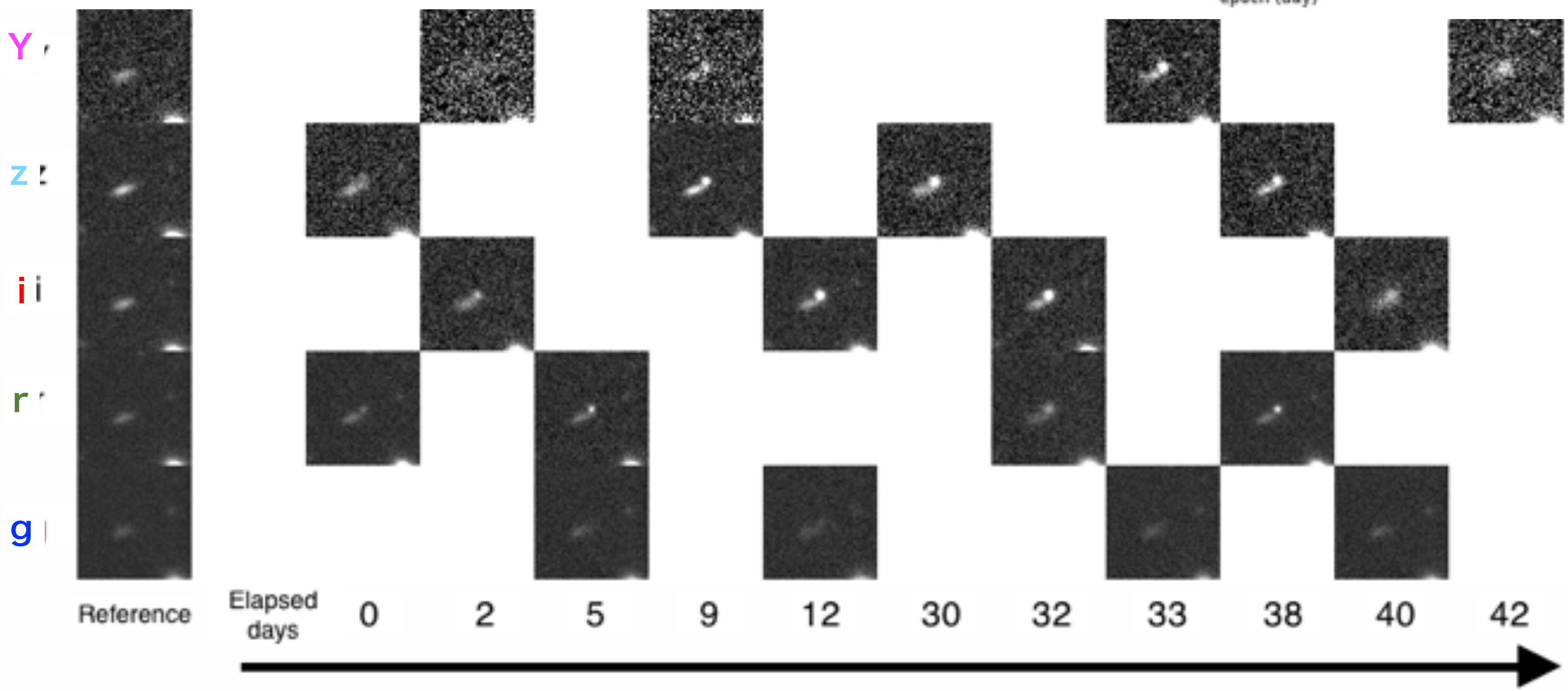
SN type
(Type Ia or not)

Redshit

A Simulated Data for training (Takahashi, Yasuda + NTT team)

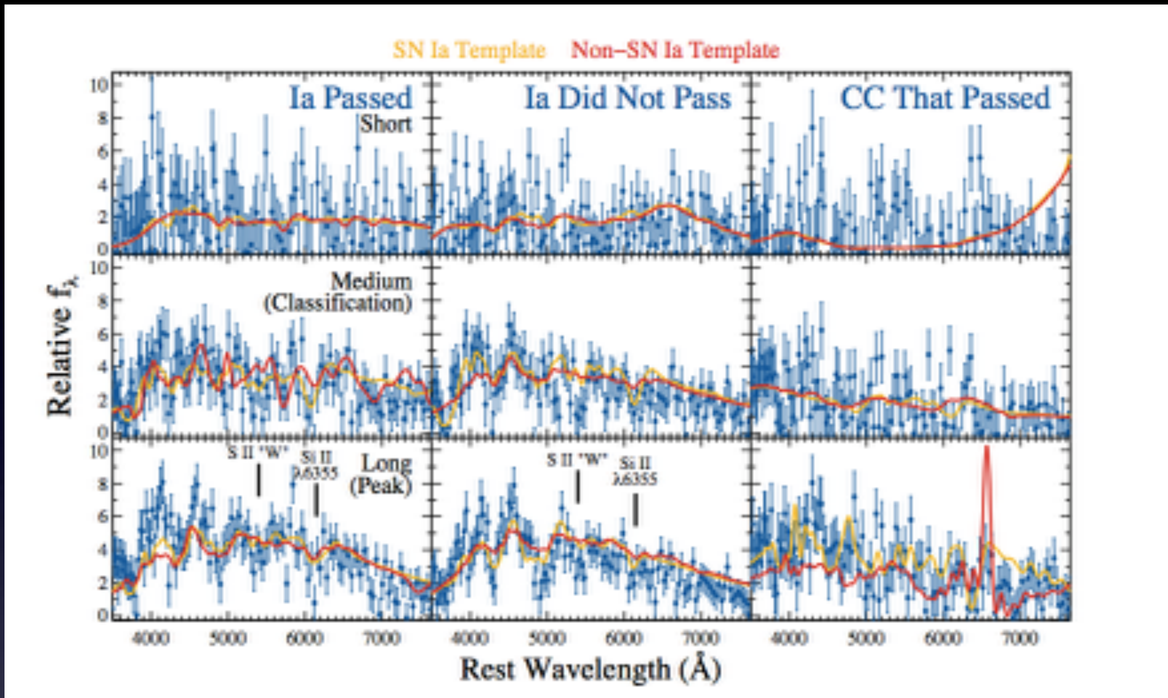
SN_Type:	Ia
Photo-z:	0.82
Stretch_x1:	-0.03
Color_c:	0.38
Offset[day]:	-24
Image_Size[pixel]:	65

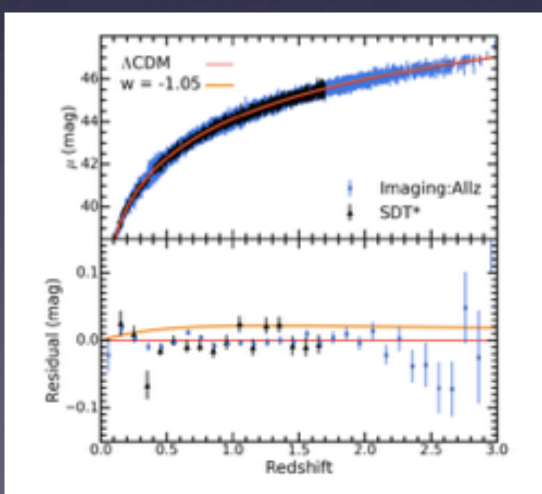


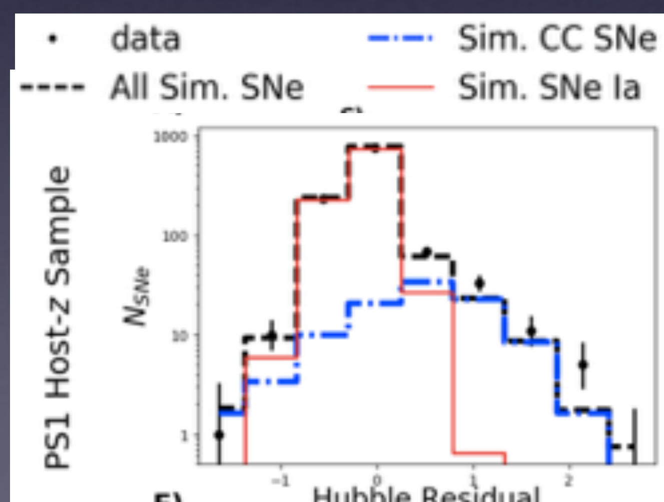


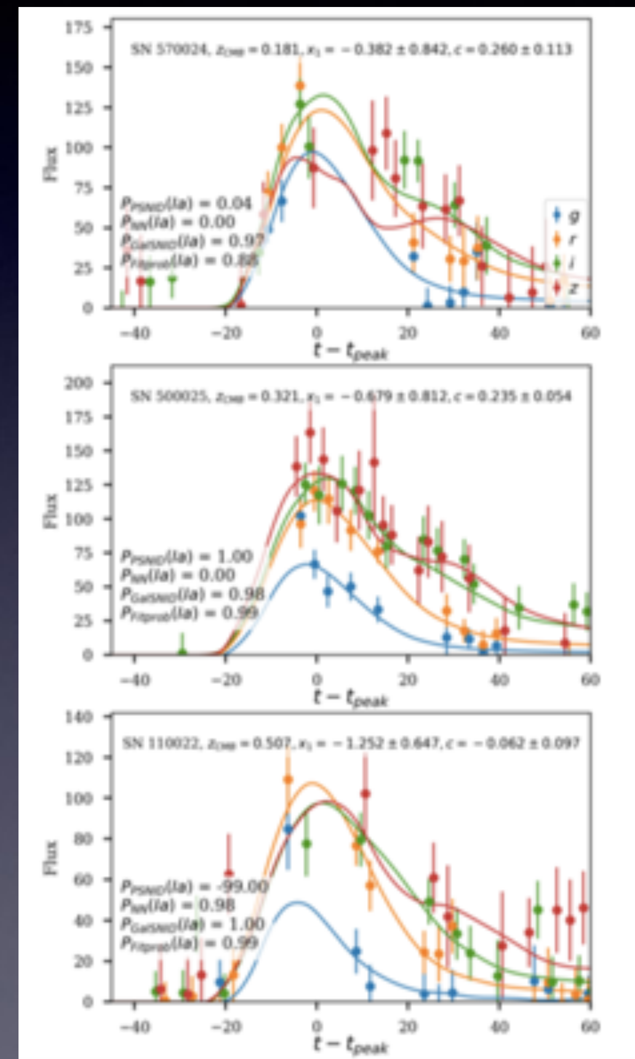
Need for IFC arxiv : 1702.01747

Joens et al 2017
Pan Starrs SN
Example:
Non-Definitive Case









Role of Subaru for Supernova Cosmology

- I : Spectroscopic Follow-up by PFS (Host Galaxy Spectrum)
- II: Opt (HSC) Discovery+ IR (WFIRST) follow-up photometry A
- III: Opt (HSC) + IR (WFIRST) photometry B
- IV: Opt(LSST)+IR(WFIRST)+PFS(Host Galaxy Spectrum)

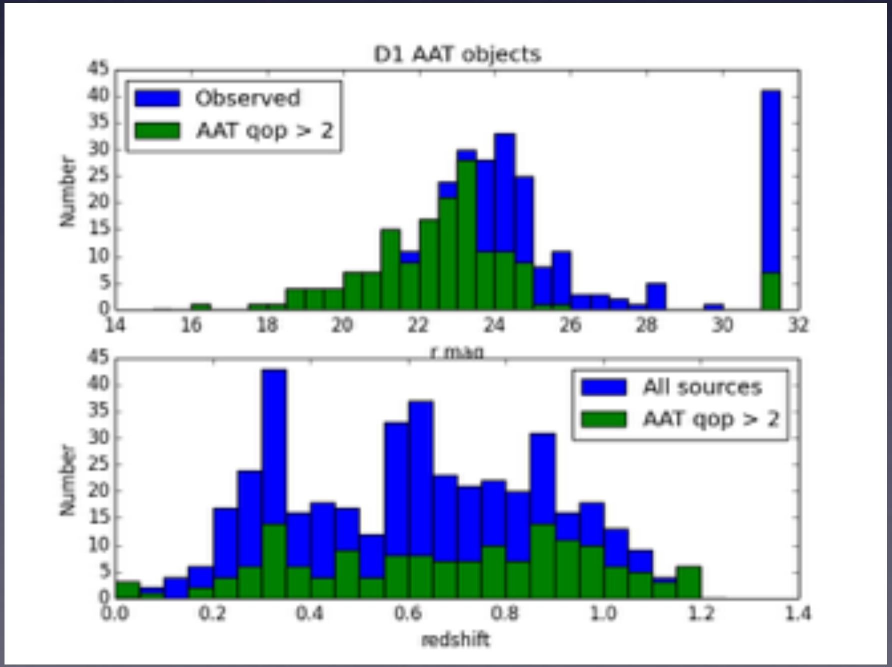
I: Spectroscopic Follow-up (Host Galaxy)

- Ongoing Example: OzDES (4m : 2012-2018)
- Imaging & Photometry by DECam (4m)
- Spectroscopic Follow-up by AAT Omega (2deg)

DECam

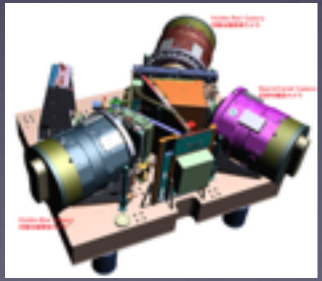
AAT Omega

AAT Data from C. Lidman

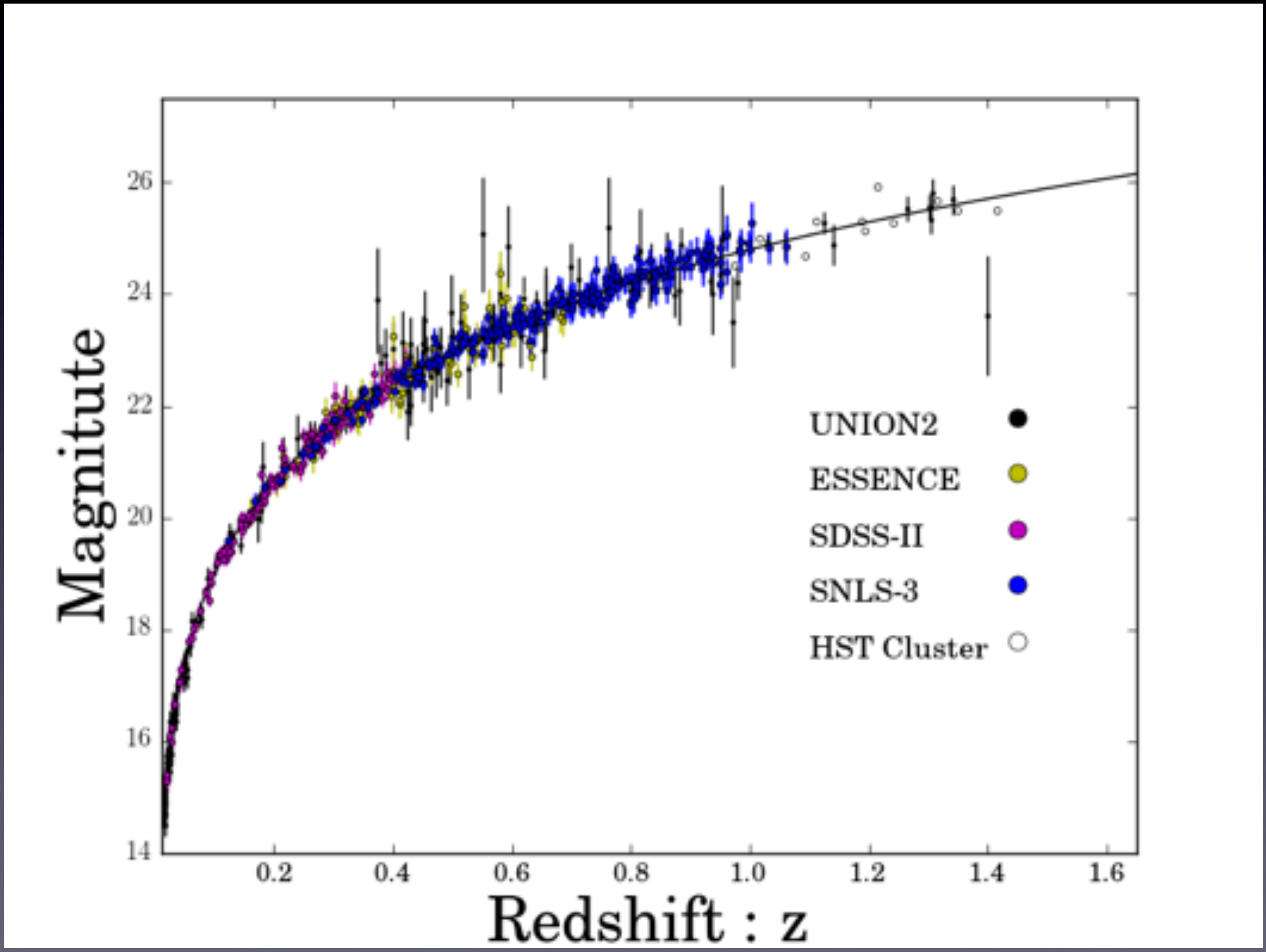


WFIRST

Subaru PFS



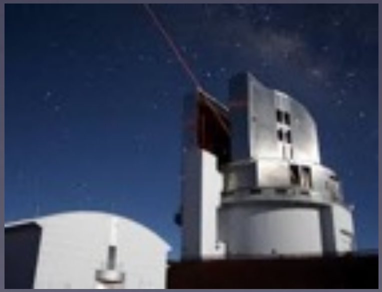
HSC SN Survey
Before HSC (2015-2018)



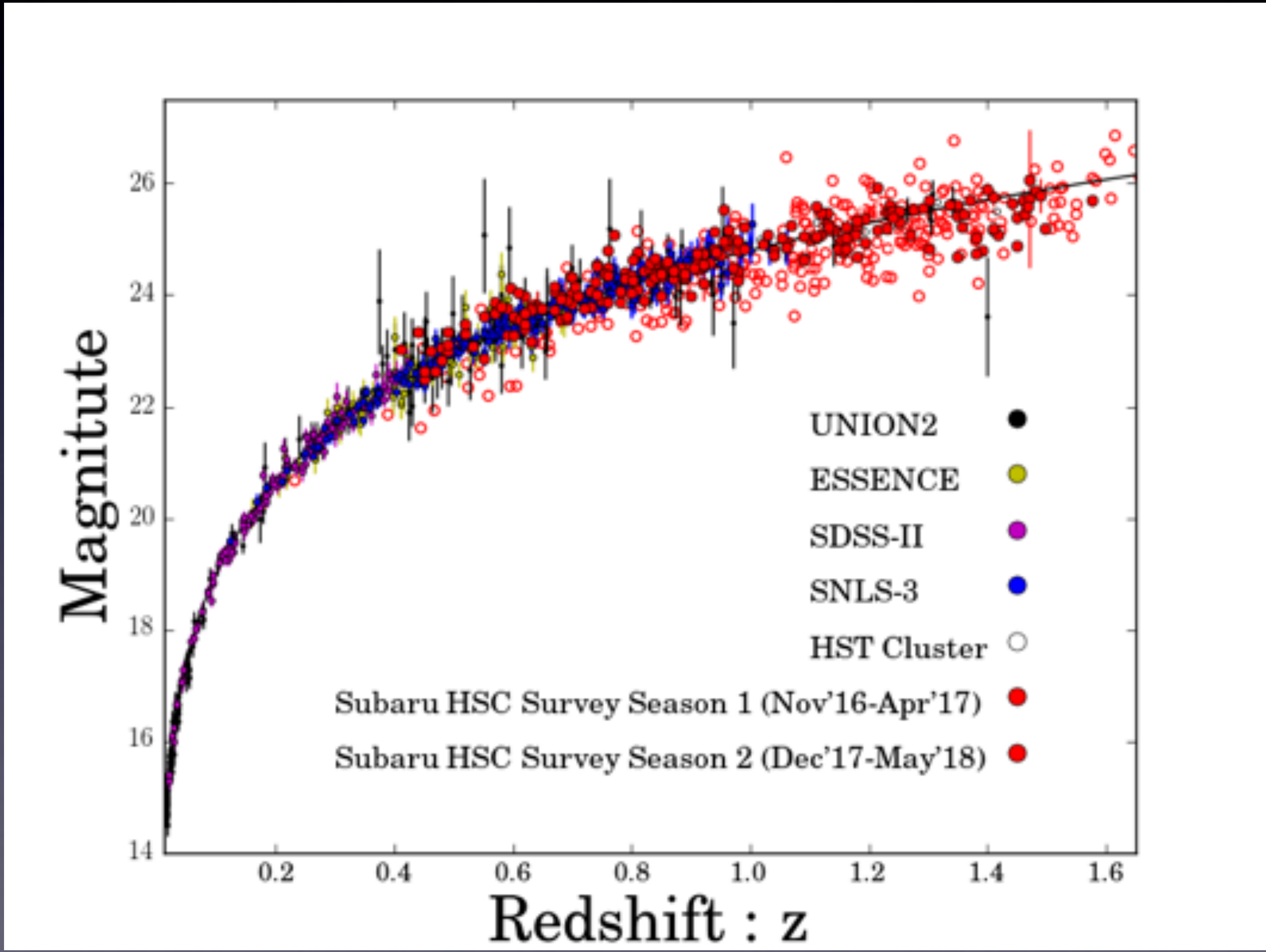
Subaru Telescope, Hubble Space Telescope Accelerating Universe & Dark Energy

Nao Suzuki (Kavli IPMU), on behalf of Yoshida Team
Naoki Yasuda, Ichiro Takahashi, Tomoki Morokuma,
Nozomu Tominaga, Masaomi Tanaka,, Naoki Yoshida
NTT Team, ISM (Institute of Statistics and Math) Team, Tsukuba Team
CREST(JST) collaboration (PI Yoshida),
JSPS Exchange Program (PI: Murayama)

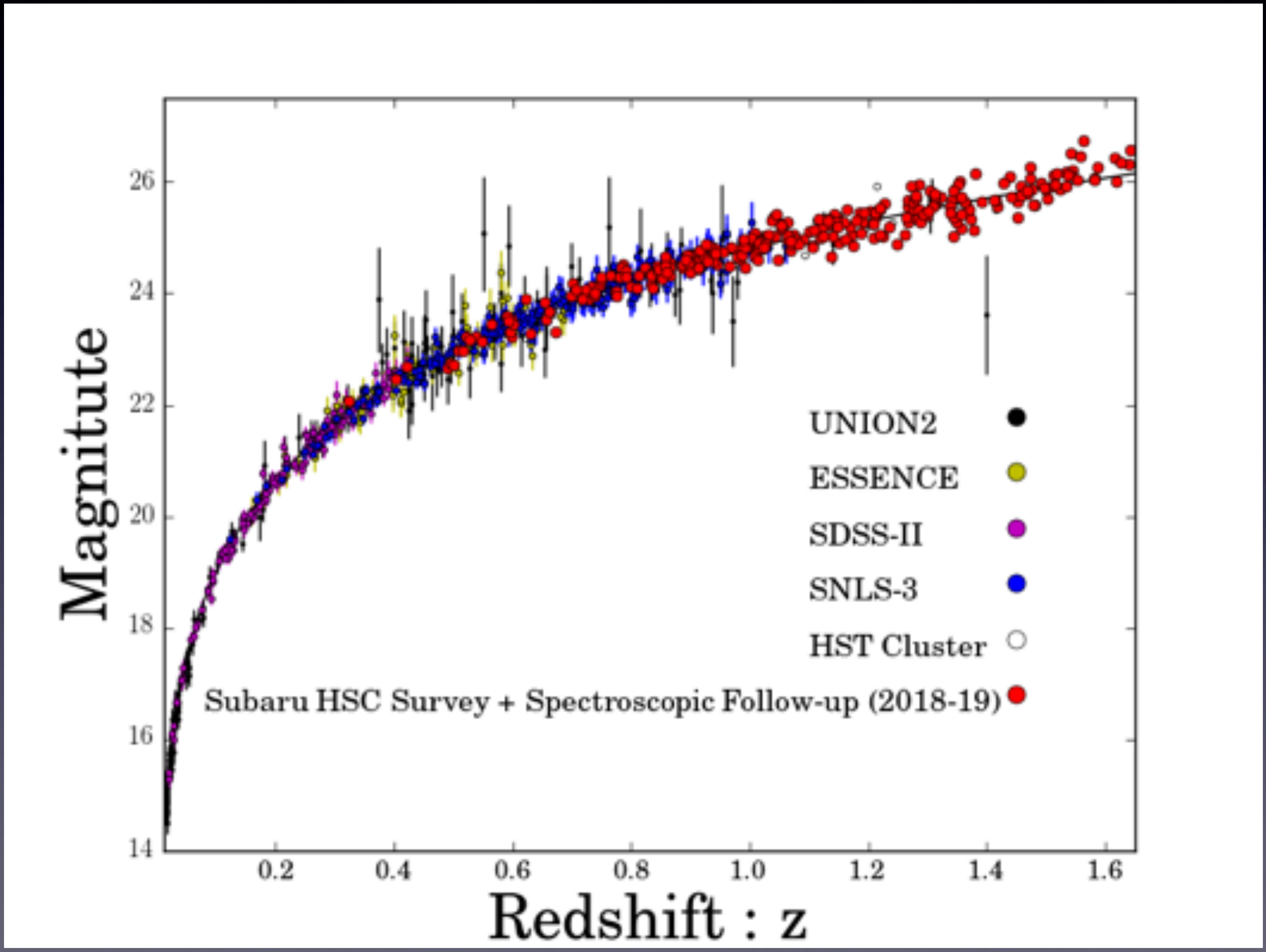
External Collaborators : Supernova Cosmology Project Team
David Rubin (STScI), Nicolas Regnault (LPNHE), Pierre Astier,
Marc Betoule, Peter Nugent, Saul Perlmutter, Pilar Ruiz-Lapuente



HSC SN Survey
HSC (2015-2018)

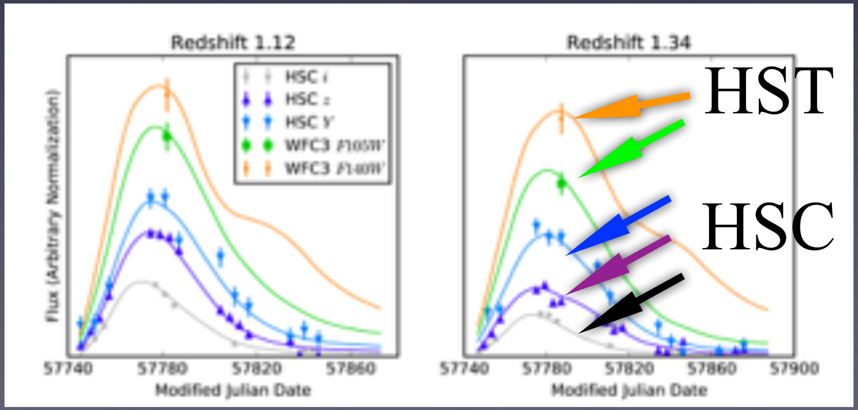


HSC SN Survey
HSC (2015-2018) + Host Spec-z



II: Opt(HSC)+IR(WFIRST) Imaging A

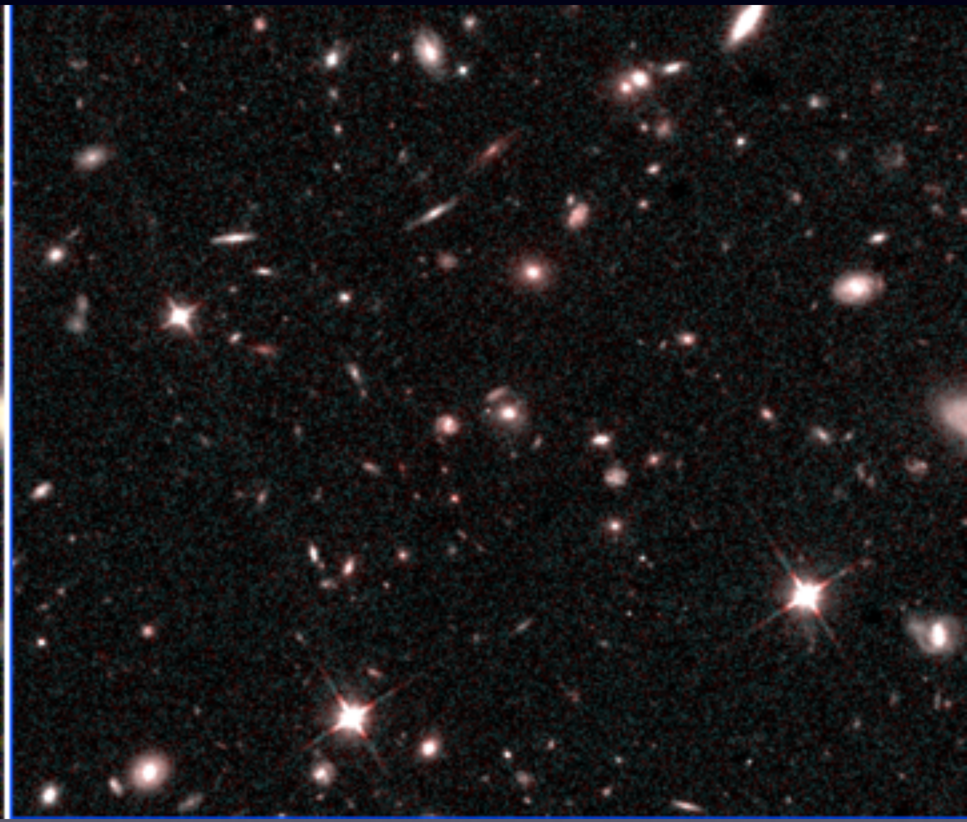
- Ongoing Example : Opt(HSC)+IR(HST)
- Method : Find SNIa by HSC and trigger HST to observe IR data point at the peak
- Pros : Very Efficient Way of finding high-z SNIa
- Cons : Accuracy Limit comes from HSC calibration and weather



HSC: r2, i2,z vs HST WFC3 : F105(J), F140(H)

Subaru/HSC (Optical)

Hubble Space Telescope (IR)



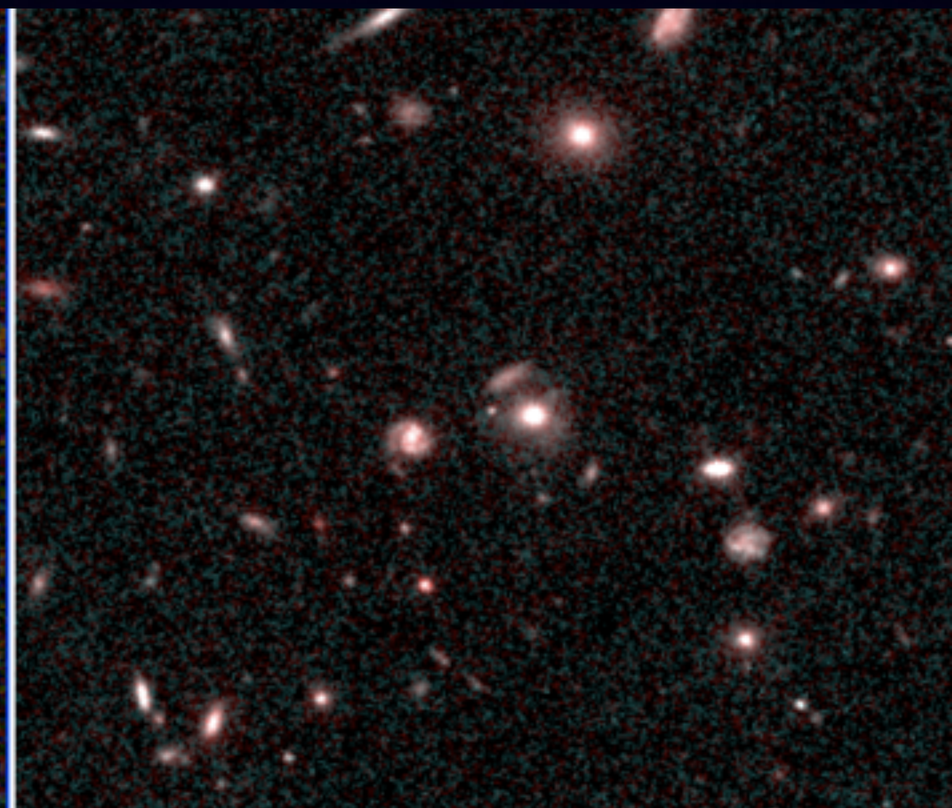
Moment of Zen

HSC/LSST can see what WFIRST will see
(optical)

HSC: r2, i2,z vs HST WFC3 : F105(J), F140(H)

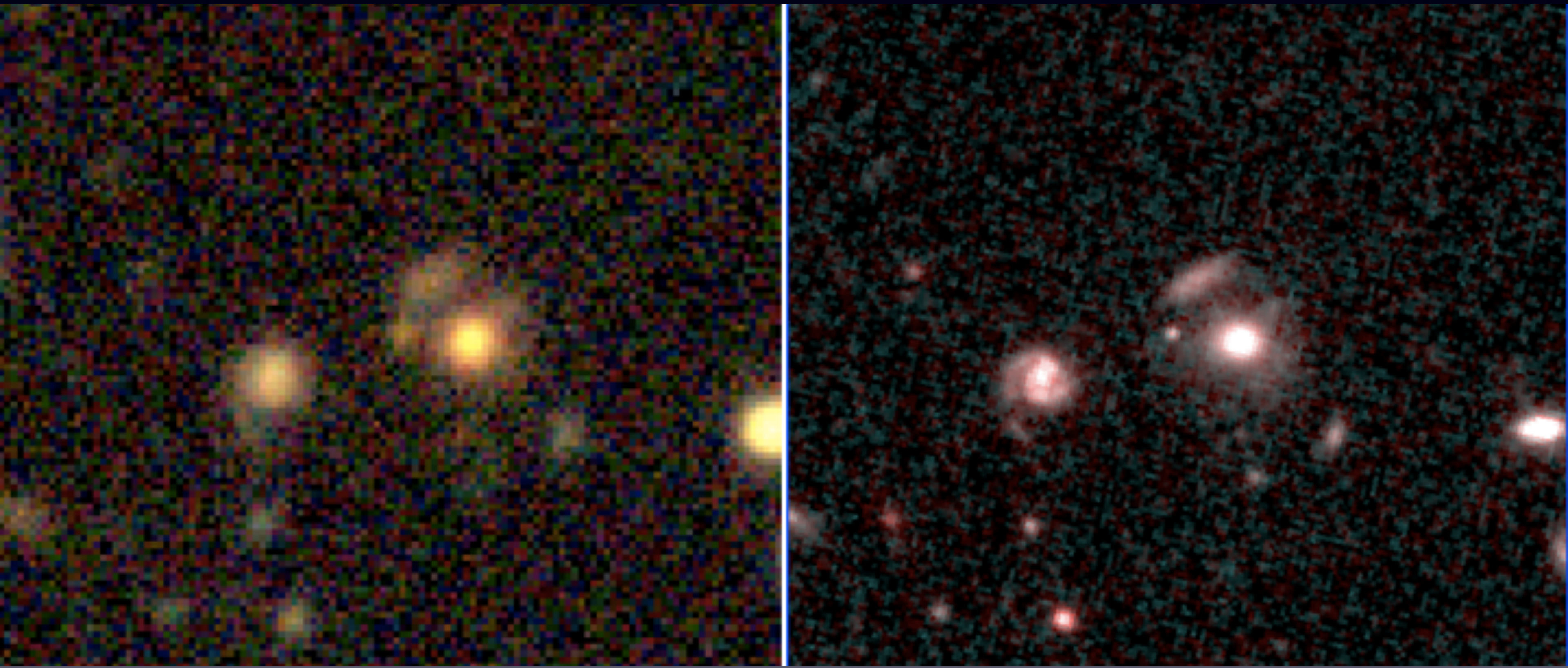
Subaru/HSC (Optical)

Hubble Space Telescope (IR)



HSC: r2, i2,z vs HST WFC3 : F105(J), F140(H)

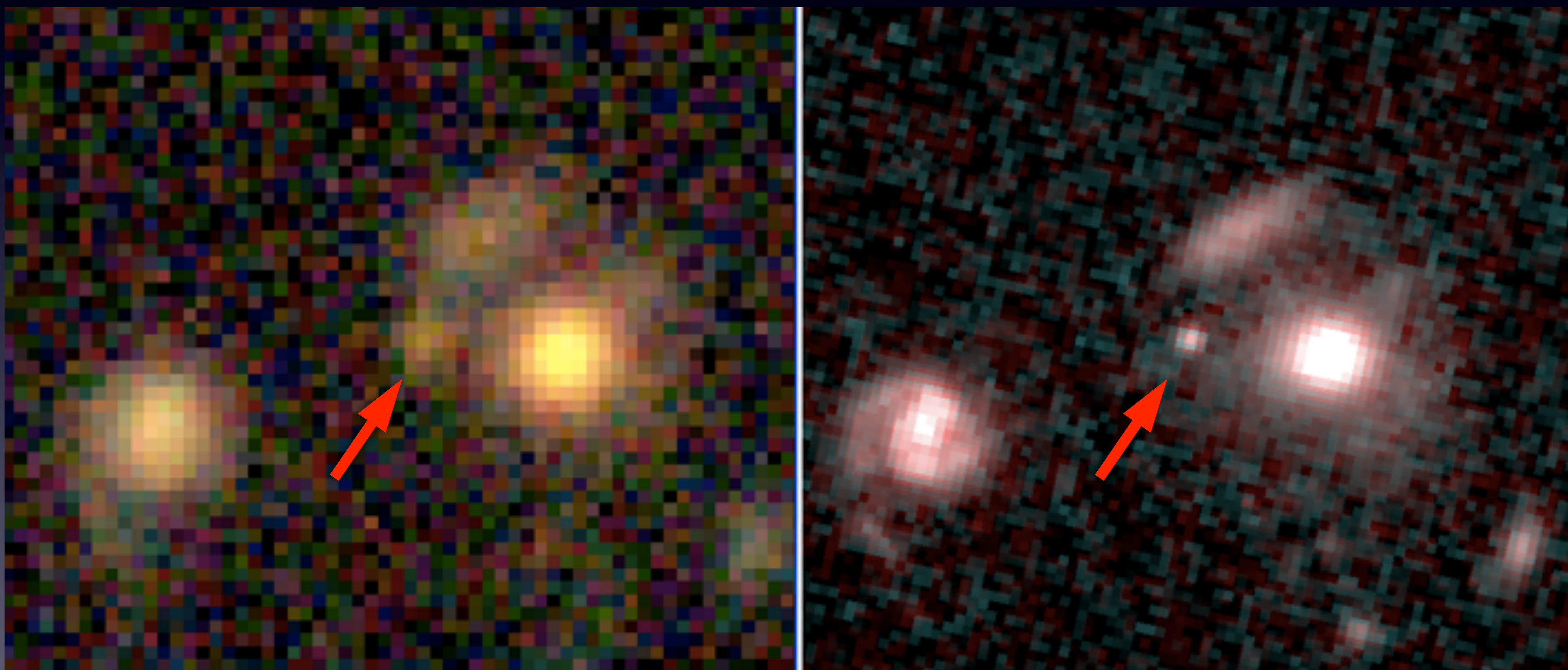
Subaru/HSC (Optical) Hubble Space Telescope (IR)



HSC: r2, i2,z vs HST WFC3 : F105(J), F140(H)

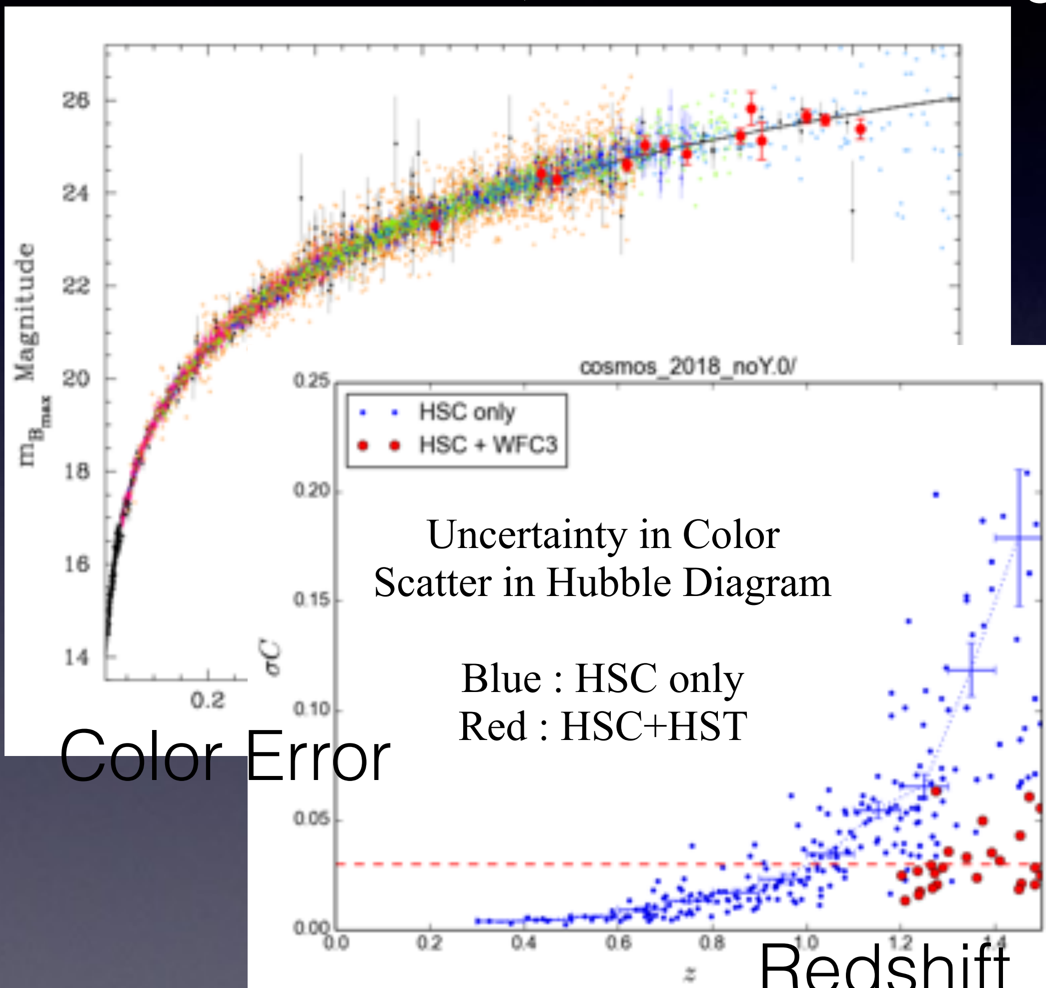
17siv : z=1.234 SNIa, 8.57 G light years

Subaru/HSC (Optical) | Hubble Space Telescope (IR)



10-15% Color Measurement | 1-3% Color Measurement

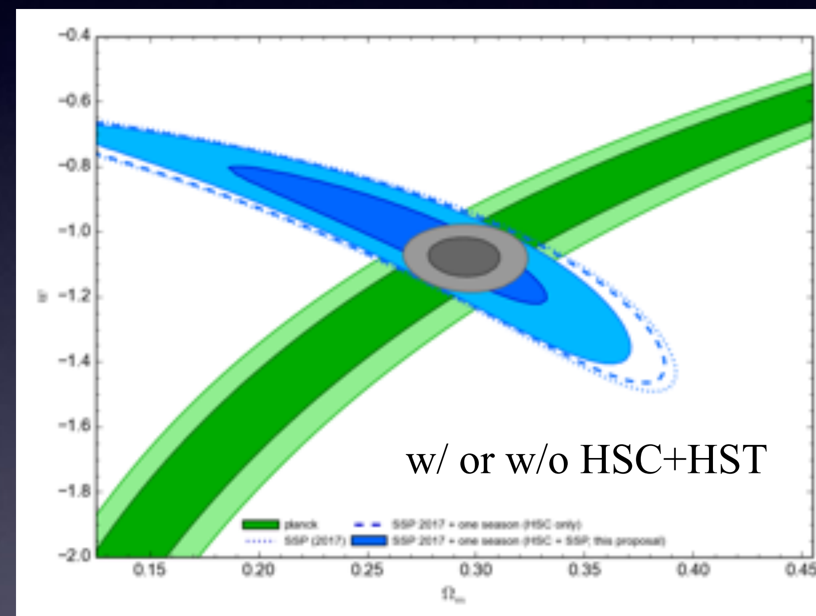
Hubble Space Telescope reduces the scatter dramatically and enhances Figure of Merit
With HST, HSC SNIa Cosmology becomes very strong!



Color Error

Redshift

FoM can be increased

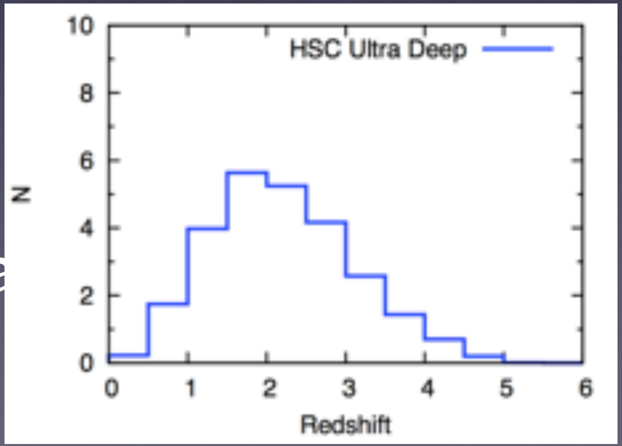


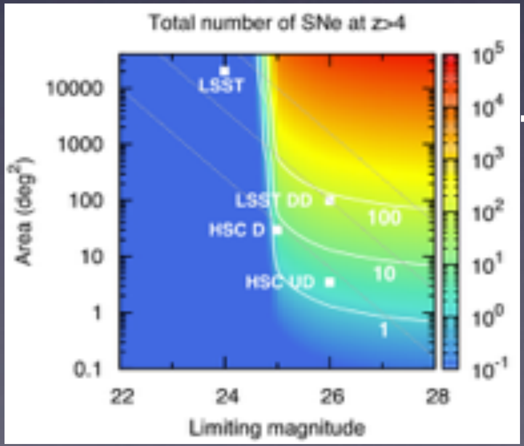
3% Error x 2 (beta)/ sqrt(49 SNe) x 0.461=0.4% Stat Error

III: Opt(HSC)+IR(WFIRST) Imaging B

- Method : WFIRST conducts STD-like SNIa Survey with IR bands (Y, H), Subaru HSC is going to observe Opt bands (i, z)
- Pros : We can confirm high-z Super Luminous SuperNova (SLSN)
- Cons : Accuracy is limited by HSC calibration and weather

SLSN# from Moriya





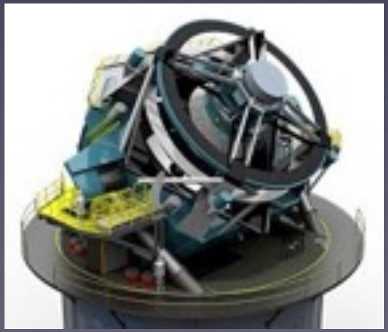
Tanaka et al 2013

IV: Opt (LSST)+IR(WFIRST)+ PFS(Spectroscopic Follow-up)

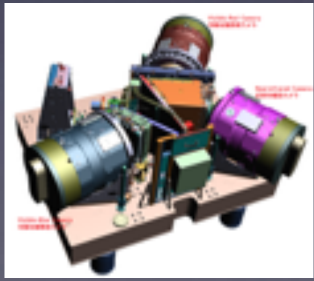
- Dream Scenario : WFIRST (NASA) wants to keep satellite mission to be self-contained. LSST is not in the plan
- Method : Simultaneous Observation by WFIRST & LSST
- Pros : The most efficient use of all of the facilities. LSST has a calibration telescope
- Cons: The field is out of CVZ…

WFIRST

LSST



Subaru PFS



Biggest Impact to Subaru

CVZ (continuous viewing zone)

North : Dec > +45, South : Dec < -45

Role of Subaru for SNIa Cosmology

- Northern Hemisphere : Telescopes in Hawaii, Subaru, Keck, Gemini
- Southern Hemisphere : LSST, VLT, SKA, ALMA, ELT + Future Spectrograph?!

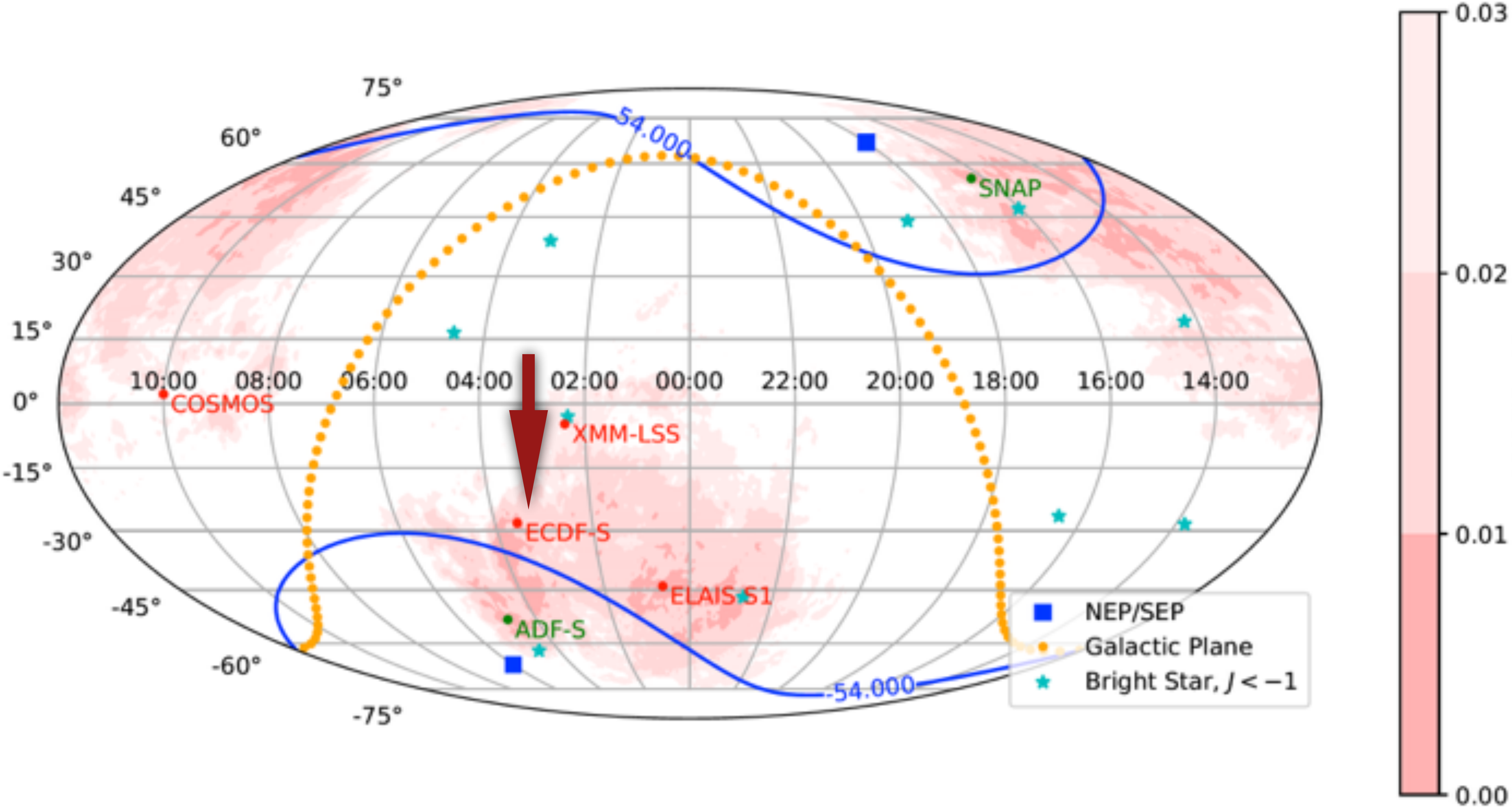
Table 11. Contribution of various source of measurement uncertainties to the uncertainty in Ω_m.

Uncertainty sources	$\sigma_x(\Omega_m)$	% of $\sigma^2(\Omega_m)$
Calibration	0.0203	36.7
Milky Way extinction	0.0072	4.6
Light-curve model	0.0069	4.3
Bias corrections	0.0040	1.4
Host relation[a]	0.0038	1.3
Contamination	0.0008	0.1
Peculiar velocity	0.0007	0.0
Stat	0.0241	51.6

Notes. For the computation of $\sigma_{stat}(\Omega_m)$, we include the diagonal terms of Eq. (13) in C_{stat}. [a] We discuss an alternative model for the environmental dependence of the SN luminosity in Sect. 6.3.

Calibration is the Key
1: Ideal to be SN field is embedded in High Latitude Survey
2: Uber Calibration
3: LSST has a calibration telescope
4: Clustering Redshift

CDF-S for Subaru and WFIRST?!
UH will observe CDFS intensively



Moment of Zen

Telescope cannot calibrate by itself

WFIRST + PFS Host-z 6000 SNe
2000 SN with IFC

Spec-z

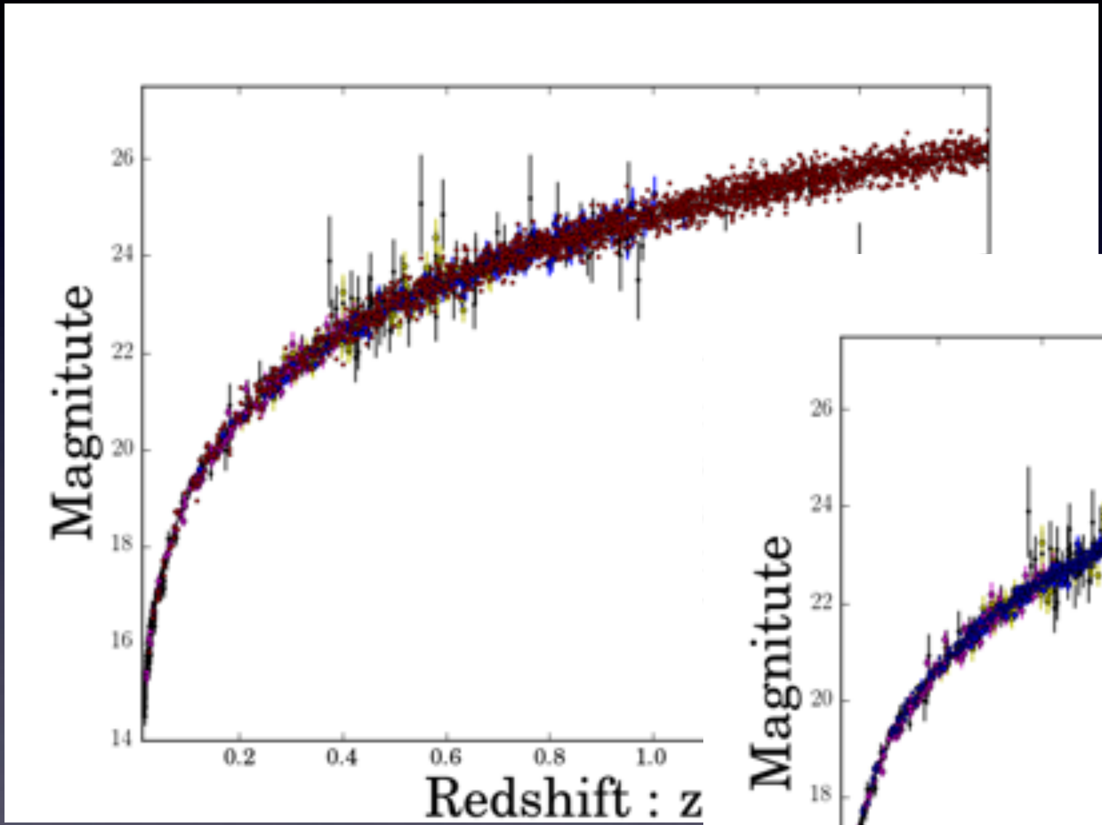
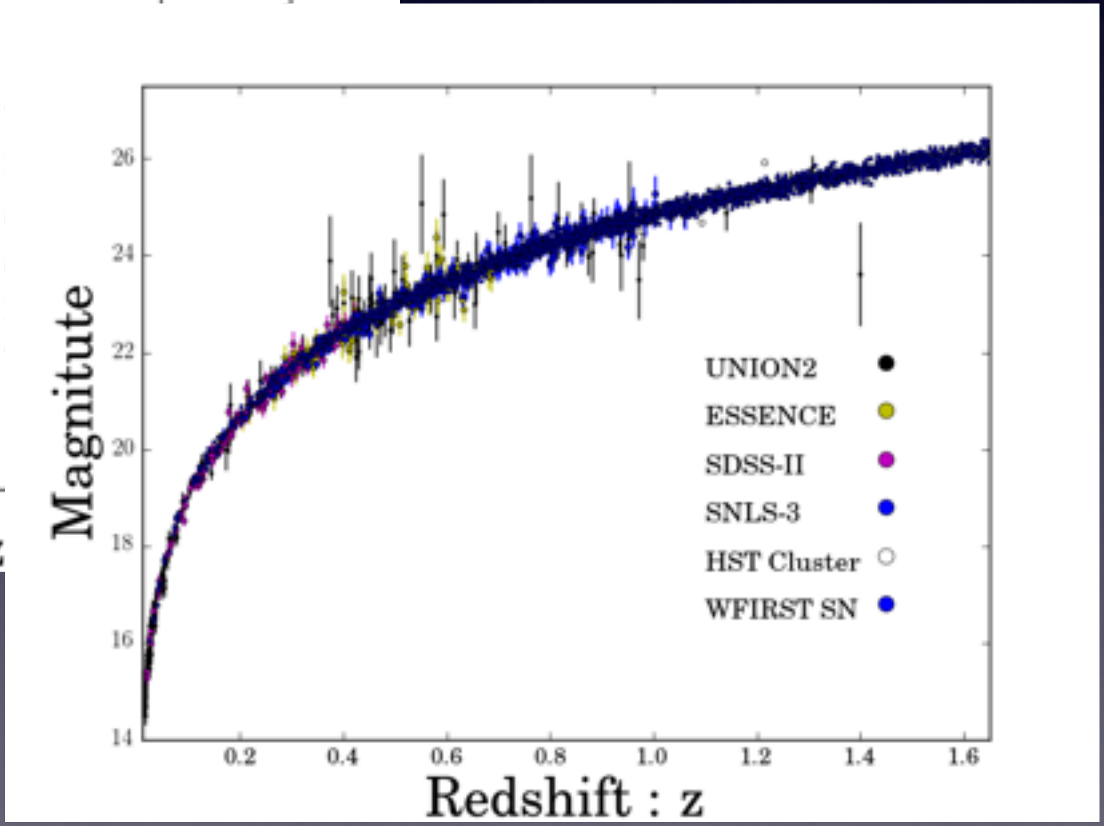


Photo-z



Summary & Conclusions:

- Subaru/PFS can obtain 6000 host-z for SN WFIRST (for both teams scenarios)
- CDF-S : Subaru can observe 4 hours in Fall
- LSST + WFIRST simultaneous observation is would help us calibrate the system
- IFC can help photo-z calibration as well