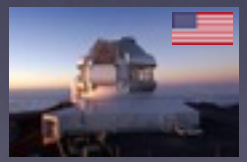
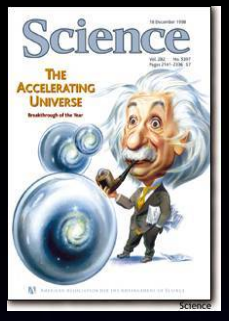
HSC Supernova Cosmology Legacy Survey with HST

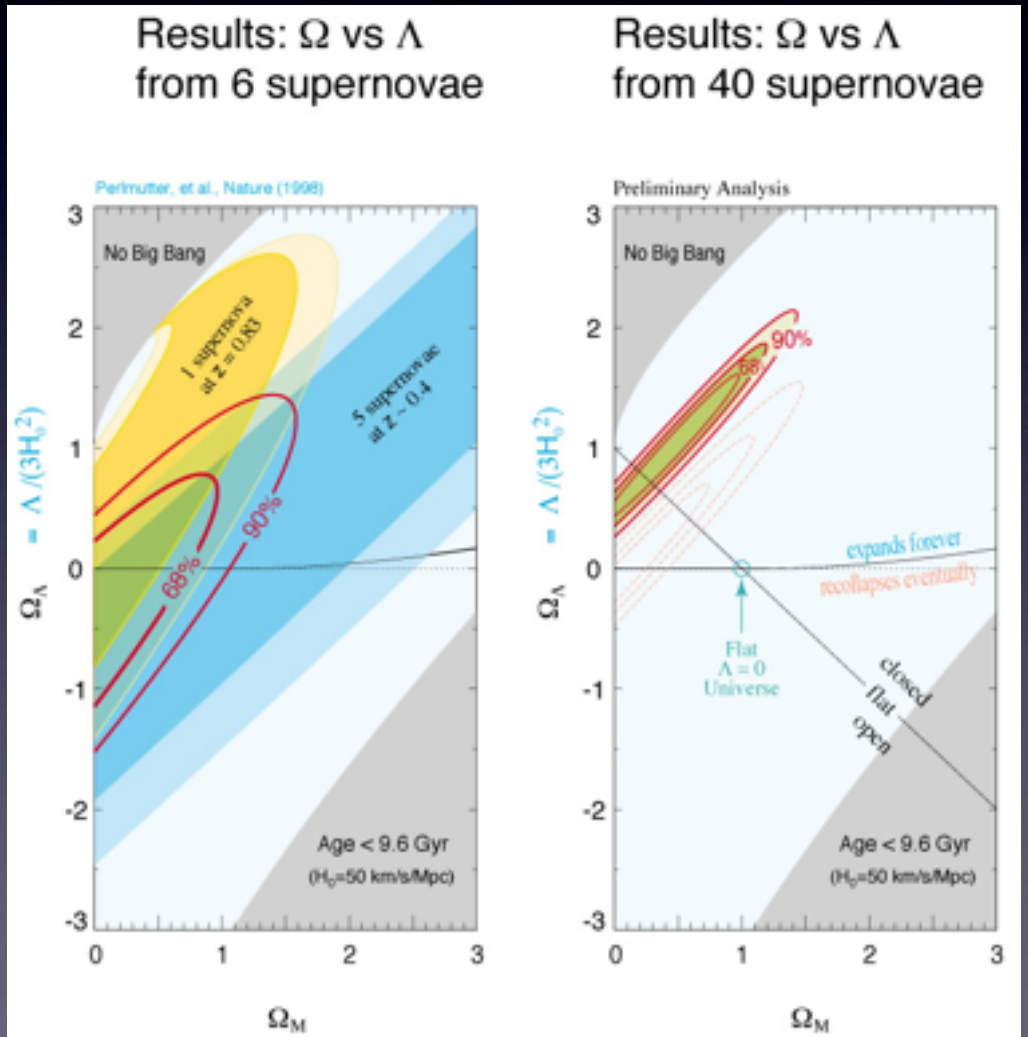
Nao Suzuki (Kavli IPMU) on behalf of transient team
Naoki Yasuda, Ichiro Takahashi, Jian Jiang, Tomoki Morokuma, Nozomu Tominaga, Masaomi Tanaka, Takashi Moriya, Masao Sako, Naoki Yoshida
NTT Team, ISM (Institute of Statistics and Math) Team, Tsukuba Team
CREST(JST) collaboration (PI Yoshida), Your Name here

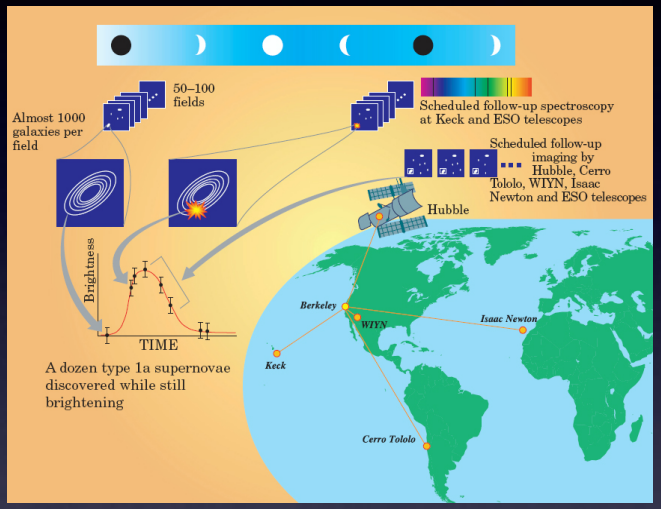
Collaborators : Supernova Cosmology Project Team
David Rubin (STScI), Nicolas Regnault (LPNHE), Pierre Astier, Marc Betoule, Peter Nugent, Saul Perlmutter, Pilar Ruiz-Lapuente

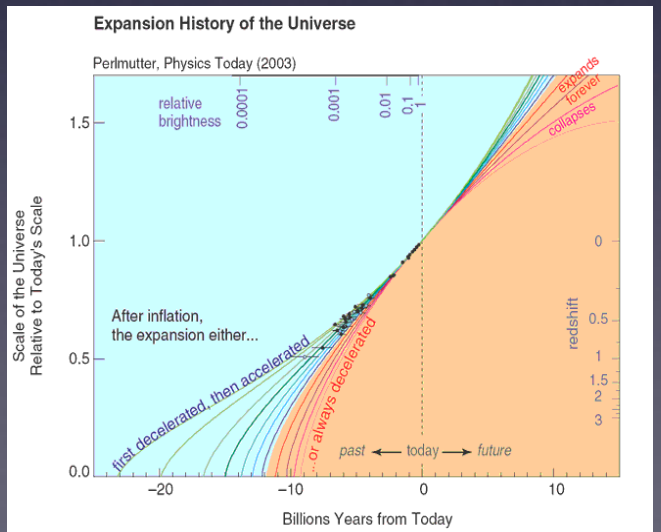




January 9th 1998
American Astronomical Society

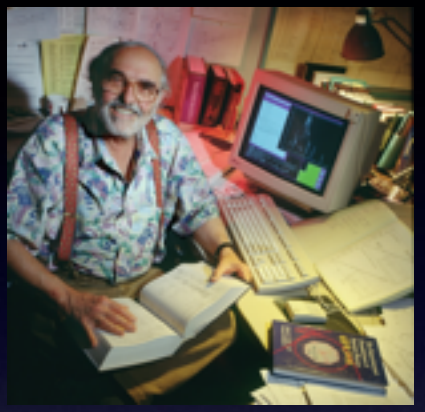


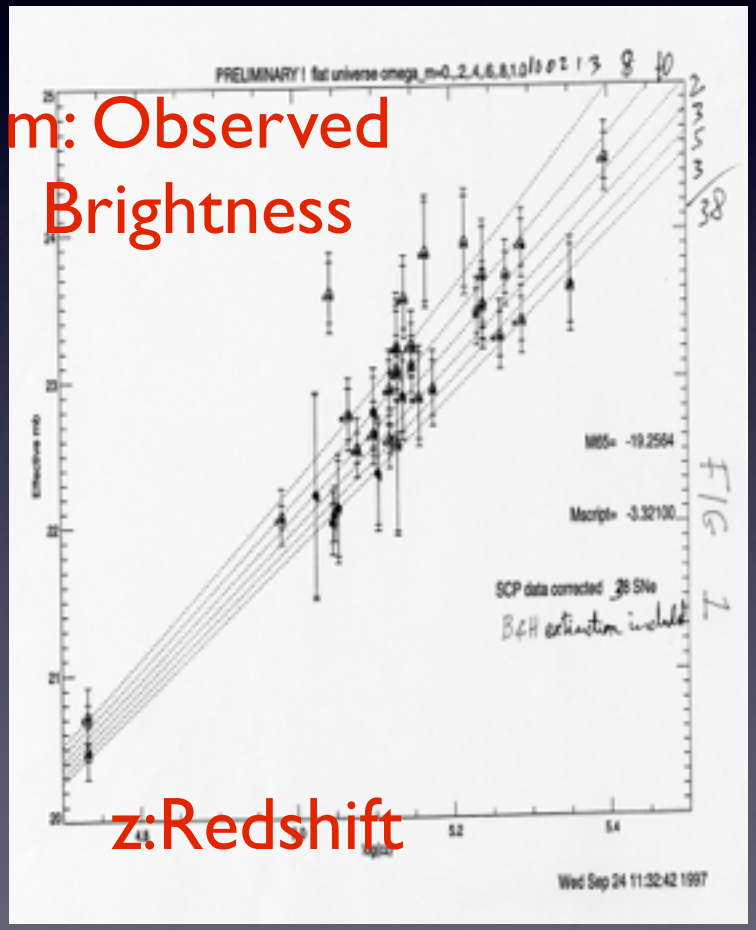




Discovery of Dark Energy (SCP 1997)

Gerson Goldhaber reported non-zero Λ on 24th in Sep '97

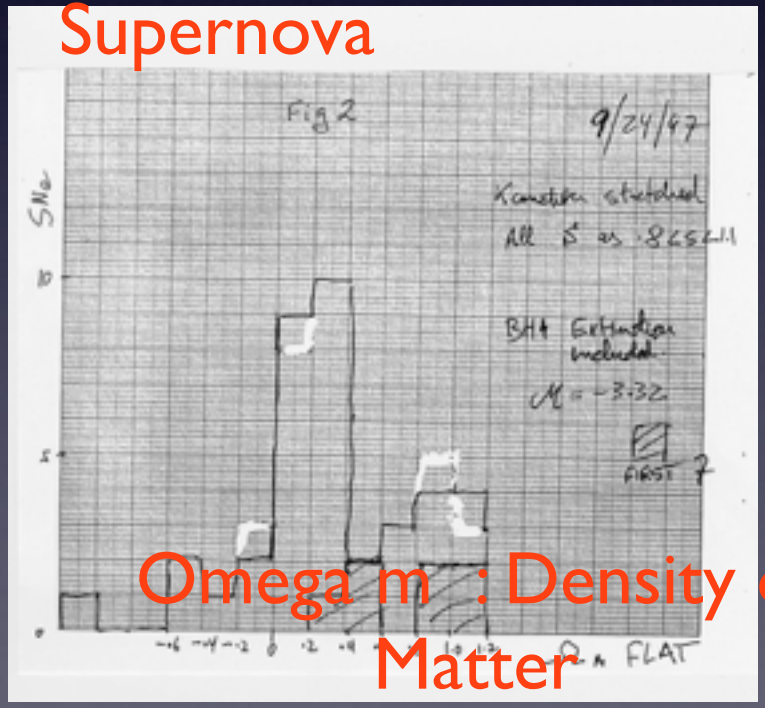




m: Observed Brightness

z:Redshift

N : Number of Supernova

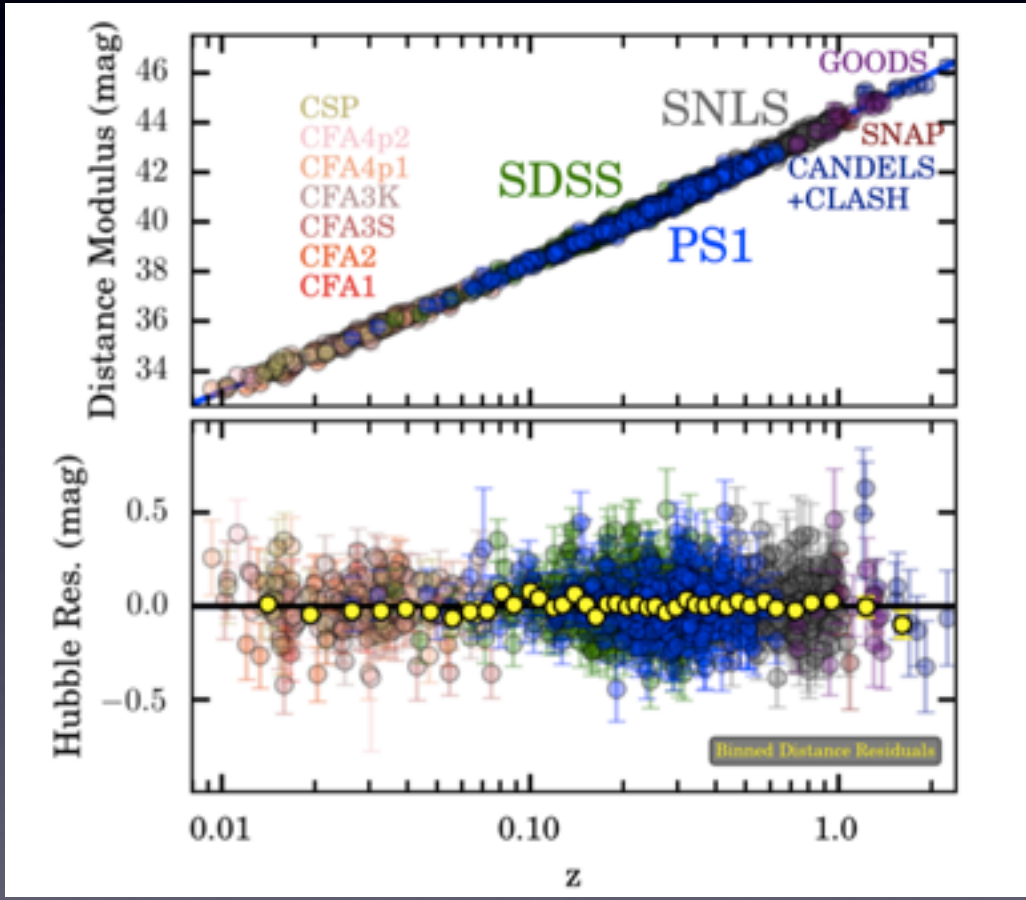


Omega m : Density of Matter

SNIa Cosmology Today

Statistical Error = 3.2%
Systematic Error = 2.4%

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



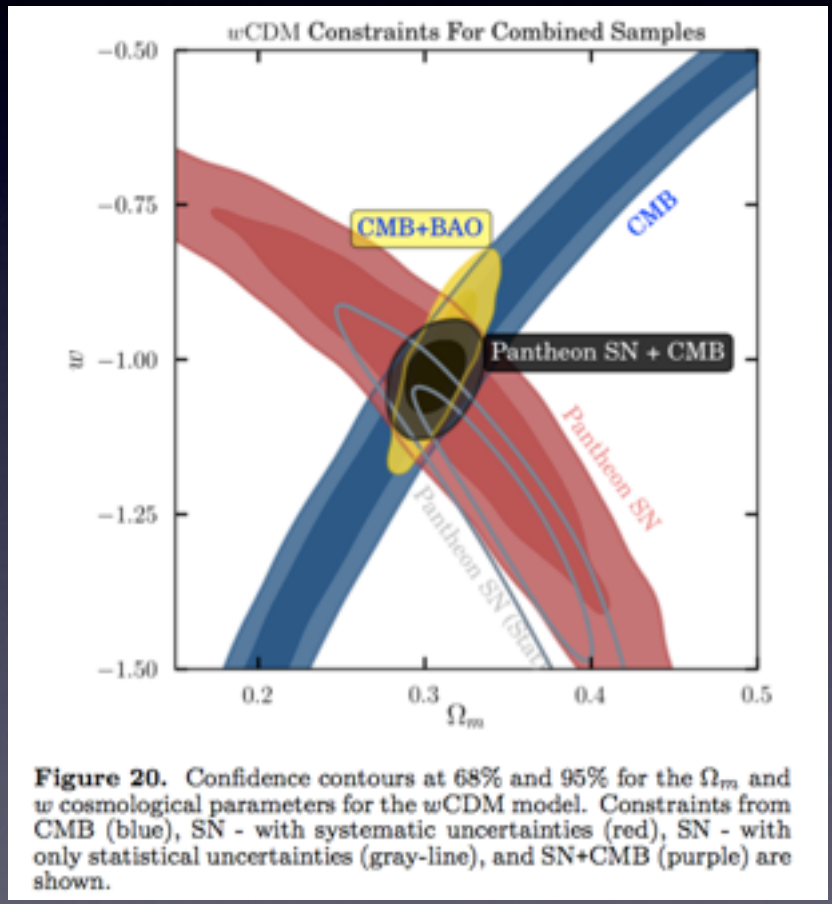


Figure 20. Confidence contours at 68% and 95% for the Ω_m and w cosmological parameters for the wCDM model. Constraints from CMB (blue), SN - with systematic uncertainties (red), SN - with only statistical uncertainties (gray-line), and SN+CMB (purple) are shown.

Scolnic et al. 2017

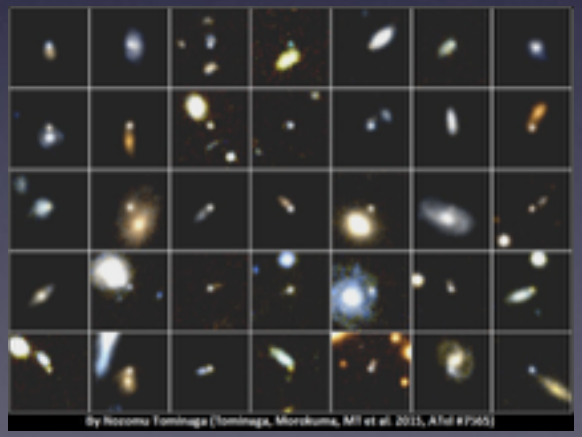
SSP Supernova Survey

Nov 2016 - Apr 2017 on COSMOS
Aug 2017 - Jan 2018 on SXDS

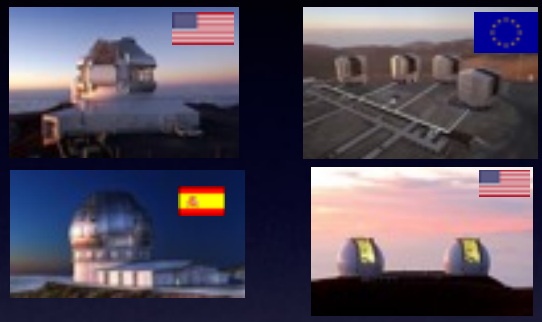
100,000 Candidates

ML Selection

HSC Imaging

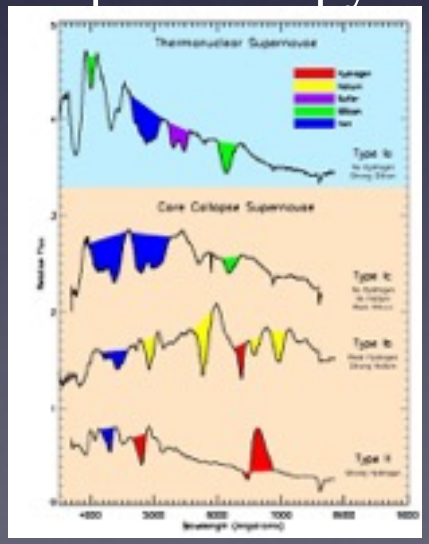


100 SN Candidates

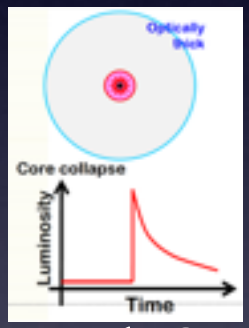


10 SN Targets

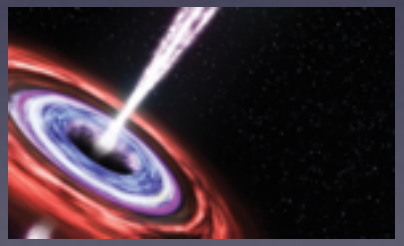
Spectroscopy



SNIa : Dark Energy



Shock Break Out / SLSN



Active Galactic Nuclei
Black Hole Science

Hubble Space Telescope(HST) Time is awarded

Cycle 24-25 (2016-2018)

First Time for Japanese Institution to win large project

Infrared Part is Observed by Hubble Space Telescope(HST)

Optical Part is Observed by Subaru (HSC)

Dear Dr. Suzuki,

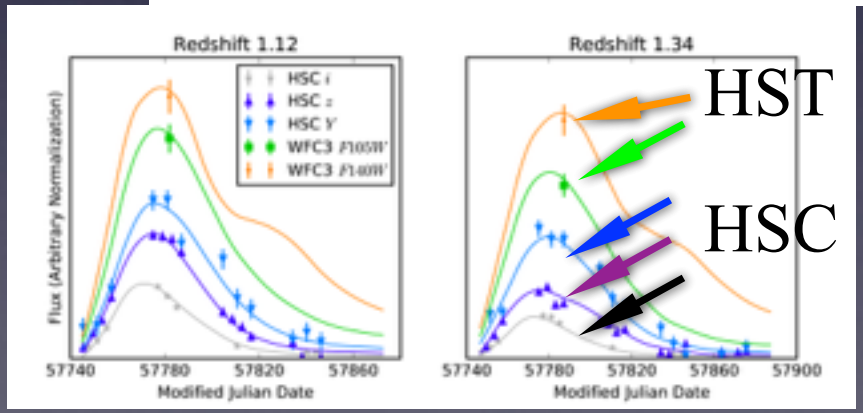
We are pleased to inform you that your Hubble Space Telescope Cycle 24 proposal

Title: SUbaru Supernovae with Hubble Infrared (SUSHI)
ID: 14808

has been approved for Hubble Space Telescope Cycle 24 General Observer time, following detailed consideration by the Cycle 24 Peer Review Panels and final review by the STScI Director. Your proposal was graded in the first quintile of proposals in your Panel, with the first quintile being the top proposals before the panel.

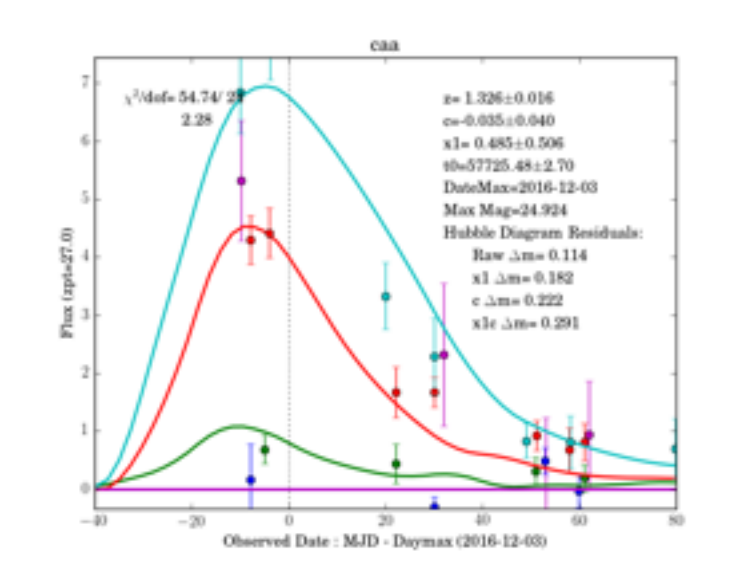
The allocations approved for your program in Phase I are:

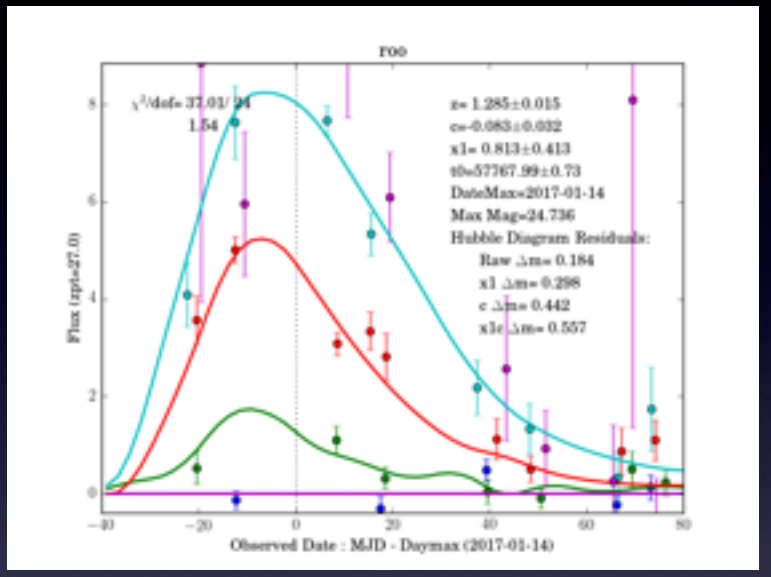
46 Primary Spacecraft Orbits in Cycle 24
50 Primary Spacecraft Orbits in Cycle 25

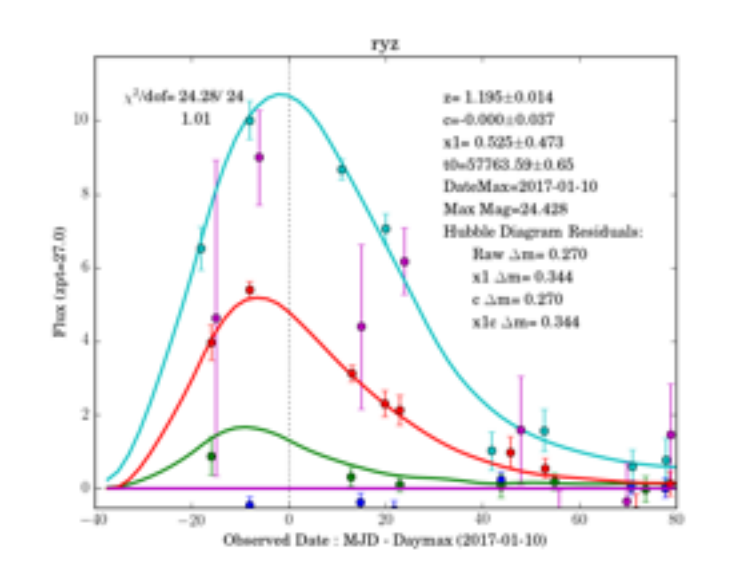


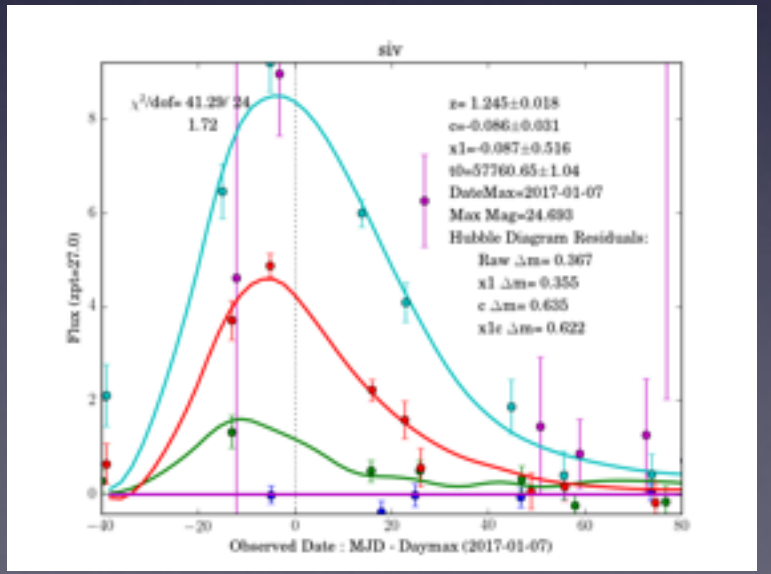
Strengths: This was a very highly ranked proposal among all the Large Proposals, and very well written. The scientific argument for obtaining more Type Ia supernovae at higher redshifts to improve the dark energy figure-of-merit is carefully crafted and compelling. This project is a key part of the Subaru telescope search, and both the search and ground-based follow-up for spectra are well documented and convincing. The idea of finding the supernovae from the ground and obtaining optical (observed frame) light curves that characterize the light curve shape, while getting a few near-ir (observed frame) points with HST to anchor the light curves in rest frame passbands that have been shown to be standard candles, is a technique that the supernova cosmology community has recently developed as an excellent way to find and measure supernovae in the most efficient manner. It is important that more than one team find and characterize distant Type Ia supernovae, and this rather modest proposal relative to the scientific impact makes a strong case for this approach and for the team's ability to arrive at their goals.

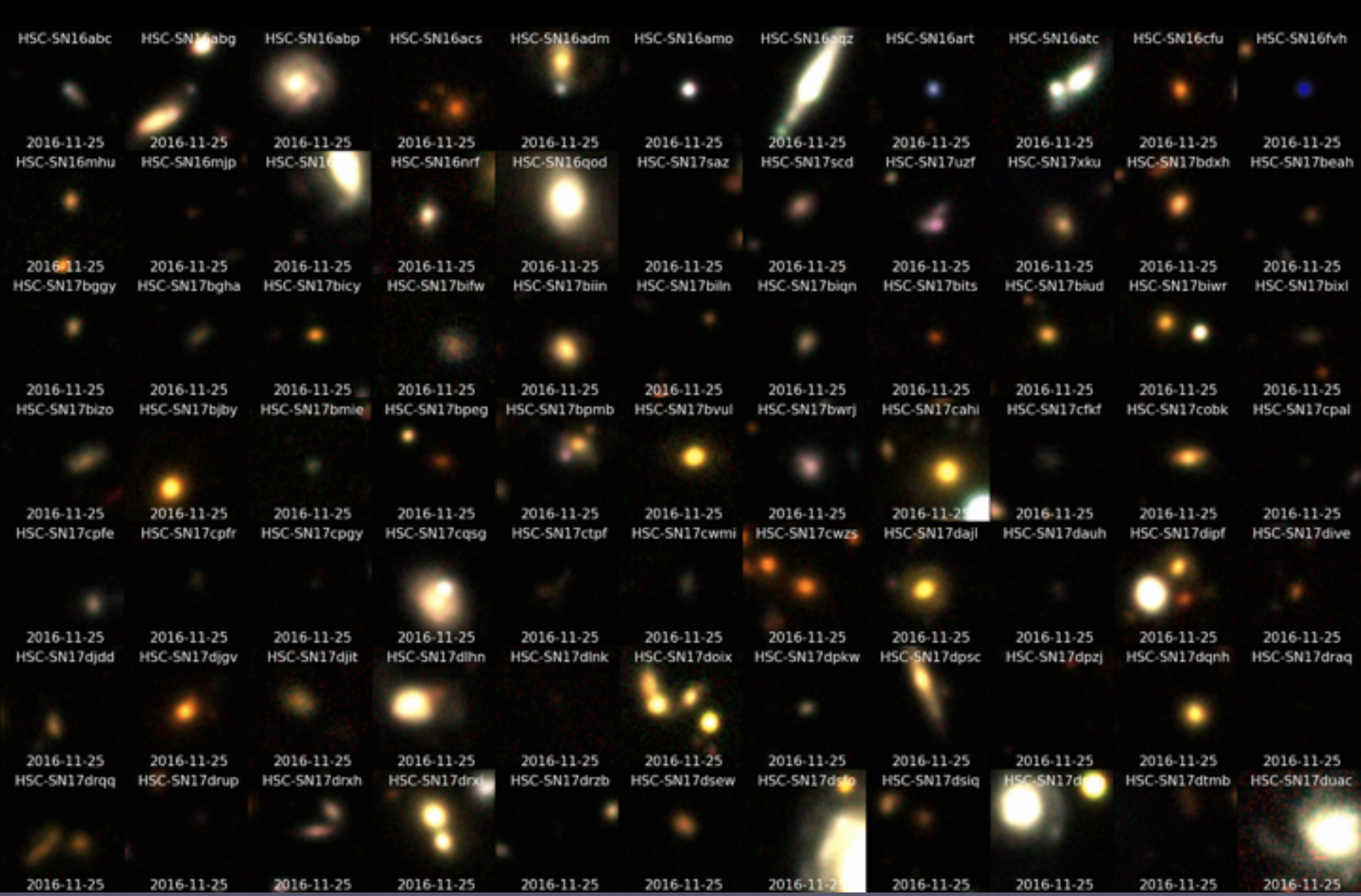
HSC discovered 26 SNeIa (1st season) observed by Hubble Space Telescope









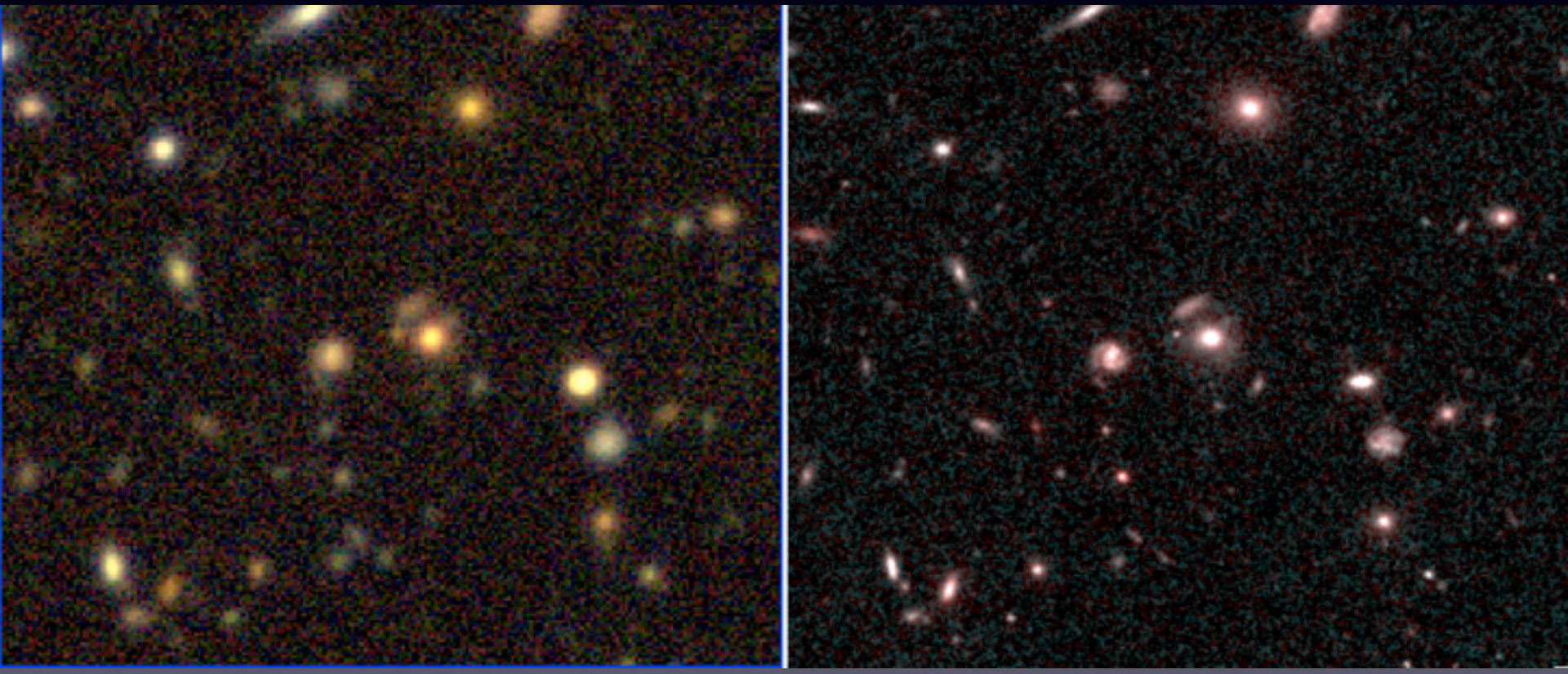


Credit : Takahashi, Tominaga, Tanaka, Yasuda + Transient Team

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

Subaru/HSC (Optical)

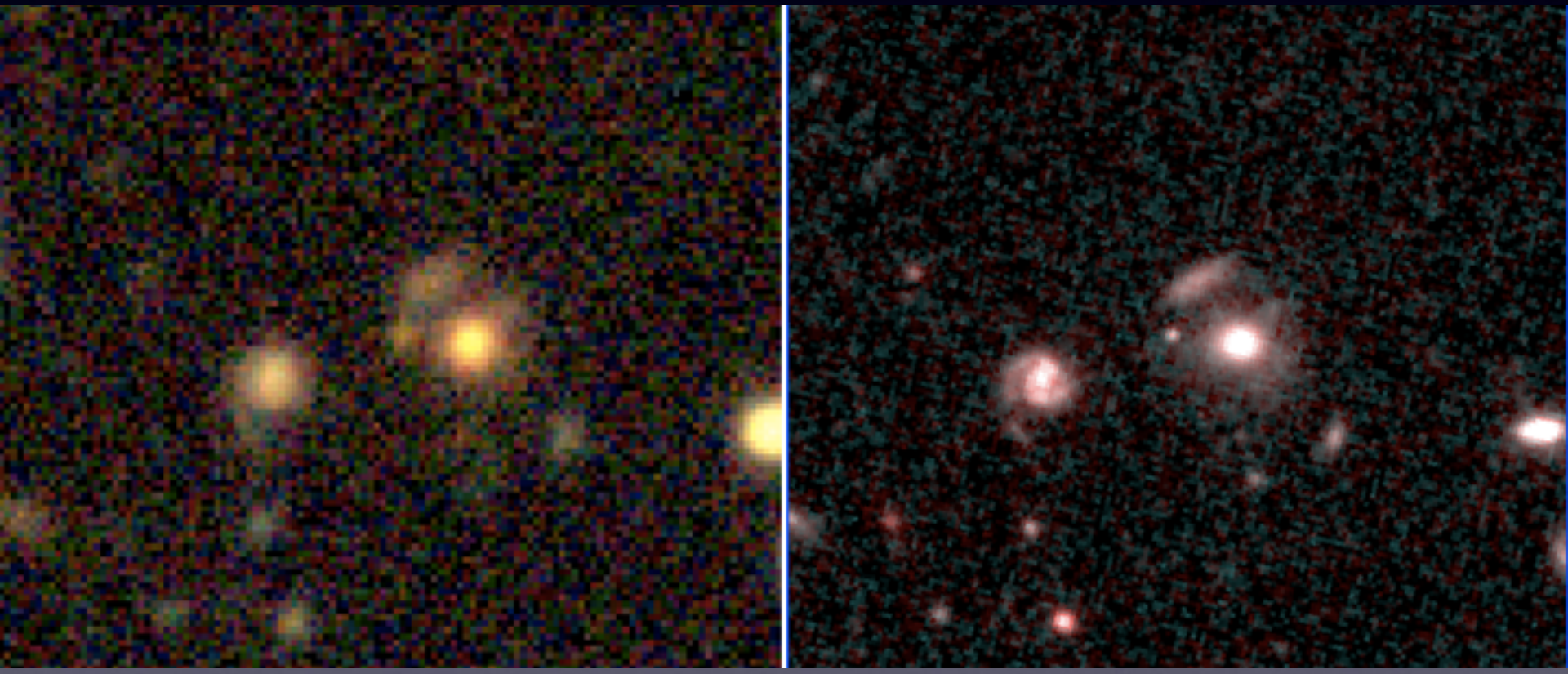
Hubble Space Telescope (IR)



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

Subaru/HSC (Optical)

Hubble Space Telescope (IR)

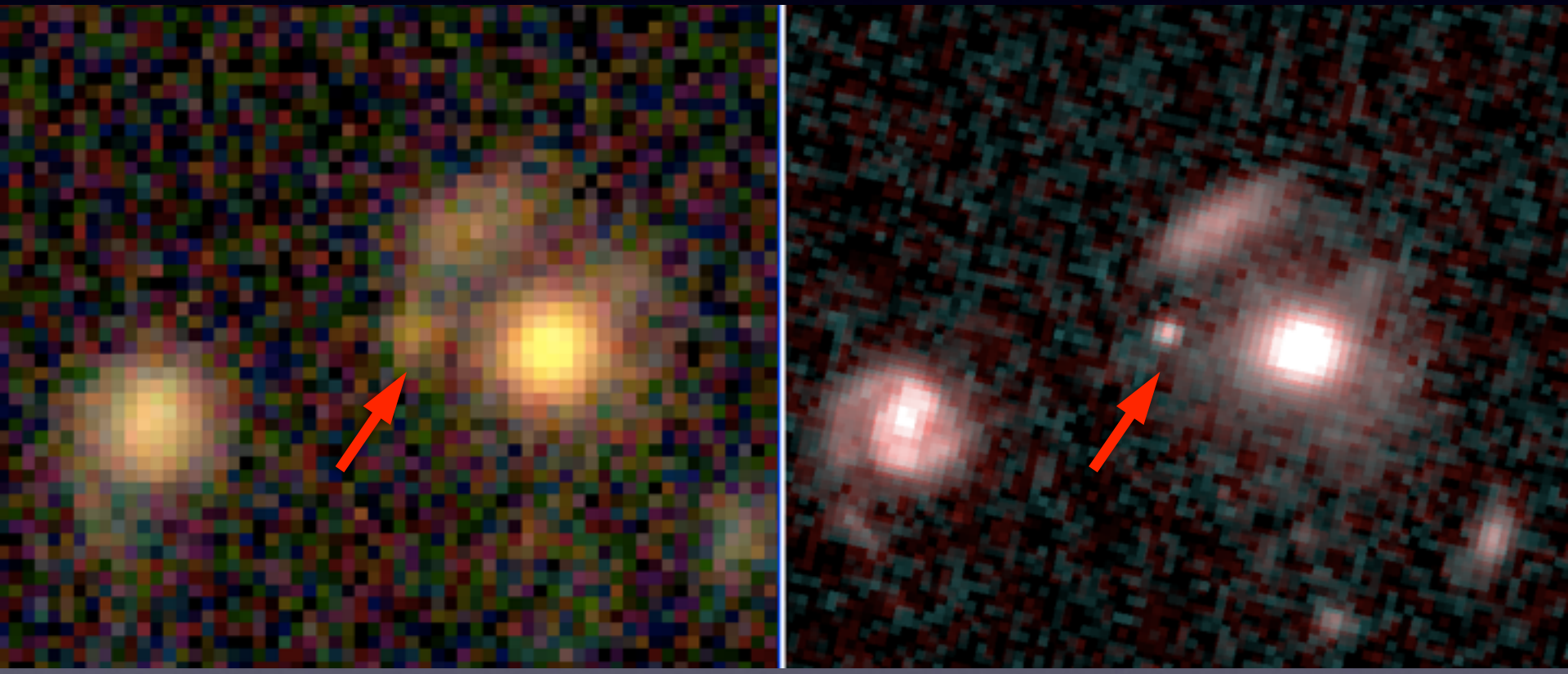


HSC: r2, i2,z vs HST WFC3 : F105(J), F140(H)

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

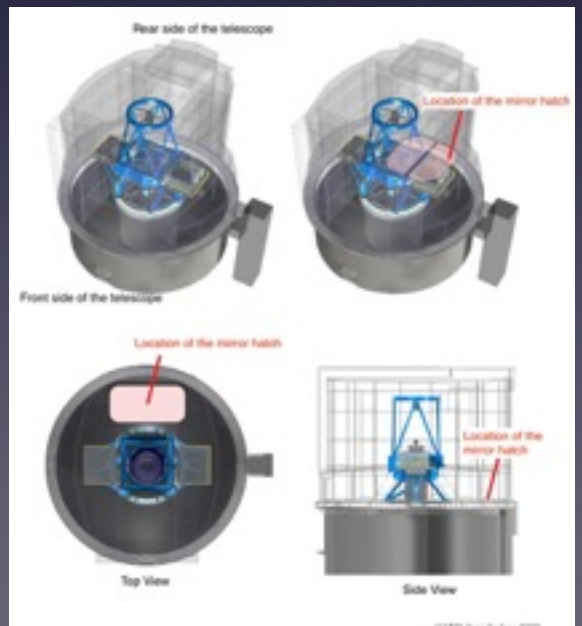
Bad News: Broken Hatch SXDS 2017-18 is cancelled

Intensive Proposal being submitted : COSMOS Survey Again

Data will be shared immediately with SSP team

with 20 half/quarter nights = 10 nights

- HSC SXDS (Aug ’17 - Jan ’18) : cancelled
- Hubble Space Telescope Time cannot be rescheduled
- VLT / GTC time has already allocated



Fixing Hatch : Jun, July

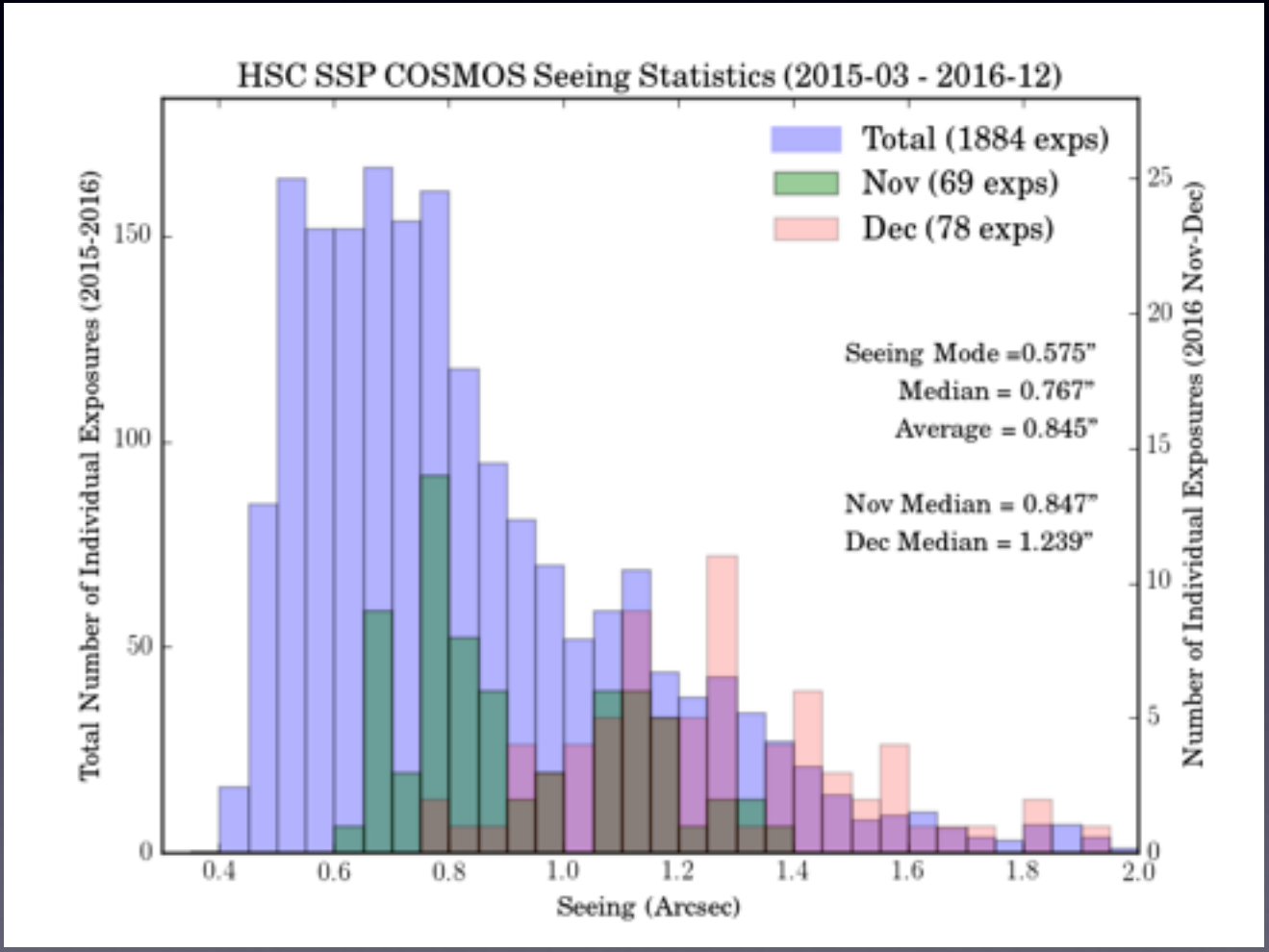
Mirror Re-alminization : Oct-Dec

Why COSMOS again?

HSC survey suffered Winter Storm at Mauna Kea

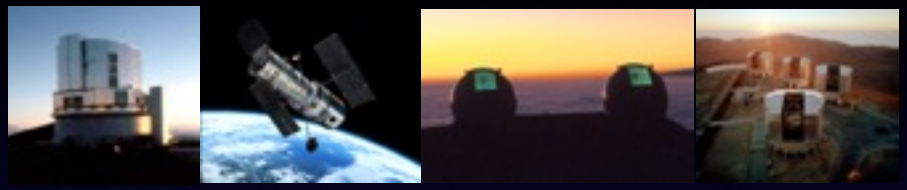
Ongoing SSP program does reach the depth originally planned (80%)

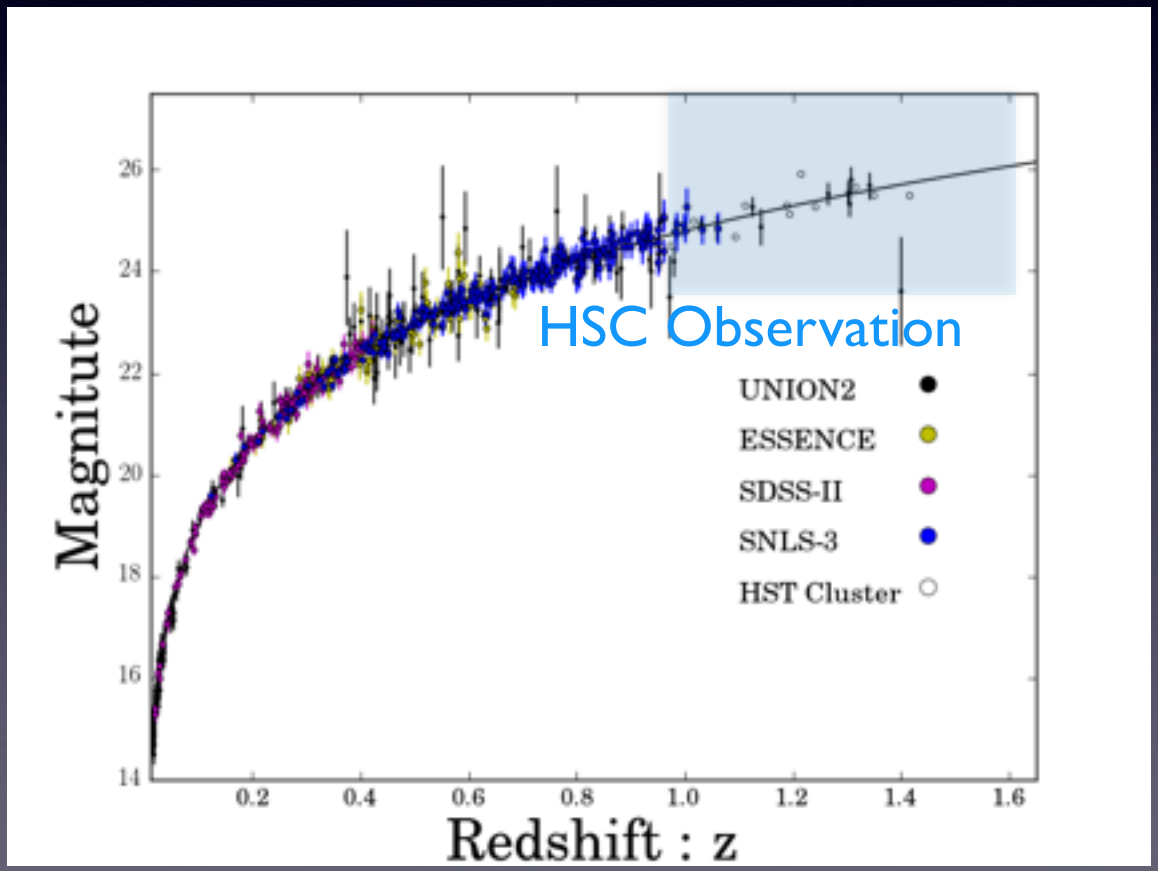
We will share our data immediately with SSP/HSC team



Hyper-Suprime Cam Supernova Survey
Supernova Observations 1990-2015

Subaru HST Keck VLT

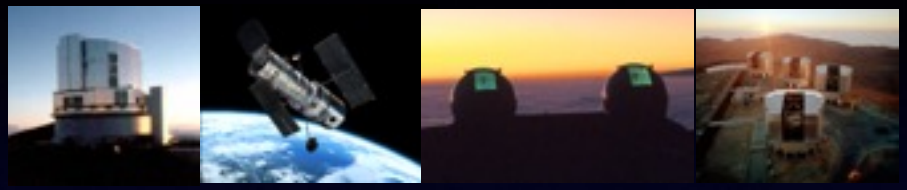


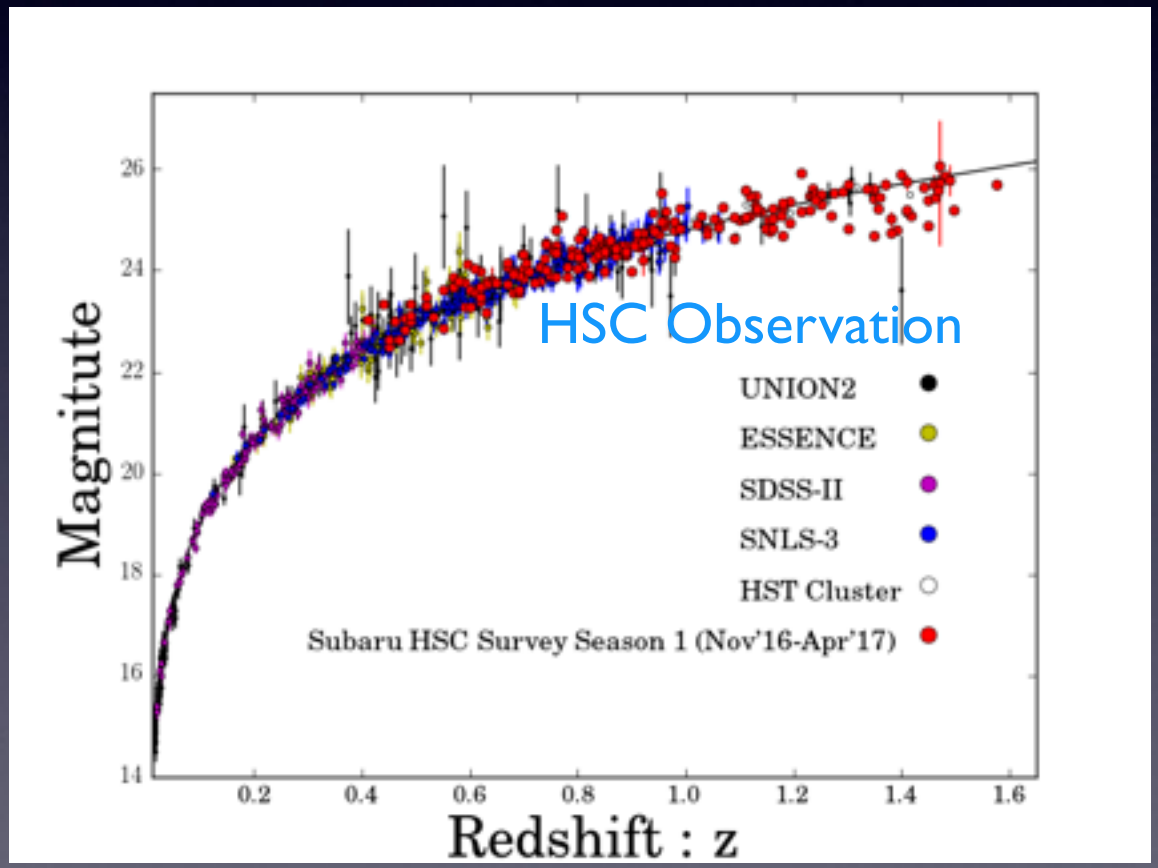


- Since its discovery in 1997, nearly 1000 supernovae are observed for dark energy
- Subaru Telescope (Hawaii) deployed the largest digital camera named Hyper Supreme Cam (HSC)
- We aim to observe the most distant supernovae with HSC and Hubble Space Telescope

Hyper-Suprime Cam Supernova Survey
Season I : Nov ’16 - Apr ‘17

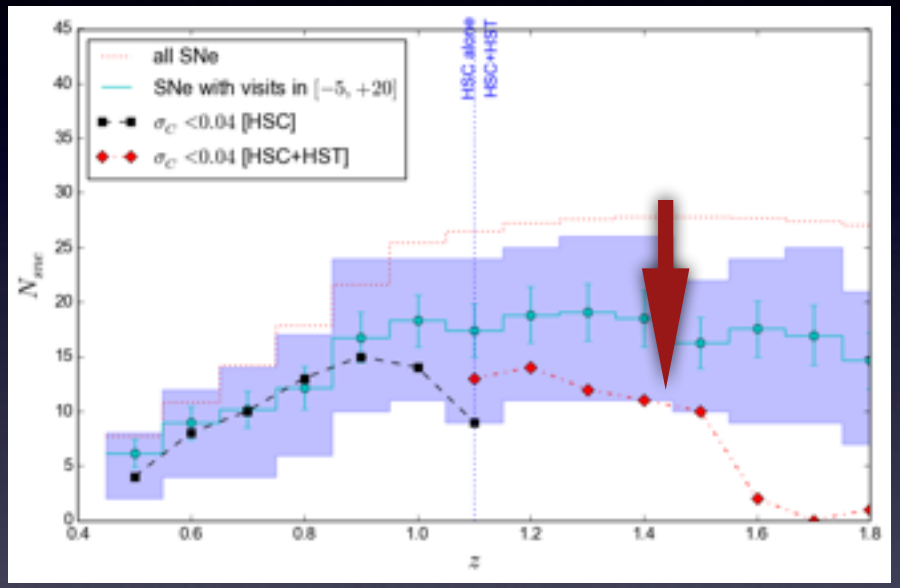
Subaru HST Keck VLT

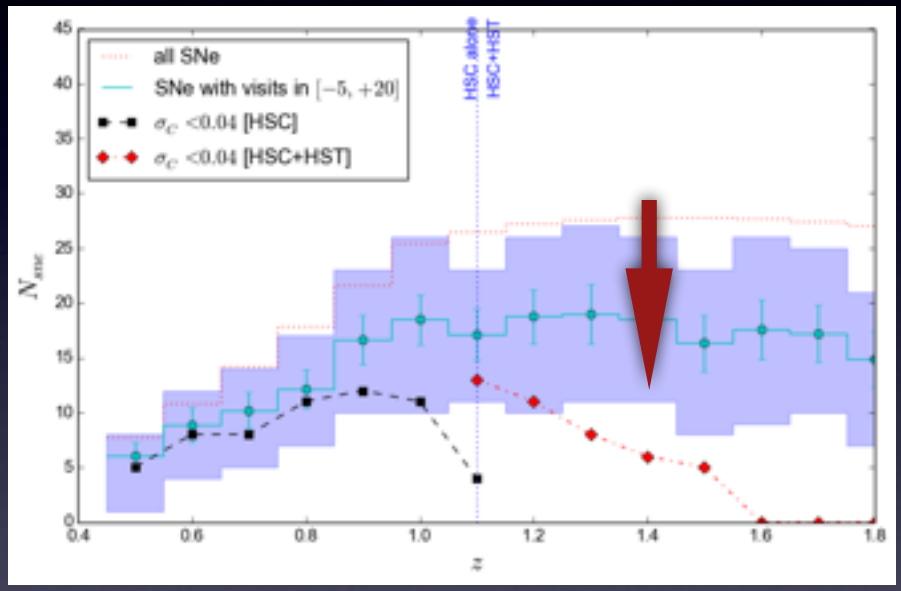




- We successfully observed more than 300 supernovae candidates
- Best Supernovae are selected through machine learning from 60,000 potential detections
- Large Telescopes and Space Telescope are conducting follow-up observations for HSC discovered supernovae

Number Estimates
before and after mirror realminization





After

Before

We aim to have higher redshift (1.2< z < 1.4)
1 hour Exp on i-band, 3 hour Exp on z-band / Epoch

Dec 2017 : Resuming HSC

Schedule for December 2017

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					Dec 01	Dec 02 ○
					Telescope Down Time (Recoating)	
Dec 03	Dec 04	Dec 05	Dec 06	Dec 07	Dec 08	Dec 09
Telescope Down Time (Recoating)						
Dec 10 ◑	Dec 11	Dec 12	Dec 13	Dec 14	Dec 15	Dec 16
Telescope Down Time (Recoating)				Eng Telescope	Keck Brown HSC	S17B-044 Yoshida HSC
				S17B-055I Suzuki HSC	Queue HSC	S16B-001I Inoue HSC
Dec 17 ●	Dec 18	Dec 19	Dec 20	Dec 21	Dec 22	Dec 23
S17B-044 Yoshida HSC	UH-18A Tholen HSC	UH-18A (Cancelled) [Winter Storm] Tholen HSC	UH-18A (Cencelled) [Winter Storm] Tholen HSC	UH-18A (Cancelled) [Snow] Tholen HSC	Gemini (Cencelled) [Snow] Sheppard HSC	Gemini Carlin HSC
S16B-001I Inoue HSC	S16B-001I Inoue HSC	S17B-055I (Cancelled) [Winter Storm] Suzuki HSC	UH-21A2 (Cancelled) [Winter Storm] Sanders HSC	UH-21A2 (Cancelled) [Snow] Sanders HSC	UH-21A2 (Cancelled) [Snow] Sanders HSC	
Dec 24	Dec 25 ◐	Dec 26	Dec 27	Dec 28	Dec 29	Dec 30
Gemini Carlin HSC	Queue (Cancelled) [Instrument] HSC	Eng HSC	Eng Telescope	S17B-140 Koptelova FOCAS	S17B-068 Katsuda FOCAS	S17B-068 Katsuda FOCAS
	S17B-055I (Cancelled) [Instrument] Suzuki HSC	Queue HSC	S17B-001 Misawa FOCAS	S17B-022 [ToO] M. Tanaka FOCAS	S17B-001 Misawa FOCAS	S17B-001 Misawa FOCAS

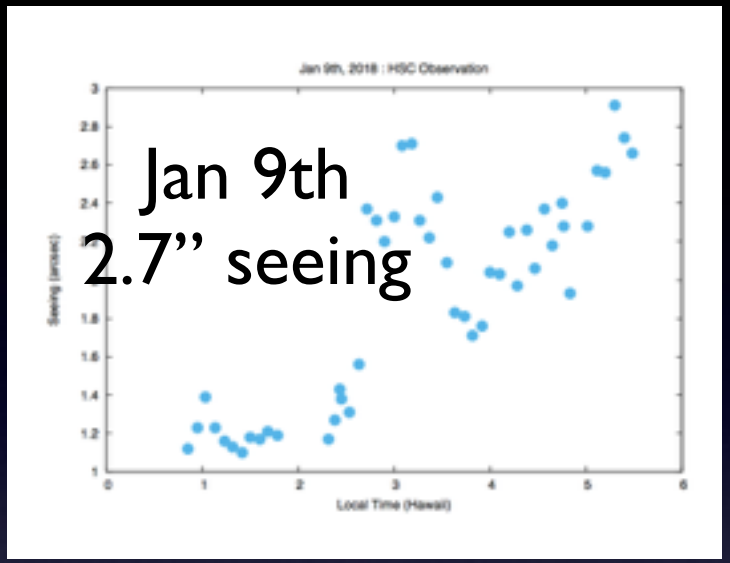
6 nights were lost:

4 nights : Weather
2 nights : Technical Problem

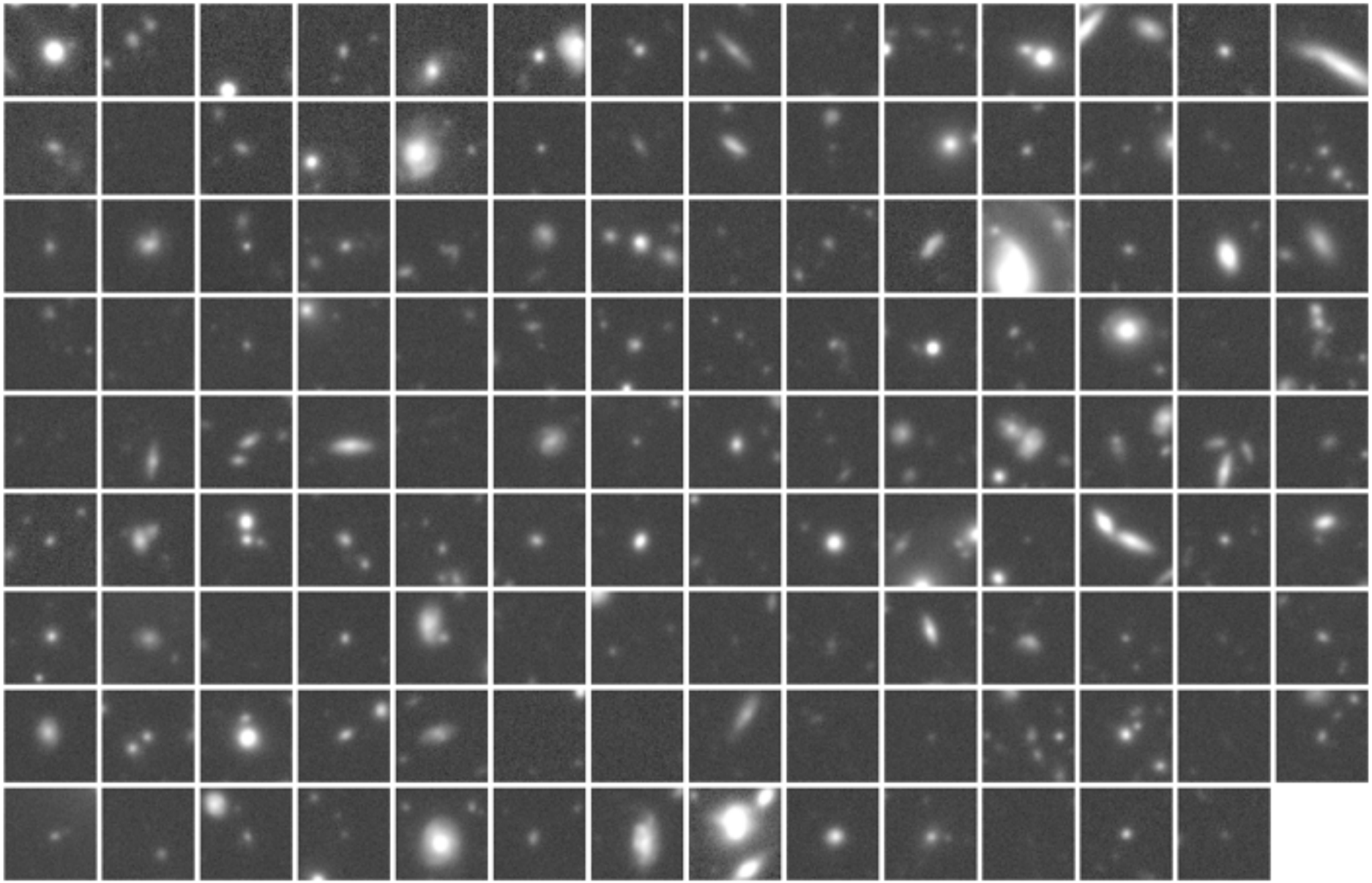
Jan 2018 : Jan 9 =2.7”, Jan 12=1.4” Seeing

Schedule for January 2018

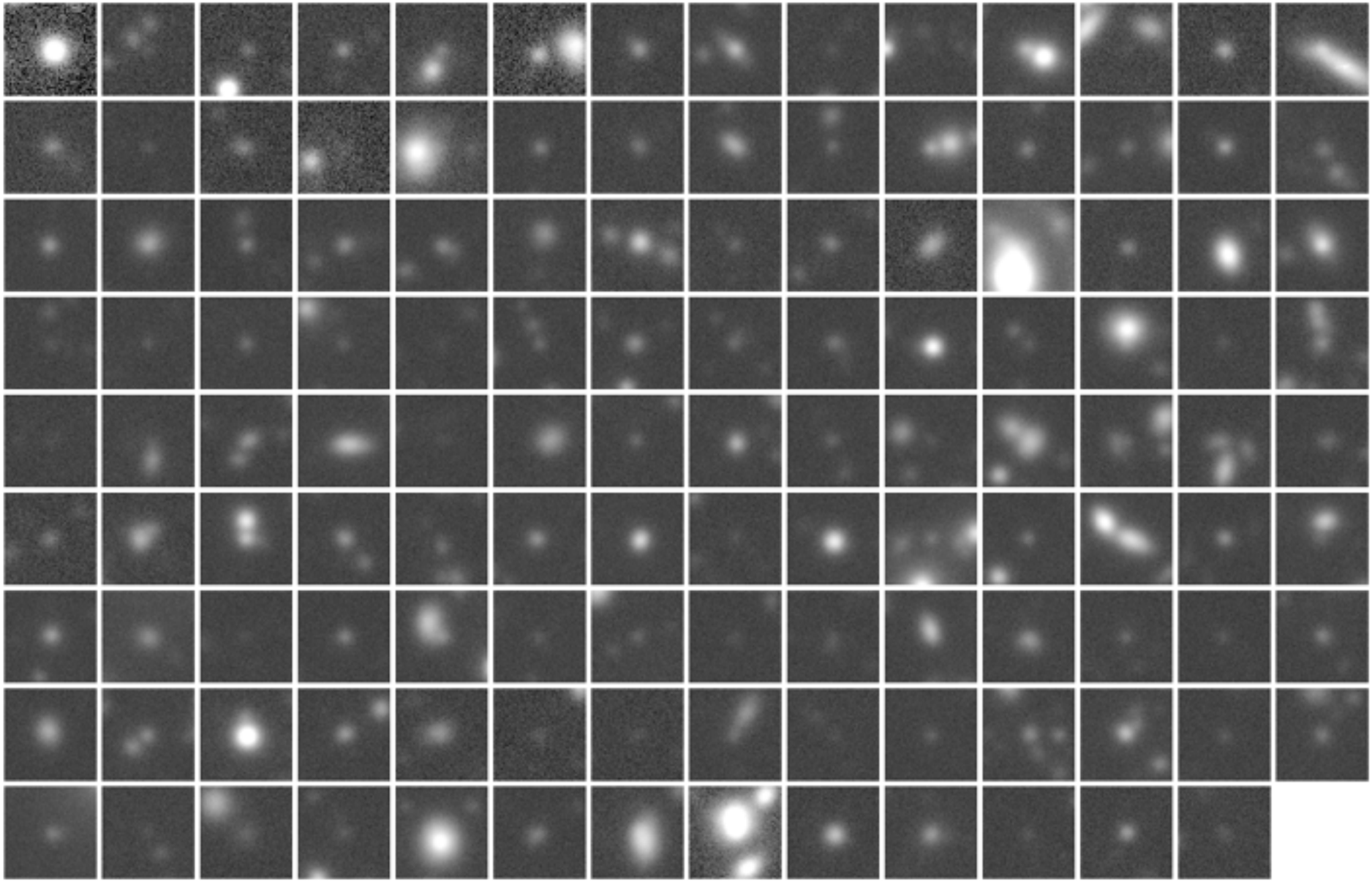
Sun	Mon	Tue	Wed	Thu	Fri	Sat
	Jan 01	Jan 02	Jan 03	Jan 04	Jan 05	Jan 06
	Obs FOCAS Obs FOCAS	S17B-002 Kodama MOIRCS		S17B-002 Kodama MOIRCS	S17B-130 Kotani CHARIS+SCExAO	UH-07B Hodapp CHARIS+SCExAO S17B-130 Kotani CHARIS+SCExAO
Jan 07	Jan 08	Jan 09	Jan 10	Jan 11	Jan 12	Jan 13
UH-07B Hodapp CHARIS+SCExAO Taiken Kikaku (1hr)/Obs HDS	SSP HSC Eng/Queue HSC	SSP HSC S17B-055I Suzuki HSC	Queue HSC	SSP HSC Queue HSC	Queue HSC S17B-055I Suzuki HSC	SSP HSC
Jan 14	Jan 15	Jan 16	Jan 17	Jan 18	Jan 19	Jan 20
UH-18B Tholen HSC	UH-18B Tholen HSC	S17B-116 [ToO] Y. Tanaka HSC SSP HSC	S16B-001I Inoue HSC	S16B-001I Inoue HSC	S16B-001I Inoue HSC	SSP HSC
Jan 21	Jan 22	Jan 23	Jan 24	Jan 25	Jan 26	Jan 27
S17B-044 Yoshida HSC Queue HSC	Keck Prochaska HSC S17B-055I Suzuki HSC	Eng/Queue HSC SSP HSC	UH-28A Goebel CHARIS+SCExAO S16A-119I Aoki HDS	S17B-093 Currie CHARIS+SCExAO S16A-119I Aoki HDS	S16A-119I Aoki HDS	S16A-119I Aoki HDS Obs IRCS+AO188(LGS)
Jan 28	Jan 29	Jan 30	Jan 31			
Keck Melis COMICS	S17B-092 Takagi IRCS+AO188(LGS)					



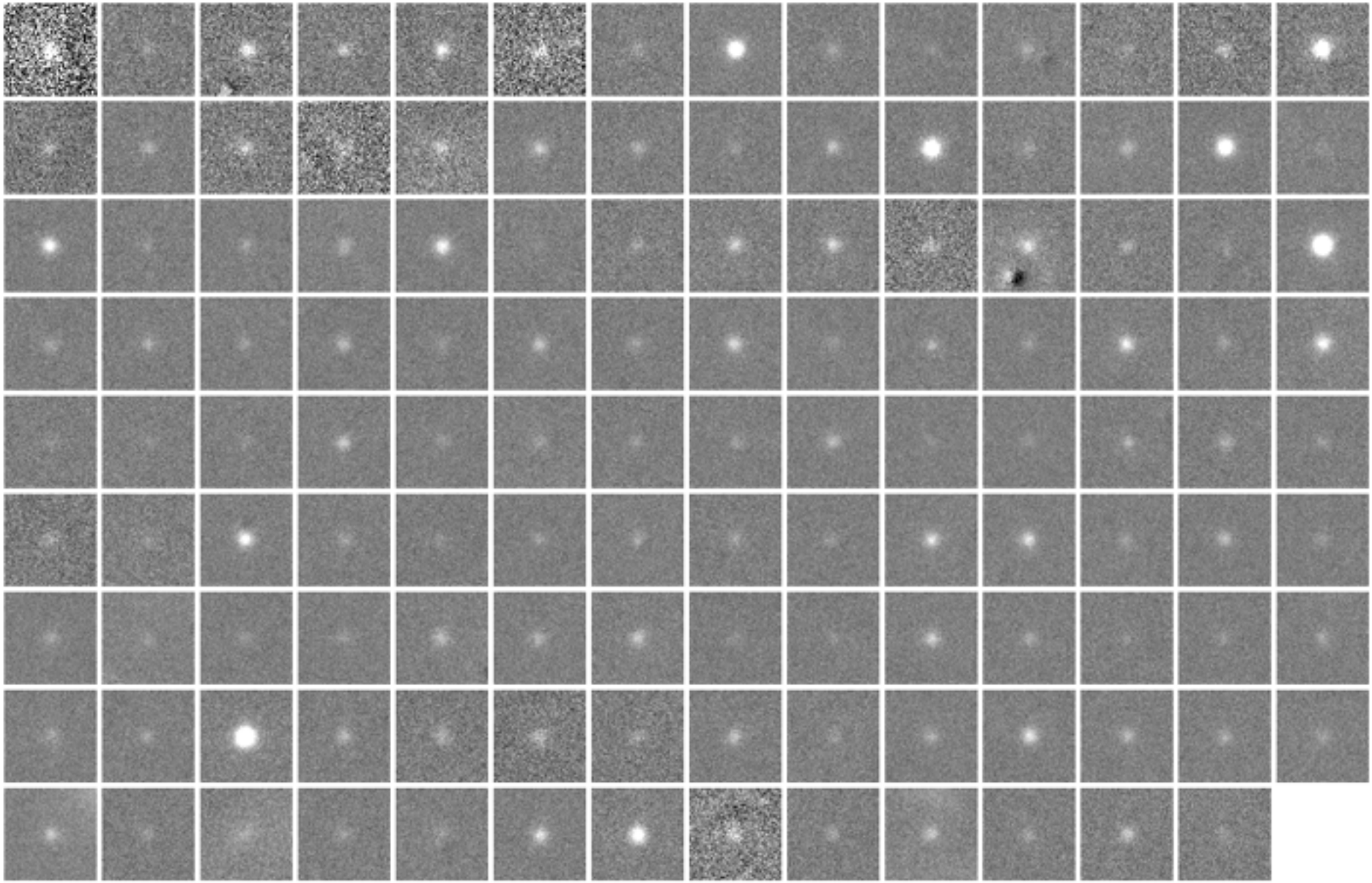
Keck LRIS Run Jan 14 & 15



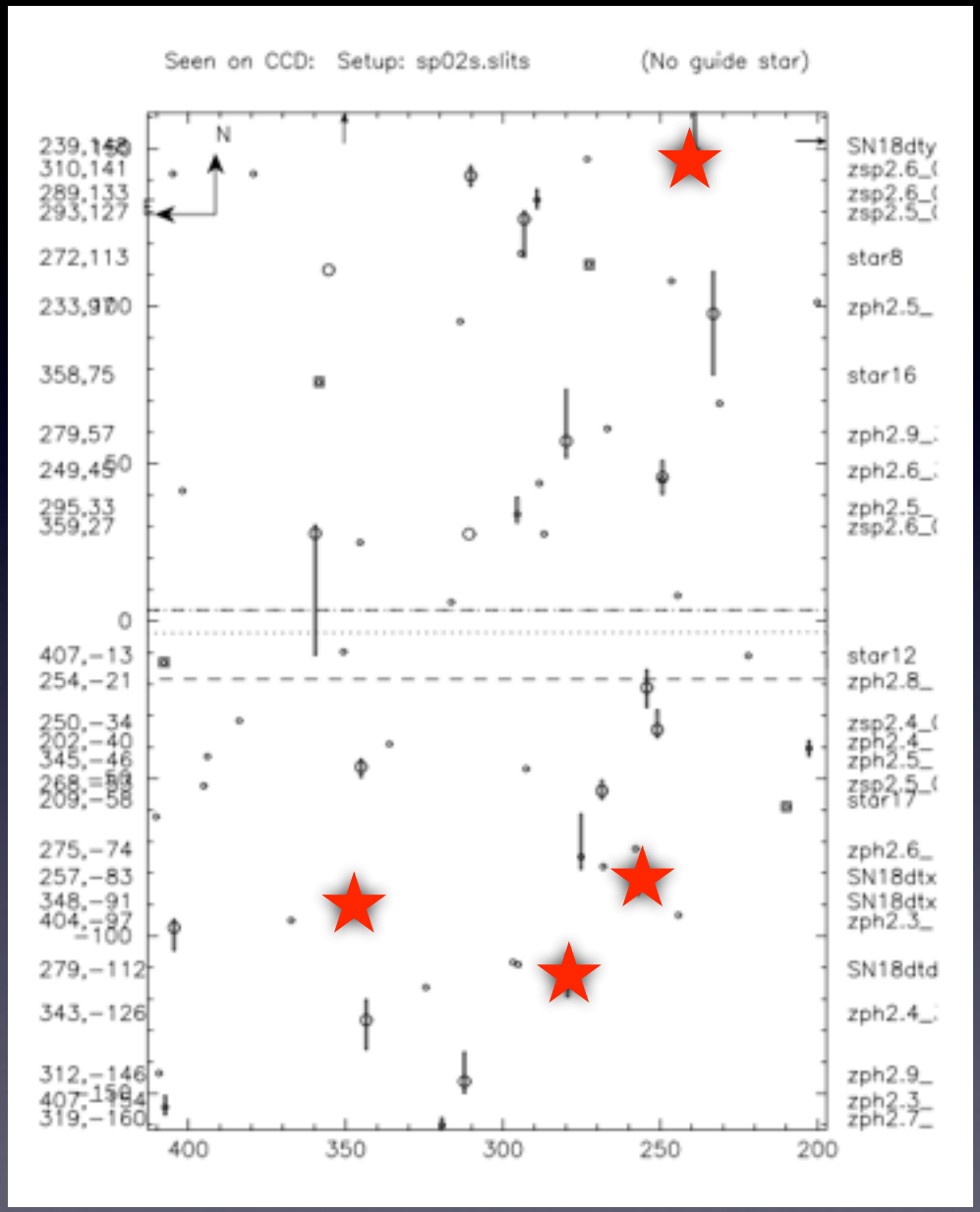
Reference



Jan 12th 2018 New Image

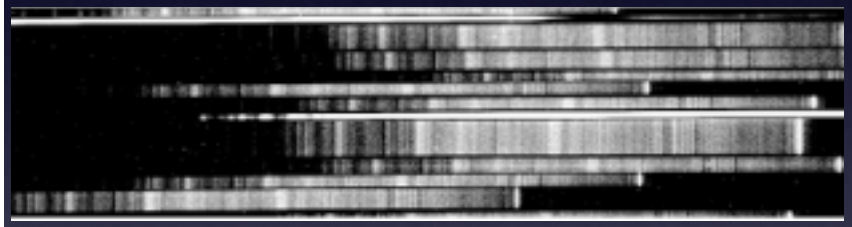


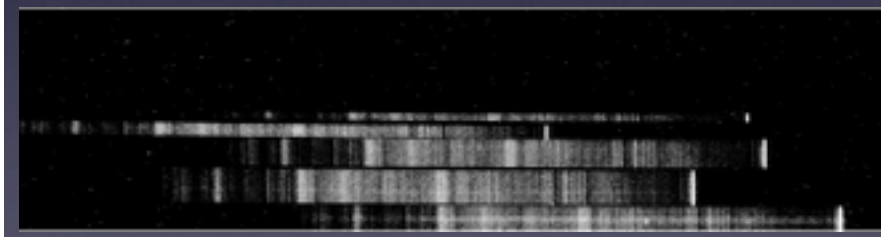
Jan 12th 2018 Subtracted Image



4 Supernovae
in One LRIS Mask!

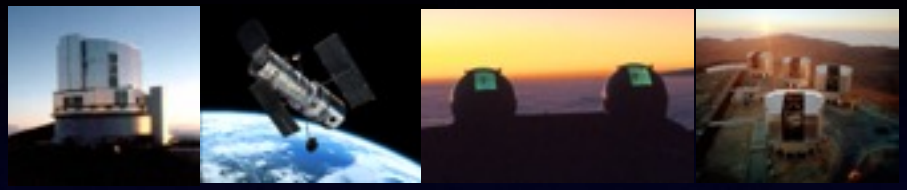
HSC Jan 9th 12th
Keck/LRIS Jan 14th 15th

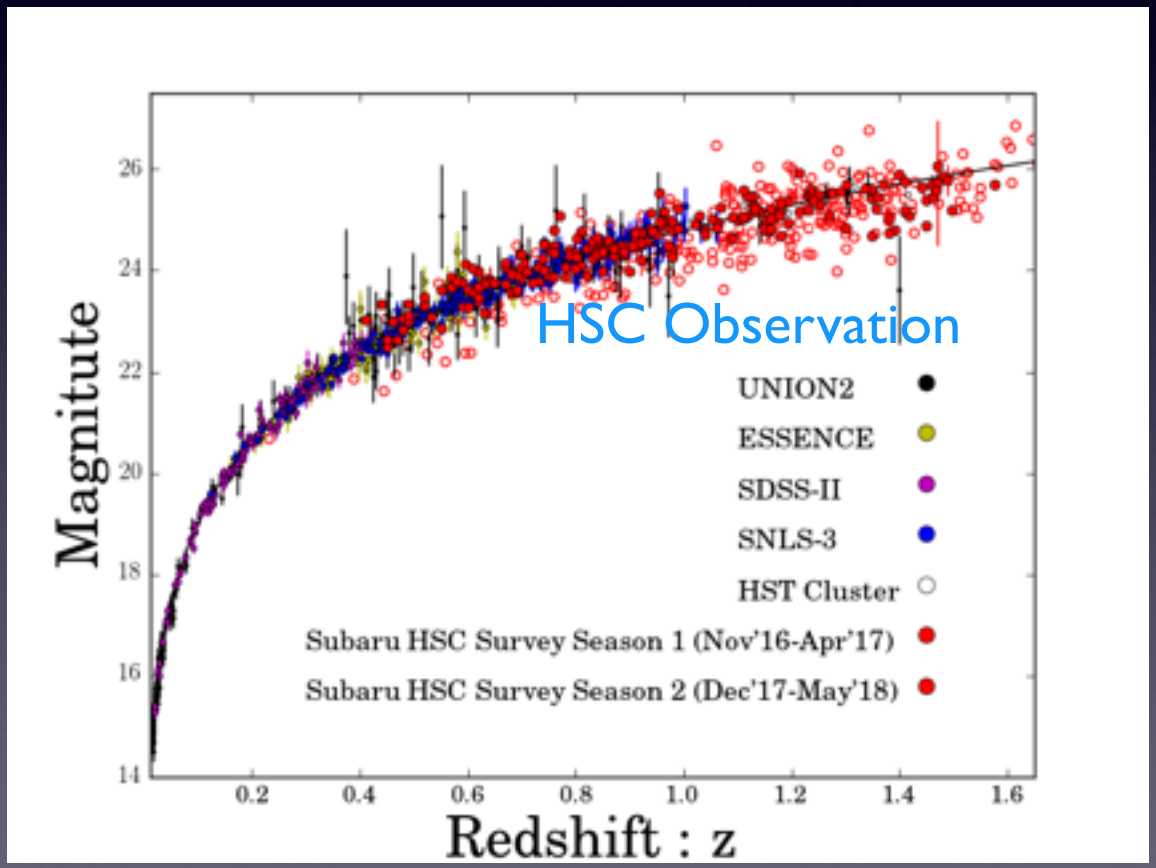




Hyper-Suprime Cam Supernova Survey Season II : Nov ’17 - May ‘18

Subaru HST Keck VLT

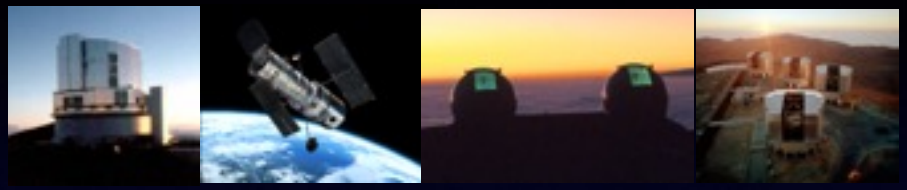


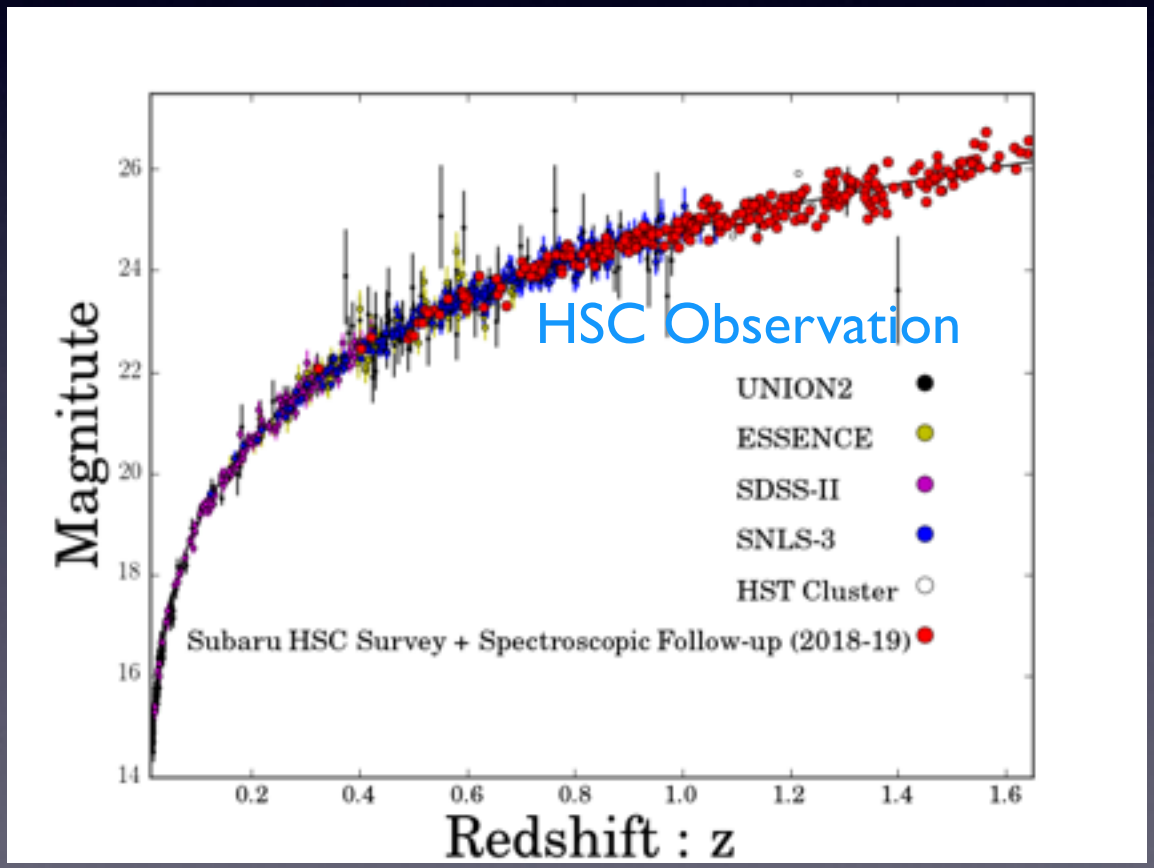


- For Season II, we aim to double the number of supernovae
- We aim to triple the exposure time and survey deeper space
- Large Telescope (Keck, VLT, Gemini and Hubble Space Telescope) in the world will follow-up our Supernovae

Hyper-Suprime Cam Supernova Survey
Season III : 2018-19 Spectroscopic Follow-up

Subaru HST Keck VLT





- We will need spectra of supernova host galaxies for precise measurement of the distances
- Subaru Telescope deploys a new instrument called PFS, it will tighten the measurement of distances
- We continue to work with large telescopes for spectroscopic follow-up

Spectroscopic Follow-up (Live Supernova & Host Galaxy)

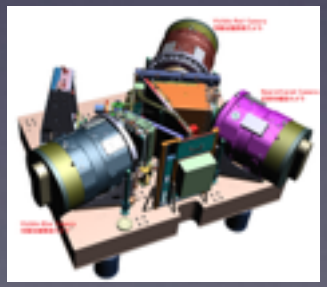
- Spectroscopic Follow-up by AAT Omega (2deg) with 400 fibers
- Keck, Gemini, VLT, GTC, Subaru/FOCAS

Subaru

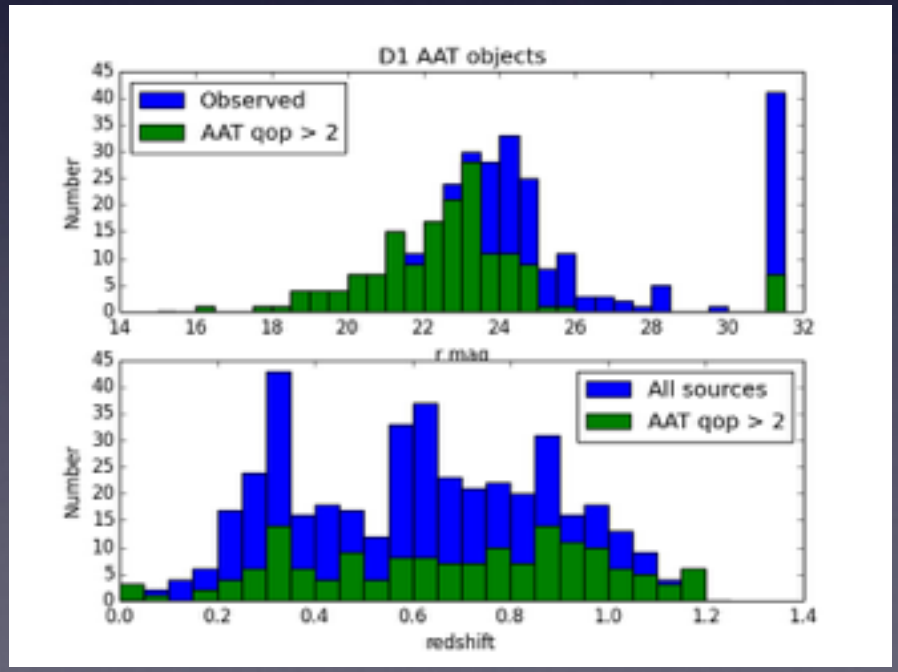
AAT Omega

WFIRST

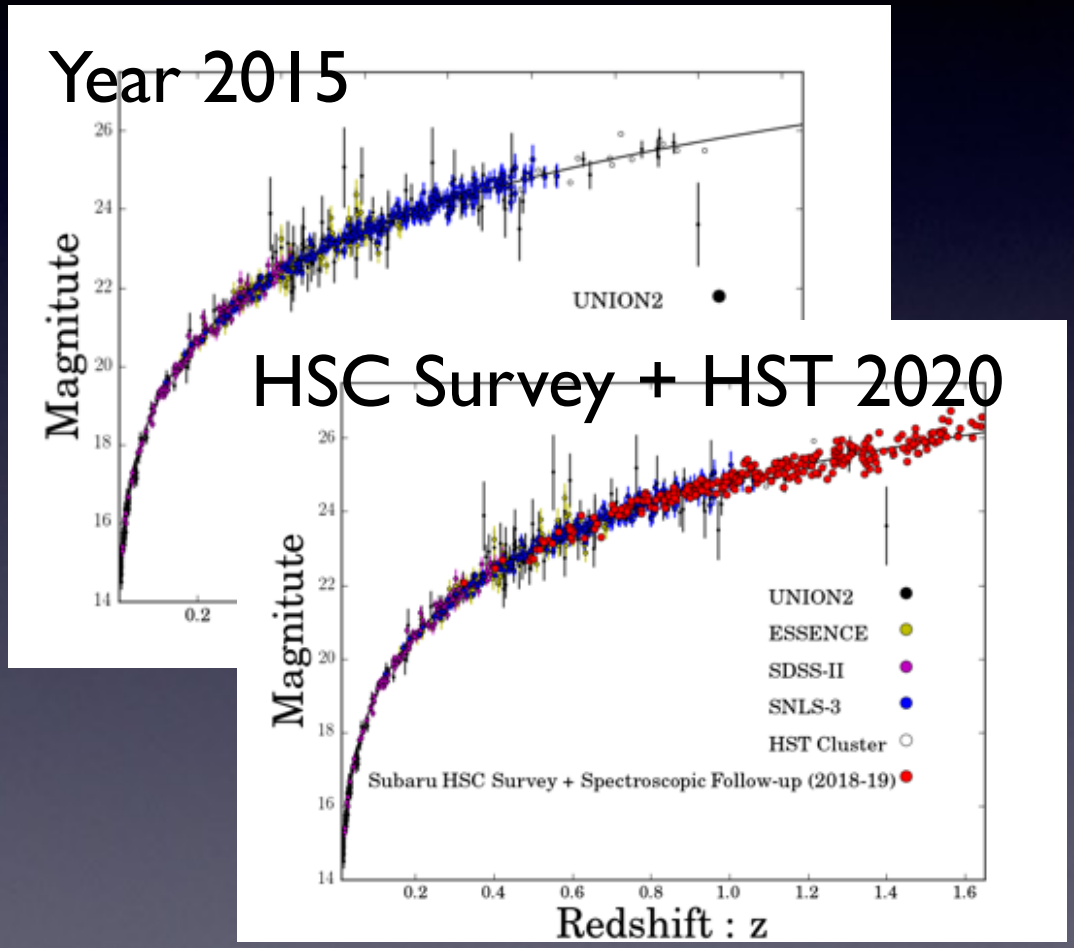
Subaru PFS

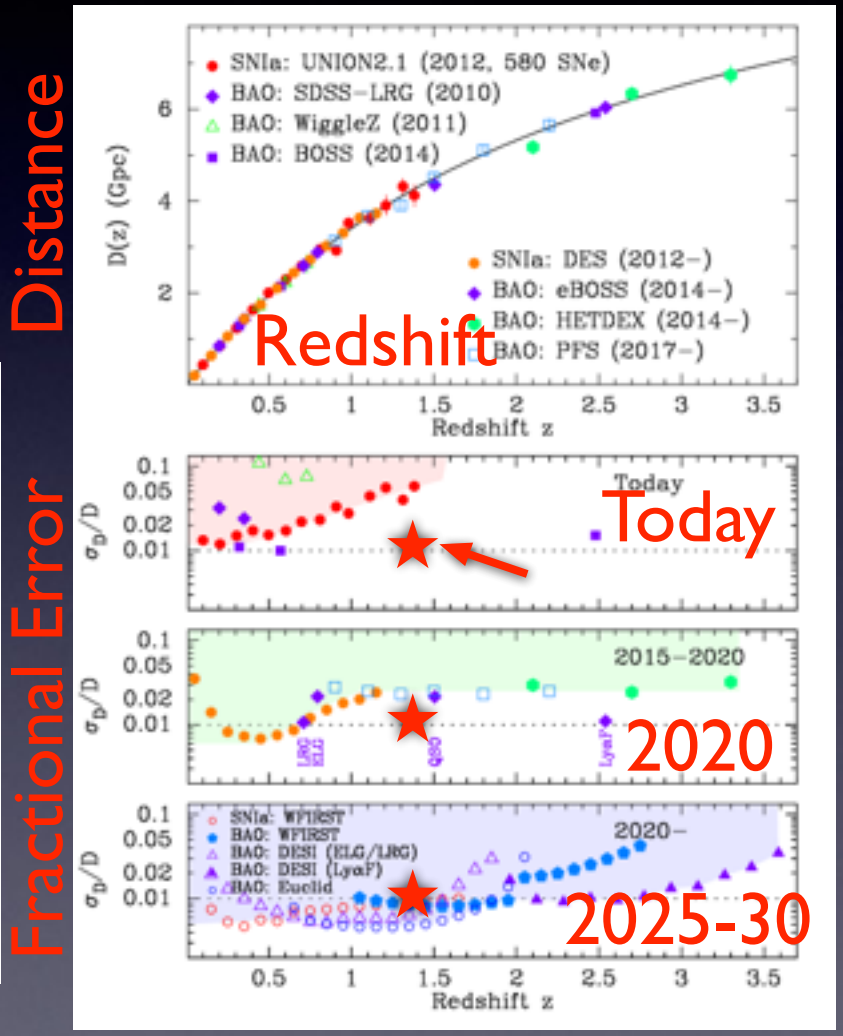


AAT Data from C. Lidman



Hyper-Suprime Cam (HSC) Supernova Survey
Most Precise Measurement on Dark Energy in 2020

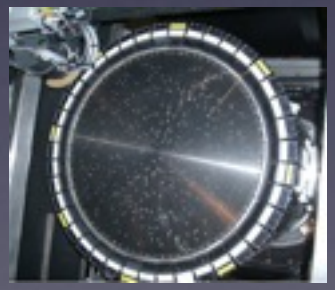




Spectroscopic Follow-up in Jan and Feb

- HSC :Dec 14, 19, 25 Jan 10, 13, 21, Feb 18, 20
- Keck/LRIS (20 slits): Jan 14, 15, Feb 12, 18
- AAT Omega (4m 400 fibers): Feb 8, 9, 10, 11
- Subaru/FOCAS : Feb 25 (Feb 24 for SLSN)

AAT Omega



HST

Keck

VLT

Subaru

Summary

- Deepest Transient Survey (i=26.3 z=26.3)
- Deepest Ground Based Data
- Equivalent of WFIRST Depth
- Expect to have 46 SNe with HST
- FOCAS, Keck, Gemini, AAT, VLT, GTC follow-up
- Data will be shared with SSP Team

Back up Slides

HSC Transient Sciences

Common Interest: How to find Transients?
Transients : Time Variable Objects
Supernova, Variable Star, Active Galaxy, Asteroids

Observation

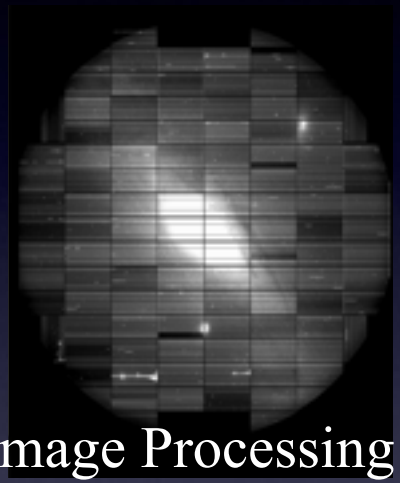


Image Processing

Processed Image

Image Comparison through Machine Learning
CREST collaboration : NTT, ISM, Tsukuba Univ

Bogus

Bogus vs Real = 100,000:100

Supernova