Measurement of expansion of the Universe using high-z type Ia supernovae

公募研究 18H04345

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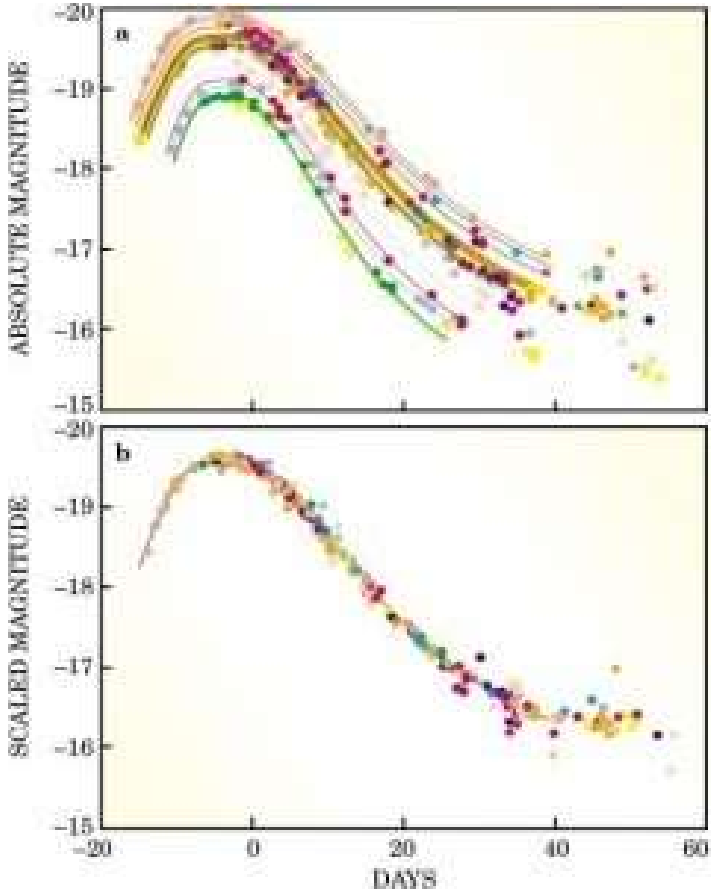
and
HSC SSP Transient team + SCP

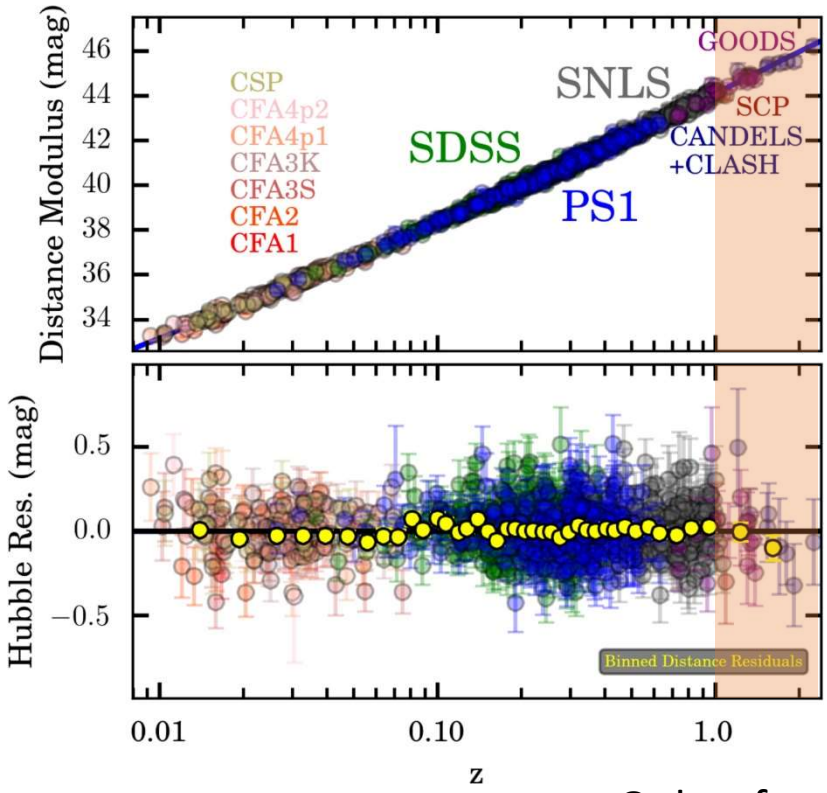
Type Ia Supernova

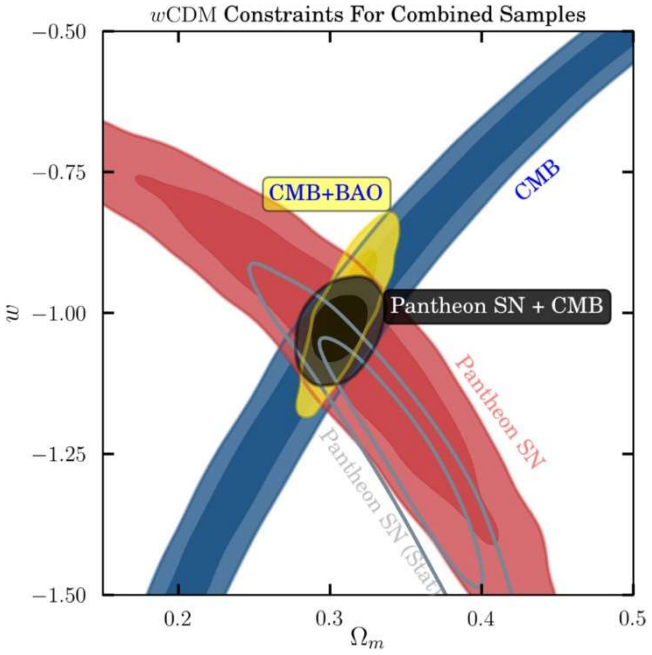
- Thermonuclear explosion of white dwarfs
- Chandrasekhar mass limit of $1.44M_{\odot}$
- Standardizable candle with a light curve shape parameter
- Bright enough (M_B~-19) to reach cosmological distance (z~1)



SN Ia cosmology

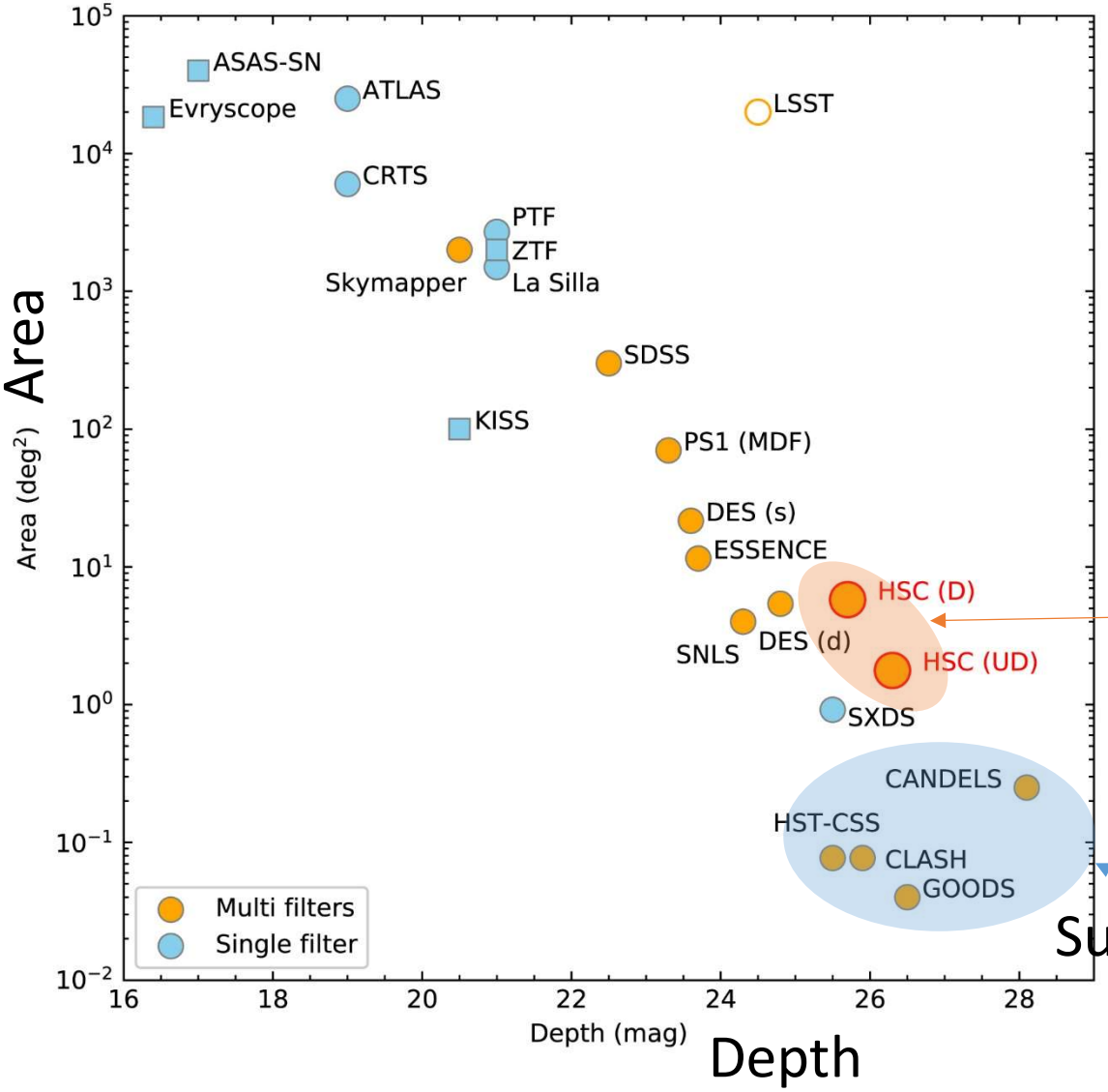
Scolnic et al. 2018 (ApJ, 859, 101)





Only a few tens of SNe Ia at z > 1 detected by HST
HSC can play an important role at this redshift range
To constrain time variability of dark energy

HSC SSP Transient Survey

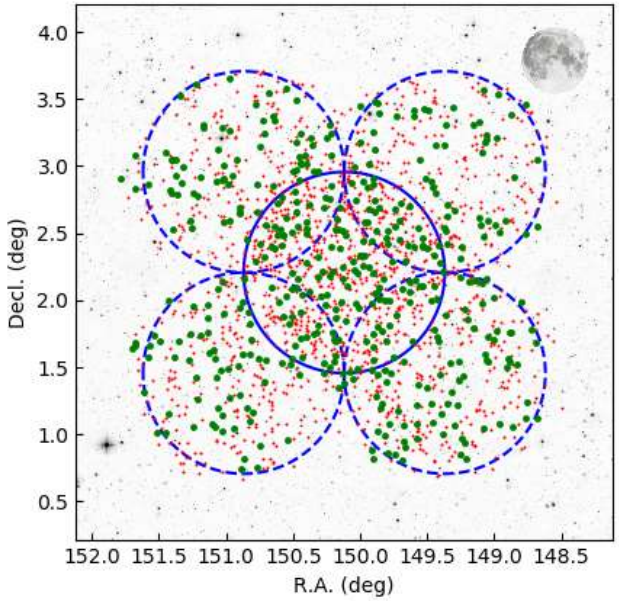


HSC Survey

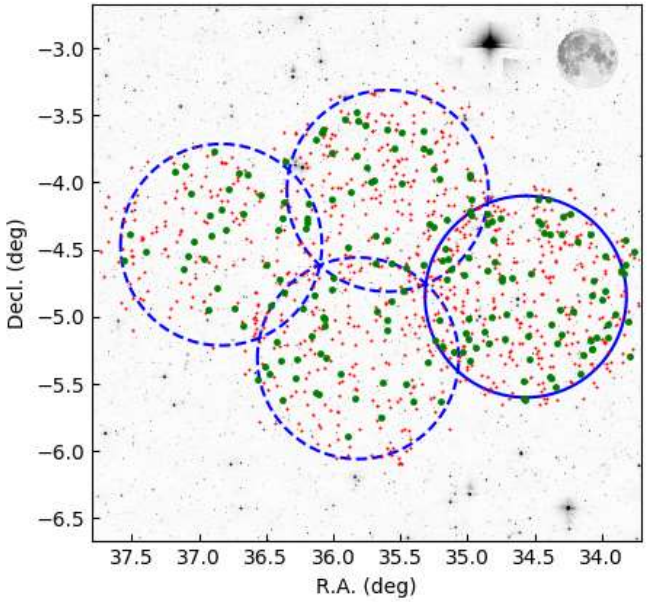
Survey with HST

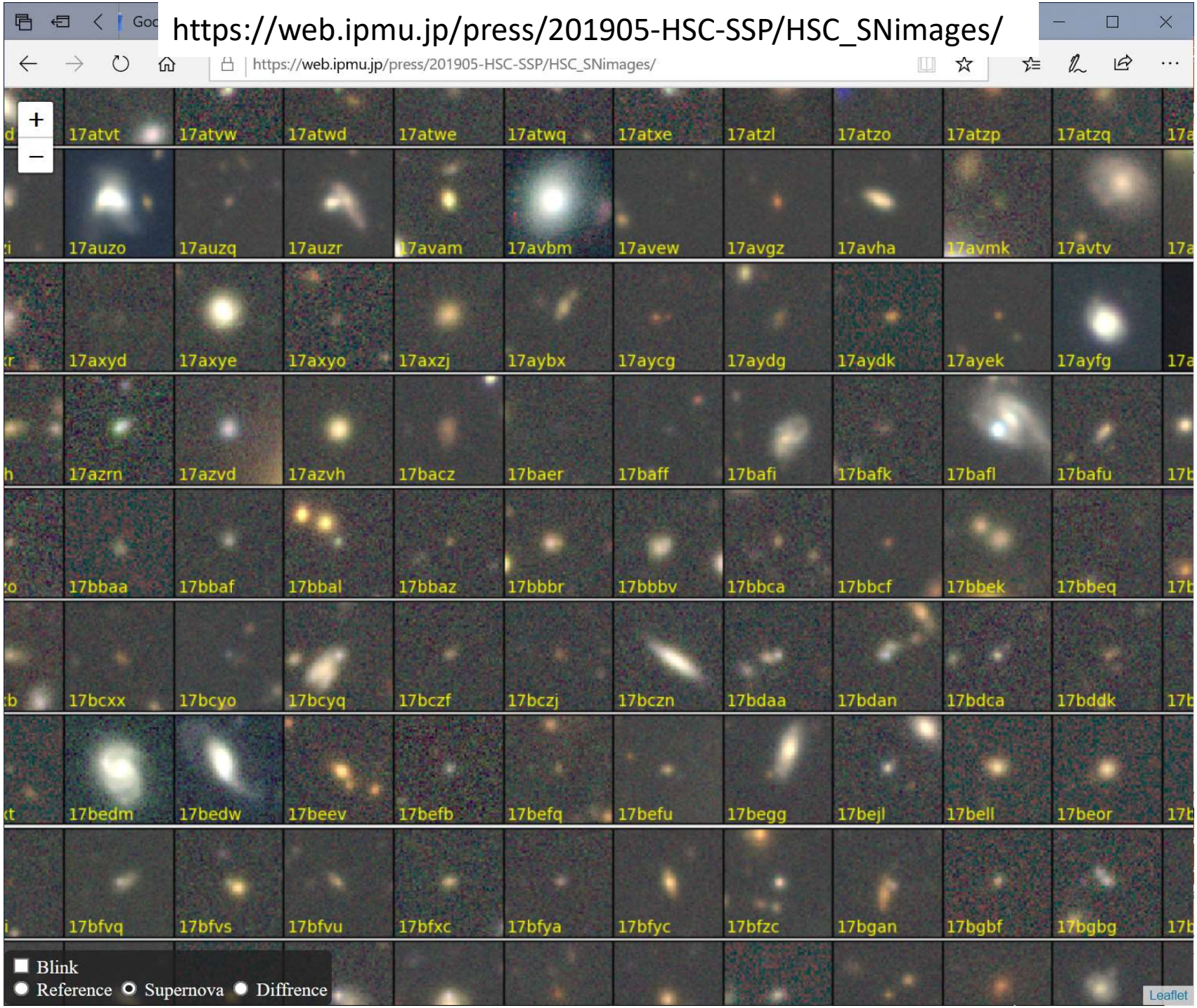
HSC SSP Transient Survey

- 1st season – COSMOS
- Nov. 2016 – Apr. 2017
  - Overview paper : Yasuda+ (2019)
- 1,824 SN candidates
- 433 SN Ia candidates
  - 163 at z > 1



- 2nd season – SXDS
- Sep. 2019 – Feb. 2020
  - Final observation from today
- 1,038 SN candidates
- 187 SN Ia candidates
  - 49 at z > 1




https://web.ipmu.jp/press/201905-HSC-SSP/HSC_SNimages/
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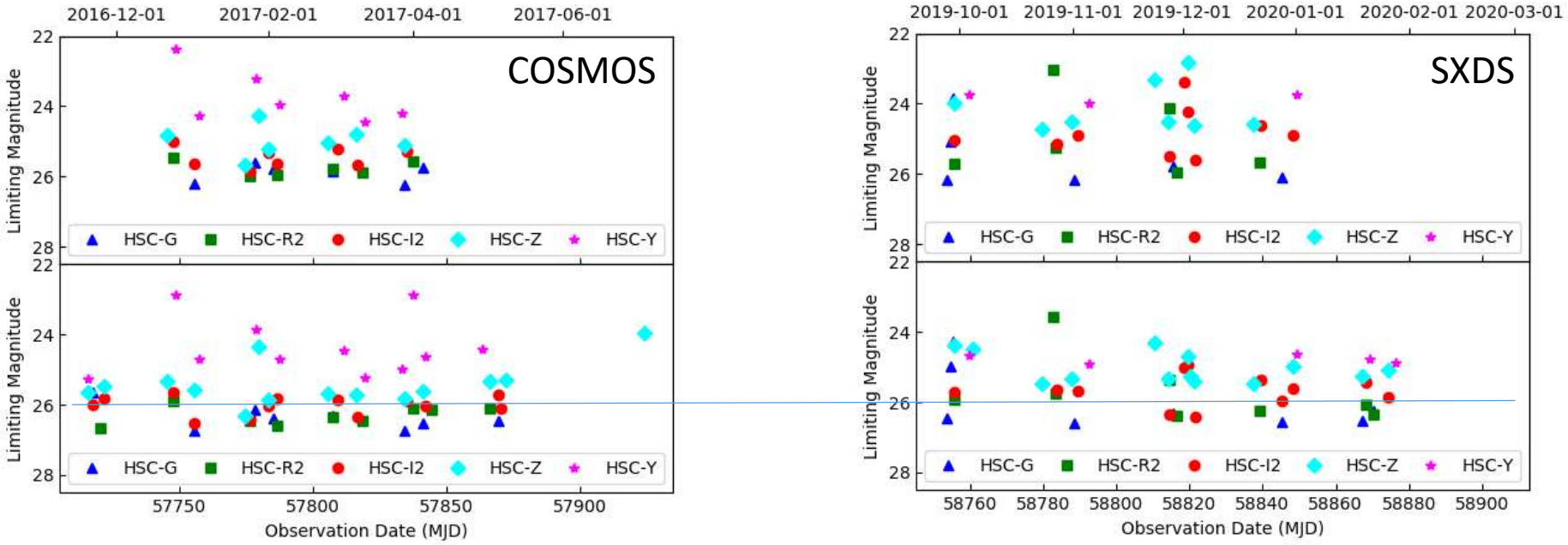
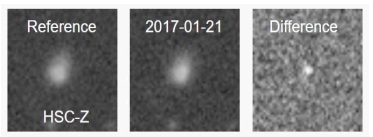
17bfvq 17bfvs 17bfvu 17bfxc 17bfya 17bfyc 17bfzc 17bgan 17bgbf 17bgbg
Blink
Reference
Supernova
Diffrence
Leaflet

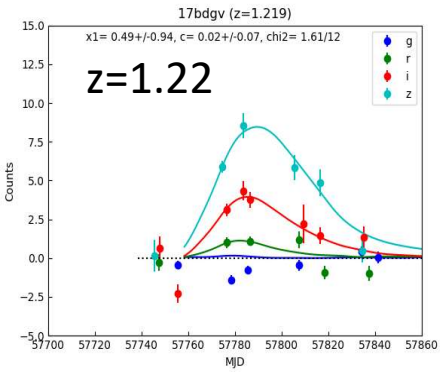
HSC SSP Transient Survey

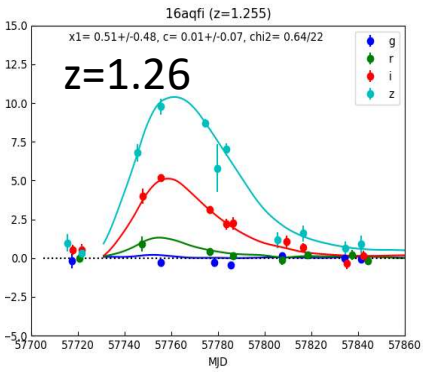
- Fewer number of candidates for 2nd season (SXDS)
  - Reference images are shallower
  - Seeing condition was worse
  - => Shallower detection limit, especially in z-band

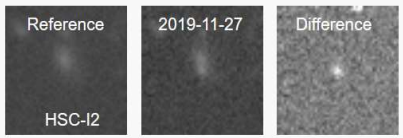


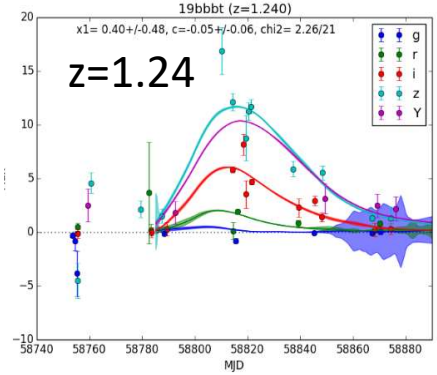
HSC SSP Transient Survey

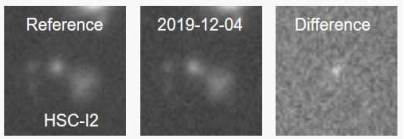


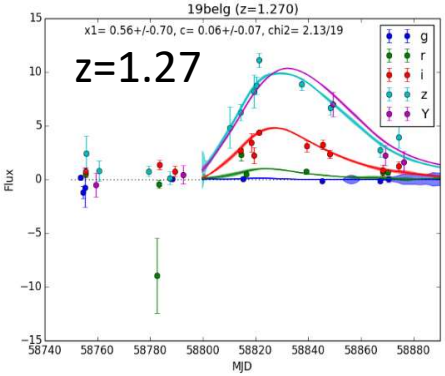


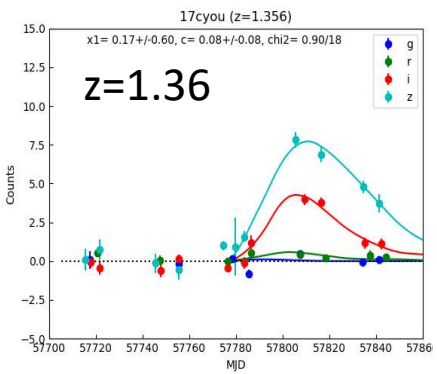


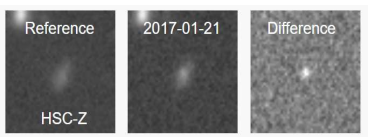


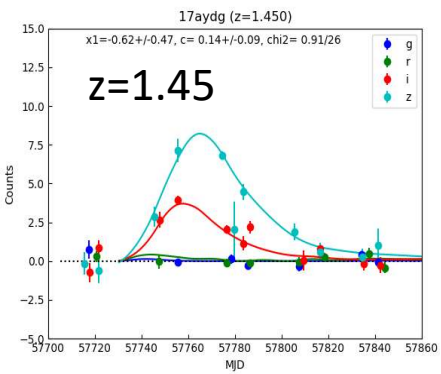


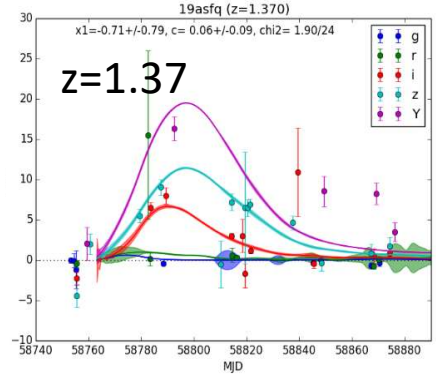


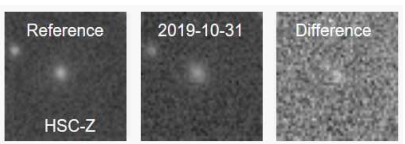


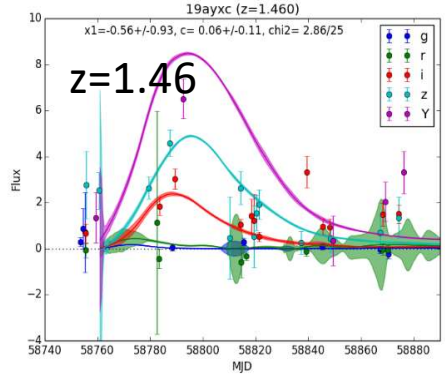












Tasks toward SN Ia cosmology

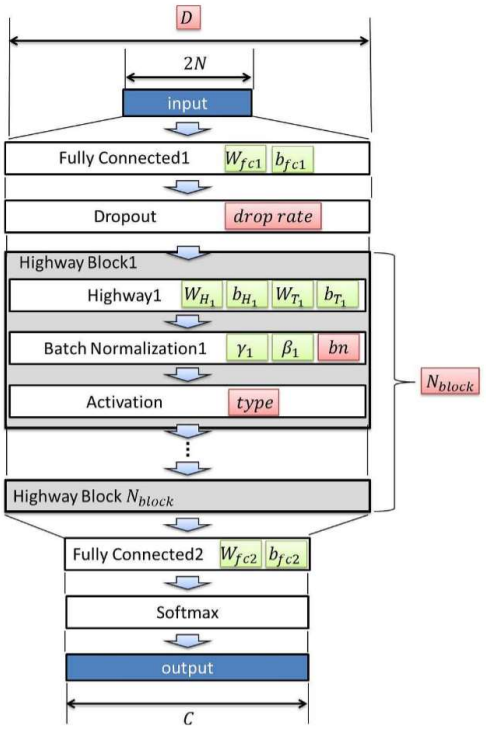
- Observation : Completed

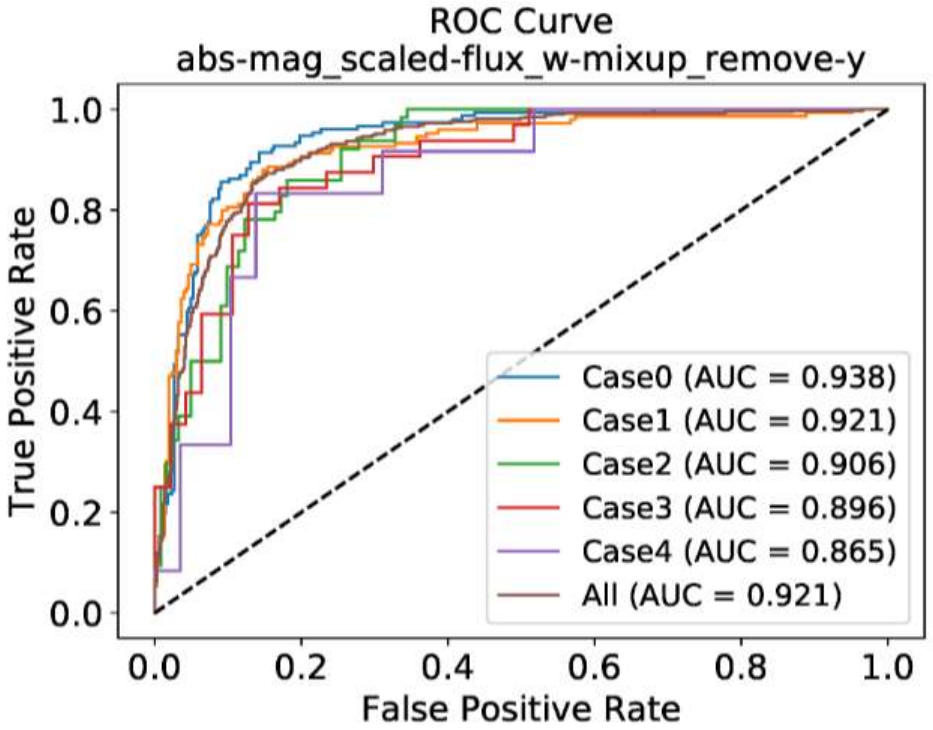
- SN Ia sample definition
- Measurement of host redshift
- Photometric calibration
- SN photometry
- HST photometry

- SN Ia cosmology

SN Ia sample selection

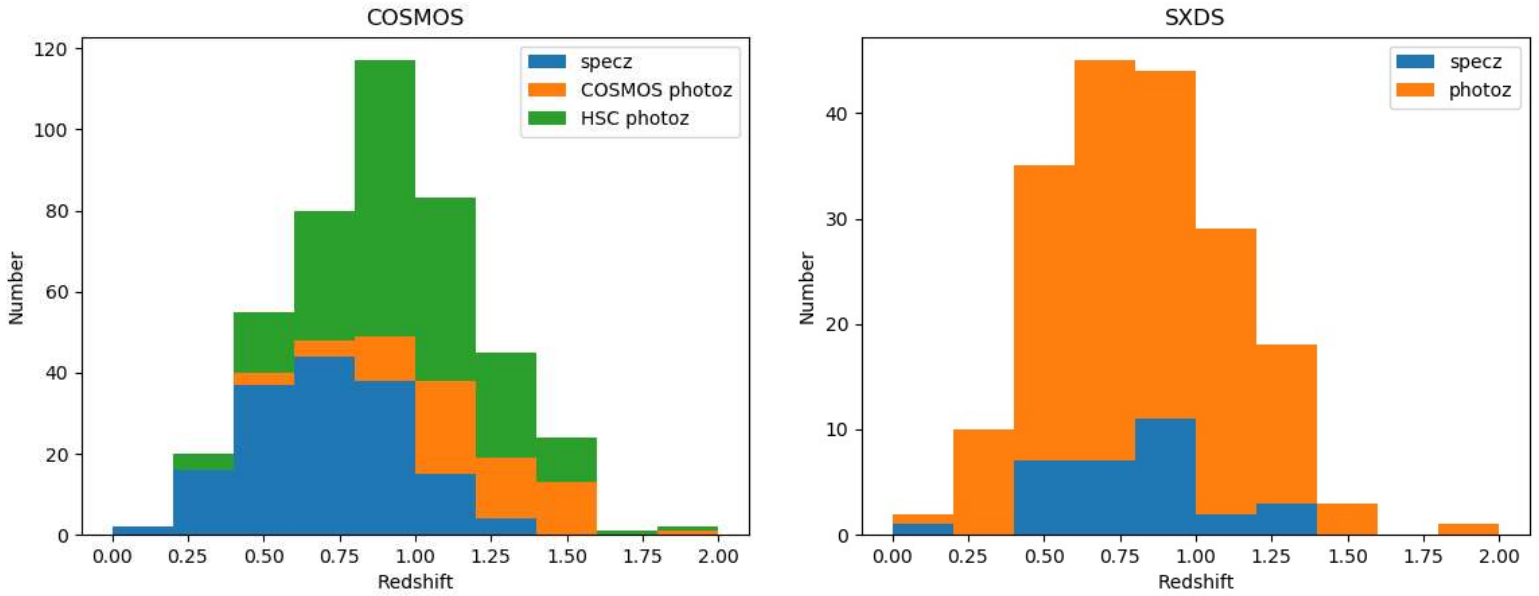
- Spectroscopic classification is available for <10 SN Ia candidates
- Photometric classifications are needed
- Various methods are applied and compiling them
- SN Ia template fit and deep neural network are used
- 80-90 % consistency can be achieved





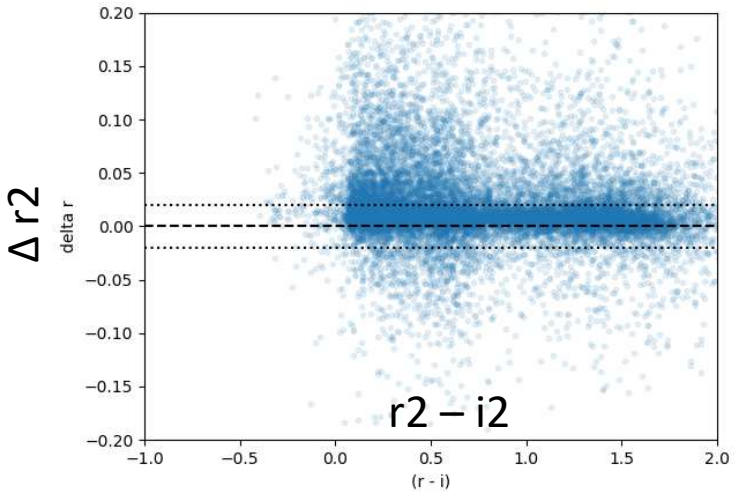
Measurement of host redshift

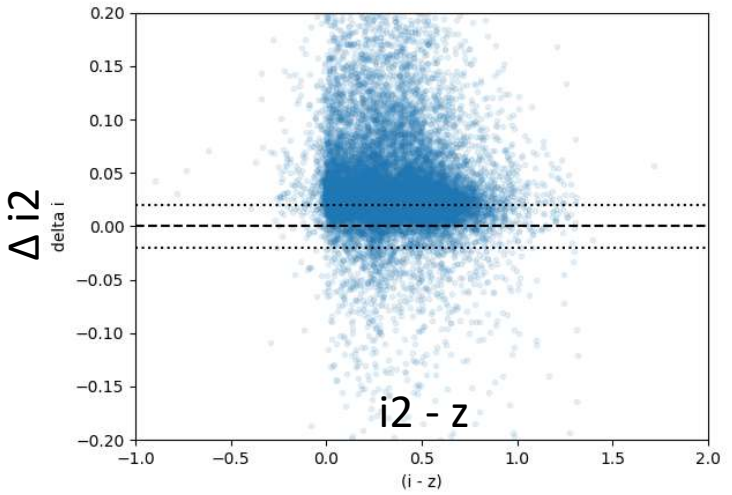
- Redshift of host galaxies should be observed for cosmology
- AAOmega, Subaru, VLT, Keck, Gemini, GTC observations are on-going
  - AAOmega can reach up to z~0.8.
  - 8-10m telescopes are need beyond that
- Each season we can get only 20-30 redshifts
- Still ~400 (~150 @ z > 1) Ia candidates need to be observed
- PFS observation is desirable even if the number of targets is small



Photometric calibration

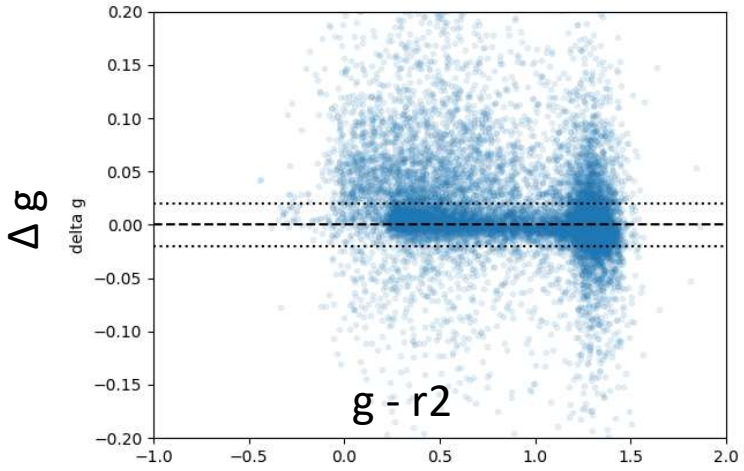
- Data processing with two pipelines
  - HSC pipeline + LSST ip_diffim
  - Pipeline developed for SNLS (CFHT)
- Calibration
  - HSC -> Pan-STARRS1 -> HST CALSPEC
  - SNLS -> Tertiary standards -> HST CALSPEC
- Comparison of tertiary stars
  - 1% / 2% offsets for r2- and i2-band. g- and z-bands are ok.

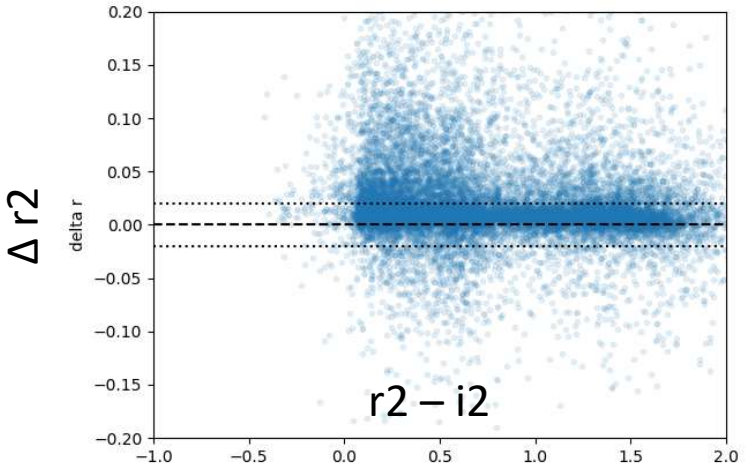


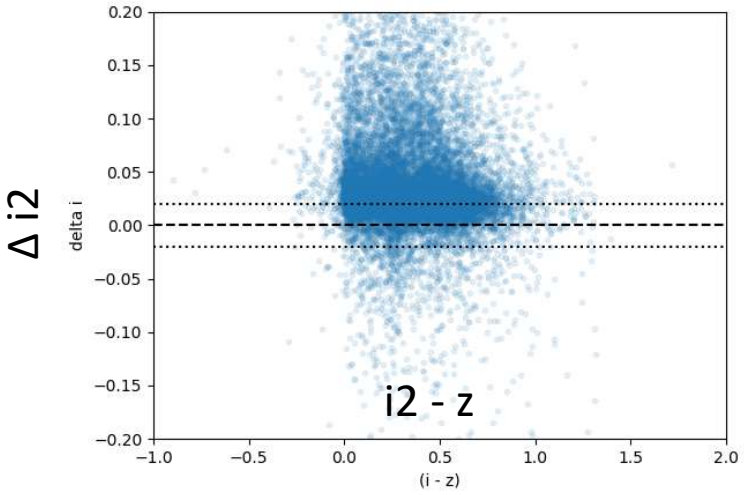


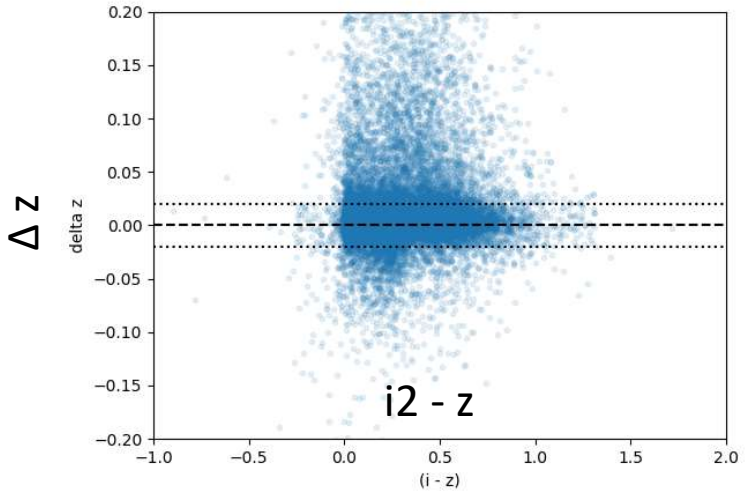
Photometric calibration

Comparison of tertiary stars



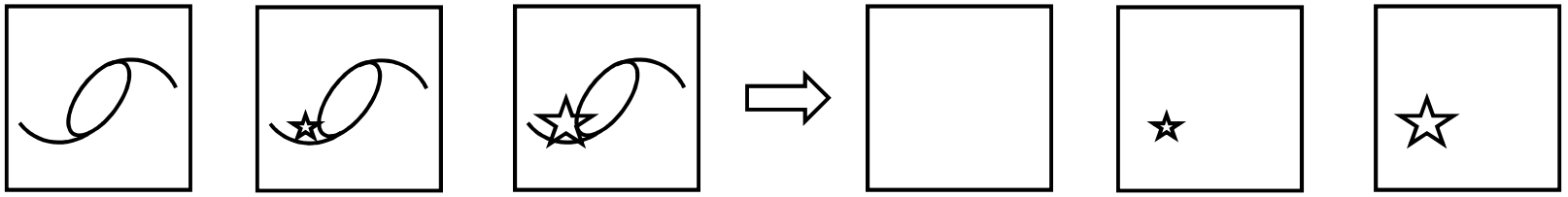






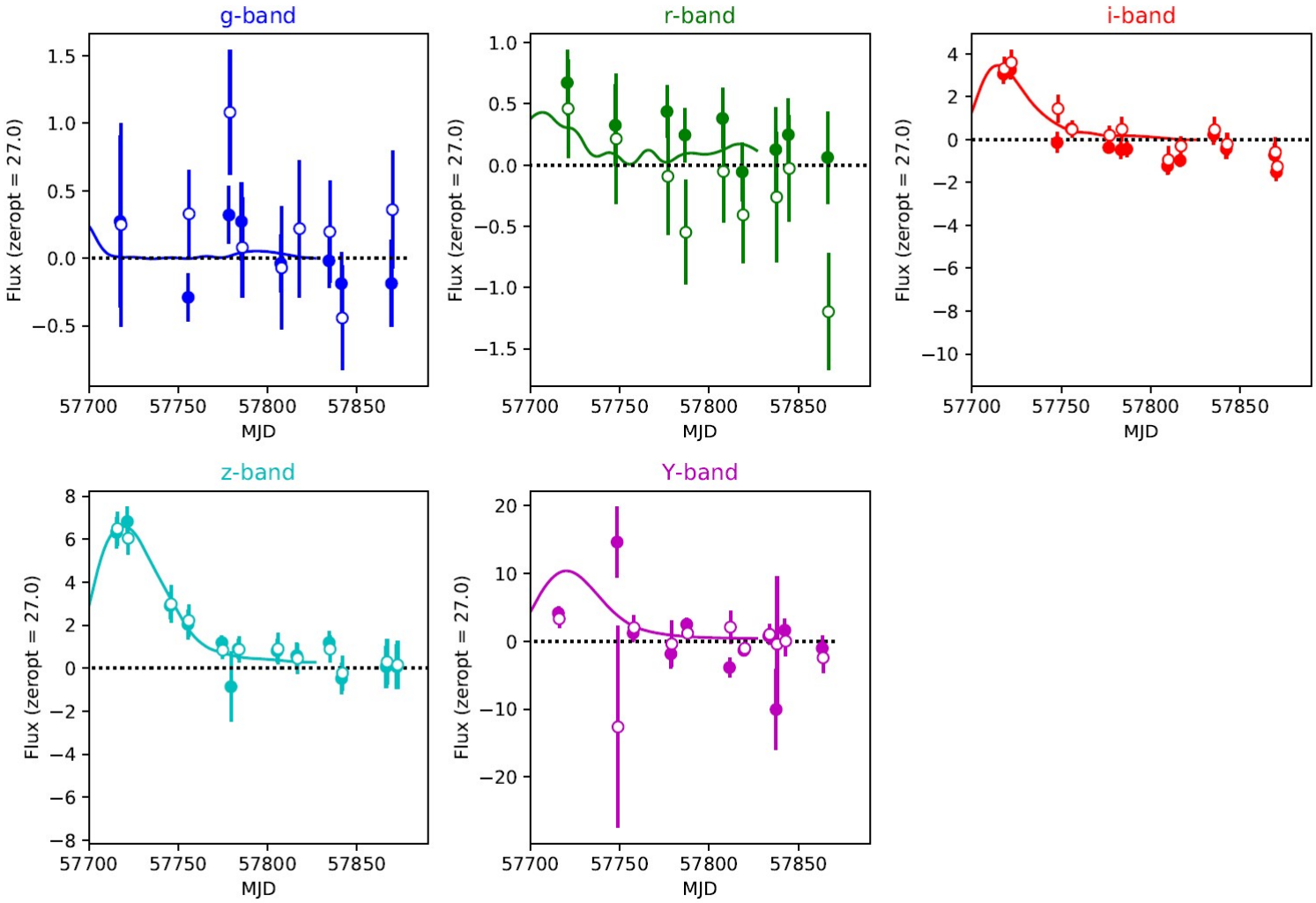
SN photometry

- Current photometry (Japanese team)

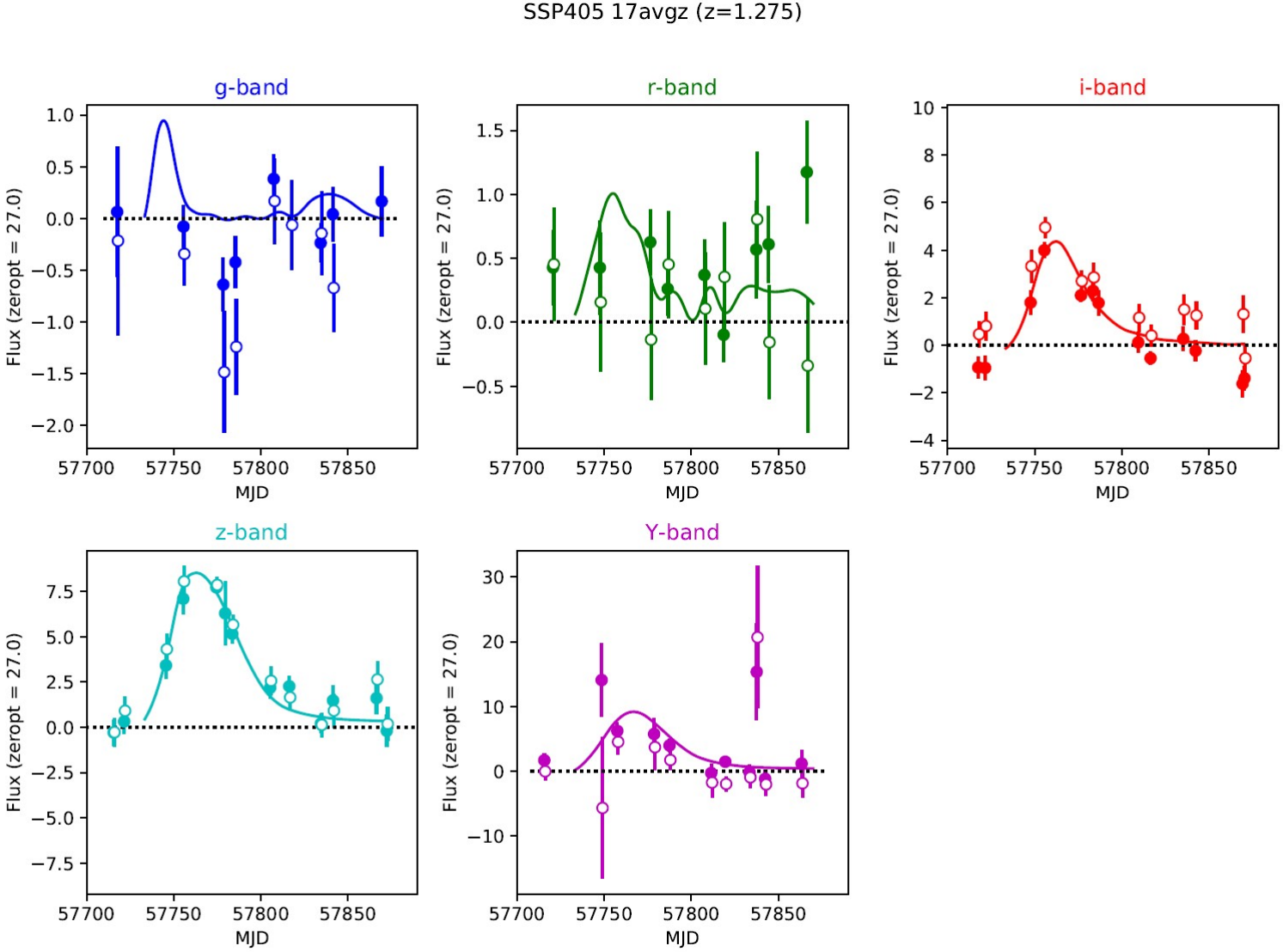


  - Subtract reference image and photometry on difference image
- Scene modeling photometry (French team)
  - Simultaneously fit constant background (pixel values) and variable SN brightness using known PSF model
  - No need for re-sampling and convolution
  - Developed for SDSS/SNLS

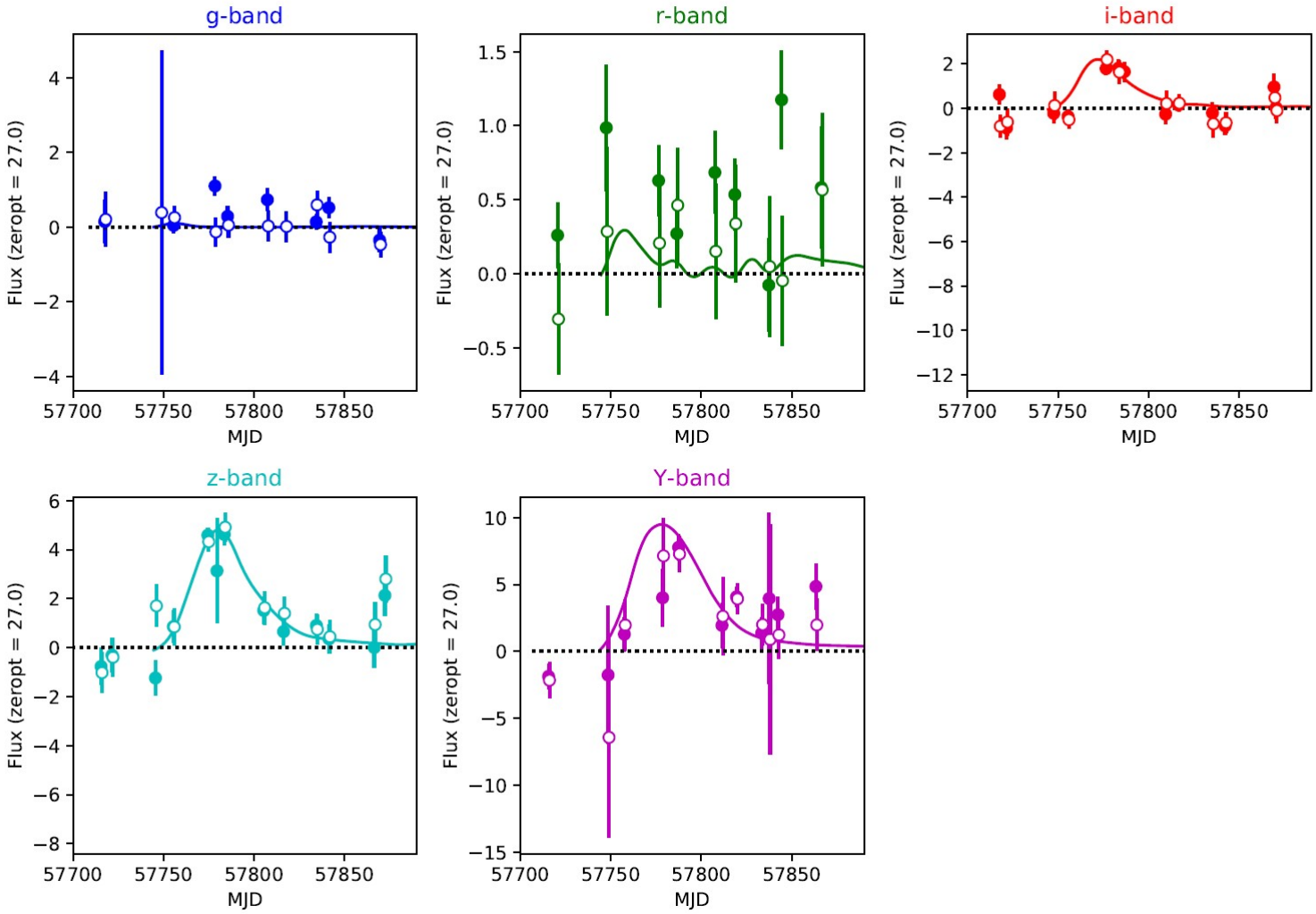
Comparison of SN photometry (filled : J, open : F)



Comparison of SN photometry (filled : J, open : F)



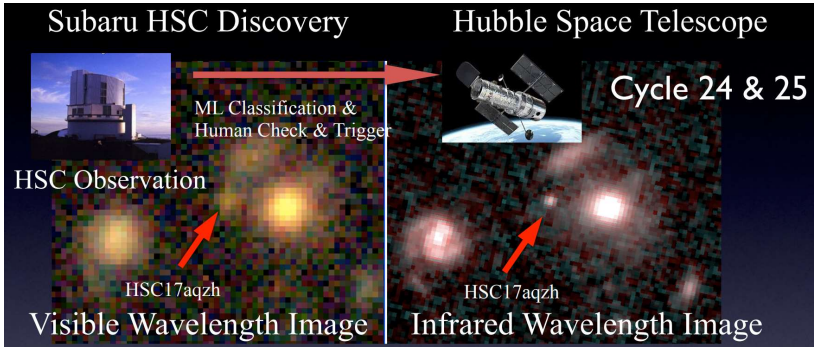
Comparison of SN photometry (filled : J, open : F)

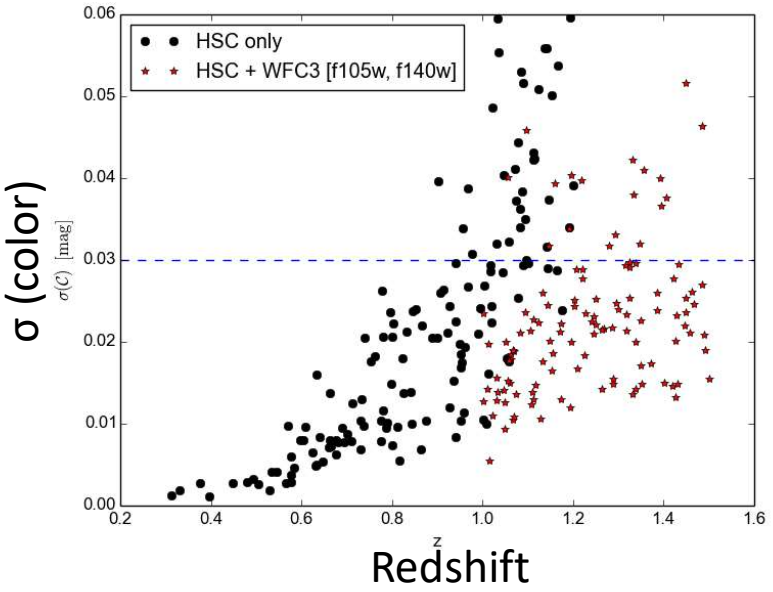


Two measurements looks consistent. Need more check

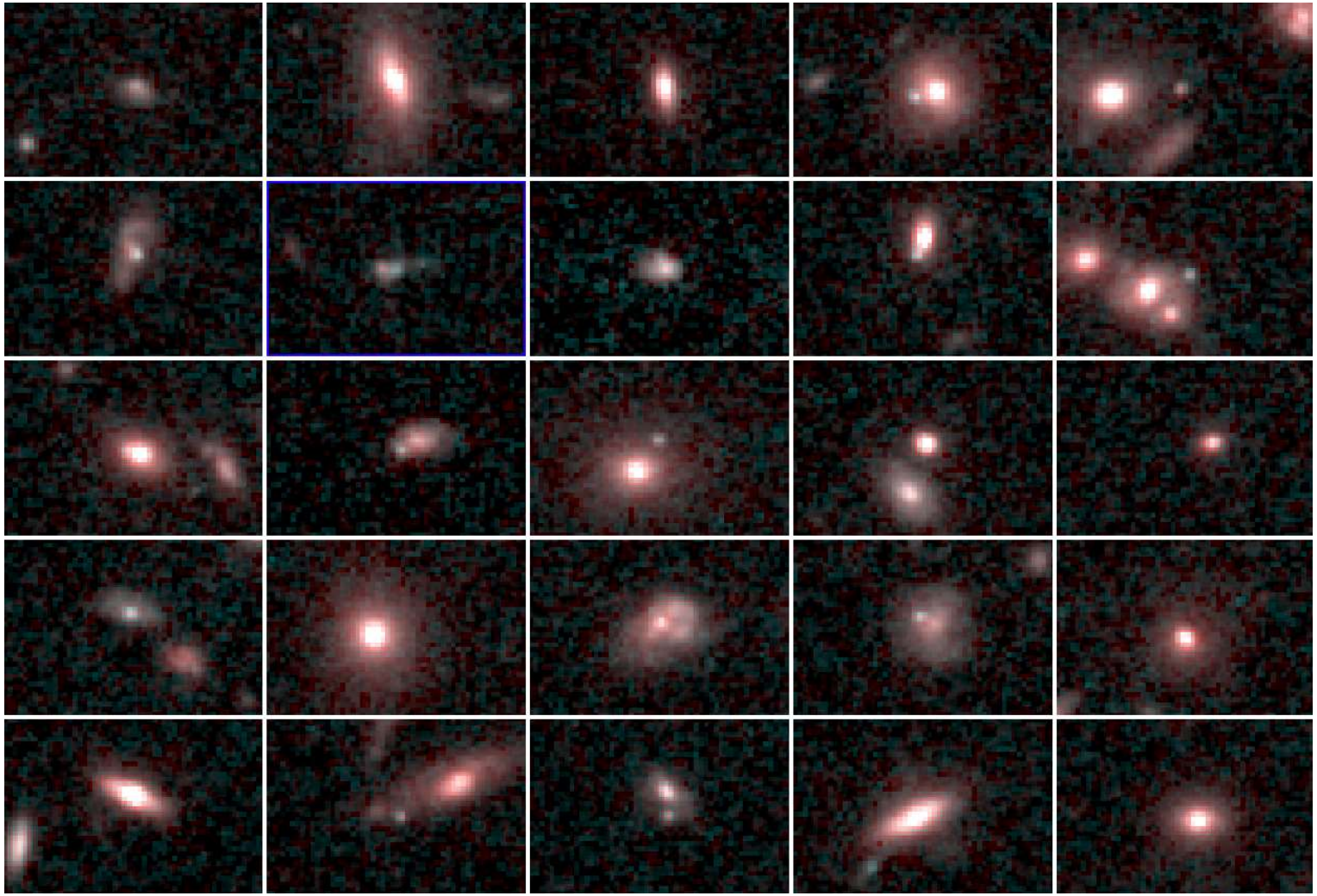
HST follow-up photometry

- HST proposal by N. Suzuki has been accepted
- 26 SN Ia candidates for COSMOS and 10 for SXDS has been observed by HST/WFC3 (F105W/F140W)
- Get accurate rest-frame optical color
- Reference images has been taken for COSMOS candidates
- Need to get final photometry for observed candidates

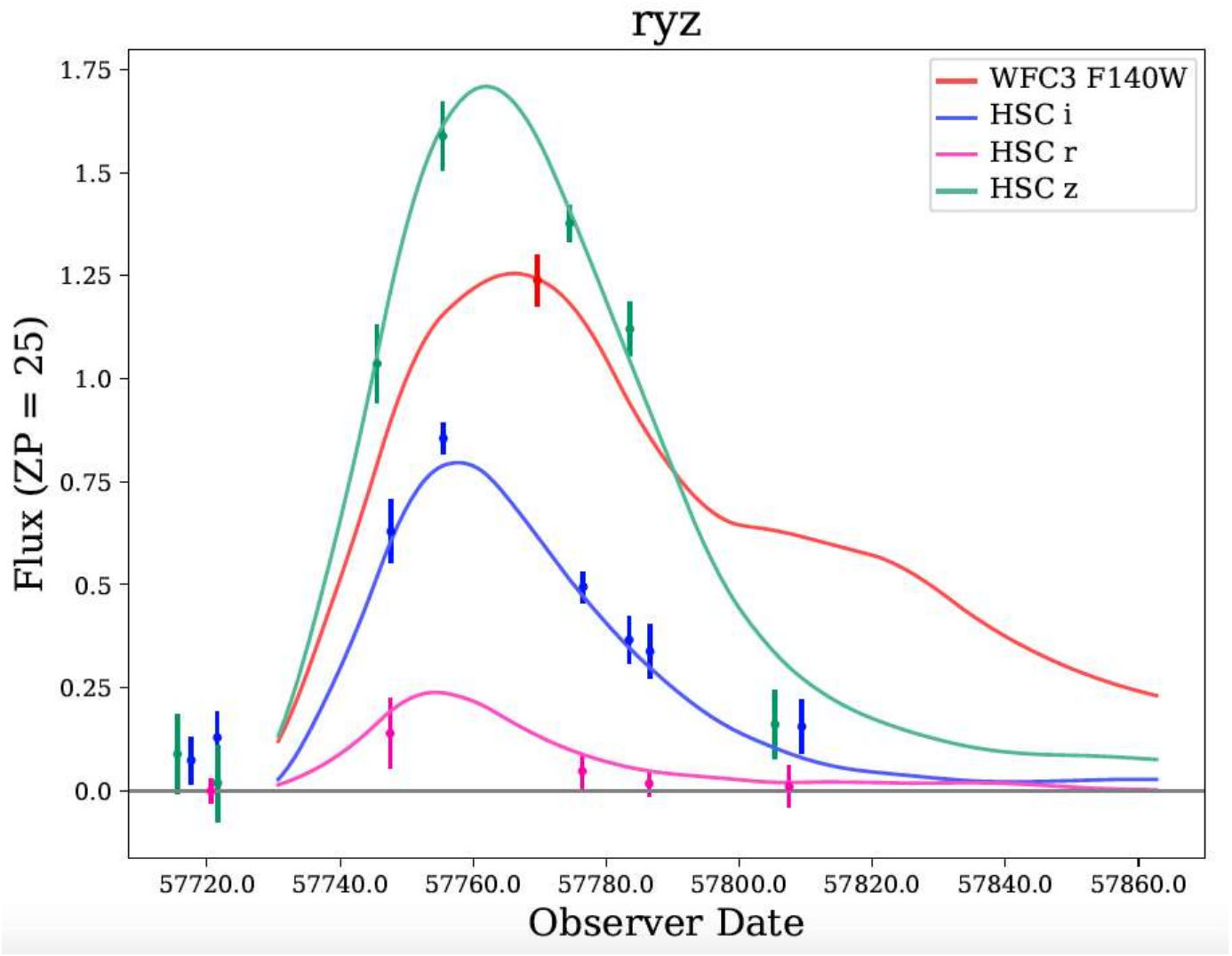




HST follow-up photometry



HST follow-up photometry



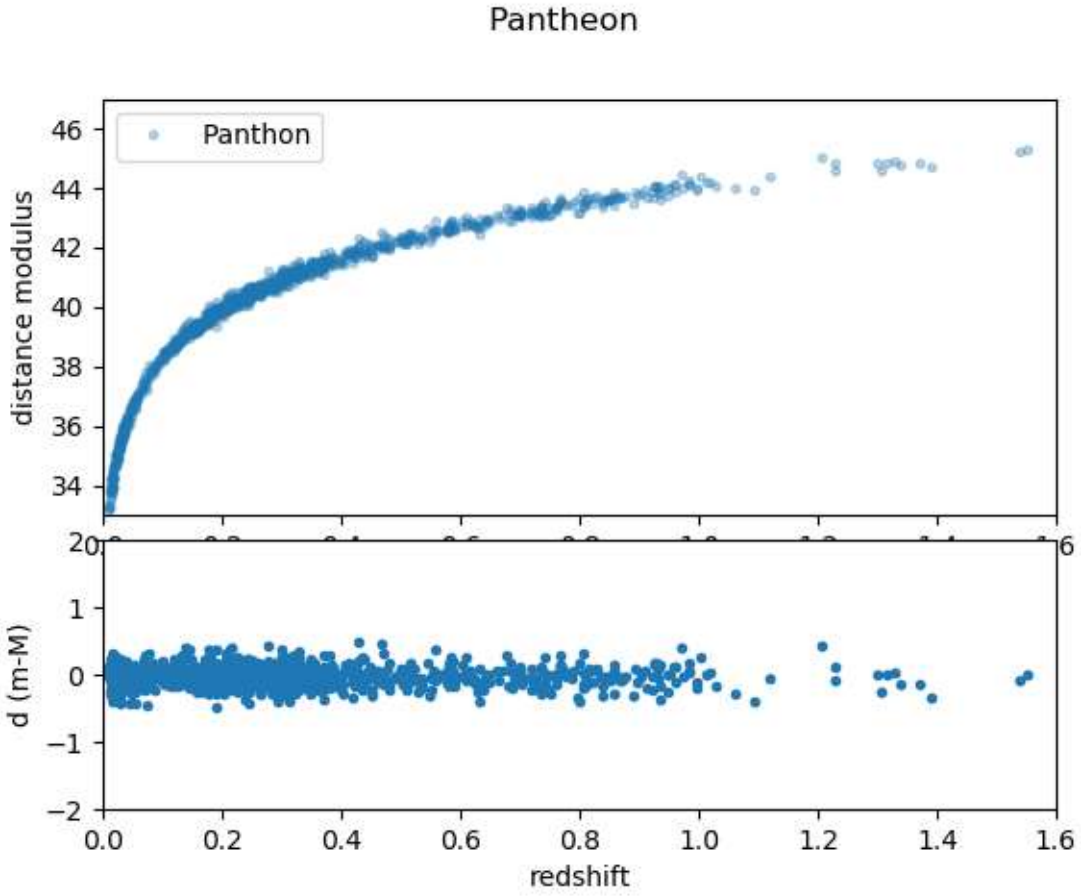
Tasks toward SN Ia cosmology

- Observation : Completed

- SN Ia sample definition : Almost done
- Measurement of host redshift : On progress but need more effort
- Photometric calibration : On progress
- Detailed photometry : On progress
- HST photometry : Need reference for SXDS

- SN Ia cosmology : Need more effort

Hubble diagram



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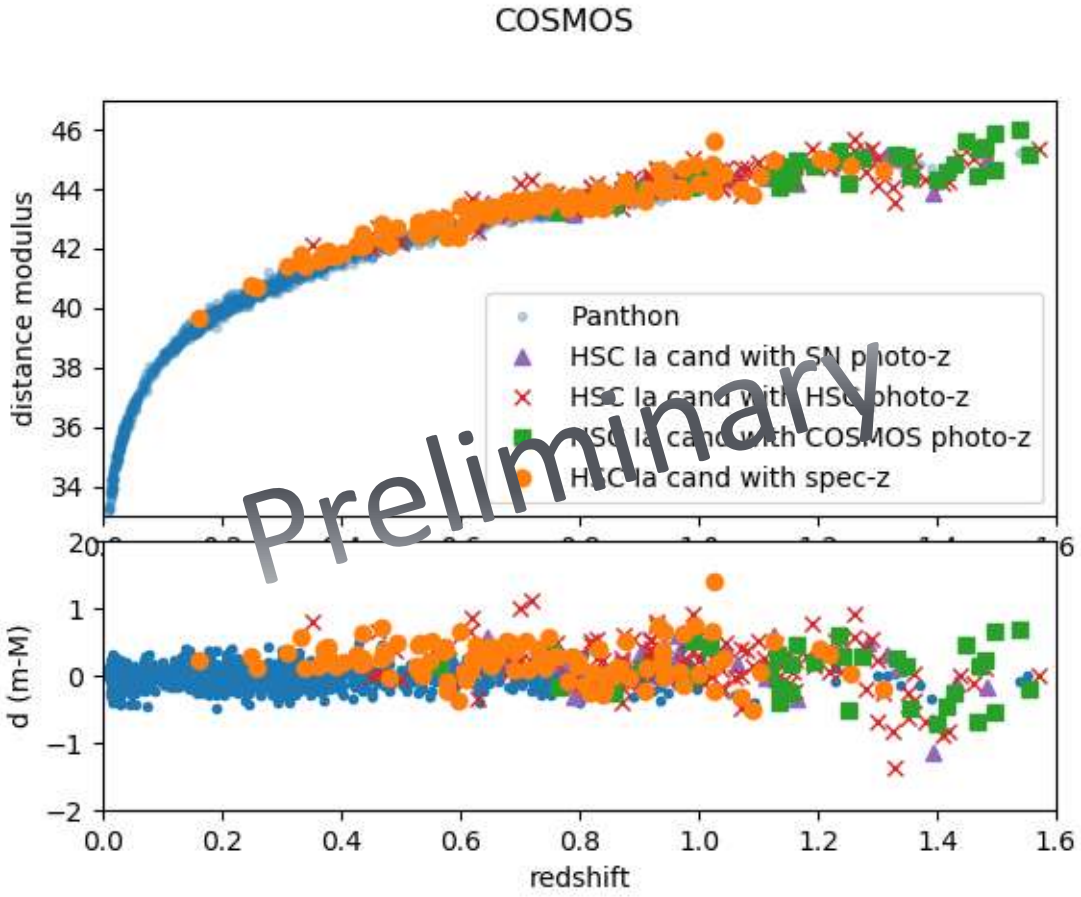

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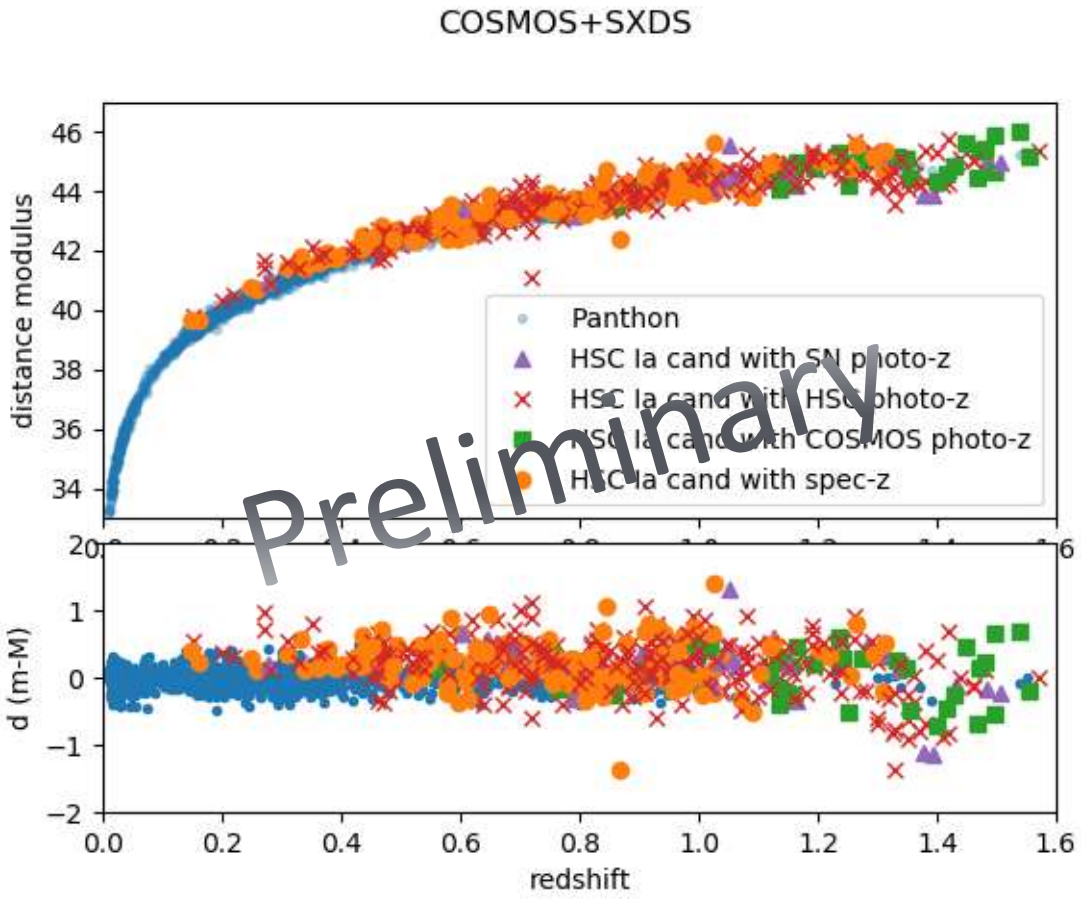

Summary

- HSC SSP Transient Survey identified large number of SN Ia candidates usable for cosmology
  - HSC is more powerful than HST
- Tasks for SN Ia cosmology are on-going
  - Photometric classification
  - Measuring host-galaxy redshifts
  - Photometric calibration
  - Detailed photometry
- Need more time for cosmology
  - Mainly due to the measurement of redshifts