

Unveiling the Nature of Type Ia Supernovae with Subaru/HSC Deep Imaging Surveys

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22 Nov 2019



Outline

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- * Type Ia Supernovae and Their Early-phase Behavior

- * The **M**ulti-band **S**ubaru **S**urvey for **E**arly-phase **SNe Ia (MUSSES)**

 - * Why Subaru/HSC, why MUSSES?

 - * MUSSES1604D, a smoking-gun of the He-detonation scenario

- * The HSC SSP Transient Survey

 - * A summary of early-phase SNe Ia study with HSC SSP Transient Survey in COSMOS

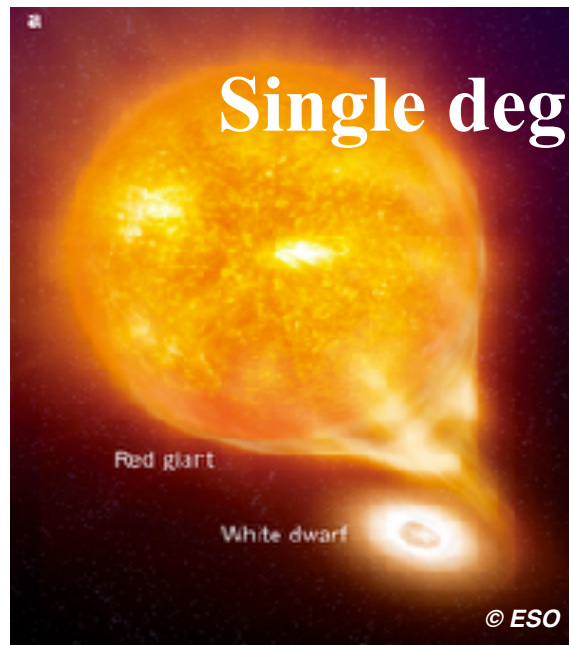
 - * Current status of the HSC SSP Transient Survey in SXDS and MUSSES

- * HSC Transient Surveys in Future

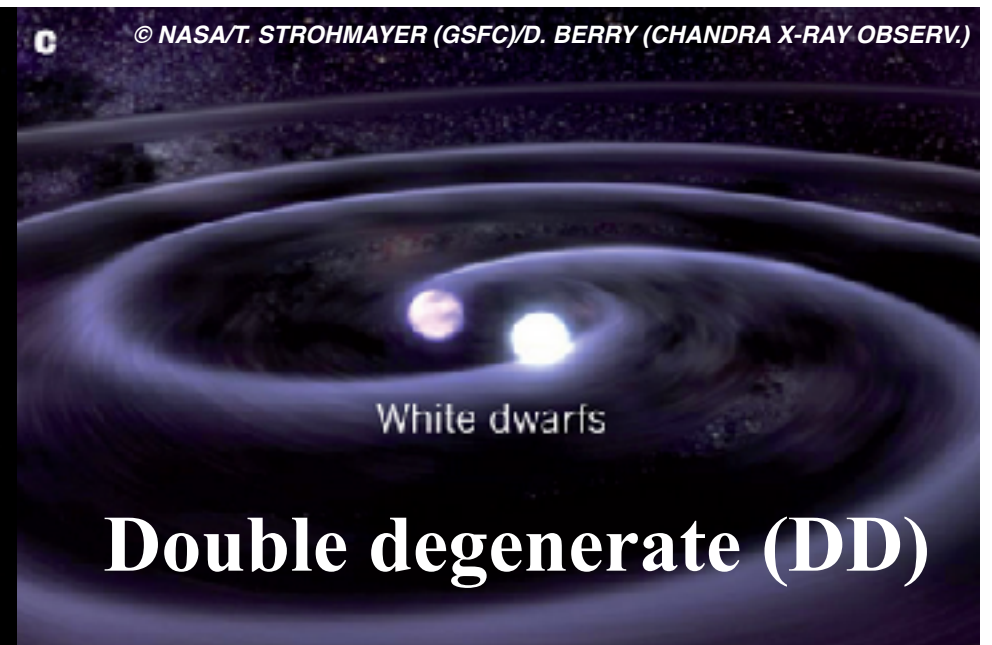
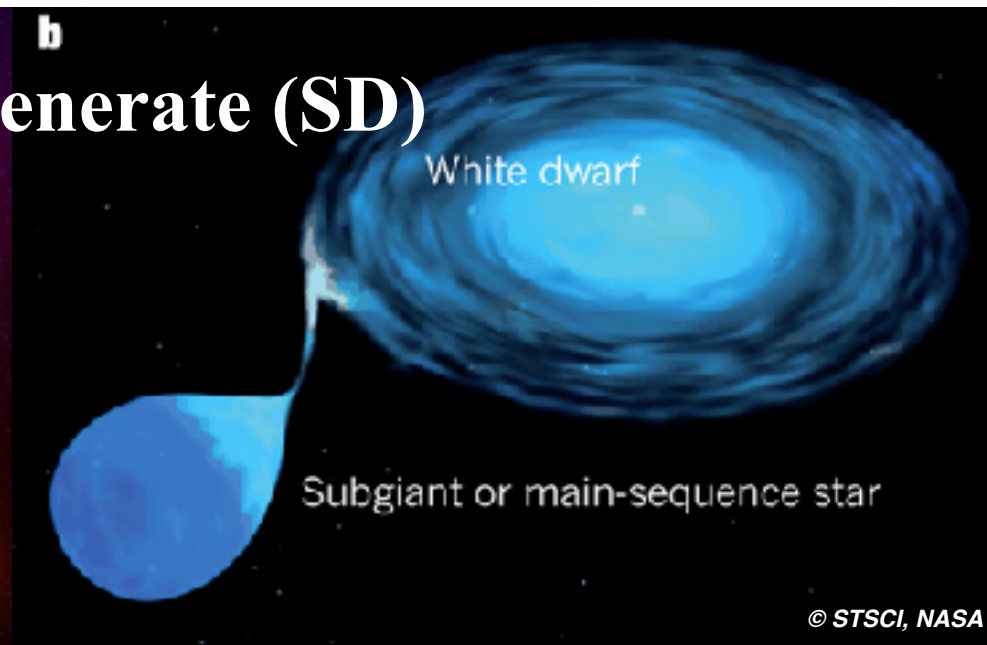
- * Summary

✿ Type Ia Supernovae and Their Early-phase Behavior

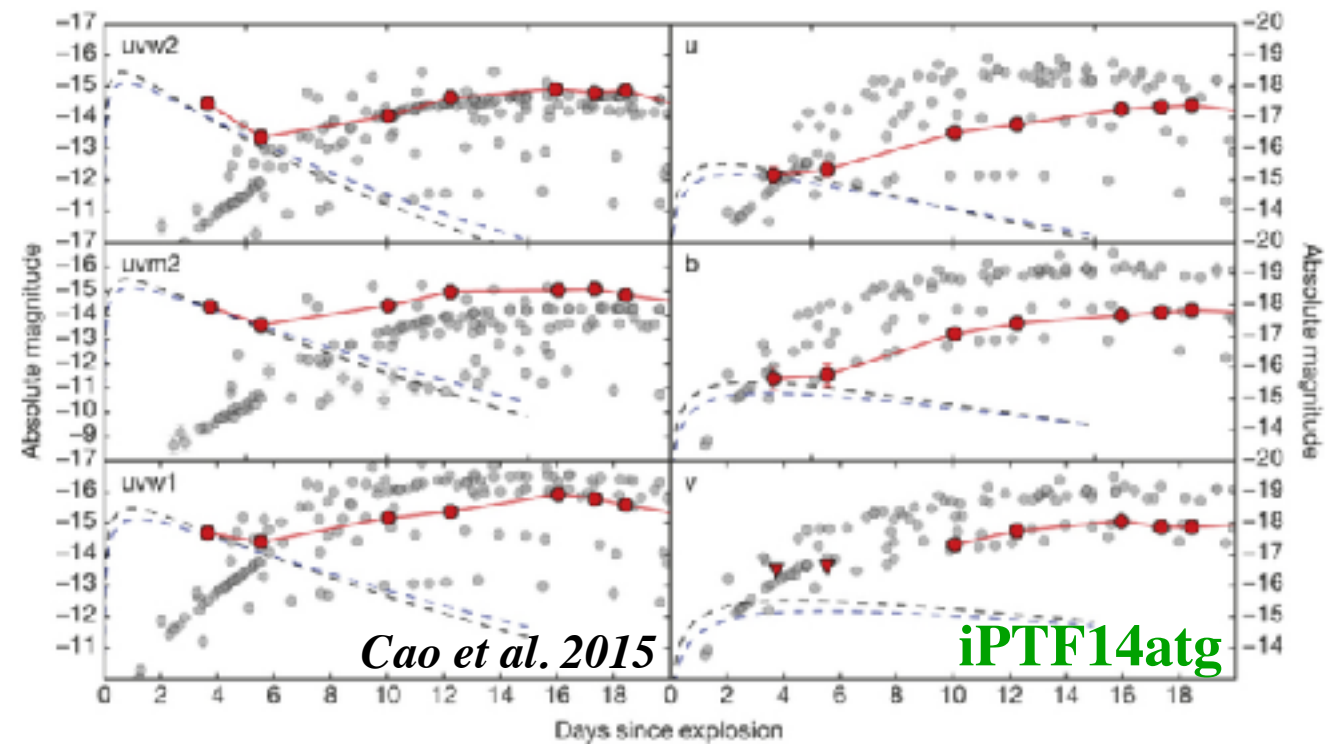
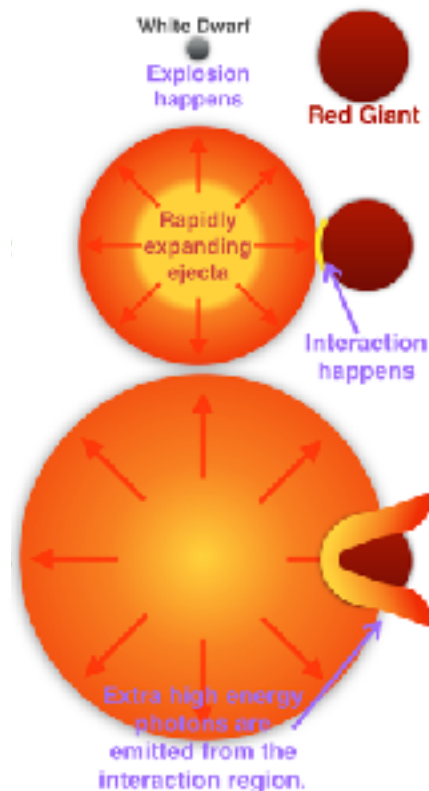
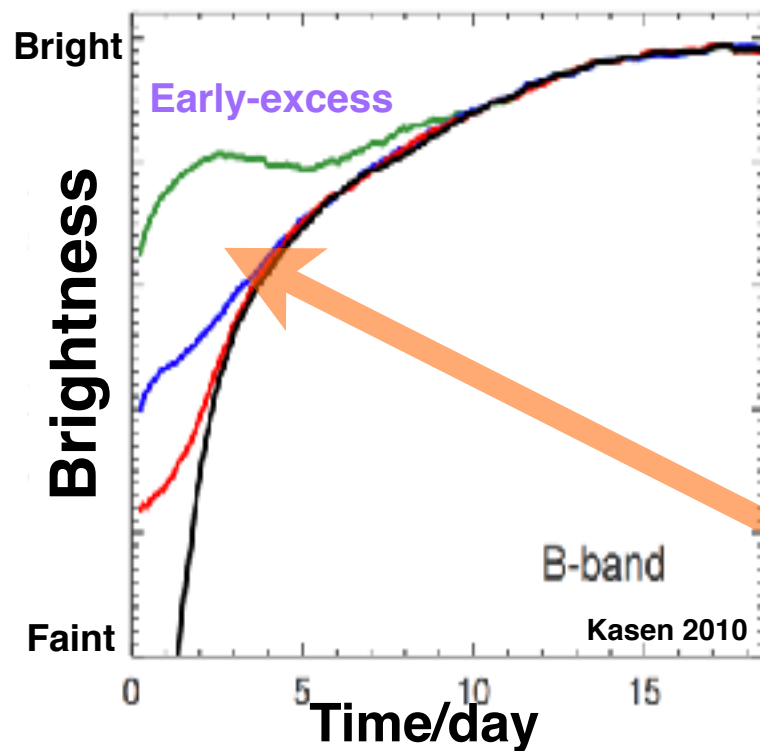
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Single degenerate (SD)

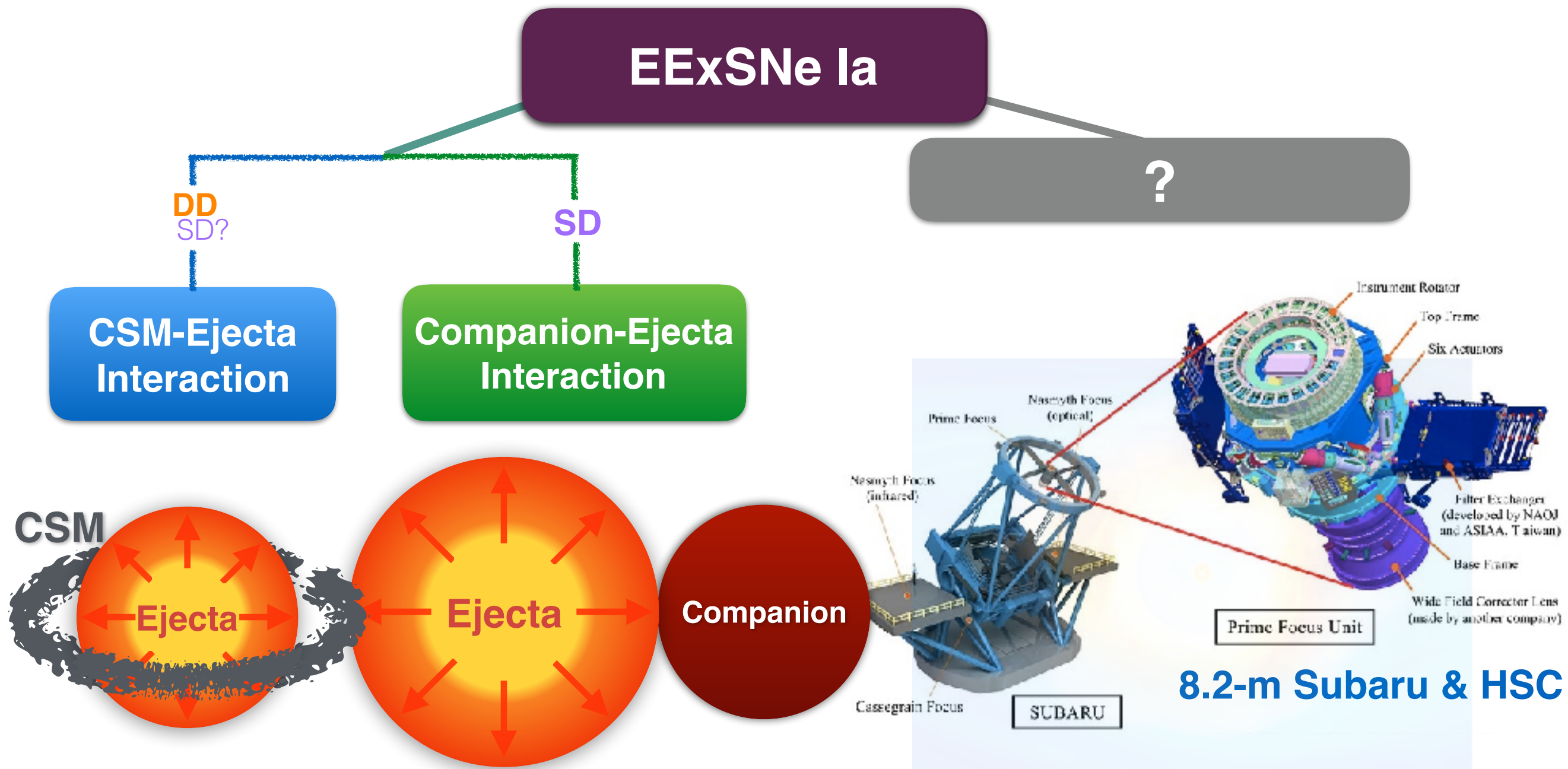


Double degenerate (DD)



✿ Type Ia Supernovae and Their Early-phase Behavior

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Interaction-induced EExSNe Ia

Surface-radiation EExSNe Ia

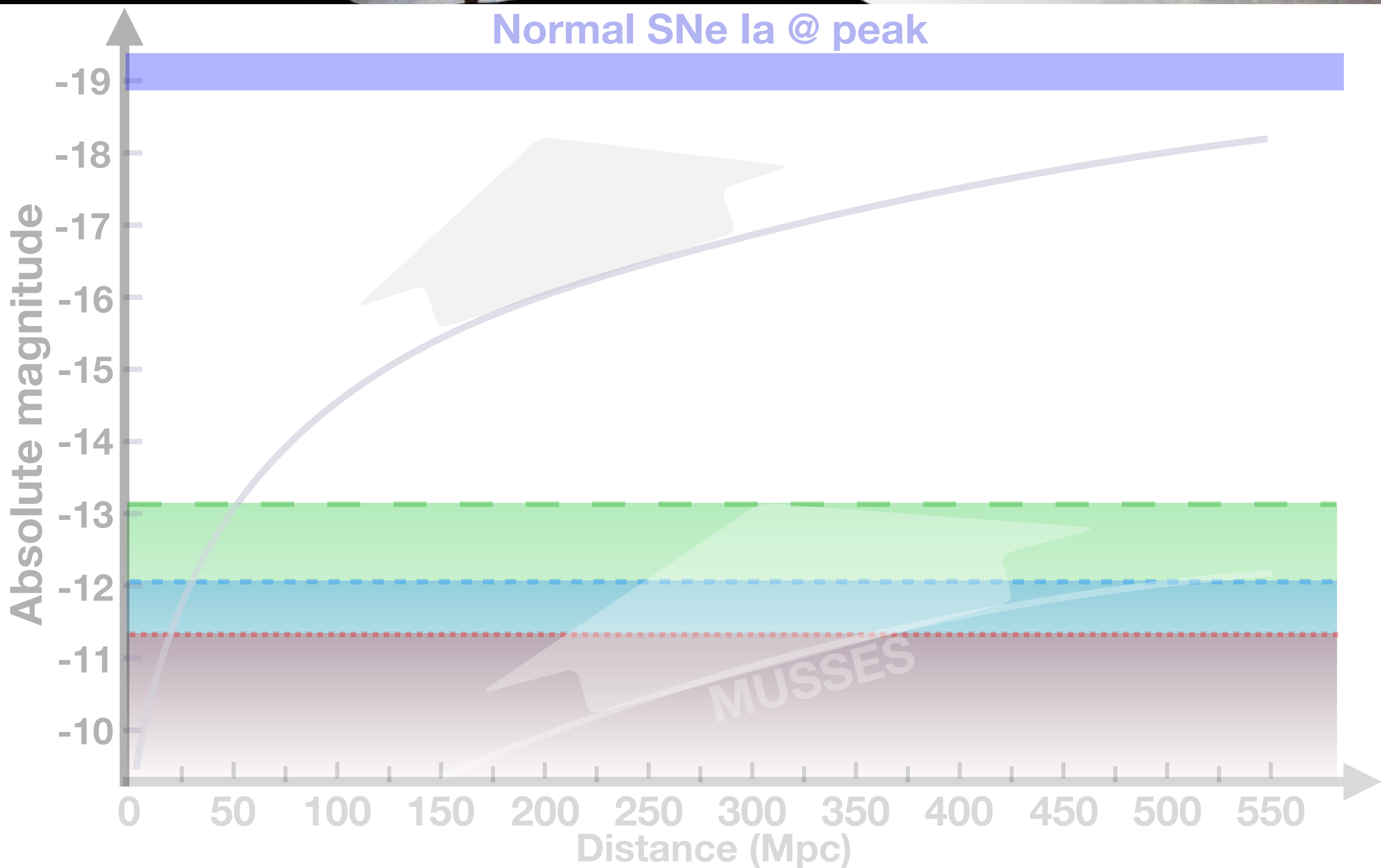
The **M**U**L**ti-band **S**ubaru **S**urvey for **E**arly-phase **S**Ne Ia (**MUSSES**)

Ji-an Jiang, Mamoru Doi, Keiichi Maeda, Toshikazu Shigeyama, Ken'ichi Nomoto, Naoki Yasuda, Nao Suzuki, Tomoki Morokuma, Masaomi Tanaka, Hisanori Furusawa, Satoshi Miyazaki, Nozomu Tominaga, Saurabh W. Jha, Zeljko Ivezic, Andrew Connolly, Peter Yoachim, Pilar Ruiz-Lapuente, Maximilian Stritzinger, Paolo Mazzali, Christopher Ashall, Ferdinando Patat, Dietrich Baade, Jeremy Mould, Lifan Wang, David Jones

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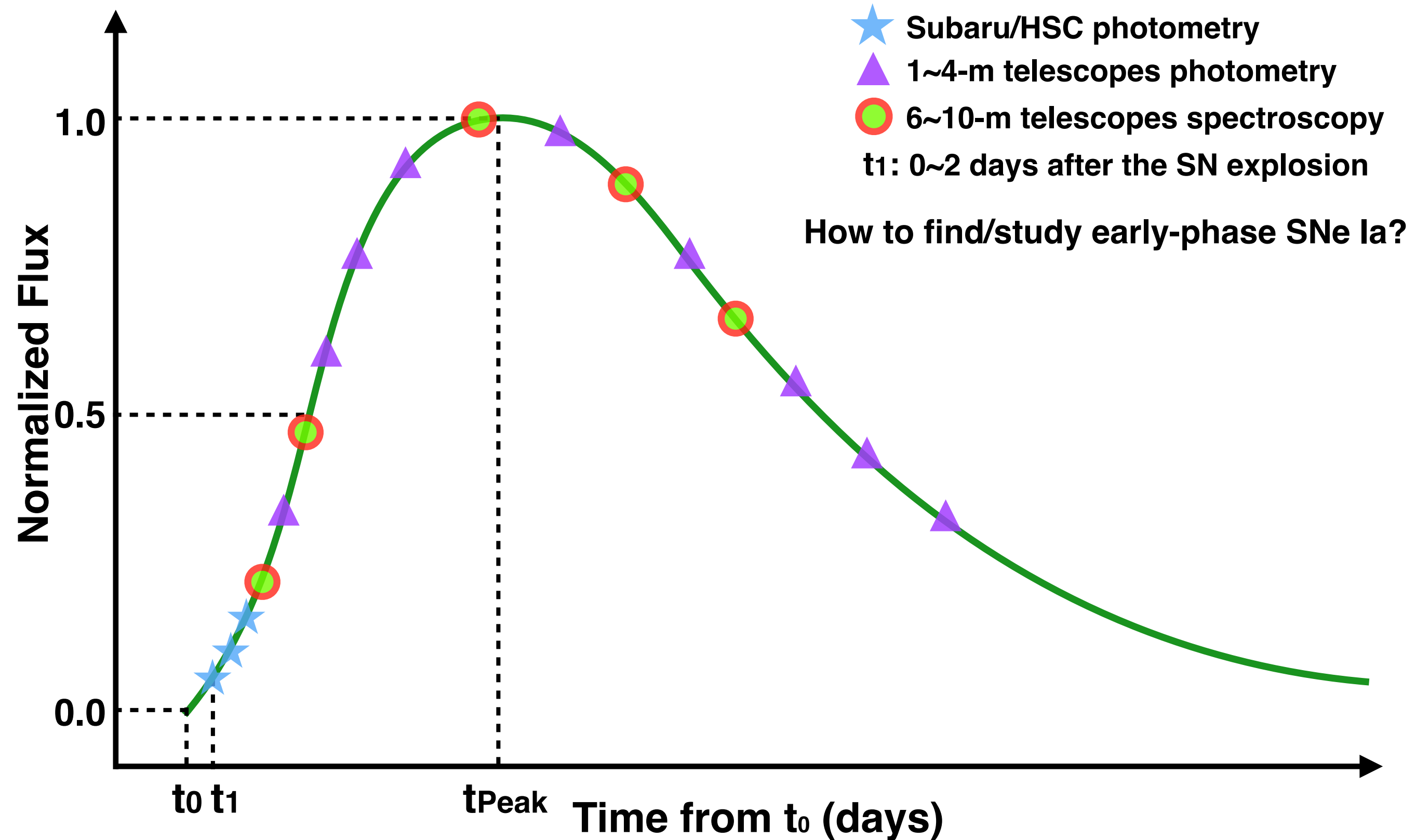
- ❖ Period: Started from April 04, 2016
- ❖ Objectives: Investigating the photometric/spectroscopic behavior of ESNe Ia
- ❖ Observing Mode: Subaru/HSC survey + follow-up observations
- ❖ Time Allocation: 2.5–3.5 Subaru/HSC nights in each observing run
- ❖ Filters: g- and r-band for the Subaru/HSC observation
- ❖ **Limiting Magnitude: 26.5 mag (5σ) in *g* & *r* bands**
- ❖ **Cadence: 1 day** **"Deep"+"Wide"**
- ❖ **Survey Area: ~60 deg² for each observing run**
- ❖ **Follow-up Network:** 10.4-m GTC, 9.2-m SALT, 8.1-m VLT, 8.0-m Gemini, 3.8-m Seimei, 3.5-m ARC, 2.5-m NOT, 2.5-m INT, 2-m LT, 1.05-m Kiso, etc.

✿ Why Subaru/HSC, why MUSSES?

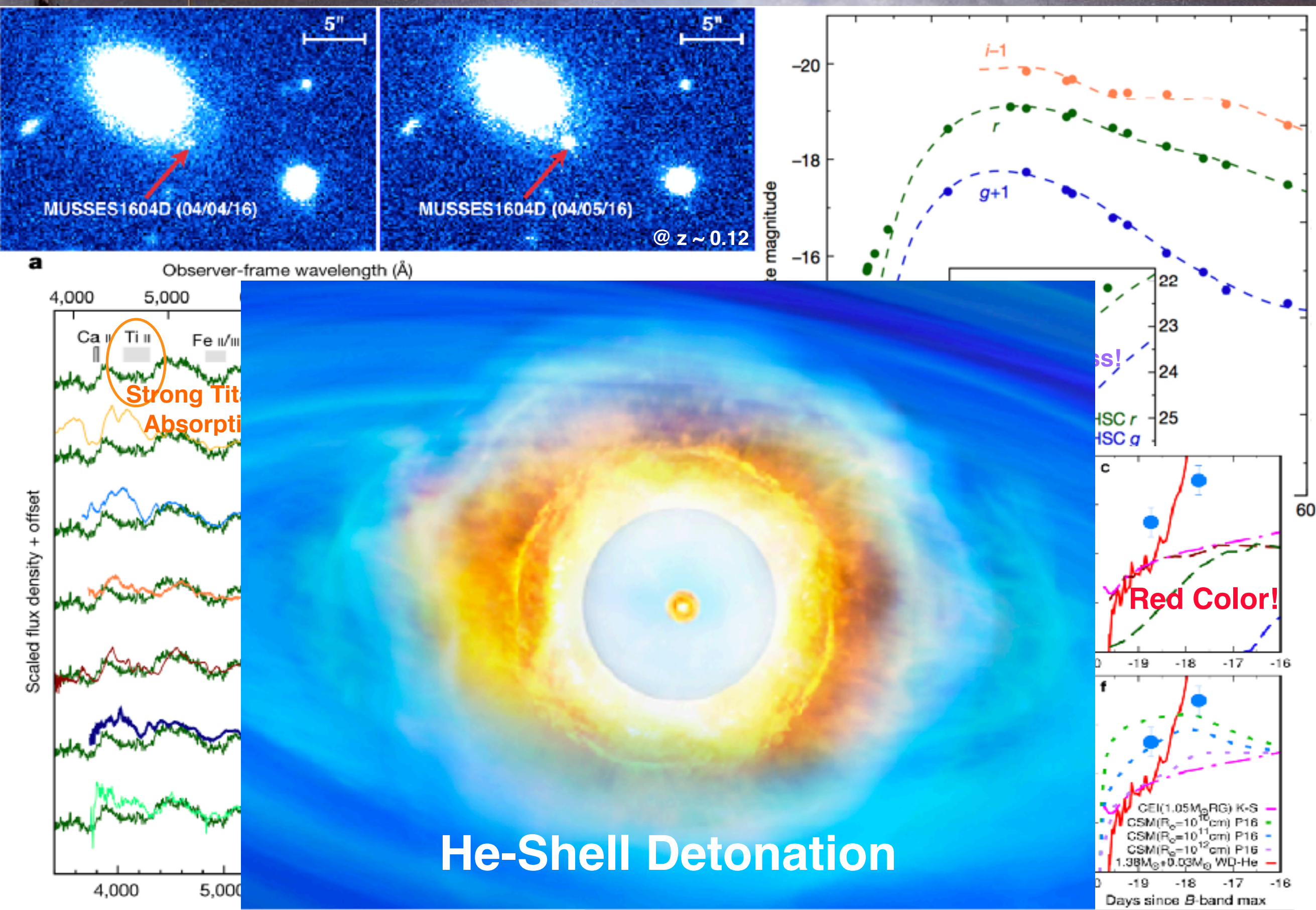


* The observing mode of MUSSES

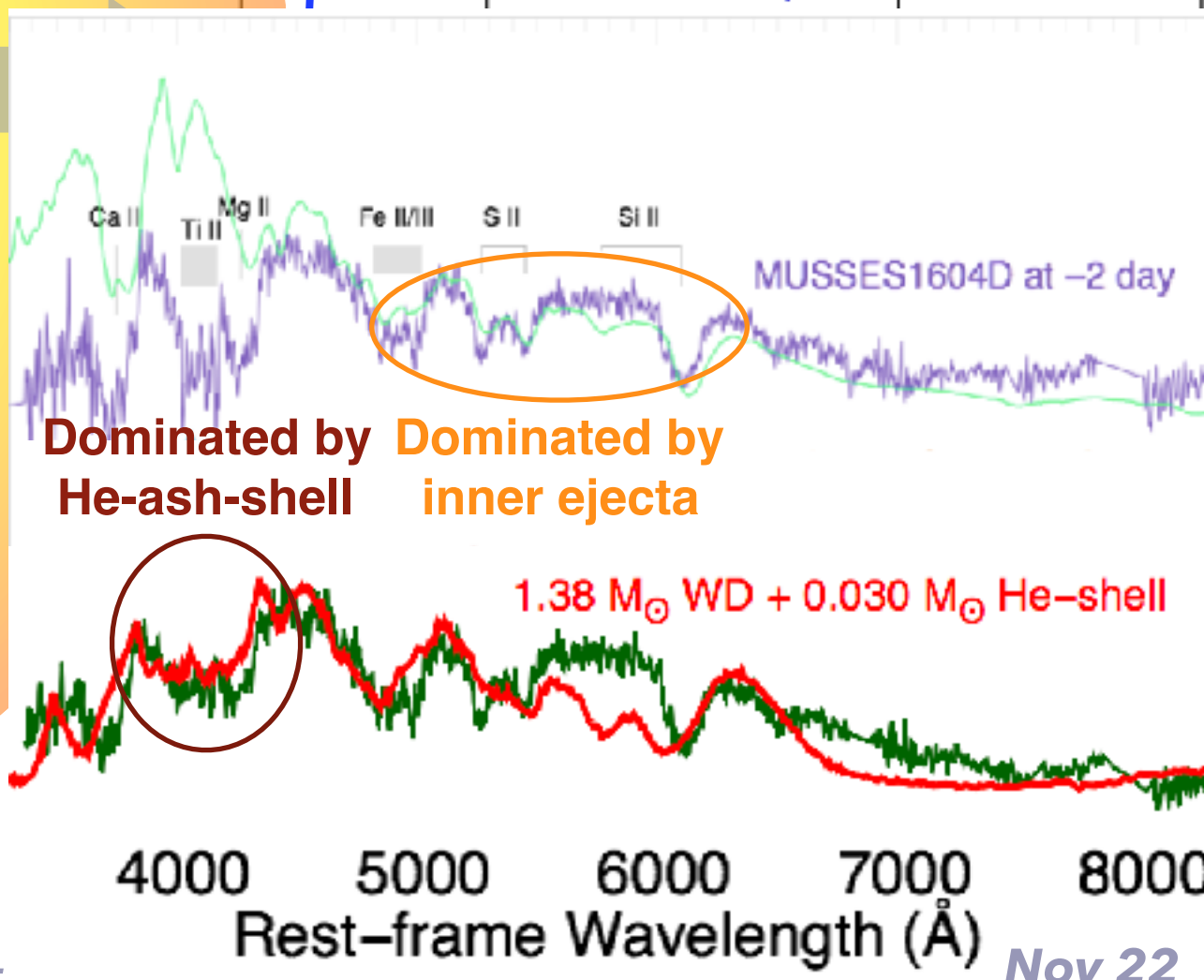
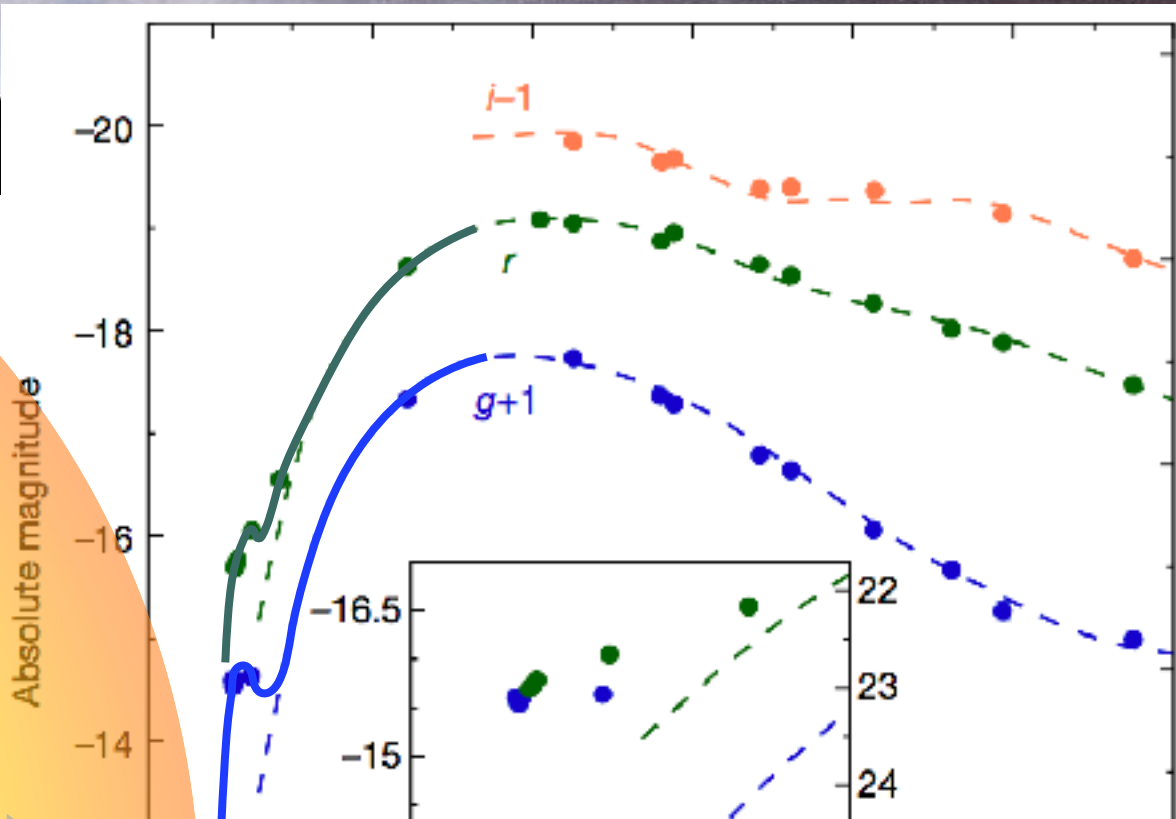
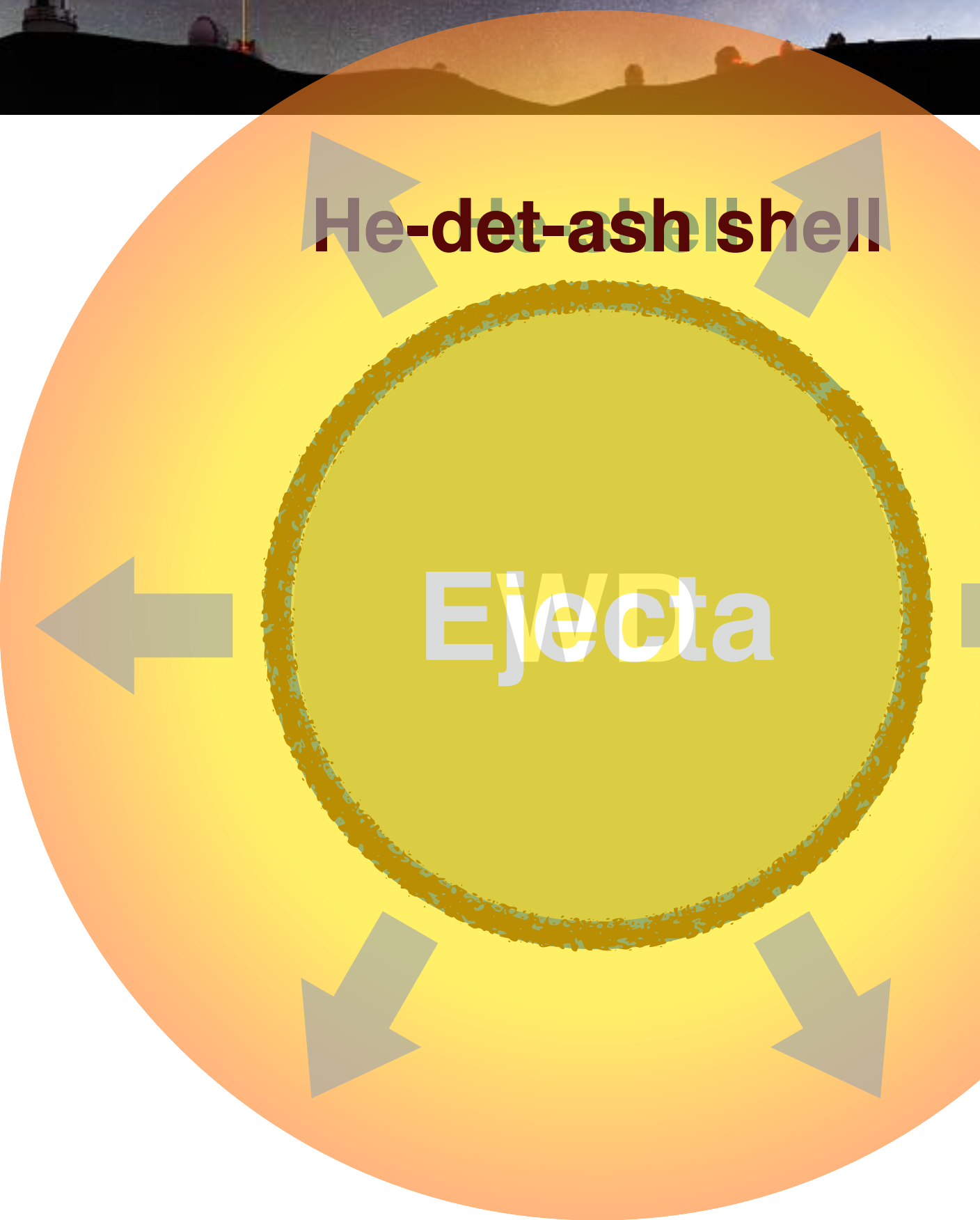
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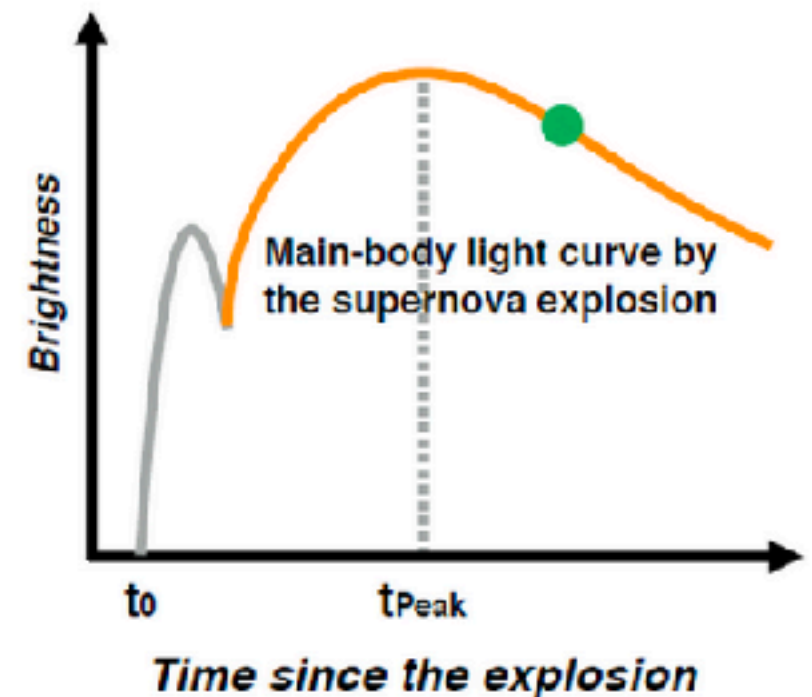
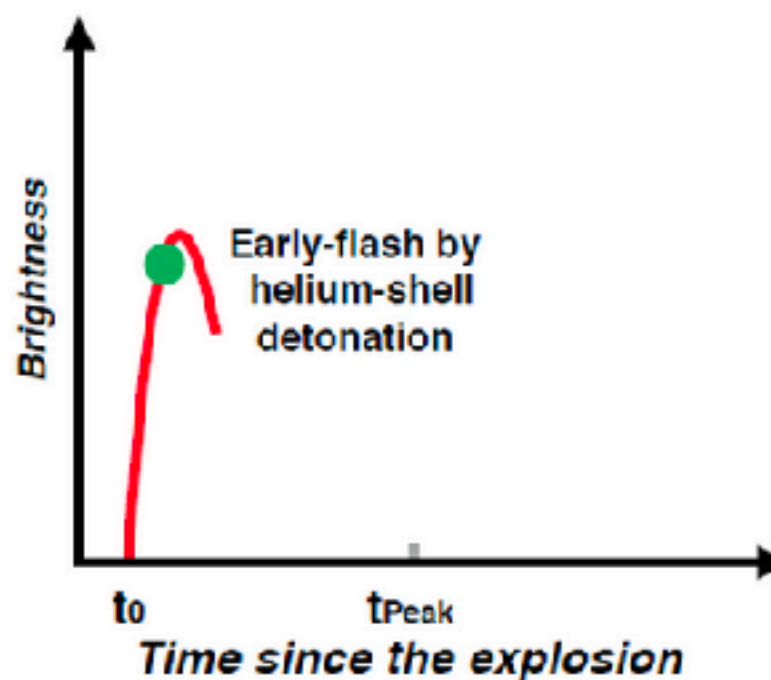
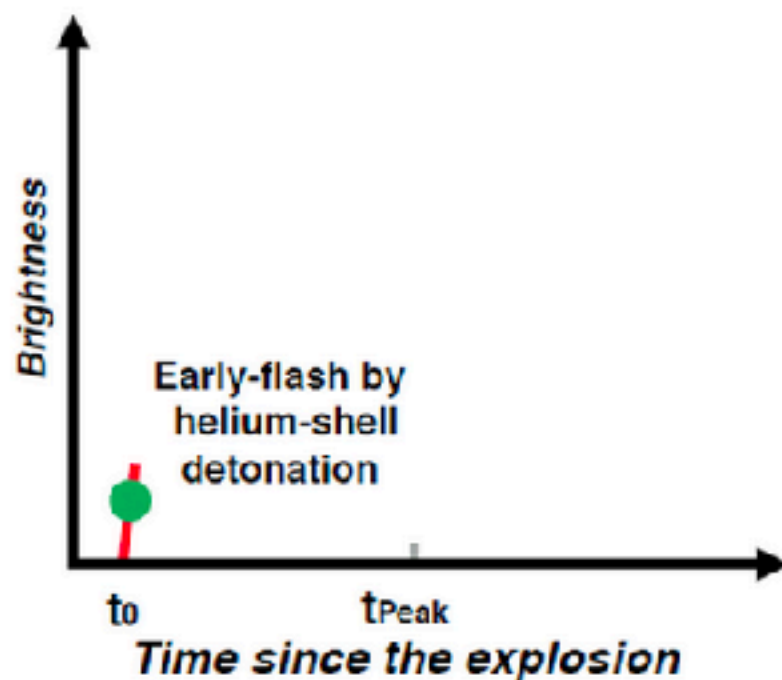
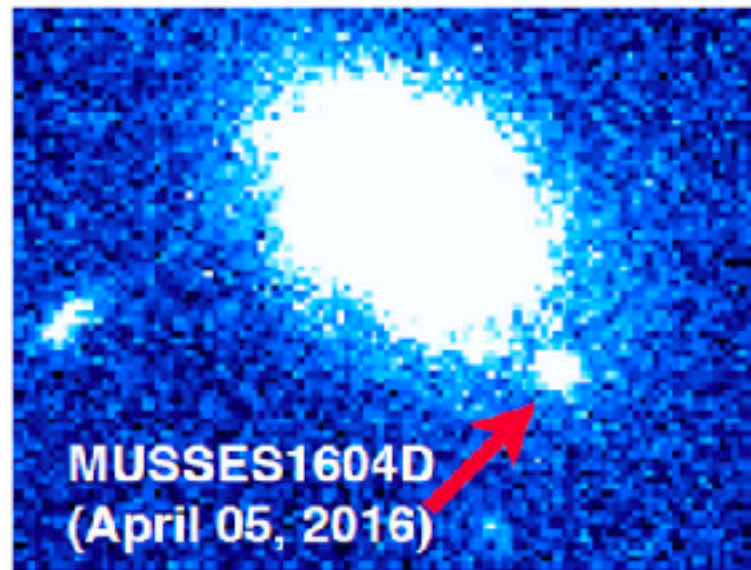
❁ MUSSES1604D, a smoking-gun of the He-detonation scenario (JJ+ 2017)



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This is the first evidence that one theoretically predicted stellar explosion mechanism proposed in early 1980's, does exist in our universe!

This is also the first evidence for multiple origins of early light curve excess in SNe Ia.

The HSC SSP Transient Survey

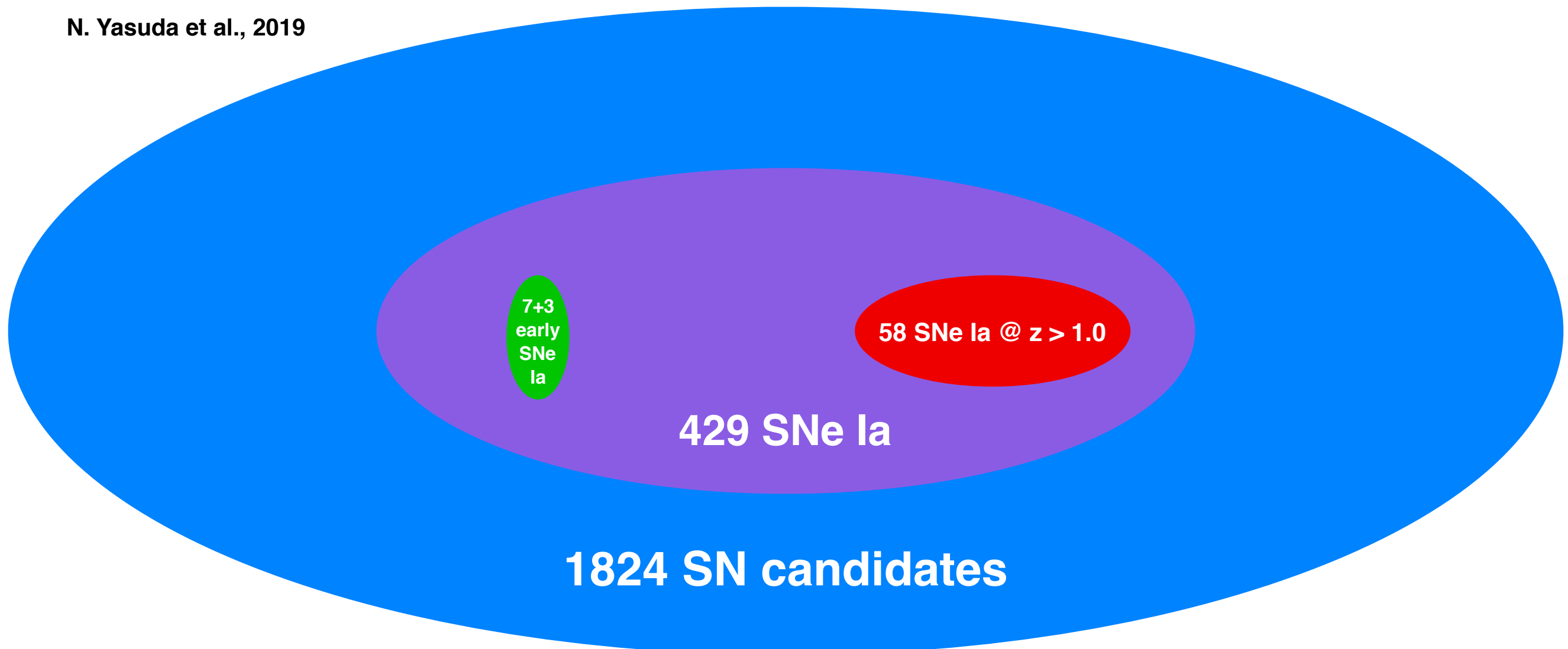
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- ❖ A one-year survey (two independent runs) optimized for high- z SN Ia cosmology
- ❖ Fields: COSMOS UD/DEEP ($\sim 7.5 \text{ deg}^2$) & SXDS UD/DEEP ($\sim 6.5 \text{ deg}^2$)

COSMOS (Nov. 2016 – Apr. 2017)

SXDS (Sep 2019 Jan 2020)

N. Yasuda et al., 2019



❁ A summary of early-phase SNe Ia study with HSC SSP Transient Survey in COSMOS

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Jiang et al. (in prep)





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Current status of the HSC SSP Transient Survey in SXDS and MUSSES (Sep. 2019 –)

MUSSES+SSP SDXS (Sep. 2019 – present)

Trouble 1. Weather;

Trouble 2. FEU trouble;

...

Sep 22	Sep 23	Sep 24	Sep 25	Sep 26	Sep 27	Sep 28 ●
SSP (Canceled) HSC	Queue (Canceled) HSC	Queue (0.4) (Canceled) HSC	SSP (Canceled) HSC	SSP HSC	S19B-023(0.8) Jiang HSC	S19B-023 Jiang HSC
SSP (Canceled) HSC		SSP(0.6) (Canceled) HSC			SSP(0.2) HSC	SSP HSC

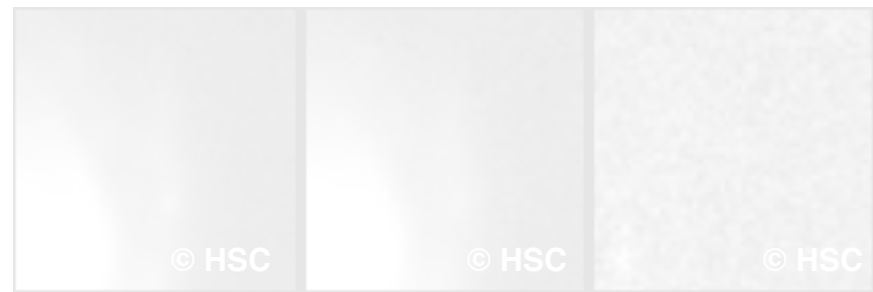
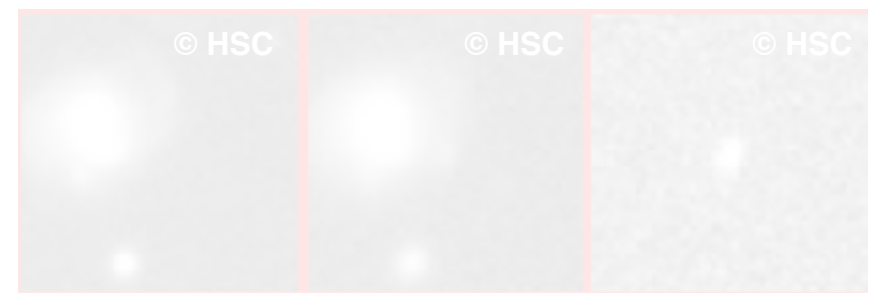
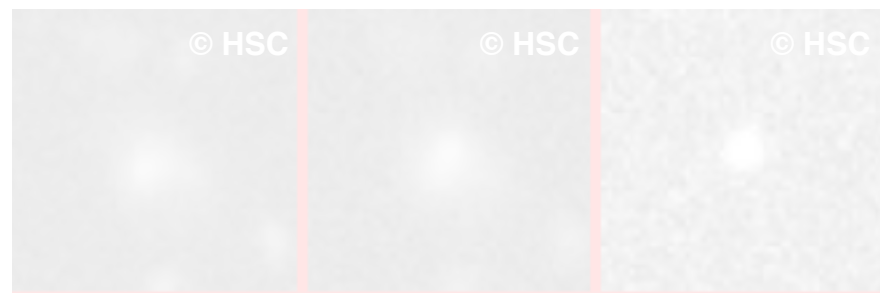
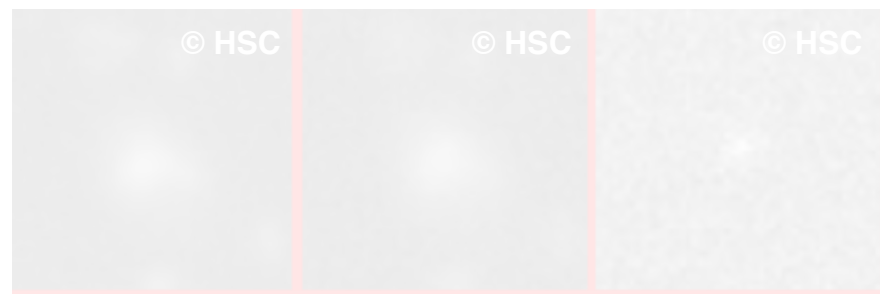
>? early SN
candidates

> ? SN candidates
@ phot-z > 0.8

> ? SN candidates



❁ Current status of the HSC SSP Transient Survey in SXDS and MUSSES (Sep. 2019 –)



- ❖ The HSC SSP project will be finished in 2020;
- ❖ A new transient survey project with HSC open-use time is in preparation;

Even in LSST era, the Subaru/HSC will keep playing an irreplaceable role in time-domain astronomy!

✧ Summary

- ✧ Early-phase photometric information is a unique indicator of not only the progenitor but also the explosion mechanism of SN Ia.
- ✧ In the first **MUSSES** observing run, we discovered **MUSSES1604D** in ~ 0.5 days of its explosion, which is **the first robust evidence** of:
 - (i) **the He-detonation-triggered stellar explosion scenario of SN Ia;**
 - (ii) **multiple origins of the early light-curve excess of SN Ia.**
- ✧ Ten early-phase SNe Ia were discovered in the HSC SSP transient survey by monitoring 7.5 deg^2 sky area around the COSMOS field in a half year. **We found one SN Ia which shows blue excess at early time.**
- ✧ Even though various kinds of troubles occurred in the ongoing HSC transient surveys, a dozen of early-phase SN candidates have been discovered successfully. **By using Subaru/HSC, our transient surveys will keep playing an irreplaceable role in time-domain astronomy in 2020s.**

Thank you!