THE UNIVERSITY OF TOKYO

Multiple Origins of Early-excess Type Ia Supernovae and Their Implications

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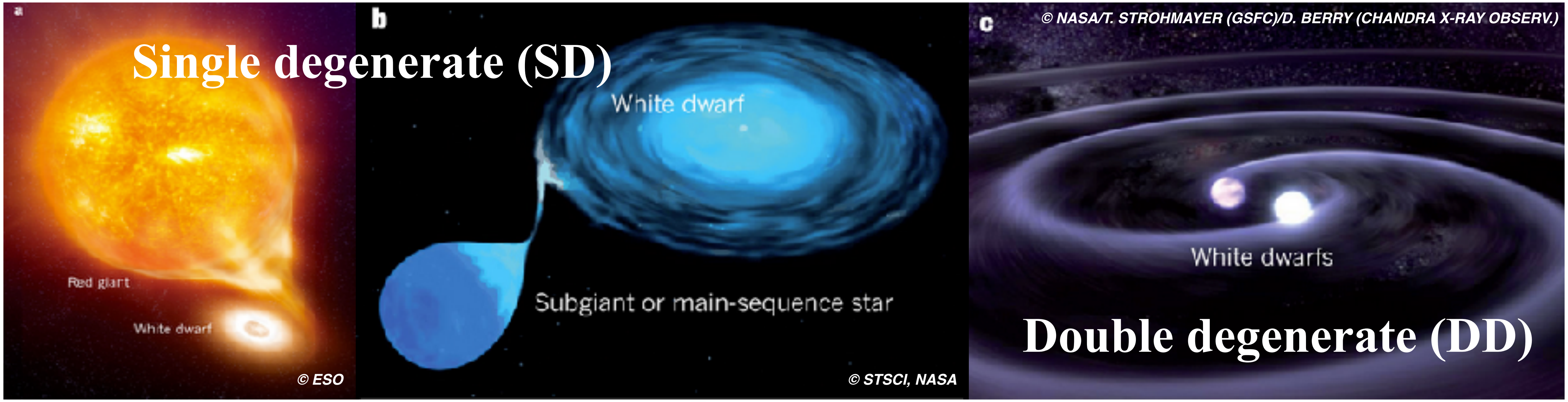
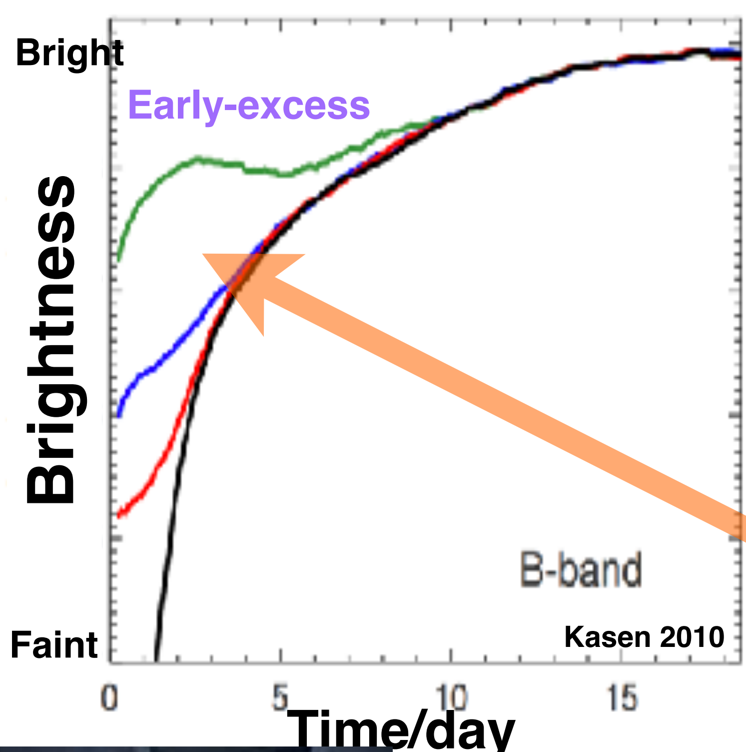
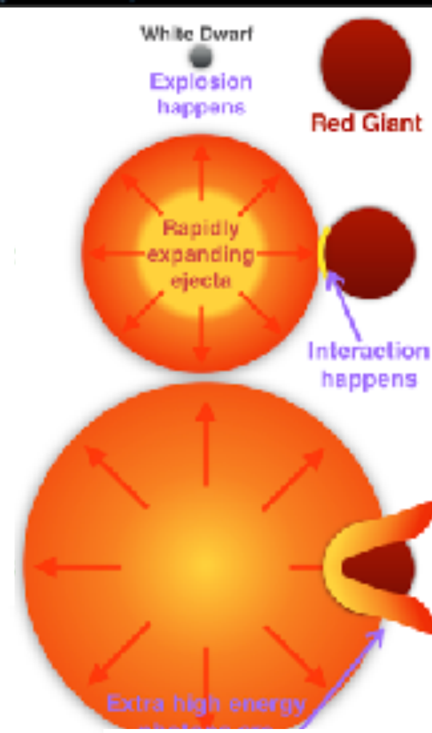
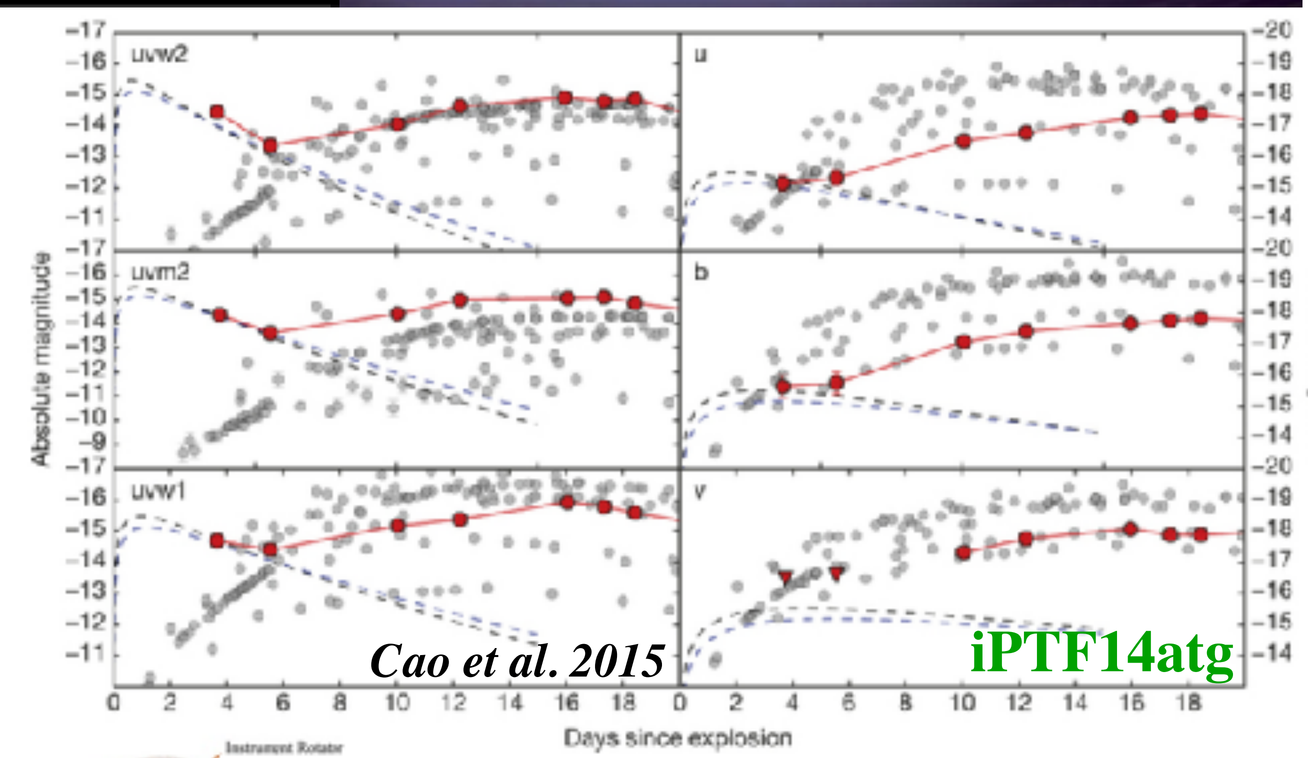
Massive Stars & Supernovae @ Bariloche

Type Ia Supernovae and Their Early-phase Behavior



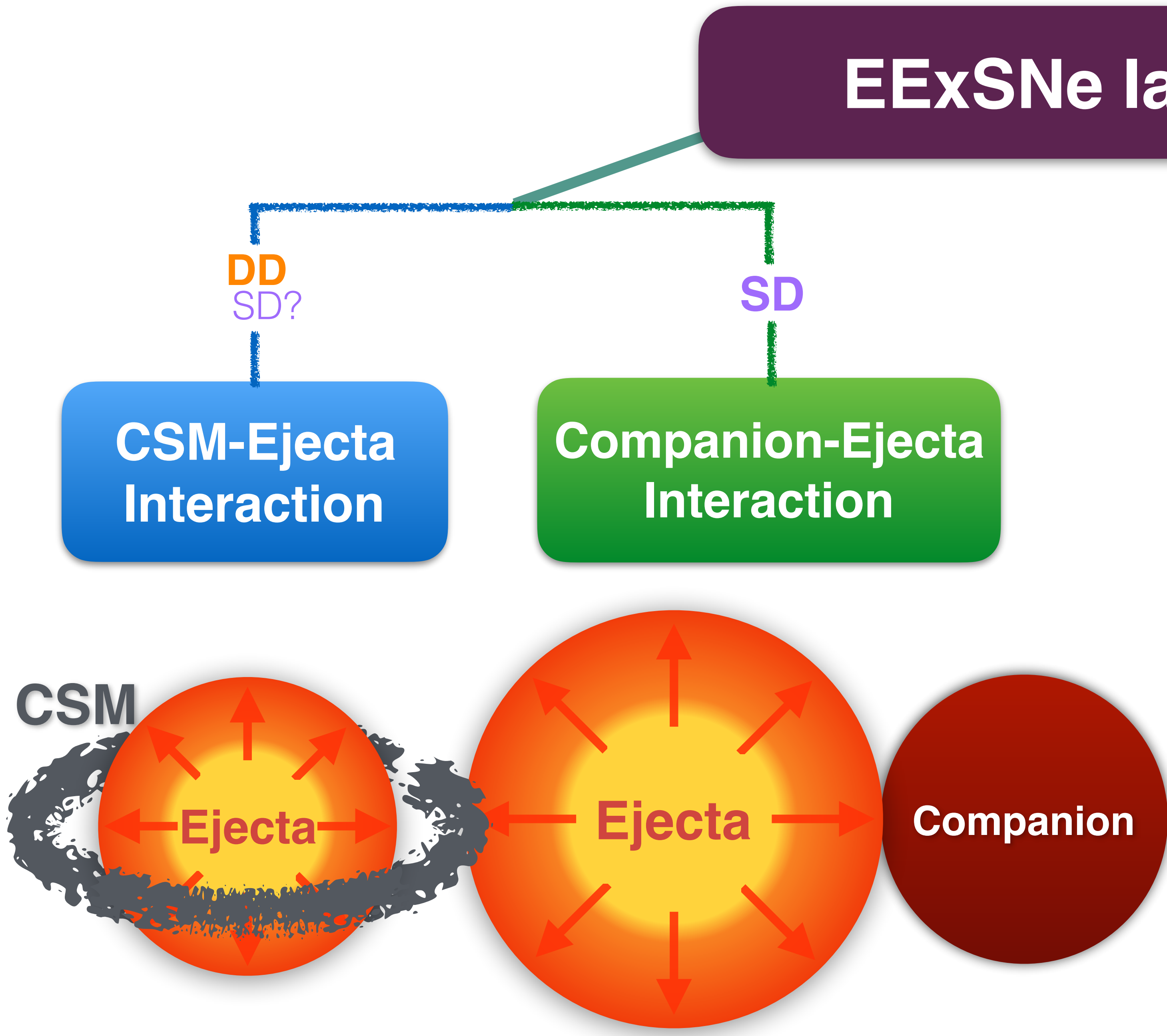






Searching for SNe Ia soon after the explosion (early-phase SNe Ia, ESNe Ia) with Japanese Wide-Field Survey Facilities.

The Diversity of Early-excess SNe Ia



Characteristics

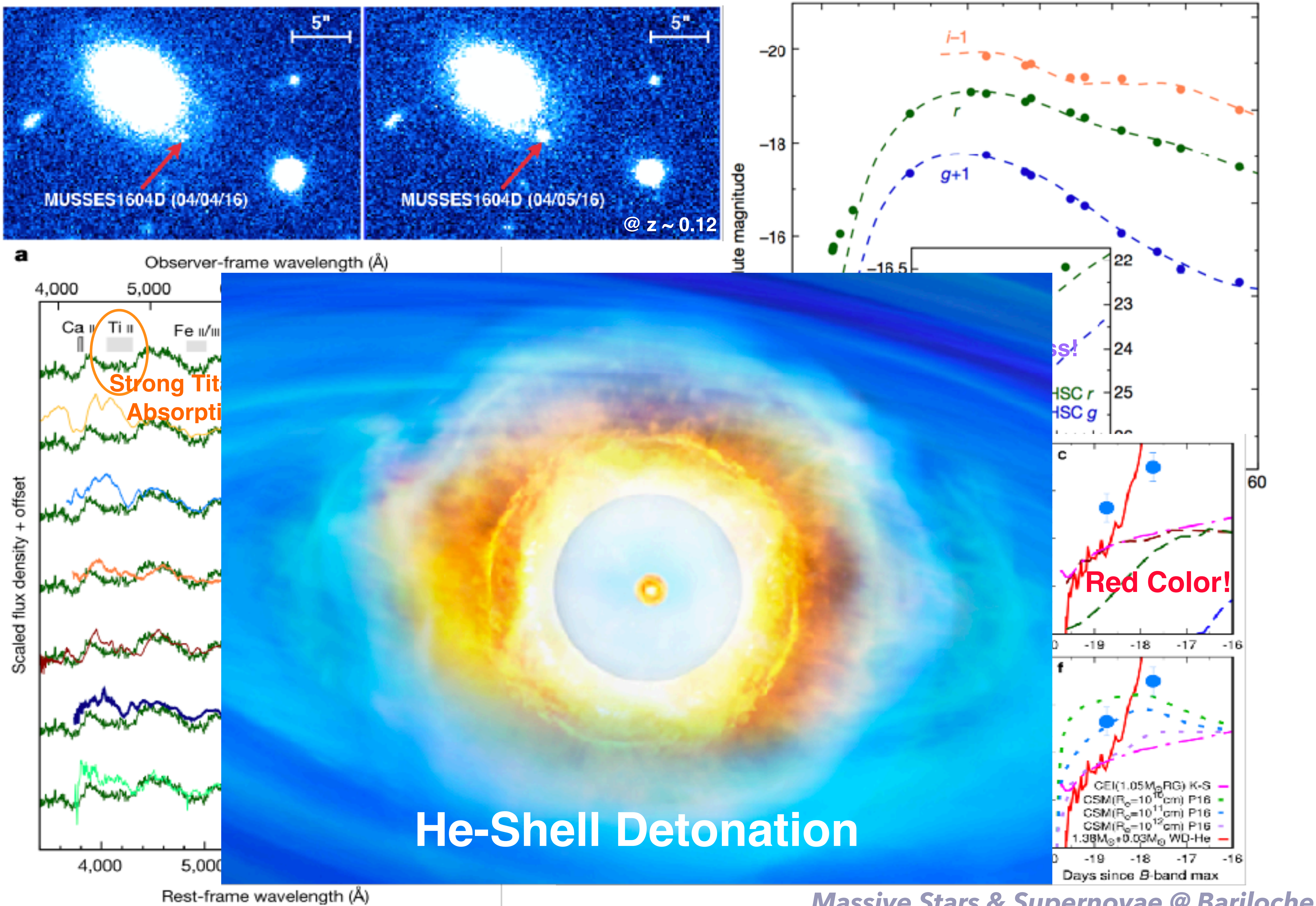
- Blue early light-curve excess;
- Viewing angle dependent;
- SD indicator;

Characteristics

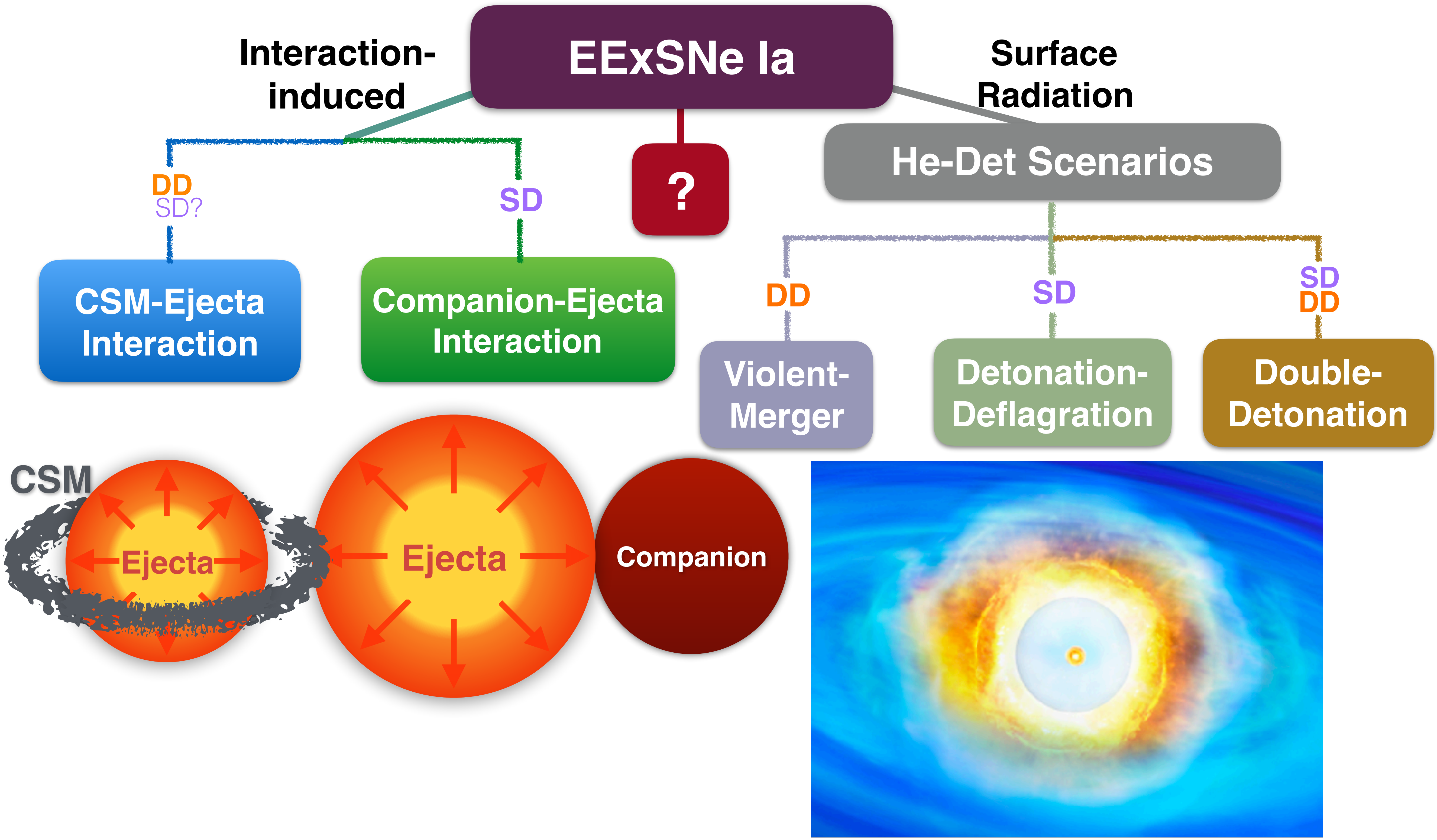
- Blue early light-curve excess;
- Weak viewing angle effect;
- DD & SD?

Interaction-induced EExSNe Ia

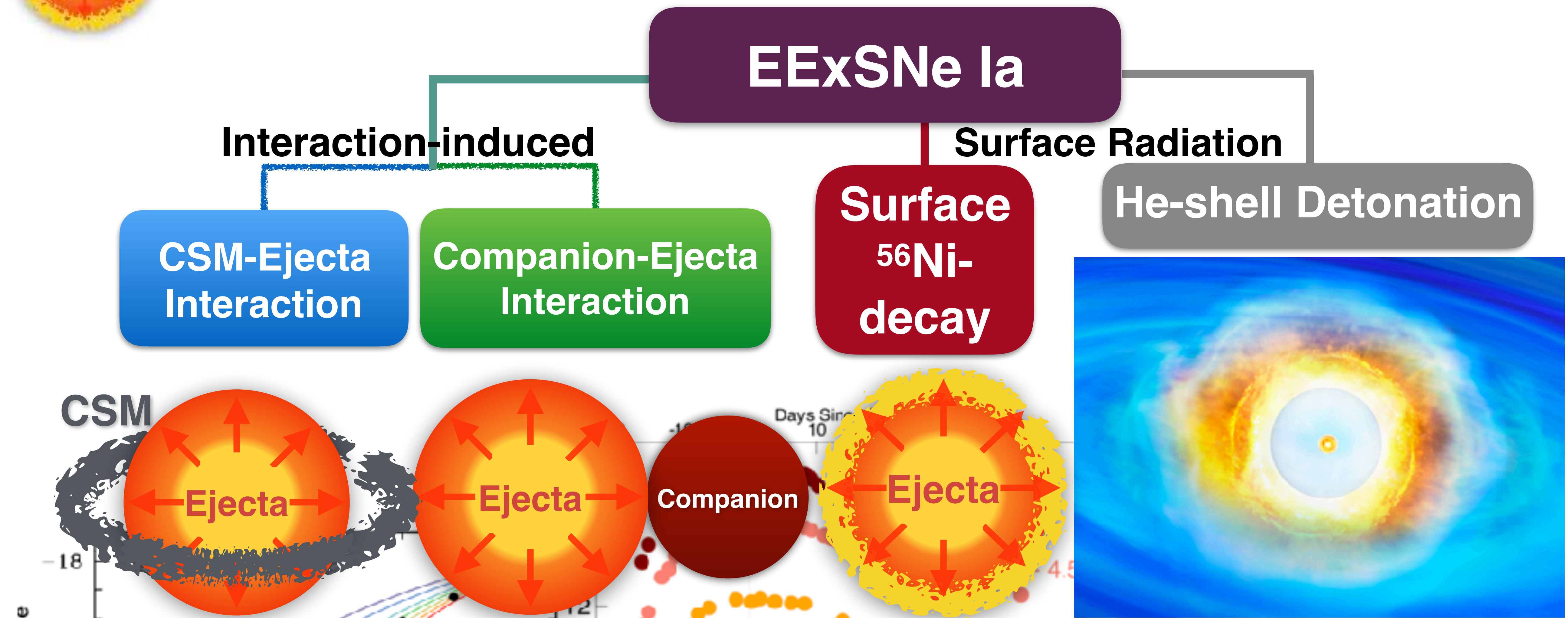
❈ MUSSES1604D, a smoking-gun of the He-detonation scenario (Jiang+ 2017)

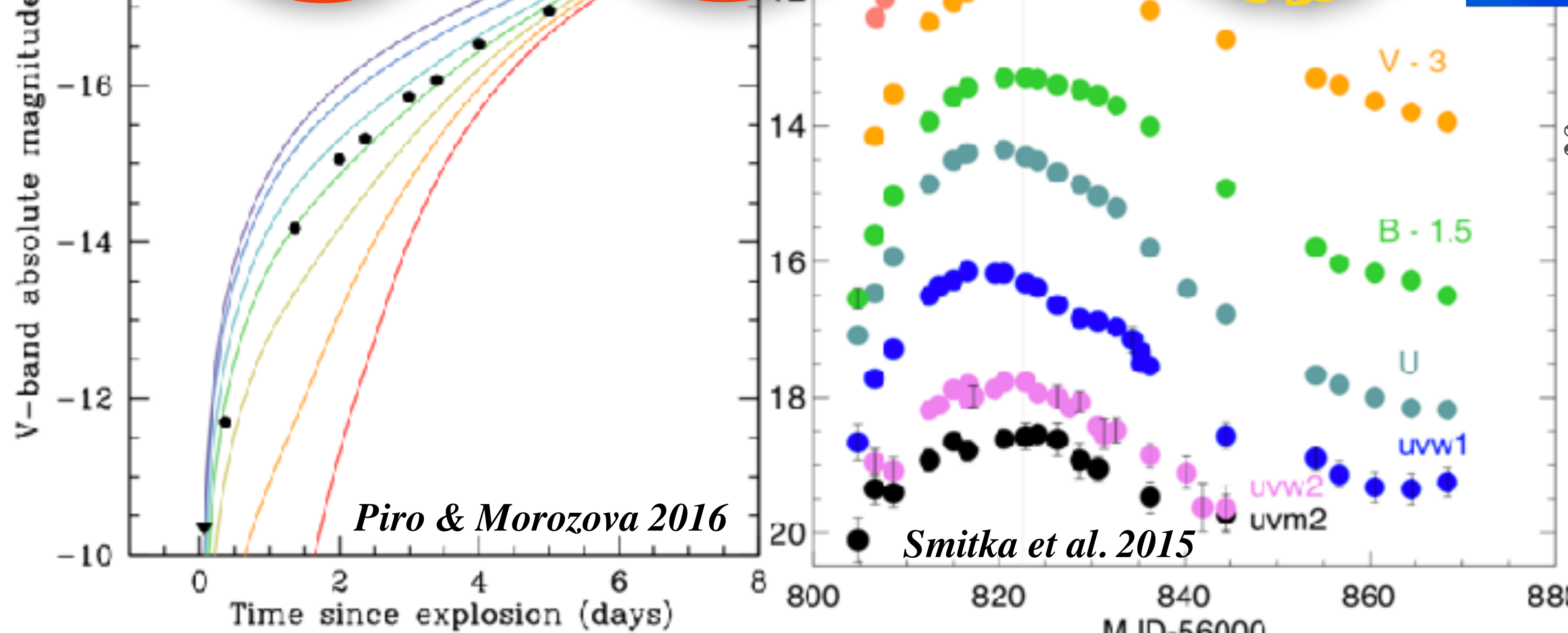


The Diversity of Early-excess SNe Ia



❋ Surface ^{56}Ni-decay EExSNe Ia



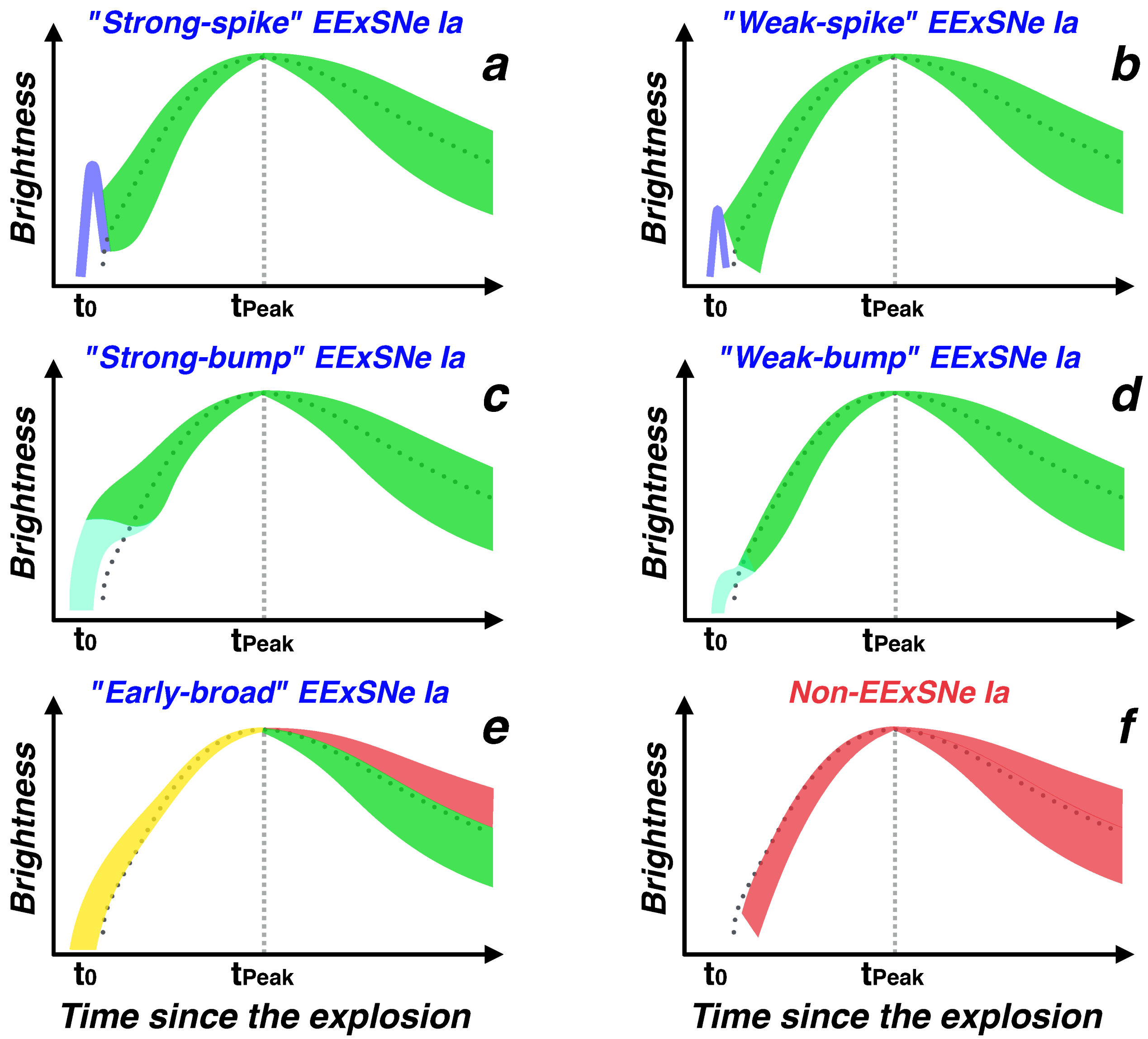


❋ Characteristics

- Blue early excess
- viewing angle independent?
- Both SD & DD?
- Luminous SNe Ia related?

Previously Discovered EExSNe Ia (reported + unnoticed)

Early Excess in observations



Jiang+ 2018

23 golden early-phase SNe Ia
+
40 SNe Ia with relatively early UV/NUV information (Incl. 14 golden SNe Ia)

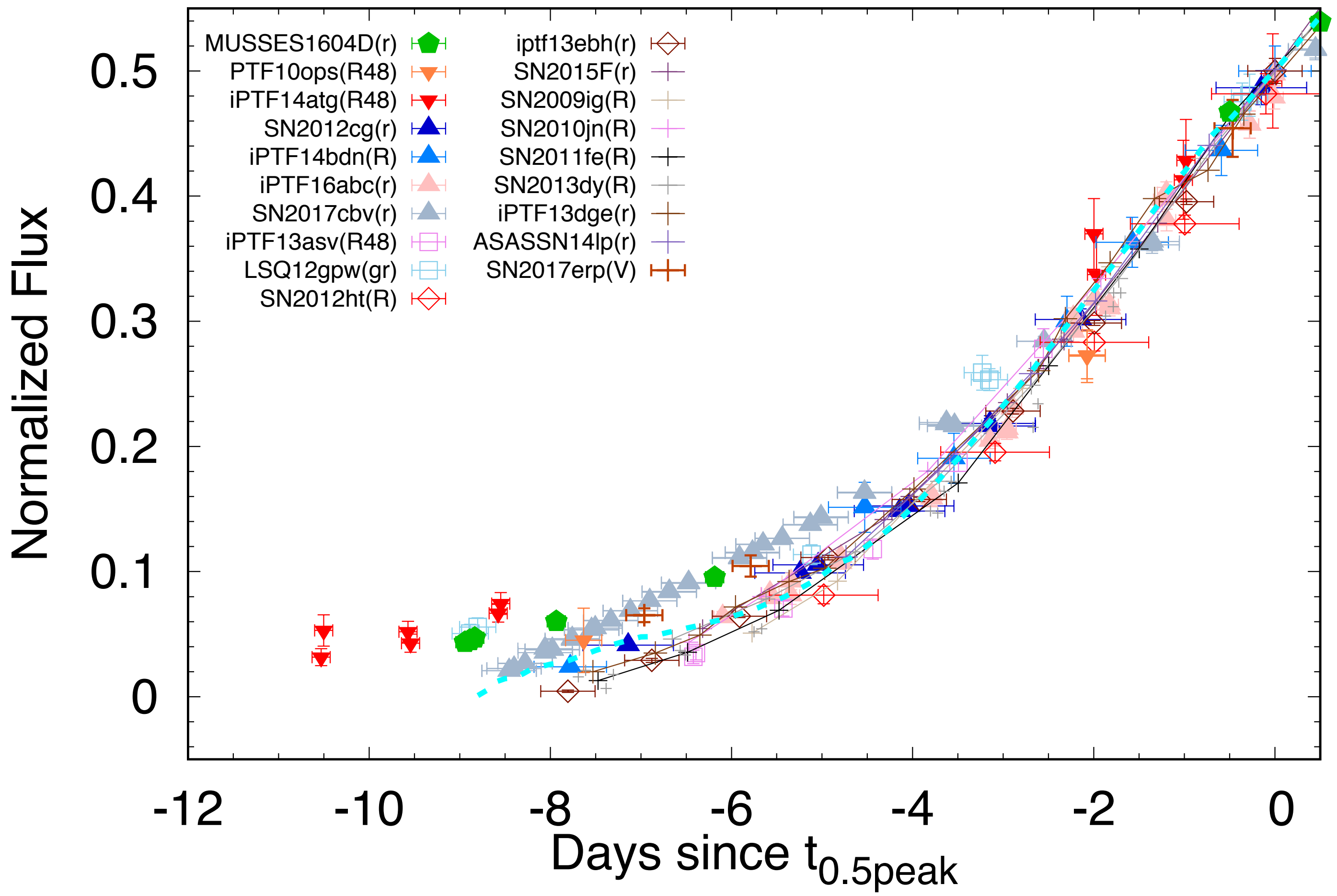
Reported EExSNe Ia

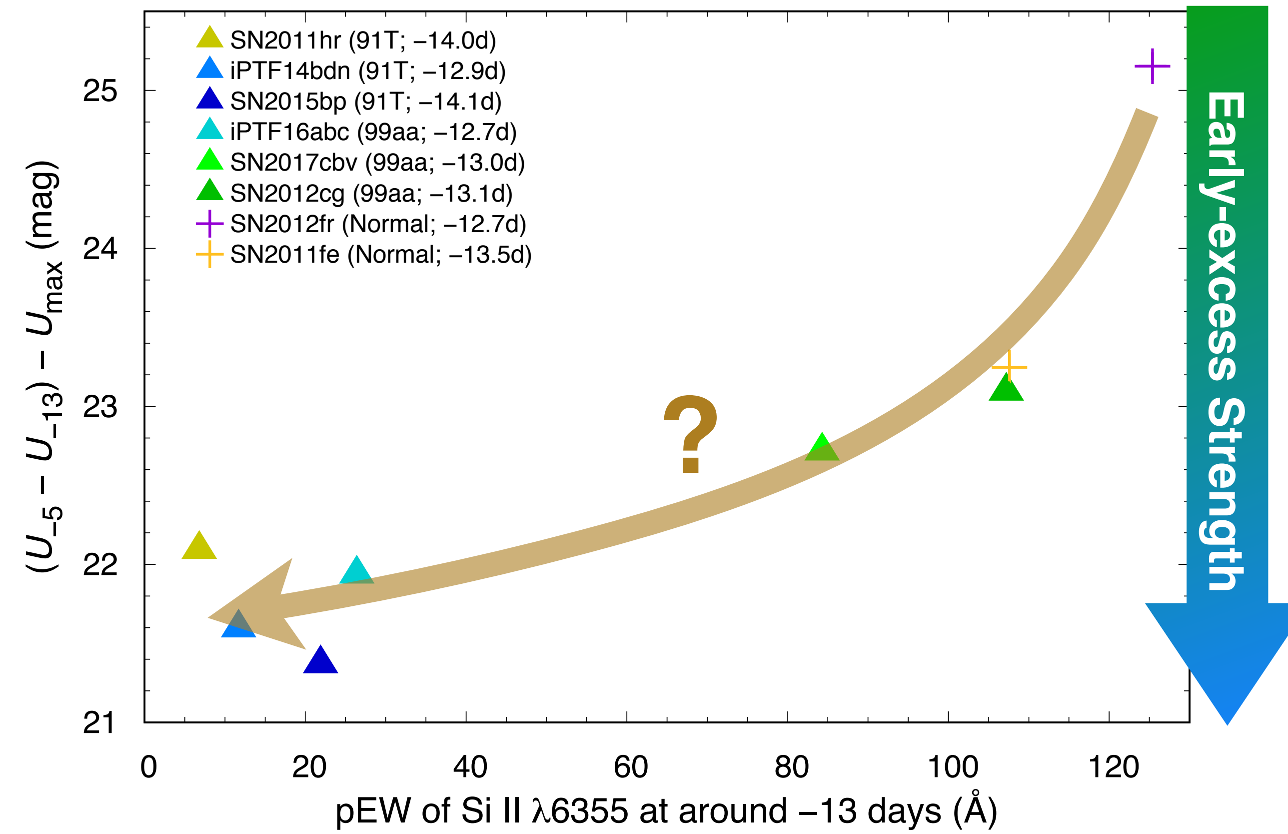
SN Name	Subclass	EEx Type
SN 2012cg	99aa-like	d/e
iPTF14atg	02es-like	a
iPTF14bdn	91T-like	c
iPTF16abc	99aa-like	c/d
MUSSES1604D	He-det	a
SN 2017cbv	99aa-like	c/d

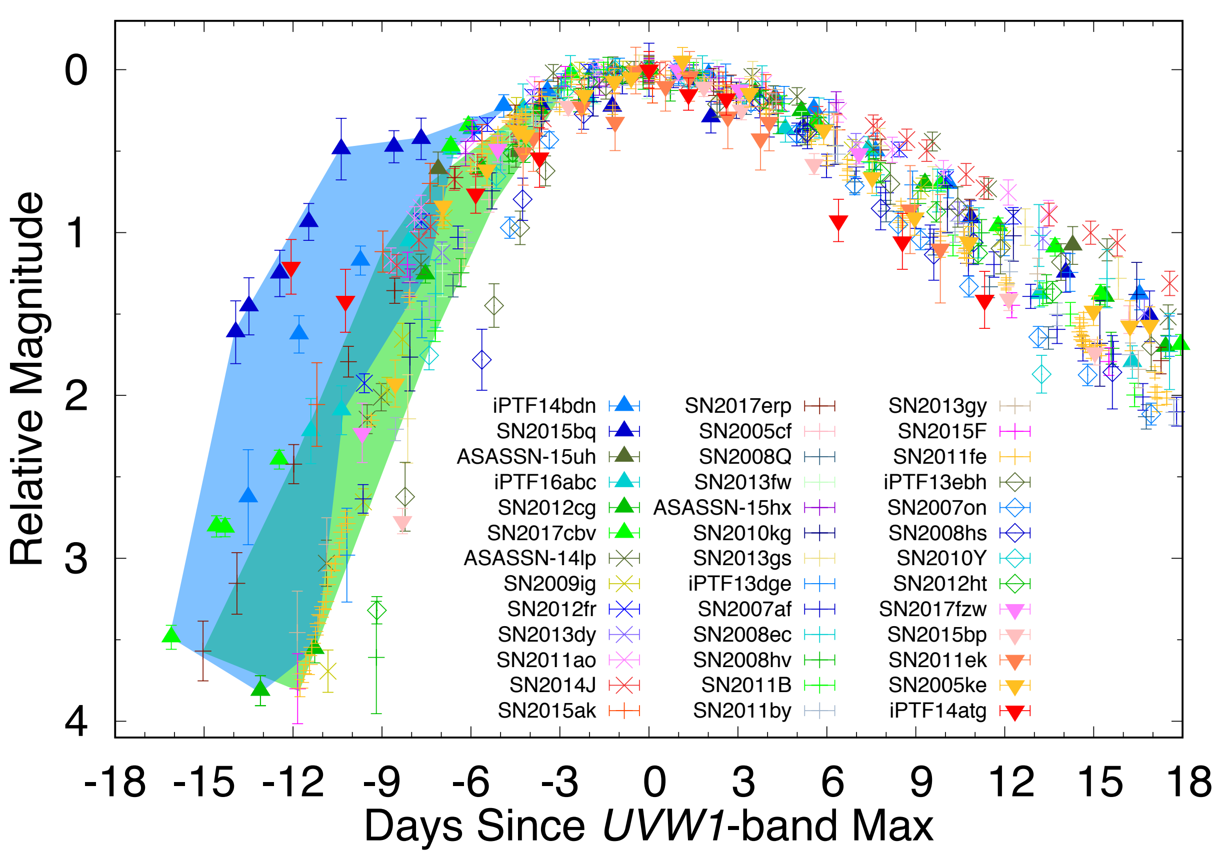
Unnoticed EExSNe Ia

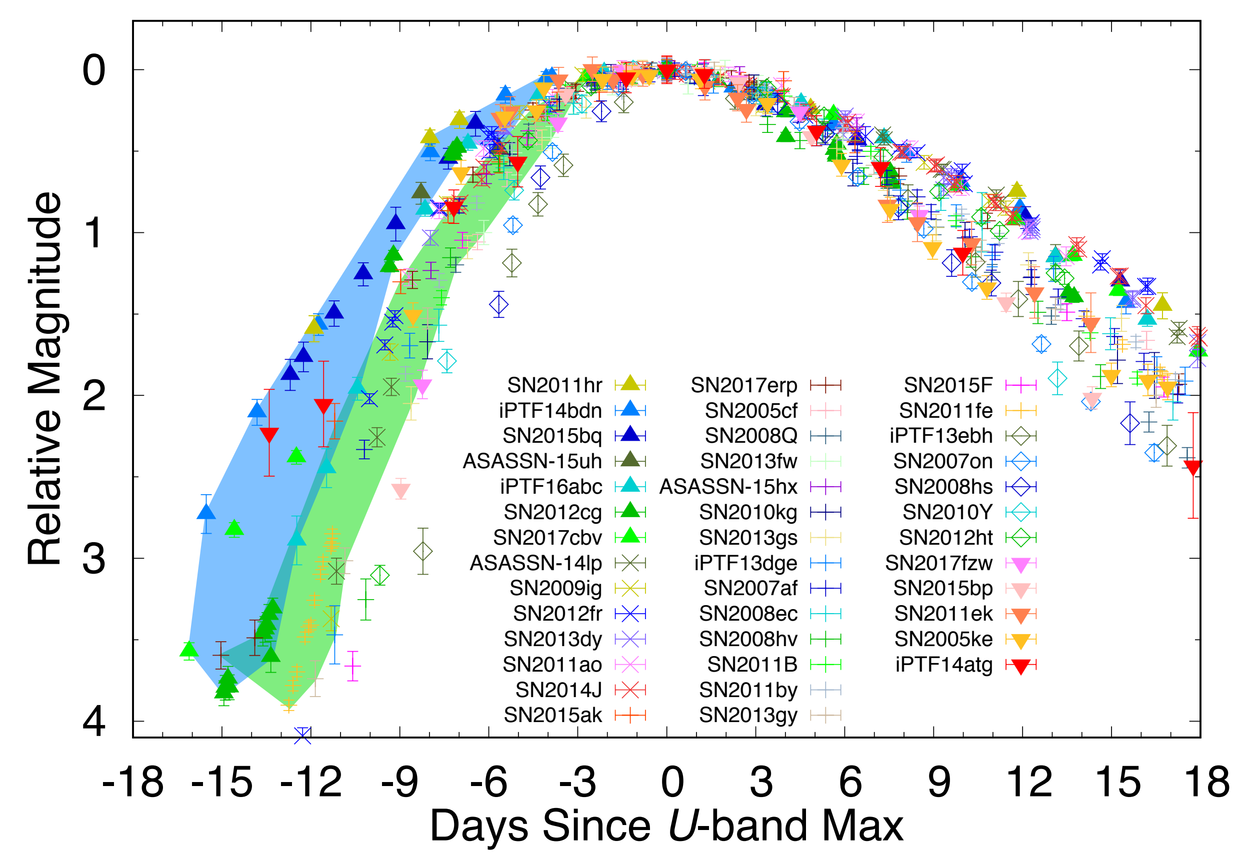
SN Name	Subclass	EEx Type
PTF10ops	02es-like	b/d/e
SN2011hr	91T-like	c
LSQ12gpw	"Super-M*Ch*"	a/c
SN2015bq	91T-like	c
SN 2017erp	Normal	e

Early-excess Diversity in Statistics (Jiang et al. 2018, ApJ, 865, 149)







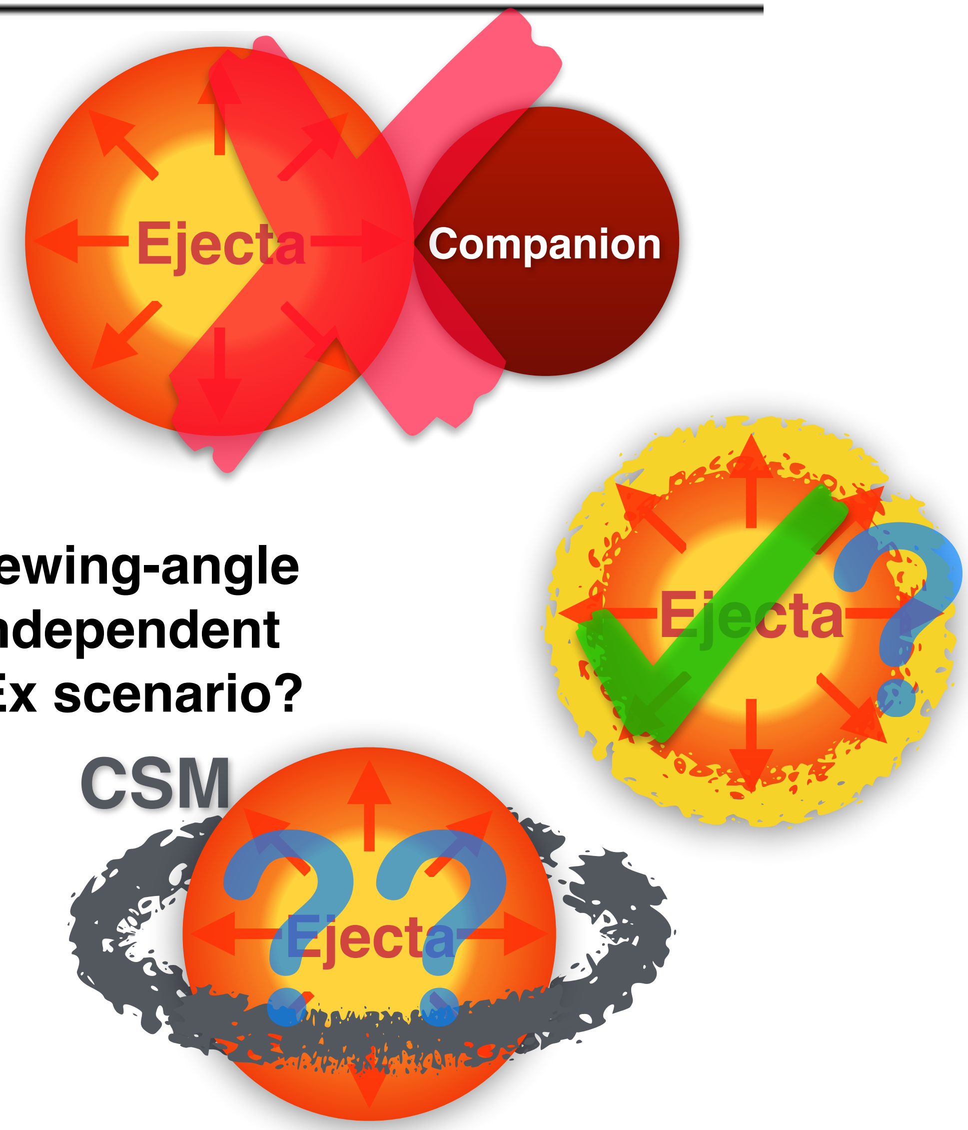


Early-excess Diversity in Statistics (Jiang et al. 2018, ApJ, 865, 149)

Subclass	Early-phase SNe Ia Golden (Final[a])	EExSNe Ia Golden (Final)	EEx Fraction Golden (Final)
Normal	12 (17)	0 (1)	0 (5.9%)
Luminous (91T/99aa)	4 (6)	4 (6)	100% (100%)
Luminous (peculiar)	2 (1)	1 (1)	50% (100%)
Transitional	2	0	0
02es-like	2	2	100%
Hybrid	1	1	100%

SN Name	Subclass	EEx Type
SN2011hr	91T-like	c
iPTF14bdn	91T-like	c
SN2015bq	91T-like	c
SN 2012cg	99aa-like	d/e
iPTF16abc	99aa-like	c/d
SN 2017cbv	99aa-like	c/d
PTF10ops	02es-like	b/d/e
iPTF14atg	02es-like	a

100% EEx fraction → Viewing-angle independent EEx scenario?

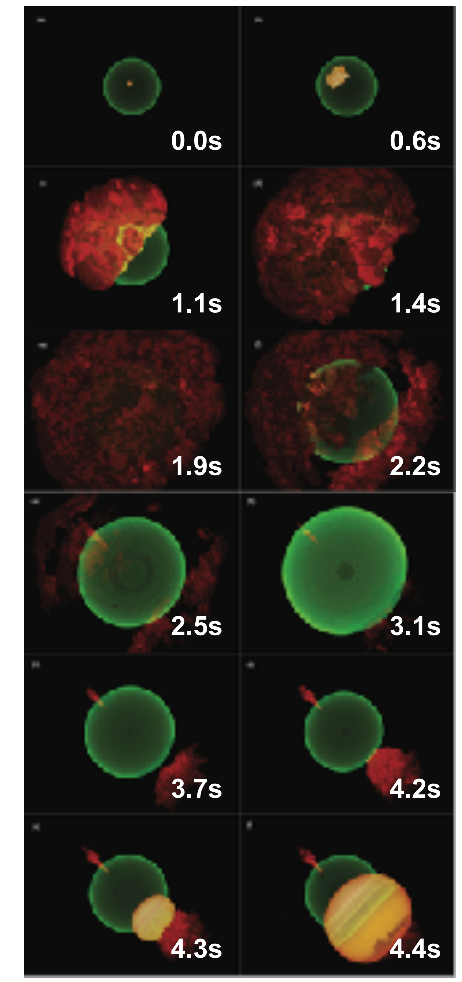


Explanations of EExSNe Ia in Specific Subclasses

91T/99aa-like EExSNe Ia

- Extremely high EEx fraction;
- Blue & prominent EEx;
- Long EEx duration;
- An efficient detonation process;

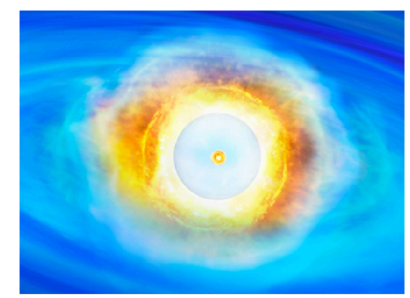
Gravitationally Confined Detonation?



Jordan et al. 2012

02es-like EExSNe Ia

V.S.



- Spike-like & fast reddening early excess;
- Subluminous & slow-evolving light curve;
- High EEx fraction?

Can be explained with the companion-ejecta interaction??

Do we find a real companion-ejecta interaction so far?

Does the surface-^{56}Ni-decay scenario the dominant EEx scenario of SNe Ia?

What is the exact physical mechanism that triggers the He-shell detonation?

❊ Conclusions

❊ Previously discovered early-excess SNe Ia indicates the multiple origins of the early light-curve excess. Such a diversity suggests that **early-excess feature may not be a good progenitor indicator as we originally expected**.

❊ In the first observing run of **MUSSES**, we discovered **MUSSES1604D** within one day of its explosion, which is **the first evidence** of:

(i) the He-detonation-triggered stellar explosion scenario of SNe Ia;

(ii) the multiple origins of the early light-curve excess in SNe Ia.

❊ **Early light-curve excess shown in 91T/99aa-like SNe Ia likely originates from the surface ^{56}Ni-decay scenario**, which can be explained by a previously proposed explosion mechanism of luminous SNe Ia, the gravitationally confined detonation, qualitatively;

❊ It is still unclear that if companion-interaction EExSNe Ia have been discovered. Further understanding of the early-excess diversity relies not only on multiband photometry and prompt-response spectroscopy of individual EExSN Ia but also on investigations of general early-phase light-curve behavior of each SN Ia subclass, which can be achieved through ongoing/forthcoming transient survey projects in the near future.

Thank you!