

Catching the Earliest Optical Emission of SN Ia 2020hvf with the Tomo-e Gozen Camera

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2021/10/05

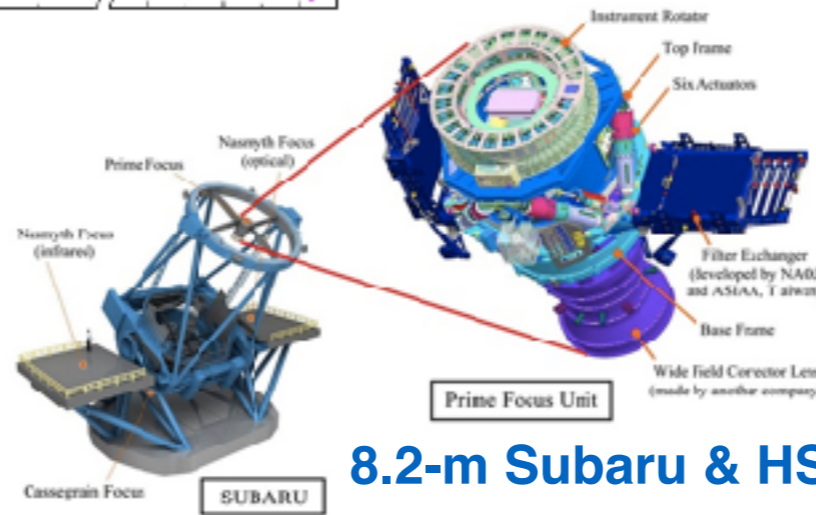
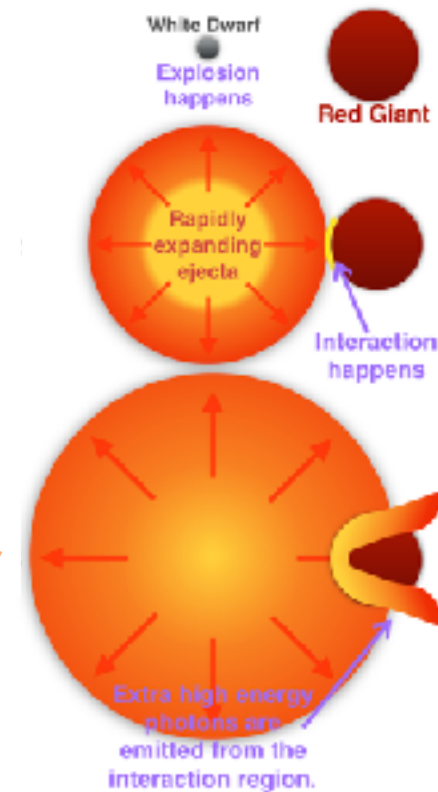
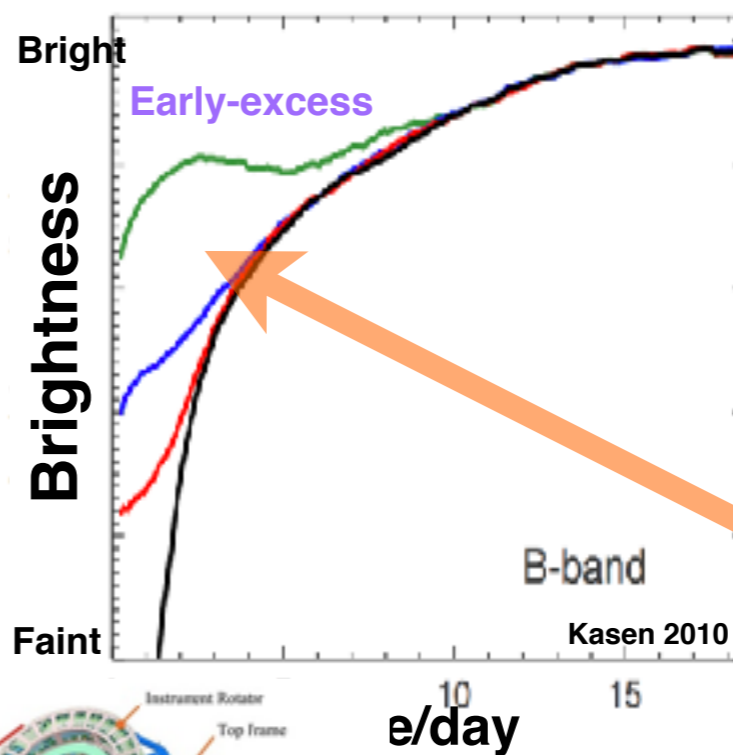
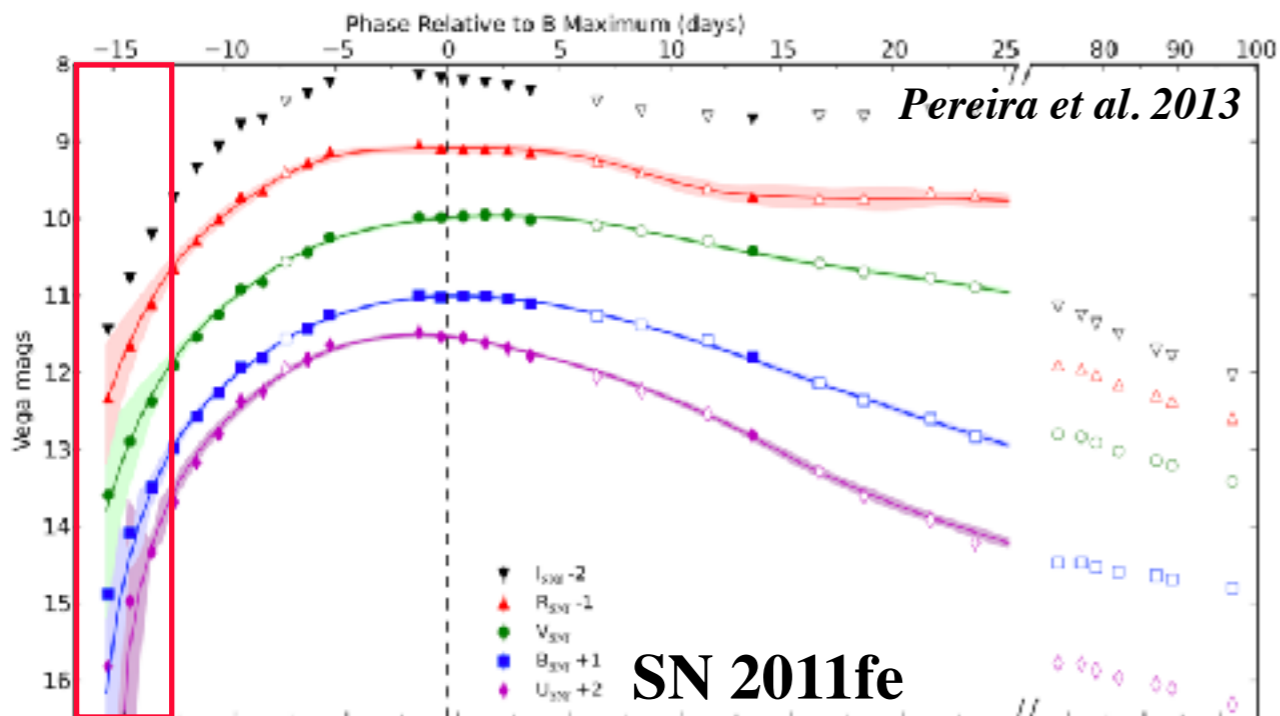
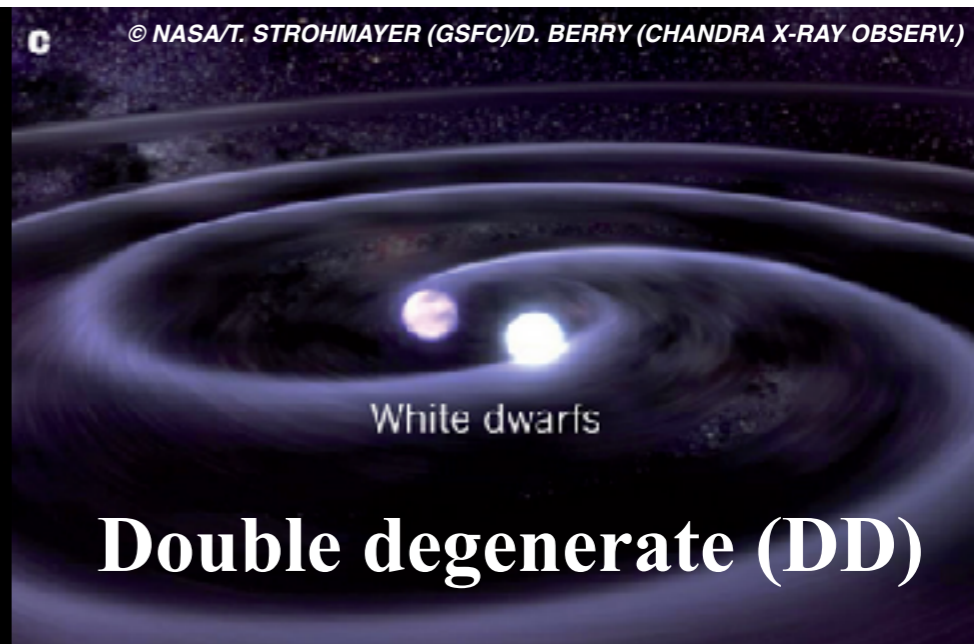
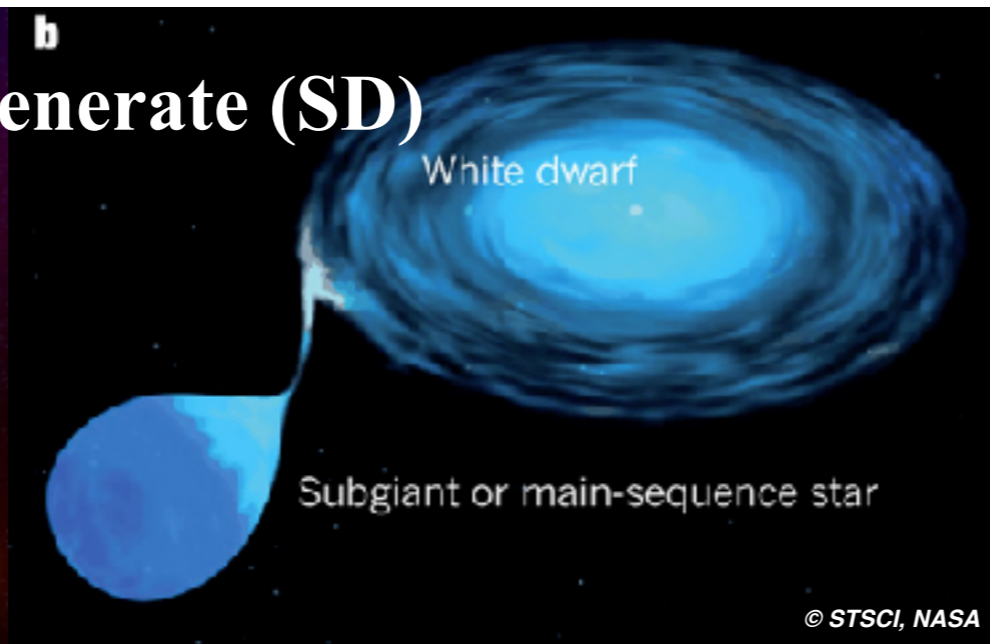
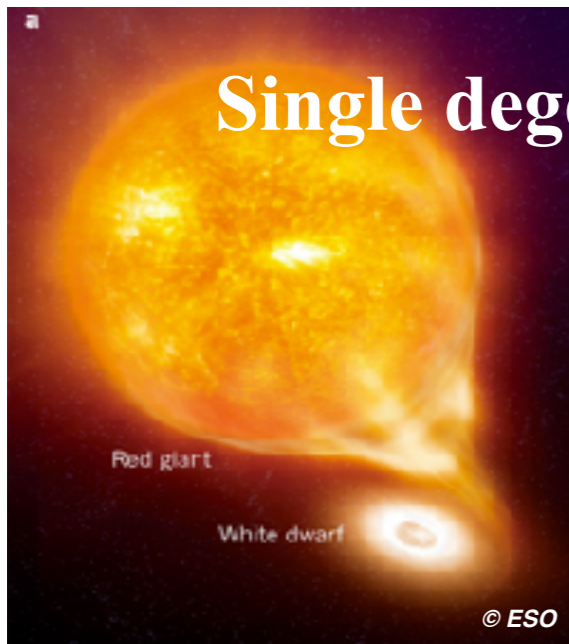


Outline

- ✿ Type Ia Supernovae and Their Early-phase Behavior
- ✿ SN 2020hvf, a peculiar SN Ia with the fastest early excess
 - ✿ The diversity and explosion mechanisms of SNe Ia
 - ✿ General Information of Tomoe202004aaelb (SN 2020hvf)
 - ✿ The Photometric Behavior of Tomoe202004aaelb (SN 2020hvf)
- ✿ The origin of the early excess emission of SN 2020hvf
- ✿ The Modeling of SN 2020hvf with a Super-Ch Model



Type Ia Supernovae and Early-phase Photometric Behavior



Japanese Wide-Field Survey Facilities

Searching for SNe Ia soon after the explosion (early-phase SNe Ia) with the most powerful survey facilities in the world!

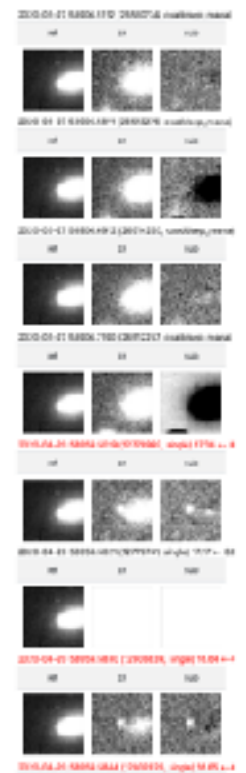
🌸 SN 2020hvf, a peculiar SN Ia with the fastest early excess

🌸 The Discovery of Tomoe202004aaelb (SN 2020hvf)

w-PS1 PS1_GPC1 2020-04-21 08:18:43 - 2021-04-07 08:31:12 2										
ID	Obs-date	Mag. / Flux	Err	Lim. Mag./Flux	Units	Filter	Tel. / Inst.	Exp-time	Observer(s)	Remarks
20000	2020-04-07 08:31:12	19.30	0.33	22	ABMag	w-PS1	PS1_GPC1	42	Robot	
ES200	2020-04-21 08:18:43	16.9	0	22	ABMag	w-PS1	PS1_GPC1	42	Robot	

cyan-ATLAS ATLAS_ACAMI 2020-04-19 09:04:19 - 2020-04-19 09:04:19 1										
ID	Obs-date	Mag. / Flux	Err	Lim. Mag./Flux	Units	Filter	Tel. / Inst.	Exp-time	Observer(s)	Remarks
ES181	2020-04-19 09:04:19	19.69			ABMag	cyan-ATLAS	ATLAS_ACAMI	30	Robot	[Limit noise detection]

orange-ATLAS ATLAS_ACAMI 2020-04-21 09:07:12 - 2020-04-21 09:07:12 1										
ID	Obs-date	Mag. / Flux	Err	Lim. Mag./Flux	Units	Filter	Tel. / Inst.	Exp-time	Observer(s)	Remarks
ES1816	2020-04-21 09:07:12	17.104	3.013	19.97	ABMag	orange-ATLAS	ATLAS_ACAMI	30	Robot	



tomoe

JJ 7:47 PM
Tomo-e discovered a very interesting SN on April 20, 202004aaelb, http://157.82.216.112/tomoesn/test/object.php?transient_id=4167922, which shows prominent early light-curve excess. Spectroscopy by LCO SN Ia. Can Seimei do spectroscopy for this object ASAP? Photometric follow-up recommended as well!! Thanks!
@Miho Kawabata @morokuma @Nozomu Tominaga (edited)

Miho Kawabata 7:53 PM
This object already performed the follow-up obs. using Kanata and Seimei

JJ 7:55 PM
Great, when did the follow-up start?

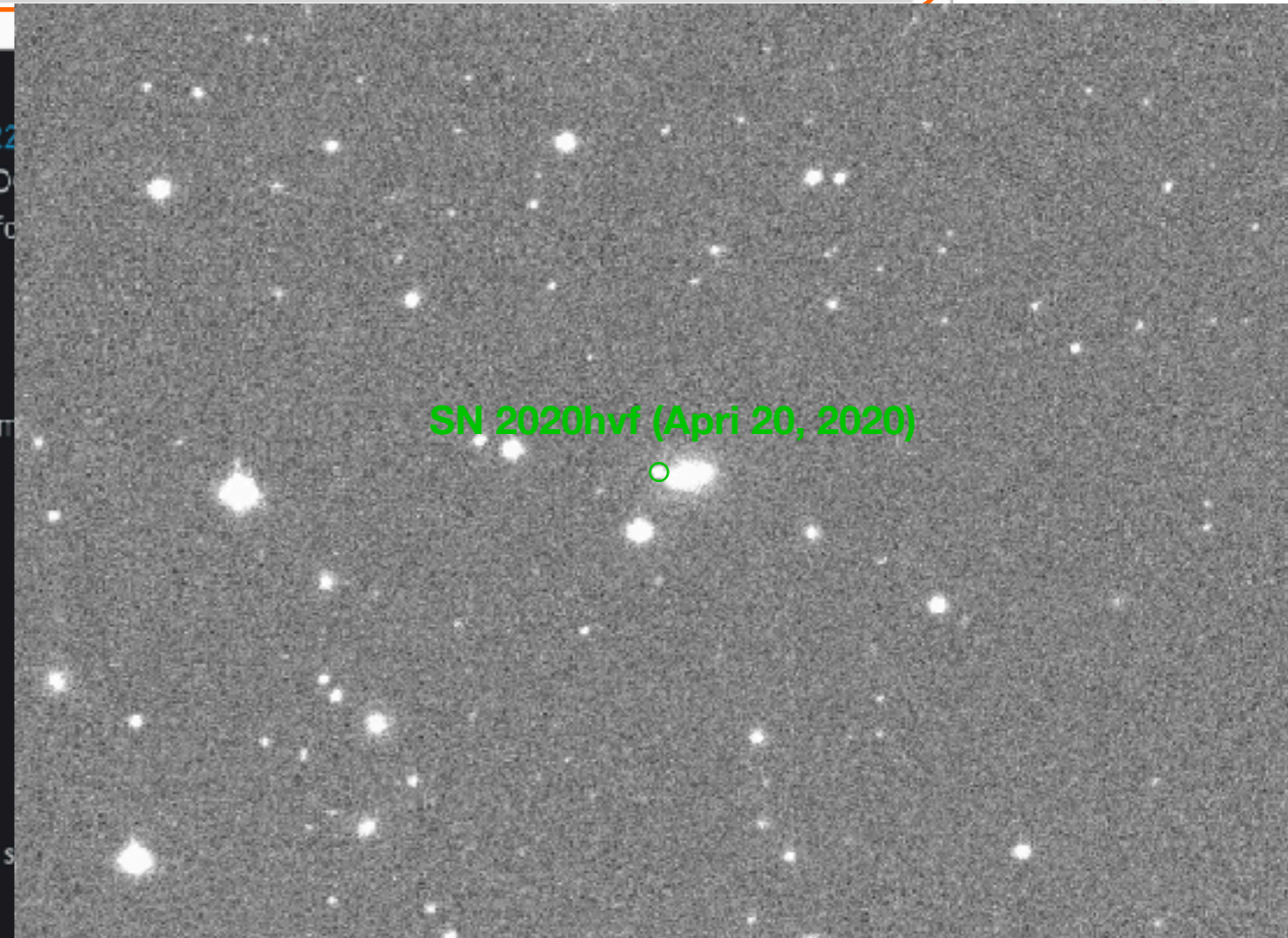
Miho Kawabata 7:57 PM
since 4/23

JJ 8:00 PM
Good, thanks for the information!

Miho Kawabata 8:00 PM
If possible, Spectroscopic observation will be done. The weather is not so good

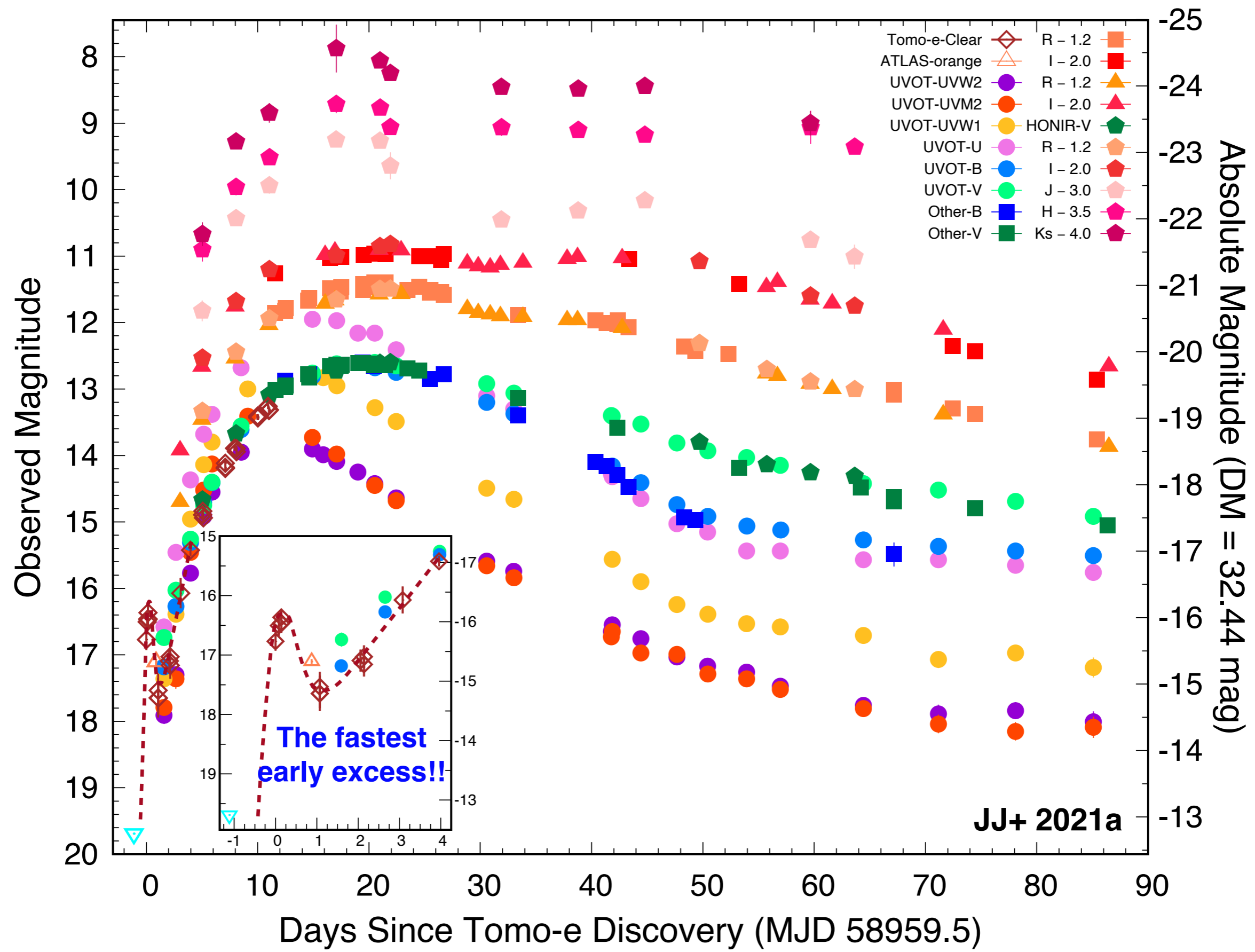
👍 2 🙏 1 😊

🗨️ 1 reply 1 year ago

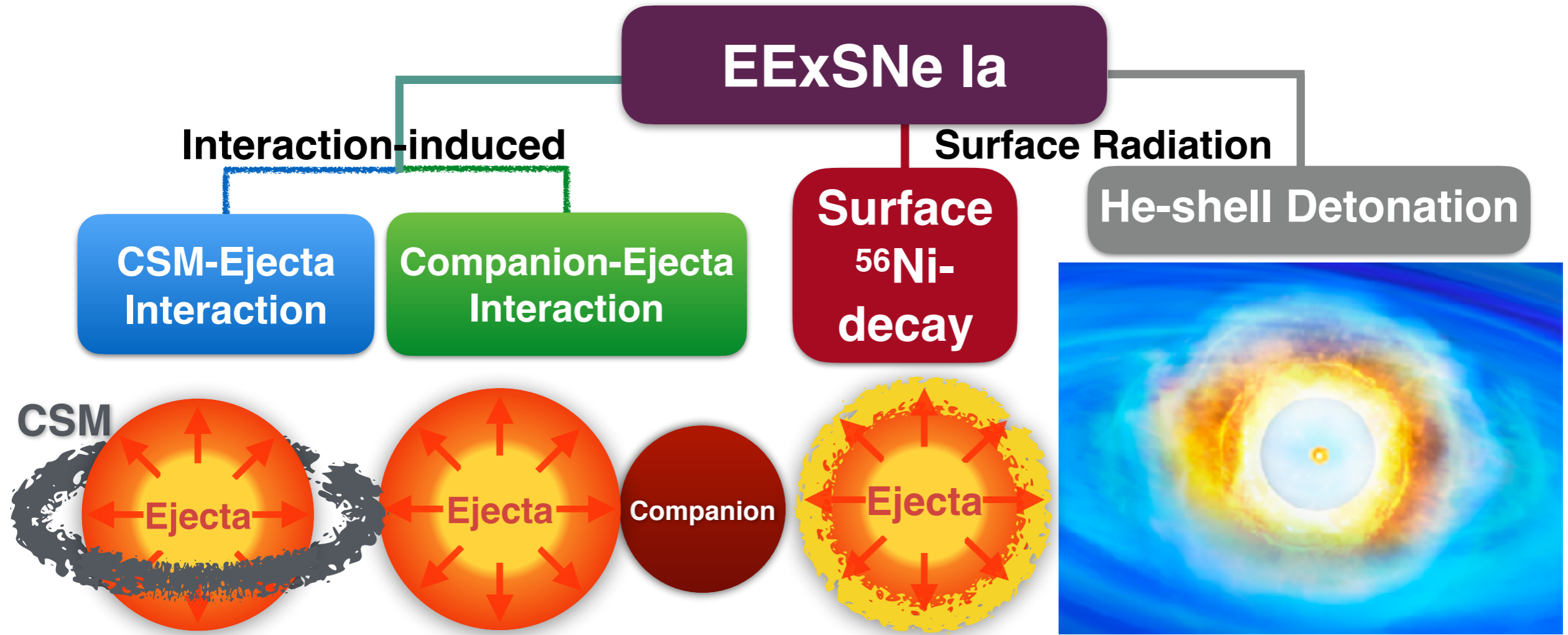




The Photometric Behavior of Tomoe202004aaelb (SN 2020hvf)

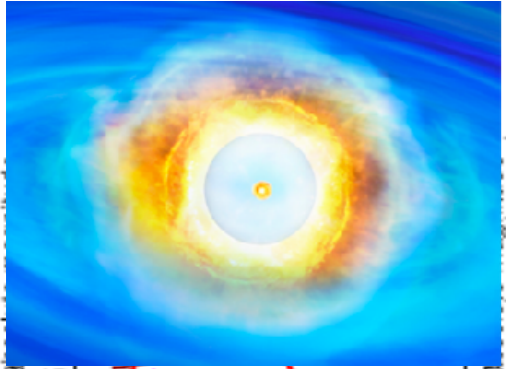


✿ The Diversity of Early-excess (EEx) SNe Ia

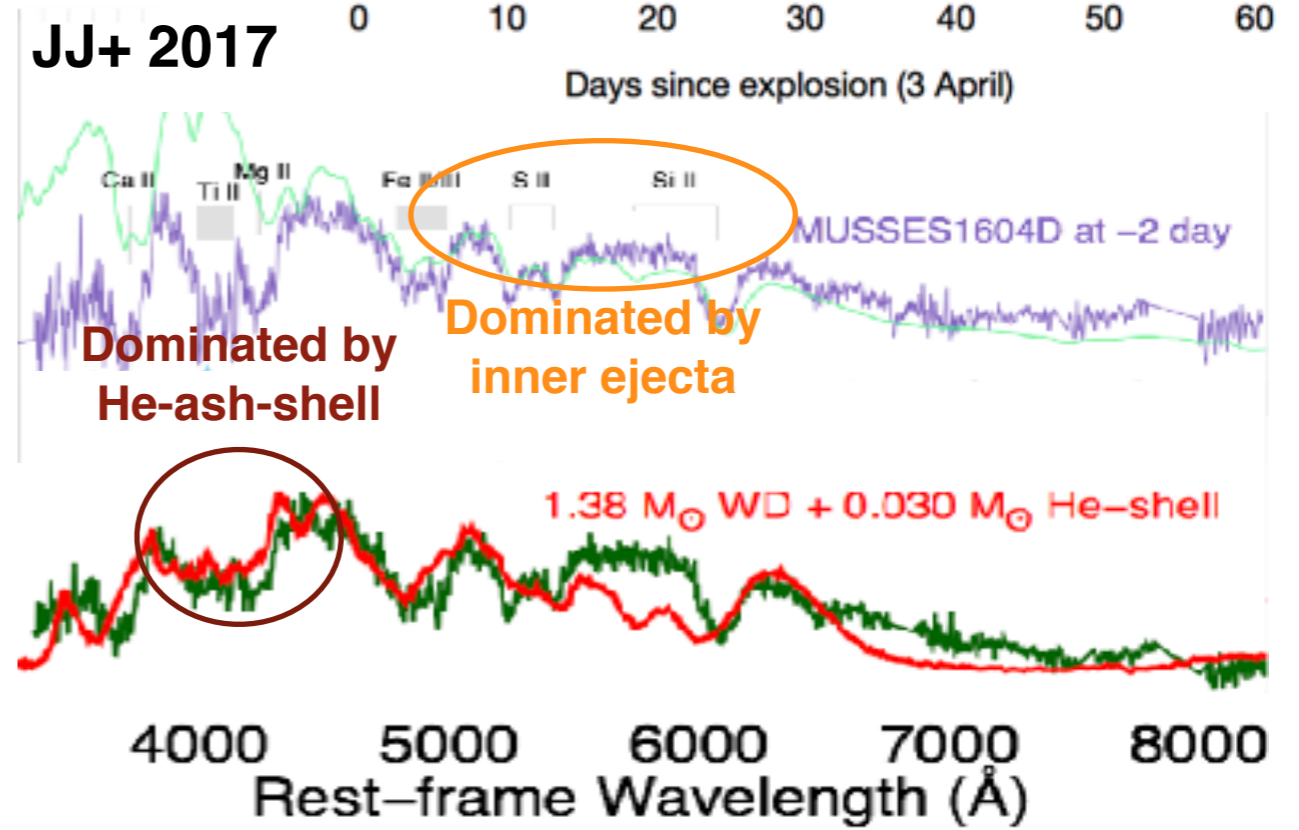
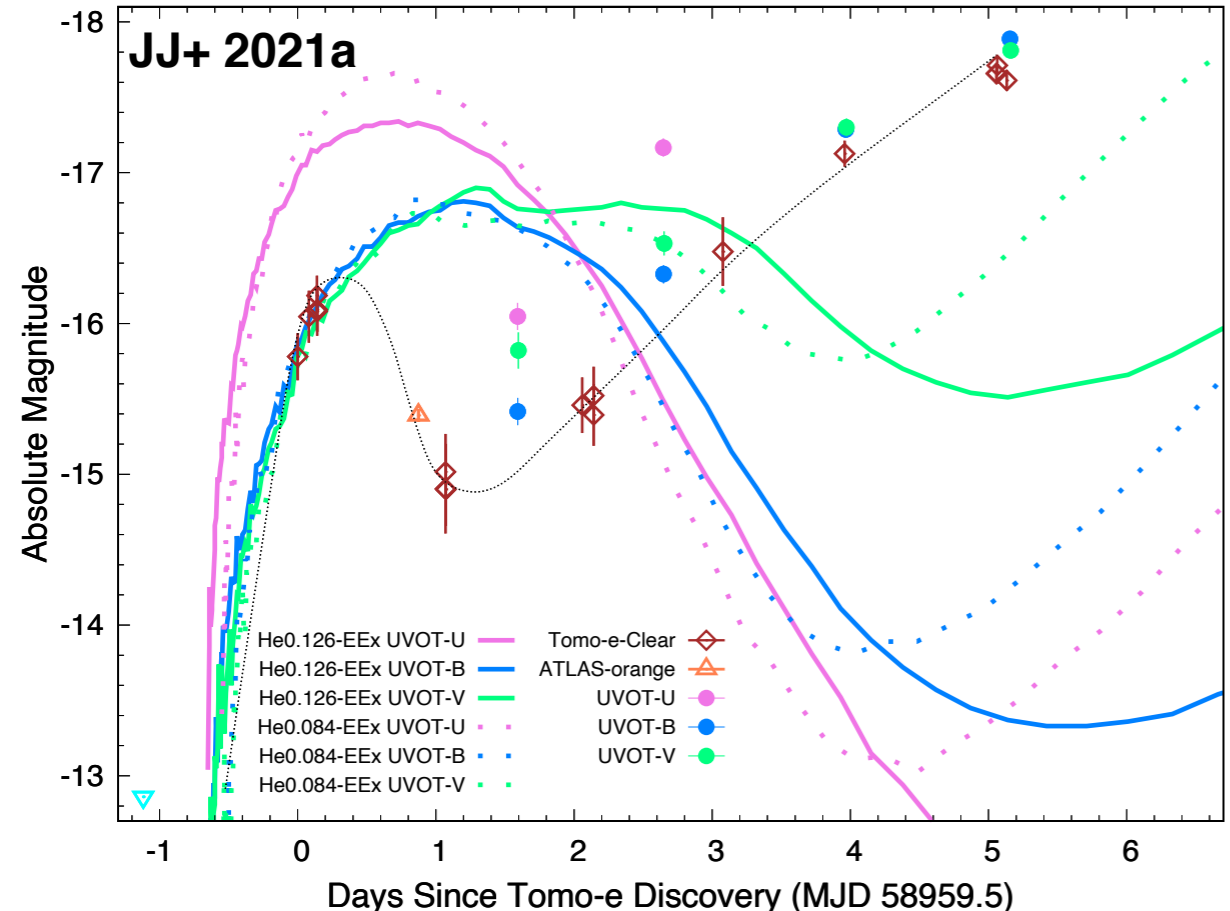
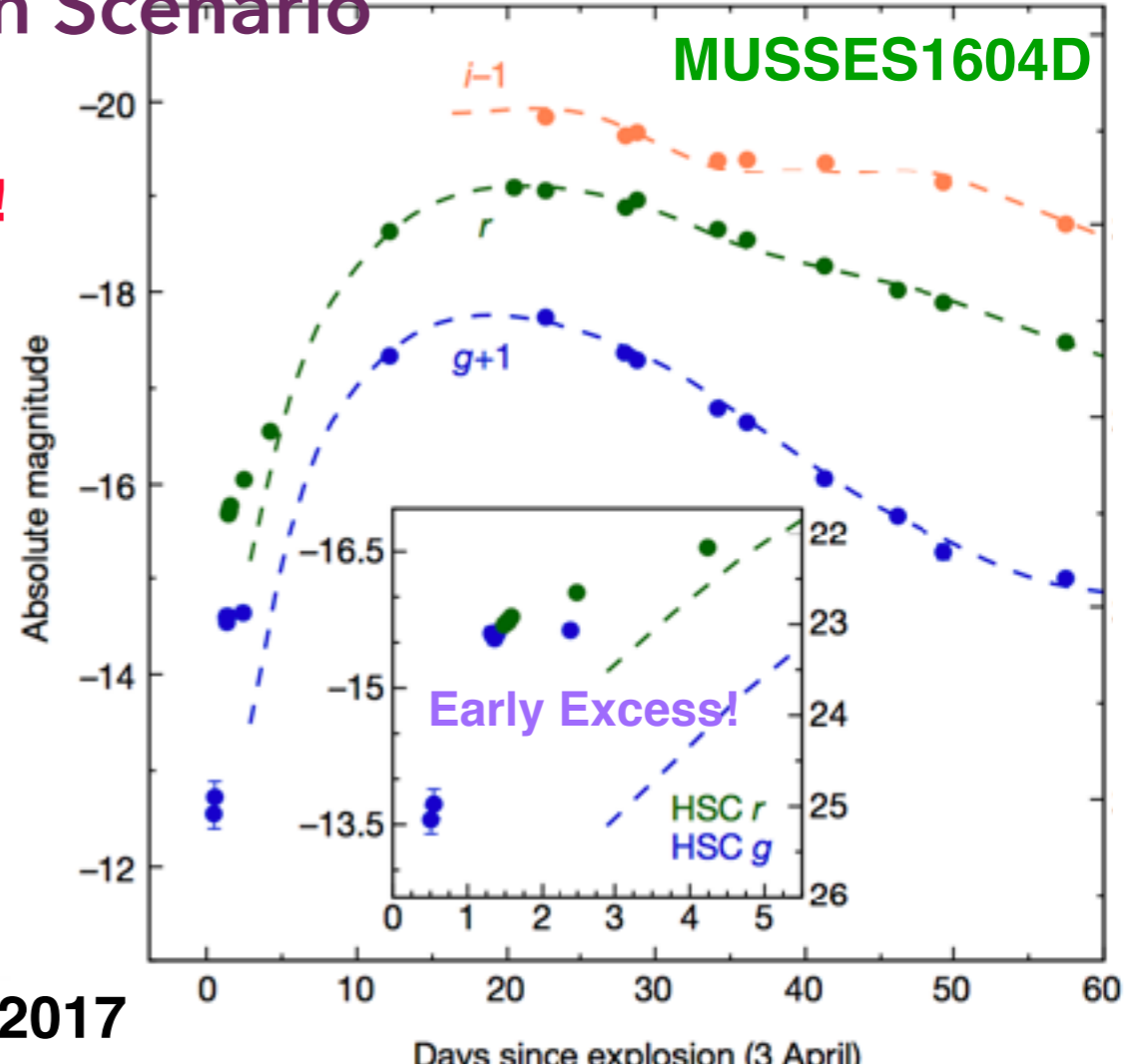
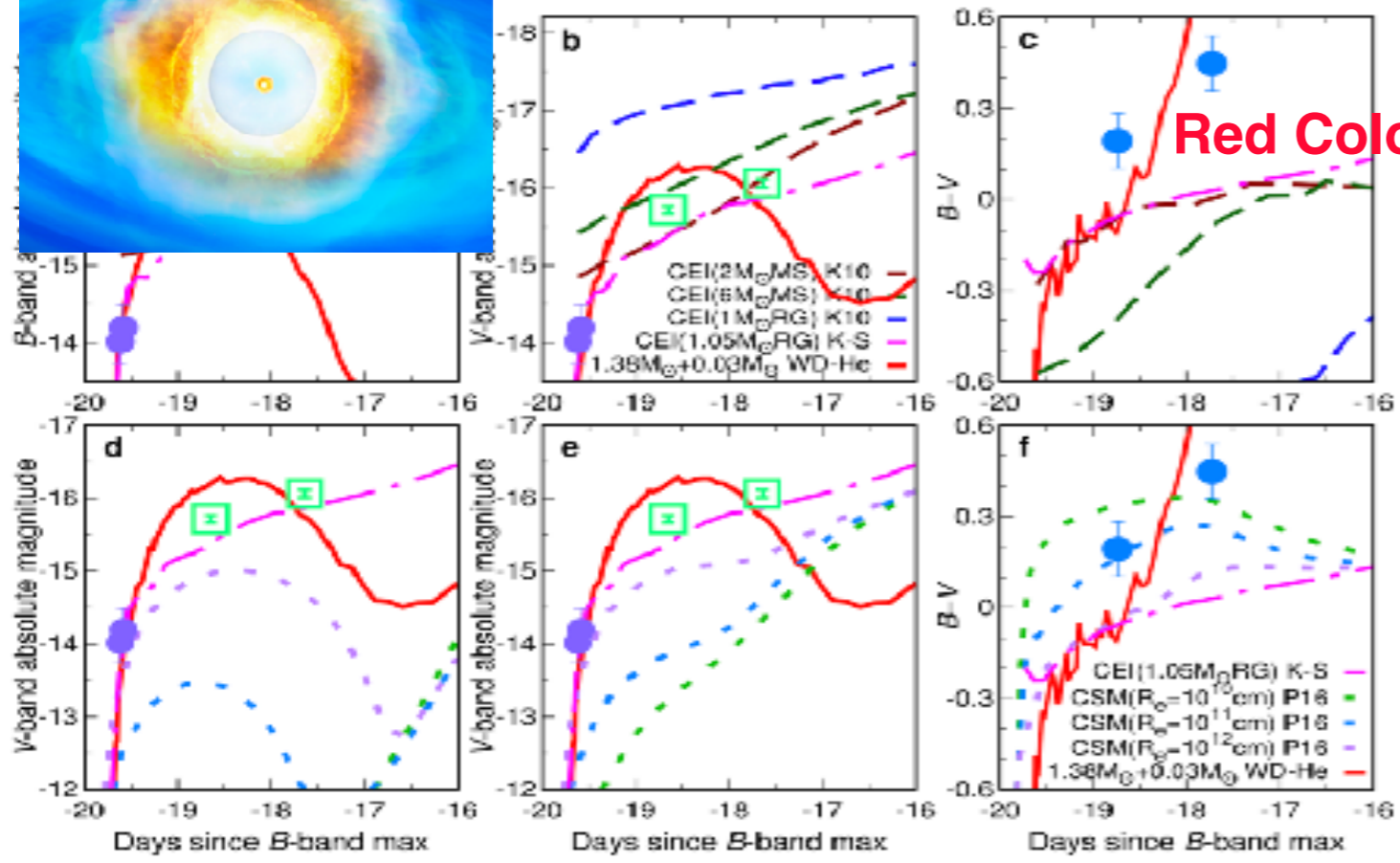


- Brightness** ↓
- 02es-like:** iptf14atg, ptf10ops, SN2019vyq?
 - Hybrid:** MUSSES1604D, SN2018byg?
 - Normal:** HSC17bmhk, SN2017erp, SN2017cbv, SN2018oh
 - 91T/99aa-like:** SN2011hr, SN2012cg, iPTF14bdn, SN2015bq, iPTF16abc
 - "Super-Chandrasekhar":** LSQ12gpw, SN2020hvf (Tomoe202004aaelb)

The origin of the early excess emission of SN 2020hvf



The He-shell Detonation Scenario

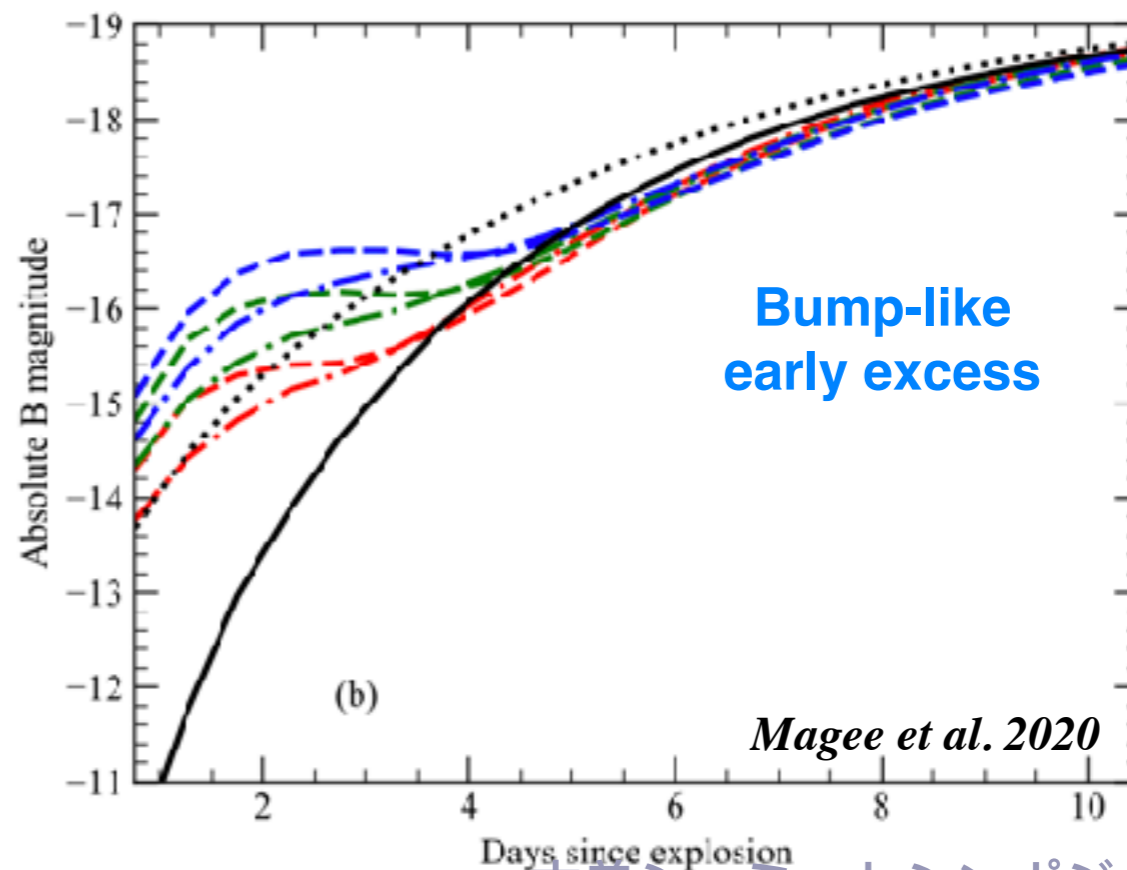
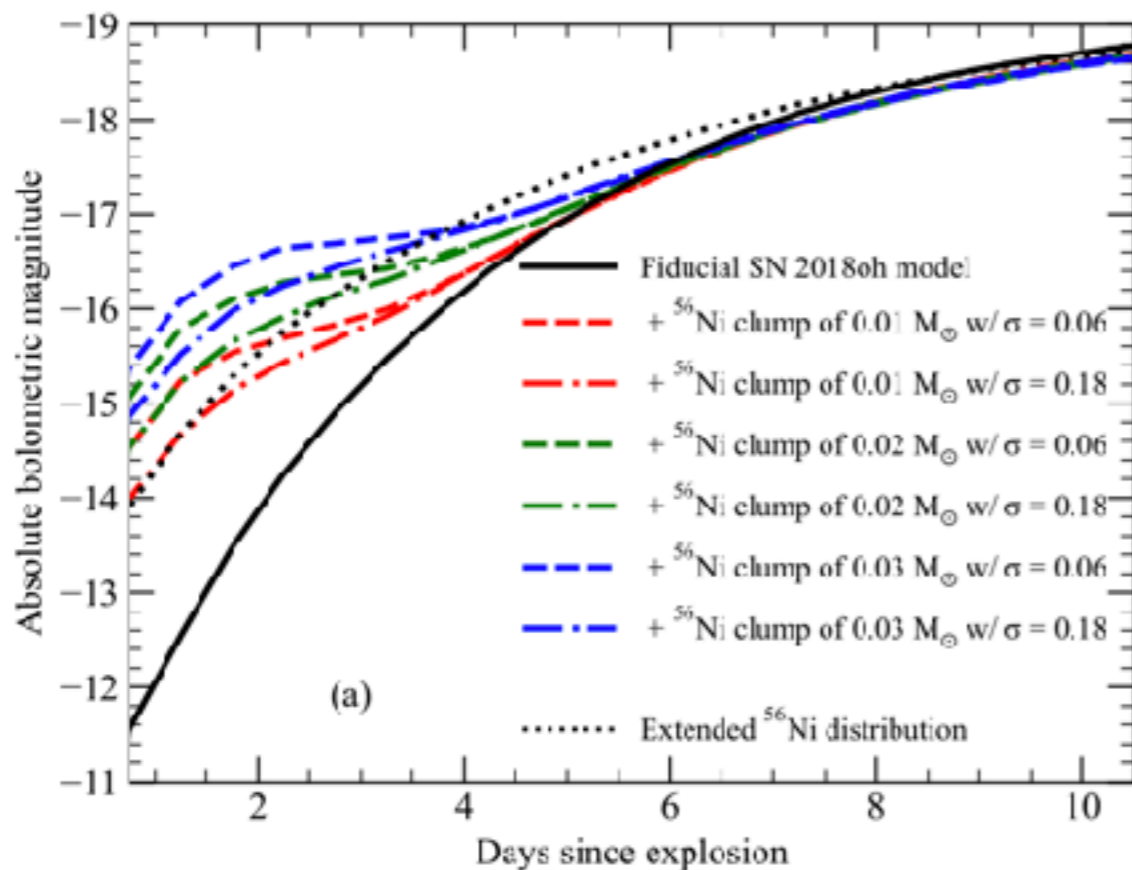
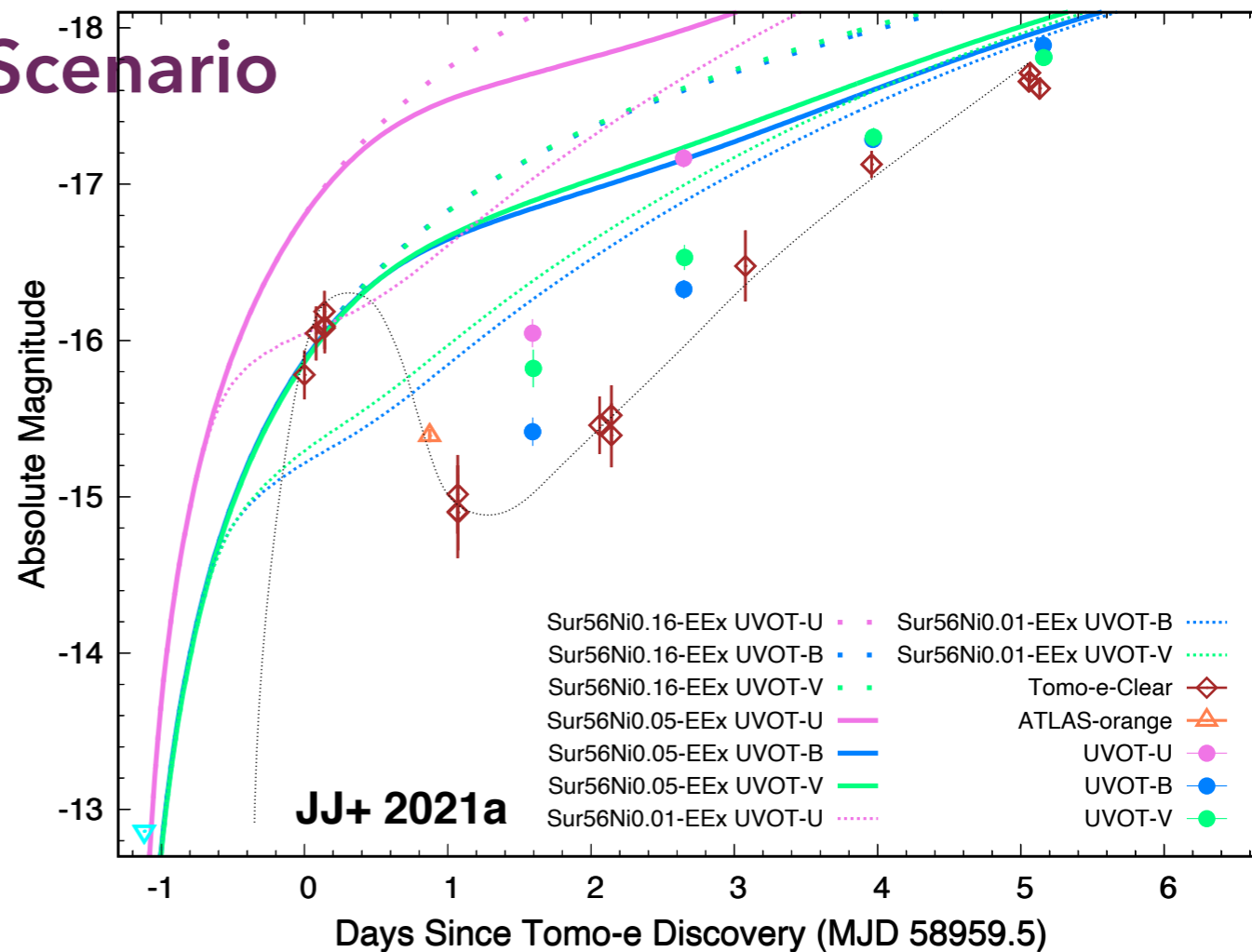




✿ The Surface-⁵⁶Ni-decay Scenario

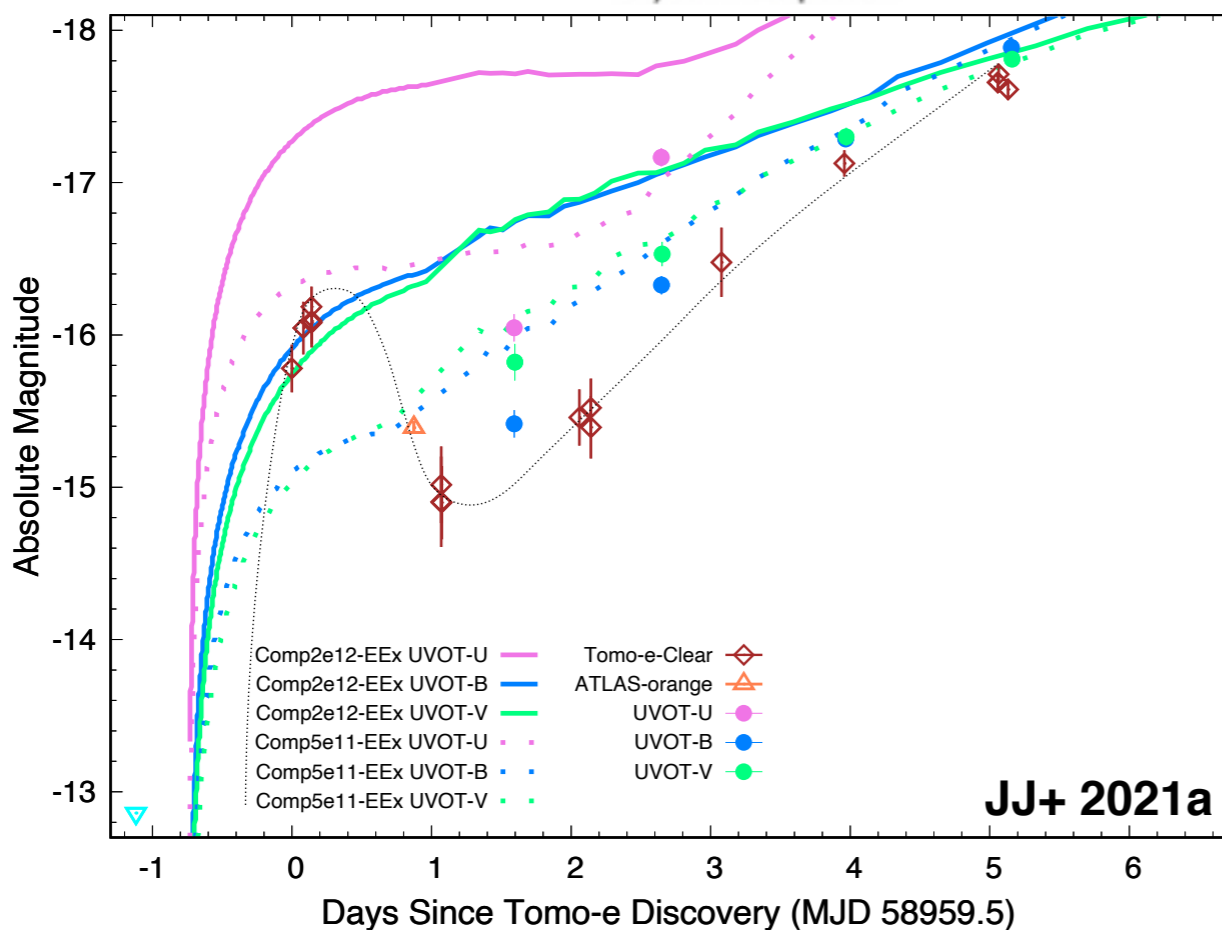
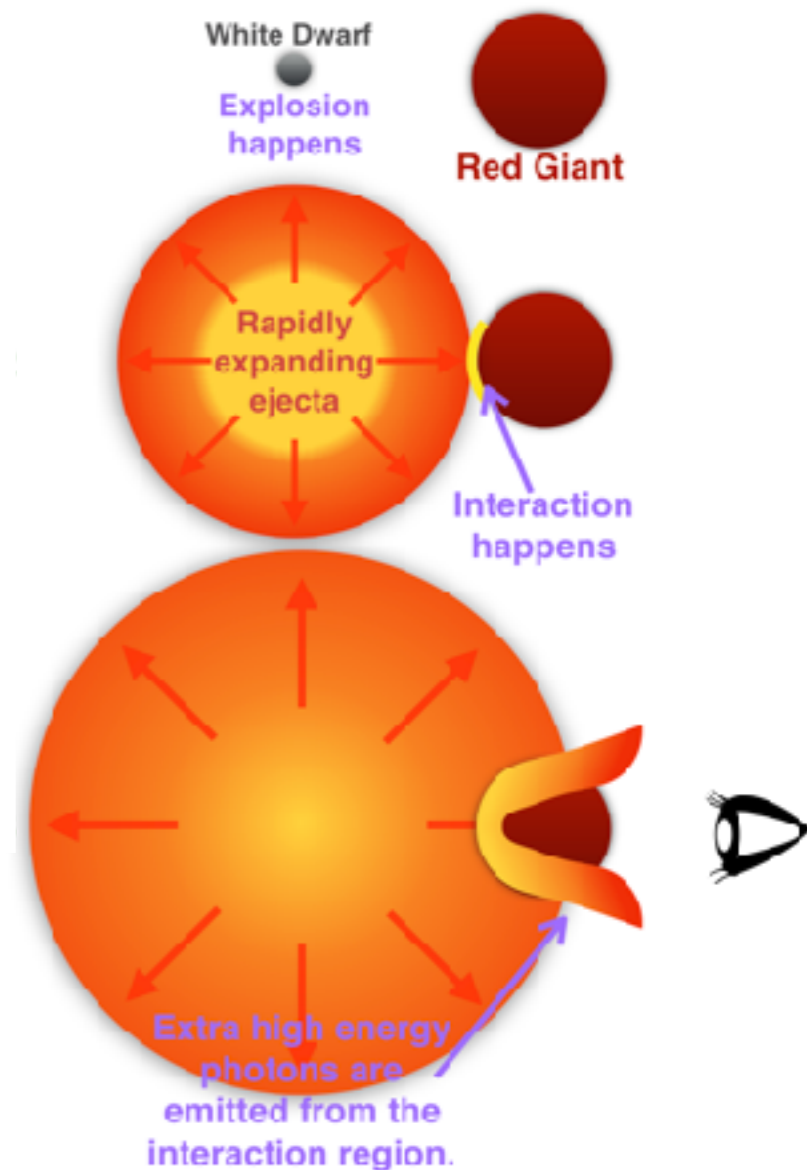
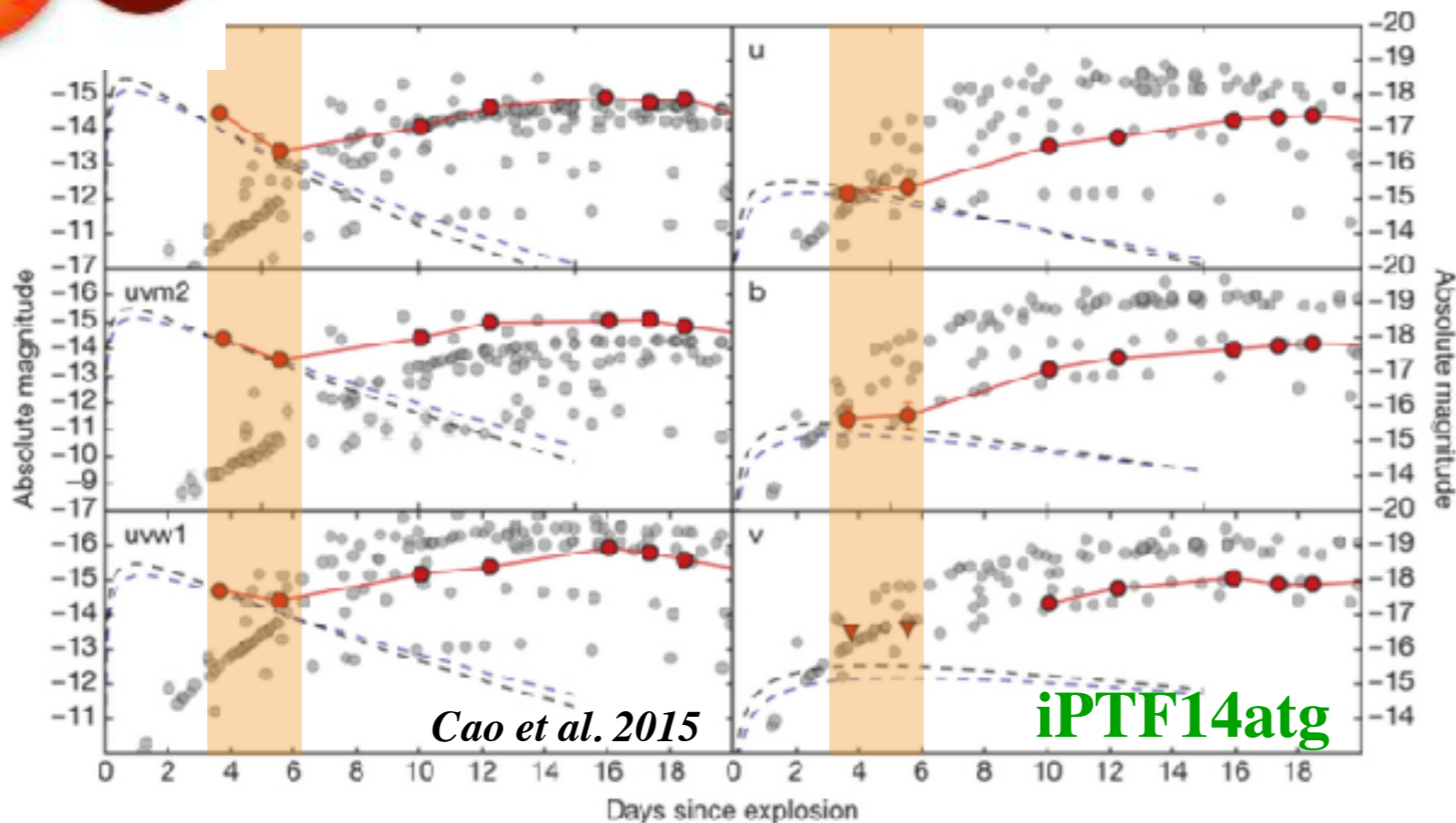
✿ Characteristics

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





The Companion-ejecta Interaction Scenario

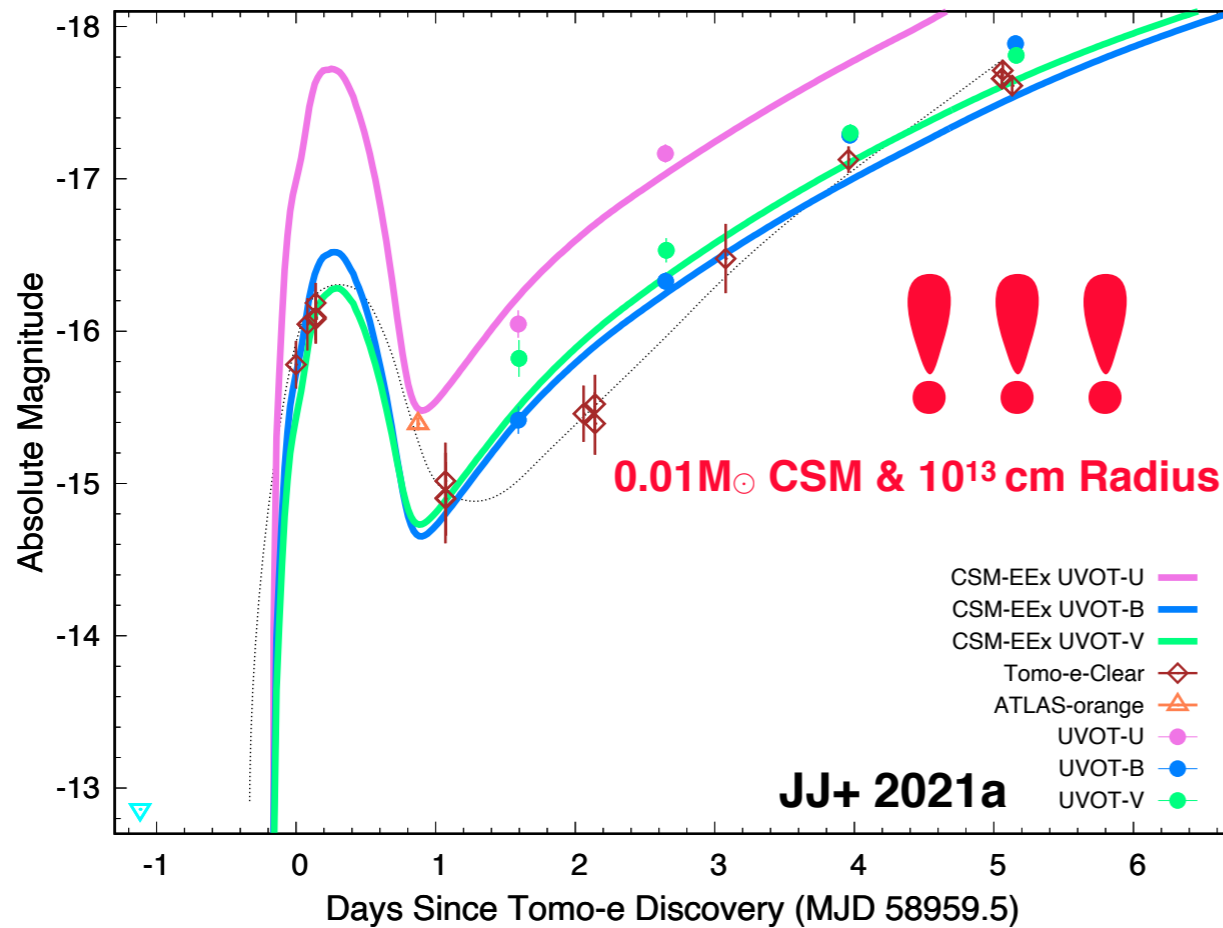
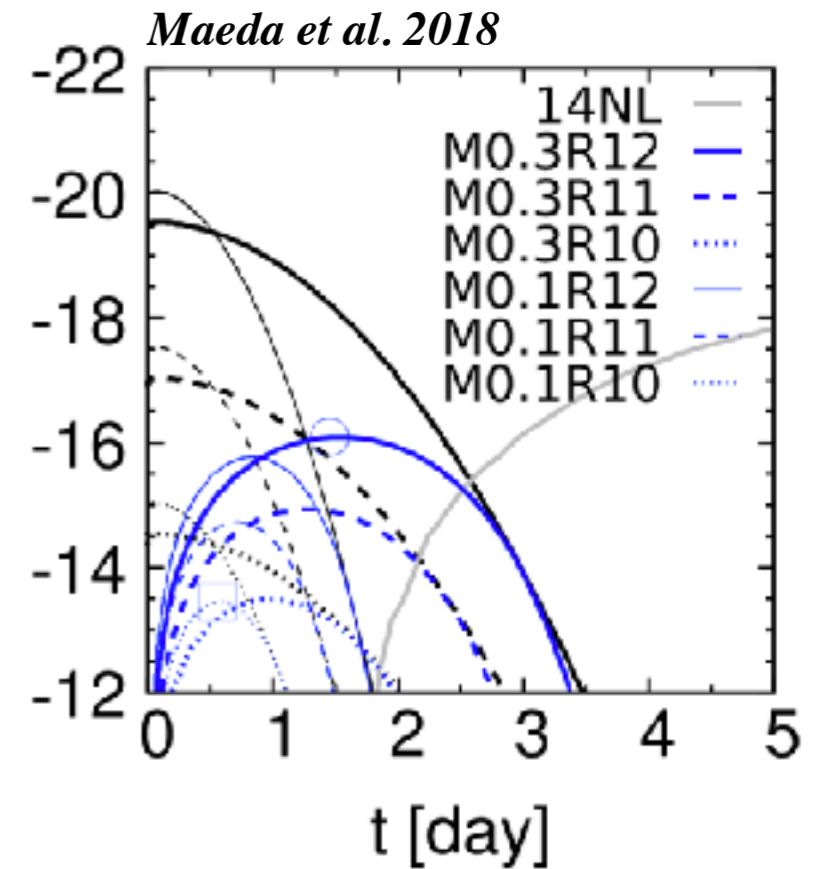
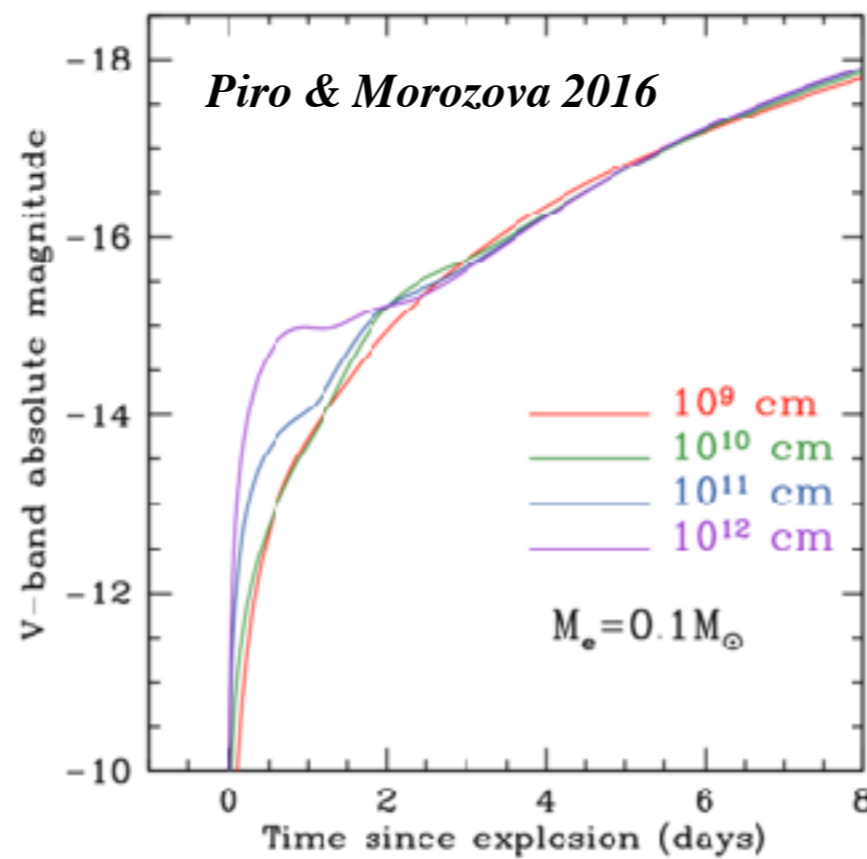
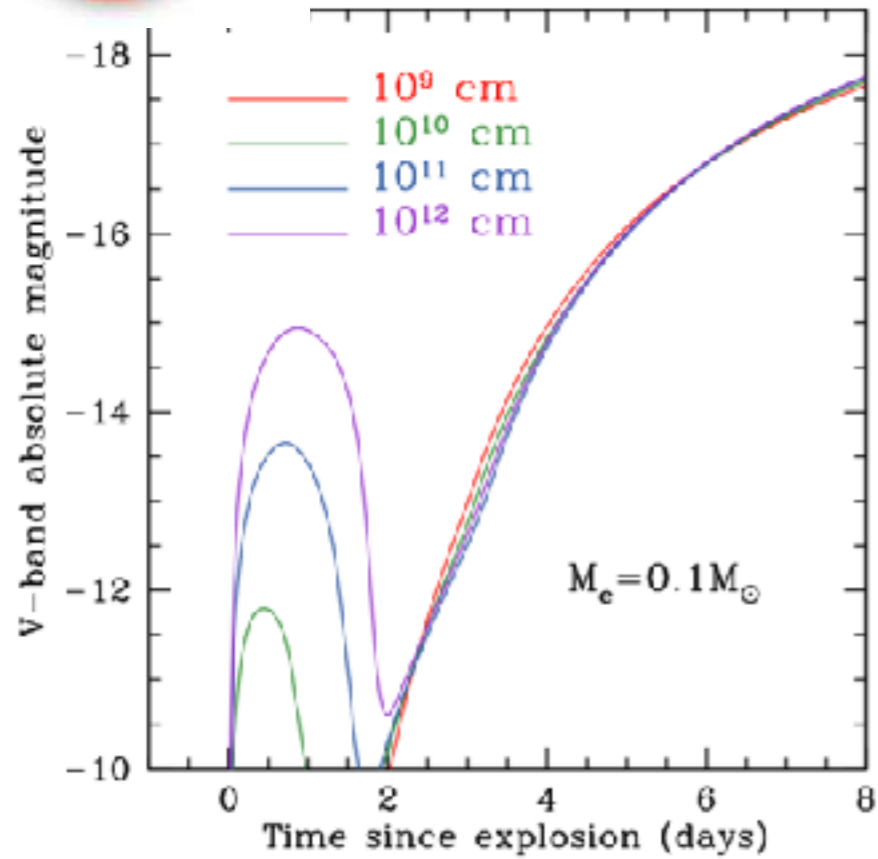


Characteristics

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



* The CSM-ejecta Interaction Scenarios



* Characteristics

- * Blue early light-curve excess;
- * Weak viewing angle effect;
- * Both SD & DD?
- * "Super-Mch" SNe Ia related?

Modelings of SN 2020hvf with a Super-Ch Model

Explanations of carbon-rich over-luminous SNe Ia

~~* CSM-ejecta Interaction~~

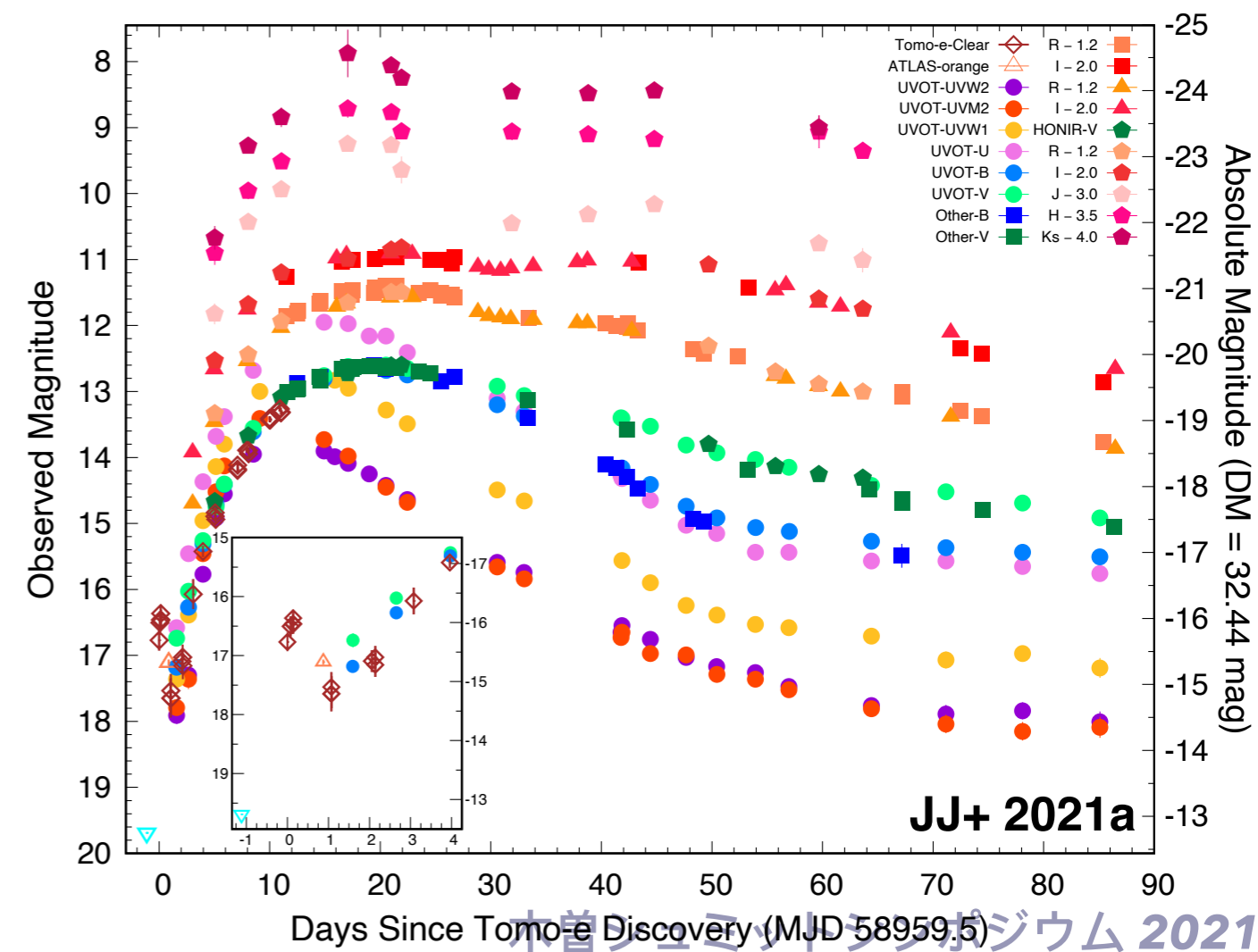
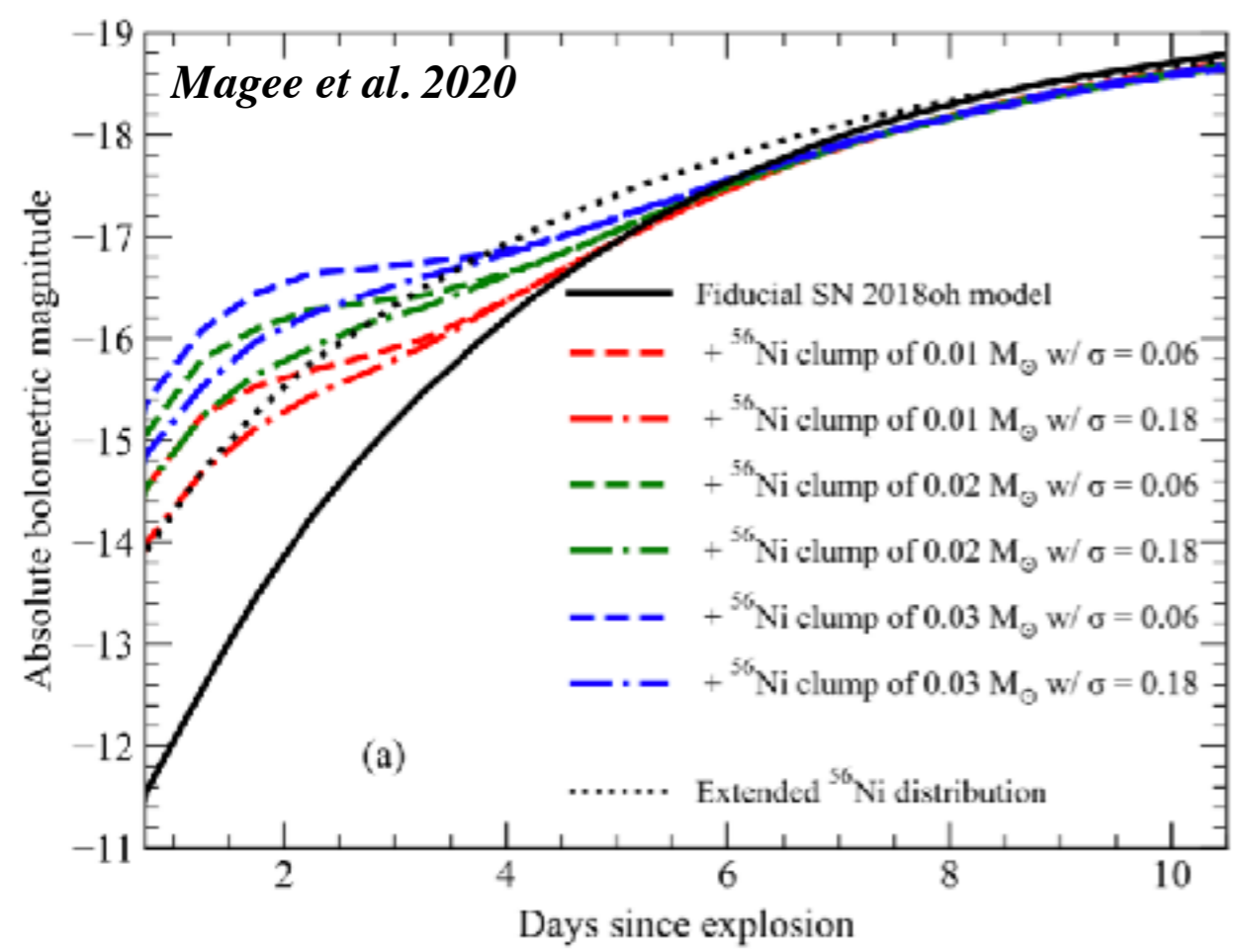
Large amount of very extended CSM is required.

Early-excess constraint: $0.01 M_{\odot}$ CSM & 10^{13} cm Radius

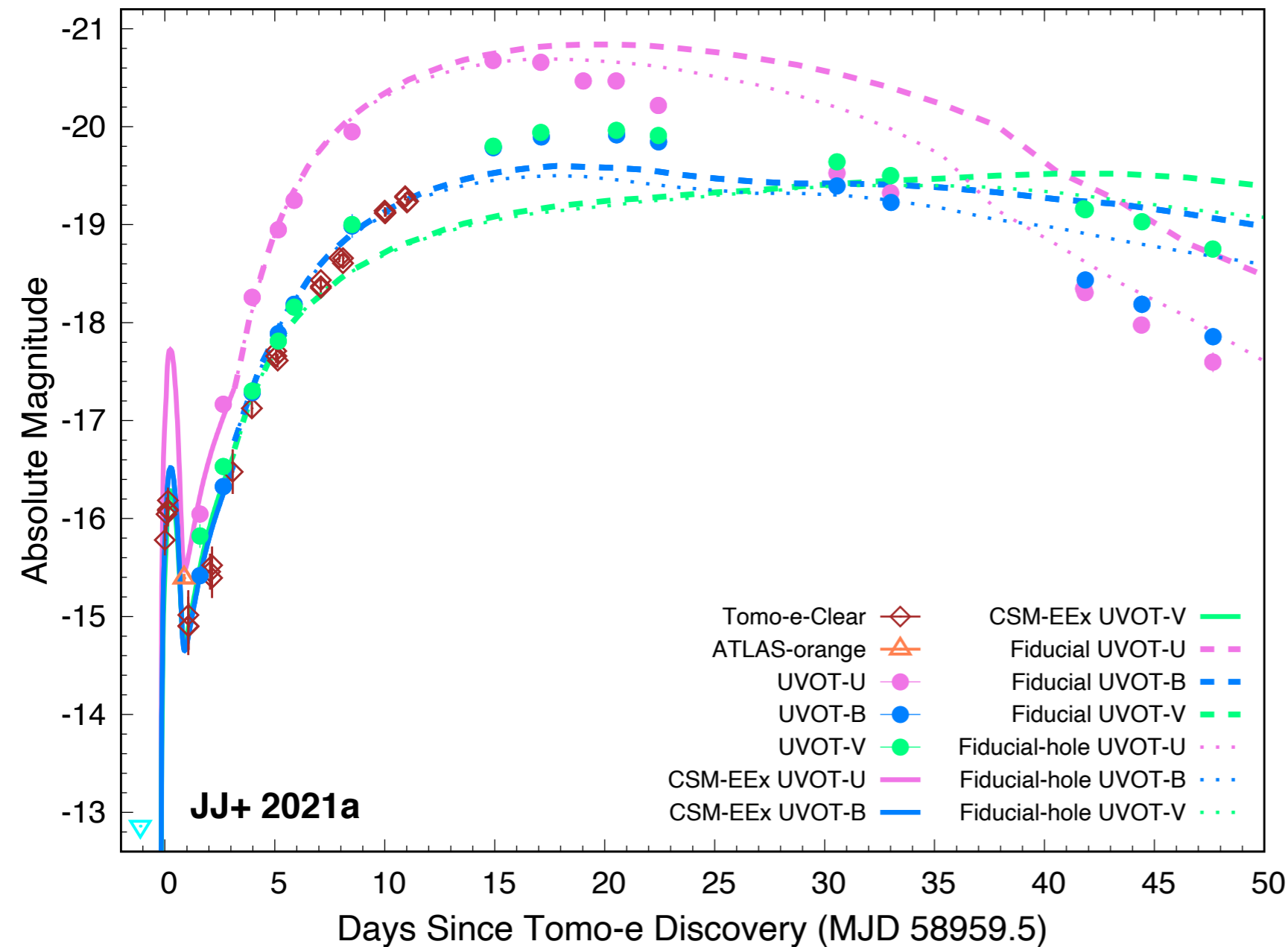
~~* Asymmetric ^{56}Ni distribution~~

A broad light curve with bump-like EEx is expected?

* Super-Ch WD explosion



🌸 Modelings of SN 2020hvf with a Super-Ch Model



🌸 Fiducial Super-Ch Model

Ejecta mass: $2.1 M_{\odot}$

^{56}Ni mass: $1.44 M_{\odot}$

Kinetic energy: 1.4×10^{51} erg

🌸 Fiducial-hole Model

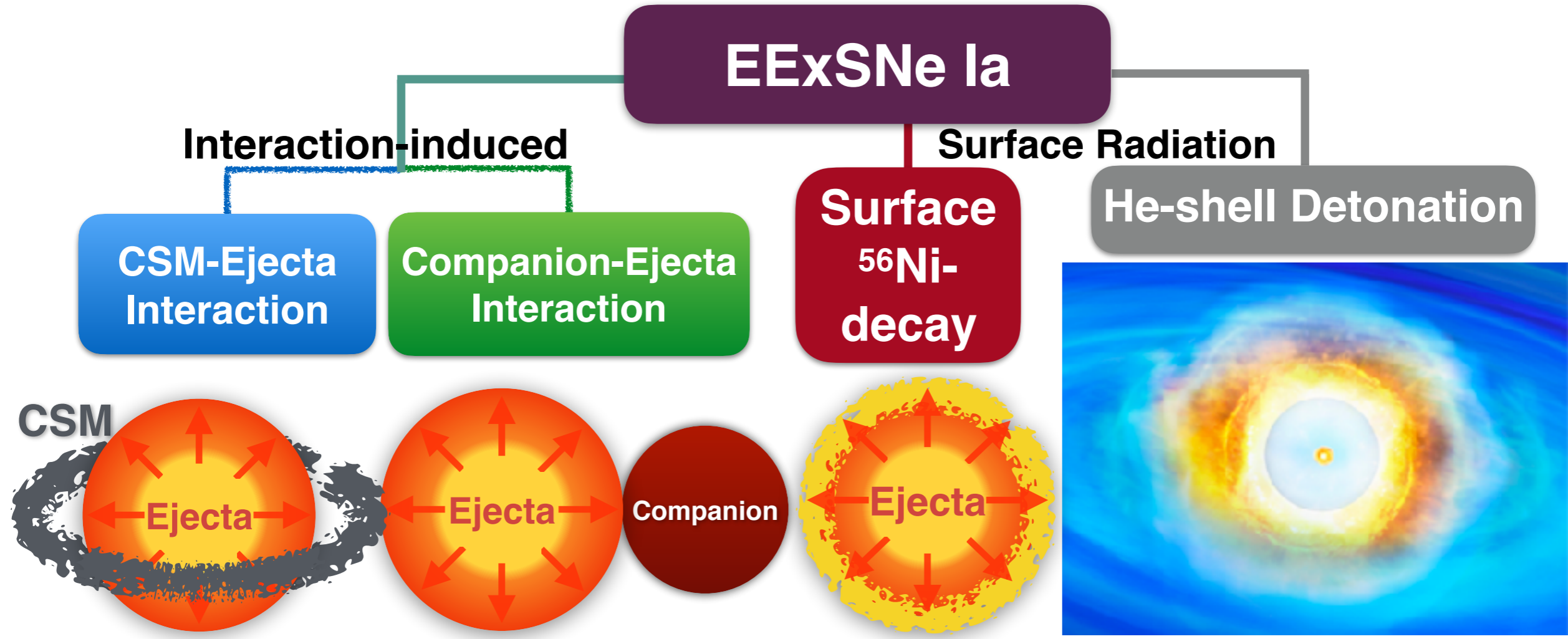
Ejecta mass: $1.9 M_{\odot}$

^{56}Ni mass: $1.2 M_{\odot}$

➤ The overall light curve is explained reasonably well, and the key features in the spectra are also explained without fine-tuning;

➤ A main drawback is the over-fitting in blue wavelengths in the declining phase. We suggest that the "super-Ch" model is a promising scenario and the models shown above can be regarded as defining a range of the "super-Ch" SN Ia light curves.

✿ The Diversity of Early-excess SNe Ia



First robust evidence
by **Kiso Tomo-e** (JJ+
2021a)



First observational
evidence (JJ+ 2018)
& new evidence by
Subaru/HSC (JJ+ 2020)

Proposed & firstly
discovered by **Subaru/
HSC** (JJ+ 2017)

Summary

- * Early-phase photometric information plays a unique role in understanding the physics and progenitors of SNe Ia.
- * The fast and prominent early excess emission of SN 2020hvf is the first robust evidence of the CSM-interaction-induced EExSN Ia.
- * Our analysis shows that the properties of SN 2020hvf is largely consistent with the expectation of a thermonuclear explosion of a massive white dwarf whose mass is above the Chandrasekhar limit and provides a hint of the confined dense CSM formation at the final evolution stage of the progenitor of SN 2020hvf.
- * Japanese wide-field facilities made great contributions to the EExSN Ia study. Three early-excess scenarios (i.e., the He-shell detonation, surface- ^{56}Ni -decay, and CSM-ejecta interaction) are proposed and/or firstly confirmed by our group. We are looking forward to more amazing discoveries (e.g., the first companion-interaction EExSN Ia) with the Kiso/Tomo-e Gozen camera in the near future!

Thank you!