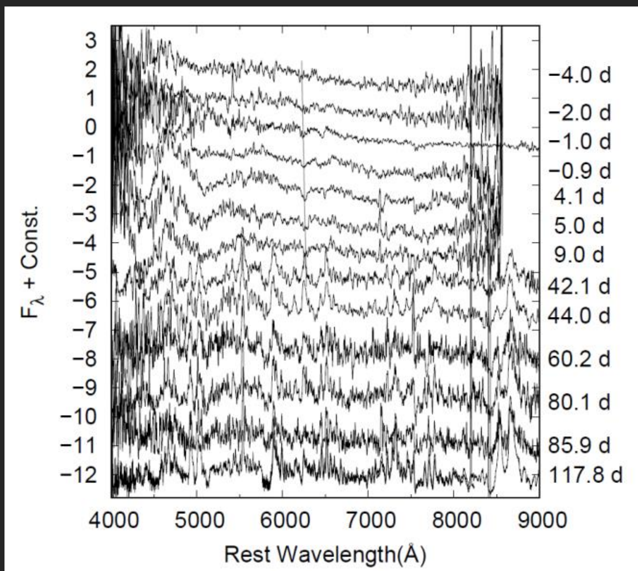
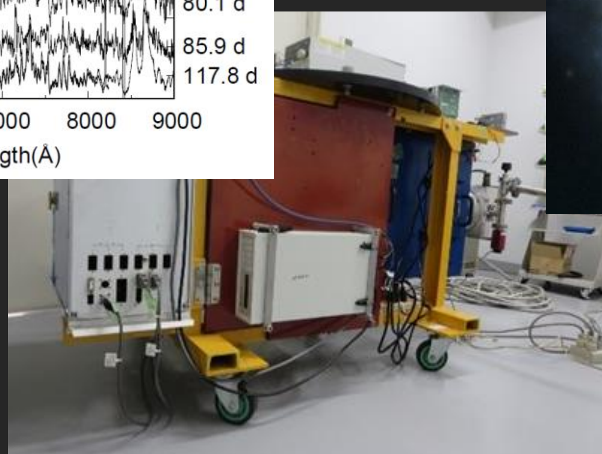
Supernovae and Extragalactic Transients

w/ Seimei and related facilities





Keiichi Maeda **(department of Astronomy, Kyoto University)**

About myself + key person for the possible collaborations b/w two Seimei's

Home | News | Members | Publications | Presentations | CV | Memorandum

日本語 (Japanese)

Welcome to Keiichi Maeda's Home page

Keiichi Maeda
Kyoto University Department of Astronomy

@ Kyoto U.

2023 Open Campus (youtube; Japanese) :
0:10～: Introduction to Department of Astronomy and Observatory
5:10～: Introduction to Theory Group

- Home
- News
- Members
- Publications
- Presentations
- CV
- Memorandum

more on transients

http://www.kusastro.kyoto-u.ac.jp/~keiichi.maeda/index_e.html

I am an astronomer, working at Department of Astronomy, Kyoto University. My main focus in on astrophysical explosive and transient phenomena in the Universe, including supernovae and gamma-ray bursts among others. The related topics covered here include stellar evolution, origins of elements, cosmic rays, and dust grains, and observational cosmology.

The methodology includes both theoretical and observational study. The theoretical research adopts various different approaches, covering both analytical work and intensive supercomputing simulations. The main physical processes ... nucleosynthesis, radiation transfer, and stellar evolution. In the observational side, we use various telescopes across the world (including those the space); I am a PI of an extensive follow-up program with the Seimei telescope ... local Universe, and also using various telescopes across wavelengths, including the Subaru, ALMA, Chandra telescopes, among others. Infrating developement in computational power and observational technology now provides extremely massive data set, both in theoretical and observational activities; the big/massive data analysis, e.g., machine learning, is also one of the forcused fields in my research projects.

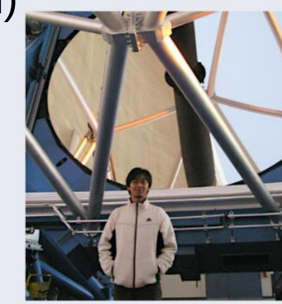
Supernovae and transients: Theory and observations

Close collaborator / family friend since ~ 2010.

27 refereed publications together on transient science (and many projects ongoing).

KTI | Home | CV | Science | Instrumentation | Publ

@ Turkk U. (Finland)



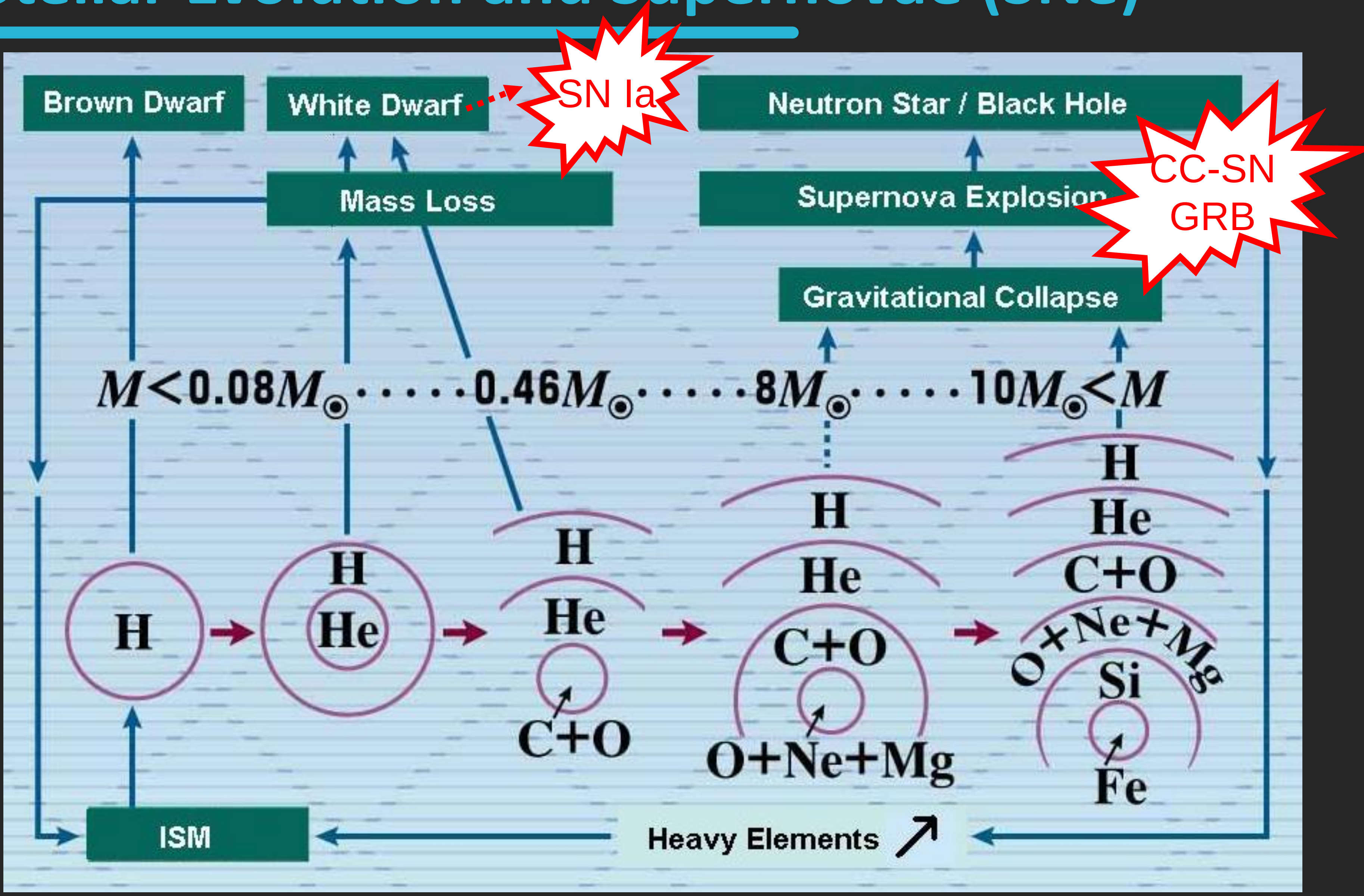
...ome to Hanin Kuncarayakti's webpage. I am an Academy of Finland ...rch Fellow / Docent at the Department of Physics and Astronomy, ...rsity of Turku, Finland, where I am part of the Stellar Explosions ...rch group. My research interest is focused on supernovae (SNe) ...elated astrophysical transients, and their progenitors and ...onments. I regularly use telescopes at world-class observatories, ...ding the ESO Very Large Telescope, for my research, and have been ...ed in a number of astronomical instrumentation projects.

https://sites.google.com/view/kuncarayakti/

Type Ia supernova

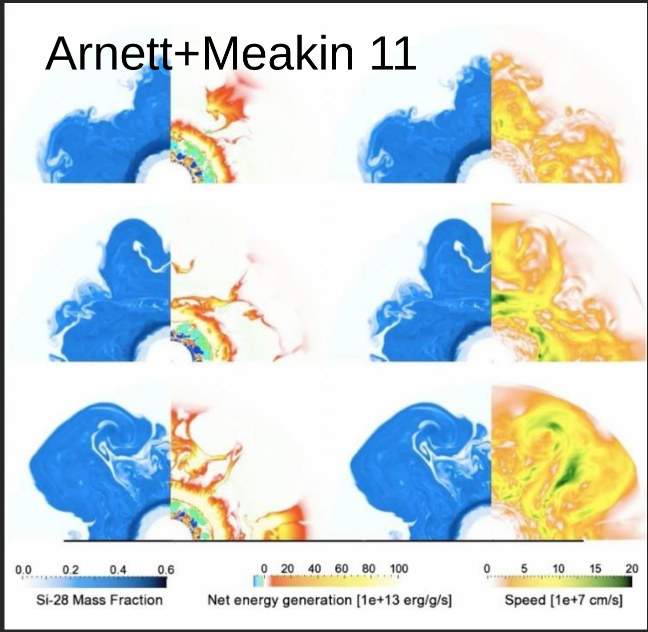
Core-collapse supernova

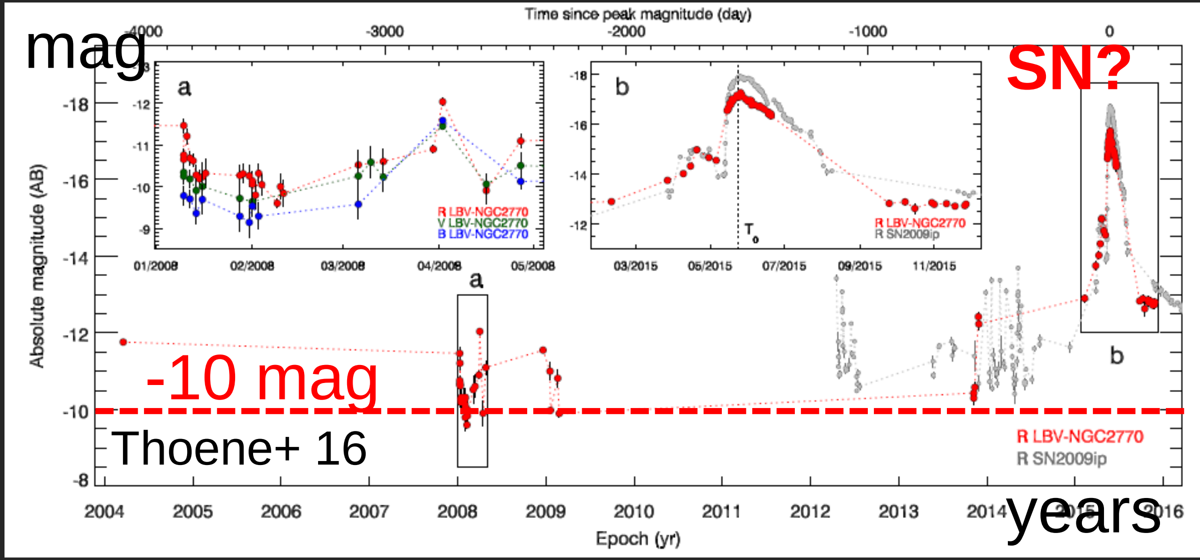
Stellar Evolution and Supernovae (SNe)



Unresolved problems for Core Collapse SNe (CC SNe)

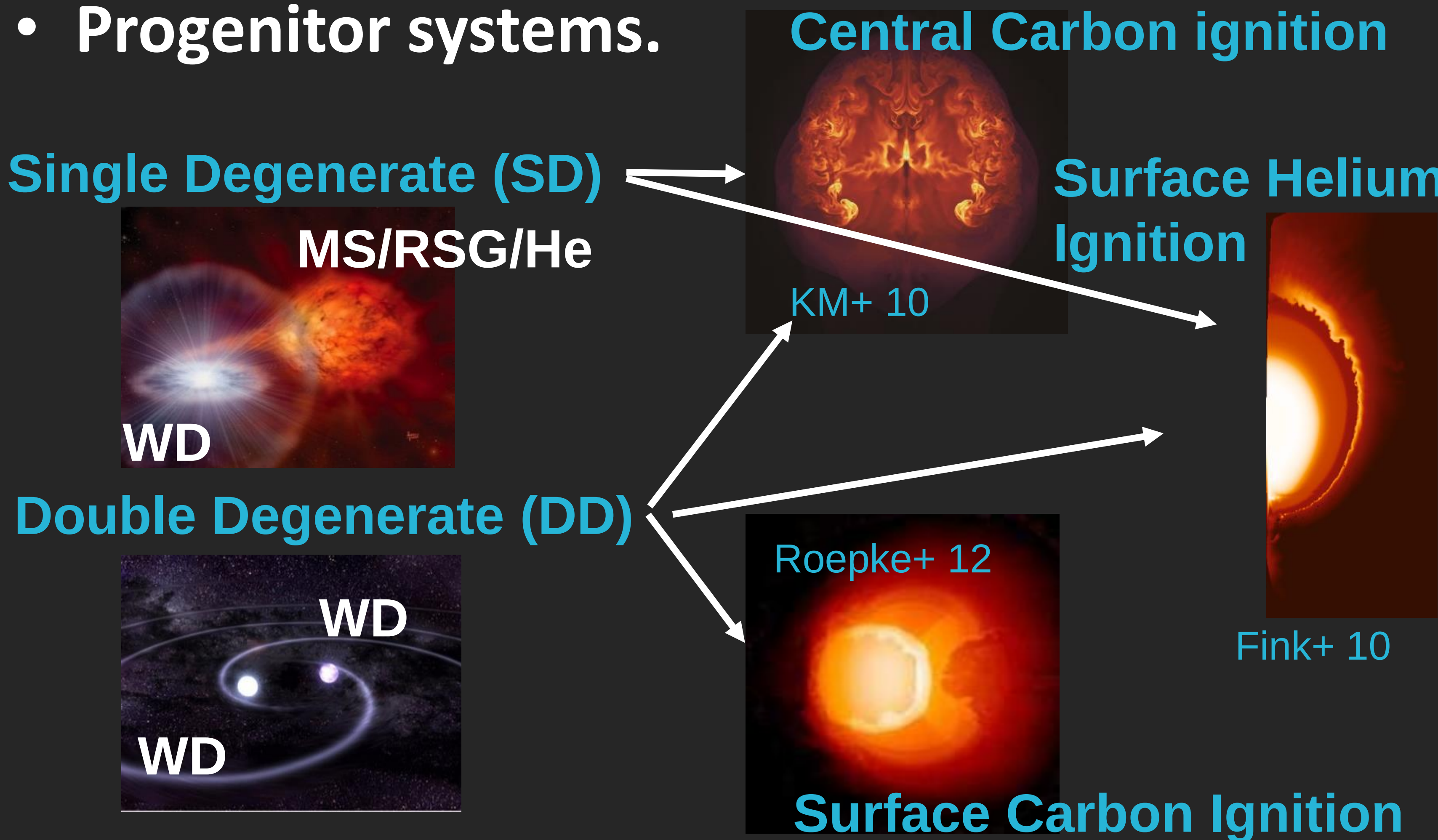
- **Explosion mechanism.**
- **Final evolution of massive stars (single & binary).**
  - **Progenitor at the time of the explosion.**
  - **Mass loss in the final decades.**



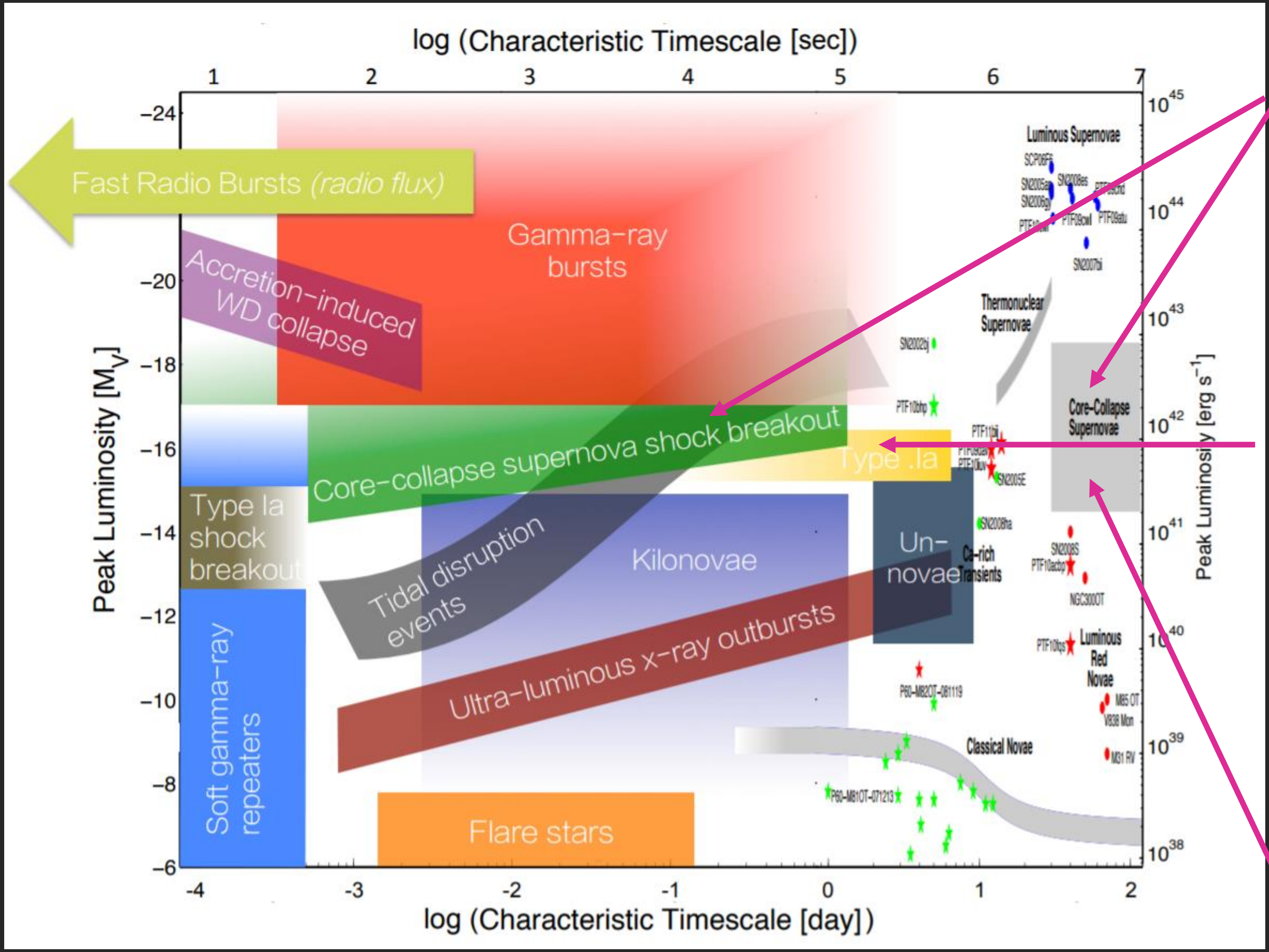


Unresolved problems for SNe Ia

- Explosion mechanism (multiple paths?).
- Progenitor systems.



Frontiers in Transient Science



Cooke+ 2015

Higher cadence

Known transients, but from the beginning.

Unknown short-time scale objects.

Larger samples

Rare types of explosions.

New Time Domain Era

Survey	Depth (mag)	Area (deg^2)	Cadence
BlackGEM	21.5	10,000	2 weeks
DES	23.5	5,000	1 week
KMTNet	~21	~6,000	1 day
MOA	~21	~1,000	1 day
TNTS	20.0	2,000	?
PTSS	20.5	4,000	1 day
HSC	25	800	1 day
Tomo-e	18/19	7,000	2 hr/1 day
ZTF	21	23,000	3 days
	21	2,000	1 day
	21	6,000	2 hr
ASAS-SN	17	40,000	1 day
DLT40	20	600 gal	1 dat

Ongoing surveys

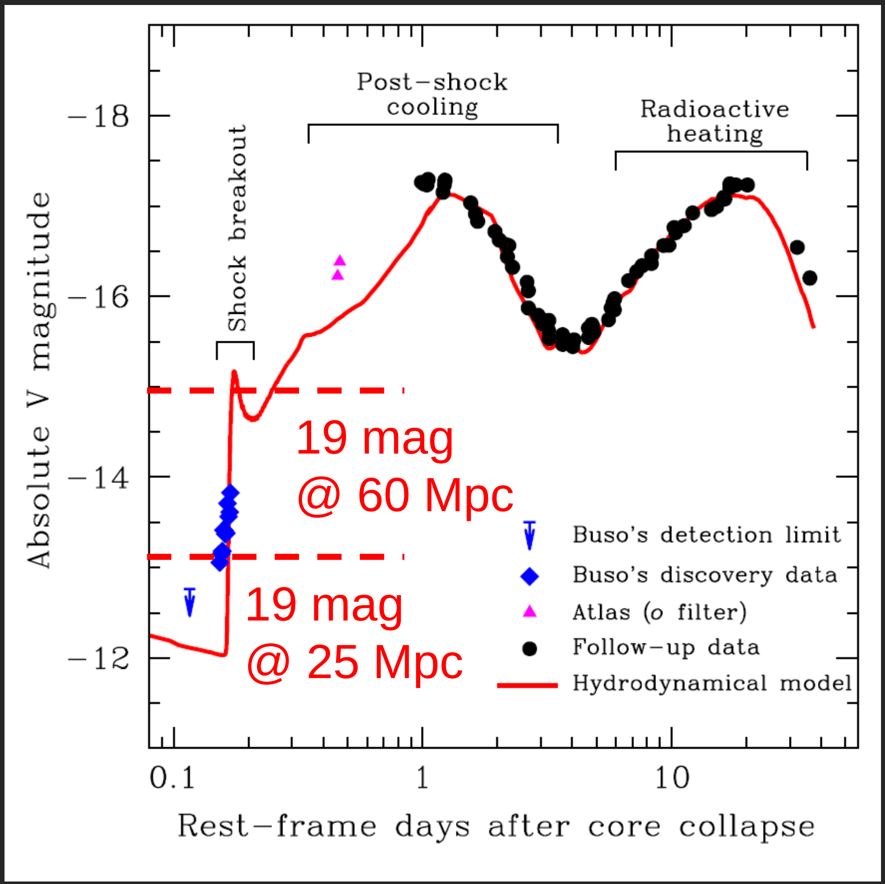
© Tanaka

	Tomo-e SN Survey
instrument	Tomo-e Gozen
sensor	CMOS
readout time	~0 sec
period	2018/9-
survey area [deg2]	10,000
cadence	2 hours / 1 day
exposure time / visit	3 sec
depth	18 mag / 19 mag
filter	no (~g+r)
#(SBOs), #(SNe) / yr	5, 1000
data storage	daily-stacked image SN cutout images
reference	-

Tomo-e survey

© Morokuma

New Time Domain Era



	Tomo-e SN Survey
instrument	Tomo-e Gozen
sensor	CMOS
readout time	~0 sec
period	2018/9-
survey area [deg2]	10,000
cadence	2 hours / 1 day
exposure time / visit	3 sec
depth	18 mag / 19 mag
filter	no (~g+r)
#(SBOs), #(SNe) / yr	5, 1000
data storage	daily-stacked image SN cutout images
reference	-

Catch SNe in the first day.

Pick up rare examples (with long-term observations).

Seimei as a key player in transient science

- Transient science:
  - The telescope site matters.
- Essentially an only > 3m telescope covering the East-Asian sky.

How we do it w/ Seimei?

Observing schedule for 3.8-m SEIMEI Telescope (2021A)

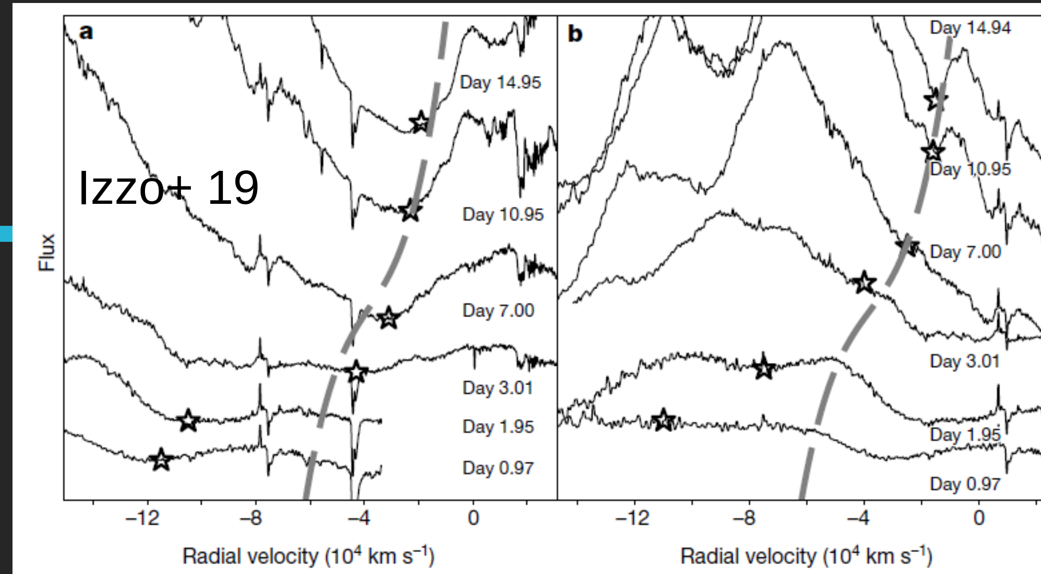
Feb-2021

	Sun		Mon		Tue		Wed		Thu		Fri		Sat	
Date			1		2		3		4		5		6	
Observer (PROP-ID)			行方(21A-K-0009)	前田(21A-N-CT02)	行方(21A-N-CN03)	前田(21A-N-CT02)	行方(21A-N-CN03)	行方(21A-N-CN03)	行方(21A-N-CN03)	行方(21A-N-CN03)	行方(21A-N-CN03)	行方(21A-N-CN03)	栗田(21A-K-0015)	前田(21A-K-0001)
Grism			B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6	
Date	7		8		9		10		11●		12		13	
Observer (PROP-ID)	栗田(21A-K-0015)	前田(21A-K-0001)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	磯部(21A-N-CN12)	前田(21A-K-0001)	前原(21A-K-0013)
Grism	B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6	
Date	14		15		16		17		18		19		20	
Observer (PROP-ID)	前田(21A-K-0001)	前原(21A-K-0013)	前原(21A-N-CN10)	前原(21A-N-CN10)	前原(21A-N-CN10)	前原(21A-N-CN10)	前原(21A-N-CN10)	前原(21A-N-CN10)	前原(21A-N-CN10)	前原(21A-N-CN10)	前田(21A-K-0001)	前原(21A-K-0013)	前田(21A-K-0001)	前原(21A-K-0013)
Grism	B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6	
Date	21		22		23		24		25		26		27○	
Observer (PROP-ID)	前原(21A-K-0013)	前原(21A-K-0013)	栗田(21A-K-0015)	Engineering (TriCCS)	栗田(21A-K-0015)	Engineering (TriCCS)	Engineering(Tel.)	Engineering (TriCCS)	Engineering(Tel.)	前田(21A-K-0001)	Engineering(Tel.)	前田(21A-K-0001)	前原(21A-K-0013)	前原(21A-K-0013)
Grism	B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6		B/R/6	
Date	28													
Observer (PROP-ID)	前原(21A-K-0013)	前原(21A-K-0013)												
Grism	B/R/6													

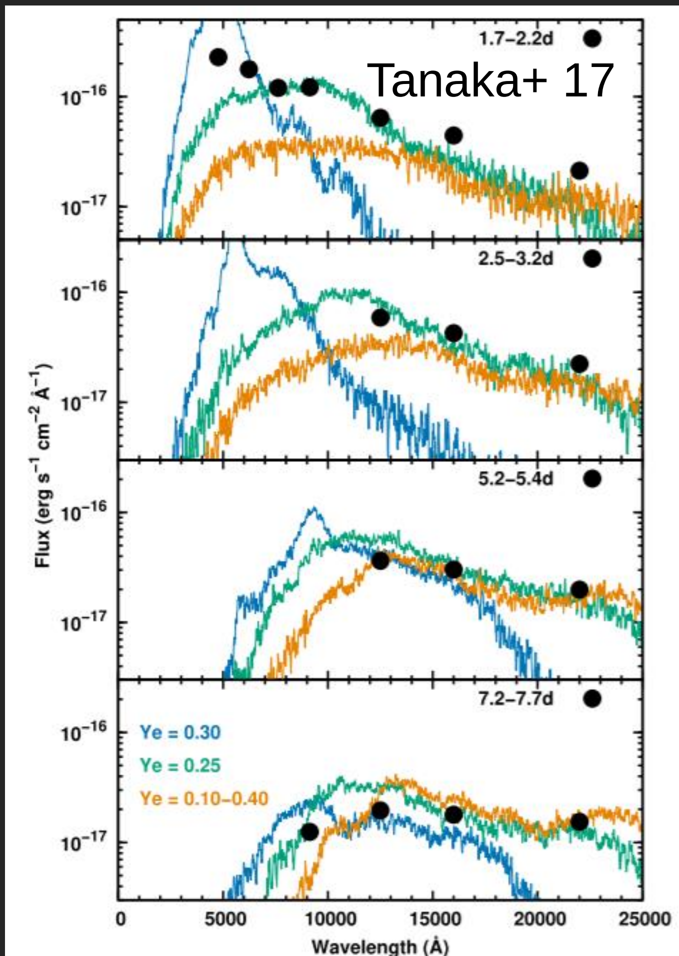
ToO: rapid classification, high-cadence especially at the beginning. Fill in the gap of the classical nights.

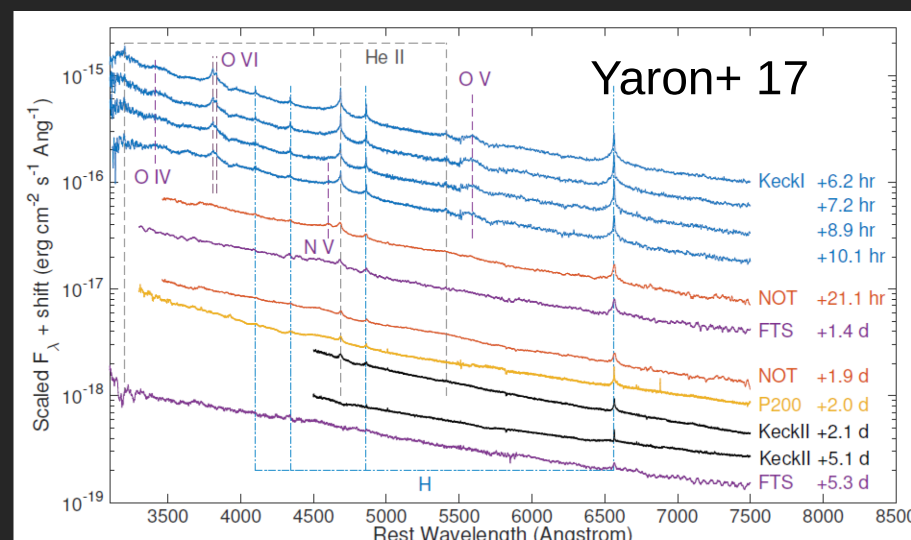
Classical: (half x 2) / a week, long monitoring.

ToO is key in transient science



Gamma-ray bursts (w/ SNe)



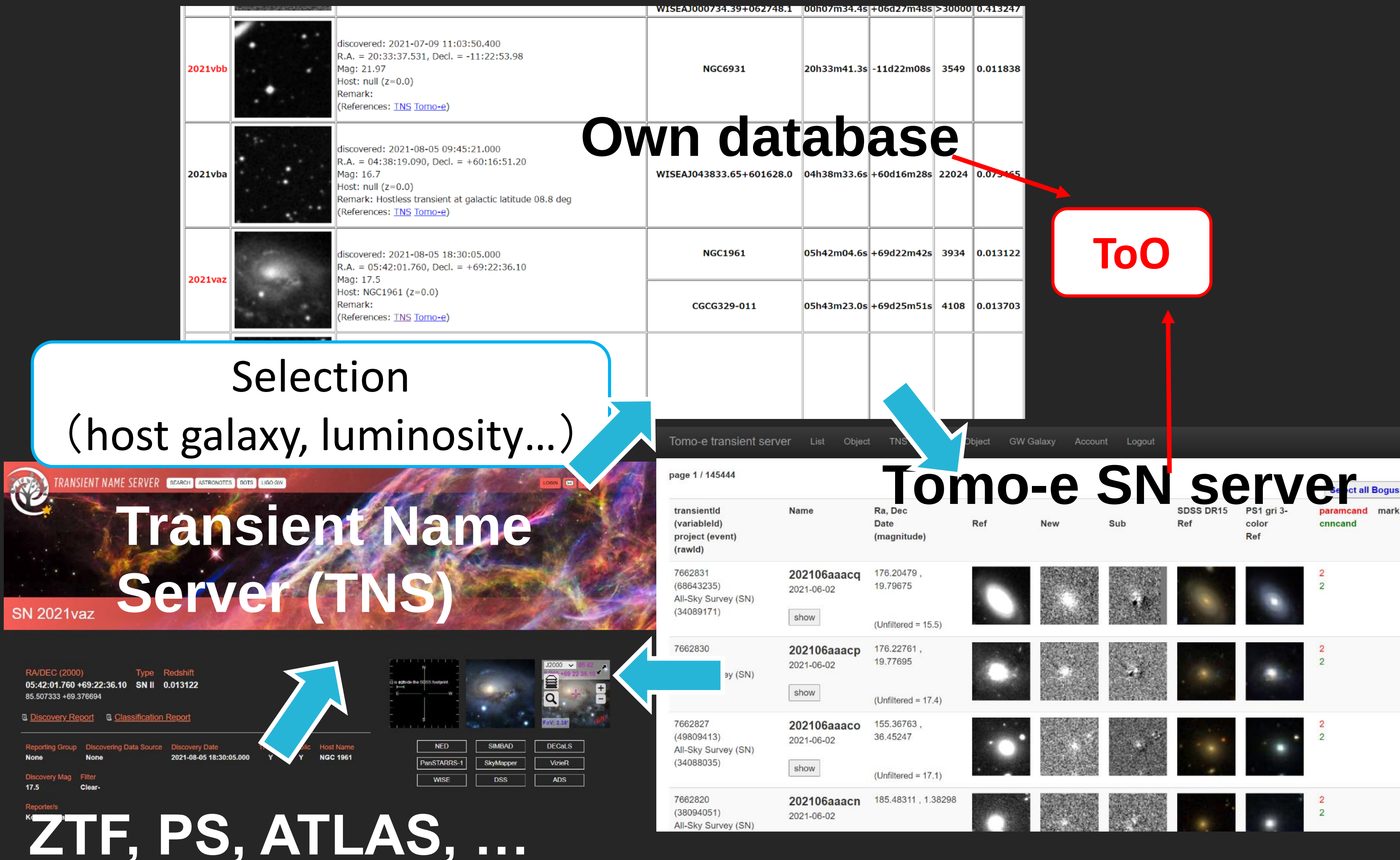


Gravitational wave counterparts

Supernovae

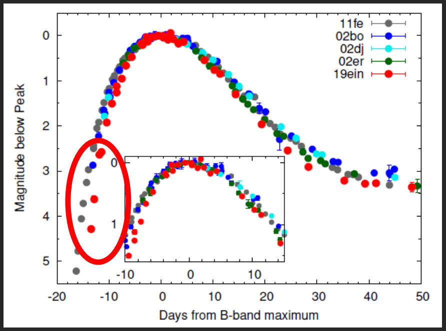
As rapid as possible after the candidate discovery

How do we do it w/ Seimei?

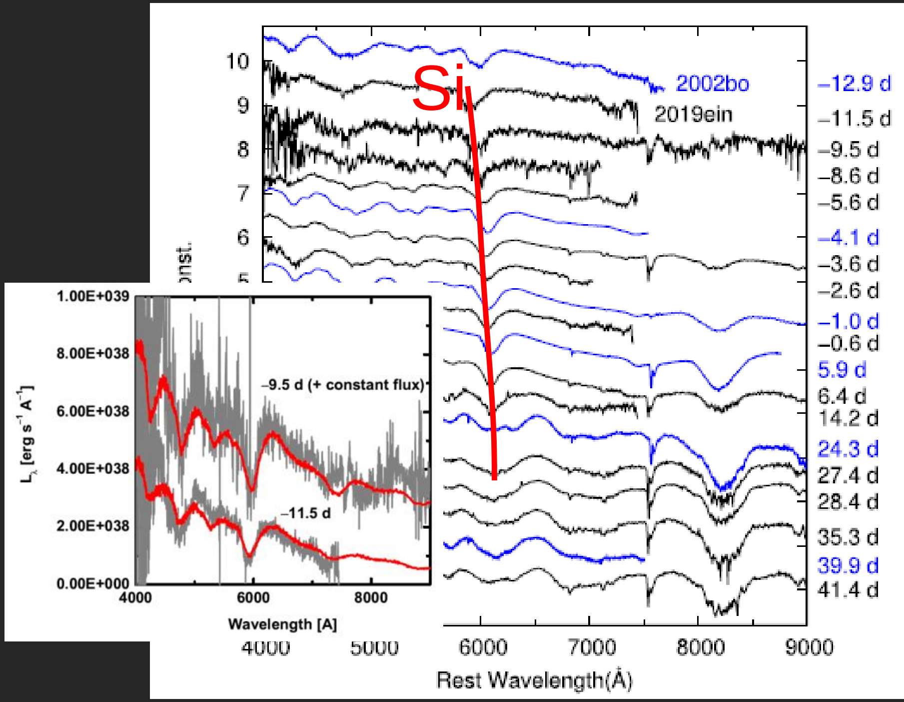


Examples of SN Ia science w/ Seimei involved

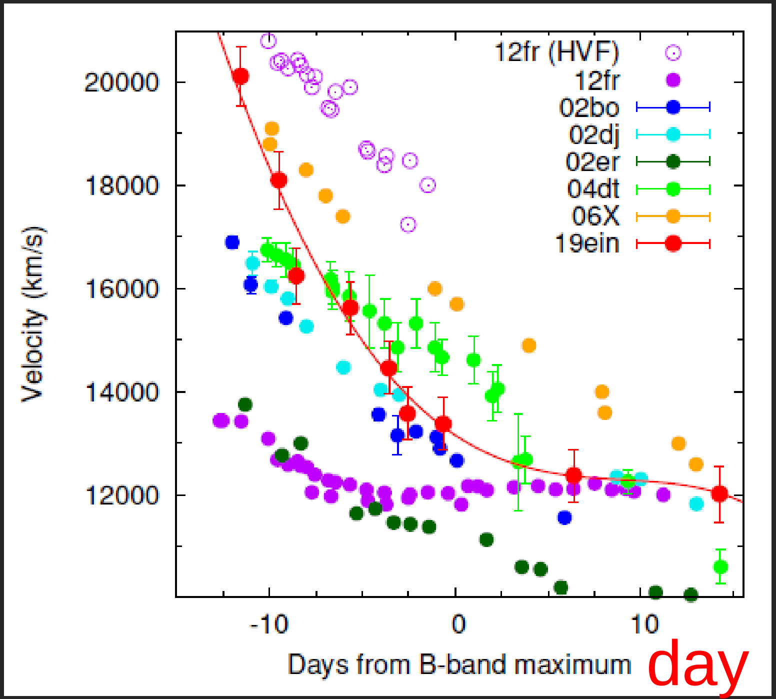
The earliest spec. for “high-V” SN Ia class



- SN Ia 2019ein (Kawabata, Maeda et al. 2020).
- **Seimei ToO on the discovery night.**
- **The earliest spec. for the “high-velocity” SN Ia class.**
- **Finding new diversity.**



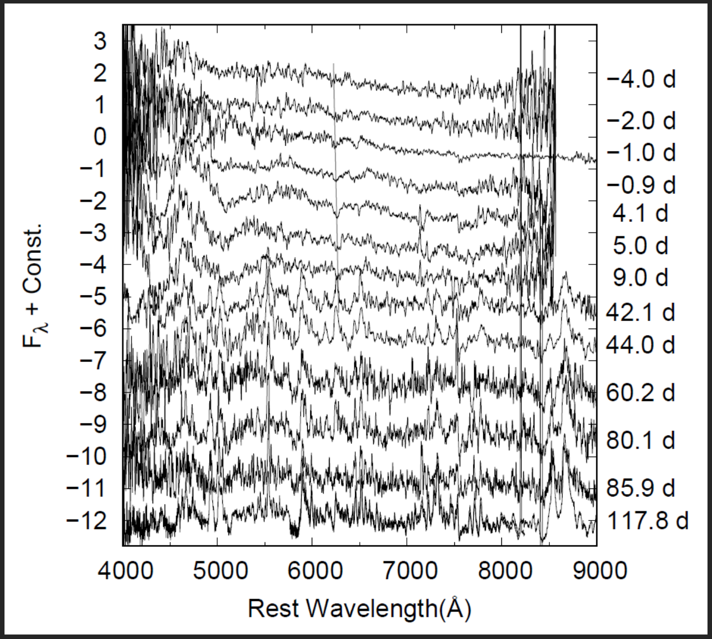
Si line velocity

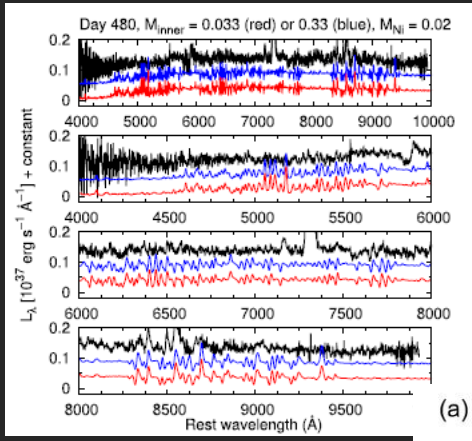


Origin of extreme faint SN Ia variant (SN “Iax”)

- SN “Iax” 2019muj (Kawabata, KM+ 2021; Maeda & Kawabata 2022).
- **Seimei ⇒ Subaru (deep spectroscopy).**
- **A “weak/failed” SN Ia leaving a surviving white dwarf?**

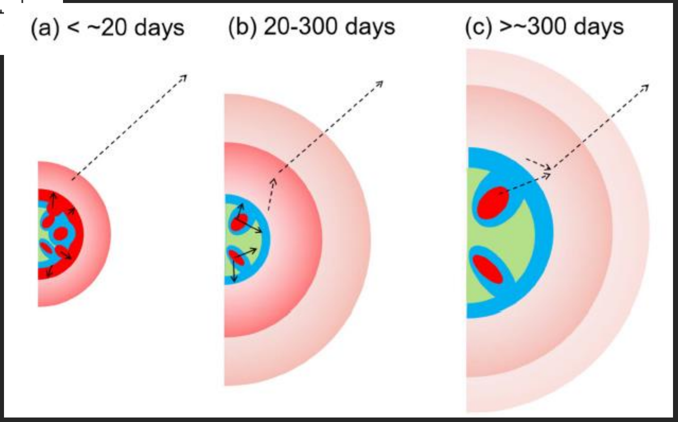
Seimei





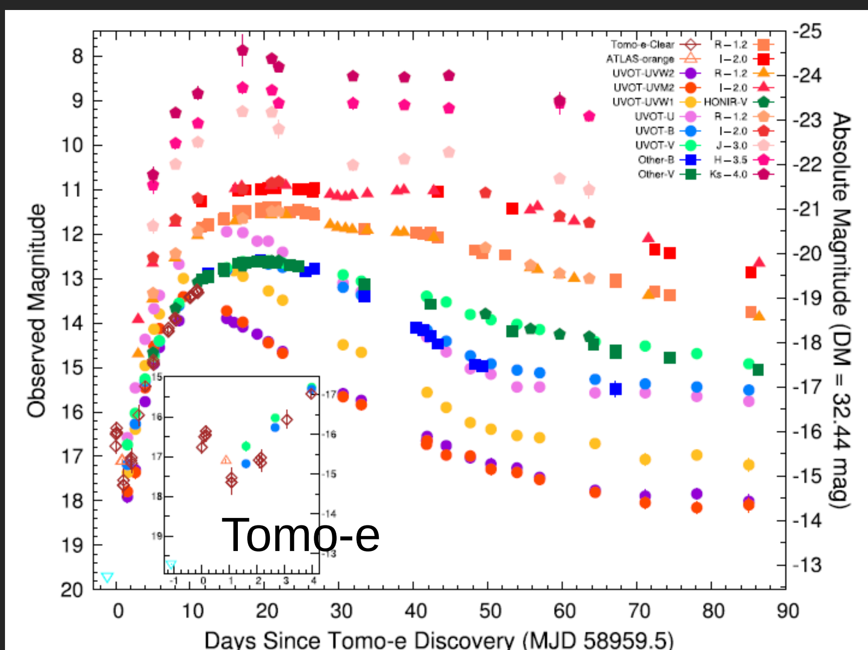
Subaru + Model

Proposed scenario

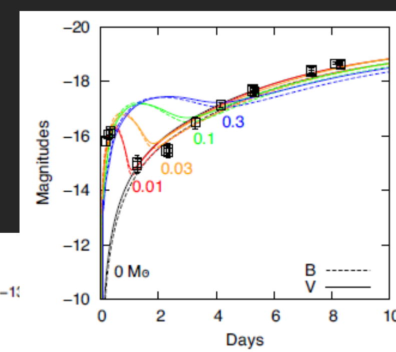


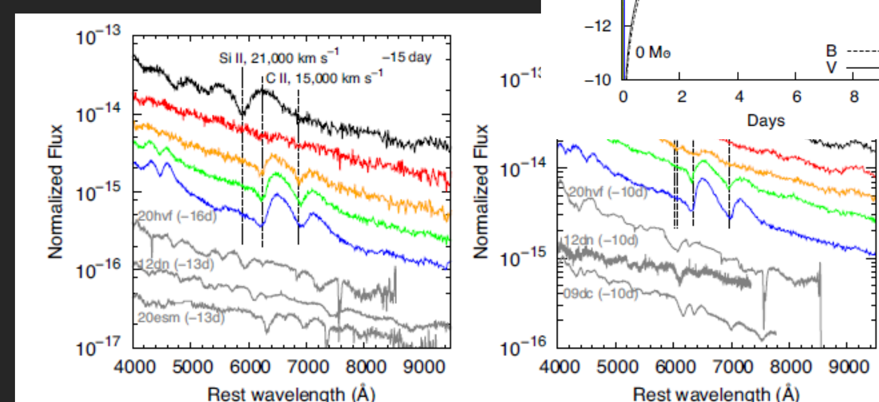
Bright flash discovered for a peculiar over-luminous SN Ia

- Over-luminous 2020hvf (Jiang, KM+ 2021).
- Suspected “super-Chandrasekhar-mass” WD.
- **Tomo-e ⇒ Seimei.**
- **Discovery of the Initial flash**
  ⇒ massive white-dwarf explosion in C-rich CSM.



Model vs. obs. (including Seimei data) KM+ 2023



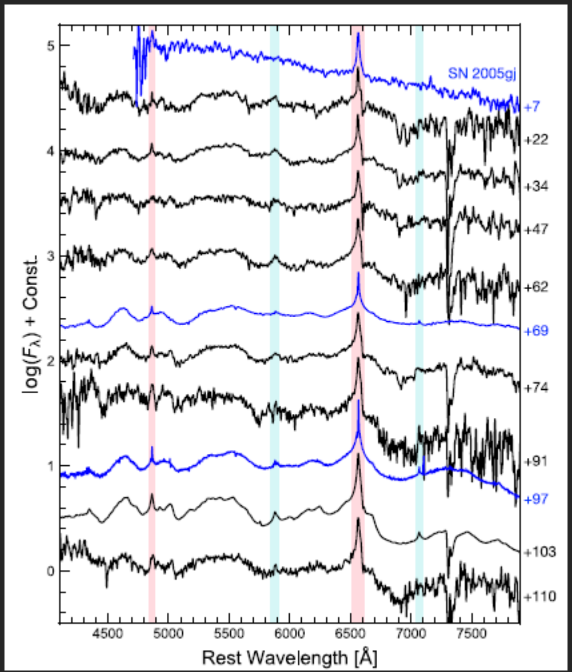


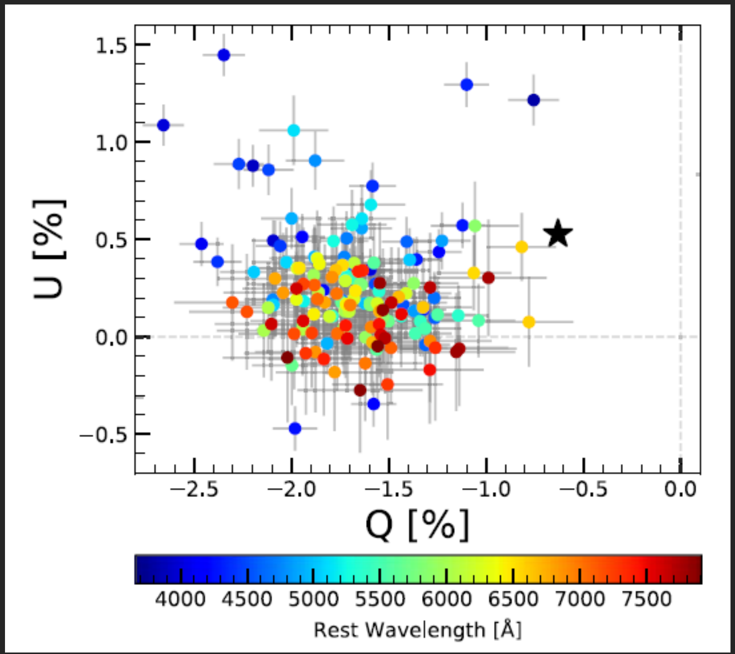
SN Ia within dense H-rich CSM

- “SN Ia-CSM” 2020uem (Uno, KM+ 2023).
- Suggested to be an SN Ia within dense H-rich CSM.
- **Seimei ⇒ Subaru (polarization).**
- **CSM: massive (Seimei) and disk-like (Subaru)**

  ⇒ A merger of a white dwarf with a giant?

Seimei (Uno, KM+ 23)



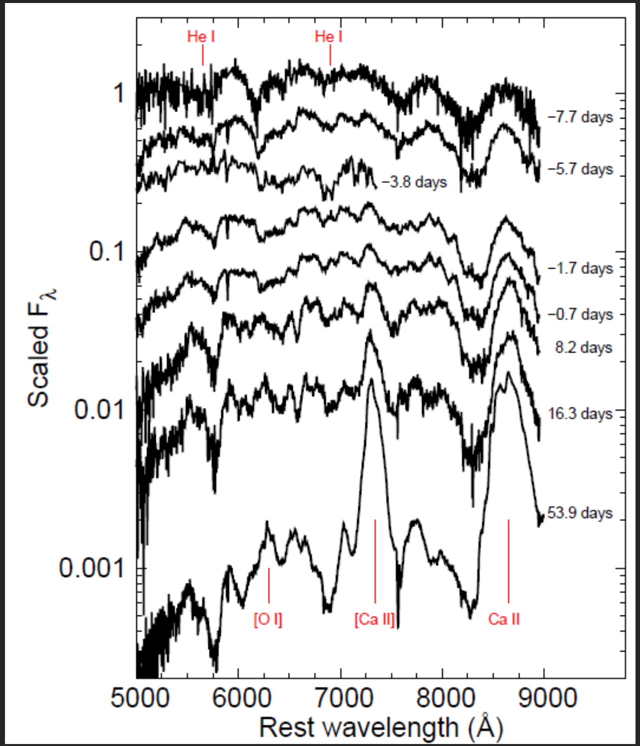


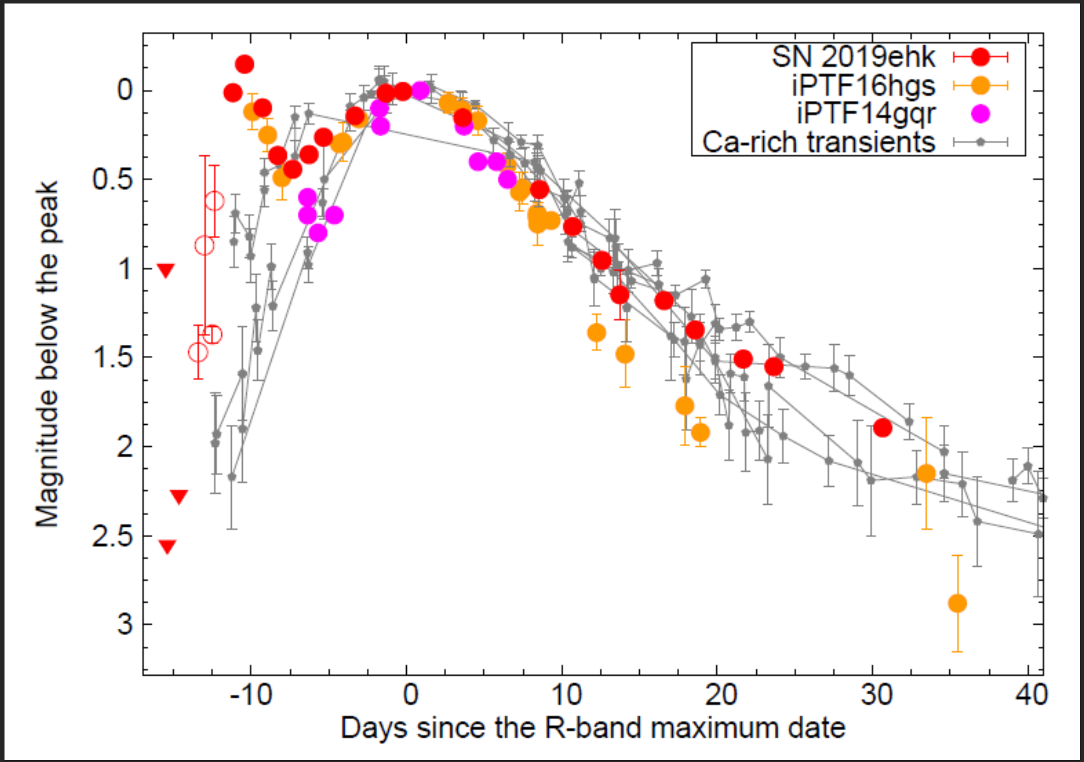
Subaru (Uno, Nagao, KM+ 23)

Examples of core-collapse SN science w/ Seimei involved

A new population within enigmatic calcium-rich transients

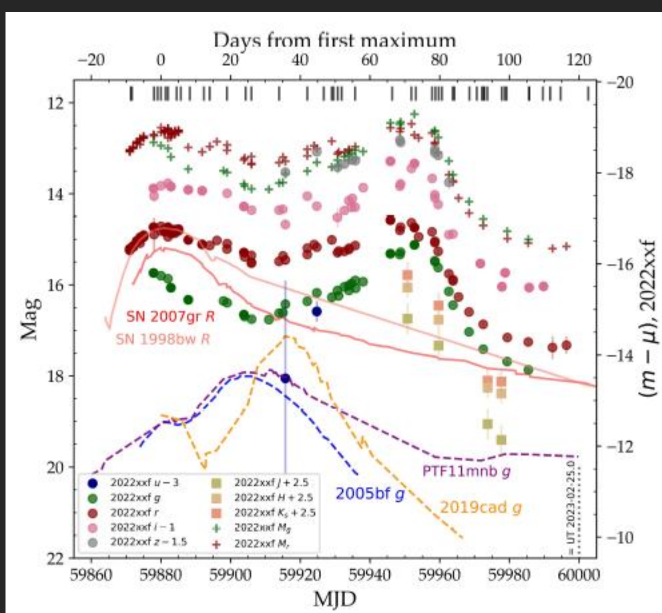
- Ca-rich transient 2019ehk (Nakaoka, Maeda et al. 2021).
- **An SN leading to binary neutron stars?**
  - **A progenitor toward "gravitational-wav emitter" hidden in a population of (enigmatic) Ca-rich transients.**

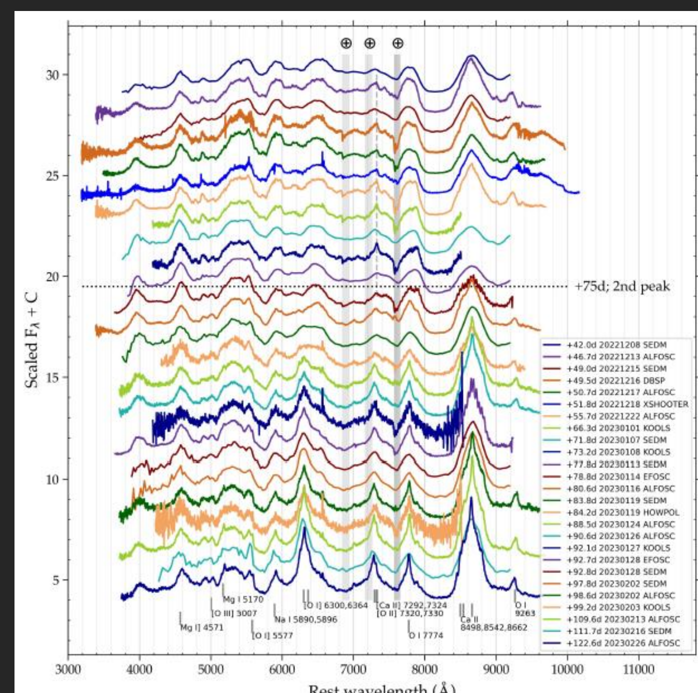




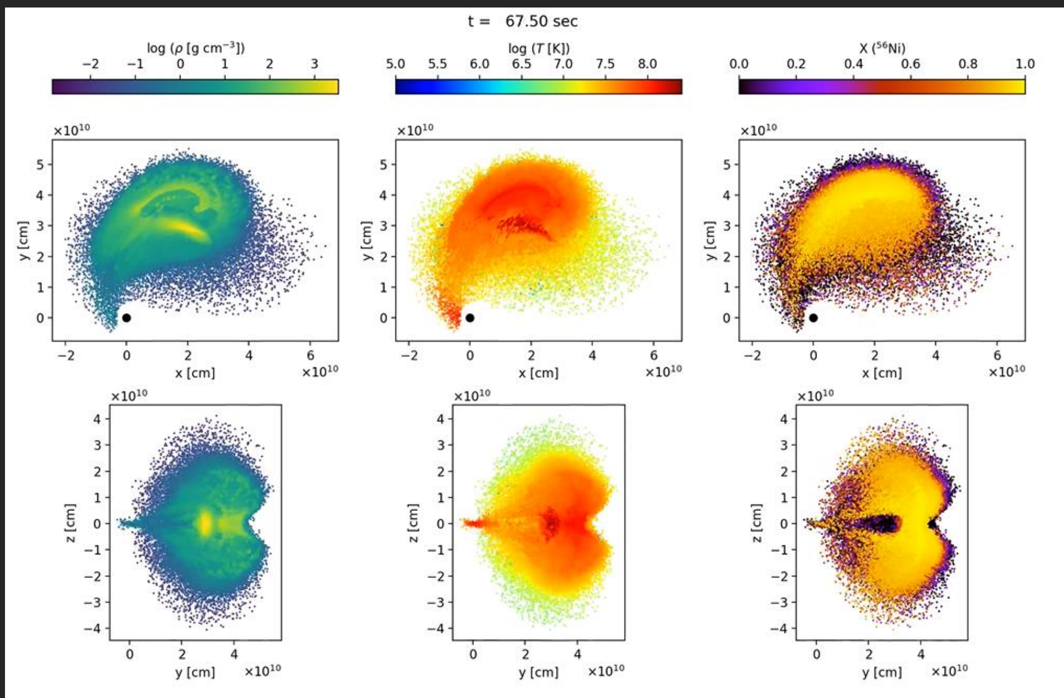
A new population of SNe within C/O-rich CSM

- Peculiar SN Ic 2022xxf (Kuncarayakti, Izzo, Sollerman, KM+ 2023).
- **Double-peaked light curve (few examples known).**
- **Global observation network, in multi-wavelength.**
- **Explosion of a C+O star, surrounded by C/O-rich CSM (huge mass-loss… challenge to stellar evolution).**





Other transients of interest (examples)



Tidal disruption events (TDEs):

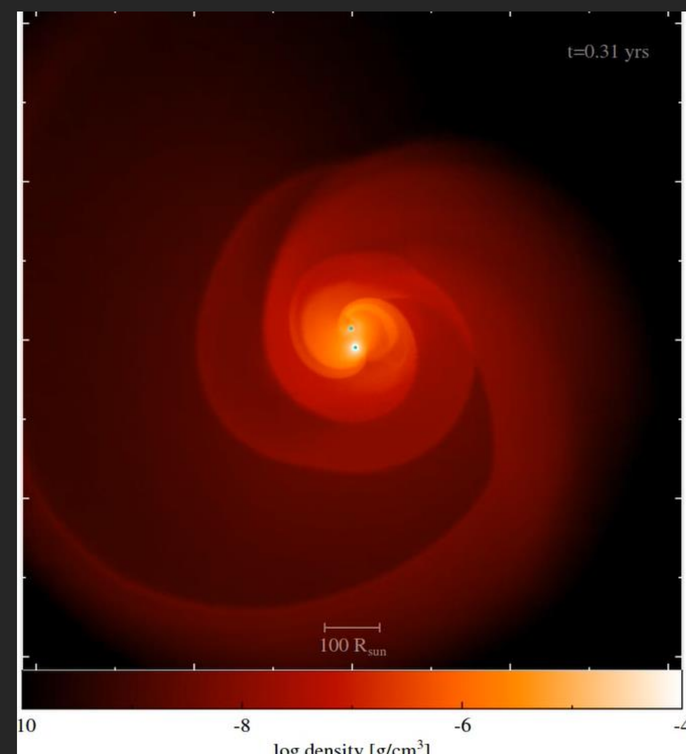
Transients powered by a star tidally disrupted by a massive black hole.

kawana, KM+ 2020

Stellar merger:

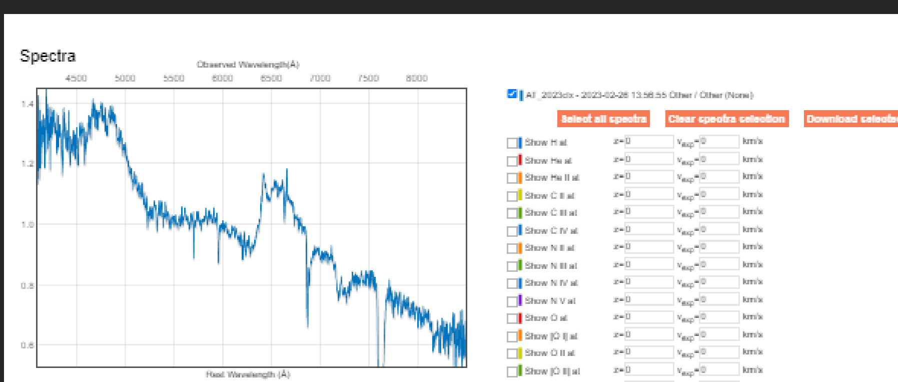
Merging binary stars.

Iaconi, KM+ 2019, 2020



One of the nearest TDEs: 2023clx

- “TDE” classified by Seimei (Taguchi, … KM+ 2023).
- **Seimei ⇒ Subaru (polarization).**
- **Strong polarization level, with interesting behaviors.**
- **Probably a “faked” TDE (identifying a new population of AGN?).**



Multi-wavelength (example)

2022.1.00115.T	Rapid ToO Observations of Nearby Supernovae: Probing The Final Evolution of Massive Stars	**Keiichi Maeda**	**EA**	**50**
COIs	Tomoki Saito; Takaya Nozawa; Takashi Moriya; Rieko Momose; Kenta Fujisawa; Stuart D Ryder; Poonam Chandra; Dan Patnaude; Hanindyo Kuncarayakti; Shiu-Hang Lee; Gaston Folatelli; Tomoki Matsuoka; Esha Kundu; Ji-an Jiang;			
Abstract	Recent observations of core-collapse supernovae (CCSNe) have led to a surprising picture that the massive stars are much more dynamic in the last few years than widely accepted previously; dense circumstellar matter confined in the vicinity of the progenitor (confined CSM) has been inferred. However, the optical emission is biased to pick up extreme CSM with large uncertainty in the interpretation. A quick ALMA ToO will yield unique and unbiased diagnostics. There are only three previous examples for which the nature of the confined CSM has been derived, using the ALMA data within ~5 days since the explosion. Contrary to the previous expectation that the confined CSM is common, a striking diversity has been emerging, but the very small sample does not allow further investigation. Inspired by this proof-of-concept, we propose ToO observations of two CCSNe at Bands 3 and 6; one SN from a compact He or C+O star and another SN from a giant progenitor. This will allow us to study whether the final activity is dependent on the nature of the stars. This project will bring us new and robust information on the yet-unclarified final evolution of massive stars.			

- ToO for SNe just after the explosion in millimeter.
- **ALMA cycle 9 (- Sep 2023) ongoing.**
- **ALMA cycle 10 accepted (Nov 2023- Sep 2024).**
- Initial results:
  - SN Ic 2020oi (KM+ 2021).
  - SN IIL 2018ivc (KM+ 2023ab).

Multi-mesenger

- Seimei as a key facility in Japan for
  - Gravitational-wave counterpart follow-up team.
  - IceCube Neutrino counterpart identification team.
- Search: imaging (TriCCS).
- Follow-up: Imaging (TriCCS) + spec (Kools-IFU).

- We are developing various observing tools/software/pipeline optimized for these activities w/ Seimei (KM, Nogami, etc).
- KM as a co-PI of TriCCS (mostly for managing, not hardware).

Indonesian telescope as a key player in transient science

- Transient science:
  - The telescope site matters.
- **Unique telescope site.**
- **Better sky than Okayama.**
  - **Ideal for transient science.**
- **Cover both N/S w/ two telescopes.**
- **Weather factor.**

Need for spectrograph

- NIRKA & OPTIKA already very useful (e.g., GW-counterpart search), but a spectrograph will change the game.

- Some of my colleagues showing interest for developing a spectrograph.
  - Hanin Kuncarayakti (Turku / Finland).
  - Jian Jiang (UTSC / China).
  - And myself.

Summary

Transient science is one of the keys w/ Seimei.

Transient Science should fit perfectly to the Indonesian Seimei sister.

Combine the two Seimei’s – even stronger.

Can also collaborate on the spectrograph development.

Please contact me and/or Hanin.