

# SN 2024acn: Follow-up observations of a Type II supernova discovered by Tomo-e Gozen

Ryotaro Koshi (The University of Tokyo)

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Kiso Schmidt Symposium

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- Observation of SN 2024acn (24acn) plays a role as
  - A case study of Type II(n) supernovae
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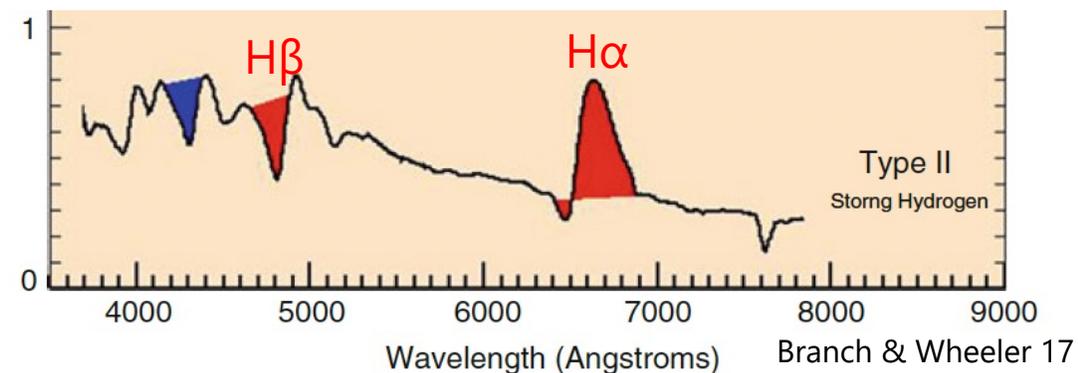
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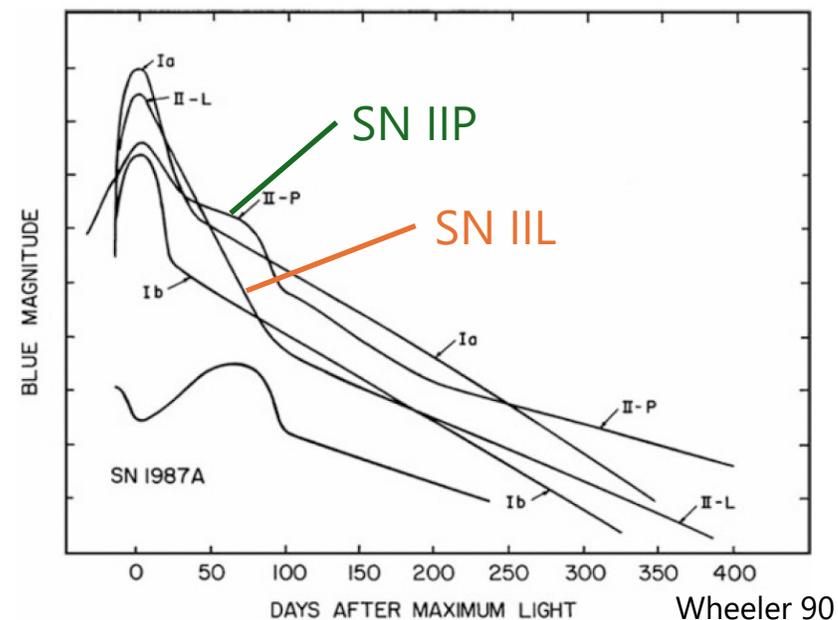
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# 1.1 Type II supernovae (SNe II)

- **SNe II** are supernovae that occur from core-collapse of massive stars ( $>8M_{\odot}$ )
  - Strong **hydrogen lines** in spectra (progenitor has a hydrogen envelope)
- SNe II can be further classified from their **light curves** / **spectra**
  - SN IIP: **"P"lateau** phase in light curve
  - SN IIL: **"L"inear** decline in light curve
  - SN IIn: **"n"arrow** lines in spectrum
    - ◆ Dense circumstellar material (**CSM**) around the SN → heavy **mass-loss** of progenitor
  - SN IIb: emergence of **He I** in spectrum



A typical spectrum of SNe II



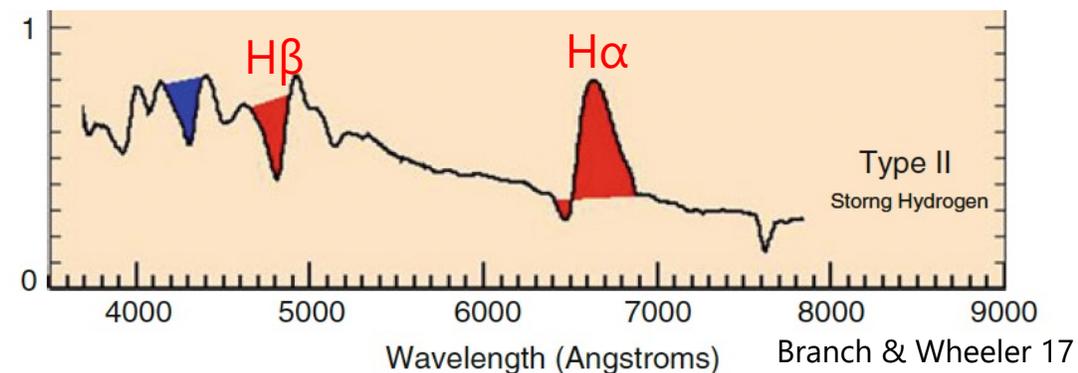
Light curves of SN IIP and IIL

# 1.1 Type II supernovae (SNe II)

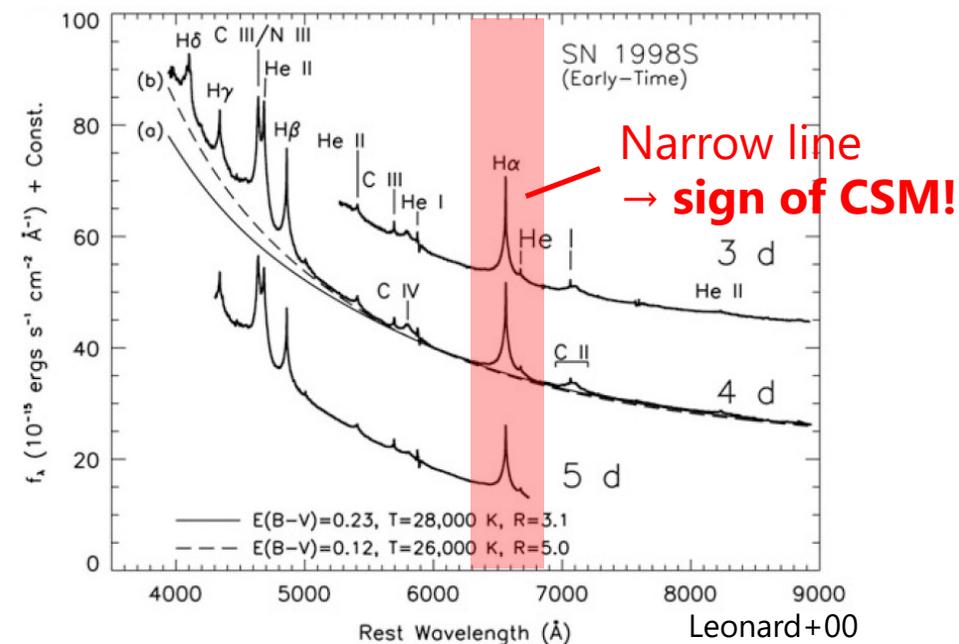
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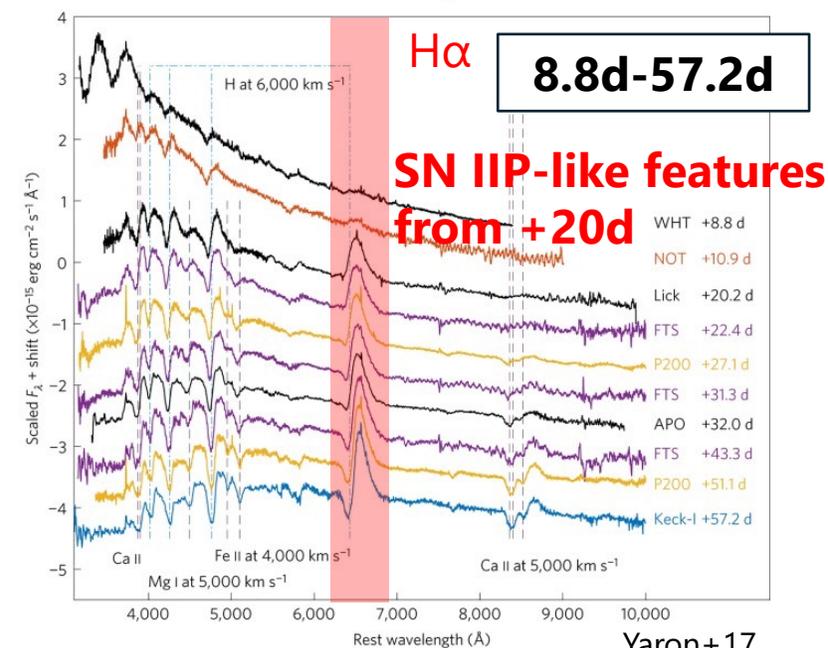
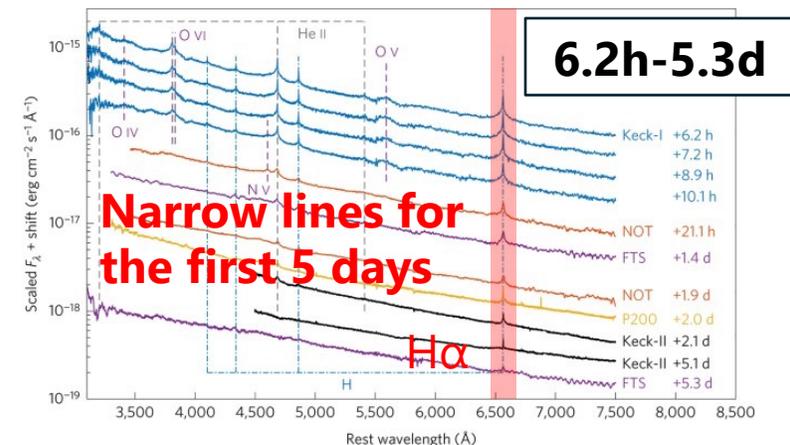
A typical spectrum of SNe II



Spectrum of SN IIn (SN1998S)

# 1.2 Mass-loss of SN II progenitors

- Wide-field surveys have enabled early SN observations, deepening our understandings
- Many SN II progenitors experience **intense mass-loss** just before explosion (not just SNe IIn)
  - These SNe show narrow lines **only for a few days** after explosion
  - Implies the existence of CSM near the SN
- There is a **diversity of mass-loss rates** within SNe II
  - We need a larger sample (e.g. SNe in between SNe IIP and SNe IIn) to understand this diversity
  - SNe should be observed as early as possible



Spectra of SN 2013fs, a SN IIP

SN 2024acn

# 2.1 Discovery of SN 2024acn

1/13

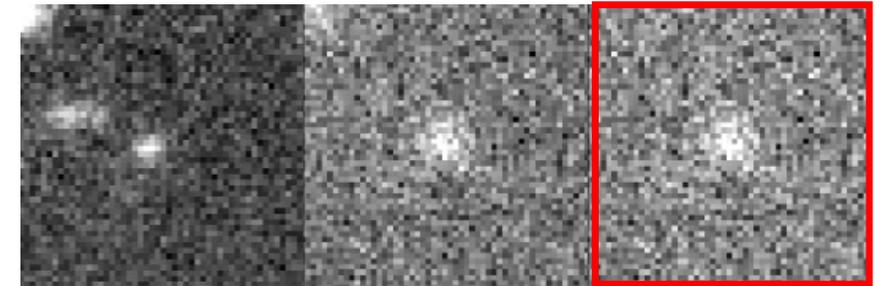
- 24acn was detected at  $17.57 \pm 0.11$  mag (Tomo-e)

1/14

- We received an alert
- 2<sup>nd</sup> observation: detection and brightening was confirmed (Tomo-e, MITSuME Akeno)

1/15

- Object was reported to the Transient Name Server (TNS) as **AT 2024acn**
  - Second object to be reported by Tomo-e Gozen (after SN2019cxx)



Reference

New

Subtracted

Image of first detection of 24acn

Koshi et al., in prep.

# 2.1 Discovery of SN 2024acn

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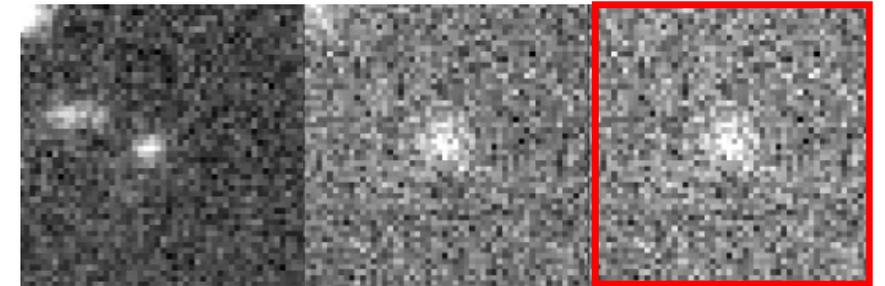
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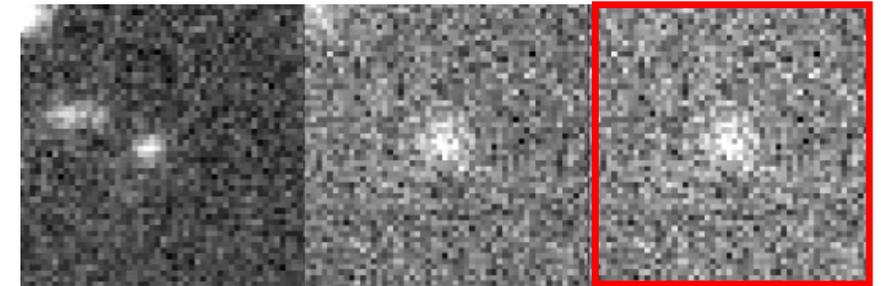
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Reference New Subtracted  
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SN 2024acn

RA/DEC (2000)	Type	Redshift
11:10:40.441 +21:06:26.87 167.668505874 +21.1074646977	SN II	0.031

[Discovery Report](#) [Classification Report](#)

Reporting Group	Discovering Data Source	Discovery Date	TNS AT	Public	Discovery Mag
Tomo-e Gozen	Tomo-e Gozen	2024-01-13 19:30:26.000	Y	Y	17.57

Filter  
Other-

Reporter/s  
Ryotaro Koshi (The University of Tokyo), Ryuichi Hoshino (The University of Electro-Communications), Ichiro Takahashi (Tokyo Institute of Technology), Shigeyuki Sako (The University of Tokyo), Taiga Sasaoka (The University of Tokyo), Nozomu Tominaga (National Astronomical Observatory of Japan), Kenta Taguchi (Kyoto University)

Discovery report of 24acn

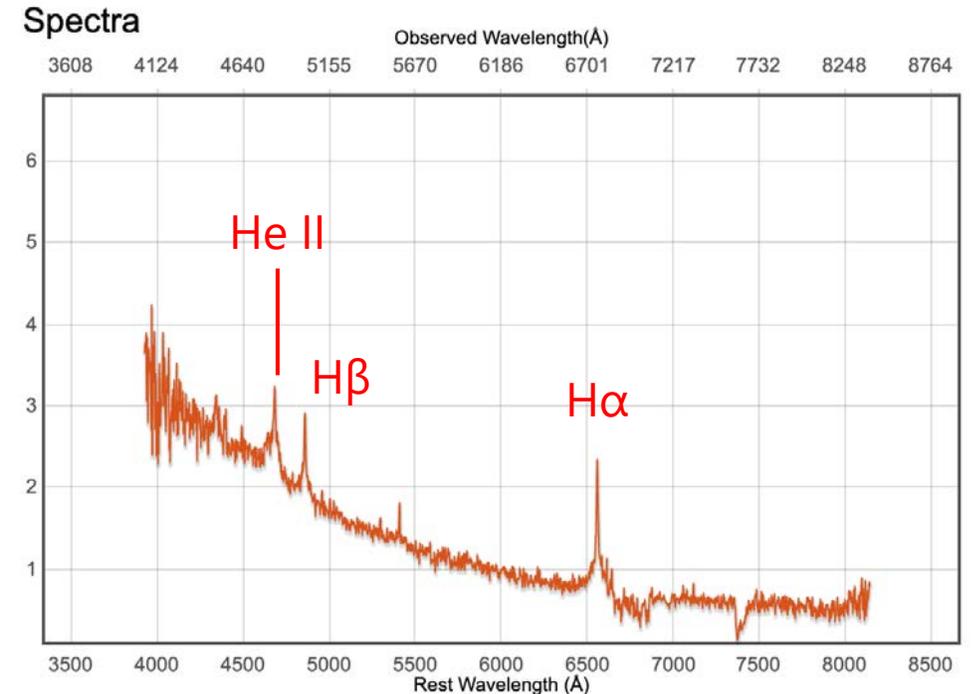
# 2.2 Classification of 24acn as a supernova

1/15

- Spectroscopy and photometry (Seimei, Prop ID: 24A-N-CT17)
- 24acn was classified as a **SN II** at  $z=0.031$  ( $\sim 130$ Mpc)
  - The existence of the **H $\alpha$**  line is a signature of SNe II

1/17

- A proposal was submitted to and accepted by OISTER
- Follow-up observations by **5** observatories started



A quicklook spectrum of 24acn taken on 1/15 by Seimei (KOOLS-IFU, VPH-blue)

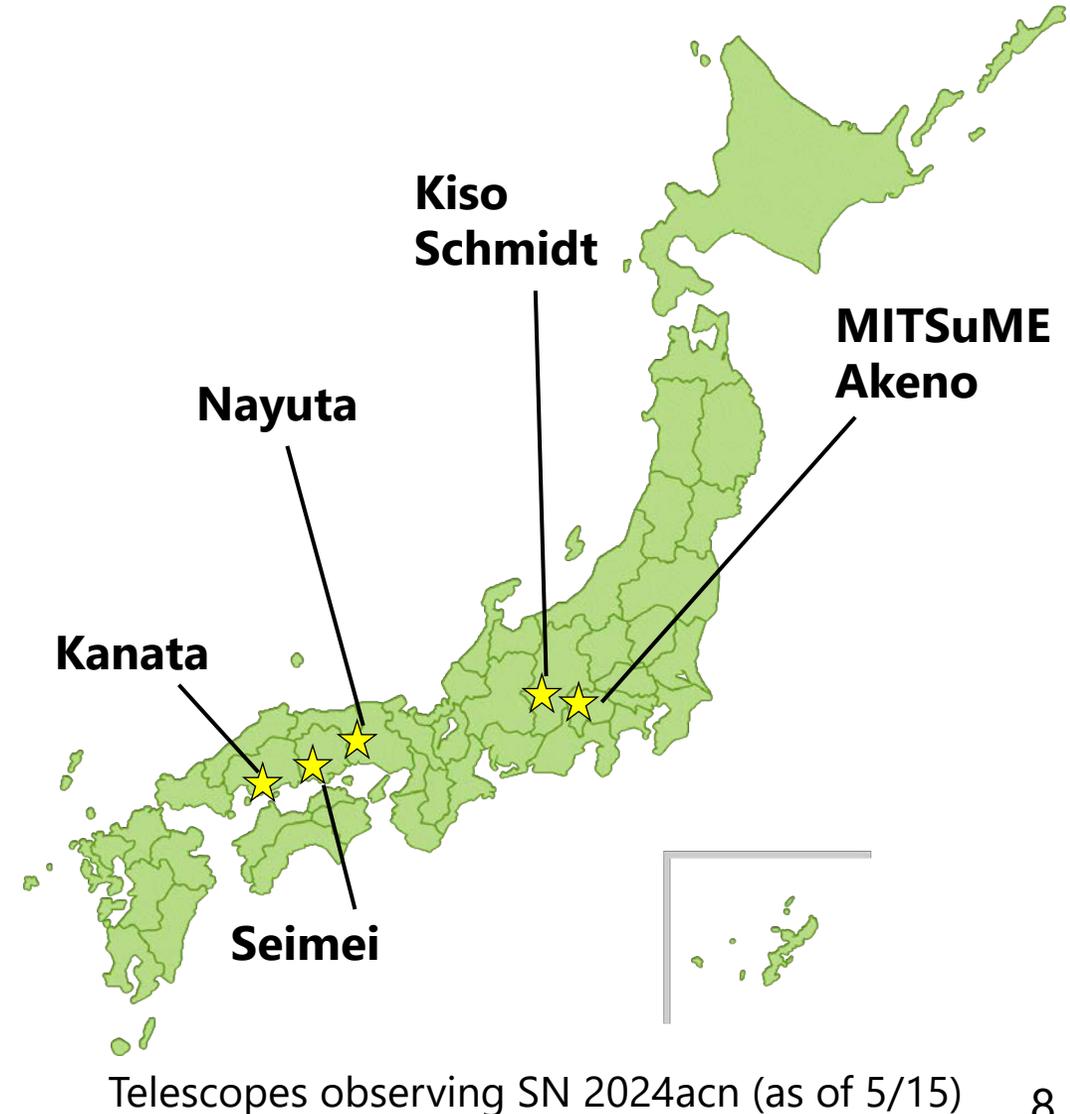
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## 3.2 Photometry of SN 2024acn

- A 10-30 day rise to an absolute magnitude of  **$g' \sim -19.6 \text{ mag}$**
- A slow decline of  **$\sim 0.02 \text{ mag/day}$**  from 30d after discovery

Koshi et al., in prep.

# 3.3 Spectroscopy of SN 2024acn

Koshi et al., in prep.

# 4.1 Comparison with other SNe IIn

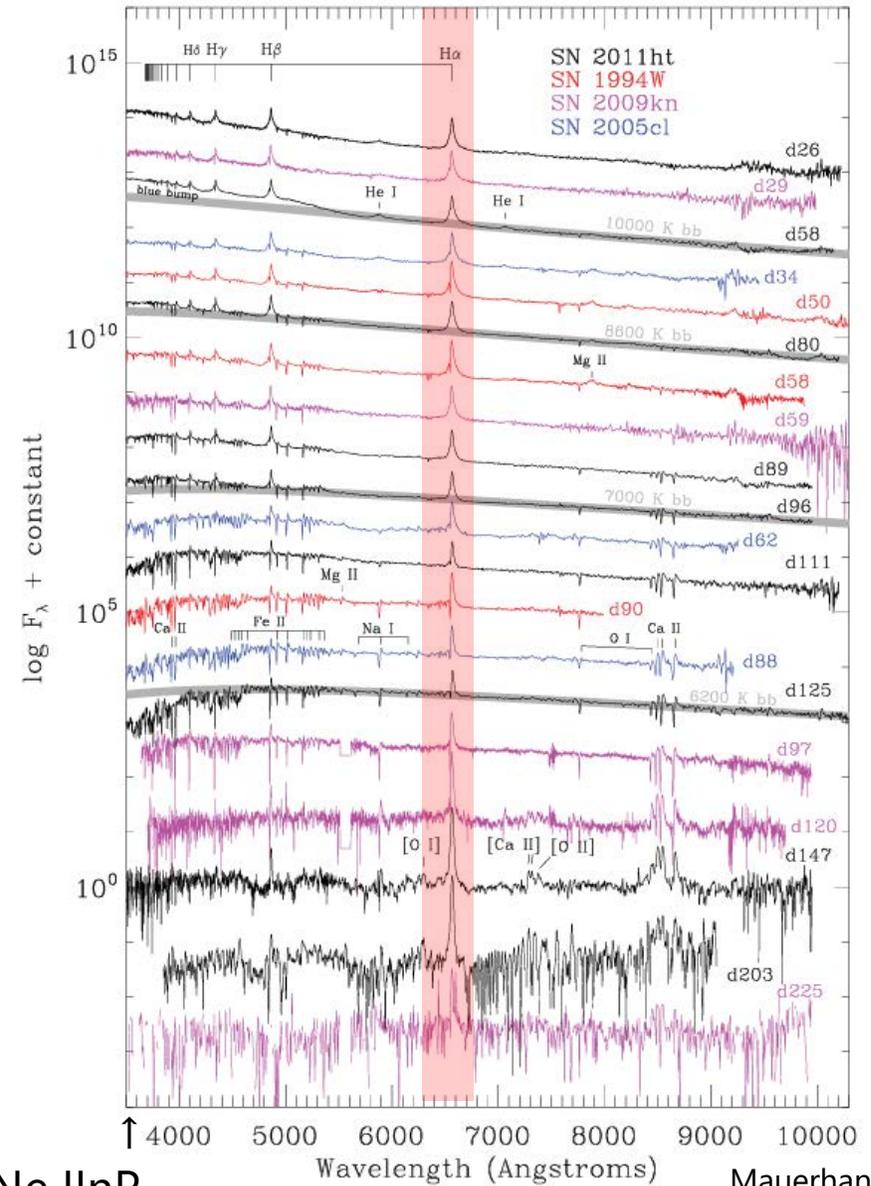
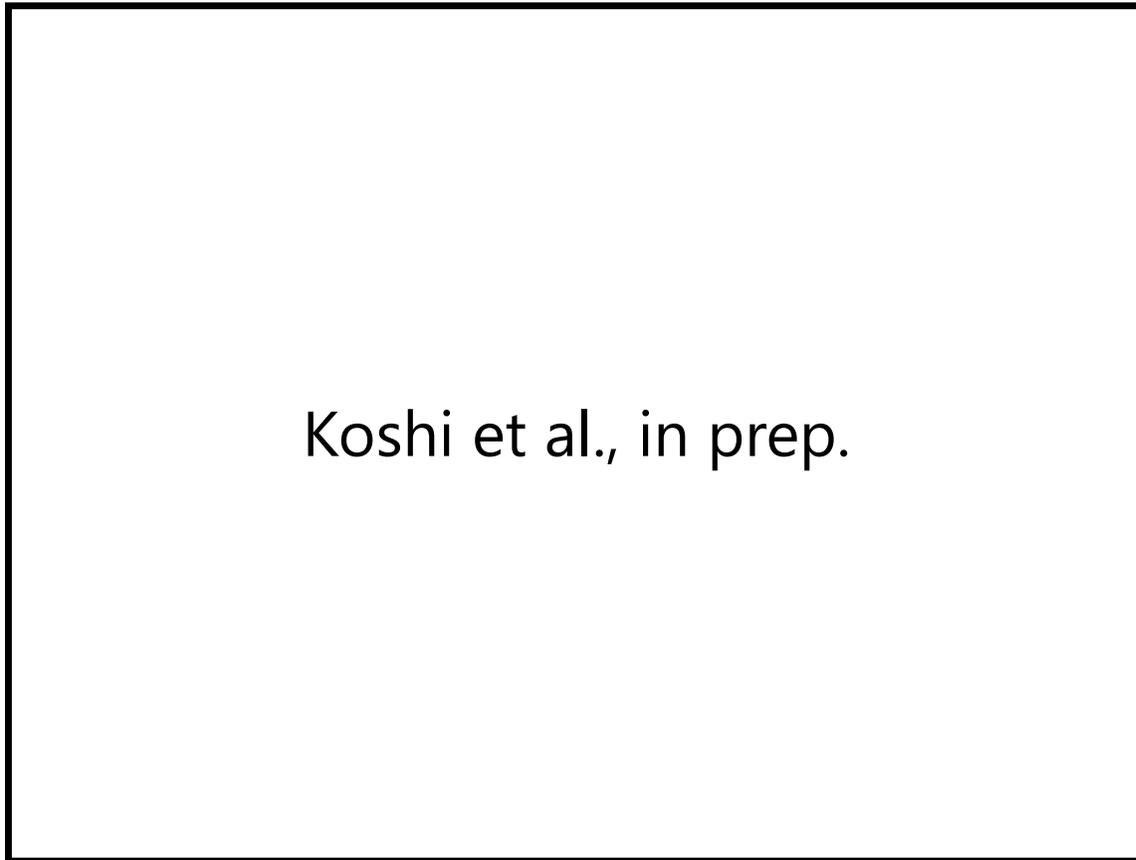
- Relatively luminous for a SN IIn
- Showing a plateau after peak
  - Subclassified as a "SN IInP"?

Koshi et al., in prep.

Koshi et al., in prep.

# 4.1 Comparison with other SNe IIn

- However, the spectra differ from most SNe IInP



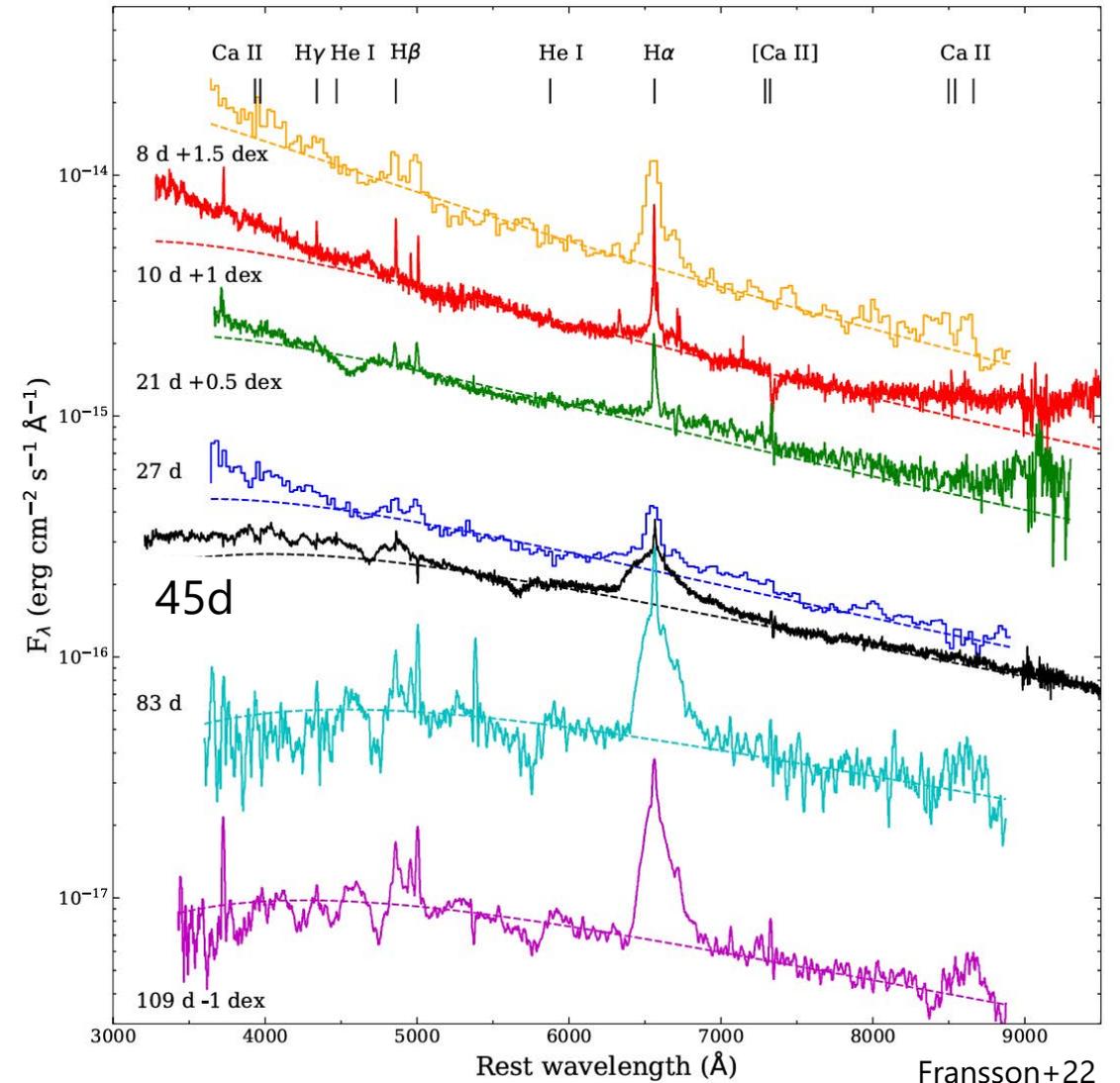
Spectra of SNe IInP

## 4.2 A multi-component H $\alpha$ profile

Koshi et al., in prep.

# 4.2 A multi-component H $\alpha$ profile

- Similar H $\alpha$  profiles are seen in a few SNe
  - SN 2019zrk (Fransson+22)
  - KISS15s (Kokubo+19)
- There are mainly two scenarios that can explain the blueshifted broad component
  - Asymmetry of the CSM region
  - Dust formation in the SN
- Existence of dust can be confirmed with NIR observations
- Light curves differ from the two above → **peculiar among SNe IIn**

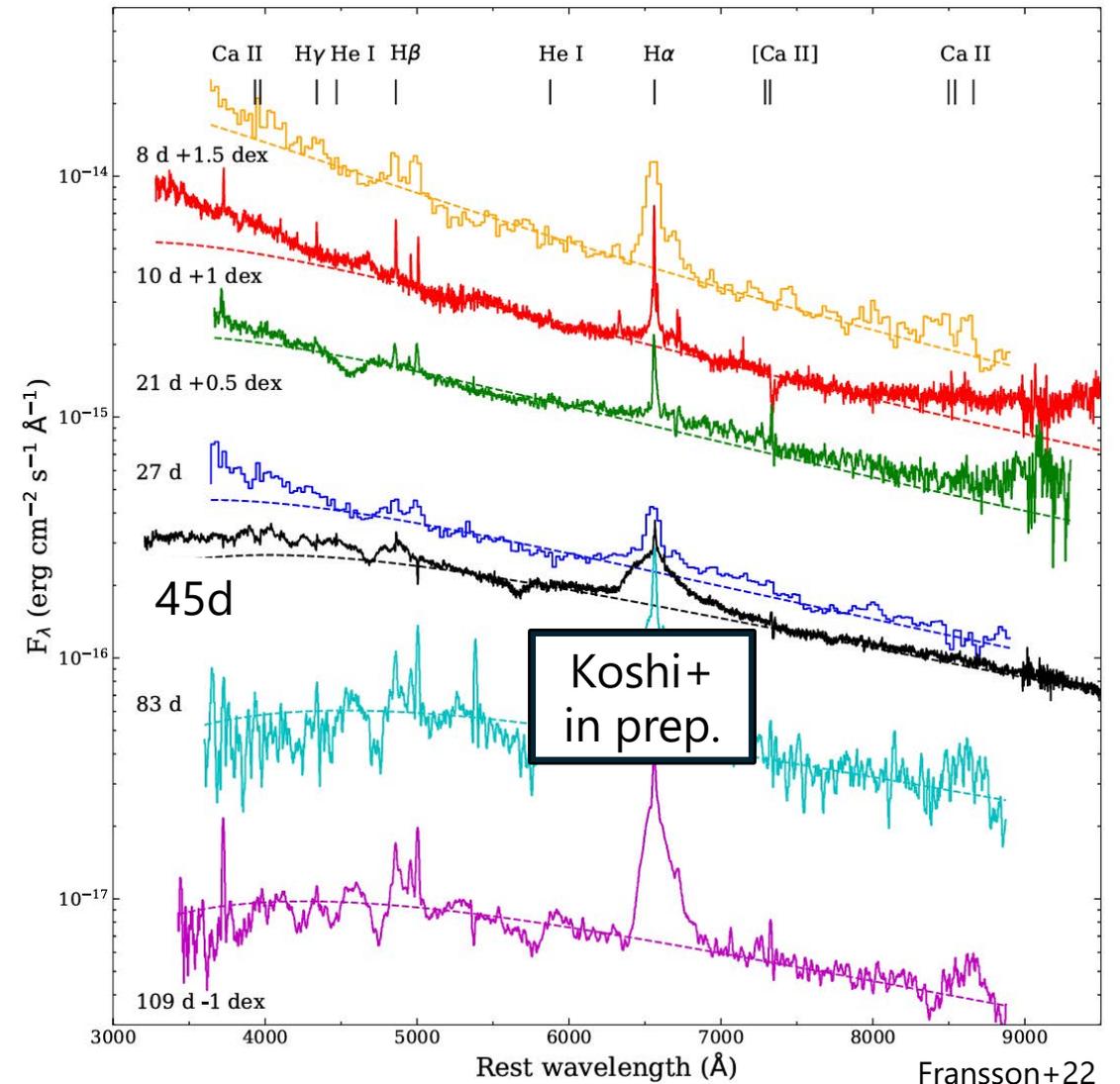


Spectra of SN 2019zrk

Fransson+22

# 4.2 A multi-component H $\alpha$ profile

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Spectra of SN 2019zrk

Fransson+22

# 4.3 Investigation of dust formation

- JHKs-band photometry is being taken with the Kanata telescope (HONIR)
- Hints of dust formation have been found
  - The **Ks-band** magnitude seem to deviate from the blackbody spectrum
  - There is another energy source in the NIR other than the expanding ejecta (i.e. dust)
- Additional observation is required to confirm and quantify the effect of dust
  - Smaller observation error in the Ks-band
  - Seeing if the SN is brightening or dimming in the NIR

Koshi et al., in prep.

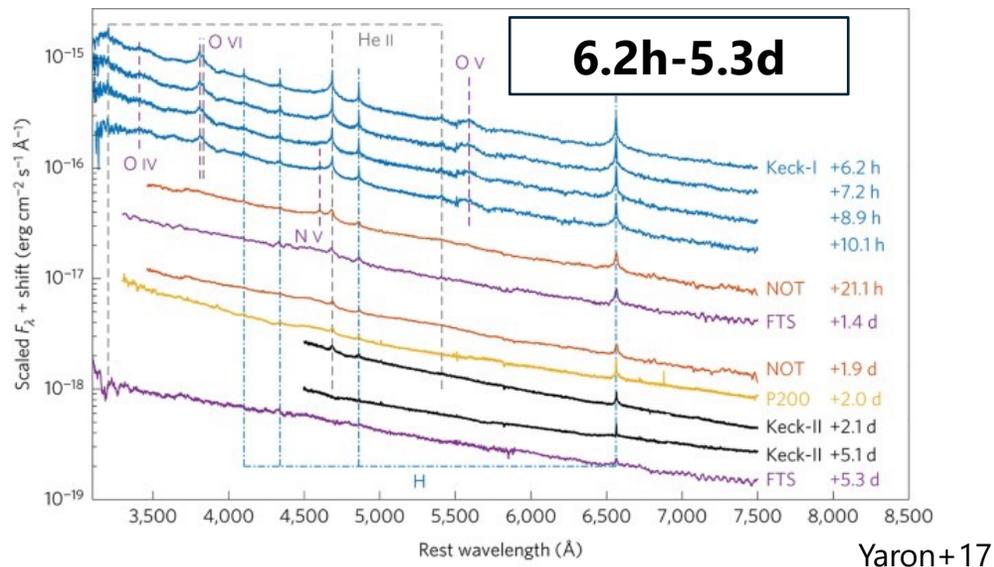
# 5.1 Future observation plans

- SNe IInP light curves drop rapidly after their plateau (**which may be soon!**)
  - We need multiple points on the tail
  - Observe until the **end of June** (visibility)
- Does 24acn have a more **compact CSM region** than normal SNe IIn?
  - Is the CSM distribution in “between” SNe IIP and SNe IIn?
- 24acn has an unusual spectral evolution for a SN IInP
  - Would the H $\alpha$  profile change with time?

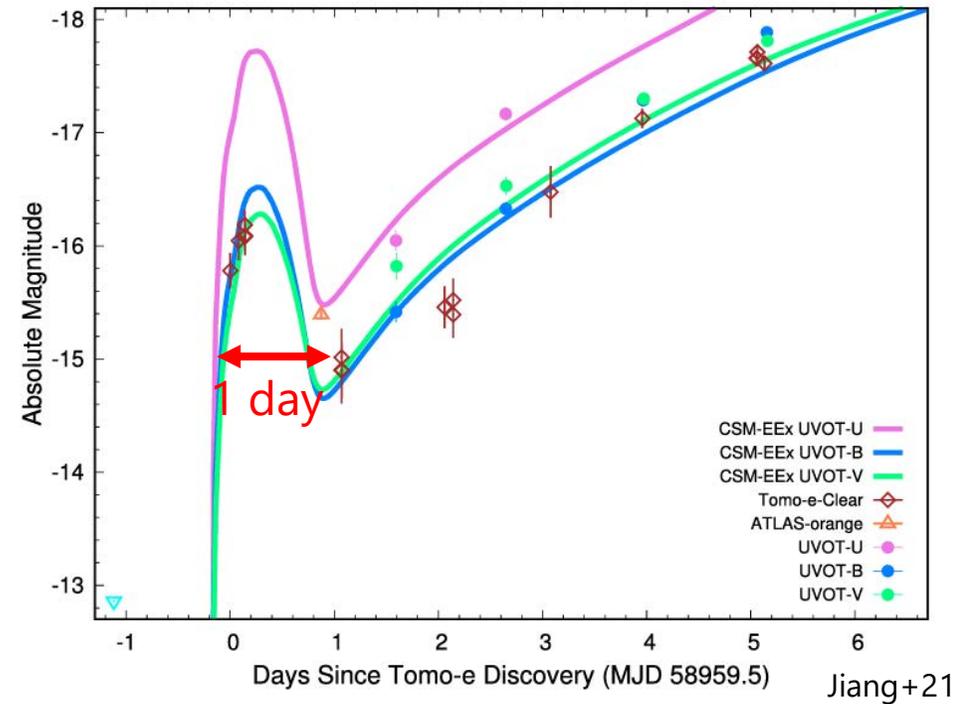
Koshi et al., in prep.

# 5.2 Necessity of continued search for early SNe

- Further efforts are expected to help discover more SNe in their early stages
  - Early spectroscopy of SNe II
    - ◆ <10 days after explosion → constraints to mass-loss history of progenitor
  - Early flux excess of SNe Ia
    - ◆ 2-5 days after explosion → constraints to Ni distribution, progenitor system, etc.
- Framework to realize rapid follow-up observations also needs to be established



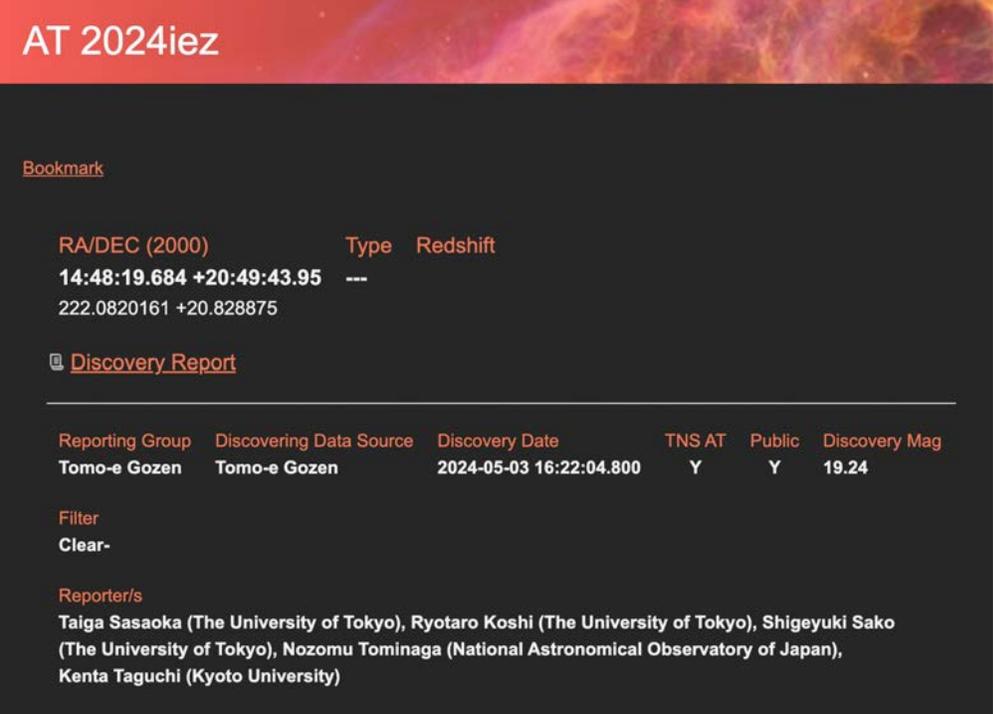
Early spectroscopy of SN 2013fs, a SN IIP



Early light curve of SN 2020hvf, a SN Ia with an early flux excess

# 5.3 Summary

- SN 2024acn is a Type II supernova that was found in its early phase by Tomo-e Gozen
- It has a SN IInP-like light curve
  - However, it also shows broad hydrogen lines (that may be seen in SNe IIP)
  - More observation is needed to discuss properties and progenitor candidates
- Observation with several telescopes enables obtainment of good data
- More SNe are expected to be found by Tomo-e
  - Follow-up with various telescopes will maximize the values of these discoveries



AT 2024iez

[Bookmark](#)

RA/DEC (2000) 14:48:19.684 +20:49:43.95 ---  
222.0820161 +20.828875

Type --- Redshift ---

[Discovery Report](#)

Reporting Group	Discovering Data Source	Discovery Date	TNS AT	Public	Discovery Mag
Tomo-e Gozen	Tomo-e Gozen	2024-05-03 16:22:04.800	Y	Y	19.24

Filter  
Clear-

Reporter/s  
Taiga Sasaoka (The University of Tokyo), Ryotaro Koshi (The University of Tokyo), Shigeyuki Sako (The University of Tokyo), Nozomu Tominaga (National Astronomical Observatory of Japan), Kenta Taguchi (Kyoto University)

Discovery report of AT 2024iez, a possible supernova detected on 5/3 (Sasaoka+24)