Observations of a Type II supernova interacting with circumstellar material:

SN 2024acn

Ryotaro Koshi

OISTER Workshop

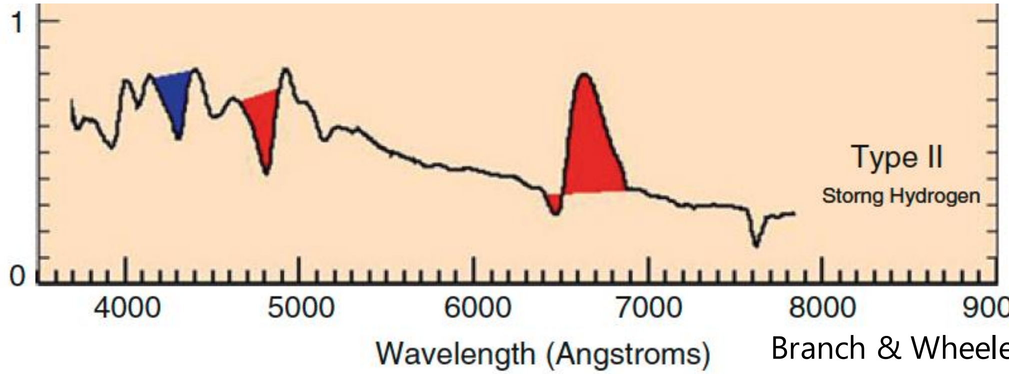
December 10th, 2024

0. Contents

1.1 Mass-loss of interacting SN progenitors

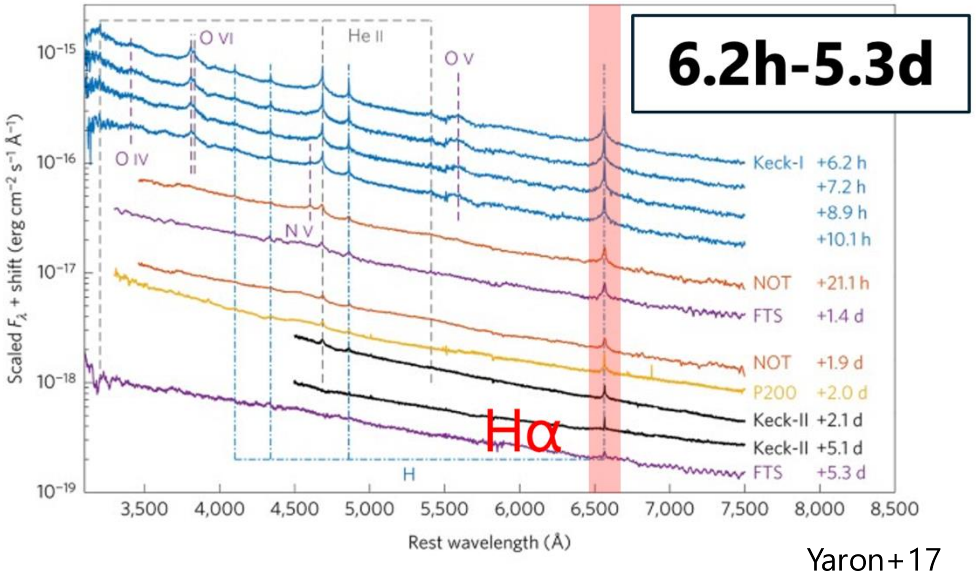
- **SNe II** are supernovae that occur from core-collapse of massive stars (>8M⊙)
  - ➢ Strong **hydrogen lines** in spectra (progenitor has a hydrogen envelope)

- Many SN II progenitors experience **intense mass-loss** just before explosion
  - ➢ Existence of CSM near the SN
  - ➢ A diversity of mass-loss rates within SNe II → more objects need to be investigated to understand this diversity!



Branch & Wheeler 17

A typical spectrum of SNe II



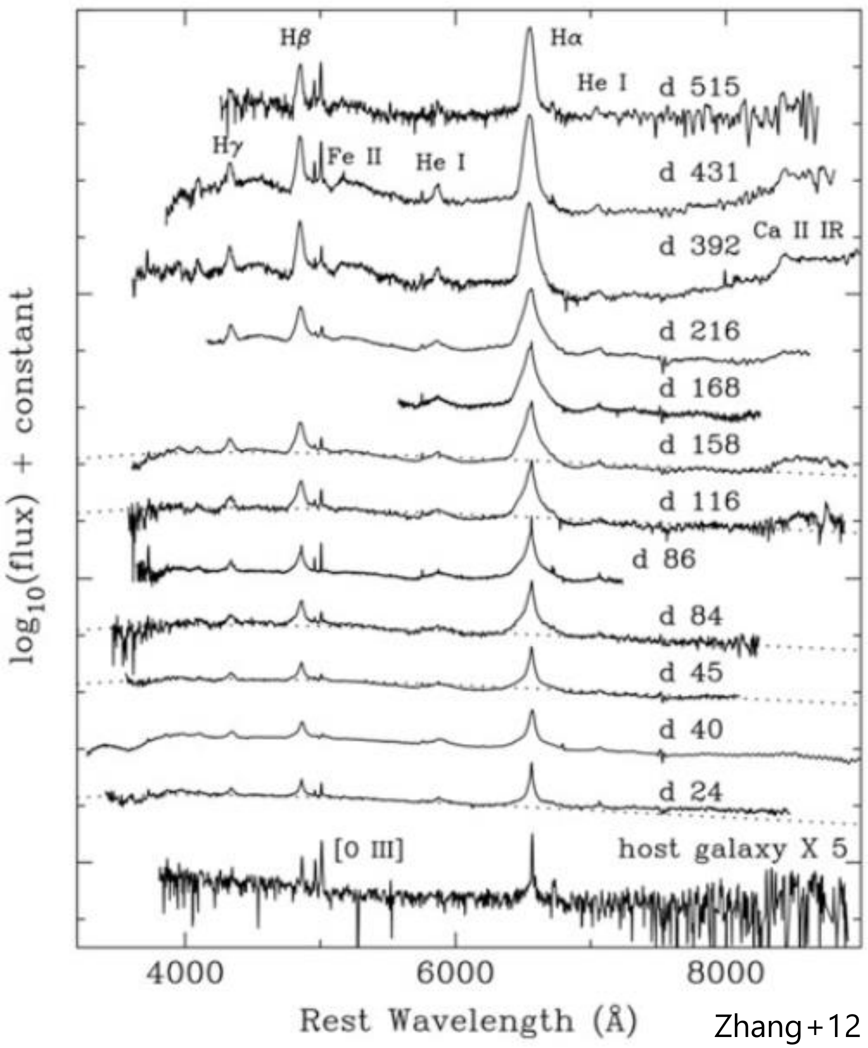
Yaron+17

Spectra of SN2013fs

1.1 Mass-loss of interacting SN progenitors

- The final stages of SN II(n) progenitors are unknown
  - Narrow emission lines imply intense mass-loss just before explosion (> $10^{-3} M_{solar}$/yr)
  - How can such a high mass-loss rate be achieved?

- More observations are necessary to grasp the nature of this phenomenon
  - Especially from an early phase
  - Progenitor properties can be inferred from signatures of CSM interaction



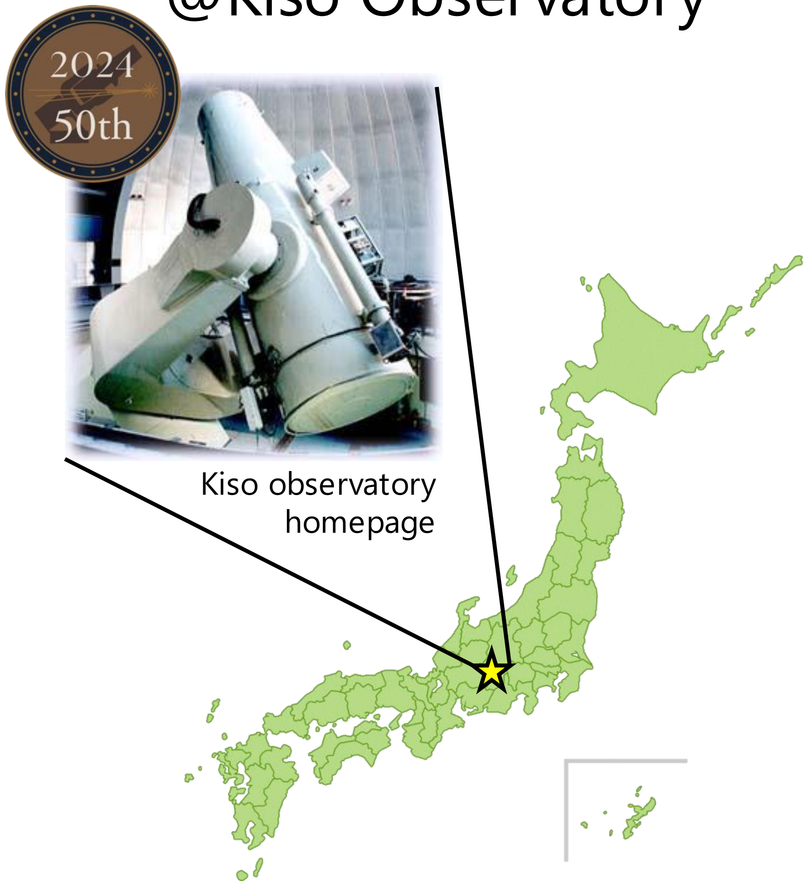
Zhang+12

Spectra of SN 2010jl (a SN IIn)

1.2 The Tomo-e Gozen camera

Telescope

1.05-m Schmidt telescope
@Kiso Observatory

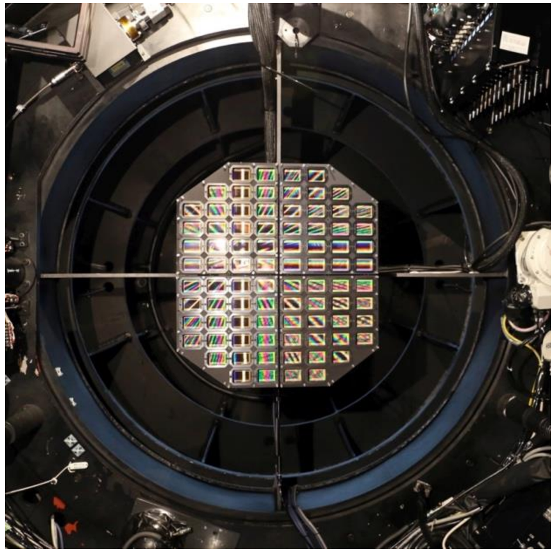


Kiso observatory homepage

Detector

Tomo-e Gozen camera

- **84** CMOS sensors



Tomo-e Gozen homepage

Instrument info

Field of view
20 square degrees

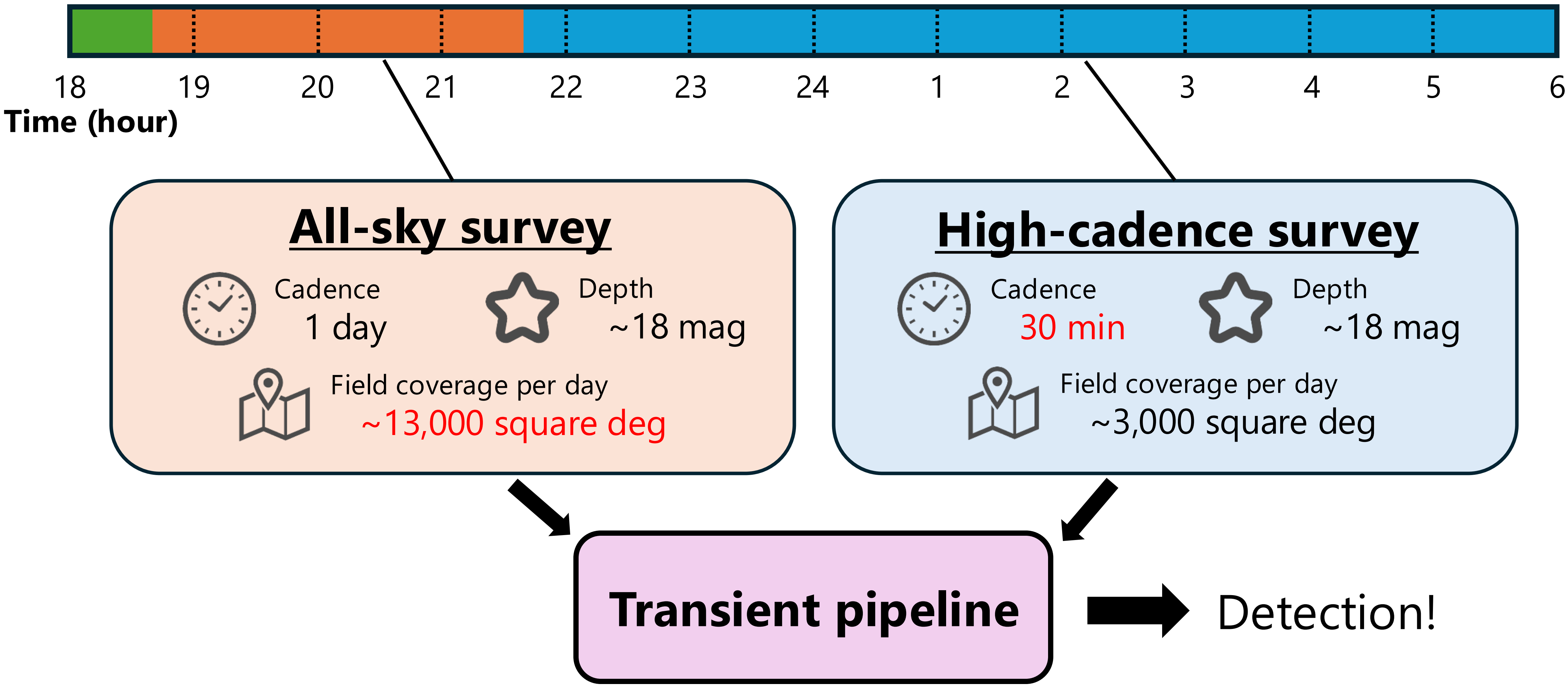
Imaging speed
2 frames per second

Data handling
30 TB per night

Filter
Clear (close to g-band)

1.3 Surveys conducted with Tomo-e Gozen

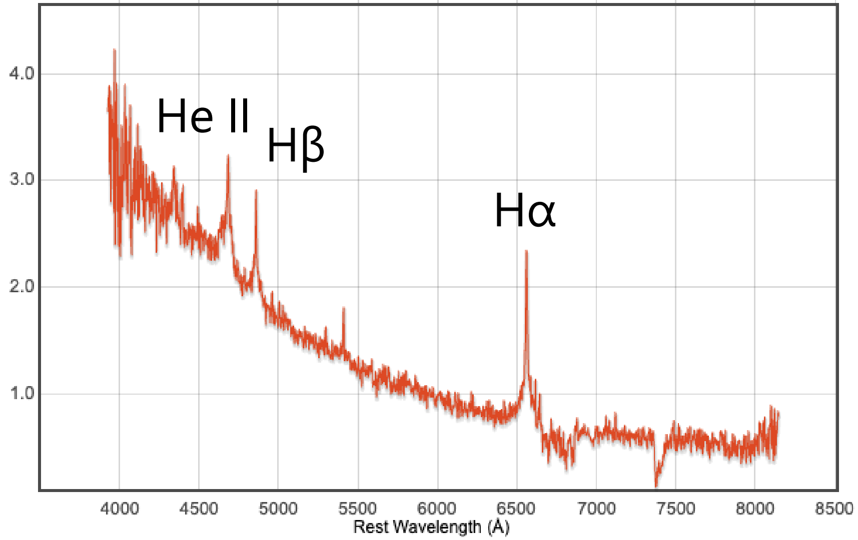
A typical observing schedule would look like…



2.1 SN 2024acn

- A Type II supernova
  - Narrow Hα line
  - A helium line was seen as well
- Discovered January 13, 2024
  - By the Tomo-e supernova team
  - 17.57 ± 0.11 mag
- Redshift z=0.031
  - Distance ~ 130 Mpc
- The host is a small, faint galaxy
  - SDSS J111040.54+210626.3
  - g = 19.49 ± 0.02 mag

An image taken with TriCCS (1/16)



The earliest spectrum by KOOLS-IFU (1/15)

2.2 Light curves

- We obtained optical and NIR light curves
  - MITSuME @Akeno (g’RI)
  - WFGS2 @Nayuta (BVRI)
  - HONIR @Kanata (JHKs)
  - TriCCS @Seimei (gri) -> to be added…
  - HOWPol @Kanata (BVRI) -> to be added…

- Peak properties
  - Rise time ~ 10-30 days
  - Peak magnitude ~ -19.5 mag

- Post-peak properties
  - A gradual decline in optical (~0.01 mag/day)
  - Possible rebrightening in Ks-band?

Koshi et al., in prep.

2.3 Spectra

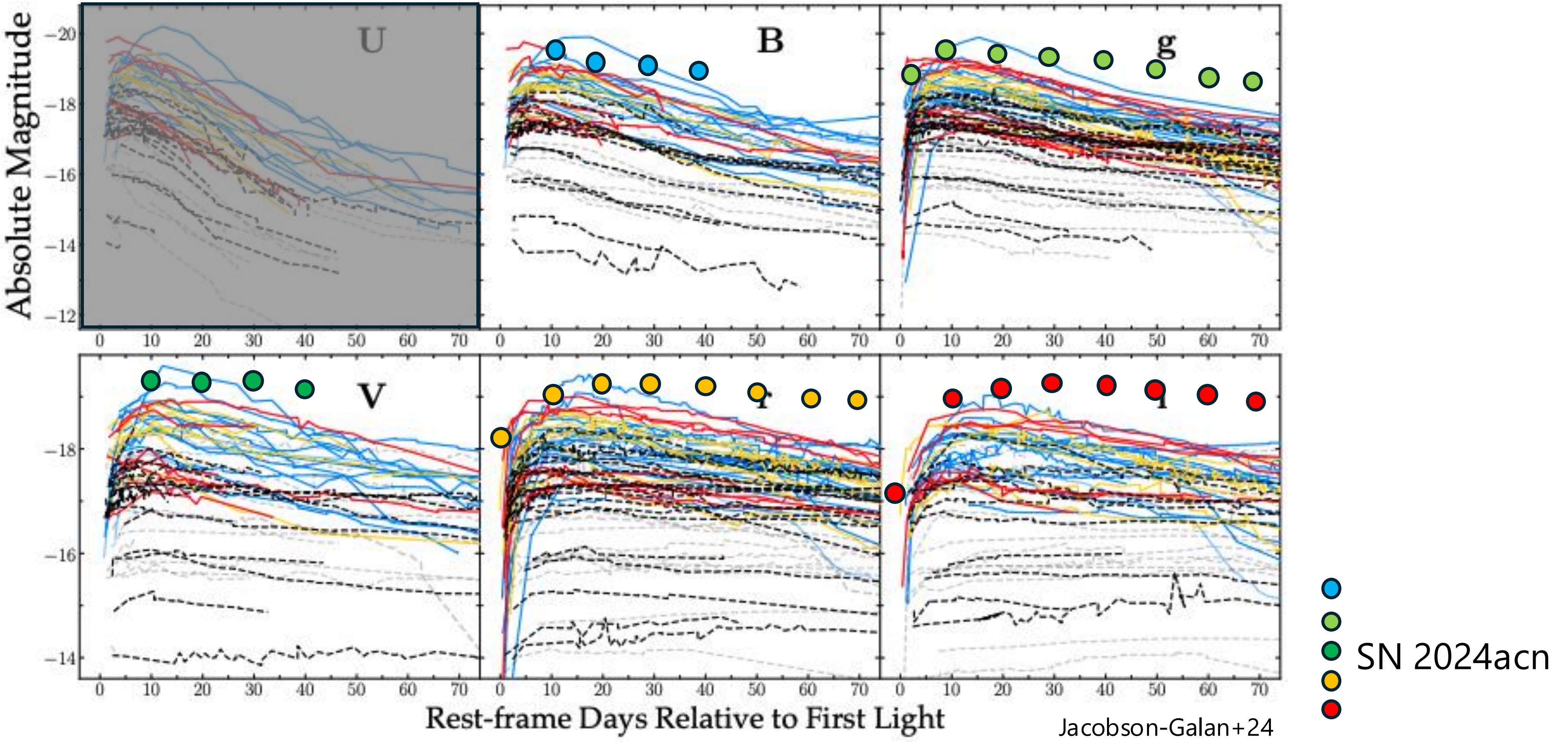
- We have obtained 18 optical spectra
  - KOOLS-IFU @Seimei
  - HFOSC @Himalaya Chandra Telescope

- Change in Hα and Hβ profiles
  - <34d: narrow, symmetric
  - >50d: broad, asymmetric

Koshi et al., in prep.

3.1 Comparison with other CSM-interacting SNe

- Photometric evolution of 24acn is “slow” -> consistent with SNe IIn



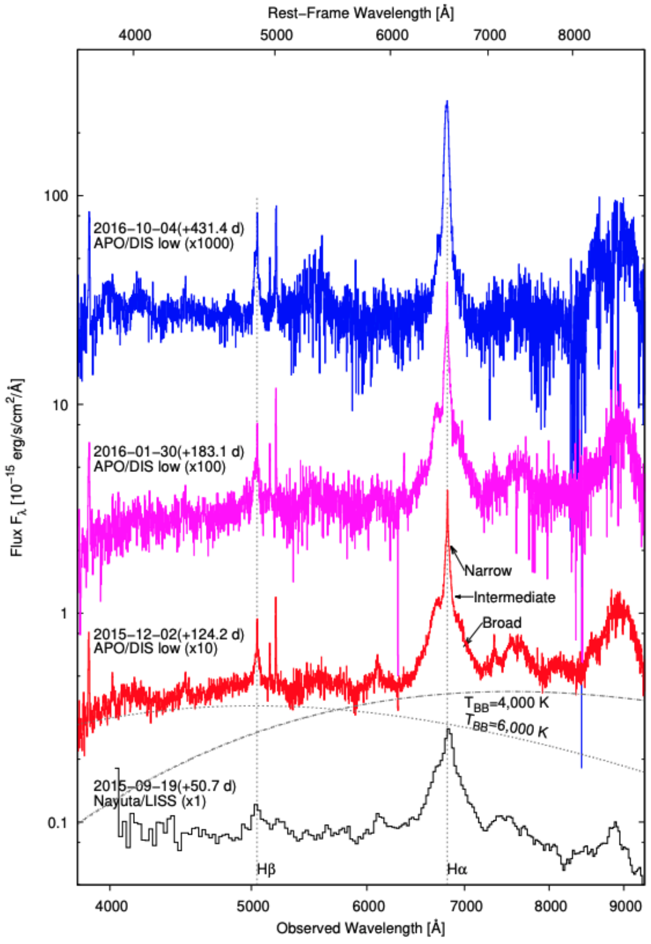
Absolute light curves of CSM-interacting SNe II (NOT SNe IIn)

3.2 An asymmetric Hα profile

- The Hα line of SN 2024acn has an asymmetric profile

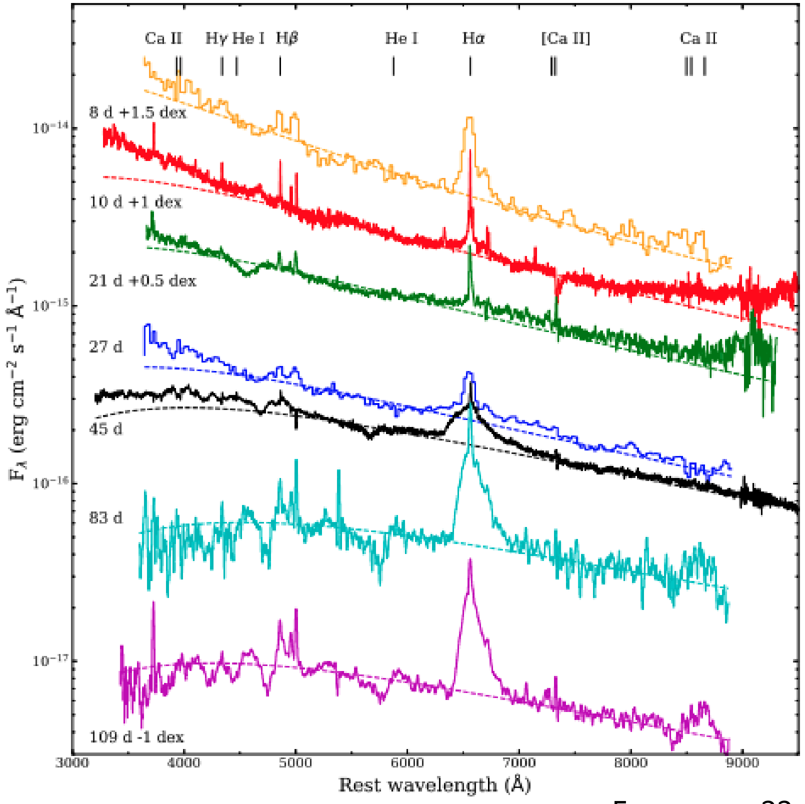
Koshi et al., in prep.

KISS15s



Kokubo+19

SN 2019zrk



Fransson+22

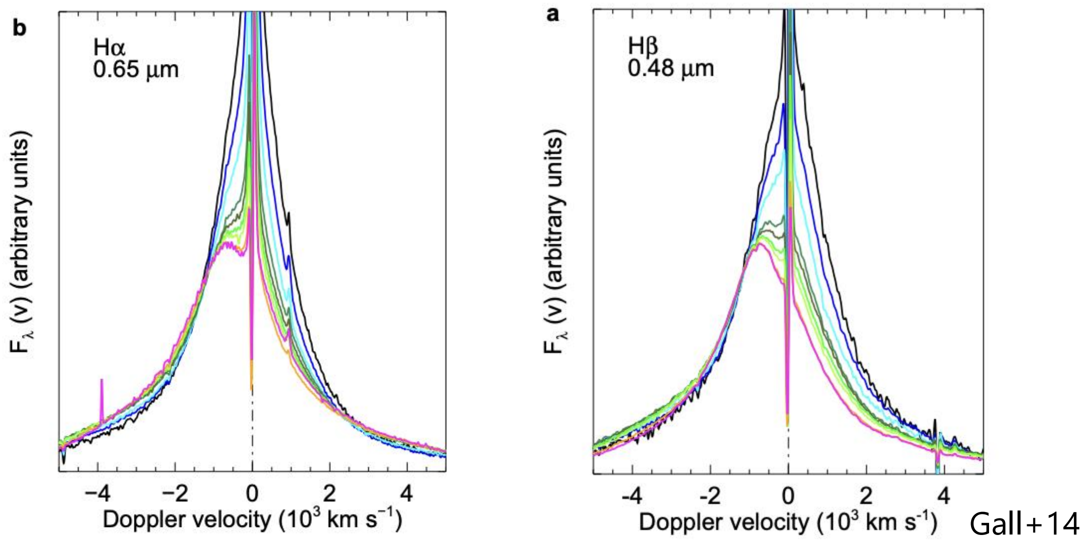
3.2 Asymmetric Hα line profiles

- Where does the blueshifted component come from?

1. Attenuation by dust

e.g. Gall et al. (2014)

The blueshifted line is a result of dust **off the line of sight** of the observer

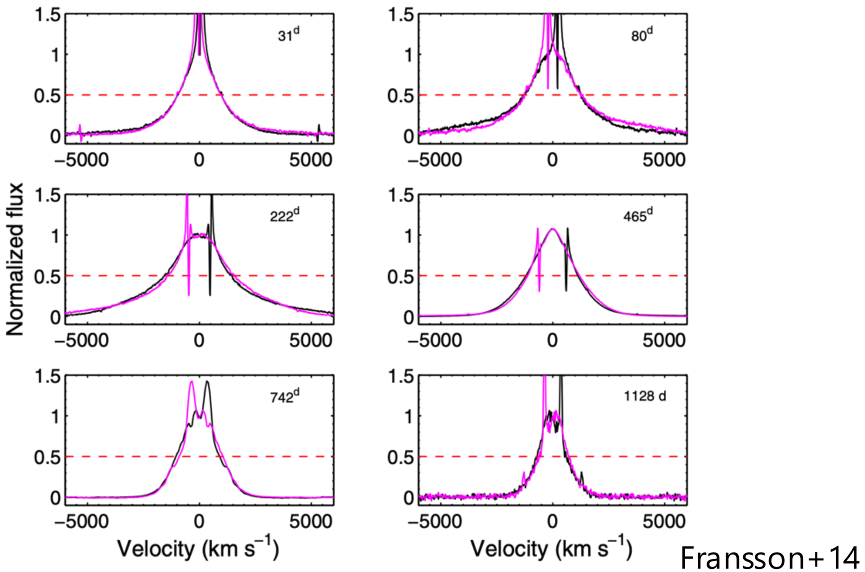


Temporal evolution of the Hα and Hβ profiles of SN 2010jl

2. Asymmetry of the CSM

e.g. Fransson et al. (2014)

The blueshifted line is a result of **a bulk of matter moving towards** the observer



Shifted (black) and reflected (pink) Hα profiles of SN 2010jl

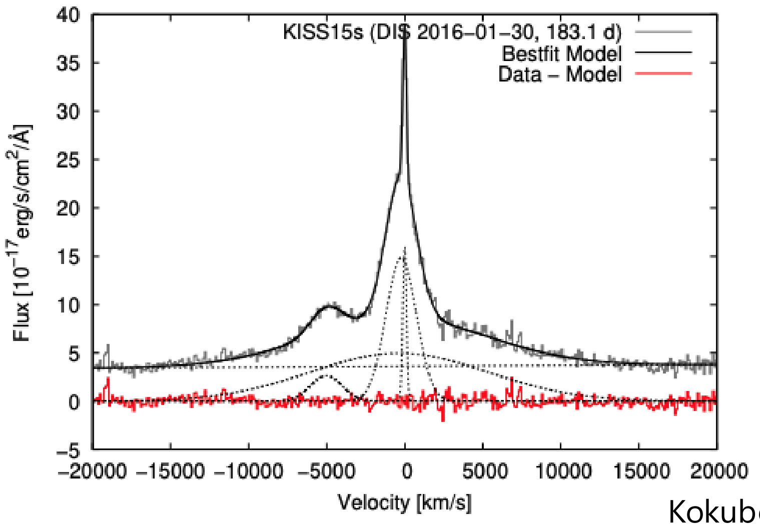
3.2 Asymmetric Hα line profiles

- Where does the blueshifted component come from?

<u>3. A mixture of dust and asymmetric CSM</u>

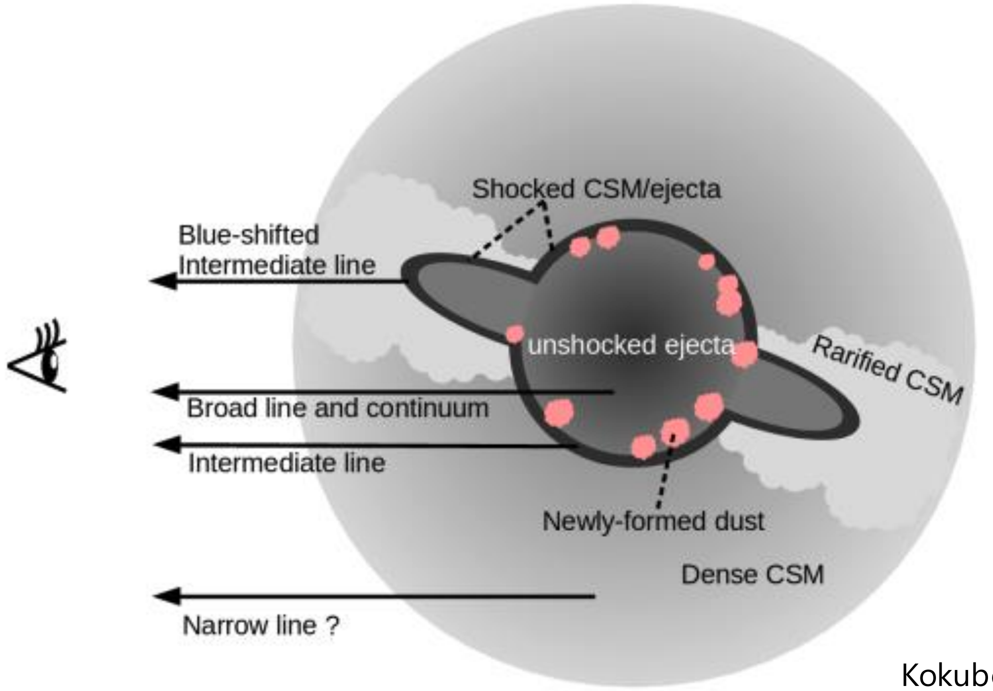
e.g. Kokubo et al. (2019)

The blueshifted line reflects matter passing a region of rarified CSM



Kokubo+19

A breakdown of the Hα profile



Kokubo+19

A physical interpretation of KISS15s

3.3 Decomposing the Hα profile

- We took a spectrum and decomposed its Hα profile in three ways
  1. A subtraction between two components
     - Dust attenuation
  2. A single blueshifted component
     - A single bulk of matter moving towards the observer
  3. A sum of two components
     - Different components coming from different regions

Koshi et al., in prep.

3.3 Decomposing the Hα profile

- The **two-component function** and the **subtracted function** are relatively well fit to the data
  - Two-component function -> The peak
  - Subtracted function -> A small bump at v~3500 km/s
- The small bump is only clearly seen at this epoch

Koshi et al., in prep.

3.3 Decomposing the Hα profile

- The **two-component function** and the **subtracted function** are relatively well fit to the data
  - Two-component function -> The peak
  - Subtracted function -> A small bump at v~3500 km/s
- The small bump is only clearly seen at this epoch

Koshi et al., in prep.

3.3 Decomposing the Hα profile

- The blueshifted component appears from 50d

Koshi et al., in prep.

3.3 Decomposing the Hα profile

- Velocity shift of the blueshifted component changes with time
  - -4200→-3500 km/s: deceleration of the matter emitting the component
- Velocity width declines for both components
- Amplitude ratio of the two components remains roughly constant
  - Originating from the same emission mechanism

Koshi et al., in prep.

3.4 Application to the Hβ profile

- The model fit to the Hα line can roughly reproduce the Hβ line
  - ➢ A possible discrepancy blueward of the profile (P-Cygni profile?)

Koshi et al., in prep.

3.5 Investigating dust formation

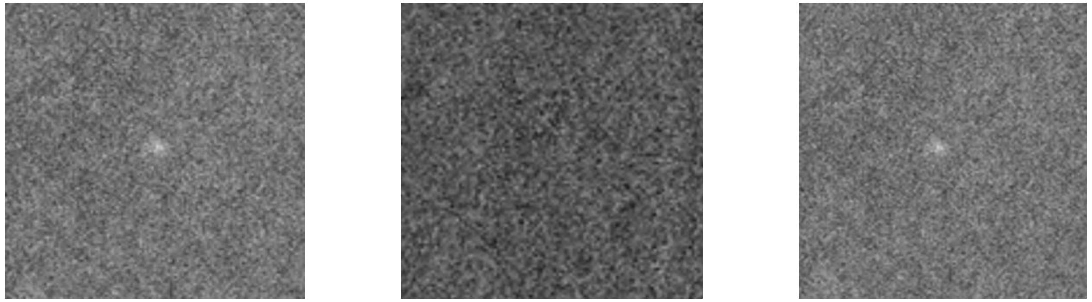
- NIR photometry (from HONIR) supports the existence of dust
  - ➢ A single blackbody cannot explain the optical + NIR magnitudes

Koshi et al., in prep.

4.1 Next steps

Observation

- Can brightening in the NIR be confirmed?
- Optical follow-up may be difficult…
  - ➢ Current photometry is consistent with the host galaxy



g r i

Images with TriCCS on 11/13

Spectral evolution

- Comparison of the Hα and Hβ line (in progress)
- Examination of the helium lines
  - ➢ Late-phase He I: P-Cygni
  - ➢ Early-phase He II: asymmetric

Koshi et al., in prep.

4.2 Conclusions

- SN 2024acn is a SN IIn that is characterized by…
  - A **slowly** evolving light curve
  - **Asymmetry** in the late phase Hα (and Hβ) profile

- This would imply that…
  - The progenitor of 24acn experienced severe mass-loss, longer than most SNe
  - Different components are thought to originate from different regions

- More transients are expected to be discovered by Tomo-e Gozen
  - Observations with OISTER will maximize the values of these discoveries!