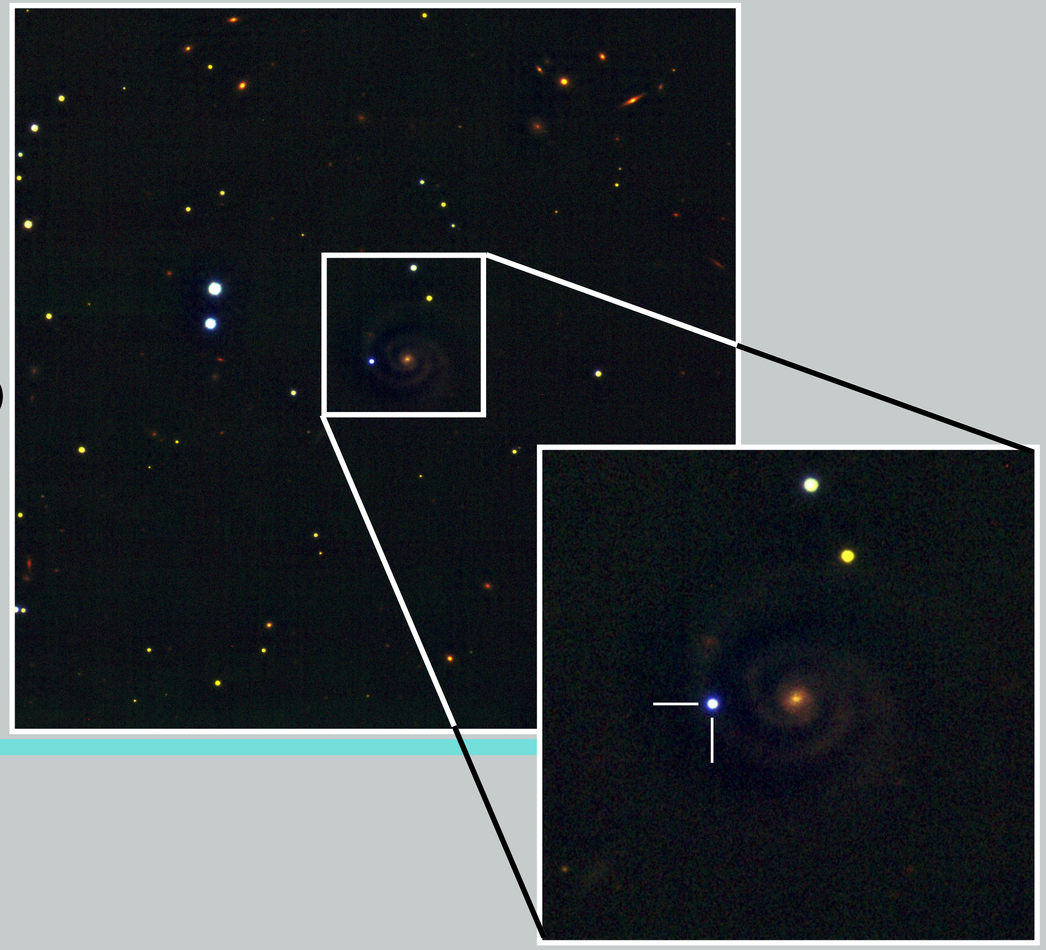
2021年度せいめいユーザーズミーティング

測光・分光・偏光観測で探る Ia-CSM型超新星 SN 2020uemのCSM構造



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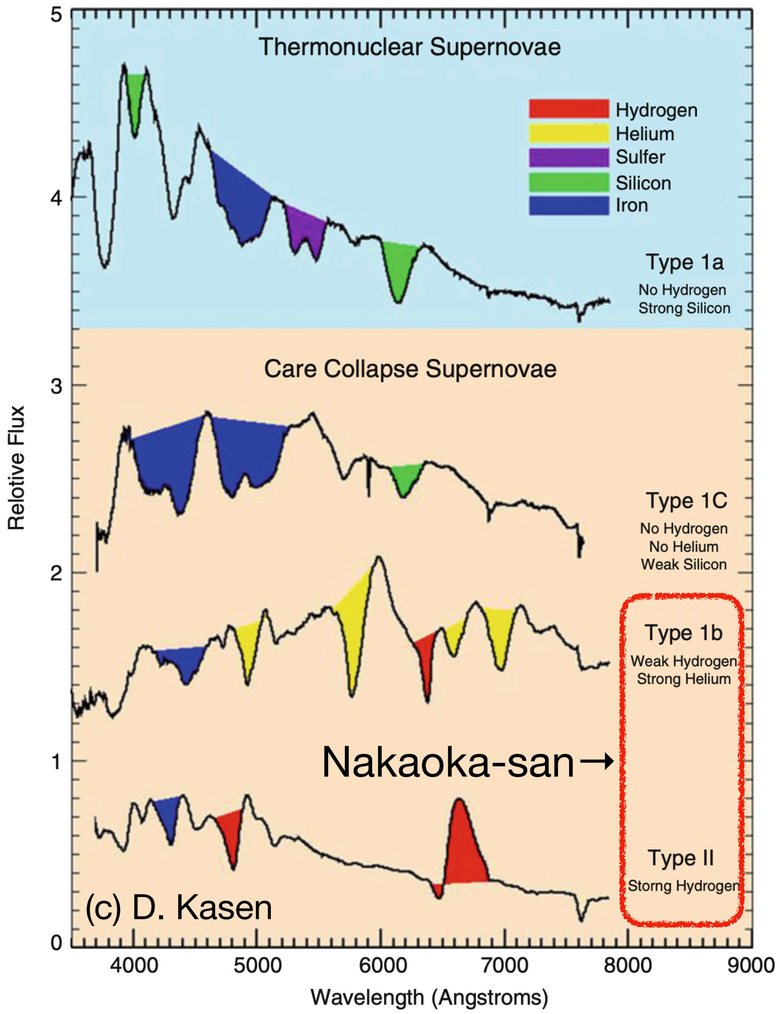
Introduction: Type Ia Supernovae

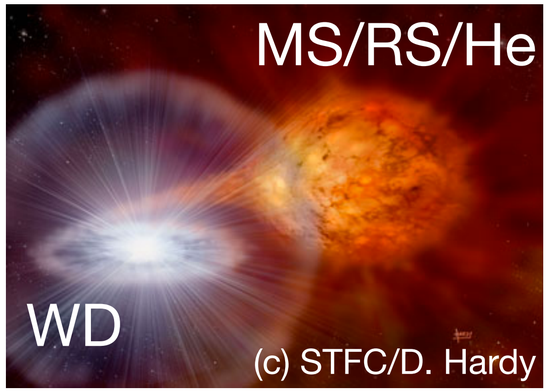
Type Ia Supernovae (SN Ia): Thermonuclear explosion of white dwarf(s), but …

Classification

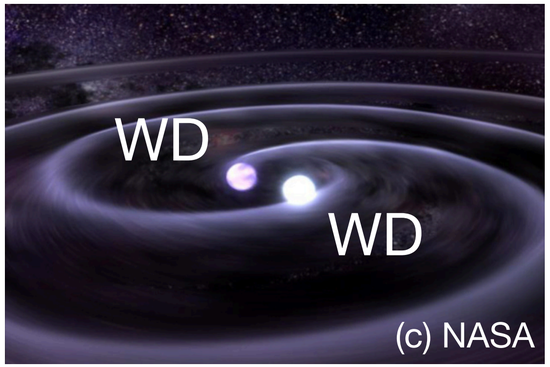


Progenitor System

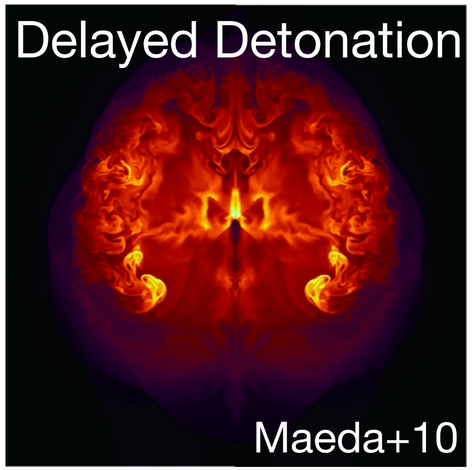
Single Degenerate (SD)

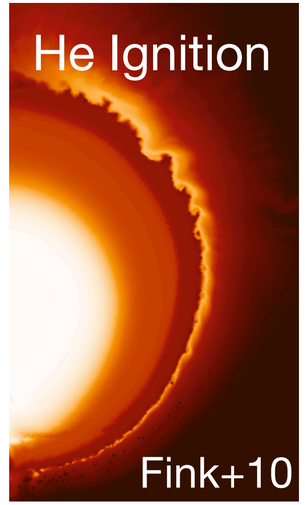


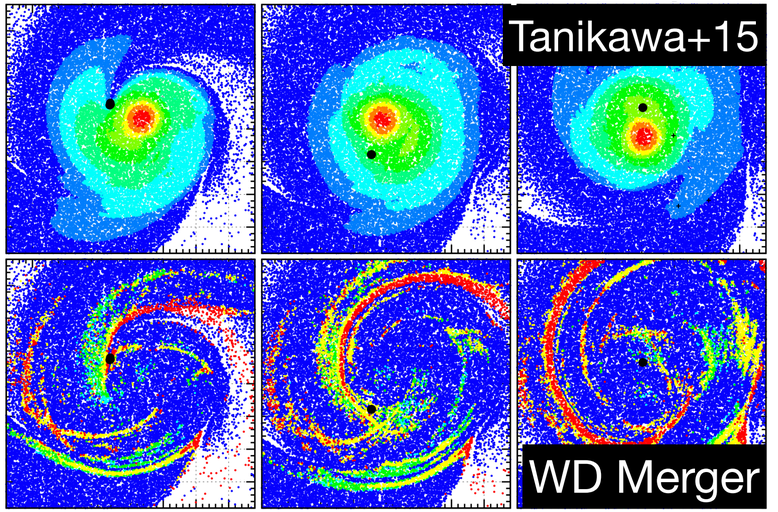
Double Degenerate (DD)



Explosion Mechanism







Introduction: Type Ia Diversity

SN Ia: Standard Candles, but…

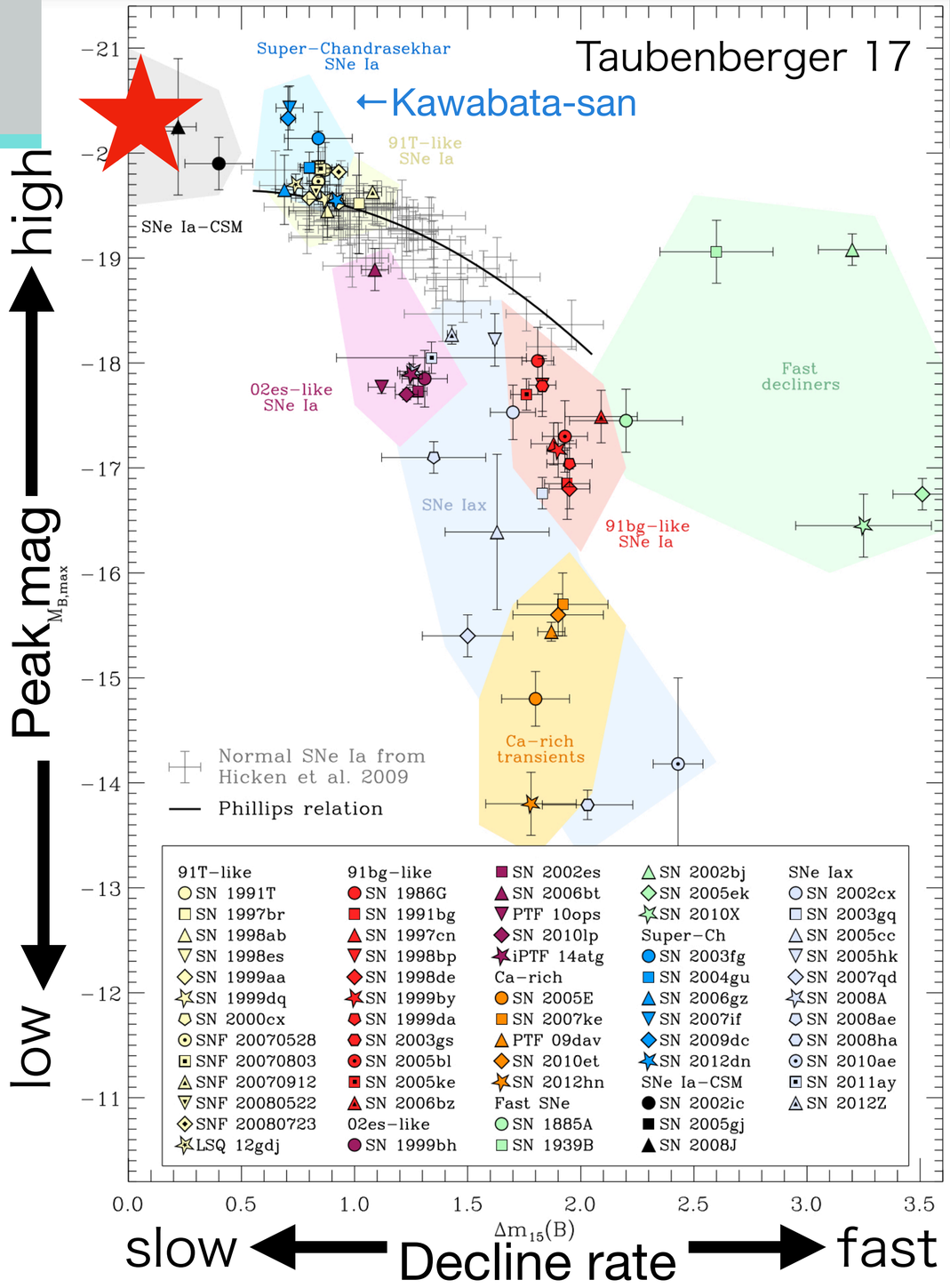
New generation surveys

ASAS-SN, Pan-STARRS, TOMO-E GOZEN, atlas, ZTF

Much more diversity than expected !

- Too much diversity indicates different progenitor & explosion mechanism.
- New insight for Stellar Evolution

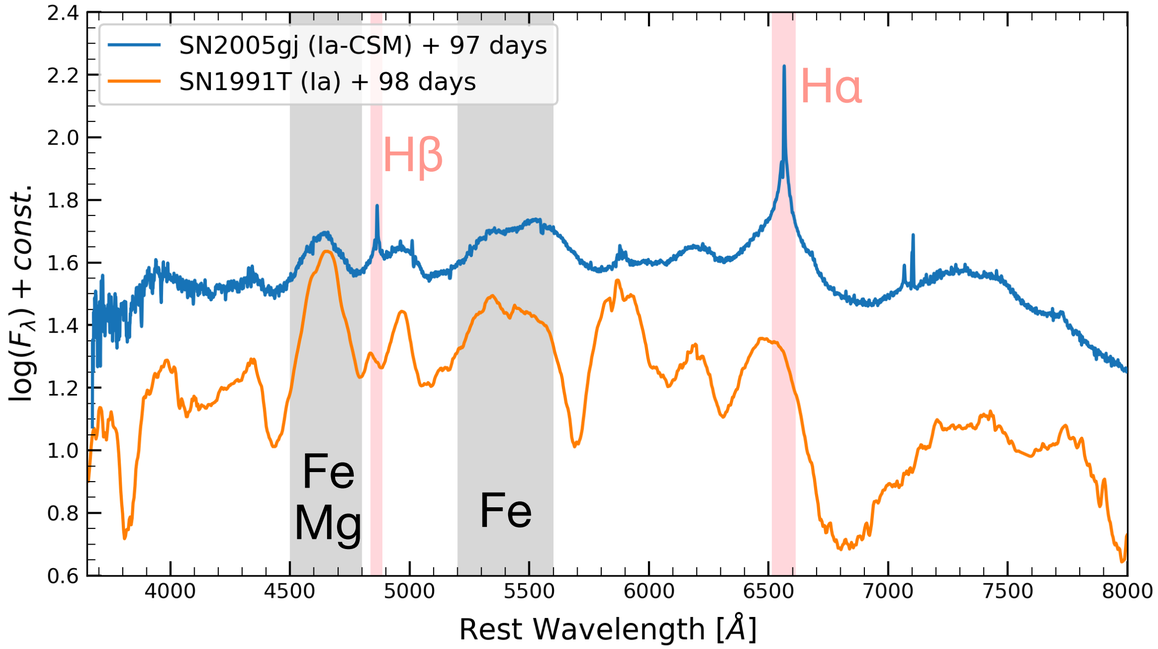
SN 2020uem is one of the peculiar SN Ia.

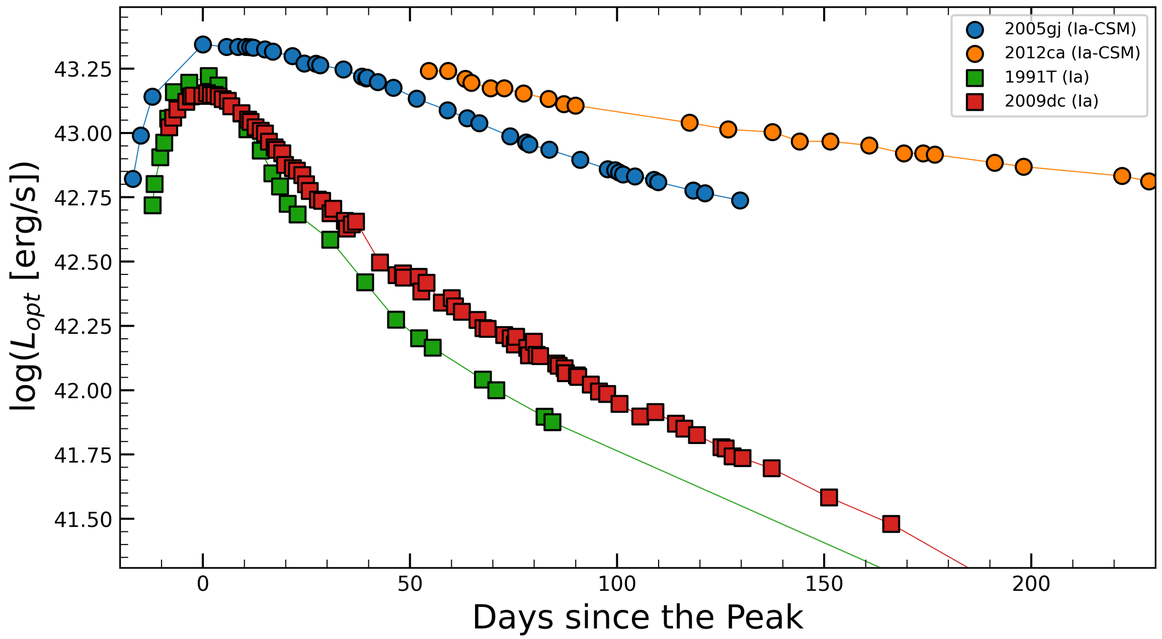


Introduction: Type Ia-CSM Supernovae

Type Ia-CSM Supernovae (or SN 2002ic-like transients)

- spectrum: high temperature Ia (like 1991T) + **narrow H emission lines** (c.f, Type IIn SNe)
- high and long-lasting luminosity (> 100 days)



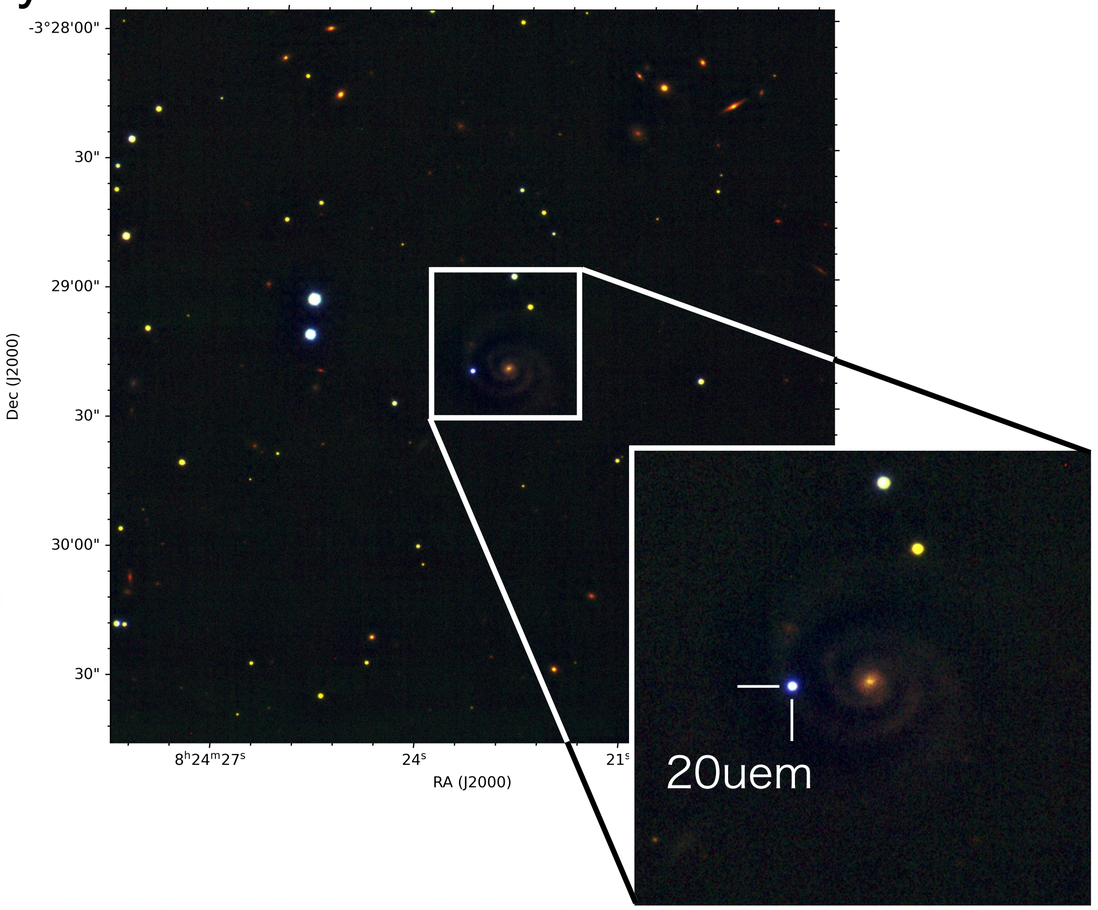


Interaction between energetic Ia and dense circumstellar matter (CSM)

➡ **Where did such a dense CSM come from ?**

Type Ia-CSM Supernova: SN 2020uem

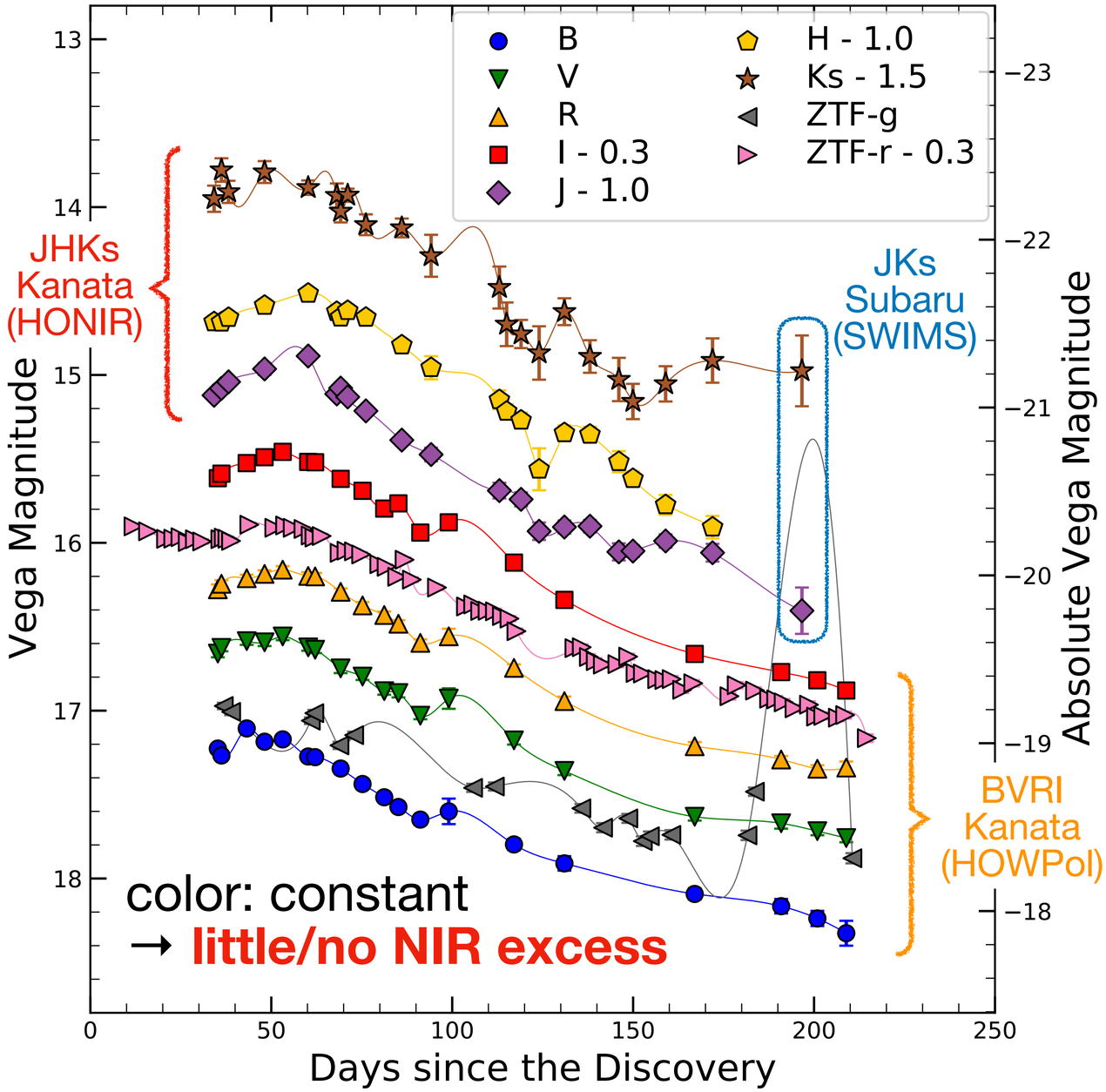
- Discovery: 16.5 mag on 2020-09-22 (MJD 59114.6) by ATLAS
- Coordinate: RA = $08^h24^m23.85^s$, Dec=-3°29′19.1″
- Distance: d_L = 173.3 Mpc (z = 0.041)
- Follow UP observation
  - Photometry: Kanata 19/21 nignts (HOWpol/HONIR)
    Subaru 1 nights (SWIMS)
  - Spectroscopy: Seimei 8 nights (VPH-blue & VPH-683)
    Subaru 3 nights (FOCAS, HDS & SWIMS)
  - Polarimetry: Subaru 1 nights (FOCAS)
    Tohoku T60 1 nights (Dipol-2)

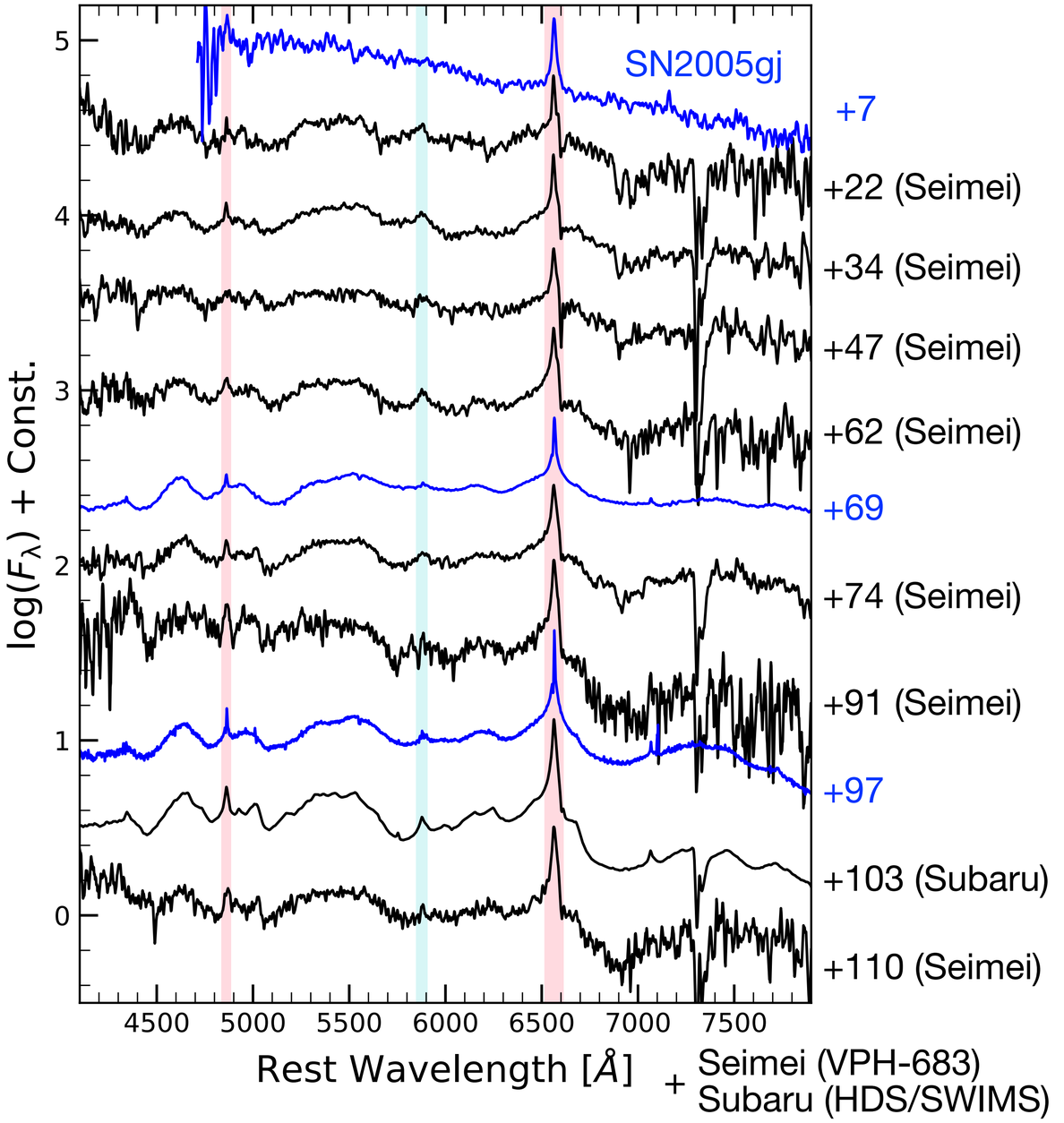


What Can We Discuss？

Light Curve Evolution, Mass-Loss History, **Spectral Evolution**, Asymmetric Hα profile, Comparison & Classification with Other SNe, Dust Mass Estimation, NIR Echo Estimation, Evolution of Polarization Degree, **CSM Geometry**, Progenitor System, Explosion Mechanism…

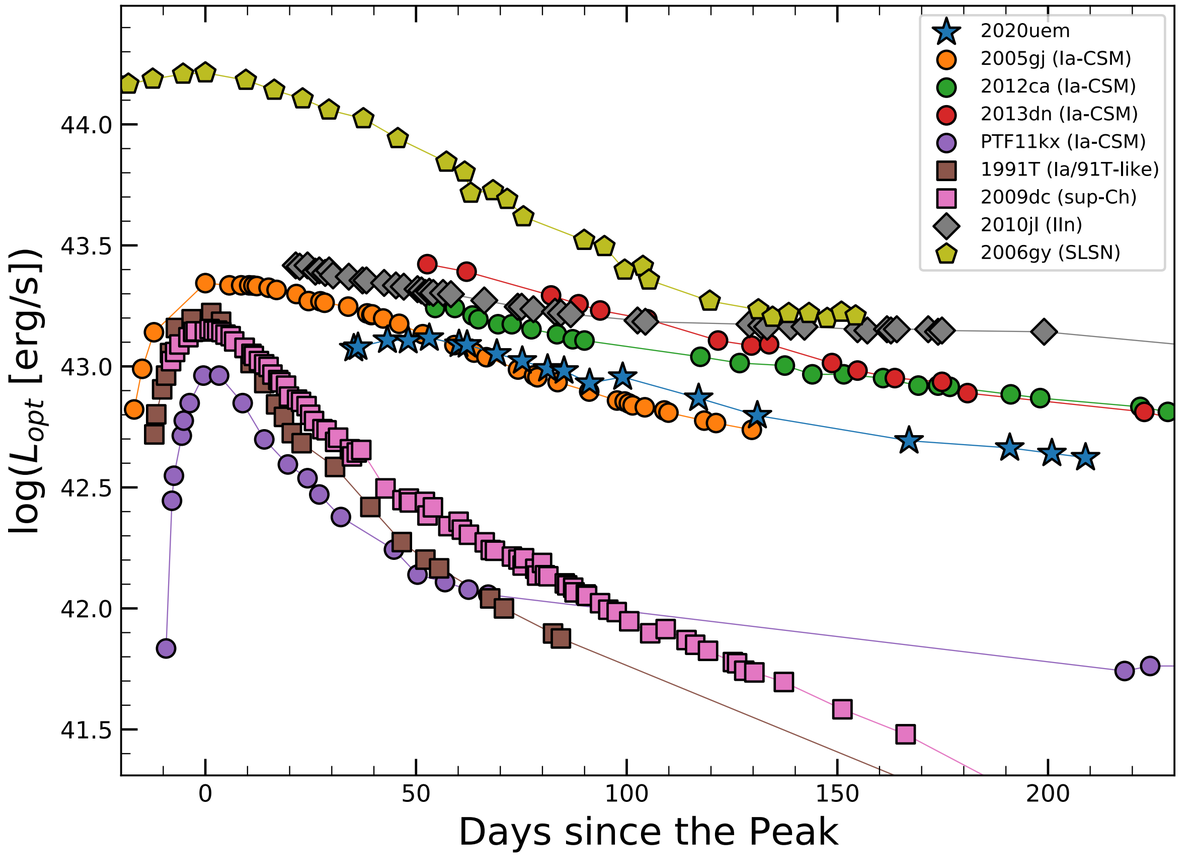
Results: Seimei, Kanata & Subaru Observation





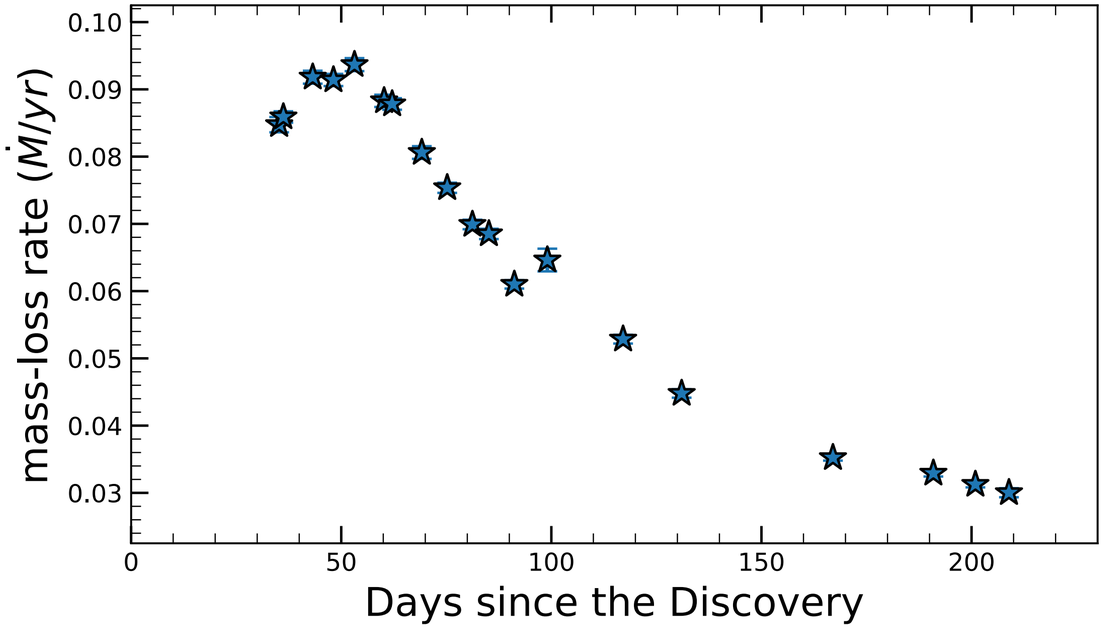
Results: Bolometric Luminosity & Mass-Loss Rate

Integrate BVRI flux to bolometric luminosity



L_{opt} ~10^{43} [erg/s]

→ consistent with other Ia-CSM/IIn SNe



Mass-Loss Rate ($\dot{M}$)

$$\dot{M} \approx 0.09 \left(\frac{\epsilon}{0.3}\right)^{-1} \left(\frac{L}{10^{43}\ \mathrm{erg\ s^{-1}}}\right) \times \left(\frac{V_{\mathrm{shock}}}{5000\ \mathrm{km\ s^{-1}}}\right)^{-3} \left(\frac{V_{\mathrm{wind}}}{100\ \mathrm{km\ s^{-1}}}\right) M_{\odot}\mathrm{yr}^{-1}$$

(Moriya+13)

→ consistent with typical $\dot{M}$ of SN IIn

M_{CSM} ~ **a few** $M_{\odot}$

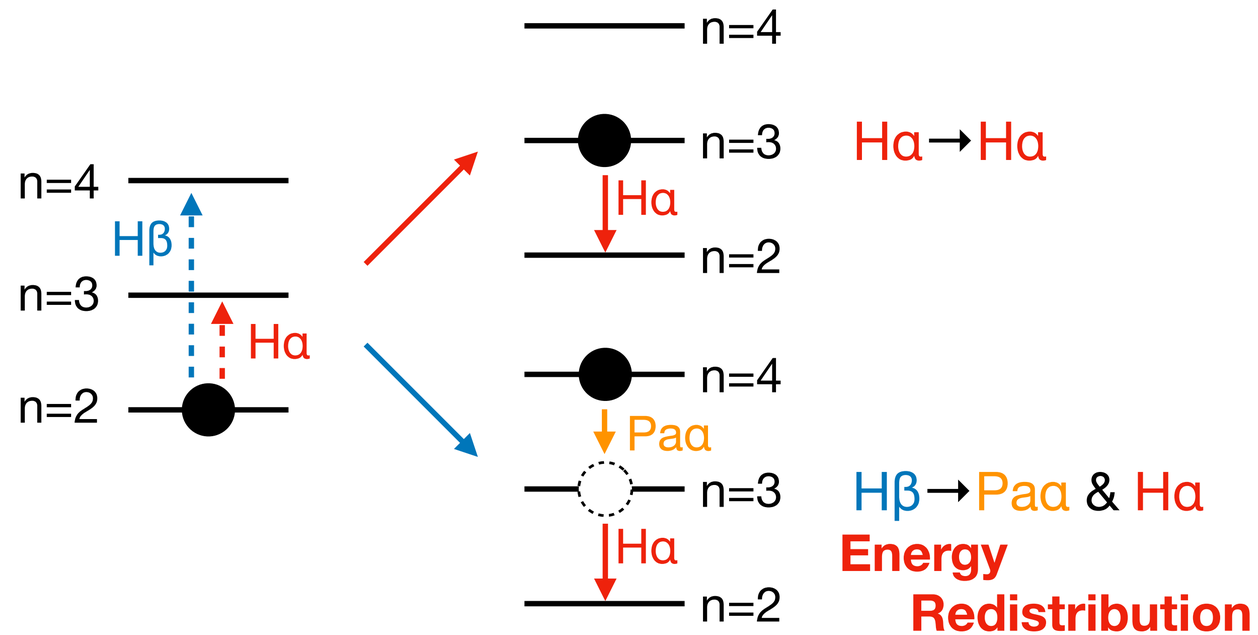
Results: Flux Ratio of Balmer Lines

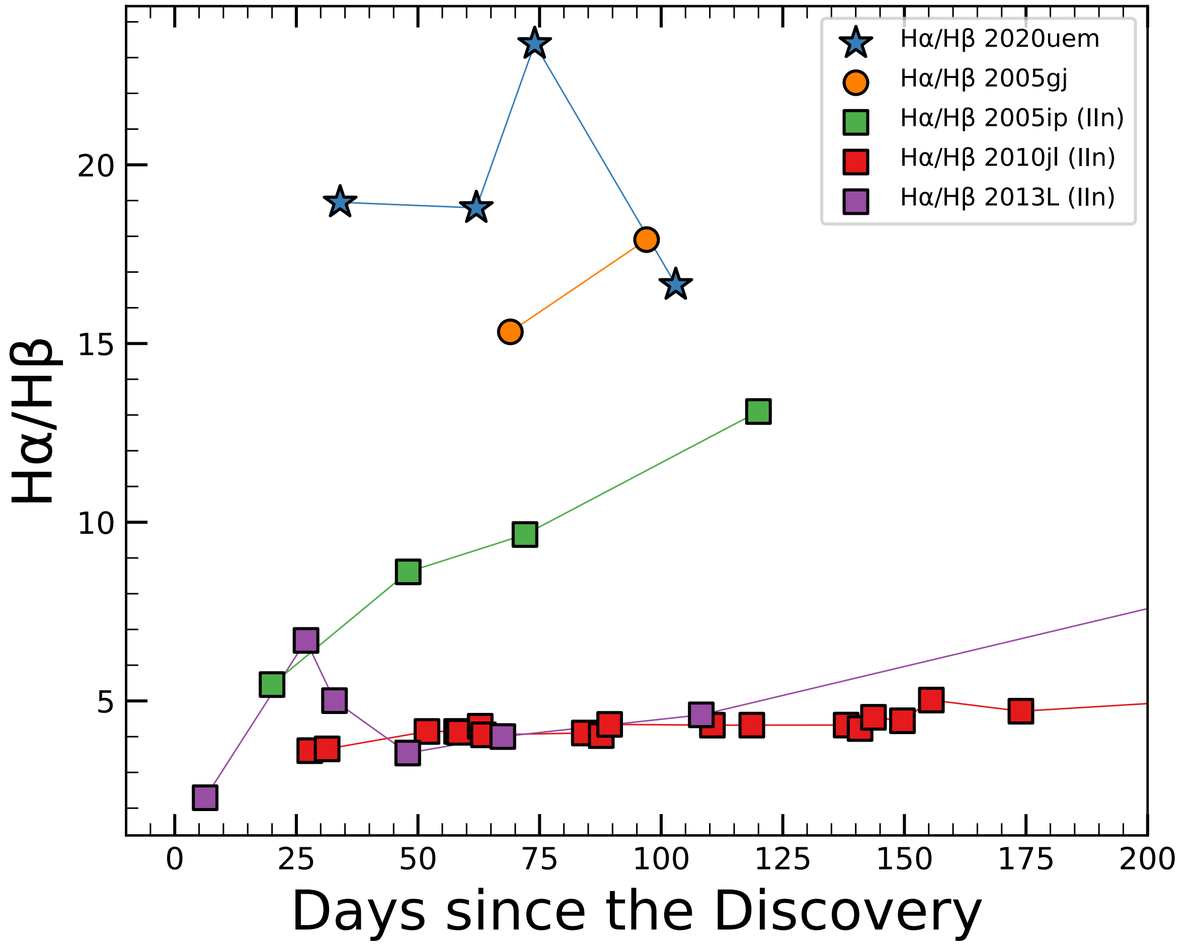
Line Flux Ratio (Hα/Hβ)

→ Indication for the CSM density (c.f., **Balmer Decrement**)

- Type IIn SNe → Ratio ~ 3
- Type Ia-CSM SNe → **Ratio > 10**

@ High Density (↔ Optically Thick)





→ **Ia-CSM is more dense than IIn.**

Results: Subaru (FOCAS) Spectropolarimetry

Date: 2021-01-02 (+103 days)

Interstellar Polarization (ISP)

$$P_{\rm ISP}(\lambda) = P_{\rm max} \exp\left[-K \ln^2\left(\lambda_{\rm max}/\lambda\right)\right]$$ (Serkowski+1975)

$$K = 0.01 + 1.66\lambda_{\rm max}\ (\mu{\rm m})$$ (Whittet+1992)

→ $P_{\rm ISP} \sim 0.7\,\%$

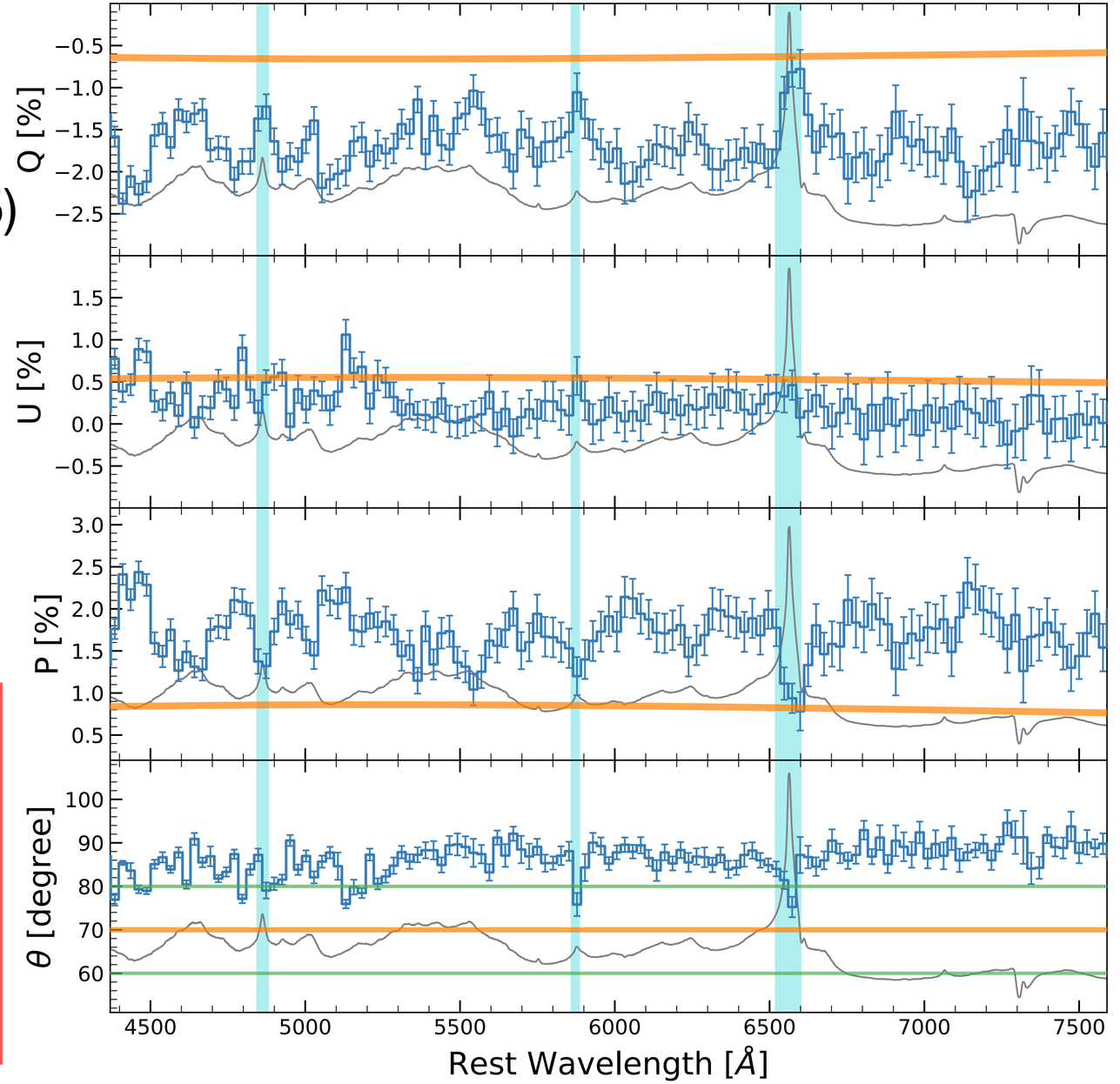
Polarization Degree:

- $P_{\rm SN} \sim 1.0 - 1.5\,\%$ (c.f., SN2002ic: $P_{\rm SN} \sim 0.8\,\%$ Wang+2004)
- No wavelength dependence

➡

(1) **electron scattering is dominant.**
- highly dense CSM
- CSM geometry: disk/clump/jet ?

(2) **no dust echo**
- little/no dust



Discussion: How Asymmetric Is The CSM?

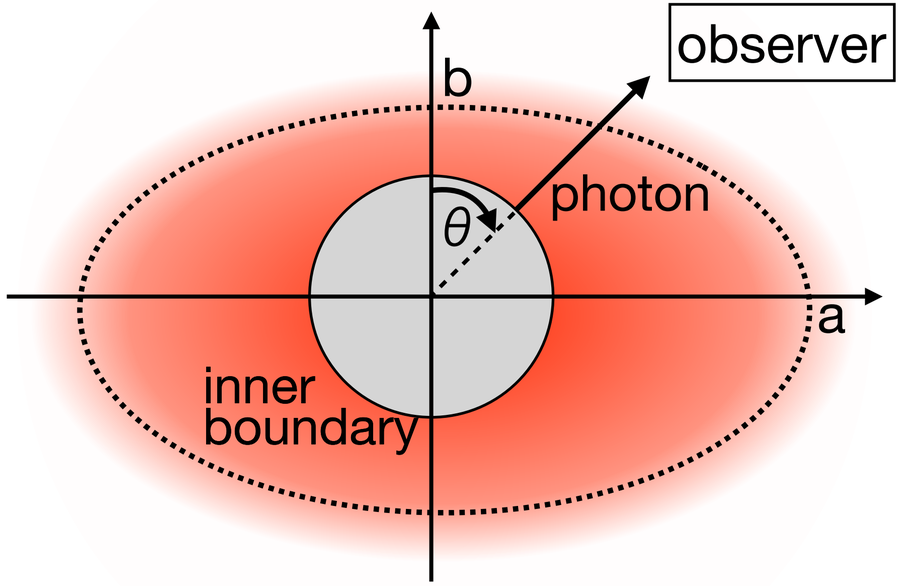
$P_{\rm SN} \sim 1.0 - 1.5\,\%$

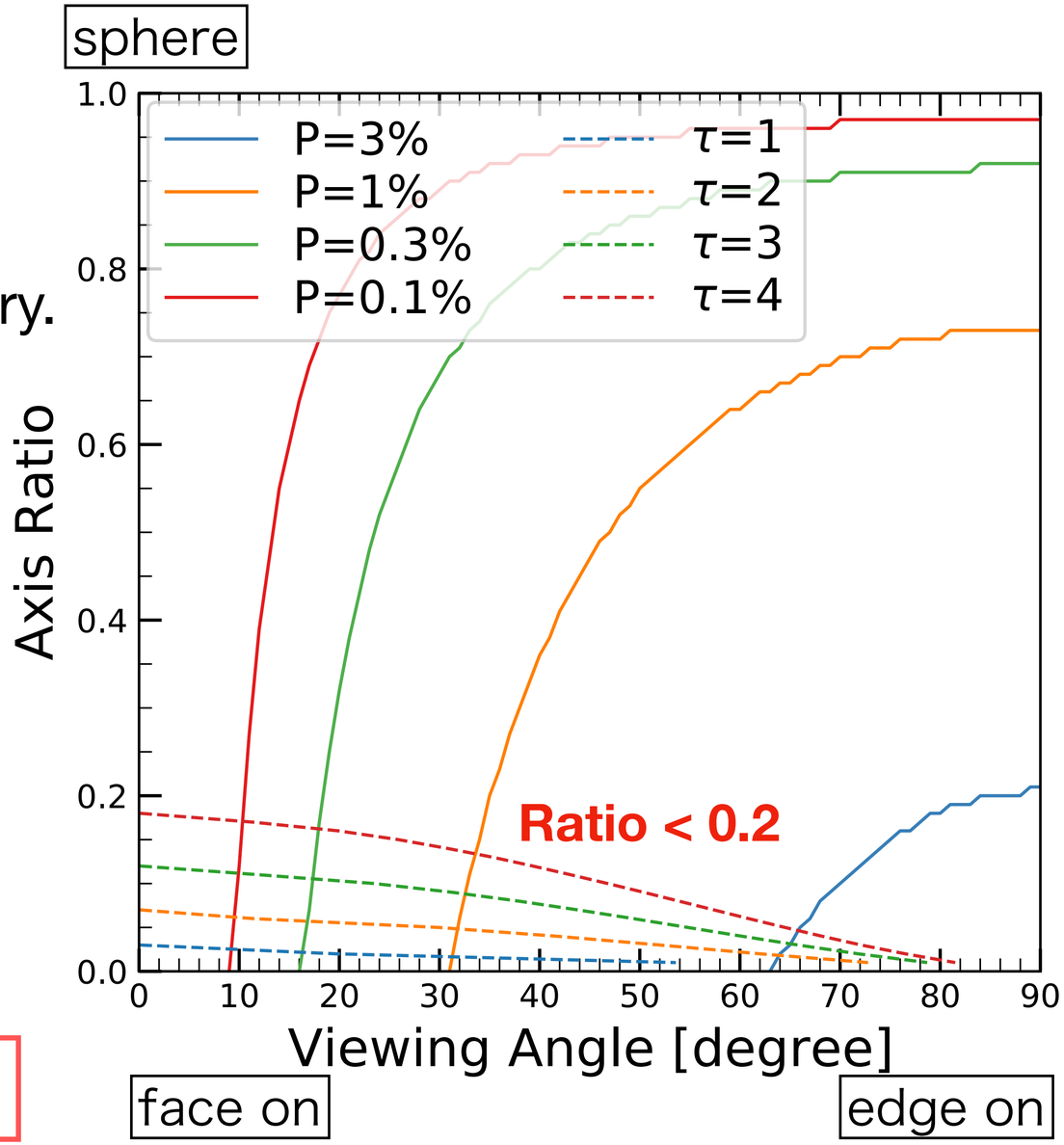
→ Indication for **asymmetric CSM geometry**

- **'Elliptical' CSM** (c.f., Hoflich 91)

(1) Photons are emitted from spherical inner boundary.

(2) Polarization in the elliptical CSM (axis ratio = b/a)





Extremely Flat CSM → Disk-Like CSM ?

Discussion: CSM Geometry of SN 2020uem

(1) Ia component at early phase

optical depth in the line of sight < 1

→ $\tau(10^{16}\ \mathrm{cm}) \approx 1$ v.s. $R_{\mathrm{ph}} \sim 10^{15}\ \mathrm{cm}$

→ **Aspherical CSM Geometry**

(2) Balmer line ratio > 10

more dense CSM than Type IIn SNe

→ $\dot{M}_{\mathrm{IIn}} \sim \dot{M}_{\mathrm{Ia-CSM}}$

→ **localized & Confined CSM**

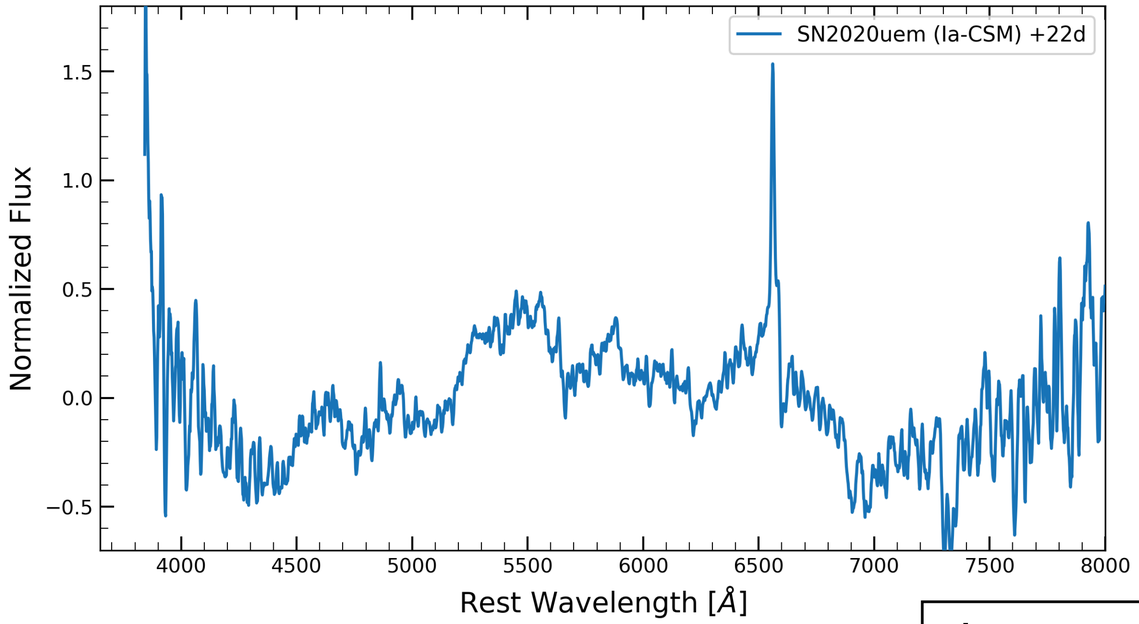
(3) $P_{\mathrm{SN}} \sim 1.0 - 1.5\,\%$ **@~100 days**

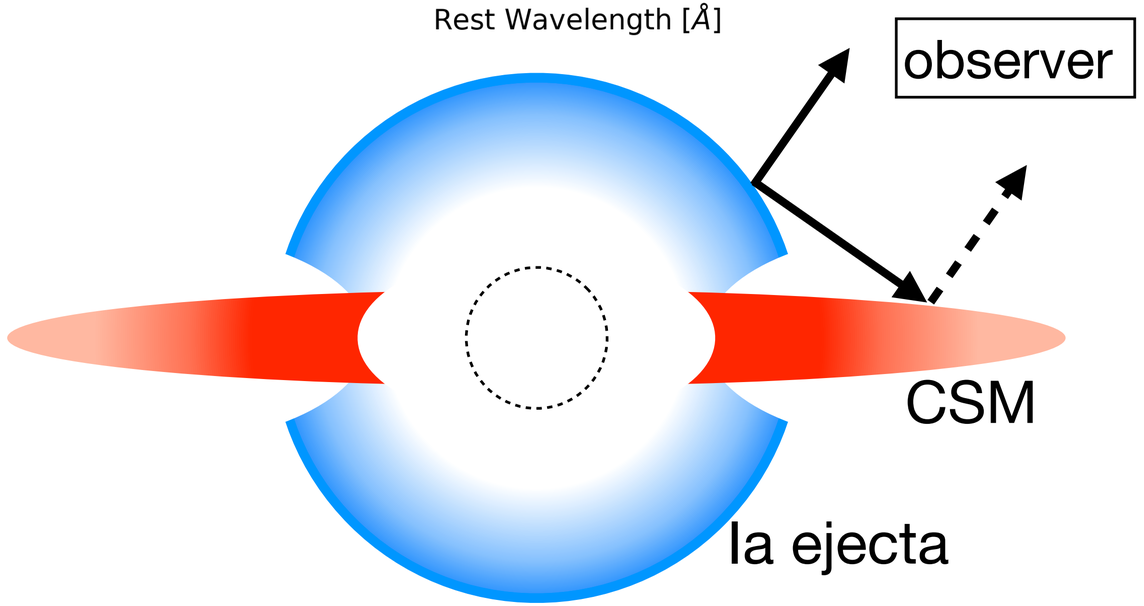
axis ratio < 0.2 @elliptical CSM

→ **Disk-like CSM**

(4) little/no NIR excess/echo

localized CSM / No CSM after 10^{17} cm





SN 2020uem has more confined disk-like CSM than general IIn SNe.

Take Away

Background

・New generation surveys have revealed the diversity of Ia SNe.

Observation

・Continuous follow up observations for a Ia-CSM SNe; SN2020uem, ware performed with Seimei, Kanata, and Subaru telescope.

Results

・SN 2020uem may have **more dense CSM than typical Type IIn SNe**.

・The CSM geometry may be **disk-like** one.

Further More

・Dust echo, Mass-Loss history, Explosion mechanism, Progenitor, …

Many things can (and have to) be discussed

Request

・KOOLS-IFU解析のノウハウを教えていただける機会があると嬉しいです。

Thanks to everyone involved with Seimei telescope！ Thank you very much！