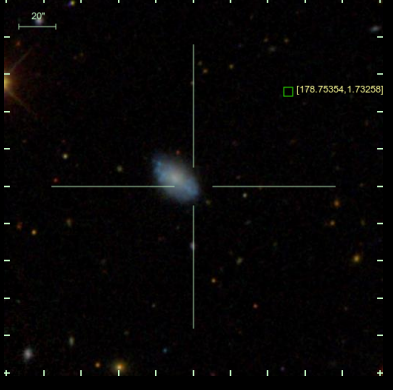
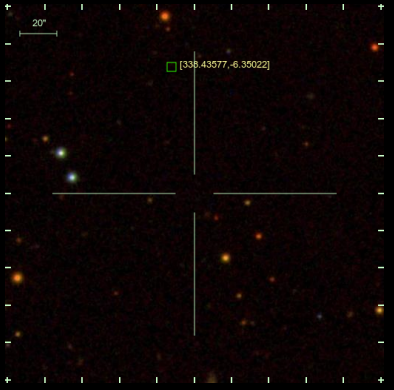
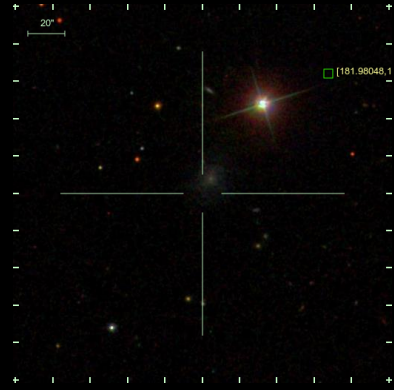
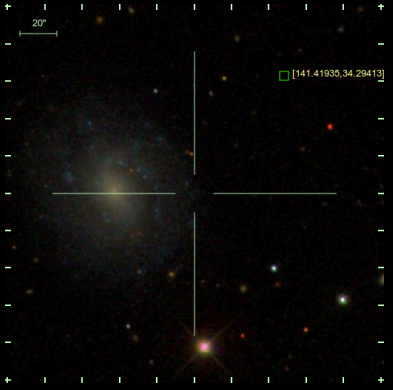
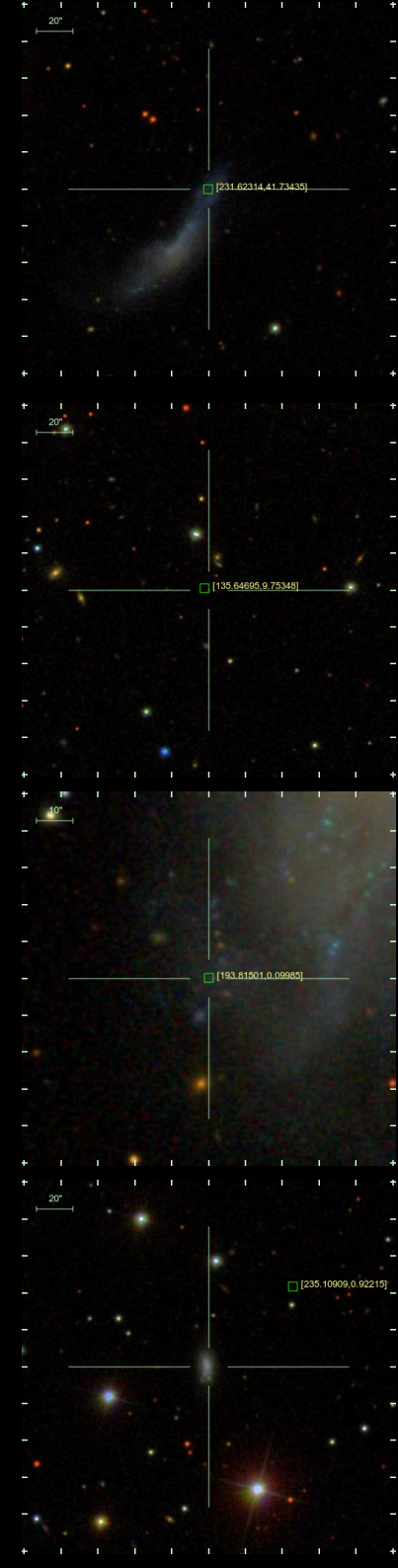


Narrow Na I D absorption lines in SN spectra

Claudia P. Gutiérrez A.

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Southampton

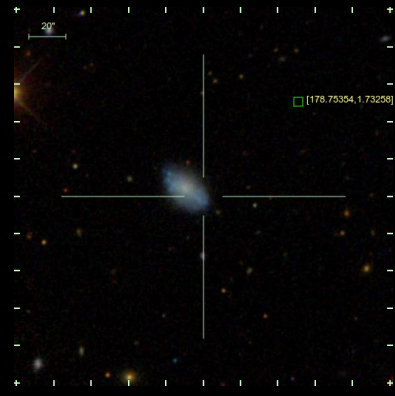
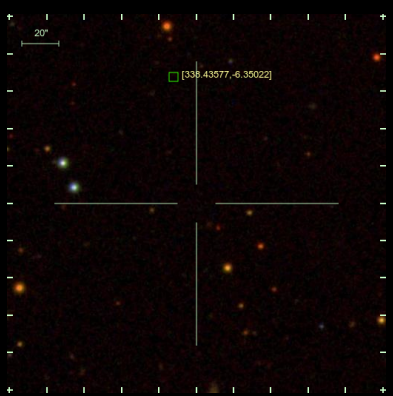
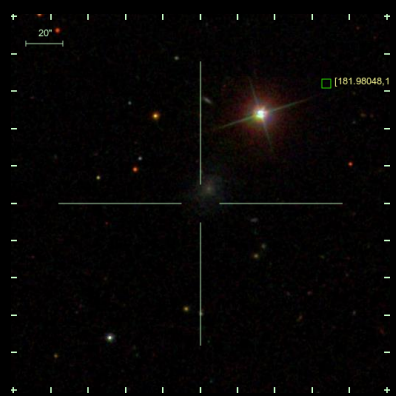
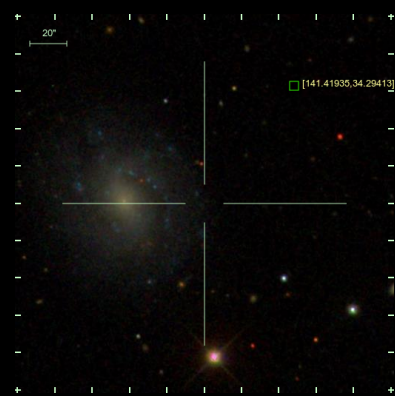
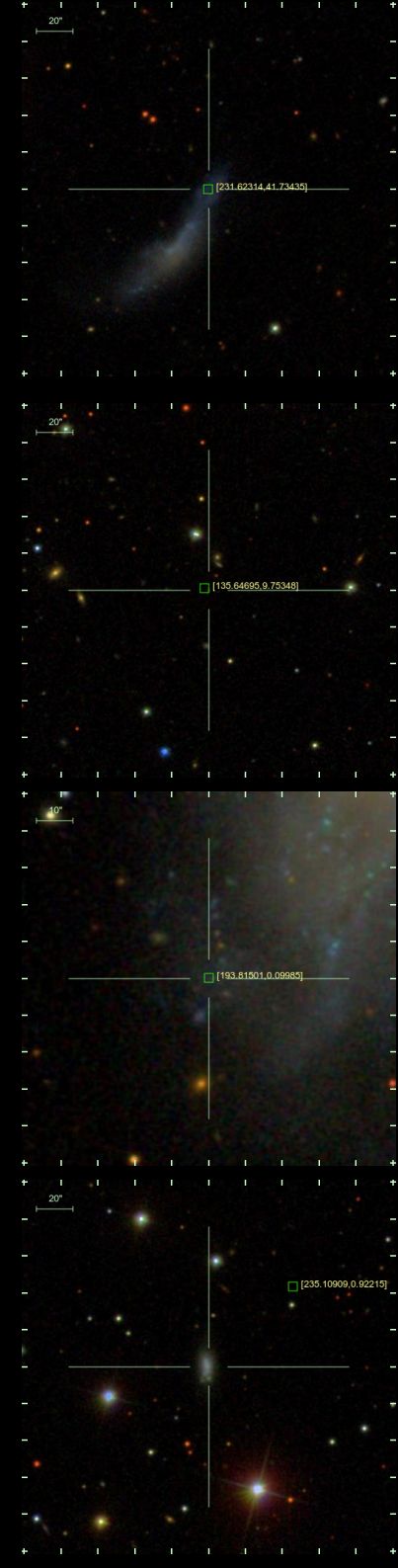


Narrow Na I D absorption lines in SN spectra

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In collaboration with Santiago González-Gaitán

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Southampton



MOTIVATION

Na I D lines



Reddening correction?
Circumstellar Medium (CSM)?
Interstellar Medium (ISM)?

MOTIVATION

Na I D lines →
(Ca II H&K and the DIBs)

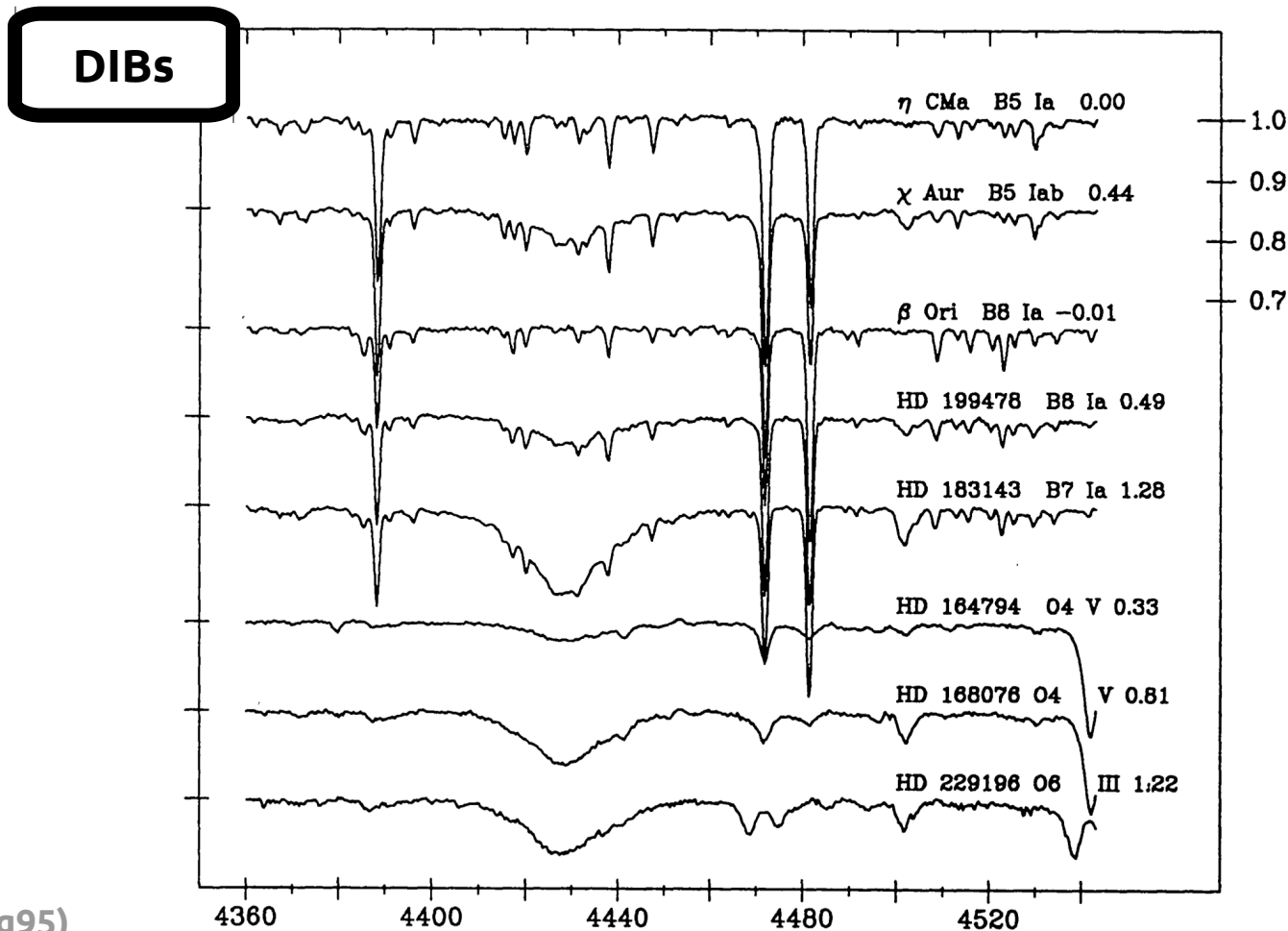
Reddening correction?
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MOTIVATION

Na I D lines
(Ca II H&K and the DIBs)



Reddening correction?
Circumstellar Medium (CSM)?
Interstellar Medium (ISM)?



(Herbing95)

MOTIVATION

Na I D lines →
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Reddening correction?
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Interstellar Medium (ISM)?

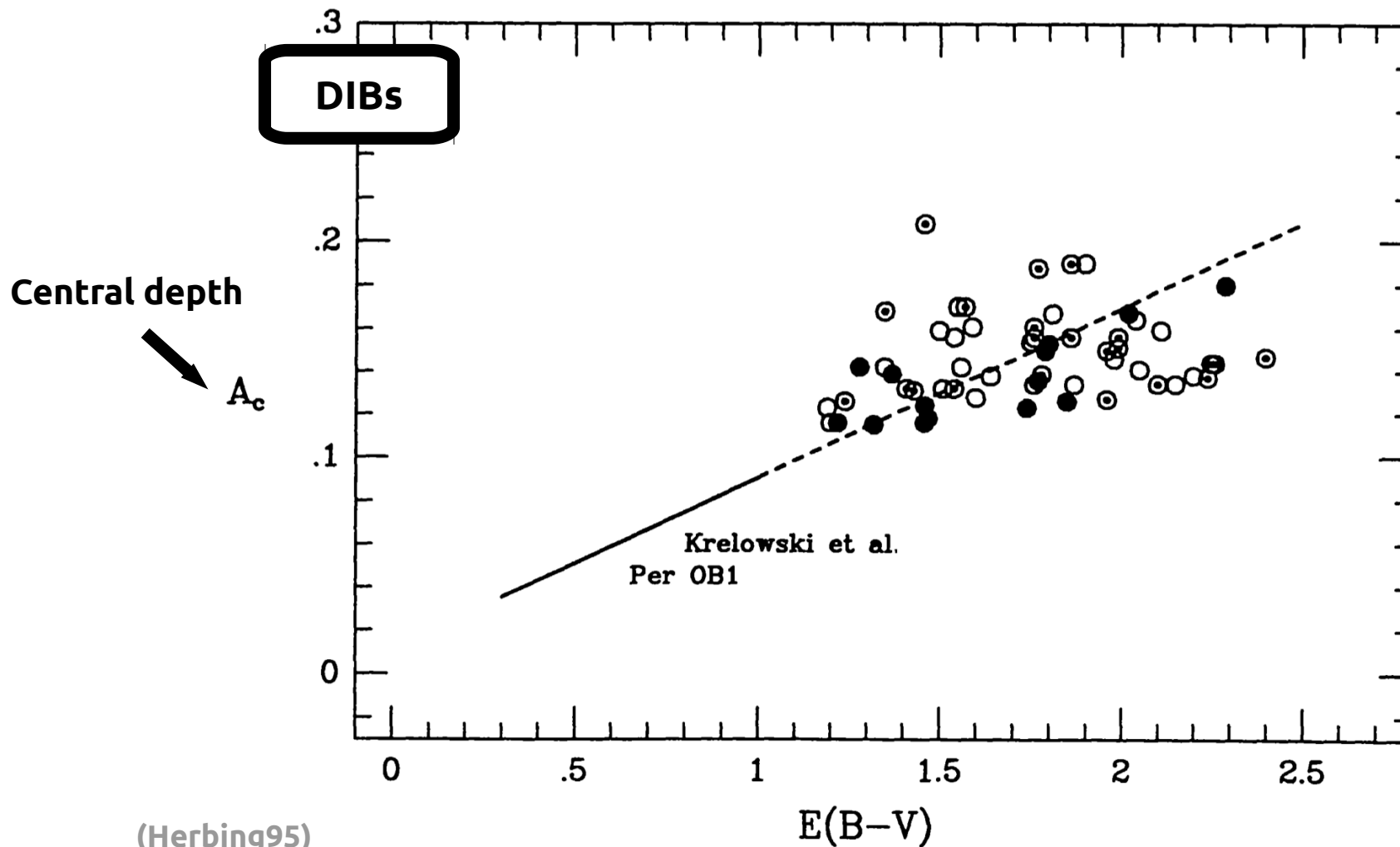
MOTIVATION

Na I D lines → Reddening correction?
(Ca II H&K and the DIBs) Circumstellar Medium (CSM)?
Interstellar Medium (ISM)?

In the Milky Way → Na I D lines and the DIBs correlate with dust extinction (Hobbs 1974; Herbing 1995).

MOTIVATION

Na I D lines \rightarrow Reddening correction?
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MOTIVATION

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(Ca II H&K and the DIBs) Circumstellar Medium (CSM)?
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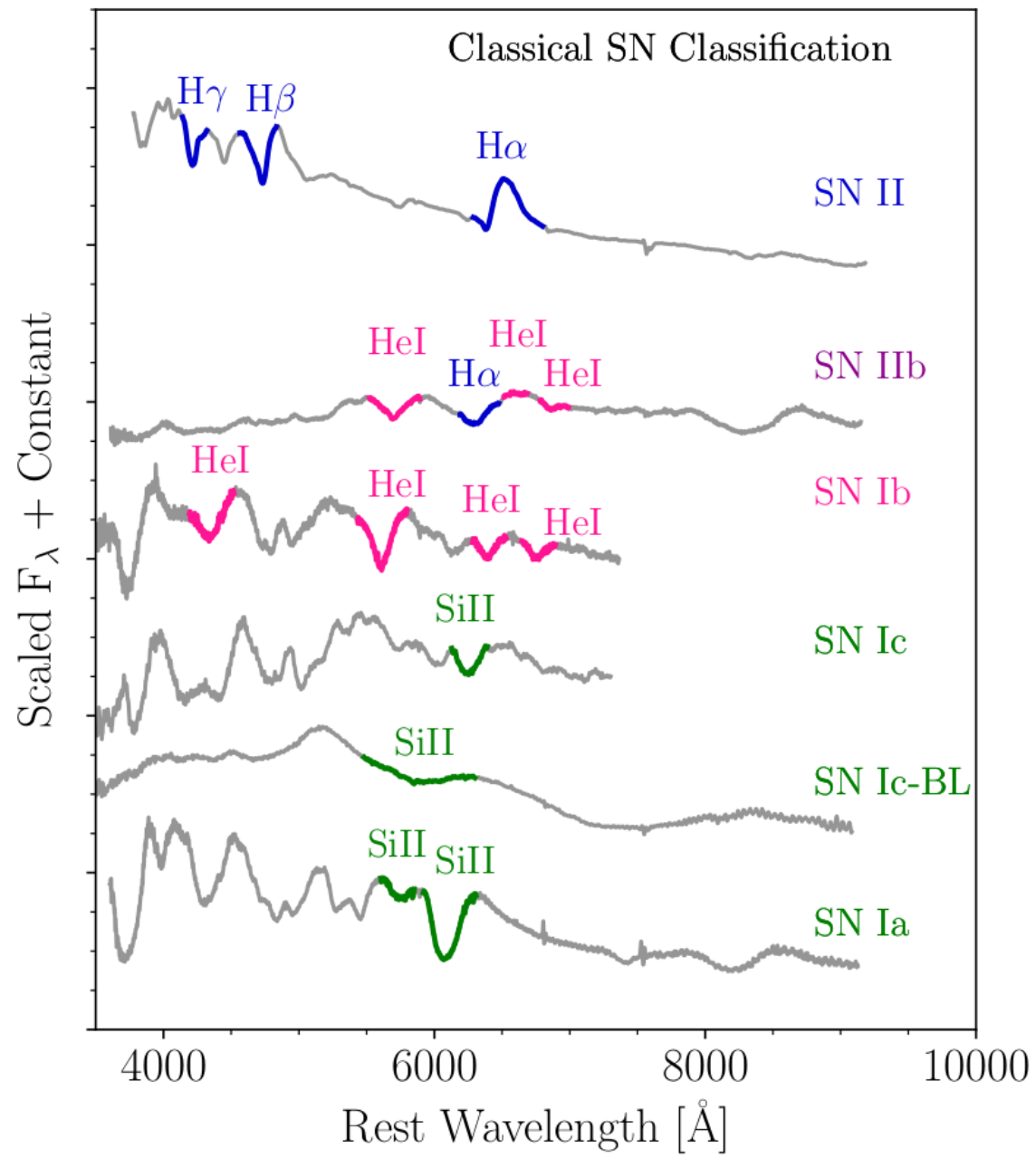
In the Milky Way → Na I D lines and the DIBs correlate with dust extinction (Hobbs 1974; Herbing 1995).



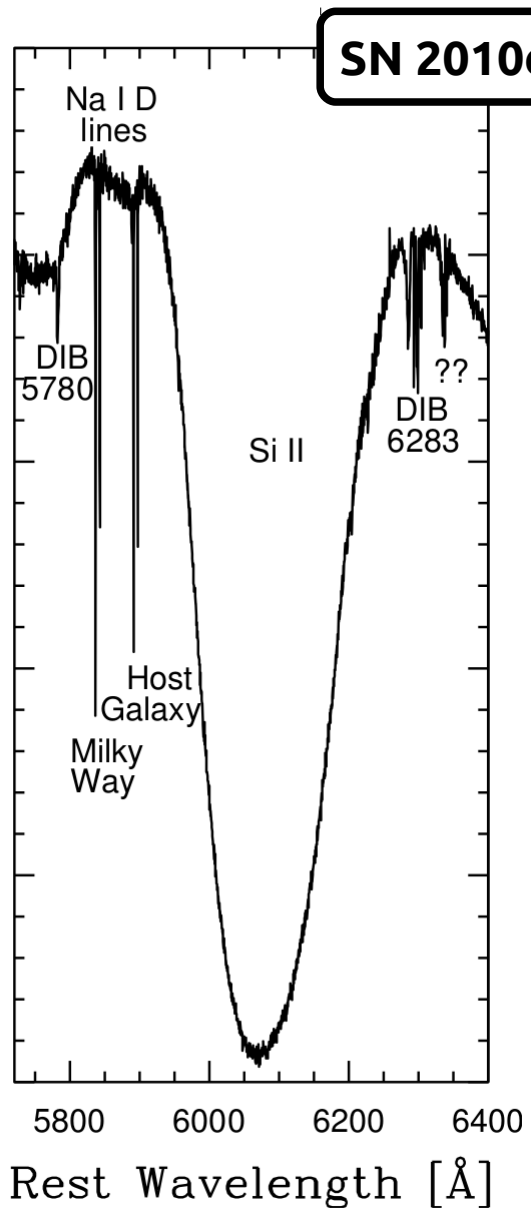
Na I D, Ca II H&K lines and the DIBs have been detected in SN spectra

The properties of the ISM of the host galaxies and also the environment of the SNe (CSM) can be studied with medium/high-resolution spectra.

Our analysis is focused on SNe II, SNe Ia and stripped-envelope SNe (Ib/Ic/Iib)

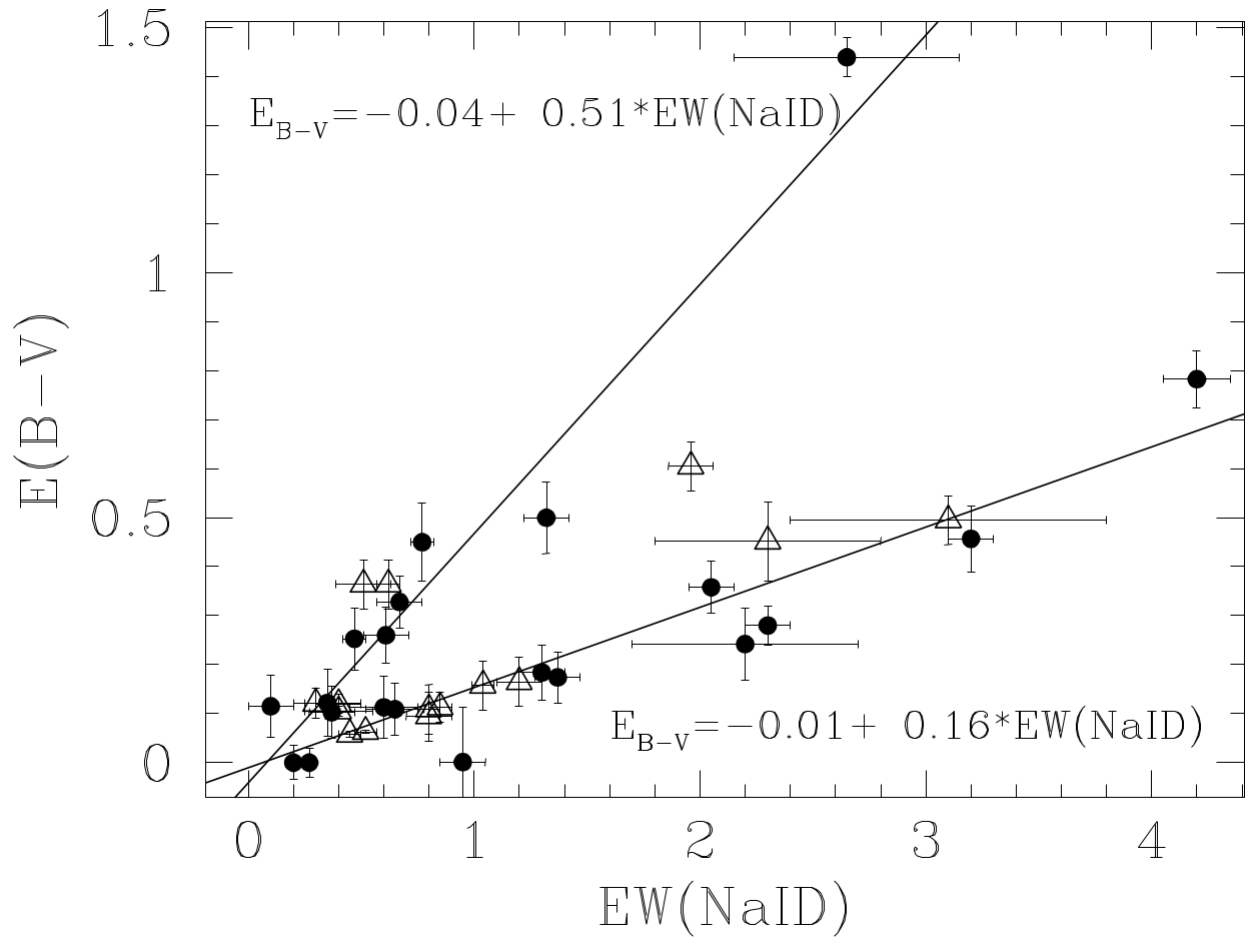
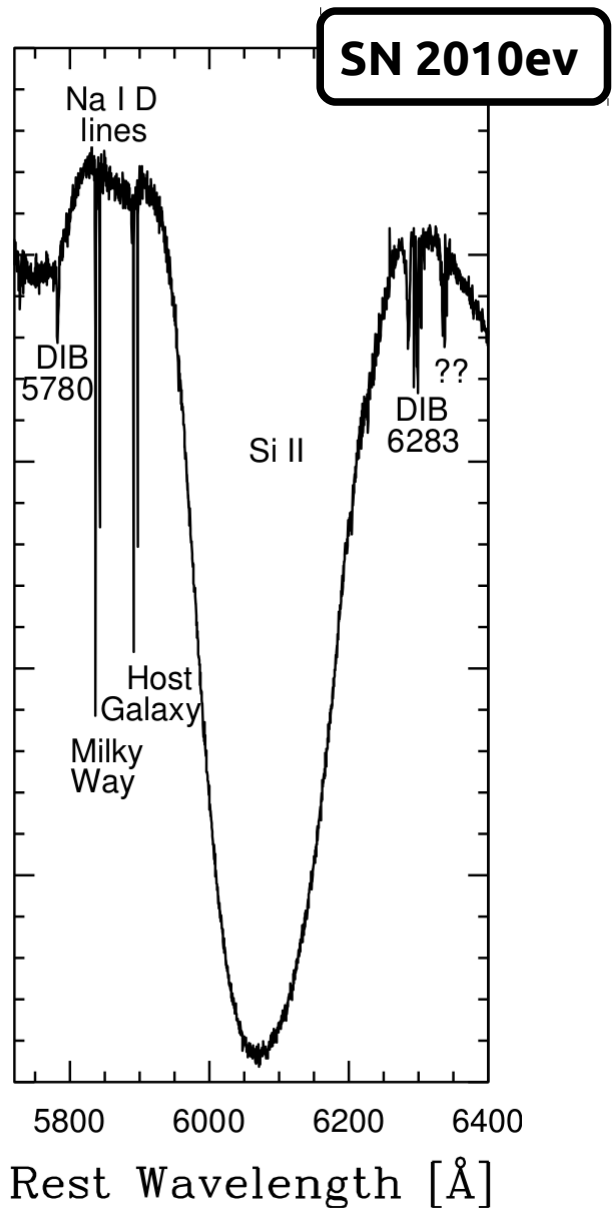


Na I D lines can give the gas column density, and then can be converted into reddening assuming an average dust-to-gas ratio.



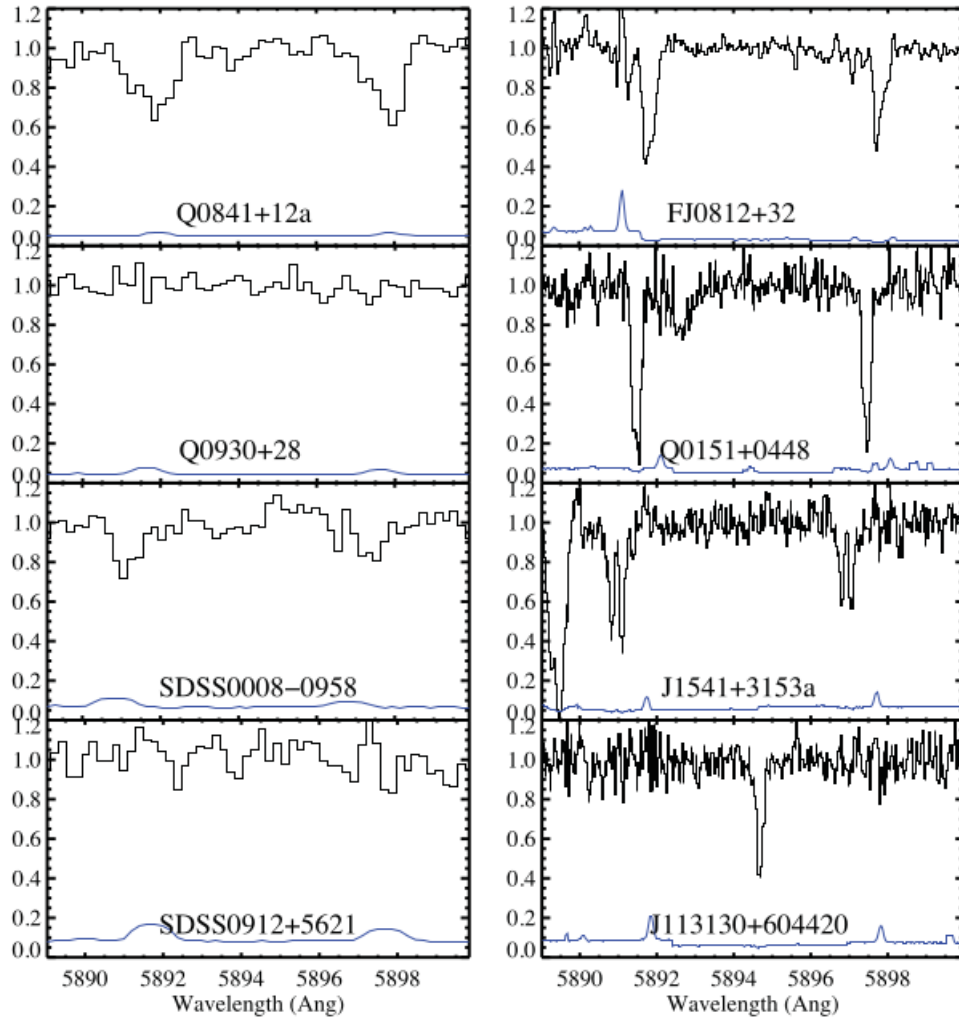
(Gutiérrez+16)

NaID lines can give the gas column density, and then can be converted into reddening assuming an average dust-to-gas ratio.



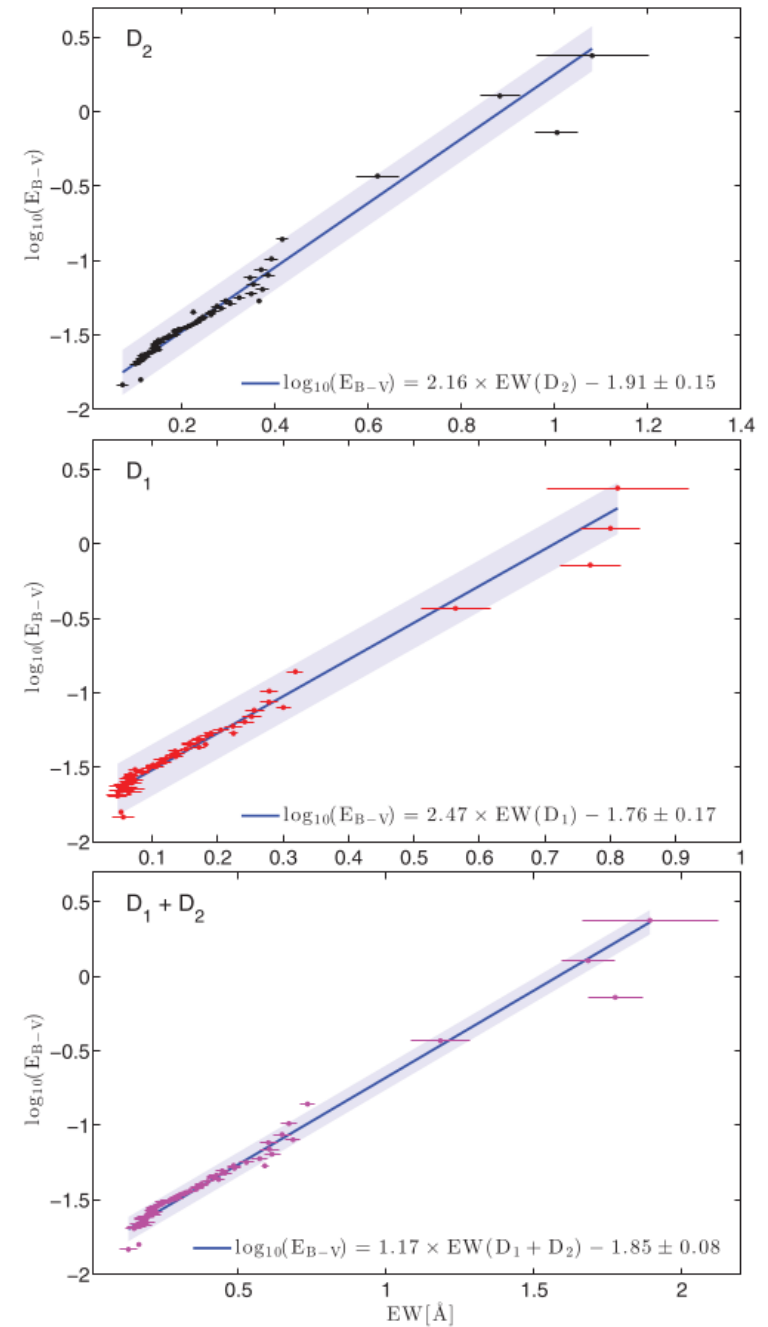
The B-V color 2-3 months after explosion is independent on the SN photometric class (Phillips+99).

Detection of blueshifted time-varying Na I D absorption lines has been interpreted as evidence of CSM

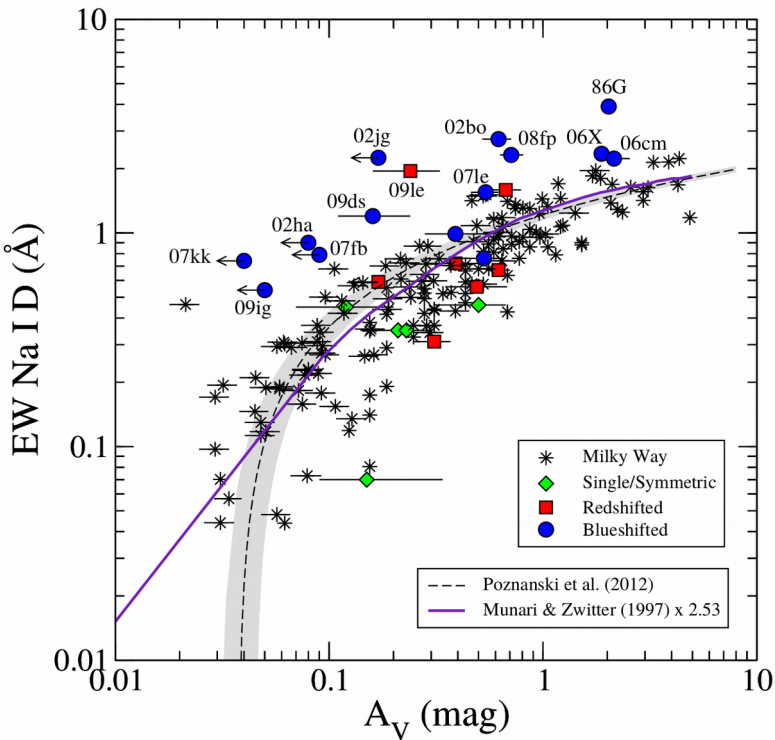
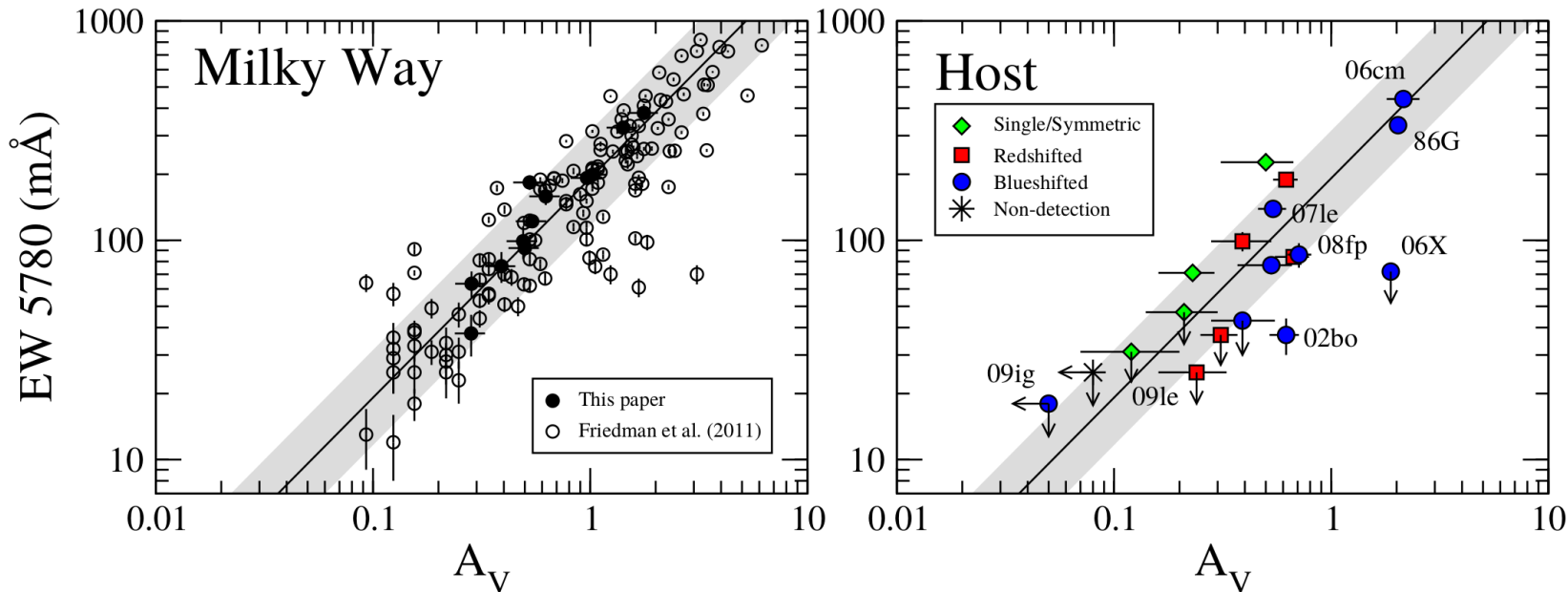


EWs of Na I D and to compare them to $E(B - V)$ values (>117 QSOs)

(Poznanski+12)



The dust producing the extinction is predominantly located in the ISM of the host galaxies

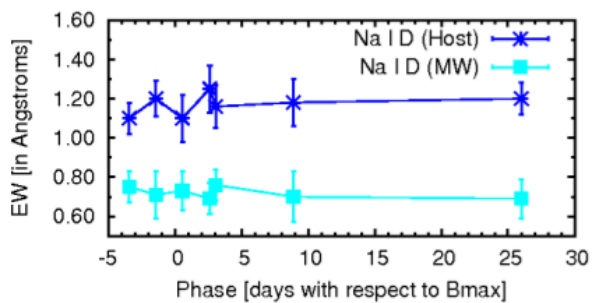
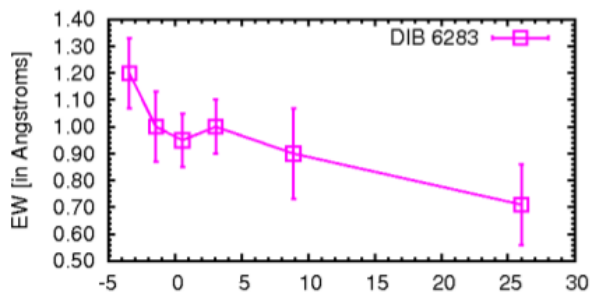
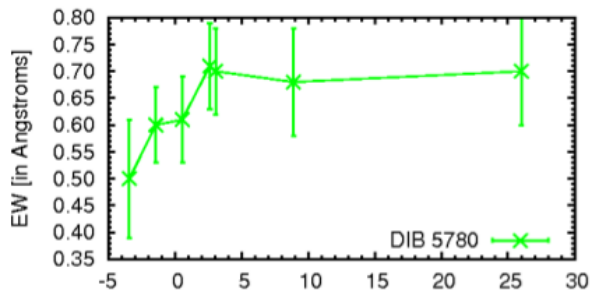
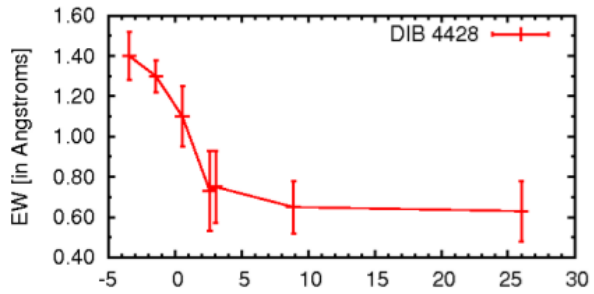
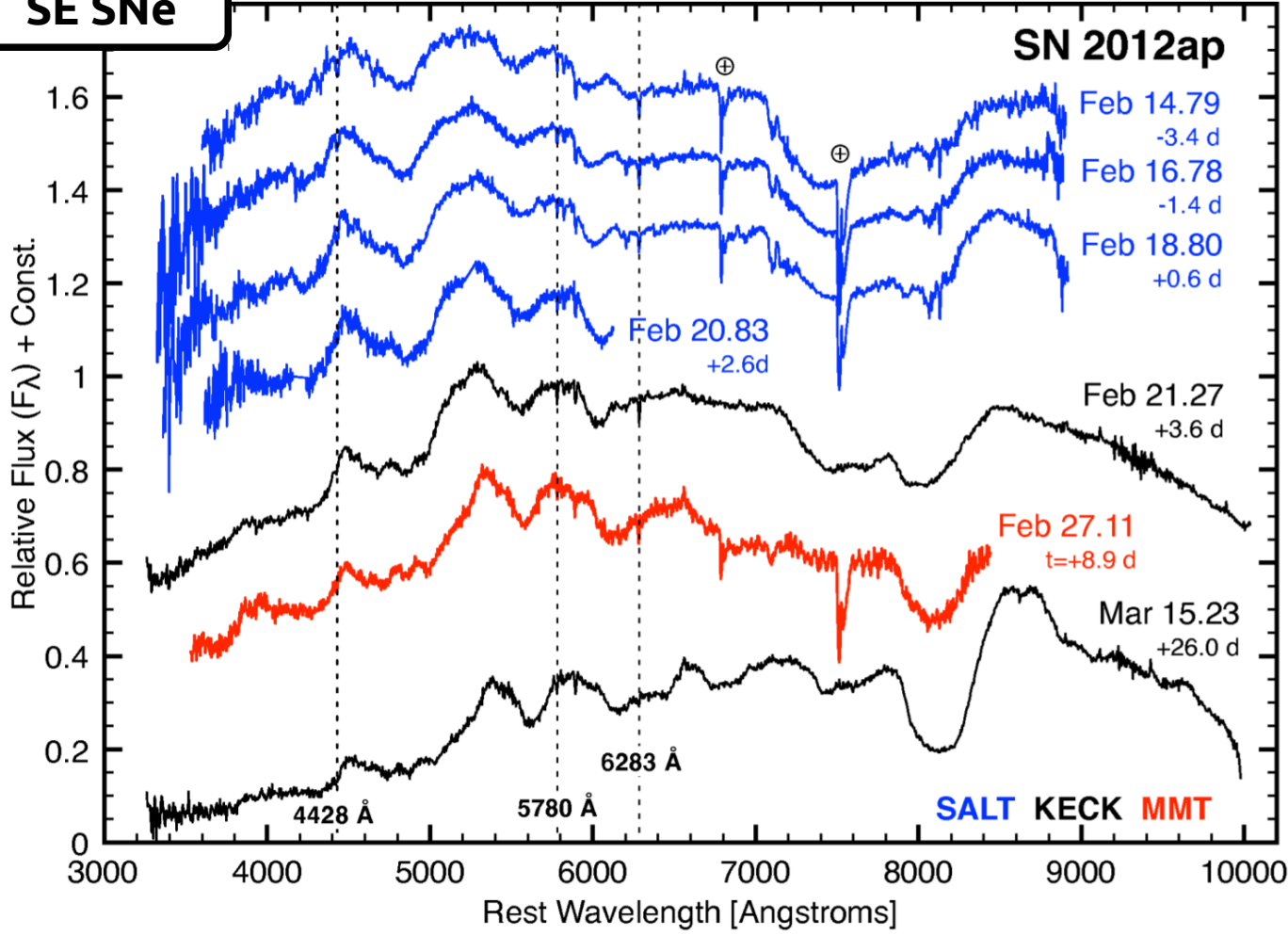


The most accurate predictor of individual SN extinction to be the equivalent width of the diffuse interstellar band at 5780 \AA

What about Core-collapse Supernovae??

What about Core-collapse Supernovae??

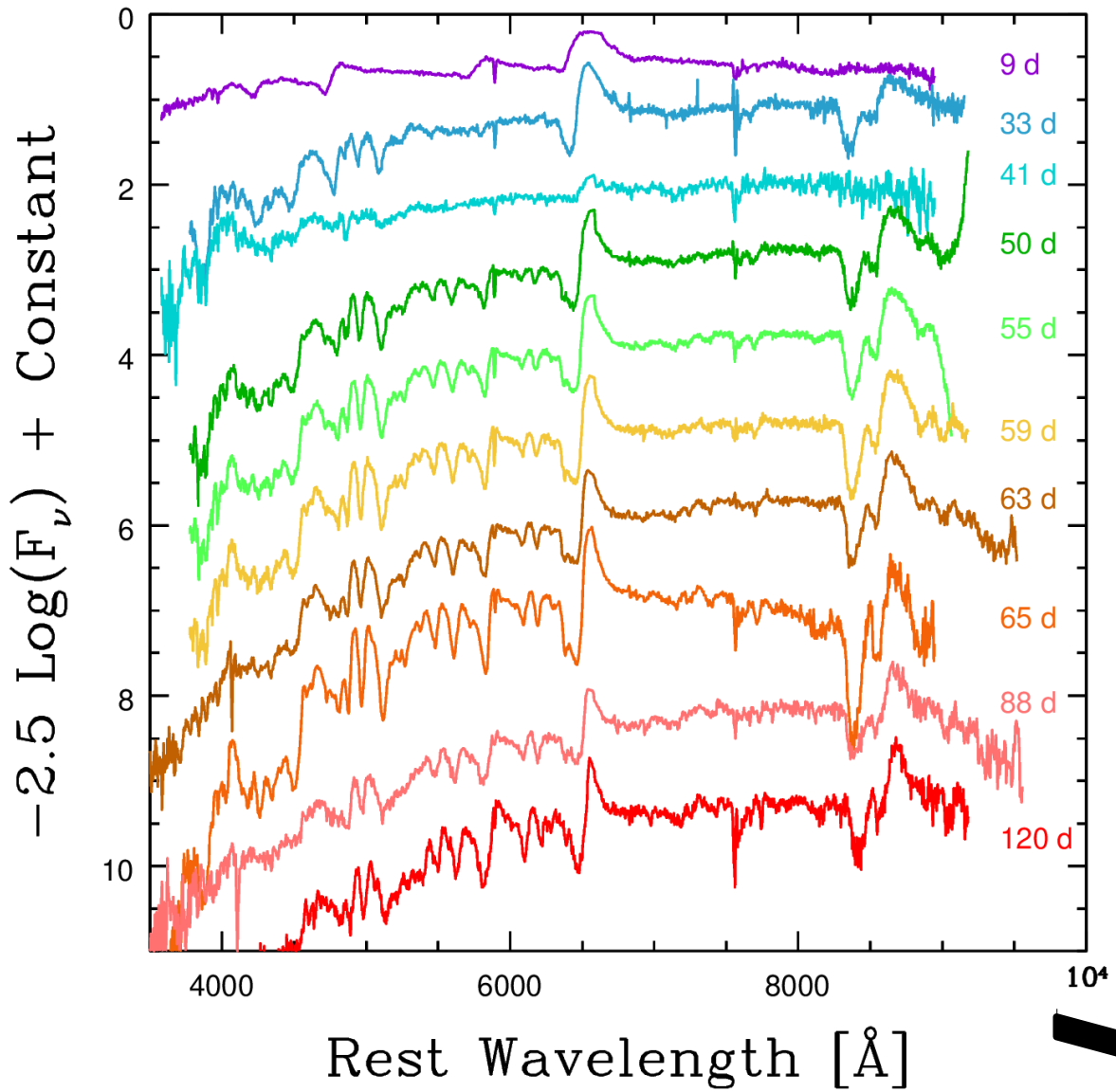
SE SNe



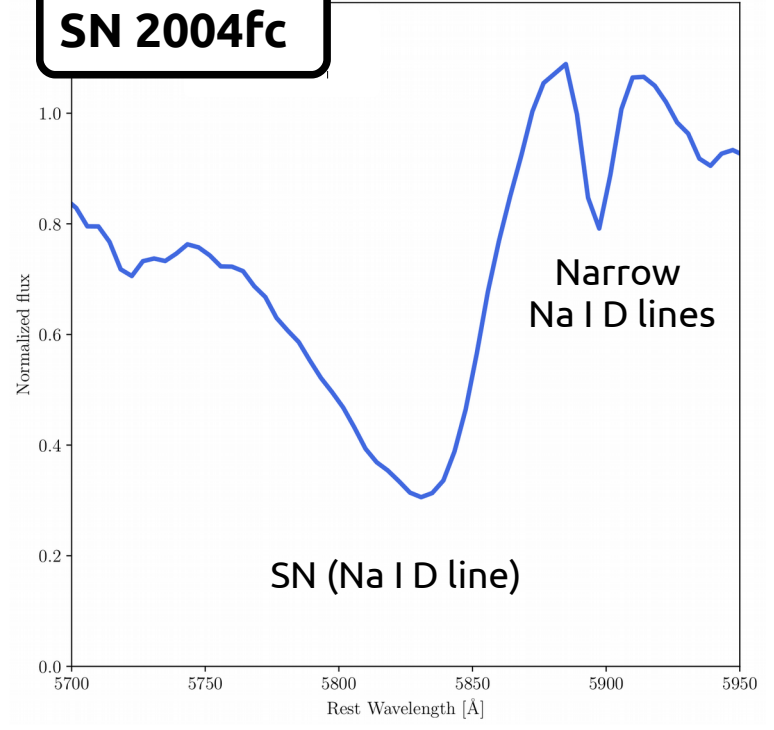
(Milisavljevic+14)

What about Core-collapse Supernovae??

SNe II



SN 2004fc

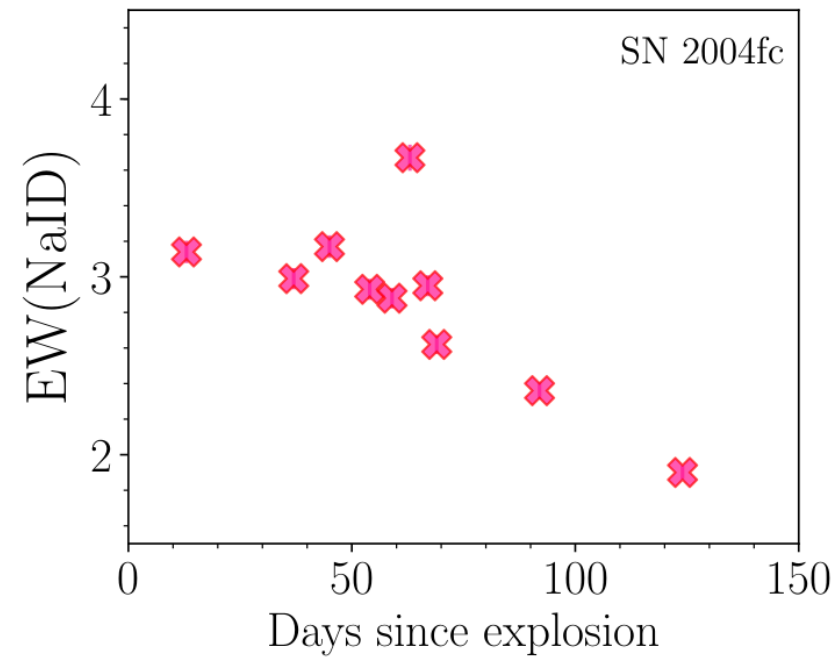
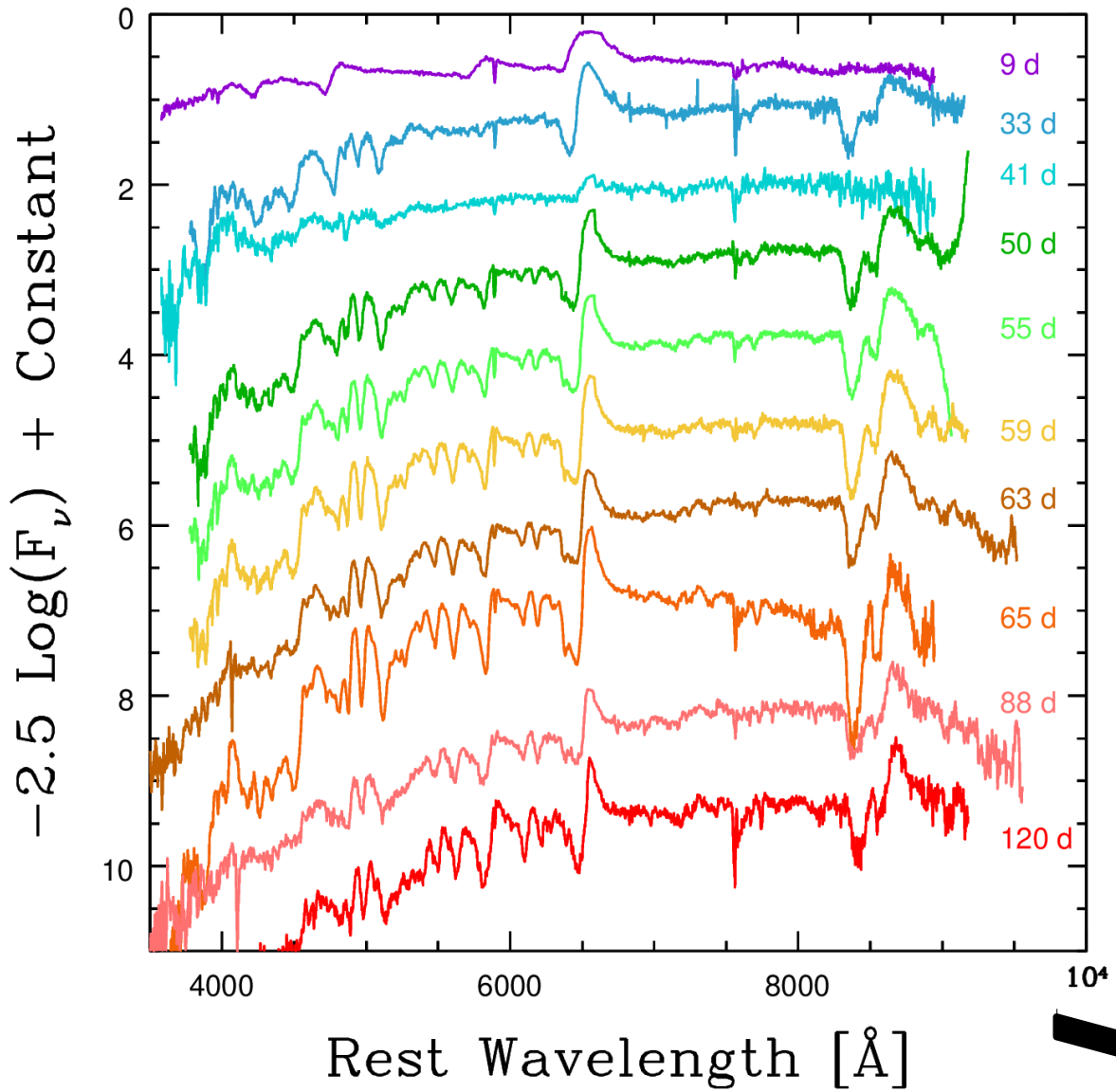


Evolution in the EW(NaID)???

(Gutiérrez+17)

What about Core-collapse Supernovae??

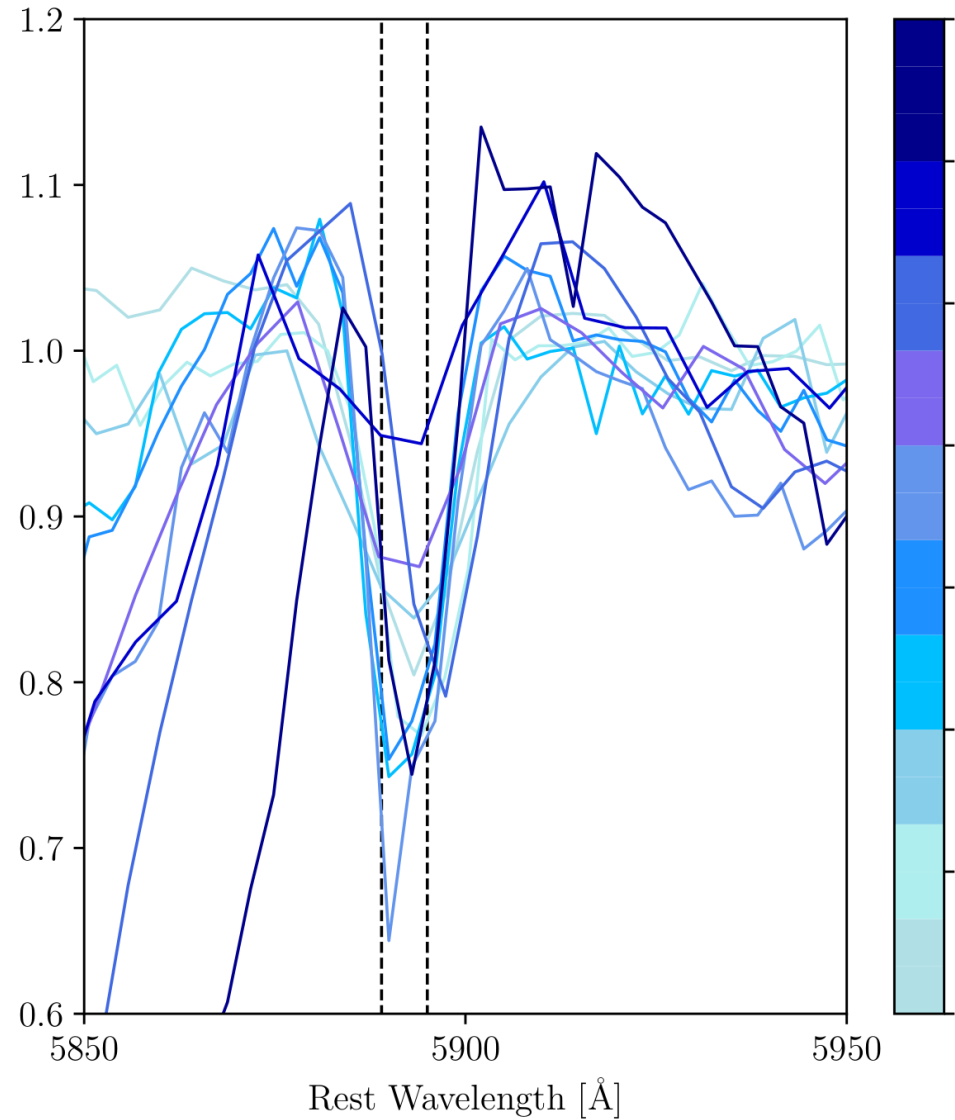
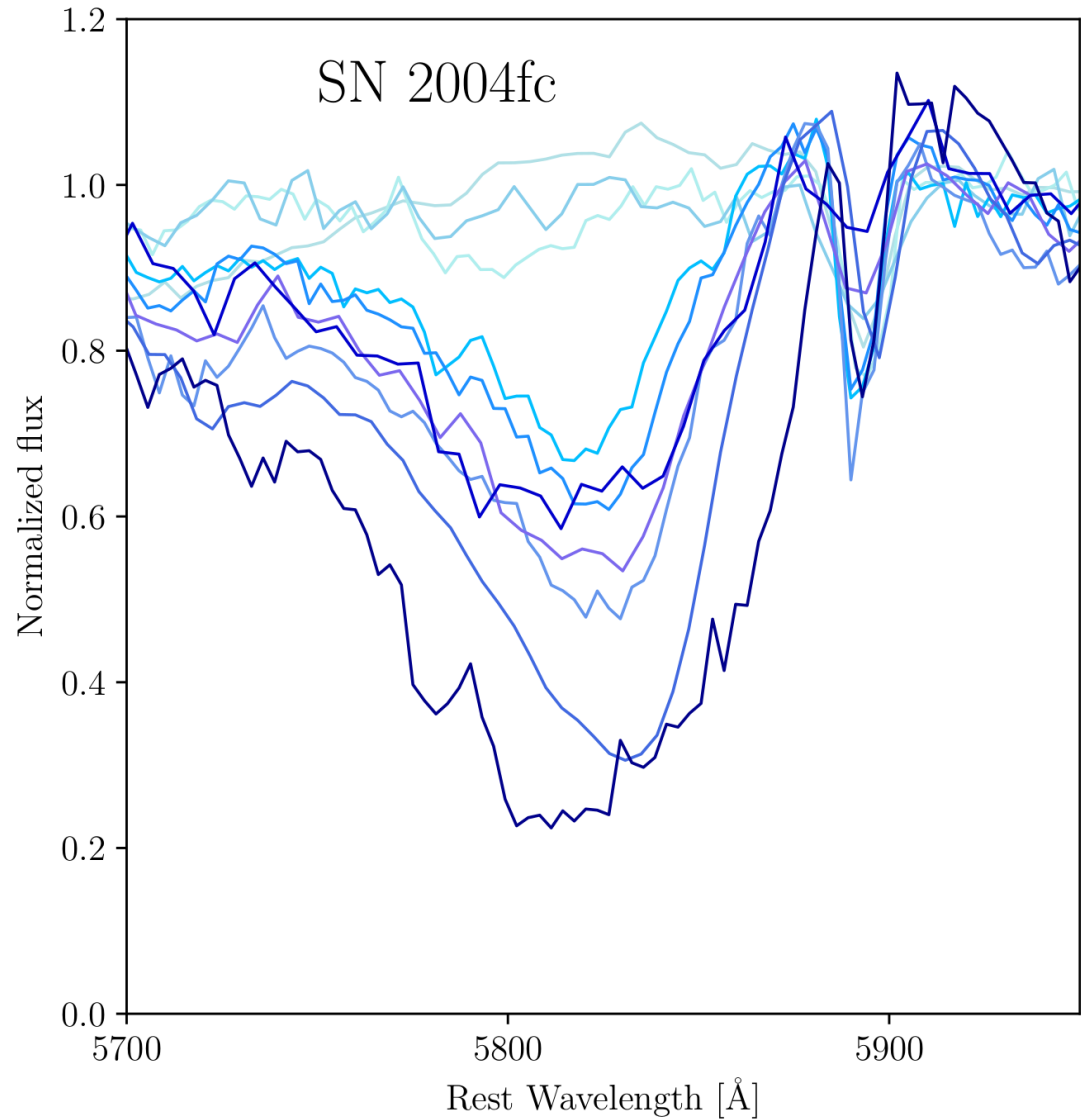
SNe II



Evolution in the EW(NaID)???

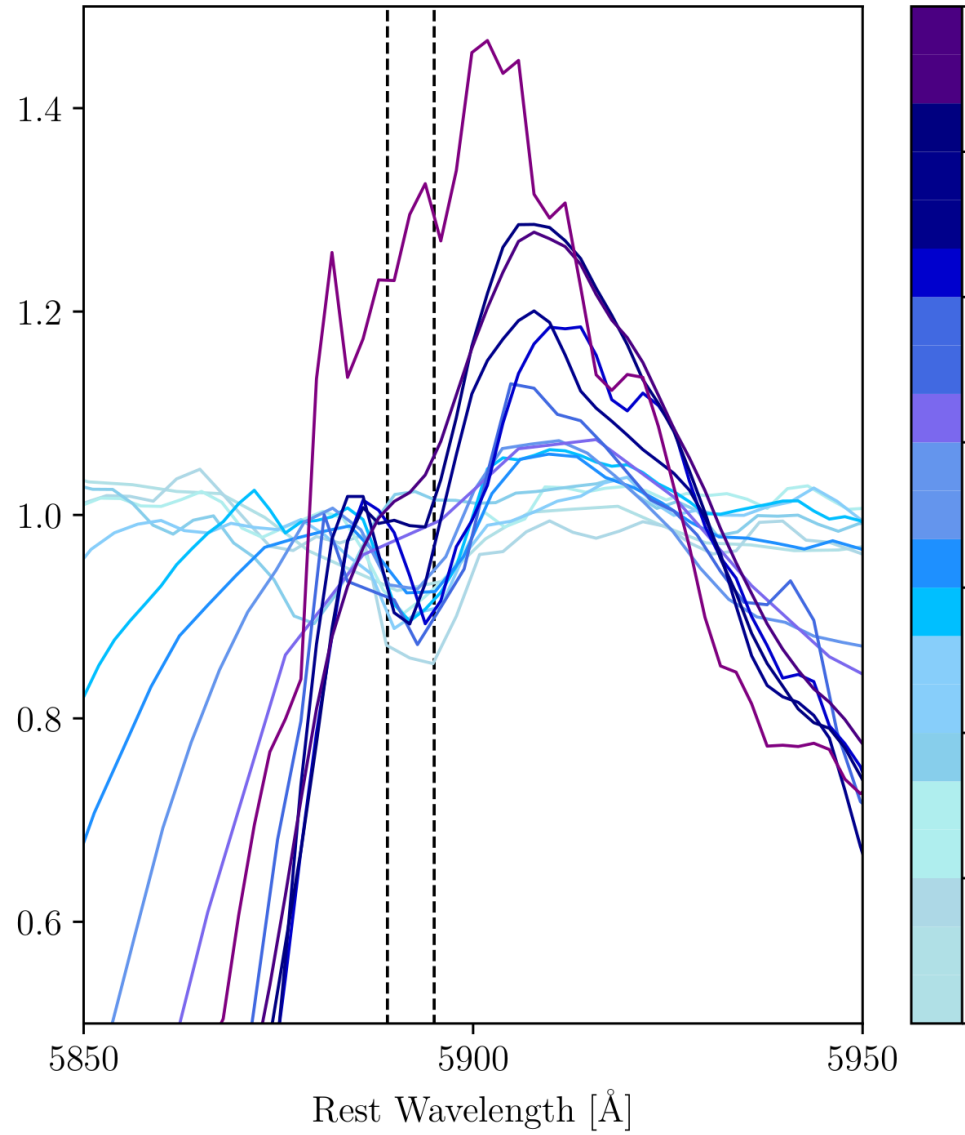
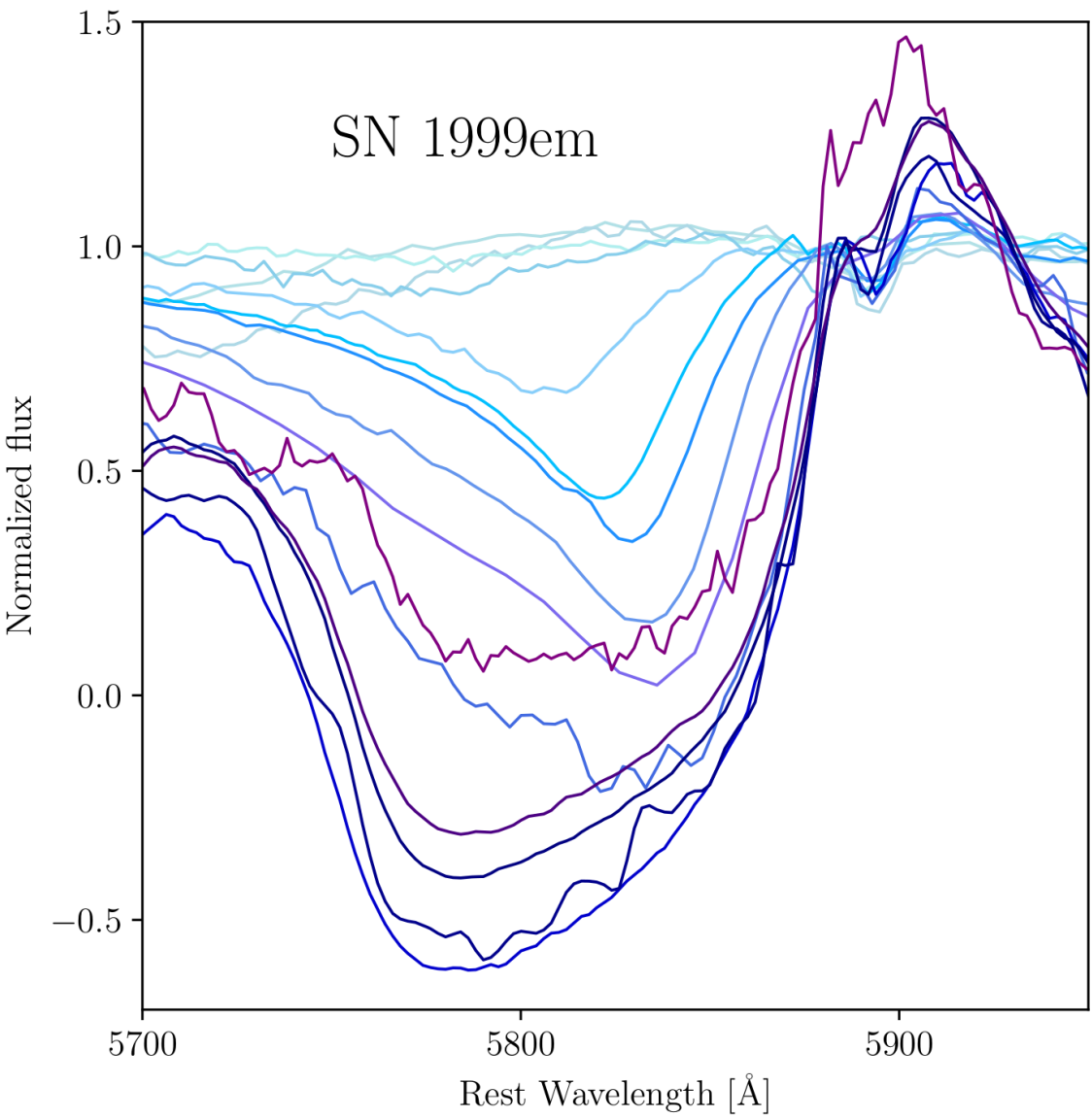
SNe II: Evolution of the NaID P-Cygni profile affects the narrow NaID line?

SNe II (CSP)

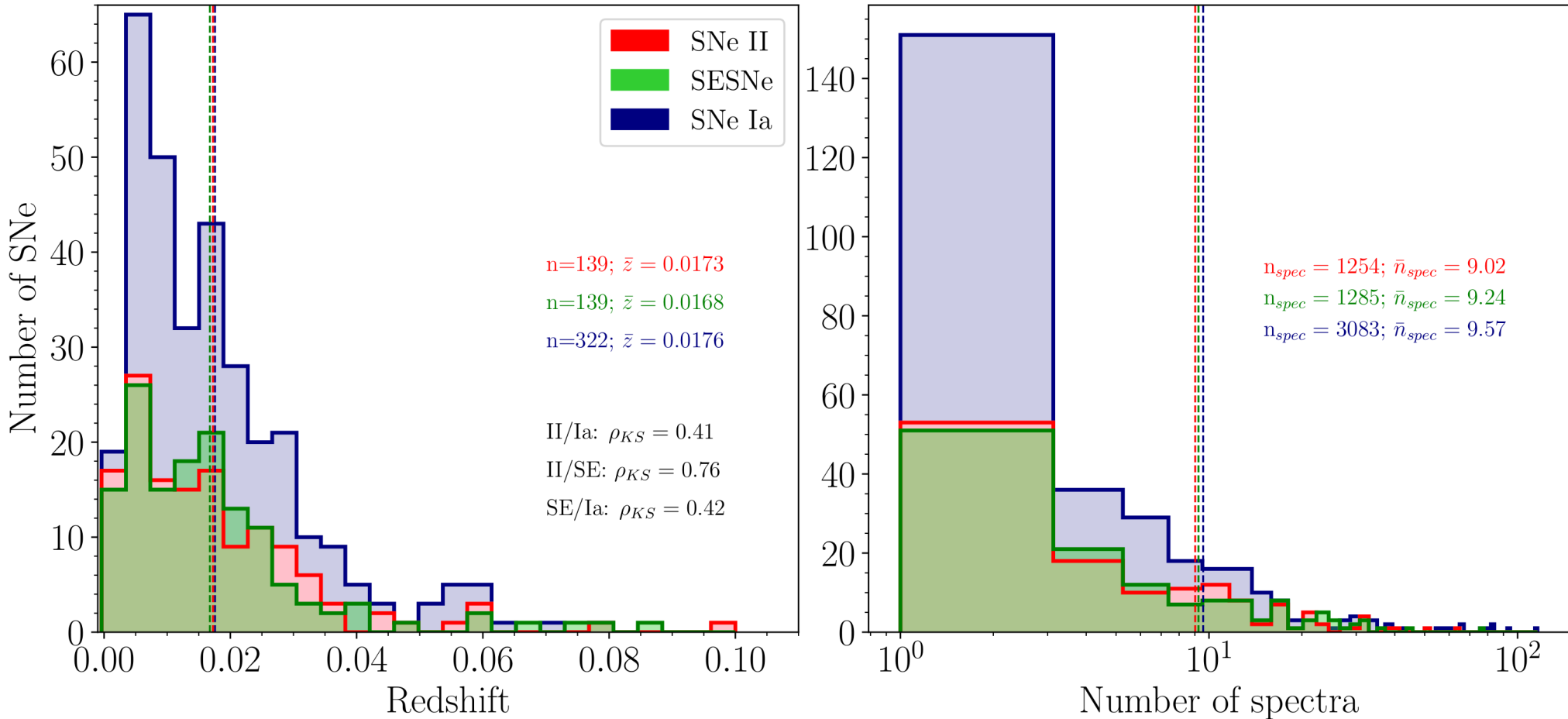


SNe II: Evolution of the NaID P-Cygni profile affects the narrow NaID line?

SNe II (CSP)



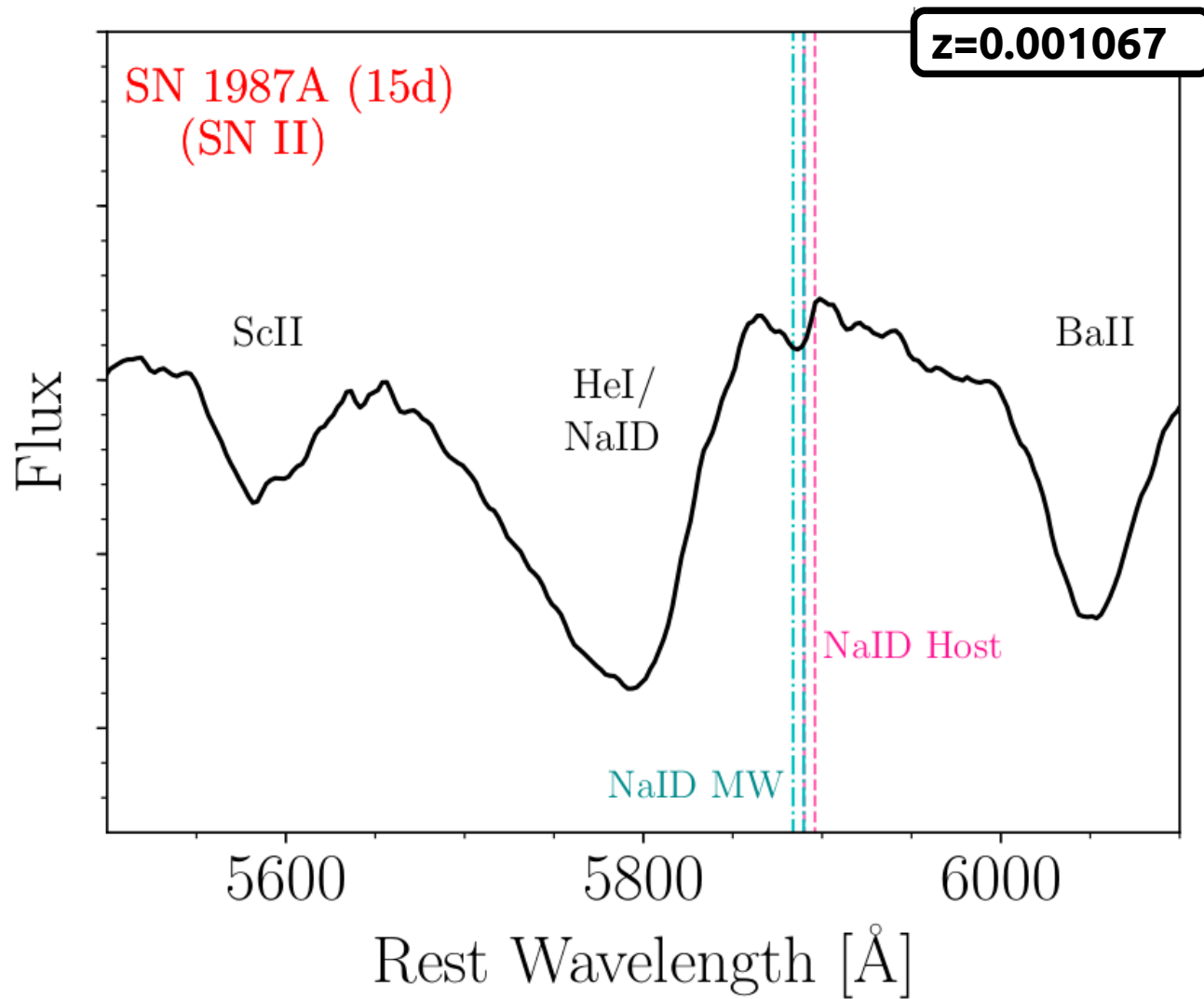
Evolution of the narrow NaID lines in SN spectra: Sample



SNe from the literature observed between 1948 to 2018.

~600 SNe
>5600 spectra

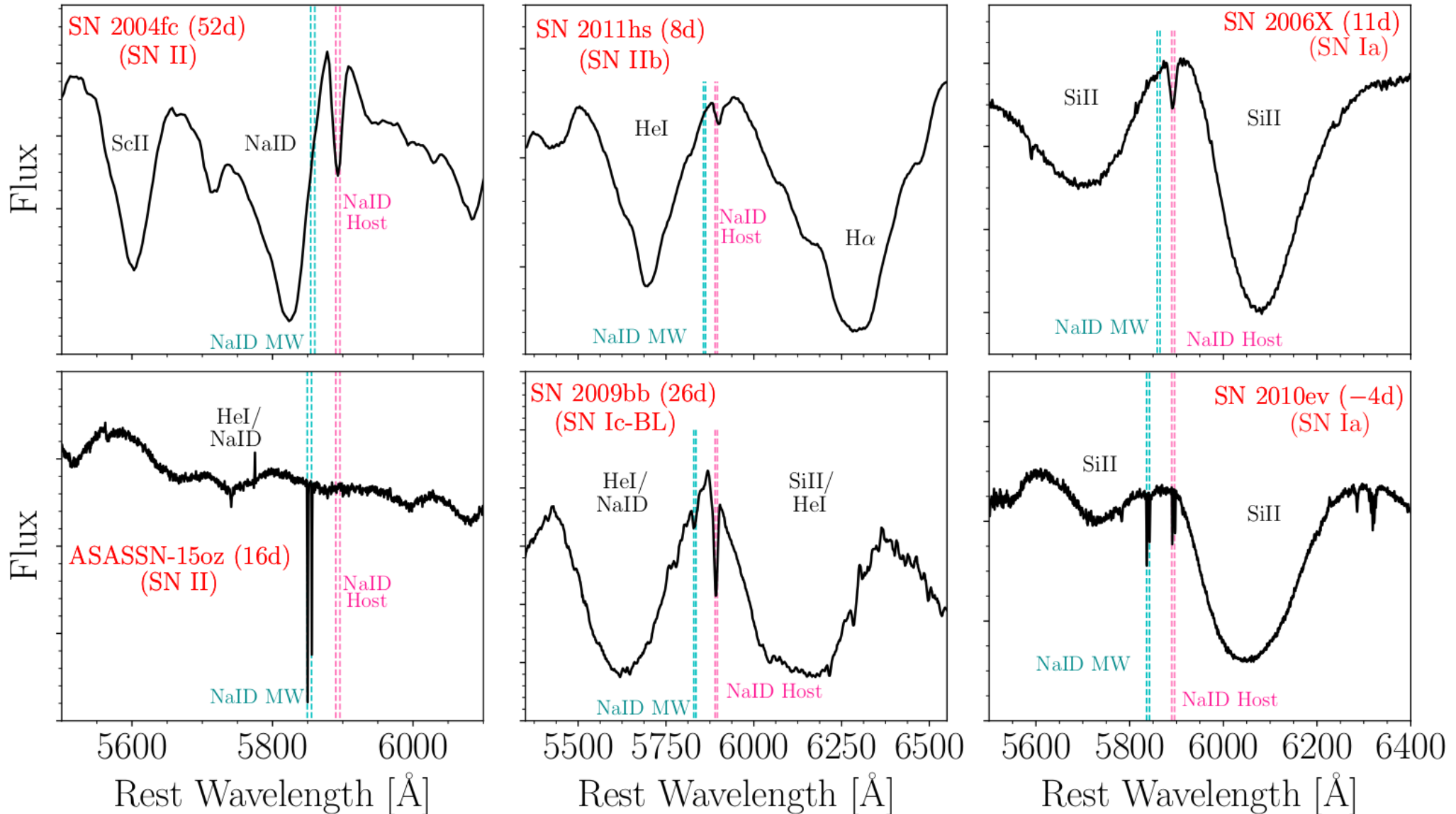
Evolution of the narrow NaID lines in SN spectra: Sample



Problems at very low-z:
Narrow NaID lines from
the MW and galaxy host
are blended

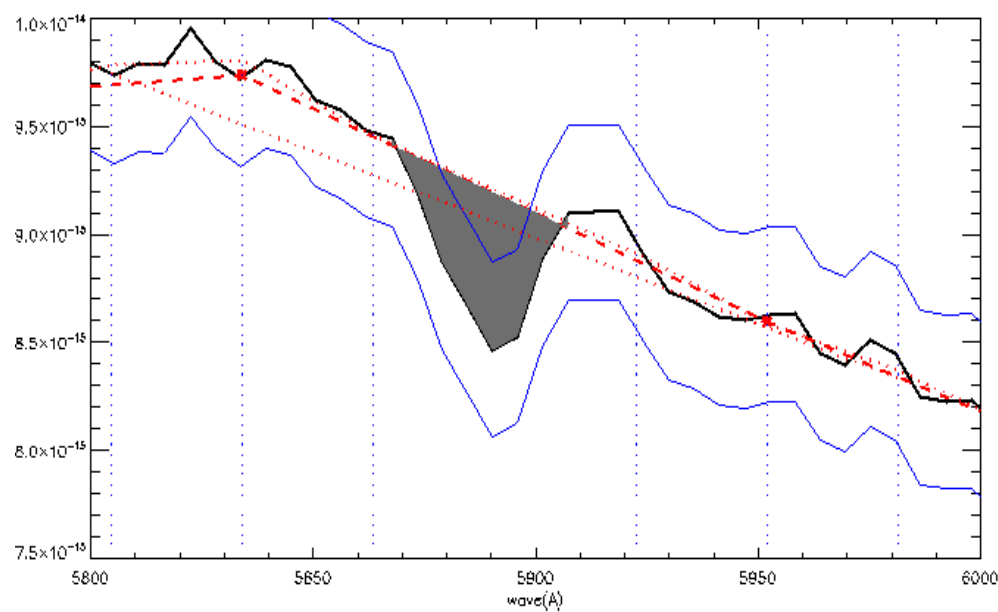
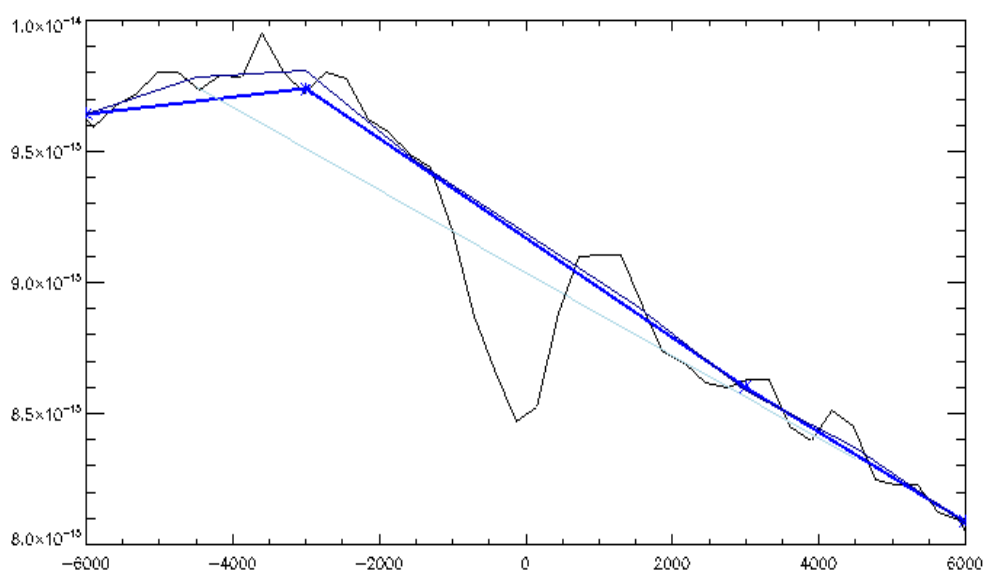
→ Evolution is not clear

Evolution of the narrow NaID lines in SN spectra: location of the lines

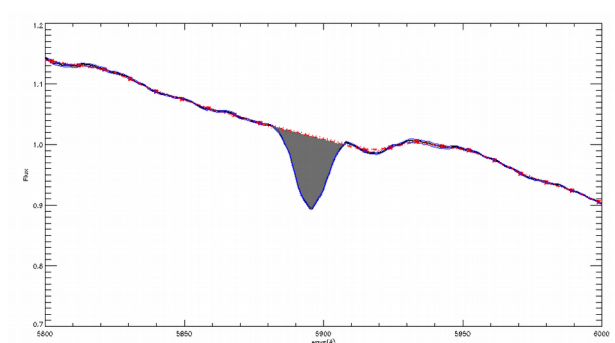
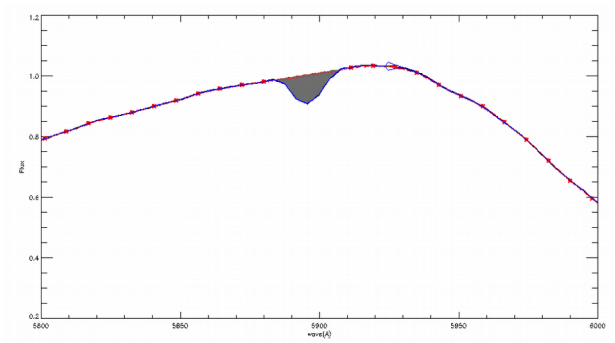
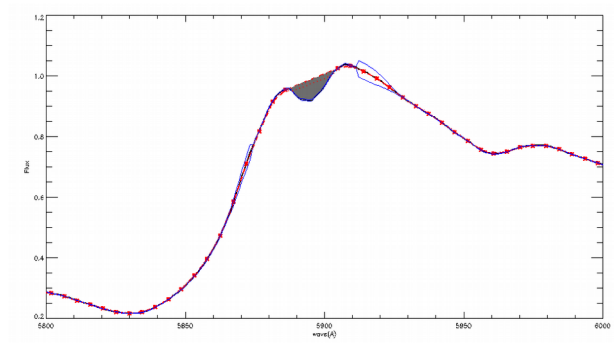
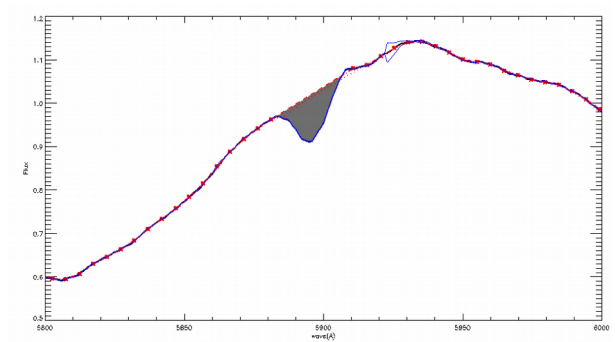
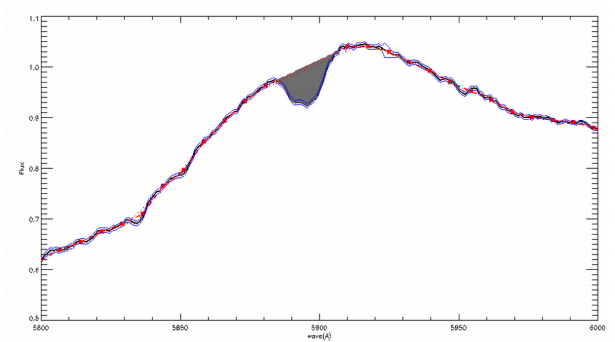
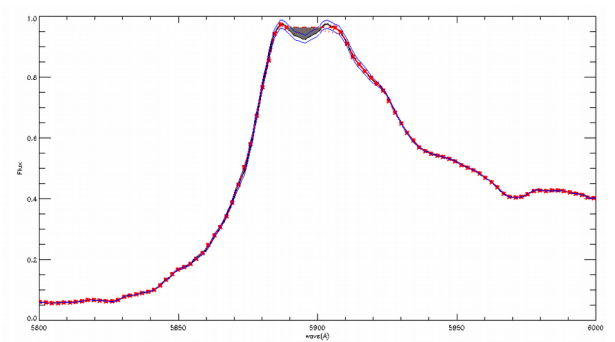
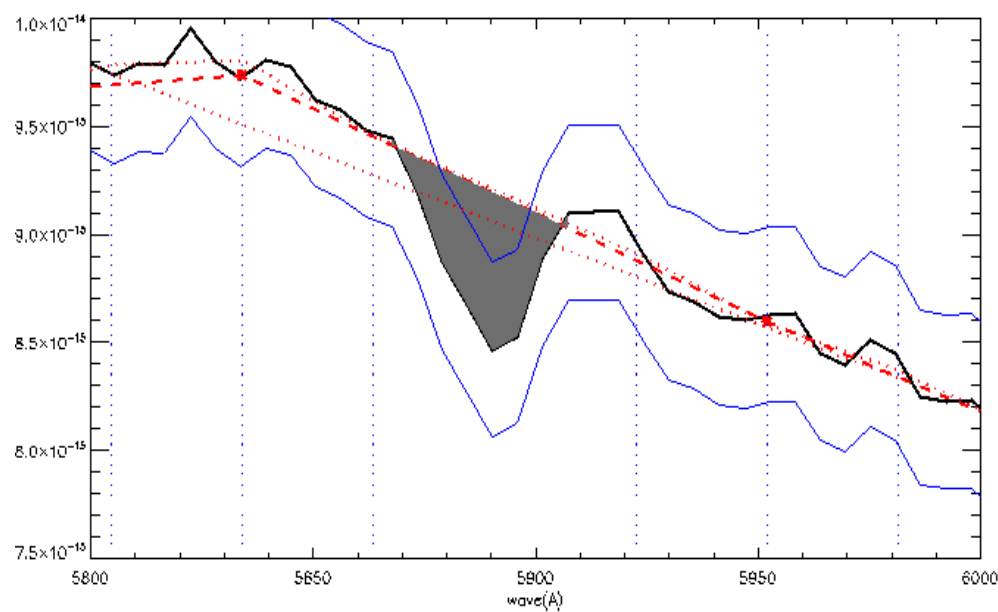
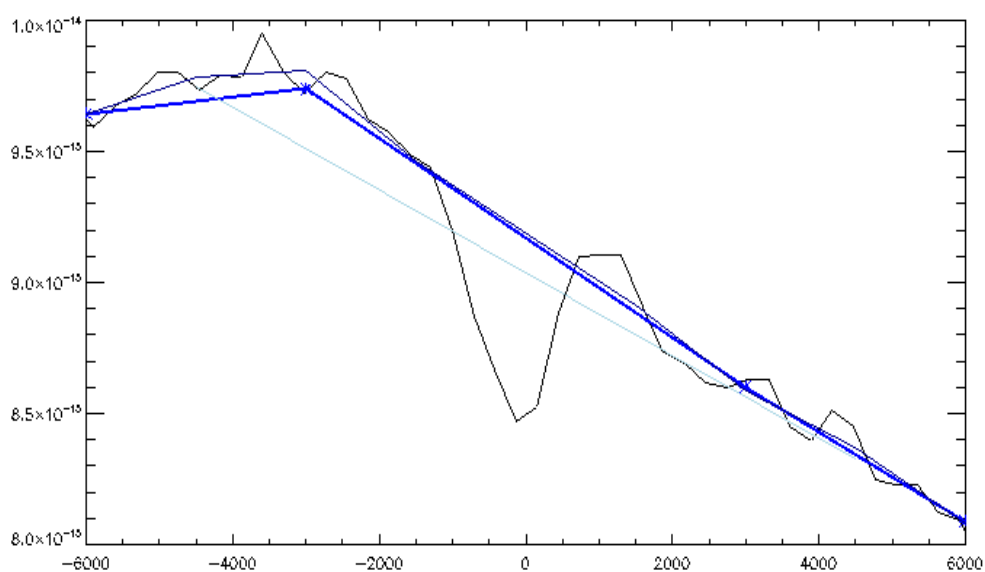


All phases w.r.t. maximum light

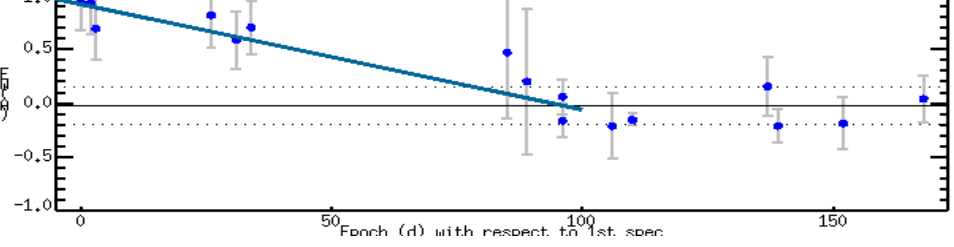
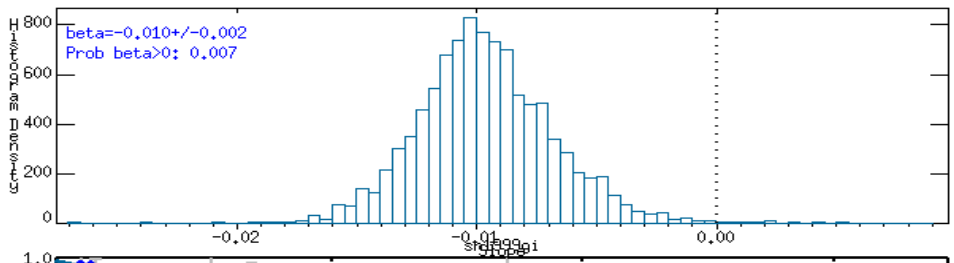
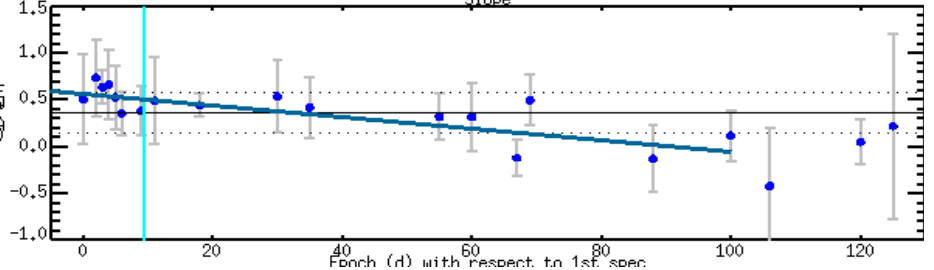
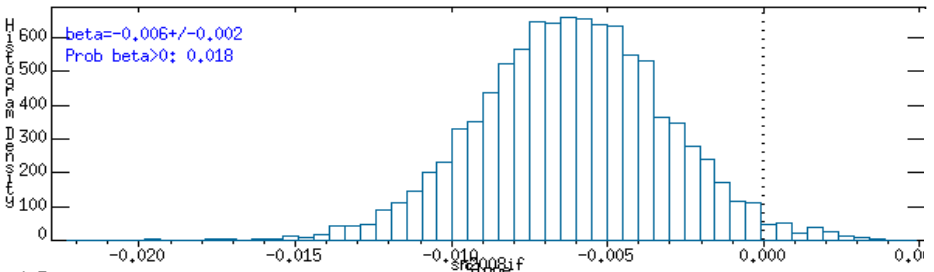
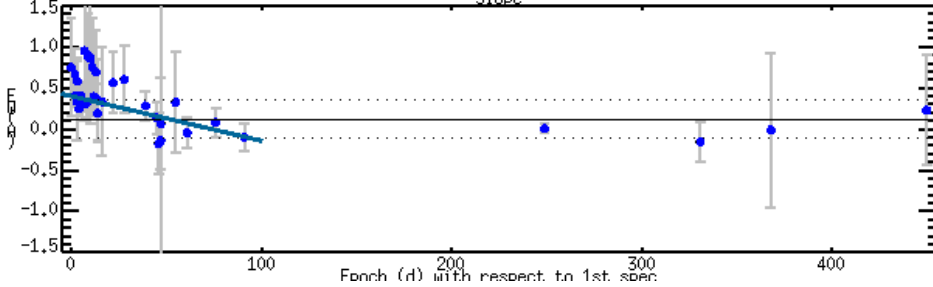
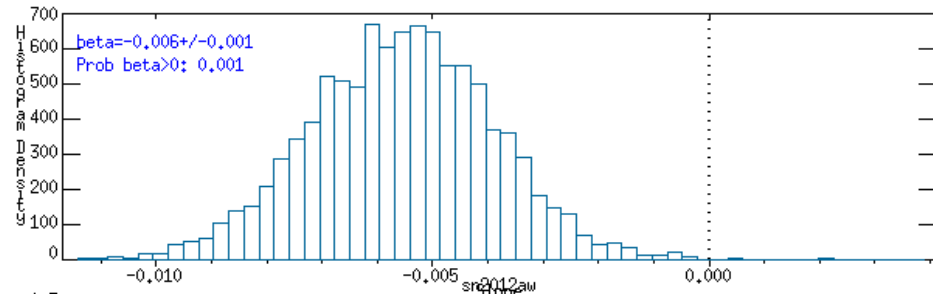
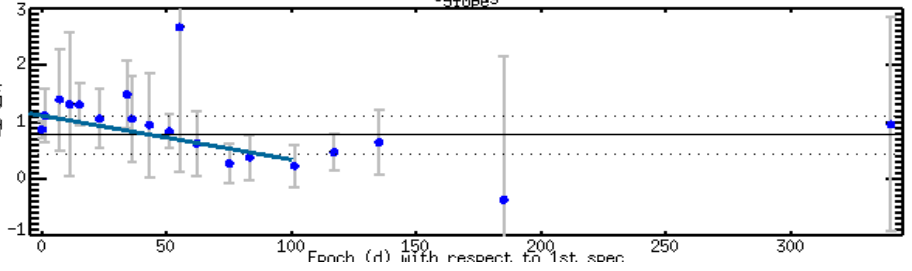
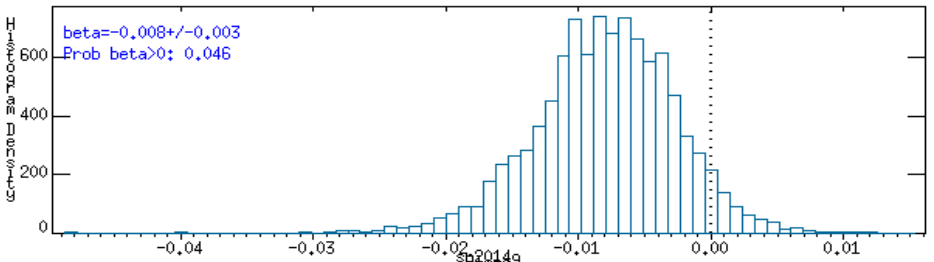
Evolution of the narrow NaID lines in SN spectra: measurements



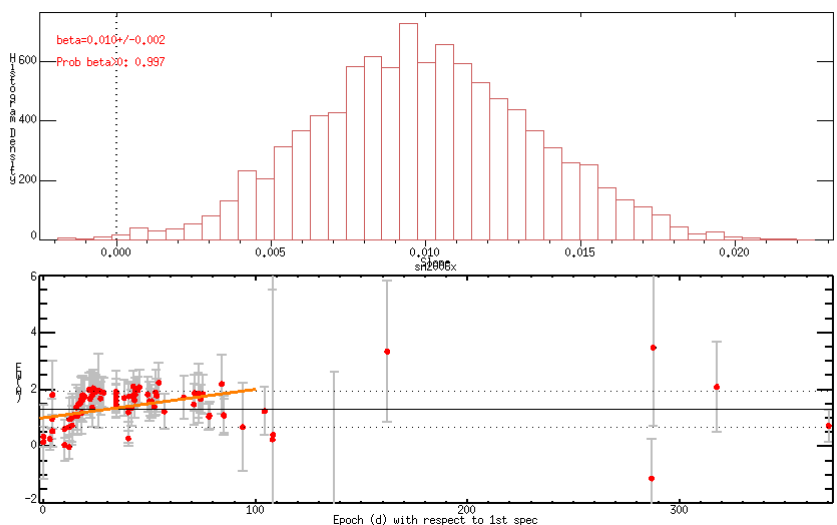
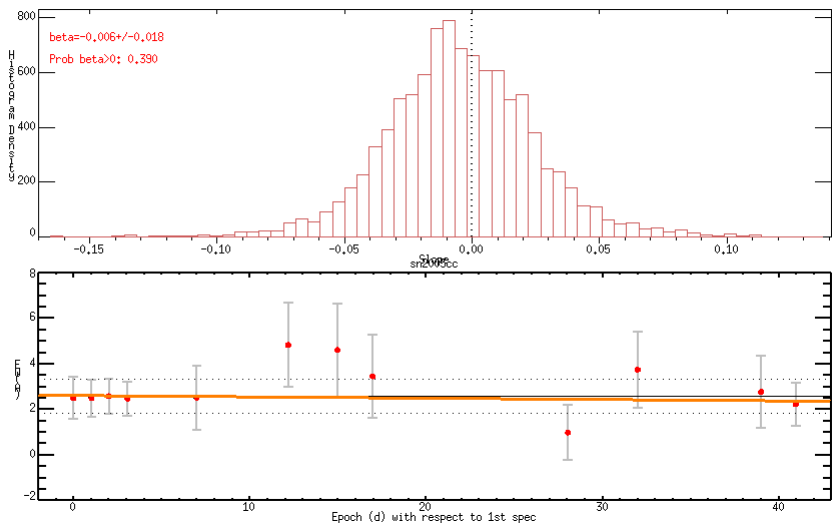
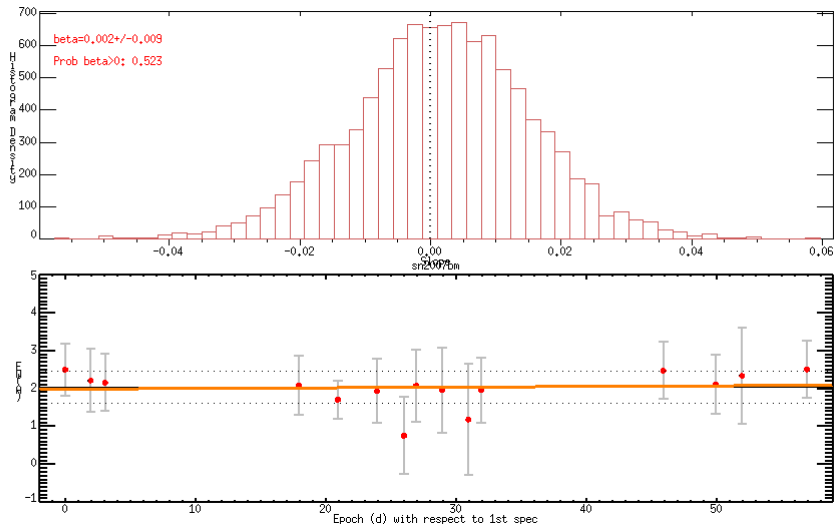
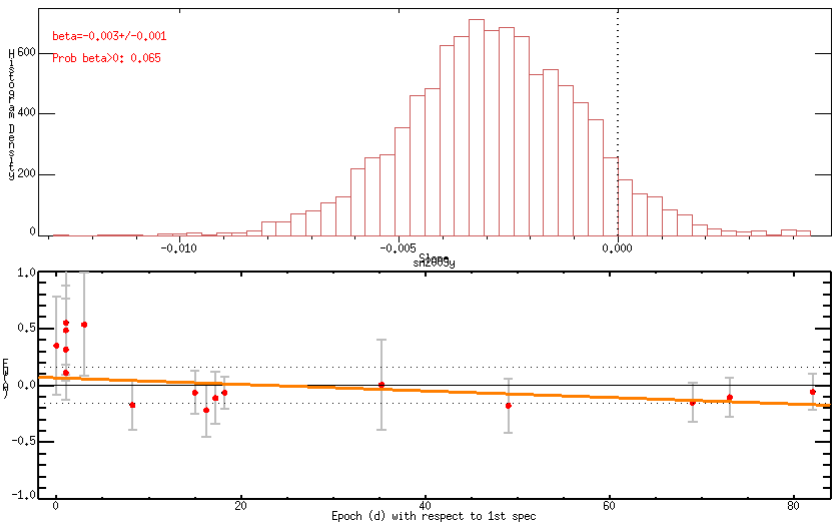
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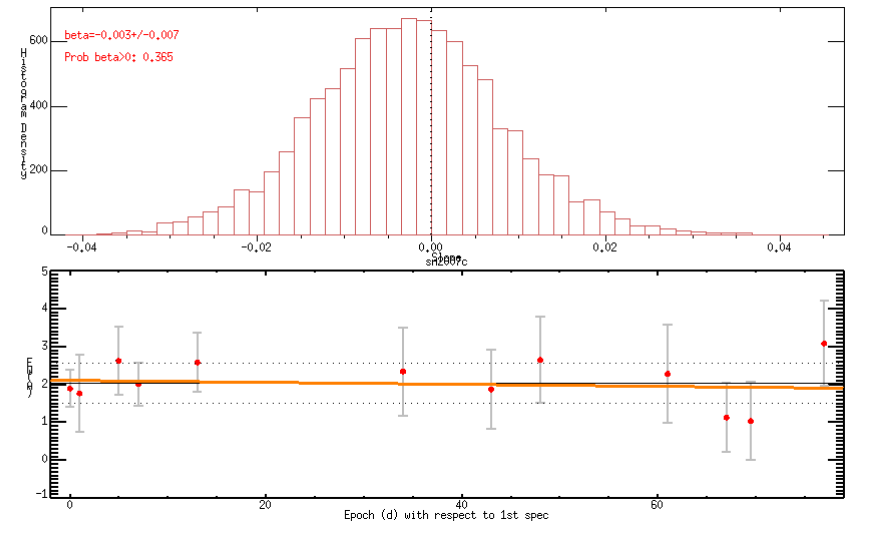
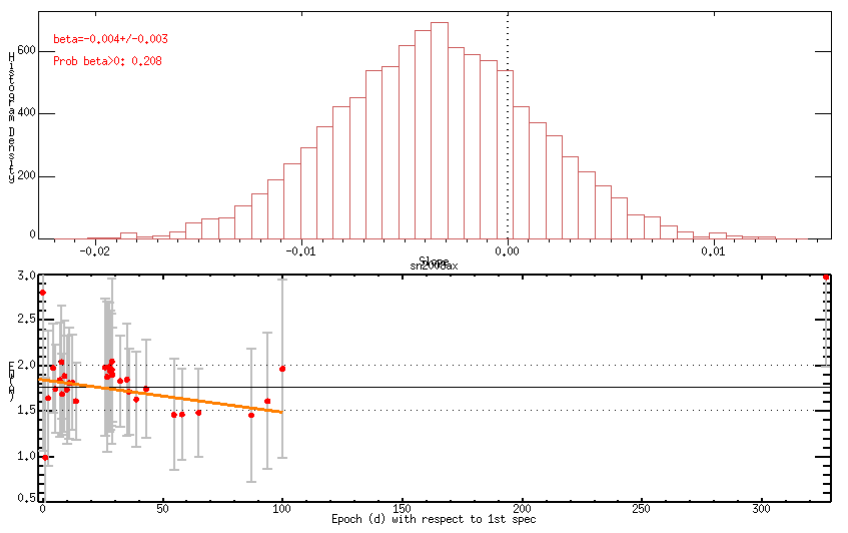
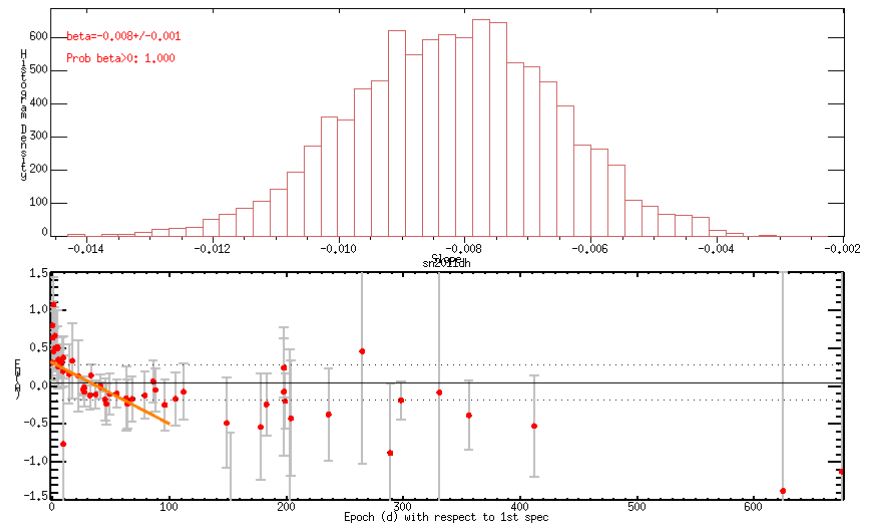
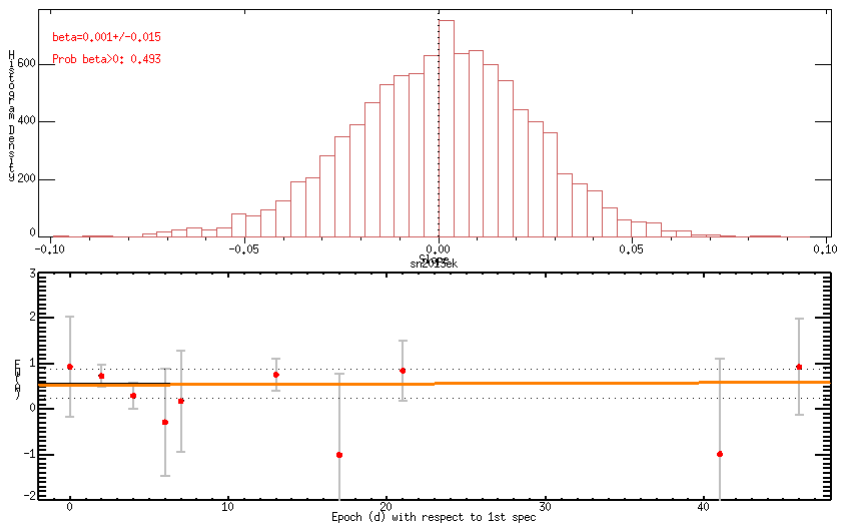
Evolution of the narrow NaID lines in SN spectra: measurements in SNe II



Evolution of the narrow NaID lines in SN spectra: measurements in SNe Ia



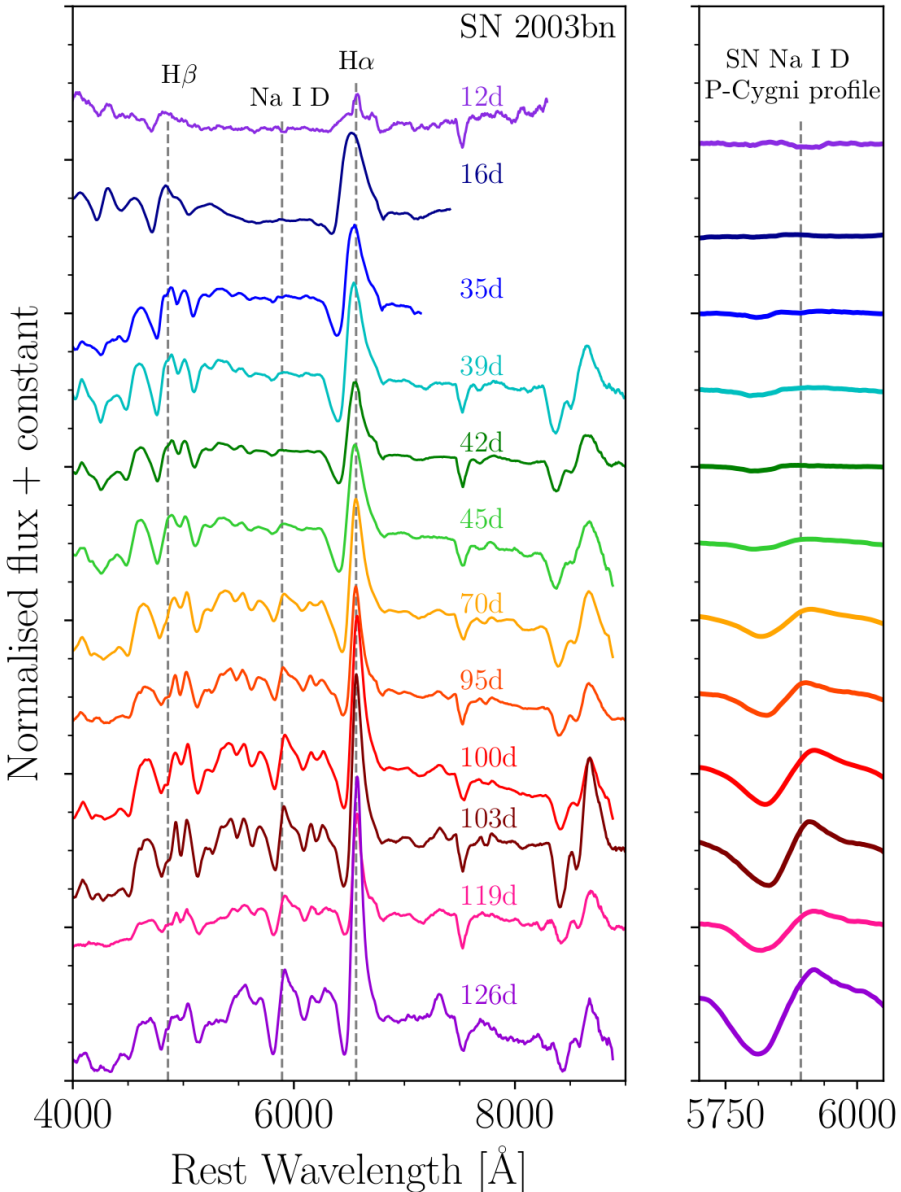
Evolution of the narrow NaID lines in SN spectra: measurements in SESNe



Evolution of the narrow NaID lines in SN spectra: simulation

Evolution of the narrow Na I D lines in SN spectra: simulation

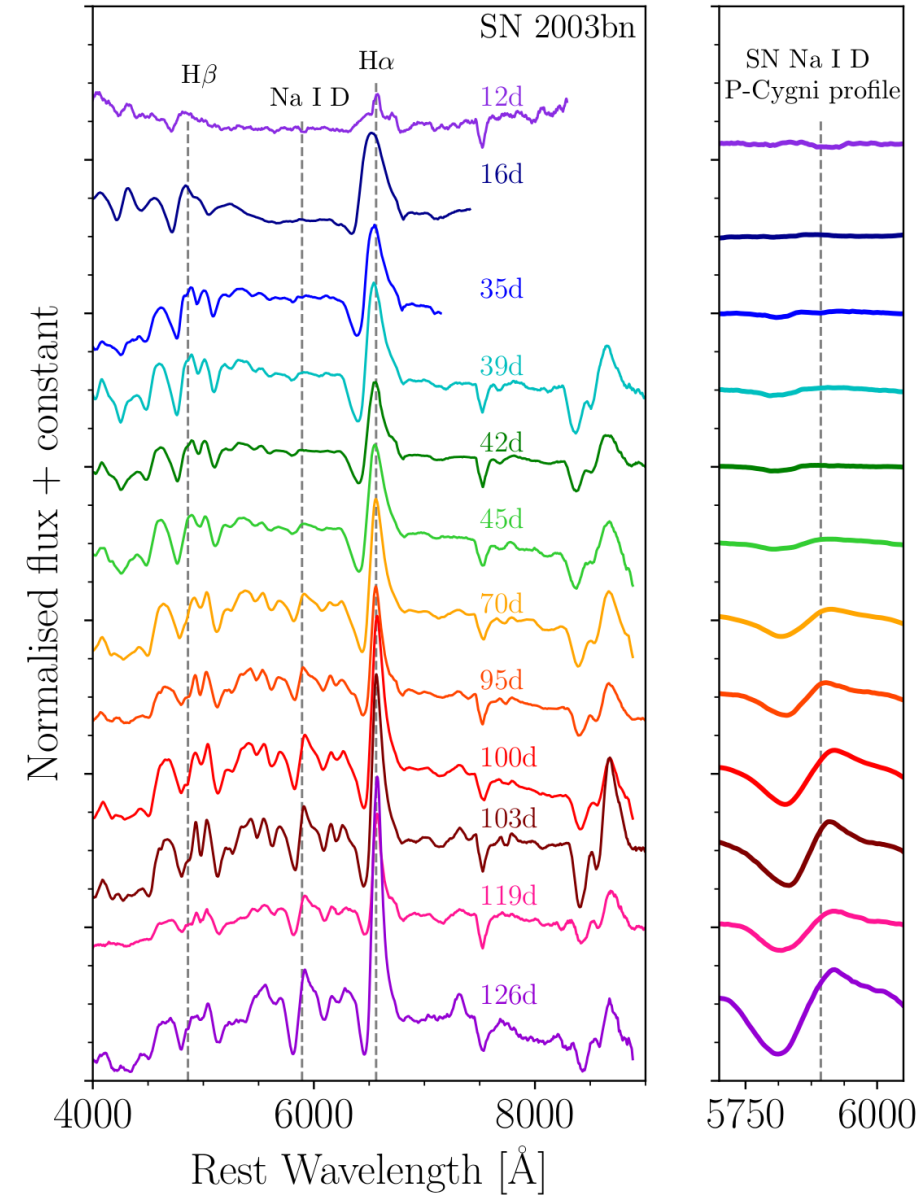
1. Smooth the data



Evolution of the narrow Na I D lines in SN spectra: simulation

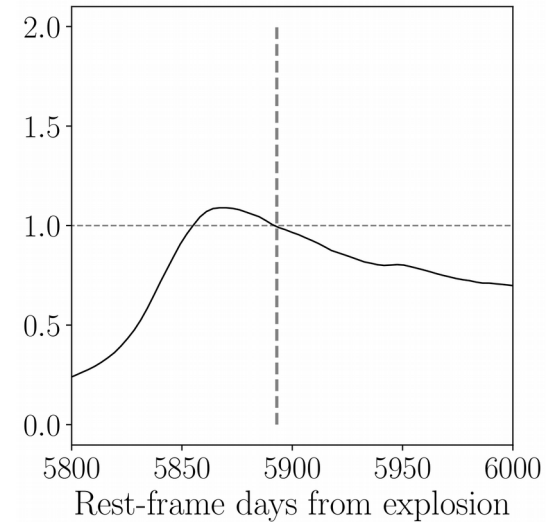
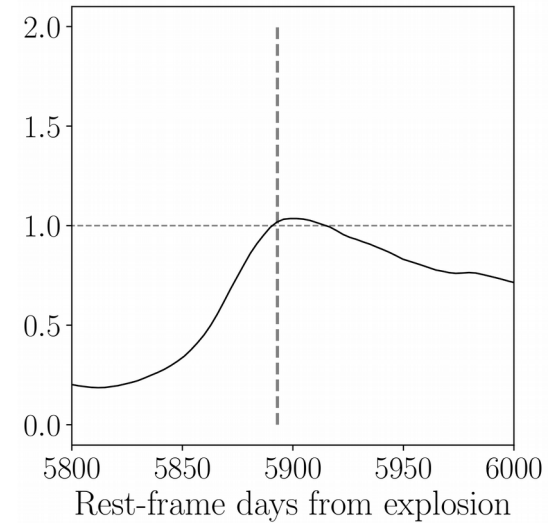
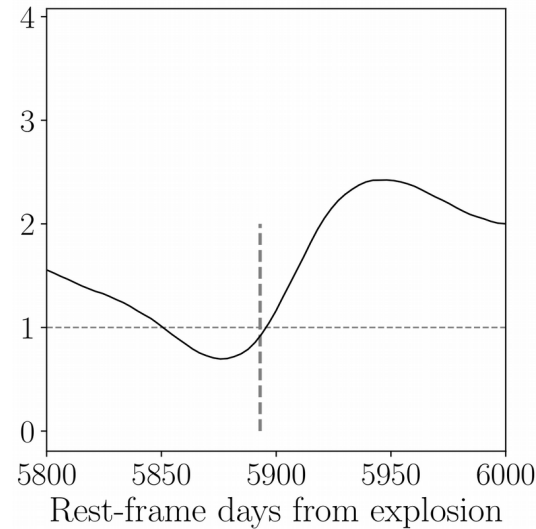
1. Smooth the data

2. Normalise the spectra



Seven different redshifts were selected:

- $z_0 = \text{Rest-frame}$
- $z_1 = 0.0014$
- $z_2 = 0.0035$
- $z_3 = 0.0063$
- $z_4 = 0.0084$
- $z_5 = -0.0054$
- $z_6 = -0.0095$



Evolution of the narrow NaID lines in SN spectra: simulation

3. Introduce a narrow line (NaID) in the SN spectra

Three different EWs for low/high resolution

Low resolution:

EW1 = 1.1 Å

EW2 = 2.2 Å

EW3 = 4.3 Å

High resolution:

EW1 = 0.56 Å

EW1 = 0.34 Å

EW2 = 1.12 Å

EW2 = 0.67 Å

EW3 = 0.28 Å

EW3 = 0.17 Å

Evolution of the narrow NaID lines in SN spectra: simulation

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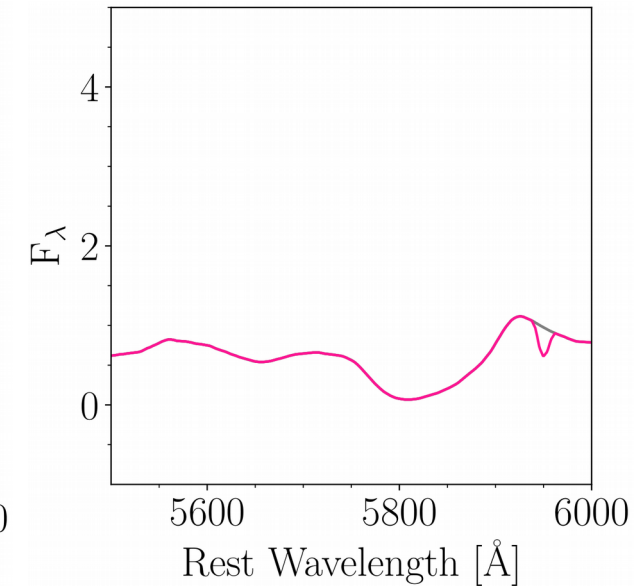
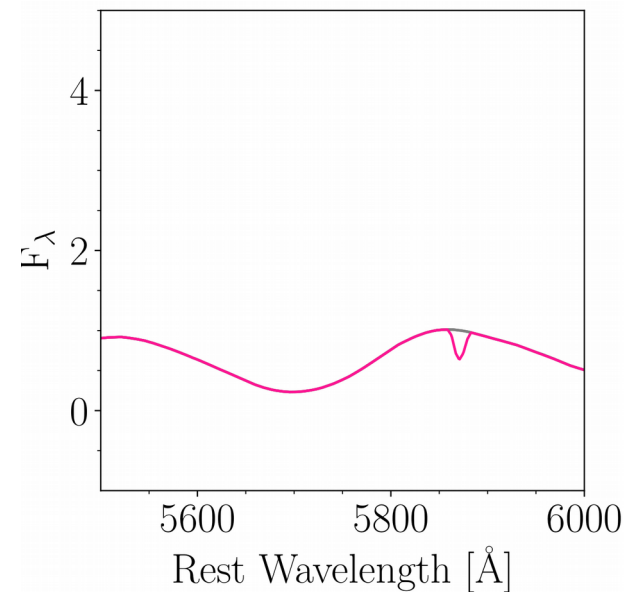
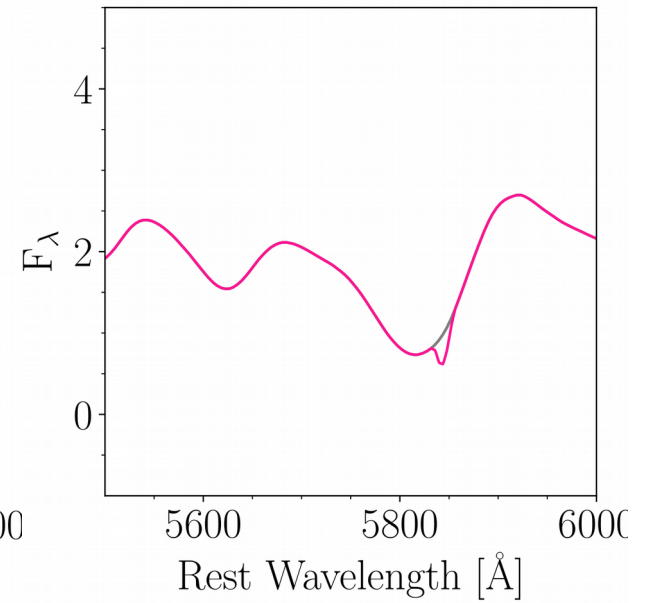
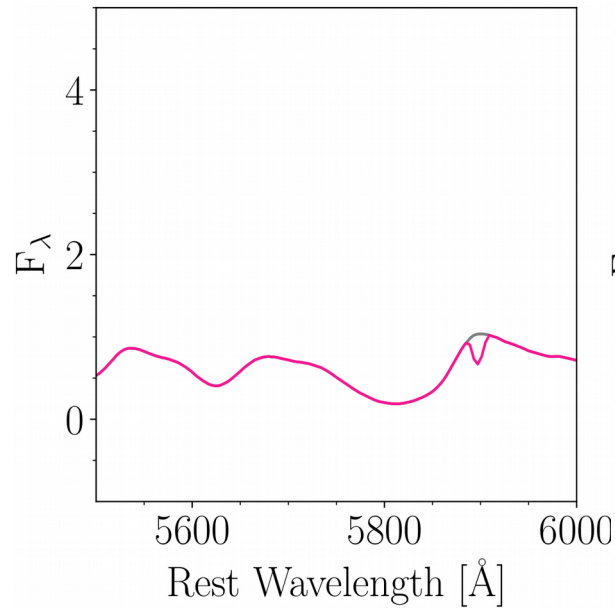
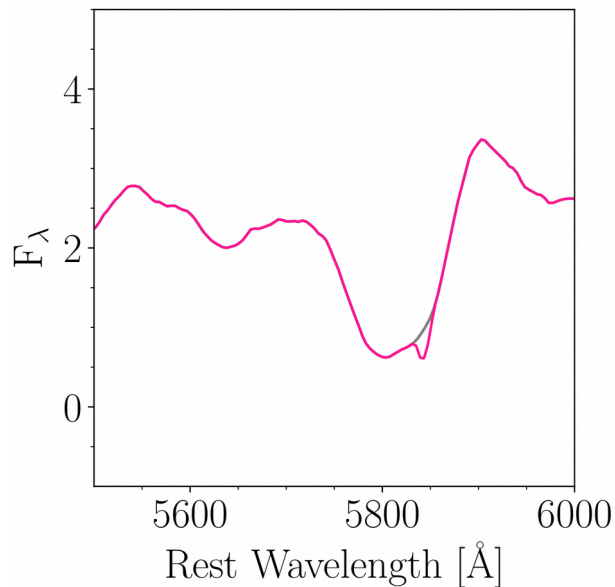
EW1 = 0.34 Å

EW2 = 1.12 Å

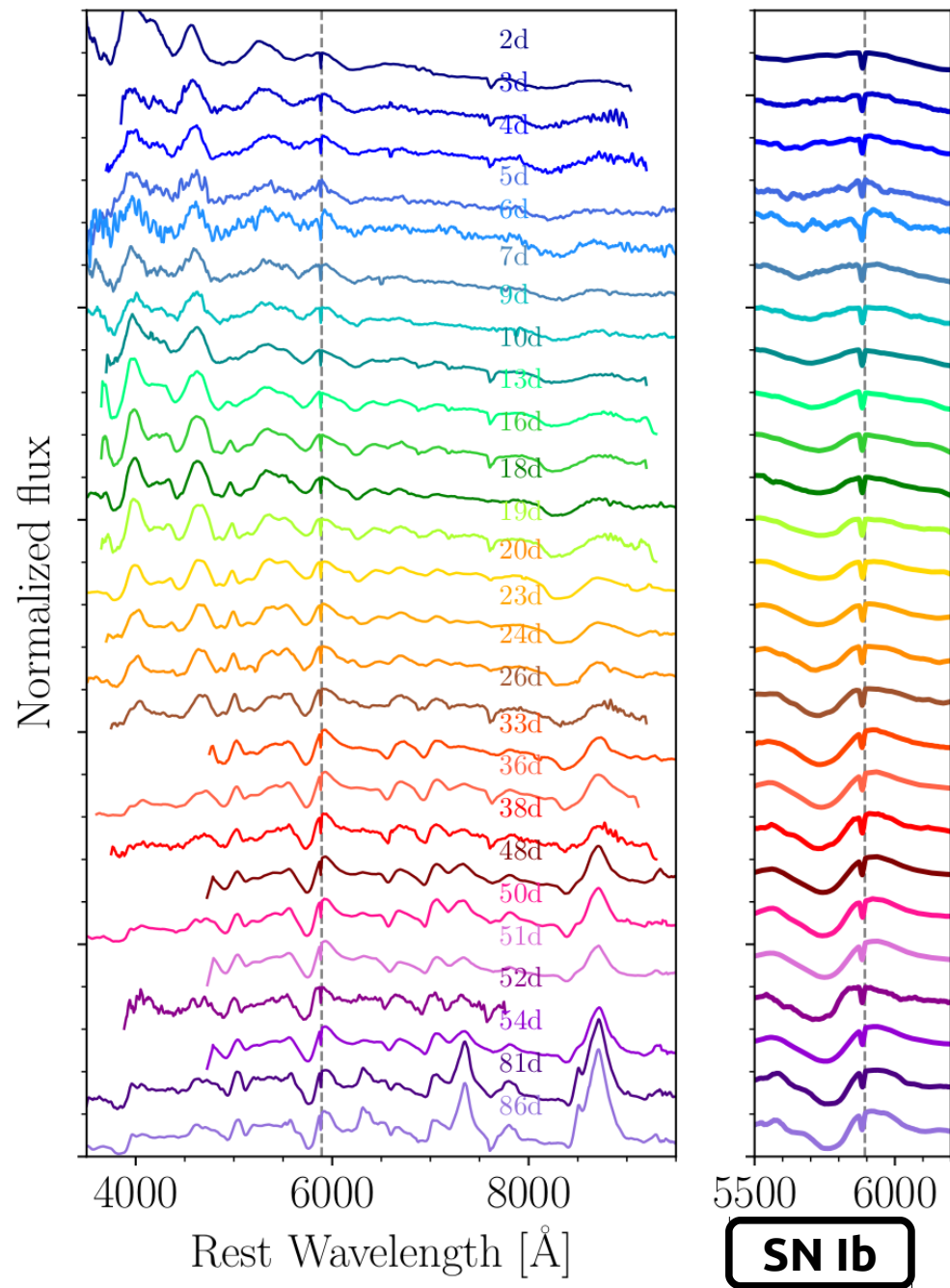
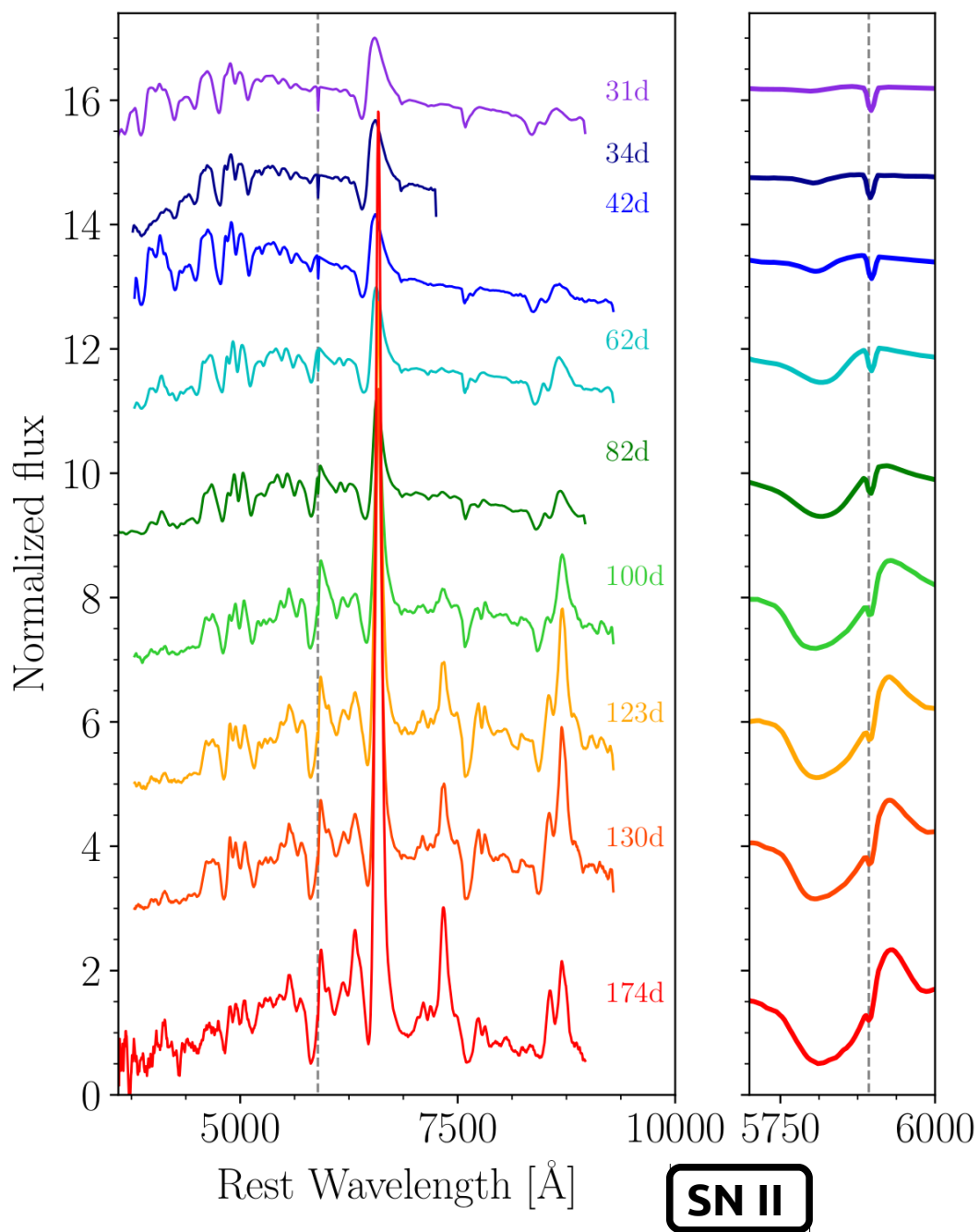
EW2 = 0.67 Å

EW3 = 0.28 Å

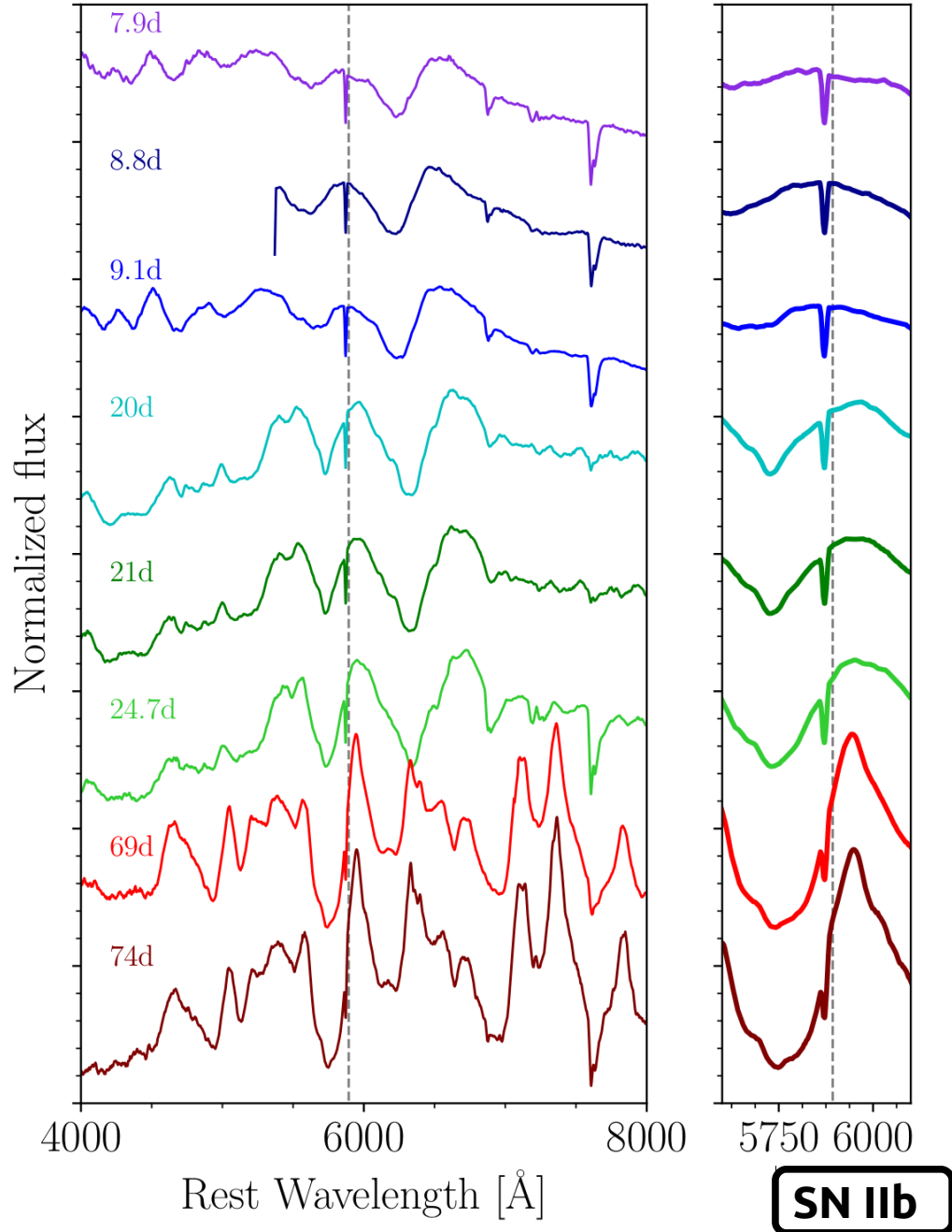
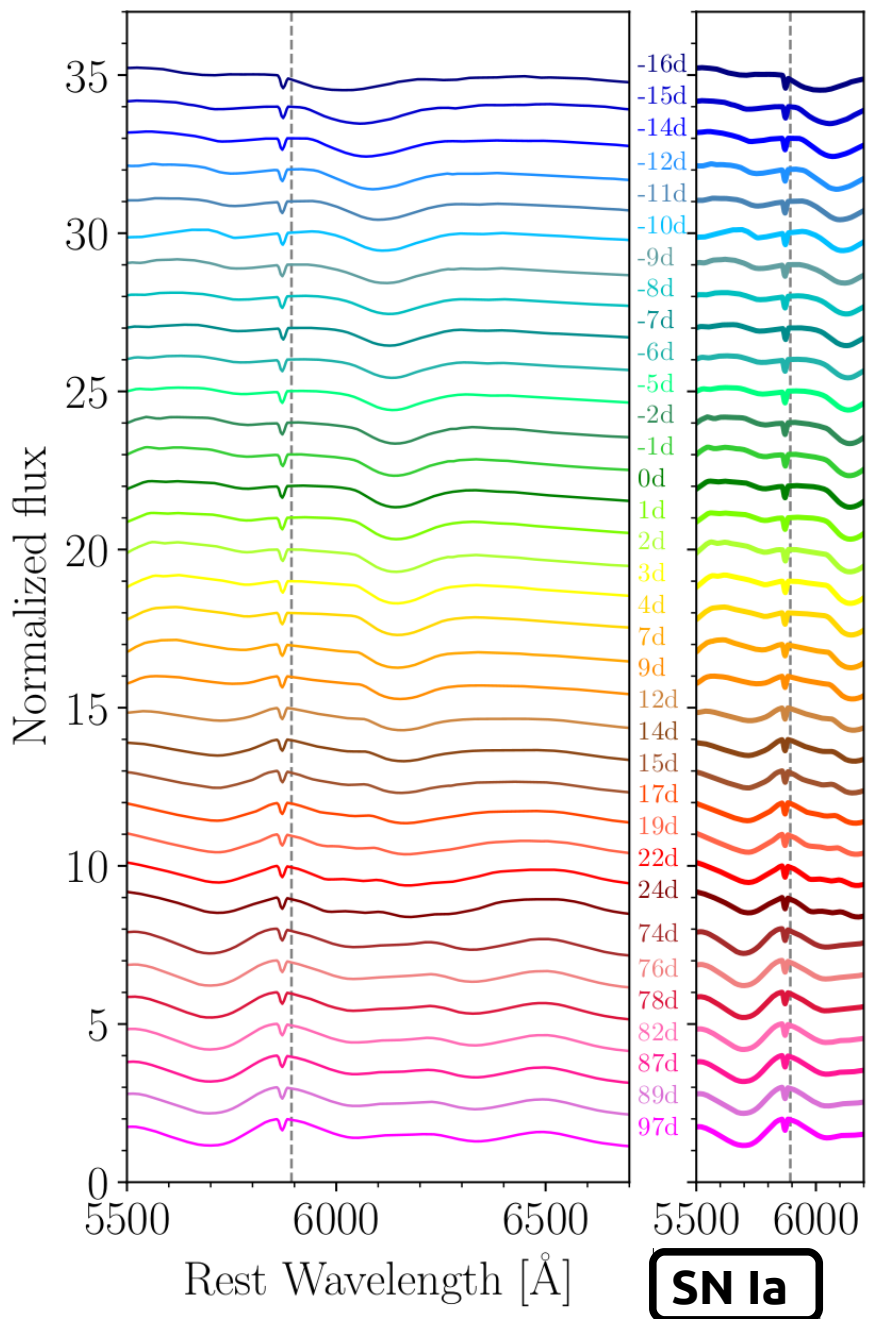
EW3 = 0.17 Å



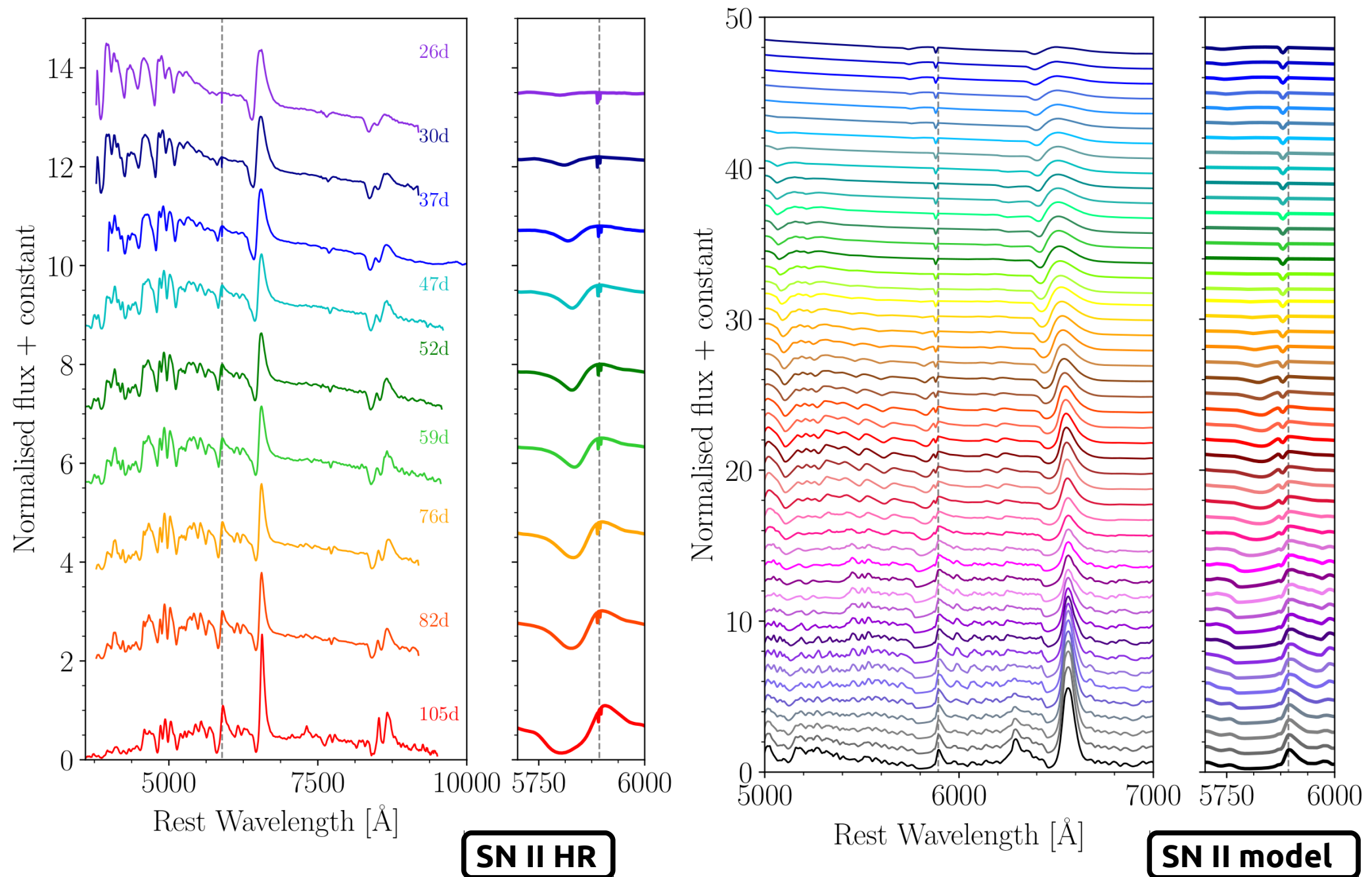
Evolution of the narrow NaID lines in SN spectra: simulation



Evolution of the narrow NaID lines in SN spectra: simulation

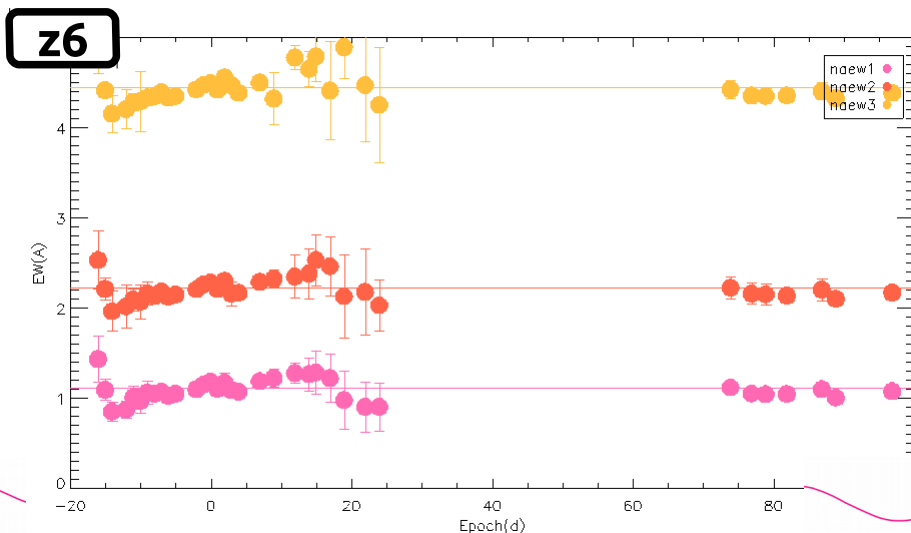
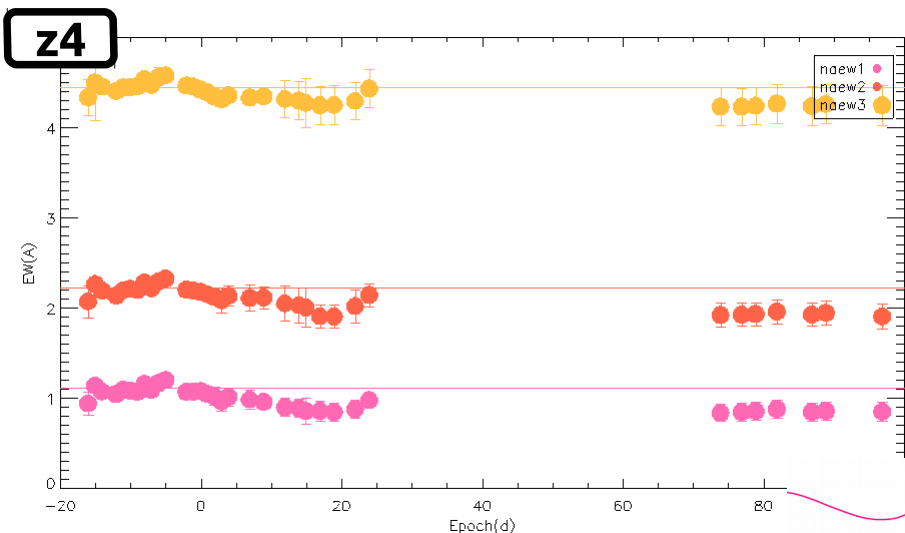
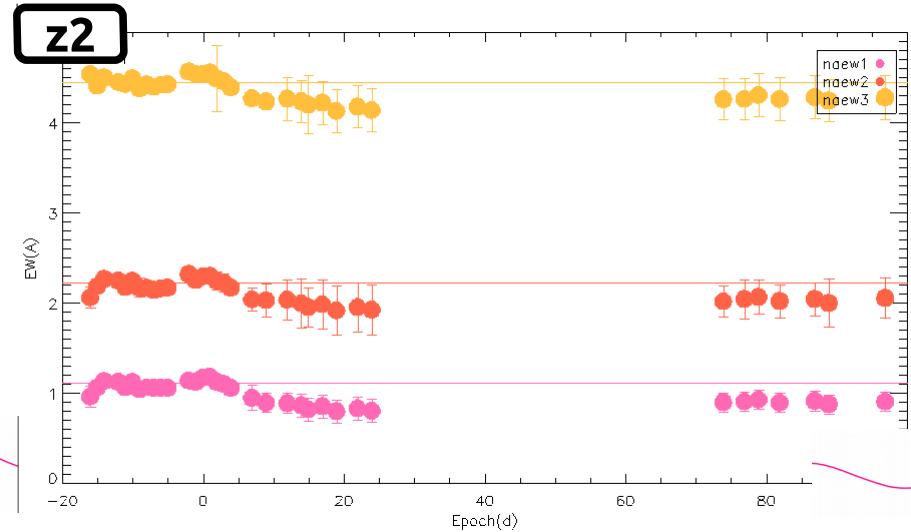
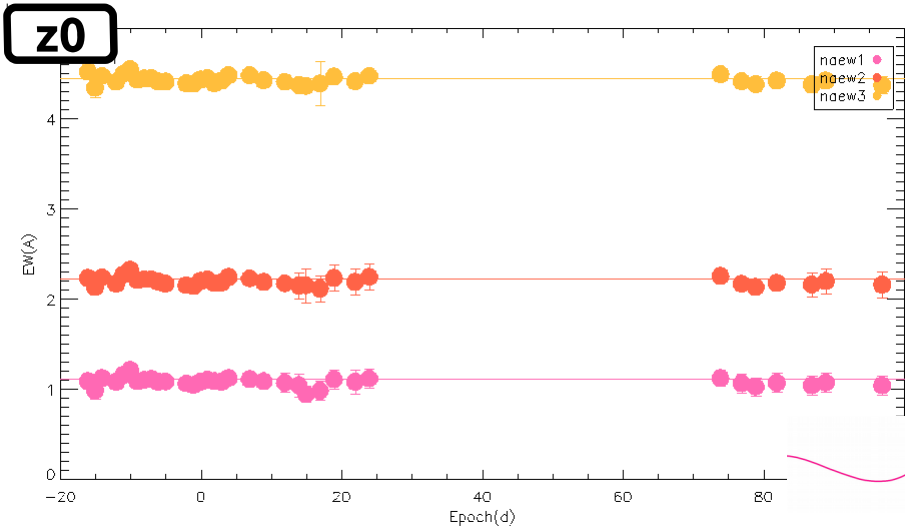


Evolution of the narrow NaID lines in SN spectra: simulation



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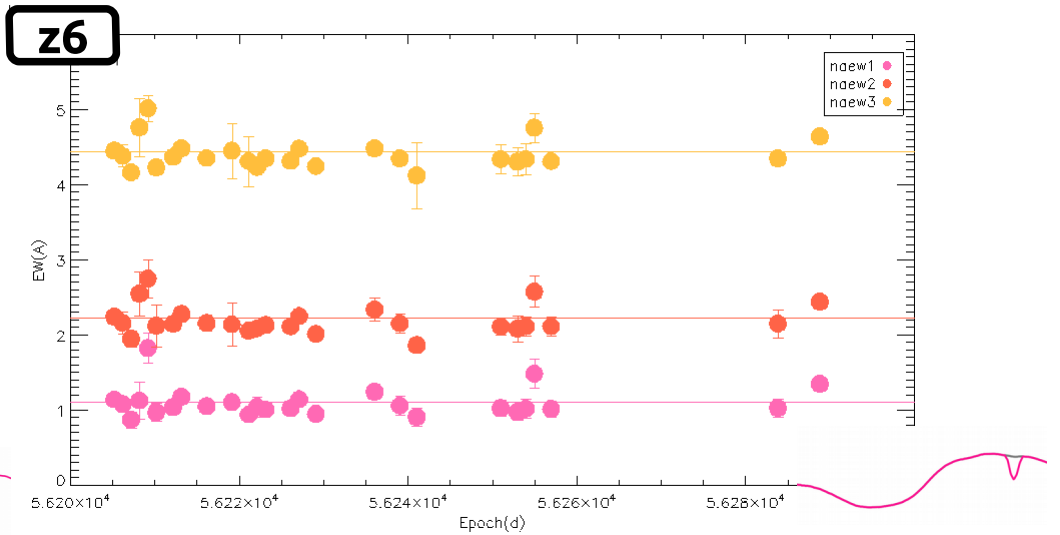
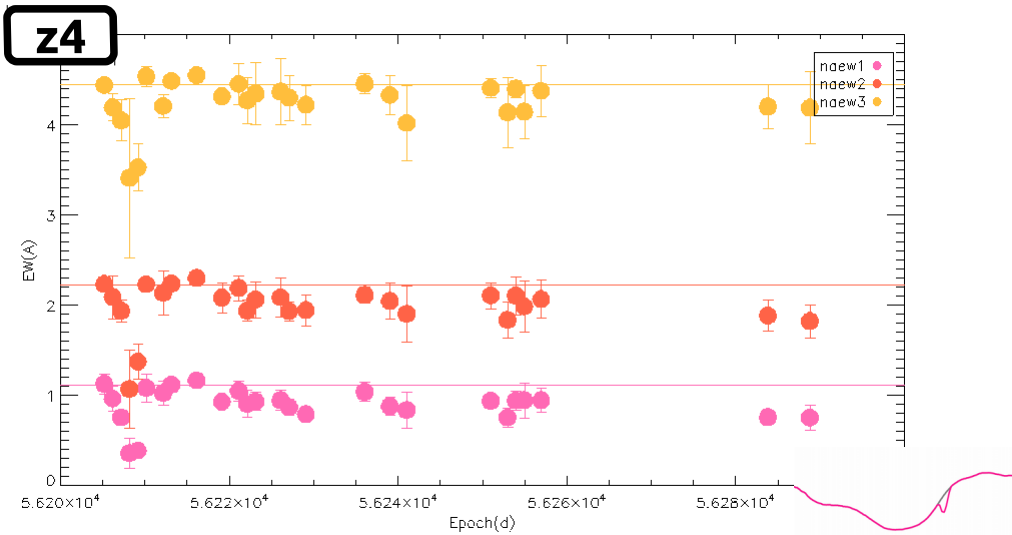
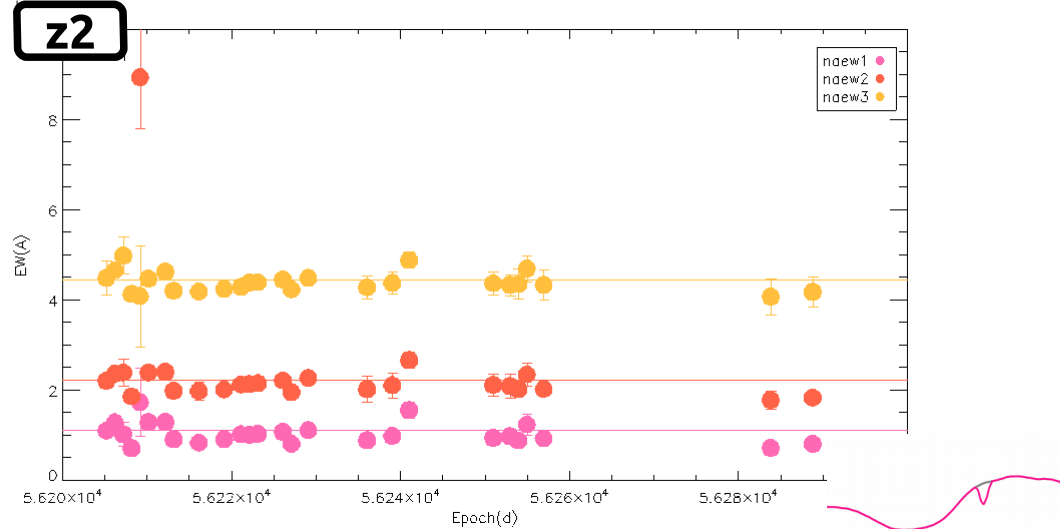
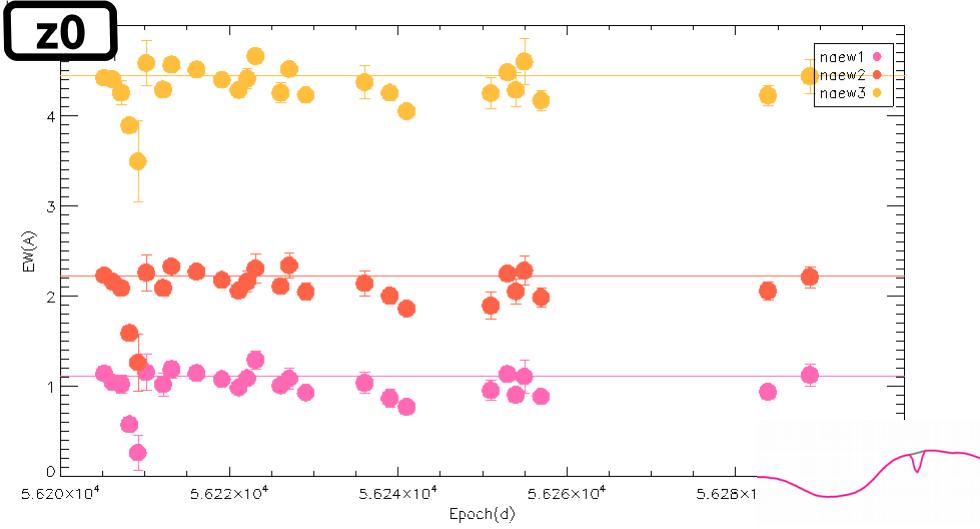
4. EW measurements



SNe Ia do not show (in general) an evolution in the EW(NaID)

Evolution of the narrow NaID lines in SN spectra: simulation

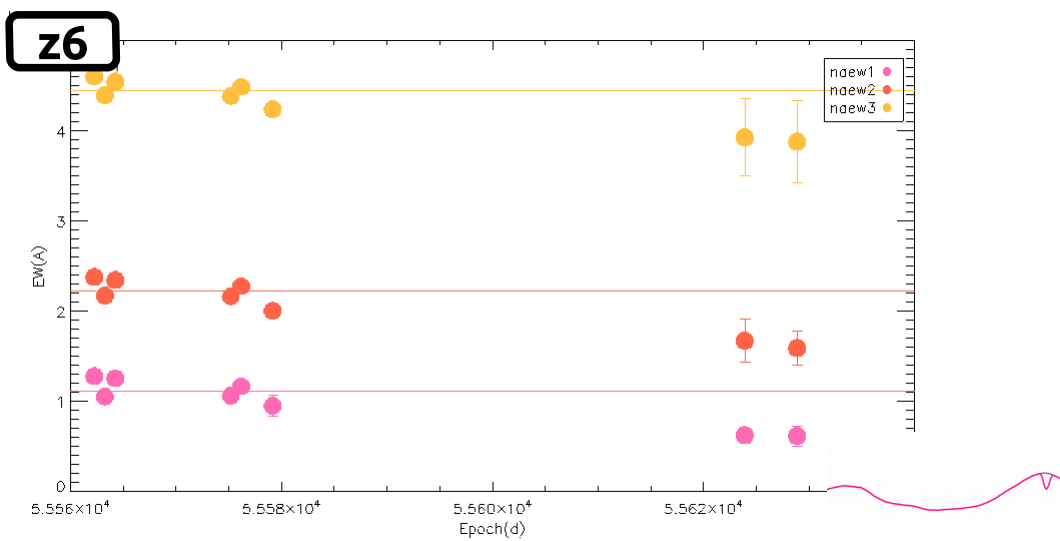
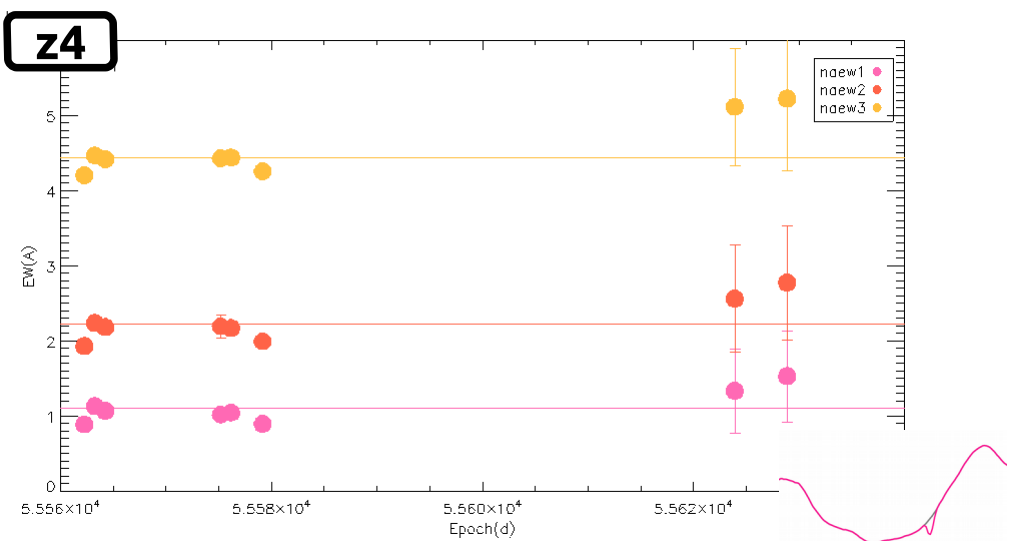
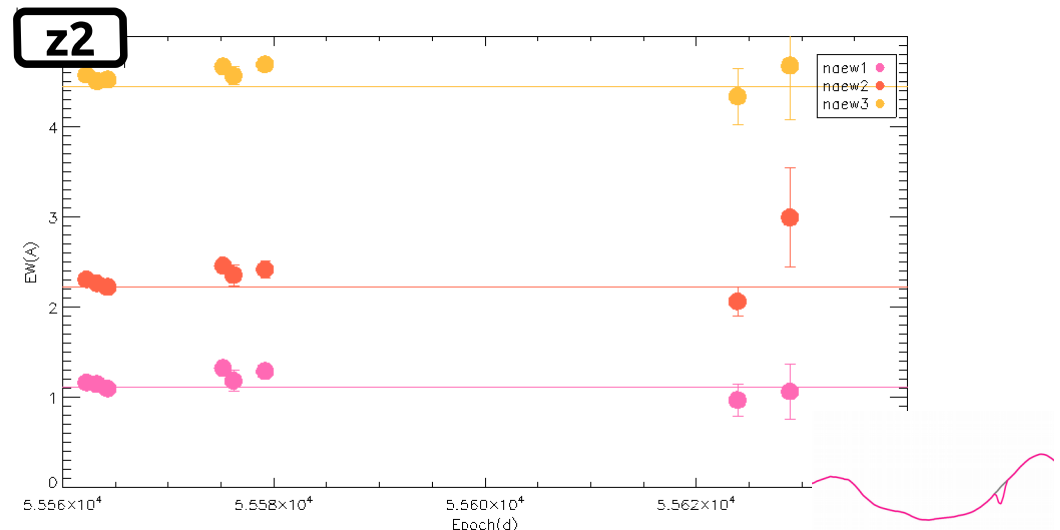
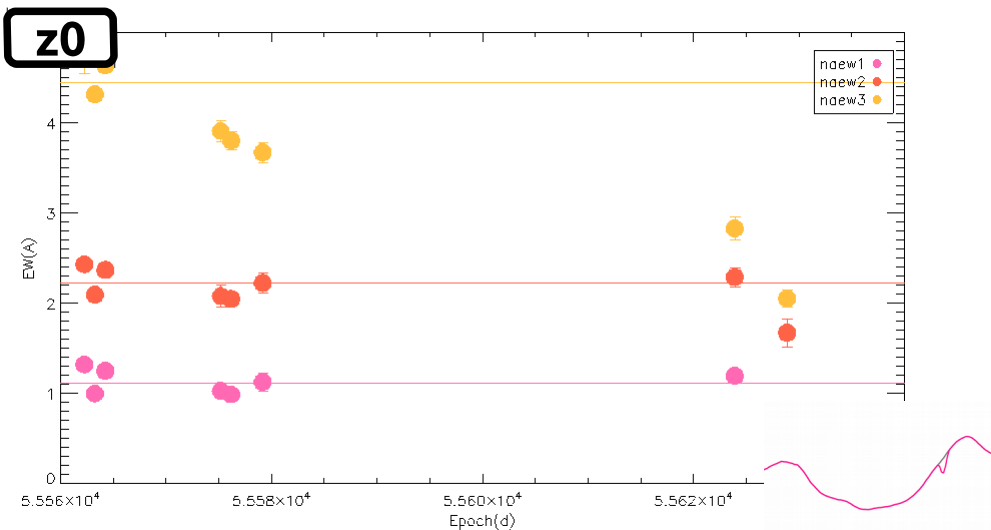
4. EW measurements



SNe Ib/c do not show an evolution in the EW(NaID)

Evolution of the narrow NaID lines in SN spectra: simulation

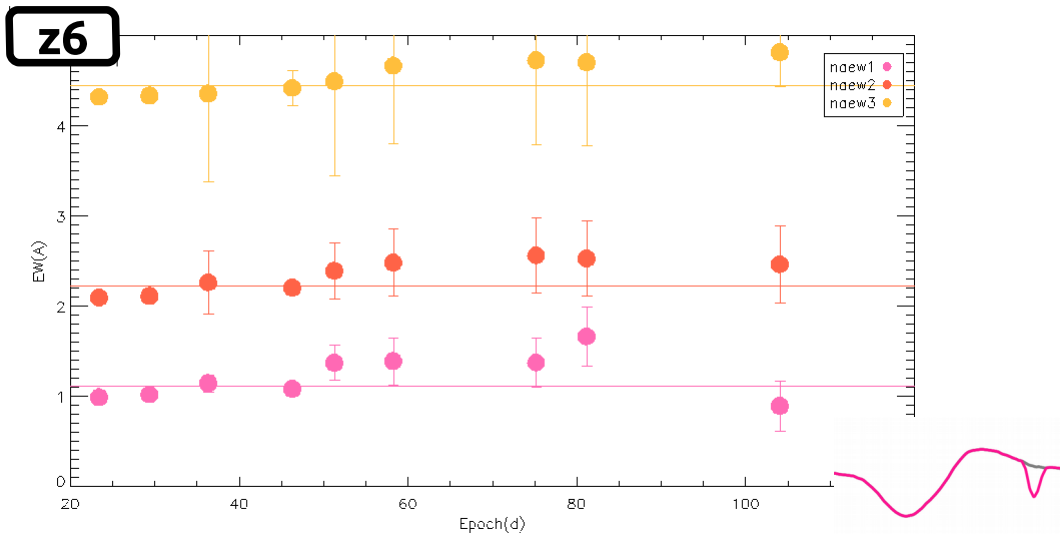
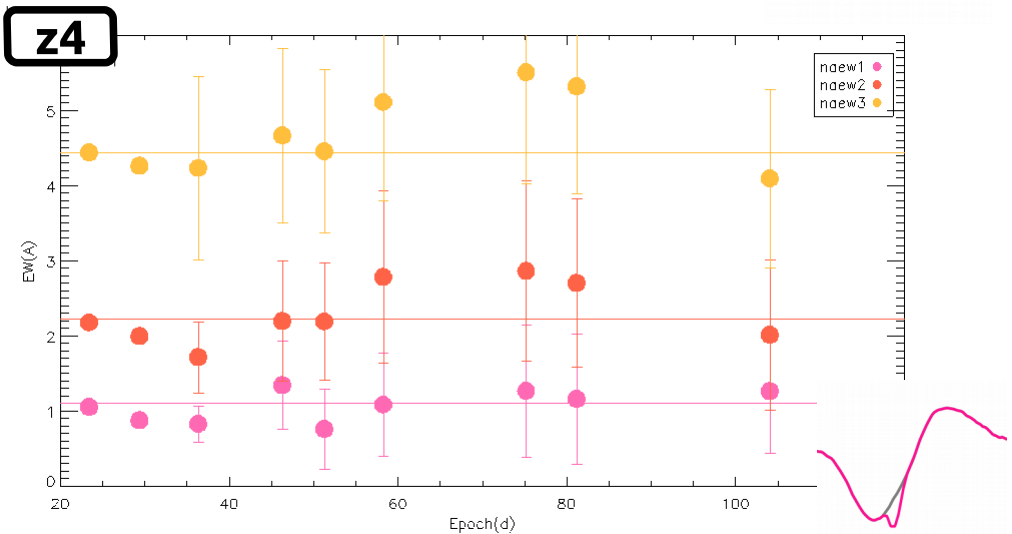
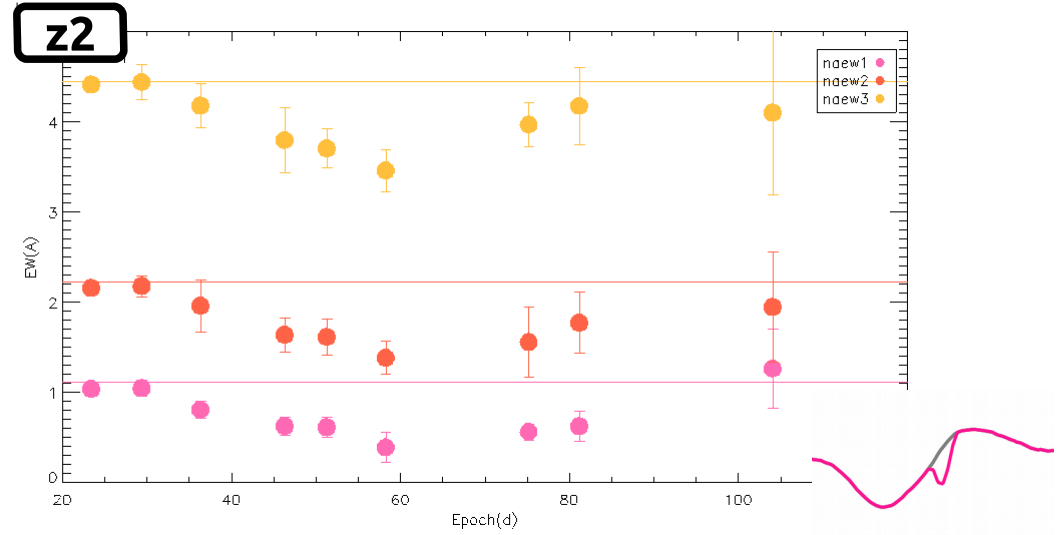
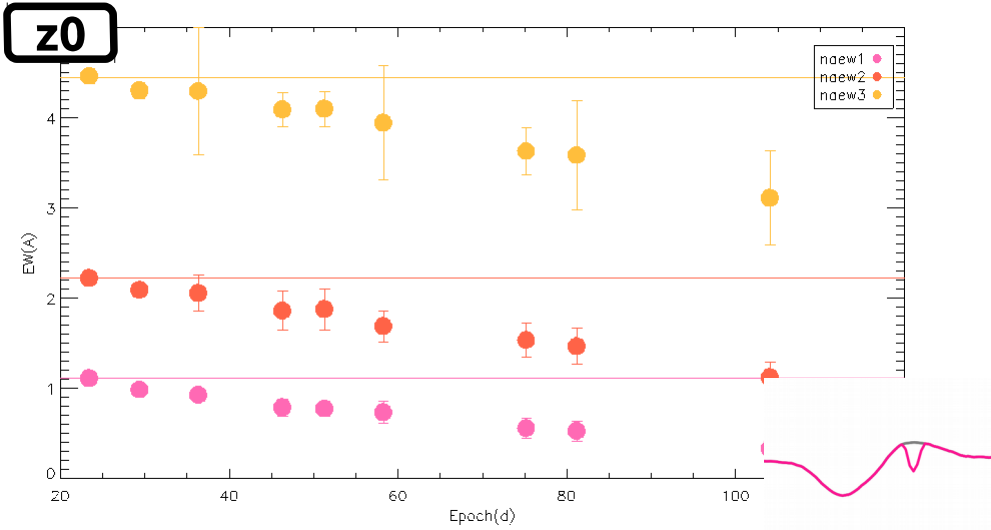
4. EW measurements



SNe I Ib show (in general) an evolution in the EW(NaID)

Evolution of the narrow NaID lines in SN spectra: simulation

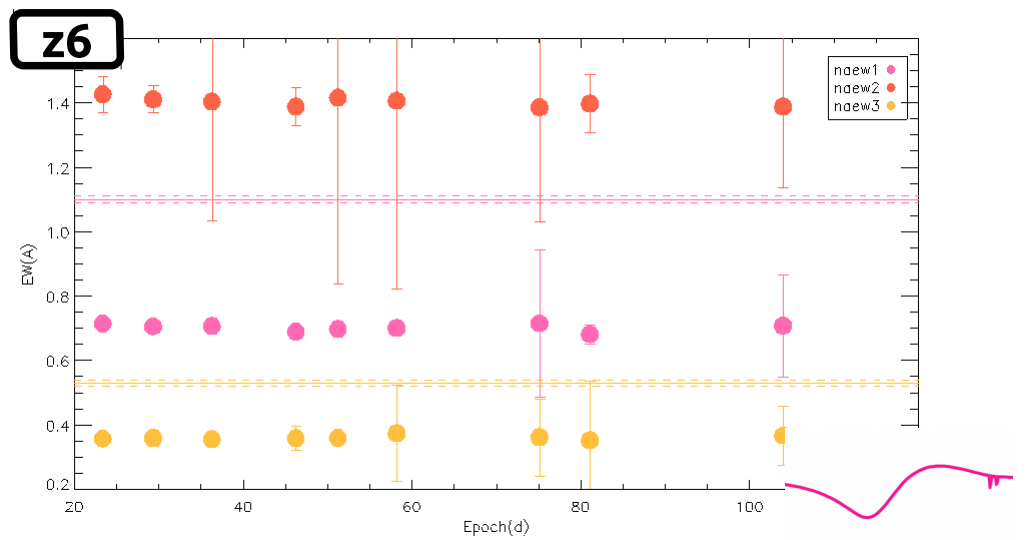
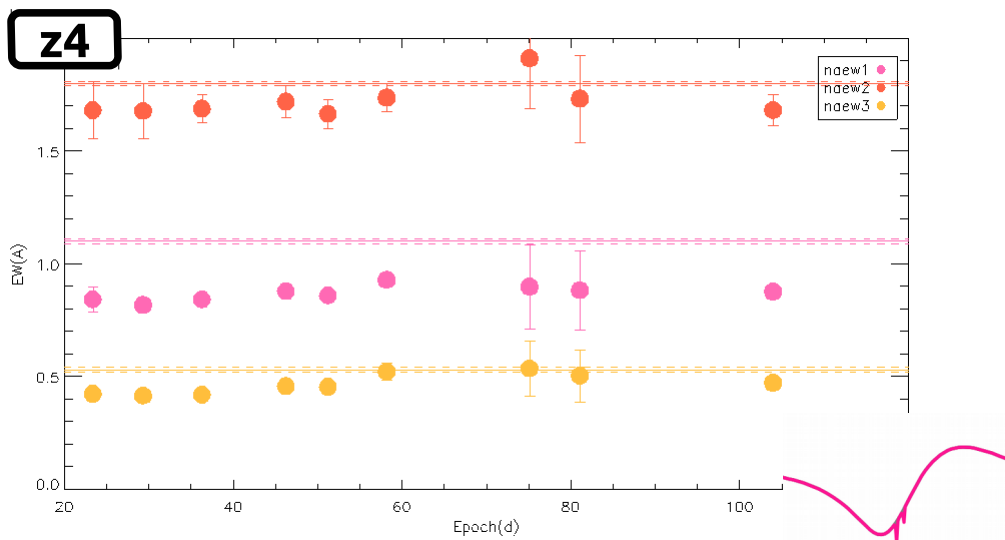
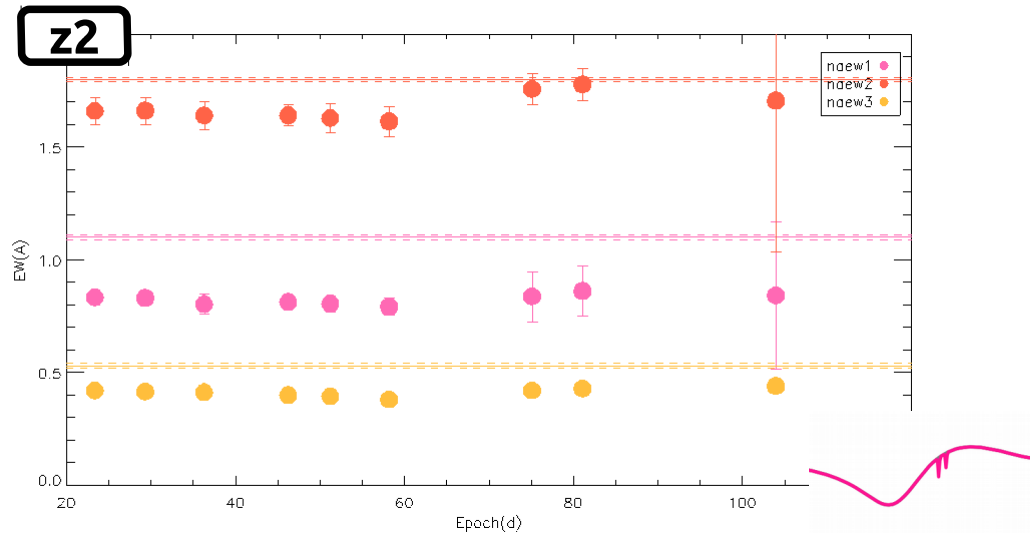
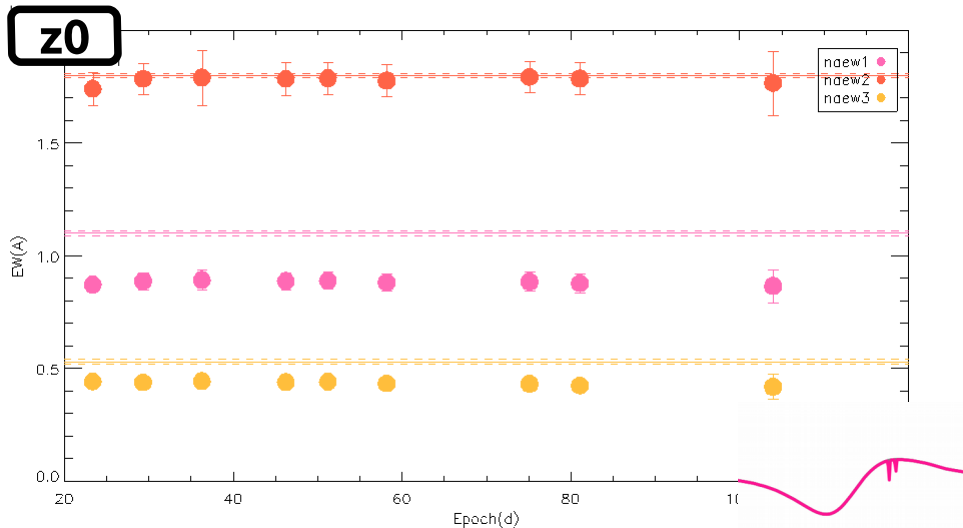
4. EW measurements



SNe II show an evolution in the EW(NaID)

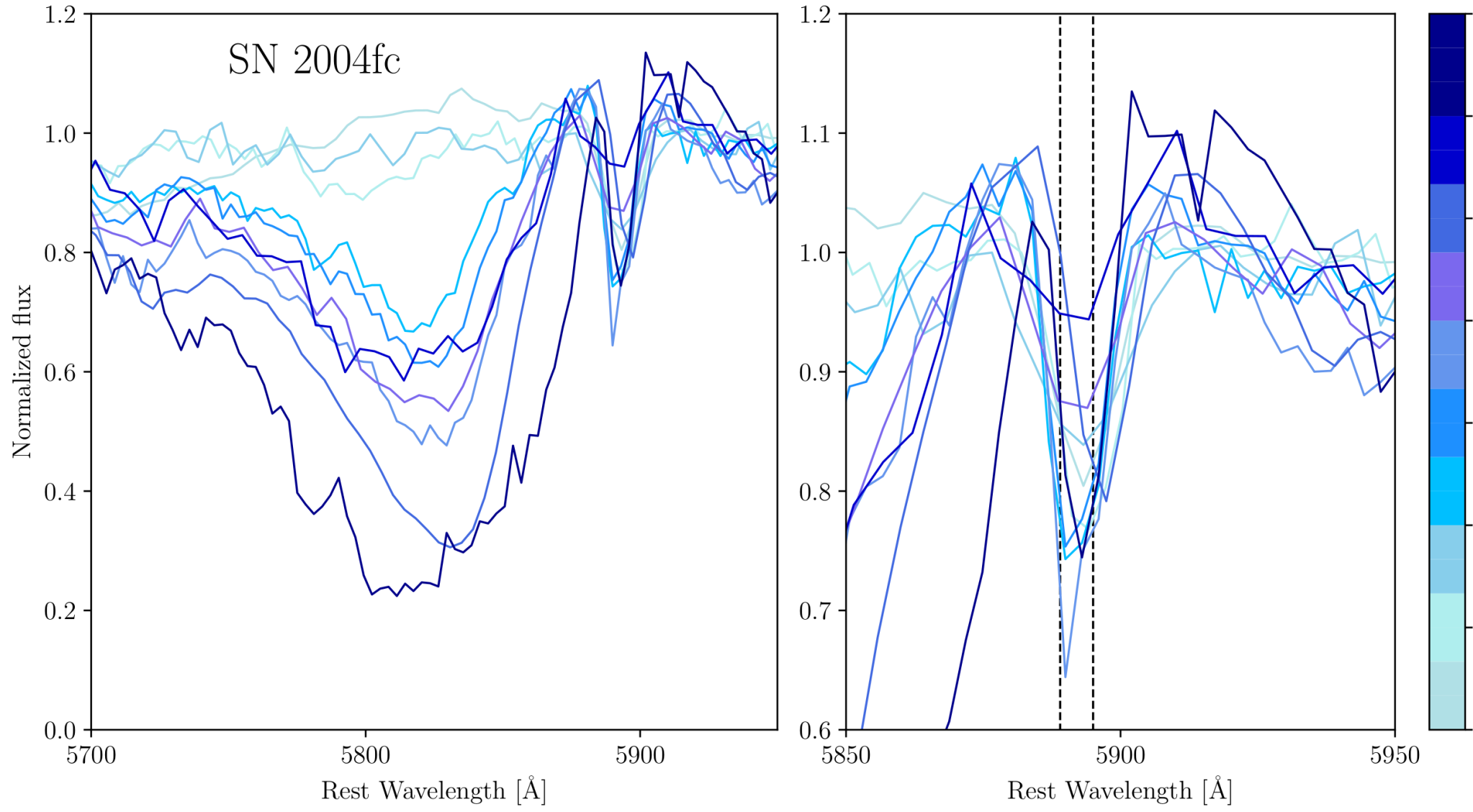
Evolution of the narrow NaID lines in SN spectra: simulation

4. EW measurements: High resolution (HR)

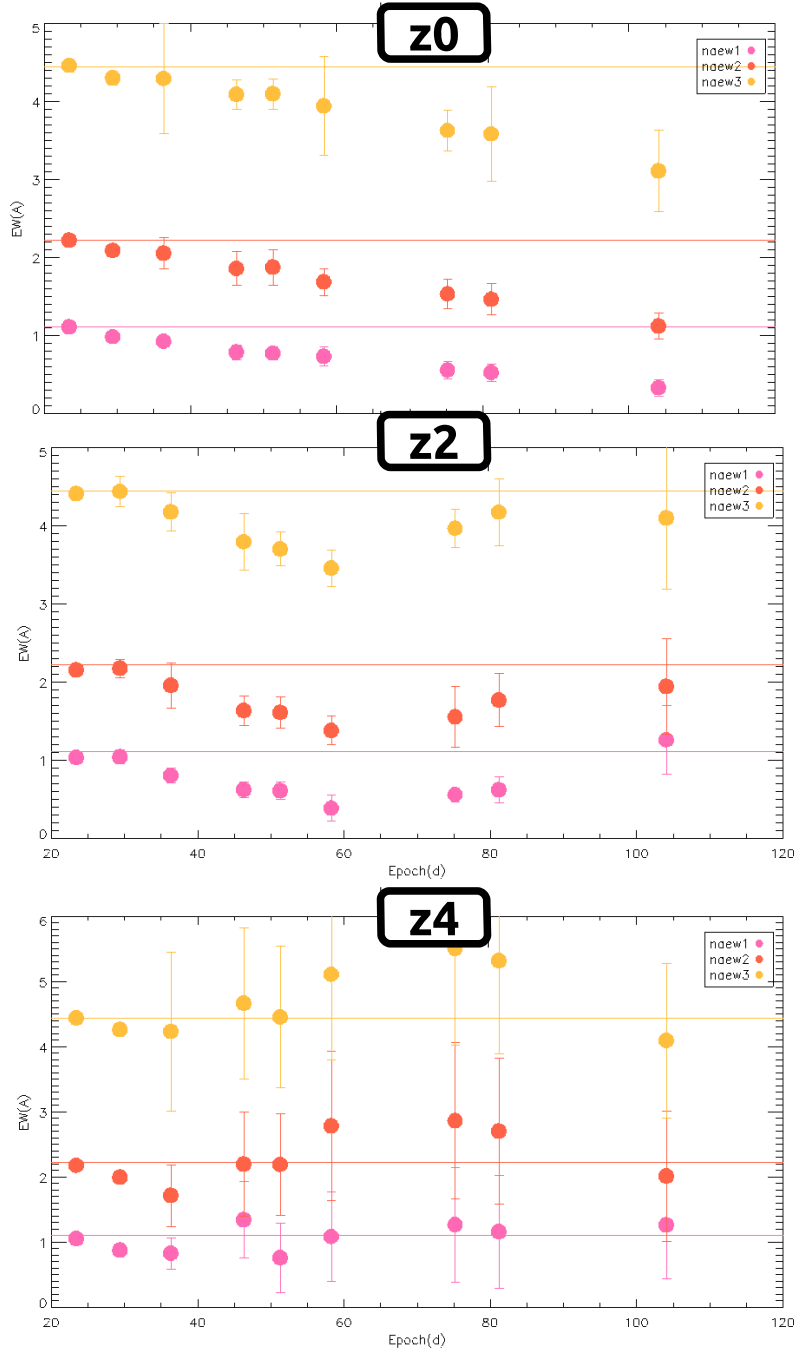
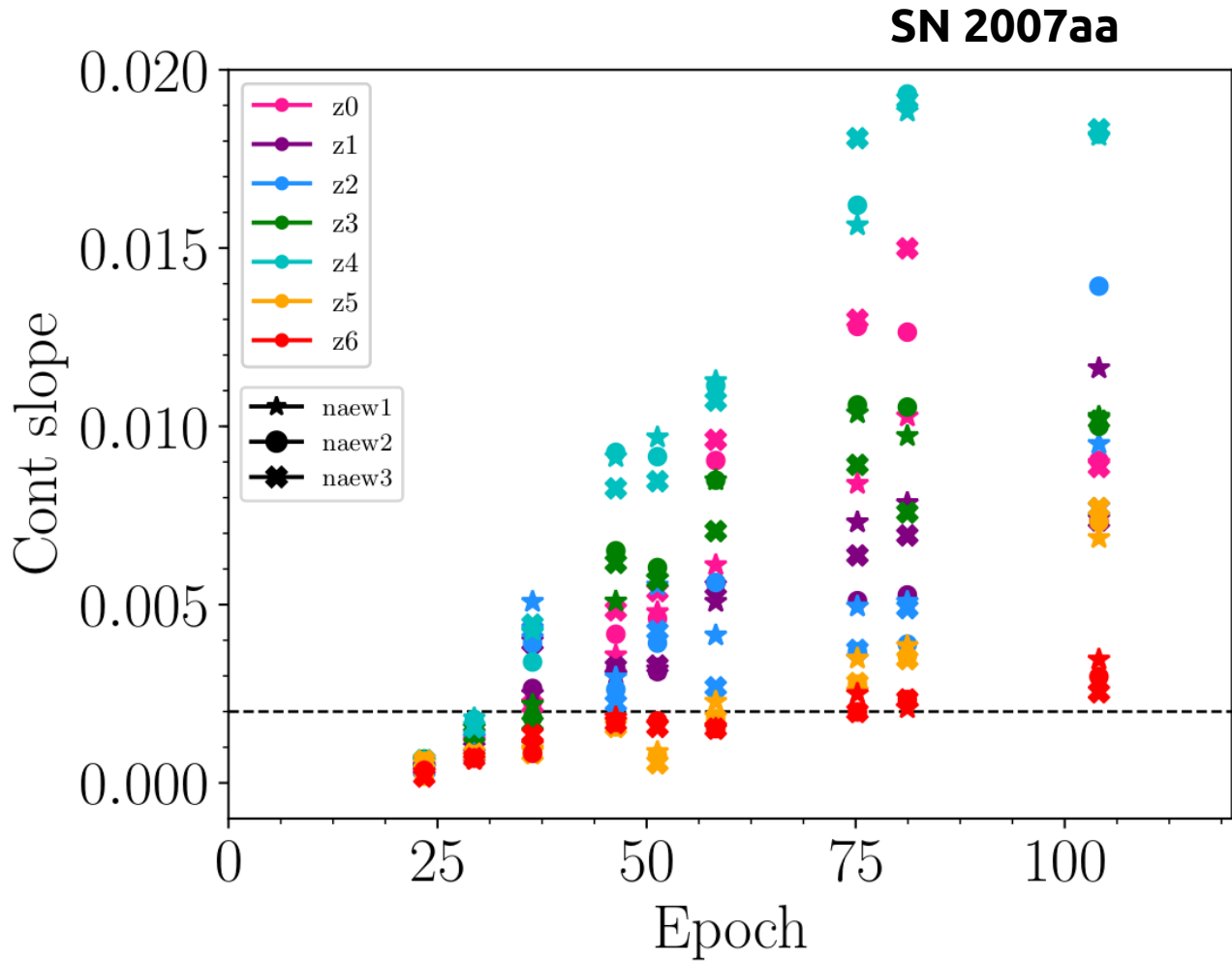


SNe II do not show an evolution in the EW(NaID) in HR spectra

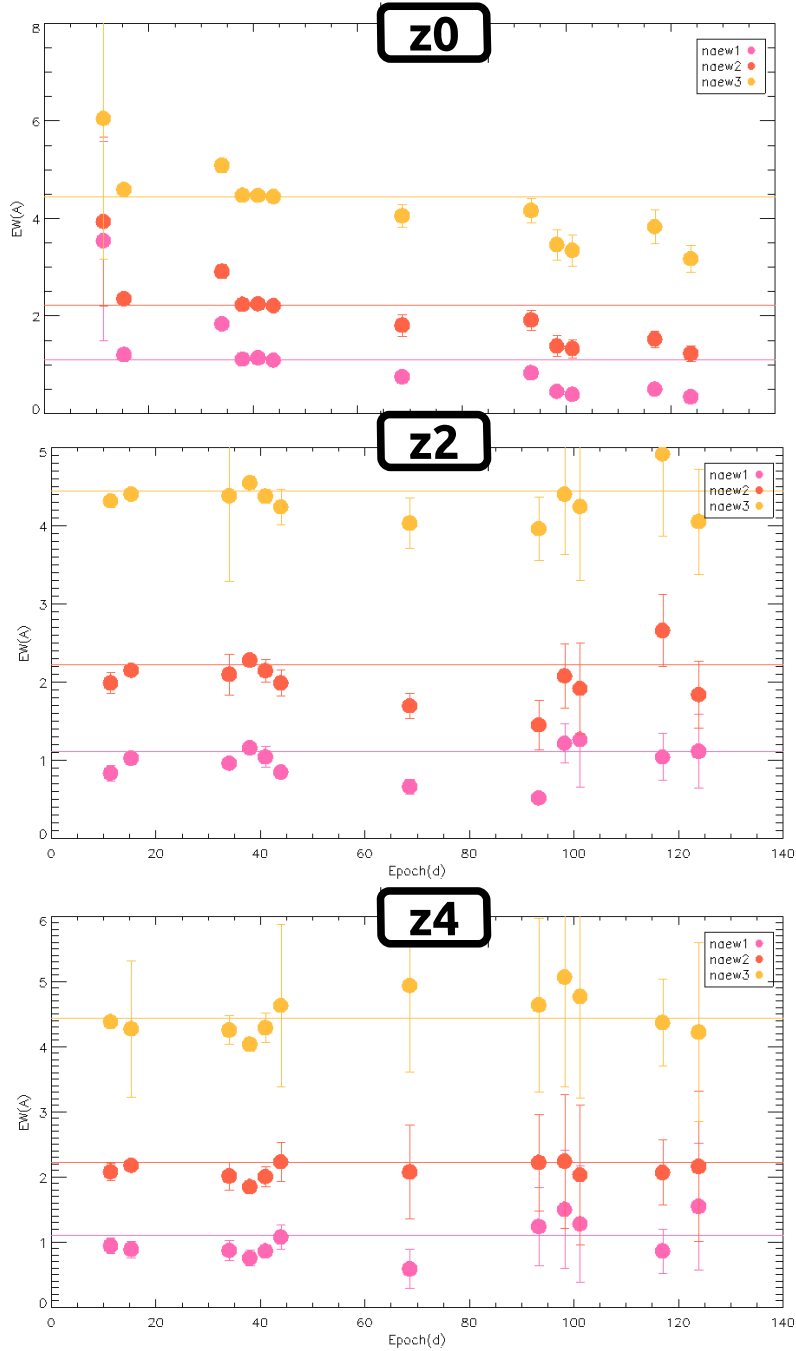
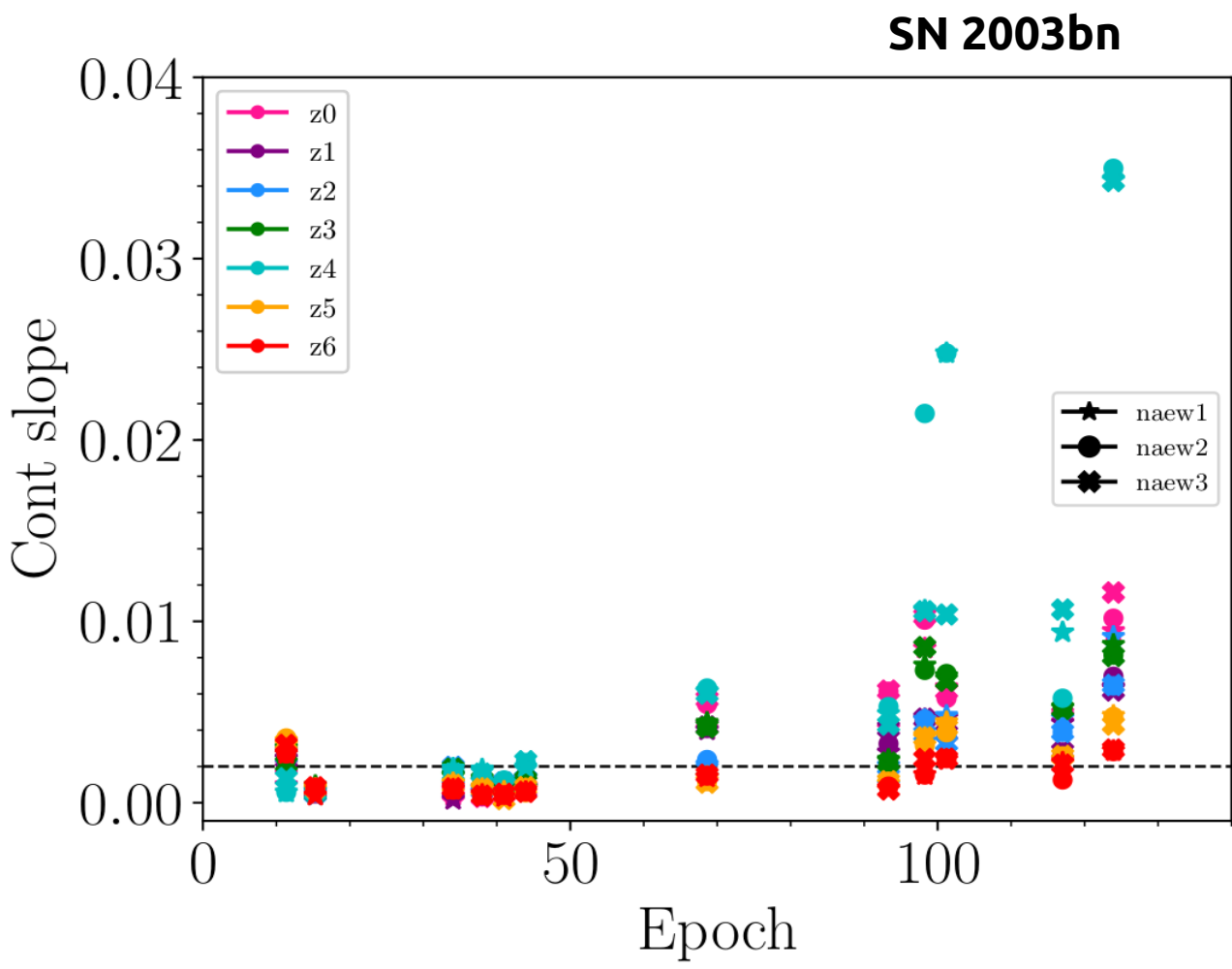
SNe II: Evolution of the NaID P-Cygni profile affects the narrow NaID line?



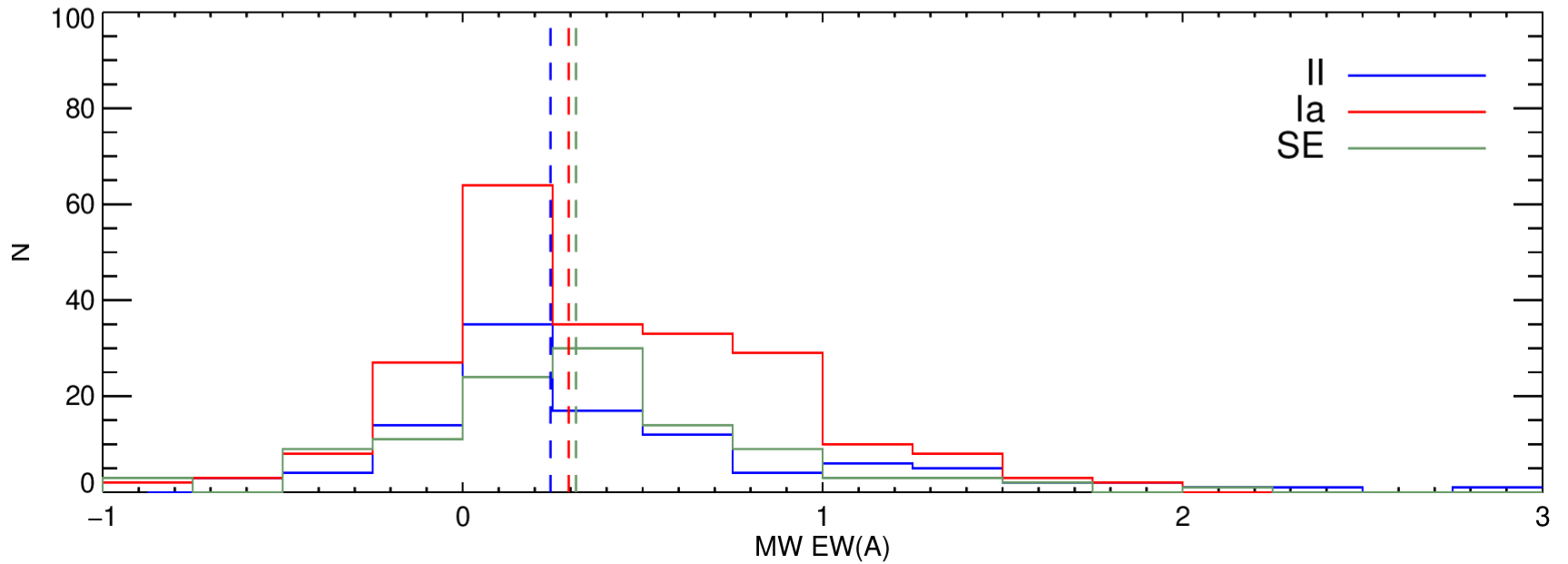
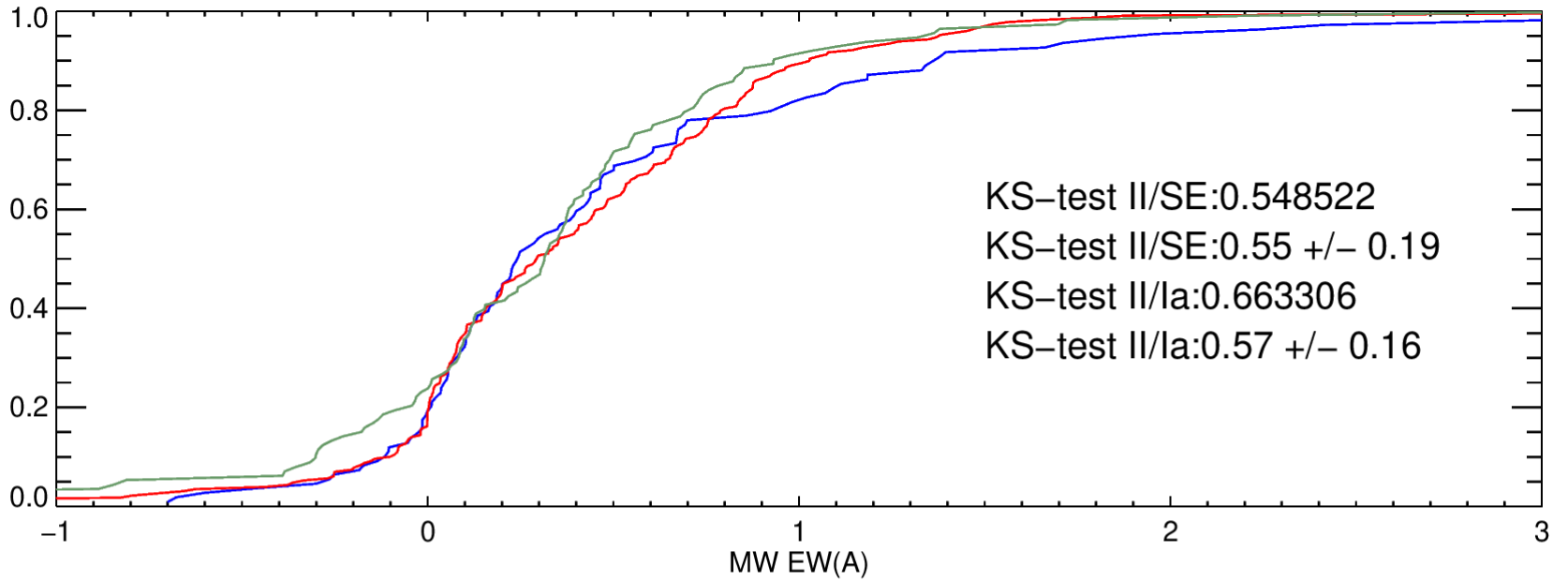
SNe II: Evolution of the NaID P-Cygni profile affects the narrow NaID line?



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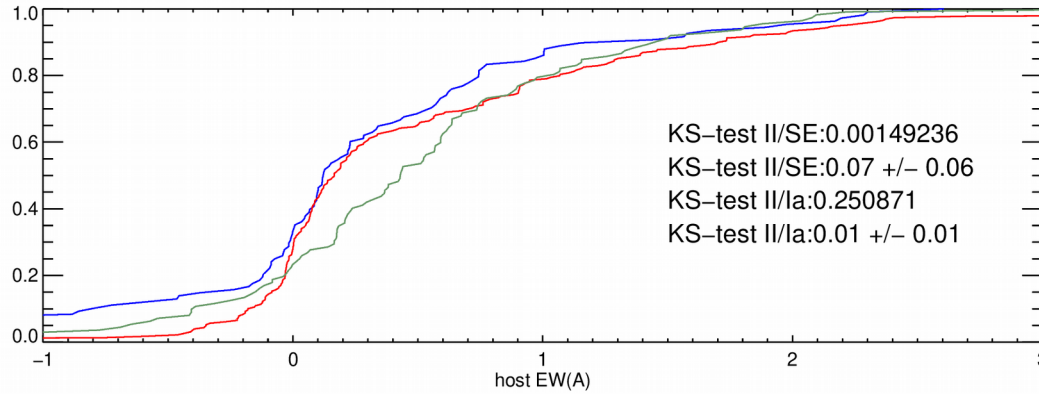


Narrow NaID lines in SNe: Results for MW

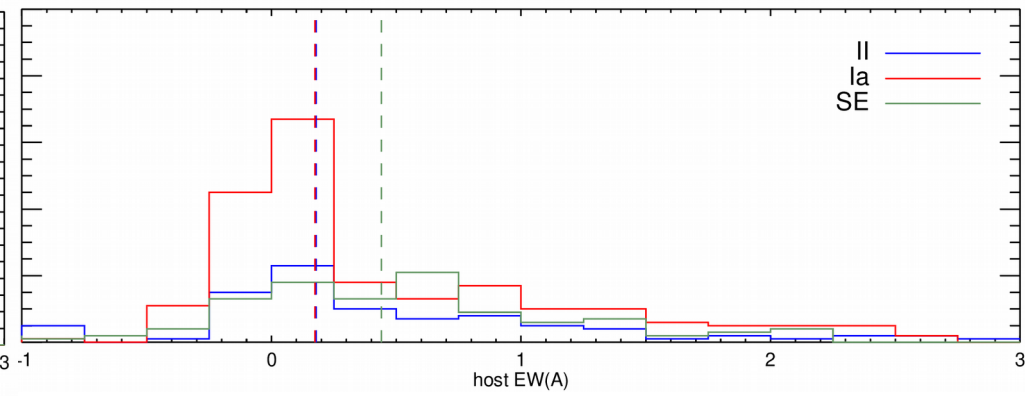
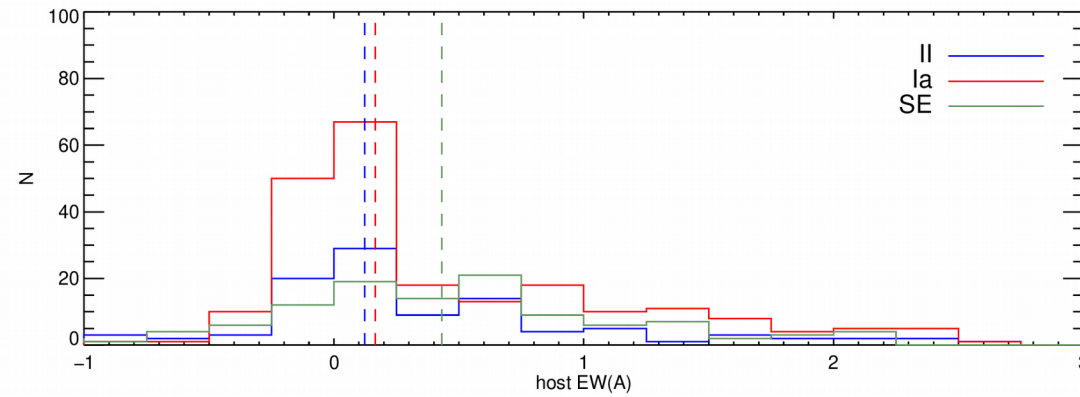
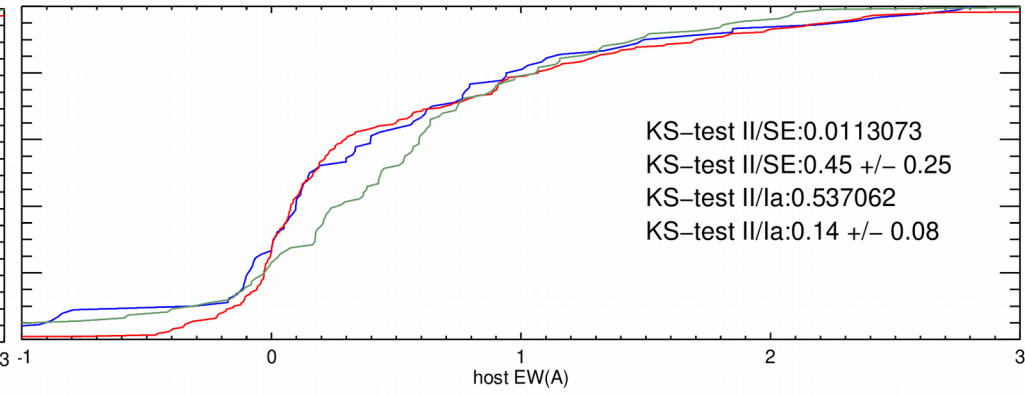


Narrow NaID lines in SNe: Results for the host

Before the cut for SNe II

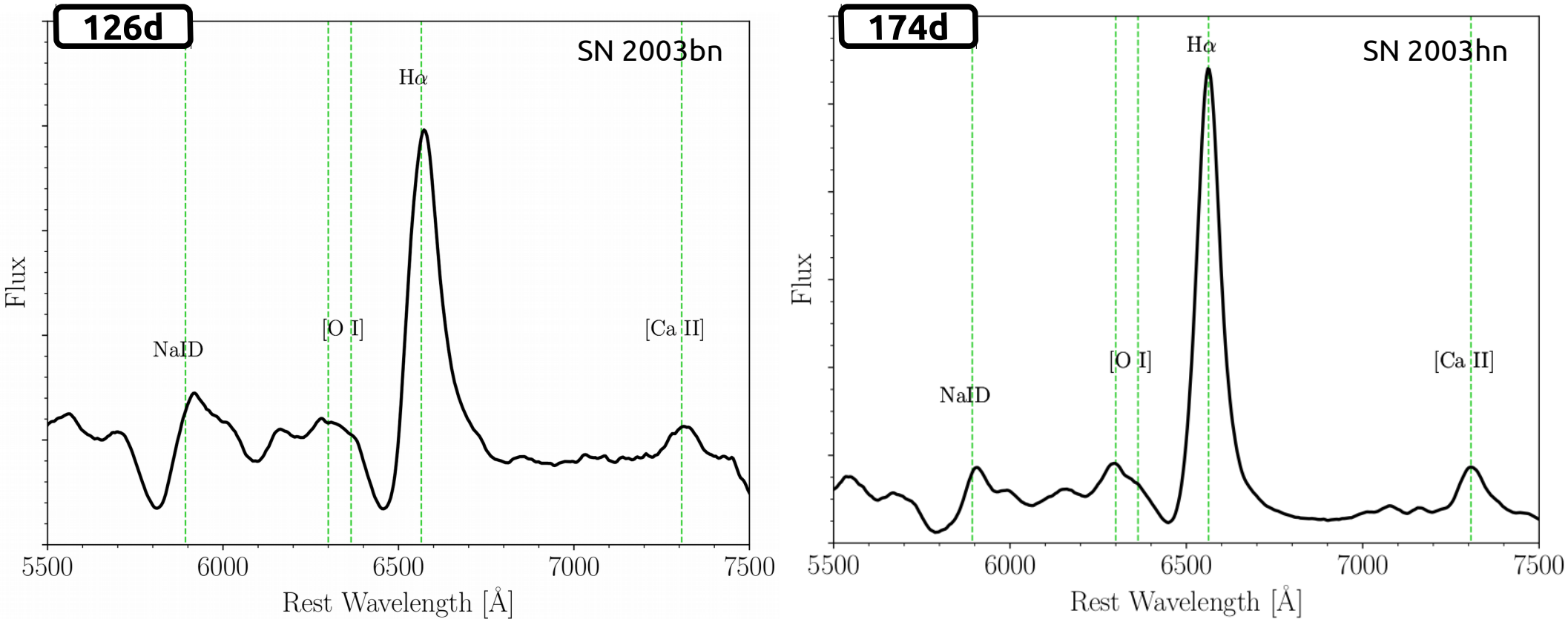


After the cut for SNe II



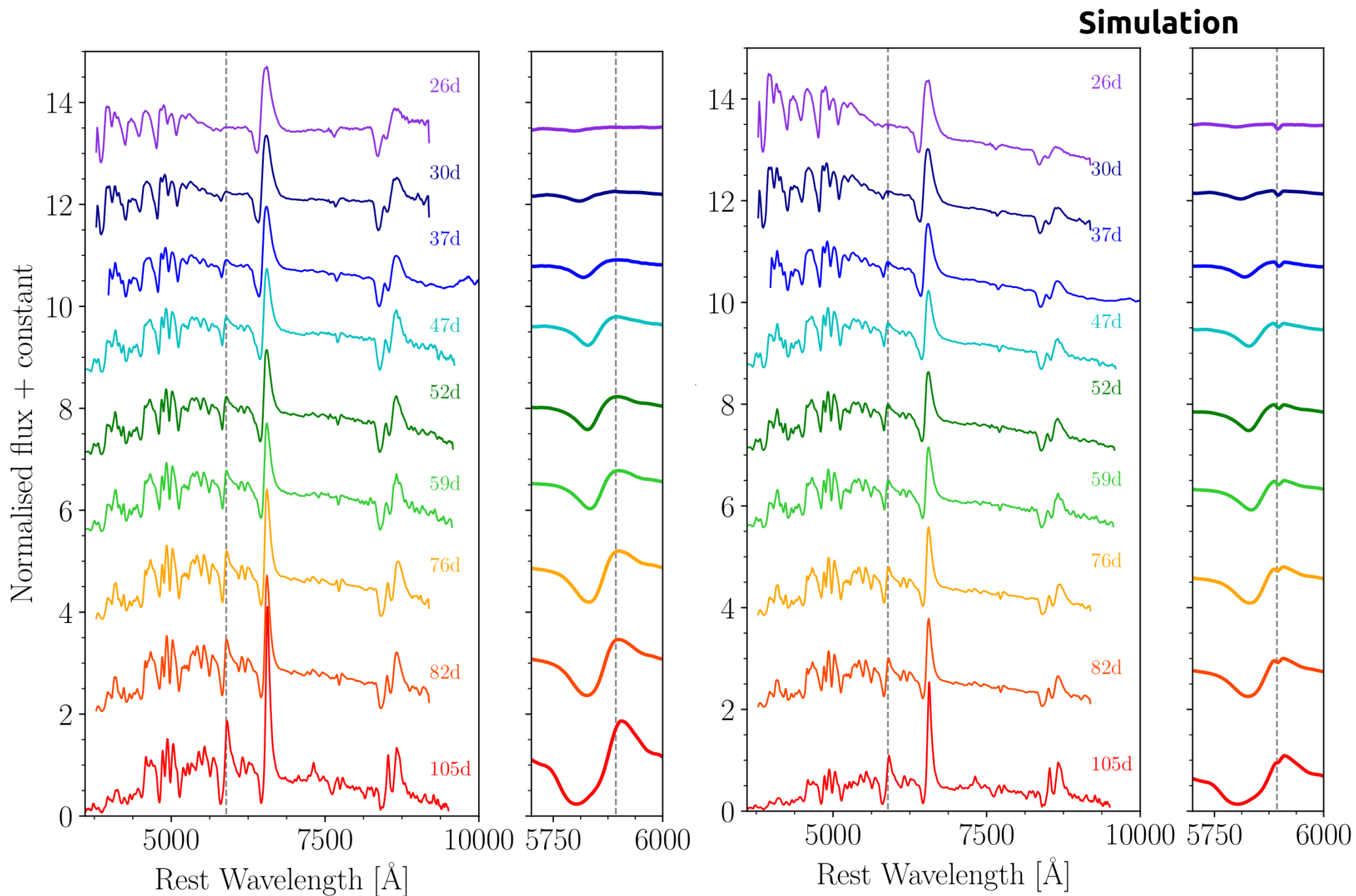
Narrow NaID lines in SNe: Results

Nebular phase (after 120-120 days)



SNe II: Emission lines are in the rest-frame, however, in most of the cases **NaID** is **redshifted**.

Narrow NaID lines in SNe: Results



Summarising

- * We observed a temporal evolution of the narrow NaID lines in SNe II.
 - Systematic effect produced by the NaID P-cygni profile.
- * A redshifted in the NaID emission peak is observed in SNe II after 100 days. Our analysis suggests it is mainly produced by the narrow NaID lines.
- * A cut based on the continuum slope can help us to determine a more accurate value for the EW(NaID).
- * In general, the narrow NaID lines are stronger in SESNe.
 - ISM? CSM?