Azores School on Observational Cosmology

SNLS SuperNova Legacy Survey

Properties of type Ia Supernovae and cosmological applications

Comparison between SNLS / SNFactory observed spectra and models

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Outline

- Cosmological context and aim
- SNela formation models : W7 and DD25
- Comparison between SNLS observations and synthetic spectra
- The use of SNFactory data to continue and improve the analysis
- Conclusion and Future

Cosmological Context and Aim

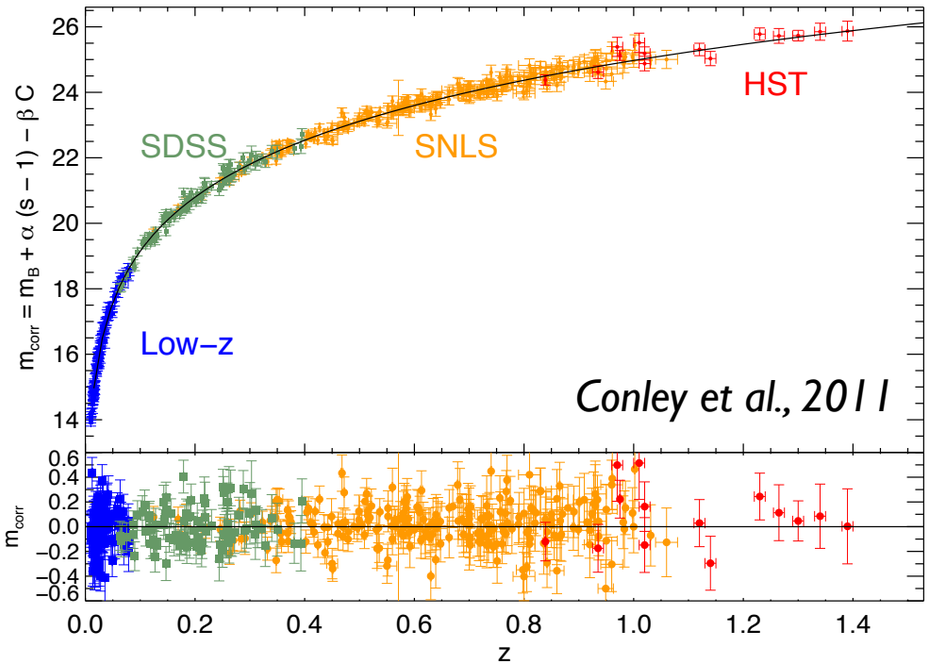
➤ **Context :** The use of type Ia supernovae (SNeIa) : the accelerated expansion of the universe

↳ cosmological parameters can be constrained

$$w = -0.91^{+0.16}_{-0.20}\,(\mathrm{stat})^{+0.07}_{-0.14}\,(\mathrm{sys})$$

Conley et al., 2011

Limit the use of SNeIa for cosmological works



➤ To reduce systematics and standardize SNeIa : better comprehension of SNeIa and their properties

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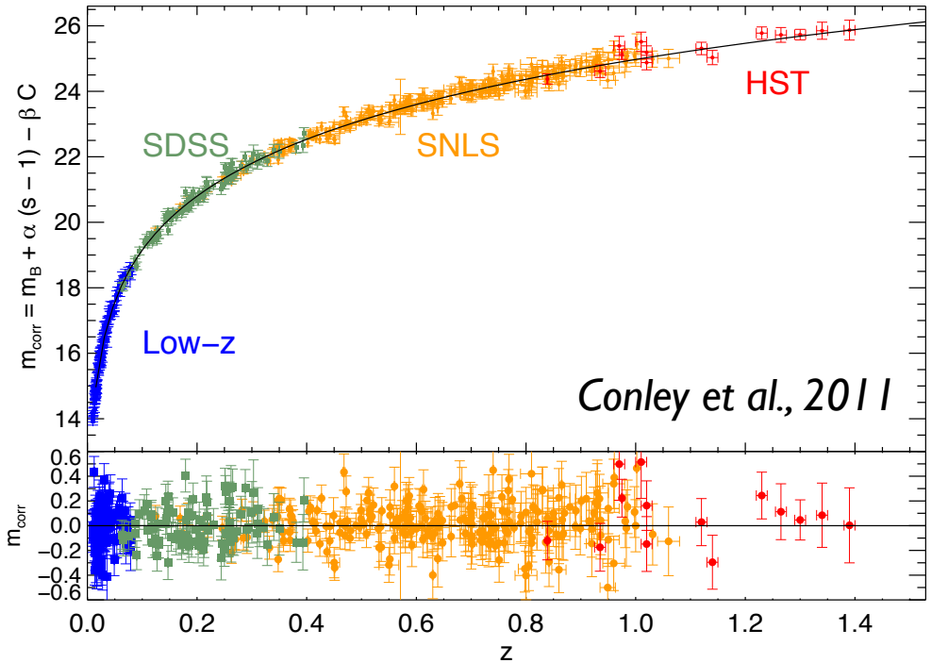

➤ To reduce systematics and standardize SNIa : better comprehension of SNIa and their properties

➤ **Method :** comparison of SNIa observed spectra from SuperNova Legacy Survey (SNLS) and SNFactory (SNF) with the predictions of various supernovae formation models (W7, Delayed Detonation models)

SNLS SuperNova Legacy Survey

➤ **Aim :** to evaluate how observations can discriminate models, in order to constrain and improve them

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➤ Explosion model + radiative transfer code = synthetic spectra (provided by *D. Jack* and *P. Hauschildt, Hambourg*)

W7 or DD25 ***Phoenix***

➤ **W7** (*Nomoto et al., 1984*) : deflagration model

DD25 (*Kokhlov, 1991 ; Hoefflich 2002*) : delayed detonation model

} 20 phases = number of days since the begining of the explosion in the supernova restframe

sperical core C + O → (+ matter: H and He) → explosive fusion of carbone → (burning front propagation: C and O burn) → production of elements + energy (expansion)

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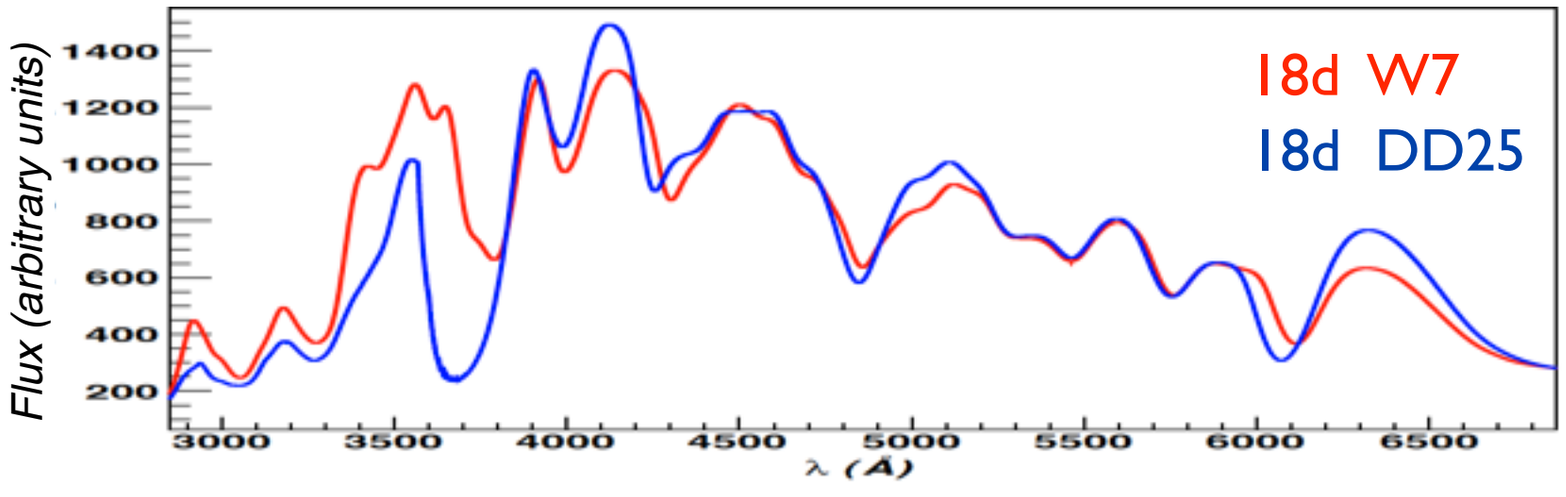
W7 ≠ DD25

burning front velocity

↳ spectral differences



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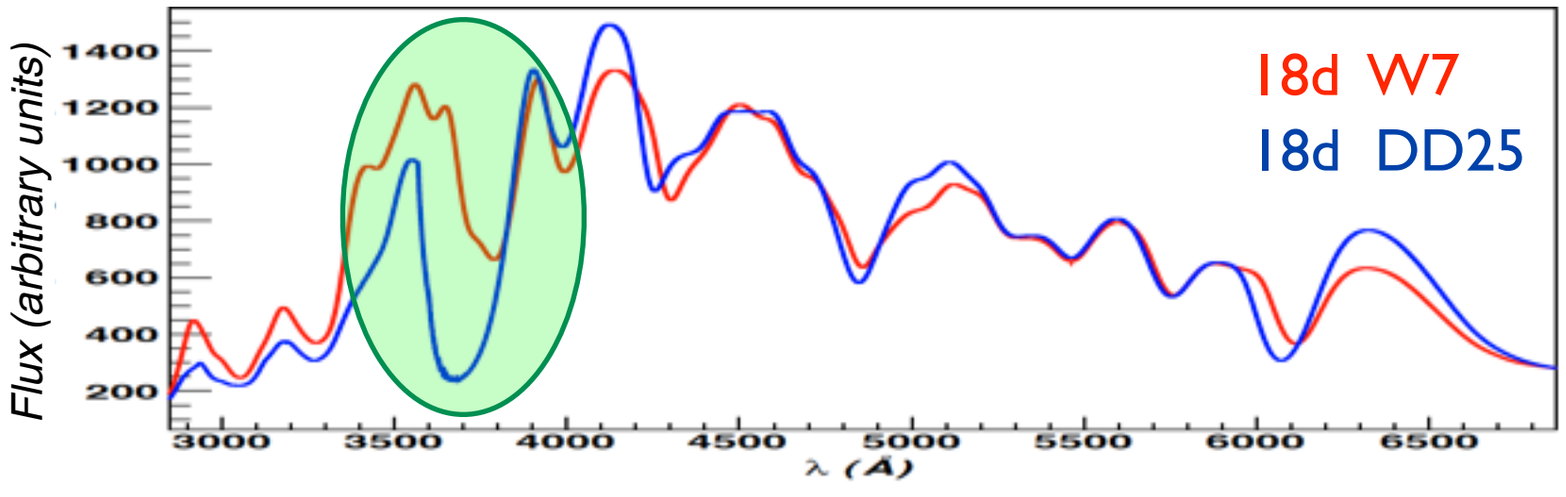

⇒ Major differences in element compositions in the UV part

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Sample of SNLS observed spectra

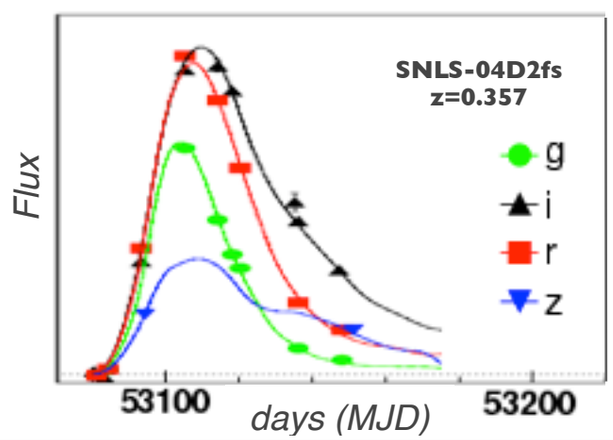
SNLS SuperNova Legacy Survey

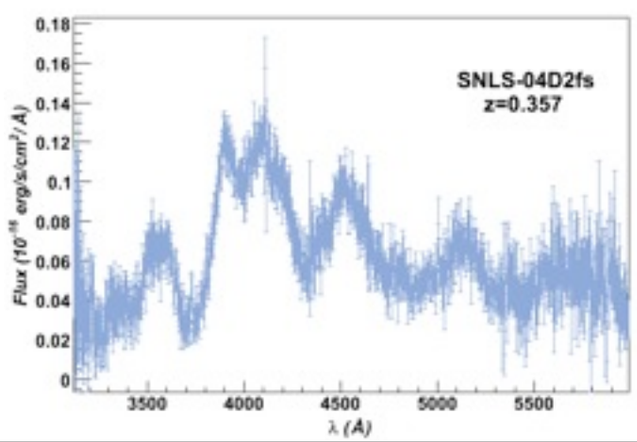
➤ Aim : redshift ($0.15 < z < 1.1$) and distance measurement of SNela to build a Hubble diagram to constrain cosmological parameters

➤ When ? 2003 - 2008

➤ Method :

imaging survey CFHT (Hawaï)	spectroscopic program VLT, Gemini, Keck telescope (Hawaï or Chile)
➔ detect SNe ➔ monitor their light-curves	➔ confirm the nature of the SNela candidates ➔ measure their redshift





First 3 years data set of 5-year SNLS

242 SNela

↓

Spectra measured at VLT

139 spectra

Balland et al., 2009

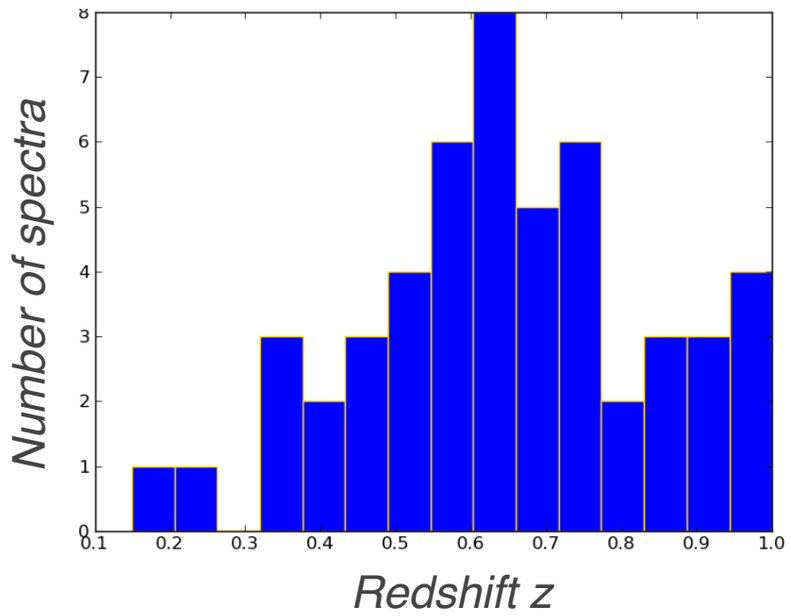
↓

Spectra extracted separately from the host

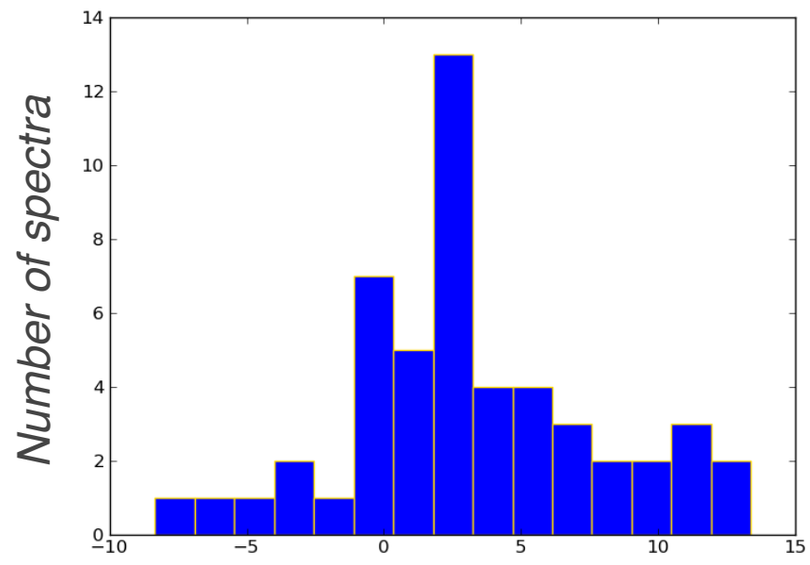
51 spectra

Sample of SNLS observed spectra

Redshift distribution for observed spectra



Phase distribution for observed spectra



$$\text{Phase} = \frac{\text{date of acquisition} - \text{date of B-band max}}{1+z}$$

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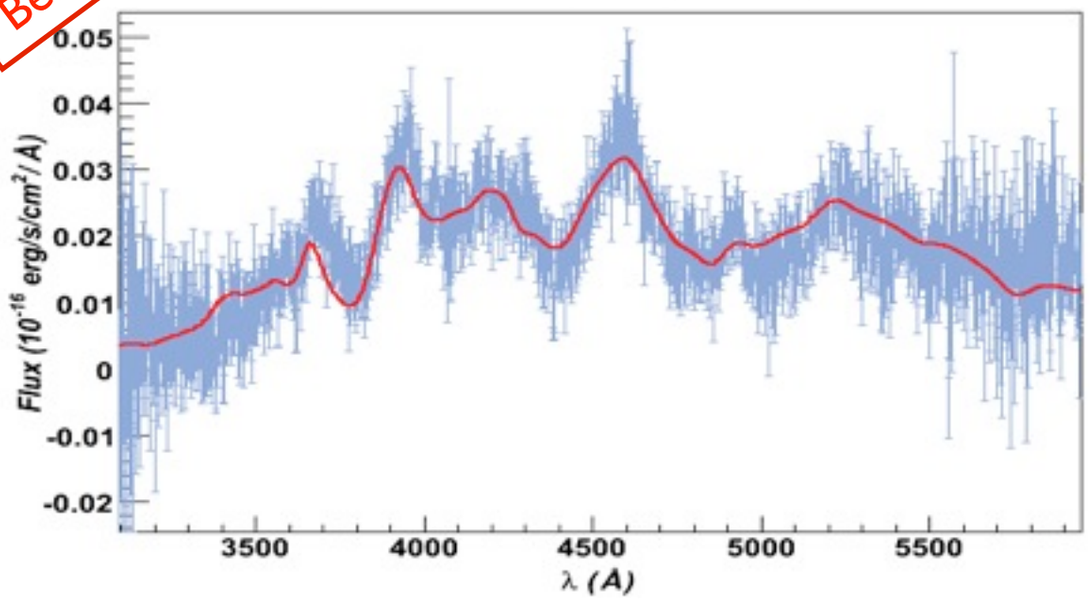
SNLS observations vs simulations

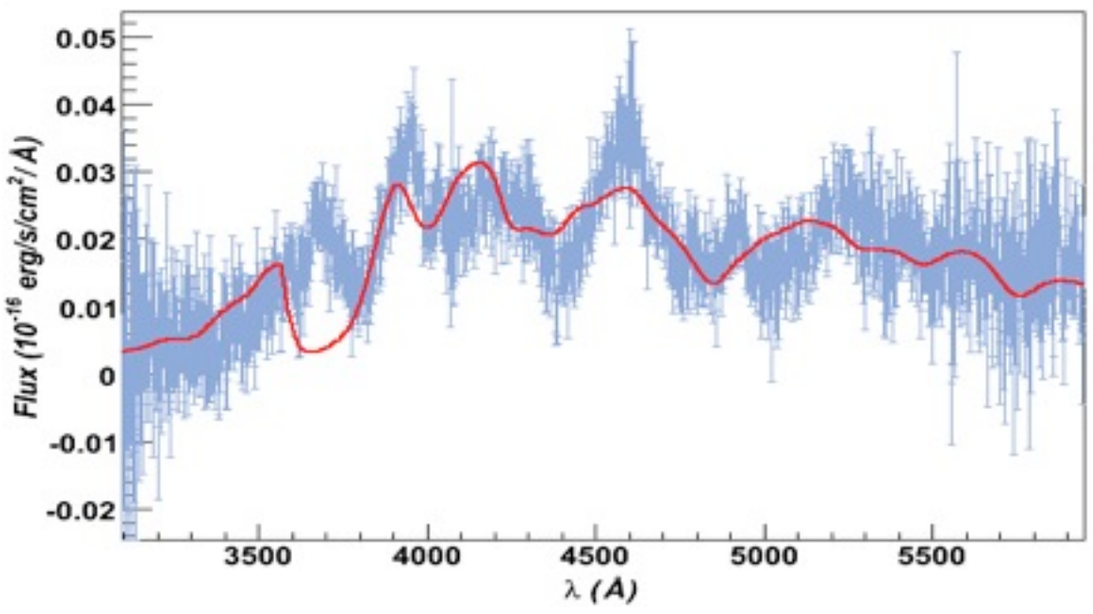
04D2cf_447 : z = 0.368 / phase = 8.48 days

Best fit

04D2cf_447 and 24 days W7 spectra

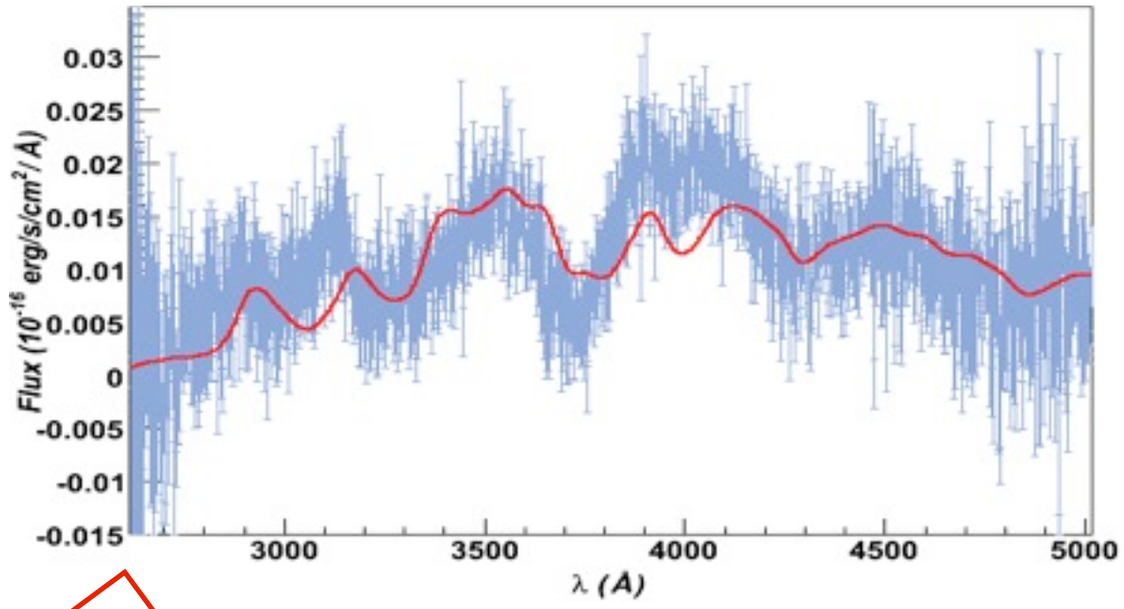


04D2cf_447 and 20 days DD25 spectra



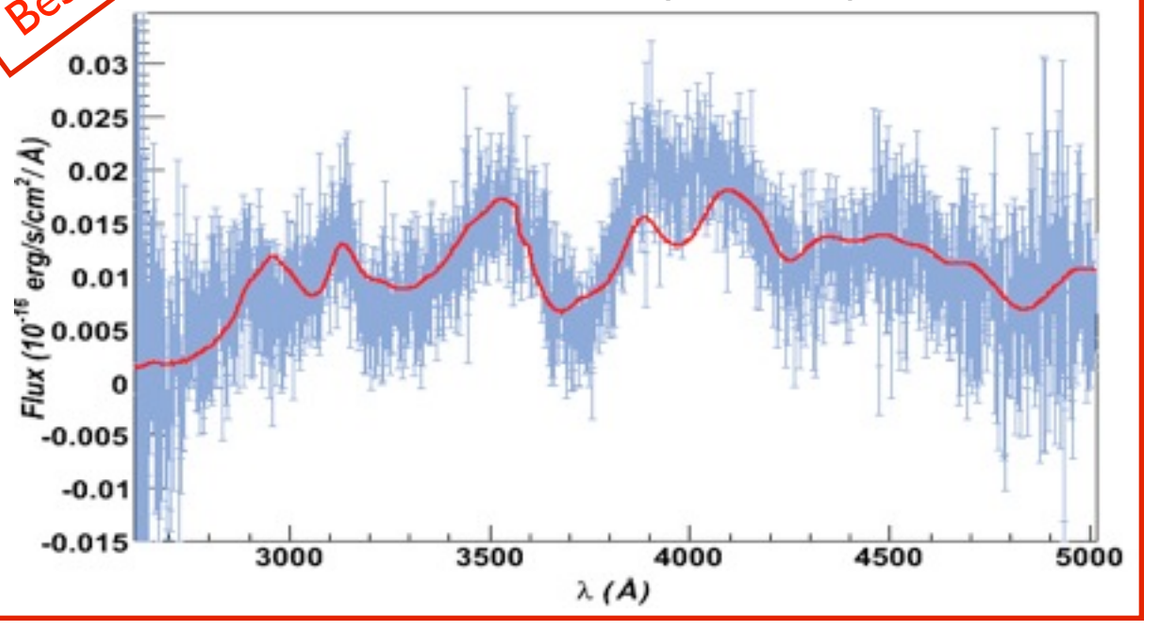
04D2an_386 : z = 0.3620 / phase = -3.39 days

04D2an_386 and 16 days W7 spectra



Best fit

04D2an_386 and 14 days DD25 spectra



Models discrimination by observed data ?

- Hypothesis testing : models are equivalent to reproduce data
- Method : $F = \frac{\chi^2_{\nu 1}}{\chi^2_{\nu 2}}$ follows a *F-Test* probability law
  - $\mathrm{P(F)} \approx 1$: true ➜ can not discriminate models
  - $\mathrm{P(F)} \ll 1$: false ➜ one of these models is favoured
- In practice : selection of spectra for which $\mathrm{P(F)} < 5\%$

  ↳ for 21 spectra the discrimination of the models by the data is significant

  ↳ 2 subsamples for W7 or DD25 best fits : Do they represent different populations of SNIa ?

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  ➜ comparison of average photometric properties :

	$< M_B >$	$< s >$	$< c >$	host type
W7 (13 spectra)	-19.20 ± 0.04	1.014 ± 0.024	-0.021 ± 0.018	50% early-type - 50% spiral
DD25 (8 spectra)	-19.30 ± 0.04	1.048 ± 0.022	0.003 ± 0.021	17% early-type - 83% spiral

→ a weak effect : SNIa

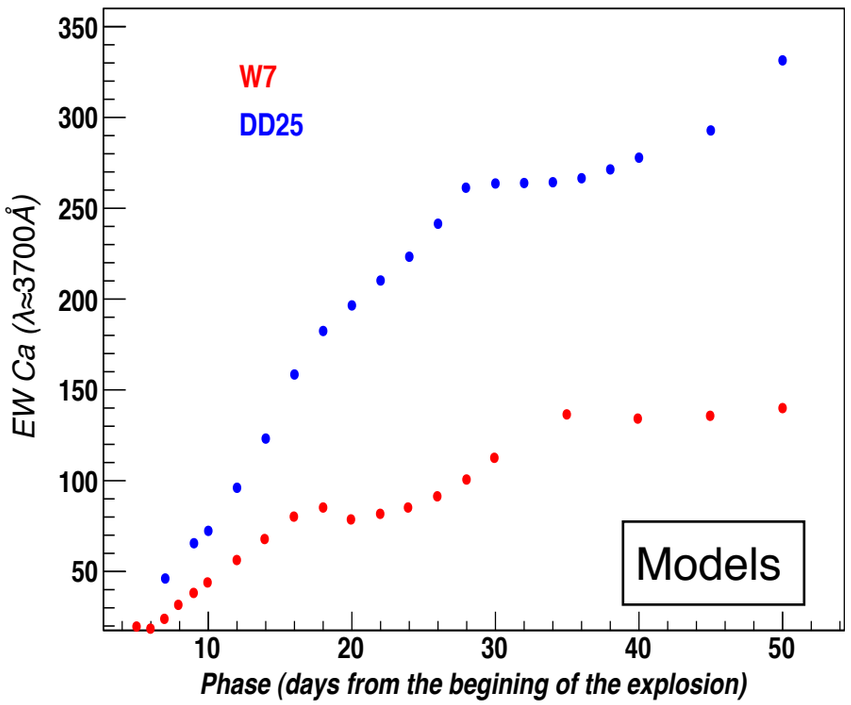
- W7 fit → fainter SNIa with a smaller stretch
- DD25 fit → brighter SNIa in spiral galaxies with an higher stretch

Why a model is favoured by the data ?

Most of the differences can be attributed to the Calcium feature (λ≈3700Å)

↳ equivalent width of Ca (EW Ca) calculation

EW Ca for W7 and DD25 spectra



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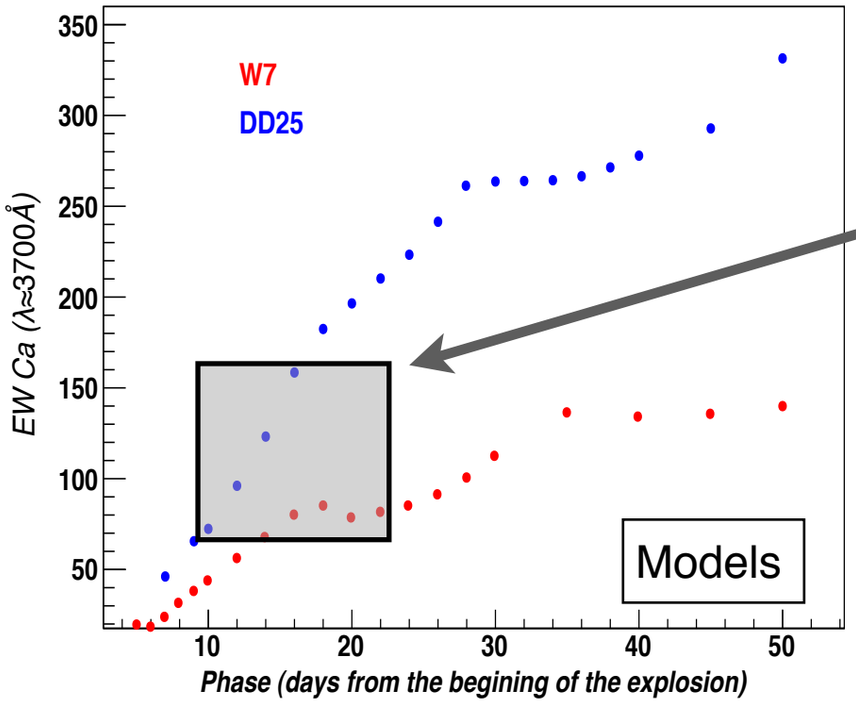
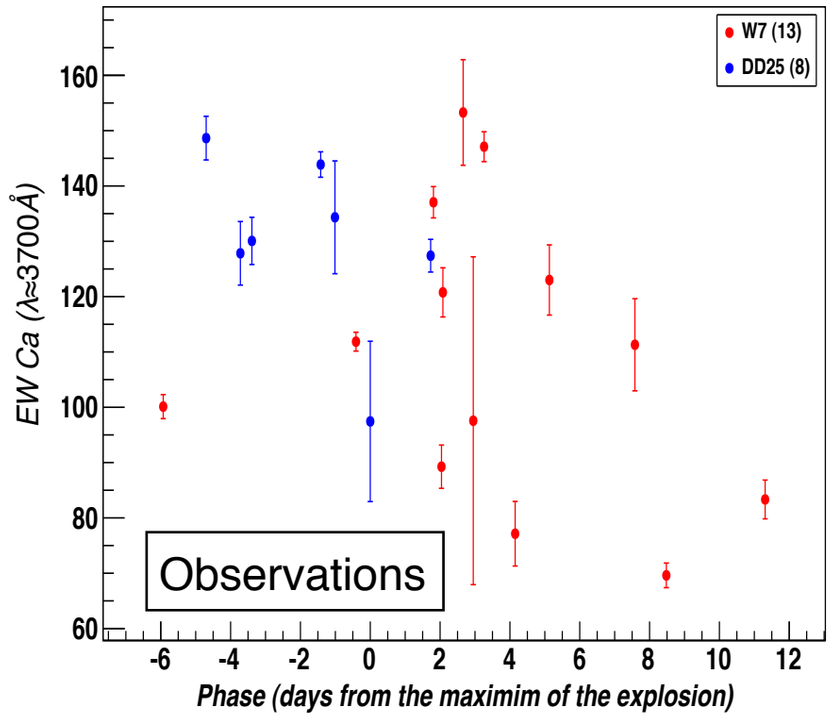


EW Ca for the two observed subsamples



➤ Earlier phases : equivalent width of Ca (EW Ca) for W7 spectra is too small compare to the data

↳ DD25 is favoured

➤ Postmaximum phases : EW Ca for DD25 spectra is too big compare to the data

↳ W7 is favoured

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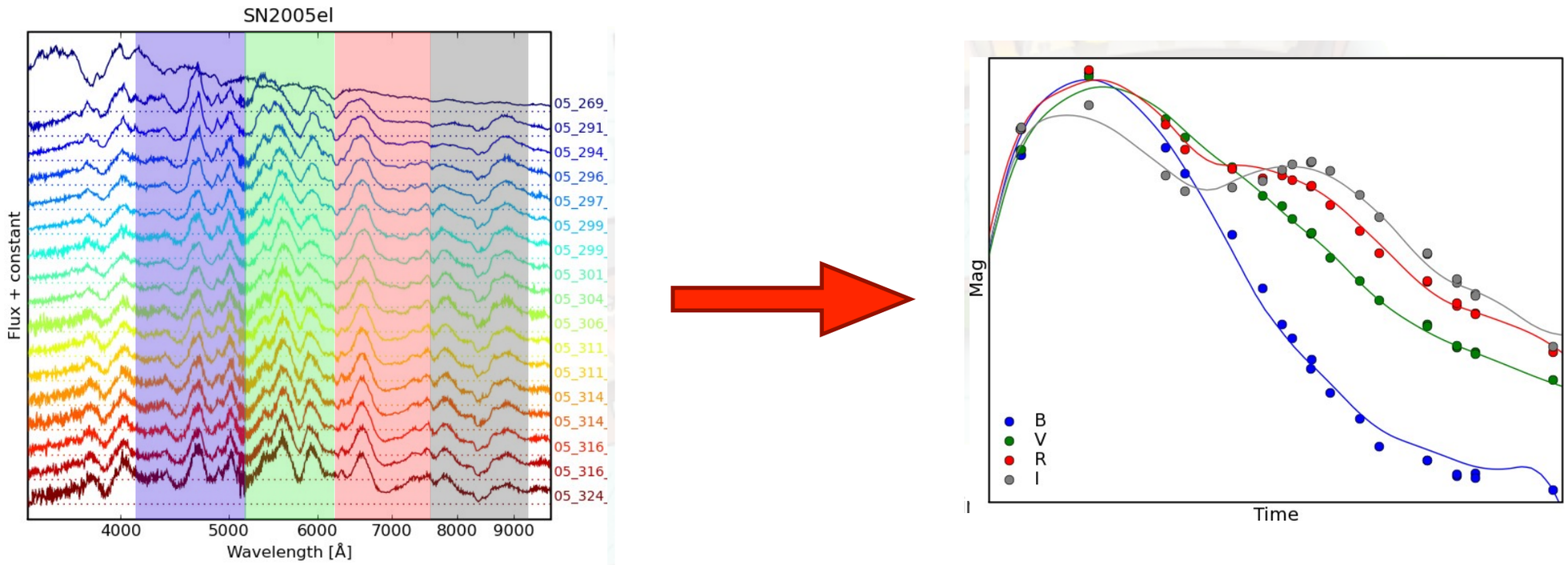
SNFactory data to continue the analysis

➤ Aim : Measure low-redshift ($0.03 < z < 0.08$) SNela to complete the Hubble diagram and to better understand SNela properties

➤ When ? 2004 - now

➤ Method :
- detection of SNela candidates by PTF (Palomar Transient Factory) telescope (California)
- spectro-photometric follow-up with SNIF (Supernovae Integral-Field Spectrograph) on the UH88 telescop (Hawaï)

  ↳ measures time series (spectra for each SN starting 1-2 weeks before peak brightness and continuing several weeks after this peak) and calculates light-curves



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SNFactory 2004 - 2009 (232 SNela)
→ at least 5 spectra with several phases + one spectrum before the maximum
→ Good SNela for cosmology (120 SNela)
→ 2 samples for cosmological analysis : "training" and "validation"
→ Training sample (62 SNela)

SNF observations vs simulations

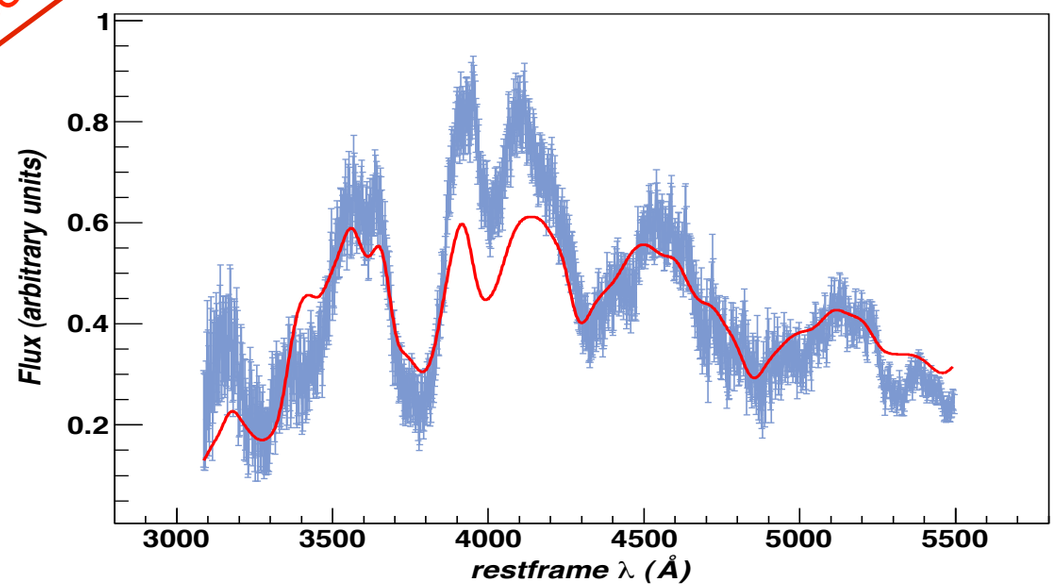
Preliminary

Preliminary

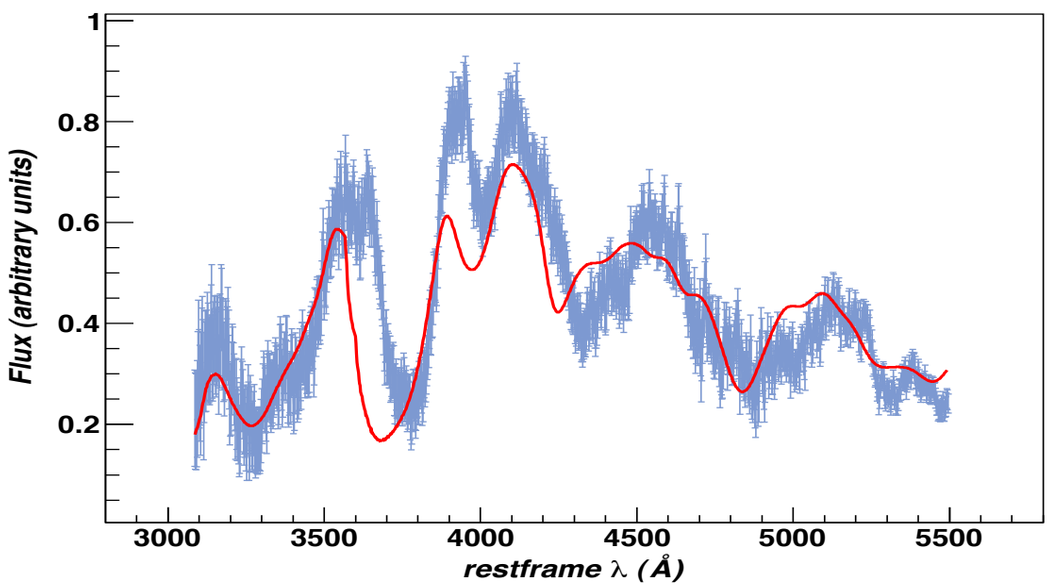
SNF20061111 : z = 0.069 / phase = 0.16 days

Best fit

SNF20061111 and 18 days W7 spectra

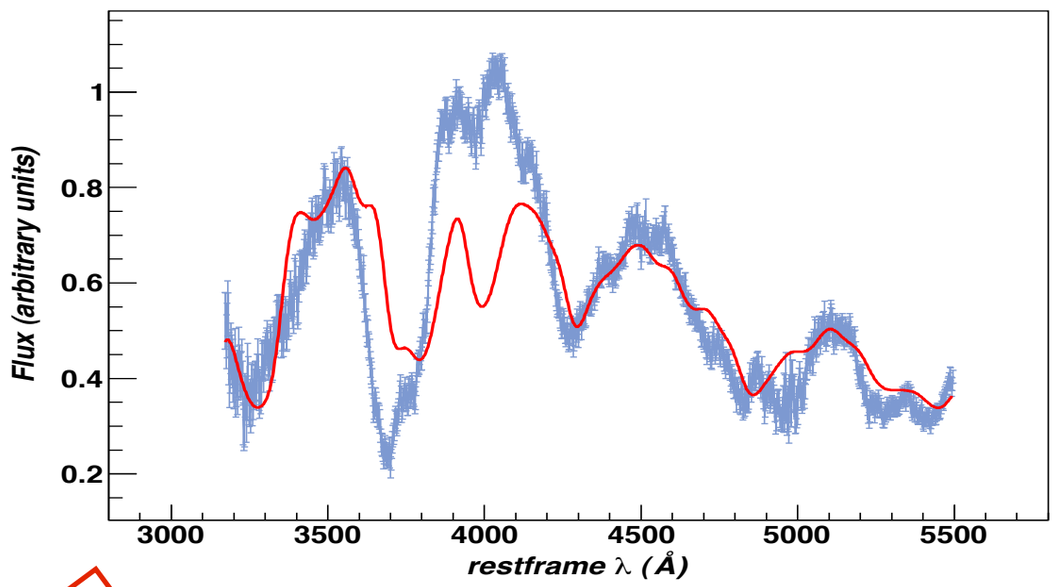


SNF20061111 and 16 days DD25 spectra



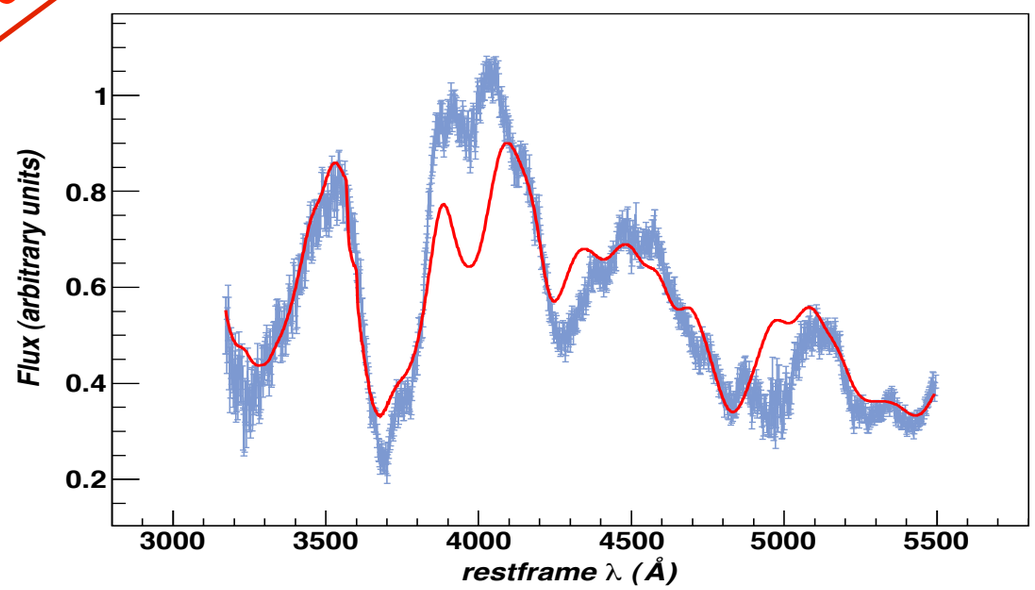
SNF20080920 : z = 0.040 / phase = -1.23 days

SNF20080920 and 16 days W7 spectra



Best fit

SNF20080920 and 14 days DD25 spectra



Model discrimination with SNF data ?

Preliminary

Preliminary

- SNF data around maximum of luminosity : same analysis with F-Test and cut when $P(F) < 5\%$
  - ↳ for 49 spectra the discrimination is significant between the models
  - ↳ 2 subsamples for W7 or DD25 best fits :
    - W7 ➜ 31 spectra
    - DD25 ➜ 18 spectra

comparison of average photometric properties : **ongoing analysis**

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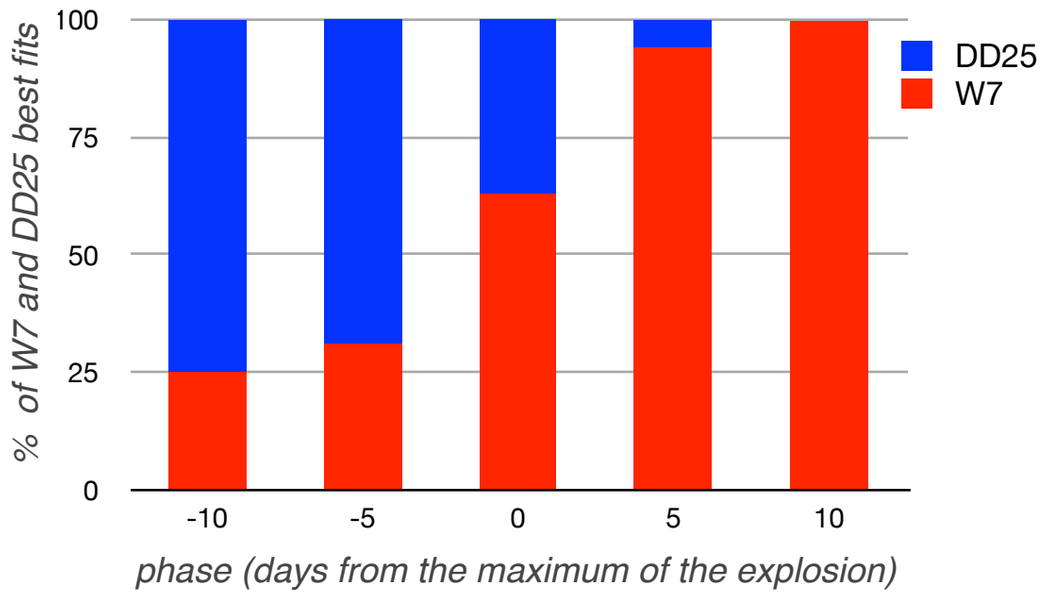
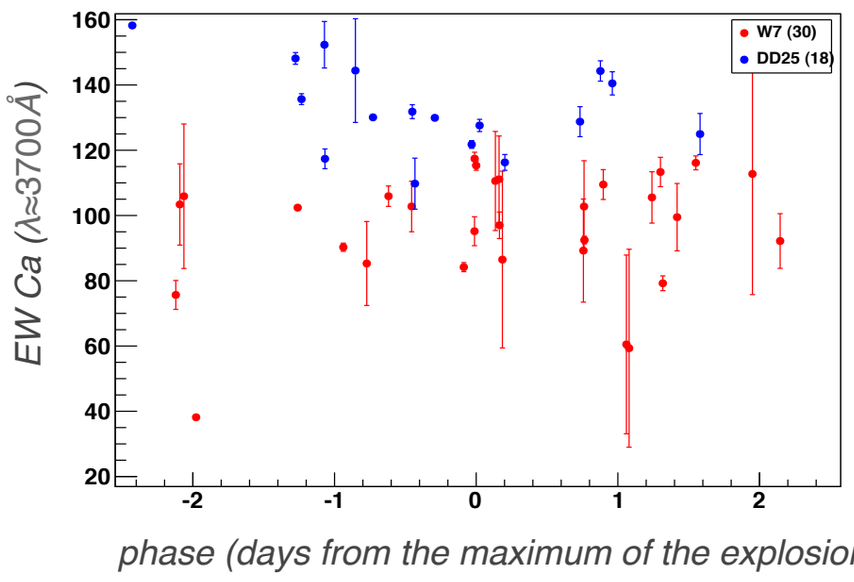
➤ Time evolution of the 2 subsamples size :

Proportion of W7 and DD25 best fit



➤ EW Ca :

EW Ca for the two observed subsamples around 0 days



➜ same results as SNLS analysis : DD25 is favoured by ealier phases and W7 by postmaximum phases

↳ can be attributed to the Calcium feature and EW Ca value

Conclusion and Future

- SNLS / SNF analysis : data have the power to disciminate models

- spectral differences between models (CaII ~3700Å)

  - identify and understand the origine
  - make the link between these differences and the physical properties of SNela
  - investigate the parameter space to reproduce observed spectra ➜ work with W. Hillbrandt team

- continue this analysis with low-redshift data : SNfactory

  - compare time evolution of observed and synthetic spectra
  - investigate others avenues and compare with high-redshift

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