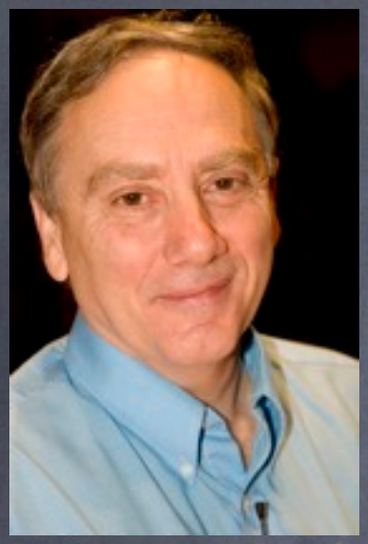
Type Ia Supernovae

Progenitor Signatures

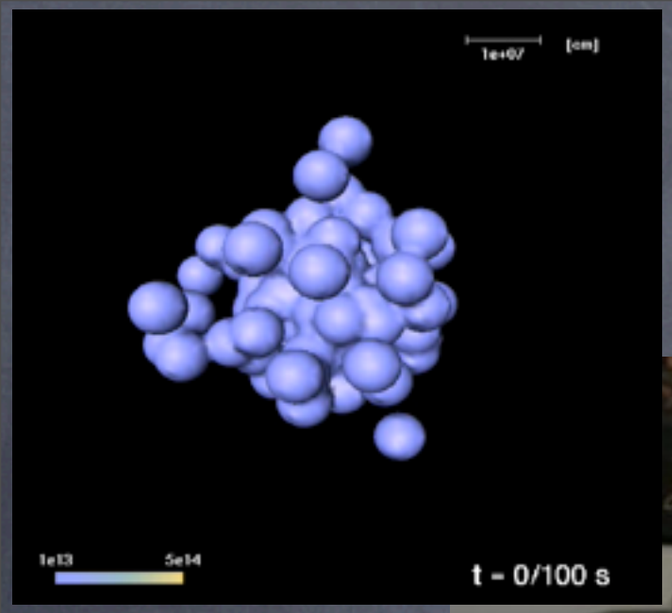
Nando Patat - ESO

Stellar Death and Supernovae - August 18th, 2009



"The fact that we do not know yet what are the progenitor systems of some of the most dramatic explosions in the universe has become a major embarrassment and one of the key unresolved problems in stellar evolution".

M. Livio (2000)

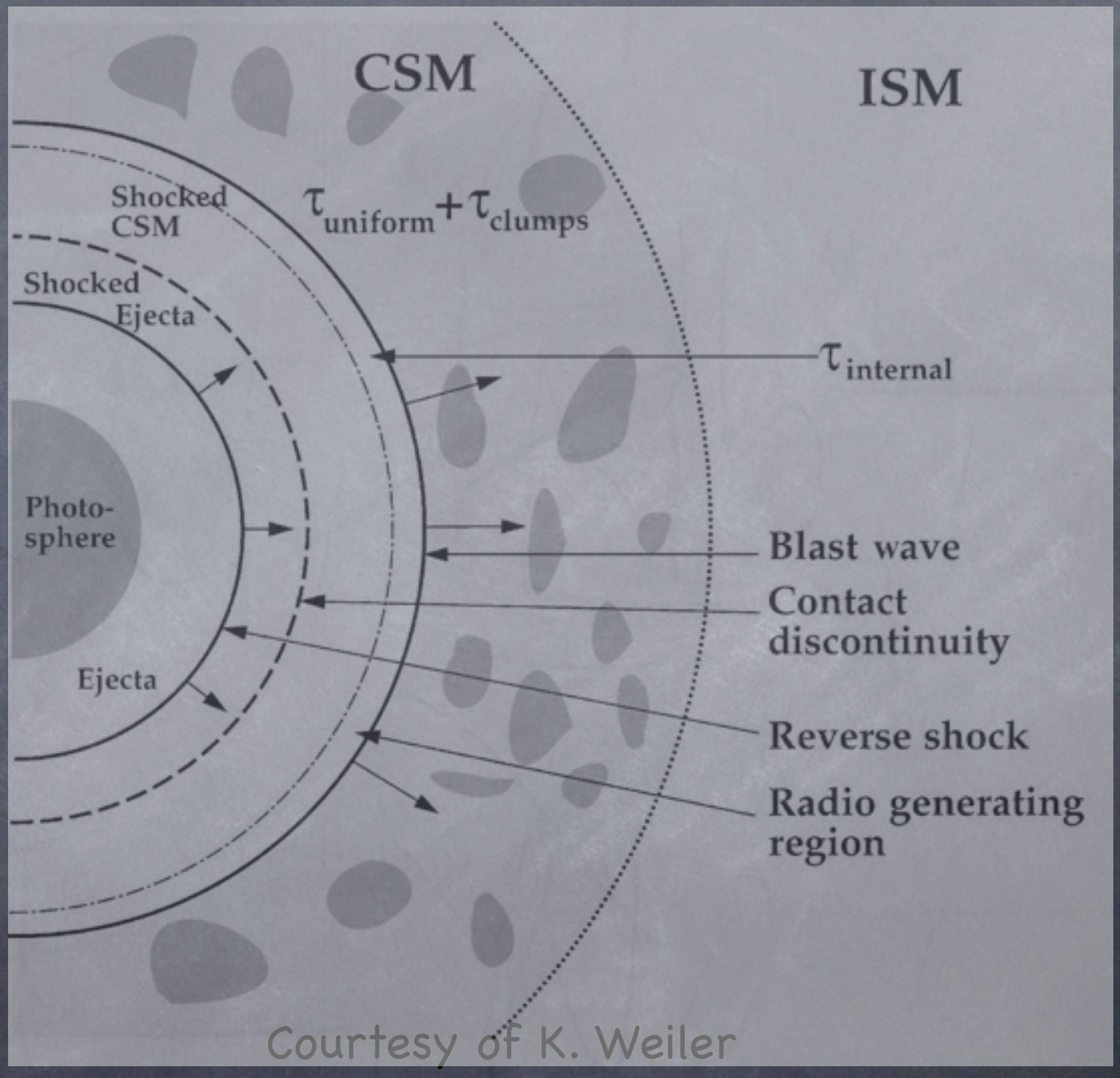


Everything taken into account, Ia's should never take place...

"the progenitor issue can be solved by (better and new) observations only"

W.H.

The SN-CSM interaction methods



Courtesy of K. Weiler

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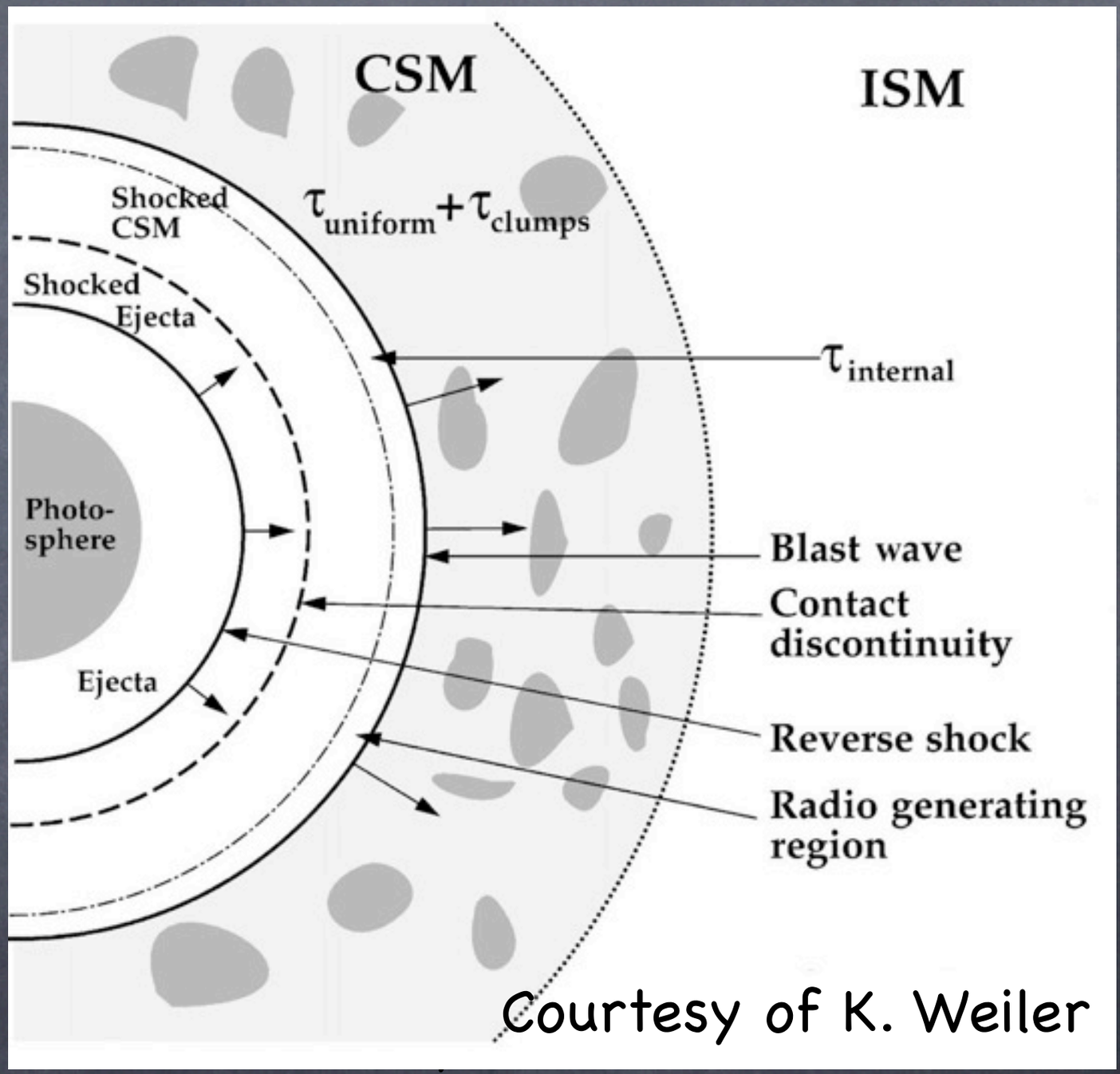

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- No narrow H/He emission line has been found in any normal Type Ia (Mattila et al. 2005). Exceptional cases do exist (Hamuy et al. 2003, Aldering et al. 2006, Prieto et al. 2007). But, if any, they must be rare (Panagia et al. 2006).

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$3 \times 10^{-8}\ M_{sun}\ yr^{-1}\ (v_{wind}=10\ km\ s^{-1})$;

Ejecta-CSM interaction has been invoked as a possible explanation for the high velocity components seen in the spectra of some Ia:

SN1999ee (Mazzali et al. 2005)
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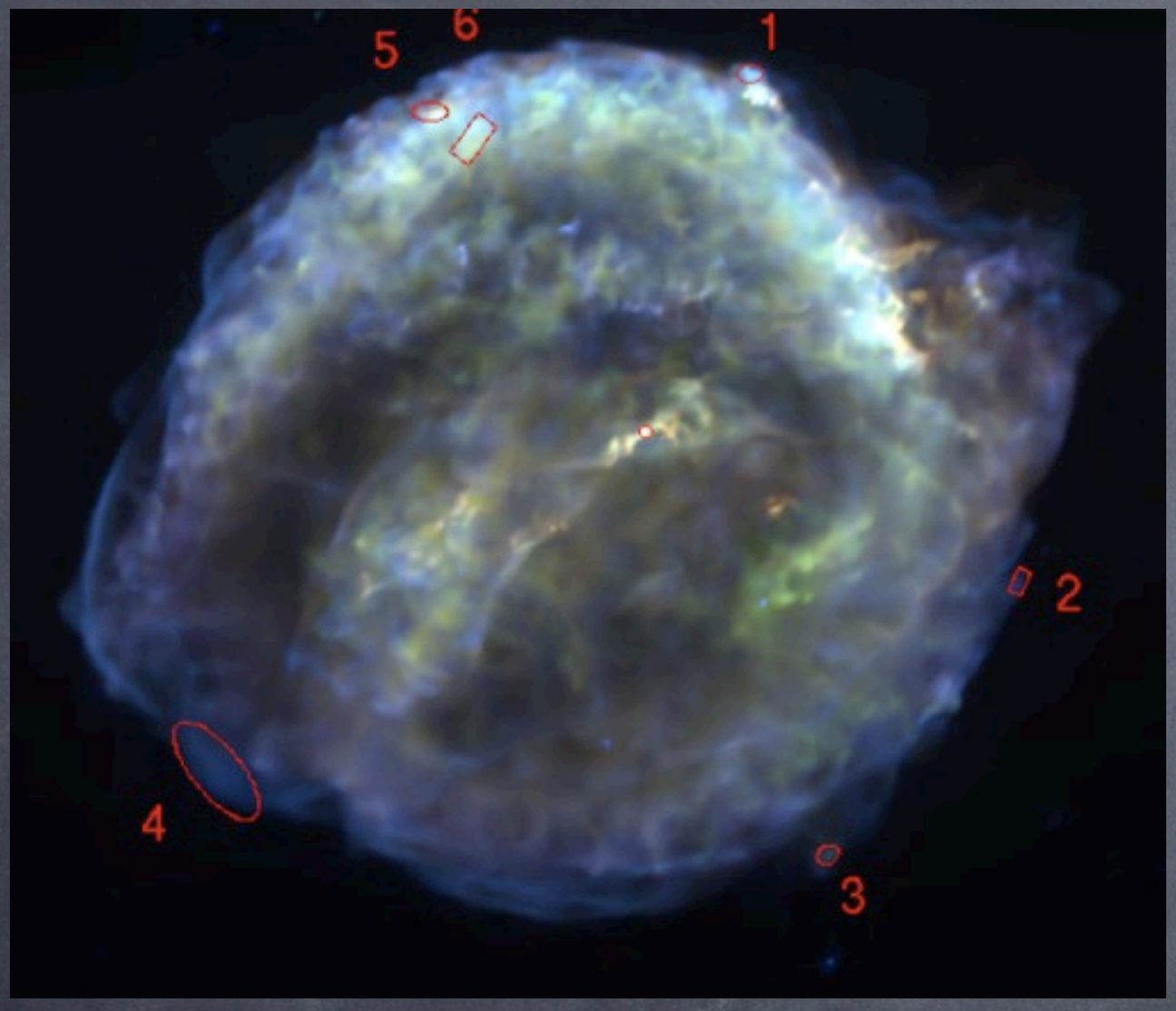
But these features can also be explained by a 3D structure of the explosion (Mazzali et al. 2005)

Observation of SN Remnants



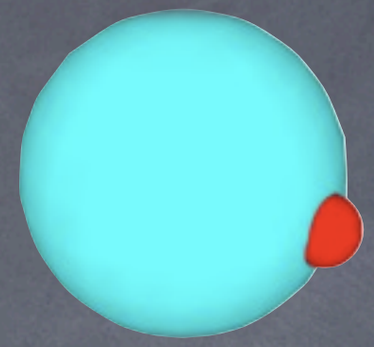
Kepler SNR

Interaction with non uniform CSM. Younger? More massive progenitor?

If v_w>200 km s^{-1}, large cavities are excavated by the WD accretion winds. Do we have an issue there?

Badenes et al. 2007; Reynolds et al. 2007

The case of entrained material



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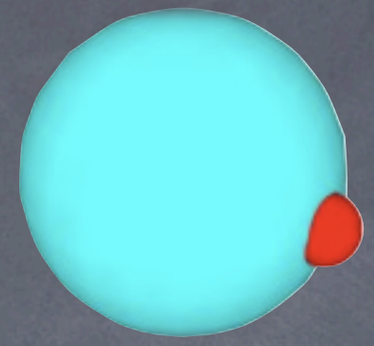

The impact of ejecta on the companion star is expected to strip its envelope. Part of it becomes entrained in the ejecta and should be observable

(Wheeler et al. 1975, Fryxell & Arnett 1981,
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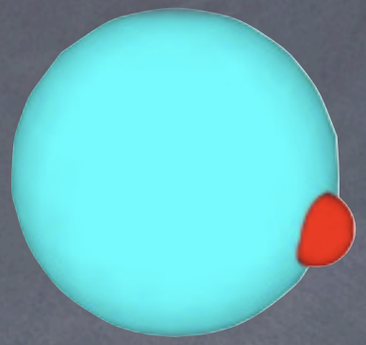

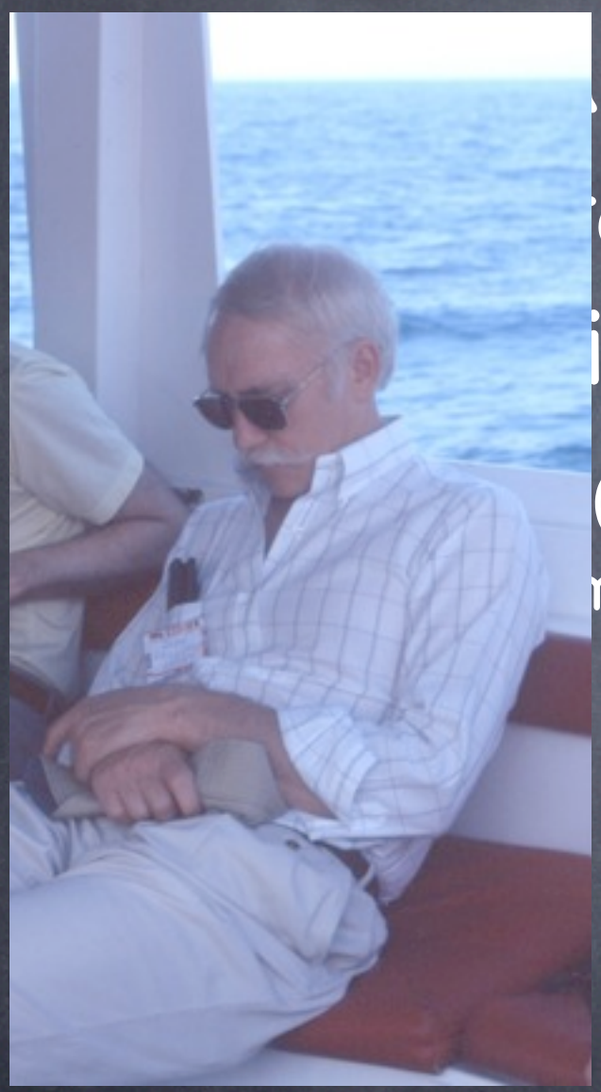

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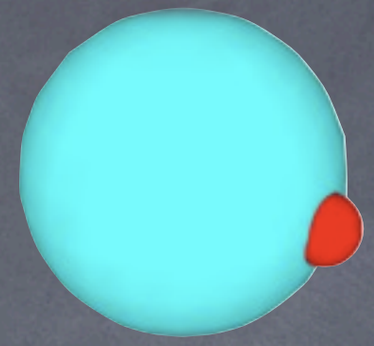

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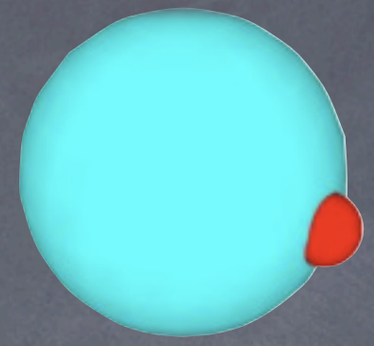

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The non-detection rules out systems with secondary stars close enough to the WD to be experiencing RLOF at the time of explosion

(Leonard 2007)

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Are there any other methods?

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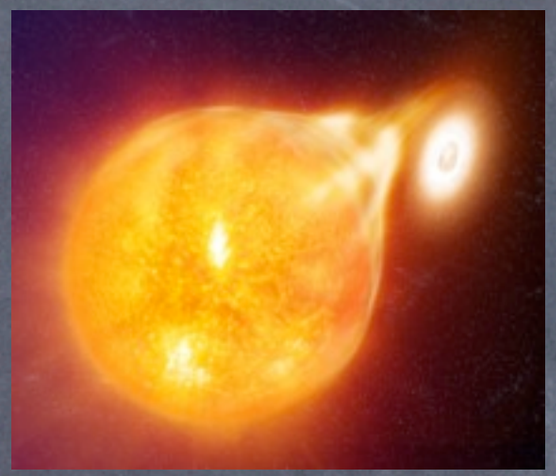

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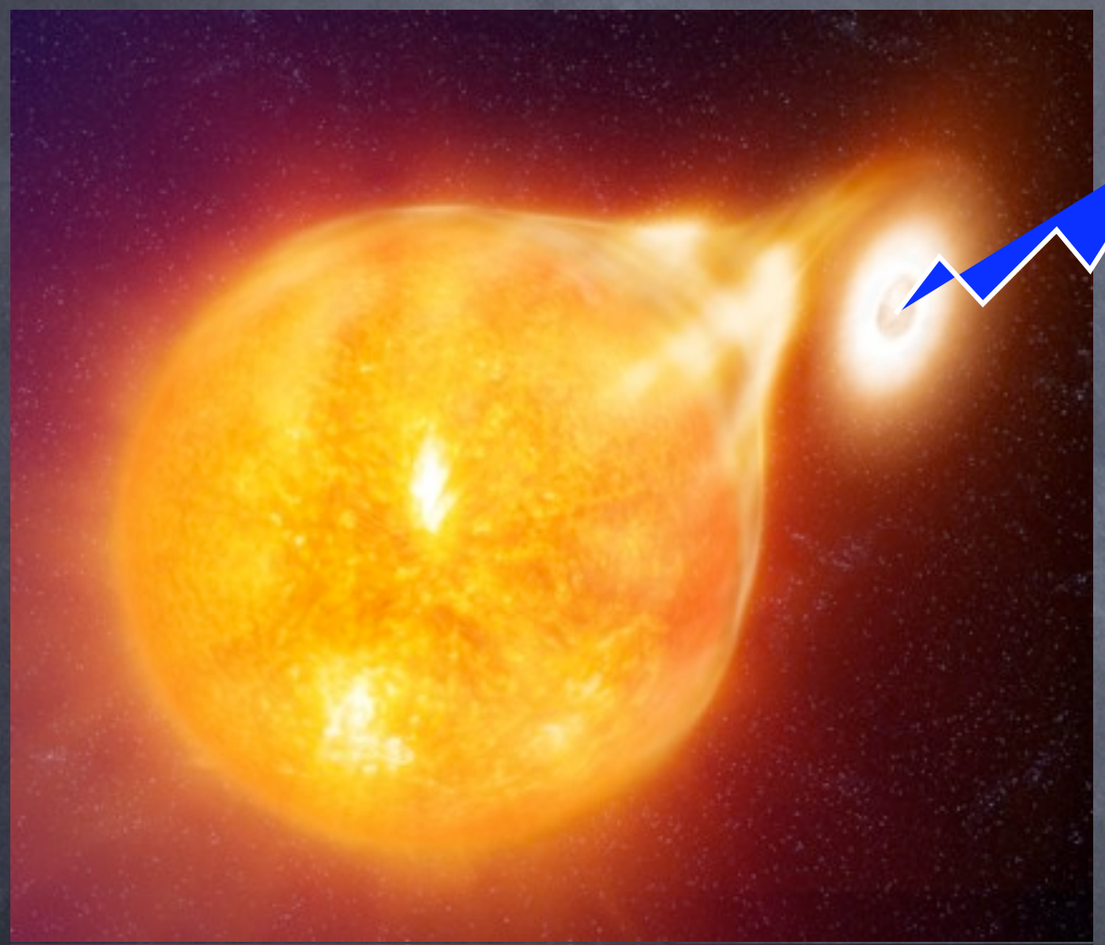
2. Direct observation of the Progenitor System ?



SS X-Ray Source

discovered in pre-explosion Chandra images of the SN2007on location

Voss & Nelemans 2008 (but see Roelofs et al. 2008)

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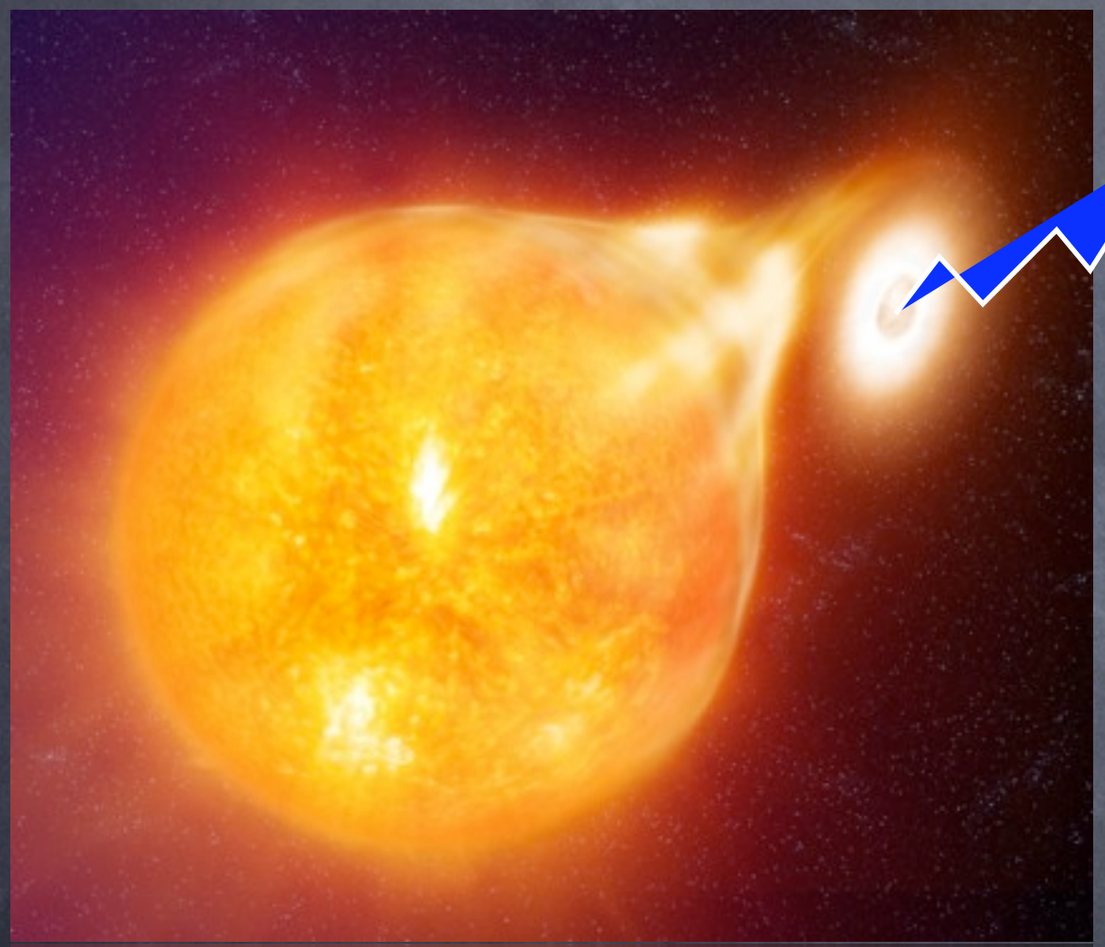

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need for archival images

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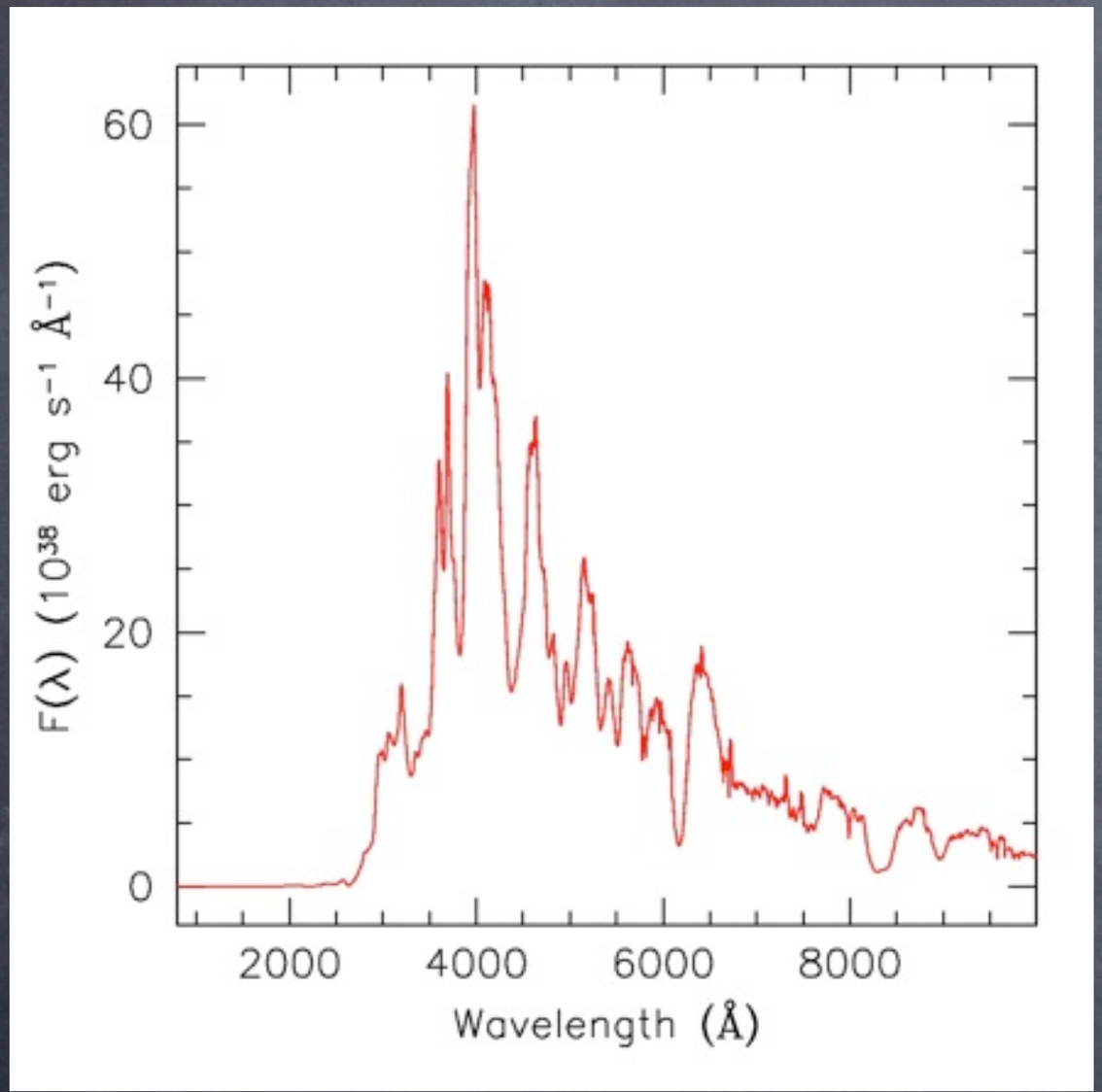

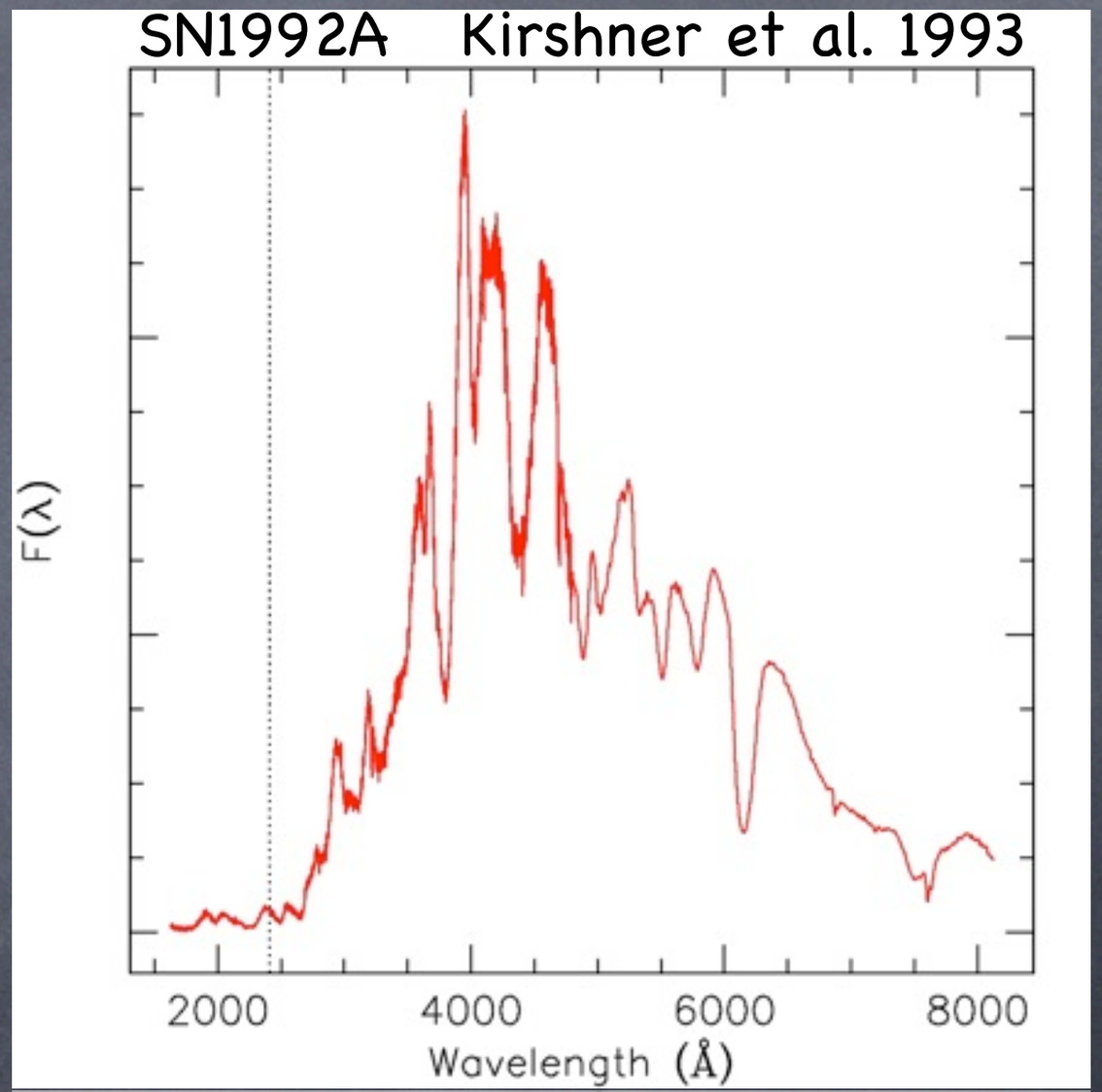

(Pauldrach et al. 1996; Mazzali 2000)

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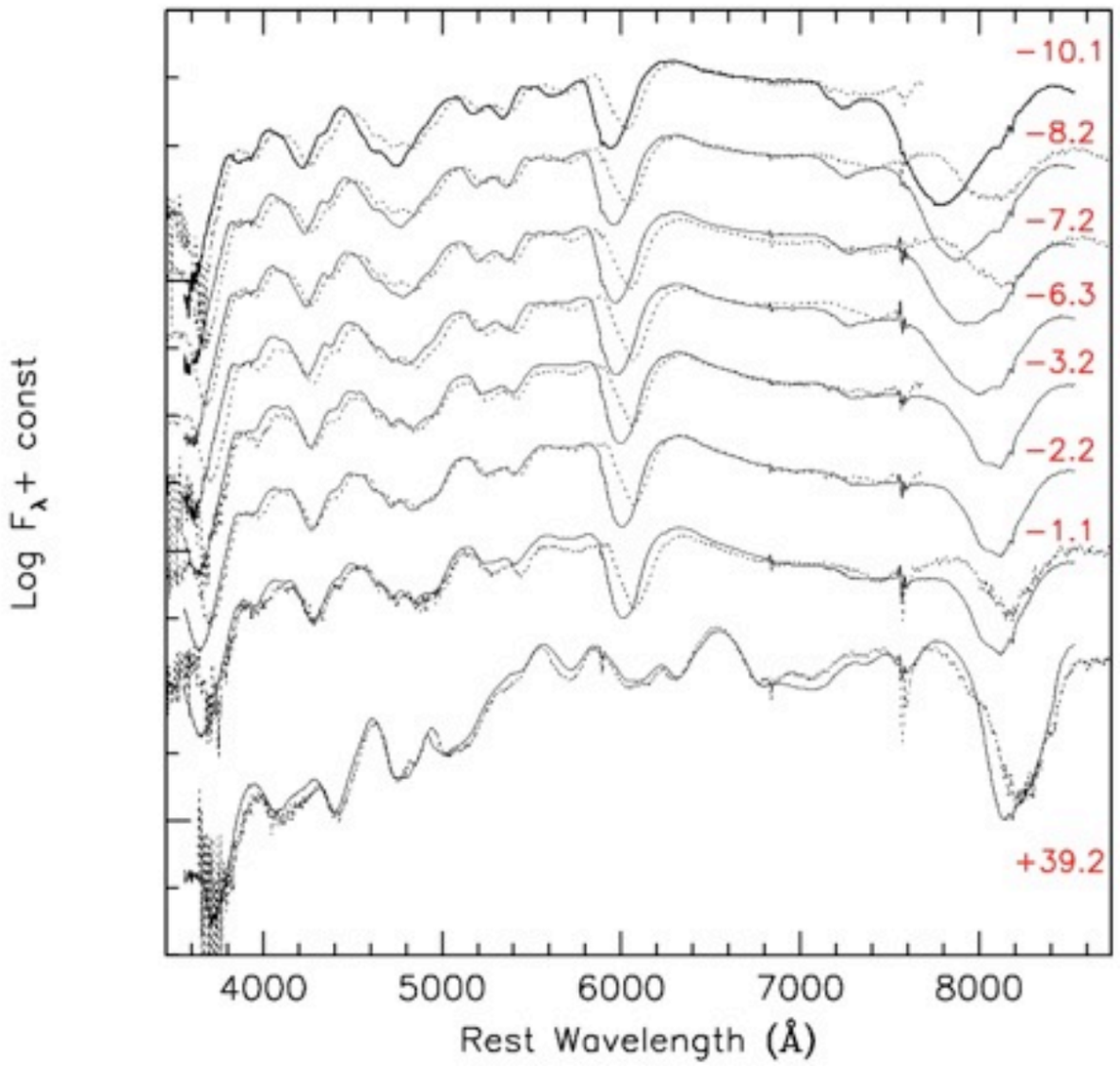
- If there is gas, we might see it in absorption in some strong optical transition (CaIIH&K, NaID, KI);
- If this gas is close to the SN, it might feel the radiation field (time evolution?)
- If it is too close, at some point it might be swept away by the ejecta;

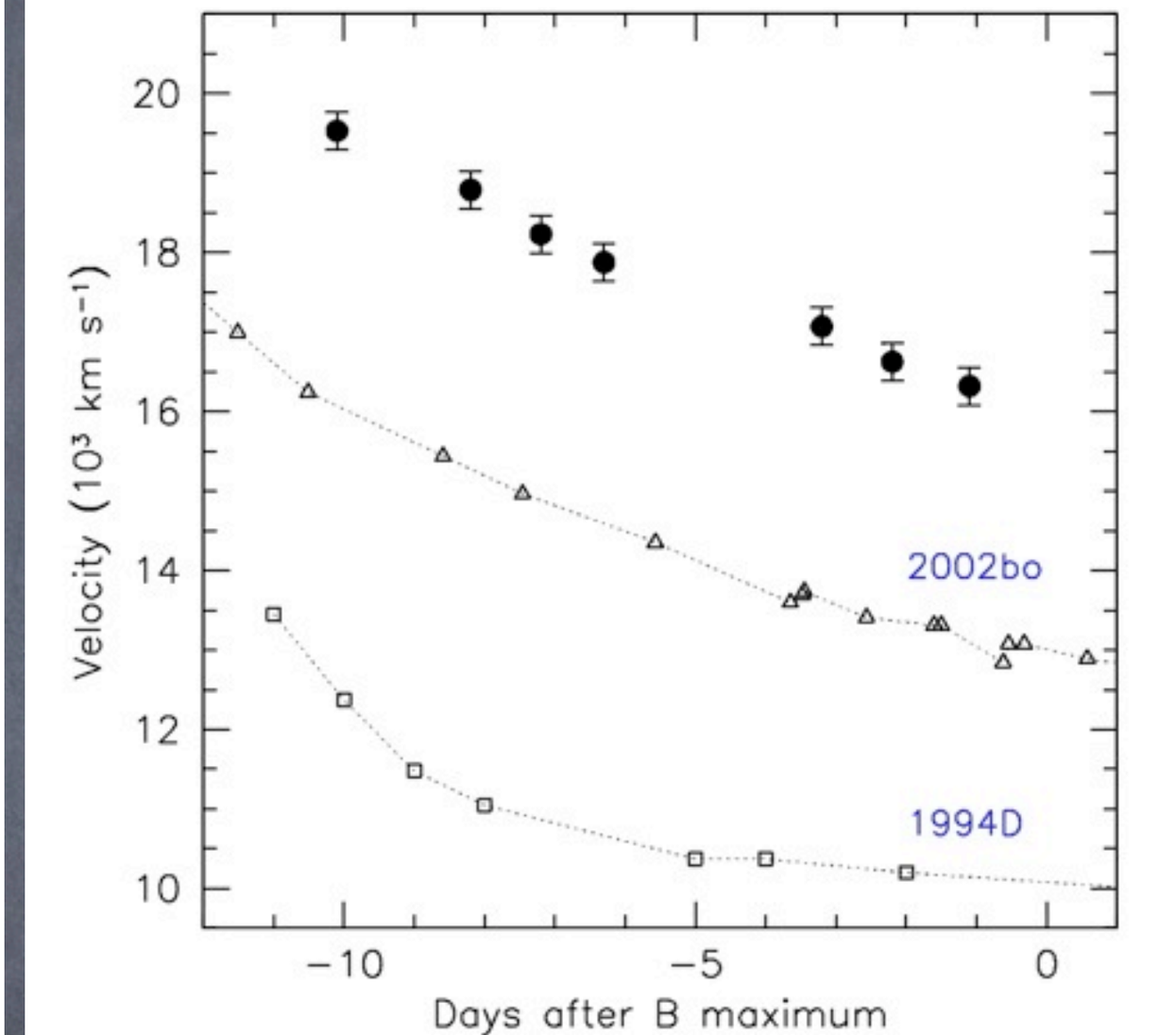
OK, let's obtain multi-epoch, high-res spectra for the next nearby SN Ia

SN2006X - February 4, 2006
a normal Type Ia (Quimby et al. 2006)

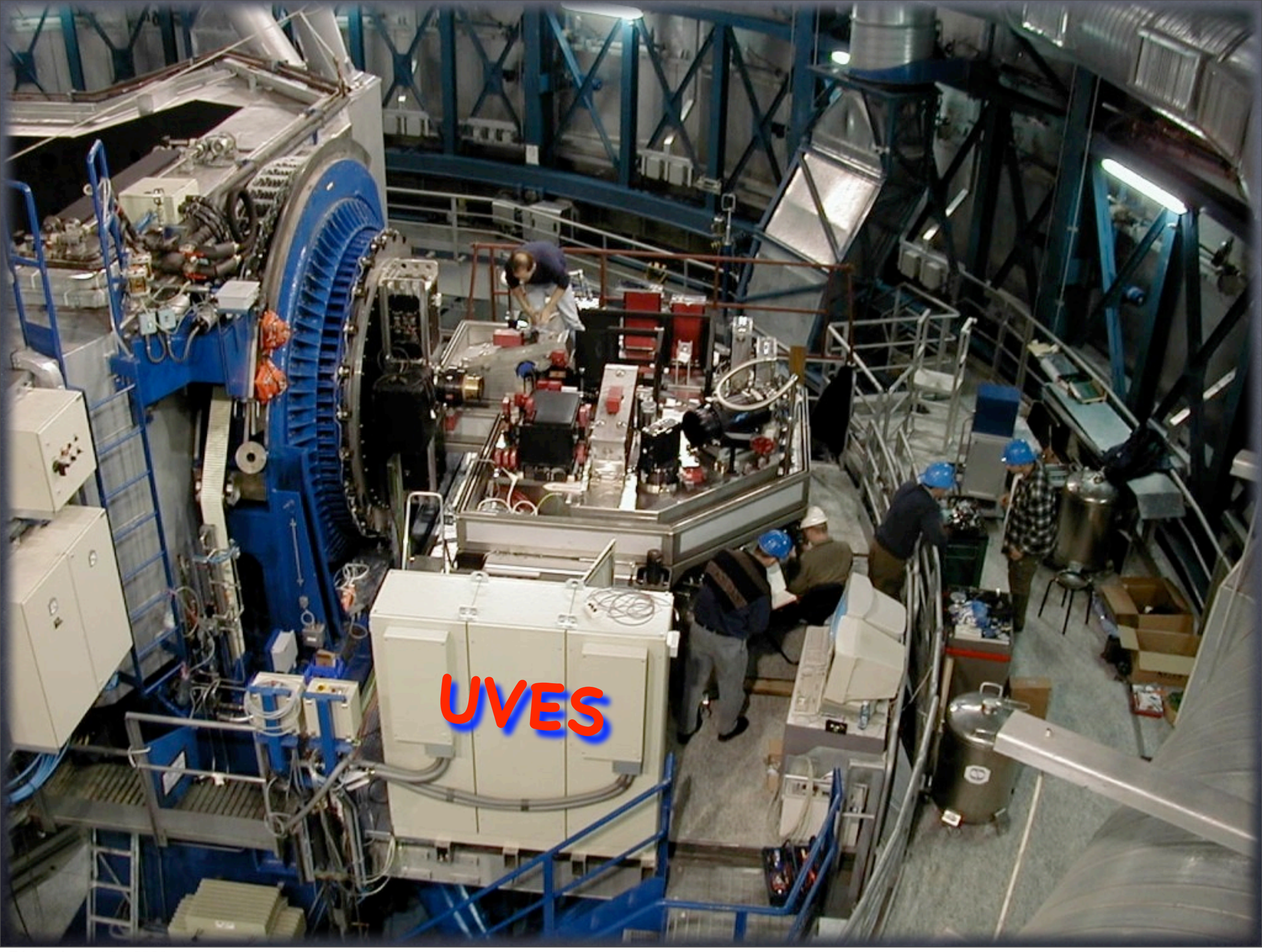
SN2006X - February 4, 2006
a normal Type Ia (Quimby et al. 2006)

2006X vs. 2002bo

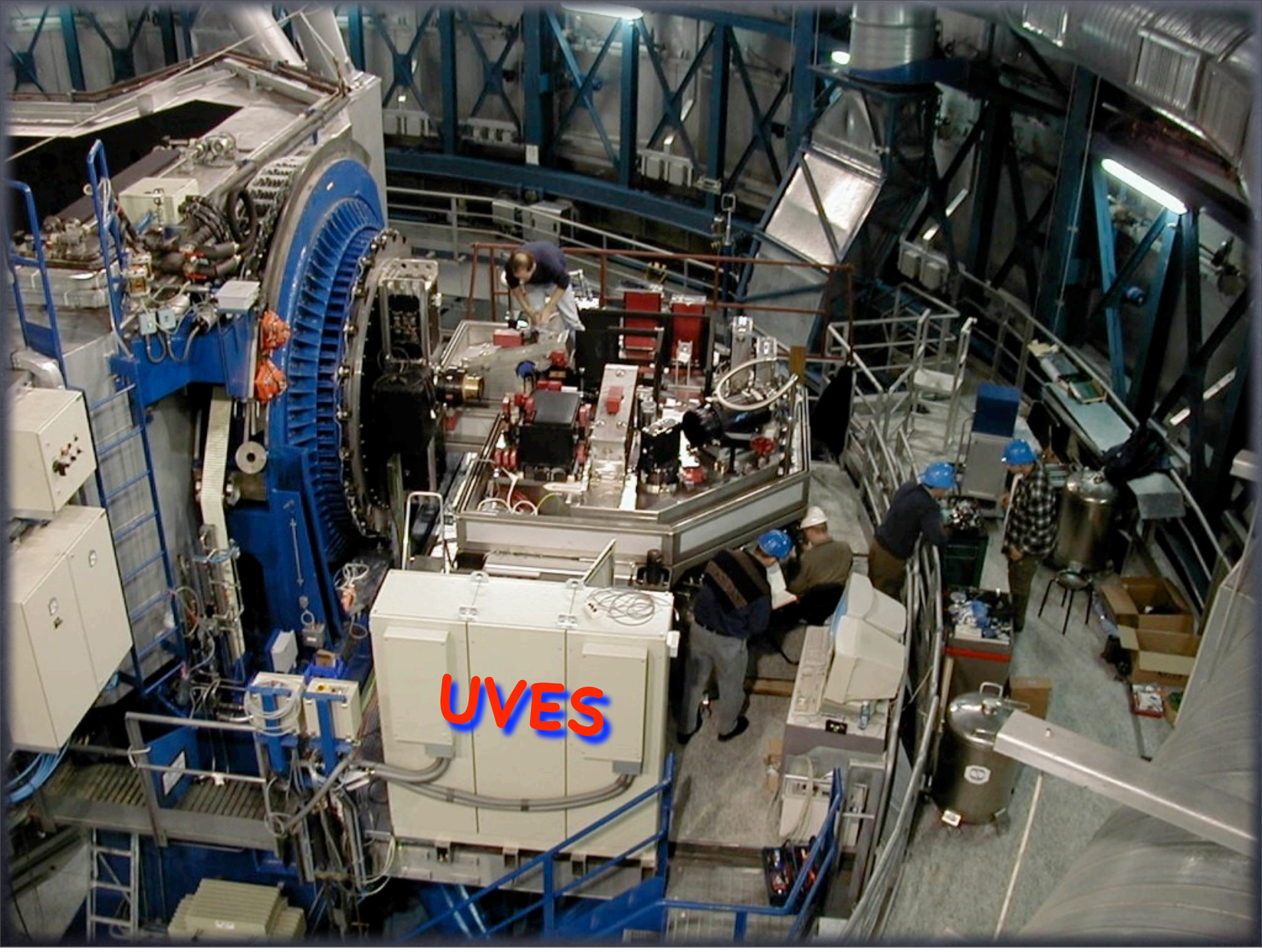




Patat et al. (2009)


UVES

Date	Phase (d)	Instr./Tel.	Expt. (s)
18/02	-2	UVES/VLT	4175
06/03	+14	UVES/VLT	8940
22/04	+61	UVES/VLT	15025
06/06	+105	HIRES/KECK	3600
25/06	+121	UVES	15025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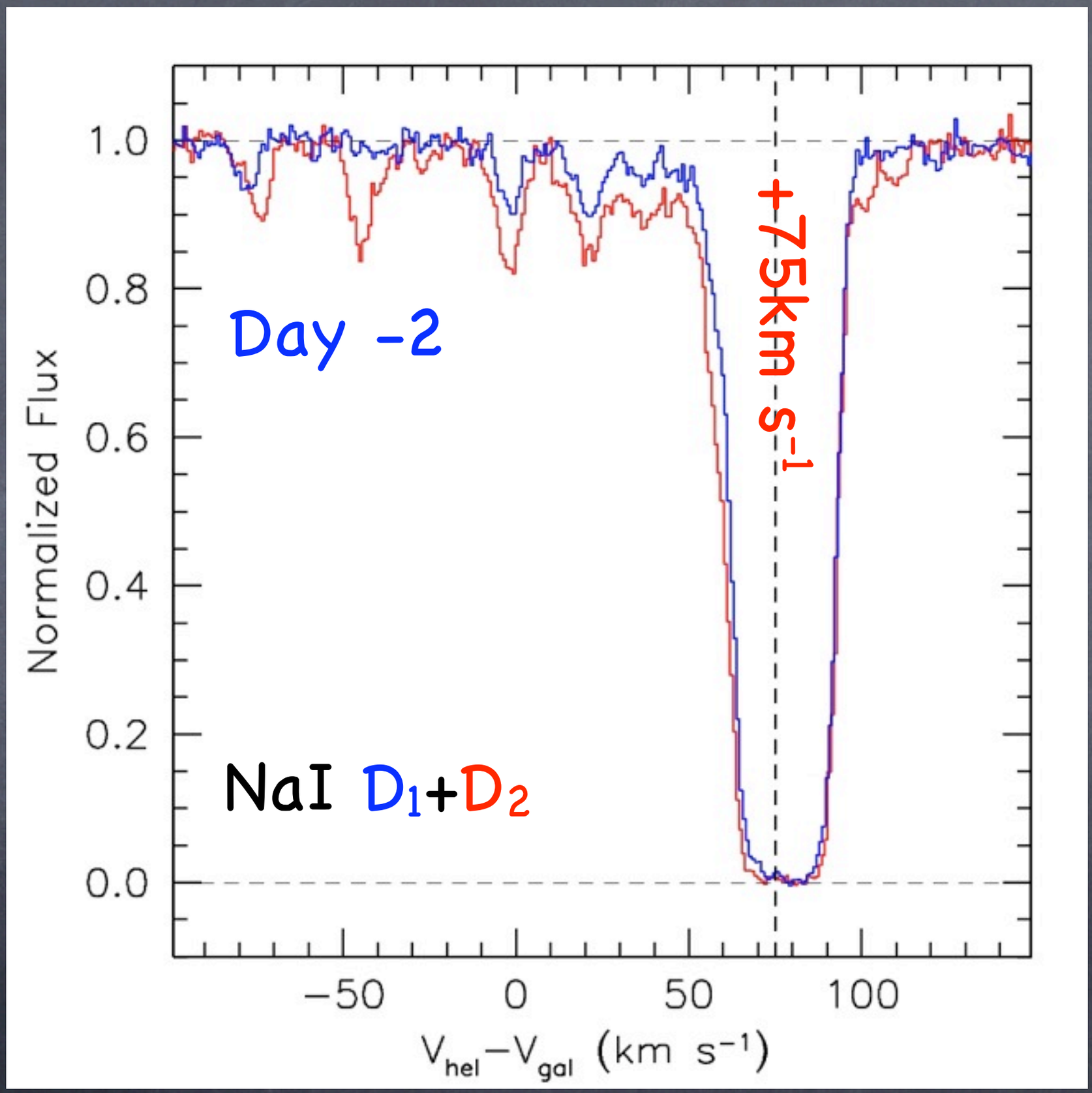
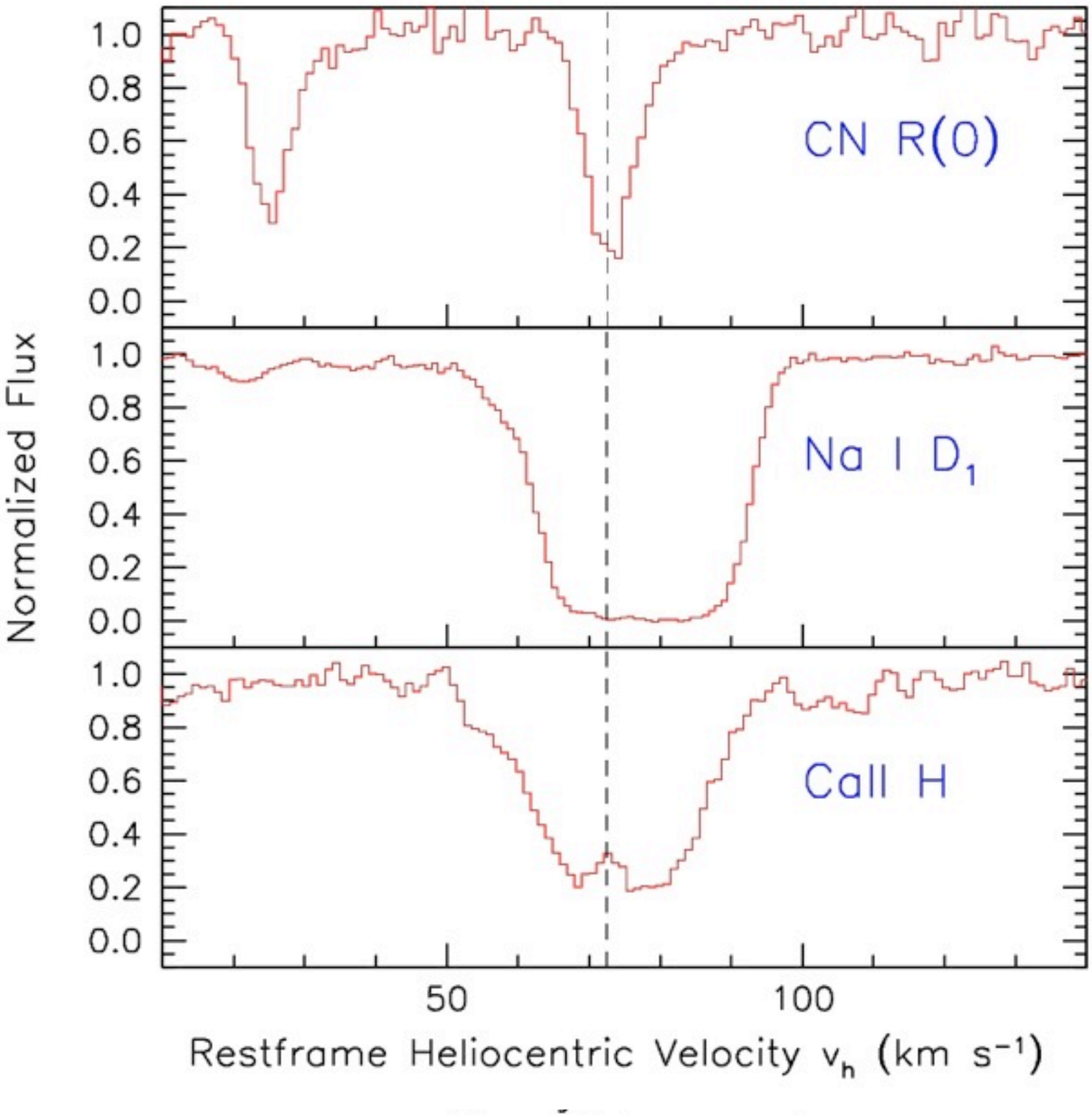
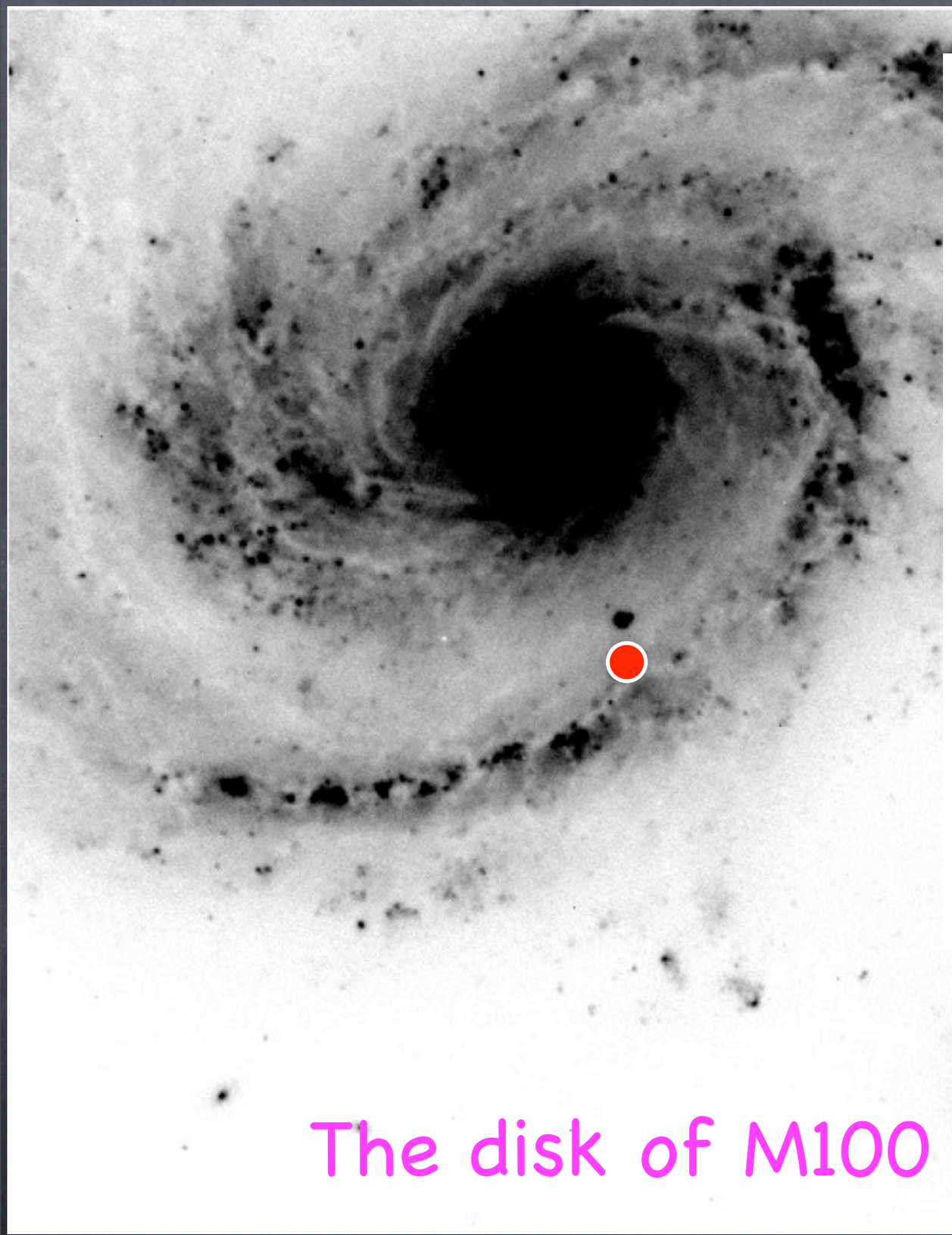
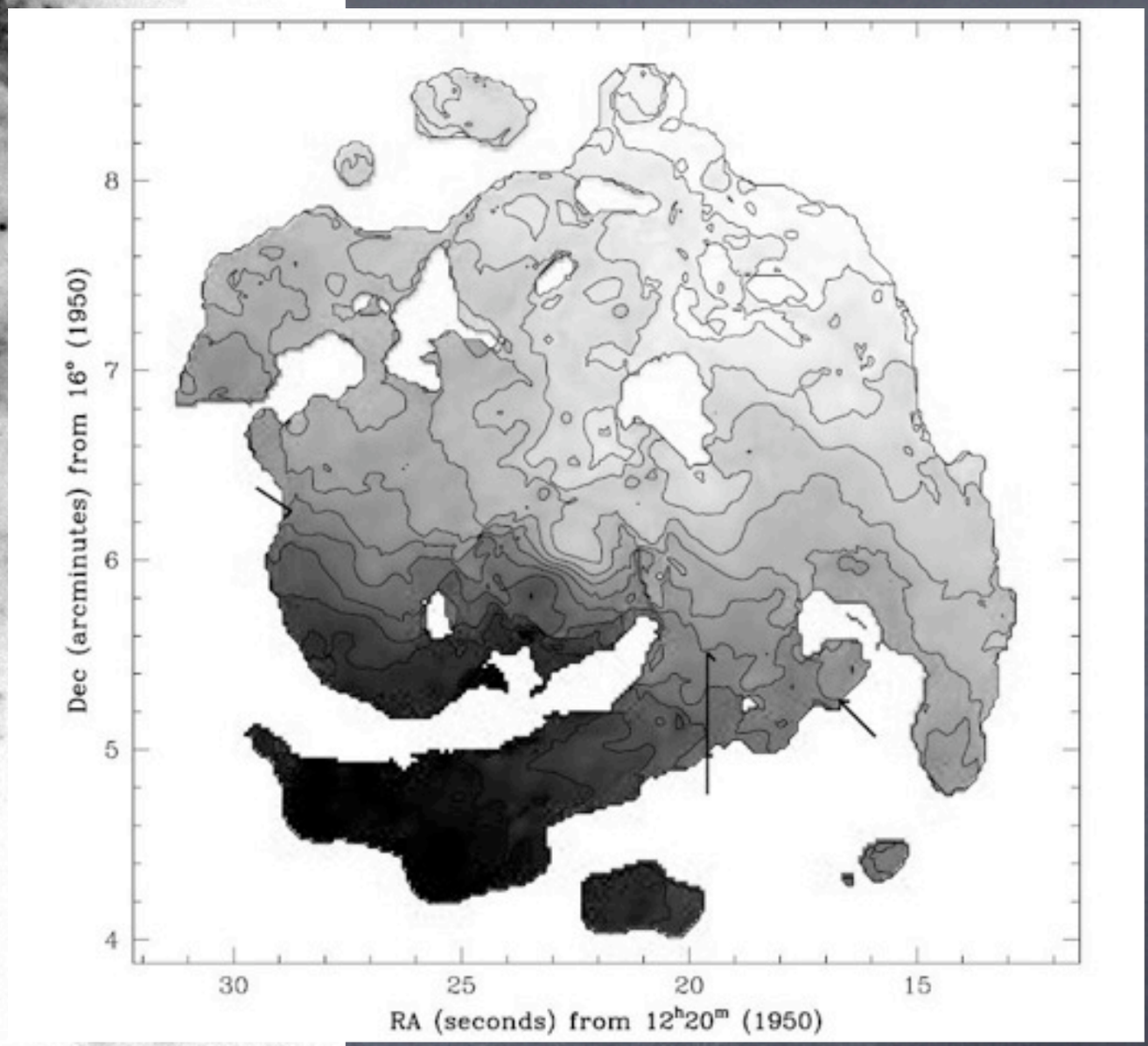

Day -2
+75km s-1
NaI D1+D2
Normalized Flux
1.0
0.8
0.6
0.4
0.2
0.0
−50
0
50
100
Vhel−Vgal (km s−1)

See also Cox & Patat 2008

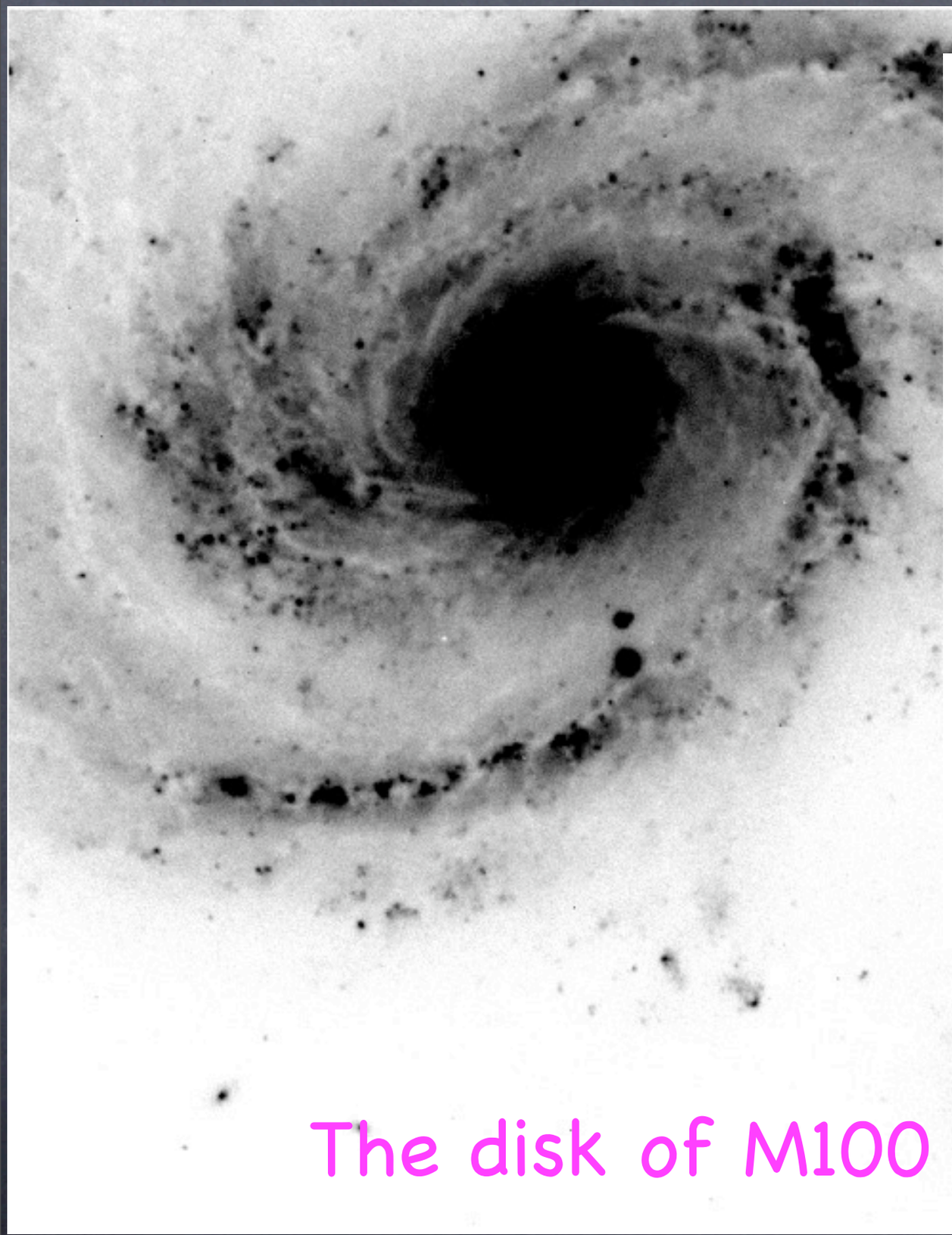


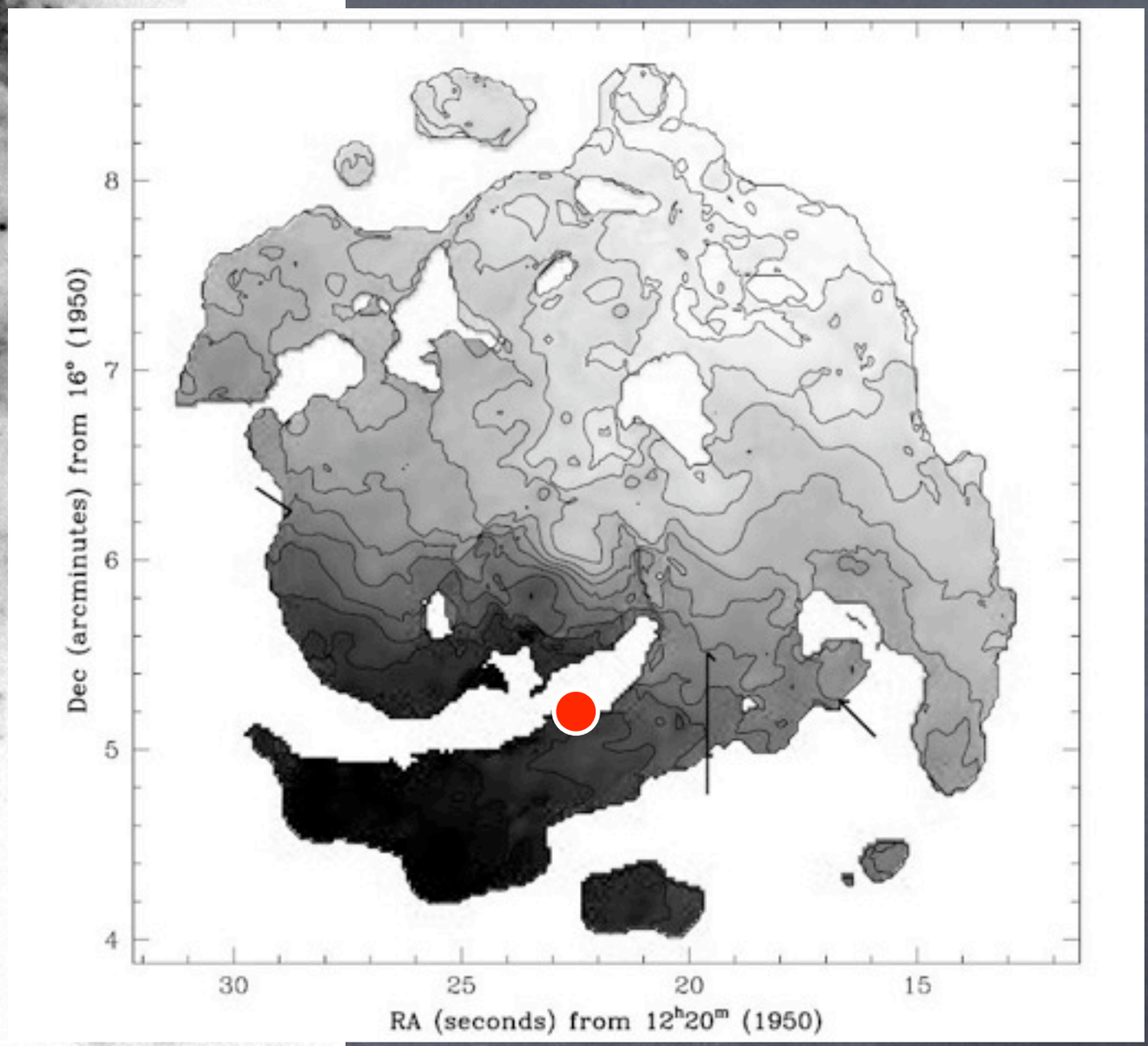




Canzian & Allen (1995)

The disk of M100





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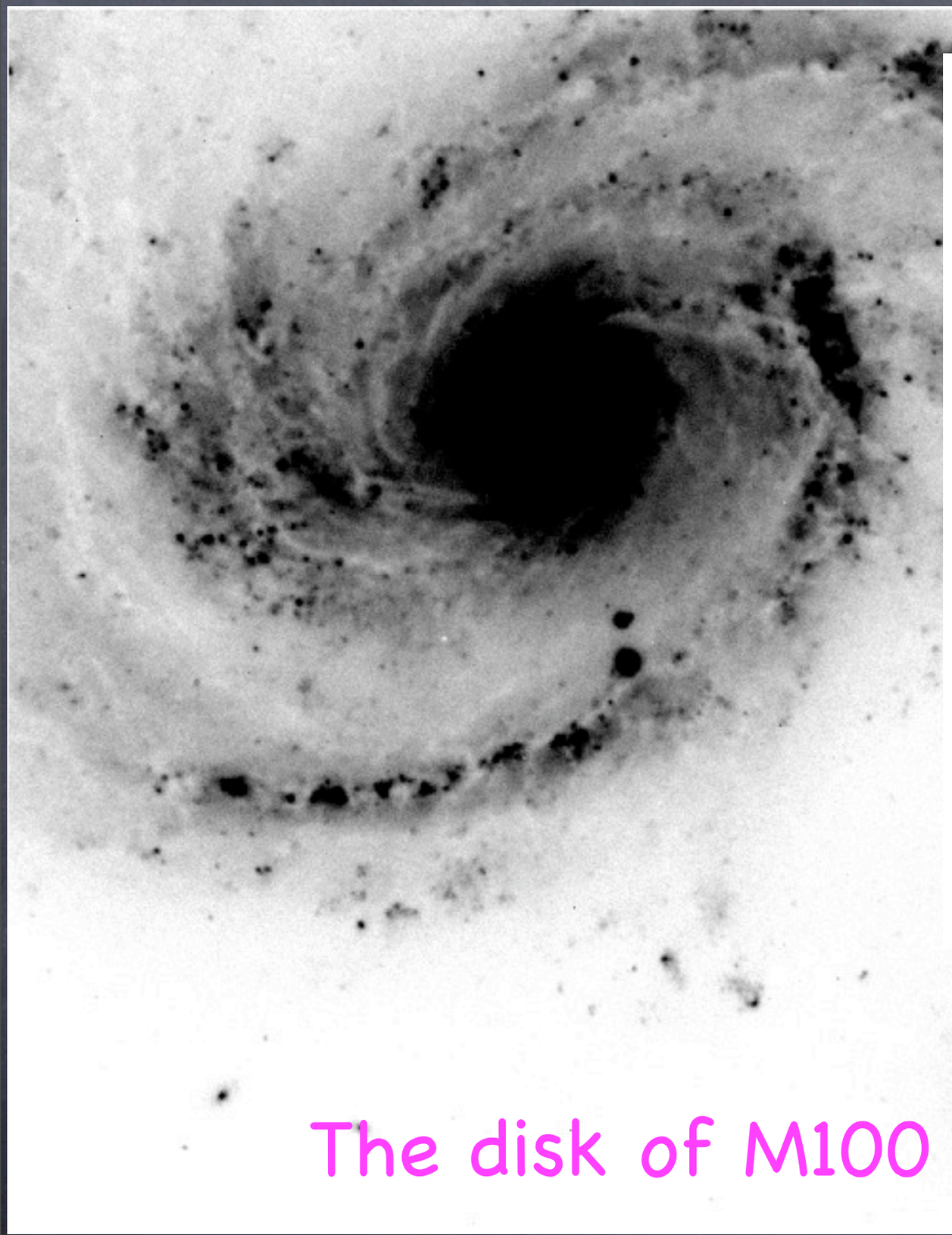

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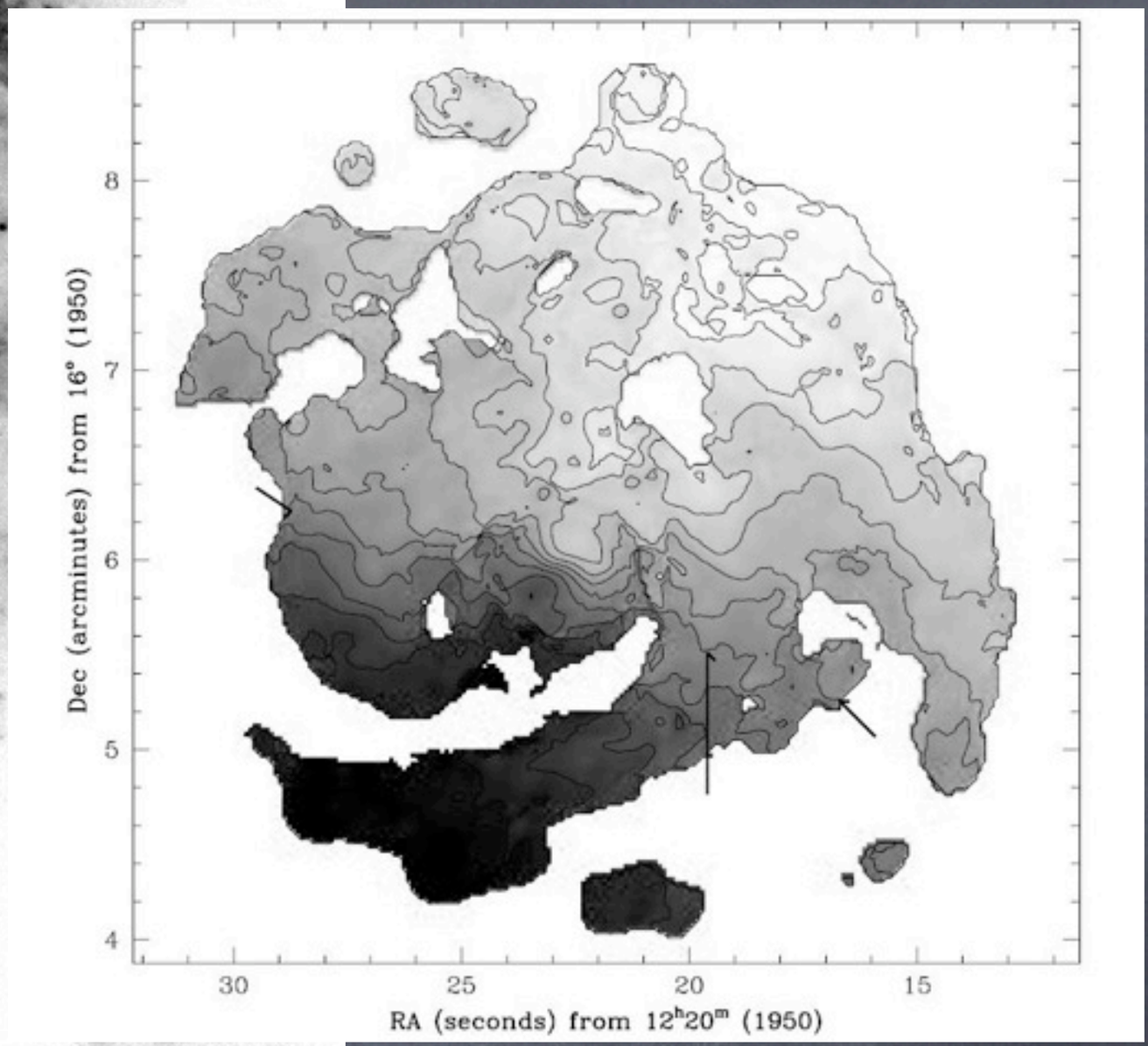
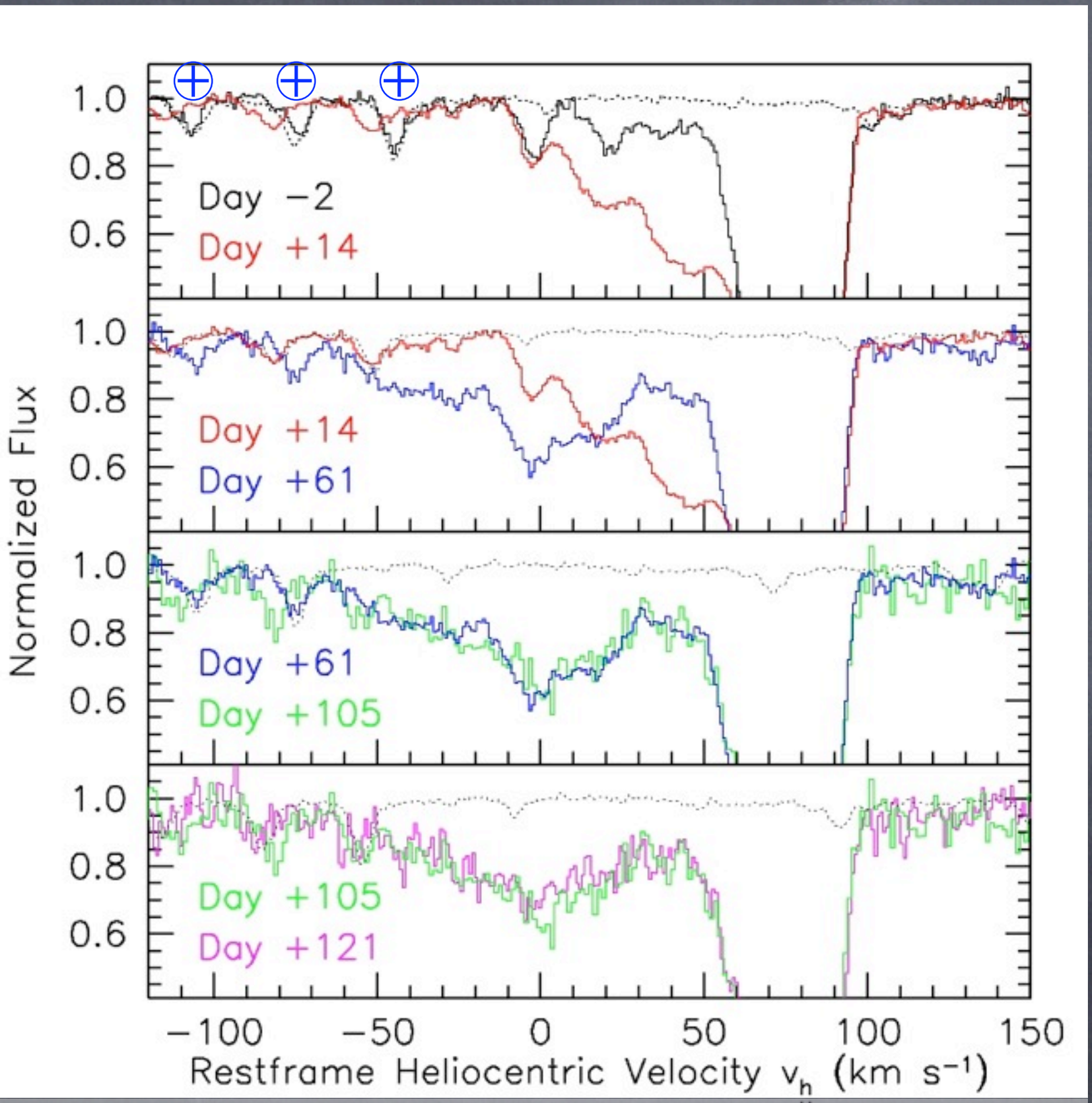


Canzian & Allen (1995)

V_{rot}=+75 km s^{-1}


Day −2
Day +14
Day +14
Day +61
Day +61
Day +105
Day +105
Day +121
Normalized Flux
1.0
0.8
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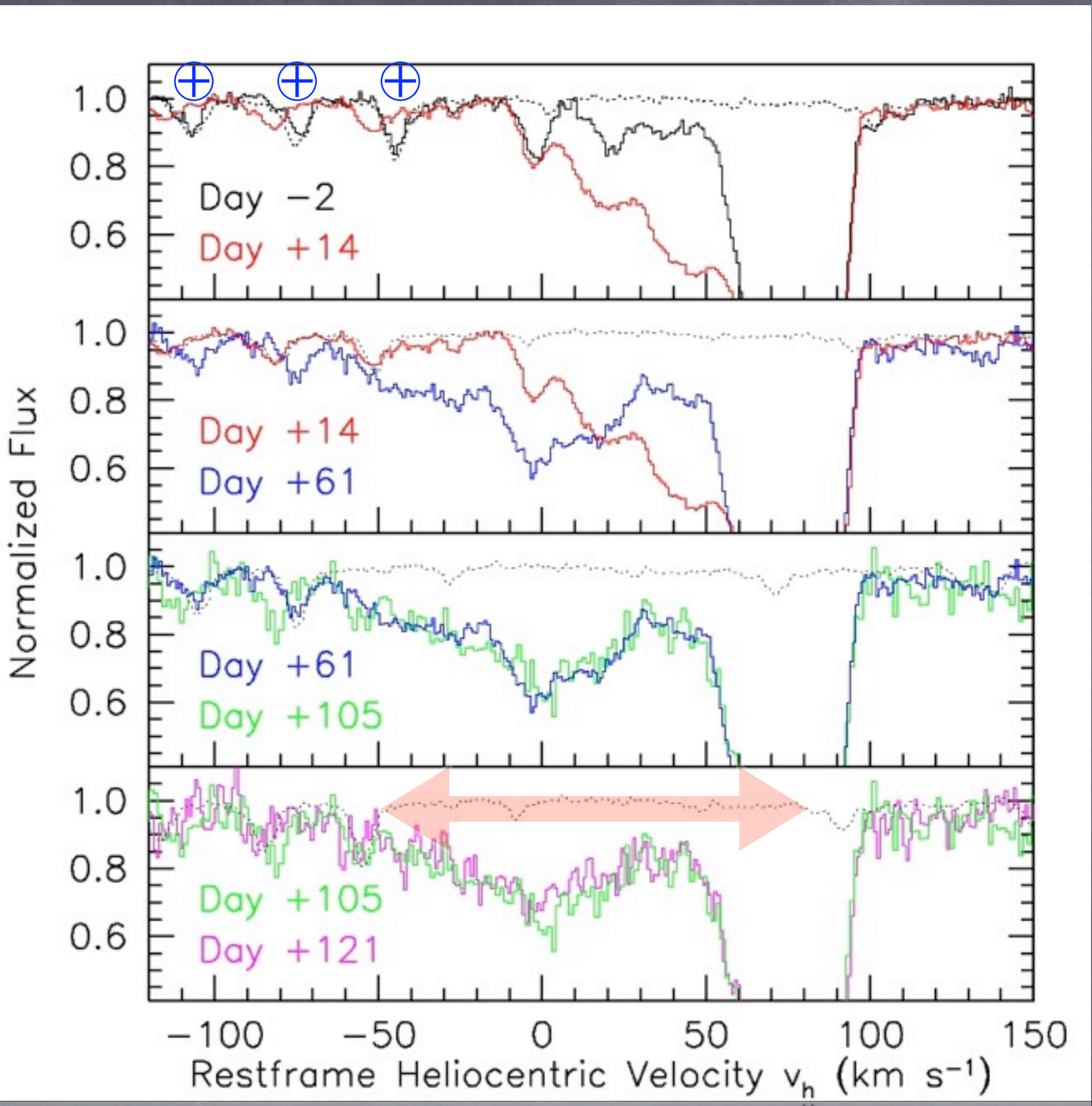
−100
−50
0
50
100
150
Restframe Heliocentric Velocity v_h (km s^{-1})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Just a Geometric Effect?

($r_{ph}=2x10^{15}$ cm @ max for $v_{phot}\sim10^{4}$ km s^{-1})

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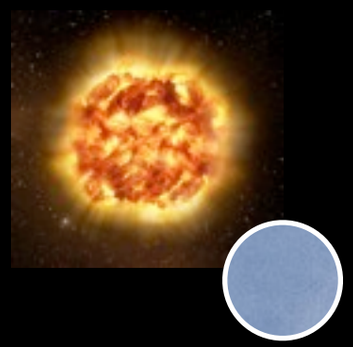

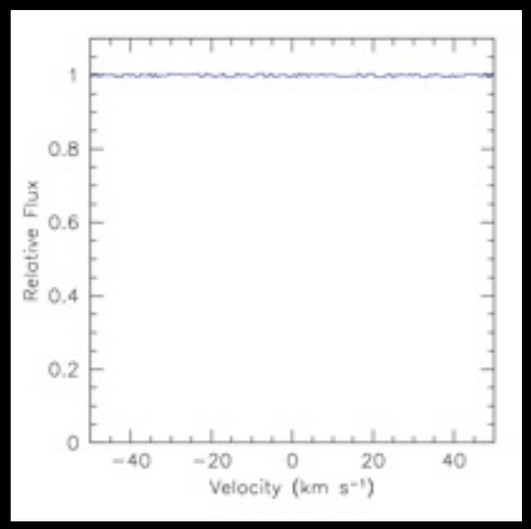

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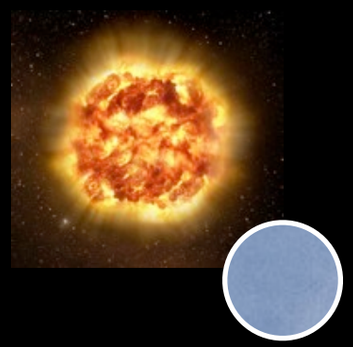

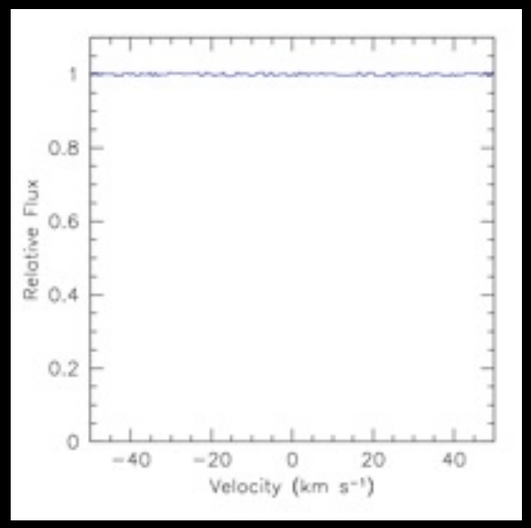

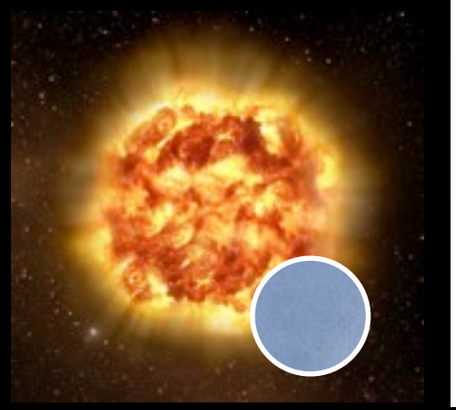

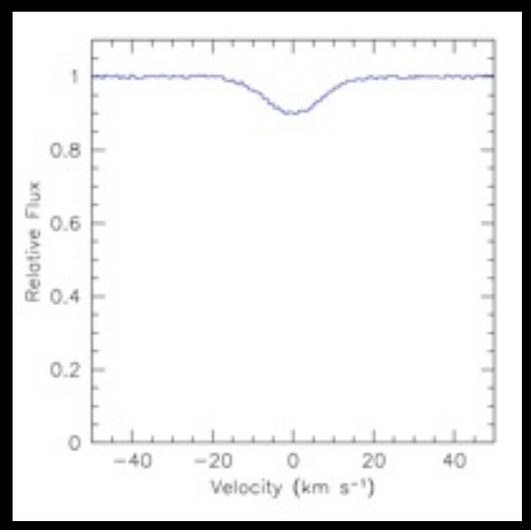

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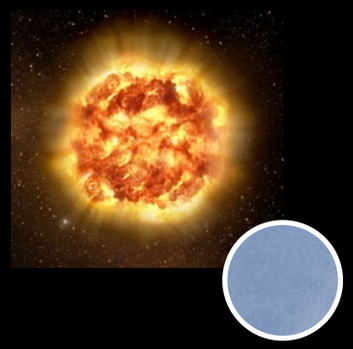
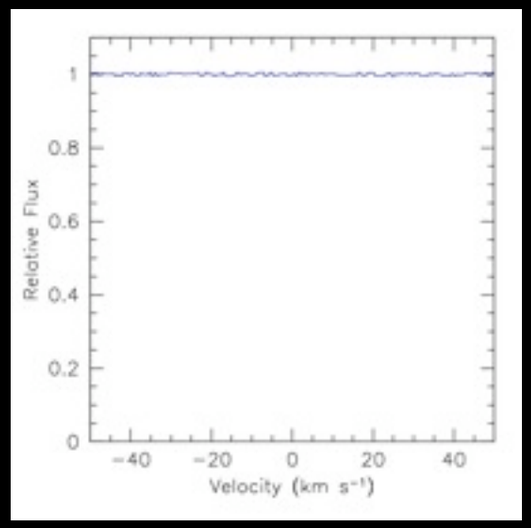
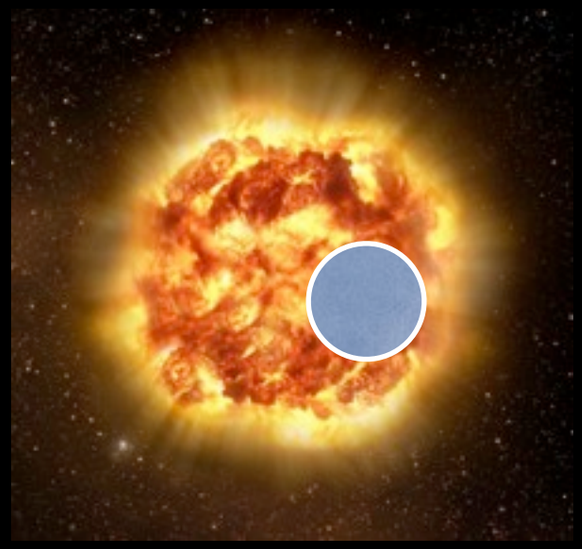
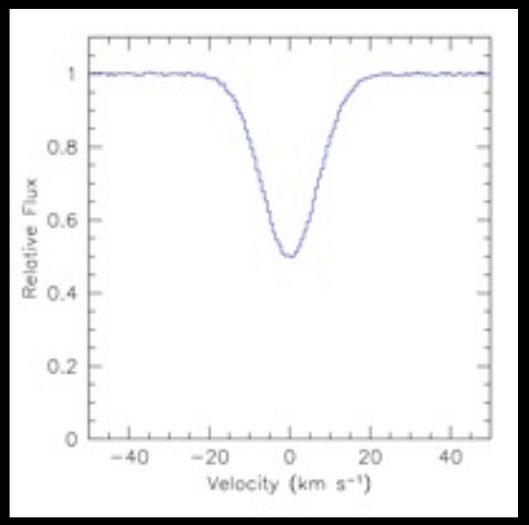
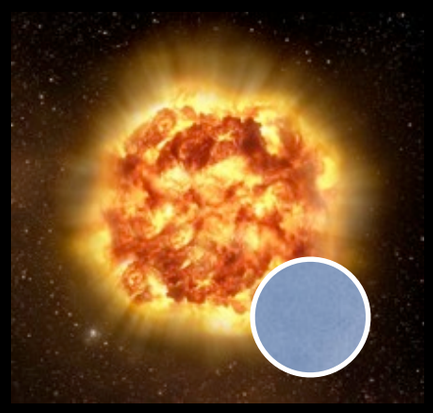
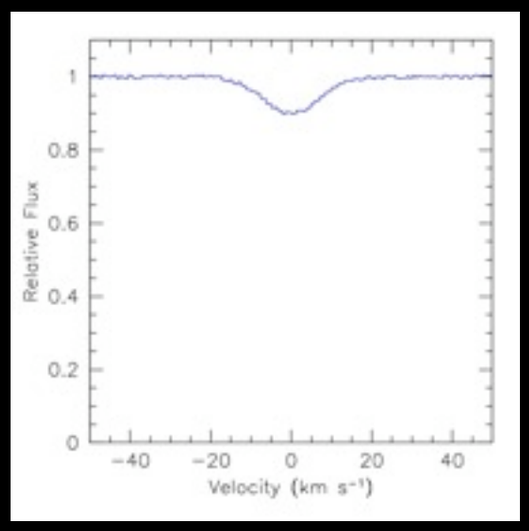






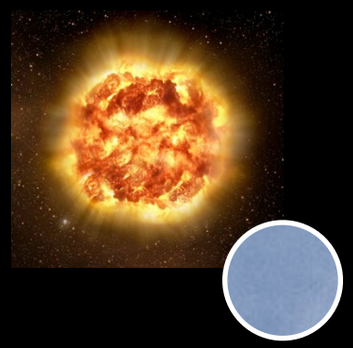


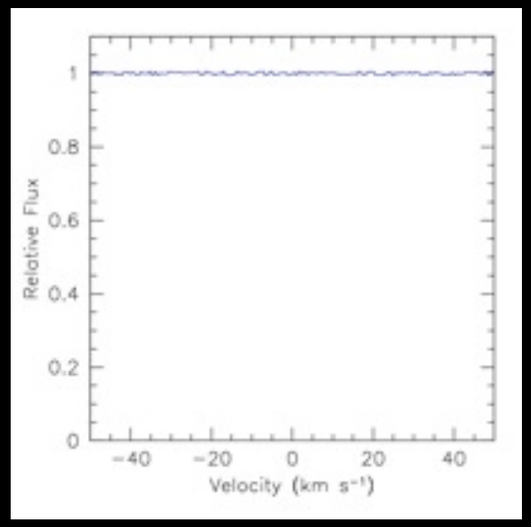


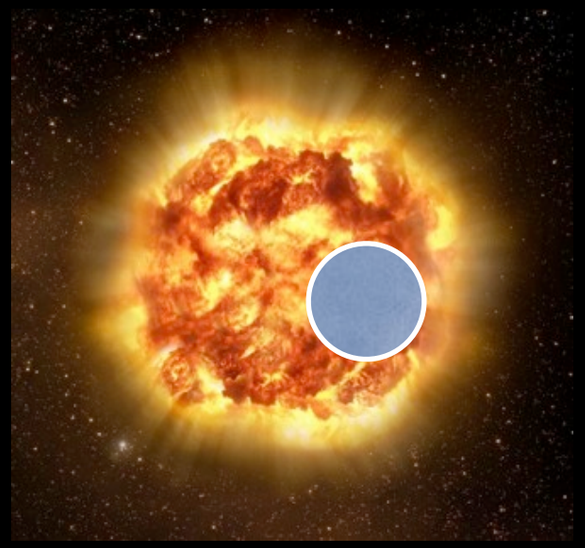


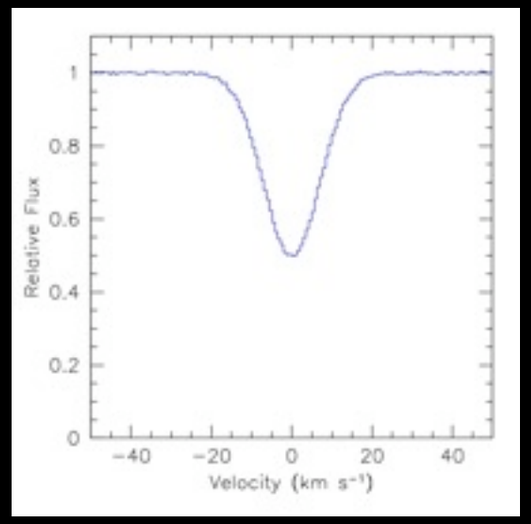
Just a Geometric Effect?

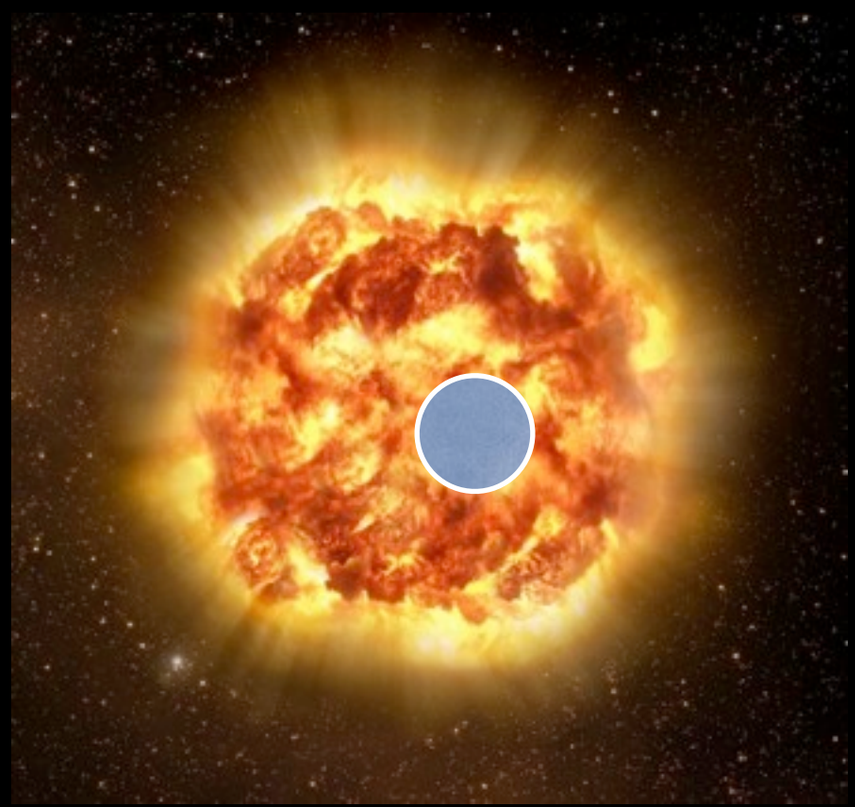
($r_{ph}=2x10^{15}$ cm @ max for $v_{phot}\sim10^{4}$ km s^{-1})

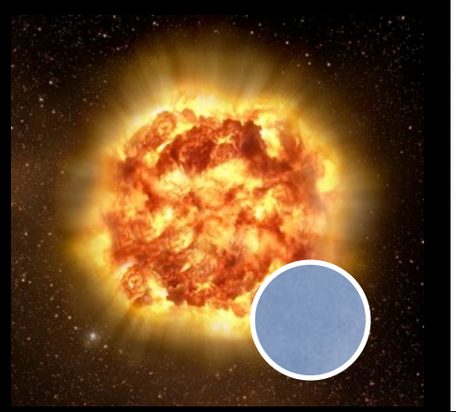


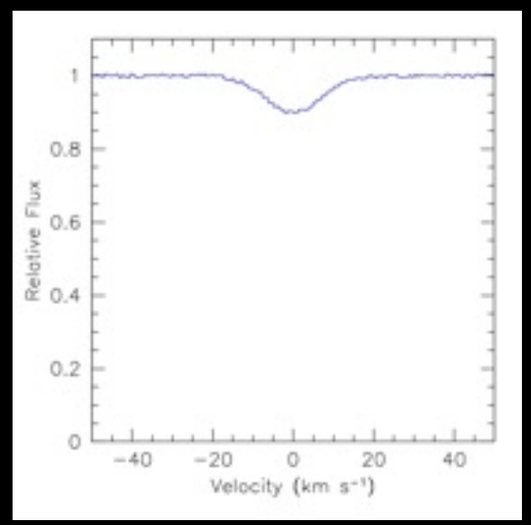


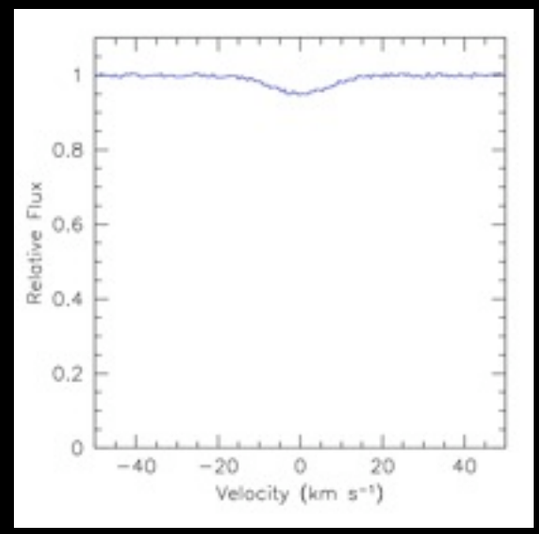




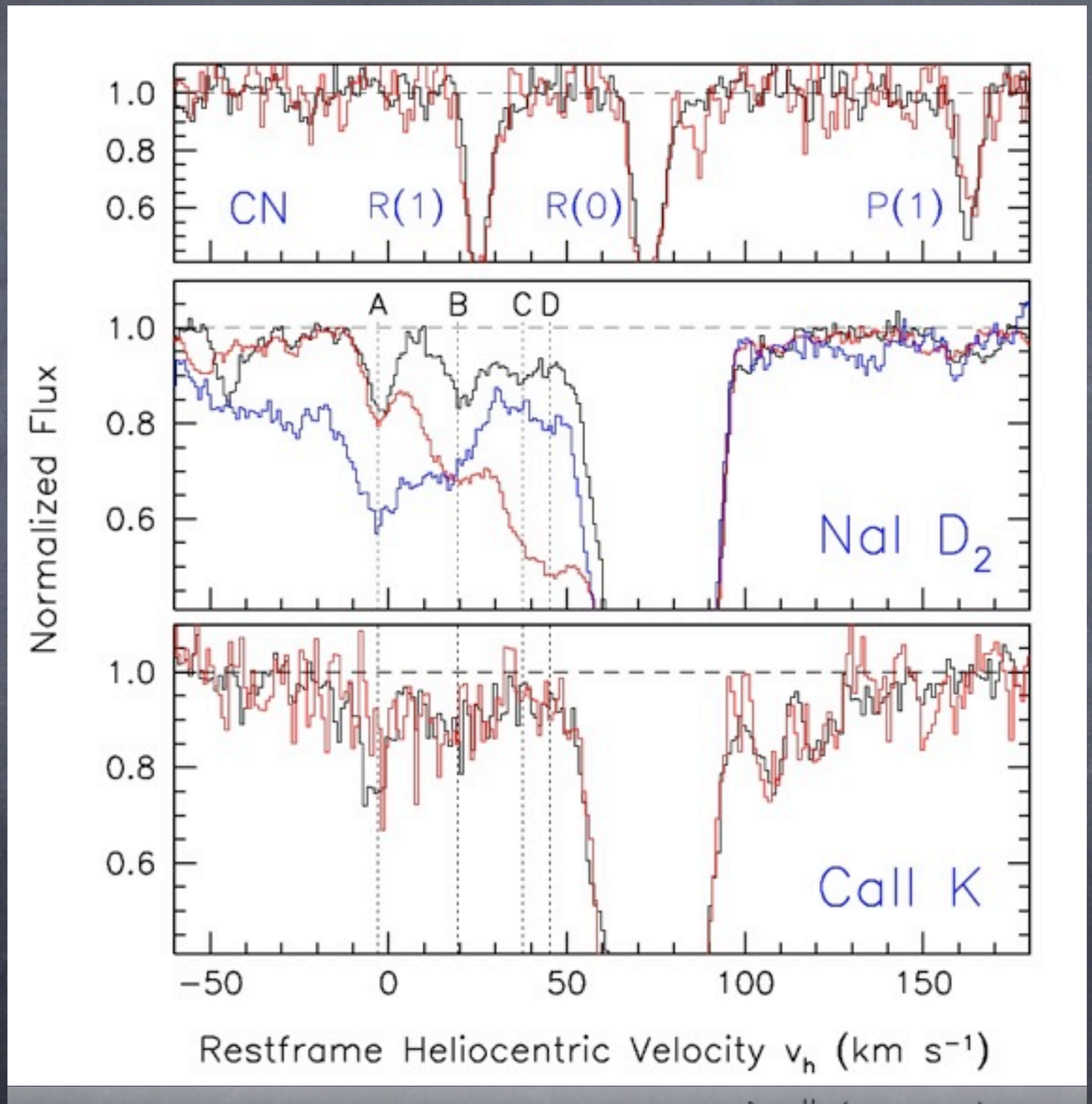








Lack of Ca II H&K time evolution



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The different behavior seen in NaI and CaII is explained in terms of the lower ionization potential of Na I (5.1 eV --> 2417Å) w.r.t. CaII (11.9 eV --> 1045Å), coupled to a UV-deficient radiation field of SNe Ia.

(but see Chugai 2008)

A Ia is UV-weak, but still can ionize NaI to ~5×10^{18} cm.

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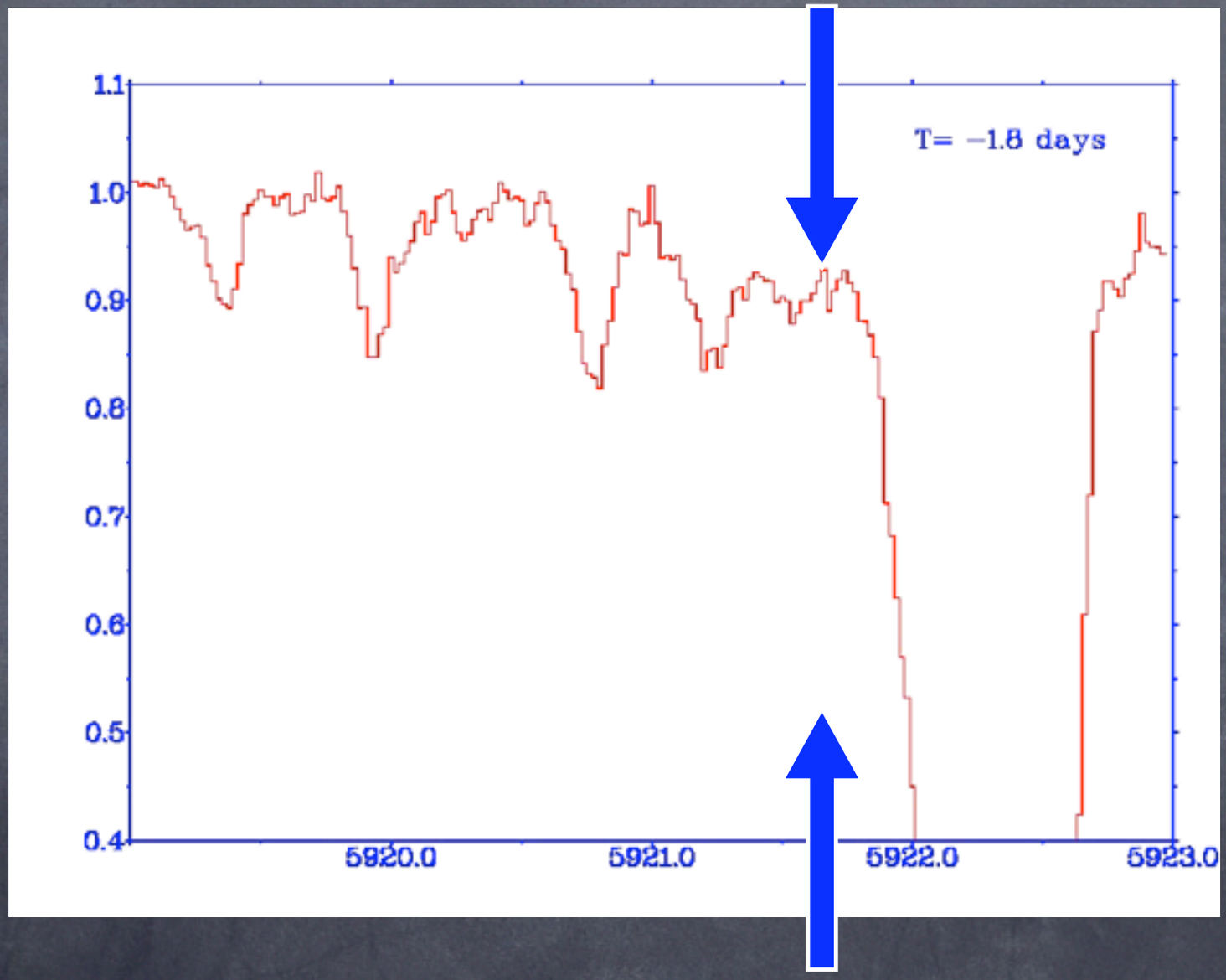
This confines the gas to within 10^{17} cm

But things are not that simple...

C D



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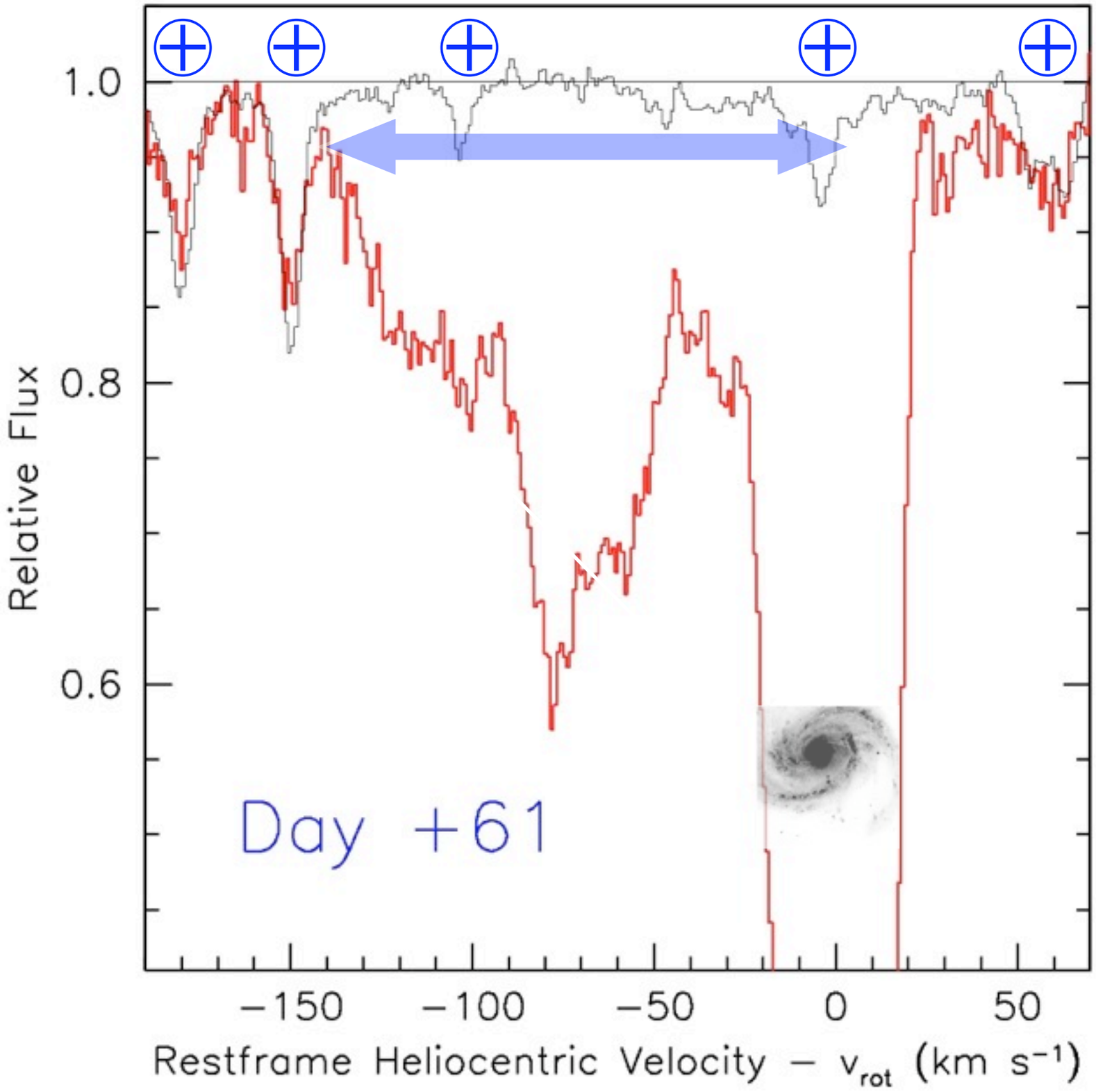
No VLA detection @ 10 months (~10^{17}cm)

(Chandra, Chevalier & Patat 2006)


1.0
0.8
0.6
Relative Flux
Day +61
−150
−100
−50
0
50
Restframe Heliocentric Velocity − v_rot (km s⁻¹)

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TUTUKOV!

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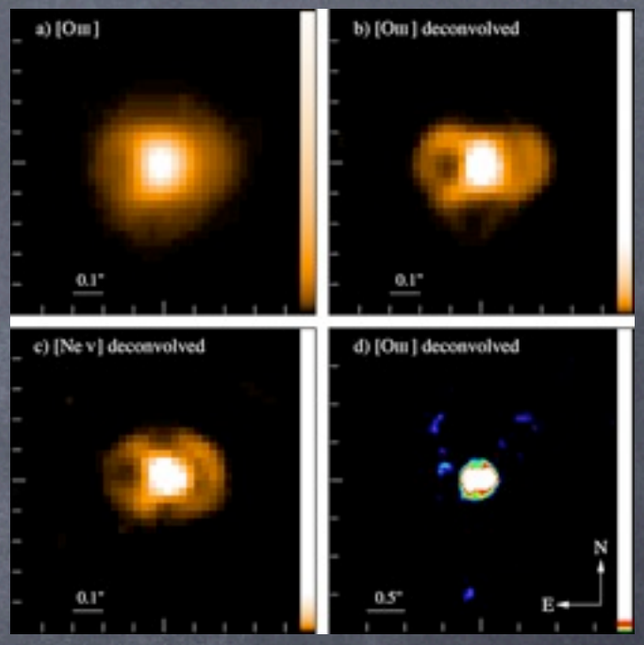
The observed velocities seem more consistent with the shorter-period end of the symbiotic formation channel (WD+RG) (Munari & Renzini 1992)

Is the structure of the CSM telling us something more?

- variability in the RG wind? (Willson 2000)
- remnant shells of recurrent novae? (Judge & Stencel 1991; Hachisu & Kato 2001; Wood-Vasey & Sokoloski 2006)
- bipolar shells? RS Oph like? (O'Brien et al. 2006, Sokoloski et al. 2006, Bode et al. 2007)



(Bode et al. 2007)

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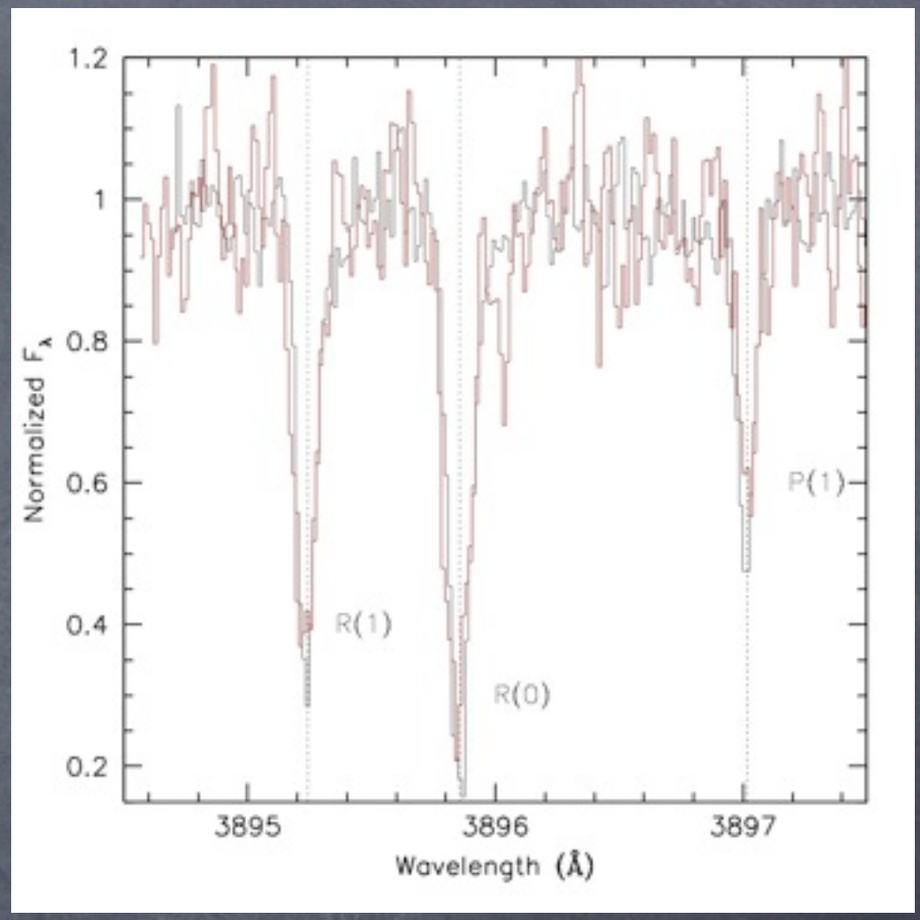

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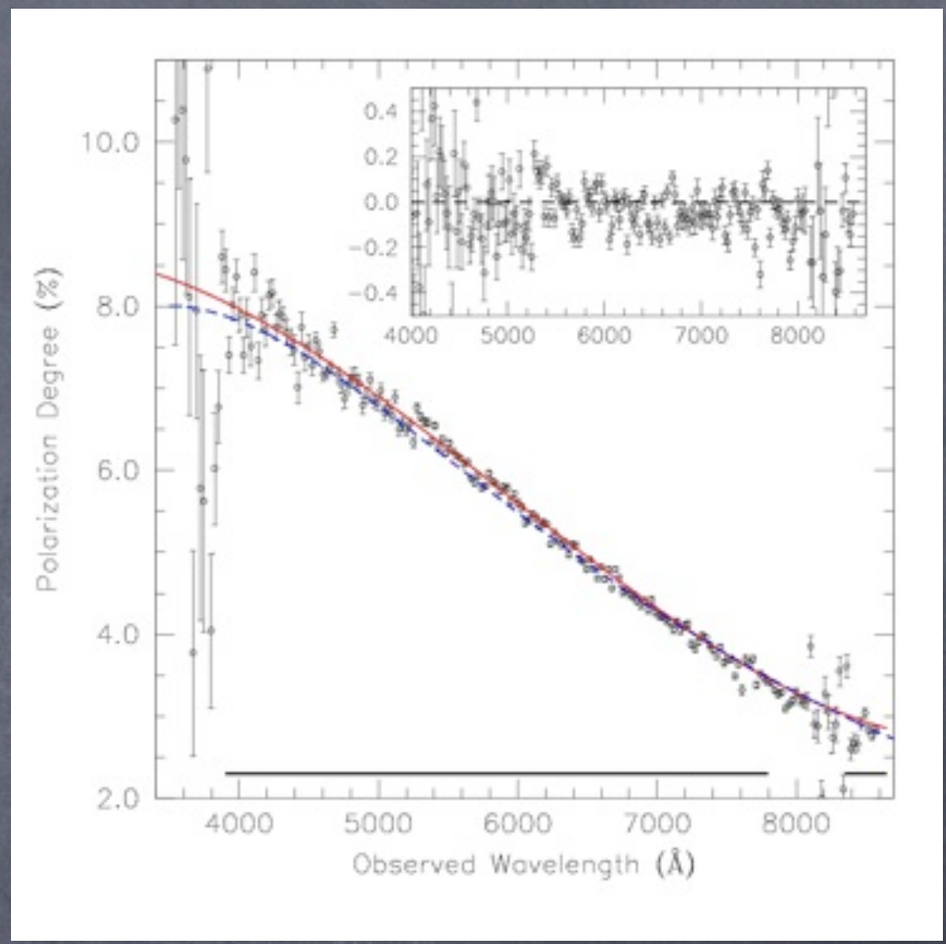

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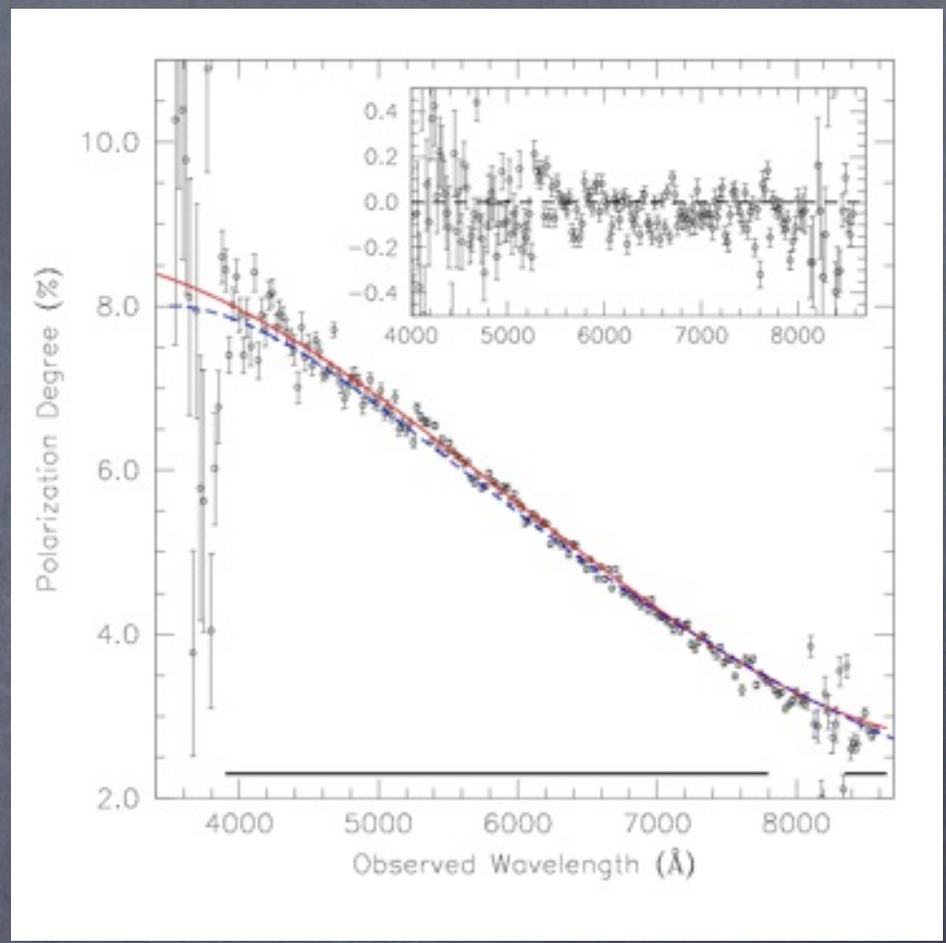

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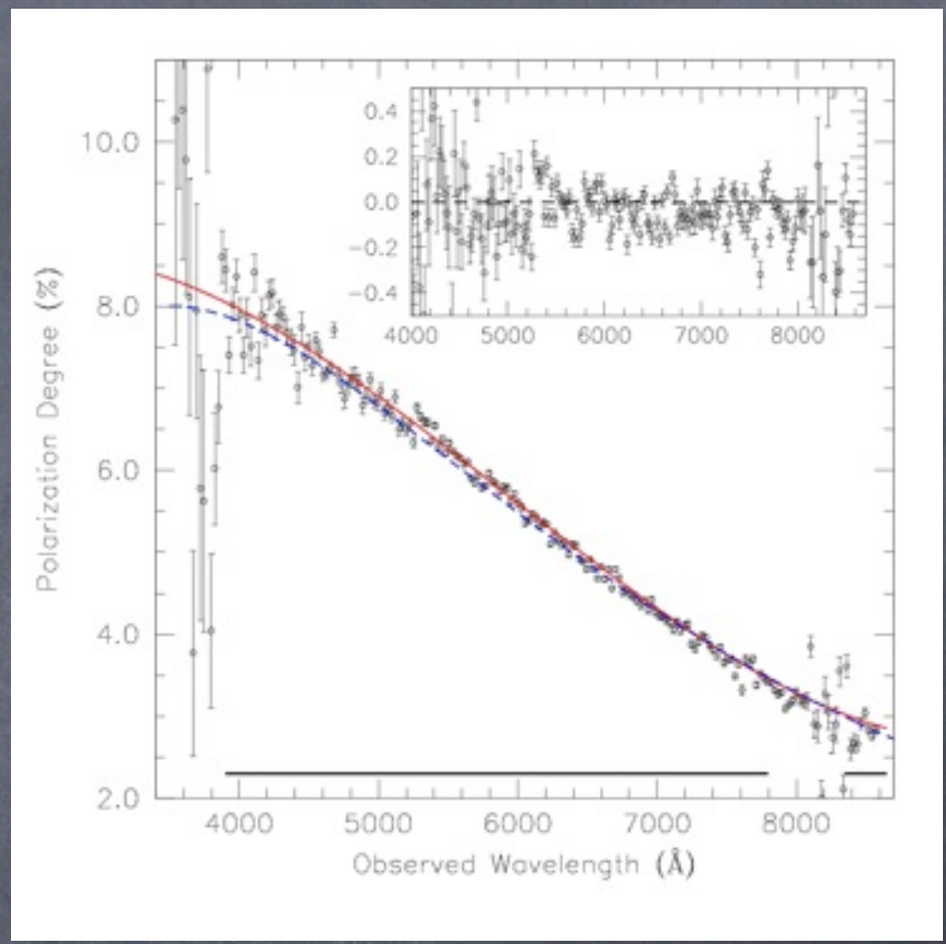

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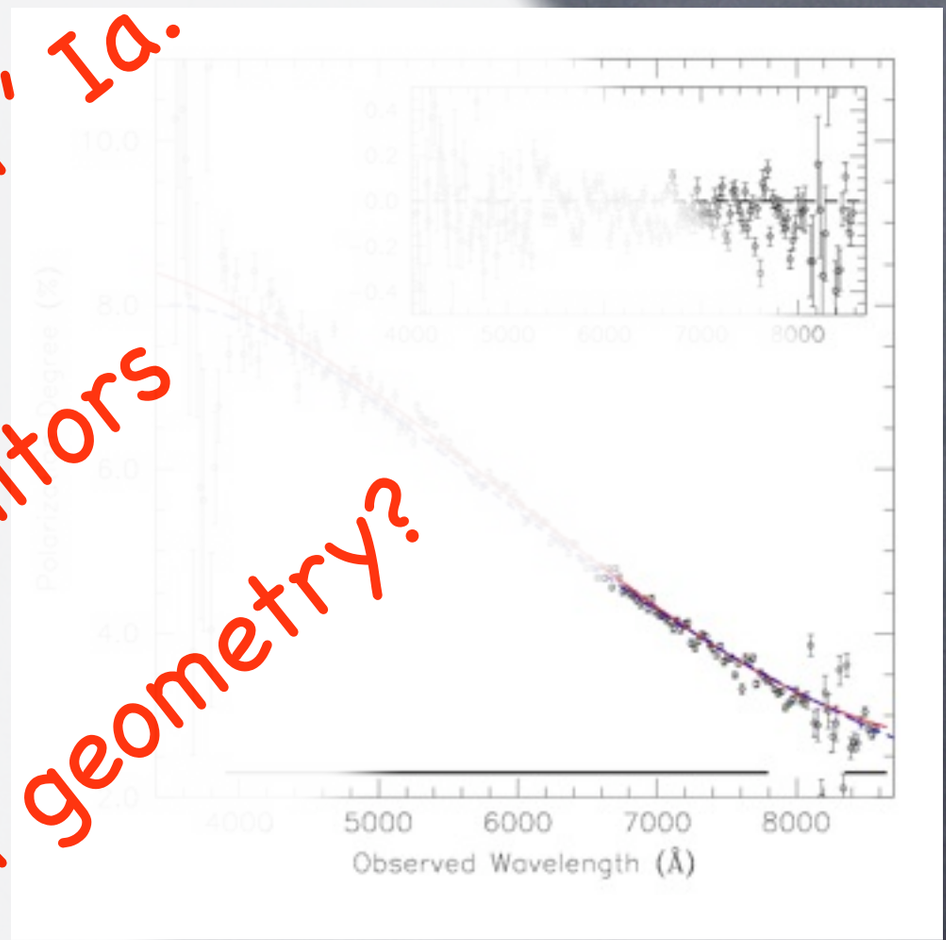

Patat et al. 2009

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Different progenitors vs. Different CSM geometry?

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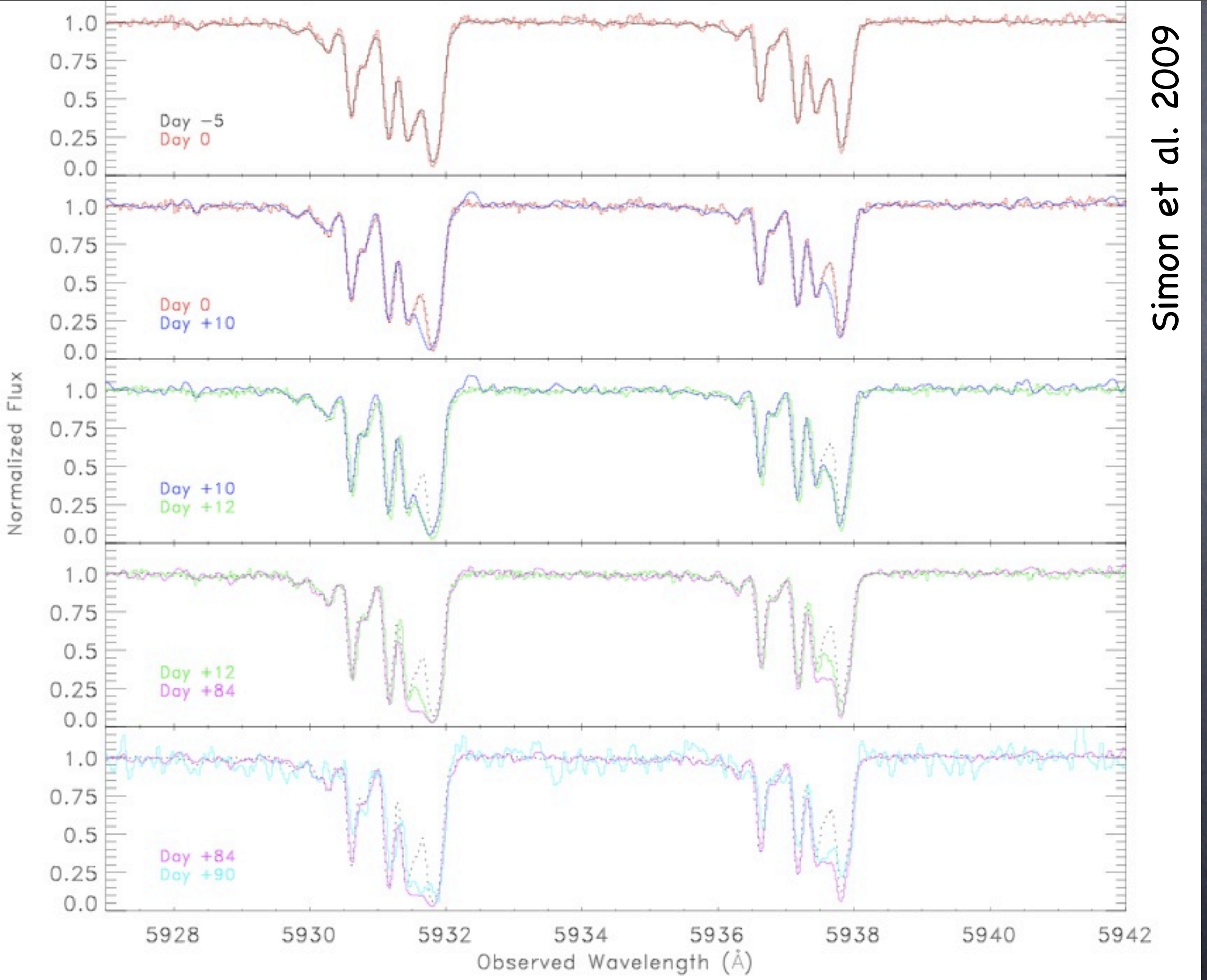
- C
- f
- S
- L



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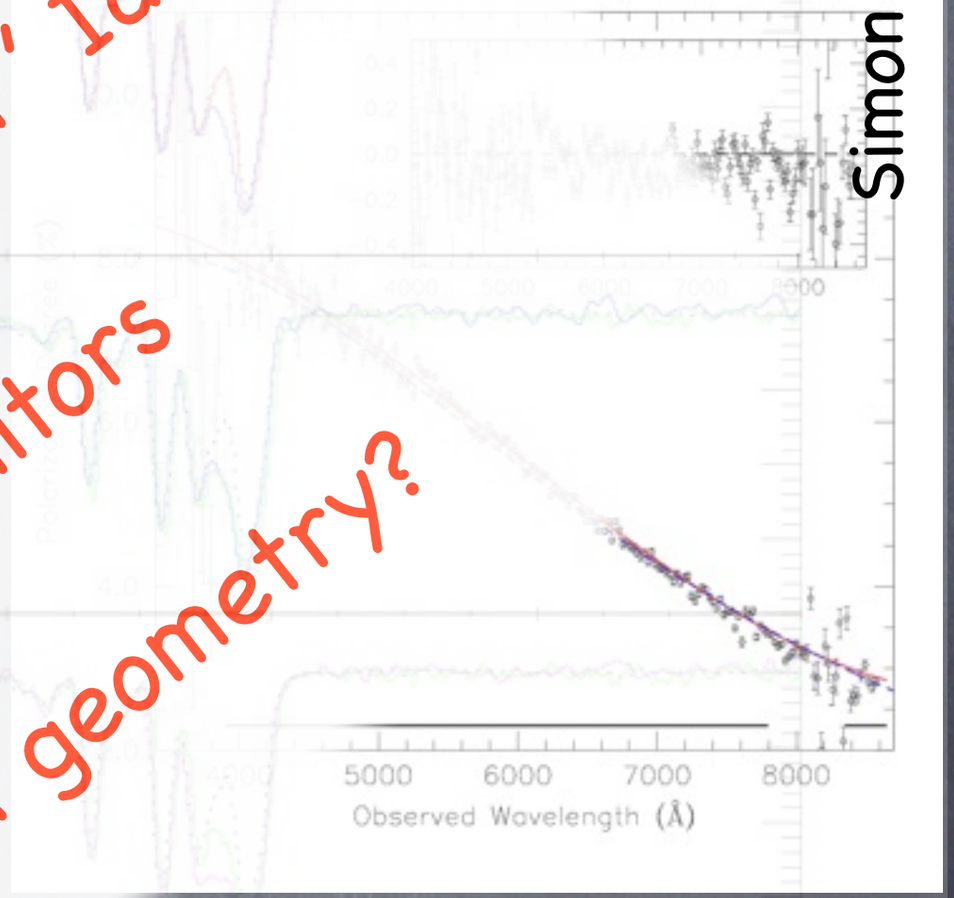

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Viewing angles might play a role and multiple channels to Ia explosion do probably exist.

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- Simon et al. 2007
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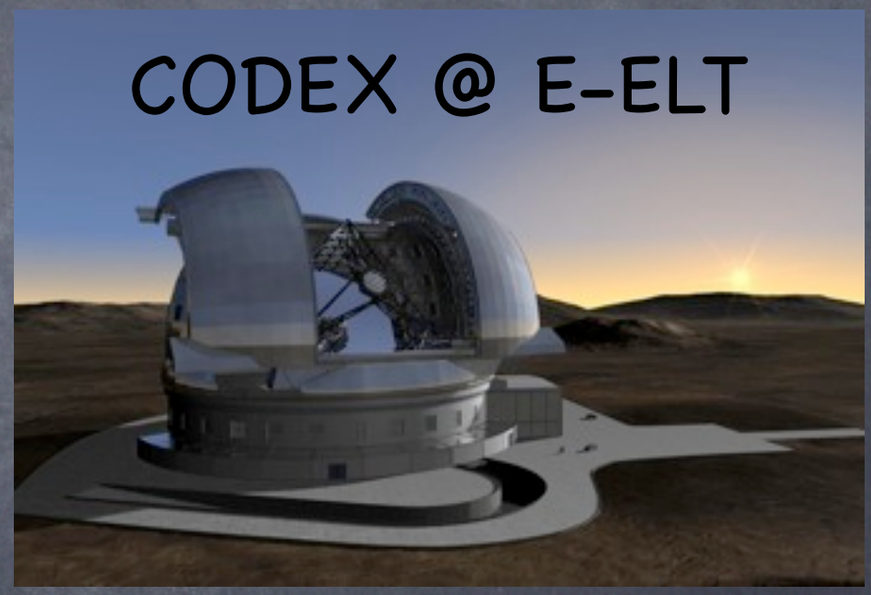

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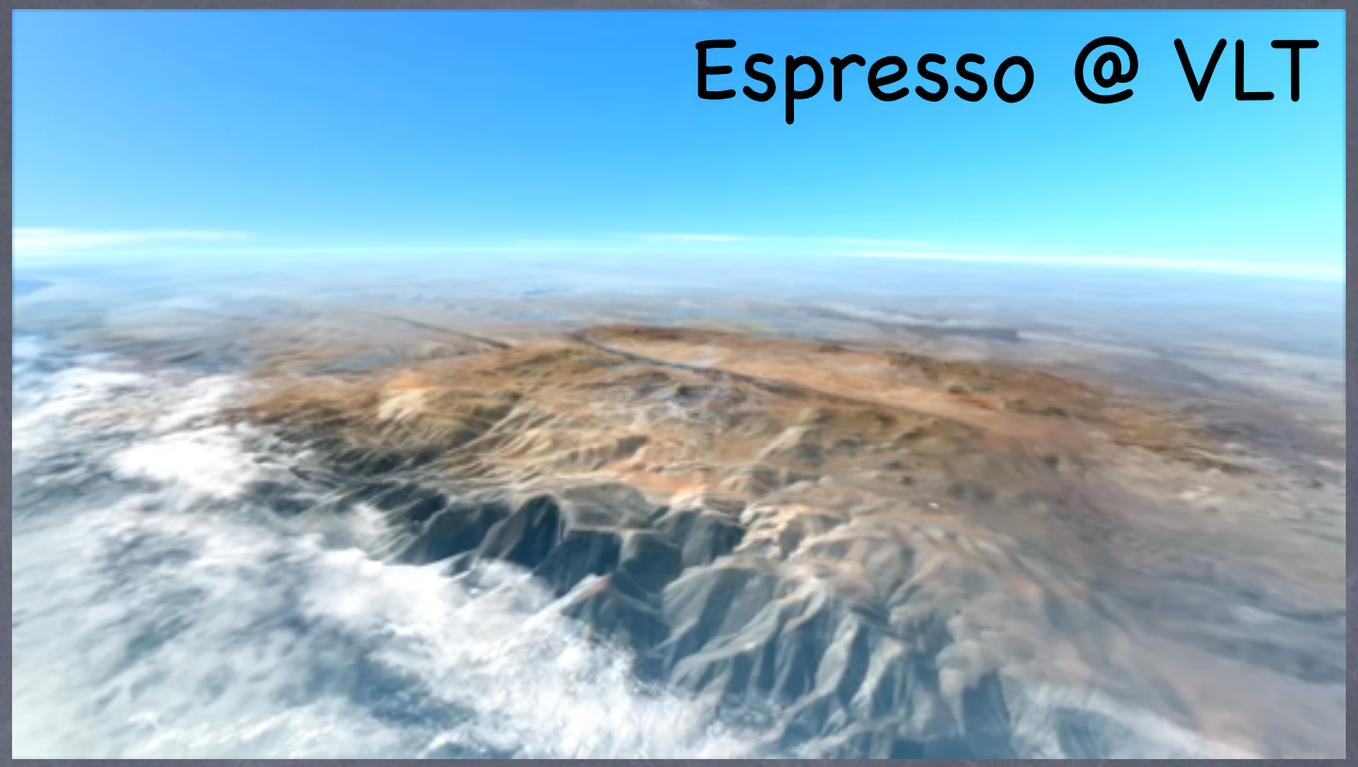

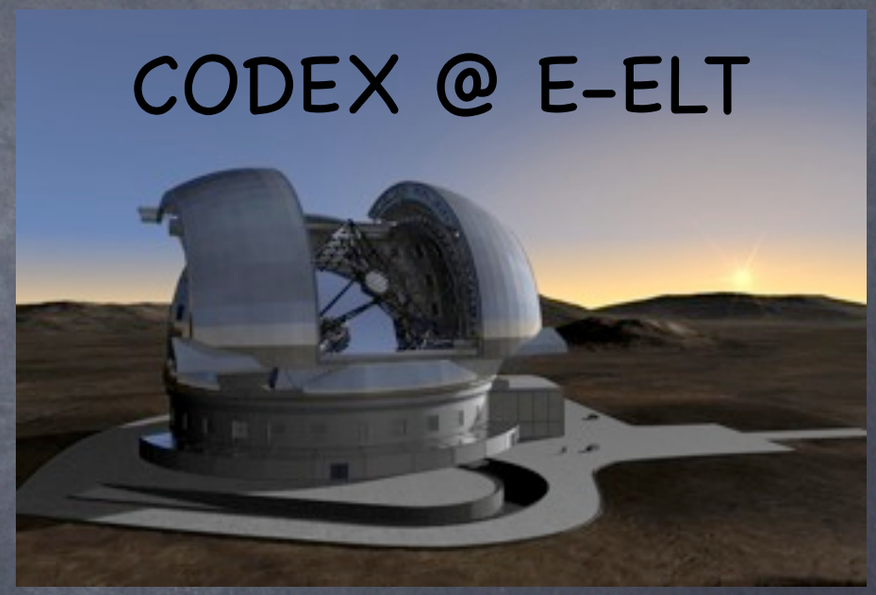

I still don't understand the supernova scene....

THANKS!

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[7] Max-Planck-Institut fuer Astrophysik, Garching b. Muenchen, Germany
[8] INAF-Osservatorio Astronomico, Trieste, Italy
[9] Institut fuer Astronomie und Astrophysik der LMU, Muenchen
[10] Department of Astronomy, University of Tokyo,
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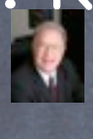

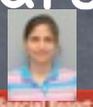

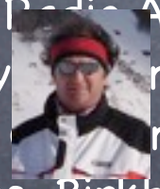

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