Carnegie Supernova Project-II: The Near-infrared Spectroscopy Program*

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Image credit: Nick Suntzeff (I think)

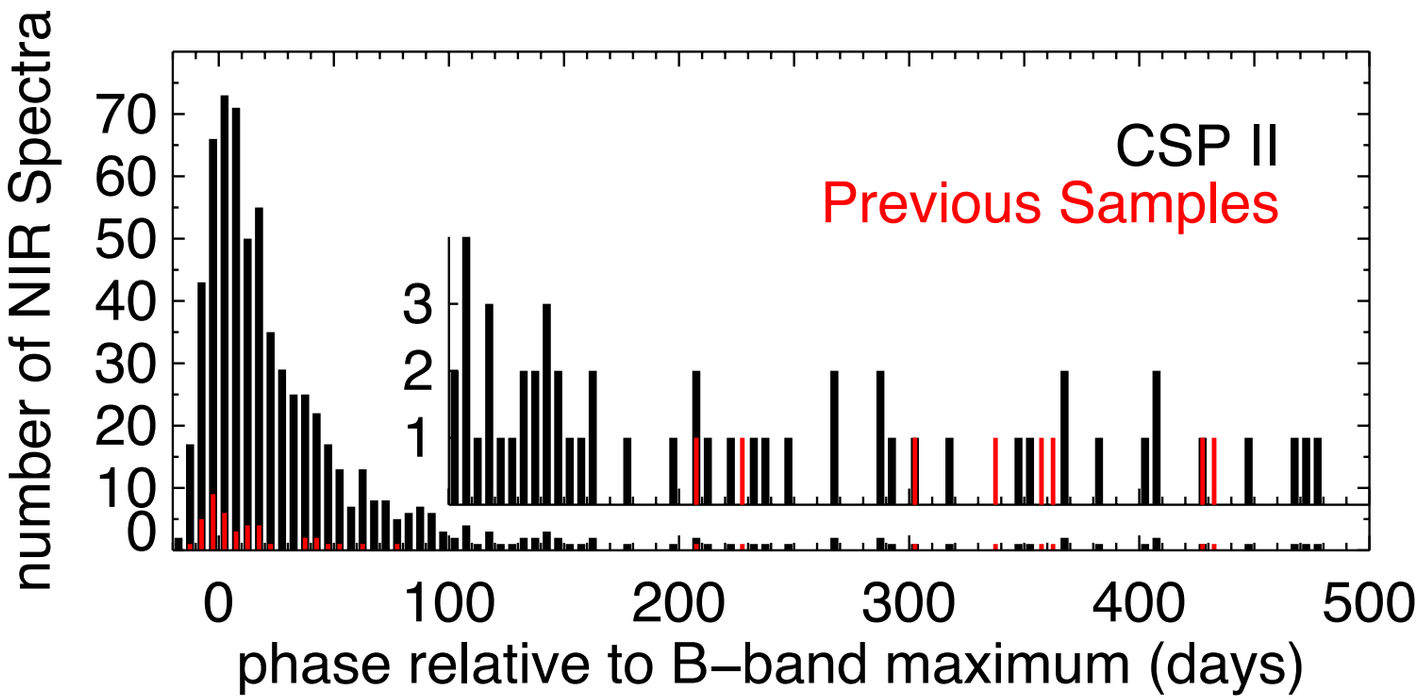
Carnegie Supernova Project

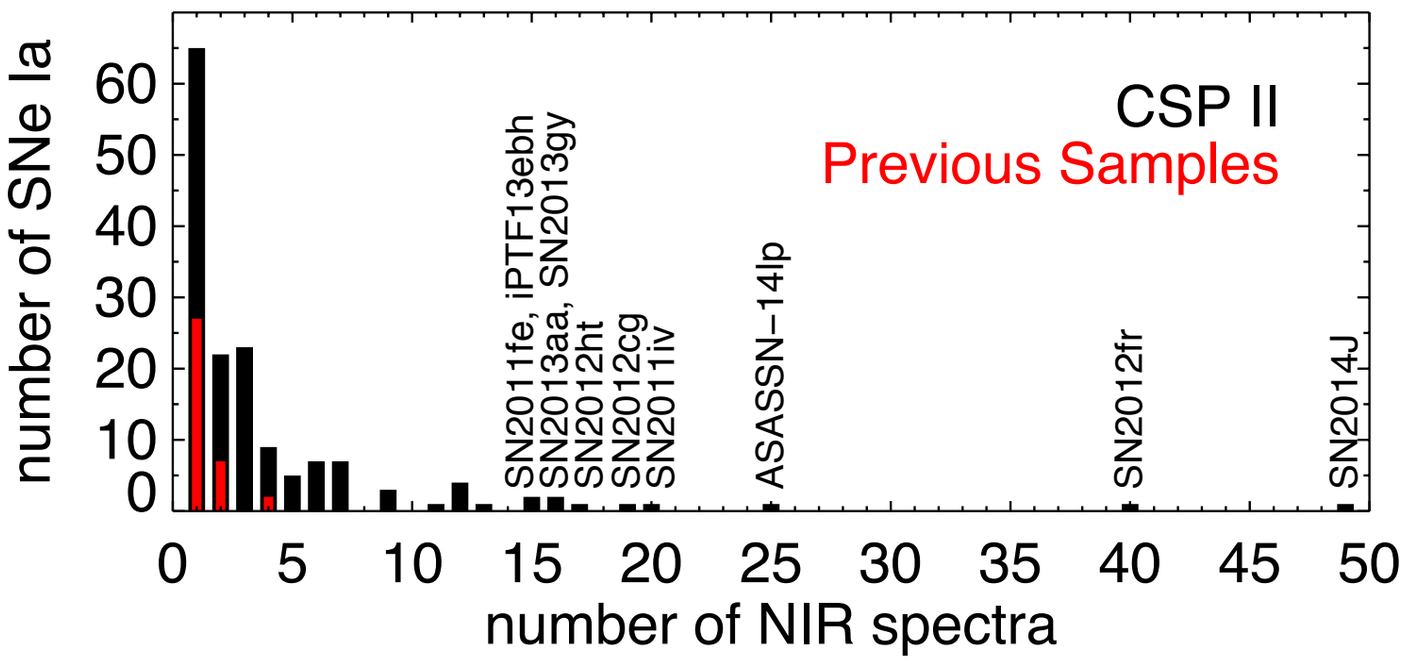
- CSP-I (2004—2008):
  - Build the low-redshift anchor for any Hubble diagram in a single, well-understood photometric system.
- CSP-II (2011—2015):
  - Observe SNe Ia in the Hubble flow to eliminate peculiar velocity errors. Phillips et al. (2018)
  - NIR spectroscopy to improve k-corrections and physics. Hsiao et al. (2018)
- Emphasis in the NIR!

Image credit: Yuri Beletsky

CSP-II NIR spectra

- 661 NIR spectra of 157 SNe Ia.
  909 NIR spectra of all types.
- ~1 order mag increase in sample size.
- 77% of the NIR spectra taken with FIRE at (the real) LCO.





Hsiao et al. (2018)

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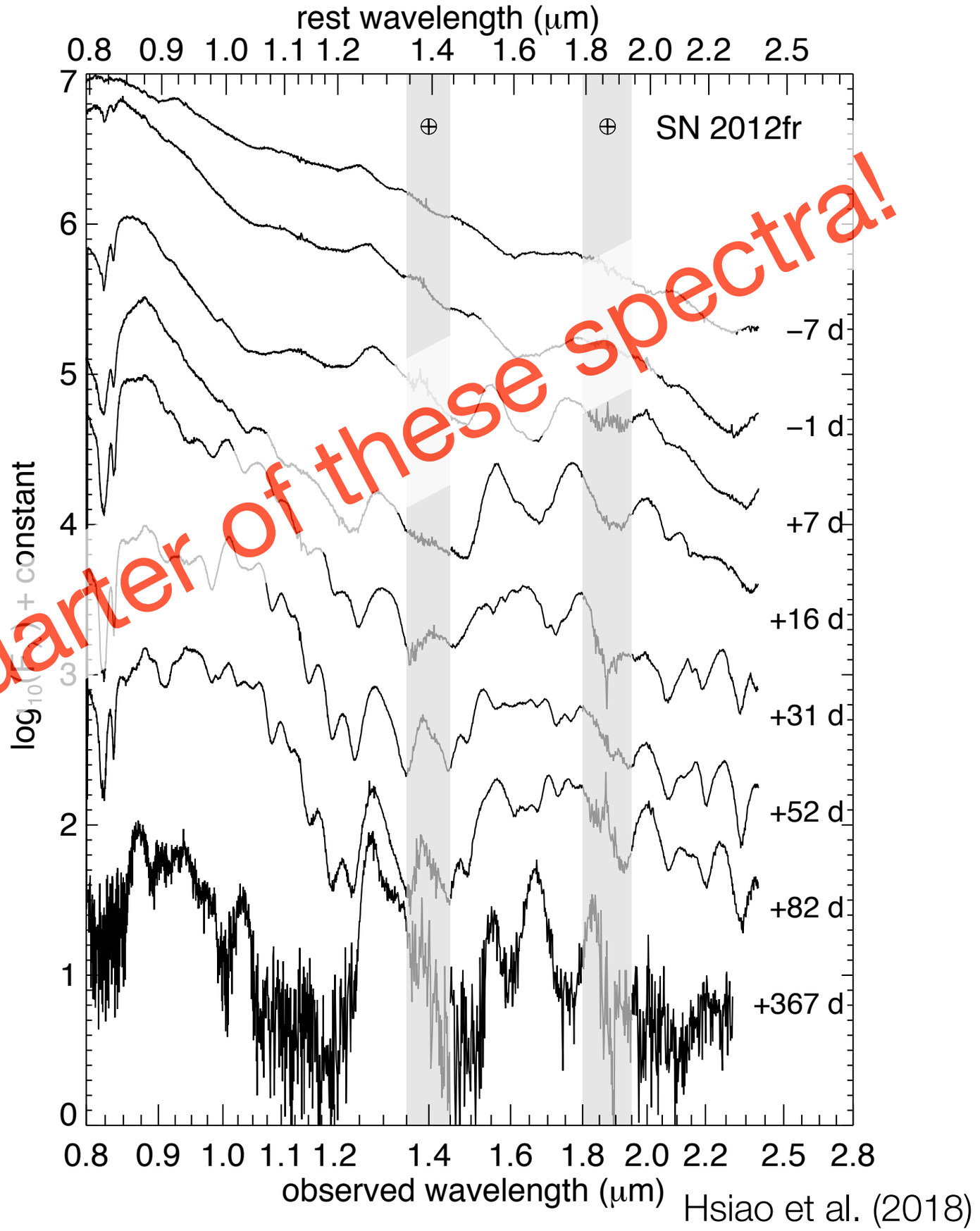
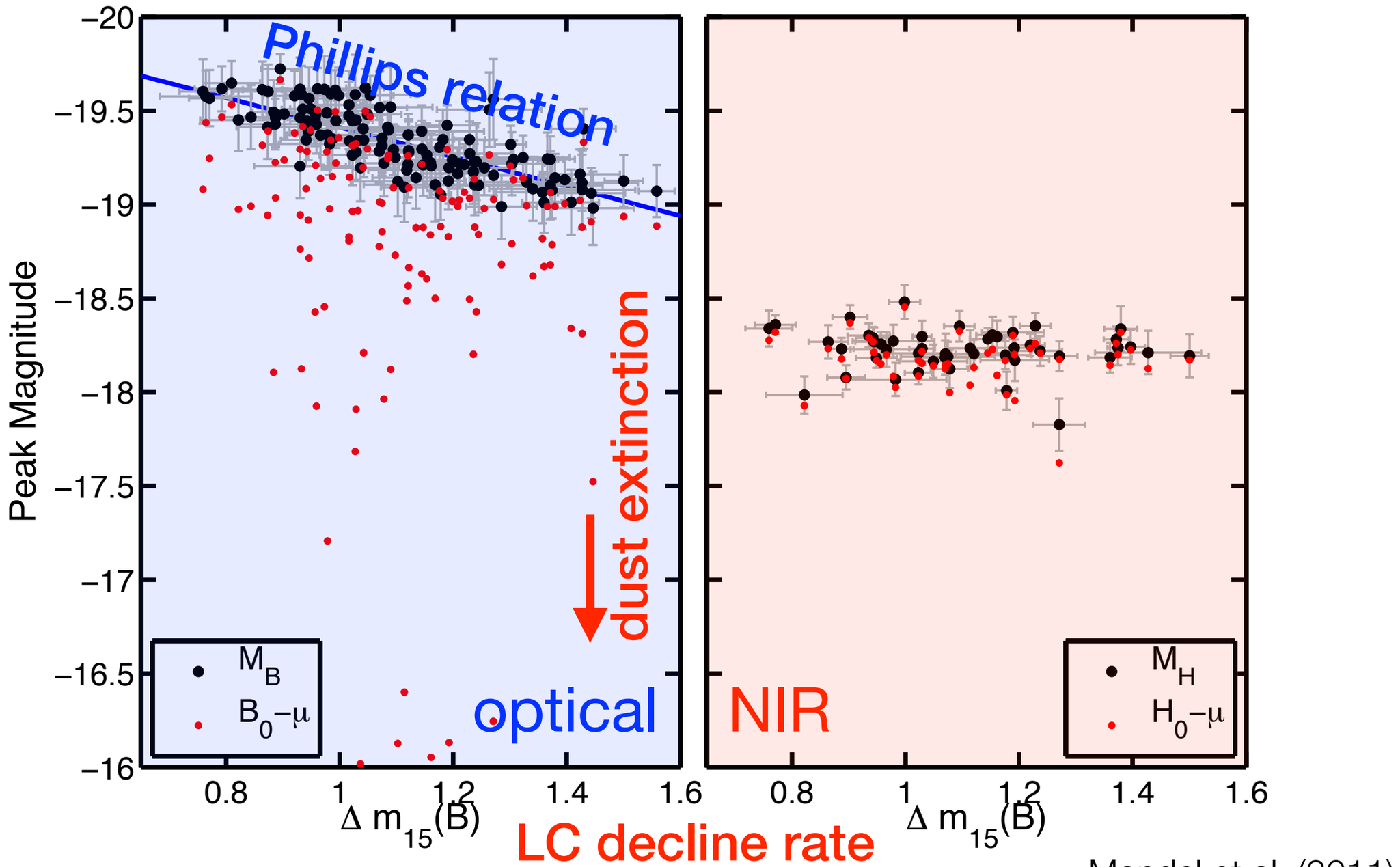


Hsiao et al. (2018)

Nidia took one quarter of these spectra!

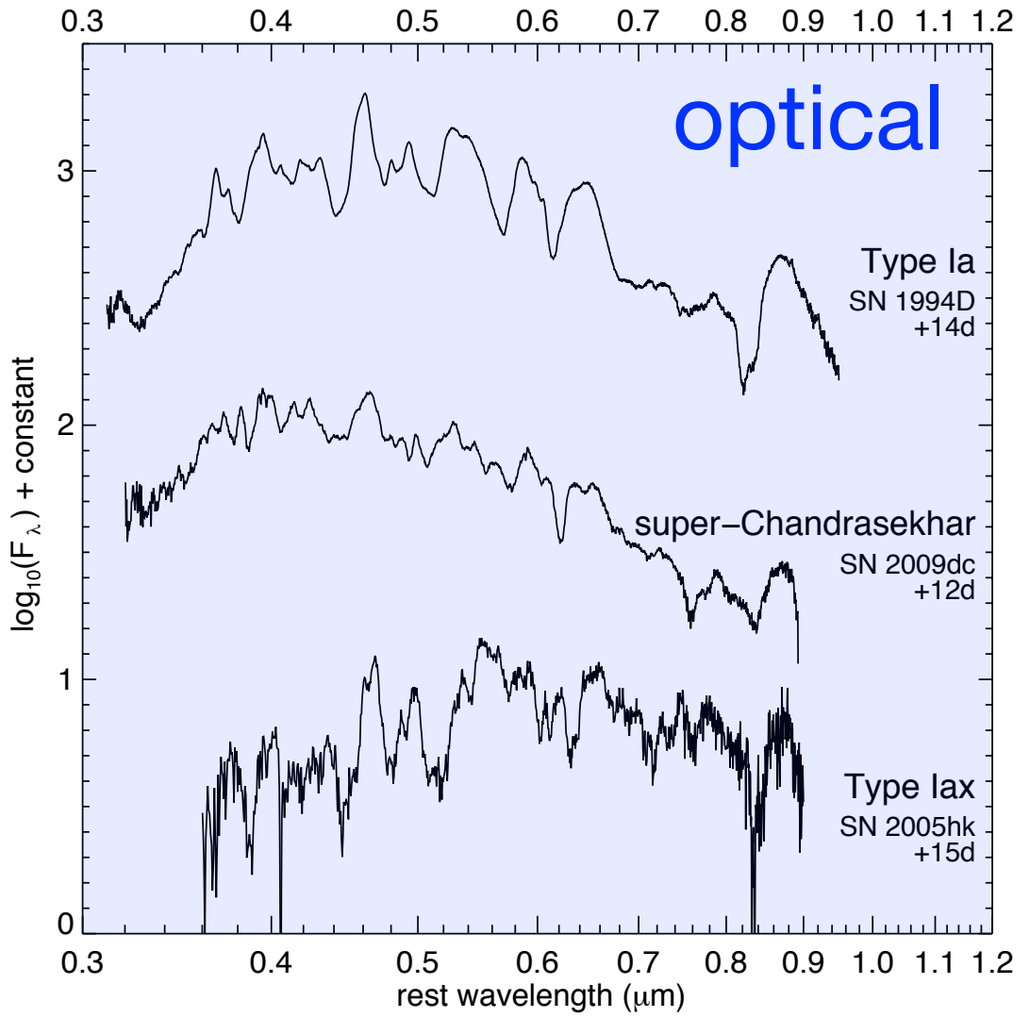
Why NIR?

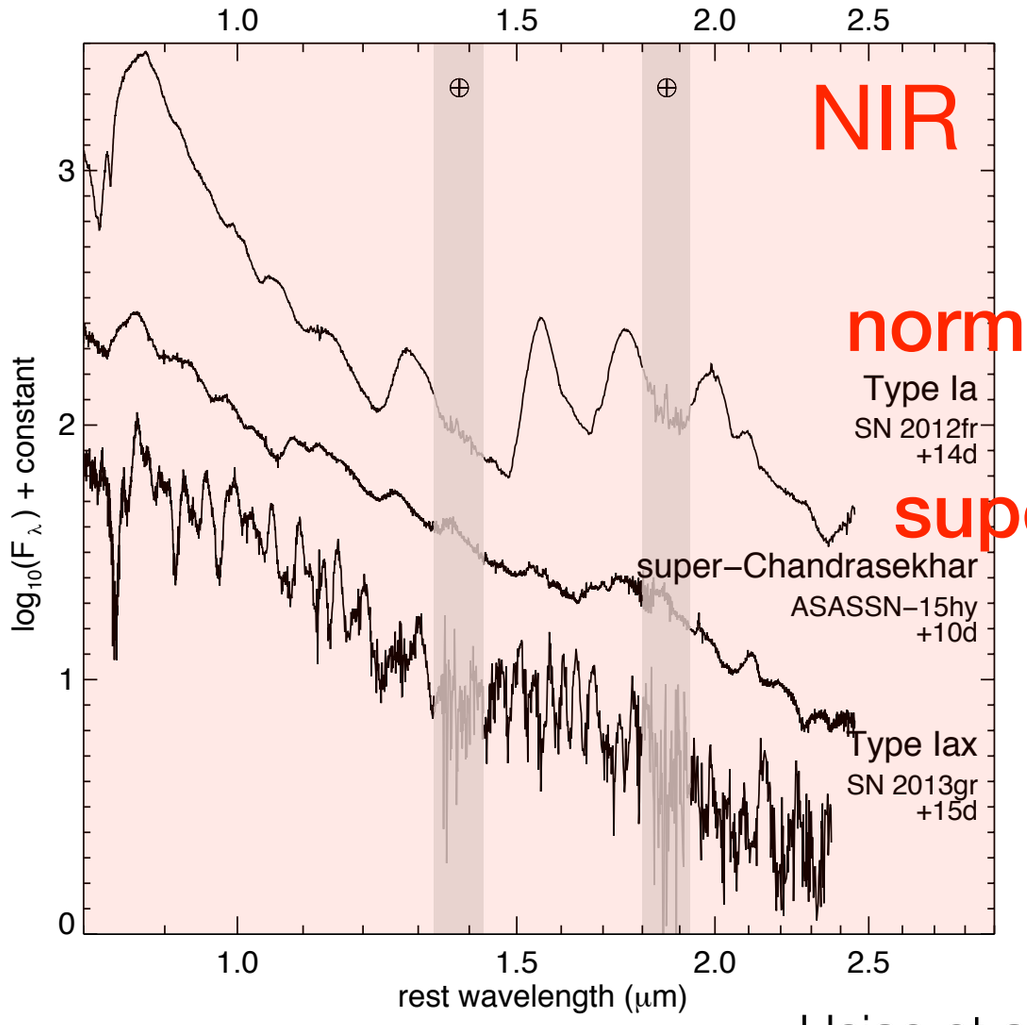


Mandel et al. (2011)

Why NIR?

- Differences between normal and peculiar Ia's are subtle in the optical.
- NIR probes deeper in the ejecta and shows drastic differences.





Hsiao et al. (2018)

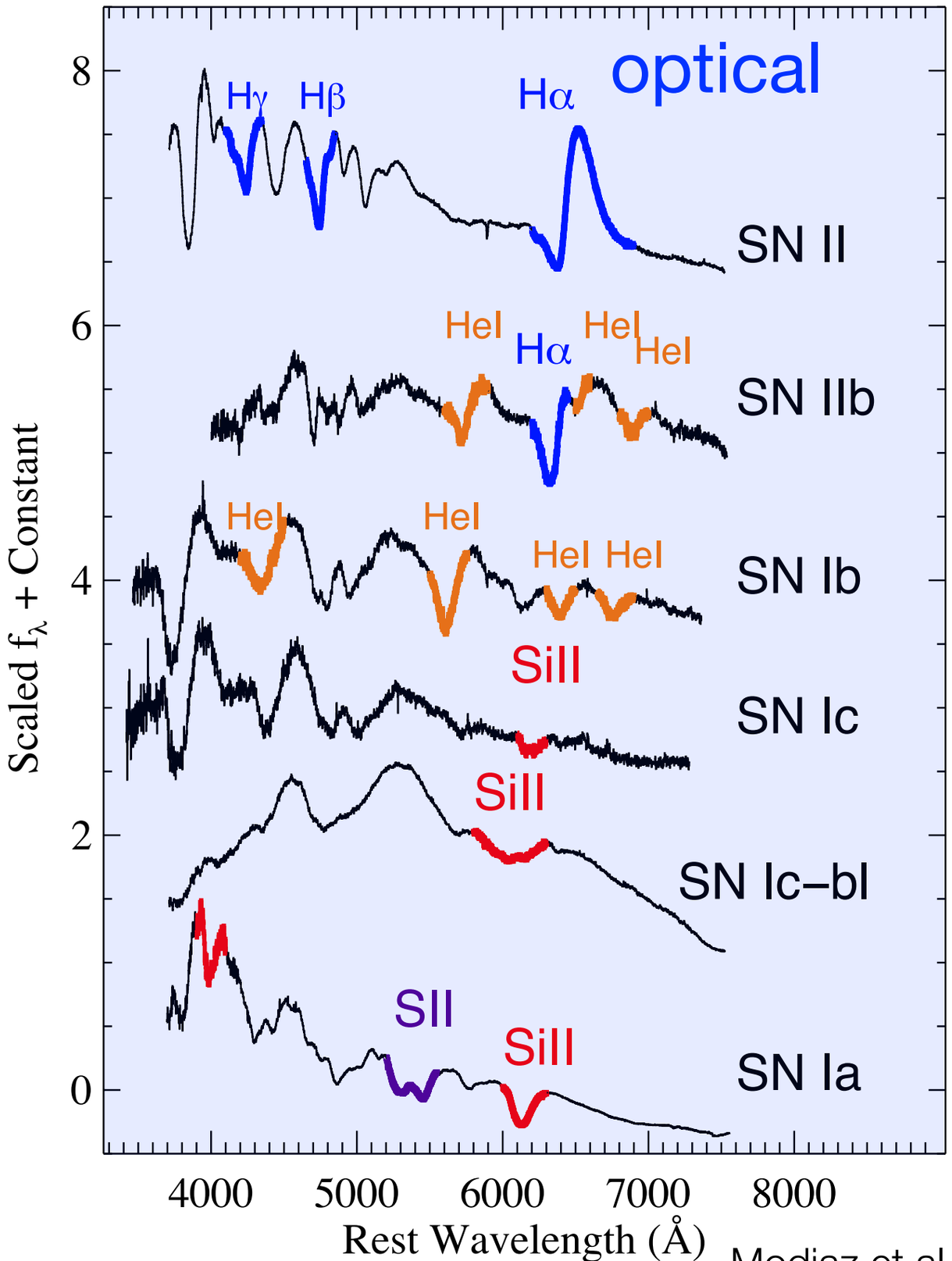
Type Ia supernova

- Unburned material
  Premax C I 1.069, He I 1.083
  Marion et al. (2006), Hsiao et al. (2013, 2015), Boyle et al. (2017)
- Boundary between C/O burning
  Premax Mg II 1.093
  Wheeler et al. (1998), Hsiao et al. (2013)
- Radioactive nickel
  Postmax H-band break
  Wheeler et al. (1998), Hoeflich et al. (2002), Hsiao et al. (2013)

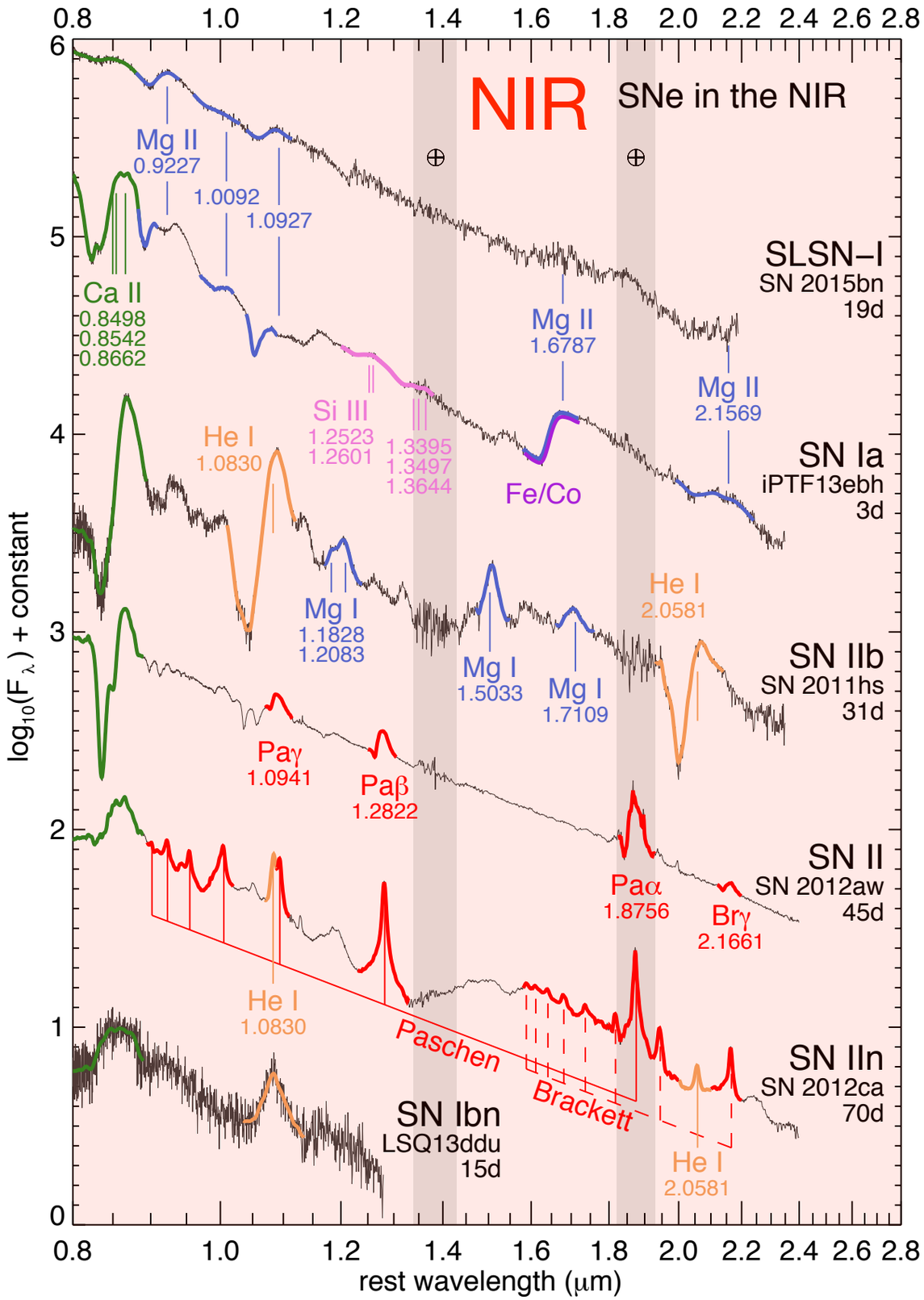
[Chris Ashall's talk]

- Stable nickel
  Transitional and nebular phase [Ni II] 1.939
  Friesen et al. (2014), Wilk et al. (2018), Dhawan et al. (2018), Flörs et al. (2018)
- Companion signature
  Postmax P-beta 1.282, He I 1.083
  Maeda et al. (2014), Sand et al. (2016), Botyanszki (2017)
- Central density and B-field
  Nebular phase [Fe II] 1.644
  Penney & Hoeflich (2014), Diamond et al. (2015), Diamond et al. (2018), Maguire et al. (2018)

[Sahana Kumar's talk]



Modjaz et al. (2014)



Hsiao et al. (2018)

Type II NIR spectroscopy of ~~Type Ia~~ supernovae

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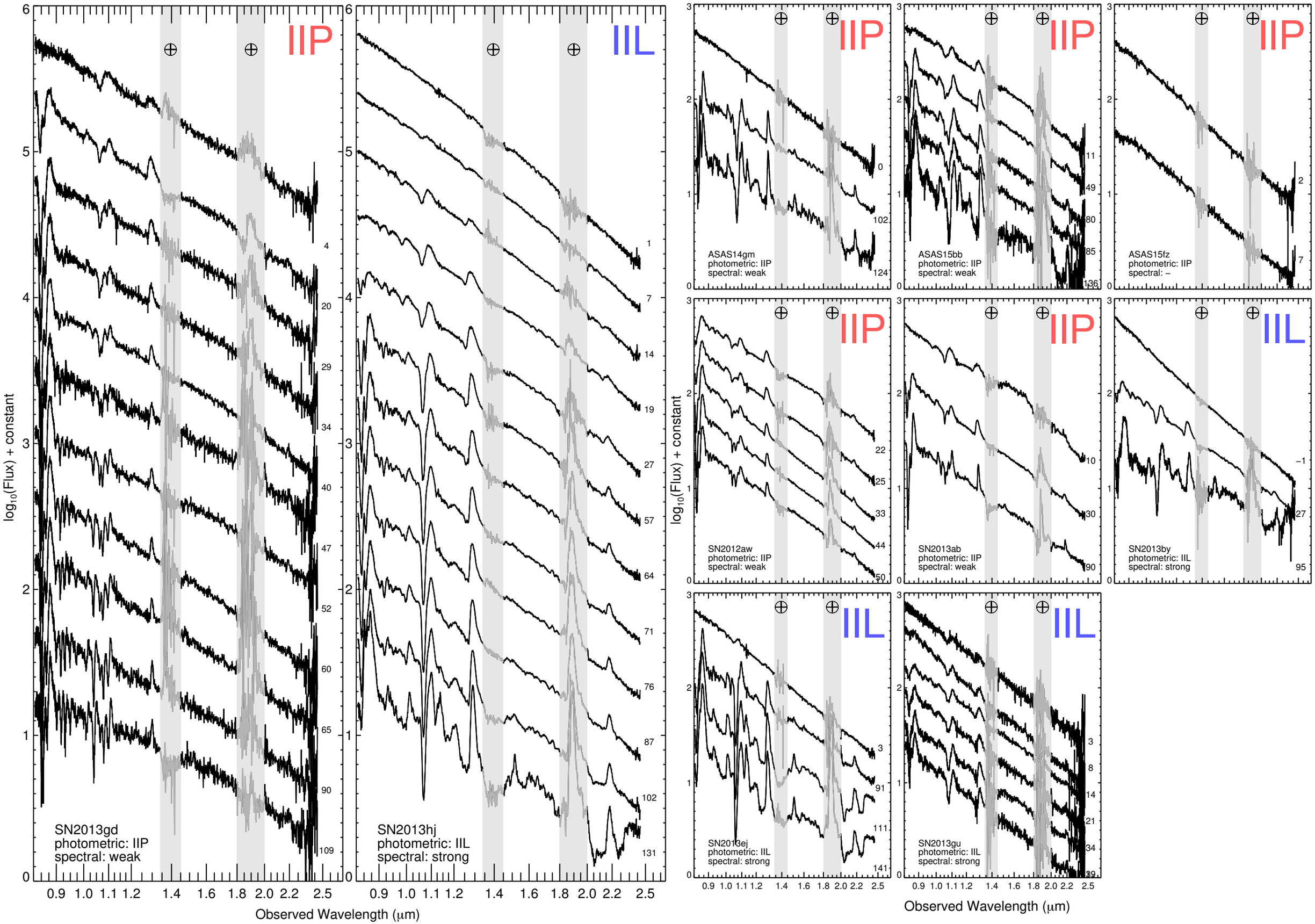
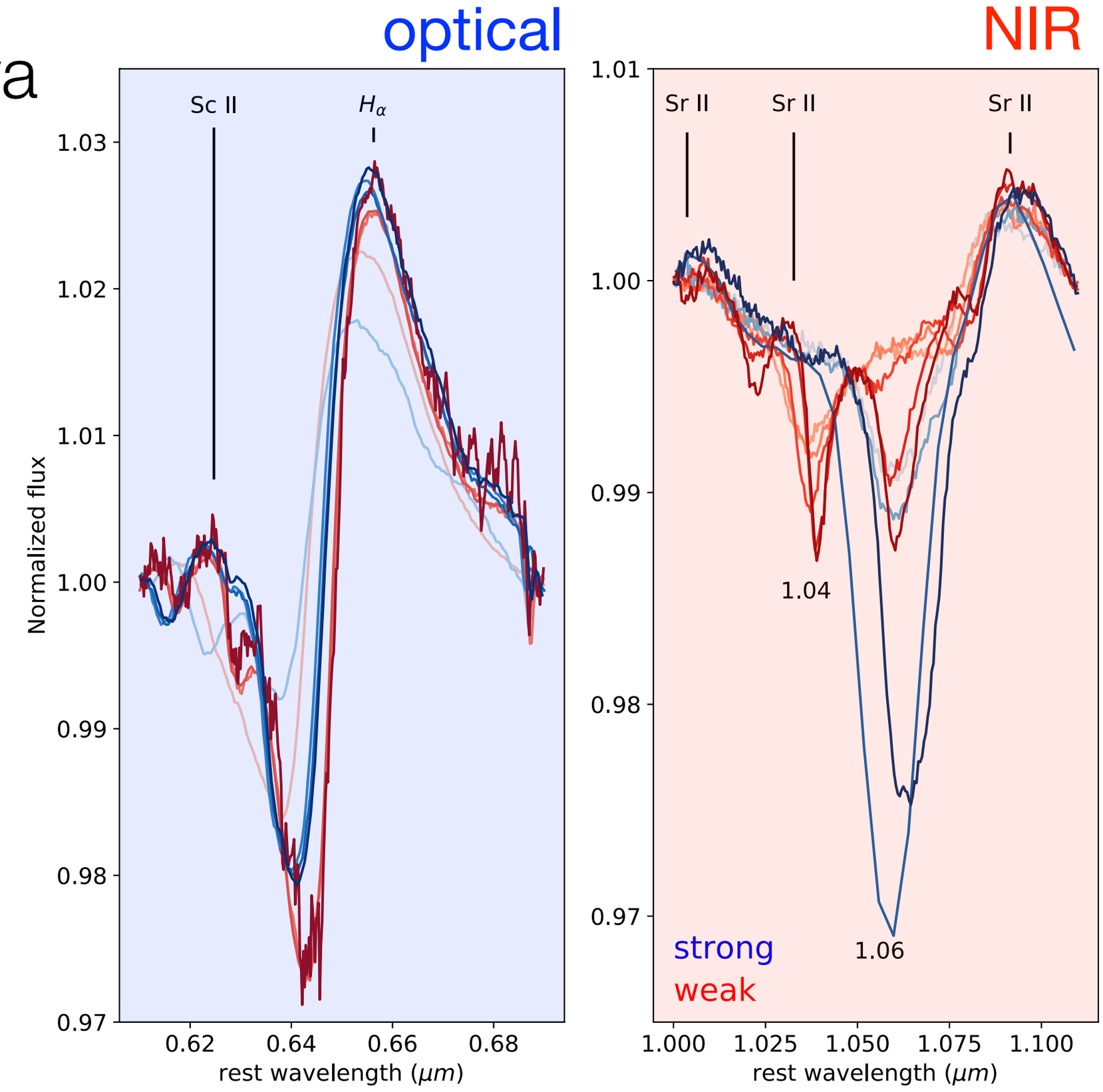
Chris Ashall
Sahana Kumar
Melissa Shahbandeh
Scott Davis
Jing Lu



Davis et al. in prep

Type II supernova

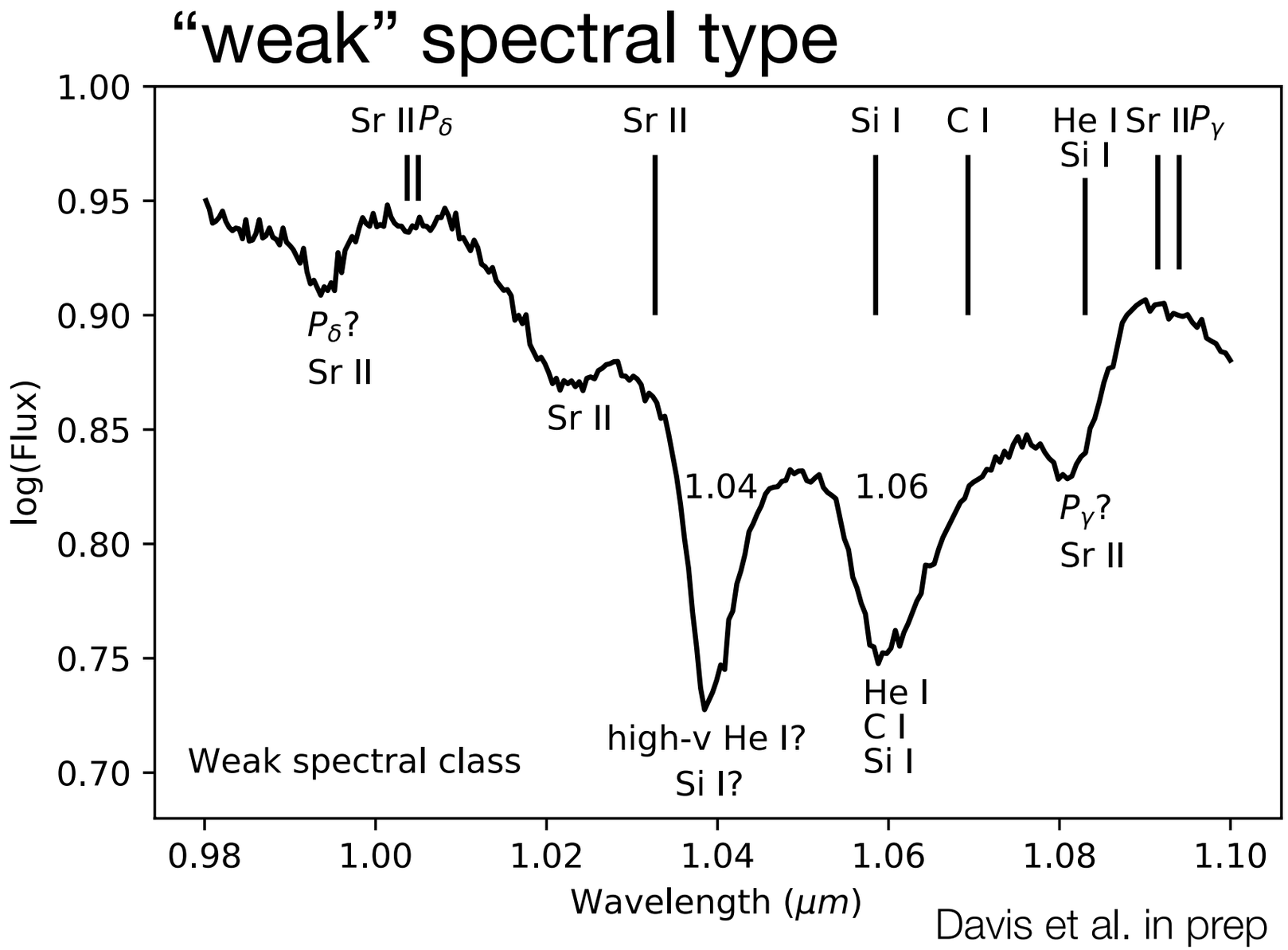
- NIR Paschen-γ region shows two distinct spectral type: strong and weak.
- Weak: weak features at 1.06 and 1.04μm. Prominent Sr II lines.
- Strong: strong feature at 1.06μm, no feature at 1.04μm. No strong Sr II lines.



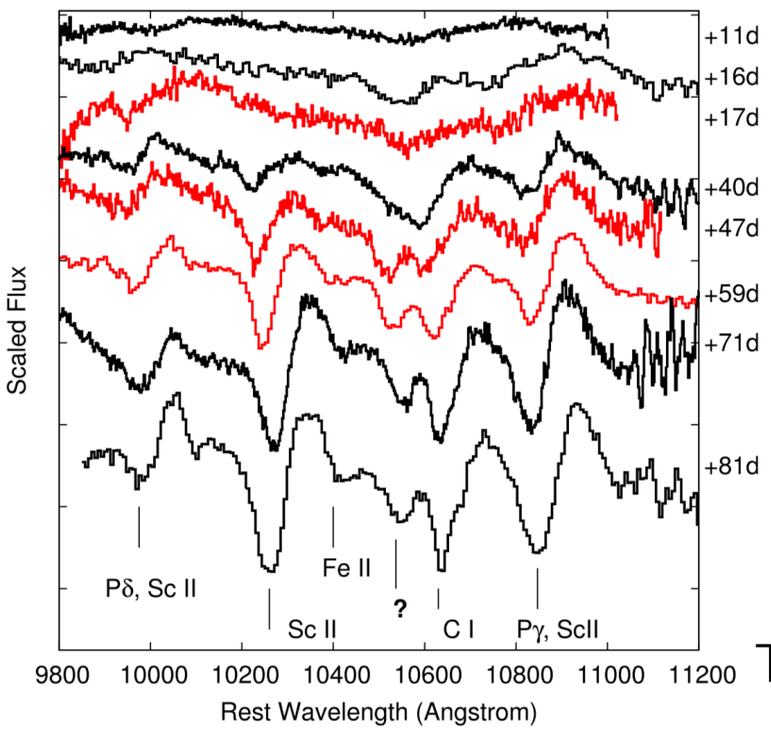
Davis et al. in prep

Type II supernova

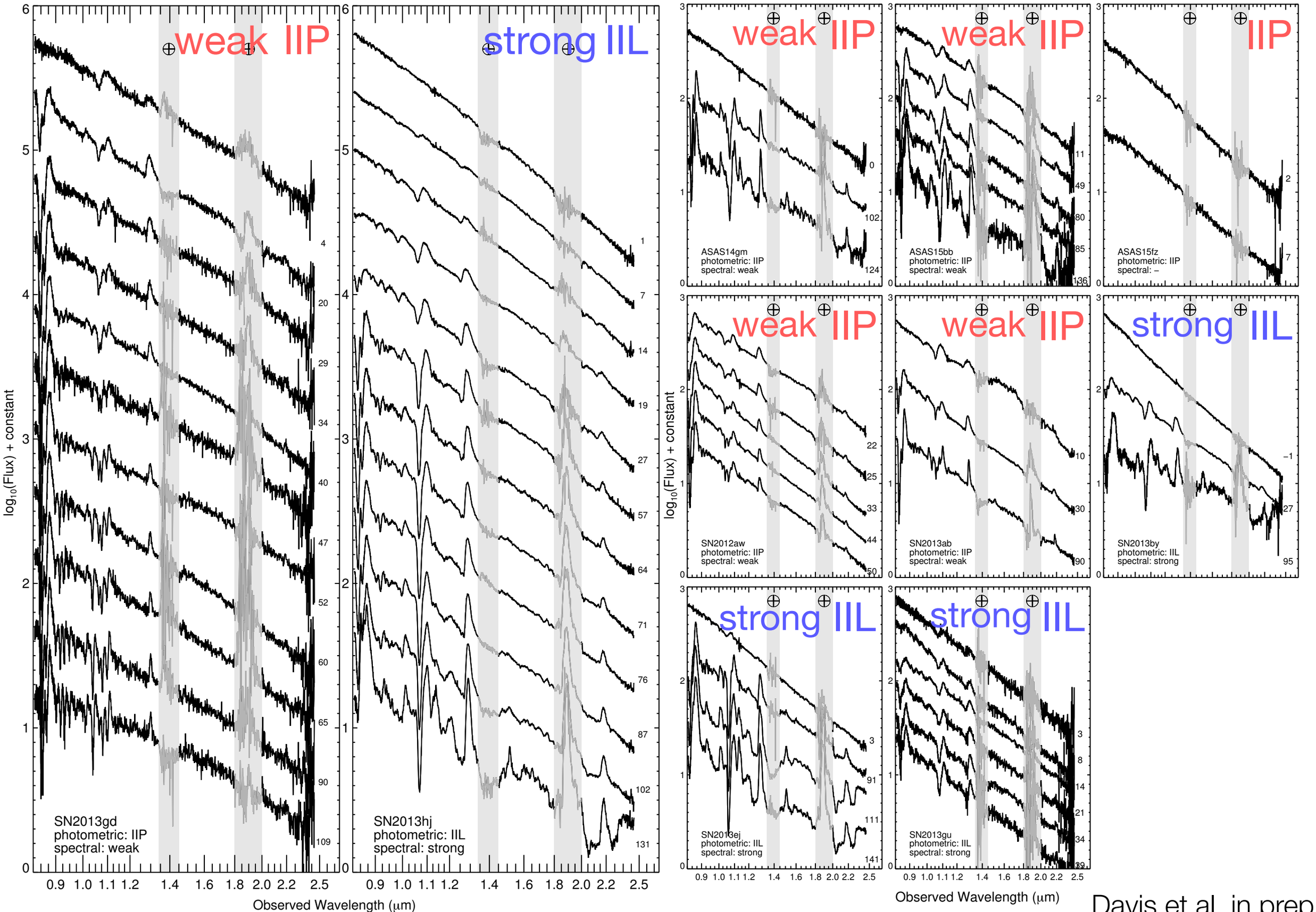
- What are the 1.06μm and 1.04μm lines?
- 1.04 shows up earlier than 1.06 and has a wide range of velocities.



Davis et al. in prep



Takats et al. (2014)



Davis et al. in prep

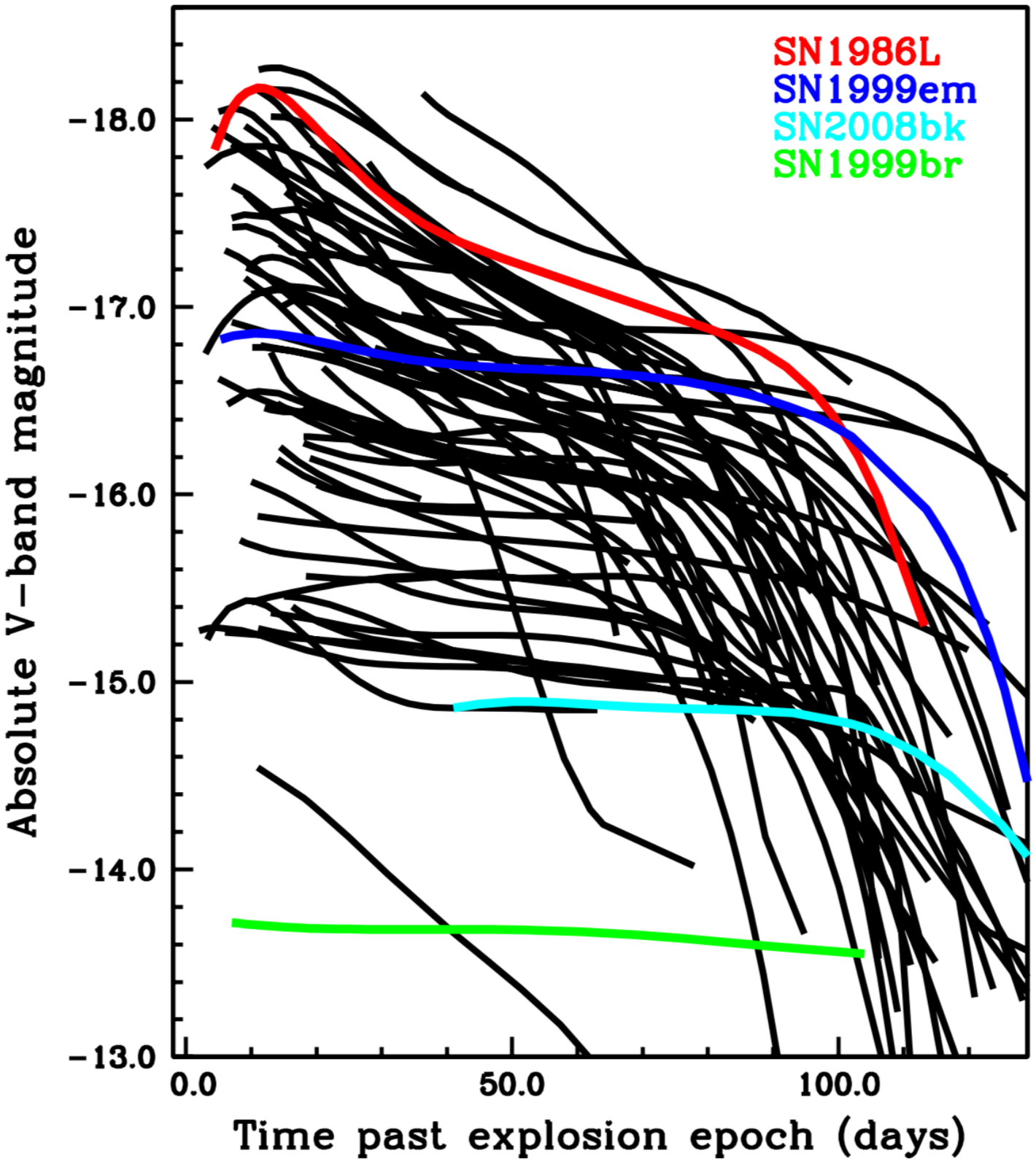
Type II supernova

Name	Photometric Classification	NIR Spectroscopic Classification	Publication
SN1999em	IIP	Weak	Hamuy et al. 2001, Elhamdi et al. 2003
SN2002hh	IIP	-	Pozzo et al. 2006
SN2004et	IIP	-	Maguire et al. 2010
SN2005cs	IIP	Weak	Pastorello et al. 2009
SN2008in	IIP	Weak	Takats et al. 2014
SN2009N	IIP	Weak	Takats et al. 2014
SN2009ib	IIP	Weak	Takats et al. 2015
SN2009md	IIP	-	Fraser et al. 2011
SN2012A	IIP	Strong	Tomasella et al. 2013
SN2012aw	IIP	Weak	Dall'Ora et al. 2014, Jerkstrand et al. 2014
SN2013by	IIL	Strong	Valenti et al. 2015
SN2013ej	IIL	Strong	Valenti et al. 2014
SN2017eaw	IIP	Weak	Rho et al. 2018

Davis et al. in prep

Type II supernova

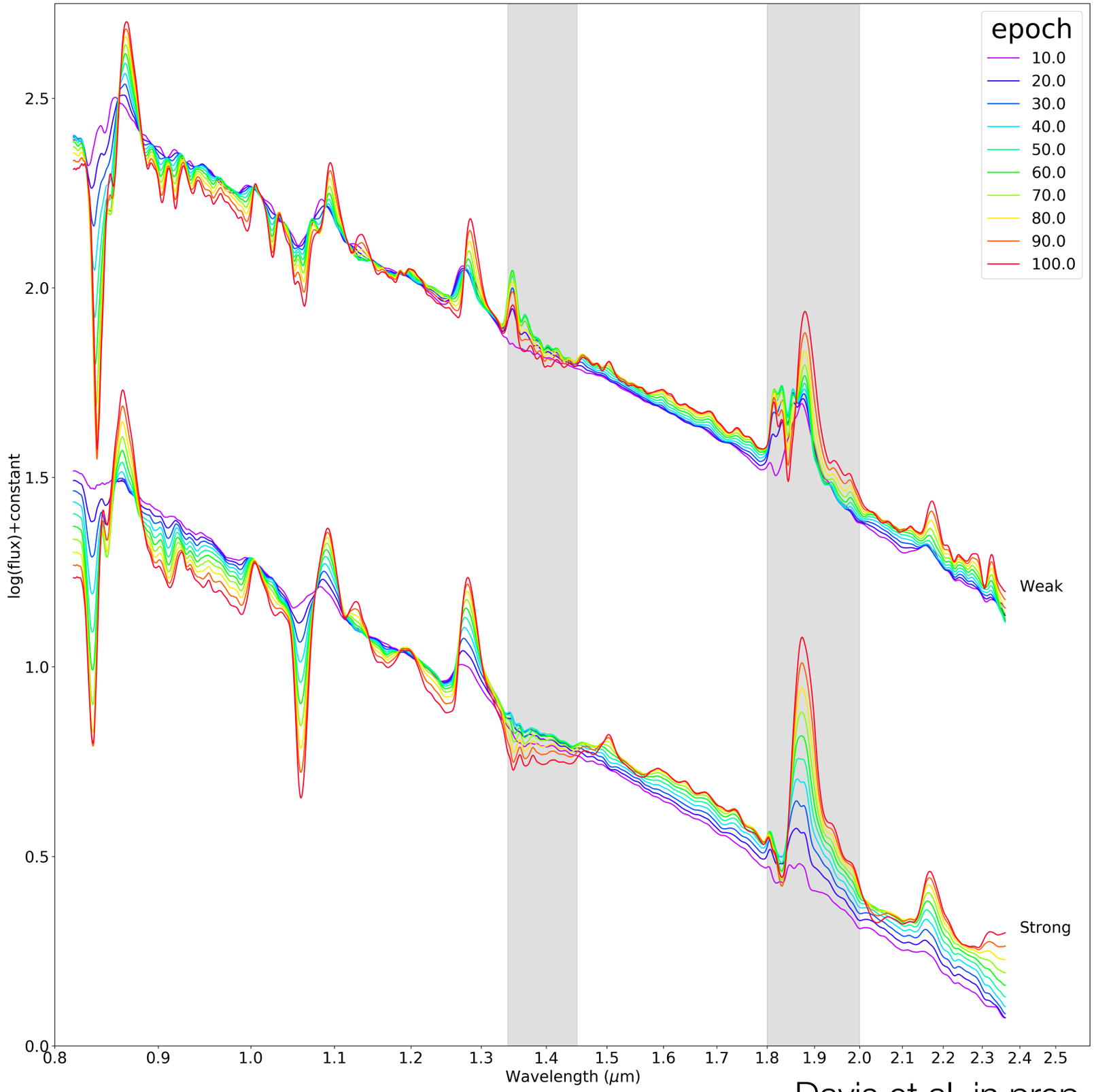
- But remember in optical LCs, we see a continuum of plateau slopes from IIP to IIL.



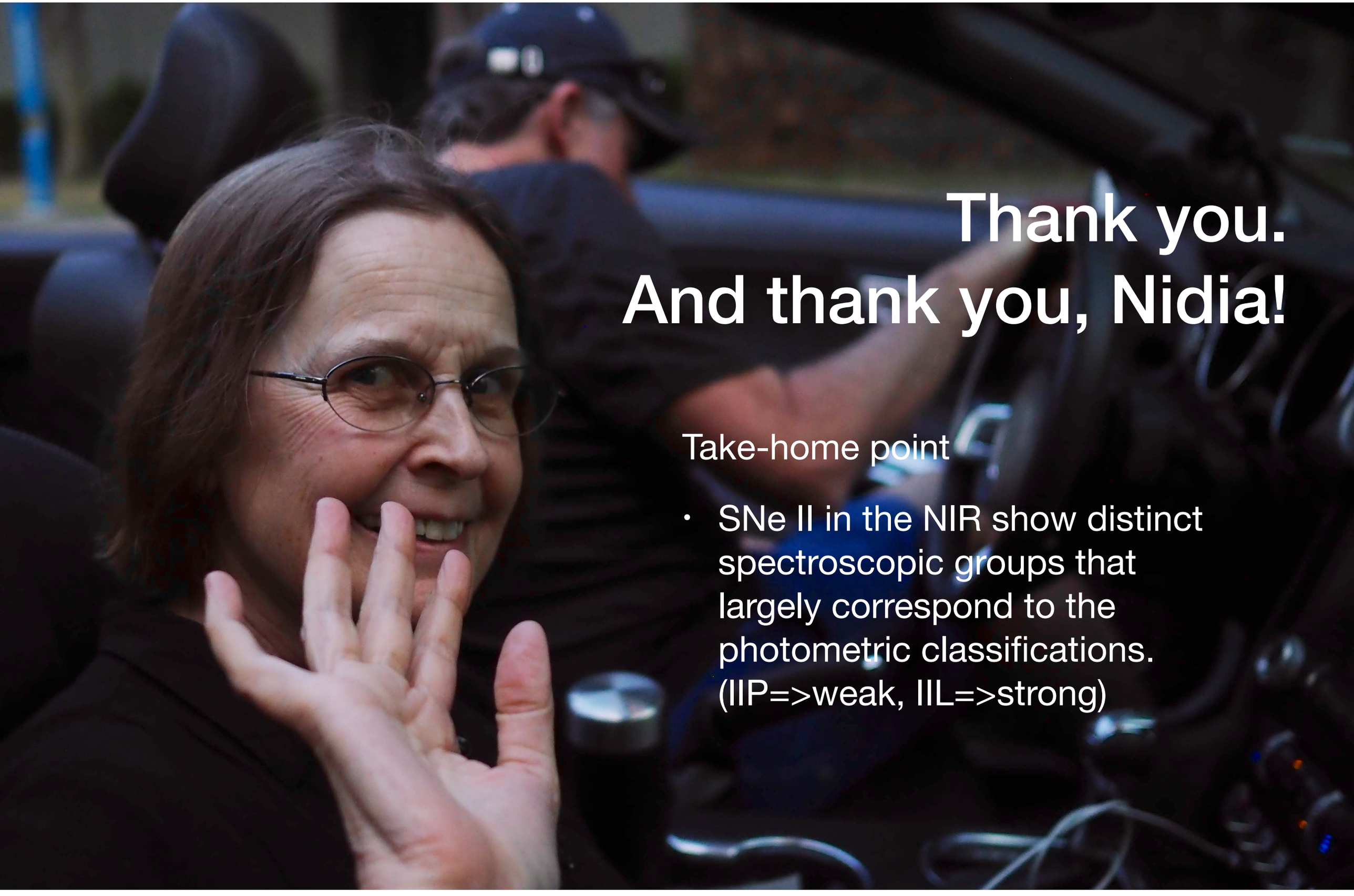
Anderson et al. (2014)

Type II supernova

- Rejoice!
- There are NIR Type II spectral templates based on principal component analysis of CSP-II sample.



Davis et al. in prep



Thank you.
And thank you, Nidia!

Take-home point

- SNe II in the NIR show distinct spectroscopic groups that largely correspond to the photometric classifications. (IIP=>weak, IIL=>strong)