

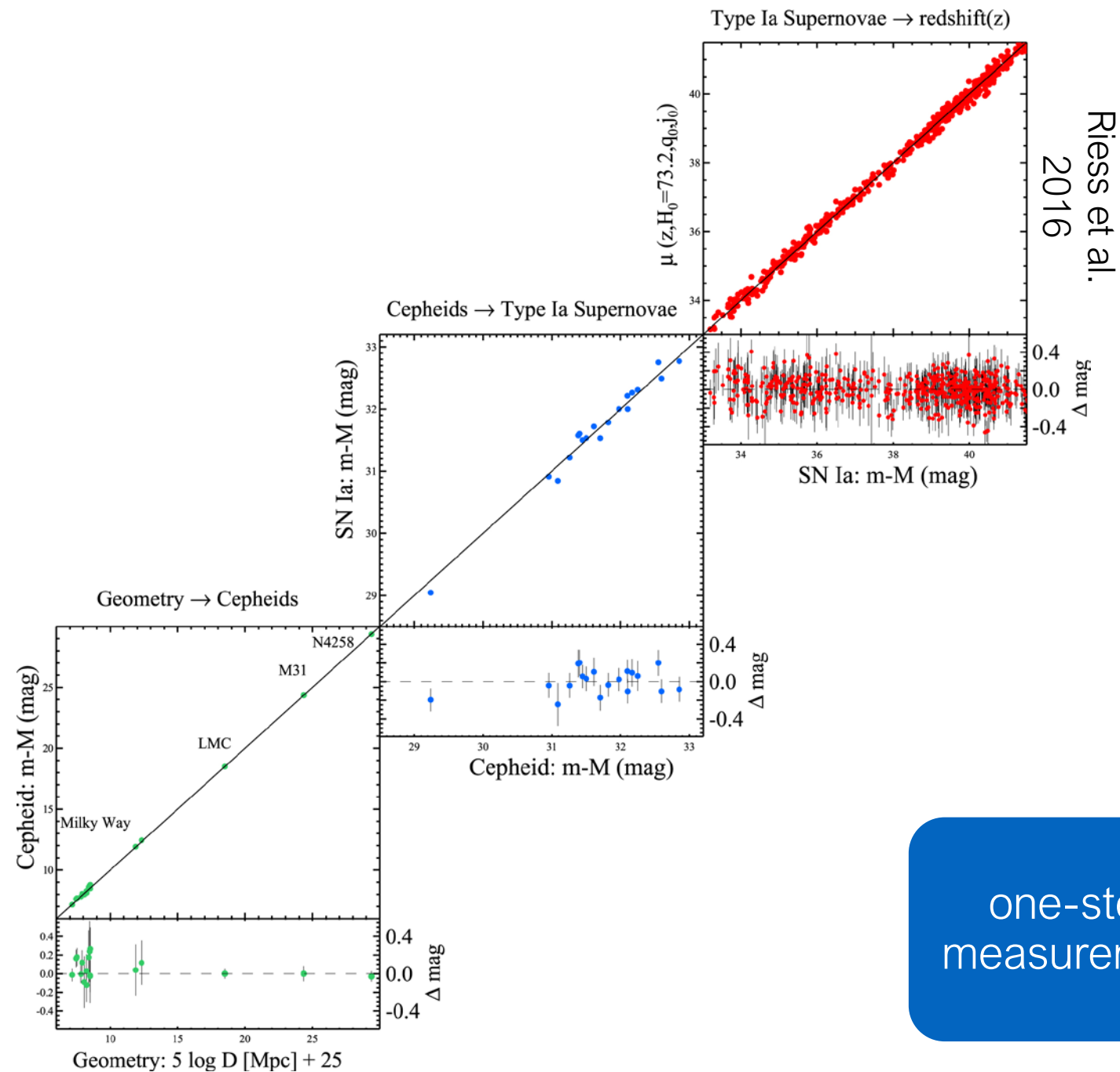
# (Type I) supernova spectroscopic analysis boosted by machine learning

Christian Vogl

Stuart Sim, Wolfgang Kerzendorf, Ulrich Noebauer, Stefan  
Taubenberger, Wolfgang Hillebrandt

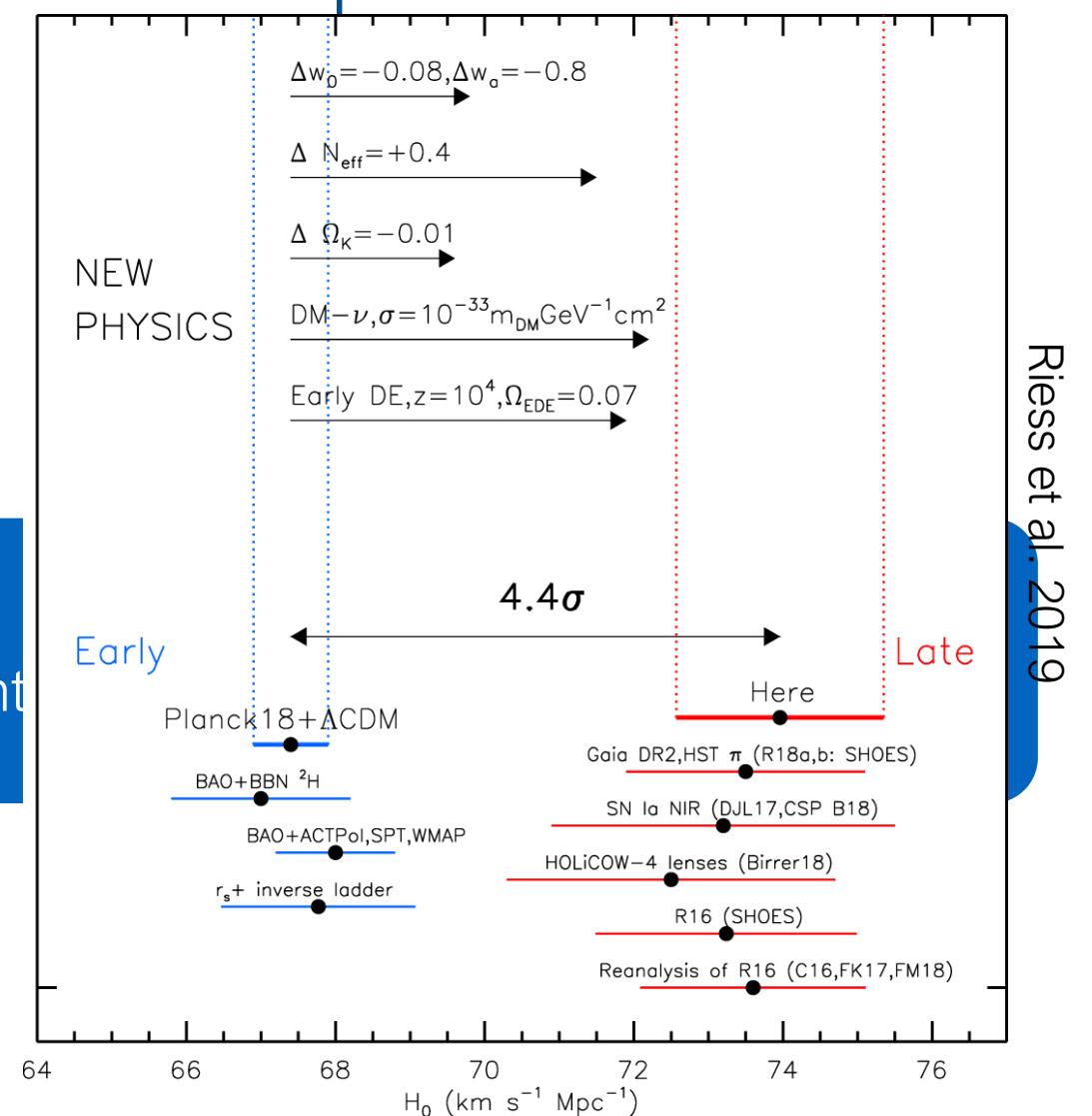


# Motivation – $H_0$



simple  
radiative  
transfer  
physics

Tension between **local**  
measurements of  $H_0$  and **CMB**



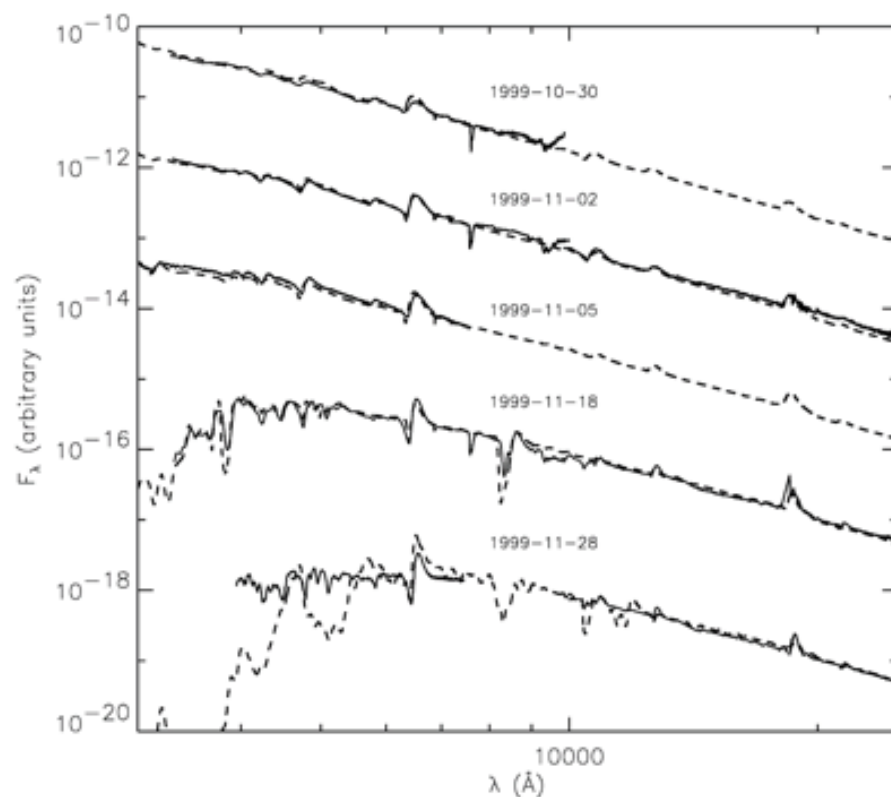
# Distances from spectral fits

## Spectral-fitting Expanding Atmosphere Method

Baron et al. (95, 96, 2004, 2007), Lentz et al. 2001, Mitchell et al. 2002

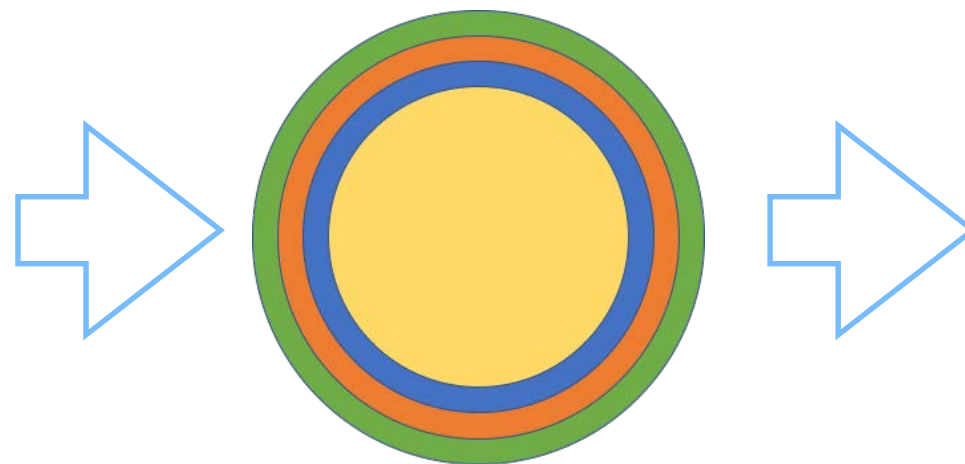
## Tailored Expanding Photosphere Method

Dessart et al. (2006, 2008)



Baron et al. 2004

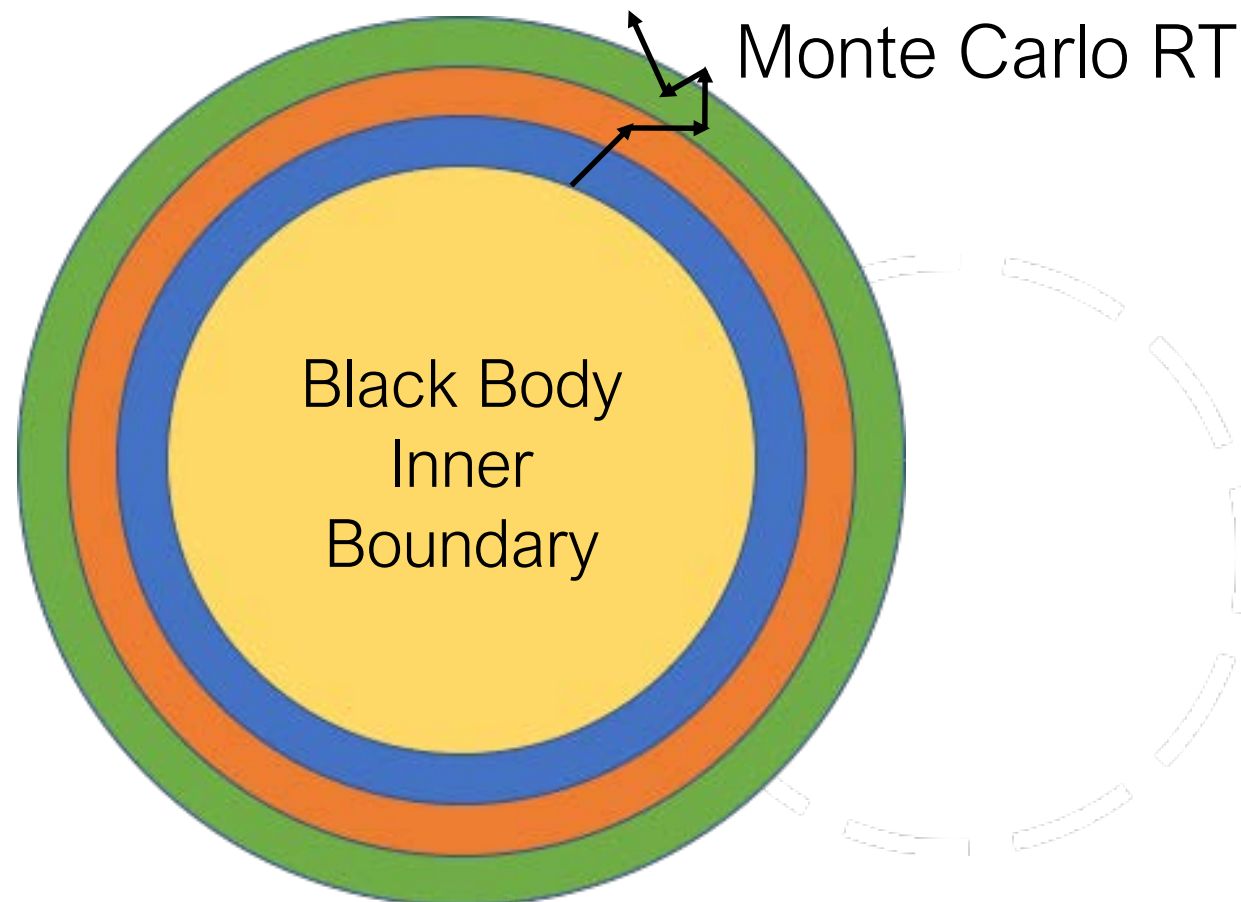
$X, \rho, L_{\lambda}, \dots$



$$D_L = \sqrt{\frac{L}{4\pi F}}$$

# TARDIS

Kerzendorf & Sim 2014



bound-free, free-free,  
collisional processes

high optical depths  
( $\tau = 20-30$ )

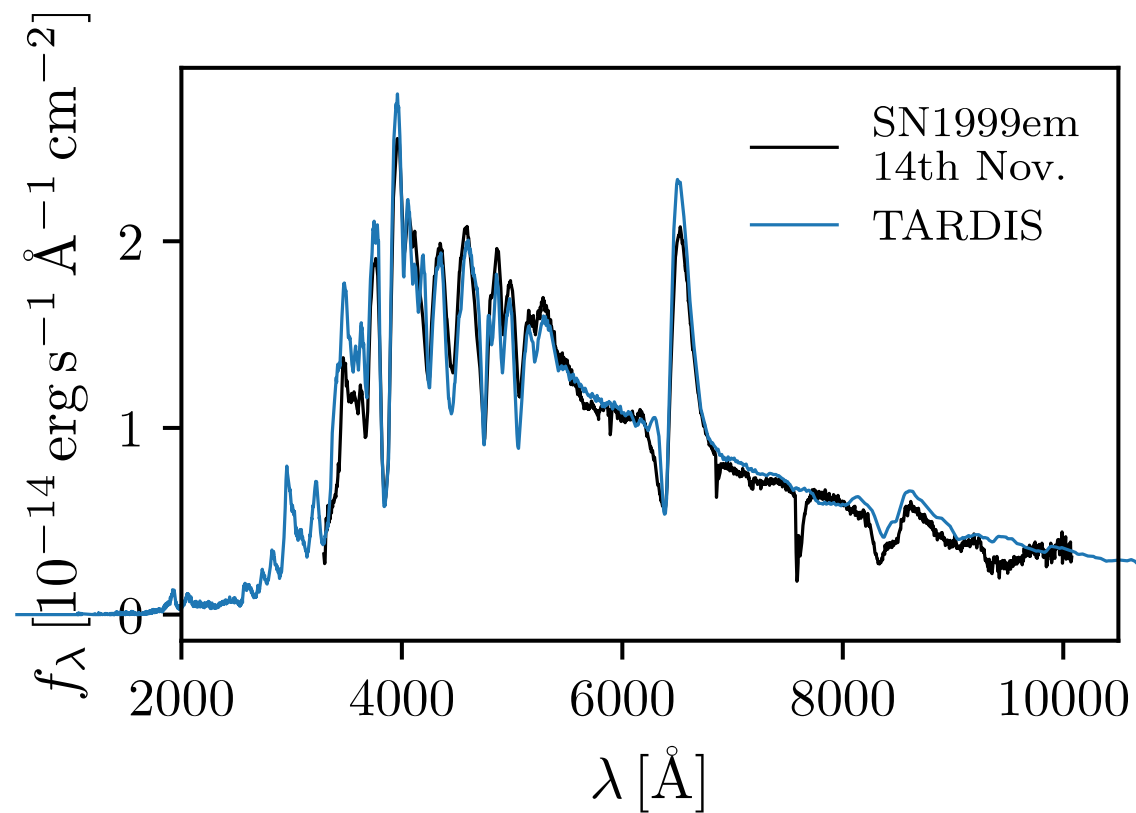
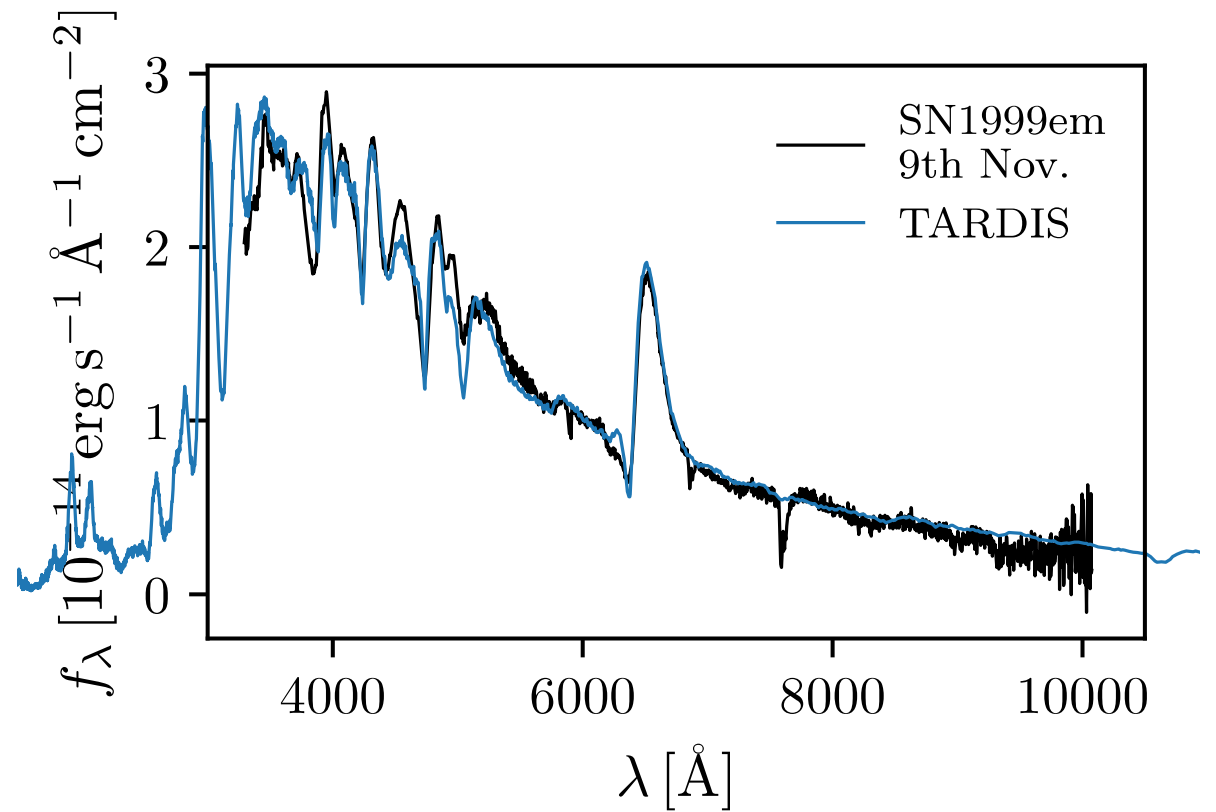
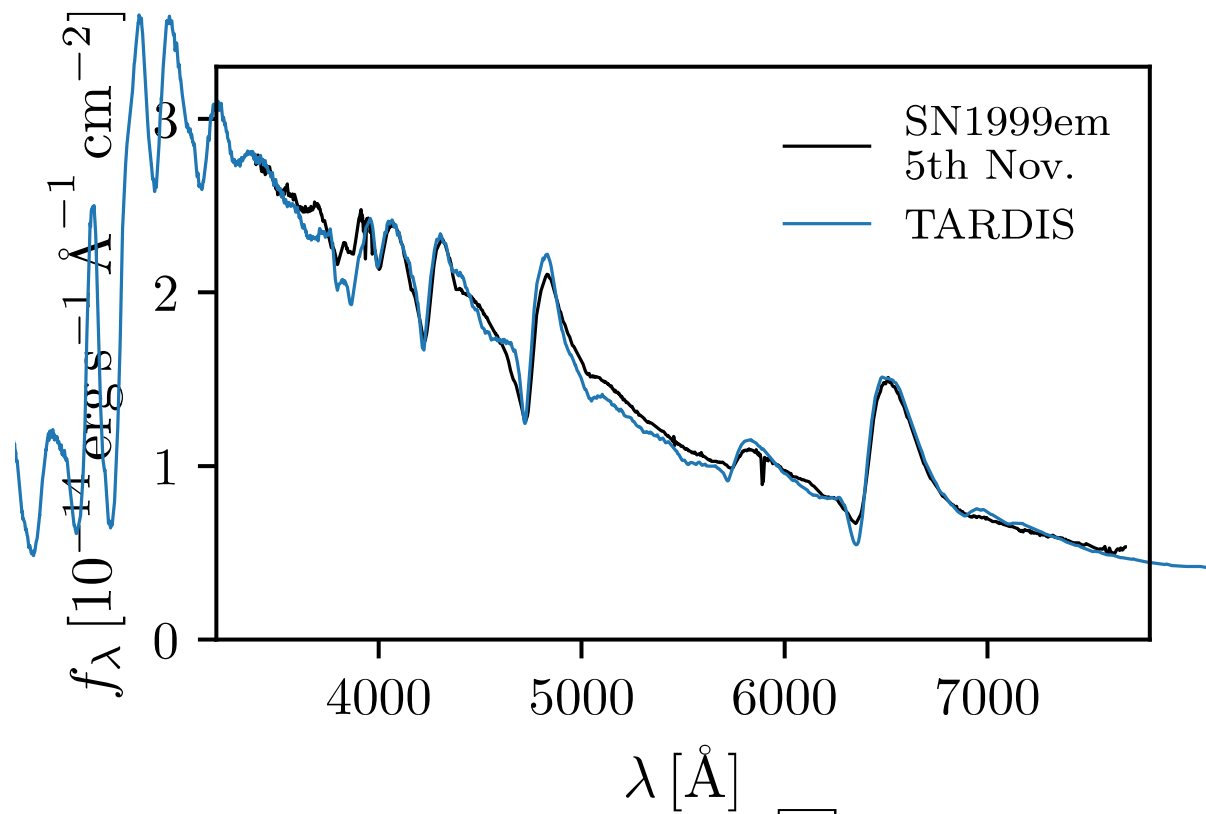
NLTE and thermal  
structure

relativistic transport

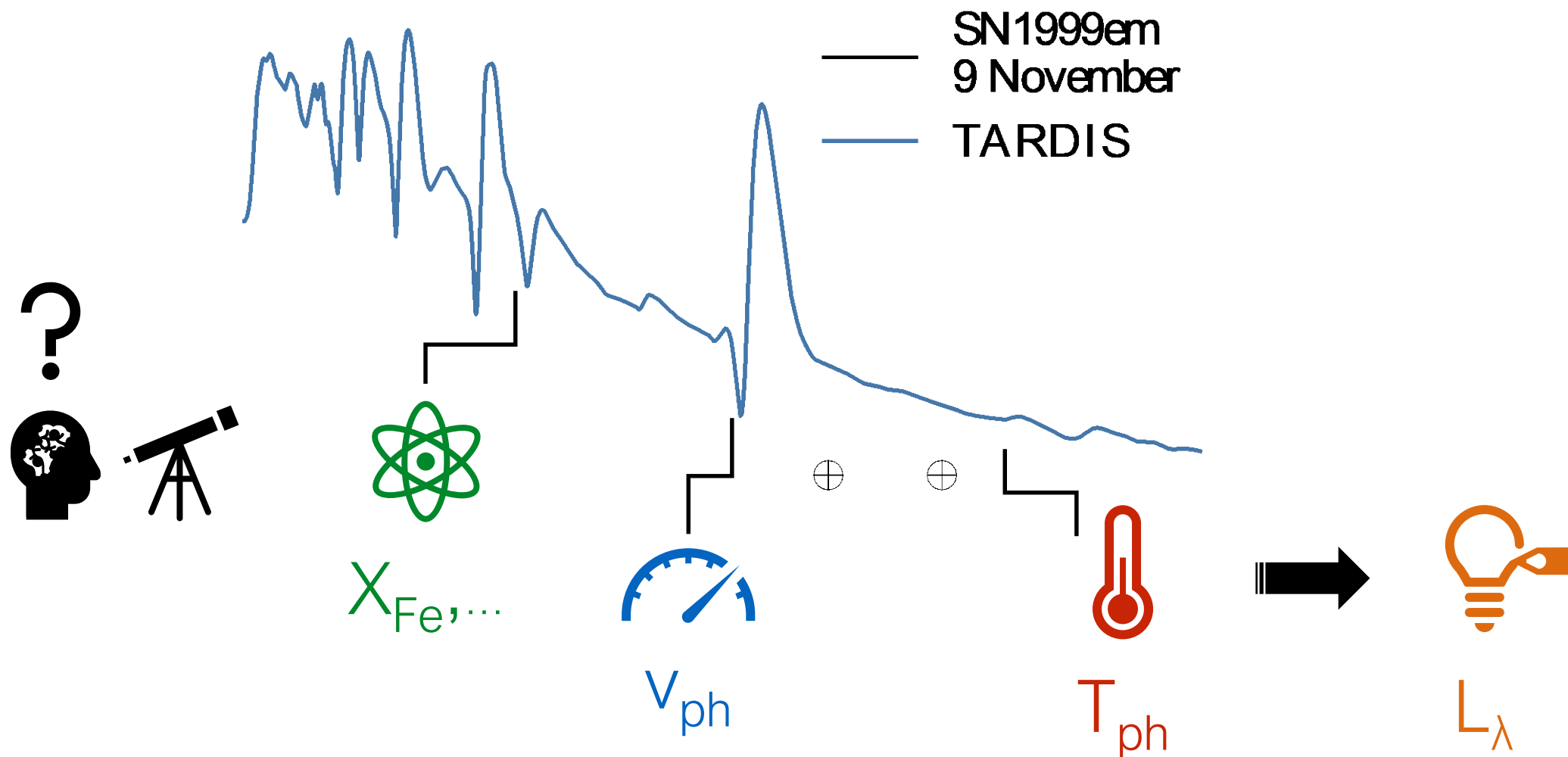
But: Developed for Type Ia SNe not Type IIP

[arXiv:1811.02543v1](https://arxiv.org/abs/1811.02543v1)

# Synthetic spectra



# Parameter inference



## Current method:

Optimization by hand and eye (e.g., Dessart & Hillier 2006, 2008)

### Advantages:

- efficiency
- uses spectroscopist's knowledge

### Drawbacks:

- not reproducible
- no uncertainties
- infeasible for large datasets

# Spectral emulation



Emulate instead of simulate

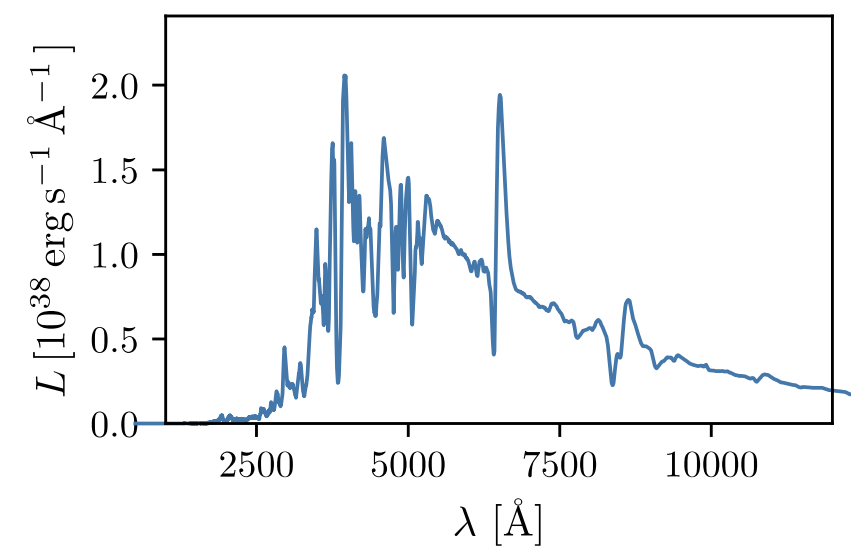
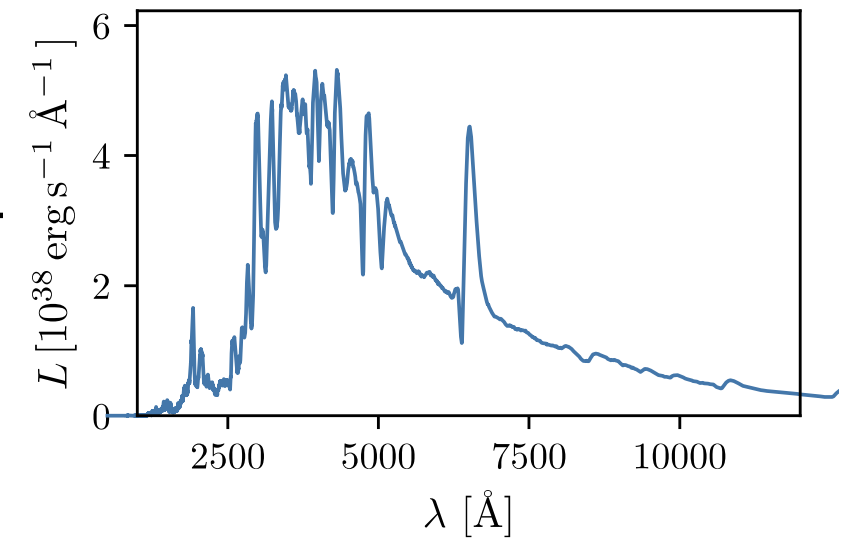
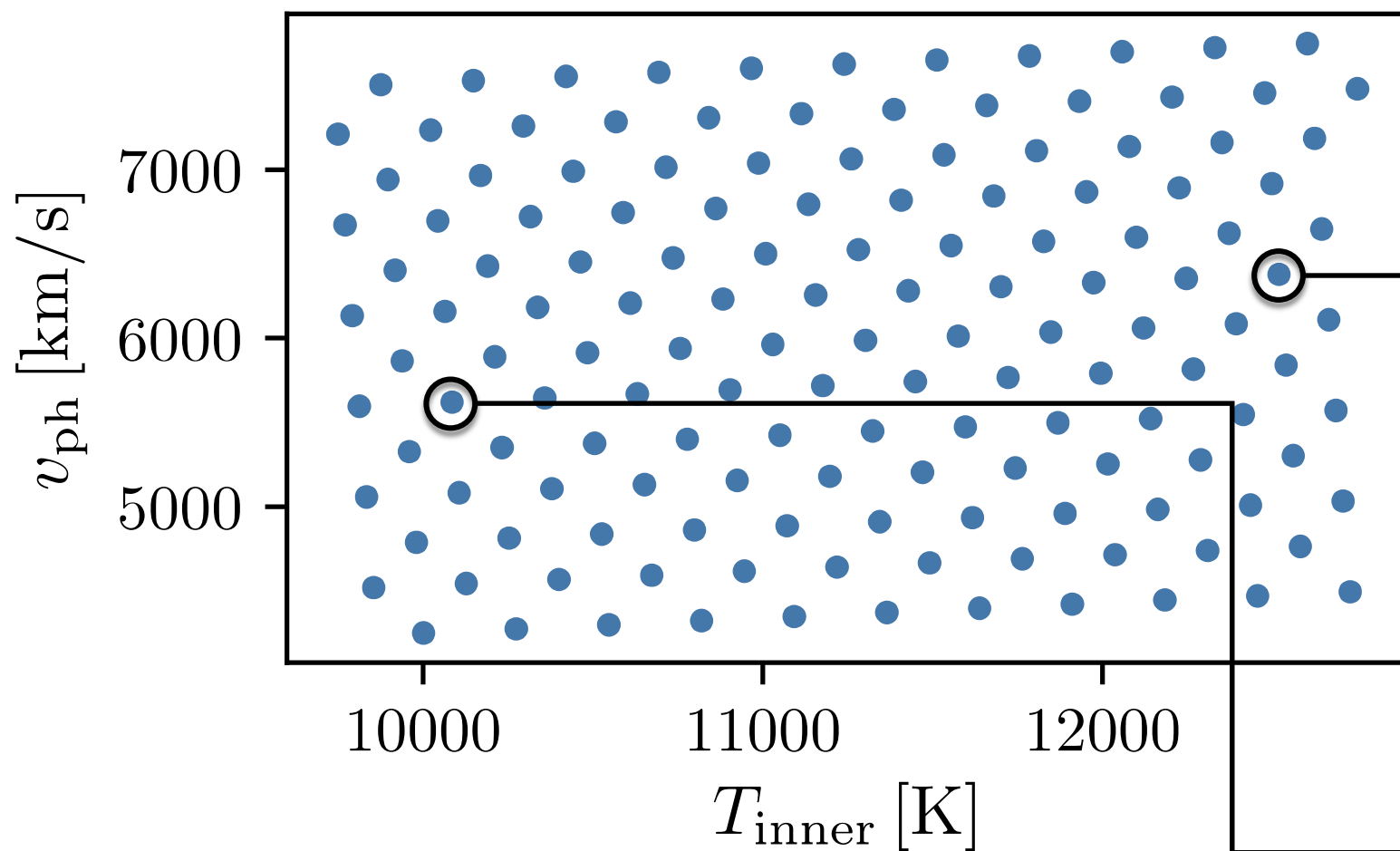
e.g. Heitmann et al. 2009, Czekala et al. 2015, [Lietzau 2017](#)

Reasoning:

- Spectra vary smoothly with the parameters  $\theta = (T_{ph}, v_{ph}, \dots)$
- Systematic errors are dominant

# Model grid

SN1999em 14<sup>th</sup> of November

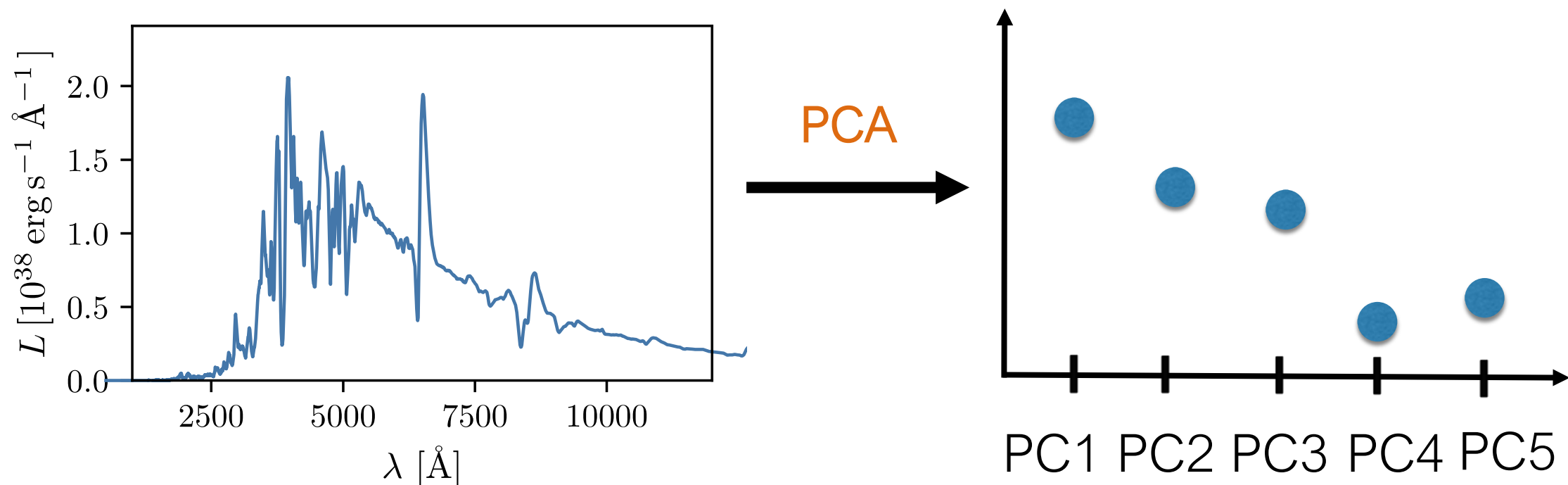




# Spectral preprocessing

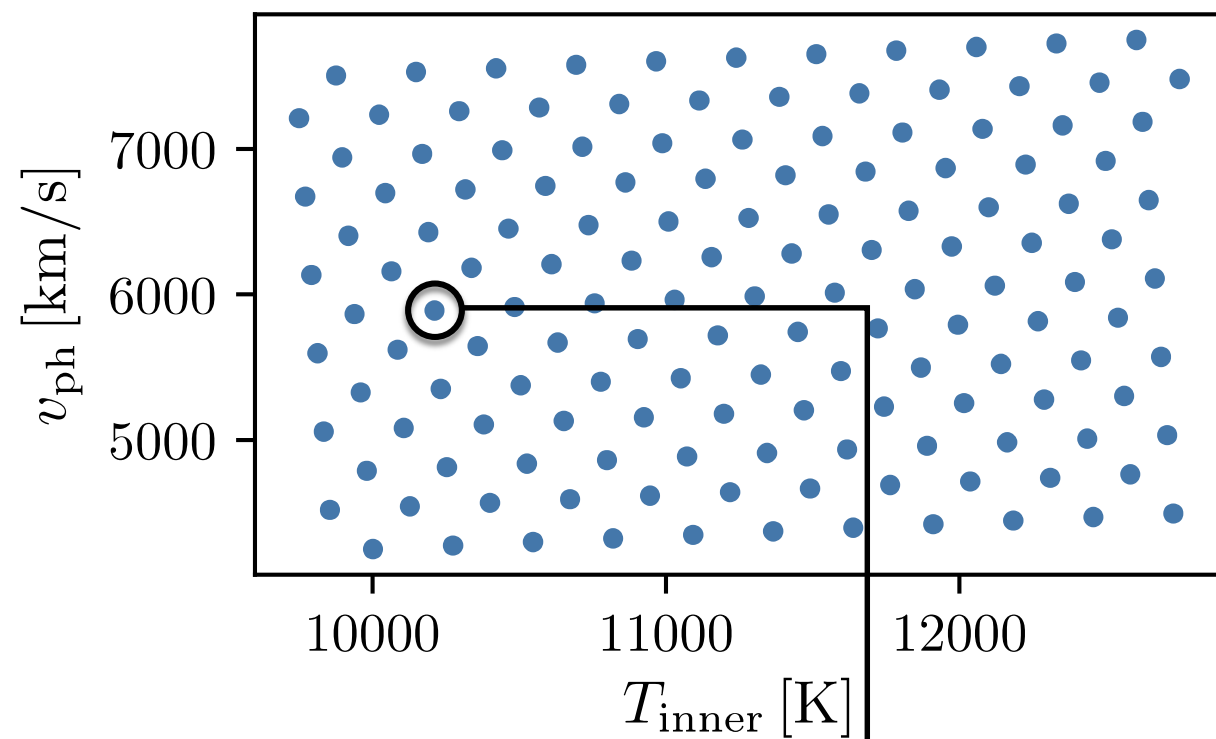
## Steps:

1. Smooth MC spectrum
2. Doppler shift smoothed spectrum
3. Normalize and scale
4. Dimensionality reduction through PCA decomposition



# Interpolation

Model grid



One possibility:  
Gaussian Processes

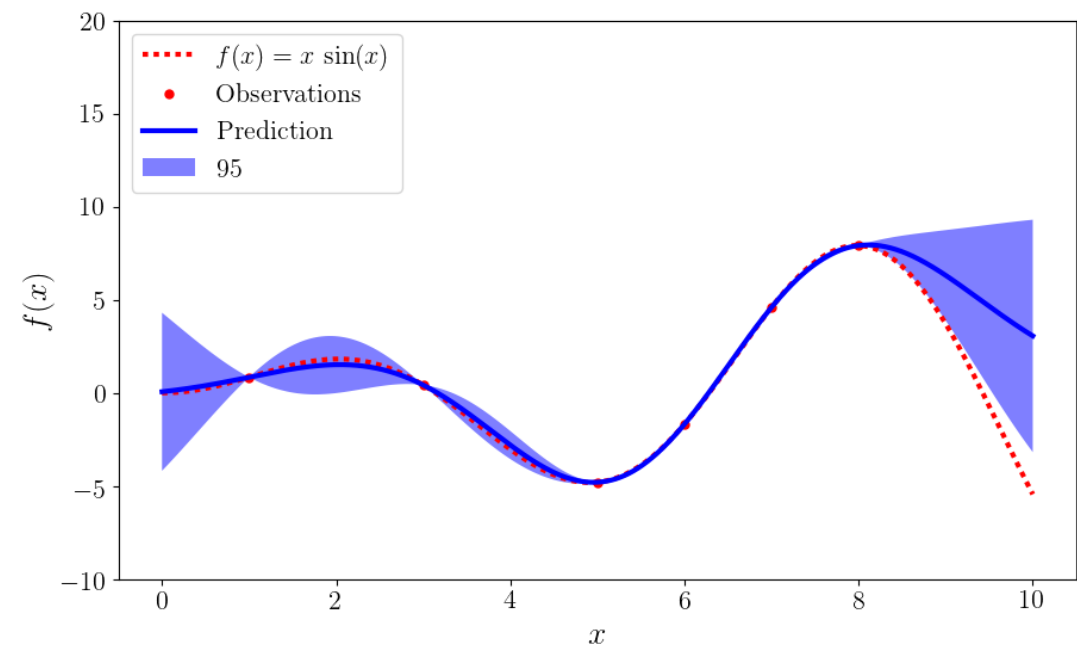
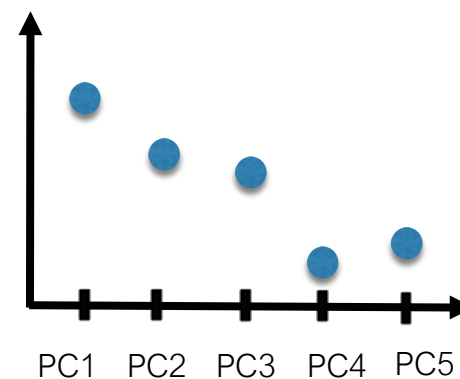
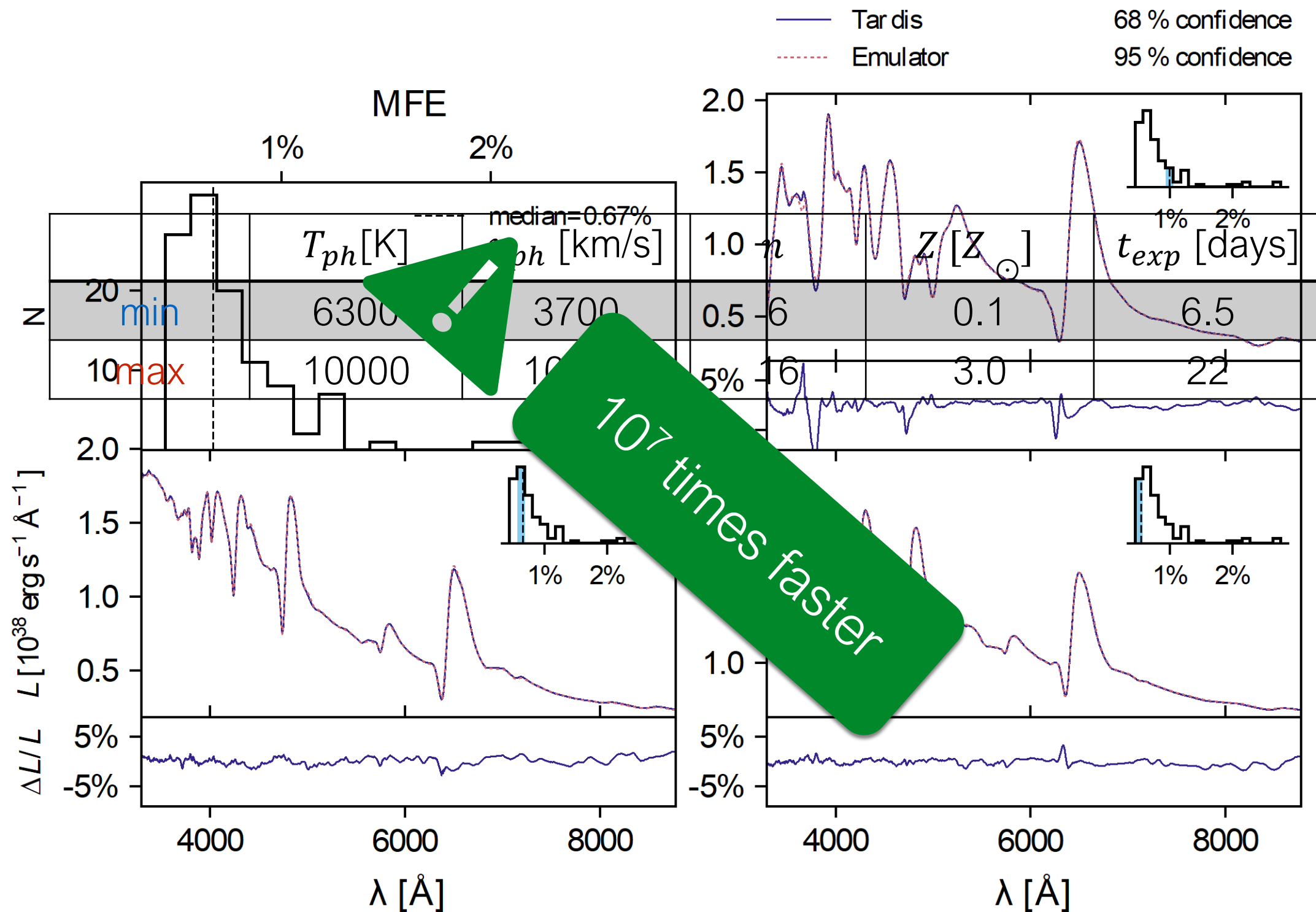


Image: Vincent Dubourg

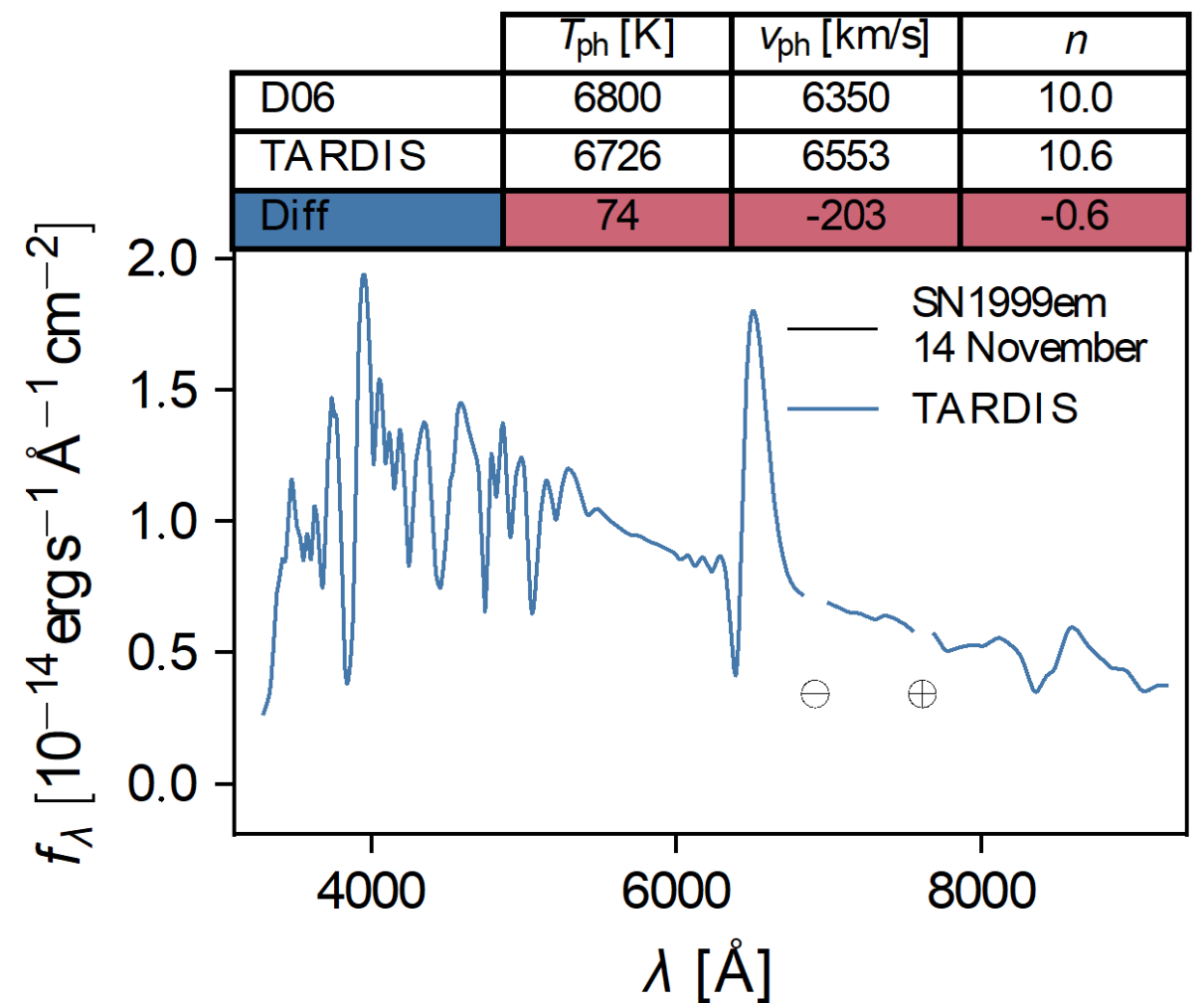
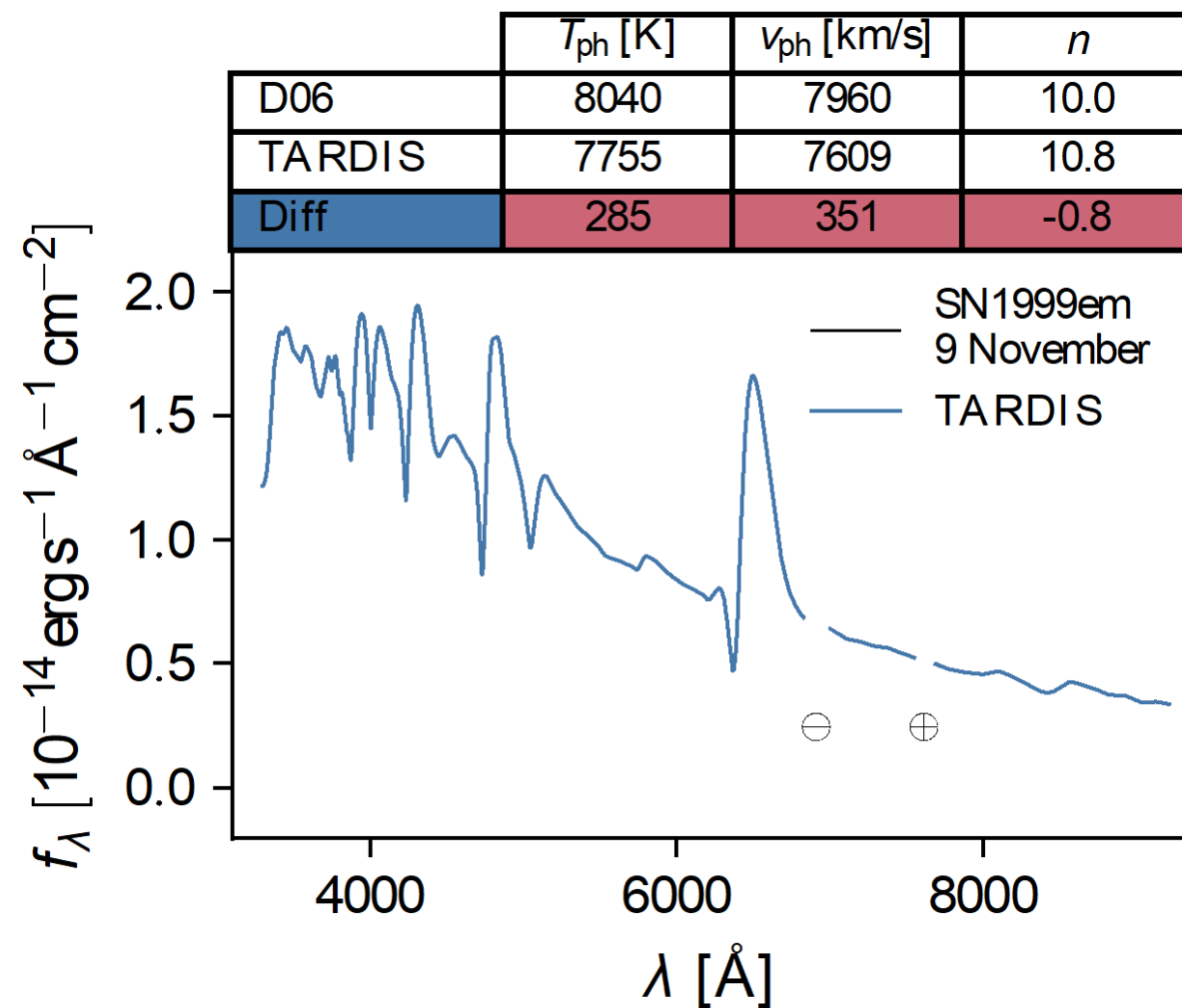


# Emulator validation



# Emulator application

SN 1999em: the prototypical SN II

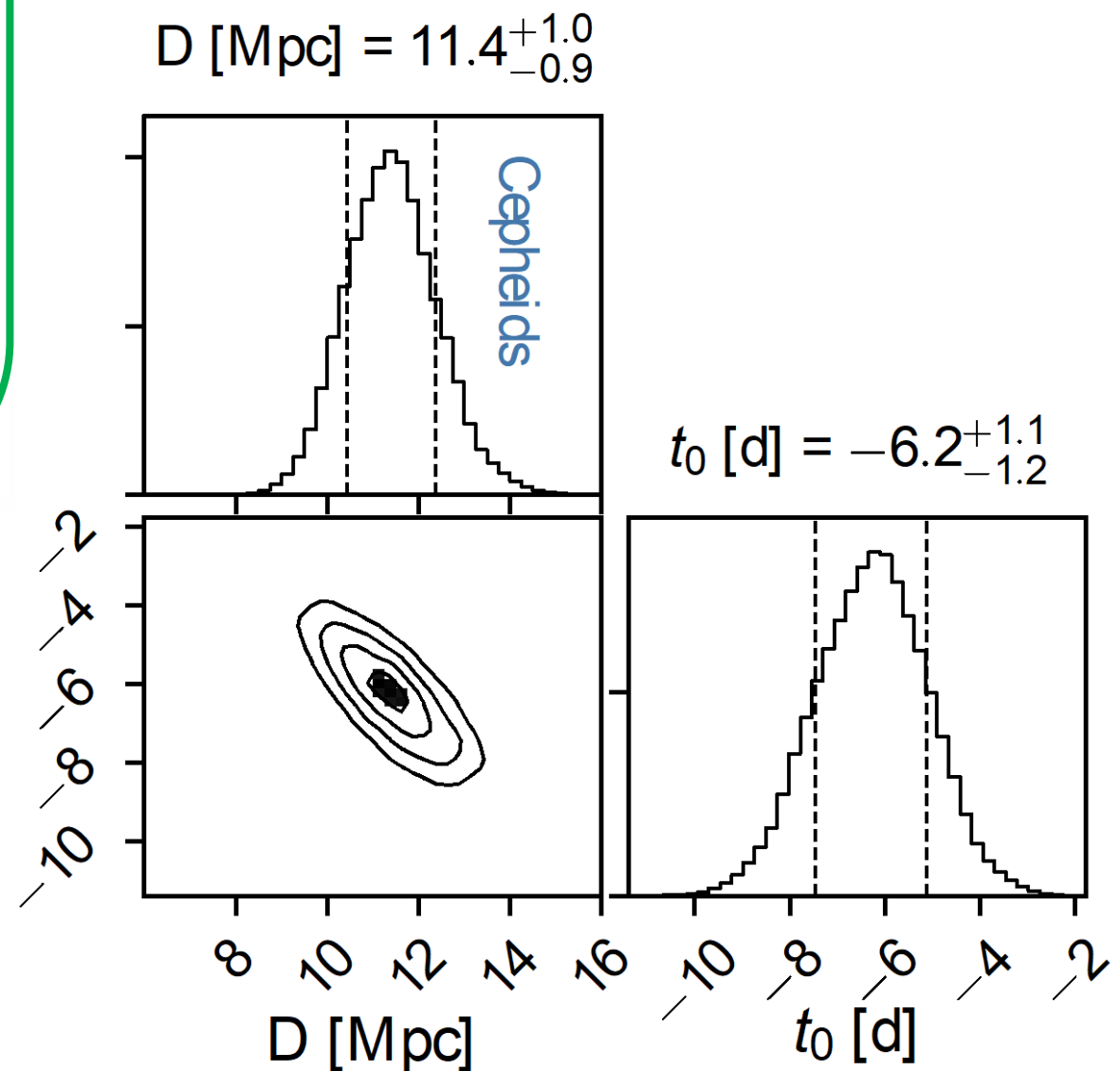
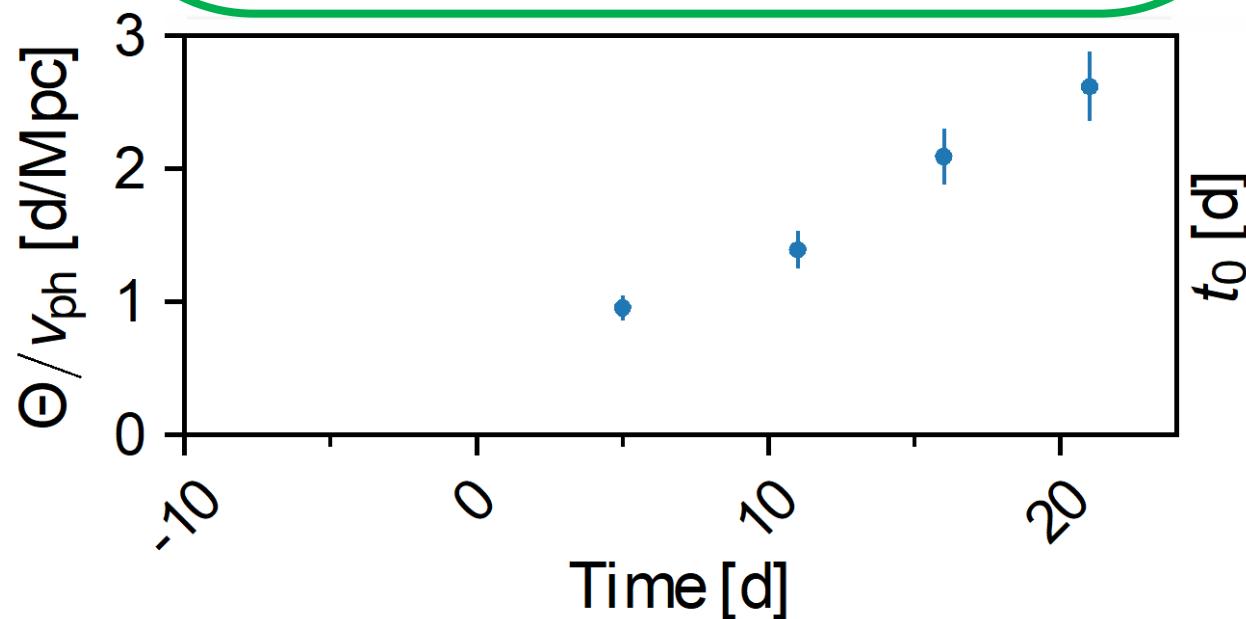
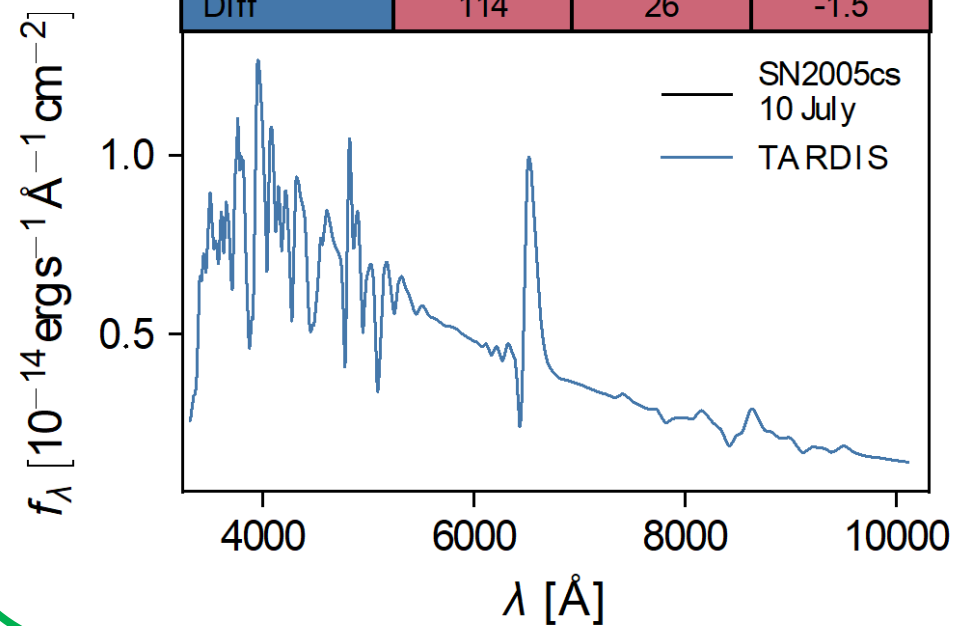




# Distance to NGC1637

## SN 2005cs

	$T_{\text{ph}}$ [K]	$v_{\text{ph}}$ [km/s]	$n$
D06	7120	4580	10.0
TARDIS	7006	4554	11.5
Diff	114	26	-1.5





# Outlook

A. Floers  
W. Hillebrandt  
R. Kotak  
B. Leibundgut (PI)  
S. Smartt  
J. Spyromilio  
S. Suyu  
S. Taubenberger  
C. Vogl

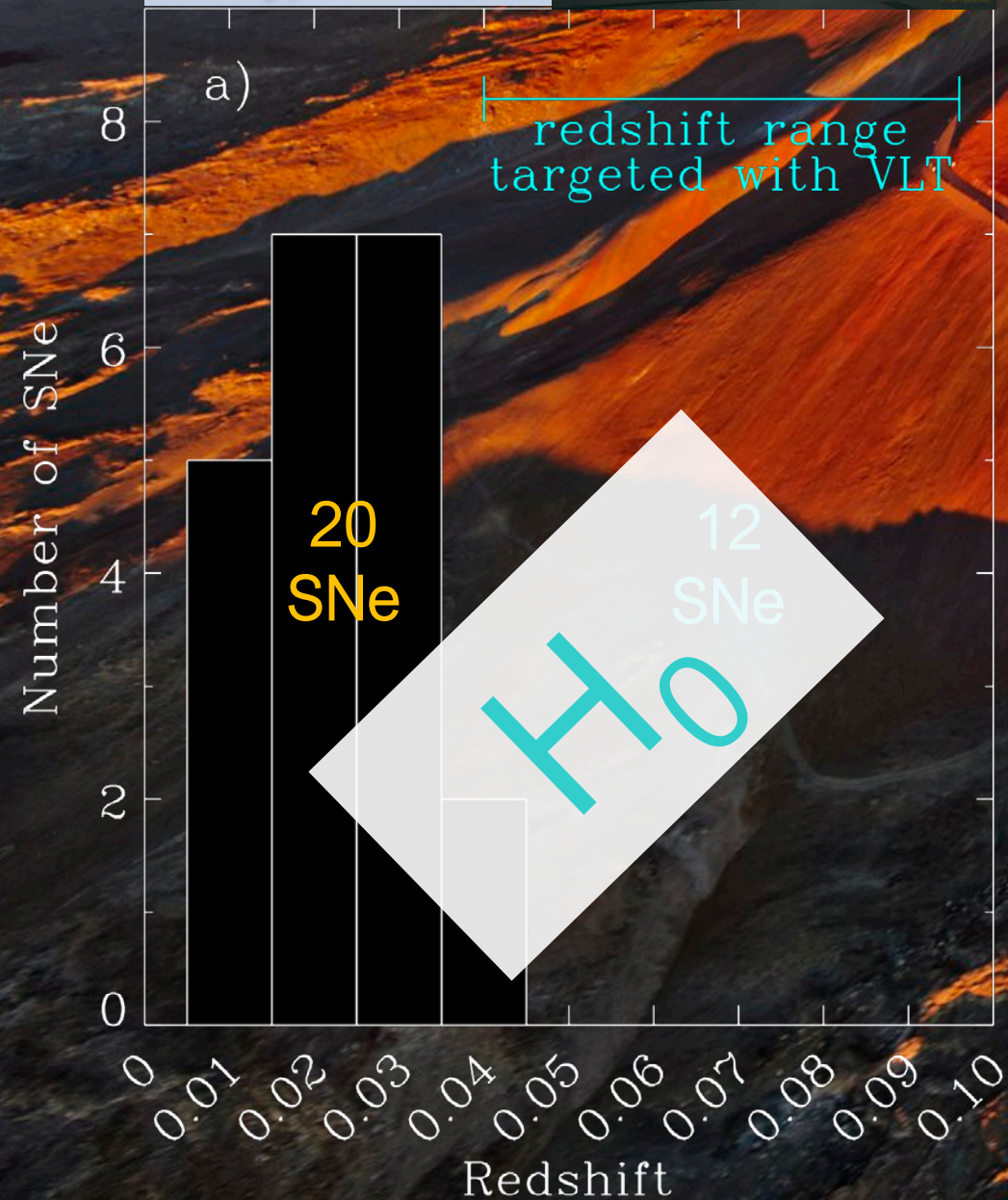
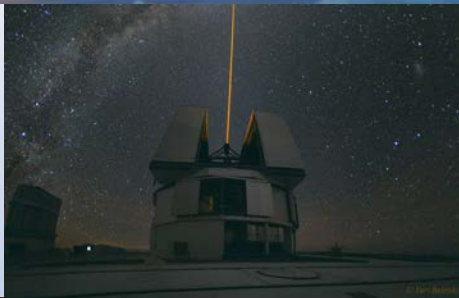


Image: Ric Noyle