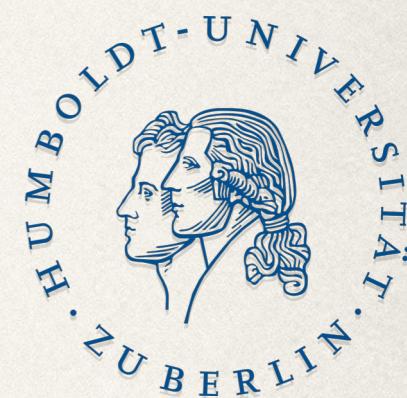


# Peculiar velocities with type Ia supernovae from the Nearby Supernova Factory

XII<sup>th</sup> Rencontres du Vietnam - Large Scale Structure and Galaxy Flows

July 4th 2016

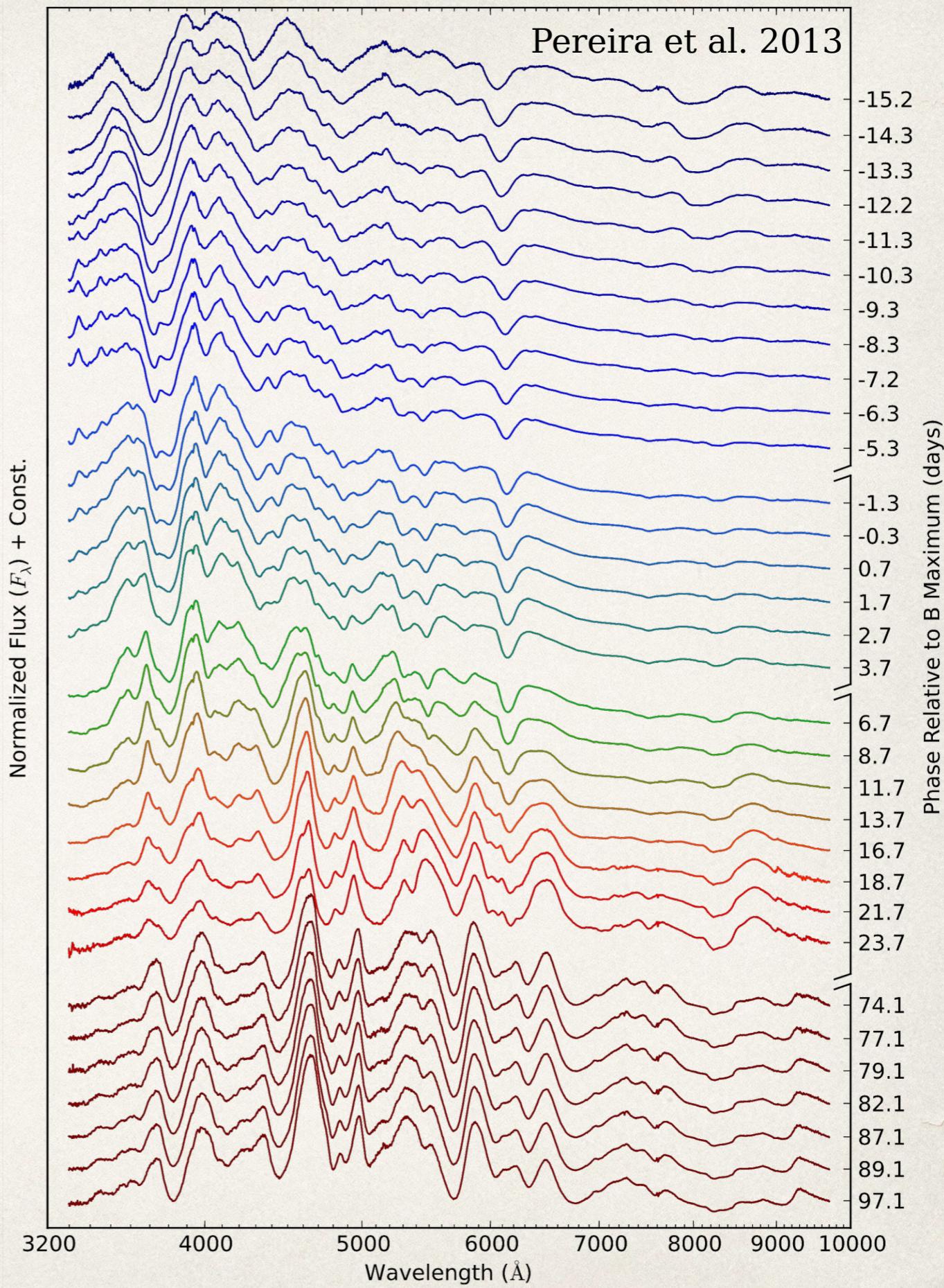
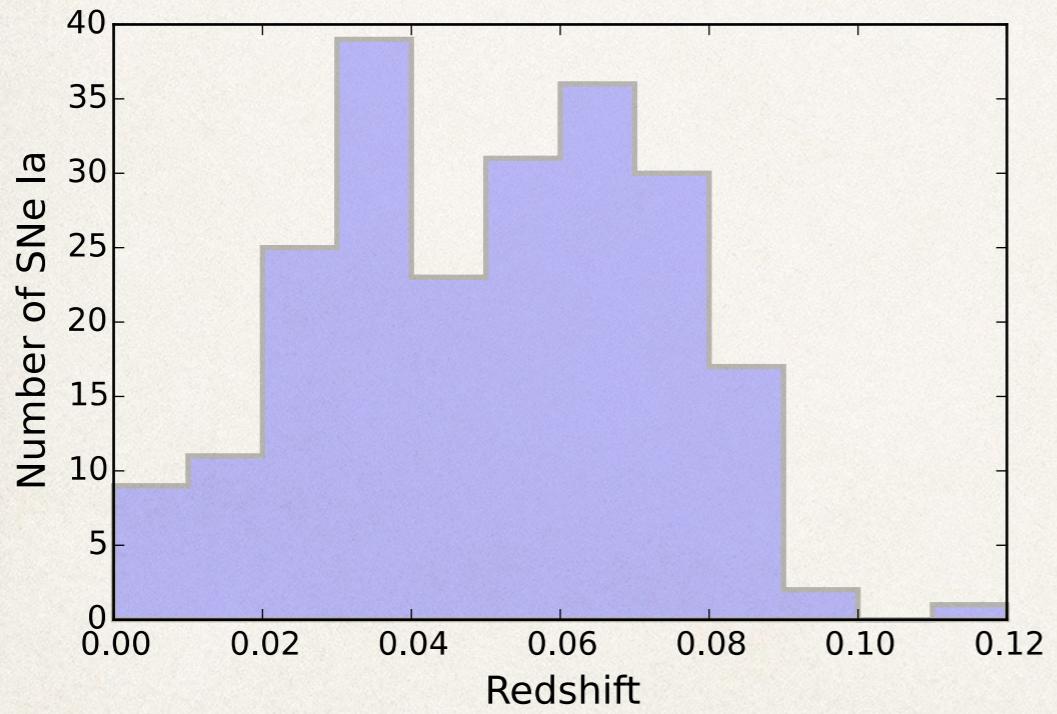
Ulrich Feindt, Oskar Klein Centre, Stockholm  
on the behalf of SNfactory



# SNfactory

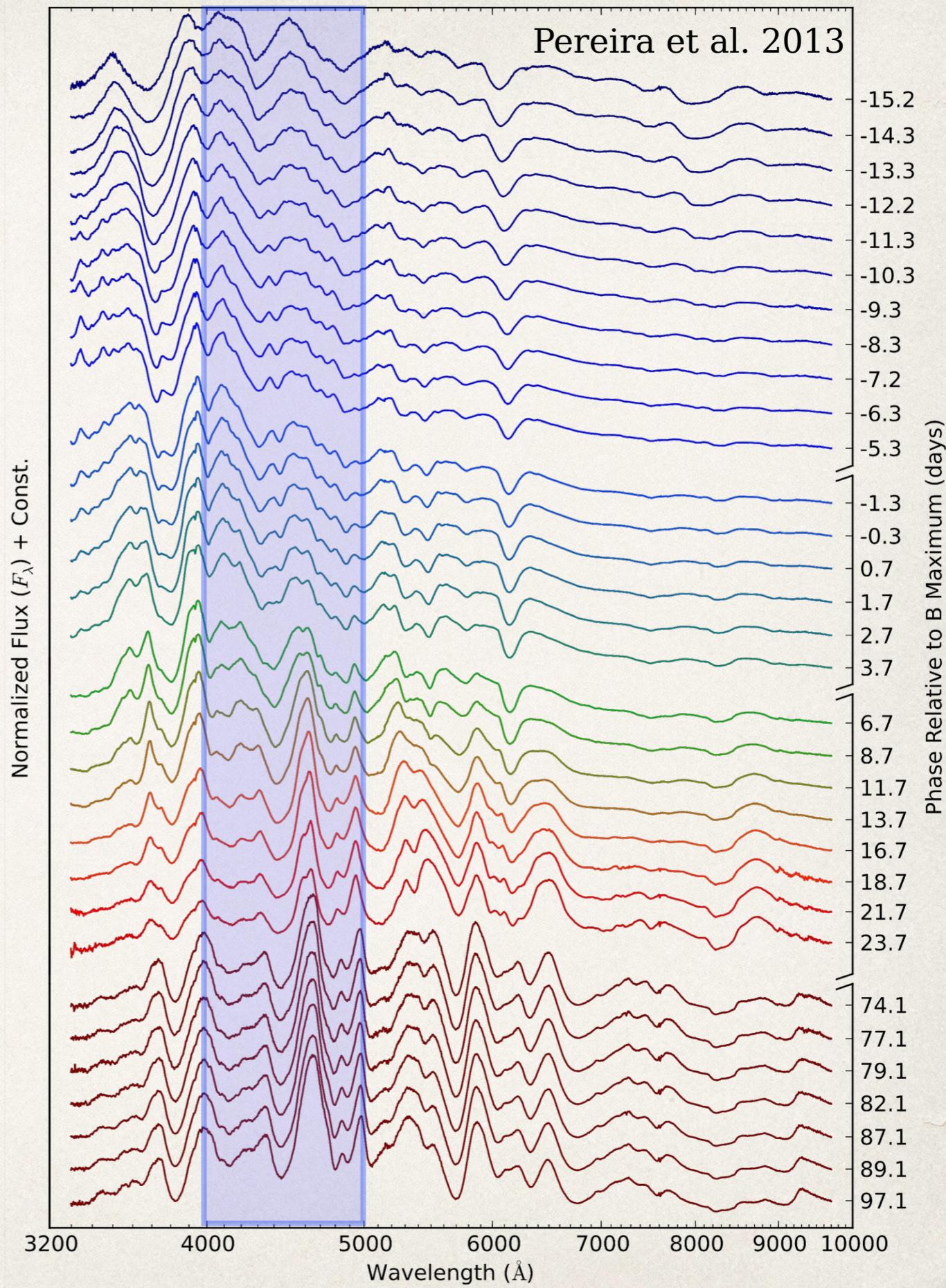
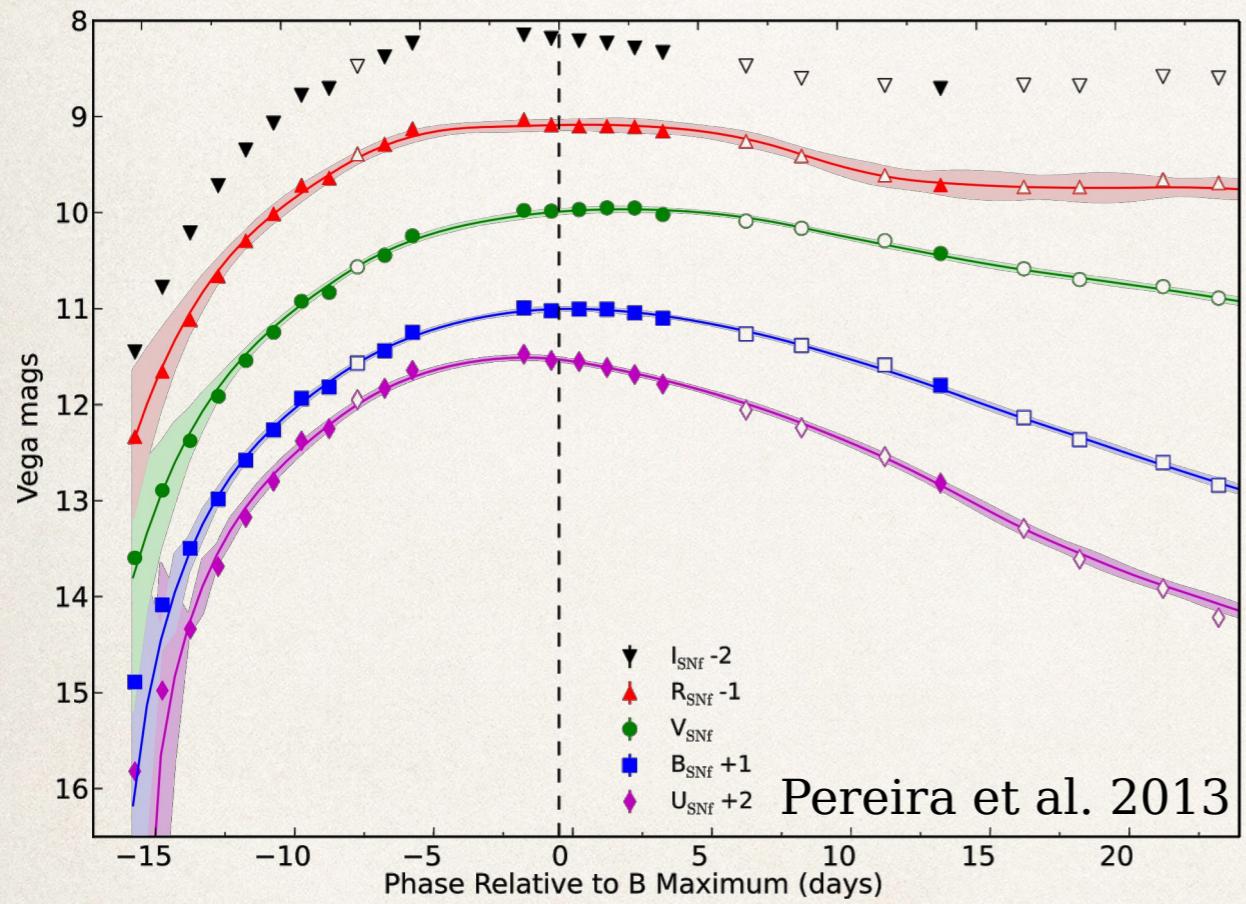
## Time Series of Type Ia Supernovae

- $\sim 200$  SNe for *classic cosmology*
- $\sim$  redshift [0.03 ; 0.08]
- $\sim 15$  spectra per SNe
- median first phase -4.6 days



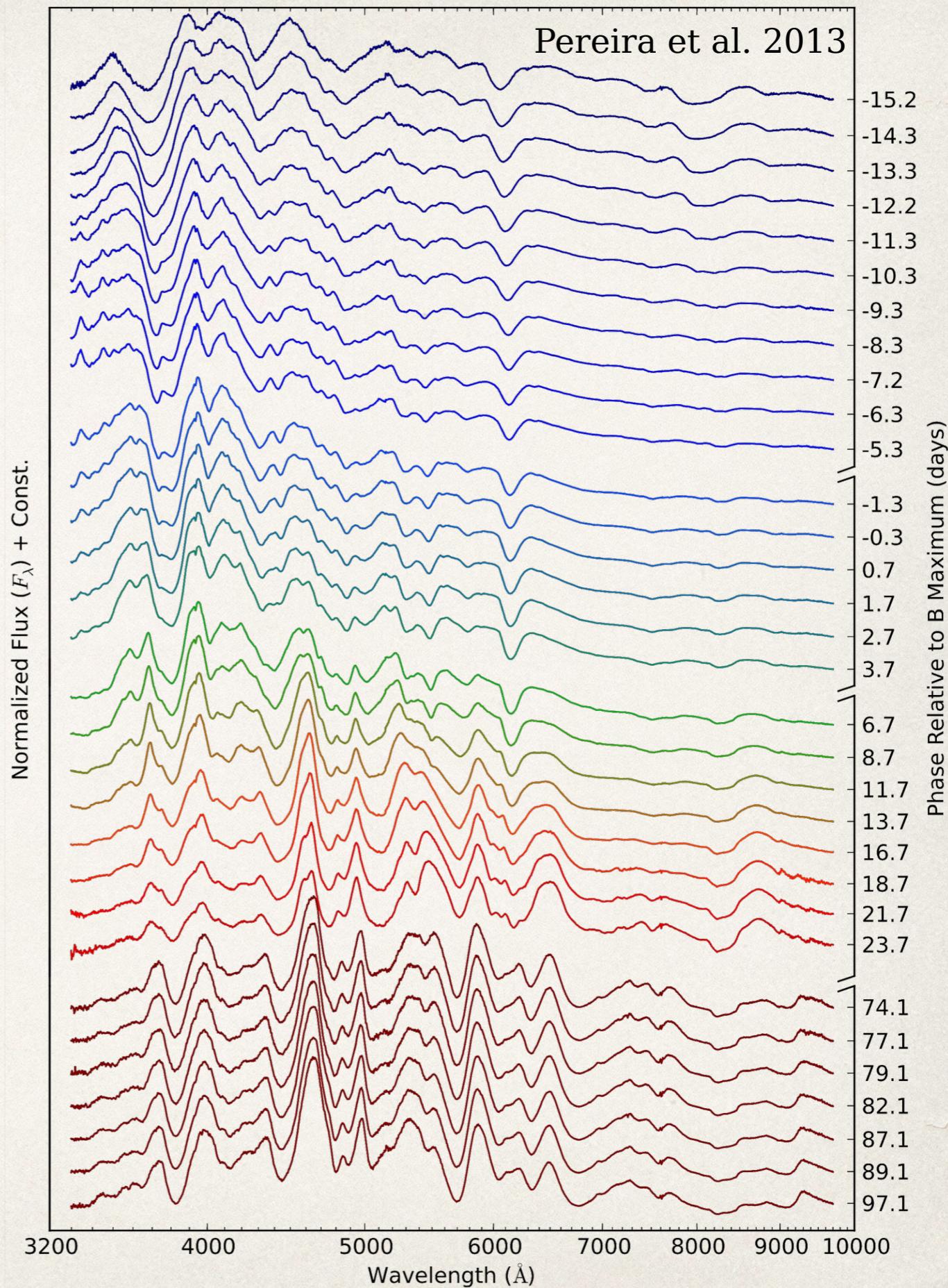
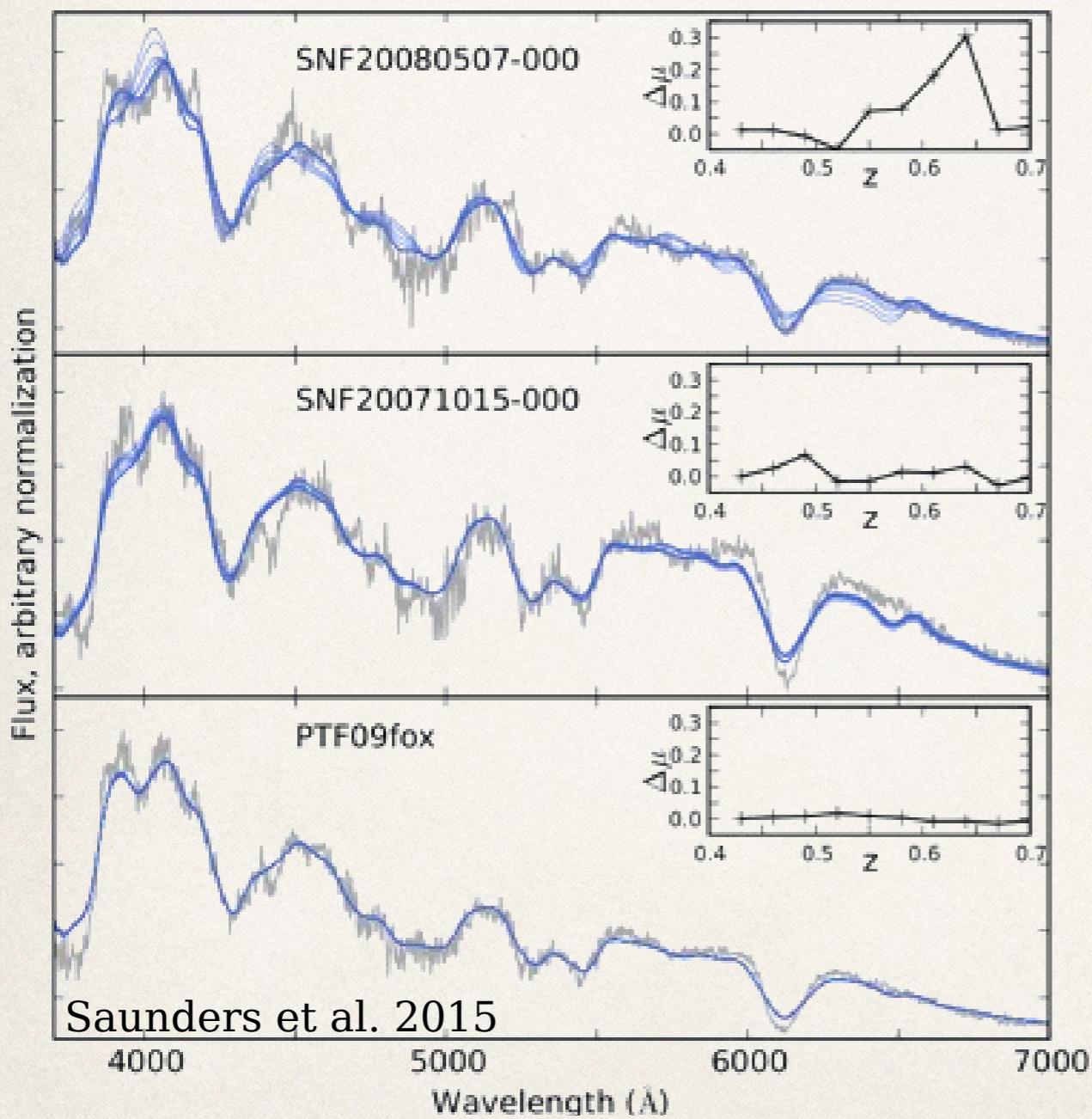
# SNfactory

**Synthesize Light Curves  
in any filter system**



# SNfactory

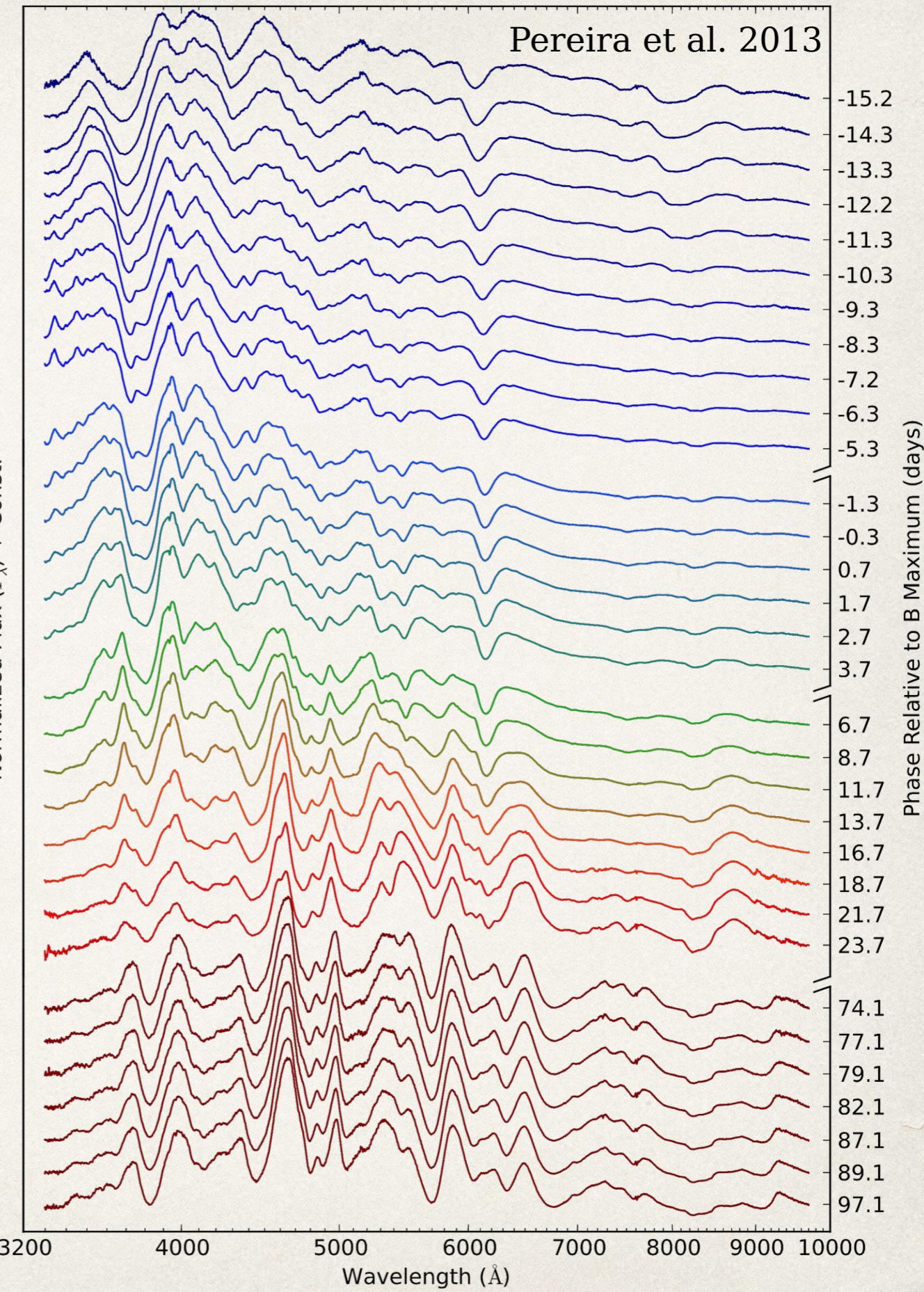
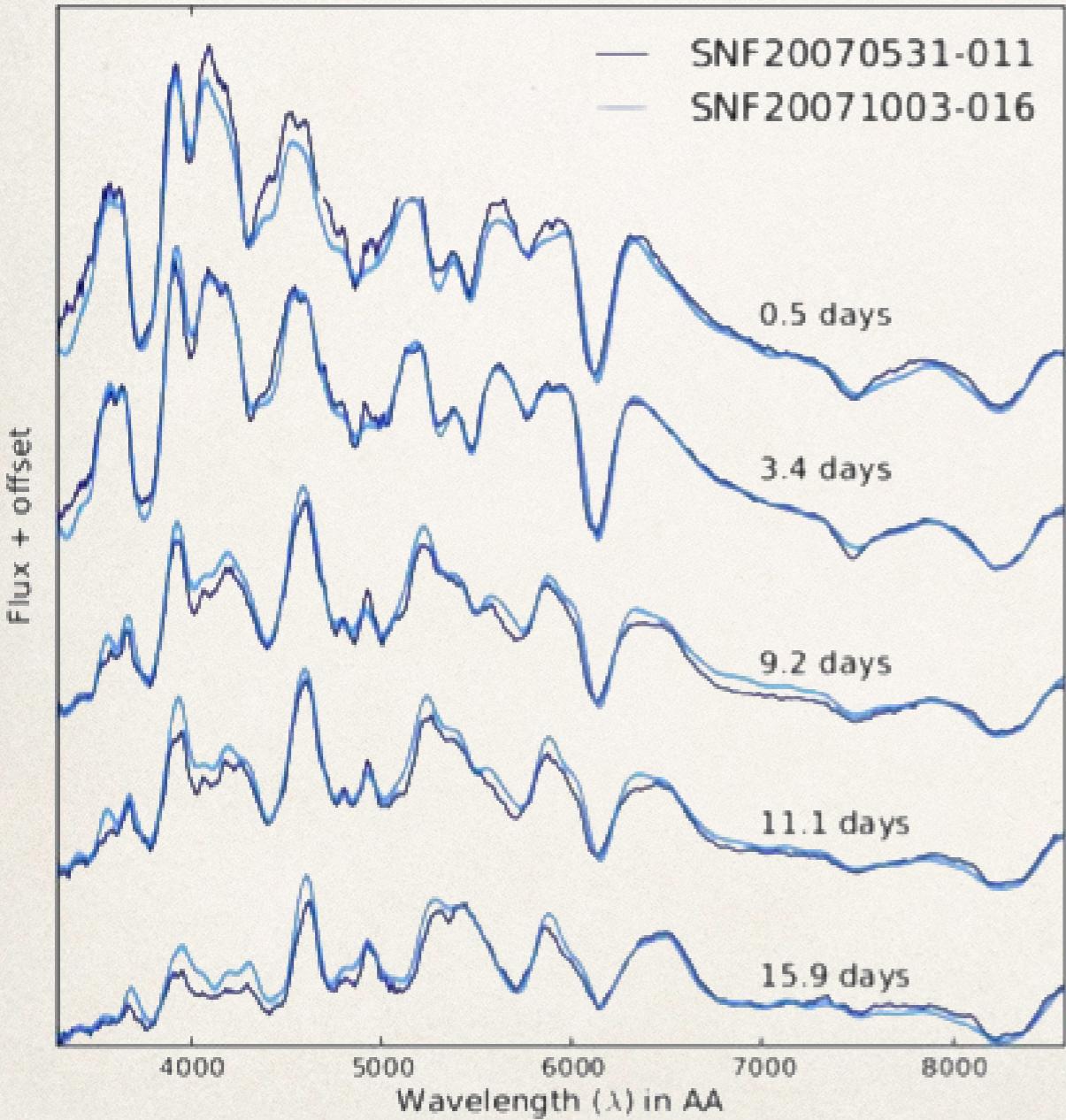
**Test the accuracy of current  
K-corrections (effect on  $w \sim 3\%$ )**



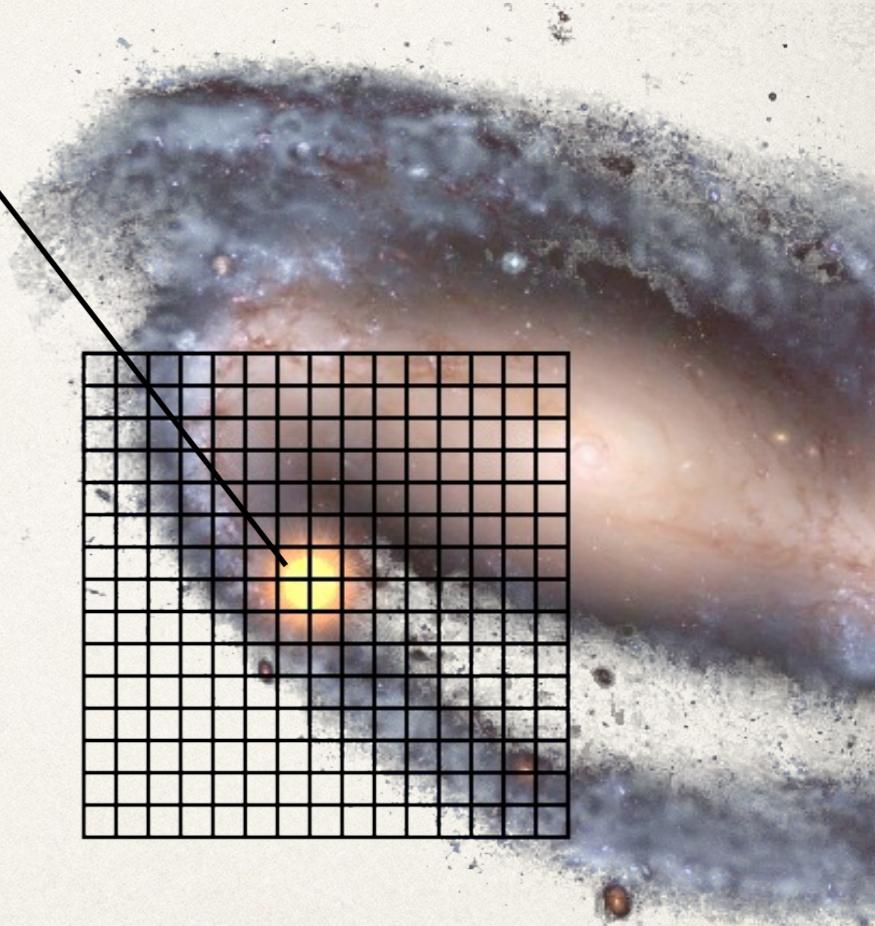
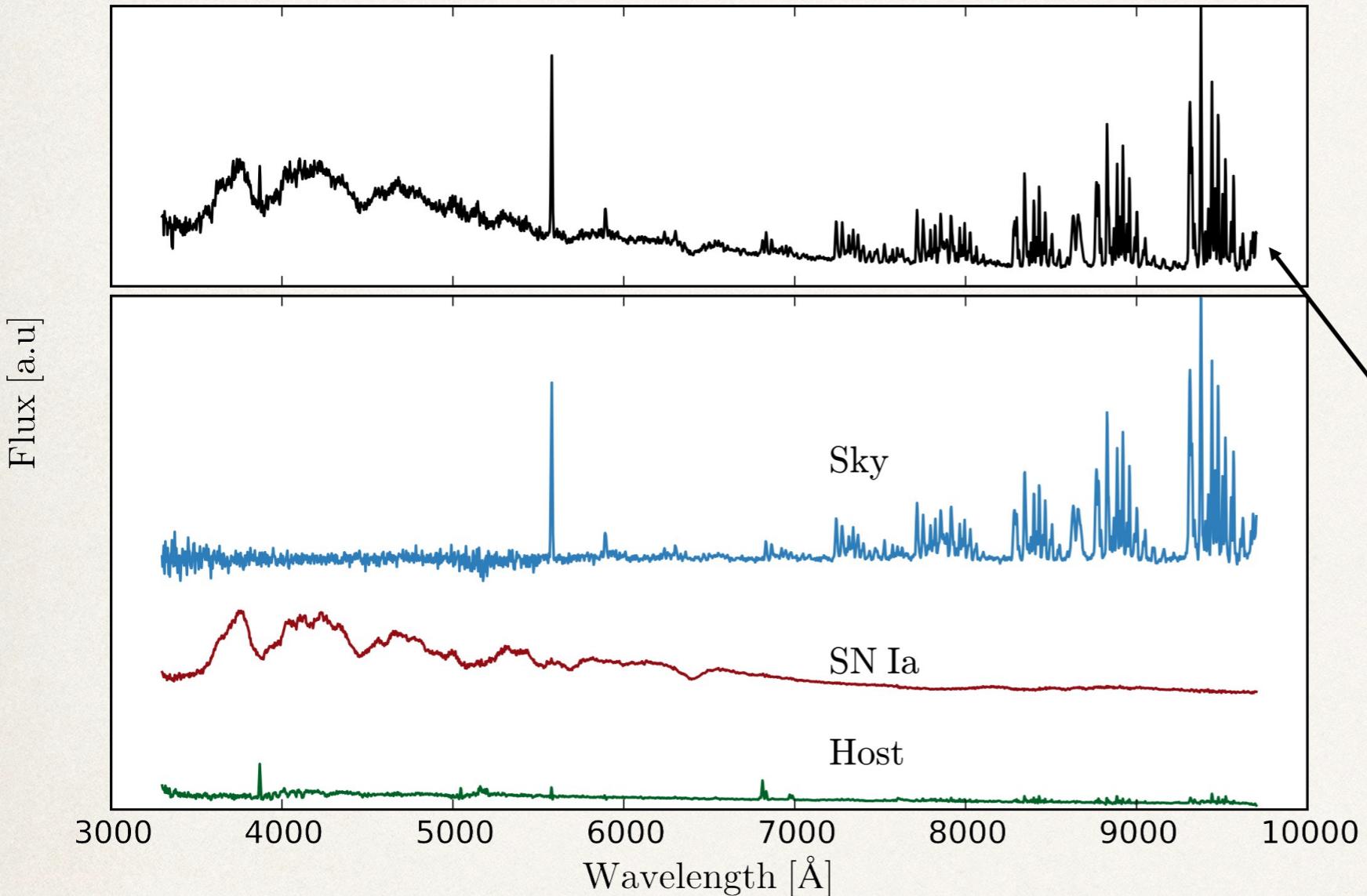
# SNfactory

**Twinning**  
dispersion as low as 0.07 mag

Fahkouri et al. 2015

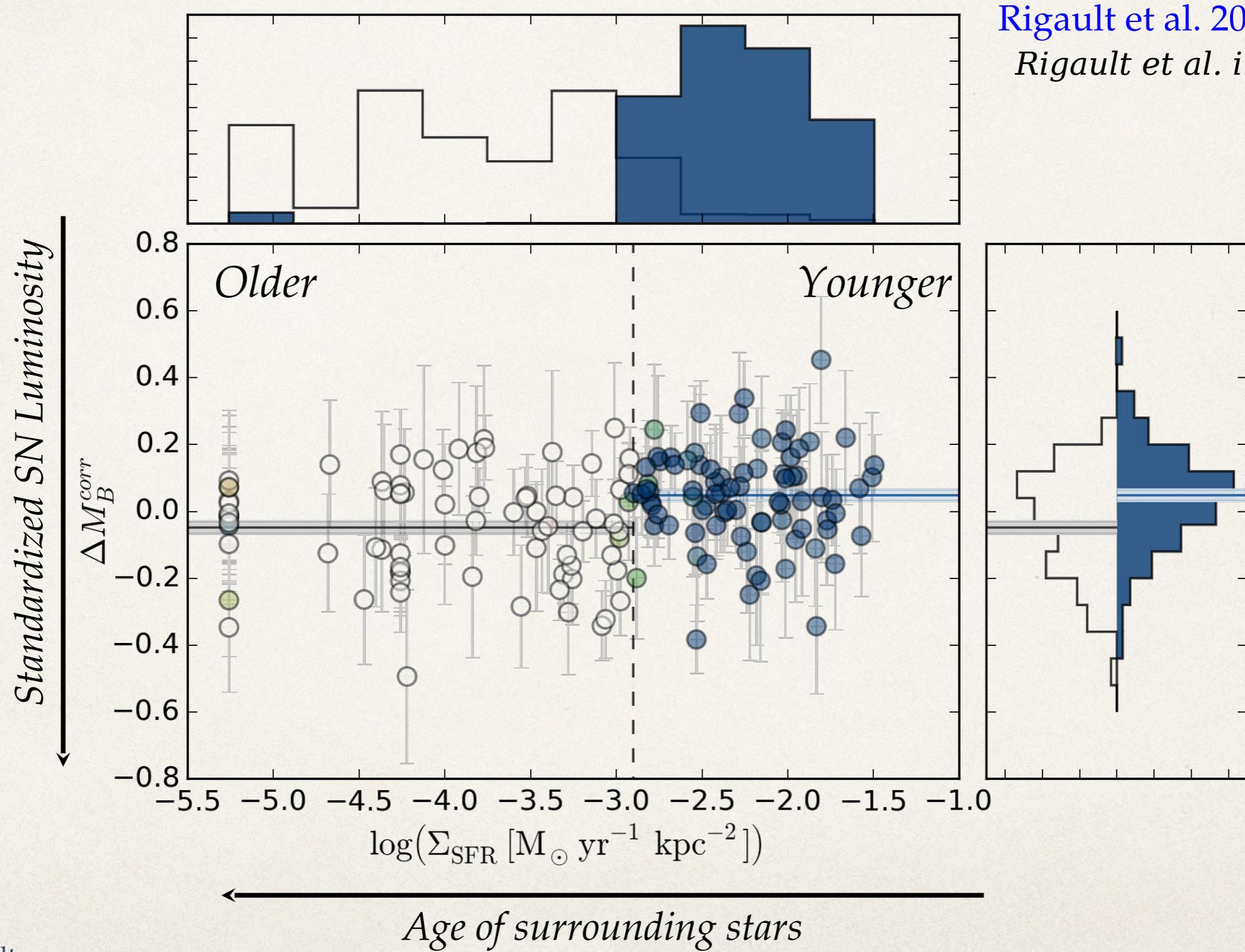


# SNfactory 3D Spectroscopy



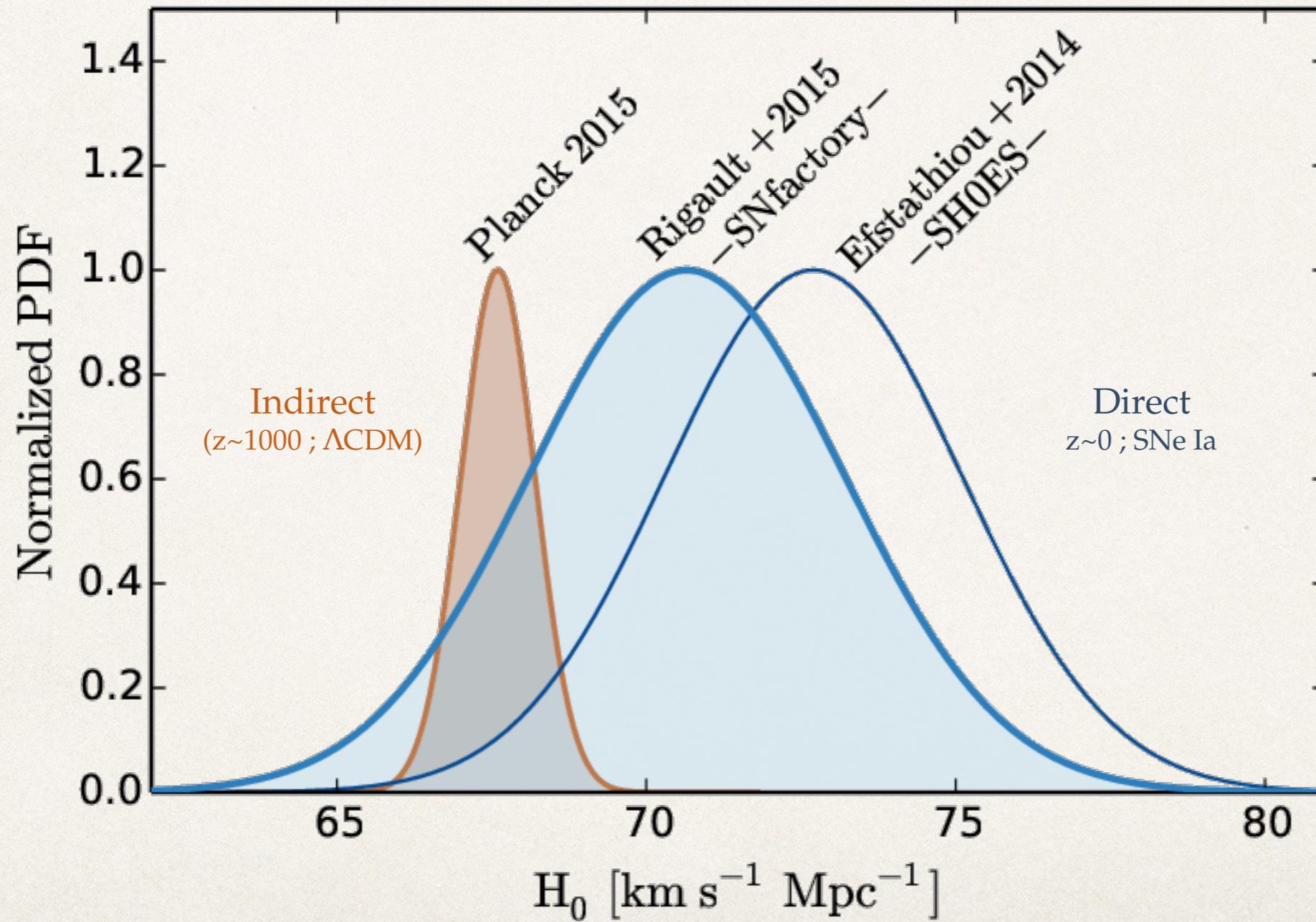
Local Environment and SNe Observed Simultaneously

# Astrophysical Bias in Cosmology



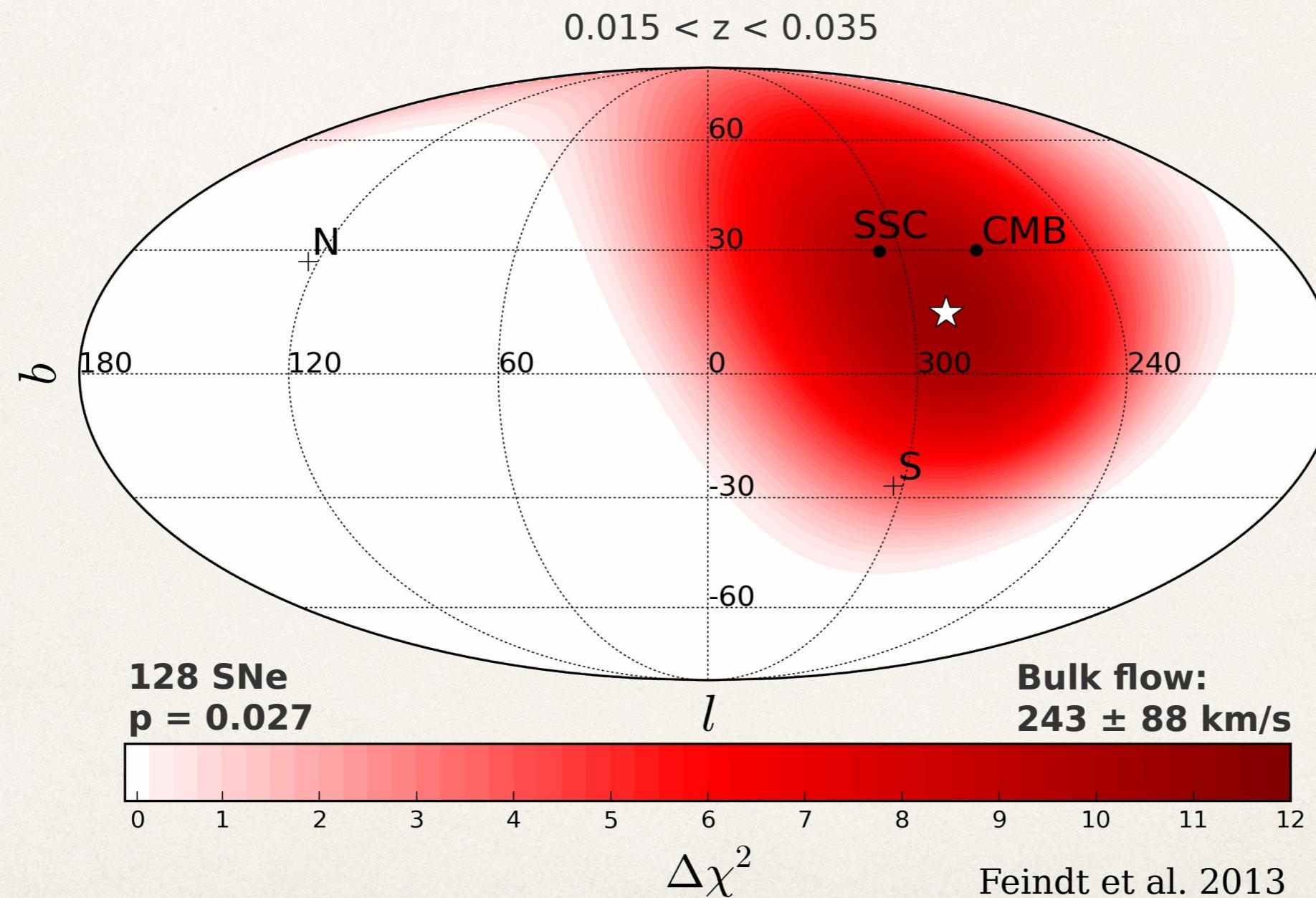
# Correct Astrophysics for Accurate Cosmology ( $H_0$ )

*Still debated (Riess et al. 2016 to be checked)*

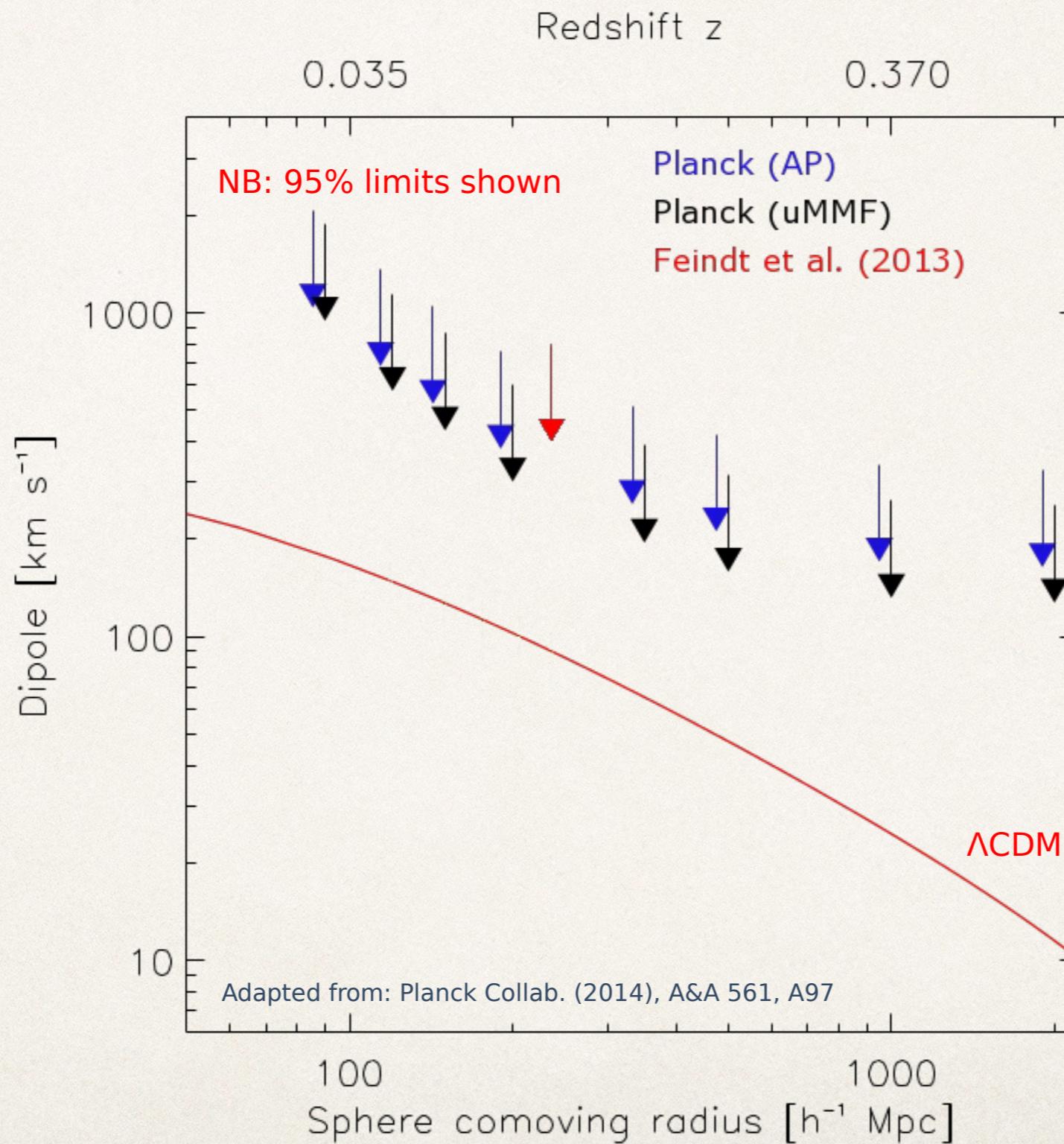


# Measuring Bulk Flows with SNfactory

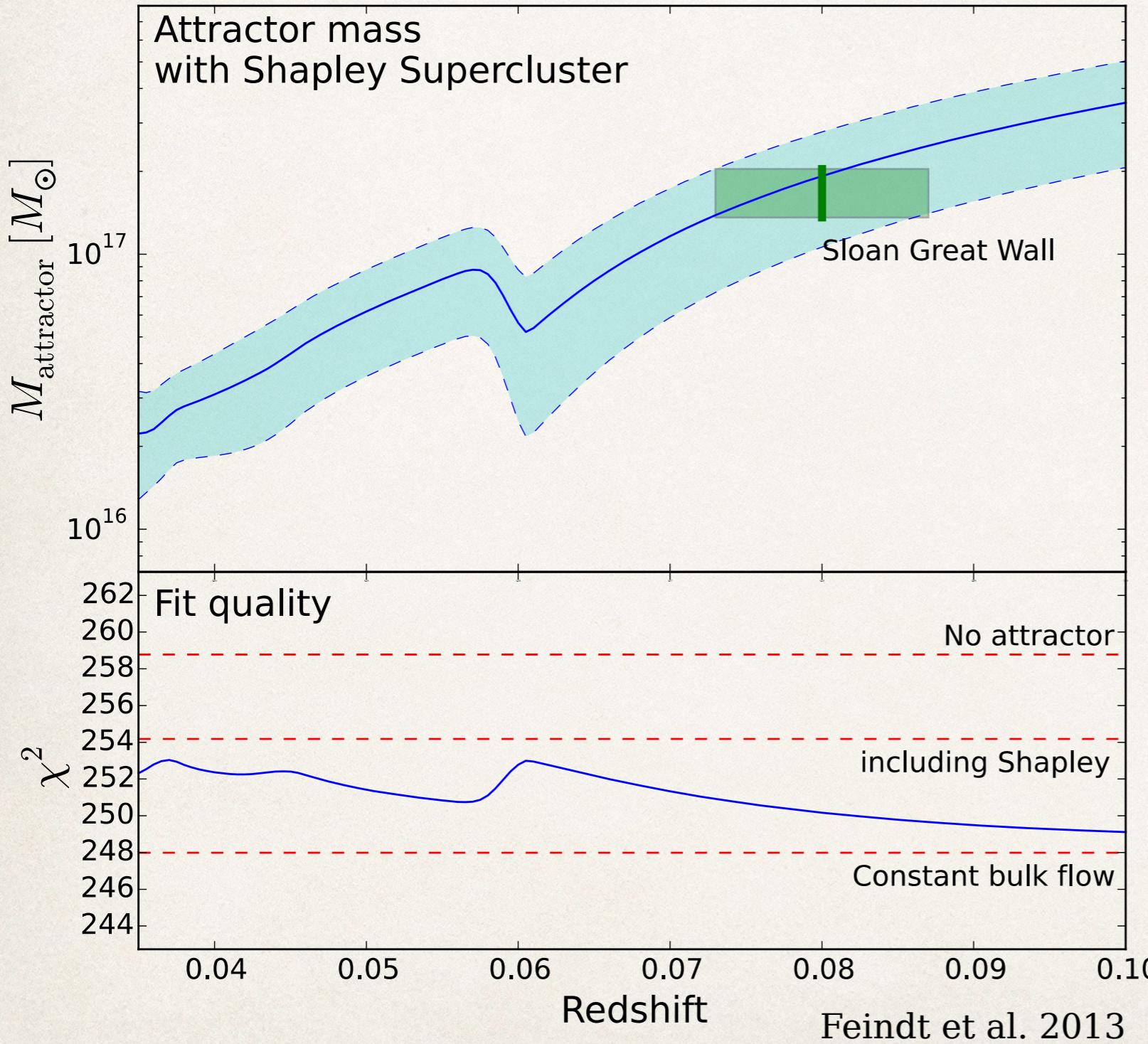
**Analysis of 279 SNe ( $z < 0.1$ ) from Union2 and SNfactory**



# Constraining “Dark Flow”



# Attractor Model for Shapley



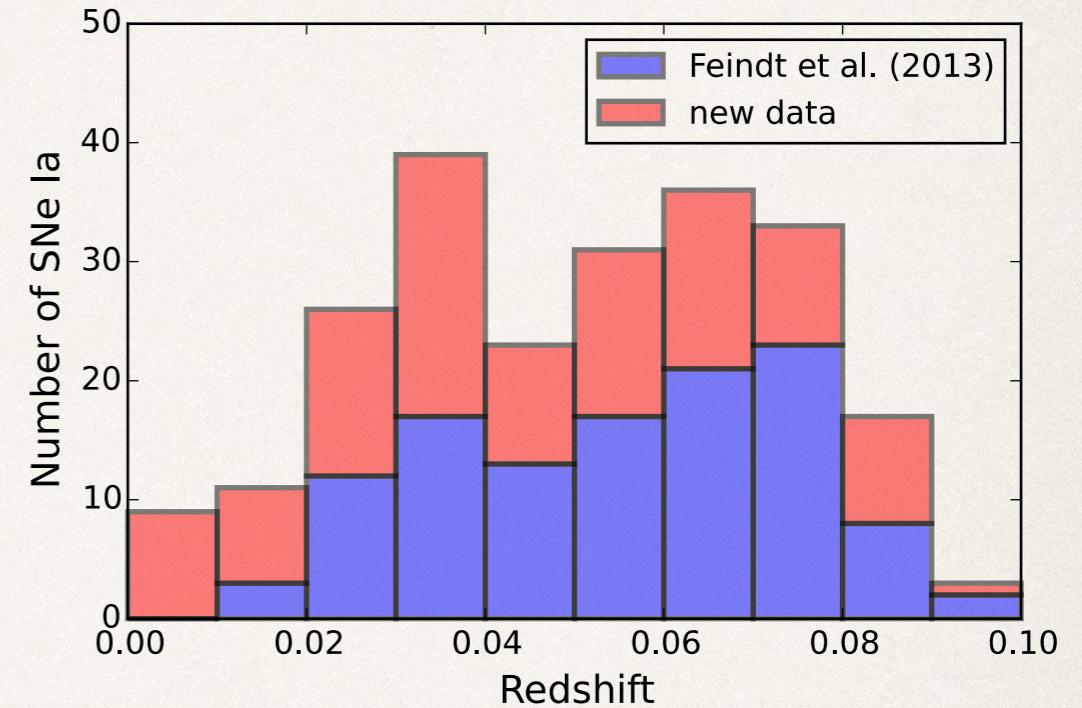
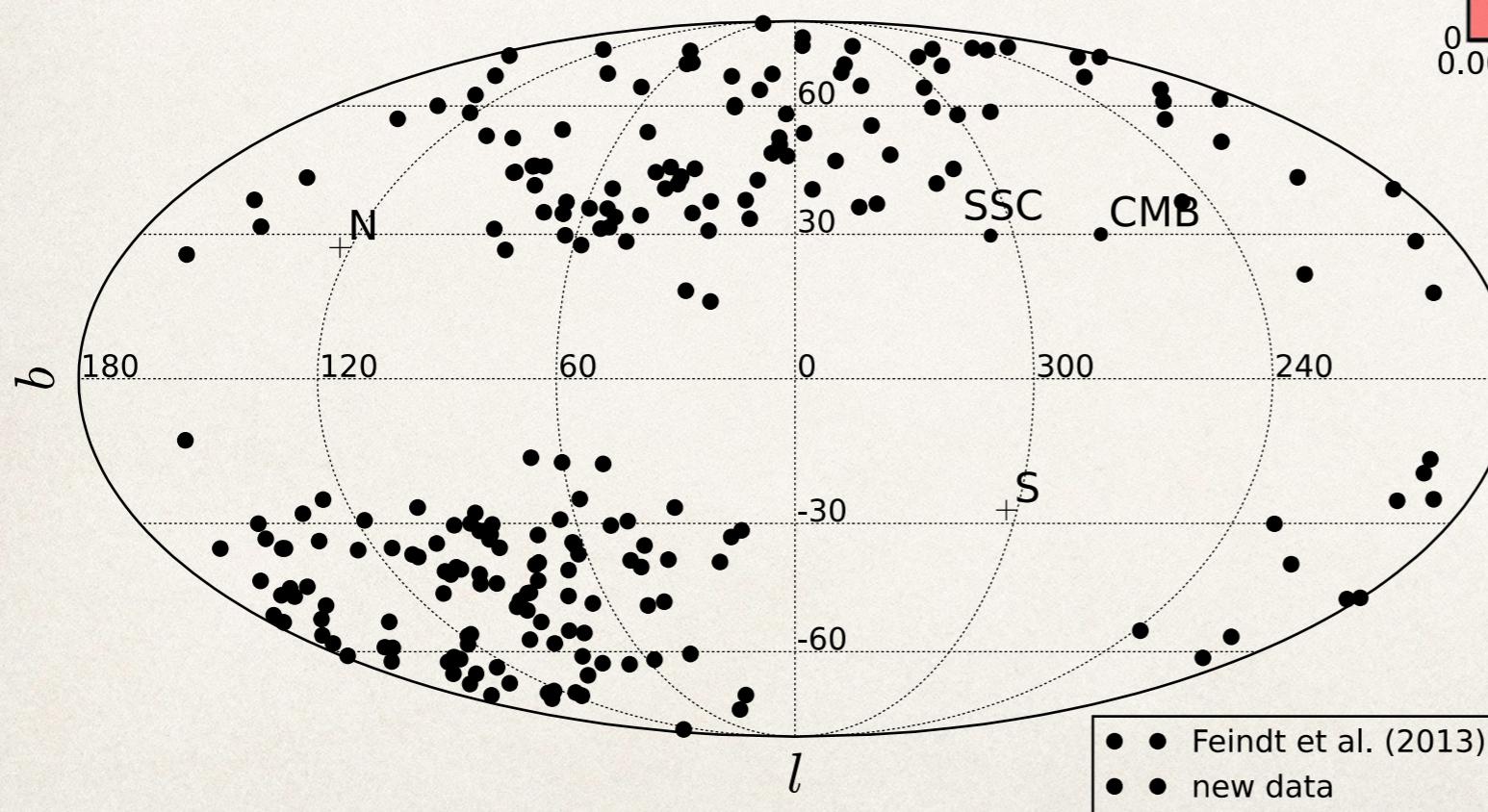
## Spherical attractor model

- Single attractor at location of Shapley supercluster disfavored at  $\sim 2\sigma$
- Sloan Great Wall could provide required additional mass

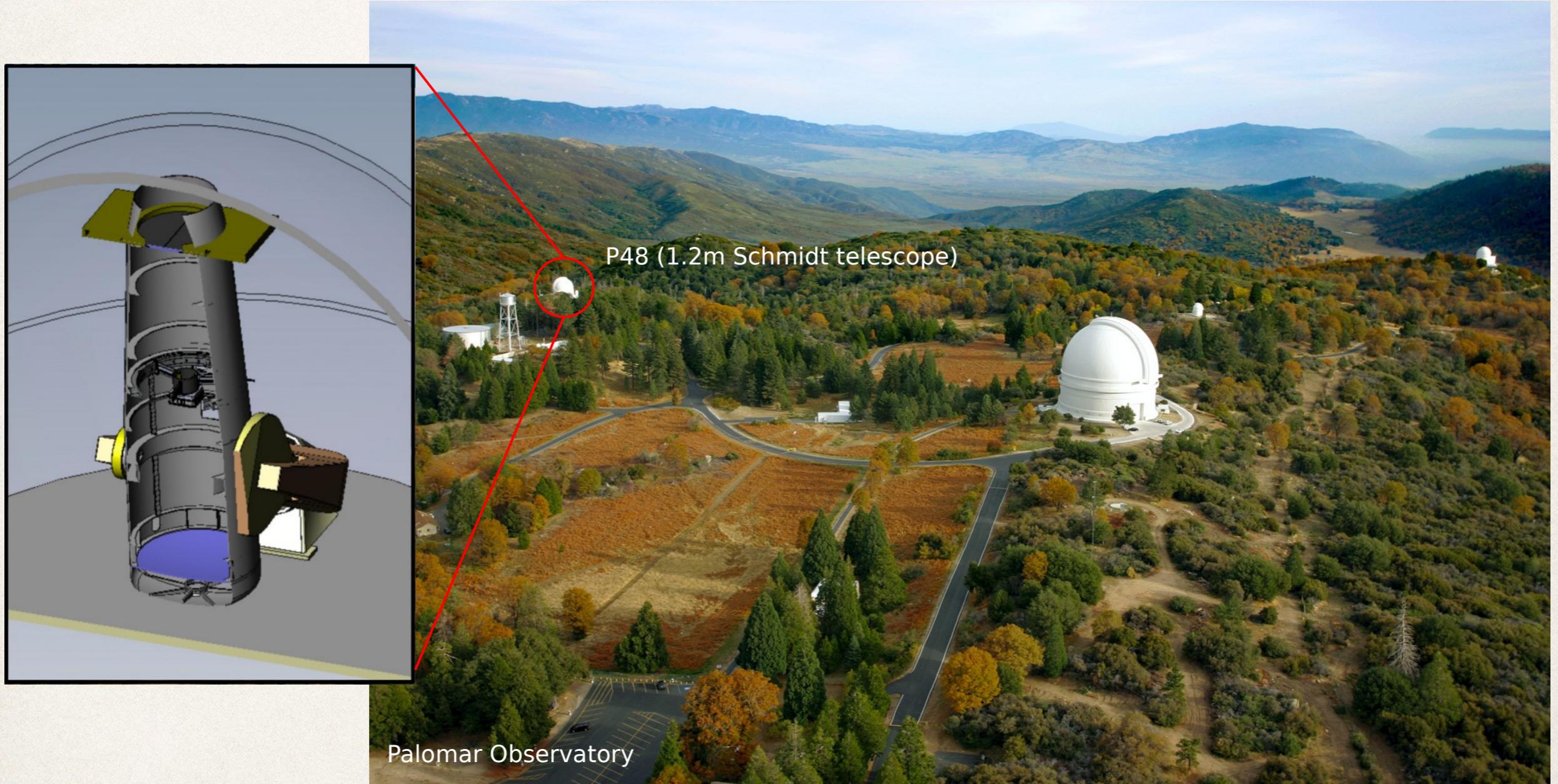
# Outlook: Updated Bulk Flow Study

## New bulk flow study in prep.

- SNfactory sample size doubled
- Based on minimum variance weights  
(Watkins et al. 2009)



# Zwicky Transient Facility





# ZTF Field of View

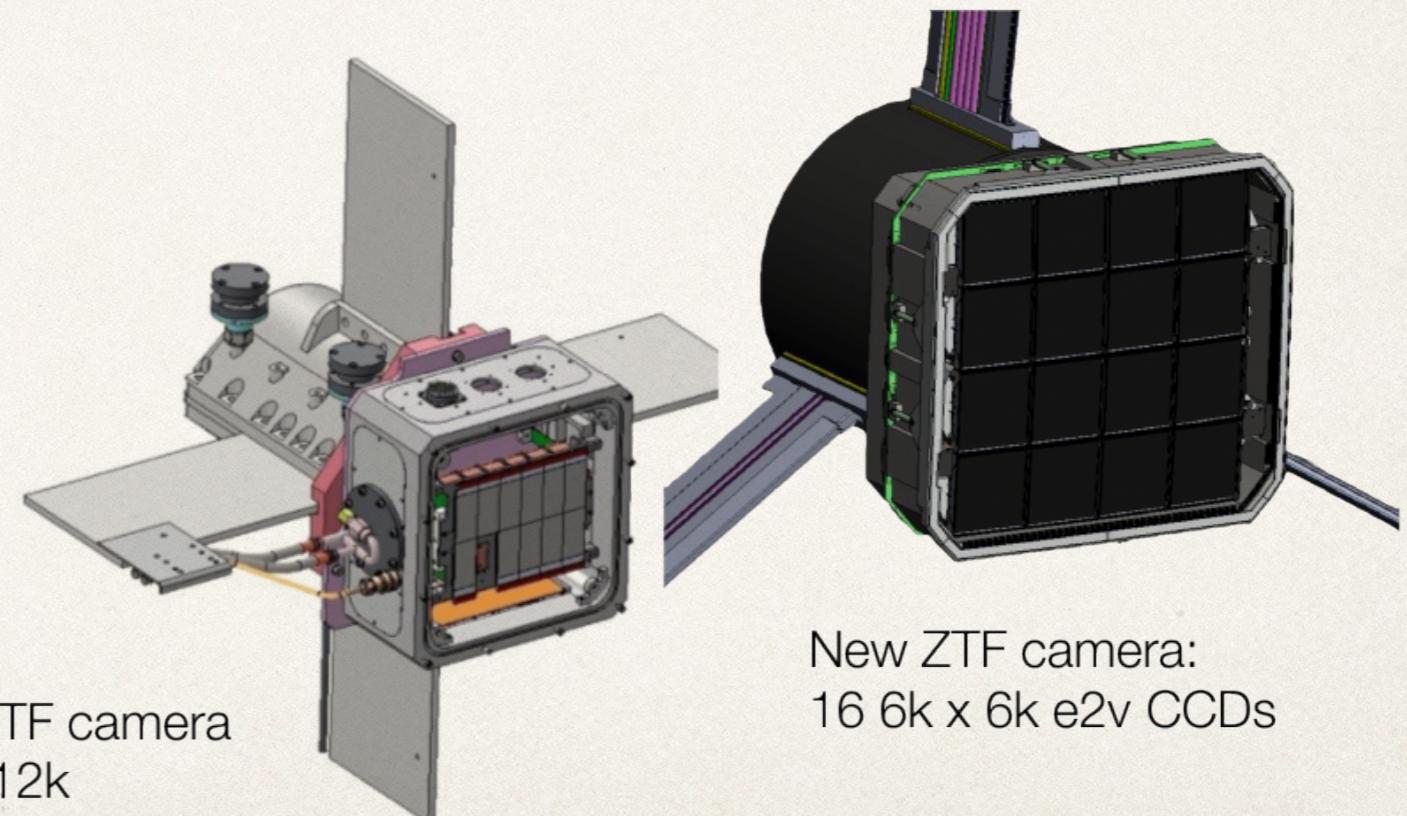


# ZTF camera

	PTF	ZTF
Active Area	7.26 deg <sup>2</sup>	47 deg <sup>2</sup>
Overhead Time	46 sec	<15 sec
Optimal Exposure Time	60 sec	30 sec
Relative Areal Survey Rate	1x	<b>14.7x</b>
Relative Volumetric Survey Rate	1x	<b>12.3x</b>

Survey speed increased by an order of magnitude:

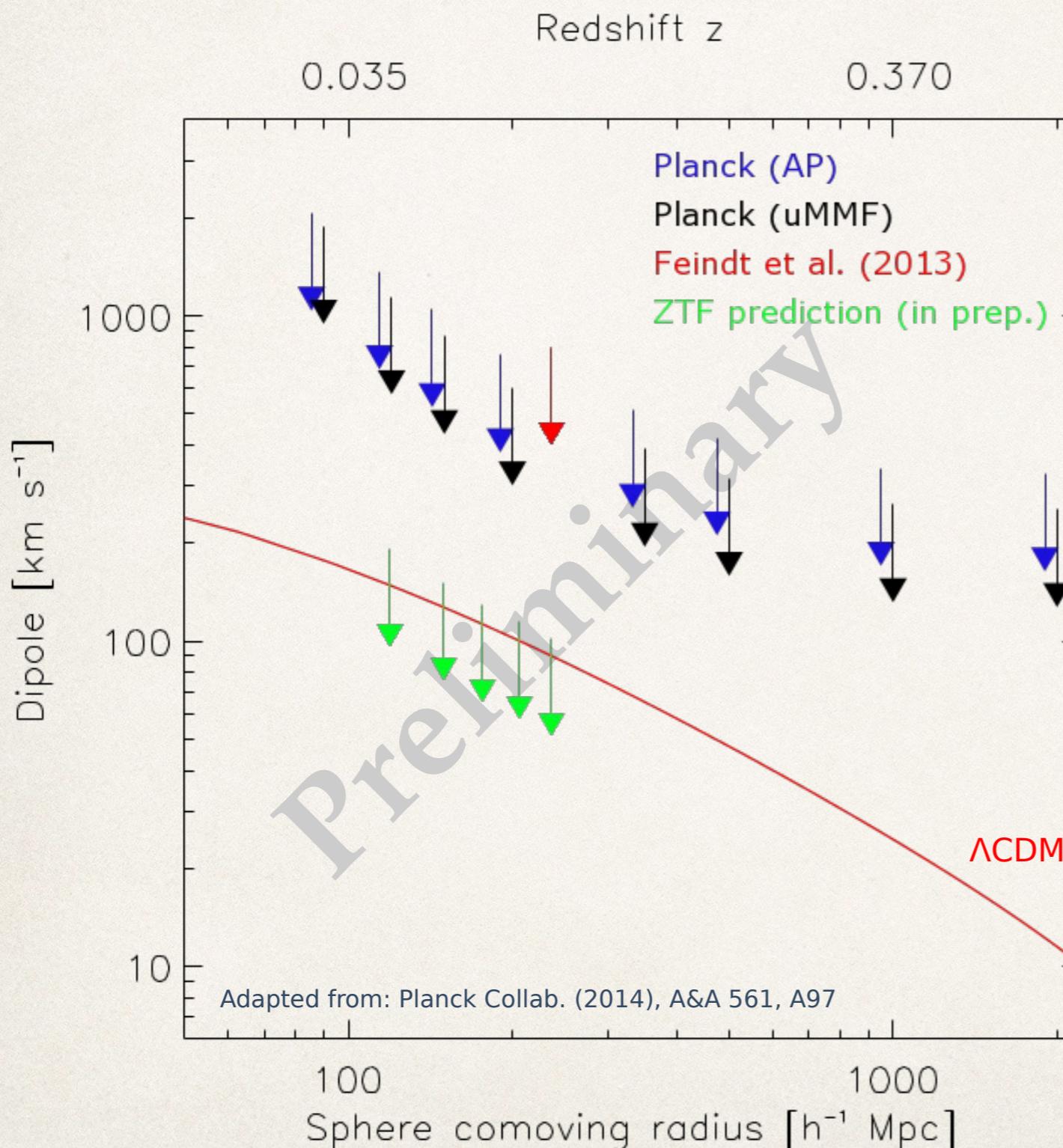
- 3750 deg<sup>2</sup>/hour (3π in 8 hours)
- Observation in g, R and I
- Expecting ~1800 well-sampled multi-color SN Ia lightcurves ( $0.03 < z < 0.08$ )



Existing PTF camera  
MOSAIC 12k

New ZTF camera:  
16 6k x 6k e2v CCDs

# ZTF Bulk Flow Prediction



## Simulation of ZTF-like survey (Feindt et al. in prep.)

- 1800 SNe Ia at Dec.  $> -20^\circ$
- Redshift  $0.03 < z < 0.08$
- Bulk flow/shear fits in spheres up to  $z = 0.08$
- Bulk flow constraints almost at size of  $\Lambda\text{CDM}$  prediction
- Shear constraints require southern data

## Further planned ZTF analysis:

- PV power spectrum;  
growth factor  $f \sigma_8$

# Conclusions

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*The Nearby Supernova Factory* has obtained  
~200 SN Ia time series

Improve SNe Ia  
as standard candles

Correct astrophysical  
biases ( $w, H_0$ )

Measure bulk flows  
out to  $z < 0.1$

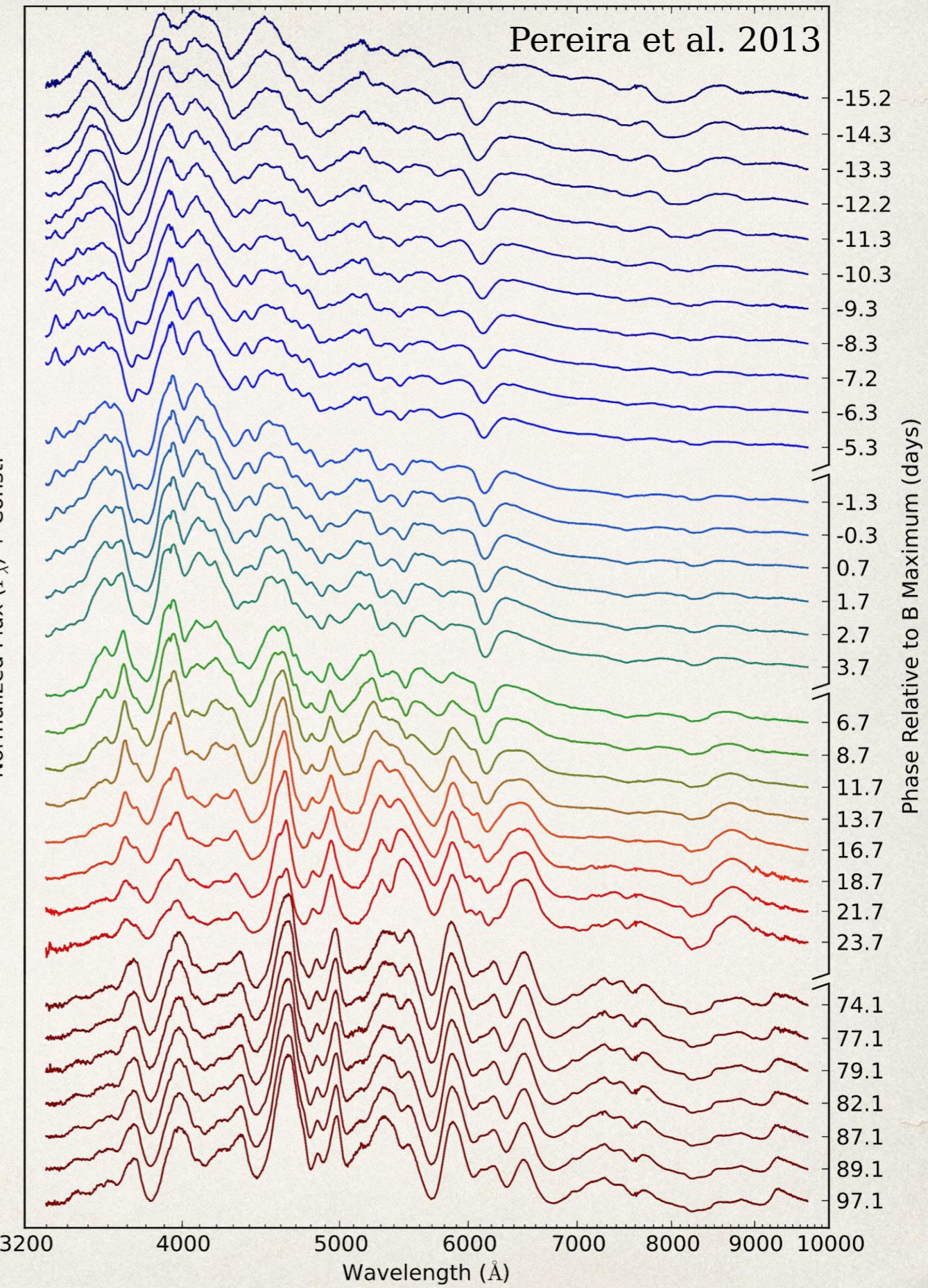
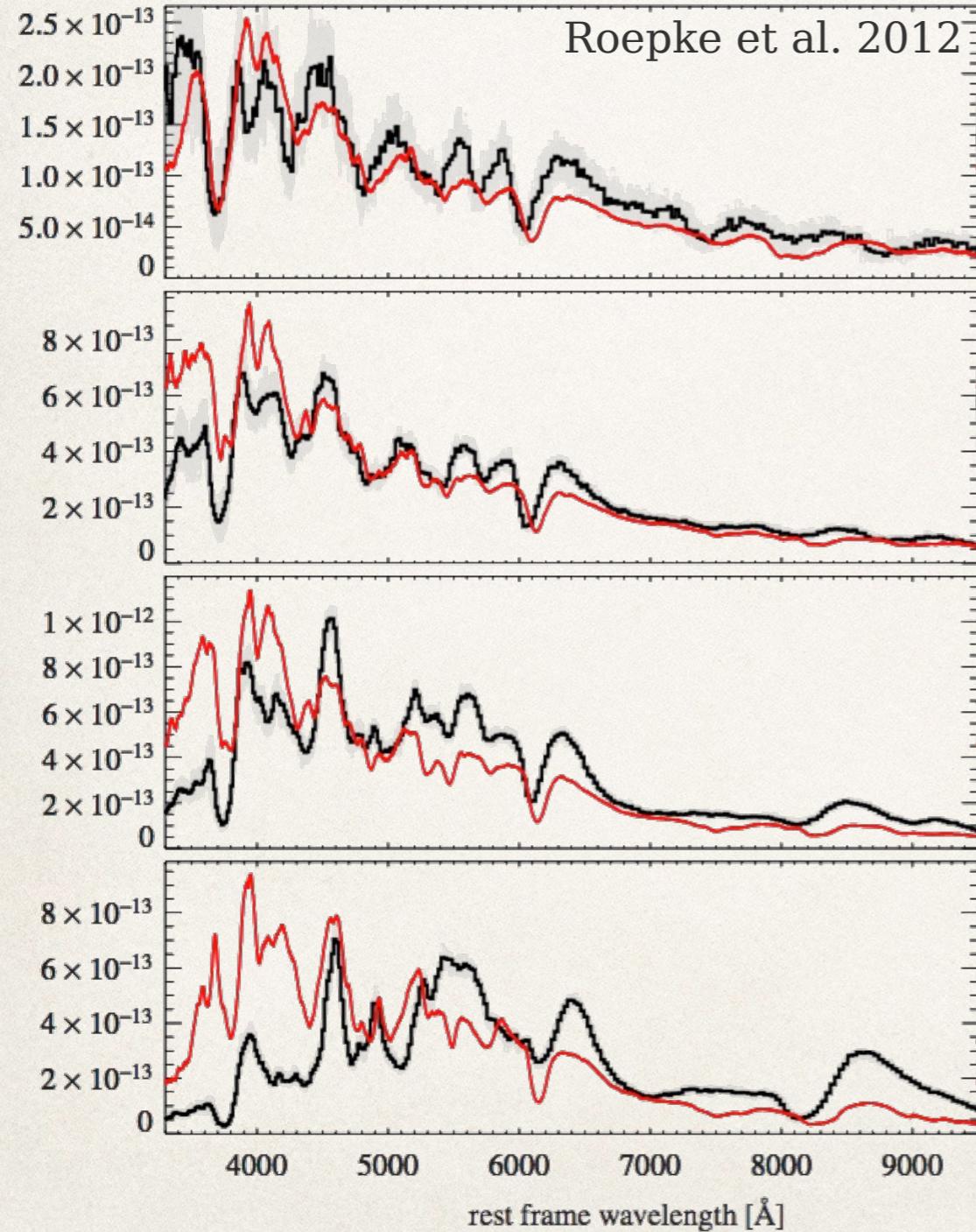
*The Zwicky Transient Facility* will obtain  
~1800 SN Ia lightcurves

Constrain bulk flows at  $z < 0.08$   
at  $< 100 \text{ km s}^{-1}$  precision

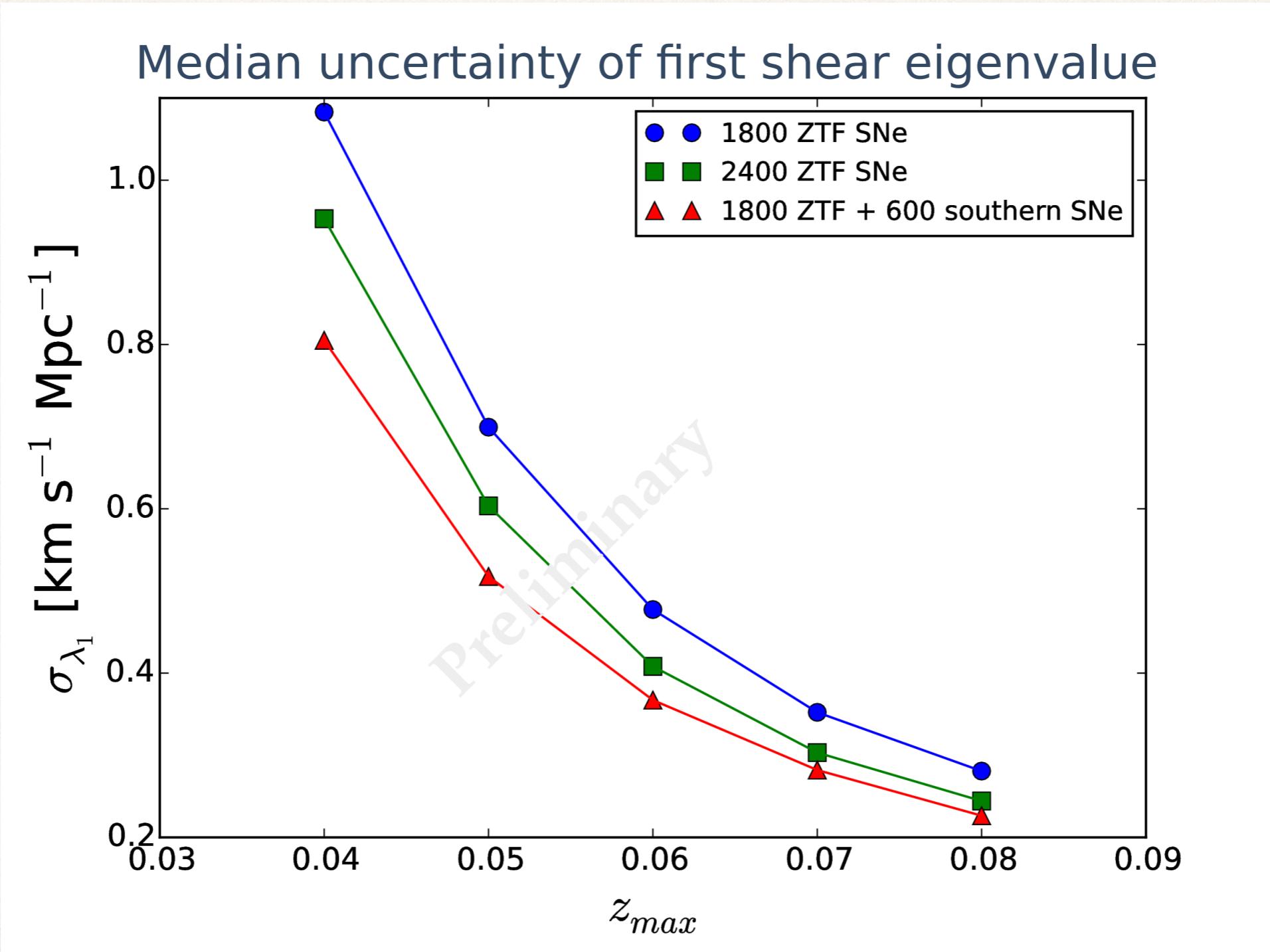
Extend SN Ia PV studies to  
shear, growth factor etc.

# SNfactory

Understand the SN Ia  
progenitor(s) (*simulations*)

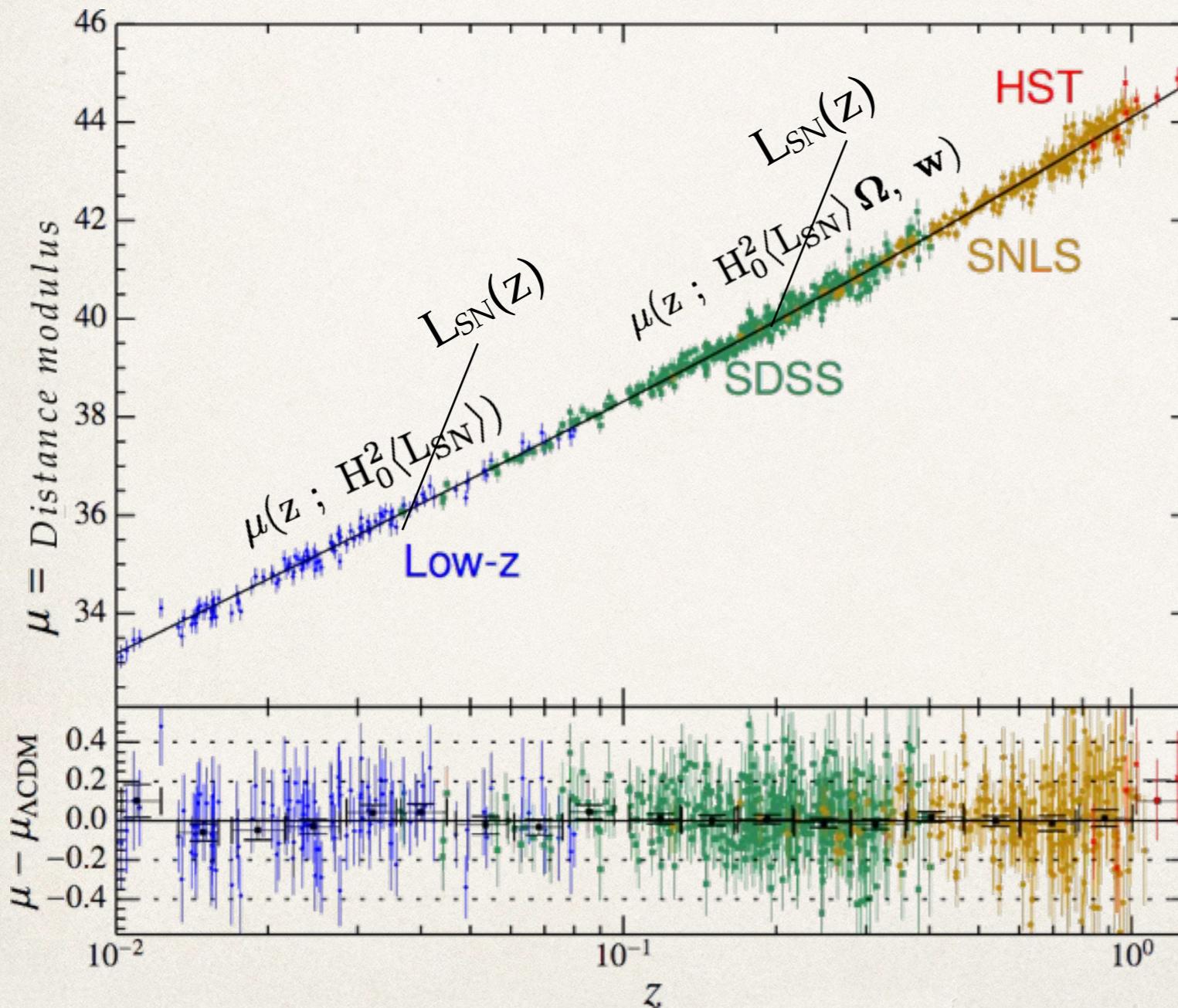
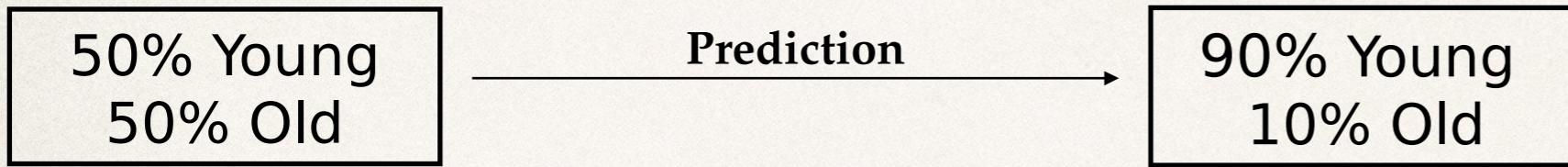


# ZTF Shear Prediction



# Correct Astrophysics for Accurate Cosmology ( $w$ )

Rigault et al. (2013)



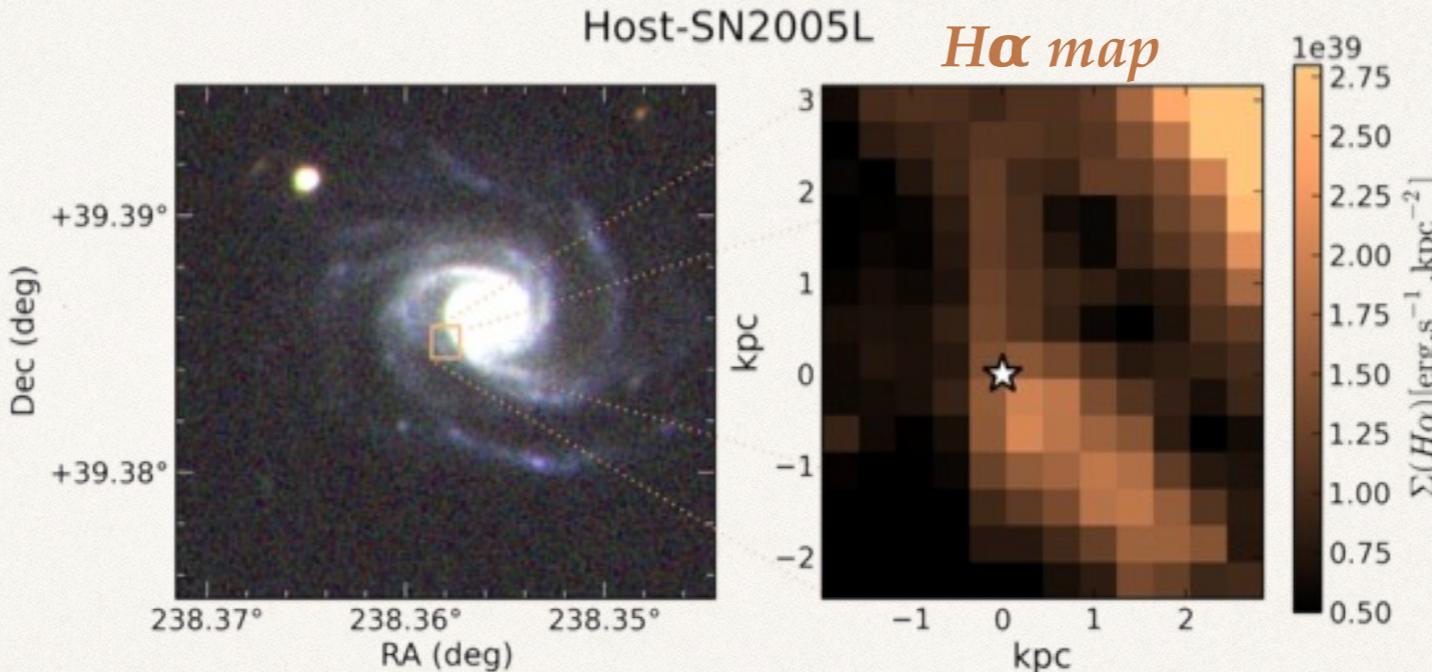
*Galaxies are more Star Forming at Higher Redshift*

Could impact  $w$  by a few %

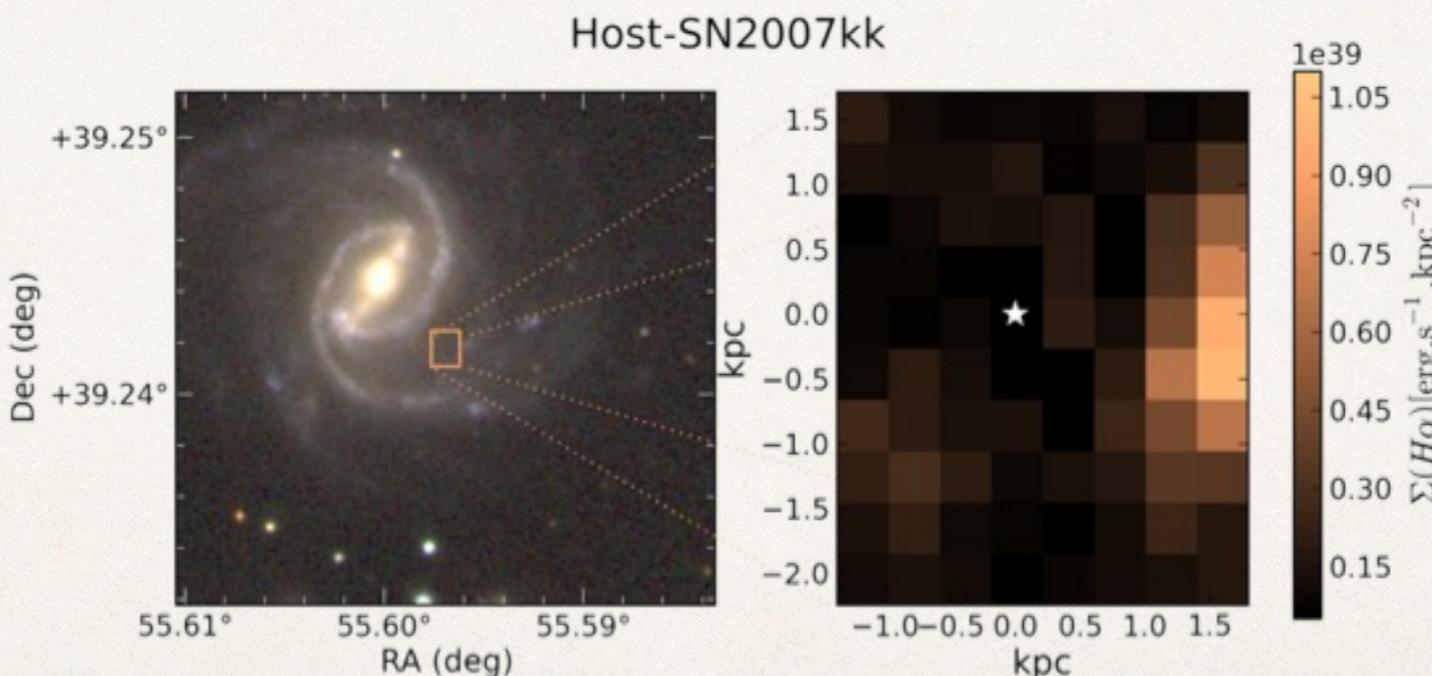
# The Local Perspective

Rigault et al. (2013)

Global



Spiral, Star forming  
Galaxies



Locale

Star forming  
Environments

Young stars

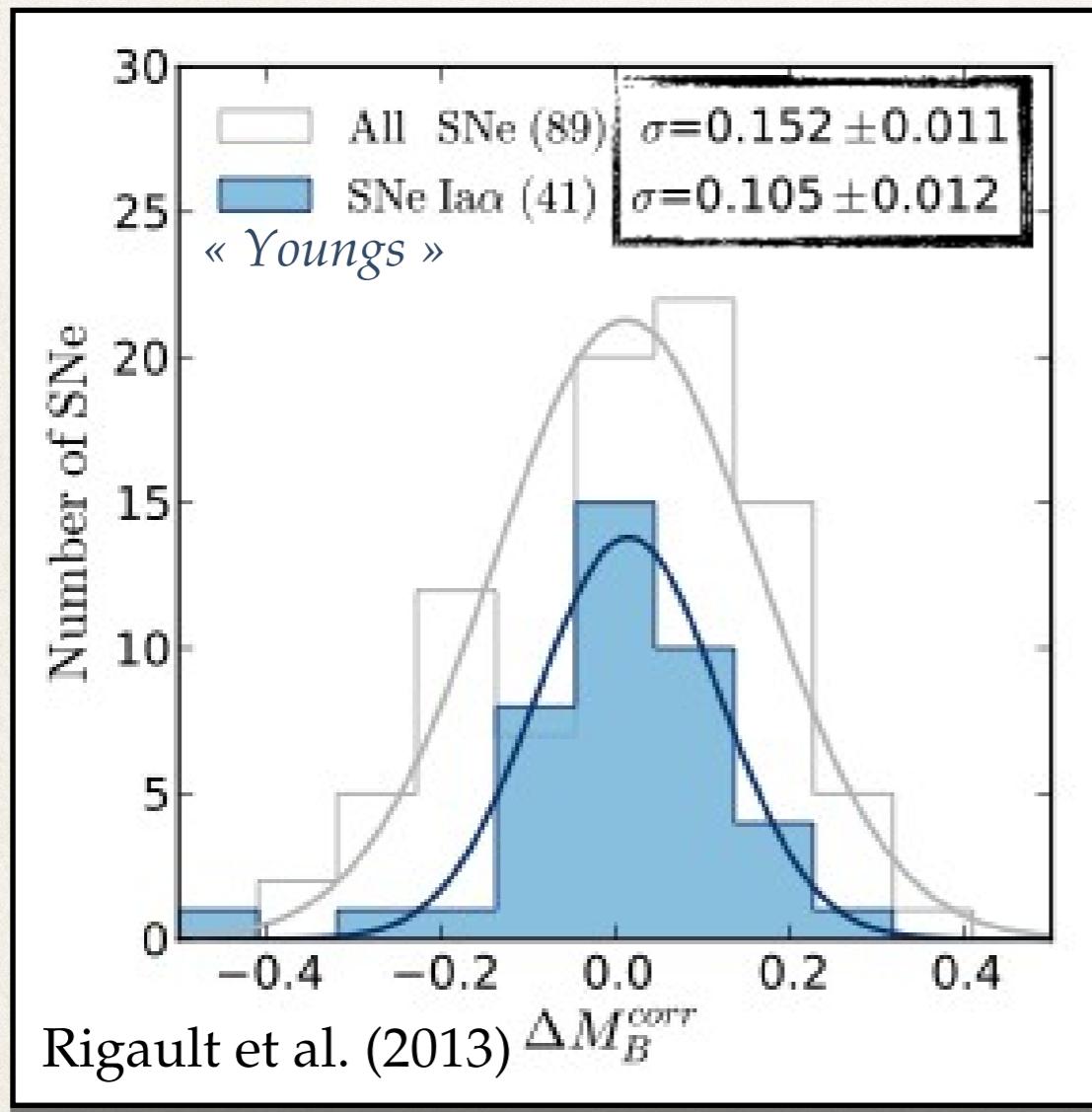
Passive  
Environments

Old(er) stars

# Correct Astrophysics for Accurate Cosmology

## Access Better Standard Candles

– Confirmed par Kelly et al. (2014) –



Strong Reduction of the Systematic Uncertainties