



# SNe II cosmology: A bright future

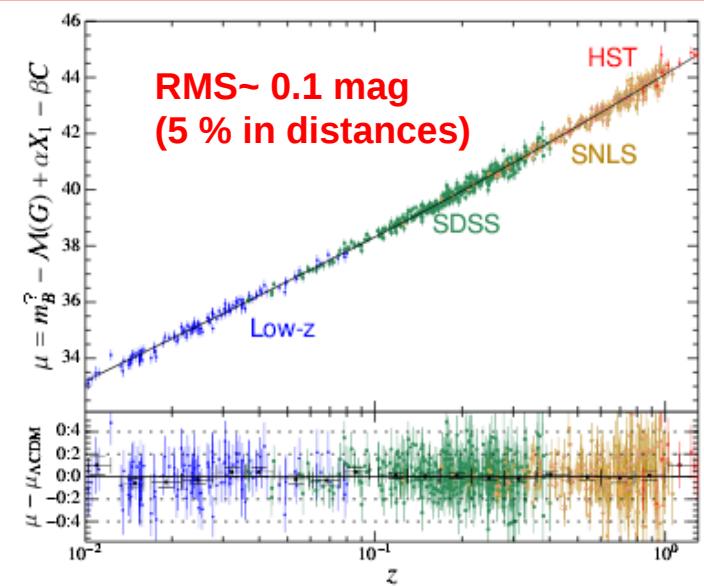


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EWASS 2018  
Liverpool, UK

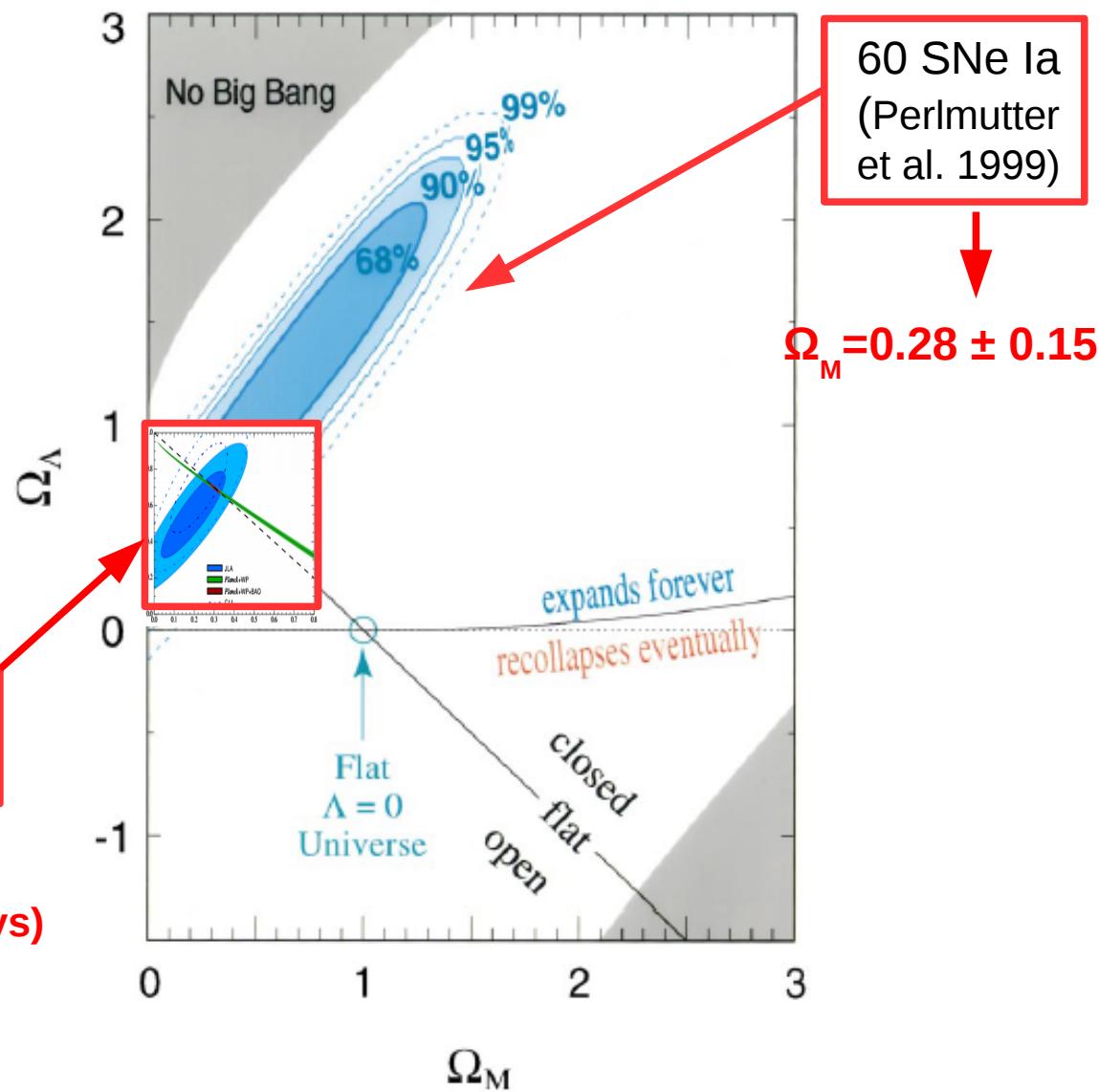
# Improvement in precision since 1998 !!

Riess et al. 1998



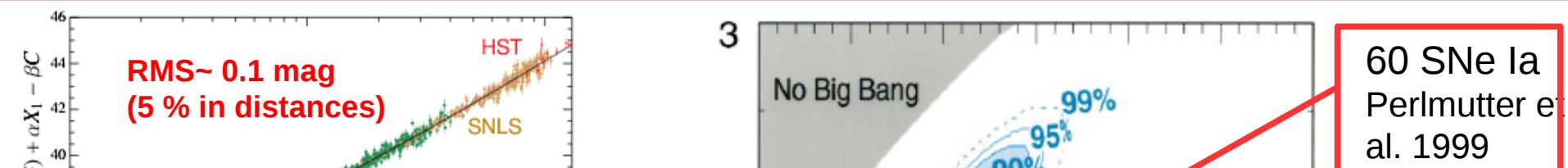
740 SNe Ia  
(Betoule et al. 2014)

$\Omega_M = 0.295 \pm 0.034$  (stats+sys)



# Improvement in precision since 1998 !!

Riess et al. 1998

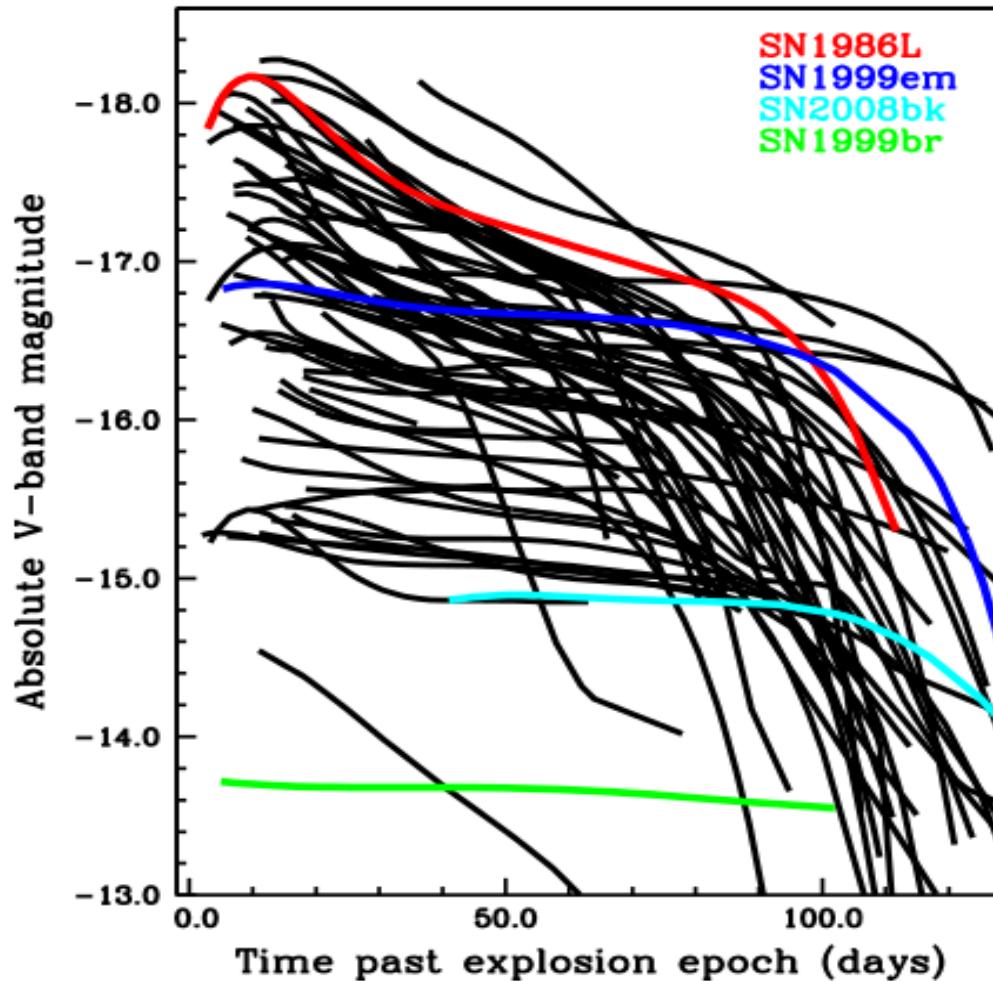


Even though SNe Ia remain the most mature and well-exploited method measuring the acceleration, further improvement to constrain the nature of dark energy requires developing as many independent methods as possible.

- **CMB** (Fixsen et al. 1996; Jaffe et al. 2001; Spergel et al. 2007; Bennett et al. 2003; Planck Collaboration et al. 2013)
- **BAO** (Blake & Glazebrook 2003; Seo & Eisenstein 2003)
- **X-ray clusters** (White et al. 1993; Schuecker et al. 2003)
- **SLSNe / SNell** (Inserra & Smartt 2014, Hamuy & Pinto et al. 2002)

Cosimo's talk !!

# Are Type II standard candles ?



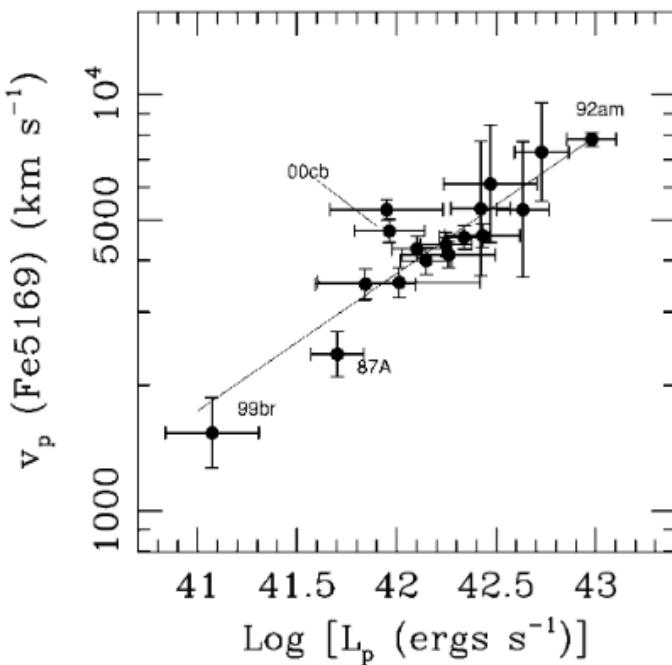
# SNe II are standardisable!!! (SCM)

Cosmology with SNe II: Two variables correlated to the intrinsic luminosity

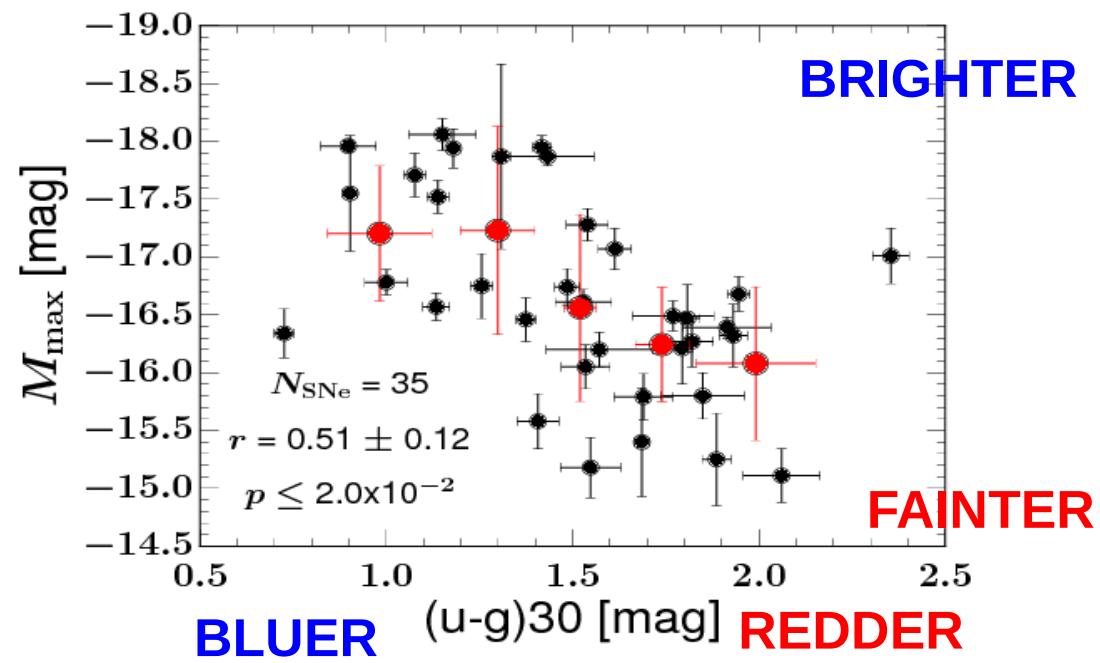
Expansion velocities of the ejecta:

More luminous SN have faster ejecta

Colour: Brighter SN are bluer  
(~ to SNe Ia) → Nugent et al. 06

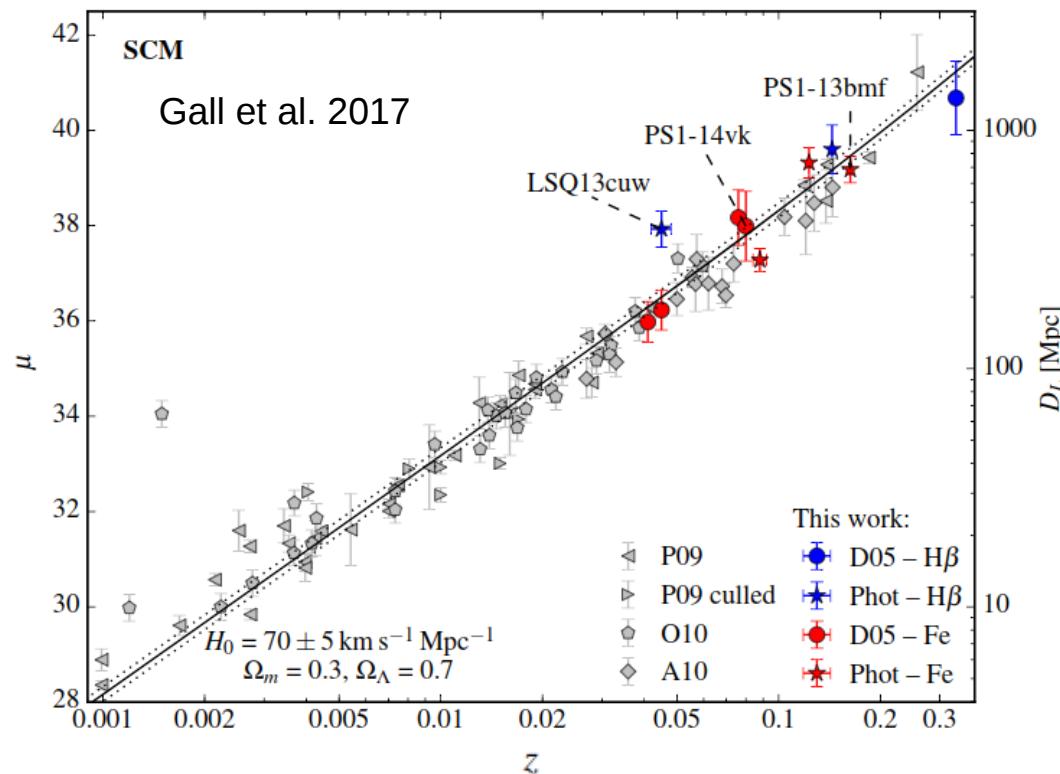
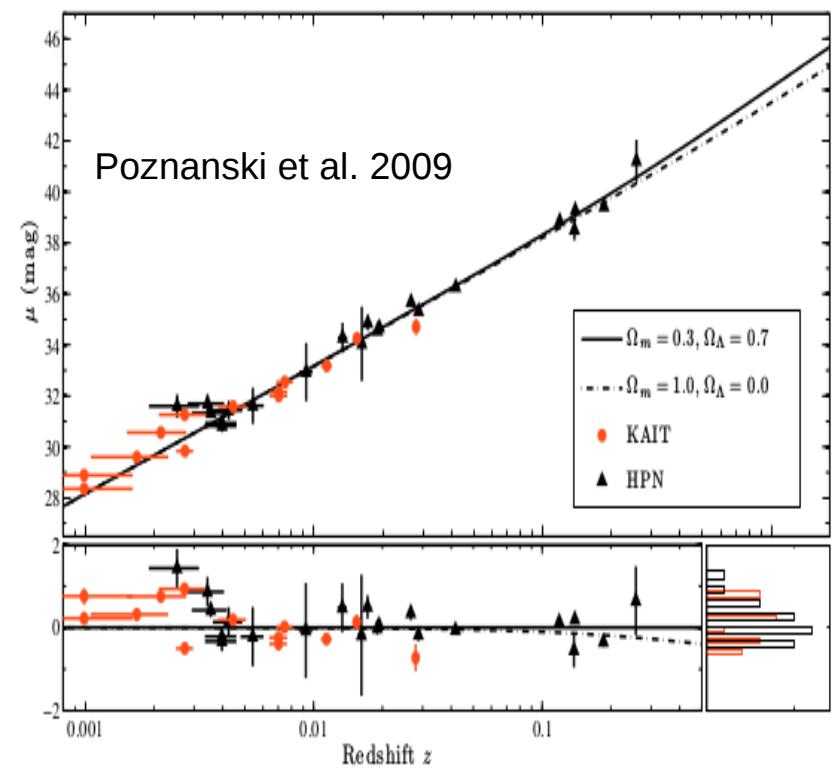


Hamuy & Pinto 2002



de Jaeger et al. 18

# Standard Candle Method



scatter~ 0.25-0.3 mag  
(10-14 % in distances)

Hamuy & Pinto 02  
Poznanski et al. 09/10  
Olivares et al. 10  
Emilio Enriquez et al. 14  
de Jaeger et al. 15a  
de Jaeger et al. 17a

Nugent et al. 06  
D'Andrea et al. 10  
Maguire et al. 10  
Rodríguez et al. 14  
de Jaeger et al. 15b  
Gall et al. 17

# Data (CSP-I)

- Data from CSP-I (Hamuy et al 06) :

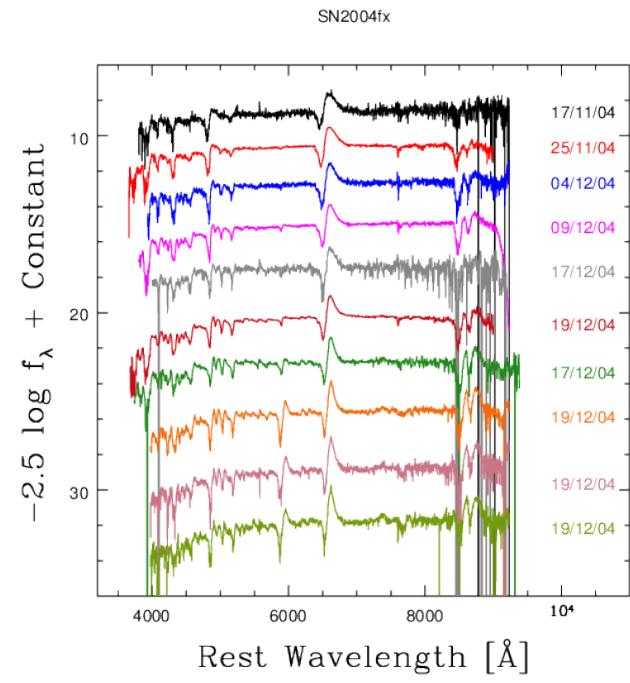
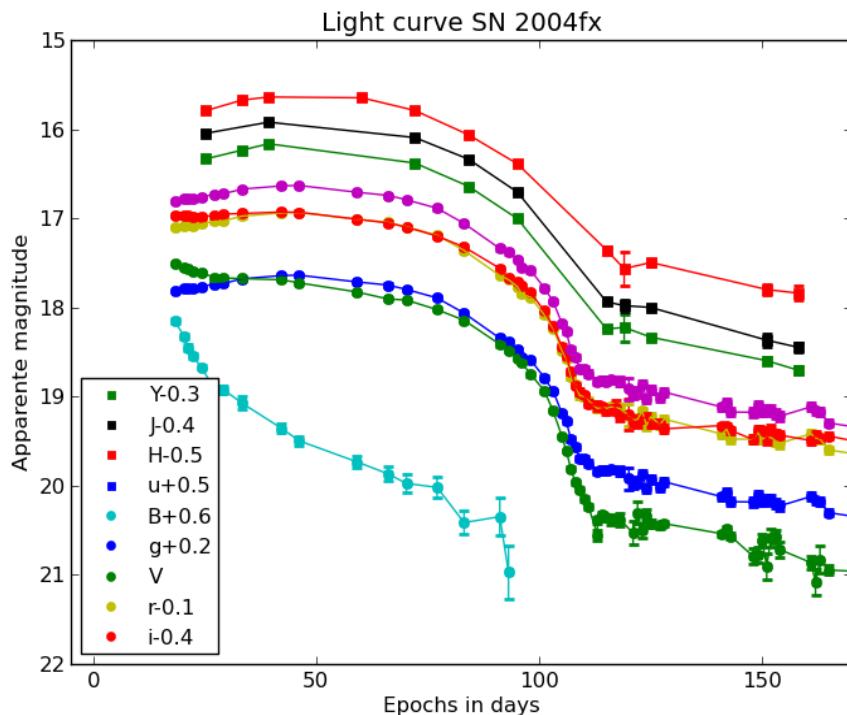
→ 2004 → 2009  
( $0.01 < z < 0.05$ )

→ 61 SNeI



Dupont telescope

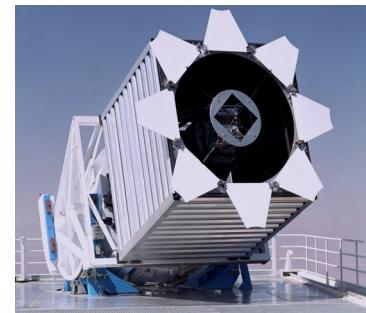
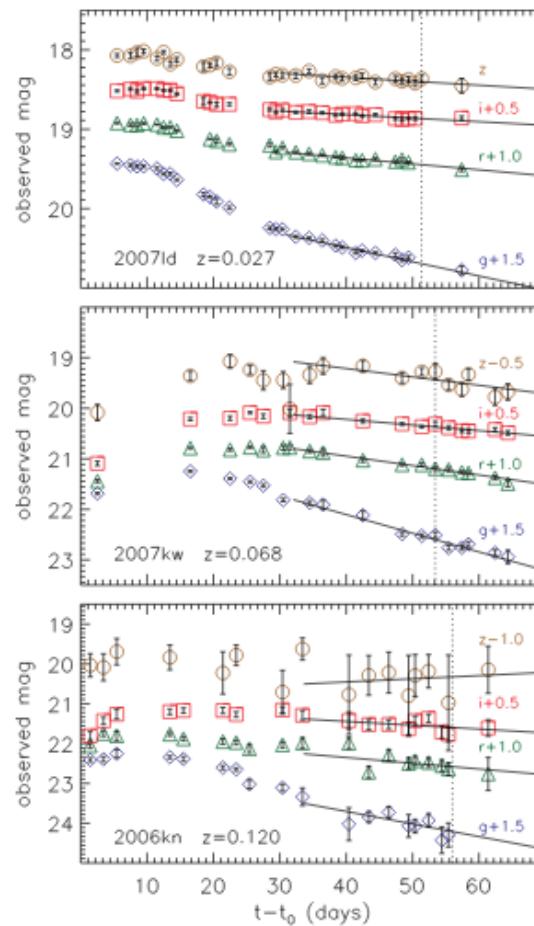
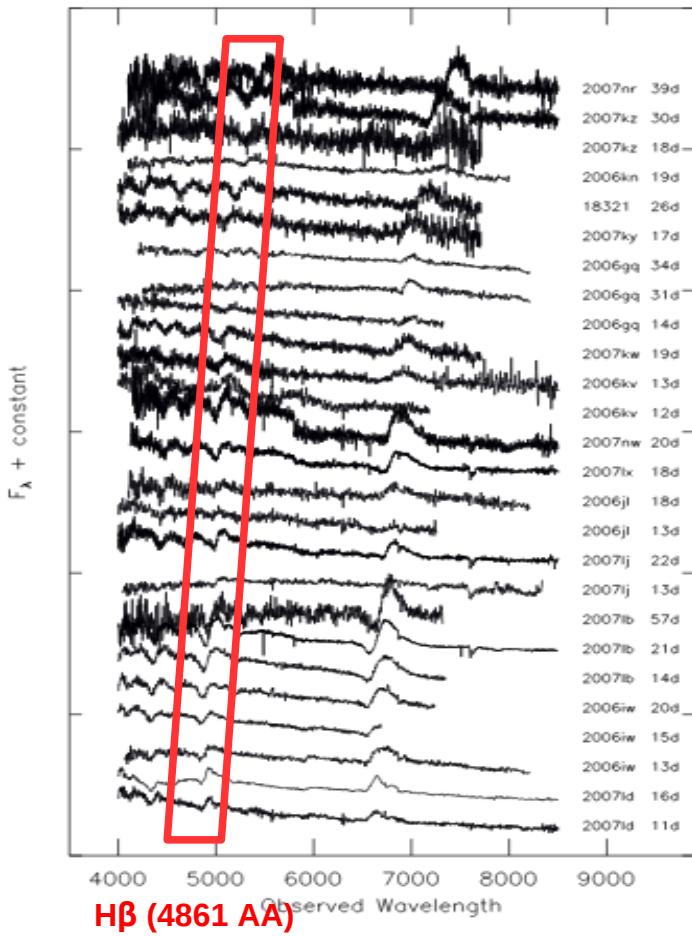
Swope telescope



# Data (SDSS-II)

- Sloan Digital Sky Survey-II (Frieman et al. 08):

→ **16 SNe II** with  $0.027 < z < 0.143$  observed in ugri (d'Andrea et al. 2010)

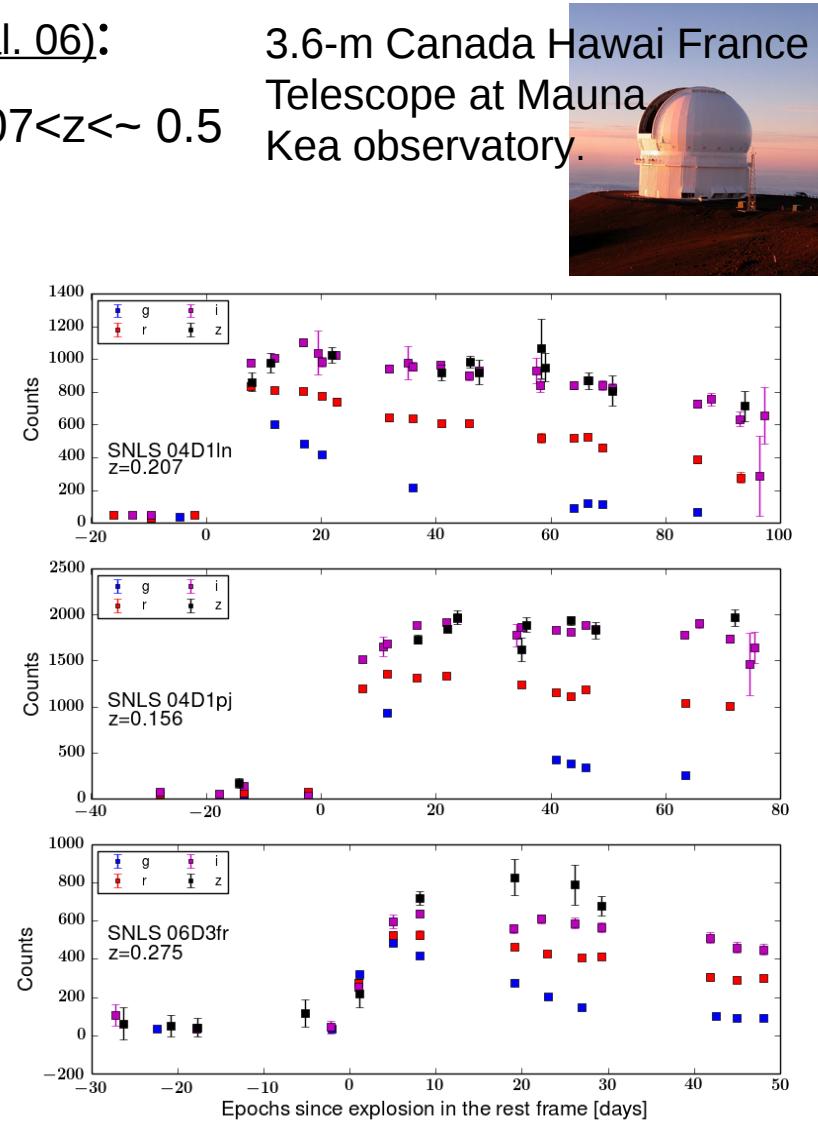
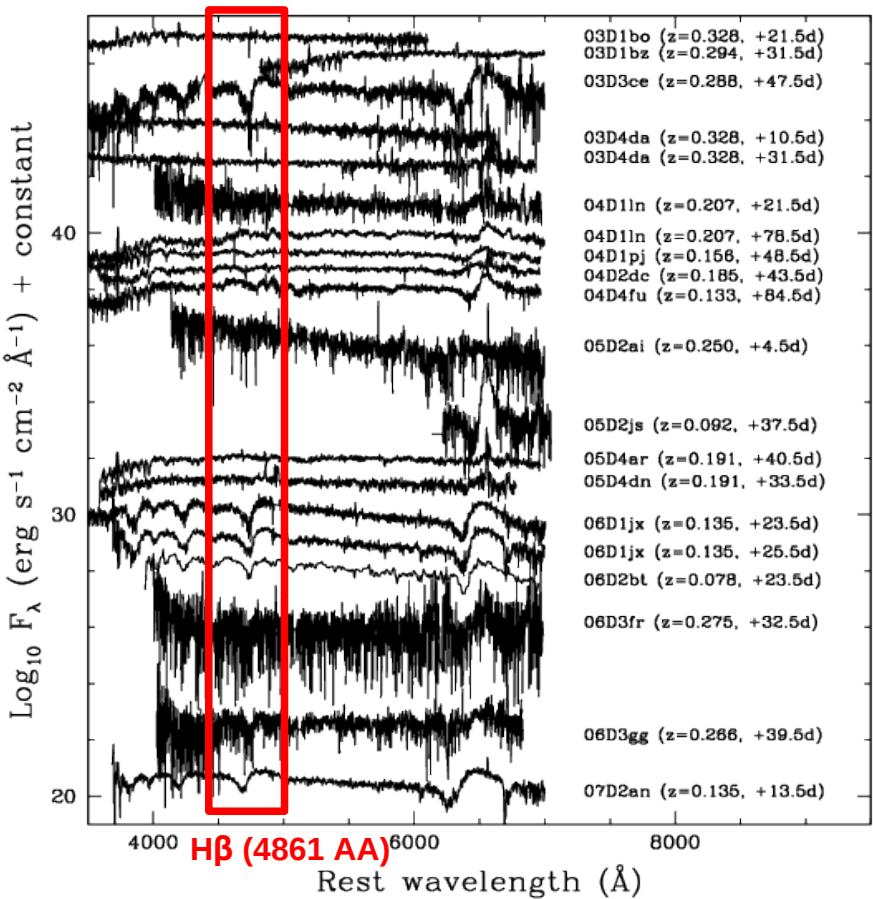


2.5-m telescope  
at Apache Point  
Observatory  
New Mexico

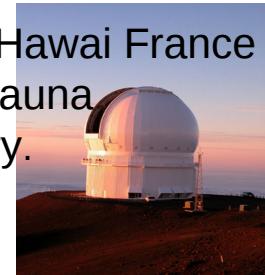
# Data (SNLS)

- SuperNova Legacy Survey (Astier et al. 06):
 

28 SNe II (17 with spectra) with  $0.07 < z < \sim 0.5$   
observed in griz



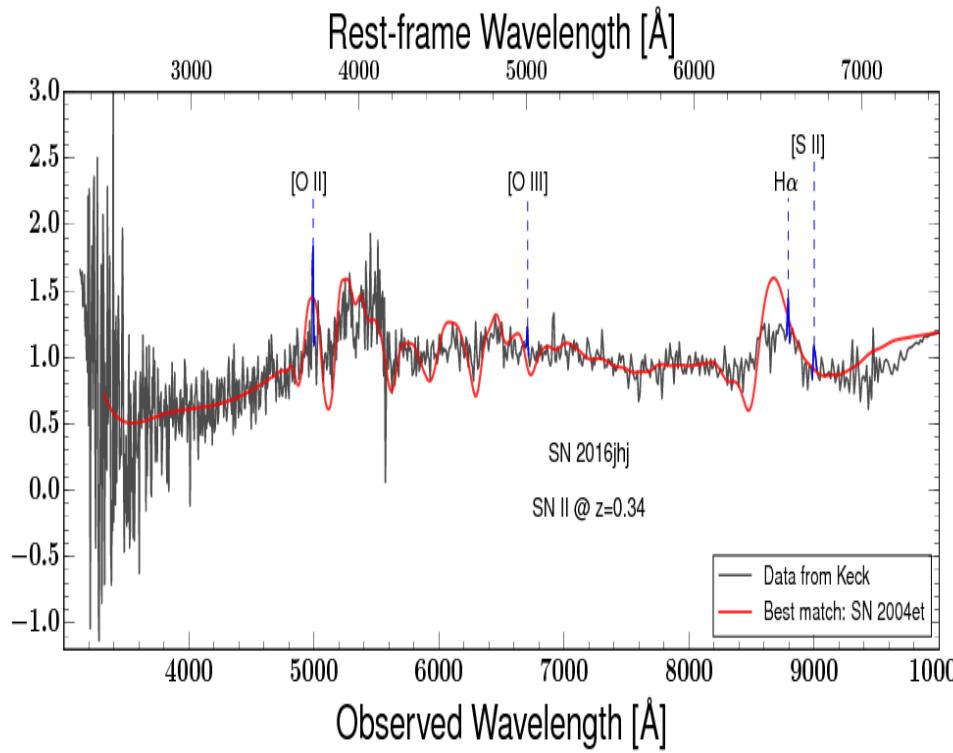
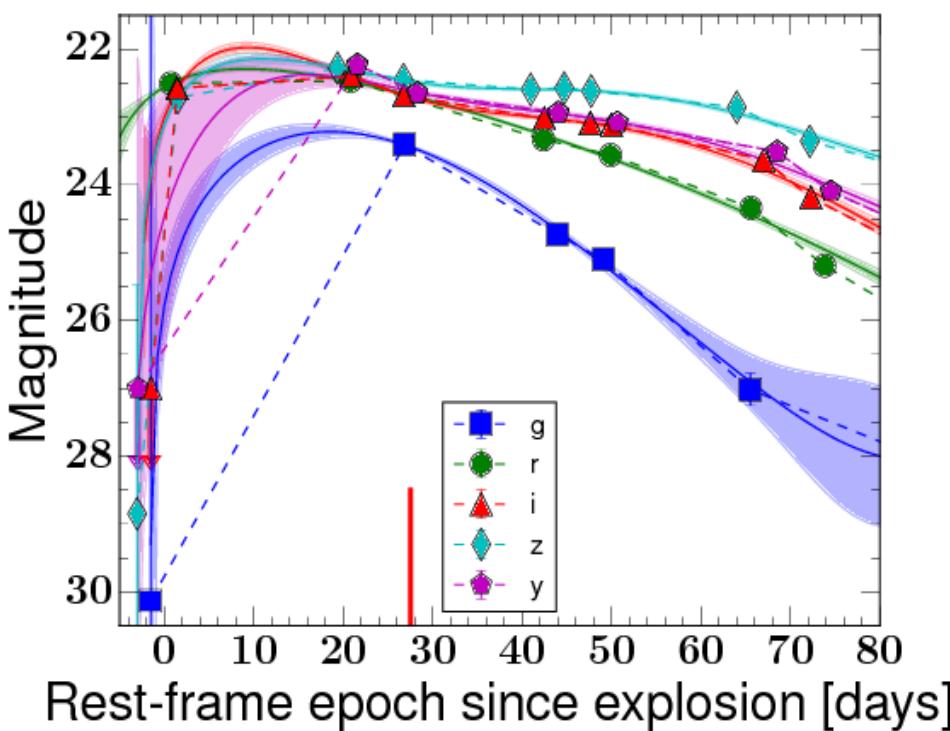
3.6-m Canada Hawaii France  
Telescope at Mauna  
Kea observatory.



# Data (HSC)

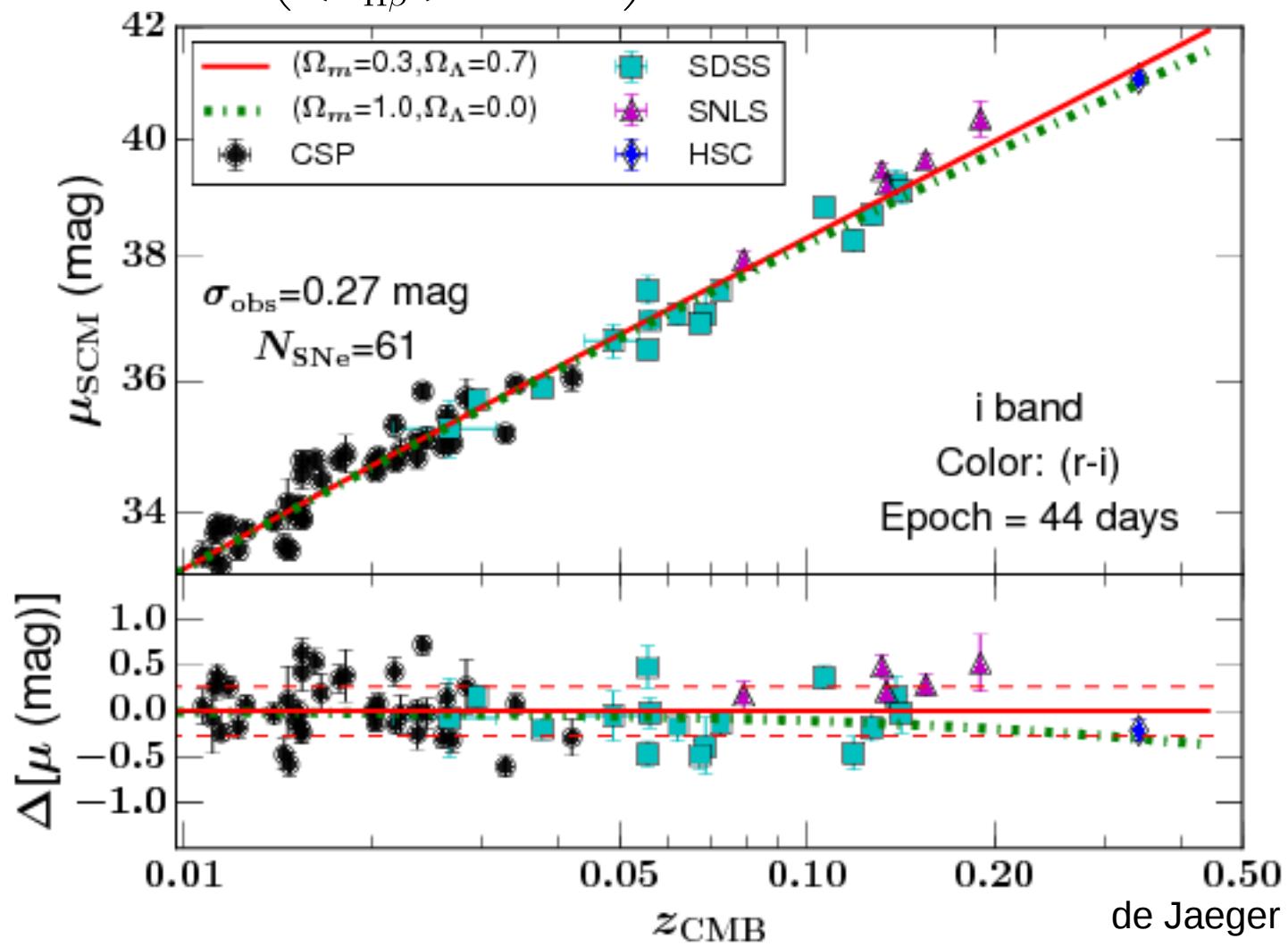
- Subaru/HSC (Miyazaki et al. 12):

→ **1 SN II @  $z=0.34$  !!!**



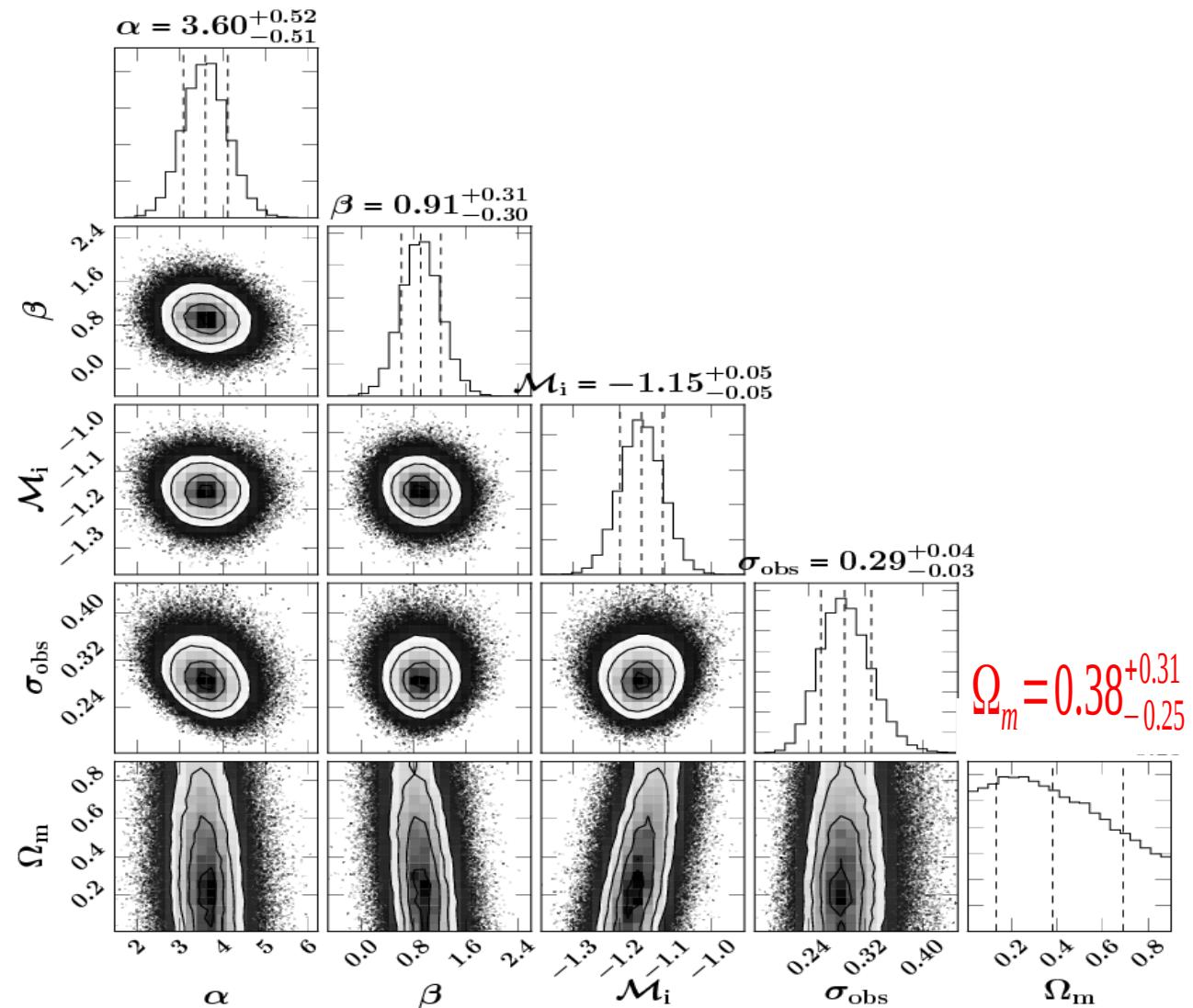
# SCM

$$m_i^{\text{model}} = \mathcal{M}_i - \alpha \log_{10} \left( \frac{v_{\text{H}\beta}}{\langle v_{\text{H}\beta} \rangle \text{ km s}^{-1}} \right) + \beta(r - i) + 5 \log_{10}(\mathcal{D}_L(z_{\text{CMB}} | \Omega_m, \Omega_\Lambda))$$



# SCM

**Assuming a flat  
Universe**  
 $\Omega_m + \Omega_\Lambda = 1$   
 $\Omega_m$  as a free  
parameter

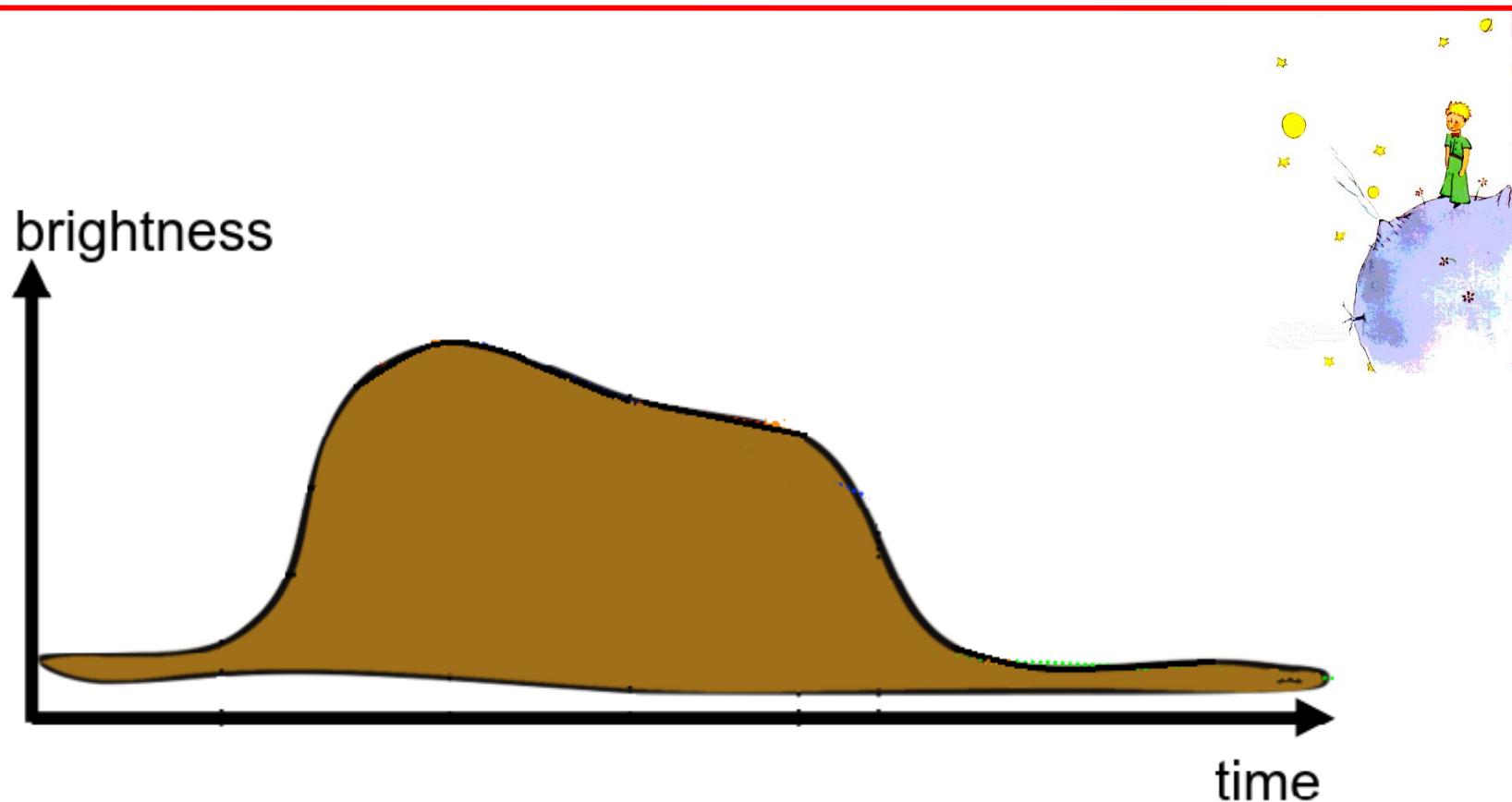




**BUT** If we did not have spectroscopic information?

Can we come up with a method solely based on photometry?

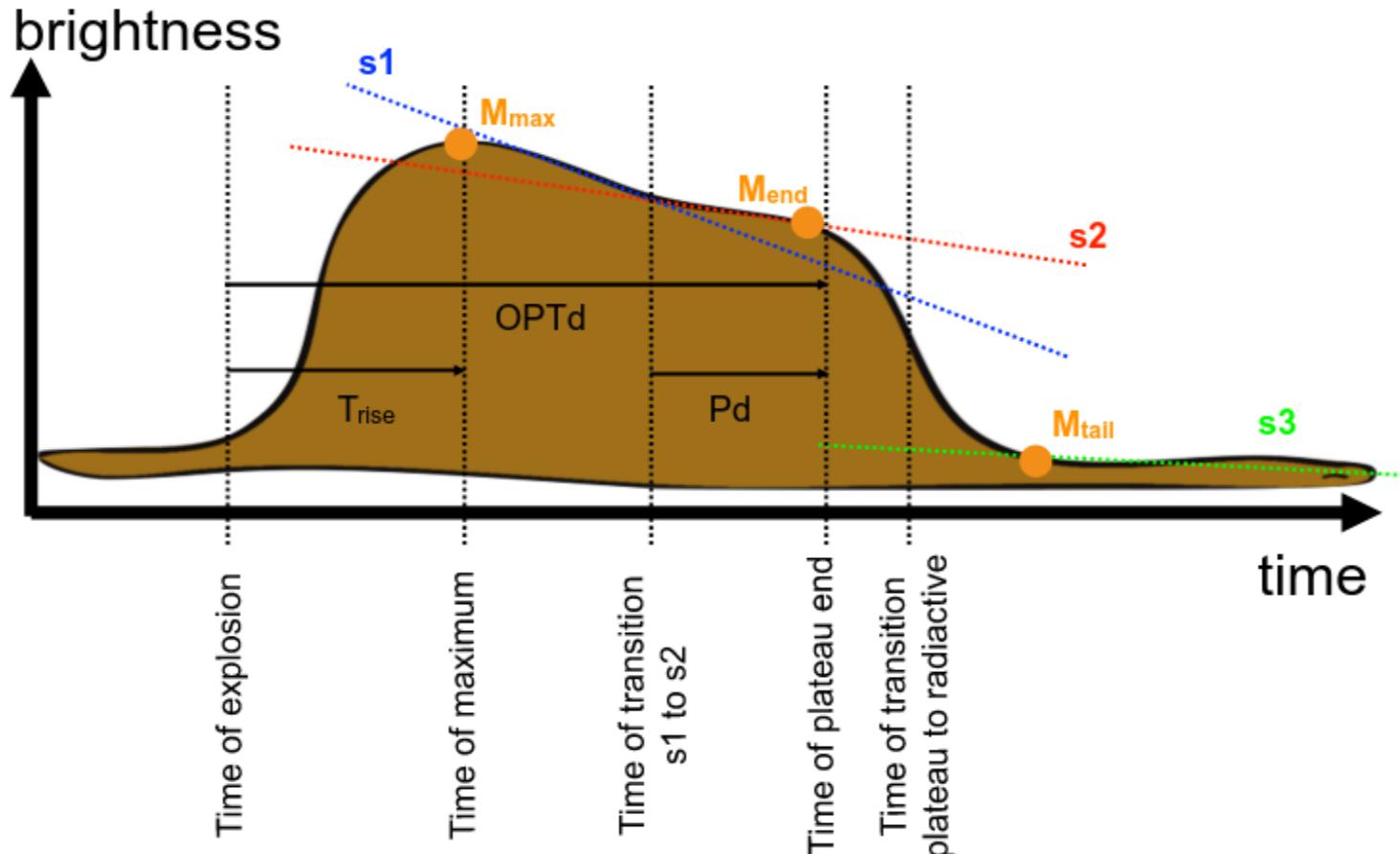
# PCM



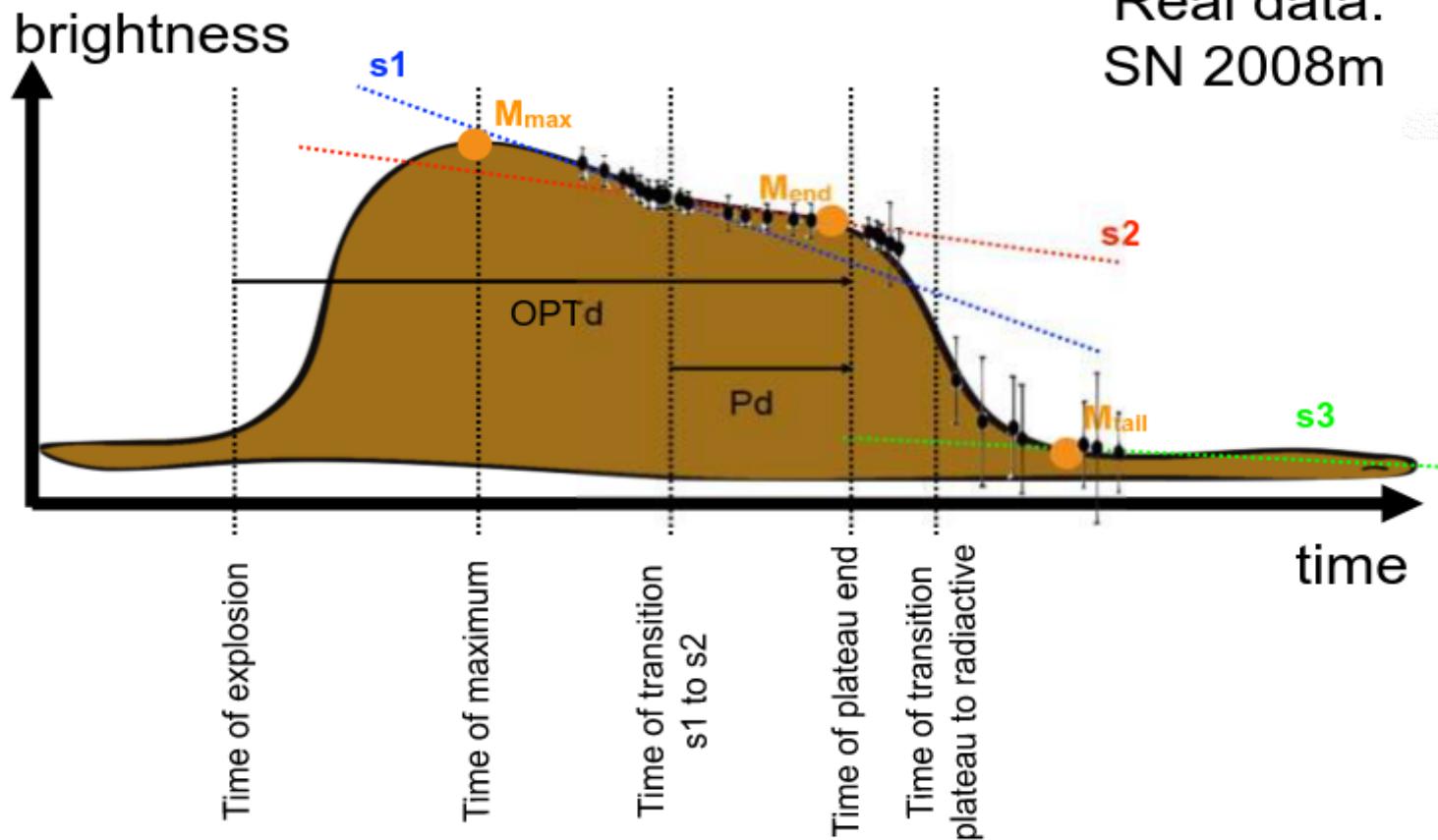
# PCM

Mon dessin ne représentait pas un chapeau. Il représentait une courbe de lumière de supernova de type II.

defined in Anderson et al. 2014

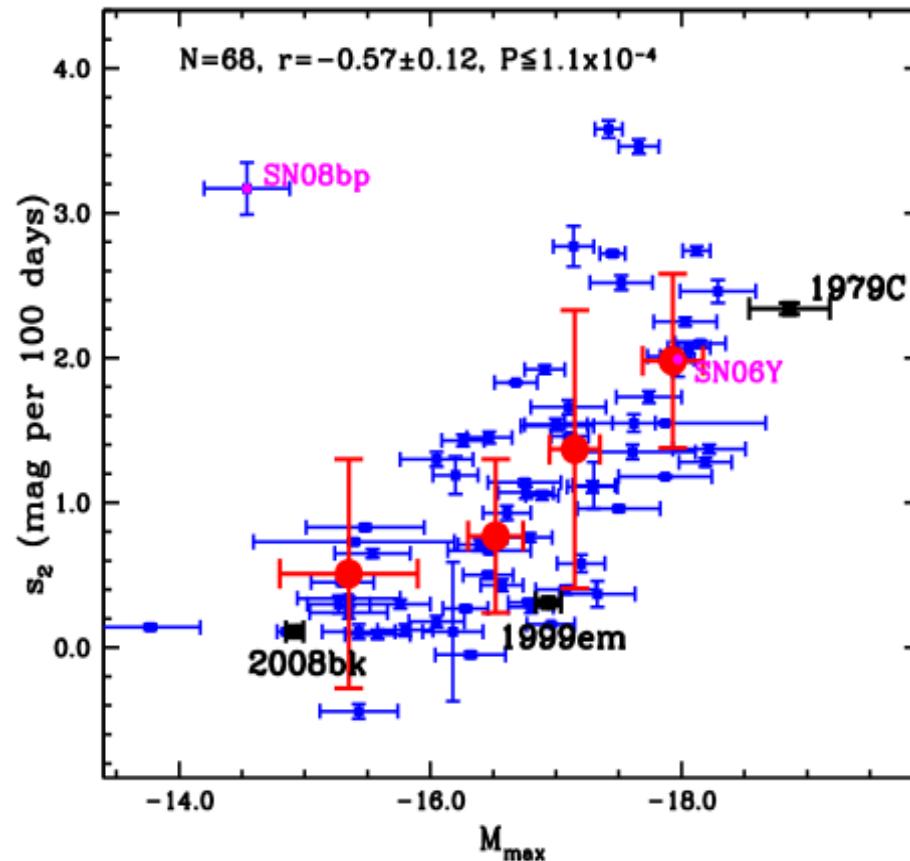


# PCM



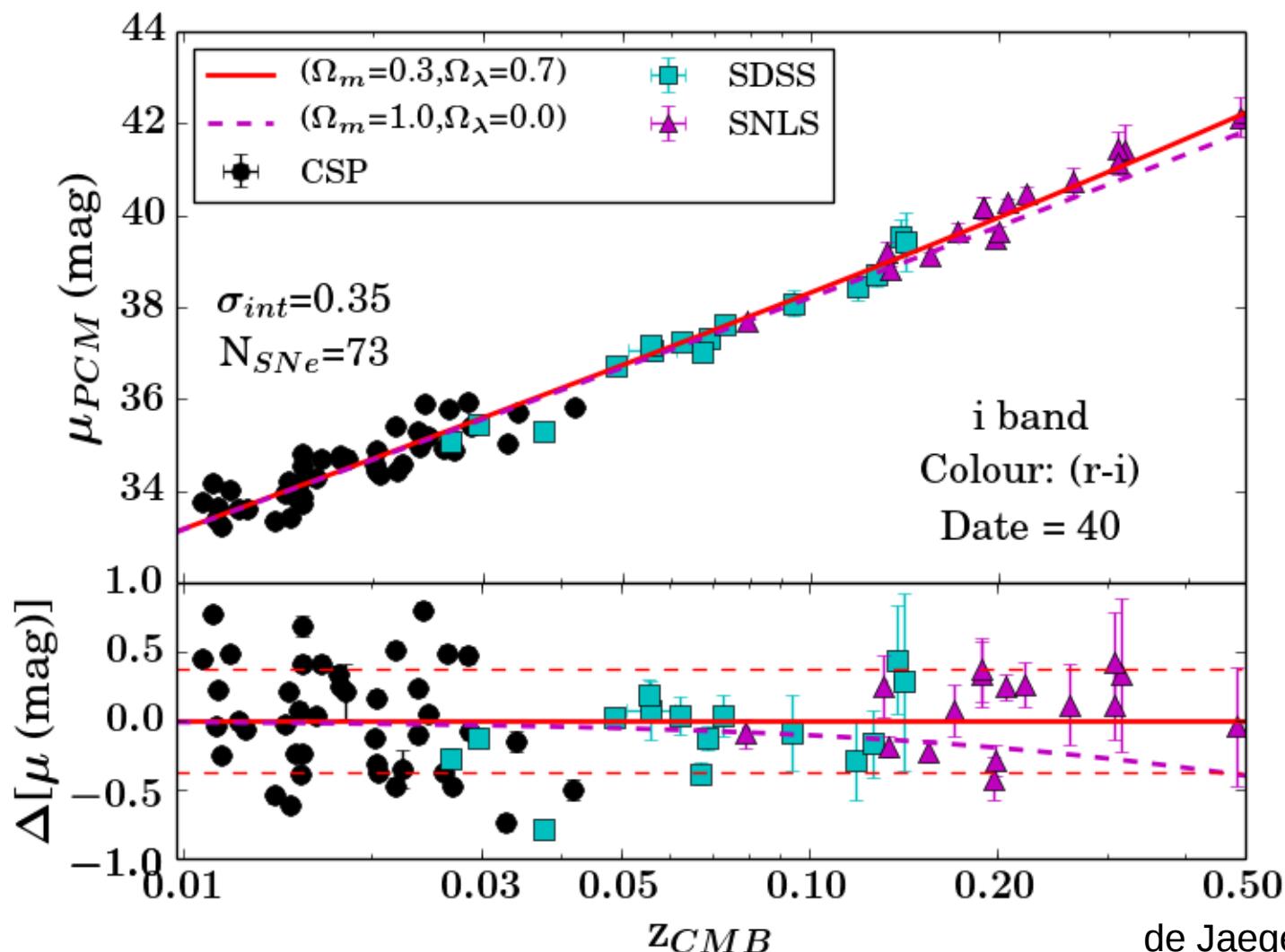
# PCM

$$m_i^{\text{model}} = M_i - \alpha s_2 + \beta(r - i) + 5\log_{10}(\mathcal{D}_L(z_{\text{CMB}} | \Omega_m, \Omega_\Lambda))$$



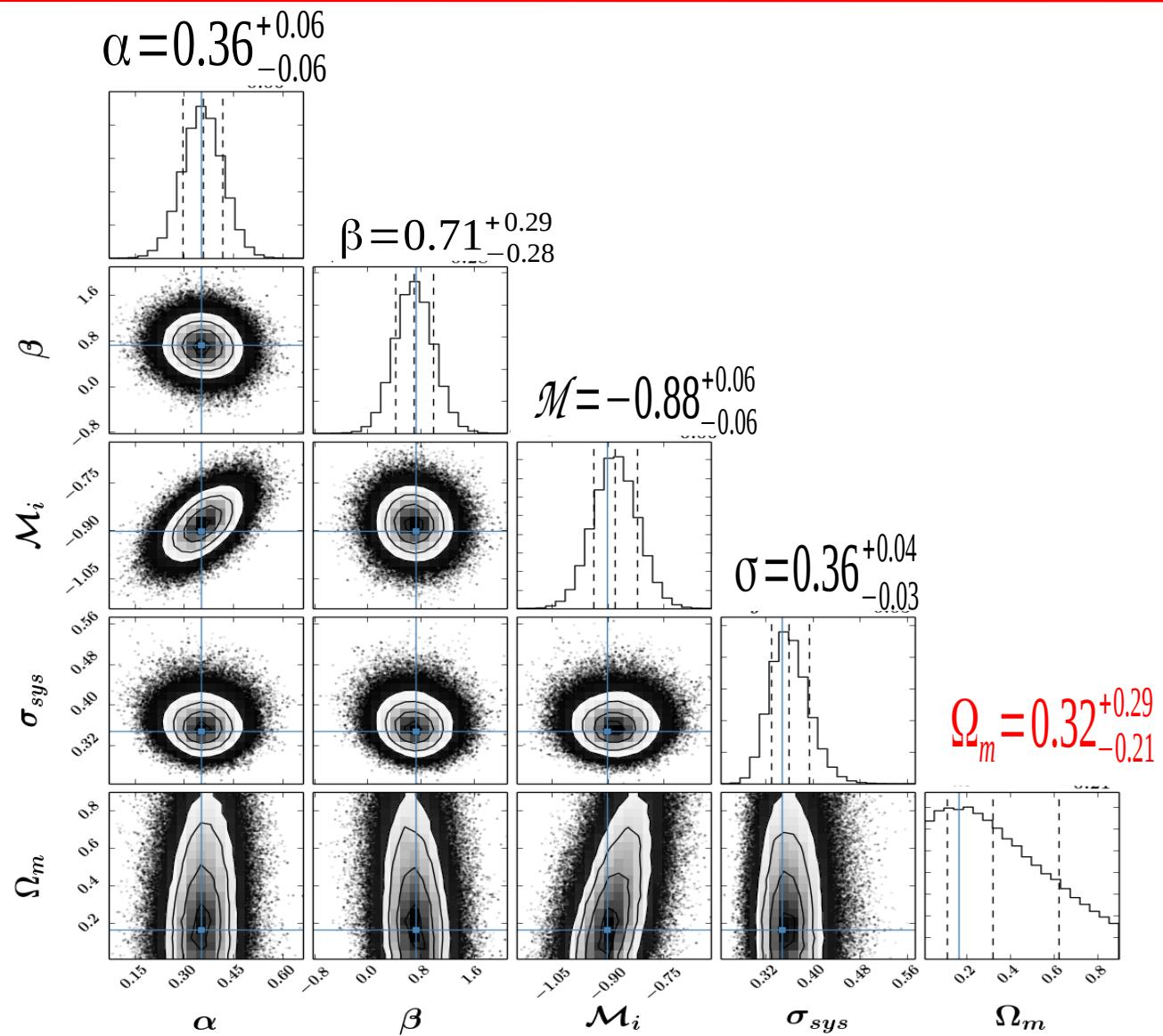
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# PCM

**Assuming a flat  
Universe**  
 $\Omega_m + \Omega_\Lambda = 1$   
 $\Omega_m$  as a free  
parameter



# Conclusions

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- Precision of SNe Ia : 0.15 mag (7% in distance)
- Precision of SCM : 0.27 mag (12% in distance)
- Precision of PCM: 0.35 mag (16% in distance)

# Next steps

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- Expand the sample to high-z supernovae :  
**SCM+PCM**
  - Dark Energy Survey (DES) supernovae
  - Subaru Hyper suprime camera
  - LSST
  - Gemini + Magellan + Keck spectroscopic followup
- New SNe II template :
  - Type II light-curve fitter? (like SALT, SiFTO, SNOOPY)
  - Improve K-corrections

# Thanks

