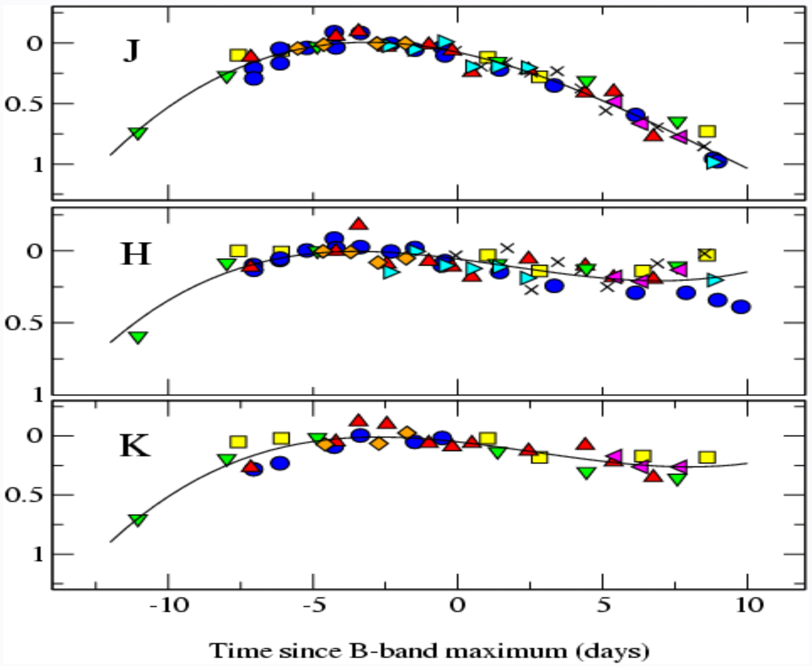
Type Ia supernovae in the near-infrared: nickel all over

Bruno Leibundgut
Suhail Dhawan
Jason Spyromilio
Kate Maguire

The promise of the (near-)infrared

- Extinction is much reduced in the near-IR
  - $A_H/A_V \cong$ 0.19 (Cardelli et al. 1989)
- SNe Ia much better behaved



SN $\Delta m_{15}(B)$

= 1980N (1.29)

= 1986G (1.79)

= 1998bu (1.05)

= 1999aw (0.81)

= 1999ee (0.94)

= 2000ca (1.01)

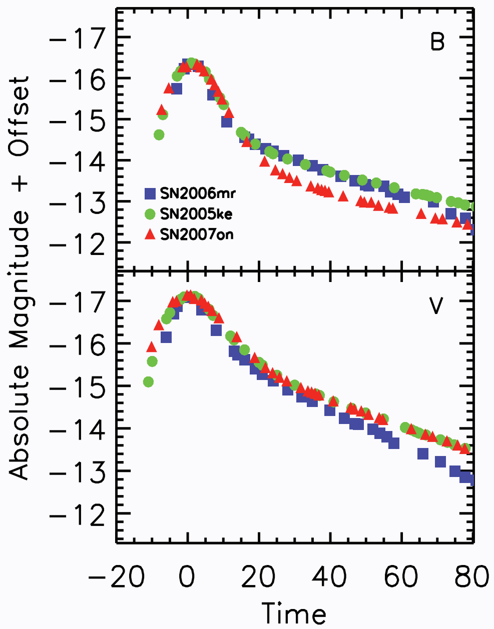
= 2001el (1.15)

Krisciunas et al. (2004)

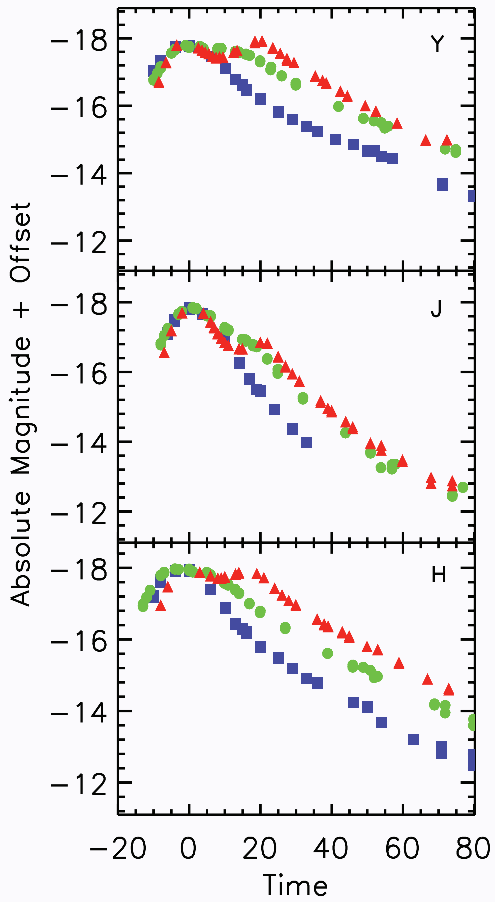
Mark Phillips

Others find this too

- Light curves in the near-IR very uniform at peak, but large differences at later times



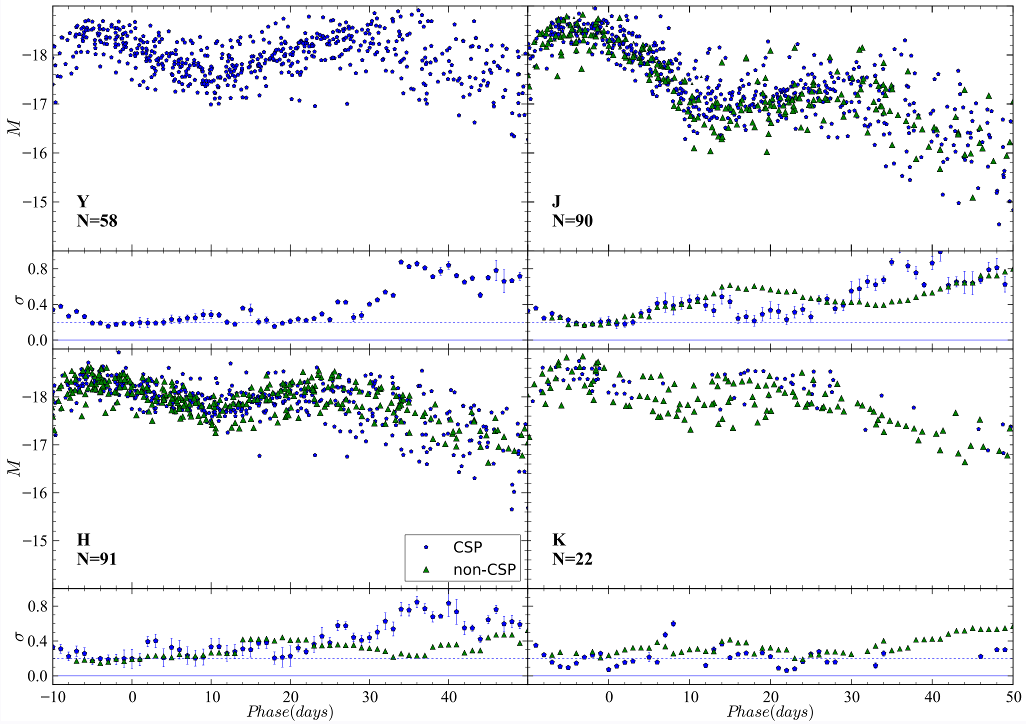
SN 2006mr
SN 2005ke
SN 2007on
Kattner et al. 2012



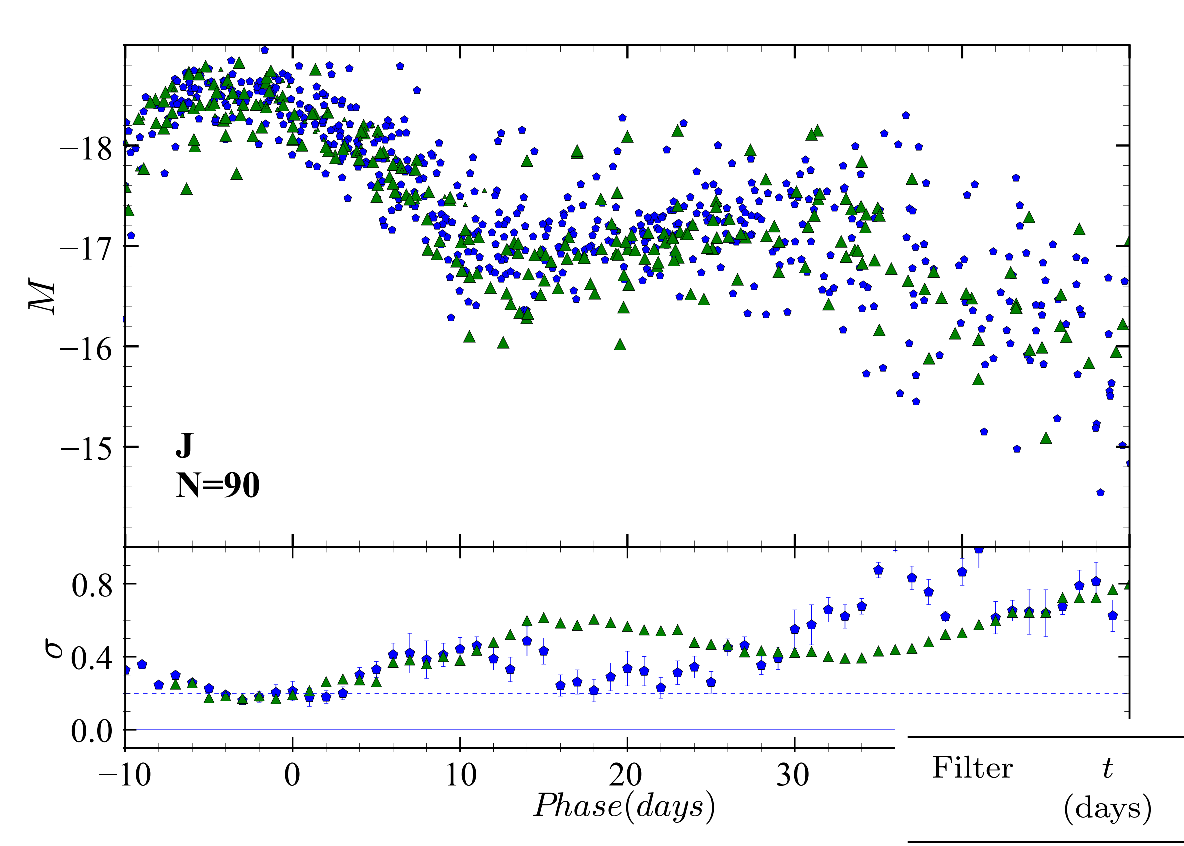
Large literature sample

- Scatter minimal at first maximum in Y (1.04μm), J (1.24μm), H (1.63μm) and K (2.14μm)
- ~90 objects in J and H
  – 58in Y, 22 in K
- Mostly Carnegie SN Project data (Contreras et al. 2010, Stritzinger et al. 2011)

Dhawan et al. 2014



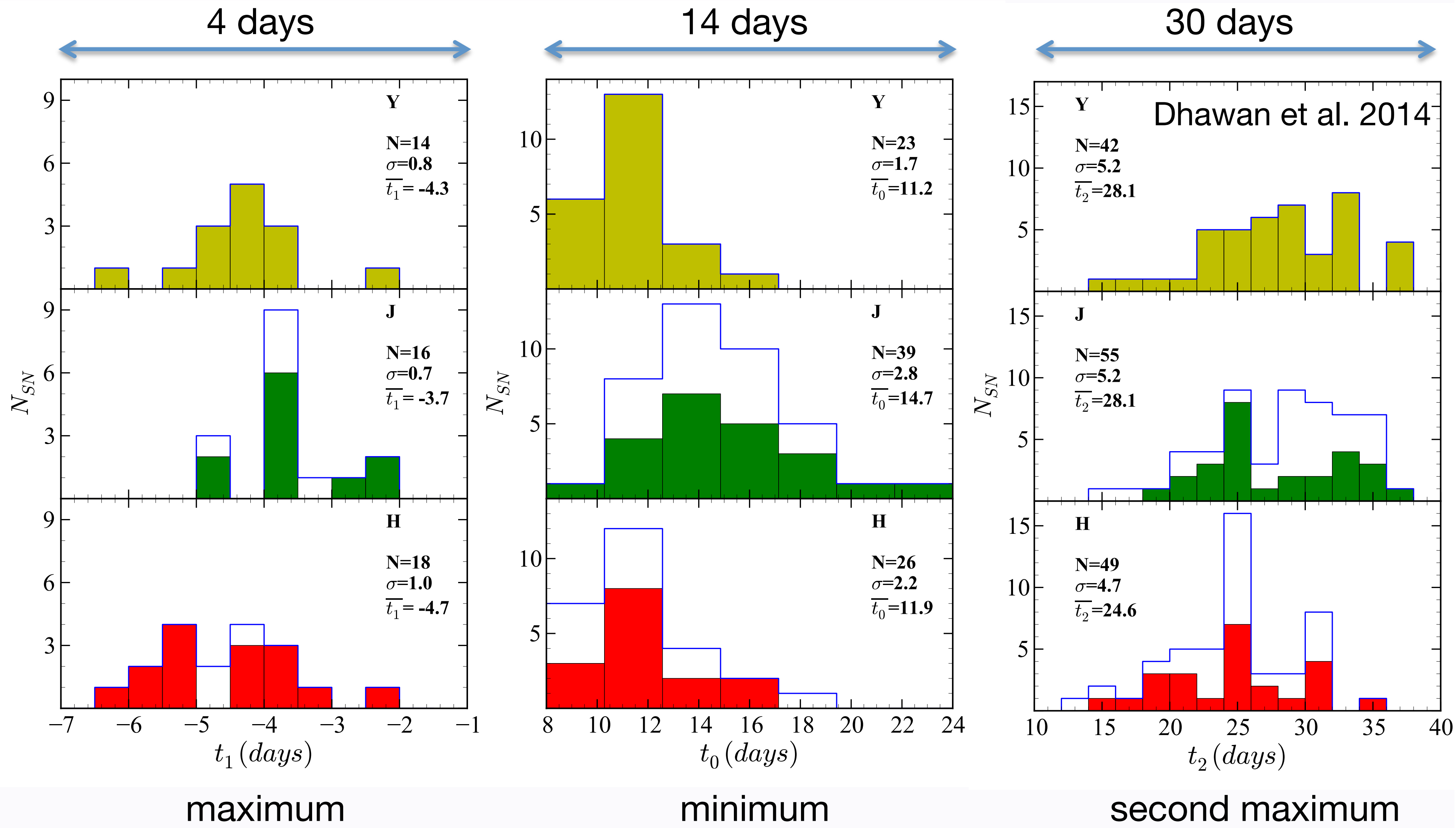
Infrared light curves



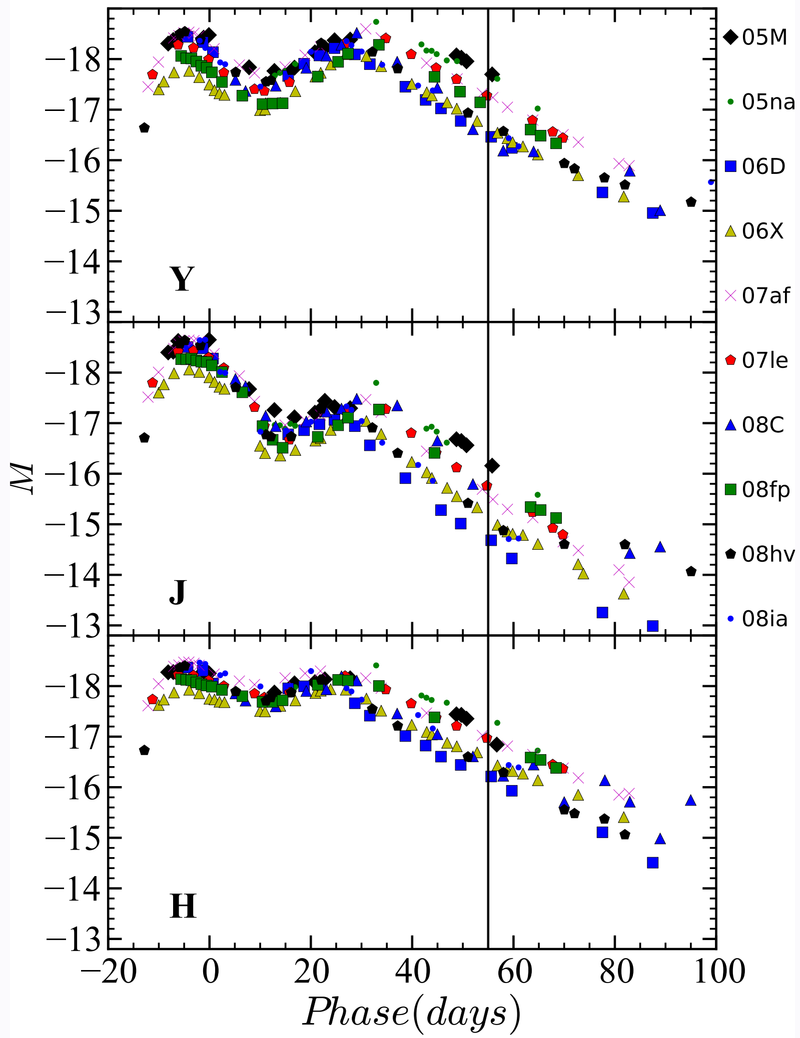
Dhawan et al. 2014

Filter	t (days)	$\sigma(M)$ (mag)	Phase range ($\sigma(M) < 0.2$ mag)	SN sample
Y	-4.4	0.15	$[-4\ ,\ +1]$	CSP
J	-3.6	0.16	$[-4\ ,\ +3]$	CSP
J	-3.8	0.17	$[-6\ ,\ +1]$	non-CSP
H	-5.1	0.17	$[-5\ ,\ +1]$	CSP
H	-4.7	0.14	$[-7\ ,\ +2]$	non-CSP

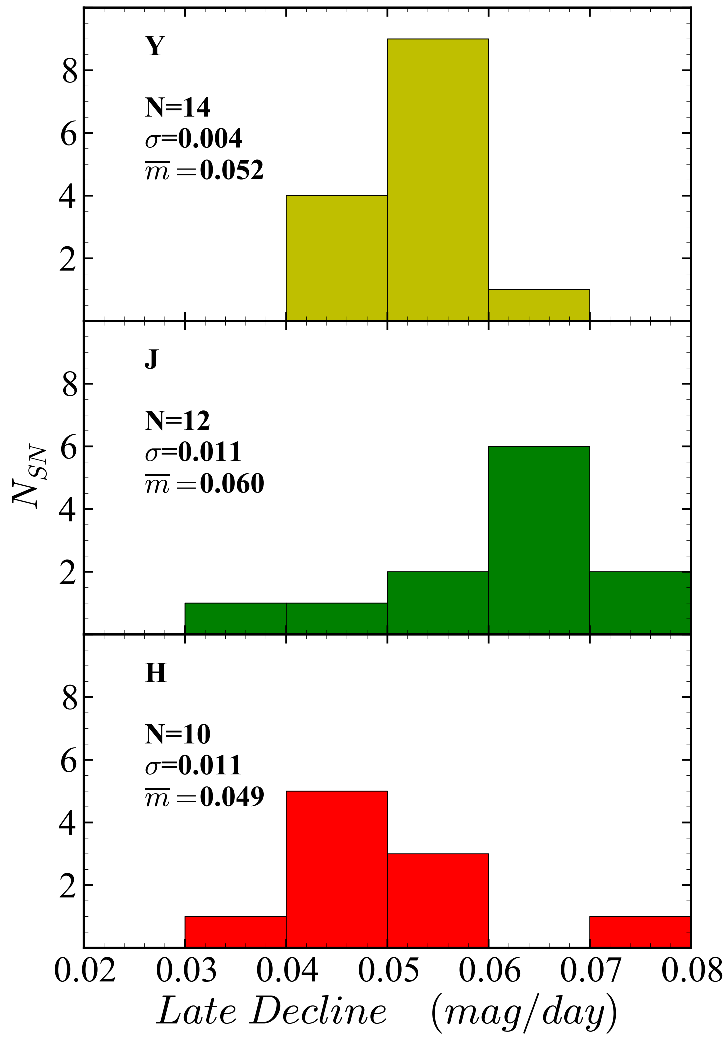
NOT after maximum



Late decline (t>40 days)

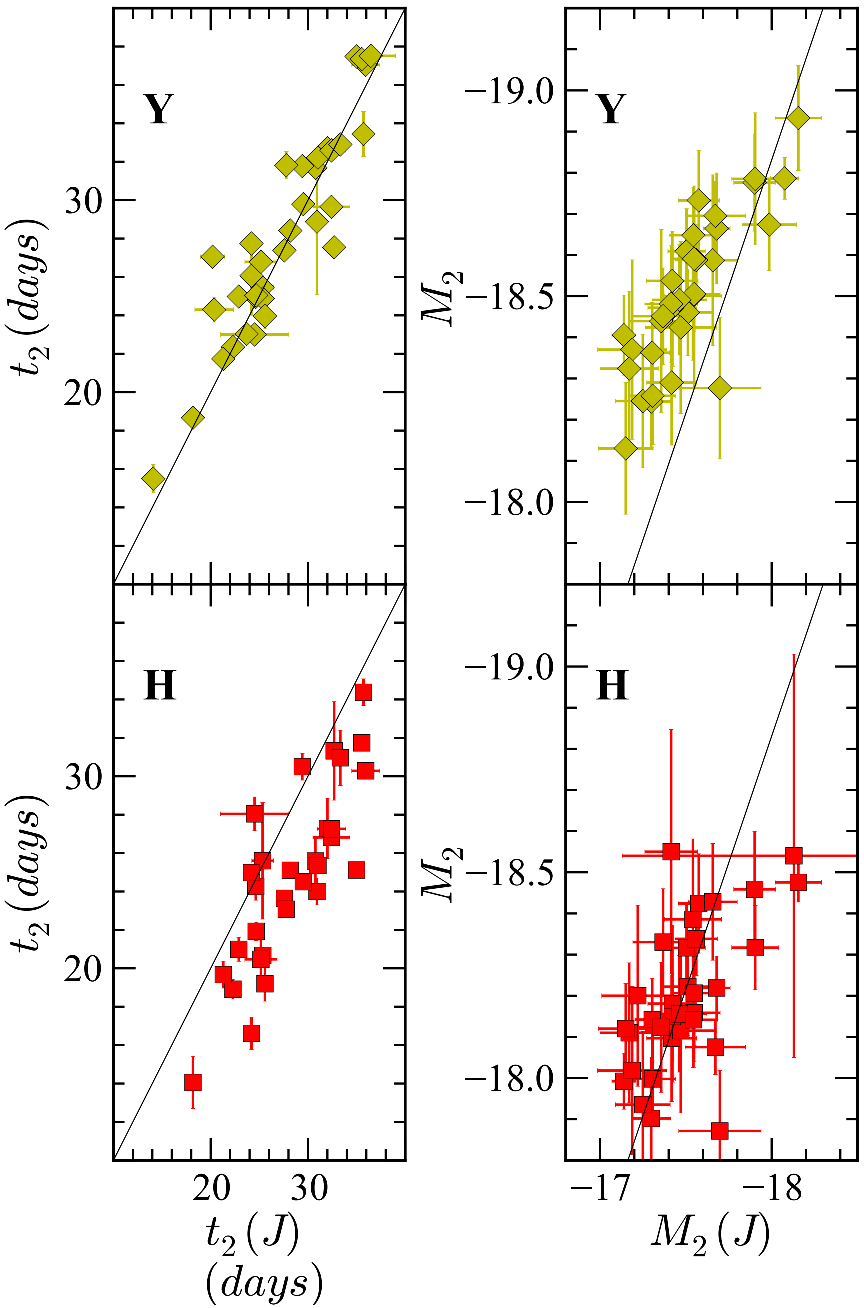


Dhawan et al. 2014



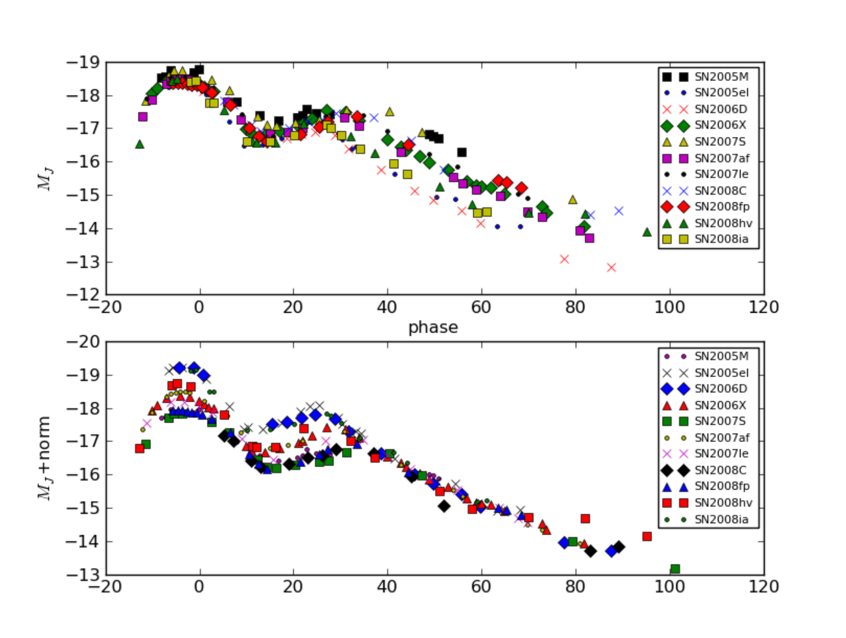
Correlations

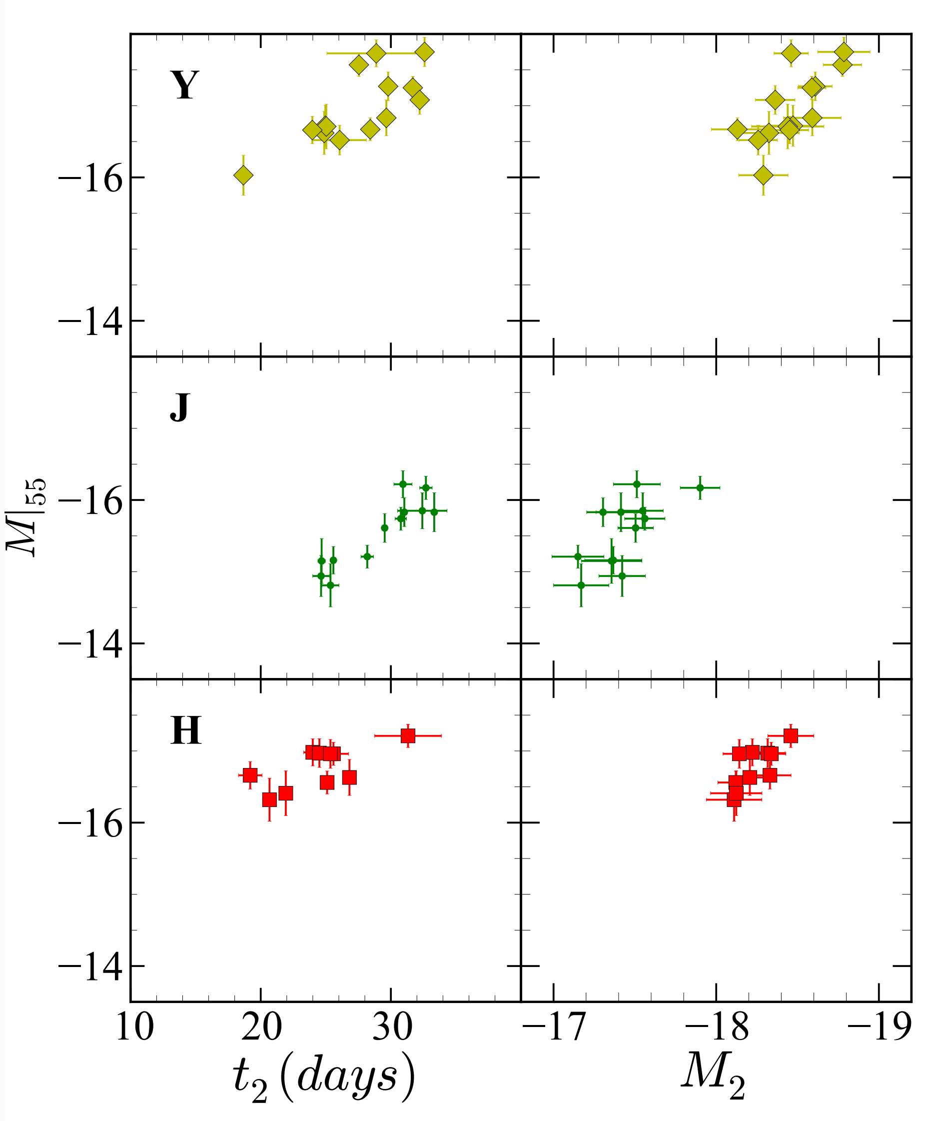
Phase of the second maximum appears to be a strong discriminator among SNe Ia



Correlations

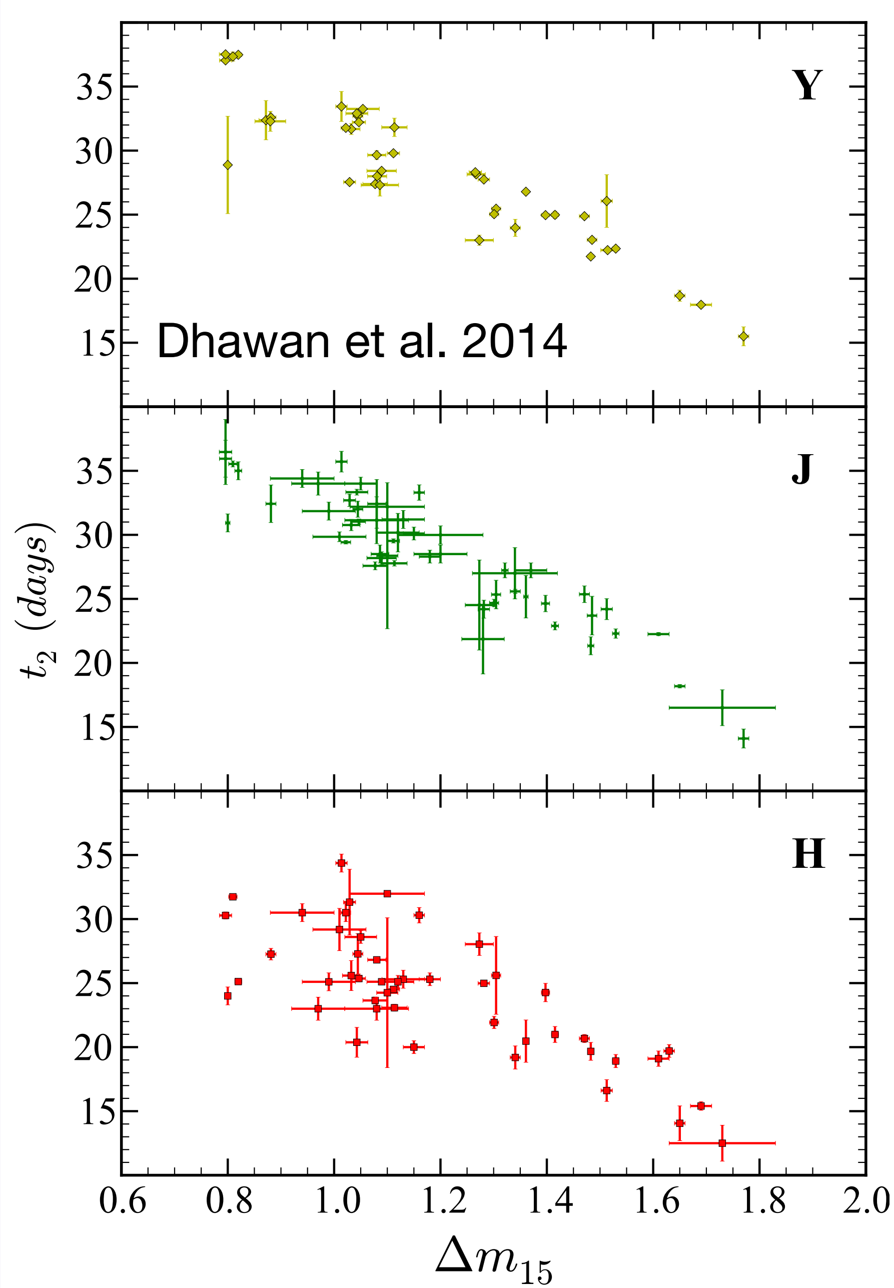
Luminosity of late decline and the phase of the second maximum are linked





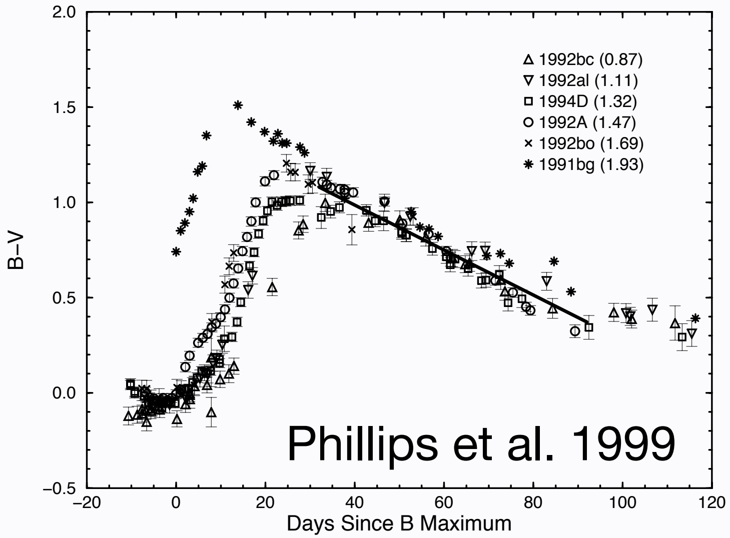
Correlations with the optical

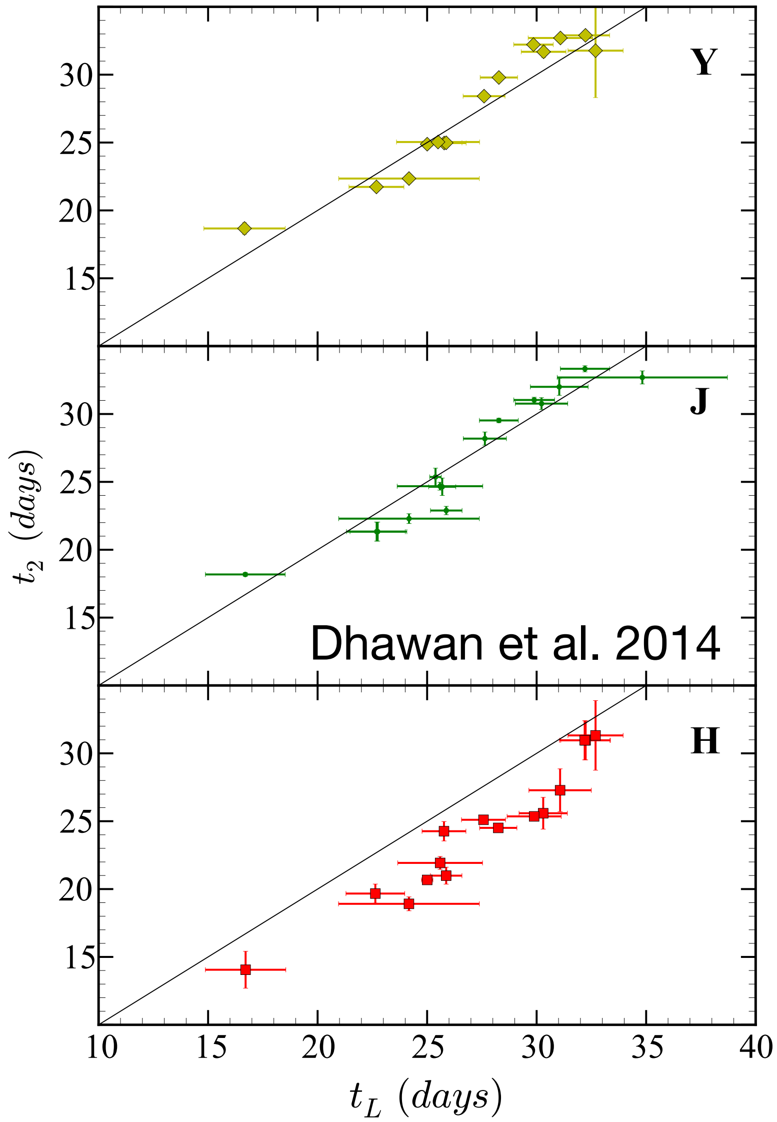
- IR properties correlate with optical decline rate
- Phase of secondary maximum strongly correlated Δm_{15}



Correlation with optical colour

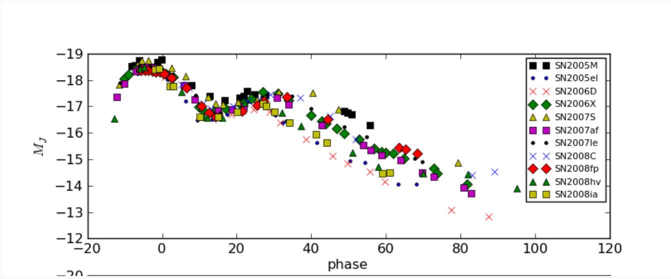
Phase of second maximum and beginning of the Lira relation are also tightly linked





Consistent picture emerging

- Second peak in the near-IR is the result of the recombination of Fe++ to Fe+ (Kasen 2006)
  - he predicted a later second maximum for larger Ni masses
- Optical colour evolution faster for objects with lower nickel mass
  (Kasen & Woosley 2007)



- Ejecta structure uniform
  - late declines very similar

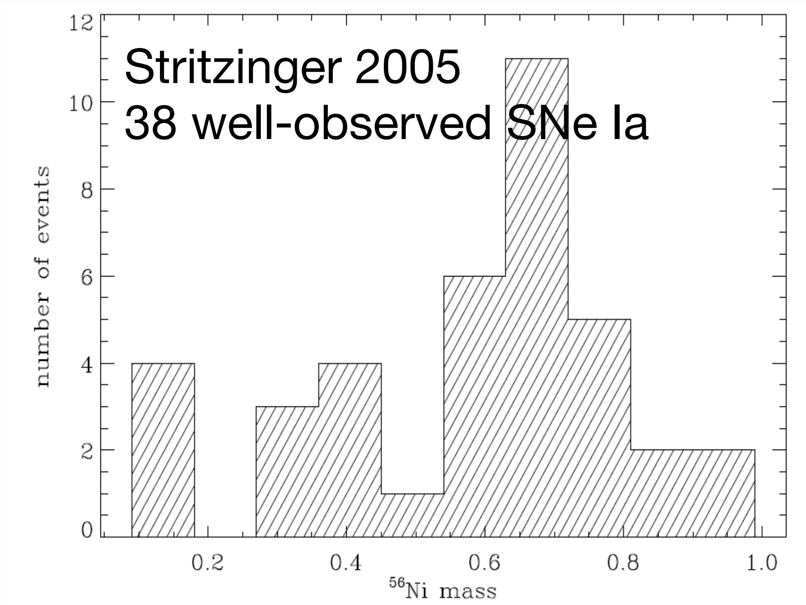
➔ higher luminosity indicates a higher Ni mass

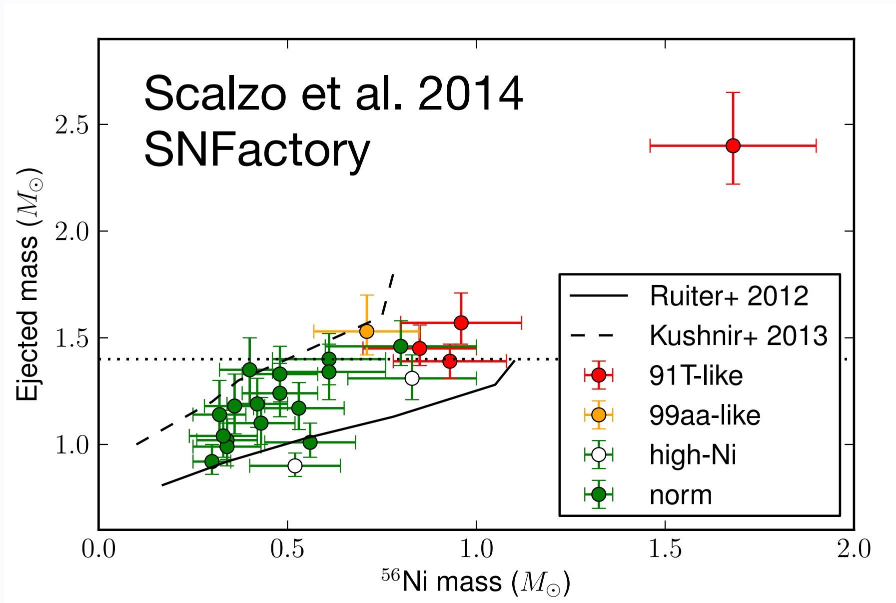
➔ later secondary peak also indicates higher Ni mass

➔ Ni mass and (optical) light curve parameters correlate (Scalzo et al. 2014)

Nickel masses directly?

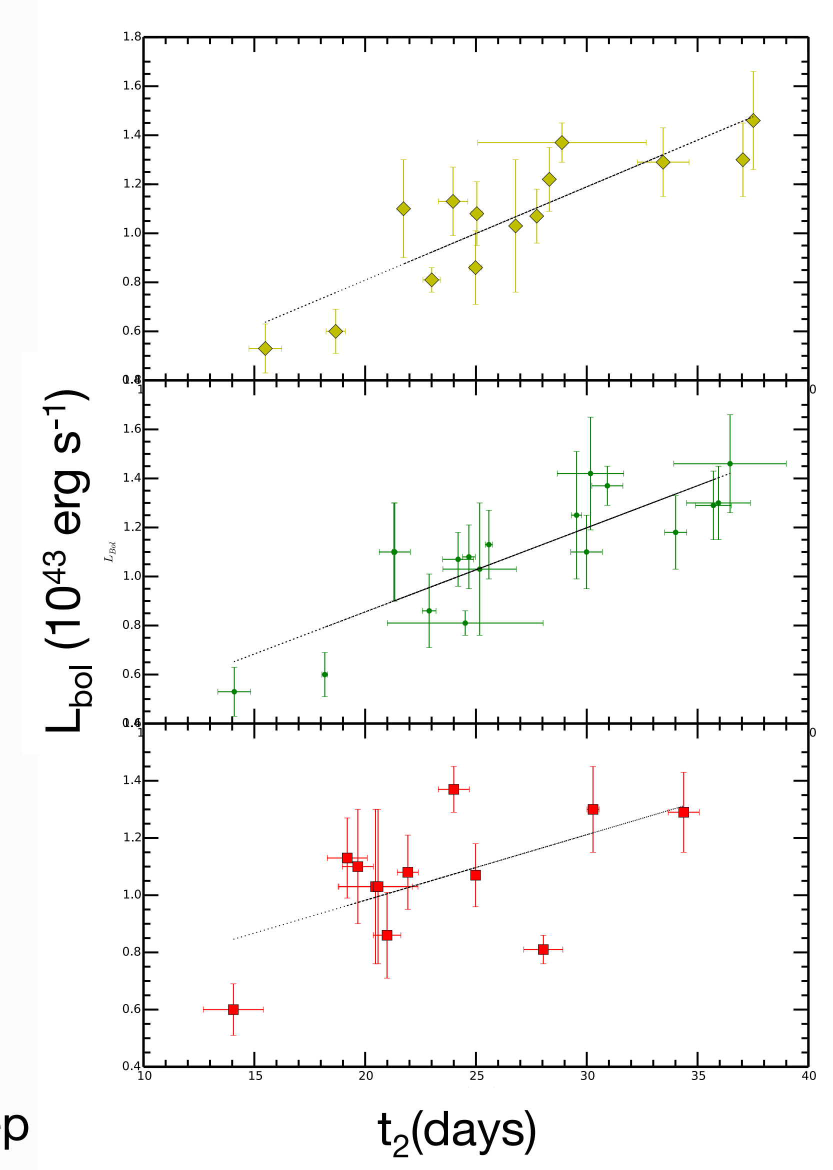
- Correlate phase of second maximum with observed nickel masses
  - – avoid ‘detour’ through optical light curve shape parameter (Δm_{15})





Absorption-free subsample

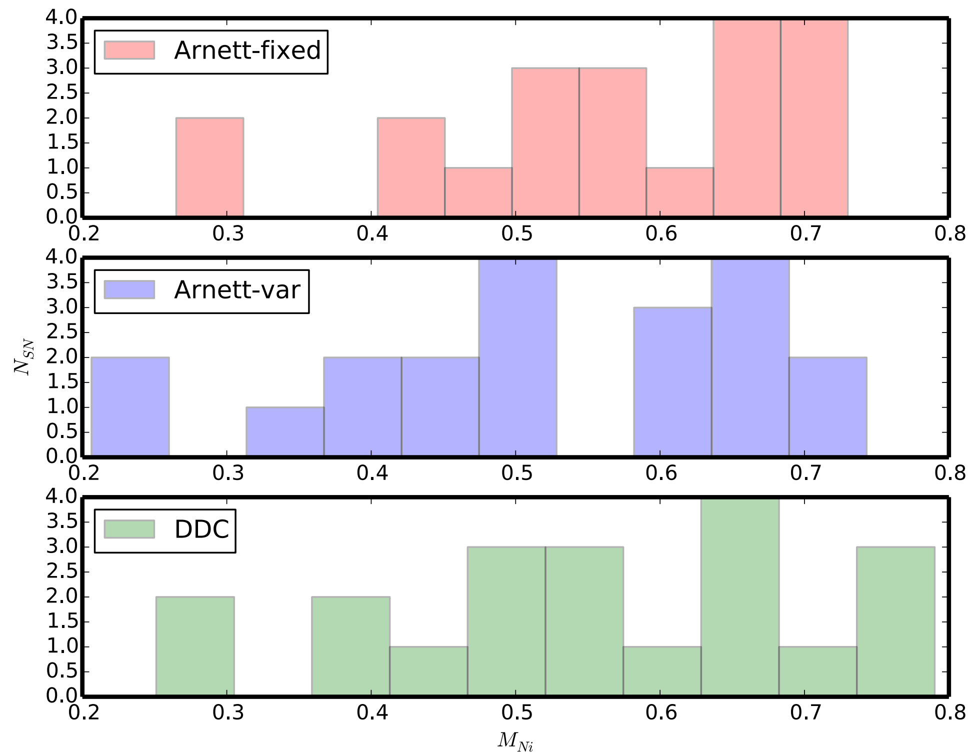
- Select SNe with E(B-V)<0.1
- Pseudo-bolometric light curves (UBVRIYJH)



Dhawan et al., in prep

Nickel masses

- Using a timing parameter for nickel masses
  - completely independent on reddening and multiple light curves
- Explore different methods to calculate the nickel mass (currently still all Chandrasekhar-mass progenitors



Dhawan et al., in prep

Summary

- Nickel seems the dominant parameter for the light curves of SNe Ia
  - phase of second maximum, start of uniform B-V colour evolution (Lira law), optical light curve shape (Δm_{15}), luminosity of the late decline phase
- Second maximum in the IR light curves strong parameter for SN Ia characterisation → simple way to measure nickel mass