To What Extent are Type Ia Supernovae Standard Candles in the Near-Infrared?

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But first, contemplate that we haven't seen a Milky Way SN since 1604. We are really overdue!

Betelgeuse will eventually explode, but what if the light of the explosion first reaches us in the month of June? α Ori is 16.0 to 24.0 degrees from the Sun in June. The only astronomical site on Earth to see it during "nighttime" is Dome A in Antarctica (latitude -80:22). α Ori (δ = +7.4) only gets 2.2 deg above the horizon at Dome A.

In June the Sun is between 13.0 and 13.8 deg below the horizon at the time α Ori is highest in the sky at Dome A. Just something to think about…

SN 1972E (Kirshner et al. 1973)

B

V

J

H

K

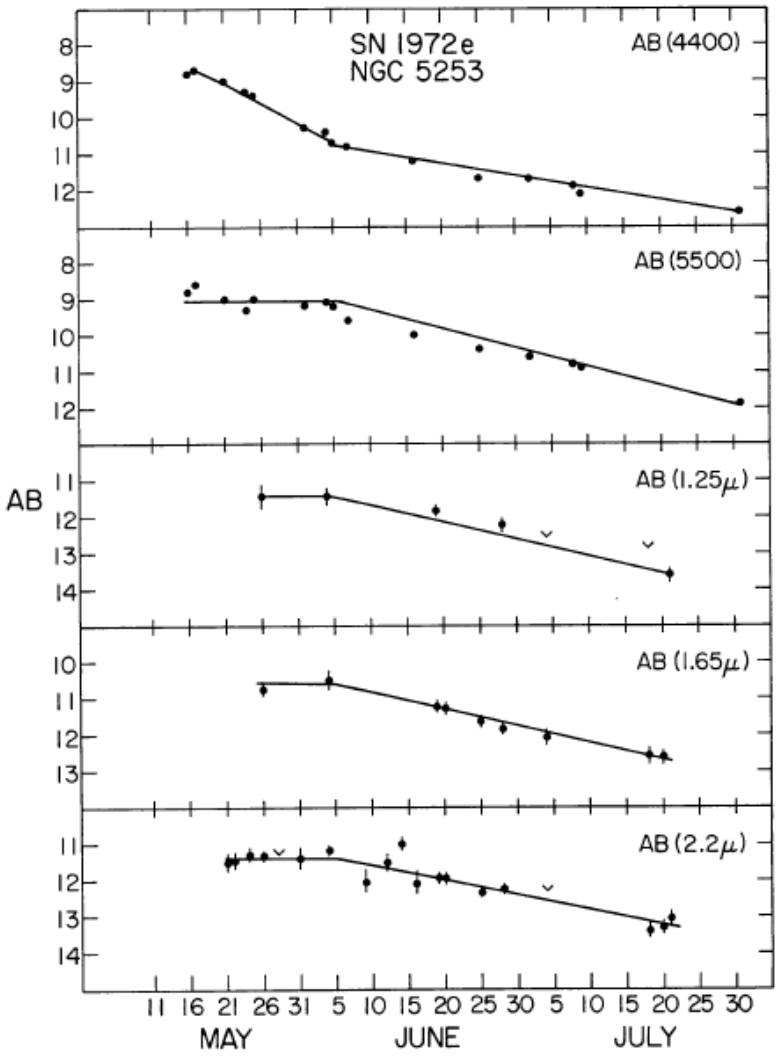
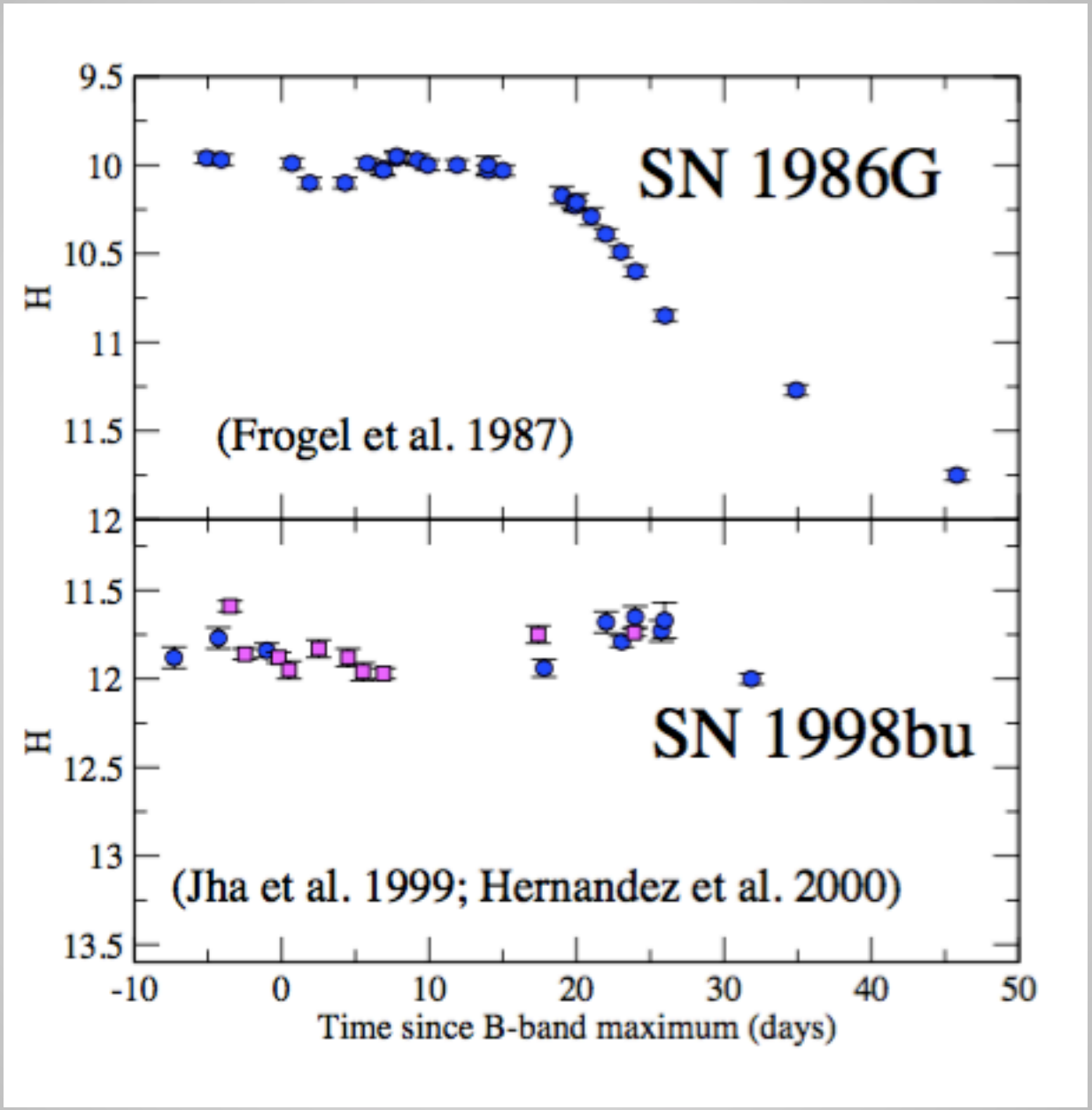


FIG. 1.—Flux density in *AB* magnitudes at five wavelengths, in 1972 from May 16 to July 31 for supernova 1972e. The solid lines have an arbitrary break at June 4, and are intended to emphasize the similarities among frequencies. (*a*) *AB*(4400) from scans; (*b*) *AB*(5500) from scans; (*c*) *AB*(1.25 μ); (*d*) *AB*(1.65 μ); (*e*) *AB*(2.2 μ).

Prior to 1999 there were very few near-IR light curves of Type Ia SNe that covered maximum light.

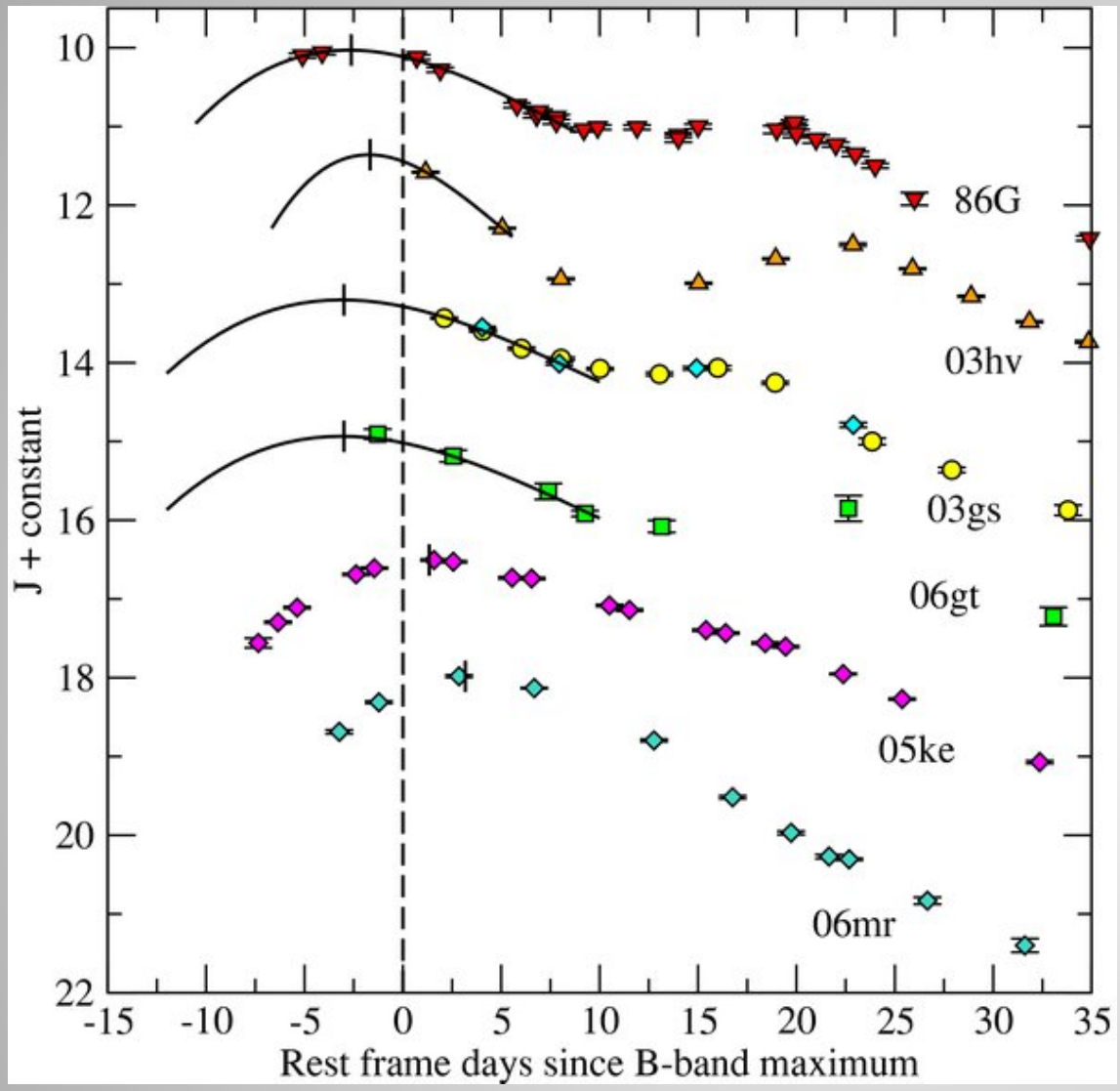

SN 1986G
(Frogel et al. 1987)
SN 1998bu
(Jha et al. 1999; Hernandez et al. 2000)
H
H
9.5
10
10.5
11
11.5
12
11.5
12
12.5
13
13.5
-10
0
10
20
30
40
50
Time since B-band maximum (days)

Photometry in the optical and near-IR of Type Ia SNe has proved useful in eliminating any serious systematic errors of distance owing to extinction by dust.

Observations ramped up:

1999 – Cerro Tololo and Las Campanas (Hamuy, Phillips, Suntzeff)

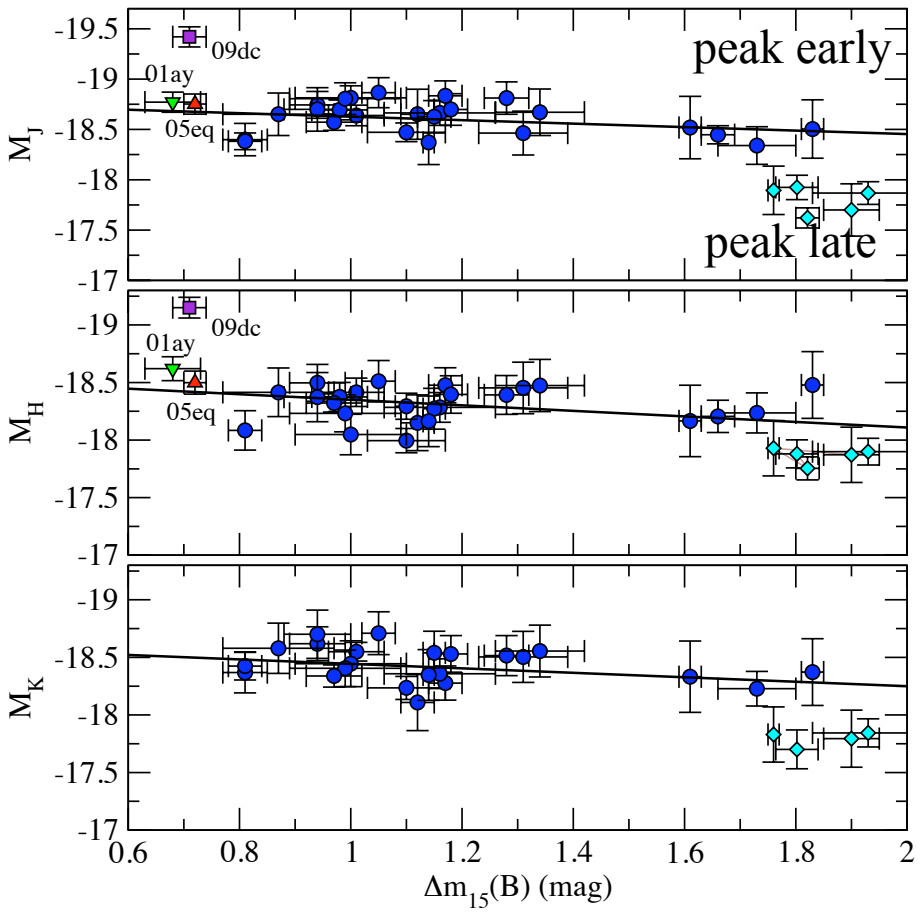
1999 – Apache Point Observatory 3.5-m (Krisciunas, Stubbs, Magnier, Diercks)



Fast declining Ia's have different absolute magnitudes at maximum light in the near-IR depending on whether or not the near-IR peak occurs before or after B-band maximum. The late-peaking objects are subluminous in all bands but the early peakers are only slightly sub-luminous at their near-IR peaks.

Krisciunas et al. (2009)

Near-IR decline rate relations (DRR):

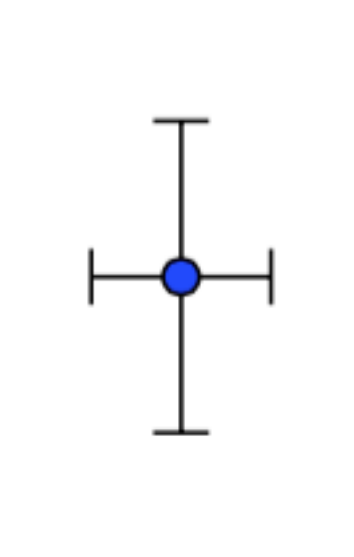


Krisciunas (2012)

Type Ia SNe that peak early in the near-IR are nearly perfect standard candles.

Here we have excluded from the regressions the late-peaking fast decliners and the possible SC object SN 2009dc.

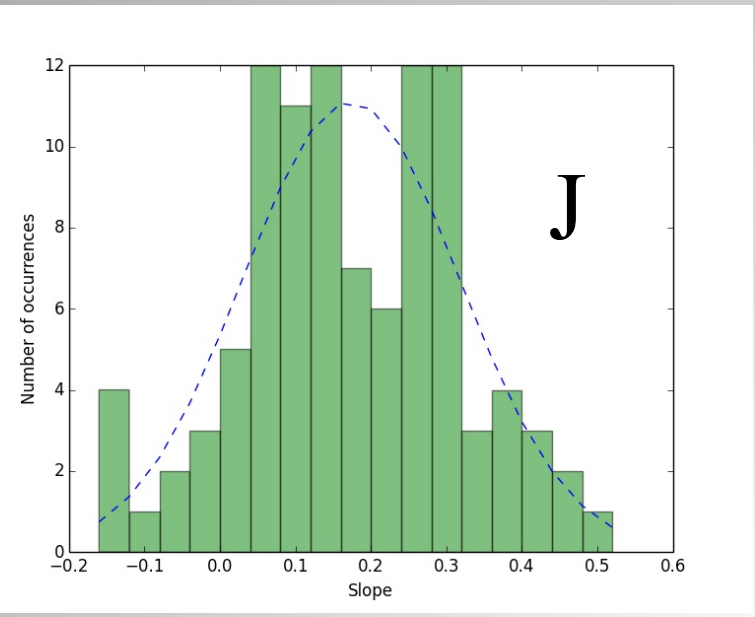
Compare to Folatelli et al. (2010) and Kattner et al. (2012).

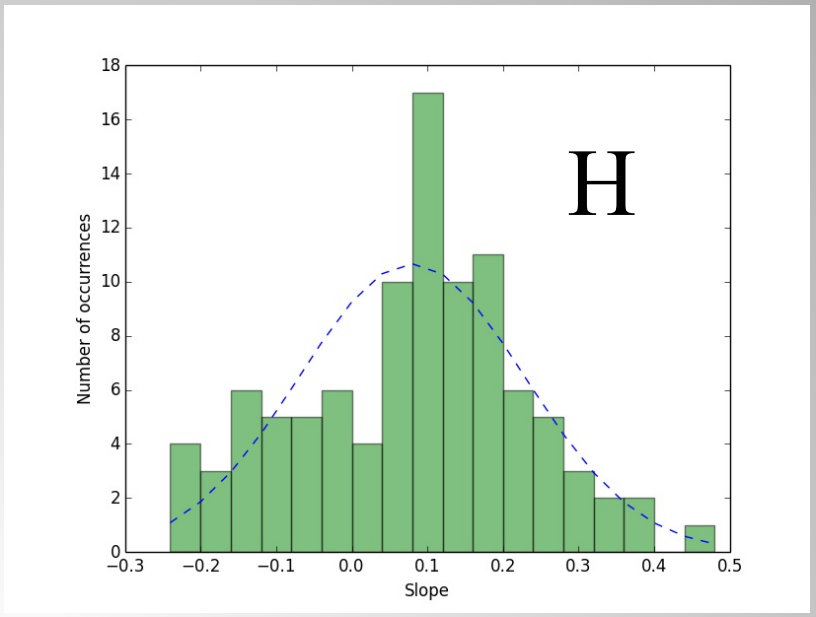


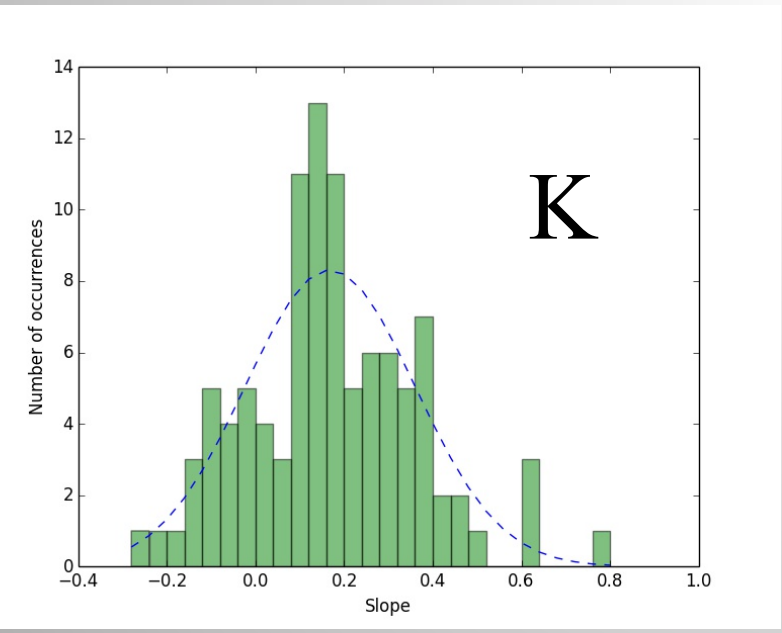
Consider that the X *and* Y value of each data point in the decline rate relations has an uncertainty. We can do a simple Monte Carlo simulation using the Python function

np.random.randn

to vary the positions of the points by a random number of standard deviations in X and Y to determine how statistically significantly different than zero are the slopes.







Slopes of decline rate relations:

J: 0.174 +/- 0.143 (1.2-σ)

H: 0.080 +/- 0.150 (0.5-σ)

K: 0.168 +/- 0.192 (0.9-σ)

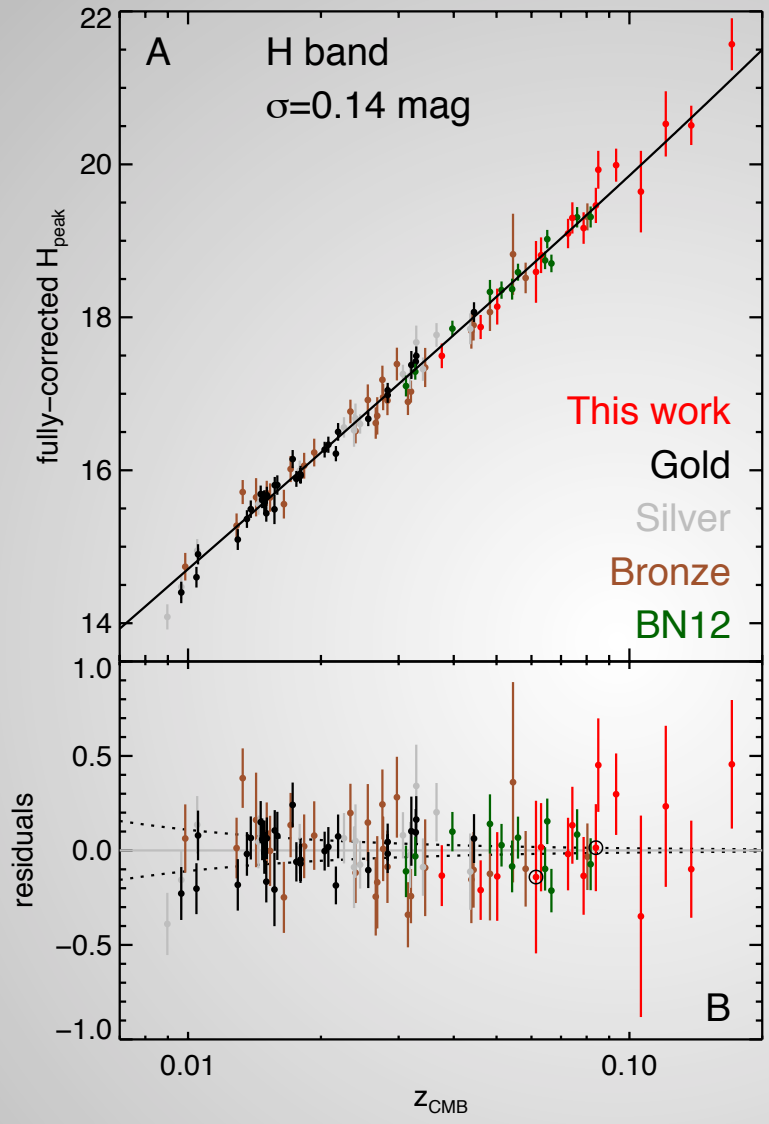
You want a bigger dataset? We are readying for publication a full reduction of the optical and near-IR photometry of 134 Type Ia SNe by the Carnegie SN Project (part I).

Presently, it would make a 375 page preprint.

In the H-band, if we exclude SC objects and the late-peaking 91bg-like objects, Type Ia SNe are essentially standard candles.

See talk by Kara Ponder this afternoon.

(In the H-band, there is the problem of telluric absorption.)



At 1.65 microns we can get distances to +/- 5 % if we observe Type Ia SNe out in the Hubble flow.

From ground-based observations we have only reached $z \sim 0.18$.

Stanishev et al. (2015), arXiv:1505.07707

It is not a good use of ground-based 8-m class telescope time to observe Type Ia SNe at redshift 0.35 and beyond in the H-band (rest frame J).

We await JWST and WFIRST.