Doing WFIRST Science TODAY!

Robert Kirshner
Harvard University

Better knowledge of dark energy through infrared observations

SN IA in the IR with Pan-STARRS1 Doing WFIRST Science TODAY!

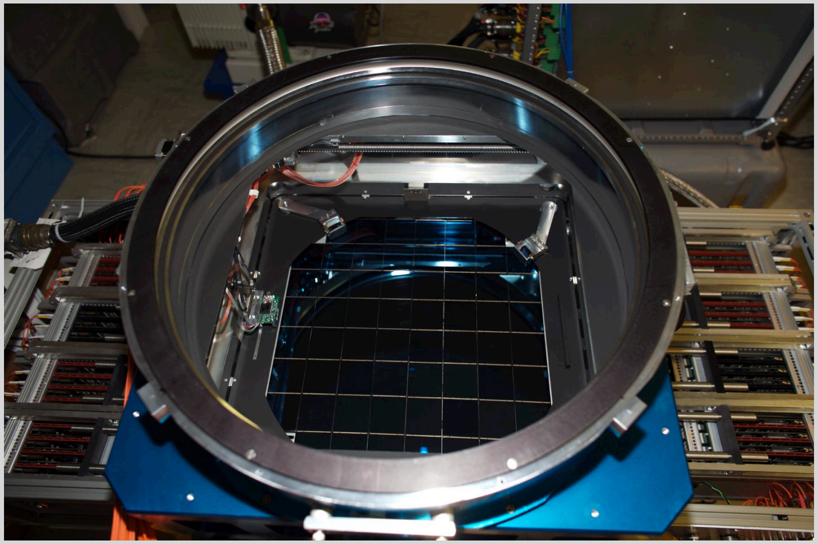
Medium-Deep Fields

Good light curves at z~0.4

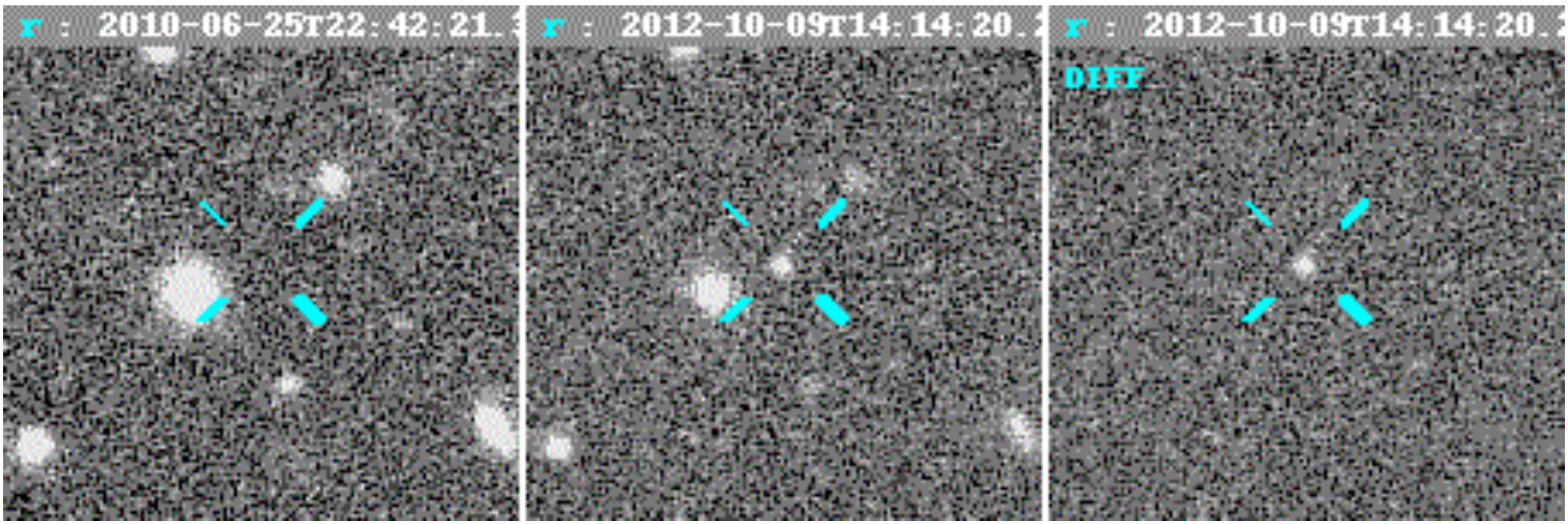
Every 4 days griz

7 square degrees 0.26”/pixel

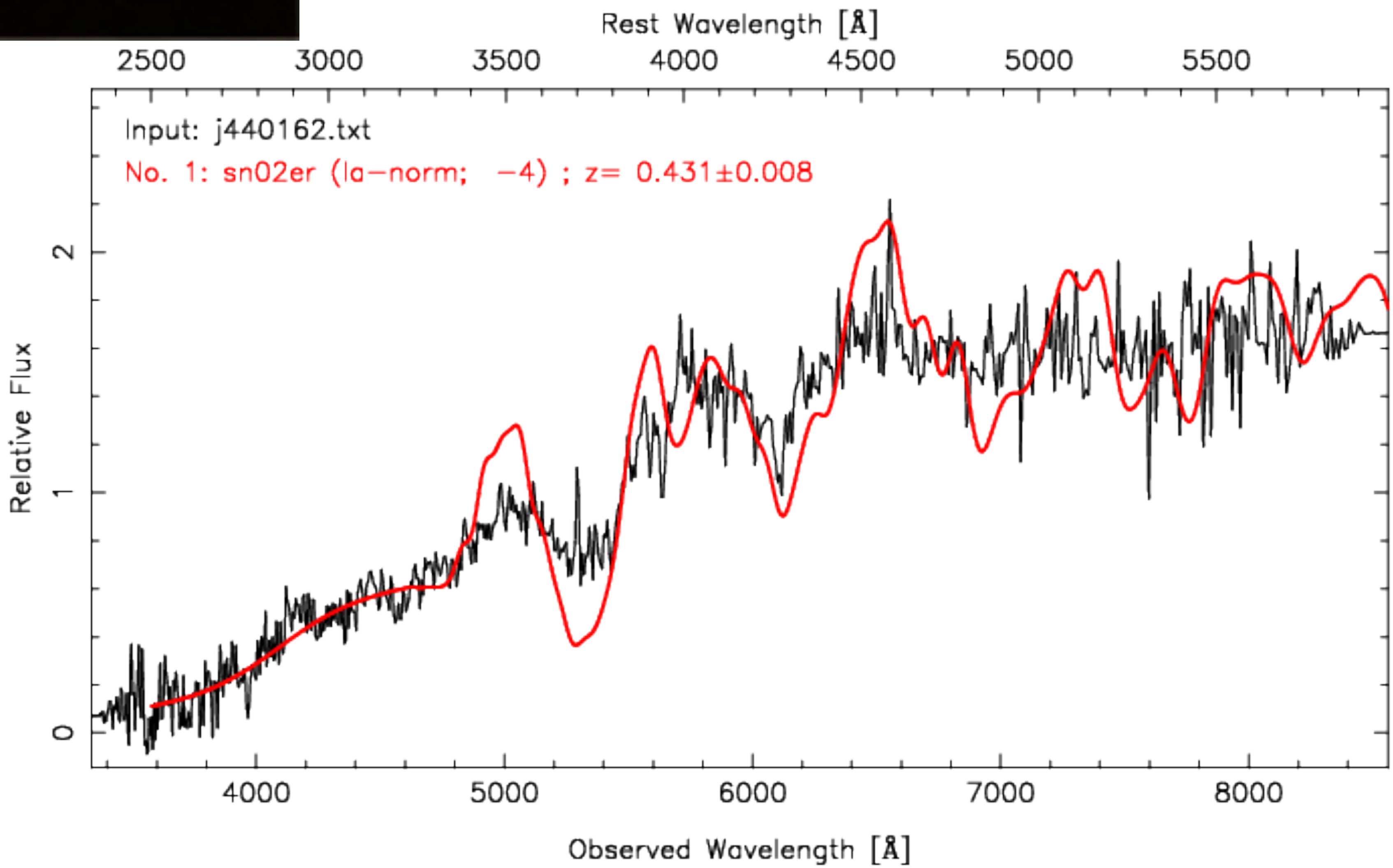
Dozens of supernova candidates every month!

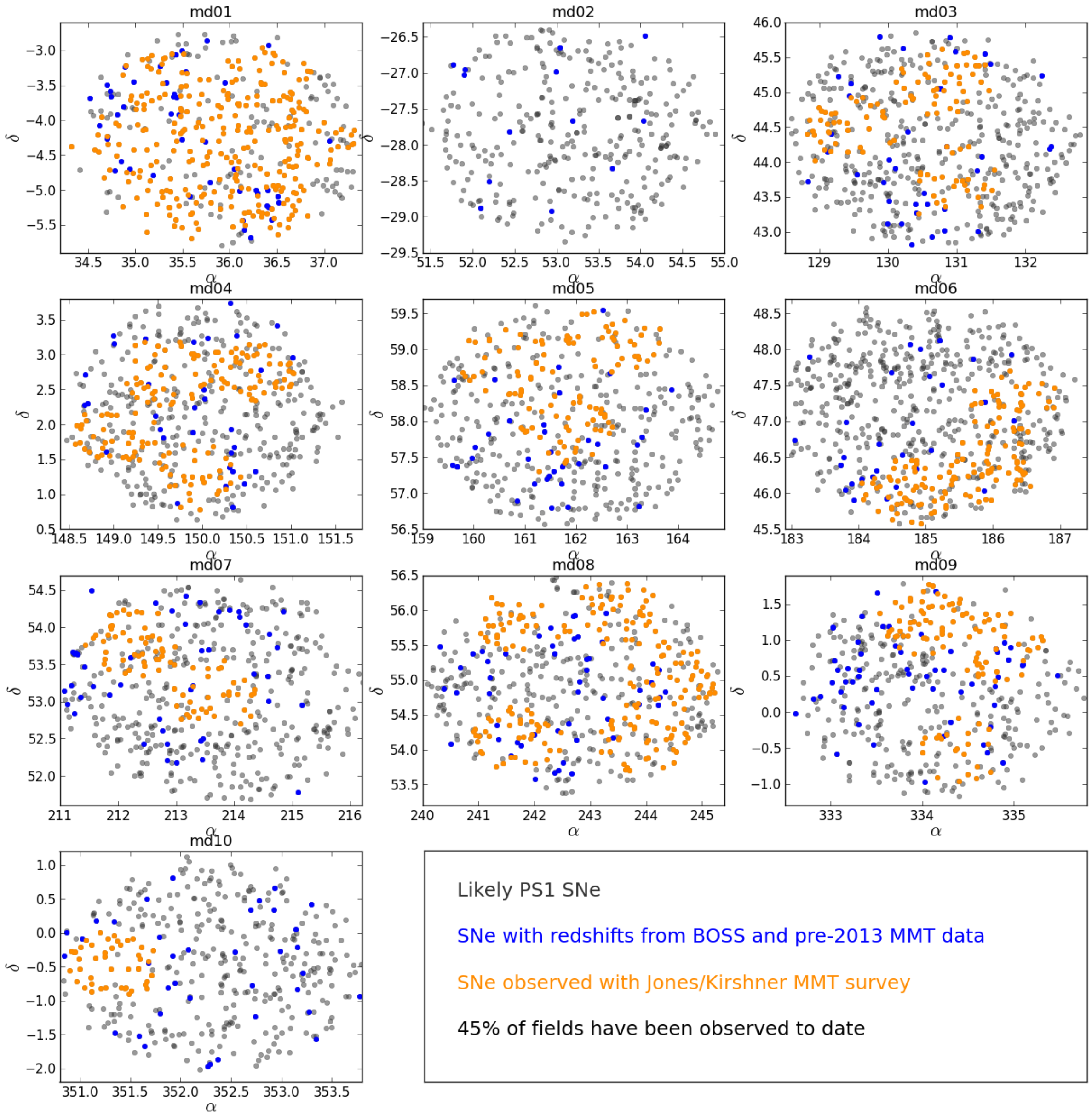


Find SN Ia with Pan-STARRS: difference imaging with Harvard's Odyssey Cluster



Get spectrum with MMT (or Magellan, Gemini or Keck) 358 Spectroscopic SN Ia





With David Jones (JHU):

Using Hectospec on MMT to get redshifts for the hosts of all the likely Pan-STARRS1 SN down to r~22 (z~0.5)

1100/1500 in hand

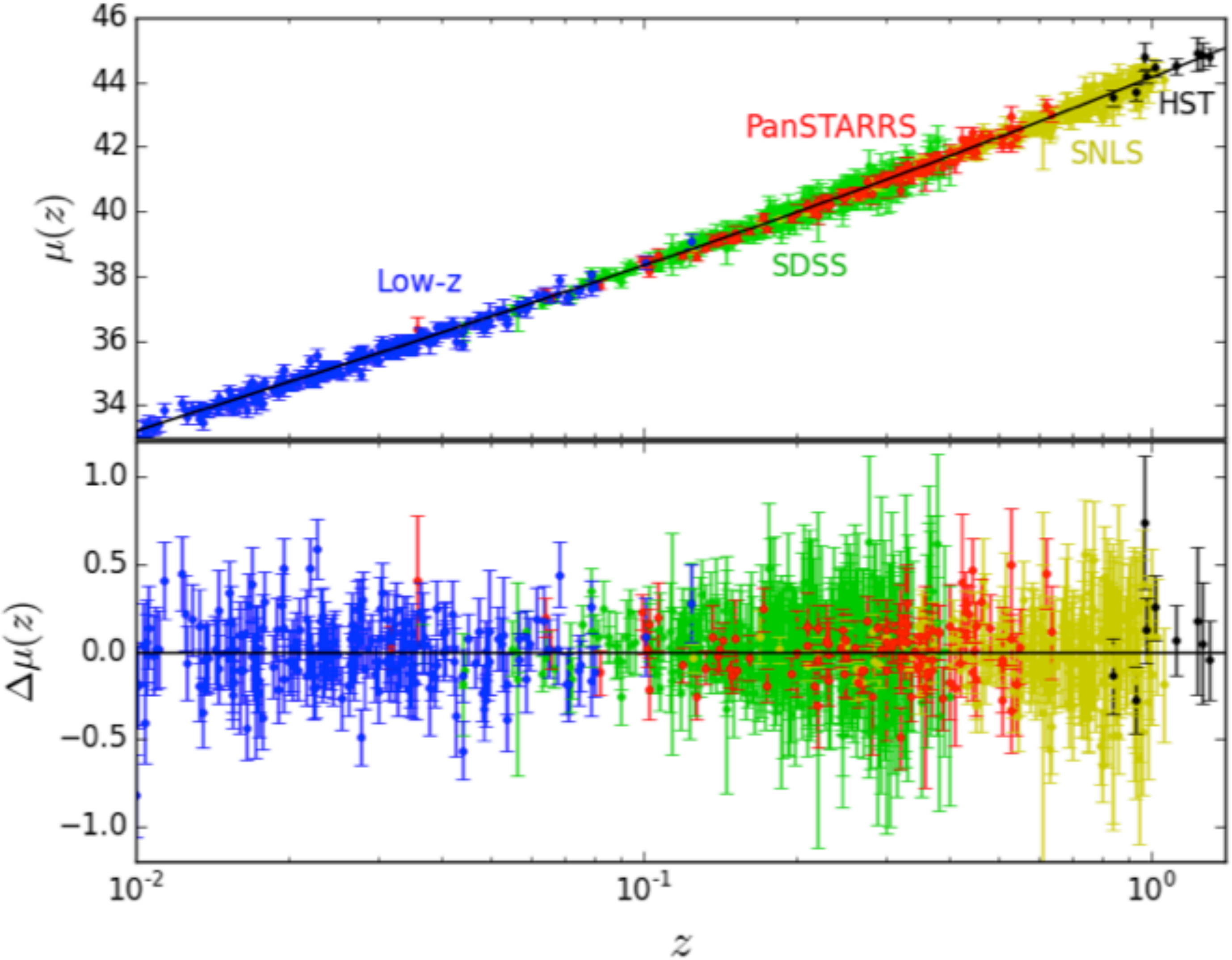
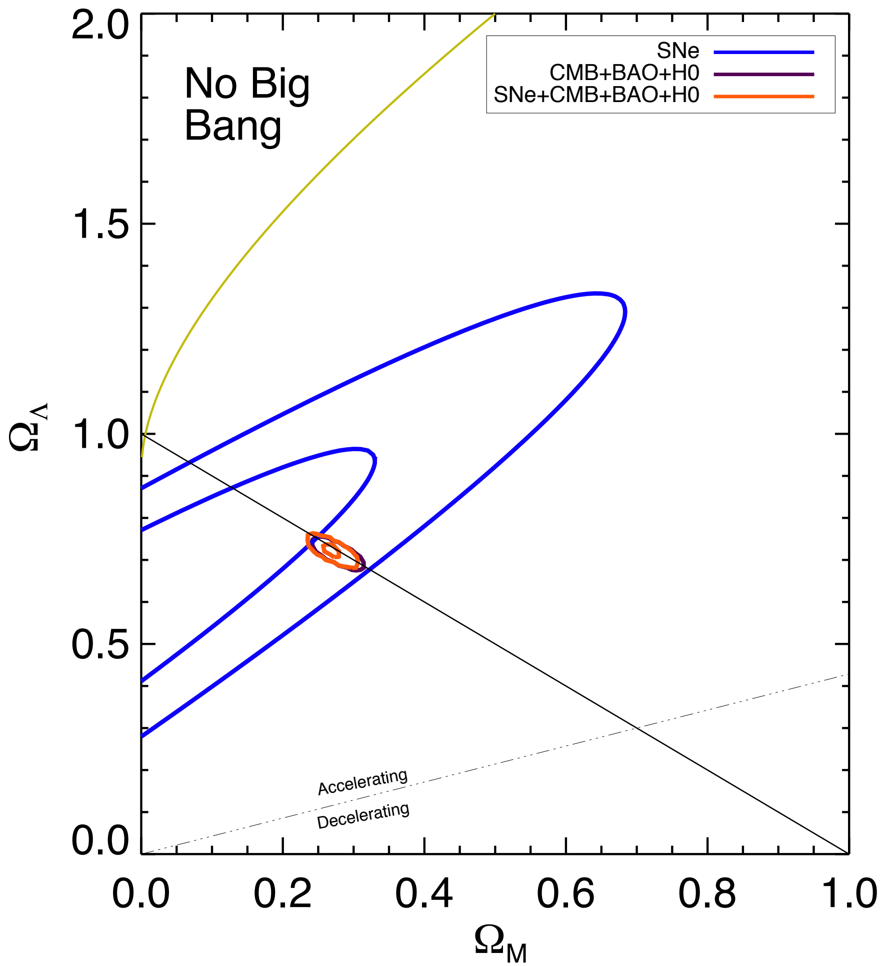


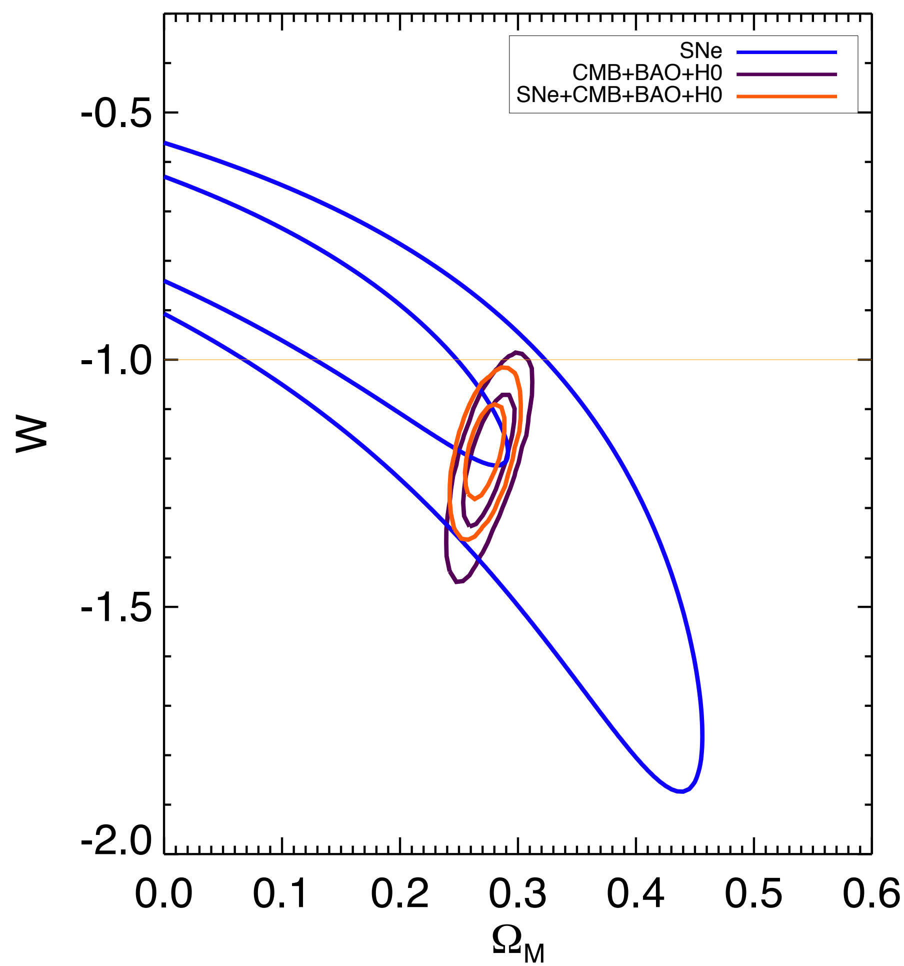
Figure by Arturo Avelino: based on Betoule+ (2014) plus PanSTARRS Rest+ (2014) and Scolnic+ (2014) Low–z is principally based on CfA observations

Cosmology Results from first 146 PanSTARRS SN Ia
Hundreds more to come!

Rest et al. Ap.J 795, 44 (2014)

Scolnic et al. Ap.J. 795, $1+w < 0$

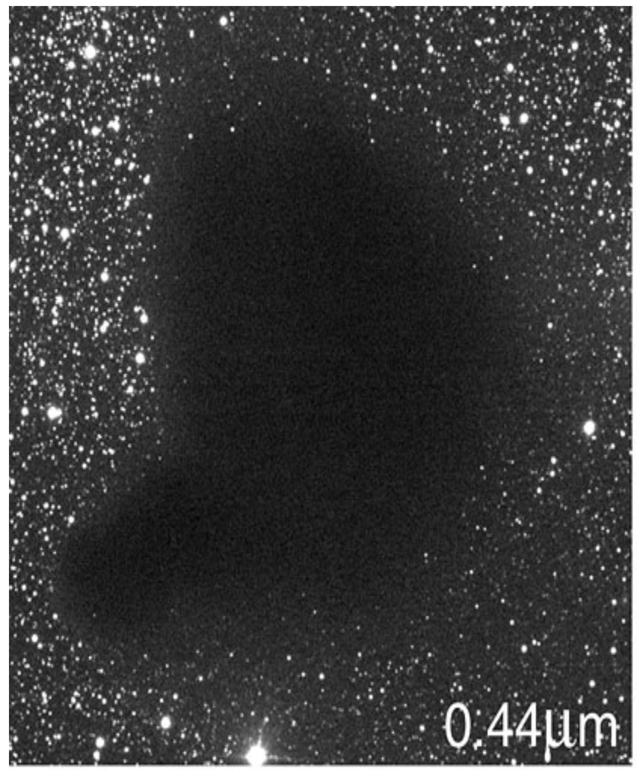





One good reason to observe SN Ia
in the infrared
NASA

Seeing through the dirt

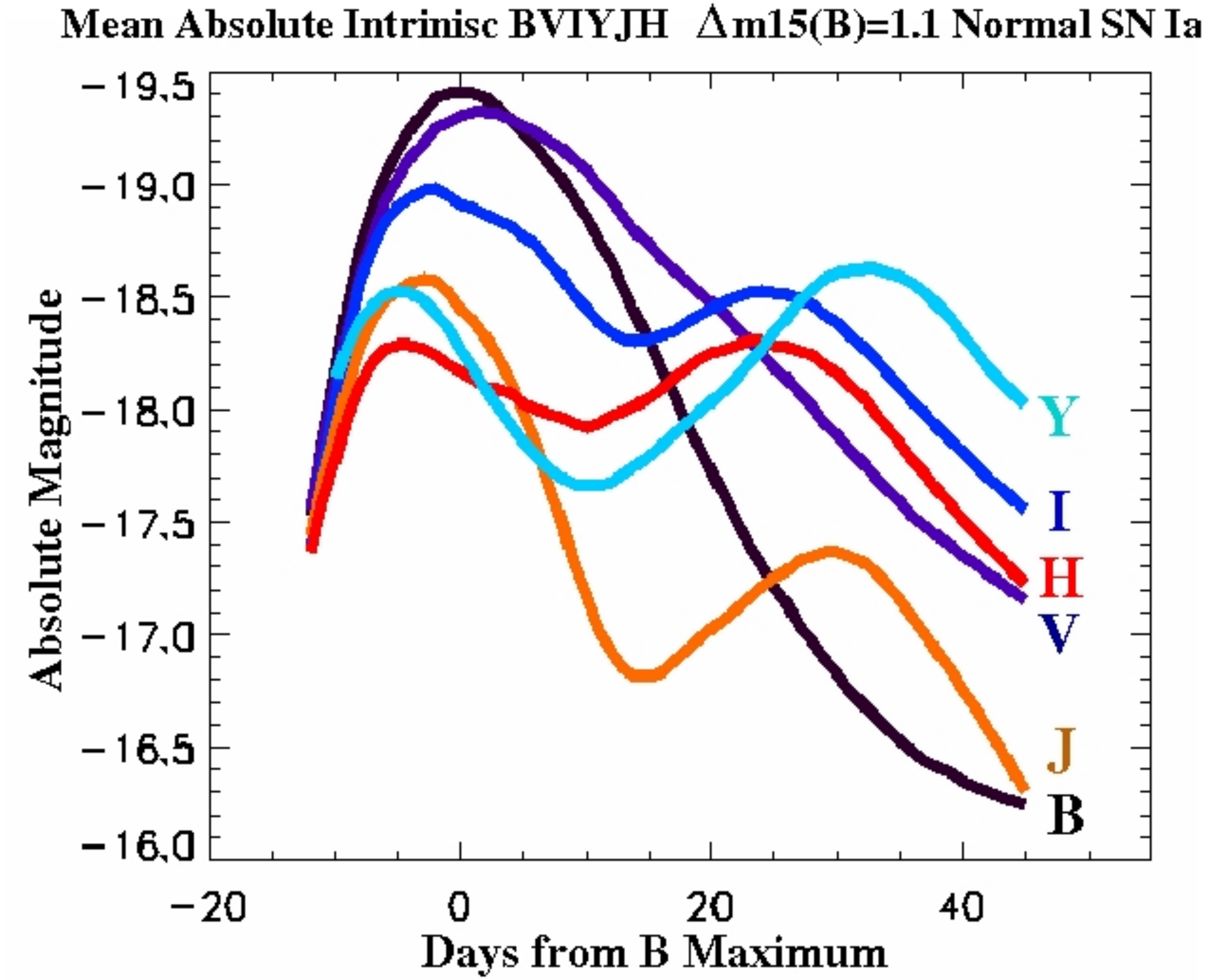
B



Seeing through the dirt

K

Another Good reason:
Infrared Light Curves are Different



Kaisey Mandel

ApJ 731, 120 (2011)

arXiv1402.7079

Postdoc @ Harvard

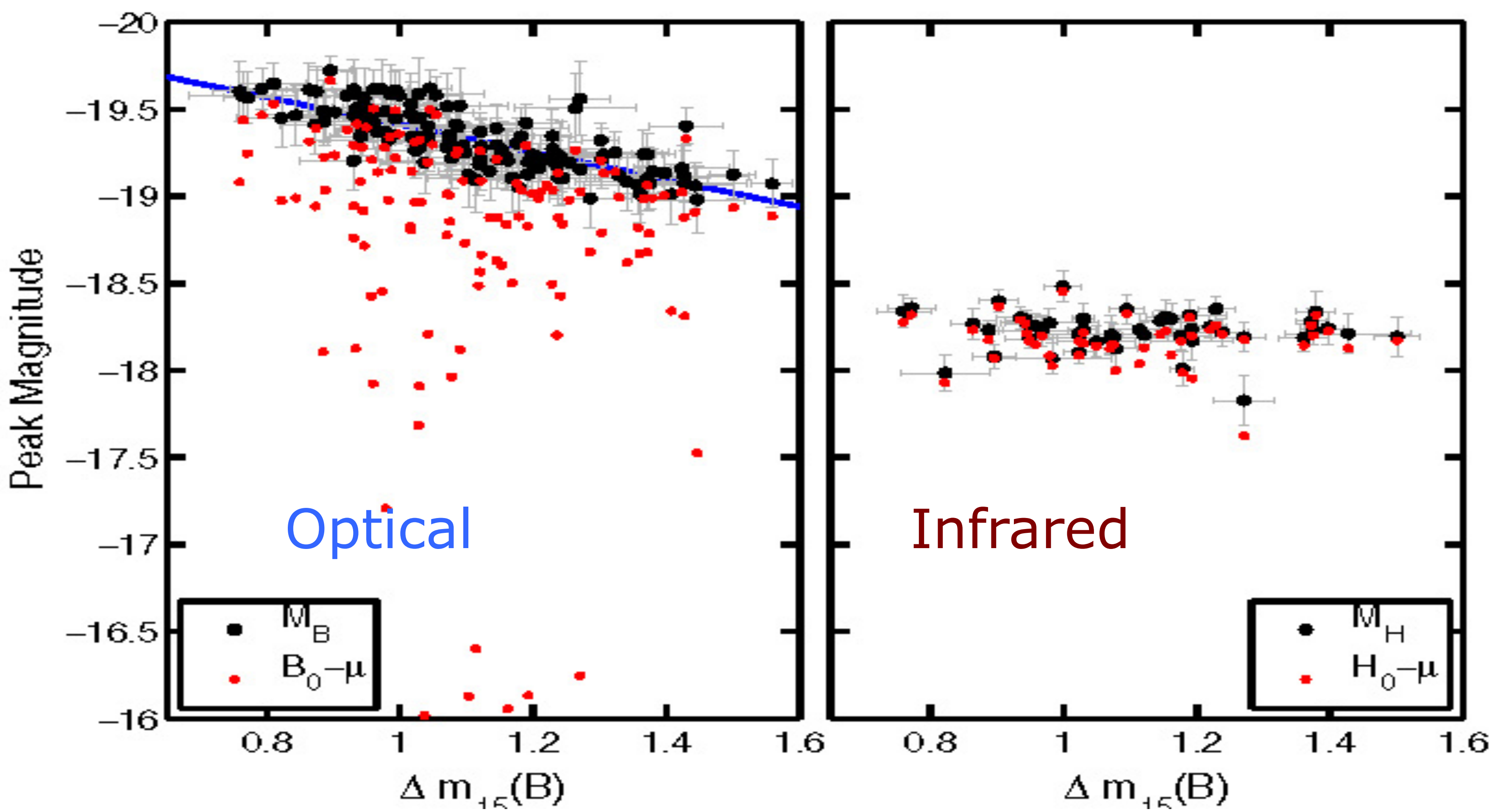
Heirarchical Bayesian Analysis

(Savage Award from ISBA)

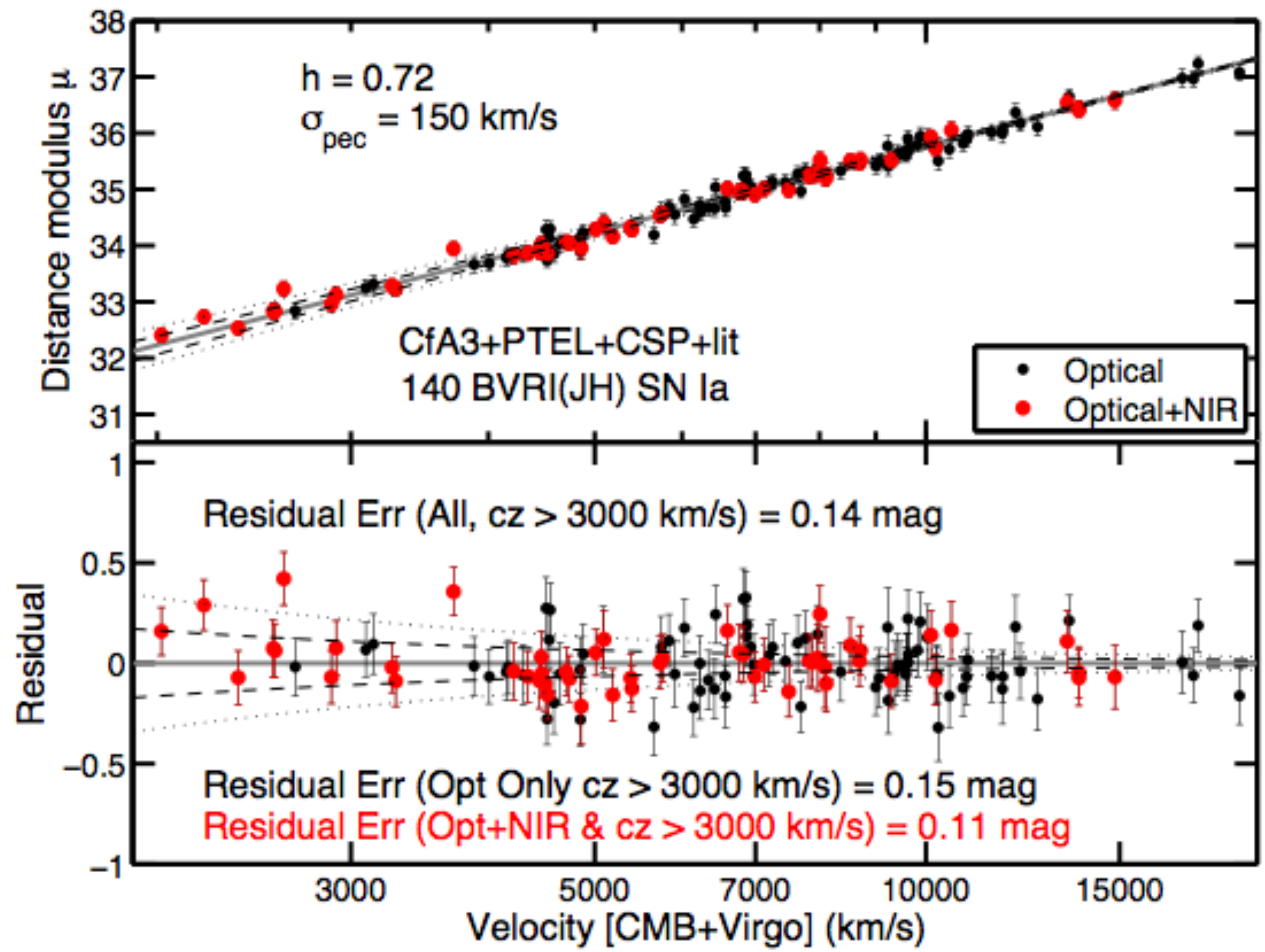
In the IR SN IA really are standard candles!

And there's less trouble with dust.

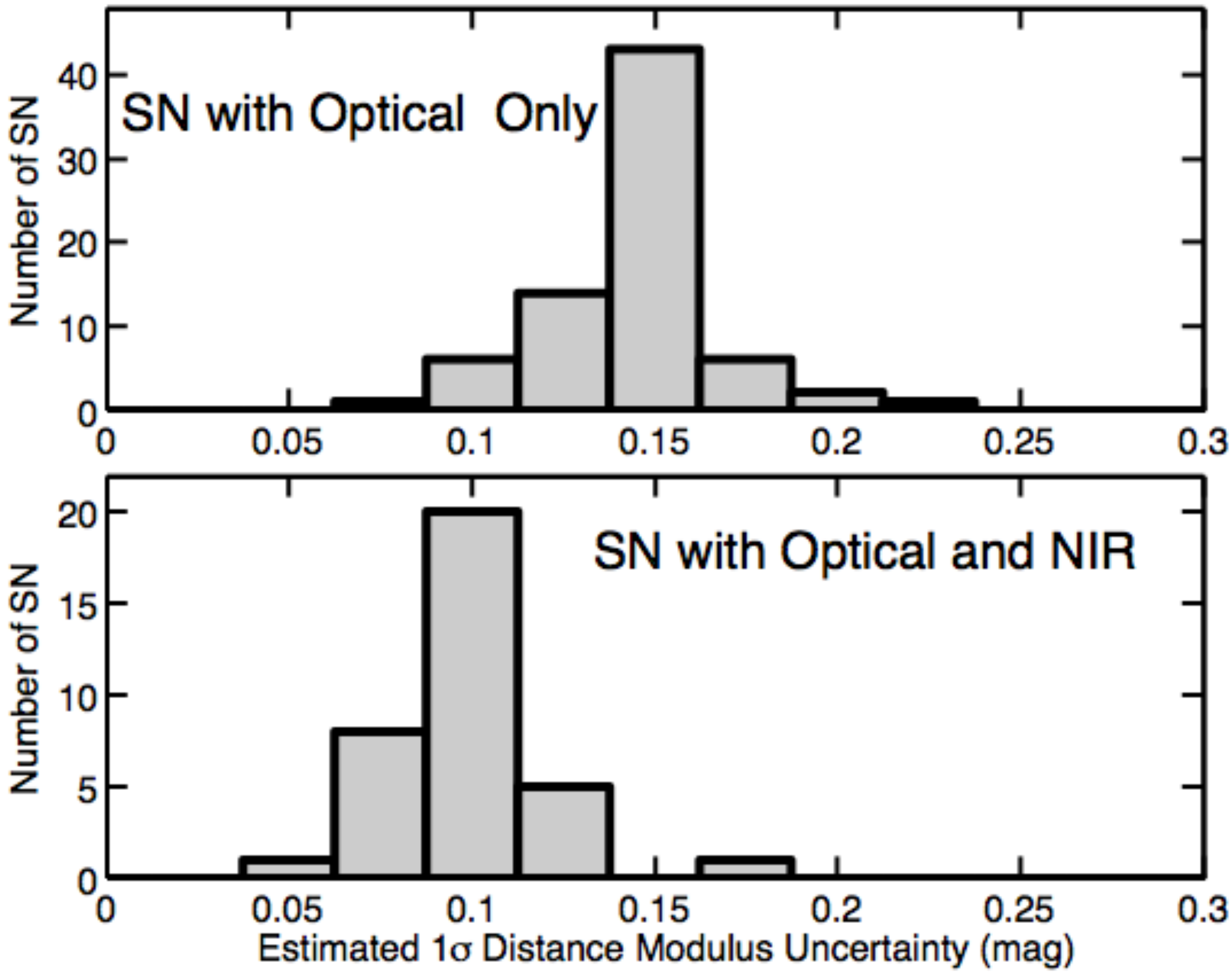
THE ASTROPHYSICAL JOURNAL, 731:120 (26pp), 2011 April 20



The payoff for nearby supernovae: (CfAIR2 (arXiv 1408.0465) + Carnegie data in hand to double this sample)



Could we get this 2x advantage for the high-z supernovae? RAISIN

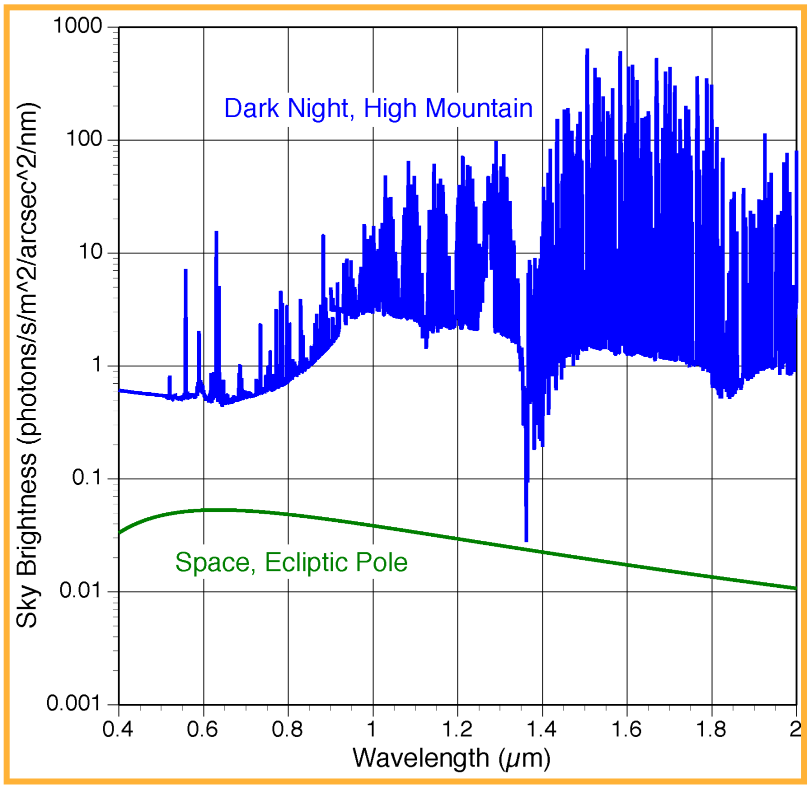


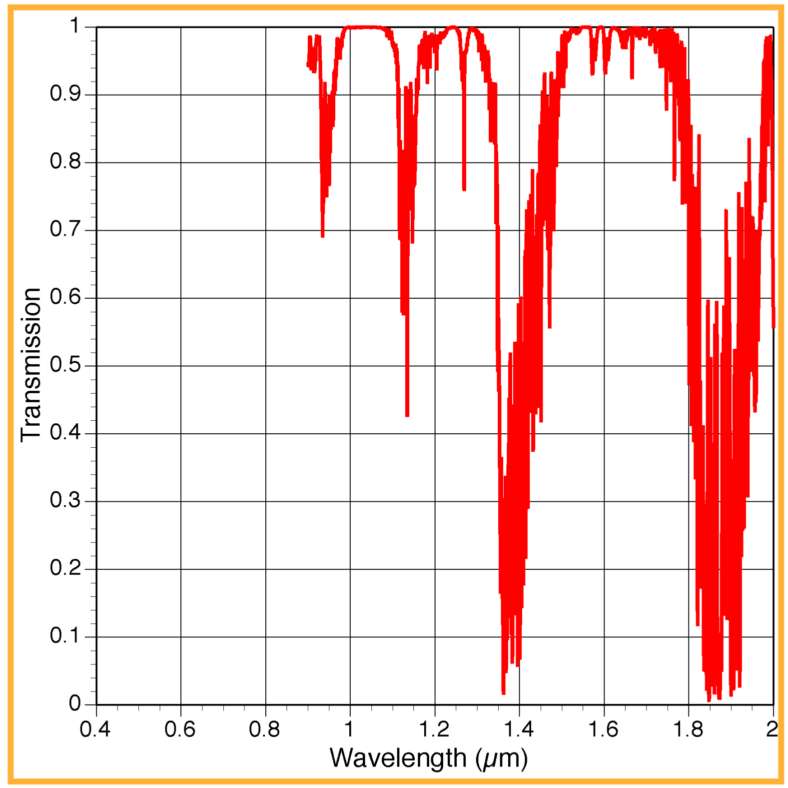
Only in space!

Good precision IR measurements (3%) of cosmologically-interesting supernovae are not possible from the ground

This is what WFIRST will do by the boatload

We are doing a little now– could help shape WFIRST





Prof. Robert P. Kirshner : RAISIN: Tracers of cosmic expansion with SN IA in the IR

Investigators:

AWARDED 100 Orbits Cycle 20/21

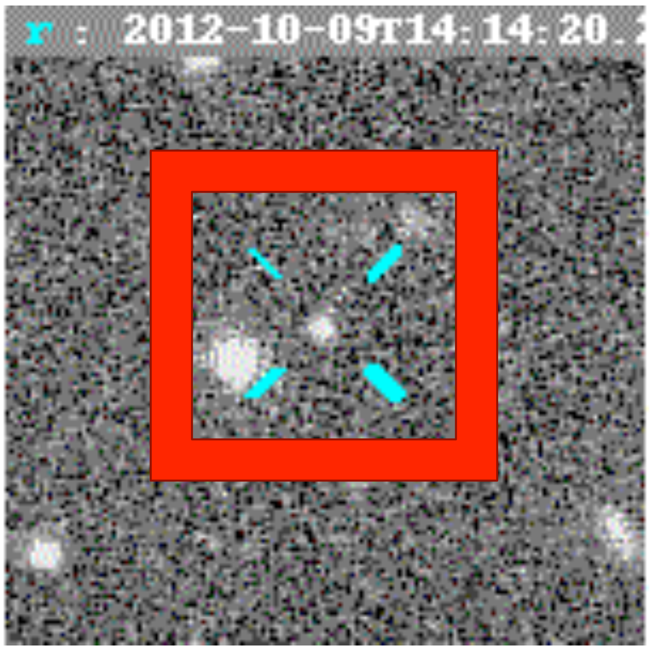
	Investigator	Institution	Country
PI	Prof. Robert P. Kirshner	Harvard University	USA/MA
CoI	Mr. Peter Challis	Harvard University	USA/MA
CoI	Dr. Ryan Chornock	Harvard University	USA/MA
CoI	Dr. Wendy L. Freedman	Carnegie Institution of Washington	USA/DC
CoI	Dr. Peter Garnavich	University of Notre Dame	USA/IN
CoI	Dr. Ryan Foley	Smithsonian Institution Astrophysical Observatory	USA/MA
CoI	Dr. Joshua Frieman	University of Chicago	USA/IL
CoI	Dr. Andrew Friedman	Harvard Universitysity	USA/MA
CoI	Dr. Eric Hsiao	Carnegie Institution of Washington	USA/DC
CoI	Dr. Mark E. Huber	University of Hawaii	USA/HI
CoI	Mr. David Oscar Jones	The Johns Hopkins University	USA/MD
CoI	Dr. G. H. Marion	Harvard University	USA/MA
CoI*	Dr. Kaisey Mandel	Imperial College London	GBR
CoI	Mr. Gautham Narayan	Harvard University	USA/MA
CoI*	Prof. Bob Nichol	University of Portsmouth	GBR
CoI	Dr. Mark M. Phillips	Carnegie Institution of Washington	USA/DC
CoI	Dr. Adam Riess	The Johns Hopkins University	USA/MD
CoI	Dr. Steven A. Rodney	The Johns Hopkins University	USA/MD
CoI	Dr. Armin Rest	Space Telescope Science Institute	USA/MD
CoI	Prof. Masao Sako	University of Pennsylvania	USA/PA
CoI	Prof. Christopher W. Stubbs	Harvard University	USA/MA
CoI	Dr. John L. Tonry	University of Hawaii	USA/HI
CoI	Prof. Michael Wood-Vasey	University of Pittsburgh	USA/PA

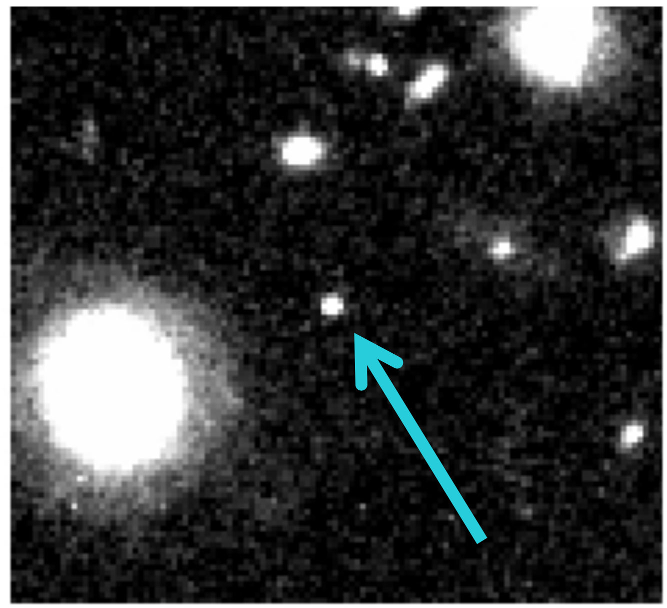
Number of investigators: 23

SN IA in the IR = RAISIN

WFIRST Science NOW with a 2.4 m IR telescope

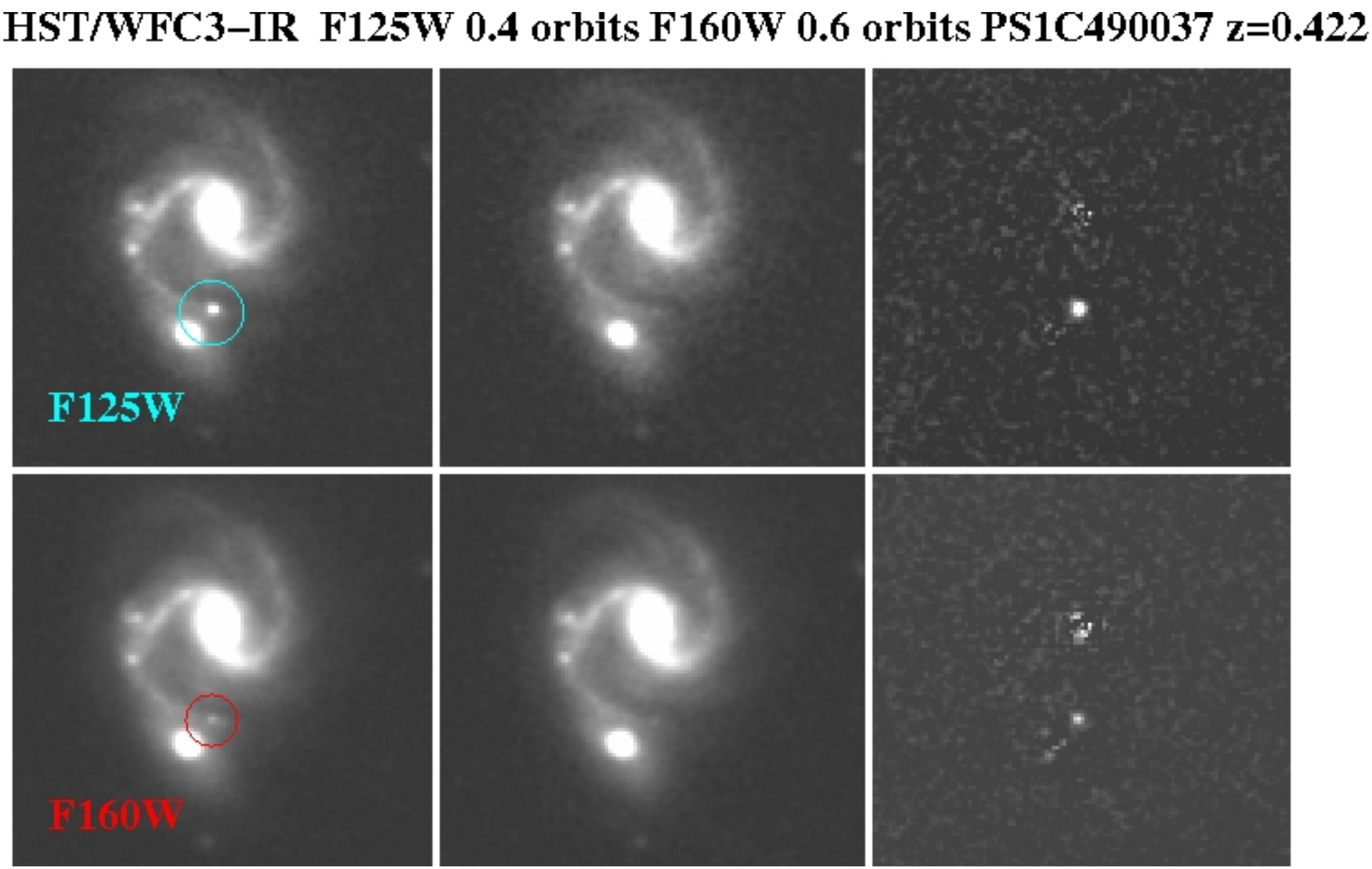
Get IR with WFC3

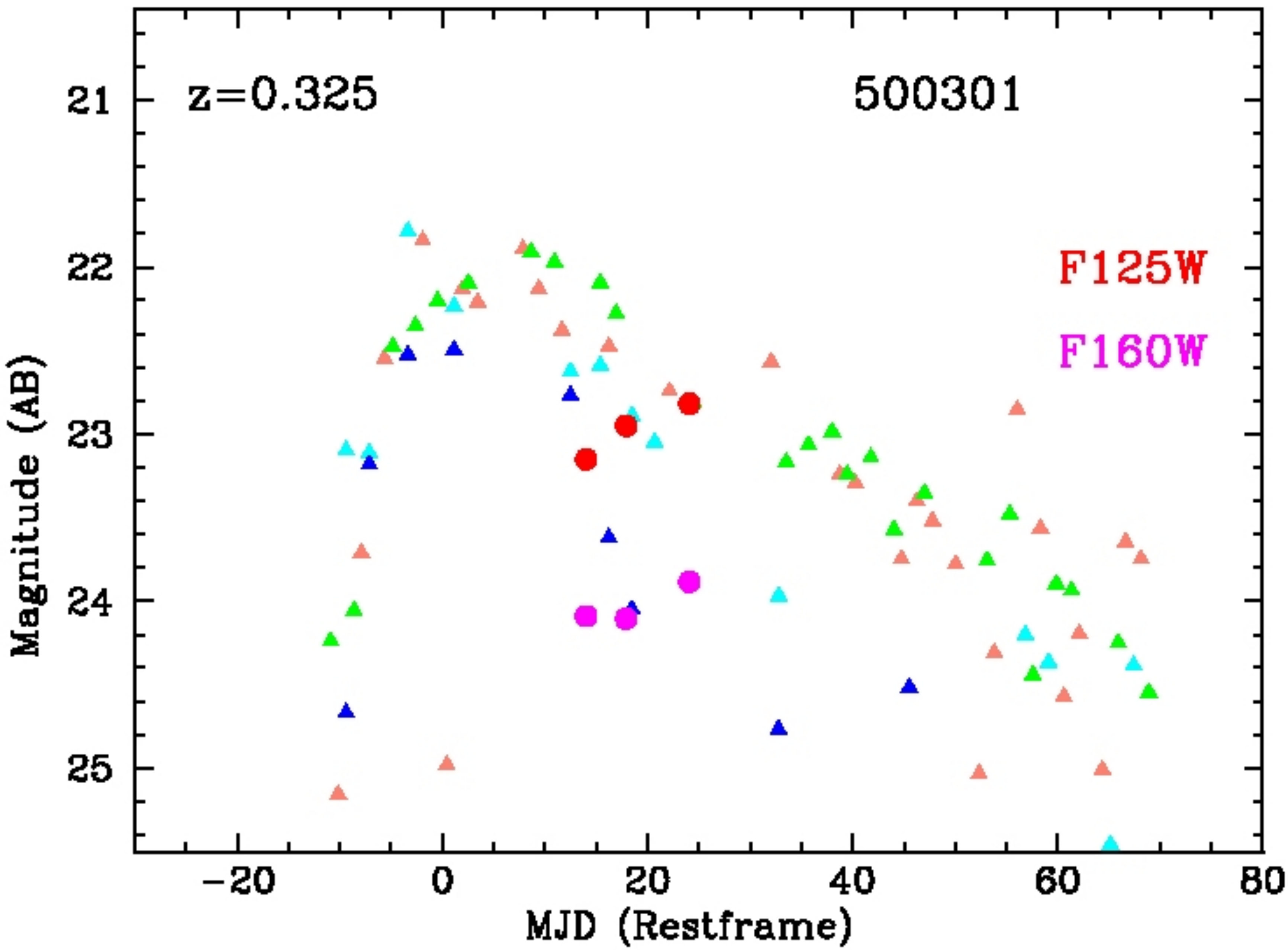


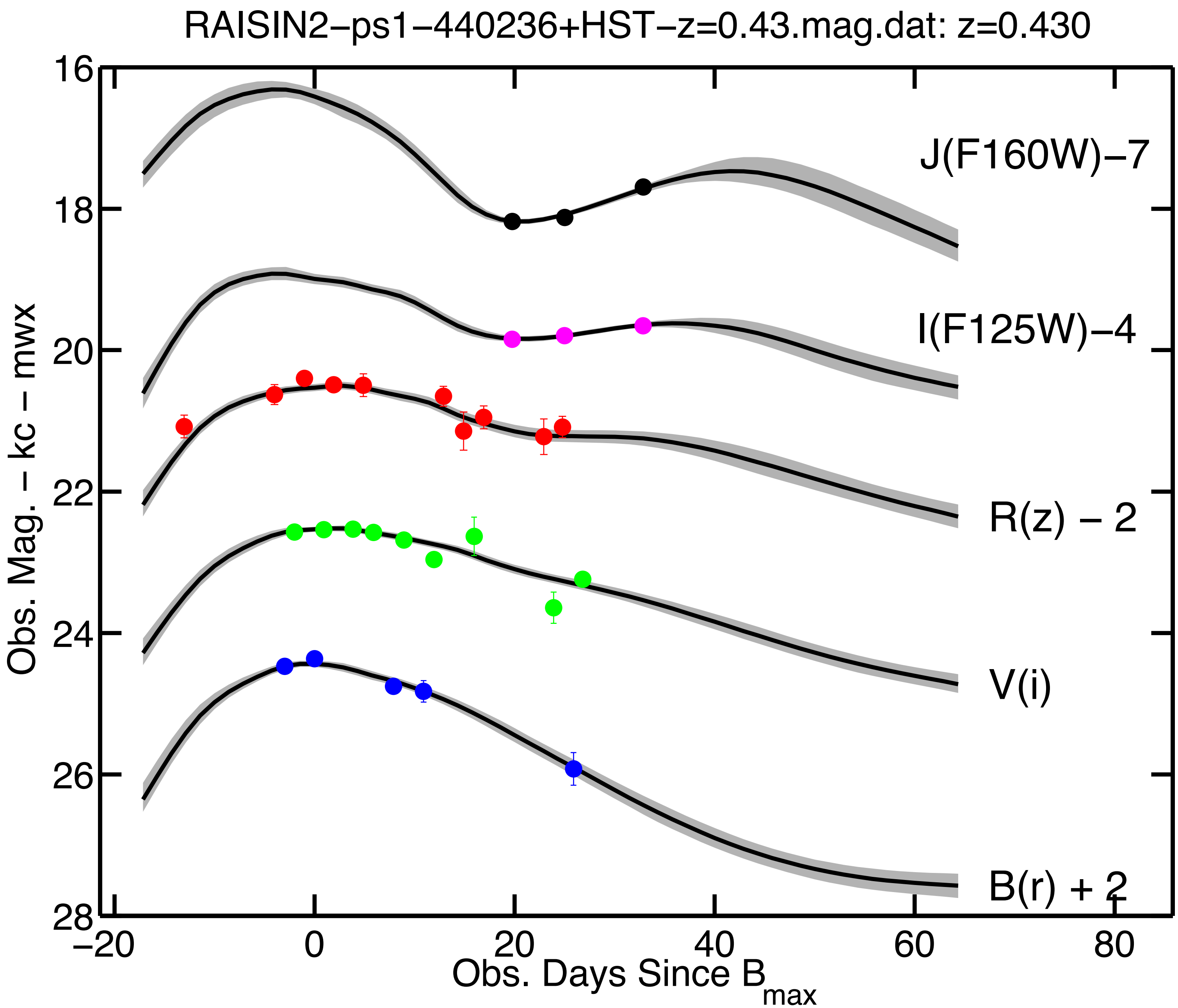


Goal: better knowledge of dark energy by avoiding systematic errors

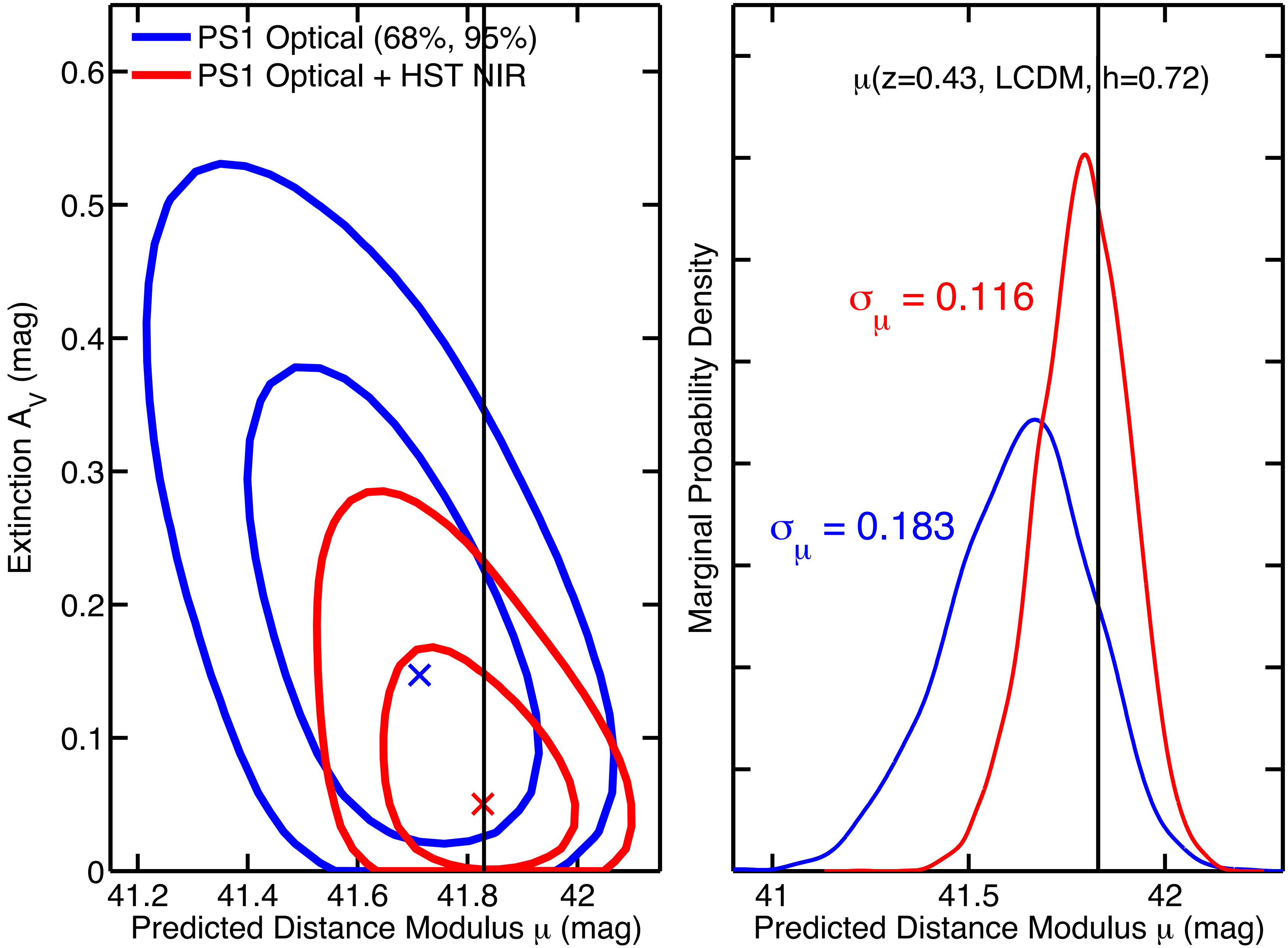
Template subtraction works well



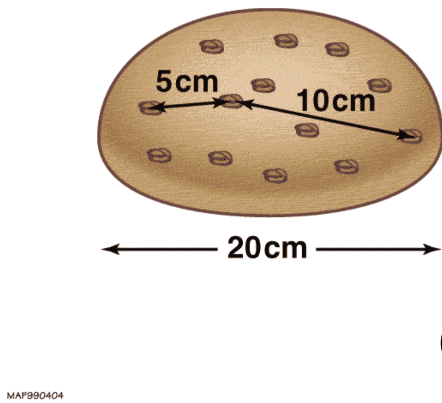

z=0.325
500301
F125W
F160W
Magnitude (AB)
21
22
23
24
25
-20
0
20
40
60
80
MJD (Restframe)



RAISIN2−ps1−440236+HST−z=0.43.mag.dat: z=0.430
J(F160W)−7
I(F125W)−4
R(z) − 2
V(i)
B(r) + 2
16
18
20
22
24
26
28
−20
0
20
40
60
80
Obs. Mag. − kc − mwx
Obs. Days Since B_max



PS1 Optical (68%, 95%)
PS1 Optical + HST NIR
Extinction A_V (mag)
0.6
0.5
0.4
0.3
0.2
0.1
0
41.2
41.4
41.6
41.8
42
Predicted Distance Modulus μ (mag)
μ(z=0.43, LCDM, h=0.72)
Marginal Probability Density
σ_μ = 0.116
σ_μ = 0.183
41
41.5
42
Predicted Distance Modulus μ (mag)



RAISIN Scorecard

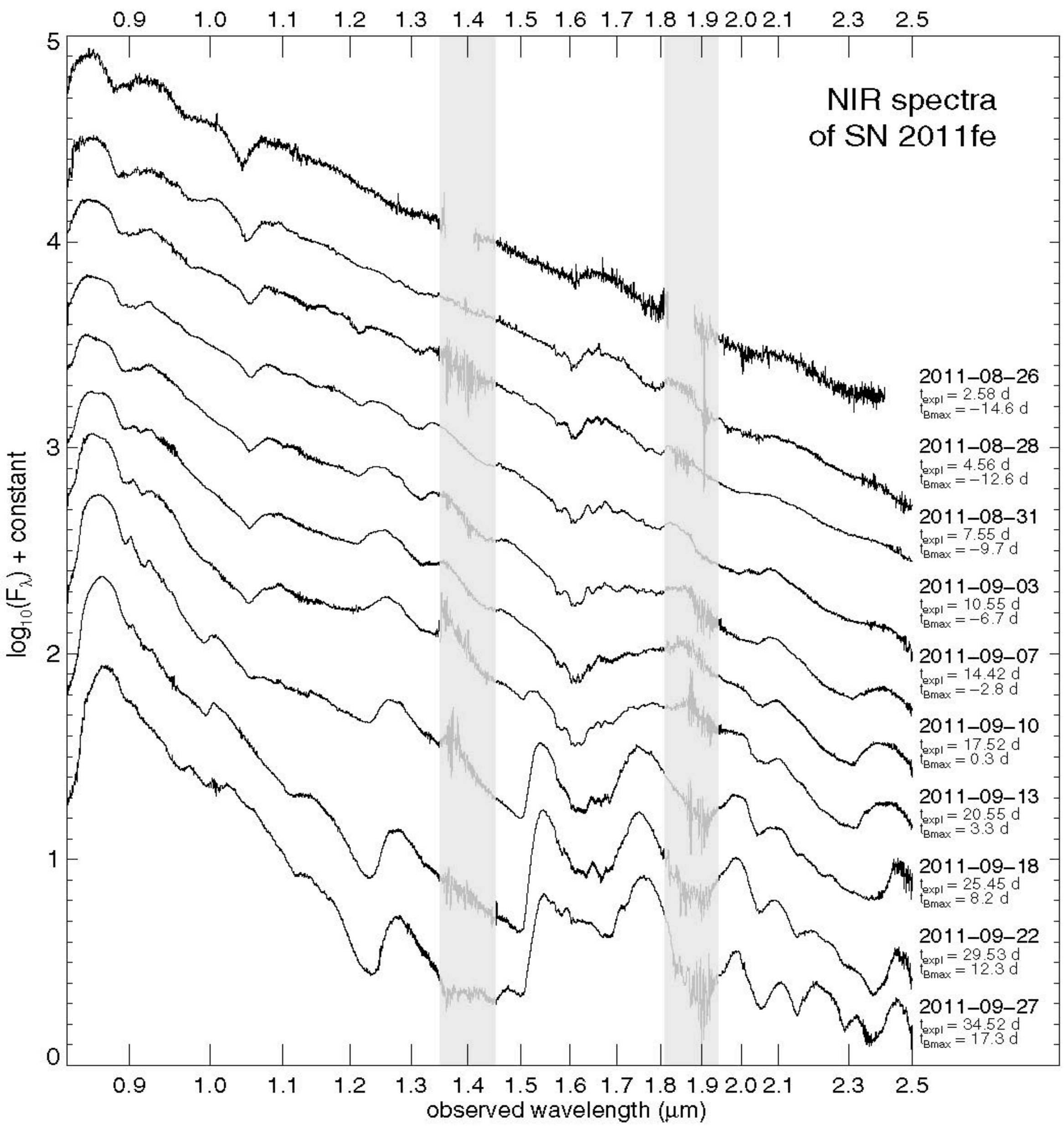
23 PanSTARRS targets—good optical light curves

3 epochs of IR with HST in two near-IR bands

Images <u>without</u> the supernovae complete

Light curves in hand
K-corrections underway

IR Spectra– needed for k-corrections



Eric Hsiao
Howie Marion
Mark Phillips
RPK

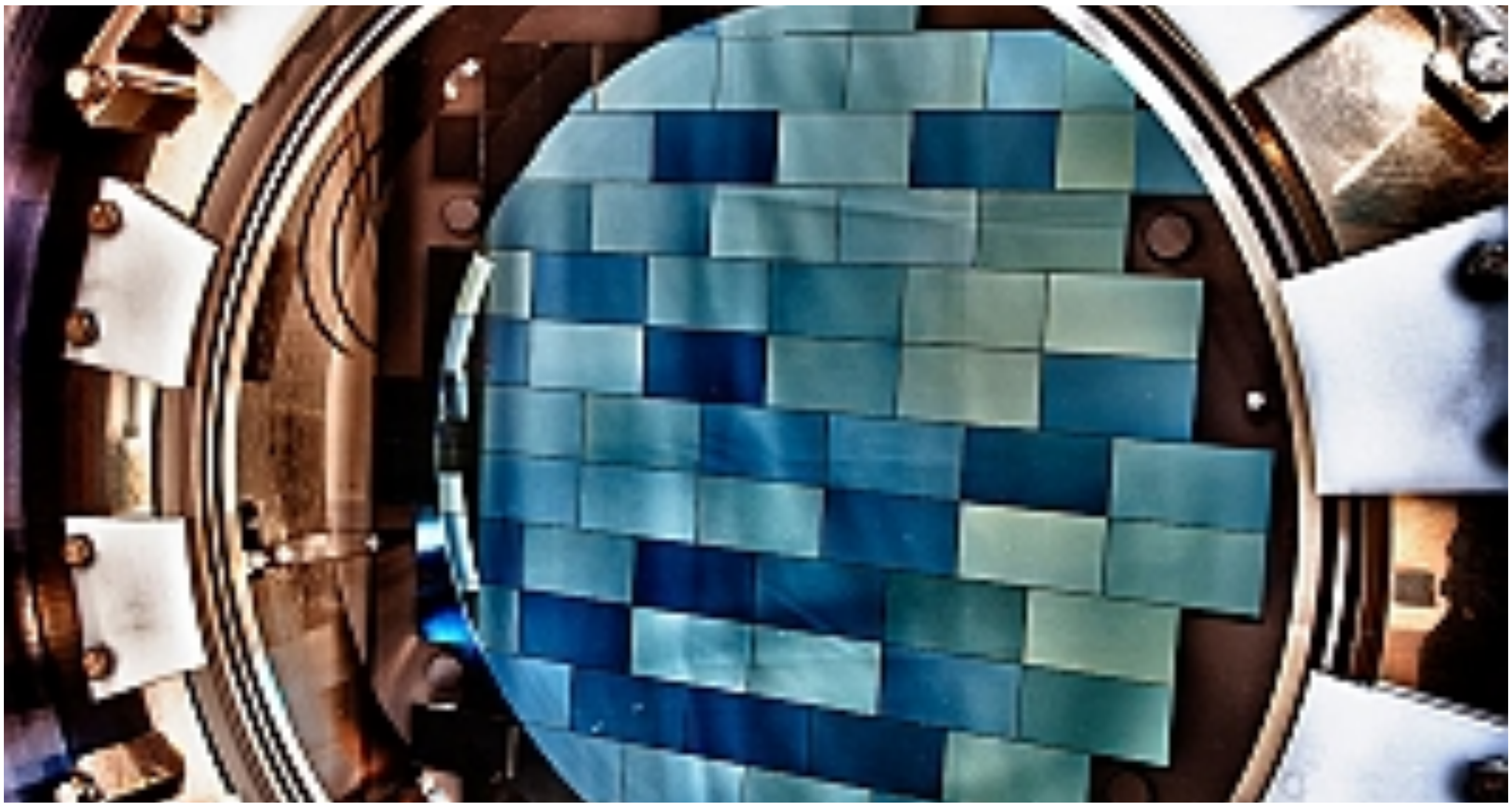
Large collection of IR Spectra using Gemini and the FIRE Spectrograph at Magellan

Spectral evolution for SN Ia of various decline rates & luminosities

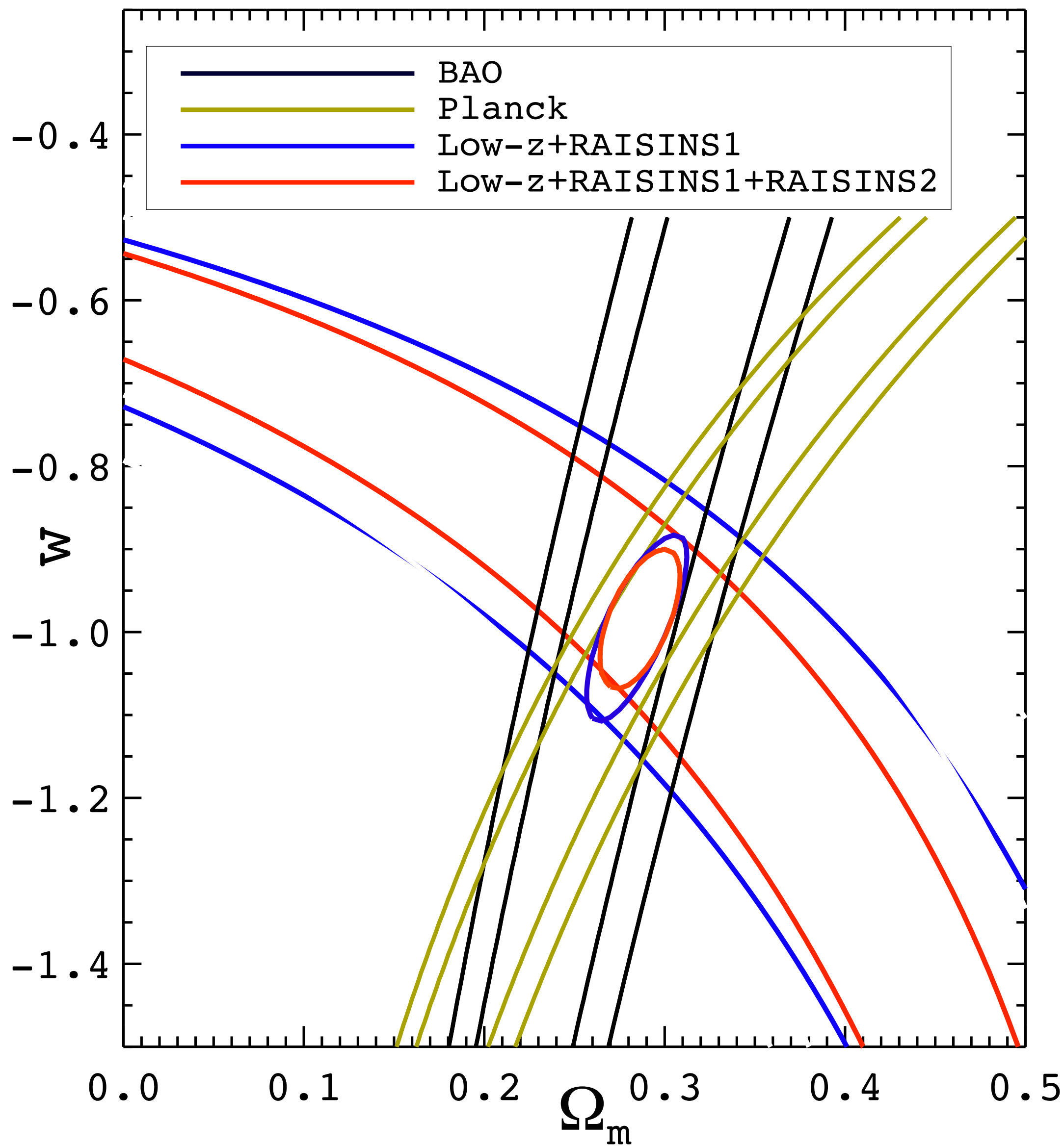
The Future

Dark Energy Survey

External Collaborators: Spectra of SN Ia with MMT & Magellan to demonstrate targets for RAISIN2



More RAISINS, please!



Based on IR + Optical for 25 additional SN Ia at z~0.5 from DES

Low-z from CFAIR2 + Carnegie

Smaller systematic errors in distances based on good behavior of SN Ia in the IR at low-z & at cosmological distances

$\sigma \sim +/- 0.07$
(Betoule $\sigma = +/- 0.06$)

We're learning today how to do WFIRST science:

- ✓ Pioneer methods for combining optical and IR measurements
- ✓ Implement k-corrections
- ✓ Reach state-of-the-art constraints on w with a moderate increase in sample size
- ✓ Lower systematic error due to good behavior of SN Ia in IR

To maximize the redshift range that has the IR advantage with WFIRST, extend the detector wavelength range as far to the red as is feasible

(I band @ z~1 is 1.6μ)

Teasing Uncle Albert