HST RAISINS:
Doing WFIRST Science TODAY!

Robert Kirshner
Harvard University & Gordon and Betty Moore Foundation

Better knowledge of dark energy through **infrared** observations

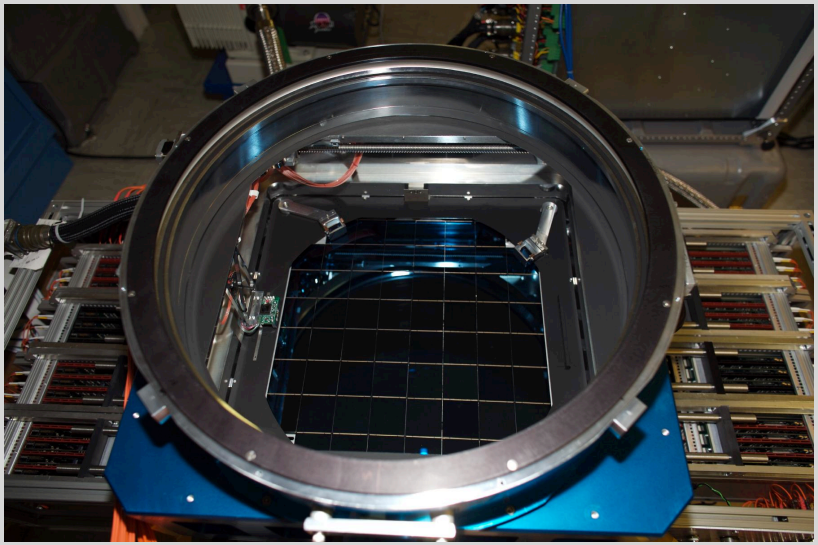
RAISIN1: 24 Targets from Pan-STARRS

Good light curves at z~0.4

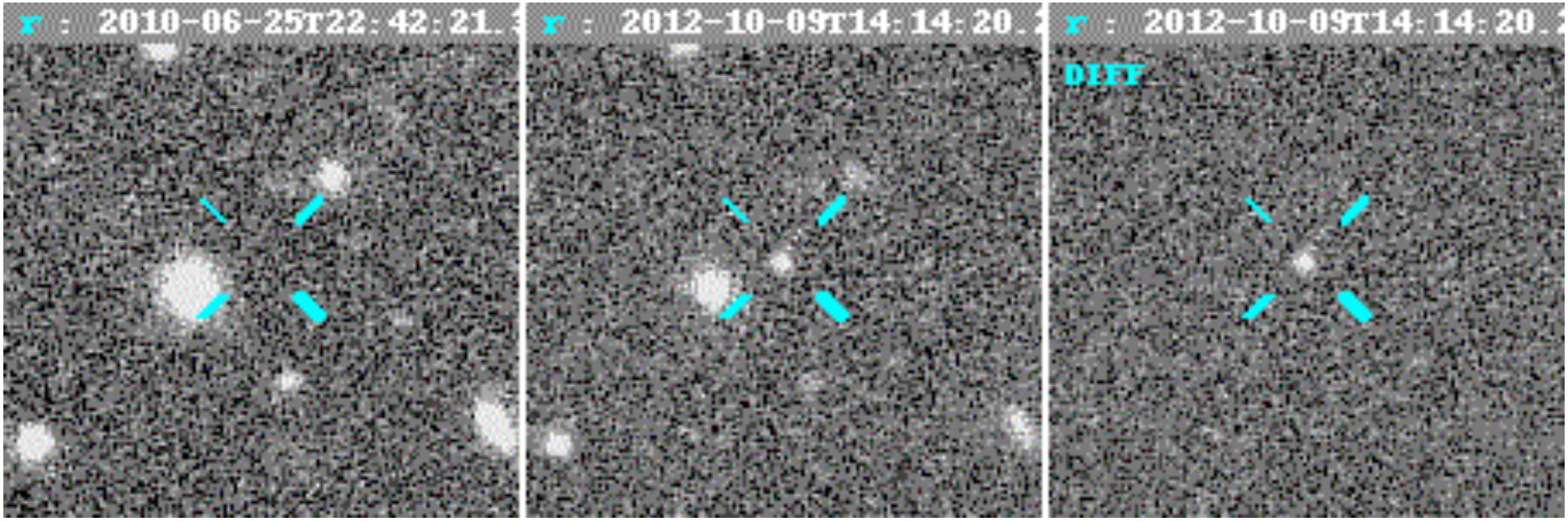
Every 4 days griz

7 square degrees 0.26”/pixel

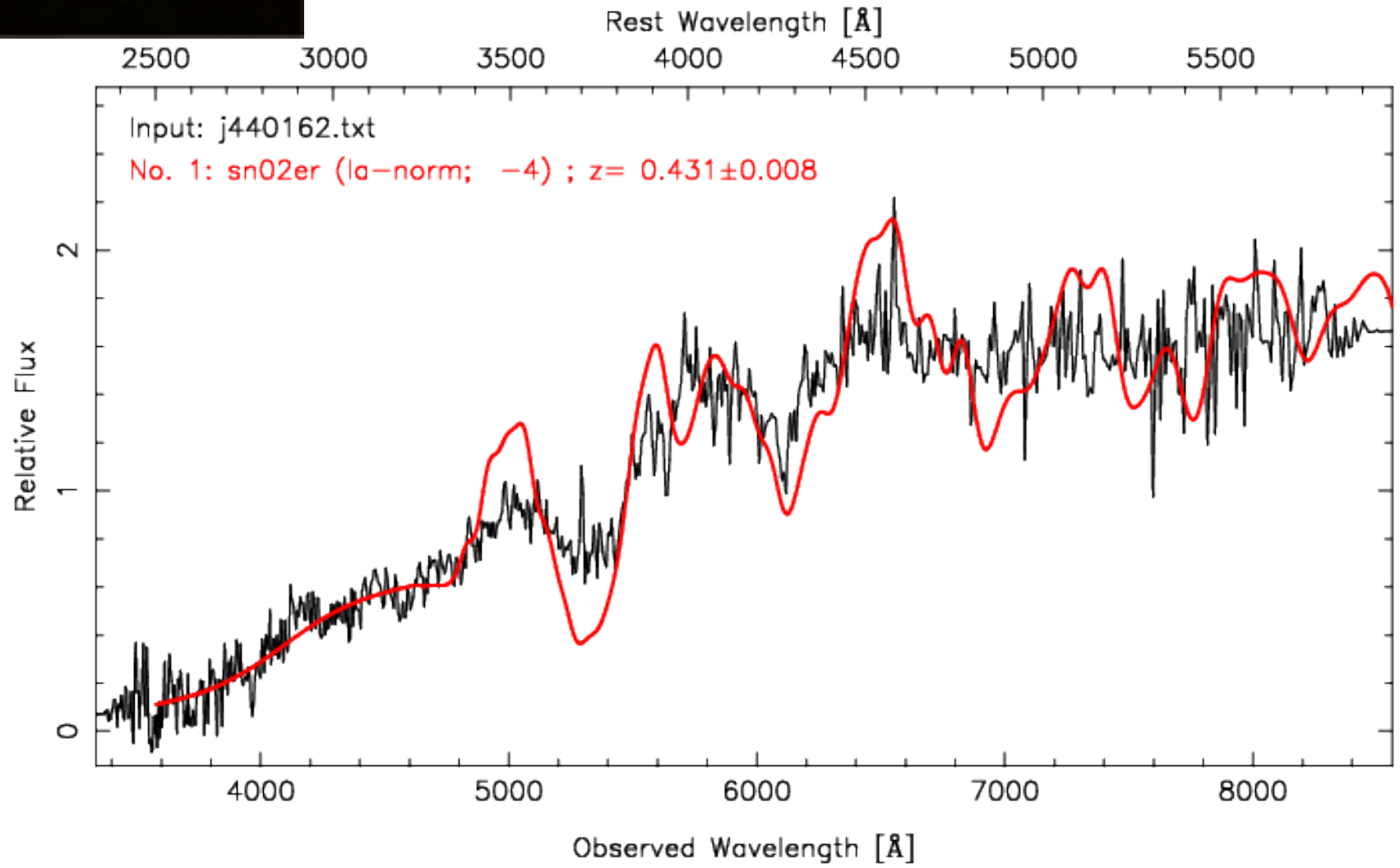
Dozens of supernova candidates every month!

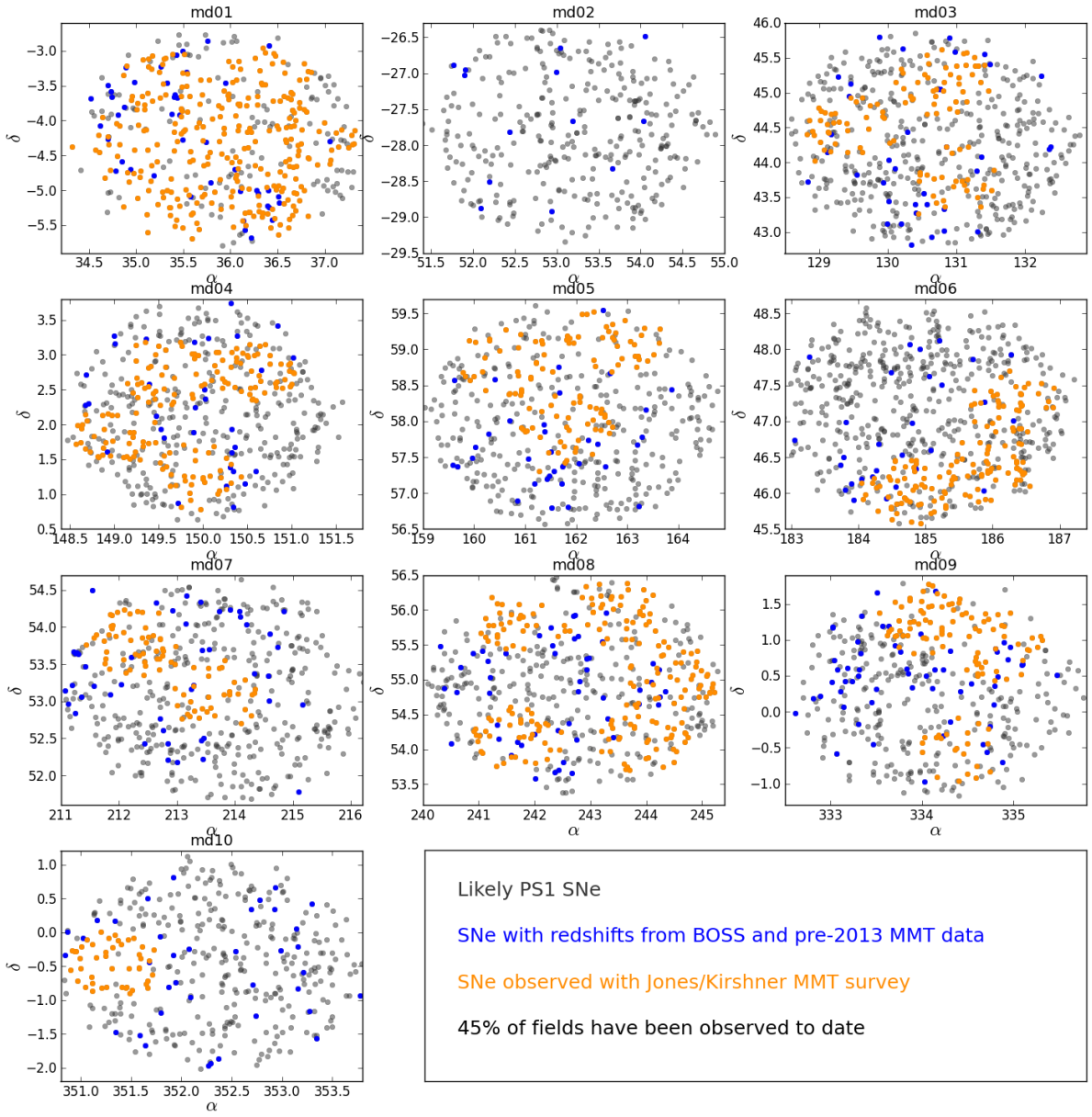


Finding SN Ia with Pan-STARRS



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)

800/1100 spectra in hand

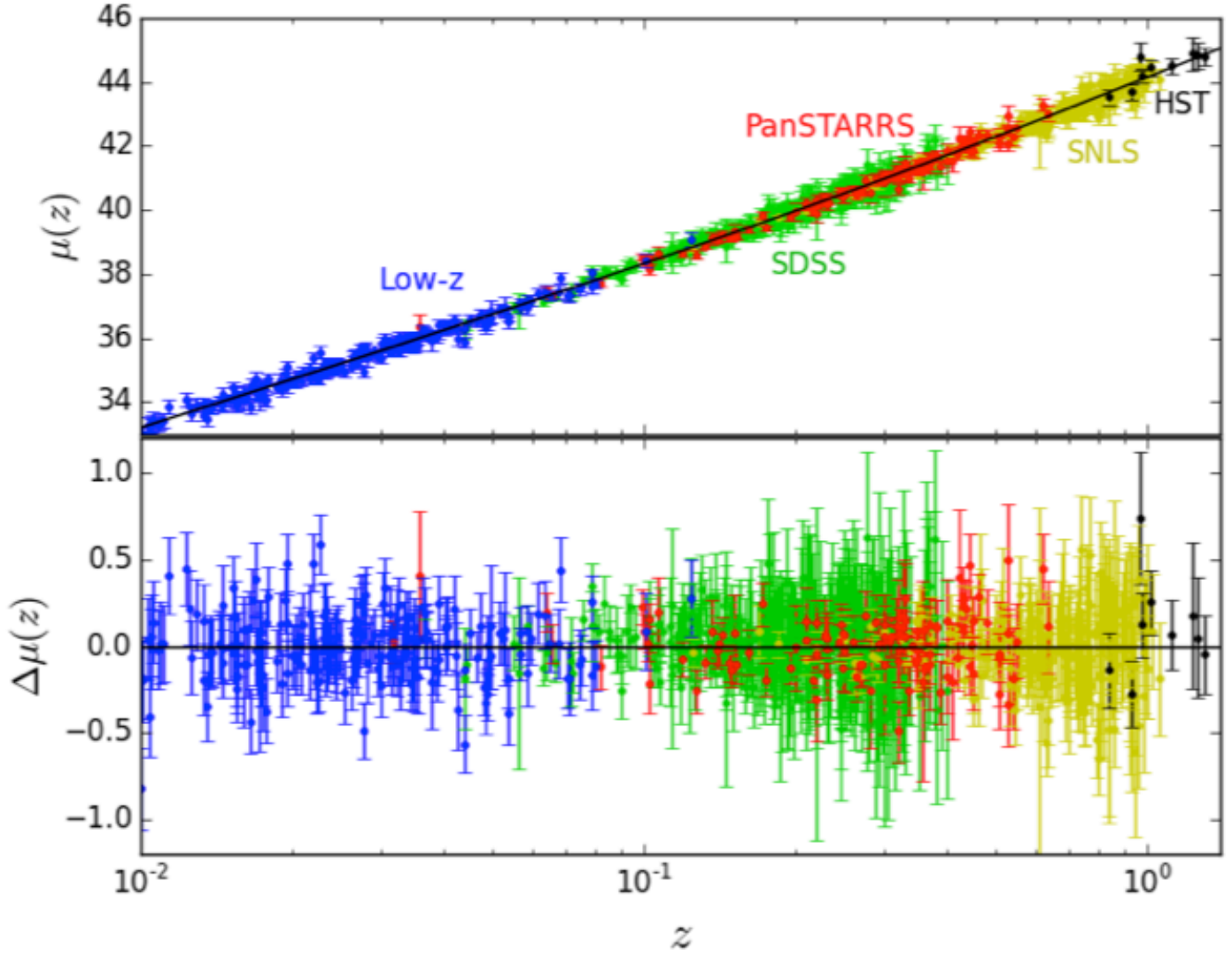


Figure by Arturo Avelino: based on Betoule+ (2014) plus PanSTARRS Rest+ (2014) and Scolnic+ (2014) Low–z is principally based on CfA observations

SN IA in the IR = RAISIN

WFIRST Science with a 2.4 m IR telescope
Cycle 21 & 23

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

Investigators:

AWARDED 100 Orbits Cycle 20/21

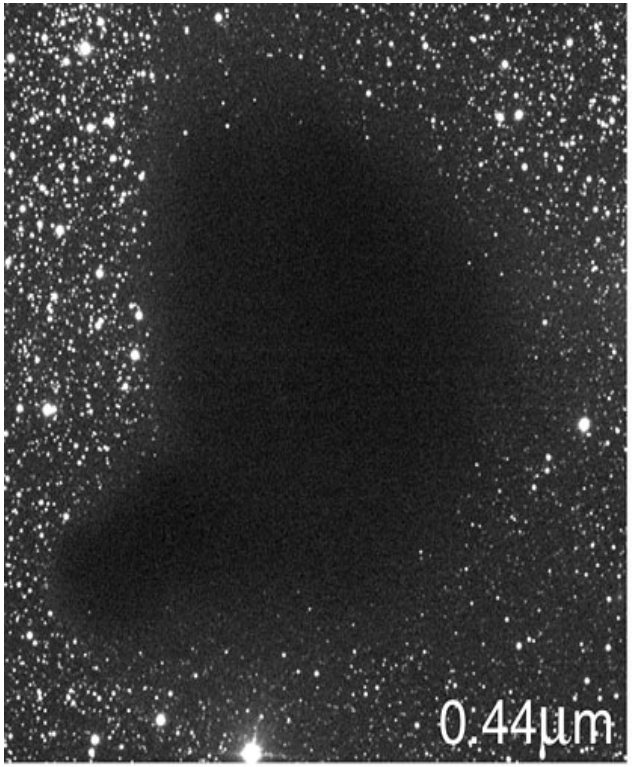
	Investigator	Institution	Country
PI	Prof. Robert P. Kirshner	Harvard University	USA/MA
CoI	Mr. Peter Challis	Harvard University	USA/MA
CoI	Dr. Ryan Chornock	Harvard University	USA/MA
CoI	Dr. Wendy L. Freedman	Carnegie Institution of Washington	USA/DC
CoI	Dr. Peter Garnavich	University of Notre Dame	USA/IN
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


One good reason to observe SN Ia
in the infrared
NASA

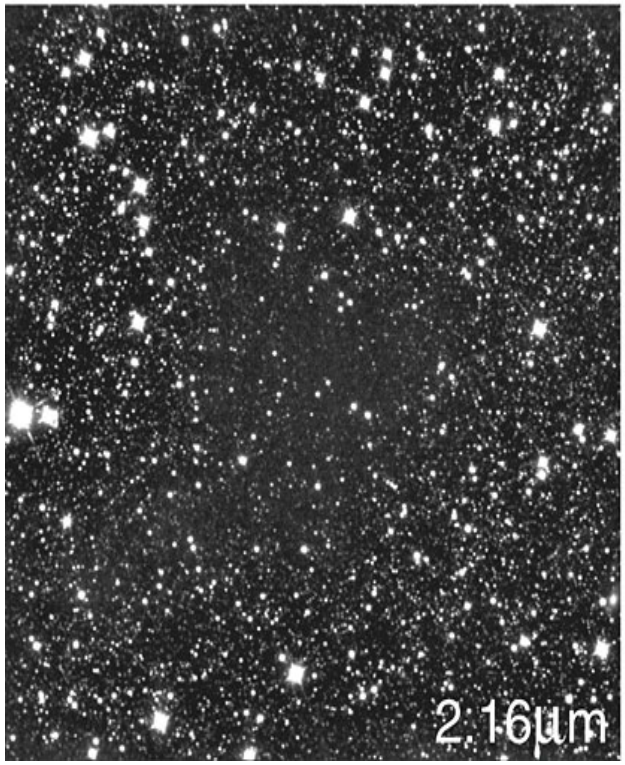
Seeing through the dirt

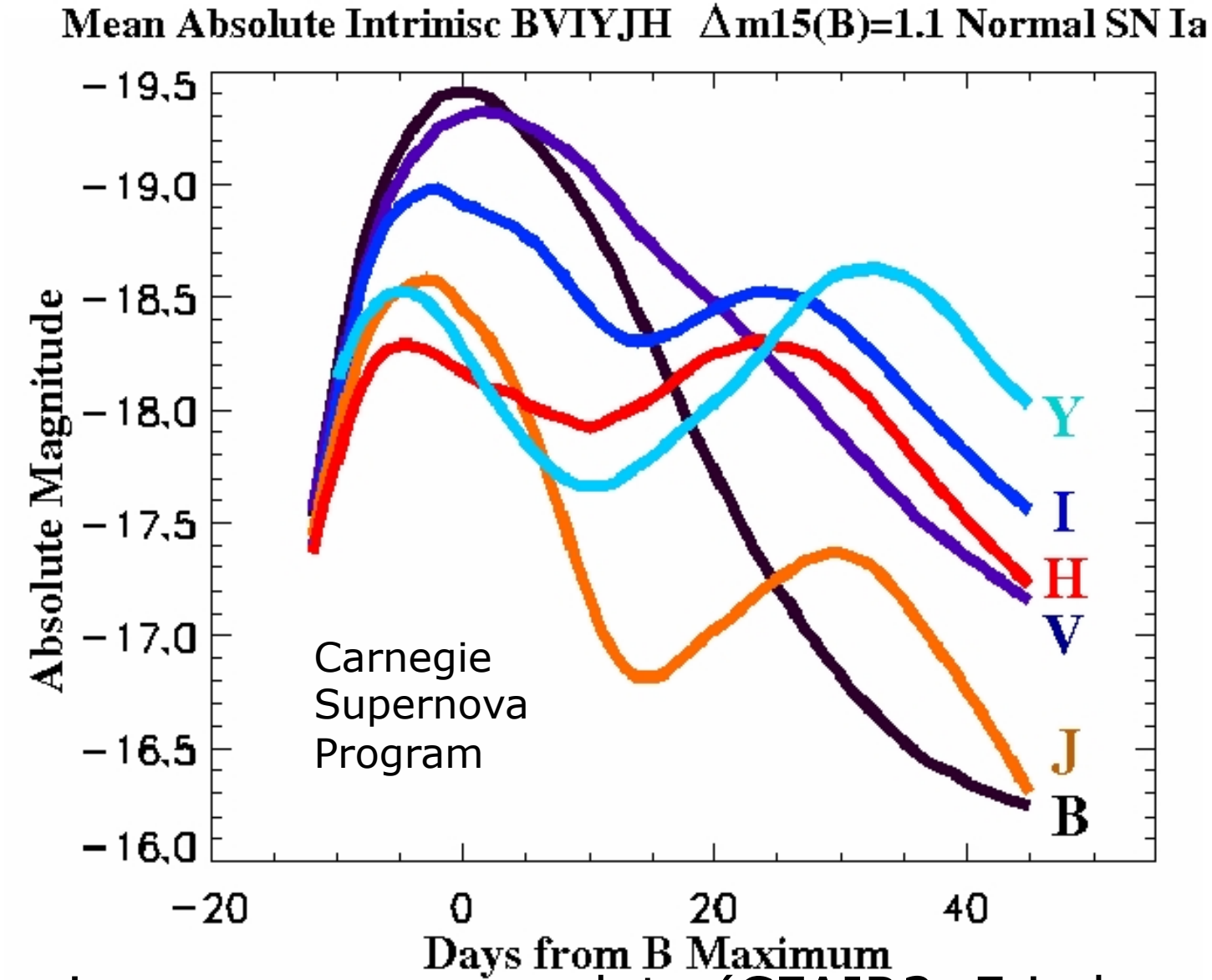
B



Seeing through the dirt

K



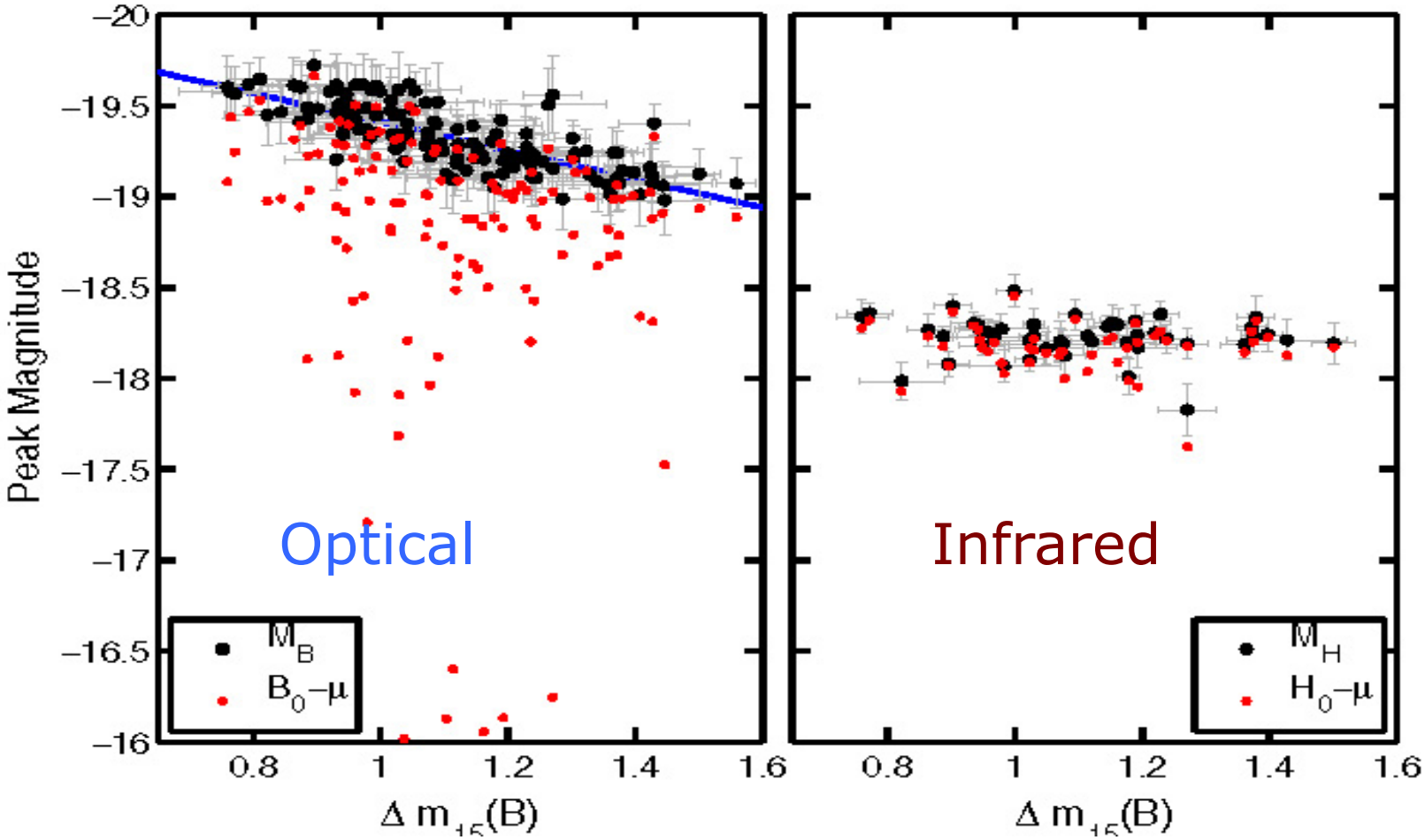


Coming soon: our own data (CFAIR2 Friedman et al. Ap.J.Supp. 220, 9 (2015)) templates by Arturo Avelino

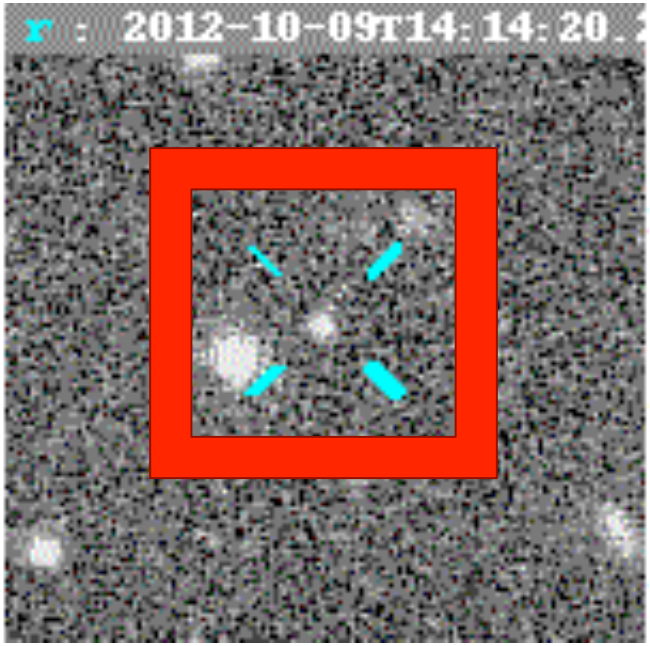
In the IR SN IA really are standard candles!

And there's less trouble with dust.

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

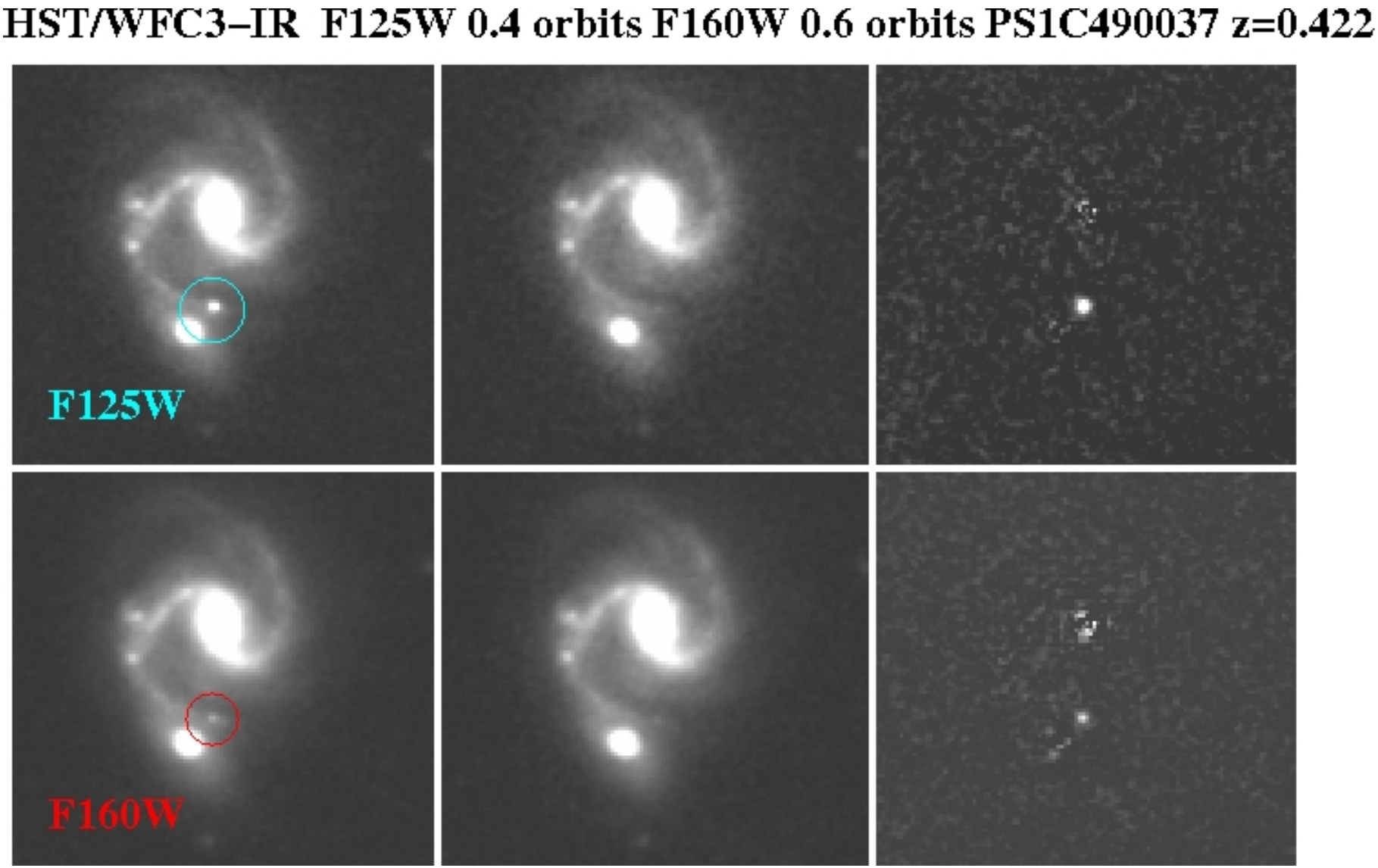


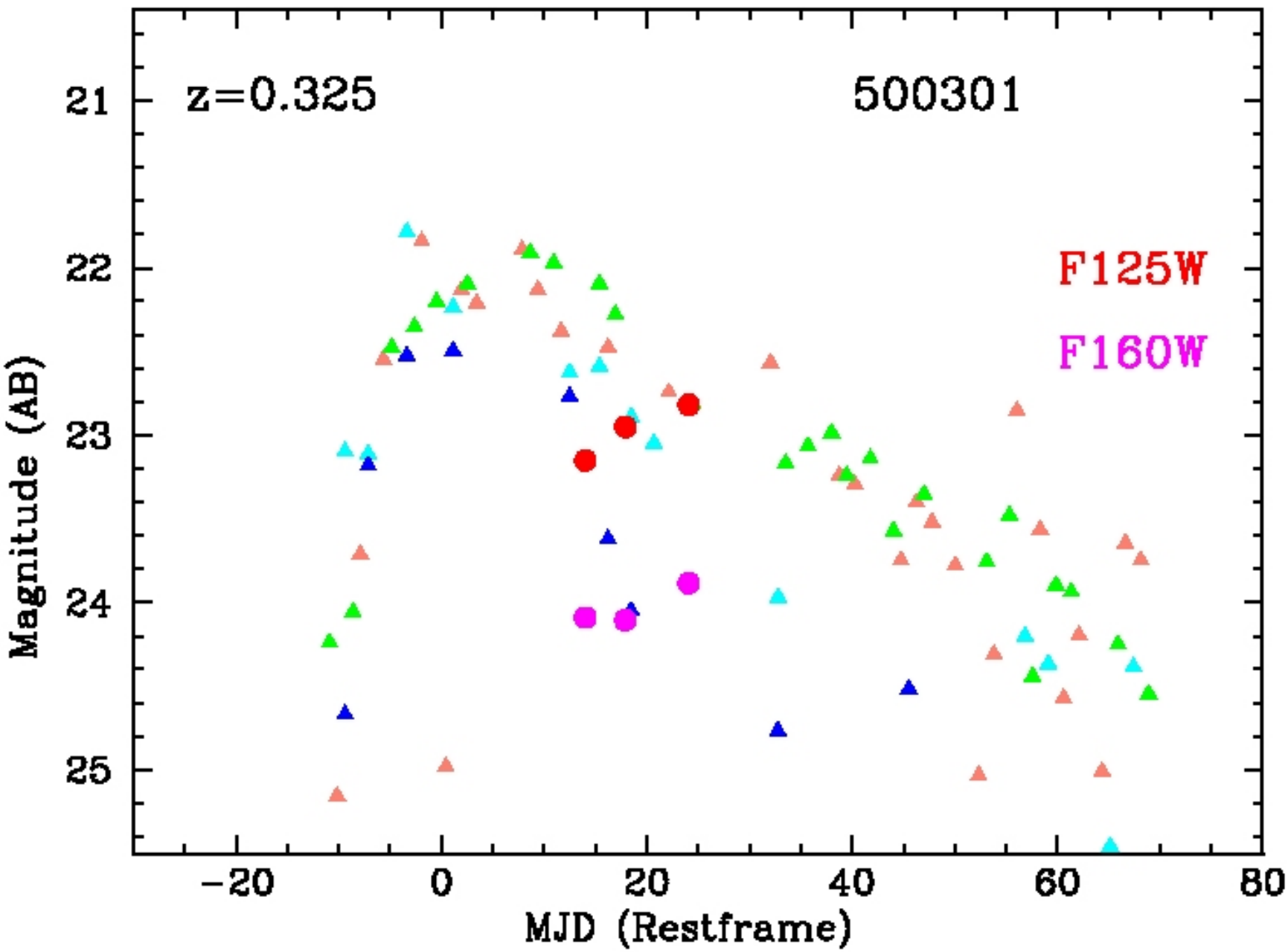
Get IR with WFC3

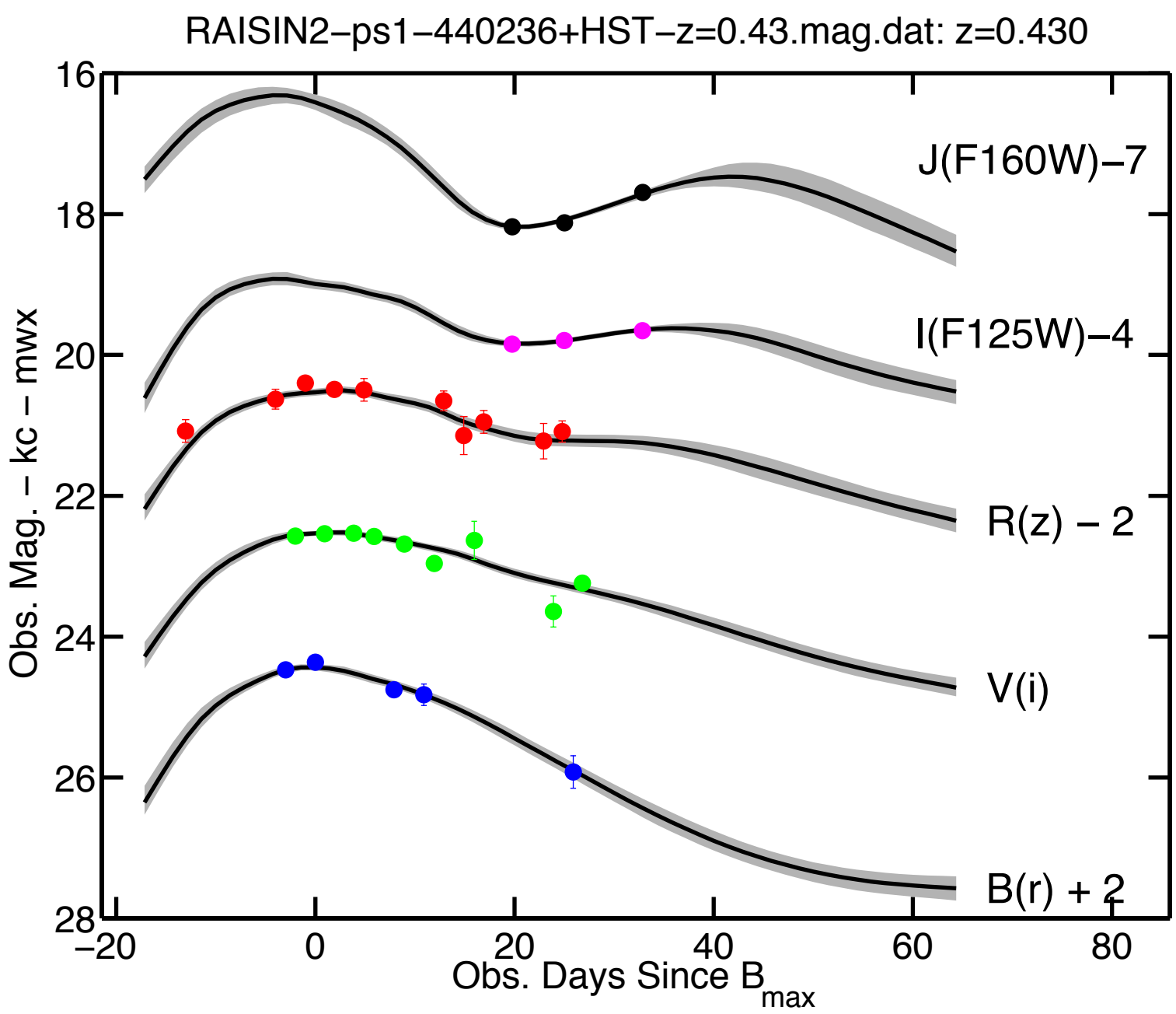


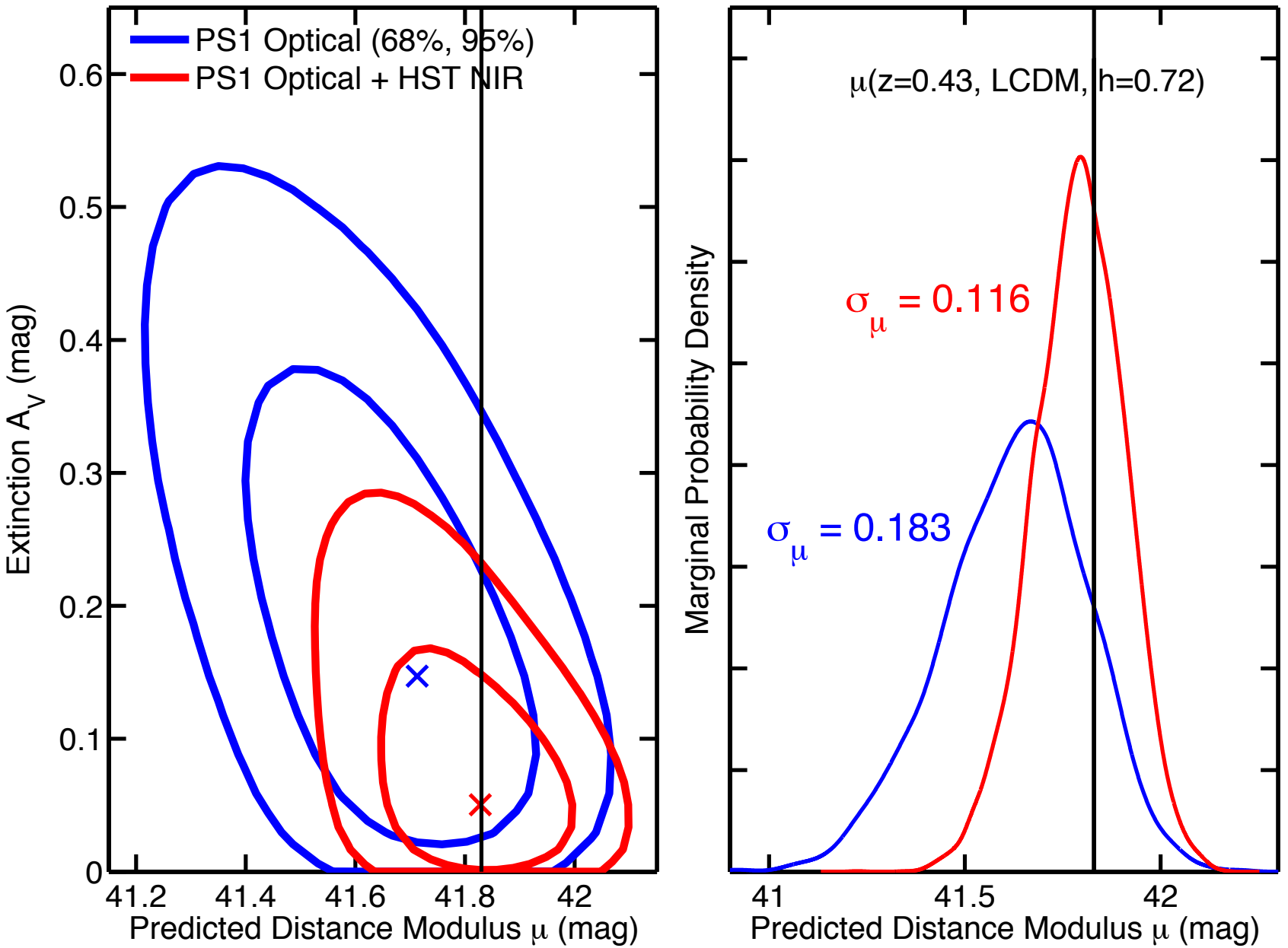
Goal: better knowledge of dark energy by avoiding systematic errors

Template subtraction works well

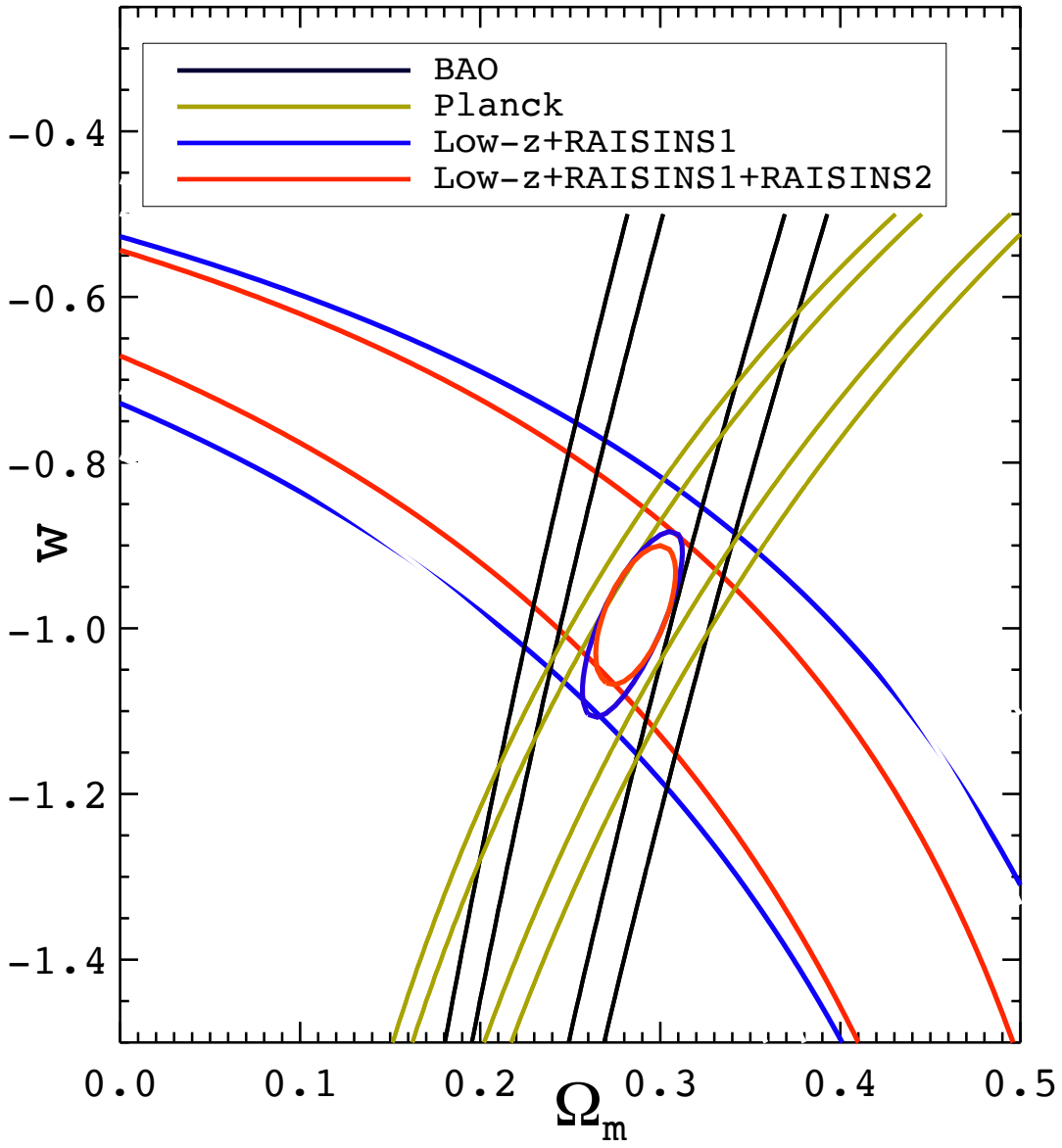



z=0.325
500301
F125W
F160W
Magnitude (AB)
MJD (Restframe)
21
22
23
24
25
−20
0
20
40
60
80


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
Obs. Mag. – kc – mwx
Obs. Days Since B max
16
18
20
22
24
26
28
–20
0
20
40
60
80


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)

More RAISINS, please!



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

Low-z from CFAIR2 + Carnegie

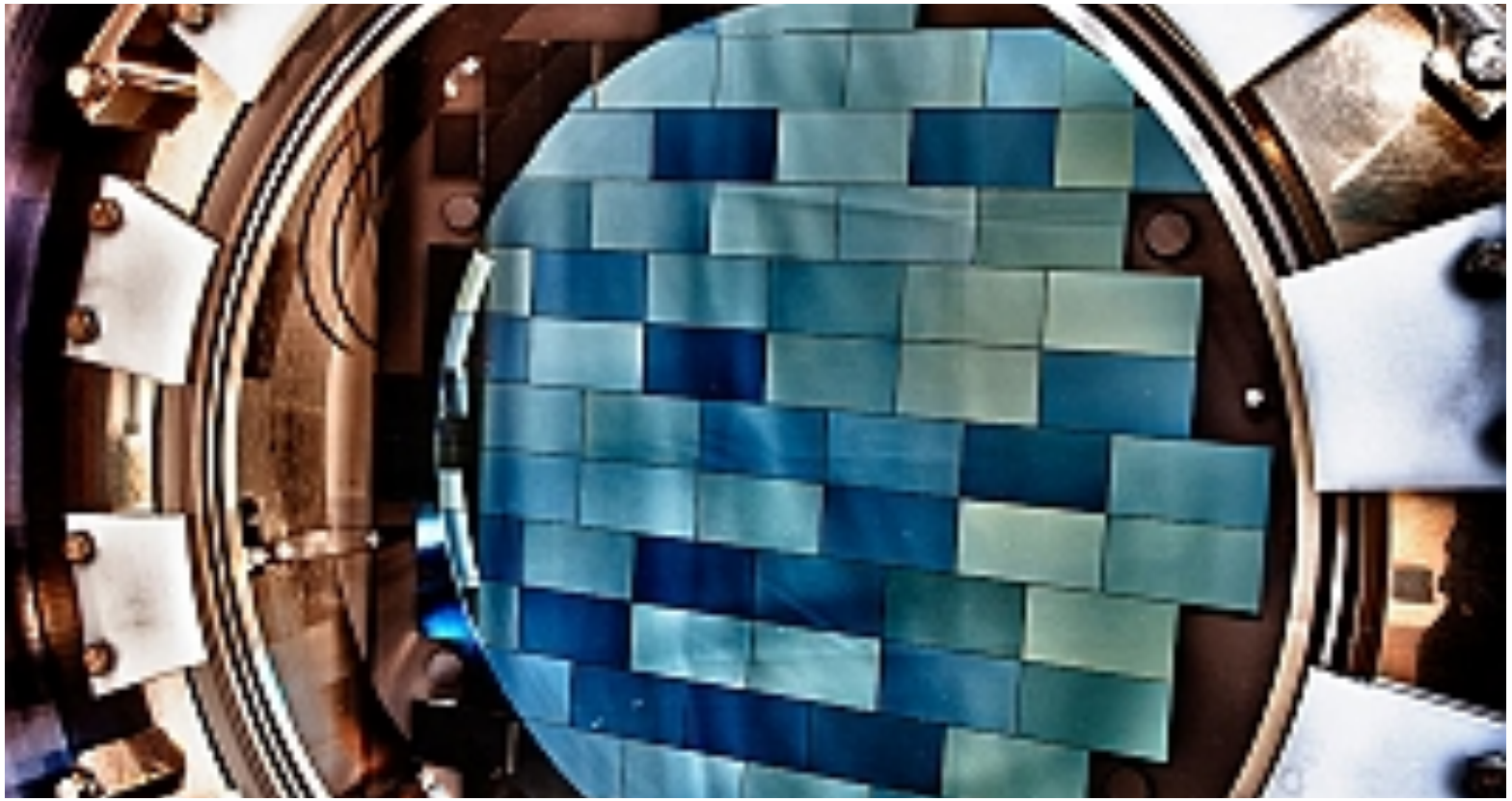
Smaller systematic errors in distances based on good behavior of SN Ia in the IR at low-z & at cosmological distances

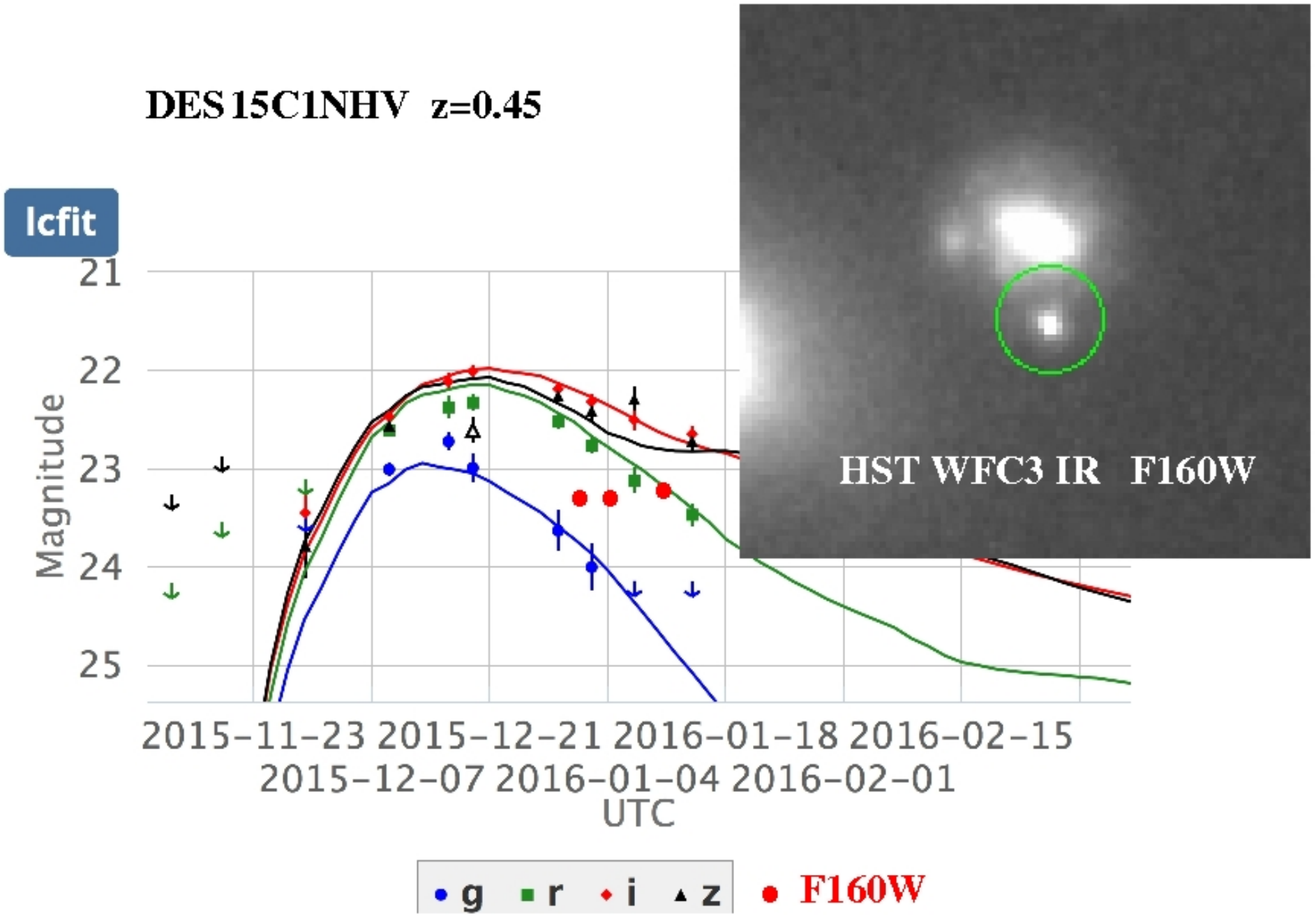
$\sigma \sim +/- 0.07$
(Betoule $\sigma = +/- 0.06$)

Cycle 23: RAISIN2
Dark Energy Survey

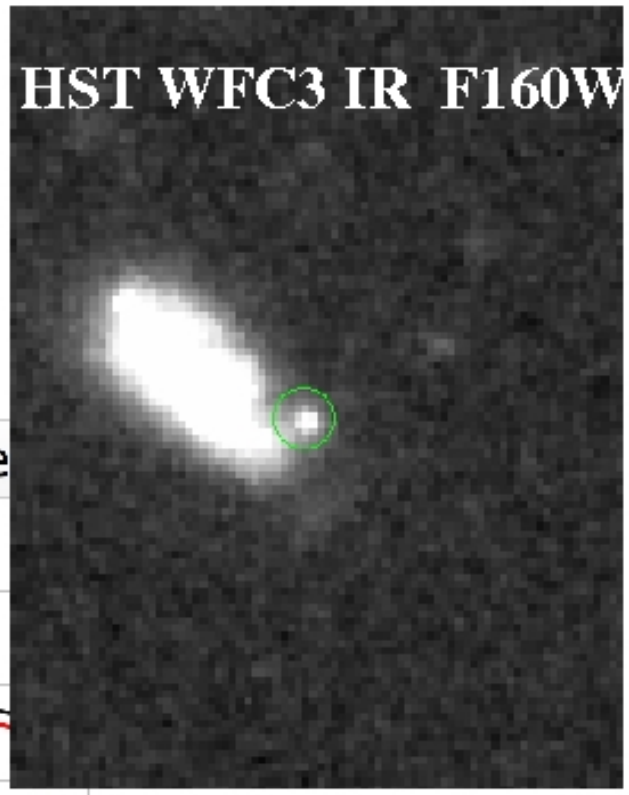
External Collaborators

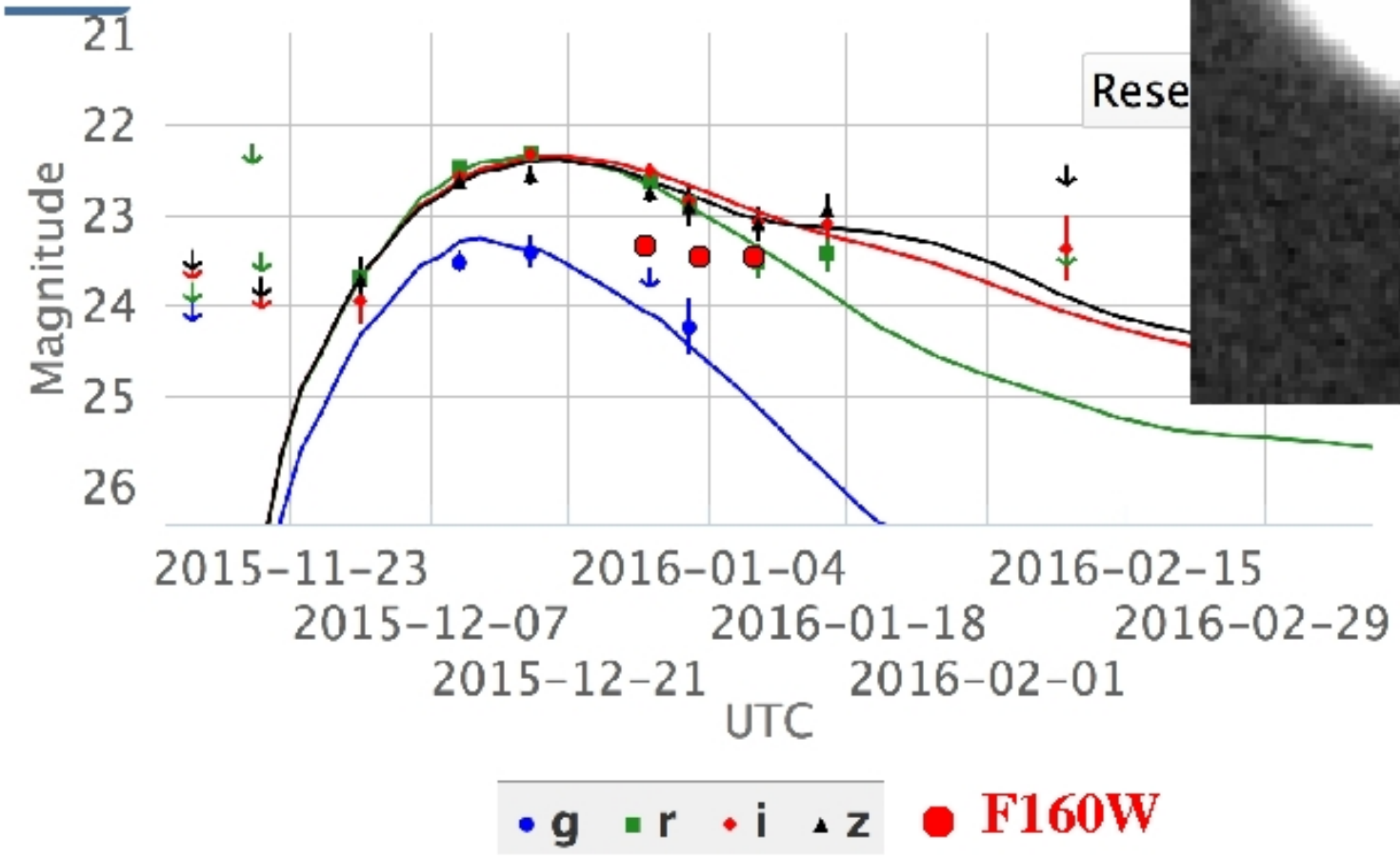
RAISIN2: <z> ~0.5

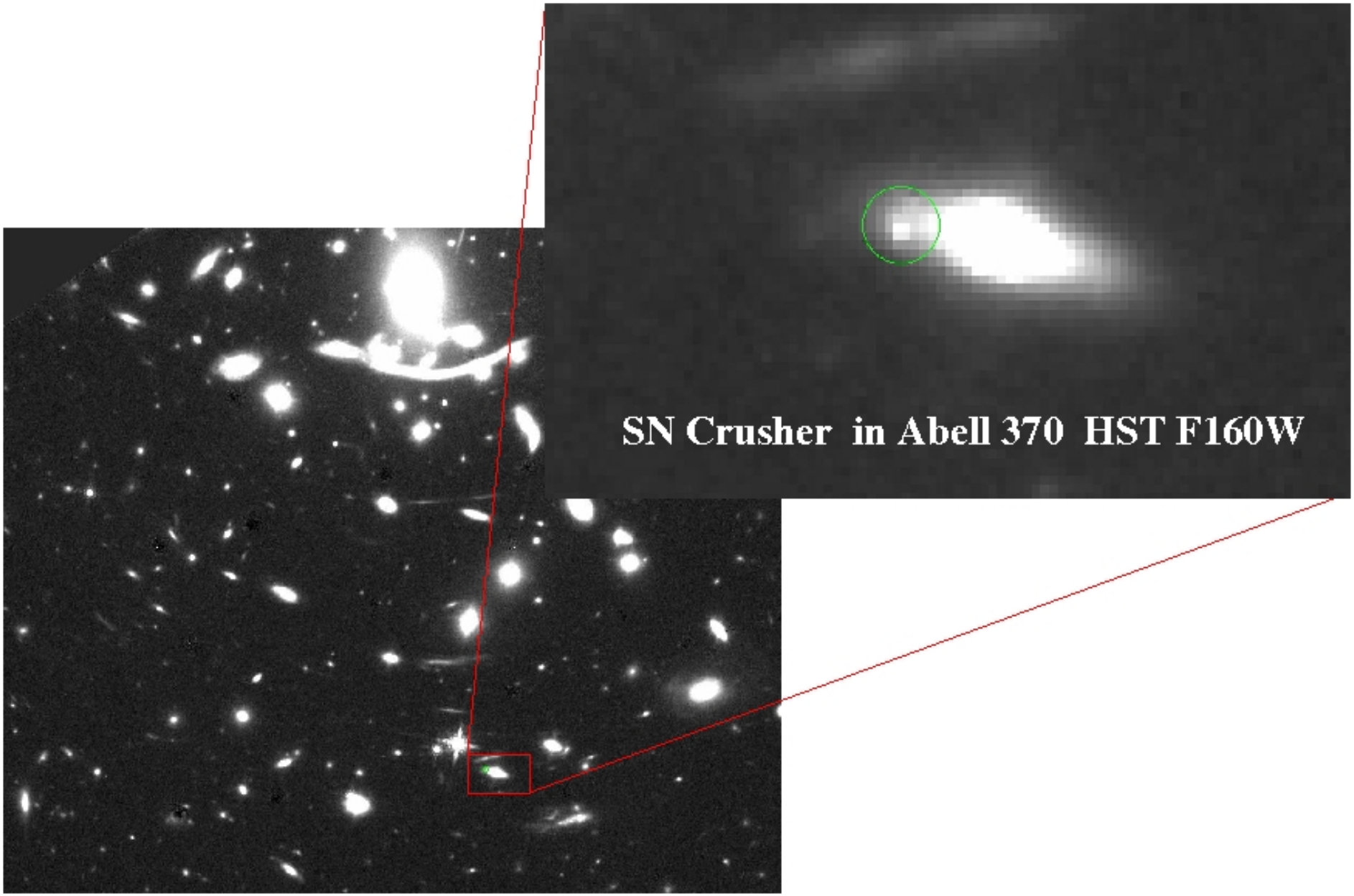



DES15C1NHV z=0.45
lcfit
HST WFC3 IR F160W
Magnitude
21
22
23
24
25
2015-11-23
2015-12-07
2015-12-21
2016-01-04
2016-01-18
2016-02-01
2016-02-15
UTC
g
r
i
z
F160W

DES15X2NKZ z=0.48






SN Crusher in Abell 370 HST F160W

Money left at end of year?
= Deficit

Nublado variando a nubosidad parcial

El Nino-driven storms to dent California's drought with inches of rain next week

By **Brett Rathbun**, AccuWeather.com Meteorologist
March 2, 2016; 9:13 PM ET

Following a warm, dry February in California, a shift in the weather pattern will open the door for several storms to soak the state during the second week of March.

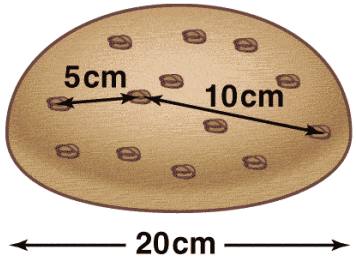
Enough rain may fall to put a noticeable dent in the drought across the state.

By the end of this weekend, storms will usher in moderate to heavy rain across California and heavy snow to the Sierra Nevada.

"A large area of low pressure will move from the central to the eastern Pacific Ocean by this weekend causing storms to steer into California," AccuWeather Senior Meteorologist Dave Samuhel said.

Inches of rain may fall from San Diego and Los Angeles to San Francisco and Sacramento through next week. Up to a foot of rain could fall across portions of northern California, including Crescent City.

In the Sierra Nevada, snow will accumulate by the foot.



RAISIN Scorecard

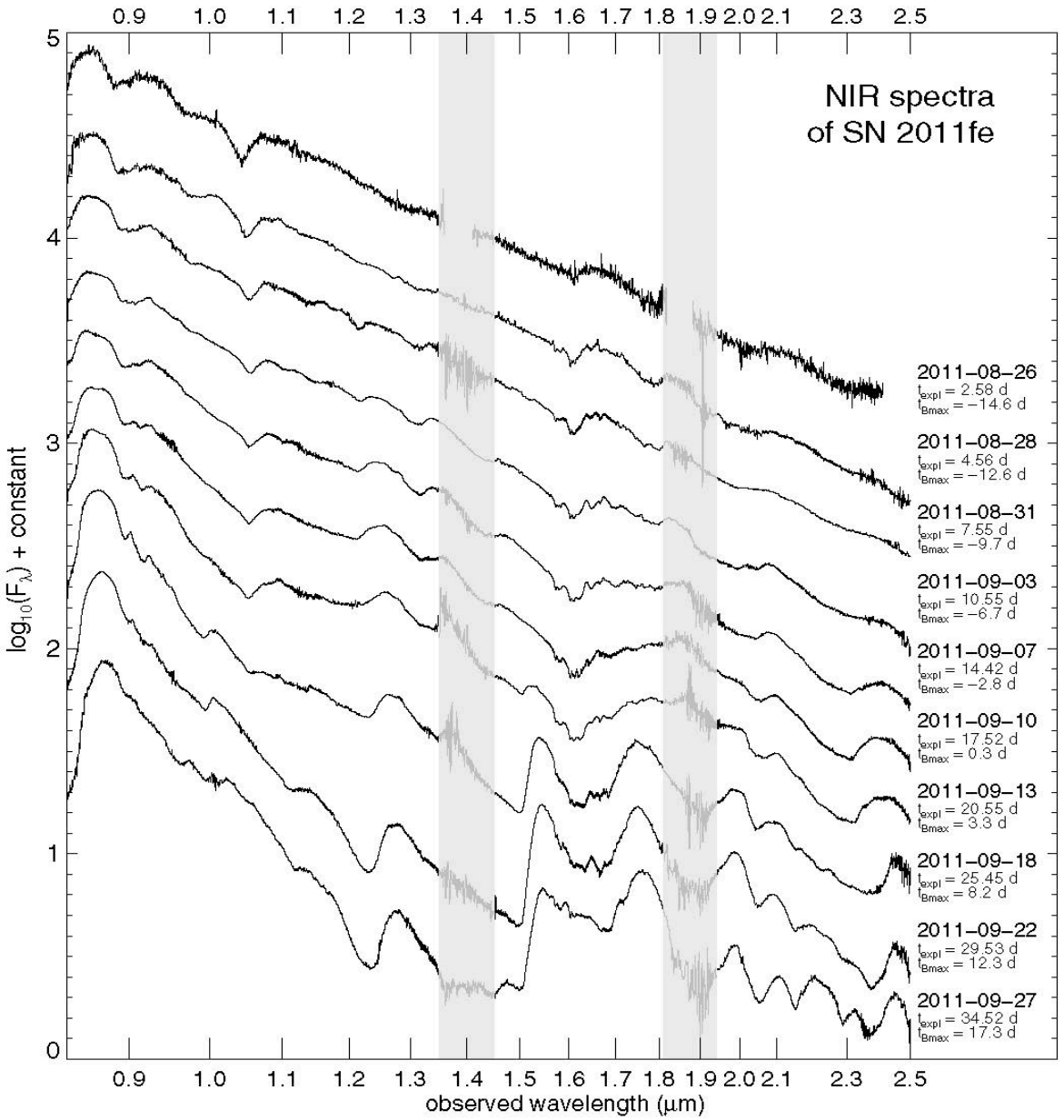
MAP980404

23 RAISIN1 {z~0.35}—Pan-STARRS light curves, spectra, 3 epochs of HST in J,H, templates

9 RAISIN2 {z~0.5} – **DES** light curves, spectra, 3 epochs of HST in H

60 orbits in hand for next DES campaign that begins in August 2016.

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

We're learning today how to do **WFIRST** science: work on **w first**

- ✓ 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

Items for Consideration

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)

Also, note that this **IR** advantage accrues best to low-z samples.