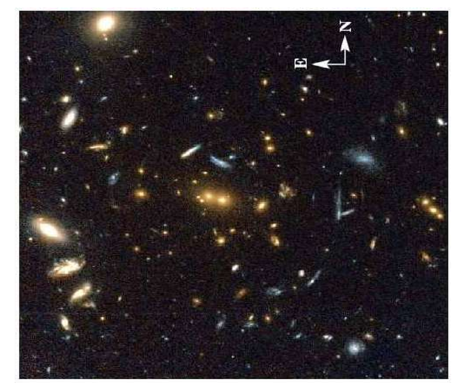
Decelerating and Dustfree: Targeting Supernovae in Very High Redshift Galaxy Clusters with HST

Supernova Cosmology Project



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Abstract

We present a novel approach to obtaining Type Ia supernovae (SNe Ia) at very high redshifts (z>~1). In a 219 orbit cycle 14 program (Perlmutter, PI), we are using the Advanced Camera for Surveys (ACS) and NICMOS on the Hubble Space Telescope (HST) to repeatedly observe massive galaxy clusters at z>~1 to find and follow SNe. Clusters of galaxies are known to be dominated by nearly dust-free early type galaxies. SNe discovered in these galaxies are expected to have negligible dust extinction, the largest source of both statistical and systematic uncertainty in SNe derived distances. In addition, galaxy clusters contain a population of early type galaxies at a density approximately five times that in the high redshift field, leading to a much higher rate of detection of SNe Ia in this well-understood host environment. With 20 scheduled half-nights on the Subaru telecope as well as multiple nights on the Keck and VLT telescopes, we are obtaining spectroscopic confirmation and redshift of newly discovered SNe and their hosts. This data will significantly improve supernova constraints of dark energy both in terms of statistical uncertainty, and perhaps more importantly, of systematic uncertainty. This sample of more than 20 galaxy clusters is also being studied for weak lensing, galaxy morphology, and color-magnitude relationship, as part of an entire program of cluster studies.

The Program: A Novel HST SNe Search in z > ~1 Galaxy Clusters

1 Why Clusters?

Major year-long HST Program in progress in collaboration with several galaxy cluster groups (219 orbits).

- searching ~ 24 massive galaxy clusters at z >~ 1 with ACS.

Why clusters?

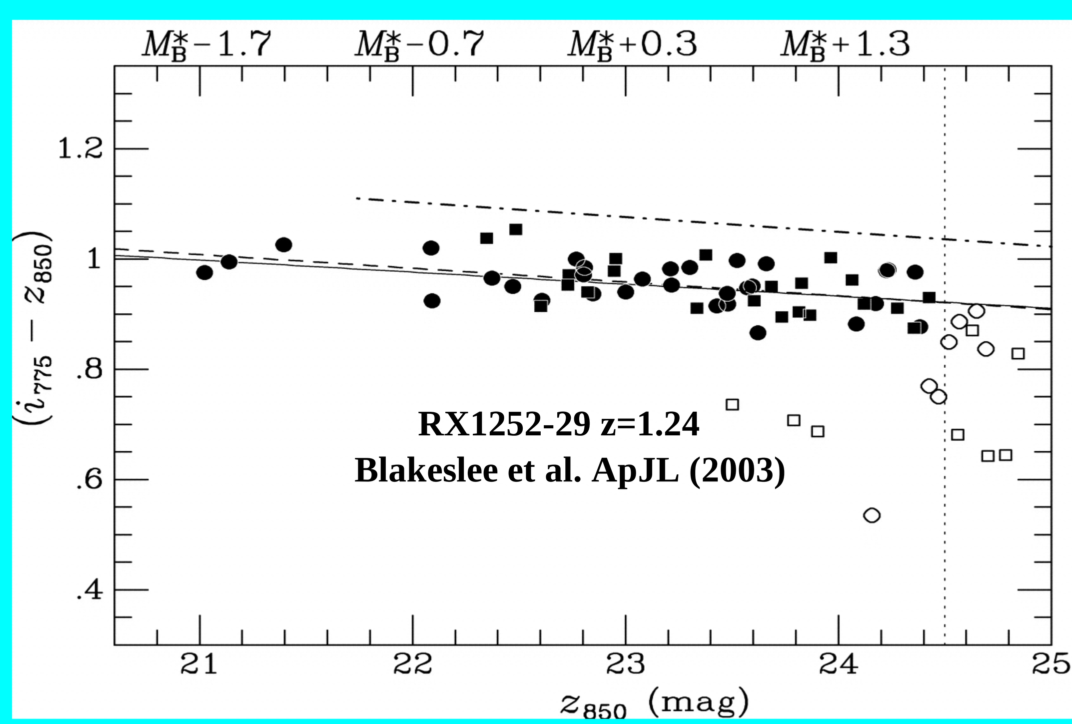
- Dominated by nearly dust-free Elliptical (E/S0) galaxies.
- ~5 times higher density of Elliptical galaxies.

Our observing strategy finds all the usual number of SNe in the field galaxies, *plus* high-quality SNe in this overdensity of ellipticals in the clusters!

Scientific goals:

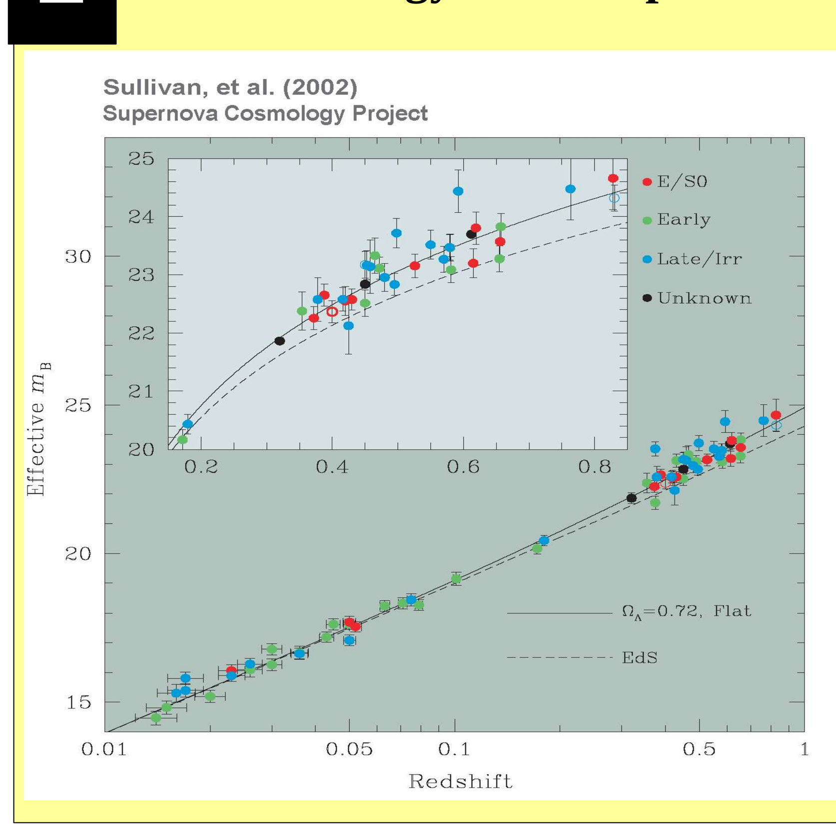
- Significantly improve SN constraints of dark energy - statistical *and* systematic uncertainties.

Cluster studies: weak lensing, galaxy morphology, and color-magnitude relationship.



The dust-free nature of cluster ellipticals (filled circles) and S0 (filled squares) is supported by the small scatter of the color magnitude relation

2 SN Cosmology with Elliptical Hosts



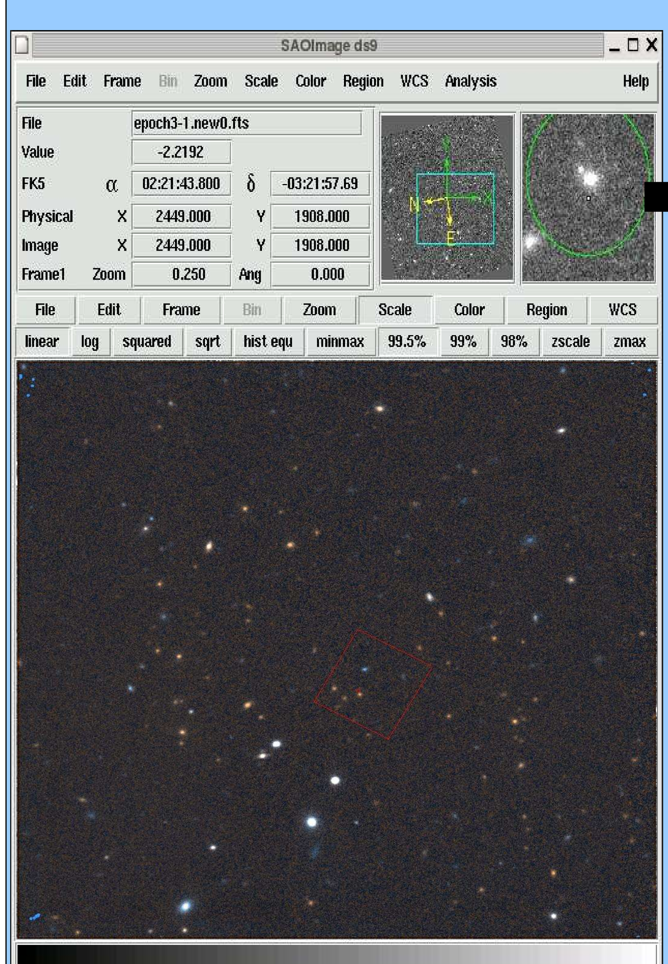
On the left: The SCP Hubble diagram broken into host galaxy types. The SNe in elliptical hosts show significantly less dispersion, σ=0.16 mag, including measurement error.

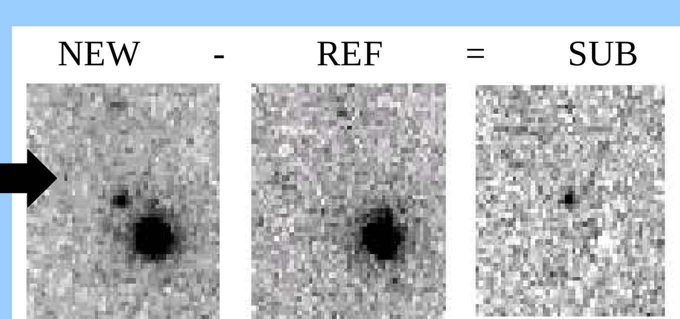
For comparison, at redshifts above z=1, the dispersion for non-elliptical galaxies is ~0.5 mag after extinction correction, due to the uncertainty in B-V color being multiplied by $R_B \approx 4$ and also the dispersion in R_B. Thus, dust-free ellipticals can have a ~9-fold advantage in statistical weight.

Moreover, since it is not known that R_B is independent of redshift, avoiding the extinction correction by using ellipticals circumvents this systematic uncertainty entirely.

The Survey

3 Clusters Are Targeted for SNe Search

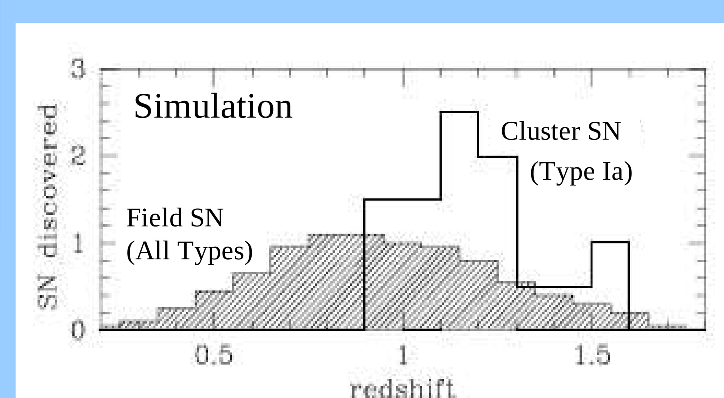




Each z >~ 1 cluster is imaged by HST 7-10 times. The first image is used as a reference. Subsequent images are aligned and subtracted from this image using advanced software. Increases in brightness are identified and flagged as SNe candidates.

On the left is the false-color imaging of our first SN (Frida), discovered in August '05 in cluster RCS0221-03. The host was determined to be a cluster-member elliptical at redshift z=1.02. The image above demonstrates the process of subtraction.

Redshift distribution of SNe



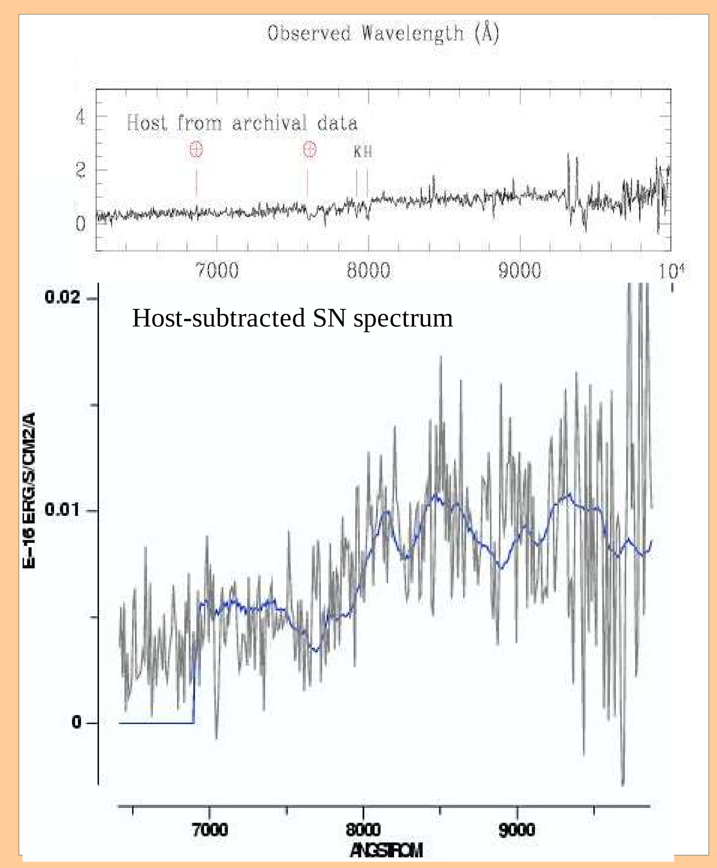
The redshift distribution of the Type Ia SNe we expect to find in the elliptical galaxies of the clusters compared to the SNe of all types (the majority not Type Ia) that we expect to find in the field. Our observing strategy will yield lightcurves for both samples of SNe.

Note the excess of high redshift cluster SNe above the rate expected from the field.

4 Follow Up Observations

Once a SN candidate is found, we trigger follow up observations: From the ground we use time during 20 pre-scheduled half nights on the 8 meter Subaru Telescope and several pre-scheduled nights on the 10 m Keck Telescope, both on Mauna Kea, HI, to obtain spectra of each SN and host galaxy. We also have queue time at the VLT for follow-up spectroscopy.

The figure on the right (bottom) shows the preliminary VLT spectrum of Frida, the first SN discovered in our survey. The spectrum matches a SN Ia template of low redshift supernovae shifted to z=1.02 (solid blue line). This is also the observed redshift of the elliptical host galaxy (top).



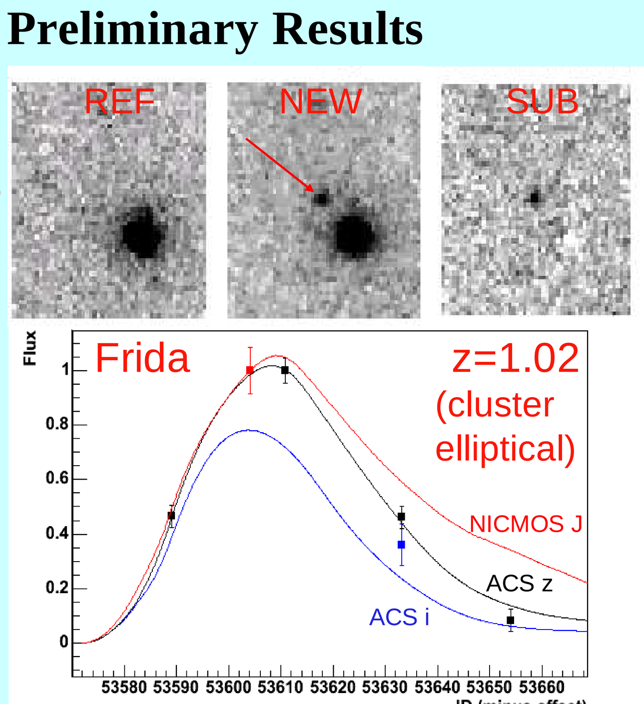
Courtesy of Stephane Basa, SNLS

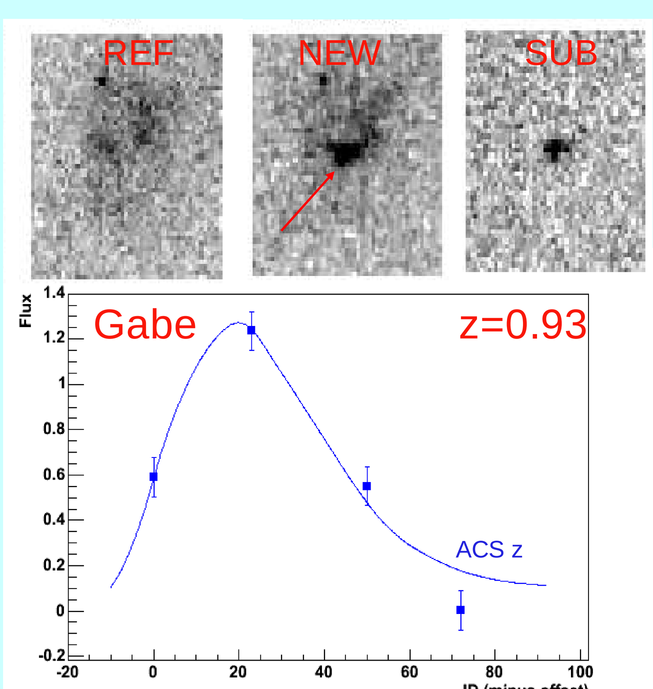
SN Discoveries So Far

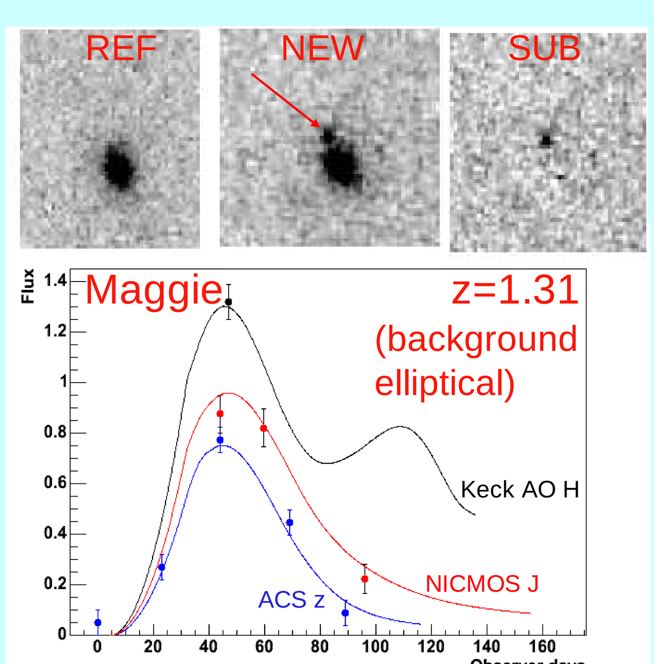
5 Preliminary Results

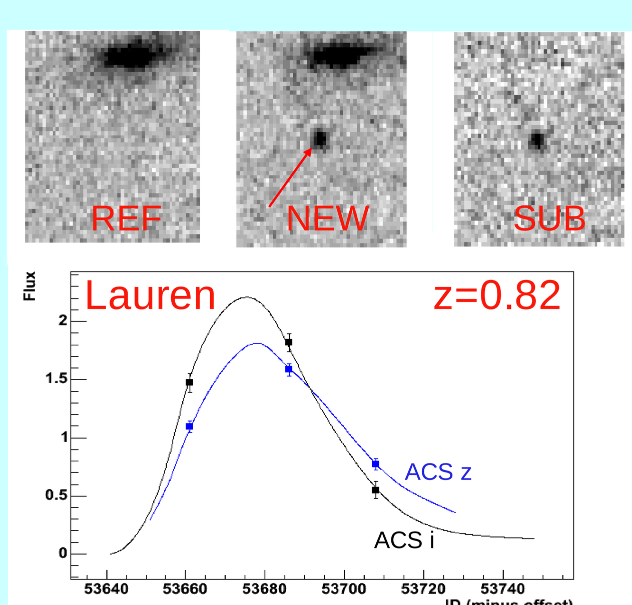
Discovery Images

Lightcurve



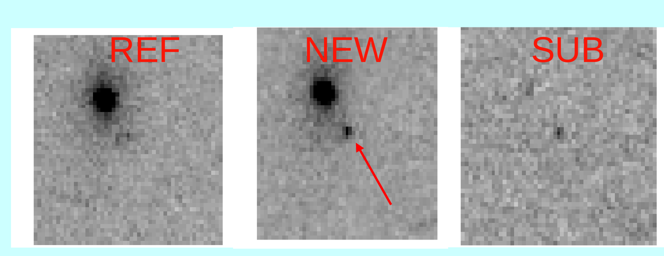




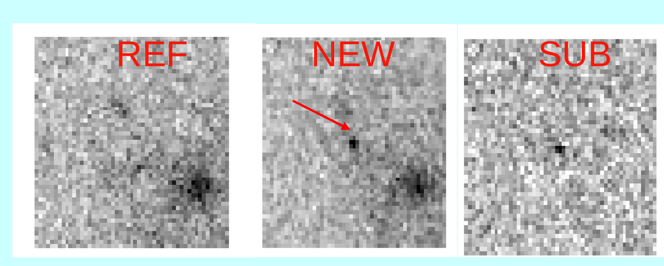


Observations have finished for 5 of the 24 clusters in the survey. A search for SNe in those fields yielded 4 SNe, of which one was hosted by a cluster elliptical (Frida) and one was hosted by a background elliptical (Maggie).

The search continues! In fact, we discovered two more SNe in data from Jan 1, one of which appears to be hosted by a cluster elliptical. Follow-up observations are pending.



C-000 (Discovered 1/01/2006) z=1.2 (probable cluster elliptical)



C-001 (Discovered 1/01/06)

6 Related Presentations and Acknowledgements

- Clusters of Galaxies in the First Half of the Universe from the IRAC Shallow Survey, Eisenhardt et al. #112.05
- Spectroscopic Confirmation of Four z>1 Galaxy Clusters in the Spitzer/IRAC Shallow Survey, Brodwin et al., #190.02
- Highlights from the Center for Adaptive Optics Treasury Survey of Distant Galaxies, Including H-band Photometry of a z=1.3 Supernova, Melbourne et al., #98.02

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