Supernovae are a powerful probe for understanding the **eventual fate** of the Universe

*Distances to ~6% from brightness*

Redshifts from features in spectra

(Hubble Space Telescope, NASA)
1917 Einstein proposed cosmological constant.

1929 Hubble discovered expansion of the Universe.

1934 Einstein called it “my biggest blunder.”

1998 Astronomers found evidence for it.
The Dark Side of the Universe

- Dark energy dominant
  - Expands forever, ever slowing

- Dark matter dominant

- Collapses

Distance vs. Age of the Universe
Calibration of, and corrections to, brightness measurements are presently the dominant source of uncertainty in measured parameters of dark energy (as well as a number of other astronomical parameters).

Unless we improve calibration standards (for flux as a function of color) to < 1%, this will continue to be the limiting uncertainty for all current and upcoming supernova cosmology projects.

7.7 billion light-years from Earth
Understanding the Acceleration of the Universe

- **LSST (Large Synoptic Survey Telescope)**
  - First light ~2019

- **Euclid**
  - Launch date ~2020 - ~2022

- **WFIRST (Wide-Field Infrared Survey Telescope)**
  - Science data arriving now

- **Pan-STARRS**
  - ... and others
**Uncertainty on supernova photometry COMPLETELY DOMINATES both present & future SN Ia dark energy measurements**

**SNLS: Conley et al (2011), ApJS 192, 1:**

<table>
<thead>
<tr>
<th>Description</th>
<th>$\Omega_m$</th>
<th>$w$</th>
<th>Rel. Area</th>
<th>$w$ for $\Omega_m=0.27$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stat only</td>
<td>$0.19^{+0.08}_{-0.10}$</td>
<td>$-0.90^{+0.16}_{-0.20}$</td>
<td>1</td>
<td>$-1.031 \pm 0.058$</td>
</tr>
<tr>
<td><strong>All systematics</strong></td>
<td>$0.18 \pm 0.10$</td>
<td>$-0.91^{+0.17}_{-0.24}$</td>
<td>1.85</td>
<td>$-1.08^{+0.10}_{-0.11}$</td>
</tr>
<tr>
<td>Calibration</td>
<td>$0.191^{+0.005}_{-0.010}$</td>
<td>$-0.92^{+0.17}_{-0.22}$</td>
<td>1.79</td>
<td>$-1.06 \pm 0.10$</td>
</tr>
<tr>
<td>SN model</td>
<td>$0.195^{+0.006}_{-0.010}$</td>
<td>$-0.90^{+0.16}_{-0.20}$</td>
<td>1.02</td>
<td>$-1.027 \pm 0.059$</td>
</tr>
<tr>
<td>Peculiar velocities</td>
<td>$0.197^{+0.008}_{-0.010}$</td>
<td>$-0.91^{+0.16}_{-0.20}$</td>
<td>1.03</td>
<td>$-1.034 \pm 0.059$</td>
</tr>
<tr>
<td>Malmquist bias</td>
<td>$0.198^{+0.008}_{-0.010}$</td>
<td>$-0.91^{+0.16}_{-0.20}$</td>
<td>1.07</td>
<td>$-1.037 \pm 0.060$</td>
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<tr>
<td>non-La contamination</td>
<td>$0.19^{+0.05}_{-0.10}$</td>
<td>$-0.90^{+0.16}_{-0.20}$</td>
<td>1</td>
<td>$-1.031 \pm 0.058$</td>
</tr>
<tr>
<td>MW extinction correction</td>
<td>$0.196^{+0.004}_{-0.010}$</td>
<td>$-0.90^{+0.16}_{-0.20}$</td>
<td>1.05</td>
<td>$-1.032 \pm 0.060$</td>
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<tr>
<td>SN evolution</td>
<td>$0.185^{+0.008}_{-0.009}$</td>
<td>$-0.88^{+0.15}_{-0.20}$</td>
<td>1.02</td>
<td>$-1.028 \pm 0.059$</td>
</tr>
<tr>
<td>Host relation</td>
<td>$0.198^{+0.005}_{-0.010}$</td>
<td>$-0.91^{+0.16}_{-0.21}$</td>
<td>1.08</td>
<td>$-1.034 \pm 0.061$</td>
</tr>
</tbody>
</table>

\footnote{Area relative to statistical only fit of the contour enclosing 68.3\% of the total probability.}

**Note.** — Results including statistical and identified systematic uncertainties broken down into contributions: In each case the constraints are given including the statistical uncertainties and only the stated systematic contribution. The importance of each class of systematic uncertainties can be judged by the relative area compared with the statistical-only fit.
Technique: A 0.1% Calibrated, Mobile Source Above the Atmosphere

Balloon Payload

100 mW lasers

440 nm
532 nm
639 nm
808 nm

Integrating Sphere

NIST Photodiode

Well-characterized Lambertian spatial profile

Known view angle

NIST-calibrated (< 0.1% absolute) photodiode spectral response
Payload
Flight Control

910 MHz directional antennas, range approx. 70 km. Always ≥ 2 ground stations in contact.

Onboard primary radio (RFM DNT900P, 1W omni, 200 kbps)

Onboard payload attitude accelerometer/magnetometer (Ocean Server OS4000T)

Onboard high-altitude-capable GPS (Inventek ISM300F2)
Twelve flights to date (most recent 2 weeks ago),
all test flights over New Hampshire so far.

All available online:
Telemetry, .kml files,
photodiode monitoring data,
ground imagery, photometry …
Imagery, and Upcoming Plans

Portable observation station:

Meade LX200GPS 12” telescope with SBIG ST-8300 camera:

We will be performing full end-to-end flight tests of ALTAIR photometric precision this summer …

… then on to flight tests over Mt. Hopkins (AZ) and Pan-STARRS (Maui).

Following that, we intend to begin flight testing in Chile in 2016.
Artificial sources are, in principle, able to reach up to two orders of magnitude better photometric calibration precision than any natural light sources.

1) Can study them into the lab before and after use, unlike stars.
2) Can monitor them in-situ, in real time.
3) Can be used to calibrate white dwarfs (and the Moon) very precisely, and on a detector-based standards scale.
4) Small balloons are inexpensive.
5) Your choice of spectrum & color on demand (including microwave! etc.), …and brightness, … location in the sky, and time of night (or day), …


This is a core program for LSST: will be a primary photometry calibration method for LSST SNIa observations.

MORE NEWS AND DATA FROM US VERY SOON !!!!
Funding graciously provided by:

Yorke Brown, Max Fagin, Cynthia Tan, Waad Kahouli
Dartmouth

Arnold Gaertner, Jeff Lundeen
NRC-INMS

Matt Dobbs, Khoi Nam, Nate Long
McGill

Keith Vanderlinde, Ray Carlberg
Toronto

Christopher Stubbs, Peter Doherty, William High, Isaac Shivvers
Harvard

Keith Lykke, Steven Brown, John Woodward
NIST

Justin Albert, Karun Thanjavur, Paul Kovacs, Divya Bhatnagar, Ryan Thomas
Univ. of Victoria