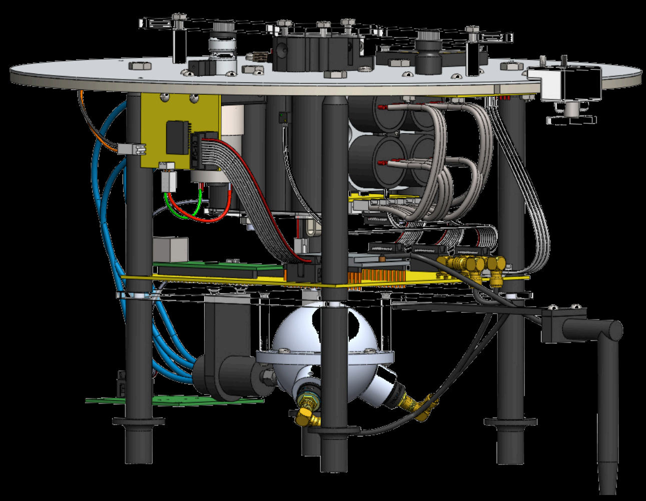
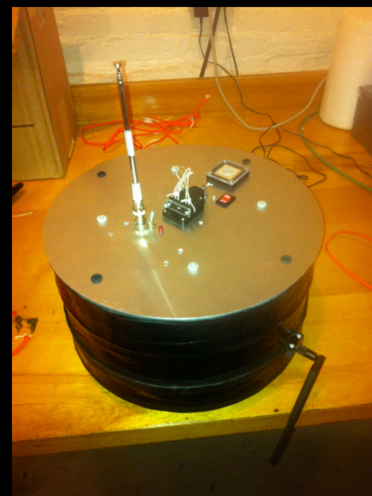
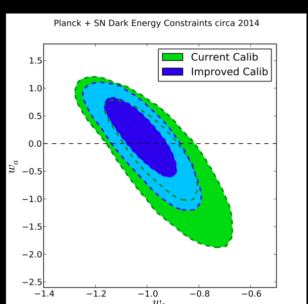
ALTAIR: Precision Photometric Calibration

via Artificial Light Sources Above the Atmosphere

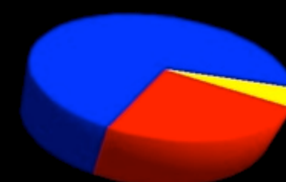




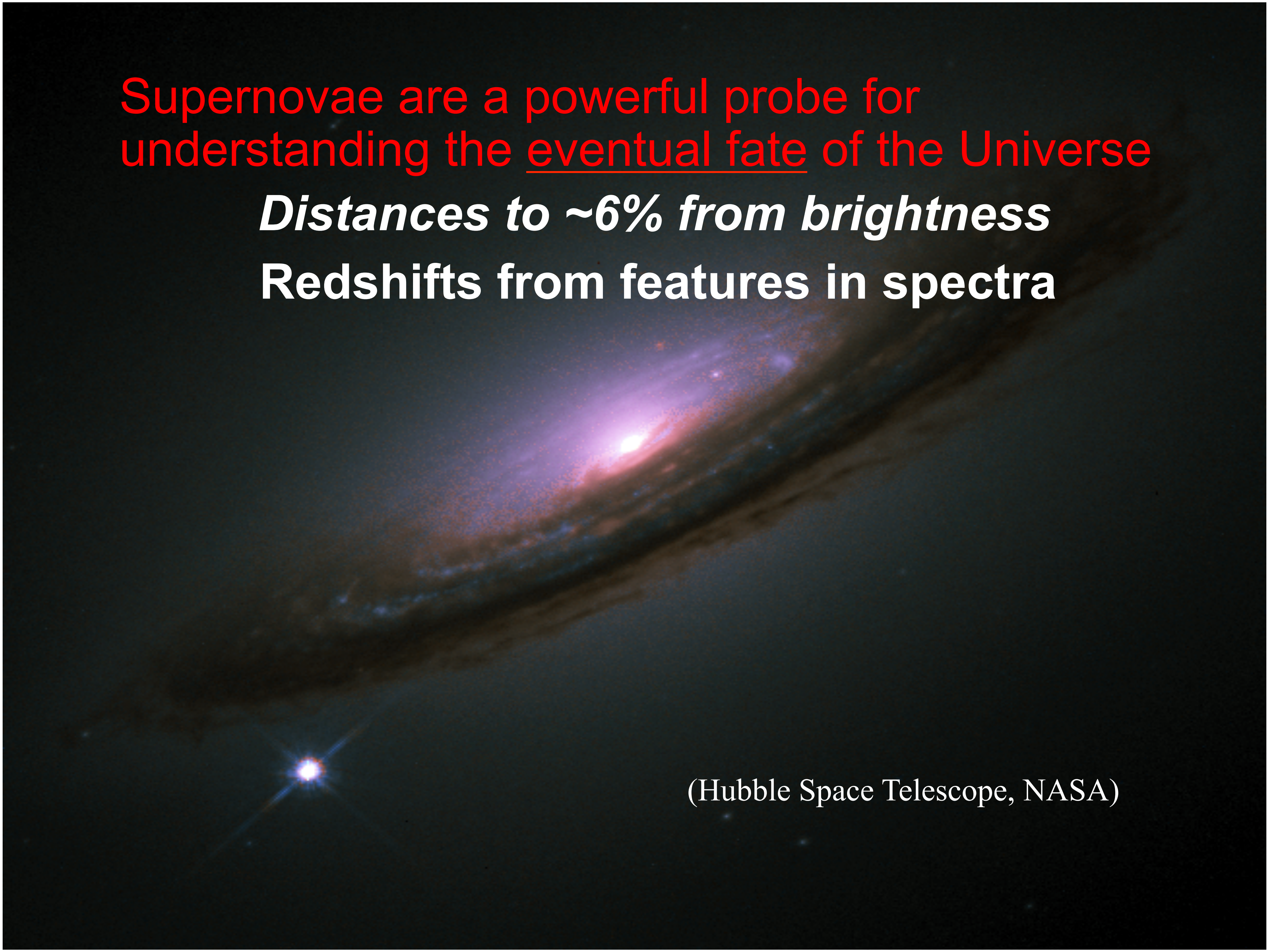


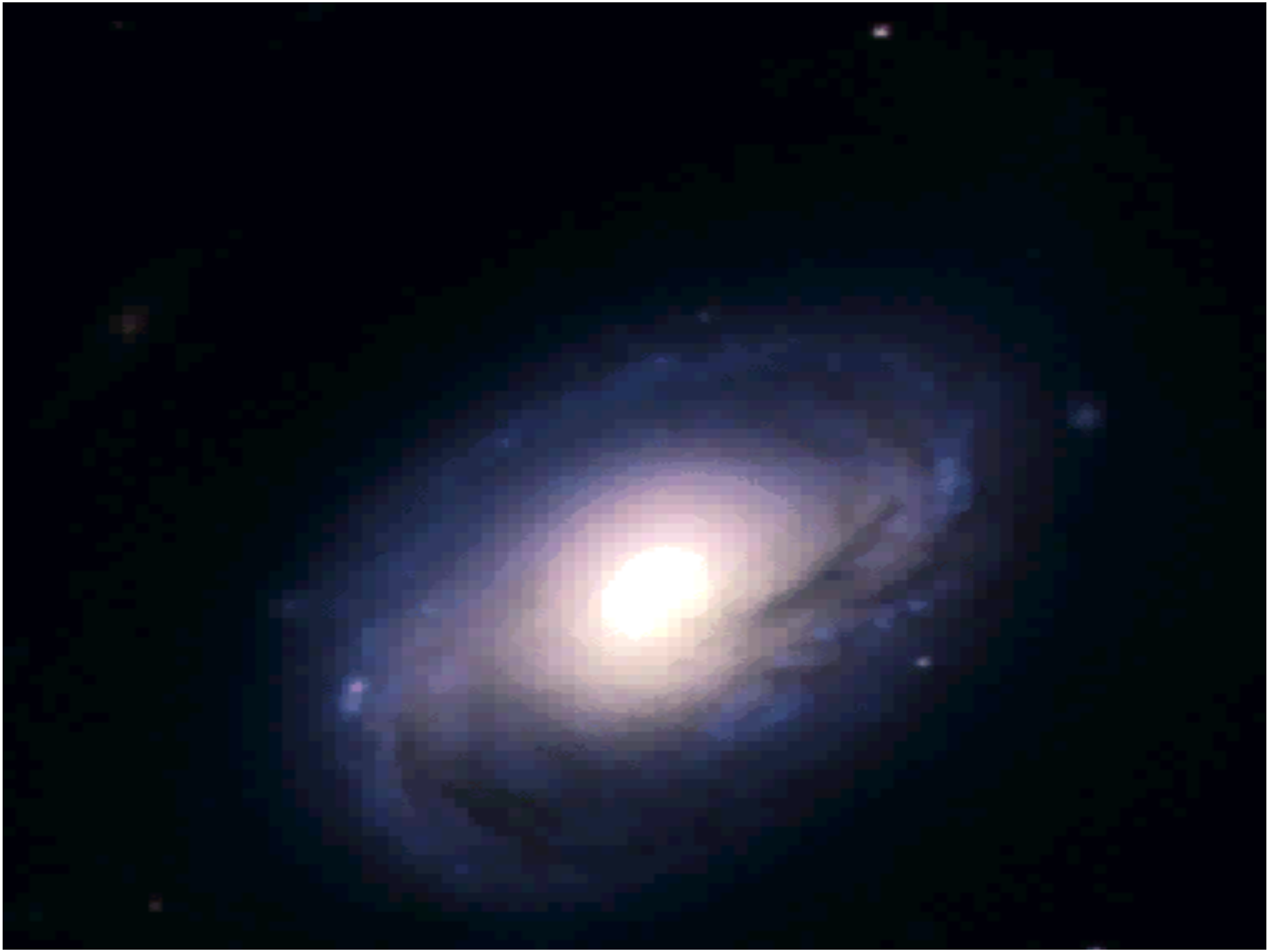
Aug. 12, 2014

Justin Albert
Univ. of Victoria

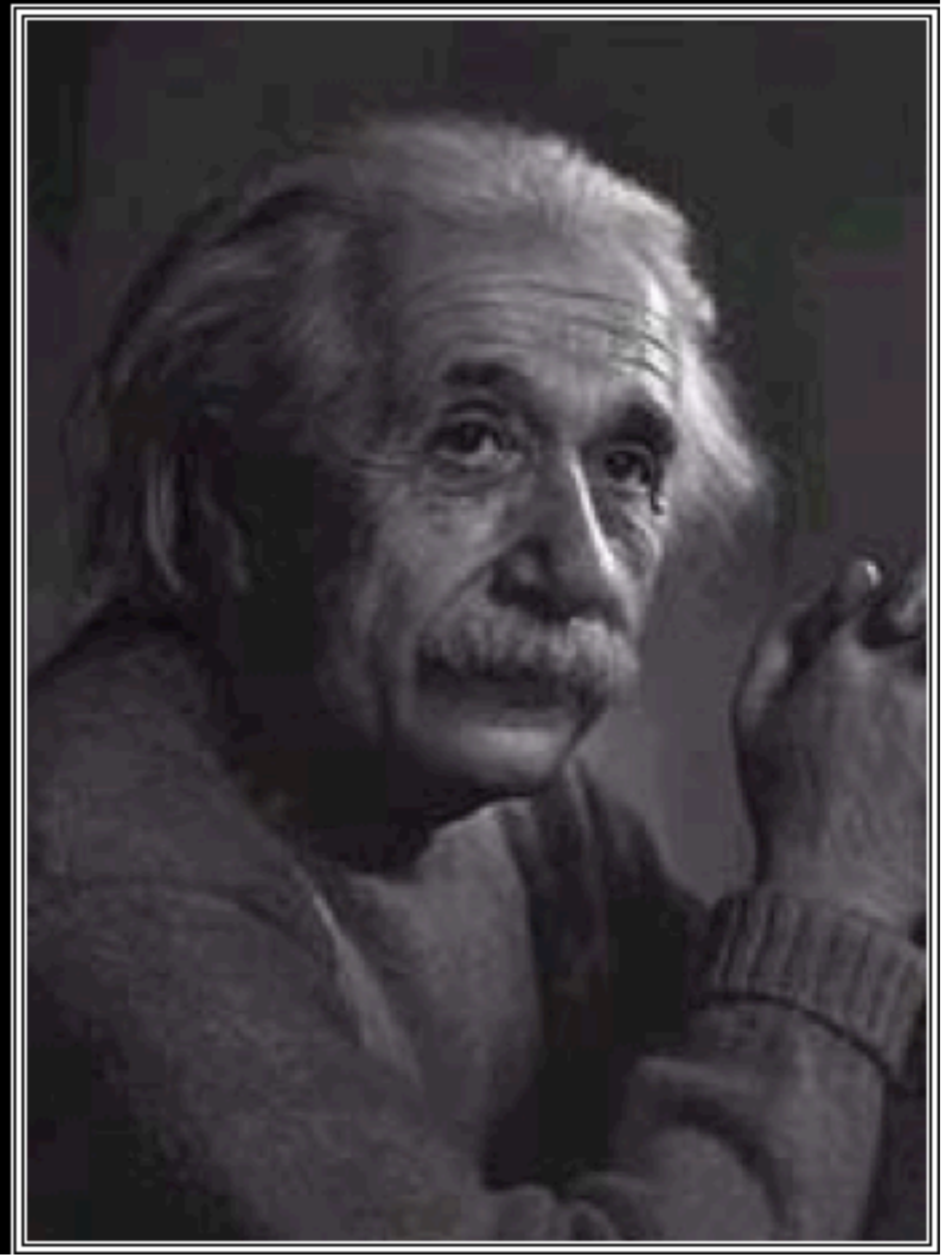


Airborne Laser
for
Telescopic Atmospheric Interference Reduction


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)



Dark Energy



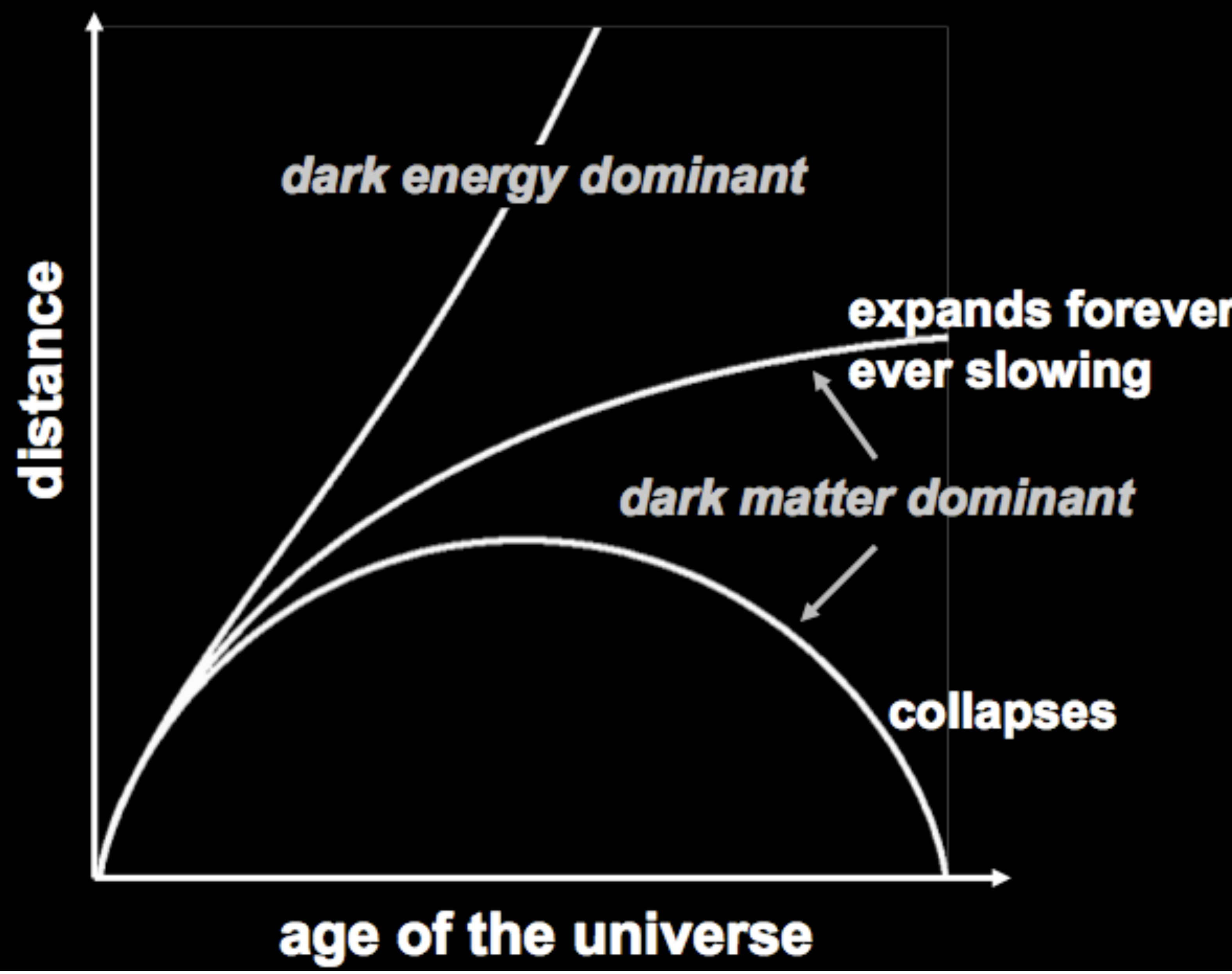
<u>1917</u> Einstein proposed cosmological constant.

<u>1929</u> Hubble discovered expansion of the Universe.

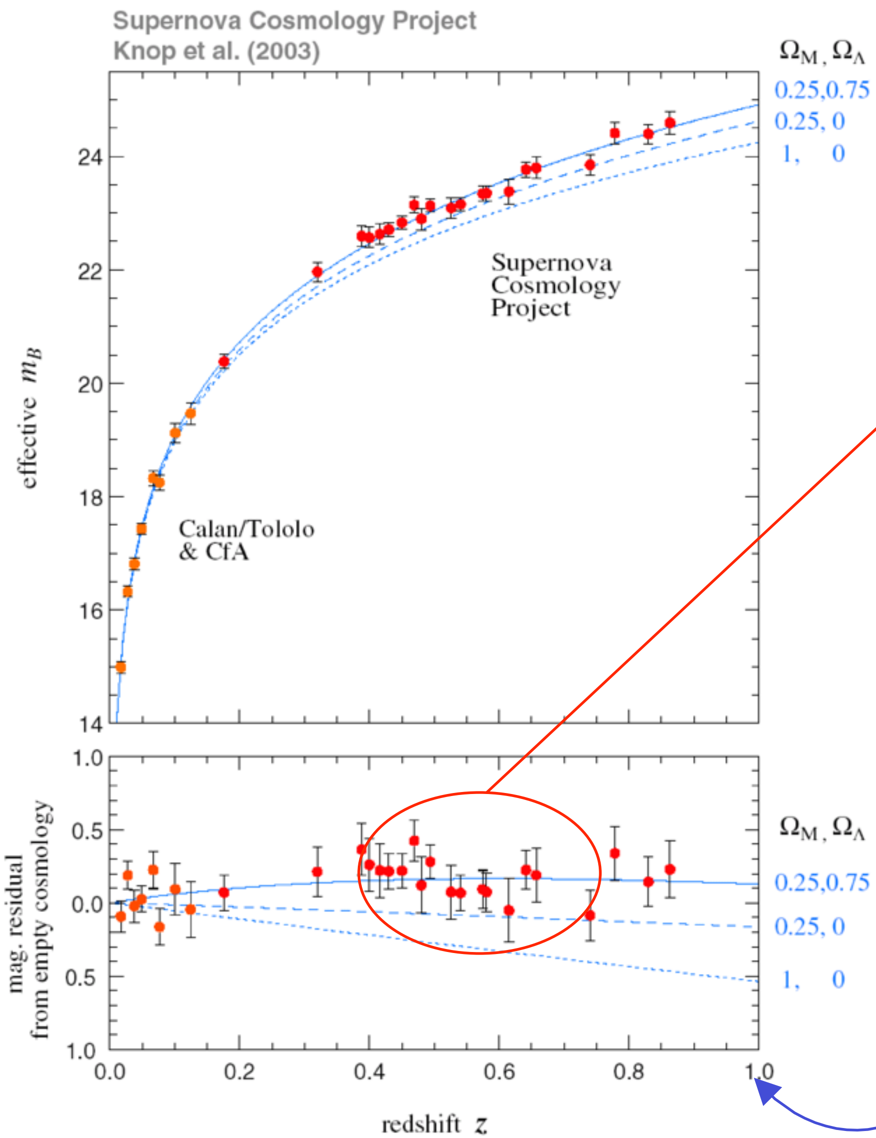
<u>1934</u> Einstein called it "my biggest blunder."

<u>1998</u> Astronomers found evidence for it.

The Dark Side of the Universe



Limitations on our Knowledge of Dark Energy



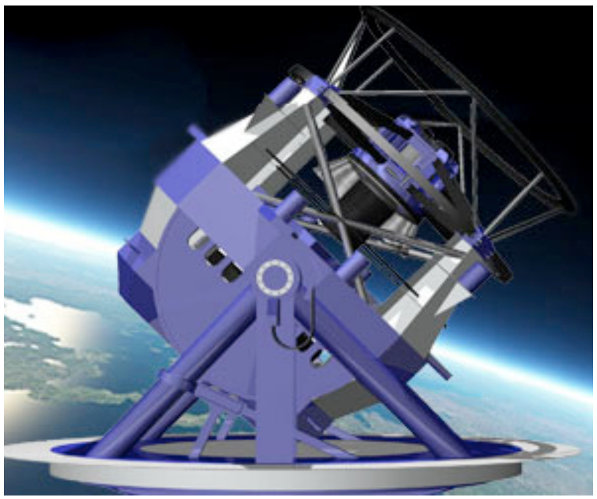
→ Calibration of, and corrections to, brightness measurements are presently the <u>dominant</u> source of uncertainty in measured parameters of dark energy (as well as a number of other astronomical parameters).

➢ Unless we <u>improve calibration standards</u> (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

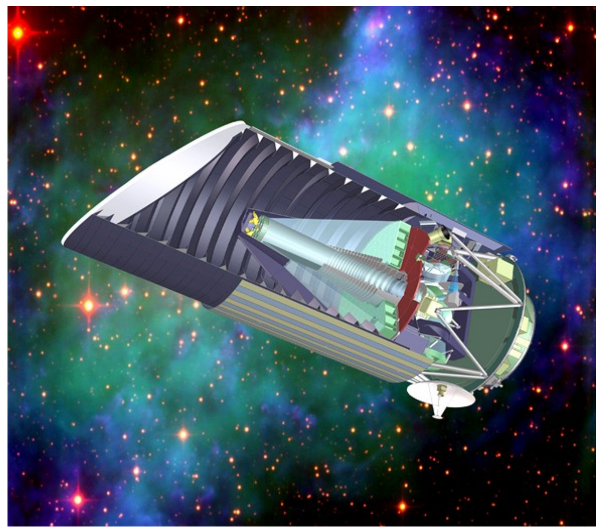
LSST
Large Synoptic Survey Telescope



First light ~2019

EUCLID

WFIRST
Wide-Field Infrared Survey Telescope



Launch date
~2020 - ~2022

Science data
arriving <u>now</u>

… and others

Uncertainty on supernova photometry **COMPLETELY DOMINATES** *both present & future SNIa dark energy measurements*

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

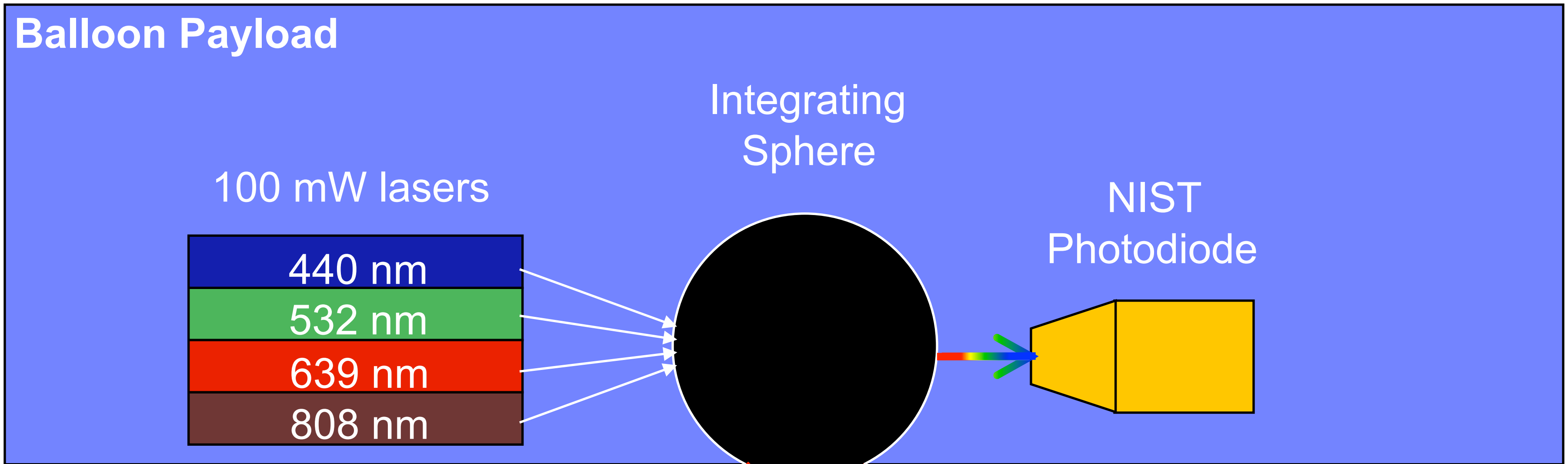
Table 7: Identified systematic uncertainties

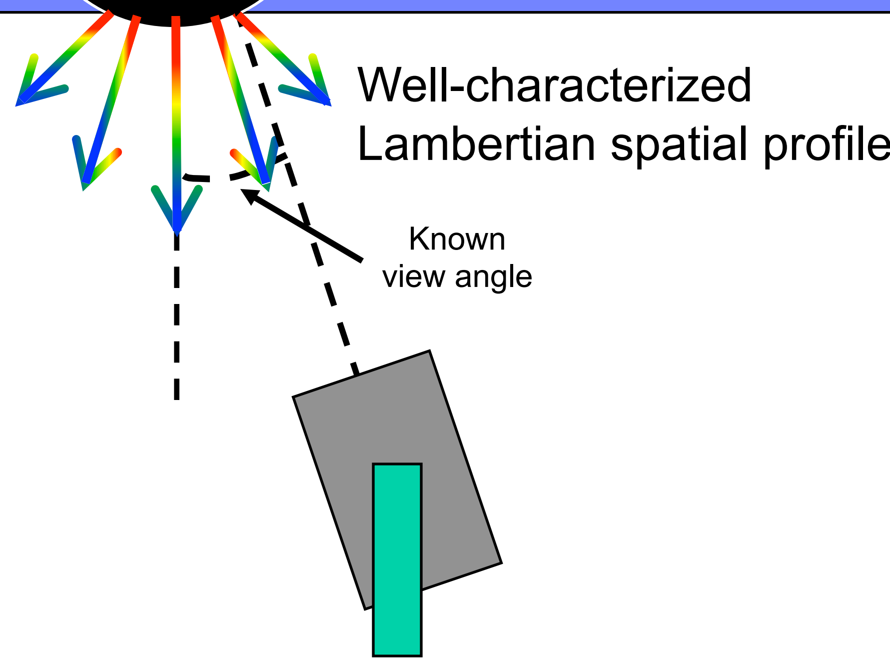
Description	Ω_m	w	Rel. Area [a]	w for Ω_m=0.27
Stat only	$0.19^{+0.08}_{-0.10}$	$-0.90^{+0.16}_{-0.20}$	1	-1.031 ± 0.058
All systematics	0.18 ± 0.10	$-0.91^{+0.17}_{-0.24}$	1.85	$-1.08^{+0.10}_{-0.11}$
Calibration	$0.191^{+0.095}_{-0.104}$	$-0.92^{+0.17}_{-0.23}$	1.79	-1.06 ± 0.10
SN model	$0.195^{+0.086}_{-0.101}$	$-0.90^{+0.16}_{-0.20}$	1.02	-1.027 ± 0.059
Peculiar velocities	$0.197^{+0.084}_{-0.100}$	$-0.91^{+0.16}_{-0.20}$	1.03	-1.034 ± 0.059
Malmquist bias	$0.198^{+0.084}_{-0.100}$	$-0.91^{+0.16}_{-0.20}$	1.07	-1.037 ± 0.060
non-Ia contamination	$0.19^{+0.08}_{-0.10}$	$-0.90^{+0.16}_{-0.20}$	1	-1.031 ± 0.058
MW extinction correction	$0.196^{+0.084}_{-0.100}$	$-0.90^{+0.16}_{-0.20}$	1.05	-1.032 ± 0.060
SN evolution	$0.185^{+0.088}_{-0.099}$	$-0.88^{+0.15}_{-0.20}$	1.02	-1.028 ± 0.059
Host relation	$0.198^{+0.085}_{-0.102}$	$-0.91^{+0.16}_{-0.21}$	1.08	-1.034 ± 0.061

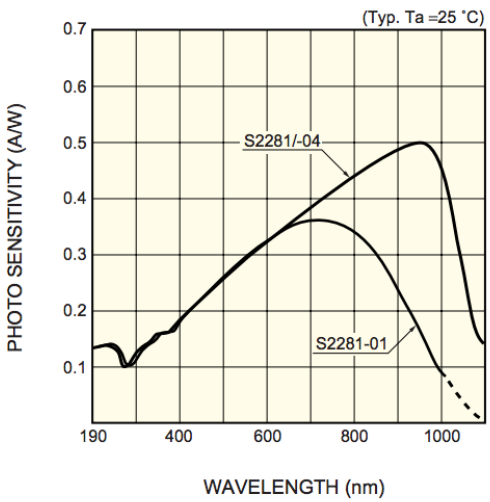
[a] Area relative to statistical only fit of the contour enclosing 68.3% of the total probability.

Note. — Results including statistical and identified systematic uncertainties broken down into cat
In each case the constraints are given including the statistical uncertainties and only the stated sys
contribution. The importance of each class of systematic uncertainties can be judged by the relat
compared with the statistical-only fit.

Technique: *A 0.1% Calibrated, Mobile Source Above the Atmosphere*

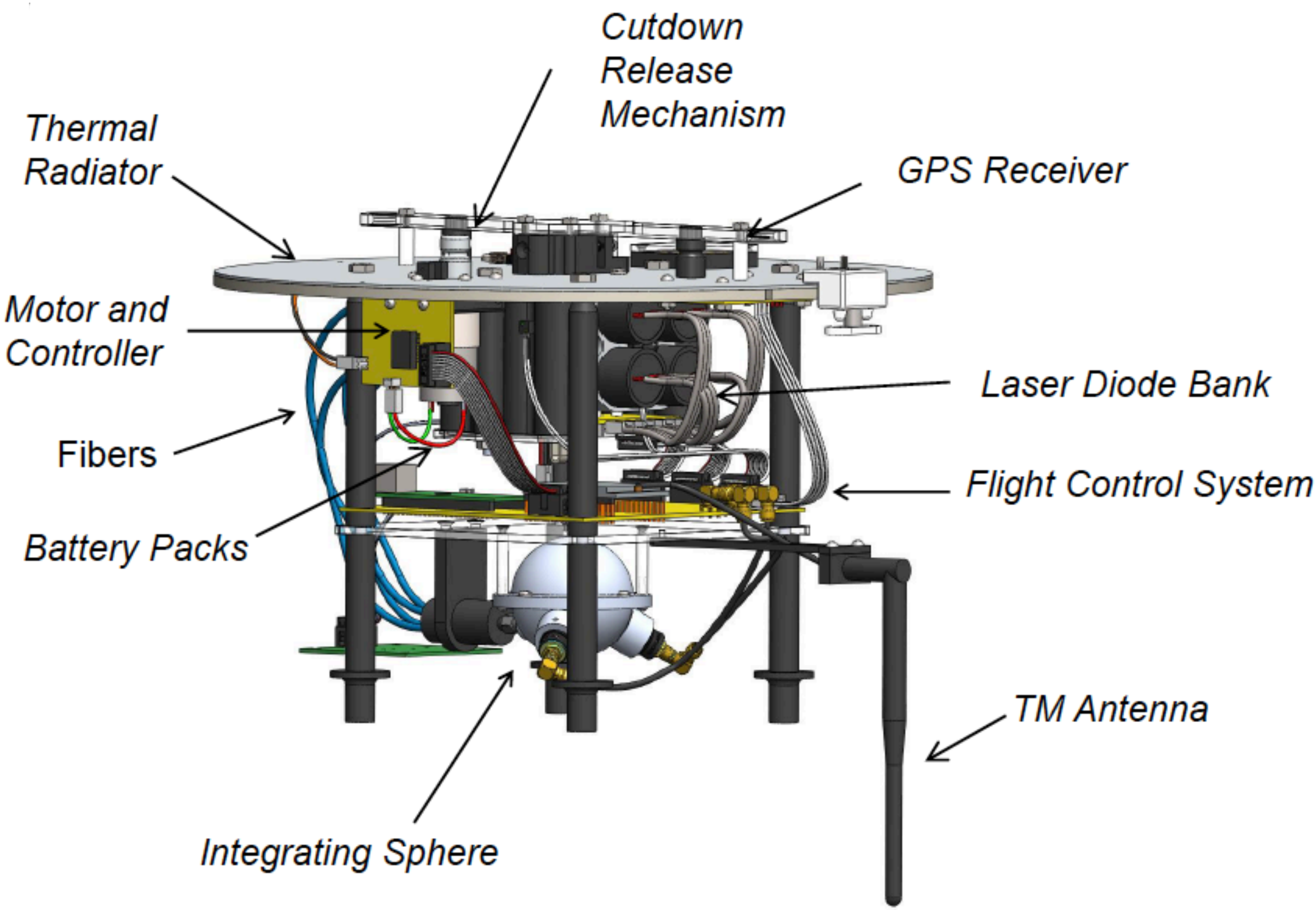




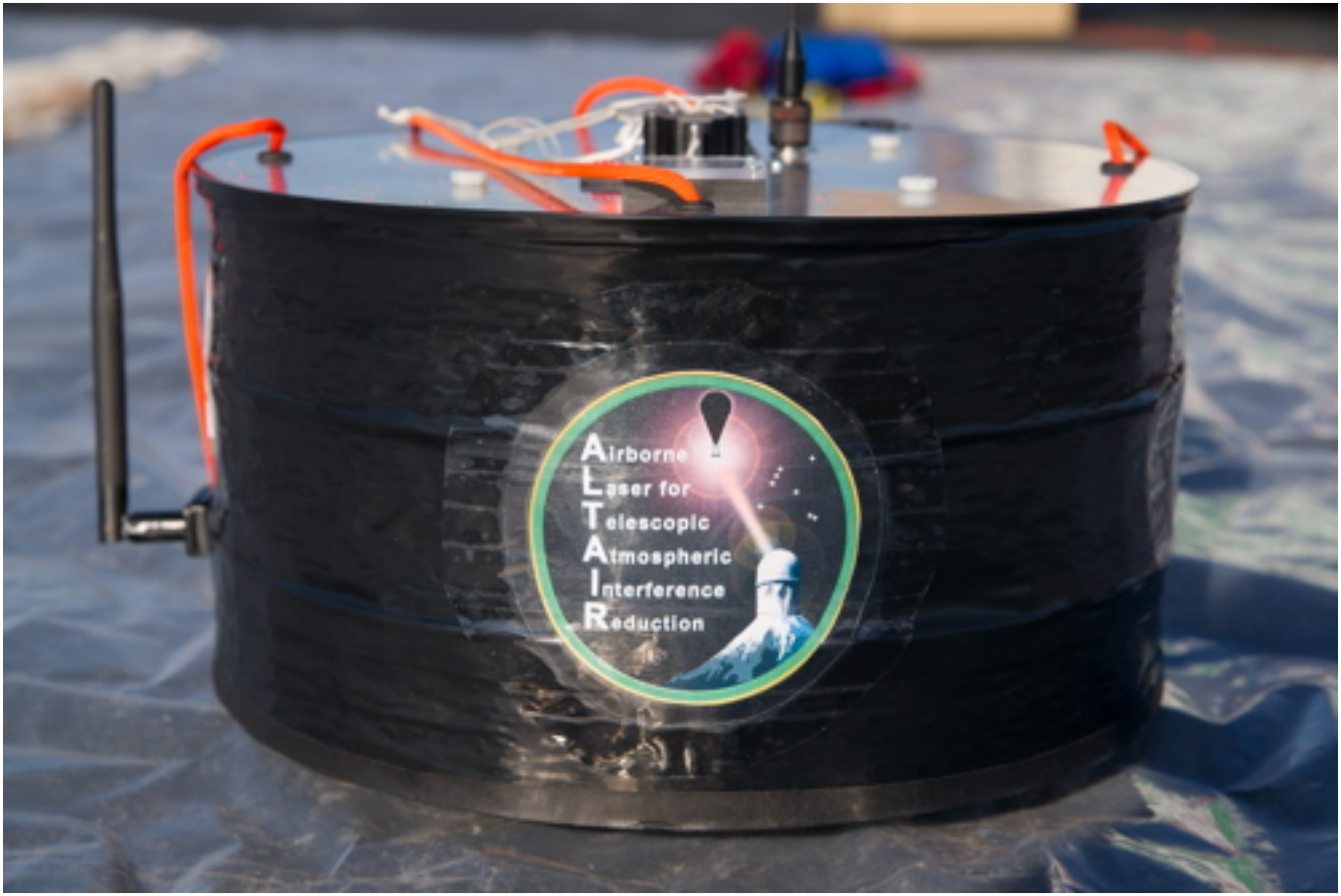


NIST-calibrated (< 0.1% absolute) photodiode spectral response

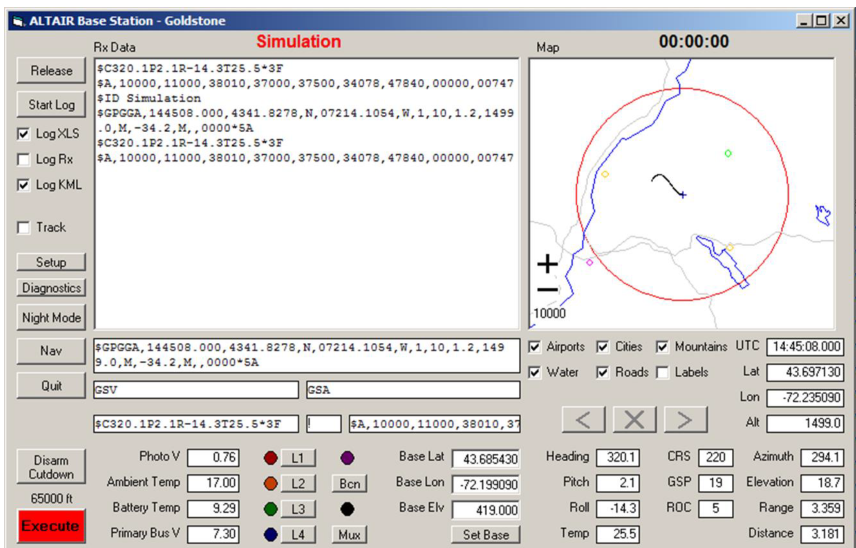
Payload Design

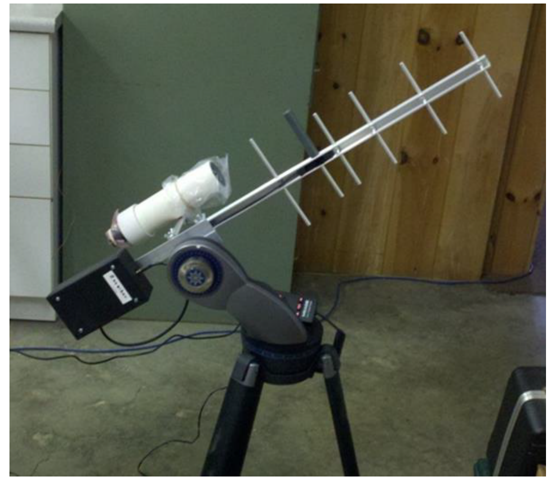


Payload


Airborne
Laser for
Telescopic
Atmospheric
Interference
Reduction

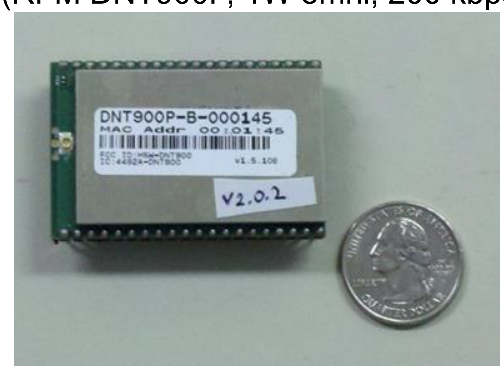
Flight Control



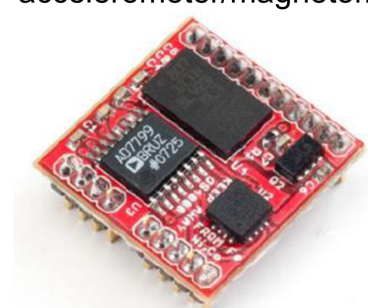


910 MHz directional antennas, range approx. 70 km. Always ≥ 2 ground stations in contact.

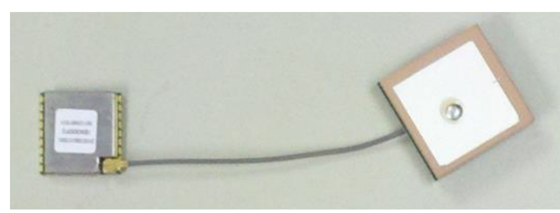
Onboard primary radio
(RFM DNT900P, 1W omni, 200 kbps)



Onboard payload attitude accelerometer/magnetometer



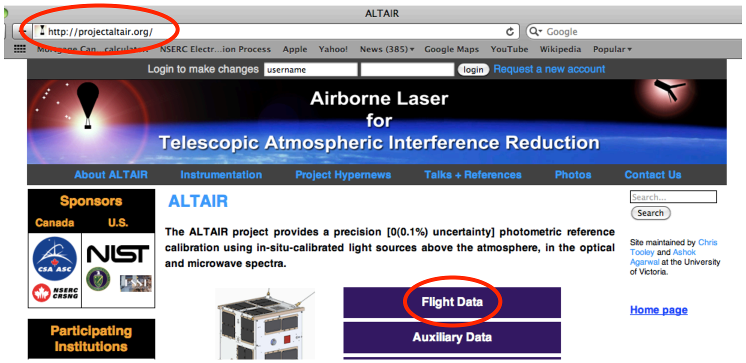
(Ocean Server OS4000T)

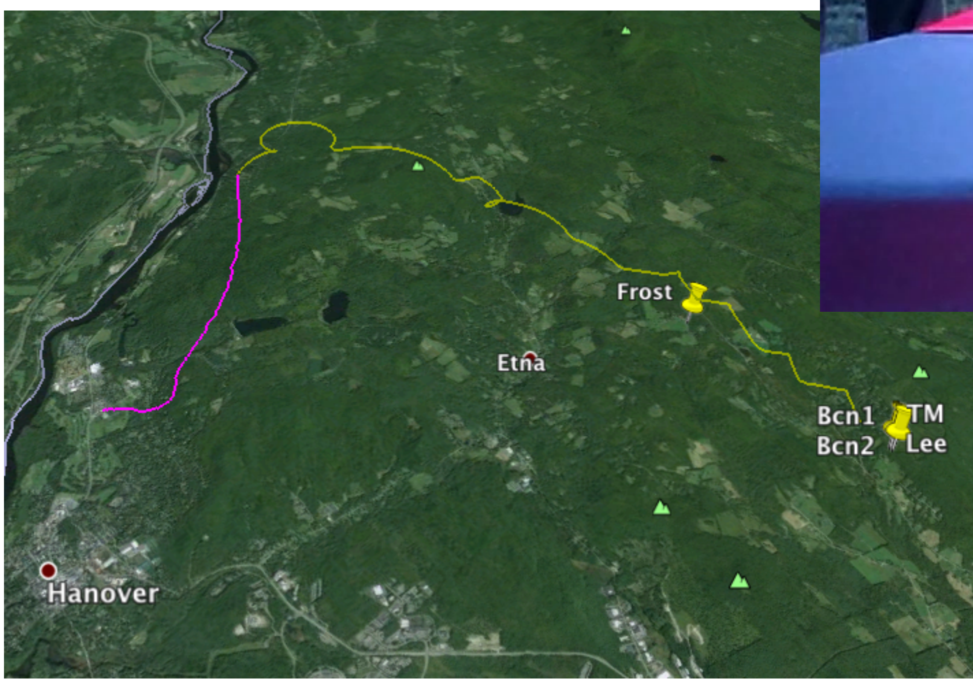


Onboard high-altitude-capable GPS (Inventek ISM300F2)

Flights and Data (so far)

Twelve flights to date (most recent 2 weeks ago),
all test flights over New Hampshire so far.





<u>All available online:</u>

Telemetry, .kml files,
photodiode monitoring data,
ground imagery, photometry …

Imagery, and Upcoming Plans

Portable observation station:

Meade LX200GPS 12” telescope

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

with SBIG ST-8300 camera:

… 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.

Conclusion

- **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), …
- **arXiv:1101.5214 (astro-ph), AJ 143, 8 (2011).**
- **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 !!!***

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