ALTAIR: Toward Accurate Spectro-Photometric Calibration for Improved Cosmological Distance Measurements

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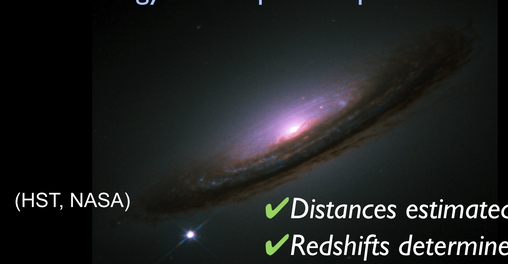
http://projectaltair.org

ABSTRACT

The precision of *luminosity* distance measurements hinges crucially on the accuracy and precision of the corresponding spectro-photometric (flux) measurements. Large area (few thousand square degrees), pan-chromatic surveys such as SDSS, Pan-STARRS, and LSST, have reduced statistical (small number) uncertainties significantly. However, systematic errors mainly due to uncorrected color dependent atmospheric extinction, lack of zeropoint uniformity across survey areas and uncalibrated telescope/optics transmission variations continue to dominate the error budget. At present, even with careful uber-calibration techniques Pan-STARRS and SDSS have achieved of order ~1% uncertainty in zeropoint uniformity. With ALTAIR, using laser diodes on high altitude balloons as standard stars monitored with NIST calibrated photodiodes simultaneously with the science observations, we aim to reduce this systematic uncertainty in absolute photometry to O(0.1%) in the near future.

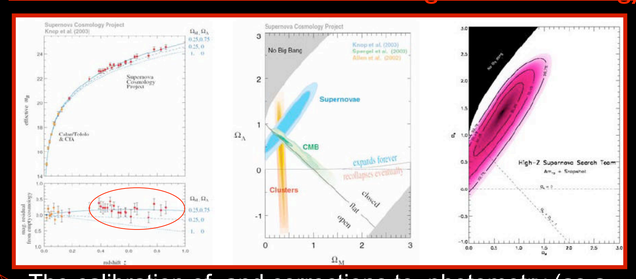
Type Ia Supernovae are (*gold*) standard candles to probe Dark Energy and map the expansion history of the Universe



(HST, NASA)

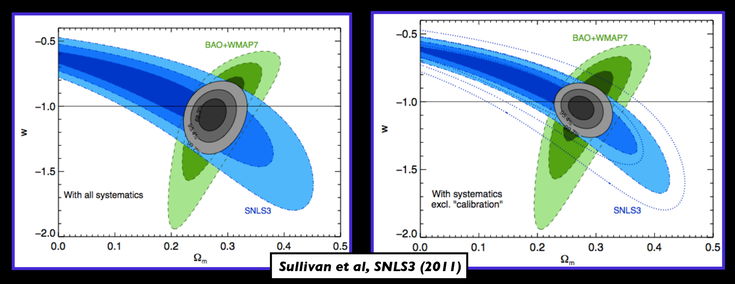
✔*Distances estimated from light curves*
✔*Redshifts determined from spectra*

Present limitations in our knowledge of Dark Energy



- The calibration of, and corrections to, photometry (as a function of filter color) is ***the dominant*** source of uncertainty in measured cosmological parameters.
- Improving the calibration standards (for flux as a function of color) to ≪ 1%, is key to tapping the full potential of upcoming Dark Energy surveys such as LSST.

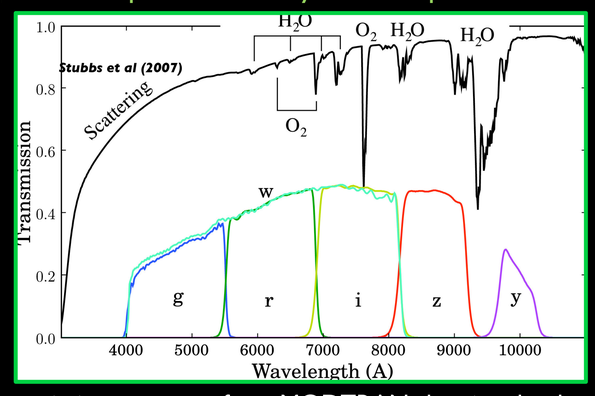
Systematic uncertainties in flux measurements dominate the uncertainties in cosmological measurements



Sullivan et al, SNLS3 (2011)

- For DE studies, statistical uncertainty (number of type Ia supernovae observed) is *no longer the limiting factor*.
- Minimizing uncertainties on cosmological parameters is dependent on minimizing systematic uncertainties (especially *flux as a function of color*, which is the dominant uncertainty).

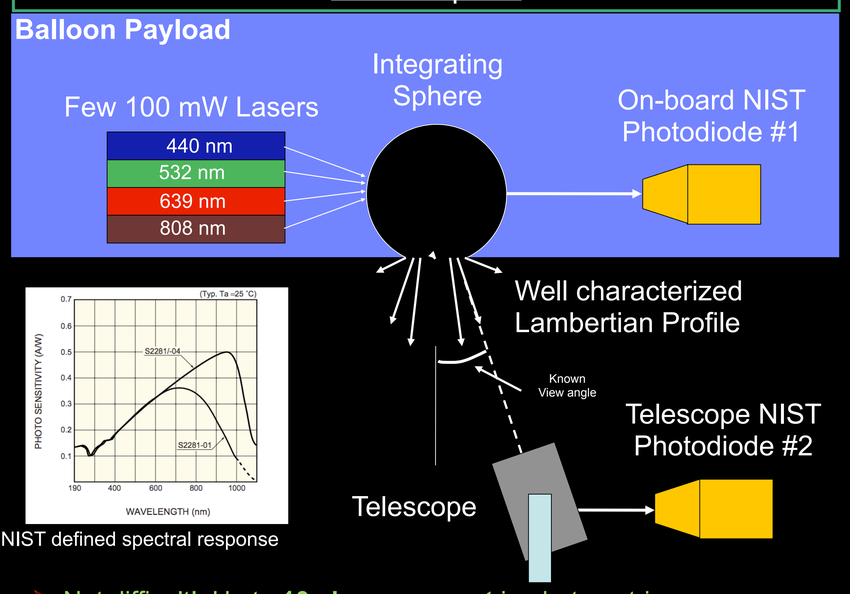
Temporal and spatial variability of atmospheric attenuation



Atmospheric transmission spectrum from MODTRAN showing the deep molecular absorption features in the broadband optical filters. Absorption depths vary independently on short time scales with changing atmospheric conditions, and with air mass, telescope azimuth and time. Therefore, airmass corrections to photometry done with a single extinction coefficient, *k* per broadband filter will be unable to reduce uncertainty to below 1% level needed by current science goals.

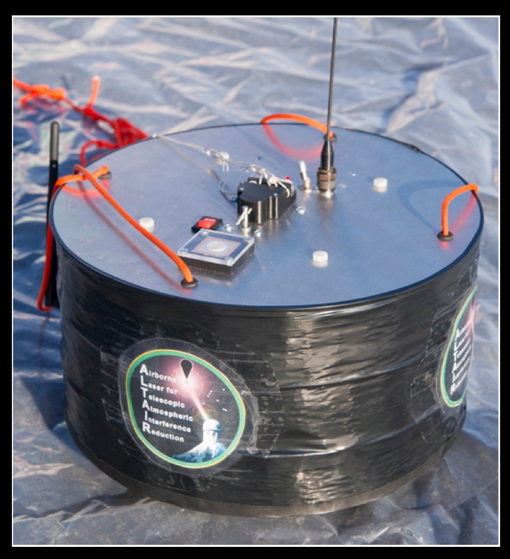
Airborne Laser for Telescopic Atmospheric Interference Reduction

ALTAIR = calibrating spectrophometric standards + atmospheric transmission using well calibrated multi-color laser sources above the atmosphere



NIST defined spectral response

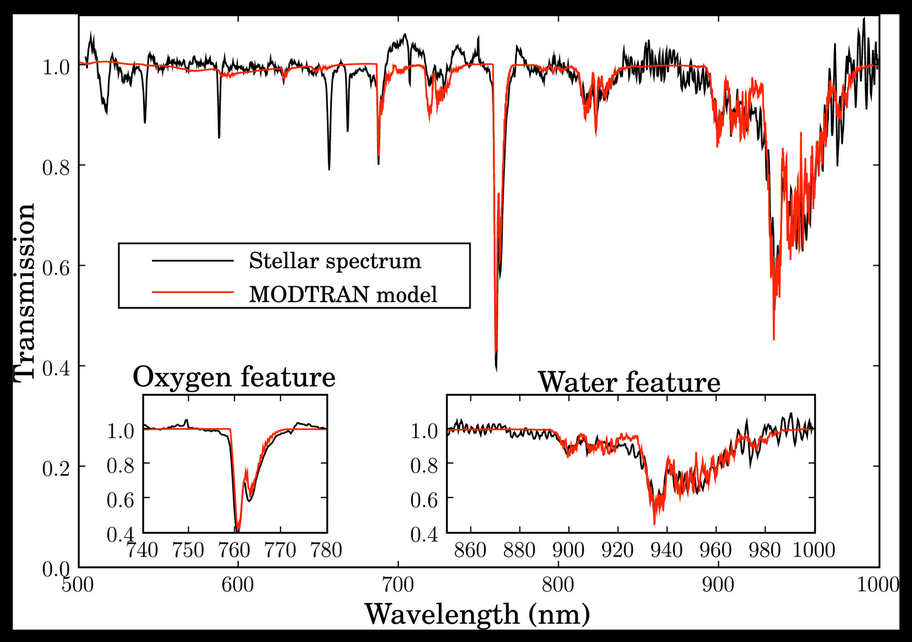
- Not difficult! Up to **10x improvement** in photometric accuracy is achievable even with simple instrumentation.

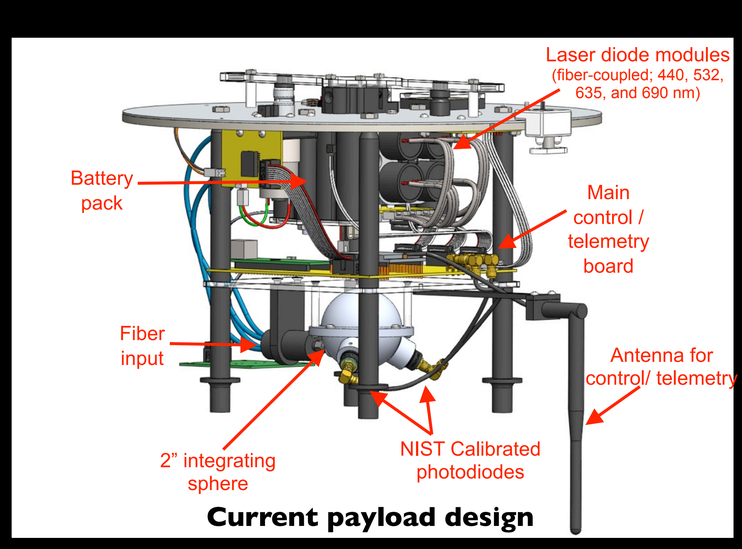


Actual payload used in test flights at Dartmouth College, Hanover, NH

Courtesy: Y. Brown

Measuring and modeling atmospheric attenuation using archival spectrophotometric standard star observations

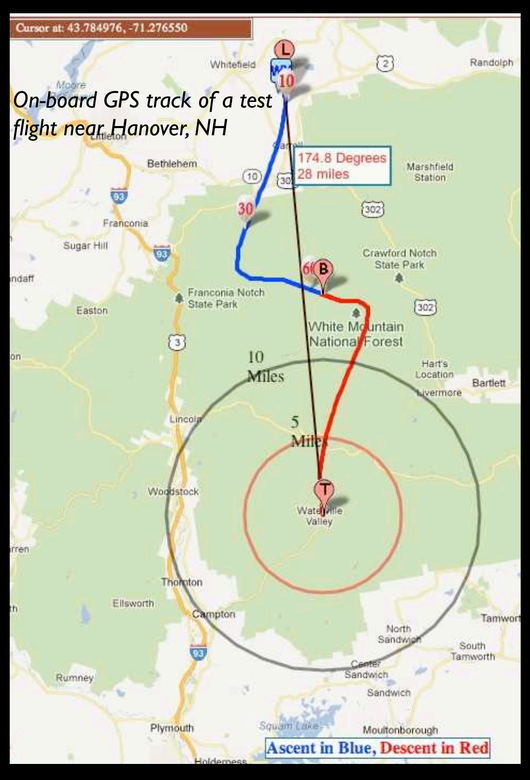




First Launch on September 2, 2011
(5 flights so far)

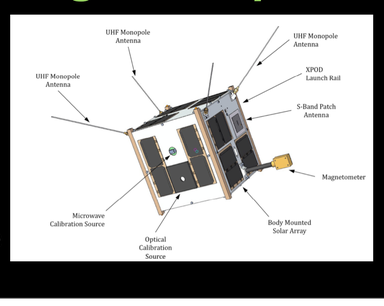
Flights over Pan-STARRS (Maui) ~ late 2014

Flights over Chile planned for 2015



We have initiated a program to use archival spectro-photometric standard star observations, done routinely each night for flux calibration, to also estimate the spatiial and temporal variability of atmospheric attenuation. Correlations of the equivalent widths of individual absorption features with the telescope orientation and prevailing atmospheric conditions, coupled with modeling on MODTRAN will yield a more robust wavelength dependent correction for atmospheric attenuation. Coupled with ALTAIR, this will significantly decrease systematics due to atmospheric transmission variability.

Longer-term plans

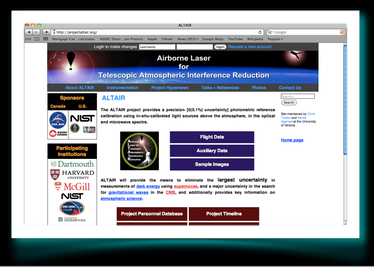


Nanosatellite

Miniature Controllable High-Altitude Blimp

Join us!

http://projectaltair.org



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