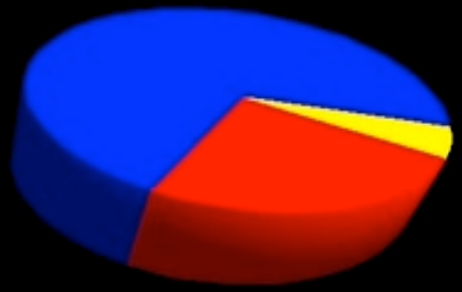
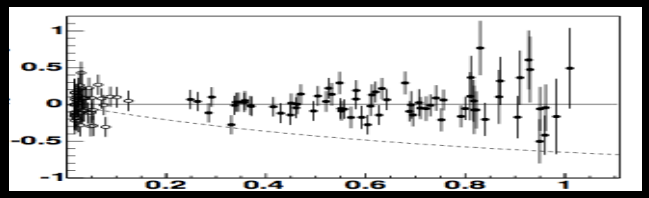
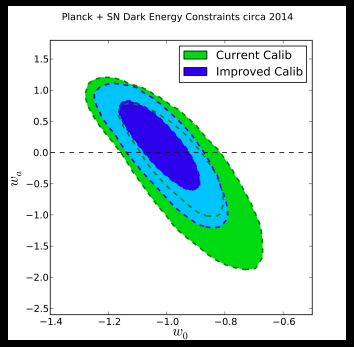
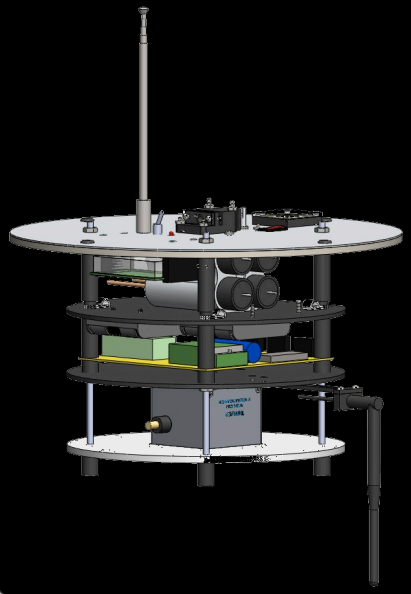
Precision Photometry via Man-Made Light Sources,

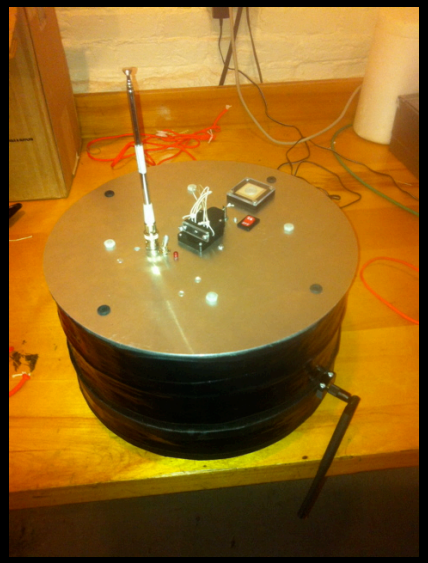






for Optical & Microwave Astronomy



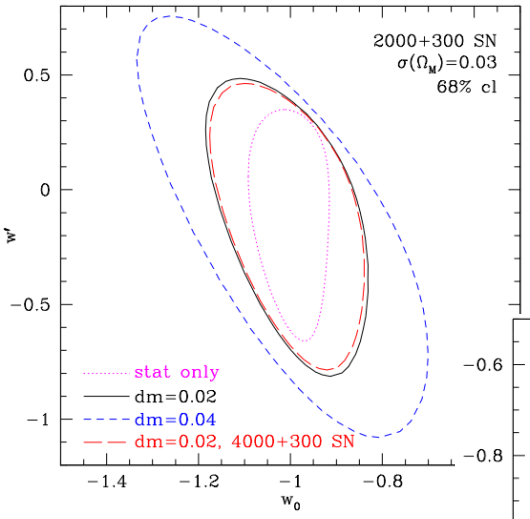


Justin Albert
Univ. of Victoria

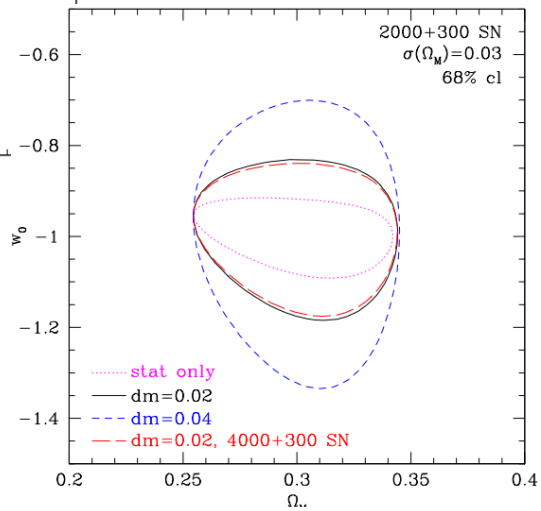
Fermilab

Apr. 16, 2012

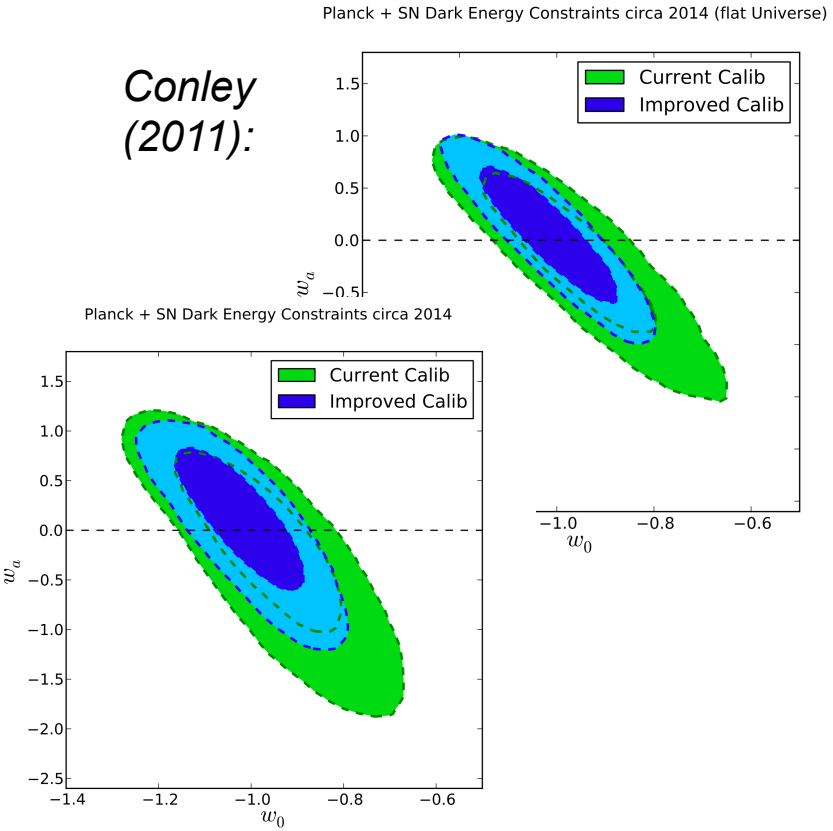
Systematic Uncertainties Dominate Both Present & Future Dark Energy Measurements



Kim, Linder, Miquel, & Mostek (MNRAS, 2004):



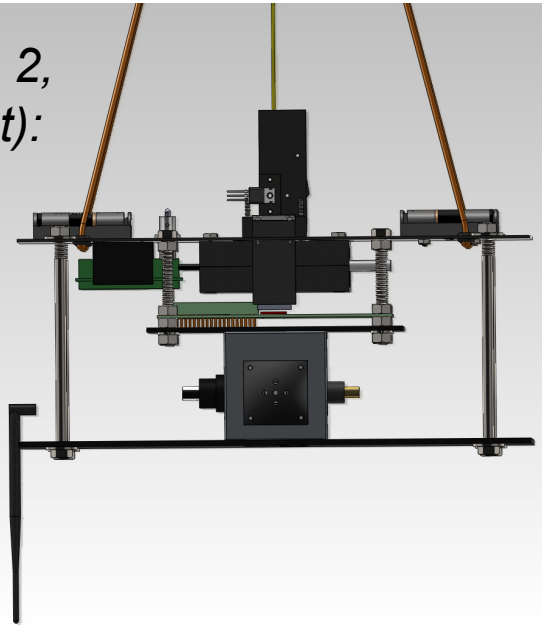
Conley (2011):

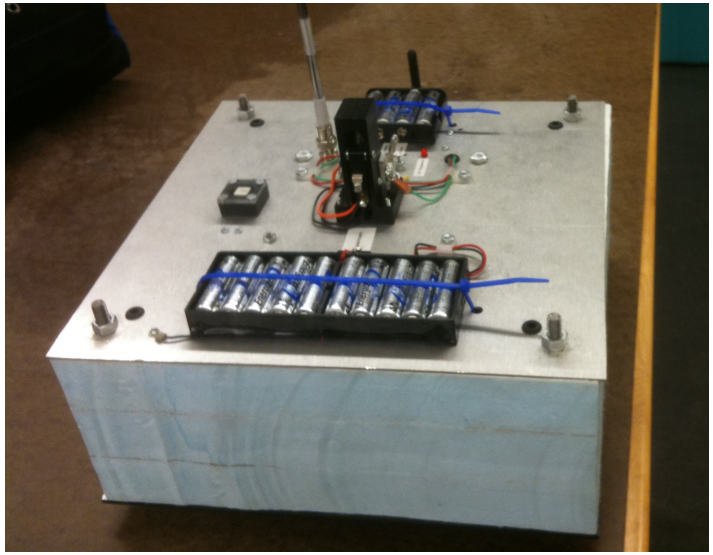


- *2%* uncertainties in photometry fundamentally limit measurements of w_a to **> ±0.40** and w_0 (when w_a is floated) to **> ±0.12**.
- Future SNIa surveys nearly useless for cosmology without significant photometry improvement.

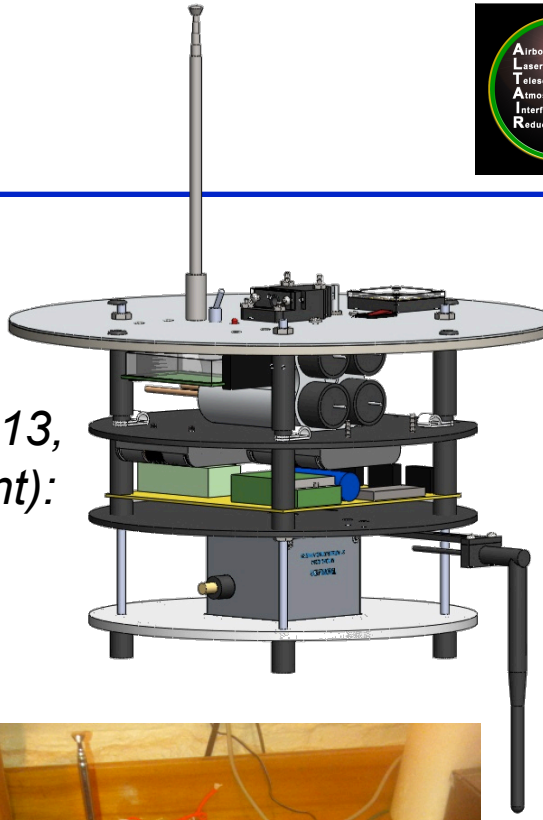
Our Payload

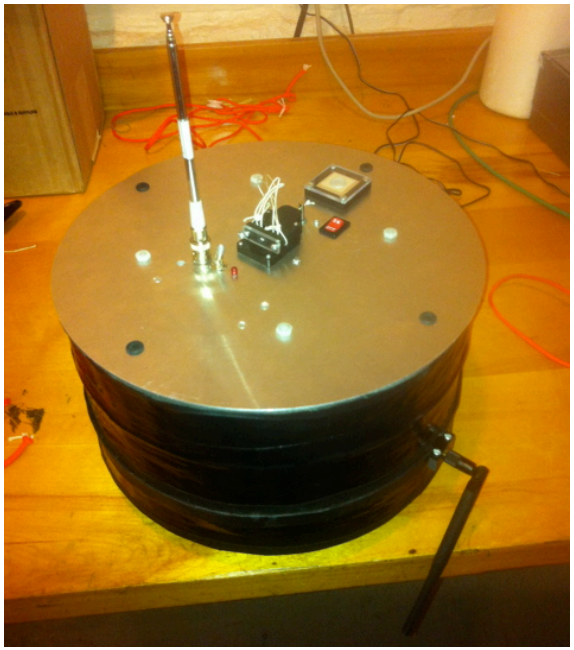
v.1 *(Sept. 2, 2011 flight):*



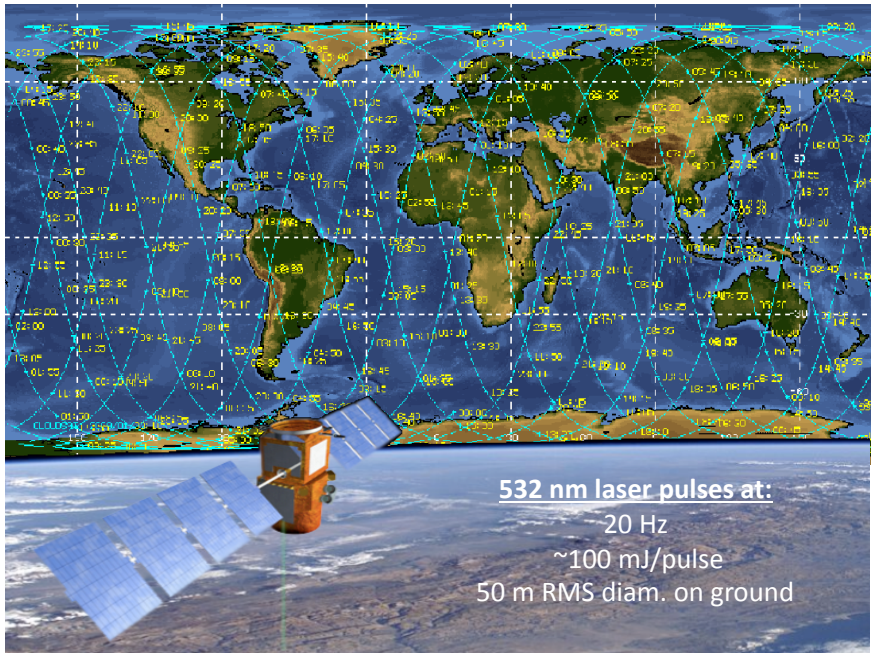


v.2 *(Apr. 13, 2012 flight):*

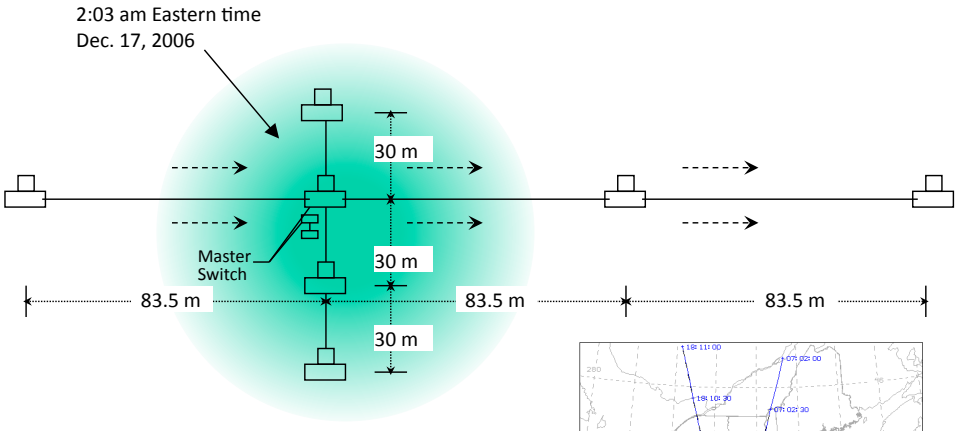


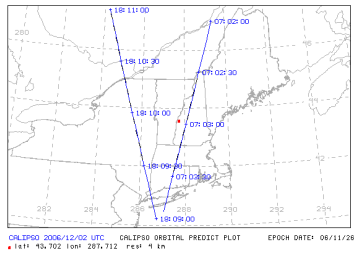


Some Pre-History, & How we Got Here

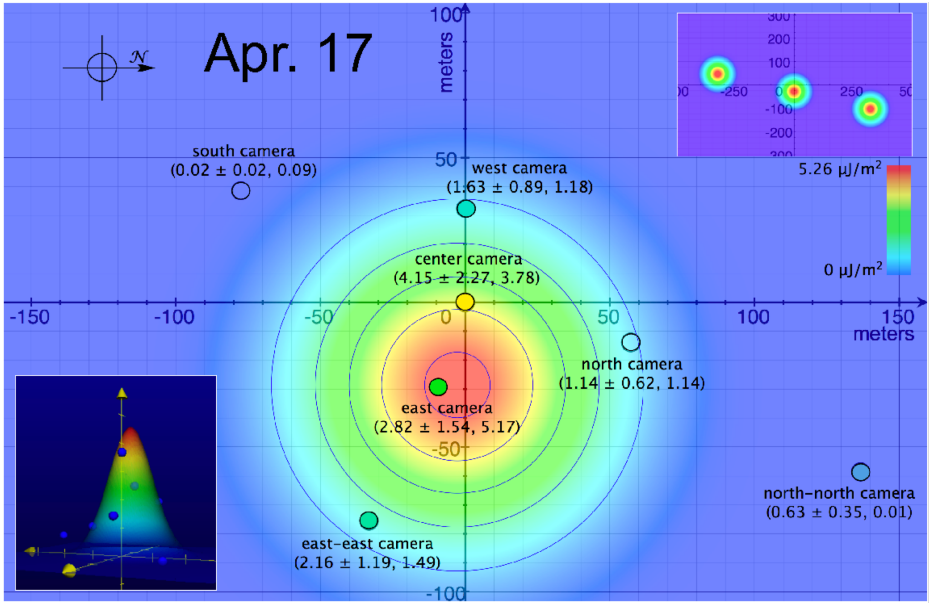


Setup for Calibrated CALIPSO Observations

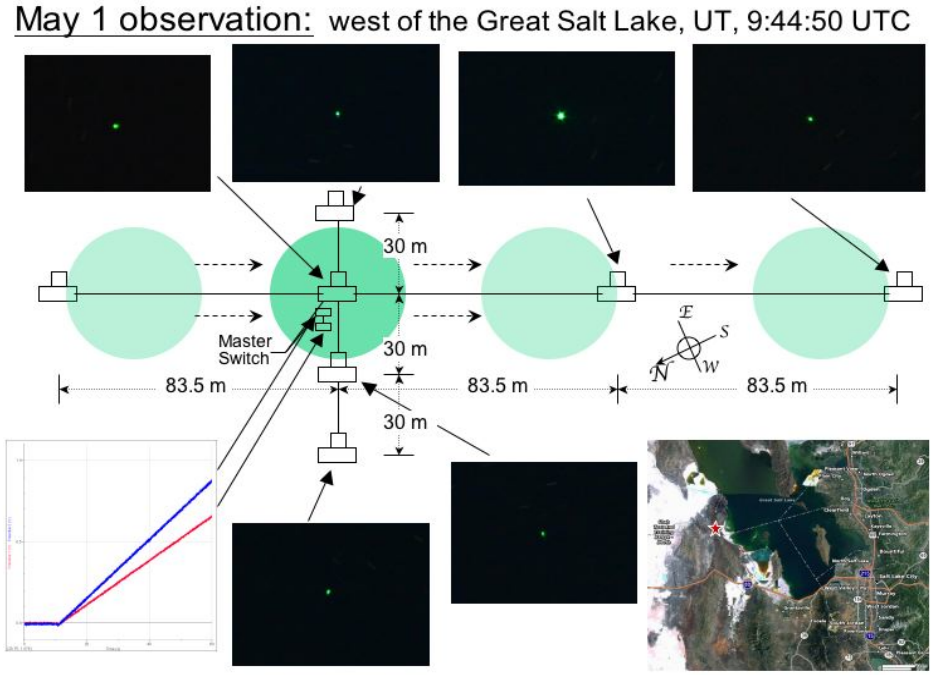




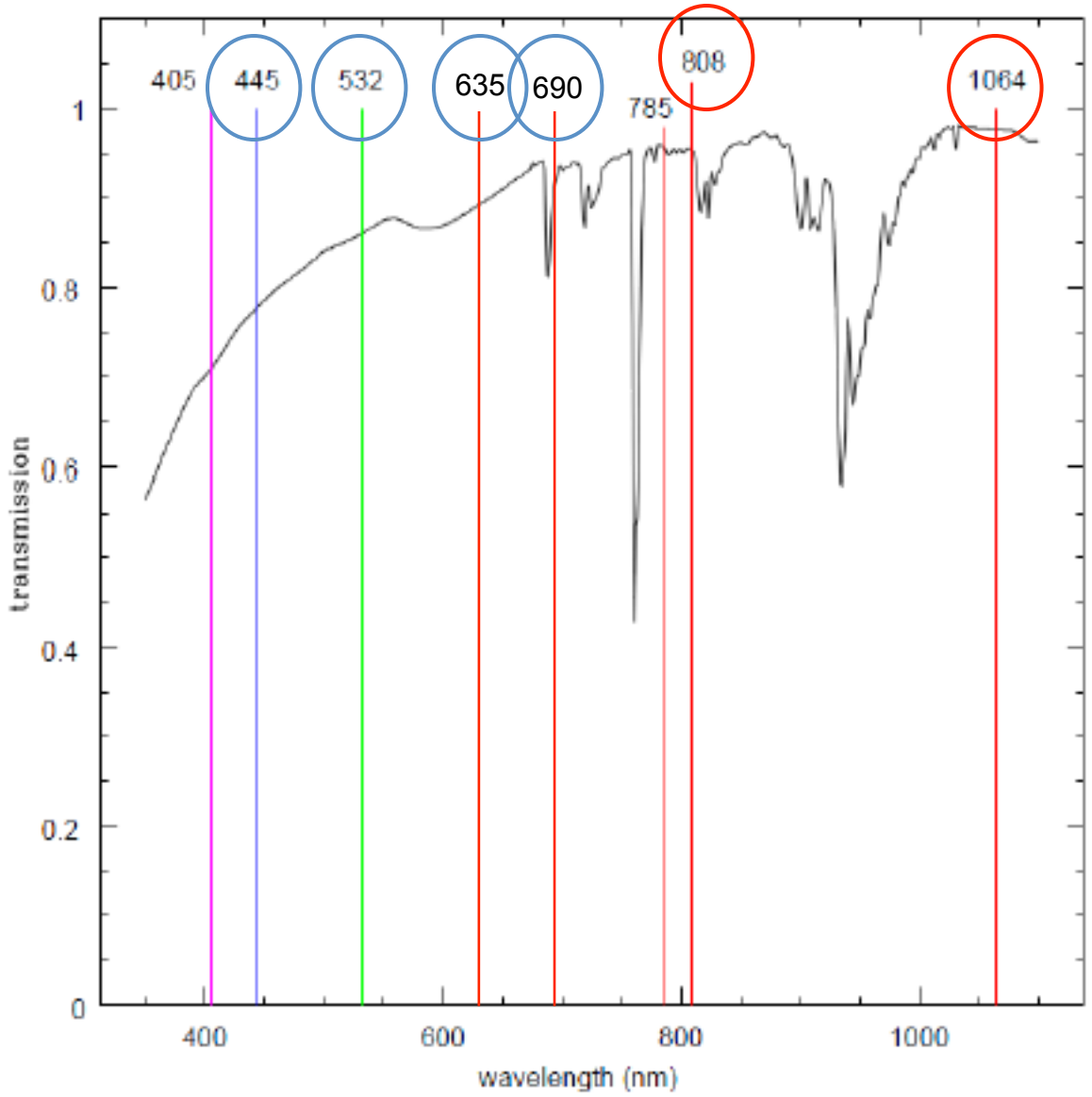
Some Pre-History, & How we Got Here



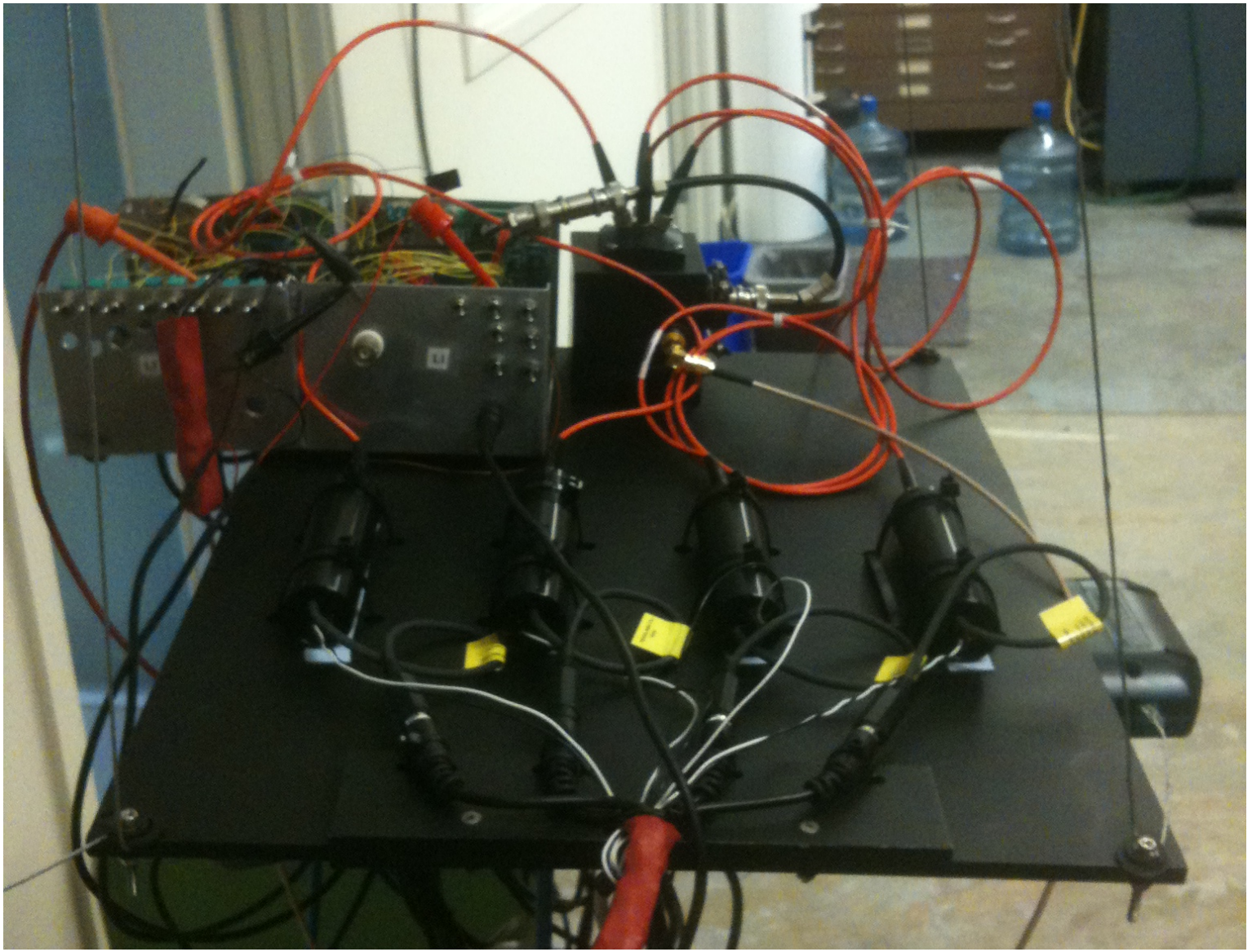
Astronomical Journal 143, 8 (2011)



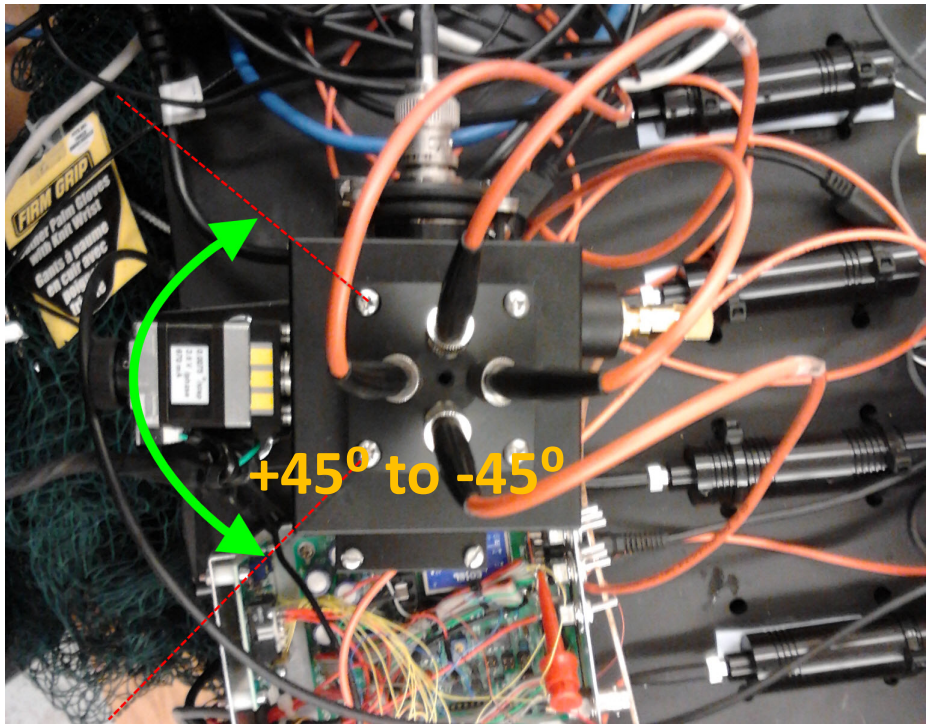
Optical Source Lines

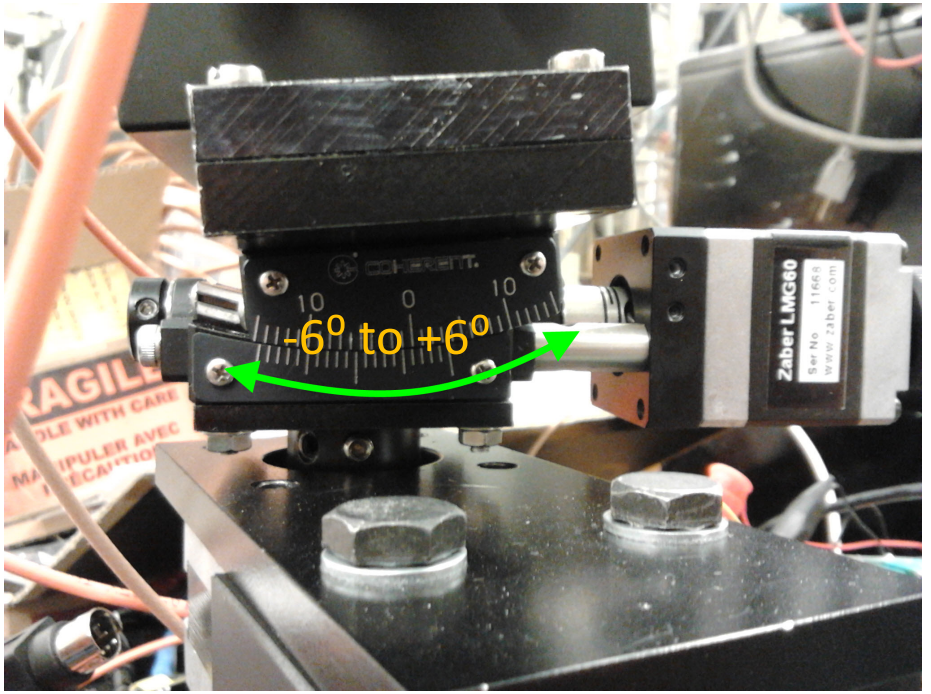


Optical Payload Test Platform



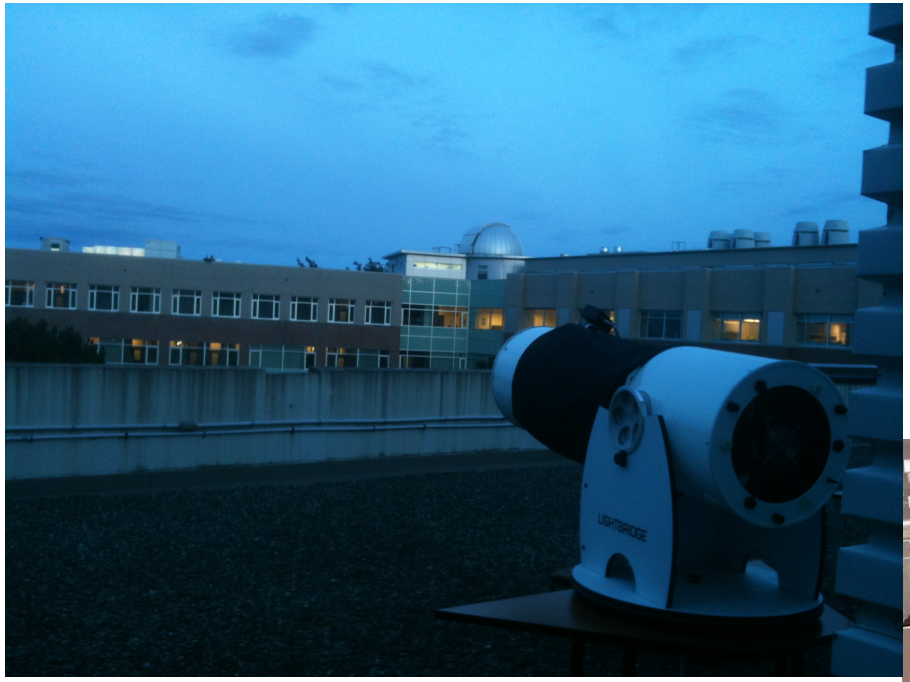
Testing the Optical Payload

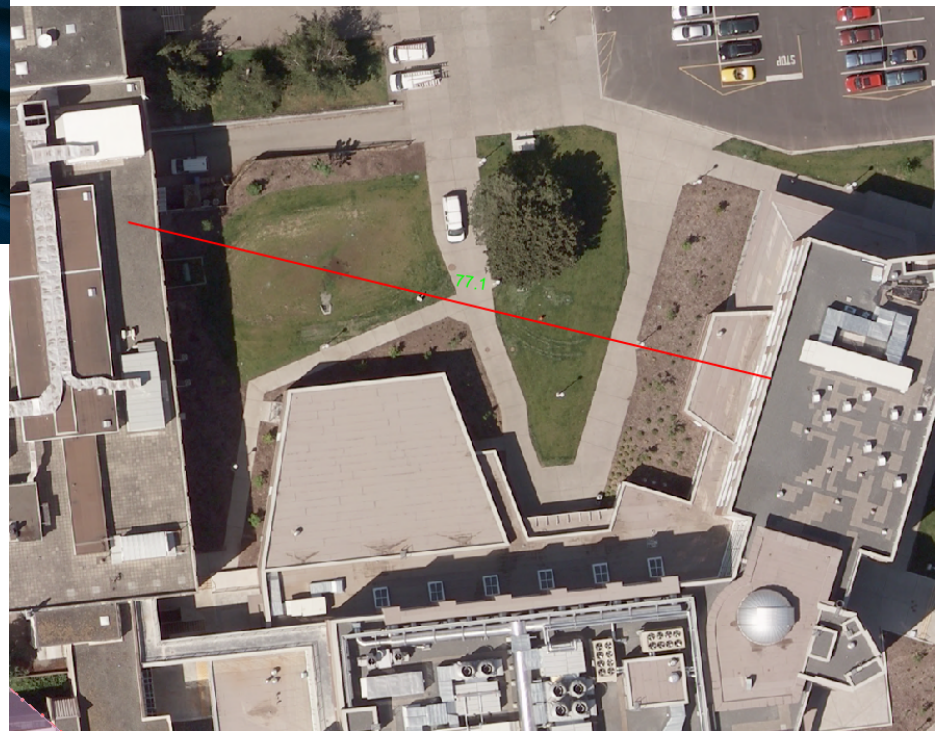




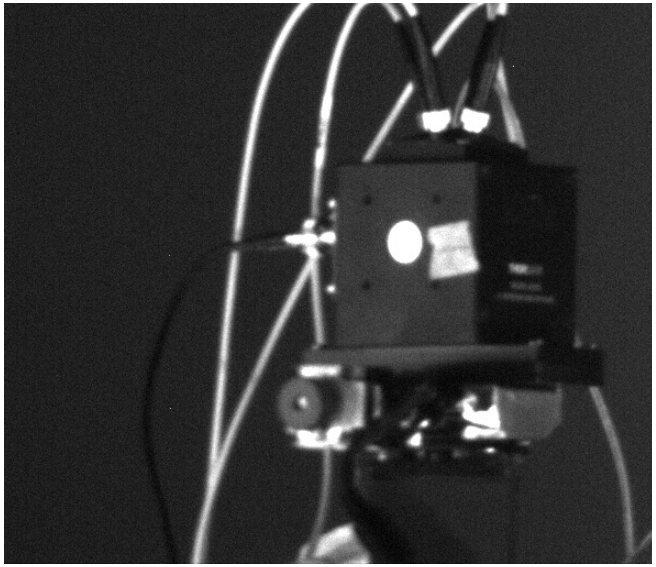
Testing the Optical Payload

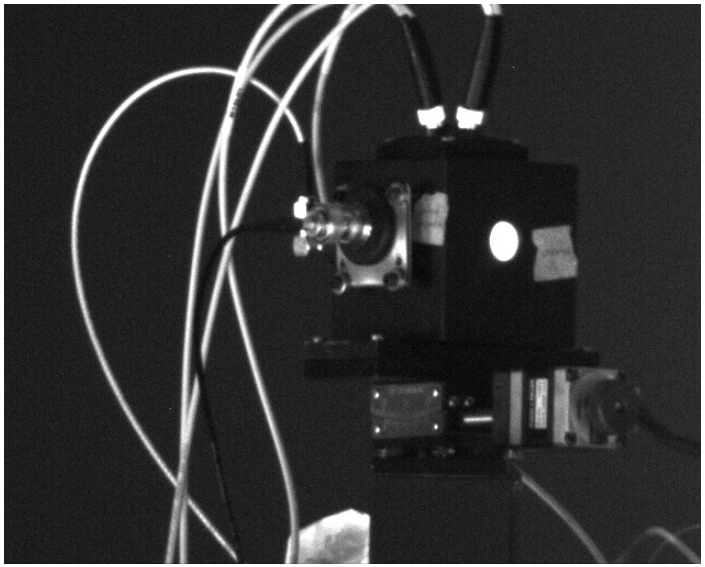
Testing the Optical Payload

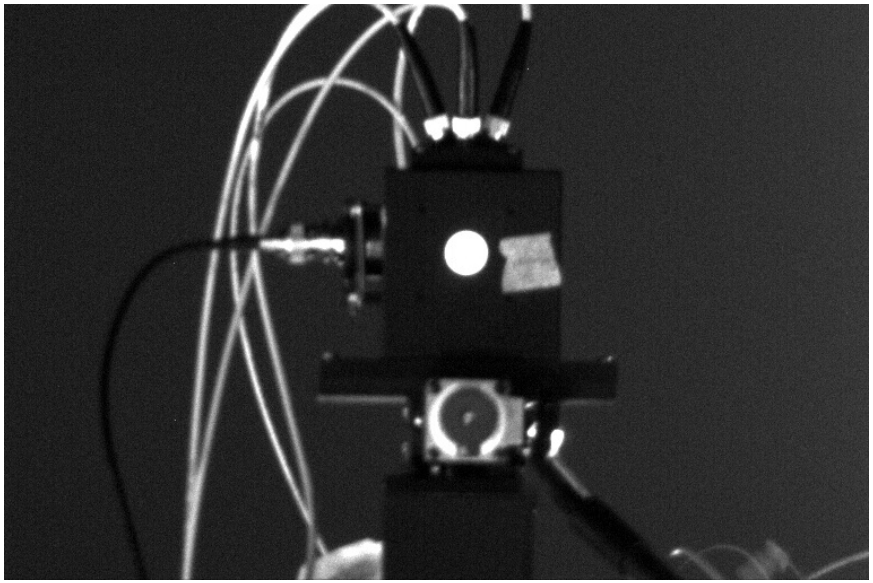




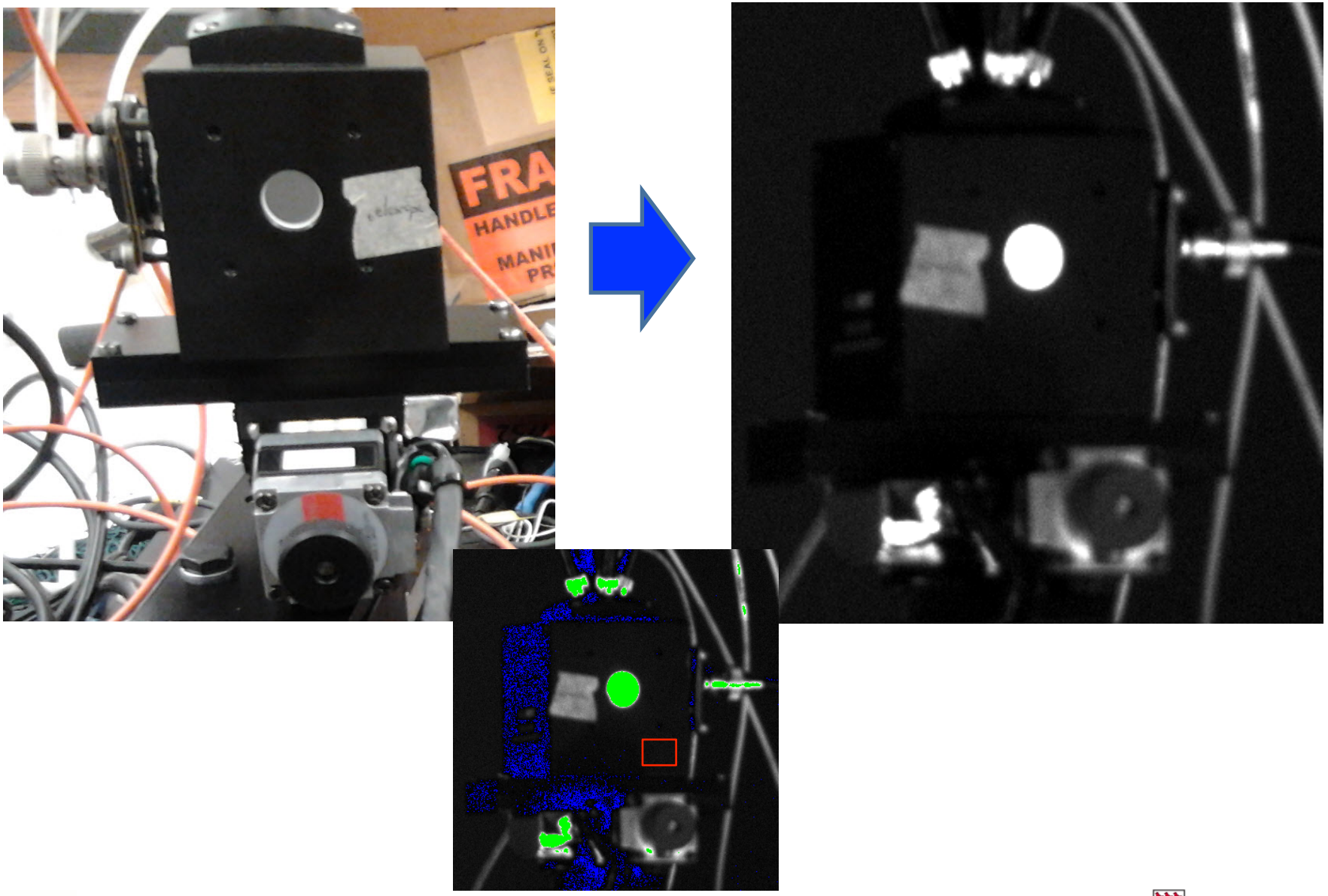
Some Near-Field (80 m) Images



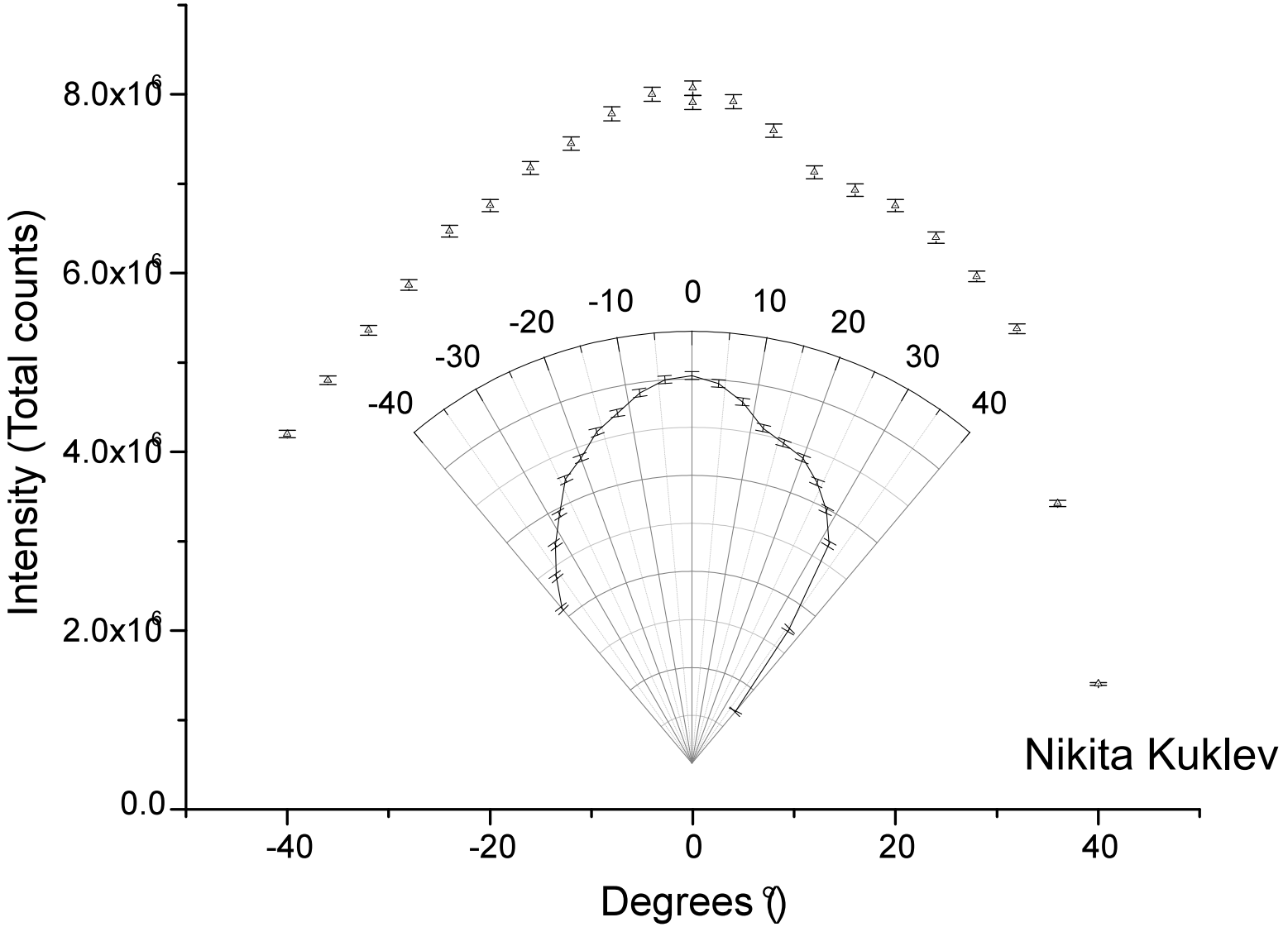




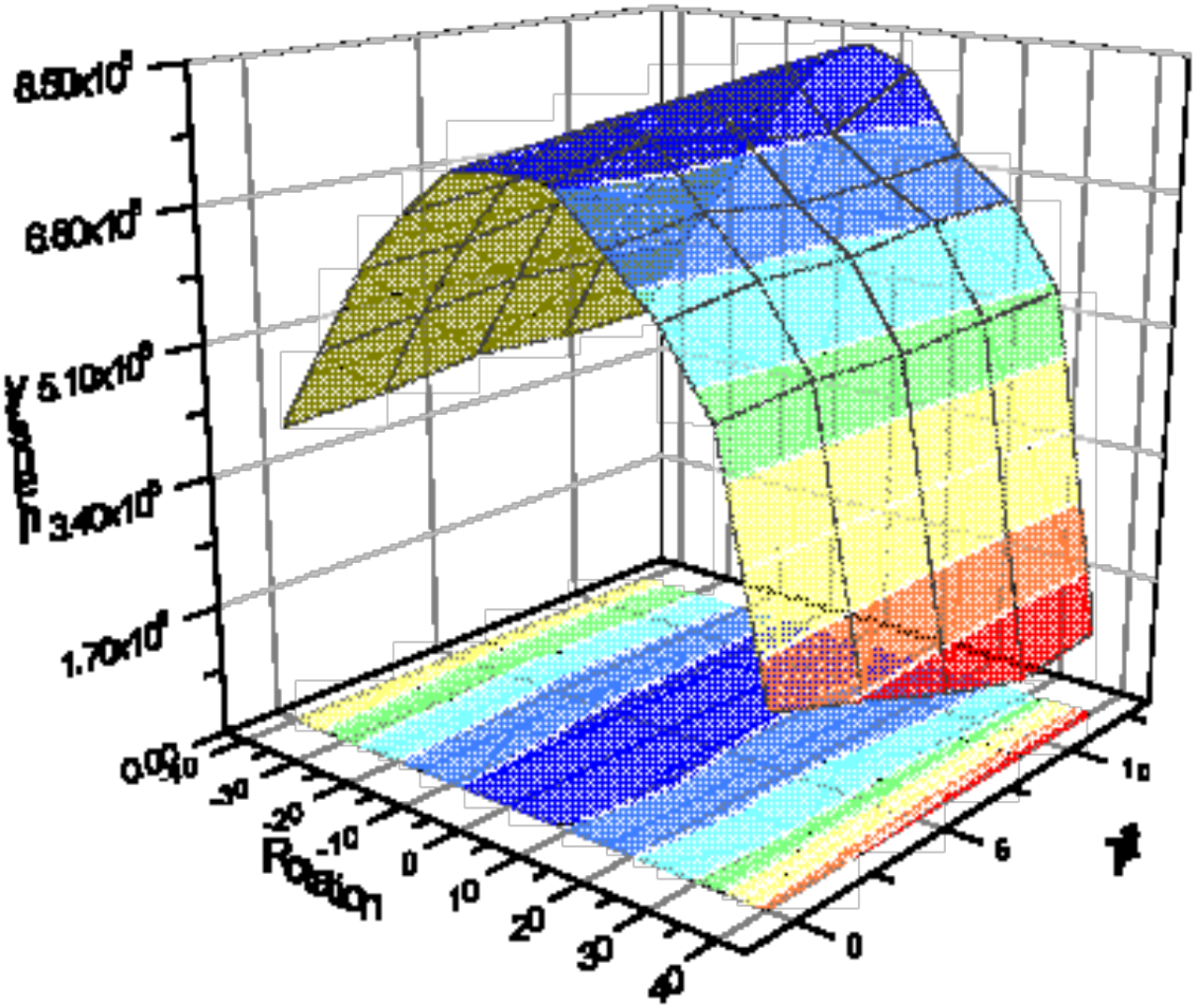
Photometry



Some Initial Results

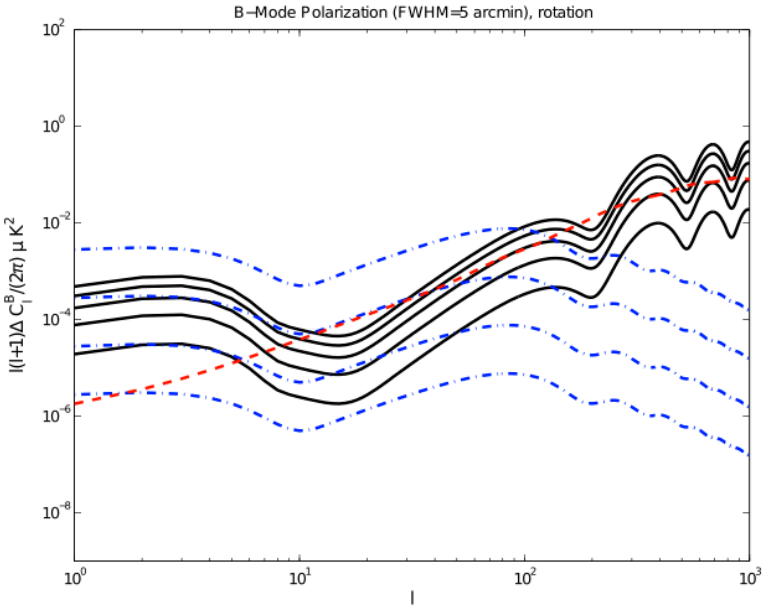


Some Initial Results

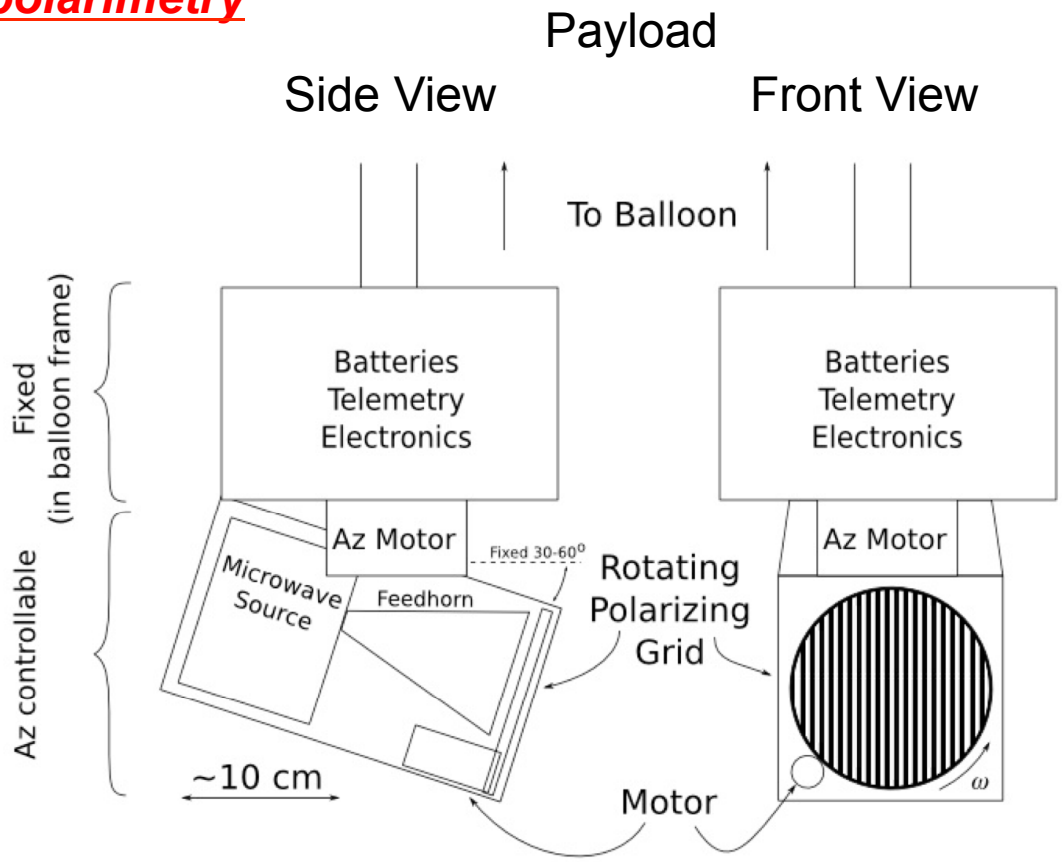


A Microwave Source …

Calibrate ***polarimetry***



Angular power spectrum of false CMB B-mode signals generated by errors in polarization sensitivity angles (from Shimon et al, PRD 77, 083003)



McGill University
(Matt Dobbs & Keith Vanderlinde)

Our Schedule & Plans

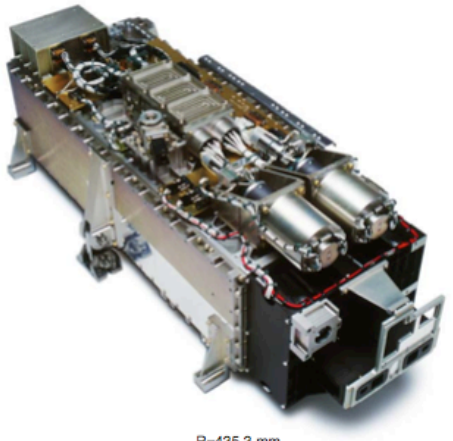
- Our next flight: New Hampshire night flight this spring – test observing strategy.
- Following that, flights over Mt. Hopkins NIST facility are planned.
- Canadian flights: over DAO (Vancouver Island) and Mont Megantic. Initial tests of microwave payload in ~ late 2013.
- Optical payload: work toward flights in Chile (and Hawaii) in 2014 and beyond.
- Microwave payload: flights over South Pole (SPT-Pol) and Cerro Chajnantor.

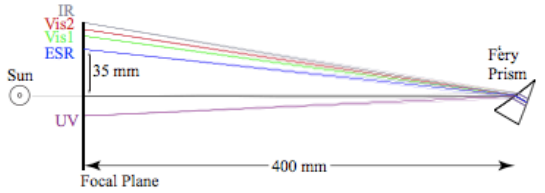
The More Distant Future: Wild Ideas

- We will achieve O(0.1%) calibration with simple NIST-calibrated photodiodes.
- Beyond that, an in-situ radiometer could achieve O(0.01%) or better …

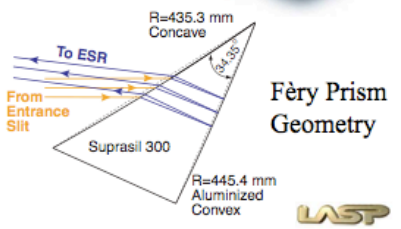
Spectral Irradiance Monitor SIM

- **Measure 2 absolute solar irradiance spectra per day**
- **High measurement accuracy**
  - **Goal of 300 ppm (±1σ)**
  - **Achieving about 2%**
- **High measurement precision**
  - **SNR ≈500 @ 300 nm**
  - **SNR ≈ 20000 @ 800 nm**
- **High wavelength accuracy**
  - **1.3 μm knowledge in the focal plane**
  - **(or $\delta\lambda/\lambda$ < 150 ppm)**
- **In-flight re-calibration**
  - **Prism transmission calibration**
  - **Duty cycling 2 independent spectrometers**



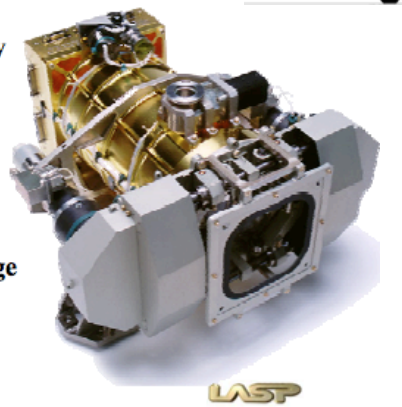


Instrument Ray Trace



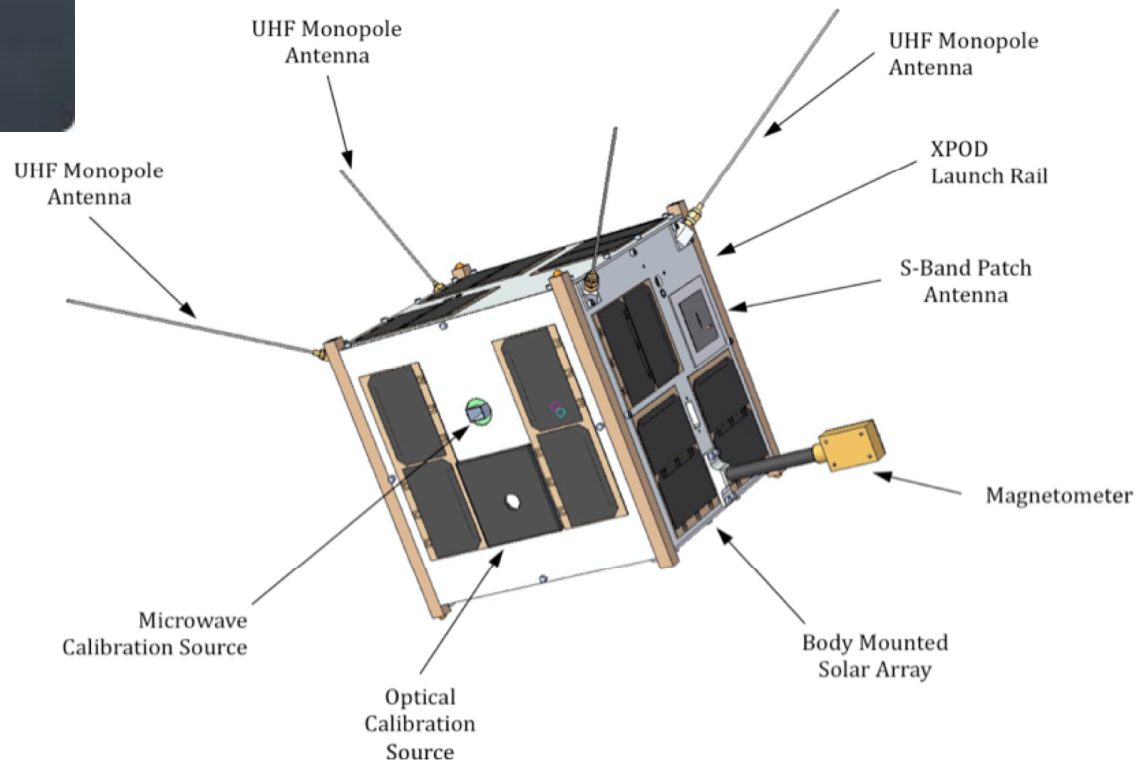
Fèry Prism Geometry

- **Provide Total Solar Irradiance (TSI) measurements**
  - **Flight history:**
    - SORCE: January 25, 2003 to 2008
    - GLORY: 2008 -2013
    - NPOESS: 2013….
  - **Extend the long-term TSI record.**
    - How does the Sun's output vary and what is its impact on terrestrial climate?
    - Address long-term climate change and natural variability
- **Measurement Requirements**
  - **Performance**
    - Accuracy 300 ppm (0.5 W/m^2) (1 σ)
    - Stability 10 ppm/yr (1 σ)
    - Noise 10 ppm (1 σ)
  - **Report four 6-hourly averages and one daily average TSI measurement per day (Level 3 data products)**



STARCal Telecom July 21, 2006 *Harder/Kopp / Page*

The More Distant Future



Conclusions

- **Man-made sources are, in principle, able to reach up to two orders of magnitude better photometric calibration precision than any natural light sources.**
  1) Can ***take 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.), ***brightness***, … ***location*** in the sky, time of night (or day), …
- **arXiv:1101.5214 (astro-ph), AJ 143, 8 (2011).**
- **This is a core program for LSST: will be the primary photometry calibration method for LSST SNIa observations.**