A Balloon-Borne Light Source for Precision Photometric Calibration

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Background

<1% (absolute) optical photometry needed for ground based cosmology surveys

Current dominant source of error is atmospheric extinction, Due to:

- H$_2$O
- Molecular
- Aerosol

Can be computed in real time with atmospheric models (MODTRAN) and ground based measurements.

Goal:
Provide a technique for real time measurement of aerosol extinction and enable <1% absolute photometry
Technique

1) Backlight atmosphere with balloon borne polychromatic light source
2) Use an on board NIST photodiode to measure absolute mag of source
3) Use a ground based NIST photodiode to measure apparent mag at detector
4) Account for extinction due to H$_2$O and molecular scattering with MODTRAN
5) Remaining difference must be due to aerosol extinction
Integrating Sphere Balloon Payload Technique

Balloon Payload

10 mW Lasers

- 440 nm
- 532 nm
- 639 nm
- 808 nm

Integrating Sphere

- NIST Photodiode #1

- NIST Photodiode #2

- Telescope

Well characterized Lambertian Profile

Known View angle

NIST defined spectral response
First flight, Hanksville Utah at the Mars Desert Research Station (2010)
Why a balloon?

- Long integrations times (>2 min) for a 2° FOV (SDSS)

- Best possible SNR for fixed photometric output

- All instrumentation is recovered after flight
  - Calibration can be re-checked in the lab

- Logistically simple
  - 4 people (2 launch, 2 recovery)
  - All equipment fits in a 4-door sedan
  - Multiple launches per night if required
Payload Design

Optical Systems
- Lasers (4)
- Integrating Sphere

Communication Systems
- GPS
- Telemetry
- ELT radio beacon

Instrumentation/Sensing
- NIST Photodiode
- Attitude

Support Systems
- Power (~2 W)
- Cutdown
- Recovery

Total weight < 6 lbs
Optical Systems

**Laser Diodes**
Photometric stability < .5%
100 g, < .5 W per laser

**Integrating Sphere**
Communication Systems

900 MHz (UHF) DNT Transceiver Radio

Robust line of sight communication
Instrumentation/Sensing

Mag/Accelerometer for real time attitude data
Challenge: Thermal Management

Peak Cooling
Ascent: airspeed 5 m/s through 30% atm at -55 °C

Peak Heating
Floating: airspeed 0 m/s in 2% atm at -45 °C
Flight Systems Test: ALTAIR 1
2011
Flight Systems Test: ALTAIR 3 & 4
Aug 16 & 24, 2012
Test Flight Results

Can maintain lasers and NIST optics at viable temperatures
Can measure attitude and source brightness in real time
Test Flight Results

Can position light source at 30 km altitude, within 2° FOV
Test Flight Results

Can track light source from incoming GPS telemetry
Long term?

Calibrate an all sky catalog of **White Dwarf** standards

- Stable <1%, ~1000 yrs
- Near black body
- Full sky coverage
- magnitudes 8-20

Credit: Fossati, Bagnulo, ApJ 08/01/12
Goals Completed:

- Maintain stable thermal conditions for flight
- Sufficient power for >2 hours of data collection
- Control, communication and data handling
- Cutdown and separation from balloon
- Telescope and radio tracking
- Precision landing targeting (+/- 2 km)
- Real-time Telescope tracking
- Night launches

Still to do:

- Zero pressure “float” balloon
- Flight over Mt. Hopkins
- First astronomical flight in early 2013
Thanks to:
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Questions?
Appendix: Flight Data

- Laser On
- Laser Off
- Dimming due to cold(?)
Appendix: Flight Data

The graph illustrates the flight data with a focus on altitude and angle over time. The red line represents the altitude, while the blue dots indicate the nadir angle. The black line shows the nadir angle averaged over 1 minute.
Appendix: Flight Data
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