Science Update
SBAG July, 2014

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BOPPS
Balloon Observation Platform for Planetary Science
Overview

- BOPPS science objectives
- BIRC calibration results
- UVVis update
- Science operations
Observable from Fort Sumner in fall

- Oort Cloud Comet PanSTARRS (C/2012 K1) near perihelion
- Oort Cloud Comet Siding Spring (C/2013 A1) within a few weeks of the Mars close encounter
  - Less than 100,000 km
- Minor Planets and Asteroids: Ceres and Vesta
- Planets: Uranus, Neptune
- Moon: depending on launch date

Excellent Science Opportunity

- Two Oort Cloud comets, both brighter than ISON during the 2013 flight opportunity
- Observe Ceres and Vesta in support of the Dawn mission shortly before the Ceres encounter
- Night time (dark sky) observations for UVVis extended exposures
- Demonstrate sub-arc second pointing with UVVis
- Characterize instrument performance
Comet Siding Spring

- Siding Spring will make an extremely close approach to Mars on October 19, 2014
  - Event to be observed by Mars spacecraft, as well as other missions
  - High resolution images and spectra of an Oort Cloud comet nucleus (HiRise 10-100 m per pixel)
- BOPPS flight from Fort Sumner can measure CO$_2$ and H$_2$O emissions from this comet a few weeks before Mars encounter
  - A more difficult observation than PanSTARRS

Unique characterization of CO$_2$/H$_2$O ratio in conjunction with an international campaign of observations
Ceres and Vesta

- Ceres, Dawn mission target in 2015
  - A dwarf planet, the largest asteroid, with ~1/3 the entire mass of the main belt
  - A hydrated asteroid with 3μm spectral features
  - Water vapor emission

- Vesta, a basaltic asteroid, unexpectedly reported by Dawn to have hydrated minerals

Demonstration of Discovery-class science and synergistic role with other missions

Ceres spectra (black and red) compared to CM meteorite (green) and model spectra (other lines) Rivkin et al. Icarus 185:563, 2006

BIRC Calibration

BIRC in environmental test chamber

Calibration target plate

August, 2013
BIRC Environmental Test

Performed functional test, cryogenic detector characterization, and radiometric calibration

BIRC instrument temperature histories shown (not chamber profile)
BIRC photon transfer test from August, 2013 in altitude thermal chamber
- Read noise is $1.67 \pm 0.059$ DN
- Measured non-linear gain characteristic
- Saturation is at 1800 DN or ~100,000 electrons
- SNR (read and shot noise) exceeds 100 above 300 DN; exceeds 200 above 900 DN
Altitude thermal test
August, 2013
BIRC radiometric model accounts for
- Telescope (but not for this test)
- Cooled relay optics
- Filter wheel
- Mini-RC telescope
- Camera inner sanctum
- Detector and readout
Include in-band and out-of-band radiation transmitted through or emitted from elements
Compare the electrons from flux model and exposure time (y-axis) to electrons converted from DN (x-axis)
### BIRC Filter Numbers

<table>
<thead>
<tr>
<th>Filter Number</th>
<th>Center Wavelength</th>
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<tbody>
<tr>
<td>1</td>
<td>R-band</td>
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<tr>
<td>2</td>
<td>4.6 µ</td>
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<td>8</td>
<td>3.05 µ</td>
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<td>9</td>
<td>2.85 µ</td>
</tr>
</tbody>
</table>

- Continuum subtraction and ratio of CO$_2$ to H$_2$O emissions, using eight NIR spectral filters; R-band filter not shown.
**UVVis Instrument Overview**

- **Science channel**
  - CCD camera with filter wheel
  - 4 bandpass filters (300 – 450 nm)
  - Broad band (<300 – 600 nm)
  - Frame format 1024x1024 with optional EMCCD
  - Plate scale 0.19 arcsec/pixel with 13 \( \mu \)m pixel pitch

- **Guide channel**
  - Fast framing CMOS imager
  - 600 – 850 nm broad band
  - sCMOS detector with image format 2560x2160
  - Plate scale 0.096 arcsec/pixel with 6.5 \( \mu \)m pixel pitch
  - Controls a fine steering mirror for fine image stabilization to ~ 0.1 arcsec

- **Inset fold mirror**
  - Movable into the telescope light beam
  - Divert light from telescope into UVVis optic
  - Open lets light reach BIRC instrument
UVVis FSM demonstration

- Star pointing with vibrational mode excited in ground hang test
- Guide camera centroids image at 50 Hz and stabilizes the image
- After fine steering starts, star image is stabilized with residual effects from seeing
BOPPS 2014 Mission Targets

- Oort Cloud comets C/2012 K1 (PanSTARRS) and C/2013 A1 (Siding Spring)
  - Measure water, CO₂, and dust activities
  - Coordinated Earth-based and Mars-based observing of Siding Spring
  - Coordinated Earth-based observing of PanSTARRS

- Dwarf Planets Ceres and Vesta
  - Hydrated surfaces on Ceres and Vesta
  - Variable water vapor emission from Ceres

- Uranus
  - Resolved disk imaging
  - Demonstrate UVVis fine pointing system
BOPPS Mission Timeline
Notional Mission on September 24

TARGETS

120,000 ft
90,000 ft
ASCENT

Commisioning
BIRC
UVVis
PanSTARRS
Siding Spring
Ceres
Vesta
Mizar
Siding Spring
PanSTARRS
Ceres
Vesta
Uranus
Mizar
Uranus

08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00

L1 mission
Baseline mission

Aurora
PanSTARRS
Siding Spring
Ceres
Vesta
Uranus
Mizar
Castor
Jupiter
Vesta
Mizar
Castor
Jupiter

9/23/2014 7:00 AM
9/24/2014 8:00 AM
PanSTARRS Brightness

- Discovered May 19, 2012
- A bright Oort Cloud comet
- Perihelion: Aug 27, 2014
- JPL predicted magnitudes are fainter than those predicted by Yoshida:
  - 8.4 on 9/15/14
  - 8.2 on 10/1/14

High SNR determination of CO$_2$/H$_2$O ratio
Comet Siding Spring

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Unique characterization of CO$_2$/H$_2$O ratio in conjunction with an international campaign of observations
• Discovered 3 Jan 2013 by R. McNaught

• An Oort Cloud comet which encounters Mars near perihelion

• JPL predicted magnitudes are fainter than shown by Yoshida:
  • 9.65 on 9/15/14
  • 10.04 on 10/1/14

• First day in September that comet gets at least 8 degrees above horizon for an hour is 9/24/14