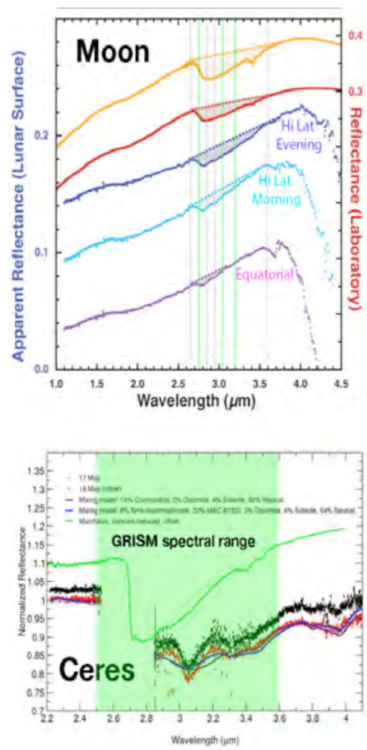
STRATOSPHERIC INFRA-RED IMAGING AND SPECTROSCOPY for PLANETARY SCIENCE (SIRIS - PS)
C. A. Hibbitts[1], T. Kremic, A. Cheng[1], P. Bernasconi[1], A. Rivkin[1], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20273, karl.hibbitts@jhuapl.edu; [2]NASA Glenn Research Center, Cleveland, OH. 44135;.

Introduction. Planetary science can be effectively conducted from the middle stratosphere (~100K to 130K ft.) using existing NASA scientific ballooning that currently supports astrophysics and heliophysics missions [e.g. 1]. Two recent planetary science ballooning flights demonstrated the great potential of these platforms for conducting solar system science [2,3,4]. Additionally, a report in preparation [5] following upon a scientific workshop held in February, 2012 to discuss the potential value of scientific balloon platforms for conducting planetary science, concluded that investigations from these platforms can potentially make significant contributions to fundamental investigations of high priority to the NRC Planetary Science Decadal Survey 2010. Specifically, the report concludes that planetary science balloon missions can significantly address 10 of the 23 "Important Questions" for small bodies as specified in the 2010 Decadal Survey. The recently completed BRRISON and BOPPS missions demonstrated some of the requisite platform capabilities and BOPPS conducted unique planetary science, including measuring the water-related infrared ν_3 absorption band on Ceres and observing CO_2 on comet C/2014 E2 Jacques [2,3].

For this mission concept we propose to leverage the success of those missions, refly the infrared portion of that mission – with some modifications – to address more of the planetary science questions within the Decadal Survey that pertain to small bodies and the Moon. This mission would also demonstrate the cost-savings of science missions conducted through reflights. Additionally, this mission philosophy is for a wide participation from the scientific community.

NASA BOPPS gondola, telescope, and instrument payload during a 'hang test'. This mission concept is to refly infrared portion of this platform, with modified filters for conducing lunar and small body science.

Science Goals. There are two science goals for this mission. One is to characterize the chemical nature of the water/OH on the illuminated Moon and by observing it over a significant portion of a lunation, to unravel the secrets to its origin and evolution. The second is to characterize the water/OH and organics that may be present on the surfaces of small bodies throughout our solar system. The measurements will span the full wavelength range of the hydroxyl and water absorptions, the C-H stretch vibration in organics, and extend to sufficiently long wavelength to enable accurate thermal correction.



Spectral sampling of the OH/H_2O band on the Moon as measured by EPOXI [4], and the spectral range of a GRISM compared to a telescopic spectrum of Ceres provided by [5]. Green is new capability; gray is heritage capability from BRRISON/BOPPS.

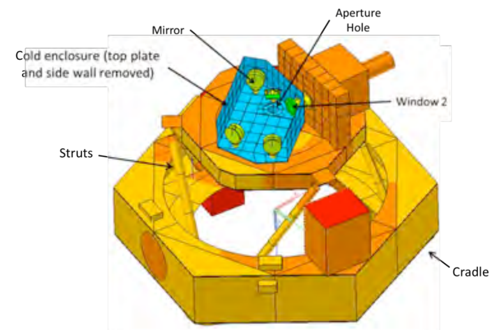
Platform. The platform consists of multiple subsystems: the gondola frame, the pointing system, the telescope, the infrared instrument, the power distribution system, communications, and a instrument package for tracking and ground communication that is provided by the Columbia Scientific Balloon Facility (CSBF). In addition, the Balloon Program Office (BPO) stationed out of the Wallops Space Flight Facility, would be responsible for the operation of and provides the balloon, the parachute, and other equipment that is common between all balloon missions.

Gondola. The gondola carries and protects the telescope and attached instrument. The frame is made of standard aluminum angles bolted together and painted with a white thermal coating. The existing BOPPS frame will be used, after repairing from its latest landing.

2. *Telescope*. The telescope is APL heritage equipment, and is a gold-coated Cassegrain, with a f/1.5 hyperboloid primary 80-cm in diameter, made of honeycombed Ultra Low Expansion titanium silicate glass and weighing just 50 Kg. The effective focal length is f/17.5. The full field of view of the Ø80 cm telescope is 3 arcminutes, and the spatial extent of the F/17.5 primary image is defined by a Ø12.7 mm field stop. A hexagonal support ring surrounding the telescope, and placed at the center of mass of the telescope near the primary mirror, acts as the interface between the elevation pointing control system and the telescope, including the instrument payload. This cradle is attached to the instrument payload through low CTE struts.

3. *Pointing system*. The pointing system is heritage APL equipment used on BRRISON and BOPPS, which was derived from > 15 years of development and many flights on heliophysics and astrophysics missions including the Solar Bolometric Imager (SBI) and the Stratospheric Terahertz Observatory (STO). The pointing system is an integral part of the gondola structure. There are three components: the elevation control, which interfaces with the cradle to move the telescope and instrument payload vertically, and two flywheels to control gondola motion against forces input from residual balloon motion transmitted to the gondola through the tether and to compensate for effects of winds. These three mechanisms alone achieve arcsecond stability of the gondola during float.

4. Infrared Imaging System. The instrument payload is mounted along the optical axis behind the telescope to the cradle through low CTE struts. The infrared system used on the BRRISON and BOPPS missions is described in great detail by [9]. The instrument is comprised of three subsystems: a collimator, a camera, and a cryogenic filter wheel (shown as part of the camera). The primary image from the telescope propagates through a CaF_2 window at the aperture hole in the box containing the collimating subsystem of BIRC . They can be maintained ~ 200K or colder to eliminate thermal self emission at these mid-IR wavelengths, valuable especially for the spectral observations of small bodies. The collimated beam then passes through the filter wheel and into the camera subassembly where it is focused by a small all aluminum, 2-inch



Thermal desktop model of the BIRC instrument mounted to the cradle of the main telescope via six graphite-epoxy struts.

aperture Ritchey-Chretien telescope onto the cryogenic H2RG Teledyne detector. Both the filter wheel and the RC telescopes are cooled to eliminate thermal self emission. The 9-position filter wheel will contain 7 filters to characterize the water absorptions on the Moon from 2.6 to 3.6 microns, a GRISM to obtain ~ 2.5 – 3.6 micron spectra of point sources, and an R-band filter to aid in target acquisition and in-flight calibration (using standard stars). Some of these filters are heritage from BOPPS. The GRISM is a new development. It is possible the Teledyne camera will be unavailable for this mission, and if so, it will likely be replaced with a COTS 1k x 1k cryocooled InSb camera.

Mission Implementation. SIRIS will launch from either Kiruna, Sweden or McMurdo, Antarctica for a multiday mission. The duration is determined by a combination of time available at float (3 days to 1 week at Kiruna, 2 to 8 weeks in Antarctica), and the depletion of resources – liquid nitrogen cryogen and power – either battery or solar. Liquid nitrogen cryogen to cool the filter wheel, and possibly the collimating optics, will deplete after two or three days. After that, the GRISM measurements will cease because of significant self-emission while filter photometry measurements will continue.

Acknowledgement: This work has been supported by NASA contract: NNN06AA01C.

References: [1] http://www.csbf.nasa.gov/; [2] Cheng, A. et al, 2014, P42A-04, Fall AGU. [3] Hibbitts et al., 2014, P23B-3988, Fall AGU. [4] Kremic et al.., 2015, in press, IEEE, 8.1003. [5] Dankanich et al., NASA/TM – 2015 – tbd. [4] Sunshine et al., 2009, Science, 10.1126/science.1179788. [5] Rivkin et al., 2006, Icarus, 185, 563-567. ;[9] McMichael et al., 2013, Proc IEEE, 9145, doi: 10.1117/12.2057619.