COMPREHENSIVE UNDERSTANDING OF LUNAR IMPACT FLASH PHENOMENA BY GROUND-BASED TELESCOPIC OBSERVATIONS, HYPERVELOCITY IMPACT EXPERIMENTS AND A 6U CUBE-SAT EXPLORATION.

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Introduction: A Lunar Impact Flash (LIF) can be detected as a short duration luminous phenomenon in VIS and NIR wavelength regions when a meteoroid impacts on the night side of the moon. The LIF provides absolutely essential for understanding meteoroid environment within the Earth-Moon (Cis-Lunar) space, especially centimeter to sub-meter sized impactors, which is as a bridge between visual meteors and small asteroids. Physical characteristics (e.g., luminous efficiency, temperature) of impact flash has not been fully understood. Here we present our comprehensive studies which were carried out using ground-based telescopic observations, hypervelocity laboratory simulations, and development of LIF camera onboard a 6U Cube-Sat which will be launched by NASA SLS in 2020.

Ground-based Telescopic Observations: Observing LIFs on the moon have an advantage to monitor much larger collecting area, which is approximately 100 to 1000 times greater than a single station observation of meteors on the Earth. Typical observable visual magnitude of LIFs by using a ground-based telescope is between 5th and 11th with the flash duration between 0.01 and 0.1 second. On the night of December 15, 2018, LIFs during the maximum of Geminid meteor shower were observed from two locations, Nihon University (35°43'31" N, 140°03'32" E, H=28 m) with a 40cm/F3.8 telescope and the University of Electro-Communications (35°39'28" N, 139°32'37" E, H=80 m) a 45cm/F4.5 telescope. 11 LIFs associated with Geminids during 3-hours were detected by both stations [1]. Magnitude distributions of the observed Geminids LIFs compared with [2,3] were summarized in Fig. 1. Note that spectroscopy of Geminids impactors were investigated by meteor observations simultaneously [4]. The variation of Na, Mg and Fe during meteor ablation in the atmosphere were shown in Fig. 2. The impacting velocity of the Geminids on the moon is about 35 km/s.

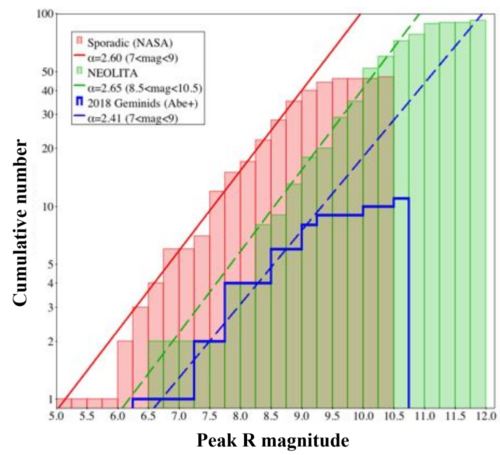

Figure 1. Cumulative magnitude distributions of 2018 Geminids' LIFs compared with previous observations. Fitted slopes are also shown for comparison.

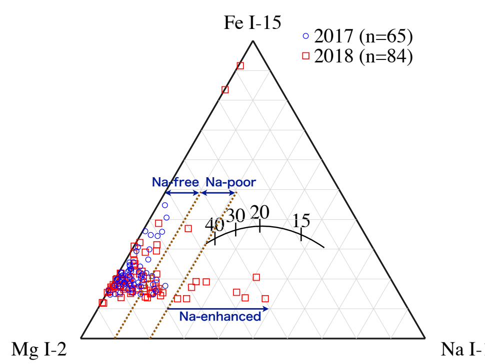

Figure 2. Ternary plot for Na I (1), Mg 1 (2), and Fe I (15) multiplets in 149 Geminid meteor spectra. The 2017 and 2018 Geminids are indicated by blue circles and red squares, respectively. The solid curve is a theoretical reference line for the chondritic (CI) meteor ablation. The velocity (in km s^{-1}) are marked with numbers.

Hypervelocity Impact Experiments: The hypervelocity impact experiments were carried out using the ISAS/JAXA hypervelocity impact facility with a hypervelocity spectrograph. The projectile was polycarbonate spheres, 4.76 mm in diameter with mass of 0.068 g, and the impact velocity was approximately 6.5 km/s. While the target was quartz sand with the mean grain size of 344.8 μm. The decay time τ of the estimated blackbody temperature was affected by the ambient pressure environment, for example, a τ for 0.1Pa pressure condition seemed to be about 4 times first than that for 530Pa. The initial and terminal temperatures are estimated to be 5,500-6,000K and ~2,000 K shown in Fig. 3.

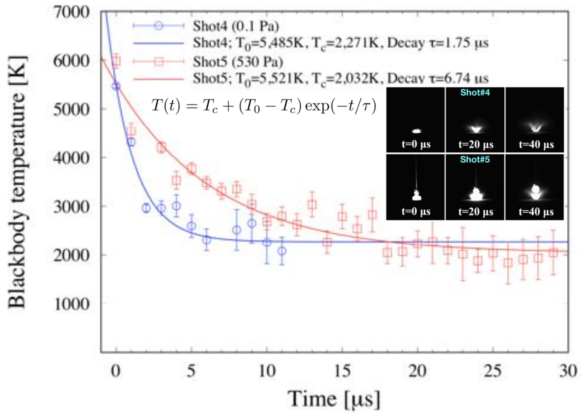

Figure 3. Decay curves of blackbody temperatures.

6U CubeSat Exploration: EQUULEUS (EQUilibriUm Lunar-Earth point 6U Spacecraft) will be the world's smallest spacecraft to explore the Earth-Moon Lagrange2 point, EML2 [6]. The spacecraft will be jointly developed by the University of Tokyo and JAXA which will be launched by NASA's SLS (Space Launch System) EM-1 (Exploration Mission-1) in late-2020. The spacecraft will fly to a libration orbit around the EML2 point and demonstrate trajectory control techniques within the Sun-Earth-Moon region. DELPHINUS (DEtection camera for Lunar impact PHenomena IN 6U Spacecraft) is one of the scientific instruments onboard EQUULEUS to observe the Lunar impact flashes and near-Earth asteroids. The specifications of DELPHINUS and the flight model pictures are shown in Fig. 4. The internal configuration of EQUULEUS and onboard DELPHINUS were shown in Fig. 5.

Table 1. Specifications of DELPHINUS

Pixel number	659 (H) x 494 (V)
Pixel size	7.4μm (H) x 7.4 μm (V)
Lens (2 pieces)	f = 50mm/F1.4
Each FOV	5.58 x 4.19 deg
Wavelength	400 ~ 800nm
Lunar impact flash mode	Exposure = 1/60 sec, 60 fps
Asteroid observing mode	Exposure = 1/4000 ~ 34 sec
Limiting V magnitude with 60 fps	5.5 (S/N~2) 4.0 (S/N~5)
Power consumption	0.8 W
Dimensions	100mm(W) x 50mm(D) x 100mm(H)
Operating Temperature	-10°C ~ +40°C
Mass	572 g excluding FPGA controller
Controller	FPGA with CPU

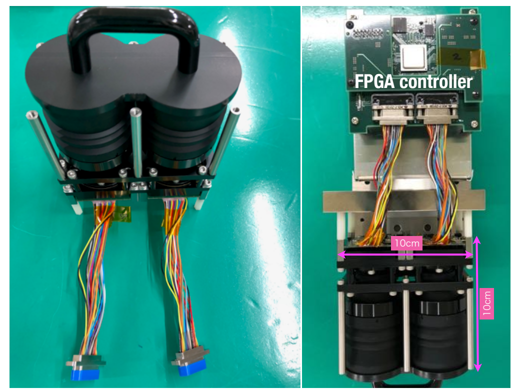

Figure 4. Flight model of DELPHINUS.

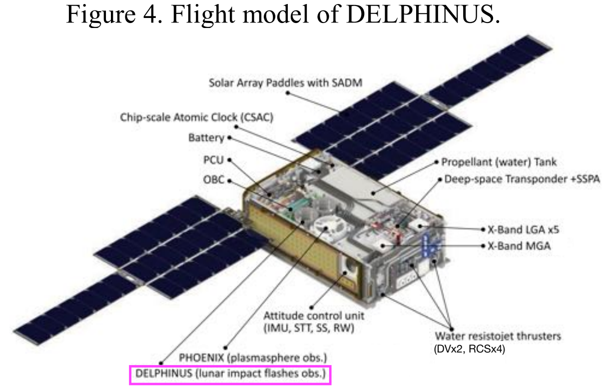

Figure 5. Internal configuration of EQUULEUS.

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