ON-GOING STATUS OF METEOR PROJECT ONBOARD THE INTERNATINOAL SPACE STATION.

T. Arai[1], M. Kobayashi[1], M. Yamada[1], H. Senshu[1], K. Maeda[1], K. Wada[1], S. Ohno[1], K. Ishibashi[1], R. Ishimaru[1], T. Matsui[1], M. Fortenberry[2], Planetary Exploration Research Center, Chiba Institute of Technology, Chiba 275-0016, Japan (tomoko.arai@it-chiba.ac.jp), [2]Southwest Research Institute, San Antonio, TX 78238 U.S.A.

Introduction: Meteor showers are observed when the Earth crosses streams of dust which are derived from specific comets or asteroids. Based on the dynamical link, parent bodies of major meteor showers are identified. Since velocity of dust for meteor showers are known, the size of dust can be estimated from the brightness and light curve of meteors. Major element composition of the dust can be constrained from the emission spectra of meteors. Photometric and spectroscopic observation of meteor showers are clues to understand physical and chemical properties for dust of meteor showers and their parent bodies. METEOR is two-year meteor observation project onboard the International Space Station (ISS) [1]. Photometric observation is done for the first year and spectroscopic observation for the second year. ISS is an ideal platform for continuous meteor observation without distortion caused by weather and atmospheric disturbances. The flux data collected will allow better comparison of physical and chemical data among major meteor showers and their parent bodies.

Method: The ISS orbits the Earth at the altitude of about 400 km, while meteors generally starts to illuminate at the altitude of 100 km. Because a distance to a meteor is three time greater from the ISS than from the ground, a meteor looks darker by one order of magnitude on the ISS than on ground. METEOR consists of a super sensitive, high definition TV (HDTV) colour camera equipped with a wide-angle, extremely bright lens (F0.95, f=10.5mm, diagonal FOV=57.8 deg) [2]. METEOR is installed in the Window Observational Research Facility (WORF) of the pressurized US Lab module (Destiny). It observes meteors through the US Lab window toward the Earth during orbital night when the Sun is beneath the horizon viewed from the ISS. The ISS orbits the Earth for 90 minutes and each orbital night is about 35 minutes except high beta periods when orbital night is shorter. Recording schedule is uploaded to the onboard PC one or two weeks in advance of observation based on the orbital prediction using two-line elements. Activation/deactivation of the camera and encoder and data processing are autonomously conducted with uploaded batch file commands.

Observation is done in visible wavelength, as the METEOR camera has an IR cut filer, allowing visible light only, up to 700 nm. A transmitted blazed diffraction grating (300 grooves/mm) is used for spectroscopic observation (Fig. 1a). It is manually installed by ISS crew in front of the lens for spectroscopic observation (Fig.1b). Target atomic emission lines are Fe I (370nm), Ca I (393nm), Mg I (518nm), Na I (589nm), which are key elements of dominant silicate minerals, such as olivine, pyroxene and plagioclase in meteorites and interplanetary dust.

On-going status and results: After two launch failures in October 2014 and June 2015, METEOR was finally delivered to the ISS in March 26, 2016 and started nominal operation on July 7th, 2016. Photometric observation was conducted until July 2017 (Table 1). Though photometric observation was complete for the first year, observations for some meteor showers were not successful due to variable constraints, such as the Moon condition, the ISS high-beta condition, time limits to open the shutter of USL window to avoid contamination by visiting vehicles and the presence of robotic arm within the FOV for maneuvering visiting vehicles (Table 1). Initial results on photometric observation on 2017 July were presented [2, 3] and further data analyses are currently being conducted.

Software developed for onboard autonomous detection and extraction of meteors in the acquired video data does not work as planned, partly due to limited capability of onboard PC. An entire 35 minutes video needs to be downlinked for us to check the presence of meteors on ground at this point. 20 Mbps data are downconverted to 2 Mbps for daily downlink. A single orbital night of 35 minutes with 20 Mbps takes 5.5 GB. With allowable data downlink rate (max. 4 Mbps) and 9 hours' daily command window, 6-9 GB is the maximum downlinkable data volume per day. All the recorded data of 20 Mbps are stored in a 750 GB HDD installed in the onboard PC and returned periodically by Space-X (SpX) dragon vehicles. Thirty five HDDs were launched with METEOR in March, 2016. So far, two HDDs were returned by SpX#9, fourteen by SpX#10, six by SpX#11, and three by SpX#12. Another ten HDDs were delivered to ISS by SpX #13 Dragon on Dec. 17, 2017 for observation in 2018.

Spectroscopic observation is currently underway and will be complete in July 2018 (Table 1). With a good Moon condition, multiple spectroscopic images of Geminids meteor shower were successfully captured (Fig. 2). Spectral data of meteor showers will be analysed to understand compositional variation within each meteor shower and among meteor showers, and thus their parent bodies. Captured meteor images are weekly uploaded to our METEOR project website for the purpose of education and public outreach.

References: [1] Arai T. et al. (2014) LPS 45th abstract #1610. [2] Arai T. et al. (2017) LPS 48th, abstract# 3034 [3] Arai T. et al. (2017) Abstract for ISS R&D conference 2017.

Fig. 1. (a) Photo of a transmitted diffraction grating of METEOR. (b) Photo of (a) manually installed in the built-in slot of METEOR lens.

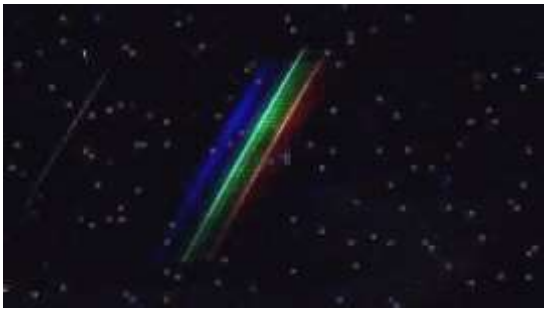

Fig. 2. Composite image of a meteor spectrum of Geminid meteor shower captured on Dec. 13, 2017.

Table 1. List of photometric and spectroscopic observation of METEOR conducted in 2016 and 2017.

Dates of observation	Target meteor shower (peak day)	Constraints for observation	Moon condition
Photometric observation			
07/07 - 07/18/2016	Initial checkout		
07/28 - 7/31/2016	Southern δ-Aquarids (7/28)	Short orbital nights due to high beta.	Good. New Moon:8/2
08/10 - 08/16/2016	Perseids (8/12)		Not good. Full Moon:8/18
09/03 - 09/12/2016	Sporadic meteors	Orbital nights except command window	
09/15 - 09/21/2016	Daytime observation	Auto shutter speed and sensivitiy setting.	
09/30 - 10/05/2016	Daytime observation	With wrong aperture setting, no night observation.	
10/05 - 10/11/2016	October Draconids (10/8)		Not bad. New Moon:10/1
10/12 - 10/26/2017	Orionids (10/21)	USL shutter closed on 10/14, 10/22-23. Upstream power loss on 10/24.	Not good. Full Moon:10/16
10/26 - 11/25/2016	Southern Taurids (11/5) Northern Taurids (11/12) Leonids (11/17)	Preliminary spectrosopic observation on 10/26-11/1. USL shutter closed on 10/30-11/2, 11/20-21. Connection failure with encoder on 11/17.	Good. New Moon:10/31 Bad. Full Moon: 11/15 Bad. Full Moon: 11/15
11/26 - 12/07/2016	Sporadic meteors		
12/07 - 12/17/2016	Geminids (12/14)		Bad. Full Moon: 12/14
01/01 - 01/08/2017	Quadrantids (1/3)	USL shutter closed on 1/6-7.	Not bad. New Moon:12/29
01/30 - 02/05/2017	Sporadic meteors		
02/12 - 02/22/2017	Sporadic meteors	USL shutter closed on 2/13-15. Robotic arm in FOV on 2/16-22.	
02/26 - 03/03/2017	Sporadic meteors	USL shutter closed on 3/2.	
03/27 - 04/05/2017	Sporadic meteors	USL shutter closed on 3/30-31.	
04/06- 04/14/2017	Sporadic meteors		
04/17 - 04/25/2017	April Lyrids (4/22)	Robotic arm in FOV on 4/18. USL shutter closed on 4/19-21.	Not bad. New Moon:4/26
04/26 - 05/12/2017	η-Aquarids (5/5)		Not good. Full Moon:5/11
05/14 - 06/01/2017	Sporadic meteors	USL shutter closed on 5/18.	
07/03 - 07/08/2017	Sporadic meteors		
Spectroscopic observation			
07/26 - 08/06/2017	Southern δ-Aquarids (7/28)	Shorter orbital night due to high beta on 7/26-30.	Good. New Moon:7/23
08/10 - 08/16/2017	Perseids (8/12)		Not good. Full Moon:8/8
08/21 - 08/23/2017	Sporadic meteors		
09/19 - 09/28/2017	Sporadic meteors		
09/28 - 10/06/2017	Sporadic meteors	USL shutter closed partly on 10/5-6.	
10/07 - 10/17/2017	October Draconids (10/8)	No data recorded on 10/10-12 due to active auto-updater of encoder	Bad. Full Moon:10/6
10/18 - 10/30/2017	Orionids (10/21)		Good. New Moon:10/20
10/31 - 11/07/2017	Southern Taurids (11/5)		Bad. Full Moon:11/4
11/11 - 11/29/2017	Northern Taurids (11/12) Leonids (11/17)	Robotic arm in FOV on 11/11-13. USL shutter closed partly on 11/14-16.	Not bad. New Moon:11/18 Good. New Moon:11/18
12/8 - 12/16/2017	Geminids (12/14)	Robotic arm in FOV on 12/08 - 12/16. USL shutter closed partly on 12/08.	Good. New Moon:12/17
1/3 - 1/7/2018	Quadrantids (1/3)		Bad. Full Moon:1/2