THE IMPACT OF METEOROID STREAMS ON THE LUNAR ATMOSPHERE AND DUST ENVIRONMENT DURING THE LADEE MISSION. T. J. Stubbs[1], D. A. Glenar[2,1], Y. Wang[2,1], B. Hermalyn[3], M. Sarantos[2,1], A. Colaprete[3], R. C. Elphic[3], and the LADEE Science Team, [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [2]University of Maryland, Baltimore County, Baltimore, MD 21250, [3]NASA Ames Research Center, Moffett Field, CA 94035, (Timothy.J.Stubbs@NASA.gov).

Introduction: The scientific objectives of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission are: (1) determine the composition of the lunar atmosphere, investigate processes controlling distribution and variability – sources, sinks, and surface interactions; and (2) characterize the lunar exospheric dust environment, measure spatial and temporal variability, and influences on the lunar atmosphere [1]. Impacts on the lunar surface from meteoroid streams encountered by the Earth-Moon system are anticipated to result in enhancements in the both the lunar atmosphere and dust environment [2,3]. Here we describe the annual meteoroid streams expected to be incident at the Moon during the LADEE mission, and their anticipated effects on the lunar environment.

The LADEE science payload consists of three instruments: the Ultraviolet/Visible Spectrometer (UVS) for measuring emission lines from exospheric species and scattered light from exospheric dust; the Lunar Dust Experiment (LDEX) for in situ measurement of exospheric dust; and the Neutral Mass Spectrometer (NMS) for in situ measurement of exospheric species. All three instruments are potentially capable of detecting the effects of an encounter with a meteoroid stream. LADEE nominally has a 100-day science mission in which its retrograde equatorial orbit (inclination ≈ 157°) will take it below 50 km altitude at periapsis near lunar sunrise. Lunar Orbit Insertion (LOI) occurred on 6 October 2013 and the current End-of-Mission (EOM) is planned for 25 March 2014 before the lunar eclipse on 15 April 2014 (although this could conceivably be extended).

Meteoroid Streams: The Earth-Moon system frequently encounters debris trails from short- and long-period comets, as well as asteroids, which are referred to as meteoroid streams [4]. The meteoroids in these streams have similar velocities and are on near-parallel trajectories, such that when they enter the Earth's atmosphere the resulting shower of meteors (or shooting stars) appears to be emanating from a virtual point on the sky called the radiant. Meteor (and meteoroid) rates vary as a function of the Earth's position in its orbit, with an activity curve that increases to a peak and then decreases. Annual streams are those that regularly encounter the Earth each year. In Table 1 we list the 18 IAU established annual streams that will encounter the Moon during the LADEE mission [5].

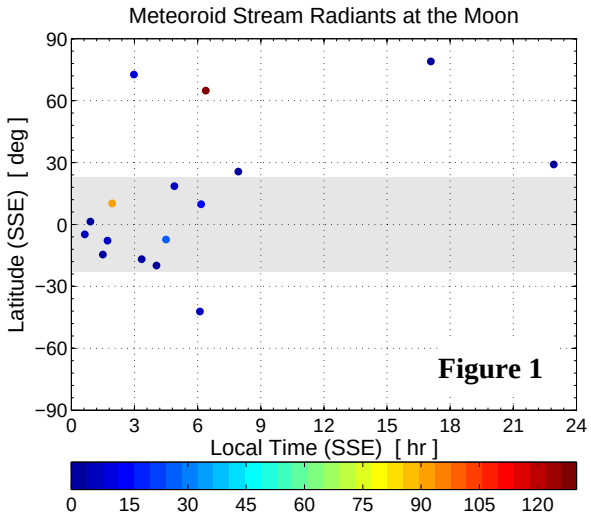

Figure 1

These streams are relatively well characterized and are broad enough that it is reasonable to assume that both the Earth and Moon will pass through them.

Unlike at the Earth, all of the stream meteoroids incident at the Moon will impact its surface and create ejecta clouds and release species into the exosphere [2,3]. Since they move on near-parallel trajectories we expect to observe asymmetries in their effects on the lunar environment. Therefore, it is necessary to know the locations where the streams are normally incident on the lunar surface (i.e., the locations of the stream radiants in the Moon frame).

In Fig. 1, the location of the radiants for the 18 annual streams at the time of peak activity are plotted as Selenographic Solar Ecliptic (SSE) latitude and local time. The points are color-coded to show the Zenith Hourly Rate (ZHR) at the peak in meteor shower activity. (ZHR is the hourly rate of meteors seen by standard a observer on the Earth under optimum viewing conditions.) For our purposes, ZHR serves as rough guide to the meteoroid flux rates incident at the Moon. For comparison, the Hourly Rate (HR) for sporadic background meteors that are no longer associated with any streams is ≈9.5. Only six of the 18 streams have peak ZHRs that exceed this background HR, so its reasonable to assume that these streams will likely have the most noticelable effects on the lunar environment compared with typical conditions. The gray shading in Fig. 1 indicates the latitudinal range of the LADEE orbit.

Date	Time	Name	Code	IAU No	RA	Dec	SL	ZHR	V_M	Lat $_{SSE}$	LT $_{SSE}$	Lat $_{ME}$	Long $_{ME}$
09-Oct-2013	12:52	October Draconids	DRA	009	264.10	+57.60	196.40	1.0	20.6	+78.98	17:05	+80.15	191.24
21-Oct-2013	20:21	Orionids	ORI	008	95.40	+15.90	208.60	25.0	66.8	-7.28	04:29	-8.62	217.75
22-Oct-2013	22:52	Leonis Minorids	LMI	022	161.40	+36.20	209.70	1.9	62.7	+25.63	07:56	+24.18	255.72
06-Nov-2013	06:10	Southern Taurids	STA	002	54.20	+14.20	224.00	7.3	28.8	-4.80	00:38	-5.21	332.11
06-Nov-2013	06:10	Northern Taurids	NTA	017	56.80	+21.20	224.00	4.0	28.7	+1.36	00:54	+0.85	336.21
13-Nov-2013	05:30	Andromedids	AND	018	24.20	+32.50	231.00	1.0	16.7	+29.06	22:55	+29.07	222.44
17-Nov-2013	07:14	Leonids	LEO	013	153.50	+22.10	235.10	13.0	71.6	+9.81	06:09	+8.37	280.59
21-Nov-2013	11:07	alpha Monocerotids	AMO	246	117.10	+0.80	239.30	4.0	63.3	-19.90	04:02	-21.46	198.30
27-Nov-2013	02:19	November Orionids	NOO	250	90.60	+15.70	245.00	5.0	42.7	-7.83	01:43	-9.08	94.91
12-Dec-2013	18:32	December Monocerotids	MON	019	102.40	+8.10	260.90	2.0	43.0	-14.58	01:29	-16.01	260.60
13-Dec-2013	22:22	Geminids	GEM	004	113.80	+32.40	262.08	92.0	35.5	+10.21	01:56	+8.70	253.36
17-Dec-2013	07:04	sigma Hydrids	HYD	016	132.40	+0.10	265.50	2.5	58.8	-16.82	03:20	-18.36	233.69
22-Dec-2013	16:37	Ursids	URS	015	219.40	+75.30	271.00	12.0	32.9	+72.62	02:58	+71.07	161.64
25-Dec-2013	15:15	December Comae Berenicids	COM	020	175.20	+22.20	274.00	5.0	63.4	+18.58	04:53	+17.43	155.28
03-Jan-2014	17:51	Quadrantids	QUA	010	230.00	+49.50	283.28	130.0	41.0	+64.82	06:23	+64.40	64.00
08-Feb-2014	06:14	alpha Centaurids	ACE	102	210.90	-58.20	319.40	7.3	58.4	-42.19	06:06	-41.65	352.24
05-Apr-2014	13:44	kappa Serpentids	KSE	027	230.60	+17.80	15.70	4.0	45.5	+34.45	01:43	+34.79	318.52
22-Apr-2014	14:50	April Lyrids	LYR	006	272.70	+33.40	32.40	12.8	46.8	+57.38	04:17	+58.78	149.48

Table 1: A summary of the 18 annual meteoroid streams that are anticipated to encounter the Moon during the LADEE mission (6 October 2013 to 25 March 2014, or perhaps later). This is based on the list of established meteor showers maintained by the IAU Meteor Data Center [5]. The given stream names, codes and numbers follow the IAU convention. Details are given for the predicted times of peak stream activity. RA and Dec are the Right Ascension and Declination of the stream radiant in degrees. SL is the solar longitude in degrees. RA, Dec, SL are given in epoch J2000. ZHR is the Zenith Hourly Rate at the peak. V_M is the selenocentric speed of the stream before acceleration by lunar gravity in km s^{-1}. Lat $_{SSE}$ and LT $_{SSE}$ are the latitude (degrees) and local time (HH:MM) of the stream normal in SSE coordinates. Lat $_{ME}$ and Long $_{ME}$ are the latitude and longitude of the stream normal in selenographic (Mean Earth) coordinates in degrees.

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