TULIP: Taiwan University Lunar Investigation Project

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Abstract

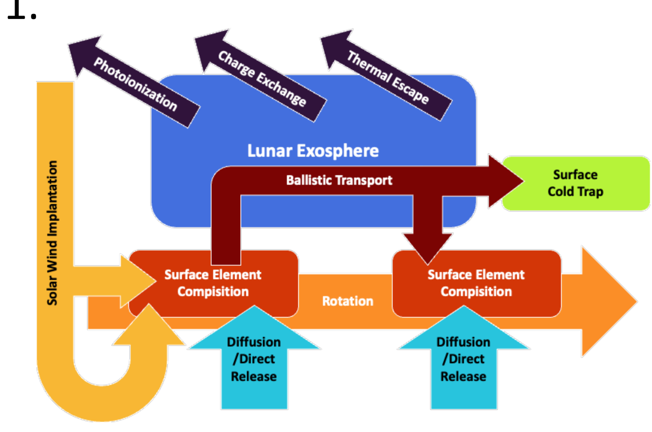
The Taiwan University Lunar Investigation Project (TULIP), supported by the National Council of Science and Technology (NSTC) of Taiwan, aims to advance lunar research in Taiwan and establish a foundation for participation in NASA's Solar System Exploration Research Virtual Institute (SSERVI). TULIP comprises several scientific components: (1) Lunar exosphere simulations focus on developing a time-dependent model for the lunar exosphere and volatile transport driven by solar radiation, solar wind interaction, and micrometeoroid bombardment. (2) Lunar flash monitoring involves constructing the Robotic Lulin lunar Impact Flash Telescope (RoLIFE) at Lulin Observatory to observe meteoroid impacts on the Moon and estimate the physical and impact physics parameters of these meteoroids. (3) Long-term sodium tail observations leverage ground-based detection of the lunar sodium tail's comet-like extension, emphasized by strong D1 and D2 sodium absorption lines.

Lunar exosphere simulations:

In the gravitationally bound exospheres of massive airless planetary bodies like the Moon and Mercury, atoms and molecules undergo far more collisions with the planet surface than with each other [1] [2]. All the species in the exosphere also behave differently. Hence, the interactions between gas and the lunar surface play a pivotal role in determining the distribution, composition, and temporal variability of the lunar atmosphere. In our research, we identify several primary sources contributing to the gaseous composition of the lunar exosphere: interactions with the solar wind, bombardment by micrometeoroids, and endogenic activities, such as radioactive decay. To comprehensively study the distribution and temporal variation within the lunar exosphere, this work aims to develop a time-dependent model.

1. Source and loss of lunar exosphere.
2. Lunar helium exosphere.
3. Lunar argon exosphere.
4. Time-dependent model of lunar radon outburst.
5. Ranon density profiles at Chang'E 6 landing site.

1.



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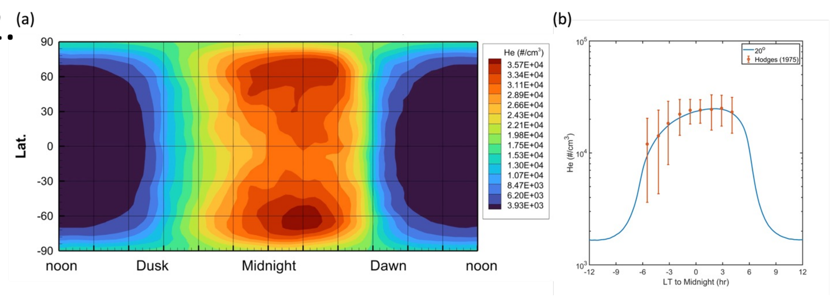

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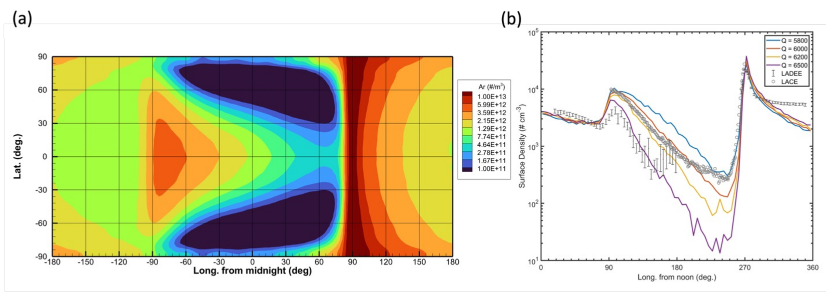

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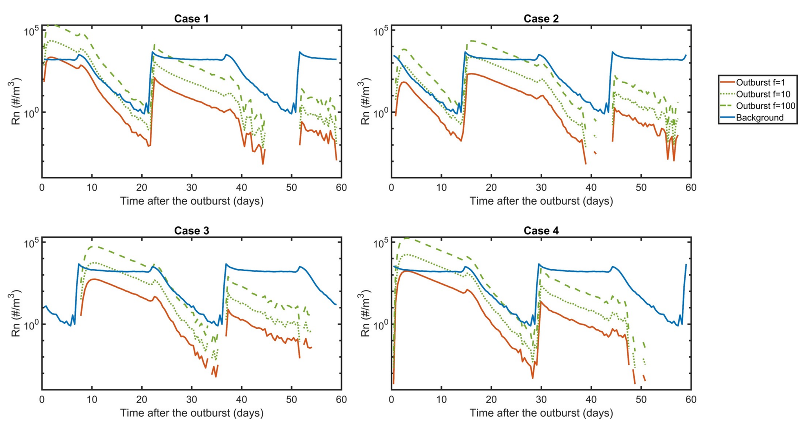

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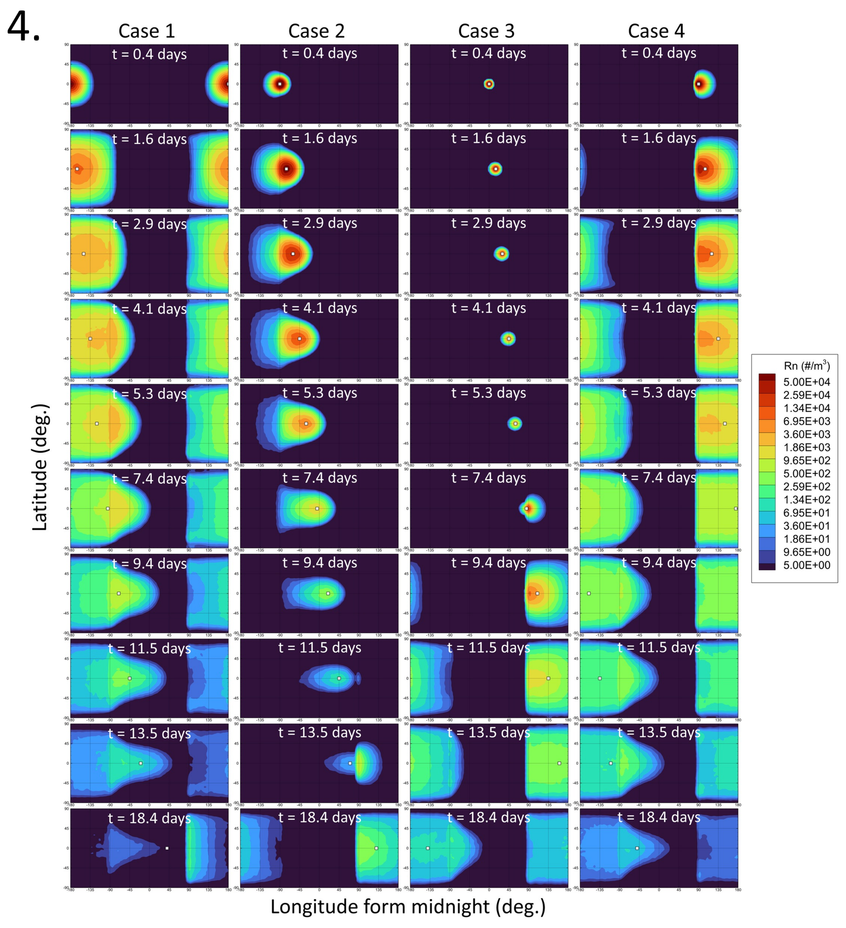
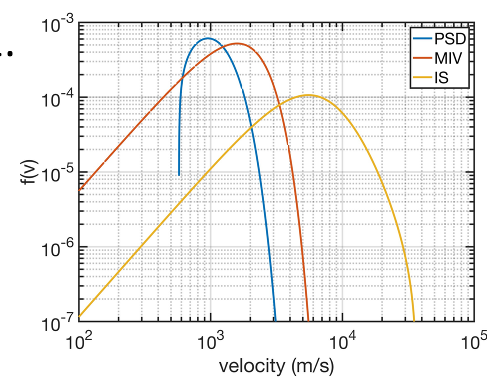


Sodium tail observations:

The lunar sodium tail is a comet-like extension of the sodium exosphere, formed by the high speed and escaping sodium atoms under the influence of solar radiation pressure. Because of the strong absorption line in D1 and D2 of sodium, the emission could be detected by the ground-based observations [4]. The sodium" bright spot" which is the sodium tail focused by the Earth's gravitational force in the anti-solar direction [5] [6]. In this work, we have set up an all-sky camera system on the Lulin observatory to monitor the lunar sodium tail bright spot.

1. Velocity distributions of sodium from photon-stimulated desorption (PSD), ion sputtering (IS), and meteoroid impact vaporization (MIV) process.
2. Doppler shift of solar radiation pressure.
3. Result of lunar sodium exosphere.
4. Simulation result of lunar sodium tail and sodium tail spot in the sky.
5. The example of the all-sky camera in future work.

1.



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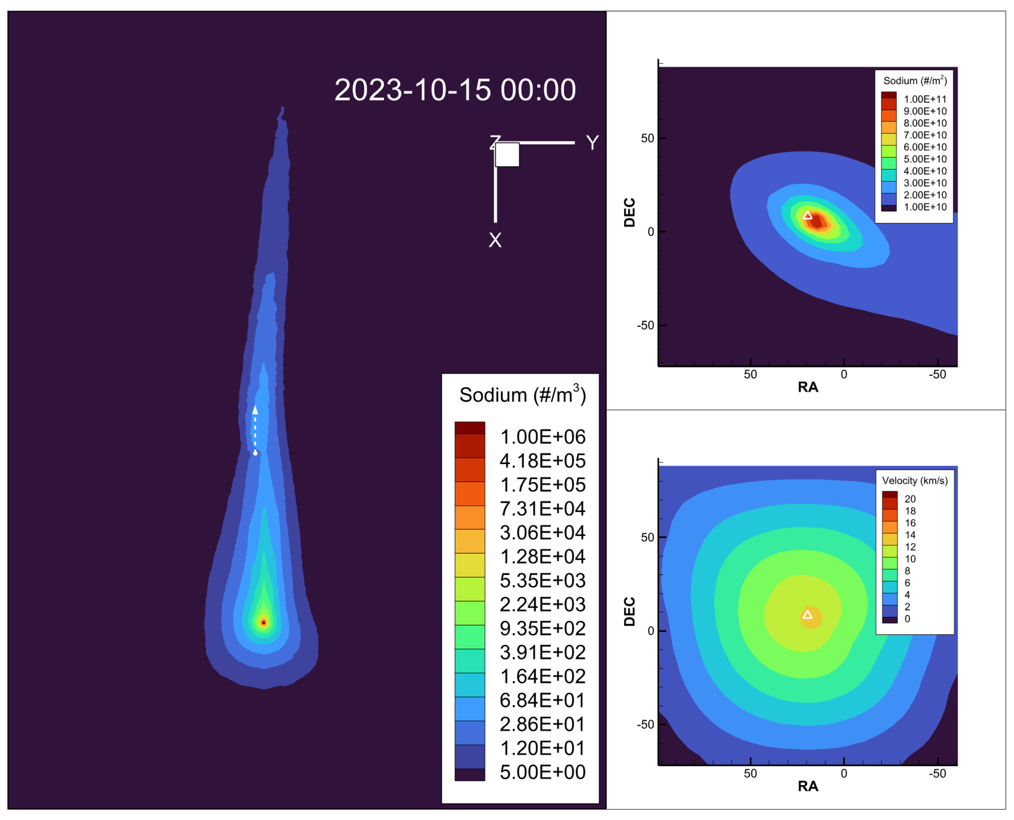

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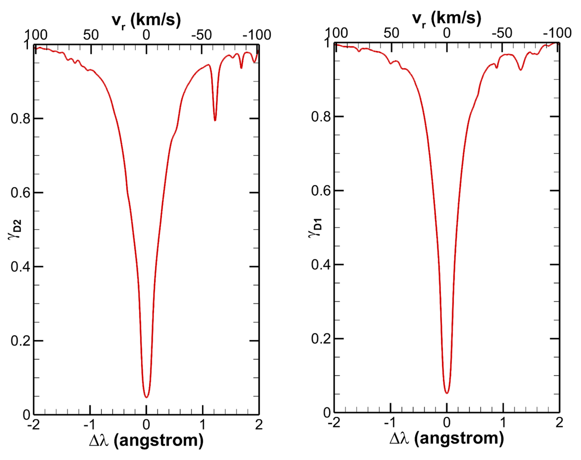

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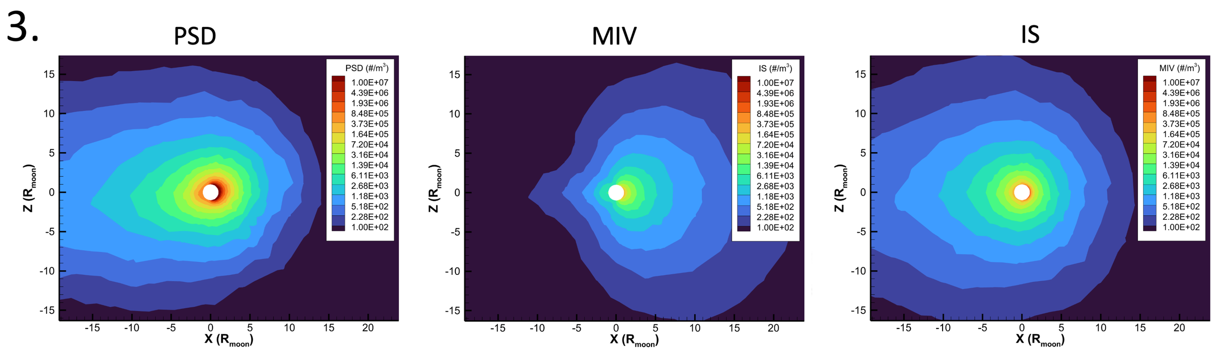


5.

Lunar flash monitoring:

Impacts of meteoroids on the Moon could be observed as optical flashes [3]. The focus of this work is on the frequency of meteoroid impacts on Moon to estimating the physical parameters of these meteoroids as well as the impact physics parameters. Therefore, we constructed the observational system RoLIFE (Robotic Lulin lunar Impact Flash tElescope) at Lulin observatory in Taiwan and set up the Taiwan Astronomical Network of Ground-based Observations (TANGO) for lunar impact flash observations.

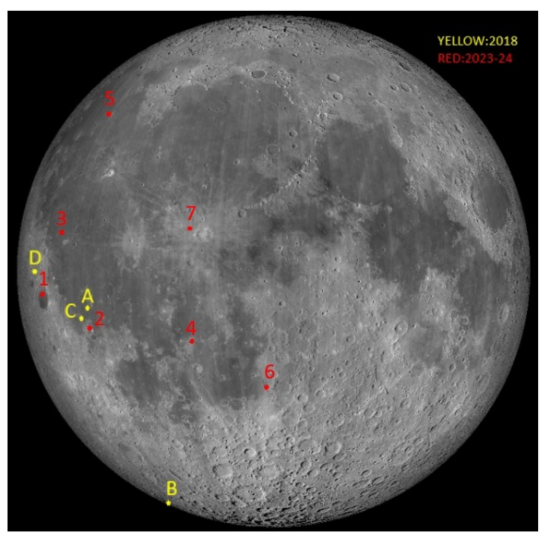
1. The RoLIFE system.
2. Example of a lunar impact flash event.
3. Result of impact flash events (fps: 15 - 20).
4. The data analysis of the impact flash events.

1.

RoLIFE (Lulin)		
Camera type	QHY 174	ASI 174MM
Diameter	300 mm	200 mm
Initial focus length	2400 mm	2000 mm
Focal reducer system	1320mm (F/4.4)	0.63x (1350mm)
Time recording system	GPS-time inserters	computer std time
FOV	29.3'x18.3'	28.9'x18.0'
Filter	I (since Oct. 2023)	R (since Mar. 2024)
Mount	CEM 120	

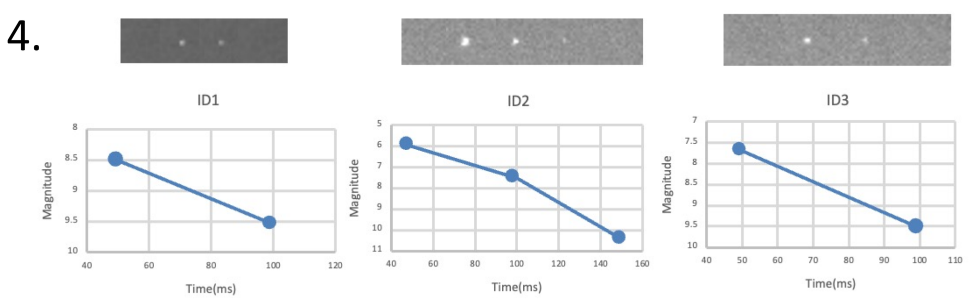
2.

3.



ID	Date & UT	Duration (ms)	Lat.	Long.	Lunar phase	Exposure (ms)	D_{EM} (10^8m)
1	2023 02 27 14:31:53.	200	-4.4	-67.9	0.52	100	3.993
2	2023 11 21 13:26:58.	150	-12.4	-50.8	0.62	50	3.656
3	2023 11 21 14:51:36.	100	9.2	-61.9	0.62	50	3.671
4	2023 12 16 10:33:24.	50	-14.2	-22.4	0.14	50	3.653
5	2024 01 16 12:46:10.	150	-57.3	38.2	0.31	50	3.657
6	2024 02 14 11:34:39.	100	-25.4	-5.6	0.26	50	3.652
7	2024 02 16 12:00:21.	50	9.9	-22.6	0.48	50	3.745

4.



$$\eta = \frac{\text{luminous energy}}{\text{impact energy}}$$

			$\eta = 1.5 \times 10^{-3}$			
ID	stream	E_I ($10^4 J$)	E_{kin} (10^6J)	m_p (g)	r_p (cm)	d_c (m)
1	SPO	9.4(1)	31.3(4)	217(27)	3(1)	3(1)
2	LEO	36.68(3)	244(2)	105(8)	4(1)	4.2(1)
3	LEO	7.3(3)	48.6(2)	21(1)	2.3(3)	2.7(3)

Acknowledgment

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Reference

[1] Milillo et al., Space Science Reviews (2023)
[2] Grava et al., Space Science Reviews (2021)
[3] Oritz et al., Nature (2000)
[4] Potter & Morgan, Science (1988)
[5] Matta et al., Icarus (2009)
[6] Line et al., Icarus (2012)