

Slutrapport / Final report

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Lunar Plasma Interdisciplinary Network (LuPIN) workshop (1)

Date: 2023-09-04 (Mon) to 2023-09-08 (Fri)

Place: Björkliden, Kiruna, Sweden

Website: <https://irfpy.irf.se/lupin/events/lupin-1/>

Registrations: 26

LuPIN: Background

Almost all space agencies, including the European Space Agency (ESA), are actively preparing for lunar exploration. It will potentially be a golden age for conducting studies of Moon-environment interaction to understand the complex but fascinating coupling between the solar wind/magnetospheric plasma–energetic particles–exosphere–dust–solid-surface–mini-magnetosphere. With this situation behind us, we are trying to build a network of scientists in this field: Lunar Plasma Interdisciplinary Network (LuPIN). As a first step, we organized a 4-day workshop. The LuPIN workshop discussed the science of the lunar space environment. Presentations included an overview of the state-of-the-art scientific knowledge, current studies being conducted by the participants, open scientific questions and their importance for future missions, and links to neighboring scientific fields (i.e., interdisciplinary context).

The LuPIN workshop (1)

The first LuPIN workshop took place in a hotel in the mountains near Kiruna. We organized the workshop entirely face-to-face in order to prioritize the real-time, intensive, interactive discussion over the days. The participants were from international, including European countries, the United States, and Japan. The generation of scientists was diverse, from young talents (graduate students and postdocs) to experienced senior scientists. The relatively small number of participants (25 scientists) allowed each presentation to be intensively discussed and debated, with many questions, comments, and new ideas exchanged. The organizer asked the presenters to emphasize the big picture (e.g., open questions, future studies, interdisciplinary aspects, new mission ideas, and so on) in addition to the scientific results. All the presenters responded to this request, which served as a high-context discussion.

Seesions and presentations

Many of the presentations were based on the invitation from the Science Organization Committee. Contributed talks were also provided. We prepared a long discussion time through the week. We advised the presentation to be about 20 minutes; discussion continued about 45 minutes on average. Some discussion lasted longer than 1 hour. Relatively long coffee breaks and hotel accommodation (with all meals included) further facilitated small-group discussions. Flexible scheduling made this discussion-oriented workshop possible.

The first 3 days were for science sessions:

- Science session 1: Current state of the field
- Science session 2: Space plasma
- Science session 3: Surface charging, plasma interaction, exosphere

- Science session 4: Energetic plasma
- Science session 5: Dust
- Science session 6: Future mission, instrument

A wrap-up discussion session was held on the final (half) day. Presenters were asked to briefly summarize the outstanding questions and future perspectives to share with the team.

Scientific discussion and outcomes (selected key points)

- Lunar science is not just about the Moon. It has synergies on the studies on Mercury, low-active comets, magnetospheres, outer planets, their moons, exoplanets, and exomoons.
- Lunar magnetic anomalies and their interactions with the solar wind are common interests. Is the name "mini-magnetosphere" proper? The workshop suggested two further naming ideas: "Hall-magnetosphere" and "electrosphere".
- The lunar surface electrodynamic environment is completely unknown. Near-surface charging is a key physics but not much explored due to the lack of measurements (even lack of adequate measurement techniques) and difficulty in numerical modeling
- Permanently shadowed regions are fascinating to the LuPIN scientists—plasma, dust, charging, water, radiation, etc.
- The term "water" on the Moon has been used ambiguously.
- Dust–plasma interaction on the Moon has not been studied well. How far up can the dust particles reach? It seriously impacts the human activity on the Moon
- Future mission ideas, requirements, and desires were raised—Multipoint measurements, spinning platform, orbiter-lander combination, very low altitude (<10 km) measurements, use of impactors, long-distance mobility of rover, sounding rocket from the Moon, etc.

Summary and Prospects for LuPIN 2

We believe that the first workshop was a great success. As an immediate next step, we agreed to prepare a short article summarizing the key open questions in the field of lunar plasma and interdisciplinary science that were raised and discussed during the event. We will prepare the second workshop to maintain the momentum of the fruitful discussion at the first workshop. The plan is to hold the Networking Workshop on an annual basis, taking into account the rapid progress of the scientific activities of the participants and the external consideration, i.e., how fast the lunar exploration preparation is progressing in the world.

The main achievements of LuPIN (1) are:

- We confirmed the strong demand of such community from the participants and others (those who could not attend the workshop)
- We submitted an abstract to the ESA Heliophysics Workshop in November 2023 based on this networking activity
- We have initiated planning the LuPIN (2) workshop. The original idea was to be held in the U.S., while the SOC/LOC currently considers the second workshop near Kiruna, Sweden. The cost of running a workshop in the U.S. is increasing, resulting in the high registration fee with accommodation.
- We have decided to document the discussion in LuPIN (1) as a peer-reviewed publication. The main focus will be formulating open questions about the lunar environmental science.

Several reflections below would be the focus of the next LuPIN workshop.

- The ample discussion resulted in a smaller number of presentations. The first LuPIN consists of 21 presentations—the limited number of the discussion is a success factor for the LuPIN (1) workshop. A more extended participants are expected and anticipated for LuPIN (2). The balance of the number of presentations and available time slots for effective discussion shall be considered.
- Presentations of the lunar plasma science topics dominated. On the other hand, scientific fields of the lunar dust environment and the exosphere were under-represented. As a result, there

were fewer discussions on interdisciplinary aspects. Interdisciplinarity is the key for the lunar environment science; thus, its emphasis is the main topic for LuPIN (2).

- The local IRF presentations dominated the future mission session. More lunar missions are ongoing and being planned, so there may be more mission-related talks, including future mission ideas. We may need to extend this session for LuPIN (2).
- Interaction between human activities and the environment on the lunar surface was not emphasized. It was partly intentional of the SOC, i.e., for the first meeting, we would have emphasized networking on the scientific side. In LuPIN (2), SOC shall attempt to extend the networking.