INDO SWISS JOINT RESEARCH PROGRAMME (ISJRP)

RESEARCH FELLOWSHIPS

EXCHANGE GRANT REPORT

Grant No.: RF 27

Part 1 - General Information

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>Chandrayaan-l: SARA data analysis</th>
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<tbody>
<tr>
<td>Keywords:</td>
<td>Moon, solar wind sputtering, Chandrayaan-l, SARA, elemental composition, space weathering</td>
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<tr>
<td>Start date:</td>
<td>1 February 2011</td>
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<td>Duration:</td>
<td>2 months</td>
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Part 2 - Exchange Participant(s) Details

VISITING SCIENTIST

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3.1 Purpose of visit

(Briefly describe the purpose and goals of this exchange.)

The lunar surface is under constant bombardment by solar wind ions. These solar wind ions consist of protons (~96%) and helium (~3%) and traces of heavier ions. SARA, an instrument on board the first Indian lunar mission Chandrayaan-1, investigated the interaction between the solar wind and the lunar surface. SARA consisted of two sensors: SWIM (Solar WInd Monitor) and CENA (Chandrayaan Energetic Neutrals Analyser). While the SWIM measured the solar wind ions impinging onto the lunar surface, the CENA measured the neutrals coming from the lunar surface. While we in Switzerland are focusing on the neutrals detected by CENA, the scientists in India are primarily analysing the solar wind ions measured by the SWIM.

On the basis of data provided by the SARA, it was recently discovered that a surprisingly significant part of the solar wind protons are reflected back from the lunar surface as neutral hydrogen atoms (Wieser et al., "Extremely high hydrogen reflection from regolith in space," Planet. Space Science, 57 (2009) 2132-2134).

The purpose of my research fellowship in India was to combine the Indian and the Swiss scientists' knowledge to analyse the data of the two sensors in a joint venture. In addition, this study was aimed to determine if we can also see backscattered helium next to the backscattered hydrogen in the data set provided by the SARA instrument.

3.2 Short description of work carried out during the visit

(Please describe the technologies acquired and the experiments/activities performed during the course of the exchange.)

Since the two sensors were operated independently, we first had to find out during what time intervals both sensors were operating simultaneously. In addition, there are several conditions with respect to the position of Moon around Earth, e.g., the Moon can be in upstream (exposed to the solar wind), in the magneto-sheath, or in the magneto-pause. Since we were interested in the data when the Moon was upstream, so we had to search through the ion data sets provided by SWIM to identify these cases.

Once the time intervals of interest were determined, we started analysing the data provided by the two sensors. For SWIM, the amount of helium contained in the solar wind can be computed from the energy spectra. All solar wind particles have more or less the same velocity, but helium is four times heavier than hydrogen. This means that the kinetic energy of helium is about four times the energy of hydrogen. Both species show a distinguished peak in the energy spectra of SWIM. By comparing the amplitude of these two peaks we can compute the ratio between helium and hydrogen. This flux ratio is quite variable in the solar wind, and since about 30% of the ion induced space weathering of the lunar surface is due to the solar wind helium, this ratio is an important quantity to know.

Since each solar wind ion loses part of its kinetic energy during the interaction with the lunar surface, but not all ions lose the same amount of energy, the energy peak of the reflected hydrogen becomes much...
broader than the width of the solar wind energy distribution. Unfortunately, it becomes so broad that it is not possible any more to distinguish the two species in the neutral energy spectra.

We therefore turned our attention to the neutral mass spectra. In our mass spectra, the species do not show up as single lines, but as Gaussian distributions of a certain width around the theoretical value. It is difficult to distinguish helium and hydrogen, because helium shows up in the tail of the hydrogen distribution and its peak is expected to have an amplitude of only a few percent of that of hydrogen.

We implemented a non-negative least square solver to fit a theoretical hydrogen and a helium peak in the neutral mass spectra. We then compared the amplitudes of the two fitted peaks to determine the ratio of helium to hydrogen.

If the solver had performed well, the helium to hydrogen ratios determined from SWIM and from CENA should correlate. Unfortunately, this was not the case. This could be due to several reasons:
- the CENA sensor is not sensitive enough to detect neutral helium,
- the fraction of reflected helium is much smaller than the fraction of reflected hydrogen, or
- the theoretical fits we used for the solver do not describe the peaks in the mass spectrum well enough.

3.3 Outcomes

(Please describe the main results obtained during the course of the exchange.)

Looking at the ion data provided by SWIM, we were able to determine how much helium ions were contained in the solar wind plasma during a certain time interval. When comparing these ratios to values provided by the Advanced Composition Explorer (ACE), which has been analysing the solar wind since 1998, we saw that our results and their results agreed well.

The ratios computed from the neutral mass spectra provided by CENA do not correlate with the ion ratios, though. This indicates, that we have so far been unable to identify neutral helium reflected from the Moon. This could mean that the fraction of reflected helium is much lower than the fraction of reflected hydrogen.

3.4 Future collaboration with host institution

(Please provide information on future collaboration opportunities and follow-up activities.)

SARA, with its two sensors, SWIM and CENA, is the first-ever instrument suite to study the space weathering of a planetary object. Since many planetary objects are not shielded by an atmosphere from the effects of the solar wind, this research has applications far beyond the Moon. While both sensors worked well, there are of course still some improvements that can be made to both of them. Having worked intensely and simultaneously on the data provided by SWIM and CENA, a lot about the instrument and its strengths and weaknesses was learned. We will use this knowledge in the current development of a similar instrumentation to be flown on the BepiColombo mission of ESA. Further, if we get the opportunity, we can build an improved version of this instrument for a future joint mission.
3.5 Various comments

(E.g., what worked well, what didn't work well, suggestions and improvement ideas, …)

From my point of view, the research fellowship in India worked out extremely well. My host had arranged everything very thoughtfully, for which I am extremely thankful. He had beforehand already organised a place where I could stay as well as a way of transportation to get to work daily. Being unsure on how I felt about Indian food, he had even arranged that they prepare a special lunch for me at the canteen during my first week at the institute. Fortunately, I can think of nothing that could have been improved.

3.6 Projected publications/articles resulting or to result from the exchange

(if applicable)

Will be informed later.