Report from Europlanet Workshop on "Outer Planet Moon-Magnetosphere Interactions"

NA1 – Innovation Through Science Networking
Task 2 – Scientific Working Groups

UCL MPS Max-Planck-Institut für Sonnensystemforschung

Selection of the Venue
Hotel Selfoss, Selfoss, Iceland, 11-15 Feb 2019
The organizers have chosen Iceland as a unique place which looks partially like the icy moon surfaces and has volcanoes, ice surfaces, geysers, glaciers like some of the moons in the outer solar system. Selfoss was chosen as a remote location to stimulate discussions during and after the presentations.

Science Organizing Committee
A science organizing committee with members from Europe, USA, and Japan was formed to cover all the various aspects of the science topic of the workshop. The members were:
N. Krupp (MPS, Germany), M. Holmström (IRF, Sweden), E. Roussos (MPS, Germany), S. Barabash (IRF, Sweden), O. Witasse (ESTEC, Netherlands), P. Brandt (JHUAPL, USA), K. Khurana (UCLA, USA), G. Murakami (JAXA, Japan), C. Paty (Univ. of Oregon, USA).

Purpose of the workshop
The main purpose of the workshop was to build up and expand the community of moon-magnetosphere interactions science on a longterm basis and to transfer the knowledge to the next generation of plasma scientists.
The idea was to use the knowledge and the findings from previous spacecraft near the outer planet moons to update our knowledge about the interaction processes between the plasma environment and the moon's surfaces, exospheres, magnetospheres. In particular, the analysis of data sets from JUNO, CASSINI, GALILEO, VOYAGER, … spacecraft and recent simulation results should be combined to describe the environments of the moons. In a further step the discussion and preparation of science and science planning for future missions (i.e. JUICE and EUROPA CLIPPER and other outer planets missions) should be started.

Format of the workshop
The workshop was set up in nine keynote talks about the physics of moon-magnetosphere interactions, the main target moons, and their environments completed by 31 contributed talks about detailed features and unique processes for each of the outer planet major moons.

Advertisement of the workshop
The workshop was advertised widely through Europlanet, Cassini, Juice, AGU-SPA newsletter, Europa Clipper, and MOP mailing lists and a workshop website was set up: http://www.mps.mpg.de/Iceland2019

Outcome
During the week excellent talks were given by all participants and a lively discussion during and after each presentation was noticed throughout the week. At the end of the workshop all participants concluded that this workshop was a great success and the purpose of the meeting was fulfilled. However, it was also made clear that this workshop was only the beginning and should definitely be continued in the future in additional workshops to keep the community together and attract even more young scientists in the future meetings.

The outcome of the workshop is summarized by quotes from the participants, by lessons learned, and by open questions in the field as follows:

> *"From this meeting I appreciate how every moon is truly unique in its own right, and all together, underscore the sheer diversity of solar system bodies."*
> *"This workshop showed how scientists from different cultures bring different perspectives – shedding new light on old problems"*

A. Lessons learned:

1. Similarities between moons is useful – but the range of atmospheres, external plasmas, magnetic fields controls a huge variety of behaviors, driven by fundamental physical processes on a spectrum of spatial and temporal scales.
2. One approach does not fit all – it takes different observational techniques and modeling methods to tackle the various moons of the outer solar system.
3. We select instruments to explore moons – but we are only guessing what they will find. There's value in analyzing past observations, exploring what models can say – as well as going in with all eyes open.
4. Collectively, we know much about the electrodynamics and physical reactions of plasma-moon interactions – but we need collaborations with atmospheric scientists and surface chemists.
5. Computational models provide a useful means of exploring a range parameters – examples of specific issues are: atmospheric asymmetries at Io, plumes at Europa, energetic particle fluxes at Ganymede, upstream conditions at Titan, etc.;
6. Earth-based monitoring of the moons has been a valuable collaboration with mission in situ measurements.

B. Open questions:

- What are the characteristics of the volcanoes on Io that modify the Io plasma torus?
- What happens to Io's atmosphere at nighttime?
- What are the densities, shapes and variabilities of the neutral clouds around Io and Europa?
- How are the electron beams generated that impact Io's wake?
- How do iogenic Alfven waves propagate to Jupiter's ionosphere?
- Where/how are electrons accelerated that cause Io auroral spots in Jupiter's atmosphere?
- What factors control the highly variable plasma impacting Europa?

- What are the vertical structure and the variability of Europa's atmosphere/ionosphere?
- What are the contributions of Europa's putative plumes to the (a) atmosphere, and (b) interaction?
- At Callisto, further studies are needed to resolve the relative roles of ionosphere vs. internal induction currents.
- How does the vast variation in plasma conditions experienced by Titan modulate the plasma interaction with the moon's atmosphere?
- What are the net sources of (a) escaping neutrals and (b) plasma from Titan?
- What are the roles of charge dust in the (a) Enceladus and (b) ring environments?
- What is the role of moon-generated waves in wave-particle interactions?
- How are ENAs produced by moon interactions, what are fluxes that could be observed by future missions?
- What is the contribution of negative ions to plasma-moon systems?
- What is the overall impact of moons on global magnetosphere structure and dynamics?
- Why is Saturn's magnetosphere neutral-dominated and Jupiter plasma-dominated? How important are (a) distances of Enceladus vs. Io, (b) planetary magnetic field strength, (c) H_2O vs. SO_2, (d) other factors?
- What are the roles of moons in the magnetospheres of Uranus and Neptune?
- How do the outcomes of such workshops impact/influence future observations?
- How can such workshops assist with future projects?

Those questions should be at least partially be addressed in future meetings.

One additional outcome of the workshop is the fact that a subgroup of the participants decided to propose a ISSI group meeting to our colleagues I Switzerland.

Participants in Hotel Selfoss, Selfoss, Iceland

List of Participants:

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Agenda of the workshop

Europlanet Workshop "Outer Planet Moon-Magnetosphere Interactions" 11-15 Feb 2019, Selfoss, Iceland

MONDAY				
Time	**Duration (min)**	**Title**	**Presenter**	**chair**
13:30	15	Welcome/logistics	Krupp/ Holmström/ Roussos	Krupp
13:45	45	Introduction to moon space environments and moon-magnetosphere interactions: the central roles of MHD waves and energetic particles	Kivelson	
14:30	20	Similarities and differences: Comparing the upstream conditions and magnetospheric interactions at Europa, Callisto, and Triton	Paty	
14:50	20	Influence of Magnetopause Dynamics on the Space Environments of Moons	Hardy	
15:10	30	Coffee Break		
15:40	45	The Space Environment of Io and Europa	Bagenal	Paty
16:25	20	Negative Ions in Saturn's Inner Magnetosphere	Jones	
16:45	20	Saturn's ionosphere: Electron density altitude profiles and ring shadowing effects from the Cassini Grand Finale	Hadid	
17:05		Adjourn		
TUESDAY				
8:45	20	Escape process of Io's atmosphere estimated from Hisaki observation	Tsuchiya	Murakami
9:05	20	Effect of Io's plasma source on plasma environment and dynamic in the Jovian magnetosphere from the HISAKI observation	Tsuchiya	
9:25	45	Io, its plasma environment, its interaction with the Jovian magnetosphere	Dols	
10:10	20	Electron measurements at Io, Europa, and Ganymede auroral footprint tail crossings	Allegrini	
10:30	30	Coffee Break		
11:00	20	Enceladus vs Io Auroral Hiss Emissions: Moon-Ionosphere Interactions in Parameter Space	Sulaiman	Barabash
11:20	20	Alfvén Wave Propagation in the Io Plasma Torus	Bagenal	
11:40	20	Neutral Tori and what they have revealed (or can reveal) about outer planet moon-magnetosphere interactions	Smith	
12:00	20	Energetic ion interactions with the neutral clouds of Saturn and Jupiter: Revisiting Cassini/CHEMS heavy ion measurements and new observations with Juno/JEDI	Clark	
12:20	15	Future plans of ultraviolet spectroscopy for planetary science	Murakami	
12:35	90	LUNCH		
14:05	20	Energetic charged particle bombardment of Europa and expected surface effects	Nordheim	Roussos
14:25	45	Moon-magnetosphere interaction in the Jovian magnetosphere near Europa	Blöcker	
15:10	20	Signatures of Europa's atmosphere in Galileo EPD data	Huybrighs	

15:30	20	Investigations of Moon-Magnetosphere Interactions by the Europa Clipper Mission	Korth	
15:50	30	Coffee break		
16:20	45	Jovian plasma interaction with Ganymede	Fatemi	Holmström
17:05	20	Plasma wave signatures of interactions of the Galilean satellites with the Jovian magnetosphere from Juno and Galileo	Kurth	
17:25	20	Radio emissions induced by moon-magnetosphere interactions	Louis	
17:45	Adjourn			
WEDNESDAY				
EXCURSION with bus leaving the hotel at 9:50am + DINNER at ~6:00pm-9:00pm				
THURSDAY				
8:40	45	Callisto's unique space plasma environment and possible ocean	Saur	Paty
9:25	20	Trapped Particle Dynamics at Galilean Moons	Guio	
9:45	20	Modeling of the LEMMS observation of the energetic ions during icy moons flybys	Kotova	
10:05	30	Coffee break		
10:35	45	Moon-magnetosphere interaction in the Saturnian magnetosphere near Enceladus	Wahlund	Brandt
11:20	20	The charge state of the Enceladus Plume	Morooka	
11:40	20	Direct detection of magnetic field-aligned electron beams near Saturn's moon Enceladus	Jones	
12:00	20	An examination of Cassini CAPS Ion Beam Spectrometer (IBS) data at Enceladus.	Haythornthwaite	
12:00	90	LUNCH		
13:30	45	Cassini at Titan: What have we learned after more than a decade of observations?	Snowden	Barabash
14:15	20	Is an ocean induction signature from Titan detectable?	Crary	
14:35	20	Variability of Titan's cold plasma environment from RPWS/LP measurements	Edberg	
14:55	20	Thermal Ion Precipitation Into Titan’s Upper Atmosphere	Snowden	
15:15	30	Coffee break		
15:45	45	Moon-magnetosphere interactions in the Uranian and Neptunian magnetospheres near Miranda and Triton	Rymer	Holmström
16:05	20	Review on low energy ENA imaging of the Jovian moons-magnetosphere interactions: comparative aspects, predictions, and JUICE/PEP capabilities	Barabash	
16:50	20	JUICE/PEP HENA imaging of the Jovian moons - magnetosphere interactions	Brandt	
17:10	20	JUICE/PEP in situ measurements near the Galilean moons	Krupp	
17:30	Adjourn			
FRIDAY				
09:00	30	Moons and wave-particle interactions in the radiation belts of Jupiter and Saturn.	Woodfield	Krupp
09:30	20	Probing moon-magnetosphere interactions and magnetospheric dynamics through energetic electron microsignatures	Roussos	
10:00	20	Io and Europa neutral gas torii and ion cyclotron waves: effects on the radiation belts	Nenon	

10:20	30	Coffee break		
10:50	60	Wrap-up and discussion of next meeting		ALL
11:50	End of meeting			

Statistics

The workshop attracted 40 participants from 6 different countries with 25% females, 20% early career scientists. The 40% from outside Europe is understandable because of the NASA involvement in the outer planets space missions. No participants from the inclusiveness states for the same reason. No industrial or amateur participants registered for the meeting.

Total number of participants	Number of participants of Inclusiveness states	Number of female participants	Number of male participants	Number of early career scientists	Participants from Industry	Amateur Participants	Participants from outside Europe
40	0	11	29	8	0	0	16

Summary

From the feedback of all participants and from the fact that all want to continue the science discussion in additional workshops the organizers think that this workshop was a great success.