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Solar Radiation for Protection of Solar Radiation on Spacecrafts and Lunar Settlements. Or the use of Miniature Magnetospheres Induced by the Photoelectric Effect

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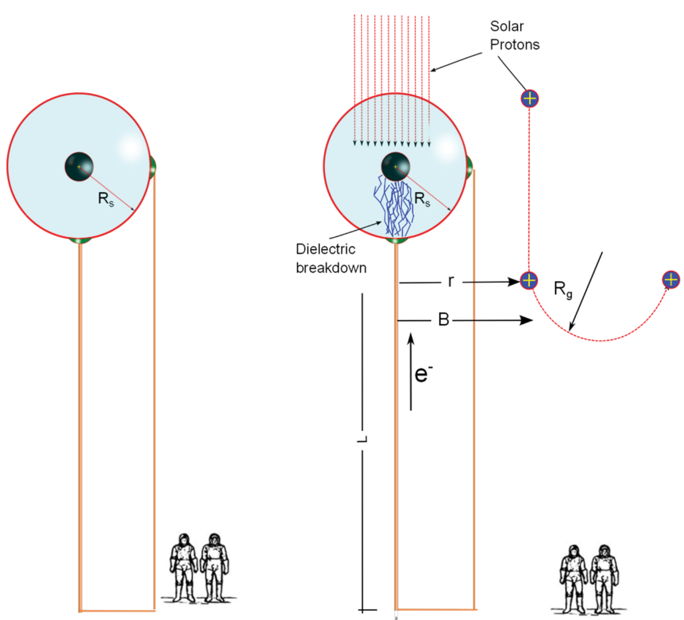
(Dated: April 5, 2018)

This manuscript is intended as a survey of the possibility of a novel idea by using solar radiation for protection against solar radiation on spacecrafts in interplanetary space as well as the moon and similar celestial bodies (which are devoid of atmosphere) by harnessing the photoelectric effect. The idea is conceptually simple: if a plate composed by a metal with a low work function -located in front of, say, a spacecraft, is under the action of solar light, then will have emission of electrons via photoelectric effect (photo electrons). Likewise, because this electron emission, the plate will get a positive charge which will increase with time until a certain saturation charge is attained which is limited by the specific stopping potential as well as the capacitance of the configuration which is a design parameter. Now, during a solar storm and solar flares events -when a large number of energetic ions and electrons can penetrate and damage electronics and human tissues, the electrostatic equilibrium in the plate is disrupted and as consequence dielectric breakdown occurs. The dielectric breakdown may generates a strong electronic current by discharging its accumulated charge which all in all can translate into the generation of a strong local magnetic field able to deflect the energetic radiation during the solar event. Utilizing a simplified geometrical model, the feasibility of generation of such miniature magnetospheres for solar flares protection on spacecrafts and lunar settlements was studied and mathematical expressions were derived as funtion of several parameters.

Keywords. *Solar flare, Radiation protection systems, interplanetary travel, Moon and Mars human lunar settlements.*



a) Before solar event
b) During solar event

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Planetary SpaceWeather Services for the Europlanet 2020 Research Infrastructure

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Abstract

Under Horizon 2020, the Europlanet 2020 Research Infrastructure (EPN2020-RI, http://www.europlanet-2020-ri.eu) includes an entirely new Virtual Access Service, "Planetary Space Weather Services" (PSWS) that will extend the concepts of space weather and space situational awareness to other planets in our Solar System and in particular to spacecraft that voyage through it.
PSWS will provide at the end of 2018 12 services distributed over 4 different service domains – 1) Prediction, 2) Detection, 3) Modelling, 4) Alerts. These services include **1.1) A 1D MHD solar wind prediction tool**, **1.2) Extensions of a Propagation Tool**, **1.3) A meteor showers prediction tool, 1.4) A cometary tail crossing prediction tool, 2.1) Detection of lunar impacts, 2.2) Detection of giant planet fireballs, 2.3) Detection of cometary tail events, 3.1) A Transplanet model of magnetosphere-ionosphere coupling, 3.2) A model of the Mars radiation environment, 3.3.) A model of giant planet magnetodisc, 3.4) A model of Jupiter's thermosphere, 4) A VO-event based alert system.** We will provide an overview of the project as an introduction to the session where some of them will be detailed.
The proposed Planetary Space Weather Services will be accessible to the research community, amateur astronomers as well as to industrial partners planning for space missions dedicated in particular to the following key planetary environments: Mars, in support of ESA's ExoMars missions; comets, building on the success of the ESA Rosetta mission; and outer planets, in preparation for the ESA JUpiter ICy moon Explorer (JUICE). These services will also be augmented by the future Solar Orbiter and BepiColombo observations. This new facility will not only have an impact on planetary space missions but will also allow the hardness of spacecraft and their components to be evaluated under variety of known conditions, particularly radiation conditions, extending their knownflight-worthiness for terrestrial applications.
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DeTeCt3.1.: A software tool to detect impacts of small objects in video observations of Jupiter obtained by amateur astronomers

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Abstract

Small objects (10-20 m in diameter) impacting Jupiter produce luminous superbolides that can be observed from the Earth with small size telescopes. Five of these impacts have been observed by amateur astronomers since July 2010. Recent analyses of these impacts try to infer the impact rate in Jupiter of such small objects towards a better characterization of the global impact rate in the giant planet [1-3]. Amateur astronomers observe Jupiter using fast video cameras that record thousands of frames during a few minutes which combine into a single image that generally results in a high-resolution image. Flashes are brief, faint and often lost by image reconstruction software. We present upgrades in the software DeTeCt initially developed by amateur astronomer Marc Delcroix and our current project to maximize the chances of detecting more of these impacts in Jupiter.

1. Introduction

The first fireball impact in Jupiter was observed by Anthony Wesley from Australia and Christopher Go from the Philippines in July of 2010 [1]. Further impacts are detailed in references [2-3]. These impacts were detected by the individual observers through the visual examen of their video observations. In most cases an individual observer reported the impact and other observers reviewed the data they have acquired during the same night finding the flash in their video observations. Sometimes these impact detections occurred days after the impact because of the faint nature of the impact and the long duration of the videos. It is recognized by many of the observers the difficulties to efficiently find the weak flashes on long night-time observing runs. Some observers storage Terabytes of past video observations of Jupiter equivalent to dozens of days of observing time and their analysis could potentially result in new detections of past impacts. Thus, a software tool able to automatically analyze video observations of Jupiter and find potential impacts could detect new impacts if its use is promoted within a number of observers large enough.

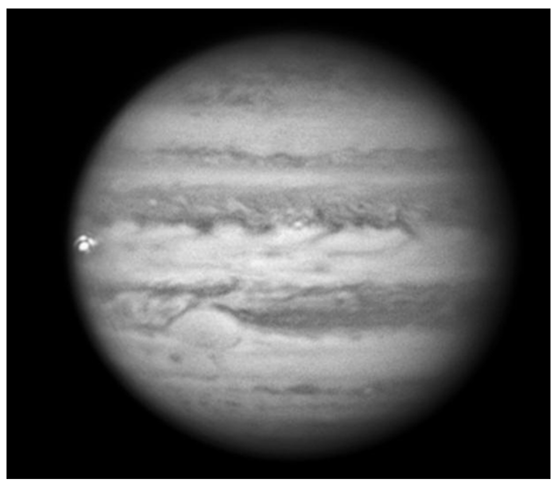

Figure 1: Image of the most intense Jupiter flash event recorded by George Hall in September 10, 2013. Background image from stacking all frames in the video sequence. The bright flash corresponds only to stacking the frames where the impact was visible in the video. Note the diffraction patterns around the punctual light source associated to the bright flash.

2. DeTeCt

DeTeCt is an open source Linux/Windows application developed by M. Delcroix that allows to search for impacts in Jupiter videos. The software has been regularly used by dozens of observers examining data equivalent to about 76 days of observations distributed unevenly over the last few years. Over the last year we have developed and released a new version of the software: DeTeCt3.1. with some technical improvements and a graphical user interface that makes its use much easier. The software is fully documented and available at:

http://pvol2.ehu.eus/psws/jovian_impacts/

DeTeCt3.1. was developed as part of the Europlanet-2020 RI Planetary and Space Weather Services (PSWS) and is integrated into the PVOL web service (also developed through Europlanet-2020 funds).

The detection algorithm is based on differential photometry on coregistered images of the video sequence. Additionally the software produces detection images for each video that can be quickly inspected by the observer (see figure 2).

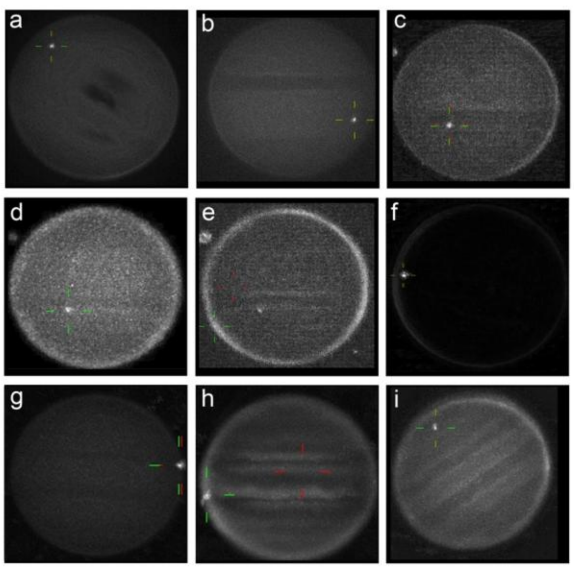

Figure 2: Collection of detection images produced by DeTeCt3.1 over past impacts in Jupiter. Although some weak flashes are missed by the software and false positives are still produced by the software the examen of these images unambiguously result in detections.

Our goal with this project is to maximize the number of users that examine their video observations of Jupiter. Large impacts (objects larger than 20 m) could also be observed in Saturn and we encourage the use of the software in video observations of both planets.

Statistics on the use of the software are prepared by one of us (M.D.) and can be accessed at:

http://www.astrosurf.com/planetessaf/doc/project_detect.shtml

3. Amateur-profesional collaboration

The latest impact events in Jupiter occurred in March 2016 and May 2017 [3]. The large number of Jupiter observations linked to the Juno mission and its call to amateur observers to participate in the mission through regular monitoring of the planet will contribute to obtain more observing time of the planet. The fact that Jupiter oppositions have moved from North hemisphere winter in the last few years to Spring in the last few Jupiter opposition will result in better chances of finding new impacts in the planet. A wide use of DeTeCt should help to identify these impact events characterizing better the flux of impacts in Jupiter.

Acknowledgements

We are very grateful to the large number of amateur astronomers running different versions of DeTecT over their video observations of Jupiter and Saturn. This work has been developed in the framework of the Europlanet 2020 RI. Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208. This work has also been supported by the Spanish MINECO project AYA2015-65041-P (MINECO/FEDER, UE), Grupos Gobierno Vasco IT-765-13 and UFI11/55 from UPV/EHU.

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The PSWS Space Weather VOEvent alerts service of the CDPP

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Abstract

The CDPP (Centre de Données de la Physique des Plasmas,(http://cdpp.eu/), the French data center for plasma physics, is engaged for two decades in the archiving and dissemination of plasma data products from space missions and ground observatories. Under Horizon 2020, the Europlanet Research Infrastructure includes PSWS (Planetary Space Weather Services), a set of new services that extend the concepts of space weather and space situation awareness to other planets of our solar system. One of these services is an Alert service associated with solar wind prediction made using the CDPP *Heliopropa* service (http://heliopropa.irap.omp.eu), and detection of meteor shower, lunar flash and cometary tail crossing. This Alert service, is based on VOEvent, an international standard proposed by the IVOA and widely used by the astronomy community. The VOEvent standard provides a means of describing transient celestial events in a machine-readable format. VOEvent is associated with VTP, the VOEvent Transfer Protocol that defines the system by which VOEvents may be disseminated to the community. VTP is managed with Comet, a freely available and open source software. Comet is used by PSWS for its Alert service and several partners of PSWS, including the CDPP and Observatoire de Paris.

This presentation will focus on the latest version of the alert system (https://alerts-psws.irap.omp.eu) implemented with the current version of the VOEvent standard.

Acknowledgements

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Several questions on the structure of the cometary induced magnetospheres

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Abstract

We will discuss several features of the cometary magnetosphere.

What is the 3D structure of the diamagnetic cavity? Does it possess closed surface as a boundary? In this case, there should be at least 2 neutral points at the boundary. What happens at the vicinity of these points? Or the tangential discontinuity is destroyed on the night side by some diffusive process and there is no closed boundary of the diamagnetic cavity.

The magnetic field in the tails of the induced magnetospheres (both comets and Venus) differs from that of the geomagnetic tail. In the latter, the magnetic field is directed predominantly along the tail axis. In the induced tail, the magnetic field component perpendicular to the axis is comparable with parallel component. There is certain contradiction with a simple draping picture and wind sock model of the comet.

What is the nature of the cometary rays? There are three possibilities: First, the rays are the magnetic flux tubes with increased plasma density. The rays parallel are parallel to the magnetic field in this case. Second, the rays are currents sheets associated with the nest draping. Third, the rays are plasma jets which are NOT parallel to the magnetic field.

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A Proxy for the Upstream IMF Clock Angle at Mars

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Abstract

A method to estimate the upstream direction of the interplanetary magnetic field using downstream magnetic field data is developed. We select MAVEN magnetic fields data in the martian magnetosheath from a single orbit. The magnetic field direction is compared to an empirical model, based on statistical averages of the draped magnetic field direction. Different rotations of the data around the Mars-Sun line are attempted to find which rotation provides the best fit to the data. The method is validated by comparing the proxy clock angle to measured values from orbits when an upstream measurement is made close in time to the downstream measurement. The distribution of proxy clock angles is compared to the observed distribution and are found to be similar.

1. Introduction

An important factor in the interaction of the solar wind with Mars is the direction of the motional electric field in the interaction region, which is set by the direction of the upstream Interplanetary Magnetic Field (IMF) in the plane perpendicular to the solar wind velocity, or the clock angle, ϕ_{IMF}. Although MAVEN often measures ϕ_{IMF}, there are some epochs in which MAVEN does not cross into the solar wind. Furthermore, ϕ_{IMF} is variable on timescales on the same order as the MAVEN orbital period. Thus, a method for estimating ϕ_{IMF} is a useful tool to enable other studies of the solar wind interaction with Mars.

2. Method

We use data from the MAVEN MAG with 30-s time resolution from the magnetosheath on a single orbit and compare those data to an empirical model of the draped magnetic field direction. Magnetosheath data from a single orbit are selected using the fitted location of the bow shock as the upper boundary and the magnetic pileup boundary as the lower boundary [1]. Various limitations of the solar zenith angle of the data included were attempted. The results provided here use data from within solar zenith angles between 45°-135°. Data from 23 Dec 2014 – 14 Aug 2017 were used in this analysis.

The empirical model is a statistical median of the magnetic field direction in the martian magnetosheath in Mars-Solar-Electric field (MSE) coordinates [2]. Three different models are implements based on the upstream magnetic field sign in Mars-Sun direction: $+B_x$, $-B_x$, and $+/-B_x$. The three cases are employed because the B_x component changes polarity as in different IMF sectors. The median approach select values close to zero when data from both sectors are used. This model is binned in Cartesian bins of 0.3 R_M on a side spanning from +/-3 R_M in x, y, and z.

For each MAG magnetosheath data point along the MAVEN trajectory, we compare the direction of the magnetic field with the direction of the model magnetic field in the relevant spatial grid cell. A goodness of fit is computed by

$$\chi^2 = \sum_i \chi_i^2 = (1 - \mathbf{b}_{i\ \mathrm{model}} \bullet \mathbf{b}_{i\ \mathrm{measured}})^2 \quad (1)$$

The orbital data are then rotated by 1° around the Mars-Sun line and χ^2 for this rotation is calculated. We iterate through 360° in 1° increments to find the rotation with the minimum χ^2 value. This angle is the angle that aligns best with the model of draping in MSE coordinates, so it is the upstream clock angle that produces MSE coordinates for the given orbit, ϕ_{proxy}.

3. Results

The distribution of ϕ_{proxy} is compared with the distribution of ϕ_{IMF} in Figure 1. The distributions are very similar, suggesting that the proxy is able to detect the upstream clock angle fairly well. In Figure

2, a comparison is made between ϕ_{proxy} and ϕ_{IMF} for the orbits when the upstream IMF is measured within 2.5 hours of the proxy value. We examine the distribution of the difference between ϕ_{proxy} and ϕ_{IMF}. Although there are many orbits in which the difference is greater than 10°, the IMF direction is known to change on timescales smaller than 2.5 hours. For example the difference between ϕ_{IMF} from one orbit to the next, or a 5 hour separation is shown in Figure 2 as well. The proxy yield more difference values in the 0-10° bin than the actual variations from orbit to orbit.

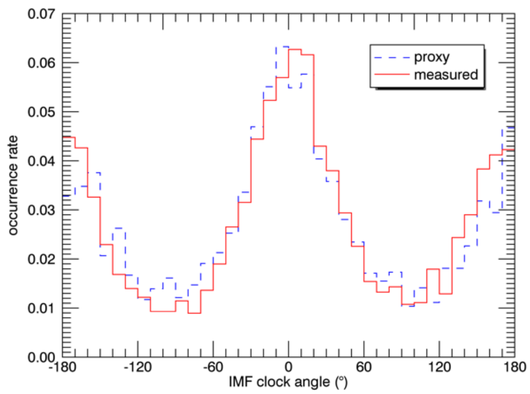

Figure 1: Comparison between the distribution of clock angles measured upstream of Mars by MAVEN and those determined through the proxy method.

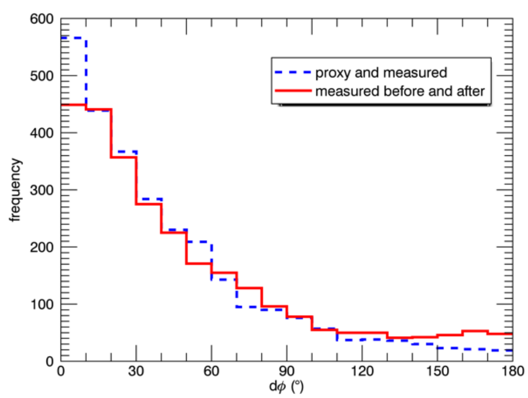

Figure 2. The difference in the proxy value and the measured upstream value is shown in blue. In addition, the natural variation in IMF direction on 5 hour time scales is also shown in red.

4. Conclusions

The proxy developed here is one way to estimate the upstream IMF clock angle using data from within the martian magnetosheath. Other methods also exist [3, 4]. This method may be employed when the spacecraft does not venture into the upstream solar wind, or when the solar wind orientation may have changed from the orientation measured when MAVEN is upstream. Future work may estimate the cone angle of the IMF and the magnitude.

Acknowledgements

Funding for this work was provided by NASA through grant NNX16AL45G. MAVEN MAG data are available at the NASA Planetary Data System.

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A Virtual Observatory (VO) Event model for the optical detection of meteors and transient luminous events

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Abstract

Optical counterparts of atmospheric transient events are subject of observation and investigation of a growing community. Professional as well as amateur observation networks are established in Europe and abroad to collect data important not only for the scientific investigation of some physical processes but also to assess their possible impacts on Earth's environment. We propose here an implementation of the Virtual Observatory Event standard to the domain of meteors and Transient Luminous Events (TLEs). A well established standard for real-time alert on those domains will facilitate coordination between networks and simplify the extraction of critical information. This will result in improved collaboration between the amateur community and agencies (e.g. the ESA Fireball Database, or the CNES TARANIS mission).

1. Introduction

Atmospheric optical transient events are observed and analyzed for space weather forecasting or for scientific research in an increasingly systematic way. This abstract focuses on meteors and Transient Luminous Events (TLEs): the first ones are linked to sky surveillance activities because of damages produced by possible collisions as for artificial space debris, the second are classified as ionospheric disturbances then belonging to the domain of space weather. They have often been subject of paired optical observation campaigns, as their monitoring benefits from continuous sky surveillance and similar hardware installations. Data provided by professional and amateur observers need to be compared, merged and archived. A well defined standard describing observation metadata is then necessary in order to efficiently process those data and enable real-time updates.

2. VOEvents for atmospheric surveillance

VOEvent[1,2] is a standardized protocol developed to report observations of astronomical events. It has been officially adopted by the International Virtual Observatory Alliance (IVOA) in 2006. A VOEvent alert has a generic structure defined by the standard tags:`<who>`, `<how>`, `<what>`, `<why>`, `<wherewhen>`. The VOEvent system is already used by several large-scale projects such as the Gamma-Ray Coordinate System (GCN), the Large Synoptic Survey Telescope (LSST), the European Low Frequency Array (LOFAR), or the Solar Dynamic Observatory (SDO). In the framework of the Planetary Space Weather Service (PSWS) of the Europlanet-H2020 Research Insfrastructure (EPN2020RI) project [3], we propose to use VOEvent for atmospheric observations like meteors and TLEs.

2.1. Meteors

Several camera networks already exist in Europe and around the world, aiming to detect and triangulate shooting stars, compute the trajectory of the possible meteorite and constrain the orbital properties of the meteoroid. Professional and amateur networks (see among others [9], [4], [5], [8]) working together will allow Europe to be completely independent in obtaining awareness about Earth space environnment and existing risks connected to atmospheric reentries. European Space Situational Awareness national programs would benefit from having a common and standard framework for sharing information on meteor and fireball detections, and their contribution to the ESA Fire-

[1] http://www.ivoa.net/documents/VOEventTransport/20170320/REC-VTP-2.0-20170320.html
[2] http://www.ivoa.net/documents/VOEvent/20110711/REC-VOEvent-2.0.pdf

ball Information System[3] would become more efficient. A Virtual Meteor Observatory initiative has already come alive in a European context [7] [2], ending up in the adoption of an XML-based communication format. Its connection to VOEvent standard will guarantee its sustainability in a larger and well documented context.

2.2. TLEs

Transient Luminous Events (TLEs) are large-scale optical events occurring in the upper-atmosphere from the top of thunderclouds up to the ionosphere. TLEs may have important effects in local, regional, and global scales of the atmosphere, but many features of TLEs are not fully understood yet. TARANIS (Tool for the Analysis of RAdiations from lightNIngs and Sprites) is a CNES satellite project dedicated to the study of impulsive transfers of energy between the Earth atmosphere and the space environment[4]. The TARANIS microsatellite will fly over thousands of TLEs for at least two years. Its scientific instruments will be capable of detecting these events and recording their luminous and radiative signatures, as well as the electromagnetic perturbations they set off in Earth's upper atmosphere. Coupling TLEs observation to the already existent meteor detection networks, will allow the observation of TLEs over unprecedented space and time scales [6], strongly increasing the probability of joint detection and hence the scientific return of space missions such as TARANIS and ASIM (ESA).

3. Summary and Perspectives

In the framework of the Europlanet-H2020 Research Insfrastructure (EPN2020RI) project, we propose to use the VOEvent standard for the surveillance of transient atmospheric events like meteors and TLEs. We have validated the proposed syntax[5,6] in the EPN2020 PSWS infrastructure.

The VOEvent syntax will be implemented in the meteor and TLE detection software FreeTure [1], and we will provide support for amateur and professional networks willing to adopt the VOEvent scheme.

[3] http://neo.ssa.esa.int/search-for-fireballs

[4] https://taranis.cnes.fr/en

[5] https://gist.github.com/cmarmo/de5c0d5332444385ac0d4afc9a5dd92e

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Space Weather in the Outer Solar System

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Abstract

Planetary space weather refers to the physical and phenomenological state of natural space environments around planetary bodies. Any variability related to the energy release from the Sun, in form of photon flux, solar wind streams, coronal mass ejections, and energetic particles, characterizes the space weather conditions around the Earth [1]. Within a giant planetary system, e.g. the Jovian or the Saturnian systems, space weather phenomena can be both of solar and internal (e.g. volcanism, plumes, fast planetary rotation) origin. The details of such interactions are planet-dependent and in some cases (e.g. Jupiter), internal processes dominate over external drivers. The study of planetary space weather considers different cross-disciplinary topics, such as the interaction of solar wind and of magnetospheric plasmas with planetary and satellite surfaces [2], atmospheres, and ionospheres (e.g. [3]) and the variability of magnetospheres under variable external conditions. Studying the interactions of planetary bodies with plasma, energetic particles and photon radiation helps us to acquire a better understanding of the circum-terrestrial space weather phenomena, pushing our theories and models to their extreme limits.

In this paper, a brief review of the scientific aspects of solar and non-solar driven space weather will be presented with special emphasis in the Outer Solar System case. The physics of the interactions between the environment of the body and the impinging photon and particle radiation will be discussed: detailed analysis considering space weather phenomena around icy satellites of giant planetary systems will be provided and the importance of understanding such conditions in view of future space missions will be outlined [1][4].

Acknowledgements

Discussions in this paper have been partially inspired by the work performed by the 2014 ISSI International Team *Towards a global unified model of Europa's exosphere in view of the JUICE mission* http://www.issibern.ch/teams/exospherejuice/.

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EPSC Abstracts
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Detection and dynamics of Martian plasma boundaries

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Abstract

Many spacecraft have probed planetary environments in order to understand their dynamics and evolution. The datasets returned from instruments on these spacecraft have been used by researchers to classify "events" and "boundaries" within the planetary environments as variations of one or more physical parameters. This has typically been a time-consuming task, leading in particular to empirical models that however often do not reflect the large dynamics observed.

In this paper we report the use of machine learning techniques, widely used to great affect in other fields (e.g. image recognition, sound analysis etc.), to automatically detect plasma regions or boundaries at Mars (e.g. the bow shock or magnetosheath). We also investigate the variability in the Martian bow shock position with different drivers, in particular regarding the influence of the Martian crustal magnetic fields.

1. Martian context

Over the last two decades, the Martian environment has been investigated by a number of spacecraft including the Mars Express (MEX) and Mars Atmosphere and Volatile EvolutioN (MAVEN) missions that are still orbiting around Mars. Consequently, a vast database is available, allowing for a detailed analysis of the Martian induced magnetosphere's structure and its dynamics.

The bow shock occurring in front of the planet is of particular interest. A number of publications have attempted to describe its dynamics as driven from the combined influence of the solar wind dynamic pressure, solar extreme ultraviolet (EUV) fluxes, and the Martian crustal magnetic fields (Edberg et al., 2008 ; Hall et al., 2016 ; Fang et al., 2018). However, the problem of how the crustal fields influence the shape and location of the bow shock is still not fully resolved.

2. Machine learning

With an ever increasing amount of data, space physics has begun entering the big data era as with other public and private sector fields. Consequently, it is becoming increasingly difficult for researchers to analyse all the data available, so that machine learning techniques are promising tools in this context. We investigate the viability of these novel techniques in automatically recognising boundaries and regions within the Martian plasma environment, and in assessing the influence the solar wind, EUV and crustal fields on the boundaries. This approach will minimise the inherent biases of empirical modelling approaches, and create catalogues of events for the community,

3. Results

Several machine learning algorithms are used to investigate the capability to detect plasma regions and boundaries, such as random forest or neural networks.

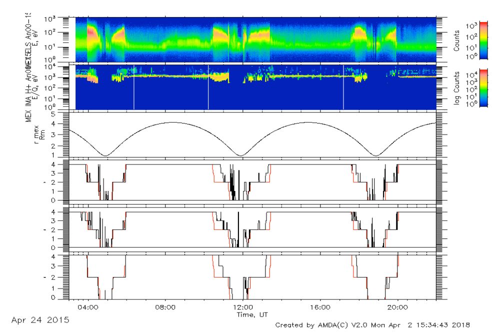

Fig 1 : (from top to bottom) MEX electron spectrograms, MEX/IMA ion spectrograms, distance to Mars, boundary/region classification by several algorithms (decision tree, random forest, neural network ; in black) compared with the manually defined classes (red) : 0=ionosphere, 1=MPB, 2=magnetosheath, 3=shock, 4=solar wind

The machine learning models were trained with datasets manually identified, or automatically identified from MEX plasma datasets by bespoke algorithms such as the large bow shock list by Hall et al. (2016). The results in Figure 1 show the possibility to correctly detect a number of boundaries/regions, with greater difficulties found in identifying the boundaries that correspond to rapid transitions. Neural networks are more promising, and other approaches are under study to improve the detection capabilities.

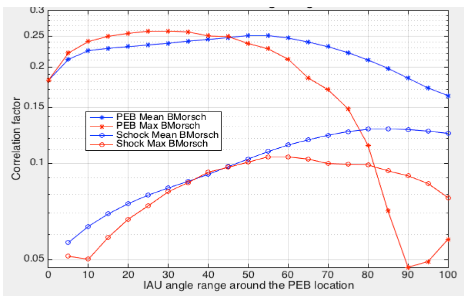

Fig 2 : correlation factor between the terminator distance of the shock (from MEX) and photoelectron boundary (from MAVEN) variability and the max/mean crustal field value in an angular range around the detection location.

To understand the complex influences of the crustal magnetic fields on the Martian plasma system, an analysis is also performed based on multi-spacecraft observations of the bow shock (MEX observations from Hall et al. (2016), MAVEN from Fang et al. (2017)), and of the photoelectron boundary (MAVEN observations from Garnier et al. (2017)). The influence is shown to be global, particularly with the boundaries located further from the planet. A magnetic perturbation propagation model will be discussed, and machine learning techniques will be used to investigate the complex influence of the various parameters from the measurements.

Acknowledgements

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Validity of planetary space weather predictions

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Abstract

Planetary plasma environments are highly influenced by the solar wind input. There are several methods, tools and services to predict the space weather conditions at a given target. In this paper we discuss their validity.

1. Introduction

In order to study solar wind interactions with planetary plasma environments ideally we would need simultaneous measurements in the pure solar wind and inside the planetary plasma environment. When there is only one spacecraft around the planet, it cannot perform such simultaneous observations, thus the prediction of solar wind properties and solar events to the different planetary objects becomes important.

2. Methods and their validity

There are several solar wind prediction methods. These apply either remote solar observations or in-situ solar wind measurements as an input. The propagation from the observation site to the target can be performed either through the ballistic or the MHD method. The prediction results can then be validated by in situ measurements onboard the planetary spacecraft while these are located in the solar wind. Besides this 'empirical' validity, we also discuss the 'theoretical' validity based on the assumptions that these models apply [1].

3. Tools and Services

The Europlanet Planetary Space Weather Services [2] provide ballistic solar wind propagation results as well as 1D and 3D MHD predictions. The propagation can be perfored from any planetary body to another. These services are very suitable for comparative studies and fast event search.

4. Summary and Conclusions

The accuracy of planetary space weather predictions is highly sensistive on the input data quality and the separation between the observation site and the target position. Due to the large spatial variability of the solar source, latitudinal effects cannot be neglected.

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Solar Windsocks: Estimating Solar Wind Speeds from Comet Ion Tail Images

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Abstract

As part of the Europlanet 2020 Research Infrastructure Planetary Space Weather Services (PSWS), University College London's Mullard Space Science Laboratory (MSSL) is making available software to estimate the speed of the solar wind at comets by measuring the orientation of their ion tails. As ion tails are cometary ions flowing downstream of the comet carried by the solar wind, images of the tails can provide a great deal of information about the solar wind speed at the comet. Software has been developed that allows the user to trace the ion tail, and, using information on the comet's position and velocity at the time the image was taken, allows estimates to be made of the solar wind speed at the comet's location in the inner heliosphere. These estimates can complement more accurate but limited measurements of the solar wind by spacecraft. We describe the software, its use, and limitations. The latter includes complications that arise when the solar wind flow is not purely radial, and difficulties in the use of the software when the Earth is crossing the plane of the target comet's orbit.

Acknowledgements

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Tailcatcher: A software tool for the finding of potential cometary tail crossings

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Abstract

As part of the Europlanet 2020 Research Infrastructure Planetary Space Weather Services (PSWS), University College London's Mullard Space Science Laboratory (MSSL) has developed software to allow the prediction of possible comet tails crossings. Comet's ion tails are produced when cometary gases are ionized and join the solar wind that flows almost radially outwards from the Sun. Spacecraft can cross these comet tails if they are both downstream of the comet's nucleus at the correct time, and that the solar wind speed is within a range that allows the cometary ions to arrive at the spacecraft when it is downstream. Several such instances of serendipitous comet tail crossings are known to have occurred.

The software – *Tailcatcher* – allows spacecraft trajectories to be uploaded, and a database of all known comets is searched for periods when nuclei were upstream of the spacecraft path to allow solar wind within a reasonable velocity range to arrive at the spacecraft to allow detection and analysis. We shall give examples of the software in use, demonstrating its ability to "predict" known tail crossings.

Acknowledgements

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The Spatial Distribution of Lunar Impact Flashes

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Abstract

Plotting the longitudinal and latitudinal distributions of observed lunar impact flashes shows that they differ substantially to impact distributions as predicted theoretically[1]. Observationally, no flashes are seen in the Moons polar regions, and there is a sharp fall in impact flux in the ±10° longitudinal degree range. 1.8 times as many impact flashes are observed Moon's western hemisphere than the eastern. A range of effects could cause this disparity. These include a light from impact flashes near the Moon's limb being blocked by topographic shielding, by observers avoiding viewing areas of the Moon illuminated by the sun, and lunar albedo.

1. Introduction

With a thorough literature search, we compiled a list of 530 observed impact flashes into a central database, see:

https://www.impactflashdatabase.com.

The majority of these were from observations by NASA[2] and NELIOTA[3], although 20% of impacts were recorded by small observing programs and amateurs. Of these, 470 have their impact coordinates quoted to the nearest degree.

It was decided to re-examine the distribution of all observed impacts on the Moon's surface as this had previously been done with only with 108 observed flashes[4] and with little discussion about observational bias. Some variation was to be expected, the synchronous rotation state of the Moon causes its leading edge to intercept 1.3 times more than the trailing edge [5], though differing sources suggest this effect may be somewhat larger. The equatorial regions of 0°-30° were expected to have 10%[5] more impacts than the 60°-90° polar regions, due to meteoroids being more likely to be in the plane of the solar system.

2. Results and Discussion

Figure 1's most notable feature is the extreme drop off in flash flux at the poles, no flashes being observed beyond 60° north or south. Whilst this was to be expected, as discussed above, it should only cause a 10% decrease, which would result in a far less extreme drop off in flux than what was observed.

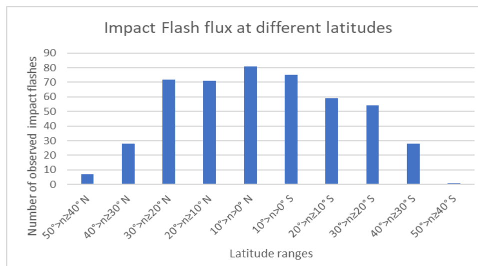

Figure 1. *Histogram of lunar impact flash flux versus latitude with 10° wide bins.*

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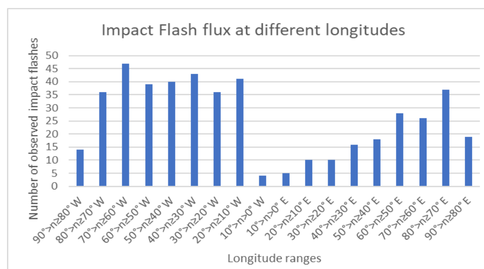

Figure 2. *Histogram of lunar impact flash flux versus longitude with 10° wide bins.*

One factor in this drop off is impactors on the lunar limbs having their flashes light blocked from Earth's view by the Moons topography. This alone cannot explain the decrease in impact flash flux though, as highland areas, nearer the limb, have far milder drops in impact flux than polar areas.

It is likely that the primary cause of the flux decrease is the shape of the Moon's illumination during its crescent phase. Observatories avoid observing near the dayside, due to it causing a high numbers of false positives in flash detection programs and from the decrease in contrast between the flash and the background glare. The crescent shape means that the poles are more illuminated than the equatorial region, discouraging polar observations. While this trend is reversed in the gibbous phase of the Moon, the majority of observing programmes only take recordings when the Moon is under 50% illuminated. Observing the poles also results in having less of the Moon in your field of view when compared to equatorial regions.

Figure 2 shows two notable features, a large drop off in impact flux in the ±10° longitude range, and a disparity between the number of flashes in the eastern and western hemispheres. The former effect is likely caused by the Moon's dayside glare issues. Again most observatories will wish to observe the portion of the Moon as far from the dayside as possible to reduce light pollution. This means that observing regions near the east and west limbs are more preferable than the central longitudinal region, which is never the area furthest from the dayside.

The leading edge effect, where more impactors strike this edge, is unlikely to be the sole cause of the disparity between the number of impacts observed in the longitudinal hemispheres. The effect predicts 1.3 times[5] as many flashes in the western hemisphere, whereas figure 2 shows the west had 1.8 times more impactors than the east. It should be noted there is still some debate about just how strong the leading edge effect is. For example, a 2010 paper by Ito *et al*[6] says that ray crater distributions imply that the western hemisphere has 1.7 ± 0.2 times as many impacts than the east, but examining NEO's only indicates the west having 1.32 ± 0.01 as many impacts as the east.

Another likely explanation for more flashes being spotted in the western hemisphere than expected is observational bias. For nights where the Moons eastern hemisphere is in earthshine and thus likely to be observed, moonrise tends to fall in the early hours of the morning, a less sociable time for most observers. Hence one would expect more observations of the western hemisphere as this is more convenient to monitor for most people.

A third factor affecting perceived impact flux could be albedo. We calculated that the mean albedo of the Moons western hemisphere is 10.5%, whilst the eastern hemispheres is 13.5%. The west's lower albedo allows for a higher contrast between the flash and background and thus makes the fainter ones easier to detect.

3. Conclusion

The observed distribution of lunar impact flashes does not reflect the expected distribution of impactors across the lunar surface. It instead may stems from observational bias and difficulties in observing certain regions of the Moon. It should be possible to either attempt to calibrate out this effect, for example by recording the number of hours spent examining the Moon, or to utilize the ALFI software[7] (in development) to extend the ability to look for impact flashes closer to the terminator, and on the dayside of the Moon.

Acknowledgements

This ALFI software[7] development has been made possible by the Horizon 2020, Europlanet 2020 Research Infrastructure (EPN2020-RI, http://www.europlanet-2020-ri.eu).

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Radiation environment at candidate landing sites on Mars: effects of Solar activity and of albedo neutrons for different mineralogical content

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Abstract

The study of the radiation environment at the surface of Mars is relevant for the degradation of instruments on rovers, for the hazard to future manned missions, and at a more fundamental level to understand the possible impact on biosignature conservation. Here we present a computational study (via the Monte Carlo Geant4 toolkit) of the radiation environment, effective doses and ambient equivalent doses at the surface of the planet for two potential landing sites, Oxia planum and Mawrth Vallis, assuming different Solar activity conditions and slightly different mineral composition (given by clay and silicate minerals). The results show how the impinging radiation varies with time and how the different hydrological and soil compositional characteristics influences the doses on a hypothetical stay on Mars of 30 days.

1. Introduction

The radiation environment at Mars is constituted by both Galactic Cosmic Rays (GCRs), thought to be accelerated by Type II supernovae and Solar Energetic Particles (SEPs) accelerated by intense flares and coronal mass ejections. radiation. The GCR spectrum is composed of 85% protons, 14% alpha (helium nuclei), and a small fraction of heavy ions (fully ionized atomic nuclei) and electrons. At solar maximum, complex interplanetary magnetic fields interact with incoming GCRs and remove lower energy particles from the incident radiation. As a consequence the GCR component in the inner environment of Mars has a higher average energy but a lower fluence at solar maximum than in the case of solar minimum. SEP are mostly composed of protons and electrons and about 10% He and <1% heavier elements, but although they produce high dose rates on the Martian surface, they penetrate only around 10 cm into the subsurface [1].

Two candidate landing sites for the ExoMARS2020 rover are Oxia planum, located at 18.2°N, 343.3°E, and Mawrth Vallis, located at 22.3°N, 343.5°E. In the first, band positions and shapes are best matched by smectite clays (Fe-Mg-rich saponite) or smectite/mica (e.g. vermiculite) with signatures of Fe2+ smectites found in the eastern part of the lower clay unit, as well as localized Al-phyllosilicate outcrops and an extensive hydrated silica stratum. The second is a wide layered phyllosilicate bearing unit with a widespread presence of a ferrous (Fe2+) phase at the transition between the Fe3+/Mg-smectite and the upper Al/Si-rich unit. Phyllosilicates (see Fig. 1) witness the presence of past water and are also fundamental minerals for water insertion and preservation and catalysis of organic molecules. Silicate minerals such as pyroxenes [(Ca, Fe, Mg)Si_2O_6] are also among the most common minerals in both the upper crust and surface of Mars. In particular, Fe2+ phase are of interest as they might be linked to respiration of Fe3+ reducing microbial communities. This raises an interest in such regions not only for the search for extant life, but also as location to be studied for possible injections of new microbes in future missions. The hazard posed by the radiation environment at such locations is thus of high interest.

1.1 Computational details

In this work, we have used MEREM (Mars Energetic Radiation Environment Model), which allows to simulate the source radiation spectra and which contains Planetocosmics, a Geant4 tool for the transport of particles, used for generating the full cascade in the atmosphere and the interaction with the soil. Only GCRs have been considered in this work, at Solar minimum and Solar maximum in cycle 23. No magnetic field has been considered in this study. The simulated system is composed by the atmosphere, the surface and the subsurface. The European Mars Climate Database has been used in order to specify required atmospheric profile parameters. The surface topography is based on data recorded by the Mars Orbiter, Laser Altimeter/MOLA instrument. The regolith composition is either automatically determined as a function of location using a default basalt/andesitic-basalt composition augmented by information regarding the surface iron concentration and hydrogen concentration (assumed to define prevailing levels of iron (III) oxide and water respectively) taken from Mars Odyssey Gamma-Ray Spectrometer/GRS data, or can be changed by the user under reasonable assumptions.

2. Results

The spectral analysis of the total downward flux, due to primary and secondary downward particles, and the total upward flux due to the albedo component (interaction of primary and secondary with soil) is presented and shows the importance of low energy neutrons in the vicinity of the surface. Doses by H, He, Li, Fe as primary GCRs sources are considered. The results show that the effective and ambient dose equivalent have a relatively strong dependence on the assumed Fe content in simulated clay compositions and Ca content in silicates, which in turn influence the production of albedo neutrons, and an expected relatively strong variation under different conditions of Solar activity. Diurnal variation effects of solar longitude and local time on the Martian atmosphere have minor effects. The results well match with the doses reported by previous studies but underestimate the ambient dose equivalent detected by the RAD instrument of the Curiosity rover (Table 1).

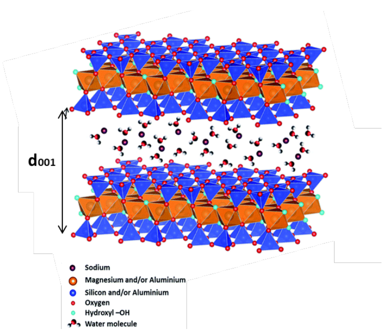

Figure 1: Crystalline structure of Montmorillonite, a typical widespread phyllosilicate. Water can easily enter the interlayer spacing

Table 1: Ambient dose equivalent from this study compared to Ref. [2] and to RAD measurements [3] (µSv per day), under quiet solar conditions

This study (Oxia planum)	Ref. [2] (Viking site)	RAD [3]
343.2	350.0	640.0

3. Summary and Conclusions

The work is inserted in a recent international effort to simulate, via accurate Monte Carlo calculations, the radiation environment at Mars. The results show a variability that should be taken into account, especially for future manned missions which will likely go beyond a 30 day-stay. Future work will focus on the evaluation of radiation doses inside potential hubs protected by different shielding types.

Acknowledgements

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