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Facts and Suggestions from a Brief History of the Galilean Moons and Space Weathering

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From Galileo Galilei's Starry Messenger of four centuries ago we began the long journey of Galilean moon exploration now planned to continue with the joint ESA-NASA Europa Jupiter System Mission. Nearly eighty years after this historic beginning, the Keplerian orbital motions of these moons could be understood in terms of universal laws of motion and gravitation with Newton's Mathematical Principles of Natural Philosophy of 1687. But now looking back from the present to long before the discovery of magnetospheric radio emissions from Jupiter by Burke and Franklin in 1955 [1], we can infer the first apparent evidence for magnetospheric space weathering of the moon surfaces only from the 1926 first report of Stebbins [2] on photometric measurements of surface albedo light curves. These observations established the tidal locking of rotational and orbital motions from leading-trailing albedo asymmetries that we now significantly (if not entirely) associate with space weathering effects of the moon-magnetosphere-moon interactions.

Of all the remote and in-situ observations that followed, those of the Pioneer (1973-1974), Voyager (1979), and Galileo (1995-2003) missions, and of the supporting measurements that followed in passing by the Ulysses (1992), Cassini (2000), and New Horizons (2007) missions, the discovery of greatest impact for space weathering may have been the first detection of Io volcanism by the Voyagers [3]. Accelerated as pickup ions in the corotating planetary magnetic field of Jupiter, atoms and molecules from the volcanic plume ejecta provide the primary source of magnetospheric ions for interactions with the other Galilean moons. These interactions include simple surface implantation of the iogenic ions, erosion of surface materials by ion sputtering, and modification of surface chemistry induced by volume ionization from more penetrating ions and electrons. From the highest energy magnetospheric protons and heavier ions, these interactions can be energetic enough to change isotopic ratios in the affected surface materials. The sputtered materials partially escape either directly to the magnetosphere or indirectly through exospheric losses, so these additionally contribute at trace levels to the magnetospheric interconnections of surface composition for all the moons.

In order to determine the intrinsic composition of the moons from EJSM surface and exospheric measurements, we must first peel back the surficial patina of space weathering products. Conversely, future measurements of the magnetospheric ion composition at high resolution in elemental and significant isotopic abundances, including as products of space weathering on the moon surfaces, can be projected back to the Io source for huge advancements of our knowledge on the origins of Io volcanism and more generally of the Jupiter system. These are some of the relevant facts for space weathering from 400 years of Jupiter system exploration, the main suggestion is that one the highest returns on international investments in the EJSM mission would be from advancement of capabilities for in-situ sample analysis in the magnetosphere and from moon surfaces to cover the full range of elements and key isotopes. Modest investments in appropriate technologies for ion and neutral gas measurements to this level would be insignificant in cost as compared to Earth sample return. This suggestion was submitted by Cooper et al. [4] to the ongoing decadal survey of planetary science and mission priorities in the United States.

References: [1] Stebbins, J., Publ. Astron. Soc. Pacific 38 (225), 321–322, 1926; [2] Burke, B.F., and K. L. Franklin, J. Geophys. Res. 60, 213–217, 1955. [3] Morabito, L. A., et al., Science 204, 972, 1979; [4] Cooper, J. F., and 21 Co-authors, Space Weathering Impact on Solar System Surfaces and Mission Science, Community White Paper submitted to Planetary Science Decadal Survey, 2013–2022. National Research Council, Washington, D.C.,

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