ADVANCED ION MASS SPECTROMETER FOR GIANT PLANET IONOSPHERES, MAGNETOSPHERES AND MOONS. E. C. Sittler[1], J. F. Cooper[2], N. Paschalidis[3], S. L. Jones[4], W. L. Brinckerhoff[5], W. R. Paterson[6], A. Ali[7], M. A. Coplan[8], D. Chornay[9], S. J. Sturner[10], M. Benna[11], F. B. Bateman[12], D. Fontaine[13], C. Verdeil[14], N. Andre[15], M. Blanc[16] and P. Wurz[17], [1]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, Edward.c.sittler@nasa.gov, [2]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, john.f.cooper@nasa.gov, [3]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, Nikolaos.paschalidis@nasa.gov, [4]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, sarah.l.jones@nasa.gov, [5]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, william.b.brinckerhoff@nasa.gov, [6]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA, william.r.paterson@nasa.gov, [7]Science Systems Applications, Inc., 6301 Ivy Lane, Suite 510, Greenbelt, MD, 20770, [8]University of Maryland, College Park, MD, coplan@umd.edu, [9]University of Maryland, College Park, MD/NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, dennis.j.chornay@nasa.gov, [10]University of Maryland Baltimore County/NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, steven.j.sturner@nasa.gov, [11]University of Maryland Baltimore County/NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, mehdi.benna-1@nasa.gov, [12]National Institute of Technology and Standards, Gaithersburg, MD, USA, fred.bateman@nist.gov, [13]LPP-CNRS Ecole Polytechnique, Route de Saclay, 91128, Palaiseau, FR, Dominique.fontaine@lpp.polytechnique.fr, [14]LPP-CNRS, 4 Place de Jussieu, tour 24-34, 75252, Paris, Cedex, FR, Christophe.verdeil@lpp.polytechnique.fr, [15]IRAP, Center National de la Recherche Scientifique, Toulouse, FR, Nicolas.andre@irap.omp.eu, [16]IRAP, Center National de la Recherche Scientifique, Toulouse, FR, michel.blanc@irap.omp.eu, [17]University of Bern, Physikalisches Institut, Bern, Switzerland, peter.wurz@space.unibe.ch

Introduction: The Advanced Ion Mass Spectrometer (AIMS) has been under development from various NASA sources (NASA Living with a Star Instrument Development (LWSID), NASA Astrobiology Instrument Development (ASTID), NASA Goddard Internal Research and Development (IRAD)s) to measure elemental, isotopic, and simple molecular composition abundances of 1 V to 25 kV hot ions with wide field-of-view (FOV) in the 1 – 60 amu mass range at mass resolution $M/\Delta M \leq 60$ over a wide dynamic range of particle intensities and penetrating radiation background from the inner magnetospheres of Jupiter and Saturn to the outer magnetospheric boundary regions and the upstream solar wind. This instrument will work for both spinning spacecraft and 3-axis stabilized spacecraft with wide field-of-view capability in both cases. AIMS will measure the ion velocity distribution functions (VDF) for the individual ion species. Ion velocity moments of the ion VDF will give the fluid parameters (density, flow velocity and temperature) of the individual ion species. Outer planet mission applications are Io Observer, (IoO), Jupiter Europa Orbiter (EurO), Europa Multiple Flyby Mission (EMFM), Enceladus Orbiter (EncO), and Uranus Orbiter and Probe (UOAP) as described in the decadal survey, but would also be valuable for inclusion on other missions to outer planet destinations such as Enceladus-Titan Joint Mission (ETJM), and Neptune-Triton and for future missions to terrestrial planets, Venus and Mars, the Moon, asteroids, and comets, and geospace applications to the Earth.

Rational for AIMS: The four giant planets of our solar system all have planetary magnetic fields containing hot plasma ions and electrons originating from solar, interplanetary, and internal magnetospheric sources. Plasma interactions both implant into, and erode materials from, moons of these planets, while also partly (Europa, Io) or wholly (Titan) obscuring subtle magnetic signatures of liquid oceans below the moon surfaces. Remote sensing analysis of surface composition at Europa, Enceladus, and other airless icy moons must account for effects of space weathering by the hot plasma and energetic radiation environments of those moons. The extreme radiation environments of Io and Europa, and the large abundances of foreground water group ions (O^+, OH^+, H_2O^+, H_3O^+) and nitrogen ions respectively at Enceladus and Titan, make precision measurements of plasma ion velocity moment fluid parameters (density, flow velocity, temperature) and abundances very challenging. Nevertheless, these worlds have significant decadal survey priorities for 2013–2022 (Visions and Voyages, 2012), all except Io also being potentially habitable ocean worlds as targets of NASA's new Ocean Worlds Exploration Program [1]. Advanced plasma instrumentation like AIMS is needed to operate in and to understand the complex plasma-field-radiation interactions in these environments.

Europa science objectives of the decadal survey are already covered in part by NASA's Europa Multiple Flyby Mission (EMFM), but later delivery of a Europa lander could be accompanied by an orbiter platform and more fully achieve all objectives.

For all of these missions, AIMS would measure the full energy/charge, mass/charge, mass, and angular distributions of the local hot plasma environments to support the following science objectives: (1) Ocean: subsurface ocean detection and global characterization at icy moons by induced magnetic fields against background of local ionospheric and magnetospheric ion currents. (2) Chemistry: ionic characterization of moon surface and atmospheric composition indicative of moon origins and evolution, internal geologic activity, volcanism, and potential habitability. (3) Magnetosphere: Evaluation of moon connections to hot plasma sources, transport processes, and sinks in the giant planet system.

AIMS Approach: The AIMS approach has a multi-mission capability because sub-systems can be removed or added to meet the planetary mission requirements. Emphasis is on an Europa class mission due to its most demanding radiation environment If this can be achieved, then the instrument has the necessary capability for missions with less demanding environments. A lower resource version would have greater emphasis on the major ions which could be applicable, for example, to support magnetometer measurements of Europa's ocean. The most capable higher resource option for which ion composition has the greatest emphasis, would measure both the major ion and minor ion species which will require a wider dynamic range in particle intensities so measurements of the more tenuous magnetospheric plasmas and denser plasmas within planetary ionospheres can both be made. The design of AIMS can be optimized for science operations in extreme radiation environments as would be encountered at Io and Europa, while also allowing full measurements in the more quiescent environments of the outer magnetospheric boundary regions and the upstream solar wind.

AIMS Design: Our design approach is to increase the signal to noise (S/N) within the instrument by 1) reduce foreground noise so scattering by major ions cannot hide the peaks of the minor ions by using our Circular Wien Filter (CWF) design with tophat electrostatic analyzer (ESA) for wide field-of-view capability and 2) reduce background noise due to penetrating particles by developing an effective gradient-Z radiation shielding design and by developing a technique that reduces the area of the detectors within the shielded cavity of AIMS without reducing geometric factor (GF) or sensitive area of AIMS. Reducing detector area also allows the shielding mass to be reduced. We have been measuring the response of microchannel plates (MCPs) to penetrating electrons and their secondaries from 100 keV to 1.5 MeV electrons using the NASA Goddard Van de Graaff accelerator and 8 MeV to 27 MeV using the National Institute of Standards and Technology (NIST) linear accelerator with and without shielding. Other mitigating techniques can also be used. By combining the mass-per-charge (M/Q) selection capabilities of the CWF + ESA, and the Linear Electric Field (LEF) time-of-flight (TOF) sub-assembly, we can separate ions of similar M/Q like O^+/S^{++} and O_2^+/S^+; our LEF will use novel tapered design whose concept was originated by the Goddard AIMS group. The tapered LEF reduces the sensor mass and allows one to optimize the performance of the LEF. A solid state detector (SSD) is included for high charge state ion measurements such as solar wind high charge state ions entering into giant planet magnetospheres [2]. The LEF allows one to locate the SSD near ground potential for a low mass and low risk design. We also have the capability to detune the instrument's GF by > 1000. Laboratory measurements of the AIMS prototype instrument performance will be presented along with our measurements of MCP response to energetic electrons and radiation shielding design approach.

References:

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