PASTELS: AN INNOVATIVE RAD-HARD, LOW-MASS SPECTROMETER FOR ELECTRON AND NEGATIVE ION CHARACTERIZATION IN PLANETARY ENVIRONMENTS (EUROPA, but also IO, ENCELADUS, TITAN, COMETS,…). N. André[1], A. Fedorov[1], N. Paschalidis[2], E.C. Sittler[2], and J.F.Cooper[2], [1]Institut de Recherche en Astrophysique et Planétologie, Centre National de la Recherche Scientifique/Université Paul Sabatier, 9 avenue du colonel Roche, 31028 Toulouse, France, nicolas.andre@irap.omp.eu, [2]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD, 20771, United States of America, nikolaos.paschalidis@nasa.gov.

Introduction: Any future exploratory mission to Europa must provide supporting measurements of the plasma ion and electron currents comprising the background environment above the moon surface in order to characterize the ocean through magnetic field measurements. Plasma parameters like densities, temperatures, and bulk velocities and pitch angle are key measurements to be obtained in order to unveil and detail the diverse and complex magnetospheric, ionospheric, neutral atmospheric and surface interactions that take place in the vicinity of Europa, in relation to the dominant volcanic inputs from Io that are redistributed through the whole Jupiter magnetosphere or to the *Europa plumes* recently discovered from HST observations [1]. A full suite of charged particle sensors (including electron, ion and energetic particle sensors would yield *unprecedented critical measurements* that bring the potential for discovery-class topical science in full alignment with the high expectations for the potential habitability of Europa. Knowledge of moon atmospheric and orbital neutral torus ionization processes requires a plasma electron spectrometer for electrons with energy range 1 eV ≤ E ≤ 30 keV.

The overarching objective of PASTELS is to provide the most comprehensive and critically needed plasma measurements in order to (1) characterize with unprecedented details the local plasma environment of Europa and disentangle **plasma-driven external magnetic field contributions** from those of internal origin in order to confirm the **presence of a sub-surface ocean**, (2) assess significance of Europa's chemical astrobiological potential by deciphering **atmospheric and orbital neutral torus ionization processes** including **negative ion chemistry**, and (3) search for **sites of geophysical activities and plumes**. Plasma electrons and negative ions are important components of the chemical reactions leading to species to be measured by a Mass Spectrometer. The density and temperature of the electrons control reaction rates. Negative ions are important in formation of complex molecular species, including those of potential astrobiological significance. Thus PASTELS would provide more environmental context for a Mass Spectrometer measurements.

Instrument Description: The Particle Analyzers for Suprathermal and Thermal ELectronegative Species (PASTELS) originally proposed for the ESA-led JUpiter ICy moon Explorer (JUICE) [2] mission consist of a compact, low mass, highly capable sensor based on a design carefully and specifically optimized for the plasma and radiation environment encountered around Europa. PASTELS on either a 3-axis-stabilized or a spinning spacecraft will provide fast 3D measurements in the energy range 1 eV-30 keV and is customized for the energy range as well as the dynamic range encompassing suprathermal and thermal plasma at Europa, including cold ionospheric species such as photoelectrons and ram negative ions of moon' origin, as well as pick-up negative ions likely to be observed. The sensor has strong heritage design and has been carefully designed to adequately operate despite penetrating particles and with stray photon rejection in the radiation environment of Jupiter, especially severe in orbit around Europa in particular. Emphasis has been placed on decreasing the total size of the detector and using ceramic channeltrons instead of MicroChannel Plates to dramatically reduce the detectors' sensitivity to penetrating particles. The sensors will provide comprehensive electron and negative ion measurements with species analysis and fine characterization of the environments of Europa, to fulfill both the planetary and magnetospheric objectives of missions to Europa. Negative ion measurements open new access to the analysis of atmospheric processes and negative ion chemistry and could have profound implications for habitability of the moon. The combination of 1) **an efficient passive multi-layered shielding**, 2) **a customized foil-based (polyimide/Al) coincidence scheme**, 3) **ceramic channeltrons,** and 4) **radiation-hardened ASIC front-end electronics**, will allow optimal science performances with a large geometric factor and adequate angular resolution while reducing significantly the background noise and keeping the overall sensor mass budget to a minimum. On the design level the PASTELS sensor has been optimized through dedicated and detailed simulations of electron optics and interaction with penetrating radiation. Some key elements of the sensor such as the ESA, and its unique foil-based (polyimide/Al) coincidence system has been fully prototyped and demonstrated in laboratory. On the component level, the critical response of ceramic channeltrons and our passive shielding strategy have been validated in a representative electron radiation environment at NIST LINAC (USA) and ONERA (France).

Instrument Summary:

Characteristics	PASTELS
Type ***Detector***	Electrostatic analyzer (ESA) Ceramic Channeltrons (CEM)
Radiation mitigation	Passive Ta/Al protection, cutting-edge electron foil-based (polyimide/Al) coincidence system, low sensitivity detectors
Geometric factor	9e-4 cm^2-sr-eV/eV per pixel
Dynamic range	5 10^3 to 5 10^9 eV/cm^2 –sr-s-eV/CEM
Mass Range	16-1000 (negative ions)
Mass Resolution	Separates M/Q >16, >32, >100, >500
Energy Range	1eV-30 keV
Energy Resolution	14%
Angular Range and Resolution	180°x90° (4π with two heads for 3-axis stabilized spacecraft) 22.5°x22.5°-40°
Time Resolution	10s, 30s, burst mode
Mass ***Power***	*0.83 kg for sensor head, plus 0.5 kg for sensor head shielding, plus 1 kg for electronics (unshielded)* *1.7 W average*

Conclusions:

PASTELS is a key payload for missions to Europa and directly addresses NASA strategic goals for the exploration of Europa's habitability, with instrumental coverage, resolution, sensitivity, high time resolution and dynamic range enabling measurement of negatively charged particle fluxes in all environments in the close or remote vicinity of Europa.

Although PASTELS has been carefully designed to operate within stringent radiation environments and, therefore, is particularly suitable for missions to Io and Europa, its innovative design and science capabilities make it also particularly suitable for future missions to Enceladus, Titan and comets.

Instrument Illustrations:

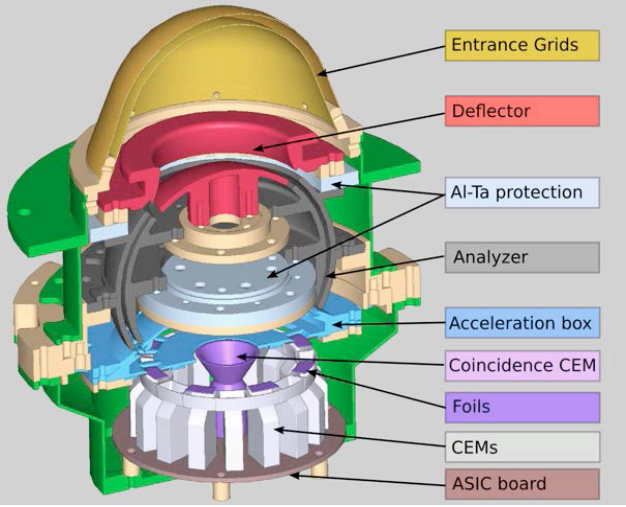

Figure: *Overview of PASTELS key susbsystems (3D cut).*

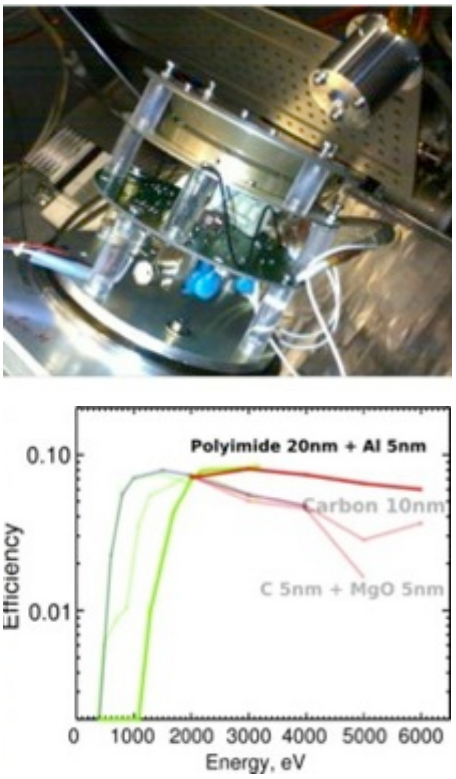

Figure: *The prototype of the coincidence-detection system in the vacuum chamber (top), measured coincidence system efficiency (bottom).*

References:

[1] L. Roth et al., Transient Water Vapor at Europa's South PoleScience, 343, 171-174.

[2] N. André et al. (2012), ChargEd Particle Analyzers for Galilean Environments, A proposal to ESA in response to the announcement of opportunity for JUICE.