THE JUPITER ICY MOONS EXPLORER (JUICE): COMPLEMENTARITY OF THE PAYLOAD IN ADDRESSING THE MISSION SCIENCE OBJECTIVES.

O. Grasset[1] N. Altobelli[2], S. Barabash[3], L. Bruzzone[4], M. Dougherty[5], C. Erd[6], L. Fletcher[7], Ph. Gare[6], R. Gladstone[8], L. Gurvits[9,10], P. Hartogh[11], H. Hussmann[12], L. Iess[13], R. Jaumann[12], Y. Langevin[14] , P. Palumbo[15], G. Piccioni[16], D. Titov[6], and J.-E. Wahlund[17], [1]Lab. Planetology and Geodynamics, CNRS, Nantes University, France, olivier.grasset@univ-nantes.fr, [2]ESA/ESAC, Spain, [3]Swedish Institute for Space Physics, Sweden, [4]University of Trento, Italy, [5]Imperial College, London, UK, [6]ESA/ESTEC, The Netherlands, [7]University of Oxford, UK, [8]Southwest Research Institute, San Antonio, TX, USA, [9]JIVE, The Netherlands, [10]Delft University of Technology, The Netherlands, [11]Max Planck Institute for Solar System Research, Germany, [12]Institute of Planetary Research, DLR, Berlin, Germany, [13]Sapienza Università di Roma, Italy, [14]IAS, Orsay, France, [15]Università Parthenope - Napoli, Italy, [16]IAPS, Roma, Italy, [17]IRF-Uppsala, Sweden.

Introduction: This presentation will give a status of the JUICE mission in the end of the definition phase, its science scenario, and the observation strategies that are foreseen with a strong emphasis on the complementarity of the suite of instruments. To summarize, the instrument suite on-board JUICE will allow the integration of datasets into a comprehensive multisensor / multitemporal / multiresolution view maximizing the scientific return of the data. This will be demonstrated using six examples that are briefly described in this abstract.

The ESA-JUICE mission: JUpiter ICy moons Explorer (JUICE) will perform detailed investigations of Jupiter and its system with particular emphasis on Ganymede as a planetary body and potential habitat. The overarching theme for JUICE is: The emergence of habitable worlds around gas giants. At Ganymede, the mission will characterize in detail the ocean layers; provide topographical, geological and compositional mapping of the surface; study the physical properties of the icy crusts; characterize the internal mass distribution, investigate the exosphere; study Ganymede's intrinsic magnetic field and its interactions with the Jovian magnetosphere. For Europa, the focus will be on the non-ice chemistry, understanding the formation of surface features and subsurface sounding of the icy crust over recently active regions. Callisto will be explored as a witness of the early solar system.

JUICE will perform a multidisciplinary investigation of the Jupiter system as an archetype for gas giants. The circulation, meteorology, chemistry and structure of the Jovian atmosphere will be studied from the cloud tops to the thermosphere. The focus in Jupiter's magnetosphere will include an investigation of the three dimensional properties of the magnetodisc and in-depth study of the coupling processes within the magnetosphere, ionosphere and thermosphere. Aurora and radio emissions will be elucidated. JUICE will study the moons' interactions with the magnetosphere, gravitational coupling and long-term tidal evolution of the Galilean satellites.

JUICE highly capable scientific payload includes 10 state-of-the-art instruments onboard the spacecraft plus one experiment that uses the spacecraft telecommunication system with ground-based radio telescopes. The remote sensing package includes a high-resolution multi-band visible imager (JANUS) and spectro-imaging capabilities from the ultraviolet to the sub-millimetre wavelengths (MAJIS, UVS, SWI). A geophysical package consists of a laser altimeter (GALA) and a radar sounder (RIME) for exploring the surface and subsurface of the moons, and a radio science experiment (3GM) to probe the atmospheres of Jupiter and its satellites and to perform measurements of the gravity fields. An in situ package comprises a powerful particle environment package (PEP), a magnetometer (J-MAG) and a radio and plasma wave instrument (RPWI), including electric fields sensors and a Langmuir probe. An experiment (PRIDE) using ground-based Very-Long-Baseline Interferometry (VLBI) will provide precise determination of the moons ephemerides.

JUICE will be a three-axis stabilised spacecraft with dry mass of about 1800 kg at launch, chemical propulsion system and 80-90 m2 solar arrays. The high-gain antenna of about 3 m in diameter will provide a downlink capability of not less than 1.4 Gb/day. The launch is foreseen is June 2022. After the Jupiter orbit insertion in January 2030, the spacecraft will perform a 2.5 years tour in the Jovian system investigating the atmosphere and magnetosphere of the giant. Gravity assists at Callisto will shape the trajectory to perform two targeted Europa flybys and raise the orbit inclination up to 30 degrees. 13 Callisto flybys will enable unique remote observations of the moon and in situ measurements in its vicinity. The mission will culminate in a dedicated 8 months orbital tour around Ganymede that will include high (5000 km), medium (500 km), and low (200 km) circular orbits.

Complementarity of P/L observations: This section gives a summary of contributions of the JUICE experiments to the main investigations and provides some important examples of synergies between experiments in addressing some of the science objectives. It also compares capabilities of the JUICE payload to those of the previous missions to the Jovian system, Galileo mission in particular.

Ganymede's ocean and icy crust. The Ganymede interior will be studied by combination of several experiments. Magnetic field measurements at multiple frequencies by J-MAG in orbit around Ganymede will constrain the electrical conductivity and extent of the subsurface ocean (Figure 1). GALA measurements of the tidal response of the icy shell and libration amplitudes, supported by JANUS and combined with an investigation of the time variability of the gravitational potential by 3GM, will constrain the thickness of the icy crust.

Ganymede's surface and sub-surface investigations. The imaging system JANUS will make a breakthrough in the Ganymede surface imaging by increasing the surface coverage by a factor of ~50 compared to that obtained by the Galileo mission. Due to changing the orbit altitude at Ganymede from 5000 km to 500 km, the mission will achieve complete global imaging with spatial resolution of better than 400 m/px that will be complemented by high-resolution imaging of selected targets with resolution better than 10 meters. The JANUS imaging and GALA sounding will provide Digital Terrain Models (DTM) of selected sites to be used for de-cluttering (compensation for the signal coming from side lobes) of the RIME data. The ice penetrating radar RIME will be the first instrument being able to acquire direct subsurface measures on the Jupiter icy moons (this is also the first time in absolute in which a radar sounder will be used in the outer part of the Solar System). The measurement on the vertical properties of the subsurface acquired by RIME will be then integrated with the vertical structure on and above the surface measure by GALA and JANUS.

Surface properties are monitored by remote sensing instruments (JANUS, MAJIS, UVS, SWI, GALA, RIME) and provide a surface (and sub-surface) context to the fields and particle investigations. The fields and particle instruments (J-MAG, RPWI, PEP) will also address several science objectives related to surface (and sub-surface) properties of the icy Galilean moons. Energetic particles (ions, electrons, neutrals, dust), monitored by the PEP and RPWI detectors, bombard the icy moons and change the composition and structure of the surface material. The magnetospheric source regions of the accelerating fields (electric potential structures or waves) will be monitored by RPWI and J-MAG, and the mechanism for the restructuring of the icy surfaces by the space environment can be found. On Ganymede, the surface is clearly divided between regions belonging to open and closed magnetic field lines respectively, indicating a division in the precipitation of energetic charged particles toward the surface.

Tenuous atmospheres of the moons.

When the energetic particles impact the icy surfaces it sputters material back into space and contribute to (or even dominate in some cases) the tenuous atmospheres/exospheres of the icy Galilean moons. Subsurface breaching of volatiles, diffusion and sublimation may be other contributions. JUICE will monitor directly the tenuous atmospheres/exospheres in terms of structure (SWI, UVS), composition (PEP, MAJIS, SWI, UVS), dust content (RPWS), and the surface sputtering process of energetic neutrals can be monitored directly by PEP. The tenuous atmospheres/exospheres are in turn partly ionized by solar EUV radiation and particle impacts from space (monitored by PEP and RPWI) and give rise to ionospheres. The ionospheres are readily monitored both by detailed in-situ measurements (RPWI, PEP) as well as by remote sounding by radio waves (3GM, PRIDE, RPWI). The magnetospheres interact with the ionospheres through electromagnetic fields and charged particles, and the fields and particle investigations monitor these processes. This electromagnetic coupling generates electric currents (monitored by J-MAG and RPWI) in the ionospheres, as well as in the conducting surfaces and sub-surfaces of the icy moons. On Ganymede, the interaction generates aurora along the open-closed magnetic field boundary, where UVS, MAJIS and JANUS will monitor the auroral emissions, while the fields and particle in-situ instruments will monitor the auroral acceleration processes themselves. A similar type of inter-instrument synergy exists with regard to observations of the Jovian auroral processes.

Composition and chemistry of Jupiter. JUICE will exploit in full the power of remote sensing by combining moderate resolution imaging with very high resolution point spectroscopy covering broad spectral range from UV to sub-millimeter wavelengths. The UVS spectrograph will take advantage of the largest cross sections and most distinctive spectral signatures of gaseous species in the FUV (50-150 nm) to study composition of the Jovian atmosphere in reflectance spectroscopy as well as in stellar and solar occultation geometry. The visible and near-IR spectral range is very rich in characteristic bands of minerals and gases.

Spectral mapping by MAJIS and imaging in narrow spectral bands by JANUS at 0.4-5.2 µm will also be exploited. Thermal radiation from the Jovian atmosphere will be sounded by SWI. The instrument will measure spectral lines of the gases present in the upper atmosphere of the giant planet with very high spectral resolution to determine composition, temperature structure and winds. A similar type of inter-instrument synergy exists with regard to the composition of both surface and atmosphere of the icy moons.

Temperature sounding of the Jovian atmosphere. Investigation of the temperature structure of the Jovian atmosphere will be performed by combination of three experiments: SWI, 3GM in radio-occultations, and UVS in stellar occultations. The first two experiments will sound the stratosphere of Jupiter (0-200 km above the visible cloud top). Despite the same altitude coverage, they complement each other in what concerns vertical resolution and longitudinal coverage. SWI is capable of providing temperature sounding at all longitudes with vertical resolution of ~15 km (half a scale height), while 3GM will achieve few hundred of meters vertical resolution but close to the terminator region and possible probe to the topmost cloud deck. UVS will extend the sounded region into the middle and upper thermosphere. The JUICE investigation of the temperature structure will complement the JUNO studies of the troposphere below the cloud tops.

Particles and fields investigations in the Jovian magnetosphere. The field and particle investigations (J-MAG, RPWI, PEP) will cover all expected spatial and temporal scales to be encountered by JUICE. The thermal plasma, DC electric fields, electric and magnetic signals from radio, plasma waves and micrometeorite impacts, as well as the spacecraft potential and integrated solar EUV flux will be sampled by the RPWI sensors. The RPWI measurements will cover all expected spatial and temporal scales to be encountered by JUICE. By contrast, the Galileo/PWS measurements did not cover fre-quencies below 10Hz, which missed all of the ion/fluid physics, and the electric measurements only reached 5.6 MHz, which missed a good portion of the Jovian radio emissions. The JUICE/RPWI also have several other additional capabilities, and will constitute a much more complete science investigation.

The fields and particle investigations will cover all energy ranges of interest for JUICE. The plasma particle population – 3D distribution functions of charged particle, plasma and neutral gas composition, as well as properties of the energetic neutral atoms (ENA), will be characterized by the PEP suite of six sensors. The PEP and RPWI experiments will together measure positive and negative ions, electrons, exospheric neutral gas, thermal plasma and energetic neutral atoms over more than nine decades from <0.001 eV to >1 MeV. In addition, micro-meteoritic impacts will be counted by RPWI, where energies of 1-10 micrometer dust grains moving with a few km/s have kinetic energies up to 10^{12} eV.

Conclusion: The JUICE mission will provide a thorough investigation of the Jupiter system in all its complexity. JUICE has been tailored to observe all the main components of the Jupiter system and untangle their complex interactions. In total, JUICE will address six science objectives fully described in Grasset et al. (2013), each of them being focused on a specific object of the system (Ganymede, Europa, Callisto, Jupiter, its giant magnetosphere, satellites and rings). The investigations that will be conducted to fulfill these objectives will strongly benefit from the synergistic capabilities of the payload. These capabilities will be demonstrated using the six investigations that are presented in this abstract.

Reference:

Grasset O., M.K. Dougherty, et al., JUpiter ICy moons Explorer (JUICE): an ESA mission to orbit Ganymede and to characterise the Jupiter system, Planet. Space Sci., 78, doi: 10.1016/j.pss.2012.12.002, (2013).