The visible and infrared imaging spectrometer MAJIS on ESA JUICE mission. F. Poulet[1] ; G. Piccioni[2] ; Y. Langevin[1] ; C. Dumesnil[1]; L. Tommasi[3]; V. Carlier[1]; G. Filacchione[2]; A. Arondel[1]; A. Barbis[3]; A. Bini[3]; D. Biondi[2]; A. Boccaccini[2]; D. Bolsée[4]; C. Caprini[3]; J.-P. Dubois[1]; J. Carter[1]; M. Condamin[1]; S. Couturier[1]; K. Dassas[1], M. Dexet[1]; I. Guerri[3]; P. Haffoud[1]; V. Hervier[1]; B. Lecomte[1]; G. Pilato[3]; M. Rossi[3]; C. Ruiz de Galarreta[1]; B. Saggin[5]; F. Tosi[2]; M. Vincendon[1]; M. Zambelli[2]; E. d'Aversa[2]; J. Barbay[1]; R. Brunetto[1]; A. Carapelle[12], M. Cisneros González[4]; B. Crane[1]; L. Fleitcher[7]; D. Grassi[2]; P. Guiot[1]; L. Gonnod[1]; C. Hannou[1]; J. Hansotte[1], J.-C. Le Cle'h[1]; C. Leyrat[6]; N. Ligier[1]; G. Morinaud[1]; N. Pereira[4], C. Pilorget[1] ; G. Poulleau[1]; S. Rodriguez[8]; B. Seignovert[9]; ; R. Sordini[2]; S. Stefani[2]; G. Tobie[9]; S. Tosti[1]; F. Zambon[2]; X. Zhang[1]; A. Adriani[2]; F. Altieri[2]; G. Arnold[10]; J.-P. Bibring[1]; D. Bockelée[5]; F. Capaccioni[2]; M.-C. De Sanctis[2]; P. Drossart[11]; T. Fouchet[5]; J.-C. Gérard[12]; N. Ignatiev[13]; P. Irwin[14]; O. Karatekin[15]; N. Mangold[9]; A. Migliorini[2]; A. Morbidelli[16]; A. Nathues[17]; E. Renotte[18]; A. Sanchez-Lavega[19]; B. Schmitt[20]; K. Stephan[10]; G. Strazzulla[21]; D. Turrini[2]; A.-C. Vandaele[4]; C. Carli[2]; M. Ciarnello[2]; S. De Angelis[2]; D. Grodent[12]; S. Guerlet[22]; E. Lellouch[6]; F. Mancarella[23]; S. Le Mouélic[9]; A. Mura[2]; E. Quirico[20]; A. Raponi[2]; G. Sindoni[24] and M. Snels[25]. [1]IAS, CNRS/Université Paris-Saclay, Orsay, France (francois.poulet@ias.u-psud.fr), [2]INAF-IAPS, Frascati, [3]Leonardo Company, Campo- Bisenzio, [4]BIRA/IASB, Bruxelles, [5]Politecnico di Milano, [6]LESIA, Observatoire de Paris, [7]University of Leicester, [8]IPGP, Paris, [9]LPG, Nantes, [10]DLR, Berlin, [11]IAP, Paris, [12]Université de Liège, [13]IKI, Moscow, [14]University of Oxford, [15]ROB, Bruxelles, [16]OCA, Nice, [17]MPS, Göttingen, [18]AMOS, Angleur, [19]Universidad del País Vasco, Bilbao, [20]IPAG, Grenoble, [21]INAF-OACT, [22]LMD, Paris, [23]University of Salento, [24]ASI, [25]CNR/ISAC, Rome

Introduction: JUICE (JUpiter ICy moons Explorer) is the first large mission in the ESA Cosmic Vision 2015-2025 program. The mission was selected in May 2012 and will be launched in April 2023 for an arrival at Jupiter in July 2031. It will make detailed observations of Jupiter and three of its largest moons, Ganymede, Callisto and Europa during a 3.4 years tour before Ganymede Orbit Insertion in December 2034. Here we describe the MAJIS (Moons And Jupiter Imaging Spectrometer) capabilities as shown prior to launch.

Instrument description: MAJIS is the visible-IR imaging spectrometer of JUICE. It is built by a consortium led by Institut d'Astrophysique Spatiale in Orsay, France with the support of CNES, the French space agency. There is a major contribution from Italy (science contributions: Istituto di Astrofisica e Planetologia Spaziale, industrial contract for the optical head of MAJIS: Leonardo Company, Florence) both supported by ASI, the Italian space agency. Belgian laboratories supported by Belspo are involved in the characterization of the MAJIS detectors. The MAJIS instrument is composed by three main hardware units: OH unit (Optical Head, Fig. 1), ME unit (Main Electronics Unit, Fig. 2) and IEH (Inter Equipment Harness) that refers to the different harness routed from ME, through the /C vault and to the OH panel.

MAJIS will investigate the spectral characteristics of Jupiter, the Galilean satellites, rings, small satellites and exospheres with two channels: the VISNIR channel in the 0.5-2.35 μm spectral range, and the IR channel (2.28–5.56 μm). Both channels operate simultaneously, the bridging region of the two channels being set at ~2.3 (±0.05) μm. Photons going through a slit defining the MAJIS FOV (0.06 radians) are sent to one of the channels by a beam splitter depending on their wavelengths. Within each channel, a grating spectrometer scatters the photons on the detector, so that the along-slit direction is spatial and the cross-slit direction is spectral.

Fig. 1. Optical head of the MAJIS instrument. Dimensions: 912x765x356 mm^3, 41 kg. The aperture of the optics is protected by a red cover.

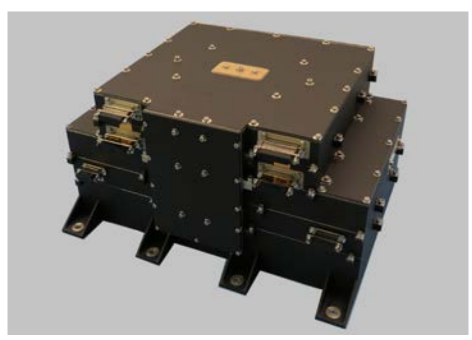

Fig. 2. Main electronics of the MAJIS instrument. Dimensions: 320 x 249 x 161 mm^3, 8.2kg

MAJIS collects photons with two HgCdTe H1RG detectors (1024 x 1024 pixels, 18x18 μm pixel pitch). HxRG detectors implement 4 lines and columns of reference pixels on each side. After binning 2x2 (nominal for MAJIS), there are 508 x 508 data collecting elements with a pitch of 36 µm x 36 µm. The IFOV after binning 2x2 is 150 µrad, with 400 pixels across the 0.06 radian FOV. In order to minimize the impact on the optical design in comparison to the proposal, the selected approach was to keep the same f-number while adjusting the slit width, leading to 400 binned pixels (IFOV = 150 µrad) across the FOV. At an altitude of 500 km (Ganymede low orbital phase), MAJIS will cover a 30 km wide swath with 75 m/pix at maximum spatial resolution. The spatial resolution can be adapted by additional binning depending on the observational conditions. The spectral sampling is 3.55-3.87 nm/band and 5.94-7.18 nm/band for VISNIR and IR spectral channels respectively. Specific spectral domains can be selected by TC for oversampling so that up to 640 spectral samples can be collected per channel. The two focal planes are equipped with linear variable optical filters (LVF) for order sorting and thermal background rejection.

In order to reach the scientific performances of the MAJIS instrument over the whole spectral range, the optical head and the detectors of the two spectral channels are cooled down to cryogenic temperatures (~130K for the OH structure and the VISNIR channel detector, and ~90K for the IR channel detector) by two dedicated external radiators (white structures in Fig. 1). The entire OH structure is kept thermally isolated from the S/C interface by an isostatic mount fiberglass bipods and multilayer insulation.

MAJIS can operate either in push-broom mode or in scanning mode, depending on the different phases of the mission. The scanning mode is implemented so as to build a cube when the S/C dwell time is too high (motion compensation for high spatial resolution observations of icy moons at low altitudes) or too low (scan mode) with respect to the exposure time. The scanning mode can be used for acquiring hyperspectral cubes and mosaics of Jupiter and Galilean satellites at medium to large distances. In pushbroom mode, the scanning mirror is fixed, acquisitions being performed while the S/C moves along the scene.

The OH is equipped with an Internal Calibration Unit (ICU) which provide reference signals for in-flight calibration. The ICU signal is acquired by commanding the scan mirror towards the telescope baffle (beyond the edge of the FOV) where the ICU is housed.

The ME Box (Fig. 2) located inside the S/C vault controls and powers the OH subsystems by means of dedicated electronic modules. It also ensures the communication and power distribution with/from the S/C On-Board Computer. All the auxiliary units located inside the OH (scanning mirror, resolver, shutter, ICUs and thermal sensors) are monitored, controlled and powered thanks to the ME/AUX Board, integrated into the ME Box. Two Proximity Electronic modules (ME/PE-VISNIR and ME/PE-IR) acquire the scientific digitized data from each FPE. The PE's perform specific preprocessing tasks before transmitting the scientific data to its associated Compression Unit (CU) inside the Digital Processing Unit (ME/DPU-CU) of the ME Box. A specific on-board despiking procedure is managed by the PE so as to meet a target of less than 1% corrupted pixels for each frame. The ME/DPU-CPCU (Command and Process Control Unit) ensures the TC, HK and science TM functions by means of the ME/AUX Board and the ME/CUs. It also powers ON/OFF the other modules of MAJIS.

Typical integration times for MAJIS observations are 800 ms (100 kHz detector readout speed, long dwell times, e.g. 7.8 s on the high-altitude orbit around Ganymede, 10 to 20 s for exospheres) and 100 ms (1 MHz readout speed, short dwell times during close flybys or on the 500 km altitude orbit around Ganymede). The 100 ms integration time is also used when high flux levels lead to saturation in a few 100 ms (VISNIR channel for icy satellites, hot spots for Jupiter in the IR). Thanks to advances in IR detectors and on-board processing since the early 1980's, the data collection rate of MAJIS is 10000 times larger than that of NIMS, the VIS-NIR imaging spectrometer of Galileo, a NASA mission which performed 34 flybys of Jupiter satellites.

Pre-launch performances. The signal level for each channel as a function of wavelength depends on the optical efficiency of the telescope, that of the spectrometer dedicated for each channel, the transmission of the filters and the quantum efficiency of the detectors. These parameters have been first modelled then measured during the development of MAJIS. For the FM and FS detectors, performance estimates were obtained first pre-delivery at Teledyne, then during dedicated characterization campaigns before integration of the LV-filters (focused on noise model, linearity, QE). A second characterization campaign was performed after integrating the LVF primarily for checking its alignment, a particularly critical issue for the narrow bandpass LVF filter of the IR channel. The optical head performances were evaluated in Italy (Leonardo Company) before delivery to IAS. The final assessment of performances was performed during instrument calibration at two thermal configurations. The results turned out to be very consistent with radiometric, spectral and geometrical modelling of the overall performances.

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