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JUICE/MAJIS hyperspectral imager: instrument calibration requirements to fulfill science objectives

Pierre Guiot (1), Mathieu Vincendon (1), John Carter (1), Yves Langevin (1), Giuseppe Piccioni (2), François Poulet (1), Gianrico Filacchione (2), Benoît Lecomte (1), Cydalise Dumesnil (1) and the MAJIS team
(1) Institut d'Astrophysique Spatiale, bâtiment 121, Université Paris-Sud, Orsay, France (pierre.guiot@ias.u-psud.fr), (2) Istituto di Astrofisica e Planetologia Spaziali, Via Fosso del Cavaliere 100, Roma, Italy

Abstract

MAJIS is the hyperspectral imager onboard the ESA JUICE spacecraft bound to explore the Jupiter system [3], with a focus on its icy moons, due for launch in 2022. MAJIS will work with two optical channels, the VISNIR one ranging from 0.5 to 2.35 μm, and the IR one ranging from 2.25 to 5.54 μm. It is developped under IAS (France) leadership, who is therefore responsible for the integrated instrument calibration. Such an extended spectral range will allow MAJIS to address various scientific cases from Jupiter's hot spots and auroral activity following Juno/JIRAM exploration to icy satellites surface composition, resurfacing processes and potential interactions with subsurface ocean. To achieve these objectives the instrument's calibration will be critical, but also challenging given the instrument's characteristics: we will quantify the requirements and detail the techincal solutions that we will implement.

1. Jovian system exploration and MAJIS goals

Most spectral imaging data of the Jovian system available so far come from Galileo/NIMS [1], though the dataset has recently increased with Juno/JIRAM [2]. Unfortunately, NIMS was highly impeded by noise levels due to the harsh radiative environment, yet it was the only instrument with a specific focus on the icy Galilean satellites, while JIRAM is mostly focusing on Jupiter's atmosphere. Galileo results allowed confirmation for the subsurface oceans of Europa and probably Ganymede, and recent HST observations (2015) revealed auroras on Ganymede [5]. MAJIS will notably aim at a better understanding of these poorly constrained or recently discovered phenomena. The Figure 1 shows sample spectrum of Ganymede obtained by NIMS and Jupiter's hotspots model as they would be seen by MAJIS using the current instrument model, highlighting the broadness of expected fluxes. The spectral ranges of interest for MAJIS goals are annoted, as well as the shallow detectors' full-well capacity, the short channels overlap range and the prominent 140 K-instrument's own thermal emission that will be calibration critical points.

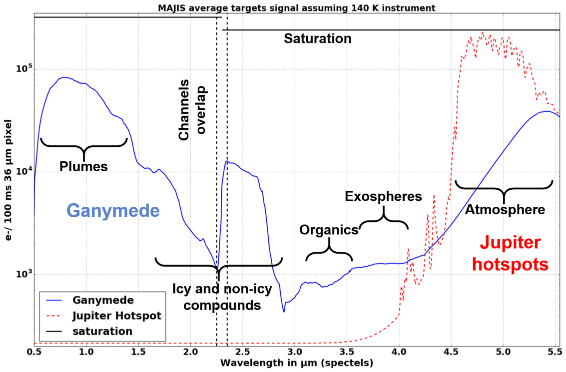

Figure 1: Galileo/NIMS average spectrum of Ganymede [4] and model of Jupiter's hotspots emission, as seen in 100 ms by MAJIS current instrument model including thermal emissions. Annotations denote MAJIS regions of interest, not features present on these spectra.

MAJIS goals will involve mapping Galilean satellite surfaces to detect their icy and non-icy compounds (potentially organic) in their geological context at various scales during flybys and orbit. It will try to distinguish endogenous processes from exogenous contributions (impacts and Io's plasma torus) in order to unequivocally identify potential products of liquid water alteration from the subsurface oceans. Limb observations are also planned, which will allow exospheres characterization and potential plumes detection.

On Jupiter, MAJIS will monitor auroras activity ($H3+$ at 3.67 μm) in coordination with other instruments to better understand the magnetosphere. It will also measure troposphere composition and dynamics, using hotspots where the cloud coverage is thinner in the 5 μm window, allowing potential H_2O, CH_4 and NH_3 monitoring down to 7 bar.

2. Calibration challenges and solutions

To achieve the objectives detailed above, MAJIS will need to be spectrally calibrated with a precision better than 0.6 nm in the VISNIR range and 1 nm in the IR range. Its spatial inhomogeneities must be known with less than 1% standard deviation over its whole Field of View (FOV), and its radiometric transfer function must be determined with less than 20% error in absolute and 1% error in relative.

To check that these requirements will be fulfilled, we are developping a calibration setup at IAS illustrated on Figure 2 and composed of a Thermo-Vacuum Chamber (TVC) which will host the instrument, mounted on an hexapod for movements, and illuminated by an optical bench feeding it with the appropriate calibration light sources. The optical bench will feature traditional sources used for the calibration of this type of instrument such as a monochromator fed by two light sources to cover the entire spectral range, additional powerful light sources to quantify straylight contributions, and mineral/gas samples as test science targets.

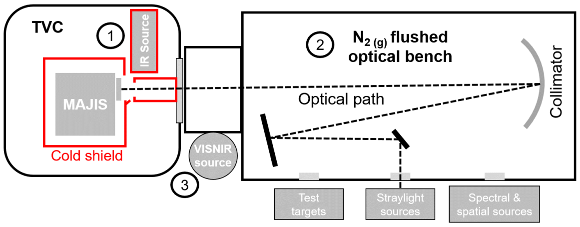

Figure 2: Calibration setup under development at IAS: the interfaces with sources and the TVC are CaF_2 windows. Only one optical path is drawn for clarity. The numbers refer to text descriptions.

The setup on Figure 2 will also include more specific solutions designed specifically for MAJIS:

1. An additional flat-field blackbody IR source for radiometric calibration will be placed inside the TVC to overcome the thermal contributions from mirrors and lenses used at ambient temperature in the optical bench. To illustrate the criticity of this aspect, it is worth noticing that the instrument's own optical head emission at 140 K is enough to saturate the detector at 5 μm within 1 s integration time. For the same reason, the whole instrument needs to be wrapped in a cold shield to cut down the emission from the 300 K TVC.
2. The whole optical bench will be baffled, hermetically closed and flushed with gaseous N_2 in order to diminish the contribution of atmospheric absorption bands below 1%.
3. To ensure good calibration in the overlapping region between both MAJIS spectral channels, we will use a custom Spectralon integrating sphere just in front of the TVC window. It will provide a stable and homogenous flux of very high intensity in VISNIR region and up to 2.8 μm to ensure sufficient overlap in the knowledge of the instrument transfer function.

Acknowledgements

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