THE CALIBRATION OF THE INFRARED SPECTROMETER OF SUPERCAM/MARS2020 : RESULTS AND PREDICTION OF THE FUTURE PERFORMANCE ON MARS

C. Royer[1], F. Poulet[1], J.-M. Reess[2], C. Pilorget[1], V. Hamm[1], T. Fouchet[2], S. Maurice[3], R.C. Wiens[4], O. Forni[3], F. Montmessin[5], [1]Institut d'Astrophysique Spatiale, Orsay, FRANCE, [2]LESIA, Observatoire de Paris, FRANCE, [3]IRAP, Toulouse, FRANCE, [4]LANL, Los Alamos, USA, [5]LATMOS, Guyancourt, FRANCE
clement.royer@ias.u-psud.fr

Introduction: The Mars 2020 Rover will be launched in July 2020 to explore Jezero Crater. The objective of this roving laboratory is to characterize the habitability of Mars, past or present, through the use of a versatile scientific payload, and to prepare for sample return.

The SuperCam instrument on board the Mars 2020 Rover will play a central role in the Mars habitability investigation by providing rapid, synergistic, fine-scale mineralogy, chemistry, and color imaging [1]. Using color imaging for context, SuperCam combines co-aligned Raman-fluorescence, visible/infrared reflectance, and laser-induced breakdown spectroscopy coupled to a microphone covering broad areas at remote distances.

This abstract focuses on the IRS instrument and its ground radiometric calibration. IRS is a near-infrared point spectrometer (1.15 mrad field of view) which ranges from 1.3 µm to 2.6 µm covering major silicate and hydrated mineral absorption features [2]. Signal measured by this instrument will contain the Mars target spectral signature convolved by the instrument response function and possibly other instrument-specific effects. The IRS instrument has thus to be fully calibrated in a controlled laboratory environment with illumination conditions as similar as possible to Martian observations.

The calibration products will be used to simulate mineral mixtures expected in a sedimentary context such as that expected at Jezero crater, so as to prepare the future observations.

IRS concept: IRS works in reflectance spectroscopy: the science scene is illuminated by the Sun and IRS collects the scattered light carrying Mars' ground spectral signatures, which allow us to deduce the composition of the selected terrains and retrieve the abundances of the detected compounds from spectral modeling. IRS uses an Acousto-Optic Tunable Filter (AOTF) as a dispersive system which provides a higher diffraction efficiency than a classical grating. It also does not require any moving part. The light beam that passes through the AOTF is focused on two photodiodes (the additional second is redundant). By tuning the AOTF frequency with the integrated radiofrequency (RF) generator, a spectrum is sequentially built channel by channel with a spectral sampling varying over the spectral range from 2 to 10 nm. The spectral resolution of IRS is 26 cm^{-1} (FWHM), which corresponds to 5 to 20 nm on the instrument spectral range. This shall enable identification of many of the minerals (silicates, hydrated minerals, oxides, salts).

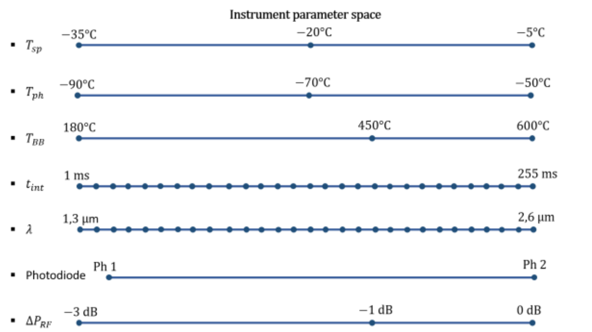

Figure 1: *Parameter space sampled during IRS calibration. Dots represent the sampled points except for the wavelength where the whole spectral range is measured (256 spectral channels), and the integration time which has been calculated to cover the entire dynamic of the detectors (up to saturation).*

Calibration goals and requirements: The radiometric calibration of IRS has been performed using IAS and LESIA joint developed facilities [3, 4]. It consisted in a campaign of spectra acquisitions, under various thermal and instrumental conditions. Its main objective was the derivation of the Instrumental Transfer Function (ITF), which provides the relationship between the measured digital numbers (in DN) and incident radiance (in $W/m^2/sr/\mu m$) on the telescope aperture, over a parameter space covering the entire science operational range. The calibration provides the relationship:

$$S = F(\phi, f_{RF}, P_{RF}, T_{sp}, T_{ph}, t_{int})$$

with S: integrated signal (including dark current and thermal background), in ADU, ϕ: incident radiance from science scene, f_{RF}: RF frequency supplying the AOTF, P_{RF}: RF power supplying the AOTF, T_{ph}: temperature of the detector cooled by the thermoelectric cooler (TEC), T_{sp}: temperature of the instrument, t_{int}: integration time (Fig. 1). All these parameters are necessary to be tested to fully understand the instrument's behavior towards internal and external conditions.

In terms of precision, the calibration had to respect the following requirements: absolute accuracy shall be better than 20%, and 1% in relative (namely between contiguous spectral channels).

Results: After the calibration campaign, data reduction was divided into three steps: **1)** development of an instrument response model that describes the instrument behavior with respect to integration time and input flux. This model appeared to be linear with integration time and following a power-law with flux. The resulting transfer function is given by:

$$S = ITF_{fac} \times t_{int} \times \phi^{ITF_{exp}}$$

where ITF_{fac} and ITF_{exp} are respectively the factor and the exponent of the transfer function.

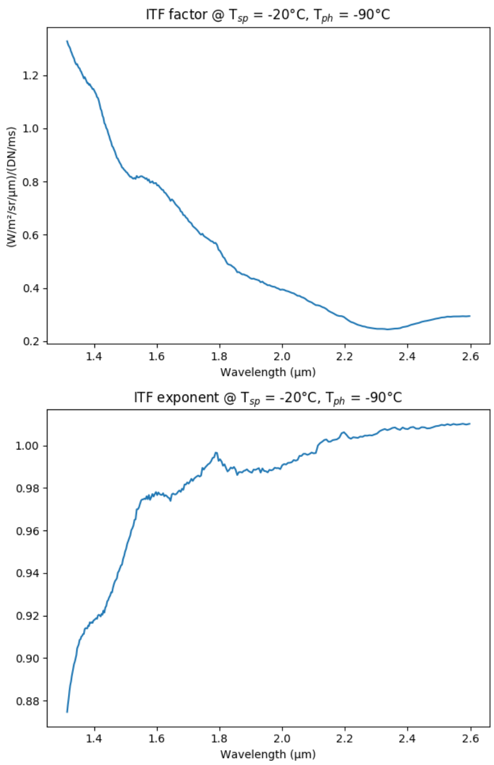

Figure 2: *ITF parameters at T_{sp}=-20°C, T_{ph}=-90°C. Top: factor of the transfer function. It has the dimension of a conversion factor between radiance and numerical signal.*
Bottom: exponent of the transfer function. This parameter models the non-linearity with flux.

2) derivation of the ITF parameters according to the previously established model, from high SNR, high spectral resolution data, in every condition (Fig. 2). Note that modulations in ITF parameters are due to instrument transmission features (mainly AOTF) and not setup contamination (water residuals for example). Due to the lack of measurements in warm conditions (Tph > -70°C), the ITF interpolation domain is (T_{sp}, T_{ph}) ∈ ([-35, -5], [-90, -70])°C, which covers the nominal operational mode of IRS.

3) uncertainty evaluation of the ITF in typical Martian conditions in terms of temperature and ambient illumination. Table 1 summarizes the error sources and their weight in the error budget. These uncertainties are in accordance with the calibration requirements.

	Absolute error	Relative error
Calib. setup	< 10 %	< 0.05 %
ITF	< 15 %	< 0.8 %
Requirement	20 %	1 %

Table 1: *Summary of contributions to the error budget for the calibration setup [6] and the derived ITF parameters.*

Modelling of spectra: A radiometric model of IRS has been developed to simulate observations on the Martian surface. This model generates reflectance spectra from illumination conditions, thermal environment and scene composition, and the SNR of the observation is calculated using the calibration-based noise model of the instrument (Fig. 3). As result, the simulator allow us to check the SNR vs. measurement duration in various expected operation conditions. A first version of this simulator shall be presented during the meeting.

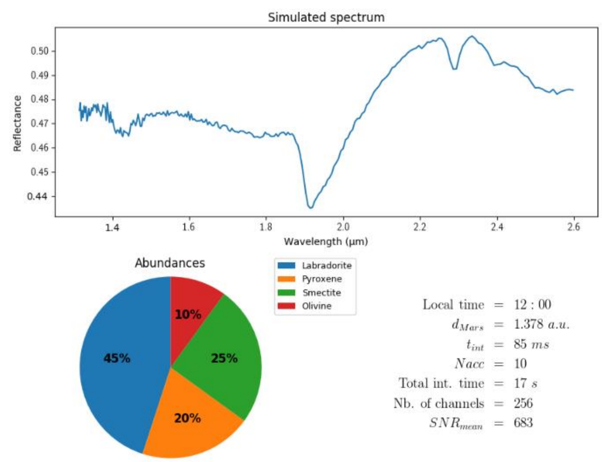

Figure 3: *Simulation of an IRS reflectance measurement of a synthetic scene (selected from [5], but considering linear mixture), at T_{sp}=-30°C, T_{ph}=-90°C. These very favorable conditions (cold instrument, Sun at zenith, perihelion) yield high SNR data. This simulation does not take into account atmospheric contributions (multiple scattering by aerosols and absorption features by atmospheric gaseous components)*

References:

[1] Wiens et al., (2017), Spectroscopy, [2] Fouchet et al., (2015), LPSC, [3] Royer et al., (2019), 9th Int. Conf. Mars, [4] Royer et al., (2020), submitted, [5] Poulet et al., (2019), 9th Int. Conf. Mars