POLE REGION OBSERVATION CAMPAIGN ON RYUGU. E. Tatsumi[1,2,3], N. Sakatani[4], S. Kameda[5], K. Kitazato[6], T. Kouyama[7], Y. Yokota[4,8], R. Honda[8], M. Yamada[9], T. Morota[3], Y. Cho[3], C. Honda[6], M. Matsuoka[4], M. Hayakawa[4], H. Suzuki[10], S. Tanaka[4], J. Takita[11], T. Nakamura[12], H. Yabuta[13], T. Hiroi[14], F. Vilas[15], D. Domingue[15], J. de León[1,2], H. Sawada[4], K. Ogawa[16], N. Hirata[6], N. Hirata[16], Y. Yamamoto[4], M. Hirabayashi[17], P. Michel[18], S. Sugita[3], S. Watanabe[19]. [1]Instituto de Astrofisica de Canarias, Tenerife, Spain (etatsumi@iac.es), [2]Dept. of Astrophysics, Univ. of La Laguna, Tenerife, Spain, [3]Univ. of Tokyo, Tokyo, Japan, [4]Inst. of Space and Astron. Sci., Japan Aerospace Exploration Agency, Kanagawa, Japan, [5]Rikkyo Univ., Tokyo, Japan, [6]Univ. of Aizu, Fukushima, Japan, [7]National Inst. of Adv. Ind. Sci. and Tech., Ibaragi, Japan, [8]Kochi Univ., Kochi, Japan, [9]Planetary Exploration Research Center, Chiba Inst. of Tech., [10]Meiji Univ., Kanagawa Japan, [11]Hokkaido Kitami Hokuto High School, Hokkaido, Japan, [12]Tohoku Univ., Miyagi, Japan, [13]Hiroshima Univ., [14]Brown Univ., RI, USA, [15]Planetary Science Institute, AZ, USA, [16]Kobe Univ., Hyogo, Japan, [17]Auburn Univ., AL, USA, [18]Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France, [19]Nagoya Univ., Aichi, Japan.

Introduction: The Hayabusa2 spacecraft has been investigating the C-type asteroid (162173) Ryugu for more than one year. Global observations at the home position (alt. of ~ 20 km) by the telescopic optical navigation camera (ONC-T) revealed the presence of blue material distributed on both poles of Ryugu [1]. Based on their correlation with topological features, the blue material is expected to be fresher (less processed) material. Moreover, the largest boulder, Otohime on the south pole has different spectral and morphological faces, being very distinct from other boulders on Ryugu's surface. In particular, The similarity between the blue material spectra to Bennu's visible spectra is especially a great topic to discuss regarding the relationship between the two bodies. Thus, we have conducted close (alt. of ~ 5 km) observations of the poles on 28 February to 1 March and from 26 to 27 July 2019. Especially, in July, the ONC-T and the spectrometer NIRS3 performed simultaneous observations to obtain both visible and near infrared wavelength information. In this study, we are focusing on the presence of 0.7-µm band which indicates an Fe^{2+} to Fe^{3+} charge-transfer transition in oxidized iron, associated with phyllosilicates [2]. The presence of 0.7-µm absorption is also important to constrain the composition of Ryugu's material. The distribution of the 0.7-µm band absorption is discussed in comparison with the solar wind flux and solar heating of Ryugu's surface.

Observations: The visible camera **(**ONC-T) onboard Hayabusa2 is equipped with 7-color band filters; ul: 0.40 µm, b: 0.48 µm, v: 0.55 µm, Na: 0.59 µm, w: 0.70 µm, x: 0.86 µm, p:0.95 µm [3]. Both north and south poles were observed with these 7 bands at every 30˚ longitudinally. The phase angle was 16˚ – 17˚ for February and March and 38˚ – 39˚ for July.

Data reduction: Radiance factors (I/F) were calculated using the calibration described in [3]. Note that we used the updated flat-fields [4] to reduce the fringe pattern in the original flat-fields. Moreover, we also implemented the radiator stray-light reduction described in [3]. The detectability of 0.7-µm band absorption was tested onground using the ONC-T flight model and CM2 chondrites [5]. We measured the degree of the 0.7-µm band absorption using the relationship

$$d_{0.7} = 1 - \frac{3.1R_w}{1.6R_v + 1.5R_x},$$

where R_v ,R_w , and R_x indicate the radiance factor at v-, w-, and x-bands, respectively. After conducting the calculation at a pixel-by-pixel resolution, we took the median value of 8 x 8 pixel boxes in order to reduce statistical noise, because the ONC-T has SNR~100 without binning and this is not enough to distinguish subtle differences in the 0.7-µm band absorption. We also measured the b-to-x spectral slope using the same methods as [1].

Results: Figure 1 shows the 0.7-µm band absorption (left column) and b-to-x spectral slope (right column) for both the north and south poles. The pole regions have bluer spectra, i.e., negative spectral slope, than other low latitudinal regions. At the same time, some of the bluer regions show a deeper absorption at 0.7 µm. Specifically, some boulders on the north pole and the Otohime boulder on the south pole exhibit stronger absorption of ~2% compared with adjacent regions. Although there are still random noise and shadows to be carefully removed, the positive identification of the absorption on the polar boulders is considered real. This 0.7-µm band absorption could indicate the presence of more hydrated minerals at the pole regions.

Discussions: The 0.7-µm band is very important to distinguish between CM or CI chondrites; CM with the 0.7-µm band absorption and CI with absence of it. Thus, the discovery of a 0.7-µm band absorption suggests that Ryugu might has been processed from CM-like material with more Fe-rich phyllosilicates. The 0.7-µm band absorption is easily lost by heating and/or space

weathering [6,7]. The 0.7-µm band absorption in the pole regions can be related to solar irradiation of the surface. Calculations of the solar wind flux to the entire surface of Ryugu shows that the irradiation rate of the pole regions is ~5 times less than that of the equatorial ridge in the asteroid's current orbit and pole position. On the other hand, the temperature of the surface was observed by the thermal infrared imager (TIR)[1]. Initial analysis of TIR data showed that thermal inertia of the surface is around 300 J $m^{-2}K^{-1}s^{-0.5}$ [8]. Figure 2 shows the modeled maximum temperature map of Ryugu at perihelion, using the shape model of SHAPE_SFM_200k_v20180804 [9] with a uniform thermal inertia of 300 J $m^{-2}K^{-1}s^{-0.5}$. The temperature map also suggests that a part of the north pole is among the coldest <100K on Ryugu's surface even at perihelion. It should be noted that Otohime's sharp cliff-like face is even hotter than average. Thus, the absorption at Otohime needs further explanation regarding the presense of the hydrated mineral. Although the current orbital distance from the Sun cannot explain the heating up to the temperature of dehydration ~600˚C [10], Ryugu could have experienced a closer encounter to the Sun in the past given its chaotic orbital motion[11]. The 0.7-µm band absorption could be weakened and the spectral slope could become redder due to the solar wind and/or the solar heat. If this is the case, there would be more hydrated material inside of Ryugu than it currently appears on the surface. The NIRS3 spectra of those regions which show the 0.7-µm band absorption and the sub-surface by the Small Carry-on Impactor experiments are under analysis. The integration of information about the relative strengths of the 0.7-µm and 2.7-µm band absorptions may provide stronger constraints to distinguish between those two scenarios.

Moreover, the bluer regions are spectrally similar in the visible range to the near-earth asteroid Bennu, which is the target asteroid of OSIRIS-REx [12]. More hydration and blueness of the spectra for less irradiated boulders suggest that Ryugu and Bennu could be siblings that had different orbital histories or different creation times.

Acknowledgement: We are grateful to the entire Hayabusa2 team for making the encounter with Ryugu possible. This study is supported by the JSPS core-to-core program "International Network of Planetary Sciences", P. M.acknowledges support from CNES and from the Academies 2 and 3 of Université Côte d'Azur IDEX JEDI. NASA's Hayabusa2 participating scientist program (grant number NNX16AL34G), and NASA's Solar System Exploration Research Virtual Institute 2016 (SSERVI16) Cooperative Agreement (NNH16ZDA001N) for TREX (Toolbox for Research and Exploration).

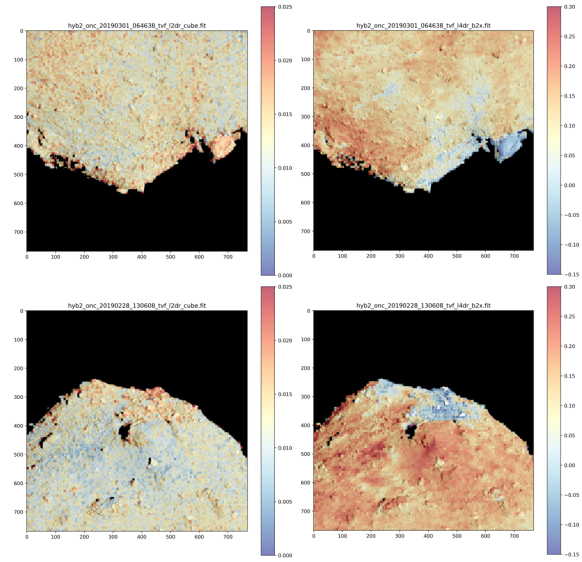

Figure 1. The 0.7-µm band absorption maps (left) and b-to-x spectral slope maps (right) for the north pole (top) and the south pole (bottom).

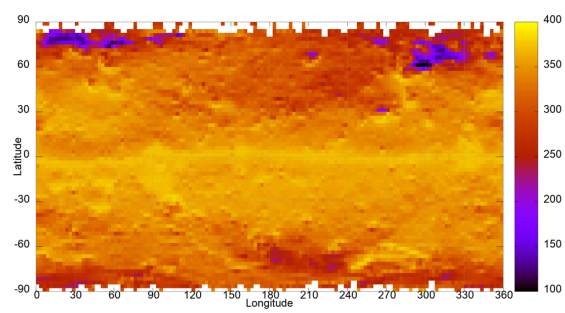

Figure 2. Maximum temperature map at perihelion calculated using the shape model. Some areas on the north pole suggest low surface temperatures. The lowest temperature can be found around (lat, lon) ~ (60˚, 300˚).

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