PHYSICAL AND CHEMICAL PROPERTIES OF PHOBOS AND DEIMOS IN A GIANT IMPACT HYPOTHESIS

Ryuki Hyodo[1] (hyodo@elsi.jp), Hidenori Genda[1], Sébastien Charnoz[2], Francesco C. Pignatale[2], Pascal Rosenblatt[3], Tomoki Nakamura[4] and MMX science team
[1]Earth-Life Science Institute/Tokyo Institute of Technology, 152-8550 Tokyo, Japan; [2]Institut de Physique du Globe de Paris (IPGP), 1 rue Jussieu, 75005, Paris, France; [3]ACRI-ST, 260 route du pin-montard- BP 234- F-06904 Sophia-Antipolis Cedex, France; [4]Tohoku University, 980-8578 Miyagi, Japan

Introduction: Phobos and Deimos are small moons orbiting around Mars. Recently, these small objects are gaining more and more attentions since JAXA (Japan Aerospace eXploration Agency) is planning the Martian Moons eXplorer (MMX) mission, in which they will send a spacecraft to a Martian moon(s) and get samples there.

The origin of Martian moons, Phobos and Deimos, is still debated. Historically, they were thought to be the products of captured asteroids because their spectral properties are similar to those of D-type asteroids [1,2]. However, the orbits of Phobos and Deimos are almost circular and equatorial around Mars and thus it is very hard to explain such orbital properties by the capture scenario due to random directions and non-circular orbits of the captured objects. In contrast, a giant impact may naturally explain these orbital properties of Martian moons [3,4,5,6]. Then, recent works have succeeded to show that Phobos and Deimos may accrete within the impact-generated disk that are extended beyond the synchronous orbits of Mars [7,8].

An evidence of such a Martian-moon forming impact may be recorded on the Martian surface as Borealis basin, the asymmetric northern lowland [9] and smoothed particle hydrodynamics (SPH) simulations have shown that the Borealis basin-forming impact can generate a suitable debris disk for the formation of Phobos and Deimos [4,7,10].

In this talk, we will present our recent works that investigated expected physical and chemical properties of the building blocks of Phobos and Deimos in a framework of such a giant impact hypothesis [10,11,12].

Method: We have performed high-resolution smoothed particle hydrodynamics (SPH) giant impact simulations that generate Martian-moons forming debris disks (impactor mass of ~0.03 mass of Mars, impact velocity of ~6 km/s and impact angle of 45 degrees) [10,11]. Then, using thermodynamic information obtained directly from SPH simulations, we have investigated the expected compositions of dust (condensates from gas) assuming various types of impactor's compositions (Mars-, CI-, CV-, EH-, comet-like) by using thermodynamic equilibrium [10,12].

Results: SPH simulations show that our canonical impact (impactor mass of ~0.03 mass of Mars, impact velocity of ~6 km/s and impact angle of 45 degrees without pre-impact Martian spin) can simultaneously explain the following three important features/origins of the Mars' system [3,9,10,11]:

1. The Borealis basin [9,11]
2. Current Martian spin period [3,11]
3. Martian-moon-forming debris disk [10,11]

Thermodynamic and physical properties of the Martian-moon-forming disk just after our canonical giant impact are found to be as follow [10,11]:

1. Almost uniform temperature of ~2000K
2. Less than ~5wt% of the disk mass is vaporized and the rest is melted
3. About ~50wt% of the disk mass comes from Mars and the rest comes from the impactor
4. About ~50wt% of the Martian material in the disk comes from Martian mantle (~50-150 km in depth) at the time of impact and the rest comes from closer to Martian surface (0-50 km in depth)
5. Less than ~5wt% of the disk mass contains ~0.1μm sized dusts that are condensed from the vapor and the rest is between ~100μm and few meter sized particles that are solidified from the melt

The thermodynamic equilibrium simulations that calculate the condensation sequence of vapor that vaporized from the mixture of half Martian composition and half a various types of impactor's composition (Mars-, CI-, CV-, EH-, comet-like) at a temperature of 2000 K and pressure of 10^{-4} bar predict that the resultant dust composition significantly differs at different impactor's compositions [12]. Gamma-ray and neutron-ray spectrometers onboard MMX spacecraft. The gamma-ray spectrometer can measure Si and Fe concentrations of bulk Phobos and the neutron-ray spectrometer can measure H concentration of bulk Phobos. Thus, Fe/Si ratio and H concentration at different impactors would be key to constrain the impactor's composition.

All these physical and chemical theoretical predictions would be useful for planning a future sample return mission to Martian moons, such as JAXA's MMX (Martian Moons exploration) mission to constrain the origin of Phobos and Deimos and to understand the accretion history of Mars' system.

References:

[1] Burns, J. A. (1978) VA, 22, 193. [2] Murchie, S. L., Britt, D. T., Head, J. W., et al. (1991) JGR, 96, 5925. [3] Craddock, R. A. (2011) Icar, 211, 1150. [4] Citron, R. I., Genda, H., & Ida, S. (2015) Icar, 252, 334. [5] Nakajima, M., Canup, R. (2017) *Lunar Planet. Sci. Conf. 48th*, No. 1964, id.2900. [6] Canup, R., Salmon, J. (2016) *Lunar Planet. Sci. Conf. 47th*, No. 1903, p.2598. [7] Rosenblatt, P., Charnoz, S., Dunseath, K. M., et al. (2016) NatGe, 9, 581. [8] Hesselbrock, A., & Minton, D. A. (2017) NatGe, 10, 266. [9] Marinova, M. M., Aharonson, O., & Asphaug, E. (2008) Natur, 453, 1216. [10] Hyodo, R., Genda, H., Rosenblatt, P., & Charnoz, S. (2017a) ApJ, 845, 125. [11] Hyodo, R., Rosenblatt, P., Genda, H., & Charnoz, S. (2017b) ApJ, 851, 122. [12] Pignatale, F., Charnoz, S., Rosenblatt, P., Hyodo, R., Nakamura, T., Genda, H., ApJ accepted (arXiv:1712.05154).