TIDALLY DISRUPTED SMALL BODIES MAY FORM GROOVES ON PHOBOS. Hiroshi Kikuchi and Hideaki Miyamoto, The University Museum, The University of Tokyo, Hongo, Tokyo 113-0033, Japan. (h-kikuchi@um.u-tokyo.ac.jp)

Introduction: The origin and the formational process of grooves on a martian moon, Phobos, are still controversial. Murray suggested that the intersections of Phobos with ejecta from impacts on Mars can explain observational characteristics of grooves on Phobos such as their morphological features, distributions, and hemispheric coverages [1]. However, Ramsley and Head show that, in order to form well organized grooves like those found on Phobos, each of fragments ejected from Mars needs no relative velocity, which requires additional explanations [2]. Nevertheless, each groove is qualitatively suggested to lie on a plane even though it sometimes appears to be meandaring on an image [3,4,5], which favors their origins as impacts of aligned fragments. Our motivation of this work is to critically evaluate if all of the grooves are actually on planes. Although the distribution of grooves on Phobos has been extensively studied and plotted on cylindrical projection map, such as Mercator (e.g., [1]), an irregular shape of Phobos suffuer for the above purpose.

Analysis: We newly map the locations of grooves as well as pit chains on a numerical shape model developed by Gaskell [6] by using approximately 3,000 high-resolution images of Phobos obtained by Viking orbiters, HRSC onboard Mars Express, and HiRISE onboard Mars Reconnaisasance orbiter. Based on this map, we determine coordinates of 3 points (two end points and one middle point) for each groove to calculate a plane vector from the 3 coordinates and define 1 vector as the plane vector passes through Phobos' central point (**Fig. 1**).

Results: We identify 488 grooves and pit changes. We carefully observe their lineality on the numerical model and confirm that each groove lie on a plane, which is previously suggested by [3,4,5], but not critically examined. We also find that grooves on Phobos have restricted length: We measure the angle between the center of the gravity and one end-point to the other of the groove. The maxmum angle is 142.7 degrees, which indicates that all grooves we identify extend less than one hemisphere of Phobos. These supports the view that grooves are formed as crater chains from linealy-lined impactors.

The locational distributions indicate that there are three types of grooves: we find that the distributions of φ (Fig. 1) has a sharp peak at 0° and thedistributions of θ (Fig. 1) has three peaks at 25°, 90° and 155°, where we call types A, B, and C, respectively. We also find that most of type B grooves exist on the northern hemisphere.

Discussions and Implications: Our observations of grooves on Phobos may be partly explained by previously-proposed formational processes, but we prefer a new hypothesis as follows to satisfy all of the observations.

1. An asteroid of a collection of smaller fragments held together by self-gravity is pulled apart by tides during a close approach to Mars.
2. The fragmented asteroid streched into a form of a train of fragments, which are caught by Mars gravity and revolve around Mars.
3. Every time they revolve around Mars, a part of the fragments hit Phobos and form a groove. This form the types A and C grooves.
4. When the eccentricity of the impartor has been low until the overlapping the trajectory of Phobos, type B grooves may be formed (**Fig. 2**).

We note that the tidal disruption of an asteroid may form linealy allingned fragments like a train as Comet Shoemaker-Levy 9 broke apart at least 21 pieces and allined before colliding with Jupiter. Many crater chains found on Ganymede and Callisto [7] may support our view of groove formations on Phobos.

Our hypothesis is partly similar to the idea proposed by Murray [1] but different in the origin of the fragments, which can resolve the difficulty pointed out by [2]. This hypothesis can also explain the morphological and geographical features of grooves on Phobos (**Fig. 3**). Importantly, this hypothesis can explain the deficiency of grooves on Deimos because the probability of impact with the tidally disrupted fragments will be significantly reduced at the orbit of Deimos. Also, even if the fragments collide with Deimos, the disteances of fragments becomes wide enough not to be recognized as a groove.

Refferences: [1] Murray J. B. and Iliffe J.C. (2011) *Martian Geomorphology. Geol. Soc. Spec. Publ.,London, pp.* 21-41. [2] Ramsley K. R. and Head J.W. (2013) *PSS, 75,* 69-95. [3] Veverka J. and Duxbury T. C. (1977) *JGR, 82*, 4213-4223. [4] Thomas P. and Duxbury T. C. (1978) Nature. 273. 282-284. [5] Thomas P. et al. (1979) *JGR, 84*, 8457-8477. [6] Gaskell R.W. (2011) Gaskell Phobos Shape Model V1.0. VO1-SA-VISA/VISB-5-PHOBOSSHAPE-V1.0. NASA Planetary Data System. [7] Schenk P. et al. (1996) *Icarus*, 121, 249.

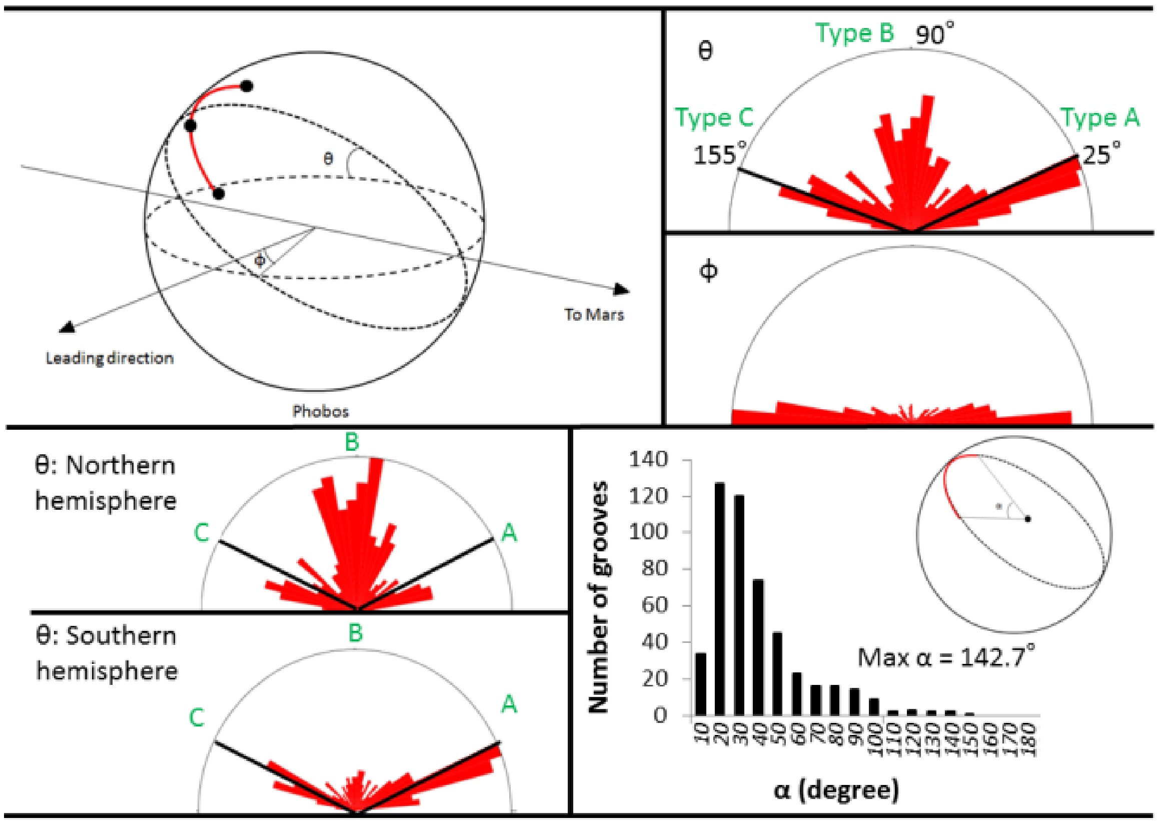

Figure 1: (left top) Geographic definition of φ and θ. Red line represents a groove. (right top) Rose diagram of the angles of planes containing grooves. Three types of grooves are identified based on this diagram. (left bottom) Rose diagram of θ into the northern and the southern hemisphere (right bottom) Frequently distributions of the angular lengths of grooves.

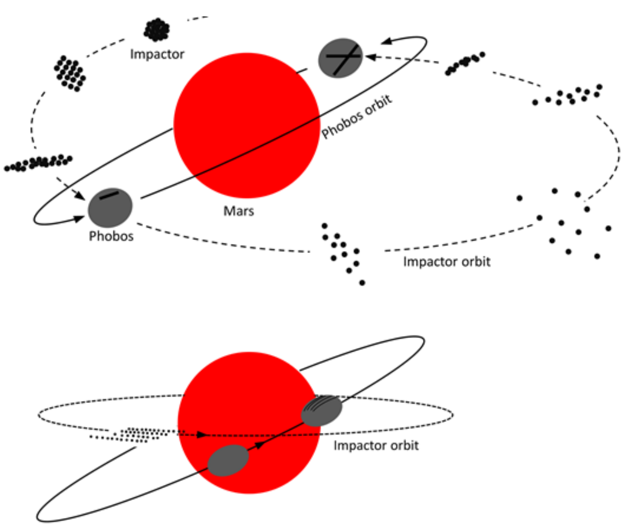

Figure 2: Conceptual figure of our hypothesis for the formation of grooves on Phobos for types A and C (top) and type B (bottom).

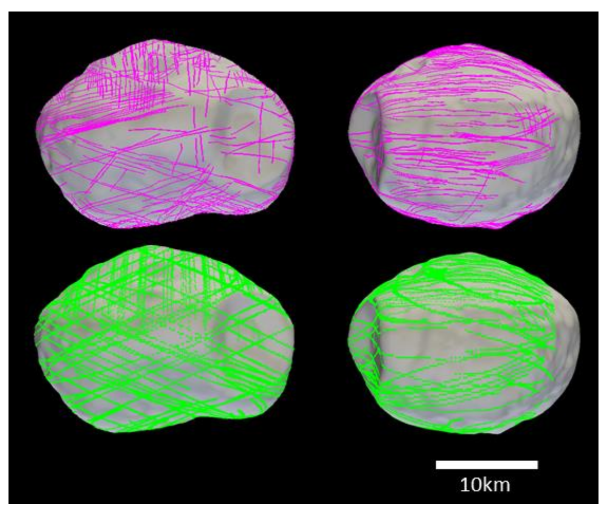

Figure 3 : Geographic distributions of grooves mapped on the shape model (top) compared with the simulation results (bottom) based on our hypothesis.