P154-016 **Room: 201B** **Time: May 16 13:58-14:11**

Impact erosion and vapor retention on early Mars: Atmospheric pressure change during heavy bombardment

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Mars exhibits geological evidence of past liquid water on its surface, such as outflow channels and valley networks. However, the Martian atmosphere today is too cold and thin for liquid water to exist on its surface. The mechanism of the atmospheric loss remains unknown. Melosh and Vickery (1989) suggested that impacts during the heavy bombardment could have blow off the substantial part of the martian atmosphere. When the impact velocity is sufficiently high, the impactor and a part of the planetary surface around the impact point can vaporize and form "an impact-induced vapor cloud." The vapor cloud has generally high-temperature and high-pressure, and thus it can accelerate the ambient planetary atmosphere with its expansion. When the energy of the vapor cloud is large, some fraction of the atmosphere can be lost, which is called the "impact erosion." Melosh and Vickery assumed that the vapor cloud would expand isotropically in a planetary atmosphere, and estimated that many impacts could reduce the atmospheric pressure on Mars by about 2-3 bars during the heavy bombardment. The effect by the stratified planetary atmosphere is ignored in their estimate. Newman et al. (1999) performed numerical calculations of the vapor expansion in a stratified atmosphere and showed that a strong shock wave, which was formed in the atmosphere with the vapor expansion, accelerates the ambient atmosphere. They also showed that the shock wave propagates preferentially vertically. They concluded that the only the atmosphere just above the vapor cloud would escape due to the vertically elongated shock and the amount of the atmospheric loss would be a factor of five less than that by the estimates of Vickery and Melosh. However, they do not calculate the amount of planetary atmospheric loss. Also, they performed calculations under only two conditions for impact and atmosphere: impacts comparable to the K-T impact event on the present Earth and Venus. The dependence of the atmospheric loss on parameters such as vapor mass and atmospheric pressure has not been studied systematically.

In contrast to the impact erosion, impacts may also bring volatile materials. When some portion of the vapor cloud is retained on the planet, volatile components in the retained vapor cloud would add to the planetary atmosphere and increase the atmospheric pressure on the planet.

We considered that the atmospheric mass (the atmospheric pressure) was determined by the competition between the impact erosion and the volatile retention during the heavy bombardment. We performed numerical simulations using a two-dimensional cylindrical hydrodynamical code and investigated the parameter dependence of the atmospheric loss and vapor retention, respectively. Then we derived empirical formulae for both mass, respectively. In this presentation, we will discuss what would control the atmospheric pressure on early Mars, using the empirical formula, assumed impact-vapor relation and impact flux during the heavy bombardment.