The formation of elongated dark areas on Pluto by a Charon-forming giant impact

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The New Horizons spacecraft has found elongated dark areas in the equatorial region of Pluto, which were informally called “the Whale” or Cthulhu Region [1]. Here we examine the possibility that the dark areas on Pluto were formed by thermal alterations and polymerization of interstellar volatiles caused by a Charon-forming giant impact.

Pluto is one of the largest Kuiper belt objects, which is highly likely to contain various interstellar volatiles, including aldehyde and ammonia. The previous study [2] shows that these interstellar volatiles are thermally polymerized in solutions at high temperatures, forming complex insoluble organic solids. Given the satellite-to-planet mass ratio, the Pluto-Charon system is suggested to be of a giant impact origin [3]. Impact-induced heating on Pluto could have converted these volatile into complex organic matter in solution near the surface, which may explain the presence of dark areas in the equatorial region of Pluto.

Here, we produce complex organic matter for various temperatures by thermal polymerization of formaldehyde and ammonia in solutions. By measuring the UV-VIS absorption spectra of the produced organic matter, we found that the color of the solution changes to be dark if the temerature is above 50ºC for months or more. This duration corresponds to the cooling timescale of a water pond with 500-km thickness.

By using SPH code [4], we carried out many simulations of a giant impact, and we found that a molten hot pond with > 500-km thickness is formed around the equatorial region of Pluto by a Charon-forming giant impact, if the water/rock mixing mass ratio is less than 1 or if the pre-impact interior temperature is ~150 K. Both the dark equatorial region and a Charon-sized moon are formed when the pre-impact Pluto is undifferentiated. To keep a rock-rich Pluto undifferentiated at time of the giant impact, Pluto may have been formed >100 Myrs after CAIs, and the giant impact may have occurred <100 Myrs after the Pluto’s formation.

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