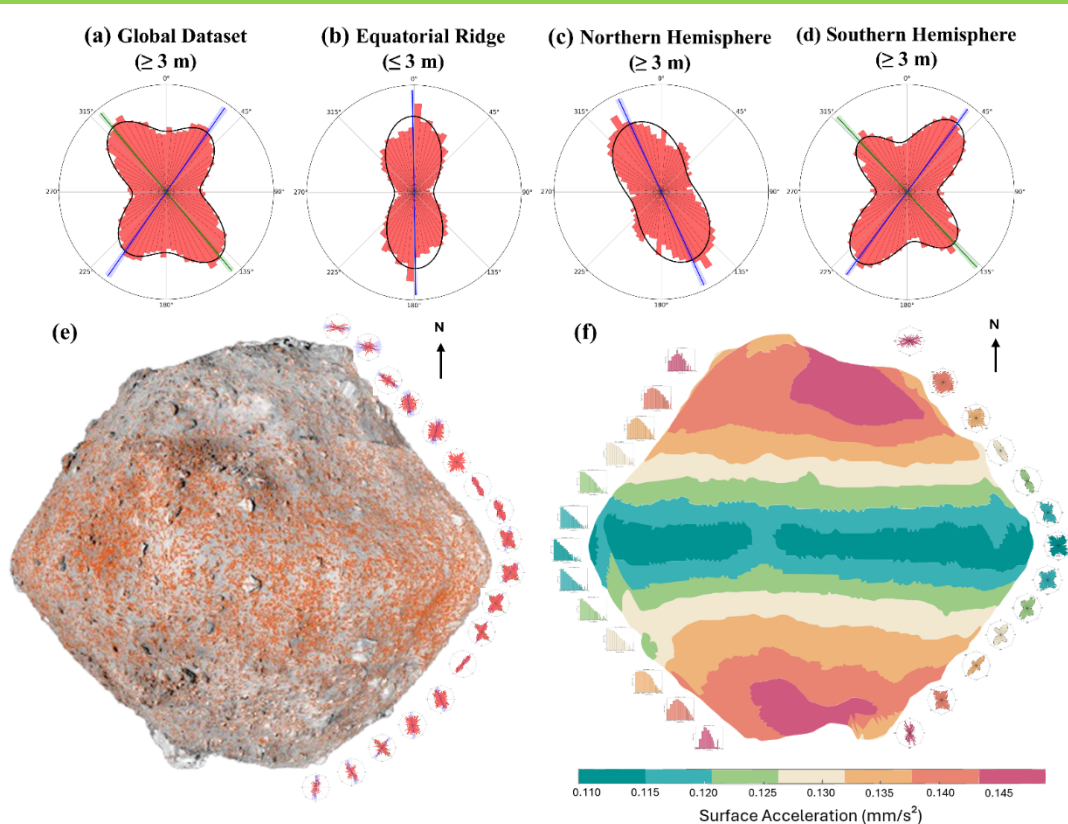


Boulder Populations and Orientation Trends on asteroid Ryugu: Implications for Rubble-Pile Surface Processes



Asteroid (162173) Ryugu is a spinning-top-shaped, rubble-pile C-type asteroid with a boulder-rich surface. Using Hayabusa2 ONC-T mosaics, we present the most comprehensive global boulder dataset to date, including the first global analysis of boulder orientations. The boulder size-frequency distribution (≥ 3 m) follows a power-law slope of -2.665 ± 0.066 , reflecting Ryugu's highly fragmented nature. Boulder densities are lower along the equatorial ridge, consistent with regolith accumulation during past spin-up and poleward migration during the current spin-down. Distinct hemispheric orientation patterns in high-slope regions indicate downslope boulder migration driven by rotation, while fresh craters show enhanced boulder densities from impact-driven resurfacing. Together, these results clarify how rotation and impacts shape rubble-pile asteroid surfaces.

Orientation of boulders on Ryugu with Von Mises fit represented by black curve. (a) Global dataset (≥ 3 m) showing dominant NE-SW ($34.8^\circ \pm 2.17^\circ$) and NW-SE ($140.2^\circ \pm 1.39^\circ$) alignments. (b) Smaller boulders on the equatorial ridge (≤ 3 m) show strong N-S clustering ($179.0^\circ \pm 0.74^\circ$). (c) Boulders in the northern hemisphere (≥ 3 m) dominated by NW-SE alignment ($155.3^\circ \pm 1.72^\circ$). (d) Boulders in the southern hemisphere (≥ 3 m) showing a major NE-SW ($36.2^\circ \pm 1.45^\circ$) and a minor NW-SE ($137.1^\circ \pm 1.32^\circ$) alignments. (e) SBMT shape model with mapped boulders and high-resolution mosaics overlain. Rose diagrams show boulder orientations per 10° latitudinal interval. (f) Surface acceleration map (modified after JAXA) with rose diagrams of boulder orientations and SFD histograms for each zone in the northern and southern hemispheres. Figure and caption adapted from Ray et al. (2026).