SURFACE SLOPES OF ASTEROIDS IN PAIRS AS INDICATORS OF MECHANICAL PROPERTIES. D. Polishook[1] and O. Aharonson[1], [1]Weizmann Institute of Science (234 Herzl St. Rehovot 7610001, Israel, david.polishook@weizmann.ac.il).

Introduction: Asteroids in pairs are those found to share almost identical orbital elements without a gravitational bond between them, and backward integration shows that they once resided in each other's Hill sphere [1]. Each pair had a single progenitor that split in the last ~10^6 years due to rotational-fission of a weak, 'rubble-pile' structured body [2]. Broadband photometry [3] and spectroscopy [4,5] of asteroid pairs have shown identical spectral signature between the members of the same pair, supporting their shared origin. In addition, some of the pairs present fresh, non-weathered, reflectance spectra [5], supporting a recent and a significant disruption. Asteroid pairs were found to belong to various different taxonomies [5], suggesting that rotational fission is not a function of the asteroid composition, but rather the asteroid's structure. Most likely being spun-up by the thermal YORP effect [6] that led to the self-disruption [7], asteroid pairs formation is related to the formation of satellites of asteroids, known as binary asteroids [8]. The unique history of the pairs render them as an excellent natural laboratory to study asteroid interiors and strength. In this abstract we study the criteria for asteroid break-up using shape models of asteroid pairs.

Observations and Shape Construction: Shape models are inversely constructed from photometric measurements using the lightcurve inversion technique [9] by fitting multiple solutions of spin axis direction, sidereal period and shape model to the photometric data. The observations were conducted at the Wise Observatory in Israel during multiple apparitions and aspect angles [7] to improve the constraints on the model inversions. We calculated the gravitational and rotational accelerations on each facet of each model, assuming a homogeneous interior density. This allows us to construct a map of topographic slopes on the shape models' surfaces. We assume a density of 2 gr cm^{-3}, similar to the measured density of the 'rubble-pile' structured, near-Earth asteroid 25143 Itokawa by the spacecraft Hayabusa [10].

Geophysical Analysis: The local slope is defined to be the angle between the inwards surface normal and the local acceleration vector. In order to test for frictional failure, for each asteroid in the set, we determine the maximum rotation rate at which an area larger than half the surface area of the secondary member (assumed to be the ejected component) has a slope value larger than 40 degrees - the approximate angle of friction of lunar regolith [11], where a loose body will start sliding. We use this critical state to indicate the location of the failure on the surface of the primary member (Fig. 1) and to constrain the failure stress operating on the body just before disruption, using the Drucker–Prager yield criterion [12]. We examined the sensitivity of the results to different choices of critical friction angle and threshold area fraction.

Results: Our current preliminary sample includes 11 primary members of asteroid pairs with diameter range of 3 to 10 km, and diameter ratio range (secondary/primary) of 0.1 to 0.6. Our spun-up models have wide enough areas with high slopes when they reach ~3.0±0.3 hours, suggesting they disintegrate at this spin, even though this value is slower than the 'rubble pile spin barrier' (~2.2 hours [13]).

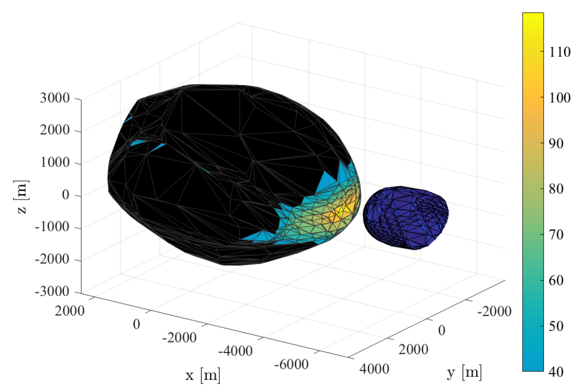

Fig. 1: An example for our disruption criteria. Shape models based on photometric measurements of the asteroid pair 2110 Moore-Sitterly (large body) and 44612 1999RP27 (secondary body). The two bodies are presented in same size scale, but currently they are completely separated. The color scheme represents the slope of every facet. All facets with a slope smaller than 40 degrees (angle of friction of lunar regolith) were colored in black.

Discussion: Using the assumptions above, we find a critical breakup spin period that is higher than that deduced from direct observations of maximally rotating asteroids. Moreover, two asteroids (3749, 16815) have rotation periods that are smaller than the critical breakup spin period. In our model, increasing the breakup spin rate to the expected 2.2 hours is possible by modifying the assumptions. We suggest several alternative scenarios, noting that combinations are possible: *i)* A higher density (up to 3 gr cm^{-3} which is within the density range of S-type asteroids and ordinary chondrites) compared to Itokawa's value (Fig. 2, top panel), suggesting that the macroporosity of a weak, disintegrating body can be lower than ~40% [14]. This supports models that suggest asteroid 'cores' are stronger than their 'shells' [e.g. 15]. *ii)* A larger ejected body than currently measured. This is possible if the ejected body was larger at the disruption, and later became smaller due to subsequent break-ups while still around the main asteroid body, as models suggest [8]. Indeed, bound satellites were found around a few primary members of asteroid pairs [16,17], suggesting the current secondary member was not ejected alone from the progenitor. *iii)* A higher angle of friction than the 40 degrees measured on lunar regolith, suggesting different properties of the asteroidal material. *iv)* A more conservative break-up criteria, in which the failure is not localized but the entire or most of the body needs to reach high slope value. Such scenario might indicate that multiple pieces slide around the entire body and ejected from the surface and only later accumulated in orbit into the secondary member of the pair [18]. *v)* A significant internal cohesion between the pieces of the 'rubble-pile' structured asteroid [12,19,20]. However, using the Drucker–Prager yield criterion, the derived cohesion value is over 1,000 Pa, larger than current estimations of asteroid cohesion [20,21] and larger than the cohesion range measured on lunar samples [11].

We will further present the parameter space of our model and discuss its implications.

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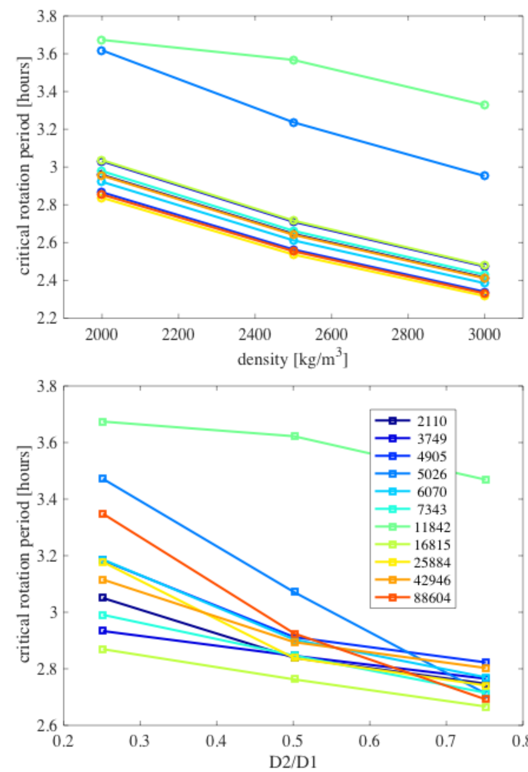

Fig. 2: Possible solutions for the discrepancy between our results of critical spins at break-up to the rubble pile spin barrier at ~2.2 h. Increasing the density of the models (top panel), or increasing the size ratio between the secondary to the primary member (lower panel), result in faster critical spins. Different lines represent different primary members of asteroid pairs we studied.