Magnetic Force Model to simulate Avalanching on Metallic Asteroids like 16 Psyche

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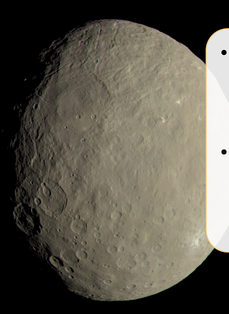
Magnetic Field on Asteroids

1 Ceres | Bow shock detected [1]



- Dawn mission orbit in Jun 2015
- Could be due to a transient atmosphere

9996 Braille | ~ 2.00 nT [2]

- Flyby by Deep Space mission in Jul 1999
- Could be spacecraft noise

No conclusive evidence of magnetic field on traditional asteroids

951 Gaspra | ~ 0.01 nT [3]

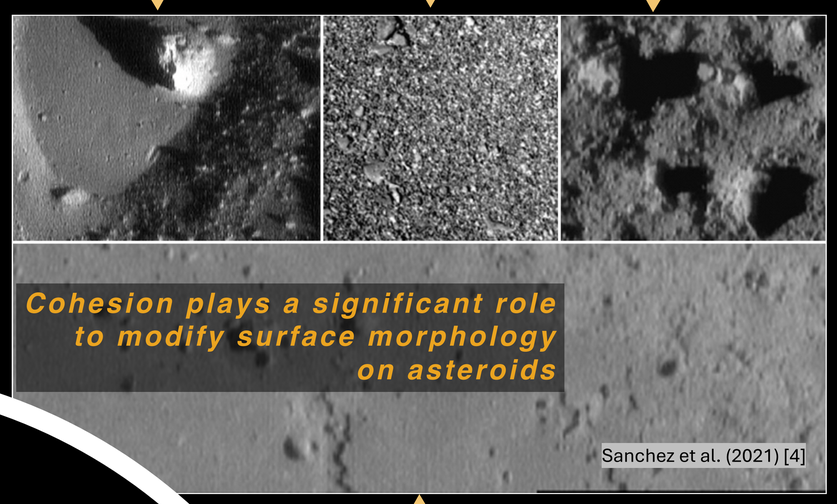
- Flyby by Galileo mission in Oct 1991
- Could be solar wind signature

Surface Morphology on Asteroids

Granular ponds on Eros

cm-sized grains on Itokawa

Granules on Itokawa at m-scale



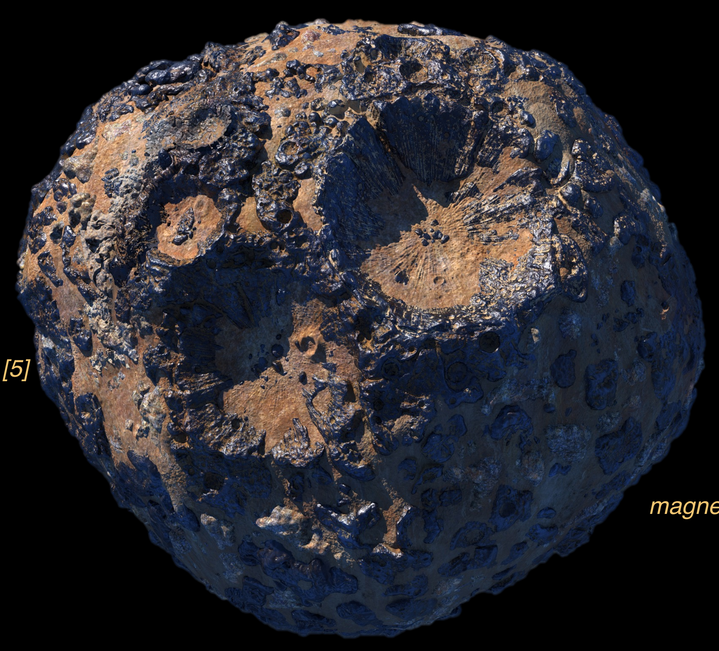
Cohesion plays a significant role to modify surface morphology on asteroids

Sanchez et al. (2021) [4]

Rivulets near the edge of Eros' ponds

16 Psyche

A metallic world



Core of a planetesimal [5]

0-500 nT magnetic fields [6]

***Psyche Mission** reaches orbit in **2029**; with **magnetometer** onboard*

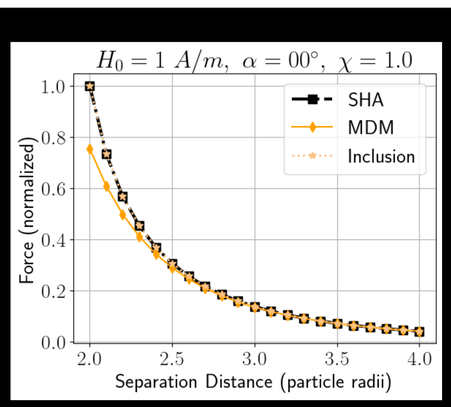
LIGGGHTS

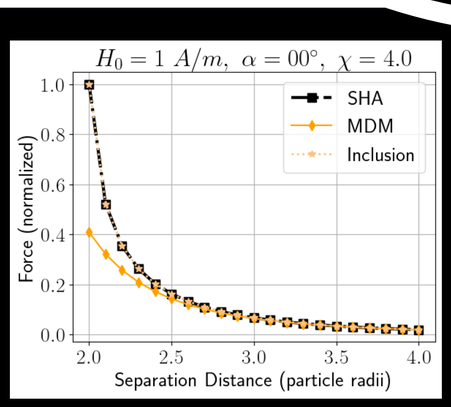
- An opensource Soft-Sphere Discrete Element Modelling (SSDEM) software
- **Collision:** Hertzian – spring-dashpot system
- **Cohesion:** Simplified JKR – Johnson-Kendall-Roberts (SJKR) model
- **Rolling Friction**: Elastic Plastic Spring Dashpot (EPSD) model
- No Magnetic Force Model

Magnetic Force Model

- Mutual Dipole Model (MDM): Dipolar magnetic moment on each particle due to every other particle [7]
- Spherical Harmonic Approximation (SHA): Truncated spherical harmonics solution to the Laplace equations [8]
- Inclusion Model: MDM for far-field calculations & SHA for particles within a cutoff distance [8]

Two-particle Validations

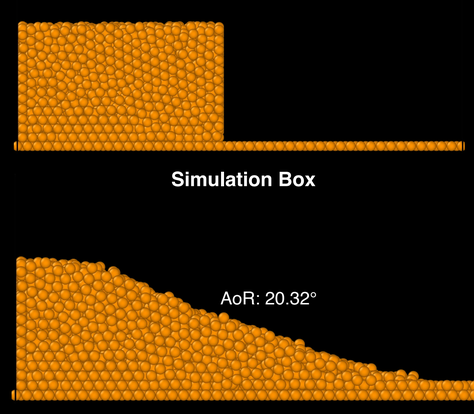


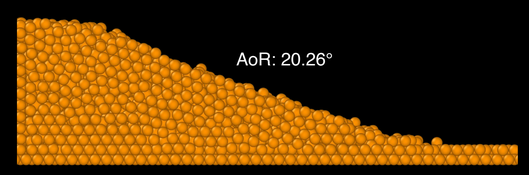


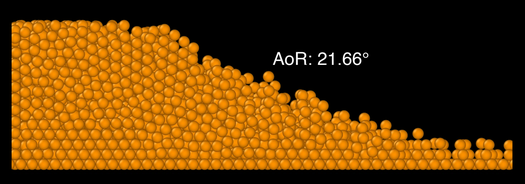
Force comparison for the three different force models. Inclusion model matches with SHA which provides exact force for a two-particle system.

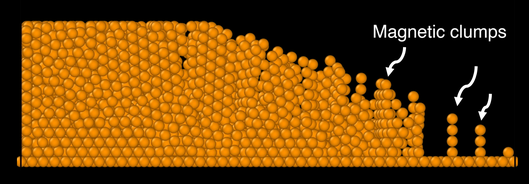
Three particle & eight particle chain validations also done

Avalanching Simulations









- Experiments performed using **Steel balls** by Sunday et al (2024) [9]
- **Friction and cohesion** properties obtained by matching **Angle of Repose (AoR)** in **no external** magnetic field case
- Results presented for **40 mT** external magnetic field using **MDM** method

Increasing Magnetic Force results in transition from granular to correlated regime, where particles move in clumps instead of flowing freely.

Increasing Magnetic Susceptibility (therefore Magnetic Force) increases net cohesion

What's Next

- Different magnetic field strengths and different magnetic susceptibilities
- Inclusion model simulations
- Psyche environment simulations
- Aspherical grains by varying friction properties

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