Rotational Breakup as the Origin of Small Binary Asteroids

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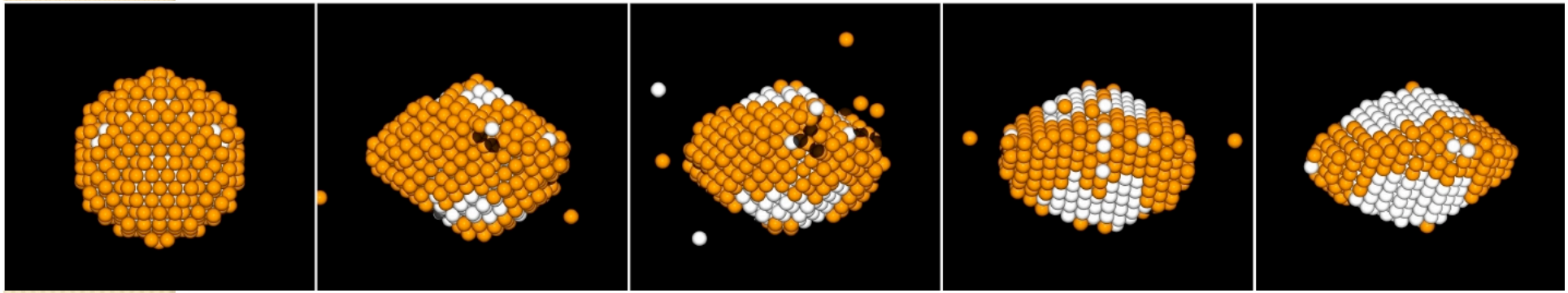
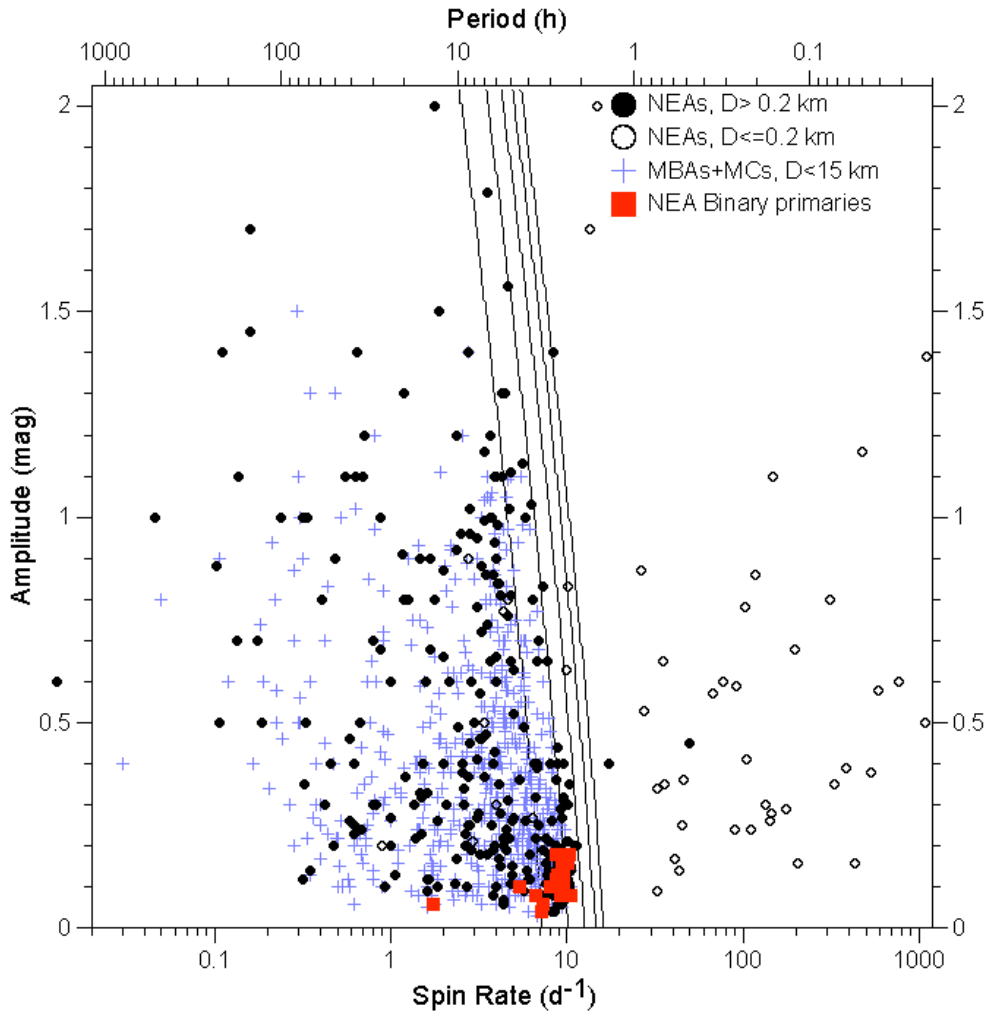


Spinning near the limit

- Many near-Earth asteroids (NEAs) spin close to the breakup limit for ~2 g/cc bulk density unconsolidated material.
  - The primaries of NEA binaries are among the fastest rotators, and are quite round/oblate.

Shape and spin data

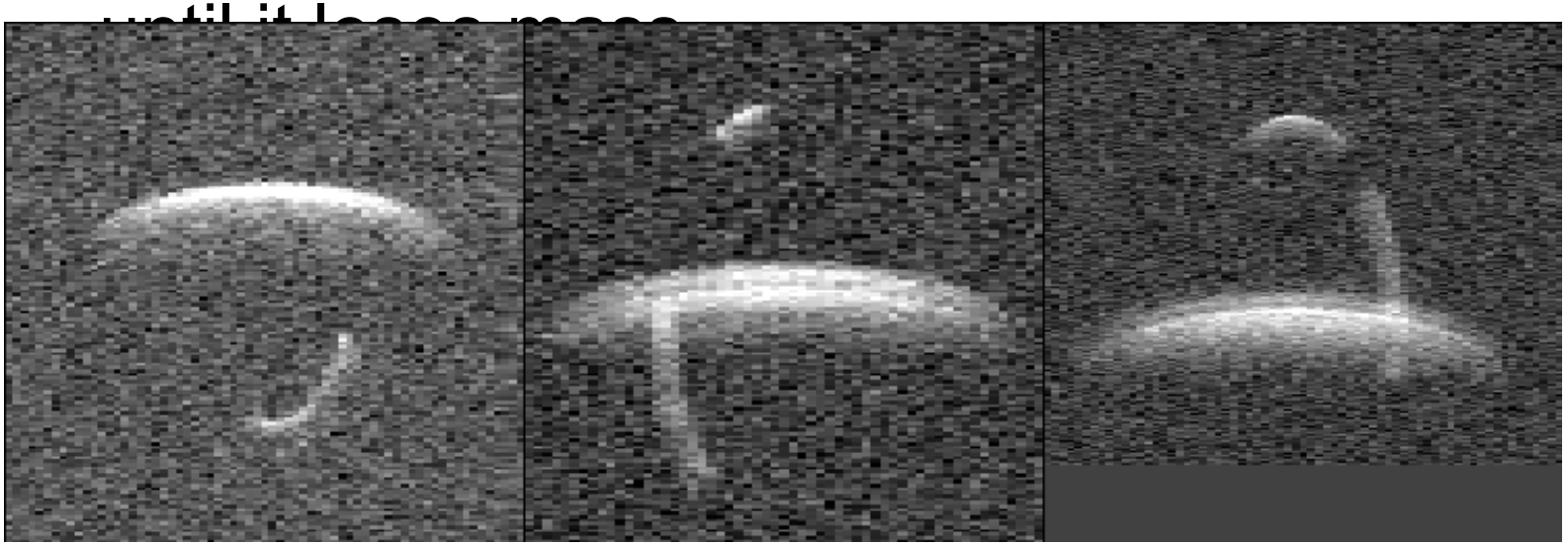


Rotational disruption

- If NEAs are *gravitational aggregates*, they can reshape, lose mass, and form satellites if they are spun past the breakup limit.
- The YORP thermal effect seems to be the best mechanism to do this.
  - Reflection/re-emission of sunlight at an angle to the incident direction results in net torque.
  - Can spin up typical NEA/small inner main belt asteroid to breakup in ~Myr or less.

Binaries from YORP

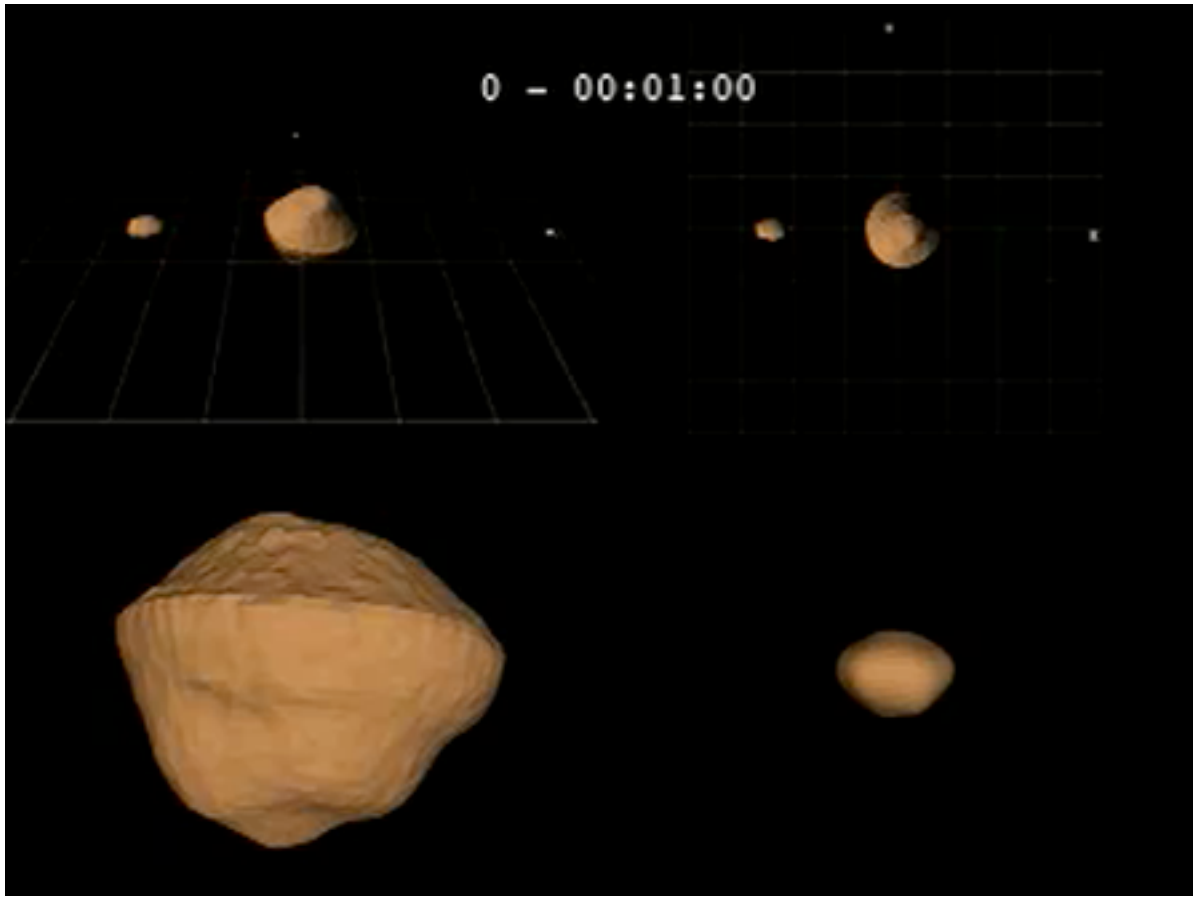
- Sunlight can spin up a grav. agg. until it loses mass



Bottke et al. 2006

1999 KW_4
1.2 & 0.4 km
diameters

1999 KW_4

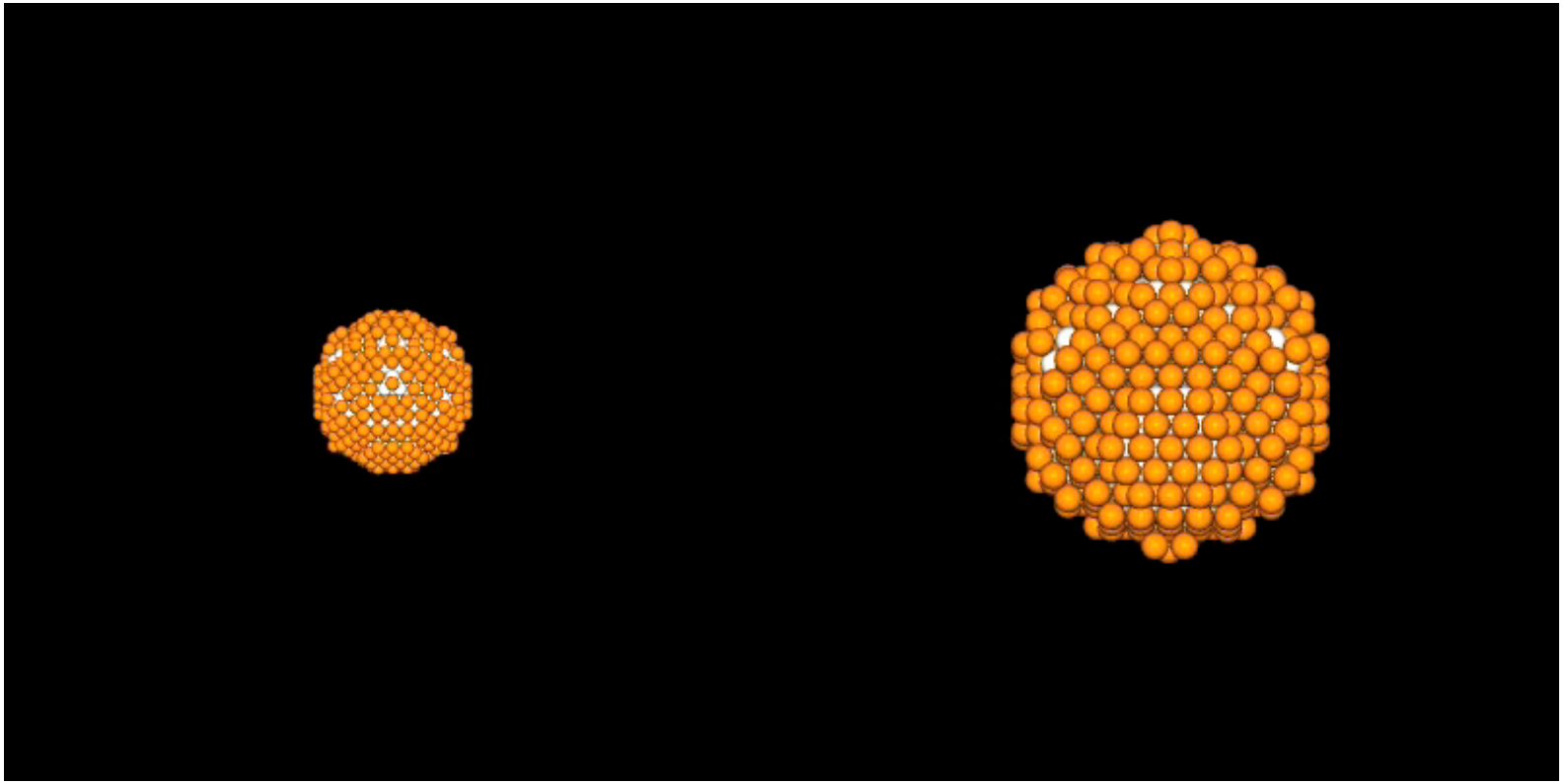


Simulating 1999 KW_4 formation

- Start with “rubble pile” of spheres in either oblate or prolate shape.
- Use “pkdgrav” *N*-body code to evolve.
- Gradually add angular momentum, allow system to equilibrate after each kick.
- Watch what happens!

Simulating 1999 KW_4 formation

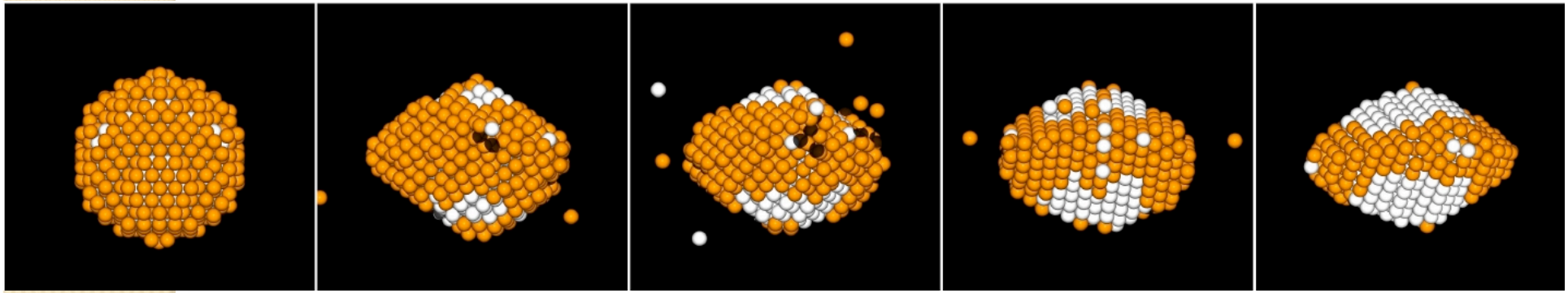
Top View Side



K. J. Walsh, D. C. Richardson, P. Michel 2008.*Nature* **454**, 188.

Simulating 1999 KW_4 formation

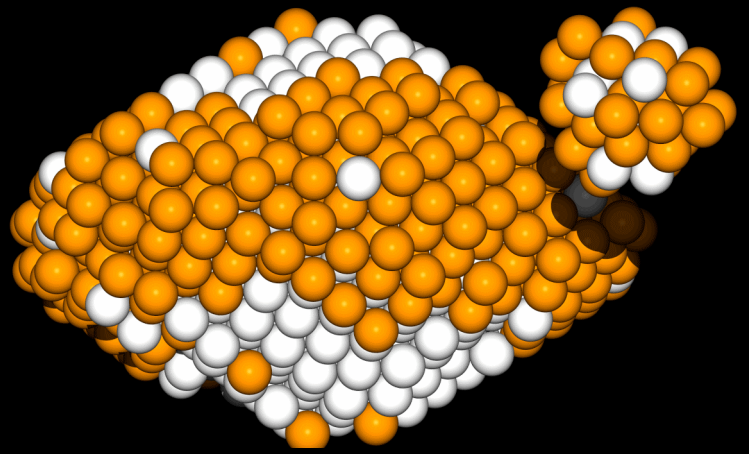
- As body spins up, it bulges at equator, mass moves down from the poles, and a satellite forms from material shed in the equatorial plane.
- Explains shape, fast rotation rate, and presence of 1999 KW_4 satellite.

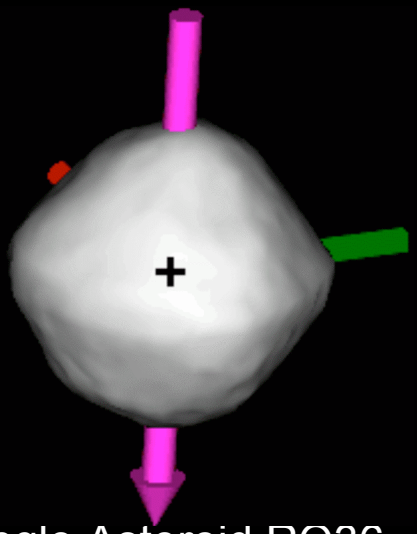


Top-shapes

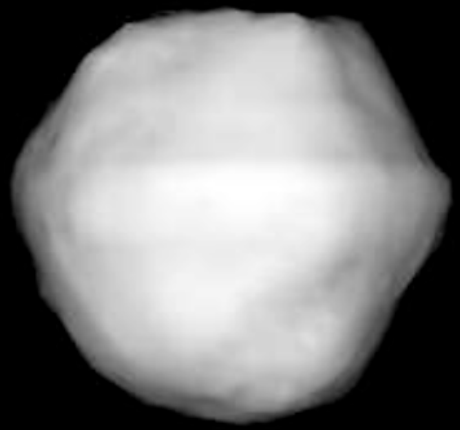
1999 KW4 Radar model, Ostro et al. 2005

YORP Spinup sims, Walsh et al. 2008





Single Asteroid RQ36
Howell et al. 2008, ACM



Binary 2004 DC
Taylor et al. 2008, ACM

Steins from Rosetta Images

Summary and next step

- Rotational disruption of gravitational aggregates via YORP can explain certain asteroid shapes and binaries.
- The next step is to self-consistently evolve the YORP torque as the primary shape changes—we're working on it!

Slow spinup with cohesion

Top View Side View

Cohesion allows fission (strong deformation before failure)