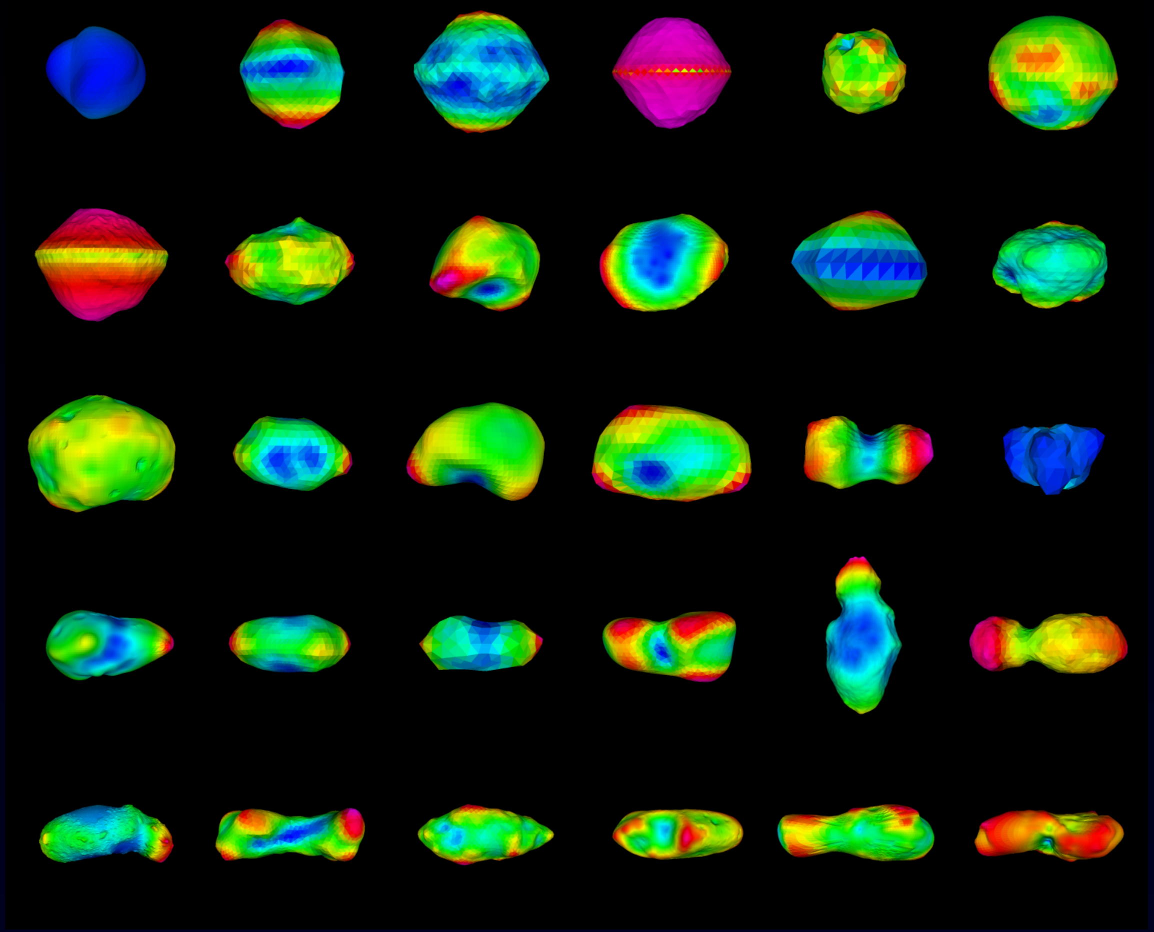
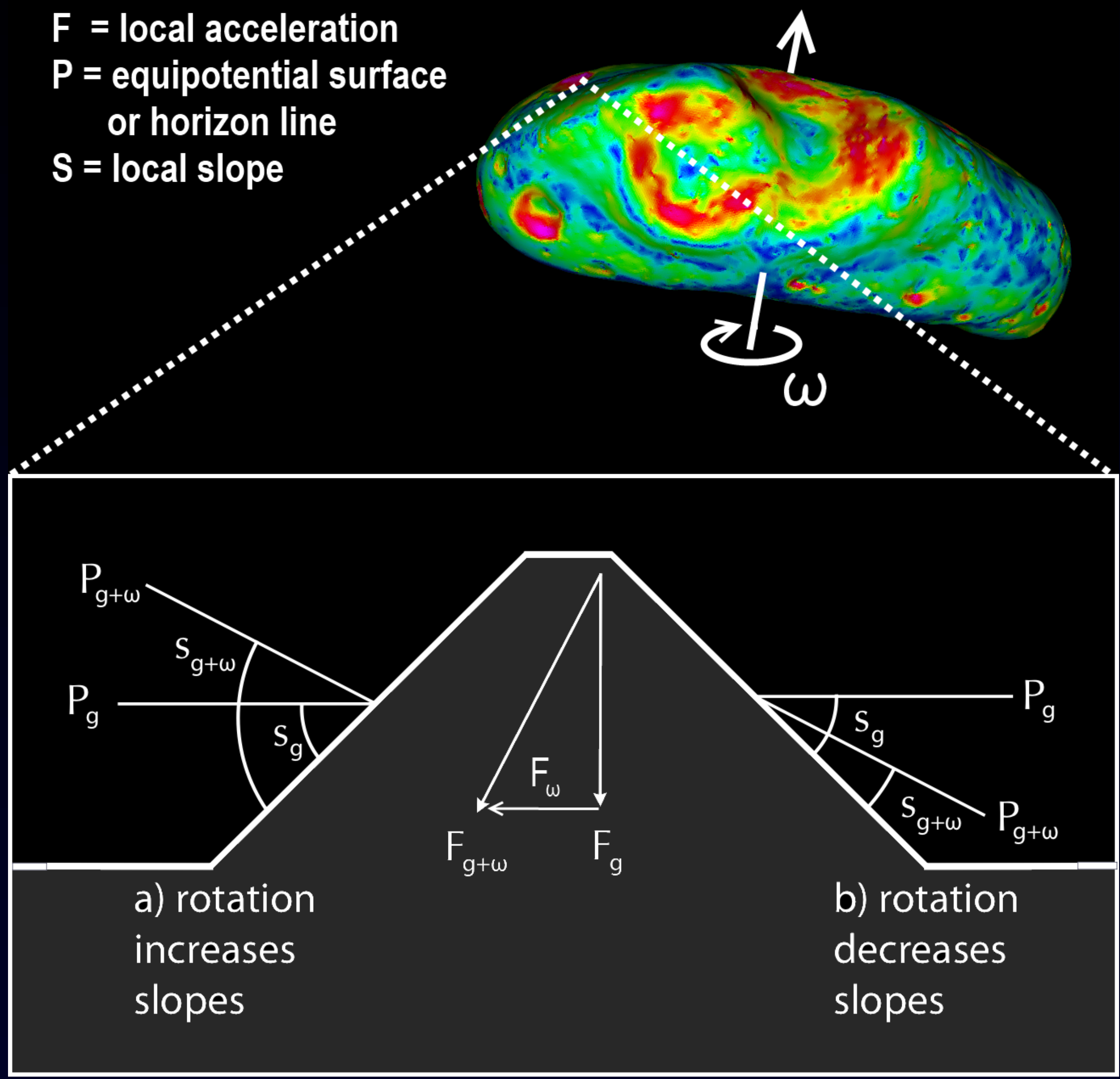
Radar-developed asteroid shapes and spins reveal a preferred state of maximum surface stability

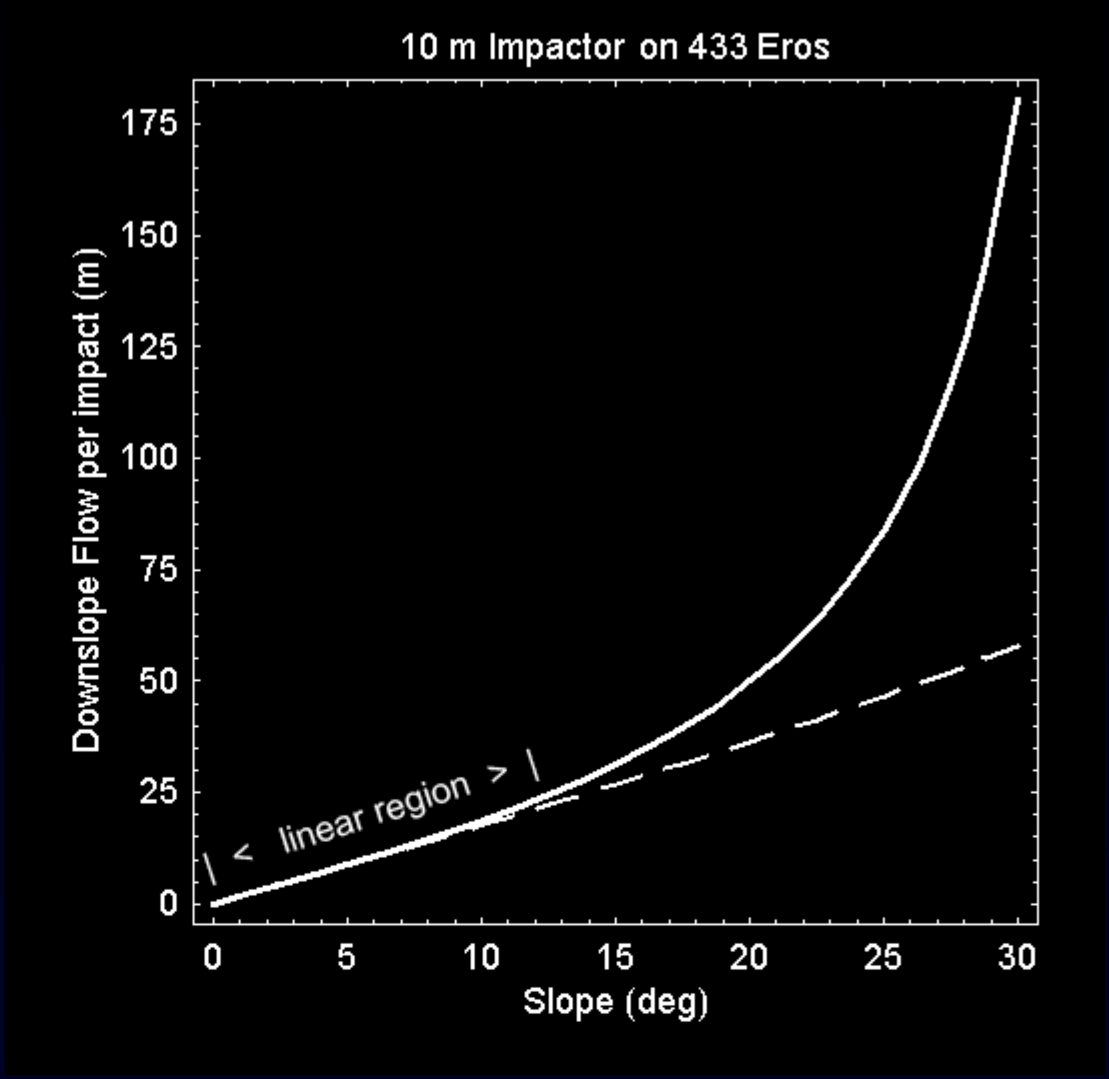


James Richardson, **Arecibo Observatory**
Kevin Graves & Tim Bowling, **Purdue University**

On many asteroids, the rotation rate can have a significant effect on local slopes

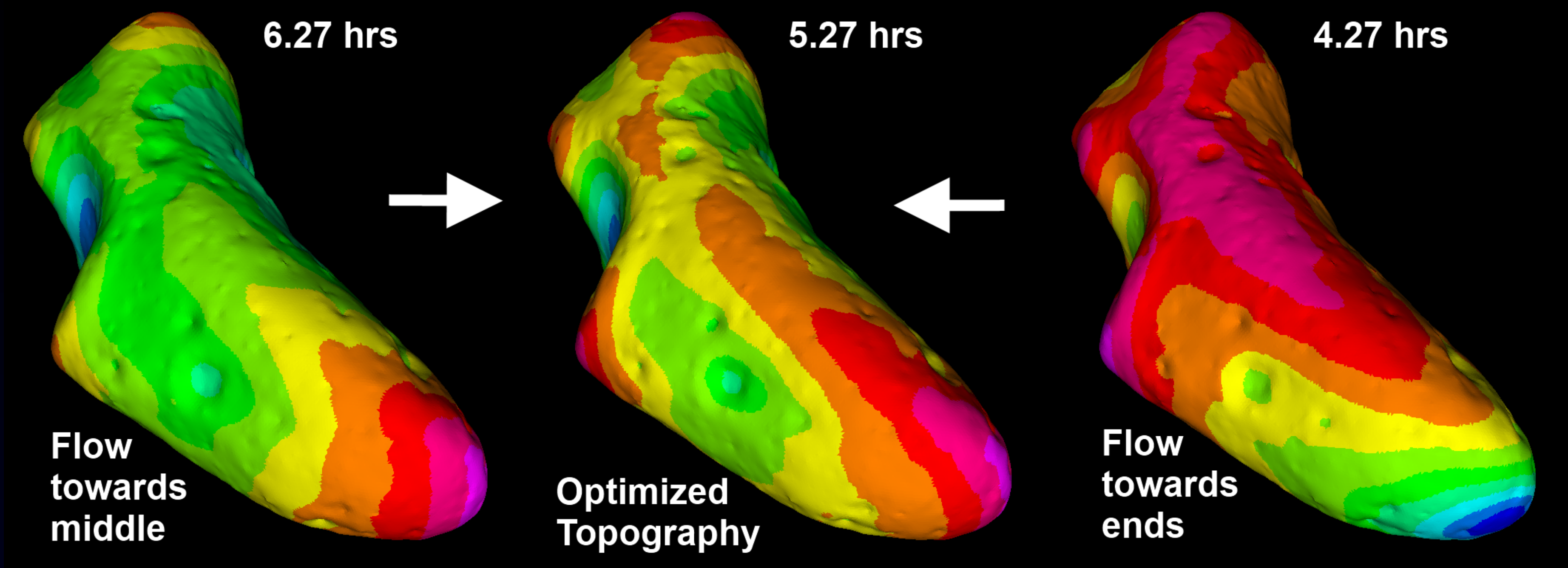


Erosion rates vary non-linearly with slope



A plot of the globally experienced, downslope regolith movement resulting from the seismic shaking produced by a single 10 m impactor striking the surface of asteroid 433 Eros at 5 km/s, plotted as a function of slope on an infinite plane, computed using the methods described in Richardson et al. (2005).

Gravity and Rotation combine to significantly effect asteroid topography



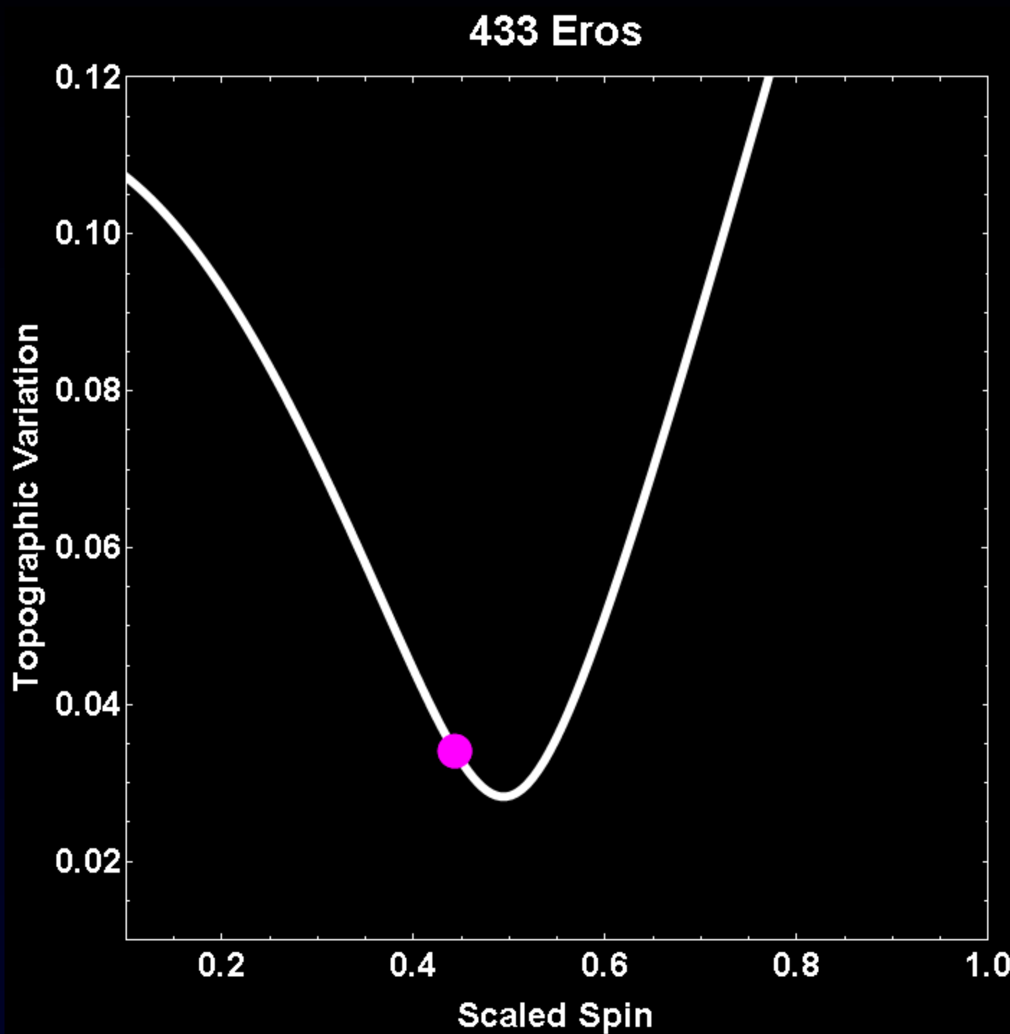
(A) High topography on the ends of an elongated body indicates slow rotation and gravity dominated slopes.

(B) Mixed topography over the surface of the asteroid is indicative of a body in an optimum spin state.

(C) Low topography on the ends of an elongated body indicates fast rotation and spin dominated slopes.

Quantified by:
Topographic Variation vs. Scaled Spin

period: 5.27 hrs, density: 2670 kg/m^3



Scaled Spin

(Holsapple, 2004)

$$\frac{\text{Rotational Potential}}{\text{Gravitational Potential}}$$

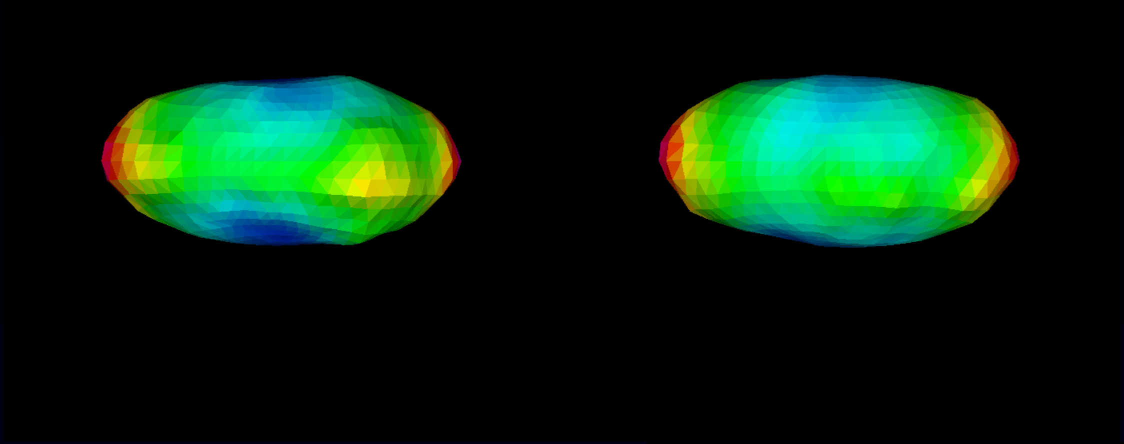
(spherical body)

$$\frac{r^2\,\omega^2}{4\,G\,\pi\,r^2\,\sigma}$$

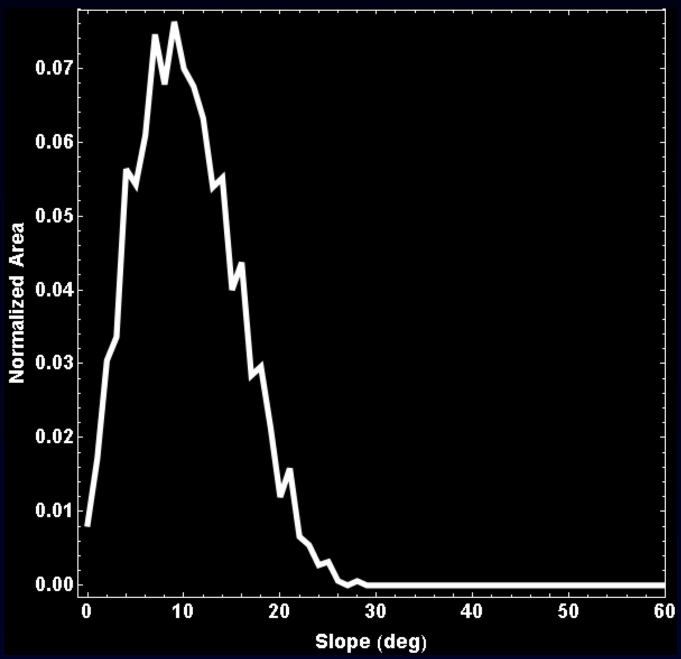
ω = rotation rate

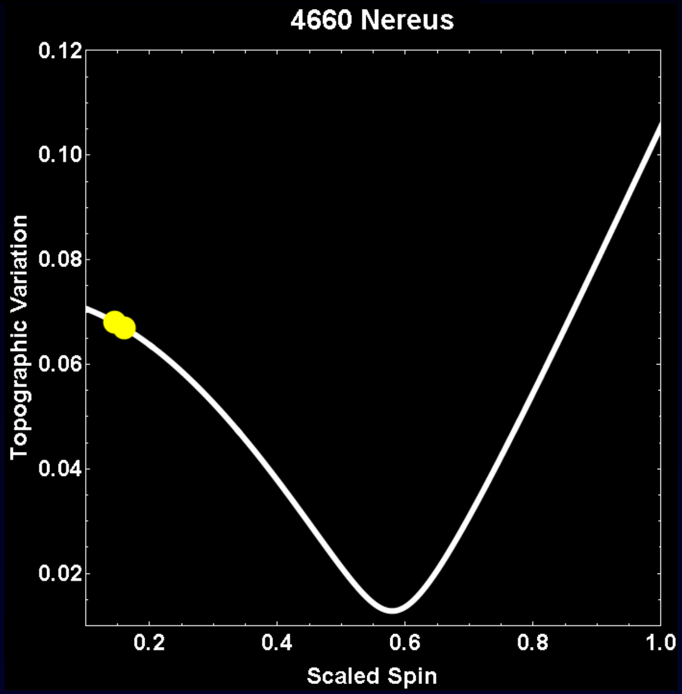
σ = density

Group A: 4660 Nereus (0.51 km, 15.1 hrs) density ~ 2500-3000

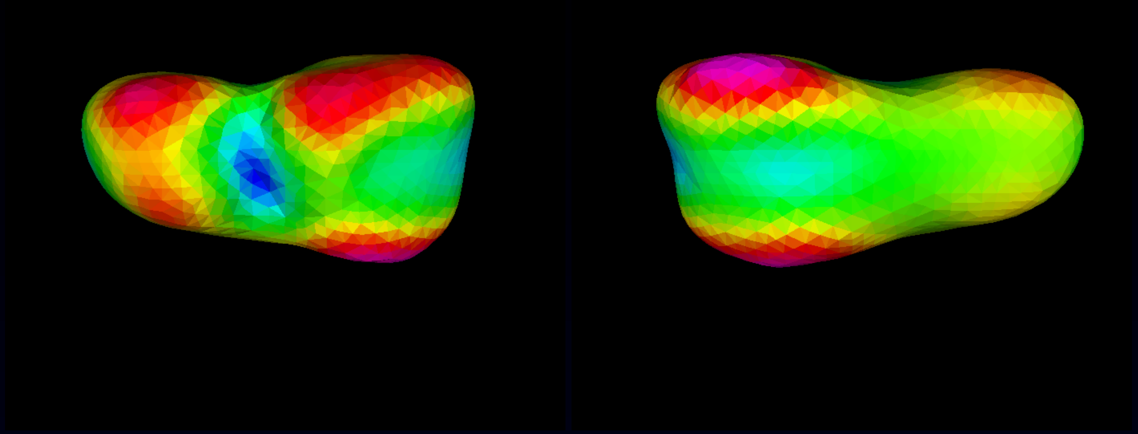


Spectral
Class: **E**

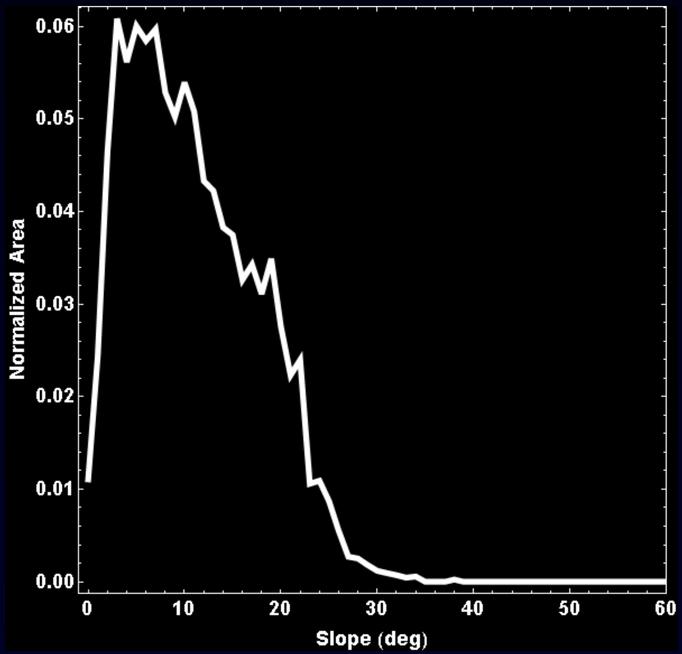


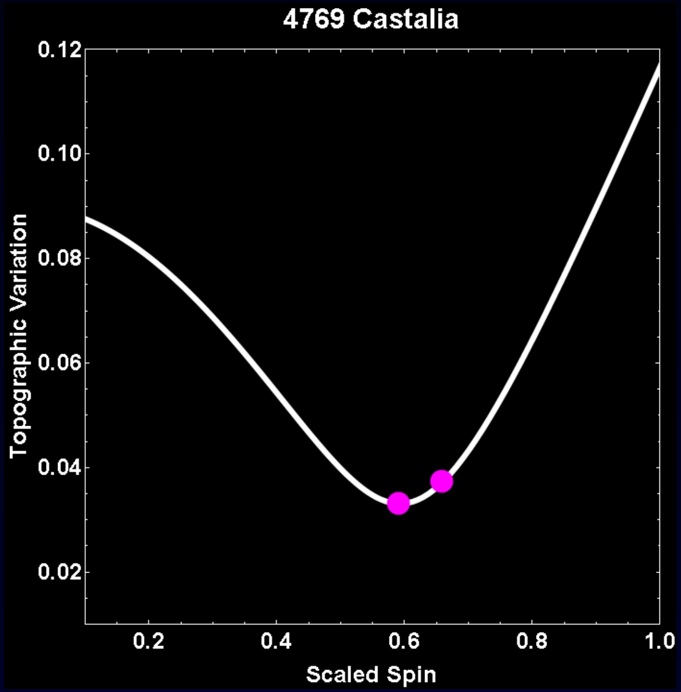


Group B: 4769 Castalia (1.6 km, 4.1 hrs) density ~ 2000-2500

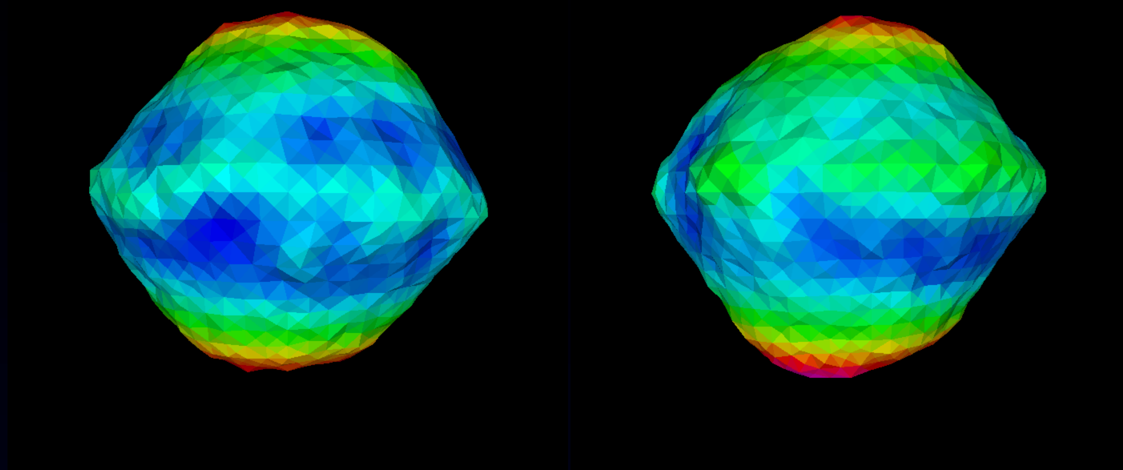


Spectral Class: **S**

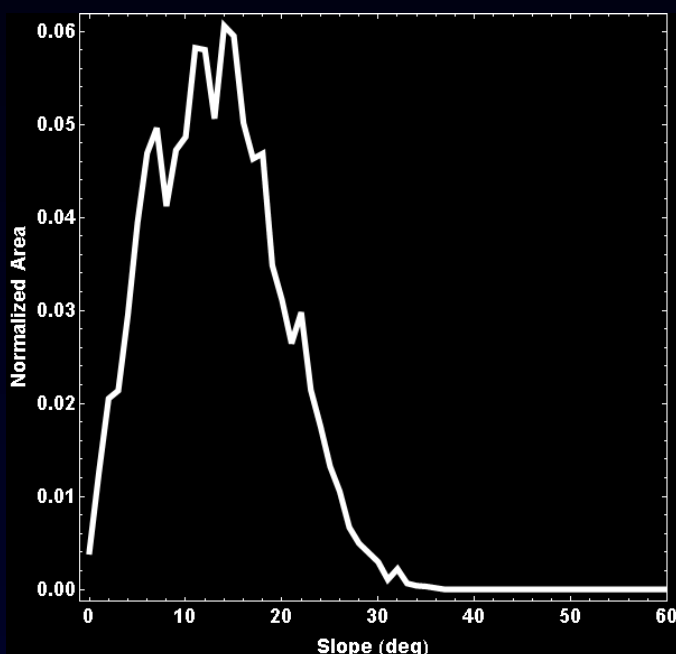


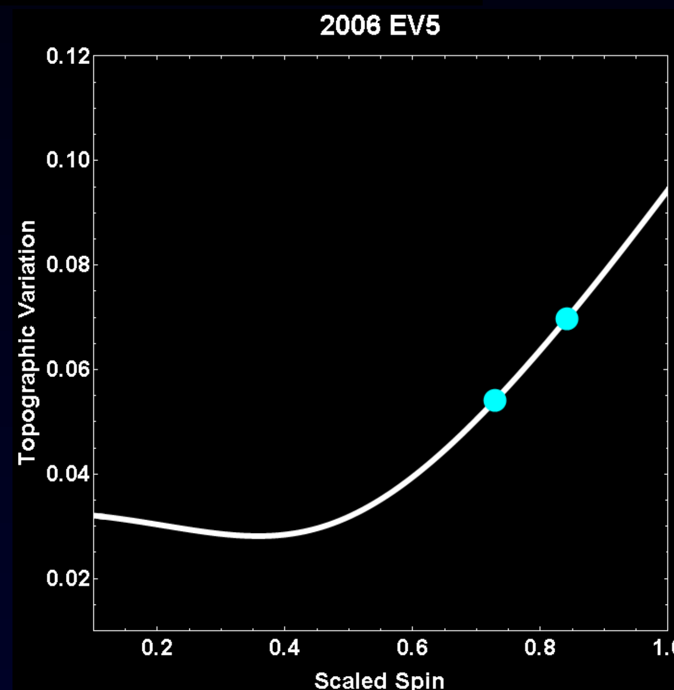


Group C: 2008 EV5 (0.42 km, 3.7 hrs) density ~ 1500-2000

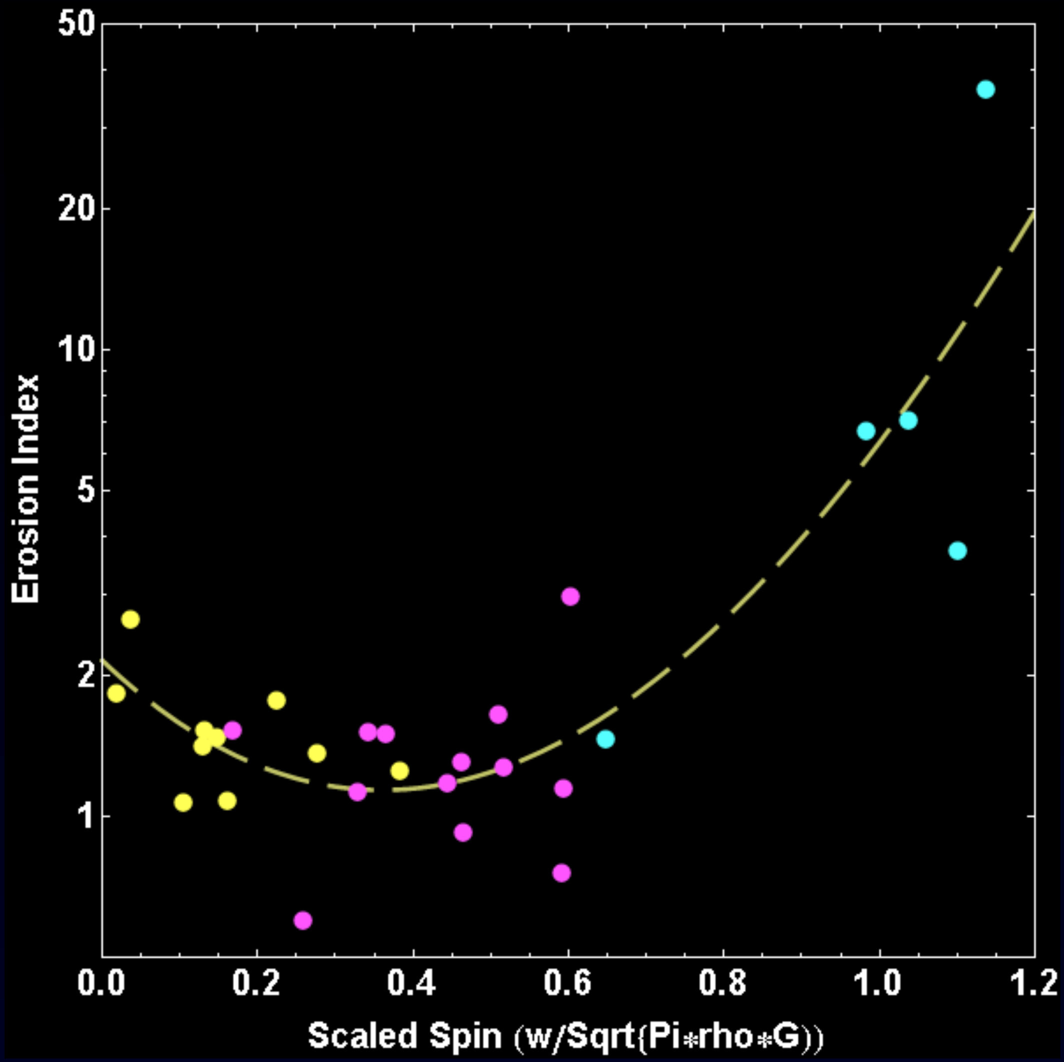


Spectral Class: **C**





Mean surface erosion rates:

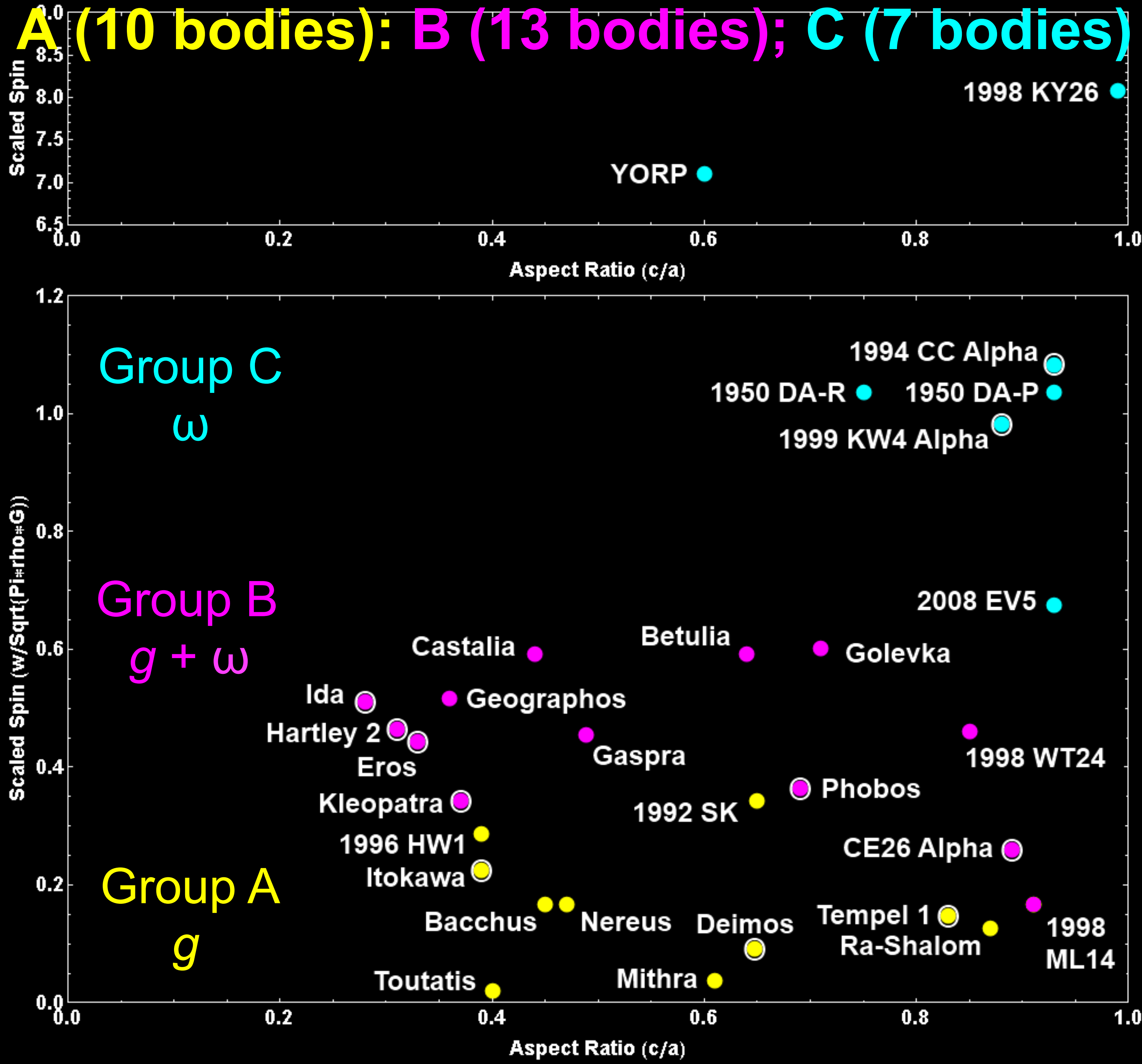


Asteroid

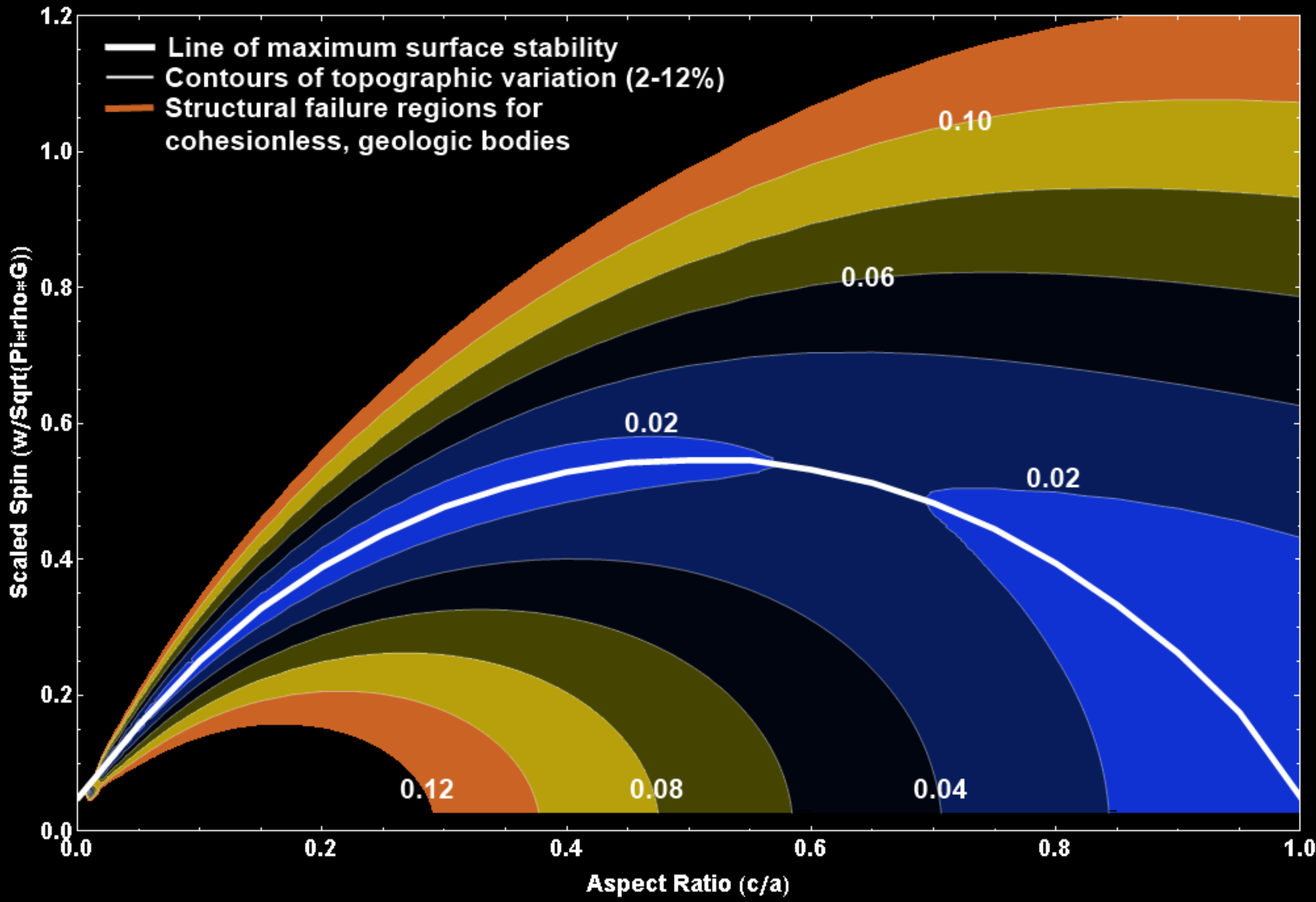
"Erosion Index"

is a measure of the mean downslope regolith flow rate, relative body with a mean slope of 10°, and assuming transport-limited material flow (not weathering-limited).

A (10 bodies): B (13 bodies); C (7 bodies)

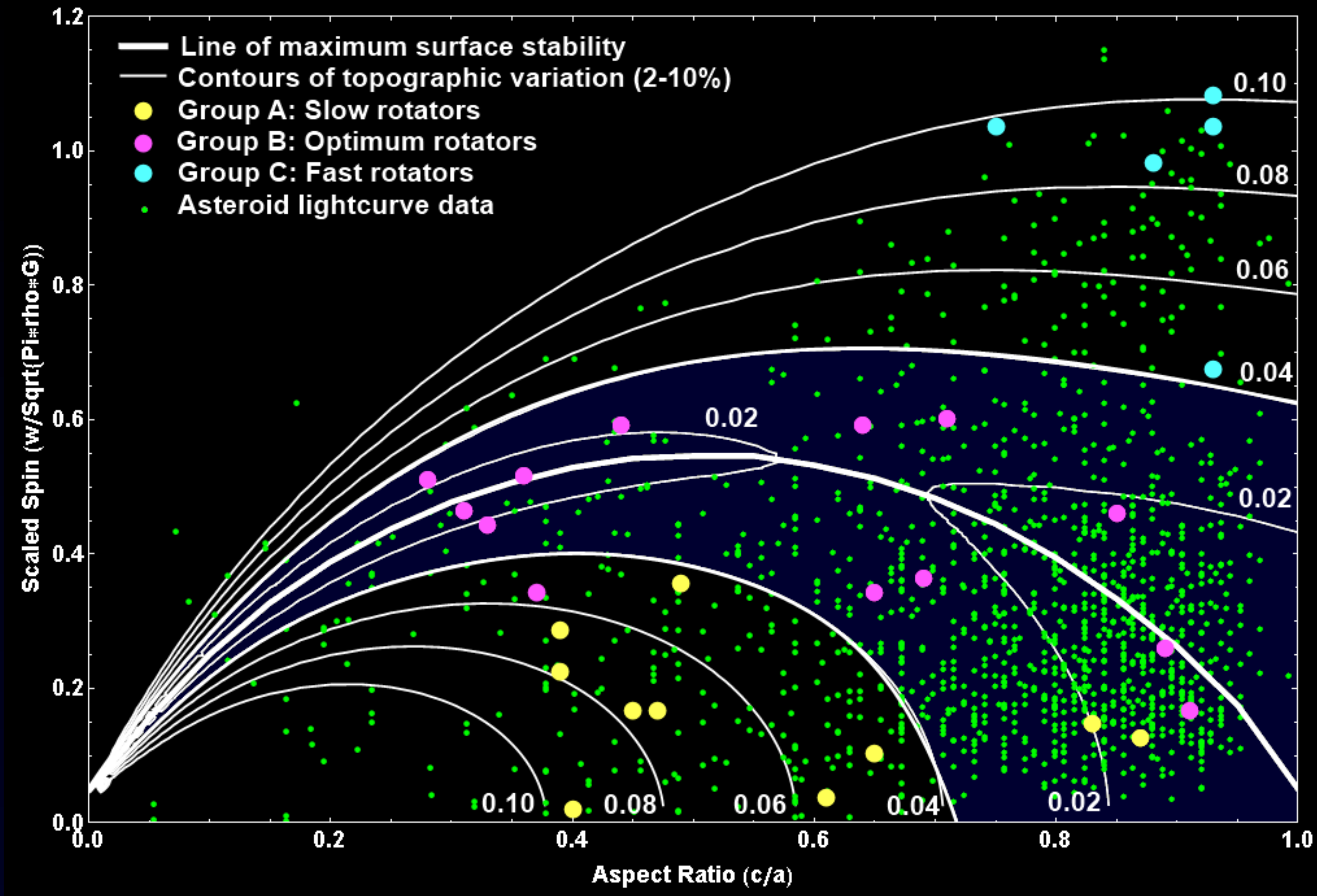


Contours of Topographic Variation for Prolate Spheroids



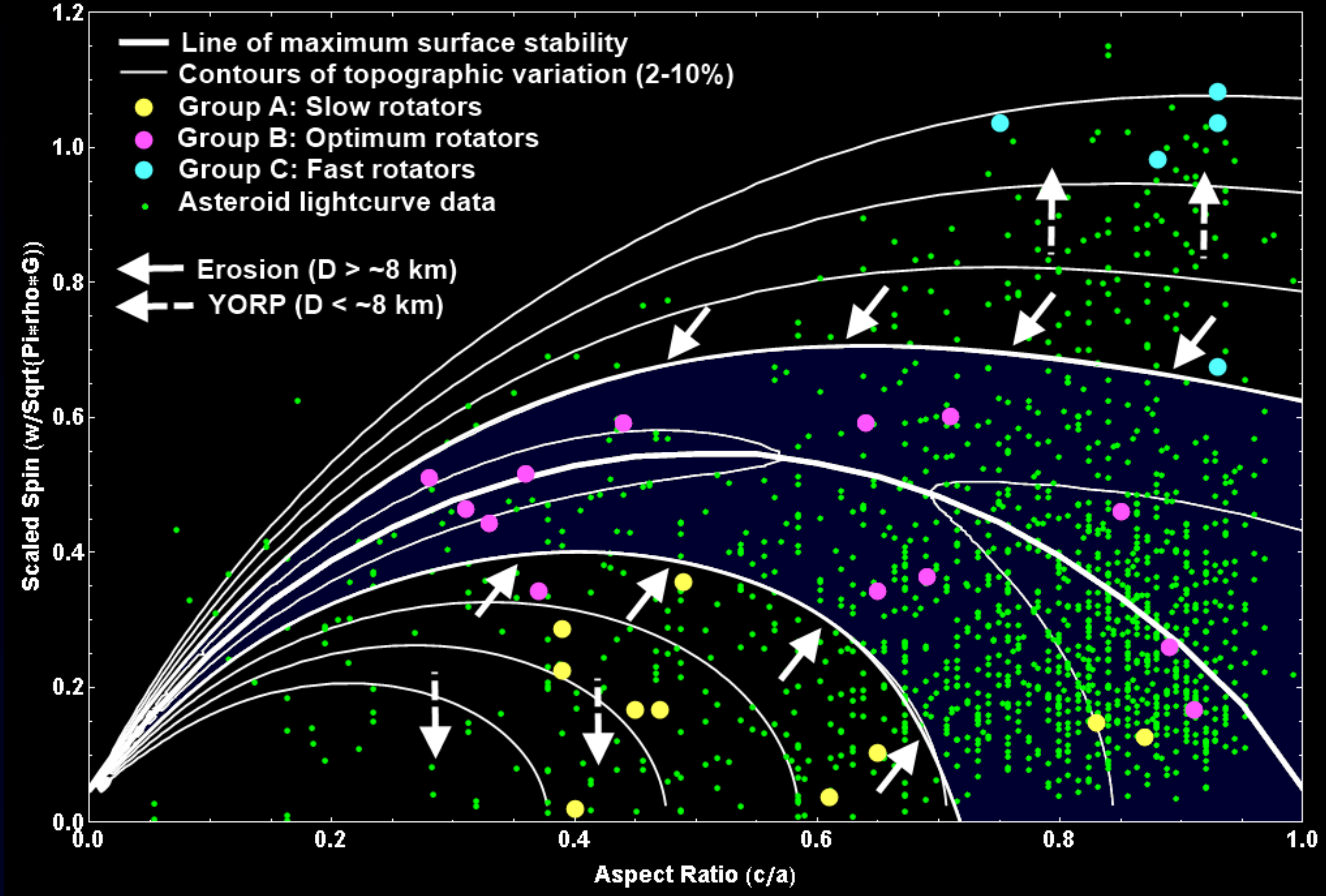
Blue: Zone of maximum surface stability: 1%-4% variation

Measured Asteroids vs. Contours of Topographic Variation



50% of 30 shape models & **75%** of 1300 lightcurve data points lie within **< 0.04** topographic variation curves.

Erosion reduces both Topographic Variation & Internal Stress



50% of 30 shape models & **75%** of 1300 lightcurve data points lie within **< 0.04** topographic variation curves.

Conclusions

- A scaled-spin zone of "maximum surface stability" (MSS) exists for each asteroid shape, wherein surface potentials, topography, and slopes are minimized.
- This MSS zone is self-correcting in that deviations from it will tend to push the surface back towards stability.
- Highly elongated bodies are more prone to migrate towards this MSS zone, and remain there, due to their steeper topographic variation gradient (with spin state).
- On small bodies (< ~8 km), YORP effects tend to outweigh erosional effects, particular where there is little loose regolith and weathering limited downslope flow prevails.