Introduction

- Slopes on the few well observed asteroids are almost always less than the angle of repose (30^o) - as predicted by the popular “rubble pile” model.
- What is the shape of an asteroid on which all slopes are as close as possible to the angle of repose?
- This endmember shape will be as far removed from sphericity as a small body can be. Properties such as its light curve amplitude and axial ratio can be compared to observed values, helping to examine the applicability of the “rubble pile” model.

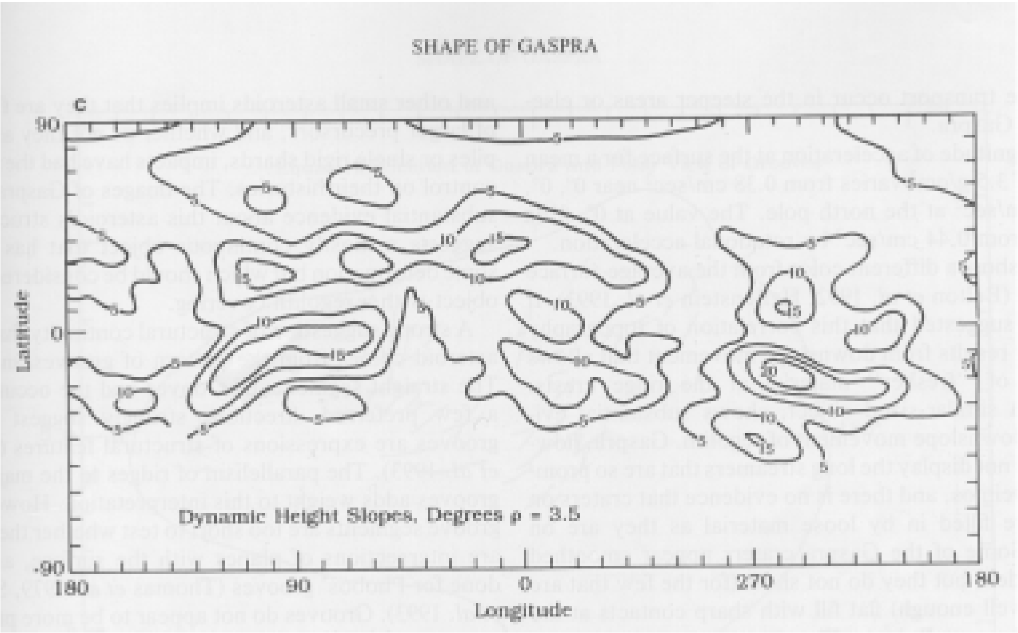

figure 1
Slopes on Gaspra
Thomas et al (1994)
Icarus, 107, 23-36

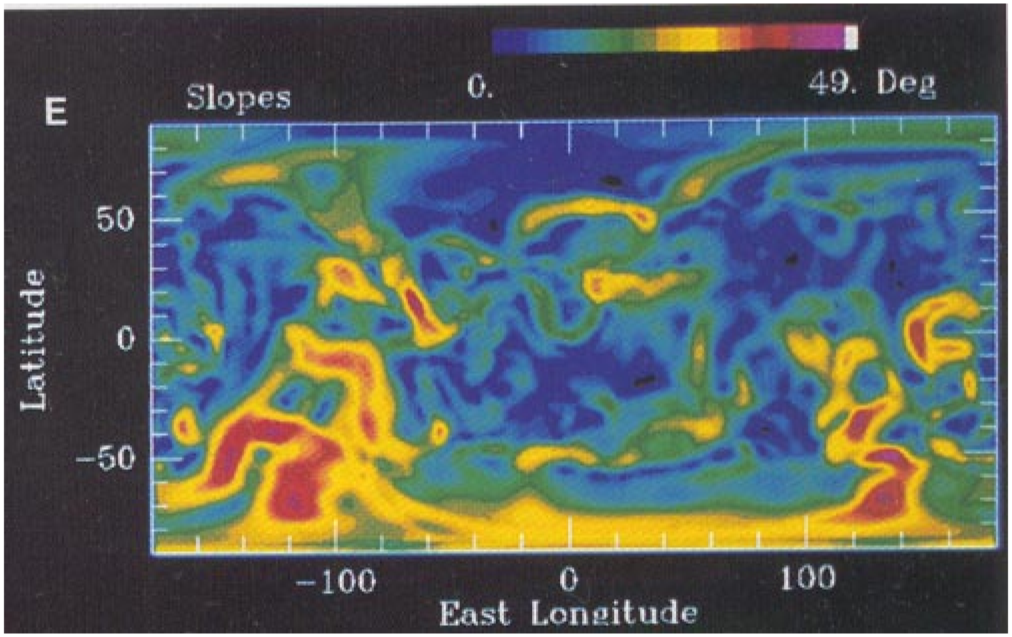

figure 2
Slopes on Ida
Thomas et al (1996)
Icarus, 120, 20-32

Procedure

- Examine two types of shape models for homogeneous, axisymmetric, rotating asteroids – irregular or elliptical limb profiles.
- 200 irregular profiles, generated as discussed next.
- Elliptical profile simply a function of axial ratio.
- Image also shows boxy profile not discussed in this poster.

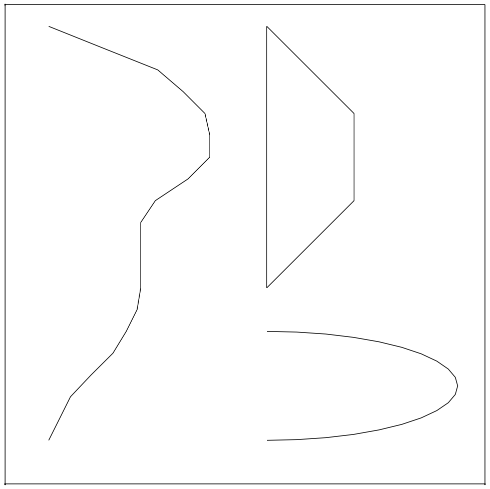

figure 3

- "Best" shape maximizes mean slope without maximum slope exceeding angle of repose.

Generating Irregular Shapes

- Irregular profile generated by constrained random walk. Start at rotation pole, move monotonically upwards parallel to axis and monotonically outwards perpendicular to axis, then flip perpendicular step direction and move move monotonically upwards parallel to axis and monotonically inwards perpendicular to axis.
- Vary probabilities of moving parallel or perpendicular or flipping perpendicular direction.
- This technique is not truly random and cannot generate large concavities in the shape.

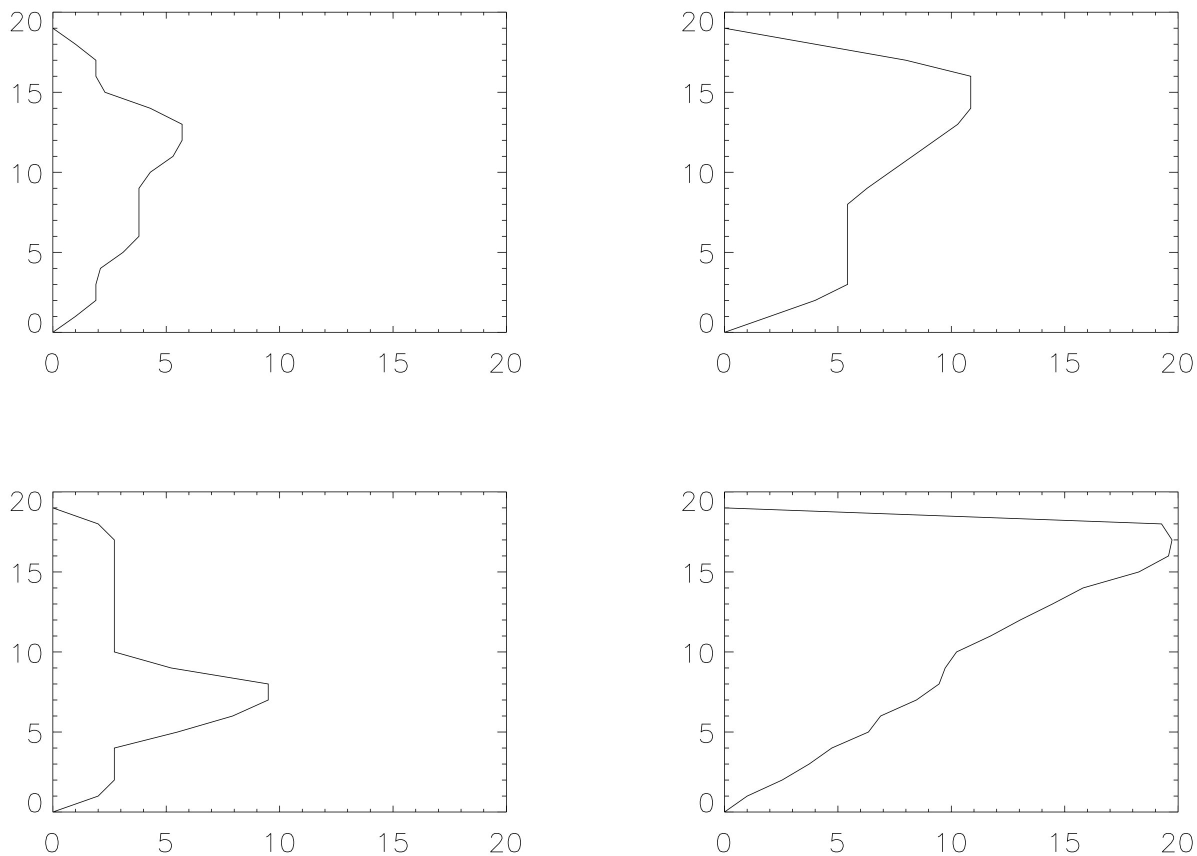

figure 4

Examples of irregular shapes.

Nonrotating Irregular Shapes

- Shapes with slopes > 30^o over > 15% of their surface are rejected as exceeding the angle of repose.
- Only 5/200 shapes are unrejected AND have mean slopes > 15^o. None of these mean slopes exceeds 18^o. See figure 5.
- This technique is failing miserably to generate angle of repose-limited shapes.

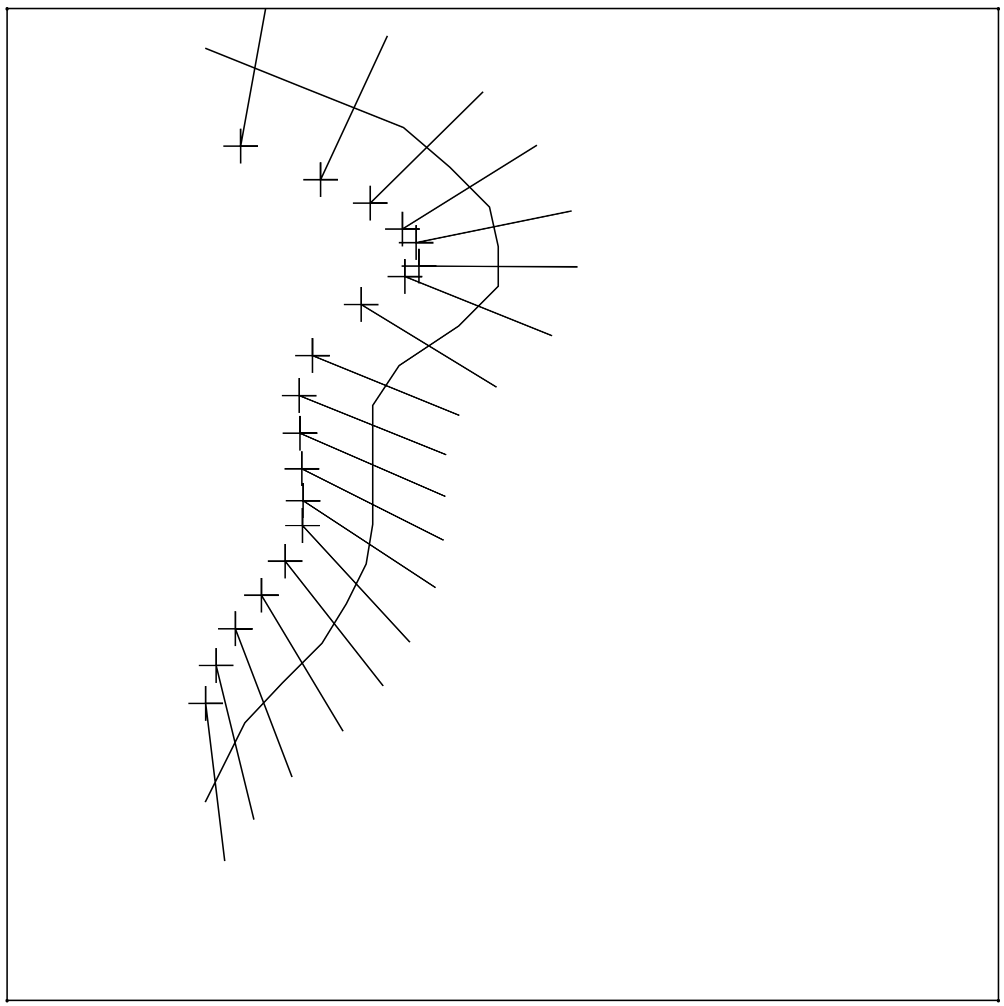

figure 5

One of the most successful irregular shapes, showing local gravity vectors. Axial ratio of 1.29. Mean slope of 18^{o}.

Nonrotating Ellipsoidal Shapes

- This shape is completely defined by one parameter, its axial ratio. Both mean slope and maximum slope are functions of this parameter.
- An axial ratio of 0.3 gives a maximum slope of 30^{o} and a mean slope of 20^{o}. See figure 6.
- The best ellipsoidal shape is better than my best irregular shape.
- An analytical relation between axial ratio and mean slope should exist. See Future Work.

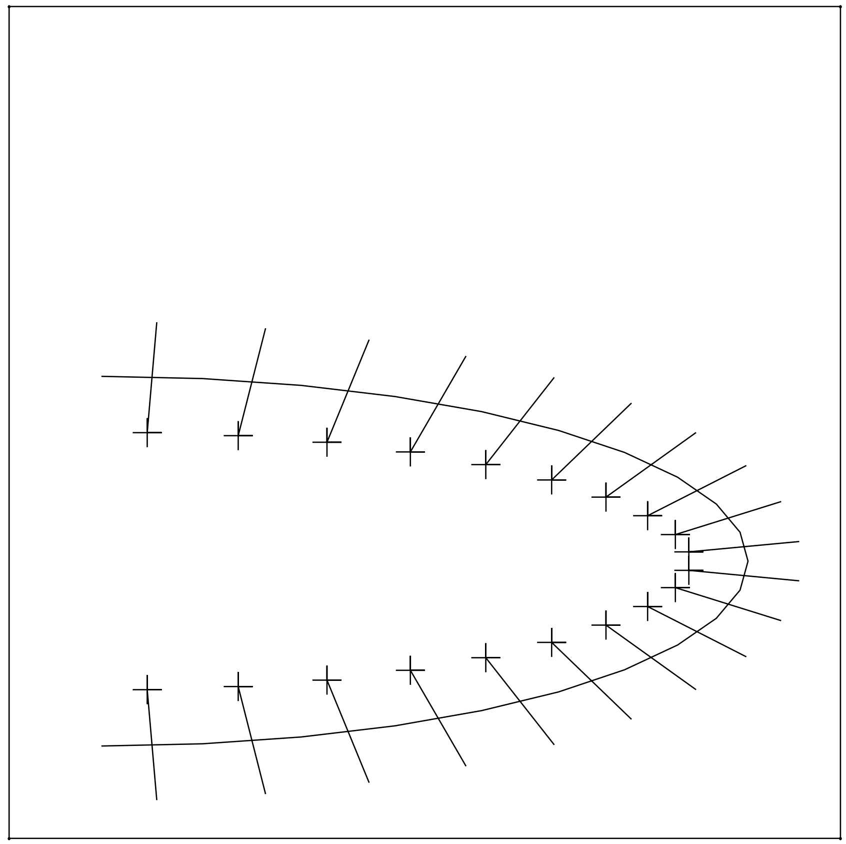

figure 6

The most successful ellipsoidal shape, showing local gravity vectors. Axial ratio of 0.3. Mean slope of 20^{o}.

Effects of Rotation

- Completely specified by “rotational parameter” – $\omega^2/G\rho$.
- Range of expected values is 0.1 - 10 for rotation period of 10 – 1 hours.
- $\omega^2/G\rho = 0.1$, negligible effects.
- $\omega^2/G\rho = 0.3$, minor effects.
- $\omega^2/G\rho = 1.0$, significant effects.
- $\omega^2/G\rho = 3.0$, large effects.

Rotating Ellipsoidal Shapes

- Two parameter problem – polar/waist axial ratio and rotational parameter. An analytical description should be possible. See Future Work.
- As the rotational parameter increases from 0 to 1.0, there is always an ellipsoidal shape with mean slope around 20^{o} but acceptable maximum slope. The best shape's polar/waist axial ratio does not change monotonically with rotational parameter.

Rotating Irregular Shapes

- Rotational parameters > 3.0 caused all 200 shapes to be rejected.
- Rotational parameters from 0 to 1.0 all cause ~5 of the 200 shapes to be unrejected and have mean slopes between 15 and 18^o.
- The best ellipsoidal shape is better than my best irregular shape for a given rotational parameter.

This irregular shape is unrejected for values of the rotational parameter between 0 and 1.0. Local gravity changes in response to the effects of rotation. Rotational parameter equals 0 (top L), 0.1 (top R), 0.3 (middle L), 1.0 (middle R), and 3.0 (bottom L).

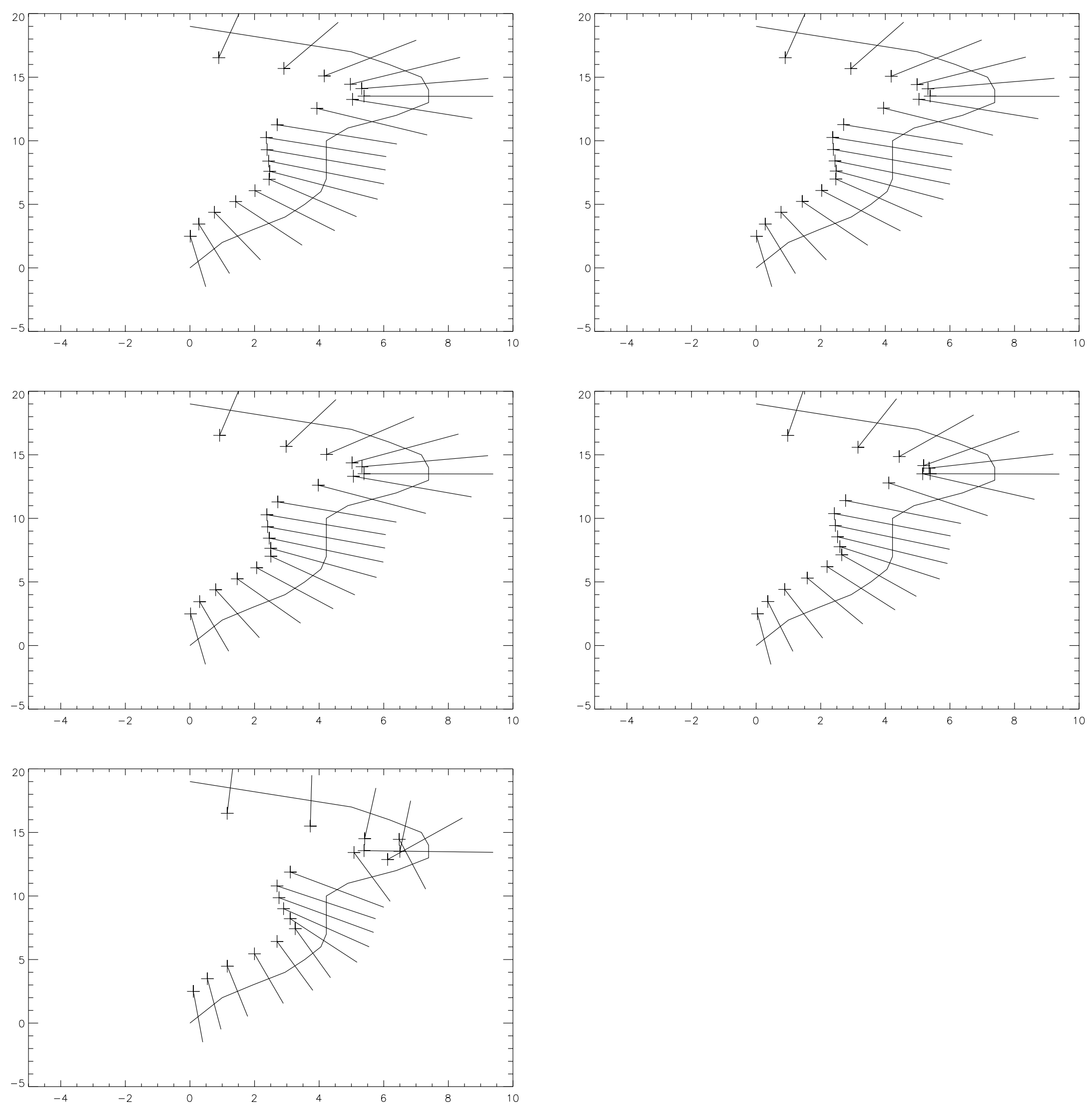

figure 7

Future Work

- Larger and more general sample of irregular shapes.
- Analytical work on ellipsoidal shapes, including rotation.
- Triaxial ellipsoids.
- Comparisons with observed asteroid shapes.
- Drizzle mass onto spherical mass and allow to flow once angle of repose is reached. Find angle of repose-limited shape directly.

Conclusions

- The shape of an asteroid that is always at the angle of repose is an important endmember shape.
- A restricted random walk shape generating method was less successful than a simple ellipsoidal shape at maximising slopes subject to the constraint that few slopes exceed the angle of repose, even with rotation.
- No mean slopes exceed 20^o, suggesting that room for improvement exists.

Where’s the author?

- Mars Meteorology Poster #1268
- “New Results from Mars Global Surveyor Accelerometer” by Withers, Bougher, and Keating.
- Both posters can be downloaded from http://www.lpl.arizona.edu/~withers/papers.html
- Email: withers@lpl.arizona.edu
- Acknowledgement: Jay Melosh