AVC-97-097

Visualization of Earth-Approaching Asteroids

November 29,1996

The video sequences on this tape are based on radar investigations of near-Earth asteroids Castalia, Toutatis, and Geographos. The Arecibo (Puerto Rico) and Goldstone (California) radar/radio antennas obtained delay-Doppler images of each object, and the images have been used to construct computer models of the shapes and rotations of Castalia and Toutatis. The overview segment that follows this text shows samples of our visualizations of those objects, the dynamics of orbits close to them, and the physics of collisions into them. A delay-Doppler movie made from Geographos images, which have not yet been used to make a computer model, follows the overview. The table below summarizes observational parameters for images used in making this tape (A = Arecibo, G = Goldstone).

Observations	**Asteroid Names**		
	4769 Castalia	**4179 Toutatis**	**1620 Geographos**
Longest Dimension (km)	**1.6**	**4.6**	**5.1**
Average Image Resolution (m)	**210**	**85**	**100**
Minimum Distance (million km)	**5.6**	**3.6**	**7.2**
Number of Radar Images	**64**	**18**	**252**
Observation Site(s)	**A**	**G, A**	**G**
Date	**Aug '89**	**Dec '92**	**Aug '94**

The first segment displays 64 radar delay-Doppler images of Castalia. The intensity of each rectangular (140 x 300 meter) resolution cell is proportional to radar echo power. The white curve traced on the image indicates the asteroid's extent. In the next sequence, the images have been filtered and color-coded to convey the bimodal distribution of echo power that persists throughout the movie.

Extensive analysis of the images yielded the first detailed three-dimensional computer model of a near-Earth asteroid and the most conclusive evidence to date of a "contact-binary" object in the solar system. Our knowledge of the asteroid's orbit and rotation, both of which were refined by the radar data, allows us to simulate the appearance of Castalia at any time and from any direction. The next sequence shows an Earth-based view of the rotating asteroid, lit by the Sun. The green "light curve" plots the object's total optical brightness.

Two sequences depict the trajectory of an object which is launched from Castalia and eventually returns to the surface. The object is represented by a gray sphere and is launched with an initial velocity of 0.2 meters/second. The blue line traces out the return orbit, first in an inertial coordinate system and next in a coordinate system which is fixed to the surface of Castalia and rotates with the asteroid. The orbit calculation assumes that Castalia is a homogeneous body with a density of 2.1 g/ cm^3.

The next sequence shows computer simulations of what happens when a target shaped like Castalia is hit by a much smaller asteroid. What does it take to destroy Castalia, or change its course? Here we see the damage and disruption that results when a 6,000 ton rock hits Castalia at 5 km/s. This is the equivalent energy of an 18 kilo-ton bomb. Here we show the damage, particle velocity, and ejecta distribution resulting from the collision. Surface and interior effects are shown first together and then in separate sequences. This impact simulation assumes that Castalia is a homogeneous rocky body with a density of 2.1 g/ cm^3. This impact severely damages Castalia, but does not blow it apart or appreciably change its trajectory.

A short sequence compares the relative rotations of the Earth (one rotation each 24 hours), Castalia (one rotation each 4.1 hours) and Toutatis, which has one of the strangest rotation states yet observed in the solar system. Instead of spinning about a single axis, it "tumbles" somewhat like a football after a botched pass. Its rotation is the result of two different types of motion with periods of 5.4 and 7.3 Earth days. In this simulation, the sizes of the two asteroids are magnified 1000 times.

We next simulate views of Toutatis as seen from the Earth, lit by the sun. The green light curve displays the instantaneous integral of the reflected light and is an estimate of the brightness that an observer on Earth would see using an optical telescope. The red asterisks are optical observations of Toutatis by a consortium of astronomers. The remarkable agreement demonstrates the accuracy of the shape model.

In the last sequence of our overview, we land on Toutatis and watch the motion of the sky from its surface.

Toutatis currently approaches Earth once every four years, and on November 29 1996 it will be 5.2 million kilometers away. On September 29, 2004, it will be less than 1.6 million kilometers from Earth. This is only four times the distance to the moon and is the closest approach predicted for any known asteroid or comet during the next sixty years.

Castalia, Toutatis and Geographos are three of the several hundred Earth-orbit-crossing asteroids (ECAs) that have been discovered. The entire ECA swarm is thought to consists of :
(1) more than 1500 ECAs larger than 1 kilometer
(2) more than 100,000 larger than 100 meters
(3) more than 100,000,000 larger than 10 meters.

Radar observations of these objects are important because :
(1) they are related to meteorites, main-belt asteroids, and comets;
(2) they are the most accessible targets for robotic and human exploration;
(3) they are sources of materials with potential commercial value;
(4) they may potentially collide with the Earth threatening long term human survival.

We hope that the video segments on this tape will provide you with an introduction to the contributions of radar observations, science analysis, computer modeling, and scientific visualization to the study of these strange worlds that share our cosmic neighborhood. A wealth of information is available about ECAs in scientific journals, in textbooks, and on the world wide web. For more information on these and related space science topics we invite you to explore the following web sites:

http://echo.jpl.nasa.gov
http://www.eecs.wsu.edu/~hudson/asteroids.html
http://photojournal.jpl.nasa.gov