RADAR IMAGING THE INTERIORS OF SMALL BODIES: INITIAL MIGRATION STUDIES

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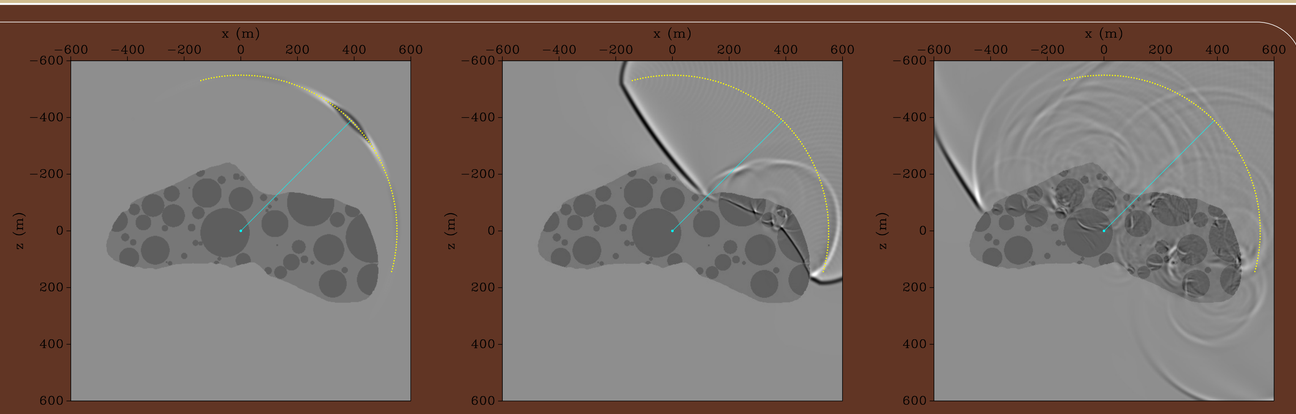
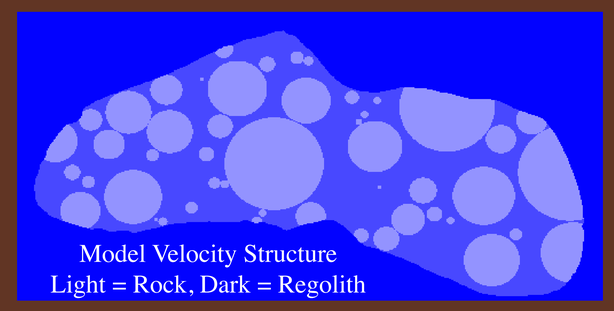
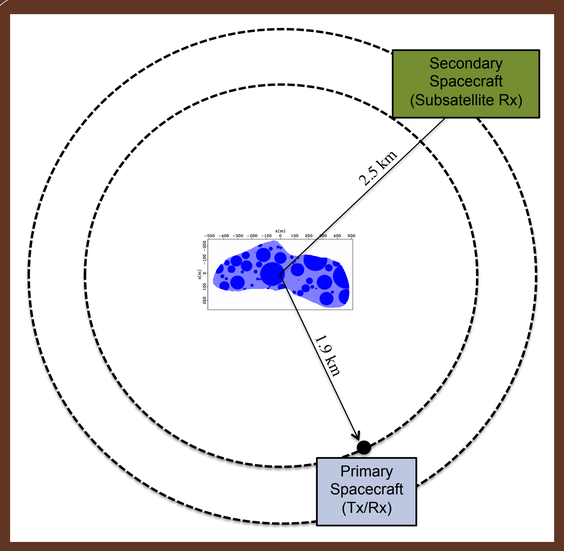
Summary

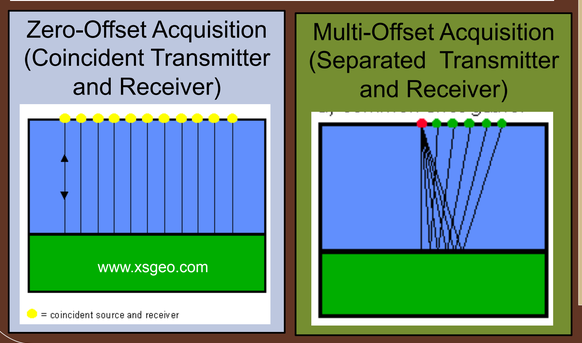
The origin and evolution of small bodies, particularly their collisional histories, may be elucidated by wavefield imaging of their interiors. Several mission and instrument concepts have been developed [e.g.,1] and the CONSERT radiotransmission experiment is flying on Rosetta [2]. However, there has been no systematic investigation of the capabilities of these methods to resolve interior structures. We have adapted the analytical methods of terrestrial exploration seismology for radar migration (imaging internal surfaces) and tomography (imaging internal volumes). To date, we have found that the strong velocity contrasts likely between solid rock, regolith, and vacuum will require full migration tomography to properly image asteroid interiors. Furthermore, deployment of a subsatellite radar receiver will greatly improve imaging of both asteroids and comets.



Asteroid and Seismic Models. We scaled the shape of 433 Eros to an NEA-sized 1.0x0.3x0.3 km.. Randomly placed [3] rock spheres (3 g/cm^3, 0.11 m/ns) populate a global regolith matrix (1 g/cm^3, 0.22 m/ns). The mean density of the object is 2 g/cm^3. A central 2D cross-section was extracted. Wavefields from a 20-MHz Ricker wavelet were calculated using finite differences. Migration was performed using the exploding-reflector method [4].

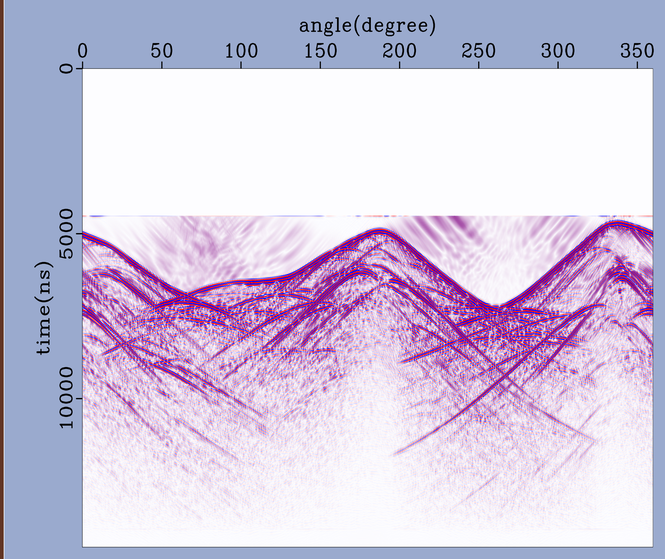




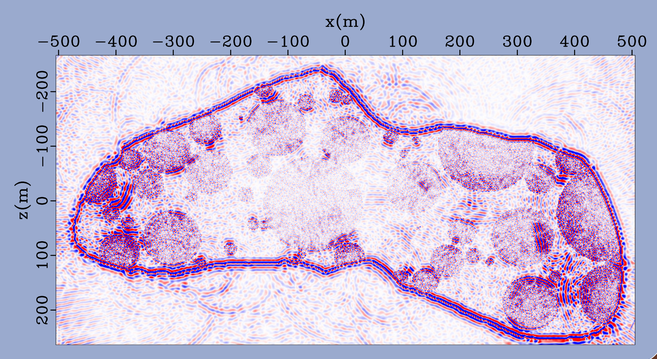


Imaging Geometry. We tested two alternative approaches for radar accquisition. In the first, (blue highlights), a single spacecraft (S/C) acts as both transmitter and receiver. This is the standard approach used for ALSE, MARSIS, and SHARAD. Its seismic equivalent is "zero-offset" acquisition. However, exploration seismology always uses a receiver array not just for geographic coverage but for geometric diversity. Today, "prestack" migration is the norm, where data from each shot are independently repositioned. We investigate using one independent receiver (green highlights), a subsatellite, akin to those flown Apollo 15-16.

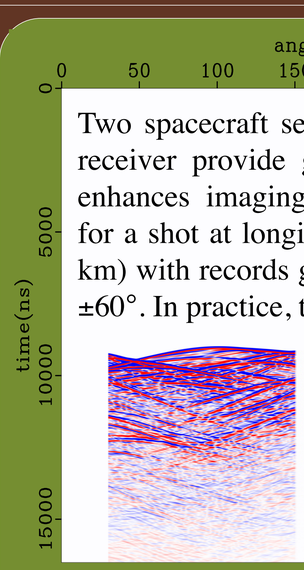
Future work will incorporate 3D imaging, asteroid spin, and S/C in different orbital planes.

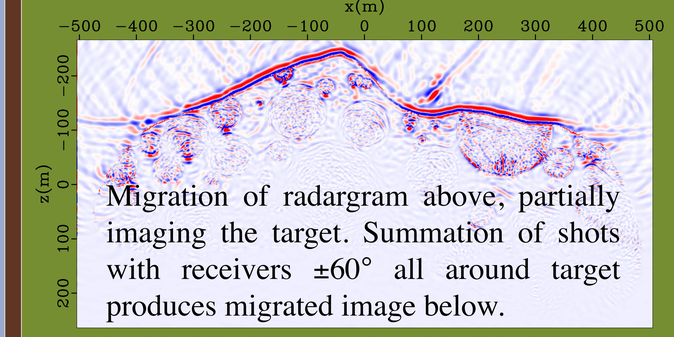


Single spacecraft produces one global radargram that is migrated (inverted) for the positions of reflectors (discontinuities) .

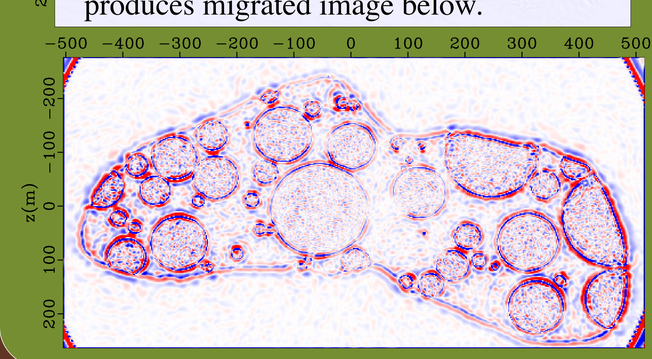


Two spacecraft separating transmitter and receiver provide geometric diversity that enhances imaging. Radargram below is for a shot at longitude 90° (x = 0, z = 1.9 km) with records gathered from longitudes ±60°. In practice, this would be from a number of different orbits, depending on the periods of the primary and secondary spacecraft.

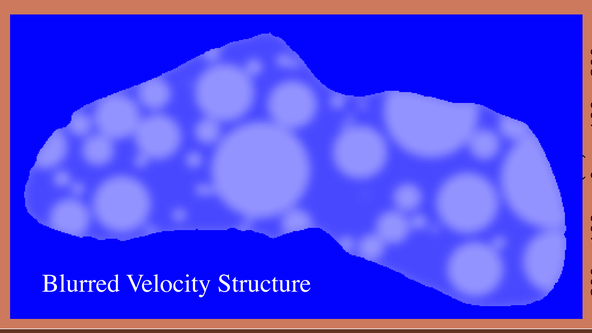


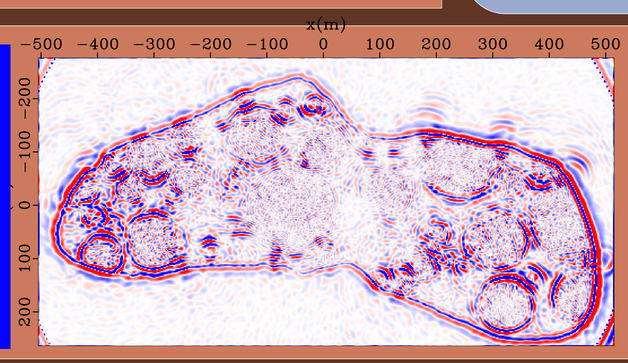


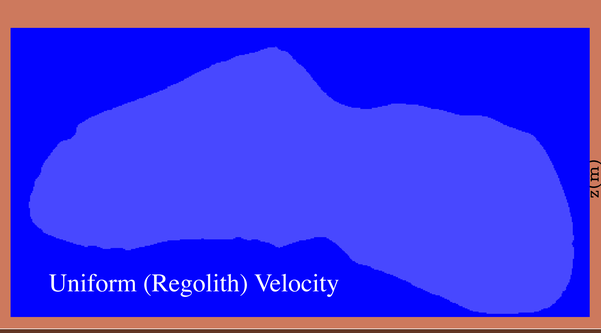
Migration of radargram above, partially imaging the target. Summation of shots with receivers ±60° all around target produces migrated image below.

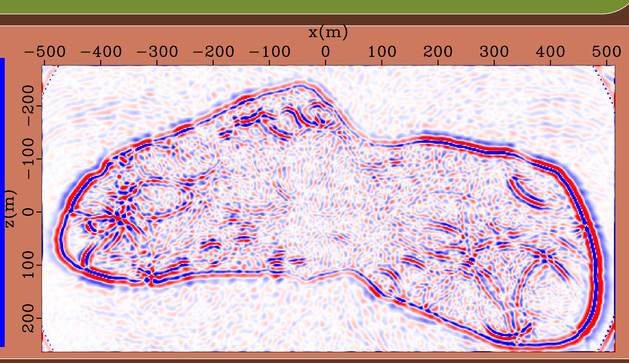


Effect of Prior Knowledge of Velocity Structure. The preliminary tests of interface imaging were performed using perfect knowledge of the velocity structure. If incorrect velocities are used, imaging is degraded (see below). In practice, velocity is derived iteratively with imaging. Elastic-wave velocity contrasts in terrestrial sedimentary basins—where seismic imaging is predominantly practiced—are generally smaller than expected for rock-regolith-vacuum EM-wave contrasts in asteroids, so it is easier to derive a matching velocity model. We will next develop joint migration tomography to solve simultaneously for velocity structure and interface positions.









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