REMOTE SEISMIC EXPLORATION OF SMALL PLANETARY BODIES

Exploring the interior structure of small planetary bodies (i.e., moons, asteroids, comets) is critical in understanding solar system evolution, developing planetary defense strategies, and supporting human exploration. Information about interior structure and composition provides direct evidence of accretion processes. Knowledge of mechanical properties is required to deflect potentially hazardous near-Earth objects. Mapping the distribution of critical resources, especially volatiles like water-ice, is paramount in sustaining human exploration.

To provide high-resolution imaging of the subsurface, the two most promising geophysical techniques are ground-penetrating radar (GPR) and seismic. GPR struggles to penetrate through rocky conglomerates, limiting penetration depths. Radar also reflects weakly in highly conductive materials like water-ice providing limited information about internal structure. Seismic methods however are sensitive to materials' mechanical properties and thus excel in probing both rocky and icy interior structures, but microgravity conditions make landing and coupling of seismic instruments challenging and costly. Moreover, active seismic sources could dislodge debris from the surface creating a hazardous environment to the seismic instrument and the monitoring spacecraft.

We propose the use of remote sensing seismometers in which two (or more) laser Doppler vibrometers (LDVs) observe the surface of a small body from orbit. Data recorded by an LDV is analogous to that of a traditional seismometer, representing the ground motion at an observation point. Instead of deploying artificial sources, LDVs used in this configuration observe seismic activity caused by naturally occurring sources like tidal deformations, thermal gradients, and spin-up effects. By utilizing techniques developed in seismic interferometry, ambient seismicity can be used to recover the travel time between virtual receivers (the LDV observation points distributed on the surface) which can then be used to perform interior seismic tomography. We demonstrate this approach by modeling remote seismic acquisition on asteroid 99942 Apophis and show that this method can successfully recover travel times between receiver arrays facilitating safe interior imaging of mechanical properties.