GRAIL Refinements to Lunar Seismic Structure

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Joint interpretation of disparate geophysical datasets helps to reduce drawbacks that can result from analyzing them individually. The Apollo seismic network was situated on the lunar nearside surface in a roughly equilateral triangle having sides approximately 1000 km long, with stations 12/14 nearly co-located at one corner. Due to this limited geographical extent, near-surface ray coverage from moonquakes is low, but increases with depth. In comparison, gravity surveys and their resulting gravity anomaly maps have traditionally offered optimal resolution at crustal depths. Gravimetric maps and seismic data sets are therefore well suited to joint inversion, since the complementary information reduces inherent model ambiguity.

Previous joint inversions of the Apollo seismic data (seismic phase arrival times) and Clementine- or Lunar Prospector-derived gravity data (mass and moment of inertia) attempted to recover the subsurface structure of the Moon by focusing on hypothetical lunar compositions that explore the density/velocity relationship. These efforts typically search for the best fitting thermodynamically calculated velocity/density model, allowing variables like core size, velocity, and/or composition to vary freely.

Seismic velocity profiles previously derived from the Apollo seismic data through inversion of travel times vary both in the depth of the crust and mantle layers, and the seismic velocities and densities assigned to those layers. The lunar mass and moment of inertia likewise only constrain gross variations in the density profile beyond that of a uniform density sphere. As a result, composition and structure models previously obtained by jointly inverting these data retain the original uncertainties inherent in the input data sets.

We will perform a joint inversion of Apollo seismic delay times and gravity data collected by the GRAIL lunar gravity mission, in order to recover seismic velocities and density as a function of latitude, longitude, and depth within the Moon. We will relate density to seismic velocity using a linear relationship that is allowed to be depth-dependent. The corresponding coefficient (B) can reflect a variety of material properties that vary with depth, including temperature and composition. The inversion seeks to recover the set of density, velocity, and B-coefficient perturbations that minimize (in a least-squares sense) the difference between the observed and calculated data.