The Lunar Physical Librations

X X Newhall / J. G. Williams
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, CA 91109-8099

Analysis both of 25 years of Lunar laser ranging observations and of an accompanying 718-year numerical integration of the Moon and planets has enabled an examination of the Moon's three dimensional rotation (physical librations). The model used for the librations in the integration includes the interaction of the lunar figure (including the effects of solid tides) with the figure of the Earth and with the point mass Sun, Venus, Earth, and Jupiter. Also modeled are tidal dissipation in the lunar mantle and viscous dissipation at the boundary between the mantle and a possible lunar core.

A Fourier analysis of the integrated librations produced results for both the forced and free librations. The forced terms arise from external torques and are predicted well. There are three free libration modes, each representing a departure from an equilibrium condition. They have known periods, but their amplitudes and phases are not predictable and must be measured.

The results for the forced terms are in general agreement with theory, except that a long-period term was found that cannot be identified with a single, constant period. For the free libration in longitude, theory predicts a period of 1056 days, a value almost identical to that of one of the forced terms. A term having precisely that period was found; its amplitude (a combination of the free and forced librations) is 1.8″.

A latitude libration at 74.59 year was found, with an elliptical amplitude of 3.3″ by 8.2″. Because free librations will normally damp out in a comparatively short time, the presence of these terms suggests some sort of stimulation mechanism.