INTACT PLANETOID CAPTURE: APPLICATION TO PLANETS VENUS AND EARTH;
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A three-body (sun, planet, planetoid) numerical integration code with an energy-dissipation subroutine (using equations from [1]) has been devised to assess the possibilities of intact gravitational capture by way of radial tidal energy dissipation within the interacting bodies. This study is restricted to venus-like and earth-like planets in appropriate heliocentric orbits interacting with lunar-like (lunar mass and density) planetoids in coplanar orbits with geometries similar to the respective planetary orbits. The major variables for the two interacting bodies are: (1) the pericenter distance (r_p) of close encounters, (2) the displacement Love number (h) for each body (see [2] for Love number discussion), (3) the effective tidal dissipation factor (Q) for each body (see [2, 3, 4] for discussions of Q), (4) the planet anomaly (the position of the planet relative to the sun at the beginning of the calculation), and (5) the planetoid anomaly (the position of the planetoid relative to the planet at the beginning of the calculation). The results of these simulations can be placed into five categories: (1) close non-capture encounters in which the planetoid is deflected into a near parabolic course by the planet and then continues on a heliocentric orbit; (2) non-capture scenarios in which the planetoid goes into a planetocentric orbit for a few orbits and then returns to a heliocentric orbit; (3) stable gravitational capture scenarios in which the planetoid enters into a planetocentric orbit because of radial tidal energy storage and concomitant dissipation within the two interacting bodies; (4) grazing collision scenarios in which the closest approach distance is greater than the sum of the planet-planetoid radii but less than the grazing limit when the equilibrium tidal bulges are considered; and (5) collision scenarios in which the distance of closest approach is less than the sum of the planet-planetoid radii. (See [5] for calculated examples of the above interactions for a lunar-like planetoid and an earth-like planet.) The minimum energy dissipation for stable intact capture depends on (1) the maximum major axis for a stable planetocentric orbit (stable relative to solar perturbations) and (2) the difference in eccentricity (Δecc.) between the planet and planetoid orbits. Calculations for planetoids in prograde geocentric orbits in an elastic system (no energy dissipation) suggest that orbits with apocenter distances beyond about 200 R_e (earth radii) are unstable. The total energy for a lunar-mass body in a geocentric orbit with a major axis of 200 R_e is about -2.3×10^{35} ergs. Thus, about that much energy must be dissipated within the interacting bodies during a close encounter cycle for stable capture, if Δecc. is near zero. A close encounter within 1.43 R_e (when $h_{planetoid}= 0.5$, $h_{earth}=0.7$, $Q_{system}=1$) is sufficient for stable gravitational capture. Calculations for planetoids in prograde venocentric orbits in an elastic system suggest that orbits with apocenter distances beyond about 150 R_v (venus radii) are unstable relative to solar perturbations. The total energy for a lunar-mass body in an orbit with a major axis of 150 R_v is about -2.6×10^{35} ergs. Thus, about that much energy must be dissipated within the interacting bodies during a close encounter for stable capture, if Δecc. is near 0. Only close encounters near 1.38 R_v (which is the grazing encounter limit when equilibrium body deformation is considered for the case where $h_{planetoid}$=0.5, h_{venus}=0.7, Q_{system}=1) can result in stable prograde capture. Retrograde, coplanar, intact planetoid capture may not be possible for an earth-like planet in an earth-like orbit. In over 50 retrograde, three-body, coplanar runs we have not been successful in capturing a lunar-like planetoid in a retrograde geocentric orbit (all encounters within the capture window have resulted in collision). However, we have been successful in capturing lunar-like bodies into retrograde venocentric orbits. The stability limit for retrograde venocentric orbits (maximum apocenter distance) in an elastic system is about 200 R_v. Thus about 2.0 X 10^{35} ergs must be dissipated within the two interacting bodies for stable capture. A pericenter distance within 1.44 R_v is necessary for dissipation of that much energy during one close encounter (using the deformation constants listed above for the bodies).

Some tentative conclusions from our limited set of calculations (all coplanar) are: (1) that prograde capture for a lunar-like planetoid encountering an earth-like planet is possible under a range of physical conditions, (2) that retrograde capture of such a planetoid is apparently not possible for an earth-like body, (3) that prograde capture of a lunar-like planetoid by a venus-like planet can only occur under very restricted conditions (a grazing encounter), and (4) that retrograde capture of such a planetoid by a venus-like planet is possible under a limited range of conditions.

REFERENCES: [1] Peale, S. J., and Cassen, P. (1978) Icarus, 36, 245-269; [2] Stacey, F. D. (1977) John Wiley and Sons, 414 p.; [3] Goldreich, P., and Soter, S. (1966) Icarus, 5, 375-389; [4] Ross, M., and Schubert, G. (1986) J. Geophys. Res., 91, D447-D452; [5] Malcuit, R. J., Mehringer, D. M., and Winters, R. R.(1989) Proc., 19th LPSC, Cambridge Univ. Press and Lunar and Planetary Inst., in press.

Figure 1. Composite diagram showing a few orbits of a stable retrograde capture scenario of a lunar-like planetoid by a venus-like planet (located at origin of plot) in a non-rotating reference frame. Some values for this run are h_{pl}=0.5, h_v=0.7, r_p=1.47 R_v, Q (system)=1, venus anomaly (initial position of venus relative to sun)=205° (venus moves counter-clockwise, day= 24 hr). (a) Orbits 1-3. Note the effects of solar perturbations to cause notably non-keplerian orbits. (b) Orbits 19-20. Note that the maximum apogee distance (reflecting total energy) has decreased from about 180 R_v in orbit 2 to about 150 R_v in orbit 20. Orbital energy dissipated during this 20 orbit scenario = 3.6 X 10^{35} ergs.