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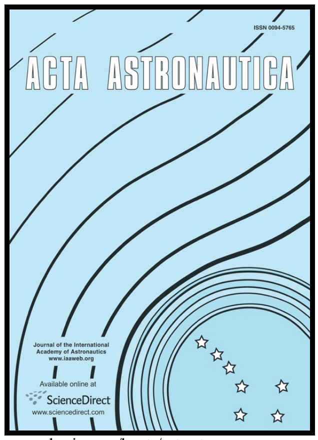

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Steady flows in rotating spherical cavity excited by multi-frequency oscillations of free inner core[☆]

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Abstract
Fluid motion in a rotating spherical cavity in the conditions of resonant oscillations of free inner core is experimentally investigated. The centrifugal force retains a solid core with density less than the fluid density near the center of the cavity. In the absence of external force field the system “solid core – liquid” performs solid body rotation. The oscillations of the core are excited by an external oscillating force field and this results in differential rotation of the core with respect to the cavity. The direction of rotation is determined by the ratio of the oscillation frequency to the cavity angular velocity. The core oscillations with the radian frequency, which exceeds the cavity angular velocity, are investigated. It is found that a steady flow in the form of a system of nested fluid columns of circular cross section, which rotate at different angular velocities, is generated in the cavity as a result of oscillations of the core and the fluid. It is shown that at simultaneous influence of several oscillating fields the resulting steady flow is determined by a linear superposition of the flows, which are excited by the oscillations of the inner core with different frequencies. At a certain ratio of the vibration frequency to the rotation one the transformation of the circular shape of the column into the elliptical one is observed.

Keywords: rotation, vibration, multi-frequency oscillations, solid core, differential rotation, steady flows

1. Introduction

A study of a fluid behavior in the cores of rotating planets is an actual astrophysical problem [1]. Rotation and inertial forces associated with it, in particular the Coriolis force, do not only change the laws of convective fluid motion [2], but also lead to the existence of specific inertial waves [3]. A characteristic feature of the rotating stars and planets is an oscillation of fluid in the cores, which may be due to various reasons. These include the tidal deformations of solid shell of a rotating planet [4–6] as a result of gravitational interaction with neighboring planetary bodies, librations [7–9] or precession of the rotation axis [10, 11]. In these cases, the periodic disturbances cause the oscillations of the liquid core, which give rise to steady flows. A review of papers devoted to the flows which are generated by a periodic mechanical forcing is presented in [12].

In addition to these reasons, the oscillation of fluid can be excited directly by oscillation of an inner solid core. An example is the free oscillations of an inner core in a planet of buoyant nature, which are named a "Slichter triplet" [13–15]. One of the modes characterizes the oscillations along the axis of rotation, and two others – the oscillations of circular polarization in the equatorial plane. Each of these modes can be excited in a resonant manner in the case of external periodic influence with a proper frequency. A theoretical and experimental study of the effect of circular oscillations of a free inner core on its dynamics has been studied in a two-dimensional problem in [16]. The investigations have shown that as a result of the oscillations the core which is located near the axis of rotation comes into a differential rotation relative to the cavity. The direction of rotation is determined by a dimensionless frequency (the ratio of vibration frequency and cavity angular velocity) $n = \Omega_{vib} / \Omega_{rot}$: for $n < 1$ a lagging rotation is excited and for $n > 1$ – a leading one. The rotation of the solid core is explained by the average forces, which are generated in oscillating viscous boundary layers near the solid boundaries. In

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