Superrotation of rarefied atmosphere of slowly rotating planets

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Experimental studies of atmospheric flows carried out for Venus, Earth, Mars and the Saturn's satellite Titan have established the possibility of superrotation of their atmospheres at large heights. This superrotation is characterized by the ratio of the angular velocities of the atmosphere and the planet. Several possible superrotation mechanisms have been discussed in the literature, but none of them was universal indeed. Here, we consider the kinetics of a rarefied exosphere replenished with particles injected from a spherical surface inside which collisions are significant. As we show, peculiarities of the motion of a rarefied gas in the gravitational field of a slowly rotating planet can give rise to superrotation. It follows from the laws of motion that suficiently fast particles can rise high and even recede to infinity. Because of the angular rotation of the planet, the particles whose velocity has the same direction as the rotational velocity of the planet will have a higher initial velocity. Primarily these particles can recede appreciably from the planet to become its "satellites" due to weak collisions. Therefore, we have reason to expect that the mean angular velocity of the particles in the upper planetary atmosphere can exceed the angular velocity at its inner boundary. A quantitative analysis of this problem based on the exact solution of the kinetic Boltzmann equation. We consider the kinetics of a rarefied rotating planetary exosphere. The spatial distributions of the atmospheric gas density and mean angular velocity were determined by analyzing the exact solution of the two-dimensional kinetic equation. We show that the angular velocity of the gas at some distance from the planet could be higher than that in the initial layer starting from which the atmosphere is rarefied. Our model calculations elucidate the superrotation mechanism under consideration.