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ANALYTICAL INVESTIGATION OF THE BEHAVIOR AND DISTRIBUTION OF DUST PARTICLES TRAPPED IN HORSESHOE ORBIT

Abstract

Interplanetary dust particles are observed from an astronomical satellite as thermal flux of infrared ray. For infrared space observatory, removal of the infrared radiation from dust particles brings higher quality of scientific observation. To produce the precise model on the distribution around Earth's orbit has been required. In our paper (2009 IAC Norizumi Motooka) the distribution was predicted and calculated numerically on the assumption that dust particles which are trapped in a horseshoe orbit by the Earth's gravity contribute the distribution. A horseshoe orbit is numerical solution of the restricted three-body problem (R3BP) which encompasses Lagrage point L3, L4 and L5. But not only numerical solution but also analytical one are required, because the analytical solution can clearly indicate the cause-and-effect relationship between external forces acting on a dust and its distribution. Therefore, this paper investigates the behavior of a dust particle on the horseshoe orbit and the dust distribution by solving two equations which incorporate solar radiation pressure as major perturbation source.

First of all, we analyzed the motion of each single dust particle on the horseshoe orbit by solving the equation of R3BP approximately. The horseshoe orbit solution is obtained by coordinate transformation and linearization of external forces on the assumption that the horseshoe orbit is the ocillation centered at L3. This solution shows that the velocity of a dust becomes minimum at both ends of the horseshoe orbit, which is consistent with numerical integration of non-linear equation of the R3BP . This result indicates that the dust density is maximum at both edges of the horseshoe orbit.

Secondly, to investigate the dust distribution or density around the Earth's orbit from other side of view, the non-collision Boltzmann equation was analyzed. The collisions and mutual attraction between dust particles on the Earth's orbit can be neglected because the distance between dust particles and the mean free path of a dust are very long. Therefore the time variation of the distribution function is expressed by the Boltzmann equation without the collision term. Analysis of the equation also produced the same prediction as described above.

Both of these analyses indicated the same fact that the number density of dust particles is maximum at both edge of the horseshoe orbit. And it was confirmed that these analyses are consistent with numerical calculation. For the future work, incorporating other perturbation forces such as Poynting-Robertson drag will bring more precise prediction.