# INVESTIGATION OF ORBITAL EVOLUTION OF INTERPLANETARY DUST PARTICLES ORIGINATING FROM KUIPER BELT AND ASTEROID BELT OBJECTS

*[1] PALAK DHARSANDIA, [2] DR. JAYESH PABARI, [3] DR. CHARMY PATEL*

**[1] Research Scholar, V. V. P. Engineering College, Rajkot**
**[2] Researcher, Physical Research Laboratory, Ahmedabad**
**[3] Associate Professor and Head of the Electronics and communication department, V. V. P. Engineering College, Rajkot**

***Palak.dharsandia@gmail.com, jayesh@prl.res.in, crpvvp@gmail.com***

***ABSTRACT :*** *It is known that interplanetary dust particles are originated from the Kuiper belt object in solar system. Asteroids and short period comets are also considered as two major sources of interplanetary dust particles. To know the expected orbital evolution of dust grains we used Mercury code. In this simulation, we have used hybrid symplectic algorithm for the integration. The code is capable of handling the close encounter between the objects. The model includes gravitational effect of known planets and the Sun, Poynting-Robertson (P-R) drag, solar wind drag, and radiation pressure. A set of β ratio of radiation pressure force and gravitational force values taken are 0.2, 0.1, and 0.05 in this simulation. The orbital evolution of dust grains of radii 1 to 10 μm are calculated. Due to the effect of the radiation forces, small dust grains spiral out from the solar system. The bigger (>0.5 μm) dust particles spiral in towards the Sun. This orbital evolution of dust particles undergo influence of gravitational perturbation and mean motion resonance with planets. When they escape the resonance, their journey start again. Our result shows that in inner solar system lesser dust are coming from Kuiper belt compared to those from asteroid belt. Kuiperoidal dust grains are seen to behave same like asteroidal dust. The result is useful to understand the dust movement in solar system.*

***Key Words : Interplanetary Dust, Kuiperoidal Dust, Asteroidal Dust***



## 1. INTRODUCTION

In recent intimation NASA founded that a cloud of dust was encircling mars above high-altitude atmosphere [Christian 2015]. This Interplanetary dust particles (IDPs) are too grandly. It is considered to have perform important role in the composition and enhancement of our solar disc.

Inter planetary dust particles are one kind of the natural component of solar system. Our solar system has with IDPs. Whose motion is governed by combined gravitational effect of the big bodies of the solar system, radiation force, P-R drag and solar wind drag [Stanley F. Dermott 1996]. Asteroids and short-period comets have been two major sources of IDPs. It is also recognized that trans-Neptunium might also be one of the sources of IDPs. In this paper, orbital pattern of IDPs is numerically simulated. We stretched out of orbital evolution of dust particles with the help of Mercury model [J. E. Chamber 1998]. By taking two different sources of IDPs, i.e. asteroid belt and Kuiper belt.

## 2. COMPUTATIONAL METHOD AND INITIAL CONDITION

Using Hybrid Symplectic integrator [J. E. Chamber 1998] we, explore the orbital evolution of interplanetary dust particles under the effect of gravitational force of all planets, the Sun, PR drag, radiation drag and solar wind. The essential theory of hybrid symplectic integrator can be clear with understanding of Hamilton's equation. These give the rate of change of position *x*, and rate of change of momentum *p*, for all objects in solar system. This equation are [Ref. J. E. Chamber 1998]

$$\frac{dx_i}{dt} = \frac{\partial H}{\partial p_i} \text{ ………. (1)}$$

$$\frac{dp_i}{dt} = -\frac{\partial H}{\partial x_i} \text{ ………. (2)}$$

The Hamiltonian H is addition of kinetic energy and potential energy of all bodies defined as [Ref. J. E. Chamber 1998]

$$H = \sum_{i=1}^{N} \frac{{p^2}_i}{2m_i} - G \sum_{i=1}^{N} m_i \sum_{j=i+1}^{N} \frac{m_j}{r_{ij}} \text{ ………. (3)}$$

where $m_i$ is mass of the body i and $r_{ij}$ is separation of body i and j.

We take the quantity $\beta$ as a ratio of radiation pressure force and solar gravitational force. In our simulation, the values of $\beta$ is consider as a 0.2, 0.1 and 0.05 for particle density 1 gm. $cm^{-3}$ are taken. [Ref. Burns et al. 1979] has given the expression of $\beta$ as

$$\beta = \frac{0.573Q_{pr}}{\rho s} \text{ ......... (4)}$$

Where $\rho$ is the particle's density in gm. $cm^{-3}$ and $s$ is the radius in $\mu m$, and $Q_{pr}$ is the radiation pressure coefficient. For particles larger than $1\mu m$ $Q_{pr}$ is close to unity.

Figure 1 shows that efficiency of drag forces decrease while increase in the particles size. Effect of radiation pressure is significant when size of particles are in order of 40 micron or less.

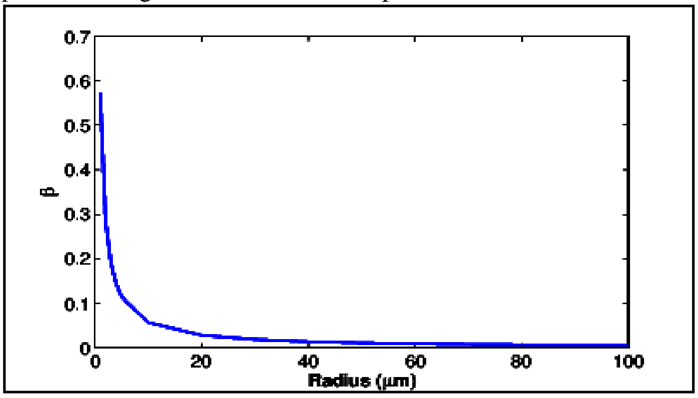


*Figure 1 : Variation of beta with particle's radius*

The particles come out of the asteroid or comets due to outgassing and collisions. When particles come out from parent body they will immediately feel drag forces like P-R drag, solar wind drags and radiation pressure and move to new semi-major axis and eccentricity, which are different from its parent body.

Let $a_n$ and $e_n$ are the new semi-major axis and eccentricity of dust particles when particle leave its parent body. The parameter $a$ and $e$ are the actual semi-major axis and eccentricity of the parent body while dust particles are part of the parent body [Jackson and Zook 1992]

$$a_n = \frac{(1-\beta)(1-e)a}{(1-e-2\beta)}$$

$$e_n = \frac{(e+\beta)}{(1-\beta)}$$

Figure 2 shows how the new semi-major axis varies for different sizes of particles while modified by radiation pressure. There are two different sizes of particles taken first is for asteroid and the other is for comet. For asteroid ($a$ = 2.77, $e$ = 0.17) taken as an average of main belt from [Allen 1962] and for a comet ($a$ = 3.5, $e$ = 0.6) taken from the range given by [Porter 1963].

One can observed from the results that the dust particles initiate their orbital evolution from starting orbits that is different from its parent body.

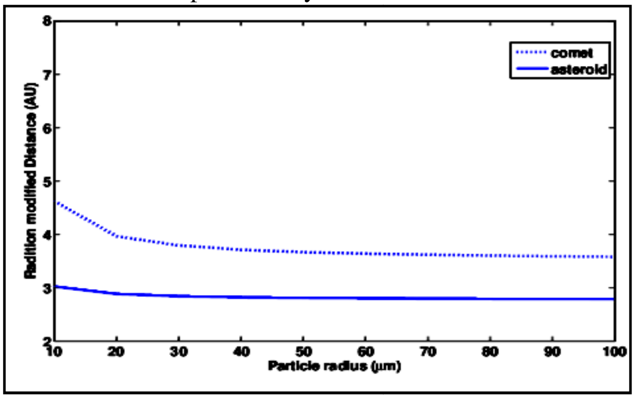


*Figure 2 : Radiation modified distance of the dust grains originated from their parent bodies*

### 3. EVOLUTION OF DUST FROM KUIPER BELT OBJECTS

The average distance of Kuiperoidal dust from Sun is far while that of asteroidal dust. Because of this large distance Kuiperoidal dust experience very little solar drag forces. The gravitational force experienced is also small compared to that experienced by asteroid belt dust.

We have taken 130 objects of Kuiper belt as a parent body of dust particles and calculated new semi-major axes and eccentricities for dust particles considering three β values. The dust initially was distributed in a spatial range of 30-70 AU. We have divided the dust into 4 bins of 10 AU according to the distance from Sun. First bin ranges from 30 to 40 AU and so on. These dust particles were simulated for $\beta = 0.05$. As $\beta$ value increases distance of the particles from Sun also increases. Table 1 summarizes initial parameters and orbital condition during the simulation time period of the dust grain under consideration.

*Table 1 Orbital condition of Kuiper belt at various distance*

| β value | Distance | Orbital condition |
|---|---|---|
| 0.05 | 30-40 | MMR |
| | 40-50 | MMR |
| | 50-60 | MMR |
| | 60-70 | Stable |
| 0.1 | 40-50 | Stable |
| | 50-60 | Stable |
| | 60-70 | Stable |
| | 70-80 | Ejected |
| 0.2 | 50-60 | Stable |
| | 60-70 | Stable |
| | 70-80 | Ejected |

The Kuiperoidal dust behaviour is same as the asteroidal dust, with the only difference that, effect of a slower P-R drag and a stronger potency of the giant planets, the preface of gravitational force and resonance captured must be more consideration for it.
Figure 3. shows the result of simulation with Kuiper belt dust of different initial semimajor axis and β combination. X axis shows time in year and Y axis shows the semimajor axis in AU. In this graph few particles are ejected, few particles are captured in Mean Motion Resonance (MMR) with planets. After the particles escape MMR, their semi-major axis decreases and they start their journey towards the Sun. Few particles stay temporally captured in solar system, they apparent do not undergo MMR nor they get ejected in the shown time period. Particles with ($\beta = 0.1$, $a = 76.6$) and ($\beta = 0.2$ and $a = 75.24$) are ejected from solar system. Particles with ($\beta = 0.05$, $a = 55.6$), and ($\beta = 0.05$, $a = 38.4$), and ($\beta = 0.05$, $a = 45.6$) are trapped in MMR with Neptune and Uranus. Other particles are stay temporally in solar system. Therefore, particles in great distance (~ 75 AU) get ejected within 100 – 1000 years of their motion almost regardless of their size. This plot also shows the particles with $\beta = 0.05$ undergoes MMR while particles with larger $\beta$ values but at similar distance does not undergo MMR.

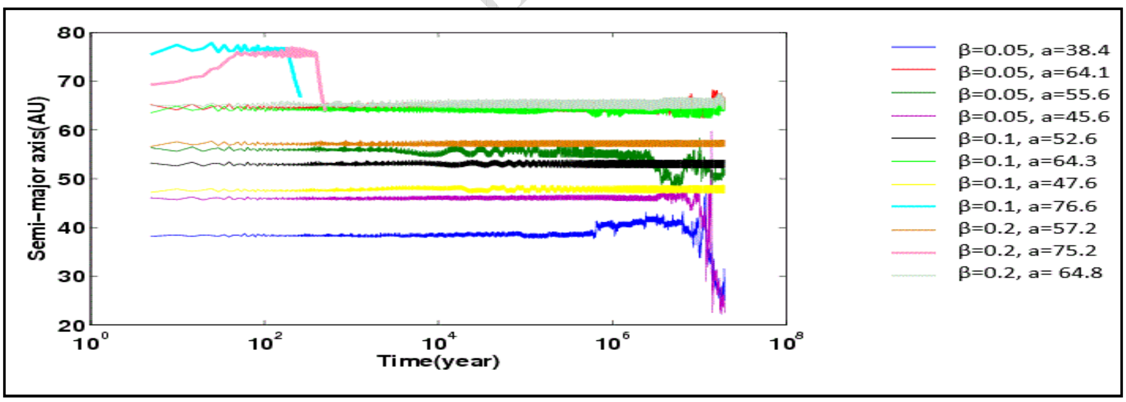


*Figure 3 : Temporally evolution of semi-major axis of dust particles from Kuiper belt objects*

Temporal Evolution of eccentricity and inclination corresponding to the particles in Figure 3 has been shown in Figure 4 and Figure 5 respectively. Particles undergoing MMR is seen to spiral in towards Sun as seen in Figure 4 and Figure 5.

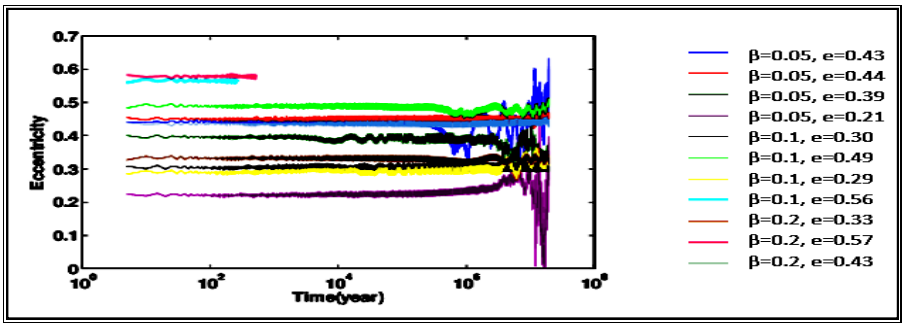


*Figure 4 : Temporally evolution of eccentricity of dust particles from Kuiper belt objects*

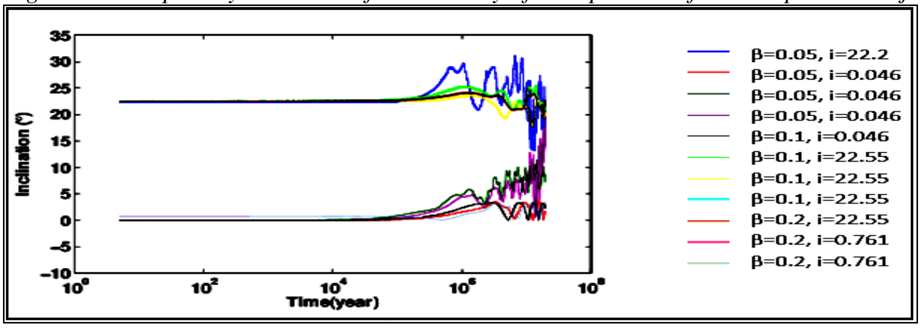


*Figure 5 : Temporally evolution of inclination of dust particles from Kuiper belt objects*

## 4. EVOLUTION OF DUST FROM ASTEROID BELT OBJECTS

This section includes the distribution of dust from asteroid belt objects. Asteroid belt is between Jupiter and Mars. Therefore, MMR with Earth Jupiter and Mars plays important role in orbital evolution of asteroidal dust. The simulation for asteroidal dust particles has been done considering three regions main belt, inner belt and outer belt. 50 objects from Main belt, 100 objects from inner belt and 97 objects from outer belt is considered as parent body in the calculation. We take a mean of semimajor axis and eccentricity for each region of the asteroid belt for three $\beta$ values in our simulation. Table 2. Summarized the simulation result of asteroid belt dust.

Table 2 Orbital condition of asteroid belt at various distance

| B | Distance | Orbital condition |
|---|---|---|
| 0.05 | Inner belt | Stable |
| | Main belt | Ejected with MMR |
| | Outer belt | Ejected with MMR |
| 0.1 | Inner belt | Ejected with MMR |
| | Main belt | Ejected with MMR |
| | Outer belt | Ejected with MMR |
| 0.2 | Inner belt | Ejected with MMR |
| | Main belt | Ejected with MMR |
| | Outer belt | Ejected with MMR |

Figure 6. Shows the result of the simulation for asteroid belt dust. X axis shows time in year and Y axis shows the semimajor axis in AU. In this simulation all the particles are seem to undergo MMR but the one with $\beta$ value 0.05 and $a$ = 2.02. This shows that for asteroid belt dust $\beta$ = 0.05 and $a$ = 2.02 can be minimum condition for stable orbit. Corresponding eccentricity and inclination are shown in figure 7 and Figure 8.

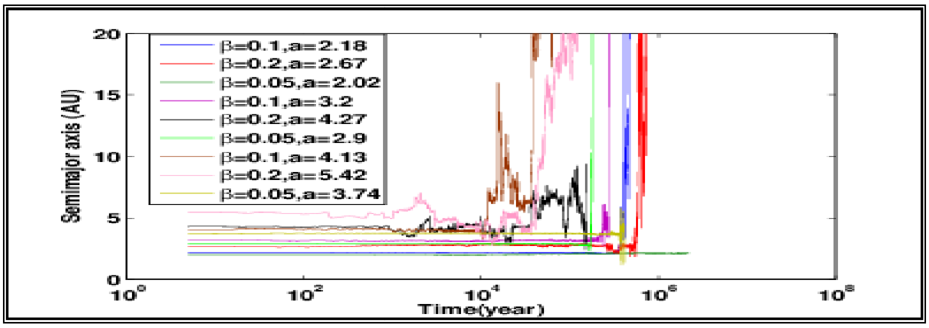


*Figure 6 : Temporally evolution of semi-major axis of dust particles from asteroid belt objects*

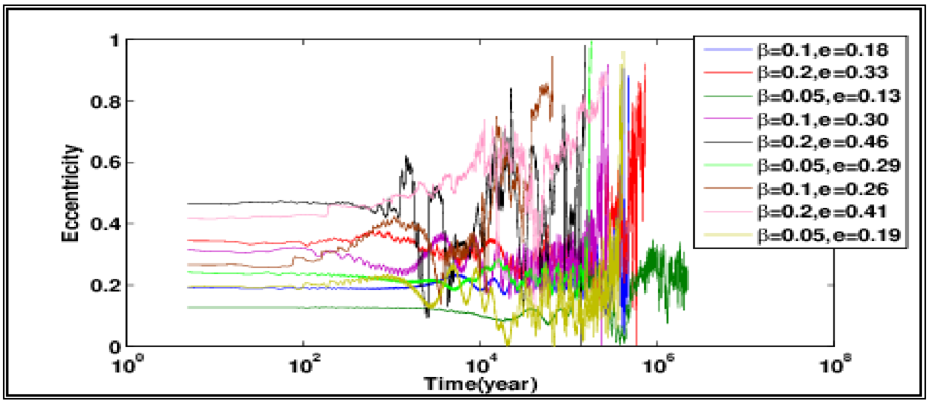


*Figure 7 : Temporally evolution of eccentricity of dust particles from asteroid belt objects*

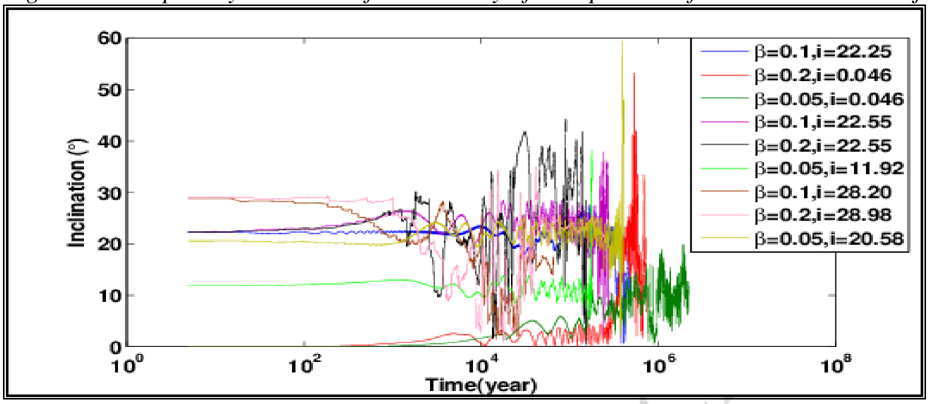


*Figure 8 : Temporally evolution of inclination of dust particles from asteroid belt objects*

## 5. CONCLUSION

We have studied the orbital evolution of dust particles originated from Kuiper and asteroid belt objects. These dust particles show different nature in their orbital evolution. We found that dust particles from Kuiper belt with a distance greater than 75 AU get ejected within 100 – 1000 years of motion. For particles with $\beta = 0.05$ within distance 38 – 55 AU undergoes MMR but if $\beta$ is increased for the same distances the MMR does not happen. Unlike Kuiper belt almost all the particles of asteroid belt get ejected after going through MMR. Particles with $a \leq 2.02$ and $\beta = 0.05$ are in relatively stable orbit. The result given in this paper are useful to understand dust movement in the solar system.

## 6. ACKNOWLEDGEMENTS

Authors thank Dr. J. E. chamber for providing suggestion for the Mercury model and Mr. Ashimananda Modak for fruitful discussion and suggestions.

## 7. REFERENCES

1. Stanley F. Dermott et al., “Kuiper belt dust grains as a source of interplanetary dust particle”, *ICARUS*, 1996 124, 429-440.
2. J. E. Chambers et al., “A hybrid symplectic integrator that permits close encounters between massive bodies”, *Astron*., 1998.
3. Alexander V. Krivov et al., “Martian dust belts: waiting for discovery”, *Icarus,* 1997, 128, 335-353.
4. A. Jackson et al., “Orbital evolution of dust particles from comets and asteroid”, *Icarus*, 1992, 97, 70-84.
5. Nick N. Gorkavyi et al., “Distribution of dust from Kuiper belt objects”, *astrophysics, 2000.*
6. Burns et al, “Radiation force on small particles in the solar system”, *Icarus*, 1979, 40, 1-48.
7. Allen C. W. et al., “Astrophysical quantities”, The athelone press, University of London,1962.
8. Porter J. G. et al., “Statistics of comet orbits, in the moon,meteorites and comets”,1963