DETACHMENT OF INTERPLANETARY DUST PARTICLES FROM ASTEROID BELT. J. P. Pabari[1], Rashmi[1], K. Acharyya[1], S. Nambiar[1], S. Jitarwal[1], V. Sheel[1], Anil Bhardwaj[1] and D. Kumar[2], [1]Physical Research Laboratory, Navrangpura, Ahmedabad-380009, INDIA. Email: jayesh@prl.res.in, [2]BITS, Hyderabad, INDIA.

Introduction: Asteroid belt is the main source of Interplanetary Dust Particles (IDPs) in our solar system. The other sources are Kuiper belt and occasional comets entering the solar system. It is expected that all size of particles starting from few hundreds of nanometer to big asteroids are present in the belt. The belt particles have been bound to it , either from the time of formation of the solar syetem or they might have been produced due to collisions of bigger objects. The dust particles remain attached to the system as long as the gravitational influence of the Sun, planets and other minor objects balance each other. In other words, the IDPs remain attached to the belt for a given orbit as long as the balancing inward force is greater than the outward force. They evolve dynamically over the geological time scale and start to deviate from their original orbits. Mathematically, this is an N-body integration problem. In an N-body problem, we simulate the dynamical system of particles under the influence of physical forces like gravity.

N-Body Integration Problem for IDP Evolution: The equations of motion in a system of N objects under the influence of mutual gravitational forces are integrated numerically in the gravitational N-body simulations. Such computations are useful to study the dynamics of planets and other objects in the solar system. Computationally, the N-body integration may be solved using a tree method, in which the volume is divided into cubic cells and only interactions between particles from neighbouring cells are treated, thus reducing the number of particles interactions that are computed. Another possibility to solve the N-body integration is the particle mesh method, in which space is discretised on a mesh and the gravitational potentials are computed for the objects. The N-body problem is a problem of predicting the individual motions of a group of celestial objects interacting with each other gravitationally.

The symplectic integrators have advantages over other N-body integrators in terms of no long-term build-up of energy error and being substantially faster for problems in which most of the mass is contained in a single body. The basic theory of symplectic integrators can be understood by starting with Hamilton's equations of motion. The rate of change of position (x) and the momentum (p) for each object within an N-body system is given by

$$dx_i/dt = \partial H/\partial p_i \quad (1)$$

$$dp_i/dt = -\,\partial H/\partial x_i \quad (2)$$

where the Hamiltonian H, is the sum of the kinetic and potential energy terms for all the bodies. The solution of the N-body problem is provided by MERCURY code [1] is a general-purpose software package for doing N-body integrations. We have used it for studying the dynamical evolution of IDPs, which are in the ateroid belt.

Simulation Parameters: The MECURY code requires some seed parameters to start the simulation. These are taken as 1 µm radius IDP with the particle density as 2 g cm^{-3}. Different values of the semi-major axis (a), eccentricity (e) and inclination (i) of IDP are taken, which indicate initial position of the particle in asteroid belt. The range of semi-major axis for the inner most part of the asteroid belt is from 2.1 to 2.5 AU [2], which has been considered for the simulation, as the objective is to study the inward motion of the particles. The range of eccentricity is made available online [3] and it is varying from 0.01 to 0.4. Also, the inclination of the objects in the inner most part of the asteroid belt is between 0° to 20° [3].

Simulation Results: The simulation was run for ~33 My by providing the seed paramerets and allowing the IDP trajectory to evolve over the geological time scale. Our results of the semi-major axis are shown in Figure 1 and Figure 2 for the initial eccentricitry of 0.2 and 0.3, respectively. One can observe from these results that the IDP start deviating from its original orbit when the value of eccentricity is between 0.2 and 0.3. We have run the code for different values and found that the deviation occurs for the initial eccentricity value greater than 0.25.

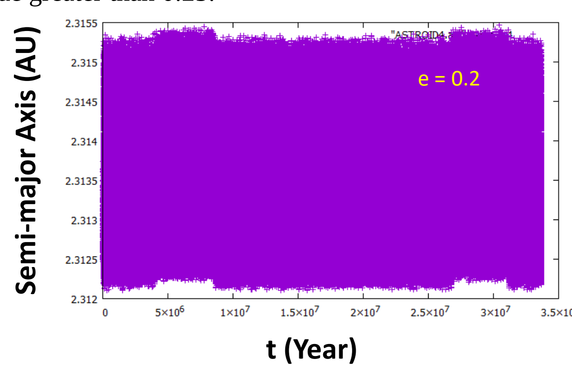

Figure 1: Semi-major axis verus time for the initial eccentricity of 0.2.

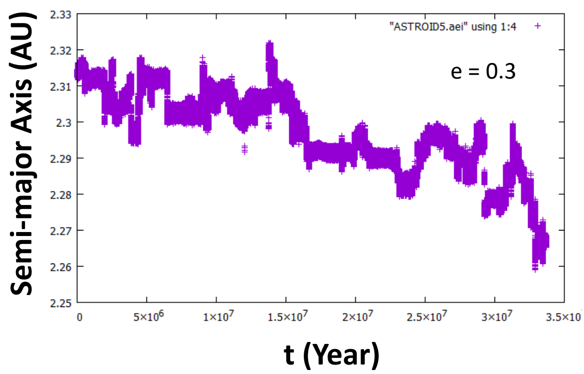

Figure 2: Semi-major axis verus time for the starting eccentricity of 0.3, showing deviation of the semi-major axis.

Furhter, the results of the inclination of IDP are depicted in Figure 3 and Figure 4 for the initial eccentricity of 0.2 and 0.3, respectively. It can be observed from the results that the IDP inclination starts deviating for the eccentricity of 0.3. It is found that the inclination of IDP increase for the initial eccentricity of 0.3 or more, through various run of the code.

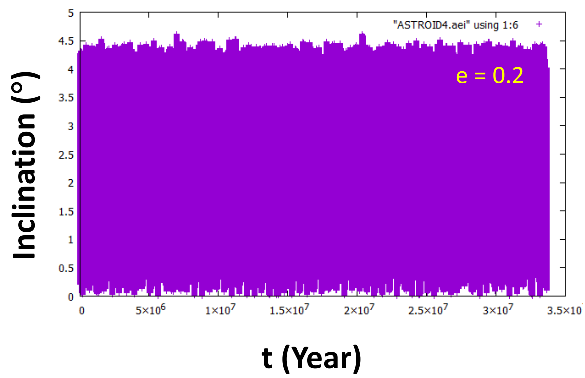

Figure 3: Inclination verus time for the starting eccentricity of 0.2.

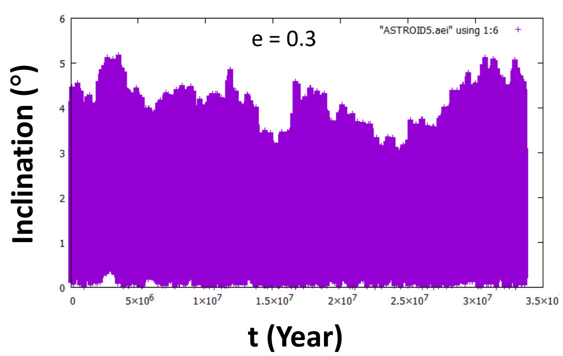

Figure 4: Inclination verus time for the starting eccentricity of 0.3, showing deviation of the inclination.

It has been observed that the eccentricity also changes as the time increases, however, for the results presented here, the eccentricity remains almost constant and maintains the same value as the starting value.

Summary and Implications: The asteroid belt is a main source of IDP in the inner solar system and the dust particles spiral in toward Sun over geological time. The dynamics of IDP is studied using N-body integration problem using MERCURY code [1]. The exercise was carried out to study the deviation in the semi-major axis as well as the inclination of the IDP, which are major parameters for the paricles to spiral in toward Sun. Our results show that the semi-major axis of IDP deviates, when the eccentricity is more than 0.25 and its inlication deviates when the eccentricity is 0.3 or larger. This implies that the IDPs are detached from the asteroid belt when the eccentricity is greater than 0.25. This has been found to occur within 33 My, which corresponds to 0.1 AU distance, inward towards Sun. It is expected that IDPs can reach Mars in about 264 My after getting detached from the belt.

References: [1] Chambers, J. E. (1999), Monthly Notices of the Royal Astronomical Society, 304, 793-799. [2] Chamberlain, Alan, JPL/Caltech, online, 8 January 2021. Available: http://ssd.jpl.nasa.gov/images/ast_histo.ps [3] Anonymous a, online, 8 January 2021. Available: https://minorplanetcenter.net//iau/MPCORB.html