The Large Scale Structures in the Solar System:

II. Resonant Dust Belts

Associated With the Orbits of Four Giant Planets

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ABSTRACT

In part I, using an effective computational approach, we have reconstructed the population of dust sources between Jupiter and Neptune. Here, in part II, we present the results on distribution of dust produced by 157 real sources (100 Jupiter-family comets with semi-major axes \( a < 20 \) AU, 51 Kuiper belt, and 6 Centaur objects) as well as 211 fictitious sources taken from our computed sample. The following processes that influence the dust particle dynamics are taken into account: 1) gravitational scattering on four giant planets; 2) planetary resonances; and 3) the Poynting-Robertson (P-R) and solar wind drags. A file consisting of \( 0.9 \times 10^6 \) particle positions has been computed to simulate the dust distribution in the outer parts of the Solar system. We find that this distribution is highly non-uniform, with most of the dust concentrating into four belts associated with the orbits of four giant planets, with a sharp rise (depending on the size of particles) at the innermost part of the ring. As in I, we reveal a rich and sophisticated resonant structure of these belts containing families of resonances and gaps. A dissipative nature of the P-R drag results in specific features of particle's capture into, and evolution in, the resonances.

Based on our simulations, we expect a new, quasi-stationary dust population to exist in the belts near Jupiter and Saturn, which is highly inclined and possesses large eccentricities. This population is basically non-resonant and is an important addition to otherwise resonant dust belts.

The simulated dust is likely the main source of the zodiacal light in the outer Solar system, which will be analyzed in our further work.
1. Introduction

As shown in part I of our work (Ozernoy, Gorkavyi, & Taidakova 1998, referred hereinafter as I), comets coming from trans-Neptune regions (mostly from the Kuiper belt) are scattered gravitationally on all giant planets and form a quasi-stationary population of sources between Jupiter and Neptune. This paper aims at examining the distribution of dust produced by those sources. The dynamics of this dust is determined by three main effects: (i) the Poynting-Robertson (P-R) drag (including radiation pressure and solar wind drag), (ii) gravitational scattering on the four giant planets, and (iii) resonances with those planets.

An extensive work on dust particle evolution governed by the above effects has been done by a number of investigators (Weidenschilling & Jackson 1993, Roques et al. 1994, Lazzaro et al. 1994, Liou & Zook 1997, Gor’kavyi, Ozernoy, Mather, & Taidakova 1997, Kortenkamp & Dermott 1998). The present paper makes a next step by accounting for the following new elements: (i) as sources of dust, we use all known Kuiper belt bodies and, as additional sources, we use fictitious minor bodies from all cometary-asteroidal belts of the four giant planets computed in I; and (ii) after computing a stationary distribution of dust particles in the space of orbital elements, \( n(a, e, i) \), we employ an analytical method to derive the 3-D model of the interplanetary dust cloud in the outer Solar system.

In Section 2, we discuss the sources of dust particles in the outer Solar system. Sec. 3 describes our numerical method that enables us, in conjunction with an analytical approach, to compute the 3-D distribution of dust in the outer Solar system. Sec. 4 contains the results of these computations, which reveal the global dust distribution as well as interesting details of its resonant structure. Our conclusions are presented in Sec. 5.

2. The Sources of Dust Particles

There is a mounting evidence that the sources of the interplanetary dust particles (IDPs) cannot be entirely reduced simply to those comets which produce the observed dust
tails or/and to asteroids which are thought to be responsible for the observed ‘dust bands’ in the IDP emission – a number of facts forces to suspect that additional sources of the interplanetary dust must exist. Among others, two such facts are worth mentioning: (i) According to Pioneer’s 10 and 11 data, the dust particles are seen up to 18 AU (Humes 1980; Divine 1993), which implies the existence of a dust source beyond 4 AU (Flynn 1996); and (ii) Chemical analyses and other space-based data indicate that a part of IDP spent in space a much larger time that the typical asteroidal and cometary particles, which is a strong evidence in favor of other, along with the known comets and asteroids, sources of dust in the Solar system (Flynn, 1996).

A new, for a long time neglected factor in the problem of the IDP origin is the Kuiper belt so that a third component of the IDP cloud might be the ‘kuiperoidal’ dust (Backman et al. 1995). In our opinion, the Kuiper belt influences the formation of the IDP cloud in two ways: 1) as a source of small-size particles slowly drifting toward the Sun under a combined action of the PR-drag, gravitational scattering, and influence of resonances [evolution of 80 such particles was computed by Liou, Zook, & Dermott (1996)]; and 2) as a source of trans-Jovian comets. It is commonly agreed that the Jupiter-family comets are produced by transporting the comets from the Kuiper belt via gravitational scattering on the four giant planets when each planet scatters the comets both toward and away from the Sun (Levison & Duncan 1997). Our numerical simulation described in I indicates that, between Jupiter and Neptune, there is a numerous population of minor bodies forming four cometary-asteroidal belts near the orbits of all giant planets.

The minor body families of Saturn, Uranus, and Neptune should contain progressively larger numbers of comets than one sees near Jupiter. Even despite a many-fold decrease of the solar heat intensity at such large distances, those numerous comets may produce dust in amounts comparable to that from a few active J-comets. Complementary mechanisms of dust release from kuiperoids and Centaurs between Jupiter and Neptune can include impacts of large grains and the solar wind. We refer to observational data indicating, for a number of kuiperoids and Centaurs, a steady cometary activity for years (e.g. Brown &
The kuiperoidal dust experiences the same dynamical effects as the asteroidal dust, with the only difference that, due to a slower PR-drift and a stronger influence of the giant planets, the role of gravitational scattering and resonance captures must be more important for it. In what follows, while computing the dynamics of kuiperoidal dust, our model incorporates 5 dust components of different origin associated with respected belts of minor bodies, viz., a) Kuiper belt; b) Neptunian belt; c) Uranian belt; d) Saturnian belt; and e) Jovian belt. We make use of the available list of 51 kuiperoids with known orbital parameters as well as 6 Centaurs (Marsden 1998). In order to reduce to a minimum the influence of poorly known observational selection effects, we add a sample of 211 fictitious sources randomly taken from our simulation of the minor body population between Jupiter and Neptune. The distribution of the used dust sources in the orbital coordinates $a, e, i$ is shown in Fig. 1.

3. Computational Method: Simulation of a Quasi-stationary Distribution of Dust Particles in the Outer Solar System

We calculate the orbital elements $a, e, i$ of particles starting from a source of dust and then drifting toward the Sun under the P-R drag. On its way to the Sun, the particle undergoes the gravitational influence of the four giant planets. As in I, we adopt the approximation of a restricted 3-body problem (the Sun, the planet on a circular orbit, and a massless particle). In order to reduce the computations to a restricted 3-body problem, we assume that the particle, while being in the planet’s zone of influence, does not feel gravitational perturbations from the three other giant planets. The planet’s zone of gravitational influence in the $(a, e)$-plane of orbital coordinates is defined by:

$$a(1-e) \leq a_p \text{ if } a > a_p,$$

$$a(1+e) \geq a_p \text{ if } a < a_p,$$
where \( a \) is the semi-major axis of a test body, \( a_p \) is the semi-major axis of the planet, and \( e \) is eccentricity of the test body. The above approximation is only temporary and will be abandoned in our further work.

As a convenient approach to simulate a quasi-stationary distribution of dust particles, we applied the following computational procedure: a record of particle’s orbital elements was taken after certain number of revolutions (usually each 10 revolutions) of the planet around the Sun and these data were then used to characterize the positions of many particles over the entire time span, beginning from an initial instant till the instant of particle’s death (impact on planet, the Sun, or particle’s ejection from the Solar system).

In order to explore the contribution of each planet’s cometary belt into the general dust distribution, we normalize to unity the dust production in each cometary belt. In physical terms, it implies that a smaller minor body abundance in the innermost giant planets is compensated by a larger dust production due to their proximity to the Sun. In our further work, we hope to abandon this approximation by an accurate computing the ‘transfer function’ (a fraction of minor bodies gravitationally scattered by all outer planets into the given planet’s zone of influence) as well as by a reasonable estimation of the cometary activity as a function of the comet’s orbital elements.

We computed more than 360 stationary distributions \( n(a, e, i) \) of dust particles from 51 kuiperoids and 211 fictitious sources. These distributions form a file consisting of \( 0.9 \times 10^6 \) positions. Numerical integrator described in Taidakova (1997) and Taidakova & Gor’kavyi (1999) was employed. Details of computational runs are given in Table 1.

4. The Results: Four Dust Belts and Their Resonant Structure

4.1. Four Dust Belts

Our computations have been done for the P-R parameter (the radiation pressure to gravitational force ratio) \( \beta = 0.1 \) and the solar wind drag to P-R-drag ratio = 0.35
(Gustafson 1994). For $\beta = 0.1$, resonances computed in I are shifted by a factor $(1 - \beta)^{1/3} = 0.965$. The larger the value of $\beta$, the larger is the drift velocity and the smaller is the probability of a resonant capture.

Representative results of the orbit integrations are shown, in the orbital coordinates $a, e$ and $a, i$, for Neptune in Fig. 2a,b and for Jupiter in Fig. 3a,b. Capture of kuiperoidal particles into Neptune’s dust belt occurs predominantly into 3:2 resonance, which takes the major responsibility for the entire dust belt. This might be partly explained by observational selection (just a few sources is presently known beyond 2:1 resonance). In Jupiter’s zone of influence, high-eccentricity cometary particles are mostly captured into two resonances, viz., 3:2 and 1:1. The capture into 1:1 resonance for asteroidal dust particles with $\beta = 0.26$ was considered by Liou & Zook (1995).

The general picture of dust distribution in the outer part of the Solar system obtained by summation of the computed particle distribution functions for every giant planet’s zone of influence is shown in Fig. 4.

We find that the simulated dust distribution is highly non-uniform, with most of the dust concentrating into four belts near the orbits of four giant planets.

The major part of the simulated Neptune’s dust belt is located between 24 AU and 60 AU and forms a flat dense disk. The simulated Uranian, Saturnian, and Jovian dust belts are essentially overlapped and form sophisticated dust structures which, in their central parts, are less dense compared to Neptunian dust belt.

The most remarkable feature found in our simulations is that they indicate the existence of a new quasi-stationary, highly inclined dust population with pericenters near Jupiter and Saturn. In Figs. 4a,b, this population is seen as a ‘Chinese wall’-like structure. This structure is found to be more steep and of a larger density for larger-size particles such as $d = 12\mu$m ($\beta = 0.037$). The above-mentioned quasi-stationarity results from a balance between the tendencies for particle’s semi-major axis $a$ and eccentricity $e$ to increase due to gravitational scattering on the planet and to decrease due to the P-R drag. As for particle’s
inclinations $i$, they substantially increase due to gravitational scattering and influence of resonances.

We note in passion that the ‘Chinese wall’-like features of dust distribution near the giant planets, especially as massive as Jupiter, can serve as signatures of exo-planets in the circumstellar disks.

Distribution of dust density in the ecliptic plane, which is of obvious practical interest for current and future spacecraft missions, is shown in Figs. 5 and 6. It reveals substantial rises and falls in dust number density. The most remarkable result is a rather steep rise (somewhat depending on the particle’s size) of dust density in the innermost part of all dust belt, especially of Jupiter’s (at $R = 4.3$ AU) and Neptune’s (at $R = 24$ AU). Rather sharp inner edges and the respected steps in dust density distribution are expected to characterize each giant planet’s dusty belt at $0.85a_{\text{planet}}$. Neptune’s dust belt is expected to have the largest number density of particles in the ecliptic plane.

We note that the ecliptic dust density is rather sensitive to a contribution of low-inclination particles [$n \propto (\sin i)^{-1}$]. A two-peak structure between Jupiter’s and Saturn’s orbit (see Fig. 5a) is produced by the dust from Neptune’s zone; this structure is formed by low-inclination particles ($i < 1^\circ$) captured into 3:2 resonance with Jupiter. With an improved statistics, the heights of those peaks may change. However, the two-peak structure in Neptune’s zone, which has been simulated by a large number of particles, is robust.

The general distribution of dust in the outer Solar system, as follows from our simulation, is shown in Figs. 7 and 8.

### 4.2. Resonant Structure of the Four Belts

Just as the parent cometary populations, the simulated dust belts reveal a sophisticated resonant structure containing rich families of resonances and gaps. The main difference
with the parent sources is that the resonant capture of dust particles occurs in a *dissipative* way, and this process takes place both inside and outside the zone of planet’s influence.

The distribution of interior resonances in the $a, e, i$-space is characterized by the presence of numerous gaps. As for the exterior resonances, the particles are dissipatively captured into those resonances (usually outside the triangle zone). Subsequent evolution is characterized by an increase of eccentricity, with oscillations in $e$ and $i$, whose amplitude is especially large where both $e$ and $i$ are high enough.

In a resonance $(j + 1)/j$, while eccentricity is close to the maximal one, $e_{\text{max}} = \sqrt{0.4/(j + 1)}$ (Weidenschilling & Jackson 1993), the particle’s life time is expected to be long enough. This results in two-peak structures seen in Figs. 5 and 6. The characteristic shape of such structures follows from the Kepler motion laws (Kessler 1981, Gorkavyi et al. 1997b). The inner and outer edges of each structure are given by $a_{\text{res}}(1 - e_{\text{max}})$ and $a_{\text{res}}(1 + e_{\text{max}})$, respectively. For all resonances, in a good approximation, the position of the inner edge is $\approx 0.85a_{\text{planet}}$. At this position, we expect to find rather sharp and steep inner edges and the respected steps in the dust density distribution (all that somewhat depending on the particle’s size) for each giant planet’s dusty belt.

Finding, by dust detectors on spacecraft, of such dust density peaks expected at $R \approx 4.3$ AU in Jupiter’s zone and at $R \approx 24$ AU in Neptune’s zone would be a direct confirmation of the dust belts, as well as their resonant nature, simulated in the present work.

The resonant nature of the simulated dust belts is seen in Fig. 7: the major part of Neptune’s dust belt has an azimuthal asymmetry. The latter is revealed as an enhanced concentration of dust particles in Neptune’s trailing zone.
5. Conclusions

1. We find that the simulated dust distribution is highly non-uniform, with most of the dust concentrating into four belts near the orbits of four giant planets. Those belts would be a challenging target to discover by space missions, either ongoing (CASSINI) or forthcoming (STARDUST, ISAS PLANET B).

2. Our simulations indicate the existence of a new quasi-stationary, highly inclined dust population with pericenters near Jupiter and Saturn. This quasi-stationarity results from a balance between the tendencies for particle’s semi-major axis $a$ and eccentricity $e$ to increase due to gravitational scattering on the planet and to decrease due to the P-R drag. As for particle’s inclinations $i$, they substantially increase due to gravitational perturbations from Jupiter and Saturn. This highly inclined population produces a very large, high altitude ‘wall’ (see Fig. 4).

3. Just as the parent cometary populations, the simulated dust belts reveal a sophisticated resonant structure containing rich families of resonances and gaps. The main difference with the parent sources is that the resonant capture of dust particles occurs in a dissipative way, and this process takes place both inside and outside the zone of planet’s influence.

4. The distribution of interior resonances in the $a, e, i$-space is characterized by the presence of numerous gaps. As for the exterior resonances, the particles are dissipatively captured into those resonances (usually outside the triangle zone). Subsequent evolution is characterized by an increase of eccentricity, with oscillations in $e$ and $i$ (the amplitude of these oscillations is especially large where both $e$ and $i$ are high enough).

5. A rather long life time in a resonance, while eccentricity is close to the maximal one, results in a rather steep rise (somewhat depending on the particle’s size) of dust density in the innermost part of all dust belts, especially of Jupiter’s (at $R = 4.3$ AU) and Neptune’s (at $R = 24$ AU). Rather sharp inner edges and the respected ‘steps’ in the dust density distribution are expected to characterize each giant planet’s dusty belt at
Neptune’s dust belt is expected to have both the largest ‘step’ and number density of particles in the ecliptic plane (Fig. 5).

6. The simulated dust is likely to be the main source of the zodiacal light emission in the outer Solar system, which will be analysed in more detail in our further work.

7. The revealed features of dust distribution near the giant planets, especially as massive as Jupiter, can serve as signatures of exo-planets in the circumstellar disks.

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**TABLE 1**
Details of Computational Runs

| Source of dust | Neptunian | Uranian | Saturnian | Jovian | kuiperoids & Centaurs | J-family comets |
|----------------|-----------|---------|-----------|--------|-----------------------|----------------|
| cometary belt  |           |         |           |        |                       |                |

| Number of sources | 59 | 50 | 55 | 47 | 57 | 100 |
| Typical life time of particles, yrs (1) | from $1 \times 10^6$ to $3 \times 10^7$ | from $2 \times 10^5$ to $1.5 \times 10^7$ | from $5 \times 10^4$ to $3 \times 10^6$ | from $2 \times 10^4$ to $1 \times 10^6$ | from $1 \times 10^6$ to $3 \times 10^7$ | from $1 \times 10^4$ to $1 \times 10^6$ |

| Number of computed positions (2) | 245,543 | 191,463 | 131,509 | 53,454 | 249,520 | 26,939 |
| Number of positions used for modelling (3) | 24,554 | 19,146 | 13,150 | 5,345 | 24,952 | – |
| Number of positions plotted in Figs. 2 to 3 (4) | – | – | – | – | 31,575 | 26,939 |

(1) until the particle impacts the Sun or is ejected

(2) taken with time step = 10 revolutions of the planet.

(3) every 1/10 position from the previous line.

(4) taken with time step = 30 revolutions of the planet.
Figure Captions

Figure 1.

a. Distribution of minor bodies as the sources of dust the between orbits of Jupiter and Neptune shown, along with asteroids of the main belt and Centaur objects, on the $(a,e)$-plane. Crosses stand for asteroids of the main belt (100 objects), triangles stand for Jupiter-family comets (112 objects), squares stand for Centaurs (6 objects), diamonds stand for kuiperoids (50 objects), and stars stand for fictitious bodies taken from our simulations (paper I). The dot-dashed line separates the comets with pericenters less than 2 AU (located above the line) from yet unrevealed comets having larger pericenters. The triangle zones of each giant planet’s gravitational influence are shown by dashed lines.

b. Same minor bodies as in a shown on the $(a,i)$-plane.

Figure 2.

a. Distribution of dust particles near Neptune’s orbit produced from 50 kuiperoids. The Neptune’s triangle zone is shown by heavy lines. For illustration purposes, gravitational influence of three other giant planets upon the distribution of dust is neglected. Positions of appropriate exterior and interior resonances are shown by arrows.

b. Same as in a shown in $(a,i)$-coordinates.

Figure 3.

a. Distribution of dust particles near Jupiter’s orbit produced by 100 comets of Jupiter family with $a < 20$ AU. The Jupiter’s triangle zone is shown by heavy lines. For illustration purposes, gravitational influence of three other giant planets upon the distribution of dust is neglected. Positions of appropriate exterior and interior resonances are shown by arrows.

b. Same as in a shown in $(a,i)$-coordinates.

Figure 4. a. Section of the simulated dust distribution in the plane perpendicular to the ecliptic plane within 30 AU. Adjoining regions of different colors have density contrast
10:1 (the densest regions are in the ecliptic plane).

b. The same within 80 AU.

**Figure 5.** Dust number density in the ecliptic plane (normalized to the maximum density of kuiperoidal dust, \(n_{\text{max}}\)) as a function of heliocentric distance. Computations were performed for \(R \geq 2\) AU. Within \(2 < R < 4\) AU where influence of Jupiter can be neglected, the dust number density follows a \(R^{-1}\) dependence, as it should be under the P-R drag influence.

a. Distribution of kuiperoidal dust (i.e. the dust originated in the Kuiper belt and then transported inward) and Neptunian dust (i.e. the dust originated in the Neptune’s cometary belt and then transported inward) within heliocentric distances of 80 AU.

**Figure 6.** Distribution of Uranian, Saturnian, and Jovian dust (i.e. the dust originated in the respected cometary belts and then transported inward) within heliocentric distances of 20 AU.

**Figure 7.** The large-scale structure of the dust cloud in the outer part of the Solar system shown face-on. For convenience, positions of Jupiter, Saturn, Uranus, and Neptune are indicated. Dust particles produced in Kuiper belt and Neptune zone, Uranus zone, Saturn zone, and Jupiter zone are shown by the black, blue, red, and violet color, respectively. The particle’s positions are given in the frame rotating with the respected planet (i.e. counter clock-wise); therefore the resonant particles form a stationary pattern. Note an asymmetry in the Neptune’s trailing zone.

**Figure 8.** The large-scale structure of the dust cloud in the outer part of the Solar system shown edge-on. For convenience, positions of Jupiter, Saturn, Uranus, and Neptune are indicated. Dust particles produced in Kuiper belt and Neptune zone, Uranus zone, Saturn zone, and Jupiter zone are shown by the black, blue, red, and violet color, respectively.
References

Backman, D.E., Dasgupta, A. & Stencel, R.E. 1995, ApJ 450, L35

Divine, N. 1993, J. Geophys. Res. 98E, 17029

Flynn, G.J. 1996, in Physics, Chemistry, and Dynamics of Interplanetary Dust, ed. B. Gustafson & M. Hanner, (San Francisco: ASP), ASP Conf. Ser. 104, p. 171

Gor’kavyi, N.N., Ozernoy, L.M. & Mather, J.C. 1997a, ApJ 474, 496

Gor’kavyi, N.N., Ozernoy, L.M., Mather, J.C. & Taidakova, T. 1997b, ApJ 488, 268

Gor’kavyi, N.N., Ozernoy, L.M., Mather, J.C. & Taidakova, T. 1998, Earth, Planets and Space, 50, 539

Gor’kavyi, N.N., Ozernoy, L.M., 1999, ApJ (to be submitted)

Gustafson, B.A.S. 1994, Ann. Rev. Earth Planet. Sci. 22, 553

Humes, D.H. 1980, J. Geophys. Res., 85, 5841

Kessler, D.J. 1981, Icarus 48, 39

Kortenkamp, S.J. & Dermott, S.F. 1998, Icarus 135, 469

Lazzaro D.D. et al. 1994, Icarus 108, 59

Levison, H.F. & Duncan M.J. 1997, Icarus 127, 13

Liou, J.-C. & Zook, H.A. 1995, Icarus, 113, 403

Liou, J.-C. & Zook, H.A. 1997, Icarus, 128, 354

Liou, J.-C., Zook, H.A. & Dermott, S.F. 1996, in Physics, Chemistry, and Dynamics of Interplanetary Dust, ed. B. Gustafson & M. Hanner, (San Francisco: ASP), ASP Conf. Ser. 104, p. 163

Marsden, B.G. 1998, MPEC 1998-v14: Distant Minor Planets

Ozernoy, L.M., Gor’kavyi, N.N., and Taidakova, T. 1998, astro-ph/9812473
Roques, F. et al. 1994, Icarus 108, 37

Taidakova, T. 1997, in Astronomical Data Analyses, Software and Systems VI, ed. G. Hunt & H.E.Payne, (San Francisco: ASP), ASP Conf. Ser. 125, p. 174

Taidakova, T. & Gor’kavyi, N.N. 1999, The Dynamics of Small Bodies in the Solar Systems: A Major Key to Solar Systems Studies, ed. A.E.Roy & B.A.Steves (in press)

Weidenschilling, S.J. & Jackson, A.A. 1993, Icarus 104, 244.
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