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Dynamics of Dust Particles near Sun, Vega and Fomalhaut

Johann Stamm (1), Carsten Baumann (1), Andrzej Czechowski (2), Ingrid Mann (1), and Margaretha Myrvang (1)
(1) UiT The Arctic University of Norway, Institute for physics and Technology, Faculty of Science and Technology, Tromsø, Norway, (2) Polish Academy of Sciences, Space Research Center, Warsaw, Poland

Several stars with debris disks show an unresolved excess emission at wavelengths shorter than 30 micrometer. It is believed that the excess emission origins from warm dust near the star. The dust is produced near the star and by collisions of planetesimals. When it is close to the star, it gets heated. In a similar way, the Sun is surrounded by hot dust of the inner planetary dust cloud. The orbits of the dust are influenced by gravitation, radiation pressure and also by the Lorentz force, since stellar wind impacts and photoionization by stellar photons charge the dust particles. The ratio of charge-to-mass (q/m) increases with decreasing dust grain radius, so that the Lorentz force is more important for the smaller dust sizes. The vicinity of the Sun will be explored with the ESA mission Solar Orbiter and these model calculations provide a basis for predicting the dust fluxes at the spacecraft.

We consider here the dust trajectories around three stars: The Sun, Vega and Fomalhaut. The stellar magnetic field is approximated as a Parker spiral in all cases. While the magnetic field strengths of the Sun and Vega are derived from observational data, the magnetic field strength of Fomalhaut is estimated. Numerical methods are used to determine particle trajectories. They show that when the radiation force exceeds the gravitation force the particles are not bound and escape from the stellar system. The calculation shows that escape occurs for dust size less than $\sim$4 μm at Vega and $\sim$1 μm at Fomalhaut. The escape from the Sun occurs for dust size less than $\sim$300 nm, but this value is different for different materials. Some materials have a size region less than $\sim$80 nm where the dust particles yet are trapped and some materials are trapped regardless of particle size.

If the particle charge is big enough, it follows the magnetic field lines of the Parker spiral. The radial part of the Lorentz force in average points outward, which restricts the conditions for particles in bound orbits further. Near the Sun, some of the particles get trapped. Trapping occurs when the orbits are initially close to the Sun and the magnetic field strongly perturbs these trajectories. We did not find such trapped orbits for charged particles around Vega and Fomalhaut and find that the particles are blown out by the radiation pressure.