SIGNATURES OF GIANT PLANETS ON THE SOLAR SYSTEM KUIPER BELT DUST DISK AND IMPLICATIONS FOR EXTRASOLAR PLANET IN EPSILON ERIDANI. J.-C. Liou[1] and H. A. Zook[2], [1]GB Tech/Lockheed Martin, C104 Lockheed Martin, 2400 NASA Rd. One, Houston, TX 77058, [2]SN2, NASA Johnson Space Center, Houston, TX 77052.

Summary: One method to detect extrasolar planetary systems is to deduce the perturbations of planets on the observed circumstellar dust disks. Our Solar System, with its known configuration of planets, provide an excellent example to study how the distribution of dust particles is affected by the existence of different planets. Numerical simulations of the orbital evolution of dust particles from Kuiper Belt objects show that the four giant planets, especially Neptune and Jupiter, impose distinct and dramatic signatures on the overall distribution of Kuiper belt dust particles. The signatures are very similar to those observed in Epsilon Eridani. Numerical simulations of dust particles in Epsilon Eridani show that if the features on the dust disk are caused by a planet, its mass has to be smaller than that of Jupiter but much larger than that of the Earth.

Micrometer-to-millimeter interplanetary dust particles (IDPs) play an important role in a planetary system. They are special because their orbital motions are heavily influenced by Poynting-Robertson (PR) drag once they are released from their large parent bodies. PR drag causes the IDPs to spiral slowly toward the central star. When observed at astronomical distances (such as several light years), they may represent the most prominent feature in a planetary system other than the central star. Stellar systems with observable dust disks have been discovered, such as Beta Pictoris [1] and Epsilon Eridani [2]. While spiraling toward the central star, IDPs interact with the planets. The interactions include the trapping of dust grains into mean motion resonances (MMRs) and gravitational ejection of the grains by giant planets. Such interactions cause strong irregular variations in the dust spatial density, and the corresponding brightness distribution. It has been shown that such planetary perturbations are responsible for certain features in the zodiacal cloud [3,4] as well as features in the Beta Pictoris dust disk [5,6].

Dust disks in Beta Pictoris, Epsilon Eridani, and other systems are analogues to our Solar System's Kuiper Belt dust disk. Therefore, it is of great interest to understanding how the Kuiper Belt IDP distribution is affected by the giant planets in our Solar System. We have numerically simulated the orbital evolution of Kuiper Belt IDPs, including gravitational perturbations from 7 planets (Mercury and Pluto are not included due to their small masses), solar radiation pressure, and PR and solar wind drag. Dust particles range from 3 to 23 micrometers in diameter. For a given size, 100 IDPs are included in the simulations. Details of the orbital evolution of several individual dust particles were given in Liou et al. [7]. All planets are gravitationally interacting with one another and acting on dust particles, while dust particles are treated as test particles that have no effect on the planets. Our analyses show that trapping into exterior MMRs with Neptune dominates the orbital evolution of all IDPs from the Kuiper Belt objects. Trapping into MMRs with interior giant planets is rare because gravitational perturbations from exterior giant planets usually make the resonance trap highly unstable. Once particles escape MMRs with Neptune, they continue to spiral toward the Sun. About 80% of the particles are eventually ejected from the Solar System by Jupiter and Saturn.

Based on our numerical simulations, we have calculated the column density as well as the brightness distribution of the Kuiper Belt dust disk, as viewed by an extra-Solar-System observer. Giant planets do produce large scale structures on the disk. The signatures of giant planets include: (i) the deviation of radial brightness profile from that determined by PR and solar wind drag alone; (ii) a ring-like structure along the orbit of Neptune; (iii) a brightness variation along the ring with an opening (a dark spot) located where Neptune is; (iv) a seasonal variation of the dark spot that moves along with Neptune's orbital motion; and (v) a relative lack of particles inside about 10 AU. Signatures (ii) and (iii) are cased by

IDPs trapped in MMRs with Neptune while signature (v) is due to the gravitational ejection of IDPs by Jupiter and Saturn.

If an extraterrestrial intelligence were observing our Solar System and had the image of our Kuiper Belt dusk disk, it would know the existence of Neptune from features (i) to (iv). The orbital period of Neptune could be obtained from continuous observation of the motion of the dark spot around the Sun. With the known orbital period, the orbital location of Neptune could easily be obtained using Kepler‘s Laws. The mass of Neptune could be estimated based on numerical simulations that produce patterns that match the brightness variation along the ring from the observations. Since Uranus does not trap IDPs efficiently and is not massive enough to eject particles from the Solar System, it could not be recognized from the structure of the dust disk. Based on features (i) and (v), at least one additional planet should be recognized in the region inside about 10 AU. Although it might be difficult to know whether there is only one planet or two planets around that location. The terrestrial planets—Mars, Earth, and Venus—do not set up observationally recognizable patterns by their gravitational perturbations on the orbital evolution of dust from the Kuiper Belt.

To apply our knowledge on the Kuiper Belt dust disk to the possible existence of planet(s) in Epsilon Eridani system, we have performed numerical simulations on the orbital evolution of IDPs in that system. Our objectives are to determine whether or not a planet can produce structures on the dust disk that are similar to those from actual observations, and to characterize the mass of the planet. Only one planet is included in our simulations. The orbital location of the planet is set at 60 AU, just inside the maximum radial brightness location from the observations [2]. The mass of the planet varies from one Earth mass to one Jupiter mass. Preliminary results from our simulations with a Jupiter-like planet show that few IDPs are trapped in long stable MMRs with the planet and most particles are ejected from the system within the first 20 million years of integration. The corresponding dust distribution can not match that from the observation. On the other hand, our simulations with an Earth-like planet show that some IDPs do get trapped in MMRs with the planet. However, the structures due to the MMR traps may not be significant enough to cause the brightness variations as observed. In additional, no IDPs are ejected from the system by the planet. This means the radial brightness of the dust disk should increase toward the central star. Again, this appears to be in contradiction to the actual observations. It is likely that to have a disk distribution similar to that from the observation, the planet has to be similar in size to that of Neptune. Once our simulations are completed, we should be able to determine whether or not the structures in the Epsilon Eridani dust disk are cased by a planet and to estimate the actual mass of the planet.

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