Asymmetric Dust Distributions in Debris Disks and Their Impact on the Direct Imaging of Earth-Mass Exoplanets

Hiroshi Kobayashi[1], Hayato Shimizu[1], and Taro Matsuo[2]

[1]*Department of Physics, Nagoya University*

[2]*Department of Earth and Space Science, The University of Osaka*

Planetary systems often host debris disks. Direct imaging observation has detected giant planets with debris disks. It is expected that Earth-like planets and debris disks will be detected using imaging. We investigate the dust distribution around an Earth-mass planet on a circular orbit at 1 au in a system like the solar system. Dust grains are supplied from a planetesimal belt at 2–3 au and drift inward by the Poynting-Robertson (PR) effect. We computed orbital evolution under stellar radiation pressure, the P-R effect, and planetary gravity. By dividing the disk into radial and azimuthal meshes and summing particle residence times, we reconstructed the steady-state dust density distribution. We find large dust grains form characteristic structures around planets, while small dust forms smooth and structureless disks. Using the results of dust structures, we evaluate the infrared flux of the debris disk relative to the star. We estimate the size distribution of drifting dust grains, which is determined by comparing collisional and drift timescales in planetesimal belts. We obtain disk structures from the integration of five representative sizes. Faint disks are dominated by large grains and have strong asymmetric features that may enhance exoplanet detectability. On the other hand, brighter disks are dominated by smaller grains and obscure planets, but retain weak detectable structures from small-population large grains. Therefore, debris disks may assist the detection of Earth-like planets via direct imaging.