Signatures of Planets: Modeling Structure in Debris Disks

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There is a connection between structure in evolved circumstellar disks and the presence of planets. Asymmetries in such a disk could be diagnostic of planets that would be otherwise undetectable. Conversely, in the case of a star that possesses a planetary system, the orbital elements of the planets can be used to predict the morphology of the circumstellar disk. We focus on Upsilon Andromedae, a binary system at a distance of 13.5 pc (Lowrance et al. 2002, ApJL, 572, L79.). Three known radial velocity planets orbit Ups And A (Butler et al. 1999, ApJ, 526, 916), the outer two of which may be in a secular apsidal resonance in which $\Delta\omega$ librates about 0° (Chiang et al. 2001, AJ, 122, 1607). Although a disk has not yet been observed around Ups And, the upcoming Space Infrared Telescope Facility (SIRTF) mission will have unprecedented sensitivity and may reveal new infrared excesses which can be followed up with other telescopes. In preparation for this work, we have endeavored to explore the disk morphology that can be expected from the Ups And system, if it does indeed have a debris disk.

In low-order secular perturbation theory, the classical method used to study the long term orbital evolution of both planets and dust particles assuming the eccentricities and inclinations are low, osculating elements are decomposed into proper elements, which depend on initial conditions, and forced elements, which are imposed on the particle's orbit by the gravitational perturbations of the planets. For particles in the disk, we use secular perturbation theory to determine the variation of the forced eccentricity (e_f) and forced longitude of pericenter ($\tilde{\omega}_f$) as a function of semi-major axis (a), and then apply it to models of a circumstellar disk around Ups And A. These disk models exhibit a noticeable asymmetry due to the apsidal alignment of the two outer planets.

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