The Astrophysics of Planetary Systems: Formation, Structure, and Dynamical Evolution
Proceedings IAU Symposium No. 276, 2010
A. Sozzetti, M. G. Lattanzi & A. P. Boss, eds.

doi:10.1017/S1743921311020771

Warm dust around ε Eridani

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Abstract. ε Eridani hosts one known inner planet and an outer Kuiper belt analog. Further, Spitzer/IRS measurements indicate that warm dust is present at distances as close as a few AU from the star. Its origin is puzzling, since an "asteroid belt" that could produce this dust would be unstable because of the inner planet. We tested a hypothesis that the observed warm dust is generated by collisions in the outer belt and is transported inward by P-R drag and strong stellar winds. With numerical simulation we investigated how the dust streams from the outer ring into the inner system, and calculated the thermal emission of the dust. We show that the observed warm dust can indeed stem from the outer belt. Our models reproduce the shape and magnitude of the observed SED from mid-IR to sub-mm wavelengths, as well as the Spitzer/MIPS radial brightness profiles.

Keywords. stars: individual (ε Eridani), planetary systems, methods: numerical

1. Introduction

The nearby K2 V star ε Eridani, has a ring of cold dust at ~ 65 AU seen in sub-mm images (Greaves *et al.* 2005), which encompasses an inner disk revealed by Spitzer/MIPS (Backman *et al.* 2009). The star is orbited by an RV planet (Hatzes *et al.* 2000) with $a = 3.4$ AU. Another outer planet may orbit near ~ 40 AU, producing the inner cavity and clumpy structure in the outer ring. The excess emission at $\lambda \gtrsim 15\,\mu$m in a Spitzer/IRS-spectrum indicates that there is warm dust close to the star, at a few AU. Its origin is puzzling, as an inner "asteroid belt" that could produce this dust would be dynamically unstable because of the known inner planet (Brogi *et al.* 2009). Here, we check the possibility that the source of the warm dust is the outer ring, from which dust grains could be transported inward by Poynting-Robertson (P-R) drag and strong stellar winds (30 times the solar wind) (Wood *et al.* 2002).

2. Simulations

With our collisional code *ACE* (*Analysis of Collisional Evolution*) (Krivov *et al.* 2006) we modeled the debris disk beyond 10 AU. This includes the outer ring between 55 and 90 AU and the intermediate region interior to it. We tried different dust compositions, pure astrosilicate (Laor & Draine 1993), as well as mixtures of silicate and water ice (Li & Greenberg 1998). We found that a composition of 30% silicate and 70% ice fits best the far-IR data points. Although the normal optical depth of the disk is rather high ($\tau \sim 10^{-4}$), the disk is transport-dominated, because of the strong stellar wind drag.

To simulate the dust transport further inward from 10 AU through the orbit of the inner planet, we used single-particle numerical integrations. Collisions are not considered in our inner disk model, because they play a minor role in the inner disk. The dust composition was chosen to be pure silicate, because at this distance sublimation of the ice takes effect. We adopted the size distribution from the outer disk simulation and calculated the thermal emission of the dust. The orbital solutions for the inner planet found by Benedict *et al.* (2006) ($e = 0.7$) and Butler *et al.* (2006) ($e = 0.25$) have little influence on the SED. In both cases one can match the Spitzer/IRS spectrum with nearly the same dust mass of $\approx 10^{-7} M_{\oplus}$ for the inner disk.

3. Conclusion

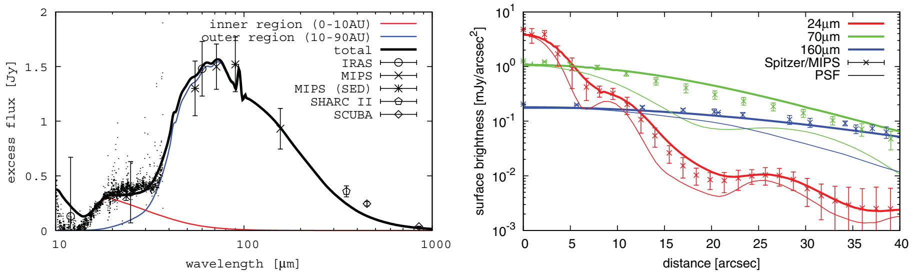

Figure 1. *Left:* SED of the inner and outer dust disk. *Right:* surface brigtness profile compared to Spitzer/MIPS measurements.

Combining the results of the simulations outside and inside 10 AU, we calculated the overall SED and radial brightness profiles at 24, 70 and 160 µm (Fig. 1). The SED is in a reasonable agreement with the available observational data, and it reproduces correctly the shape and the height of the Spitzer/IRS spectrum. Likewise, the surface brightness profiles are consistent with the Spitzer/MIPS data.

The observed warm dust in the ε Eridani system can indeed stem from the outer "Kuiper belt" and be transported inward by P-R and stellar wind drag. The inner planet has little effect on the distribution of dust, so that the planetary orbit could not be constrained. Reasonable agreement between the model of the outer disk and observations can only be achieved by relaxing the assumption of purely silicate dust and assuming a mixture of silicate and water ice.

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https://doi.org/10.1017/S1743921311020771 Published online by Cambridge University Press