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WARM DEBRIS DISKS: WHERE IS THEIR DUST AND WHY?

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Abstract. The few Vega-type stars whose dusty debris disks have been resolved show this dust to lie in cool Kuiper belt-like rings. However, roughly half of all debris disk candidates exhibit little or no cool dust, since their dust emission peaks at about 25 μm. By analogy with the solar system, these warm disks would lie mid-way between the asteroid and Kuiper belt regions in their systems. Are these disks the Kuiper belt-like rings of a truncated planetary system? Or do they represent the destruction of massive interplanetary asteroid/comet belts? Or maybe these systems are in a transitional stage and have yet to evolve into classically cool debris disks? To answer these questions we need to know where the dust lies, and for that we require the resolving power of mid-IR interferometry with the VLTI.

1 Kuiper Belt-like Debris Disks

Analysis of the IRAS database over the last 15 years has shown that there are over 300 nearby main-sequence stars that have disks of dust around them, thought to be the debris material left over at the end of the planet formation process (e.g., Mannings & Barlow 1998). The spectral energy distribution of this excess in the best studied cases (e.g., Vega, β Pictoris, Fomalhaut, and ϵ Eridani) peaks at a wavelength longer than 60 μm, implying that this dust is cool (< 80 K) and so resides in Kuiper belt-like regions in the systems. The Kuiper belt location and analogy is confirmed in the few cases where these disks have been resolved (e.g., Holland *et al.*1998), since the dust is shown to lie > 40 AU from the stars. Also the short lifetime of this dust means that it must be continually replenished, probably by the collisional destruction of km-sized planetesimals (Wyatt & Dent 2002). The inner ~ 40 AU radius hole is thus thought to arise from clearing by an unseen planetary system, the existence of which may be supported by the presence of clumps and asymmetries in the structure of the dust rings (e.g., Greaves *et al.*1998; Wyatt *et al.*1999).

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2 Warm Debris Disks

However, as noted in the review article of Zuckerman (2002), out of a large sample of main sequence stars that were shown to exhibit excess IR emission in the IRAS Faint Source Catalog (Mannings & Barlow 1998), about half of these showed an excess at 25 μm only; this is confirmed in a recent more extensive survey of the IRAS catalogs (Wyatt et al., in prep.). Zuckerman also remarked that "it would be worthwhile to verify the 25 μm excesses with a ground based camera". Indeed it would – these systems could represent a departure from the canonical picture that extrasolar debris systems very much resemble our own. Typically the IRAS fluxes of these systems are close to photospheric at 12 μm, exhibit a significant excess at 25 μm, but there is no detection at 60 μm and 100 μm. This suggests an excess peaking at $\sim$ 25 μm or $\sim$ 120 K, which if this originates from a ring would lie $\sim$ 4, 7, 15, 44 AU from main sequence K0, G0, F0, A0 stars respectively. So this dust should lie at distances intermediate between our asteroid and Kuiper belts, in fact in the region where we expect gas giant planets to form, and so just where we expect there to be no dust!

Thus these disks pose several fundamental questions about the outcome of planet formation in these systems. Are these the Kuiper belts of systems in which planet formation failed before it could extend past 10 AU? Or maybe we are witnessing the collisional destruction of massive asteroid belts or the sublimation of comets in the middle of fully formed planetary systems? Or perhaps these are systems which are in a transitional (mid-planet formation) stage, and these will eventually evolve into classically cool debris disks? There could be a different explanation for each disk, or this sample could represent a separate class of system with a common, but as yet unsuspected end-state to planet formation.

To begin to tackle these issues, we need to know where the dust lies in these systems. Mid-IR imaging from an 8 m class telescope can be used to confirm that this excess is centred on the star and to determine its spectrum. However, as these stars typically lie at $\sim$ 100 pc, this emission would not be resolved with such observations. Mid-IR interferometry from the VLTI is ideally suited to resolving this emission, since the disks are anticipated to emit a flux between 0.1 and 1 times that of the photosphere in the N band (0.1 to 1 Jy), and to be between 0.01 and 0.1 arcsec in radius. Such observations will tell us the location of the dust, whether it lies in a ring or an extended disk, whether this disk is face- or edge-on, and whether there are any large-scale asymmetries in its structure.

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