SPITZER SPACE TELESCOPE STUDIES OF THE FOMALHAUT DEBRIS DISK.


Introduction: Fomalhaut (ω Pisces Austrinus) is a bright A3 V star at a distance of 7.7 pc. Its strong far-infrared excess, discovered by IRAS [1], indicated the presence of substantial circumstellar dust. Submillimeter continuum maps resolved the dust cloud into two lobes NW and SE of the star [2], consistent with a ring/torus ∼36° (280 AU) in diameter and inclined 20° from edge-on. Higher resolution 450 μm maps [3] found a ring brightness asymmetry interpreted as a dense clump near the ring SE ansa. Early Spitzer Space Telescope observations [4] showed that an asymmetric ring morphology is also present in the mid-infrared, with the SE ansa ∼30% brighter than the NW ansa at 70 μm. While no emission was seen exterior to the submm ring, the Spitzer data demonstrated that the ring interior is at least partially filled in with warm dust emitting between 20-35 μm.

Remarkable progress in our understanding of the Fomalhaut ring has taken place in 2005. High-quality 350 μm maps [5] have resolved the two ring anesa into connected arcs that completely encircle the star: a complete ring, rather than just the two anesa previously seen. There is some evidence at the resolution limit that the ring center is displaced from the star. This was spectacularly confirmed in new Hubble Space Telescope coronographic images [6] which finally detected the ring in scattered light. The ring is found to be narrow (∆r= 25 AU) and elliptical (e= 0.11), with the star offset by 2" from its geometric center. With some regions of the ring closer to the star (and therefore warmer) than others, the asymmetry in the far-IR emission seen by Spitzer is thus readily accounted for. A planetary perturber on an eccentric orbit is required to maintain apsidal alignment of particles in an eccentric ring [7].

New Observations: In November 2004 we observed Fomalhaut for a second time with Spitzer’s Multiband Imaging Photometer (MIPS). Here we report on 70 μm observations made in the fine scale mode (4.99′′ pixel−1) using 10 sec exposures. A total of 32 dithered images, each with individual S/N ≥ 200, were processed with version 2.92 of the MIPS instrument team’s Data Analysis Tool (DAT [8]). The increased integration times, more optimal detector bias settings, and calibration improvements combine to make these observations significantly more sensitive than those first reported by Stapelfeldt et al. 2004 [4]. With its high S/N and multiple subpixel dithers, this dataset is well-suited to the application of resolution enhancement / deconvolution techniques. The HIRES algorithm [9] was used, along with a model point spread function produced by the STinyTIM software [10].

Results: Figure 1 shows Fomalhaut at the native 70 μm resolution, and after progressively increasing the number of iterations of image deconvolution. After about 50 iterations, the asymmetric bar of emission described in [4] begins to resolve into a complete ring. Little improvement in the result appears beyond 150 iterations. A completely independent deconvolution using a maximum entropy method yields produces an image very similar to the HIRES result; we therefore conclude that the image features are robust. The ring has the same position angle and outer radius as seen in the 2005 optical and submillimeter images [6,5]. The asymmetry between the two anesa is also enhanced by the deconvolution, growing to almost 60%. The asymmetry appears not only in the anesa themselves; between the two anesa, the ring appears bright over a broad azimuthal region passing through the SE ansa, and fainter at azimuths straddling the NW ansa. This effect is likely to be another manifestation of the varying distance between the star and the elliptical dust ring.

Future work: Along with these new 70 μm results, we have obtained additional 24 μm images, MIPS SED observations covering the wavelength range 55-90 μm, high resolution spectroscopy covering 10-37 μm, and a deep 4.5 μm imaging search for possible brown dwarf or planetary companions. Some of these will also be presented on the meeting poster, and in combination with disk image models, will be presented in an upcoming paper.

Figure 1: Spitzer/MIPS 70 μm maps of the Fomalhaut debris disk, with resolution enhanced by (top row) 0, 10, 40; and (bottom row) 70, 100, and 130 iterations of the HIRES algorithm. The final resolution achieved is about 7′′ FWHM, a factor of ~2.5 enhancement over the nominal Spitzer diffraction limit. In each panel, the field of view is 96′′.