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Resolved Scattered Light Images of the Edge-On Protoplanetary Disk ESO Hα 569

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Abstract. We present detailed models of the edge-on protoplanetary disk ESO Hα 569 (SSTgbs J111110.7-764157) from resolved scattered light images from HST and a complete spectral energy distribution. Data was obtained as part of an HST campaign to catalogue edge-on disks around young stars in nearby star forming regions (HST program 12514, PI: Karl Stapelfeldt). We confirm that this object is an optically thick edge-on disk around a young star with an outer radius of 125 AU. Using full radiative transfer models, we probe the distribution of dust grains and overall shape of the disk (inclination, scale height, dust mass, maximum particle size, inner radius, flaring exponent and surface/volume density exponent).

Keywords. Protoplanetary Disk, Young Stars, Planet Formation

1. Introduction and Observations

The unique geometry of edge-on circumstellar disks provides the best opportunity to study the detailed structure as the bright central star is occulted, providing contrast. The spectral energy distribution can place constraints on the mass and distribution of grain sizes within a disk, while the scattered light images place constraints on the geometry of the disk. ESO-Hα 569 is a member of the Chameleon I star forming region which is known to have a distance of 160 $\pm$ 15 pc and an age of 1-2 Myrs (Whittet *et al.* 1997). The central star has a spectral type of M2.5 (Luhman *et al.* 2007) and is known to be under-luminous (Comerón *et al.* 2004). For more information on this edge-on disks campaign see the proceedings by Stapelfeldt *et al.* and Duchêne *et al.* in this volume.

Scattered light images were obtained using HST ACS/WFC in F814W and F606W (Figure 1; left panel). The disk has a radius of $\sim 0.8'' = 125$ AU. The top nebula's peak surface brightness is $\sim$ 20x the bottom, suggesting an inclination of $\sim 80°$. It is close to left/right symmetric, though the southern side is very slightly brighter. There is a clear jet present in F606W. The SED compiled from various catalogues is shown in Figure 1 (Right Panel). It shows the double-peaked shape typical of edge-on disks, with a minimum near 11 μm and thermal emission peaking at $70 - 100$ μm.

2. Radiative Transfer Modeling and Results

Using the MCFOST radiative transfer code (Pinte *et al.* 2006), we construct spectral energy distributions and 0.8 μm scattered light images for a grid of over 200,000 models (Table 1; Column 2). Baysian analysis was performed to arrive at the best fit parameter values (Table 1; Column 3-6). For similar work see Pinte *et al.* 2008 and Duchêne *et al.* 2010. The best fit image and SED are shown in Figure 1.

We found that a sharp edged disk gave the overall shape of the upper disk but failed to get the flux ratio between the top and bottom and didn't yield enough diffuse material

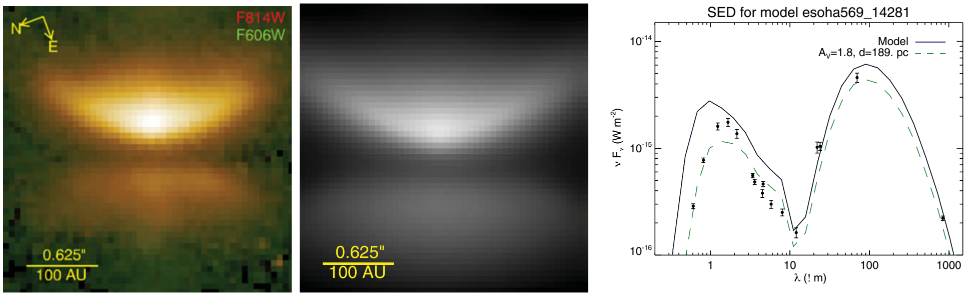

Figure 1. Left: False color composite HST images of the protoplanetary disk ESO-Hα 569 with a log stretch. (F606W and F814W). Both filters show the dust lane and asymmetries between the top and bottom of the disk, while only F606W establishes the presence of an outflow jet. Center: Best fit 0.8 μm model image from the combined SED and image χ^2 analysis. Right: Observed (data points) and best fit spectral energy distribution (dashed line).

Table 1. Modeled Disk Parameters and Best fit values from the χ^2 distributions.

Parameters	Range of Values	SED	Image	Weighted	Total
Inclination (degrees)	60 to 90	77.63	75.52	75.52	75.52
Scale Height (AU at r = 100 AU)	10, 15, 20, 25, 30	15	25	20-25	20
Dust Mass ($M_\odot$)	10^{-4}, 3×10^{-4}, 10^{-3}	10^{-3}	3×10^{-4}	3×10^{-4}	3×10^{-4}
Flaring Exponent (Beta)	1.0,1.1, 1.2, 1.3, 1.4,1.5	1.5	1.4	1.4	1.3
Surface Density (Alpha)	–2, –1.5, –1.0, –0.5, 0.0	–2.0	–0.5	–1.5	–0.5
Max Particle size (μm)	10, 100, 1000, 3000	3000	3000	1000-3000	3000
Grain Porosity	0.0, 0.5	0	0.5	0.0	0.0
Structure	Disk, Tapered-edge Disk	sharp	tapered	tapered	tapered

above the disk. This was solved with a tapered edge model where the density Σ, falls off exponentially with some critical radius R_C of material outside of the disk (Hughes *et al.* 2008).

$$\Sigma = \Sigma_c \left(\frac{R}{R_c}\right)^{-\gamma} exp\left[\left(-\frac{R}{R_c}\right)\right]^{2-\gamma}$$

Using the tapered edge disk model, we can simultaneously fit the spectral energy distribution and images well. We are continuing to refine the parameter grid for the fit. The large scale height (relative to typical protoplanetary disks) is consistent with the low mass of the central star.

References

Comerón, F., Reipurth, B., Henry, A., & Fernández, M. 2004, *A&A*, 417, 583
Duchêne, G., McCabe, C., Pinte, C., *et al.* 2010, *ApJ*, 712, 112
Hughes *et al.* 2008, *ApJ*, 678, 1119H
Luhman, K. L. 2007, *ApJS*, 173, 104
Pinte, C., Menard, F., Duchêne, G., & Bastien, P. 2006, *A&A*, 459, 797
Pinte, C., Padgett, D. L., Menard, F., *et al.* 2008, *A&A*, 489, 633
Whittet, D. C. B., Prusti, T., Franco, G. A. P., *et al.* 1997, *A&A*, 327, 1194

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