EPSC Abstracts
Vol. 6, EPSC-DPS2011-409, 2011
EPSC-DPS Joint Meeting 2011

The circumstellar disk of HH30: Searching for signs of disk evolution with multi-wavelength modeling

D. Madlener[1] , S. Wolf[1], A. Dutrey[2], and S. Guilloteau[2]
(1) Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany
(2) Observatoire Aquitain des Sciences de l'Univers, Université de Bordeaux, France
[dmadlener;wolf]@astrophysik.uni-kiel.de, [Anne.Dutrey;Stephane.Guilloteau]@obs.u-bordeaux1.fr

Abstract

We conducted a parameter study based on simulated annealing to construct a self-consistent model of HH30's circumstellar disk using all available observations in the wavelength domain $\lambda{\sim}1\mu$m . . . 3mm. Recently made high-resolution observations of continuum visibilities at $\lambda = 1.3$mm with the Plateau de Bure Interferometer [1] and the spectral energy distribution (SED) in the mid infrared with IRS on the Spitzer Space Telescope (SST) [2] significantly increased constraints on our modeling attempt.

We present models of the edge-on disk featuring an inner depletion zone with ~100AU diameter explaining subsets of the available data and conclude the presence of dust growth and settling.

1. Introduction

HH30 is a young stellar object located in the dark cloud L1551 at a distance of ~140pc in Taurus. The accreting protostar features an indirectly illuminated edge-on flared disk, appearing in the optical and near infrared (NIR) as a nebulosity separated by an obscuring belt with wavelength-dependent thickness [3, 4]. Observed variability of HH30 shows periodicity on the scale of a few days and seems to be due to either a light-house effect, periodic shadowing, or a close companion [5]. The impressive bipolar jet features an undulating morphology and ballistic motion suggesting a precession of the source due to interaction with a partner [6]. Interferometric imaging in the continuum at $\lambda = 1.3$mm shows a region of reduced brightness at the center of the system suggesting a hole in the dust distribution of ~40AU radius probably induced by tidal clearing of an unresolved binary [1]. The jet induces a conical molecular outflow featuring an opening angle of ~30° [7], consistent with a close binary [8]. Interferometric observations of ^{13}CO (J = 2-1) show a gaseous disk in Keplerian rotation around an

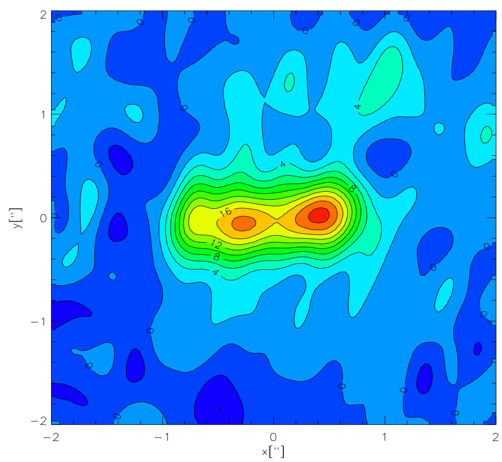

Figure 1: The continuum brightness map of HH30 at $\lambda = 1.3$mm exhibits a central dip consistent with a depleted inner zone [1].

enclosed mass of $(0.45 \pm 0.04)\mathrm{M}_\odot$ that corresponds to a typical T Tauri star with spectral class M0±1 [7].

2. Methods

The standard model for an accreting disk assumes cylindrical symmetry and describes the dust distribution as product of a radial power law and a gaussian distribution in height [9]

$$\rho_{\text{dust}}(R, z) \sim R^{-\alpha} \exp\left[-\frac{z^2}{2h^2}\right]. \quad (1)$$

This parametrization allows flaring by varying the scaling height according to

$$h(R) = h_{100} \left(\frac{R}{100\mathrm{AU}} \right)^{\beta} \quad (2)$$

with the scaling height h_{100} at 100AU and the flaring exponent β. We modified the density distribution by multiplication with the step function

$$\theta(R) = \begin{cases} \eta: & R_{\mathrm{in}} \leq R \leq R_{\mathrm{att}} \\ 1: & R_{\mathrm{att}} < R \leq R_{\mathrm{out}} \\ 0: & \text{else} \end{cases} \quad (3)$$

introducing the *attenuation* $\eta \in [0, 1]$ to add warm dust near the central source while retaining the observed brightness dip at $\lambda = 1.3$mm, see Fig. 1.

We used the code MC3D to solve the radiation transfer problem self-consistently with the Monte-Carlo method [10] and implemented *simulated annealing* to search for the best fit [11]. The method creates a Markov chain through parameter space by comparing predictions generated by the radiation transfer code with observations and has advantages for high-dimensional optimization as no gradients must be calculated and local minima are overcome intrinsically.

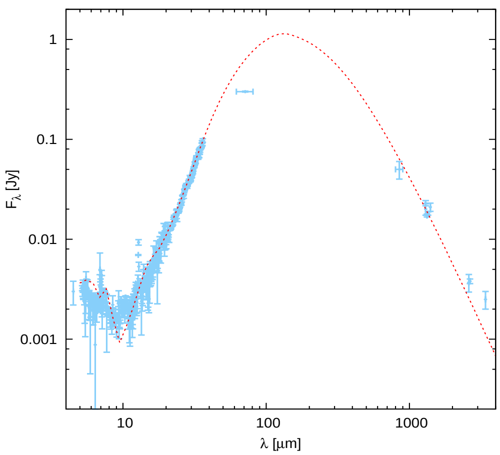

Figure 2: Direct comparison of the observed SED with our best-fit model. Observations made with IRS/SST in the mid infrared [2] put stringent constraints on emissions from the depleted zone while the low spectral index β_{mm}~0.4 [7] requires grains with $a_{\mathrm{max}} >$ 1mm.

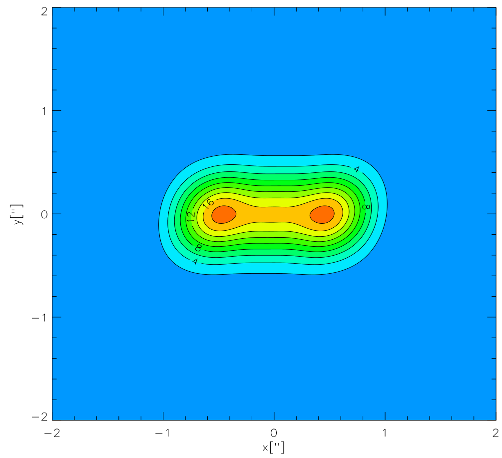

Figure 3: Brightness map of our best-fit model for the continuum visibilities at $\lambda = 1.3$mm convolved with a gaussian PSF with FWHM of $0.32" \times 0.59"$ as described in [1].

3. Summary and Conclusions

We found incongruent models explaining the appearance of HH30 in scattered NIR and for $\lambda > 5\mu$m respectively. The models have a comparable geometry featuring a depleted zone with ~50AU radius, but exhibit different dust grain size distributions. The presence of larger grains is necessary to explain observations at longer wavelengths. Our inability to find a unified model suggests dust settling and hence the need to extend future models by introducing dust species with individual spatial distribution.

Modification of the density by an attenuated zone was selected for its simplicity and many configurations compatible with the observed flux are conceivable. The findings of our parameter study verify and extend results of previous works. This is not self-evident as our study was not biased by fixing parameters *a priori* and the standard ansatz was modified thus introducing new degeneracies. By combining different classes of observations degeneracies could be reduced using a new *staggered* MCMC method that does not weigh individual χ_i^2 during optimization.

References

[1] Guilloteau, S., Dutrey, A., Pety, J., Gueth, F. 2008, A&A, 478, L31-L34

[2] Furlan, E., McClure, M., Calvet, N., Hartmann, L., D'Alessio, P., Forrest, W., Watson, D., Uchida, K., Sargent, B., Green, J., Herter, T. 2008, ApJS, 176, 184-215

[3] Burrows, C., Stapelfeldt, K., Watson, A., Krist, J., Ballester, G., Clarke, J., Crisp, D., Gallagher, III, J., Griffiths, R., Hester, J., Hoessel, J., Holtzman, J., Mould, J., Scowen, P., Trauger, J., Westphal, J. 1996, ApJ, 473, 437-451

[4] Cotera, A., Whitney, B., Young, E., Wolff, M., Wood, K., Povich, M., Schneider, G., Rieke, M. 2001, ApJ, 556, 958-969

[5] Durán-Rojas, M., Watson, A., Stapelfeldt, K., Hiriart, D. 2009, AJ, 137, 4330-4338

[6] Anglada, G., Lopez, R., Estalella, R., Masegosa, J., Riera, A., Raga, A.C. 2007, AJ, 133, 2799-2814

[7] Pety, J., Gueth, F., Guilloteau, S., Dutrey, A. 2006, A&A, 458, 841-854, P06

[8] Tambovtseva, L., Grinin, V. 2008, MNRAS, 387, 1313-1317

[9] Shakura, N., Sunyaev, R. 1973, A&A, 24, 337-355

[10] Wolf, S. 2003, Computer Physics Communications, 150, 99-115

[11] Kirkpatrick, S., Gelatt, C. D., Vecchi, M. P. 1983, Science, 220, 671-680