A Dust Trap in the HD 34700 Protoplanetary Disk

Sub-Millimeter Array Observations of a Young Multiple System

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Introduction

In recent years, millimeter wavelength observations of protoplanetary disks around young stars have revealed substructures, including asymmetries, gaps, and rings [1]. These substructures could be indicative of phenomena that create gas pressure maxima which trap large dust grains. This is necessary for grains to overcome the drift and fragmentation barrier that otherwise prevents their growth, and to form planets in the relatively short timescale before the gas disk dissipates [7].

HD 34700Aa/Ab is a young, close binary of two Herbig Ae stars (Age ~ 5 Myr [3], T ~ 23 days [6], M ~ 2M⊙ [3]) . Observations by Monnier et al. (2019) reveal a spiral arm distribution of micron-sized dust grains in the disk around the central binary [3]. This system also contains the distant companion HD 34700B of stellar type K and mass 0.7M⊙ at a projected distance of 1850 AU from the central binary, and another more distant companion at a projected distance of 3300 AU [3, 4].

We present new, high resolution SMA observations of this system.

Observations

We observe the HD 34700 system in both Subcompact and Very-Extended configurations at a wavelength of 1.3 mm. This also allows us to observe the CO J=2-1 transition at 230.538 GHz and therefore observe the CO gas.

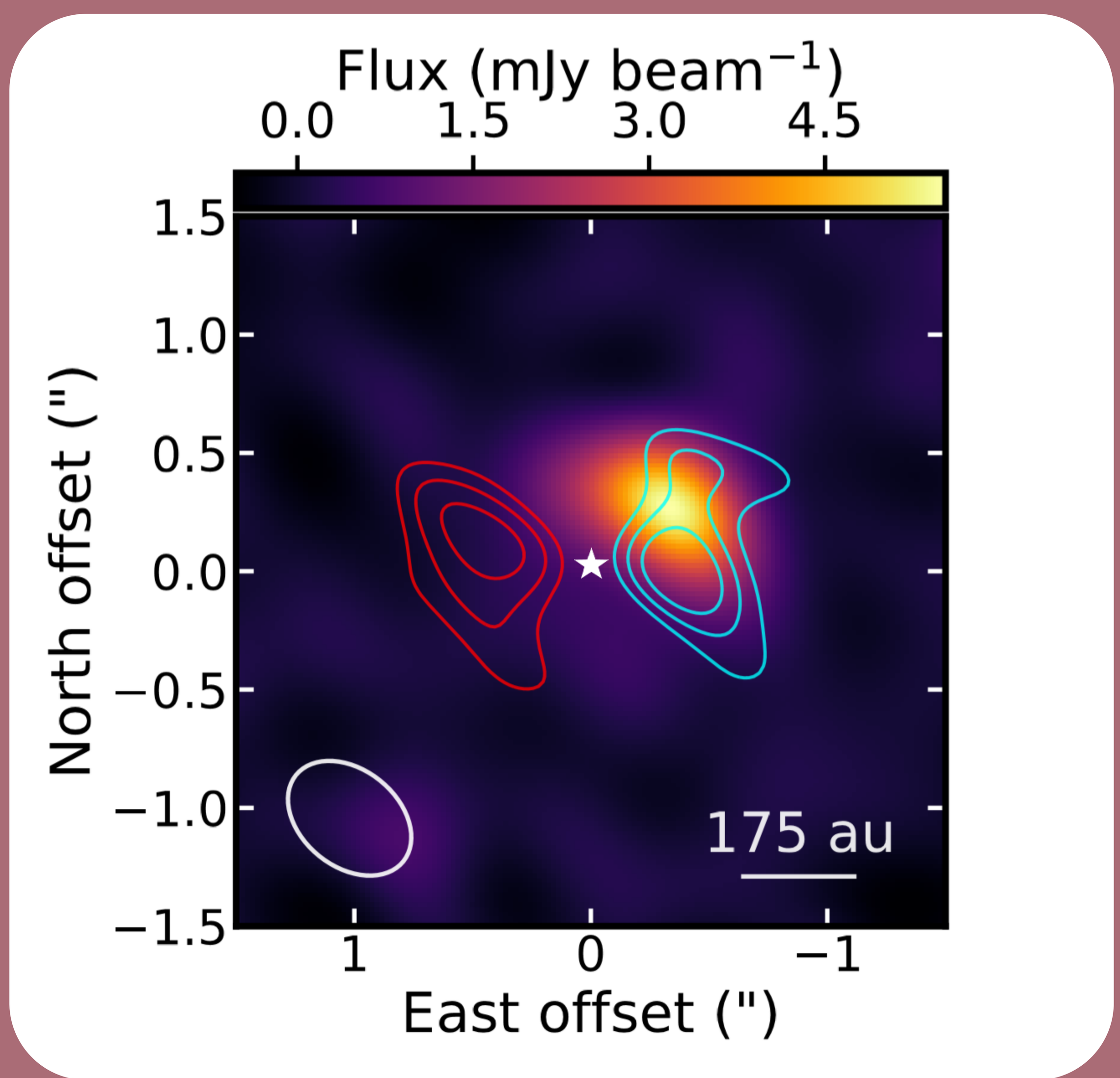


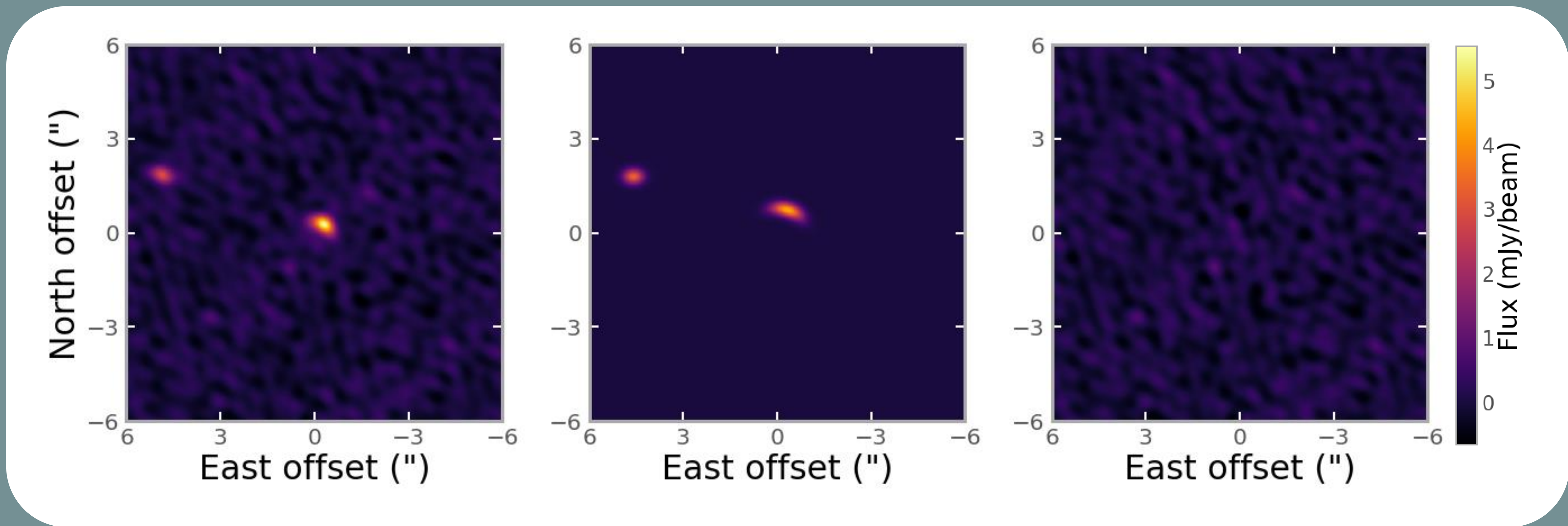
Fig. 1: CO emission contours plotted over the continuum emission near the central binary. The location of the central binary is indicated by the white star. Contours shown in red are redshifted, and contours shown in blue are blueshifted, indicating the rotation of a Keplerian gas disk around the central binary. (Contour interval = 1.2 mJy)

Modeling

We performed forward modeling on the interferometric visibilities (sampled at the same u-v coordinates as our observations) using the GALARIO [5] package combined with Markov Chain Monte Carlo [2]. This enabled us to robustly determine the optimal parameter values and their uncertainties, presented in Table A.

We modeled the continuum emission as an azimuthally asymmetric Gaussian ring, and the emission around HD 34700B as a Gaussian centered on the star. The model and its residuals are shown in Figure 2 below.

Fig. 2:
Left: Data from VEX observations of HD34700.
Center: Best fit model, as determined by MCMC fitting.
Right: Residual of the best fit model.



Results

We find the millimeter grains to be highly concentrated at ~168 AU from the central binary, with the emission resolved azimuthally (57 deg FWHM) and radially (~80 AU). We also resolve the emission around the B companion with a 2σ Gaussian outer radius of ~87 AU.

We estimate the mass of the trap to be at least 16 $M_{\oplus}$, assuming optically thin dust emission and a temperature of 30K. Under the same assumptions, the mass of the companion disk is 8 $M_{\oplus}$.

Table A: Optimal Parameter Values from MCMC fitting

Parameter	Value
Trap Radius (r_c) [AU]	168^{+14}_{-11}
Trap Radial FWHM [AU]	79^{+17}_{-17}
Azimuthal Peak Location (θ_c)	-110.0^{+2}_{-1}
Azimuthal FWHM	57^{+8}_{-8}
Total Flux [mJy]	$7.8^{+0.2}_{-0.2}$
Inclination of Trap [deg]	31^{+8}_{-10}
Companion Flux [mJy]	$3.4^{+0.2}_{-0.2}$
RA Offset of Companion [arcsec]	$4.9^{+0.2}_{-0.3}$
Dec Offset of Companion [arcsec]	$1.8^{+0.02}_{-0.03}$
Companion FWHM [AU]	102^{+26}_{-30}
Position Angle of Companion	61^{+14}_{-23}
Inclination of Companion	84^{+24}_{-32}
RA Subcompact Offset [arcsec]	$0.11^{+0.03}_{-0.03}$
Dec Subcompact Offset [arcsec]	$0.06^{+0.02}_{-0.02}$

Conclusion

Our new observations of the HD 34700 system find:

- An azimuthally asymmetric distribution of large dust grains that indicates the presence of a dust trap, offset from the central binary
  - Possibly indicative of planet formation
- Confirmation of the central disk's rotation with CO gas emission
- A previously unknown dust disk around HD 34700B

Due to the large size of the cavity and the small separation of the central binary, the gravitational interactions are unlikely to be the cause of the dust trap. The dust trap could be caused by past fly-bys of the distant companions, or by the presence of a planet orbiting the central binary.

References

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