Measuring Dynamical Masses of Gas-Bearing Debris Disk Host Stars

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Gas in Keplerian Rotation for Stellar Mass

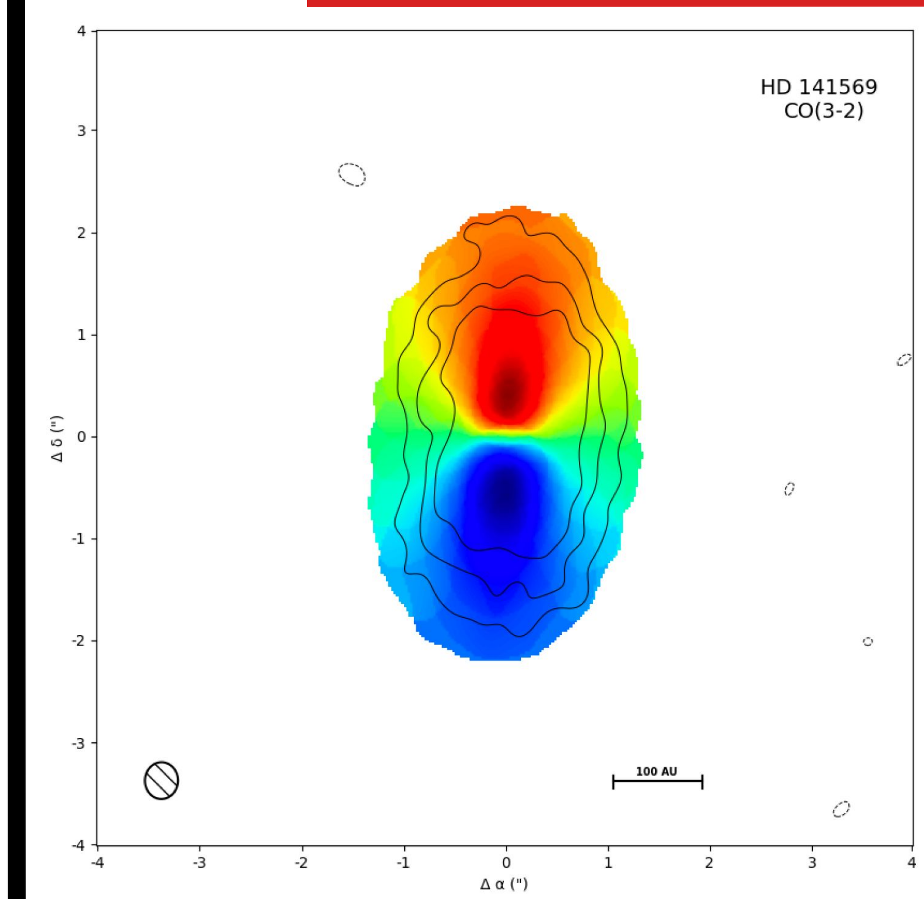
- Debris disks are circumstellar disks composed primarily of dust created by collisions between planetesimals. Since the dust is produced by collisions, they were assumed to contain no gas.
  - But recent ALMA observations have discovered 18 debris disks with gas emission (Hughes et al. 2018)
- Dynamical mass measurements have not always aligned with stellar evolution models (eg. Pegues et al. 2021)
  - Now extended to main sequence stars
- Goal: Using new Gaia distance measurements, measure dynamical mass with uncertainties for each disk

Table 1. Gas-Bearing Debris Disks

Star	ALMA Band of Observation ()	Gaia Distance (pc)	Supposed Mass ($M_\odot$)
HD 141569	7	111.61	2.22
HD 131488	6	152.24	2.19-2.40
HD 32297	6	129.73	1.59
HD 121191	6	132.29	1.6
49 Ceti	7	57.233	2.10
HD 156623	6	108.33	2.2
HD 121617	6	117.89	1.9
HD 138813	6	136.60	2.2
HD 131835	6 and 7	129.74	1.77
HD 181327	6	147.78	1.36
Fomalhaut	6	7.6988	1.92
HD 146897	6	132.19	1.23-1.31
HD 110058	6	130.08	2.40
HD 129590	6	136.32	1.3
η Corvi	7	18.244	1.43
HD 21997	6 and 7	69.686	1.8
β Pictoris	7	19.635	1.75
NO Lup	7	132.90	0.7

Table 1: the 18 debris disks that will be analyzed in this study as well as their distances via Gaia measurement, the frequency band of observation, and the most recent literature finding on the host star mass.

Initial Data Management and Imaging



- Data for the CO(J=3-2) moving in the HD 141569 debris disk was taken under project ID #2012.1.000698.S.

Figure 1. The zeroeth (contours) and first (colors) moment maps for HD 141569 displaying the velocity integrated intensity and the intensity-weighted mean velocity for the CO(3-2) in the disk.contours with lines corresponding to [-3σ, 3σ, 6σ, 9σ] where σ is equal to the rms noise: 1E-2 Jy/beam.

MCMC Results: Not Great

- Once the data had been properly managed, cleaned, and imaged, more refined parameters were searched for via a Markov Chain Monte Carlo (MCMC) technique that iteratively created a disk model, compared it to the data, and then accepted or rejected the model based on Chi-squared values.

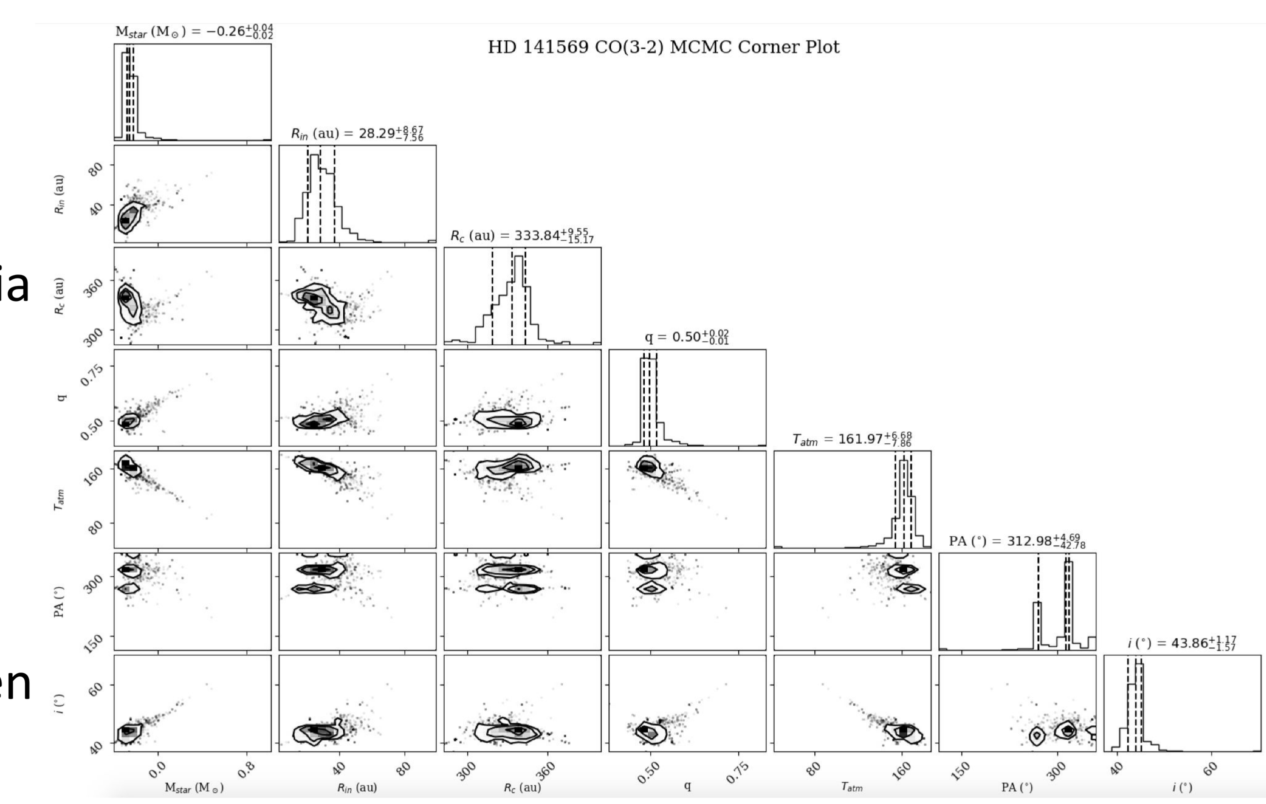
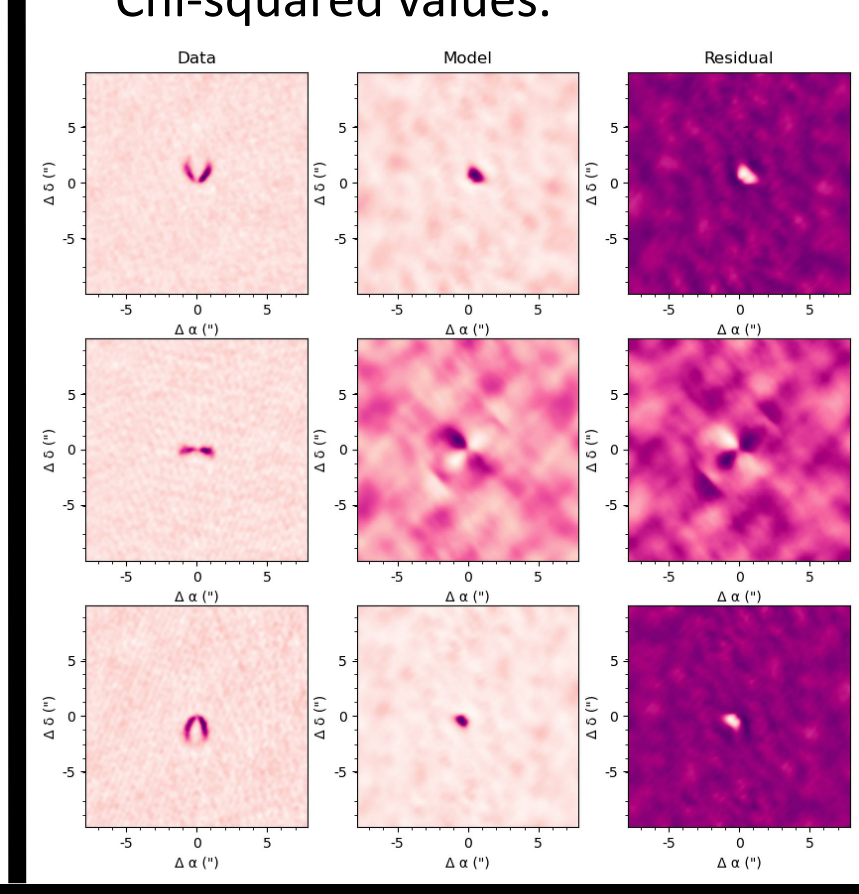


Figure 2. The corner plot and histograms for the MCMC process showing the exploration of parameter space with each variable post burn-in.



- The benefit of implementing a Bayesian, Affine-Invariant MCMC process is that this returns the best-fit parameter values for the disk as well as the uncertainties in those values.

Figure 3. Model with the current best fit parameters for HD 141569.

Comparison to Literature and Next Steps

- The MCMC run found a best fit host star mass of 0.55 +/- 0.1 solar masses which is not in very good agreement with the literature on the subject:
  - White et. al 2016 star mass: 2.39 + 0.04 / - 0.05 solar masses via MCMC
  - Di Folco et. al 2020 star mass: 2.22 +/- 0.01 solar masses via MCMC
- Future prospects: running these star masses through the stellar evolution software, Mesa, to verify values

Table 2 reporting the best fit parameters and their related uncertainties for the HD 141569 system.

Table 2. HD 141569 Best Fit Parameters

M_* ($M_\odot$)	R_in (au)	ΔRc (au)	q	Tatm (K)	Position Angle (°)	Inclination (°)
$0.55^{+0.05}_{-0.02}$	$28.29^{+8.67}_{-7.56}$	$333.84^{+9.55}_{-15.17}$	$0.50^{+0.02}_{-0.01}$	$161.97^{+6.68}_{-7.86}$	$312.98^{+4.69}_{-42.78}$	$43.86^{+1.17}_{-1.57}$

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References: