# Investigating the Origin of the Gas in the Debris Disk Around 49 Ceti

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## Gas-Rich Debris Disks

- Debris disks are flat structures of dust around main sequence stars, analogous to the Kuiper Belt in our own solar system
- Gas is common in young disks, but generally dissipates by the time planets are fully formed
- However, gas has been detected in a growing number of older debris disks and the origin of this gas is unknown
- Observing the gas yields constraints on giant planet formation timescales, composition, and mass limits

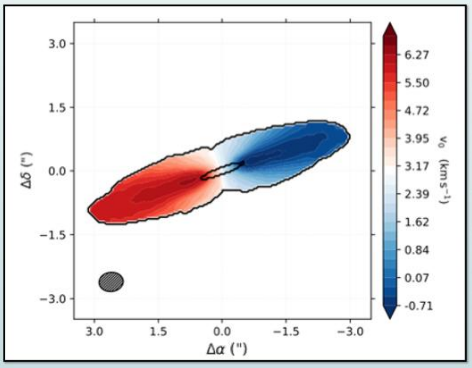



**Figure 1:** Intensity-weighted velocity (moment 1) map of CO (3-2) emission from 49 Ceti. The left side of the disk is moving away from the observer (red shifted), while the right side moves toward the observer (blue shifted).

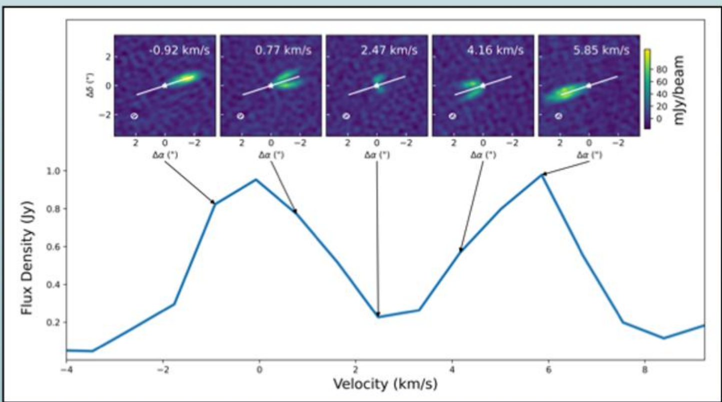



**Figure 2:** Spectral line profile of 49 Ceti and selected velocity channel maps. The star symbol represents 49 Ceti, the white line represents the disk midplane, and the white ellipse shows beam size and orientation.

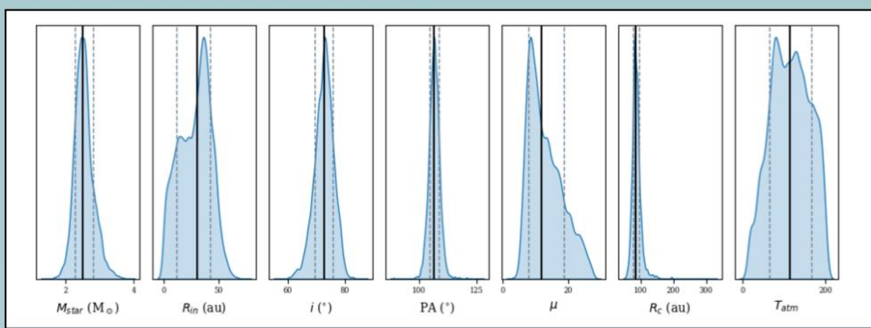
## Gas Origin: Primordial or Second Generation?

- If the gas has primordial origins, then it has survived past when most of the dust dissipates. If it has second generation origins, then it is from collisions of icy planetesimals
- Primordial gas is $H_2$ dominated, while second generation gas is primarily carbon and oxygen
- We fit the vertical structure of the gas around 49 Ceti to determine whether it is primarily $H_2$ or C and O

## Modeling with Markov Chain Monte Carlo (MCMC)

- MCMC algorithms are used to compare models with data, and help us to characterize the uncertainties on model parameters
- We used the circumstellar disk modeling code `disk_model3` (Rosenfeld et al., 2013) (Flaherty et al., 2015) to model the disk while varying stellar mass ($M_{star}$), disk inner radius ($R_{in}$), inclination (i), position angle (PA), mean molecular weight (μ), critical radius ($R_c$), and atmospheric temperature ($T_{atm}$)
- Scale height is a measure of vertical puffiness of the disk, and is greater for gas with primordial origins than gas with second generation origins
- The best fit model had a scale height of $h = 9^{+5}_{-3}$ au at a radius of 150 au, which suggests consistency with second generation origins of the gas
- We expect to confirm these results with a $C^{18}O$ line ratio

**Figure 3:** Posterior distribution histograms for the MCMC results. The black line represents the mean value, while the dotted lines represent values at plus or minus one standard deviation.




| Parameter: | $M_{star} (M_\odot)$ | $R_{in}$ (au) | $i$ (°) | $PA$ (°) | $\mu$ | $R_c$ (au) | $T_{atm}$ (K) |
|---|---|---|---|---|---|---|---|
| Best Fit | 2.5 | 38 | 73 | 107 | 8 | 83 | 180 |
| Median | $2.5^{+0.3}_{-0.3}$ | $30^{+13}_{-19}$ | $73^{+4}_{-4}$ | $107^{+2}_{-2}$ | $12^{+7}_{-4}$ | $87^{+15}_{-10}$ | $110^{+50}_{-50}$ |

**References** Hughes et al., 2008, ApJ Hughes et al., 2017, ApJ Flaherty et al., 2015, ApJ Rosenfeld et al., 2013,

**Acknowledgements** Thank you to Meredith Hughes, Kevin Flaherty, and the members of Disk Detectives for their mentorship. Hannah Lewis gratefully acknowledges funding from the Wesleyan Mathematics and Science Scholars (WesMaSS) program. A.M.H is supported by a Cottrell Scholar Award from the Research Corporation for Science Advancement. Software: CASA (McMullin, J.P., Waters, B., Scheibel, D., Young, W., & Golap, K., 2007), emcee (Foreman-Mackey et al., 2013), GALARIO (Tazzari et al., 2018).