

project name (acronym): ?. Multiple ringed-structure in AS209

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ABSTRACT

All the emission can be explained by 7 concentric rings. The emission is axisymmetric. Gaps are not empty – CO emission is present within the gaps. We detect CO outside the millimeter dust edge (two outer rings?).

Keywords: circumstellar matter — planetary systems: formation, protoplanetary disks — dust

1. INTRODUCTION

2. OBSERVATIONS

Refer to overview paper Andrews et al. (2018)

3. RESULTS

Include table with fit results of 7 rings: position, width, normalized peak, contrast.

3.1. *Dust continuum emission*

- Describe the surface brightness radial profile (the emission consists of a series of concentric narrow rings; the emission is axisymmetric; high contrast for the outer rings).
- Describe the fit done to the visibilities to extract the position and width of the ring components.
- Describe the main results: 1) All the emission can be explained by 7 concentric rings, 2) the rings are concentric, 3) a faint ring is found between the 2 outer rings, at around 100 au (the gap is not completely empty).

- Compare results with Jane’s fit to the image.

3.2. *CO emission*

- Dust gaps are not empty. CO emission is present within the gaps.
- CO emission extends outside the millimeter dust edge. This shows the radial drift of large dust grains. Put limit on dust/co emission?
- There are 2 rings outside the millimeter dust emission. Need to confirm this. Maybe we want to show channel maps.
- Note the change of the slope at 50 au.

4. DISCUSSION

- Compare with rings in HL Tau and TWHya. The continuum emission in the AS209 disk shows deeper gaps.
- Discuss possible explanations for the formation of the gaps. Dust trapping (refer to Dullemond et al. 2018). The low viscosity model shown in Fedele’s paper predict that a single planet can create multiple gaps in the disk, but this gaps are not completely empty. We do observe faint emission between the 2 main outer rings, which is consistent with these models.
- Compare ¹²CO and dust. Huang et al (2016) detected C¹⁸O extended emission that spatially coincides with the outer dust ring. With ¹²CO we trace the disk surface.

5. SUMMARY

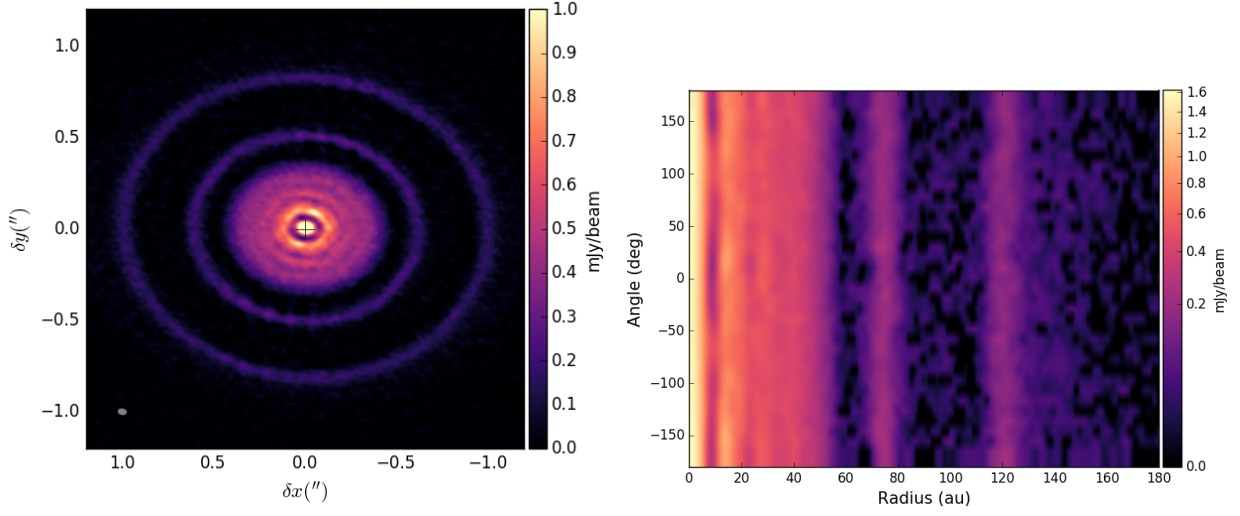


Figure 1. Dust continuum emission map (left), and in polar coordinates (right). The beam is shown in the bottom left.

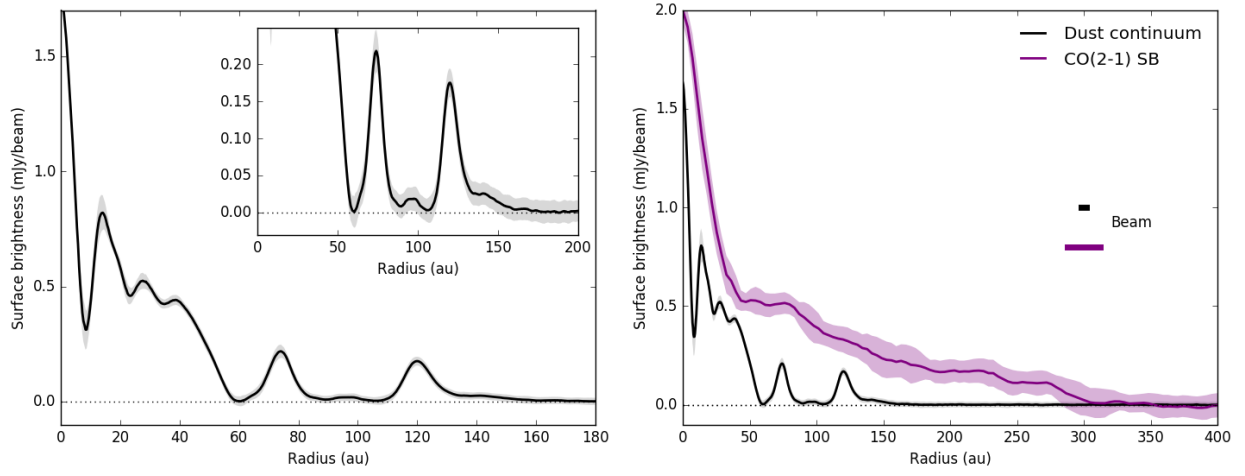


Figure 2. Deprojected radial profiles of the dust continuum emission (black lines). The ^{12}CO emission profile is shown in right panel (short-baselines only map).

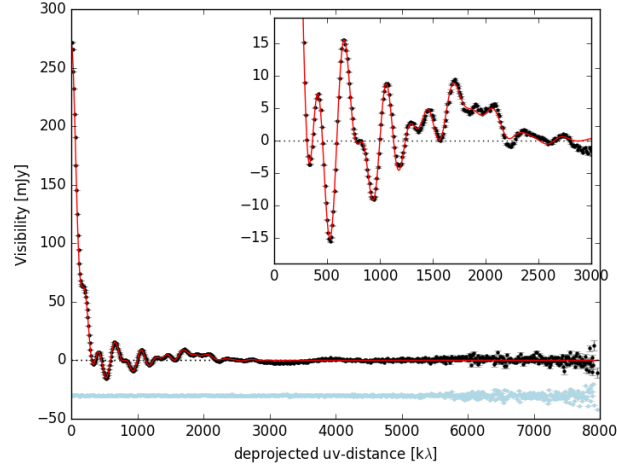


Figure 3. Observed (black) and modeled (red) deprojected visibilities. The imaginary part of the observed visibilities are shown in lightblue (shifted to -0.03 Jy). We only fit $u - v$ distances $< 3000k\lambda$, and assume the emission is axisymmetric.

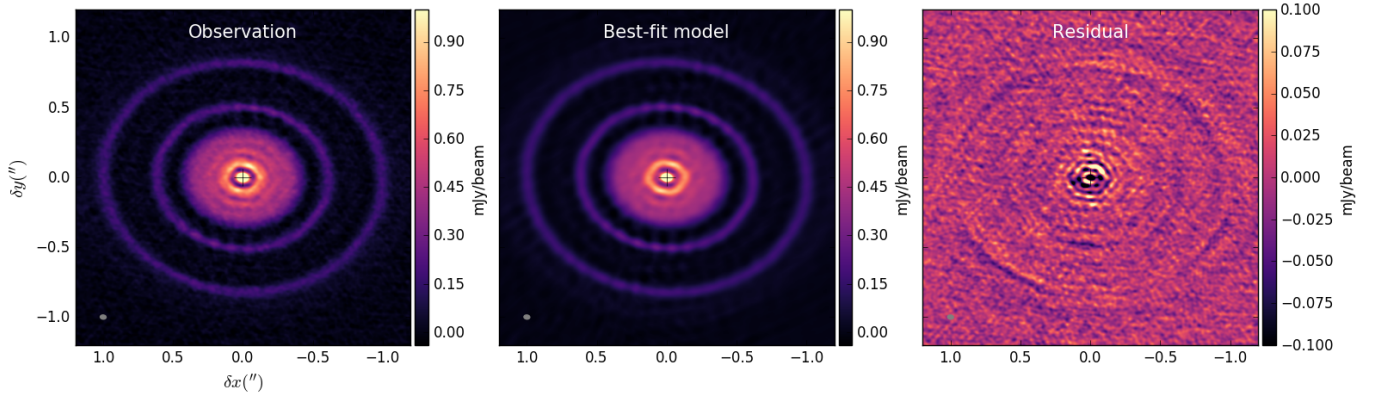


Figure 4. Observed dust emission map (left), the best-fit model (middle) and the residuals (right).

Table 1. Best-fit parameters.

<i>Disk parameters</i>		<i>Gaussian Rings parameters</i>								
i (deg)	34.9		Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
PA (deg)	85.7	Rel. Amp	1.00	0.26	0.12	0.11	0.07	0.00	0.05	0.01
Offset-x (arcsec)	0.0017	R_c (au)	0.00	15.06	26.76	41.04	74.11	92.99	120.47	138.38
Offset-y (arcsec)	-0.0031	FWHM (au)	6.51	7.48	11.66	17.99	7.31	22.79	9.62	24.72

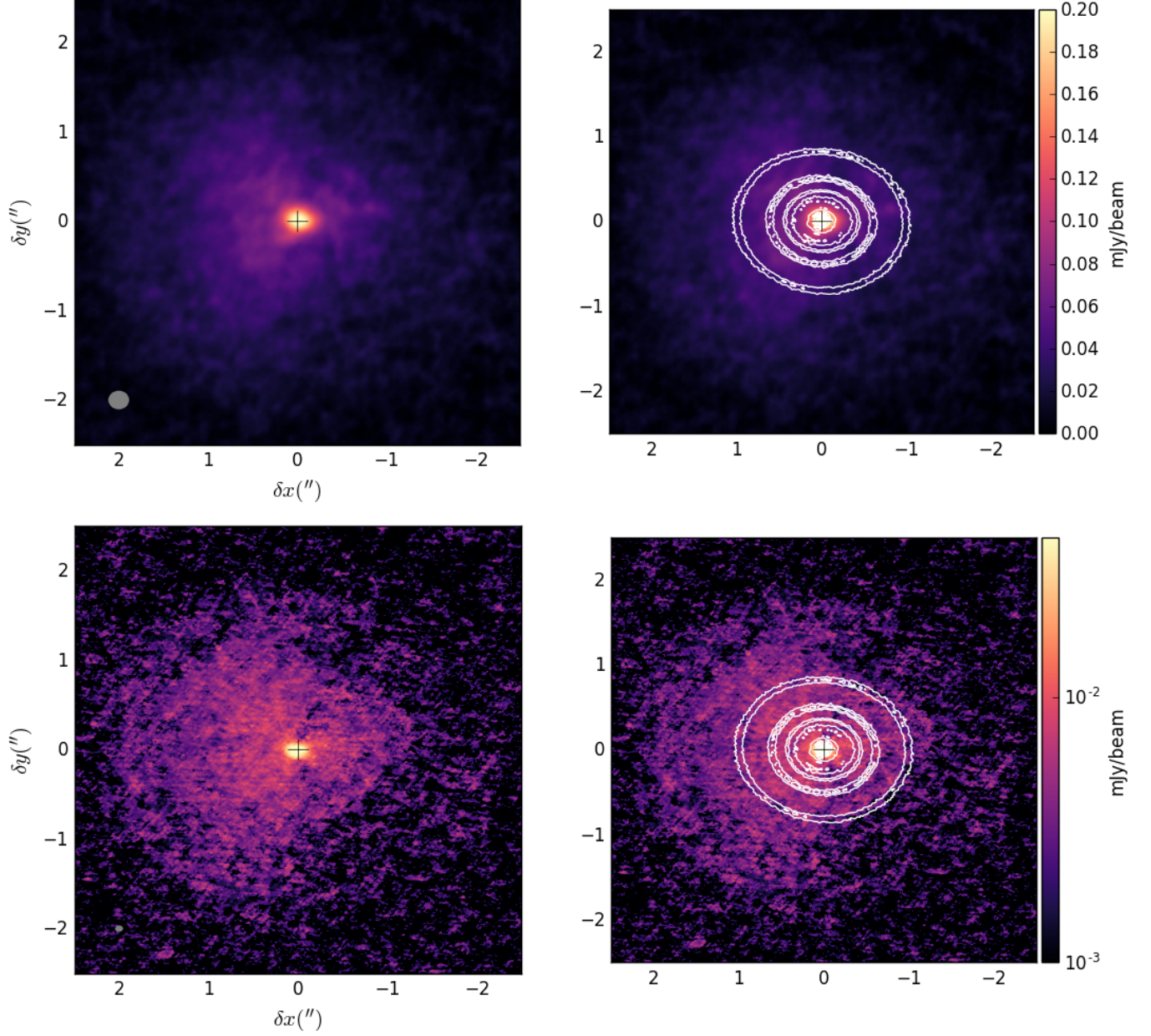


Figure 5. Moment-zero map of the $^{12}\text{CO } 2-1$ line. The maps shown in the upper panels include the short-baselines only. The lower panels include combined short+long baselines (beam is $0.075 \times 0.052''$). The dust continuum emission is shown in white contours in the right panels.