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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 axysimmetric; 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 ^{12}CO and dust. Huang et al (2016) detected C^{18}O extended emission that spatially coincides with the outer dust ring. With ^{12}CO we trace the disk surface.

5. SUMMARY

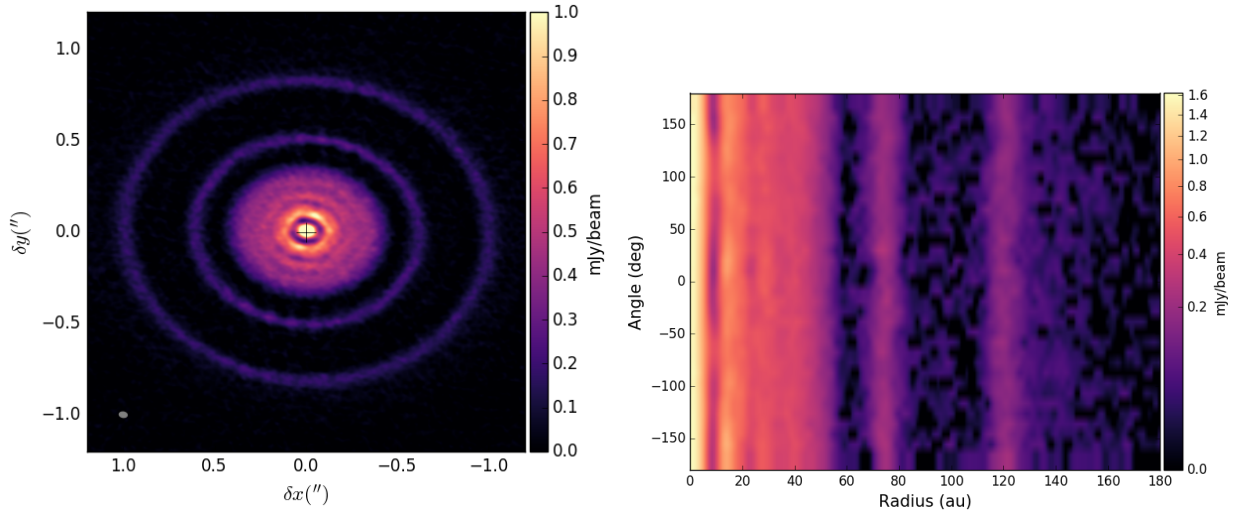

Figure 1. Dust continuum emission map (left), and in polar coordinates (right). The beam is shown in the bottom left.

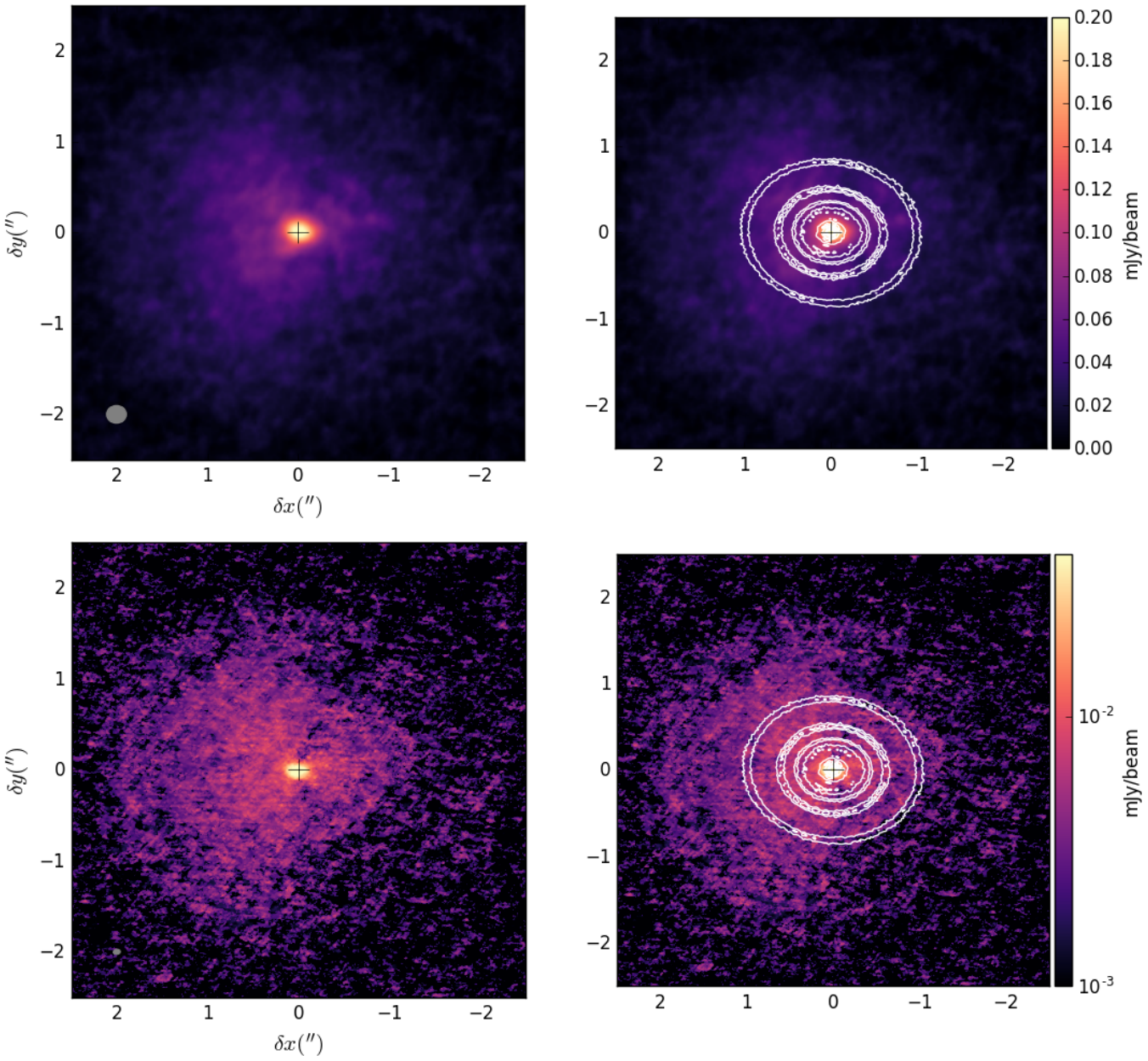

Figure 2. Moment-zero map of the ^{12}CO $2-1$ line. The maps shown in the upper panels include the short-baselines only. The lower panels include combined short+long baselines (beam is $0.075 \times 0.052''$). The dust continuum emission is shown in white contours in the right panels.

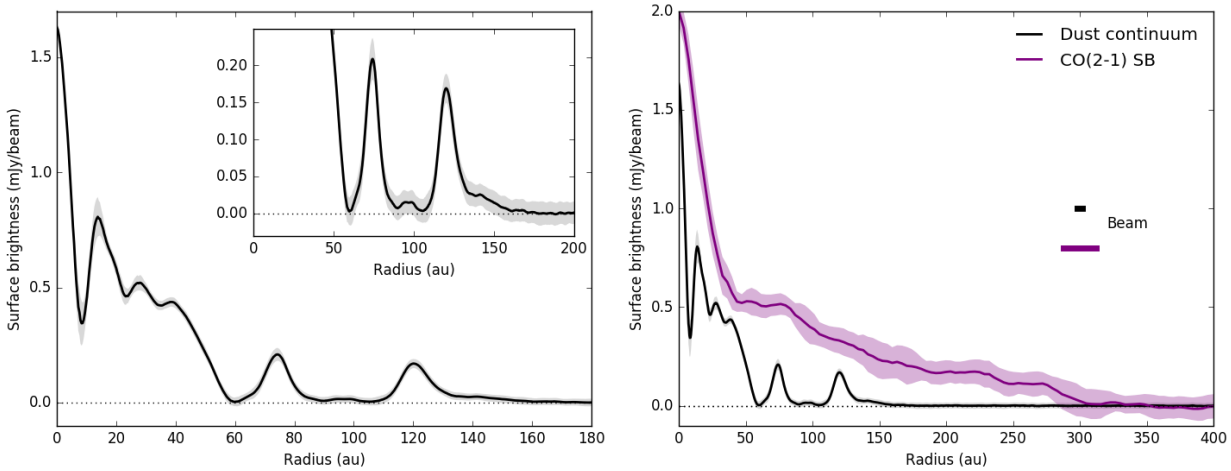

Figure 3. Deprojected radial profiles of the dust continuum emission (black lines). The ^{12}CO emission profile is shown in right panel (short-baselines only map).

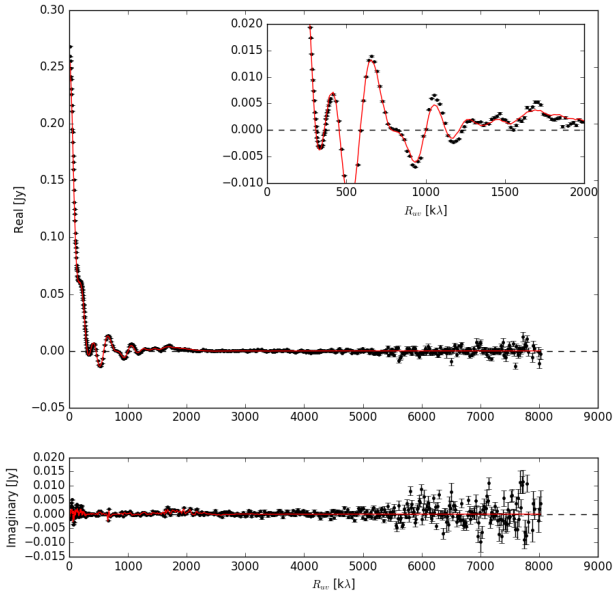

Figure 4. Observed (black) and modeled (red) deprojected visibilities.

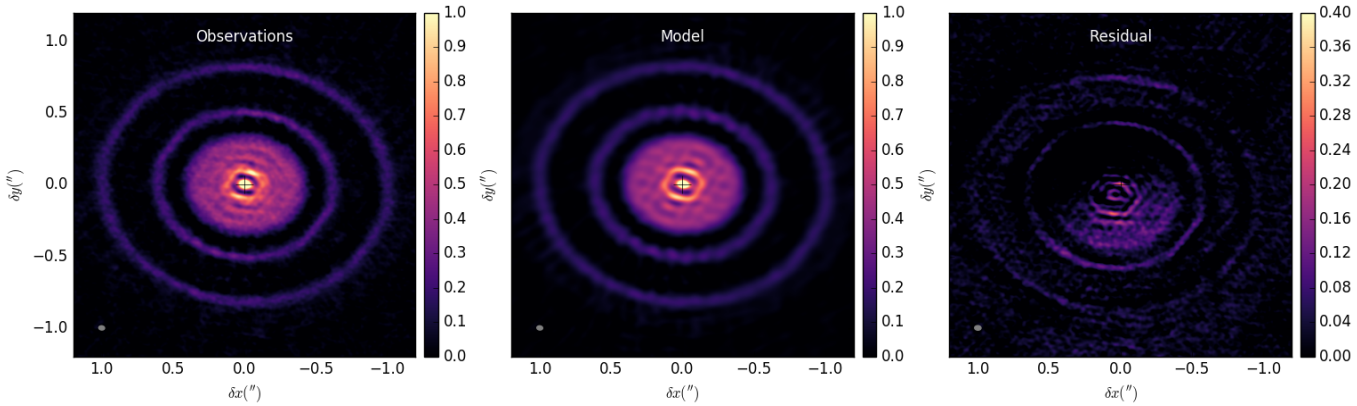

Figure 5. Observed dust emission map (left), the best-fit model (middle) and the residuals (right). (to be updated).