First ALMA observations of the HD 105211 debris disc: A warm dust component close to a gigayear-old star

Qiancheng Yang, **Qiong Liu**[1,2*], Grant M. Kennedy , Mark C. Wyatt, Sarah Dodson-Robinson, Rachel Akeson, and Nenghui Liao

1. Department of Physics, Guizhou University, Guiyang 550025, PR China **e-mail: qliu1@gzu.edu.cn**

2. Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK

UKI Discs Meeting 2024

Abstract

In this work, we investigate the structure of the disc surrounding the nearby F2V star HD 105211, which has a warm excess and a potential asymmetry in the cold belt. We applied the CASA pipeline to obtain the ALMA 1.3 mm continuum images. Then we constructed the SED and performed MCMC simulations to fit a model to the ALMA visibility data. To characterise the disc asymmetry, we analysed the ALMA images of two individual observation blocks and compared them to the previous Herschel images. Our modelling reveals that the disc is a narrow ring (23.6 ± 4.6 au) with low eccentricity positioned at a distance of 133.7 ± 1.6 au from the central star, which differs from the broad disc (100 ± 20 au) starting at an inner edge of 87 ± 2.5 au, inferred from the Herschel images. We found that both observation blocks show excess emission at the stellar position, while OB1 shows an offset between the star and the phase centre, and OB2 shows brightness clumps. We used a two-temperature model to fit the infrared SED and used the ALMA detection to constrain the warm component to a nearly pure blackbody model. The relatively low ratio of actual radius to blackbody radius of the HD105211 debris disc indicates that this system is depleted in small grains, which could indicate that it is dynamically cold. The excess emission from the stellar position suggests that there should be a warm mm-sized dust component close to the star, for which we suggest two possible origins: in situ asteroid belt or comet delivery.

Observations

- The star HD 105211 was observed with ALMA Band 6 (1.3 mm) under the Cycle 4 project 2016.1.00637.S (PI: Dodson-Robinson, Sarah).
- Fig. 1 presents the ALMA 1.3 mm continuum image of the HD 105211 system.
- To further study the disc structure and properties, we analysed the surface brightness profiles along both the major and minor axes with radial averaging using deg-wide swaths, as Fig. 2 shows. It imply a potential asymmetry or eccentricity within the disc.

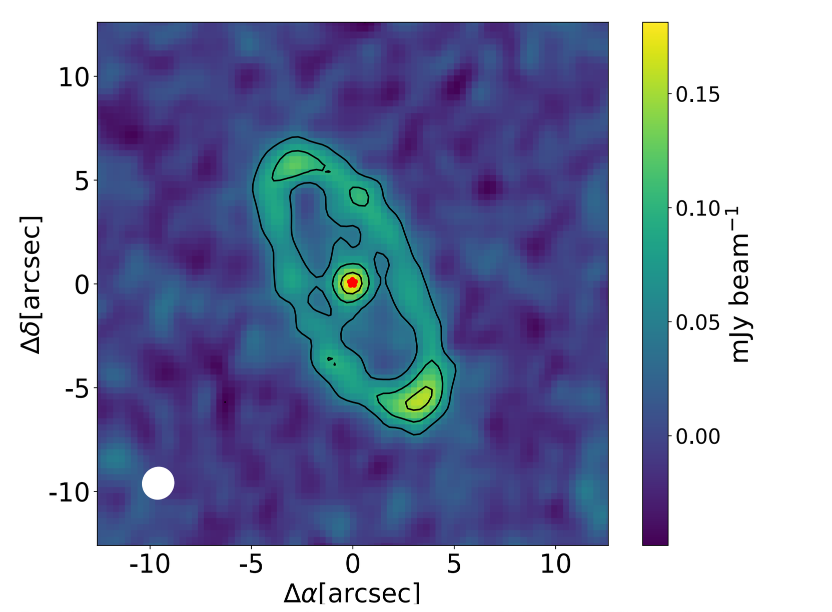


Fig. 1. ALMA 1.3 mm continuum image of HD 105211 obtained using natural weights. Contours are drawn at the levels [−3, 3, 6, 9] × σ_{rms}(rms = 16 μ Jy beam^{-1}). The beam size is represented by a white ellipse (1.62″ × 1.57″) in the bottom-left corner. The star location is marked as a red star symbol.

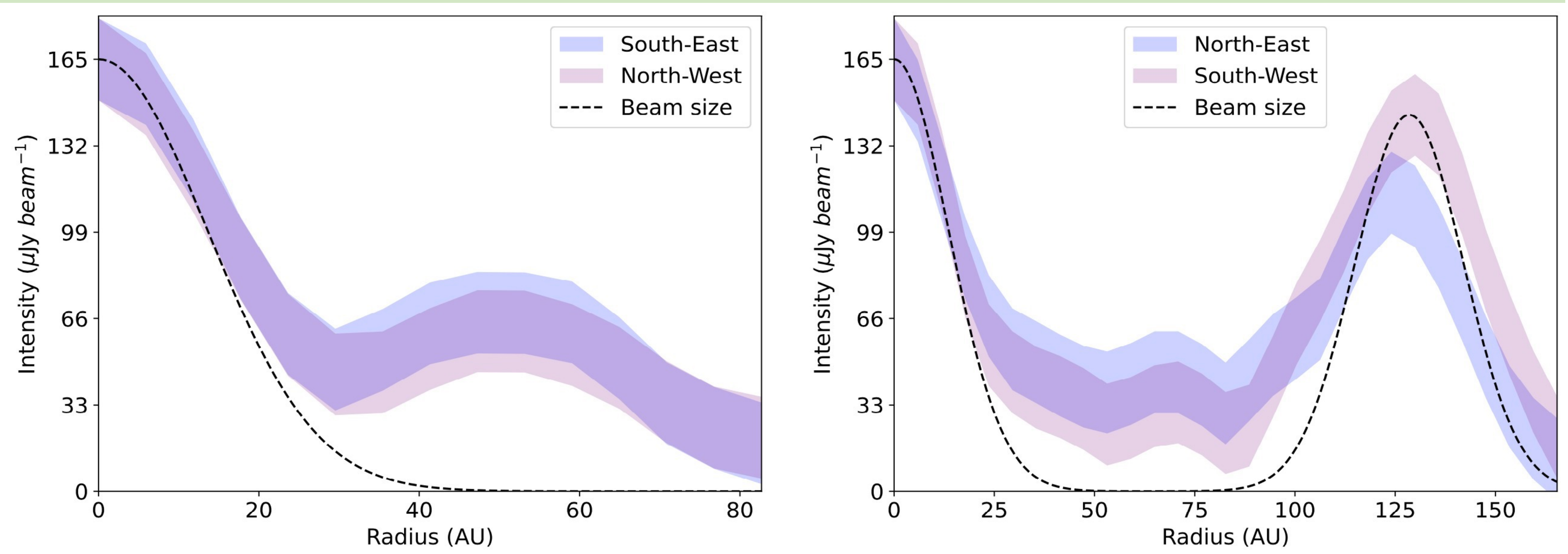


Fig. 2. Surface brightness profile of disc cut along the minor (left) and major (right) axis. The blue and purple shaded regions correspond to the 1 σ uncertainties of flux, and the dashed line corresponds to the beam size.

Modelling

- **SED results**

$L_\star = 6.8 \pm 0.05\ L_\odot$, $T_{eff} = 6990 \pm 100$ K .

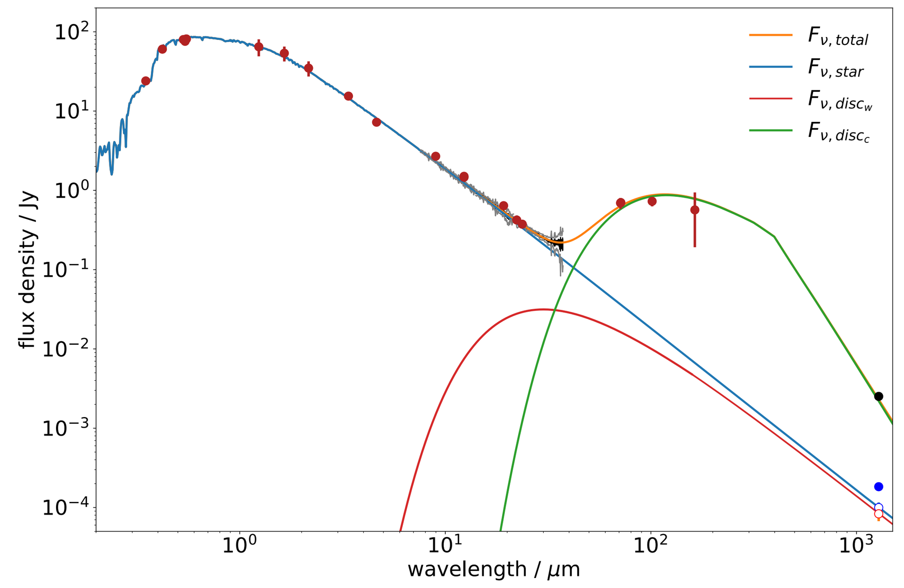
For the warm component:

$T_{bb} = 43 \pm 1$ K, $R_{bb} = 110 \pm 5$ au, $L_{disc}/L_\star = 6.3 \pm 0.3 \times 10^{-5}$

For the cold component:

$T_{bb} = 170 \pm 20$ K, $R_{bb} = 7 \pm 1$ au, $L_{disc}/L_\star = 9 \pm 1 \times 10^{-6}$

The estimated stellar flux at ALMA 1.3 mm is 100 ± 2.5 μJy.



- **Parametric model**

Our model is an axisymmetric Gaussian ring which yields a disc radius of 133.7 ± 1.6 au, with a width of 23.6 ± 4.6 au, an inclination of 67.0 ± 0.7°, and a position angle of 28.3 ± 0.7°. The residual maps of the Gaussian model is shown in Fig. 5.

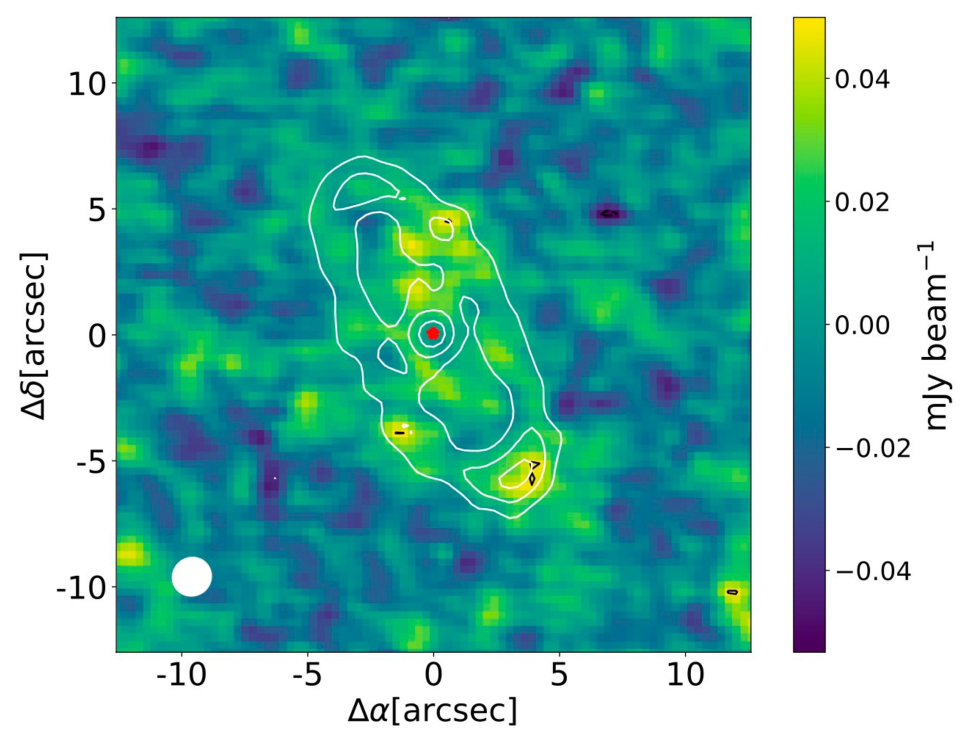


Fig. 5. Residual of the Gaussian model using the same contour levels and beam size as the continuum image with 3 × σ_{rms}(σ_{rms}= 16μJy beam^{-1}) and beam size in 1.62″ × 1.57″. The red star symbol is the star's location. We added contours of the continuum image (white) for comparison with the residual image.

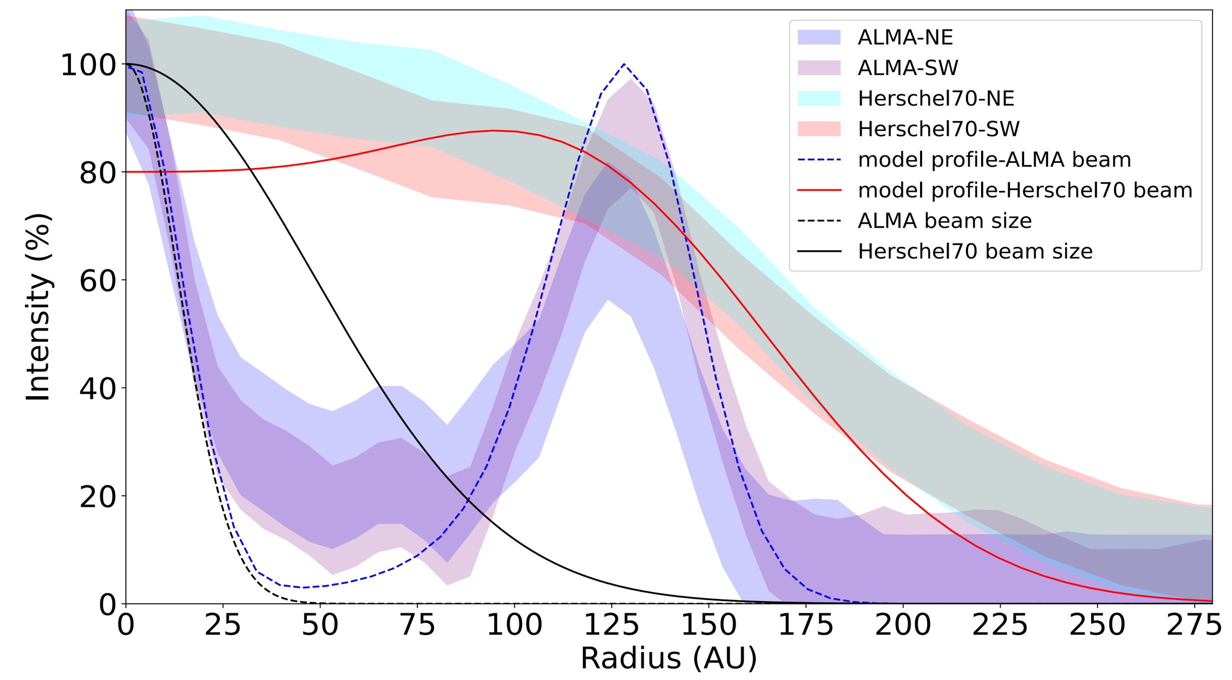


Fig. 7. Surface brightness profile of the disc along the major axes in the ALMA and original *Herschel* 70 μm images. The shaded regions correspond to the 1 σ uncertainties. The blue dashed line represents the radial profile of our best-fit parametric model convolved with the ALMA synthesised beam, while the red line represents the radial profile of the model convolved with the *Herschel* 70 μm beam. The black line corresponds to the *Herschel* 70 μm beam size, and the black dashed line denotes the ALMA beam size.

Discussion

- **Comparison with Herschel**

We compared the radial profiles between ALMA and the Herschel 70 μm original image in Fig. 7. The Herschel observations presented a closer inner edge and a further outer edge, suggesting that there might be a different radial distribution of dust between the infrared and millimetre wavelengths for the reason that they trace grains of different sizes.

- **Collisional status of the disc**

We found the ratio of the actual radius to the black- body radius, denoted as Γ, to be 1.2 ± 0.2, significantly lower than the expected value of 2.8 ± 0.1. This discrepancy suggests that the emission spectrum in the HD 105211 debris disc is primarily governed by large particles, indicating a relatively lower abundance of smaller particles.

- **Warm inner dust component**

By comparing our results to those from observations at different time points and examining the SED, we have detected warm dust surrounding the central star at a wavelength of 1.3 mm for the first time.

Conclusions

- In this paper, we have presented high-resolution observations of the HD 105211 debris disc at ALMA 1.3 mm for the first time.
- The structure distribution in the ALMA images displays a narrow ring, different to the broad structure of Herschel images, which indicates the distribution of the smaller grains is modified by radiation forces.
- Considering the distribution of dust, we posit that this warm dust likely originates from both the in situ broad disc and comet delivery, hinting at the potential presence of planets formed through comet interactions.
- These possibilities could be tested with upcoming JWST observations (PI: Matrà Luca, Proposal ID: 5650).

Acknowledgements. We like to thank **Shane Hengst** for providing the Herschel original and deconvolved images, and the fruitful discussion on comparison between ALMA and Herschel surface brightness profiles from **Yinuo Han**.