A Tale of Two Transition Disks: ALMA long-baseline observations of ISO-Oph 2 reveal two closely packed non-axisymmetric rings and a ∼2 au cavity

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Abstract

ISO-Oph 2 is a wide-separation (240 au) binary system where the primary star harbors a massive ($M_{dust} \sim 40\ M_{\oplus}$) ringlike disk with a dust cavity ∼ 50 au in radius and the secondary hosts a much lighter ($M_{dust} \sim 0.8\ M_{\oplus}$) disk. As part of the high-resolution follow-up of the "Ophiuchus Disk Survey Employing ALMA" (ODISEA [1]) project, we present 1.3 mm continuum and ^{12}CO molecular line observations of the system at 0.02" (3 au) resolution. We resolve the disk around the primary into two nonaxisymmetric rings and find that the disk around the secondary is only ∼ 7 au across and also has a dust cavity (r ∼ 2.2 au). Based on the infrared flux ratio of the system and the M0 spectral type of the primary, we estimate the mass of the companion to be close to the brown-dwarf limit. Hence, we conclude that the ISO-Oph 2 system contains the largest and smallest cavities, the smallest measured disk size, and the resolved cavity around the lowest-mass object ($M_{star} \sim 0.08\ M_{\odot}$) in Ophiuchus. From the ^{12}CO data, we find a bridge of gas connecting both disks. While the morphology of the rings around the primary might be due to an unseen disturber within the cavity, we speculate that the bridge might indicate an alternative scenario in which the secondary has recently flown by the primary star causing the azimuthal asymmetries in its disk. The ISO-Oph 2 system is therefore a remarkable laboratory to study disk evolution, planet formation, and companion–disk interactions.

Primary

In the figure 1 top-left panel shows the continuum image for the system with a zoom for both sources. There exists evidence of two apparent rings around the big cavity, Therefore, an unsharp masking process was carried out, to try to highlight the morphology of the possible rings, deprojecting the image obtained to finally make radial (top-left) and azimuthal (bottom) intensity profiles, where it can clearly see the existence of two rings and a gap that divides them at a radius of ∼ 3.5", with a very particular asymmetry, where the maximum intensity in one corresponds to the minimum in the other and vice-versa.

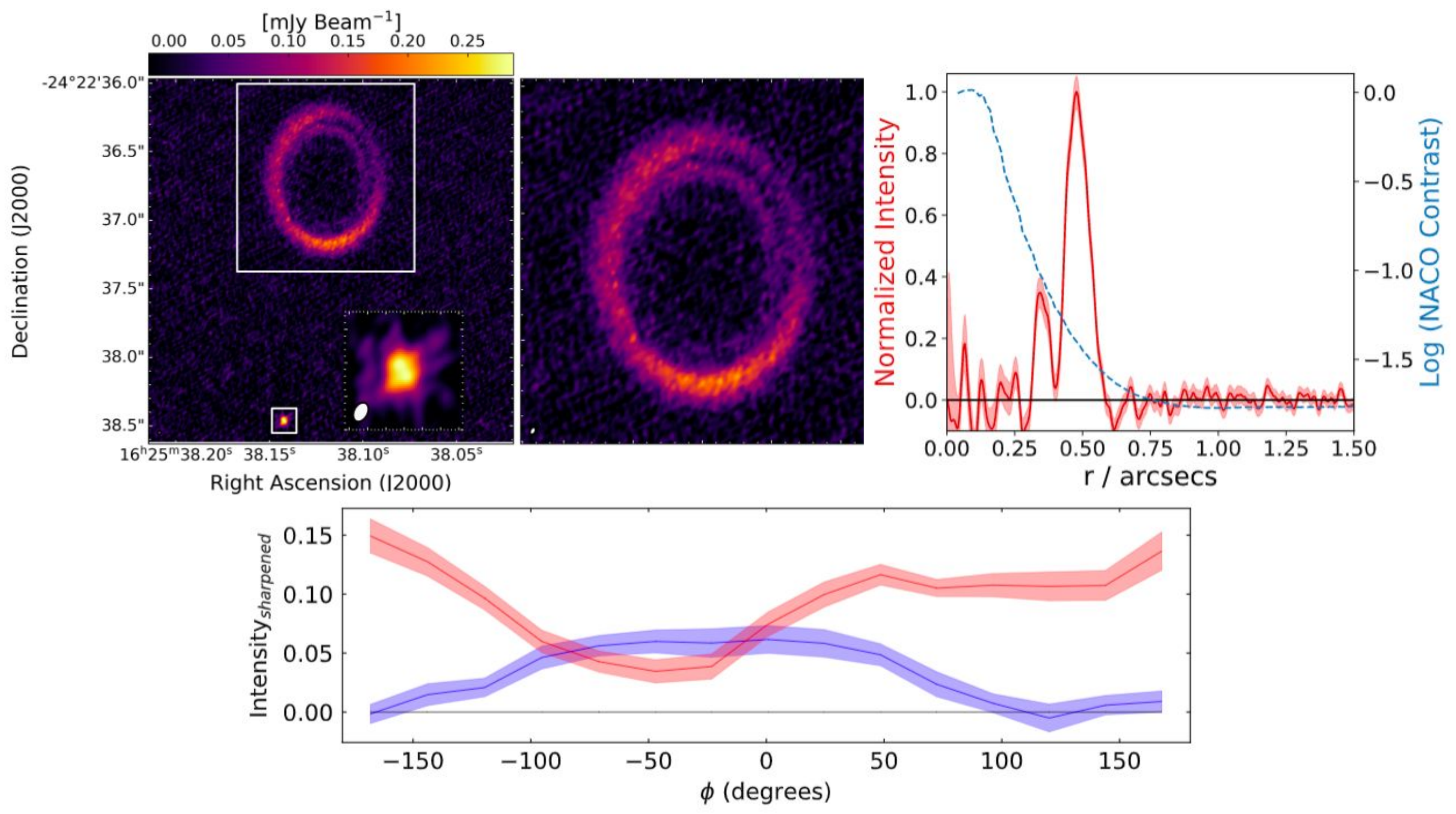

Figure 1

^{12}CO

The Figure 3 shows the moment maps corresponding to a combination of the aforementioned observations and ALMA cycle 4 observations with an angular resolution of 0.2 , using the CASA TCLEAN tool. The moment 0 map (left panel), corresponds to the velocities of the blue shifted part in the visibilities, with white contours of the continuum in the observations of poorer resolution [1] and black contours the signal of the image itself (both contours correspond to intensities > 3*rms in their respective images). At moment 1 map, the same contours of the continuum are shown and the position of each star is shown in sky-blue color using the coordinates from the GAIA's DR2.The existence of a gas bridge that joins the two sources can be clearly seen, in addition to the existence of a signal and Keplerian rotation within the cavity of the primary.

Secondary

Using the CASA software [2], not only self-calibration and imaging were done, the primary disk was also subtracted from the observations, leaving only the secondary disk. Later these new visibilities were plotted in figure 2, to find the baseline where the real part was made null and thus apply the analogous procedure proposed in [3], Obtaining that this secondary disk has a cavity of radius ∼ 2.2 au, being the smallest cavity observed in this molecular cloud.

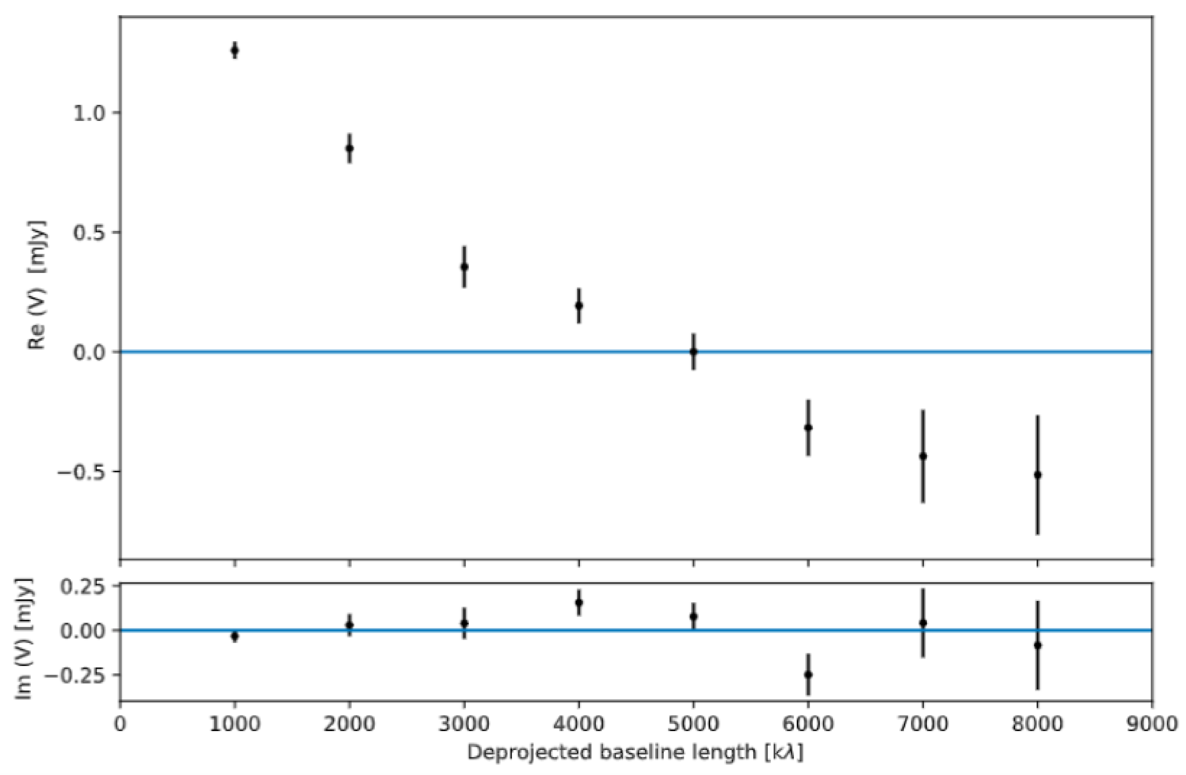

Figure 2

Moment 0 and 1 maps

For the presented moment 0 map, the velocities are between 0 and 2 km s^{-1}, where the bridge is clearly visible. We can note that the primary disk has keplerian dynamics with higher velocities than the bridge.

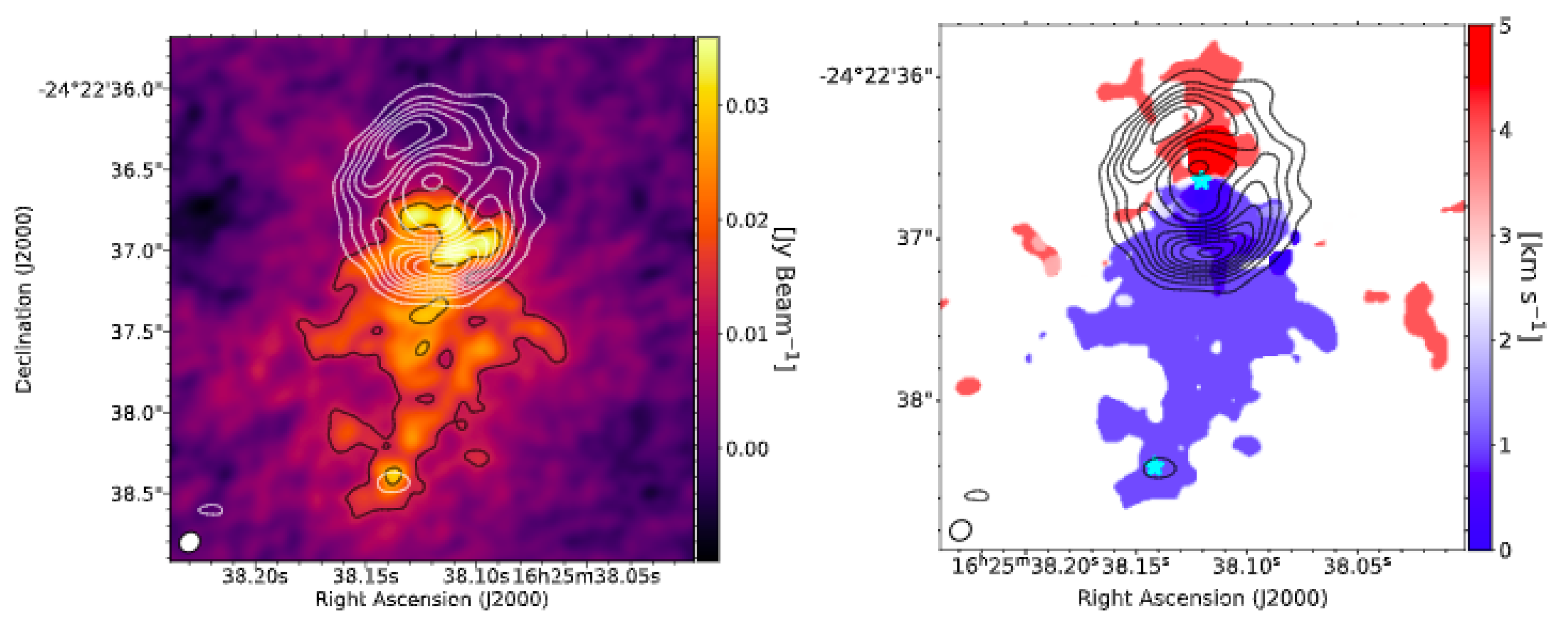

Figure 3

Discussion

The strange morphology of the primary disc for dust could have several explanations, but the presence of the gas bridge observed in 12CO could be evidence of the interaction between both sources as a possible flyby [4], which added to the presence of planets [5] could concisely explain the asymmetries of the two rings, which are also very close to each other. We propose hydrodynamic simulations that can recreate similar structures for this case.

Future work and paper link

A modeling process considering a possible flyby of the secondary combined with a deeper observations in (sub)mm with ALMA could explain the bidge in gas and the asymmetries in the dust on primary. The paper's link is: https://iopscience.iop.org/article/10.3847/2041-8213/abbcce/pdf

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