Multiple systems observed with ALMA.

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ABSTRACT

Here goes the abstract.

Keywords: wow much keywords

1. INTRODUCTION

Here goes the Introduction.

- Most stars are in binary systems

- However, few binary protoplanetary systems are known.

- And none of them has been studied at high resolution, to understand how companions affect the evolution and substructure of each one.

- Spirals and substructures have been usually assumed to be caused by companions, however, in most cases that is hard to be confirmed.

- In this case, we can safely assume the substructures have been caused by companions, because they are in fact binaries.

- We'll show the results of the first analysis in the binaries detected in our alma large program.

- in section 2 we blablabla...

2. HT LUP

HTLup is a known multiple system, ghez et al, where they identified three point sources. However, because of the unavailability to resolve both closest sources, until now most researches has taken them as a binary (citas citas) instead of triplet. This is not different in the latest data release from GAIA (cite to gaia), where the

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parallax for the main source is of 6.49 ± 0.06 mas, or a distance of $154\pm?$ pc, and the farthest source of the system has a parallax of 6.46 ± 0.13 mas. This shows that their proximity in the sky is not only a projection artifact, but they are in fact in the vicinity of each other.

Here I have to write about the physical known parameters, like mass, magnitudes, etc, luminosity class if possible, and cites.

3. AS205

In AS205 system we also have a multiple system. The brightest source is AS205 north (AS205N) (citas), a disk with a star type X and mass X, and located at $1.3''$ is the spectroscopic binary AS205 south (AS205S) (citas), where Almeida2018 proved through radial velocities the existence of a binary interaction between a star of $0.9\,M_\odot$ and a substellar companion with a mass of $19.25 \pm 1.96\,M_{Jup}$, with a orbital period of 24.84 ± 0.03 and a semimajor axis of 0.16 ± 0.04 AU.

The distances of each source in the AS205 system were obtained from the last (second) GAIA data release, however, we found a discrepancy between the GAIA distances and previous researches. For AS205N the parallax is 7.82 ± 0.1 mas, which are $127.93 \pm XX$ pc, but for AS205S the parallax is 6.37 ± 0.19 mas, and that puts them at more than 30pc of distance. Even when the proximity in the sky of this sources could be a just projection effect, we know from (Salyk et al 2014) that there is a gas flow between disks, extending even to X'' from the main source, and which we are able to confirm with our data. Since the luminosity of AS205S is the weaker than AS205N, we are using the distance of the later as the true one for this system.

[In this paragraph I have to discuss about the gas flow, what is known.]

4. DATA

The datasets presented here are part of the ALMA Large Program number XXX (citar paper) to observe with very high resolution 20 classical disks in band 6, including the molecular line 12CO 2-1 in one of the spectral windows. For AS205, we also used archival data corresponding to observations in band 6 from cycle 0? (PI: Collete Salyk 2014?).

We calibrated the observations following the standard procedure guidelines of this Large Program (cita). Before any treatment, for each source we flagged the channels that were $25 km\,s^{-1}$ around known systematic velocities, making a total width of $50 km\,s^{-1}$. Using the software CASA5.1 we applied the tasks `imfit`, `fixvis` and `fixplanets` to respectively find the 2D gaussian centroid of each disk, align it to the phase center in each observation, and then correct the coordinates positions of all observations with the centroid position of the longest baseline dataset, because of the highest angular resolution and signal to noise. For HT Lup, however, we faced the problem that the two closest disks observables in long baselines *** CORRECT USING THE TABLE NAMES *** are unresolved in the short baselines configuration, showing them as if they were just one disk. To solve this, we used the binary component located at 2.8arcsec as a reference to align the observations.

4.1. HT Lup

For HT Lup we had 4 observations in ALMA band 6. All of them had 4 spectral windows, where 3 were dedicated to observe continuum and 1 contained the 12CO 2-1 line. A summary of the observational setup can be found in Table 1.

4.2. AS205

For AS205 we had 6 observations, 3 from Colette (agregar cita) and 4 from our ALMA Large Program. Because of climatological conditions, only 1 of our ALMA Large Program observations were executed in configuration [Long baseline configuration], corresponding to the largest baselines, and the remaining 3 with [Short Baseline configuration]. We self-calibrated the [short baselines datasets] before concatenating them to the [LB data] to take advantage of the bigger beam and highest signal to noise. After joining all datasets, we performed 4 phase and 2 amplitude self-calibrations (more details in apendix).

5. RESULTS
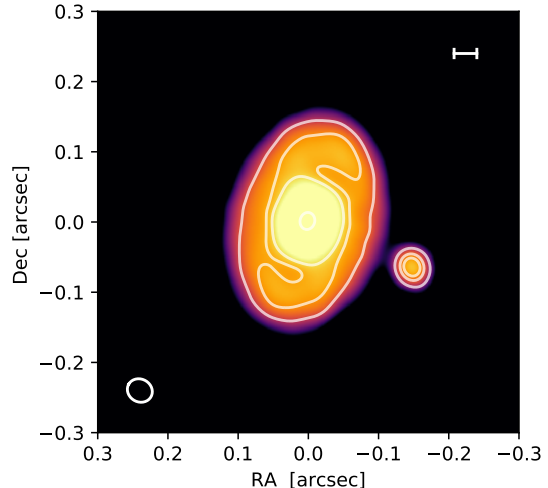
Figure 1. Continuum brightness distribution of the closest sources in the HTLup system, in logarithmic scale. The contour levels come from the unsharp image to help visualize the spiral substructure in the disk. There is still left to add the colorbar. Probably final displaying continuum image.

5.1. HT Lup

For HT Lup we could spatially resolve the close companion that were first detected with speckle imaging in the K band by (Ghez et al. 1997) using speckle photometry. Figure 1 shows the high resolution continuum map obtained from our data calibration, where the spiral structure of the main disk in the continuum is clearly seen with contour levels.

5.1.1. Spirals

In the continuum image, we calculated the mean radial profile of the main disk, and substracted it until deprojected 28 AU, that mark the point were the flux between the disk peaks is minimum. The spiral is very low contrast, in fact, the differences for a fixed radius are in the order of [X percent] (as it can be observed in the [figure X]), so the contribution of this substructure in the mean radial profile negligible, and therefore we can substract it from the deprojected continuum image to enhance the assymetries.

The deprojected spirals are displayed in figure X, where the mean radial profile was substracted. The pitch angle of each spiral is ......

5.1.2. Mass ratio

The peak of the secondary is located at $0.16''$ from the peak of the main disk, which represent ≈ 35 AU if we deproject using the inclination and position angle of the main disk. We threw a line between the peaks and calculated the luminosity profile along the line, presented in

Table 1. Observational setup for both sources. I have to adjust the column width, and fill with the data.

Source	Date	Freq. Range (GHz)	Antennas	Baselines (m)	On Source time (minutes)	Spw
AS 205	2012-03-27	13	$\sim 0.''5$			1 continuum, 12CO 2-1
		56013.944	$0.''0$			
		56014.984				
		56016.978				
HTLup						

^{a} At exposure start.

figure X. From the contour levels it can be seen that each object holds its own disk, and they interact surrounded by a cloud of X flux, and the line that separates them is X of the flux. From this, we use the formalism of roche lobes to calculate an approximation of the mass ratio between the disks. (I have to explain that the radiative profile of each disk is decreasing, so the minimum point between them must be related to the L1 point). From this, we obtain a mass ratio of q=13.

Previous photometric studies took HT Lup as if it were just one source (), calculating a photometry of X in the band K. from Ghez1997 we now that, roughly, the flux ratio between the sources is , so we can use it to calculate the corrected magnitudes in K band, which are X for the main source, and X for the secondary. Using as the age X Myr from XX et al, by the position in the HR diagram, the masses of the sources is approximately X and Y, which is in good agreement to the mass ratio calculated from the roche lobes approximation.

5.1.3. *Terciary Component*

The terciary component is found at $2.8''$ from the peak of the main disk. This binary was already known (citas citas citas)

5.1.4. *CO map*

We found the CO map to be highly contaminated by the cloud contribution.

5.2. *AS205*

In AS205 we are able to resolve at a scale of 5 projected AU two disks, with peaks located at a distance of $1.31''$. Their continuum maps are shown in Figures 2 and 3, and in the apendix can be found a figure of both disks together.

5.2.1. *Main disk*

For the main disk we applied a 2D gaussian fit using `imfit` in CASA5.1 to find the inclination and position angle of the main disk, and we found the values $i =$
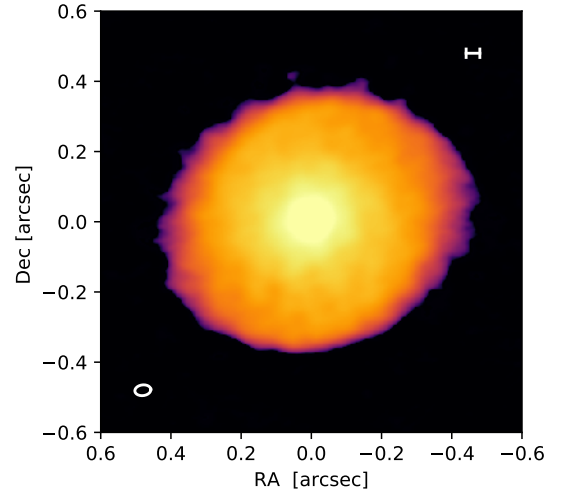

Figure 2. Continuum emission of main AS205 disk in logarithmic scale. ***I have to add the colorbar***.
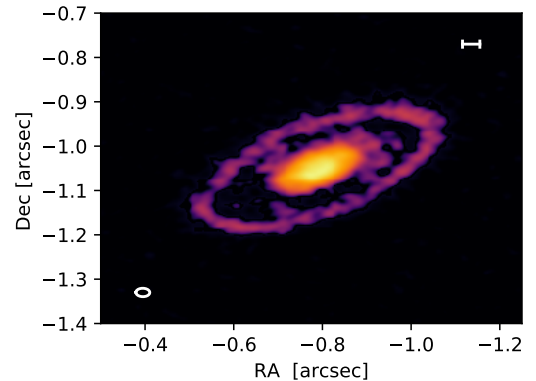
Figure 3. Continuum emission of main AS205 secondary in logarithmic scale. ***I have to add the colorbar***

$16.24° \pm x$ and PA = $11.6° \pm x$ measured from north to west. Similar to the main disk in HT Lup, we also found here a spiral structure of low contrast, that can be seen deprojected in polar coordinates in figure X.

To calculate the pitch angle of the spirals, we substracted from the continuum image the average azimuthal profile, calculated the maximums in the radial luminosity profile in steps of 10°. The spirals can be traced between 32 and 58 AU, and the peaks found are displayed in the Figure 4. Each spiral was adjusted separately, following the spiral equation $\log(R) = A + B\phi$, which gave us a pitch angle of X and Y for the northern and southern spiral respectively.
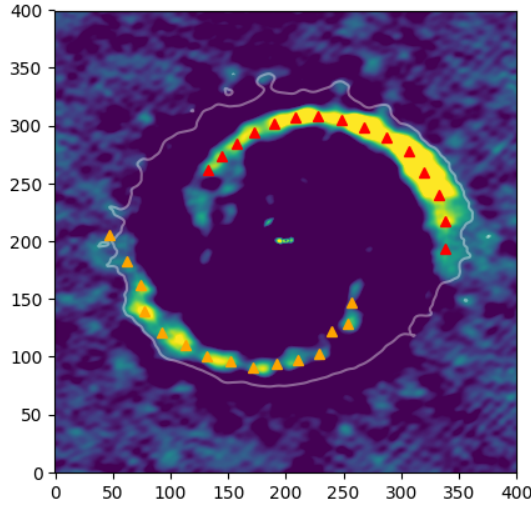
Figure 4. Continuum emission of AS205N, with the azimuthal average profile substracted. Triangles show the spiral trail of both arms, while the contour level marks the 3σ level of the not substracted image.

In this paragraph I have to analyze the luminosity profile of spirals in AS205N

5.2.2. *AS205 South*

Even when the secondary disk AS205S is well resolved, it luminosity peak is only 29% of the main disk peak, and the rings has luminosities around 5% *** Rewrite using sigma values, probably there are better ways to explain this disk is very faint***. Differently from the previous disk, this one shows a central disk and a ring-like structure, separated by a cavity that is not empty in continuum emission. The mean radial profile, calculated from the image, is shown in figure 7, where it can also be seen the luminosity dispersion inside the cavity.

*** THE NEXT PARAGRAPHS MUST BE MERGED IN ONE***

To obtain the mean radius of the ring, we calculated the mean radial profile in the continuum image in re-
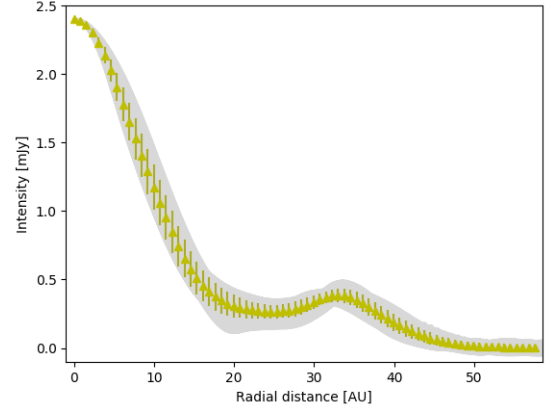
Figure 5. Mean azimuthal profile of the secondary disk in AS205 system. In gray are shown the raw points directly deprojected from the image.
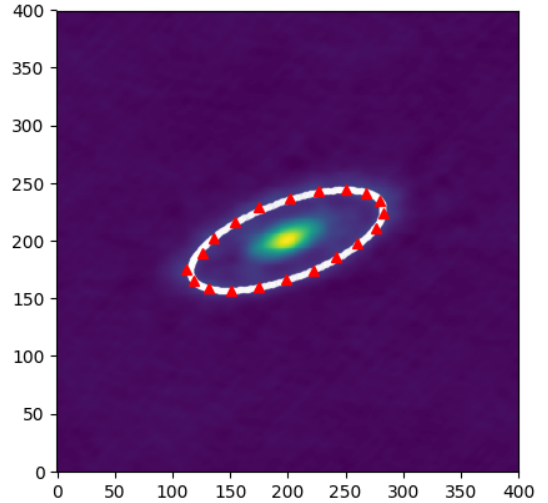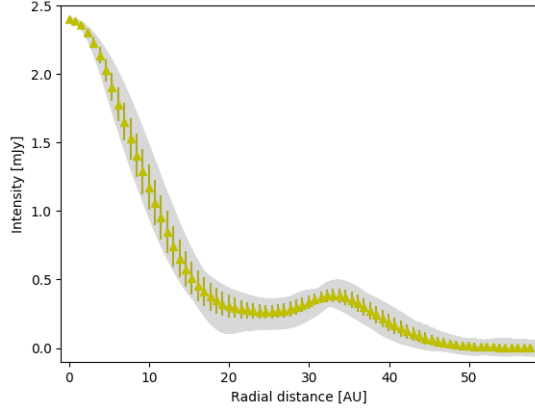

Figure 6. Mean azimuthal profile of the secondary disk in AS205 system. In gray are shown the raw points directly deprojected from the image.

gions of 18° (which are approximately 10AU in the deprojected ring), and searched for the position of the maximum emission in the ring. The points were then fitted with an ellipse using an MCMC routine, letting the center, major and minor axis, and position angle free to vary. We found a mean radius of which resulted in a radius of 32.5 ± 1.4 AU *** THIS MEAN VALUE MUST BE UPDATED FROM MCMC*** from the peak emission, with a center that the peak luminosity and center of the central disk.

To confirm that the ring was aligned with the central cavity, we used the peaks previously identified to fit an ellipse through them, results that are shown in figure X. The ellipse has a position angle of X, which is in agreement with the 2d gaussian we perform previously. The

center of this ellipse matches the peak luminosity position of the central disk within ¡1 mili arcsec. (I NEED TO GET THE RESULTS FROM THE MCMC FIT, TO COMMENT THEM HERE).

Figure 7. Mean azimuthal profile of the secondary disk in AS205 system. In gray are shown the raw points directly deprojected from the image.

5.3. *CO map*

The CO map shows interaction between the disk with gas travelling at velocities between X km/s and Y km/s, as it can be seen in figure X.
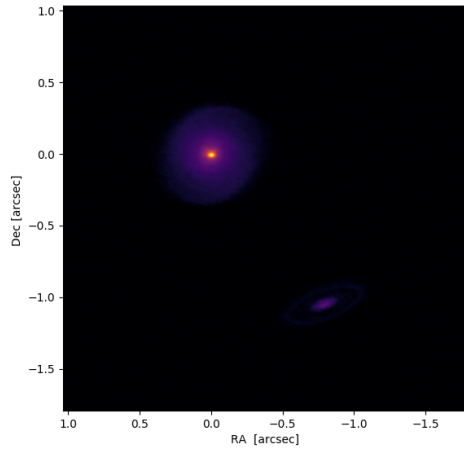
6. DISCUSSION

- GAIA distances.

- AS205 Secondary disk, binary component. high CO speeds around them.

- Interactive closest disks in HTLup: discuss about the orbit plane.

- Spirals origin, compare with other known spirals.

- HTLup CO, compare with simulations.

- Next steps: Hydrodynamic simulations, other lines observations.

7. CONCLUSION

8. ANEXOS

REFERENCES

Astropy Collaboration, Robitaille, T. P., Tollerud, E. J., et al. 2013, A&A, 558, A33

Ghez, A. M., McCarthy, D. W., et al., 1997. MNRAS

Figure 8. AS205 system.