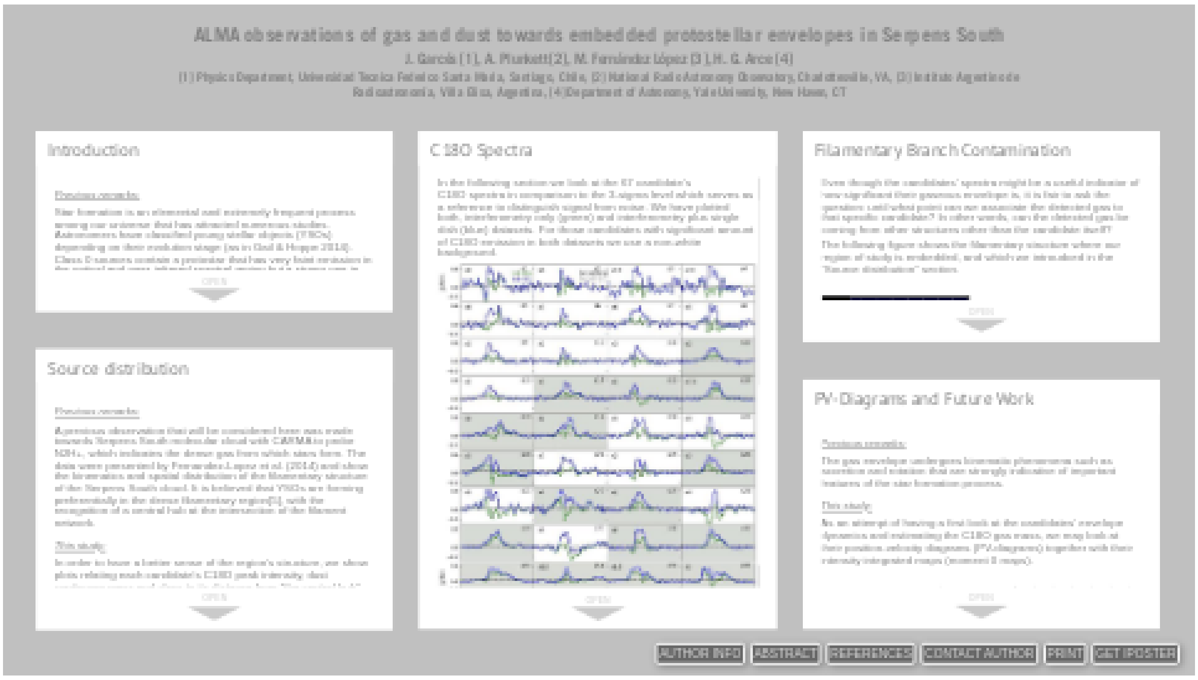
ALMA observations of gas and dust towards embedded protostellar envelopes in Serpens South



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PRESENTED AT:

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237TH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY
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INTRODUCTION

Previous remarks:

Star formation is an elemental and extremely frequent process among our universe that has attracted numerous studies. Astronomers have classified young stellar objects (YSOs) depending on their evolution stage (as in Gail & Hoppe 2014). Class 0 sources contain a protostar that has very faint emission in the optical and near-infrared spectral region but a strong one in the sub-millimeter region (and therefore can be observed with ALMA). In this youngest phase, the molecular cloud starts to collapse and form a disk due to rotation. Class I protostars have circumstellar disks and gas envelopes, and the last amount of mass is accreted from them. Class II sources have observable disks, and Class III sources have no detectable accretion.

Region of study:

Here we analyze information related to the C18O gas surrounding 67 different dust sources in the Serpens South protocluster (Plunkett et al. 2018) which is located at a distance of approximately 436pc and with an estimated age between 0.1 and 0.3 million years (Friesen et al. 2013), making it a very good candidate for the study of nascent stars. Also, this region is related to a filamentary cloud comprising several branches that merge at a junction, which is the region studied in this work (shown in Figure 1).

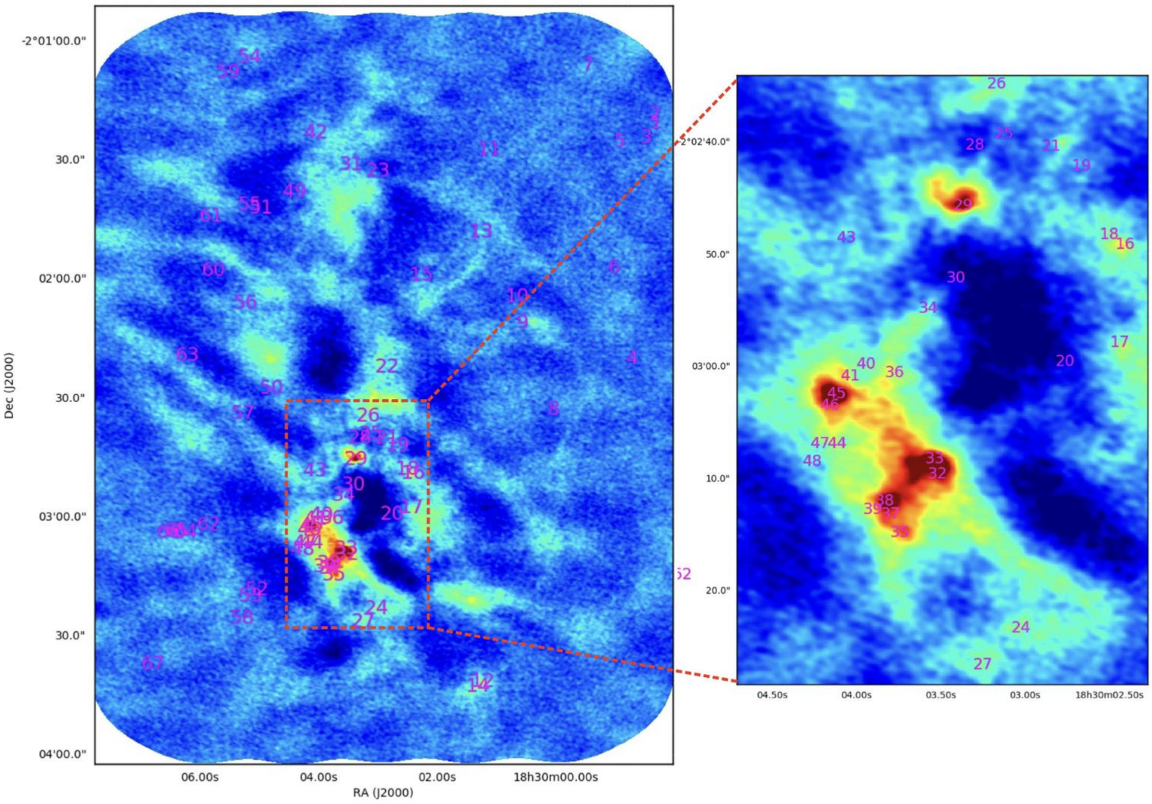


Figure 1: *Left panel:* C18O intensity-integrated map with markers indicating the position of the 67 source candidates and their assigned numbers[5]. *Right panel:* “zoom” of the central cluster and highest emitting region surrounded with the red box in the left panel.

SOURCE DISTRIBUTION

Previous remarks:

A previous observation that will be considered here was made towards Serpens South molecular cloud with CARMA to probe N2H+, which indicates the dense gas from which stars form. The data were presented by Fernandez-Lopez et al. (2014) and show the kinematics and spatial distribution of the filamentary structure of the Serpens South cloud. It is believed that YSOs are forming preferentially in the dense filamentary region[5], with the recognition of a central hub at the intersection of the filament network.

This study:

In order to have a better sense of the region's structure, we show plots relating each candidate's C18O peak intensity, dust continuum mass and class to its distance from "the central hub". The class information (0/I, F, II) are based on the results of Spitzer’s IR observations (Dunham et al. 2015). The “None” sources are those that couldn’t be classified.

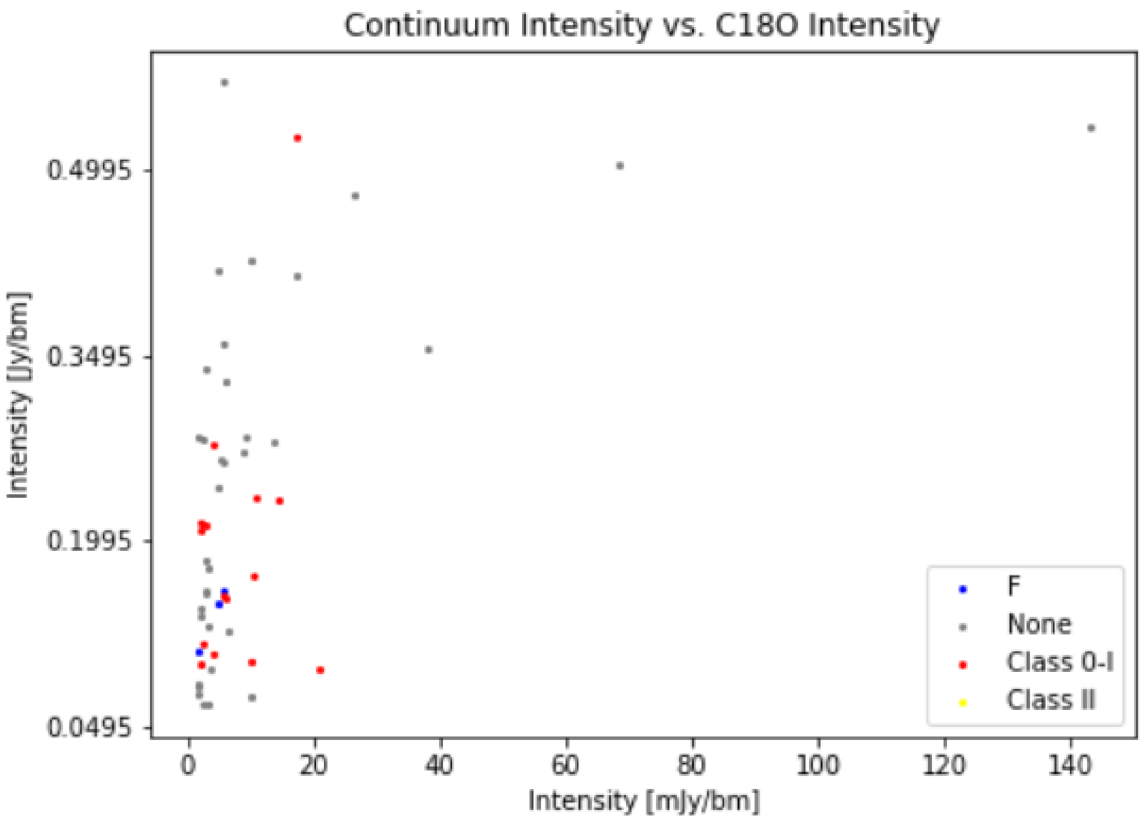
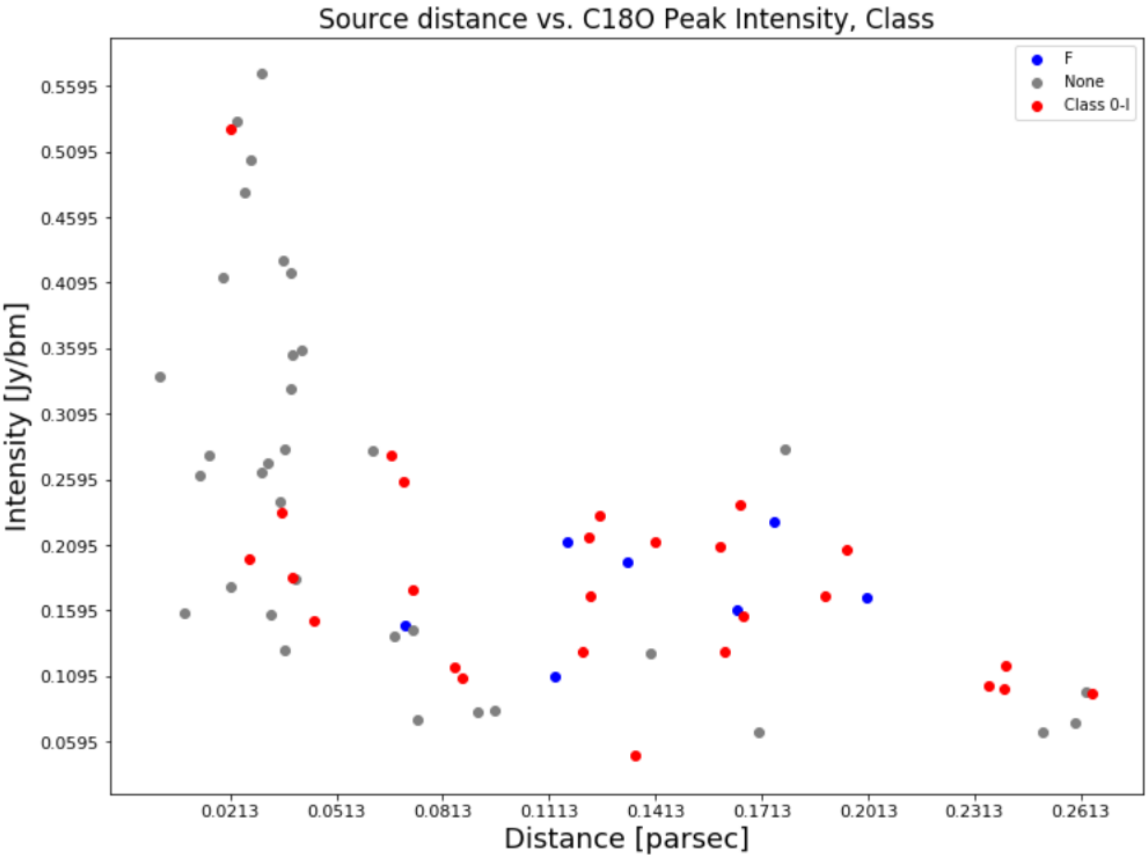


Figure 2: Continuum and C18O peak intensities of the 67 sources in the region of Serpens South [5] shown in Figure 1. The class information is shown by coloring.

From this plot it seems that the C18O emission tend to be grater for increasing dust masses, but no strict relation can be pointed out.



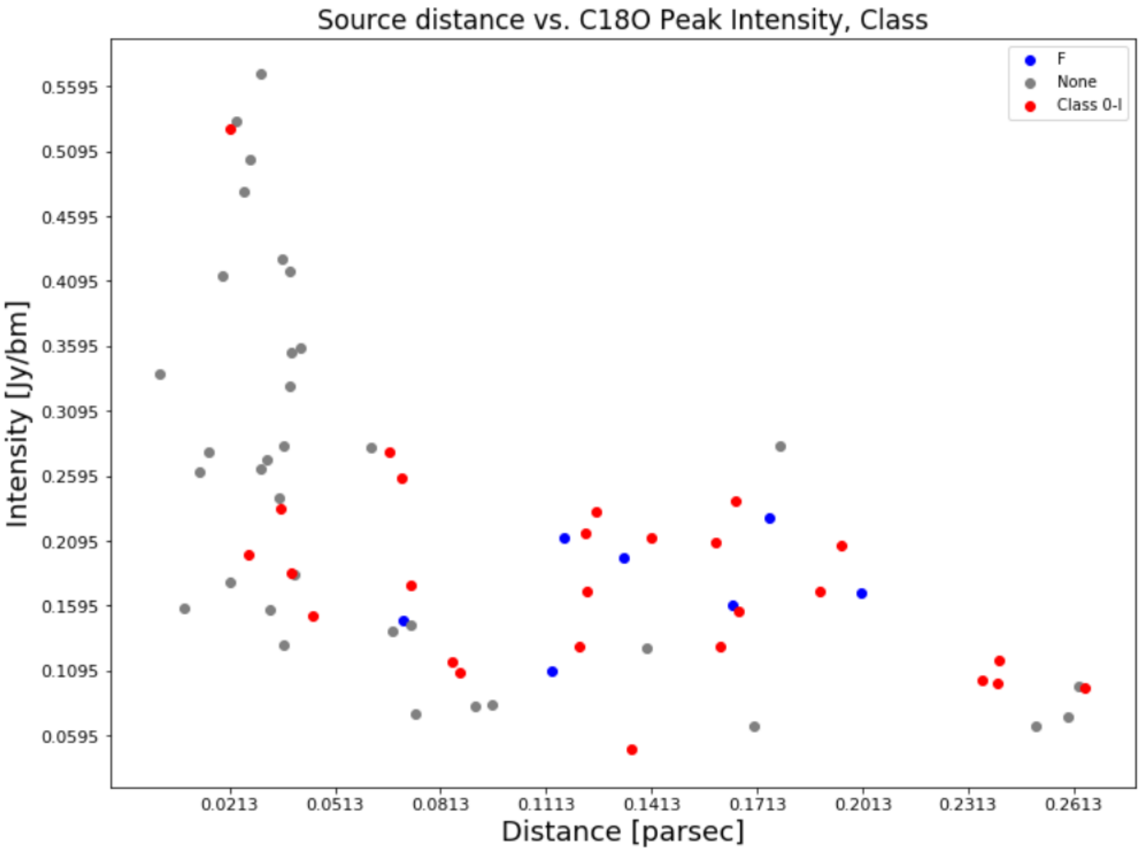


Figure 3: Distance from central hub and C18O peak intensity of the 67 sources. The class information is shown by coloring.

This plot shows that more distant sources tend have less C18O intensity than the ones closer to the central hub. This agrees with the fact that we expect the intersection of filaments to concentrate more mass than the filaments themselves. Also, it looks like Class 0-I candidates are distributed quite homogeneously.

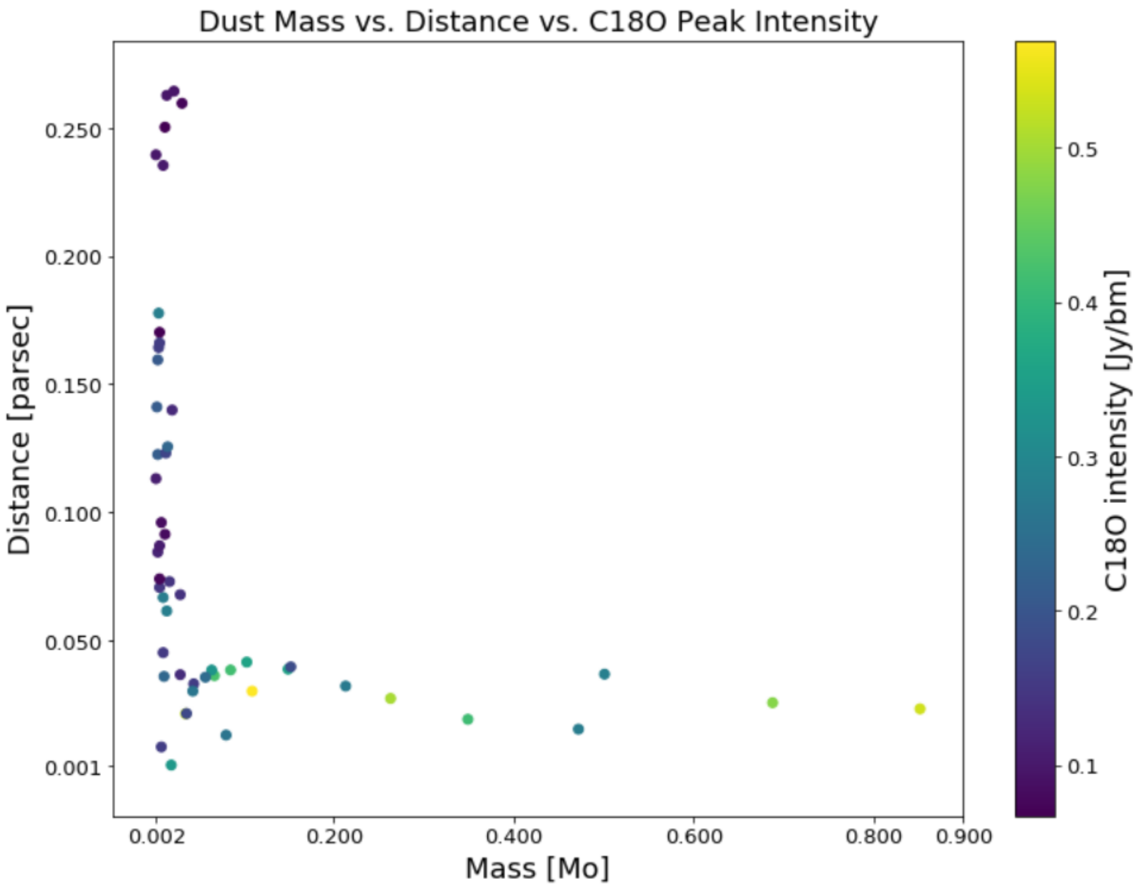
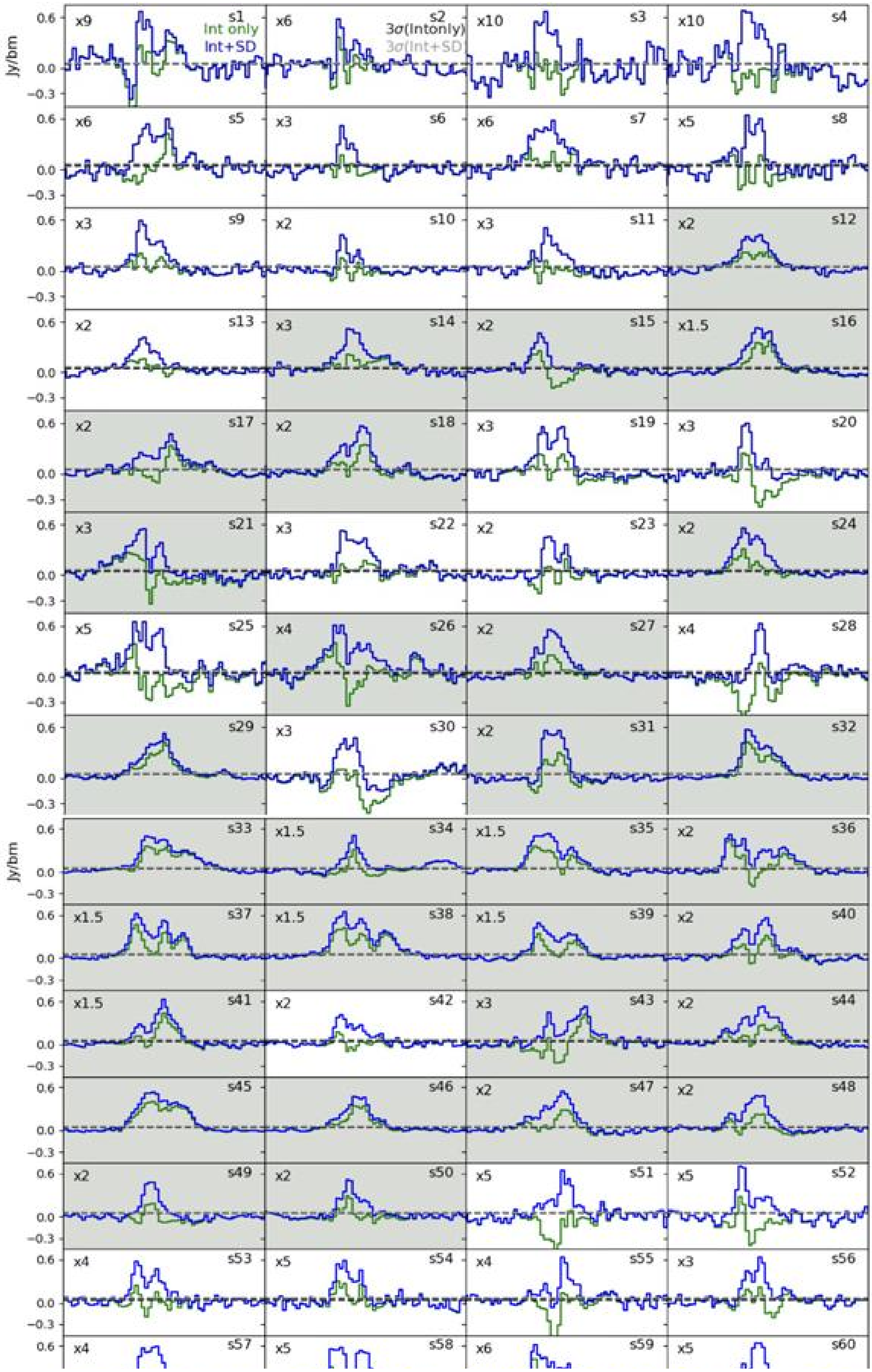


Figure 4: Distance from central hub, dust continuum mass and C18O peak intensity for 52 of the 67 sources. The class information is shown by coloring.

Here we can clearly see that candidates with more dust continuum mass are located systematically closer to the central hub. Also, for distances larger than 0.05 [parsec] the candidate's masses are very similar and small, which might be due to a fairly isotropic media. This is the opposite of what happens closer to the hub, where the dust masses can vary a lot, pointing towards a clustered and less homogeneous region.

C18O SPECTRA

In the following section we look at the 67 candidate's C18O spectra in comparison to the 3-sigma level which serves as a reference to distinguish signal from noise. We have plotted both, interferometry only (green) and interferometry plus single dish (blue) datasets. For those candidates with significant amount of C18O emission in both datasets we use a non-white background.



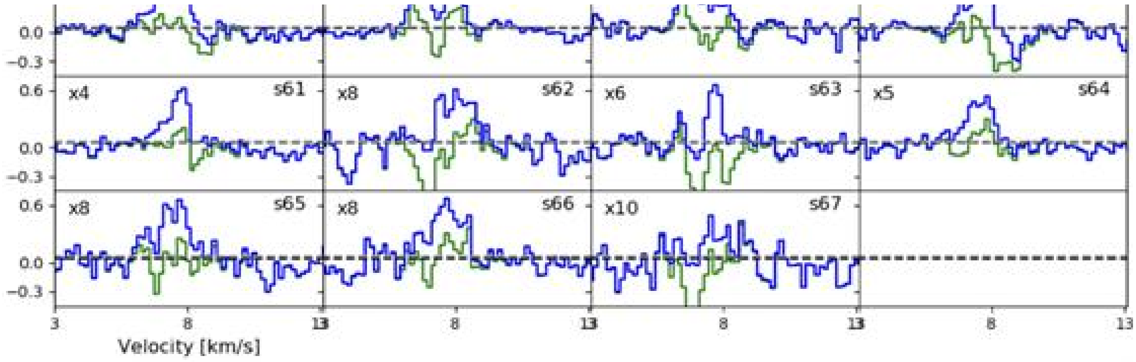


Figure 5: C18O spectra for the 67 sources in Serpens South protocluster [5]. The "Int only" and "Int+SD" labels refer to interferometry-only and interferometry plus single dish datasets, respectively. The horizontal dashed lines correspond to the 3-sigma level. The top-left label informs the amplification performed to each plot in order to have all of them readable while the top-right label is the candidate's number.

Even though the "int+SD" dataset indicates that all candidates have a distinguishble-from-backgorund C18O signal, the "int only" dataset makes it doubtful for about 26 of them. We also see that there are around 15 sources with a multiple-peaked spectrum.

FILAMENTARY BRANCH CONTAMINATION

Even though the candidates' spectra might be a useful indicator of how significant their gaseous envelope is, it is fair to ask the question: until what point can we associate the detected gas to that specific candidate? In other words, can the detected gas be coming from other structures other than the candidate itself?

The following figure shows the filamentary structure where our region of study is embedded, and which we introudced in the "Source distribution" section.

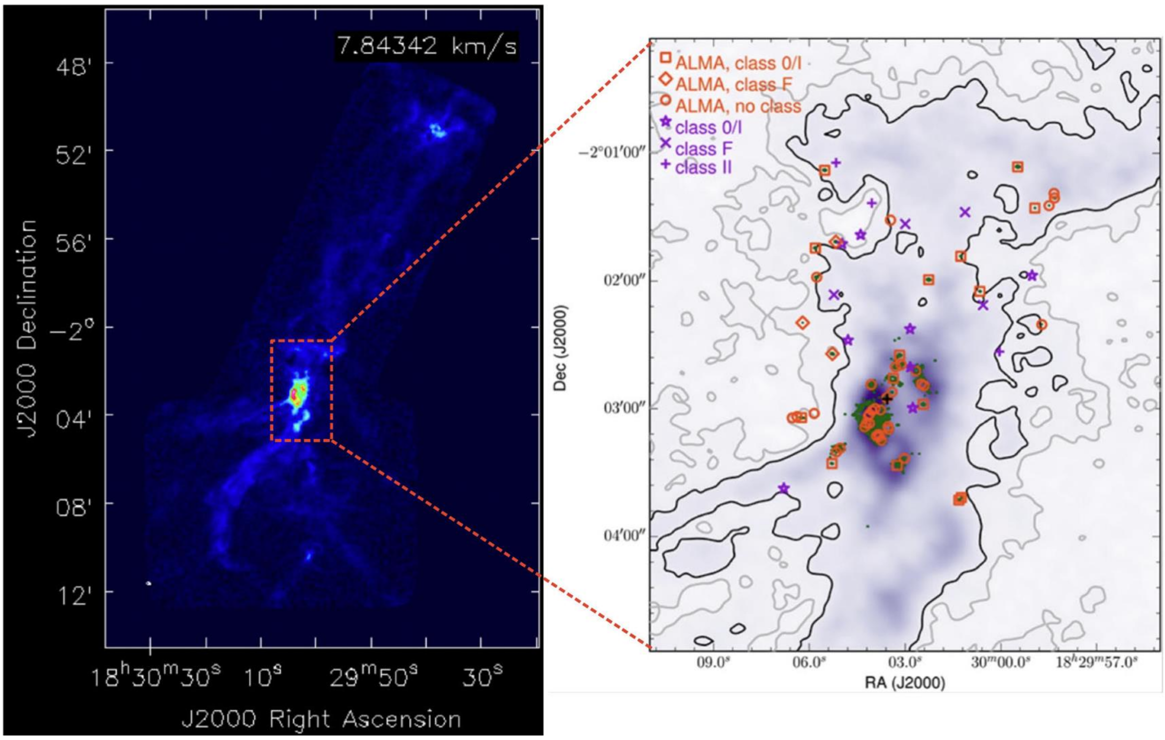


Figure 6: *Left panel:* N2H+ map showing the filamentary structure in which the Serpens South protocluster is located [3,5]. *Right panel:* “zoom” towards the region shown in left panel of Figure 1. Here the N2H+ emission is shown with grayscale and the symbols indicate the identified sources [5].

This filamentary structure if formed by multiple subfilaments or “branches” carrying, among other things, C18O gas which might, in principle, create higher-than-normal concentrations of C18O when crossing each other. The main purpose of the following plots is to show how the candidates’ spectra compares to that of one of the branches that appears to include the candidate. The branch’s spectra is taken from a position located farther than at least one beamsize from the source. We present three examples which serve to illustrate the different possible outcomes.

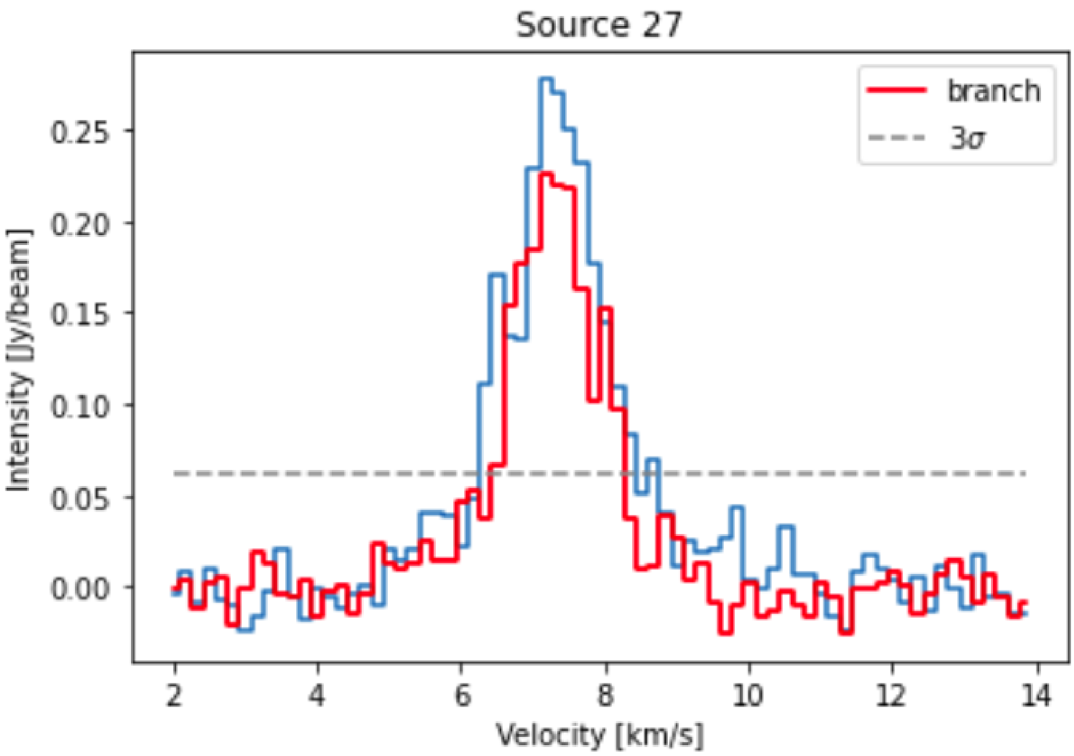


Figure 7: C180 spectrum for source 27 (blue), filamentary branch spectrum (red) and the 3-sigma level (grey).

Here the branch's spectra are extremely similar to that of the candidate, not only in the intensity values, but also in the overall shape. This implies that an important part of the emission we attribute to this candidate might be actually coming from the branch in which it is embedded, and, therefore, it might be an older-than-expected or fainter-than-expected source (a source with no envelope).

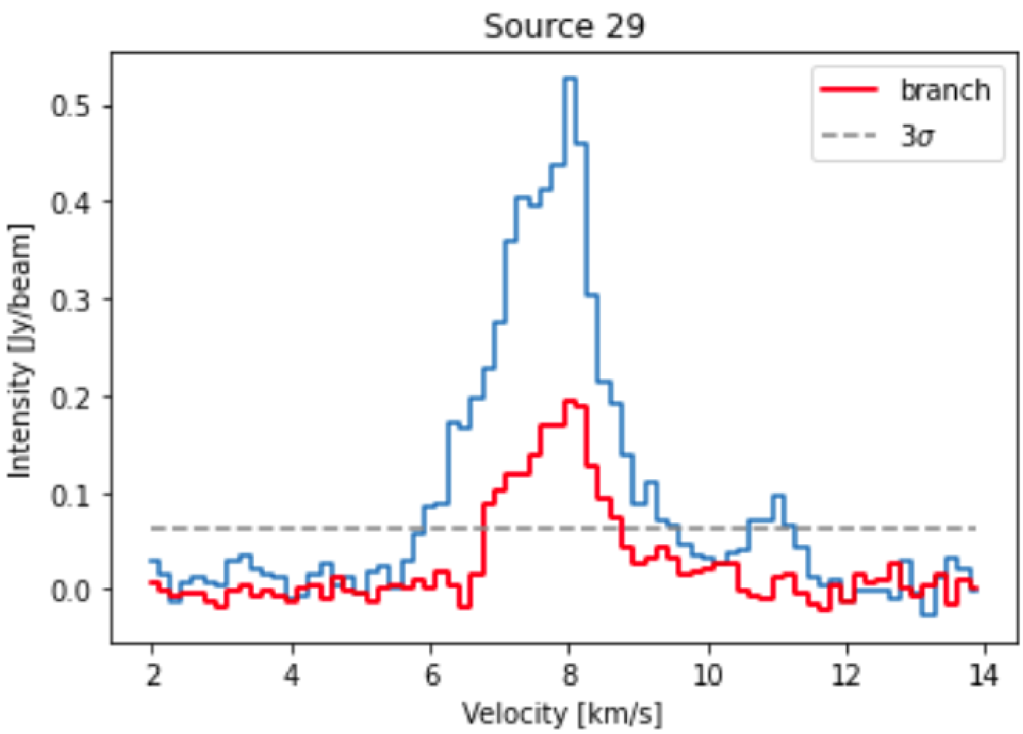


Figure 8: C180 spectrum for source 29 (blue), filamentary branch spectrum (red) and the 3-sigma level (grey).

This second plot shows the opposite behavior than that of the previous one, i.e. a candidate whose emission can be easily distinguished from that of the branch mainly due to its higher intensity. Then, this candidate it's very likely to be a source with an envelope.

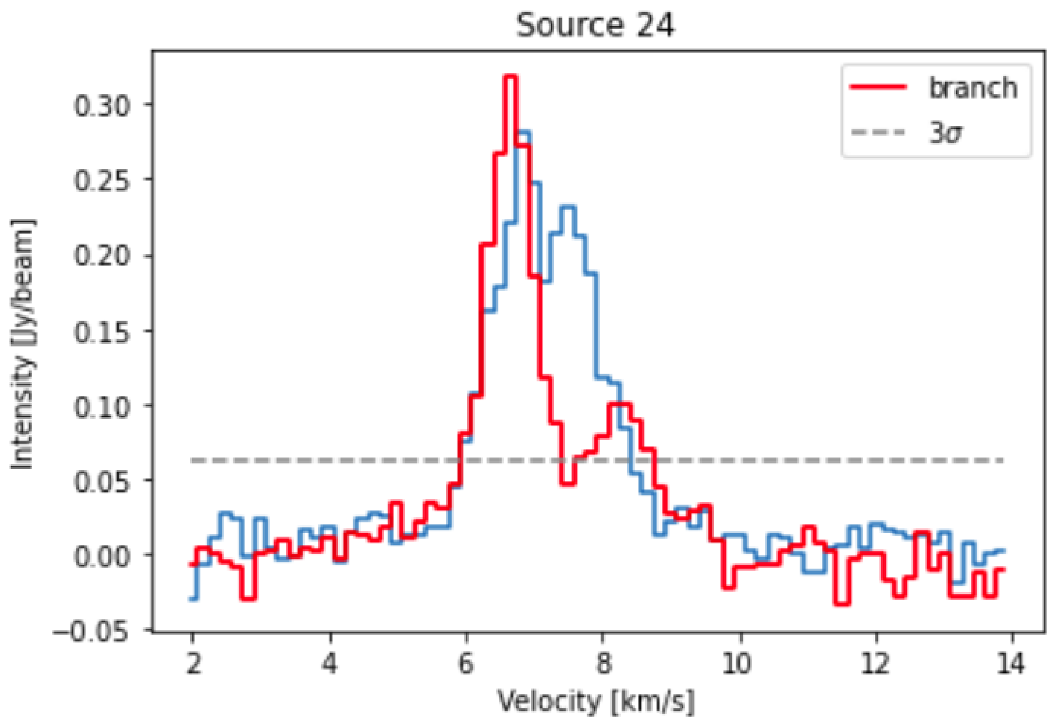


Figure 9: C180 spectrum for source 24 (blue), filamentary branch spectrum (red) and the 3-sigma level (grey).

Finally, this third plot pictures a sort of mixture between the two previous ones. At one side we see that the branch's spectrum has a similar intensity value than that of the source. However, their shapes are very different; there is a velocity range for which the branch's spectrum has very low values while the candidate's emission is significant. This might imply that even though there is an important part of the candidate's spectrum which might be due to the branch, there is still an important amount of emission that may be attributed to the candidate. If this is the case, the branch would be simply making the candidate's spectrum wider or more funny-looking by introducing double peaks. Therefore, knowing this could be useful for filtering out spectra from the background.

PV-DIAGRAMS AND FUTURE WORK

Previous remarks:

The gas envelope undergoes kinematic phenomena such as accretion and rotation that are strongly indicative of important features of the star formation process.

This study:

As an attempt of having a first look at the candidates' envelope dynamics and estimating the C18O gas mass, we may look at their position-velocity diagrams (PV-diagrams) together with their intensity integrated maps (moment 0 maps).

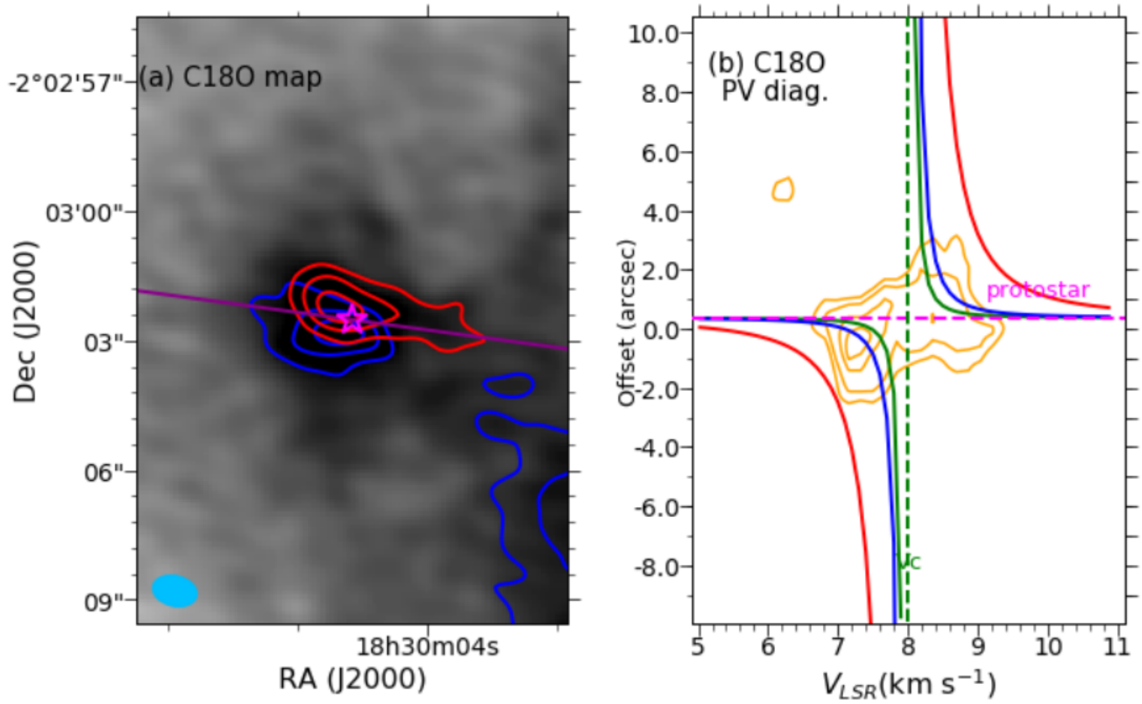


Figure 10: *Left panel:* moment 0 map of source 45 overlayed with the blue/red shifted contours and the position-velocity cut. The red and blue contour levels are (20,25,30)*sigma, respectively. *Right panel:* PV-diagram of source 45 with Keplerian models for three different fractions of solar masses: 0.05 (green), 0.15 (blue), 1.4 (red). The contour levels are (12,15,20,23)*sigma.

The fairly symmetric yellow contours in the PV-diagram might point to a stable rotation. This is reinforced by the blue/red shifted contour on the left plot, which shows a clear rotating envelope. The overlayed models show that the envelope's mass is closer to 0.1 than 1.4 solar masses.

Two examples of PV-diagrams for sources that adjust less to a purely Keplerian model are shown below.

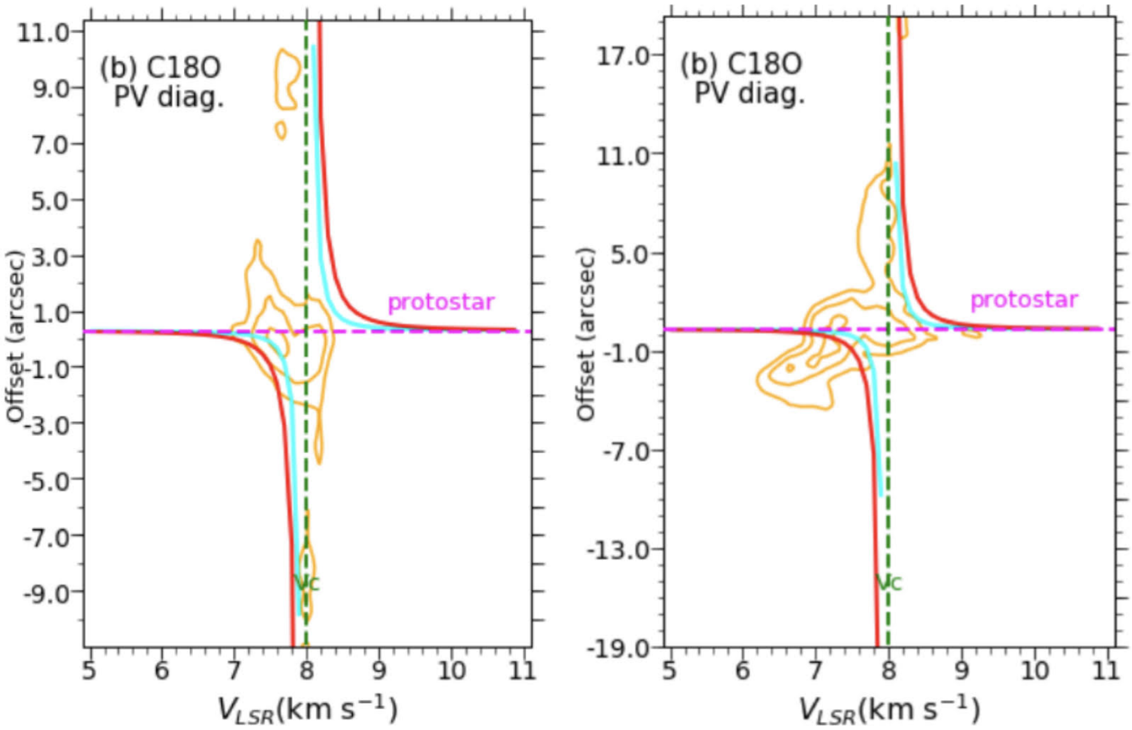


Figure 11: PV-diagrams for sources 16 and 33 (from left to right) with contour levels of (15,20,25)*sigma.

The fact that the Keplerian model doesn't present a good fit for these sources indicates that they are not in a purely-rotation stage but instead they might still be undergoing significant accretion bursts, which would mean they are younger sources. To check this hypothesis, we should see if a pure infall or infall plus Keplerian rotation models explain the kinematics of these sources more coherently. This is the main goal of our future work.

An alternative envelope mass estimate can be obtained by extracting the rotation radii from a 2D-fitting performed on the candidate's gas envelope and the rotating velocity from the its spectrum. The 2D fitting can be performed in CASA while the rotating velocity can be approximated by fitting a gaussian distribution to the spectra and calculating its full width at half maximum. This last idea can be visualized in the following plot.

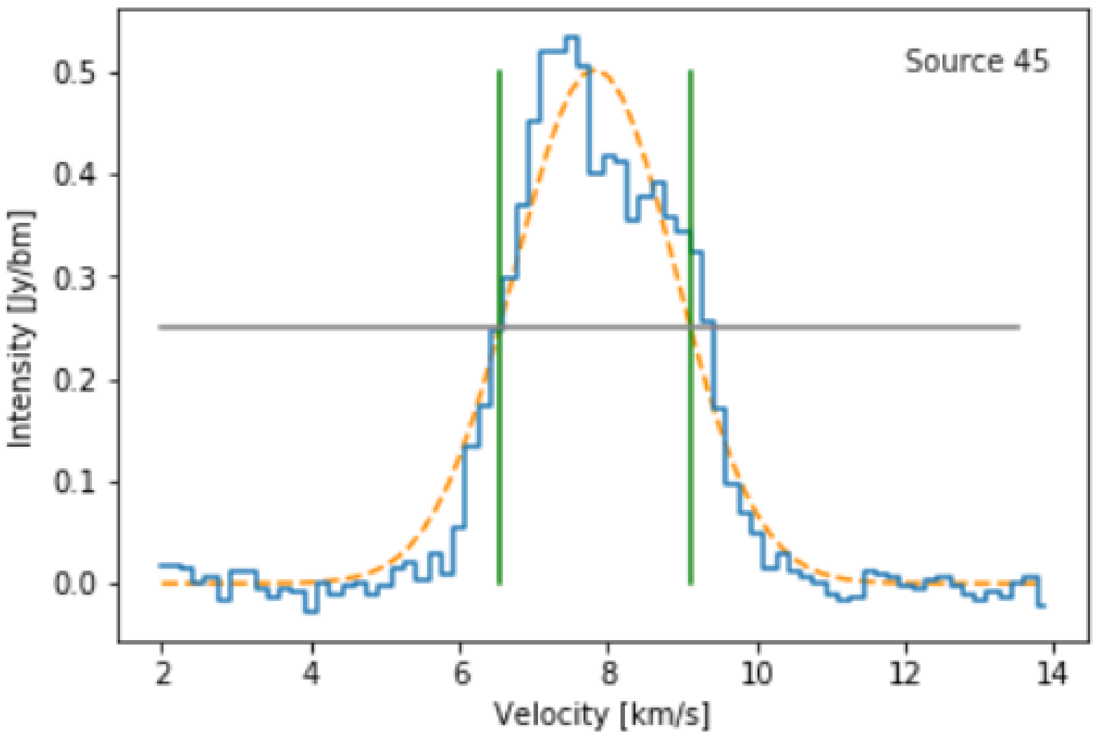


Figure 12: . Source 45 spectrum (blue) and gaussian fit (orange). The green vertical lines show the width at half maximum for the gaussian fit while the half maximum value is given by the horizontal grey line.

The gas mass estimate obtained using this method for source 45 is around 1.4 solar masses, which doesn't agree with what is shown in Figure 10. This might be due to the fact that there is a significant amount of infalling material which makes the spectrum wider and therefore increases the mass estimate. If this is the case, we should be able to get a better estimate by implementing more sophisticated models that include the influence of infalling material as mentioned above. The only conclusion we can make from Figure 10 and 12 is that a purely Keplerian model doesn't fit source 45 perfectly and, therefore, it is likely to be in an earlier evolutionary stage than that of source with a purely rotating envelope.

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ABSTRACT

Protostellar sources are characterized by continuum emission, as well as molecular emission tracing the gaseous envelope. The morphology and kinematics of the envelope are useful to study physical characteristics of protostellar candidates and their evolution, revealing aspects of the still unknown process of star formation. Our aim is to study protostars within the very young, active, and relatively nearby Serpens South cluster by analyzing their dense C18O envelopes/disks, enhancing the continuum source census of Plunkett et al. (2018). Most of these sources lie within a predominant filamentary structure. 67 protostellar candidates have been identified as continuum and/or IR sources, and the C18O data have been imaged by combining ALMA 12m-array, 7m-array, and single dish observations.The C18O spectra were organized in different groups according to their spectral shape and intensity. Also, given the fact that this region is embedded in a filamentary structure, we have made attempts to identify the level of line emission contribution that is most probably due to the filament instead of the source candidate itself. To get a better idea of the region's structure we show trends associated to mass distribution among the filament, including information of dust masses and C18O intensity. Finally, tuture work will go further on the analysis of the sources' kinematics and their mass estimates.

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