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Disc stuff

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In original form 2012

ABSTRACT
Abstract here

Key words: circumstellar matter – infrared: stars.

1 INTRODUCTION

1. description of what has been done so far on the modelling and radiative transfer of disks (this includes also more evolved disks – Visser et al., Walsh et al., Aikawa et al. ..) 2. focus on the young disks (work done by Machida et al., Dapp, Basu & Kunz 2012, .. for their formation; work by Boley et al. on the physical evolution ; Ilee et al. for chemistry) 3. previous attempts to observe these young disks: (a) simulations (Cossins et al. 2010); (b) observations: Fuente et al. 2010 (AB Aur); Jorgensen & van Dishoeck ($H_2^{18}O$ and the HDO/H2O ratio); Pineda et al. (2012); other papers talking about "hot corinos" (Bottinelli et al. ....)

2 DESCRIPTION OF THE MODEL

The model used to simulate the emission from a young protoplantary disc is a hybrid model created from hydrodynamical models of an infalling prestellar core and a gravitationally unstable protoplanetary disc. The prestellar core model is based upon the model of Keto & Caselli (2010). This describes an infalling pre-stellar core, with densities temperatures and velocities given by the model of the collapse of a 10 solar mass Bonnor-Ebert sphere and provides a match to line profiles seen in the pre-stellar core L1544. Some slight modification due to the addition of Oxygen lines (Keto et al 2012 in prep) have been been added to this model resulting in a slight decrease in the peak infall velocity. This prestellar core model extends from 80 au out to 10,000 AU. The model is a 1D spherically symmetric model with inward motions (see figure 2).

At radii less than 80 au the physical structure is the given by the hydrodynamic model described in Ilee et al. (2011), based on the work of Boley(2007), and Boley(2009). This model describes a 0.39 $M_\odot$ self-gravitating disc featuring prominent spiral arms. H_2 number densities in the disc range from 10^{10}-10^{19} m^{-3}, and temperatures range from 30-400 K. The dust and gas temperatures in the disc are assumed to be in equilibrium. The model is sampled over a regular grid of size 256×256×64 with spatial resolution of 0.5 au in x, y and z. The majority of the mass lies in the mid-plane of the disc. For the models using a smoothed disc the same physical and chemical model is used but with the temperature, density and abundance averaged in ϕ. The gas/dust mass ratio was assumed to be 1/100 throughout both sections model and the opacities were given by the model of dust grains with thick icy mantles and 10^6 yr coagulation from Ossenkopf and Henning (1994)

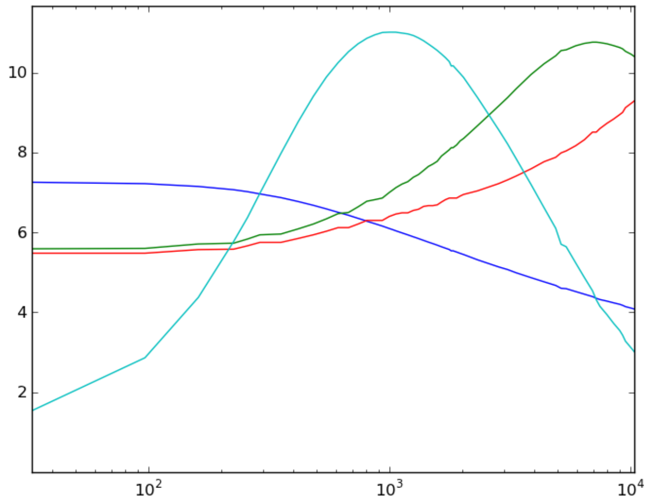

Figure 1. envelope model showing temp and dust temp (red, green) in kelvin, log number density (blue) in cm^{-3} and inward velocity×10 (cyan) in m s^{-1}, adapted from Keto & Caselli (2010)

Chemical abundances in the disc were taken from Ilee et. al (2011) which followed the changes of chemical abundances of trace particles moving through the disc as it evolved. The abundances of 125 species related by 1334 reactions were followed through the time evolution of the disc. These abundances were interpolated onto a 51^3 grid covering the disc with cells of size 2.2×2.2×0.22 au. Abundances in the envelope model were as follows:

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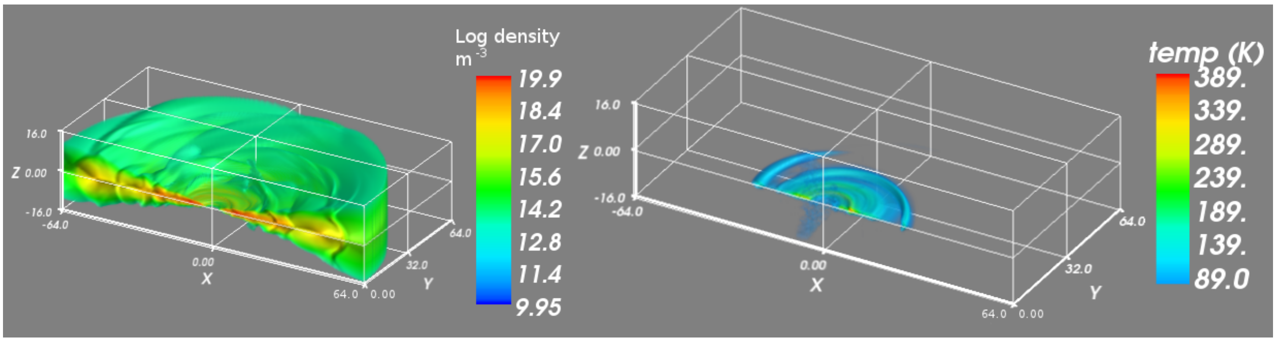

Figure 2. The density and temperatures of the 0.4 $M_\odot$ gravitationally unstable disc model used in inside 80 AU. The dense and hot regions are confinded to a few AU about the rotation plane.

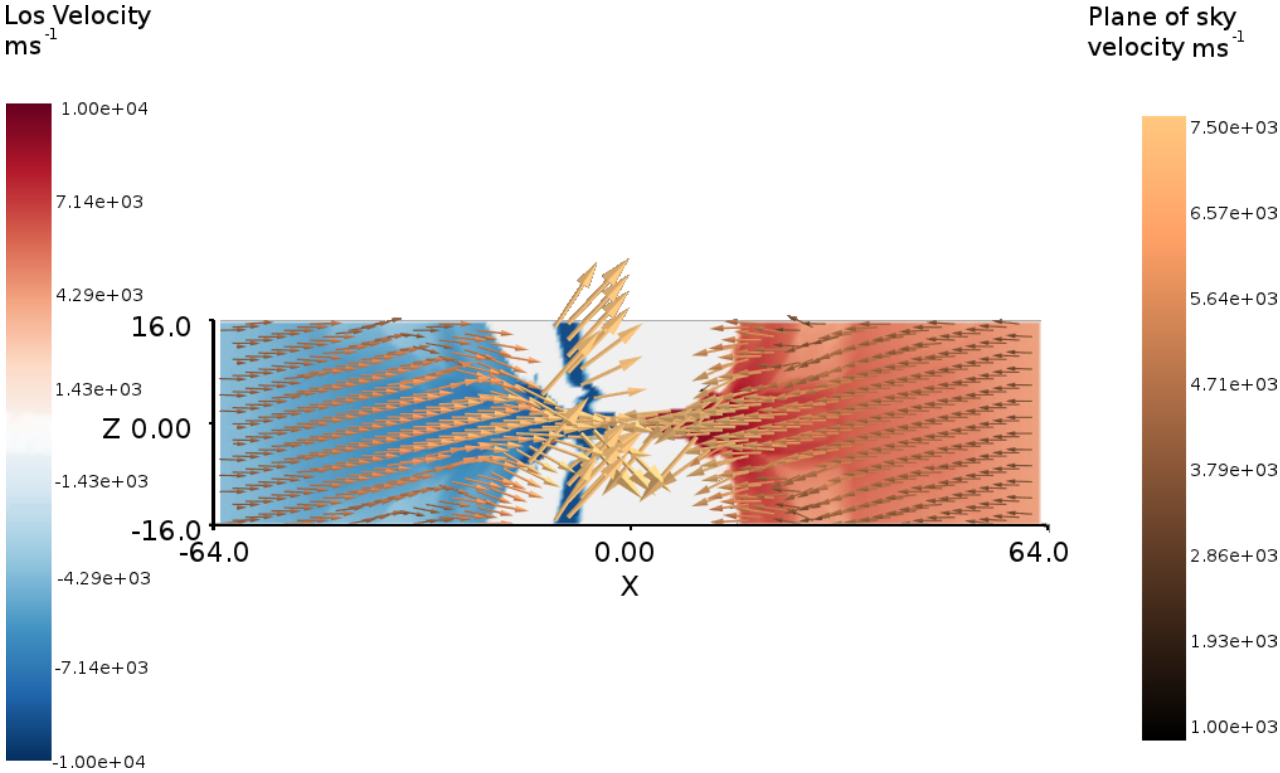

Figure 3. The line of sight (colour scale) and plane of sky (arrows) velocities in the y=0 slice through the disc model.

(tableify this?)
HCO^+: as the H2O profile from (find out where L1544 H2O profile is from) scaled so that the maximum abundance is 10^{-8}
HNO: constant abundance of $5\times10-11$
HCS^+: 10^{-11}
OCS: constant abundance of 10^{-9}
H_2CO: 1.5×10^{-9} decreased by a factor of 40 at radii less than 8250au (Young et al 2004)
CS: 3×10^{-9} decreased by a factor of 10,000 at radii less than 6700au (Tafalla, santiago-garcia and myers 2006)
CO: as the H2O profile from before scaled so that the maximum abundance is CO maximum

3 DESCRIPTION OF RADIATIVE TRANSFER PROGRAM

LIME (Brinch 2011), the radiative transfer program used, calculates line intensities based on a weighted sample of randomly chosen points in a continuous 3d model. The method of selecting these points is given in the griding section. At each of these points the density of the main collision partner (in this case H_2), gas and dust temperatures, velocity, molecular abundances and turbulent velocity and taken from the model. These points are then smoothed by Lloyds algorithm (Lloyd 1982) in order to minimise the variation in distance between points whilst keeping the same underlying distribution. These points are then connected by Delaunay triangulation and it is down these paths that photons are restricted to propagating (figures 3). The levels of molecules in question are then calculated at each of these

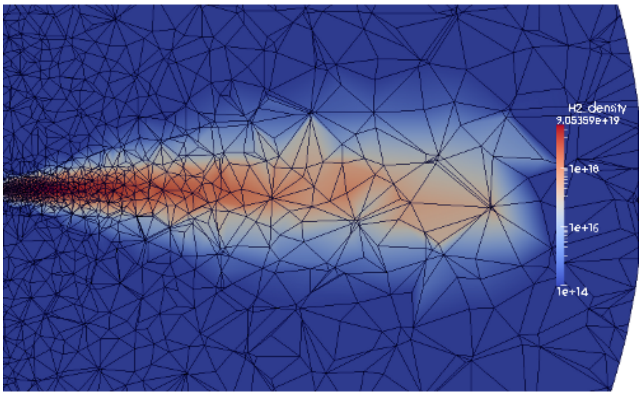

Figure 4. An example of the points distribution chosen by lime for a model of a smooth protoplanetary disc. The nodes of the grid are the points at which the underlying physical model is sampled and the edges are teh paths down which photons can travel during the excitation-radiation emission stage of the computation.

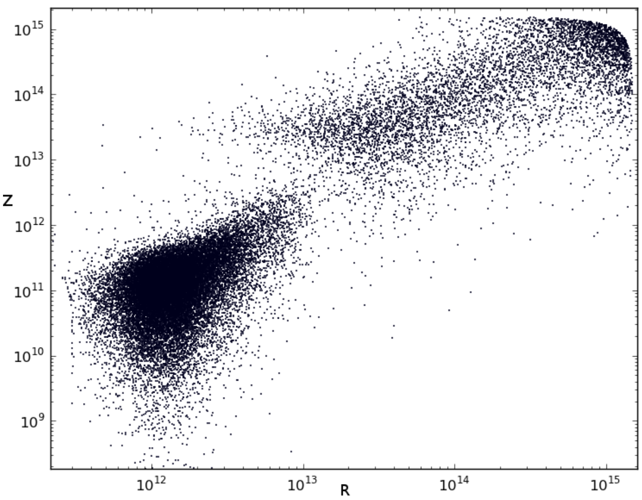

Figure 5. the rz distribution of points selected to sample the model. The points in the dense region at $10^9 < z < 10^12$ and $7*10^{11} < r < 10^{13}$ are sampling the disc model and the points at larger values are those foreced into the outer regions to sample the envelope.

points from collisional and radiative (de)excitation and the local radiation field is calculated. This is repeated 20 times with the populations of each level converging towards a single value.

In order to construct the grid, points are randomly selected from the volume being simulated then compared against a reference point. Grid points are selected at random in cylindrical co-ordinates, linearly spaced in z and ϕ and logarithmically spaced in r. For each point to be selected a random number α is drawn from the semi-open set $[0, 1)$ as a threshold. After selection of random co-ordinates the Hydrogen density and molecular density at the point (n and m) are compared against the densities of a reference point on the inner edge of the disc (n_0 and m_0). If $\alpha < \left(\frac{n}{n_0}\right)^{0.3}$ or $\alpha < \left(\frac{m}{m_0}\right)^{0.3}$ then the point is selected for use, if not

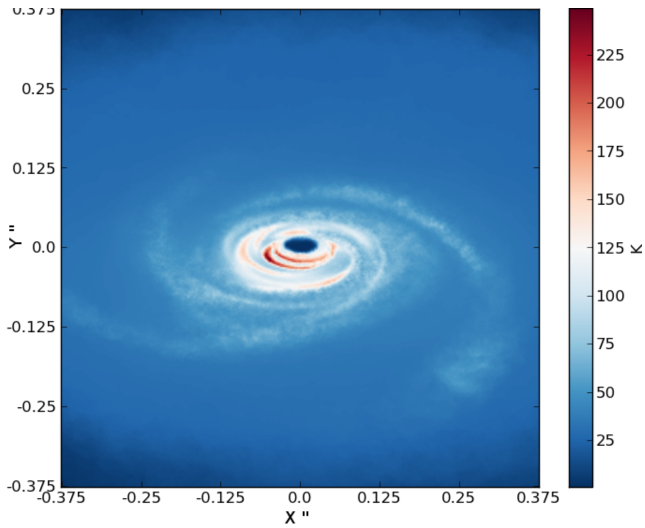

Figure 6. A composite image of 100 runs of continuum emission at 350 GHz

then another r, ϕ, z co-ordinate is selected. The weighting function and griding functions were selected empirically to sample both the all scales while ensuring the majority of the points went into the inner disc which is the region of interest. 20% of these points are forced to be at radii greater than $\sqrt{R_{min} R_{max}}$ (where R_{min} and R_{max} are the inner and outer radius of the model) in order to stop too many of the selecected points clustering in the high density disc and leaving the envelope undersampled. In addiation to this method of selection 5% of the points are linearly distributed in x, y and z with no bias with regards to density or abundance. This provides a minimum level of sampling for the large low density regions in the outer parts of the simulated volume. See figure 3 for example of the points distribution in r, z.

4 MODEL RESULTS

Continuum emission from the model. Able to do this as the majority of the computing time on the model is taken up with calculating molecule population levels. This image has been created by averaging the output images of 100 unique runs. This averaging mitigates the granularity of output images from lime due to the nature of the gridding.

Figures showing the RT results in a few molecules/transitions (CO, HCO^+, HCN, OCS, H2CO, NH3 — maybe H2O,$H2^{18}O$ [to try first]) (Note the moment 1 and 0 map were created by integrating between -12.5 to -0.5 $\mathrm{km\,s^{-1}}$ and +0.5 to +12.5 $\mathrm{km\,s^{-1}}$ to avoid being dominated by the contribution from the envelope, this can be seen in the some PV diagrams as the strong absorption feature at all positions around zero velocity, mom1maps are shown with a cutoff of 1/1000 of the peak emission/absorption value)

These synthetic images of the CO 3-2 line at 345.8 GHz. As the upper level for this line is at 33 K above the ground state this transition should be excited through out disc. CO

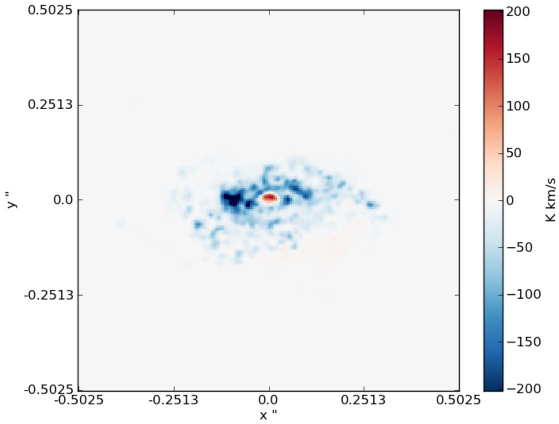

Figure 7. CO 3-2 Continuum subtracted mom0

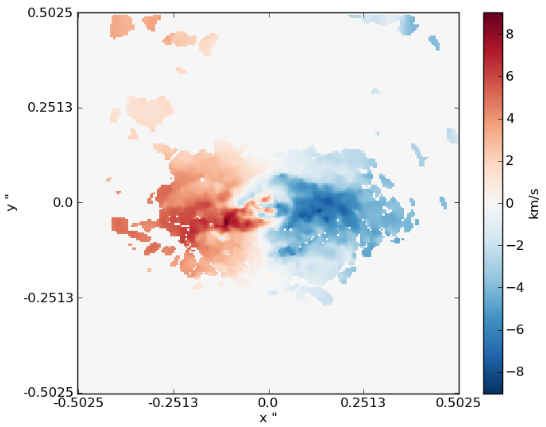

Figure 8. CO 3-2 mom1map

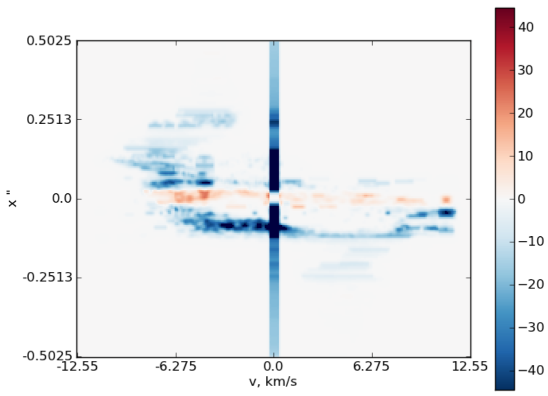

Figure 9. CO 3-2 PV through centre

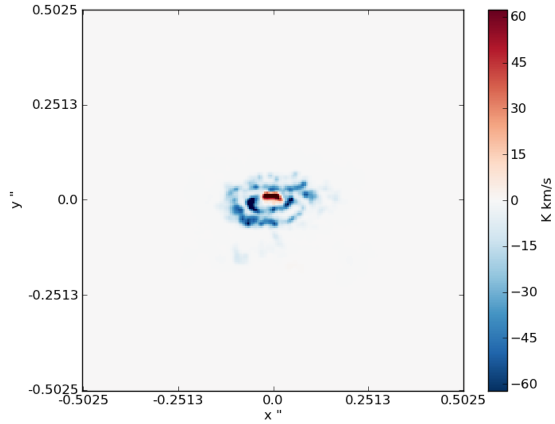

Figure 10. OCS 28-27 Continuum subtracted mom0

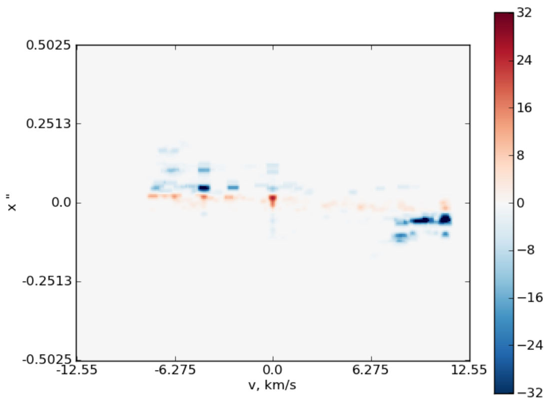

Figure 11. OCS 28-27 PV through centre

line will be thick so this is only mapping the outer regions of the disc. Spiral structure can be seen.

The OCS lines in alma band 7 (22-21 through 30-29) with upper energy levels between 161 and 271 K above the ground state provide a way to trace hot shocked gas in spiral arms without resolving structure.

In comparison to the model with spiral arms the absorbtion and emission from this smoothed model is far weaker.

line ratios of many lined spieces can help us calculate temperatures of the emitting regions.

(figure of temperature as a function of line ratio for 2 sets of formaldehyde lines and map of derived temperature, talk to P about this)

some molecules such as HCO^+ trace only the inner disc (ref ilee 2011) and so can be used to look at the extended velocity and physical structure.

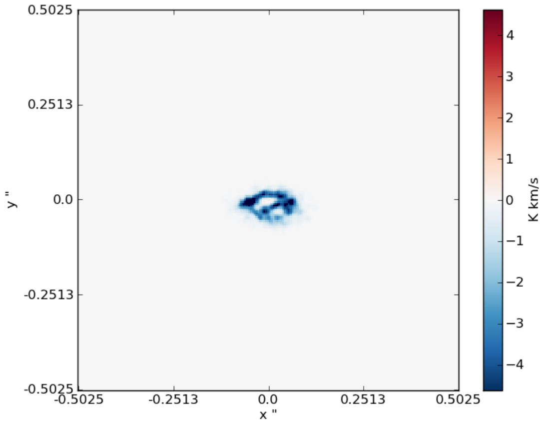

Figure 12. SmoothedOCS 28-27 Continuum subtracted mom0

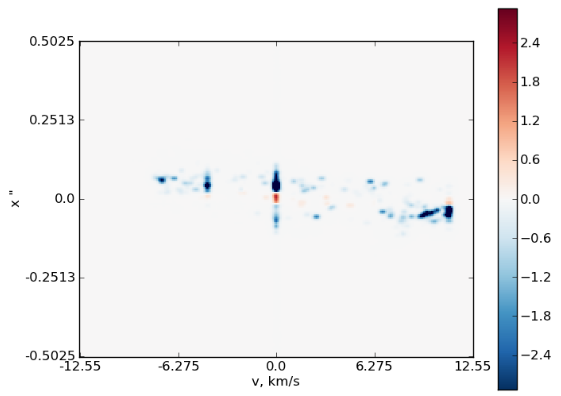

Figure 13. SmoothedOCS 28-27 PV through centre

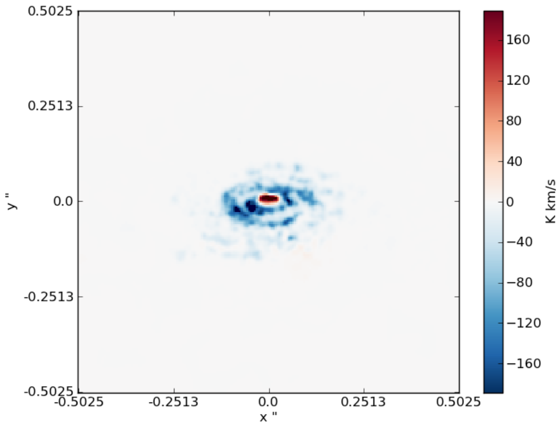

Figure 14. H_2CO 4 0 4 - 3 0 3 Continuum subtracted mom0

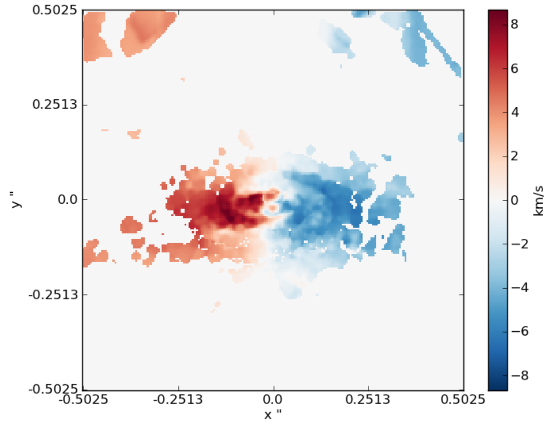

Figure 15. H_2CO 4 0 4 - 3 0 3 PV through centre

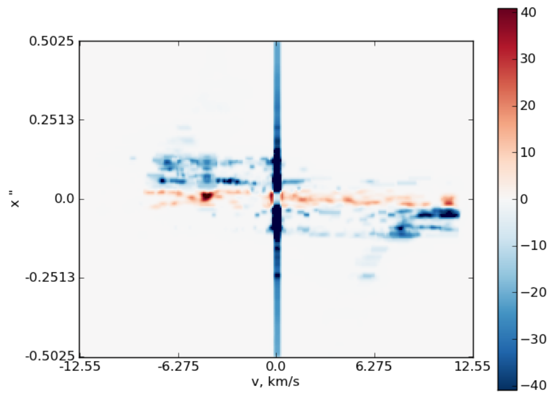

Figure 16. H_2CO 4 0 4 - 3 0 3 PV through centre

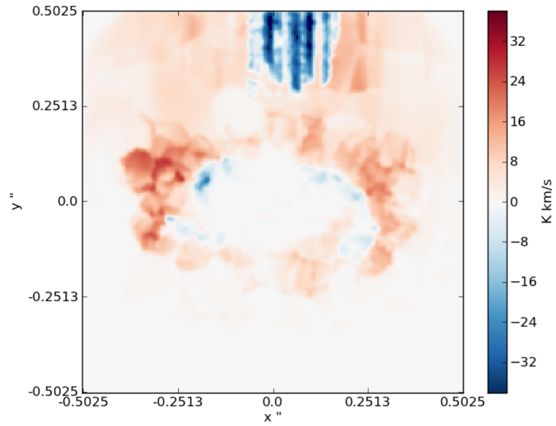

Figure 17. HCO^+ 1-0 Continuum subtracted mom0

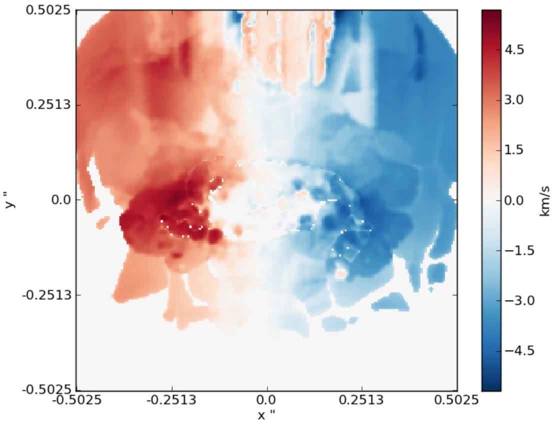

Figure 18. HCO^+ 1-0 mom1map

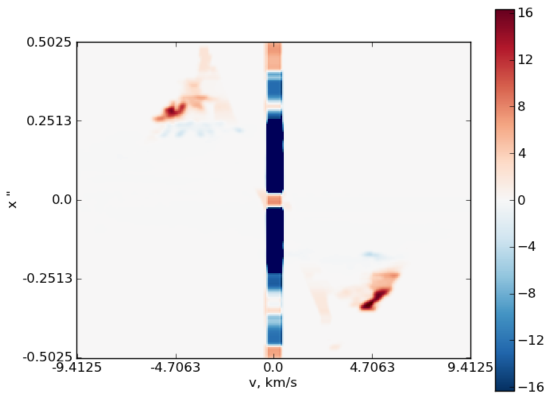

Figure 19. HCO^+ 1-0 PV through centre

Figures showing different inclinations

fdagfdabfdsbfdbds fdbfd fdfbfvdfd g rbfd fdbfdbc fdagfdabfdsbfdbds fdbfd fdfbfvdfd g rbfd fdbfdbc fdagfdabfdsbfdbds fdbfd fdfbfvdfd g rbfd fdbfdbc fdagfdabfdsbfdbds fdbfd fdfbfvdfd g rbfd fdbfdbc fdagfdabfdsbfdbds fdbfd fdfbfvdfd g rbfd fdbfdbc fdagfdabfdsbfdbds fdbfd fdfbfvdfd g rbfd fdbfdbc

nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj nfsdankjdsankj vdjsk nvjdks nvkds jkkd jkvd jkvf djk fj

Figure showing different transitions of the same molecule (e.g. CO(1-0), ...(7-6) , OCS, H2CO) for same inclination but in different disks (Boley et al. and the smooth disk)

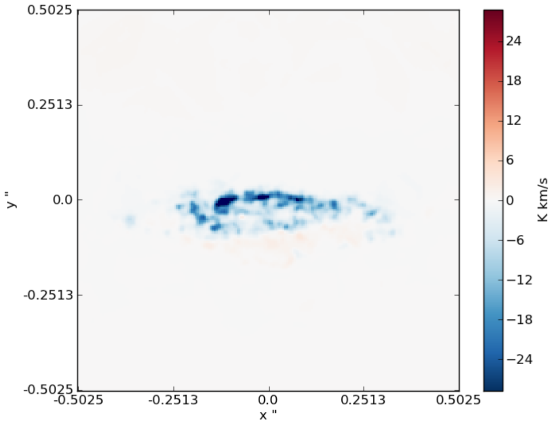

Figure 20. C18O 3-2 15 deg Continuum subtracted mom0

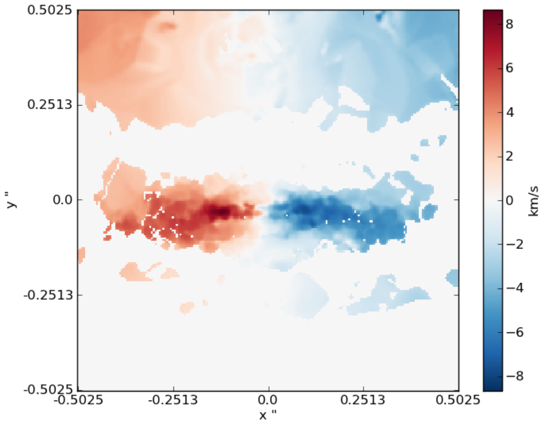

Figure 21. C18O 3-2 15 deg mom1map

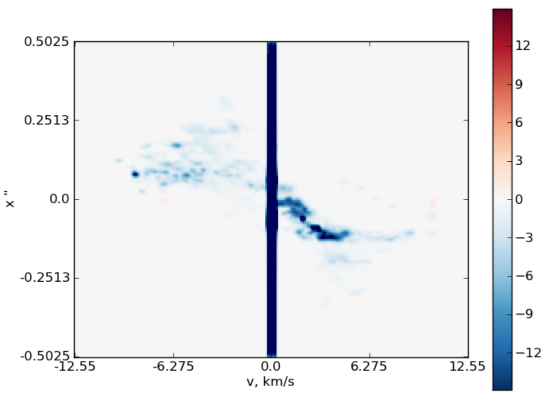

Figure 22. C18O 3-2 PV 15 deg through centre

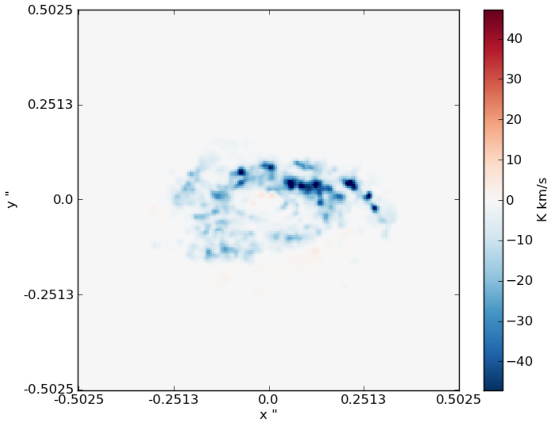

Figure 23. C18O 3-2 30 deg Continuum subtracted mom0

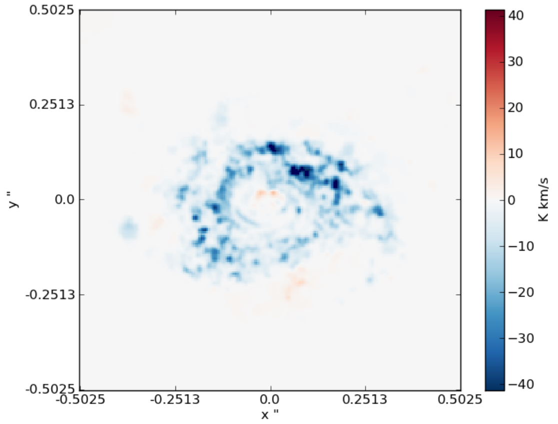

Figure 26. C18O 3-2 45 deg Continuum subtracted mom0

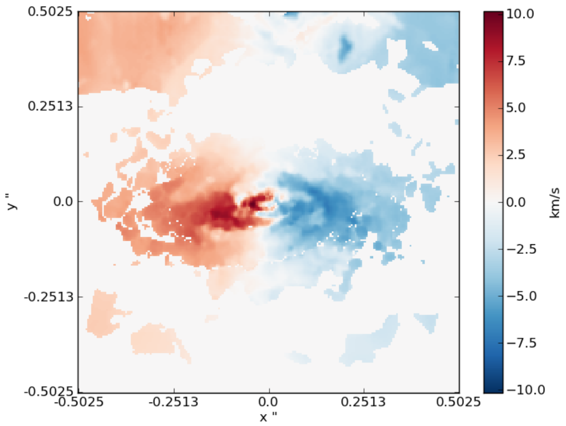

Figure 24. C18O 3-2 30 deg mom1map

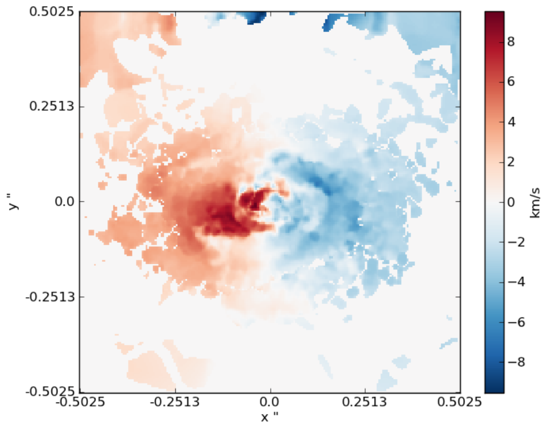

Figure 27. C18O 3-2 45 deg mom1map

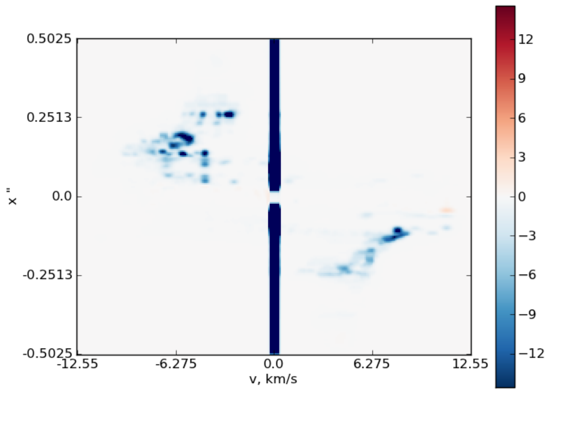

Figure 25. C18O 3-2 30 deg PV through centre

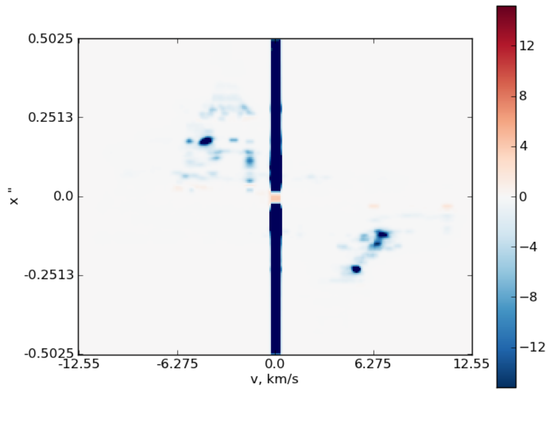

Figure 28. C18O 3-2 45 deg PV through centre

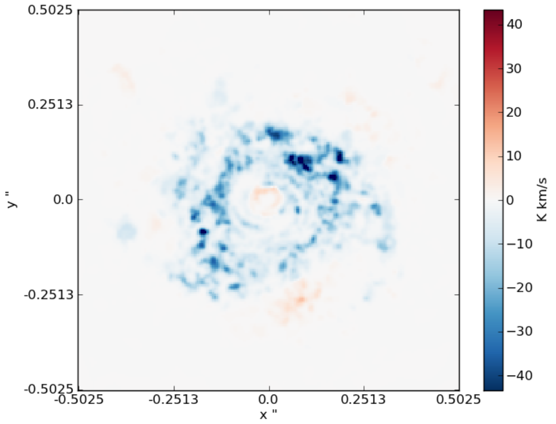

Figure 29. C18O 3-2 60 deg Continuum subtracted mom0

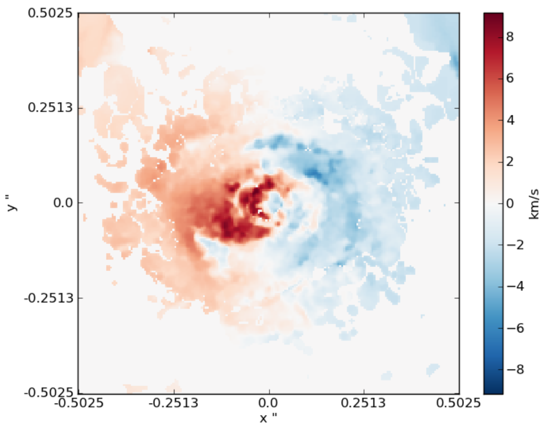

Figure 30. C18O 3-2 60 deg mom1map

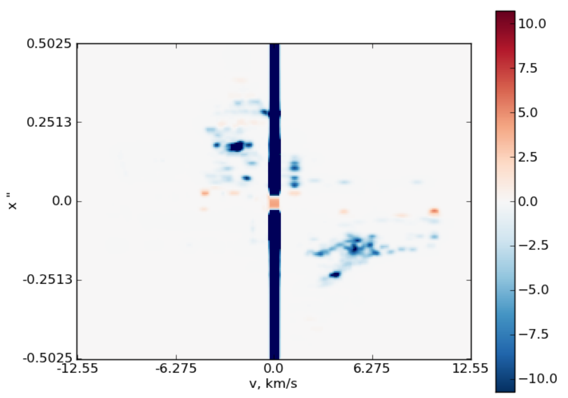

Figure 31. C18O 3-2 60 deg PV through centre

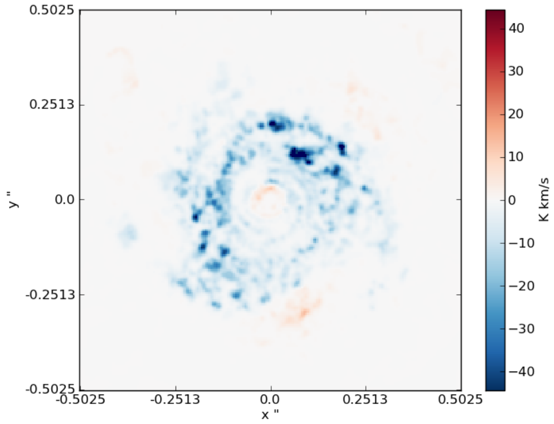

Figure 32. C18O 3-2 75 deg Continuum subtracted mom0

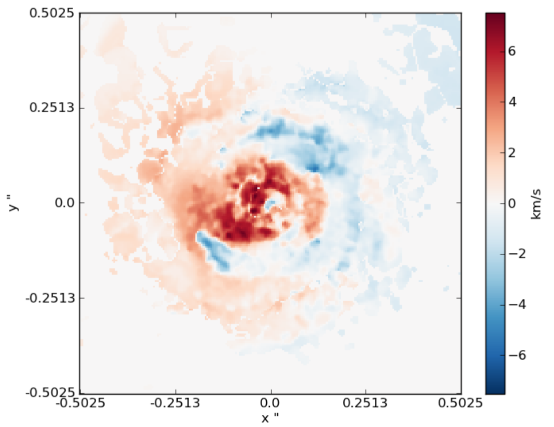

Figure 33. C18O 3-2 75 deg mom1map

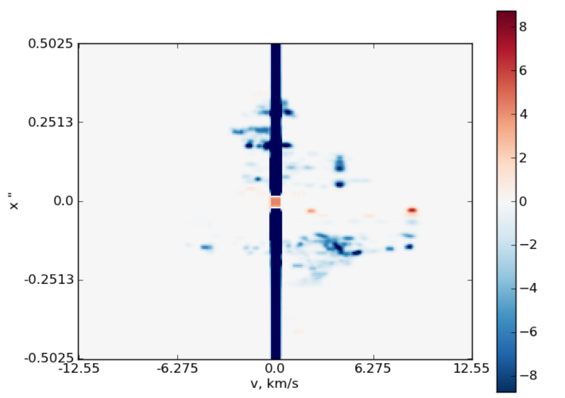

Figure 34. C18O 3-2 75 deg PV through centre

5 ALMA PREDICTIONS

- current status (Cycle 1) - Figure OCS + C18O + H2CO + HNO/CS/ - final status - Figure

6 CONCLUSIONS

note that all species show up in absorption and some show a little bit of emission around the edges of the disc OCS is good for showing up spiral structure without being able to resolve it. envelope only contaminates the central plus-minus 500 m/s or so

ACKNOWLEDGEMENTS

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