Mapping the magnetic field structure of massive star-forming regions through molecular line polarization

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Content

一、The origin of my project

A. The origin

In star formation theories, especially in low mass star formation, we think the magnetic field may be important in playing a role to resist the gravitational collapse. So in massive star forming region, we may reasonably view magnetic field as an important role. If we can developed some methods to measure magnetic field in massive star forming region, we can prove which theory is right. By using line polarition method, we may detect whether there is magnetic field and their magnitude in the plane of sky.

B.Line polarization(GK EFFECT)

Stars form in molecular clouds. Until now, we only have three methods to measure magnetic field in molecular clouds, which are Zeeman effect、dust polarization and line polarization. Zeeman effect could give us magnetic field magnitude along our line of sight, whereas dust and line polarization could give us magnetic field magnitude in the plane of sky. By measuring the optical depth in different position of the molecular clouds, we can easily determine the direction of polarization by chosing the minimum optical depth as the polarization direction. Optical depth is a dimensionless quantity that describe the ability of radiative transfer, which is a process describe photons released and absorbed by molecular energy levels. And the whole process including radiative transfer and measuring optical depth is called GK effect.

二、Why we want to build ALMA?

From optics theory, we know angular resolution is determined by wave length we measured and diameter of the dish. If we want higher resolution, we need shorter wave length or longer diameter. In detecting millimeter and sub millimeter wave length, we need at least 16 Km for diameter, and it is beyond our technology limit. By constructing many tiny single dishes, we can produce same effect by making the longest baseline length of these single dishes to be 16 Km or longer and the longest baseline length of these single dishes is equal to the diameter of a single dish. This is the reason of why we build ALMA, an interferometer that help us detect millimeter and sub millimeter wave length. By handling SMA data, which is also an interferometer, it prepares me in the future to handle ALMA data.

三、Linux system

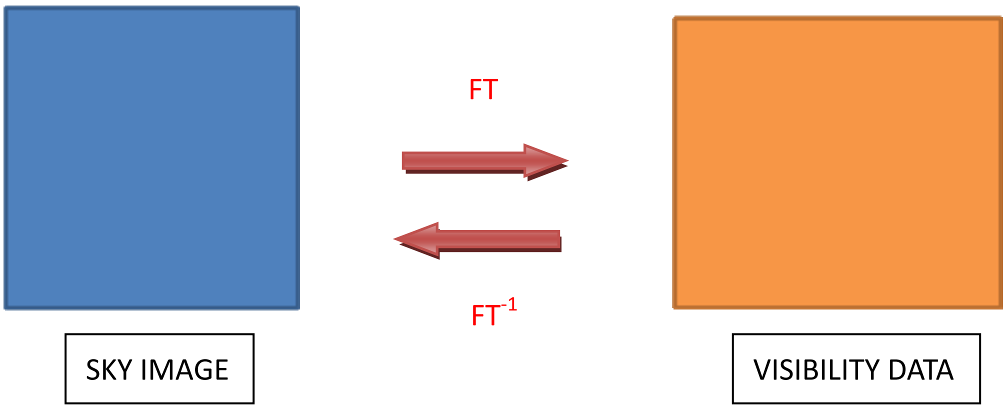
There are many operating system that are suitable for astronomers. Actually, we use miriad, which is a software runs in Linux's terminal . By using miriad, we can easily transfer our visibility data to sky images we expected.

四、Using miriad to generate continuum image

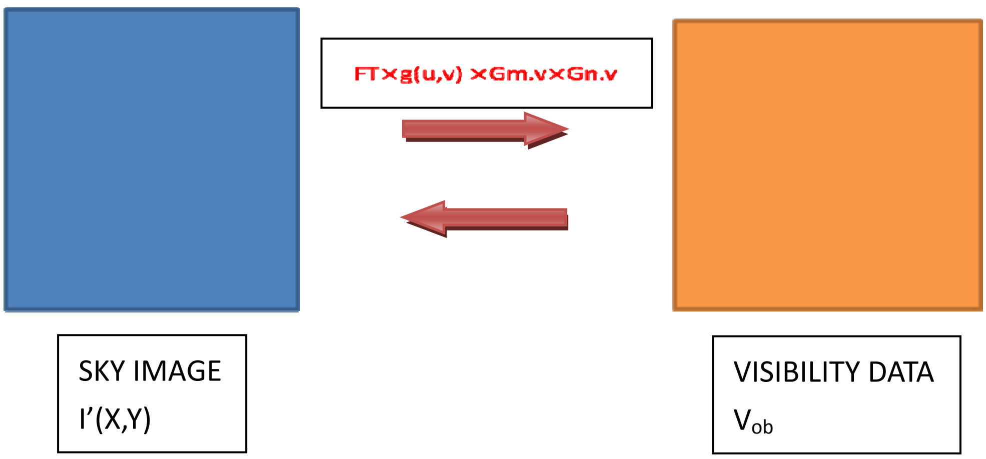
A. Interferometric imaging

Before start using miriad, we need to know some background knowledge of how to transfer our visibility data to sky images, and that is why I want to talk about Interferometric imaging.

If we are in ideal world, sky image and visibility data can be easily transfer by fourier transform, which is the following :



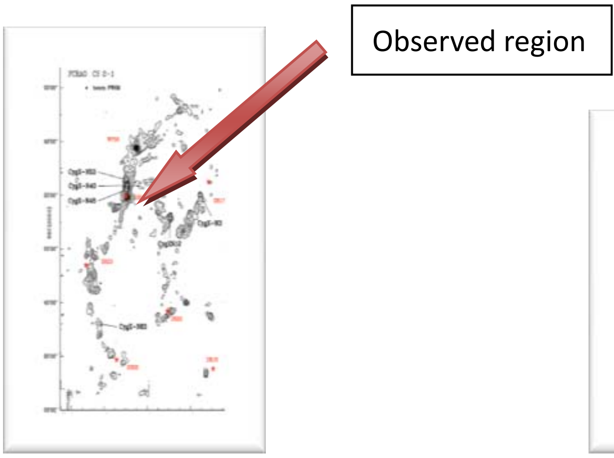
Unfortunately, in the real world, we need to consider the rotation of earth and limit of our device, that is to say, the transformation between sky image and visibility data is now more complicated :

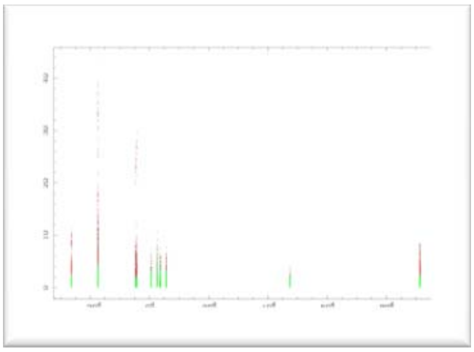


Now our sky image through telescope is the combination of true sky image I(X,Y) and antenna response A(X,Y) caused by limit of our device (i.e. I'(X,Y) = I(X,Y) A(X,Y)). Then it is multiply by uvcoverage function g(u,v) (which is caused mostly from the rotation of earth) and gain function G_{mv}/G_{nv} after doing fourier transform in order to get the visibility data we observed V_{ob}.

B.Data information

The visibility data I got was the SMA data(Which is from sub,com,ext,vex), my observed region was a small box of DR21OH . I will use these calibration data to make my continuum dust image in part C and CO line image in the following next session.

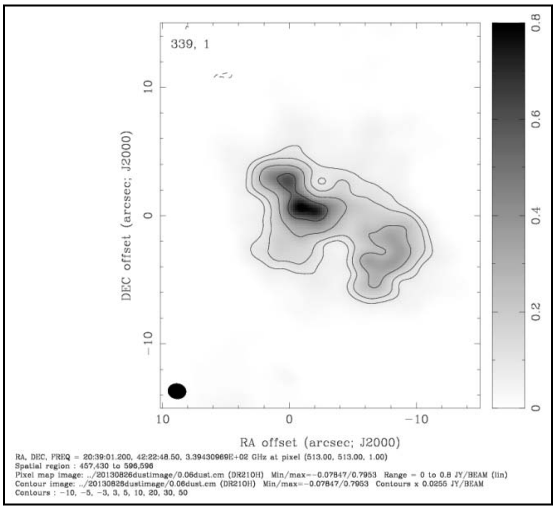




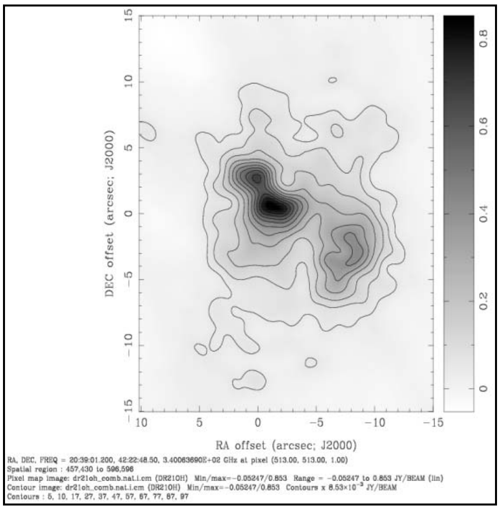
(b-1)DR21OH, from dauw **(b-2)visibility data for my dust image**

C.Result and comparision

Picture(c-1) is my dust continuum image, compared to picture(c-2) from same scale and wedge, you can see we have nearly same center parts, which located near (0,0) and (-8,-3). We have quite different edge outside the source center, though we use the same visibility data. After discussing with my professor, we thought the main reason is because I use quite different ''clean region''. There is a process called CLEAN in miriad in the process of transporting visibility data to true sky image, when we got dirty map, we only got sky image mixed up with beam, which is a way how our device view our true sky as. We need to deconvolve dirty map in order to get our true sky image, which is called clean map, such as picture(c-1) and (c-2), this step is so called CLEAN and RESTOR. Different way in deconvloving dirty map may get different result, that is now we are concerned about. In picture(c-2) , which is ''cleaned'' from professor's colleague, was specified by a polygon near the edge of sources where he thought there were sources. On the other hand, I use a bigger box to cover my source (where I saw apparently near (0,0) and (-8,-3)). What I want to say is if we only specified the region where we thought there has source, we may miss other potential sources and didn't clean them. But there is another advantage---we will not include sidelobes and clean it as source. So it depends on experience and whether you believe there is source or not. Because this is the first time I make continuum image, I rather choose a bigger box instead of a polygon and believe there is still sources outside (0,0) and (-8,-3). Another reason I believe there still have potential source is because when I check my residual map I found in the center part of the map(where I mentioned there have apparently emission sources), its intensity was lower then outside part which is around the center and we usually think it as sidelobes, it is not ‘’clean too deep’’, cause the cutoff I set is much higher than the best cutoff I found (=1.5*noise level), and they are all included in my ‘’clean box’’.



Picture(c-1) continuum dust image cleaned by a rectangular box,done by me

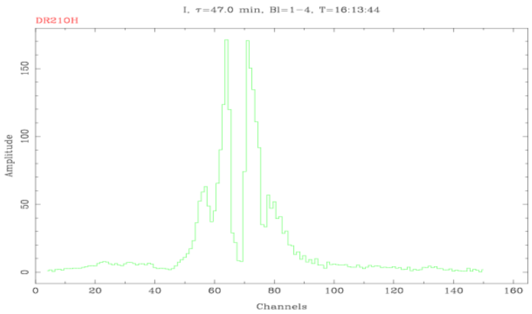


picture(c-2) continuum dust image cleaned by a polygon, done by prof. lai’s colleague

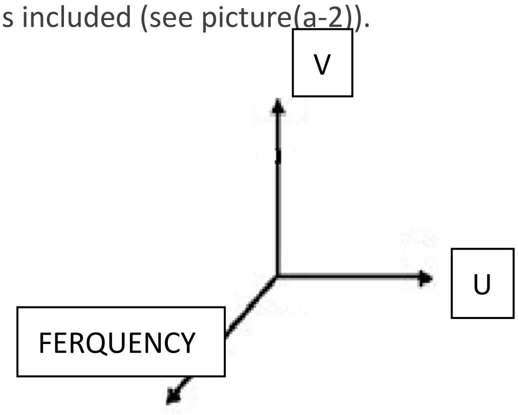
五、Using miriad to generate line image

A.Background knowledge

Until now we know we are in a none ideal world, we can only measure points on the uvcoverage and every point on the uvcoverage measures one spectrum (picture(a-1)), which is frequency versus amptitude (i.e visibility). (If you are in ideal world, you can measure every point on sky plane to get visibility and easily transfer it to sky image .) We are now focus on the peak part of the spectrum, which was caused by CO molecular emission(j=3-2), the other continuum part was caused by dust emission. So every frequency on every point in the uvcoverage forms one image, many frequency form many images, these are called line image. Unlike dust image, which is formed by the average visibility of continuum part in the spectrum , line image is three dimension with frequency axis included (see picture(a-2)).



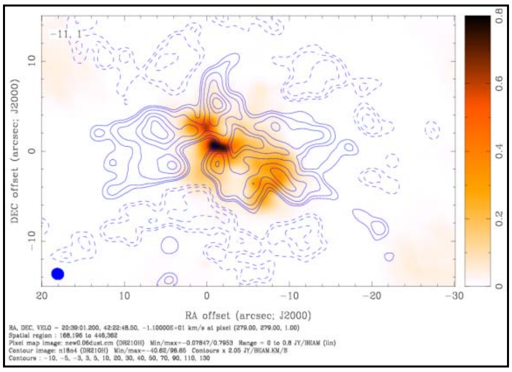
picture(a-1)spectrum from one point on uvcoverage



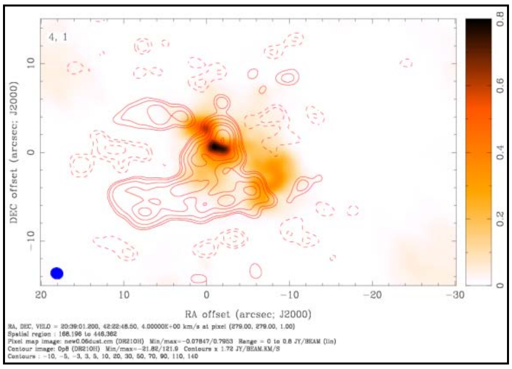
picture(a-2) line image with three dimension

B.Result and comparision

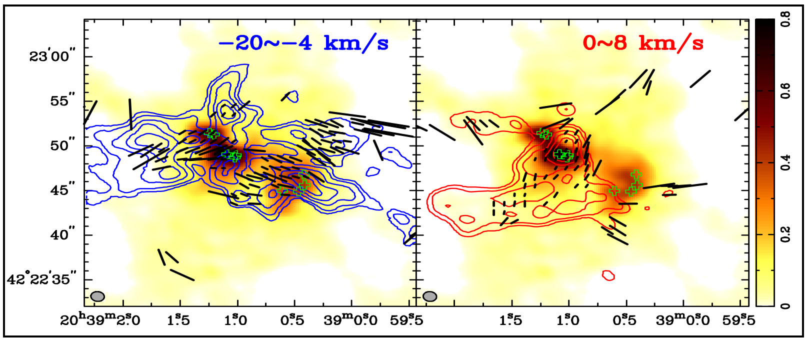
The last result is the overlap of continuum dust image and moment map of CO line image. From picture(b-1) (b-2) and (b-3), you can see my result is similar to my teacher, with low speed blue shift out flow spread out almost everywhere(from source) and low speed red shift out flow spread from source half of left plane, unlike picture(b-4)(b-5) which is high speed out flow, low speed out flow is hardly to distinguish which part of source cause this out flow. For example, from picture(b-3), you can see the V shape out flow may be released from (-10,5), which may be consider as a new born proto star, and this part also released a red shift out flow (see picture(b-5)). The dense part (nearly black color part) also released an upward out flow both red shift and blue shift included, but mostly blue shift.



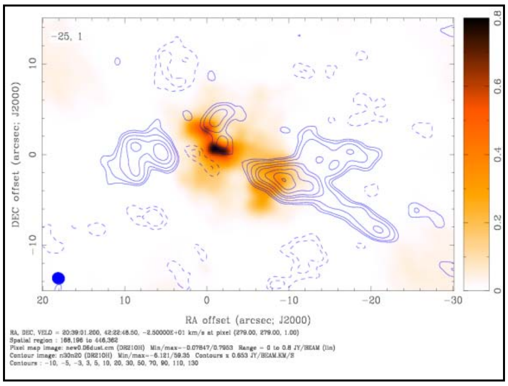
Picture(b-1)-20~-4 Km/s
Low speed blue shift



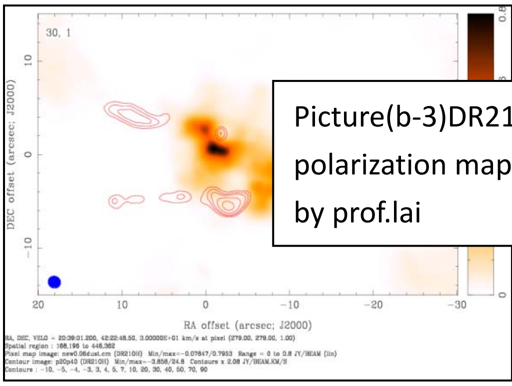
Picture(b-2)0~8 Km/s
High speed red shift



Picture(b-3)DR21OH polarization map done by prof.lai



Picture(b-4)-30~-20 Km/s
High speed blue shift



Picture(b-5)20~40 Km/s
High speed red shift

六、 Future

In this two month, from a girl that doesn't undersatnd any thing of Linux and hasn't learned any thing about astronomy before, I can controll Linux system(miriad) well and I can now generate a good sky map that used to see in some astro academic papers. But I still need to learn an important part------how to generate line polarization map , because if we have these polarizaton map of CO molecular, we can use it to map magnetic field and check which theory of star formation is right. You can say I haven't finish my topic, but I will try my best to finish it in the near future.

七、 **Acknowledgment**

Starting a summer project of star formation is really a harsh task for a student who doesn’t have any background knowledge of astronomy like me. Before this summer, what I know is basic electrodynamics、classical mechanics and a little bit about PYTHON. Thankfully, during those days my teacher at USA, she assigned a teaching assistant who is really serious in teaching me. He not only pushed me to finish my schedule in time and in the same time he taught me a lot about some basic knowledge in astronomy and star formation. Because of this reason, after my professor came back and taught me, I was more easily to understand more difficult part in star formation of analyzing data than other students. Too many people to thanks, this is the first time I think I really learned something that is related to my future, my interesting , and also I meet some good friend who has same interesting as me and may be become my classmate or colleague in the future. I think I am not going to give up any chance that related to my interesting and keep working hard to fulfill my dream.