DENSE AND COLD GAS IN THE CHAMELEON I CLOUD: CO AND IRAS OBSERVATIONS

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Abstract. The southern low mass star forming cloud Chameleon I has been observed in CO $J = 1 \rightarrow 0$ using the 15m Swedish-ESO Submillimeter Telescope. The cloud has been fully mapped in $C^{18}O$ and is found to be higly fragmented. Two cloud cores were detected south of the known star-formation sites in the cloud. The total mass of the gas in Chameleon I, as observed in $C^{18}O$ is 240 $M_\odot$ and is fragmented into nine separate clumps the masses of which range from 12 $M_\odot$ to 70 $M_\odot$. The fragments associated with newly born stars are warmer and/or less dense than the quiescent fragments lying farther away from the star formation centers. Good correlation of the cold dust IR emission (as calculated from IRAS data) with the observed $C^{18}O$ emission was found. The regions of active star formation have been further observed in the ^{12}CO and ^{13}CO $J = 1 \rightarrow 0$ transitions. Numerous molecular outflows were detected. Some of these are associated with known young stellar objects and some do not have an obvious central source.

1. Introduction

Molecular line observations play a major role when the structure of a star-forming cloud is studied. The basic structure of molecular clouds is best studied in nearby high latitude dark clouds and globules. Because of the lack of large millimeter telescopes in the southern hemisphere before SEST, the necessary basic information regarding the distribution of dense molecular matter in many of the southern nearby molecular clouds does not yet exist. $C^{18}O$ $J = 1 \rightarrow 0$ is the most convenient molecule when mapping the large

scale structure of dense molecular clouds. Practice has shown (eg. Myers and collaborators) that this CO isotope is a good tracer of dense cloud cores. Because of the low optical depth of the $C^{18}O$ emission (radiative trapping is not important), the effective critical density of this isotopic species is an order of magnitude higher than that of the more abundant ^{12}CO. On the other hand the critical density is still lower than that of, e.g., CS. Besides within the cores, the $C^{18}O$ molecule can also be used to map the less dense regions where no emission from the CS molecule is expected.

The Chameleon I dark cloud is an active site of recent star formation with some 75 associated pre-main-sequence stars. For a review see, e.g., Schwartz (1991). The cloud is nearby and lies at a high galactic latitude ($b = -15°$). Therefore, it is ideally suited for detailed molecular line study of a star-forming cloud.

The SEST telescope has been used to map large areas of this cloud in the CO $J = 1 \rightarrow 0$ transition. A first report of the observations was given by Mattila *et al* (1989) where also the discovery of two major outflows was discussed. A similar study of the CrA star-forming site has been conducted at SEST (Harju *et al* 1993)

2. Observations

The SEST telescope has been used during several observing runs since 1988 to map Chameleon I in $C^{18}O$ and partly in the more abundant CO isotopes. The $C^{18}O$ mapping (altogether some 1600 positions) was done in a 1min grid and is therefore slightly undersampled. The known star-forming sites around the three bright reflection nebulae in the cloud and the infrared nebula in the south were further observed in the main CO isotope. The emission in the latter isotope is always strongly self absorbed and can be used only to locate the possible molecular outflows. The observed ^{13}CO lines are often flat topped and show very little structure. This is an indication of a large optical depth for this isotope. The optical depth of the $C^{18}O$ isotope is mostly below 1 and is higher only in the centers of the star-forming cores around HD 97300 in the north, Ced 110 in the centre and HD 97048 in the south.

Strong 100 micron emission is seen in IRAS data in the direction of the cloud. Much of this emission comes from warm (24K), IR cirrus-like material and the distribution of this emission does not trace the molecular cloud accurately. The emission from cold dust at 60 microns is small and the contribution of the cirrus-like emission at 100 microns can be approximated by multiplying the IRAS 60 micron emission by 5. This corresponds roughly to the 100 to 60 micron colour ratio from 24K dust. Subtracting this emission from the 100 micron IRAS map, only the part of the emission

coming from cold dust remains. The correlation of this "cold dust emission" and the $C^{18}O$ emission in Chameleon I is excellent, although, due to the course resolution of the IRAS data, much more details are seen in the CO map.

3. Results

In $C^{18}O$, nine separate (spatially or in velocity) cores can be separated. The $C^{18}O$ line widths, corrected for line opacity, range from 0.5 to 0.9 km s^{-1} and velocities between 3.8 and 4.9 km s^{-1}. The maximum column densities in the cores are between 1.5 $10^{22}cm^{-2}$ and 2.5 $10^{22}cm^{-2}$. The properties of the clumps have been calculated assuming a distance of 140pc to the cloud.

The northernmost core has already been discussed in Mattila *et al* (1989). The position velocity diagram of this region indicates a possible rotating toroid in the center of which is the center of a molecular outflow. The mass of this structure is $\approx$20 $M_\odot$.

The reflection nebula Ced 110 lies near the centre of the most massive core in the region. This 0.5 by 0.2 pc and 70 $M_\odot$ core is elongated in the NE-SW direction. Projected on this core, near its center, is a smaller (20 $M_\odot$) 0.15 pc diameter core. The two cores are easily separated in velocity.

The active star-forming location around HD 97048 lies at the eastern rim of a 20 $M_\odot$ core. Several CO outflow lobes were detected. Due to the large number of young stars, it is difficult to identify the central sources but at least the stars HD 97048 (or Sz 22), Sz 19 and T33 seem to be associated with moderate molecular outflows. The infrared nebula, located SE from HD 94078 is associated with a small size, not very massive core and possibly with a bipolar outflow.

Two cloud cores, which are elongated in the same direction as the core associated with Ced 110, lie to SW from HD 94078. The masses of these cores are 60 and 20 $M_\odot$. No star formation is known in their direction and the $C^{18}O$ emission correlates here well with the IRAS "cold dust emission".

References

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