Dense Core Evolutions Induced by Shock Triggering and Turbulent Dissipation

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Abstract

We report statistical properties of $C^{18}O$ and $H^{13}CO^+$ dense cores whose typical densities are 10^4 and 10^5 cm^{-3}, respectively. In general, one $C^{18}O$ core fragments into one or a few $H^{13}CO^+$ cores in isolated SFRs, in contrast to the typical triggered cluster-forming region of the ρ Oph cloud, which consists of 57 $H^{13}CO^+$ cores. The statistics of the $C^{18}O$ cores show a remarkable trend that more evolved $C^{18}O$ cores associated with $H^{13}CO^+$ cores and young stars have larger masses and smaller line widths. This suggests that the turbulent decay is required for the $C^{18}O$ cores to gain more mass and contract to form dense $H^{13}CO^+$ cores spontaneously. On the other hand, no clear trend is seen in the physical properties between star-forming and starless $H^{13}CO^+$ cores. Among the nearby SFRs, the $H^{13}CO^+$ cores in Taurus are larger in number and mass than others. On the other hand, triggered SFRs of the ρ Oph and Cha I clouds have larger mass fraction of the total $C^{18}O$ cores to the ^{13}CO clouds. These different condensation properties may come from the shock triggering and initial condition of the turbulence.

Introduction

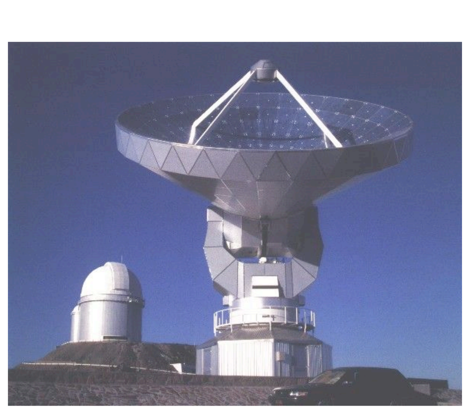
Recent observational and theoretical studies have shown that external triggering and internal turbulence play major role for the condensation of the ISM and star formation. Some evidences of non-isotropic compression is seen in the cloud morphology and associated active cluster formation such like the ρ Oph and Cha I clouds. Survey for $C^{18}O$ dense cores have shown that internal turbulence dominates the core dynamics and regulate star formation activity (e.g. Tachihara et al. 2002).

Observations

Based on the precedent $C^{18}O$ core surveys by the NANTEN radio telescope, (Tachihara et al. 2002 and the references therein), Taurus, Ophichus North, Lupus, and Chamaeleon clouds were surveyed for denser and more compact cores in $H^{13}CO^+$ (J=1–0) by the 45m telescope at the Nobeyama Radio Observatory and the SEST 15m telescope at La Silla. The results obtained in Taurus were published by Onishi et al. (2002). For a comparison, $H^{13}CO^+$ survey with the 45m telescope in the ρ Oph cloud by Umemoto et al. (2002) are compiled.

Results

- In total, 148 $H^{13}CO^+$ cores are sampled including the ρ Oph cloud. Their physical properties are summarized in Table. 1.
- In the isolated SFRs, one $C^{18}O$ core generally contains a few $H^{13}CO^+$ cores, while the ρ Oph cloud fragments into 57. In the Cha I cluster, $H^{13}CO^+$ cores seem to have already dissipated.
- The $C^{18}O$ cores with larger mass and smaller line width tend to have embedded $H^{13}CO^+$ cores (Fig. 2). This clear trend indicates that the turbulent dissipation leads the cores into virial equilibrium and further condensation.
- Remarkably massive and many $H^{13}CO^+$ cores are formed in Taurus showing active and ongoing star formation in contrast to the inactive SFRs of the Oph North and Cha II/III clouds.
- In the Oph North region, $H^{13}CO^+$ cores are low mass despite the high detection rate. It is suggested that they are not massive to form stars, while Cha II/III clouds are immature and have only 2 $H^{13}CO^+$ cores.
- No clear difference in the core properties is seen between star forming and starless $H^{13}CO^+$ cores.



SEST 15m

NRO 45m

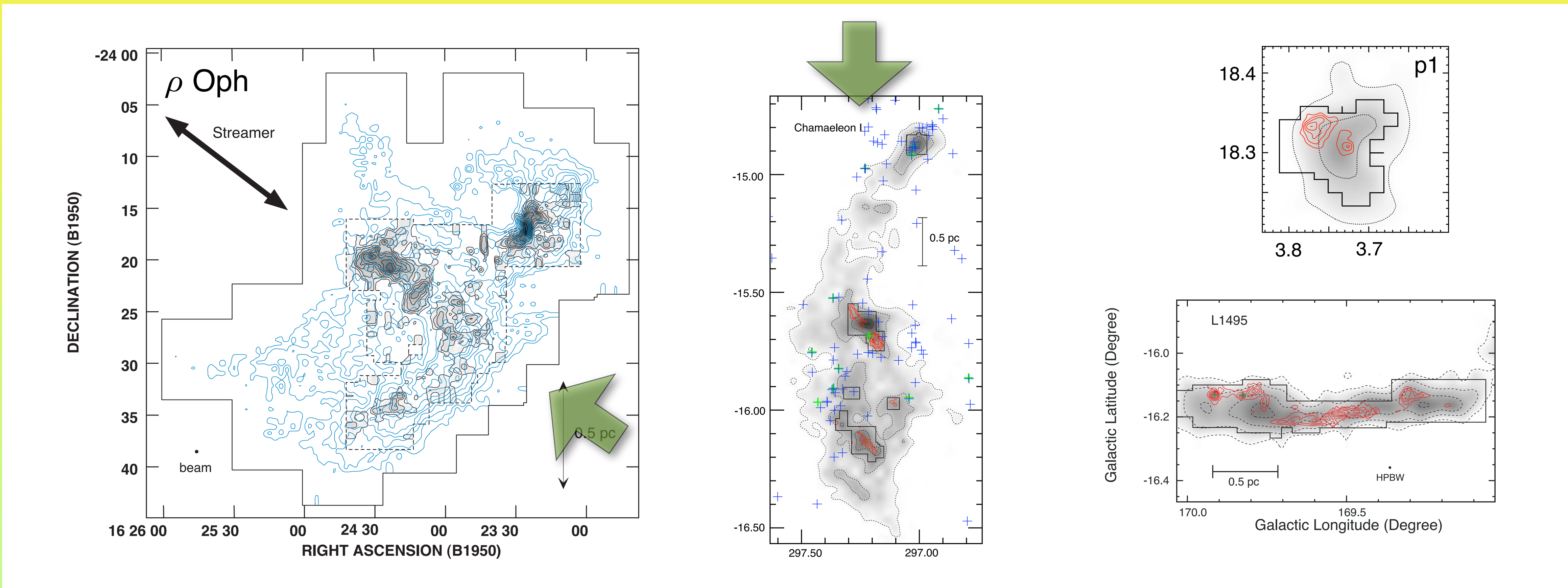


Fig. 1 Four examples of the $H^{13}CO^+$ dense cores sampled in the triggered (ρ Oph and Cha I clouds) and spontaneous (core p1 in the Oph North region and L1495 in the Taurus clouds) SFRs. Integrated intensity maps of $H^{13}CO^+$ is overlapped on the $C^{18}O$ integrated intensity maps. For the triggered SFRs, directions of the shock wave are shown by arrows. The maps are arbitrary scaled. Note that one $C^{18}O$ core typically breaks up into a few $H^{13}CO^+$ cores except that ρ Oph cloud contains 57 $H^{13}CO^+$ cores. On the other hand, no $H^{13}CO^+$ cores are detected in the region of the Cha I YSO cluster.

Table. 1 Physical properties of the $H^{13}CO^+$ cores

	number of cores	M [$M_\odot$]	R [pc]	ΔV [km s^{-1}]	detection rate [%]
Taurus	56	5.9	0.04	0.62	45
Oph North	25	2.0	0.03	0.55	52
Lupus	10	4.0	0.05	0.66	20
Cha II/III	2	3.4	0.07	0.75	12
ρ Oph	57	2.5	—	—	100
Cha I	3	4.9	0.06	0.66	33

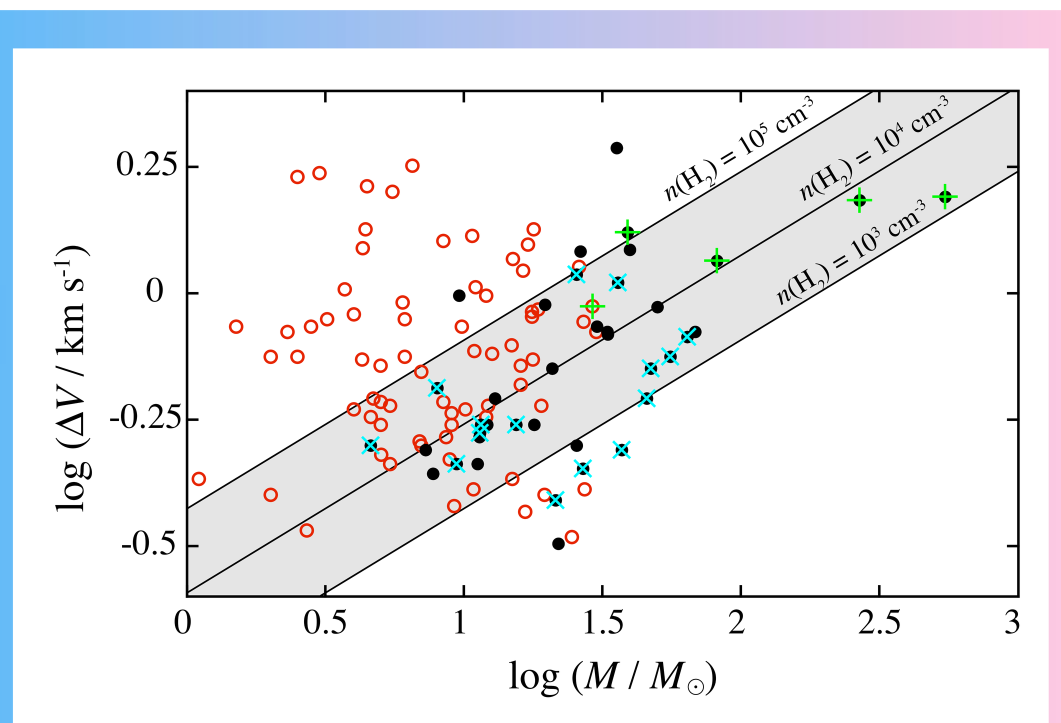


Fig. 2. Log-log plot of the mass vs ΔV for the $C^{18}O$ cores. The filled and open circles show those with and without $H^{13}CO^+$ core detections, respectively. The X and cross denote the cores associated with YSOs and clusters (more than 10 YSOs), respectively. The gray region illustrates the area where the cores are in the virial equilibrium with the average densities between 10^3 and 10^5 cm^{-3}.

Discussion

The property of gas condensations represented by mass ratios of low to high density regions are quite different among the SFRs (Fig. 3). The total $C^{18}O$ core mass divided by the ^{13}CO mass is high in the 2 triggered SFRs (ρ Oph and Cha I clouds). It suggests that the external pressure helps the low density gas with compression. Further contraction to form $H^{13}CO^+$ cores is triggered by the internal turbulence decay. Among the studied SFRs, the Taurus cloud has remarkably smaller ΔV of the $C^{18}O$ line, that may induce spontaneous $H^{13}CO^+$ core formation and thus high mass fraction of the total $H^{13}CO^+$ cores to the $C^{18}O$ cores.

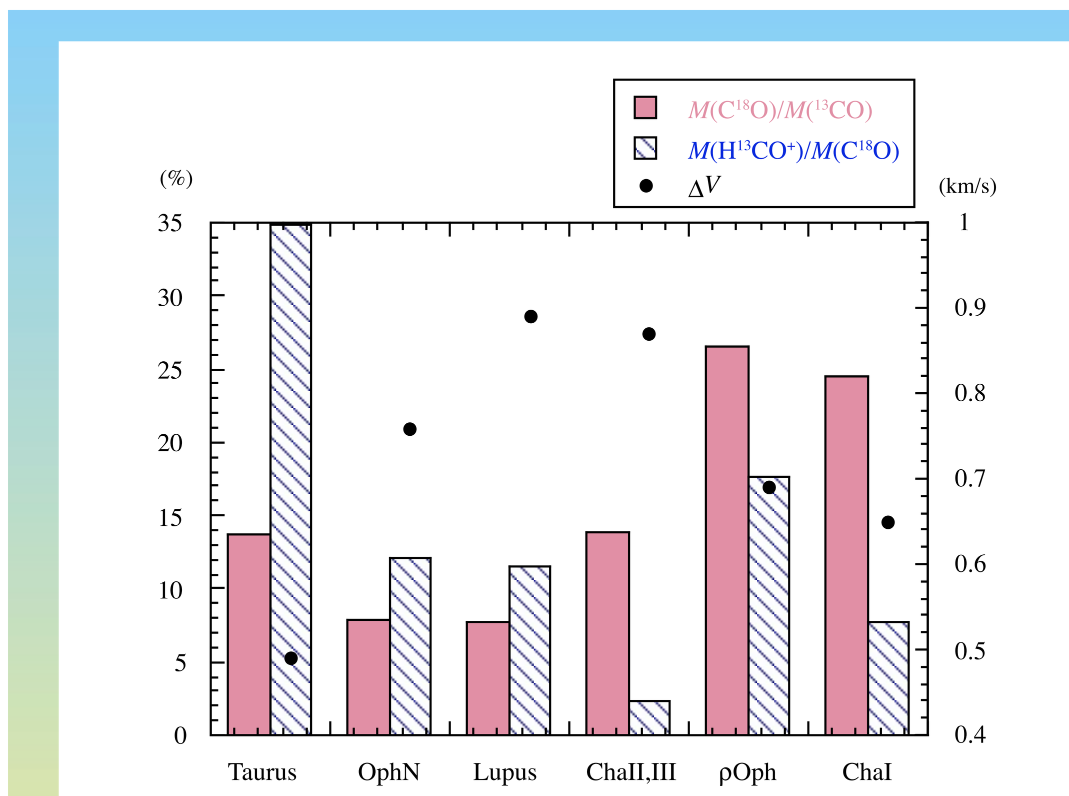


Fig. 3 Comparison of the mass fractions in different molecular tracers among the surveyed SFRs. The red filled bars and blue hatched ones denote the total $C^{18}O$ core mass divided by the total ^{13}CO cloud mass and the total $H^{13}CO^+$ core mass divided by that of $C^{18}O$. The average velocity dispersions derived from the $C^{18}O$ line width are over-plotted.

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