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Head-tail molecular clouds falling onto the Milky Way disk

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Abstract

We report discovery of two CO clouds which are likely falling down to the Galactic plane at more than 35 km s^{-1} . The clouds show head-tail distributions elongated perpendicular to the Galactic plane at $l = 331.^\circ 6$ and $b = 0^\circ$ as revealed by an analysis of the Mopra CO $J = 1-0$ survey data. We derived the distance of the clouds to be 2.46 ± 0.18 kpc based on the Gaia Data Release 3. The CO clouds have molecular masses of $4.8 \times 10^3 M_\odot$ and $3.5 \times 10^3 M_\odot$, respectively, and show kinetic temperature of 30–50 K as derived from the line intensities of the $^{13}\text{CO } J = 2-1$, $^{12}\text{CO } J = 1-0$, and $^{13}\text{CO } J = 1-0$ emission. The temperature in the heads of the clouds is significantly higher than 10 K of the typical molecular clouds, although no radiative heat source is found inside or close to the clouds. Based on the results, we interpret that the present clouds are falling onto the Milky Way disk and are significantly heated up by the strong shock interaction with the disk HI gas. We suggest that the clouds represent part of the HI intermediate velocity clouds falling to the Galactic plane which were converted into molecular clouds by shock compression. This is the first case of falling CO clouds having direct observed signatures of the falling motion including clear directivity and shock heating. Possible implications of the CO clouds in the evolution of the Galactic interstellar medium are discussed.

Наблюдения

- Морга-обзор (Австралия, 22 м, южное полушарие), 2011-2018, в линиях CO (с изотопами)
- APEx (Чили, 12м), обзор SEDIGISM
- Разрешение $\sim 30''$
- Плюс данные Herschel на 160 мкм, разрешение $12''$
- Оценка расстояний – по звездам из Gaia DR3

Изображения Мопра

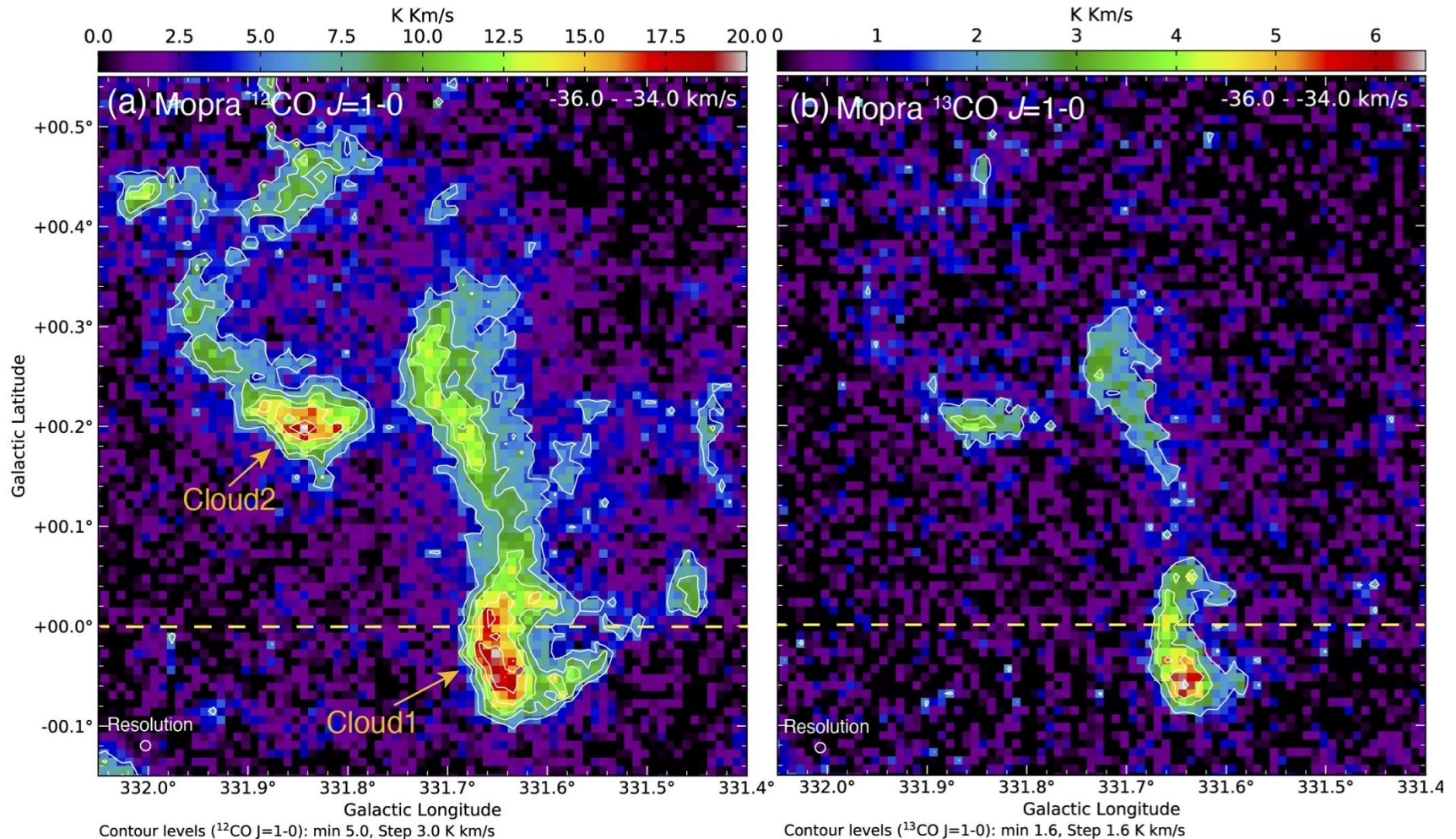


Fig. 1. (a) The Mopra $^{12}\text{CO } J = 1-0$ integrated intensity map of the head-tailed molecular clouds. The lowest contour levels and intervals are 5.0 K km s^{-1} and 3.0 K km s^{-1} . (b) Same as (a), but for $^{13}\text{CO } J = 1-0$. The lowest contour levels and intervals are 1.6 K km s^{-1} and 1.6 K km s^{-1} . The integrated velocity ranges are from -36 km s^{-1} to -34 km s^{-1} . The yellow dotted lines show the Galactic plane ($b = 0^\circ$). Alt text: Mopra 12-CO and 13-CO integrated intensity maps.

Скорости

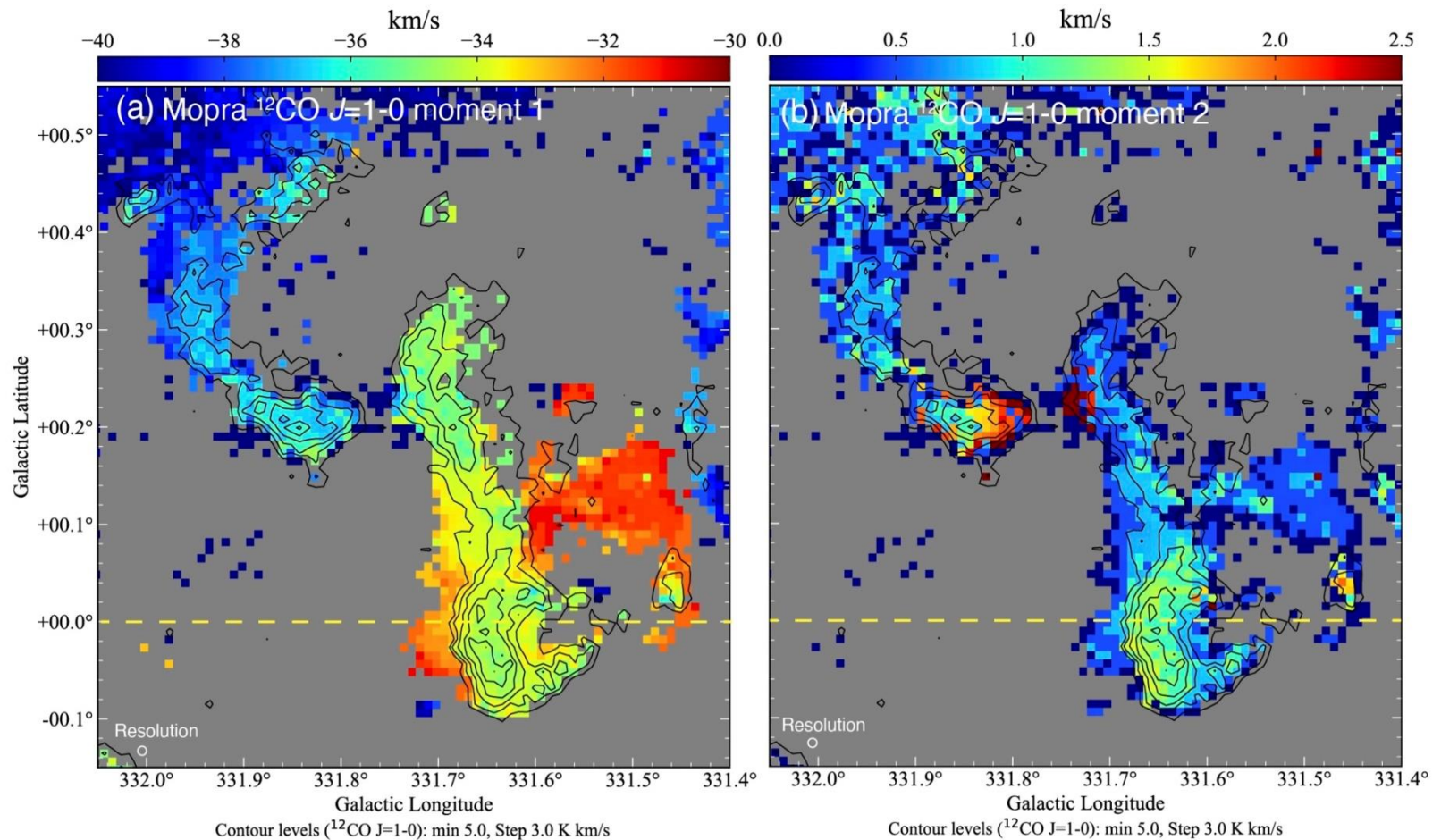


Fig. 2. The Mopra $^{12}\text{CO } J = 1-0$ velocity-field (first-moment) map. (b) The $^{12}\text{CO } J = 1-0$ velocity dispersion (second-moment) map. The adopted velocity range extends from -40 km s^{-1} to -30 km s^{-1} . The yellow dotted lines show the Galactic plane ($b = 0^\circ$). The contour levels and intervals are the same as in Figure 1(a). The data points are plotted above 4.5 K km s^{-1} of the $^{12}\text{CO } J = 1-0$ integrated intensity. Alt text: Mopra 12-CO first and second moment maps.

Карты в 160 мкм: нет источников нагрева (до 50К)

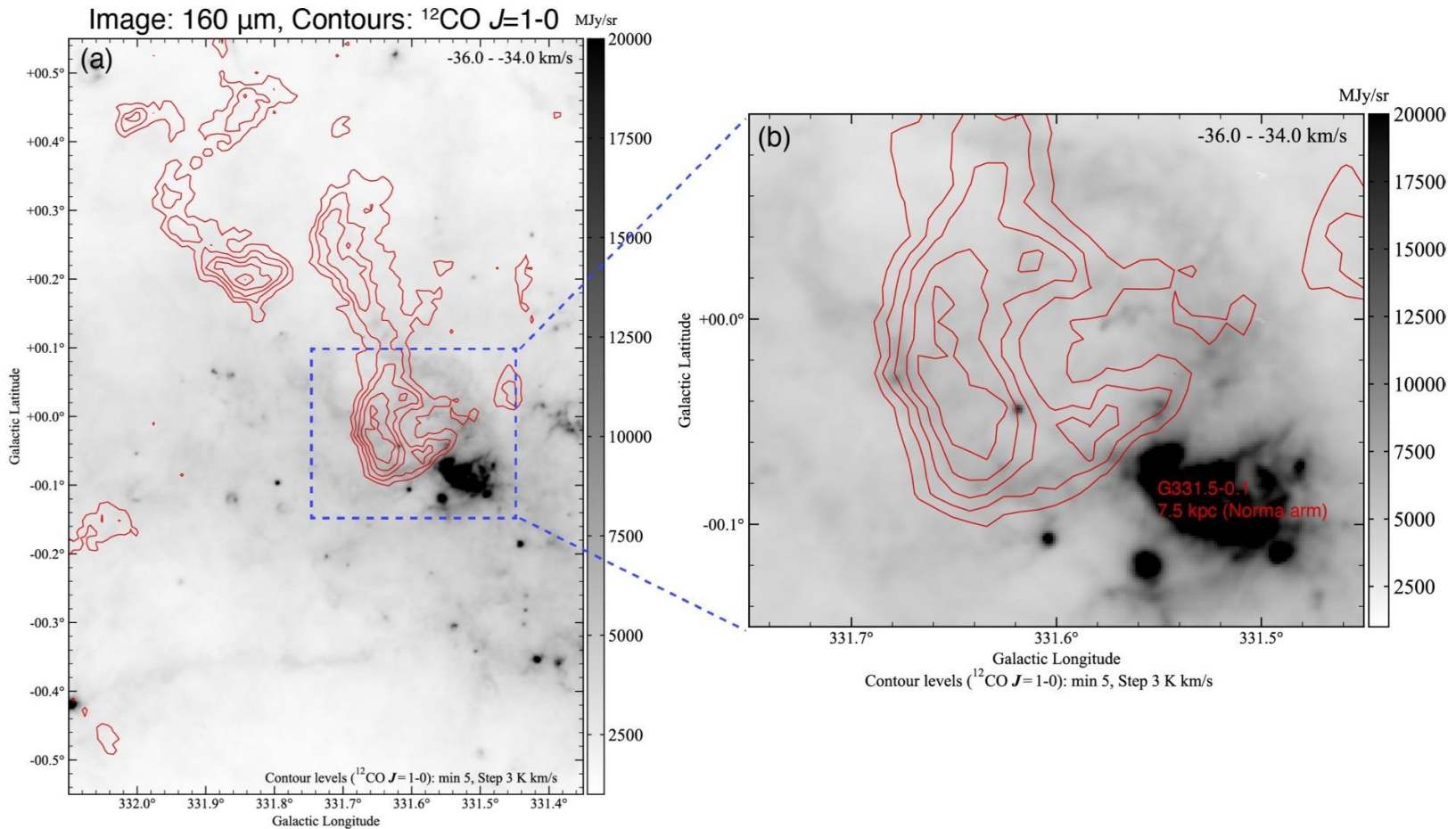


Fig. 5. (a) $^{12}\text{CO } J = 1-0$ spatial distributions of head-tail molecular clouds superposed on the Herschel 160 μm continuum image (Molinari et al. 2010). The lowest contour levels and intervals are 5.0 K km s $^{-1}$ and 3.0 K km s $^{-1}$. (b) The close-up image of panel (a). Alt text: Mopra 12-CO spatial distributions of head-tail molecular clouds superposed on the Herschel 160 micrometer continuum image.

Локализация: НЕ В РУКАВАХ!

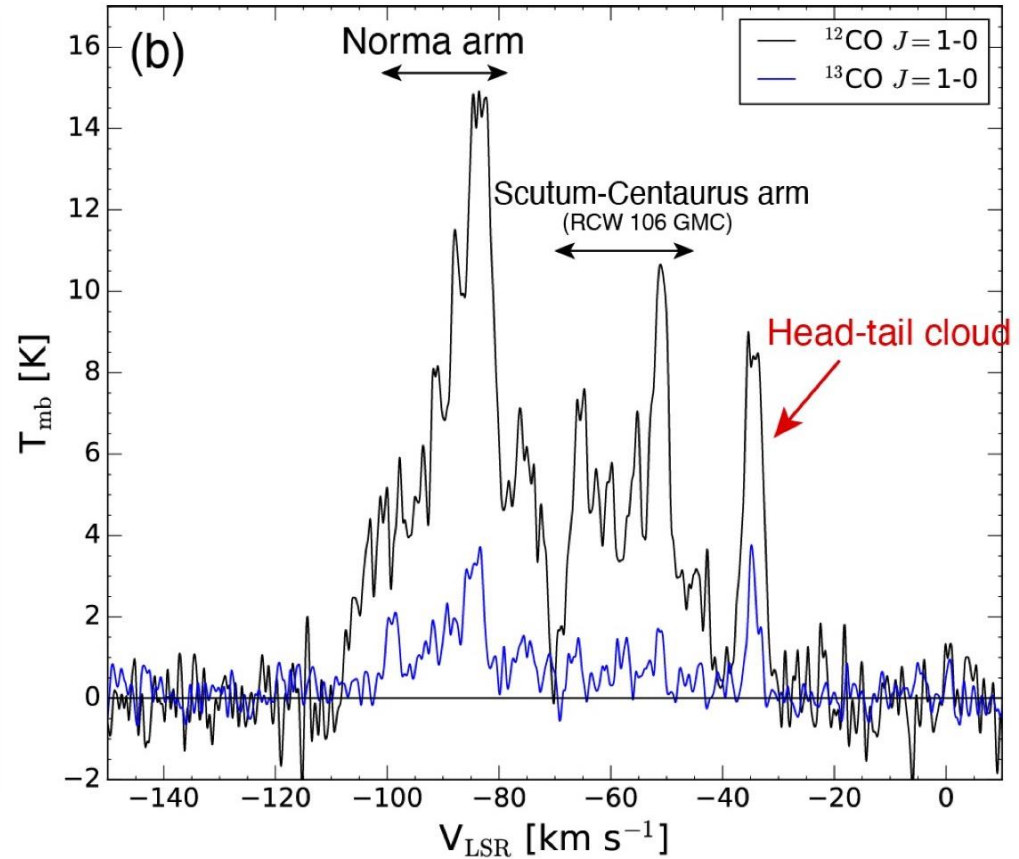
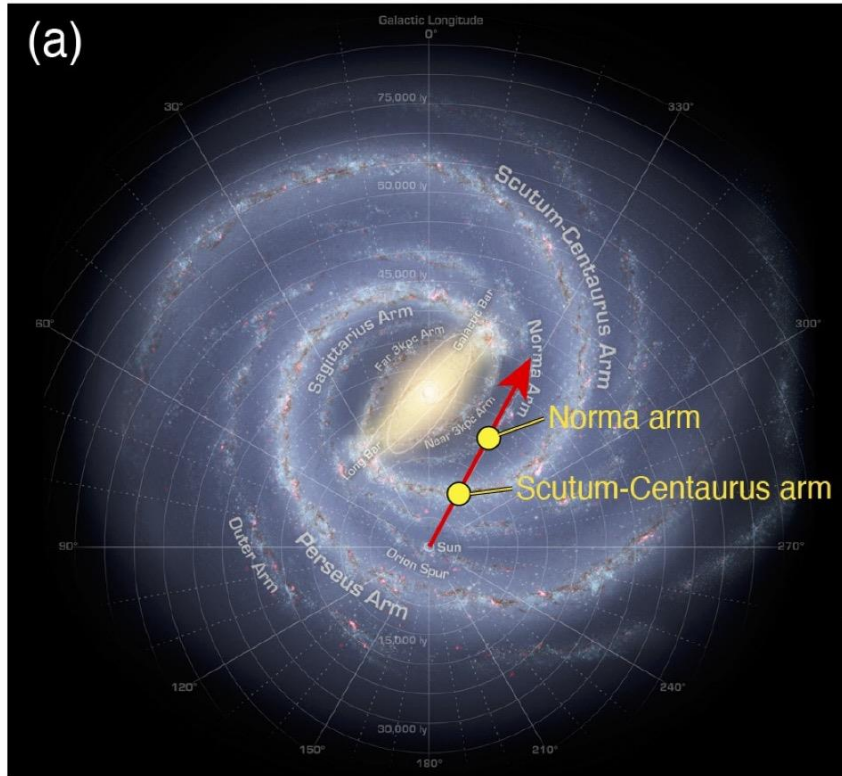


Fig. 6. (a) The top schematic view of the Milky Way (NASA/JPL-Caltech/ESO/R. Hurt). The red arrow indicates the direction of $l = 331^\circ$. Two yellow circles are present at the intersections of the line-of-sight with the Scutum-Centaurus and Norma arms. (b) Spectra of Mopra ^{12}CO and ^{13}CO $J = 1-0$ at $(l, b) = (331.^\circ627, -0.^\circ0604)$. Alt text: The top schematic view of the Milky Way and spectra of Mopra 12-CO and 13-CO.

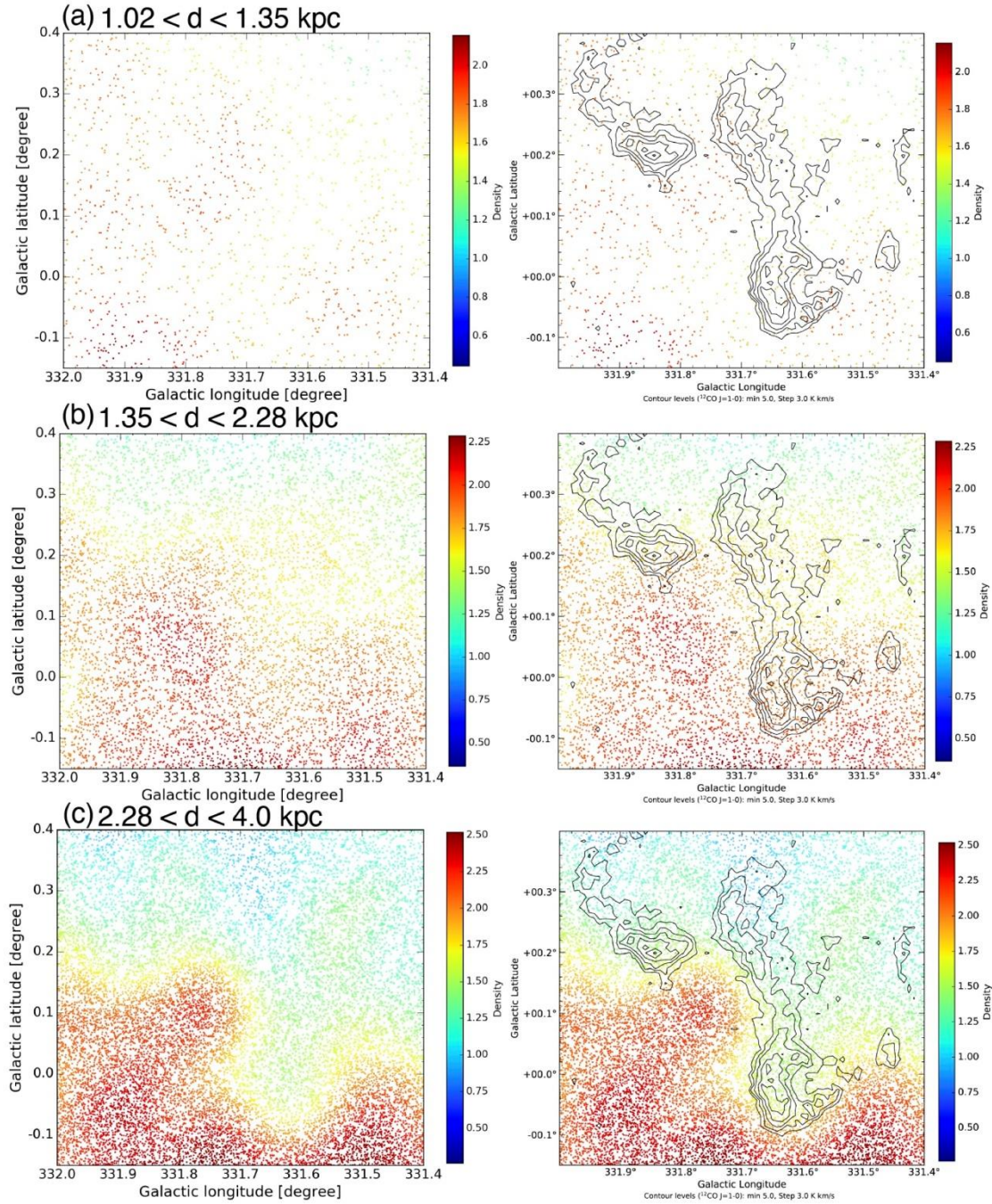


Fig. 8. The stellar density map of fixed stars obtained by Gaia DR3. The panels (a), (b), and (c) show from 1.02 kpc to 1.35 kpc, from 1.35 kpc to 2.28 kpc, and from 2.28 kpc to 4.0 kpc, respectively. The black contours in the right column are the same as Figure 1 (a). All text: The stellar density map of fixed stars obtained by Gaia DR3.

- Если предположить расстояние до облака 1 равным 2.46 кпк, то его размеры будут 15x5 пк, а масса – 4.8 тыс. солнечных масс
- Далее – перед рукавом Scutus-Centaurus есть диффузный газ в диске со скоростью -44 км/с; с ним взаимодействуют падающие молекулярные облака.

Диаграммы «Широта-скорость»

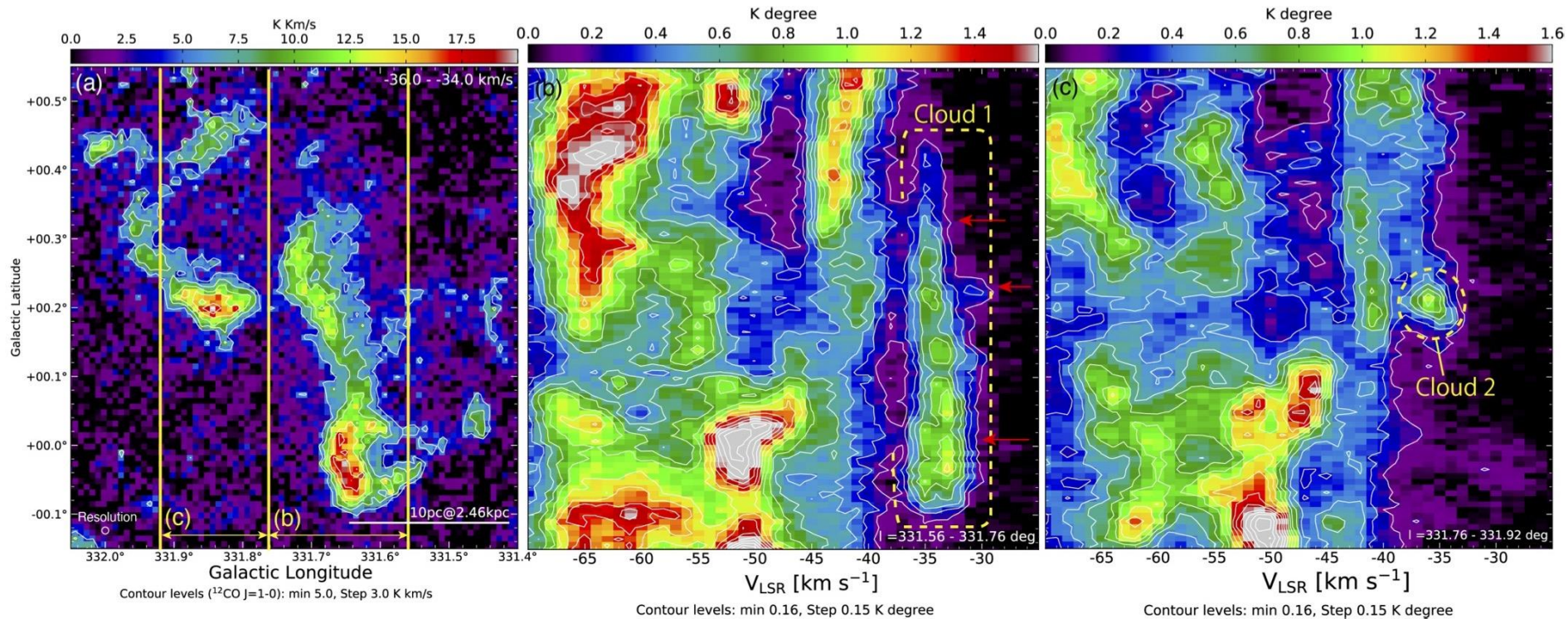


Fig. 9. (a) Same as Figure 1(a). The yellow lines show the integrated longitude ranges in the panels (b) and (c). (b) The $^{12}\text{CO } J = 1-0$ latitude-velocity diagram of Cloud 1. The red arrows indicate the bridge features connecting to the disk velocity component. The integrated longitude range is from $331.^\circ 56$ to $331.^\circ 76$. (c) The $^{12}\text{CO } J = 1-0$ latitude-velocity diagram of Cloud 2. The integrated longitude range is from $331.^\circ 76$ to $331.^\circ 92$. The lowest contour levels and intervals are 0.16 K degree and 0.15 K degree, respectively. Alt text: Mopra ^{12}CO integrated intensity map, latitude-velocity diagram of Cloud 1, and latitude-velocity diagram of Cloud 2.