The measurement of the CO rotational temperature in the W28A region

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Star formation processes are very complex and their studies are hampered by dust and gas is molecular clouds. Infrared and millimeter radiation gives us insight into these otherwise hidden processes. Here, we analyze *Herschel*/PACS spectral map for a high-mass star-forming region W28A to determine gas rotational temperature using CO lines. We find a temperature of $T = 265 \pm 12$ K, which is similar to gas temperatures for the low-mass protostars.

1 Introduction

High-mass stars have a significant impact on the evolution of galaxies and are important in their energy budget (Zinnecker & Yorke (2007)). Yet, physical conditions in high-mass star-forming regions are poorly constrained. Observations in the far-infrared provide us the means to determine gas temperature as a first step towards understanding the underlying processes.

2 Observations

W28A is a high-mass star-forming region located in Sagittarius near the Trifid Nebula (d =1.3kpc). The source was observed as part of the Water in star-forming regions with *Herschel* key program (van Dishoeck et al., 2011).

We use data from *Hershel* / PACS instrument which conducted observations in the range from 50 to 200 μm. PACS data have a form of an array of 5×5 spaxels, each of them containing full spetrum (Fig. 1). The spaxel size covers 9.4"×9.4" and a total field of view is $\sim$ 47"×47".

3 Results

As the first step of data analysis, we identified lines from CO molecule located in the PACS spectra and calculated their fluxes using Gaussian fitting (Fig. 2). Subsequently, we used Eq. 1 and molecular data about CO to determine the amount of emitting particles in a particular energy state. Here, d is a distance, F is the calculated flux, h is Planck's constant, ν is a frequency of the line and A is the Einstein coefficient for spontaneous emission:

$$N_{\rm u} = \frac{4\pi d^2 F}{h\nu A}, \tag{1}$$

$$\frac{N_{\rm u}}{N_{\rm l}} = \frac{g_{\rm u}}{g_{\rm l}} \exp(-\frac{h\nu}{k_{\rm B}T}), \tag{2}$$

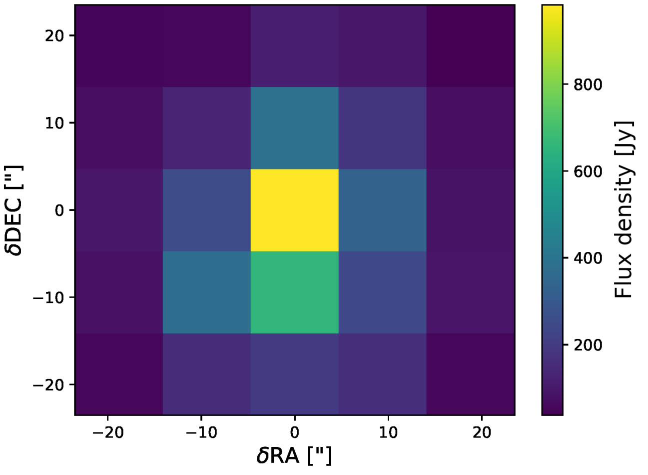

Fig. 1: PACS map of CO 14-13 at 186μm. The central coordinates are R.A. $18^h 00^m 30.4^s$ and Dec. -24^{o}03'58".

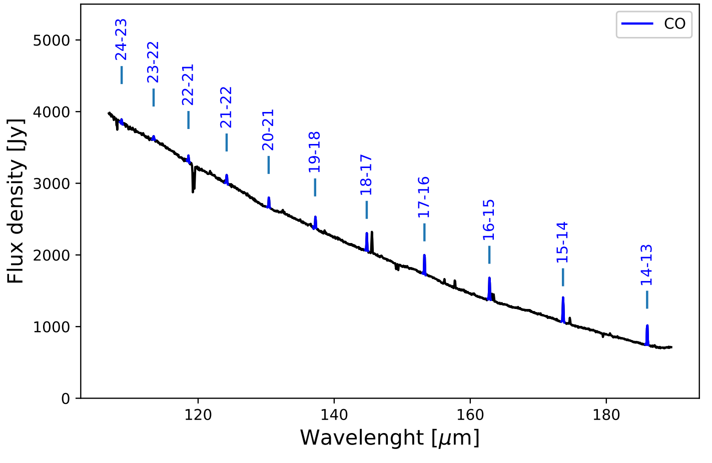

Fig. 2: Part of the spectrum of W28A region where CO lines are detected.

$$\ln \frac{N_\mathrm{u}}{g_\mathrm{u}} = \ln \frac{N}{Q(T)} - \frac{E_\mathrm{U}}{T}. \tag{3}$$

If the cloud of gas is in a state of local thermodynamic equilibrium, the particles are subject to Boltzmann distribution (Goldsmith & Langer (1999)). In this case, we can determine the numbers of emitting molecules in different energy states (Eq. 2). If N_i is the number of molecules in the energy state E_i and g_i is the degeneracy of this state, we can calculate the total number of emitting molecules N using Eq. 3. The $Q(T)$ is partition function and T is rotational temperature. Equation 3 describes a linear function; if the observations are aligned along a straight line, we can fit it and

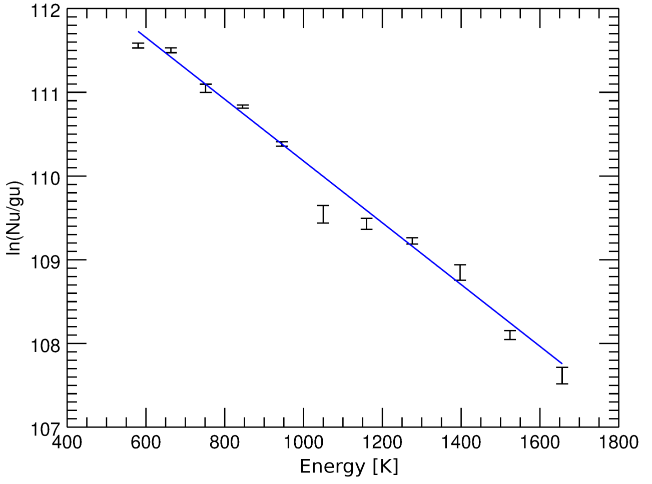

Fig. 3: CO rotational diagram for W28A.

determine the values of N and T.

Figure 3 shows the CO rotational diagram for W28A. Eleven CO lines are detected and fit with a linear function. The CO rotational temperature and the number of emitting molecules are $T = 265 \pm 12$ K and $N = 2.8 \pm 0.8 \cdot 10^{51}$, respectively.

4 Conclusions

The rotational temperature of CO in W28A is consistent with the warm gas component with temperature of $\sim$300 K commonly detected in low-mass star-forming regions (Karska et al., 2018). Thus, the physical conditions of the gas in low- and high-mass protostars are similar and may indicate that the processes leading to star formation are comparable independent of the mass.

References

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