



Studying star-forming processes towards G29.862–0.044

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Resumen / Presentamos un estudio multispectral hacia el objeto estelar joven (YSO, por su sigla en inglés) G29.862–0.044 (en adelante G29), localizado en la región de formación estelar G29.96–0.02, y ubicado a una distancia de aproximadamente 6.5 kpc. Para estudiar el medio interestelar circundante a G29 se utilizaron datos de líneas moleculares (resolución angular de 15'') obtenidos de la base de datos del Telescopio James Clerk Maxwell. Se caracterizó la nube molecular en la que se encuentra embebido el YSO y se determinaron parámetros físicos del *outflow* molecular relacionado. Adicionalmente se analizaron datos del infrarrojo cercano (resolución espacial del orden de 0.5'') obtenidos con el instrumento NIRI en Gemini Norte con el fin de observar más detalladamente el ambiente circumestelar de G29. La emisión en la banda Ks hacia G29 presenta una morfología en forma de cono que apunta hacia el outflow molecular rojo. El objetivo de este trabajo es obtener un panorama lo más completo posible del YSO, de los procesos que generan la formación estelar, y del medio interestelar circundante. Estudios como este son de relevancia porque contribuyen a una comprensión integral de la formación de estrellas.

Abstract / We present a multi-wavelength study towards the young stellar object (YSO) G29.862–0.044 (hereafter G29), which is embedded in the massive star-forming region G29.96–0.02, located at a distance of about 6.5 kpc. The surrounding interstellar medium of G29 is studied using molecular lines data (angular resolution about 15'') obtained from the databases of the James Clerk Maxwell Telescope. The physical conditions of G29 molecular outflows and the clump where the YSO is embedded are characterized. Near-IR data is also analyzed (spatial resolution of about 0.5'') obtained with NIRI at Gemini North to have a detailed view of the circumstellar ambient of G29. The Ks emission towards G29 exhibits a cone-like feature pointing to the red molecular outflow. The aim of this work is to obtain a complete picture of this YSO, the related star-forming processes, and the interstellar medium around it. Studies like this are important because they contribute to a comprehensive understanding of star formation.

Keywords / ISM: clouds — jets and outflows — molecules

1. Introduction

Young stellar objects (YSOs) are usually found embedded in dense molecular clumps, environments with plenty of molecular gas and interstellar dust. The region G29.9–0.02 (see Fig. 1), located at the distance of 6.2 kpc, is very active in massive star formation. Figure 1 is a three-colour image displaying the Spitzer-IRAC 8 μm emission in red, the Herschel-PACS 70 μm emission in green, and in blue, the radio continuum emission at 20 cm as extracted from the New GPS of the Multi-Array Galactic Plane Imaging Survey (MAGPIS). The emissions were selected to highlight the borders of the photodissociation regions (PDRs) (displayed in the 8 μm emission), the distribution of the ionized gas (shown with the 20 cm emission) and the warm dust (70 μm emission). In a previous work we studied the $^{13}\text{CO}/\text{C}^{18}\text{O}$ abundance ratio throughout the whole region, in relation with these sources and with star-forming processes (Paron, Areal & Ortega, 2018). In the present work we focus on studying the southern massive YSO, cataloged as the Red MSX source G029.862–0.044 (hereafter G29).

2. Data

In order to perform a multispectral study of G29, we used public data (^{12}CO , ^{13}CO and C^{18}O J=3–2), and dedicated observations (near-IR data).

The data of the CO isotopes were obtained from public databases generated with observations of the 15-m James Clerk Maxwell Telescope. The ^{12}CO J=3–2 data belong to the COHRS survey (Dempsey et al., 2013), while the data of the other CO isotopes belong to the CHIMPS survey (Rigby et al., 2016).

The near-IR observations were carried out with the Near InfraRed Imager and Spectrometer (NIRI; Hodapp et al. 2003) at the Gemini-North 8.2-m telescope, on July 2017 in queue mode (Band-1 Program GN-2017B-Q25). NIRI was used with the f/6 camera that provides a plate scale of $0''.117 \text{ pix}^{-1}$ and a field of view of $120'' \times 120''$. The seeing of the Ks image presented here is about $0''.4$.

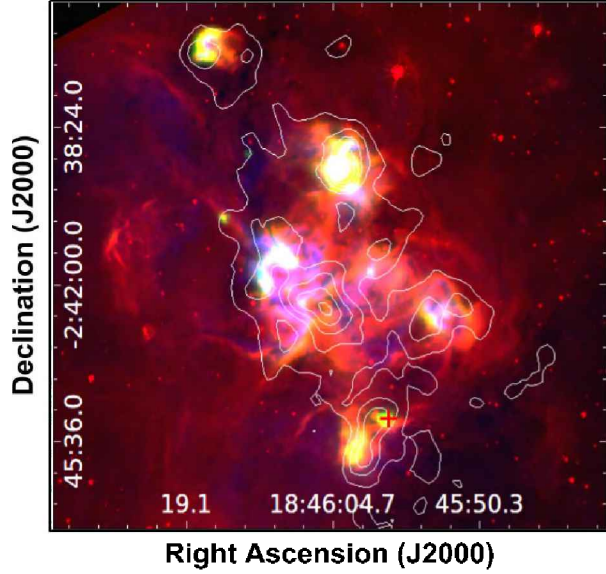


Figure 1: Three-colour image towards G29.96–0.02 displaying the Spitzer-IRAC $8 \mu\text{m}$ emission in red, the Herschel-PACS $70 \mu\text{m}$ emission in green, and the radio continuum emission at 20 cm, as extracted from the MAGPIS, in blue. Contours of the C^{18}O J=3–2 line integrated between 96 and 106 km s^{-1} with levels of 5, 11, 16, 22 and 27 K km s^{-1} are included. The YSO position is indicated with the red cross.

3. Results

3.1. Molecular cloud

To characterize the molecular cloud in which the YSO is embedded we used the C^{18}O J=3–2 emission, because it is an optically thin tracer of the molecular gas. The C^{18}O emission integrated between 96 and 106 km s^{-1} is presented in Fig. 2 showing the morphology of the molecular cloud associated with G29.

Assuming local thermodynamic equilibrium and using its typical formulae, the mass of the cloud was obtained. The H_2 column density, $N(\text{H}_2)$, was calculated from the C^{18}O column density and the conversion factor $X^{18} \sim 1.7 \times 10^{-7}$ (Wilson, 1999). The estimated mass is $M \sim 1 \times 10^4 M_{\odot}$.

3.2. Molecular outflow

The YSOs at the earliest stages of formation are characterized by the presence of molecular outflows. We used the ^{12}CO J=3–2 data to find the molecular outflows related to G29. We identified the presence of a red molecular outflow, but the blue molecular outflow could not be distinguished. This can be due to the presence of a dense concentration of cold dust southwards the YSO, AGAL G029.852–00.059 from Urquhart et al. (2014), that could hide the blue molecular outflow. Also the molecular gas related to the cold dust feature may confuse the observation of the gas associated with the blue outflow. This result is in agreement with that of Li et al. (2016), who studied the outflowing activity of G29 using the ^{12}CO J=1–0 line.

The ^{12}CO emission integrated between 108 and

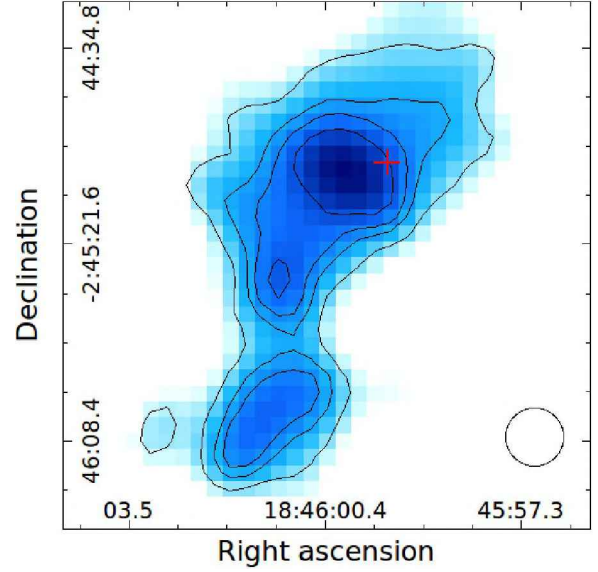


Figure 2: C^{18}O J=3–2 emission integrated between 96 and 106 km s^{-1} . The contour levels are 3, 5, 9 and 13 K km s^{-1} . The YSO position is indicated with the red cross and the beam is represented by the circle.

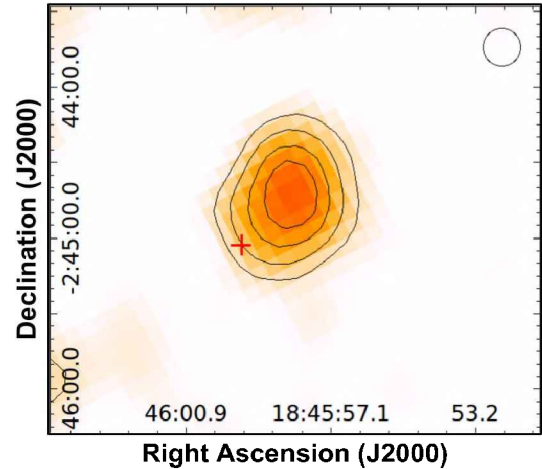


Figure 3: ^{12}CO J=3–2 emission integrated between 108 and 113 km s^{-1} . The contour levels are 7, 11, 14 and 18 K km s^{-1} . The YSO position is indicated with the red cross and the beam is represented by the circle.

113 km s^{-1} is presented in Fig. 3, which shows the morphology of the molecular outflow. We estimated the outflow physical parameters from the ^{12}CO emission, obtaining a mass of $M_{\text{red}} 82 M_{\odot}$ and an energy $E_{\text{krad}} \sim 2 \times 10^{46} \text{ erg}$. These are typical values of massive molecular outflows according to Maud et al. (2015).

3.3. Circumstellar ambient

With the aim of studying in more detail the YSO and its surroundings we performed near-infrared observations using NIRI at Gemini North. The J, H and Ks broad bands, and some narrow bands such as molecular hy-

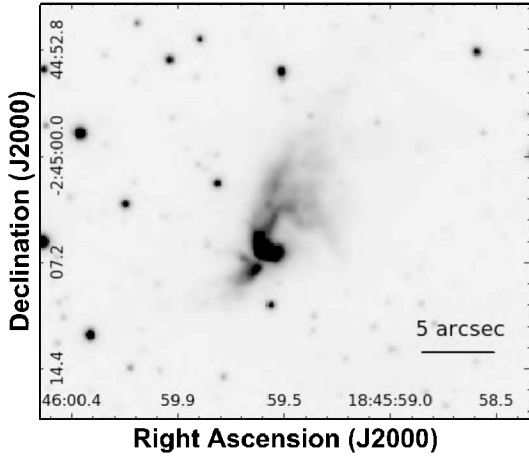


Figure 4: Ks emission obtained with NIRI-Gemini.

drogen lines, among others, were observed. In this work we present only the Ks emission (see Fig. 4).

The Ks emission towards G29, exhibits a cone-like feature pointing to the northwest in direction to the red molecular outflow. It can be seen that there are two arc-like features inside the cone-like structure, which is very similar to what was found towards massive young stellar objects characterized by the presence of precessing jets (Weigelt et al., 2006; Paron et al., 2013, 2016). Also in Fig. 4 it is observed a smaller structure towards the southwest, which may be generated by a jet extending to the opposite direction.

As proposed in previous works (see for example Weigelt et al. 2006), the near-IR emission at the Ks band

towards this kind of objects likely arises from a cavity cleared in the circumstellar material by the action of a jet, and may be due to a combination of different emitting processes: radiation from the central protostar that is reflected at the inner walls of the cavity, emission from warm dust, and emission of some lines that these bands contain. Further investigation is needed in order to determine such processes. We are currently analyzing in detail the near-IR data set (the JHKs broad-bands and specially the emission lines observed with the narrow-bands), which will provide valuable information about the origin and physical processes taking place in this intriguing structure.

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References

- Dempsey J.T., Thomas H.S., Currie M.J., 2013, *ApJS*, 209, 8
 Hodapp K.W., et al., 2003, *PASP*, 115, 1388
 Li F.C., et al., 2016, *AJ*, 152, 92
 Maud L.T., et al., 2015, *MNRAS*, 453, 645
 Paron S., Areal M.B., Ortega M.E., 2018, *A&A*, 617, A14
 Paron S., Fariña C., Ortega M.E., 2013, *A&A*, 559, L2
 Paron S., Fariña C., Ortega M.E., 2016, *A&A*, 593, A132
 Rigby A.J., et al., 2016, *MNRAS*, 456, 2885
 Urquhart J.S., et al., 2014, *A&A*, 568, A41
 Weigelt G., et al., 2006, *A&A*, 447, 655
 Wilson T.L., 1999, *Reports on Progress in Physics*, 62, 143