

Hidden Star Formation in High-Velocity Gas Clouds in Clump 2 near the Edge of the CMZ

Volker Tolls, Howard A. Smith and HIGGS Team

Smithsonian Astrophysical Observatory
60 Garden Street
Cambridge, MA 02478, U.S.A.
email: vtolls@cfa.harvard.edu

Abstract. We present a snapshot of our ongoing investigation of molecular clouds in Clump 2 located in the Galactic Bar region at a projected distance of ~ 400 pc from the Galactic Center. We show that the analysis of the Clump 2 molecular clouds is complicated because of many fore- and background clouds in the line of sight. Of all clouds, IGGC 22 is the most interesting one, showing very high dust column densities, significant high-J CO emission, and, potentially harbors star formations as eluded to by the detection of [OIII] emission.

Keywords. Galaxy: center, Galaxy: kinematics and dynamics, Galaxy: structure, ISM: clouds, ISM: kinematics and dynamics, stars: formation

1. Overview

The inner few hundred parsecs of the Galaxy are dominated by the Central Molecular Zone (CMZ) containing the densest concentration of gas and dust in the Galaxy (c.f. Stark 2004, Bally 2010, Molinari 2011, Etxaluze 2011, Kudo 2010) at the very center of which lies a massive black hole. Farther out from the center, to about 400 parsecs, is the region called Inner Galaxy (IG) whose dynamics are dominated by the gravitational potential of the Galactic Bar. Material that slowly falls from the outer parts of the Galaxy towards the CMZ encounters extreme physical conditions. Dust and molecular material form dense massive clouds, the so-called Inner Galactic Gas Clumps (IGGC, Martin 2010), but star-formation in them has been suppressed compared to other star-forming regions in the Galaxy. The Herschel Inner Galaxy Gas Survey (HIGGS) observed [CII], [NII], [OI], [OIII], and high-J CO emission lines in selected regions of IG Clump 2 with Herschel/HIFI; These data are complemented by Herschel PACS and SPIRE photometry, Spitzer Space Telescope IRAC and MIPS, APEX/ATLASGAL (Schuller 2009), and BOLOCAM data (Ginsburg 2013). We also have a large, new set of molecular line observations of the Clumps obtained with MOPRA and APEX, supplementing existing JCMT and AST/RO spectroscopy data sets.

2. Observations

Clump 2. Figure 1 shows a map of Clump 2 in CO J=3-2 (JCMT archival data). Overlaid are the HIGGS fields observed with Herschel HIFI and PACS. The sources IGGC 15, 18, 19, and 21 (their positions are listed in Table 1) form a ridge of clouds with $0 \text{ km s}^{-1} < v_{LSR} < 80 \text{ km s}^{-1}$ from the north east to the south west, while there is a second, almost perpendicular ridge on the northern edge of Clump 2 that ends with IGGC 16. Comparing the velocities with the model by Rodriguez-Fernandez 2008, these

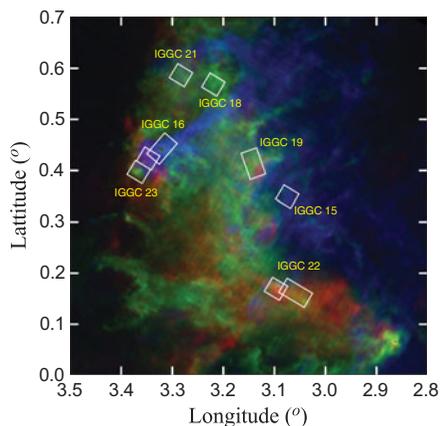


Figure 1: Clump 2: JCMT CO J=3-2.

Table 1. Clump 2 Sources and their positions as identified by AST/RO (Martin 2010) CO J=7-6 observations.

ID	l	b	v_{LSR} $km\ s^{-1}$
IGGC 15	3.073	0.348	25.0
IGGC 16	3.304	0.425	41.3
IGGC 17	3.277	0.613	44.7
IGGC 18	3.218	0.568	75.2
IGGC 19	3.160	0.400	83.2
IGGC 20	3.205	0.614	99.9
IGGC 21	3.282	0.587	102.6
IGGC 22	3.056	0.159	146.1
IGGC 23	3.353	0.394	147.5
IGGC 24	3.150	0.771	107.0

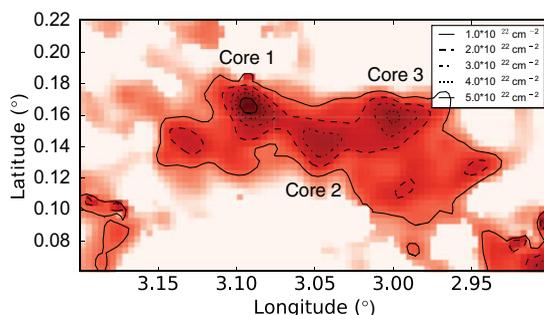


Figure 2: Column density map of IGGC 22. The map shows three distinctive peaks in the column density, Cores 1, 2, and 3.

clouds could be foreground clouds, possibly part of the near 4-kpc arm. The central area of Clump 2 with $3.1 < l < 3.4$ and $0.1 < b < 0.5$, including IGGC 23, harbors clouds primarily with $80\ km\ s^{-1} < v_{LSR} < 160\ km\ s^{-1}$, which could be located in the far 4-kpc arm, and the southern area clouds including IGGC 22 between $b = 0.1 - 0.2$ have $160\ km\ s^{-1} < v_{LSR} < 240\ km\ s^{-1}$, which are clouds in the Galactic Bar region.

IGGC 22. The largest dust column densities have been measured around IGGC 22. The map shown in 2 reveals denser 3 cores in IGGC 22, tagged with Core 1, 2, and 3. Upper limits for the masses of these cores are ~ 7500 , ~ 13500 , and $\sim 11400\ M_{\odot}$ for Core 1, 2, and 3, respectively. Core 1 is the most interesting densification because it is not only the area with the highest dust column density, but has also significant CO J=7-6 emission centered at the dust peak and to the south of the peak we detected [O III] emission. The analysis of these detections will be presented in an upcoming paper.

References

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