The Warm ISM in the Sgr A Region: Mid-J CO, Atomic Carbon, Ionized Atomic Carbon, and Ionized Nitrogen Line Observations with the Herschel-HIFI and NANTEN2/SMART Telescopes

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Figure 1-5 and 7. Spatial distribution of integrated intensity (in K km s⁻¹) of the observed CO (J = 2-1), 13CO (J = 2-1), 12CO (J = 1-0), and CO (J = 4-3) submillimeter lines. Each figure shows the integrated intensity in a 20 km s⁻¹ velocity interval. The black contours in each panel correspond to the 1, 2, 3, 4, 5, 10, and 20 K km s⁻¹ levels. The CO (J = 4-3) levels are in units of K km s⁻¹, and the 20 cm VLA continuum data shown in Figure 7. The CND is indicated by the arrow in Figure 8. The CND is the location of the gas in the Position-Velocity (PV) diagram at Galactic latitude b = -3.5°. The blue contour indicates the integrated emission shown by Figure 3.

Overview

The interstellar medium (ISM) in the few central hundred parsecs of the Milky Way has physical properties that differ strongly from the rest of the ISM in the Galaxy; violent motions in dense high-mass star clusters and the ISM around massive black holes, magnetic and radiation fields, and a rich chemistry make the Galactic Center (GC) of the Milky Way a unique testbed for studies of the ISM and star formation under such extreme conditions and a powerful tool in understanding the physical processes in the nuclei of other galaxies.

In order to study the warm ISM around the Sgr A Region in the GC, we observe Herschel-HIFI sub-mm atomic carbon ([CII] 1-0, -2P, and [CII] 2-1), ionized carbon ([CII] 13CO -2P, -2S, and [CII] 2-1), ionized nitrogen ([NII] -2P, -2S, and [NII] 2-1) line observations obtained within the frame of the Herschel Guaranteed Time HEXGAL (Herschel EXtragalactic key program (P.I. Rolf Güsten, MPIfR), and NANTEN2/SMART carbon monoxide (CO J = 4 - 3) line observations, as part of NANTEN2/SMART CMZ Survey (P.I Pablo García, I. Physikalisches Institut, Universität zu Köln).

Observations

The 3.3 m Herschel Satellite, with the onboard Heterodyne Instrument for the Far-Infrared (HIFI) [2], and the 4 m NANTEN2 telescope, with the 16 element Sub-Mm Array for Two Frequencies (SMART) were used to detect the sub-mm emission tracing the warm (~50 K) component of the ISM. In Table 1, all relevant parameters for the lines observed, and the equivalent energy transition, measured from the ground state, are shown.

Table 1: Summary information of the observed datasets. From left to right: telescope, spectral line, observed frequency, telescope, spectral line, observed frequency, telescope, spectral line, observed frequency, telescope, spectral line, observed frequency, telescope, spectral line, observed frequency.

Spatial and Velocity Distribution of the Sub-mm Emission

The spatial and LSR velocity distributions of the emission show large scale structures, with complex line shapes over a wide velocity range from -200 km s⁻¹ to +200 km s⁻¹. Figures 1 to 5 show the integrated intensity spatial distribution in each dataset for each panel. The position-velocity diagrams (PV diagrams) at Galactic latitude b = 0° in Figures 2 to 5 show the location of the gas in the Position-Velocity diagram (P-V diagram) at Galactic latitude b = 0° in Figures 2 to 5. The location of the gas in the Position-Velocity (PV) diagram coincides with the position of the Hul orbits, that appear to be the response of the gas to the barred gravitational potential of the Galactic Bulge [2]. The CO(1-0) observations of [3] show a stripey envelope in PV diagrams (see PV diagram at Galactic latitude b = 0° as example). The LSR velocities of this structure coincide with the ones of this source. The CNDs of this structure are much higher than any of the CNDs found in the line of sight, indicating physical conditions that differ strongly from the gas at other LSR velocities.

In order to identify the different physical conditions of the gas, spatially as well as spectrally, we calculate integrated intensity ratios (IIRs) using different integrations intervals Jv. In Figure 8, the velocity distribution of the IIRs for gas at high LSR velocities is shown as an example. In this case, we use a Jv = 1 km s⁻¹. The IIRs are defined by the ratio of the IIRs that extends from approximately +187 km s⁻¹ to +188 km s⁻¹ in LSR velocity. In the figure, only the most relevant IIRs channels are shown. The location of the gas in the Position-Velocity (PV) diagram coincides with the position of the Hul orbits, that appear to be the response of the gas to the barred gravitational potential of the Galactic Bulge [2]. The CO(1-0) observations of [3] show a stripey envelope in PV diagrams (see PV diagram at Galactic latitude b = 0° as example). The LSR velocities of this structure coincide with the ones of this source. The IIRs of this structure are much higher than any of the IIRs found along the line-of-sight, indicating physical conditions that differ strongly from the gas at other LSR velocities.