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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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Abstract. We present *Herschel*/HIFI sub-mm atomic carbon ([CI] $^3P_1 - {}^3P_0$ and [CI] $^3P_2 - {}^3P_1$), ionized carbon ([CII] $^2P_{3/2} - {}^2P_{1/2}$), and ionized nitrogen ([NII] $^3P_1 - {}^3P_0$) line observations obtained in the frame of the *Herschel* Guaranteed Time HEXGAL (Herschel EXtraGALactic) key program (P. I. Rolf Güsten, MPIfR), and NANTEN2/SMART carbon monoxide (CO($J = 4-3$)) observations of the warm gas around the Sgr A region. The spectrally resolved emission from all lines, and the corresponding line intensity ratios, show a very complex morphology. The determination of spatial and spectral (anti)correlation with known sources in the Sgr A region such as the Arched Filaments, NTF filaments, the Sickle, Quintuplet cluster, CND clouds, is ongoing work.

Keywords. Galaxy: center, ISM: clouds, submillimeter

1. Introduction

The interstellar medium (ISM) in the few central hundred parsecs of the Galaxy has physical properties that differ strongly from the rest of the ISM in the Galaxy: violent motions in dense high temperature gas, strong 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 comprehending the physical processes in the nuclei of galaxies. Observations of bright ISM cooling lines of tracers such as CO and CI will allow to shed new light on its physical parameters obtained through modeling (such as PDR models) of the observed line intensities.

2. Overview

The 3.3 m *Herschel* satellite, with the onboard Heterodyne Instrument for the Far-Infrared (HIFI) (Roelfsema *et al.* 2012), and the 4 m NANTEN2 telescope, with the 16 pixel Sub-Mm Array for Two Frequencies (SMART) were used to detect the sub-mm emission tracing the warm ($\sim$50 K) component of the ISM. The spatial and LSR velocity distributions of the emission show large scale structures and complex line shapes over a wide velocity range from -200 km s^{-1} to $+200$ km s^{-1}. In the following we describe the integrated emission spatial distribution for four characteristic radial velocities where known sources in the Galactic center are found. In all cases, a 10 km s^{-1} velocity width was used to create the integrated intensity maps.

First, the integrated emission centered at -78.5 km s^{-1} shows circular shape structure, south of the circumnuclear disk (CND, Yusef-Zadeh *et al.* 1984 and Requena-Torres *et al.* 2012) that can be seen in both [CI], CO $J = (4-3)$, and [CII] lines. The lack of [NII] emission at the same position indicates a PDR-like region (Abel *et al.* 2005). Second, the emission centered at -33.5 km s^{-1} shows very bright emission in the [CII] and [NII] lines with a ring-like structure matching the location of the known Arched Filaments, also seen in 20 cm continuum emission (Yusef-Zadeh *et al.* 1984). The ring-like structure is also seen in the lower frequency lines, but it is much weaker at that LSR velocity. Third, in the integrated emission centered at $+20.5$ km s^{-1}, the known "$+20$ km s^{-1} Cloud" can be clearly identified especially in CO $J = (4-3)$ with very bright and widespread emission. For the [CI] lines, a local intensity maximum can be seen close to the CO $J = (4-3)$, but the extension of the emission is much less than that of the CO $J = (4-3)$ line. The [NII] and [CII] emission does not correlate with the position of the source, but surrounds it. Fourth, the emission centered at $+56.5$ km s^{-1} shows the known "$+50$ km s^{-1} Cloud". It contains the brightest [CI] emission in both lines as within a "crescent-shape" structure, surrounding the CND. It is also seen in CO $J = (4-3)$ as the second brightest region on the map. The [CI] emission of the cloud wraps around the brightest VLA 20 cm continuum emission, while some bright [CII] spots fall inside the CND region.

A very distinctive feature shows up in the integrated intensity ratio (IIR) distribution (integrated over 1 km s^{-1} velocity width) of the [CI]$(1-0)$/CO $J = (4-3)$ ratios at high positive velocities. The IIR distribution shows a large arc-like structure that extends from approximately $+157$ km s^{-1} to $+188$ km s^{-1} in LSR velocity. The location of the gas in the position-velocity (PV) diagram coincides with the position of the x_1 and x_2 orbits that appear to be the response of the gas to the barred gravitational potential of the Galactic Bulge (Mezger *et al.* 1996). The CO $J = (1-0)$ observations of Oka *et al.* (1998) show a trapezoidal envelope in PV diagrams (see PV diagram at Galactic latitude $b = 0°$ as an example). The LSR velocities of this structure coincide with the ones of this feature. 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.

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