ISO-LWS OBSERVATIONS OF [OI] 63 μm IN ABSORPTION TOWARDS SGRB2

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Abstract

We present high spectral resolution observations of the high mass star formation region Sagittarius B2, with the *Long Wavelength Spectrometer* on board the ISO satellite in Fabry-Pérot mode. Previous grating observations of the [OI] 63 μm line in absorption against the high far-infrared continuum of the source were used to compute the minimum atomic oxygen column density along the line of sight. We have performed a more detailed analysis and interpret the observed [OI] 63 μm line absorption as due to the oxygen associated with both atomic hydrogen clouds and molecular clouds present on the line of sight. We found that HI clouds are responsible only for a fraction of this absorption and that the total atomic oxygen column density is around 1.1×10^{20} cm^{-2} compatible with the minimum column density of 10^{19} cm^{-2} computed in the grating mode.

1. Introduction

The star-forming region Sagittarius B2 is one of the largest HII/molecular cloud complexes in the Galaxy. At about 100 pc from the Galactic Centre, Sgr B2 is the most massive of an ensemble of dense cloud cores in the central (400-600 pc) region of the Galaxy. The brightest source at FIR wavelengths is the Middle source of the SgrB2 complex.

Many recent observations have suggested that in the interstellar medium, most of the gas-phase oxygen might be in atomic form. A first suggestion was made by Schulz et al. (1991) in order to interpret their HDO observations. From HST ultraviolet spectroscopy, Sofia et al. (1994) derived an oxygen abundance in two molecular clouds as high as 1/3 of the cosmic abundance of oxygen. On the other hand, recent observations of the [OI] 63 μm line in absorption towards three massive star forming regions, DR21 (Poglitsch et al. 1996), NGC6334V (Kraemer et al. 1998) and W49N (Vastel et al. 2000), revealed large O column densities between the sources and us and suggested that most of the oxygen is in the atomic form. Furthermore, Caux et al. (1999) reported the detection of the [OI] 63 and 145 μm lines in emission towards the molecular cloud L1689N and showed that in this cloud, oxygen is mainly in the atomic form. Furthermore, Baluteau et al. (1997) reported the detection of [OI] 63μm in absorption toward the main core of SgrB2. The data, based on grating spectra of the LWS-ISO instrument, provided a first estimate of the atomic oxygen content along the line of sight.

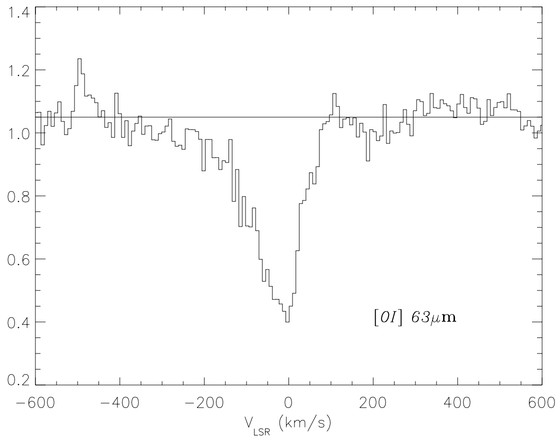

Figure 1. [OI] 63 μm line seen in absorption towards SgrB2. Units are 10^{-8} erg s^{-1} cm^{-2} μm^{-1}.

In this paper we present higher spectral resolution data of the atomic oxygen line in absorption at 63 μm taken with the LWS Fabry-Pérot and concentrate on the atomic and molecular content of the many different clouds along the line of sight.

2. The [OI] 63 μm line observations

We performed observations centred on the [OI] 63 μm line using the *Long Wavelength Spectrometer* instrument on board the ISO satellite in the Fabry-Pérot mode. These Fabry-Pérot observations using AOT LWS03 were carried out during revolution 504 with the 80″ beam centred at α_{2000}=17h47m21.75s, δ_{2000}=-28°23′14.1″. The ISO 80″ encompasses the M(iddle) component of dust emission.

Figure 1 presents the observed [OI] 63 μm line profile.

3. The Spiral Arm clouds

Individual absorbing clouds can be distinguished in the line of sight only if they have an unique radial velocity. For

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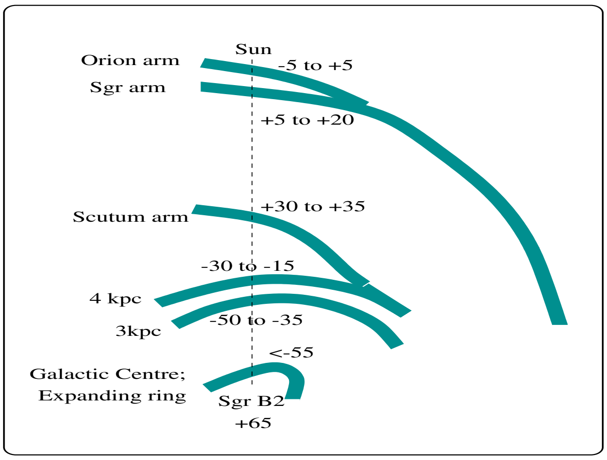

Figure 2. Schematic diagram of part of the Galactic Plane, showing the position of the background source, and proposed locations of the foreground clouds, with their associated velocities (from Greaves & Williams 1994).

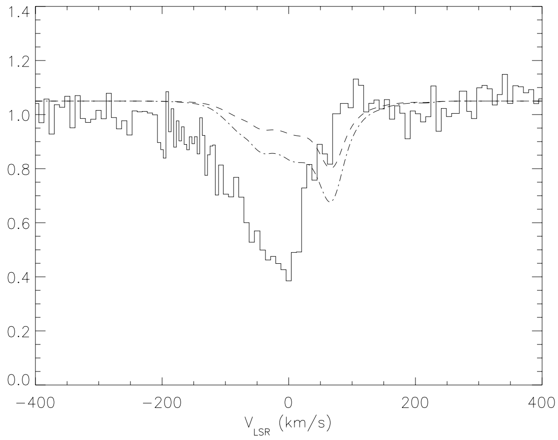

Figure 3. Predicted [OI] 63 μm absorption profile for HI spin temperatures of 50 K (dashed line) and 100 K (dot-dashed line) and plotted with the observed profile (histogram). The velocity is calculated in the Local Standard of Rest of the 63.184 μm line. It can be noticed that the absorption around 60 km s^{-1} will be compensated by the emission component of the source itself. Units are 10^{-8} erg s^{-1} cm^{-2} μm^{-1}.

lines of sight away from the galactic centre the distances to absorbing centres at different velocities can be calculated from the galactic rotation curve. When the line of sight is directly towards the galactic centre all gas should have a radial velocity of zero in a perfectly circular rotation curve. However, not all material in the galaxy rotates with perfectly circular orbits (Burton 1992). A schematic of known arms and bar features is shown in Fig. 2, together with the observed spiral cloud velocities.

3.1. The diffuse atomic components

HI 21cm observations in absorption of SgrB2 were taken by Garwood and Dickey (1989) with a spectral resolution of 2.58 km s^{-1}. The fitted Gaussian parameters for the main HI absorption components are listed in table 1. We computed the HI column densities with the standard relation:

$$N(HI) = 1.823 \times 10^{18} \times T_{spin} \times \int \tau(v)dv \quad (cm^{-2}) \quad (1)$$

where T_{spin} is the spin temperature. For absorbing clouds the range of temperatures is 30 - 80 K (Kulkarni & Heiles 1988) but has been found as high as 100 K in the local arm gas by Normandeau (1999). We will show results for spin temperatures equal to 50 K and 100 K.

The computed column densities of HI at each velocity can be converted into an atomic oxygen column density if the oxygen abundance in the gas phase is known. We used the galactocentric abundance determined by Afflerbach et al. (1997), as each component observed in HI is associated with a spiral arm of known galactic distance:

$$[O/H] = (-2.85 \pm 0.06) - (0.064 \pm 0.009)D_G \quad (kpc) \quad (2)$$

Assuming that in the absorbing region, all the oxygen atoms are in the ground state, the minimum column density of atomic oxygen is directly proportional to the optical depth (Spitzer 1978) through the relation:

$$N(OI) = \frac{g_l}{g_u}\frac{8\pi}{\lambda^3 A_{ul}}\tau\sqrt{\pi}\frac{FWHM}{2\sqrt{ln2}} \quad (3)$$

$$= 2.1 \times 10^{17} \times \tau \times FWHM \quad (cm^{-2}) \quad (4)$$

where g_i is the statistical weight of level i, A_{ul} = 8.46 × 10^{-5} s^{-1} (Baluja & Zeippen 1988) is the Einstein coefficient, λ = 63.184 μm and FWHM is the full width at half maximum in km s^{-1}. As we know the width of the HI lines, we can fit the absorption due to the diffuse clouds considering the atomic oxygen in the diffuse clouds and convolve the profile with the instrumental profile of the LWS-FP at 63 μm constructed in Vastel et al. (2000).

The total column density of atomic hydrogen from the diffuse clouds is, for a spin temperature of 50 K (100 K), 2.9 × 10^{22} cm^{-2} (5.8 × 10^{22} cm^{-2}). The total column density of atomic oxygen from the diffuse clouds is, for a spin temperature of 50 K (100 K), 7.1 × 10^{18} cm^{-2} (1.4 × 10^{19} cm^{-2}).

It can be seen in Figure 3 that only a small fraction of the observed [OI] absorption can be accounted for by the HI clouds even for a spin temperature of 100K as we are only interested in velocities lower than 60 km s^{-1}. This implies that most of the [OI] absorption is due to the cold molecular clouds and not to the diffuse ones.

3.2. The cold molecular components

Molecular observations of SgrB2 have been carried out in the 6 cm line of H_2CO by Mehringer et al. (1995). They used the VLA to obtain spectra with spectral resolution of

Table 1. Fitted Gaussians to the HI spectrum of Garwood and Dickey (1989) showing absorption components and their association with the galactic spiral arms. The distances to the galactic centre (D_{GC}) are then estimated. EMR is the Expanding Molecular Ring.

V_{LSR} ($km\,s^{-1}$)	τ	FWHM ($km\,s^{-1}$)	location	D_{GC} (kpc)	[O]/[H] (10^{-4})
-107.6	0.15	4.7	EMR	≤ 0.3	14
-81.7	0.18	19.8	EMR	≤ 0.3	14
-51.9	0.42	12.2	3kpc arm	3	9.3
-44.0	0.89	5.3	3kpc arm	3	9.3
-24.4	0.49	9.7	4kpc arm	4	7.8
0.0	1.91	13.3	Orion arm	8.5	3.2
15.7	1.17	5.1	Sgr arm	7.2	4.9
31.4	0.27	14.7	Scutum arm	5.5	6.3
52.8	0.83	7.8	Sgr B2	0.1	14
66.7	2.31	11.4	Sgr B2	0.1	14

Table 2. H_2CO components for the two sources in the LWS beam showing the radial velocities for each source, their linewidth, the H_2CO optical depth, the computed OI optical depths and column densities.

Line V_{LSR}	Source n^o	FWHM $km\ s^{-1}$	τ_{H_2CO}	τ_{OI}	N(OI) cm^{-2}
-104	15	10	0.11	5	$1.1\ 10^{19}$
-60	15	3	0.01	20	$1.3\ 10^{19}$
-46	15	2.3	0.053	20	
-41.2	14	2.0	0.14	20	$2.7\ 10^{19}$
-41.1	15	2.2	0.215	20	
-26.5	15	4.3	0.023	6	
-21.2	15	3.4	0.072	6	$9.9\ 10^{18}$
-18.8	14	4.1	0.290	6	
1.8	15	8.2	0.29	10	
4.0	14	12	0.10	10	$4.3\ 10^{19}$

1.5 km s^{-1} in the range -85 to +85 km s^{-1} and an angular resolution of 15″. Two of their sources (labelled 14 and 15) are included in the LWS beam of 80″ and their characteristics are listed in table 2. Assuming that the atomic oxygen absorption in the cold molecular component occurs in the same medium as the H_2CO, we can estimate that in each cloud the linewidth is the same for the two species. Combining the absorption due to the atomic clouds and that due to the molecular clouds, we can fit the absorption after convolution with the instrumental profiles, varying the OI optical depth in the different molecular clouds. Due to the large number of radial velocities found in the two sources, we matched similar velocities probably due to the same molecular cloud and attributed them a unique OI optical depth (see table 2). It was extremely difficult to parameterise clouds with velocities greater than 10 km s^{-1} because the emission from the SgrB2 region can compensate for the absorption due to these molecular clouds. Molecular observations in ^{13}CO, $C^{18}O$ and CS (Sato et al., 2000) of this region showed the large velocity width of the emission component at around 65 km s^{-1} probably affected by self-absorption. Therefore we concentrated on the molecular clouds with velocities lower than 10 km s^{-1} and computed the OI column densities using Equation 3.

The result for a combination of the molecular and diffuse clouds with T_{spin} = 50 K is shown in figure 4. The difference between the spin temperatures of 50 and 100 K will not affect the absorption at velocities lower than 10 km s^{-1} very much. The computed atomic oxygen column density in the molecular clouds in the line of sight to SgrB2 is $\sim 10^{20}$ cm^{-2}. The central source was fitted with an emission component but we do not present any results for the central HII region itself in this paper. We have only focused on the clouds present in the line of sight to SgrB2. The total column density of atomic oxygen in the line of sight is $\sim 1.1 \times 10^{20}$ cm^{-2}.

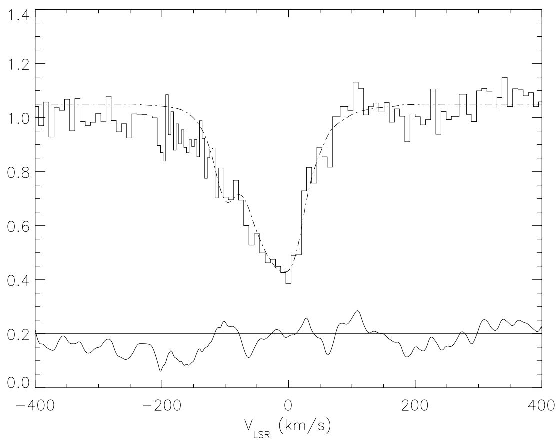

Figure 4. Observed absorption profile with the best fit for T_s = 50 K (dashed line) for atomic and molecular components. Residuals are also shown (solid line). Units are 10^{-8} erg s^{-1} cm^{-2} μm^{-1}.

4. Conclusion

- The atomic fine structure oxygen line at 63 μm has been observed towards SgrB2. It is found to be in absorption, due to clouds in the galactic spiral arms that cross the line of sight.

- The contribution to the observed absorption that is due to diffuse atomic clouds is calculated and is found to account for a small fraction of the total absorption. The remaining absorption is fitted by molecular clouds in the line of sight using H_2CO measurements.

- The total [OI] column density in the spiral arm clouds is estimated to be 1.1×10^{20} cm^{-2} in agreement with the lower limit of 10^{19} cm^{-2} computed in the grating mode by Baluteau et al. (1997).

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