Hydroxyl, water, ammonia, carbon monoxide and neutral carbon towards the Sgr A complex

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Abstract

We have studied the morphology, abundances and kinematics of different species towards the Sgr A complex and the line-of-sight spiral arm features. Strong OH absorption, H_2O emission and absorption lines were seen at all observed positions, and the $H_2^{18}O$ line was detected in absorption towards the +20 and +50 km s^{-1} clouds, the CND, the expanding molecular ring, and the 3-kpc arm. Strong CO, C^{18}O and neutral carbon C I emissions were seen towards the +20 and +50 km s^{-1} clouds. NH_3 was detected in weak absorption only originating in the line-of-sight spiral arm features.

The abundances of OH and H_2O indicate that shocks and star formation prevail in the +50 km s^{-1} cloud, and also in the CND where cloud collisions are frequent, and furthermore that the CND is subject to intense UV-radiation emanating from the supermassive black hole and the central star cluster. The CND is rich in H_2O and OH, and these abundances are considerably higher than those in the surrounding clouds. It is likely that PDR chemistry including grain surface reactions, and perhaps also the influences of shocks, has led to the observed abundances of the molecular species studied here. In the redward high-velocity line wings of both the +20 and +50 km s^{-1} clouds and the CND, the H_2O abundances are estimated to be similar to the water abundances in outflows of the Orion KL and DR21 molecular clouds, which are said to be caused by the combined action of shock desorption from icy grain mantles and high-temperature, gas-phase shock chemistry.

The compact H II region D, in the eastern part of the +50 km s^{-1} cloud, was observed in OH absorption at velocities between 32 and 59 km s^{-1}. In the C^{18}O $J = 2 - 1$ line it was observed at velocities between about 35 and 54 km s^{-1} with two velocity components, which may indicate a bipolar outflow in this region.

The basis for this poster is a paper that recently was published in Astronomy & Astrophysics, vol. 554, A141 (2013). The paper has Open Access status.

Observations

Spectral line observations of the Galactic Centre (GC) were performed by using two ground-based telescopes (VLA and SEST) and one telescope on board a satellite (Odin). Four molecules, hydroxyl (OH), water (H_2O), ammonia (NH_3), carbon monoxide (CO), and one atom, carbon (C I), were studied at certain energy transitions in molecular clouds within 15 pc (in projection) from Sgr A*, assuming a distance to the GC of 8 kpc. The rarer isotopologues of water ($H_2^{18}O$), and carbon monoxide ($^{12}C^{18}O$) were also observed in this region. The VLA was used to map OH absorption at 1665 and 1667 MHz, and the Odin satellite mapped the 557 GHz emission and absorption of H_2O, as well as absorption of the $H_2^{18}O$ line at 548 GHz and the NH_3 line at 572 GHz. The CO $J = 5 - 4$ line at 576 GHz, and the C I line at 492 GHz were observed in emission. Furthermore, the SEST was used to map a $4.5' \times 6'$ region of the Sgr A complex in the C^{18}O $J = 2 - 1$ line at 219.6 GHz. The observed positions include the +50 km s^{-1} cloud, the molecular belt, the CND, and the +20 km s^{-1} cloud. Parts of the expanding molecular ring (EMR), the line-of-sight spiral arm features: the Local/Sgr arm, the -30 km s^{-1} arm, and the 3-kpc arm were seen in the data, as well as the high negative velocity gas (HNVG). In Fig. 1 the positions observed by Odin are overlaid on our VLA map of the 18 cm continuum emission (Karlsson et al. in preparation), and numbered from 1 in NE, to 9 SSW of Sgr A*.

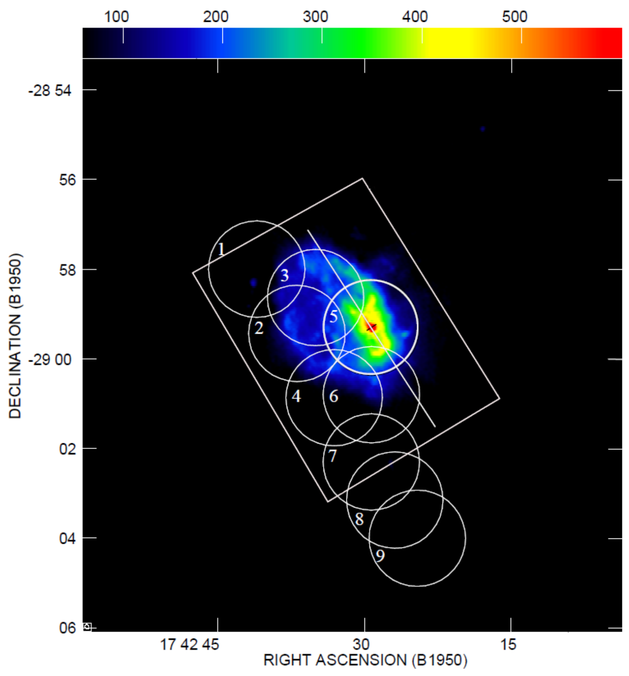

Fig. 1. VLA observations of the Sgr A complex at 18 cm continuum emission with a resolution of 7"x 5". Sgr A East is shown in blue and Sgr A West in yellow colour. The wedge scale is in mJy/beam. The numbered circles represent the positions and size of the Odin beam at 557 GHz. Positions 1, 5 and 7 are aiming at the +50 km s^{-1} cloud, Sgr A*/CND, and the +20 km s^{-1} cloud, respectively. The white rectangle delineates the area observed by SEST, the white diagonal line is parallell to the Galactic plane, and the red spot marks the position of Sgr A*.

References

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Results

The figures below represent an extract of some of the highlights in the paper. Furthermore, possible relations between the large clumps of C^{18}O emission, seen NE of Sgr A* (Fig. 3), the SNR (G359.92−0.09) and Sgr A East are discussed in the paper.

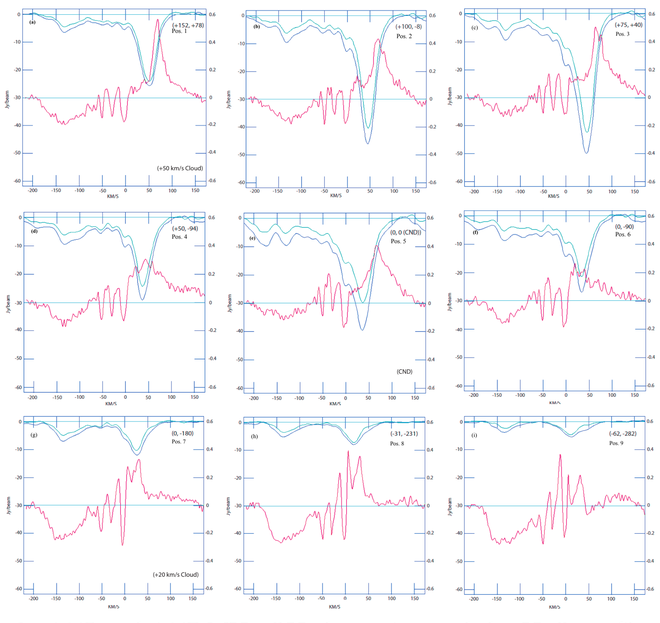

Fig. 2. 1665 and 1667 MHz OH absorption and the H_2O profiles towards the Sgr A complex. The upper (cyan) line profiles refer to the 1665 MHz OH line, and the lower (blue) absorption profiles belong to the 1667 MHz OH line. The (red) profiles in the middle of the diagrams are the H_2O profiles. The scale on the left side of the diagrams (0 to −60 Jy/beam) corresponds to the OH absorption, and the scale on the right side (±0.6 K) is the antenna temperature of the H_2O profiles. The equatorial offset coordinates in (arcsecs) from Sgr A* are given in the upper right corner in each figure. Our high resolution OH data have been convolved here with a 126" circular beam to resemble the angular resolution of the Odin H_2O data.

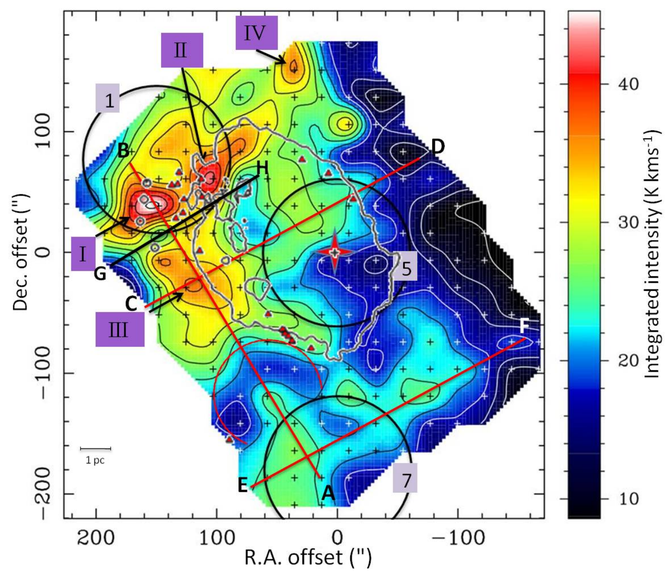

Fig. 3. Total integrated intensity (−200 to 200 km s^{-1}) of SEST C^{18}O $J = 2-1$ antenna temperature towards the Sgr A complex. Sgr A* is marked with a red star, and the large black circles mark the main positions of the +50 km s^{-1} cloud (1), the CND (5), and the +20 km s^{-1} cloud (7). The grey contour line delineates the Sgr A East 18 cm continuum emission at 150 mJy/beam. The small circles indicate the positions of the four compact H II regions (Ekers et al. 1983). The red triangles indicate positions of 1720 MHz OH SNR masers (Yusef-Zadeh et al. 1996, 2001; Karlsson et al. 2003; Sjouwerman & Pihlström 2008). The red arc line indicates the expanding shell associated with the SNR (G359.92−0.09). Offsets in the map are in arcseconds in the equatorial coordinate system, and relative to the position of Sgr A*. The HPBW is 24".

Table 1. Molecular abundance comparisons

Region in Sgr A (Abs. feature)	X(OH) ($\times 10^{-6}$)	X(o-H_2O) ($\times 10^{-9}$)	X(o-NH_3) ($\times 10^{-9}$)
+50 km s^{-1}	8	40	–
+50 km s^{-1} red wing	–	>1000	–
CND	35	70	–
CND red wing	–	>5700	–
+20 km s^{-1}	13	20	–
+20 km s^{-1} red wing	–	>800	–
Local/Sgr arm	2	–	3
−30 km s^{-1} arm	6	30	5
3-kpc arm	4	–	3

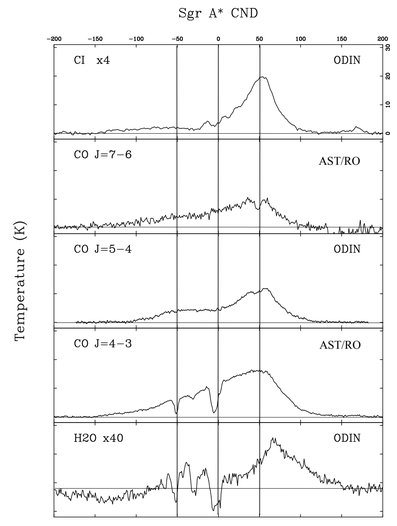

Fig. 4. Odin C I, CO $J = 5 - 4$ and H_2O profiles towards the CND. The H_2O zero-line is nominally drawn at the 8 K level. Note that the H_2O and C I intensities have been multiplied by factors of 40 and 4, respectively. Odin-beam-smoothed ground-based observations with the Antarctic Submillimetre Telescope and Remote Observatory (AST/RO) of the $J = 4 - 3$ and $J = 7 - 6$ transitions of CO (Martin et al. 2004), are included for comparison. The velocity scale (−200 to 200 km s^{-1}) is shown on top of the diagram, and the temperature scale (−2 to 31 K) is on the top right side of the diagram.

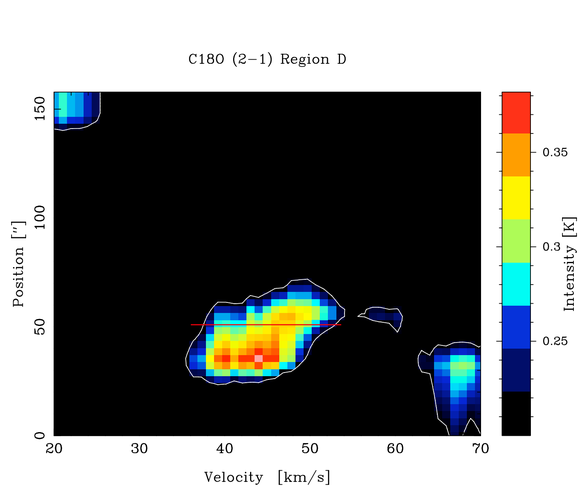

Fig. 5. Position-velocity cut of C^{18}O $J = 2 - 1$ emission through the position of the compact H II region D (Ekers et al. 1983), along the line G - H in Fig.3. The red line indicates the position of the compact H II region D , with reference to point G in Fig. 3. Two velocity components can be seen in the figure between about 35 and 54 km s^{-1}. To reduce the emission from the surrounding molecular belt, we have subtracted the average of the C^{18}O emission cuts NE and SW of the source from the cut shown in Fig. 3.

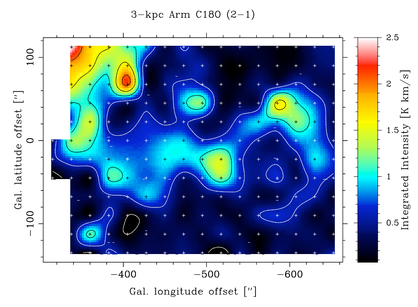

Fig. 6. (l, b) diagram of the C^{18}O $J = 2 - 1$ integrated emission of the line-of-sight 3-kpc arm at −60 to − 45 km s^{-1}. The structure is clumpy, and an 80" wide horse-shoe like cavity is seen in the figure. The lowest integrated intensity contour level is $\sim 3\sigma$. The offsets (in arcseconds) are in the Galactic coordinate system and are relative to the position (l, b) = (+5′,−3′). Sgr A* is located at (-500", 14").