Sgr A West in the light of molecules: cold and dense gas east of the circumnuclear disk

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Abstract. We present the very first detection of $N_2H^+$ $J = (1 - 0)$ and CH$_3$OH($2_k-1_k$) line emission on $5''$ scales in the circumnuclear disk (CND) around Sgr A*. The emission matches the position and shape of the dark clouds in the near-infrared. Our findings suggest that these molecular clouds in the eastern CND are significantly colder and denser than the rest of the CND, and partially shocked. The research on these dark clouds will contribute to understanding the processes of star formation close to a supermassive black hole.

Keywords. molecular data, ISM: clouds, ISM: molecules, Galaxy: center, Galaxy: nucleus

1. Introduction

The Galactic center is a unique laboratory to investigate the complex physical processes taking place in the vicinity of a supermassive black hole (Sgr A*), i.e. the matter transport to the center and star formation in such a violent environment. We have detected $N_2H^+$ $J = (1 - 0)$ and CH$_3$OH ($2_k-1_k$) (96 GHz) line emission in the circumnuclear disk (CND). The observations have been conducted with the Combined Array for Research in Millimeter-wave Astronomy (CARMA) in continuum mode around 95 GHz. The data comprise also the emission of H$^{13}$CO$^+$ $J = (1 - 0)$, SiO $J = (2 - 1)$, HCN $J = (1 - 0)$ and HNC $J = (1 - 0)$.

2. Results

The emission of $N_2H^+$ and CH$_3$OH mimics the distribution of the H$_2$CO emission (Martín et al. 2012) and of the dark clouds in the near-infrared (Figure 1): It is strong in the northeast arm (A, B) and the region (C) east of the southern extension (nomenclature as in Martín et al. 2012) and faint in the central ring outlined by the SiO. In cold, dark clouds, the $N_2H^+$ abundance is high when its main destroyer CO is depleted by freezeout onto dust grains (T = 20 - 25 K, Vasyunina et al. 2011, and references therein). Indeed, the $N_2H^+$/H$^{13}$CO$^+$ line ratio in A, B and C is about 5, which is exceptionally high compared to the rest of the CND (< 1), indicating the presence of cold, dense gas (Sanhueza et al. 2012). This is further supported by a HNC/HCN line ratio > 0.3 in these regions, which is higher than that of the CND (< 0.2): HNC may be preferentially formed in cold environments (T < 24 K, Hirota et al. 1998).
**Figure 1.** N$_2$H$^+$ (black) and CH$_3$OH (grey dashed) in contours of 3, 6, 9, 12, 18, 24, 30 (, 36 for CH$_3$OH) Jy beam$^{-1}$ km s$^{-1}$ with a beam size of 9.5$''$ x 5.0$''$. Both are overlayed on our SiO $J=(2-1)$ map in greyscale (left) and on an Hubble NICMOS 1.87 $\mu$m image (right, MAST/STScI - GC Fao survey).

H$_2$CO and CH$_3$OH are efficiently formed on dust grains (Shalabiea & Greenberg 1994, Watanabe & Kouchi 2002), which explains the coincidence of their distribution. The presence of these species in the the vicinity of the strong UV radiation from the nuclear stellar cluster (Martín et al. 2012, Yusef-Zadeh et al. 2013, and references therein) suggests self-shielding of the clumps. N$_2$H$^+$/CH$_3$OH line ratios in clumps A and B are higher ($\sim 2.5$) than in C ($\sim 0.8$) indicating different conditions. Shocks are the best explanation for this increased release into the gas-phase: the CH$_3$OH (and H$_2$CO) emitting regions A and C are also traced by SiO (Figure 1). The likely origin of the shocks is the expanding shell of Sgr A East interacting with the 50 km s$^{-1}$ GMC and compressing the gas (e.g., Martín et al. 2012). This is supported by the clumps’ velocities of $\sim 50$ km s$^{-1}$. A detailed discussion of the full data set will be published in Moser et al. (2014; in prep.).

3. Conclusions

We have obtained unprecedented maps of N$_2$H$^+$ and CH$_3$OH emission in the CND. We suggest that the molecular gas in the northeast arm (A, B) and the region (C) east of the southern extension is significantly colder and denser than the rest of the CND and partially shocked. Such dark clouds are likely sites of pre-stellar cores (e.g., Sanhueza et al. 2012). In the context of research on star formation in the immediate vicinity ($\sim 2$ pc) of the supermassive black hole, these regions deserve further investigation.

**References**