The Galactic Center: Feeding and Feedback in a Normal Galactic Nucleus
Proceedings IAU Symposium No. 303, 2013
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doi:10.1017/S1743921314000222

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 $CH_3OH(2_k\text{-}1_k)$ 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_3OH $(2_k\text{-}1_k)$ (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_3OH mimics the distribution of the H_2CO 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).

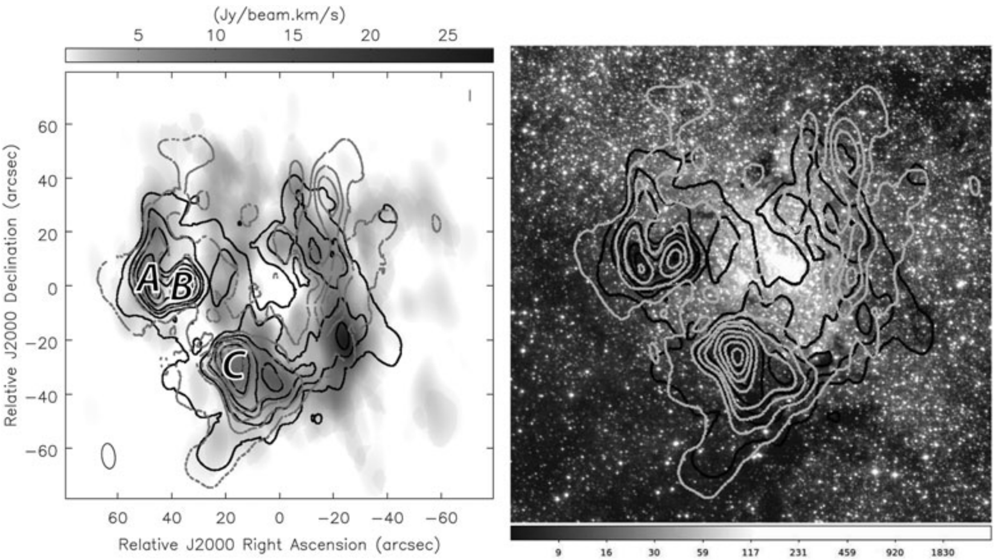

Figure 1. N_2H^+ (black) and CH_3OH (grey dashed) in contours of 3, 6, 9, 12, 18, 24, 30 (, 36 for CH_3OH) Jy beam^{-1} km s^{-1} with a beam size of 9.5″ x 5.0″. Both are overlayed on our SiO $J = (2-1)$ map in greyscale (**left**) and on an *Hubble* NICMOS 1.87 μm image (**right**, MAST/STScI - GC Paα survey).

H_2CO and CH_3OH 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_2H^+/CH_3OH line ratios in clumps A and B are higher (~ 2.5) than in C (~ 0.8) indicating different conditions. Shocks are the best explanation for this increased release into the gas-phase: the CH_3OH (and H_2CO) 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 ~ 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_2H^+ and CH_3OH 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 (~ 2 pc) of the supermassive black hole, these regions deserve further investigation.

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