Molecular Chemistry in the Central Molecular Zone

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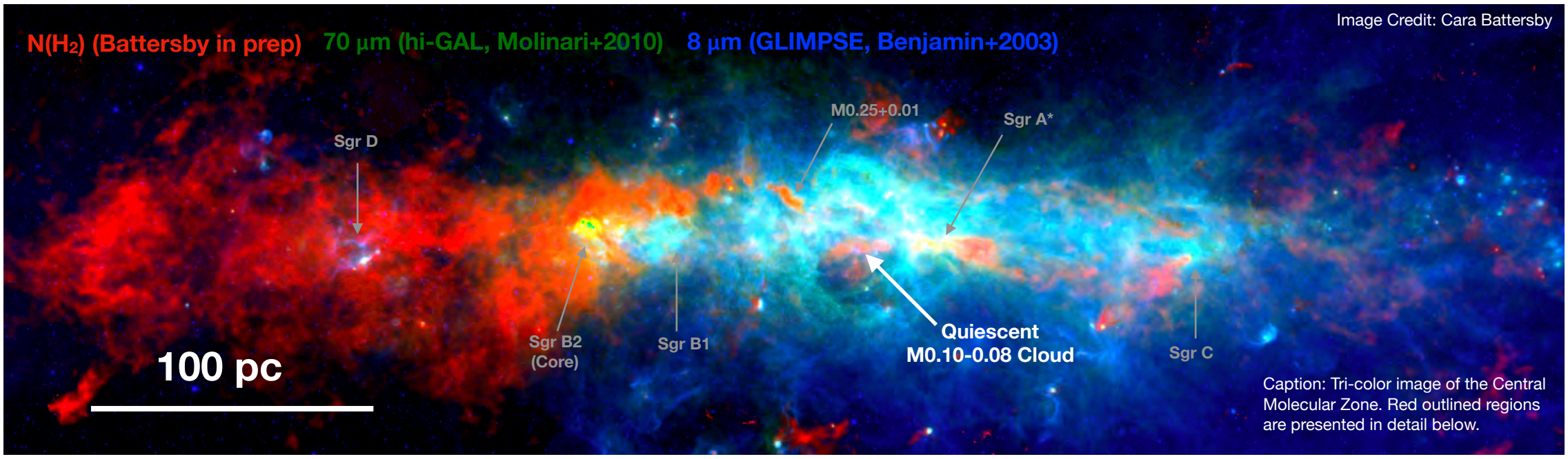
GREEN BANK OBSERVATORY



Wide-Spread Molecular Enrichment

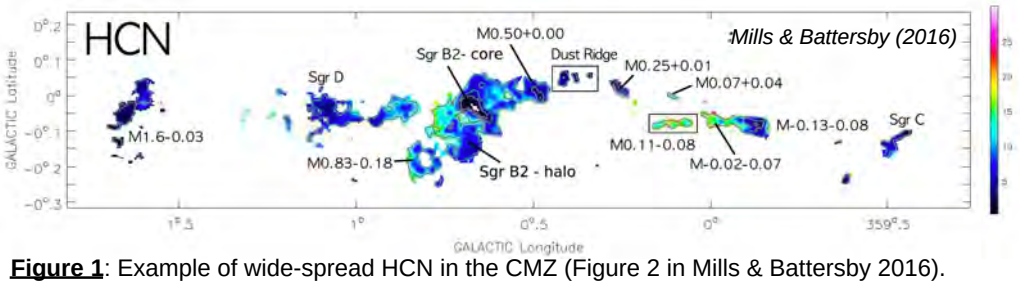


Figure 1: Example of wide-spread HCN in the CMZ (Figure 2 in Mills & Battersby 2016).

The Central Molecular Zone (CMZ) is known to be molecularly enriched compared to the Disk ISM. Many molecules that are typically only detected in star forming regions of the Galactic Disk, are commonly found in the Galactic Center CMZ (e.g., NH_3, HCN). However the cause of this wide-spread enrichment is not well understood.

3 mm ALMA Observations

M0.10-0.08 Cloud

The targeted cloud is located ~25 pc in projection of SgrA*. The cloud is relatively compact (~3 pc) and quiescent, showing no signs of current star formation (i.e., no radio continuum; Butterfield et al. 2018).

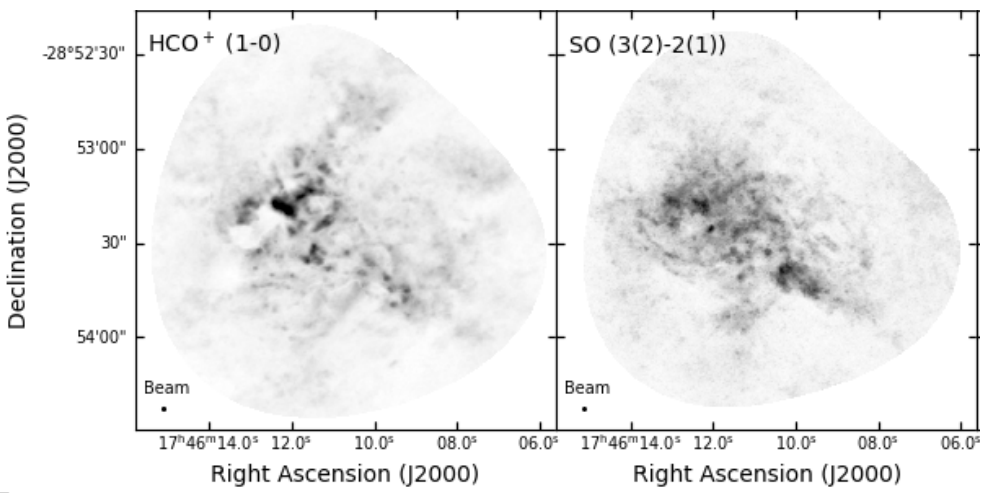
Observations

We obtained high spatial (<1"; 0.04 pc) and spectral (0.5 km/s) resolution ALMA observations. The observations achieved high sensitivity (2 mJy/beam/channel) and targeted 13 spectral lines (see Table 1). The list of targeted lines includes dense gas tracers (HCN), shock tracers (SiO) and isotopologues ($H^{13}CN$).

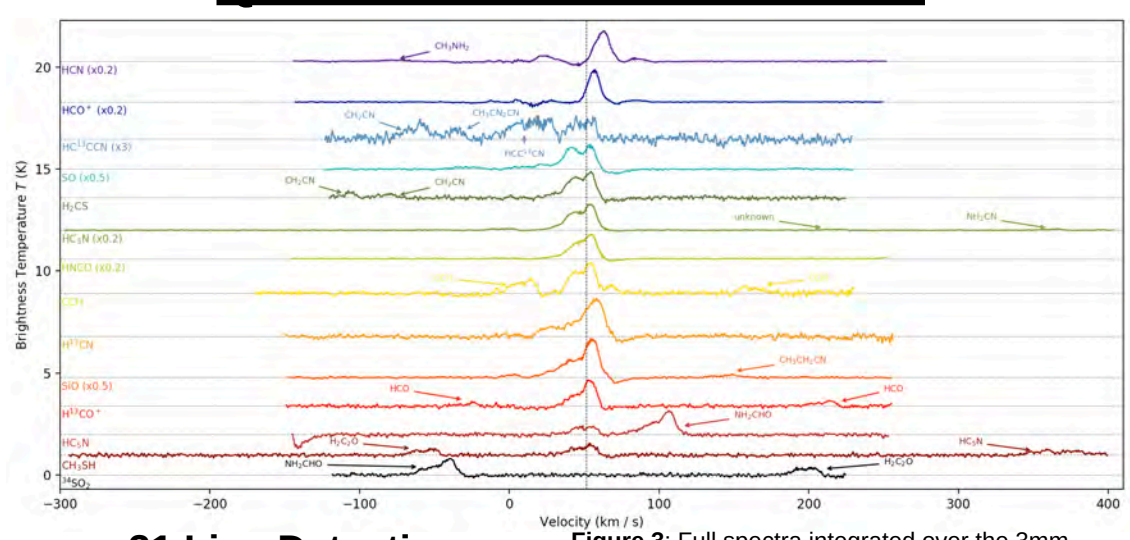
Molecular Transition	Rest Frequency (GHz)
$H^{13}CN$ (J=1−0)	86.3399214
$H^{13}CO^+$ (J=1−40)	86.7542884
SiO (J=2-1)	86.8469600
C_2H (J=3/2-1/2, F=2-1)	87.3169250
HC_5N (J=33−32)	87.8639156
HNCO (J=4(0,4)−3(0,3))	87.9252370
HCN (J=1−0)	88.6318470
HCO^+ (J=1−0)	89.1885247
SO $^3\sum$v=0 (3(2)−2(1))	99.2998700
$HC^{13}CCN$ (J=11−10)	99.6518490
HC_3N (J=11−10)	100.0763920
CH_3SH (J=4−3)	101.1391600
H_2CS (J=3(1,3)−2(1,2))	101.4776200
$^{34}SO_2$ (3(1,3)-2(0,2))	102.0318784

Table 1: List of targeted spectral lines. All above lines were detected except $^{34}SO_2$.

Figure 2: 3 mm ALMA data of the HCO^+ and SO line detections showing the high angular resolution and large dynamic range of these observations.



Numerous Molecules Detected in the Quiescent M0.10-0.08 Cloud



31 Line Detections

We detect 21 unique molecular species (31 line detections; Table 2):

- $HCC^{13}CN$
- $HC^{13}CCN$
- CH_3CH_2CN
- NH_2CHO
- NH_2CN
- CH_2CN
- CH_3CN_2
- HNCO
- SiO
- SO
- HCO
- HC_5N
- HC_3N
- C_2H
- H_2CS
- H_2C_2O
- HCN
- HCO^+
- $H^{13}CN$
- $H^{13}CO^+$
- CH_3SH

Many of these species have only been previously detected in the star forming complex: Sgr B2. However their presence in a quiescent CMZ cloud, could mean these exotic species form well-before the onset of star formation. Further, these exotic molecules could also be wide-spread across CMZ clouds.

Butterfield et al. 2020 (in prep)

Figure 3: Full spectra integrated over the 3mm continuum peak. Annotated are additional line detections.

Molecular Transition[a]	Rest Frequency (GHz)	Name
$H^{13}CN$ (J=1−0)	86.33992140	Hydrogen Cyanide, isotopologue
HCO 1(0,1)-0(0,0) J=3/2-1/2, F=1-0	86.70836000	Formyl Radical
$H^{13}CO^+$ (J=1−0)	86.75428840	Formylium, isotopologue
HCO 1(0,1)-0(0,0) J=1/2-1/2, F=1-1	86.77746000	Formyl Radical
CH_3CH_2CN (10(1,10)−9(1,9))	86.81984500	Ethyl Cyanide
SiO (J=2−1)	86.84696000	Silicon Monoxide
C_2H (N=1-0, J=3/2-1/2, F=1-1)	87.28415600	Ethynyl
C_2H (N=1-0, J=3/2-1/2, F=2-1)	87.31692500	Ethynyl
C_2H (N=1-0, J=3/2-1/2, F=1-0)	87.32862400	Ethynyl
NH_2CHO (4(1,3)−3(1,2))	87.84891480	Formamide
HC_5N (33−32)	87.86391560	Cyanobutadiyne
HNCO (J=4(0,4)−3(0,3))	87.92523700	Isocyanic Acid
HCN (J=1−0)	88.63184700	Hydrogen Cyanide
CH_3NH_2 (2−1)[b]	~88.668	Methylamine
HCO^+ (J=1−0)	89.18852470	Formylium
SO $3\sum$v=0 (3(2)−2(1))	99.29987000	Sulfur Monoxide
$HC^{13}CCN$ (J=11−10)	99.65184900	Cyanoacetylene, isotopologue
$HCC^{13}CN$ (J=11−10)	99.66146740	Cyanoacetylene, isotopologue
CH_3CH_2CN (11(2,9)−10(2,8))	99.68146100	Ethyl Cyanide
CH_2CN (5(1,5)−4(1,4) J=11/2-9/2)	99.68929440	Cyanomethyl
NH_2CN (5(0,5)−4(0,4))	99.97266400	Cyanamide
Unknown[c]	~100.0191	....
HC_3N (J=11−10)	100.07639200	Cyanoacetylene
H_2C_2O (5(0,5)−4(0,4))	101.03663000	Ketene
CH_3SH (4(0)−3(0) A)	101.13916000	Methyl Mercaptan
HC_5N (38−37)	101.17512710	Cyanobutadiyne
H_2CS (J=3(1,3)−2(1,2))	101.47762000	Thioformaldehyde
CH_2CN (5(1,4)−4(1,3), J=9/2-7/2)	101.52315320	Cyanomethyl
CH_2CN (5(1,4)−4(1,3), J=11/2-9/2)	101.53197390	Cyanomethyl
H_2C_2O (5(1,4)−4(1,3))	101.98142900	Ketene
NH_2CHO (5(1,5)−4(1,4))	102.06438020	Formamide

Table 2: Full list of all line detections with targeted lines listed in Bold.

Potential for Argus144 in CMZ Studies

The fast survey speeds and high sensitivity of the Argus144 instrument would allow for us to determine if these exotic 3 mm molecules (e.g., H_2C_2O) are widespread throughout CMZ clouds. Further, the advanced capabilities and multiple pixels of the Argus144 receiver would allow for quick mapping time to achieve the sensitivity needed to detect these molecules (~2 mJy/beam).

Argus Instrument