

Unveiling the Central Molecular Zone with Mopra

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Met the telescope!

Mopra
22m MM-Wave
Telescope
Coonabarabran,
NSW
Australia

UNSW-MOPS:
8 GHz bandwidth
spectrometer
Receivers: 100 + 40 +
25 GHz bands



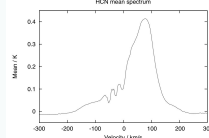
CMZ vs. GMC Characteristics

Characteristic	CMZ	GMC
Denser	$n \sim 10^4 \text{ cm}^{-3}$	$n \sim 10^2 \text{ cm}^{-3}$
Warmer	$60\text{K} < T < 120\text{K}$	$10\text{K} < T < 20\text{K}$
More Turbulent	$\Delta V \sim 10\text{--}20 \text{ km/s}$	$\Delta V \sim 5 \text{ km/s}$
Organic Species	Widespread	In HMCs only

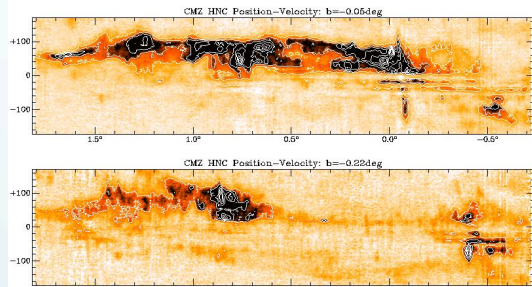
Observations

Molecular Lines Mapped in the CMZ	
3mm Band: 85-93 GHz	
C ₂ H ₂	85.34
CH ₃ CCH	85.46
HOCO ⁺	85.53
SO	86.09
H ¹³ CN	86.34
H ¹³ CO ⁺	86.75
SiO	86.85
HN ¹³ C	87.09
CCH	87.32
HCN	87.40
HNCO	87.93
HCO ⁺	88.63
HNC	89.18
HNC	90.66
HC ₃ N	90.98
CH ₃ CN	91.99
¹³ CS	92.49
N ₂ H ⁺	93.17

On-the-Fly-mapping
2.5° x 0.6° with 400 x 5' grids
35" + 1 km/s resolution
7 weeks over 3 seasons
18 molecular + 2 hydrogen lines
T_A ~40-80 mK per channel
More data in the cubes available!
The 7mm survey has another ~20
molecules and the 12mm one about 15!



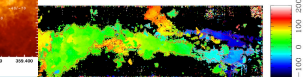
Galactic Longitude
Complex Dynamics +
Some Foreground Absorption
by Spiral Arms
Check P-V diagrams below



Rotating Disk

Herschel:
Dust column density +
CS velocity ranges

Mopra:
N₂H⁺ Peak Velocity

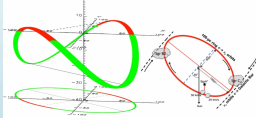


S. Molinari et al. 2011 ApJ 735 L33

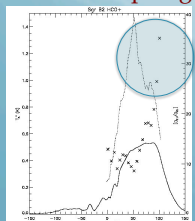
Coherent velocity structure along ~10°
M_⊙ twisted molecular ring.

V_{rot} ~ 80 km/s, r~100x60 pc

Rotating ring, tracing the stable, non-intersecting x₂ orbits??



Optical Depth Corrections and [¹²C/¹³C] Isotopologue Variations



Signatures of infall of more nuclear-processed gas into the Galactic centre??

[HCO⁺/H¹³CO⁺]_{max}

> [12C/13C] ~ 24

at large positive velocities

... Line

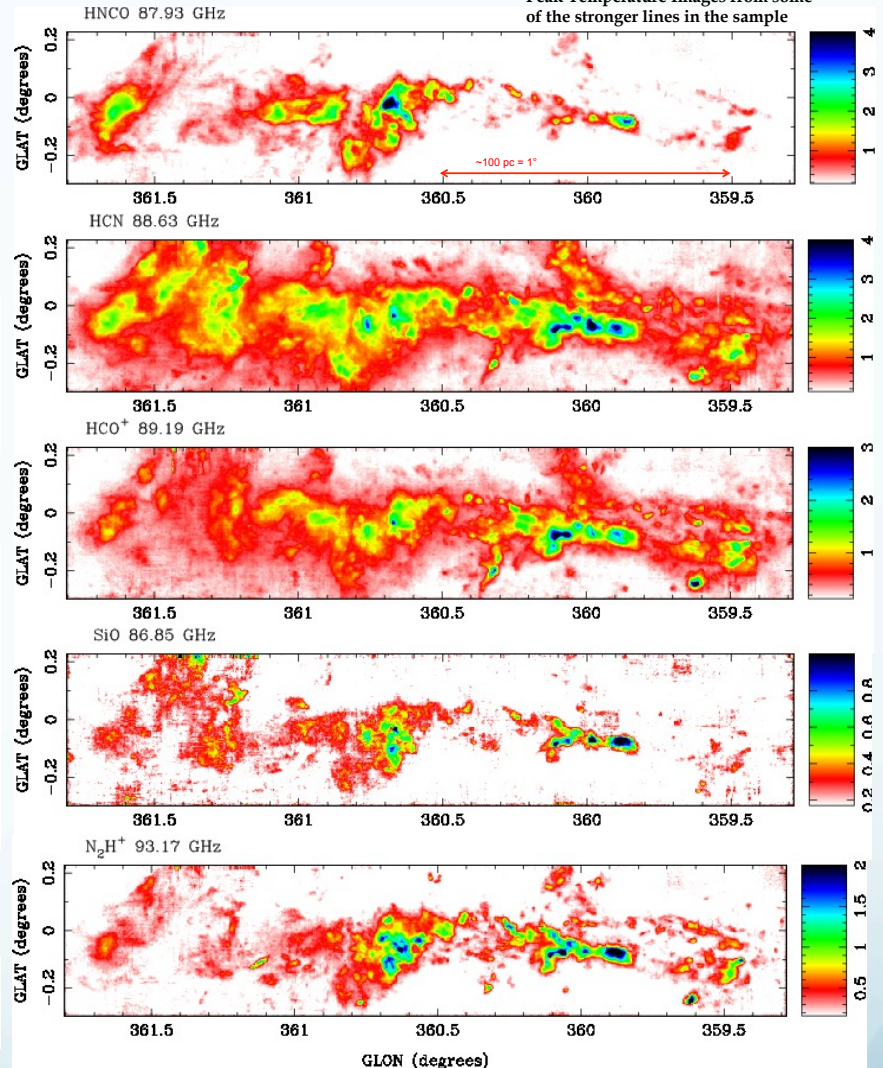
... Line (tau corrected)

xxx: Isotopologue ratio

Abstract. We have mapped a 2.5°x 0.5° region of the center of the Galaxy using the Mopra radio telescope in 18 molecular lines emitting from 85 to 93 GHz. This incorporates most of the region known as the Central Molecular Zone (CMZ). The molecular maps have 40 arcsec spatial resolution and 2 km s⁻¹ spectral resolution, with emission extending to velocities of 220 km s⁻¹. Line profiles are both very wide and complex, and do vary considerably across the CMZ. The analysis of the data has started with three different topics: To quantify the overall emission morphology, and its variation between molecules, we conducted a principal component analysis (PCA) of the integrated emission from 8 brightest species. We have selected apertures around the bright dust cores, as well as for the total region mapped, in order to study line ratio variations and to calculate optical depths so that column densities and molecule masses may be determined. We have studied the line luminosities, relative to that of CO. The luminosities are also typically 0.1-10 percent of the corresponding values that have been measured in other galaxies. The full data set, comprising the data cubes for the 20 emission lines, is publicly available for further analysis.

The Central Molecular Zone

Peak Temperature Images from some of the stronger lines in the sample



Molecular Masses

	HCN	HCO ⁺	HNC	Fraction
CMZ	29	9	11	100%
Sgr A	4	0.8	0.6	11%
Sgr B2	5	1	2	14%
Sgr C	2	0.4	1.5	8%
GL3	3	0.7	1	10%

Half the gas spread over CMZ, half in the principal dust cores. Total Molecular Mass in CMZ ~ 5 x 10⁷ M_⊙ from CO

Line Luminosities

	CO	HCN	HCO ⁺	HNC
CMZ	2 x 10 ⁷	2 x 10 ⁵	1 x 10 ⁵	6 x 10 ⁴
Ratio with CO	1.0	0.1	0.06	0.03

Star Forming Galaxies: L_{CO} ~ 5 x 10⁸ - 2 x 10¹⁰ K km/s pc²

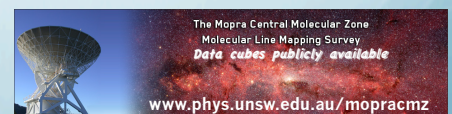
(Gao & Solomon 2004) L_{HCN}/L_{CO} ~ 0.03 - 0.2

L_{HCO+}/L_{HCN} ~ 0.5 - 1.6

• CMZ Line Ratios at lower end of Starburst range (availability of dense gas?)

• CMZ Line Luminosity orders of magnitude smaller

For more information



Sgr B2 3mm (82-114 GHz) Jones et al. 2008
Sgr B2 7mm (30-50 GHz) Jones et al. 2011
CMZ 3mm (85-93 GHz) Jones et al. 2012
CMZ 7mm (42-50 GHz) Jones et al. 2013
CMZ 12mm (HOPS - 20-28 GHz) Walsh et al. 2011, Purcell et al. 2012
CMZ CO (J=1-0 Lines) Observations need reducing - collaborators welcome!!