

Scientific Justification

The high mass star forming region Sgr B2(N) is perhaps the most molecule-rich interstellar environment observable within our Galaxy. For this reason among others, it has received much observational attention by the astrochemistry community. Of all the molecules detected in astronomical environments, more than half have been detected toward SgrB2(N) first. Various complex molecules, including but not limited to CH_3OH , $\text{CH}_3\text{CH}_2\text{CN}$, CH_2CHCN , CH_3CN , CH_3OCHO , CH_3COOH and HCOOH , (Remijan et al., 2002; Snyder et al., 2002; Liu and Snyder, 1999; Liu et al., 2001; Pei et al., 2000; Friedel et al., 2004) have been detected by single dish observations and imaged by millimeter interferometers, mostly at low spatial and spectral resolution. Yet, relatively few molecules have been imaged with the high angular resolution available with the VLA.

Ethyl cyanide ($\text{CH}_3\text{CH}_2\text{CN}$) is among the few complex molecules that have been imaged at high angular resolution in Sgr B2(N) with the VLA. Hollis et al. (2003) imaged the 43 GHz $J=5\rightarrow 4$ line of ethyl cyanide using the DnC configuration and determined three spatially distinct ethyl cyanide peaks, two in emission and a third in absorption. In addition, each peak has a unique velocity within the SgrB2(N) region. The ethyl cyanide emission regions are located toward the “Large Molecular Heimat” (LMH) (Snyder et al., 1994) (coincident with the HII region K2) (Gaume et al., 1995) and in a region $\sim 5''$ north of the LMH at a location coincident with the quasi-thermal methanol emission core (“h”) (Mehring and Menten, 1997). The ethyl cyanide absorption region is located $\sim 10''$ NE of the LMH peak, which we will hereafter refer to as the “NE absorption region”. The NE absorption region also contains an HII emission peak, K6 (Gaume et al., 1995). The resulting map of ethyl cyanide emission and absorption is shown in Figure 1 (Hollis et al., 2003). Emission features are shown in solid contours, and absorption features are shown in dashed contours. In addition, the ethyl cyanide absorption region is located just inside an ionization front (Gaume et al., 1995), which is illustrated in Fig 1.

Given the velocity structure of ethyl cyanide features resolved by the VLA observations, comparable single dish spectra toward the Sgr B2(N) pointing position should contain both emission and absorption line profiles of ethyl cyanide separated by the velocity components measured by Hollis et al. 2003. The high signal-to-noise (noise $\approx 2\text{-}5\text{mK}$), high spectral resolution (64.4kHz) single dish data available through the PRIMOS Survey conducted on the Green Bank Telescope show this velocity structure (Remijan et al., 2008) (available at www.cv.nrao.edu/~aremijan/PRIMOS). In addition to ethyl cyanide, acetonitrile (CH_3CN) and cyanoacetylene (HC_3N) have both absorption and emission features, and other nitriles, including vinyl cyanide (CH_2CHCN), cyanomethyl (CH_2CN), and methyl isocyanide (CH_3NC), appear in absorption. Examples of the complex emission and absorption features due to the combination of hyperfine splitting and multiple velocity components toward the SgrB2N region associated with cyanoacetylene and acetonitrile are shown in Figure 2. Given the distinct regions responsible for the ethyl cyanide emission and absorption features identified by Hollis et al. (2003), we expect the nitrile absorption features to be primarily associated with the NE absorption region, placing the nitrile species in a coincident region and indicating the possibility of common chemical pathways.

The velocity structure of the absorption and emission features seen in the transitions of nitriles detected by the GBT become particularly interesting in light of recent laboratory results obtained at the University of Virginia. Acetonitrile (CH_3CN) and hydrogen sulfide (H_2S) were exposed to electron bombardment via a 1600V discharge nozzle (McCarthy et al., 2000) generating rich and unanticipated results. The bombardment produced 22 molecular species, of which 16 are confirmed astronomical species. Figure 3 lists some of the product species and indicates interstellar species

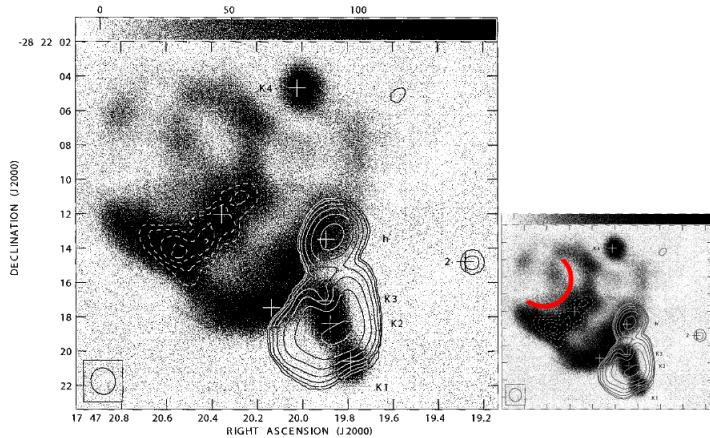


Figure 1: Contour plot of the ethyl cyanide $J=5\rightarrow 4$ line overlaid on a map of continuum emission at 43.5 GHz. Emission contours are in solid lines, and absorption features are in dotted lines. Crosses represent the K1-6 HII peaks and “h”, the quasi-thermal methanol emission core. Red curved line indicates the location of the ionization front. (From Hollis et al. 2003)

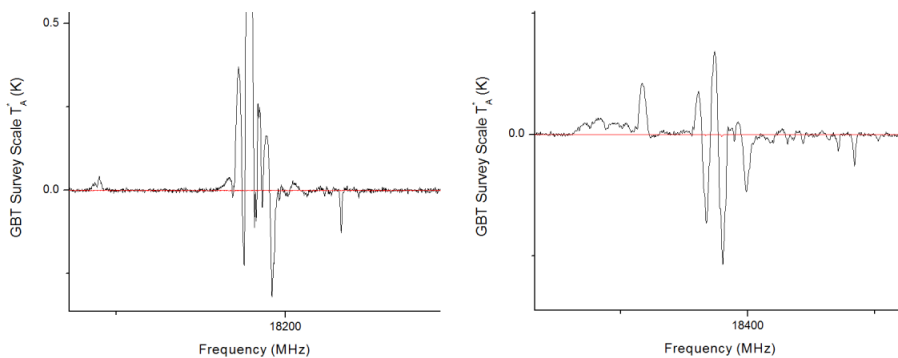
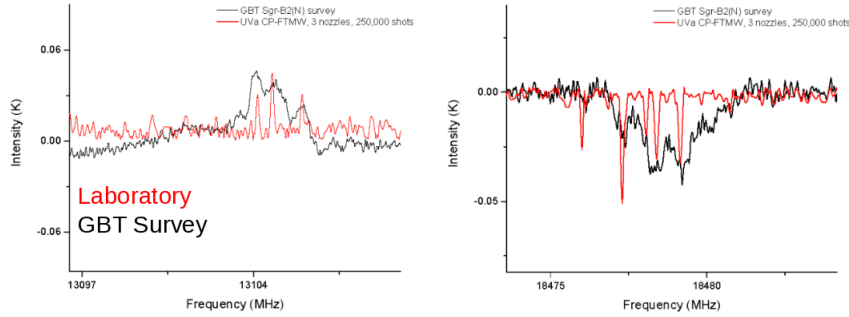


Figure 2: Spectral features of cyanoacetylene at 18196 MHz (left) and acetonitrile at 18396 MHz (right) from PRIMOS Survey Data. The lines contain emission and absorption features at multiple velocity components and exhibit hyperfine splitting.

with an asterisk. The identified species constitute 13% of all confirmed astronomical molecules. The lab spectra also include approximately 200 unidentified lines, some of which correspond to unidentified lines in PRIMOS data on Sgr B2(N) (Figure 4). Two examples of an unidentified transition in the GBT data and lab data are shown in Figure 4. What is even more interesting is that the measured abundance ratios of molecules detected in the lab experiment are in qualitative agreement with abundance estimates obtained using the GBT PRIMOS line data. Table 1 provides lab abundance ratios and Sgr B2(N) abundance ratio estimates of nine species.

The laboratory results suggest the possibility of an electron bombardment scenario for the formation of nitrile species in Sgr B2(N). The results presented by Hollis et al. (2003) support this hypothesis because there is indication of a region rich in nitriles (at least ethyl cyanide) behind an arc-shaped ionization front (Gaume et al., 1995). In the laboratory, the mechanism by which acetonitrile and hydrogen sulfide react to form 22 distinct molecular species includes radical-radical reactions involving cyanomethyl (CH_2CN). The electron bombardment of acetonitrile produces the cyanomethyl radical, which then immediately reacts with other radicals to form more complex species. If this key species, which is detected in absorption in Sgr B2(N), is spatially coincident with the other nitriles, this would support our hypothesis for an electron bombardment formation pathway in this region. Finally, extension of this theory would place the other nitriles detected with absorption features in the same location.



Molecules Synthesized in H_2S/CH_3CN discharge

Cyanides/isocyanides:

*cyanoacetylene HCCCN
 *isocyanoacetylene HCCNC
 *vinyl cyanide CH_2CHCN
 *vinyl isocyanide CH_2CHNC
 *ethyl cyanide CH_3CH_2CN
 *cyanoallene $H_2CCCHCN$

Sulfur-containing:

*thiocyanic acid HSCN
 *isothiocyanic acid HNCS
 thioufulminic acid HCNS
 thioisofulminic acid HSNC
 *mercapto radical SH
 thiosulfeno radical S_2H
 *thioformaldehyde H_2CS

Figure 3: Molecular species produced in an electron bombardment of acetonitrile and hydrogen sulfide. Species detected in the interstellar medium are indicated with an asterisk

Figure 4: Matching unidentified lines in PRIMOS data toward SgrB2(N) (shown in black) and laboratory spectroscopy of the electron bombardment of acetonitrile and hydrogen sulfide (shown in red).

Molecule	Relative Abundance (lab)	Relative Abundance (SgrB2(N))
CH_3CN	---	0.54
CH_3NC	---	0.01
HCCCN	1	1
HCCNC	0.05	---?
CH_2CHCN	1.12	1.86
CH_2CHNC	0.18	0.01
CH_3CH_2CN	0.21	0.18
CH_3CH_2NC	<0.013	<0.06
$H_2CCCHCN$	0.02	---?

Table 1: Measured lab abundances and estimated SgrB2(N) abundances of nine molecules. Highlighted rows indicate similar abundances.

We propose a test of the electron bombardment scenario in the NE absorption region via spectral line imaging of nitriles with the EVLA. Very few astrochemical investigations are motivated by direct lab results. As such, we are applying a new model for astrochemical searches whereby direct laboratory measurements provide a testable hypothesis that can be followed on directly by astronomical observations. Though the astronomical molecular inventory currently stands at ~ 169 detected species and their isotopologues, the formation mechanisms of even the simplest molecular species are not well understood. In previous efforts, searches for interstellar species have rarely been motivated with an aim of obtaining information on chemical formation pathways. As such, we are presenting a new methodology for accumulating fundamental information on chemical reaction dynamics within astronomical environments. In addition to the valuable information for chemical formation scenarios, our observations will also help constrain the dynamics and kinematics toward the NE region of SgrB2(N) containing the NE absorption region, the associated ionization front, and ionizing source(s).

Technical justification

We propose to image the NE absorption region and the LMH emission peak toward SgrB2(N) with the EVLA at K-Band. Single dish K-Band data on Sgr B2(N) are available from the PRIMOS Survey (Remijan et al., 2008), allowing for a direct comparison between the single dish and array data. We will set a 2 GHz window from 18.15 to 20.15 GHz, to image at least 17 transitions from

various complex nitriles including cyanomethyl, cyanoacetylene, methyl cyanide, ethyl cyanide, vinyl cyanide, methyl isocyanide, and ethene isocyanide that were present in the PRIMOS Survey. Given the high sensitivity associated with the large spectral bandwidth available with the eVLA, we expect to see additional lines from these and other nitrile species, including ketenimine (CH_2CNH), that were just below the sensitivity limit of the PRIMOS Survey. Using the eVLA exposure calculator, in 8 hours of on source integration time, we can achieve an RMS noise of 0.4mK, compared to PRIMOS noise of $\sim 2\text{-}5\text{mK}$. We request 2 additional hours for overhead (e.g. pointing, flux, passband calibration observations, etc...), totalling 10 hours of telescope time, or 2 sidereal passes on the SgrB2(N) region. The spatial resolution available ($\theta \sim 3''.3$) will allow us to determine the distribution of these species, providing the first observational test of a lab-driven electron bombardment hypothesis for nitrile chemistry in the NE absorption region.

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