Identification of interstellar amino acetonitrile in the hot molecular core G10.47+0.03: Possible glycine survey candidate for the future

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Abstract

Amino acids are the essential keys that contribute to the study of the formation of life. The simplest amino acid, glycine (NH₂CH₂COOH), has been searched for a long time in the interstellar medium, but all surveys of glycine have failed. Since the detection of glycine in the interstellar medium was extremely difficult, we aimed to search for the precursor of glycine. After detailed searches of the individual prebiotic molecular species, we successfully identified the emission lines of possible glycine precursor molecule amino acetonitrile (NH₂CH₂CN) towards the hot molecular core G10.47+0.03 using the Atacama Large Millimeter/Submillimeter Array. We estimated the statistical column density of amino acetonitrile was (9.10±0.7)×10^{15} cm⁻² with rotational temperature (T_{rot}) 122±8.8 K. The estimated fractional abundance of amino acetonitrile was 7.01±10⁻³. We found that the estimated fractional abundance of NH₂CH₂CN fairly agrees with the theoretical value predicted by the three-phase warm-up model from Garrod (2013).

1. Introduction

In the interstellar medium, more than 260 molecules have been detected using the millimeter/submillimeter radio telescopes. The hot molecular cores are chemically rich complex systems in the interstellar medium, and several complex organic molecules have been detected in the hot molecular core regions (Garrod et al., 2017; Belloche et al., 2016; Gorai et al., 2020; Manna & Pal, 2021). In this article, we give priority to the study of prebiotic organic molecular spectral lines towards the hot molecular core region G10.47+0.03 (hereafter, G10), which was observed at a distance of 8.6 kpc (Sanna et al., 2014). The luminosity of the hot molecular core G10 was 10⁶ L_☉, which indicates that G10 is one of the highest luminosity star-forming region in the galaxy and particularly interesting to the investigation of the molecular lines (Rolffs et al., 2009). The emission lines of NH₃CHO, CH₃NCO, and HNCO were detected towards G10 using the Atacama Large Millimeter/Submillimeter Array (Gorai et al., 2020). Recently, the complex molecular emission lines of CH₃OH, (CH₃OH)$_2$, CH₃CHO, CH₃CH₂CHO, HOCH₂CHO, CH₂COCH₃, CH₂OCHO, and CH₃OCH₃ were also detected towards G10 using the ALMA (Mondal et al., 2021). Earlier, the emission lines of prebiotic complex molecules methanimine (CH₃NH) and methylamine (CH₃NH₂) were detected towards G10, which are the simplest imine and amine, respectively (Suzuki et al., 2016; Ohishi et al., 2019). The prebiotic molecule CH₃NH₂ plays an important role in the formation of the glycine isomer CH₃NHCOOH towards the hot molecular cores (Holton et al., 2005). The bio-molecule CH₃NH₂ will be produced during the warm-up phases between the reactions of NH₃ and CH₃ under cosmic ray irradiation on the grain surface (NH₂+CH₃—→CH₃NH₂) (Kim & Kaiser, 2011). When CH₃NH₂ molecule reacts with CO₂ under UV irradiation, it forms the glycine isomer molecule CH₃NHCOOH in the solid phase (CH₃NH₂$ightarrow$CH₃NHCOOH) (Holton et al., 2005). In another way, CH₃NH₂ molecule can be produced in the interstellar medium due to hydrogenation of HCN on the dust surface of hot molecular cores (HCN + H₂ → CH₃NH + H₂) (Theule et al., 2011). As two possible precursors of glycine CH₃NH₂ and CH₃NH were already detected towards G10 (Ohishi et al., 2019; Suzuki et al., 2016), we tried to search for another prebiotic molecule, amino acetonitrile (NH₂CH₂CN) towards G10, which was known as another possible precursor of glycine (Brown et al., 1977; Elsila et al., 2007; Ohishi et al., 2019).

The complex nitrile molecule amino acetonitrile (hereafter, AAN) is known as one of the important rare compounds in the interstellar medium, which is also known as glycine nitrile (Wirström et al., 2007). The AAN molecule is one of the important species for astrochemists and astrobiologists because AAN can be converted into glycine after hydrolysis via glycaminde (NH₂CH₂(O)NH₂) (Alonso et al., 2018; Peltzer et al., 1984; Wirström et al., 2007). Earlier, astrochemists suggested the possible chemical pathways for the formation of glycine from AAN via glycaminde on the dust surface of the hot molecular cores:

\[
\begin{align*}
\text{HCN} + \text{H}_2 &\rightarrow \text{CH}_3\text{NH} \\
\text{CH}_3\text{NH} + \text{HCN} &\rightarrow \text{CH}_3\text{NH}_2\text{CN} \\
\text{NH}_2\text{CH}_2\text{CN} &\rightarrow \text{NH}_2\text{CH}_2\text{C(O)NH}_2 \\
\text{NH}_2\text{CH}_2\text{C(O)NH}_2 &\rightarrow \text{NH}_2\text{CH}_2\text{COOH}
\end{align*}
\]

Reaction 1 indicated that the CH₃NH₂ molecule was produced on the dust surface via the hydrogenation of HCN (Theule et al., 2011; Woon et al., 2002). Reaction 2 presented the formation pathways of AAN between the reactions of CH₃NH and HCN via the Strecker synthesis reaction (Danger et al., 2011). Now, in the interstellar medium, the hydrolysis of AAN in the gas phase or the icy mantle on the grain sur-

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ABSTRACT

Amino acids are the essential keys that contribute to the study of the formation of life. The simplest amino acid, glycine (NH₂CH₂COOH), has been searched for a long time in the interstellar medium, but all surveys of glycine have failed. Since the detection of glycine in the interstellar medium was extremely difficult, we aimed to search for the precursor of glycine. After detailed searches of the individual prebiotic molecular species, we successfully identified the emission lines of possible glycine precursor molecule amino acetonitrile (NH₂CH₂CN) towards the hot molecular core G10.47+0.03 using the Atacama Large Millimeter/Submillimeter Array. We estimated the statistical column density of amino acetonitrile was (9.10±0.7)×10^{15} cm⁻² with rotational temperature (T_{rot}) 122±8.8 K. The estimated fractional abundance of amino acetonitrile was 7.01±10⁻³. We found that the estimated fractional abundance of NH₂CH₂CN fairly agrees with the theoretical value predicted by the three-phase warm-up model from Garrod (2013).
face produces glycinamide (NH$_2$CH$_2$C(O)NH$_2$), as shown in reaction 3 (Alonso et al., 2018). The hydrolysis of glycinamide forms glycine on the grain surface, which was presented in reactions 4 (Alonso et al., 2018). Recently, Kisiel et al. (2022) searched for the emission lines of glycinamide from Sgr B2(N) but they cannot find any evidence of glycinamide within the limit of the Local Thermodynamic Equilibrium (LTE) model. They estimated the upper limit column density of glycinamide towards Sgr B2(N) was $\lesssim 1.5 \times 10^{16}$ cm$^{-2}$. Earlier, Koch et al. (2008) found that H$_2$O can efficiently catalyze a reaction between CH$_2$NH and HNC to form AAN in the grain mantles at a temperature of 50 K. The AAN molecule contains both amino and nitrile groups (Sharma, 2019). The survival of AAN against UV photoly-
sis in the interstellar ices was ~5 times longer than glycine (Bernstein et al., 2004). Earlier, Wirström et al. (2007) did not find the molecular lines of AAN from hot molecular cores Orion KL, W51 e1/e2, S140, and W3(OH) using the Onsala 20 m telescope. The emission lines of interstellar AAN were first time detected towards Sgr B2(N) with the Onsala 20 m telescope. The emission lines of interstellar complex organic prebiotic molecules using the high-resolution Atacama Large Millimeter/submillimeter Array (ALMA)2 with band 4 in cycle 4. The hot molecular core G10 was observed on 28th January 2017, 5th March 2017, 6th March 2017, and 7th March 2017 with phase center of (α, δ)2000 = (18:08:38.232, −19:51:50.400). The on-source integration time on these days was 2026.080 sec, 3810.240 sec, 6804.000 sec, and 1723.680 sec, respectively, and a total of thirty-nine, forty, forty-one, and thirty-nine antennas were used during these observations. The observation aimed to study five-strong emission lines of interstellar glycol towards G10. The observations of G10 were carried out in four spectral windows with frequency ranges 129.50–134.44 GHz, 147.50–149.43 GHz, 153.00–154.93 GHz, and 158.49–160.43 GHz with a spectral resolution of 1128.91 kHz and 488.28 kHz. The angular resolution of different frequency ranges was 1.67″ (14362 AU), 1.52″ (13072 AU), 1.66″ (14276 AU), and 1.76″ (15136 AU) respectively. During the observation, J1733–1304, J1832–2039, and J1924–2914 were used as flux calibrator, phase calibrator, and bandpass calibrator respectively. The systemic velocity (VLSR) of G10 is ~68.50 km s⁻¹ (Rolffs et al., 2011).

For initial data reduction and spectral imaging, we used the Common Astronomy Software Application (CASA 5.4.1) with the standard ALMA data reduction pipeline (McMullin et al., 2007). During the analysis of the raw data of G10, the continuum flux density of the flux calibrator for each baseline was scaled and matched with the Perley-Butler 2017 flux calibrator model with 5% accuracy using task SETJY (Perley & Butler, 2017). We made flux and bandpass calibration after discarding the bad data using CASA pipeline with task

### Table 1

| Frequency range (GHz) | Observed frequency (GHz) | Transition (J, K) | Jk | Peak intensity (K) | Spw (Dopplerb) | FWHM (km s⁻¹) | J, K (VLSR) | VLSR (km s⁻¹) | Remark |
|-----------------------|--------------------------|-------------------|----|------------------|----------------|--------------|------------|--------------|--------|
| 147.55–148.61         | 147.558                  | (15, 16) – (14, 15) | 1.23 | 3.8347         | 6.6123         | 0.09         | 20.824       | 68.820      | Blended with CH₃OH |
| 148.50–149.43         | 149.128                  | (16, 17) – (15, 16) | 0.96 | 1.1241         | 4.5832         | 0.32         | 31.425       | 68.509      | Detected     |
| 151.00–152.33         | 151.402                  | (17, 18) – (16, 17) | 0.71 | 1.3741         | 4.8031         | 0.26         | 23.547       | 68.807      | Blended with CH₃OH |
| 154.0–154.93         | 154.392                  | (17, 18) – (16, 17) | 1.07 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.3744              | 154.426                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.4264              | 154.517                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.517              | 154.520                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.520              | 154.529                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.5424              | 154.544                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.544                 | 154.566                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.566                 | 154.617                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |
| 154.617                 | 154.674                 | (17, 18) – (16, 17) | 1.04 | 1.1541         | 6.9752         | 0.13         | 72.498       | 68.992      | Blended with CH₃CN |

1. T – Those transitions of AAN were also detected in Sgr B2 (Belloche et al., 2008).
2. * – Transitions contain double with frequency difference less than 100 kHz. The quantum numbers of the second are not shown.
3. ° – Spectral resolution 488.28 kHz
4. † – Spectral resolution 1128.91 kHz

2. Observations and data reductions

The hot molecular core G10 was observed to study the interstellar complex organic prebiotic molecules using the high-resolution Atacama Large Millimeter/submillimeter Array (ALMA) with band 4 in cycle 4. The hot molecular core G10 was observed on 28th January 2017, 5th March 2017, 6th March 2017, and 7th March 2017 with phase center of (α, δ)2000 = (18:08:38.232, −19:51:50.400). The on-source integration time on these days was 2026.080 sec, 3810.240 sec, 6804.000 sec, and 1723.680 sec, respectively, and a total of thirty-nine, forty, forty-one, and thirty-nine antennas were used during these observations. The observation aimed to study five-strong emission lines of interstellar glycol towards G10. The observations of G10 were carried out in four spectral windows with frequency ranges 129.50–134.44 GHz, 147.50–149.43 GHz, 153.00–154.93 GHz, and 158.49–160.43 GHz with a spectral resolution of 1128.91 kHz and 488.28 kHz. The angular resolution of different frequency ranges was 1.67″ (14362 AU), 1.52″ (13072 AU), 1.66″ (14276 AU), and 1.76″ (15136 AU) respectively. During the observation, J1733–1304, J1832–2039, and J1924–2914 were used as flux calibrator, phase calibrator, and bandpass calibrator respectively. The systemic velocity (VLSR) of G10 is ~68.50 km s⁻¹ (Rolffs et al., 2011).

For initial data reduction and spectral imaging, we used the Common Astronomy Software Application (CASA 5.4.1) with the standard ALMA data reduction pipeline (McMullin et al., 2007). During the analysis of the raw data of G10, the continuum flux density of the flux calibrator for each baseline was scaled and matched with the Perley-Butler 2017 flux calibrator model with 5% accuracy using task SETJY (Perley & Butler, 2017). We made flux and bandpass calibration after discarding the bad data using CASA pipeline with task
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Figure 2: The integrated emission map of unblended transitions of AAN towards G10 which was overlaid with the 1.87 mm continuum emission (red contour). Contour levels are at 20%, 40%, 60%, and 80% of the peak flux. The blue circle indicated the synthesized beam of the integrated map.

3. Result
3.1. Analysis of the emission lines of interstellar AAN towards G10

We extracted the sub-millimeter spectra of hot molecular core G10 from the continuum subtracted spectral data cubes to make a 2.5″ diameter circular region at the center of RA (J2000) = (18h08m38s.232), Dec (J2000) = (−19°51′50″.440). The systematic velocity of the sub-millimeter spectra towards G10 was 68.50 km s⁻¹. After the extraction of the sub-millimeter spectrum, we used CASSIS (Vastel et al., 2015) for the identification of the emission lines of interstellar molecules towards G10. After careful spectral analysis, we identified the emission lines of the complex organic molecule AAN (a-type), which was known as a possible precursor of glycine. We used the Cologne Database for Molecular Spectroscopy (CDMS)³ (Müller et al., 2005) to identify the emission lines of AAN. The hot molecular core G10 was chemically very rich and the detection of AAN was extremely difficult due to contamination of other nearby molecular lines. We detected a total of twenty-one rotational transition lines of AAN between the frequency ranges of 147.55–148.01 GHz, 148.50–149.43 GHz, 153.00–153.93 GHz, 154.0–154.93 GHz, and 158.49–159.43 GHz towards G10.

After the identification of emission lines of AAN from the submillimeter spectra of G10, we fitted the Gaussian model over the observed spectra of AAN using the line analysis module in CASSIS. After the fitting of Gaussian model over the observed spectra of AAN, we estimated the Full-Width Half Maximum (FWHM), quantum numbers (J_k^a K_c^a − J_k'^a K_c'^a), upper state energy (E_u), Einstein coefficients (A_ij), peak intensity and integrated intensity (∫ T_{mb} dV). There was no missing a-type transition of AAN in this data. The summary of the observed transitions of AAN and Gaussian fitting of spectral parameters were presented in Table 1 and the observed spectra of AAN with the best fitting Gaussian model were shown in Figure 1. Earlier, the emission lines of AAN

³https://cdms.astro.uni-koeln.de/cgi-bin/cdmssearch
were first detected from Sgr B2(N) using the IRAM 30 m single-dish radio telescope (Belloche et al., 2008). The spectral linewidth of observed emission lines of AAN towards Sgr B2(N) was \( \sim 7 \text{ km s}^{-1} \) (Belloche et al., 2008). So, there was a high probability of the contamination of other nearby molecular transitions with AAN towards Sgr B2(N) whereas our detected spectral width of AAN towards G10 was found between the range of 4–6 km s\(^{-1}\). Our observed maximum transition lines of AAN towards G10 were blended with other nearby molecular lines because the observed transitions of AAN did not resolve due to the low spectral resolution. Our identified transitions of AAN between the frequency range of 147.55–148.01 GHz and 154.0–154.93 GHz towards G10 were also detected towards Sgr B2(N) by IRAM (Belloche et al., 2008).

### 3.2. Spatial distribution of AAN

After the identification of the emission lines of AAN towards G10, we extracted the integrated emission map of AAN using task IMFIT in CASA, which was shown in Figure 2. The integrated emission map of AAN was overlaid with the 1.87 mm continuum emission map of G10\(^{4}\). We also observed that the emission map of AAN has a peak at the position of the continuum. The integrated emission maps were generated by integrating the spectral data cubes in the velocity range where the emission line of AAN was detected. We generated the integrated emission map only for the unblended transition of AAN towards G10. The integrated emission map indicated that the AAN molecule arises from the warm inner region of the hot core. We estimated the emitting region of AAN by fitting the 2D Gaussian over the integrated emission map of AAN using the CASA task IMMOMENTS towards the G10. The deconvolved beam size of the emitting region was calculated by the following equation

\[
\theta_S = \sqrt{\frac{\theta_{\text{beam}}^2 - \theta_{\text{beam}}^2}{2}} \quad \text{Eq. 1}
\]

where \( \theta_{\text{beam}}^2 = 2\sqrt{A/\pi} \) was the diameter of the circle whose area \((A)\) was enclosing 50% line peak and \( \theta_{\text{beam}} \) was the half-power width of the synthesized beam (Rivilla et al., 2017; Mondal et al., 2021). The estimated emitting region of AAN with transitions \( J = 17(1,17)\)–16(1,16), \( J = 17(4,14)\)–16(4,13), \( J = 17(13,4)\)–16(13,3), \( J = 17(14,3)\)–16(14,2), and \( J = 18(0,18)\)–17(0,17) were 1.12\( '' \), 1.13\( '' \), 1.11\( '' \), 1.12\( '' \), and \( \sim 1.13'' \) respectively. So, the emitting region of AAN towards G10 varied between 1.11\( '' \)–1.13\( '' \). After the fitting of the 2D Gaussian over the integrated emission map of AAN, we also estimated the integrated flux, peak flux, and position angle, which are presented in Table 2. We noticed that the emitting region of AAN is smaller than the synthesized beam size, which indicates the unblended transition lines of AAN are not well spatially resolved or, at best, marginally resolved.

### 3.3. Rotational diagram analysis of AAN

In this work, we have detected the multiple hyperfine transition lines of AAN towards G10. The rotational diagram method is one of the best ways to obtain the column density \((N)\) in cm\(^{-2}\) and rotational temperature \((T_{\text{rot}})\) in K of the detected emission lines of AAN. We assumed that the observed AAN spectra were optically thin and that they obeyed the Local Thermodynamic Equilibrium (LTE) conditions. The assumption of the LTE condition was reasonable towards the G10 because the density of the inner regions of the hot core was \( \sim 7\times10^7 \text{ cm}^{-3} \) (Rolffs et al., 2011). The equation of column density can be written as in the case of optically thin lines (Goldsmith & Langer, 1999),

\[
N_{\text{thin}} = \frac{3k_B T_{\text{rot}} dV}{8\pi^3 h^2 \mu^2} \quad \text{Eq. 2}
\]

where, \( k_B \) is the Boltzmann constant, \( \int T_{\text{mb}} dV \) is the integrated intensity, \( \mu \) is the electric dipole moment, \( g_u \) is the degeneracy of the upper state, \( v \) is the rest frequency, and the strength of the transition lines were indicated by \( S \). The total column density of detected species under LTE conditions can be written as,

\[
\frac{N_{\text{thin}}}{\mu} = \frac{N_{\text{total}}}{Z(T_{\text{rot}})} \exp(-E_u/k_B T_{\text{rot}}) \quad \text{Eq. 3}
\]

where \( Z(T_{\text{rot}}) \) is the partition function at extracted rotational temperature \((T_{\text{rot}})\). The rotational partition function at 75 K is 4403 and 150 K is 12460, respectively. The upper state energy of the observed molecular lines defined as \( E_u \). In another way, the Eq. 3 can be rearranged as,

\[
\ln \left( \frac{N_{\text{thin}}}{\mu} \right) = \ln(N) - \ln(Z) - \left( \frac{E_u}{k_B T_{\text{rot}}} \right) \quad \text{Eq. 4}
\]
2.1. Estimating Column Density and Rotational Temperature

The computed rotational diagram was shown in Figure 3. In this analysis, the rotational diagram was used to estimate the column density and rotational temperature of AAN towards G10. The rotational temperature indicated that the AAN molecule was mainly coming from the hot core of G10 because the temperature of the hot core was above 100 K (Rolffs et al., 2011). Earlier, the emission lines of AAN were detected from another hot molecular core Sgr B2(N) with fractional abundance $2.2 \times 10^{-9}$ (Belloche et al., 2008). The fractional abundance of AAN in G10 was $\sim 10$ times higher than Sgr B2(N). In Sgr B2(N), the emission lines of AAN arise from the hot core region, which is also known as the ‘large molecule heirant’ (Belloche et al., 2008). Recently, Melosso et al. (2020) detected the emission lines of AAN from Sgr B2(N1S) using ALMA with ReMoCA spectral line survey and they estimated the column density of AAN was $1.1 \times 10^{17} \text{ cm}^{-2}$ with excitation temperature 200 K. The estimated column density of AAN derived from LTE modelling of ReMoCA spectral line survey toward Sgr B2(N1S) was $1.1 \times 10^{17} \text{ cm}^{-2}$, which was $\sim 3.9$ times higher than the column density reported in Belloche et al. (2008) for Sgr B2(N) from observations with the IRAM 30 m telescope. During the analysis of the column density of AAN, Belloche et al. (2008) and Melosso et al. (2020) both assumed the same emission size. There are several reasons for this difference. First of all, Belloche et al. (2008) did not account for the contribution of the vibrational partition function. They assumed the temperature of AAN was 100 K and this contribution amounts to a factor of 1.09 and after accounting for this, the column density derived from the IRAM 30 m data becomes $2.8 \times 10^{16} \text{ cm}^{-2}$.

4. Discussion

4.1. AAN in the G10

The emission lines of AAN towards the hot molecular core G10 were the first time detected using ALMA with an estimated source size of $1.11^\prime\prime$–$1.13^\prime\prime$ which is presented in this article. After the spectral analysis using the Gaussian model, it was found that the maximum transition lines of AAN were blended with nearby molecular lines as presented in Table 1. We observed that the $J = 17(1,17)$–$16(1,16)$, $17(4,14)$–$16(4,13)$, $17(13,4)$–$16(13,3)$, $17(14,3)$–$16(14,2)$, and $18(0,18)$–$17(0,17)$ transition lines of AAN were not blended with nearby other molecular lines, and these transition lines were used during rotational diagram analysis to estimate the column density and gas temperature of AAN. The line contamination of AAN with other molecular lines towards G10 was less with respect to Sgr B2(N) because the estimated source size of G10 was $1.11^\prime\prime$–$1.13^\prime\prime$ whereas the source size of Sgr B2(N) was $2^\prime\prime$. The estimated column density of AAN towards G10 was $(9.10 \pm 0.7) \times 10^{15} \text{ cm}^{-2}$ with rotational temperature ($T_{\text{rot}}$) $122 \pm 8.8 \text{ K}$, and corresponding line width $4$–$6 \text{ km s}^{-1}$ with a centroid velocity $68.50 \text{ km s}^{-1}$. The fractional abundance of AAN with respect to $H_2$ was $7.01 \times 10^{-8}$ where the column density of $H_2$ was $1.3 \times 10^{23} \text{ cm}^{-2}$ (Suzuki et al., 2016). The estimated rotational temperature indicated that the AAN molecule was mainly coming from the hot core of G10 because the temperature of the hot core was above 100 K (Rolffs et al., 2011). Earlier, the emission lines of AAN were detected from another hot molecular core Sgr B2(N) with fractional abundance $2.2 \times 10^{-9}$ (Belloche et al., 2008). The fractional abundance of AAN in G10 was $\sim 10$ times higher than Sgr B2(N). In Sgr B2(N), the emission lines of AAN arise from the hot core region, which is also known as the ‘large molecule heirant’ (Belloche et al., 2008). Recently, Melosso et al. (2020) detected the emission lines of AAN from Sgr B2(N1S) using ALMA with ReMoCA spectral line survey and they estimated the column density of AAN was $1.1 \times 10^{17} \text{ cm}^{-2}$ with excitation temperature 200 K. The estimated column density of AAN derived from LTE modelling of ReMoCA spectral line survey toward Sgr B2(N1S) was $1.1 \times 10^{17} \text{ cm}^{-2}$, which was $\sim 3.9$ times higher than the column density reported in Belloche et al. (2008) for Sgr B2(N) from observations with the IRAM 30 m telescope. During the analysis of the column density of AAN, Belloche et al. (2008) and Melosso et al. (2020) both assumed the same emission size. There are several reasons for this difference. First of all, Belloche et al. (2008) did not account for the contribution of the vibrational partition function. They assumed the temperature of AAN was 100 K and this contribution amounts to a factor of 1.09 and after accounting for this, the column density derived from the IRAM 30 m data becomes $2.8 \times 10^{16} \text{ cm}^{-2}$.
the addition of radical CH$_2$CN in this hot molecular core.

To understand the chemical evolution of AAN towards the G10, Garrod (2013) proposed that AAN is produced mainly by gas-phase protonation and electron recombination reactions. The proposed chemical modeling of Garrod (2013) satisfied the environment of G10.

### 4.3. Searching of interstellar glycine towards G10

After the successful detection of AAN, we also looked for the emission lines of glycine towards G10. After the deep searches of glycine conformer I and II using the LTE module in CASSIS, we did not detect this molecule within the limits of our LTE analysis. Using the same parameter of AAN ($\theta_g \sim 1.12\circ$ and $T_{\text{ex}} = 122$ K), the estimated upper limit column density of glycine conformer I was $\leq 1.25 \times 10^{15}$ cm$^{-2}$ and conformer II was $\leq 4.86 \times 10^{13}$ cm$^{-2}$. The dipole moment of glycine conformer I is 705 cm$^{-1}$ (1012 K) lower than that of glycine conformer II (Lovas et al., 1995). The dipole moment of glycine conformer I is $\mu_a = 0.911$ D and $\mu_b = 0.607$ D, whereas conformer II is $\mu_a = 5.372$ D and $\mu_b = 0.93$ D (Lovas et al., 1995). In the interstellar medium, the a-type transitions of glycine are more prominent because the molecular line intensity is proportional to the square of the dipole moment (Lovas et al., 1995).

After the detection of CH$_3$NH$_2$ and CH$_3$NH towards G10, Ohishi et al. (2019) claimed that the hot molecular core G10 was one of the sources in an interstellar medium where glycine would be detectable. Our detection of AAN in G10 using ALMA gives more confidence that the hot molecular core G10 has the ability to form glycine. Earlier, Ohishi et al. (2019) estimated the upper limit column density of glycine conformer I with respect to CH$_3$NH$_2$ was $\leq 1.1 \times 10^{15}$ cm$^{-2}$ which satisfied our estimated upper limit column density of glycine with respect to AAN. We propose to conduct a survey of glycine conformer I and II and its precursors (CH$_3$NH$_2$, CH$_3$NH, AAN, and NH$_2$CH$_2$C(O)NH$_2$) molecules towards the hot molecular core G10 with a higher integration time and better spectral resolution to solve the puzzle of the glycine lines in the interstellar medium.

### 5. Conclusion

In this article, we presented the detection of the glycine nitrile molecule AAN towards G10 using ALMA band 4. The main results are as follows.

1. We successfully detected a total of twenty-one rotational emission lines of AAN towards the hot molecular core G10 using ALMA band 4 observation.

2. The derived column density of AAN using the rotational diagram method was $(9.10 \pm 0.7) \times 10^{15}$ cm$^{-2}$ with rotational...
temperature 122±8.8 K. The relative abundance of AAN with respect to H₂ was 7.01×10⁻⁸ where column density of H₂ in hot molecular core G10 was 1.3×10⁻²³ cm⁻² (Suzuki et al., 2016).

3. In the discussion, we compared our fractional abundance of AAN with the three-phase warm-up model by Garrod (2013) and we found that the medium warm-up model satisfied our AAN abundance.

4. After the detection of AAN in G10, we also looked for the emission lines of glycine conformers I and II. Within the limits of our LTE analysis, we did not detect the emission lines of glycine conformer I and II towards G10. We calculated the upper limit column density of glycine conformer I as ≤1.25×10¹⁵ cm⁻² and conformer II as ≤4.86×10¹³ cm⁻².

5. After the unsuccessful detection of glycine conformers I and II using ALMA, we conclude that the emission line of glycine may be below the confusion limit in G10.

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Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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