OBSERVATIONS OF NITROGEN FRACTIONATION IN PRESTELLAR CORES: NITRILES TRACING INTERSTELLAR CHEMISTRY
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Introduction: Primitive materials provide important clues on the processes that occurred during the formation and early evolution of the Solar System. Space-based and ground-based observations of cometary comae show that comets appear to contain a mixture of the products of both interstellar and nebular chemistries. Significant 15-nitrogen enrichments have been measured in CN and HCN towards a number of comets [1,2] and may suggest an origin of interstellar chemical fractionation. Additionally, large ^{15}N enhancements are found in meteorites and has also led to to the view that the ^{15}N traces material formed in the interstellar medium (ISM) [3,4], although multiple sources cannot be excluded [5]. Here, we show the results of observations of the nitrogen and carbon fractionation in prestellar cores for various N-bearing species to decipher the origin of primitive material isotopic enrichments.

In the ISM, observations show that, in contrast to CO, nitrogen does not deplete from the gas phase in dense cores. Nitrogen species can therefore show significant enrichments in deuterium due to low temperature chemical effects [6] and may also show enrichments in ^{15}N. Charnley and Rodgers (2002) theoretically showed that significant ^{15}N enhancements can occur for N_2 and ammonia in N-rich CO-depletion cores [7]. Their model was expanded to study fractionation of nitrile species, and found that significant ^{15}N enrichments are likely and may exceed ammonia or other N-bearing species fractionation at earlier periods [8]. New observations have confirmed the presence of nitriles in high density regions of prestellar cores where CO is depleted [9].

Observations: Observations have been conducted at millimeter and submillimeter wavelengths employing various facilities in order to both spatially and spectrally, resolve emission from these cores. The data was collected at the Arizona Radio Observatory's 12m telescope on Kitt Peak, AZ, and the Submillimeter telescope on Mt. Graham, AZ. Spectra were obtained at high resolution (0.08 km/s and 0.2 km/s, respectively) in order to resolve dynamic properties of each source as well as to resolve hyperfine structure present in certain isotopologues (see Figure 1). Most of the previous work on nitrogen and carbon isotopes in dense cores have applied a double isotope method to their analysis to overcome large opacity effects, requiring assumptions for one of the isotopes as either a measurement of

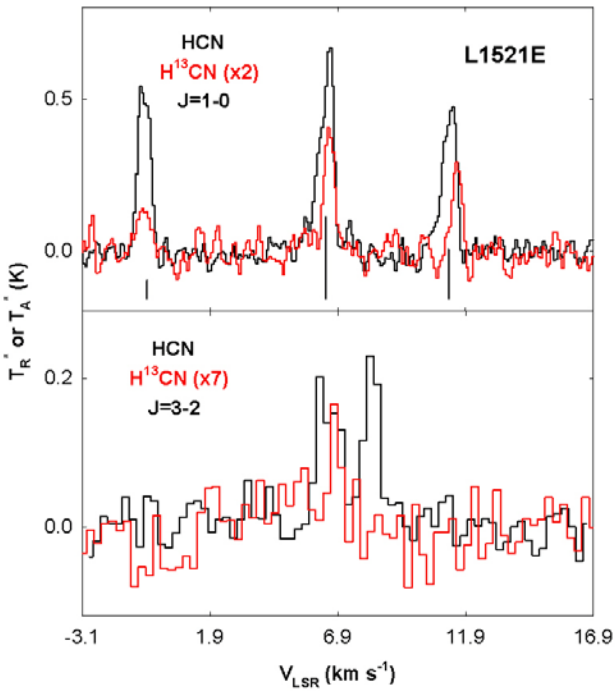

Figure 1. Arizona Radio Observatory spectra of the J=1→0 and J=3→2 emission lines of HCN (black) and H^{13}CN (red) towards L1521E [14]. The hyperfine components of the J=1→0 transition are resolved for both species and are indicated by black lines below the spectra.

a different species known to trace different regions (i.e. ^{12}CO and ^{13}CO) or using the local ISM values. These methodologies may provide false abundances for various species. Thus, we are directly measuring all isotopologues for a given species and employ a direct analytical method for determining abundances from hyperfine analysis (when possible) and thus the isotope ratios. Multiple transitions are being measured to confirm abundances for those isotopologues that do not exhibit resolved hyperfine structure with radiative transfer models.

Results and Discussion: Some work on the ^{14}N/^{15}N ratio has been conducted on L1521E, L1498 [10], and L1544 [11,12]. The analysis of the first objects employed double isotope ratio methods assuming a local ISM ^{12}C/^{13}C ratio of 60 or the value obtained from measurements of ^{12}CO/^{13}CO, which is not likely to represent the same carbon-fractionation chemistry.

Table 1: INTERSTELLLAR NITROGEN ISOTOPE RATIOS

Source	Type	NH_3	N_2H^+	HCN	HNC	Reference
L1544	dark core	>700	446±71	261	>27	11,13,14,12
				69-154		14
L1498	dark core	...	...	>813	>90	10,14
				>75		14
L1521E	dark core	...	...	151±16	...	10
				>35	>36	14
L1521F	dark core	...	...	>51	24-31	14
B1	protostar	334±50	...	...	...	15
NGC 1333	protostar	344±173	...	...	...	15
		350-850				12
Cha-MMS1	protostar	...	...	...	135	16

Studies for L1544 were done with N_2H^+ and NH_3 and obtained a nitrogen isotope ratio of 446 and >700, respectively. The discrepancy observed in these two measurements suggests a strong chemical dependence on the fractionation of nitrogen.

To further investigate this, and test current theoretical studies on variations in fractionation chemistry (e.g. Ref. 7, 8, 12), we have conducted observations of nitriles, namely HCN and HNC, towards a few select cores, L1521E, L1498, L1544, and L1521F. Figure 1 shows select isotopologues of HCN, plotted in high resolution comparing the ^{15}N-isotopologue to main isotope counterpart for L1521E in both the J=1-0 and J=3-2 transitions. Ideally, one can obtain ratios for carbon, nitrogen, and deuterium from isotopologues of the same molecule. Ratios obtained in this manner are likely tracing the same chemical heritage and are most likely directly comparable within a given source. From these data, an assessment of fractionation for the nitriles in both carbon and nitrogen can be determined for starless and prestellar cores at various stages of evolution.

Preliminary results of the ^{14}N/^{15}N ratio determined from HCN and HNC isotopologues towards the four dark cloud cores, that have varying levels of CO depletion, are presented in Table 1. The values presented from this work are preliminary and do not include the full analysis with the J=3-2 data. Results from previous studies on both nitriles and other N-bearing species are also presented. These initial ^{14}N/^{15}N ratios show significant fractionation in the nitrile species compared to the other molecules within each object. Furthermore, the derived ^{12}C/^{13}C ratio from HCN towards L1544 is ~88, not the typically employed value of 67 obtained from the nearby interstellar medium. The extremely low values of ^{14}N/^{15}N and the higher ^{12}C/^{13}C ratios measured are comparable to those obtained in comets and IDPs.

Further results and comparisons between the protostellar evolutionary state and isomer isotope fractionation will be presented.

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