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Search for Interstellar Furan and Imidazole

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Results are reported of an unsuccessful 6-cm search for the hetrocyclic carbon ring molecules furan and imidazole. Upper limits in brightness temperature of 0.25 K or less are found for furan in 11 galactic sources, and of less than 0.1 K for imidazole in Sgr A and Sgr B2.

The recent and rather surprising discovery of a number of comparatively complicated interstellar molecules, including methanol (CH_3OH), formamide ($HCONH_2$), methyl acetylene (CH_3C_2H), methyl cyanide (CH_3CN), and cyanoacetylene (HC_3N) suggests a search for simple organic ring compounds. We have made a preliminary search for two such molecules and report here negative results in a number of standard sources.

The simplest hydrocarbon ring compounds with permanent dipole moments are cyclopropene (C_3H_4) and hetrocyclic variations involving substitution of oxygen (oxirane), sulfur (thiirane), nitrogen (aziridine), etc., for one carbon atom. The bond structure in these three-member rings, however, gives rise to a low resistance to photodissociation even at fairly long wavelengths. To a lesser extent this will also be true of cyclobutene and similar four-member hetrocyclic molecules.

The five-member rings promise better stability and yet are not too complex to rule out the likelihood of finding them in some abundance in interstellar clouds. Based on the composition of presently discovered molecules, good candidates for an initial search would seem to be furan (C_4H_4O), pyrrole (C_4H_5N), imidazole ($C_3H_4N_2$), and oxazole (C_3H_3NO) (along with isomeric forms of the latter two).

These molecules are all polar and are nearly symmetric oblate rotors, exhibiting K-type doublet transitions at frequencies of a few gigahertz or less. The K-doubling frequency in general is found to decrease slowly as K increases: in furan, for instance, the transitions 1_{10}–1_{11}, 2_{20}–2_{21}, and 3_{30}–3_{31} occur at 4576, 4382, and 4103 MHz, respectively.

Our search frequencies were based on recent unpublished laboratory measurements. For furan the 1_{10}–1_{11} transition is observed in the laboratory as a narrow unresolved line complex with a central frequency of 4575.910 ± 0.001 MHz (Tomasevich and Tucker, private communication), while for imidazole (1, 3 diazole), the more complicated hyperfine splitting caused by the presence of two nitrogen nuclei gives rise, for this same transition, to a broad complex of lines peaking at 4601.63, 4602.30, and 4603.80 MHz (Brown and Elsum, private communication). The central frequency was used for the present search. The 1_{10}–1_{11} transitions were chosen because their frequencies lie within the passband of the low-noise 6-cm cooled parametric amplifier used at the National Radio Astronomy Observatory (NRAO) for formaldehyde observations.

During the period 1971 April 7–10, a total of 13 hr on the NRAO 140-ft radiotelescope at Green Bank was devoted to a search for furan and imidazole. The 384-channel NRAO autocorrelation receiver was used in conjunction with the 6-cm parametric amplifier referred to above. Observations were made while frequency switching the first local oscillator. The system temperature was typically 90–100 K and the half-power beamwidth was approximately 6 arc min; the beam efficiency was

TABLE 1

Green Bank upper limits

Location	α(1950)	δ(1950)	Integr. time (min)	Velocity range (km sec^{-1})	Upper limit to T_B(K) (peak-to-peak noise)
		Furan (1_{10}–1_{11}, 4575.91 MHz)			
NGC 2024	5^h 39^m 09.1^s	−01° 57′ 24″	60	−30 to + 40	0.10
Ori A	5 32 48.0	−05 25 47	60	−28 to + 40	0.15
Ori A	5 38 16.2	−05 21 34	60	−25 to + 40	0.10
IRC+10216	9 45 15.5	13 30 48	150	−33 to + 30	0.05
Sgr A	17 42 27.5	−28 58 36	60	−18 to + 98	0.08
Sgr B2	17 44 08.0	−28 25 01	120	−15 to +122	0.08
W33N(OH)	18 12 03.7	17 53 12	60	0 to + 68	0.05
W51	19 21 25.9	14 24 22	60	+28 to + 96	0.10
Cas A	23 21 07.8	58 31 43	60	−58 to + 5	0.25
		Imidazole (1_{10}–1_{11}, 4602.30 MHz)			
Sgr A	17 42 26.9	−28 57 17	45	−52 to +158	0.08
Sgr B2	17 44 07.4	−28 24 24	50	−52 to +158	0.08

0.82. A background measurement for each run was taken off-source and subtracted from the on-source data. Hints of a furan signal were seen in some of these data upon reduction, and therefore an additional search was undertaken by H. Weaver and D. R. W. Williams with the 85-ft Hat Creek telescope. No confirmation was obtained, and it is clear from the low upper limits obtained at Hat Creek that the suspected signals were spurious.

The observational data obtained with the 140-ft telescope are summarized in Table 1. For furan, the spectral resolution was 0.5 km sec^{-1} in all cases except Sgr A and B where it was approximately 1.1 km sec^{-1}. For imidazole, the spectral resolution was approximately 1.2 km sec^{-1}. The raw data were computer-filtered by averaging adjacent channels, but this process alters the resolution only slightly from the values given above, assuming that signals would be roughly Gaussian in shape and at least a few km sec^{-1} in width. The upper limits on the line brightness temperature T_B in Table 1 are equal to simple peak-to-peak antenna temperature noise after adjacent channel averaging, divided by the beam efficiency.

The Hat Creek furan limits, obtained at a spectral resolution of 2 km sec^{-1}, are summarized in Table 2. Because of longer integration, a slightly lower system noise temperature, and somewhat poorer spectral resolution, these are roughly two to four times lower than the Green Bank limits for the four sources (Sgr A, Sgr B2, Ori A, and W51) observed with both telescopes.

To translate the limits given here on line intensities into limits on the molecular column number densities requires some knowledge or assumptions as to the molecular excitation. Furan and imidazole, because of their rather large moments of inertia and hence closely-packed rotational levels, will be distributed over a number of levels even at an excitation temperature of only ~ 3 K. At the very high neutral particle densities (10^5–10^6 cm^{-3}), and moderately high kinetic temperatures (60–100 K) which apparently exist in at least some of the most prominent molecular sources (cf. Penzias *et al.* 1971, Thaddeus *et al.* 1971) a great many more levels will be populated. For this reason the number of furan or imidazole molecules which might lie in front of even a strong continuum source without having been detected by us is rather substantial, in Sgr B2 the number being of the order of 10^{15} cm^{-2}, which is not much below the column density for formaldehyde obtained by Zuckerman *et al.* (1970). It is thus clear that more and very sensitive observational work on

TABLE 2

Hat Creek upper limits for Furan

Location	α(1950)	δ(1950)	Integr. time (min)	Velocity range (km sec^{-1})	Upper limit to T_B(K) (peak-to-peak noise)
Sgr A	17^h 42^m 37.3^s	−28° 55′ 59″	267	−34 to +162	0.04
Sgr B2	17 44 23.0	−28 24 54	267	−34 to +162	0.03
W 51	19 21 24.8	14 24 53	160	−33 to +163	0.04
W49B	19 8 43.6	9 0 37	160	−78 to +118	0.04
Ori A	5 32 48.6	5 25 16	520	−98 to + 98	0.03
L 134	15 50 48.4	−4 25 54	267	−98 to + 98	0.023
Cloud 2	4 38 30	25 18 16	253	−93 to +103	0.03

furan and imidazole will have to be done before their existence in interstellar clouds can be definitely ruled out. It is interesting to note, however, that at least four other ring molecules have now been unsuccessfully sought by various observers, and it is perhaps not entirely premature to wonder whether some barrier to the production of rings exists in the interstellar production mechanism.

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