defect provides strong evidence that the new species is planar.

All the transitions listed in Table 1 are active through a component of the permanent electric dipole moment lying along the axis of the smallest moment of inertia, designated as the *a* axis. Transitions active through a dipole moment along the other principal axis in the plane of the molecule were not detected, thus suggesting a twofold symmetry (C_{2v}) about the *a* axis. Preliminary measurements of the Stark effect place the permanent electric dipole moment near 1.6 debye.

A comparison of the relative intensities between the $K_p = 1$ and $K_p = 2$ series Q branch transitions ($\Delta J = 0$) indicated that the observed intensities were being altered by the effects of nuclear spin statistics. An arrangement in which two hydrogen atoms with the nuclear spin $I = \frac{1}{2}\hbar$ were placed symmetrically off the *a* axis brought the observed relative intensities into agreement with theory. Isotopic studies now under way have established that the atoms lying on the symmetry axis are indeed carbon and sulfur. The assignment of this newly observed species to thioformaldehyde has therefore been positively confirmed.

The lowest-lying rotational energy levels of thioformaldehyde are illustrated schematically in Fig. 1, with the transitions listed in Table 1 indicated by heavy black lines. The diagram has been divided into two "stacks" to illustrate that electric dipole transitions between the two sets of levels are forbidden by selection rules. In the absence of collisional transfer, the 1_{11} level will, therefore, become metastable with respect to lower lying levels. This feature of the energy structure will considerably increase the chances of observing the $1_{10} \leftarrow 1_{11}$ transition of thioformaldehyde in the interstellar medium as it did for the same transition in formaldehyde (*1*).

The $1_{10} \leftarrow 1_{11}$ transition in formaldehyde has been detected in absorption in an estimated 50 galactic sources (*6*). At least three of these sources proved intense enough to allow the detection of signals due to the less abundant carbon-13 isotopic form of formaldehyde (*7*). This fact coupled with current estimates of stellar oxygen-sulfur abundance ratios ranging from 10 to 1 (*8*) to 50 to 1 (*9*) provide a strong case for the prediction of detectable signals from interstellar thioformaldehyde.

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A Search for the $1_{10} \leftarrow 1_{11}$ Transition of Interstellar Thioformaldehyde

Abstract. *A search has been made for the $1_{10} \leftarrow 1_{11}$ transition of thioformaldehyde in interstellar clouds where formaldehyde is known to exist. Failure to detect this transition indicates that the ratio of thioformaldehyde abundance to that of formaldehyde is probably less than the abundance ratio of sulfur to oxygen.*

Formaldehyde ($H_2C^{12}O$) absorption has been observed by Snyder *et al.* in many directions in the galaxy (*1*). Zuckerman *et al.* (*2*) have found interstellar absorption by the isotopic species $H_2C^{13}O$. The microwave spectrum of the analog thioformaldehyde ($H_2C^{12}S$) has recently been observed in the laboratory by Johnson and Powell (*3*). Since the cosmic abundance of sulfur is about 1/40 that of oxygen (*4*), we might expect to detect absorption by $H_2C^{12}S$ in the interstellar medium. Our failure to detect the $1_{10} \leftarrow 1_{11}$ transition of $H_2C^{12}S$ at 1046.48 Mhz indicates that the abundance of $H_2C^{12}S$ is, in fact, less than 1/40 that of $H_2C^{12}O$.

The expected optical depth of $H_2C^{12}S$ may be calculated by comparison with $H_2C^{12}O$. We consider the relative abundance of $H_2C^{12}S$ to $H_2C^{12}O$ to be 1/40, the cosmic abundance of S to O, and assume an excitation mechanism which populates the relevant levels in $H_2C^{12}S$ in the same ratio as those in $H_2C^{12}O$. The same ratio for the populations of the two levels, rather than the same excitation temperature, is assumed, because interstellar $H_2C^{12}O$ is not generally in equilibrium with its surroundings. Johnson and Powell (*3*) report that the dipole moment of H_2CS is 0.7 times that of $H_2C^{12}O$. Thus the relation between the two optical depths is $\tau(H_2C^{12}S) = 1.2 \times 10^{-2}\ \tau\ (H_2C^{12}O)$. On the other hand, if equal excitation temperatures are assumed, rather than equal population ratios, $\tau\ (H_2C^{12}S) = 2.6 \times 10^{-3}\ \tau\ (H_2C^{12}O)$. We use the former assumption, that of equal relative populations, in all of the ensuing discussion.

Because absorption due to the lowest rotational doublet of $H_2C^{12}O$ may show saturation in some cases, we have also estimated the optical depth of $H_2C^{12}S$ by comparisons with other lines. Saturation effects should be much less in the case of absorption by $H_2C^{13}O$; absorption lines from this molecule have been detected in several of the sources we examined (*2*). If we assume that $H_2C^{12}O$ and $H_2C^{13}O$ exist in the ratio 89 : 1 (the ratio of terrestrial abundances of C^{12} and C^{13}), we find $\tau\ (H_2C^{12}S) = 1.1\ \tau\ (H_2C^{13}O)$.

The expected optical depths for H_2CS may also be estimated by comparison with measurements of $H_2C^{12}O$ in the $2_{11} \leftarrow 2_{12}$ transition (*5*) or in the $3_{12} \leftarrow 3_{13}$ transition (*6*). By direct comparison, $\tau\ (H_2C^{12}S) = 1.2 \times 10^{-2} R\ \tau\ (H_2C^{12}O;\ 2_{11} \leftarrow 2_{12})$, where R is defined as the theoretical ratio of optical depths $\tau\ (H_2C^{12}O;\ 1_{10} \leftarrow 1_{11})/\tau\ (H_2C^{12}O;\ 2_{11} \leftarrow 2_{12})$, which is also roughly equal to the ratio of the populations in the $J = 1$ and $J = 2$ levels. We have used a Boltzmann population ratio, assuming that the two levels are in equilibrium with the radiation flux at 2 mm. If we assume a radiation temperature of 2.7°K, we find $R = 12$; if the radiation temperature is 5°K, we find $R = 4$.

Our search for the $1_{10} \leftarrow 1_{11}$ line of $H_2C^{12}S$ at 1046.48 Mhz was made with the 85-foot (26-m) antenna at the Hat Creek Radio Observatory. The half-power beam width was approximately 48 minutes of arc. The transistor amplifier receiver yielded a system noise of about 700°K. We analyzed the frequency-switched signal with a 100-channel filter bank, using 10-khz filters. The observed upper limits on the line antenna temperature and the expected values for the sources observed are given in Table 1.

Clouds which may contain H_2CS lie in front of bright sources of continuum radiation. The depth of the absorption line we expect to see depends not only upon the optical depth of the H_2CS, but also upon the brightness temperature of the continuum and the angular sizes of the H_2CS cloud and the antenna beam. The expected values for the live antenna temperatures were calculated with the following approximate formula:

$$\frac{\Delta T_A(H_2CS)}{\Delta T_A(X)} = \frac{F(H_2CS)}{F(X)} \frac{T_B(1046\ \text{Mhz})}{T_B(\nu_X)} \frac{\tau(H_2CS)}{\tau(X)}$$

where X is the transition in $H_2C^{12}O$ or $H_2C^{13}O$ used for comparison, T_B is the source brightness temperature at the respective frequencies, and F is the beam-filling factor for the respective beams. The observations of the $1_{10}\leftarrow 1_{11}$ and $2_{11}\leftarrow 2_{12}$ transitions in $H_2C^{12}O$ and of the $1_{10}\leftarrow 1_{11}$ transition in $H_2C^{13}O$ were used as comparisons. In all cases, we have used the theoretical ratios, $\tau(H_2CS)/\tau(X)$, computed under the assumptions stated above, so that the only factor for which observational data have been used directly is $\Delta T_A(X)$. A ν^{-2} dependence of T_B was assumed for H II regions and spectral indices of −0.25 and −0.20 were used for the fluxes of Sagittarius A and Sagittarius B2, respectively. For the $1_{10}\leftarrow 1_{11}$ transitions the beam-filling factor is taken as the average of the factors for source sizes of 4 to 10 minutes of arc, over which range the factor varies by ± 20 percent. The results given in Table 1 for the $2_{11}\leftarrow 2_{12}$ transition were calculated on the basis of a source size of 6 minutes of arc. If the source size is 3 minutes of arc, then the expected line antenna temperatures are decreased by about a factor of 2. These values are meant simply to be representative of the range of possible cloud sizes.

All predictions discussed above were based on the assumption that the cosmic abundance of H_2CS relative to that of H_2CO is 1/40, the same as that of sulfur relative to oxygen. The failure to detect H_2CS in its expected abundance provides some evidence for the chemical and excitation processes involved. Mechanisms which establish the H_2CO level populations are not well understood and may yield quite different distributions for H_2CS. This might be true, for example, if these mechanisms involved resonant radiative pumping, but it is less likely if collision mechanisms dominate. If the species of interest are formed through reactions involving CS and CO, then the abundance of the diatomic molecules is relevant. Since the dissociation energy of CO is 11 ev, as compared to 7.8 ev for CS, there are roughly four times as many ultraviolet photons able to dissociate CS, if the spectrum in the ultraviolet from 912 to 1590 Å is flat and the radiation density at 1000 to 1400 Å predicted by Habing (*7*) is typical. Since photons of Lyman α radiation will dissociate CS, but not CO, the large flux of Lyman α radiation found by some observers (*8*) would tend to decrease the amount of CS relative to CO by several orders of magnitude. If H_2CO and H_2CS are formed on dust grains, then the relative stabilities of CO and CS are less important, but the abundance of H_2CS might be reduced relative to that of H_2CO because of the greater susceptibility of H_2CS to dissociation by ultraviolet radiation. Since we do not as yet know the amount of obscuration of ultraviolet radiation in the regions where most of the H_2CO exists, no good numerical estimate of such a reduction is possible at present.

Table 1. Observational upper limits and predicted line antenna temperatures computed by means of the following hypotheses: Hypothesis A, prediction made from the $1_{10}\leftarrow 1_{11}$ transition in $H_2C^{12}O$; hypothesis B, prediction made from the $1_{10}\leftarrow 1_{11}$ transition in $H_2C^{13}O$; hypothesis C, prediction made from the $2_{11}\leftarrow 2_{12}$ transition in $H_2C^{12}O$ with a microwave background temperature of 5.0°K; and hypothesis D, prediction made from the $2_{11}\leftarrow 2_{12}$ transition in $H_2C^{12}O$ with a microwave background temperature of 2.7°K. Equal relative populations have been assumed in all cases.

Source	Predicted ΔT_A (°K)				Observational limit ΔT_A (°K)
	Hypothesis A	Hypothesis B	Hypothesis C	Hypothesis D	
Sgr B2	0.058	0.78	0.24	0.71	≤ 0.08
Sgr A	0.040	0.23	0.06	0.19	≤ 0.05
W 12 (NGC2024)	0.019				≤ 0.10
W 43	0.016				≤ 0.16
W 49	0.004				≤ 0.15
W 51	0.027	0.041	0.031	0.089	≤ 0.16

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Formaldehyde Absorption Coefficients in the Vacuum Ultraviolet (650 to 1850 Angstroms)

Abstract. *The absorption spectrum of formaldehyde has been measured photoelectrically from 650 to 1850 angstroms. A broad continuum observed at wavelengths shorter than 1570 angstroms will be the major spectral feature contributing to the formaldehyde lifetime in the interstellar radiation field.*

Recently, as a result of observations made with the 190-foot (58-m) telescope at the National Radio Astronomy Observatory, Snyder *et al.* (*1*) have reported the presence in the interstellar media of the organic molecule formaldehyde (H_2CO). Formaldehyde is the first polyatomic organic molecule observed in the intersteller environment and, as such, the study of its