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A RADIO SEARCH FOR INTERSTELLAR PHOSPHORUS COMPOUNDS

J. M. HOLLIS
National Radio Astronomy Observatory[1,2]

L. E. SNYDER
University of Illinois, Urbana

F. J. LOVAS
National Bureau of Standards

AND

B. L. ULICH[3]
National Radio Astronomy Observatory
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ABSTRACT

The $J = 1$–0 and 3–2 transitions of phosphorus nitride, PN, with resolvable hyperfine components at 46.99 GHz and blended components at 140.97 GHz, and transitions of phosphine, PH_3, at 47.39 and 46.94 GHz, arising from a small induced dipole moment, have been searched for but not found in interstellar molecular clouds. The $J = 3/2$–$1/2$, $F = 3/2$–$3/2$ transition of nitric oxide, NO, and the $J_{K-K+} = 16_{4,12}$–$15_{5,11}$ transition of sulfur dioxide, SO_2, have been detected in Orion and Sagittarius B2. An unidentified emission line, U140921.8 MHz, has been observed in IRC +10216.

Subject headings: interstellar: molecules — line identifications — radio sources: lines

I. INTRODUCTION

It may be that critical initial stages of prebiotic chemical evolution transpire in interstellar clouds long before the advent of "warm little ponds" on a planet formed within the life zone surrounding an F or G spectral class star. Neglecting minor elemental constituents, an empirical formula for living matter (Deevey 1970) would contain the following elements and their relative percentages by number: H(49.84), O(24.92), C(24.92), N(0.27), P(0.03), and S(0.02). While observations with the *Copernicus* satellite of nearby stellar atmospheres have detected ionized phosphorus (Jura and York 1978), interstellar searches have successfully detected compounds containing all of the above elements with the notable exception of phosphorus. PN and PH_3 are two of the few simple phosphorus compounds with measured molecular parameters which allow meaningful interstellar searches. Encouraged by this and noting that the cosmological abundance of phosphorus is reasonably significant (cf. Allen 1973, who tabulates phosphorus $\sim 20\%$ as abundant as either sodium or calcium, each a well-known carrier of optical interstellar absorption lines), we searched for PN and PH_3 in interstellar clouds.

[1] The NRAO is operated by Associated Universities, Inc., under contract with the National Science Foundation.

[2] Presently at the Laboratory for Astronomy and Solar Physics, NASA Goddard Space Flight Center.

[3] Presently at the University of Arizona.

II. OBSERVATIONS

The observations were made in 1978 March and 1979 April with the 11 m radio telescope of the National Radio Astronomy Observatory on Kitt Peak, Arizona. The spectrometer consisted of two 256 channel banks with 250 kHz (100 kHz for Cloud 2 observations) filters in one bank and 1000 kHz filters in the other bank. The 1978 observations were made with the NRAO 33–50 GHz cooled mixer and the 1979 observations were made with the NRAO 120–170 GHz uncooled mixer with single-sideband system temperatures of 1000 K and 2250 K, respectively. Each system had a sideband separation of 9500 MHz. Each receiver was calibrated by observing an absorbing mechanical vane for signal and cold sky for reference, while the telescope was at the same elevation as the source in order to correct for atmospheric extinction and telescope losses (Ulich and Haas 1976). Data were taken while position-switching the telescope in azimuth between the source and a reference position 30′ (1° for Sgr B2) away on the sky. System checks were conducted on the 43 GHz line of SiO or the 141 GHz line of H_2CO. The corrected antenna temperatures $T_A{}^*$ quoted in this paper have been corrected for antenna and atmospheric losses, but not for possible beam dilution.

If PN were a gas phase constituent of interstellar clouds, its detection and identification would be favored because of its large dipole moment (2.75 debye), simple structure, and the relatively high abundance of

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TABLE 1

PN AND PH_3 SEARCH DATA SUMMARY

Source (1)	α(1950) (2)	δ(1950) (3)	PN $J = 1–0$ T_A^* (K) (4)	PN $J = 3–2$ T_A^* (K) (5)[a]	PH_3 $J = 6$ T_A^* (K) (6)[a]	PH_3 $J = 8$ T_A^* (K) (7)[a]	Assumed LSR Radial Velocity (km s^{-1}) (8)
W3(OH)	$2^h23^m17.0^s$	61°38′54″	<0.5[b]	...	...	<0.3	−48.2
Cloud 2	4 38 38.6	25 35 35	<0.5[c]	...	...	<0.2	+6.0
Ori A	5 32 47.0	−05 24 21	<0.2[b]	<0.1	...	<0.2	+8.8
NGC 2024	5 39 12.0	−01 55 42	...	...	<0.6	...	+8.8
IRC +10216	9 45 14.8	13 30 41	<0.2[b]	<0.15	<0.2	<0.1	−22.0
Sgr B2	17 44 11.0	−28 22 30	<0.2[b]	<0.2	<0.2	<0.1	+60.0
W51	19 21 27.0	14 24 30	<0.2[b]	<0.3	<0.4	<0.2	+58.3

[a] Peak-to-peak noise level in the 1000 kHz filter bank.

[b] Peak-to-peak noise level in the 250 kHz filter bank.

[c] Peak-to-peak noise level in the 100 kHz filter bank.

interstellar nitrogen. Moreover, the hyperfine structure for the $J = 1–0$ transition of PN has been observed in the laboratory (cf. Lovas and Tiemann 1974) and would allow easy identification of an interstellar feature; the hyperfine components for which we searched were the $F = 1–1$ *at* 46,989.017(.03) MHz, the $F = 2–1$ at 46,990.559(.02) MHz, and the $F = 0–1$ at 46,992.862(.04) MHz. During the post-observational analysis of our PN $J = 1–0$ transition results, we noted that the $J = 2–1$ transition of PN was nearly coincident in frequency with U93980 as reported by Clark, Lovas, and Johnson (1979). We therefore conducted a search for the $J = 3–2$ transition with blended components at 140,967.75(.10) MHz (cf. Lovas and Tiemann 1974), since the 3–2 transition is theoretically a factor of 3 stronger than the 2–1 transition. Subsequent review of the Clark *et al.* data has indicated that U93980 should be designated U93780.

A detection of the $J = 1–0$ transition of PH_3 was not possible because it lies at 267 GHz (beyond the range of NRAO receivers), which forced us to search for less desirable $\Delta k = \pm 3$, $\Delta J = 0$ transitions of PH_3 caused by small induced dipole moments (Chu and Oka 1973). We concentrated our PH_3 search on the least intense ($J = 6$) transition at 47,390.3(.8) MHz and one of the more intense ($J = 8$) transitions at 46,938.4(.3) MHz. PH_3 transition frequencies and calculated intensities were used from Chu and Oka (1973).

III. CONCLUSIONS

No indication of the 1–0 and 3–2 transitions of PN and the $J = 6$ and 8 transitions of PH_3 was found. Our results are summarized in Table 1. The values of T_A^* in columns (4)–(7) are the line detection limits estimated from the peak-to-peak noise levels. Column (8) gives the local standard of rest (LSR) radial velocity assumed for each source searched (cf. Hollis *et al.* 1975 and Broten *et al.* 1978). Several new spectral lines were found during these observations; Table 2 summarizes our detection of the $J = 3/2–1/2$, $F = 3/2–3/2$ transition of nitric oxide, and the $J_{K-K+} = 16_{4,12}–15_{5,11}$ transition of sulfur dioxide in Ori and Sgr B2, as well as U140921.8 detected in IRC +10216. Our search results for the 47 GHz transitions of PH_3 are not unexpected since transitions with small induced dipole moments are probably rare in the interstellar medium. At the present time the $J = 1–0$ transition of PH_3 at 267 GHz seems a good candidate for interstellar detection since it is analogous to the abundant interstellar ammonia, NH_3, molecule. On the other hand, PN may not be in the gas phase in interstellar clouds

TABLE 2

SUMMARY OF NEW SPECTRAL LINES

Molecule (1)	Transition (2)	Frequency (MHz) (3)	Ori A T_A^* (K) (4)	Ori A ΔV (km s^{-1}) (5)	IRC +10216 T_A^* (K) (6)	IRC +10216 ΔV (km s^{-1}) (7)	Sgr B2 T_A^* (K) (8)	Sgr B2 ΔV (km s^{-1}) (9)	W51 T_A^* (K) (10)	W51 ΔV (km s^{-1}) (11)
U140921.8	...	140921.8	<0.1	...	0.20 (3)	25 (2)	<0.2	...	<0.3	...
SO_2	$16_{4,12}–15_{5,11}$	150381.1	0.38 (2)	25 (3)	<0.15	...	0.25 (4)	22 (3)	<0.3	...
NO	$J = 3/2–1/2$ $F = 3/2–3/2$	150439.22	0.15 (2)	17 (3)	<0.15	...	0.21 (4)	20 (3)	<0.3	...

NOTE.—Source positions and assumed LSR radial velocities are given in Table 1. Limits are peak-to-peak noise levels in the 1000 kHz filter bank. Uncertainties are 1 σ on 1000 kHz data.

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since it is a refractory molecule like SiO; it therefore is probably an interstellar grain molecule but may yet be detected in high-temperature (~ 800 K) stellar envelopes.

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JAN M. HOLLIS: Laboratory for Astronomy and Solar Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771

F. J. LOVAS: Molecular Spectroscopy Division, Building 221, National Bureau of Standards, Washington, DC 20234

LEWIS E. SNYDER: Department of Astronomy, 341 Astronomy Building, University of Illinois, Urbana, IL 61801

B. L. ULICH: Multiple Mirror Telescope Observatory, University of Arizona, Tucson, AZ 85721

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