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RADIO OBSERVATIONS OF COMETS

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Three general techniques of radio science have been used to attempt to observe comets: spectral line, continuum and radar observations. Of these, only radio spectral line observations have achieved a degree of success but, more often than not, the results have been negative. Thus any study of cometary radio spectroscopy must examine what is known about cometary excitation and why radio searches can fail.

The molecules which have been detected via radio spectroscopy include HCN, CH_3CN, OH and CH from comet Kohoutek (1973 XII) and possibly H_2O from comet Bradfield (1974 III) (see Snyder 1976). In addition, radio detections of OH have been reported for the following comets:

Kobayashi-Berger-Milon (1975 IX): Gerard et al. (1977)

West (1976 VI): Snyder et al. (1976); Bowers and A'Hearn (1976); Gerard et al. (1977).

p/d'Arrest (1976 XI): Webber and Snyder (1977).

p/Encke (1786 I): Webber, Snyder and Ensinger (1977).

Kohler (1977 XIV): Despois et al. (1977).

Bradfield (1978 VII): Despois et al. (1978).

Meier (1978 XXI): Despois et al. (1979); Webber (1979); Giguere, Huebner, and Bania (1981).

The negative result list from report radio searches includes:

Bennett (1970 II): H_2O, H_2CO (see Snyder 1976).

Kohoutek (1973 XII): H_2CO, OH (excited states), HC_3N, (ground and $2\nu_7$), HCN (ν_2 and $2\nu_2$), H_2O, NH_3, $CH_2(CN)_2$, CH_3OH, CH_3C_2H, $(CH_3)_2O$, SiO (V = 1), HNCO, HCO^+, HNC, CO and CN (see Snyder 1976).

Kohler (1977 XIV): H_2O (Crovisier et al. 1981).

Bradfield (1978 VII): HCN, CO and CH_3CN (Schloerb, Irvine and Robinson 1979).

Meier (1978 XXI): H_2O (Crovisier et al. 1981).

Bradfield (1979 X): OH (excited state), H_2CO, $HCOOCH_3$, H_2O, and NH_3 (Hollis et al. 1981).

Other comets have been searched for radio lines but the negative results have gone unreported.

Clearly OH is the best established radio molecule in comets. Even so, I remind participants at this workshop that the very first radio OH results, those observed by Turner (1974) from Comet Kohoutek (1973 XII), were so weak that they were hardly believed to be real by many experienced observers. Now we know that not only were the OH real data (as confirmed by Biraud et al. 1974) but also many comets exhibit detectable radio OH. Furthermore the radio OH signal strength is strongly affected by the Swings effect and somewhat by the Greenstein effect. A bibliography of these and other exotic effects is given in the paper presented by Professor Delsemme at this meeting. In the Swings effect, the cometary OH absorbs the Doppler-shifted solar UV Fraunhofer bands which give rise to steady-state fluorescent pumping of the $^2\pi_{3/2}$ ground state doublet levels to the electronically excited $^2\Sigma^+$ state. The OH molecules return to the ground state doublet via UV and IR radiative cascade, thereby determining the relative populations of the ground state doublet levels, the ensuing sign (absorption or emission), and the intensities of the radio OH signals from the comet (Biraud et al. 1974; Mies 1974). The Greenstein effect provides additional inversion due to the expansion velocity of the OH relative to the cometary nucleus (see Despois et al. 1981 for an analytic treatment of the radio case). To further complicate the OH detection problem, Elitzur (1981) has shown that small optical depth effects can alter the OH inversion so that, for example, the 1665 MHz line is detectable in emission at a few mK while the normally strong 1667 line has zero intensity. Clearly the Swings effect with optical depth could cause observers to entirely miss detection of radio OH in a comet. The point to be made here is that even a well established cometary molecule such as OH may elude radio detection due to common cometary physical conditions which dominate the radiative transfer. The case with the 6_{16} - 5_{23} transition of H_2O at the 1.35 cm is even worse. At this point, almost everyone agrees that the H_2O excitation will have to be nonthermal in order to be observed at 1.35 cm in a comet (see Crovisier et al., 1981, for the latest discussion of this problem).

To conclude, let us summarize what we may learn about radio molecular detections of molecules beyond OH from the past observations of all molecules. A set of empirical rules for molecular detection would be:

1. The best results may be expected around perihelion.

2. The best comets are those with close perihelion passage. It appears that huge comets with R ~ IAU, like Meier (1978 XXI), are not as good as dusty comets with small perihelion distances, like Kohoutek (1973 XIII) which had R ~ 0.14 AU. A dusty comet which breaks up during perihelion passage would be ideal.

3. In all cases, radio observers should concentrate on comets for which optimum values of R and Δ can be obtained. Optimum R is believed to give optimum molecular production and excitation while optimum Δ gives minimal beam dilution.

We need to build observational statistics for molecules more complex than OH so that we can learn if esoteric excitation conditions determine the rules for detectability of cometary polyatomic moles just as they do for OH. Only then will we be able to fully utilize radio observations of complex cometary molecules for serious physical modeling.

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