RADIO OBSERVATIONS OF COMETS

L. E. Snyder
Astronomy Department
University of Illinois
Urbana-Champaign, IL

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$_3$CN, OH and CH from comet Kohoutek (1973 XII) and possibly H$_2$O from comet Bradfield (1974 III) (see Snyder 1976). In addition, radio detections of OH have been reported for the following comets:

- West (1976 VI): Snyder et al. (1976); Bowers and A'Hearn (1976); Gerard et al. (1977).
- Meier (1978 XXI): Despois et al. (1979); Webber (1979); Giguere, Huebner, and Bania (1981).

The negative result list from report radio searches includes:

- Kohoutek (1973 XII): H$_2$CO, OH (excited states), HC$_3$N, (ground and 2υ7), HCN (υ2 and 2υ2), H$_2$O, NH$_3$, CH$_2$(CN)$_2$, CH$_3$OH, CH$_3$C$_2$H, (CH$_3$)$_2$O, SiO (V = 1), HNCO, HCO$^+$, HNC, CO and CN (see Snyder 1976).

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 $2^3/2$ ground state doublet
levels to the electronically excited $2^3/2$ 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
crystal 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$_2$O at the 1.35 cm is even worse. At this point, almost
everyone agrees that the H$_2$O 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 $R \sim \text{IAU}$, like Meier (1978 XII), are not as good as dusty comets with small
perihelion distances, like Kohoutek (1973 XIII) which had $R \sim 0.14$ 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 $A$ can be obtained. Optimum $R$ is believed to give optimum molecular production and
excitation while optimum $A$ 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.

I wish to thank Professor Delsemme for sharing his extensive list of cometary effects. This
work was partially supported by NSF grant AST 79-07830 to the University of Illinois.

References

Astrophys. 34, 163.


Crovisier, J., Despois, D., Gerard, E., Irvine, W. M., Kazes, I., Robinson, S. E., and Schloerb,

Observatory) 13, 8.

Despois, D., Gerard, E., Crovisier, J., and Kazes, I. 1979, preprint, IAU General Assembly. XVII,
Commission 15.


Webber, J. C., Snyder, L. E., and Ensinger, J. 1977, BAAS 9, 564.