PdS = Average: Too much time
Give them 2 weeks.

PfS = Good; Rumors of HCN detection
make this reasonable.

P5
36 ft
CN, CO, HCN Line detection
90-140 GHz Bell Tel Rx
40 ch, 1 MHz NRAO Backend
2, 4 week periods, Sep. by 1 mo.
March 15 - June 15, 1970

**Bell Telephone Laboratories**
Crawford Hill Laboratory
Box 400, Holmdel, N.J. 07733
Telephone 201 949-3000

February 27, 1969

Sched Mar 31 - Apr 15 } 1970
(Heut) May 7 - 21

DR. WILLIAM E. HOWARD
National Radio Astronomy Observatory
Edgemont Dairy Road
Charlottesville, Virginia 22901

Dear Dr. Howard:

We are writing to propose an experiment using your Kitt Peak Antenna. Briefly, we propose to construct a receiver to operate in the RG138/U waveguide band (nominally 90-140 GHz) for the purpose of searching for line emission. The sources we intend to investigate are, in descending order of our interest, CN, CO and HCN in addition to a number of recombination lines.

The well known optical detection of CN, not only in its ground state, but also in its first rotational level, (approx. 114 GHz higher), corresponds to an excitation of approximately 3°K (Field, G. B. and Hitchcock, J. L., Ap. J., 146, 1, (1966)). If this excitation is attributable to a general cosmic microwave background radiation, then it will produce no net emission at the frequency of the transition. If, on the other hand, the microwave background does not extend to this frequency, the excited CN will produce a detectable emission. Thus this measurement can provide valuable information on the microwave background, given adequate receiver sensitivity.

On the basis of the attached calculation, we estimate that $10^{14}$ atoms/cm$^2$ in the line of sight would give an absorption coefficient of unity. This would correspond to an average density of $10^{-9}$ atoms/cc along a path through the galactic center, a not unreasonable density.

This may be compared with the expected fluctuation level in our receiver. We expect a receiver noise temperature on the order of 300°K. For a 1 MHz bandwidth and a fifty percent switching cycle we have:

3000°K!

$$\Delta T = \frac{0.1^\circ K}{\sqrt{H}}$$

where $\Delta T$ is the RMS fluctuation in output and H is the number of hours of integration time.

Thus, in the absence of a microwave background, an opacity as low as 0.1 in the excited CN would be readily detectable. In the presence of the background radiation, the CN could still be detected against a continum source near the galactic center with a flux sufficient to produce an antenna temperature of the order of a few tenths of a degree.

Although CO has a much smaller dipole moment than CN, it is also worth looking for owing to the fact that its dissociation energy is above the Lyman continum making it potentially much more abundant than other gases heretofore detected in which this is not the case.

The other lines mentioned above would be searched for as time permits. Some early effort on recombination lines is planned in the program in part at least as a convenient check on the sensitivity of the receiver.

The receiver we plan to build would employ diodes like those in the 90 GHz receiver you are now using, but mounted in a higher frequency holder. The main features of this new receiver include a stabilized local oscillator and a 100 MHz IF frequency. The IF frequency is selected to be compatible with your 40 channel, 1 MHz per channel line receiver which we would use as the "back-end".

Should you approve our program, we would proceed to insure the compatibility of our receiver with your equipment. It seems advisable for you to provide us with a feed box in which to mount our receiver to minimize the possibility of mechanical problems with the antenna. Other details would naturally be worked out with the NRAO people concerned as they have been in our past associations.

Specifically, we are therefore requesting a total of eight weeks of observing time between March 15, 1970 and June 15, 1970, preferably in two four week periods seperated by about one month.

The peak absorption intensity $V_{max}$

$$V_{max} = \frac{8\pi^2 N f |\mu_{IJ}|^2 \nu_o^2}{3CKT\Delta\nu}$$ (Townes & Schawlow Eq. 1-50)

where

$N$ = molecular density

$f$ = fraction in absorbing state

$|\mu_{IJ}|^2$ = dipole moment squared, averaged over direction.

If $N$ = 1 molecule/cc, $V_{max} = \sigma$ (cross-section)

$$\sigma = \frac{8\pi^2 f |\mu_{IJ}|^2 \nu_o^2}{3CKT\Delta\nu}$$

Now $f = f_v f_J$

$$f_{\substack{v \\ v=o}} \approx 1-e^{-\frac{h\nu}{KT}} = 1-e^{-\frac{hc}{KT\lambda}} = 1-e^{-\frac{h\omega_e c}{KT}}$$

$$f_{\substack{v \\ v=o}} = 1-e^{-800} \cong 1 \quad \begin{pmatrix} T = 3^\circ \\ \omega_e = 2.17\cdot 10^3 cm^{-1} \end{pmatrix}$$

$$f_J = \frac{(2j+1)e^{-\frac{hBJ(J+1)}{KT}}}{\sum_{n=o}^{\infty}(2n+1)e^{-\frac{hBn(n+1)}{KT}}}$$

for $J = 0$

$$f_J \simeq \frac{1}{\frac{KT}{hB} + \frac{1}{3} + \frac{1}{15}\left(\frac{hB}{KT}\right) + \frac{4}{3.5}\left(\frac{hB}{KT}\right)^2 + \frac{1}{3.5}\left(\frac{hB}{KT}\right)^3 + \cdots}$$

$$f_J \cong 0.62 \left(\frac{hB}{KT} = \frac{6.10^{27} \cdot 5.8 \cdot 10^{10}}{1.14 \cdot 10^{-16} \cdot 3} = 0.83\right)$$

So

$$f = f_v f_J = 0.62$$

$$|\mu_{IJ}|^2 = \mu^2 \frac{(J+1)}{(2J+1)} \quad J \rightarrow J+1 \left(\begin{matrix} T \text{ \& } S \\ \text{Eq. 1-76} \end{matrix}\right)$$

for $J = 0 \rightarrow J = 1$

$$|\mu_{IJ}|^2 = \mu^2$$

So

$$J_{co} \cong \frac{8 \cdot 10 \cdot 0.62 \cdot 10^{-38} \cdot 34 \cdot 10^{20}}{3 \cdot 3 \cdot 10^{10} \cdot 1.4 \cdot 10^{-16} \cdot 3 \cdot 10^{6}}$$

($\Delta\nu$ = 1 MHz)

($\mu = 10^{-19}$ = 0.1 debye)

$\sigma_{co} = 4.4 \cdot 10^{-17} cm^2$ ←

and,

$\sigma_{cn} = 5.3 \times 10^{-15} cm^2$ ←

($\mu = 1.1 \times 10^{-18}$)

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March 18, 1969

Dr. A. A. Penzias
Bell Telephone Laboratories
Crawford Hill Laboratory
Box 400
Holmdel, New Jersey 07733

Dear Arno:

I am replying to your letter of February 27 to Bill Howard, since I am currently doing the scheduling of the 36-ft telescope.

I think that at this early date I can't guarantee the full eight weeks that you have requested. However, I can schedule you now for four weeks next spring, with the understanding that another four weeks will probably be forthcoming. We already have several other proposals to search for lines in the 90-140 GHz band, and some of these will undoubtedly get on the telescope before you do. You may therefore ultimately want to modify your program in the light of their results.

If we have a spare feed box we can loan it to you to mount your receiver in. Otherwise, we can certainly send you the drawings of our feed box so that you can make one yourselves that will be compatible with the antenna.

Best wishes.

Sincerely yours,

Dave

D. S. Heeschen

DSH:fmc

cc: S. Weinreb
W. E. Howard