Dec. 25, 1938
212 W. Seminary Ave.
Wheaton, Illinois

Dr. F. L. Whipple
Harvard College Observatory
Cambridge, Massachusetts

Dear Dr. Whipple:

Thank you for your letter of the 22nd. Since I am unable to attend the Astronomical Society meeting this rather long letter will have to take the place of a talk with you.

At the very beginning I had better point out that my education is as an electrical engineer and my experience has been with the radio industry. While last year I took several courses on astronomy, optics, etc. at the University of Chicago I am not much of an astro-physicist. To me extraterrestrial static appears as one field of physics upon which little has been done and consequently the hunting should be good. My primary interest is the experimental side and while the explanation of all things is important it seems that more data should be obtained to explain before a great deal of effort is made on theory.

A series of papers on this subject will appear in the 1939 issues of "Communications", however for your convenience a synopsis of theory as I have developed it follows.

Free-Free Transitions.

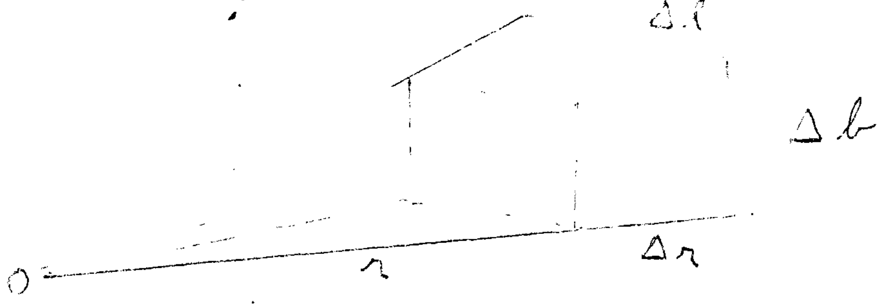
In 1923 Kramers[1] gave the energy liberated due to these free-free transitions as

$$\rho = \frac{32\pi^2 Z^2 e^6}{3\sqrt{3}\, C^3 m^2 U} d\nu \quad \text{ergs/cm}^3\text{/sec} \qquad (1)$$

Eddington[2] applied this theory to the material inside a star. At that time he argued a certain correction due to Einstein should not be applied to Kramers formula. This correction takes into account the stimulation of such radiation due to the transition occuring in equilibrium with an electromagnetic field. Later Eddington[3] applied Kramers theory to the material of interstellar space with the specific argument that the average velocity loss of an electron due to free-free transitions could not exceed 13%. In 1930 Gaunt[4] rederived Kramers formula on the basis of quantum mechanics. He decided that Kramers work is correct for the visual range, too high for the X-Ray range and too low for the low frequencies. Since no application was known he did not go into the low frequency case in detail but definitely stated Kramers formula does not include the effect of stimulated radiation. See pages 196 line 16, page 197 line 9, page 197 line 25, page 203 part 7 "Conclusions". Partly on this authority and partly to fit the theory to the measurments this correction is included in what follows. The correction[2] for stimulated radiation may be reduced to differential form such that true radiation becomes

$$\rho' = \frac{kT}{h\nu}\rho \quad \text{ergs/cm}^3\text{/sec.} \quad (T = 3.2^\circ)\ d\nu \qquad (2)$$

Eddington[3] has evaluated ρ as $\rho = 8.7 \times 10^{-42}$/ergs/cm^3/sec. therefore ρ' becomes $\rho' = 5.8 \times 10^{-31}\ d\nu/\nu$ ergs/cm^3/sec.



The incremental volume in sketch is $\Delta V = r^2 \Delta l \Delta b \Delta r$. The incremental energy arriving at O from ΔV is

$$\Delta I = \frac{\rho'}{4\pi} \Delta l \Delta b \Delta r \qquad (3)$$

Integrating this for 10^4 parsecs in direction of galactic center gives

$$I = \frac{3.43 \times 10^{-17}}{\nu} \text{ watts/cm}^2\text{/cir. deg./kc. band} \qquad (4)$$

Jansky's Data

The intensity of the electromagnetic field in space is

$$I = \frac{C E^2}{36 \pi 10^4} \text{ ergs/cm}^2\text{/sec.} \qquad (5)$$

where
E is electric field strength in volts/cm
C is velocity of light in cm/sec

The graph on page 1931 Dec. 1932 Proc IRE gives thermal noise at 25.2 DB below 1 microvolt/meter/kc band. This figure is checked fairly close by graph on page 1934 and amounts to 0.055 microvolt/meter/kc band. Inspection of data shows the maximum values of major peak to be 4.8 DB above thermal noise. Since the signal in question and thermal noise add on a power basis this corresponds to 0.078 microvolt/meter/kc band. The effective acceptance cone of Jansky's antenna may be taken as an ellipse of 30° azimuth and 37° altitude. The average intensity of the energy at 20.5 megacycles per circular degree becomes.

$$I = 1.45 \times 10^{-24} \text{ watts/cm}^2\text{/cir. deg./kc band} \qquad (6)$$

This is in close agreement with the value calculated from (4)

$$I = 1.67 \times 10^{-24} \text{ watts/cm}^2\text{/ cir. deg./kc band}$$

I have deliberately ignored Jansky's 0.39 microvolt/meter/kc band figure as he gives no evidence to substantiate it while later data compare well on the thermal noise basis of smaller figure. So far we have delt with average values. Eddington's figure for ρ being an average and Jansky's measured intensity is the average over the large acceptance cone of his antenna.

Tests at 160 megacycles.

The simple conditions of above calculations do not exist when sufficient resolving power is applied. Actually a large number of point sources and a few patches several degrees in diameter were found. To get a figure comparable with the above calculations the various sources in neighborhood of galactic center were averaged out graphically. This gave an average input power to receiver of 3×10^{-21} watt. The drum efficiency is about 50%, reflector efficiency 85%, reflector area 7×10^5 sq.cm. and the acceptance cone of system about 20' diameter. This gives

$$I = 9 \times 10^{-26} \text{ watt/cm}^2\text{/cir.deg./kc band} \qquad (7)$$

which agrees fairly well with value calculated from (4) of

$$I = 21 \times 10^{-26} \text{ watt/cm}^2\text{/cir.deg./kc band}$$

Remarks

This theory may not be very good but it seems to fit the measurments better than any other. It gets into trouble at zero frequency but there probably more corrections are necessary. The thermodynamics people at Williams Bay also point out the black-body maximum and seemed to indicate an intensity which increases as the frequency cubed similar to Planck's law. The available data does not subscribe to this. I think the fact my points fall on dark areas is pure chance. The size of the particles usually assumed in these clouds may redden or totally obscure light but have no effect on radio wavelengths. Papers published during the last year in the Astrophysical Journal indicate little or no correllation between color index of stars and the intensity of interstellar lines. While discrete clouds of interstellar Na & Ca are indicated (my patches of radiation at Dec.-27,RA 1600; Dec.-26,RA 2000) I view them as an entirely separate and distinct phenomenon from the dark clouds of photography. To make the theory explain any given source will require a re-evaluation of ρ and T for the point in question. The necessary astronomical data may be difficult to get.

It is very unfortunate that I cannot pick out with certainty any absolute direction as I have no absolute calibration on my machine, merely relative direction as indicated by Dec. scale and sidereal time. To get an absolute calibration will require the use of some type of aircraft.

The method of taking data is very laborious in that I must take readings every minute for several hours and then plot.

At the present I am trying to get apparatus into shape for automatic recording. Since I work on this alone I must try to chose the most profitable line of endeavor. Instead of getting a lot of data by hand (and there are no doubt a multitude of points and patches) I have decided to build more sensitive apparatus to measure the known points over again at 800mc. This should be far more useful to the theory than merely more points. Probably no results will be available until March because some of the parts take 8 weeks after order is placed to get delivery. In the mean time a few conspicuous objects like Andromeda nebula etc. will be tried by hand and perhaps an absolute calibration obtained.

While this has been rather long the subject is complicated and if I have not made myself clear please write me again.

Yours very truly,

Grote Reber

Grote Reber

P.S. It would be highly desirable to get data at 10mc and down in frequency. Since my machinery will not work at low frequency perhaps you could contact some communication company in the east for the loan of a directive antenna pointed south. When certain types of wire arrays are used the acceptance cone can be raised and lowered in altitude by completely electrical methods and no fancy mechanical devices are required.[5]

References

1. Theory of the Continuous X-Ray Spectrum, H.A.Kramers, Phil. Mag. Vol 46; page 836, 1923.

2. Absorption of Radiation Inside a Star, A.S.Eddington, Monthly Notices, Vol 84, page 104, 1924

3. Diffuse Matter in Interstellar Space, A.S.Eddington, Proc. Royal Soc. Vol. 111, page 424, 1926

4. Continuous Absorption, Gaunt, Trans. Royal Soc. Vol 229, page 163, 1930

5. Certain Factors Affecting the Gain of Directive Antennas, C.G.Southworth, page 1502, Sept. 1930 Proc. IRE.

See especially chart opposite page 1518 for sixteen groups of one couplet each.