30th December 1964

Dear Hap:

It has been a long time since I've written to you in person. Thanks for your good letters of the 1st September and 6th October. I appreciated your Christmas card and that from Sam Smith. They make me feel not so far away after all.

It is well for one to occasionaly write down just how matters stand as it clarifies the thinking. Enclosed are two copies of the pregress report I promised some months ago. After reading it over I am rather more pleased with it than I expected. Most was typed in the office here. I completed the last two pages to prevent loose talk and speculation which might be a nuisance.

The last 1963 night providing useful data was december 6th. This year it was December 5th. Probably merely a coincidence. Using last year as a guide, data should appear again about the middle of January.

A few weeks each year the pastures are green at Bothwell. This provides good contrast and makes the grey poles stand out. I have had some good aerial fotos taken of my installation. The only prints received are too large for mailing. I will have small ones made and sent in due time.

The cosmic ray analysis is nearly completed. It has turned out much better than I expected. I intend to write the results into a short paper with a few graphs and send it to the Franklin Institute Journal. They seem to like this kind of thing. The Bartol Research Foundation does cosmic rays, I am told.

A lot of time, money and effort has gone into the archeology affair. I must organize it into a finished picture and close it up.

Somewhat against my better judgement, I planted a couple of rows of beans which seem to be doing well. These should be the last. I intend to shift over to climbing lilies.

Enclosed is a note to Jennie. 1965 should be a very busy year.

Happy New Year.

Grote

Grote Reber

30th December 1964

Greetings Jennie:

Thanks for your letter of the 15th and note of the 23rd. They arrived here on the 21st and 28th. The package of chart paper arrived in good order on the 9th. The radio condenser has not appeared. If it has not gone off, forget it as it is too late to be of use here.

The microbarograph chart sample 5-448N is satisfactory. Please order 100 and send by sea.

Enclosed is the slip from Central Aguirre Sugar Co. My savings account is 99-14343 Chase-Manhattan, 422 Lexington Ave., William Martin is Assistant Treasurer.

Something is odd about the IEEE charts. They returned my original drawings to me here last september. You must have copies or somebody else drawings. Please keep them until the reprints show up. A comparison can be made. If mine, please hold. If not, return to IEEE.

Enclosed are three reprints of "Reversed Bean Vines" in Journal of Genetics.

Thanks for ordering the maps. I look forward to perusing them closely.

Happy New Year.

Grote Reber

Grote Reber

Radio Astronomy Results from Bothwell

by Grote Reber

Introduction

The radio sky at meter waves is rather similar to the optical night sky. A dark background of low luminosity is split by a bright streak of high luminosity, namely the Milkyway. A typical set of luminosity contours are portrayed by my map published in the Astrophysical Journal 1944. Part of the energy of the radio Milkyway is produced in local galactic objects radiating by the synchrotron mechanism. A diffuse source of energy is the result of free-free transitions in the ionized hydrogen which pervades the plane of the Milkyway. Cerenkov radiation may contribute in a minor fashion. Sprinkled over the background at high galactic latitude are assorted bright dots. These are mostly objects beyond the confines of the Milkyway.

Observations

The radio sky at hectometer waves bears some resemblance to the optical day sky. A bright background of high luminosity is split by a dark streak of low luminosity, namely the Milkyway. This dark streak is another manisfestation of the ionized hydrogen which pervades the plane of the Milkyway. At hectometer waves the ionized hydrogen absorbs the energy coming from behind it in same manner as radio waves are absorbed during the day in the terrestrial ionosphere at about 80 kilometers altitude. This different manifestation of the ionized hydrogen in the plane of the Milkyway is interesting. Its study can tell more about the details of the constitution of our galaxy.

However, the important phenomenon before us is the bright background which reaches greatest luminosity near the south galactic pole. Where does this unexpected energy come from and how is it produced? Examination of the dark streak will provide some hints. The luminosity is lowest, approaching complete extinction over a small region at longitude 330° which is in the direction of the Milkyway center. Thus, most of the energy in this direction must come from behind the nucleus of the Milkyway. The absorption becomes less as one examines longitudes on either side of 330°. Feeble bright anomalies appear near longitudes 320° and 348°. These are probably local radiators. Perhaps the former is associated with our spiral arm, and the rather weaker latter with a hypothetical arm opposite to ours. As one observes farther around the plane of the Milkyway the absorption trough becomes more wide and shallow. At 210° longitude the bottom of trough has a luminosity nearly half that observed at the pole. Thus the absorption must be feeble toward the periphery of the Milkyway. The absorption may be nearly zero at longitude 150° which is the anticenter. Unfortunately this direction cannot be observed from Tasmania.

Apparently the background energy comes from well outside the immediate plane of the Milkyway. It might be from a halo surrounding our galaxy. However the position of the Small Magellanic Cloud coincides with a small dip in the bright background. Apparently this object also has some ionized hydrogen

within. If such be correct, at least part of the background energy comes from a vast distance beyond the Clouds of Magellan. Observations on the larger cloud were inconclusive due to poor conditions.

Theory

A scientific axiom is that, when evidence is lacking, the best assumption is the simplest. Up to a half century ago this was practiced within our Milkyway. The stars were considered discrete entities in a void. Interstellar space was a perfect vacuum. Gradually the void has been filled with gas, dust and magnetic fields. Stellar atmospheres have become larger so that now our entire planetary system is within the solar exosphere.

Peculiarly, this enlightened view has not extended outside the milkyway. Today the nineteenth century void concept is still practiced for intergalactic space. Such is most remarkable when the ratio (distance between the stars)/(diameter of stars) is about 10^6 times the ratio (distance between the galaxies)/(diameter of galaxies). The void hypothesis is at the bottom of the scientific bankruptcy manifest by assorted expanding universe theories.

Conditions

The gas within the galaxies is in violent turbulence. It is ionized by the hot stars and has a commensurate kinetic temperature of about 10^4 degrees. It is retained by combinations of galactic gravitational and magnetic fields. However in any

boiling medium there is a wide scatter of energies among the particles. A few hydrogen atoms will receive sufficient velocity to escape into intergalactic space. These may average about 10^5 degrees. Eventually they will be swept up by another galaxy. These two mechanisms will come to an equilibrium.

Assumptions.

To fill the void, I will assume a mean density of 0.1 atom per cc and a velocity equal to a kinetic temperature of 10^7 degrees. The mean free path will be about one tenth parsec.

Radio Consequences

These conditions will produce 99 percent opacity of the medium to 144 meter wave energy at a distance of 10^7 parsec. The apparent luminosity will be that of the kinetic temperature. This agrees with the observed bright background. Since the medium is essentially opaque beyond 10^7 parsecs, the only radio sources available for observations must be within this distance. Centaurus A corresponding to NGC 5128 at 7.5×10^5 parsec appears strongly. Fornax A corresponding to NGC 1316 at 5×10^6 parsec is much weaker. Pictor A, which so far has not been associated with any visible object, is just detectable. A few other faint unidentified radio sources have been turned up at high galactic latitude. Several low latitude sources, prominent at meter waves, have not been found. These results tend to confirm the above descriptive hypotheses.

Optical Consequences

If the above be approximately correct the assumptions may have other inbuilt connotation. For instance, ionized hydrogen may be regarded as an electron gas. The protons are inactive due to their large mass. ' Such a gas will have a refractive index less than unity. Electromagnetic wave energy travelling thru such a medium will not speed up but its phase velocity will increase above that of a void. Consequently the wavelength will increase. Engineering-wise this condition is sought after. A parallel wire line merely guides the wave energy surrounding the wires. A perfectly matched line free from standing waves has infinite phase velocity.

A light wave will interact with free electrons if a feeble magnetic field is present. Such can be produced by the moving charges. Some of the energy of the light quanta will be transferred to the electrons which raises their velocity and consequently the kinetic temperature of the medium. Thus the desired 10^7 degrees may be achieved from the 10^5 degrees at which the particles are injected into the intergalactic medium.

Returning to the wave, we find it has been lengthened and it has lost energy. The energy of a light quanta is $Q = hv = hc/\lambda$ where h is Planoks constant, c the velocity of light in vacuum, v the frequency and λ the wavelength. Since h and c are constant, v must decrease or λ increase when Q decreases. The phenomenon is cumulative with distance and accounts for the well known optical

red shift of spectral lines in distant sources. Thus the red shift is an indicator of distance, but not an indicator of relative velocity.

Briefly, the light energy is transferred to the intergalactic medium, observed as a bright background at hectometer waves and is ultimately soaked up by low temperature ionized hydrogen within the various galaxies such as our Milkyway, Small Magellanic Cloud, etc. This helps stoke the furnaces at the center of galaxies and build new stars. It also prevents the kinetic temperature of the intergalactic medium rising indefinitely and keeps the medium transparent when observed at meter waves.

A measure of distance

Consider again the discrete sources immersed in a medium which is more transparent at shorter waves. If the source is nearby it may be observed up to hectometer waves. If source is at a middle distance it can be observed only to dekameter waves. If source is at a large distance it can be found solely by meter waves. Thus the spectra will have a declining intensity-wavelength characteristic which is a function of distance. Once this turn down wavelength has been calibrated, radio astronomy will have an independent indicator of distance. It may then be applied to any radio source, even if not associated with a visible object.

Retrospect

Recently I have secured data from Alouette satellite which shows the ionosphere has a rather deep minimum in its electron

density between 40° and 45° South latitude. This confirms my deductions of a dozen years ago based upon ground ionosphere observations. The ionosphere is most transparent near the latitude of Bothwell at 42.5°S.

Small sunspots of the past solar activity cycle still appear irregularly at low solar latitude where they can spray the earth with particles from time to time. These cause weak ionospheric upsets. They will gradually disappear. However over six months ago a few spots of the new cycle appeared at high solar latitude. Their presence is not yet apparent at the earth, but they will be increasingly effective as they gain in number, size, persistence and move toward the solar equator. Apparently we are right at solar activity minimum. This agrees with my guess of five years ago. The present solar activity minimum has been a short and rather high one as the new spots appeared before the old ones went away. Rarely has the sun been without some spots. Obviously this is a disappointment. However, it confirms my estimate from radio observations that the present minimum is not nearly as low as the minimum of the early thirties.

Before coming here I was sold a bill of goods by the promoters of cross antennas. Such a device was designed and a complete survey laid out. Fortunately I decided that techniques suitable for meter waves were not necessarily applicable to hectometer waves. All the survey pegs were pulled up. A new design was made of a

filled in array with circular periphery. Experience has shown this to be a very satisfactory configuration. It has extremely low side lobes. Atmospherics and station interference are far below, a level causing difficulty. The entire system is limited by ionospheric transparency and stability.

The scientific strategy has been good in that I came to the right place at the right time and did the right thing. The satellite fellows have not yet gotten to where I was in 1955. I doubt they will ever get to where I am now. To do so, they will have to put my entire installation at Bothwell into orbit. Much better approaches are outlined in my review article entitled Hectometer Cosmic Static.

The scientific tactics have been influenced too much by expediency and available time. Now it is easy to see many small improvements which could have been made in antenna design. However things work reasonably well and maintenance is not prohibitive. Like most things, it could be done better a second time.

Future

Some discrepencies exist between my 1963 and 1964 data. One more year will be needed to consolidate these and put things in good shape. Probably 1965 is the last available year of this solar activity cycle. It must be used to maximum capability.

The theory described verbally above should be called ideas. The various parameters must have numbers attached and the whole matter reduced to quantitative analysis.

A large number of poles and wires are available. This is the time and place to carry out engineering development on antenna design. An assortment of changes in support and termination of the wires are indicated. Special tools for handling this hard stiff wire need to be designed and tried. New smaller, better and cheaper antenna tuners and impedance transformers have already been designed, constructed and tested. I intend to install a complete east-west line of these to be certain of the overall performance. The problem of pole rot near ground line appears to be solved. These poles have been in the ground three years. The normally soft sap wood on the surface is hard as stone and will not even sliver. It seems to becoming petrified.

The most important development is apparatus improvement to make better use of good observing periods when the ionosphere is transparent and stable. Only one beam is now in use. A better system would have five to nine slightly overlapping beams to scan several declinations simultaneously. These would multiply the rate of data taking and greatly reduce the time to make a survey. An even better scheme is to use a pair of beams which slowly sweep respectively north and south from zero to fifty degrees zenith angle. These would be similar to the motion of butterfly wings. By suitable output portrayal the device could be made to plot a sky map directly. The complexity would be little, if any more than a multiple beam system. Whatever is designed, the beam direction should be adjustable by means of knobs from inside a comfortable

building. The present system of changing a multitude of connections on many overhead wires outdoors is cumbersome, inefficient and unpleasant during winter. Bad connections are made too easily.

A further search

The southern sky is far from worked out. Much more can be done and learned about absorption within the Milkyway. However, I prefer to leave that for someone else. I think I have skimmed off the cream and should get on with other matters.

The most important phenomenon is the bright background and its features. The region toward the anticenter of Milkyway is particularly important. This is only visible from the northern hemisphere. If the above descriptive theory and evidence are even approximately correct, a few predictions can be made of how the northern sky will appear at hectometer waves.

a. The hydrogen absorption in plane of Milkyway will decrease to practically zero at the anticenter. There, the background should be as bright as at the galactic poles.

b. At meter waves the anticenter is in Perseus. At hectometer waves the anticenter will be in Taurus.

c. Cassiopeia A, at meter waves is the second brightest source in the sky. It is a local object in plane of Milkyway in region of moderate hydrogen absorption. It should be visible at Hectometer waves.

d. Cygnus A is the brightest source at meter waves. It is at a distance of over a hundred million parsec; far beyond the opaque visibility limit for hectometer waves. Consequently it should be absent.

e. Andromeda nebula, M31, is a nearby normal galaxy probably with much ionized hydrogen. It should appear as a low luminosity dimple on the bright background.

f. Taurus A, the Crab Nebula, is a local Milkyway object in region of low hydrogen absorption. It should be bright. The ratio of intensity of Cassiopeia A to Taurus A will give information on the ionized hydrogen toward the periphery of the Milkyway.

While data taking is in progress and a map of the southern sky is worked up; all these matters may be considered. Probably new ones will appear. I expect to study the maps Jennie sends in great detail and pick out a score of possible sites. This is the simplest and cheapest method of touring the country. It will provide me with a goodly selection of sites to examine in person when I return.

Gradually I am evolving an improved antenna design which should cover an elliptical area about 7500 feet east-west by 8600 feet north-south. The beam will be about four degrees in diameter. The ground should be flat plus or minus 16 feet, equal to 1/30 wavelength or equal to a phase change of 12 degrees.

Grote Reber

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30th December 1964