July 16th, 1946
212 W. Seminary Ave.
Wheaton, Illinois

Dr. Otto Struve, Director
Yerkes Observatory
Williams Bay, Wisconsin

Dear Dr. Struve:

Enclosed is a rather long monograph on the future of Cosmic Static. This outlines my ideas substantially as they are today. It was my original intention to bring this material with me on the 24th. However it appears more practical to send it on in advance so that you will have time to go over it and organize your ideas before we discuss the situation.

Recently I have had some correspondence (which I will also bring) with Dr. Shapley who believes we can secure some funds in moderate amount. The remaining item necessary is a good location. In securing this I believe you can be of great assistance.

If possible I would like to set program B in motion in the near future and get everything removed from Wheaton before cold weather sets in.

Sincerely yours,

Grote Reber

Grote Reber

PROGRAM FOR THE INVESTIGATION OF COSMIC STATIC

Introduction

A comprehensive investigation of cosmic static may well consist of two parallel, complimentary and simultaneous programs.

Astronomical Program "A"

Astronomical studies involving measurement of the phenomena, interpretation of the results and theoretical analysis of sources.

Development Program "B"

Engineering development of improved electronic equipment and methods of detecting these radiations.

From an astronomical point of view the greatest need in this cosmic static investigation is increased resolving power. Such may be achieved by using higher frequency electronic equipment or a larger mirror or both alternatives.

At the present time 480mc is quite far into the region of diminishing returns for the electronic equipment. By continuation and refinement of the present techniques it may be possible to go up another octave. This development would take two or three years to arrive at apparatus of useable sensitivity. Beyond that will require something new and yet unknown in the electronic art. The expense of these electronic development programs is quite substantial when probing into unknown fields. Consequently the best and most certain road to success in securing greater resolving power is by means of a large mirror.

ASTRONOMICAL PROGRAM "A"

Astronomical Work

The details of the astronomical studies must be left to persons skilled in these matters. In general the program will consist of making there surveys of the source of this radiation and measuring its intensity at a variety of frequencies. A second problem which can be attacked is the spectral distribution, if any, from given directions with the aid of radio frequency spectrometers (wave analysers). The design and construction of such apparatus falls in ~~program B~~ Part IV. It is for these spectroscopic investigations that an equitorial motion of the mirror is absolutely necessary to counteract the effect of the rotation of the earth.

Theoretical work may be carried out at any observatory or university where such skilled scientists are now located. Data may best be accumulated and stored at one location however and not necessarily at the place of observation. The theoretical men should be in close touch with the observers so that maximum observational results may be secured.

Location of the Observatory

The mirror should be located at a southern latitude and in the country far away from man made electrical noises. Of all these noise sources, auto ignition systems are by far the worst. Natural static is very weak and uncommon at these frequencies, even in the tropics.

A southern latitude is necessary because the structure will stand out of doors with no protection from the weather. Snow and ice will cause serious unbalance. One accident has already been had due to this cause (see Ap. J., Nov. 1944, page 284, next to the last paragraph).

Likewise a larger part of the celestial sphere is available for measurement at a southern latitude. To this end the mirror should be located on a cliff which drops abruptly to the south with a long level plain stretching from the base of the cliff to the southern horizon. The reason for this is as follows. When the acceptance pattern (single lobed) of the mirror is pointed horizontally, ground reflections break the single lobe up into a diffraction pattern. The angle which the lowest lobe of this pattern makes with the horizon is inversely proportional to the height of the mirror in wavelengths above the reflecting plane. This difficulty will be mitigated by mounting on a cliff which overlooks a plain to the south; as it is in this direction that the lowest angle to the horizon will be desired. Terrain in other directions is not important provided large obstructions such as mountains are not close by.

Clear weather is desirable but not of primary importance because haze and light clouds have small effect upon these wavelengths. A wide variety of suitable locations is available in the south west Texas. McDonald Crest observatory would be a suitable base of operations to provide living quarters for

To inaugurate a worth while astronomical program will require a very large mirror as the major piece of equipment. Such mirror should be about 200 feet in diameter and represents a substantial capital investment. Probably $100,000 will be necessary to build it. The maintenance and operating charges will be relatively small however. Maintenance will consist of painting and lubricating costs. The operating charges will consist of bills for electrical power necessary to run the apparatus plus small sums for upkeep of the electronic equipment, forinstance tube replacements, and recorder supplies such as record chart and ink.

A small capital investment will be necessary for a structure to house the control and recording equipment.

The program will have to include personnel salaries also. These however can probably be absorbed by existing observatories where such personnel skilled in astronomical procedure is already available.

Mirror

The only presently available mirror is of transit telescope design. Since motion in declination only is provided it is necessary to rely upon the rotation of the earth to sweep out a band in the sky. Only one sweep can be made in each day. At least two charts must be made at each declination for confirmatory purposes. Thus a great many days will be required to cover the sky using such a system. Even with the present 31 foot mirror at 160mc it consumed the better part of a year to secure the information presented in figure 4, page 285 of the Nov. 1944 Ap. J. New apparatus is now functioning at 480mc with this same mirror. Something over two years will be required to make a comprehensive study using these slow and laborious methods. Obviously such procedure involving a really large mirror is absolutely out of the question.

Mounting

The obvious solution to the above difficulty is to provide the mirror with an equitorial mounting. Such a mounting for a 300 foot mirror would be a really gigantic affair and would more than double the cost of the mirror. A suitable alternative may be had in an altiazimuth mounting with proper drive. This drive must so control two motions (altitude and azimuth) that one effective motion (right ascension) is produced.

Such can be accomplished by a suitable control box. This

box will consist of one motor driving an equitorially mounted shaft at a speed equal to the desired rate of rotation of the mirror. By a combination of cams and levers this equitorial motion will be transformed into two separate motions (altitude and azimuth). The separate motions will operate separate selsyn generators. These inturn will control an amplydine drive which will supply power to the main driving motors of the mirror mounting. Thus complete and instantaneous control may be had over the main mirror mounting at all times from the control box at a remote location.

Provision must be made for locking or braking. Such mechanism should be push button operated from the same control box and supplied with suitable electrical interlocks to prevent power being applied to drive motors when brakes are on. Since this mirror will stand outside with no dome for shelter, a braking mechanism is absolutely necessary to prevent damage from the wind.

A remotely controlled drive of this type would be impossible to build for use with a conventional telescope where the angular accuracy desired may be on the order of a second of arc. However for this mirror the accuracy desired need only be on the order of a few minutes of arc (see below) and therefore it enters the realm of practicability.

Accuracy

Upon canvassing the field of electronic equipment it appears that 3000mc is the top frequency that will be useful at any time in the visible future. Little is to be gained by constructing a mirror with an accuracy greater than a quarter of a wavelength

which for this frequency is one inch. How this inch deviation should be distributed is a matter for the mirror designers to decide. Probably the mirror itself can be made accurate to about one half inch and the remaining half inch allowed for flexture of the supports during movement. The greater the allowable flexture, the lighter the whole assembly need be and the cheaper it may be constructed.

The resolving power of a mirror 300 feet in diameter at 3000mc is plus or minus 3 minutes of arc, or the acceptance pattern is 6 minutes wide at half intensity (3DB down). Consequently if the drive is able to reproduce a motion in right ascension with an accuracy of plus or minus 3 minutes of arc it should be satisfactory.

Electronic Equipment

Suitable electronic equipment is now available for use at 160mc and 480mc. Due to the large size of the mirror it will be desirable to make measurements at lower frequencies also. Therefore electronic equipment for frequencies of 20mc and 60mc should also be provided. The development of such equipment comes under program B. However lower frequency design presents no particular problems and should be readily constructed. Recording apparatus is now available. Power may be secured from the plant of program B.

DEVELOPMENT PROGRAM "B"

Development Work

The operations of this program will concern themselves with matters ~~more~~ closely associated with the art of radio communication as well as with than the science of astronomy. Tentatively this program may be divided into five parts.

I. Make astronomical investigations at 480mc using present mirror until large one becomes available.

II. Design of electronic equipment for use at frequencies above 480mc.

III. Improve the sensitivity of lower frequency apparatus.

IV. Design waveanalysers.

V. Design the altiazimuth to equitorial control.

Upon setting up the equipment at a good location (~~see program A~~), part I should be immediately put into operation. When that is going well part II should next be attacked. On parts II & III cooperation may be secured from M.I.T. Research Laboratory of Electronics (see pages 81 483, Feb. 1946, Rev. Sci. Inst.).

Capital Cost

Most all the capital equipment for ~~program~~ this has already been accumulated. It is presently in partial operation or stored at Wheaton, Illinois. To put the program in motion, funds will be needed as follows.

1. Purchase a three car garage with concrete floor to house the apparatus. It should be divided by partitions and interconnecting doors into three separate rooms. Overhead car doors will then open up one side of each room to facilitate entry and removal of equipment. These rooms will provide space for respectively the library and study at north side, shop in

center and power plant and storage at south side. Some plumbing and wash facilities will be necessary. Cost about ~~$1500~~ 2500

2. Concrete foundations for outdoor part of power plant and azimuth turntable of mirror. Cost about ~~$250~~ 500

3. Transportation of equipment from Wheaton, Illinois to location in Texas. This will require about six truckloads as follows. One of structural steel, mostly turn table; one of power plant, mostly lead acid batteries; three of parts of disassembled mirror; one of library and instruments. Each load about $200 or total of $1200

4. Cost to disassemble mirror and pack up library and instruments about $350

5. Cost to assemble turntable, mirror and power supply about ~~$500~~ 1000

6. Fund for purchase of additional instruments; namely, High Frequency "Q" machine, Vacuum tube transconductance and plate resistance tester and a small bench mill. Cost about ~~$1000~~ 2000

The above ~~six~~ eight items total ~~$4500~~ 9450 and represent the capital investment necessary to put the program on a going basis.

Above this charge will be personnel salaries. Probably one man and a helper will be all that is required initially. It is suggested that provision be made for personnel for two years work. Further operating expenses will be encountered in this work if sections II, III & IV are to be prosecuted with vigor. This will involve the purchase of various electronic components such as tubes, condensers, resistors, etc. Further, considerable raw material will be expended in the form of copper and brass tube, rod, sheet, wire, nuts, bolts etc. and gasoline for truck. Estimated annual expense 1000. Thus, unlike program A, the initial capital charges will be small but quite large operating expenses will be encountered if program B is prosecuted with vigor.

7. Small truck or station wagon for hauling material and equipment, most of which is large and heavy 1500.
8. Road work and fence to [illegible] damage to apparatus from cattle 500

Equipment on Hand

The writer has on hand the following apparatus. *Considerable effort has been expended in going over all the bills to procure all the charges. Cash expenditure is given; cost of reproducing it today is quoted in parenthesis.*

One mirror 31.4 feet in diameter, 20 feet focal length on a transit mounting, complete and assembled. Also various structural steel parts for reinforcing *and new track,* to be added when reassembled.

One steel turntable with track *30 ft diameter* and electric drive to give the above mirror an altiazimuth mounting, complete but disassembled.

One new heavy duty wind driven 3.5 KW 110v DC power plant with *60 cells of 615AH farm lighting type* batteries, complete but disassembled. *Generator driven by 3 blade self feathering vanes 16 ft diameter on 80 ft self supporting tower.*

One set of recorder apparatus complete and assembled.

One set of electronic apparatus for use at 160mc complete but disassembled.

One set of electronic apparatus for use at 480mc complete and assembled.

One set of machine tools consisting of South Bend bench lathe, *and assorted tools and fittings 220 or 300* *with set of drills, reamers etc $65 or ($85)* Dunlap drill press *325 or (30)* and grinder. Also *new* Thor electric hand drill and a large variety of accessories and hand tools. *estimated 150 or $150*

Purchased electronic measuring apparatus as follows. Measurements Corp. vacuum tube voltmeter *135 or (135)*, RCA signal generator *350 or (350)*, Lavoie Frequency meter *175 or (190)*, National HRO communications receiver *190 or (230)*, General Radio resistance boxes, output meter and variacs. *also Triumph Circuit analyzer 280 or (320)*

The main piece of home made test equipment is a special high power signal generator. *The equivalent cannot be purchased today. Cost of parts about 90 with labor by the writer; cost to build today with labor (250)*

A large assortment of electronic components including special tubes, power supply parts and over fifty Weston type 301 meters of assorted ranges are on hand. *450 or (500)*

Considerable raw material in the form of copper, brass, bronze, mica, bakelite, etc is also on hand. This might be assumed to be merely junk; however such a suitable collection is valuable if any construction work is to be undertaken. *The very wide variety is difficult to estimate but probably cost about 150. Today figure about (200) plus a lot of procurement effort to get it altogether.*

(over)

The above cash expenditures total about.

~~About $10,000 and~~ untold hours of labor have been expended over about ten years collecting and building the above apparatus. If the program were to start from scratch today about ( ) would be necessary. At least two years continuous work would be necessary to carry the program to its present state. In the aggregate it is eminently suitable for this type of development and investigation of cosmic static. Its main function and value is with such work. For other purposes its value would greatly decrease. Consequently, for this reason, among others, the writer desires that it be kept together and put to the use for which it was collected.

Proposal

The writer proposes to donate the use of all the above equipment to the project and agrees not to remove any therefrom during the active life of the project. The title of ownership will remain with the writer however. After the initial period of two years has been completed the situation will be re-evaluated.

If it is decided that important results have been secured and that the project will be continued on an expanded scale ~~along the lines of program A~~; then the writer proposes to donate the equipment outright in such fashion as he determines may be most advantageous for tax purposes. The project will then become the owner.

If, on the other hand, it is decided for any reason that the project is not to be continued; then the writer reserves the right to remove any and all of the above loaned equipment at his convenience.

Library

The writer is also owner of a rather substantial electronic library. This consists of a few of the later better books (about $50) on the subject but mainly extensive files (mostly unbound) of the leading journals as follows. The figures given are merely the yearly subscription rates multiplied by the number of years. No present day cost is possible as most of the material is impossible to secure at any price.

Proc. I.R.E. 1928 to date complete plus some earlier $230

Bell Technical Jnl. 1925-date, $30

Jnl. Franklin Inst. 1924-date #132

Jnl. Applied Physics, Complete-date 106

Electrical Engineering, 1930-date 160

Review of Sci. Inst., complete-date 85

R.C.A. Review, complete-date 4

Electrical Communications, 1924-date 35

Wireless Engineer, complete-date 150

Philips Tech. Review, complete-prewar 15

Gen. Elect. Review, 1930-date 51

Jnl. I.E.E. (british), nearly complete 1930-date 102

Communications, 1935-1944 20

Westinghouse Engineer, 1944-date 4

QST, 1927-1934 20

Physics Abstracts A & B, 1945-date 12

Also wide variety of bulletins, pamphlets and monographs on electronic subjects approx 50. Grand total 1266.

For the time being the writer wishes to include his library with the above apparatus. However ownership is to remain with the writer. Quite likely at some time in the future it will become apparent that the library will be more useful elsewhere than at the scene of observations. At such time the writer reserves the right to remove the library at his wish.

Recapitulation

~~Program B~~ The above can be put into operation quite readily. It is requested funds be made available for two years work. The writer hopes that all details can be ironed out promptly so that all material can be removed from Wheaton before cold weather sets in. ~~Program A requires large capital investment but has tremendous possibilities for securing new information. Serious consideration should be given to setting it in motion as soon~~ as ~~program B~~ this program is well underway and substantial results are being secured. serious consideration should be given to acquiring a large mirror for an expanded program.

July 15th, 1946

Grote Reber

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