Historical Introduction to Radio Astronomy

Jansky's Discoveries (1932-1933)
- Reber's First Surveys of the Radio Sky (1937-1944)
- First detections of the Sun (~1943)
- Switching receivers and calibrating (~1946)
- Prediction and detection of Hydrogen line emission (1944-51)

Green Bank Single Dish Summer School
Frank D. Ghigo, August 10, 2003

References

"Classics in Radio Astronomy", edited by W. Sullivan (Reidel, 1982)

"The Evolution of Radio Astronomy", by J.S.Hey.
(Science History Publications, 1973)

"Serendipitous Discoveries in Radio Astronomy", edited by Kellermann and Sheets.
(published by NRAO, 1983)

"The Early Years of Radio Astronomy", edited by W.T.Sullivan
(Cambridge Univ.Press 1984).

"Early Radio Astronomy at Wheaton, Illinois", by G. Reber,
in Proceedings of the IRE, vol.46, page 15, Jan.1958.

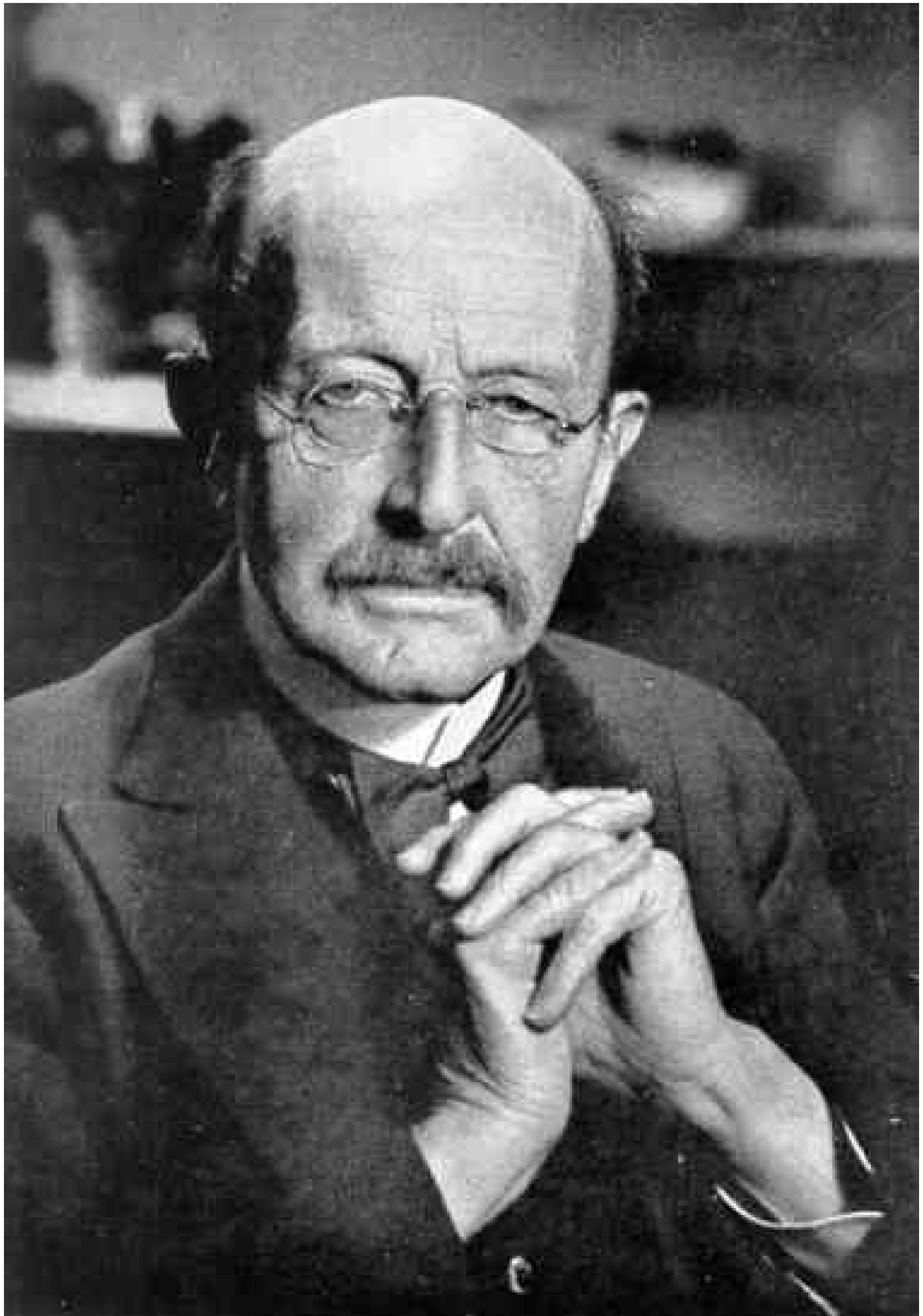
"A Play entitled The Beginning of Radio Astronomy", by G. Reber,
in J.Roy.Astron.Soc.Canada, Vol 82, page 93, 1988.

"A New Look at Karl Jansky's Original Data", by W. Sullivan,
Sky and Telescope, August 1978, Vol.56, page 101.

James Clerk Maxwell

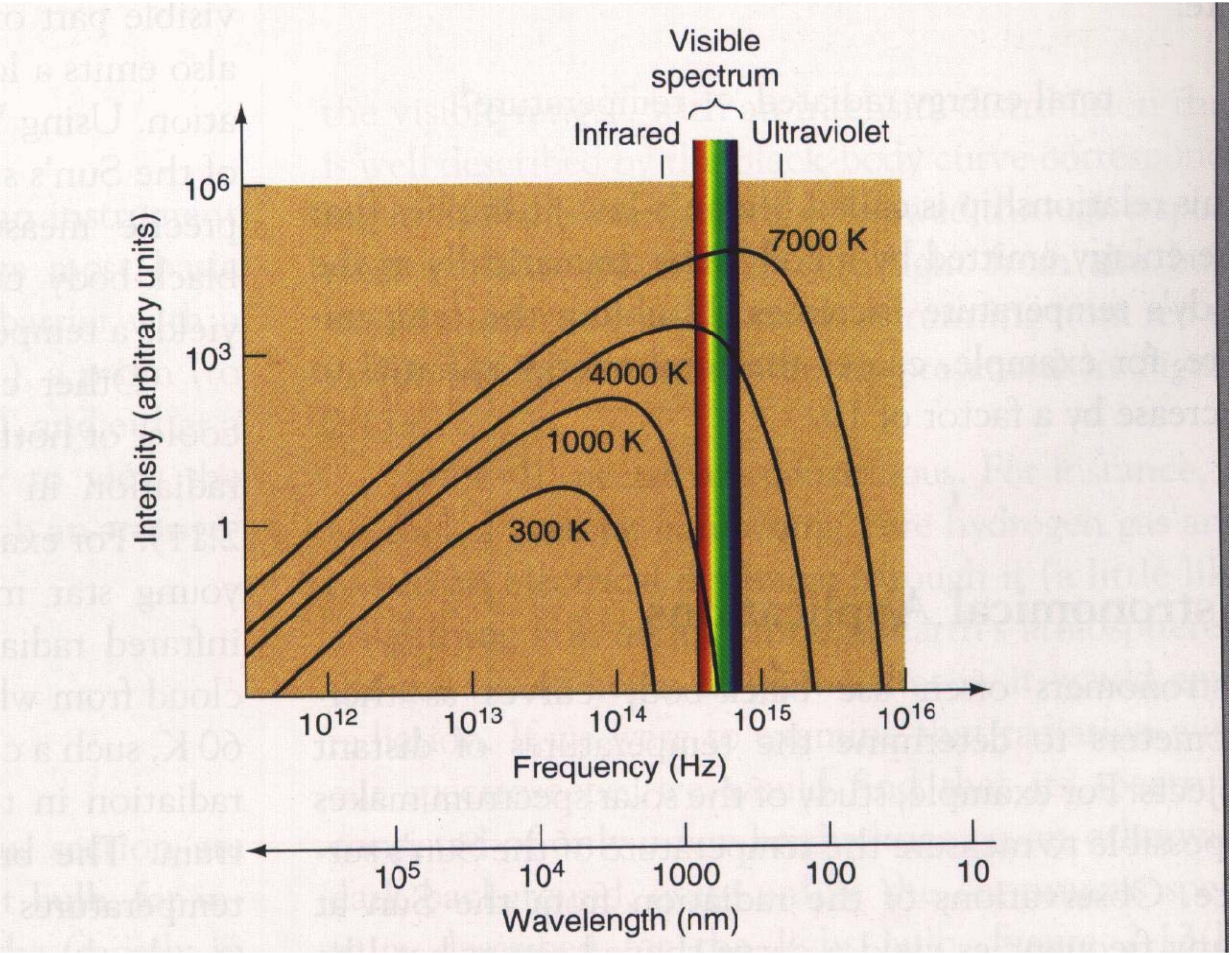
James Clerk Maxwell

Heinrich Hertz



Max Planck
(1858-1947)

Planck's radiation curves



X

Planck Radiation Law
(thermal radiation)

$$B = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT}-1}$$

Rayleigh-Jeans Law
(For the radio region of the spectrum, in the limit $h\nu << kT$)

$$B = \frac{2\nu^2 kT}{c^2} = \frac{2kT}{\lambda^2}$$

Karl Jansky

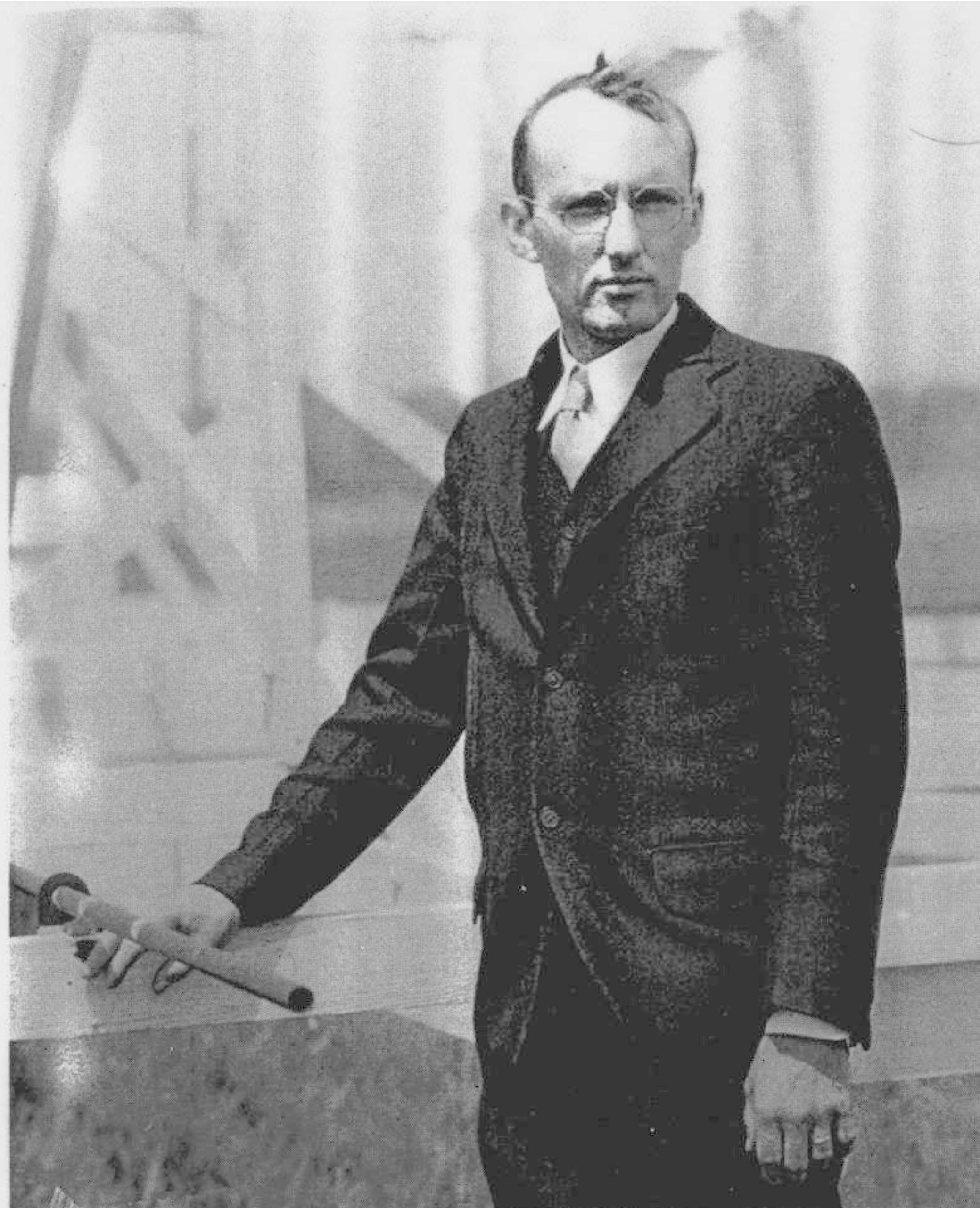
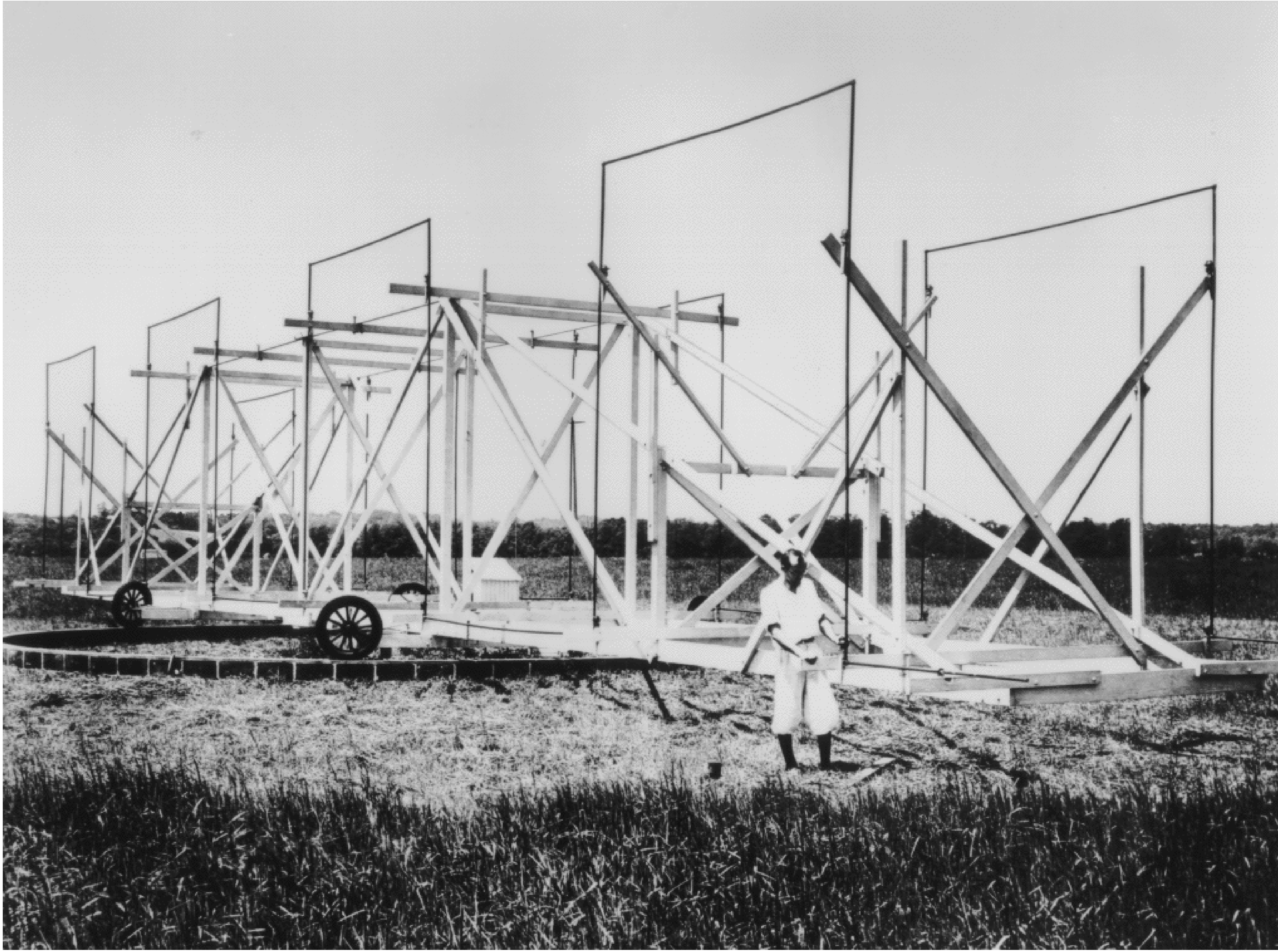


FIG. 1—Karl Guthe Jansky, about 1933.



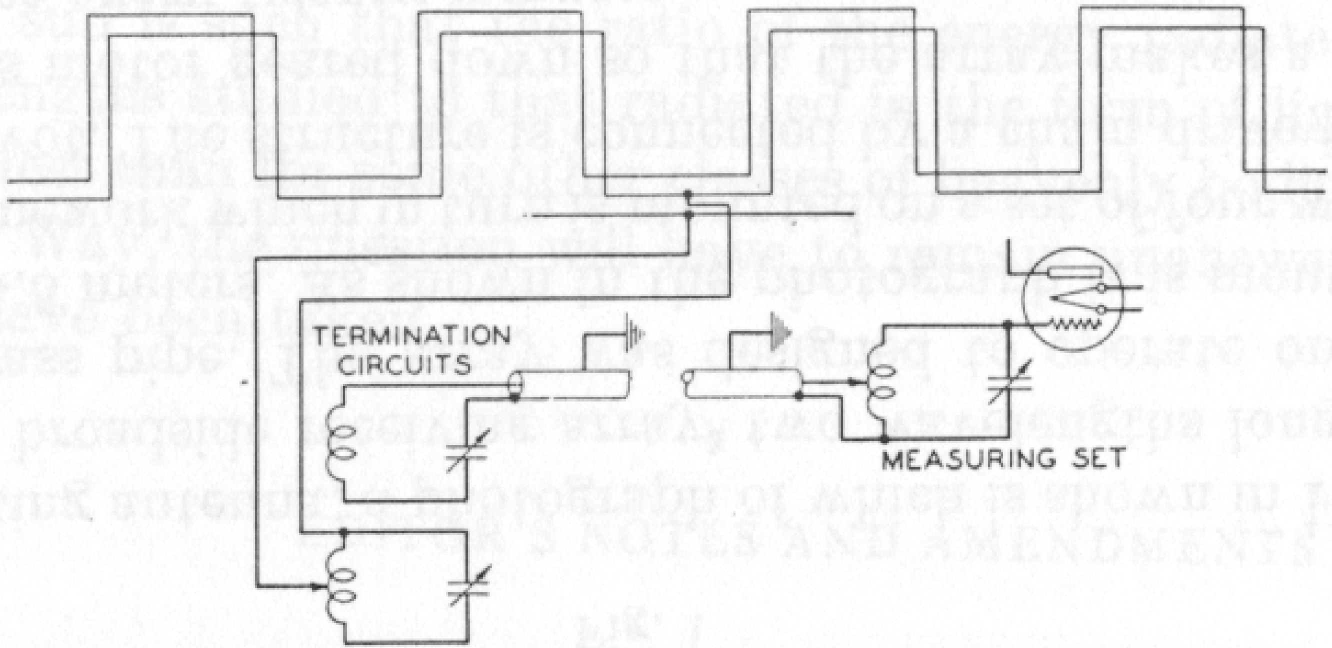


Fig. 4—Schematic diagram of array, termination, and pipe transmission line.

Chart recording

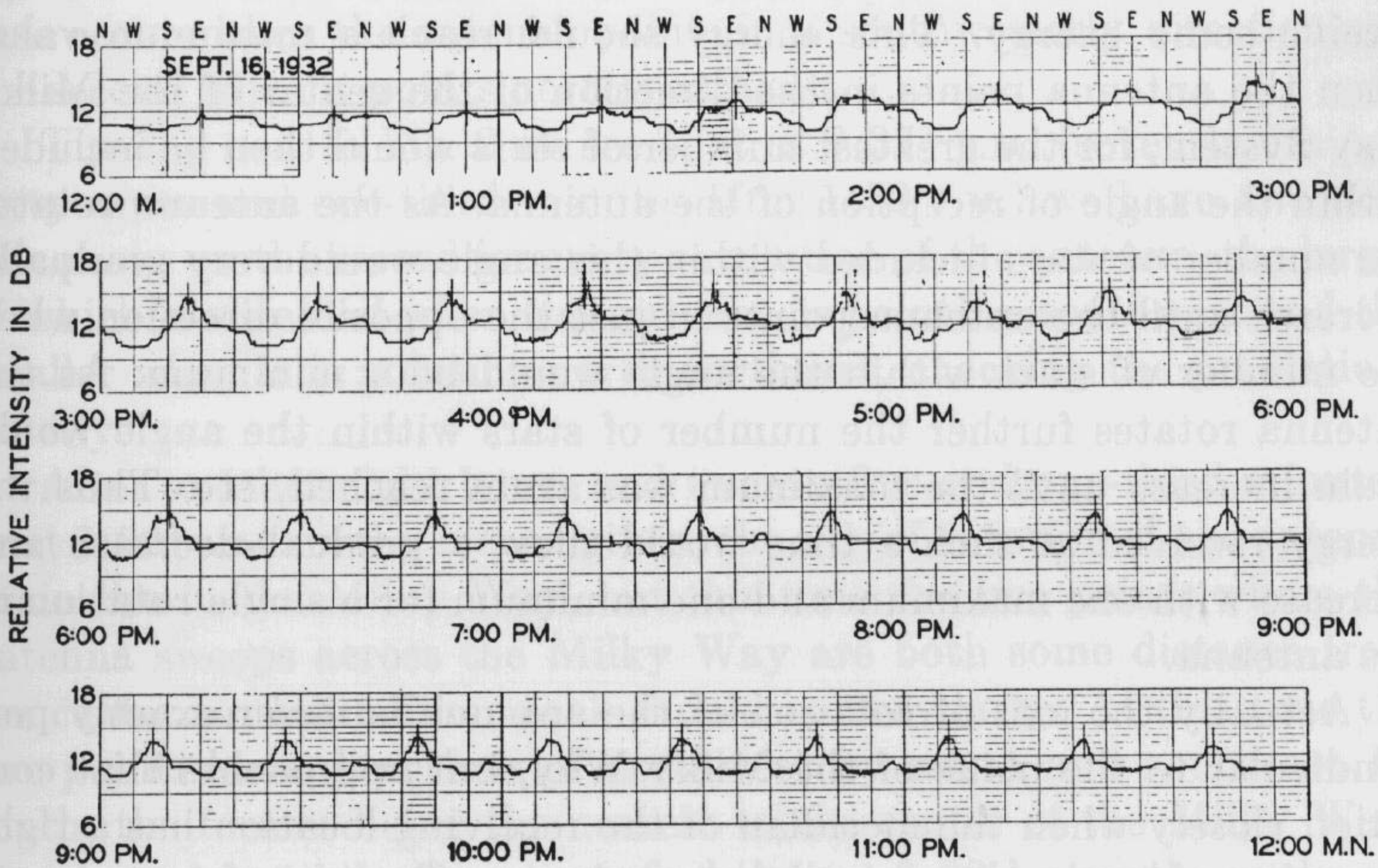
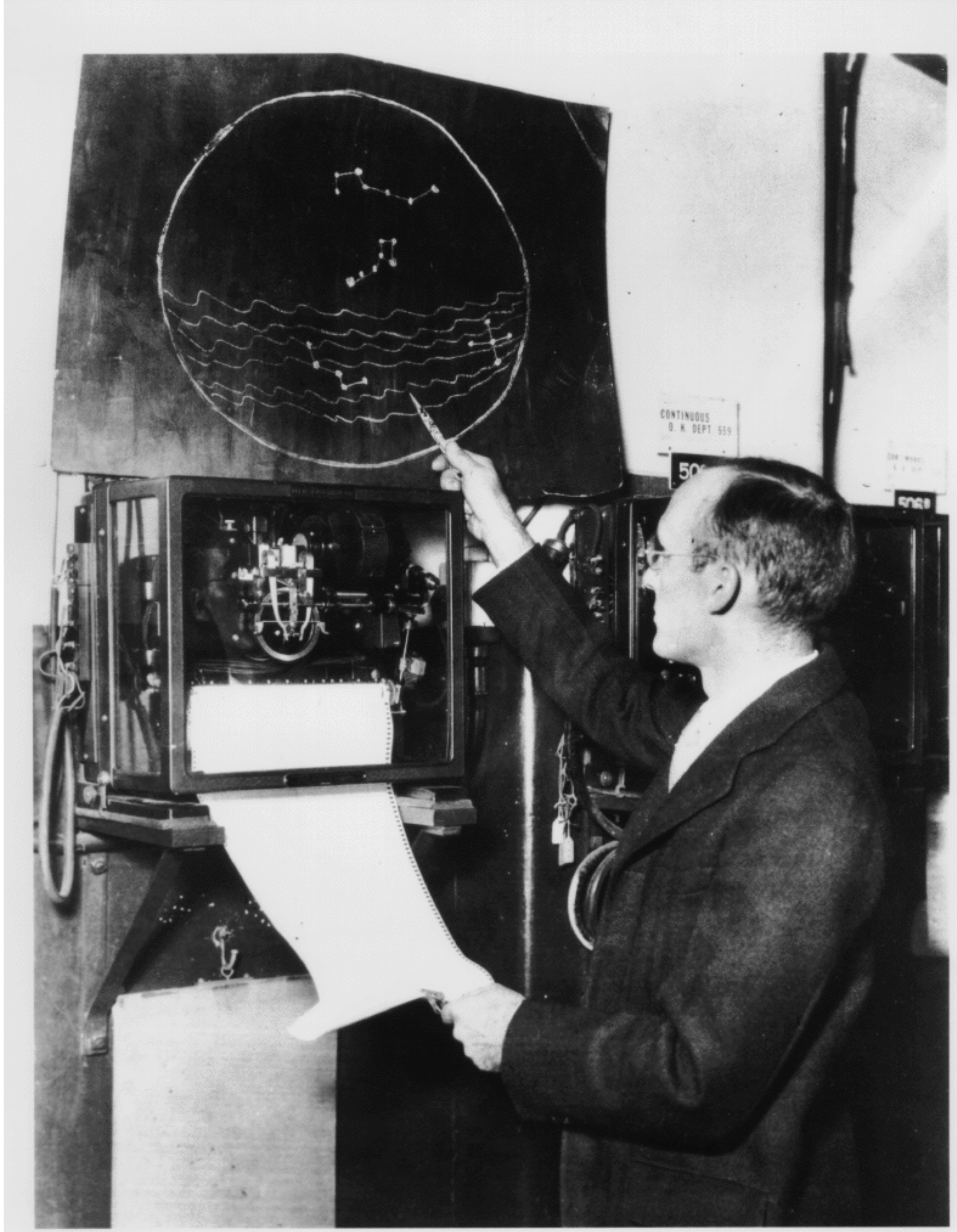
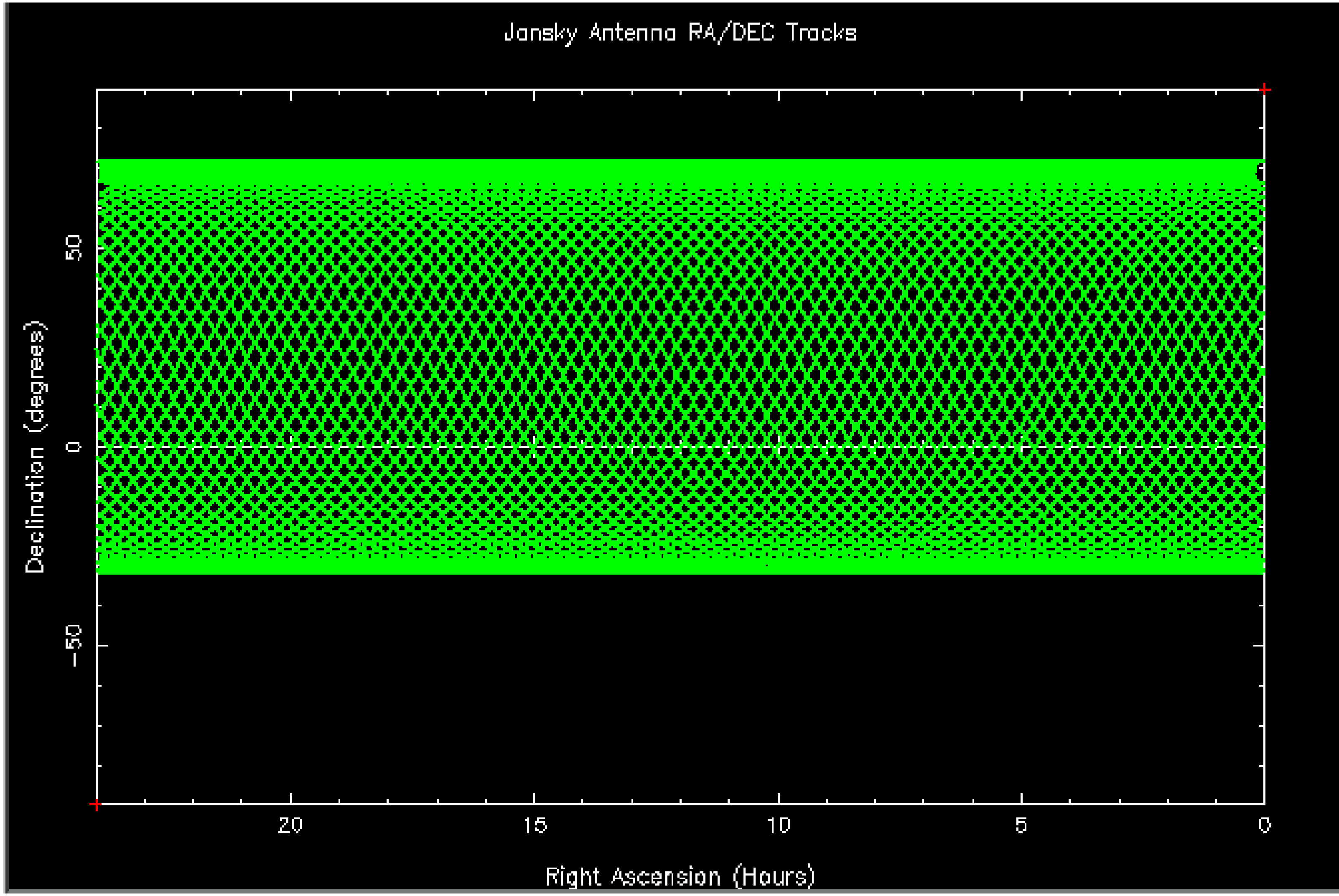


Fig. 2—Sample record of waves of interstellar origin. Record taken 12:00 noon to 12:00 midnight on September 16, 1932.


CONTINUOUS
O. K. DEPT 559


Jansky Antenna RA/DEC Tracks
Declination (degrees)
50
0
−50
20
15
10
5
0
Right Ascension (Hours)

Contour map

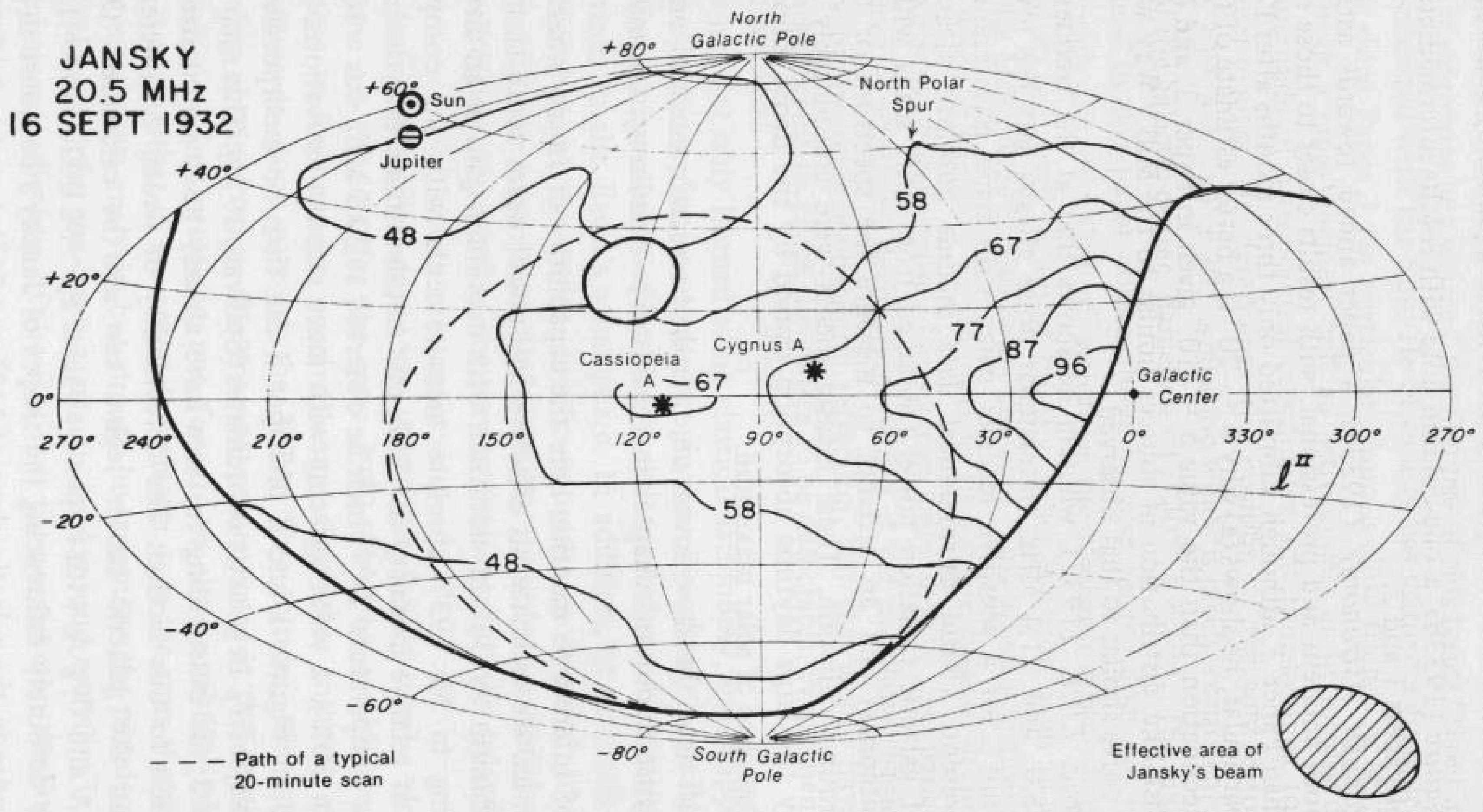


Fig. 3. Radio brightness temperature (in Kelvins) derived (Sullivan, 1978) from the drift scans at a wavelength of 14.6 m given by Jansky in 1935 (Paper 3). Coordinates are *modern* galactic, i.e., $l^{II} = 0°$ corresponds to the galactic center. The approximate size of Jansky's primary beam is also indicated.

"All the News That's Fit to Print."

VOL. LXXXII....No.

NEW RADIO WAVES TRACED TO CENTRE OF THE MILKY WAY

Mysterious Static, Reported by K. G. Jansky, Held to Differ From Cosmic Ray.

DIRECTION IS UNCHANGING

Recorded and Tested for More Than Year to Identify It as From Earth's Galaxy.

ITS INTENSITY IS LOW

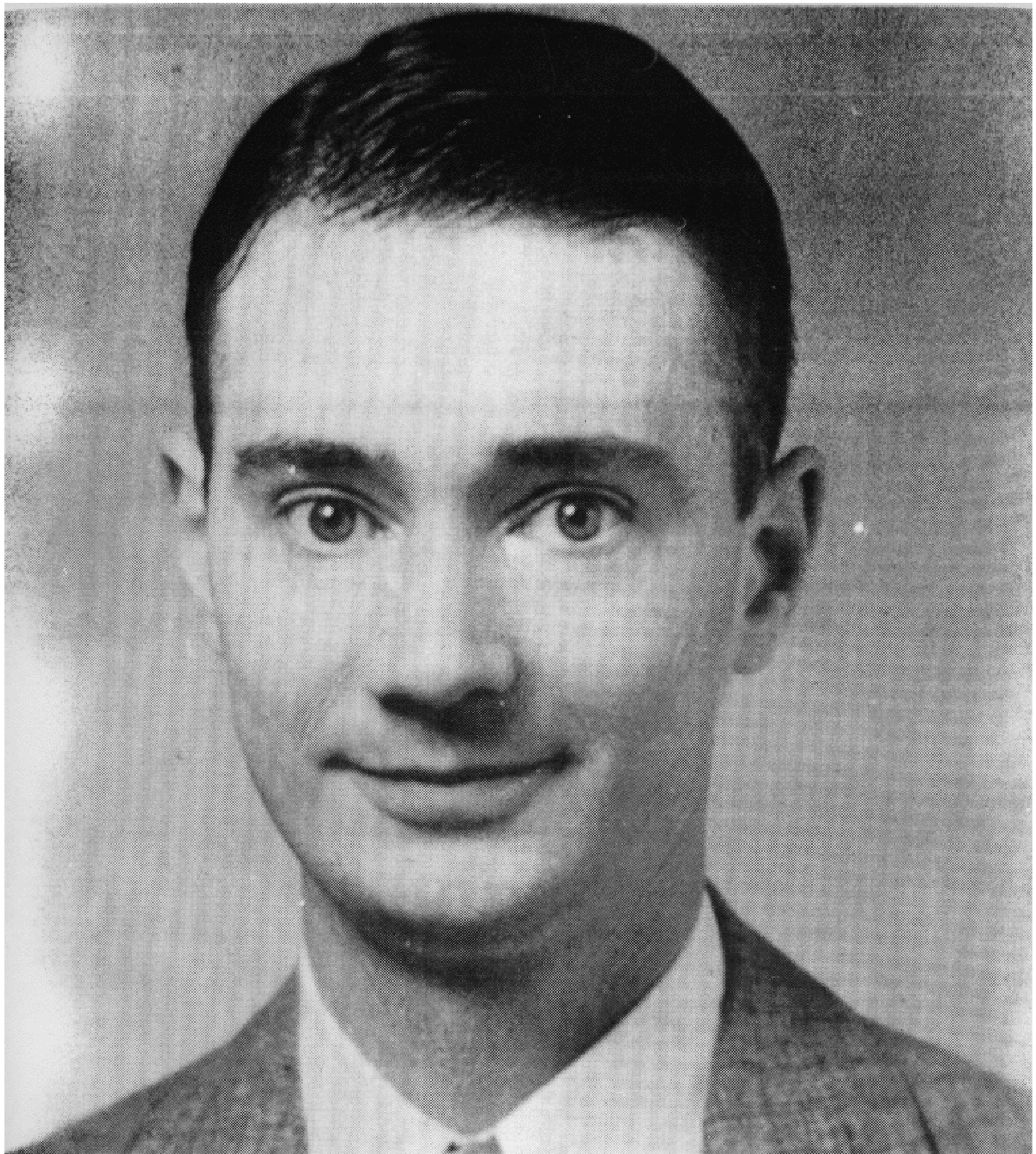
Only Delicate Receiver Is Able to Register—No Evidence of Interstellar Signaling.

Discovery of mysterious radio waves which appear to come from the centre of the Milky Way galaxy was announced yesterday by the Bell Telephone Laboratories. The discovery was made during research studies on static by Karl G.

Discovery of mysterious radio waves which appear to come from the centre of the Milky Way galaxy was announced yesterday by the Bell Telephone Laboratories. The discovery was made during research studies on static by Karl G. Jansky of the radio research department at Holmdel, N. J., and was described by him in a paper delivered before the International Scientific Radio Union in Washington.

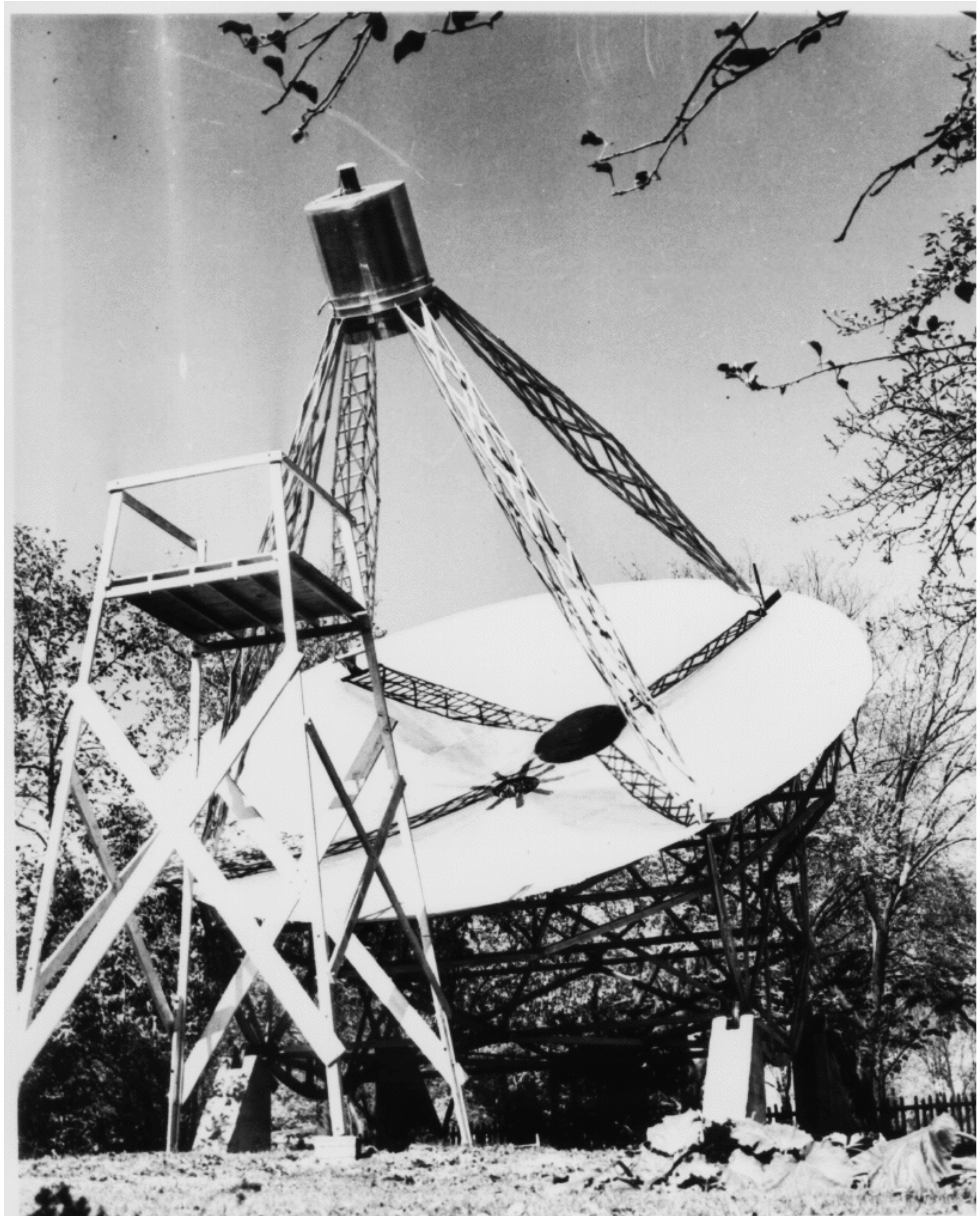
The galactic radio waves, Mr. Jansky said, differ from the cosmic rays and also from the phenomenon of cosmic radiation, described last week before the American Philosophical Society at Philadelphia by Dr. Vesto M. Slipher, director of the Lowell Observatory at Flagstaff, Ariz.

Unlike the cosmic ray, which comes from all directions in space, does not vary with either the time



–Grote Reber, about 1937.

Wide frequency range	→ parabolic reflector
$\Theta = \lambda/D$	→ large dish; high frequency
Planck Law	→ high frequency
Simplicity and cost	→ meridian transit; wooden support structure



Reber's first observations at 3300 MHz (9cm)

"Various parts of the Milky Way, Sun, Moon, Jupiter, Venus, Mars, and several of the bright stars, such as Sirius, Vega, Antares, etc., were all examined.

… Observations were made visually of the meter indication and were tabulated, sometimes at minute intervals…

… Some small irregular fluctuations were encountered, but no repeatable results were secured which might be construed to be of celestial origin. All this was rather dampening to the enthusiasm."

Next try: observations at 910 MHz (33 cm)

"During the autumn of 1938 and during the following winter, a variety of observations, both by day and by night and with various polarizations, were made at 910 mc. All the same objects were examined again without any positive results. In a measure, it was disappointing. However, since I am a rather stubborn Dutchman, this had the effect of whetting my appetite for more."

160 MHz (187cm) receiver system

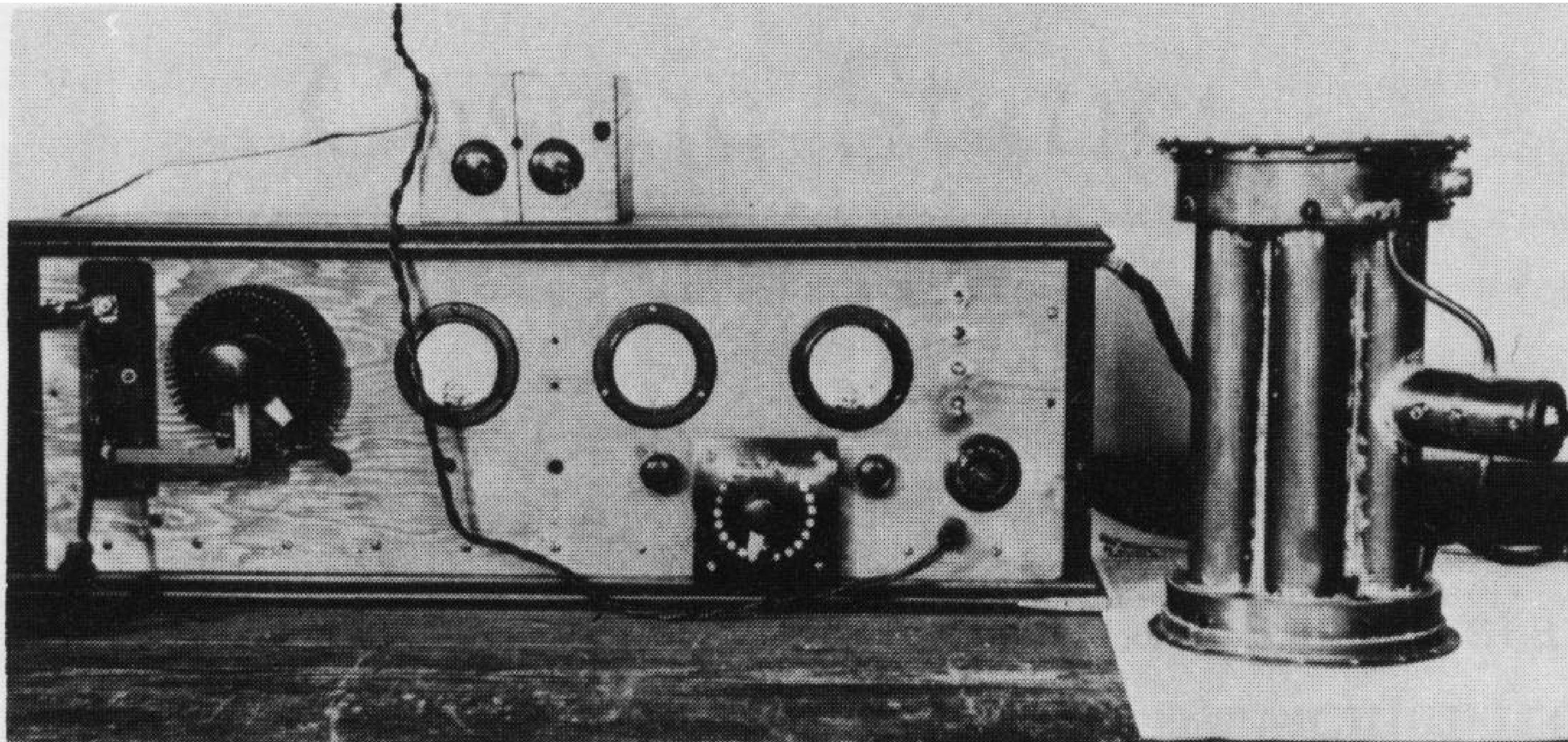


Fig. 2—Control and indicating equipment. The amplifier is shown at right.

Reber's 160 MHz (187 cm) system.

"Before hoisting this cumbersome assembly atop the parapet of the mirror, some ground tests were made. These provided quite a shock, since all kinds of manmade electrical disturbances now could be heard which before were not known to exist. The main one was caused by automobile ignition sparking. However, this trouble mostly disappeared after 10:00 P.M.; this was reassuring."

"About two hours were required for equipment warmup. After 10:00 P.M., disturbances quieted down and observations were made in earnest. Data were taken by manually recording the meter indications every minute. Continual aural monitoring was employed to delete those times when interference was present. This data was then plotted as meter reading vs time."

Collecting data at 160 MHz

"By early April, the plane of the galaxy was crossing the meridian during hours of darkness and good reproducible plots were secured every night when observations were made. It was now apparent that cosmic static from the Milky Way had really been found and that it was of substantial strength, especially to the south."

"The above success further whetted my appetite on the basis of, "If a little is good, more is better." A survey of the sky was contemplated; this would mean collecting a lot of data. Obviously, an automatic recorder was a primary necessity."

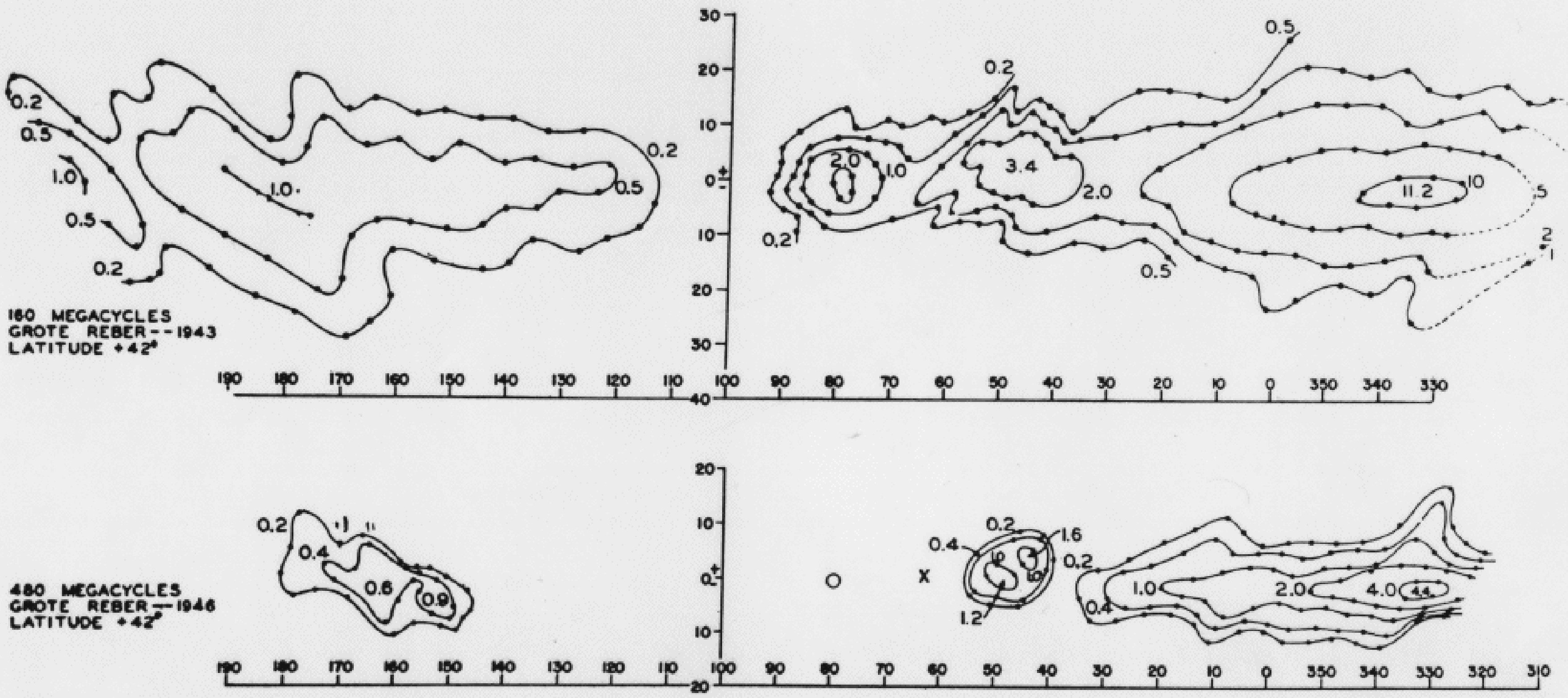
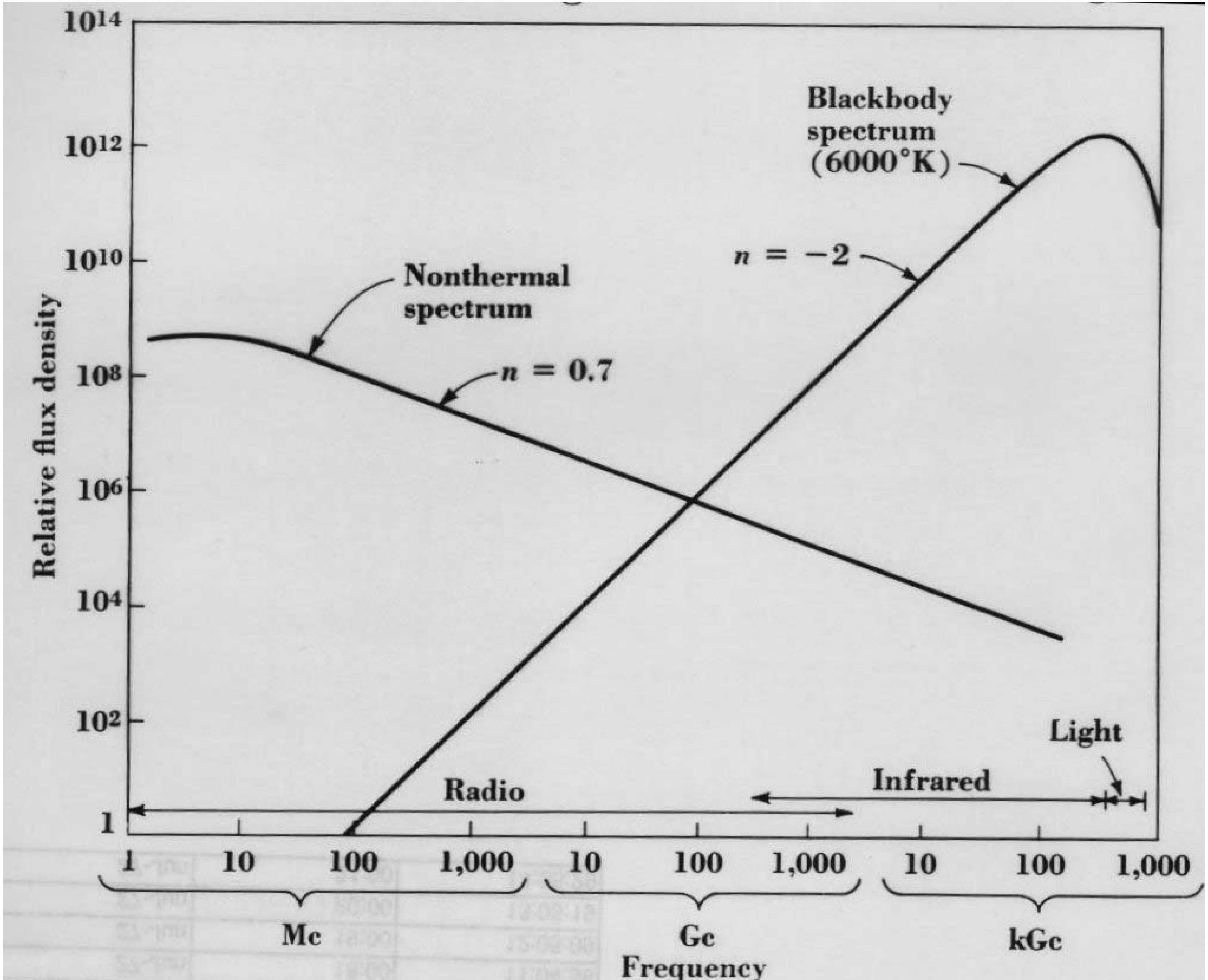


FIG. 7—Contours of constant intensity at 160 MHz and 480 MHz, taken at Wheaton, Illinois.



Blackbody
spectrum
(6000°K)
n = −2
Nonthermal
spectrum
n = 0.7
Relative flux density
10¹⁴
10¹²
10¹⁰
10⁸
10⁶
10⁴
10²
1
Radio
Infrared
Light
1
10
100
1,000
10
100
1,000
10
100
1,000
Mc
Gc
kGc
Frequency

John S. Hey, in Nature (1946)

Reporting measurements in the 4-6 meter band (50-75 MHz)

The main evidence that the disturbance was caused by electromagnetic radiations of solar origin was obtained by the bearings and elevations measured independently by the receiving sets, sited in widely separated parts of Great Britain (for example, Hull, Bristol, Southampton, Yarmouth). The operators determined the bearings according to the normal practice for finding the direction of a source of interference. It was found that the bearings moved throughout the day and were always within a few degrees of that of the sun. The most striking results came from two sites, about 150 miles apart, where the elevation was also measured. These sites were able to follow the source continuously in bearing and making an allowance for cosmic noise, it can therefore be shown that the noise-power received from the sun on this occasion was of the order of 10^{-13} watts per square metre per megacycle band-width. This unusual intensity, of the order of 10^5 times that corresponding to the calculated black-body radiation, appears to have been associated with the occurrence of a big solar flare reported to be in a central position on February 28, 1942.

J. S. Hey.

Ministry of Supply,
London. Oct. 17.

George C. Southworth

Bell Labs, published in Journal of the Franklin Institute 239, 1945.

Measurements at 3.1, 9.4, and 24 GHz.

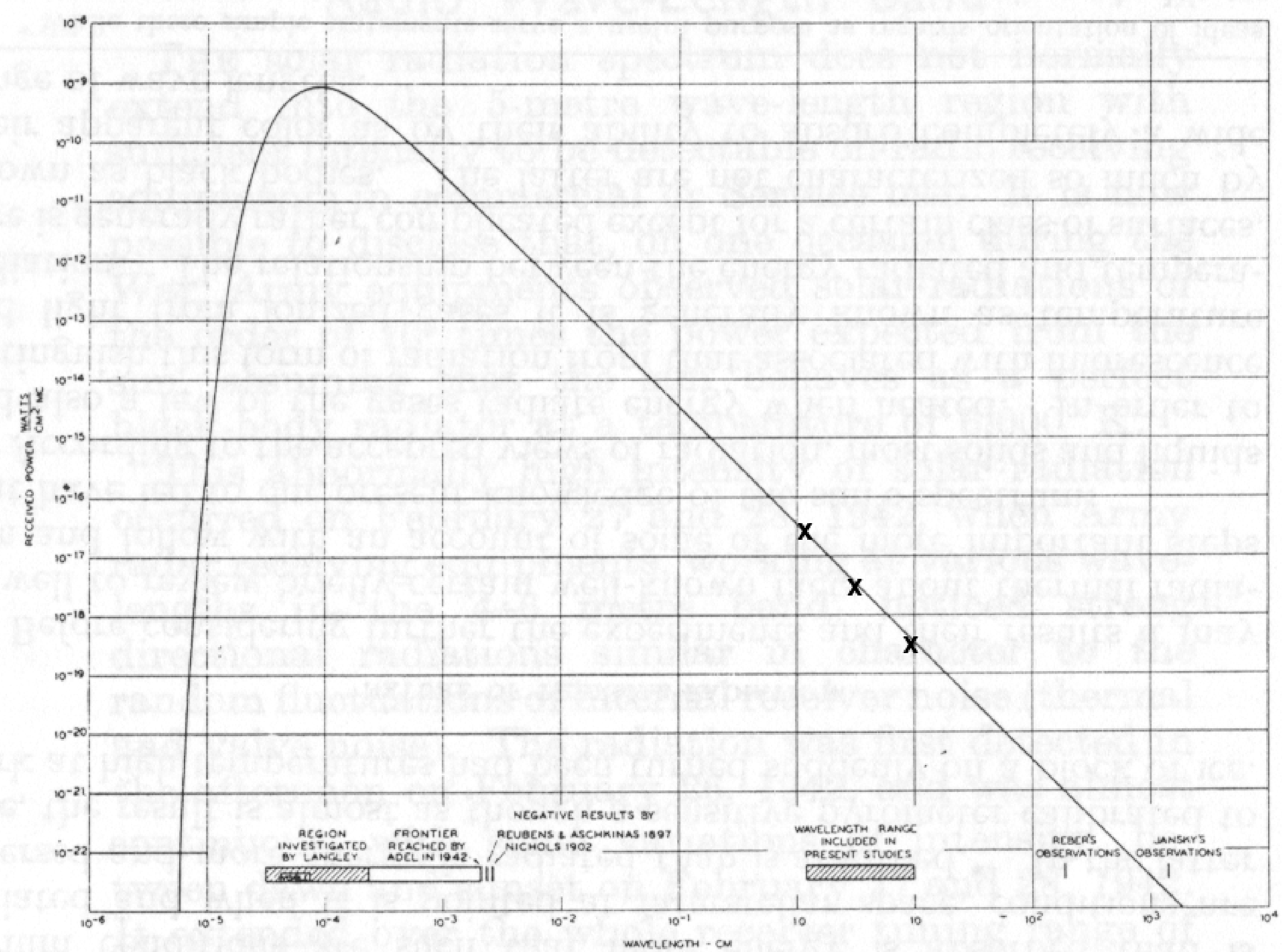
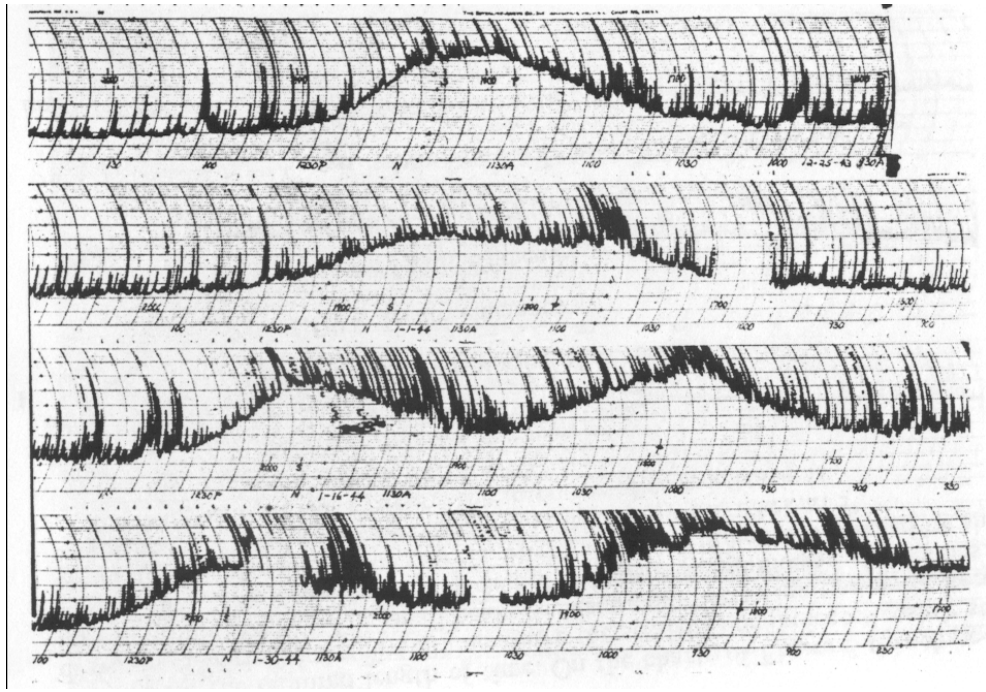


FIG. 2. Calculated energy distribution in the sun's spectrum. Crosses indicate measured points.*

Reber's chart recordings showing solar bursts

From his survey of the sky at 160 MHz (ApJ 100, p.61, 1944)



From the later survey at 480 MHz:

"The galactic radiation was markedly weaker than at 160 mc, as was expected. However, the quiet sun was much stronger. …
…it seemed that perhaps the sun was a black body radiator but the temperature would have had to be nearer a million degrees than the optical value of six thousand degrees."

(Proc.IRE, vol.46, p.15, 1958)

Why did Jansky not detect the Sun?

-very quiet Solar minimum in 1932-33

- ionosphere so quiet that the galaxy was observable in the daytime.

- If Sun had been active, non-thermal bursts would be very obvious at 20 MHz

Plate 1.7 Preparing to make measurements with the Dicke radiometer in 1945. Left to right: R. L. Kyhl, E. R. Beringer, A. B. Vane, R. H. Dicke (*by courtesy of R. H. Dicke, Princeton University*)

Noise power from antenna
in constant temperature oven

$$P = \frac{kT}{\lambda^2} A_e \Omega_A$$

Noise power from resistor

$P = kT$ (W/Hz)

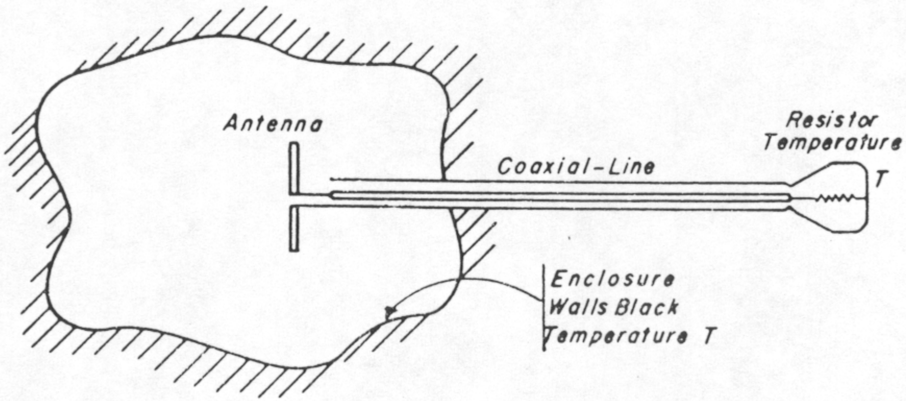
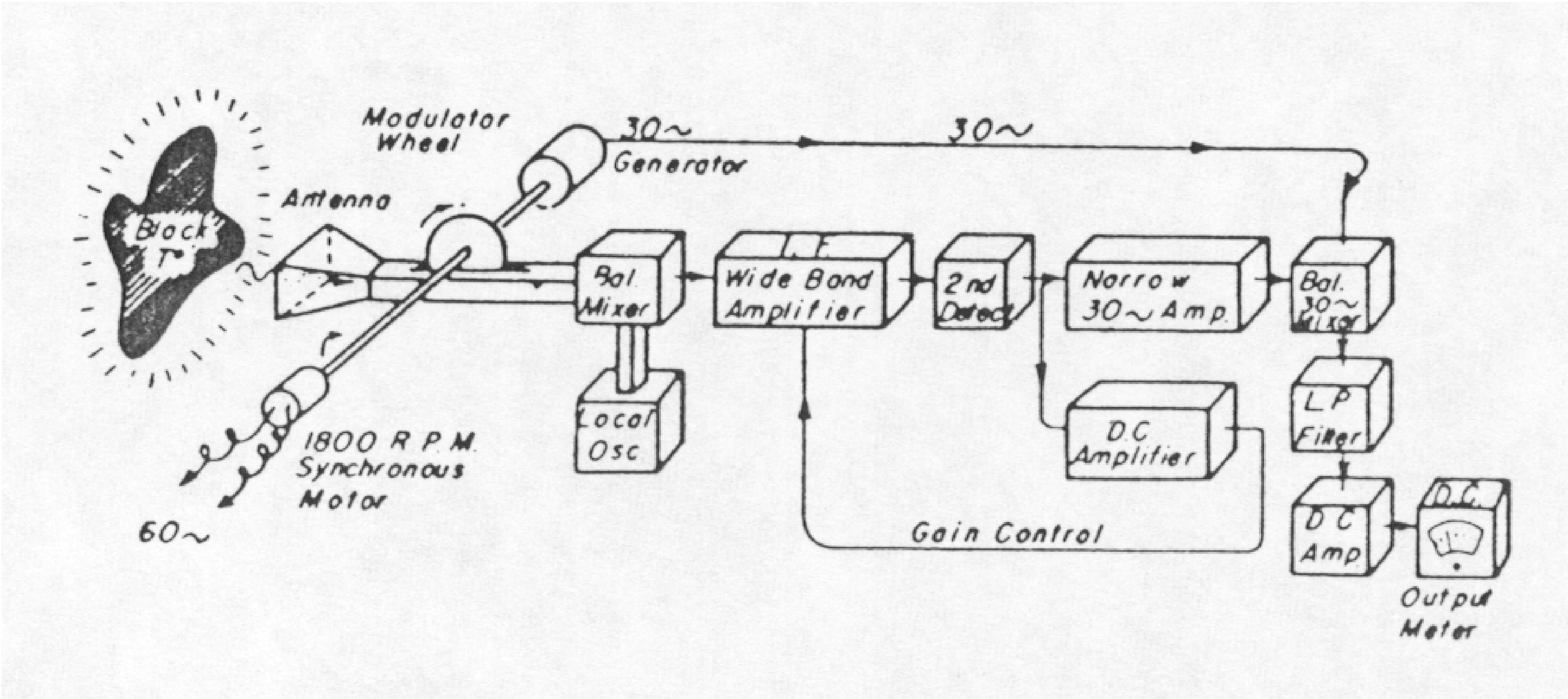


FIG. 1. Antenna system in black enclosure.

Rms noise fluctuations given by

$$\Delta T_{rms} = \frac{K\, T_{sys}}{\sqrt{t \Delta \nu}}$$



Robert Dicke's chopping radiometer. The receiver is connected alternately to the antenna and a thermal load. The receiver detects the average of the difference between the sky and the reference load.

(Rev.Sci.Instruments, vol.17, p268, 1946)