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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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PHYSICS

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STUDY OF THE RADIO LINE OF EXCITED HYDROGEN AT A WAVELENGTH OF 5 cm USING A QUANTUM PARAMAGNETIC AMPLIFIER

(Presented by Academician V. A. Kotelnikov on 31 XII 1964)

In 1959 N. S. Kardashev showed the possibility of observing a number of lines lying in the radio-wave range, emitted by regions of ionized hydrogen (^{1}). Since ionized hydrogen is more closely associated with stars than is neutral hydrogen, the study of its radio lines can supplement our knowledge of the structure of the Galaxy and of the Universe surrounding us. An attempt to observe the radio line of excited hydrogen was carried out in Pulkovo as early as 1958 (^{2}). The first successful attempt to detect the radio line of excited hydrogen at a wavelength of 5 cm in the emission of hot nebulae was undertaken by two of the coauthors in 1963 (^{3}).

Fig. 1

The studies described in the present article, carried out in 1964, confirmed the presence of the radio line and made it possible to record its profile in the Omega nebula. This became possible only with the use of a quantum paramagnetic amplifier.

The radiometer uses a traveling-wave quantum paramagnetic amplifier (QPA) of the 5-centimeter range, operating at the temperature of liquid helium, 4.2°K (^{4}), with gain coefficient $G = 25$ dB and bandwidth $\Delta f = 26$ MHz. It employs the quantum transition in ruby between energy levels 1—4 for pumping and 1—2 for the signal, in contrast to those used in (^{5}), which made it possible

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

operate without pumping helium vapor. The use in the QPA of a broadband slow-wave system (comb) with a built-in low-temperature ferrite valve makes it possible to tune it in frequency (150 MHz) and reduces the dependence of the QPA gain on the change of impedance at its input, in comparison with a resonator QPA, and, what is especially important for radio astronomy, gives high gain stability. (The gain instability was less than 0.05 dB over 10 sec.) The measured total noise temperature of the radiometer with the QPA is 32°K, of which 18°K is the noise of the superheterodyne balanced receiver (referred to the QPA input). The total noise temperature of the antenna (with the waveguide path), the ferrite switch, and the radiometer is 116°K. The fluctuation sensitivity of the radiometer with the QPA is $\delta T = 0.035°\text{K}$ for a passband $\Delta f = 20$ MHz and a time constant $\tau = 3.5$ sec, which is somewhat worse than theoretically possible. A magnetic field of strength $H = 4000$ Oe is produced by a permanent magnet. To cool the QPA, a metal cryostat with a capacity of about 5 liters of liquid helium is used, which ensures continuous operation of the QPA for 8 hours.

Fig. 2

Fig. 3

The radiospectrograph used for the observations is a modulation-type radiometer with triple frequency conversion, with tuning of the third heterodyne and sequential analysis of the spectrum. After the square-law detector there followed a balanced low-frequency amplifier and the usual radio-astronomical output.

Observations of the Omega Nebula, in order to record the radio line $\lambda \approx 5$ cm, were carried out in May and July 1964 on the radiospectrograph using the QPA described. The passband of the contour analyzer was 280 kHz in both cases. In the first case, the emission spectrum of the nebula was compared with the emission spectrum of the atmosphere and the Earth and was analyzed in a band of 5.5 MHz; in the second, it was compared with the emission spectrum of the extragalactic radio source Cygnus A and was analyzed in a band of 3.5 MHz. Similar results were obtained in both cases.

Fig. 4

Fig. 4

Figure 4: Fig. 4

Figure 1 presents a single record made in May with a time constant $\tau = 3.5$ sec. The dotted curve is the spectrogram of the emission of the atmosphere and the Earth, and the solid curve is the spectrogram of the emission of the Omega Nebula. The spectrograms are aligned along the frequency axis. In the region of frequency 5763 MHz, enhanced emission in the spectrum of the nebula is clearly visible.

Figure 2a shows the frequency dependence of the ratio of the spectral flux density of the nebula' s radiation to the spectral flux density of the nebula in the continuous spectrum; the curve was obtained by averaging four spectrograms taken in May. In Fig. 2b this curve is averaged over the width of the analyzer contour.

Figure 3 presents a spectrogram, similar to Fig. 2b, obtained in July 1964. The intensity of the radio line at maximum is $3.8 \pm 0.5\%$ of the intensity of the continuous spectrum. The line width at the half-intensity level is 1.2 ± 0.3 MHz. The position of the line maximum in frequency must shift periodically because of the Doppler effect associated with the Earth' s motion around the Sun. This shift has been detected.

Figure 4 gives the curve of the sinusoidal change in the frequency of the line maximum as a function of the time of year, obtained on the basis of optical data. Our measurements of the frequency of the line maximum are shown by points.

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Note: Figure translations are in progress. See original paper for figures.