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ABSTRACT

A new type of ion cyclotron whistler associated with ions having a mass-to-charge ratio of 8-amu/unit charge is reported from very-low-frequency (VLF) radio noise observations with the Injun 5 satellite. This observation confirms earlier measurements by the Explorer 31 satellite identifying the presence of 8-amu/unit charge ions in the ionosphere and represents the third type of ion cyclotron whistlers found in satellite VLF data. From crossover frequency measurements the fractional concentration of the 8-amu/unit charge ions has been determined to be a few percent or less. This new ion cyclotron whistler has been observed most often during local night, at altitudes ranging from 1200 km to 2100 km and invariant latitudes from 37° to 58°.

A new ion cyclotron whistler associated with ions having a mass-to-charge ratio of 8-amu/unit charge has been found in the Injun 5 satellite very-low-frequency (VLF) radio noise data. This 8-amu/unit charge ion cyclotron whistler is the third type of ion cyclotron whistler found in satellite VLF data, the previous types being the proton whistler, which was first reported by Smith et al. [1964] and explained by Gurnett et al. [1965], and the helium whistler, which was first reported by Barrington et al. [1966]. This observation of an 8-amu/unit charge ion cyclotron whistler confirms earlier measurements by Hoffman [1967] who first identified the presence of ionospheric ions with mass-to-charge ratios of 8-amu/unit charge using a mass spectrometer on the Explorer 31 satellite. The corresponding ion species is thought to be either O^{++} (a doubly charged mass 16 ion) or He_2^+ (a singly charged mass 8 molecule [Hoffman, 1967]). At the present time the identity of this ion has not been clearly established [see discussions by Banks and McGowan, 1968; Ferguson and Fehsenfeld, 1969; Banks and McGowan, 1969a; Gerardo and Gusinow, 1969; and Banks and McGowan, 1969b].

An example of an 8-amu/unit charge ion cyclotron whistler observed with the Injun 5 VLF experiment (see Gurnett et al. [1969] for a description of this experiment) is shown in Figure 1. This illustration shows the frequency-time spectrogram of a short fractional hop electron whistler followed, in order of decreasing frequency, by a proton whistler at about 432 Hz, a helium whistler at about 108 Hz, and an 8-amu/unit charge whistler at about 54 Hz. The ion species corresponding to each of these ion cyclotron whistlers can be determined from the asymptotic frequency of the whistler signal (the ion gyrofrequency) which is inversely proportional to the mass-to-charge ratio of the corresponding ion species [see Gurnett et al., 1965]. The asymptotic frequency of the 8-amu/unit charge whistler in Figure 1 was determined to be 1/8±3% of the proton gyrofrequency thereby identifying the charge-to-mass ratio to be 8-amu/unit charge.

The relative abundances of each ion species can be obtained from measurements of the crossover frequency, the frequency at which the ion cyclotron whistler signal meets the short fractional hop whistler signal [see Gurnett et al., 1965; Shawhan and Gurnett, 1966; and McEwen and Barrington, 1967]. Considering the uncertainties in measuring the crossover frequencies in Figure 1, the fractional concentrations, α, have been determined within the following limits:

$$0.76 > \alpha(H^+) > 0.56$$
$$0.37 > \alpha(He^+) > 0.16$$
$$0.14 > \alpha(O^+) > 0.03$$
$$0.03 > \alpha(m/q=8) > 0.0$$

The large uncertainty in the fractional concentration of the 8-amu/unit charge ions (0 to 3%) arises because the difference between the crossover frequency and the ion gyrofrequency of the 8-amu/unit charge whistler is very small ($\sim$5 Hz) and difficult to determine with good accuracy.

At the present time, after surveying data from several hundred passes, 8-amu/unit charge whistlers have been observed on only six passes, much less frequently than either proton whistlers or helium whistlers. This decreased occurrence may be due in part to the increased background noise and decreased receiver sensitivity at these extremely low frequencies. The satellite coordinates at which 8-amu/unit charge whistlers were observed on each pass are given in Table 1. In all cases the fractional concentration of the 8-amu/unit charge ions was a few percent or less.

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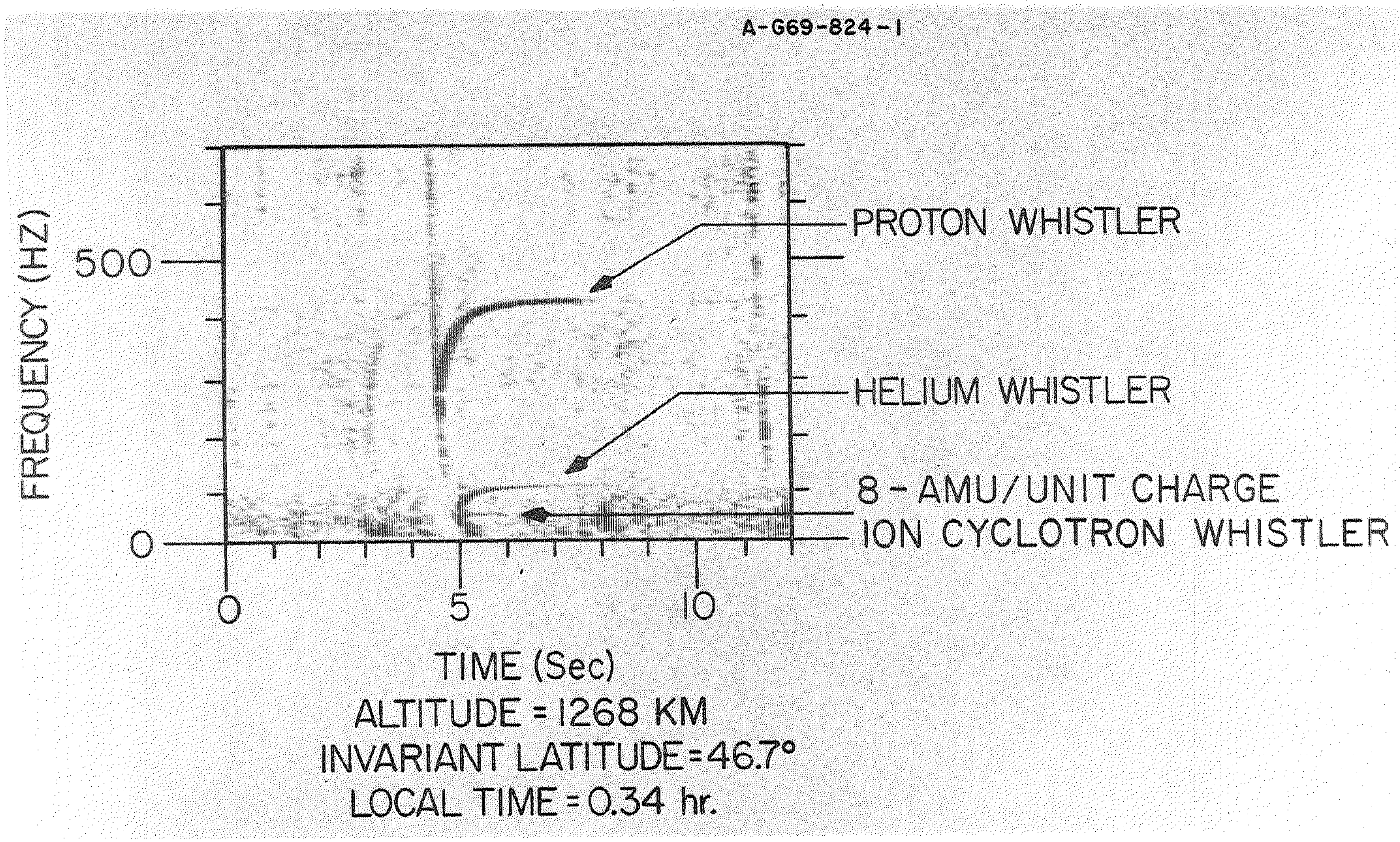
TABLE 1

Date	Universal Time	Altitude	Invariant Latitude	Local Time
	hr min:sec	km	degrees	hours
March 2, 1969	0549:38	1425	50.1	1.20
August 11, 1969	1150:27	2130	41.2	6.10
August 15, 1969	1234:52	1814	48.0	5.89
August 24, 1969	0939:28	1450	53.7	4.95
August 24, 1969	0941:24	1346	58.6	5.05
September 2, 1969	0836:06	1373	42.7	3.70
September 2, 1969	0834:03	1337	37.4	3.30



A-G69-824-1
FREQUENCY (HZ)
500
0
PROTON WHISTLER
HELIUM WHISTLER
8-AMU/UNIT CHARGE
ION CYCLOTRON WHISTLER
0
5
10
TIME (Sec)
ALTITUDE = 1268 KM
INVARIANT LATITUDE = 46.7°
LOCAL TIME = 0.34 hr.

Figure 1