EVIDENCE FOR THE SOLAR CORPUSCULAR ORIGIN OF THE DECAMETER-WAVELENGTH RADIATION FROM JUPITER*

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(Received August 22, 1960; revised manuscript received October 3, 1960)

Various speculations have been made regarding the origin of the intense but sporadic radiation emitted by Jupiter at decameter wavelengths. Discharges of atmospheric electricity,[1] volcanic explosions,[2] atmospheric chemical reactions,[3] and charged particles arriving from the sun[4] have all been suggested as possible sources of the energy. Dr. Eugene Epstein of Harvard College Observatory pointed out to the writers that if solar particles are the cause, one would expect the radio emissions to be correlated with geomagnetic activity at the time of Jovian opposition. A search for such a correlation was made by the writers during the recent opposition. An apparent correlation was found to exist.

The radio observations were made at the Maipú Radioastronomical Observatory near Santiago, Chile. The observations used in the present analysis extended from April 29, 1960, to August 3, 1960. Opposition occurred on June 20, 1960. The frequencies employed were 18 Mc/sec until May 30, and both 18 Mc/sec and 10 Mc/sec after May 30. The antennas were dipole arrays providing about 6 hours of Jupiter coverage each night. Commercial receivers and low-speed pen recorders were used. Geomagnetic and solar data were obtained from the High Altitude Observatory, Boulder, Colorado.

The daily Jupiter activity index is plotted as a function of date in the upper part of Fig. 1. The Jupiter activity index for a given date is defined as the mean height of the three largest noise pulses (corrected for any variations in gain) multiplied by the duration of the activity, divided by the duration of the observation period. The geomagnetic *A* index is plotted as a function of date in the lower part of Fig. 1. The histograms have been so displaced that the dates on the lower one match dates 9 days later on the upper one. Some degree of correlation between the two histograms is apparent.

The letters on the lower histogram indicate the starting times of all geomagnetic storms reported during the period. Capitals indicate storms for which the associated solar flare had been observed earlier; no associated flares were observed for the storms indicated by lower case letters. The velocities of the leading particles in those storms

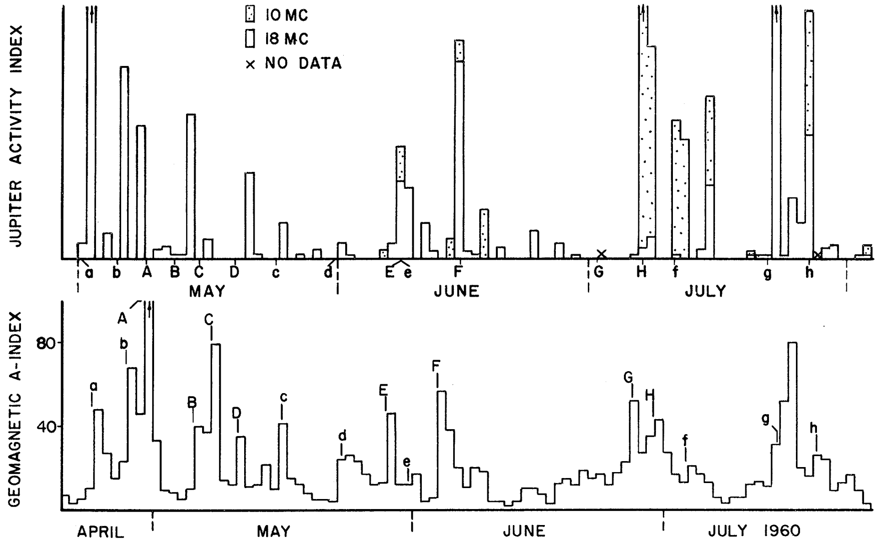

FIG. 1. Upper histogram: Jupiter activity index plotted as a function of date. Clear bars and dotted bars refer to 18 Mc/sec and 10 Mc/sec reception, respectively. Dates for which data were not available are indicated by ×. Lower histogram: Geomagnetic *A* index plotted as a function of date. All dates are Universal Time.

designated by capitals could be calculated, since their times of departure from the sun and arrival at the earth had been observed. The arrival times at Jupiter were determined for these particles; they are indicated by capitals on the upper histogram. Approximate arrival times for the leading particles in the storms not preceded by observed flares are determined by assuming that the travel time from the earth to Jupiter is 8 days. This is approximately the average time for those particles of known velocity to travel the same distance.

There seems to be a pronounced correlation between the arrival dates of storm particles at Jupiter and the dates of occurrence of major Jupiter noise storms. In most instances the indicated arrival dates and the days of greatest Jupiter activity coincide or are separated by only a day or two.

Data on the events identified by capitals are given in Table I. The angular distance of a flare from the center of the sun's disk as viewed from Jupiter is designated by α. For the events in Table I, one would expect the best correlation with Jupiter activity for small values of α and for times close to opposition. Most of the events identified by lower case letters were due to the passage of solar M regions. For these events, correlation with Jupiter activity should not be limited to the time of opposition, although deviations of at least a day or two in the actual arrival times from the indicated values are to be expected. It should be noted that the correlation would not have been as good if only the 18 Mc/sec data had been used. Some intense noise storms occurring at the lower frequencies are not detected at 18 Mc/sec (although very few are entirely confined to frequencies above 18 Mc/sec). It is believed that the correlation would be better if there were wider frequency coverage and 24-hour-per-day time coverage (from a world-wide chain of observatories).

The results presented in Fig. 1 seem to indicate that the radiation from Jupiter at decameter wavelengths is caused by the influx of charged particles from the sun. A theory of the radiation based on this conclusion must account for at least two other well-established phenomena, namely, the concentration of the noise sources into one or more relatively narrow longitude zones which maintain the same rotational period for at least several years, and the great predominance of radiation which is right-handed elliptically polarized.[5] To account for the longitude effect, the writers propose that there are one or more magnetic poles (or other field anomalies) near the surface of the planet which are some distance from the geographical poles. The charged solar particles tend to spiral into the magnetic poles, causing a local increase in particle concentration. Whatever the actual radiative process is, more radiation would be expected from such regions, and the source areas would thus rotate with the period of the solid crust of the planet.

If Jupiter's magnetic field is a dipole field, then it must be assumed that the dipole axis and the rotational axis do not coincide. Since observations do not indicate two equal noise source areas 180° apart in longitude, the additional assumption must be made that the dipole center does not coincide with the center of the planet. However, another possibility is that the radiation is emitted by electrons in the vicinity of anomalies in the

Table I. Data on flares and associated particles.

	Flare		Particle travel time		
Event identification	Date	Importance number	Sun to Earth	Earth to Jupiter	α (degrees)
A	April 28	3	48.0 hr	9 days 4 hr	83
B	May 4	2	33.7 hr	6 days 8 hr	53
C	May 6	3+	38.3 hr	7 days 4 hr	58
D	May 9	3	45.6 hr	8 days 11 hr	92
E	May 26	2+	59.2 hr	10 days 12 hr	4
F	June 1	3+	66.5 hr	11 days 17 hr	56
G	June 25	3	29.0 hr	5 days 1 hr	18
H	June 27	3	45.9 hr	8 days	45

intense dipole field which has been postulated by Field[6] to account for the decimeter (microwave) radiation from Jupiter. In this case the dipole axis and rotational axis are assumed to coincide, the rotation of the field anomalies causing the observed periodicity. Both the decameter and the decimeter radiation could thus be due to cyclotron emission if this model is assumed.

The observations which have been described cannot be repeated until the period from about June through August, 1961, when the earth will again pass between the sun and Jupiter. Observing conditions at this time will be best in the southern hemisphere, since severe interference from summer thunderstorms will be experienced in the northern hemisphere.

The writers are greatly indebted to Dr. Federico Rutllant, director of the National Astronomical Observatory and the Maipú Radioastronomical Observatory of the University of Chile, without whose assistance the Chilean observations would have been impossible.

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*This program has been supported by the National Science Foundation, the U. S. Army Office of Ordnance Research, and the Office of Naval Research.

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MAGNETIC SUSCEPTIBILITY OF THE TWO PHASES OF LITHIUM AT LOW TEMPERATURES

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(Received August 26, 1960; revised manuscript received October 4, 1960)

Since the initial discovery of a phase transformation in lithium,[1] experimental studies of the influence of the transformation on various physical properties have been undertaken.[2-4] Some of these measurements[3] can be interpreted on the basis of a change in the equilibrium electron properties when transforming from the bcc to the low-temperature hcp phase. To be specific, the resistance results can be interpreted as due to a change of approximately 20% in the density of states on transforming lithium to the hcp phase. Since the magnetic susceptibility may be considered to consist of the sum of the susceptibility of the lithium ions and the susceptibility of the conduction electrons, a density-of-states change should be observable as a change in the total susceptibility of lithium. Preliminary results have been reported on the susceptibility of lithium at low temperatures[5] but considerable doubt existed as to whether the observed change in the susceptibility was actually related to the phase transformation. Present difficulties in the interpretation of measurements on the susceptibility of lithium involve apparent changes in the ferromagnetic corrections on temperature cycling of the sample. However, owing to the considerable interest in the properties of lithium and since specific heat measurements at present yield no information about electronic changes associated with the low-temperature phase transformation, more recent measurements on the susceptibility of lithium in the temperature region 115°K-60°K where the transformation takes place have been made and are reported here.

The samples of lithium used in these measurements were of the highest purity available and were supplied by the Lithium Corporation of America.[6] The Curie method was used to determine the susceptibility of the lithium samples which were in the form of bare rods. The amount of ferrous impurity present in precipitated form would correspond to two parts per million of iron if a saturation value of 200 emu/g is assumed for the saturation magnetic moment. The absolute room temperature susceptibilities of the samples used range from $(1.89 \pm 0.01) \times 10^{-6}$ to $(1.93 \pm 0.01) \times 10^{-6}$ emu/g and are in reasonable agreement with the value reported by Pugh and Goldman.[7] Investigations of the temperature