LONG TERM CHANGES IN COSMIC RAY DIURNAL VARIATIONS OBSERVED BY ION CHAMBERS IN HONG KONG AND JAPAN

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ABSTRACT

Yearly average solar diurnal variations of cosmic ray ion chamber data are inspected from a view point of the eleven and the 22 year solar activity cycle modulations. The ion chamber data are from Tokyo for 1948-77, Mt. Norikura for 1958-77, and Hong Kong for 1970-83. Those of Carnegie Institution of Washington are also used. The neutron data from various stations are further added. From an inspection of observed data, we propose a simplest approximation that the 11 year and the 22 year variations of the solar diurnal variation are along 18-hour and 12-hour axes, respectively. The 18-hour component of diurnal variation in the 11 year cycle increases toward the solar active years. The 12-hour component is enhanced when the solar general magnetic field is parallel to the rotation vector, and is almost zero for the other state. The transition occurs when the amplitude of the 18-hour component is greater owing to the transition of the field during the maximum phase of solar activity. The 22 year shift is consistent with the drift modulation model in heliosphere. While the 11 year variation along the 18-hour axis is not interpreted yet.

1. Introduction. The present paper follows after the discovery of the 22 year variation in the phase of solar diurnal variation by Thambyahpillai and Elliot (1953), the invariant 18-hour anisotropy which is agreeable with the Axford-Parker theory (McCracken and Rao, 1965), and the two component analysis of the eleven and the 22 year variation in the diurnal variation by Forbush (1969).

Continuous observations of cosmic ray intensity by means of identical ion chambers have been started in 1948 at Tokyo, then Mt. Norikura, Sapporo (now stopped), Hong Kong, and Kochi. Though the observation accuracy is not so high as current muon telescopes and the neutron monitors, the data can be used as tools to inspect the diurnal variations in yearly basis for long time period.

If the deflection of the cosmic ray particles through the geomagnetic field, and the background diurnal variation due to, say, the temperature effect are taken into account, the observed diurnal variation can be converted to the anisotropy detectable in space. The greatests of all the yearly average diurnal variations are the eleven year solar cycle variation and that related to the reversal of the solar general magnetic field at nearly the years of maximum activity which makes the 22 year variation.

Though there are fluctuations, from an inspection of the vector diagrams of diurnal variation, the eleven year and the 22 year variation can be separated into the amplitude variations along 18-hour and 12-hour axes, respectively. Such an approximation is given from a very rough idea, but the shift along 12-hour axis accords with the drift model of heliospheric modulation.

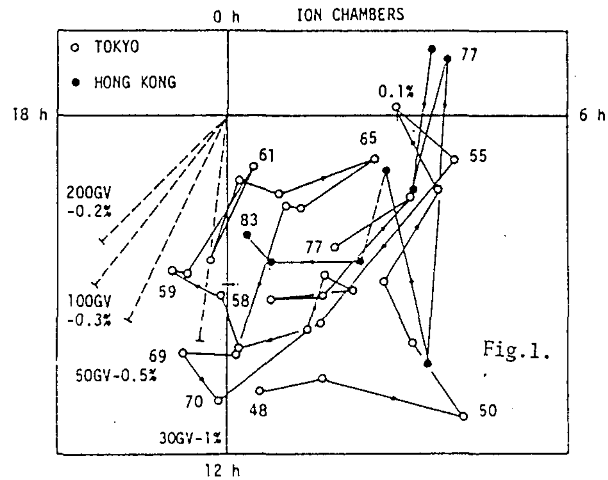
2. Display of the diurnal variations. Fig. 1 shows the vector diagram of the solar diurnal variation observed at Tokyo. Hong Kong data are added to extend the years. The data have only been corrected for the barometer effect. The broken lines indicate expected observations if the direction of anisotropy in space is 18 hour. The variation spectrum is assumed to be flat upto rigidity given in the figure. The values with % in the figure is the amplitude observable in space. If the diurnal variation due to the temperature effect is concerned, the origin of the observed vectors must be shifted, though the amount of shift can not reasonably be given, for the temperature diurnal variation is not known accurately. It can be allowed, however, the origin can be shifted so that the pattern becomes similar to those observed by the neutron monitors. The diagrams for other stations including those of the Carnegie Institution (Forbush, 1969) and of some neutron monitors are seen in the following Figs. 2-5.

3. Discussion. The hand writing drawing in Fig. 6 indicates our idea to interpret approximately the variations during 11 and 22 year periods. It can be shifted and rotated to fit the observed diagram of the anisotropy. There are appreciable scatter around the proposed simple variation, but one can see this kind of interpretation is possible. It is seen that the transition from different 12-hour states occur at around years of the reversal of the solar general magnetic field. This situation is understandable if the drift effect of modulation in heliosphere is concerned (Jokipii and Kopriva, 1979).

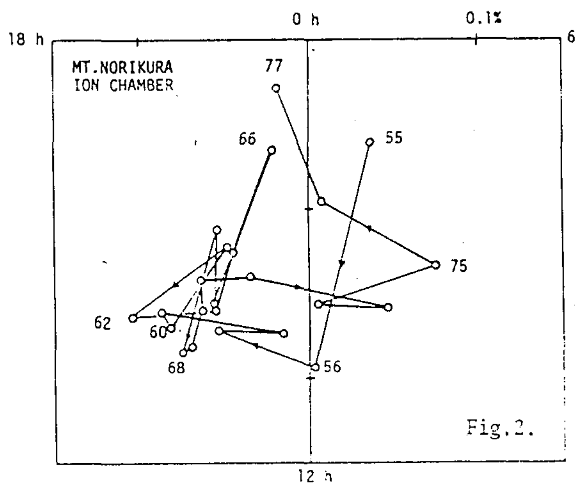
Kadokura and Nishida (1984) have simulated the anisotropy of cosmic rays in heliosphere putting the effect of drift as well as the diffusion through the interplanetary magnetic field (IMF) and Compton-Getting effect in the system of solar wind. They compared the results for different states of the solar general magnetic field which is parallel or anti-parallel to the rotation vector. The difference appears in the term of diffusion if restricted the position at the earth orbit. The anisotropy due to the diffusion is enhanced during the anti-parallel state. Since the diffusion is along IMF, the anisotropy is along 21-hour axis. That makes the 18-hour component greater than that of the other state. On the other hand, because of the enhancement of 0-hour component, the overall effect of the 12-hour component is almost canceled out, while that in the parallel state remains to be significant. It appears as the enhancement of the 12-hour component during the parallel state compared with that of the anti-parallel state.

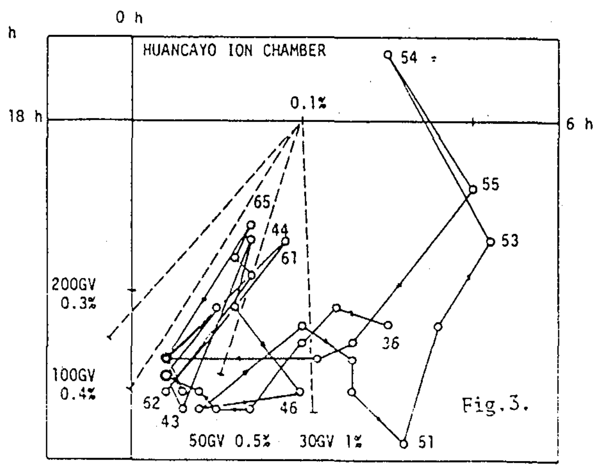
As for the eleven year variation of the diurnal variation, though the observed variation is clearly seen, the model for that has not been fixed yet. One point which should be examined further is the distribution of the diurnal vectors in daily basis. While the average amplitude changes, at least two patterns can exist. The one is that the total distribution shifts without change in shape. The other is that the shape of distribution is distorted; for example, the frequencies at greater amplitudes increase compared with those at lower amplitudes. If the latter is a real case, there are various origins which enhance the amplitude during the solar active years. For example, the frequencies of occurrence of solar flares, Forbush decreases and so on are greater during the active years. Still, why the enhancement occurs along the 18-hour direction during the active years is an open question. We leave this problem for further studies

Fig.1. Observed yearly average diurnal vectors for ion chambers in Tokyo and Hong Kong. The broken lines indicate expected observations if the direction of anisotropy is 18 hour in space The spectrum is flat upto GV written inside. The % values correspond to the amplitude in space.



Figs.2-5. The same as Fig.1, but for ion chambers at Mt.Norikura, Huancayo, and Cheltenham (Forbush, 1969), and neutron monitor at Mt.Norikura (Kawasaki et al. 1983), respectively.





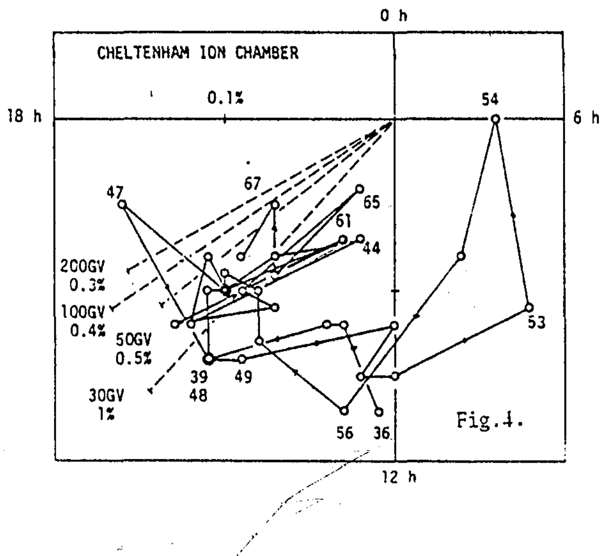


Fig.4.

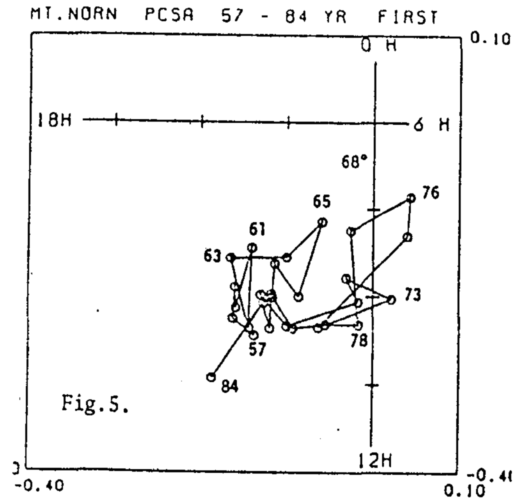
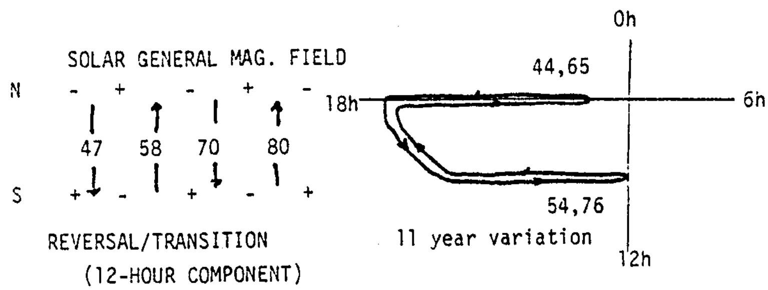


Fig.5.

Fig.6. Simplest and approximate aspect of the 11 and the 22 year variations of the solar diurnal variation. See text.



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