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ABSTRACT

The first two harmonics of sidereal wave in the intensity variations of the Budapest underground telescopes are studied on a year-to-year basis. By comparing the sidereal daily vectors obtained in sectors of opposite IMF directions at a pair of similar telescopes located at conjugate latitudes, one is able to disentangle the solar effects from a galactic anisotropy. Applying this procedure for the Budapest and Hobart measurements, the vector ascribable to galactic anisotropy has an amplitude of ~0.02% and phase ~5 hr. An attempt is made to draw some conclusion on the undistorted galactic anisotropy by taking into account the heliomagnetospheric deflection.

АННОТАЦИЯ

На основе измерений, проводящихся в течение нескольких лет с помощью подземных телескопов в Будапеште исследуются первые две гармоники звездно-суточной вариации интенсивностей. Сравнением звездно-суточных векторов, полученных в секторах противоположного знака межпланетного магнитного поля для двух похожих телескопов, расположенных на сопряженных широтах, возможно отделить солнечные эффекты от галактической анизотропии. Применяя этот метод для данных измерений, проведенных в Будапеште и в Хобарте, получено, что вектор, происходящий от галактической анизотропии, имеет амплитуду 0,02% и фазу ~5 часов. Принимая во внимание отклонение в гемомагнитосфере, делаются попытки дать некоторые выводы относительно неискаженной галактической анизотропии.

KIVONAT

Évenkénti felbontásban vizsgáljuk a budapesti földalatti müonteleszkóp intenzitásváltozásaiban fellépő sziderikus hullám első két harmonikusát. Összehasonlítva a bolygóközi mágneses tér ellentétes szektoraiban két hasonló felépítésű, ellentétes földrajzi szélességen elhelyezett teleszkópra kapott sziderikus vektorokat, a szoláris effektusokat el tudjuk választani a galaktikus anizotrópiától. Ezt az eljárást alkalmazva a budapesti és a hobarti mérésekre, a galaktikus anizotrópiából származó vektor amplitudójára 0,02%-ot, fázisára ~5 órát kapunk. Figyelembe véve a heliomagnetoszféra eltérítő hatását, következtetünk a torzitatlan galaktikus anizotrópia nagyságára.

1. INTRODUCTION

In spite of the growing material from new underground muon telescopes, the interpretation of the sidereal daily wave appearing in the intensity variations of $10^{11}-10^{12}$ eV cosmic rays is still rather controversial. While above $\sim 10^{13}$ eV, which is beyond the solar influence, there is no doubt about the existence of a genuine sidereal anisotropy, it is widely believed that any galactic effect is entirely concealed by solar modulation below a few hundred GeV. There are two groups of solar effects on sidereal variation: a sidereal wave is produced by solar anisotropy having nonzero component perpendicular to the ecliptic plane on the one hand, while the heliomagnetosphere significantly distorts the external distribution on the other hand.

The solar originated part of the sidereal wave was studied in connection with the sector structure of the interplanetary magnetic field /Swinson, 1969, 1976; Humble and Fenton, 1977/ and showed a strong dependence on the field polarity. As for the second problem, one has to determine the asymptotic viewing directions by carrying out trajectory calculations in IMF models /Davies et al., 1978/. The reduction of the lower energy limit to significant galactic anisotropy demands the more thorough knowledge of the three-dimensional structure of the IMF.

2. DATA ANALYSIS

Below we present the analysis of data obtained by the underground telescopes at Budapest /40 mwe/ which was performed for separate groups of days according to the sectors of different magnetic field polarities. On the basis of the statistical method discussed by Benkó et al./1977/, the first two harmonics of the solar, sidereal and antisidereal waves has been determined for the periods of 1958-63 and 1967-68. Unfortunately, due to the insufficient operation of the telescopes, we have not managed to obtain significant results for 1967. For the selection of days according to the different sectors the terrestrial magnetometer records published by Svalgaard /1972/ were used. The year-to-year variation of the sidereal first harmonic is presented in *Fig. 1.* in comparison with the Hobart data for the same period. The second harmonics of the sidereal wave are shown in *Fig. 2.*

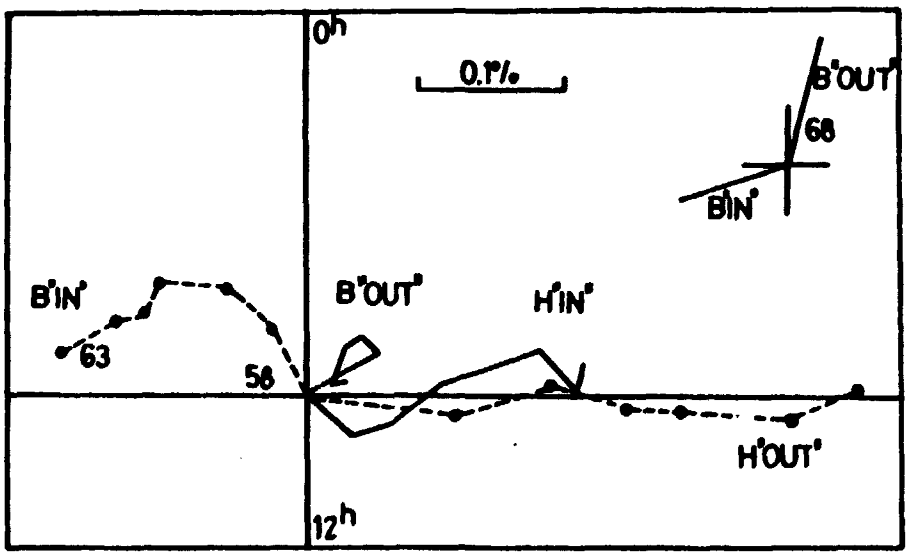

Fig.1. Summation dial of Budapest and Hobart sidereal first harmonics for 1958-63. The Budapest 1968 vectors are indicated in the upper right corner.

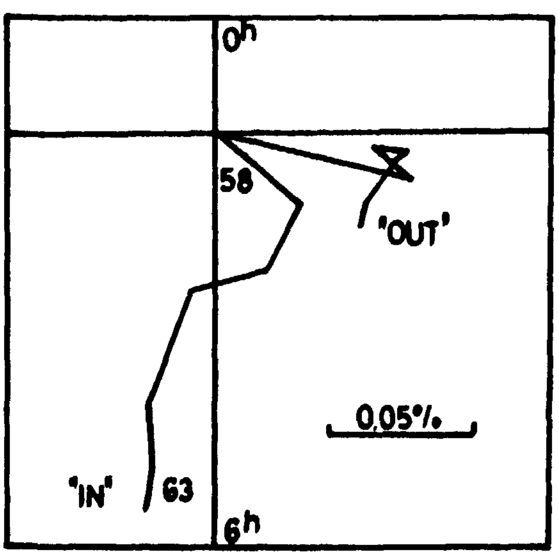

Fig.2. Sidereal 2^{nd} harmonics at Budapest during 1958-63.

3. DISCUSSION

Sidereal variations which are spurious from the point of view of galactic anisotropy mainly arise from anisotropy of solar origin. Vector-type anisotropies perpendicular to the ecliptic plane were first discussed by Swinson /1969/ suggesting that a BxVN streaming arises as a consequence of the radial density gradient. However, according to spacecraft measurements at lower energies, the value of this gradient is likely too low to produce the observed anisotropy. Another suggestion was made by Swinson /1976/ that a similar streaming may occur due to the electric field introduced by the corotation as observed at the Earth. Both effects give rise to anisotropies depending on the magnetic field polarity, the phases are opposite in the alternate sectors. Tensor anisotropies of solar origin also contribute to the sidereal wave /Kóta, 1975/, but they are not essentially field dependent. This way, the first and second order contributions from solar anisotropy can be separated on the basis of dependence on magnetic field polarity.

Although we have not much information on the three-dimensional shape of the modulation region, a plausible assumption is that it is not very much distorted by the interstellar wind, so it does not exhibit strong north-south asymmetry. This assumption together with that of azimuthal symmetry in the helioequatorial plane allows to compare the measurements made in the northern and southern hemispheres. Namely, the Budapest /47 ^{o}N/ and Hobart stations /43 ^{o}S/ lie at almost the conjugate latitudes, their energy ranges are practically the same /40 and 36 mwe depths, respectively/. Moreover, a continuous six year data set is available /1958-1963/ for both stations. Under the above assumptions, the even harmonics of the solar originated sidereal variation should be of the same amplitude and opposite phase as observed in the alternate sectors in each of the two measurements. Thus, by summing up the Budapest IN and Hobart OUT as well as the Budapest OUT and Hobart IN sidereal vectors, the major part of the solar contribution can be eliminated. The result of this procedure is displayed in *Fig.3*. While because of the yearly variability of the vectors the close coincidence seen in Fig.3. seems to be accidental /the statistical error is ~ 0,008%/, it supports that the residual vectors are free of solar effects.

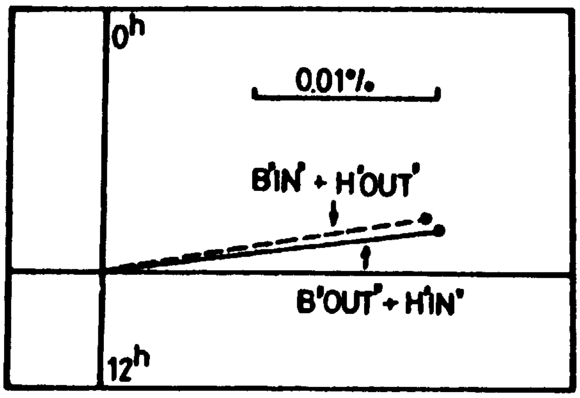

Fig.3. Summation of Budapest and Hobart sidereal first harmonics for opposite sectors

3.

*I*n order to remove solar effects from sidereal variation several inclined telescopes having equatorial viewing directions were installed. The south-pointing telescope in London yielded a small solar wave due to the higher mean rigidity /~500 GV, Davies at al., 1978/. The sidereal wave obtained by the Hobart north-pointing telescope turned out to be field-dependent, the summation of the three-year period results in an IN+OUT vector of 0.02% with phase of ~3.5 h /Humble and Fenton, 1977/. The comparison of these results together with galactic anisotropies obtained at higher energies is presented in *Fig.4*.

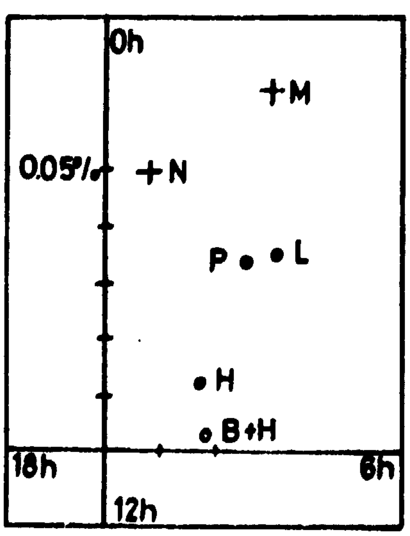

Fig.4. First sidereal harmonics at Musala/M/, Norikura/N/, Poatina/P/, London /L/, Hobartincl./H/ and $B_{in}+H_{out}$ *vector*

Trajectory calculations performed in a realistic IMF model /Erdős & Kóta, 1979/ indicate that the amplitude of the galactic wave is reduced by a factor of ~2/3 with respect to the free space anisotropy, while the phase remains virtually unchanged. A further reduction is due to the high latitude of the stations, so the total reduction factor is roughly 0.4. Thus, assuming that the vector of Fig.3. is of galactic origin, the free space amplitude would be about 0.05%, compatible with the London results. The phase difference between them also decreases if the Compton-Getting effect arising from the motion of solar system is taken into account.

Turning to the solar originated parts, we can compare them by subtracting the G=1/2 $B_{in}+H_{out}$ vector from the total observed ones: $B^*_{in}=B_{in}-G$ and $B^*_{out}=H_{out}-G.B_{out}$ vectors have the phase at ~18h, the amplitudes are 0.045% and 0.010%, respectively. While it is supposed that B^*_{in} and B^*_{out} are responsible for the solar originated parts, the presence of galactic tensor anisotropy cannot be excluded. If we assume that the above vectors are composed of a field-dependent, B_1, and a field-independent part, B_2, one arrives at

B_1: 0.017% 18h /IN sector/, 6h /OUT/

B_2: 0.028% 18h.

The field-independent part probably originates from a solar tensor anisotropy which can also be accounted for the solar semidiurnal variation. The phase of B_2 is in agreement with the pitch angle distribution model /Nagashima et al., 1971/, while it contradicts to the symmetric density gradient model /Quenby & Lietti, 1968/. By comparing the amplitudes the former model results in 0.029% also in good agreement with observations. The phase of the sidereal second harmonic also supports the validity of a pitch angle distribution around the IMF, although the amplitude obtained experimentally is larger than expected. It should be mentioned, however, that the contribution of higher galactic harmonics cannot be identified as galactic if the observed phase is near to either 6 or 0 hr.

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