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LARGE-SCALE MOTIONS OF THE SOLAR QUIESCENT FILAMENTS AND THE TORSIONAL OSCILLATIONS OF THE SUN

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In the past few years the interest in the large-scale movements in the solar atmosphere greatly increased in connection with the torsional oscillations of the Sun /Howard and LaBonte, 1980/. This problem is requiring a new development of the Sun's dynamo theory /Schlüssler, 1980, 1981/. There is a generally shared opinion that the regularities in these motions will reveal the physical nature of the solar activity.

The space and time regularities in the distribution of some active formations on the Sun lead to the conclusion that at least two activity cycles are present simultaneously: one at low heliographic latitudes and in its interim large-scale active regions are generated while the other is formed at high heliographic latitudes and is marked by the polar prominences /L.d'Azambuja and M.d'Azambuja, 1948/, the ephemeral active regions /Martin and Harvey, 1979/, the coronal holes /Simon, 1979/, etc.

Recently Howard and LaBonte /1980/ found out a new evidence for cyclic activity at higher heliographic latitudes expressed by the torsional oscillations. On the basis of analysis of photospheric plasma dopplergrams for a period of 12 years they pointed out that symmetric zonal structures are observed. They are moving from east to west /E-W/ with velocity amplitudes 3 m/s superposed to the mean differential rotation. This reduced flow consists of alternate quick and slow zones. During most of the time there are two quick and two slow zones in each hemisphere and they are symmetric with respect to the equator which is always in a slow zone. This global structure moves towards the equator in roghly 22 years so that the new zones appear at the poles. The central part of the magnetic active region /sunspot region/ is situated at the pole-side boundary of a quick zone.

These results are a serious proof of the solar magnetic cycle's not being a random process created by a surface drift of magnetic fields but one generated deeply under the solar surface by means of resonant large-scale motions.

If we accept such description of a large-scale cyclic circulation we may expect the motions of long term active formations in the solar atmosphere to be influenced. The best objects for testing this hypothesis are the quiescent prominences because some of the live till 8 solar rotations and their projections on the Sun, named filaments, are ideal tracers to investigate the solar differential rotation as well as the large-scale circulation in the solar atmosphere.

There are also another considerations to suppose the quiescent prominences suitable for such investigations. For example, their regions of activity reveal a fine structure /Ananthakrishnan, I952; Dermendjiev, I980/. Moreover, the quiescent prominences themselves are laid over magnetic arch structures whose "legs" are connected with the subphotospheric layers /Kieppenhahn and Schluter, I957/ so that they would have responded to the E-W flows and the meridional circulation of the photospheric plasma.

It is the purpose of this paper to give a brief description of the main results obtained in our study of the long living filaments associated with the centres of activity and to test the correctness of the above mentioned hypothesis.

For the aims of our study we have used the coordinate data of the long living filaments published in the catalogues of the Meudon Observatory and covering a period from I957 /rotation No I389/ till I963 /rotation No I475/. For each of the 247 filaments the longitudinal ΔB and latitudinal ΔL shifts of the centre were defined for every two succeeding rotations and thus a series of samples $\{\Delta B\}^k$ and $\{\Delta L\}^k$ was obtained /k=I,2,...,8 runs the rotations measuring the duration of the filaments/.

The most representative statistical characteristics of ΔB and ΔL treated as random quantities are the medians $M_e\{\Delta B\}^k$ and $M_e\{\Delta L\}^k$ of their empirical distributions.

The dependences of the medians with the time in terms of solar rotations are plotted on fig. Ia /for the total sample/ and on fig.Ib,c /for the subsamples in the epochs of minimum and maximum of the solar activity cycle/.

From these figures it is possible to draw the conclusion that the latitude motion of the filaments consists of two parts each of them including acceleration and deceleration. In broad lines this tendency is retained for the total sample as well as for the subsamples in the epochs of minimum and maximum. Also it is possible phases of accelerated and decelerated longitudinal E-W motions to be defined from the temporal variations of $M_e\{\Delta L\}^k$.

What explanation is possible to be given of this interesting regularity?

If this effect is due to a decay process of the centres of activity, the temporal variations of medians will look like a diffusion, i.e. the shift of the filament from its initial position will be proportional to $t^{I/2}$ along both longitudinal and latitudinal coordinates. Therefore such assumption is unacceptable. The suggestion that this effect is caused by the simultaneous action of the meridional circulation and the faster differential rotation of the strong magnetic field regions, like the centres of activity, is also unsatisfactory. This conclusion is drawn from the cross-correlation functions $C_{\Delta B,\Delta L}(\tau)$ plotted on fig.2. They have, except the maximum at $\tau=0$, a secondary one at $\tau=4$ /for the South hemisphere/ and at $\tau > 9$ /for the North hemisphere/.

The result obtained in our study may be explained satisfactory if we suggest that the filaments during their migration to the poles consecutively pass through alternating fast and slow zones, i.e. zones of accelerated and decelerated photospheric plasma.

In fact, according to fig.2 if a filament is formed during a solar activity maximum, it will be situated in the poleward side of a magnetic activity region, i.e. according to Howard and LaBonte /I980/ in a slow zone and will perform a decelerated E-W longitudinal motion for a period of 3-4 rotations. After its passage across the slow zone the filament is pushed towards the pole by the meridional circulation, falls into a fast zone and starts an accelerated E-W motion.

A similar interpretation for the minimum phase is more uncertain because the torsional oscillations are not fully investigated yet and it is not clear whether the magnetic belt migrates only towards the equator keeping its position in relation to the fast and slow zones or splits into two belts each of them performing an independent migration towards the equator and towards the pole of the corresponding hemisphere. Fitting into the pattern of the above interpretation our results show that at the time of minimum the filamenta are formed in a fast zone and later pass through the neighbouring slow zone.

As a conclusion we would like to note that the discussed problem is very interesting and our investigation will continue.

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