# CONJUGACY OF AURORAL OVAL

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***Abstract:*** Results of statistical studies so far made hitherto on the auroral ovals in the northern and southern hemispheres are reviewed. Then, a same analysis method is applied on both northern and southern optical auroras to identify the auroral ovals as a function of magnetic activities. The result shows that a good geomagnetically conjugate relationship of the auroral oval is established.

In the end, the configurations of the northern auroral oval at different universal times for different magnetic activities are projected along the real magnetic field lines onto the southern hemisphere surface.

The most frequent occurrence of auroras in the northern and southern hemispheres which are close to geomagnetic parallels 67° was described by VESTINE (1944) and GEDDES and WHITE (1939). However, only after the publication of a paper by HULTQVIST (1958), who calculated the real field lines of geomagnetic field, it became possible to perform the investigations of the conjugacy of the regions of most frequent aurora occurrence in both hemispheres at the modern level. The comparison of statistical distributions of auroras in the northern and southern hemispheres has been performed by FELDSTEIN (1963a) and BOND and JACKA (1963). It is shown by them that aurora distributions within the limits of accuracy of these data are conjugate with respect to the geomagnetic field lines.

In Fig. 1, the isoauroras (*i. e.* the lines of equal frequency of aurora occurrence in the zenith) are illustrated for the northern and southern hemispheres in the night and day hours for the IGY period (FELDSTEIN, 1963a), when the most comprehensive observations of auroras were performed. In Fig. 1, the night hours cover six hours centered at the local midnight while the day hours twelve around the midday. The figures represent the frequency of aurora occurrence in per cent, calculated from ASCA (Annals IGY 1962), the maximal isoauroras being plotted by thick lines. A beautiful conjugate relationship between the maximal isoauroras has already been reported by FELDSTEIN (1964).

A rather close conjugacy of forms, intensity, spatial and time variations of auroras at a nearly conjugate station pair, Farewell-Campbell ($\phi \sim 61°$), was pointed out by DEWITT (1962). A conjugacy of night aurora in magnetically quiet periods was observed on latitudes $66° \leqq \phi \leqq 71°$ by airjets (BELON *et al.*, 1969). During the magnetic disturbances, a good conjugacy holds near the equa-

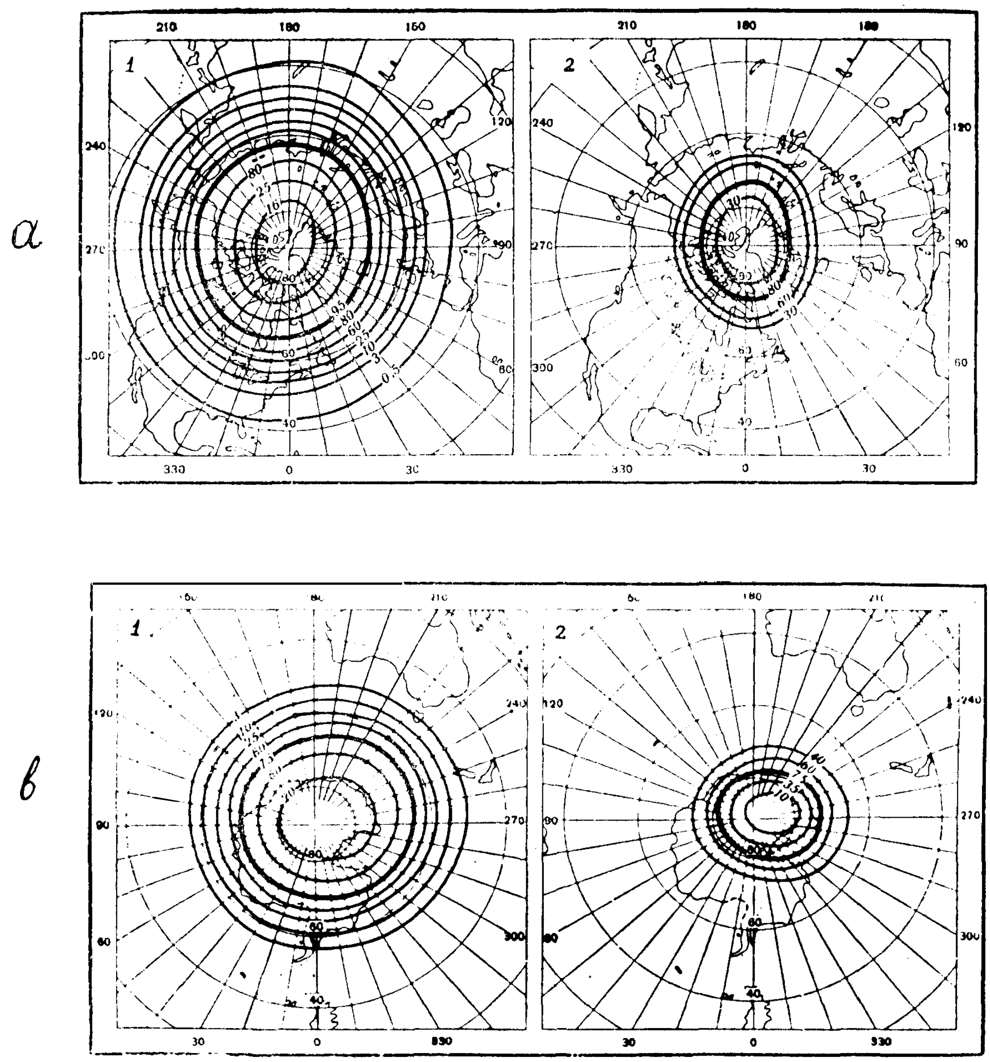

*Fig. 1. a) Isoaurorae in the northern hemisphere for IGY period.*
*1) night hours, 2) day hours*
*b) Isoaurorae in the southern hemisphere for IGY period.*
*1) night hours, 2) day hours*

torial boundary of luminescence region (FERENBACK *et al.*, 1973; STENBAEK-NIELSEN *et al.*, 1972), but on higher latitudes the conjugacy is disturbed by rather intensive substorms (BELON *et al.*, 1969; STENBAEK-NIELSEN *et al.*, 1972).

According to FELDSTEIN *et al.* (1970), the equatorial boundary of a discrete form luminescence region coincides with the boundary of the outer radiation belt, which is determined by a sharp decrease of trapped electron flux of energy of some tens of keV. The field lines on this boundary are always closed, which cause a good conjugacy of auroras. At higher latitudes, auroras are observed along magnetic field lines which penetrate the plasma sheet of the magnetotail on the night side

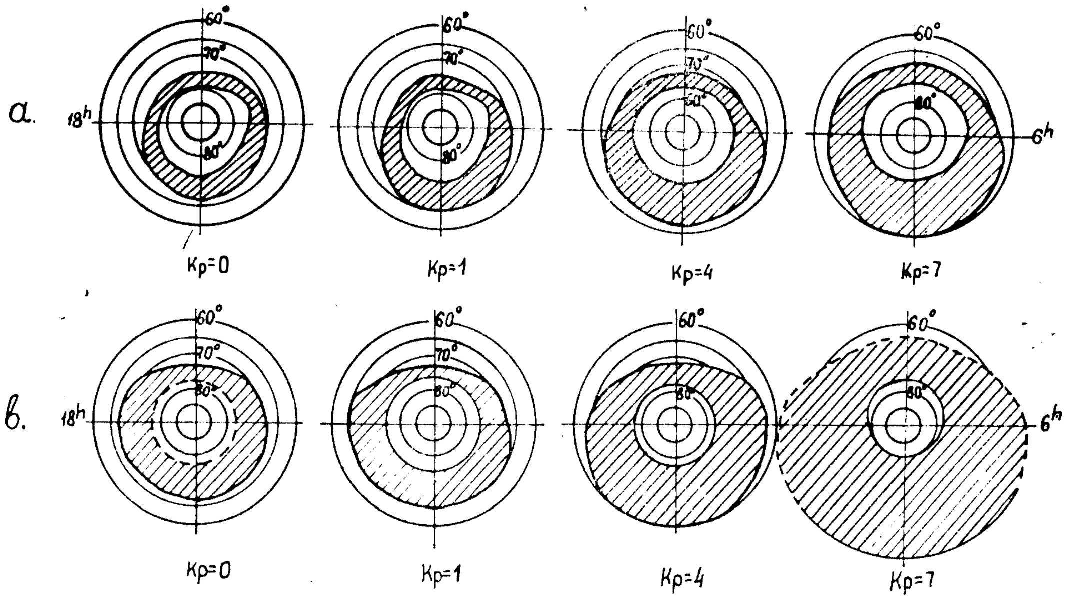


*Fig. 2. The regions of most frequent auroral occurrence (shaded) in the northern (a) and southern (b) hemispheres for different levels of the planetary magnetic activity (Kp index).*

but along the high latitudinal cusp on the day side of the earth. It seems that the particular configurations of magnetic field lines determine the auroral conjugacy, especially during magnetospheric substorms.

The investigations performed during IGY period have shown that the discrete auroral forms most frequently appeared along the auroral oval located at $\phi \sim 77°$ in the day hours and at $\phi \sim 67°$ in the night ones. The dynamics of the oval depending on the magnetic disturbance intensity has been studied for the northern hemisphere by FELDSTEIN *et al.* (1967) and for the southern hemisphere by BOND *et al.* (1971). In Fig. 2, the position of aurora oval is presented for different *Kp* values (FELDSTEIN *et al.*, 1967; BOND *et al.*, 1971). Comparing the northern auroral oval with the southern one in Fig. 2, it will be noticed that the size of oval is different from each other, though the shape of oval reasonably well resembles each other. It seems that the difference in the oval size is due to a difference in the method to determine the boundary of auroral luminescence area; In the work by FELDSTEIN *et al.*, the median position of the boundary for a given value of *Kp* is presented, while in the work by BOND *et al.*, the low and high latitudinal envelopes of all rather quiet forms of auroras are defined as the boundaries. According to BOND *et al.* (1971), however, the positions of the average lines of the ovals in both hemispheres are in good agreement within the limits of observation accuracy.

In Fig. 3, the dependence of the corrected geomagnetic latitude of the luminescence band upon the magnetic activity (*Kp* or *Q*) in the midnight sector is presented for the northern and southern hemispheres. The solid lines show the

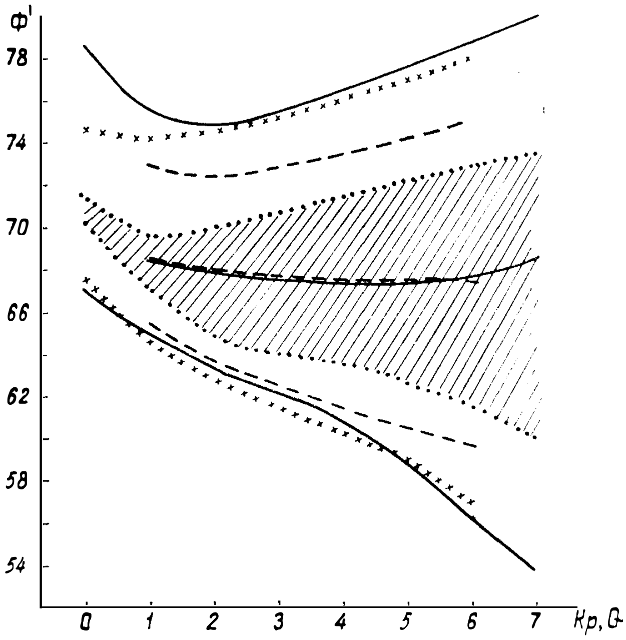


*Fig. 3. The dynamics of liminescence band in midnight sector with magnetic disturbance increase (Kp index). Boundary for the southern hemisphere-solid line, for the northern-dashed line. The corresponding lines in the middle of the picture is the position of the mean line of the luminescence band. Crosses show envelopes of all aurora forms in the northern hemisphere. Dotted lines show the boundary variations dependent on Q-index of magnetic activity.*

dependence of the boundary variations on $Kp$ for the southern hemisphere (BOND *et al.*, 1971), and the dashed lines indicate that for the northern hemisphere (FELDSTEIN *et al.*, 1967). The solid and dashed lines in the middle of the figure present the positions of the mean lines of the luminescence bands in the south and north respectively. In order to make a more precise comparison of the northern auroral oval with the southern one, the same method of analysis as that adopted by BOND *et al.* is applied on all auroral forms in the midnight sector for the northern hemisphere data. Namely, the positions of lower and higher envelopes of all auroras are determined. The results of the analysis are shown by crosses in Fig. 3. As shown in the figure, except for the higher boundary for $Kp=0\sim1$ (whose position is of a small reliability owing to small numbers for statistics) the positions of auroral luminescence bands practically coincide between the northern and southern hemispheres. It may then be concluded that a good conjugate relationship exists for the aurora ovals in the northern and southern hemispheres regardless of the magnetic activity values.

The auroral oval is definitely oriented towards the sun. Therefore, the oval

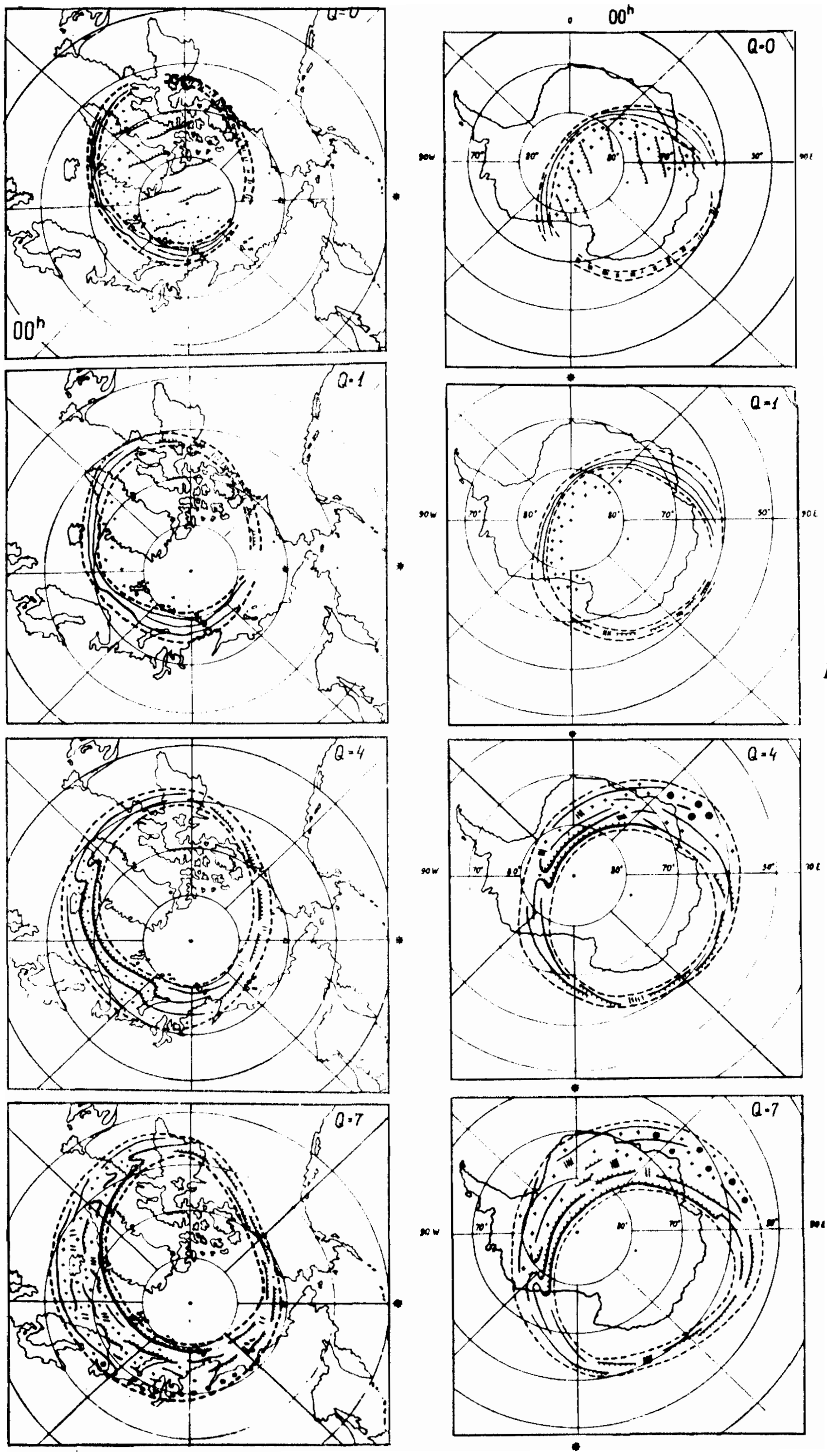

*Fig. 4. Synoptical maps of auroras in the auroral ovals for the northern and southern hemispheres at 00h UT (a), 06h UT (b), 12h UT (c), 18h UT (d) and for magnetic activity indices Q=0, 1, 4, 7. The oval boundaries are plotted by dotted lines.*

*Aurora forms inside the oval: homogeneous arc or band is depicted by a solid line; ray arc or ray band by a solid line with vertical strokes; rays or groups of rays by vertical strokes; diffusive luminescence by crosses; the spots and pulsating spots are noted by crosses in circles. The black circle represents the Sun's direction.*

*Fig. 4 (a).*

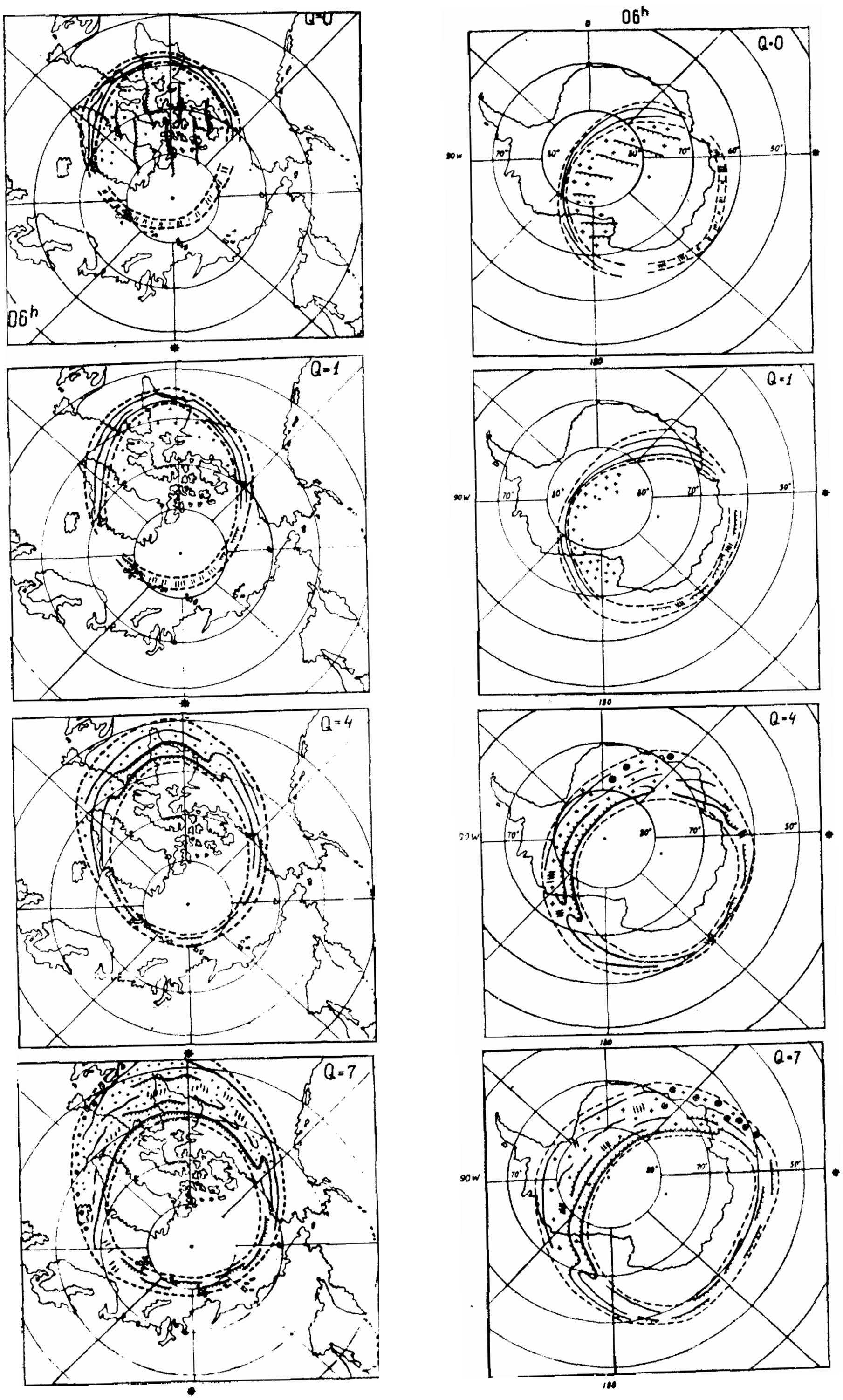


*Fig. 4 (b).*

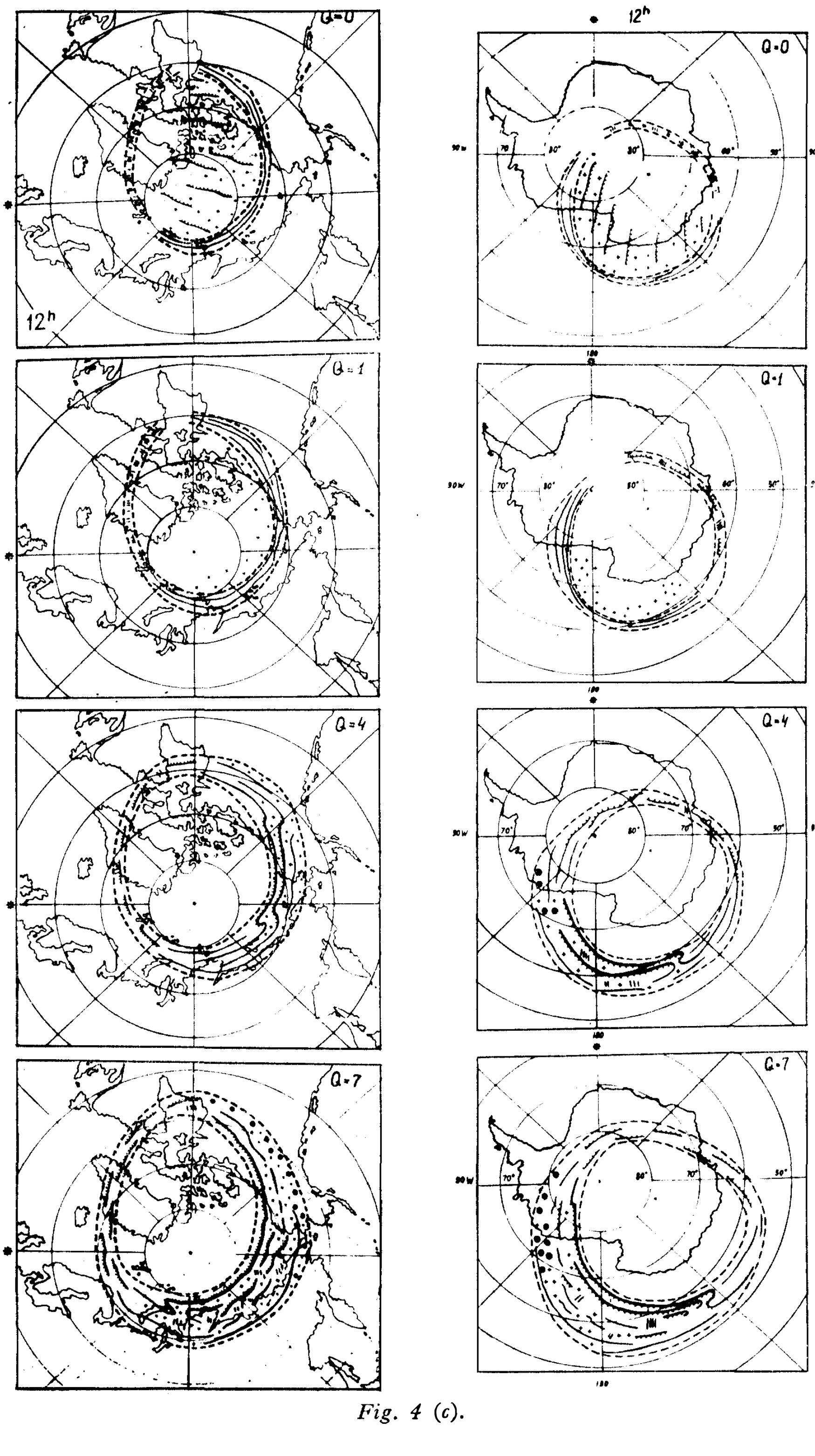


*Fig. 4 (c).*

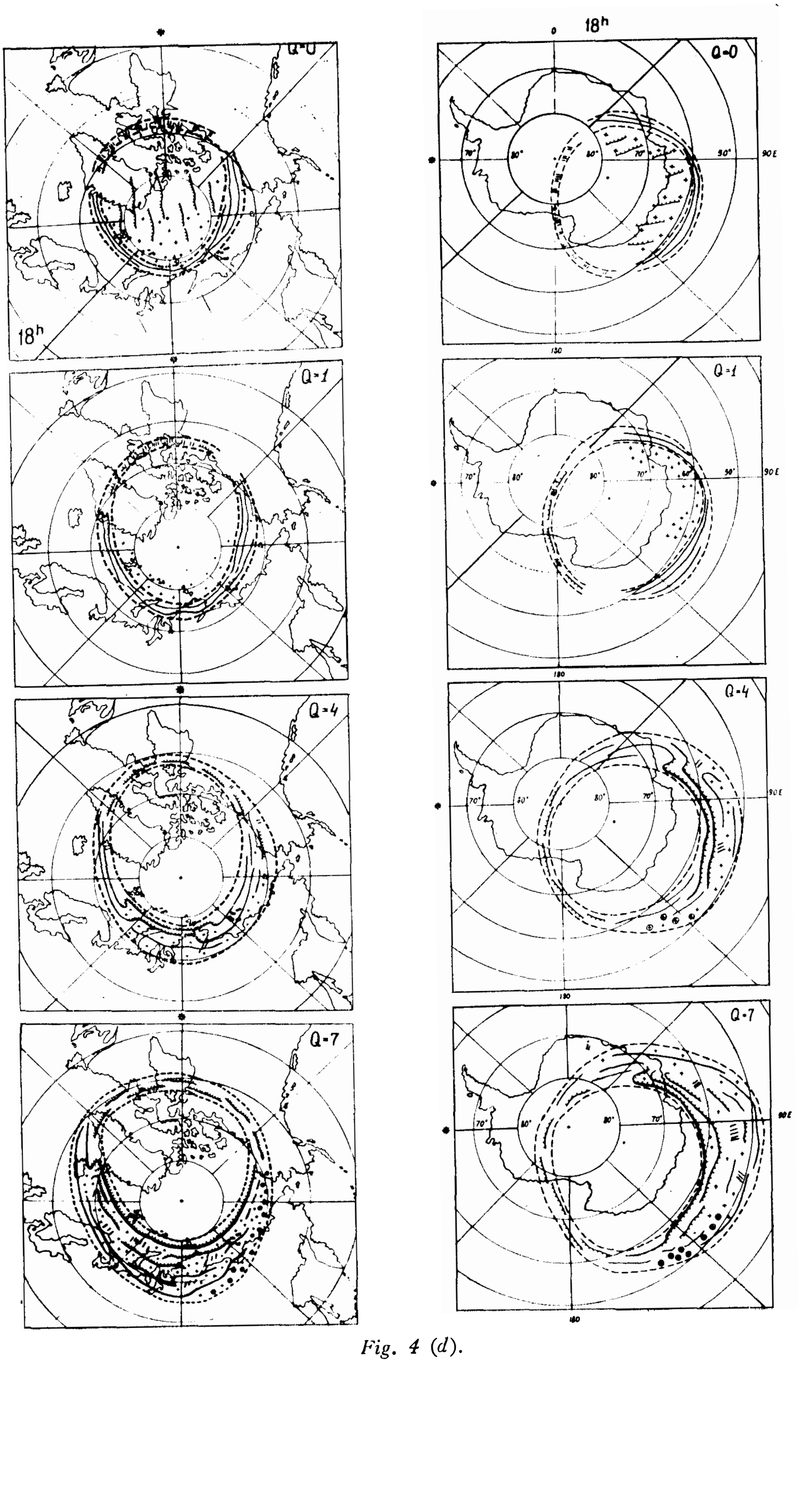


*Fig. 4 (d).*

projection on the earth surface changes with the universal time. AKASOFU (1968) has shown the positions of auroral oval for different universal times for the northern hemisphere. According to FELDSTEIN (1963b), 75% of the isoauroras are along the oval boundaries. The determination of oval position is significant for a comparison of aurora dynamics with other geophysical phenomena and also studies on the aurora oval in association with the large scale structure of the magnetosphere are important (AKASOFU, 1968; FELDSTEIN, 1972).

In Figs. 4a and 4b, the auroral oval positions for the northern and southern hemispheres are illustrated for four different universal times, 0, 6, 12, 18 UT, for different level of magnetic disturbances represented by $Q$-indices. Owing to differences in the magnetic field line configuration in both hemispheres and the noncoincidence of the axis of eccentric dipole with that of the earth rotation, the geographical coordinates and real sizes of auroral ovals may have essential differences even if the level of magnetic activity is the same. The positions of auroral oval boundary for $Q=0$, 1, 4, 7 based on the results of analysis by FELDSTEIN *et al.* (1967) for the northern hemisphere are transferred along the real magnetic field lines onto the southern hemisphere.

The distribution of auroral forms inside the oval was determined by the local time and auroral substorm phase (AKASOFU, 1964). In Fig. 4, a distribution of aurora forms under quiet conditions ($Q=0$) is taken from the report by FELDSTEIN (1966), while possible discontinuities between the day and night sectors of the oval are taken from the diagrams given by FELDSTEIN and STARKOV (1967), and the polar cap aurora from the work reported by LASSEN (1972).

In the course of calculating the oval position, it is taken into account that the day boundary variation of the luminescence region depends on the magnetic axis orientation with respect to the ecliptic plane (FELDSTEIN and STARKOV, 1970). The condition of $Q=1$ corresponds to the growth phase end and that of $Q=4$ and $Q=7$ to the end of expansion phase of the magnetospheric substorms of the average intensity.

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