CHANGE IN THE ZODIACAL LIGHT WITH SOLAR ACTIVITY

Robley R.
Observatoire du Pic du Midi et Toulouse
1, Avenue C. Flammarion, 31500 Toulouse, France

Abstract - The Gegenschein observed at the Pic du Midi Observatory during a solar cycle has a behaviour similar to that of the brightness of the eclipsed Moon. It is assumed that in both cases the solar wind ejected through the polar coronal holes is responsible for these variations.

INTRODUCTION

The influence of solar activity on the zodiacal light is not universally accepted. According to Weill (1966), Dufay (1966) and Asaad (1967), the zodiacal light might be influenced during the solar cycle, but according to Tanabe (1965), and Dumont and Levasseur (1978) the zodiacal light does not change. Besides, the space observations analysed by Gillett (1967), Sparrow and Ney (1972), Hanner et al (1974) and Levasseur and Blamont (1973) have not shown any evidence for a solar activity effect, but it is important to note that no space observations have ever been conducted during a complete solar cycle and for this reason they have not produced proof that the zodiacal light is not affected by solar activity.

THE OBSERVATIONS

Observations have been made at the Pic du Midi Observatory (Robley 1973, Robley and Prêtre 1974). Those made in the antisun direction from 1964 until 1978 show a rapid decrease of the brightness between the years 1967 and 1968, followed by a very slow increase during the decreasing phase of the solar activity; this slow increase of the Gegenschein brightness is stopped by a weak secondary minimum in 1974. The variation of the antisun brightness is presented in figure 1a by the quarterly average values; the standard deviation of these average values (not shown on the figure) varies from 10% to 25%; the rapid decrease observed from 1967 until 1968 is similar to that obtained by Danjon (1920) after analysing the data related to the eclipsed Moon

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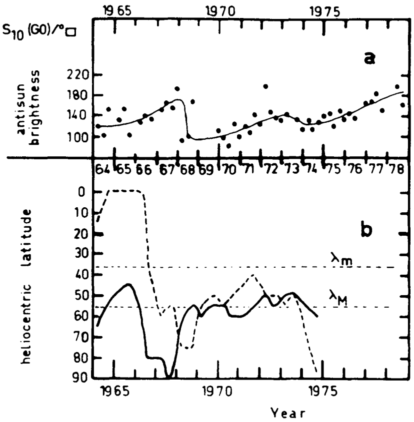

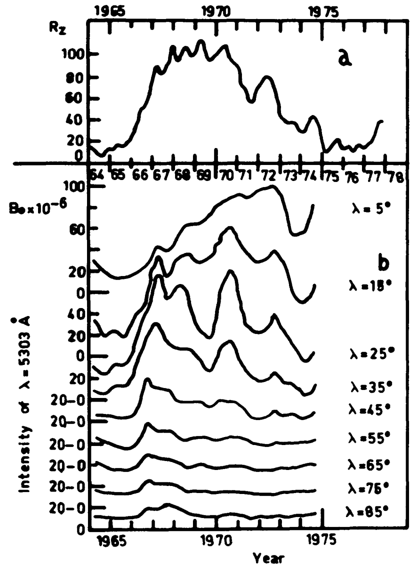

left FIG. 1(a) Brightness of the Gegenschein. (b) Extension of the polar coronal holes. The solid line refers to the northern hemisphere, the dashed line refers to the southern hemisphere.
right FIG. 2(a) Relative sunspot number. (b) Intensity of the coronal green line for various heliocentric latitudes λ.

obtained between the years 1823-1920 (fig. 3c).

ANALYSIS OF THE RESULTS

Obviously the variation of the Gegenschein brightness (figure 1a) is not correlated with the relative sunspot number (figure 2a). On the other hand, examination of the variation of the coronal green line for several heliocentric latitudes and during a solar cycle (figure 2b gives the green line for the solar northern hemisphere) shows that the behaviour of the green line, observed at the mean latitudes, is opposite to that of the Gegenschein: after the solar minimum the green line increases very rapidly; later it decreases slowly until the next solar minimum. This change of the green line is opposite in phase also to the brightness of the eclipsed Moon (figure 3c). It is suggested that the apparent coupling of the green corona with the zodiacal light and the eclipsed moon is due to the solar wind and that both phenomena are related to the polar coronal holes. According to Hundhausen (1977) the solar poles are permanent coronal holes which can reach the solar equator in the period near solar minimum; with the approach of the maximum of activity, the rapid development of the corona moves these regions without corona again towards the poles. The polar coronal holes are of great interest because the high speed plasma ejected through them

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can reach along the ecliptic as far as and perhaps beyond the terrestrial orbit. It is now obvious that if the Gegenschein and the eclipsed Moon brightnesses are out of phase with the green corona, then they are necessarily in phase with the enlargement of the polar coronal holes. It is possible to plot the evolution of the coronal holes versus heliocentric latitude as follows: the data produced by the Pic du Midi solar service show that the coronal green line varies from 10 to about 140 times 10^{-6} of the mean solar brightness; in figure 1b, we have plotted versus time, for cycle 20, the heliocentric latitude reached by the green line of which the intensity I is not greater than 20 units; this for both solar hemispheres. From fig. 1, it is clear that the change in Gegenschein brightness is strongly correlated with the boundary of the southern coronal hole until 1968. Later each hemisphere adds its effect and we find a secondary maximum in 1972. Next, a recession of the hole boundaries produces the secondary minimum in 1974. A similar correlation can be found during cycle 19, by using data according to Weill (1966); in that case the zodiacal light was observed near the northern celestial pole and figure 3a reproduces the brightness variation; figure 3b shows the variation of the polar holes boundaries, as previously described, during cycle 19; finally we give in figure 3c the data related to the eclipsed Moon. Figure 3 indicates clearly that the rapid decrease of both brightnesses coincides with the rapid recession of the coronal holes towards the poles; later the slow enlargement of the coronal holes towards low latitudes induces the increase of both brightnesses.

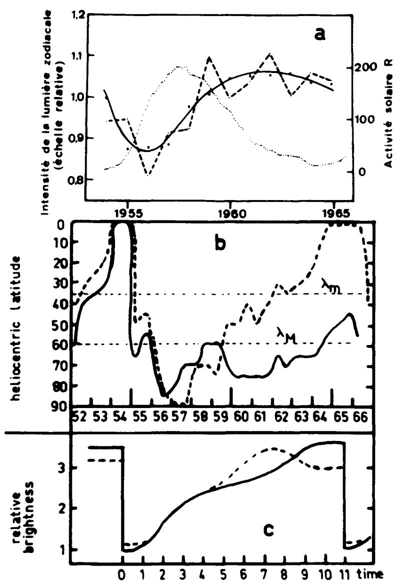

FIG. 3: (a) Brightness of the zodiacal light according to Weill (1966).
(b) Extension of the polar coronal holes for both hemispheres.
(c) Brightness of the eclipsed Moon according to Danjon (1920).

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The results presented by Weill do not imply a radical change in the nature of the zodiacal light, but suggest that under the solar wind effect, the fluorescence of the dust is added to the scattered solar light. Since the zodiacal cloud is not eclipsed, the ratio "fluorescence/scattered light" must be high enough and the antisun is the most favourable direction for that. Finally it should be noted that Derham et al (1964) have produced luminescence in meteorites with a 40 kev proton flux.

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DISCUSSION

Feldman: Would the fluorescence be in the form of a continuum or is it line emission that could be separated spectroscopically from the solar scattered component?
Robley: I think that such effects can be detected with appropriate means.

Leinert: Your proposed mechanism of dust fluorescence and/or phosphorescence should lead to a solar cycle variation and also to short-time variations due to high-speed plasma streams. Neither effect appears in the Helios zodiacal light measurements. (Leinert et al., this volume.)
Robley: I think that short-time variations due to solar flares cannot be detected because of the small impact on the whole zodiacal cloud.

Lamy: Fluorescence of interplanetary grains under solar wind proton irradiation is observed on the moon as it fills the H and K lines. Our results for the electrostatic potential of grains (Lafon et al., this volume) show a strong dependence on solar activity (i.e. quiet solar wind versus high-speed solar streams) essentially controlled by the protons; the potential changes by a factor of about two.