PRELIMINARY OBSERVATION ON THE GLOBAL ENERGY BALANCE OF SUNSPOT AND PHOTOSPHERIC FACULAE

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The following problems are treated in this report : first whether the missing energy flux of the sunspot appears as the extended bright ring surrounding it and secondly whether the excess energy flux in the active region represented as the photospheric faculae is compensated by the extended dark region surrounding the active region, if it exists at all.

For this purpose we used white-light photographs (5300A) of the Sun taken at Mitaka for routine observations (seven plates of 10cm solar diameter) and at Mt. Norikura (five plates of 2cm solar diameter). We measured the whole disk in 250 x 250 arrays and subtracted for limb darkening.

To search for the <u>extended bright ring</u> around the sunspot (EBR) we averaged the excess intensity over concentric rings surrounding a selected spot. The result shows that some spots do have EBR with the excess intensity of 0.5-0.8% near the penumbral border which decreases to the value of 0.1-0.2% at the distance of 10-15 $\times 10^4$ km from the center of big spots. Beyond this distance it becomes impossible to determine the excess intensity because of the large scale inhomogeneity of the emulsion. These excess intensity distribution can be converted to the total energy of EBR using the relationship between the monochromatic flux and the total flux from the radiative equilibrium models of Kurcz(1969) where the grid of models with different effective temperatures for the same surface gravity is given and $\Delta\pi F / \pi F = 0.81 \times \Delta\pi F_\lambda / \pi F_\lambda$ can be deduced. The total energy flux of EBRs is found to be 0.3-1.2 x 10^{29} erg/s. Missing flux of the sunspot is, for example, about 1.3 x 10^{29} erg/s for the spot of diameter of 3×10^4 km. Whether the EBR does really compensate the missing energy is critically dependent on the precise determination of further extended regions than our limit of $10\text{-}15\times 10^4$ km.

Some other spots, however, did not show any enhancement or revealed only marginal one even in the immediate vicinity of the penumbra. Interesting examples are given for two cases, April 10, 1980 and May 27, 1980 in which solar constant measurements by the SMM satellite showed 0.2-0.3% depression in the total solar energy flux received from the earth, compared with the averaged value (Willson and Hudson, 1980). For these two plates we could only deduce the average excess intensity distribution for groups of big spots because big spots are aligned closely together and it is not possible to determine the excess intensity from a single concentric ring because of overlapping. In case for May 27th it shows that the excess brightness is less than 0.2% even in the neighborhood of the penumbra and it is consistent with the SMM solar constant measurement. The case for April 10 shows slight emission near the spot but because of the inhomogeneity of the emulsion the clear-cut conclusion was not reached.

Now we turn to the problem of the total energy balance of photospheric faculae : Active regions which do not contain large spots have been selected and the measured data are represented as the function of position angle and the radial distance from the disk center. The total excess energy from the facular region was, then, estimated using the known center-limb contrast of facular granules and the relation between the monochromatic flux and the total flux. It ranges from 1.5×10^{28}erg/s to 6×10^{29}erg/s and, as would be expected, the larger the Ca^+ plage area ($S(Ca^+)$ in $2\pi R^2 \cdot 10^{-6}$), the larger the total excess flux (E in erg/s) : $\log S(Ca^+) = 0.6 \times \log E - 14.2$. Scatter around this relationship is quite large, amounting to ± 0.6dex. Next in order to search for the extended dark region around the active region the curvature of the intensity distribution of adjacent quiet region along the position angle was inspected. If this intensity curve is concave towards the facular region it means there exists dark region and if convex, vice versa. The result indicates that the characteristic distance of the dark region must be larger than 35000km if we alow 95% statistical significance for the distribution of the curvature for fifty active regions. Or simply we did not detect the dark regions in the present investigation.

If we suppose that the facula is truely excess emitter and if we use the relationship between the Ca plage area and excess facular energy, we can conclude that the missing flux of sunspot might be balanced by the excess facular flux. And the SMM result does not prove that the sunspot energy flux is really missing since the satellite does not receive most of the excess facular flux of active regions around disk center. There are two possibilities in interpreting the present problem : (a) Sunspot and facular energy flux are independent and either they are balanced separately over very large area or they are not balanced because of the long time scale of convective motion if they are seated below the photosphere deeper than 40,000km (b) Both energy flux are closely interrelated in the sense that the energy flux from sunspot is converted to the facular energy flux in the convection zone. In this case (b), problem is how to interpret the big, long-lived facular regions without spots.