Latitude and Cycle Variations of the Photospheric Network

R. Muller and Th. Roudier

Observatoire Midi-Pyrénées, URA 1281 Pic du Midi,
65200 Bagnères de Bigorre

Abstract

New measurements of the number density of the Network Bright Points confirm the variation of the density of the photospheric network at the centre of the disk during the solar cycle and that in the period 1983-1985, this number density (i.e. the magnetic flux in the quiet sun) was maximum, both at the poles and at the equator.

1. Introduction

The irradiance of the Sun varies with time scales of days, months, and 11-years, directly related to active regions, active complexes, and the solar cycle of activity (Livingston et al., 1992 and references therein). Irradiance variability, as well as the solar cycle, are due to the interaction between convection and magnetic fields. Consequently, in order to understand this variability, it is important to know how the solar magnetic flux varies. The magnetic field manifests itself on the solar surface, at the photospheric level, as dark sunspots and bright faculae in active regions, and elsewhere as a cellular network, called the photospheric network.

Most observed irradiance variation of short period can be explained satisfactorily by active region modulation. It is, however, not clear "whether the additional solar-cycle variation is caused by global solar changes or by simply the enhanced emission from the bright regions" (the photospheric network), as questioned by Livingston et al., 1992.

It thus appears important to know the variation of the photospheric network for two reasons. First, for its contribution to the variation of the solar irradiance; second, for the amount of flux contained in the quiet sun and its variation, in order to understand the interaction between convection and magnetic field which is responsible of the solar cycle and the solar variability.

Solar Physics **152**: 131–137, 1994.

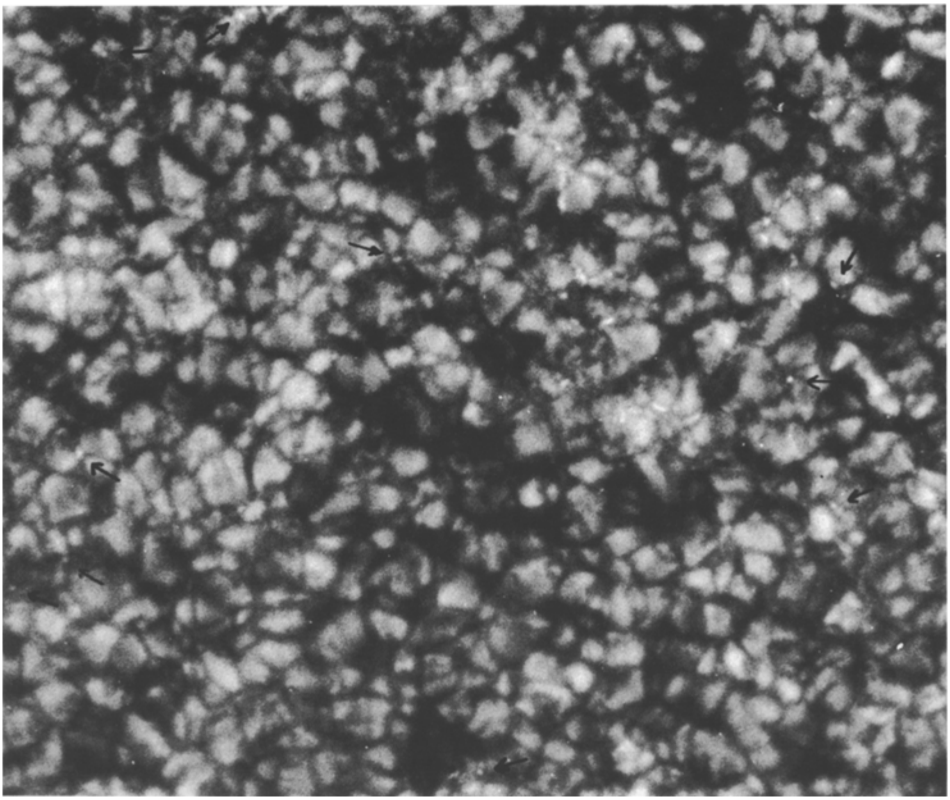

Figure 1 : Network Bright Points embedded in the granular pattern, observed through a 10 Å interference filter, centered at 4308 A, with the 50 cm refractor of the Pic du Midi Observatory. Many NBPs are clustered in a supergranule boundary, while others appear as isolated points (some shown by an arrows).

Magnetic flux is measured with full disk magnetographs, like those of Mount Wilson, Stanford or Kitt Peak. They provide daily magnetograms from which it is possible to derive the distribution of the flux over the solar surface, or the flux integrated over the whole Sun, and their variations with time (Rabin et al., 1992 and references therein). The spatial resolution of the observations is rather poor, not better than 1". In addition, they are integrated over a much larger area, when they are presented as synoptic maps (1° square, for example, in the case of the Kitt Peak synoptic magnetograms, Rabin et al. 1992). This spatial integration is required to improve sensitivity. The main disadvantage of such a magnetogram processing, is that the smallest magnetic elements are lost, especially in the quiet Sun, and some magnetic flux of opposite polarity is lost, too. Another weakness of magnetograms is that they do not provide a measure of the brightness of the magnetic features.

Magnetic features can also be observed on filtergrams, where they appear as dark (sunspots and pores) or bright (faculae and photospheric network) features. In the quiet Sun, the photospheric network is formed from very small (<0"5) bright points called Network Bright Points (NBPs). For this reason, high resolution observations are required. NBPs are visible either in white light filtergrams or in spectral line filtergrams, where they are easier to identify because they are much brighter than in white light. Our observations are made in the CN band at 4308 A, through an interference filter, 10 A wide (Figure 1). We use NBPs as indicators of magnetic elements, and because they have a small range of sizes and magnetic field strengths, we can assume that each of them carries a quantum of magnetic flux (2.5×10^{17} Mx for flux tubes of diameter 150 km and field strength 1500). Thus, counting the number of NBPs per surface unit is an indirect measurement of the solar magnetic flux (Muller and Roudier, 1984). Of course, in such a way, it is not possible to map the whole Sun. The observations are restricted to the disk centre and to various positions along the central meridian, and also along the equator for comparison. They are useful for the study of meridian and cycle variation. The contribution of the network to the solar luminosity and variance can also be derived. Although the resolution of our filtergrams is as high as 0"25, it must be noted that all the magnetic elements present at the surface of the Sun are not detected : those which are singificantly smaller than this limit and those which are darker than the average photosphere. The drawback to our method is that we have no direct measurement of magnetic fluxes and that we cannot map the whole Sun.

In our previous papers (Muller and Roudier, 1984; Muller, 1989) we have reported the following results :

- at the centre of the disk, the number of NBPs (that means the magnetic flux in the quiet Sun) varies in antiphase with the sunspot number, in the period 1975-1987, by a factor 3 or so ; surprisingly this variation is opposite to that shown in Livingston et al., 1992 ;
- the number density of NBPs (the magnetic flux) is not uniform along the central meridian: in 1983, it was maximum at the equator and at the poles.

In this paper we extend the observed variation at the disk centre, by a new measurement made in 1988 and we present a centre-to-limb variation for 1985, which will be compared to that of 1983. NBPs identification and correction for centre-to-limb loss of visibility has been described in Muller and Roudier 1984.

2. Variation at the Disk Centre for the Period 1975-1988

The measurements of 1988 confirm the decrease of the number of NBPs observed since 1983 (Figure 2). This figure shows that the number (it is equivalent to, say, the magnetic flux of the photospheric network) varies almost in antiphase with the sunspot number; it was a minimum in 1979, at the time of sunspot maximum, and a maximum in 1984, in between the Sunspot maximum of 1979 and the Sunspot minimum of 1986.

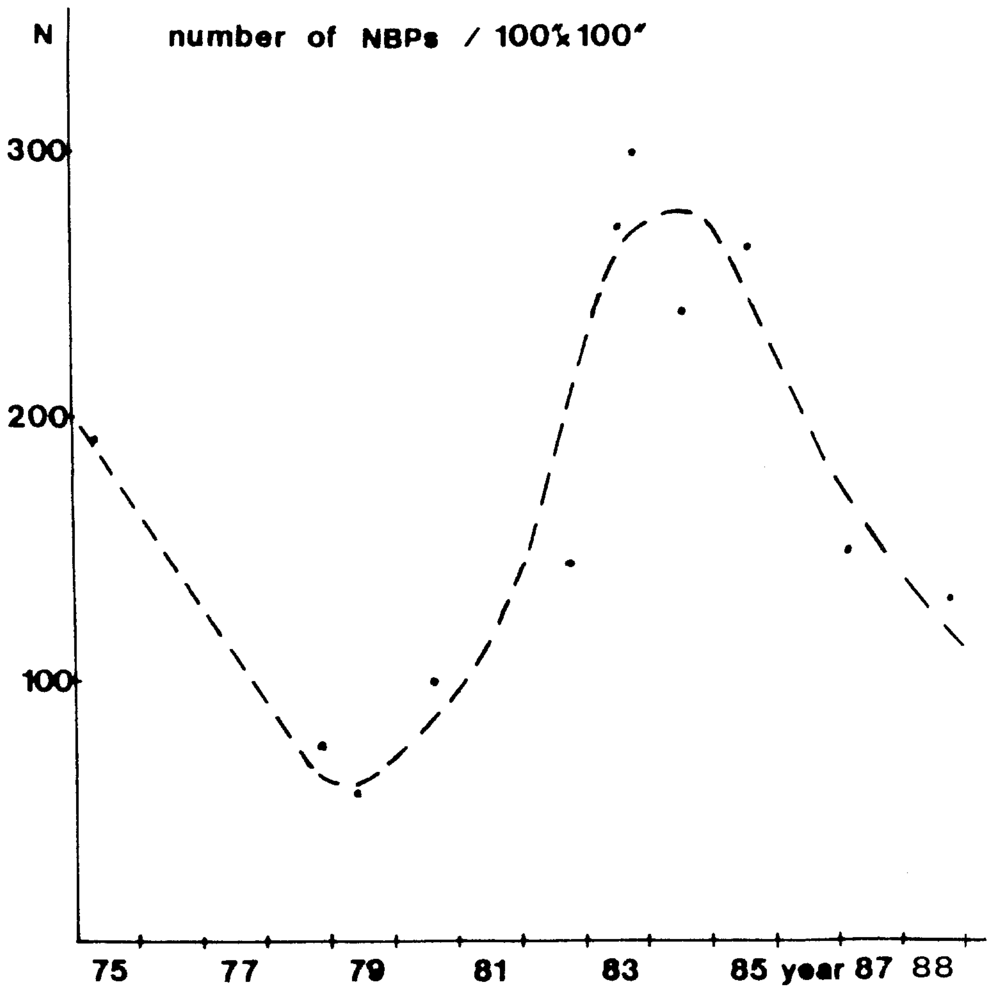

Figure 2 : Time variation of the number of Network Bright Points (per surface unit of 100" x 100") at the solar disk centre.

3. Latitude Distribution of NBPs : Comparison of 1983 and 1985

The latitude distributions show that NBPs are not uniformly distributed over the surface of the Sun. In 1983 and in 1985, the number was maximum at the centre of the disk and at the pole. In 1983, the number at the pole was very high, in agreement with Sheeley (1964) who reported that the number of polar faculae reaches a maximum value about 4 years after the maximum. It is interesting to note that the maximum of NBPs at the centre of the disk is also reached 4 years after the sunspot maximum (Figure 2).

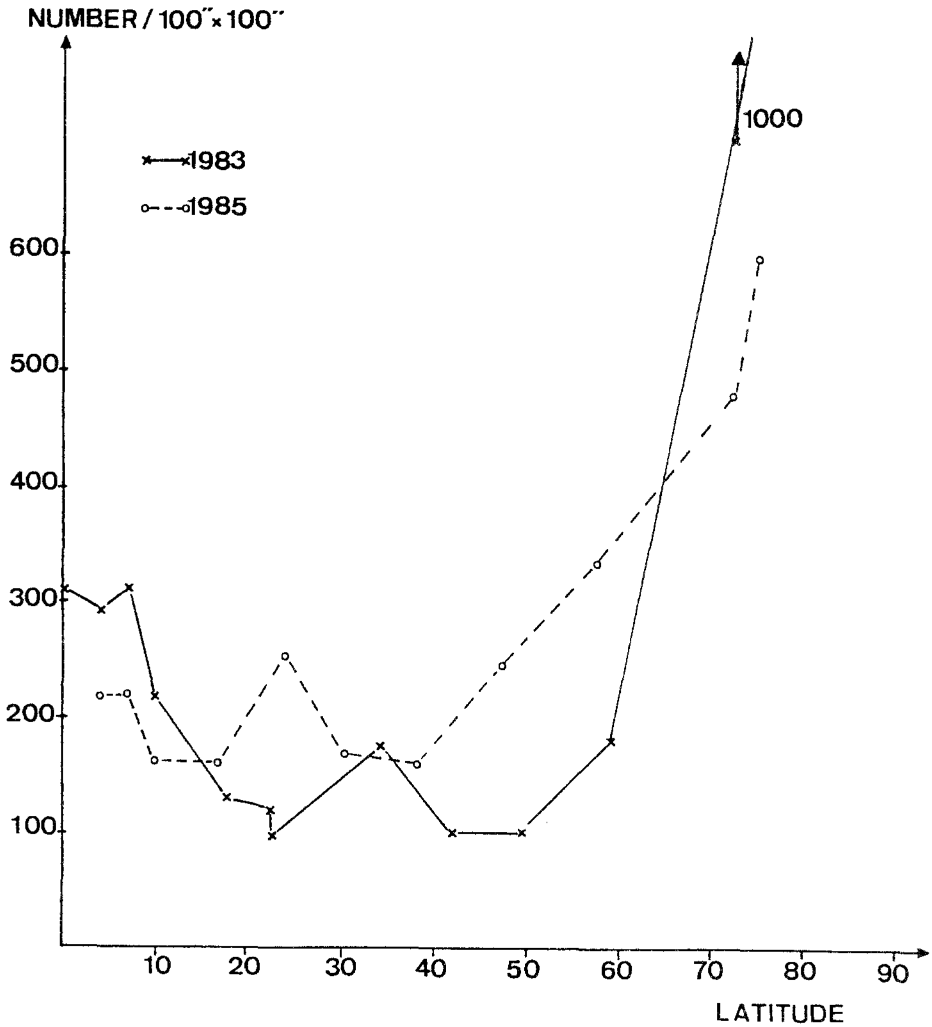

Figure 3 : Meridional variations of the number of Network Bright Points (per surface unit of 100" x 100").

The lower number in 1985, rather than in 1983, is also in agreement with the variation observed by Sheeley. Both distributions exhibit a small maximum at median latitudes (25° in 1985, 35° in 1983), just in between the sunspot latitude belt and the polar active latitude. This maximum must be confirmed, however.

4. Discussion

Our high resolution filtergrams allow us to observe the distribution of the magnetic elements at the surface of the Sun, away from active regions. As we cannot map the whole Sun, our observations are made along the central meridian; in the following discussion we assume that the distribution is homogenous in longitude. This is certainly true if we avoid active regions in the quiet Sun and the concentrations of magnetic elements found in remnants of old plages. The longitude homogeneity is verified by our observations along the equator (Muller and Roudier, 1984). Because of the very high resolution of the filtergrams (0"2), many more magnetic elements are identified than on classical magnetograms. Only the magnetic features smaller than the resolution and those which do not show up as bright features (Keller, 1992 ; Title et al., 1992) are not detected.

We have found that the magnetic flux of the quiet Sun was a maximum at the equator and at the poles from 1983 through 1985. It was a minimum at a latitude close to the sunspot belt. This minimum shifts from 35° to 25° during this period. A small secondary maximum visible in between the sunspot and high latitude belts must still be confirmed. The accumulation of magnetic flux both at the poles and at the equator, a few year after the solar maximum, certainly results from the diffusion of flux emerged in active regions in the sunspot belts. The accumulation at the poles correspond to the transformation of the toroidal magnetic field into a poloidal field.

For the moment we have only analysed the observations obtained during these two years, although we have observed the Sun regularly from 1983 until now. The complete results will be given in subsequent papers. At the centre of the disk we are able to present the analysis of a much more extended set of observations, from 1975 to 1988, covering more than one solar cycle. The result is a variation of large amplitude, almost in antiphase with the sunspot number. The maximum number of NBPs is at least three times larger than the minimum number, observed 4 years after a solar maximum. On the contrary, the Kitt Peak magnetograms show a variation of the magnetic flux of the quiet Sun, in phase with the sunspot number (Livingston et al., 1992 ; Harvey, this volume), while the Mt

Wilson magnetograms did not show any variation (La Bonte and Howard, 1982). The discrepency between the two kinds of variations can be understood if we keep in mind that, with our high resolution filtergrams we have observed the weakest network at the disk centre, excluding remnants of activity, while the Kitt Peak and Mt Wilson magnetic flux measurements map the whole Sun and include some remnants of active regions.

At the centre of the disk, there are about 150 points per surface unit 100" x 100" (Figure 3). Their average observed size is 0"33 = 230 km, and their average brightness is 1.08, relative to the mean photosphere. The filling factor is about 0.1 % (150 NBPs of diameter 0"33 pers surface unit of 100" x 100" correspond to a filling factor of 150 x $\pi/4$ 0"33 x 0"33 / 100" x 100" $\approx$ 0.1 %). If we assume, as a first approximation, that their distribution and brightness are uniform on the Sun, the excess of brightness of the photospheric network is 0.01 % of the luminosity of the Sun. The amplitude of the variation is about 100 points around the average value of 150, which means a variation of luminosity of about 0.01 % too. This is one order of magnitude smaller than the observed variation of irradiance measured by NIMBUS and ACRIM. In addition, the variation of the network excess is opposite to the variation of the solar irradiance, which is in phase with the activity cycle.

The results presented in this paper confirm that high resolution filtergrams provide a powerful tool for investigating the variability of the quiet Sun magnetic flux on the one hand, and the contribution of the photospheric network to the cycle variation of the solar irradiance, on the other hand.

References

Harvey, K. : 1994, in "The Sun as a Variable Star", IAU coll. no. 143, ed. J. Pap.

Keller, C.U. : 1992, Nature **359**, 307.

La Bonte, B.J. and Howard, R. : 1982, Solar Phys. **80**, 15.

Livingston, W., Donnelly, R.F., Grigoriev, V.G., Demidov, M.L., Lean, J., Steffen, M., White, D.R., and Willson, R.L. : 1992, in : "Solar Interior and Atmosphere", eds. A.N. Cox, W.C. Livingston, M.S. Matthews, p.1109.

Muller, R. : 1989, Adv. Space Res. Vol.8, N°7, p.159.

Muller, R. and Roudier, Th. : 1984, Solar Phys. **94**, 33.

Rabin, D.M., De Vore, C.R., Sheeley, N.R., Harvey, K.L., and Hoeksema, J.T. : 1992, in : "Solar Interior and Atmosphere", eds. A.N. Cox, W.C. Livingston, M.S. Matthews, p. 781.

Sheeley, N.R. : 1964, Astrophys. J. **140**, 731.

Title, A.M., Topka, K.P., Tarbell, T.D., Schmidt, W., Balke, C., and Scharmer, G. : 1992, Astrophys. J. **393**, 782.