# ON THE EFFECT OF ACTIVE REGIONS ON THE SOLAR IRRADIANCE

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ABSTRACT

The limb brightening of the faculae associated with active regions has been studied with data obtained during the period of minimum solar activity in 1996-1997 by the VIRGO instrument on SOHO. The contribution of the active regions to the total solar irradiance is investigated. The period of minimum solar activity is particularly favourable, because frequently there is only a single active region on the whole solar disc, thus making more simple the identification of the effects. Preliminary results of work in progress are presented.

## 1. INTRODUCTION

Effects of solar active regions on the total solar irradiance were observed in the early 1980's, in particular the prominent irradiance decreases due to sunspot blocking (Willson, 1982). It was pointed out (Foukal and Lean, 1985), that facular regions increased the solar irradiance and could compensate the loss of irradiance due to the sunspot blocking, and later it has been proposed (Lean, 1991) that the irradiance increase due to faculae could entirely explain the solar constant evolution during the solar cycle. But it has also been proposed that the faculae would only account for one part of the irradiance increase, and that the solar cycle evolution would be driven by changes in the area of the photospheric magnetic network (Foukal et al. 1991). The variation due to the photospheric network would be the background upon which the active region effect would be superimposed. Kuhn et al (1988) have found that the latitudinal distribution of temperature on the limb changes as the solar cycle progresses, a finding that would support the idea of the presence of an underlying effect on the irradiance different of that of active regions. But so far one has been unable to arrive to a conclusive explanation of the observations, let alone to determine the physical mechanism by which the solar energy is radiated and redistributed in time and space (see Kuhn 1996, for a review of the subject).

In this research we attempt to obtain information about the large scale effect of solar active regions on the solar irradiance. We make use of the fact that during several months, in 1996, a single major active region was in the solar surface, thus allowing us to separate its effects form those of the quiet sun.

## 2. INSTRUMENT

One of the instruments of the VIRGO experiment aboard SOHO (Fröhlich et al. 1995) is the Low-resolution Oscillations Imager (LOI) that measures the solar radiance in a 5 nm wavelength band around 500 nm with a 12 pixel detector surrounded by 4 pixels that are used to maintain the image of the sun centred with an stability better the 0.1 arcsec (Figure 1). The telescope is designed so that the limb of the sun is centred on the four external pixels. The LOI telescope produces a measurement of the radiance in its 12 pixels every minute. An analysis of its performance can be found in Appourchaux et al. (1997). The measurements along the first 20 months of operation indicate a near exponential decrease of sensitivity, due the ageing of the filter, superimposed to the changes in intensity that derive from the yearly change of size of the solar image. In principle these effects can be taken into account by comparing the LOI measurements with those of the sunphotometer in VIRGO (SPM) that measures the differential irradiance of the sun at the same wavelength than the LOI, and which is calibrated. However, for this study, we have assumed a long term (months) constant sun. This assumption is fully justified because we are observing short term effects on the total irradiance.

## 3. OBSERVATIONS

During the low solar activity period between May 1996 and January 1997, the Sun was rather quiet and, frequently, only one significant active region was visible on the solar disc. This constitutes an excellent opportunity to study the effect of an active region on the solar irradiance without having to disentangle concurrent effects from other ones. The solar irradiance measured by the VIRGO radiometers on SOHO during this period (Figure 2) was relatively constant, except for the passage of

*Figure 1. VIRGO/LOI detector. The four external pixels are used to feed a servo system that maintains the telescope pointed to the center of the Sun.*

the active region over the solar disk, which was associated with a solar radiation change (Fröhlich et al. 1997). Figure 3 shows how this region, that was recurrently observed in every solar rotation between July and November 1996 (Carrington rotations 1911 through 1916), was centered at about 270 degrees Carrington longitude and 12 degrees South latitude.

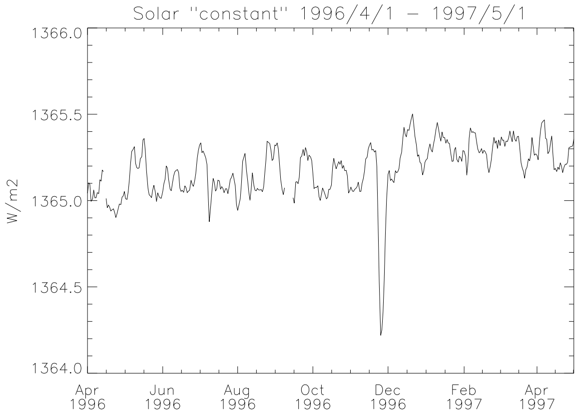


*Figure 2. Solar irradiance as measured by the SOHO/VIRGO radiometers.*

Because the active region was located at solar latitude 12 degrees south, we need to consider only pixels 5, 9, 10 and 6 on the images obatined with the LOI, the remaining pixels being uneventful. The broad increase in radiance due to the large facular regions with their limb brightening effect is well documented by these observations (Figure 4).

On Carrington Rotations (CR) 1911, 1912 and 1916, the narrow decreases with the sharp transition between pixels illustrate the effect of sunspots on the solar radiance. We see the radiation source pass over pixels 5, 9, 10 and 6 successively, generally producing an increase of the radiance as the image of the region passes over the pixel. But the enhancement of the radiance gets interrupted by a sharp decrease. This is due to the apparition and evolution of a sunspot. In this study we address only the effect of the facular regions, as seen more clearly on CR 1913, 1914 and 1915. We will consider the sunspot effects in a further study. These time profiles are indicative that active regions produce an enhancement when they traverse the solar disk with a minimum flux when passing near the disk center, as is to be expected from previous observations.

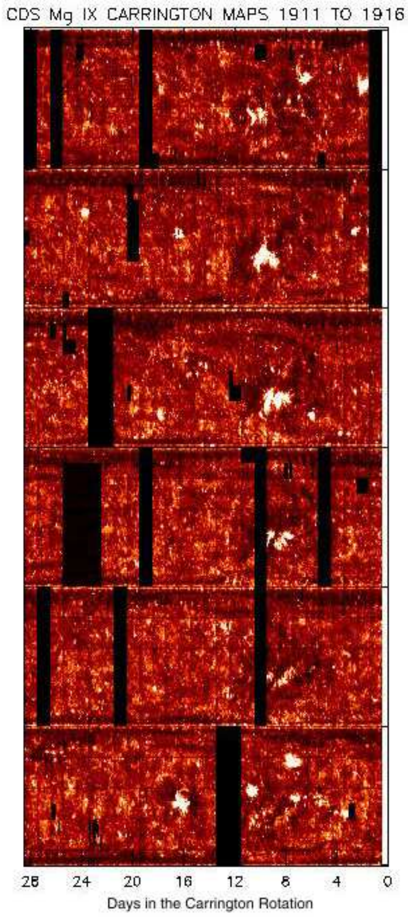


*Figure 3. Solar Carrington Rotation (CR) maps for the period May-December 1996 of central meridian measurement at 368 nm (Mg IX line) . Notice the persistent active region around CR longitude 270 (courtesy of SOHO/CDS team)*

In order to achieve a quantitative estimate that can be translated to other periods when no quiet sun will be available, we need to relate the global active region effects to the detailed physical phenomena that produce them. The most detailed study of facular properties is being carried out studying high resolution images (Topka el al 1992). We intend to bridge the gap between statistical and global sun observations on one hand, and the high resolution studies on the other. We study individual active regions that are, in fact, for this purpose, a collectivity of faculae and occasionally one or more sunspots.

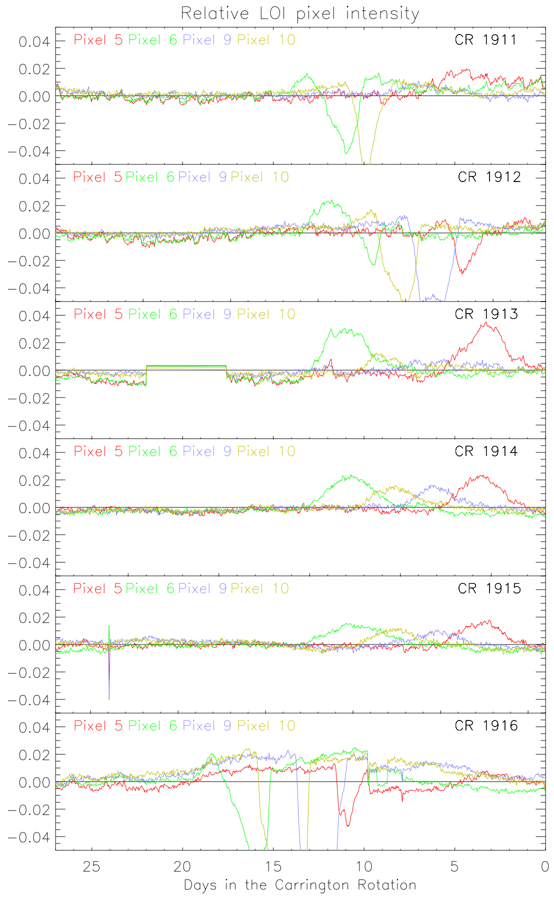


*Figure 4. The radiance at 500 nm measured by the four LOI pixels that see the passage of the active region visible in Figure 3.*

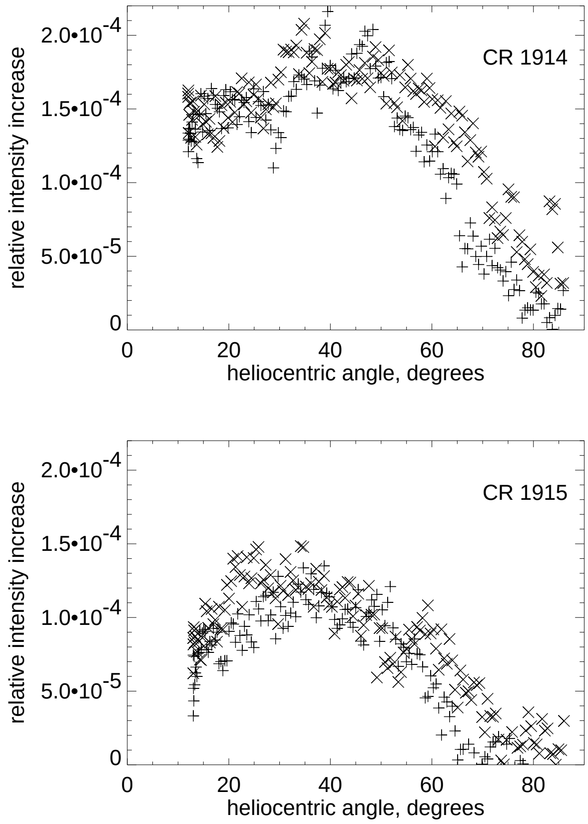


*Figure 5. Angular distribution of the excess irradiance (at 500 nm) of hte active region during CR 1914 (top) and CR 1915 (bottom).*

To better describe the effect due to individual active regions, we have plotted the angular distribution of the relative brightening due to them (see examples in Figure 5. To do so we have assumed a number of simplifications:

A. The active region is considered a punctual source.

B. The active region has been assumed located at the geometric center of the magnetic field intensity peak i.e. no account has been taken of the actual distribution of the faculae in the active region.

C. The brightness is calculated as the increase of the radiance respect to an assumed "constant" background, defined by a digital filtering process, followed by an approximate appreciation of the underlying level of the background radiance.

D. The active region is assumed invariant in the time scale of 14 days.

Although it is obvious that these oversimplifications may distort the interpretation of the measurements, the obtained results are indicative the potential of the 1996 measurements for the study of the solar irradiance effects of faculae.

One should not confuse brightness enhancement, that we define here as the additional radiation measured from the Sun due to the active region, with the commonly used "contrast".

Topka, et al. (1992) in a continuing work on highly resolved solar images, have measured the center-to-limb function of the contrast of faculae, showing that it becomes negative at heliocentric angles smaller than 20 degrees. The distributions in Figure 5 show a limb brightening effect that might be in disagreement with the observations of Topka et al. or indicate the presence of another component, but we need to analyze higher resolution data (from SOHO/MDI and perhaps from ground based observatories) to be able to achieve a quantitative comparison.

CONCLUSION

During a period of quiet Sun at solar minimum it appears that active regions are the dominant source of solar irradiance variations.

The angular distribution of the radiance increase produced by the large facular regions associated with active regions appears to be difficult to explain under the assumption that the active region is simply constituted by a group of faculae and that the faculae irradiate as described by previous observations. There is an indication that the limb brightening effect due to the active region decreases as the region becomes older. This observation may be a consequence of the evolution in space of the region.

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