*Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles*
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# Century long study of sunspot activity using the Kodaikanal white-light data

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**Abstract.** Sunspots are the most obvious and high contrast observable feature of solar magnetic activity in the photosphere. The morphological and kinematic behavior of sunspots on the solar surface need to be studied over a long time period to understand solar magnetic activity. For this, it is important to understand the long term emergence patterns, and developments, decay of the sunspots on the solar surface over many cycles. The long time sequence of the Kodaikanal white-light images provide a consistent data set for this study. The digitized images were calibrated for relative plate density and aligned in such a way that the solar north is in upward direction. A sunspot detection technique was used to identify the sunspots on the digitized images. In addition to describing the calibration procedure and availability of the data, we here present results on the sunspot, umbral and penumbral area measurements and their variation with time.

## 1. Introduction

Complexity of an active region is defined by the area and position distribution of sunspots. The complexity of sunspot groups seen on the photosphere primarily drive the coupling with higher atmosphere and cause solar activities like flares, CMEs etc. Hence, it is also important to study the way in which complexity evolves in different sunspot groups over time. The darkness of umbra and penumbra,compared to quiet sun, is caused by magnetic field.Hence, the relative intensity is used to study complexities of sunspot groups for long term intensity images.

## 2. Data and Calibration

At the Kodaikanal observatory, the white-light observations of the Sun started since 1904 and continued till today. These images are taken in photographic plates and films. Recently, all these data have been digitized and calibrated. This calibration process involves flat-fielding, centering the solar disk with the image window, orient the north polarity upward, and conversion of photographic density to relative values (Figure 1(left)) (Ravindra *et al.* (2013)). Later, in Fourier domain a Gaussian Noise filter is used to remove center to limb intensity variation (Figure 1 (right)).

## 3. Results

Sunspot's, penumbral and umbral area measurements are made for the year 1923-2011. The obtained sunspot area from the Kodaikanal data is highly correlated with that from the Greenwich data (Figure 2 (top)). Now, the penumbra to umbral ($p/u$) area ratio is computed as suggested by Hathaway (2013). We then seggregated the ratio in accordance with a bin size of 20 $\mu$H for the sunspot area data starting from 10 to 2000 $\mu$H. Figure 2

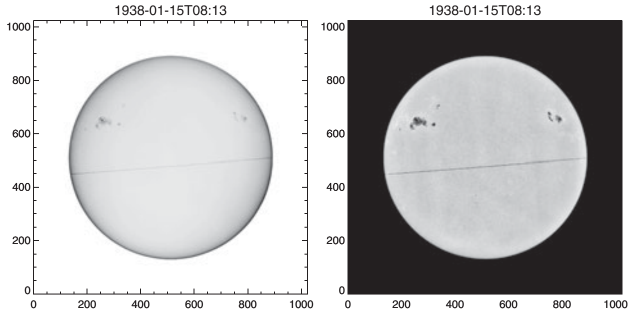


**Figure 1.** Left: A sample white-light image of the Sun taken at the Kodaikanal Observatory. Right: Same as left side image but corrected for limb darkening effect.

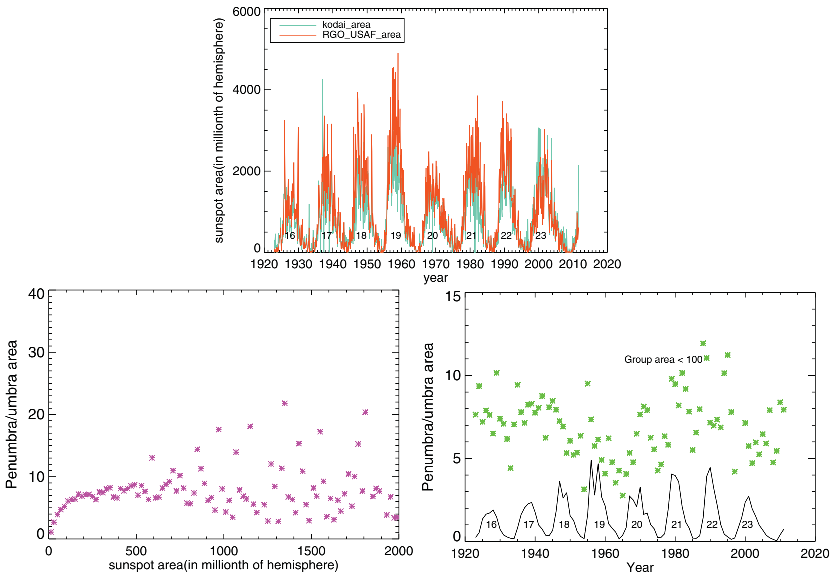


**Figure 2.** Top: A monthly averaged sunspot area is plotted against time (shown in green) and the Greenwich sunspot number is also show for comparison. Bottom-left: Penumbra to umbra ratios of spots in bins 20 $\mu$H wide from 0 to 2000 $\mu$H. Bottom-right: Yearly averaged of the penumbral to umbral area ratio as a function of time.

(bottom-left) shows the penumbral-to-umbral area ratio for all the sunspot whose area covering from 10 to 2000 $\mu$H. The plot shows that $p/u$ area increases with increasing the size of the sunspot till 200 $\mu$H and after that it is independent of it. The raio also exhibit a pattern of solar cycle behaviour (not shown here). On the other hand, the $p/u$ area ratio for the sunspots whose area less than 100 $\mu$H shows a different pattern than solar cycle as suggested by Hathaway (2013) (Figure 2 (bottom-right)). In future, we need to look at this data more carefully and do a comparison with other data sets.

## References

Hathaway, D. H. 2013, *Solar Phys.*, 286, 347

Ravindra, B., Priya, T. G., Amareswari, K., Priyal, M., Nazia, A. A., & Banerjee, D. 2013, *A&A.*, 550, 19