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Exploiting Four Historical Ca II K Spectroheliogram Archives

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Abstract. Here we briefly review the status of the project aimed to analyse the potential of historical Ca II K archives for studies of long-term (decades to a century) solar variability.

1. Introduction

Regular measurements of the solar irradiance began in the late 1970s (Willson et al. 1981; Froehlich 2005). Longer time-series are crucial in order to assess the magnitude and to understand the mechanisms of solar influence on Earth's climate, as well as to improve our understanding of the solar dynamo.

Reconstructions of past irradiance variations have been done using sunspot data, e.g. sunspot number and areas (Lean et al. 1995; Solanki & Fligge 2000; Wang et al. 2005; Krivova et al. 2007, 2010; Dasi-Espuig et al. 2014), or concentrations of cosmogenic radionuclides, e.g. ^{14}C and ^{10}Be measured in tree rings and ice cores, respectively (Steinhilber et al. 2009; Delaygue & Bard 2011; Shapiro et al. 2011; Vieira et al. 2011). However, these reconstructions are not free of shortcomings. The sunspot data only indirectly provide information on the bright plage component in active regions and do not adequately describe the weaker ephemeral regions that are believed to be the main driver of the longer-term secular changes. The radionuclide data also lack temporal resolution and suffer from uncertainties introduced by the geomagnetic field and atmospheric influences.

Full disc Ca II K spectroheliograms can potentially give information about the surface distribution of the solar magnetic flux (Skumanich et al. 1975; Schrijver et al. 1989; Loukitcheva et al. 2009). Since regular observations in the Ca II K line started at the beginning of the 20th century at various observatories around the globe, some of which have been digitised, these observations represent unique datasets to study the solar variability, in a much more complete manner, for over 100 years.

However, a broad and accurate analysis of these observations requires a prior development of automatic procedures that allow to work out image artefacts and problems raised by e.g. defects in and decay of spectroheliogram photographic plates, missing photographic calibration, undocumented changes of the instrumentation (Ermolli et al. 2009).

Here we present a brief overview of the datasets we processed and the main steps of the techniques developed to process the data.

2. Data

The data we processed are from the Coimbra, Kodaikanal, Mount Wilson and Mitaka observatories. Table 1 contains some basic information about them, i.e. the period of observations, the number of images, the data type and the pixel scale of the digitized files. These observations are spectroheliograms taken at the centre of the Ca II K line at $\lambda = 3933.67$ Å.

Dataset	**Years**	**Images**	**Data type** [bit]	**Pixel scale** ["/pixel]	**Reference**
Coimbra	1926-2007	~16000	16	1.8	Garcia et al. (2011)
Kodaikanal	1907-1999	26640	8	2.0	Makarov et al. (2004)
Mitaka	1917-1974	8585	8-16	0.9-2.9	Hanaoka (2013)
Mount Wilson	1915-1985	~40000	16	2.7	Bertello et al. (2010)

Table 1. List of datasets analysed in this study with information on the period of observations, the amount of available data, the data type and the resulting pixel scale of the digitized data.

3. Methods

The main problems of the historical datasets are large-scale inhomogeneities due to observational procedures and plate ageing, a variety of smaller-scale artefacts (e.g. scratches, dust), and lack of calibration wedges for most of the images. To account for these problems we developed methods that convert the data values to photometric density, account and correct any large-scale inhomogeneities, perform the photometric calibration by using information that these observations intrinsically carry under certain assumptions and finally compensate for the limb darkening.

4. Examples of the Code's Performance

To illustrate the ability of our method to process diverse datasets and return consistent results, Figure 1 shows different steps of the procedure as applied to images from the archives listed in Table 1. The steps included there are: the produced density image (1st column), the calculated background that contains the large-scale inhomogeneities and some smaller-scale artefacts (2nd column), the calibrated image (3rd column) and finally the image corrected for the limb darkening (4th column). The observations shown there are from Coimbra taken on 05/02/1994 (1st row), Kodaikanal taken on 04/02/1970 (2nd row), Mount Wilson taken on 19/08/1938 (3rd row) and Mitaka taken on 10/01/1970 (4th row). The code is able to recover the background quite accurately, the final flat contrast images show no residual inhomogeneities and it works consistently with large samples of images extracted from the 4 archives.

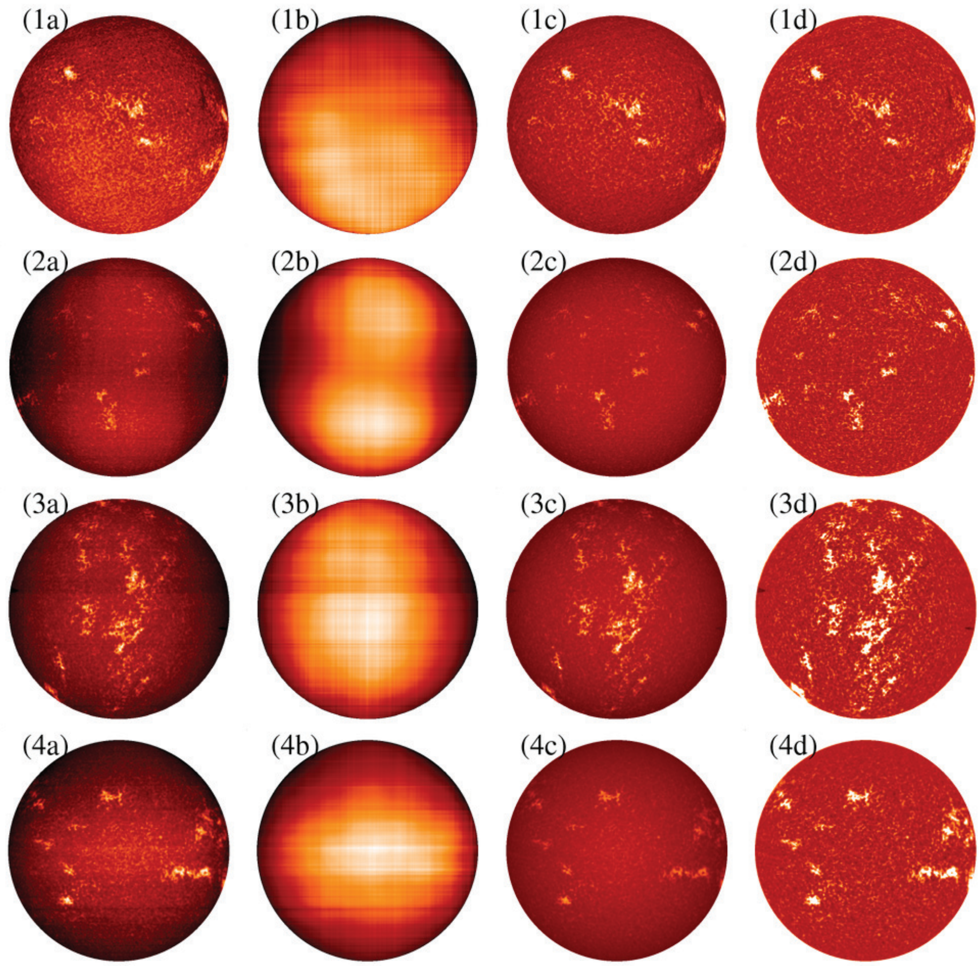

Figure 1. Examples of historical observations and of different steps of the application of the code to these data. The first row is for Coimbra observation taken on 05/02/1994, the second row is for Kodaikanal observation taken on 04/02/1970, the third row is for Mount Wilson observation taken on 19/08/1938 and the fourth row is for Mitaka observation taken on 10/01/1970. Images in column (a) display the density, (b) the background containing the inhomogeneities, while in column (c) are plotted the calibrated and in column (d) the corrected for the limb darkening images. The colored figure can be found in the electronic version.

5. Summary

We have developed a code that automatically corrects for most problems affecting the historical observations and performs the photometric calibration, an overview of which was given here. More details will be given in a forthcoming paper. The next step is to further process the available datasets, with the identification of solar disc magnetic features and measurement for their properties in time.

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