Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
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Multivariate analysis of intermediate periodicities of the green corona

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Abstract. Solar activity is observed to fluctuate with time, undergoing a wide range of periodicities from minutes up to thousands of years as evinced from proxies based on cosmogenic isotopes. In this work, we apply Multichannel Singular Spectrum Analysis (MSSA), a data-adaptive, multivariate technique that simultaneously exploits the spatial and temporal correlations of the input data to extract common modes of variability to investigate the intermediate quasi-periodicities of the green coronal emission line at 530.3 nm for the period between 1944 and 2008. A preliminary MSSA analysis confirms the presence of significant quasi-biennial oscillations in the data with amplitude varying significantly with time and latitude. On the other hand, a clear North-South asymmetry is observed both in their intensity and period distribution.

Keywords. Sun: corona, Sun: evolution, methods: data analysis

1. Introduction

Solar activity fluctuations at interannual timescales, such as the so-called quasi-biennial oscillations (QBOs; Bazilevskaya *et al.* 2014) at timescales between about 1 and 4 yr appear to be ubiquitous, having been detected in activity proxies that are sensitive to the solar interior, the solar atmosphere, the corona and the interplanetary medium. These periodicities, often referred to as intermediate- or mid-term quasi-oscillations show variable periodicity and asymmetric, independent development in the northern and southern solar hemispheres. The origin of the 11-yr sunspot cycle is believed to be governed by the global solar dynamo mechanism, but the physical reason for the occurrence of these shorter periodicities is not completely clear, although a number of candidate mechanisms have been proposed in the literature. The most plausible explanation for their origin is related to the possible presence of two different dynamo processes acting in the deep and near-surface layers of the convective zone that are responsible, respectively, for the sunspot cycle and the shorter variations (Benevolenskaya 1998). Alternatively, non-dynamo-based interpretations involve magnetic Rossby waves in the solar tachocline leading to the periodic emergence of magnetic flux at the solar surface due to magnetic buoyancy (Zaqarashvili *et al.* 2010). Intermediate-range periodicities, however, are not continuously detected in the solar datasets and most of these variations might be attributed to stochastic processes of magnetic flux emergence through the photosphere and interaction with existing coronal structures and plasma flows (see Wang & Sheeley 2003 for a discussion on this topic). For this reason, the use of a technique that is able to distinguish pure oscillatory signals from colored noise at a specified confidence level (c.l.) can be important in determining the actual existence and persistence of these oscillations.

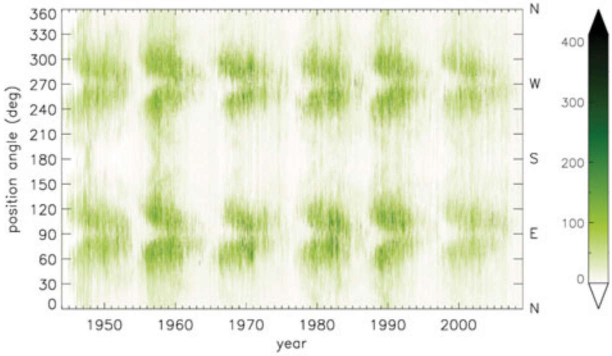

Figure 1. The east and west-limb daily intensity emission of the green coronal emission line Fe XIV at 530.3 nm (in coronal units and converted to the photometrical scale of Lomnický Stít Station at a height of 1.04 $R_\odot$ above the solar limb) as a function of time and position angle.

2. Analysis and Preliminary Results

Over the last few decades, a technique called singular spectral analysis (SSA; Vautard & Ghil 1989) and its multivariate extension (MSSA; Ghil *et al.* 2002) have been widely used in the identification of oscillations in climatic time series (e.g., Taricco *et al.* 2015ab). Recently, this technique has been successfully applied in the analysis of Doppler shift oscillations in the UV corona (Mancuso *et al.* 2015, 2016). One of the main advantages of MSSA with respect to classical Fourier methods is its ability to detect common non-sinusoidal oscillations that are modulated both in amplitude and phase so that the original signals are no more simply decomposed into periodic sinusoidal functions but into data-adaptive waves. Through a Monte Carlo significance test, it is then possible to determine whether the detected oscillations can be distinguished from colored noise at a specified c.l.. In this work, the MSSA technique was applied to investigate the presence of intermediate-range oscillations in a set of data of the green coronal Fe XIV emission line (see Rybansky *et al.* 1994) covering six full solar cycles (Fig. 1). A preliminary MSSA analysis confirms the presence of significant (> 95% c.l.) QBO-type oscillations in the data with amplitude varying significantly with time and latitude. On the other hand, a clear North-South asymmetry is detected both in intensity and period distribution. In conclusion, we have introduced an alternative, powerful approach to extract time-variable oscillations from coronal intensity time series, thus showing that MSSA is a viable and complementary tool for exploring the spatio-temporal behavior of intermediate oscillations in coronal databases.

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