Effect of the inclination angle of the solar rotation axis on disk-resolved indices from full-disk solar images in the Ca II K line

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1 Introduction

Context : The chromospheric plages, main contributors to the Ca II K emission, are distributed between mid-latitude and the Equator. We suspect an impact of the inclination angle of rotation axis on the chromospheric emission. While other stars are observed at unknown inclinations, our results can improve the understanding of magnetic activity of solar-type stars. Stellar chromospheric activity is monitored with the S-index in the Ca II lines and we have shown in Vanden Broeck et al. 2024 that the plages area fraction is a good proxy for this index. The effect of the inclination angle has not been extensively studied through direct solar observations. To analyse this impact, we have reconstructed Ca II K images of the Sun seen under various inclinations and studied the variation of plages area fraction.

Method : We segmented the brightest structures of the chromosphere and constructed synoptic map to map the entire solar surface during a full solar rotation (3). Based on those maps, we have reconstructed solar images seen under other inclinations (4) and we extracted the area fraction of the plages for each inclination (5). The time series for each inclination were analysed with Fourier power spectra to detect periodical modulations (6).

2 Dataset

USET : « Uccle Solar Equatorial Table »

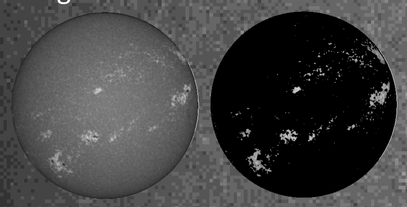
- Ground based station
- Location: Royal Observatory of Belgium
- Monitoring the Sun's photosphere (Wight-light) and chromosphere (Ca II K and Hα)

Ca II K images :

- Starting in July 2012 → Total of ~ 23.000 images
- Acquired 7 days/week when the weather permits
- CCD images : 12 bits | 2048 x 2048 pixels

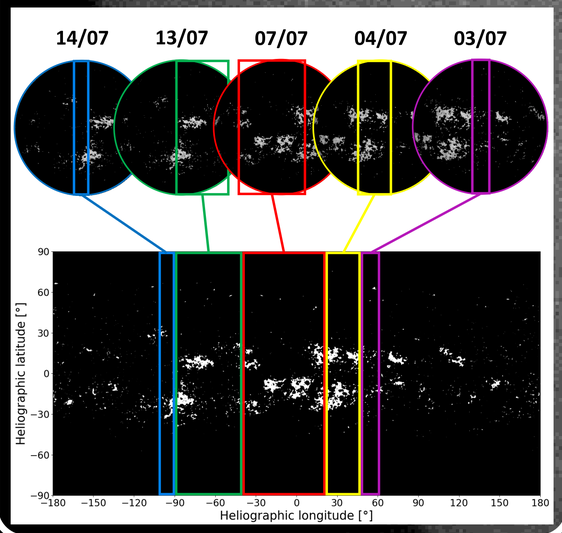
3 Segmentation

Plages and enhanced network

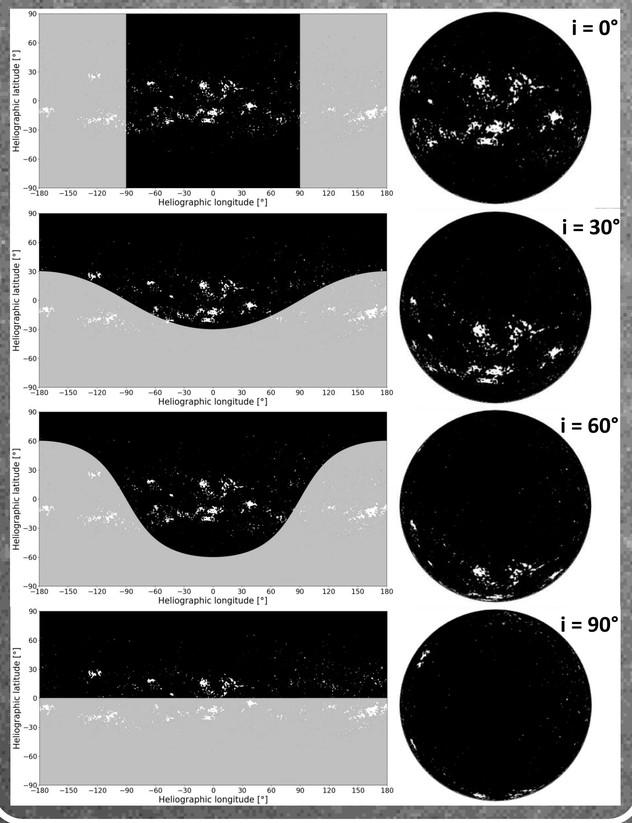


Synoptic map construction

Distribution during a full solar rotation

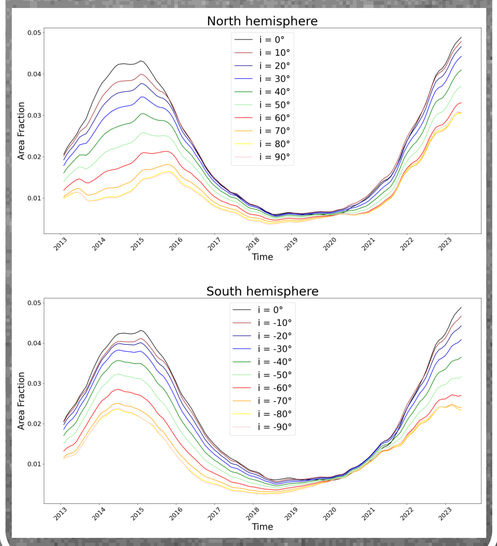


4 Solar images reconstruction under different inclination angles



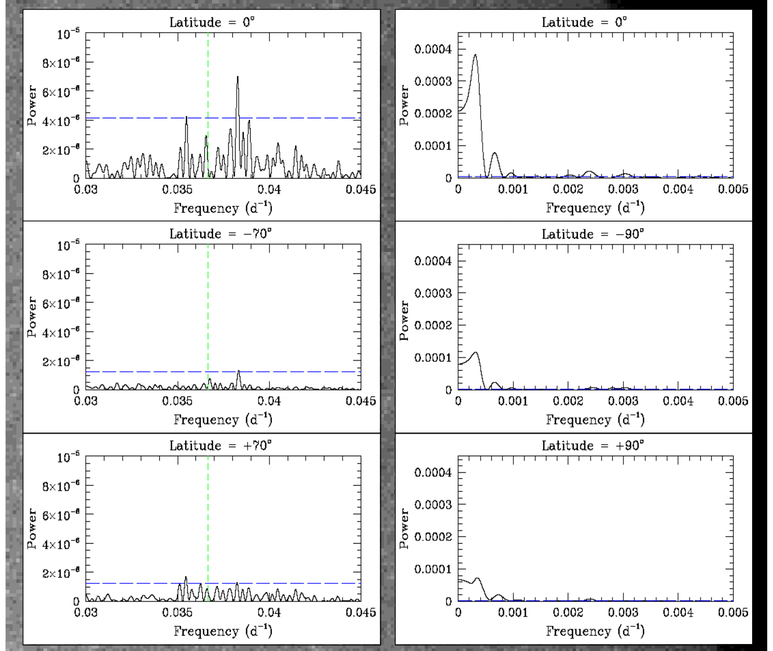
USET website

5 Temporal variation of the area fraction



6 Temporal modulations of the area fraction time series

Solar rotation timescale | *Solar cycle timescale*



- Multiple peaks of signal detected around the Carrington rotation period (green line)
- Rotational modulation non-remarkable above $|i| = 70°$
- North and South hemispheres give different results due to the asymmetry of the solar activity
- Detection of the activity cycle remains visible up to $|i| = 90°$

7 Conclusions and discussions

- Plages area fraction is a good proxy for the S-index → Good connection between the Sun and Sun-like stars. This could be used to better understand the detection of temporal modulations for the other stars, that are not necessarily viewed from their Equator plane.
- Long-term chromospheric activity cycles of Sun-like stars should be detectable even for stars seen under a near Pole-on view. Inclination is unlikely to be the main reason for the relative scarcity of well-established cycles.
- On the short-term timescale, the rotational modulation is no longer remarkable for an inclination $|i| > 70°$ and would certainly be missed in noisy and less densely sampled time series of other stars.