Stellar rotation from starspot variability

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Introduction

The long duration data sets provided by the *Kepler* mission give us an excellent opportunity to study stellar rotation from photometric variability. Using a simple periodogram analysis we search for periodicity in the light curves of $\sim$ 192 000 stars in the *Kepler* field. Out of these we find 12,151 stars with rotation periods that are stable over at least six *Kepler* quarters. The stars in our sample range from M-type all the way up to late B-type stars. We find good agreement of these periods with archival $v \sin i$ and other rotation period measurements. In the event of a re-purposed *Kepler* mission, we anticipate that this simple and straightforward method may be easily adjusted to search for rotation in a different sample of stars.

Selection Criteria

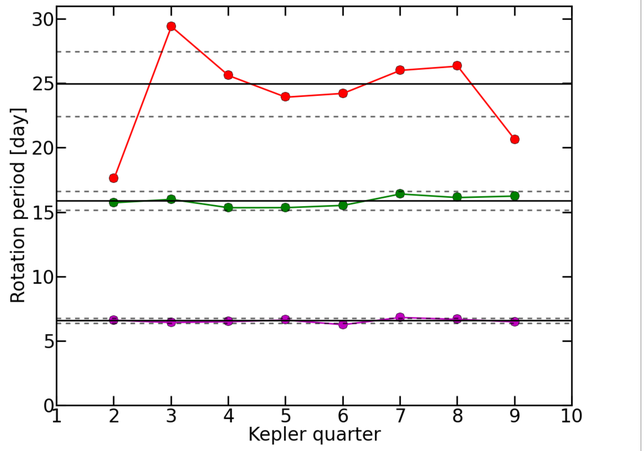

Fig. 1: Periods measured from three targets from Q2 through to Q9. The two target indicated in green and purple have very stable spot patterns and are therefore accepted by the algorithm. The top-most target shows a high scatter in the measured periods and is rejected.

Period Criteria

Periods detected in the *Kepler* data must satisfy the following criteria to be carried forward in the analysis:

- We compute the Lomb-Scargle periodogram for individual quarters of every star, between 1 and 100 days, using PDC_MAP data.
- The peak of maximum power is found in this period range.
- The peak must be at least 4 times higher than the white noise level (calculated based on RMS in the time series).
- If the peak falls within 1-30 days we consider it stellar variability and not due to instrumental variability or signal injected by the PDC_MAP reduction pipeline.

Rotation determination

Periods that satisfy the above criteria are subjected to further constraints to make sure the periodicity is stable over long periods:

- Calculate the median of the recovered periods.
- Select only stars with median absolute deviation (MAD) less than 1 day.
- Of these select only stars with more than 6 out of 8 periods within 2 MAD of the median.

Rotation periods

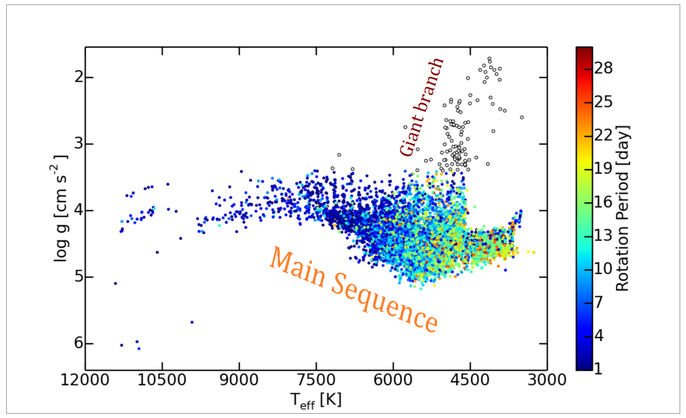

Fig. 2: Rotation periods measured for 12 151 stars in the *Kepler* field. A clear increase in rotation period is seen along the main sequence going from the magnetically inactive hot stars, to the more active cool stars. Stars with $\log g < 3.4$ were removed from the sample to exclude giant stars (open circles).

Testing the Sun

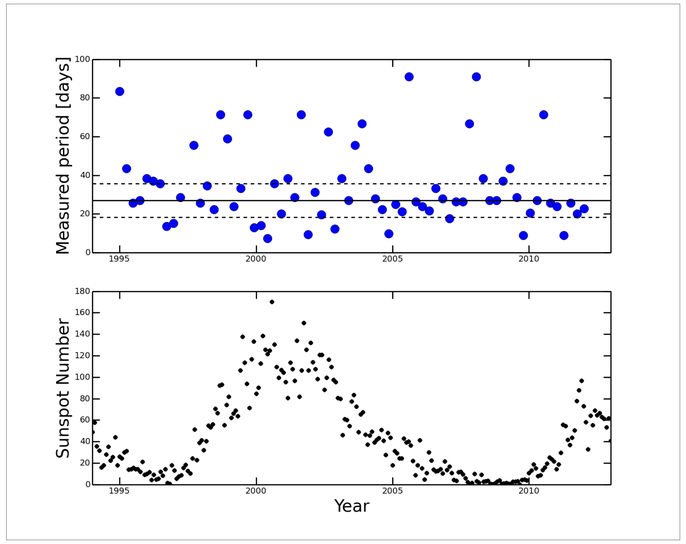

Fig. 3: Top: Periods measured as a function of time using VIRGO data (SPM, Green channel). The solid line indicates the median of 27.03 days and dashed lines represent $\pm$8.7 days (one median absolute deviation). Bottom: Sunspot numbers measured over the period spanning the VIRGO mission, indicative of the magnetic activity variability.

Consistency check

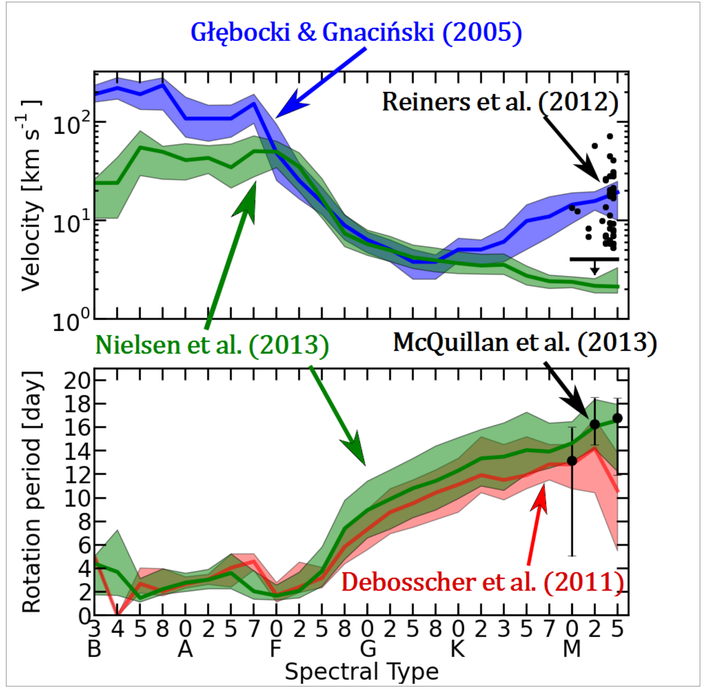

Fig. 4: Median rotation values as a function of spectral type from this work and other studies. Top frame: Measured rotation periods (green) converted to equatorial velocity using KIC radii, compared to $v \sin i$ measurements compiled in Głębocki & Gnaciński (2005) (blue) and Reiners et al (2012) (black); note that these two samples do not contain *Kepler* targets. Bottom frame: Median rotation periods compared to the studies by Debosscher et al. (2011) (red) and McQuillan et al. (2013) (black), both of which analyze *Kepler* targets.

Acknowledgments

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References

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