

# Starspot Activity and Differential Rotation in KIC 11560447

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Reference: Özavcı et al. 2018 MNRAS 474, 5534

## ABSTRACT

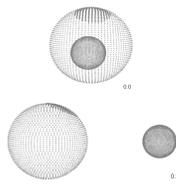
Using four years of high-precision photometry from the Kepler mission, we investigate patterns of spot activity on the K1-type subgiant component of KIC 11560447, a short-period late-type binary system. Prior to light curve inversions, we test the validity of maximum entropy reconstructions of starspots by numerical simulations. Our procedure successfully captures up to three large spot clusters migrating in longitude. We suggest a way to measure a lower limit for stellar differential rotation, using slopes of spot patterns in the reconstructed time-longitude diagram. We find solar-like differential rotation and recurrent spot activity with a long-term trend towards a dominant axisymmetric spot distribution during the Kepler period of observations.

## Introduction

- AIMS
- Time-resolved photometric mapping of stellar surfaces
- Differential rotation by tracking starspot groups
- Tests of photometric inverse modelling starspot activity, by forward modelling

• **TARGET: KIC 11560447** ( $V_{\max} = 11^{\text{m}}.1$ )

Orbital period :  $\sim 0.5277$  day  
 semi-detached binary : [ K1IV + M5V ]  
 Luminosity contributions: [ 97% + 3% ]  
 Effective temperatures : [ 4969 | 3068 ] K  
 Stellar radii : [ 1.22 | 0.52 ]  $R_{\text{sun}}$

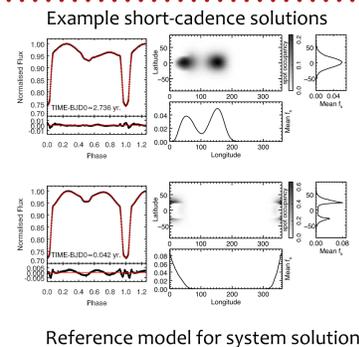


## KEPLER data

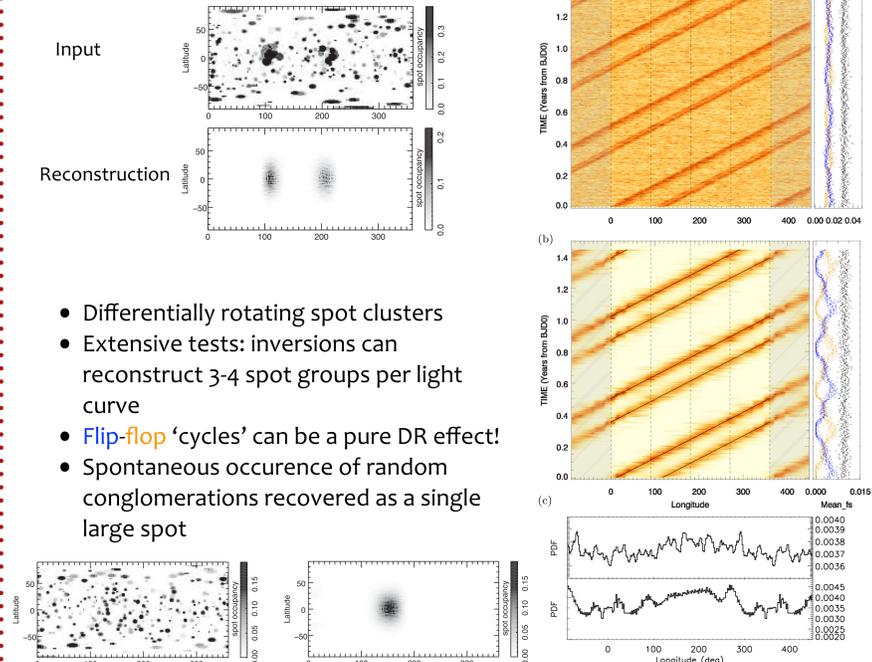
- 18 quarters Long-Cadence, 4 quarters Short-Cadence data
- KEPLER PDC from Multimission Archive at STScI (MAST)
- PyKE cross-check for flux contamination in the target pixels
- PDC-pipeline-specific misinterpretations fixed, by copying the pixel mask used in a reliable quarter and re-performing photometry for the problematic quarters.
- Stitching performed by matching the average flux of the last 50 points of the leading quarter to the first 50 points of the trailing quarter.

## Light curve and spot modelling

- High-res. spectroscopy from 2.1-m Otto Struve Telescope at the McDonald Observatory  $\rightarrow$  radial velocities (RV)
- Simultaneous {light curve + RV} solution
- System parameters with high accuracy, put into DoTS code, which solves for the spot filling fraction (normalised for each LC)

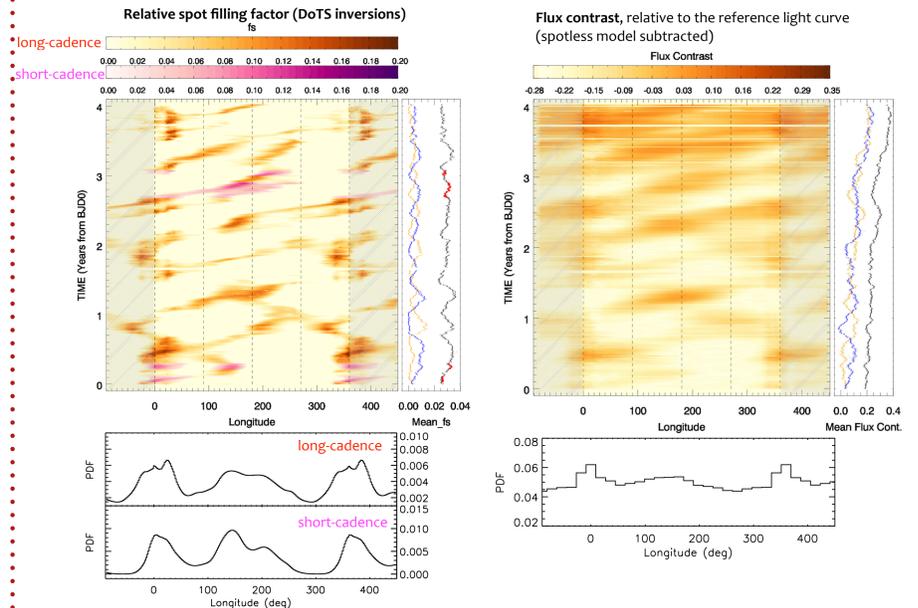


## Numerical simulations



- Differentially rotating spot clusters
- Extensive tests: inversions can reconstruct 3-4 spot groups per light curve
- Flip-flop 'cycles' can be a pure DR effect!
- Spontaneous occurrence of random conglomerations recovered as a single large spot

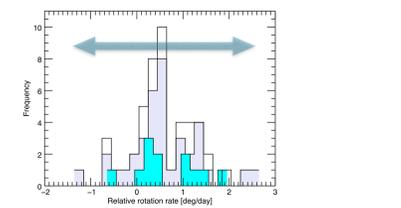
## Spot patterns on a K1-subgiant in 4 years



## Differential rotation (DR): time and frequency domains

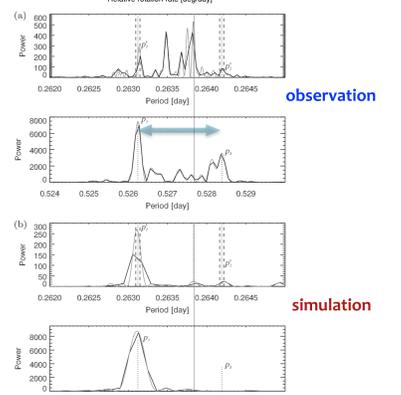
**Time domain (values relative to  $\Omega_{\text{orb}}$ )**

- Linear fits to spot drifts in longitude
- Mean relative rotation:  $0.55 \pm 0.13$   $^{\circ}/\text{d}$
- Relative rotation rates: [ -1.35, 2.44 ]  $^{\circ}/\text{d}$



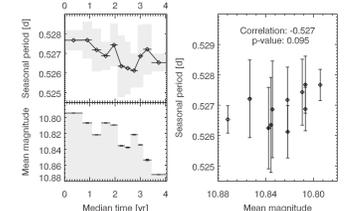
**Frequency domain (values relative to  $\Omega_{\text{orb}}$ )**

- LS periodogram of entire light curve (eclipses eliminated)
- Range of peaks:  $2.77$   $^{\circ}/\text{d}$
- Range of rotation rates: [ -1.35, 2.44 ]  $\text{d}^{-1}$
- Type of DR: solar-like (faster equator), using Reinhold & Arlt's (2015) method
- 2-cluster simulation: compatible drift rate



**Secular change in period and brightness**

- Seasonal periods & brightness decrease in 4 years, hinting at formation of polar caps and/or equatorward migration



## Conclusions

- Maximum-entropy-based DoTS is successful in detecting spot clusters
- Simulations & observations: [two large spot groups + DR]  $\rightarrow$  flip-flop cycles
- K1IV component of KIC 11560447:
  - Recurrent spot patterns cluster around  $0^{\circ}$  and  $140^{\circ}$  in longitude
  - Spots rotate largely prograde up to  $2.4^{\circ}/\text{d}$  in orbital frame
  - Indications for solar-like differential rotation,
  - High latitudes synchronised with the orbit
  - Axisymmetric component of activity shows a secular increase, while the mean spot period decreases
    - \* equatorward propagation of dynamo wave and/or
    - \* strong polar accumulation of dark spots

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