Searching for Magnetic Activity in Solar-Like Stars Observed by *Kepler*

Lauren Balliet[(1)], Savita Mathur[(2)]

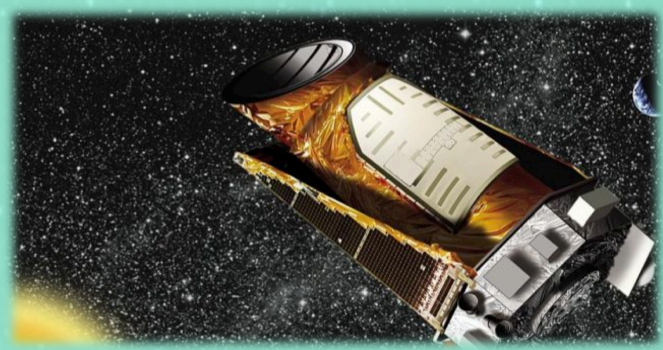
(1) Clarion University of Pennsylvania, Clarion, PA (2) Space Science Institute, Boulder, CO

Introduction

The exact mechanisms causing solar magnetic activity are not completely understood. In order to determine what is generating the dynamo of the Sun, a broader study needs to be conducted. Studying solar-like stars allows for various perspectives. Many spectroscopy surveys that were conducted to study stellar magnetic activity. They have shown that when stars are plotted against their rotation period and cycle period, they can be part of an active or inactive magnetic activity branch. These surveys showed that some stars seem to show cycles while others can have flat or variable magnetic activity. We selected a sample of 540 pulsating solar-like stars observed by the *Kepler* mission [1]. This sample is interesting because the asteroseismic studies of these stars have provided accurate stellar properties. Magnetic cycles result from the relationship between the rotation, convection and magnetic field. In the first part of my project, I analyzed the data set of 540 solar-like stars to determine their rotation periods. To do so, I looked at the autocorrelation and the time-frequency analysis of the light curve. To verify the reliability of the measurements, I performed a visual check of the results. Then from this subsample, I performed an analysis to determine if magnetic cycles are present by computing the magnetic proxy based on photometric data and by doing a time-frequency analysis. We found 15 candidates that are believed to have magnetic cycles present. In addition, we looked at the changes in the amplitudes of acoustic modes. From these results we can provide a sample of well-characterized stars to better understand the dynamo of our Sun.

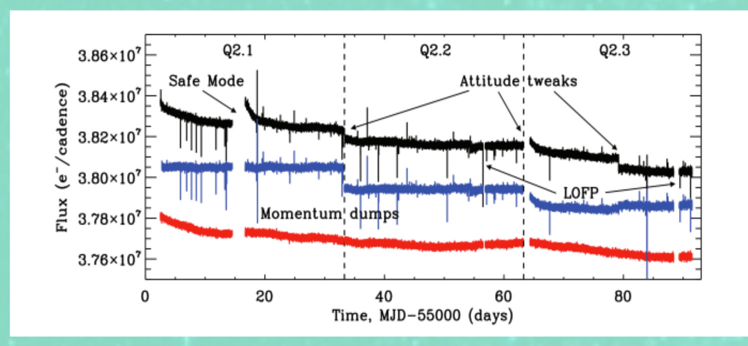
Kepler

- ✧ Four years of ultra-high precision photometry of long continuous photometric data set for about 200,000 stars
- ✧ Long Cadence observations were made every 29.4244 minutes
- ✧ Short Cadence observations were made every 58.84876 seconds for 510 stars



Light Curve

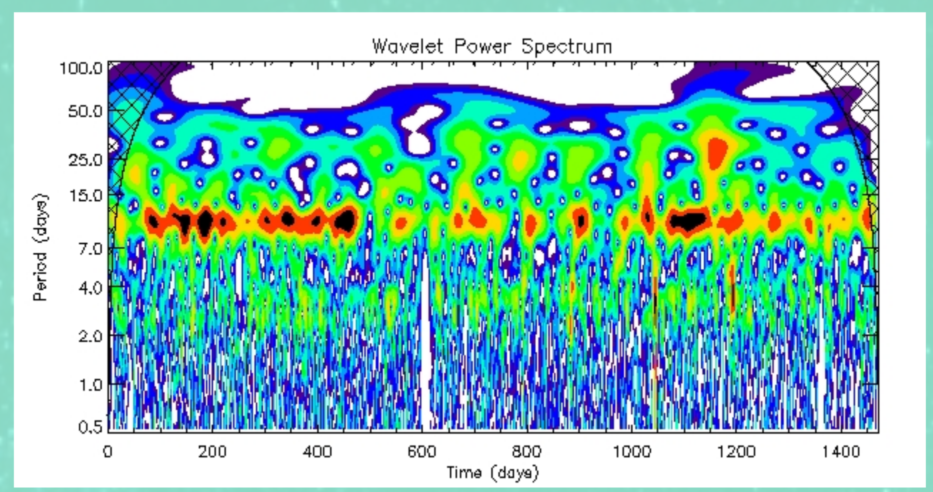
- ✧ Calibration to correct for instrument issues such as jumps, outliers and trends [2]
- ✧ From the light curve we can calculate the rotation of the stars as spots that come in and out of the visible disk create a modulation related to the rotation of the star



Rotation

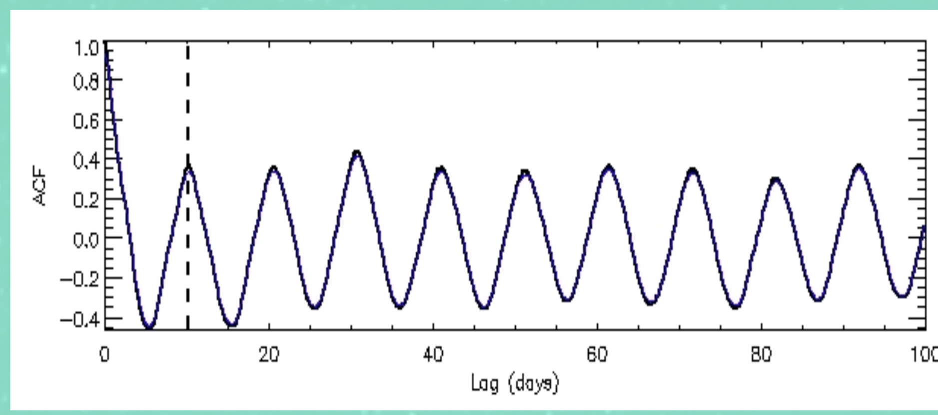
Time Frequency Analysis

- ✧ Compute the correlation between the mother wavelet and the time series and slide it along the time axis [3]
- ✧ The dark red areas show regions of high power



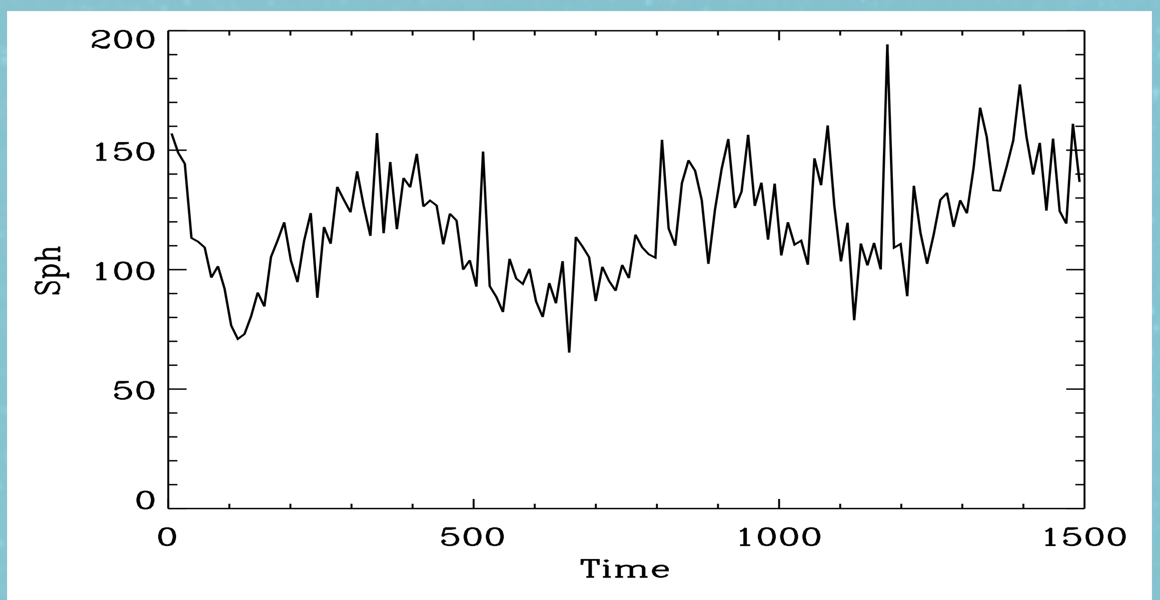
Autocorrelation Frequency Analysis

- ✧ The correlation of the light curve separated by various time lags
- ✧ The location of the maximum correlates with the rotation period [4]



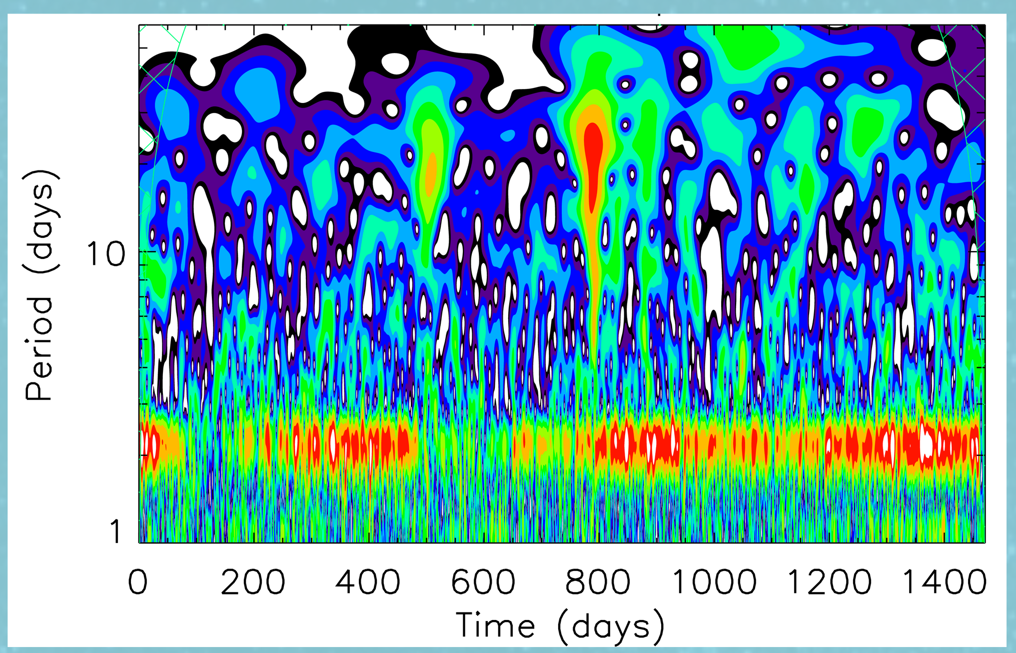
Magnetic Activity

Magnetic Proxy (S_{ph})



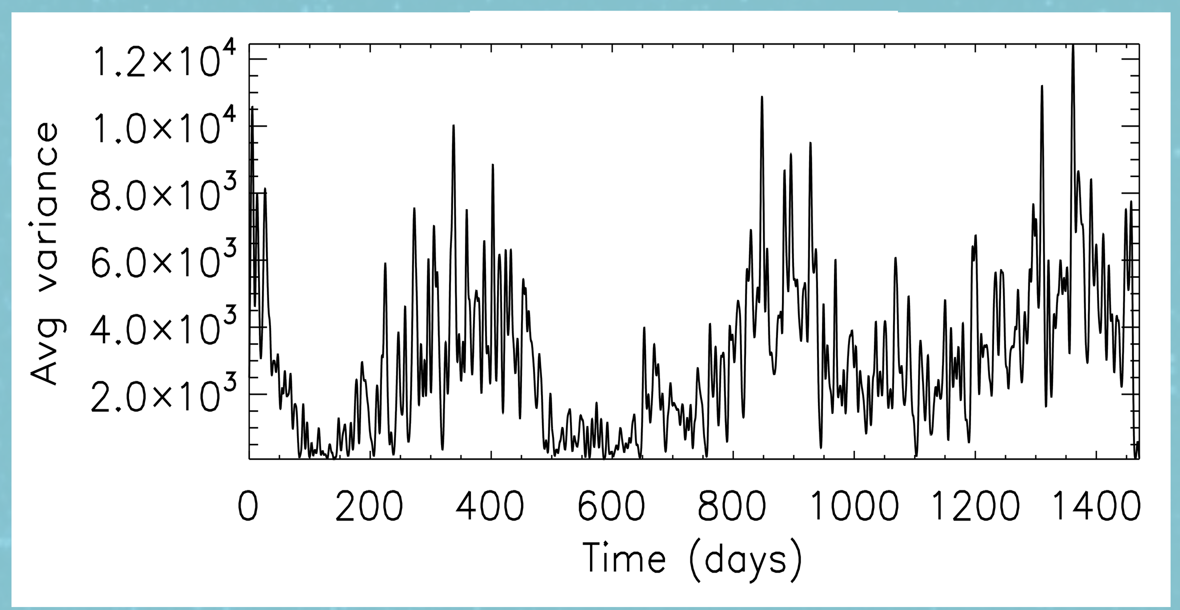
- ✧ Standard deviation of the subseries of length equal to the rotation period times a constant (k)
- ✧ Measure of the global activity from the flux by taking the subseries to show how it is changing over time
- ✧ Larger number of spots relates to a higher S_{ph}

Wavelet Power Spectrum



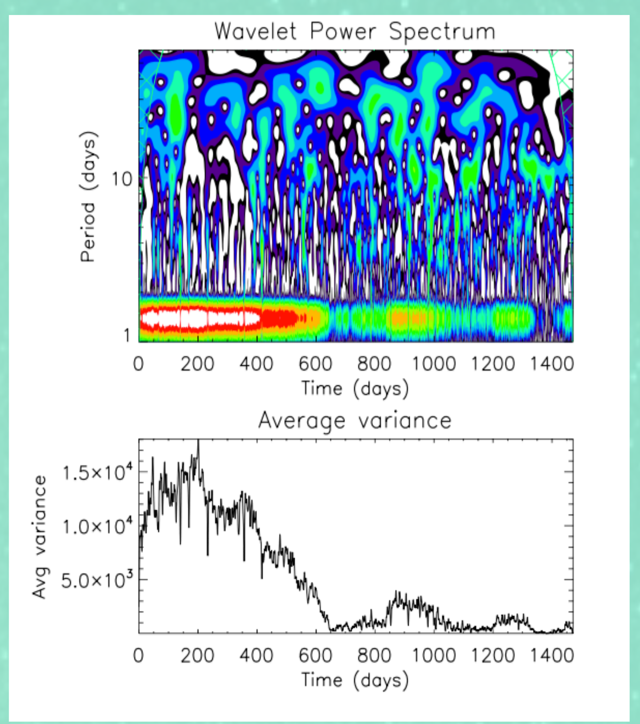
- ✧ Displays the power due to rotation
- ✧ Higher magnetic activity levels are represented by the red areas showing regions of high power

Scale Average Variance

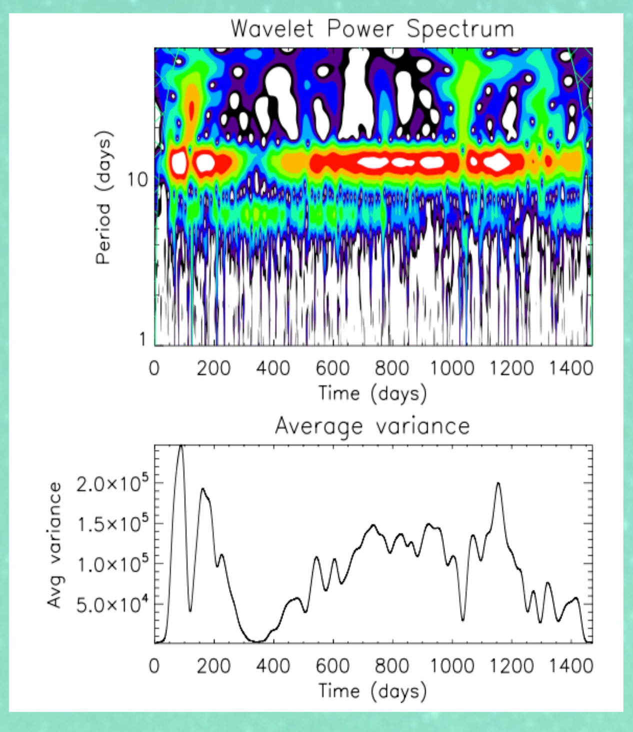


- ✧ Displays the magnetic activity as it corresponds to rotation
- ✧ Projection of the wavelet power spectrum in the range +/-20% P_{rot} on the time axis
- ✧ Similar to the S_{ph} but with more resolution

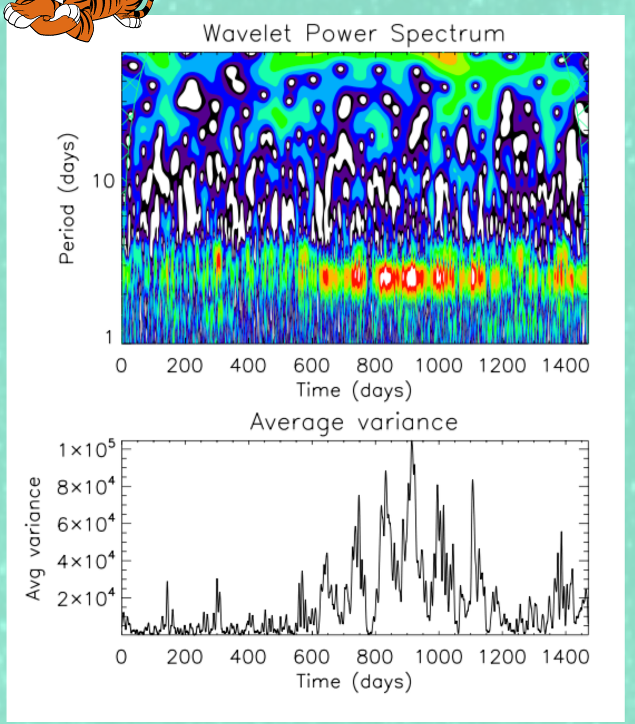
Magnetic Cycles



KIC	10794845
T_{eff}	6137 K
Mass	1.0110 $M_\odot$
Gravity	4.375 dex
Rotation Period	1.4 days



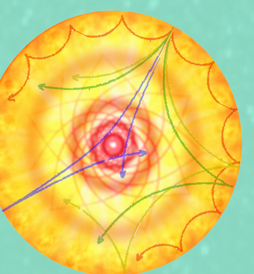
KIC	10129349
T_{eff}	6917 K
Mass	1.383 $M_\odot$
Gravity	4.050 dex
Rotation Period	12.5 days



KIC	3733735
T_{eff}	6676 K
Mass	1.3030 $M_\odot$
Gravity	4.274 dex
Rotation Period	2.5 days

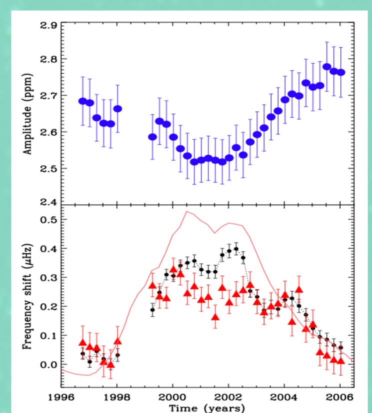
Asteroseismology

- ✧ Helio and asteroseismology aim at studying the internal structure and dynamics of the Sun and other stars by means of their resonant oscillations [5]
- ✧ In the interior of solar-like stars we can define two main types of oscillations modes: the acoustic and the gravity modes [5]
- ✧ Acoustic modes reflect on surface of a star
- ✧ Gravity modes are confined in the radiative zone and evanescent in the convective zone

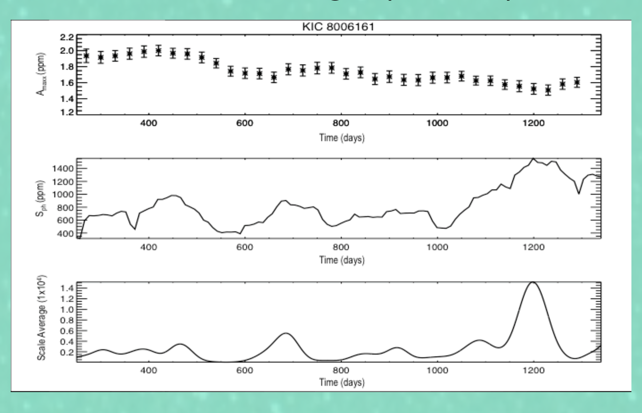


Anti-Correlation

- ✧ As magnetic activity in the Sun increases the amplitude of the modes decrease [6]
- ✧ Sun spots show a correlation with magnetic activity [6]



- ✧ There is an anti-correlation between magnetic activity and amplitude of the modes by correlating with the S_{ph} (-0.587) and Scale Average (-0.254)



Conclusions

- ✧ 304 stars with reliable rotation periods
- ✧ 15 candidates exhibit magnetic cycle like features
- ✧ 13 stars show anti-correlation between acoustic modes amplitude and S_{ph} and Scale Average
- ✧ 3 of the cycle candidates show this anti-correlation

Future Goals

- ✧ Analysis of frequency shifts
- ✧ Stellar Modeling to infer the structure in combination with stellar dynamo model
- ✧ Propose to have spectroscopic observations to have a full analysis

References

[1] Chaplin et al. 2011, ApJ, 732, 54
[2] García et al. 2011, MNRAS, 414, 6
[3] Mathur et al. 2014, A&A, 562, 124
[4] García et al. 2014, A&A, 572, 34
[5] García et al. 2015, EAS, 73, 193
[6] García et al. 2010, Science, 329, 1032

Acknowledgements : *National Science Foundation REU grant 1157020 to the University of Colorado; LASP, Boulder, CO*