Migrating Starspots: A Possible Explanation of the Period O'Connell Effect in *Kepler* Eclipsing Binaries

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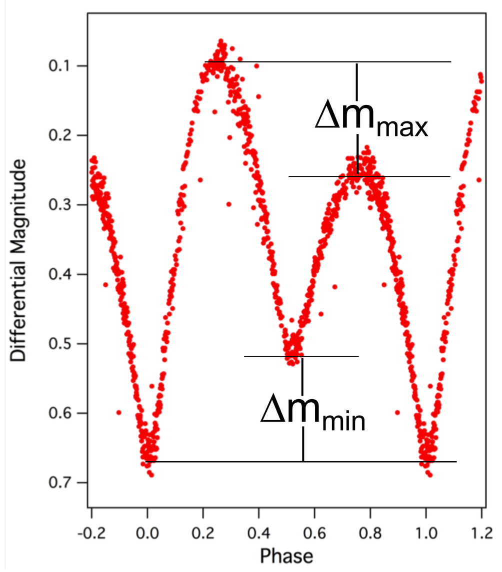
Introduction

The O'Connell Effect

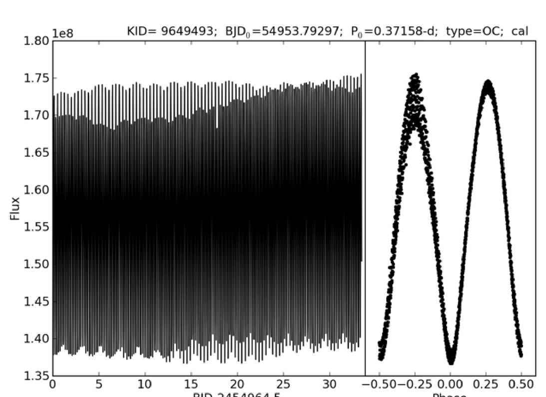
- Asymmetry in the maxima of a light curve of an eclipsing binary is known as the O'Connell effect (Δm_{max})
- Asymmetry in the minima - Δm_{min}
- Starspot theory widely used to explain it.
- Other theories - Hotspot, Circum-stellar dust cloud, Coriolis force.
- Actual cause yet unknown.



A light curve of V573 Lyr showing the O'Connell effect. Data taken at the Truman Observatory.

Methodology

- Analysed data from the *Kepler* space-mission in search of eclipsing binaries with the O'Connell effect.
- The *Kepler* space-mission - continuous coverage of EBs for several days and nights.
- Data downloaded from the public light curve database of the *Kepler* mission.
- Every light curve fitted to a synthetic light curve using the fourier fitting.
- Values of Δm_{max} and Δm_{min} computed for all the light curves from the synthetic light curves.
- Plotted Δm_{max} and Δm_{min} versus revolution to observe how they change and evolve over time.



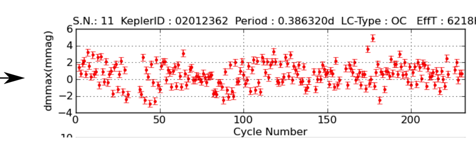
A continuous coverage light curve (KID: 09649493) from the *Kepler* space-mission showing the variable O'Connell effect.

Results

- 408 over-contact EBs studied.
- In almost all the systems some kind of asymmetry observed in both maxima and minima of the light curves.
- In many systems random (non-periodic) variation in Δm_{max} and Δm_{min} observed.
- Few systems with periodic variation in Δm_{max} and Δm_{min} found.
- Possible Causes
  - Periodic variation - Migrating Starspots.
  - Random variation - Distortion of Starspots due to differential rotation in stars.

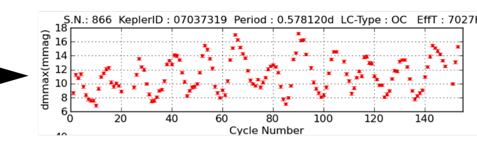
Classification of the systems based on Δm_{max}

1. Systems with no O'Connell effect

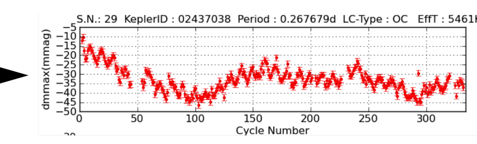


2. Systems with definite O'Connell effect

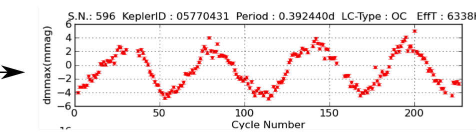
   2.1. Positive



   2.2. Negative

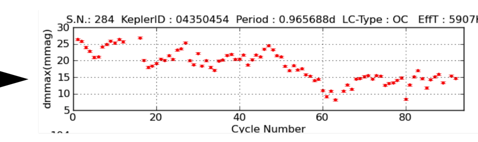


   2.3. Both positive and negative

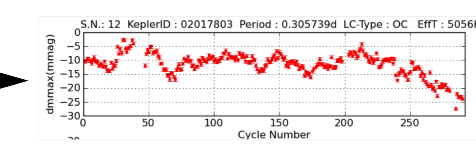


3. Systems with random O'Connell effect

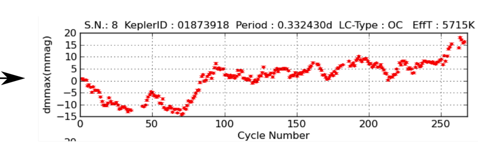
   3.1. Positive



   3.2. Negative

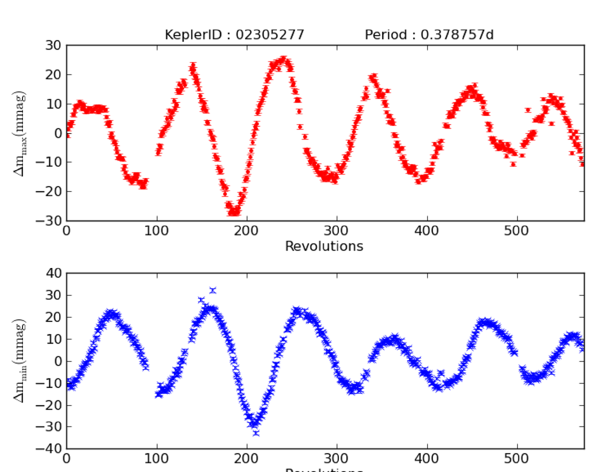


   3.3. Both positive and negative

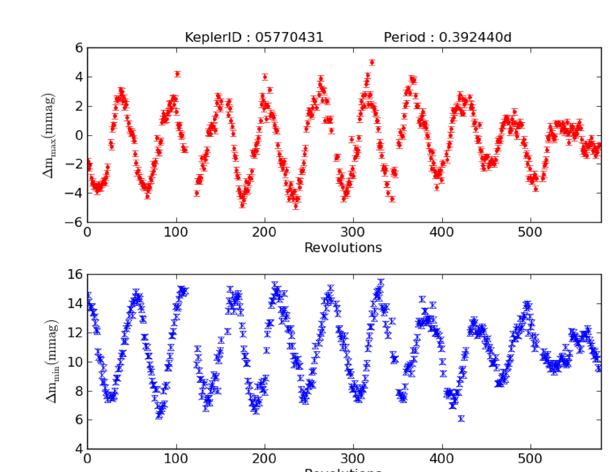


Period Analysis of the Systems with Periodic O'Connell Effect

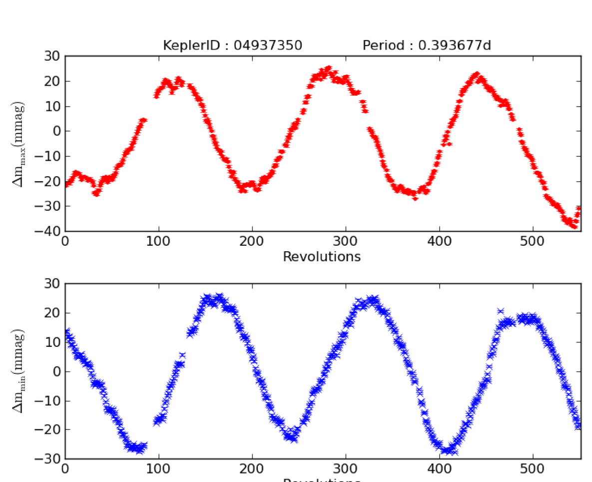
The plots show the periodicity observed in Δm_{max} (red) and Δm_{min} (blue) versus the revolutions of the component stars around each other.



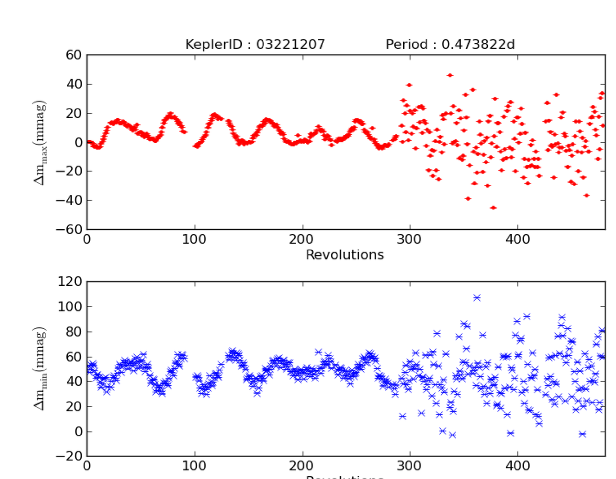
Period of 103 ± 5 revolutions (~ 39 ± 2 days) observed in both Δm_{max} and Δm_{min}.



Period of 55 ± 1 revolutions (~ 21.6 ± 0.4 days) observed in both Δm_{max} and Δm_{min}.



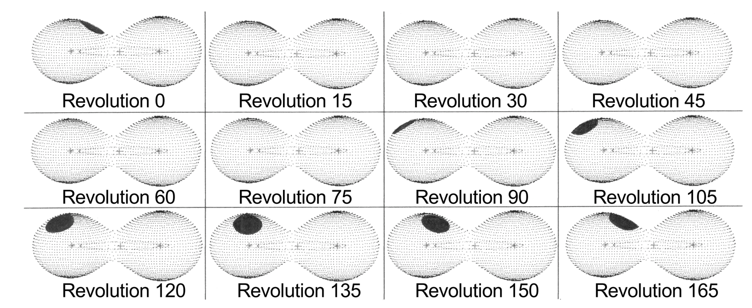
Period of 166 ± 20 revolutions (~ 65 ± 8 days) observed in both Δm_{max} and Δm_{min}.



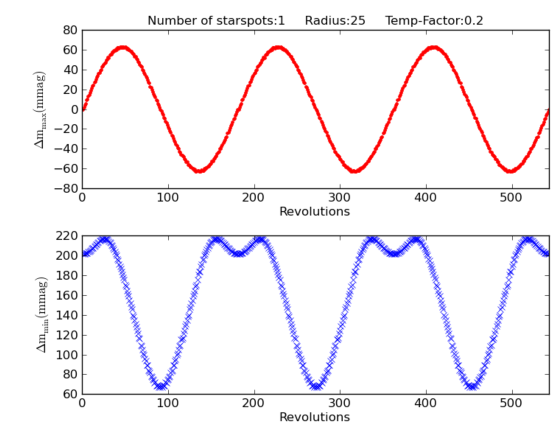
Period of 46 ± 3 revolutions (~ 22 ± 1 days) observed in both Δm_{max} and Δm_{min}.

Migrating Starspot Models

Model 1

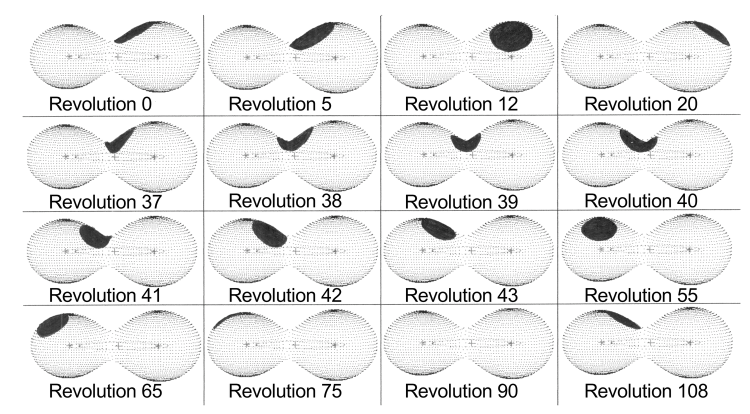


A migrating starspot model in an eclipsing binary to explain the periodicity in the O'Connell effect. Mass-ratio: 1.212360, Temp(Star 1): 3500 K, Temp(Star 2): 3700 K, Inclination: 85 degrees, Number of starspots: 1 (in Star 2), Spot radius: 25, Temperature factor of the starspot: 0.2, Co-Latitude of the starspot: 40 degress, Latitude of the starspot: changes by 2 degrees in each revolution.

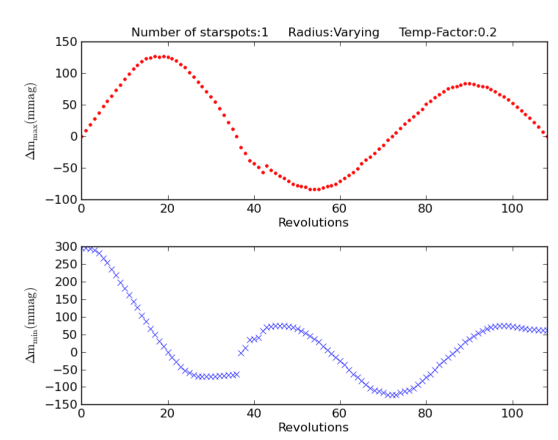


Δm_{max} (red) and Δm_{min} (blue) versus revolution for model 1. It shows similar characteristics to the system with Kepler ID 04937350.

Model 2



A migrating starspot model in an eclipsing binary to explain the periodicity in the O'Connell effect. Mass-ratio: 1.245, Temp(Star 1): 3500 K, Temp(Star 2): 3550 K, Inclination: 85 degrees, Number of starspots: 1 (in Star 2), Spot radius: Varying, Temperature factor of the starspot: 0.2, Co-Latitude of the starspot: 40 degrees except during the transfer of the starspot from star 2 to star 1, Latitude of the starspot: changes by 7 degrees in each revolution.



Δm_{max} (red) and Δm_{min} (blue) versus revolution for model 2. It shows similar characteristics to the system with Kepler ID 02305277.

Conclusion

- The O'Connell effect is a common phenomenon in eclipsing binaries.
- Results from the migrating starspot models are consistent with observations of the periodic O'Connell effect in systems studied from the Kepler database.
- The randomness in the O'Connell effect observed in many of the systems remains a mystery, though distortions in starspots due to differential rotation may account for this.

Acknowledgement

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