The KEPLER Space Telescope’s primary mission is to search out earth-like extra-solar planets. KEPLER uses photometry (counting photons that hit a certain part of the sensor) to look for planets. It looked at the same spot in the sky, counting photons from about 200,000 stars for 4 years, waiting for telltale dips in brightness that indicated a planet passing in front of the star. Though not intended, KEPLER’s precise photometry is perfect for studying variability in stars. This research solar radii. Using light curves, and higher level KEPLER uses photometry (counting photons that hit a certain part of the sensor) to look for planets. Though not intended, KEPLER’s precise photometry is perfect for studying variability in stars. This research focused on the analysis of a number of red giants. Red giants were selected from the KEPLER Database for consistency of data over the four year period and having a radius more than eight solar radii. Using light curves, and higher level analysis such as power spectra, new information was gained about the harmonic oscillations of this selection of red giants.

What are Red Giants?

![Red Giants](https://example.com/red-giants.png)

Red giants come from stars that are very much like our sun. Typically starting off somewhere between 0.4 and 8 solar masses. As solar-like stars get older, they run out of hydrogen to burn in their core. Without fusion in the core to balance gravity the core of star collapses until temperatures get high enough to start burning helium in the core and hydrogen in a shell around the core. This more than overcomes the gravity of the star, expanding it outwards to many times its original size.1

Solar-Like Oscillations in KEPLER Red Giants

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Abstract

The KEPLER Space Telescope’s primary mission is to search out earth-like extra-solar planets. KEPLER uses photometry (counting photons that hit a certain part of the sensor) to look for planets. It looked at the same spot in the sky, counting photons from about 200,000 stars for 4 years, waiting for telltale dips in brightness that indicated a planet passing in front of the star. Though not intended, KEPLER’s precise photometry is perfect for studying variability in stars. This research solar radii. Using light curves, and higher level analysis such as power spectra, new information was gained about the harmonic oscillations of this selection of red giants.

Introduction

Data from KEPLER are given in the form of FITS files. These files contain large amounts of data about a particular stellar object. This data is divided with respect to time into cadences. For each time slice, photon count and flux is stored per pixel. Desired data can be extracted and used to form light curves. These light curves can be used to perform high-level analysis.

Why do Stars Vary in Brightness?

All Stars vary. Even our own sun varies in brightness by very small amounts. There numerous reasons for this, such as spots or orbiting planets. The two types of variation in this study were radial pulsations and pressure waves (also called p-waves). Radial pulsations are when the entire star expands and contracts, keeping a nearly spherical shape. P-waves are similar to earthquakes.

Methods of Analysis

All data were downloaded in FITS file format. We used a program to linearly interpolate short gaps. Data series with more than 2% of the points missing were thrown out. This left us with around 30 stars to look at.

Next, using the program OriginPro 9.1, Fourier power spectra were obtained. A power spectrum is a plot of frequency on the x-axis and relative power on the y-axis (Fig. 3). All of the stars’ power spectra were analyzed for harmonic and solar-like oscillations. Harmonic oscillations indicate a fundamental frequency of oscillation that is equal to the separation of the harmonic frequencies. These occur in binary periodic drops of brightness. Solar-like oscillations are excited stochastically by convection.

Each of their modes is characterized by three integers: radial order n, angular degree l, and azimuthal degree m.

In the spectrum we define:

\[ \Delta \nu = \text{large separation (n-l,1)} \text{ and (n,1)} \]
\[ \nu_{\text{max}} = f \text{ of maximum of comb} \]
\[ \delta \nu_{\text{LP}} = \text{- small separation, f spacing (n,l) and (n-1,l,2)} \]

Large separations measure the average density. Small separations measure the core composition. They allow us to infer the mass and age of a star.

Conclusion

The next step was to determine whether the pulsation stemmed from p-waves or radial pulsations. Using existing empirical formulas3,4, mass and densities were calculated for each of the red giants assuming each type of variation. The masses were expected to fall within the .4 to 8 M☉.

When tested the formulas against an array of known stars of each type (radial pulsator and p-wave pulsator) the calculated masses were always within 20% of the known mass. With this in mind no stars in the group we selected could be experiencing radial pulsations as those calculations resulted in measurements outside of an acceptable margin of error.

Most of the stars gave calculated masses within .5 and 4M☉ for the p-wave equation. For the radial pulsation calculation all of the stars gave masses that were three orders of magnitude or more off the expected values.

This indicates that some other cause of variability is present most of these stars. It is almost certainly not a planet (period of oscillation is too short). It is possible that it could be a spot on the star. But it is impossible to say for sure without studying the stars further.

Acknowledgements and References

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4. Mikulski Archive for Space Telescopes (MAST) for distribution of the FITS files.
5. C. Shoop for writing the Bloomberg KEPLER View (BKV).
6. L. Liberadic for writing the interpolation software.

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