

TESS Observations of Eclipsing Binary V477 Cyg

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Abstract: The Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2015) has produced extremely accurate observations of eclipsing binary systems that contain pulsating components, particularly δ -Scuti pulsators. These binaries fall into two basic types, detached systems and semi-detached systems. This study looks at V477 Cyg which is a combination of an EA β Persei-type (Algol) star and a Heartbeat star. The light curve and the periodogram is analyzed from TESS photometry data contained in the Mikulski Archive for Space Telescopes (MAST). Pulsations within the δ -Scuti component of the binary (the EA star) are examined in detail to extract the frequency relations among the pulsations.

1. Introduction

The Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2015) has produced extremely accurate observations of eclipsing binary systems that contain pulsating components, particularly δ -Scuti pulsators. These binaries fall into two basic types, detached systems and semi-detached systems. This study looks at V477 Cyg which is a combination of an EA β Persei-type (Algol) star and a Heartbeat star. The light curve and the periodogram is analyzed from TESS photometry data contained in the Mikulski Archive for Space Telescopes (MAST). Pulsations within the δ -Scuti component of the binary (the EA star) are examined in detail to extract the frequency relations among the pulsations.

The EA β Persei-type (Algol) eclipsing system is a binary with spherical or slightly ellipsoidal components. The light may remain almost constant between eclipses and a secondary minimum may be absent. Periods can range from 0.2 to over 10000 days with amplitudes which can vary by several magnitudes. Heartbeat stars are eccentric ($e > 0.2$) binary stars whose light curve resembles a cardiogram. They are ellipsoidal variables that undergo extreme dynamic tidal forces, especially during periastrons, that cause changes in brightness (photometric periastron variation or heartbeat).

δ -Scuti pulsators are main sequence or post main sequence stars with luminosity classes between III and V. Their spectral types range from A1 to F7 and are located in the lower part of the classical Cepheid instability strip of the [Hertzsprung-Russell diagram](#). These objects exhibit single or multimode radial and non-radial behavior. The pulsation modes are usually low-order radial or non-radial p and g modes. P modes are pressure modes where standing acoustic (sound) waves provide a pressure gradient acting as a restoring force. For radial p modes, the entire star acts as the resonant

pulsation cavity. For non-radial p modes, the resonant cavity is determined by a given depth below the surface of the star based upon several related parameters. G modes or gravity modes are standing waves of buoyancy (i.e., gravity) as the restoring force. Gravity modes have only non-radial components that are of lower frequency than the pressure mode components. P radial modes change the size (radius) of the star while g non-radial modes change the shape of the star. The EA β Persei-type (Algol) star in this system is the δ -Scuti pulsator.

2. Methods

This study looks at V477 Cyg which is a combination of an EA β Persei-type (Algol) star and a Heartbeat star. The light curve and the periodogram is analyzed from TESS photometry data contained in the [Mikulski Archive for Space Telescopes \(MAST\)](#). Pulsations within the δ -Scuti component of the binary are examined in detail to extract the frequency relations among the pulsations. For the binary system, the common name of the star from SIMBAD Astronomical Database-CDS Strasbourg or other databases (V477 Cyg) is entered in the MAST portal along with the desired search radius (the default being 0.2 degrees). From this, the TESS Input Catalog (TIC) number will be displayed (TIC 89522181). One or more downloadable files are listed. The target file(s) are then downloaded and unzipped, yielding light curve information. The American Association of Variable Star Observers (AAVSO) [VStar](#) (Benn, D. 2012) photometry processing software was used to analyze the TESS photometry. In VStar, the “New Star from Kepler/TESS FITS File v2.4” option is selected from the dropdown File menu. This will produce the TESS light curve. To extract the pulsation data, the “DC DFT with Period Range” is selected from the “Analysis” dropdown menu. The desired period range parameters (low period, high period, resolution) is entered. This yields the periodogram of pulsations for the star.

3. Analysis and Results

The binary variability type is EA + HB (Algol + Heartbeat) and the spectral type is A1V+F5V, respectively. The orbital period is 2.34699 days. For the EA, the mass is 1.80 solar masses, the radius is 1.60 solar radii, and the temperature is 8730 K. For the HB, the mass is 1.35 solar masses, the radius is 1.42 solar radii, and the temperature is 6531 K. The EA star in this system is the δ -Scuti pulsator. From Figure 1, we see the pulsation characters of this pulsator.

Figure 1 shows the TESS light curve for V477 Cyg (upper left), the folded phase plot for V477 Cyg (upper right), the periodogram for the period interval 0.4 to 5.0 days (lower right) and the periodogram for the period interval 0.01 to 0.40 days (lower left). Starting with the binary system orbital period of 2.34699 days (1 in Figure 1), half the period is 1.173 days (2), one quarter is 0.587 days (4), one-eighth is 0.294 days (10),

and one-sixteenth is 0.147 days (15). These are subharmonics of the binary system orbital period. The signal at 0.782 days (3) is a fundamental pulsation of the EA (δ -Scuti) component. The signal at 0.391 days (6) is one-half of this period, and the signal at 0.196 days (12) is one-quarter of the fundamental pulsation period. These are subharmonics of the primary pulsation. The signal at 0.235 days (9) is a fundamental pulsation with a harmonic at 0.469 days (5). The signal at 0.335 days (7) is another fundamental pulsation with a one-half subharmonic at 0.168 days (14). The other signals at 0.138 (16), 0.181 (13), 0.213 (11), and 0.261 (8) days have no obvious relation to the orbital period or the pulsation frequencies. However, as previously mentioned, gravity modes have only non-radial components that are of lower frequency than the pressure mode components. These four frequencies may be gravity mode non-radial components. These are shown in Figure 1 in the lower left hand corner.

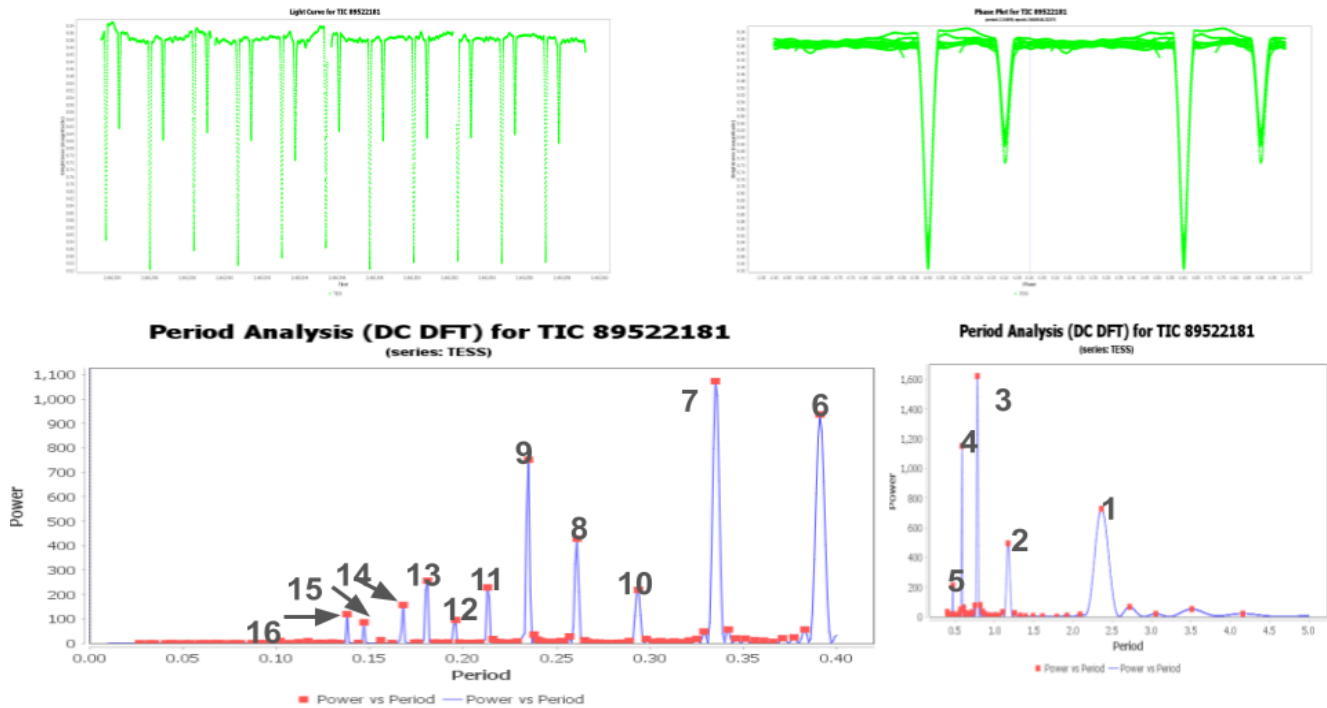


Figure 1: Light Curve, Phase Plot, and Period Analysis for V477 Cyg/TIC 89522181

4. Discussion

Stellar pulsation modes directly probe a star's internal structure, including interior physical conditions and transport processes. The self-excited resonant pulsation modes of a star represent small perturbations to the hydrostatic equilibrium structure. Each pulsation is a standing wave with unique geometry, frequency, and pulsation signal structure including harmonics, subharmonics and signal higher order products that reflect nonlinear processes within the star. The frequencies can be separated into radial and angular components. Radial components are characterized by a radial order n ,

describing the number of interior shells acting as resonant cavities. Each resonant cavity supports characteristic vibration modes. Angular components are characterized by an angular degree l , and an azimuthal order m , that describes the number of surface nodal lines.

There are two main pulsation excitation mechanisms. The first is a stochastic mechanism that operates within large convective envelopes. Turbulent convection continually drives and damps the resonant frequencies of the star. These produce radial order pressure modes within certain frequency ranges determined by the resonant cavity. The second main pulsation excitement mechanism is a heat-engine mechanism in which mechanical work is converted to heat. This heats the various zones and causes them to expand. After expanding, the radiation is able to flow through the zones which releases the heat so the layers cool down and contract again. This periodic expansion-contraction cycle allows heat from the star to be converted into mechanical work and excite pulsations. Additionally, if the star is rapidly spinning, gravity can be important as a restoring force, resulting in additional frequencies and pulsation modes. Different stellar structures provide the necessary conditions to excite different pulsation modes with pulsations in stars across the Hertzsprung-Russell diagram.

5. Conclusions

Asteroseismology is the study of the interior physics and structure of stars using their pulsations. It is applicable to stars across the Hertzsprung-Russell diagram and is a powerful technique to measure masses, radii, and ages, but also to directly study interior rotation, chemical mixing, and magnetism. In the case of eclipsing binary systems, important orbital information can also be determined. As such, asteroseismology would seem to be an underutilized tool for studying stars. In particular, the asteroseismology of eclipsing binary systems is a particularly fruitful area for continuing research.

References

Benn, D. 2012, "Algorithms + Observations = VStar", JAAVSO, v40, n2, pp.852-866 (<https://www.aavso.org/vstar>) AAVSO VStar data analysis software.

[MAST: Barbara A. Mikulski Archive for Space Telescopes](#)

Ricker et al. 2015, [Transiting Exoplanet Survey Satellite](#)

[SIMBAD](#)