Brown Dwarf Variability in the Optical: Results from K2 and TESS

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ABSTRACT

Here, we report the variability of two very low mass objects, spectral types M9V and L5V, whose previously reported periods we were able to independently confirm. These objects, as well as the other's in our survey, are low-mass, cool, and faint. Observing them in the optical requires pushing K2 to the edge of its potential. TESS provides a unique opportunity to expand our sample size of optical observations of low-mass, cool, faint objects, allowing more opportunities to observe variability.

INTRODUCTION

What is a Brown Dwarf?

- Sub-stellar object with about the same radius as Jupiter
- Forms like a star but cannot sustain Hydrogen fusion
    - Cools over time
- Star begins to shrink and as it does so, it spins faster

Brown Dwarf Evolution

- Spectral types are determined by presence of atoms and molecules in the atmospheres
- As dwarfs cool, more molecules are able to form
    - Spectral type changes

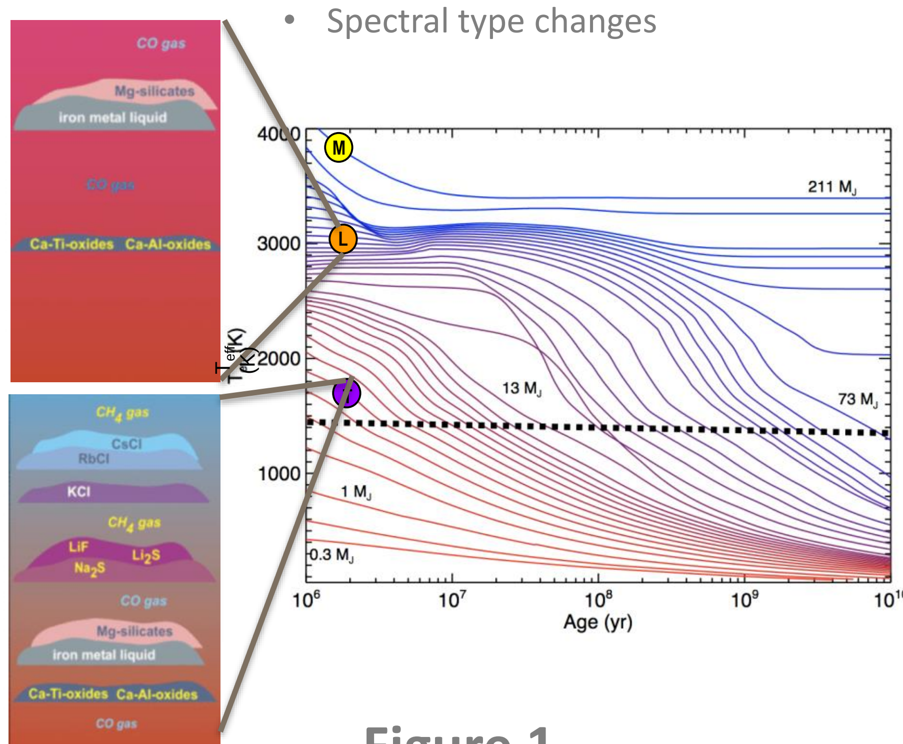


Figure 1

(Burrows et al. 1997, Lodders & Fegley 2004) The figures to the left show the increasing cloud layers at two different spectral types, L and T. As dwarfs evolve, and cool, more clouds are able to form, and thus their spectral type can change from L to T as shown on the figure on the right. Dwarfs whose lifetime path ends below the dotted line are considered brown dwarfs or planets, while above the dotted line, are considered low-mass stars.

VARIABILITY

Late M and Early L Dwarfs

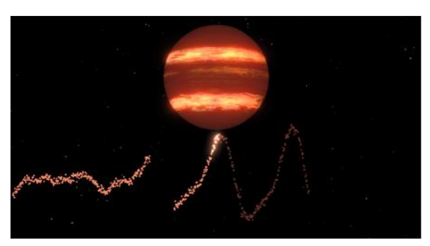
- Have stellar spots like the sun
- Stellar spots are cooler regions on the surface of the dwarf caused by strong magnetic fields
- Size and shape can vary with time

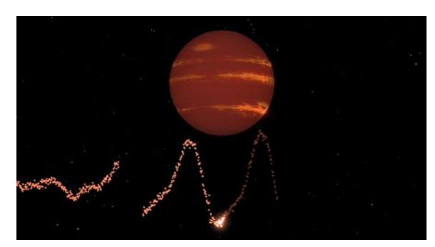
Brown Dwarf

- Variability on brown dwarfs is from cloud cover
- Similar to solar spots, size and shape of clouds can vary with time

Light Curve Evolution

- As clouds (dark bands) rotate in and out of view, the light curve shows the brightness of the source.





METHODS

Observations

- K2 Mission
    - 80 Day campaigns
    - Short and Long Cadence Observations
    - 4-5 campaigns per orbit
    - Most objects are in more than one campaign
        - Observe the same object 2-3 years apart

Data Analysis

- Completed with Lightkurve
    1. Extract photometry using the pipeline mask provided
    2. Remove outliers, normalize the light curve, fill in gaps and use self- flat-fielding (SFF) corrector to produce a Lomb-Scargle periodogram of the corrected data.
    3. Phase-fold the light curve at the highest power period in Lomb Scargle Periodogram
- For variable (the peak in the periodogram showed a significant signal to noise ratio, and a well fit sin curve in the binned folded data) objects, the evolution of their light curves were then analyzed.
    1. The corrected light curve is split into 10 ~8 day segments
    2. Create a Lomb Scargle Periodogram and phase folded light curve over the correct period

SAMPLE

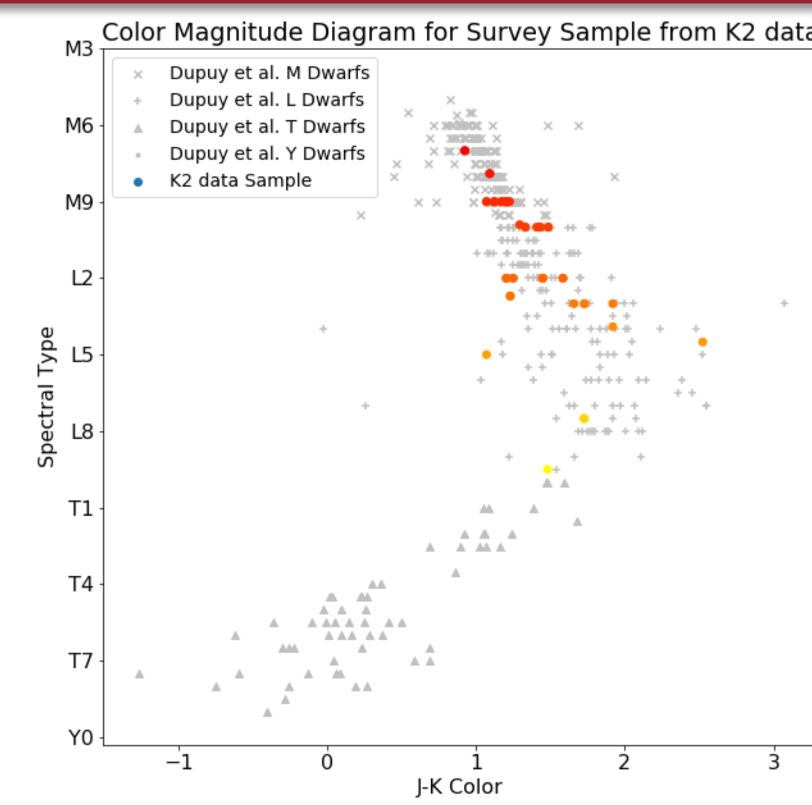
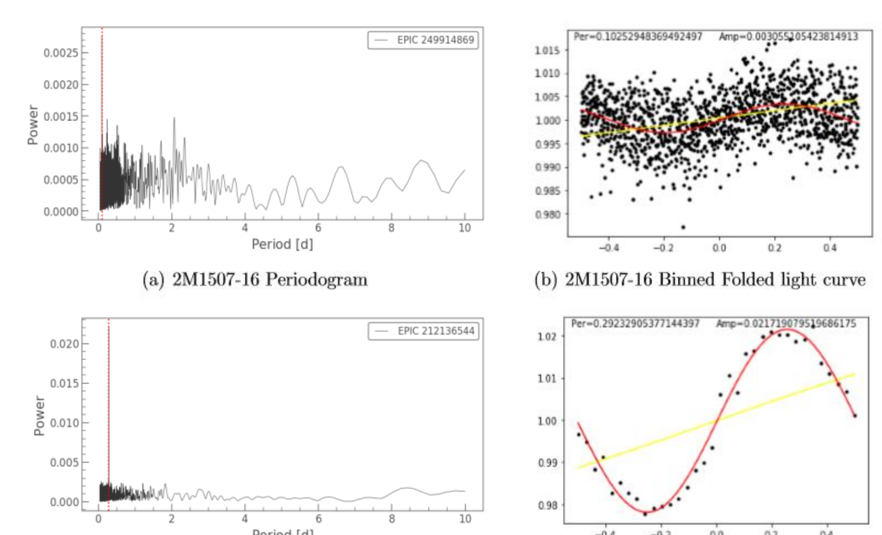


Figure 2

Shows the sample of our data. Data from 26 late M and L dwarfs were taken from the K2 missions campaigns 4,5,16, and 18. These observations were part of GO4030 (PI:Patience), GO5036 (PI: Gizis), and GO 15012 (PI: Muirhead).

RESULTS

Variable Light Curves



(a) 2M1507-16 Periodogram (b) 2M1507-16 Binned Folded light curve

(c) 2M0831+22 Periodogram (d) 2M0831+22 Binned Folded light curve

Figure 3

Shows the two variable objects periodogram and corrected light curves. The red lines in (a) and (c) signal the period at which the light curves were folded over. The yellow lines in (b) and (d) signal the initial guess of the curve fit, while the red shows the final curve fit. 2M1507-16 is an L5V object, so its variability may be caused by either spots or clouds. 2M0831+22 is an M9V, so its variability is likely caused by spots.

RESULTS CONTINUED

Evolving Light Curves

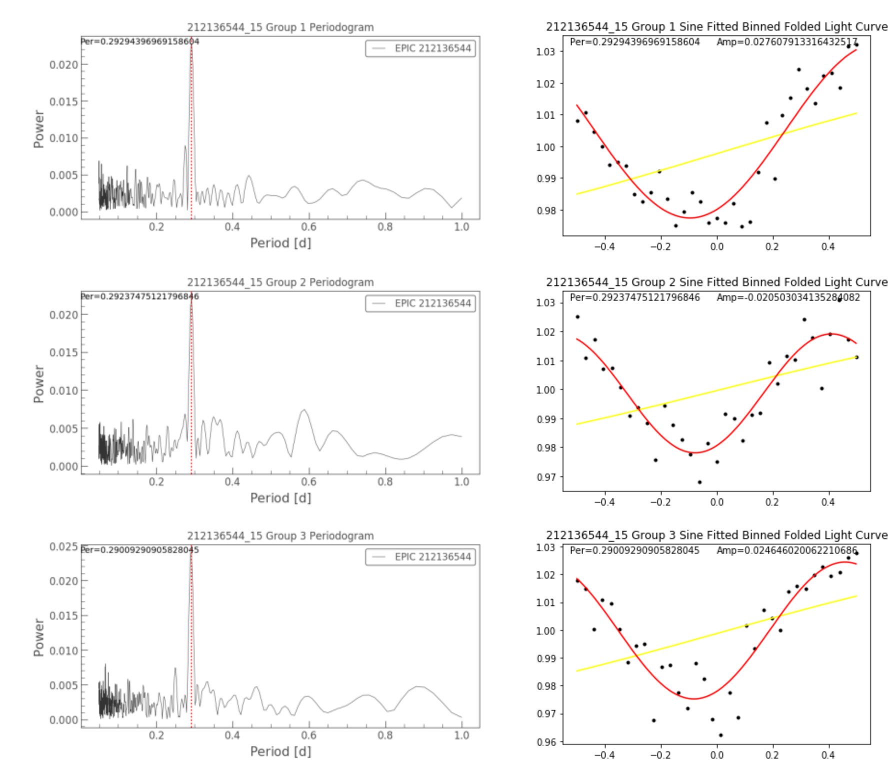


Figure 4

Shows the variable object 2M0831+22's periodogram and binned folded light curves for the first three, ~8 day segments. The dotted red lines in the periodogram show the actual period of the object. Between each segment, the amplitude of the light curve fluctuates between 2.7%, 2%, and 2.5% showing an evolution of the light curve.

CONCLUSIONS

- Light Curves of 26 different objects with spectral types M7-L9.5 from the K2 mission were measured
- 2 were determined to be variable
    - 2M1507-16 and 2M0831+22 with rotation rates of 2.46 and 7.015 hours respectively.
    - Amplitudes of 0.611% and 4.633% were determined for each object, respectively.
- The light curve of 2M0831+22 could be broken down into ~8 day segments so an analysis of the evolution of the light curve could occur.
- 2M0831+22 does have an evolving light curve

FUTURE DIRECTIONS

- Systematic errors need to be corrected
    - Rotation rates can be determined for more objects
- Using this method, investigate light curves obtained from the TESS mission.
    - TESS mission can test the lower boundary limits for brightness

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