2-300

Kepler Variable Star Interactive

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Abstract

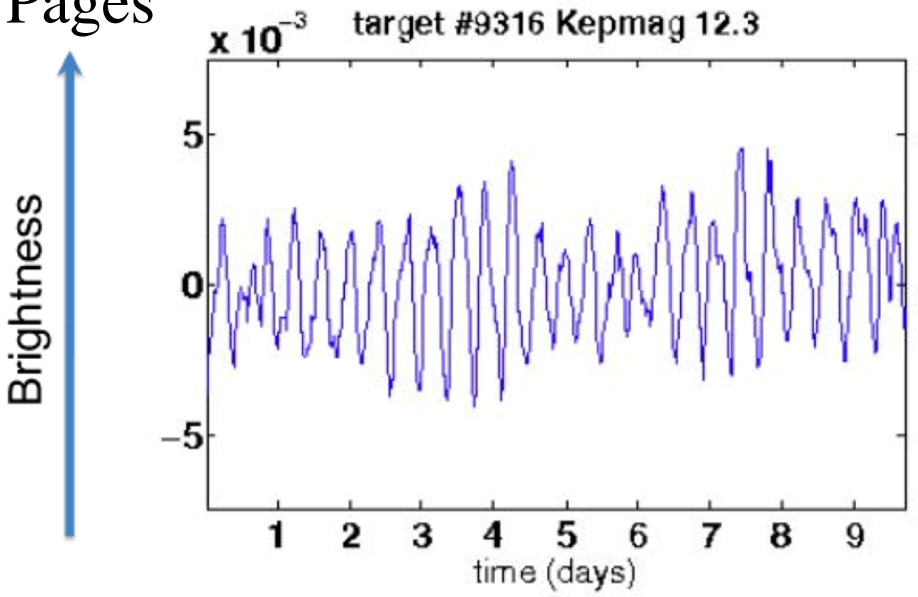
The Kepler Education and Public Outreach (EPO) has a modest plan for new activities in the Kepler Extended mission, but we have been fortunate to add an unexpected new element thanks to Kepler Guest Observer Jennifer Cash from South Carolina State University who is working on a related NASA funded JOVE project for development of an activity to teach the general public about the types of variable stars that might be seen by Kepler and walk them through the process of examining a light curve to determine the type of variability present. This presentation gives status of the project including results from in-person meeting 2013 July 9-12, progress in Javascript programming by team member Shilindria Rivers to create light curve plots with interactivity, creating a unified light curve data format compatible with both Kepler light curves and AAVSO reference light curves and that can be read by our javascript. Conversion of Kepler flux values into magnitudes to be consistent with AAVSO data will also make it easier to construct explanations to public audience of the web site. Professor Cash is identifying the Kepler targets that have light curves that show clear types of variability across a range of intrinsic variables from both pulsators and cataclysmic variables as a "challenge set" for website visitors to identify variable star types. The already-approved EPO projects in the Extended Mission include an online teacher workshop, a public exoplanet artwork project, and mini-planetarium shows.

1. South Carolina State University
2. The Lawrence Hall of Science, University of California, Berkeley
3. SETI Institute

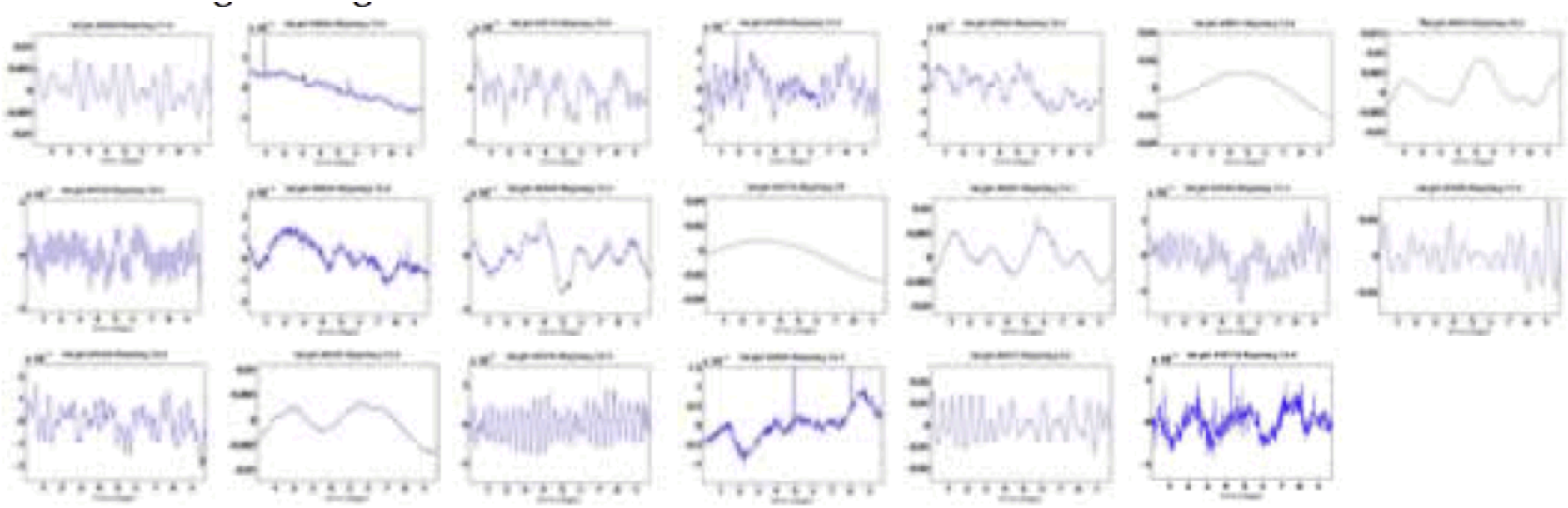
2. The Old Kepler Variable Star Pages

Early on in the NASA Kepler mission, the Education and Public Outreach (EPO) team realized that Kepler light curves could be a great opportunity to teach about star variability. Under the "Science" section of the website, there is a page titled "Stellar Variability" http://kepler.nasa.gov/science/about/targetFieldOfView/stellarVariability/ which mostly is concerned with the effects of stellar variability on planet detection by transits. In particular, the Kepler team sought stars that did not have much variability, to make it easier to detect transits.

At the very bottom of the Stellar Variability page, there has been a link to "Light Curves of Different Types of Stars." That page has 20 sample Kepler target light curves, each one clickable to see larger detailed version (right).



Currently on the Kepler website, low resolution thumbnails (below) are clickable to show higher resolution images, such the one above.

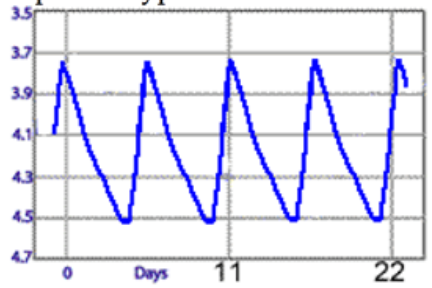


3. AAVSO Reference Curves (from existing/old site)

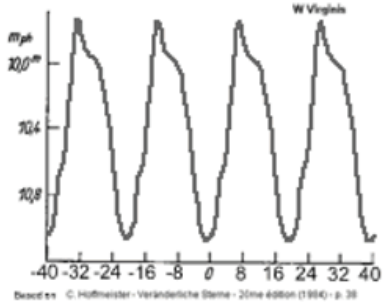
Below the selection of sample light curves is this challenge:
"Does this Kepler target star light curve match any of the light curves for different types of variable stars shown below?"

PULSATING STARS

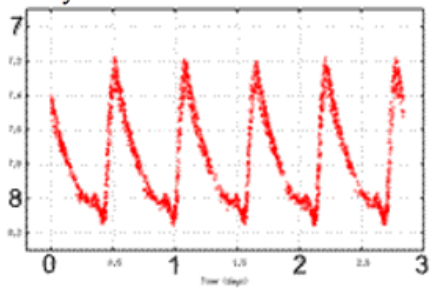
Cepheid - type 1



W Virginis - Cepheid type 2

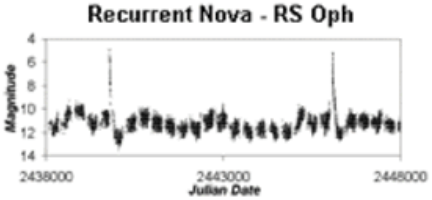


RR Lyrae

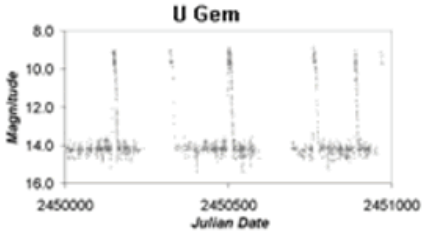


ERUPTIVE STARS
(Cataclysmic)

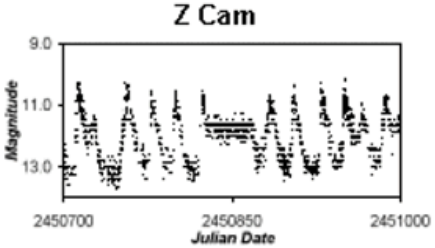
Recurrent Nova



Dwarf nova

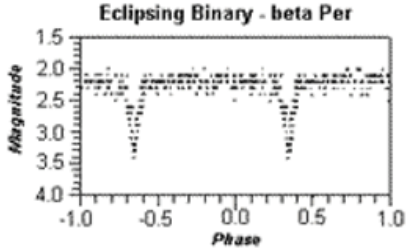


Dwarf nova

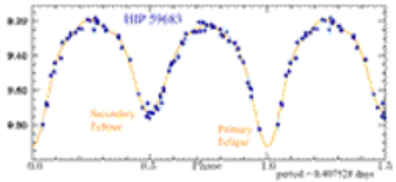


ECLIPSING BINARIES

Eclipsing binary star - Beta Persei



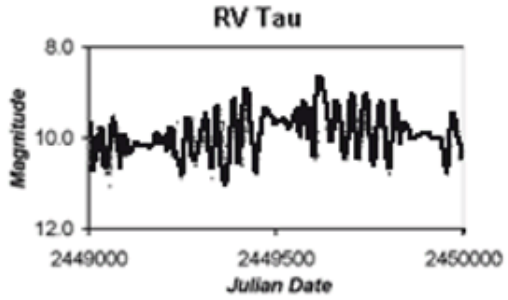
Eclipsing binary star - HIP 59683



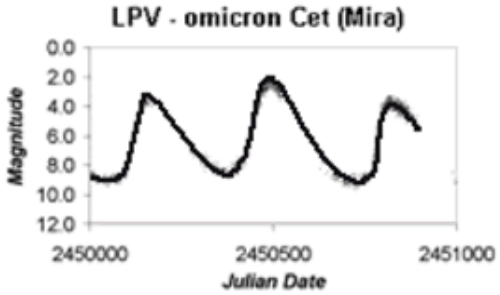
4. More AAVSO Reference Curves (from existing/old site)

PULSATING

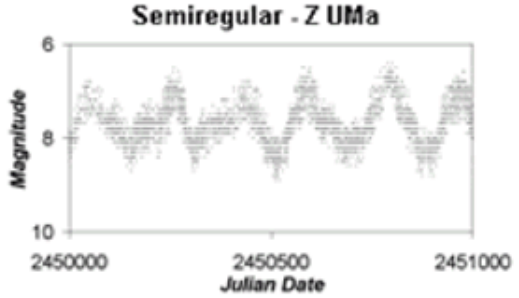
RV Tauri



Mira

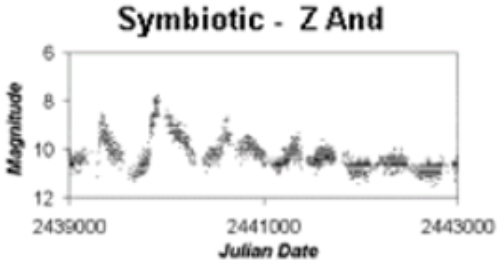


Semi-regular Long Period Variable

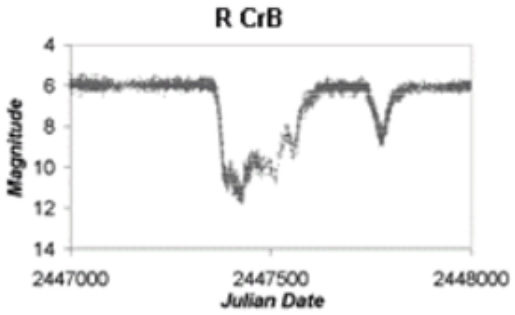


ERUPTIVE

Symbiotic - Z Andromedae



R Coronae Borealis



5. Variable Star Types—AAVSO Explanation of Categories

[http://kepler.nasa.gov/Science/about/targetFieldOfView/stellarVariability/variablestaroutline/]

Intrinsic variable stars (Internal physical changes—pulsations or eruptions)

Pulsating Stars - Size and/or shape of star changes or "vibrates"

- Cepheid Variables- Period 1 to 70 days, strict period-luminosity relationship
- RR Lyrae - Short pulsation period from .05 to 1.2 days with light variations between .3 and 2 magnitudes
- RV Tauri Stars - Alternating deep and shallow minima
- Long-period Variables (LPVs)
    - Mira type – Red giants with well defined 80-1000 day periods
    - Semiregular - Giants are periodic with intervals of irregular variation

Eruptive (Cataclysmic) Stars - Binary system consisting of one giant, and one white dwarf star that leads to "outbursts" of activity

- Supernovae - Sudden, dramatic, magnitude increase from stellar explosion
- Novae - Thermonuclear fusion explosion increases brightness and then fades
- Recurrent Novae - System that has undergone two or more nova-like eruptions in recorded history
- Dwarf Novae - Close binary system made up of a Sun-like star, white dwarf, and accretion disk surrounding the white dwarf
    - U Geminorum - Well-defined quiescence at minimum then erupt by 2 to 6 mag. for 5 to 20 days
    - Z Camelopardalis - Similar to U Gem except no well-defined quiescence and has "standstills" of brightness
    - SU Ursae Majoris - Similar to U Gem except have short orbital periods of less than two hours, and have two distinct outbursts that are both short (duration one to two days, faint and more frequent) and long (duration ten to twenty days, bright and less frequent)
- Symbiotic Stars - Semiperiodic nova-like outbursts of up to three magnitudes
- R Coronae Borealis - Go into outburst by fading and then return to maximum brightness

Extrinsic- Eclipse or stellar rotation

- Eclipsing Binaries - Binary star systems with an orbital plane lying near the line-of-sight of the observer. Members periodically eclipse each other, blocking one another's light, causing the system to appear fainter during an eclipse, on earth
- Rotating Variables - Rotating stars vary light output due to dark spots or bright spots on the star's surface

6. Details of Variable Star Types—from AAVSO

DETAILED DESCRIPTIONS…
http://kepler.nasa.gov/Science/about/targetFieldOfView/stellarVariability/variablestardescriptions/
Example:
Type I Classical Cepheids
These stars take their name from δ Cephei. Most have a period of between 5 -10 days and an amplitude range of 0.5 - 2.0 magnitudes in visible light. They are 1.5 - 2 magnitudes more luminous than Type II Cepheids.
The light curve for δ Cephei shows a distinctive rapid rise in brightness followed by a more gradual decrease. δ Cephei has a period of 5.366 days and a magnitude range of just under 1. This means that it is about twice as bright at its maximum than at its minimum.
Classical Cepheids follow a well-defined period-luminosity relationship. This means that the longer the period of the Cepheid, the more intrinsically luminous it is. This has important implications as it allows Cepheids to be used as standard candles for distance determination.x

7. JOVE Project Opportunity

In November of 2012, Jennifer Cash, a Kepler Guest Observer from South Carolina Space Consortium, South Carolina State University (SCSU, a minority institution), contacted Kepler EPO team about a funded JOVE Project with NASA research that could involve students. Since Professor Cash specializes in study of variable stars, we naturally explored the idea of making improvements to the Kepler website variable star pages. As the idea grew, we had a telecon meeting 2013 May 23 in which we planned the JOVE project to focus on creating an effective replacement for existing Kepler website variable star pages to explain the variety of stellar variability seen by Kepler. Several improvements were recognized as first priority tasks, Phase A:

- identify Kepler light curves that have clear types of variability
- get clear examples of standard light curves from AAVSO
- create a uniform plot format for both data types—time scale and brightness scale
- create a JavaScript plotter that allows people to adjust the scale for time and brightness

Then to make sure that the information is understandable to the general public we also planned to work on these tasks, Phase B:

- develop a "decision tree" to help guide people through the task of matching a Kepler light curve to the correct variable star category
- develop an introduction to explain the light curves axes
- develop introductory information for explaining variable star categories
- create layers to present the introductory information in such a way that website visitors can get more information if needed but can also skip right to the light curves

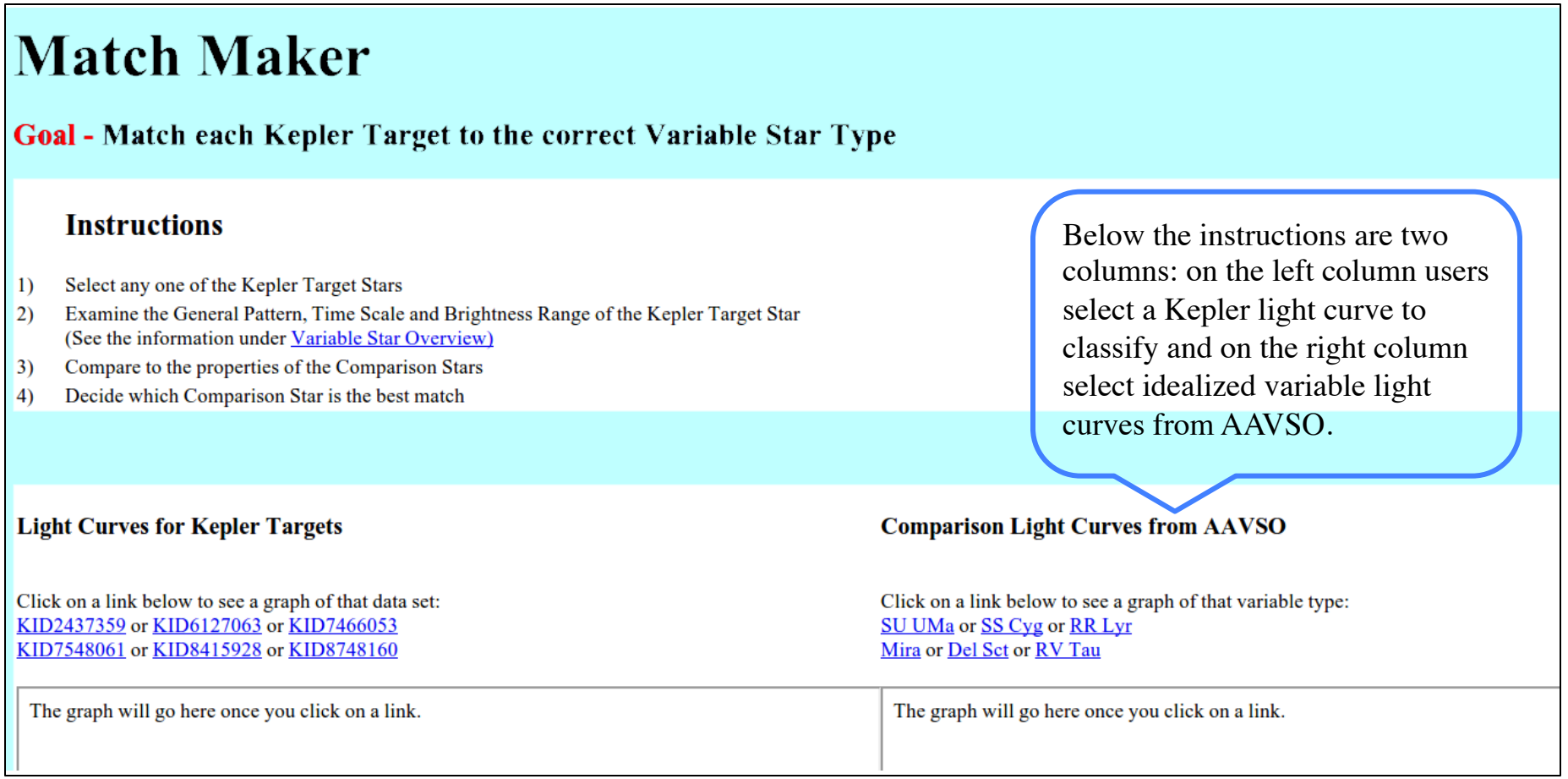
Three more desirable goals were identified, time permitting, Phase C, D, and/or E:

- identify a broader set of Kepler light curves that are more challenging to match to the variable star categories
- create a tutorial for getting Kepler light curves from the archives (starting with a more technical one before trying to do a tutorial for the general public)
- create lesson plans for teachers to use at different levels

In early July 2013, Professor Cash and her student Shilindria Rivers visited the Lawrence Hall of Science (UC Berkeley) and Ames Research Center to facilitate collaboration and develop broader networking.

8. Current status of the Kepler Variable Star Interactive JOVE project.

There were limitations in use of javascript on the Kepler website, that may or may not be solved, but in the meantime, the development team at SCSU created a prototype site there. The URL for that site is http://physics.scsu.edu/~jcash/research/jove/matchmaker.html
The site has instructions at the top as shown in this screenshot of the Kepler Variable Star Interactive:



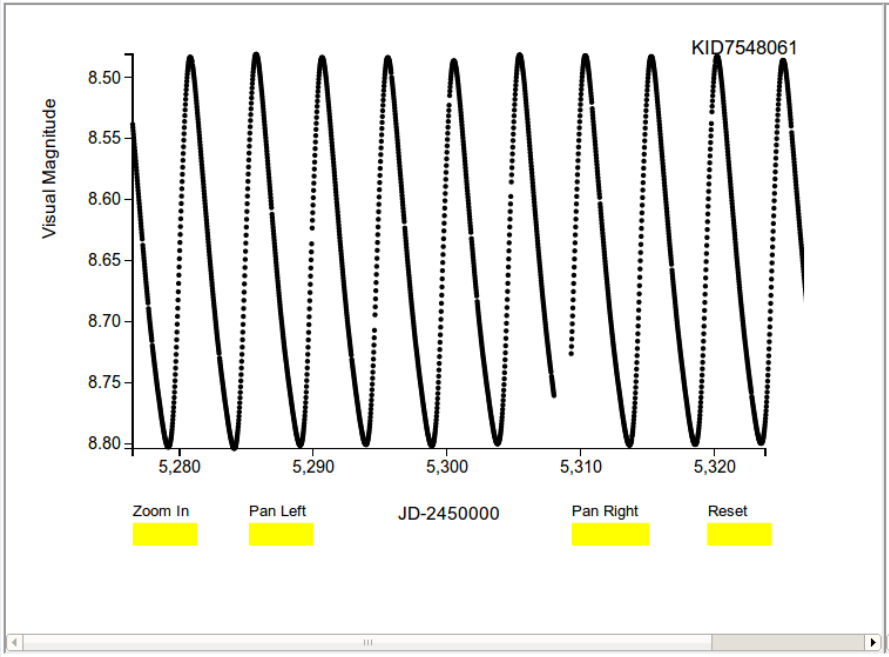
On the next 3 panels of this poster are examples, one where there is no match between the Kepler light curve and the AAVSO sample, and two which illustrate matches.

9. Kepler Variable Star Interactive—Screenshots

A: Non-matching light curves

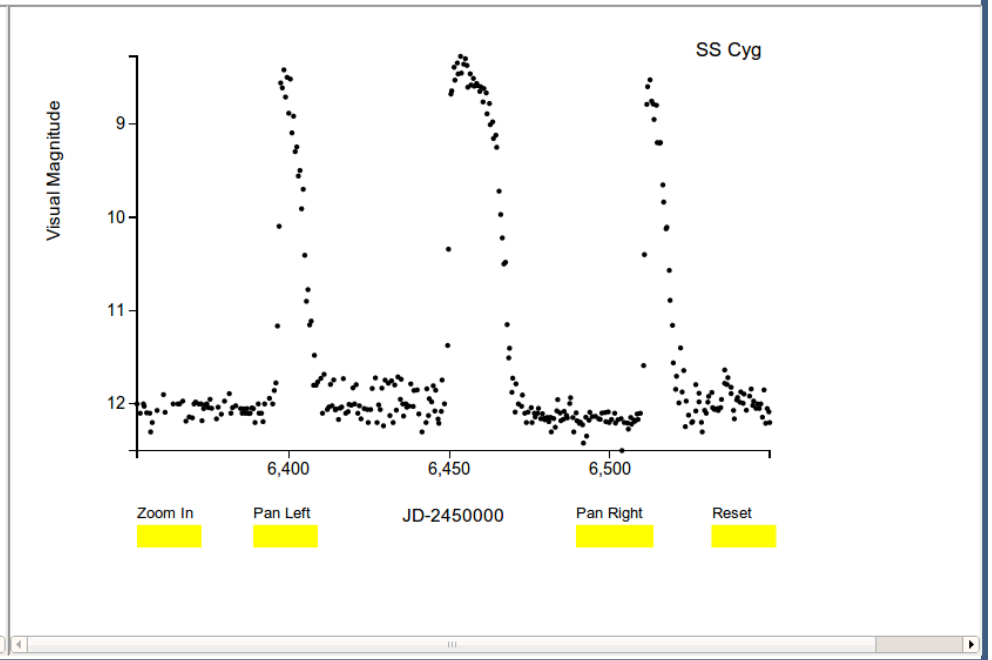
Light Curves for Kepler Targets

Click on a link below to see a graph of that data set:
KID2437359 or KID6127063 or KID7466053
KID7548061 or KID8415928 or KID8748160



Comparison Light Curves from AAVSO

Click on a link below to see a graph of that variable type:
SU UMa or SS Cyg or RR Lyr
Mira or Del Sct or RV Tau

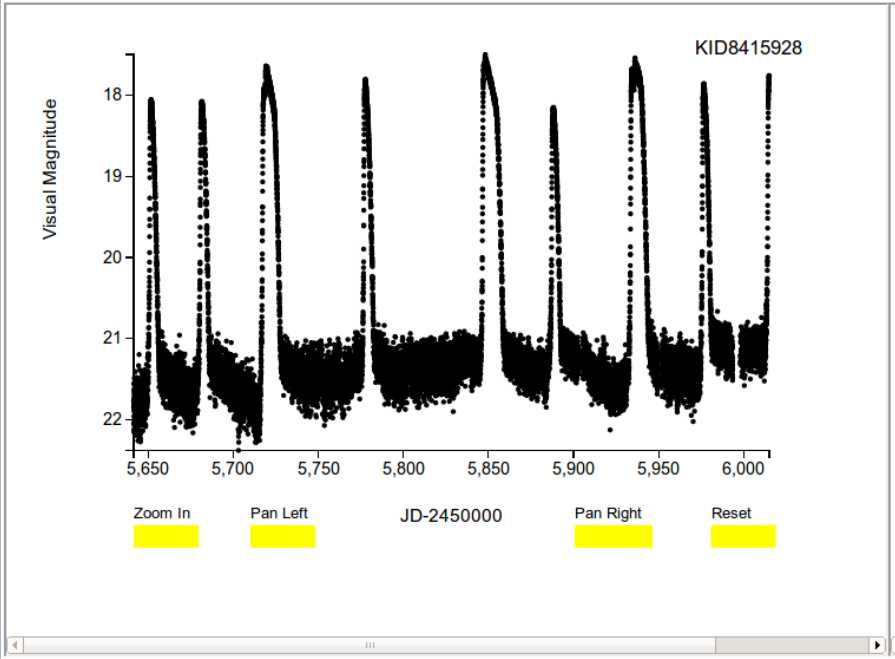


10. Kepler Variable Star Interactive—Screenshots

B: KID 8415928 … a match with SS Cyg type variable star!

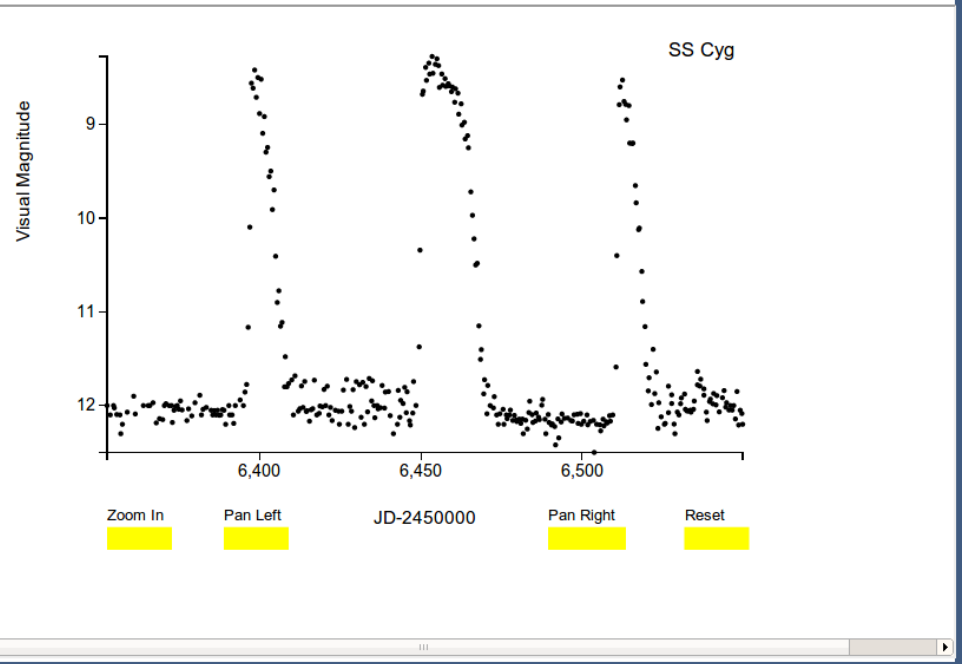
Light Curves for Kepler Targets

Click on a link below to see a graph of that data set:
KID2437359 or KID6127063 or KID7466053
KID7548061 or KID8415928 or KID8748160



Comparison Light Curves from AAVSO

Click on a link below to see a graph of that variable type:
SU UMa or SS Cyg or RR Lyr
Mira or Del Sct or RV Tau

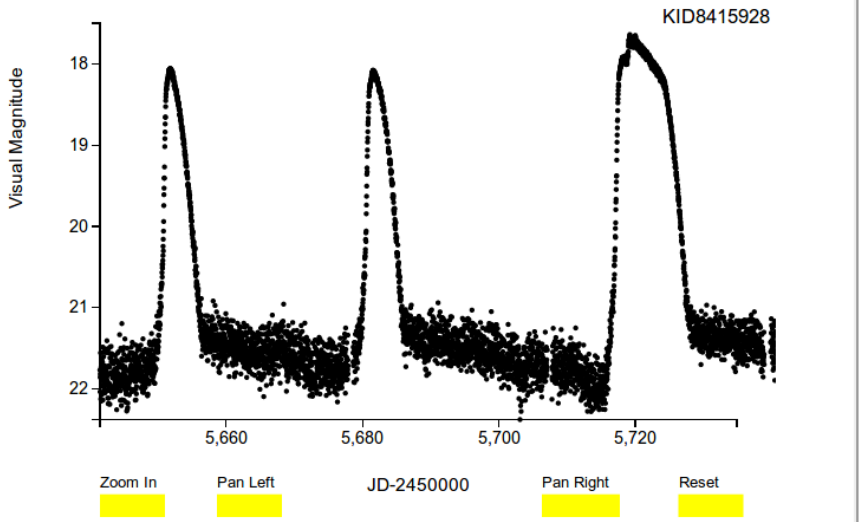


11. Time scale adjusted on KID 8415928 SS Cyg match

Early on in the project, we realized the importance or providing tools for the user to adjust the time scales.

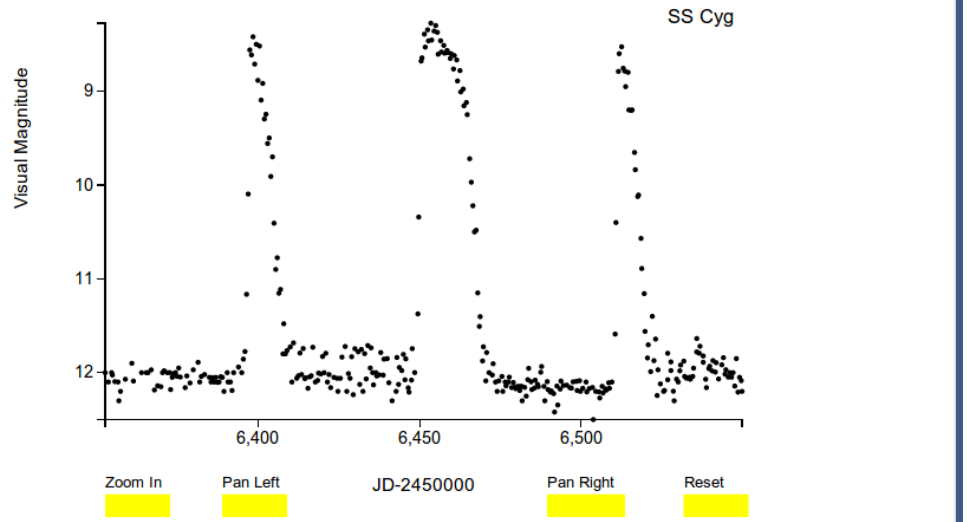
Light Curves for Kepler Targets

Click on a link below to see a graph of that data set:
KID2437359 or KID6127063 or KID7466053
KID7548061 or KID8415928 or KID8748160



Comparison Light Curves from AAVSO

Click on a link below to see a graph of that variable type:
SU UMa or SS Cyg or RR Lyr
Mira or Del Sct or RV Tau



12.

Acknowledgments

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We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.

Steve Howell, Kepler Project Scientist, has been advisor for this project from the outset.

Johnae Eleby, South Carolina State University student, has made recent contributions to the light curve preparations.

References

1. Kepler website – kepler.nasa.gov
2. AAVSO website - www.aavso.org/vstar/types.shtml

Other sources of light curves:

3. outreach.atnf.csiro.au/education/senior/astrophysics/variable_pulsating.html
4. outreach.atnf.csiro.au/education/senior/astrophysics/variable_types.html
5. RR Lyrae light curve - spiff.rit.edu/classes/phys230/lectures/mw_size/mw_size.html
6. cdsweb.u-strasbg.fr/afoev/vary/var

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