Measuring the Persistence of Stellar Variability using a Two Epoch Imaging Survey

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Using the Case Western Burrell Schmidt we have re-observed a field first surveyed for stellar variability five years ago. Our preliminary results are that all of the pulsating variable stars have been recovered in the new survey, but a significant fraction (at least 20%) of the unclassified variables were not. Analysis is ongoing.

Introduction

Although many bright variable stars are known to pulsate stably for as long as they have been observed, there are some notable exceptions: Macri et al. (2001) report the disappearance of variability from a Cepheid star first detected by Hubble (see Figure 1), and the photometric variability amplitude of Polaris has been declining for the last sixty years (Brown & Bochonko 1994; Evans et al. 2002). Vogt, Kroll & Splittgerber (2004) report 0.1 – 0.3 magnitude variations in stars over a 34 year periods. However, there is little data on the persistence of milli-mag variability seen in many stars.

In the process of testing the photometric stability of the Burrell Schmidt Telescope, we re-observed a stellar field first observed by Everett et al. (2001, 2002). These data provide an opportunity to study the persistence of stellar variability, and make progress on the question:

How likely is it for variable stars to stay variable?

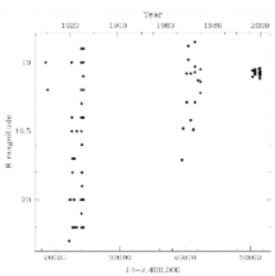


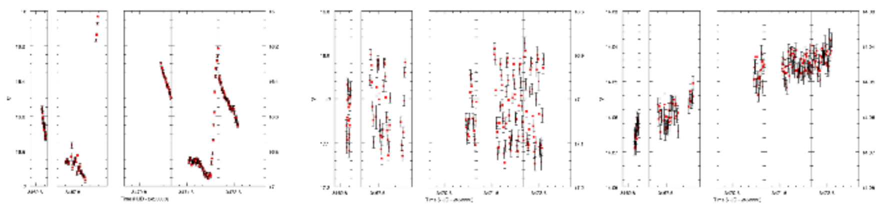
Fig 1. – An example of a dramatic change in stellar variability from the observations of Macri, Sasselov, & Stanek (2001). The star, Hubble's Variable 19 in M33, decreased from an pulsation amplitude of ~1.1 mag to less than 0.1 mag, over a span of ~80 years.

Observations and Methods

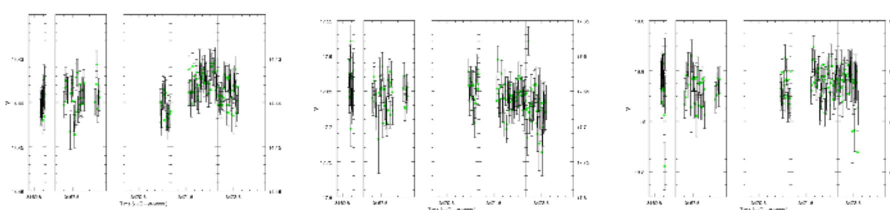
We used the 0.6m Burrell Schmidt telescope on April 1, 6, 9-11 2005 to re-observe a stellar field observed for variability by Everett et al. (2001, 2002). This field is located at α = 14 09 30, δ = +53 20 00, and is at high galactic latitude (b = 60 degrees). Over the five nights, we obtained 170 exposures of 240s each in the Washington M filter (we then convert our magnitudes to V). We are sensitive to objects with apparent V magnitudes between 14 and 20. Conditions varied from perfectly clear, to cloudy with 0.5 magnitudes of extinction.

As much as possible, we attempted to duplicate the procedures of the earlier survey, using the same software, and similar analysis techniques. The primary difference is the poorer spatial sampling of the Burrell Schmidt (1.45”), compared to the original survey (0.43”). We used aperture photometry, and local ensembles to perform high-precision relative photometry. Our errors range from 0.003 magnitudes at the bright end of the survey to 0.2 magnitudes for the faintest stars.

Recovered Variables



Absent Variables



New Variables

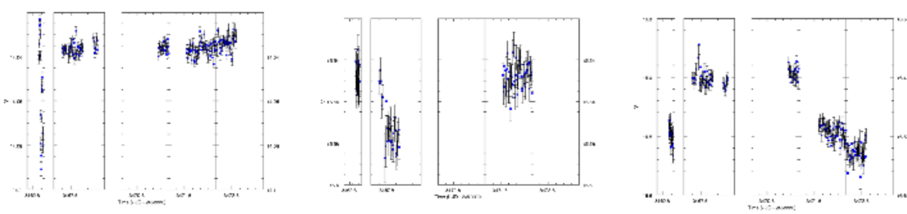


Fig 2. - A sample of light curves from this variability survey. The Red Light Curves indicate variables recovered from the original variability survey. The Green Light Curves indicate stars that were found to be variable in the original survey, but are non-variable ($\chi 2 < 3.0$) in this survey. The Blue Light Curves indicate new variable stars found in this survey. Note that all of the light curves have significantly different magnitude axes.

Results

A total of 3530 stars were measured in this variability survey. Of these, 20 were originally found to be variable by Everett et al (2001, 2002). From visual inspection, six of these objects appear non-stellar on the Schmidt images, and were removed, leaving 14 stars for further analysis. Using a $\chi 2$ test, and a conservative level for variability, we find that 7 are variable and 7 are not. Both of the previously identified pulsating variables (a RRab and a SX Phe/ δ Scuti) were recovered.

In Figure 3, we plot the magnitudes and colors of the stars recovered (as the red squares), compared to the stars not recovered (plotted as the green triangles) Using cuts at B = 16, 18, 20, we find that the fraction of stars that are no longer variable are 20%, 22% and 50% respectively. We are investigating possible intrinsic causes for the differing behavior of these stars as well as looking in detail into any yet unknown instrument/software issues that might be the cause

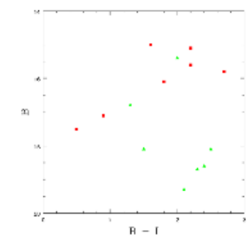


Fig 3. – The color-magnitude diagram of the 14 variables found by Everett et al (2001, 2002). Red squares denote the stars recovered by this survey, while green triangles denote the objects that are now consistent with being constant.

Conclusions

Our results imply that a significant fraction (20 – 50%) of non-pulsating, non-periodic variable stars can change their variability amplitude over a timescale of years. We plan follow-up spectroscopy of these stars to better determine their properties.

However, our primary goal for this study was to verify that the Burrell Schmidt could do high-precision relative photometry. Our results show that milli-mag photometry is possible on Schmidt telescopes, even with a relatively large pixel scale. One possible application is for transit surveys for large extra-solar planets (“hot Jupiters”). Figure 4 shows our variability limits over a 1.47 hour timescale. From these data, we could detect a hot Jupiter transit in stars as faint as V = 17.8 mag.

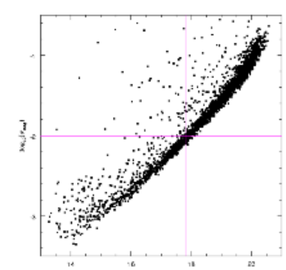


Fig 4. – A plot of the logarithm of the photometric standard deviation measured in 1.47 hour light curves versus mean magnitude. The region below and to the left of the purple lines indicate the stars where we could detect the transit of a “hot Jupiter” extra-solar planet.