Sherlock: An Automated Follow-Up Telescope for Wide-Field Transit Searches

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ABSTRACT: The current challenge facing photometric surveys for transiting gas-giant planets is that of confusion with eclipsing binary systems that mimic the photometric signature. A simple way to reject most forms of these false positives is high-precision, rapid-cadence monitoring of the suspected transit at higher angular resolution and in several filters. We are currently building a telescope that will perform higher-angular-resolution, multi-color follow-up observations of candidate systems identified by Sleuth (our wide-field transit survey instrument at Palomar), and its two twin instruments in Tenerife and northern Arizona.

BLENDS/NEED FOR SHERLOCK: Wide-field photometric surveys for transits of short-period gas-giant planets consist of several months of single band observations of typically 5000 targets in a six degree square field of view. A number of such surveys, including the network consisting of Sleuth (Palomar, PI: D. Charbonneau), STARE (Tenerife, PI: T. Brown) and PSST (Lowell, PI: E. Dunham) have been running for some time and have produced candidates. The current challenge facing surveys is not the difficulty of obtained the requisite precision and phase coverage, but rather the ability to rule out the large number of false positives that are typically encountered. Brown (2003, ApJL, 593, L125) discusses these false positives and classifies them into a number of specific types. There are three such types that are the primary sources of these false positives. The first of these are binary stars undergoing a grazing eclipse (MSU). The second and third types involve blends between a binary star undergoing a deep transit and a third star, either a foreground object (MSDF) or a third member of the system (MSDT). Using a typical transit campaign for the STARE instrument, Brown (2003, see figure 3) calculates that for every 10000 stars observed, 0.39 planets will be observed with three transits. However, 2.27 false positives of type MSU will also appear, 1.26 false positives of type MSDF will be present, and 0.98 candidates of type MSDT will be observed. Combining these figures, one finds that a transit survey will observe more than 10 false positives for every true planet that it finds. These false positives can be removed through radial velocity studies, as was done in the case of the OGLE-III transit candidates by Konacki et al (2003, astro-ph/0306542). However, for relatively bright stars, there is a simpler way to reject such candidates. Figures 1 and 2 show an example of a false positive (type MSDF), and how secondary examination by a relatively small telescope can identify it as such.

We are currently assembling Sherlock (figure 4), which will be a telescope dedicated to examining candidates from Sleuth, STARE, PSST, and other transit surveys that monitor stars brighter than V=13. Completely automated and observing in SDSS g', r', i', and z' filters with a better angular resolution than most survey telescopes obtain (1 arcsec/pixel, compared with 10 arcsec/pixel for Sleuth), Sherlock will be able to reject most of the contaminants. Measurement of the color dependence of the transit depth should remove both grazing incidence binaries (due to the effect of limb-darkening on the eclipse depth), and blends of eclipsing binaries (due the change in relative brightness of the blending and occulted stars as a function of color). When stars of different colors eclipse one another, this, too, causes variation of depth over colors, which does not happen in a planetary transit. Furthermore, the increased angular resolution will separate the light from blended stars, and subsequent photometry will reveal which object is undergoing eclipses. Sherlock will not replace radial velocity confirmation for planets, as some eclipses with very dim objects (such as M dwarfs) will not show variation with color. In addition, blends of eclipses between identical stars might not be recognizable by However, it will greatly reduce the ratio of false positives to a manageable rate.

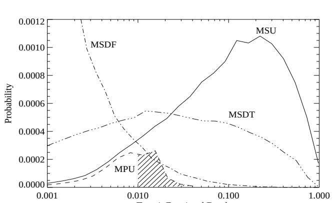


Figure 3: [Taken from Brown 2003] The estimated probability of detection of a transit per unit log transit depth. The shaded area is represents planets detectable in current surveys; note that this area is very small compared to most of the other sources of candidates.

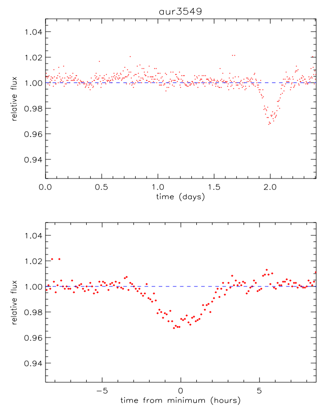


Figure 1: Phased R-band light curve of a star in Auriga as observed by E. Dunham & G. Mandushev (Lowell Observatory). Based on this light curve alone, this appears to be a reasonable candidate, as the period, duration, and depth are consistent with the passage of an inflated gas-giant across a Sun-like star. However, follow-up photometry shows this object to be a blend containing an eclipsing binary (see Figure 2)

Although Sherlock is intended primarily as a support and follow-up telescope for Sleuth, STARE and PSST, it is anticipated that there will be time available for other groups as well. For more information, contact D. Charbonneau or L. Kotredes.

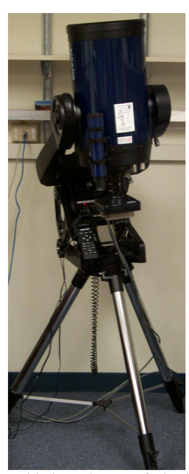
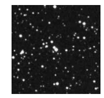


Figure 4: This is a picture of Sherlock as it is currently being assembled at Caltech.



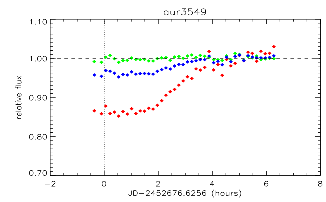
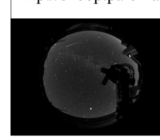


Figure 2: (Upper panel) The Digitized Sky Survey image shows this target to consist of a central bright source (center of image), and an adjacent fainter star to the NE. Both of these stars appeared as a single target to the PSST. (Lower panel) We carried out follow-up photometry of this field with the 14" Celestron (located on the roof of the Caltech astronomy building), during a night when an eclipse was predicted to occur. Observations began during mid-eclipse. The green points show the relative brightness

SHERLOCK SPECIFICATIONS:
Meade LX200GPS 10" f/6.3 Schmidt-Cassegrain Telescope
1024 x 1024 pixel back-illuminated CCD camera
Filter wheel containing SDSS g',r',i',z' filters
SBIG STV Autoguider
Automated Operation controlled by Linux workstation
Cloud cover monitored by Snoop, the Palomar All-Sky Camera (see boxed text below)

The system will be located in the same clamshell enclosure as Sleuth, our primary transit search instrument. Weather decisions are made by the on-site 200"-telescope night assistant, with additional protection provided by a weather station that can close the clamshell roof. Sherlock will also be completely automated, calculating future times of eclipse for all active candidates, and observing the highest priority object in eclipse each night. The lack of human interaction is an advantage over comparatively labor-intensive multi-epoch spectroscopic follow-up.

SNOOP: We have just installed Snoop, our new all-sky camera located in the same clam-shell enclosure as Sleuth. Using a modified SBIG CCD camera, it is intended for weather monitoring for all users of Palomar Observatory. Current and archived images and movies from Snoop can be viewed at http://snoop.palomar.caltech.edu



CONCLUSIONS: Using readily available components, we are in the process of setting up and testing a telescope for use at Palomar Observatory. When this telescope becomes operational in late 2003, it will be capable of examining transit candidates and other targets of interest. Blends and other events that mimic transits can be identified without requiring radial velocity studies. This telescope will be open for requests for photometric follow-up of transit candidates from outside groups, so anyone desiring further information should contact us.