Burrell Optical Kepler Survey (BOKS) I: Survey Description

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Introduction
Detection of large statistical samples of extrasolar planets is now a major goal of astronomy. A proven method of finding extrasolar planets is searching for planetary transits, where the extrasolar planet slightly dims the star's light as it moves across the line-of-sight. Transiting systems allow for measurements of the mass and radii of extrasolar planets, making these systems crucial in our understanding of these objects (see Charbonneau et al. 2006 for a recent review). There are over twenty research groups undertaking photometric surveys to search for transits, and at least ten verified extrasolar planet detections have been made using this method.

Here, we present a new stellar variability survey, entitled BOKS (Burrell Optical Kepler Survey). BOKS used the Case Western Burrell Schmidt telescope to survey a portion of the planned survey field for the NASA Kepler transit mission (see Figure 1). The goals of BOKS are: 1) to search for transiting Very Hot Jupiter (P = 1-3 days) and Hot Jupiter (P = 3-9 days) extrasolar planets within the survey field and 2) to compile high precision stellar variability data that the Kepler mission can later use for comparison purposes. As with all transit surveys, a secondary goal will be 3) to characterize the hundreds of other variable stars within the survey region.

For our particular survey, we attempted to maximize the number of bright stars to be searched, while minimizing the inevitable crowding coming from a Galactic plane survey. We chose a field centered on the open cluster NGC 6811. This allows us to search for extrasolar planets in both the field and cluster environment.

BOKS Summary:

- Telescope: 0.6m Burrell Schmidt, Area: 1.36 sq degrees
- Cadence: every 4 minutes
- Number of Nights: 38 (27 with data)
- Number of Images: 1936 Gunn r images and 20 V, Located within the Kepler field

Comparison of BOKS to other Transit Surveys

BOKS is a moderate-field (1.65 x 0.825 degrees), moderate aperture (61cm) transit survey, deeper than the wide-field, small aperture (~10 cm) transit surveys (TRES, BEST, HAT, KELT, Super-WASP), but much shallower than large aperture transit surveys (~400 cm; EXPLORE). It is similar in properties to such transit surveys as EXPLORE/OC (von Braun et al. 2005), PISCES (Moczepa et al. 2006), and STEPS (Burke et al. 2006). BOKS has a larger angular area than most of these surveys (1.36 sq. deg. versus ~0.3 sq. deg), but with slightly larger pixel scale (1.45” versus ~0.4”). Figure 2 compares BOKS with other transit surveys, and although the true survey efficiency of each project is a complex combination of observing properties and data reduction procedures, BOKS appears to be competitive with these surveys.

Observations, Data Reduction and Analysis

The observations for BOKS began on September 1, 2006, and continued for the next 38 days. Of these nights, 27 had useful data acquired, including a 22 day consecutive sub-section. There are approximately 60,000 stars within the BOKS field, with magnitudes between r = 14-20. The data was electronically transferred to the Michelson Science Center, and Youngstown State University for data reduction and analysis. Our data reduction pipeline, using differential aperture photometry over small sub-regions of the image is almost identical to that of Everett & Howell (2001) and Everett et al. (2002), with some small adjustments and additional tests included.

With the Burrell having a larger pixel scale than the average CCD, there might be concerns about the potential photometric precision of the survey. To ensure this would not be a problem, we undertook a small pilot photometric survey to test the entire system before BOKS began (Feldmeier et al. 2006; Feldmeier et al. 2007). From that pilot survey, our photometric noise floor appears to be 2-3 milli-magnitudes, before any systematic corrections normally applied to transit surveys (Tamuz, Mazeh, & Zucker 2005). Figure 3 shows an example light curve from the pilot survey, showing the photometric precision we can achieve with the Burrell.

Observability of Extrasolar Planets

The probability of observing an extrasolar planet in transit is related to the window function of the observations. We have calculated this in simplified form for the BOKS data, and it can be seen in Figure 4. For the requirement of two transits for a detection, we are approximately 89% complete for Very Hot Jupiter planets, 45% complete for Hot Jupiter planets from short periods (P = 3-6 days), and 31% complete for all Hot Jupiter planets (P = 3-9 days). These estimates do not include assumptions about the distribution of extrasolar planet sizes, nor do they correct for lunar phase. We plan on undertaking extensive Monte-Carlo simulations to better quantify our survey efficiency.

However, since this field will be re-observed with Kepler, there will be opportunities to follow-up any single transit of high enough statistical significance to place stronger limits on the planetary fractions. Given that BOKS has been completed two years before the launch of Kepler, we should be able to place a limit on longer-term transits as well.

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