Early Results from the KELT Transit Survey

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Abstract. The Kilodegree Extremely Little Telescope (KELT) project is a small-aperture transit survey of bright stars. The project has completed commissioning runs searching for transits in the Hyades and Praesepe, and is well into a multi-year survey of a large portion of the Northern Hemisphere. Here we describe the setup of the telescope and discuss the early data.

There is great scientific potential in the discovery of transiting planets with bright host stars. Follow-up observation of such systems can determine properties of the planets that are not measurable in non-transiting systems, or in transiting systems where the host stars are too faint. The Kilodegree Extremely Little Telescope (KELT) project is a wide field, small-aperture survey for such transits, based on a theoretical optimization of all-sky transit searches (Pepper, Gould, & DePoy 2003). It is similar to the other small-telescope transit surveys with wide fields (Alonso et al. 2004; McCullough et al. 2006; Bakos et al. 2004; Cameron et al. 2006), but it surveys a larger area of sky than the other surveys. KELT is designed to target stars with magnitudes 8 < V < 10; a range fainter than the stars observed in radial-velocity surveys but brighter than those targeted by most existing transit surveys. KELT consists of a single automated telescope located at the remote telescope hosting site Winer Observatory in Sonoita, AZ. The primary KELT mission is a survey of a strip of sky 26 degrees wide at $\delta = +32^\circ$, broken into 13 equally-spaced fields. The telescope began operations in October 2004, and spent two commissioning runs observing the open clusters Praesepe and the Hyades. We then began observing the 13 survey fields, which together cover about 25% of the Northern sky.

We have been gathering data for the past two years, with gaps due to the need to shut down during the summer monsoons, and also due to periodic equipment problems. The telescope is currently operating well, and returning data regularly. In this proceeding, we briefly describe the telescope instrumentation, the survey area and observing strategy, and we discuss the telescope performance and show sample lightcurves.
1. Instrumentation

KELT employs an Apogee AP16E thermoelectrically cooled CCD camera. This camera uses the Kodak KAF-16801E front-side illuminated CCD with 4096 × 4096 9µm pixels (36.88 × 36.88 mm detector area). We use two different lenses with KELT. For the wide-angle survey mode, we use a Mamiya 645 80 mm f/1.9 medium-format manual-focus lens with a 42 mm aperture. This lens provides a roughly 23′′ pix−1 image scale and a 26° × 26° field of view, with vignetting at the corners, so the effective clear field of view is circular. Figure 1 shows a sample image of a survey field. We selected the field with galaxy M31 to give perspective on the size of our fields. To provide a narrow-angle campaign mode used for the Hyades and Praesepe observations, we use a Mamiya 645 200 mm f/2.8 APO manual-focus telephoto lens with a 71 mm aperture. This provides a roughly 9.5′′ pix−1 image scale and effective 10′.8 × 10′.8 field of view.

To reject the mostly-blue background sky without greatly diminishing the sensitivity to stars (which are mostly redder than the night sky), we use a Kodak Wratten #8 red-pass filter with a 50% transmission point at ∼490 nm (the filter looks yellow to the eye). The filter is mounted in front of the KELT lens during operations.

The optical assembly (camera+lens+filter) is mounted on a Paramount ME Robotic Telescope Mount manufactured by Software Bisque. The Paramount is a research-grade German Equatorial Mount designed specifically for robotic operation with integrated telescope and camera control. The CCD camera and mount are controlled by a PC computer located at the observing site that runs Windows XP Pro and the Bisque Observatory Software Suite from Software Bisque.

2. Survey Area and Strategy

The main targets for KELT are a series of fields, all at δ = +32°, the latitude of Winer Observatory. The fields are spaced equally in Right Ascension, and we tile between two fields at any given time, observing each once before slewing to the next field, yielding a cadence on a single field of about six minutes, with an exposure time of 2.5 minutes and 40 seconds for readout and slewing. Over the course of a year, we take about the same number of images from each field. Since beginning operations, we have taken over 40,000 images of our 13 survey fields. We are still building the software pipeline for the data and gathering images from certain fields. By spring 2007, we expect to begin searching our data for transits.

Each survey field is about 500^2 degrees, and together they fill about 25% of the Northern sky. This amount of coverage and the magnitude range of our target stars set KELT apart from similar wide-angle surveys. This setup allows KELT to search for the most scientifically interesting transits over the largest part of the sky. Based on estimates from Pepper, Gould, & DePoy (2003), we expect to find ∼ 4 transiting planets in these fields.
3. Performance

The critical threshold for sensitivity to transits is generally taken to be an RMS of less than 1%, which corresponds to the transit by a Jupiter-sized planet of a solar-type star. In order to achieve this level of precision, we employ image subtraction using the ISIS package (Alard 2000). Difference imaging is often difficult to implement in general, and is especially prone to complications with very large fields of view. After overcoming various problems, we were able to successfully implement ISIS. Among transit surveys, KELT has the largest field of view for which image subtraction has been successfully employed.

Figure 2 shows the RMS for one of our survey fields from one night of observing. There are over 6000 stars in the field showing sub-1% variation, which would make it possible to detect transits in their lightcurves. A more robust measure of transit sensitivity would require computing RMS over the entire course of observations of the field, but would also require the application of a detrending algorithm, such as SYSREM (Tamuz, Mazeh, & Zucker 2005), that would remove nightly atmospheric and airmass variations. We are still testing detrending algorithms with our data, and thus do not yet have a complete analysis for our long-term RMS sensitivity. However, the quality of the single-night lightcurves demonstrate the potential of the data. A full description of the performance of the telescope will appear in an upcoming paper, which will also provide a detailed discussion of the telescope instrumentation and control and data handling procedures (Pepper et al. 2006).

4. Example Lightcurves

Along with the survey data taken to date, we have been analyzing the commissioning data on Praesepe, which consists of over 3,000 observations taken on 34 nights over the course of 74 days, using the 200 mm lens with the 10:8×10:8 fields of view. We have found a large number of variable stars, of which we show three examples in Figure 3. We have also begun searching the Praesepe data for transits. We are still sorting through the data, but we have found two-transit-like curves, shown in Figure 4. These signals are probably not planetary transits, based on their depths and periods, but they demonstrate our ability to detect transits with the KELT data. We will be publishing an upcoming paper describing the analysis of the Praesepe data for variable stars and transits (Pepper et al. 2007).

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Figure 1: Image of one 26° × 26° survey field from the KELT camera. The extended object at the upper right is M31.

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Figure 2.: RMS magnitude scatter of a time-series of magnitude measurements of one of the survey fields. This plot shows the RMS for 33 images of 73,000 stars over one night of observing, with no detrending applied.

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Figure 3.: Examples of newly discovered variable stars in Praesepe. Each light curve contains over 3000 points.

Figure 4.: Transit-like light curves from KELT observations of Praesepe. These objects are probably not planets, but demonstrate the ability of KELT to detect transits.