Further Sleuthing: Candidates from a New Field in Andromeda

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1. Summary

We present planet candidates identified with Sleuth, the automated 10 cm telescope (6 degree square FOV) located at Palomar Observatory in Southern California. We selected candidates from a field in Andromeda, monitored for approximately 40 clear nights between UT 2003 August 27 to October 24. By switching from weighted-aperture photometry to difference image analysis, we have improved our photometric precision and increased the number of stars that we can monitor for transiting Jupiters. Using 2MASS colors, proper motions and multi-epoch spectral monitoring, we segregated false positives from planet candidates. Sleuth, together with STARE (located in Tenerife) and PSST (Arizona), form the Transatlantic Exoplanet Survey (TrES) network of telescopes. We have combined the observations made with Sleuth and PSST to improve our transit phase coverage.

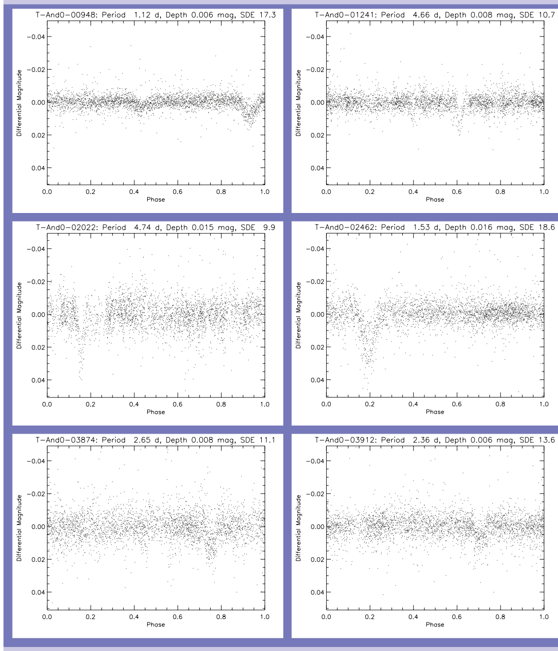

Figure 2 Phased light curves of six candidate transiting systems observed in a field in Andromeda as part of the Transatlantic Exoplanet Survey. The timeseries show data obtained with Sleuth (located at Palomar Observatory, California), from which we identified the systems, together with observations made with PSST (Lowell Observatory, Arizona). The period, depth and Signal Detection Efficiency (SDE) of each derived transit is given, together with our designation for the candidate.

4. The True Nature of Our Candidates

T-And0-00948: the combined data confirmed our initial suspicions that this light curve displays a secondary eclipse.

T-And0-01241: the blue color and hot T_{eff} of this star imply a large stellar radius, hence the companion cannot be planetary.

T-And0-02022: another blue and hot star, so a planetary companion is unlikely.

T-And0-02462: a blue and hot star. The eclipse is V-shaped (rather than flat-bottomed), indicative of a grazing incidence binary.

T-And0-03874: the red color of this star and the absence of radial velocity variations are consistent with the presence of a planetary companion. However, the surface gravity estimate and the negligible proper motion suggest a blended triple is still a possibility.

T-And0-03912: similar to T-And0-02022.

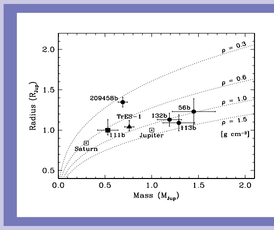

Figure 1 Radii of the six known transiting planets plotted versus their masses, with two solar system gas giants for comparison. Lines of constant density are designated by dashed lines.
(Sozzetti et al., astro-ph/0410483.)

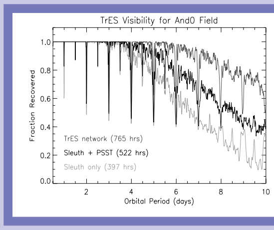

Figure 3 The three TrES network telescopes observed the field in Andromeda during the late fall of 2003. Shown are the calculated recovery rates for subsets of this dataset, under the assumption that we require at least three distinct half-transits to be observed. In this poster, we have considered only the combined Sleuth and PSST data (black line), which should allow a recovery rate of greater than 80% for periods less than 6 days.

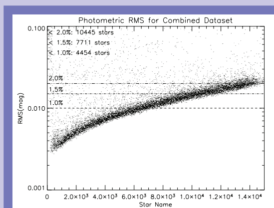

Figure 4 The improved photometric precision we obtain with our new difference image analysis pipeline has increased the fraction of observed stars around which we can detect hot Jupiters. Combining datasets from our two telescopes increased this number further. Above we show the calculated RMS magnitude for the stars in our combined dataset. The number of stars with RMS(mag) less than 1.0%, 1.5% and 2.0% are listed.

Table 1 As part of our false positive rejection procedure, we obtained spectra of our candidates with the CfA Digital Speedometers and measured spectral properties, listed to the right. Also given are the proper motions and the Tycho and 2MASS colors of the stars, where available.

2. Identifying Transit Candidates

The TrES collaboration recently announced the sixth known transiting planet, TrES-1 (Alonso, R., et al. 2004, ApJ, 613, L153), the closest planet discovered using the transit method. TrES-1 has a mass similar to HD209458b but a radius more that those of the OGLE planets (Fig.1). Clearly, more transiting planets must be identified before we can understand the mass-radius relationship for hot Jupiters.

As part of our transit survey, we observed a field of approximately 15,000 stars ($9.5 < V < 13.0$) in Andromeda. Initial analysis was based on Sleuth observations. We applied a difference image analysis (DIA, based on Alard, C. 2000, A&AS, 144, 363) to obtain the stellar light curves. Using the box-fitting algorithm of Kovacs, G., Zucker, S. and Mazeh, T. (2002, A&A, 391, 369), we examined these light curves for transits with periods ranging from 0.1 to 10 days. Based on the Signal Detection Efficiency (a measure of detection significance) assigned to the transits and our own visual examination, we identified six potential transit candidates (Fig.2).

The Andromeda field was also observed for 19 clear nights between 2003 November 14 and 2004 January 11 using PSST (Dunham, E.W., et al. 2004, PASP, 116, 1072), and we have combined the two timeseries. This led to an increase in the field coverage (Fig.3) and in the number of stars we can search for transits (Fig.4). We are examining the new light curves for transits which may not have been detectable in the original Sleuth data.

3. Weeding Out False Positives

We gathered futher data to identify imposters.The brightness of the candidates from our wide-field survey facilitates such follow-ups. We searched the Tycho, 2MASS and USNO-B catalogs to obtain the proper motions and visible and infrared colors of our candidate host stars (Tab.1). We estimated their spectral type, surface gravity and rotational velocity from observations made with the CfA Digital Speedometers (Latham, D.W. 1992 in IAU Colloq. 135, 110) (Tab.1). Since a high rotational velocity impedes precision radial velocity observations, we repeated the observations only for the two candidates with low vsini to estimate radial velocity variations (see for example Fig.5).

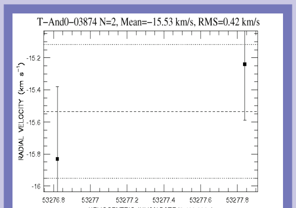

Figure 5 Two Doppler measurements for T-And0-03874 are plotted as a function of time. The observations are consistent with no variability on the scale of km/s (implying that any potential companion must have a sub-stellar mass), although further observations are scheduled to better constrain this measurement.

5. Future Observations

We intend to perform multi-color, high angular resolution photometry on T-And0-03874 using Sherlock (our 25 cm telescope) to discern the color-dependence of the transit and to help identify blends. Our eventual goal is to observe the remaining candidate using HIRES on KECK in order to measure precisely the radial velocity variations and to examine the spectra for evidence of asymmetric bisector spans, an indicator of blended systems.

Name	Type	T_{eff} (K)	$\log g$	$v \sin i$ (km/s)	μ^c (mas/yr)	$B-V^a$	$J-K^b$
T-And0-00948	G–K	5250	3.0	3	–	0.87	0.60
T-And0-01241	–	9600	4.5	55	6.43	−0.07	0.01
T-And0-02022	F	7000	3.5	27	–	–	0.24
T-And0-02462	F	6250	3.5	74	–	–	0.14
T-And0-03874	G	5500	3.6	2	–	–	0.66
T-And0-03912	F	7750	3.5	88	–	–	0.25

[a] Tycho-2 visible colors.

[b] 2MASS infrared colors.

[c] USNO-B1.0 Catalog (Monet, D.G., et al. 2003, AJ, 125, 984)