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Photometric transit search for planets around cool stars from the western Italian Alps: The APACHE survey

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Abstract

We present the APACHE Project, a collaboration between INAF-OATo and OAVdA (PI A. Sozzetti) started in 2009, aimed at discovering transiting small-size planets around nearby early and mid-M dwarf stars. We describe the most important steps undertaken for the purpose of the design and development of the APACHE survey.

1. Introduction

Small-size ground-based telescopes can effectively be used to look for transiting rocky planets around nearby low-mass M stars, as recently demonstrated for example by the MEarth project [3].
The application of the transit technique to M dwarfs presents several exciting opportunities, and the advantages are especially compelling for the detection of transiting habitable, rocky planets. These include improved observing windows due to the short periods of potential planets in the stellar habitable zone (the range of distances from a given star for which water could be found in liquid form on a planetary surface), or the possibility to reach detection of rocky planets due to the small radii of M dwarfs, leading to deep transits ($\Delta mag \sim 0.005$) easily detectable from the ground and readily confirmable with present-day precision RV measurements (RV amplitudes, on the order of $5 - 10\ m/s$).
Since 2009 at the Astronomical Observatory of the Autonomous Region of Aosta Valley (OAVdA), we have been preparing for the long-term photometric survey APACHE aimed at finding transiting small-size planets around thousands of nearby early and mid-M dwarfs.

2. APACHE survey design: major steps

2.1. Site characterization study

With the site characterization study we focused the attention on those site-dependent factors that can have the largest impact on the ultimately achievable precision of the photometric measurements, such as seeing, extinction and night-sky brightness. We then correlated them with the quality of the photometric measurements of selected target fields analyzed using standard techniques of differential aperture photometry using an ad hoc developed data processing and analysis pipeline (TEEPEE).
The results of the site testing campaign show conclusively that OAVdA is a suitable choice for hosting a long-term photometric survey for transiting planets around cool stars in the solar neighborhood [1].

2.2. The pilot study

The results of a year-long photometric monitoring campaign of a sample of 23 nearby ($d < 60$ pc), bright ($J < 12$) dM stars represents the 'pilot study' for a long-term photometric transit search for planets around a large sample of nearby M dwarfs [2].
In this study, we set out to a) demonstrate the sensitivity to $< 4\ R_{\oplus}$ transiting planets with periods of a few days around our program stars, through a two-fold approach that combines a characterization of the statistical noise properties of our photometry with the determination of transit detection probabilities via simulations, and b) where possible, improve our knowledge of some astrophysical properties (e.g., activity, rotation) of our targets by combining spectroscopic information and our differential photometric

measurements. We achieve a typical nightly RMS photometric precision of 5 mmag, with little or no dependence on the instrumentation used or on the details of the adopted methods for differential photometry. The presence of correlated (red) noise in our data degrades the precision by a factor 1.3 with respect to a pure white noise regime.
Around pilot study stars with phase coverage $> 50\%$ we would have had $> 80\%$ chances of detecting planets with $P < 1$ day inducing fractional transit depths $> 0.5\%$, corresponding to minimum detectable radii in the range $1.0 - 2.2\ R_{\oplus}$.

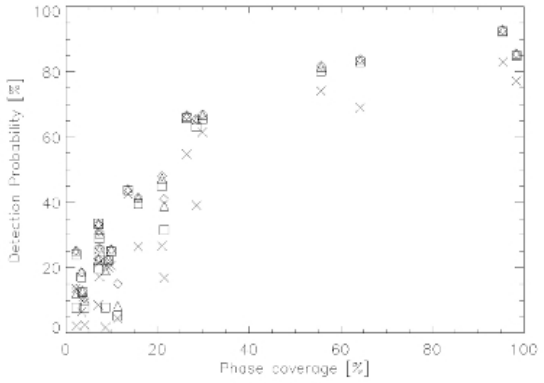

Figure 1: Detection Probabilitiy VS Phase Coverage.

These findings are illustrative of our high readiness level ahead of the main survey start [2].

3. Summary and Conclusions

The APACHE survey is set to officially start in Spring 2012 (it is possible to follow the status of the Project at the official Web site http://apacheproject.altervista.org/) with an array of four (the last one is under construction) identical 40-cm Ritchey-Chrtien telescopes.
The photometric database populated by our survey data will be of great help a) to improve the characterization of nearby M dwarf stars, when combined with Gaia's exquisitely accurate astrometry (e.g., [4]), and b) to optimize the target selection criteria for red dwarfs which might be included in next-generation space-based transit survey programs, such as TESS [5], or which might be selected for spectroscopic characterization of planetary atmospheres of transiting planets found orbiting cool, nearby stars with future space-borne infrared observatories such as EChO [6] and FINESSE [7].

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