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Photometric Software for Transits (PhoS-T) [1]

D. Mislis[1], *R. Heller*[2], *J. Fernandez*[3], *U. Seemann*[3], *P. Ioannidis*[4], *C. Avdelidou*[4]
[1]Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK
[2]Astrophysikalisches Institut Potsdam (AIP), An der Sternwarte 16, 14482 Potsdam, Germany
[3]Institut fur Astrophysik, Georg-August-Universitat Gottingen, 37077 Gottingen, Germany
[4]Aristotle University, Department of Physics, Section of Astrophysics, Astronomy and Mechanics, GR 54124, Thessaloniki, Greece

Abstract: We present the Photometric Software for Transits (PhoS-T), a user-friendly stand-alone astronomical software built to study in detail photometric data of transiting extra-solar planets. Through a simple and clean graphical environment, PhoS-T can perform data calibration, point-source differential photometry, and transit light curve modeling. Here we present a detailed description of the software, together with the analysis of a recent transit of the extra-solar planet HAT-P-19b, observed from Holomon Astronomical Station (University of Thessaloniki). The results obtained using PhoS-T are in good agreement with previous works, and provide a precise time-of-transit for HAT-P-19b.

1 Introduction

PhoS-T The main window of PhoS-T contains information about the program status, the data quality, and plots and it provides access to the subroutines. The sub-routines that PhoS-T contains are : (a) master frame creation, (b) data reduction, (c) offset analysis, (d) target comparison star selection (e) aperture and pixel-to-pixel photometry, (f) time and airmass analysis, (g) LC extraction, (h) transit modeling, and (i) Monte Carlo error analysis.

2 Align Function

Telescopes used for the parametrization of exoplanets typically have primary mirros with diameters larger than 1m. These are significantly larger and have a much smaller field of view (FOV) than the instruments used by most survey teams, which prefer large FOVs and very often lenses instead of mirrors. The photometric data obtained for the detailed (follow-up) characterization of the transit is thus assumed to be not crowded with stars. The software selects the two brightest stars of the FOV. The impact of bad pixels is diminished to insignificance because we are using the sum of a full line or column. As an output we have two graphs with various peaks. Each peak represents to a star of which PhoS-T selects the two highest for the alignment of the images. The combination of the two largest peaks in both dimensions yields the coordinates of the two brightest stars. If, for any reason, a combination of the two brightest stars does not suit well they might be located at the edge of the frame or the tracking might be bad the software selects the next most plausible pair of bright stars. With two stars as references we can then calculate the offset and the rotation angle of each frame with respect to the reference frame.

3 Photometry

The Aperture Photometry is different from the usual methods as used by Mighell 1999[3]. First, it calculates the frame coordinates of the target star and then applies the Offset Rotation sub-routines

[1] www.ast.cam.ac.uk/∼misldim

of the Align function to each frame. Then, it finds the new coordinates of the star and creates a sub-frame with the same measures as the photometric window. The software now finds the standard deviation of the sky using the pixel values of the sky background. All the pixels with values 1.5σ higher than the sky background are replaced with the new sky values. To derive the new sky values, we are using random numbers from a Gaussian distribution where equals the sky standard deviation. The new frame is called Sky Frame. The Sky Frame is subtracted from each raw frame. The result of this subtraction has a very dim background and an enhanced contrast to the flux values of the target. With this method it is not necessary to define an aperture because the flux of the star is the sum of all pixel values in the Final Frame. PhoS-T does not use apertures, thus it can easily handle defocused data, which is common for follow-up observations of transiting planets around bright stars.

4 MCMC Transit Model Fitting Results

The model Fit sub-routine uses the analytical transit model from Pal (2008)[5]. It is most efficient, if a rough parametrization of the transiting system, i.e of the host star and the transiting object, is already available. Provided that the period is given, PhoS-T can fit the radius of the star R_S, the radius of the planet R_P, the semi-major axis and the orbital inclination with respect to the line of sight. Another set of input parameters are the limb darkening coefficient. However, the user is free to select the parameters to be fitted and which parameters should be fixed. At the Figure above we present the fit for the transit of HAT-P-19b as an example.

The Errors sub-routine relies on the bootstrap method([1] & [4]). After 1000 Monte Carlo simulations, a Gaussian distribution is fitted to define errors in all output parameters: the time of the center of the transit, the transit duration, inclination, the ratio α/R_S and the ratio of R_P/R_S.

References

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