Extra-solar Planet Transit UROP Project Summer 2010

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Abstract

Nargiss Mouatta and I observed several extra-solar planet transits this summer using the 14-inch telescopes at the Wallace Astrophysical Observatory (WAO). After the data was collected, we analyzed the results using IRAF and a Mathematica pipeline written by Elisabeth Adams. The results produced seven light curves for four separate transiting planets. The planets associated with these transits are XO-1b, TrES-1, TrES-3, and WASP-2b. After the light curves were produced, they were added to a separate Mathematica notebook for fitting.

Introduction

The project for this summer involved extra-solar planet transit photometry, which is the measurement of a star's brightness as an orbiting planet passes in front of the star (as seen from Earth). The purpose of the project was to gather more precise data so that error bars on the radii of extra-solar planets could be adjusted. Extra-solar planets with relatively short periods (on the order of < 10 days) were observed because of their higher frequency, and the transit depths observed varied between 1% and 2.6%. Plots of the brightness of the extra-solar planet's parent star were produced as light curves and further analysis of the data was achieved via Mathematica notebooks.

Procedure

At the beginning of the summer, Nargiss and I added information on newly discovered extra-solar planets to a Mathematica notebook written by Elisabeth Adams in order to predict which transits would be visible over the summer. The prediction table was then used to determine when it was best to travel to WAO to observe transits. Nargiss and I decided to only observe a transit if the predicted cloud cover was 30% or lower in order to reduce noise in the data.

On a clear night during a transit, Nargiss and I would go to WAO and take data with the 14-inch telescopes. The coordinates of the star would be entered into the Sky program and then the star would be located using star finder charts. Nargiss and I would take data from the star for at least an hour before and after the predicted time of transit in order to create enough base line to produce a light curve. We also took flats either during sunrise or sunset (depending on the transit), darks at the same exposure time as the flats, and darks at the same exposure time as the science images.

After data was taken and saved onto the server titania, we would then reduce the data using IRAF. The data was reduced by dark subtracting the flats and the science images and by dividing the science images by the flats. After the data was reduced, we followed the instructions in the photometry Mathematica pipeline written by Elisabeth Adams in order to produce a light curve. Once the light curve was produced, we would then add that data to a second Mathematica notebook and we would run a script that produced a least squares fit of the data.

Below are the figures produced from the Mathematica notebooks, along with a table containing useful values.

Table of Combined Information

Planet Name Date	Aperture Size (px)	Sky Size	Meridian Flip?	Flats used from same night?	Telescope	Frames Used	Exposure Time (s)
WASP-2b 6/19	10	80	No	No	Pier 3	144	90
XO-1b 6/21	9	30	Yes (Frame 30)	Yes	Pier 3	108	60
XO-1b 6/29	7	10	No	Yes	Pier 4	211	60
TrES-3 7/18	5	30	Yes	Yes	Pier 4	200	90
TrES-3 7/22	7	30	Yes (Frame 50)	Yes	Pier 4	96	90
TrES-1 7/27	7	30	Yes (Frame 25)	Yes	Pier 4	125	90
WASP-2b 7/30	6	30	Yes	No	Pier 4	144	90

WASP-2b

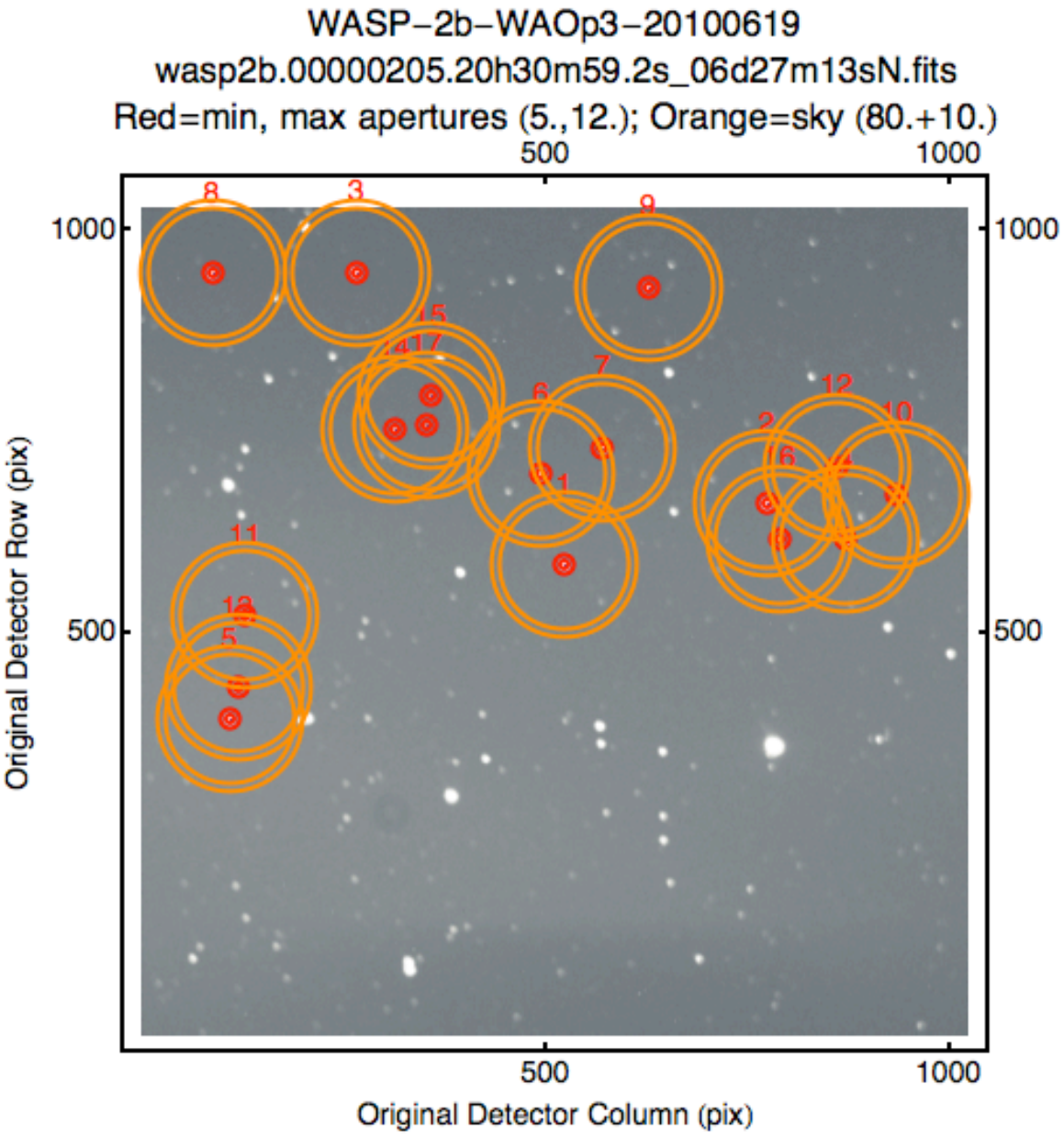

Fig. 1: Comparison stars for WASP-2b 6/19.

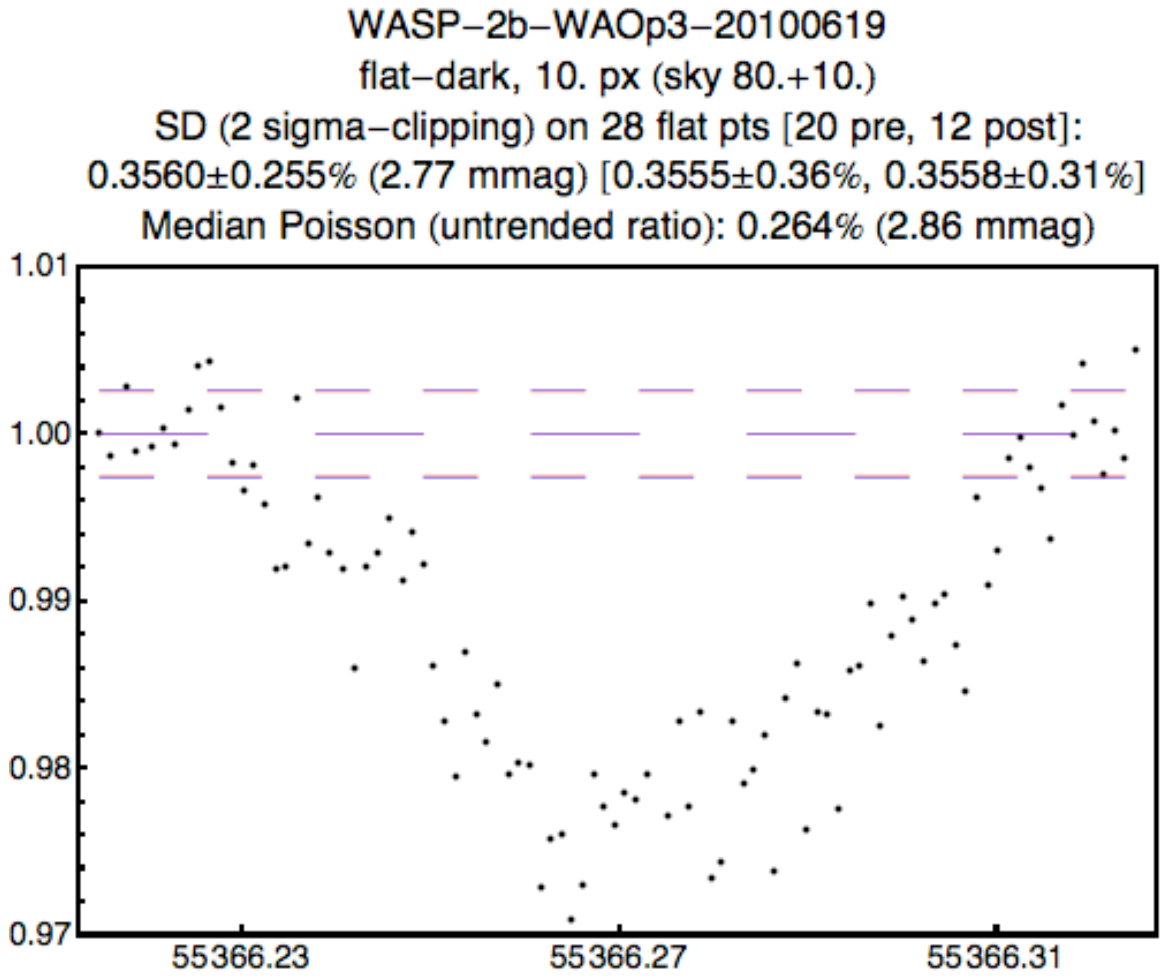

Fig. 2: Norm-Detrended light curve of WASP-2b on 6/19. . Comparison stars used to create light curve: 2,4,6.

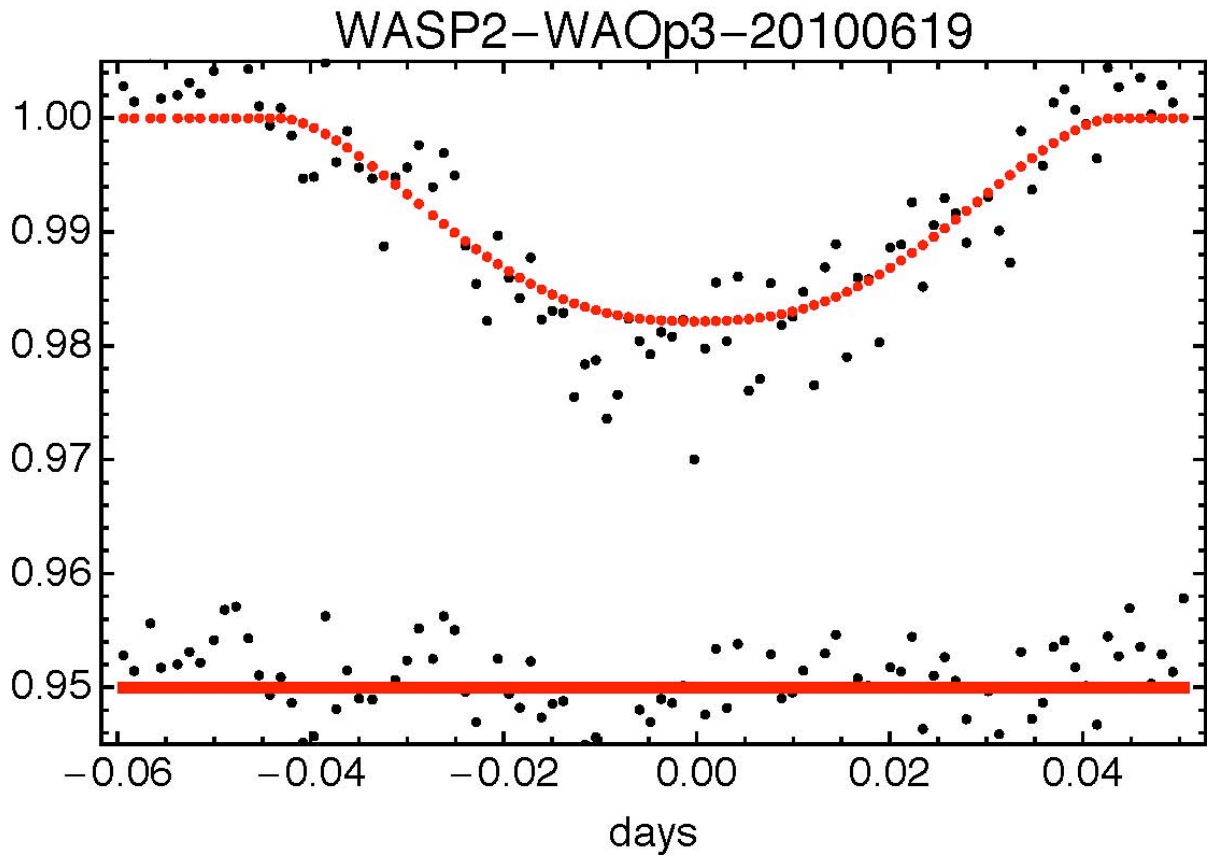

Fig. 3: The normalized ratio of the light from WASP-2b to several comparison stars is plotted (top points), with a model light curve (solid line). Residuals plotted below.

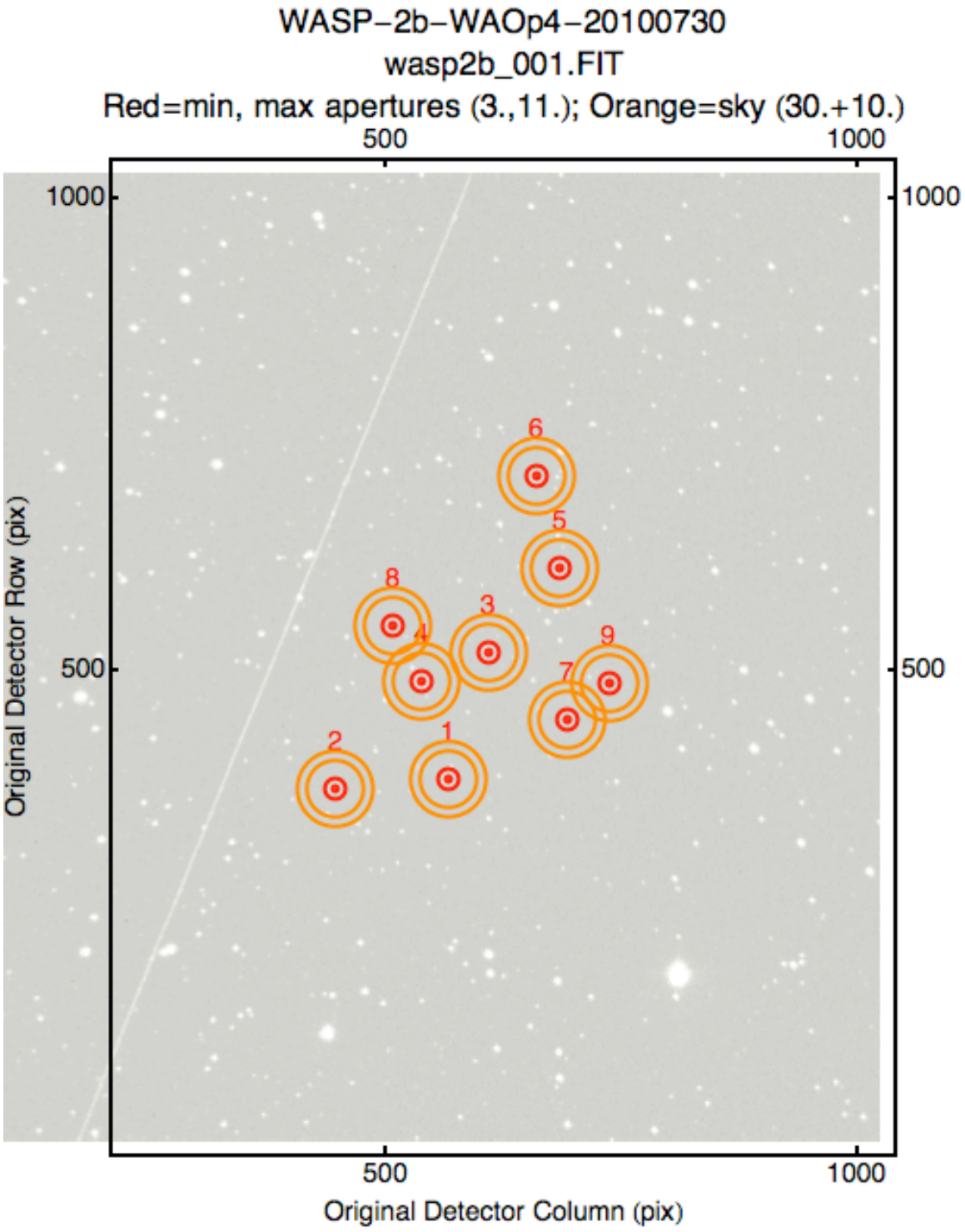

Fig. 4: Comparison stars for WASP-2b on 7/30.

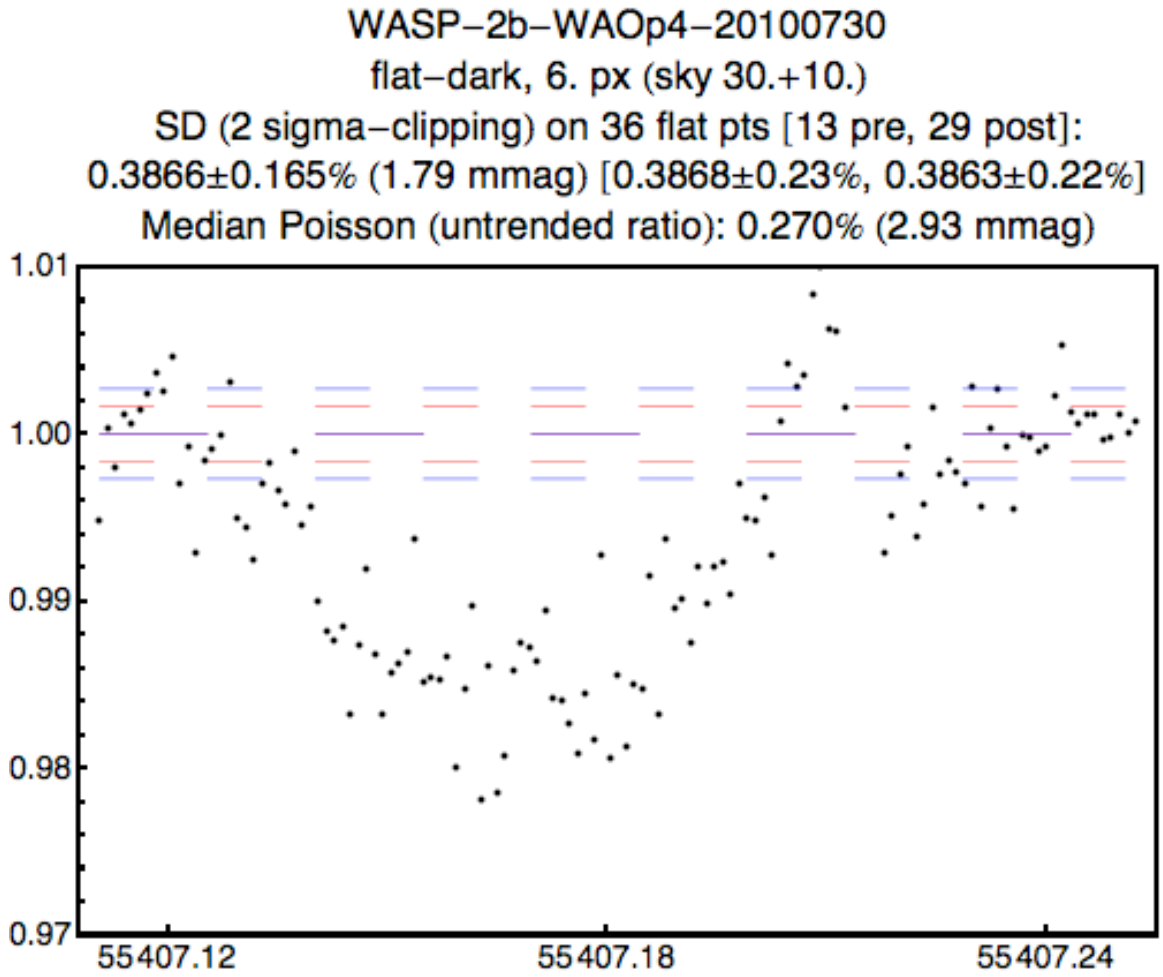

Fig. 5: Fig. 2: Norm-Detrended light curve of WASP-2b on 7/30. Comparison stars used to create light curve: 7,8,9.

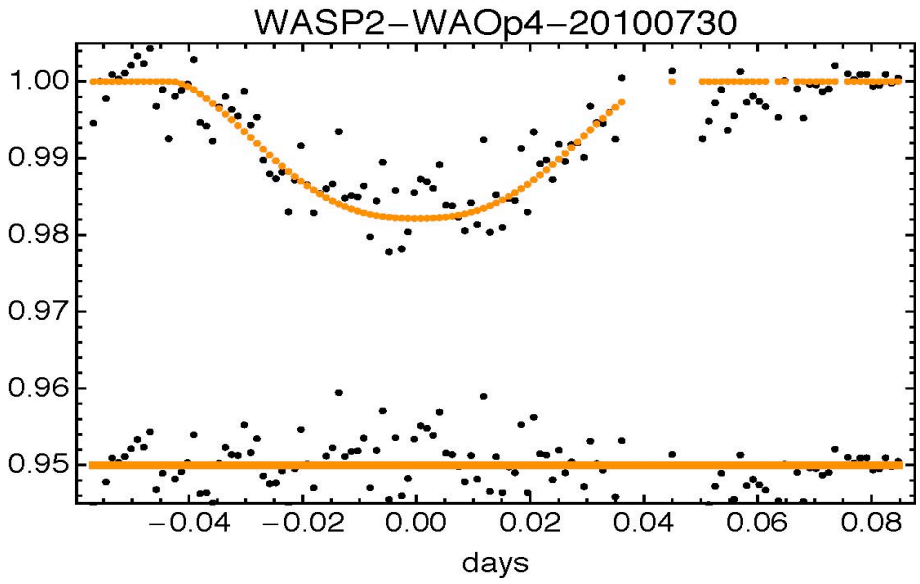

Fig. 6: Wallace 14-inch Telescope Transit: WASP-2b. The normalized ratio of the light from WASP-2b to several comparison stars is plotted (top points), with a model light curve (solid line). Residuals plotted below.

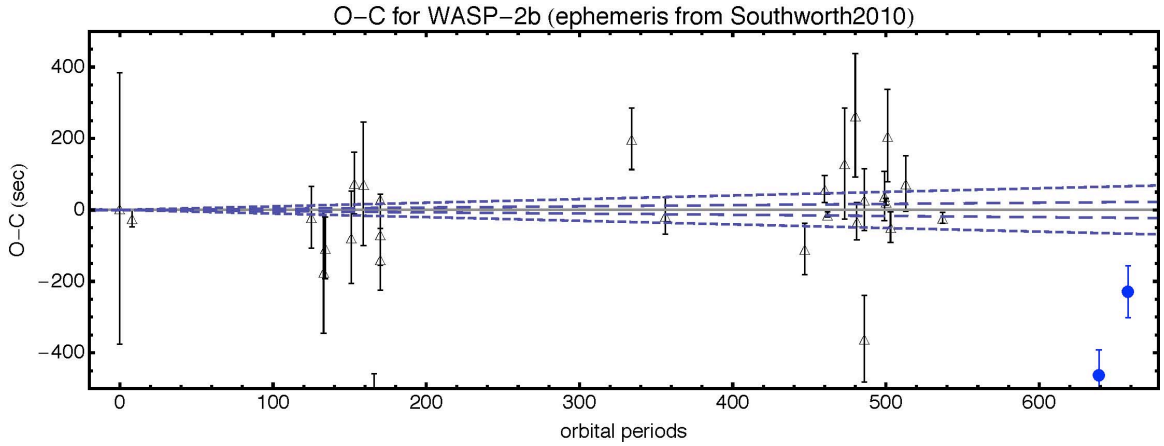

Fig. 7: WASP-2b O minus C Graph. The diagonal lines shown represent 1 sigma and 2 sigma deviations from the transit time. Points from the data from the summer project are shown in blue. This plot shows the midtime of the transit.

TrES-3

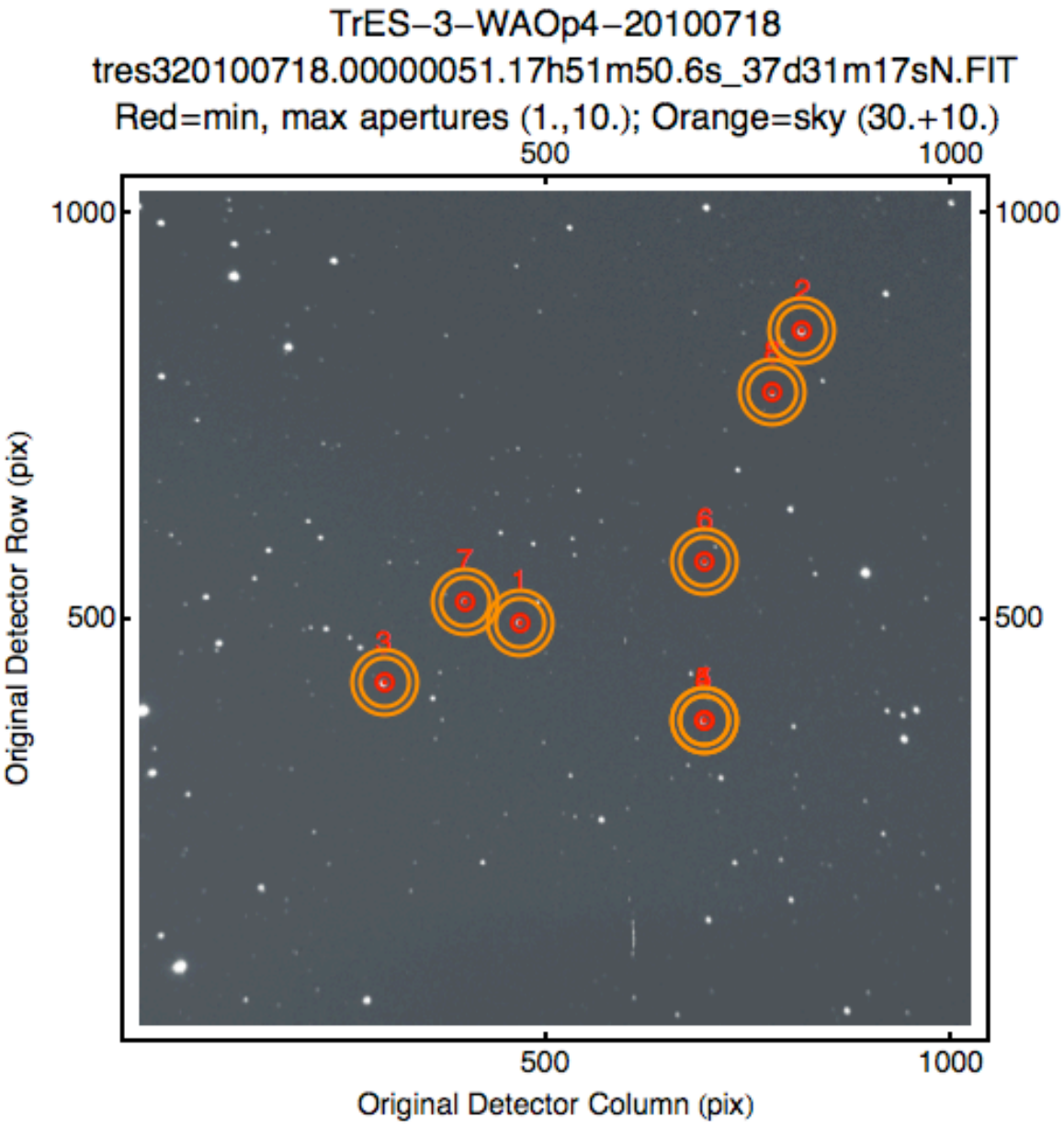

Fig. 8: Comparison stars for TrES-3 on 7/18.

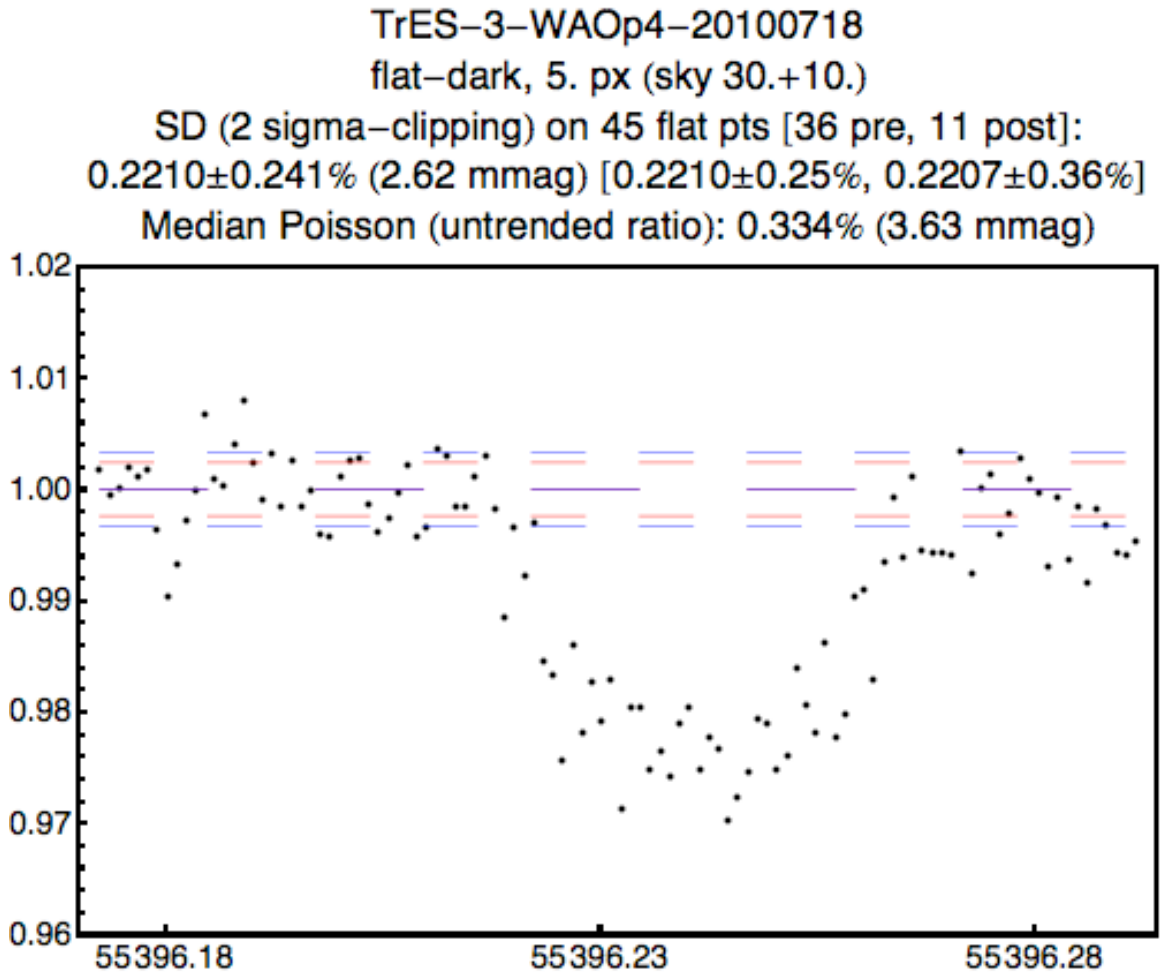

Fig. 9: Norm-detrended light curve of TrES-3 using comparison stars 3,4,5,7.

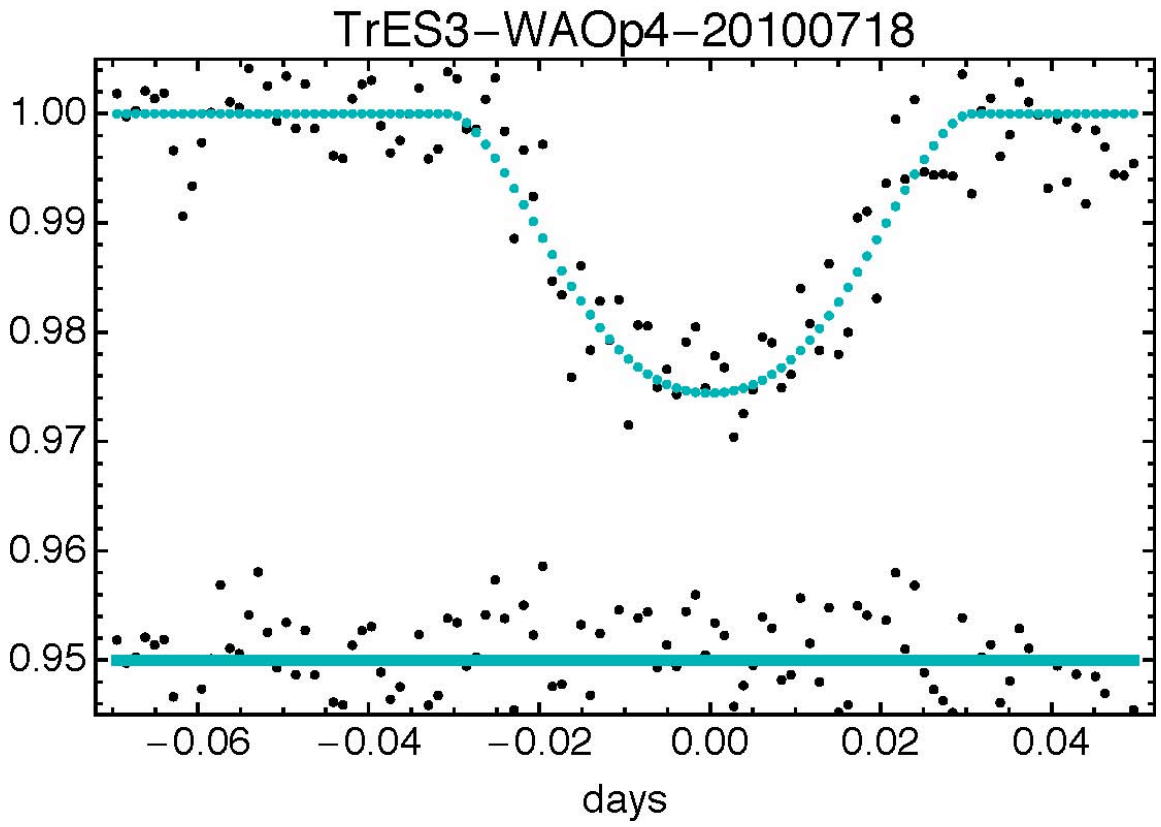

Fig. 10: Wallace 14-inch Telescope Transit: TrES-3. The normalized ratio of the light from TrES-3 to several comparison stars is plotted (top points), with a model light curve (solid line). Residuals plotted below.

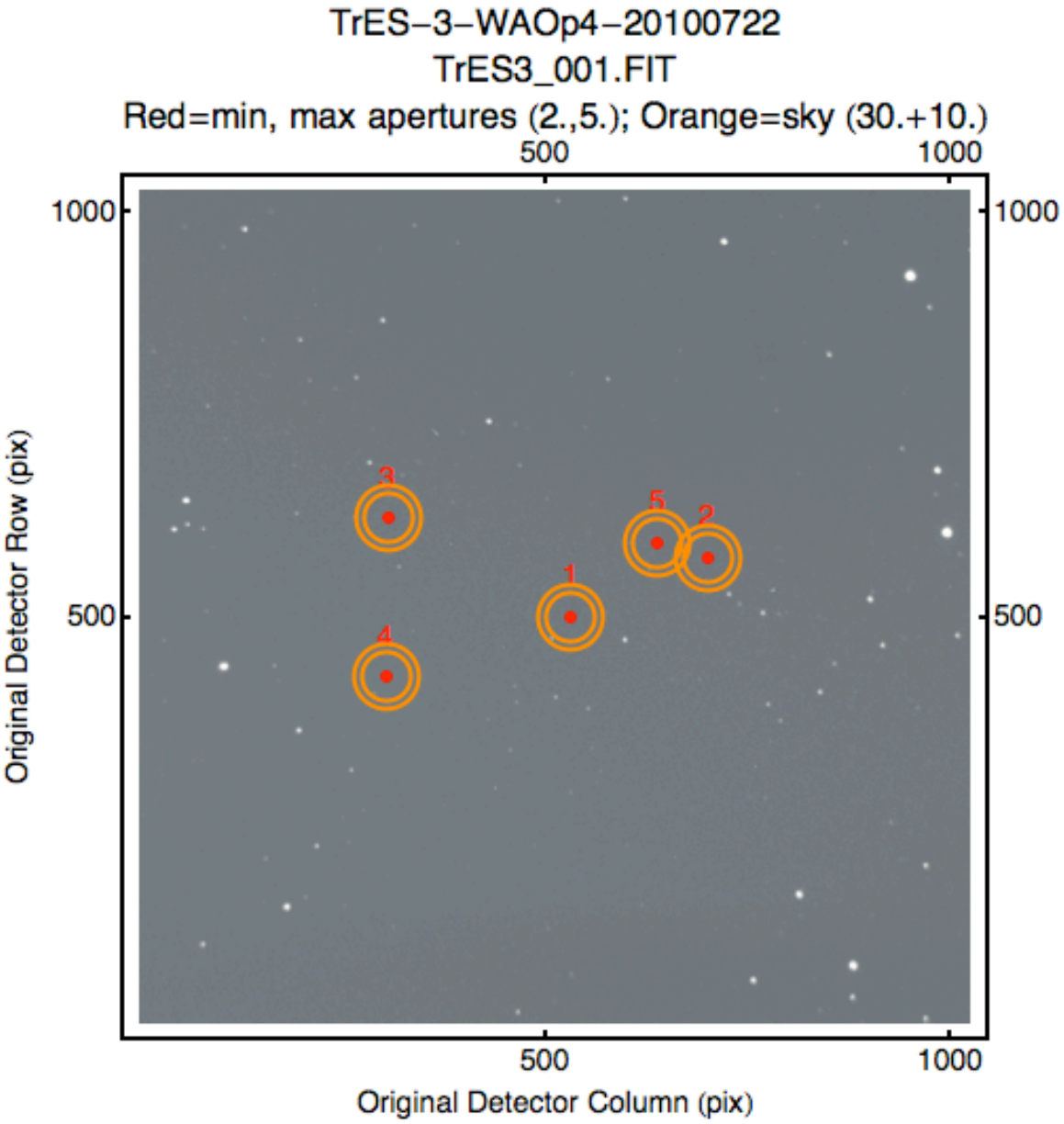

Fig. 11: Comparison stars for TrES-3 on 7/22.

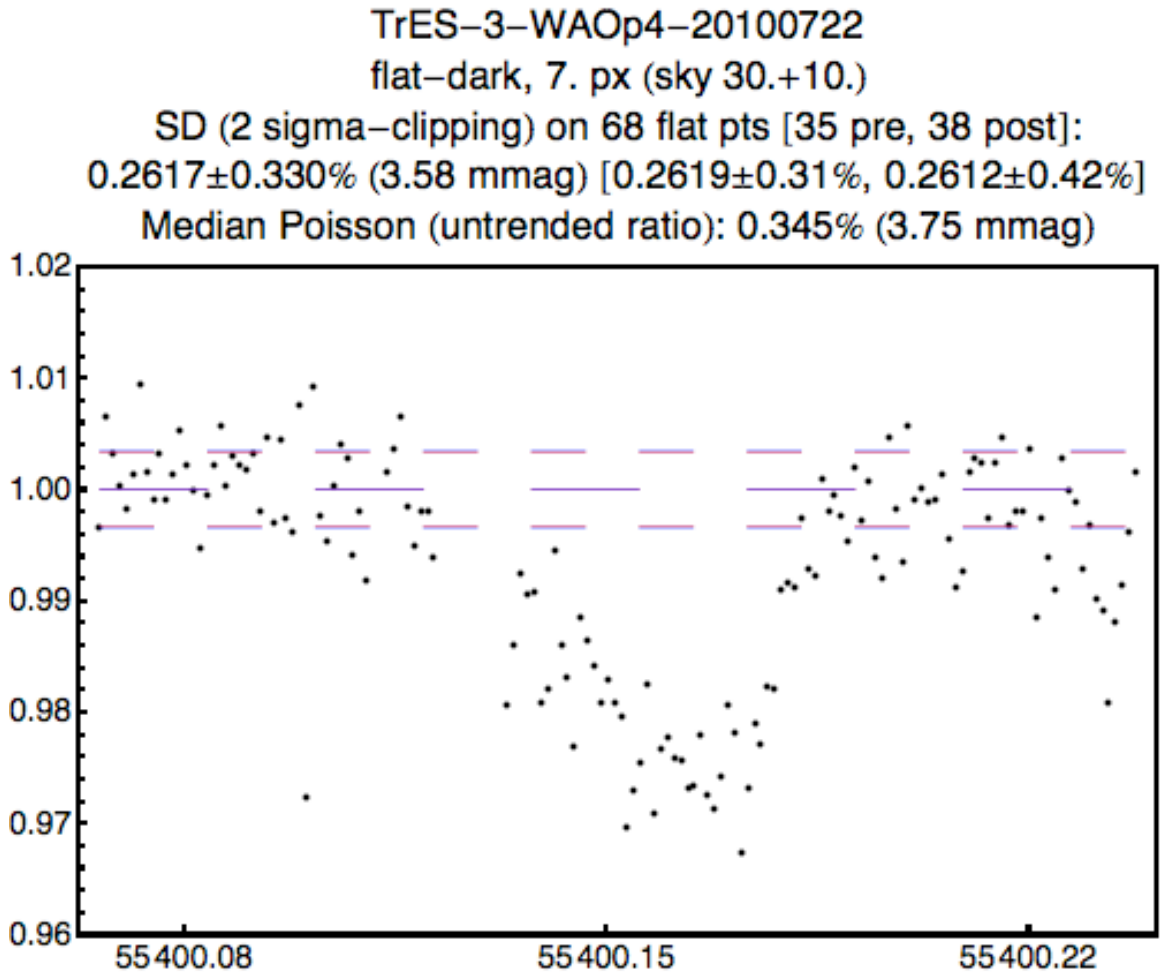

Fig. 12: Norm-detrended light curve of TrES-3 on 7/22 using comparison stars 2,3,4,5.

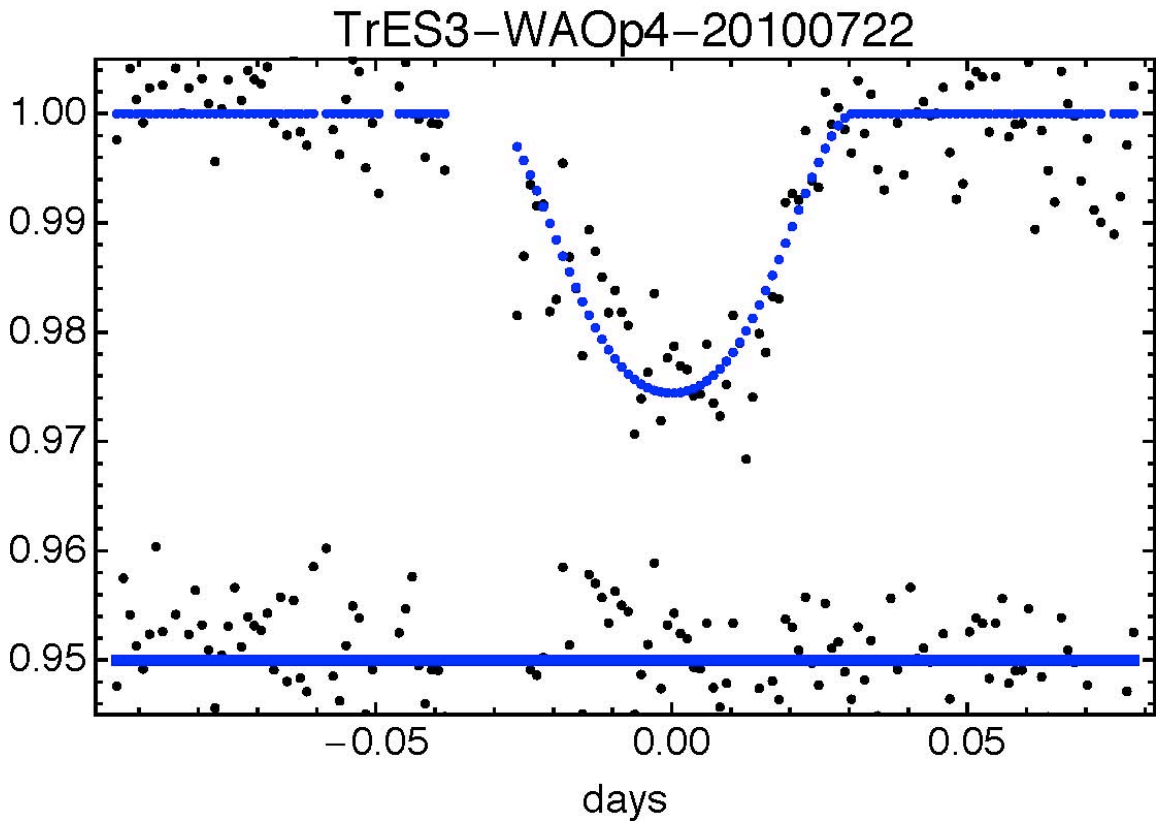

Fig. 13: The normalized ratio of the light from TrES-3
to several comparison stars is plotted (top points), with a model light curve
(solid line). Residuals plotted below.

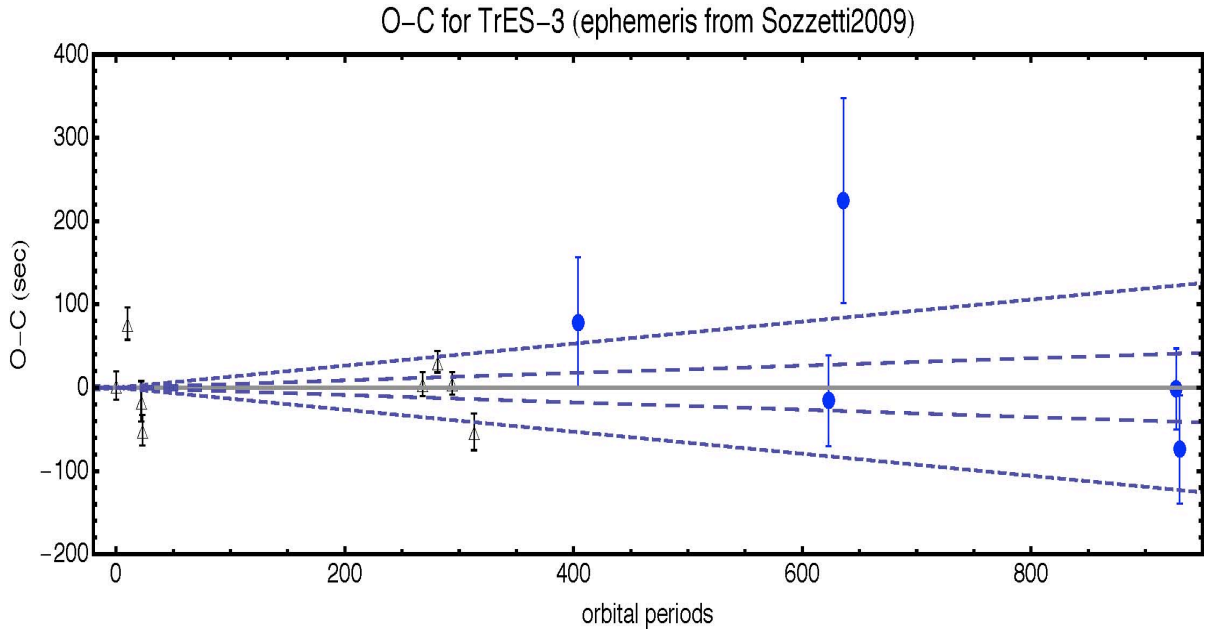

Fig. 14: TrES-3 O minus C Graph. The diagonal lines shown represent 1 sigma and 2 sigma deviations from the transit time. Points from the data from the summer project are shown in blue. This plot shows the midtime of the transit.

XO-1b

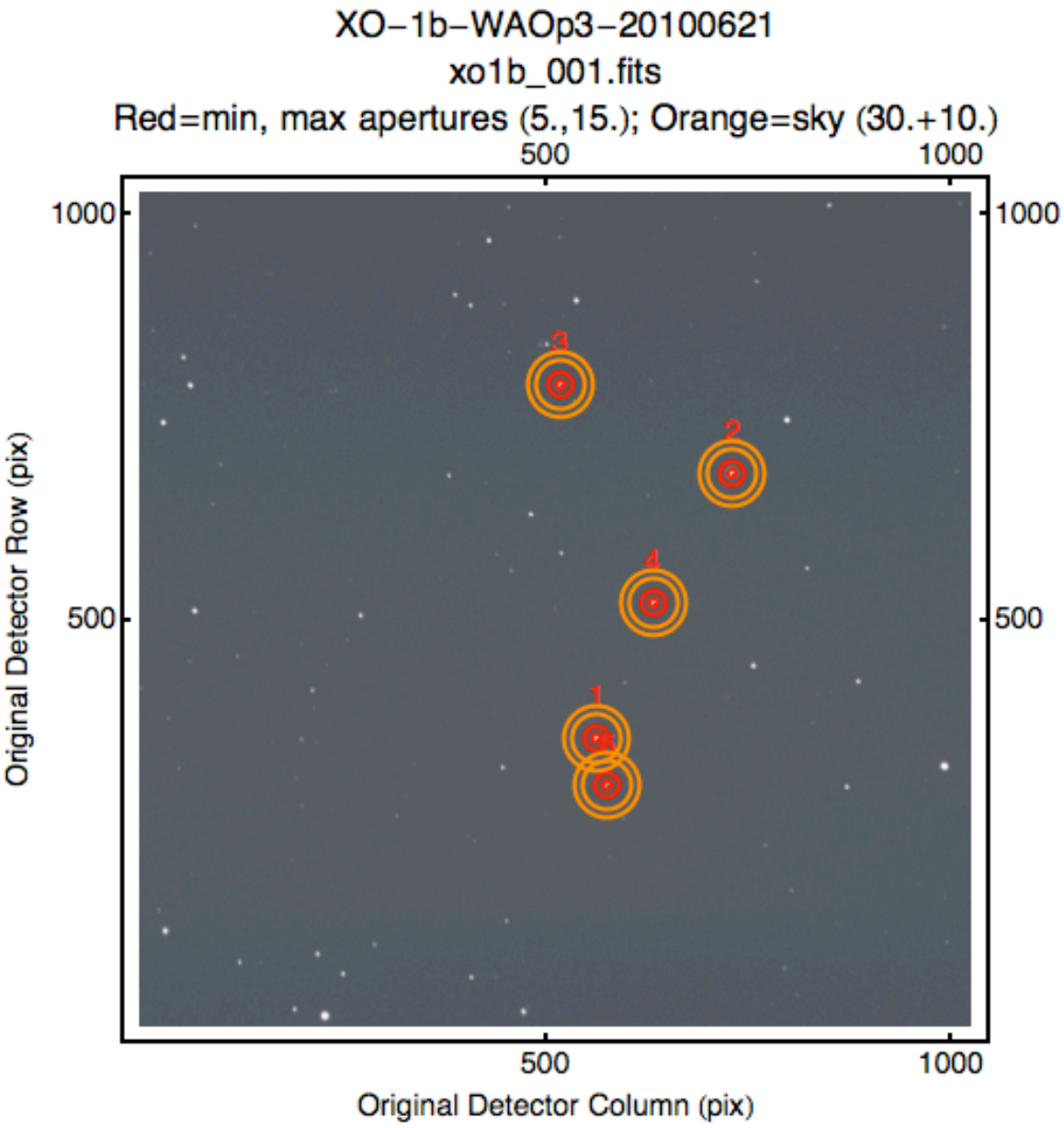

Fig. 15: Comparison stars used for XO-1b on 6/21.

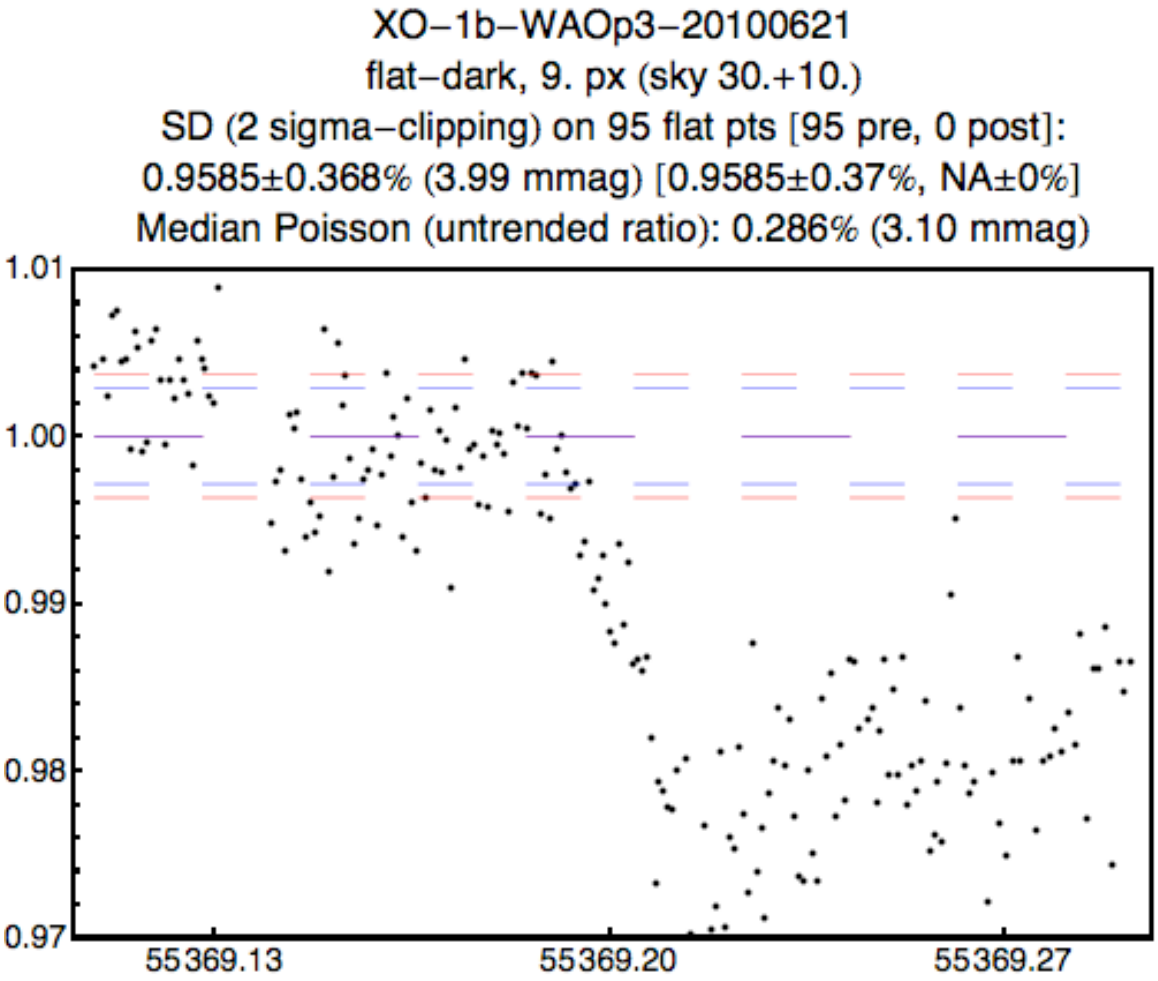

Fig. 16: Norm-detrended light curve of XO-1b using comparison stars 4,5.

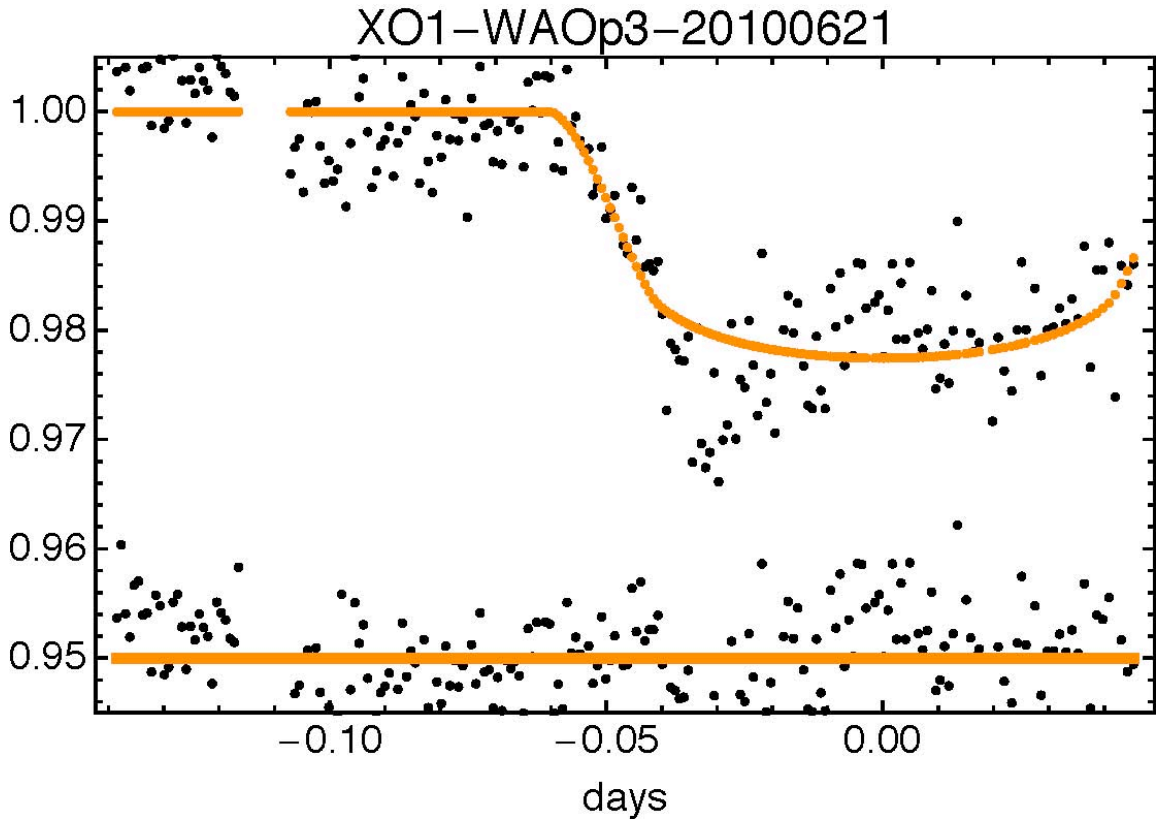

Fig. 17: The normalized ratio of the light from XO-1b
to several comparison stars is plotted (top points), with a model light curve(solid lin
e). Residuals plotted below.

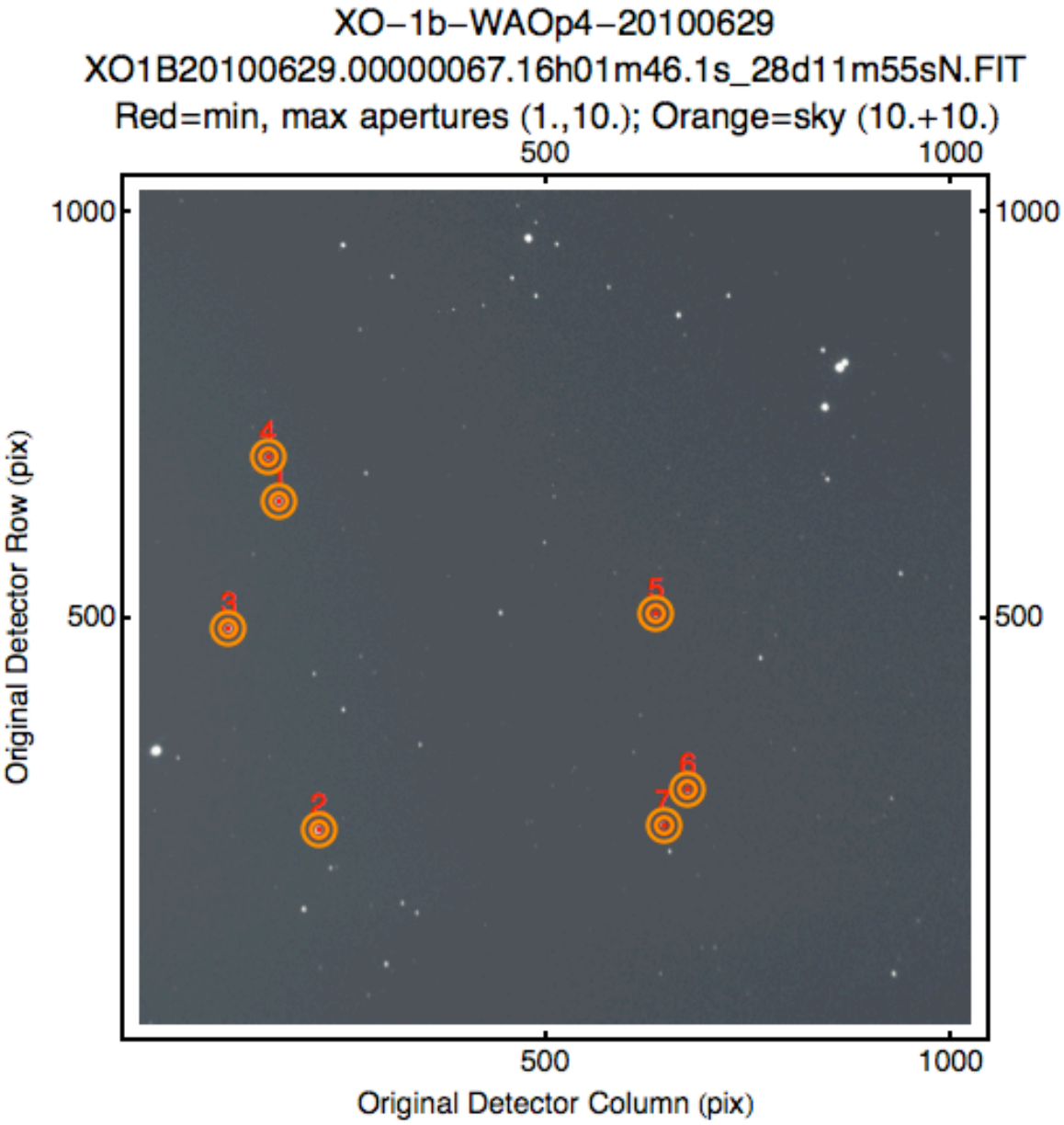

Fig. 18: Comparison stars used for XO-1b on 6/29.

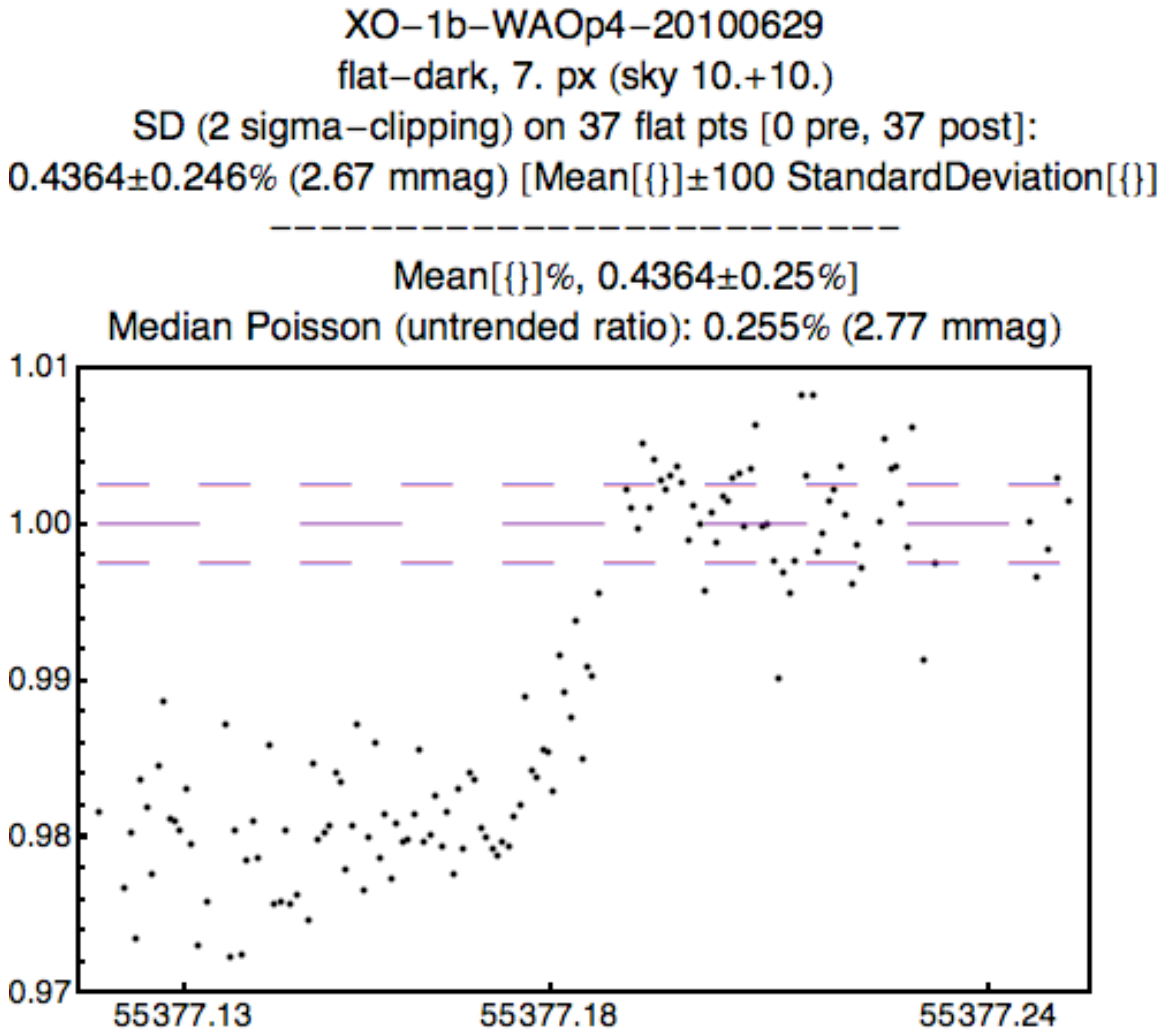

Fig. 19: Norm-detrended light curve of XO-1b using comparison stars 2,3,4,5.

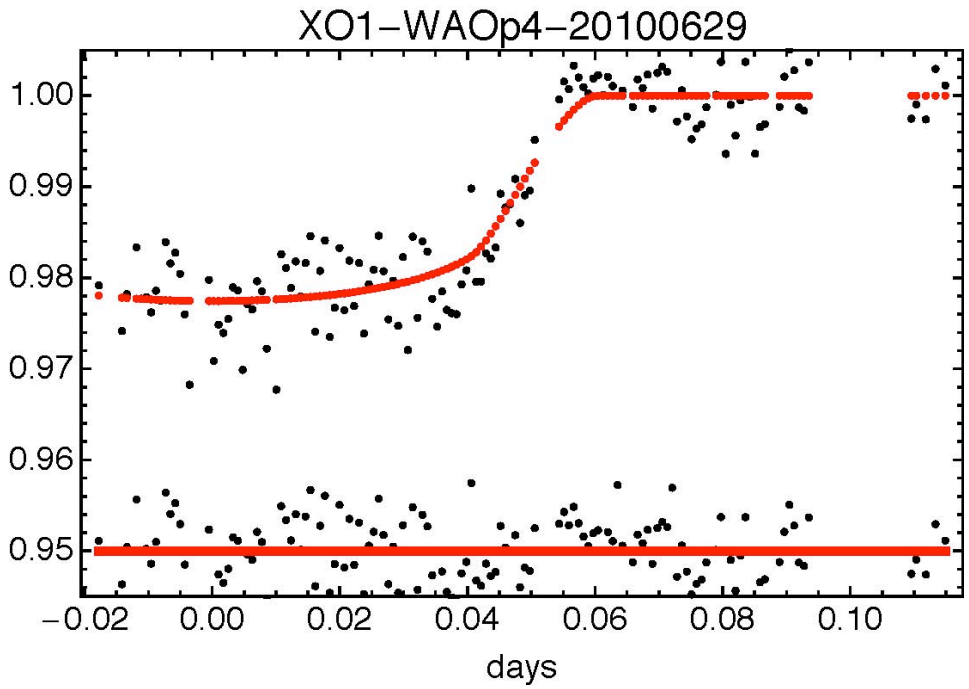

Fig. 20: The normalized ratio of the light from XO-1b to several comparison stars is plotted (top points), with a model light curve (solid line). Residuals plotted below.

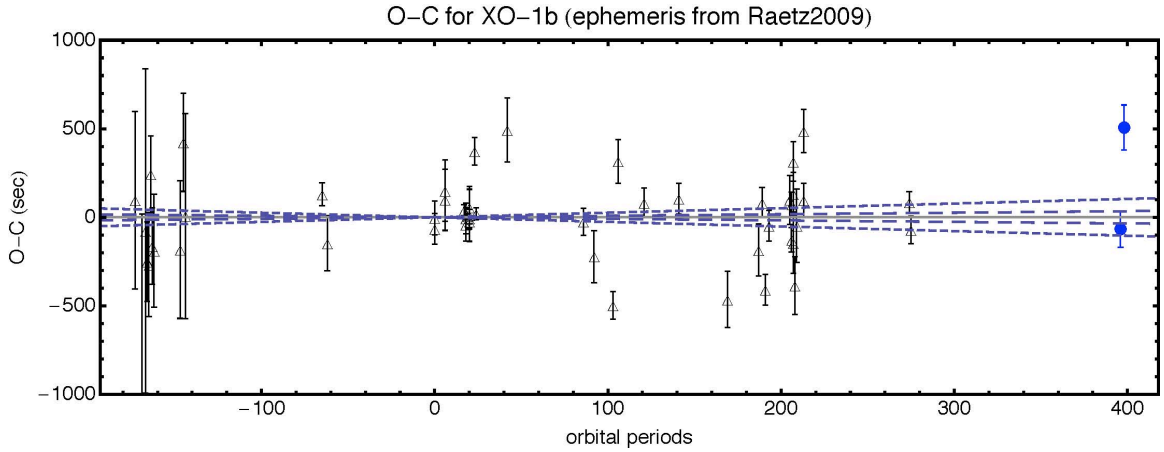

Fig. 21: XO-1b O minus C Graph. The diagonal lines shown represent 1 sigma and 2 sigma deviations from the transit time. Points from the data from the summer project are shown in blue. This plot shows the midtime of the transit.

TrES-1

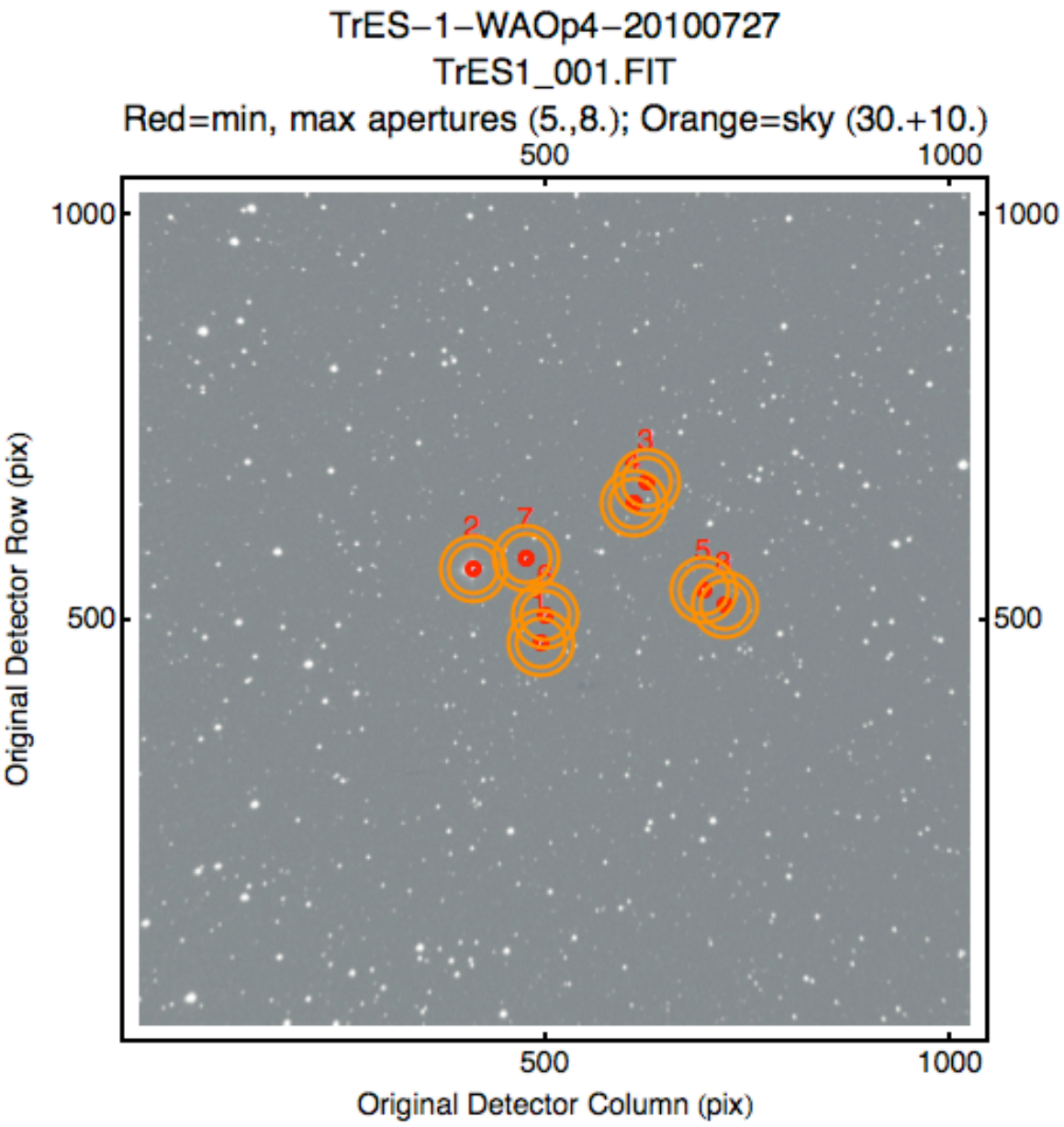

Fig. 22: Comparison stars used for TrES-1 on 7/27.

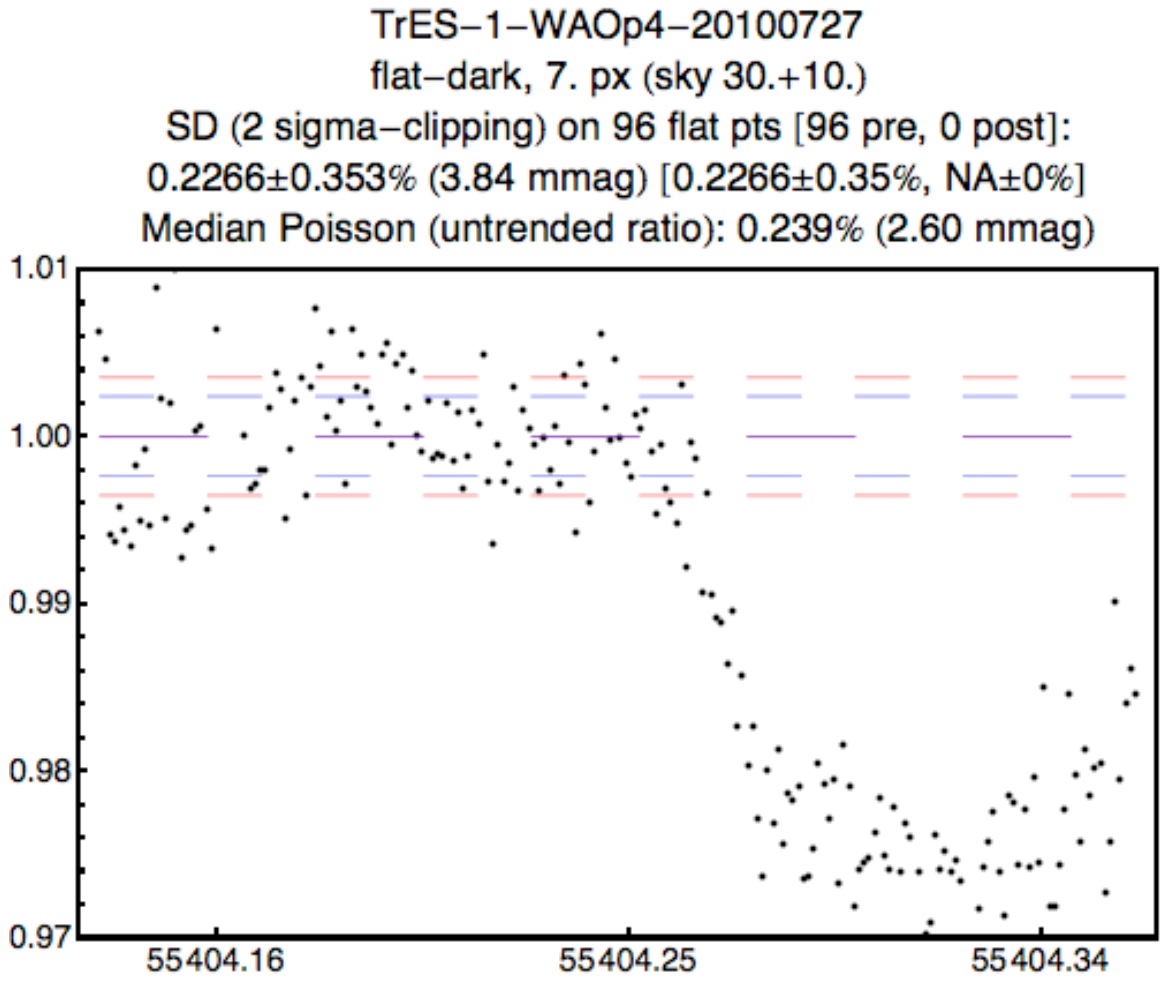

Fig. 23: Norm-detrended partial light curve of TrES-1 using comparison stars 3,4,5,7.

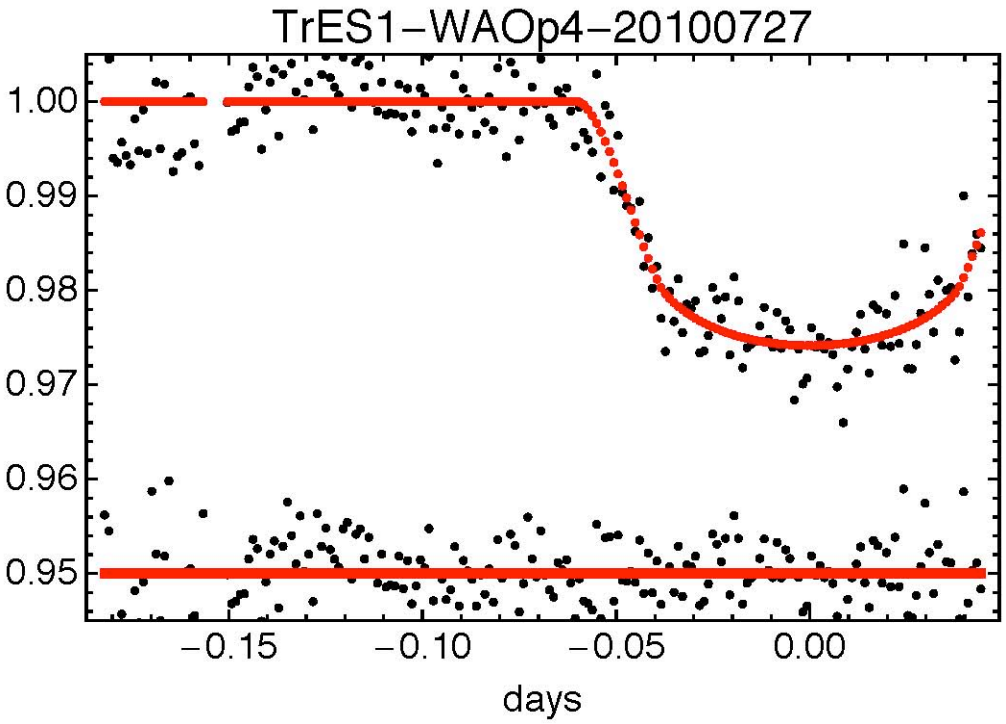

Fig. 24: The normalized ratio of the light from XO-1b
to several comparison stars is plotted (top points), with a model light curve(solid lin
e). Residuals plotted below.

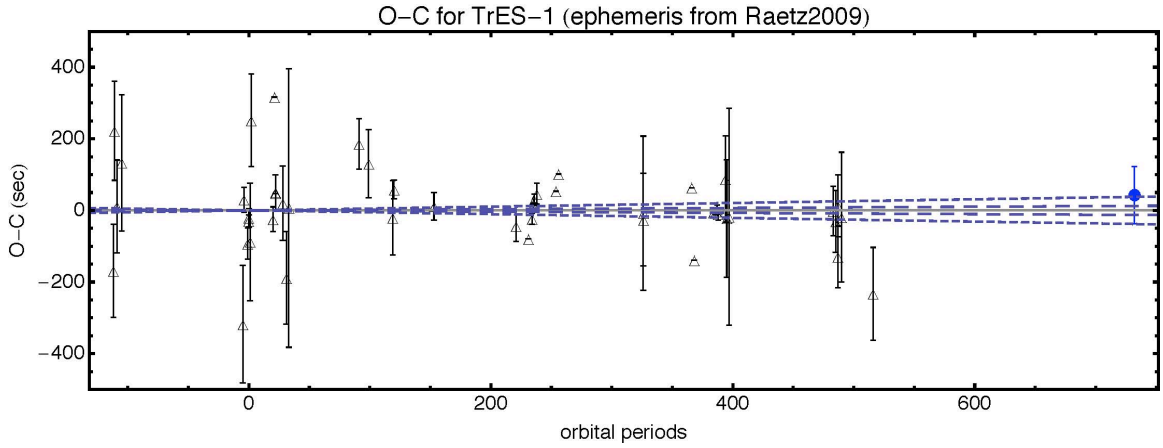

Fig. 25: TrES-1 O minus C Graph. The diagonal lines shown represent 1 sigma and 2 sigma deviations from the transit time. Points from the data from the summer project are shown in blue. This plot shows the midtime of the transit.

10 other transits were observed, but the data could not produce reliable light curves either because of cloud coverage or telescope failure.

Acknowledgements

I would like to thank Michael Person and Jim Elliot for organizing the UROP and being supportive, Timothy Brothers for training us at WAO, Elisabeth Adams for her tremendous help in creating light curves, Merritt and Will for driving us all out to WAO, Becky for helping out whenever I was stuck in IRAF or the Mathematica notebooks, and Nargiss for being an excellent partner during this summer project.