Freshening Exoplanet Transit Midpoints

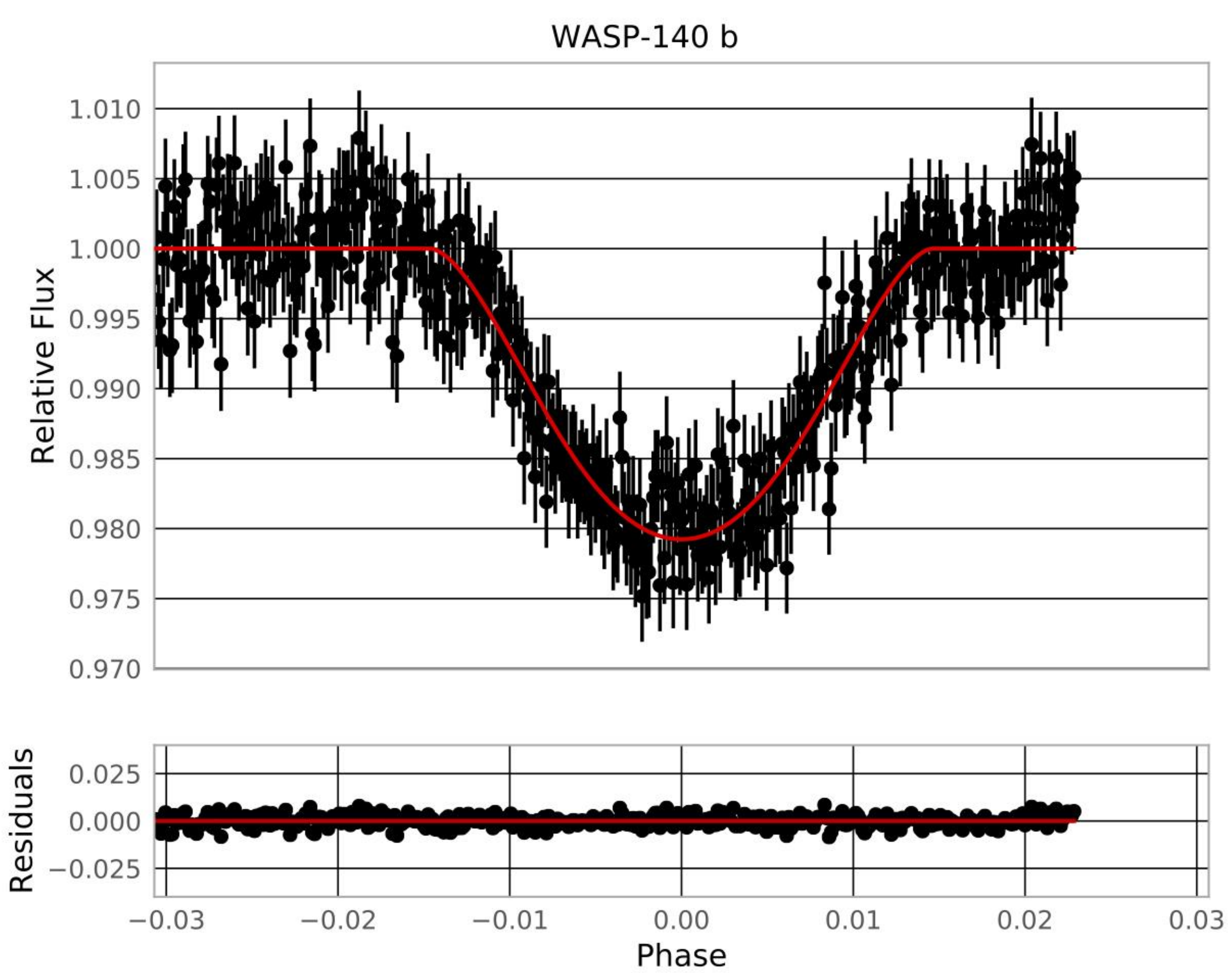
Quinn Perian, Sujay Nair, Kalée Tock

Stanford Online High School, Stanford, CA

Abstract

Without continuous monitoring, exoplanet transit midpoints quickly become stale. Ongoing transit measurements by small telescopes allow for optimal time allocation on larger ground-based telescopes and space telescope missions such as TESS. In this study, we use the robotic 0.4m telescopes of Las Cumbres Observatory (LCOGT) to capture transits of hot Jupiter exoplanets. Comparison star selection is optimized using Gaia Data Release 2. We find that brightness has a significantly greater impact on the efficacy of a comparison star than color, and that it is not helpful to merge multiple comparison stars or photometric reduction techniques for better signal-to-noise. We also contrast photometric reduction algorithms, including three types of aperture photometry, three point spread function models, and the EXOTIC optimal aperture algorithm. The EXOTIC method seems best suited to the image data analyzed here, with PSF Extractor and Source Extractor being frontrunners among the remaining six. The EXOTIC data reduction pipeline was used to fit whole and partial transits of several systems and calculate transit midpoints for eventual inclusion in the AAVSO database. This database will keep track of multiple exoplanet observations, continuously aggregating and freshening transit midpoints.

EXOTIC Data Reduction Pipeline



EXOTIC was used to fit lightcurves both with pre-reduced PSF-extractor (PSX) photometry from the Our Solar Siblings pipeline and also with the EXOTIC internal optimal aperture photometric algorithm. The figure shows our best fit in which we used EXOTIC's optimal aperture algorithm. Others can be found at the QR code link.

Las Cumbres Observatory

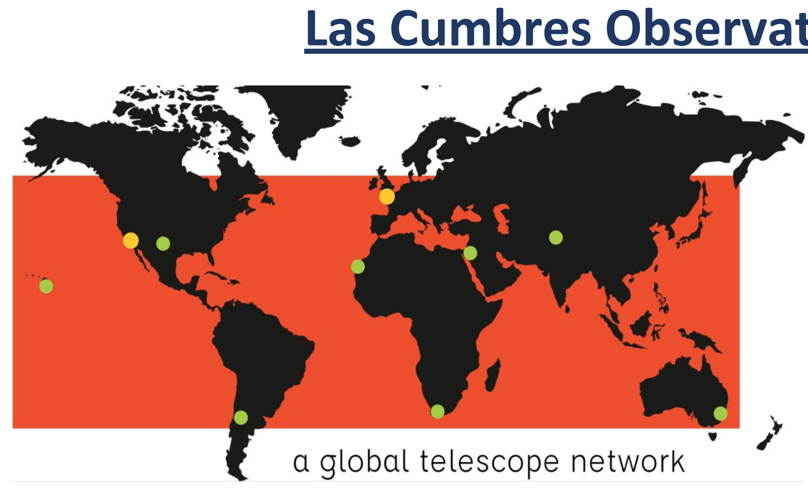
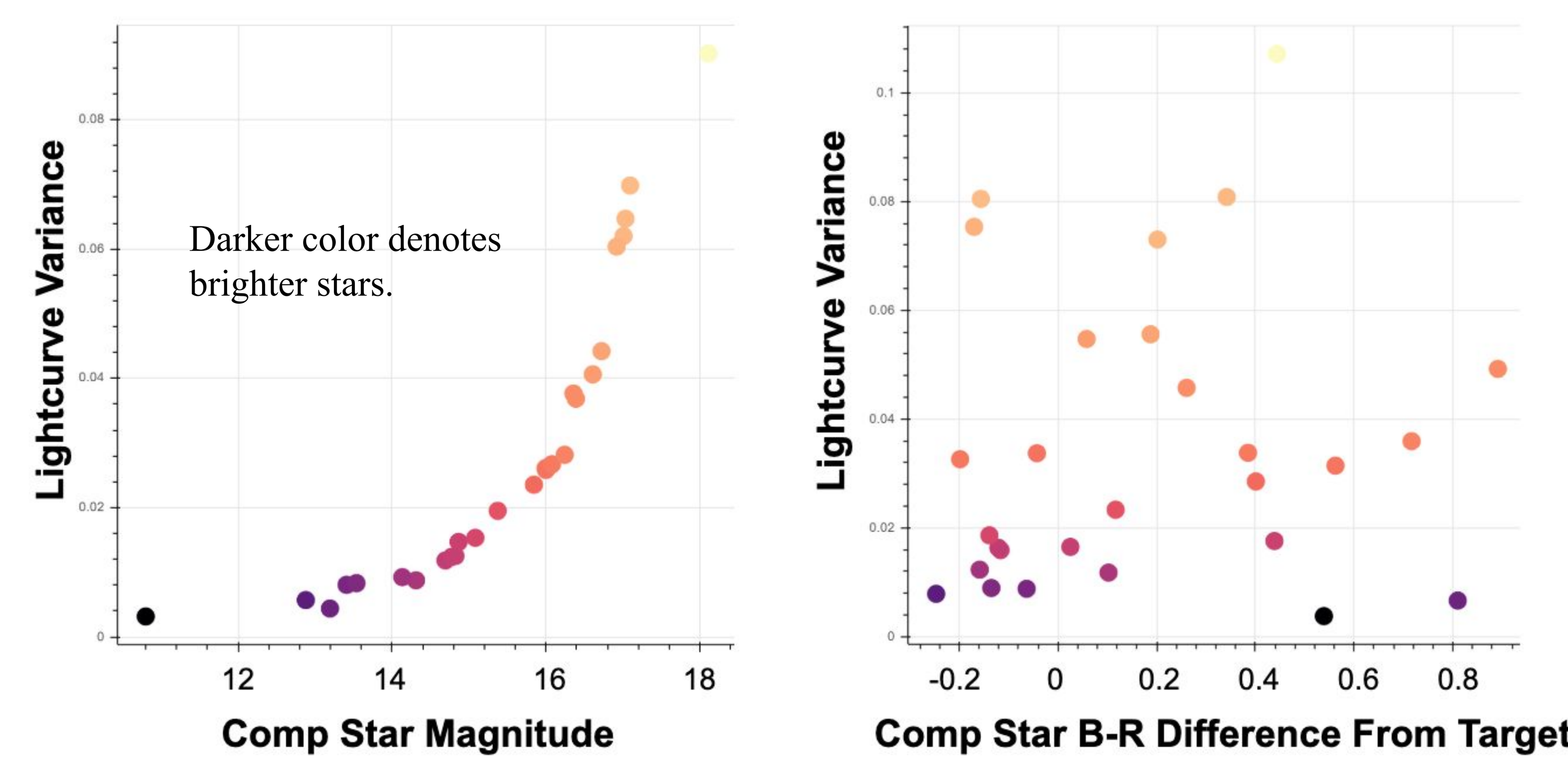


Image credit: LCOGT

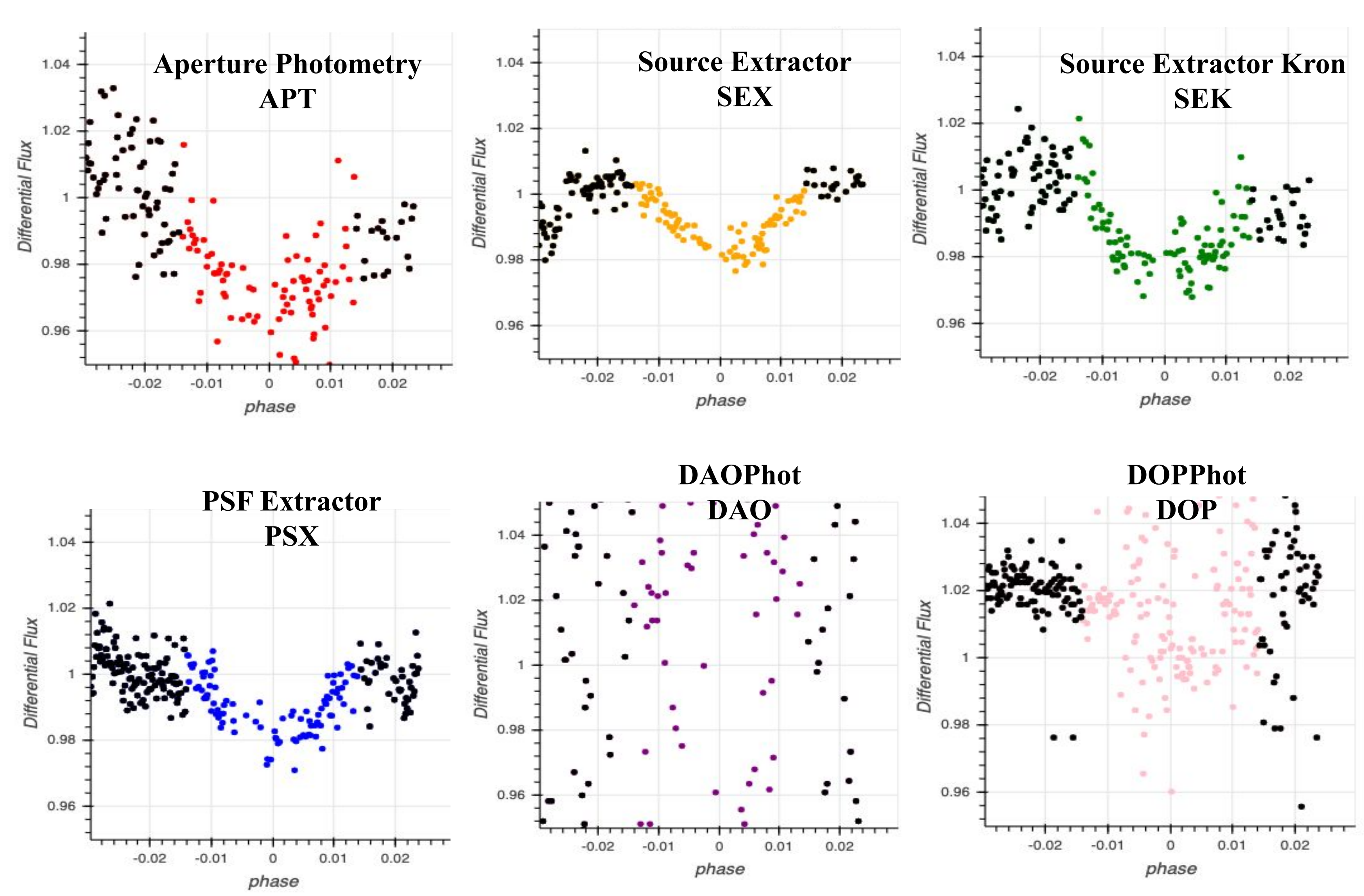
Comparison Star Selection: WASP-140b

- Lightcurve scatter is measured as total deviation from average flux of nearby points
  - Correlates with comparison star variability
- Brighter comparison stars yield less noisy lightcurves.
- Color (Gaia DR2 B-R) relative to target does not have a significant effect on lightcurve variance.
- Standard deviation of lightcurve outside transit is the same for the best comp alone as for a weighted merged system.
- Combining photometric reduction techniques does not decrease lightcurve variance.

Magnitude Dominates Color



Averaging Photometries is Ineffective



Partial Transits Have Higher Scatter

Catching partial transits is common, so we compared EXOTIC fit statistics for partial versus full transits of two different systems, using both pre-reduced PSX photometry and the EXOTIC internal optimal aperture photometry. As expected, partial transits had greater transit depth uncertainty and greater residual scatter. The internal EXOTIC photometry minimized both transit depth uncertainty and residual scatter for the full transit, and minimized residual scatter for the half transit. Uncertainty is expected to be reduced further by including more out-of-transit observations of the system in our image requests.

System	WASP-140b (whole transit)	HAT-P-16 b (half transit)
Transit Depth Uncertainty PSX (%)	0.271	1.374
Residual Scatter PSX	0.463	1.102
Transit Depth Uncertainty EXOTIC (%)	0.187	2.25
Residual Scatter EXOTIC	0.311	0.684

More Information

Quinn Perian (qperian@ohs.Stanford.edu)
Sujay Nair (sujaynr@ohs.Stanford.edu)
Kalée Tock (kaleeg@Stanford.edu)

Special Thanks To:

Rob Zellem, NASA Jet Propulsion Laboratory
Michael Fitzgerald, Our Solar Siblings
Robert Buchheim, Society for Astronomical Sciences
Edward Gomez, Las Cumbres Observatory

Stanford Online High School