OSCAAR: Open Source differential photometry Code for Amateur Astronomical Research

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Abstract

We present a cross-platform, open-source differential photometry package written in Python, called OSCAAR (Open Source differential photometry Code for Amateur Astronomical Research). It is **designed for production of bright transiting exoplanet light curves with small telescopes and consumer-grade CCDs**. The code is intended for use by undergraduate students, small observatories or serious amateurs, or it may be used as a scaffolding upon which more sophisticated photometry routines can be developed by advanced users. OSCAAR **can be controlled with a graphical user interface** for those unfamiliar with Python. OSCAAR makes extensive use of existing scientific software packages, and the implementation of classes and methods within OSCAAR is designed to be highly modular and interchangeable. **The aim of OSCAAR is to provide a free, practical differential photometry toolkit with which users can easily create transit light curves, and to provide a flexible starting point for users with programming experience to designing their own, customized photometry codes.**

OSCAAR's Goals

OSCAAR is a photometry tool designed for observations with small telescopes and consumer-grade CCDs. Some of the common challenges for non-professional observers that OSCAAR seeks to resolve are:

- Inaccurate polar-alignment, poor sidereal tracking
  - Must track stars with large drifts between exposures
- Lack of coding experience among users
  - Must be interactive, GUI-based component
- Existing codes are often "black-boxes"
  - Must be well-documented and open source
- Lack of support for existing codes
  - Must have a platform for troubleshooting and collaborative development
- Defocused observations produce better photometry
  - Must track stellar centroids for stars with unknown PSFs
- Cost minimization
  - Must be free

How OSCAAR Works

- OSCAAR can be run from a **graphical user interface** (GUI), which allows users to adjust with the running parameters for the science algorithms (see Figure 1)
- A **data storing and organizing class** is implemented to manage the various data generated by the tracking and photometry processes

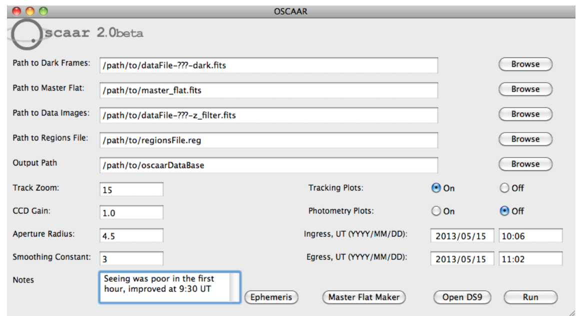

Figure 1: The OSCAAR GUI allows users to access files with Unix shell-like wilds or with interactive "Browse" selectors. DS9 regions files are used to identify the starting positions of each star. Algorithm parameters can be set here without opening the source code.

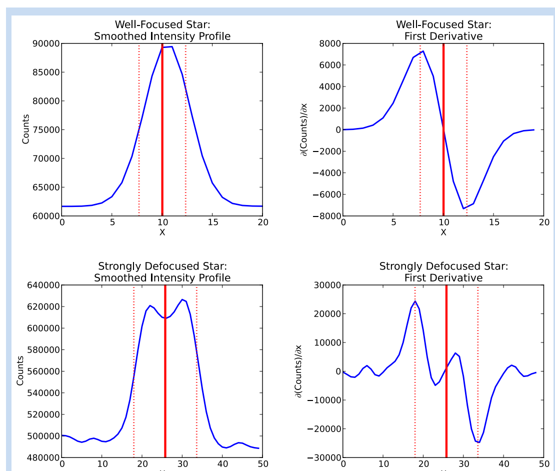

Figure 2: Flexible Stellar Centroiding The top row of plots show the sum of intensities in each pixel along the columns a well-focus star, the bottom row shows a **highly defocused** star. The plots on the left show the counts summed along the pixel columns (smoothed). The plots on the right show the first spatial derivatives of the intensity profiles. A quadratic is fit to the three points closest to each of the extrema in the derivative (best-fit vertex position marked with dotted vertical red lines). The midpoint between these best-fit extrema is taken as the stellar centroid (solid vertical red line).

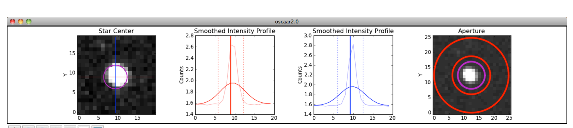

Figure 3: Real time plotting can be useful for identifying good aperture radii and other algorithm-specific parameters.

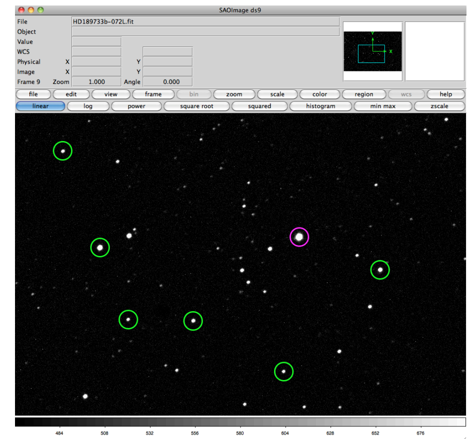

Figure 4: Target and Comparison Identification is done via SAOImage DS9 by creating and parsing a regions file. The user simply clicks on each star that OSCAAR should track and measure photometry from, and saves a regions file from within DS9.

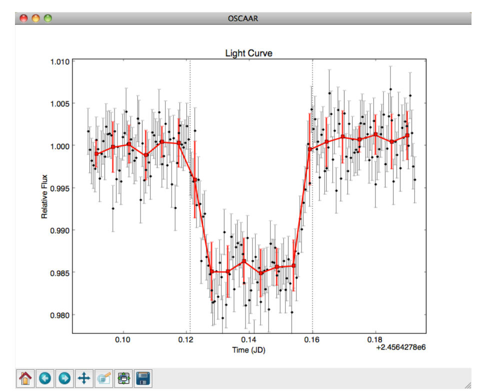

Figure 5: Light curves are plotted with the Python package **matplotlib** for interactive plotting that users can experiment with. The plot above shows the light curve generated with simulated data that we include in the OSCAAR distribution for testing. Users can set the binning plotted over the light curve (red points).

Supported Platforms

Windows XP+ | Mac OS X 10.6+ | Ubuntu 12+ or similar

How OSCAAR Works (cont'd)

- The tracking algorithm takes numerical derivatives of the intensity profiles of each star on each spatial imaging axis and uses the "edges" of stellar PSFs to efficiently extract stellar centroids of even **defocused** stars (see Figure 2)
- The raw fluxes are normalized to the flux of the target star
- A composite comparison star is assembled by finding the linear combination of comparison star fluxes that minimizes the difference between the composite comparison star fluxes and the target star fluxes
- Comparison stars with significant anomalous flux trends are rejected outright (variables, improperly tracked stars)
- The target star fluxes divided by the composite comparison star fluxes yields the transit light curve, which is plotted interactively with custom binning (see Figure 5)
- A model transit light curve of the Mandel & Agol (2002) form is fit to the user generated light curve using Levenberg-Marquardt least squares or Markov Chain Monte Carlo (MCMC)
  - Analytical light curve and MCMC calculations are **written in C and wrapped in Python** for efficiency

Collaborative Development

We use GitHub for **collaborative revision control** and open source repository hosting. GitHub also provides a platform for collaborative **Wiki** development for **user support and tutorials**, and **Issue Tracking** for collaborative troubleshooting. These features foster a community around the code to continually provide enhancements and support.

OSCAAR is distributed under the liberal MIT License, allowing users to **freely modify and redistribute the code**.

The OSCAAR Community

Most contributors are undergraduate or graduate students of astronomy and computer science and **we welcome new contributors**, wherever they may be.

We're getting observers started with OSCAAR at the University of Maryland Observatory (College Park, MD), Kopernik Observatory (Vestal, NY), Perseus Observatory (Athens, Greece), and more soon to come.

To get involved in coding with us or using OSCAAR to analyze your observations, contact us at oscaarteam@gmail.com

View OSCAAR on GitHub at http://oscaar.github.io

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