High Precision Photometry of Bright Transiting Exoplanets with MINERVA

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MINERVA

- Mission: Detect exoplanets, confirm candidate exoplanets, and characterize Earth-like exoplanets
- Location: Mt. Hopkins in Arizona
- 4 telescope array
- PlaneWave CDK-700 telescopes, 0.7m diameters

Objectives

- Photometric precision of < 1 millimagnitude
- Doppler Shift precision of ≤ 0.8 m/s
- Automate analysis of photometric data via software for photometry pipeline

Significance

- For exoplanets with a radius 1 to 5 times the radius of Earth, the physical properties evaluated for most of these planets either have high uncertainties or cannot be ascertained at all. This problem is exacerbated by the faintness of the host star. However, the rate at which **transiting Earth-like exoplanets** around **bright stars** are detected and characterized with **satisfactory precision** can be substantially increased with MINERVA.

The struggle of Bright Star Photometry is overcome with MINERVA

- To **precisely determine the physical properties of an exoplanet**, such as the mass and radius, both high precision spectroscopic and high precision photometric data on the host star are needed [1].
- To achieve high precision spectroscopy of **Earth-like** exoplanets, we observe bright stars.
  - Thus, high precision photometry must come from the same **bright stars.**
- To find precise mass and radius of planets, we analyze exoplanets that **transit** their bright host stars.

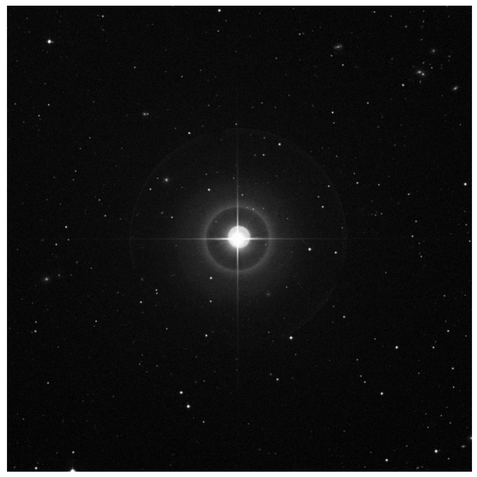

Fig. 1: Bright star with transiting exoplanet: Tau Boötis (archive.stsci.edu). Analysis of this bright star calls for **relative photometry**, which requires the use of several **comparison stars**—i.e., stars that are similar in brightness and color to primary target star. Within this field of view, no other star is equally as bright as Tau Boötis; therefore, we cannot conduct relative photometry and find the mass and radius of its exoplanet.

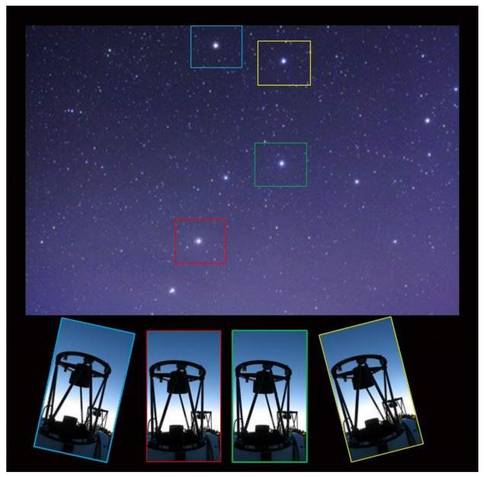

Fig. 2: Demonstration of MINERVA's 4 telescopes observing distinct regions of the sky (Credit: Miguel Claro). Figure 1 showed how one telescope's field of view usually contains very few—if any—bright stars. With MINERVA, 3 additional telescopes are used to find those necessary comparison stars that are as bright as our primary star with the transiting exoplanet(s).

Sub-millimagnitude precision is achieved with one MINERVA telescope

Fig. 3: Defocused star (astronomyforum.net)

To avoid the **saturation of CCD** from bright stars like that of Figure 1, we employ the **defocusing technique**:

the dispersion of stellar photons across many more CCD pixels allows for a drastically **longer exposure time** than otherwise capable with a bright star in focus. Such an increase in the exposure time substantially reduces flat fielding errors, decreases the fractional overheads, and thus results in high precision photometry.

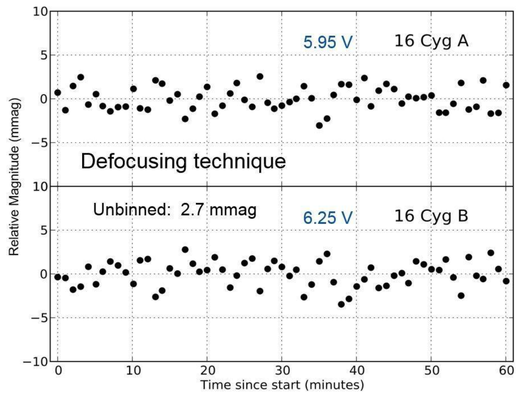

Fig. 4: Light curves of star system 16 Cyg. After observations of two defocused bright stars (undergoing no exoplanet transit) via 1 telescope, a photometric precision of 2.7 mmag was achieved [2].

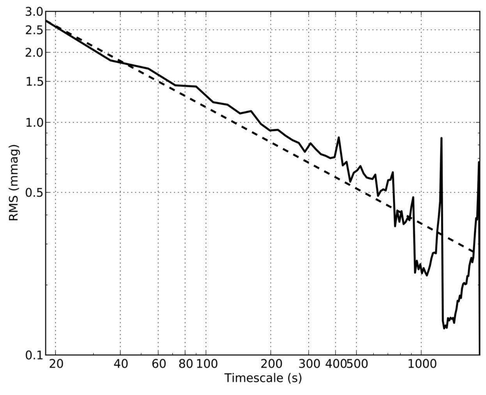

Fig. 5: Precision varies with binning of data in 16 Cygnus A light curve. Once binned down to timescale of ~200s (or 3 min), the observational scatter of newly binned light curve is proven to be < 1 mmag [2].

Photometry pipeline will expedite results from bright star survey

Automated Photometry Pipeline

Data Reduction

Ana Colón

Data Analysis

Maurice Wilson

We will **combine the multi-telescope aspect of MINERVA with the defocusing technique** throughout the **bright star survey** we plan to conduct in 2016.
Due to the substantial amount of data coming from this bright star survey, there is a need for software that can **automate the photometric data analysis** so that the physical properties of the detected Earth-like exoplanets may be deduced. Here are the most significant capabilities of my code:

Pre-observation

- User can query for satisfactory comparison stars
- Creates observation schedules which can be read by the autonomous MINERVA telescopes

Post-observation

- Perform aperture photometry and relative photometry
- Produce light curve of primary target star

References

[1] Winn, J., 2010, ArXiv:1001.2010

[2] Swift et al., 2015, JATIS, 1, 2

Want More Details?

Visit http://mwilson1.github.io/cool_research/High_precision/high_precision.html

Acknowledgements

This work was supported by the Banneker Institute at the Harvard-Smithsonian Center for Astrophysics and Embry-Riddle Aeronautical University's Honors Program, Ignite Spark Funds, and the McNair Scholars Program.

I am grateful to have collaborated with all of my fellow Banneker Institute peers as we shared our ideas and expertise to help each other with class work and research.