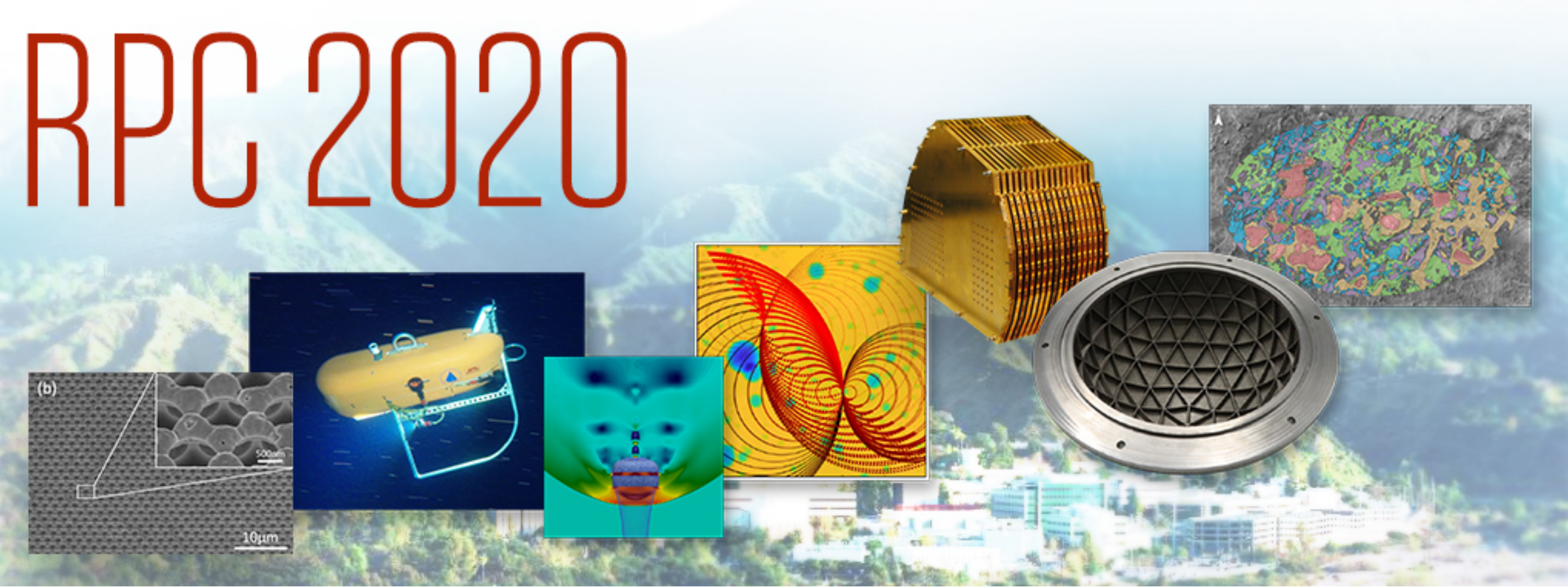

Virtual Research Presentation Conference

Searching for new super-Earth exoplanets with ASTERIA

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Program: ASTERIA In-Flight Autonomy Technology Development Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

Assigned Presentation RPC-018

Tutorial Introduction

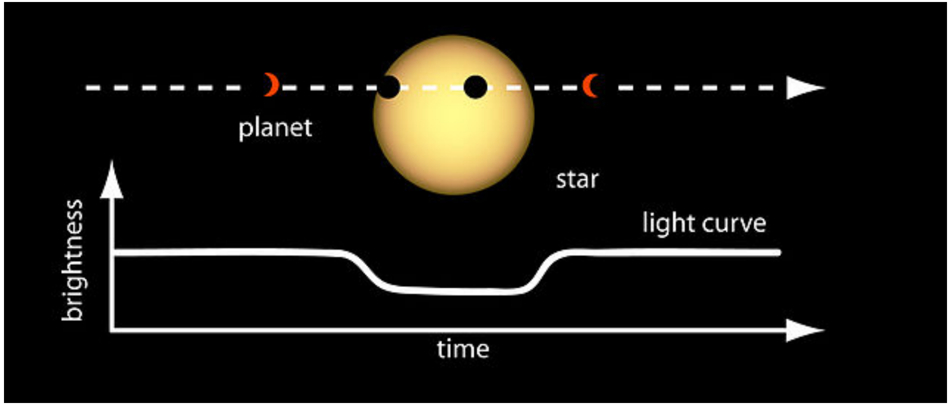
Abstract

The Arcsecond Space Telescope Enabling Research In Astrophysics (ASTERIA) was a CubeSat that demonstrated how key technologies for exoplanet detection via the transit method can be scaled down to small platforms.

ASTERIA demonstrated precision pointing and thermal control as well as visible-light CMOS for precision photometry.

These technologies together enabled ASTERIA to measure the brightness of its targets stars to a precision of ~100 parts per million (ppm) RMS. An Earth-like planet transiting a Sun-like star produces an ~80 ppm dip in brightness.

Originally funded as part of the JPL Phaeton Program for training early career employees, ASTERIA searched for and detected transiting exoplanets in its RTD-funded extended mission.



Problem Description

a) Context:

   a) ASTERIA was an in-flight mission with the capability to detect small exoplanets around bright stars. ASTERIA could search for planets around stars too bright for most other transit search facilities. One enticing target was the binary star system alpha Cen AB – our nearest Sun-like neighbors.

b) SOA:

   a) The Kepler and TESS missions achieved exquisite sensitivity to small planets around faint and moderately bright stars, but they saturated on the brightest stars, like alpha Cen. While other facilities exist that could observe alpha Cen with high precision, these facilities are generally not available for the long-duration observing campaigns needed for blind searches for new exoplanets.

   b) All previous missions used visible-light CCDs for precision photometry. Due to volume and power constraints, ASTERIA needed its single detector dual-purpose as both fast guider and science camera, necessitating a move to visible-light CMOS technology, despite the lower heritage for precision photometry.

c) Relevance to NASA and JPL:

   a) How can we reduce the cost of detecting small transiting exoplanets, especially around bright stars? The atmospheres of transiting exoplanets can be characterized spectroscopically by future missions like James Webb, but only when the planets orbit bright stars.

Methodology

a) Formulation, theory or experiment description

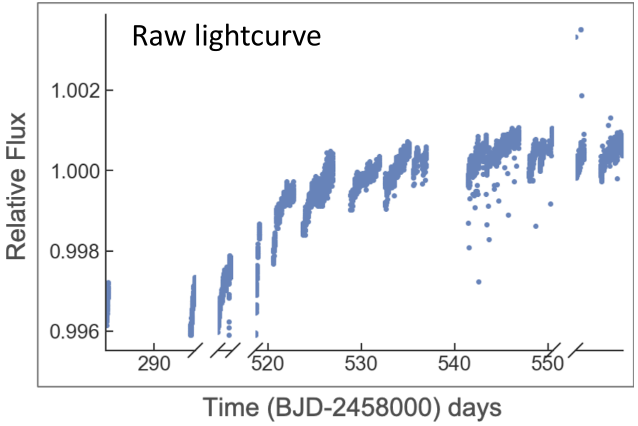
   a) Built on FY19 SURP for lab characterization of flight-like ASTERIA CMOS detector. Integrated lessons for image processing and systematics detrending into ASTERIA science pipeline.

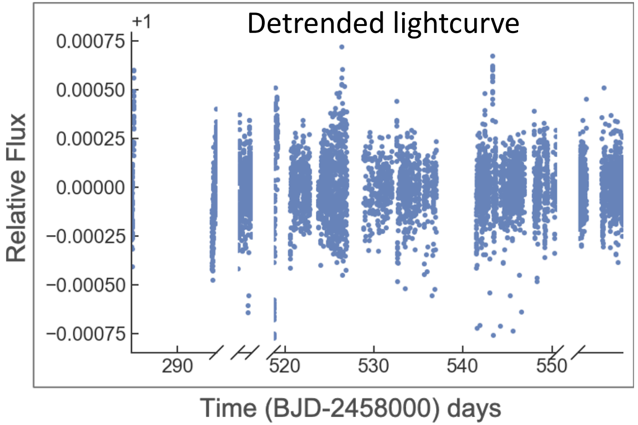
   b) Conducted a guest observer program for the TESS mission and for a proof-of-concept Uranus observations. Conducted observing campaigns to search for new transiting exoplanets around alpha Cen A & B. Used transit signal injection/recovery to assess detection limit.

b) Innovation, advancement

   a) Enhanced custom pipeline for extracting ASTERIA lightcurves to better suppress systematics.

   b) Attempt to partner with new student-run Caltech Mission Operations Center (CMOC) as proof-of-concept.





Results

a) Accomplishments

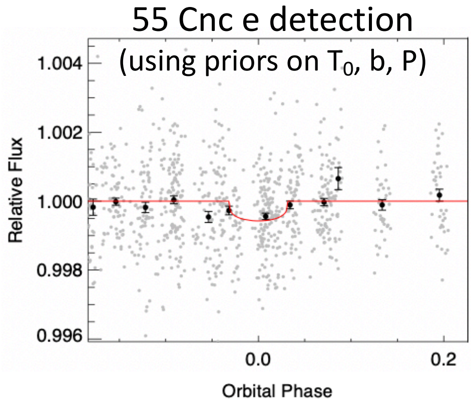
- a) Published detection of super-Earth 55 Cnc e. [A]
- b) Non-detection for alpha Cen: rule out Jupiters and Neptunes on <6 day periods. New constraint on planets < 2day periods [B]
- c) Submitted papers on joint transiting exoplanet search with TESS [C] and on CMOS characterization [D]
- d) Did not succeed in CMOC operations partnership due to JPL and Caltech security concerns, staff reassignment to anomaly resolution, and early end of ASTERIA mission. CMOC began addressing security concerns and will attempt partnerships with future missions.

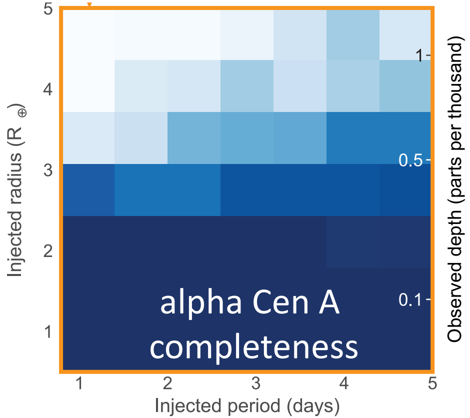
b) Significance

- a) First CubeSat to detect an exoplanet. Proof-of-concept that CubeSats can contribute to transiting exoplanet science. Proof-of-concept precision photometry with visible-light CMOS.

c) Next steps

- a) Continue posting imaging data to NExScI Exoplanet Archive ([link]) as papers are accepted and/or proprietary period expires
- b) Funded concept study (PI Seager) for small constellation of ASTERIA-like CubeSats. Incorporate lessons learned about limiting systematics to improve design, calibration strategies, and operations.





Publications and References

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[A] Knapp, M., Seager, S., Demory, B.-O., et al., "Demonstrating High-precision Photometry with a CubeSat: ASTERIA Observations of 55 Cancri e," 2020, Astronomical Journal, 160, 23

[B] Krishnamurthy, A., Knapp, M., Gunther, M., et al., "Transit Search for Exoplanets Around Alpha Centauri A and B with ASTERIA," submitted to the Astronomical Journal

[C] Seager, S., Knapp, M., Demory, B.-O., et al., "HD 219134 Revisited: Planet d Transit Upper Limits and Planet f Transit Non-Detection with ASTERIA and TESS," submitted to the Astronomical Journal

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