Space mission and instrument design to image the Habitable Zone of Alpha Centauri

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Alpha Centauri Exoplanet Satellite (ACESat) Mission Overview

ACESat will directly image and characterize the planets and circumstellar debris disks of Alpha Centauri A & B, with the specific objective of identifying potentially habitable Earth-like planets.

Mission Time Life and Orbit
SMEX-Class, 2-Years (>90% completeness), Earth trailing

Spacecraft Bus
LADEE Type, Secondary Payload to GTO

Instrument/Telescope
Unobstructed 45cm, Full Silicon Carbide

Coronagraph architecture
Baseline: PIAA Embedded on Secondary and tertiary telescope mirror. PIAACMC backup

Coronagraph performance
1x10^{-8} raw, 6x10^{-11} @ 0.4” (With ODI)
2x10^{-11} @ 0.7”

Field of View (OWA)
2.5” x 2.5”

Imaging detector
1k x 1k EMCCD 0.08”/px Sampling

Wavelength
400 to 700 nm, Dichroics 5 bands @ 10% each.
**Scientific requirements**

**Goal:** Image 0.5 to 2.0 $R_e$ planets’ equivalent brightness, in the HZ of αCen A&B during a 2 year mission

**Credit:** Billy Quarles, NASAAmes

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<thead>
<tr>
<th>Contrs.</th>
<th>IWA</th>
<th>OWA</th>
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<tbody>
<tr>
<td>αCen B</td>
<td>$6 \times 10^{-11}$</td>
<td>0.4”</td>
</tr>
<tr>
<td></td>
<td>$6 \times 10^{-11}$</td>
<td>0.95”</td>
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<tr>
<td>αCen A</td>
<td>$2 \times 10^{-11}$</td>
<td>0.7”</td>
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<tr>
<td></td>
<td>$2 \times 10^{-11}$</td>
<td>1.63”</td>
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<tr>
<td>Stablility limit (αCen A)</td>
<td>$2 \times 10^{-11}$</td>
<td>2.07”</td>
</tr>
<tr>
<td></td>
<td>$2 \times 10^{-11}$</td>
<td>8.3λ/D</td>
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**Sensitivity**

- SNR=5: 1.6 Days
- ODI Calibration: 30 Days
Instrument Building blocks

45 cm off-axis telescope with an **embedded** PIAA -> $10^{-5}$ (1.6 – $10\lambda/D$)

WFC (Multi-Star Wave Front Control) -> $10^{-8}$

Continuous observation ODI -> $10^{-11}$

AAS 225, Seattle, January 2015
Optical and system design

TOP VIEW

SIDES VIEW

Science image output 5 frames 100x100px

Payload Computer

Controllers (Electronics Box Assembly)

DM Controller TRL-5

PIAA Coronograph TRL-5

Primary Mirror (45 cm of axis)

Secondary (PIAA 1) Tip/Tilt (5°) Focus (10 µm)

Tertiary (PIAA 2) Images pupil on DM

DM TRL-5 Kilo DM 32x32 - 1 µm
Multi-Spectral Imager

- Wavelength: **400 nm to 700 nm** (Contains 40% aCen Aflux)
- **Five channels** of 10% bandwidth each.
- SW (400nm): Blue rayleigh scattering indicates **earth-like atmosphere**. (Const. coatings and QE)
- LW (700): **CH₄ absorption bands**. Limited by QE and WFC bandwidth.

- E2v EMCCD 201-20 almost zero RON
- Short 10s exposure time to avoid cosmic rays
Telescope Hardware

- Full SiC 45cm, Off-axis telescope, L/25 max end-to-end WFE (Total 45Kg mass)
- Active thermal control to maintain 10°C operation with 0.1°C PV stability
- 0.5mas RMS stability LOWFS (Demonstrated for CAT III EXCEDE Lockheed Martin)
Mission operations

High stability pointing spacecraft

Unperturbed observation per quarter, 1.6 days/band/star

Quarterly operations:

- **DSN Downlink** and reaction wheels desaturation and quarter end.
- **90° Roll** to keep sunshield in position
- **Calibration** per quarter (Speckle MSWC, LOWFS).
Conclusion

1) We developed an instrument design to achieve the science goals

2) We developed a mission concept that satisfies instrument stability requirements

3) We are advancing key technologies (PIAA, DM, WFC, Post-processing) for ACESat and other direct imaging missions (AFTA-C, EXO-C, EXCEDE)
Questions?

Image credit: Juan Nabzo, Jan 5th 2015, Chilean Patagonia