Ames Coronagraph Experiment:
Enabling Missions to Directly Image Exoplanets

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Is there another Earth out there?
Is there life on it?
1. **Planet size:**
   ~ 0.5 – 2 Earth size

2. **Temperature:**
   0-100 °C

3. **Biomarkers:**
   water and oxygen

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**not habitable**
- (too large, hydrogen gas does not escape)

**habitable**
- (too small to keep oxygen and water)

Credit: Petigura/UC Berkeley, Howard/UH-Manoa, Marcy/UC Berkeley

(Schematic representation only)
Detecting atmospheric oxygen and water likely indicates life (because very few non-biological processes can sustain an oxygen atmosphere)
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Beyond Kepler: Direct imaging missions

2010

Kepler

2020

Small sats (0.25-0.7m, ~$10 – 200M)
Earth-size
Habitable zone
Spectroscopy
Two stars: \( \alpha \)Cen

Exo-C or AFTA
(1.5m / 2.4m, $1B / $2B+)

New Worlds Telescope
($4-8m, $4B+)

2030

Earth-size
Habitable zone
Spectroscopy
~100s of Earths

Another Earth?

Simulation of an exo-Earth around \( \alpha \)Cen with a $1B mission (1.5m telescope)

All these missions also do ground-breaking science on non-habitable planets
The Ames Coronagraph Experiment (ACE)
People and organizations partnering with ACE

NASA ARC
- Ruslan Belikov
- Thomas Greene
- Eugene Pluzhnik
- Sandrine Thomas
- Fred Witteborn
- Dana Lynch
- Paul Davis
- Eduardo Bendek
- Kevin Newman

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- Glenn Schneider
- Julien Lozi

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- Asfaw Bekele
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- Titus Roff
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STScI
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JPL
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- Andy Kuhnert
- John Trauger
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- John Krist
- Marie Levine
- Stuart Shaklan
- K. Balasubramanian

Lockheed Martin
- Domenick Tenerelli
- Rick Kendrick
- Alan Duncan
- Wes Irwin
- Troy Hix

UofA

L3 Tinsley

Princeton

STScI

JPL
Stars are a billion times brighter...
than the planet

hidden in the glare.
Like this firefly.
Blocking the star: the PIAA Coronagraph (phase-induced amplitude apodization)

- PIAA is a powerful technology to block the star in order to reveal planets
- Successful track of technology development at Ames over the past 6 years (as well as at partner institutions)
- One of the potential architectures selected by NASA for the Exo-C and AFTA missions

Mission concepts using PIAA

Small Sats (0.25-0.7m)  Exo-C (1.4m)  AFTA (2.4m)  NWO (4m)

PIAA M1

- Original uniformly illuminated pupil plane
- Focal plane
- Shaped pupil Apodizer
- New, apodized pupil plane
- Focal plane

PIAA M2

Mission concepts:

- Alpha Centauri
- Tau Ceti
- ExoEarth direct image simulations

Ruslan Belikov, NASA Ames Coronagraph Laboratory
Testbeds and critical hardware

ACE testbed

Lockheed Martin

JPL

PIAA lenses

PIAA mirrors

State of the art performance in the lab

Deformable mirror

Ruslan Belikov, NASA Ames Coronagraph Laboratory
Highlighted effort: \(\alpha\)Cen imager

- Recently started
- 0.25m telescope
- \(~\$5M\) (rough estimate)
- Theoretically capable of finding biomarkers on habitable planets around \(\alpha\) Centauri (if they exist)
Conclusions

- Technology to find biomarkers and life on other worlds is rapidly maturing.
- If there is a habitable planet around the nearest star, we may be able to detect it this decade with a small satellite mission.
- In the 2030 decade, we will likely know if there is life in our Galactic neighborhood (~1000 nearest stars).