Ames Coronagraph Experiment:
Enabling Missions to Directly Image Exoplanets

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Is there another Earth out there?
Is there life on it?
Requirements for habitability

1. Planet size: 
   ~ 0.5 – 2 Earth size

2. Temperature: 
   0-100 °C

3. Biomarkers: 
   water and oxygen

Credit: Petigura/UC Berkeley, Howard/UH-Manoa, Marcy/UC Berkeley
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**
  - Earth-size
  - Habitable zone
  - No spectroscopy (biomarkers)
  - Not nearby systems

**2020**

- **Small sats**
  - (0.25-0.7m, ~$10 – 200M)
  - Earth-size
  - Habitable zone
  - Spectroscopy
- **Exo-C or AFTA**
  - (1.5m / 2.4m, $1B / $2B+)
- **New Worlds Telescope**
  - ($4-8m, $4B+)

**2030**

- **Another Earth?**
  - Simulation of an exo-Earth around αCen with a $1B mission (1.5m telescope)
  - Earth-size
  - Habitable zone
  - Spectroscopy
- **~2-6 stars**

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
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K. Balasubramanian

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

PIAA M1
- Shaped pupil Apodizer
- Original uniformly illuminated pupil plane
- New, apodized pupil plane
- Focal plane

PIAA M2
- Focal plane

Mission concepts using PIAA
- Small Sats (0.25-0.7m)
- Exo-C (1.4m)
- AFTA (2.4m)
- NWO (4m)

ExoEarth direct image simulations
- Alpha Centauri
- Tau Ceti

Courtesy of K. Cahoy

Ruslan Belikov, NASA Ames Coronagraph Laboratory
Testbeds and critical hardware

ACE testbed

Lockheed Martin

JPL

PIAA lenses

PIAA mirrors

Deformable mirror

State of the art performance in the lab

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

- Recently started
- 0.25m telescope
- \(~\$5\text{M (rough estimate)}\)
- 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).