#### Understanding the Impact of Polarization Aberration on Direct Exoplanet Detection

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#### l'm a Hawaii-born Optical Engineer UCSB Slide 2 **B.S.** Optical Engineering Ph.D., M.S. Optical Sciences Learned to be a human here Waikoloa Village Flagstaff University of Anzona Roct este College of egetical Science Syracuse **NEW YORK** TUCSARIZONA National For • Phoenix SAN CARLOS University of Rochester Institute of Optics PENNSYLVANIA

Hey Telescopes are cool! - Young Jaren, probably

Hey Optics is cool! - Slightly older Jaren, probably

Hey Telescope optics are cool! - 5 months ago Jaren, definitely

## NHFP Sagan Fellow





### Polarization and High-contrast Imaging

How the direction light wiggles interferes with our goal to find aliens with strategic light-blocking

## **Defining Polarization**



"Light wiggles in a direction"

We typically concern ourselves with the electric field because it's easy to detect

Definition

The Polarization is the orientation of the  $\vec{E}$  vector



Source: Wikimedia commons



# Defining High-contrast Imaging



#### The Star and Exoplanet



#### What a telescope sees





# Effect of Coronagraphy



#### Without Coronagraph



(b)

#### With Coronagraph







Ground-based

All will experience polarization aberration

Space-based



All will experience polarization aberration

Space-based







Ashcraft et al in Review, JATIS

### The Path Forward



There exist modeling tools that allow us to simulate an observation

Leverage astrophysical degrees of freedom (integration time, number of observations) to optimize detection!





### HWO Parameter Study Team





# Polarimetry in the Laboratory

How we validate our optical modeling tools

## Polarimeter Operation in Python



<u>Katsu</u> is a platform for integrated Mueller calculus simulation and polarimetry in the laboratory



Ashcraft et al in Review, JOSS





Ashcraft et al 2024

# Polarimetry of a Coronagraph





Indicative of coating inhomogeneity and/or anisotropy Ashcraft et al 2024



Ashcraft et. al 2022

# Moving Forward with

Guess the Name!



A remotely-operable polarimetry testbed at UCSB Exopol lab



### Moving Forward with Derp\*



#### A remotely-operable polarimetry testbed at UCSB Exopol lab



Pushing the sensitivity limits of polarimetry in the lab with:

Polarization phase retrieval

Polarimetric digital holography

Minimum-covariance polarimetry

\*The phoneticization of the Dual-Rotating Retarder Mueller Polarimeter (DRRP) acronym (I blame my grad students)

# Summary



- HCl in the next decade must now contend with polarization aberration
- Open-source tools help us model & validate the polarization of optical instrumentation

<u>Goal</u>: Validate optical models of polarization aberration



# Mahalo Nui Loa

Thank you very much!

# Backup Slides





## Metasurface and Polarimetry Team





Jaren Ashcraft NHFP Fellow



Skyler Palatnick UCSB Physics Graduate



Will Melby UCSB Physics Undergraduate



Max Millar-Blanchaer UCSB Physics Faculty

How do we make and measure spatiallyvarying polarization optics?

### Internships at UH IfA



Akamai 2016 Cohort, UH IfA Maui



Worked with Dr. Jeff Kuhn and Dr. Andre Fehlman Did a 2<sup>nd</sup> Akamai in 2018 with Reni Kupke at UCSC

UH IfA REU 2017 Cohort, IfA Hilo



Worked with Dr. Christoph Baranec

#### Connection to Akamai





# Summary



- Polarization is an exciting phenomenon in astronomical telescopes that can both help and hurt high-contrast imaging
- We've developed open-source modeling tools to determine sources of polarization aberration
- We are designing methods by which to measure polarization aberration
- I am doing this work from Hawai'i to assist with the development of the local STEM workforce

### UASAL's Gromit Polarimeter





Capable of direct Mueller Matrix measurements

Dual-rotating retarder Mueller polarimetry



Ashcraft et. al 2024

#### Space Coronagraph Optical Bench



Yes, <u>that</u> Scoob



Ashcraft et. al 2022

### Observing SCoOB with Gromit



Enables Full Mueller Polarimetry of a Coronagraph's Exit Pupil

*Direct* measurement of polarization aberrations!

 Rotating PSA

 Quarter-wave Plate

 Fixed PSA

 Quarter-wave Plate

 Guarter-wave Plate

 Fixed PSA

 Outration

 Fixed PSG

 Polarizer

 Rotating PSG

 Collimating

 Lens

Ashcraft et. al 2024











Takes about 45mins to generate on an NVIDIA V100S GPU node

Ashcraft et al in Review, JATIS











5.0

4.5

5.5

6.0

4.0

3.5

4.5

5.0

Angular Separation,  $\lambda/D$ 

5.5

6.0

2.5

3.0

3.5

4.0

Angular Separation,  $\lambda/D$