



A journey through grad school

Adam B. Johnson (he/him)

Ph.D Candidate

Dept. of Mech. Engineering

University of Victoria

Where it began

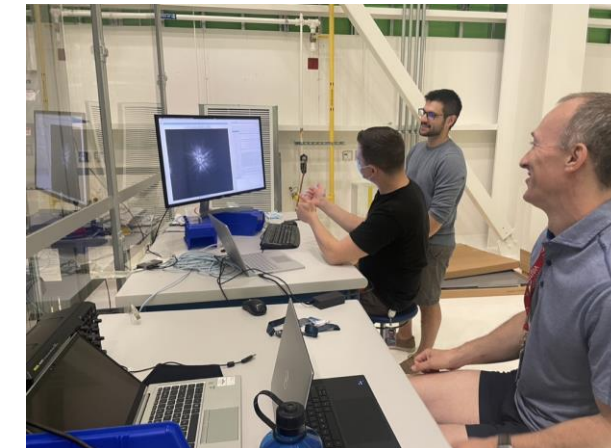
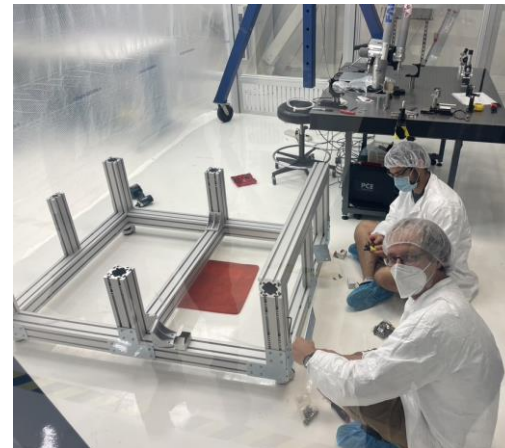
- Born 1995, Brentwood Bay, BC, Canada
- Stelly's Secondary High School 2013
- Camosun College
 - Mech. Engineering Technology 2015
 - Bridge Mech. Engineering Technology 2018
- University of Victoria
 - BEng - Mech. Engineering 2021
 - PhD - Mech. Engineering 2021~2025
- NRC HAA – 2021 and beyond
 - NEW EARTH Lab team
 - GPI2 CAL2 team



Joining the NEW EARTH Lab team

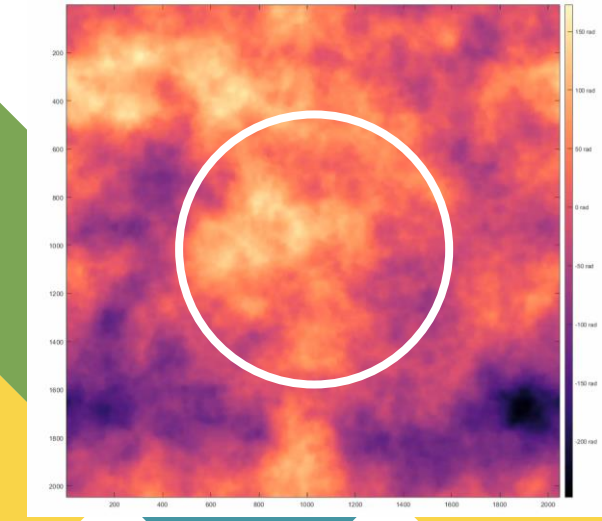
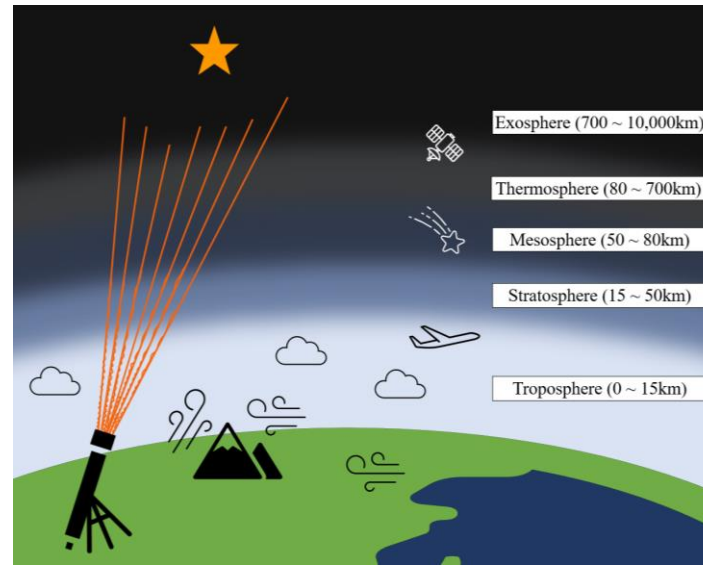


- NRC's Extreme Wavefront control for Exoplanet & Adaptive optics Research Topics at Herzberg (NEW EARTH)
 - A lab where we try new and crazy ideas
- Subaru Pathfinder Instrument for Detecting Exoplanets and Retrieving Spectra (SPIDERS)
 - Student built exoplanet imager with new technologies
 - Lead on mech. structure, FTS, and chopper.

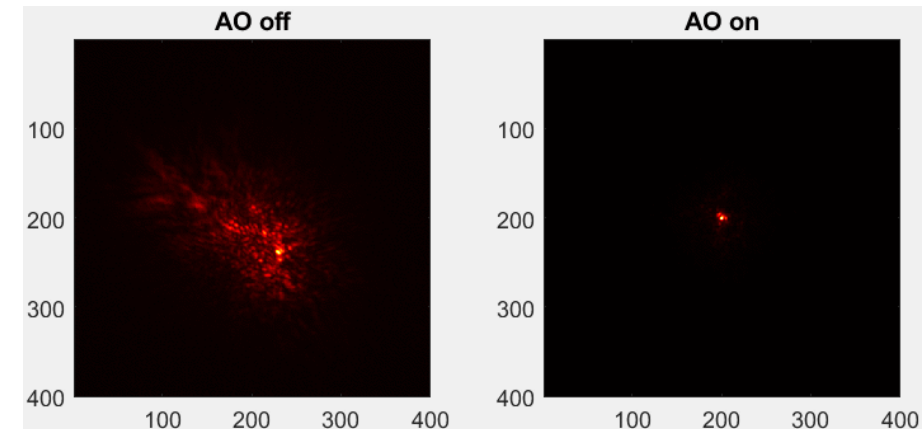
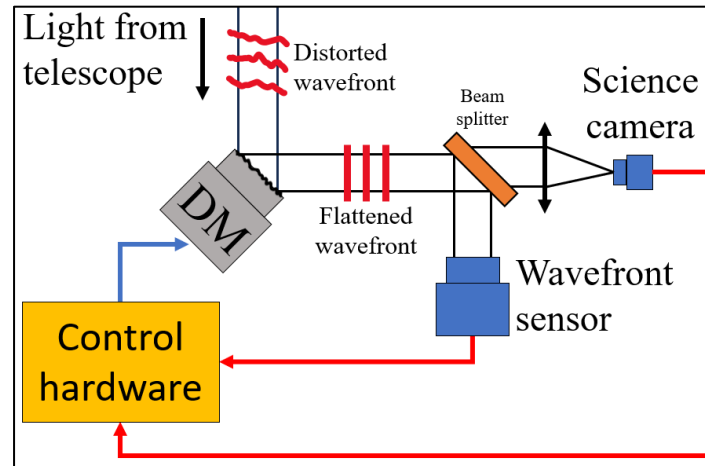


What our research focuses on

- Atmospheric turbulence distorts the image we are trying to capture
- Adaptive Optics (AO) uses wavefront sensing (WFS) to measure and reshape the wavefront
- The deformable reflective surface can change shape at kHz speed



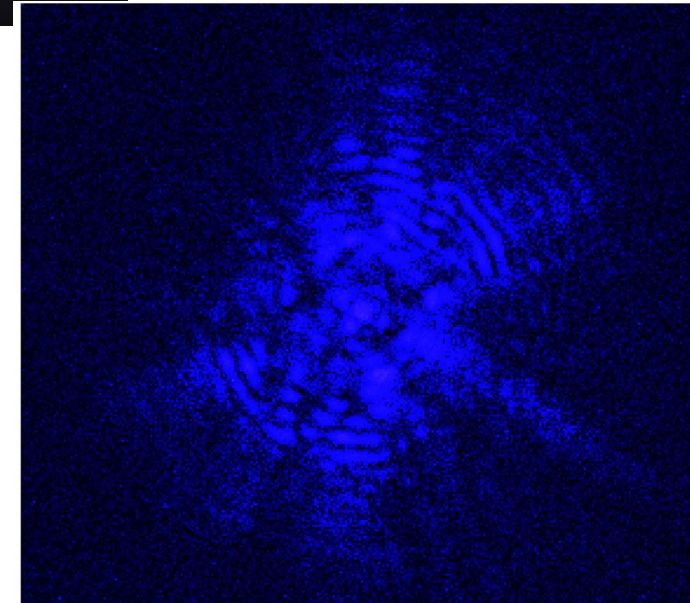
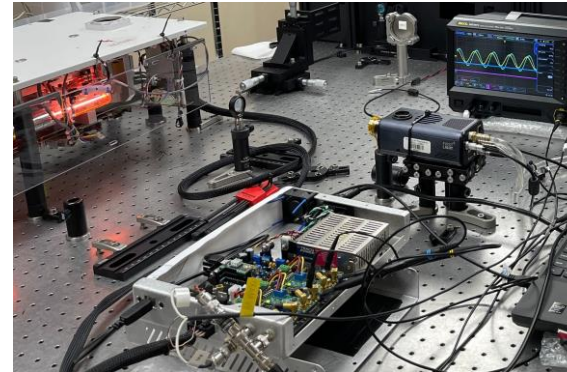
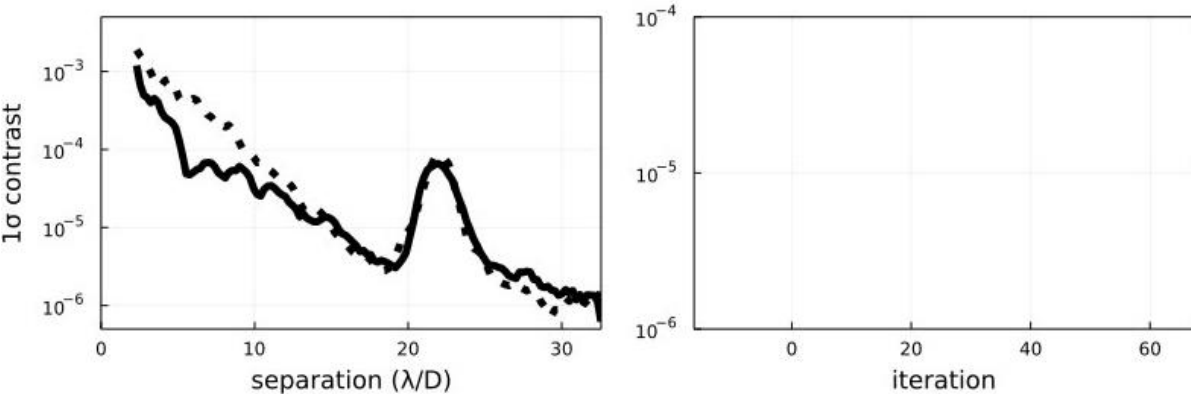
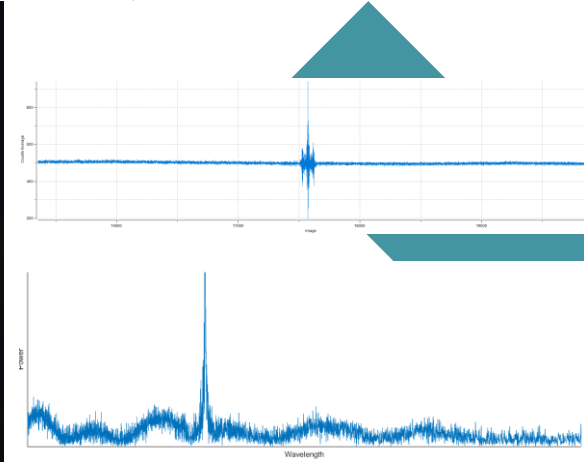
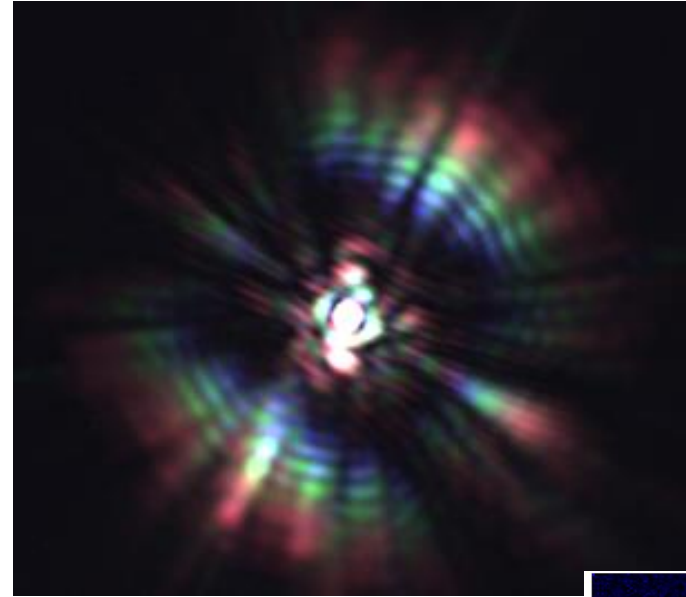
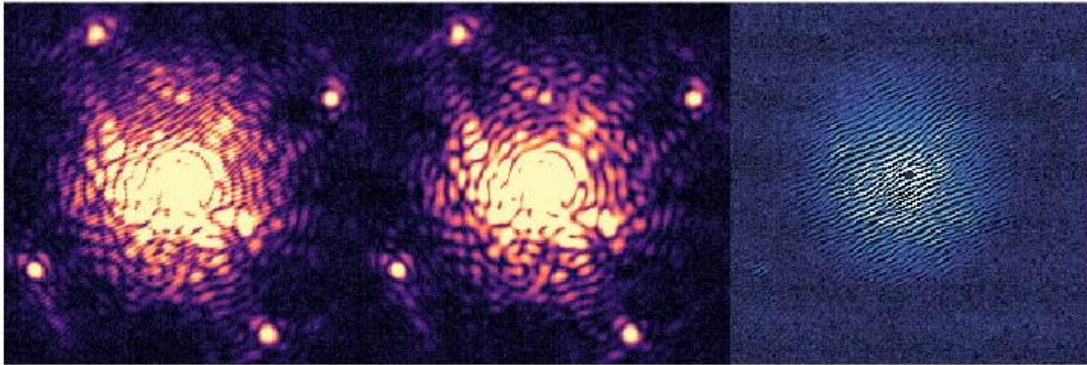
<https://www.alpao.com/products-and-services/deformable-mirrors/>



<https://www.lam.fr/en/new-results-for-papyrus-at-ohp/>

First lab results with SPIDERS

- Initial AO and characterization results 2023
- Development still underway for delivery and commissioning at Subaru telescope ~2025

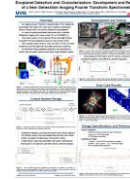
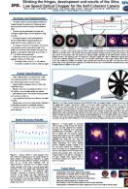


Sharing knowledge through publications

Conference proceedings and posters help build reputation

Poster presentations/talks provide great practice for public speaking

Traveling to network with and learn from experts in the field



Blinking the fringes, initial development and results of the Ultra-Low Speed Optical Chopper for the Self-Coherent Camera

Adam B. Johnson^{a,b}, Christian Marica^{a,b}, Darryl Ganzioli^a, Joffel Fitzsimmons^a, Olivier Lardiere^a, William Thompson^a, Garima Singh^a, and Colin Bradley^a

^aUniversity of Victoria, Victoria, BC, Canada.
^bNational Research Council Canada, HIA, Victoria, BC, Canada.

ABSTRACT

Optical chopping is a step taken to acquire calibrated images for high-contrast instruments such as our SPIDER instrument, the CALZIO Gemini Phase Imager II upgrade, and other future projects. A unique design with smooth, continuous, and slow operation is needed to blink the fringes and self-align images for fine and bright stars. The Ultra-Low Speed Optical Chopper (ULSOC) must blink between 0.01 Hz and 100 Hz with some fine operations, step in the 'on' or 'off' position, and have the timing controlled by an external trigger. Because designers are obliged to ensure it is vibration-isolated from other components in the system. The self-aligning system accepts any chopping wheel between 10-20 blocks without the need to reconfigure software and will find its better position on every power-up. The ULSOC communications actively to start and stop as needed during operation. Long operational periods (during steady operations) over a lifetime of at least 10 years, closed-loop stepper motor control and optical feedback from the chopper wheel guarantee accurate and repeatable velocity and position. Initial prototype show that smooth and some fine operations are possible for the desired speed range, and vibration is well-managed. Further development this year will lead to a fully functional device to be tested closely with our SPIDER instrument and test the way to overcome the road for future projects.

Keywords: Optical chopper, high-contrast imaging, differential imaging, self-coherent camera, exoplanet, smart motor, SPIDER, NEW HORIZON Lab.

1. INTRODUCTION

Optical systems use devices known as optical choppers for a variety of reasons. Although the system is being used in one either gravity, the primary purpose of an optical chopper is simply to block and unblock a beam of light, in a consistent and periodic manner. By rotating a blade with slanted and evenly distributed gaps, light traveling through the gap will blink on and off. Figure 1 below illustrates an incoming beam with some constant intensity as a function of time. As the beam passes through the rotating blade, the intensity as a function of time is divided into discrete and evenly distributed intensity pulses.

Figure 1. Chopping an optical beam with a rotating segmented blade. The intensity is "chopped" into discrete pulses.

AO4ELT7 - June 2023 - Abstract

Exoplanet Detection and Characterization: Development and Results of a New Generation Imaging Fourier Transform Spectrometer

Adam B. Johnson^{a,b}, William Thompson^a, Kris Caputa^a, Frédéric Grandmont^a, Christian Marica^{a,b}, Tim Hardy^a, Joffel Fitzsimmons^a, Olivier Lardiere^a, and Colin Bradley^a

^aUniversity of Victoria, Victoria, BC, Canada
^bNational Research Council Canada, HIA, Victoria, BC, Canada
^cABB Inc., Montréal, QC, Canada

ABSTRACT

Spectroscopy in exoplanet imaging has been used to characterize exoplanets in astronomy for the last two decades. To optimize new and existing techniques, such as using very high-spectral resolution to identify exoplanet molecules in a speckle-limited image, new imaging spectrograph technologies are needed. These new techniques are difficult to implement as they require both a large field-of-view (FOV) to search for hidden exoplanets, and a high-resolution spectrum for every resolution element of the FOV. The Subaru Pathfinder Instrument for Detecting Exoplanets & Retrieving Spectra (SPIDER) will discover a new generation imaging spectrograph, using an imaging Fourier transform spectrometer (FTS) to acquire a wide FOV from low R-R to high R-R/2000 spectral resolution. On-chip detector have low cost for area speed and shape control as typical applications can provide a bright light source to take advantage of faster scan speeds with a high spectral signal-to-noise ratio. Implementing new imaging methods and faster techniques, SPIDER requires an FTS that can scan much slower than usual to minimize the impact of detector read noise while prioritizing scan stability. Using an off-the-shelf Metrolab instrument, a custom PCB was developed and implemented to facilitate a slow and driving and telemetry feedback circuit that will provide complete control over scan speed, length, and shape. A ball-balancing laser provides fringe quadrature feedback that is used to determine Algorithm-level positional feedback for closed-loop control. The C-based controller generates a 1-bit current command at 10kHz to provide stable scanning and accurate pointing. Preliminary results are proving the success of the drive and telemetry event design, the quadrature algorithm, and the closed-loop control. The paper will present the controller design and implementation, along with its performance and initial results on the bench.

Keywords: Imaging Fourier transform spectrometer, Metrolab instrument, fringe quadrature, fringe quadrature, closed-loop control, exoplanet imaging and characterization, adaptive optics

Send correspondence to: adam@johnsonbc.ca

A SmallSat mission study for STARLITE: Superluminal Tomographic Atmospheric Reconstruction with Laser-beacons for Imaging Terrestrial Exoplanets

Adam B. Johnson^a, Ashley Padua^a, Ryan Hughes^a, Christine Brannon^a, Zane Chapman^a, Alexis Kelso^a, Veronica Hryckto^a, Milan Malzer^a, Adler Smith^a, Aliu Taqi Md Taha^a, Akshita Parashar^a, Rishi Hrudanesh^a, Qishi Lu^a, Andrew Adam Kowalik^a, Devin Dreyfus^a, Verena Padua^a, Juan Lopez^a, Dariah Srivastava^a, Joshua Umanov-Castro^a, Andrew van Peltkoo^a, and Elaine Pritz^a

^aUniversity of Victoria, British Columbia, Canada
^bCornell University, Ithaca, NY, United States of America
^cDipartimento di Fisica, Milano, Italy
^dUniversity of California Los Angeles, Los Angeles, CA, United States of America
^eCalifornia Institute of Technology, Jet Propulsion Laboratory, Pasadena, CA, United States of America
^fGeorgia Institute of Technology, Atlanta, GA, United States of America
^gUniversity of Michigan, Ann Arbor, MI, United States of America
^hBoston University, Boston, MA, United States of America

ABSTRACT

In the search for life in our galaxy, and for understanding the origins of our solar system, the direct imaging and characterization of exoplanets is a key research objective. One of the most significant challenges in this search is the detection and characterization of exoplanets in the habitable zone of their host stars. The STARLITE mission (Superluminal Tomographic Atmospheric Reconstruction with Laser-beacons for Imaging Terrestrial Exoplanets) is a SmallSat mission designed to address this challenge. STARLITE will use a highly optimized and novel optical path to enable tomographic reconstruction of the atmosphere for exoplanets using adaptive optics (AO). Through the use of current and next-generation extremely large ground-based telescopes, the STARLITE constellation of six ~1000kg cubesat will provide 3 magnitude artificial guide stars from a 10m basing telescope in a sub-arcminute field of view for up to an hour. Careful selection and design of the 1000m basing laser will allow AO detection and characterization of exoplanet atmospheres. At a size of 100kg, each satellite weighs only 10kg and utilizes newly commercially available off-the-shelf parts to keep costs per satellite around \$2M. In this paper we will present the satellite mission concept and early 3D system design for the STARLITE constellation.

Keywords: Manuscript format, imaging, SPIE Proceedings, LaTeX

1. INTRODUCTION (0.5 PAGE)

One of the biggest challenges of imaging exoplanets from Earth is the turbulent atmosphere that distorts the incoming wavelength, adding speckles to the captured images and hiding potential exoplanets. Communication techniques to space allow us to avoid the turbulent atmosphere, but at substantial cost and constrained observation times. Direct observation of the FTS with a tiny primary mirror (using many billions of dollars in construction) compared to ground-based observations like Keck I and II with 10m primary mirrors around \$100M each. Using smaller 8m and future 10m ground-based telescopes, adaptive optics (AO) can help us correct and see through the turbulent atmosphere, utilizing the resolving power of larger and cheaper telescopes on Earth. STARLITE uses principles of AO and tomographic reconstruction to reconstruct and correct multiple layers of the atmosphere in real-time to enable higher contrast and more efficient detection and characterization of exoplanets. Using a ground-based laser guide star (LGS) to improve imaging detection and characterization of exoplanets, STARLITE can take full advantage of AO to improve imaging detection and characterization of exoplanets orbiting nearby sun-like stars. This paper will discuss the satellite mission and

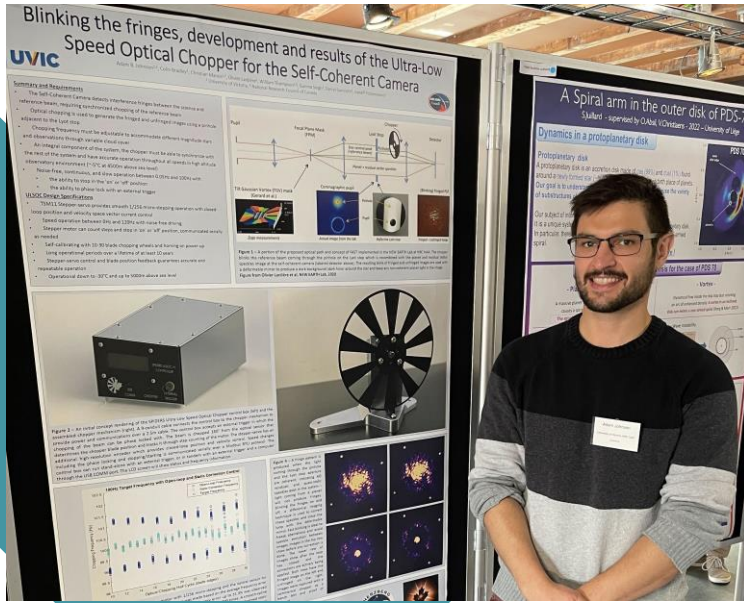
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SPIE.



SPIE.

Traveling to share and learn 2022



NTCO AGM
Poster presentation
Montréal, Canada

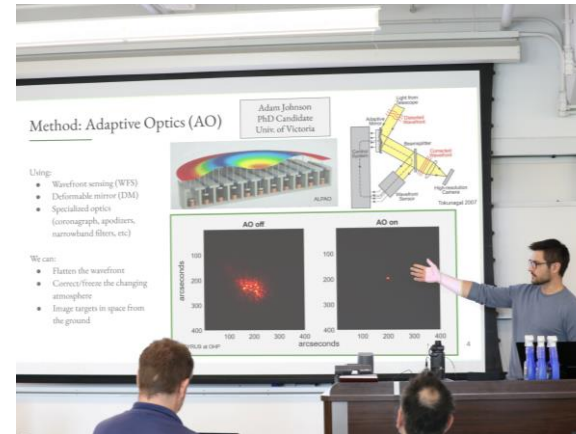
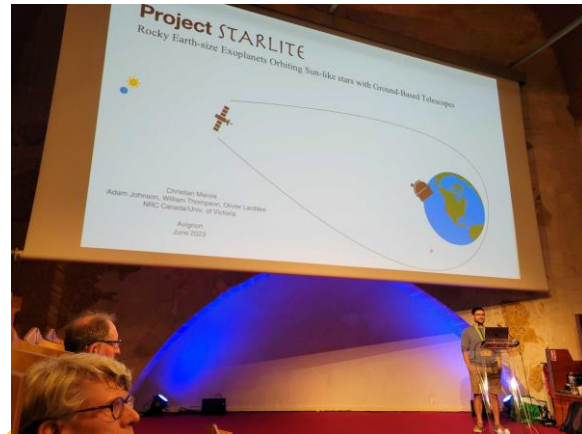
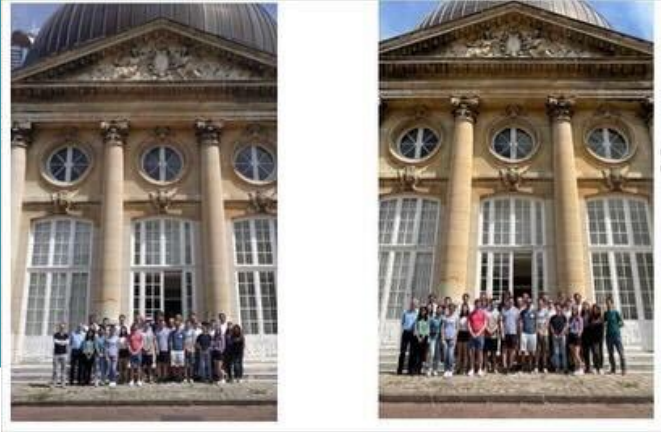
Spirit of Lyot Conference
Poster presentation
Leiden, Netherlands



SPIE Conference
Poster presentation
Montréal, Canada



Traveling to share and learn 2023



CDI Workshop
Paris, France

A04ELT7 Conference
Talk
Poster presentation
Avignon, France

SmallSat Design Course
PI for STARLITE Mission
Cornell University, USA

Dunlap Institute
Instrumentation Workshop
Toronto, Canada

Making sure to enjoy the city



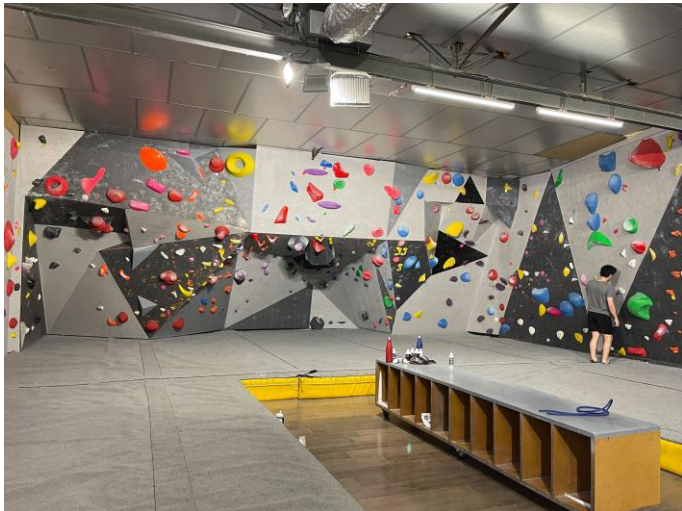
Leiden, Netherlands



Montréal, Canada



Montréal, Canada



Avignon, France



Cornell University, USA



Toronto, Canada

Where my research is now

~1.5 years of PhD remaining

STARLITE PhD thesis – optical simulations and system design

GPI2 CAL2 mech. Eng.

FPM Wheel Engineering Lead

PM Engineering Lead

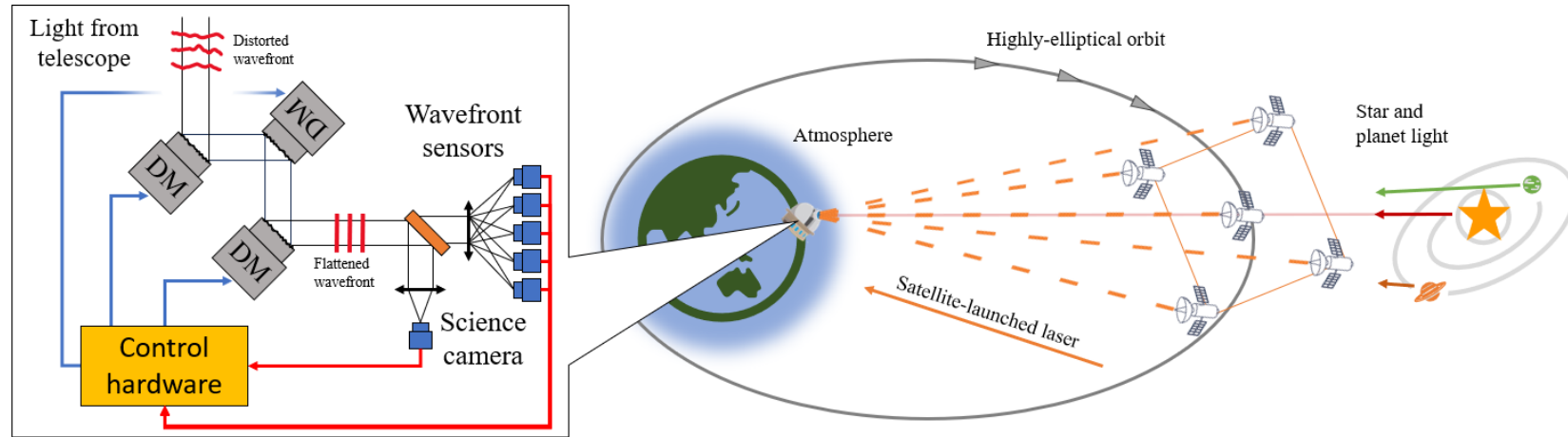
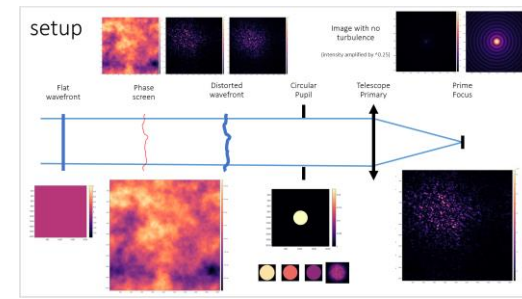
Chopper Lead

SPIDERS Mechanical Eng. Lead

IFTS Engineering Lead

Chopper Engineering Lead

Small engineering jobs with REVOLT and NFIRAOS



https://commons.wikimedia.org/wiki/File:Panorama_of_Mauna_Kea_Observatories.jpg

Lessons learned and final takeaways



- Seek feedback and ask questions
- Build an effective network
- Set personal goals, schedules, and be organized
 - Grad school is a marathon, not a sprint
- Be yourself, have fun

2008

Thank you

HR 8799
Keck 3.8 μm

W. Thompson
and C. Marois

