Updated Polarimetric Calibration for the Subaru/SCExAO/CHARIS High-Contrast Imager

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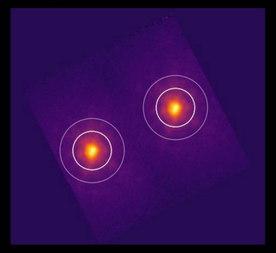
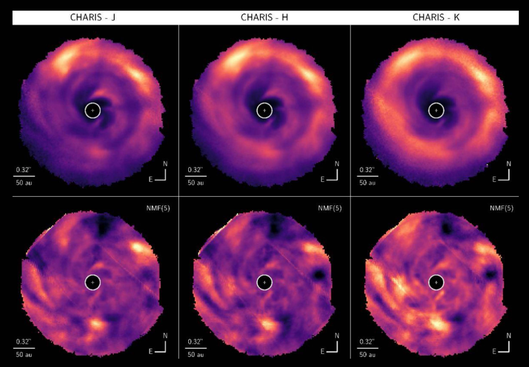
Introduction

CHARIS is an integral field spectrograph (IFS) fed by the SCExAO extreme adaptive optics system with a spectropolarimetric mode. This enables **polarimetric differential imaging** (PDI) across 22 wavelength bins.



CHARIS PDI image: unpolarized standard star

PDI across wavelengths facilitates direct imaging of circumstellar disks, brown dwarfs, and exoplanets.



AB Aurigae, Lucas et. al in prep

Accurate polarimetry requires regular updates to the **Mueller matrix model** to account for **instrumental polarization** and changes in the instrument.

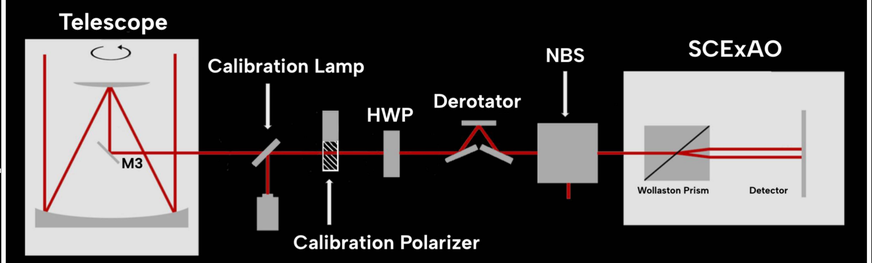
The Math of the Model

Mueller matrices transform **Stokes vectors**: vectors that describe polarized light in a basis of orthogonal polarizations.

$$M \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix} \rightarrow \begin{pmatrix} I' \\ Q' \\ U' \\ V' \end{pmatrix}$$

How the Optical Path Affects Polarization

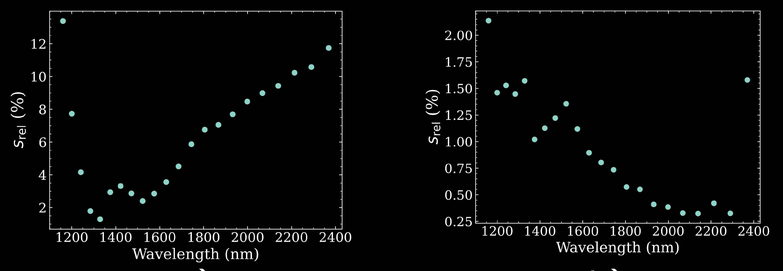
Anytime incident light hits a component in the optical path, the polarization state is altered. We use a chain of Mueller matrices to quantify this effect and recover a target's original polarization state.



Polarizing optical components in the Subaru/SCExAO optical path, adapted from Hart et. al 2021

Improving the Existing Model

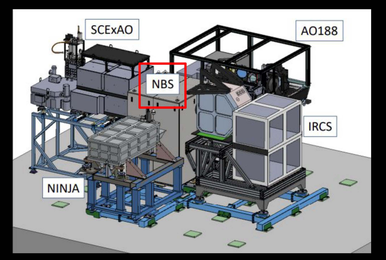
Using calibration data from 2025, we found that the Hart+ 2021 model produced poor accuracy with this new data set, likely due to changes within the instrument over the years since that model's creation. After adjusting the model and characterizing the near-infrared wavefront sensor dichroic, the **relative polarimetric accuracy,** the accuracy that scales with how polarized the target is, now is comparable to what was achieved in 2021.



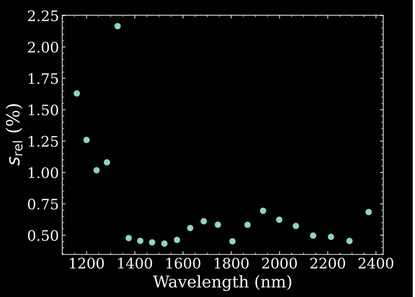
*Relative polarimetric accuracy with the Hart et. al 2021 model (**a**) and the updated model (**b**) on the June 2025 calibration data*

The NBS Install

In September 2025, we received a new batch of calibration data following the major Nasmyth beam-switcher (NBS) install. We found that this beam-switcher had minimal impact on the polarimetric accuracy, and slight model adjustments with the new data further improved relative polarimetric accuracy.



Nasmyth platform, Hattori et. al



Post-NBS relative polarimetric accuracy

Making the Code Open-Source

Making source code public increases the transparency and accessibility of our work. It is available as part of a user-friendly polarimetric calibration package, pyPolCal, currently compatible with CHARIS and SCExAO/VAMPIRES.

pyPolCal