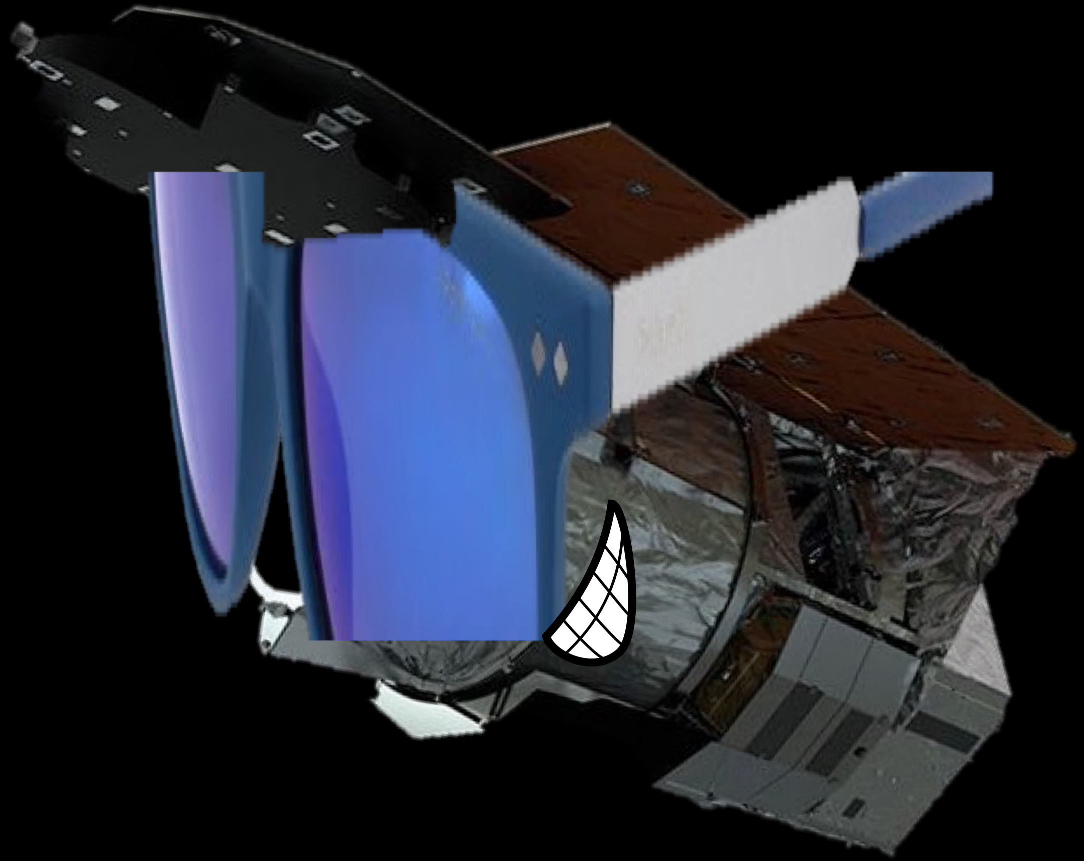
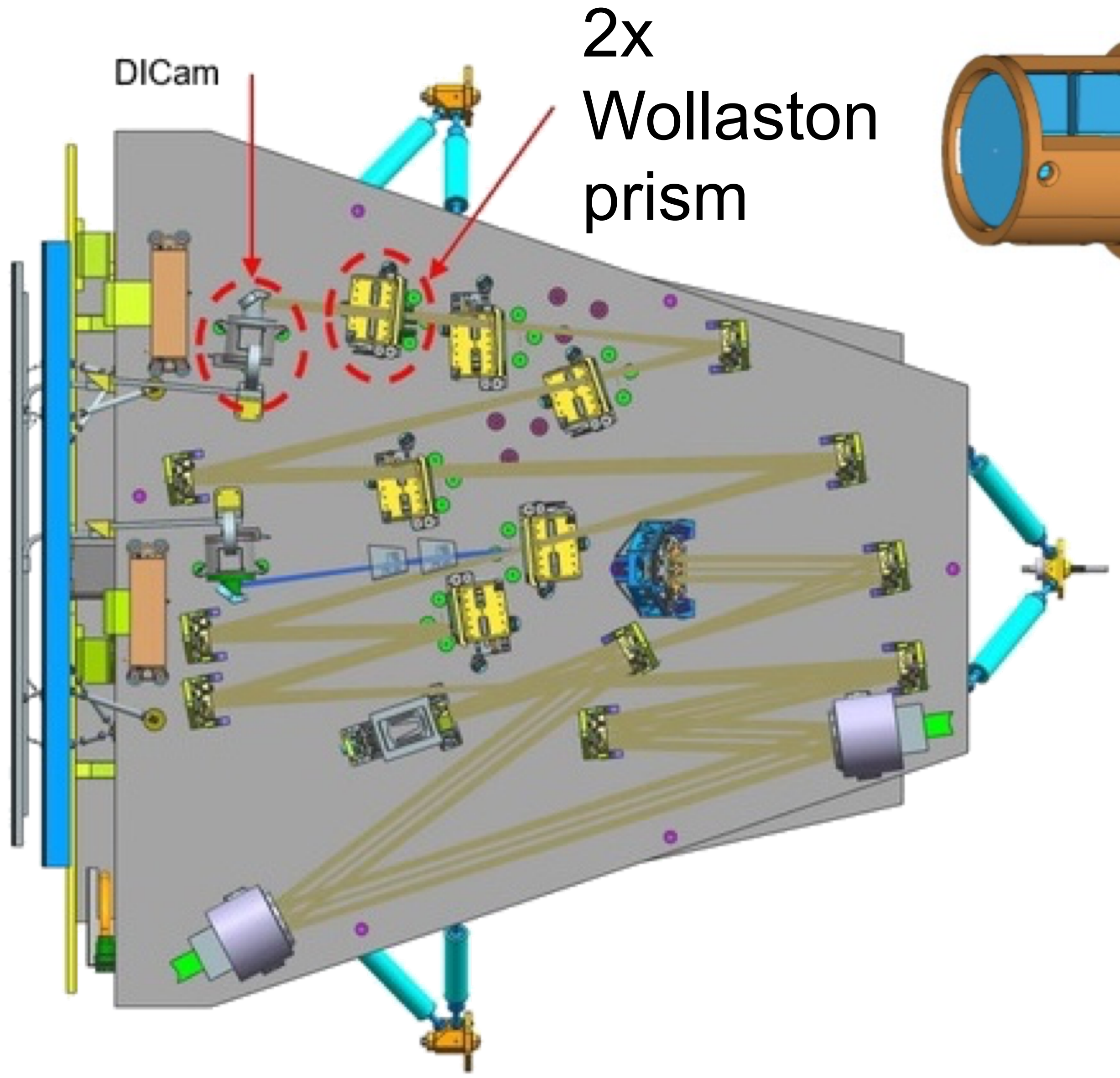
Polarimetric characterization of exoplanets and debris disks

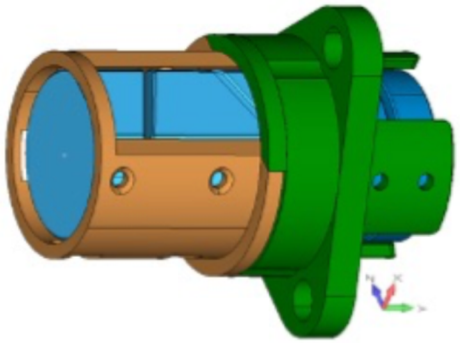
with the Nancy G. Roman Space Telescope Coronagraph Instrument

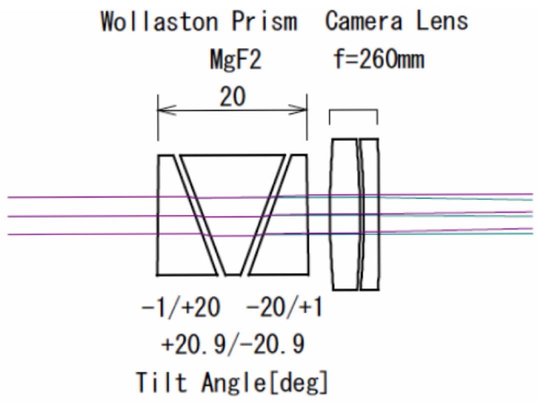


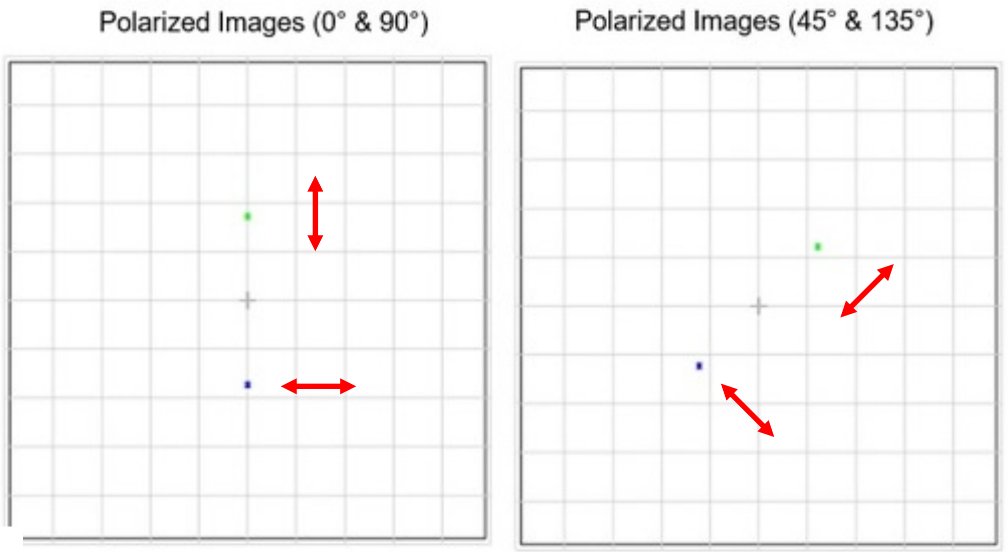
Frans Snik, David Doelman, Rob van Holstein | *Leiden*
Jeroen Rietjens, Michiel Min | *SRON*
Daphne Stam | *Delft*
Christian Ginski, Carsten Dominik | *Amsterdam*
with input from Bertrand Mennesson, Vanessa Bailey | *JPL*

polarimetry with RST-CGI





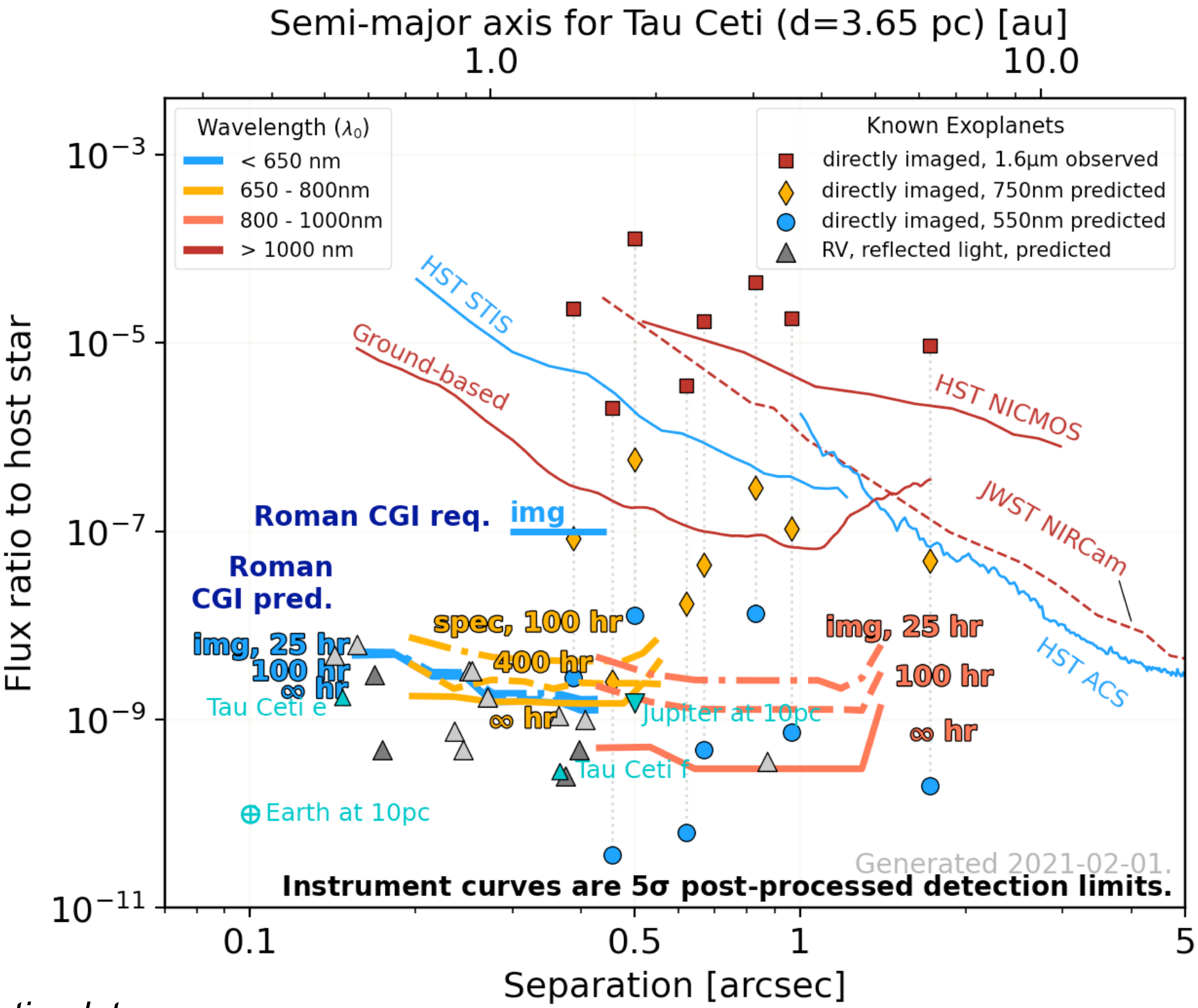




polarimetric mode offered in
band 1 (575 nm) and band 4 (825 nm)

Tang et al. (2019), Kasdin et al. (2021)

RST-CGI contrast performance



https://github.com/nasavbailey/DI-flux-ratio-plot

high-contrast imaging + polarimetry

- **Massive success story for ground-based high-contrast imagers:**
  - disk science: planet-forming disks around range of stars;
  - structure (due to planets?) + dust properties;
  - SPHERE-IRDIS: ~50% of the publications from ~15% of the observing time.

- **Main challenges that cannot be solved from the ground:**
  - sensitivity for faint disk structures;
  - image quality in visible light;
  - fractional polarization from polarized flux and intensity.

- **Instrumentation challenges:**
  - make the combination (HCI + polarimetry) at the least the best of both worlds;
  - calibrate all the many systematics that degrade the polarimetric performance.

polarimetric science cases for RST-CGI

1. **Debris disks & faint young disks:**
   - structure;
   - phase function;
   - dust properties.

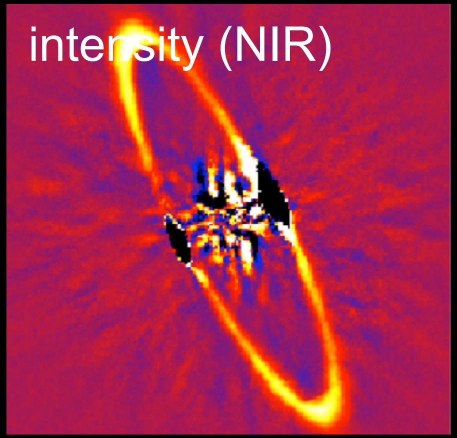
2. **Jupiters in reflected light:**
   - detection likelihood;
   - atmospheric properties.

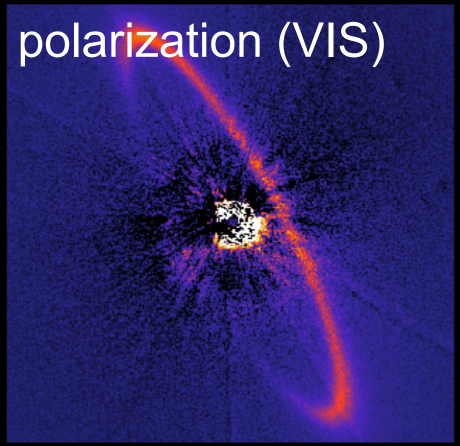
3. **Stuff around massive stars:**
   - dust shells;
   - clumps, ejecta, jets;
   - etc.

disk polarimetry with RST-CGI

- **Debris disks & faint young disks:**
  - around bright stars;
  - structure much brighter than contrast floor.
- **Unique spatial resolution and sensitivity in the visible:**
  - dust distribution;
  - disturbances due to planets.
- **Fractional polarization + two colors :**
  - dust particle size distribution.

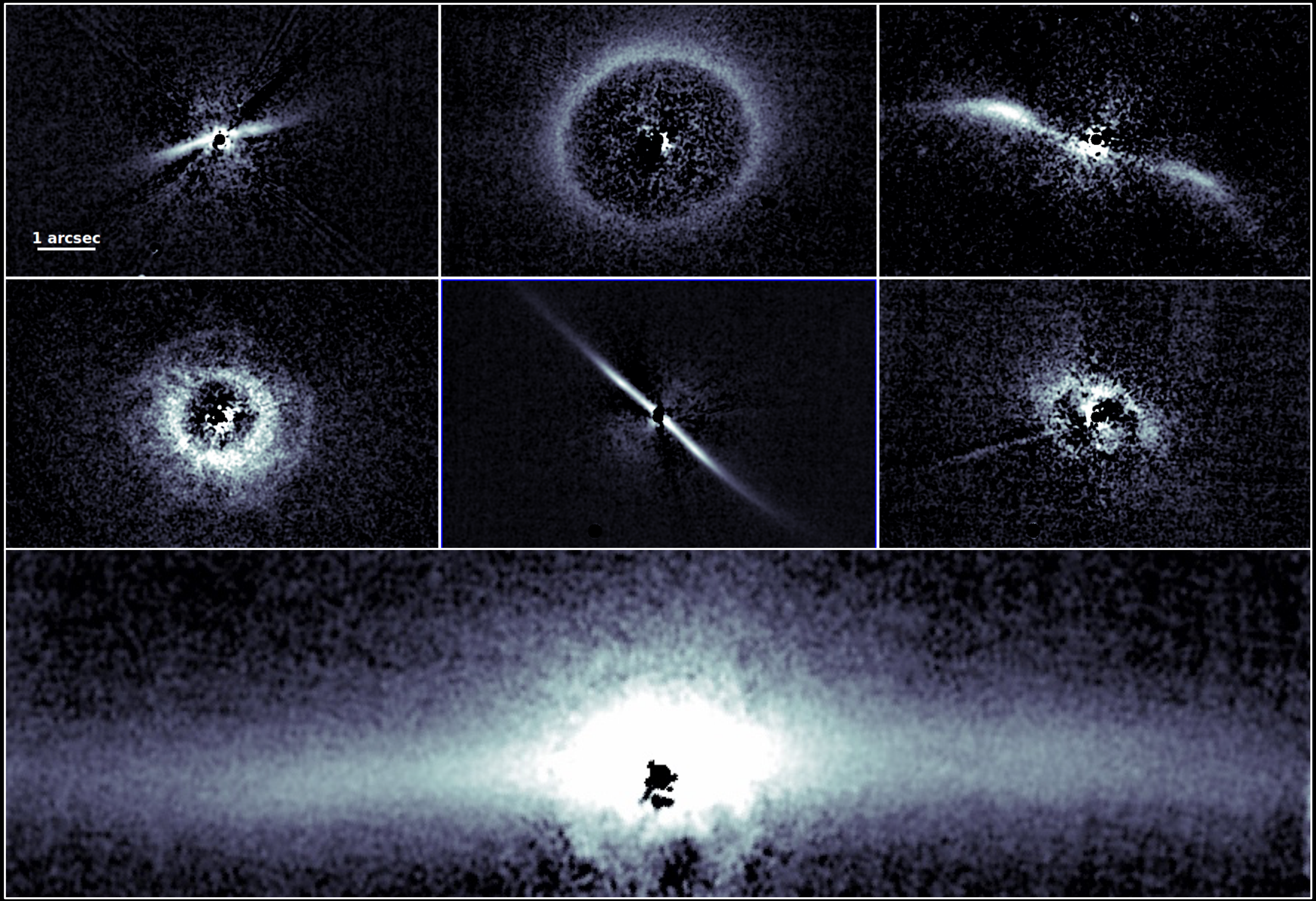
HR 4796





Milli et al. (2017, 2019)

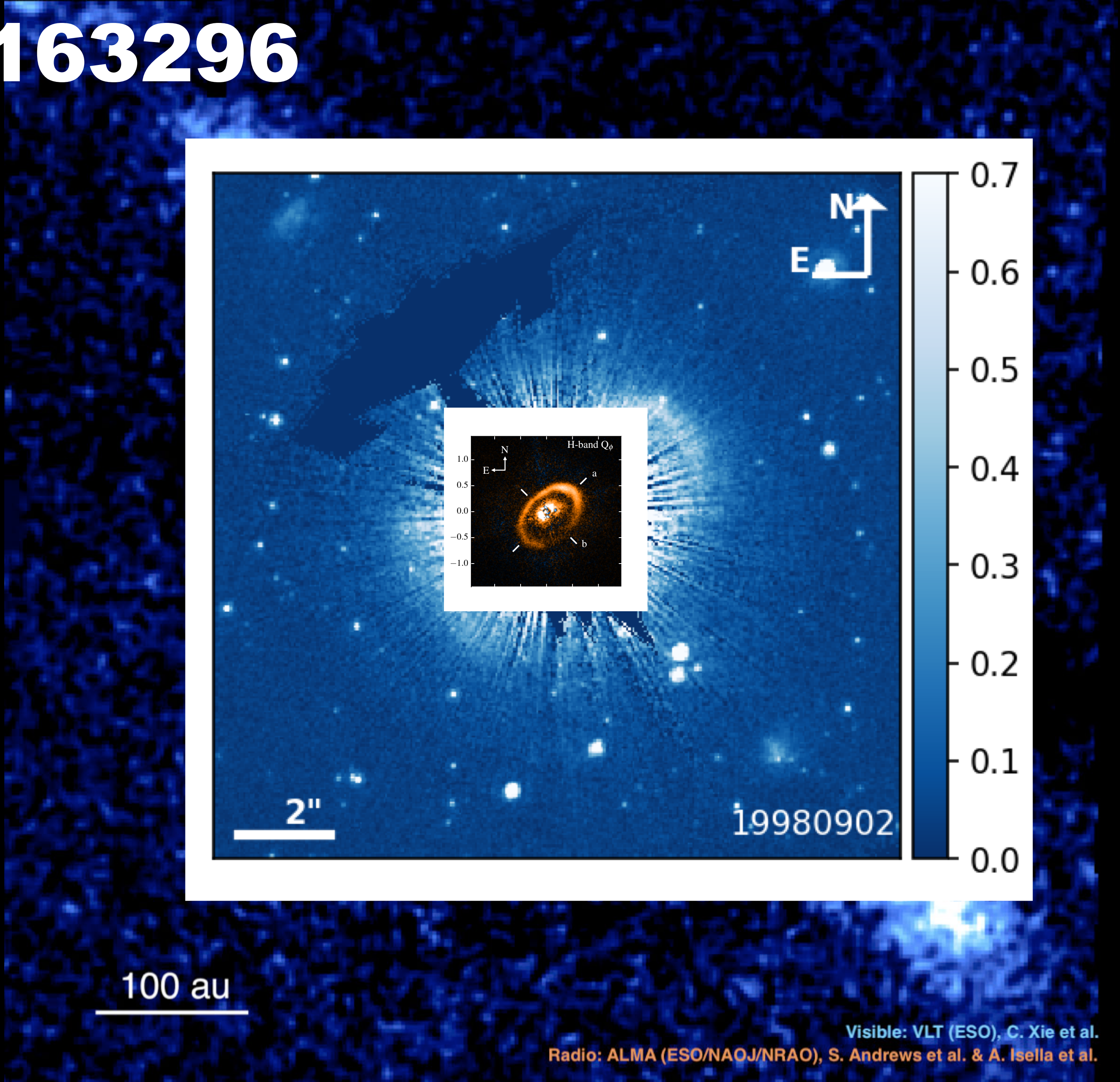
debris disk polarimetry from the ground



limited to massive (large and dense) disks...

SPHERE-IRDIS results
courtesy: Christian Ginski
see also Esposito et al. (2020)

HD 163296

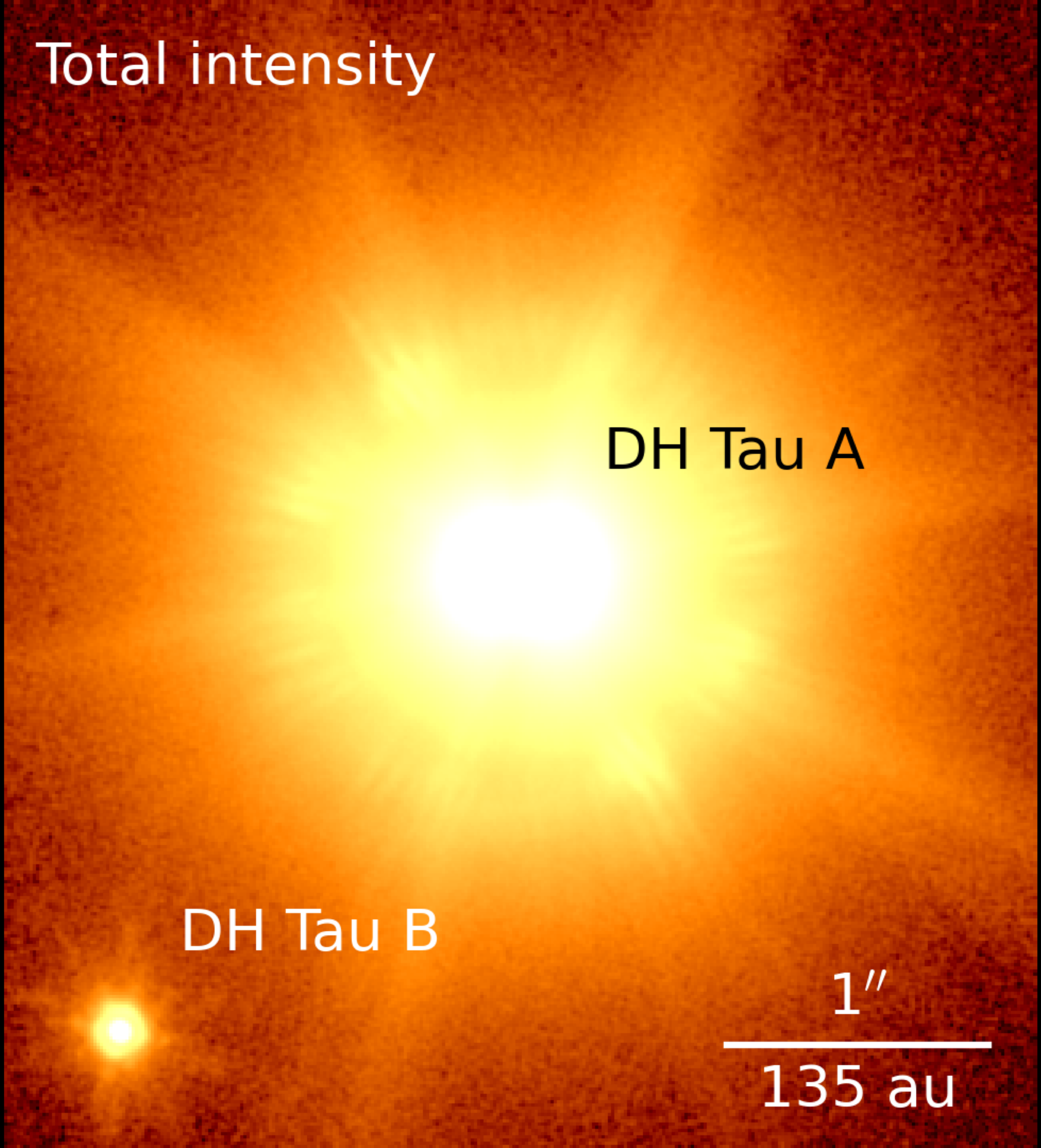


Xie et al. (2020); APOD 22 Jun 2021

Rich et al. (2020)

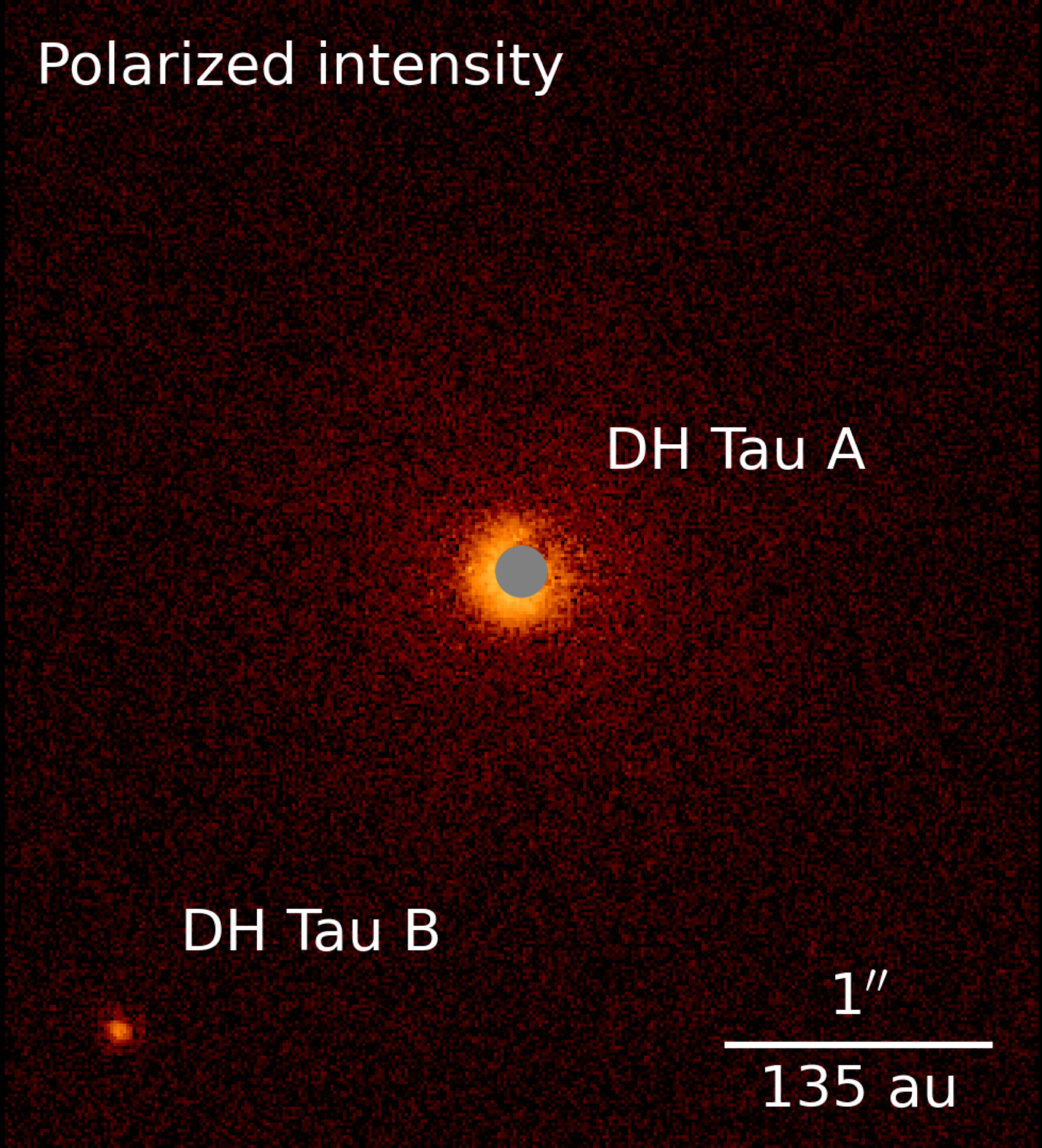
Muro-Arena et al. (2018)

exoplanet polarimetry



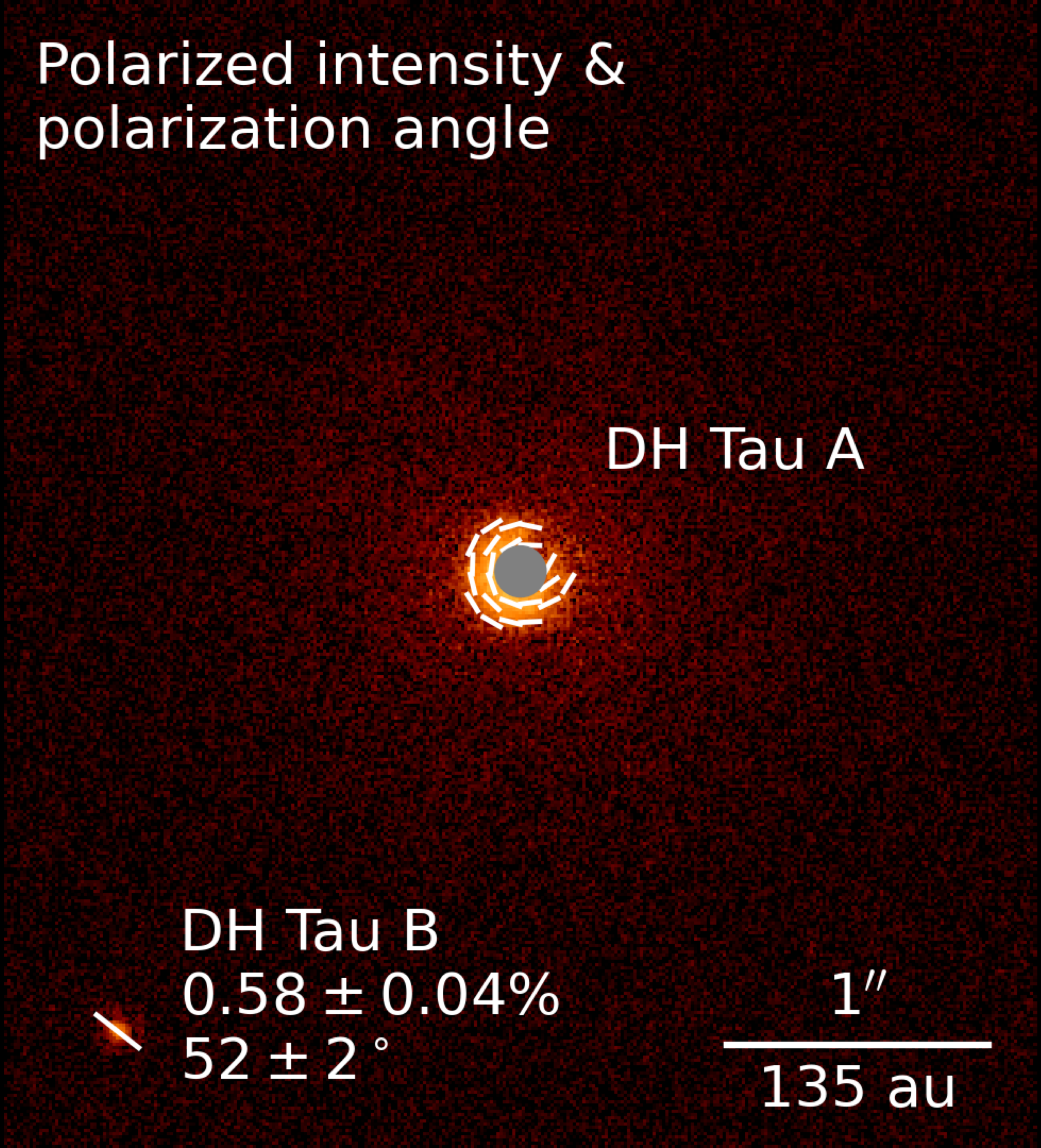
van Holstein et al. (2021)

exoplanet polarimetry



van Holstein et al. (2021)

exoplanet polarimetry

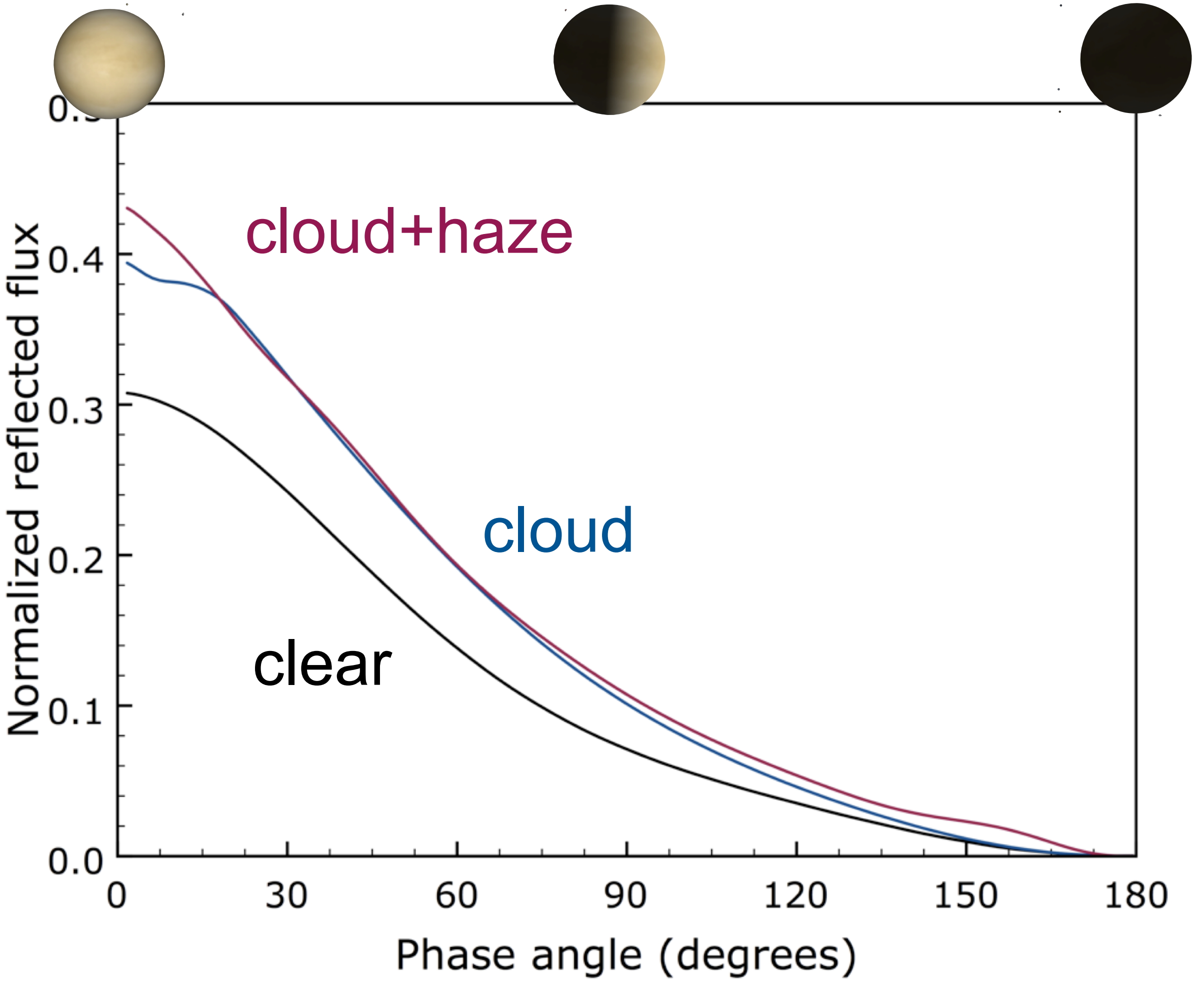


enabled by advanced polarimetric calibrations by van Holstein et al. (2020)

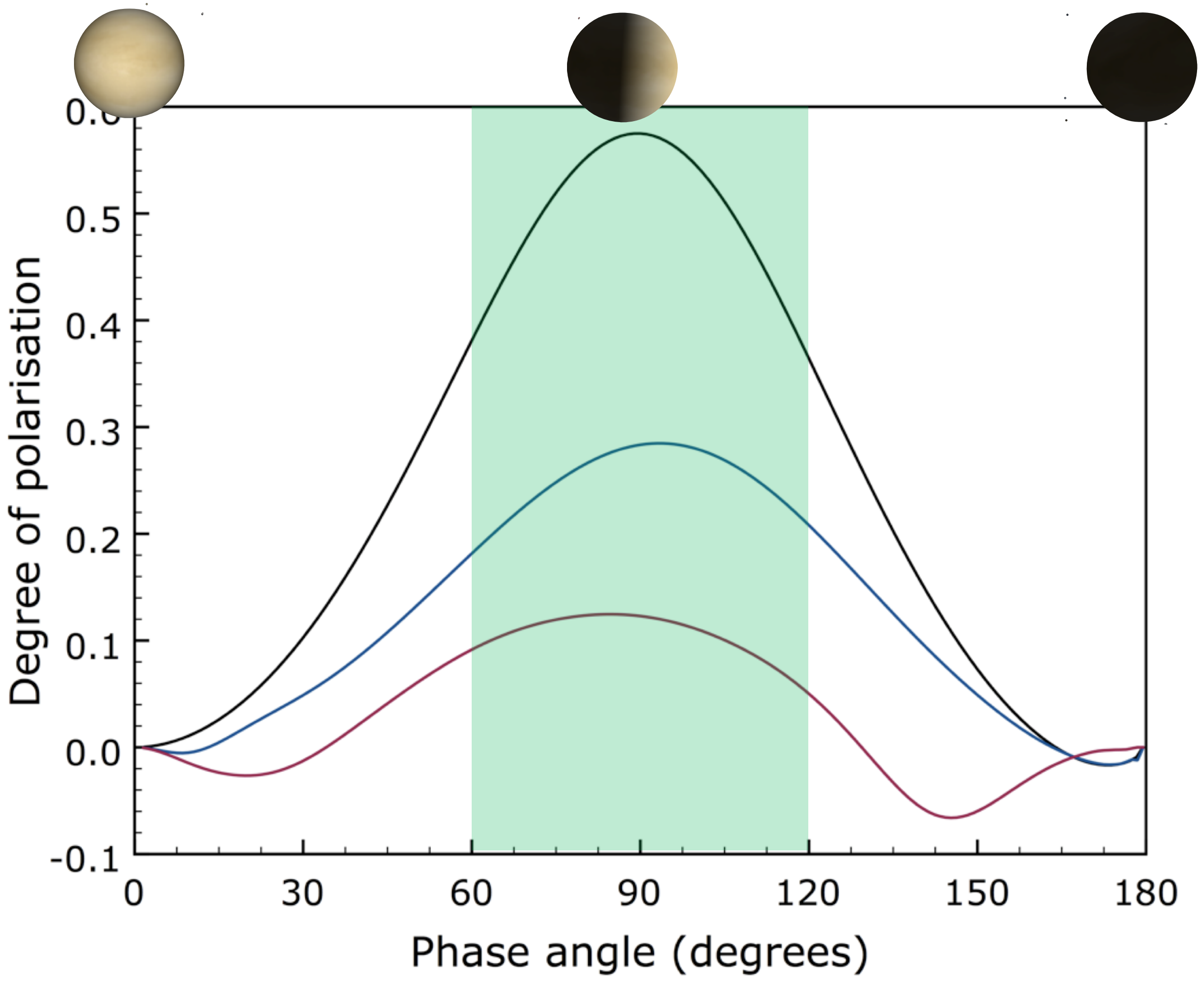
van Holstein et al. (2021)

exoplanet polarimetry

intensity



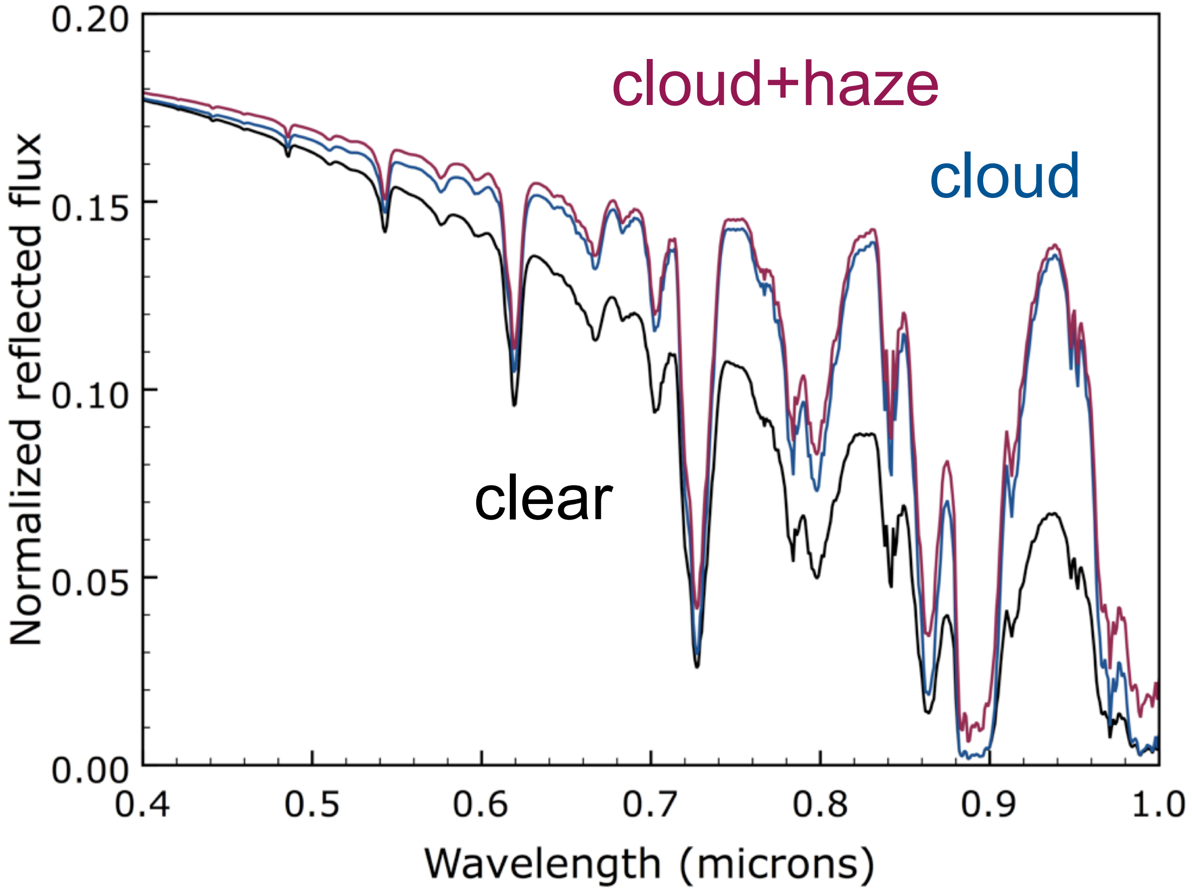
fractional polarization



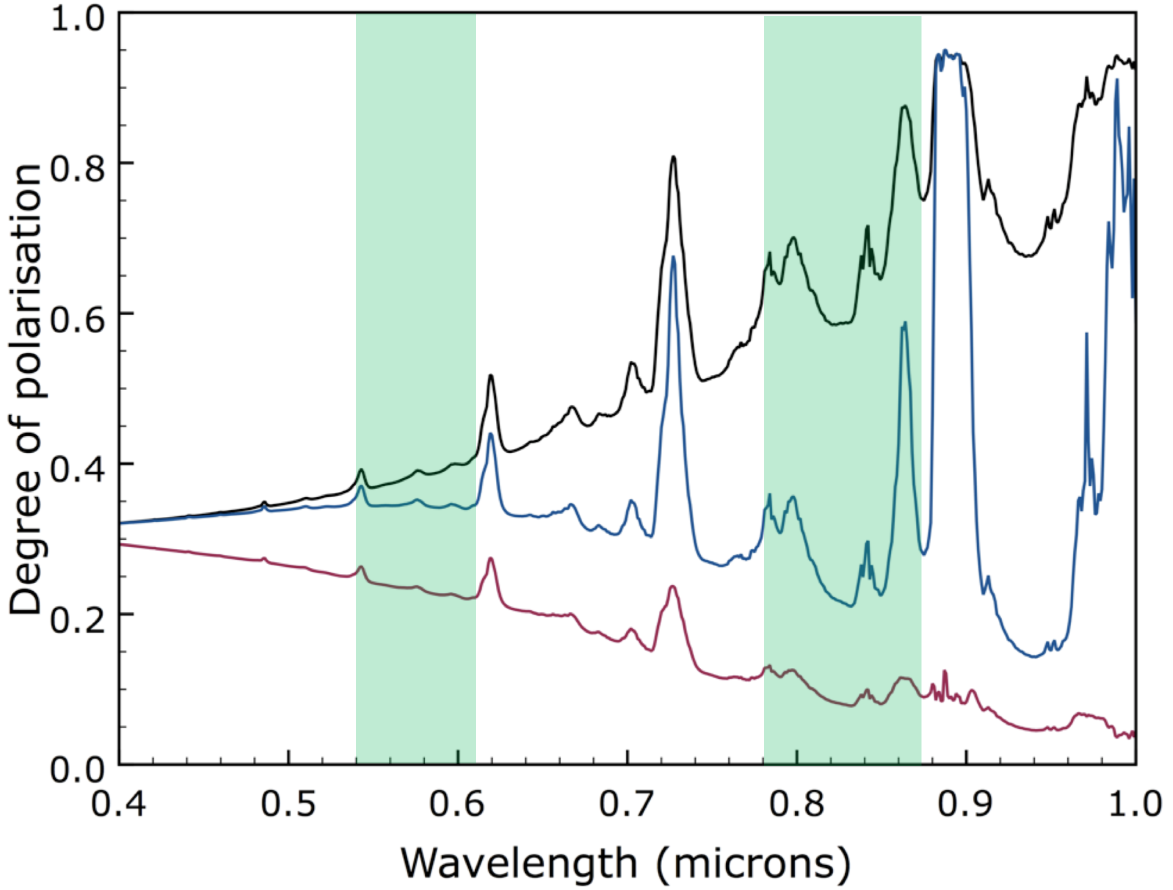
Stam et al. (2004)

exoplanet polarimetry

intensity

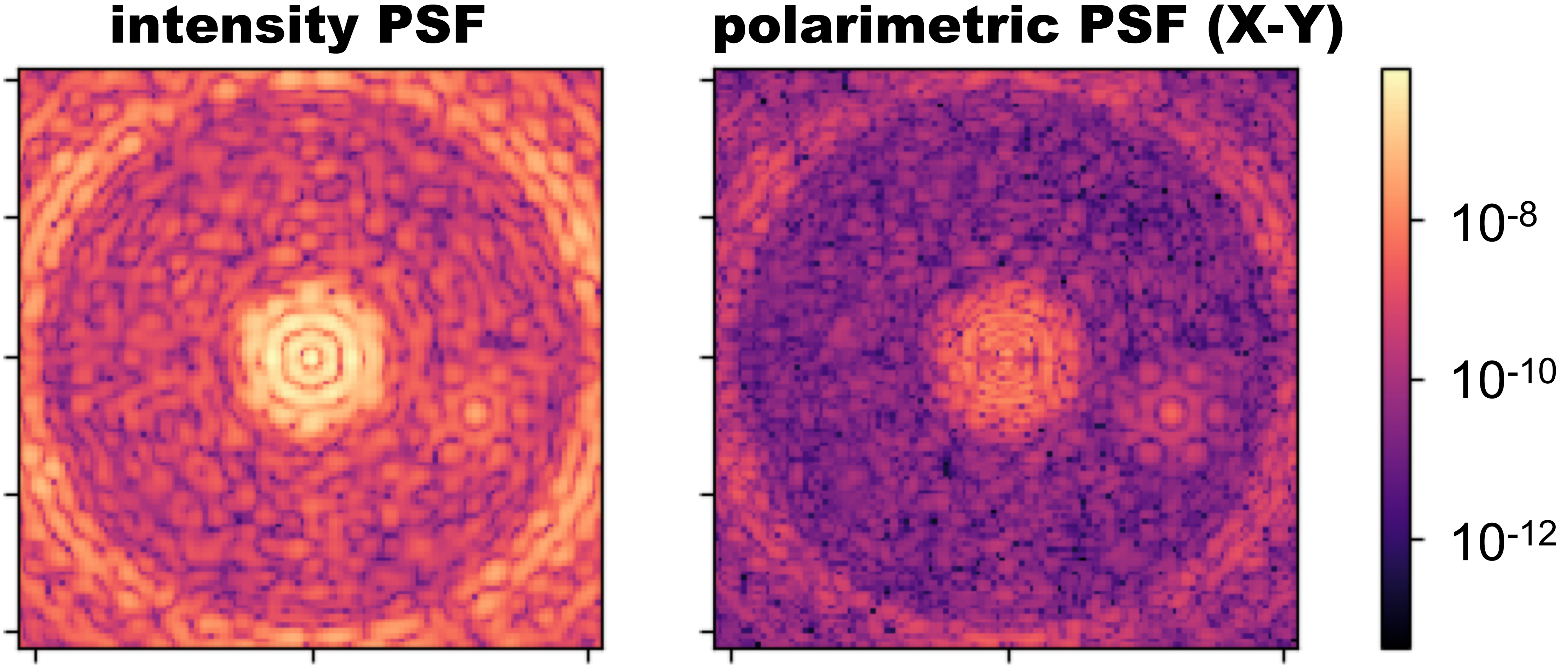


fractional polarization



Stam et al. (2004)

exoplanet polarimetry with RST-CGI
initial simulation



SPLC, band 4, 4 iterations pair-wise probing
Jupiter-like planet at 10^{-8} intensity contrast and 10% polarization

simulations by Hanae Belaouchi & Mireille Ouellet
using FALCO by A.J. Riggs

improving polarimetric accuracy

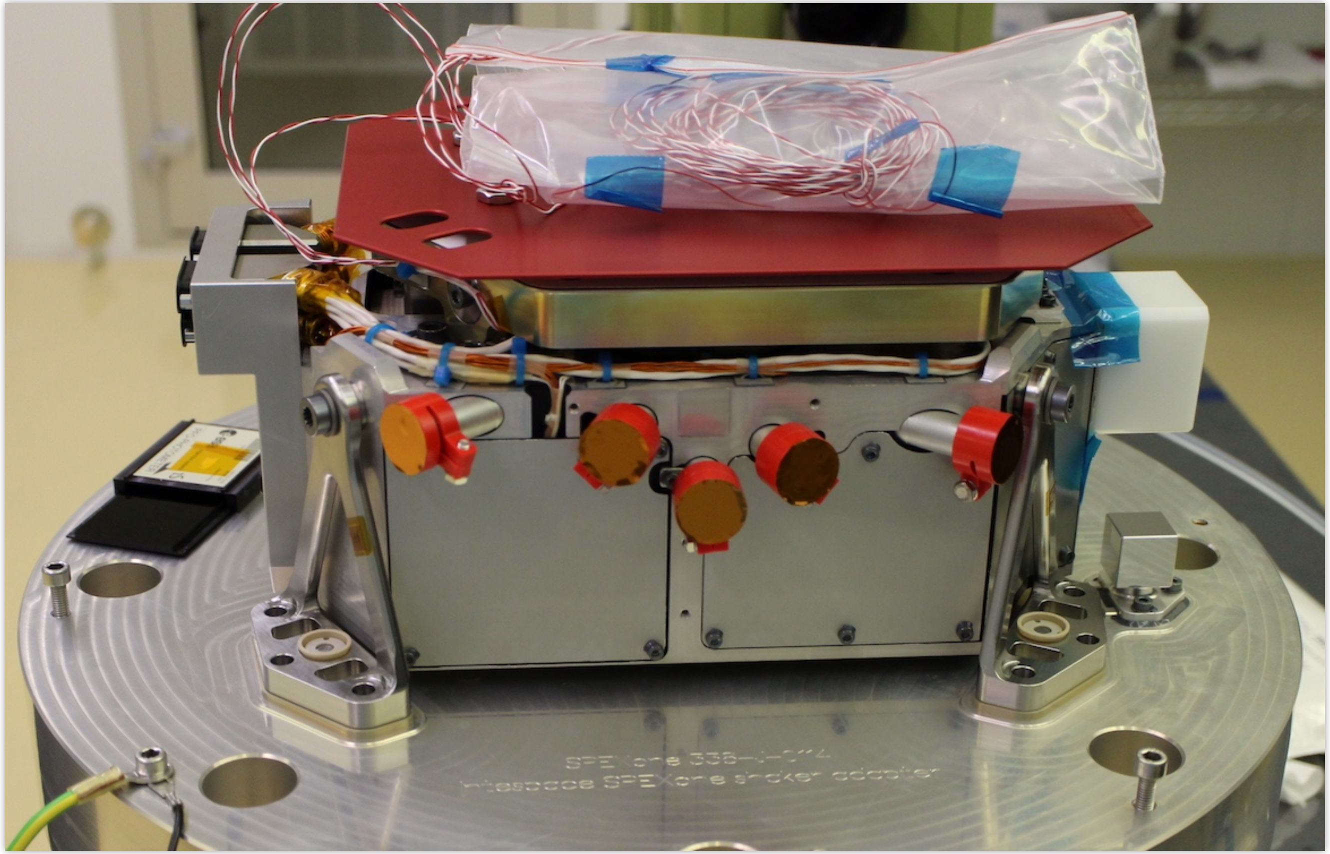
- **Detector flat-fielding** (pre/in-flight).

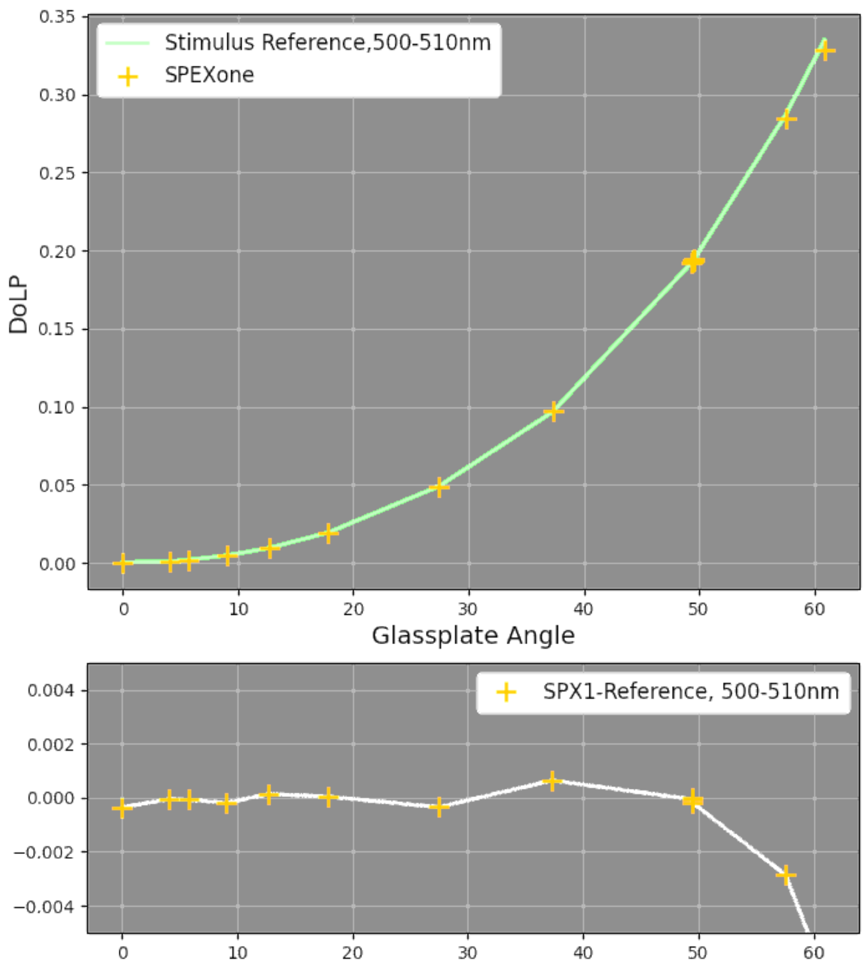
- **Differential transmission correction.**

- **Instrumental polarization effects:**
  - Induced polarization (mostly Stokes *Q*);
  - Cross-talk (mostly losing Stokes *U* into *V*);
  - Wavelength variation (and dependence on source spectrum);
  - Error budgeting: degradation?

- **“Modulation” using 28-deg spacecraft roll.**
  - Demodulation in combination with ADI.

improving polarimetric accuracy





- fully space-qualified
- *absolute* polarimetric accuracy of ~10^{-3}

Netherlands Institute for Space Research

courtesy: Martijn Smit (SRON)

enhancing polarimetric contrast

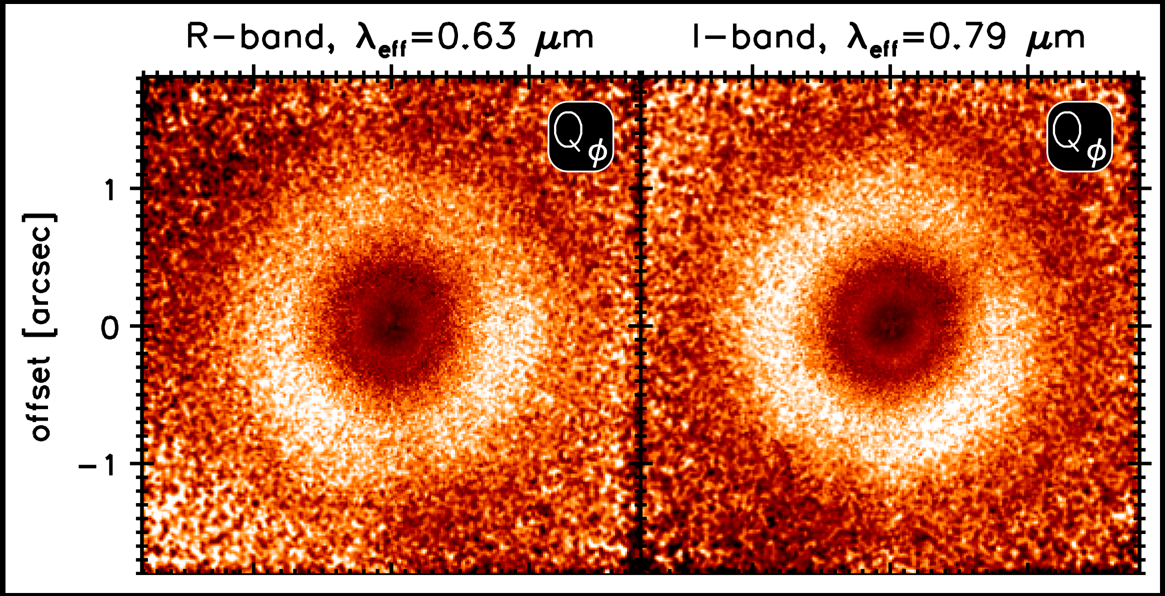
- **Polarization aberrations:**
  crucial to understand/mitigate for both achievable contrast and polarimetric performance.
  - Minimal by coating design (offsets/degradation?)
  - Speckle subtraction floor ($I_X - I_Y$) and ($I_{45} - I_{-45}$) ?
  - Reference star subtraction?
  - Wavelength variation.

- Polarimetric dark-hole techniques?
- APOGEE testbed validations.
- Ultimate polarimetric noise floor? Varying speckles, photon noise?

polarimetric calibration/validation

- **AIT support**

- **Calibration targets**
  - unpolarized standard stars
  - polarized standard stars
  - validation targets with SPHERE-ZIMPOL (e.g TW Hya)



Van Boekel et al. (2017)

- **Observing strategy + pipeline development**

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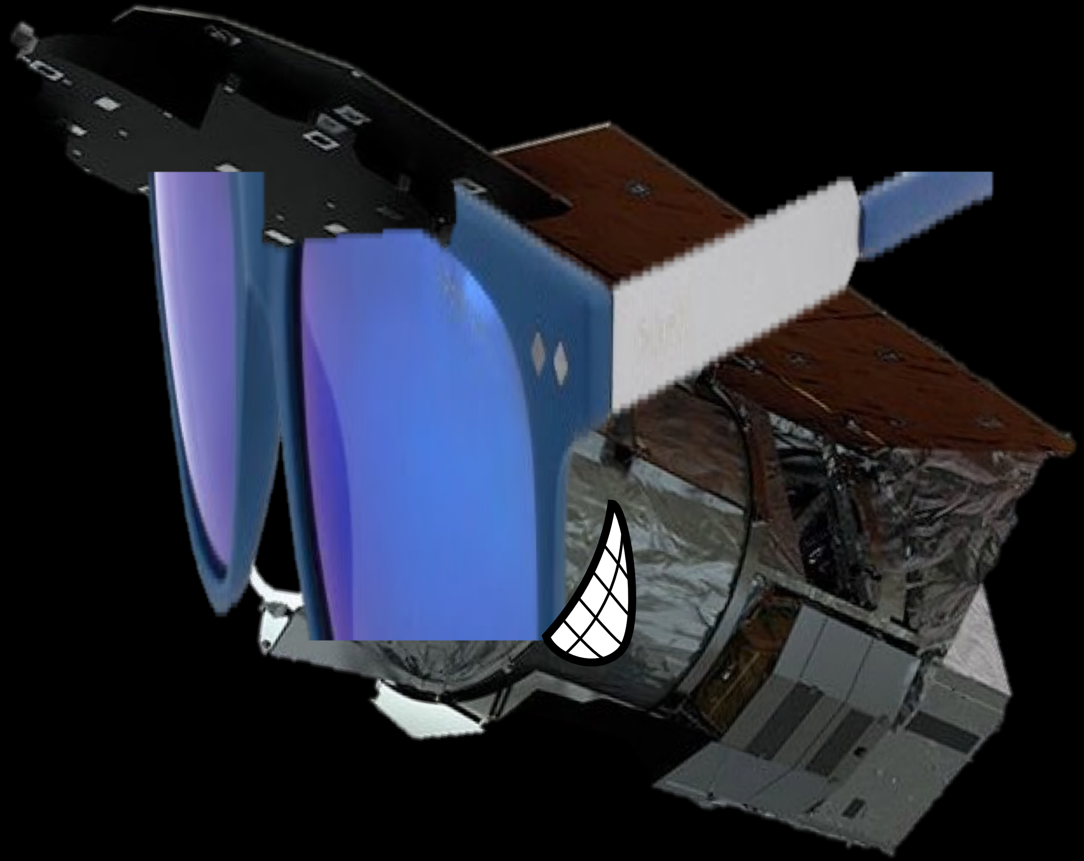

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