Upgrading the Gemini Planet Imager calibration unit with a photon counting focal plane wavefront sensor

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SUMMARY

- Speckle limit the Gemini Planet Imager (GPI)[1], while its calibration unit (CAL 1.0)[2] designed to correct them suffers from vibrations.
- We're building a new CAL system (CAL 2.0) using FAST [3], a version of the self-coherent camera (SCC) concept [4] to operate in narrow bands between 0.8μm and 1.8μm.
- The CAL 2.0, based on a common-path interferometer, will be less sensitive to vibrations [5].
- The FAST focal plane mask (FPM) greatly increases the light intensity in the SCC reference beam, allowing for >100 Hz closed-loop deformable mirror control on bright stars using a SAPHIRA camera.
- The system will have a chopper to blink the SCC pinhole light, allowing for hundreds of Hz coherent different imaging (CDI) [4].
- Our goal is to improve the achievable contrast for the SCC camera and the GPI imaging spectrograph by up to 100x in a half-dark hole, or achieving ~1E-8 contrast at a few lambda/D on bright stars, opening an exciting new regime of scientific discoveries!

SCIENCE OBJECTIVES

CAL 2.0 main science cases are,

- Imaging of closer in <15 AU sub-Jupiter mass giants
- Discovery of Myr old very young gas giants at Solar System scales in star-forming regions
- High SNR exoplanet detections: variability analysis, in-depth characterization, and orbital dynamic analysis
- Imaging of nearby RV exoplanet in reflected light
- Debris disk total intensity imaging
- Asteroid imaging at 0.85 μm

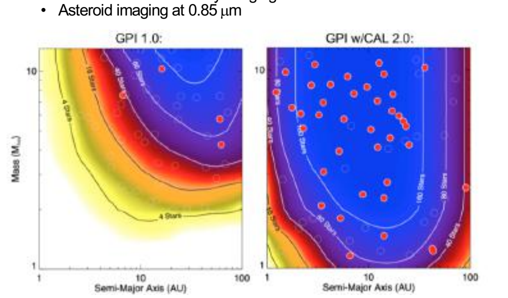


Fig. 1: Left panel, exoplanet sensitivity and detections for a 300-star survey using GPI1.0 and (right) for CAL2.0 as a science camera (credit: E. Nielsen). Detected planets in the sample are shown as red-filled circles, while undetected planets are shown as open white circles. The new CAL system is expected to increase the sensitivity to lower mass exoplanets at smaller separations.

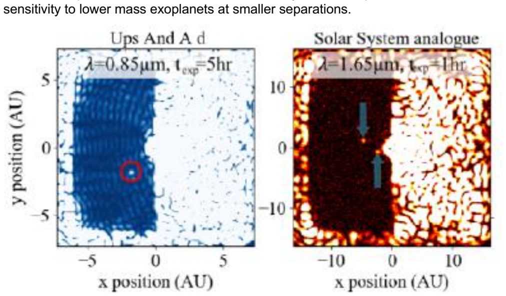


Fig. 2: Simulated examples of science enabled by the CAL2.0 for GPI[6]. Left: reflected light imaging of the radial velocity exoplanet Ups And A d (10 Jupiter masses, 2.5 AU semi-major axis at 13.5 pc). Right: thermal imaging of two Jupiter mass planets at 5 and 10 AU orbiting a 30 Myr old star at 30 pc.

FOCAL PLANE WFS CONCEPT and OPTICAL DESIGN

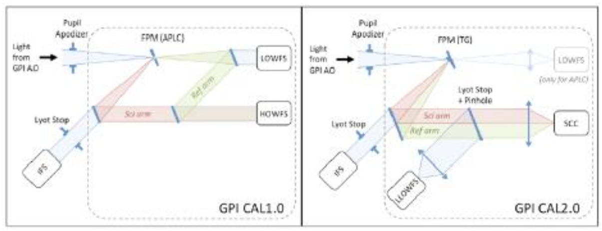
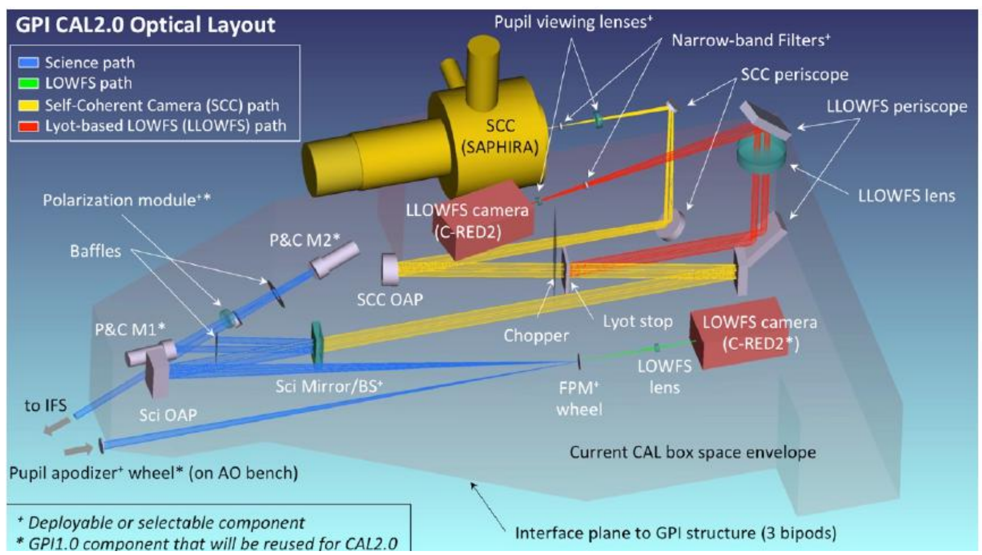


Fig. 3: Schematic view of our CAL 2.0 upgrades (right) compared to the CAL1.0 subsystem (left).

One of the CAL 1.0 main issues is a few microns worth of vibrations at the focal plane mask; the optical surface that splits the two interferometer beams. The CAL 2.0 is a focal plane common-path interferometer, and is thus much more resilient to vibrations.

The CAL 2.0 system will allow simultaneous imaging with the GPI IFS. It will include a Lyot-based low-order sensor (LLOWFS)[7] and FAST. The CAL 2.0 narrowband images will be used for science discoveries.



- A bigger CAL box will host the SAPHIRA-based FAST focal plane WFS camera.
- The current CAL LOWFS will be conserved for non-FAST operations.
- The CAL 2.0 will showcase a FAST FPM, a dual aperture SCC Lyot stop, a chopper to blink the pinhole light, a filter wheel and a SAPHIRA camera.
- Lenses can be deployed to change the SAPHIRA camera to image the Lyot pupil plane for diagnosis.
- A CRED2 camera will be used for the LLOWFS path to perform the tip/tilt and focus control loop.
- A lens can also be deployed in front of the CRED2 to image the Lyot stop.
- The system can operate up >100 Hz on bright stars using the NRC HEART RTC framework[8]. It will do both deformable mirror control and coherent different imaging (CDI) at high speed.
- Phase diversity, speckle nulling and electric field conjugate methods will also be implemented.
- The FAST and CAL 2.0 concept are being studied by simulations and validated at the NRC NEW EARTH laboratory (see 11448-85 and 11448-282)

SCHEDULE

STATUS

FUNDED!

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