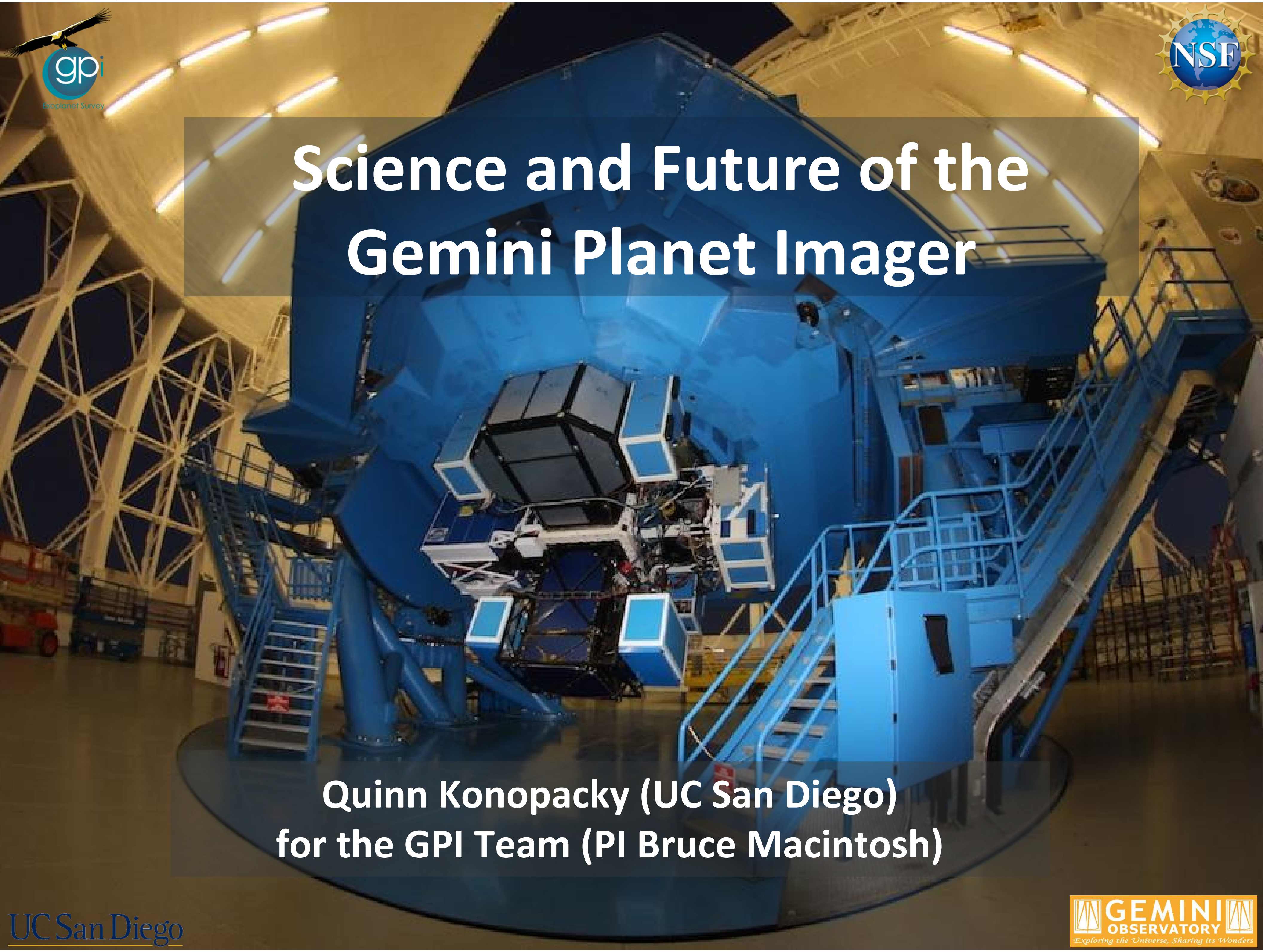
Science and Future of the Gemini Planet Imager



Quinn Konopacky (UC San Diego)
for the GPI Team (PI Bruce Macintosh)

gpi Exploplanet Survey

NSF

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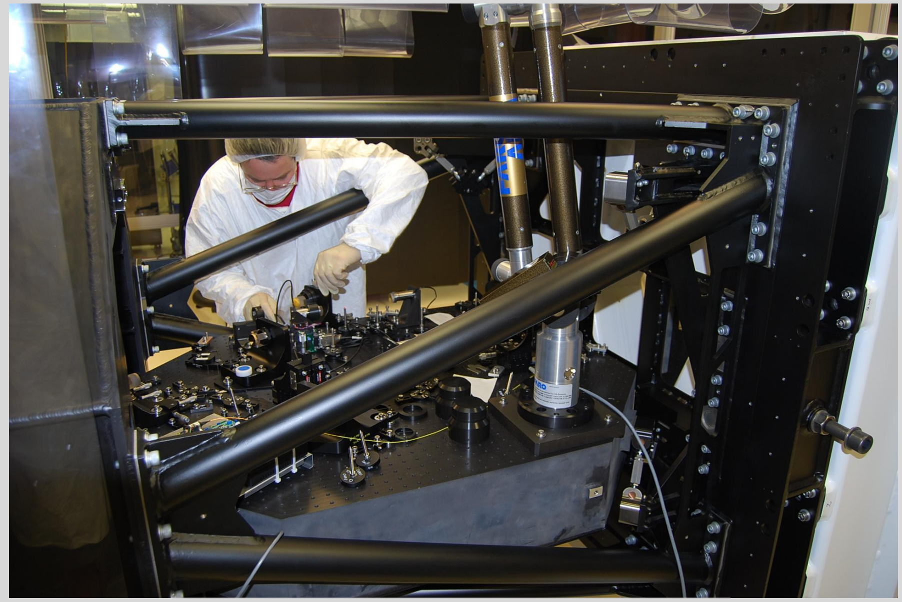
The Gemini Planet Imager (GPI) in a Nutshell

- GPI is an advanced high contrast imager with a high-order adaptive optics system, coronagraph and interferometric calibration unit, all feeding a 1-2.4 µm integral field spectrograph
- Components built by 7 institutions in the US and Canada
- GPI achieved first light on Gemini South November 11, 2013
  - Routine operations since 2014B



Assembly at HAA, Victoria, BC

Mounting on Gemini South

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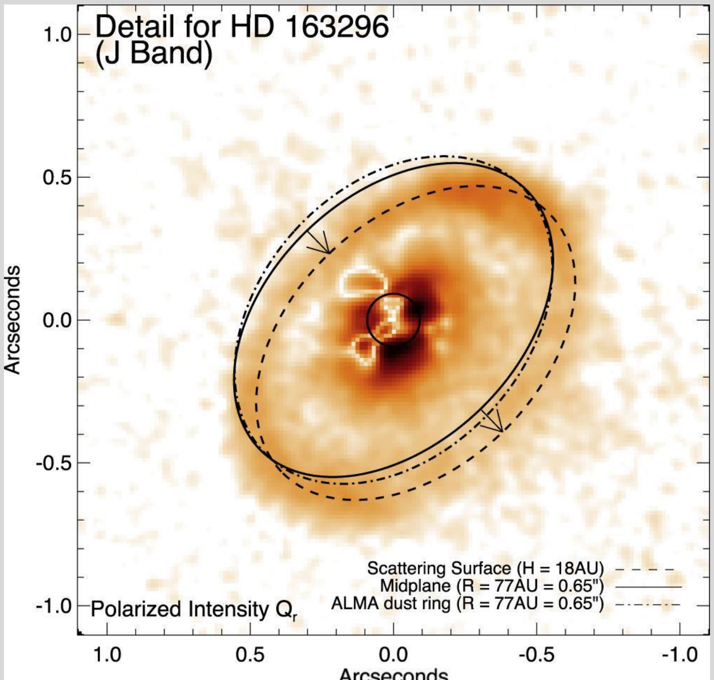
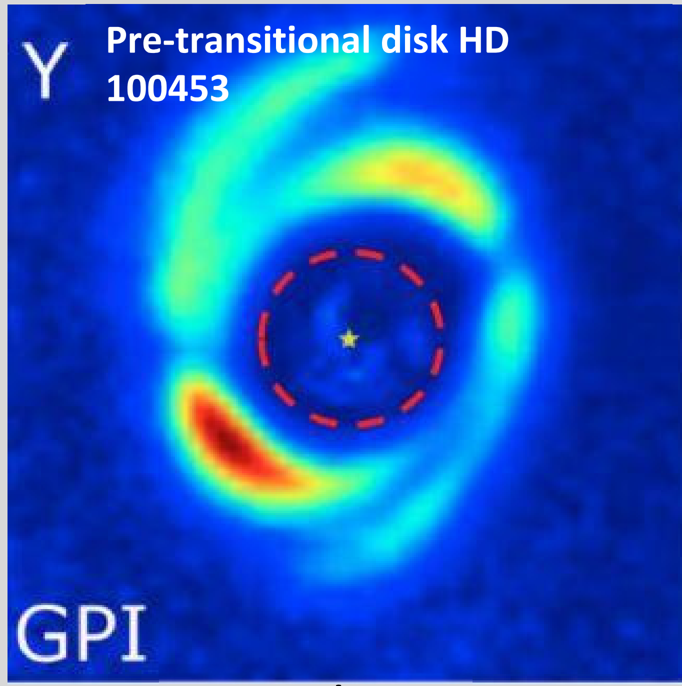
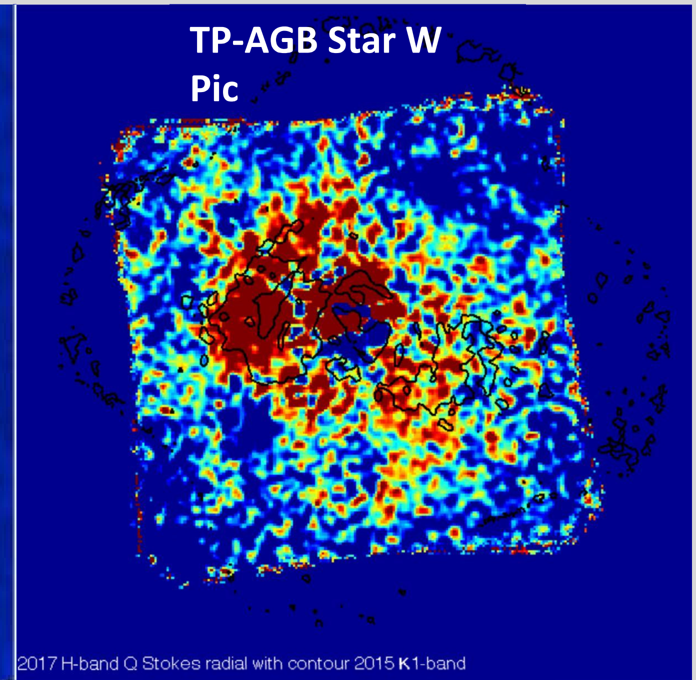
GPI has been a scientifically productive instrument utilized by a broad community for Galactic science.



Monnier et al. 2017



Long et al. 2017



Shirman et al. in prep

- Two large and long programs and 76 regular programs
  - 50% exoplanets, 33% circumstellar material with polarimetry, 17% other (evolved stars, binaries, etc.)
- Since 2014, 48 peer-reviewed publications, 27 technical publications, 10 PhD theses
  - h-index ~ 20

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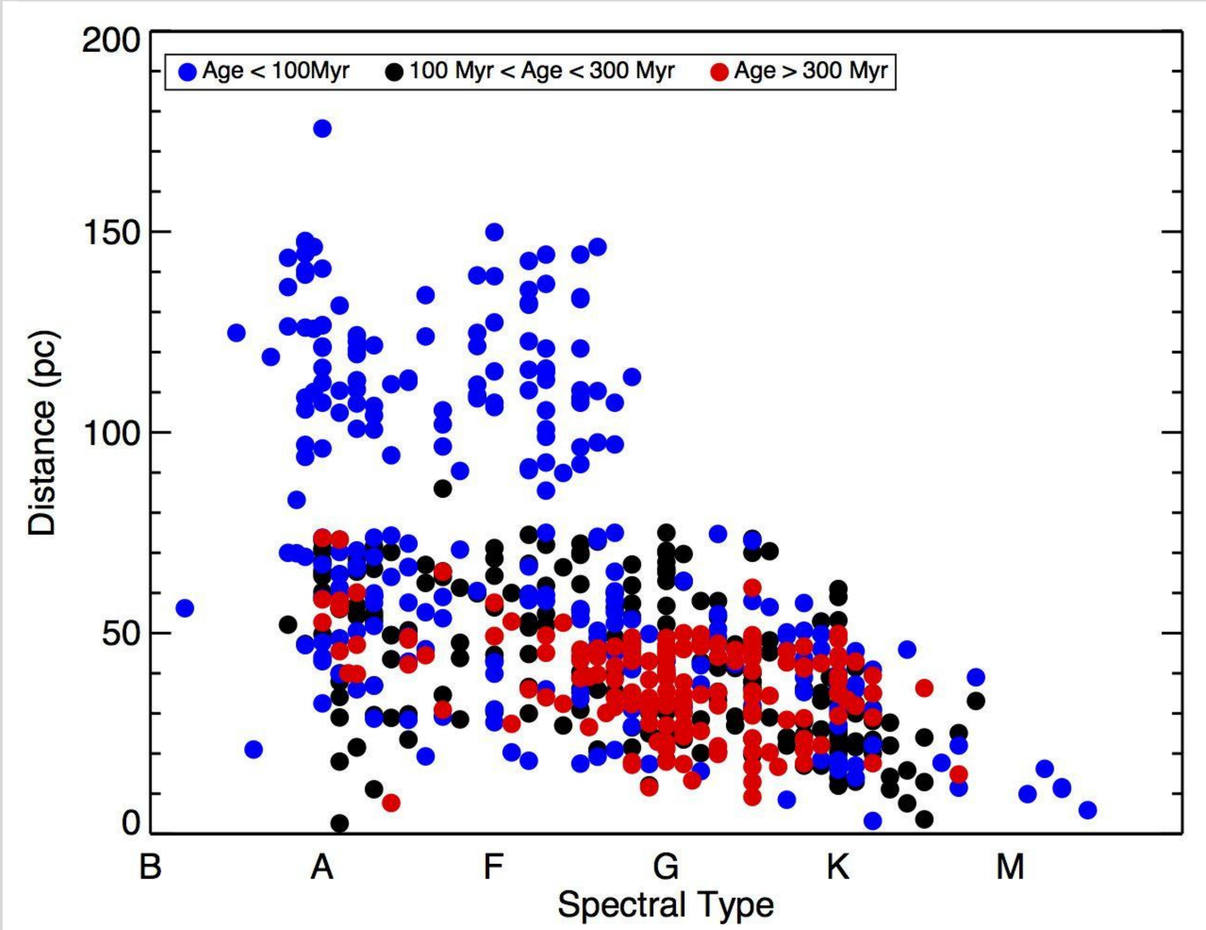
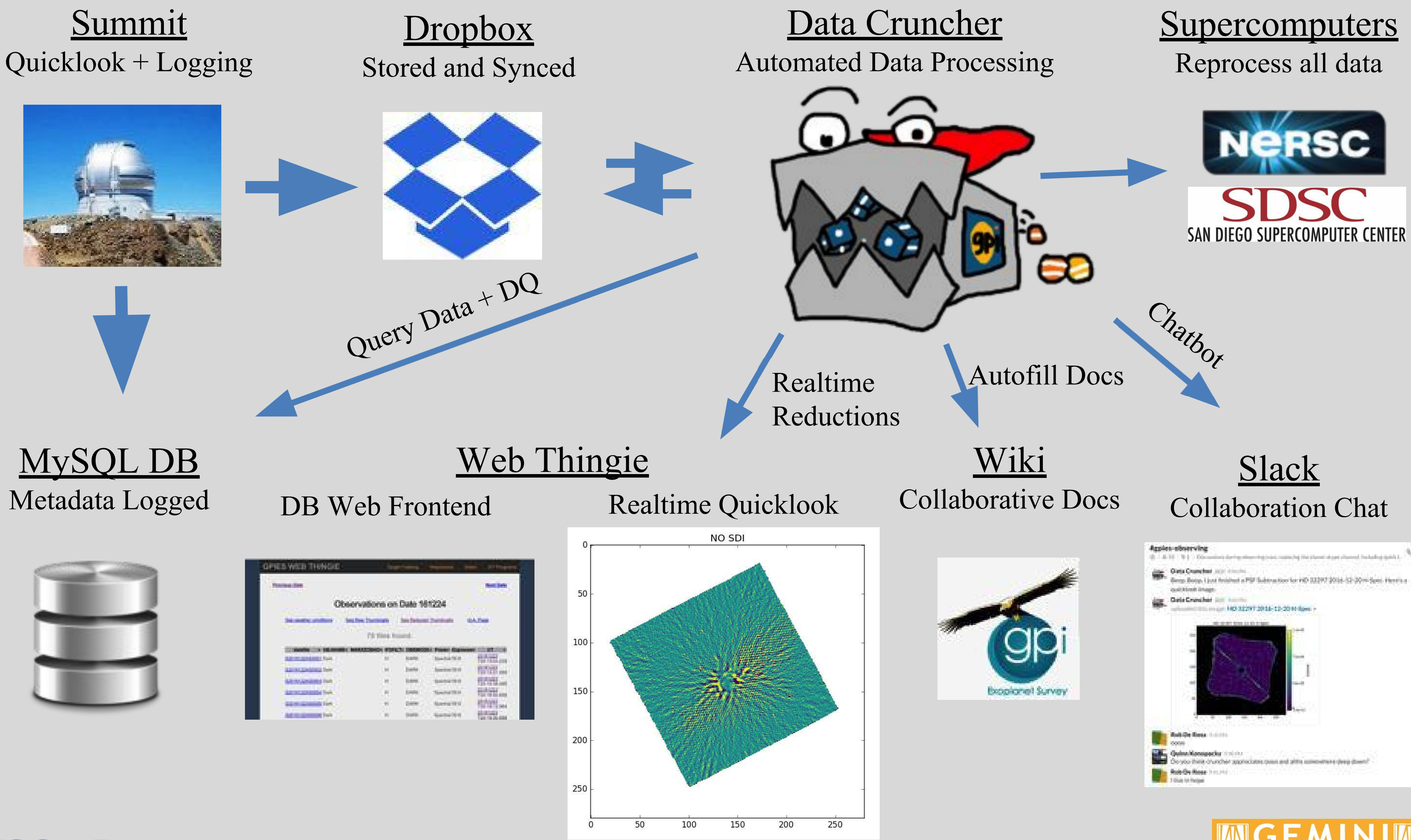
The Gemini Planet Imager Exoplanet Survey (GPIES) is a statistically-designed experiment to determine the frequency of widely separated gas giant planets.

- Initially a 3 year campaign to survey 600 stars
- Ultimately a 5 year campaign surveying 532 stars
- Commenced November 8, 2014 – last new target observed December 22, 2018
  - Follow-up of a few candidates during 2019 will complete survey



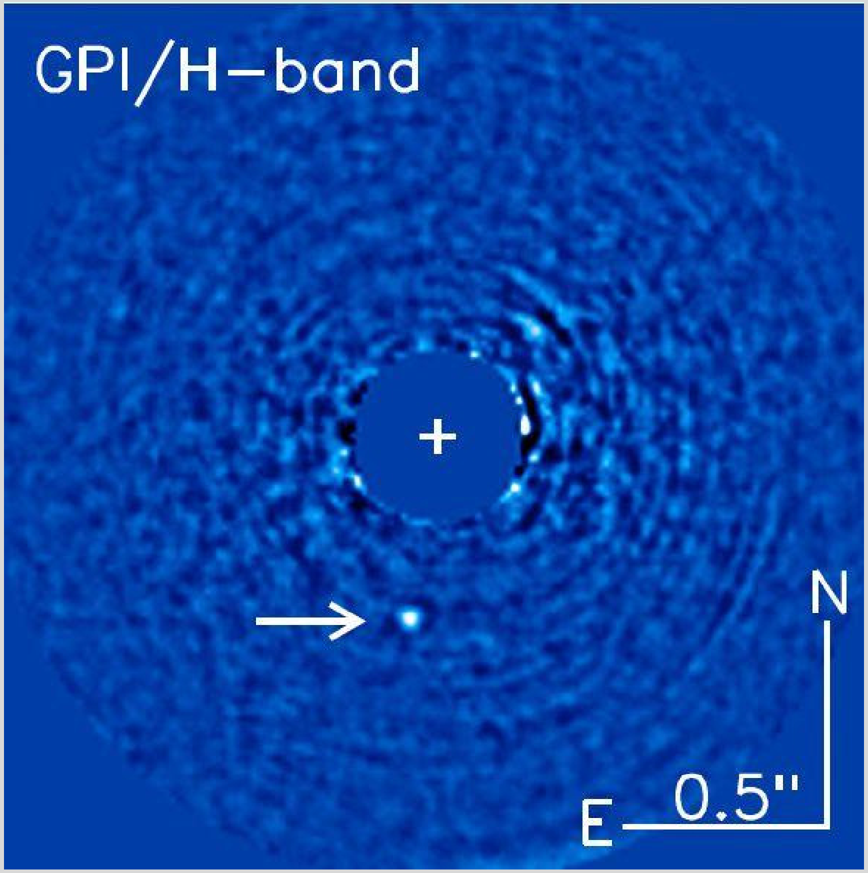
GPIES target star properties

The GPIES team has an advanced, automated data processing infrastructure.



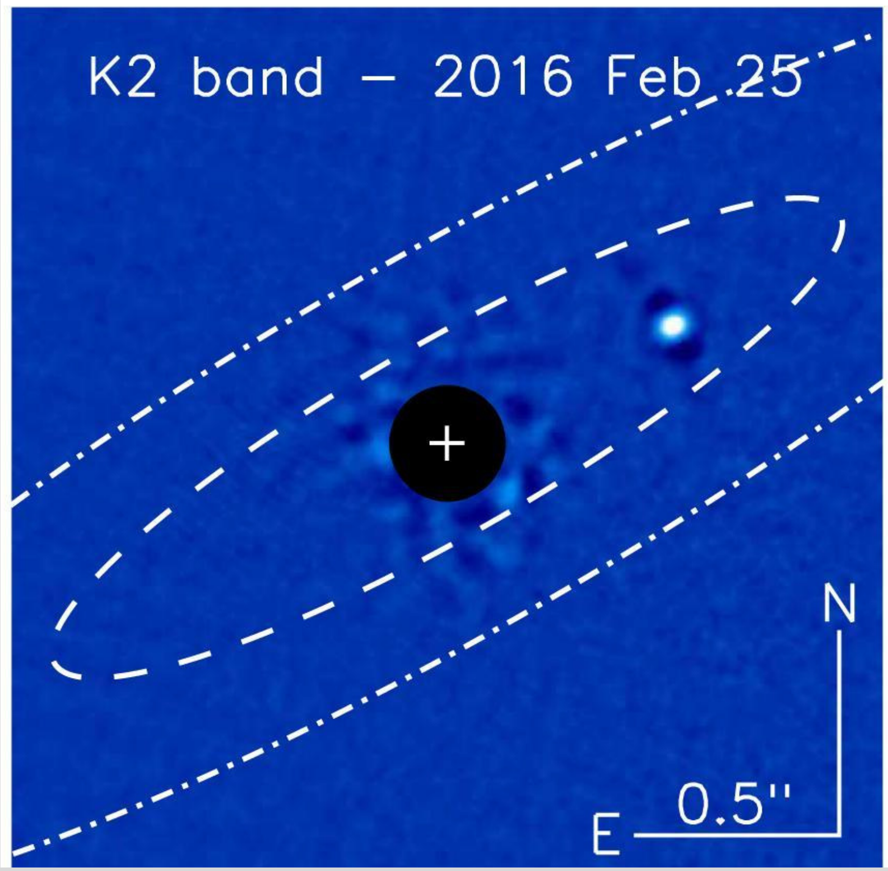
Wang et al. 2018 JATIS

The primary goal of the survey was to detect new substellar companions.



51 Eridani b, Macintosh et al. 2015

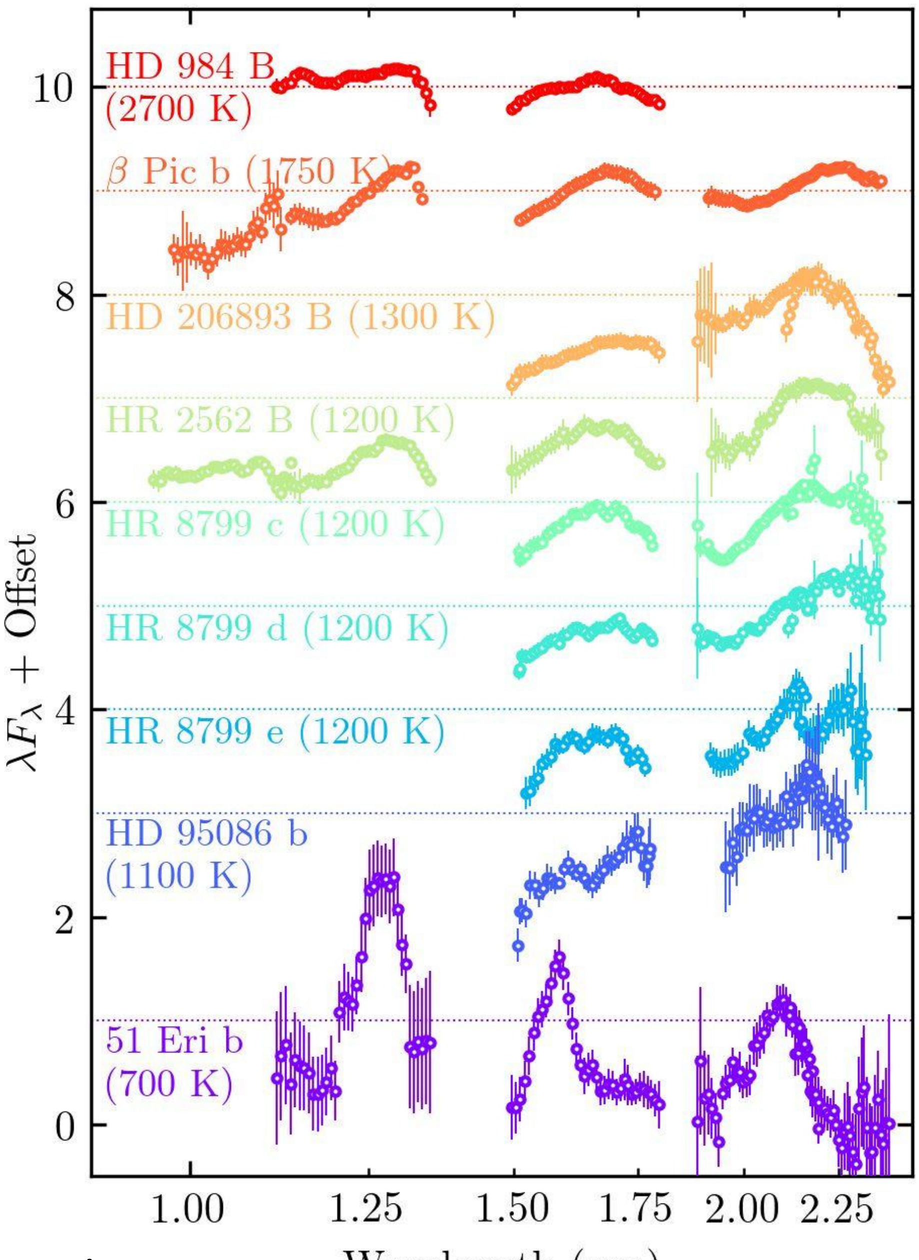
2 – 10 M_{jup}
13.2 ± 0.2 AU



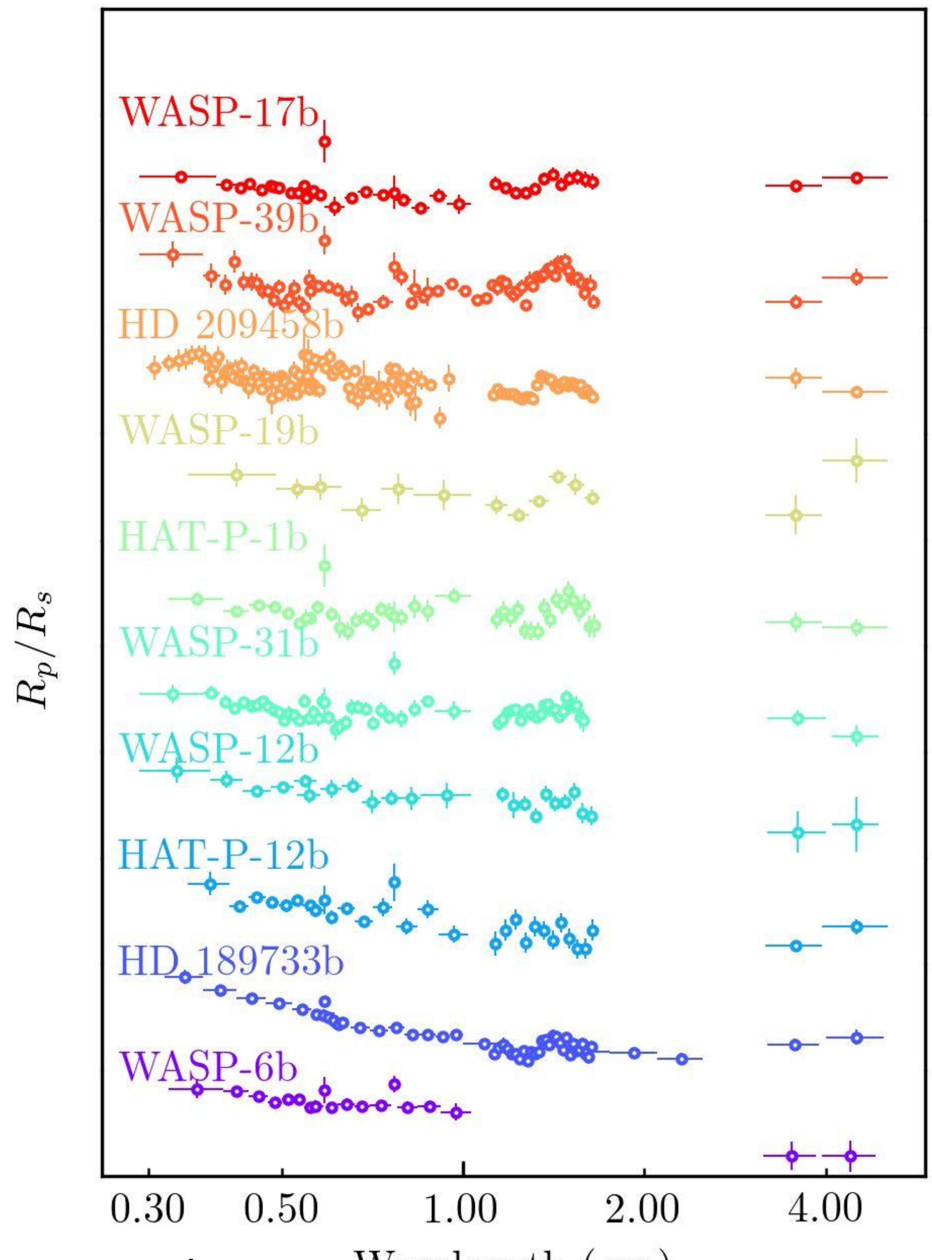
HR 2562B, Konopacky et al. 2016

30 ± 15 M_{jup}
20.3 ± 0.3 AU

The full GPI spectral library is comparable in quality to the best space-based transit spectroscopy.

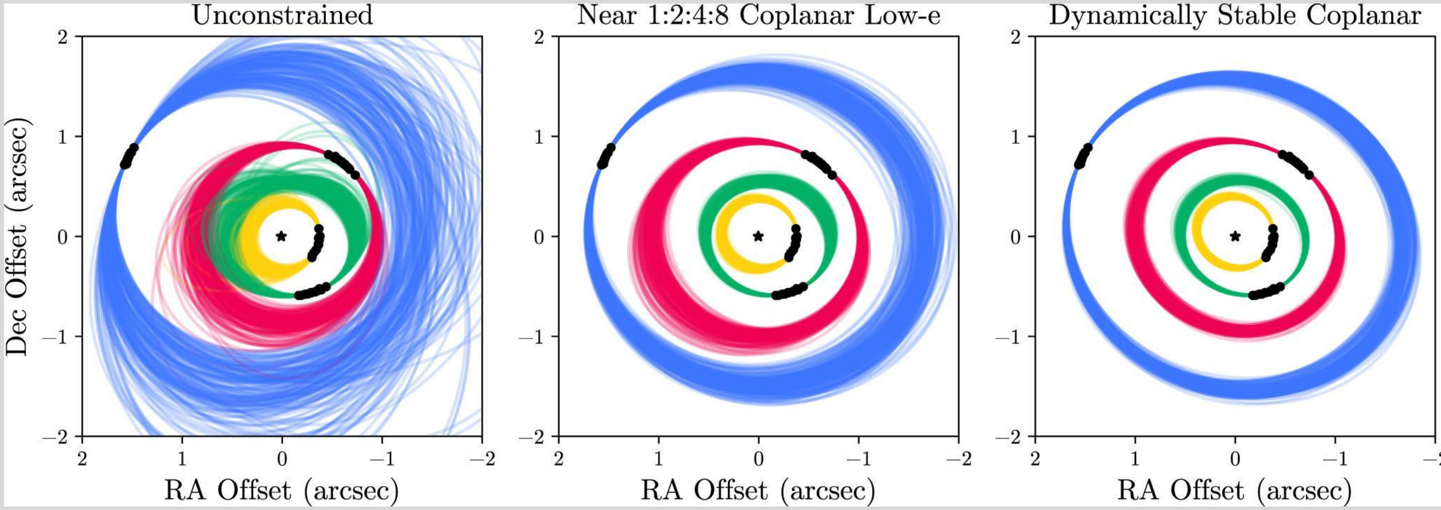


Rob De Rosa

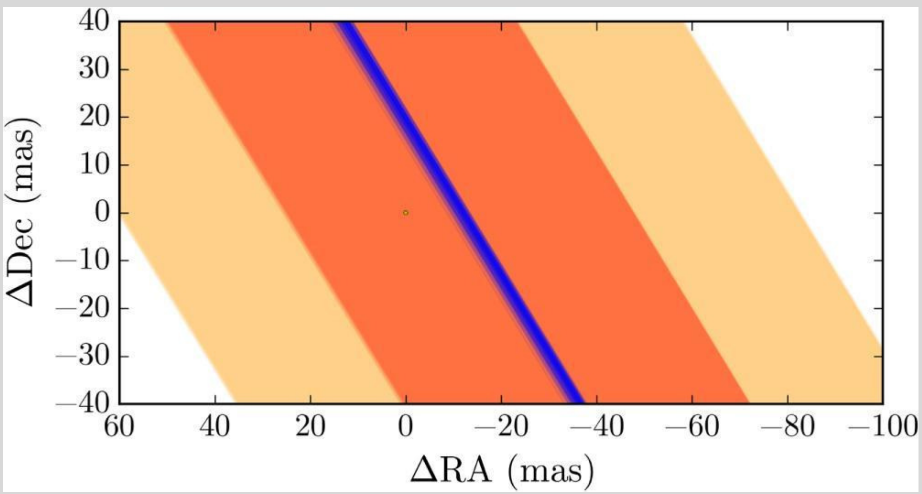


Sing et al. 2016

Orbital monitoring of discovered companions has shed light on system architectures.



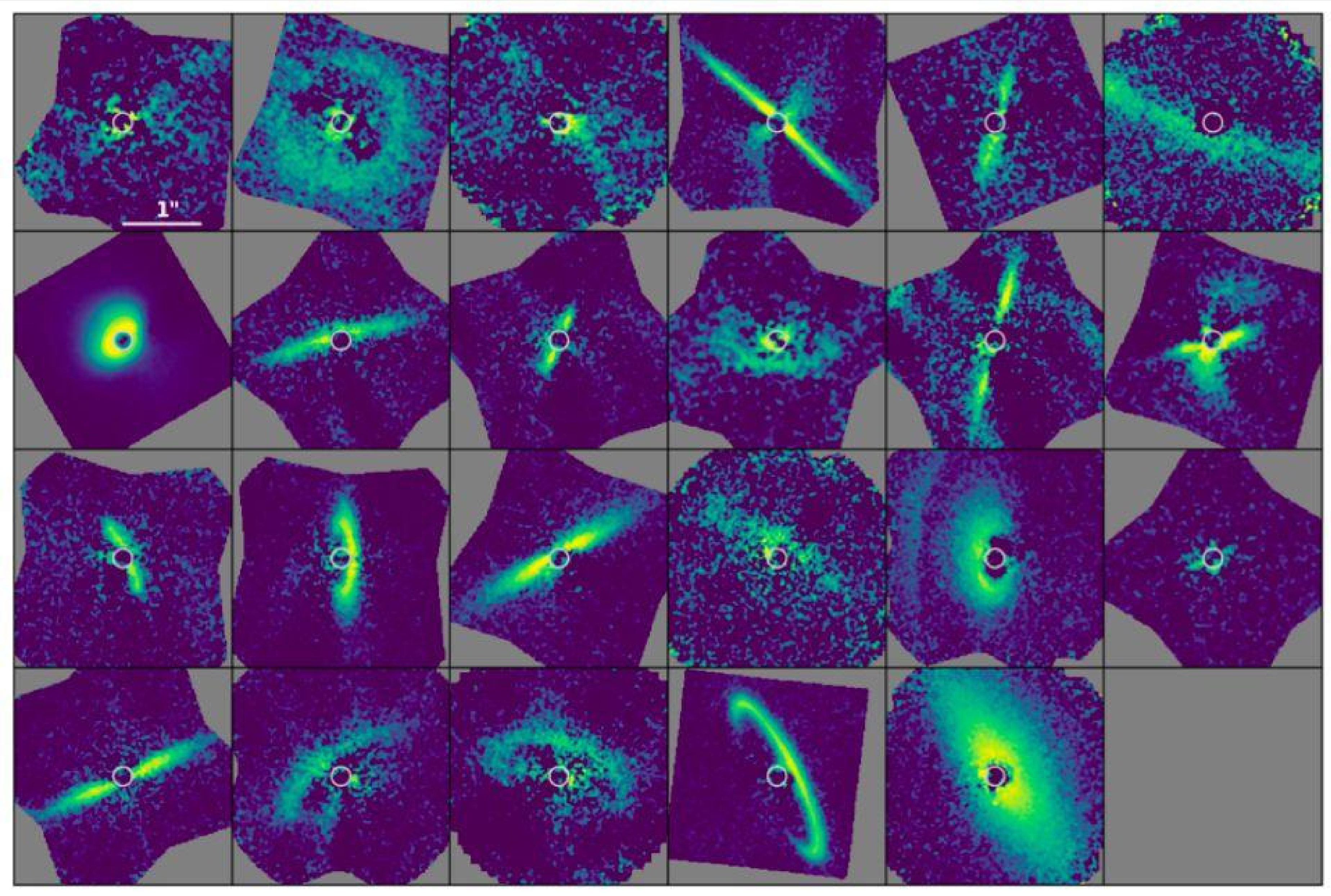
HR 8799bcde
Wang et al. 2018



B Pictoris b
Wang et al. 2018

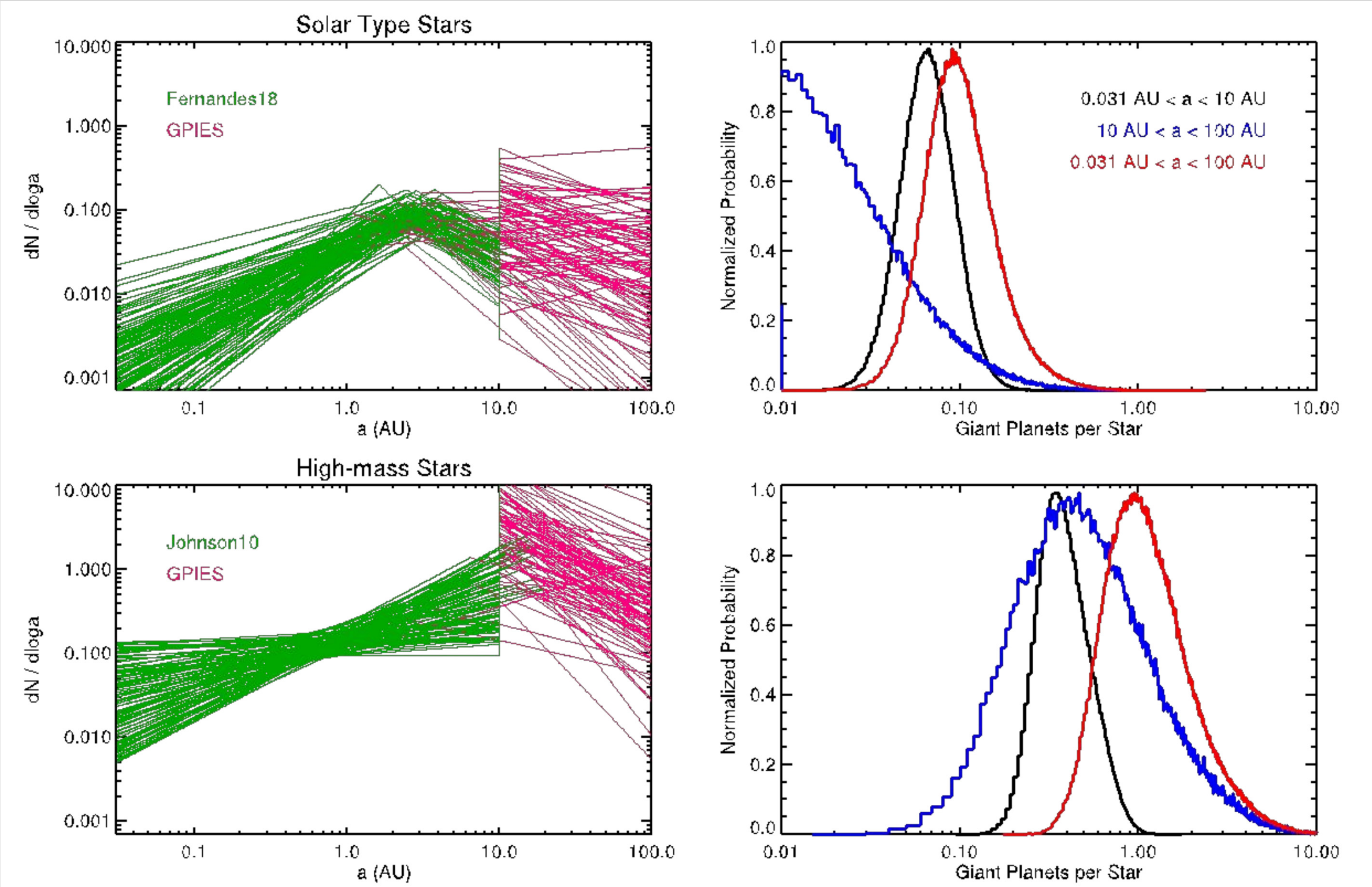
Astrometric Precision ~ 1 mas

Disk imaging and characterization was a fundamental component of GPIES.



Esposito et al. in prep

With data in hand, we can constrain the occurrence of giant planets as a function of stellar mass and separation.

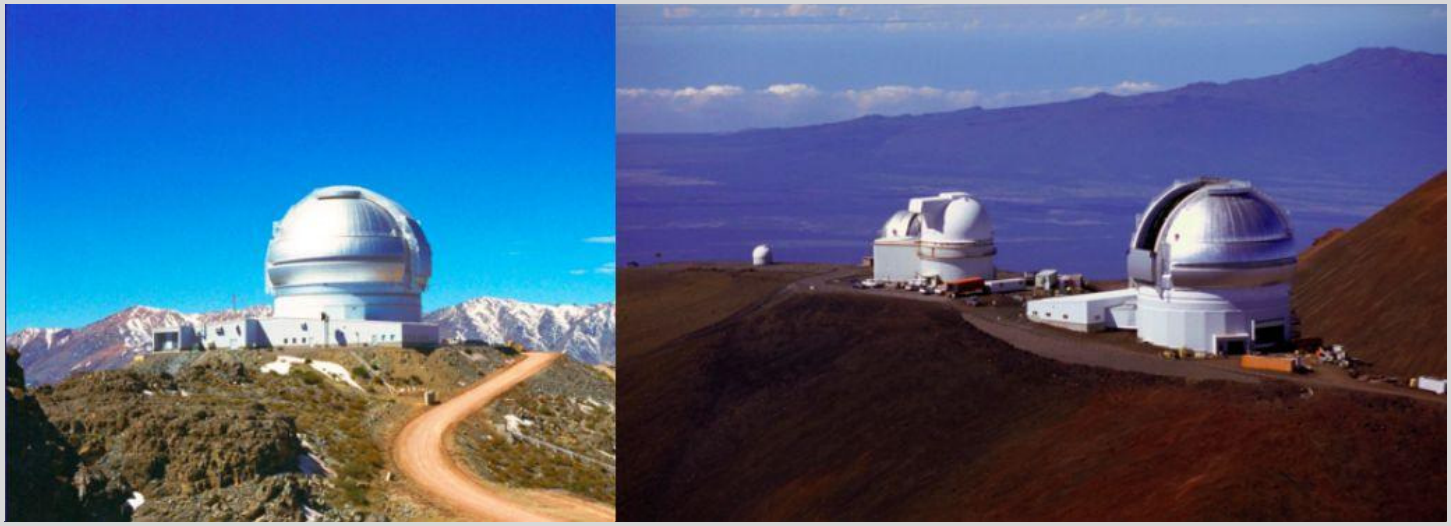


Nielsen et al. submitted

The GPIES survey has taught us what is required to make fundamental advances in direct imaging in the 2020s.

- With potential peak in planet population right below our separation limit, inner working angle is critical
- Contrast scales with $\boldsymbol{\tau}_0$, which is a function of both r_0 and wind speed – improved AO site alone can offer major gains in sensitivity to lower mass planets
  - Note – 51 Eri b discovered on one of best weather nights of campaign
  - A faster AO system will also offer major contrast improvements
- Performance on faint (I>9) is limited due to AO wavefront sensor sensitivity
- Additional scientific gains can be made by exploring other modes, including both lower and higher resolution spectroscopy

GPI 2.0 – A Facility-Class High Contrast Imaging System in the North for the 2020s

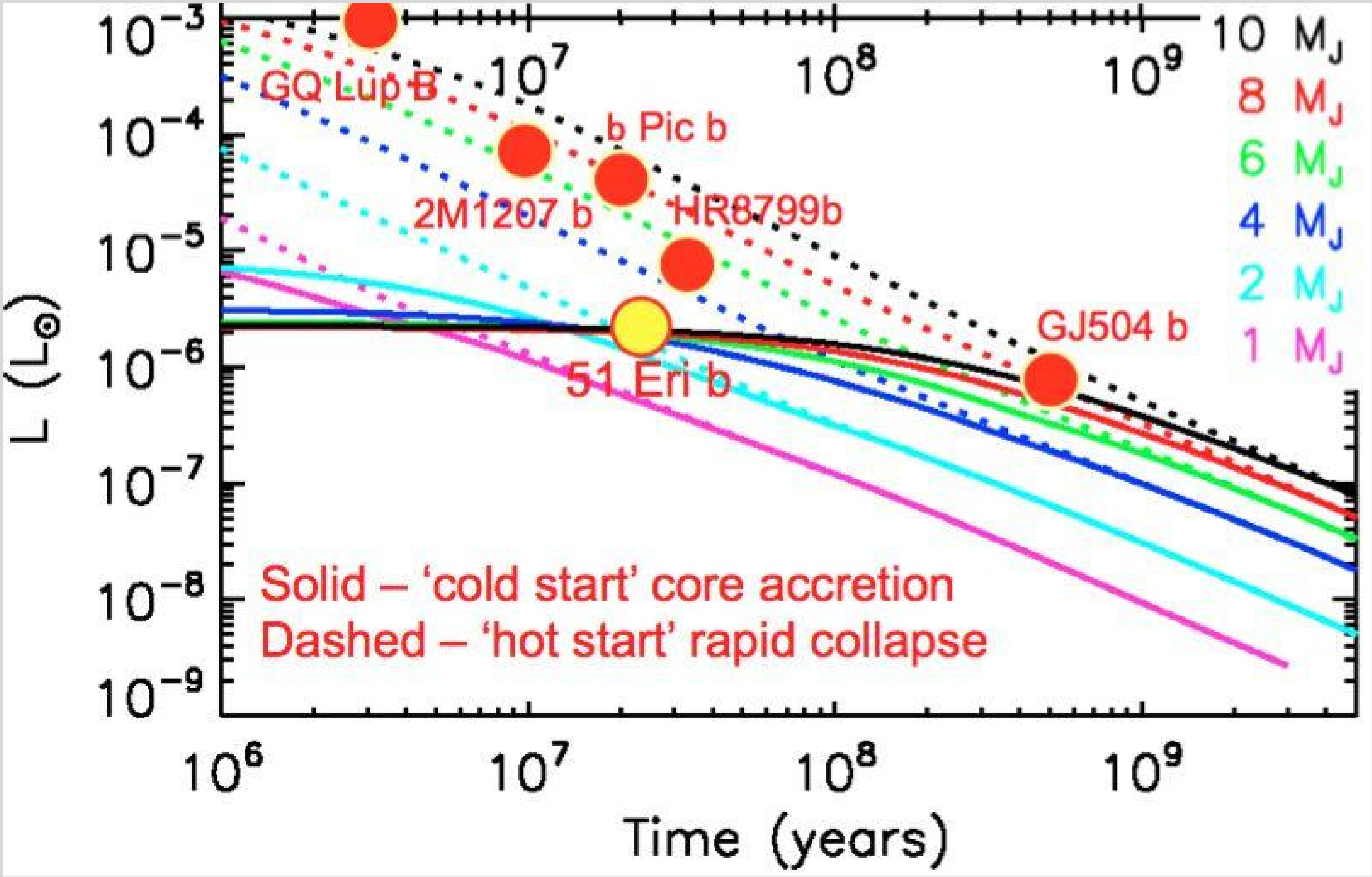


- Propose moving GPI to Gemini North, and in the process performing an upgrade to bring the technology into the current era
- Notional timing
  - Upgrade planning and design happening now through 2020
  - Actual upgrade 2020-2021
  - Back on-sky 2022
    - Note: ELT High-Contrast imagers on-sky ~2030s, HabEX/LUVOIR ~2040

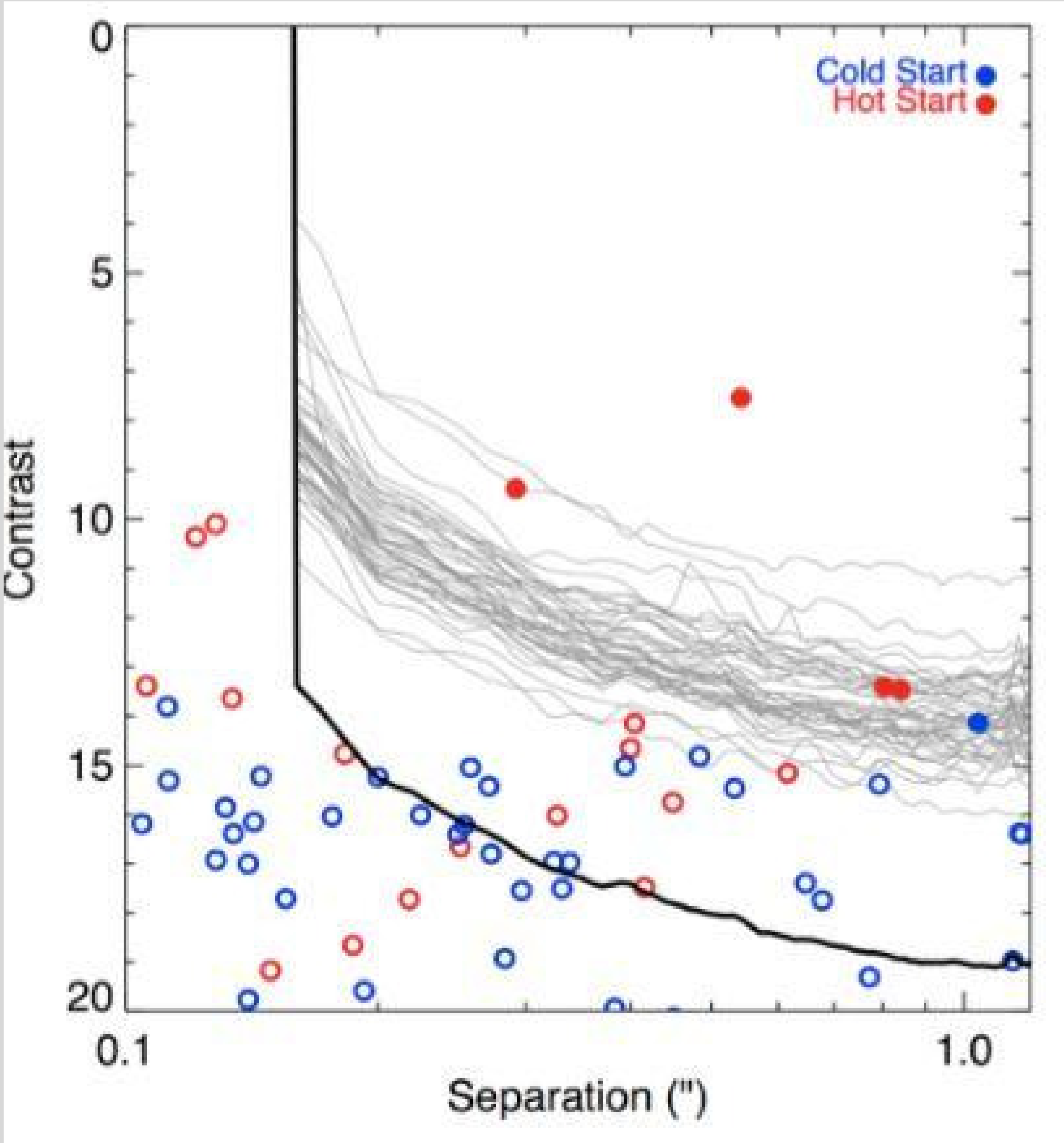
Several upgrade pathways are being explored for GPI 2.0 based on science goals.

- Upgraded wavefront sensor to allow operation to I~14
- New realtime computer based on common architecture with other Gemini AO systems
- Enhanced coronagraphic masks with smaller inner working angle (<0.1”) or higher throughput
- Broadband spectrograph mode for simultaneous JHK observations
- A fiber-feed for a separate high resolution spectrograph for characterizing known planets
- A fast infrared camera for ultra-high-contrast imaging and focal-plane wavefront sensing
- Enhanced software environment to provide fast, efficient queue observing

GPI 2.0 Science Case - Distinguishing “Cold Start” vs “Hot Start” Planets

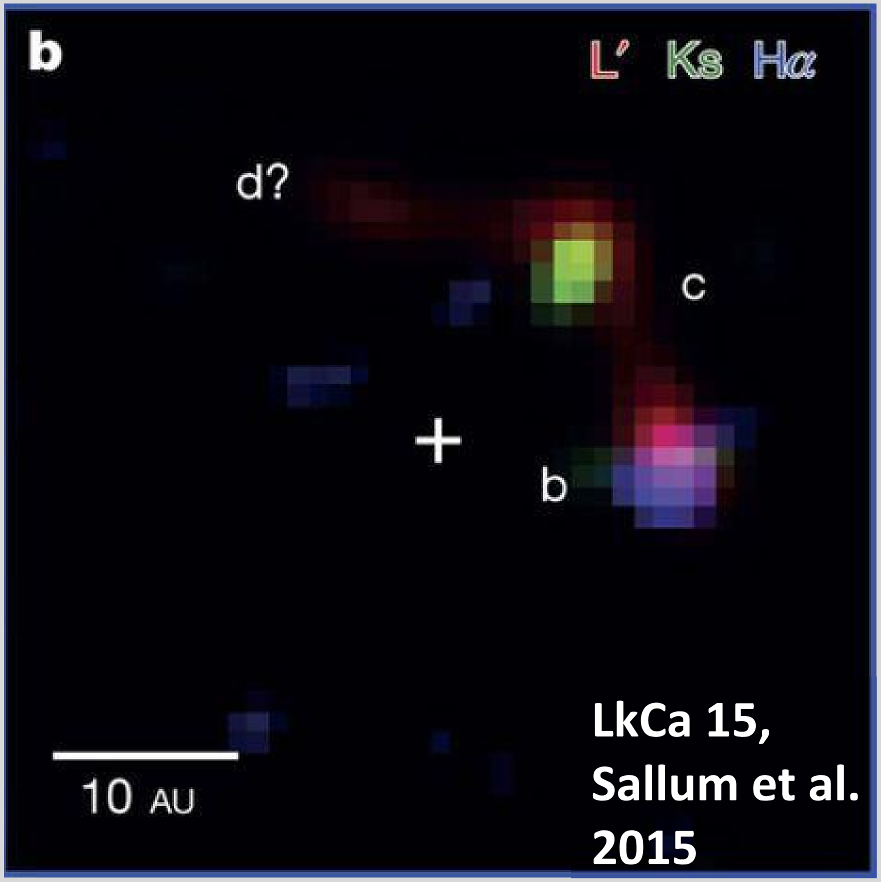


GPI 2.0 Science Case - Distinguishing "Cold Start" vs "Hot Start" Planets

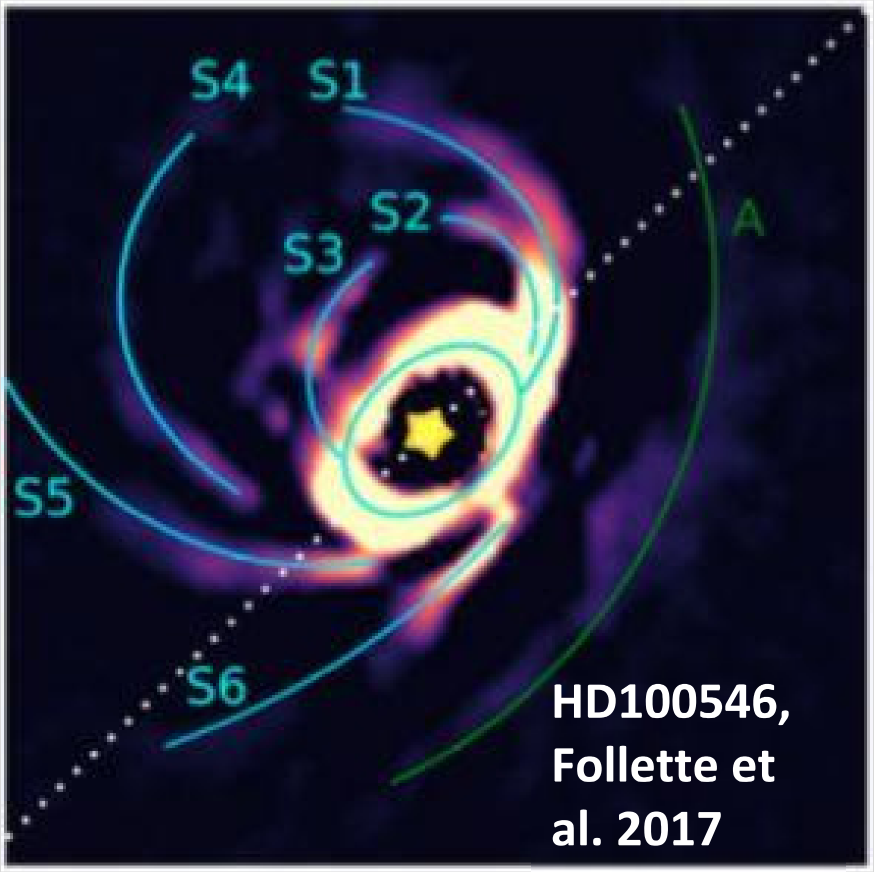


Simulations by Eric Nielsen

GPI 2.0 Science Case - Imaging Forming Protoplanets and Transition Disks



LkCa 15, Sallum et al. 2015



HD100546, Follette et al. 2017

- GPI 2.0 would have the ability to probe very young targets (~1-3 Myr) to search for forming Jupiters and image transition disk structure
- Taurus (~140 pc away) is challenging from the southern hemisphere
- Improved limiting magnitude unlocks >50 targets in Taurus, including ~2 dozen transition disk hosts

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Summary

GPIES Science Team Meeting, UC San Diego, July 2017

- GPI has been a scientifically productive instrument on Gemini South that has revealed fundamental properties of planet formation and evolution
- With GPI 2.0 on Gemini North, new, transformative scientific potential will be realized
  - **For more about additional science with GPI, come to "The Future of Ground-Based High Contrast Imaging" Splinter Session on Wednesday, 10-11:30 am, Room 304 (www.highcontrastimaging.rocks)**
- GPI 2.0 will offer a technology testbed for the next generation of high contrast imagers being planned for the ELTs

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