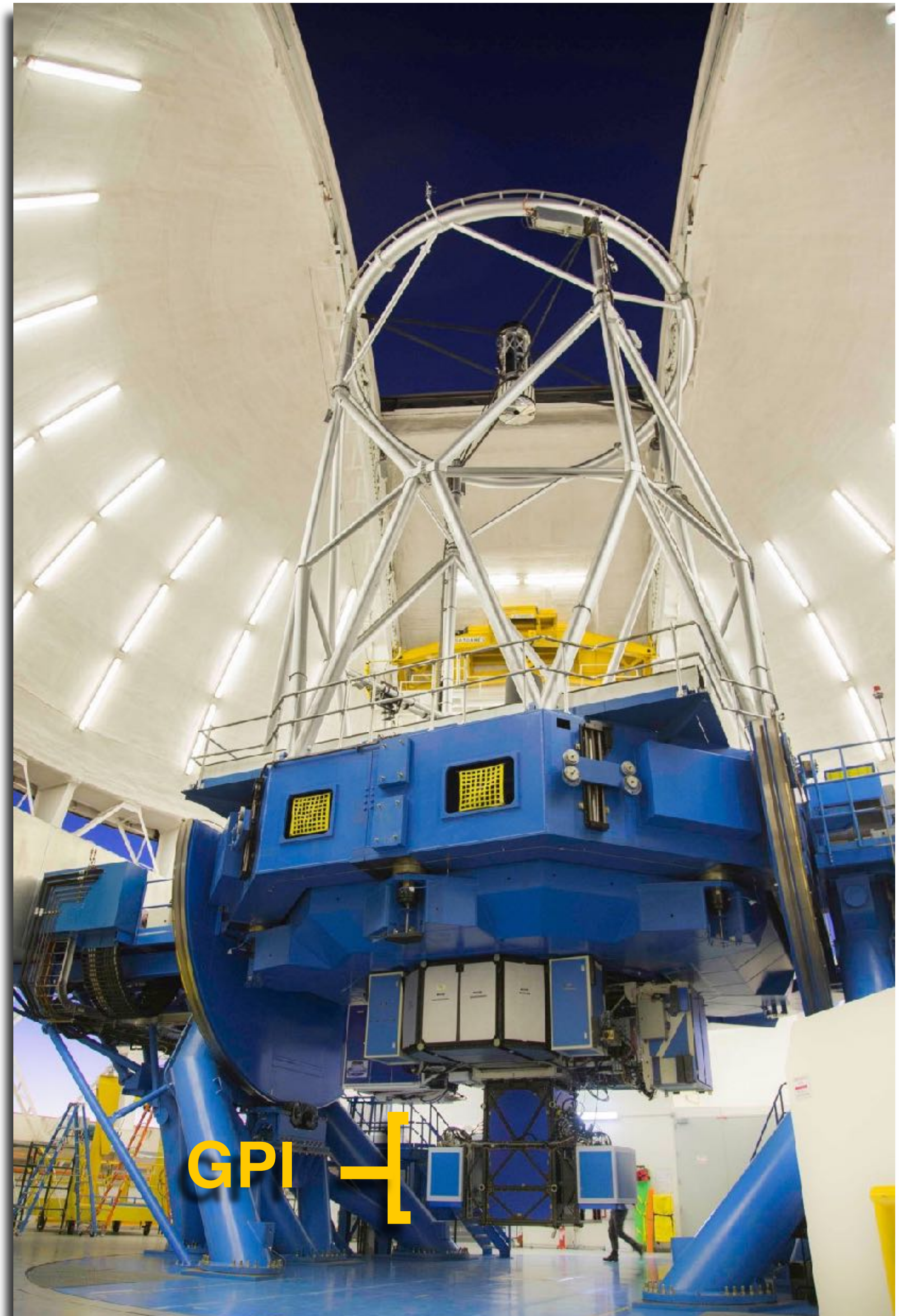



# Recent results from the Gemini Planet Imager
^
*& Disk*
*& Binary Star*

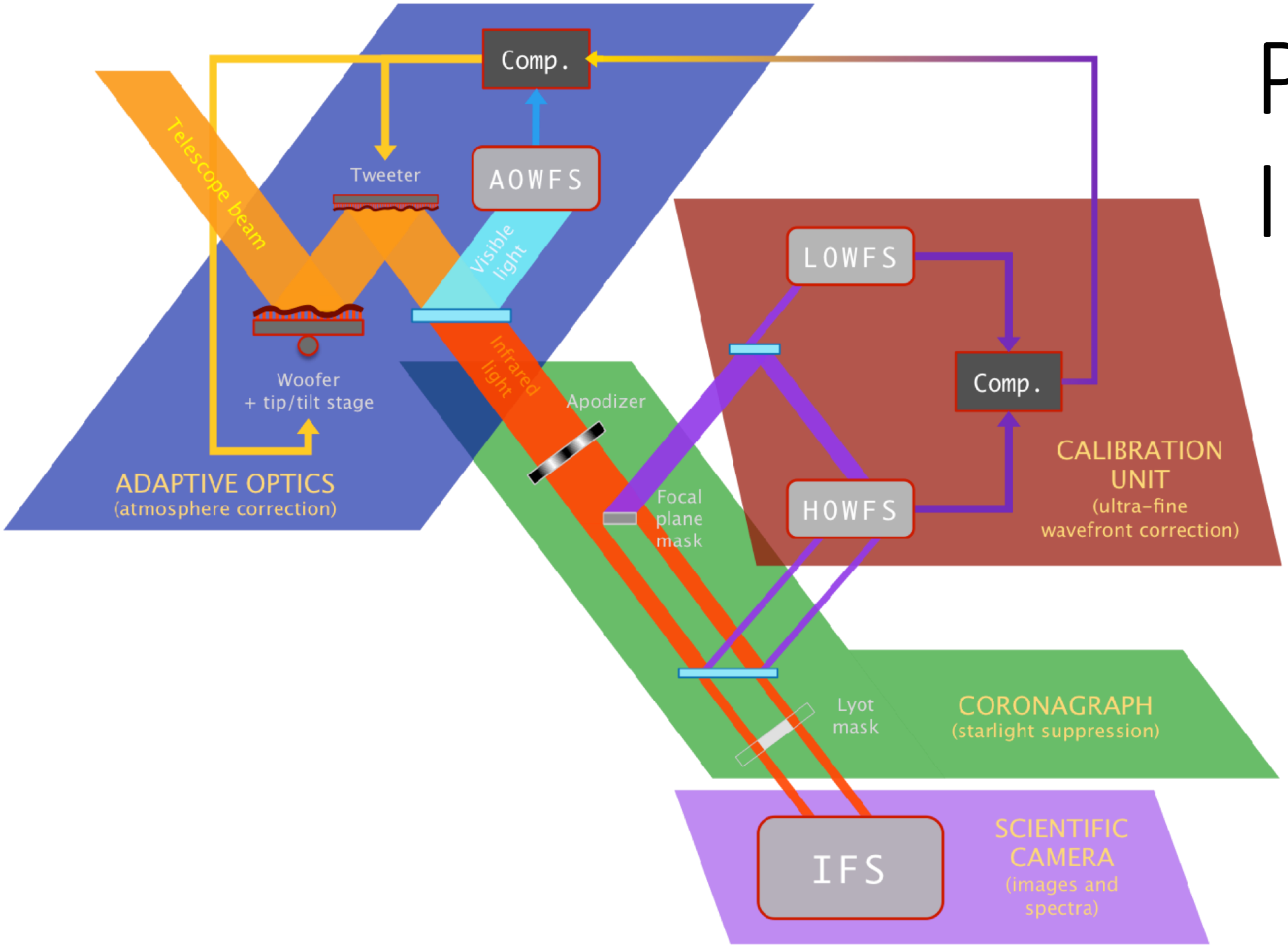
Vanessa Bailey
Jet Propulsion Laboratory / California Institute of Technology

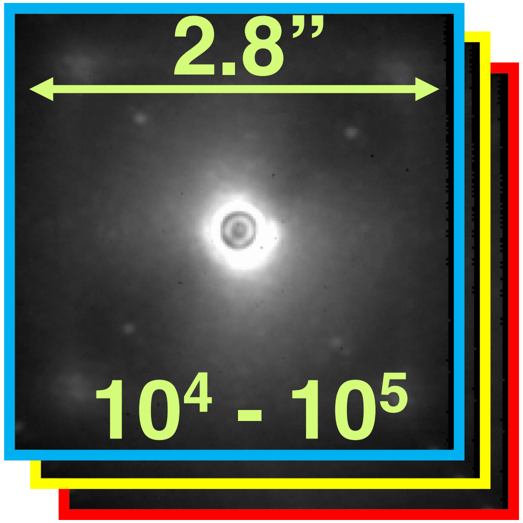
*And the GPI(ES) team*

# The GPIES collaboration

Macintosh, B.
Graham, J. R.
Barman, T
Doyon R.
Fabrycky, D.
Fitzgerald, M.
Kalas, P.
Konopacky, Q.
Marchis, F.
Marley, M.
Marois, C.
Patience, J.
Perrin, M.
Oppenheimer, B.
Song, I.
Artigau, E.
Beckwith, S.
Burrows, A.
Chen, C.
Chiang, E.
Chilcote, J.
De Rosa, R. J.
Duchene, G.
Fortney, J.
Hinkley, S.
Ingraham, P.
Lafreniere, D.
Larkin, J.
Maire, J.
Matthews, B.
Metchev, S.
Morzinski, K.
Murray-Clay, R.
Palmer, D.
Poyneer, L.
Pueyo, L.
Rafikov, R.
Rice, E.
Ruiz, M. T.
Savransky, D.
Saumon, D.
Schneider, A.
Soummer, R.
Sivaramakrishnan, A.
Thomas, S.
Vasisht, G.
Wallace, K.
Wiktorowicz, S.
Zuckerman, B.
Ammons, S. M.
Arriaga, P.
Bailey, V.
Bruzzone, S.
Bulger, J.
Burmingham, B.
Cady, E.
Choquet, E.
Cotten, T.
Czekala, I.
Dawson, B.
Dong, R.
Draper, Z.
Esposito, T.
Follette, K.
Fulton, B.
Gerard, B.
Greenbaum, A.
Hibon, P.
Hirsch, L.
Hom, J.
Howard, A.
Hung, L.-W.
Jensen-Clem, R.
Johnson-Groh, M.
Lawler, S.
Lee, E.
Lee, J.
Line, M.
Johan M.
Millar-Blanchaer, M.
Morley, C.
Nielsen, E.
Norton, A.
Patel, R.
Poteet, C.
Rajan, A.
Rameau, J.
Rantakyro, F.
Ren, B.
Rice, M.
Rodigas, TJ
Ryan, D.
Ruffio, J.-B.
Salama, M.
Shapiro, J.
Stahl, K.
Vega, D.
Wang, J.
Ward-Duong, K.
Wolff, S.

# Gemini Planet Imager

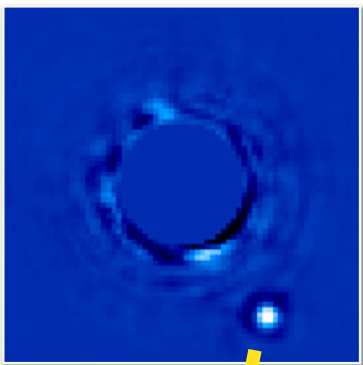


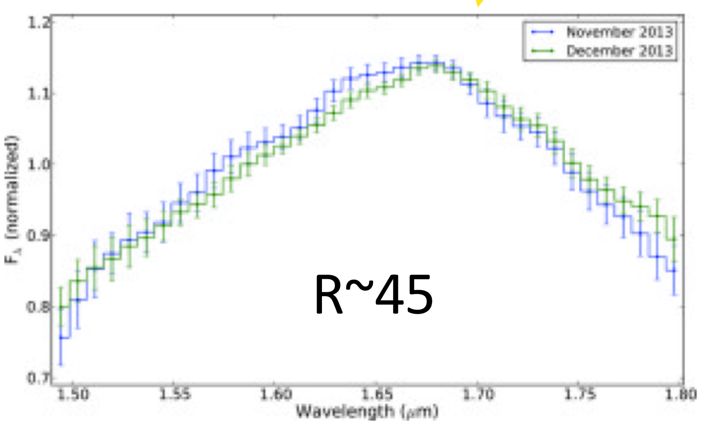




Credit - Paul Langlois

# 2 observing modes

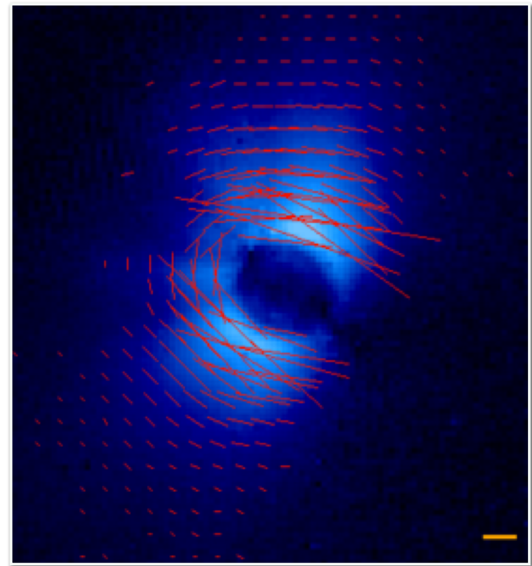
## Spectroscopy / Photometry






R~45

## Polarimetry

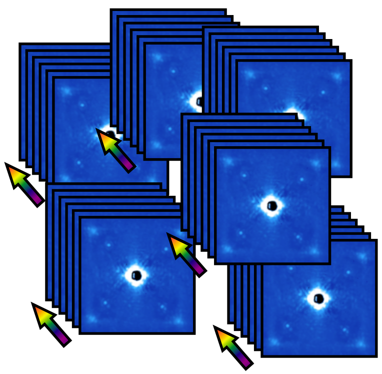


J, H, and K bands

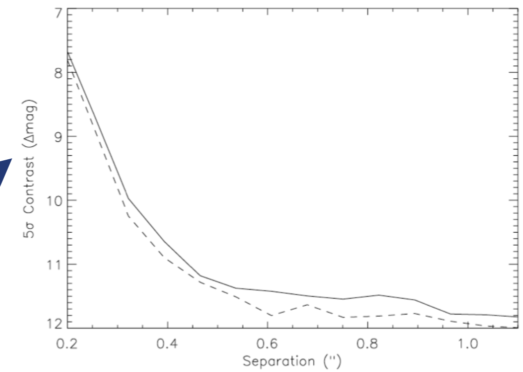
14mas plate scale

# “Data Cruncher”

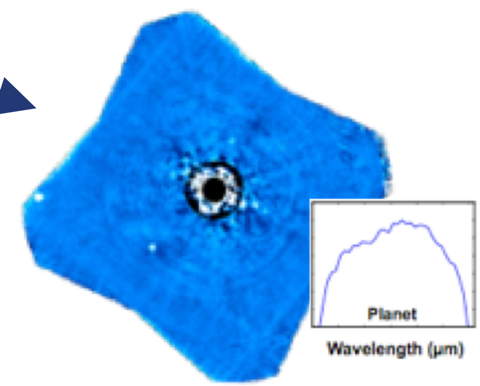
## Observing sequences -> detections & limits



**“Final” contrast**

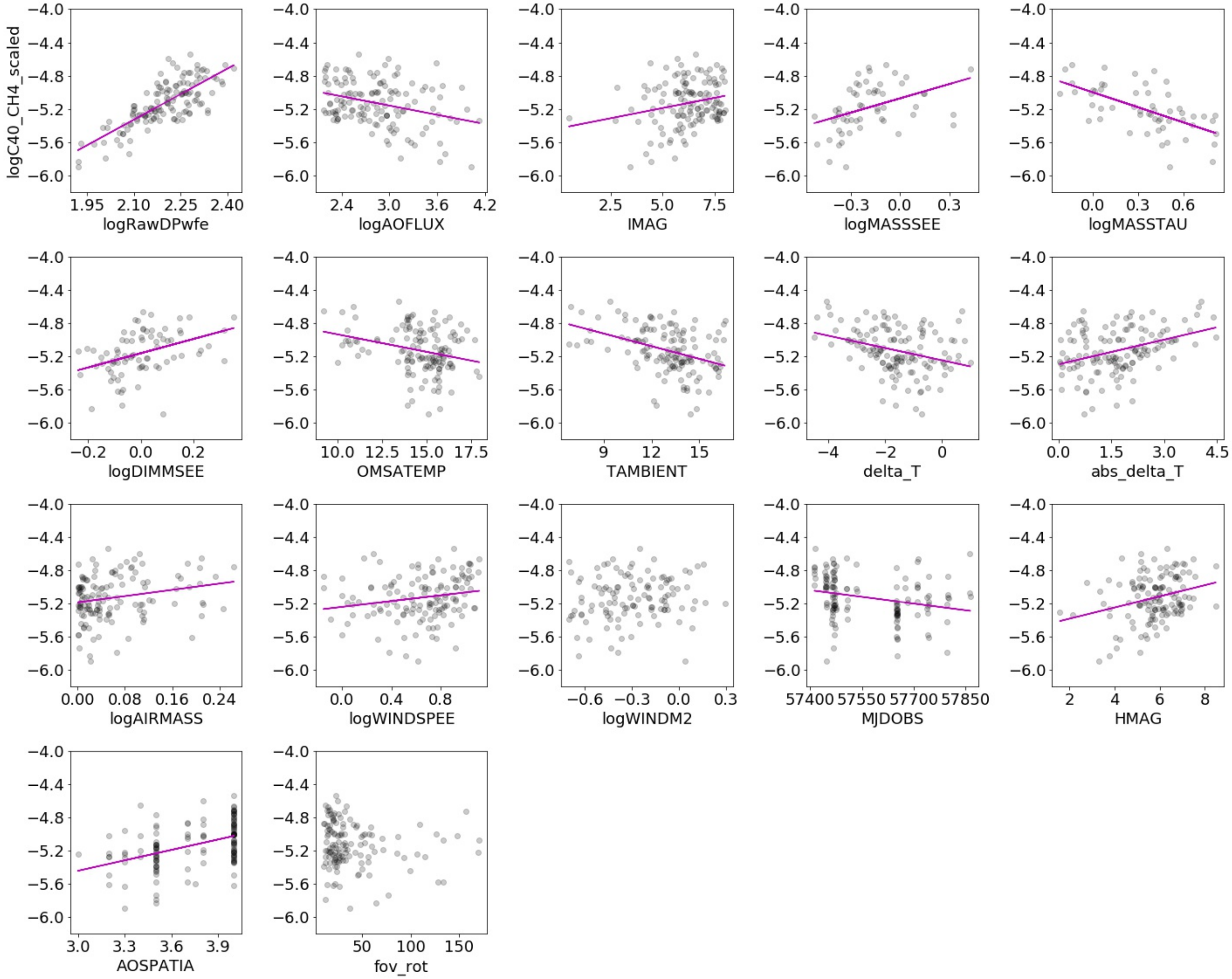



!!!




Led by Jason Wang;
other pipelines: Christian Marois, Julien Rameau, Jean-Baptiste Ruffio

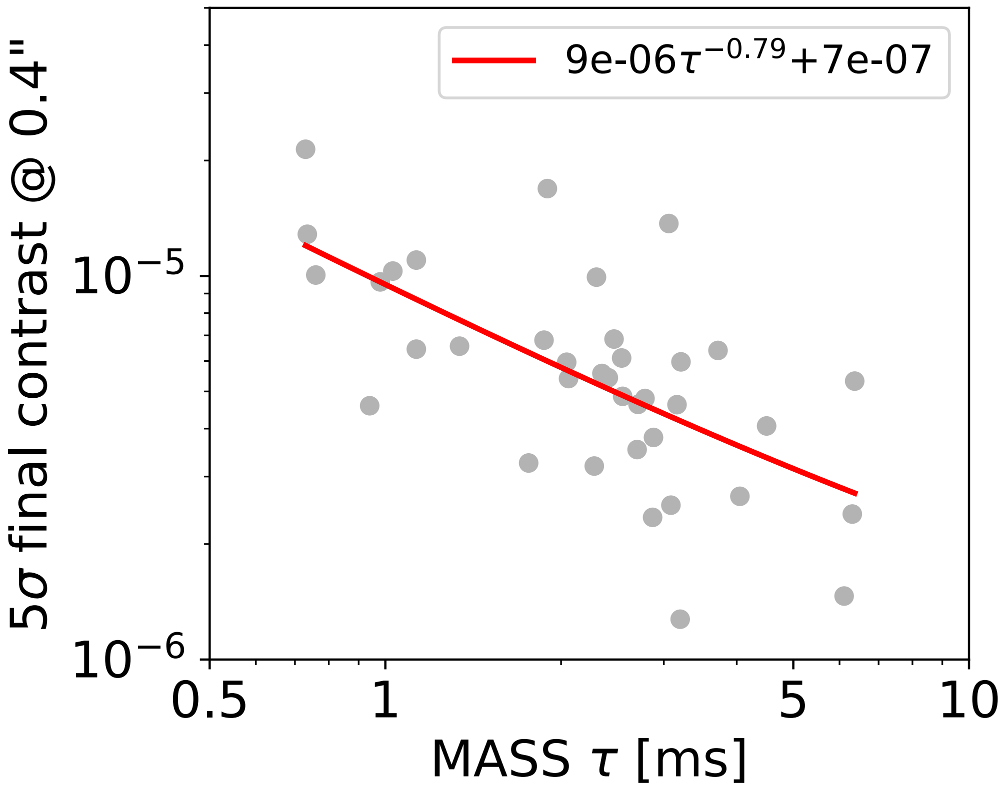
# What factors determine contrast?



# Seeing coherence time matters more than seeing amplitude

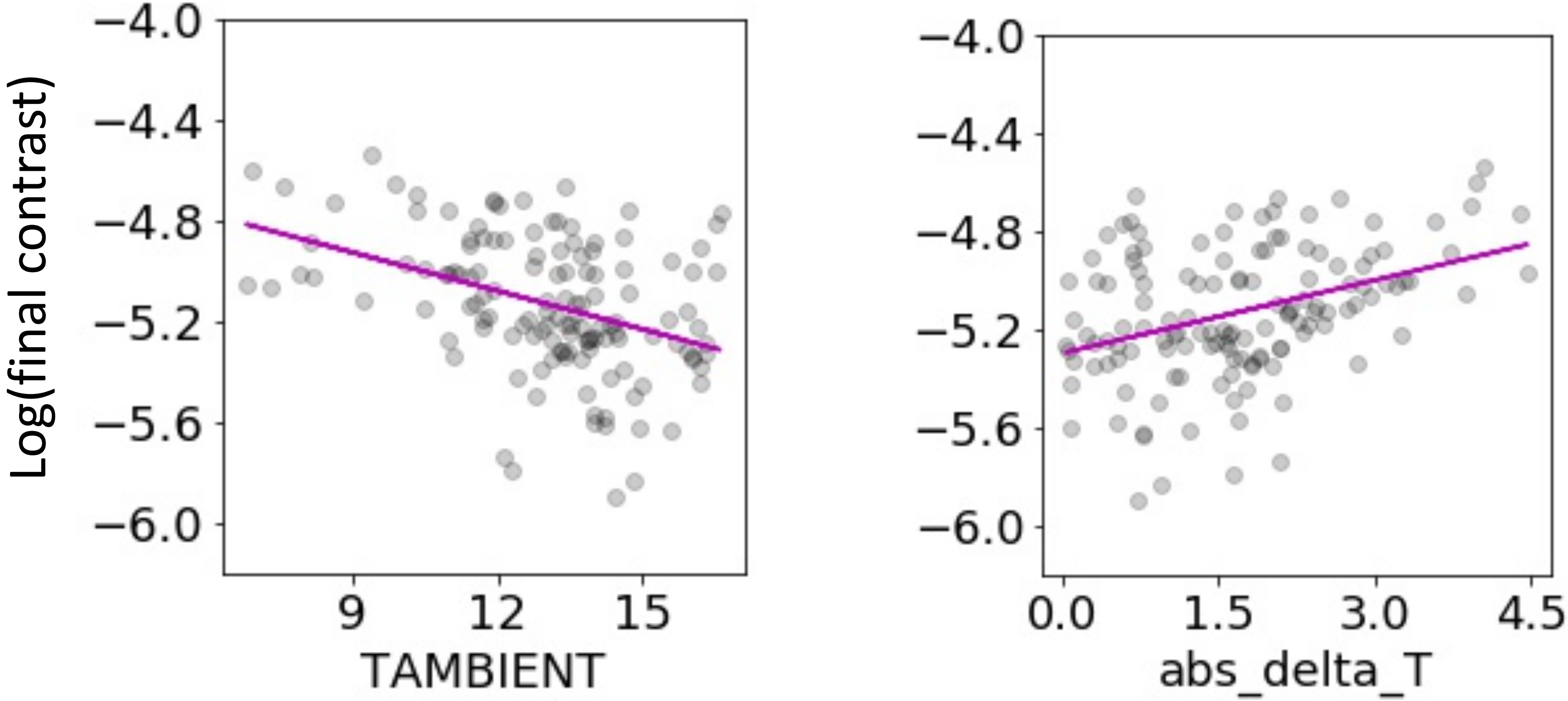
slower
turbulence

poorer detection limits



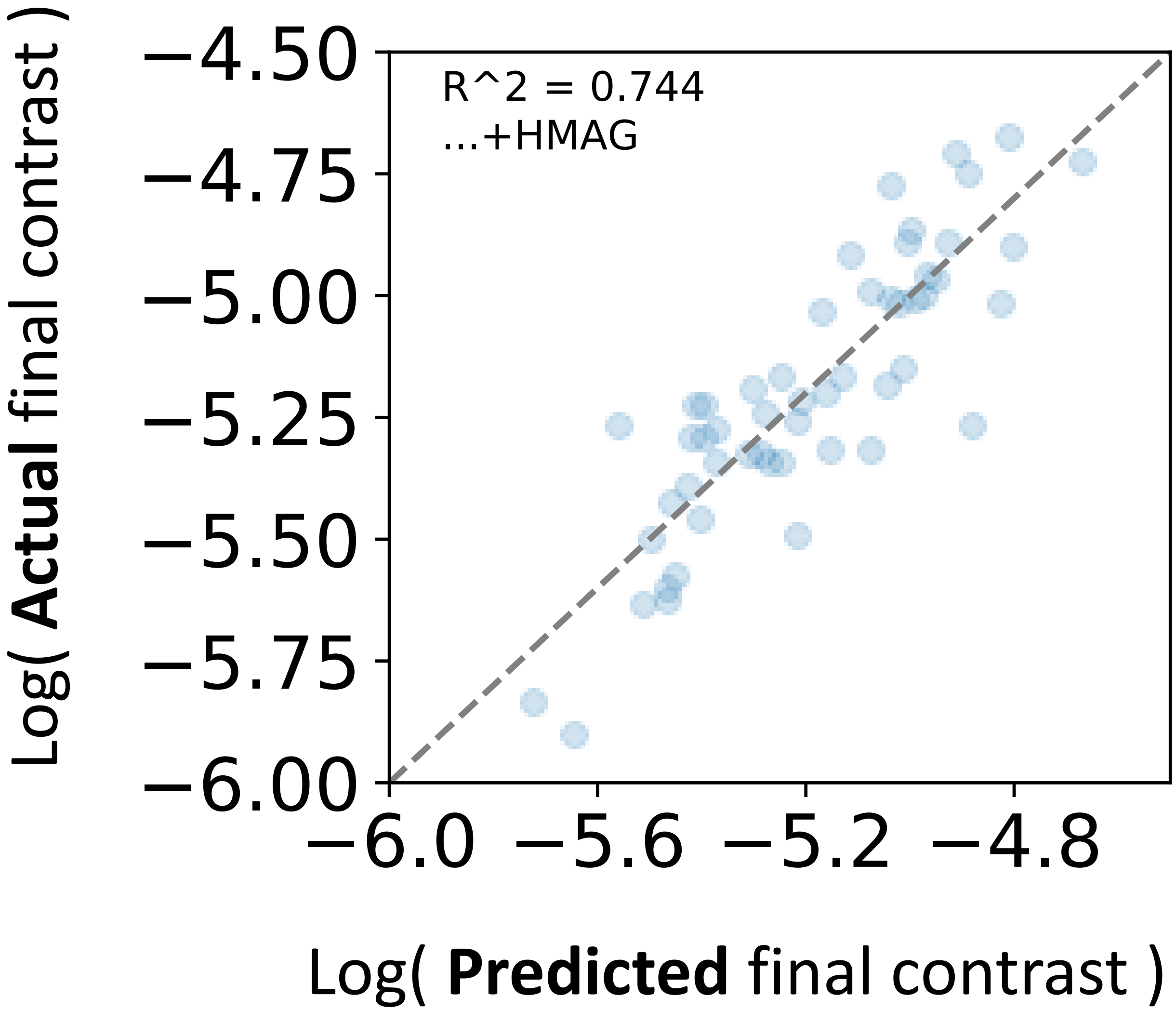

- Bailey et al; SPIE 2016
- Rantakyro, Bailey, et al; SPIE 2018

# Performance depends on temperature?

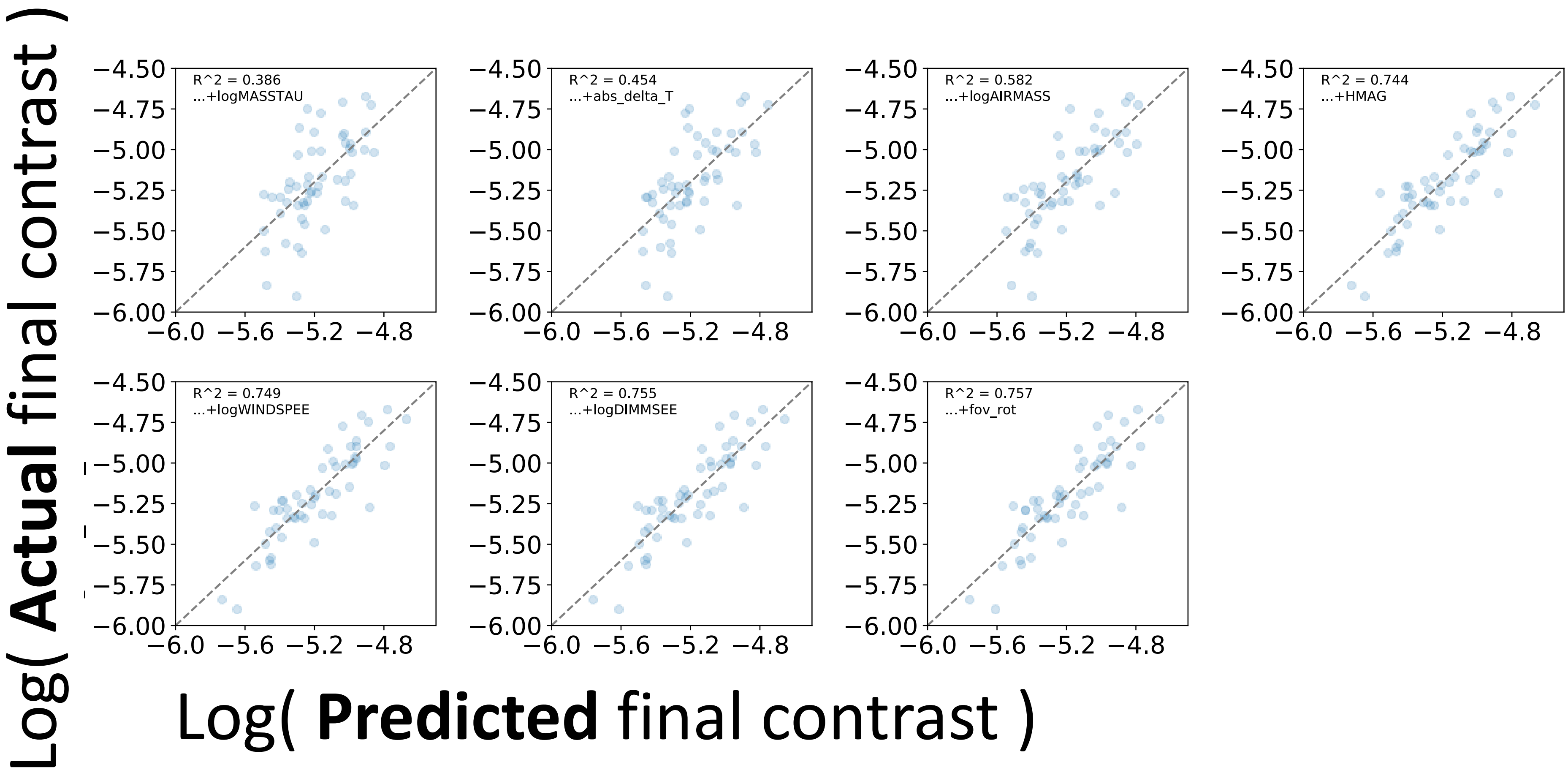


# Only need 4 variables to (mostly) predict final contrast: *τ, ΔT, airmass, H mag.*

Rantakyro, Bailey, et al; SPIE 2018



# Only need 4 variables to (mostly) predict final contrast: *τ, ΔT, airmass, H mag.*



# GPI & dome turbulence

- **Melisa Tallis**; Stanford University
- SPIE proceedings 2018

# SPIE 2018 10703-267; arXiv 1807.07157

## Air, Telescope, and Instrument Temperature Effects on the Gemini Planet Imager's Image Quality

Melisa Tallis[a], Vanessa P. Bailey[b], Bruce Macintosh[a], Jeffrey K. Chilcote[a], Lisa A. Poyneer[c], Jean-Baptiste Ruffio[a], Thomas L. Hayward[d], Dmitry Savransky[e], and the GPI Team

[a]Kavli Institute for Particle Astrophysics & Cosmology, Physics Department, Stanford University, Stanford, CA, 94305, USA
[b]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA
[c]Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, CA, 94550, USA
[d]Gemini Observatory, Casilla 603, La Serena, Chile
[e]Sibley School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY, 14853, USA

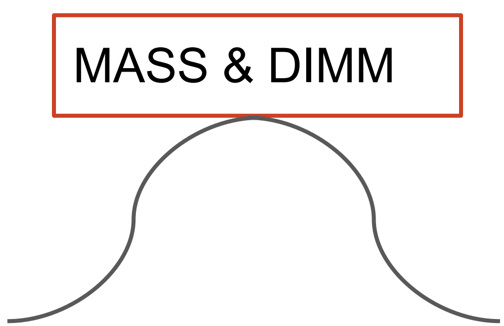
### ABSTRACT

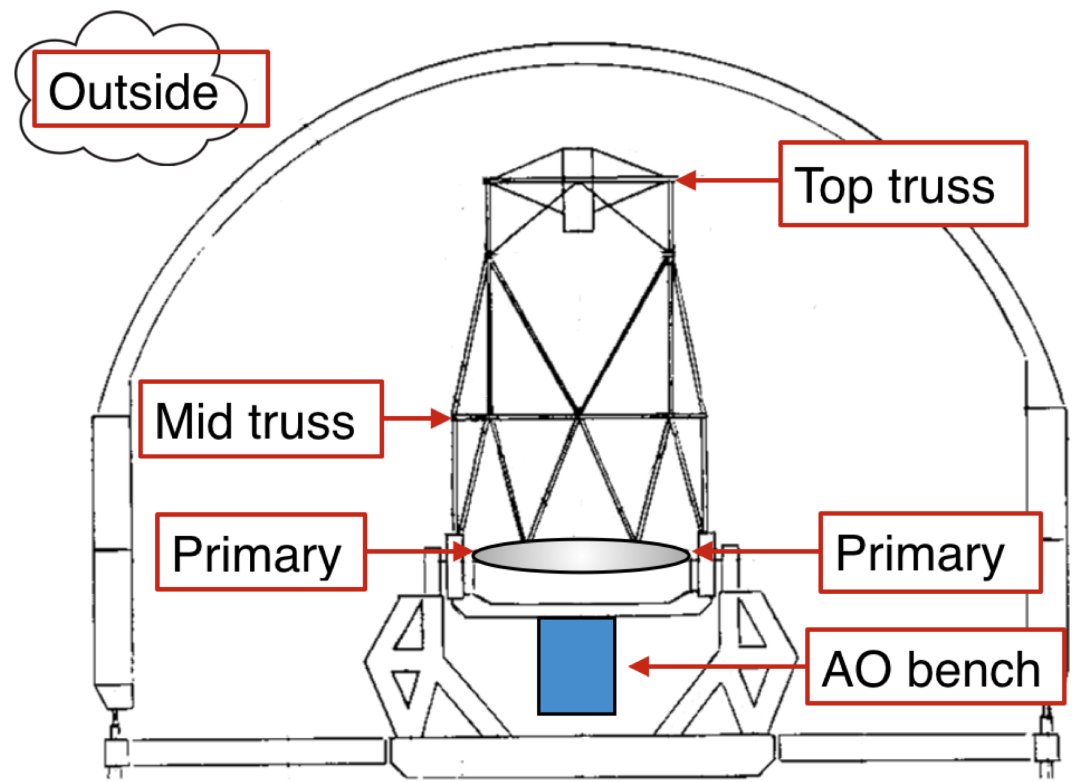
The Gemini Planet Imager (GPI) is a near-infrared instrument that uses Adaptive Optics (AO), a coronagraph, and advanced data processing techniques to achieve very high contrast images of exoplanets. The GPI Exoplanet Survey (GPIES) is a 600 stars campaign aiming at detecting and characterizing young, massive and self-luminous exoplanets at large orbital distances ($> 5$ *au*). Science observations are taken simultaneously with environmental data revealing information about the turbulence in the telescope environment as well as limitations of GPI's AO system. Previous work has shown that the timescale of the turbulence, $\tau_0$, is a strong predictor of AO performance, however an analysis of the dome turbulence on AO performance has not been done before. Here, we study correlations between image contrast and residual wavefront error (WFE) with temperature measurements from multiple locations inside and outside the dome. Our analysis revealed GPI's performance is most correlated with the temperature difference between the primary mirror of the telescope and the outside air. We also assess the impact of the current temperature control and ventilation strategy at Gemini South (GS).

# Gemini South environment data

- temperatures: 5 min night & day
- GPI contrasts: 1 min
  - Select frames with best seeing using MASS/DIMM

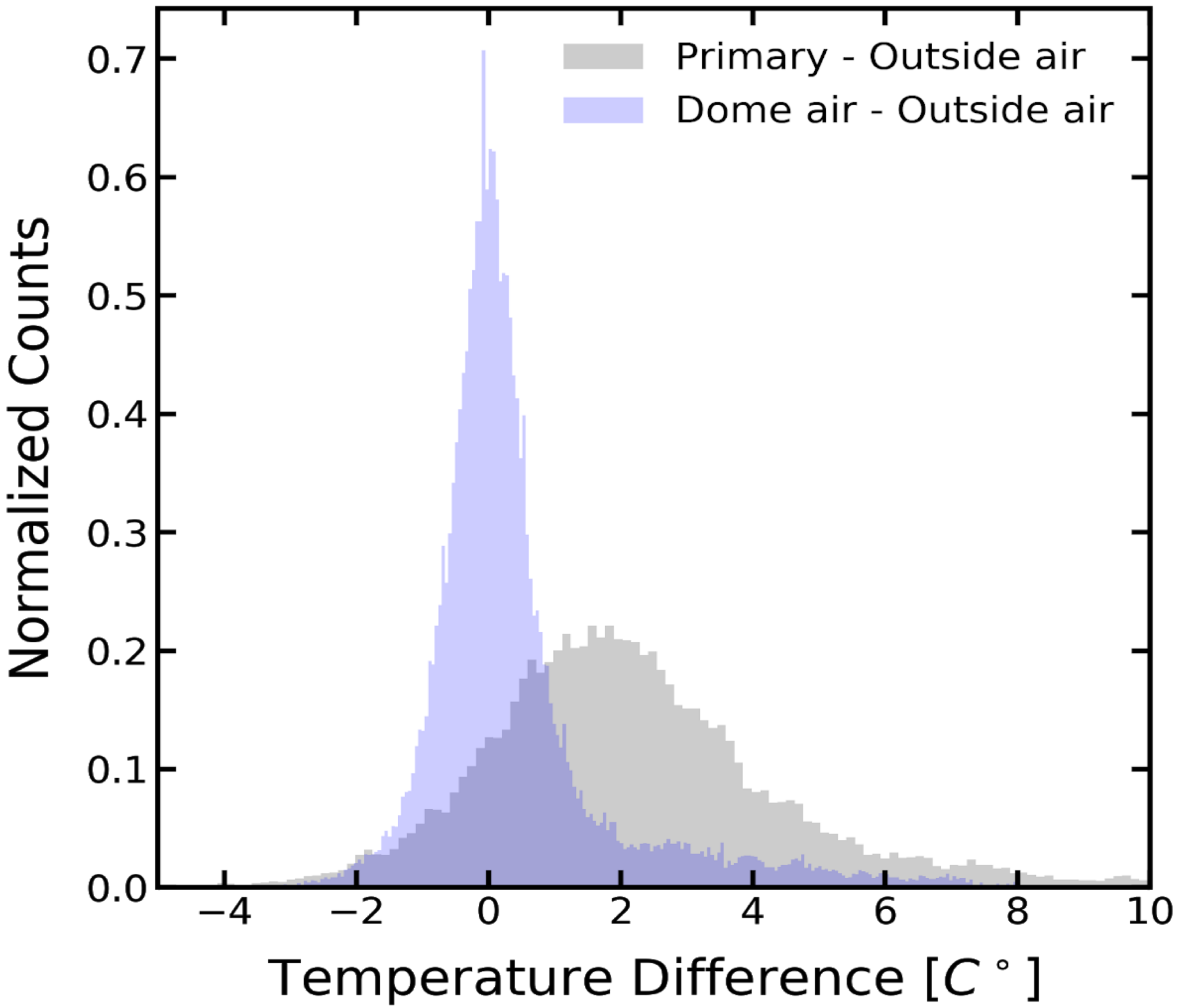

Melisa Tallis
Thomas L. Hayward

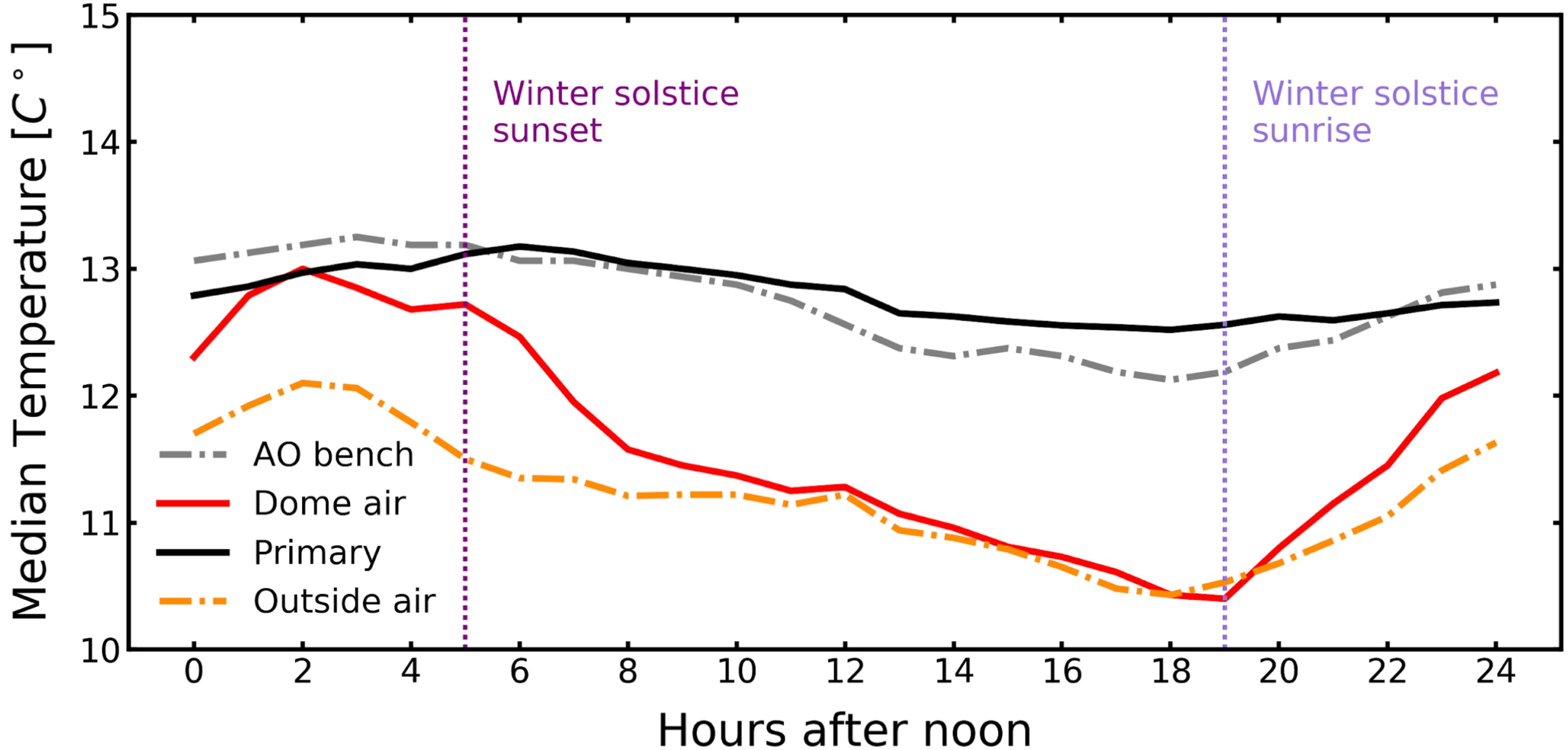



Tallis et al; SPIE 2018

# M1 is not equilibrated with ambient air



# Large thermal inertia of the primary mirror



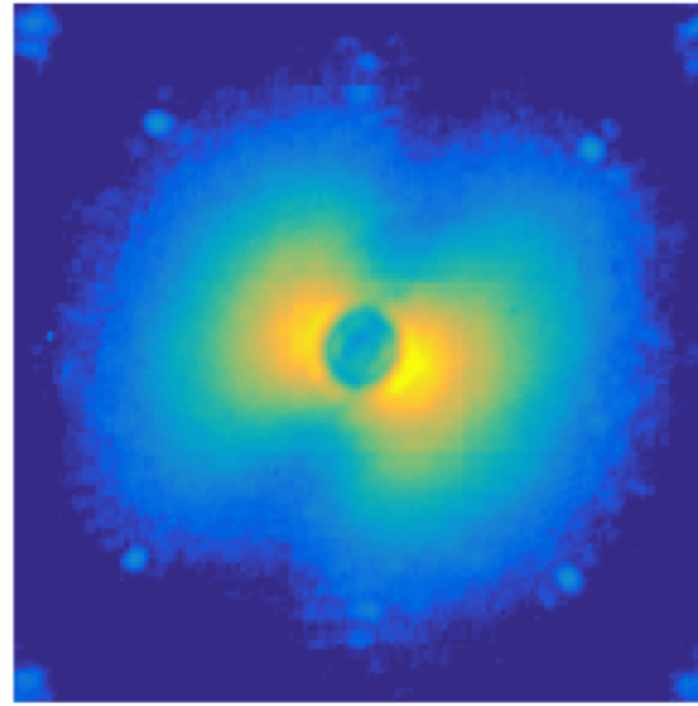

Tallis et al; SPIE 2018

*Preliminary results removed…email if interested in discussing.*

# GPI wind butterfly

- **Alex Madurowicz**
- Stanford University
- SPIE proceedings 2018

- The following slides are from Alex



# Characterization of lemniscate atmospheric aberrations in Gemini Planet Imager data

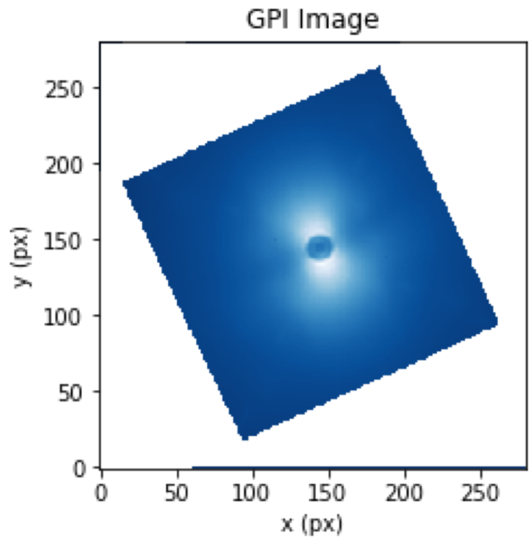
Alexander Madurowicz[1], Bruce A. Macintosh[1], Jean-Baptiste Ruffio[1], Jeffery Chilcote[1], Vanessa P. Bailey[2], Lisa Poyneer[3], Eric Nielsen[1], and Andrew P. Norton[1]

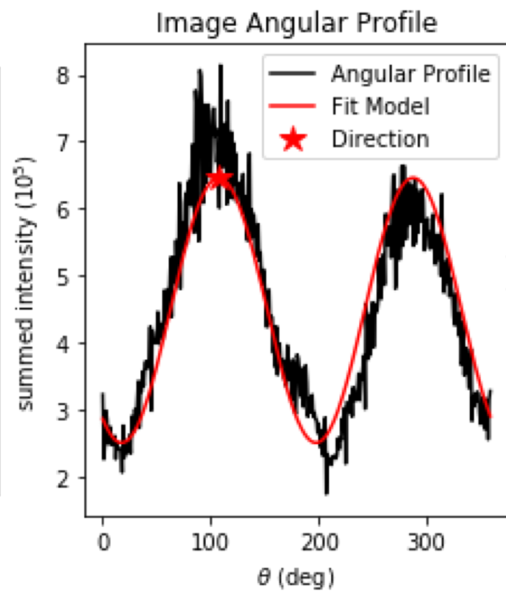
[1]Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, Stanford, CA, 94305
[2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109
[3]Lawrence Livermore National Laboratory, Livermore, CA 94550

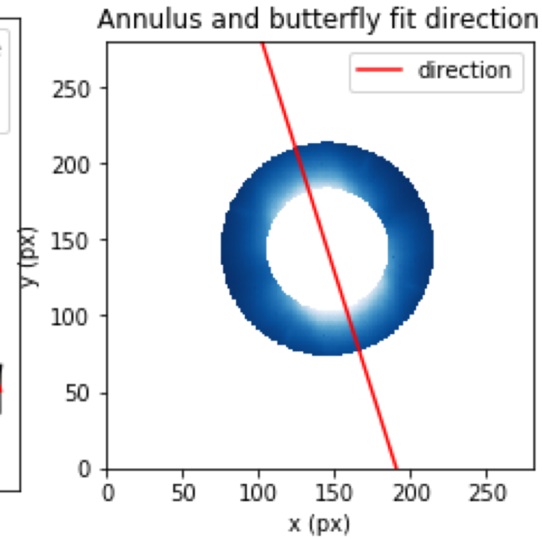
## ABSTRACT

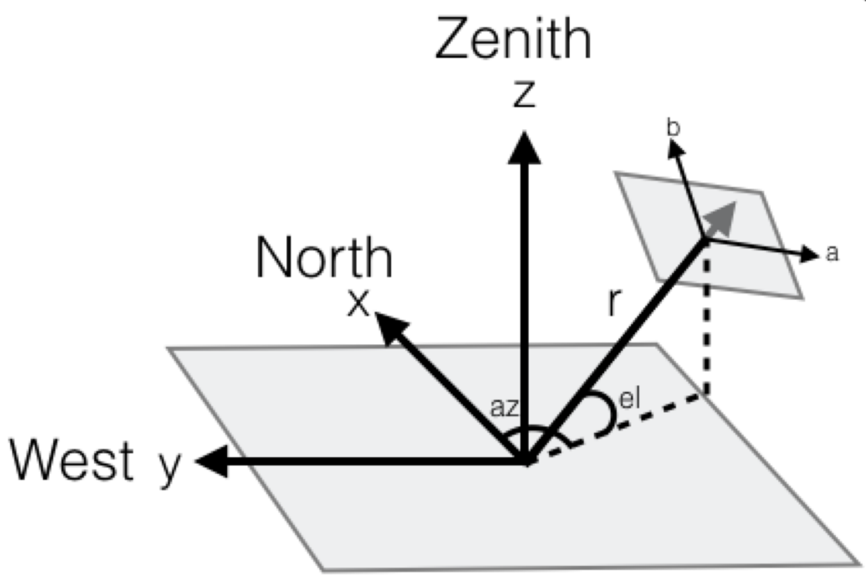
A semi analytic framework for simulating the effects of atmospheric seeing in Adaptive Optics systems on an 8-m telescope is developed with the intention of understanding the origin of the wind-butterfly, a characteristic two-lobed halo in the PSF of AO imaging. Simulations show that errors in the compensated phase on the aperture due to servo-lag have preferential direction orthogonal to the direction of wind propagation which, when Fourier Transformed into the image plane, appear with their characteristic lemniscate shape along the wind direction. We develop a metric to quantify the effect of this aberration with the fractional standard deviation in an annulus centered around the PSF, and use telescope pointing to correlate this effect with data from an atmospheric models, the NOAA GFS. Our results show that the jet stream at altitudes of 100-200 hPa (equivalently 10-15 km above sea level) is highly correlated ($13.2\sigma$) with the strong butterfly, while the ground wind and other layers are more or less uncorrelated.

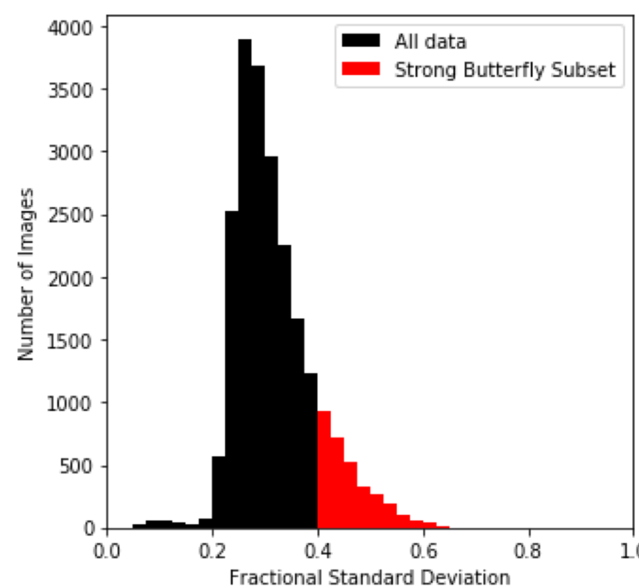
Arxiv:1807.07179 Proc. SPIE 10703-230



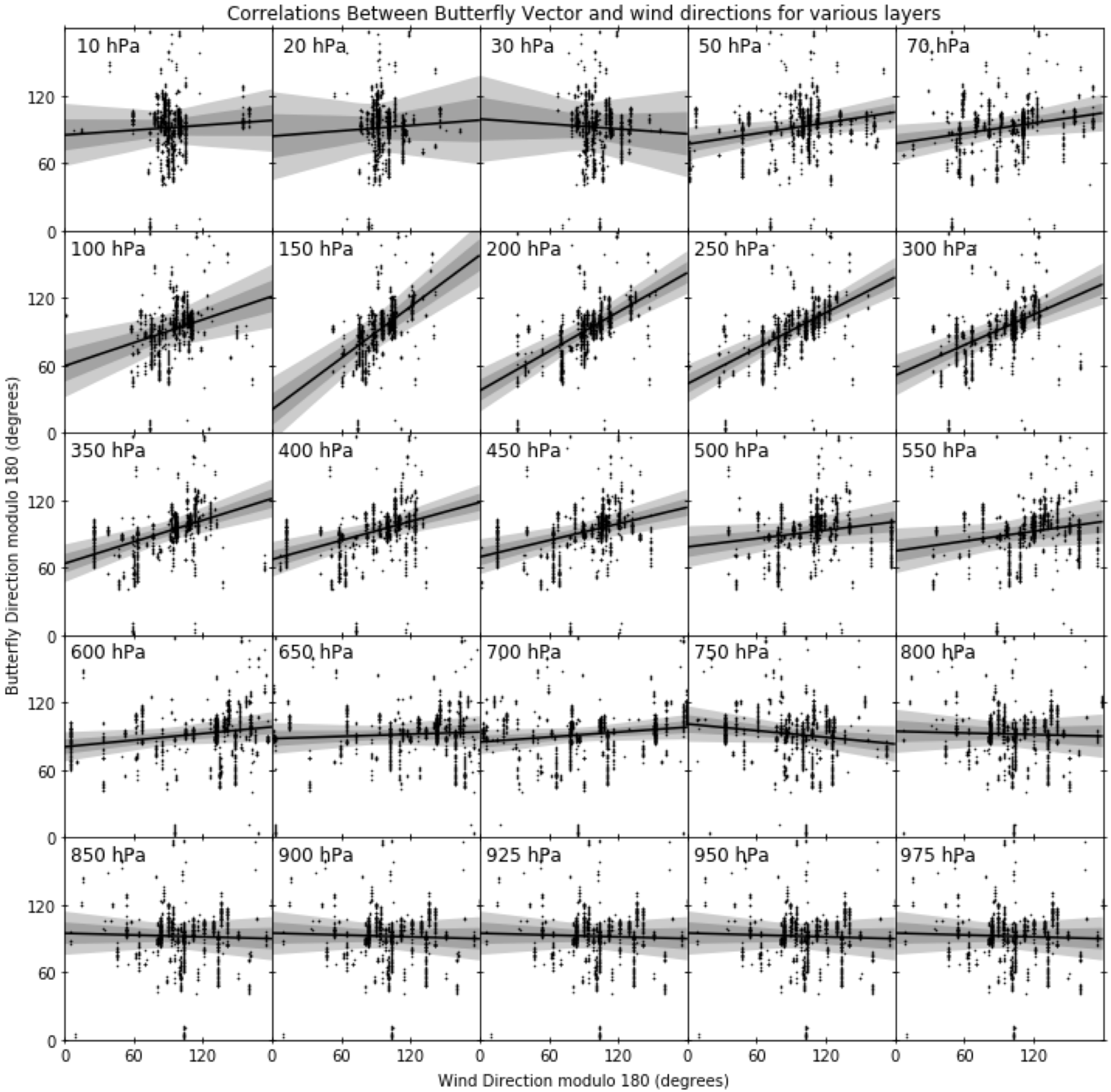




Madurowicz et al; SPIE 2018




Madurowicz et al; SPIE 2018

# Conclusions/Takeaways

- Servo-lag error in AO correction is responsible for the wind-butterfly

- well correlated with the jet stream (~ 10-15 km attitude)

*Preliminary results removed…email if interested in discussing.*

# What’s next for GPI: the move North

- Stay at Gemini South through 2019 (A or B?)
- GPI 1.1: *May* move to Gemini North in ~2020
  - relocation study just submitted to Gemini. Maintenance on compatibility only – no upgrades.
  - Uncertainty: $\tau_0$ at Mauna Kea vs Cerro Pachon.  Contrast improvement of 1.5-2.5x.
- GPI 2.0 : *May* move to Gemini North *and* have hardware upgrade

# GPI 2.0 science cases under development

- Cold Start Planets
- Very Young Planets
- Variability and Weather
- Orbital Monitoring of Known Substellar Companions
- Spectral Characterization of Known Substellar Companions

- Protoplanetary and Transition Disks
- Debris Disks

- Spectropolarimetry
- High Resolution Spectroscopy
- Ultra-high-contrast science with FPWFS

- Solar System Bodies
- Evolved Stars
- Extragalactic Science

# Coming soon: new GPI sat spot flux calibration