GPI: things that worked

- Dedicated, effective team has been crucial to GPI productivity (in both commissioning and campaign)
  - Strong collaboration with observatory
- Well-constructed and validated data pipeline
- High-quality optics and stable structure
- Efficient top-level software
- Extensive archiving of data and metadata
- Flexible interfaces and scripting
- MEMS deformable mirror
GPI: things that could be improved

• Lack of EMCCD hurts faint-star performance (I=10 mag)
• Environmental testing is often too optimistic
  – Therefore, computation times / frame rate are critical
• Should have included a ND filter!
• Idealized picture of observatory software differs from reality
  – Software development stalls at ‘good enough’
  – GPI queue utilization limited
Strongest contrast predictor: \( \tau_0 \)
\( \tau_0 = r_0/v_{\text{wind}} \) much worse than predicted

Bad conditions dominated by jet stream – Madurowicz et al 2018
Dome seeing also degrades performance

Tallis et al 2018

![Graph showing the correlation between primary and outside air temperature difference and raw 5-σ contrast. The graph indicates a trend where higher temperature differences correlate with lower raw contrast, suggesting that the primary temperature plays a critical role in contrast degradation.](image-url)
Integrated contrast model

- $R^2 = 0.27$ for $\log C_{40, CH4, scaled}$
- $R^2 = 0.38$ for $\Delta-T$
- $R^2 = 0.39$ for Total R0
- $R^2 = 0.53$ for Airmass
- $R^2 = 0.68$ for H mag

Additional relationships:
- $R^2 = 0.289$ for $\log \text{MASSTAU}$
- $R^2 = 0.382$ for $\text{abs}_\Delta T$
- $R^2 = 0.386$ for $\log \text{DIMMSEE}$

Graphs showing the relationship between predicted and observed values for each parameter.
GPI Relocation

Photo by Dmitry Savransky
### GPI 2 science development

Developing science cases relevant to 2020-2025

1. **Emphasize GPIs strengths: reliable, efficient operation**
2. **Quantify science requirements -> practical design**
3. **Complement Subaru and Keck capabilities**

<table>
<thead>
<tr>
<th>Science Cases</th>
<th>WFS I mag limit</th>
<th>Inner working angle</th>
<th>Contrast Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Scale Survey / Cold-start planets</td>
<td>10</td>
<td>0.15</td>
<td>2+ mag</td>
</tr>
<tr>
<td>Very young stars + transitional disks</td>
<td>13 (or IR WFS)</td>
<td>0.1&quot;</td>
<td>0</td>
</tr>
<tr>
<td>Spectropolarimetry</td>
<td>7</td>
<td>0.15&quot;</td>
<td>1% polarimetry</td>
</tr>
<tr>
<td>Low-mass Stars</td>
<td>13</td>
<td>0.1&quot;</td>
<td></td>
</tr>
<tr>
<td>Asteroids &amp; Solar System Objects</td>
<td>14</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Debris Disks</td>
<td>9</td>
<td>0.2&quot;</td>
<td>0</td>
</tr>
<tr>
<td>Planet Variability &amp; abundance characterization</td>
<td>6</td>
<td>0.2”</td>
<td>1% photometry, high-res spectroscopy feed</td>
</tr>
</tbody>
</table>
"Cold start" planets

Solid – ‘cold start’ core accretion
Dashed – ‘hot start’ rapid collapse
Detecting cold-start planets
Younger planets: Taurus

Closest active planet formation?
140 pc, 1-2 Myr
Requires I~13 mag or IR WFS
Desirable: <0.1” IWA
High spectral resolution mode

- High spectral resolution could determine rotational velocity (Snellen et al 2014) and abundances (Konopacky et al 2013)
- Fiber-feed off-bench spectrograph
- Optimal resolution unclear

OSIRIS spectra of HR8799c (Konpacky et al 2013)
Variability, clouds, rotation

- Rotating planets could be variable at the 1% level
- Combined with high spectral resolution could map out cloud structure
- Are there enough photons?

Luhman 16B (Crossfield et al)
Risks: Gemini North M1 printthrough
Build on GPI and observatory’s strengths – reliability, data pipeline, survey and monitoring capability

AO: pyramid sensor + 2 kHz + predictive control?
- I=13 mag limit
- 2-4x better contrast close to star

- **IFS**
  - One-shot JHK R~15 mode
  - SpecPol mode

- **Highres spec mode**
  - Fiber-fed R=4,000 or 70,000?

- **Coronagraph**
  - High-throughput broadband mode for surveys and variability
  - Small IWA mode for distant targets
  - Mask M2 bumps?

- **Calibration**
  - Modulated ref spots
  - Fast IR APD camera for imaging and focal-plane WFS (self-coherent, Gerard et al 2018)
  - Precorrect for M2 bump aliasing