High-Contrast Exoplanet Imaging @ Gemini

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Gemini Altair 2001

ADI first ever testing

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Exoplanet Science with Altair/NIRI

GDPS/IDPS/SONIC/Janson/DavidL (young stars)

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Altair NIFS science

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Altair Issues

- **<u>Low Strehl</u>** (half Keck while being a smaller telescope): mirror <u>vibrations</u> (NIRI cryocooler)

- Gemini is optimized for **<u>IR imaging</u>**, yet Altair **<u>transmits ~5% of the Lp science light</u>** (was never designed to do Lp, yet Gemini offers it). Gemini+Altair could have been the best combination to find planets for the past 10 years (low background with queue scheduling). ~20k fix that never happened... (replace WFS/SP beam-splitter).

First “optimize” exoplanet imager NICI (ADI+SSDI)

Science with NICI

Campaign/IDPS/PSYM

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GPI DI Exoplanet discoveries vs the competition

Gemini

HR 8799 system + b
I6RSX
ADI first ever test
GDPS 2003-2007
IDPS 2007-
NICI campaign 2008-2012

Subaru

None

SEEDS survey since 200?

Keck

HR 8799cde

Macintosh survey since 2000

VLT

Beta Pic b

Dysinas survey 200?-200?

LBT

None

Starting surveys

Palomar

None

P1640 (20??-)
Metchev (??)

The near future with GPI

Spectro-imaging HC, low res: finding and “rough” characterization

GPI is only a baby step into a new realm of discoveries

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GPI vs other NextGen instruments

- LBT: (JHKLM) pyramid, deformable secondary (high throughput for Lp).
- Magellan: Pyramid Lp coro
- Subaru: SEEDS + SCEXAO (small field of view PIAA in R&D)
- VLT: SPHERE (similar to GPI)
- Palomar: P1640 (same concept as GPI)

The power of optimized instruments

GPI vs NFIRAOS/TMT

To Boldly Go Where no One Has Gone Before...

GPI 2.0

Higher contrast
Better charact.

IR AO

New star sample

Astrometry

Improve the characterization of known systems

GPI 2.0

Higher contrast

(more closer in/lower mass planets)

- Pyramid WFS or NIcWFS, or ?
- More advance coronagraph (PIAA/ Vortex)
- Replace CAL with SCC or other FPWFS method.
- 1 or 2 DMs phase/amplitude corrections
- Predictor controller
- Open loop crazy ideas

Higher resolution

(better knowledge of GPI planets)

- Replace GPI IFS with highres (with R >1,000)
- Fiber-fed to other IR spectrograph.
- For atmospheric model fitting

The IR path

Deformable M2

- High throughput
- Less optics (lower background)
- Benefits from Gemini small secondary/ spider supports
- Lp imaging and coronagraphy
- Lp/M-band characterization of GPI planets

IR WFS

(low mass stars opt. AO)

- Optimize IR WFS.
- IFS OH line blocking?
- Advance coronagraph PIAA/vortex?
- TMT precursor "M stars" super-Earth precursor.

High Accuracy Stellar Astrometry

- Wide field AO imaging
- Extreme plate scale/distortion stability (< 100 microarcsec astrometry)
- Pupil grating for off-axis star calibration (solve the relative brightness issue)

Goal: when combined with direct imaging, derive the dynamical mass of GPI planets (cooling tracks & atmospheric model calibration).

Also feasible with GAIA (acc?) and PRIMA at VLT (acc?)

We got GPI, why again fund a new DI exoplanet instrument?

- **Gemini at the forefront of exoplanet imaging** field since early 2001 with Altair, then NICI and now GPI.

- A 10 year instrument development hiatus would mean **Gemini will loose its edge in the field**. Still a lot of interesting science TBD.

- GPI might only be on the telescope for 3 years. Most of the US/CAN direct imaging field will be left without any optimize instruments, force to go back to 1st gen instruments. Loose interest in Gemini (force to collaborate with Subaru/VLT/Arizona). **Dedicated instruments ARE needed to do this science NOW**, can't rely on general use instruments as these are no longer competitive. With all fields now going along the optimize instrument path, observatories will need to specialize also what fields they are prioritizing. The era of a general use observatory that can do everything is over.

- **Highly competitive and rapidly growing field** with significant ongoing R&D.

- **High visibility science** - path to Earth-like planets with ELTs and space coro

- **It's fun & exciting!**

Conclusions

- Gemini at the forefront of AO direct Exoplanet imaging since 2001
- Several areas of possible exciting new developments
  - GPI 2.0 upgrades or new instruments
  - IR WFS (deformable M2 or IRWFS)
  - Wide field AO Stellar astrometry