Synergies of Subaru and CGI

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High Level “What can Subaru observations do for CGI”

- Precursor Observations with extreme adaptive optics (ExAO)
  - Any CGI targets of opportunity are generally Vmag~5,
  - Well within the wheelhouse of target brightness for SCExAO’s modules
  - If observable from Mauna Kea they are highly complementary
  - Detection and characterization of binaries and bright (>5x10^-6 contrast) companions in the near-infrared
    - Potentially some value added science
    - Basic vetting of targets for suitability of target at 10^-5 contrast levels
  - Disk detection

- Small inner working angle detections using VAMPIRES module
  - Measured spin axis of host star, but generally there will be a performance mismatch.
  - Disk measurements at small separations, but nearest RV stars likely won’t have bright disks

- Conventional AO detection of background objects ahead of CGI observations
  - IRCS
Instrument Phasing with CGI observations

- SCExAO+CHARIS and modules are PI instruments with a 3-year phasing and re-evaluation
- SCExAO+CHARIS will likely not exist at Subaru by 2026
- Plan is to evolve SCExAO+CHARIS into a TMT instrument by the time CGI observations and potential GO/Starshade missions are in operation

Consequence

- Subaru/SCExAO observations of CGI strategic targets would have to be identified and observed in the next few years
- We should be looking to the ELTs
- Assuming a US-Japan collaboration on developing SCExAO+CHARIS for TMT, observations could be planned with CGI to both vet targets and do follow up science if the GO program happens and/or CGI finds something interesting during the technology demonstration
- The TMT US-Japan collaboration would provide a healthy base for data processing and analysis if CGI has a GO program
The wavefront control feeds a high Strehl PSF to various modules, from 600 nm to K band.

Visible (600 – 950 nm):
- **VAMPIRES**, non-redundant masking, polarimetry, with spectral differential imaging capability (h-alpha, SII)
- **FIRST**, non-redundant remapping interferometer, with spectroscopic analysis
- **RHEA**, single mode fiber injection, high-res spectroscopy, high-spatial resolution on resolved stars

Infrared (950-2400 nm):
- Various small IWA (1-3 l/D) **coronagraphs** for high contrast imaging – PIAAA, vector vortex, 8OPM
- **CHARIS** - IFS (J to K-band)
- **MEC** - MKIDs detector, high-speed, energy discriminating photon counting imager (y to J-band)
- **NIR** single mode injection, high throughput high resolution spectroscopy. Soon will be connected to the new IRD
- **SAPHIRA** - high-speed photon counting imager, (H-band for now)
- **GLINT** - NIR nulling interferometer based on photonics

SCExAO and CHARIS

- Major Science Objective:
  - Spectral characterization
  - Exoplanets
  - Disks
  - Brown dwarfs
  - Supports Coronagraph IWA = 3 λ/D = 90 mas

Current coronagraphs are pushing inside

- 2.07’’x2.07’’ FOV
- R~19, J+H+K Band
  - ~53% Throughput
- R~65-85: J,H, and K Bands
  - ~40% Throughput

CHARIS work was performed under a Grant-in-Aid for Scientific Research on Innovative Areas from MEXT of the Japanese government (Number 23103002) (Hayashi, Kasdin)
First Light 5-sigma Contrast Curve for CHARIS

Angular Separation (arcseconds)

Contrast

$5\sigma$ Single Wavelength Raw Contrast (1.6 micron) - 5th magnitude star
Brown Dwarf HD 1160

Intensity

DM Satellites
Astrometric Calibration
Photometric Calibration
Occulted Star
Brown Dwarf

\( \lambda = 1.17 \, \mu m \)

Broadband data by Jeff Chilcote and Tyler Groff
Pretty GIF made by Tim BRandt
Polarimetric Imaging

AB Aur
(preliminary data reduction)

Non-Polarized Mode, Aperture Masking

Observed S-type star chi Cyg
V ~ 8 at time of observation
VAMPIRES UD Diameter
32.2 ± 0.1 mas (750 nm)
c.f. CHARM Catalogue,
Richichi et al. 2005:
UD = 32.8 ± 4.1 mas (V band)

Observed close binary eta Peg
Detection confidence (MC) > 99.9%
Separation 48.9 ± 0.6 mas
c.f. orb. params. Hummel+ 1998 → 49.9 mas
Contrast 3.55 ± 0.06 mag
c.f. Hummel+ 1998: 3.61 ± 0.05 mag

Chi Cyg Power spectrum (log scale)
Note fall-off in power at longer BLs, since object is resolved.

Thanks to Olivier Guyon and Vampires Team
Post-processing techniques are being assumed for CGI performance

Great successes with this on the ground

Progress and extension to WFIRST models

- Apply extensive experience from ground observers to help define CGI post-processing and calibration needs
ADI+SDI detection of HR8799 c,d,e at SNR of 50, 35, and 15 respectively (~2-3 x 10^-5)

Predicted Visible contrast:
- Beta Pic Contrast ~ 8 x 10^-7
- HR8799c,d,e ~ 10^-7

HR8799 preliminary data processing by Tim Brandt, HD32297 Processing by Thayne Currie
Example Observational Overlap

M5 Globular Cluster

Published CGI FOV overlaid onto a CHARIS image from the Subaru telescope

HR8799 w/Post-Processing

Detector field of view
- 10 $\lambda/D$ (~0.5") Coronagraph outer working angle
- 3 $\lambda/D$ radial inner working angle

Angular separation where requirements are set