SCExAO: the Subaru Coronagraphic Extreme AO Project

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Adaptive Optics: required but not sufficient!

AO stabilizes the wavefront but cannot do a perfect job. You are at best left with static or slowly varying aberrations that set contrast detection limits.
Take care of an ill-posed problem

\[ I = O \otimes PSF \]

Eliminate the PSF out of the equation

the ADI way...

the exAO way...


SCExAO
Angular Differential Imaging

The “state of the art”: optimized Angular Differential Imaging called LOCI

LOCI led to the obtention of direct images of sub-stellar companions around HR 8799, GJ 758, etc.

Remarkable... but reaches peak performance somewhere around 0.5 arcsec

example of LOCI observations

“conservative” LOCI image of LkCa 15 by HiCIAO


“iconic” LOCI image of the planetary system orbiting HR 8799

Marois et al, 2008, Science, 322, 1348
95% of known exoplanets are here!!
HiCIAO+ fore-optics

HiCIAO+ SCExAO
SCExAO engineering run September 2011
Common Injection module

Internal calib. source

Visible imaging channel soon to become polarimetric NRM interferometry

Pyramid WFS

IR channel
The SCExAO project

Taking advantage of a series of in house developments (PIAA, CLOWFS) and the existing infrastructure (AO188 + HiCIAO) to put in the same box:

- a high-efficiency, high-performance PIAA-based coronagraph
- all the calibration tools we can think of now (wavefront sensors, active control of the focal plane image with a DM, post processing techniques, optional NRM)
- simultaneous diffraction limited visible imager

While keeping the design flexible for future improvements.

**Optical design**

- f/14 beam from AO 188
- tip-tilt field mirror
- tip-tilt mounted deformable mirror
- collimated beam for visible path (science and WFS)
- SRP
- PIAA
- dichroic
- apodizer
- focal plane mask
- inverse PIAA
- beam splitter/fold mirror
- focal plane internal detector
- 50 Hz low-order wavefront sensor
- collimated beam to feed HiCIAO
Active speckle control

Instead of using a passive approach, and wait for the sky rotation like in ADI, use a DM with many actuators (~1000) gives active control of the speckles.

Image with flat DM volt-map
Image with dark-hole DM volt-map

Strategy shared with comparable projects (GPI, SPHERE).

The true advantage of SCExAO is its small IWA

Martinache & Guyon, 2011, AO4ELT
On sky results soon!
PIAA optics on SCExAO

First on sky demonstration (Sept. 2011)

Martinache & Guyon, 2011, AO4ELT

Images by HiCIAO
Active speckle control

Example of PIAA-based coronagraph high contrast results (laboratory):

DM diversity identifies “coherent” fraction of the light in control FOV.
Gains two orders of magnitude over raw contrast


DM wavefront diversity in the presence of turbulence with SCExAO

Martinache et al, 2012, in prep
SCExAO plans

Phase 1:
1. High efficiency PIAA-based coronagraph
2. Active speckle probing with DM to measure the coherence of the field

Full phase 1 demonstration, summer 2012

Planned and ongoing upgrades:
1. Fast wavefront sensor for true extreme-AO
2. Visible polarimetric NRM-interferometry
3. J,H,K-band IFS (CHARIS) by Princeton University