The Subaru Coronagraphic Extreme AO Project

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Project URL: http://www.naoj.org/Projects/SCEXAO/

Abstract:

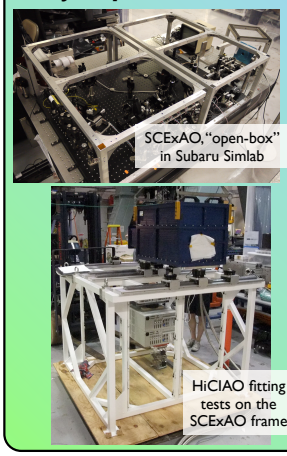
In 2009 our group started the integration of the SCExAO project, a highly flexible, open platform for high contrast imaging at the highest angular resolution, to be inserted between the coronagraphic imaging camera HiCIAO and the 188-actuator AO system of Subaru. In its first version, SCExAO combines a MEMS-based wavefront control system feeding a high performance PIAA-based coronagraph, that suppresses the central obscuration and the thick spider vanes while preserving throughput and angular resolution. It also includes a coronagraphic low-order wavefront sensor, a non-redundant aperture mask and a visible imaging mode, all of them designed to take full advantage of the angular resolution (40 mas in the H-band) that an 8-meter telescope has to offer.

A dynamic, evolutive approach to tackle a multi-level challenge:

Because of the fast evolving technology and the new ideas accompanying them, SCExAO's design deliberately follows a **modular**, **evolutive** and **easily upgradable** path. SCExAO itself is an upgrade to the already successful HiCIAO camera, used with Subaru's AO188 in the context of a large survey for exoplanets and disks, called SEEDS. SCExAO specializes in the detection of high contrast companions at small angular separation (within 20 λ/D). It addresses the main issues that all extreme AO systems face:

- the high throughput high-efficiency PIAA-based coronagraph (Lozi et al, 2009) has demonstrated its ability to achieve high contrast (beyond 10^{-7}) at separations as close as 1.5 λ/D (Guyon et al, 2010)
- the low-order wavefront sensor is an efficient tip-tilt tracker (Guyon et al, 2009), that can be used to suppress tip-tilt attributable coronagraphic leaks in post processing (Vogt et al, 2010)
- a MEMS based deformable mirror for additional post AO188 wavefront corrections is the ideal tool, not only to calibrate out static and quasi static aberrations, but also to actively probe the field of speckles, taking over approaches like ADI (Lafreniere et al, 2008) that can only be used at large angular separations
- diagnostic of the whole optical chain, using the final focal plane is the definitive answer to non-common path errors that affect science images taken with AO. Closure phases in masking interferometry (Martinache et al, 2009) and their extension to continuous pupil (Martinache, 2010) open the doors of high-contrast super resolution (i.e. within λ/D)

Project pics:

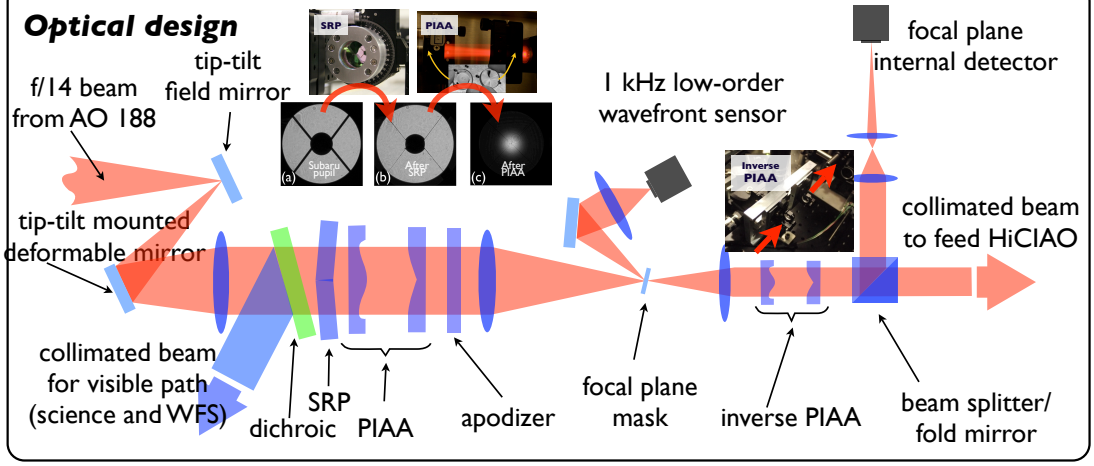


Phase 1:

SCExAO Phase I won't use a fast wavefront sensor. The DM will be used to calibrate static aberrations and actively probe the speckles and measure their coherence.

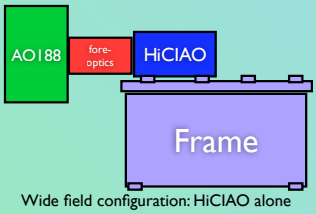
SCExAO Phase II will include a visible non-linear curvature wavefront sensor

Optical design

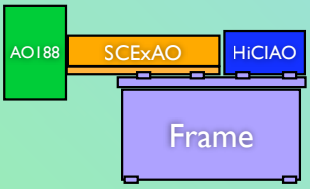


Project status:

The integration of the frame hosting both SCExAO and HiCIAO at the Subaru IR Nasmyth focus is complete. Mechanical fitting tests at the telescope are scheduled to start mid-July 2010. SCExAO's phase I optical design is now fully operational at infrared wavelength, and coronagraphic performance in the lab is being evaluated. Integration with AO188 will follow the upcoming mechanical fitting tests: with its two tip-tilt mirrors, SCExAO can steer both the pupil and the image, which makes it quite tolerant to mechanical alignment errors.



Wide field configuration: HiCIAO alone



Narrow field configuration: HiCIAO+SCExAO

References:

Guyon et al, 2010, PASP, 122, 71
Guyon et al, 2009, ApJ, 693, 75
Lozi et al, 2009, PASP, 121, 1232
Murakami et al, 2010, this conf.
Vogt et al, 2010, this conf.
Martinache, 2010, submitted to ApJ

Conclusion:

With HiCIAO alone already successful at probing the outer parts of planetary and proto-planetary systems, SCExAO specializes in the exploration of a narrow field of view, using the best of the recent developments of this fast moving field: last generation coronagraphs (PIAA, 8-octant) and interferometric calibration methods (phase diversity, closure phase).
SCExAO is a unique testbed where such ideas can be quickly tested on the sky.