An IFS for the Subaru Telescope HiCIAO System

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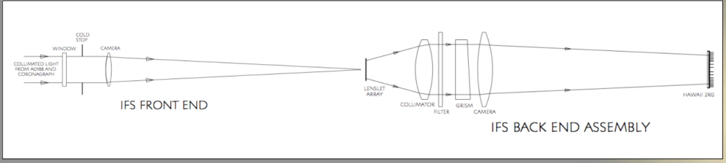
The direct detection and investigation of extrasolar planets is a landmark scientific achievement that is within the current technological limits of ground-based observatories equipped with adaptive optics systems and high contrast instrumentation. We present the latest design of high contrast instrumentation for the Subaru Telescope, the Planetary Origins Imaging Spectrograph (POISE). POISE is a lenslet-based infrared integral field spectrograph (IFS) that will operate as part of the AO188/HiCIAO system on the Subaru infrared Nasmyth deck. The optical design draws on the lenslet-based IFS heritage of the Tiger and OSIRIS instruments, but our design is specialized for speckle suppression. POISE can operate simultaneously with the HiCIAO SDI instrument, which not only increases telescope efficiency, but it also allows for focal plane wavefront sensing to improve the AO correction. The spectral information provided by POISE will be critical in the characterization of companions found in the Subaru SEEDS survey.

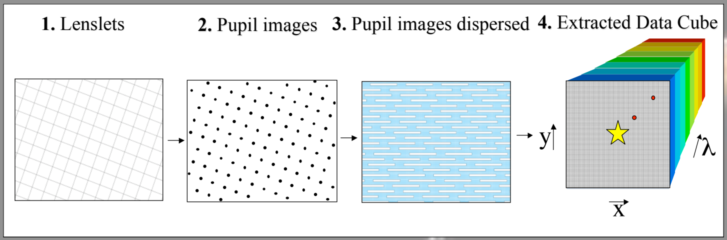
POISE: An Infrared Lenslet-Based IFS

Optical Design



Cartoon schematic of the POISE IFS optical layout. The instrument is fed a beam corrected by the Subaru AO188 system. The filter wheel can be used to select among the z, J, H, and K bands. Otherwise, the internal optics are static.

How it Works



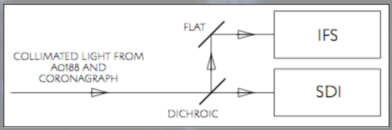
A lenslet array is placed at the focal plane of the instrument (1). Each lens focuses the light incident on it to a very small, well-separated grid of pupil images behind the lenslet array (2). These pupil images are dispersed onto a near infrared Hawaii 2RG HgCdTe 2048x2048 pixel detector (3). The lenslet array is rotated slightly to fit thousands of spectra on the detector without spectral overlap. The spatial location corresponding to each spectrum on the detector is known from calibration data, and each spectrum is extracted and placed in its respective position in the data cube (4).

IFS Summary Specifications

Location	Nasmyth focus
Input Beam Diameter	Collimated, 0.01m
Filters	z, J, H, K
Spaxel scale	0.015 ($\lambda/2D$ at 1.18μm)
Lenslet Pitch	200 μm
F/# at lenslets	333
Spectral Resolution	~100
Detector	2048x2048 HgCdTe Hawaii 2RG
Detector Controller	ASIC SIDECAR
Optical Throughput	42%
Wavefront Error	< 50 nm
Field of View	1.8”x1.8”

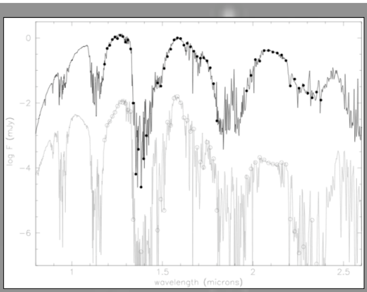
AO 188 Focal Plane Wavefront Sensing

Since the HiCIAO SDI and IFS instruments can be used simultaneously, either instrument can be used for focal plane wavefront sensing to improve the AO quality. The Hawaii 2RG detector allows a subarray of the detector to be read at high frequency. Focal plane wavefront sensing and a dedicated MEMS AO device will enable corrections to non-common path errors over the full spatial frequency range of aberrations. In addition, the IFS can be used to characterize the chromatic behavior of the coronagraph.



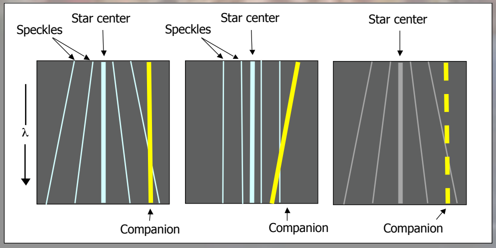
POISE and the Subaru Strategic Exploration of Exoplanets and Disks (SEEDS) High Contrast Imaging Survey

Spectra of Substellar Objects



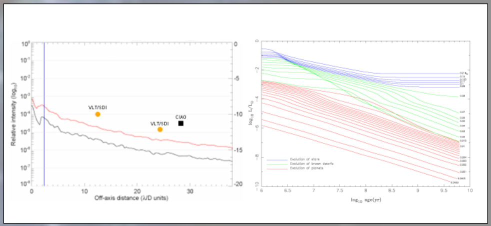
Comparison of two model spectra, both with solar metallicity and with temperatures of 800 K (above) and 400 K (below) at a distance of 10 pc, according to the models of Burrows et al. 2006. In this figure, the central wavelengths of the IFS spectral samplings are overplotted as filled points for the 800 K spectrum and as open circles for the 400 K spectrum, providing sampling of the strong H_2O, CH_4, and NH_3 absorption features. The effective temperature of 400 K is expected to be that which marks the transition to the next coolest spectral type, the so-called “Y” dwarf, and is only about twice Jupiter’s effective temperature of 170 K (Leggett et al. 2007).

Speckle Suppression



A variation of the Simultaneous Differential Imaging (SDI) technique will be used to reduce the contamination from speckles (Racine et al. 1999). (Left) The fully--reduced and mosaicked POISE data cube. The primary and the companion both travel straight through the cube in wavelength, while the speckles travel radially outward towards increasing wavelength. (Center) The spatially rescaled data cube to make the speckles align at each spatial location. In the rescaled cube, the companion now travels radially inward. An azimuthal median spectrum is composed for each radius from the primary, and this median spectrum is scaled to and subtracted from the spectrum at each spatial location. (Right) The cube is rescaled back to its original scaling. In this cube, the speckles are suppressed while the companion signal is spatially realigned.

Simulated Sensitivity



(Left) Predicted 5σ sensitivity of the HiCIAO SDI curve (red) and the theoretical contrast limitation of the telescope (black). The less than 50 nm non-common path wavefront error in the IFS is expected to increase the achieved SDI contrast by an order of magnitude. (Right) This improvement in contrast corresponds to an increased sensitivity to planets (in M_J) by a factor of 3 (Burrows et al. 1997).

Background image is courtesy of space artist Lynette Cook.