

# OSIRIS Spectral Imaging of Closely Separated Binaries

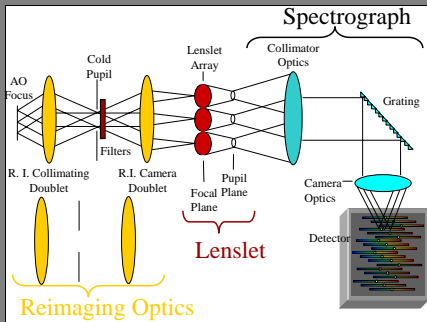
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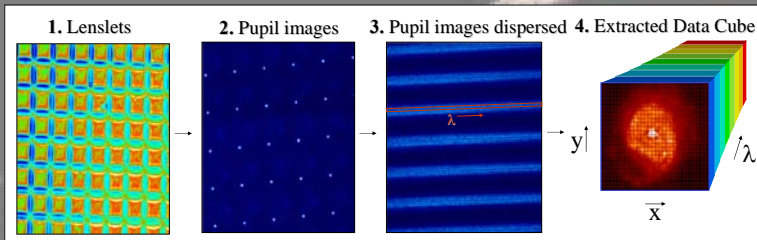
We present OSIRIS spectral imaging of small separation ( $< 2''$ ) high contrast binary systems resolved with the Keck II adaptive optics (AO) system. OSIRIS is an infrared integral field spectrograph, with a spectral resolution of 3800 and diffraction limited sampling. OSIRIS is ideal for observing binary systems, because it can simultaneously measure the astrometric, photometric, and spectroscopic properties of a system. In addition, the integral field nature of OSIRIS can be used in high contrast observations to identify and subsequently suppress the diffraction features that commonly mask faint point source detections. We employ speckle and spectral suppression techniques to search for non-stellar (brown dwarf and planetary) companions in the halos of nearby, young stars.

## OSIRIS – OH Suppressing InfraRed Imaging Spectrograph



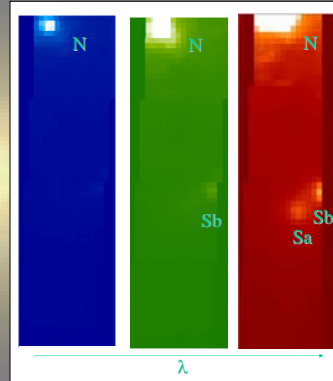
LEFT: Schematic of the OSIRIS integral field spectrograph optical layout. The instrument is fed a beam corrected by the Keck Adaptive Optics (AO) system. Four plate scales are changed by using different reimaging optics, thereby making different spatial samplings at the lenslet array.

BELOW: 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 pupil image behind the lenslet array (2). These pupil images are dispersed by a grating onto a near infrared Hawaii II HgCdTe  $2048 \times 2048$  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).



## Closely Separated Binaries

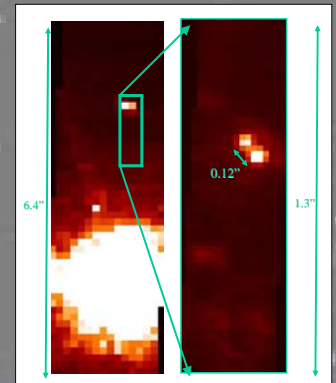
### T Tau South



LEFT:  $K$  narrow band images of T Tau (Dyck et al. 1982) with a PA of  $43.5^\circ$ . These images were created by collapsing together 100 spectral channels ( $\sim 1\%$  band pass filter) from a full  $K$  broad band data cube. T Tauris are very young stars, still contracting to eventually become normal stars. This phase of stellar evolution is typically accompanied by accretion disks, surface magnetic activity, and surrounding dust. It is known that T Tau is a triple system with a northern component (N) and two southern components (Sa & Sb), and the two components Sa and Sb offered the first system to measure a dynamical mass for T Tauri stars. This systems also happens to be in a complex environment of high extinction ( $A_V \sim 5-30$  mag). High spatial resolution spectroscopy of the components helps unravel this puzzle by identifying accretion generated  $Br\gamma$  emission, as well as the CO band head.

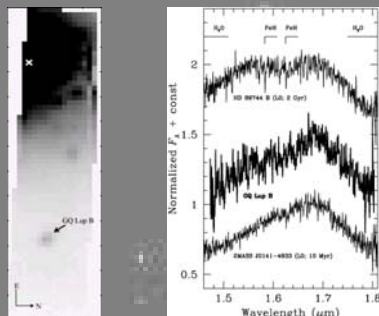
### HD 130948

RIGHT: Collapsed  $K$ -band cubes of the binary system HD 130948 (Potter et al. 2002). The image at left is taken in the  $0.100''$  plate scale, showing the young ( $< 0.8$  Gyr) G2V host star and the companion separated by  $2.6''$  at a PA of  $104^\circ$ . At right we center on the companion in the  $0.020''$  pixel scale and obtain resolved spectroscopy of the L0/L4 binary system. We find a brightness ratio of 0.8 and separation of  $0.12''$ , which is consistent with the literature. Resolved spectroscopy of these low mass objects reveals strong  $H_2O$  and CO bands and the Na I alkali line. With one observation, accurate astrometric, photometric, and spectral characteristics are determined.



## High Contrast Imaging – Detecting Substellar Objects around Nearby Stars

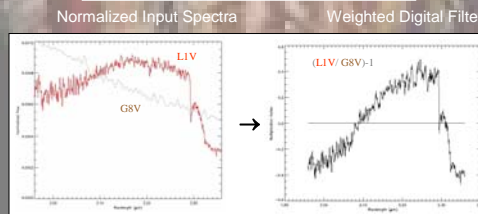
### GQ Lup B



ABOVE: High contrast  $H$ -band imaging of the planetary candidate system GQ Lup, showing its 7.5 mag fainter companion with a separation of  $0.73''$  at PA  $273^\circ$ . In the collapsed cube, OSIRIS provided a  $370\sigma$  detection of GQ Lup B in a 10 minute exposure, before any speckle suppression algorithms were applied to enhance the contrast. The extracted spectrum of GQ Lup B is compared to the spectra of L0 dwarfs of different ages.

Background image is courtesy of space artist Lyndee Cook.

### Speckle Suppression



ABOVE: A variation of the Simultaneous Differential Imaging (SDI) technique will be used to reduce the contamination from speckles (Racine et al. 1999). High contrast imaging with moderate Strehl ratios are limited by speckles; however, these speckles are wavelength dependent. An IFU is the ideal instrument for high contrast imaging because a different speckle pattern will exist at each wavelength. A radial rescaling of the cube can allow for each speckle to occur in the same spatial location, and then a subtraction of the rescaled channels will significantly reduce the speckle noise. This technique will not subtract the signal from the planet, which will extend straight through the cube. Spectral filtering will be employed as a post processing algorithm to enhance the signal from the planet relative to the background.

### Future Sample Description

LEFT: Histograms displaying the distances and ages of stars to be targeted in a survey for substellar companions. We have culled our sample from a current list of nearby, young stars identified through many independent searches of variant approaches. The target list is comprised of the 48 preeminent candidates which were chosen by proximity to Earth, youthful age, accuracy of age estimates, and on-sky availability from the Northern Hemisphere. We have currently observed 16 targets in this sample. Another 6 targets with known companions were observed to refine observing strategies.

