Extra-Solar Planet Detection at Gemini Observatory

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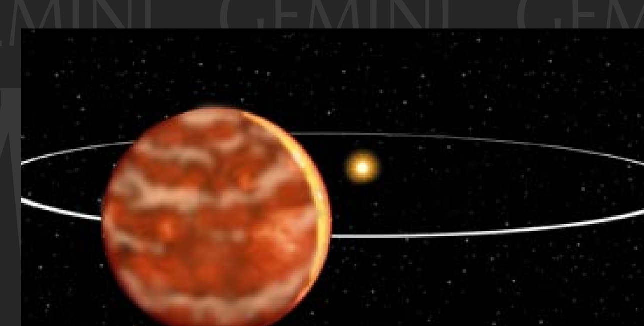
This Gemini South image shows a small section of the "Trapezium" region of the Orion Nebula as seen at infrared wavelengths using the Flamingos near IR imager. Astronomers in the UK are currently analyzing the data from this spectacular image for exciting new discoveries in the realm of extra-solar planet detection. (Gemini Observatory/University of Florida - Flamingos-I/Phil Lucas, P.I., United Kingdom)

The Gemini South telescope prepares for another exquisite night of observing over the Chilean Andes.

For the first time in history, astronomers throughout the 7-country Gemini partnership have access to twin state-of-the-art 8-meter telescopes that provide complete sky coverage. During the past year the Gemini Telescopes on both hemispheres have begun to operate as one observatory - here are the present and future of Extra-Solar Planet detection underway at Gemini.

Flamingos-I/NIRI

FLAMINGOS is a near IR multi-object spectrograph and imager built by the University of Florida. Currently a group from the UK headed by Matthew Burleigh at the University of Leicester is using Flamingos+GS (as well as NIRI+GN) to directly image massive planets around nearby white dwarfs with intermediate mass progenitor stars. White dwarfs from these progenitor stars will be about 1-10 thousand times less luminous than the progenitors producing a strong gain in brightness contrast between a planet and a white dwarf when compared to a main sequence star. It is likely that any planet at the minimum of a Jovian radius from the progenitor star will not fall within the red giant envelope during evolution hence will not be destroyed, but rather it will be relocated by a factor of 3. It will be most likely to be able to detect extra-solar planets around relatively warm, young, massive white dwarfs descended from an intermediate mass progenitor with a short main sequence lifetime. Burleigh proposes to obtain deep J band images of young, nearby white dwarfs to detect massive planetary companions. Since the white dwarfs are evolved from ~1.5-4 solar mass stars, they will in effect be probing the frequency of massive planetary companions to solar type stars. By targeting these white dwarfs they will obtain better contrast and angular separation than surveys around main sequence stars. These observations will provide significant constraints on the frequency of massive planetary companions to solar type stars, and potentially provide the first sample of extra-solar planets that can be directly observed. (M. Burleigh; F. Clarke; S. Hodgkin; Monthly Notices RAS, 9 February 2002)

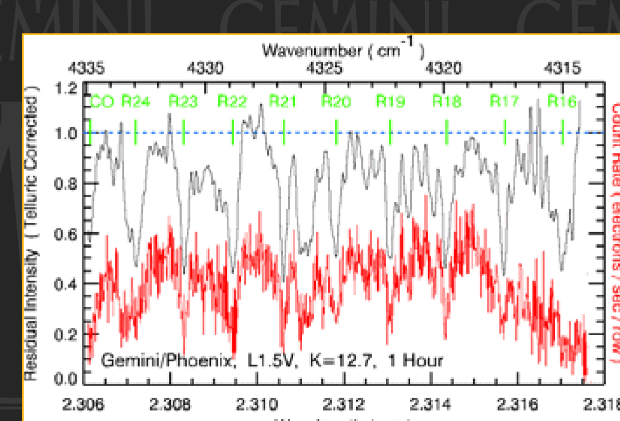


Flamingos+GS is being used to search for giant planets orbiting carefully selected white dwarf stars.

The University of Florida's Flamingos-I near IR imager and spectrograph being mounted on Gemini South. Flamingos is being used this semester to search for giant extra-solar planets orbiting white dwarfs in the nearby stellar neighborhood. Flamingos is available for use on Gemini South for 6 months out of the year from June through November.

Phoenix

Phoenix is a near IR high resolution spectrograph built by NOAO in Tucson. A group from the US headed by Joan Najita at NOAO and Bernadette Rogers at Gemini South Observatory is using Phoenix+GS to search for gaps in the disks around young stars that may indicate the presence of giant planet formation. Giant planets that form early, during the disk accretion phase, are likely to migrate in close to their parent stars, sweeping along any Earth-like planets that have already formed at smaller radii. Solar systems in which giant planets form late, at the end of the disk accretion phase, have the best chance of preserving Earth-like planets at AU distances. One of the more promising approaches to detect giant planet formation is via the dynamical impact of the planet on the structure of its parent disk. Dynamical theory predicts that as a giant planet forms, tidal interactions between the planet and the disk clear a gap within which the planet orbits. The gap width depends on both the mass of the planet and the disk viscosity. Since more massive planets clear wider gaps, gap width provides a relative measure of planetary masses. Hence, a detailed understanding of the location and width of gaps in protoplanetary disks can ultimately provide a method of inferring both planet formation distances and masses. A detailed understanding of radial structure can be obtained from high resolution infrared spectroscopic study of residual gas in the gap, which will appear in emission against the weak dust continuum from the gap. Very small gas column densities can be detected with a variety of IR molecular line diagnostics like the fundamental CO transition. (J. Carr; R. Mathieu; J. Najita; ApJ, 551:454-460, 10 April 2001)



High resolution spectra such as this one from Phoenix will provide valuable insight to extra-solar planet formation.

During the Gemini South Dedication ceremony in January of this year the Gemini Director, Matt Mountain, had the opportunity to show the President of Chile, Ricardo Lagos, Phoenix mounted on Gemini South. Phoenix is a very high resolution near IR spectrograph that will undoubtedly yield exciting new discoveries in the realm of giant planet formation in young stellar systems.

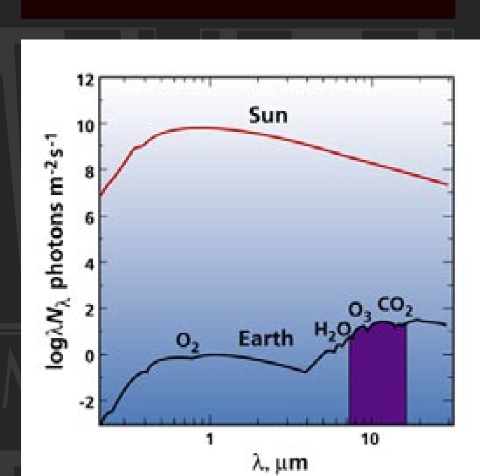
Hokupa'a/Altair

Hokupa'a is a natural guide star, curvature-sensing adaptive optics system built by the University of Hawaii. It gives near diffraction limited resolutions in the K and H bands. It's successor, Altair, is also a natural guide star adaptive optics system for use on Gemini-North and is under construction at the Herzberg Institute for Astronomy. It is currently estimated for delivery to Gemini Observatory during the second half of 2002. A University of Arizona team led by Laird Close using adaptive optics technology on Gemini North have discovered a brown dwarf orbiting a low-mass star at a distance of 3 AU. This is the closest separation distance ever found for this type of binary system using direct imaging. The record-breaking find is just one of a dozen lightweight binary systems observed in the study. The detection of brown dwarf companions within 3 AU of another star is an important step toward imaging massive planets in our stellar neighborhood. Very few Sun-like stars have brown dwarf companions inside this distance, according to radial velocity studies. This lack of brown dwarf companions within 5 AU of Sun-like stars has been called the 'brown dwarf desert'. However, there is likely no brown dwarf desert around low-mass stars. These results form important constraints for theorists working to understand how the mass of a star affects the mass and separation distance of the companions that form with it. Hence any accurate model of star and planet formation must reproduce these observations. Direct observations of these brown dwarfs are just the precursor for direct imaging of giant extra-solar planets using AO on the Gemini telescopes. (L. Close; N. Siegler; D. Potter; W. Bradner; J. Liebert; ApJ Letters, 567:L53-L57, 1 March 2002)

This discovery image has a resolution of 0.1 ". At a separation of 3 AU this is the nearest brown dwarf ever directly imaged around a parent star. This is the first step for giant planet detection using AO on Gemini.

T-ReCS/Michelle

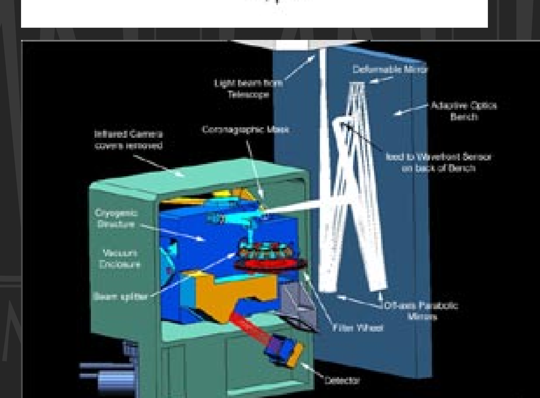
T-ReCS and Michelle are mid IR imagers and long-slit spectrographs that are expected to go into operation at Gemini South and North respectively during the second half of 2002. They will have science modes that include broad-band imaging at N and Q, narrow-band filter imaging from 8-26 microns, as well as low and medium resolution spectroscopy, with Michelle also providing a high resolution mode. The solar and planetary spectra in our solar system at wavelengths ranging from optical to near IR are very similar in shape. Unfortunately at these wavelengths the planet flux is also 10 orders of magnitude weaker than that of the star. However in the mid IR the difference is closer to 6 orders of magnitude, leading to a significant gain in flux contrast. There are a variety of prevalent molecular features in the mid IR that may be detectable using medium resolution spectroscopy from these instruments. For example, prominent emission features like acetylene (C2H2) appear due to atmospheric constituents on both Jupiter and Saturn at 13.7 microns. Other features that may be resolvable include methane (CH4) at 7.7 microns as well as the C2H6 band at 12.2 microns and the C2H2 band at 13.7 microns, both are products of methane photochemistry in a molecular hydrogen atmosphere. At higher spectral resolution absorption and emission features due to the presence of molecules such as these in the planet's atmosphere may appear reflected in the stellar spectrum and may produce either absorption or emission features in the thermal spectrum of the planet itself. Direct detection of any of these molecular features would be the beginning of an exciting new period in giant extra-solar planet characterization.



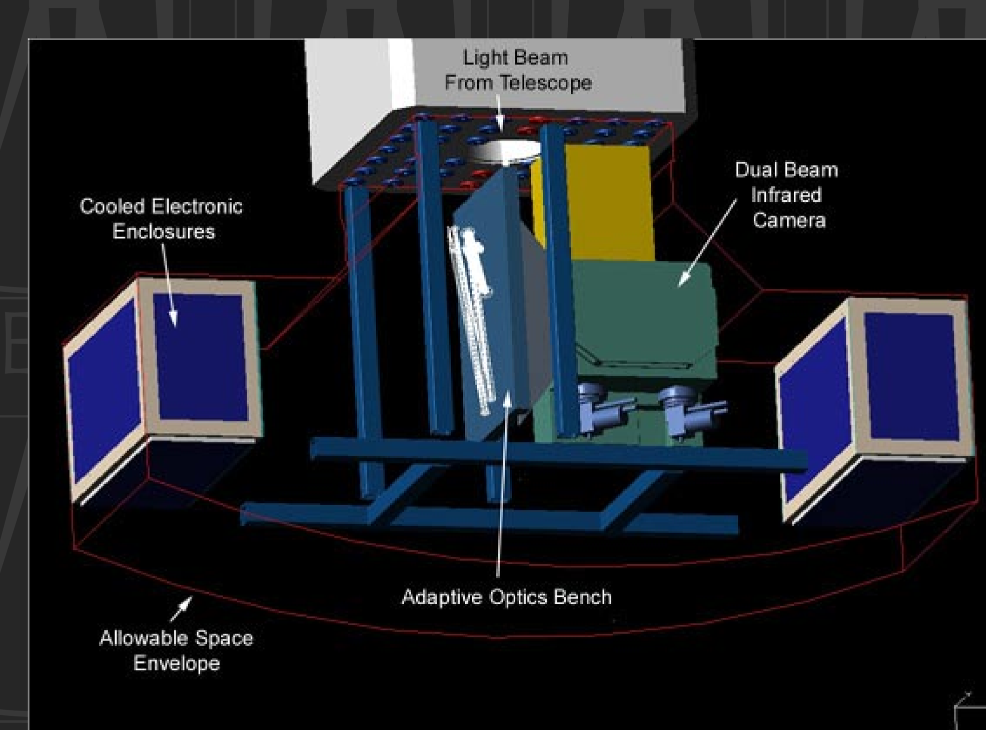
This graph clearly shows the improvement in flux contrast in the mid IR for the Earth. The same gain can be beneficial for extra-solar planet detection with TReCS and Michelle.

NICI

NICI is a dual-channel near IR coronagraphic imager, for use on Gemini South, under construction at Mauna Kea Infrared (MKIR). The current estimate for delivery of NICI to Gemini Observatory is the second half of 2004. This is the most promising facility instrument in the future suite at Gemini South that is specifically designed to directly image extra-solar planets. The fundamental goal of NICI is to enable imaging of faint regions, in the immediate vicinity of bright sources. Here, by "faint" we mean that the object under study has an intensity significantly fainter than the local background and by "bright" we mean that the halo of the primary source is the dominant source of the local background. Thus the two elements of NICI emerge: the adaptive optics system and the coronagraph. The former gives high resolution and produces compact images that pick up less of the local background giving higher sensitivity. The latter reduces the background due to the central source to the fundamental limit imposed by the residual, uncorrected atmospheric scatter. NICI employs a dual channel architecture to enable post processing differencing techniques to isolate the faint source from the background source. The most powerful NICI observation is one in which a key spectral or polarization feature differentiates the target from the background and is observed simultaneously in two channels. One channel is used to highlight the feature and the other as a reference, for example, in and out of the methane band on an extra-solar planetary system. Thus one is observing in a differential mode and high fidelity frame differencing is possible. The number of directly imaged extra-solar planets will dramatically increase with the onset of NICI mounted on Gemini South.



This diagram shows the AO bench, dual channel IR imager, and the internal optics that comprise NICI.



The future of extra-solar planet detection at Gemini observatory! NICI employs a dedicated AO system along with a dual channel IR imager and a variety of pupil masks, dichroics, filters, neutral splits, and polarizing elements. This will be the only instrument in Gemini's suite dedicated to extra-solar planet detection.