Discovering Terrestrial Extrasolar Planets Using Near-Infrared Searches

Since the detection of a planet around 51 Pegasi (Mayor & Queloz, 1995), extrasolar planet research has gone from a fringe field to one of the most prolific and exciting areas of astronomy. Nearly all of the 160+ known extrasolar planets were found with optical radial velocity (RV) surveys, with a handful discovered by optical transit surveys. Both approaches are most sensitive to Jupiter-sized planets in close orbits around sun-like stars. To detect smaller planets around a more complete sample of stars, observations of low-mass stars (M, L, T dwarfs) are necessary. Dr. James Lloyd is an expert in adaptive optics and interferometry at Cornell. He has the ambitious goal of detecting and eventually directly imaging rocky, Earth-like extrasolar planets around dim, low-mass stars by observing in infrared wavelengths.

In the next five years I will complete a PhD in Astronomy at Cornell University under the guidance of Dr. Lloyd. Cornell's program provides excellent background in observation techniques, astrophysics, data mining, and instrumentation. I will acquire training in interferometry, infrared photometry and spectroscopy, and adaptive optics. On an NSF Graduate Research Fellowship I will design and execute complementary RV and transit near-infrared searches to discover and characterize planets around the unexplored domain of low-mass dwarfs.

RV measurements are used to constrain the mass of the orbiting body. RV surveys of low-mass dwarfs are particularly important; the star's lower mass makes the RV signature of smaller planets detectable. An NSF/ATI grant is funding the development and use of an externally dispersed interferometry (EDI) system (Erskine, 2003) to be used with the TripleSpec spectrograph on the Palomar 200-inch telescope. Triplespec-EDI will obtain excellent radial velocity measurements ($\sim 100\,\mathrm{m/s}$) and will detect Jupiter and Saturn-mass planets around nearby dwarf stars. The EDI unit is a low-cost instrument that could be applied to a number of observatories, including relatively small ($\sim$1-2 meter) telescopes owned by undergraduate institutions (such as Harvey Mudd College), opening up research opportunities for undergraduates.

RVs do not directly measure the planet's mass M; RVs actually measure $M \sin i$, where i is the inclination of the orbital plane to the observer. Consequently, RV measurements determine only the minimum mass for the companion. RV measurements are also limited by the quality of the spectra, which is limited by stellar flux. These shortcomings can be mitigated by combining RV measurements with transit observations. Observing a transit constrains i to small values, establishing the mass of the planet. Transits also allow astronomers to measure the planet's radius.

Transits around low-mass stars are particularly interesting. Figure 1 illustrates that the smaller size of these low-mass stars makes it much easier to detect all planetary transits. Earth-sized planets around low-mass dwarfs create transit depths of about 1%, which is within the detectable limits for existing infrared instrumentation (Persson et al., 1998). Since RV signatures of terrestrial planets are much less than the precision limits of ground-based RV measurements, infrared transit photometry provides the single best chance of detecting a rocky extrasolar planet.

I am presently studying the photometric stability of a number of near-infrared

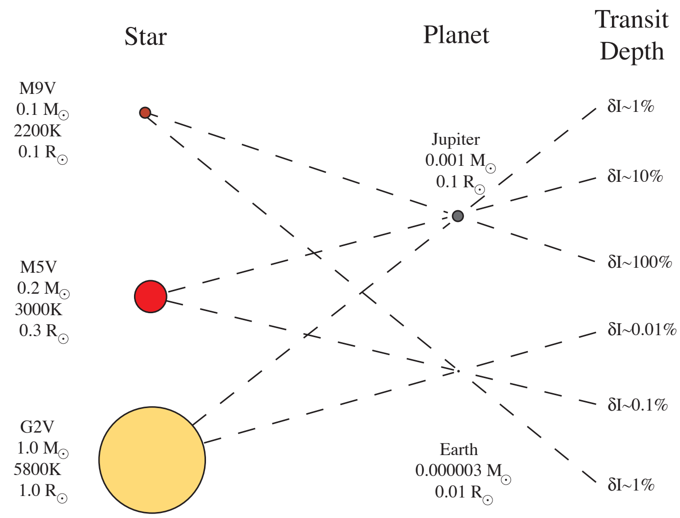

Figure 1: Transit depths for sun-like stars and low-mass dwarfs

filters. To do this I am using synthetic and observed spectra of M, L, and T dwarfs and K giant standard stars, the MODTRAN atmospheric model, and the instrument responses for a number of facilities, including Palomar. This study will determine the best near-infrared filter for transit searches of extrasolar planets. With these results, I will develop a robotic telescope system (camera, optics, filters, computer, and software) for targeted photometric observations of transit candidates. A transit search must be amenable to a distributed consortium of small telescopes. This includes undergraduate facilities, which are excellent candidates for a robotic telescope upgrade and capable of photometry at the 1% level (Hudgins & Filipović, 2002). RV measurements are still needed to confirm a planetary transit; they are needed to provide constraints on the mass of the object, and will distinguish bona fide planets from brown dwarf companions or a grazing incidence binary. Transit candidates will be confirmed and further researched with RV measurements on the Palomar 200-inch.

Extrasolar planet research is very popular with the general public, and a survey dedicated toward looking for rocky planets around low-mass stars will receive strong public interest. I will present our research to the local public during department open houses. I will also maintain a website that will provide technical data for professionals and general information for the public. Currently I am developing an educational unit on extrasolar planet research, which will encourage students to think about careers in science. It will be field-tested with the help of a Cornell graduate student and a Harvey Mudd graduate who is teaching physics at an underserved high school.

Cornell has an unparalleled reputation for excellence in infrared astronomy and instrumentation. I will depend heavily on this wealth of expertise, and am confident that our professional competence, dedication, and resources will prove equal to the challenges of this ambitious project. A combined RV and transit search should yield a number of new planets. With this project plan, resources, and technical training, I believe I have a chance to detect the first Earth-like extrasolar planet.