DSSI at DCT: Superearth Validation with High-Resolution Speckle Interferometry

Gerard T. van Belle[1], Elliott Horch[2], Steve Howell[3], David Ciardi[4], Mark Everett[5]

[1]Lowell Observatory, [2]S. Connecticut State Univ., [3]NASA Ames, [4]Caltech, [5]NOAO

Abstract: We will be bringing the Differential Speckle Survey Instrument (DSSI), a speckle camera, to Lowell Observatory's 4.3-m Discovery Channel Telescope (DCT) in March of 2014. DSSI will be employed in high-angular resolution work for the Kepler Follow-up Program; at the shortest wavelengths of operation (370nm), DSSI@DCT will have a limiting resolution of 22 milliarcseconds (mas). DSSI has already been on sky in this capacity with WIYN and Gemini-N, detecting faint nearby companions to KOIs. For the brighter KOIs (mag~10-12), we expect a companion detection limit of delta_m=5.5 at 200mas separations, which degrades linearly between mag~12-15.5 to delta_m=3.0. Guaranteed access to the DCT will enable us to perform a complete census of exoplanet validation for the ~600 Kepler stars thought to be hosting one or more super-earth-sized (>2.5R_Earth) planetary candidates. Additional applications of DSSI@DCT include diameters, shape measures, and crude surface maps of the largest stars and solar system asteroids.

Lowell Observatory's 4.3-m Discovery Channel Telescope saw first light in 2012 and has been entering science operations in 2013

Figure 1: Kepler-37 system in comparison to the solar system planets. Kepler-37b is slightly larger than the Moon. Speckle imaging at Gemini was one key to the validation of the system, as the planets are too small for radial velocity confirmation (Barclay et al. 2013).

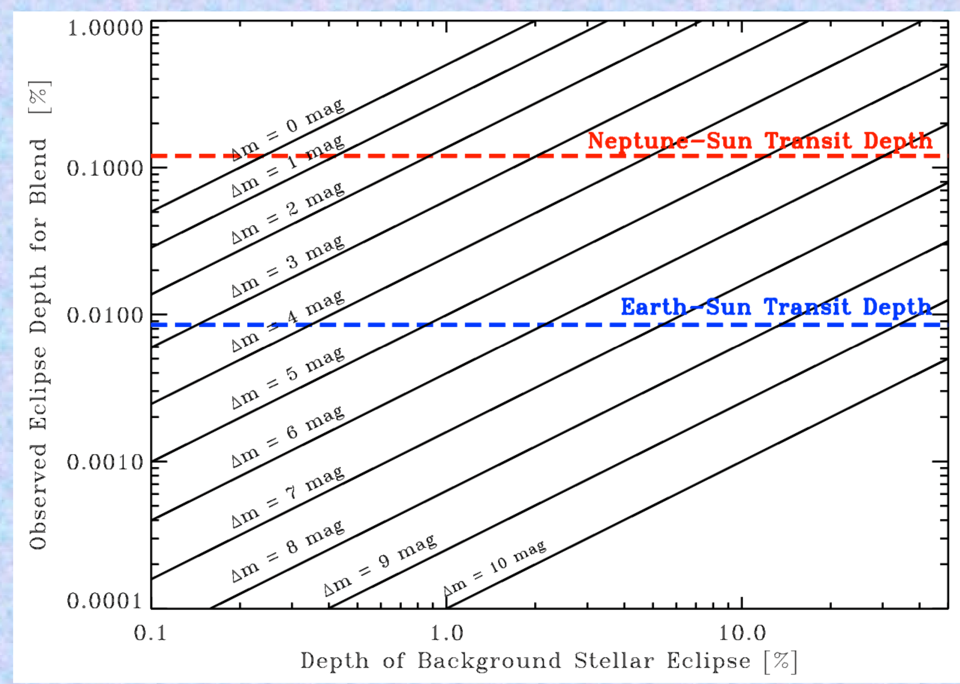

Figure 2: The observed eclipse depth is plotted against the real stellar eclipse depth for a foreground star blended with a background eclipsing binary. The diagonal lines represent curves of constant magnitude differences between the target star and the background eclipsing binary. The horizontal dashed lines represent the transit depths expected for Neptune and Earth transiting the Sun.

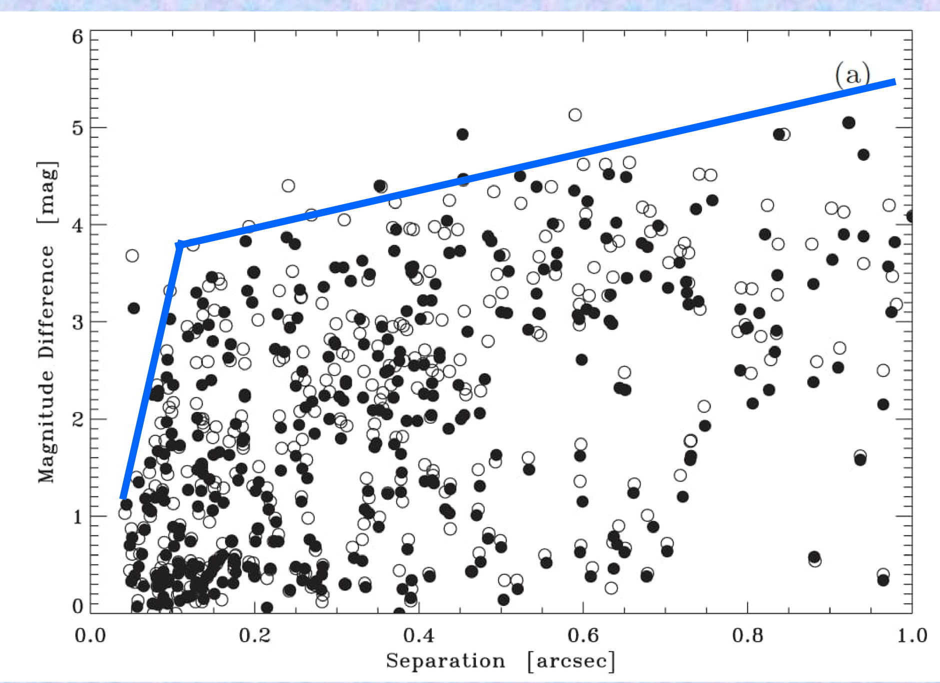

Figure 3: Typical binary star detections (mag. difference vs. separation) with the speckle camera on the WIYN 3.5m telescope (open: 592nm, filled: 692nm; Horch et al. 2011). The blue line shows the response envelope of contrast versus separation for good signal-to-noise.

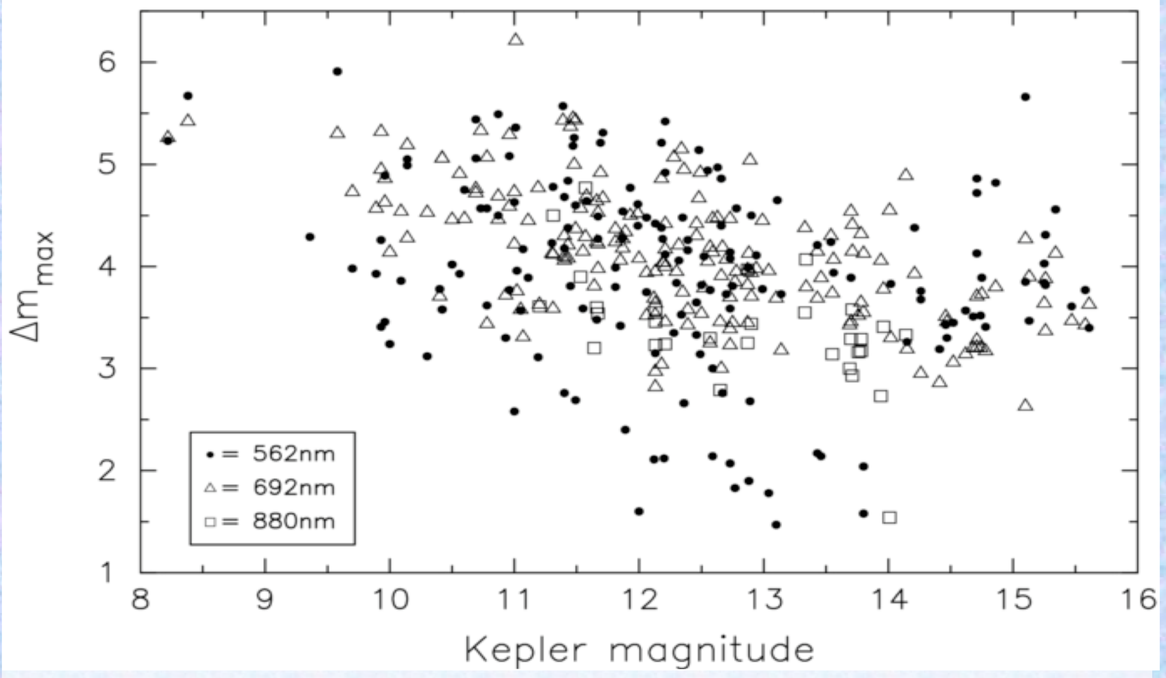

Figure 4: Contrast limits as a function of primary target brightness for the speckle observations on the WIYN 3.5 m telescope (Howell et al. 2011).

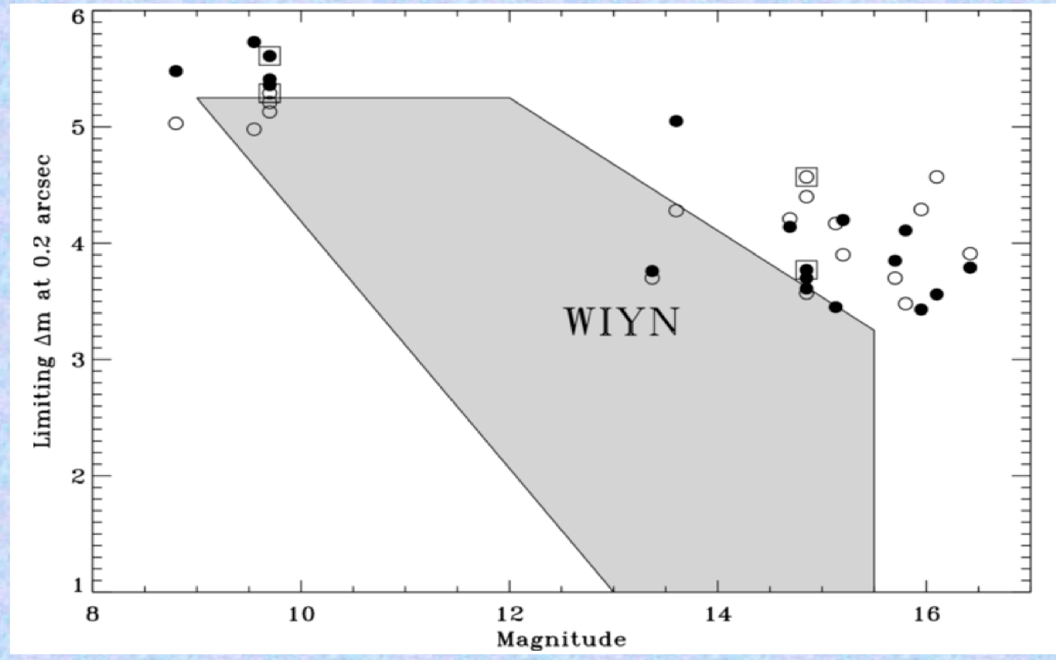

Figure 5: Comparison of the WIYN 5σ contrast levels to the Gemini contrast levels equal integration times per star. 3 σ limits are 0.6 magnitudes deeper (open: 592nm, filled: 692nm; Horch et al. 2012).

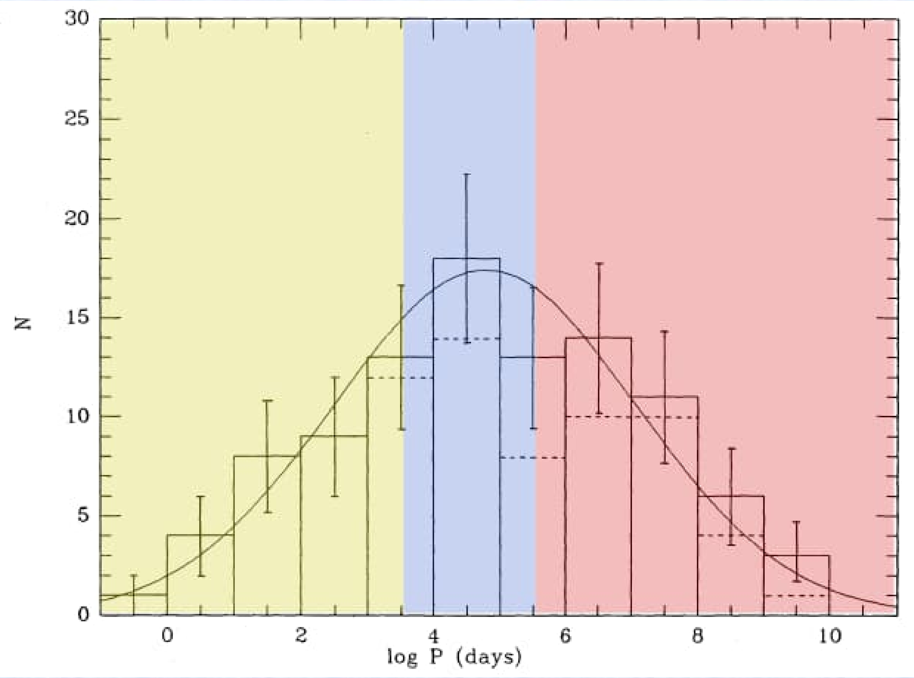

Figure 6: Period distribution from Duquennoy & Mayor (1991) showing rough estimates of where the Kepler FOP radial velocity work is most sensitive (yellow < 1000 days), where the Kepler FOP near-infrared adaptive optics work is most sensitive (red, >200 years, >40AU) , and where the speckle on Gemini and the DCT is most sensitive (blue+red, >30 years, >10 AU).

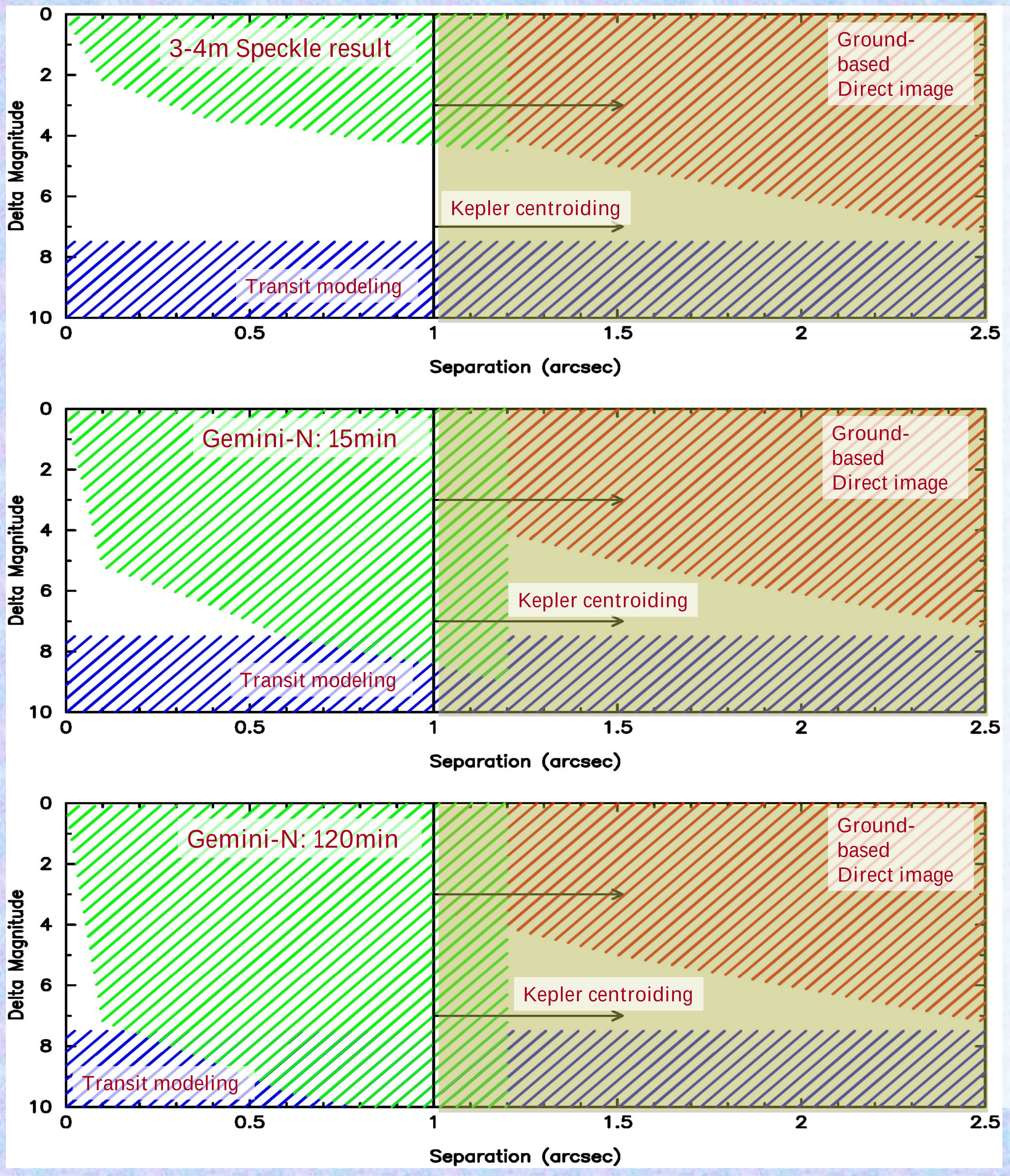

Figure 7: This three panel figure shows the impact of high resolution speckle imaging of exoplanet validation. The X-axis shows the spatial separation in arcsec between the target star and any imaged companion stars while the Y-axis presents the magnitude difference between the target star and the sky background. The blue hatched region shows the typical area where confounding stars can be fully eliminated by transit modeling of Kepler data alone. The red hatched region shows the typical region that can be eliminated by a good seeing ground-based direct image - here we use the publically available J-Band images covering the Kepler field. The vertical black line and all the region to its right (shaded yellow) shows the area one can eliminate based on Kepler difference images and Kepler centroiding of the exoplanet host star based on Kepler images taken in-and-out of transit. The green hatched region shows the area eliminated by our visible light speckle imaging. The top panel shows a typical 3-4m telescope speckle result; the middle and bottom panels show our speckle results at Gemini-North for 15 min and 2 hour on-source times respectively. Speckle images, along with public Kepler data products, can fully validate ALL of the small Kepler exoplanets candidates at the 99% confidence level.

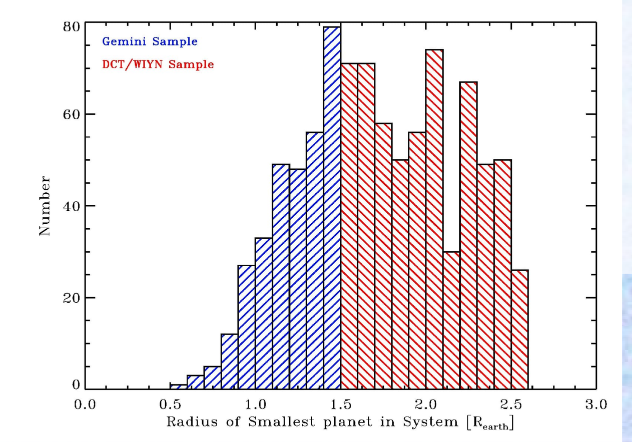

Figure 8a: Separation of the sample set for observation by planet radius for Gemini-North (blue) and the DCT 4.3m (red) telescopes.

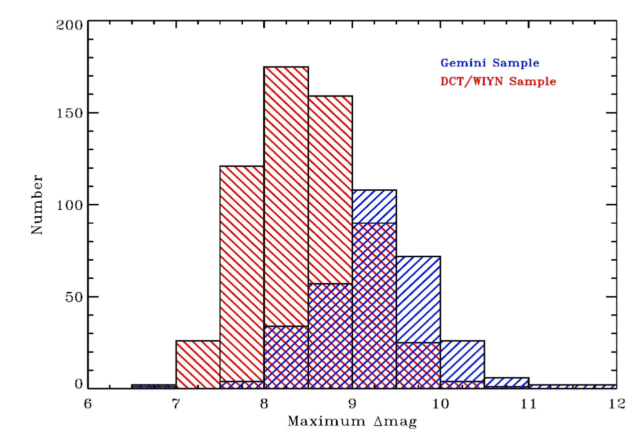

Figure 8b: Required contrast levels needed to eliminate background binaries with 100% eclipses. The required Δmag lessen by 0.75 mag and 1.5 mag if the eclipsing binary depth is 50% or 25%. Blue sample is for the earth-sized planets (Gemini) and the red sample is for the super-earths (DCT). All bound stellar companions, down to M2 with separations >10AU, will be detected by the DCT observations (Δmag < 6 mag).

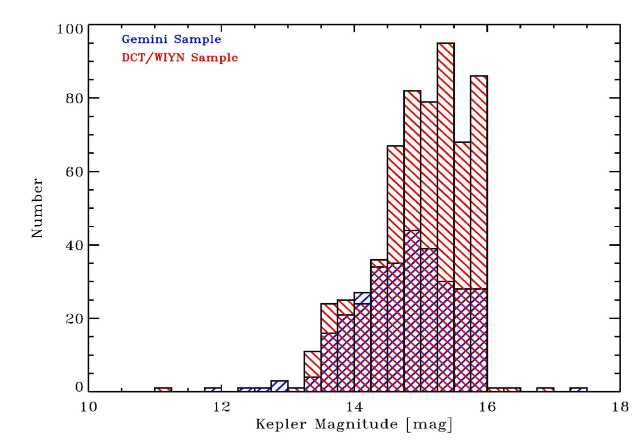

Figure 8c: Kepler magnitude distribution for the Gemini (blue) and the DCT (red) samples.

Contact:
Gerard T. van Belle
Lowell NPOI Principal Investigator
gerard@lowell.edu