# DSSI Data Reduction and Examples

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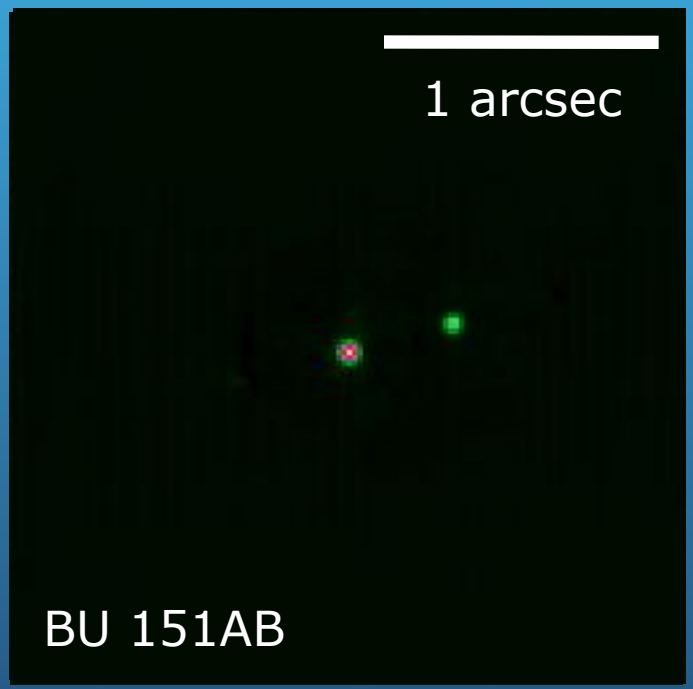
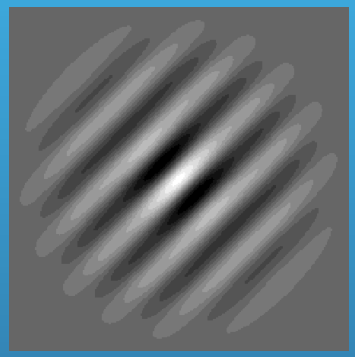
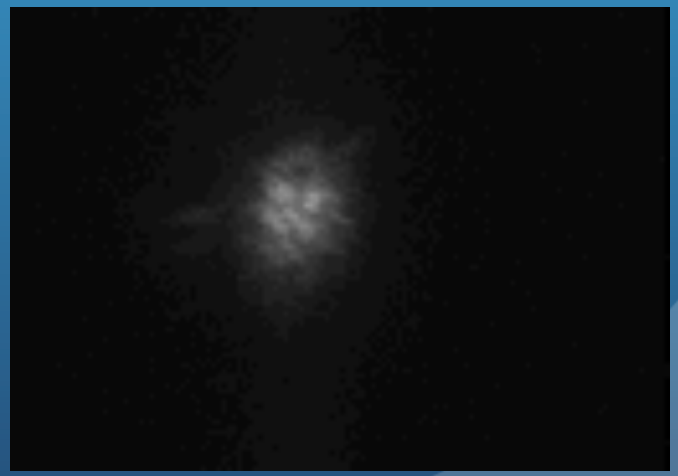
Southern Connecticut State Univ.



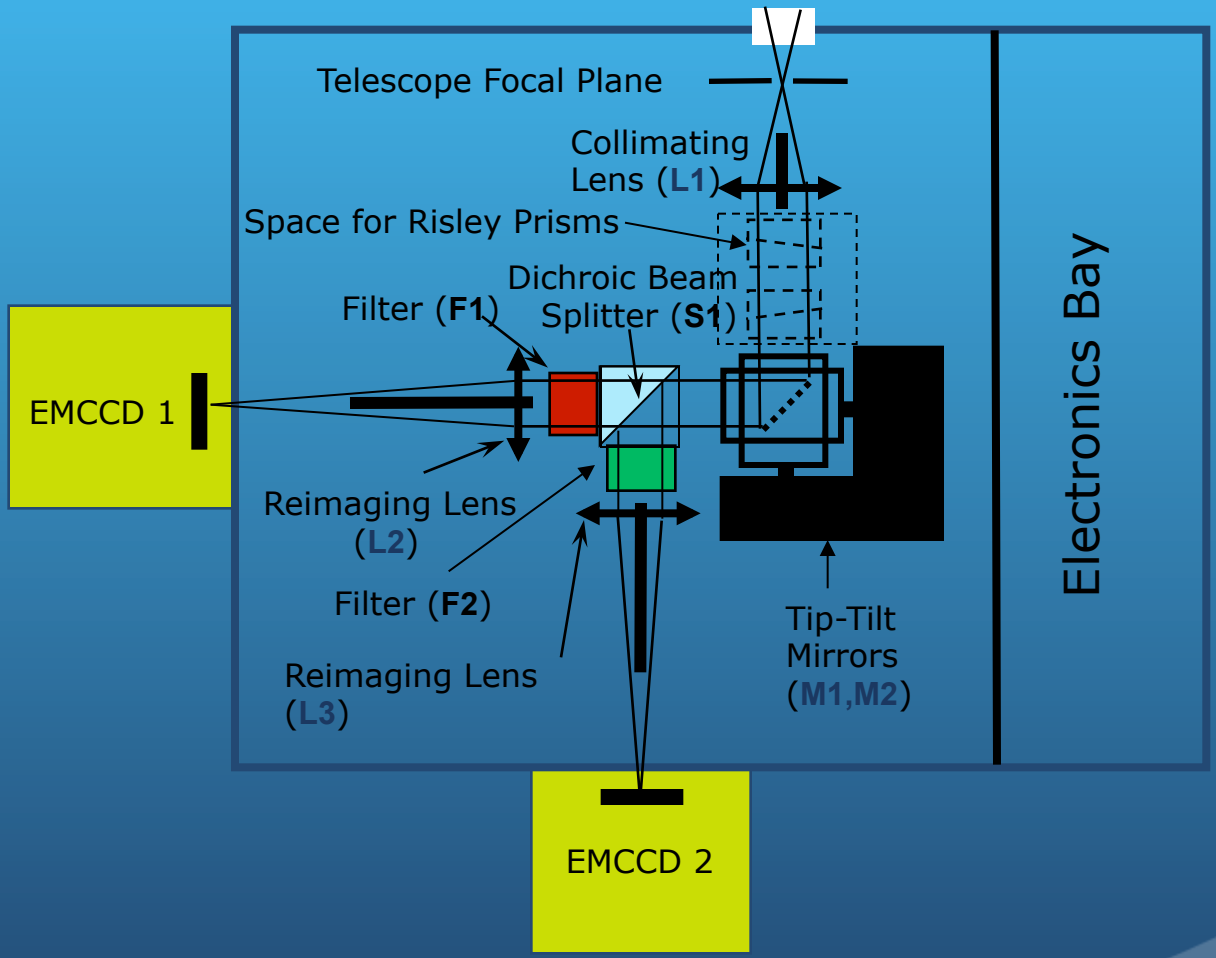





# Collaborators

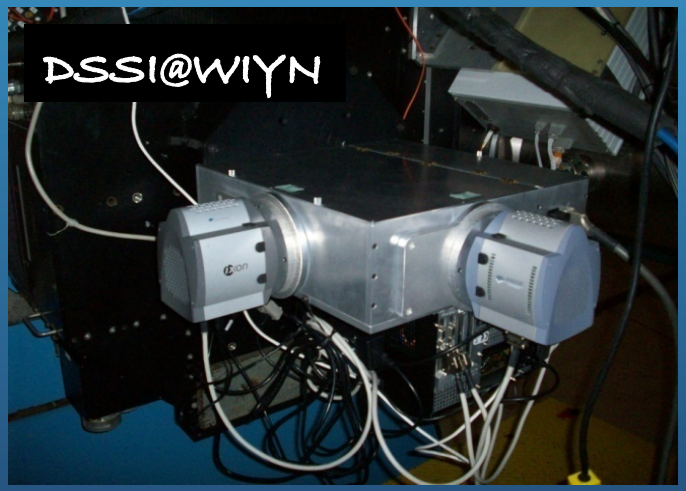
- Kepler
  - Steve Howell (NASA)
  - Mark Everett (NOAO)
  - David Ciardi (Caltech)
- Field Binary Survey
  - Bill van Altena (Yale U.)
  - Pierre Demarque (Yale U.)
  - Y. -C. Kim (Yonsei U.)
- Cluster Binaries
  - Bob Mathieu (U. Wisconsin)
  - Aaron Geller (Northwestern U.)

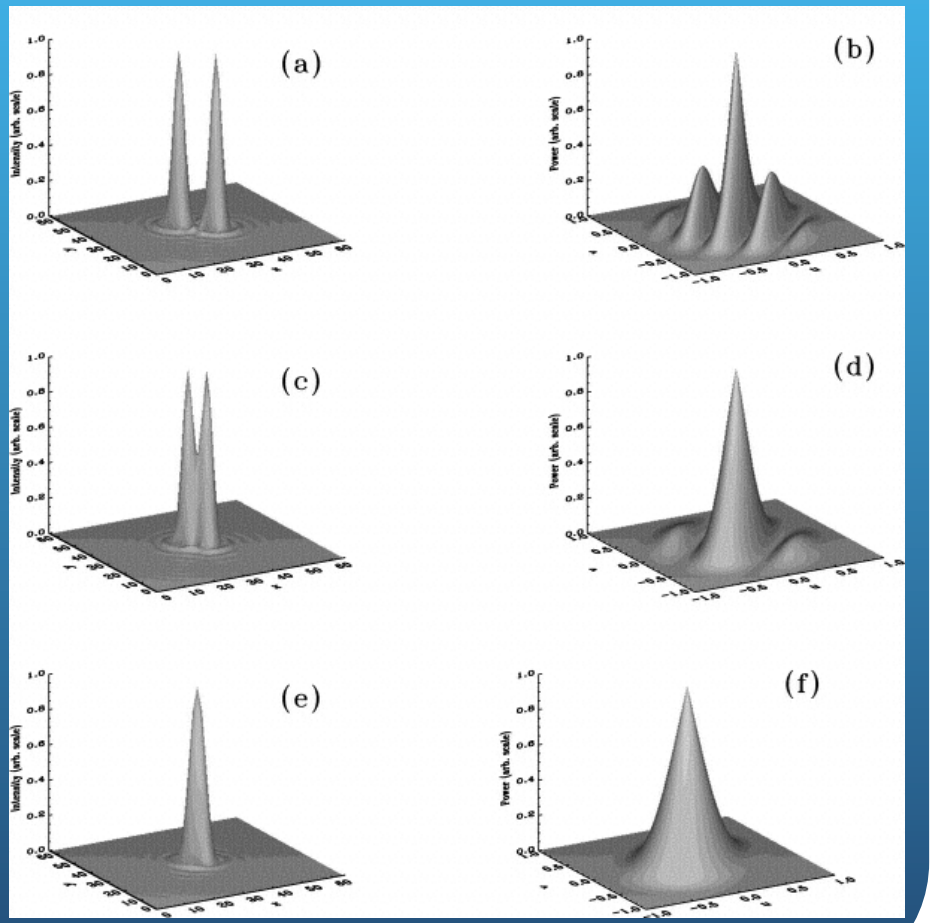
# A Uniquely Capable Speckle Imager Built at SCSU



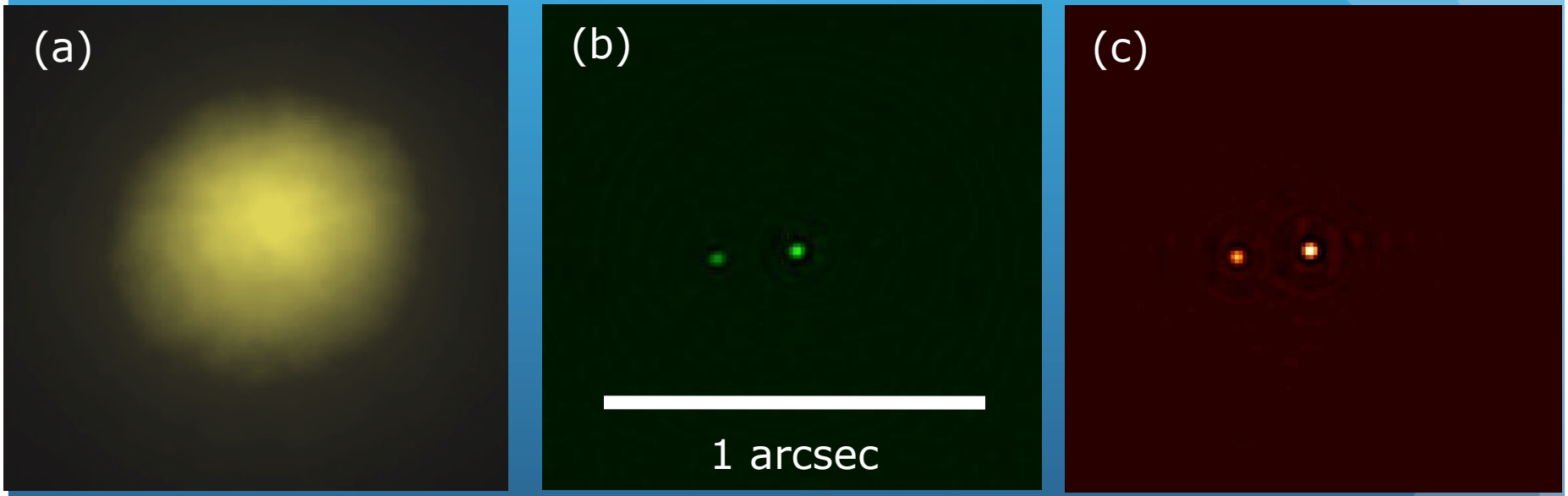
# The Differential Speckle Survey Instrument (DSSI)

- Two channel EMCCD-based speckle camera, completed in August, 2008
- Observe two colors at the same time (dichroic beamsplitter inside).
- Differential refraction



# DSSI Result: A Binary Star (WIYN)




Panchromatic Integrated Image

562 nm

692 nm

Reconstructed Images

# Basic Data Reduction Steps

- Debias frames.
- Compute autocorrelation of each frame, sum these. Compute FT and take the square root.
- Divide this by same function computed for a point source.
- Compute 10 bispectral subplanes (5 each in two orthogonal image directions (x,y). This gives robust phase estimate.
- Combine modulus and phase estimates, filter and inverse-transform.

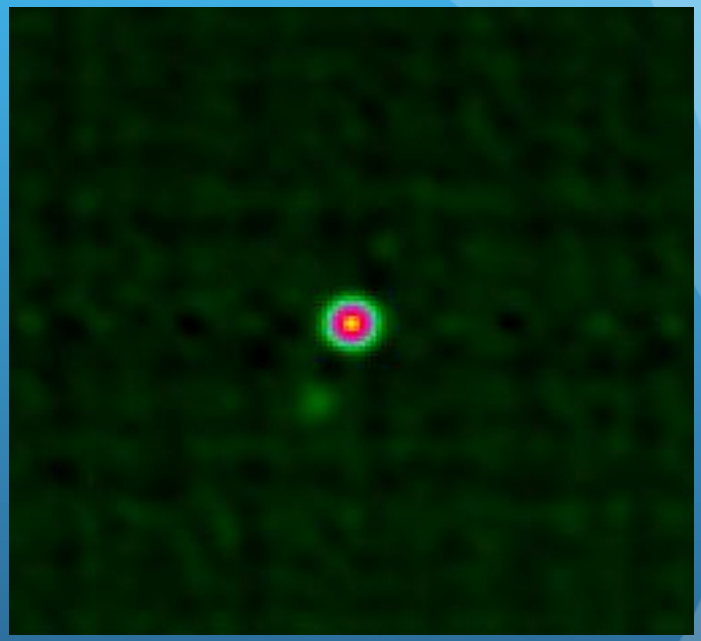
# Data Reduction, Part 2

- Look for companions in reconstructed image.
  - Visually look, using ds9
  - Use a program to identify 5-sigma peaks in IDL:
    - Look inside annuli centered on central star.
    - Determine all local maxima in the annulus – “peaks”
    - Compute average peak height.
    - Source is considered a star if it is greater than 5*sigma above the average peak height.
    - Express peak heights as magnitude differences from central star
    - Plot 5-sigma detection limit as a function of separation.

# WIYN Binary Discovery: A CoRoT Source

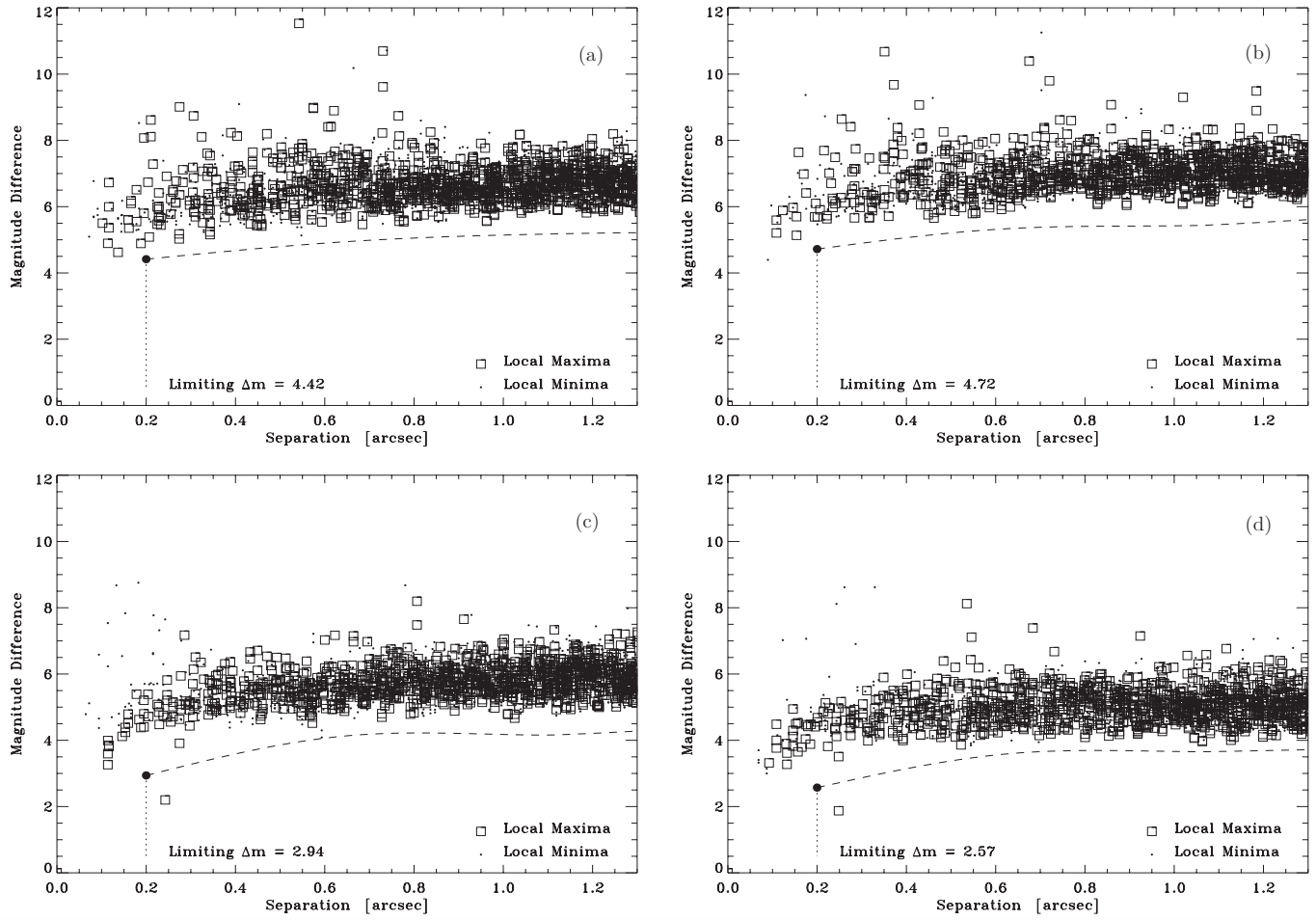


- We have done ground-based follow-up work for CoRoT and (mostly) Kepler.
- Kepler: about 10 nights of WIYN time per year.
- DSSI is helping to vet planetary candidates for binarity.
- Speckle image reeconstructions have appeared in a number of Kepler papers.



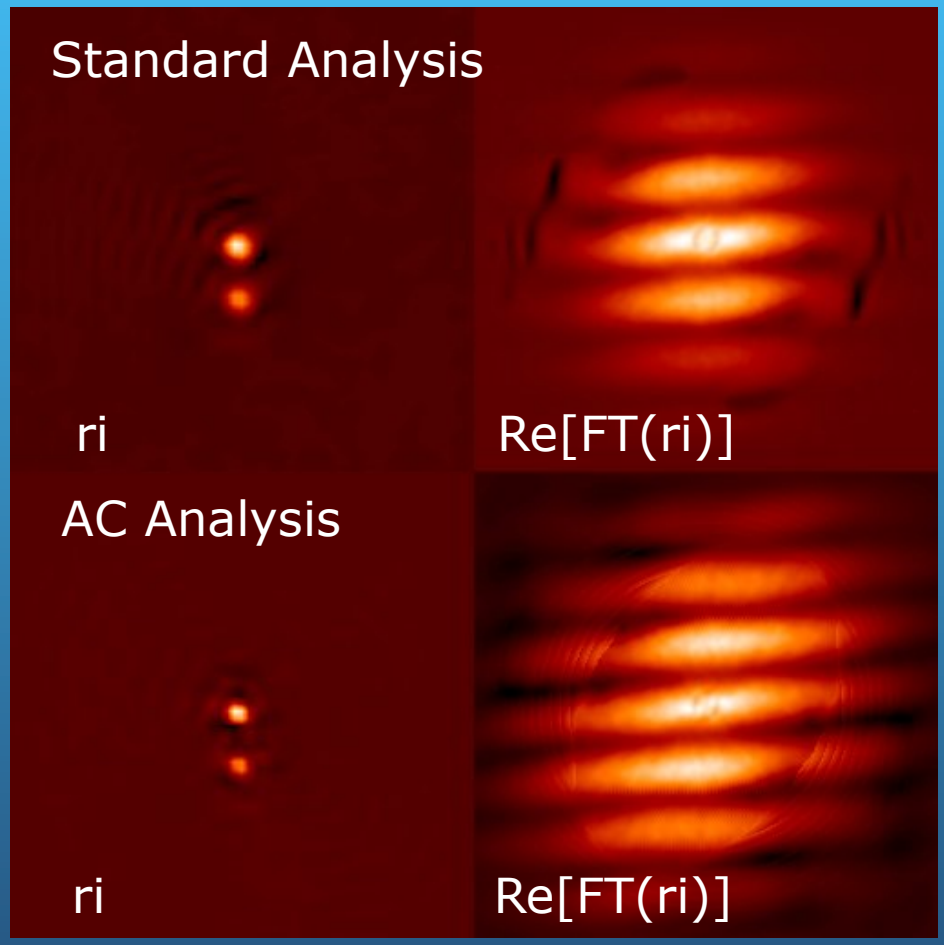
14.2-mag star shown to be binary at WIYN.

# Companion Detection at WIYN: Bright Sources

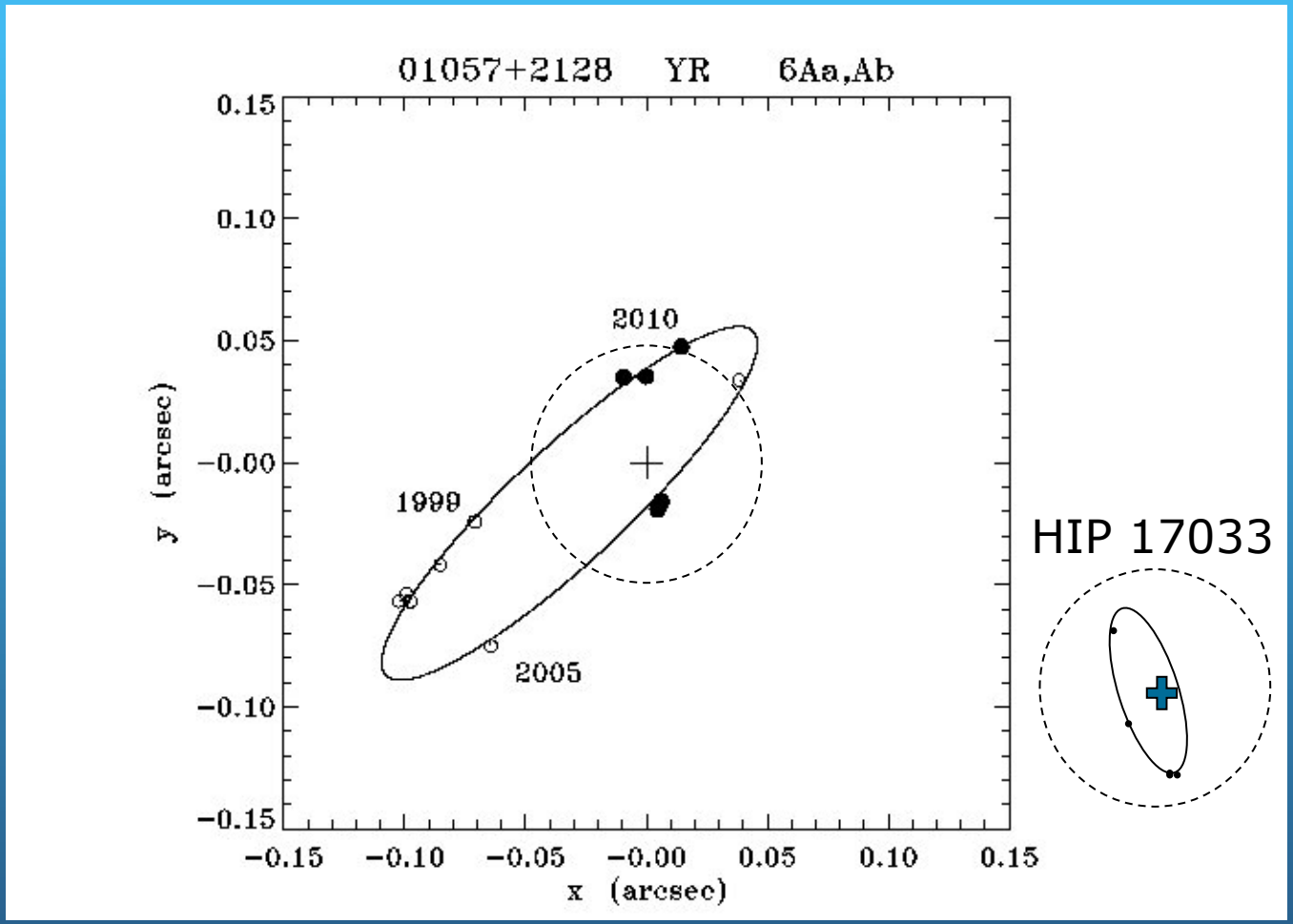


# Analytic Continuation

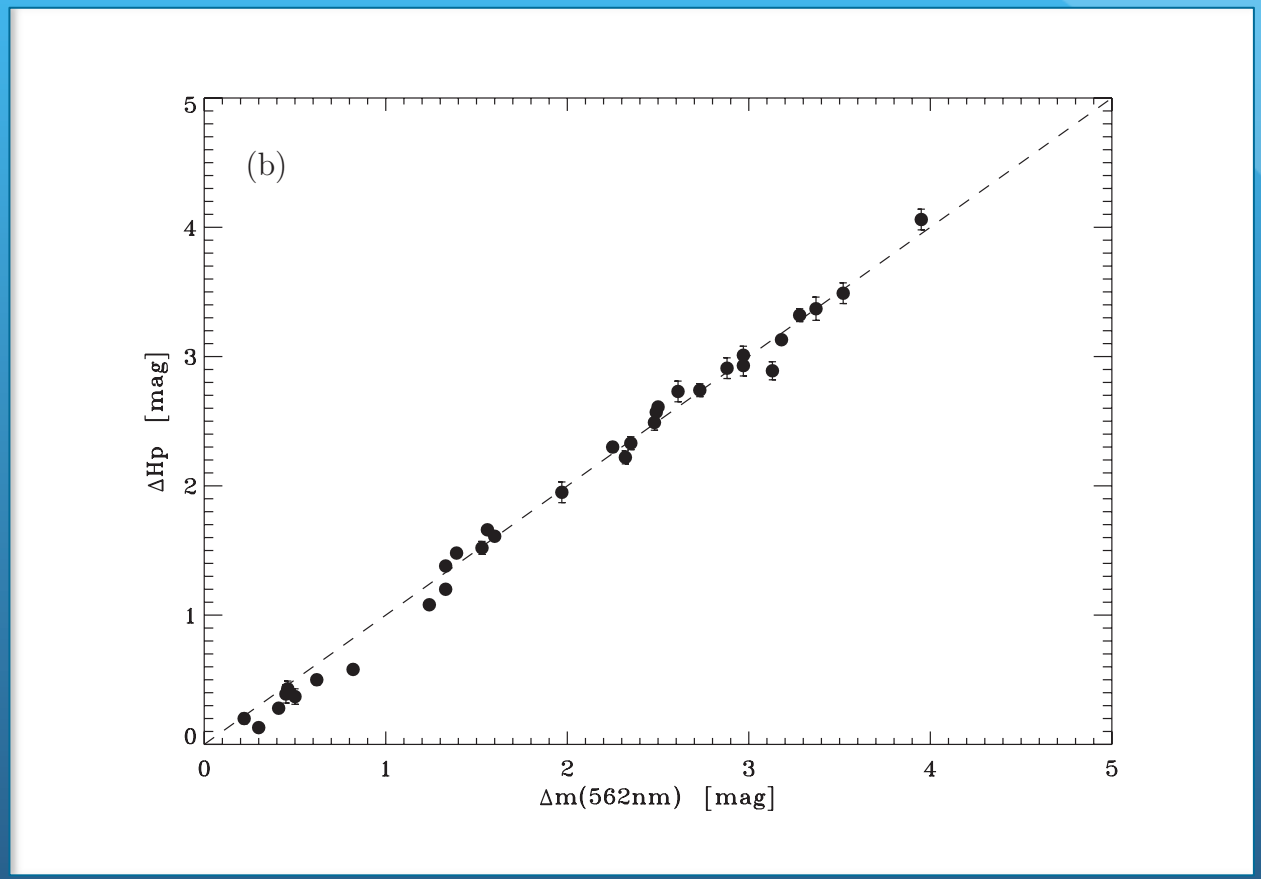
- Bright object on a black background = “finite support.”
- FT is analytic.
- In the absence of noise, a unique extrapolation to arbitrarily high spatial frequencies.



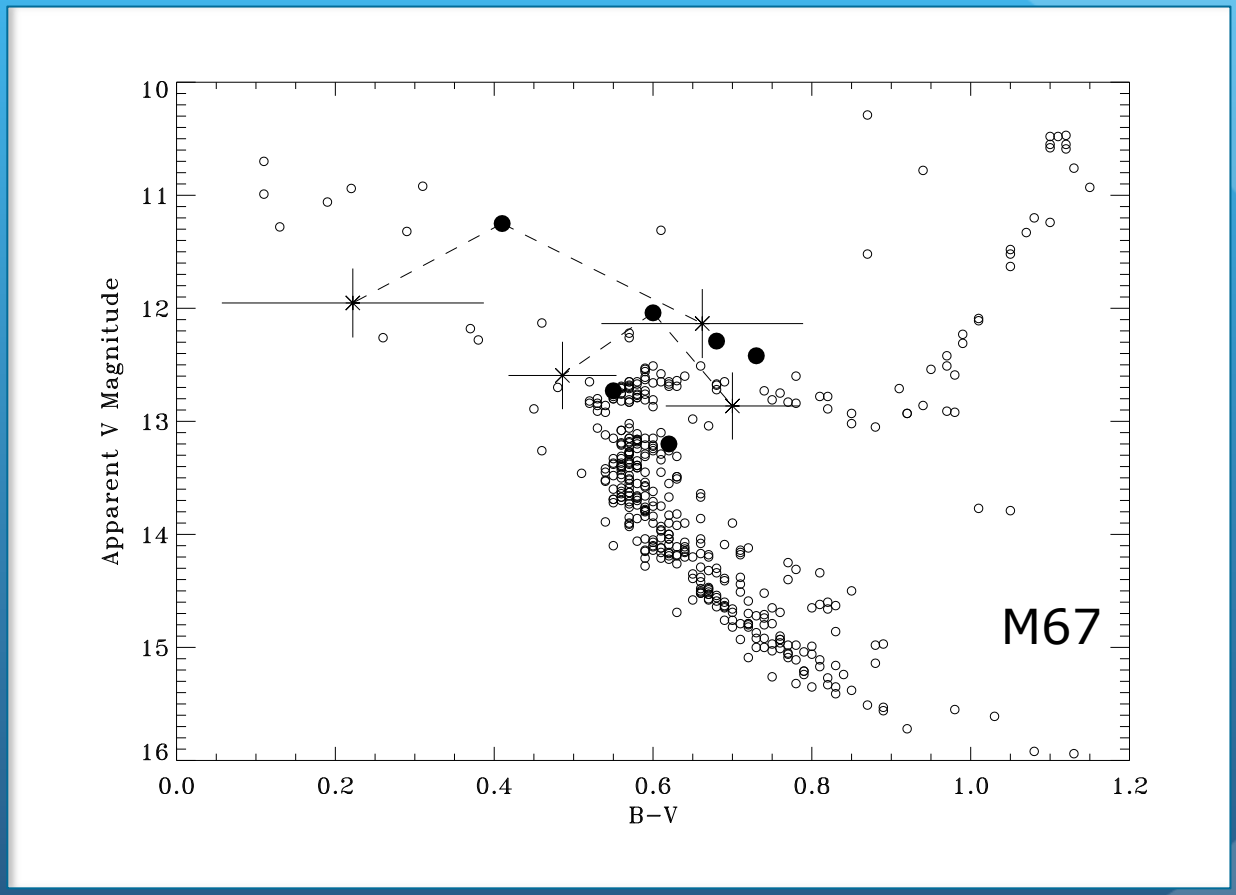
# Science: Orbits and Masses



# Differential Photometry versus Hipparcos

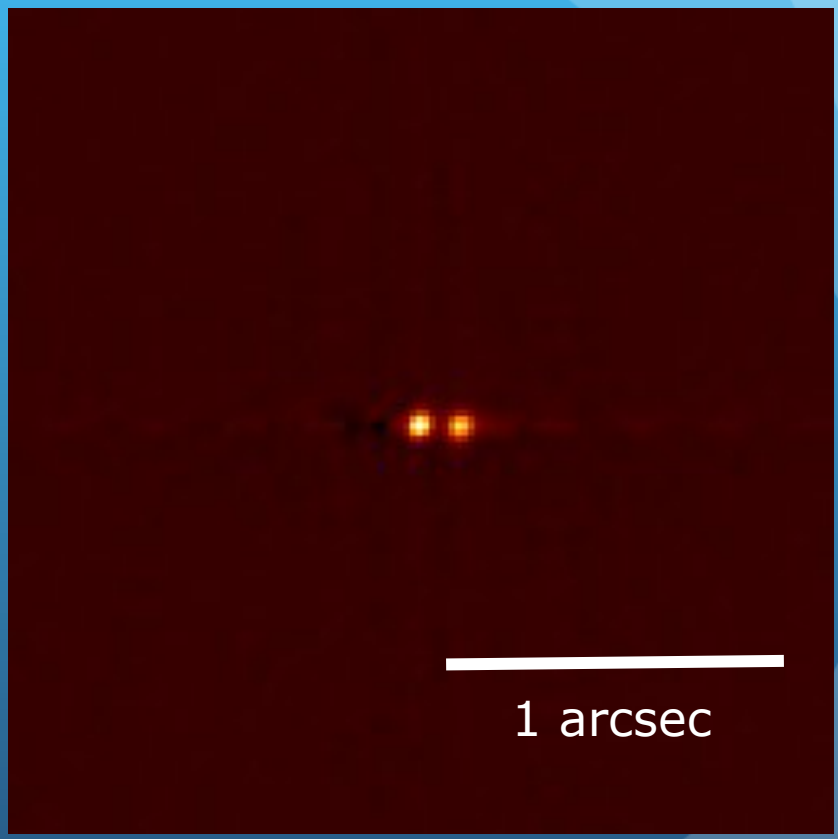


# Cluster Binaries: Comparing M67 and M35

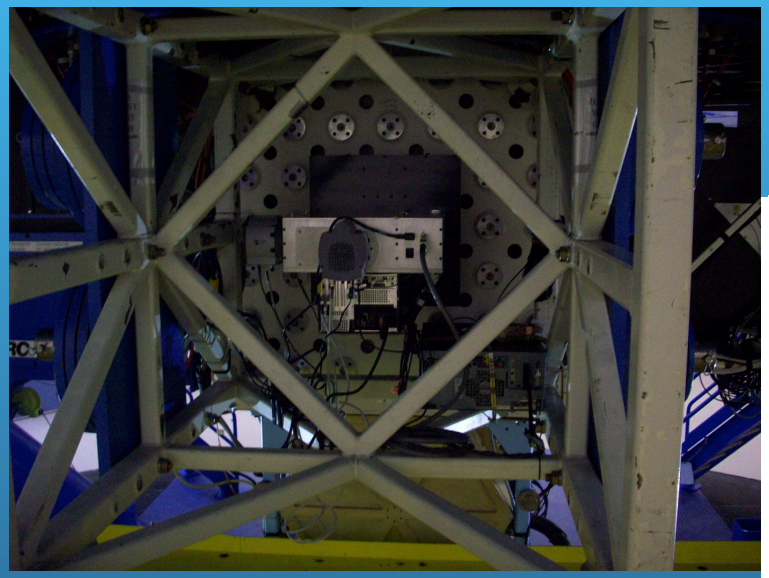


# Quick result from DCT

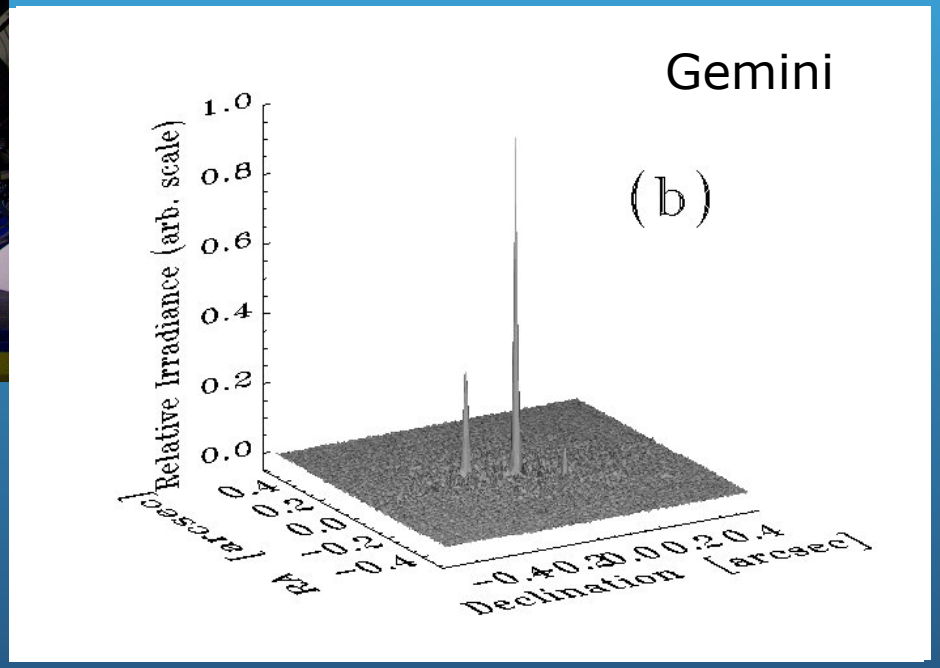
- M dwarf pair
- Mag = 15.2
- Separation: ~0.12 arcsec
- ~30 minutes of data, at 880 nm.
- Investigators:
  - **Evgenya Shkolnik (Lowell)**
  - **Ben Montet (CfA)**



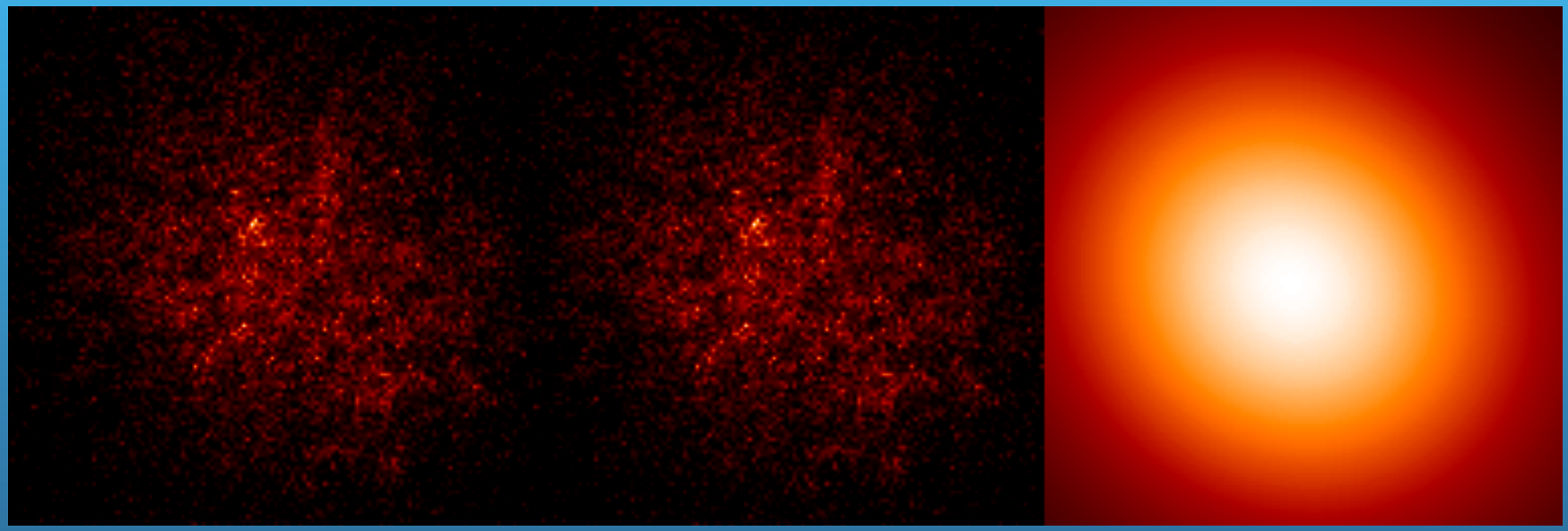
# Gemini-N



Used in July 2012, now here again this week for ~8 nights, 5 different science projects.

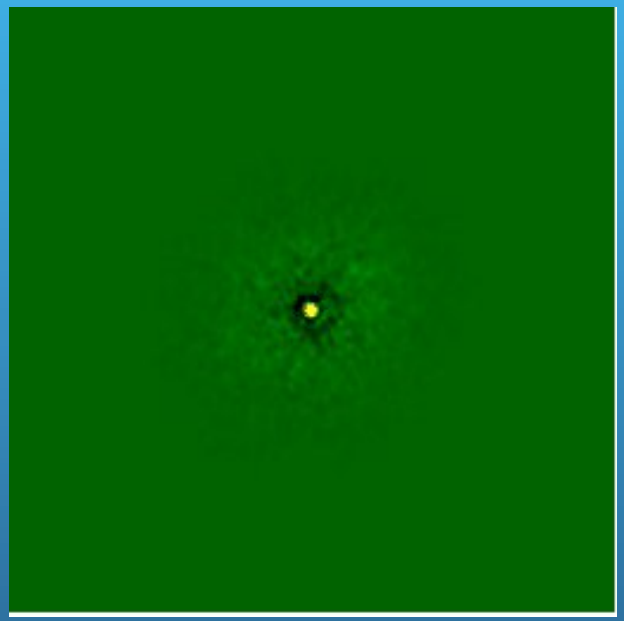


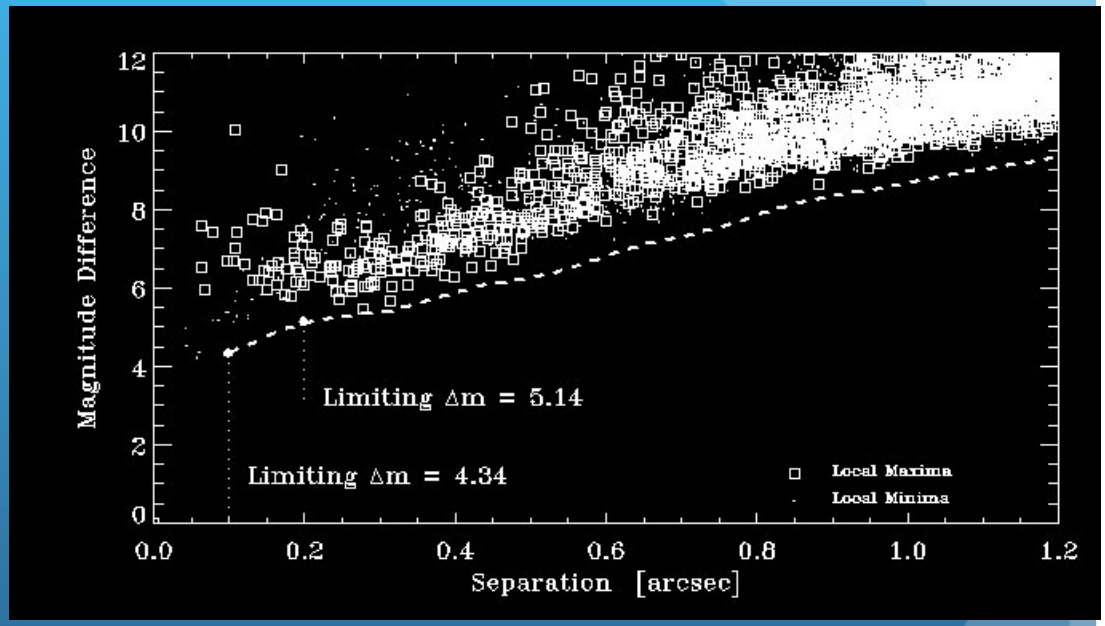
# Image Reconstruction from Gemini Data



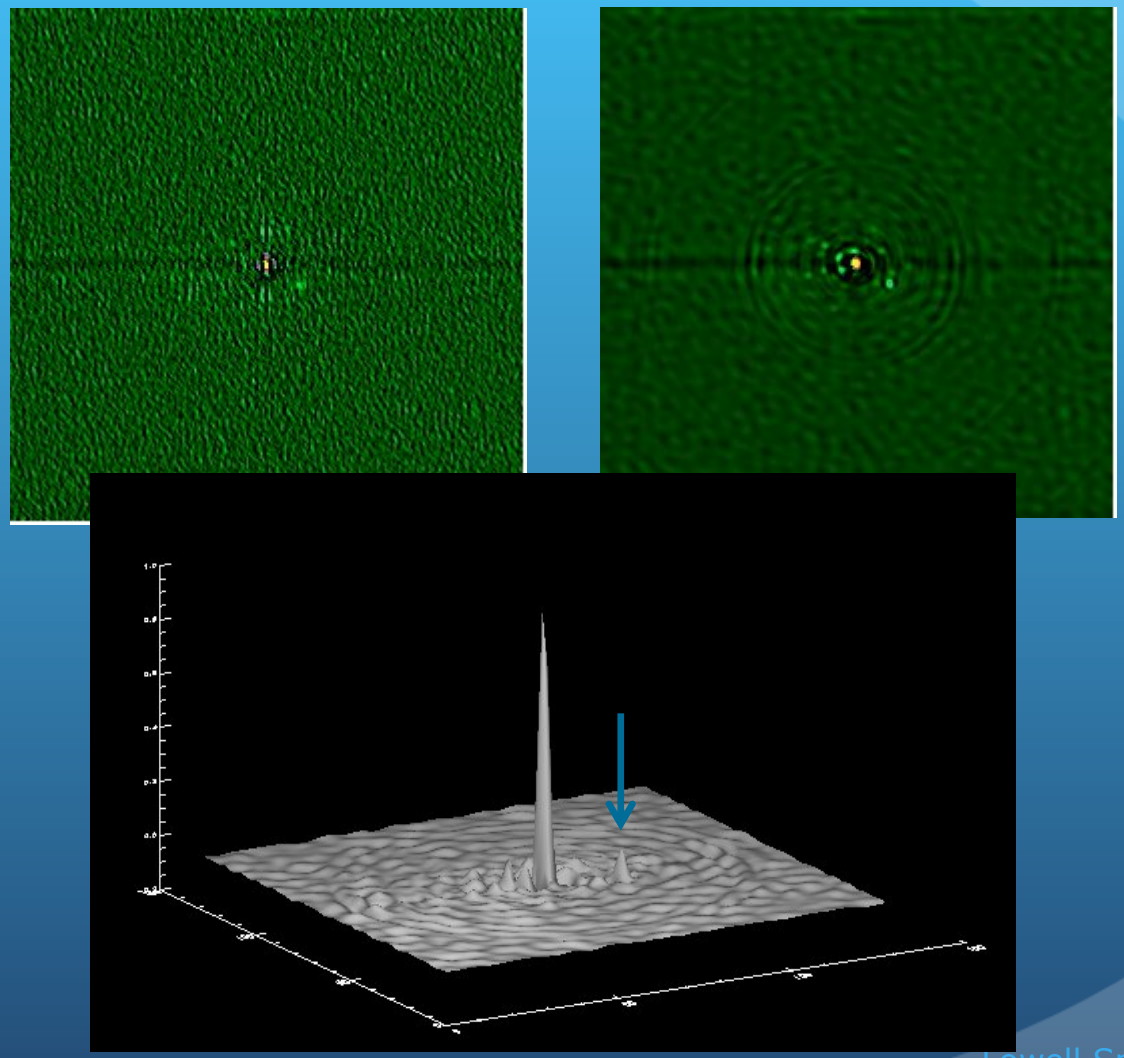
Speckles | Integrated Image | Reconstructed Image

# Gemini-N: Bright Source



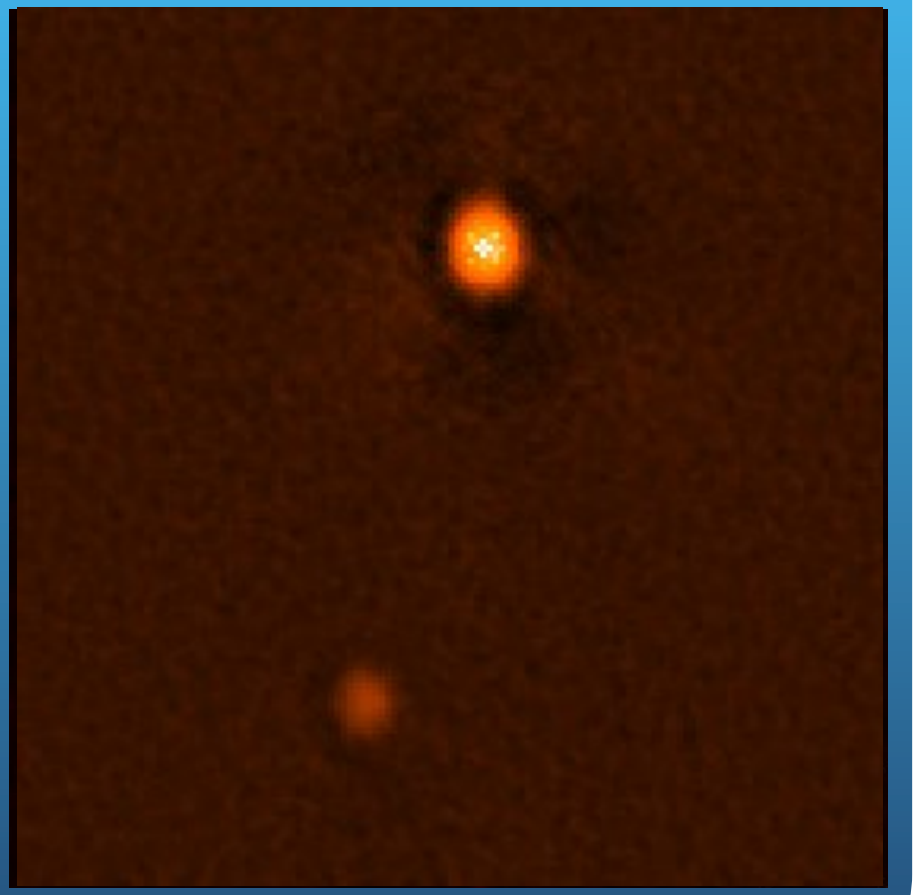


# Analytic Continuation… KOI 1422, Mag=15.92



# Gemini-N: Extended Objects

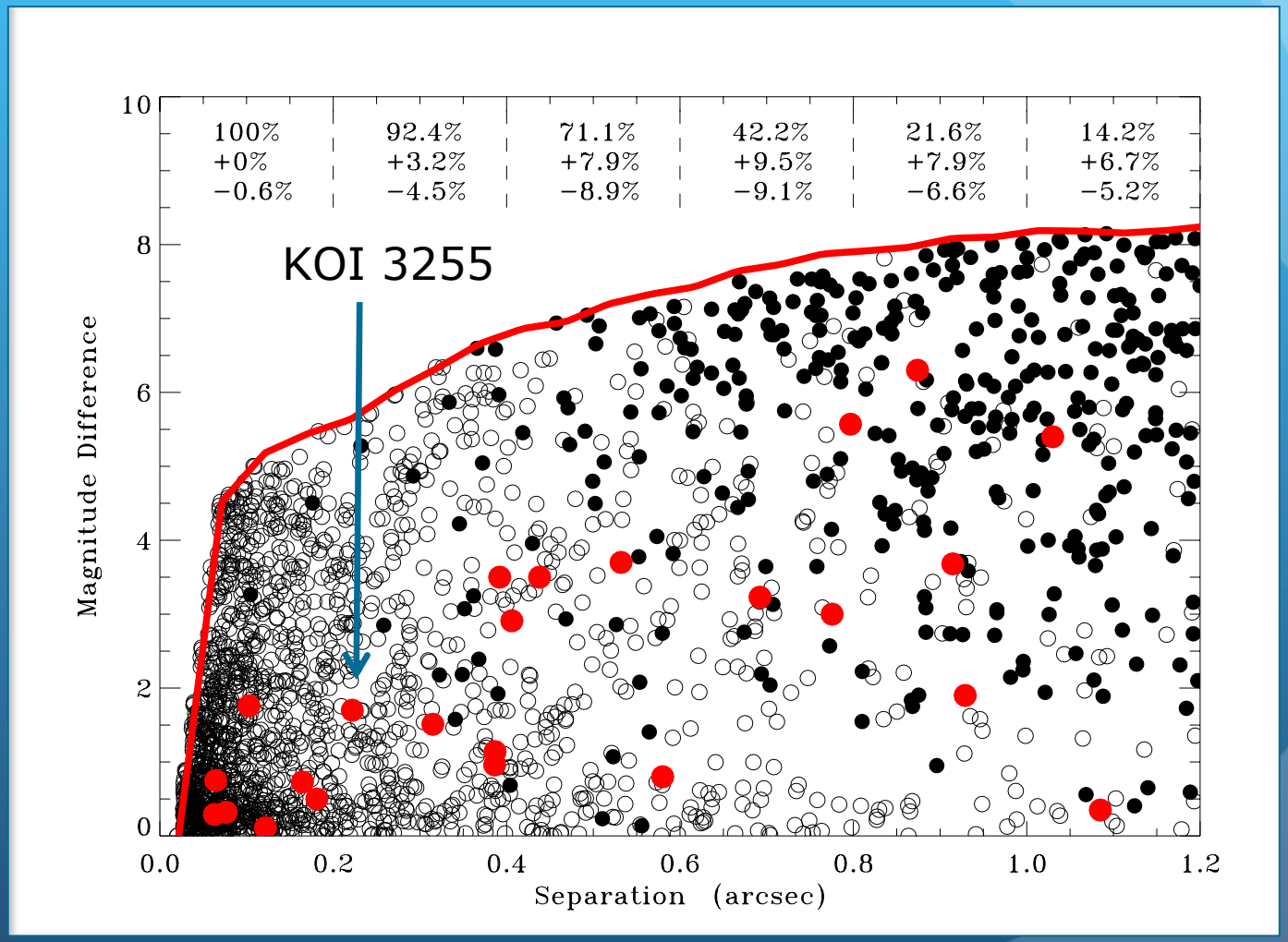
- Pluto/Charon
- ~30 minutes of observing time
- See Howell et al. in PASP 9/2012 issue.
- Measured radii.
- Working on better image reconstruction algorithms for future projects.



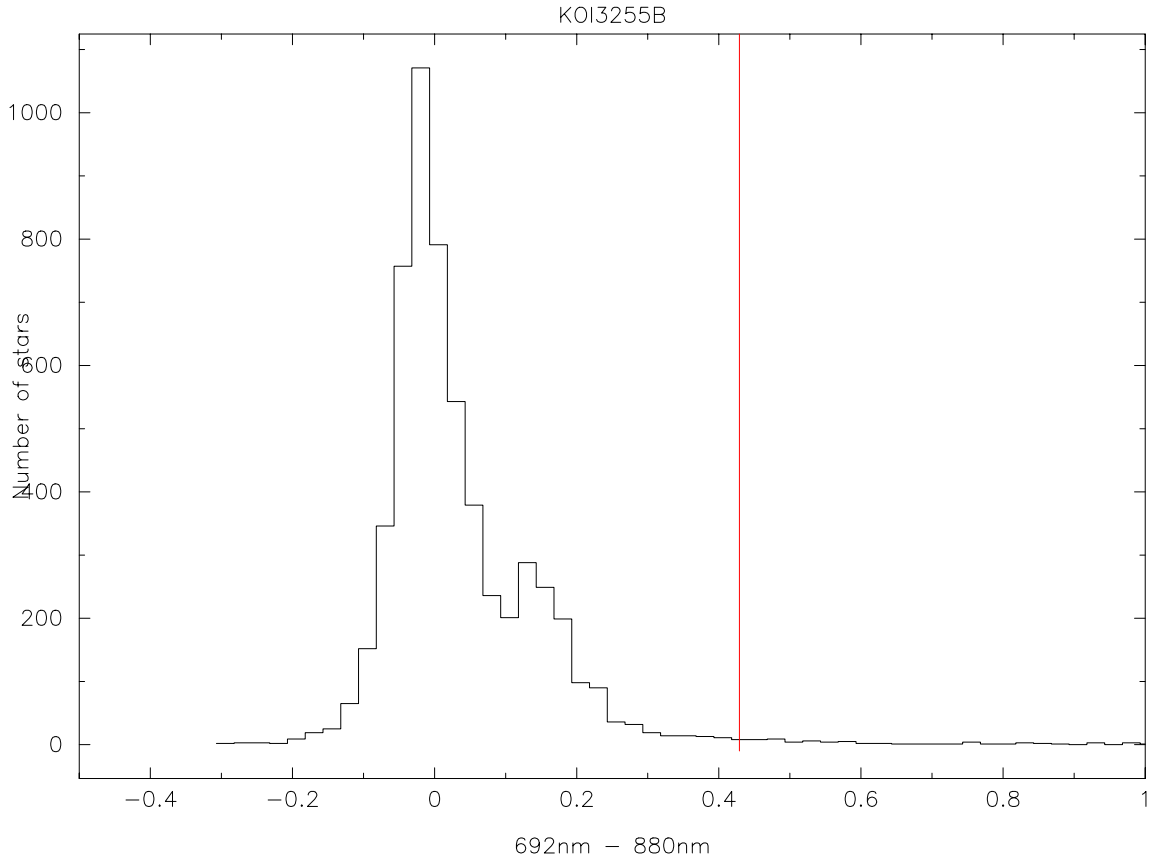
# Companion Detection Simulations

- Use Raghavan 2010 binary/multiple star statistics from the field.
- Simple galaxy model, star with M.S. stars only, no reddening (yet).
- Look in Kepler field at the appropriate distance range.
- Add in background giants.
- Ask with what frequency DSSI would detect Kepler star with a companion.

# Gemini: Kepler Stars with Companions



# KOI 3255


KOI3255B
1000
800
600
400
200
0
Number of stars
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
692nm − 880nm

# So Far This Work Suggests that Most Sub-Arcsecond Companions of Kepler Exoplanet Candidate Host Stars are Gravitationally Bound.