Searching for Wide Companions and Identifying Circum(sub)stellar Disks through PSF-Fitting of IRAC Archival Data (arXiv:1907.06767)

Raquel Martinez, Adam Kraus, The University of Texas at Austin

About the Author

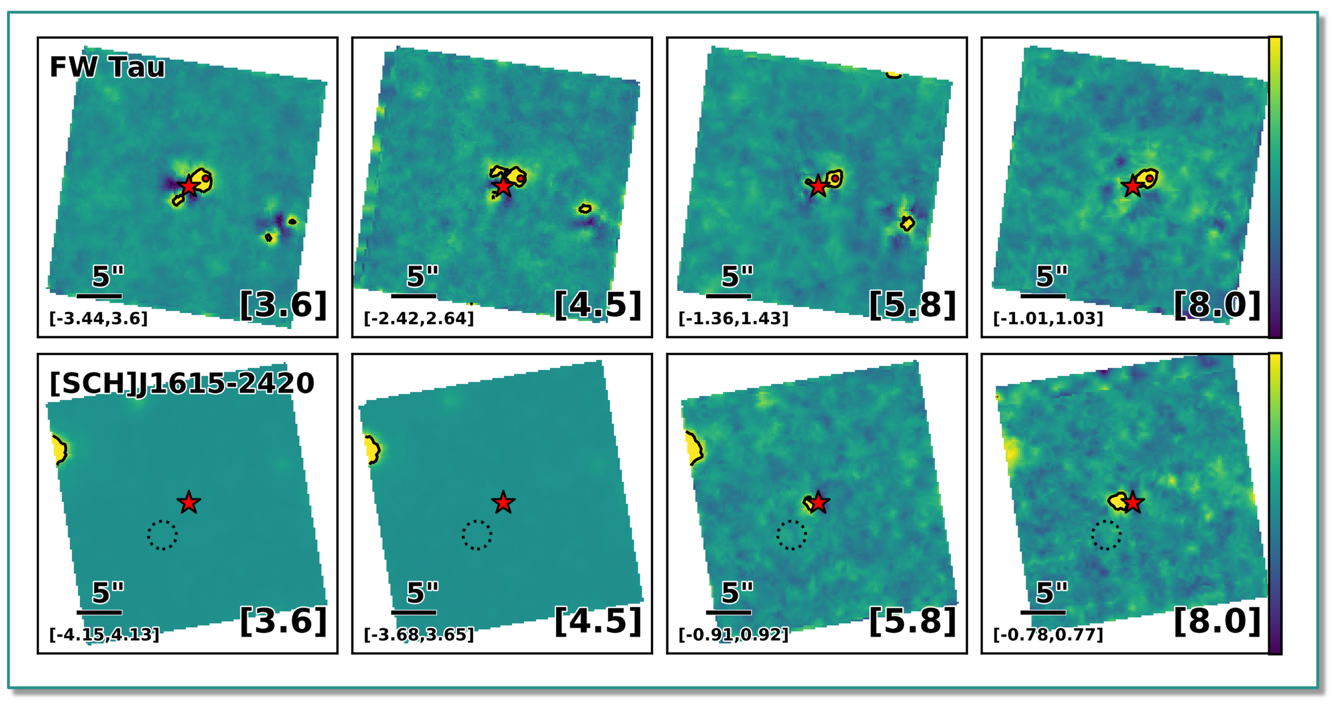
Raquel Martinez is a Ph.D. candidate at the University of Texas with research interests in planet formation and high-contrast imaging of exoplanets. When not searching for PMCs, she enjoys all that Austin has to offer. Hook 'em!
Email: **ram@astro.as.utexas.edu**

DONALD D. HARRINGTON FELLOWS PROGRAM
THE UNIVERSITY OF TEXAS AT AUSTIN

Leveraging Spitzer to Increase Number of Known PMCs

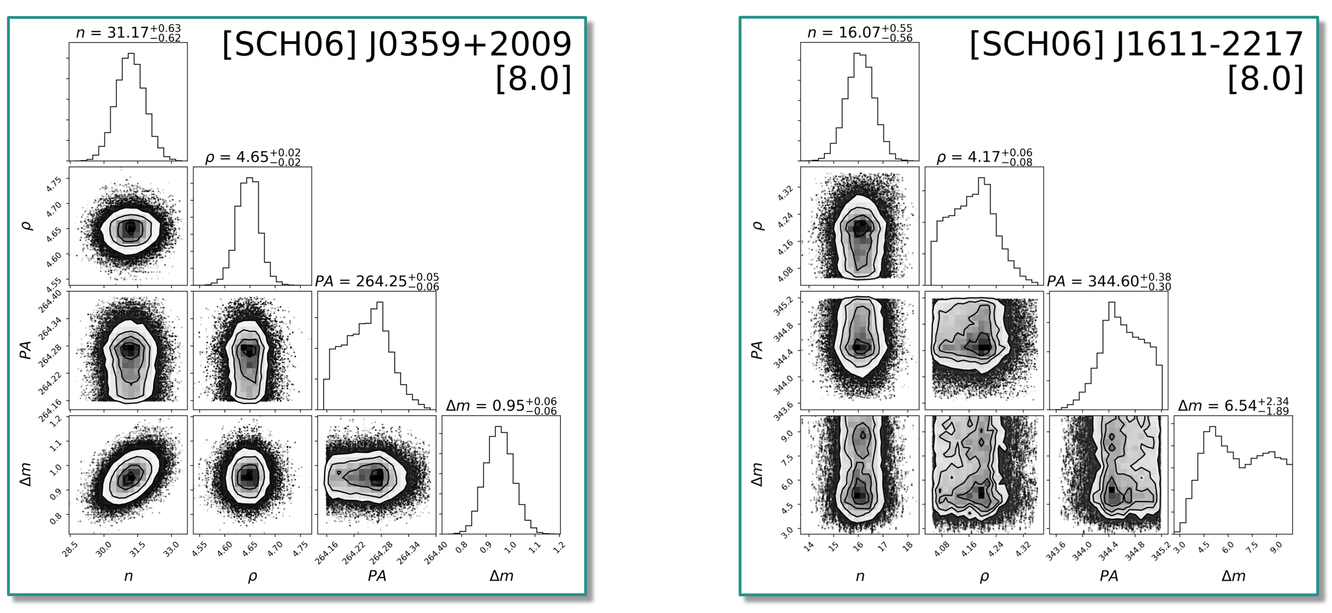
- Planetary-mass companions (<20 M_{Jup}; PMCs) are being discovered at wide separations (>100 AU) from their host stars (e.g. Chauvin+04, Lafreniere+08, Ireland+11, Bailey+14)
- **It is unclear whether these systems represent low-mass extreme of stellar binary model** or **high-mass and wide-orbit extreme of planet formation theories** (Kratter+10)
- *Spitzer*/IRAC observations of nearby star-forming regions and associations have great potential to be mined for undiscovered PMCs orbiting their host stars at distances >250 AU. IRAC is sensitive enough to detect photospheres and disks of proto-brown dwarfs and protoplanets.
- **I am developing an automated pipeline to find faint wide-orbit PMCs via PSF subtraction in existing *Spitzer*/IRAC images, identify promising candidates for further characterization**
- Previous analyses searched for companions at >>λ/D (e.g. Janson+2012, Durkan+2016). We are looking at 1-3 λ/D where IRAC PSF core modeling is crucial.
- **Statistically robust samples of PMCs are required to assess occurrence rates, demographics, and formation pathways. Identification of accretion and accurate spectral types via spectroscopic follow-up are needed to investigate mass-accretion rates, disk structure, and moon-forming capabilities**

PSF-Fitting Pipeline Workflow



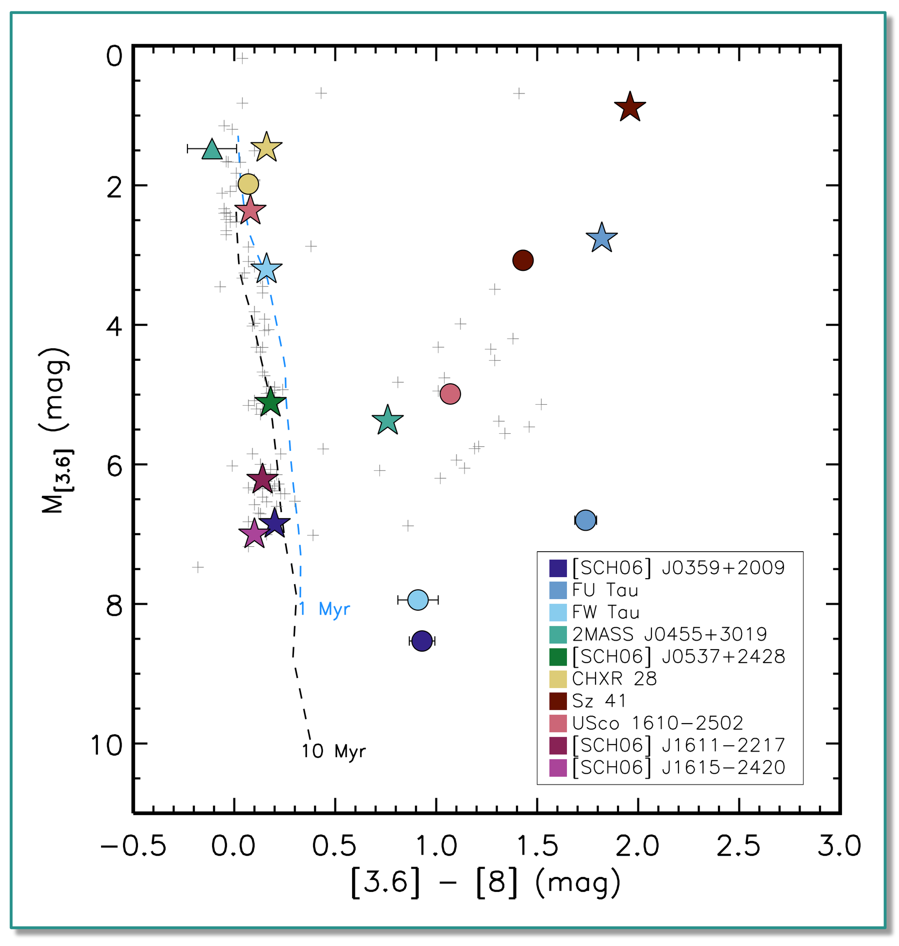
Above: Stacked residuals for FW Tau (detection; top row) and [SCH06] J1615-2420 (non-detection; bottom row) across all four IRAC channels (columns) created by combining individual residuals images after the primary PSF has been subtracted. The pipeline is generalized to subtract a model PSF then measure photometry across all four IRAC channels.

- Publicly available observations sent through MCMC algorithm (Metropolis-Hastings fitter with Gibbs Sampler) that models "effective PSF" provided by *Spitzer* Science Team
- Images of individual systems are processed simultaneously, iterating between image-specific and system-specific MCMC fits. Image-specific parameters are primary centroid and background; system-specific parameters are total flux, separations, PA, and **Δm**.

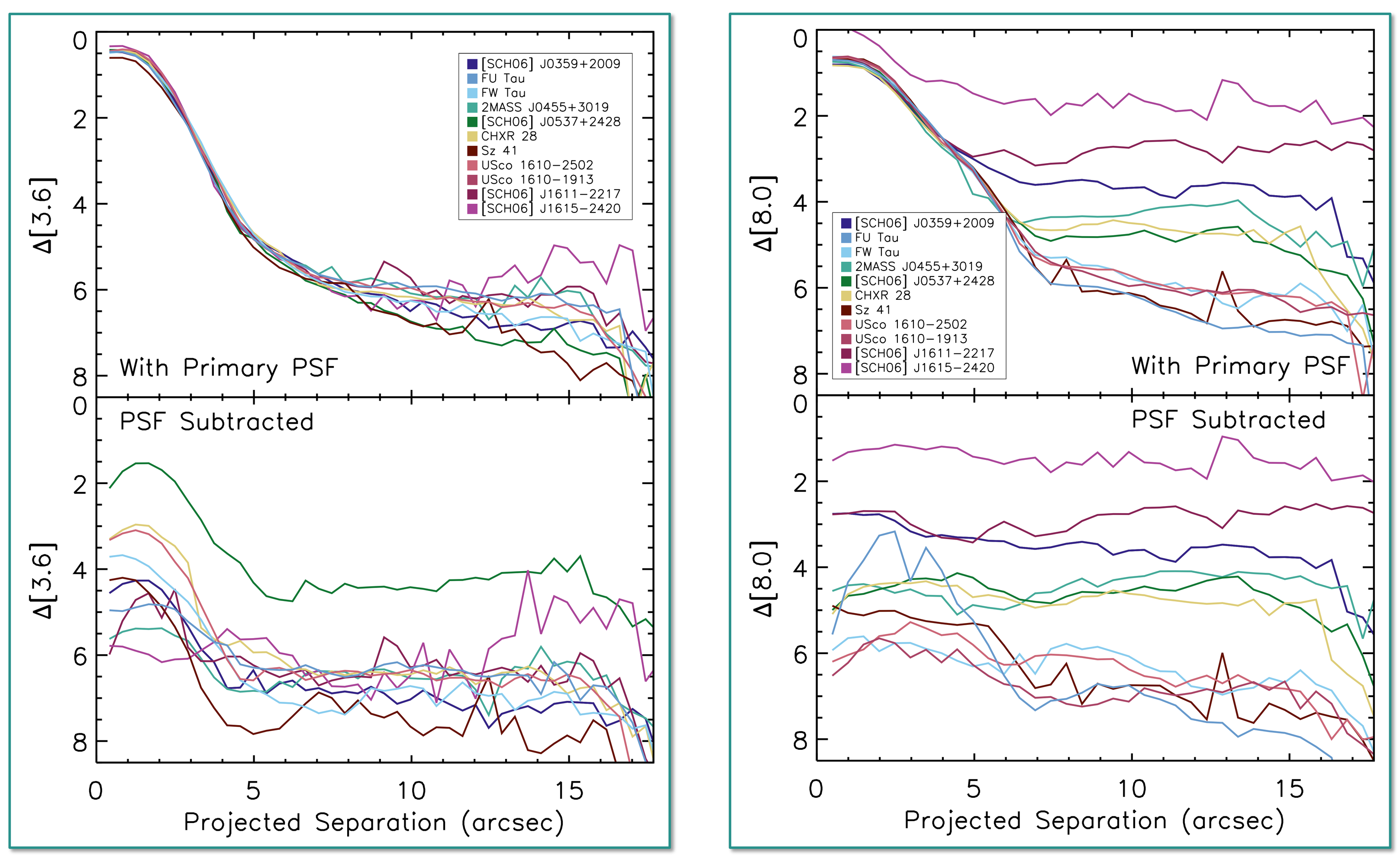


Above: Example system-specific posterior distributions. The MCMC formalism quantifies the degeneracy between fit parameters while also allowing for use of prior information from previous adaptive optics imaging in a robust way

Pipeline Performance

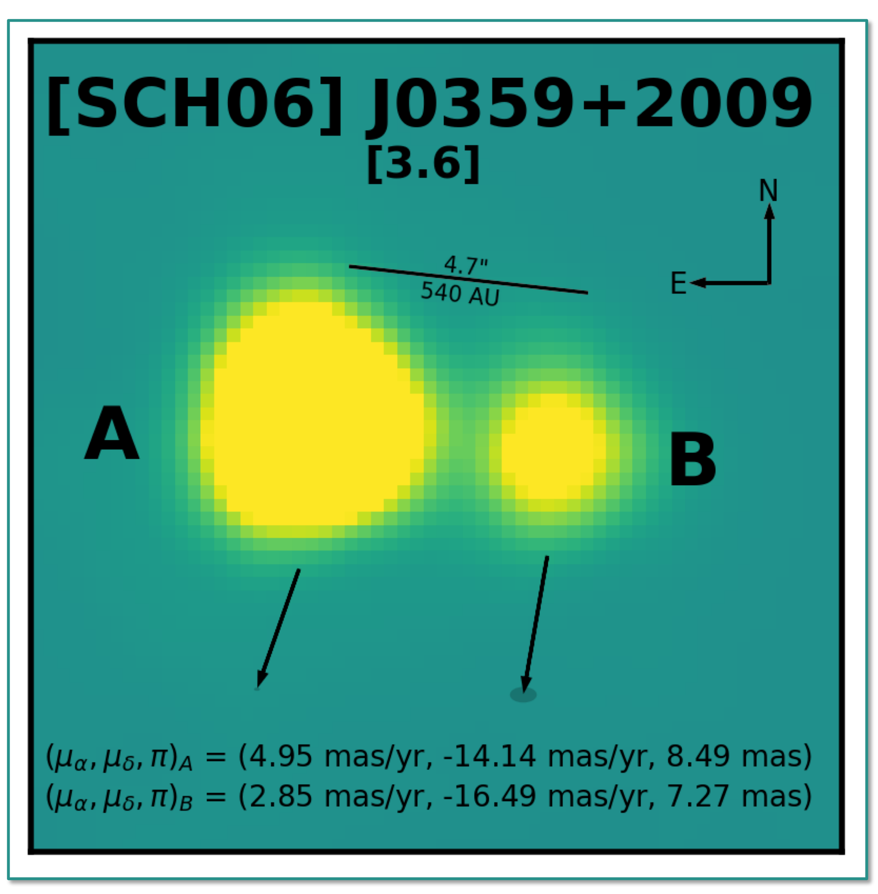


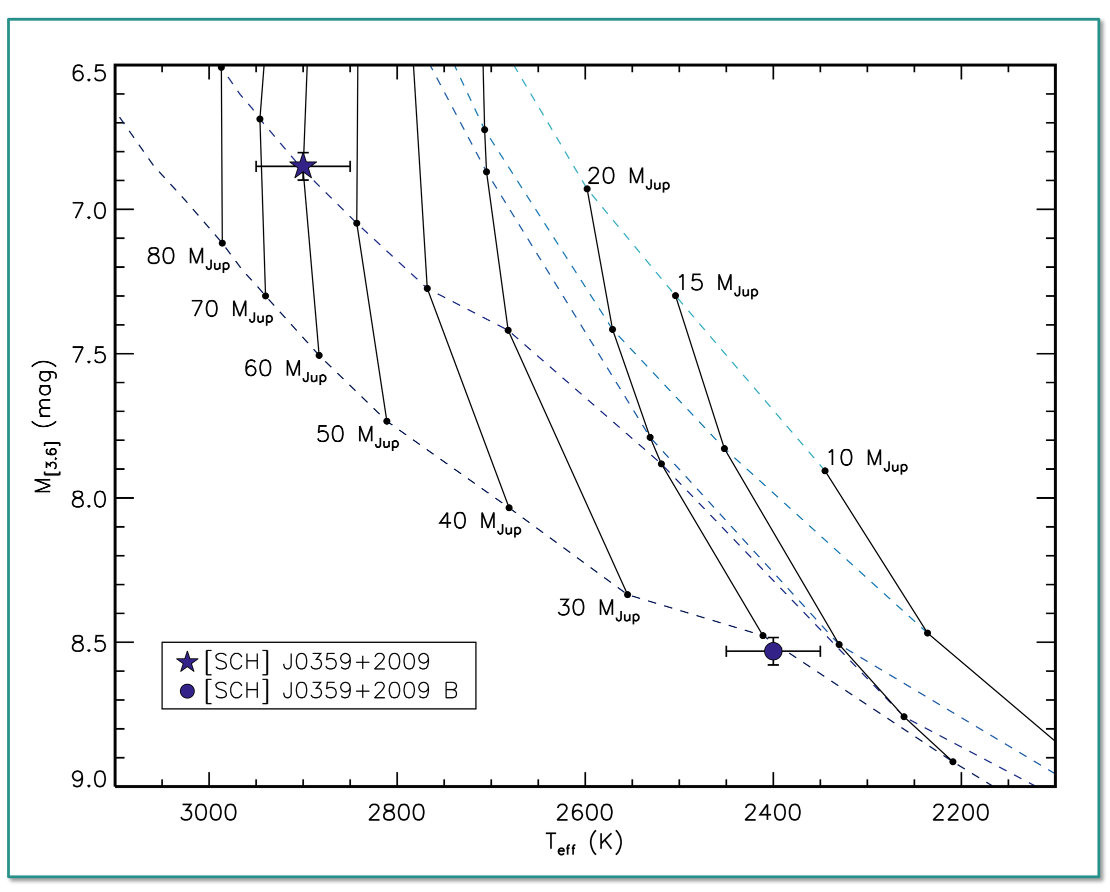
Left: Color-magnitude diagram for our 11 target systems known to have faint, low-mass companions and Upper Scorpius members with IRAC [3.6] and [8.0] measurements. The primary components of the target sample members are indicated as stars while confirmed companions are indicated as filled circles. Three sample primaries and five secondaries have [3.6]-[8.0] colors indicative of a circumstellar or circum(sub)stellar disks.



Above: Contrast limits for the stacked IRAC Channel 1 (left) and Channel 4 (right) images of our target sample. The top panel shows the contrast curves prior to PSF subtraction as a function of projected separation from the primary star in arcseconds. The bottom panel shows the corresponding contrast curve once the primary PSF has been subtracted.

A New Wide Companion Near the Planet-Brown Dwarf Boundary





IRAC Ch 1 (left) and H-R diagram (right) for [SCH06] J0359+2009 and its 4.7" (540 au) companion. For both components, the temperatures are estimated from SED fits. The H-R diagram positions are nominally consistent with isochronal ages of 10-20 Myr. The position of the primary indicates a mass of 60 ± 10 M_{Jup} while the position of the companion indicates a mass of 20 ± 5 M_{Jup}. **Given the component masses and projected separation, this system appears to be an older analog of ultrawide brown dwarf pairs like FU Tau (Luhman et al. 2009).**

Learn More!

Martinez & Kraus 2019, AJ, in press

arXiv:1907.06767

Future Work

- Pipeline will enable a systematic exploration of the demographics and properties (e.g., companion mass functions, semi-major axis distributions, disk frequencies) of wide-orbit, low-mass companions systems for samples of discrete stars
- In the process of measuring the mid-IR photometry of directly-imaged substellar companions such as DH Tau, CHXR 73, SR 12, and AB Pic with existing *Spitzer*/IRAC data.
- Observational follow-up of known and candidate wide companions is being performed. We have obtained optical spectroscopy of FW Tau C, DH Tau b, and [SCH06] J0359+2009 B with the Hobby-Eberly Telescope 2nd generation low resolution spectrograph. We have also been awarded 1.5 hr on Gemini-N/GNIRS to obtain a near-infrared spectrum of the [SCH06] J0359+2009 system.