

Searching for Wide Companions and Identifying Circum(sub)stellar Disks through PSF-fitting of Spitzer/IRAC Archival Data

Raquel Martinez, UT Austin

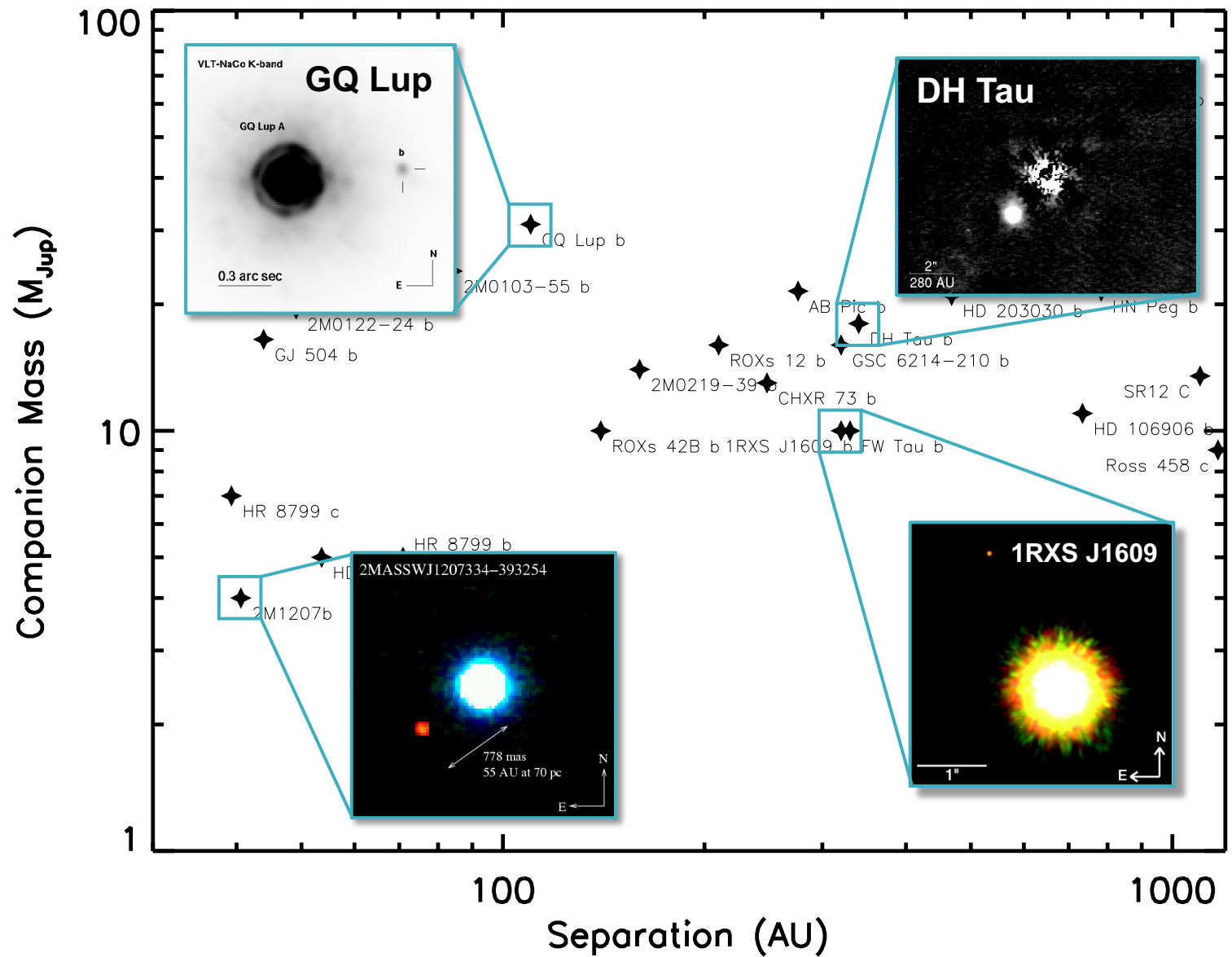
NASA Earth & Space Science Fellow

BDEXOCON III

October 22, 2019

Outline


- **Wide-Orbit Low Mass Companion Formation Scenarios**
- **Building the Wide Companion Population**
- **Pilot Study: Results and a New Wide Companion at the Planet-Brown Dwarf Boundary**
- **Future Directions & Summary**



Fragmentation of Collapsing Molecular Cloud

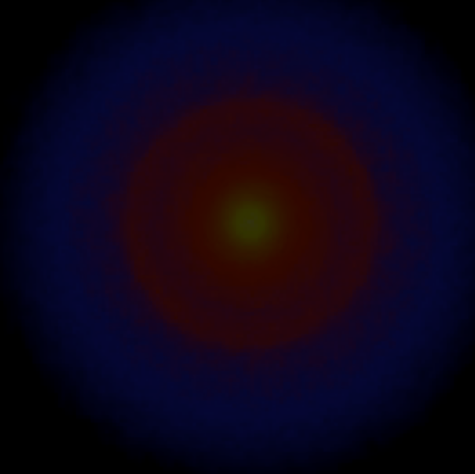
UK Astrophysical
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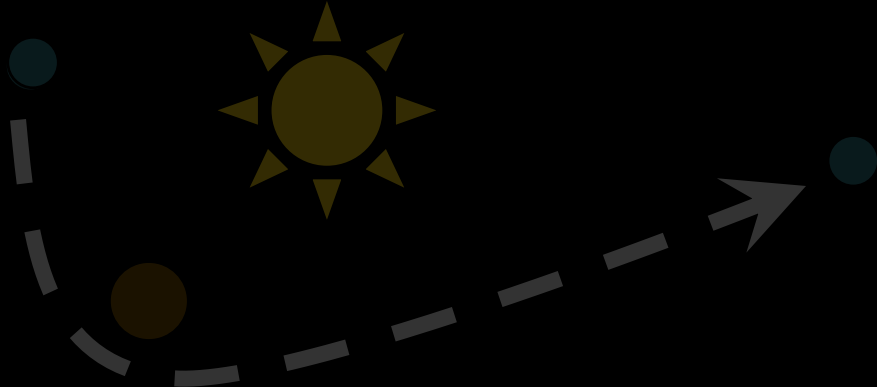
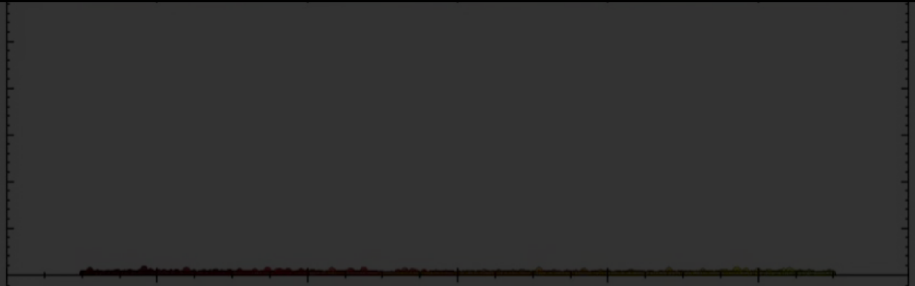
Matthew Bate 

Core Accretion

Gravitational Instability in Disks

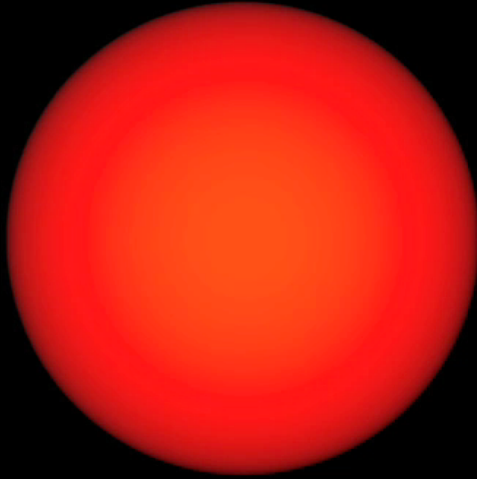


Dynamical Processes



Fragmentation of Collapsing Molecular Cloud

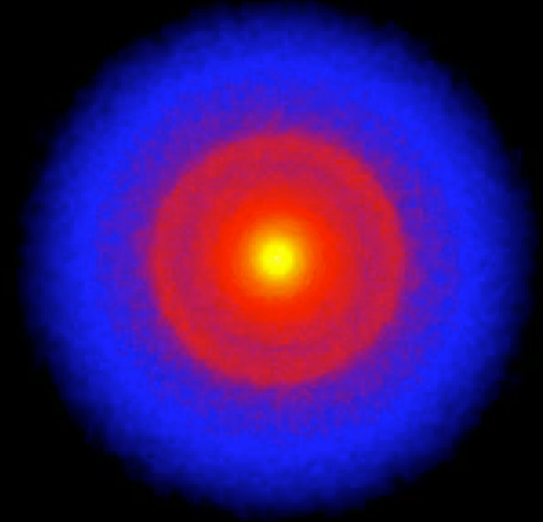
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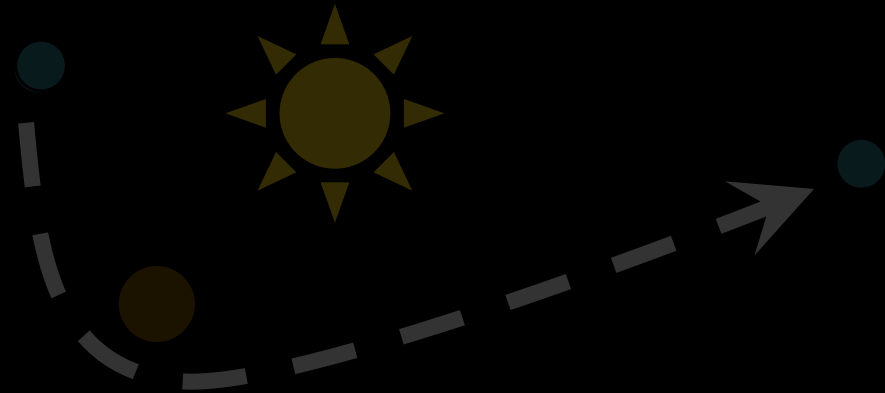
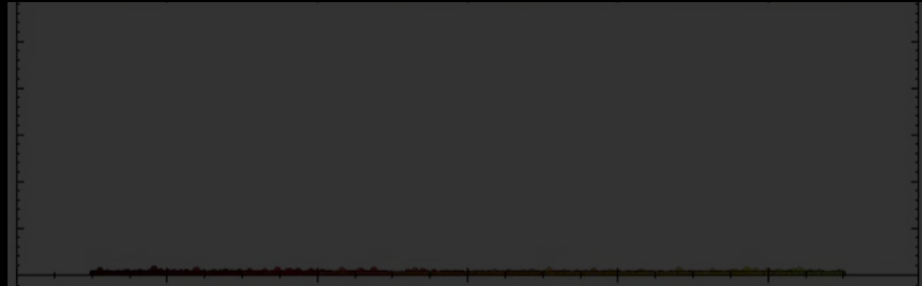
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Core Accretion

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Dynamical Processes



Fragmentation of Collapsing Molecular Cloud

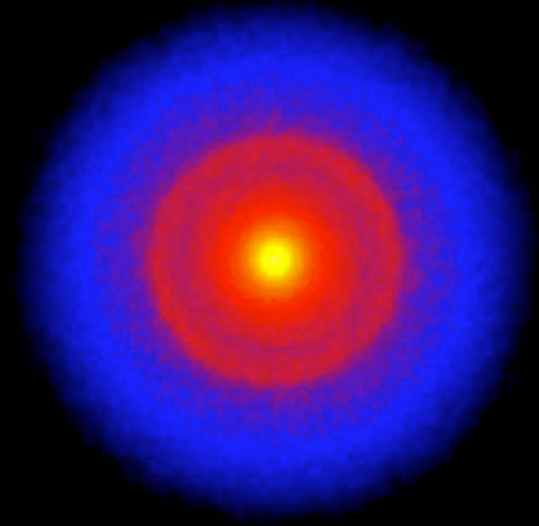
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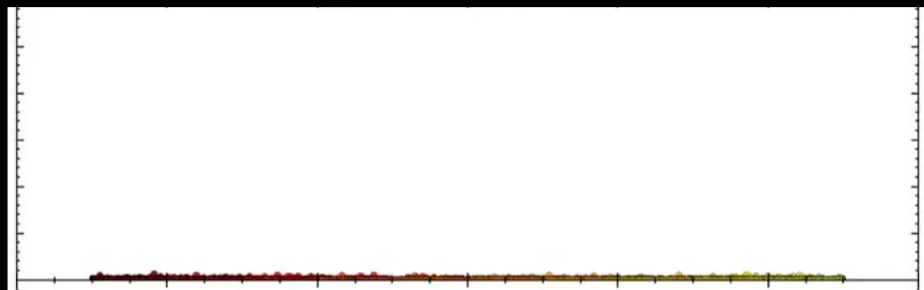
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Core Accretion

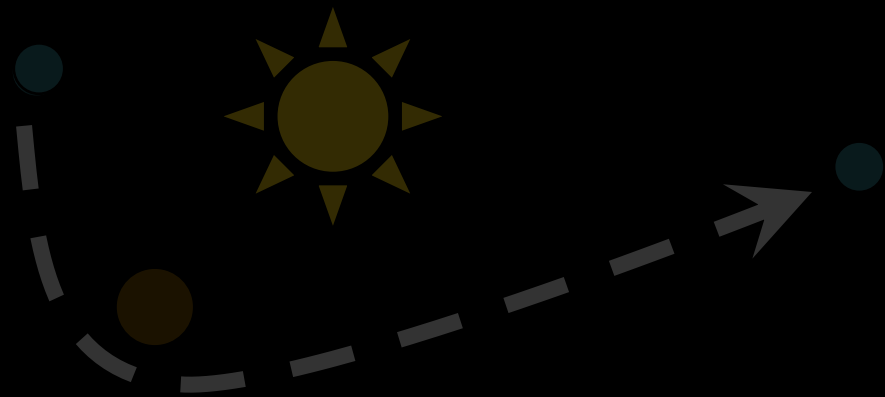
Gravitational Instability in Disks



Dynamical Processes



Radial Distance from Star 



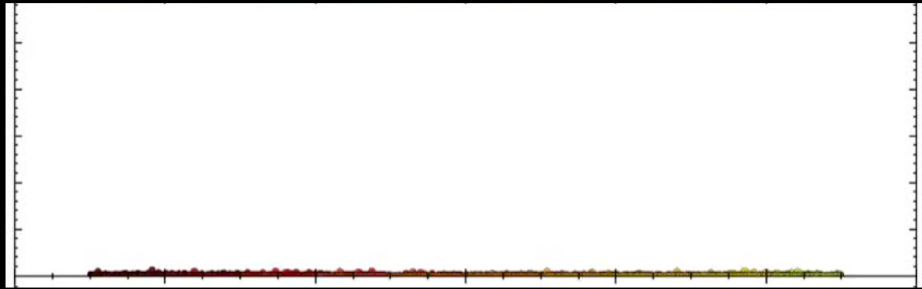
Fragmentation of Collapsing Molecular Cloud

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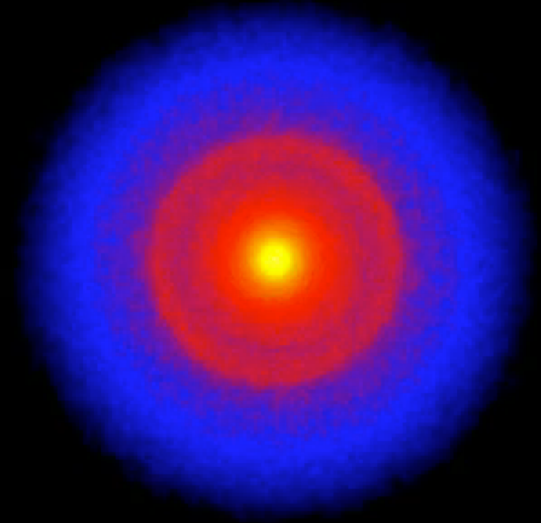


Matthew Bate 

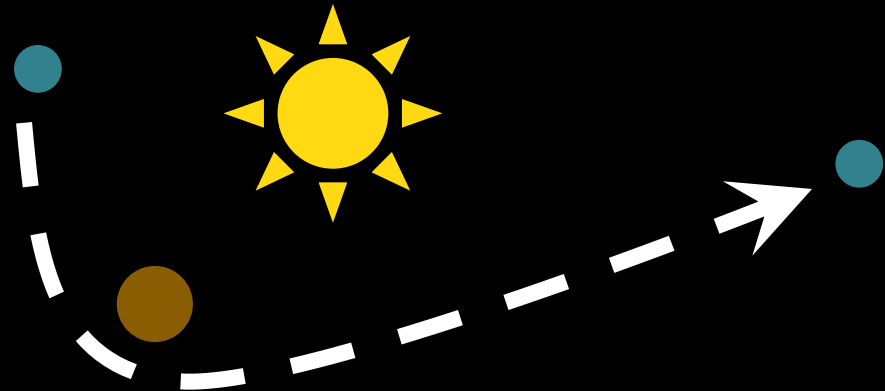
Core Accretion



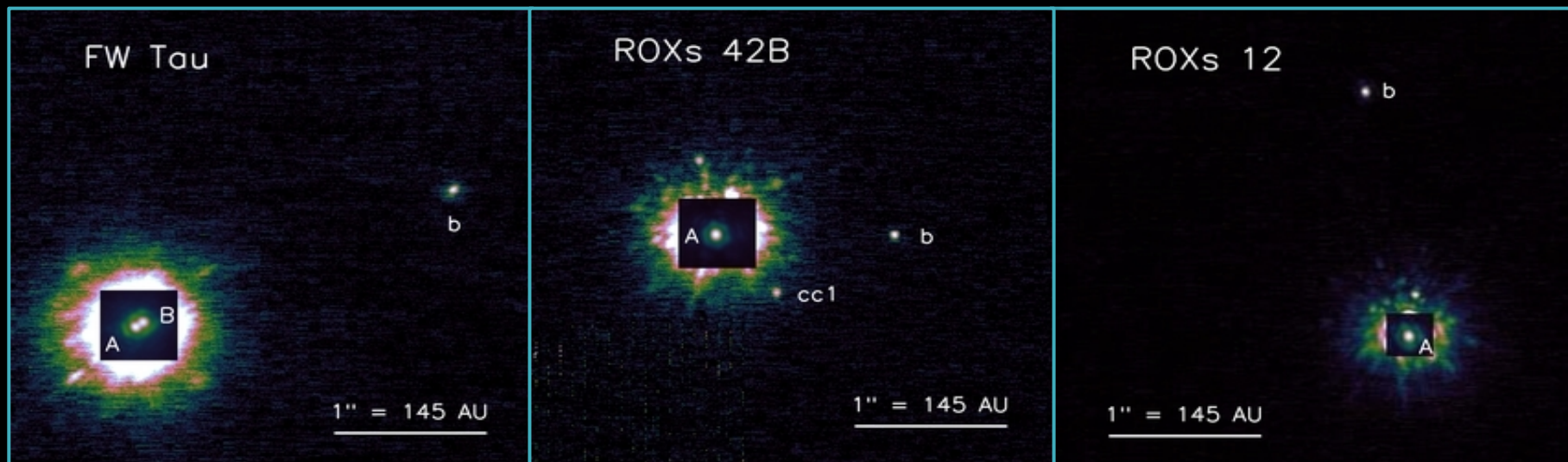
Gravitational Instability in Disks



Dynamical Processes



Wide-orbit low mass companions represent low-mass extreme of stellar binary model and high-mass and wide separation extreme of planet formation theories



Kraus et al. 2014

The demographics and properties of wide companions will constrain the extreme limit of their formation mechanism

Building the Wide Companion Sample

- Star-forming Regions

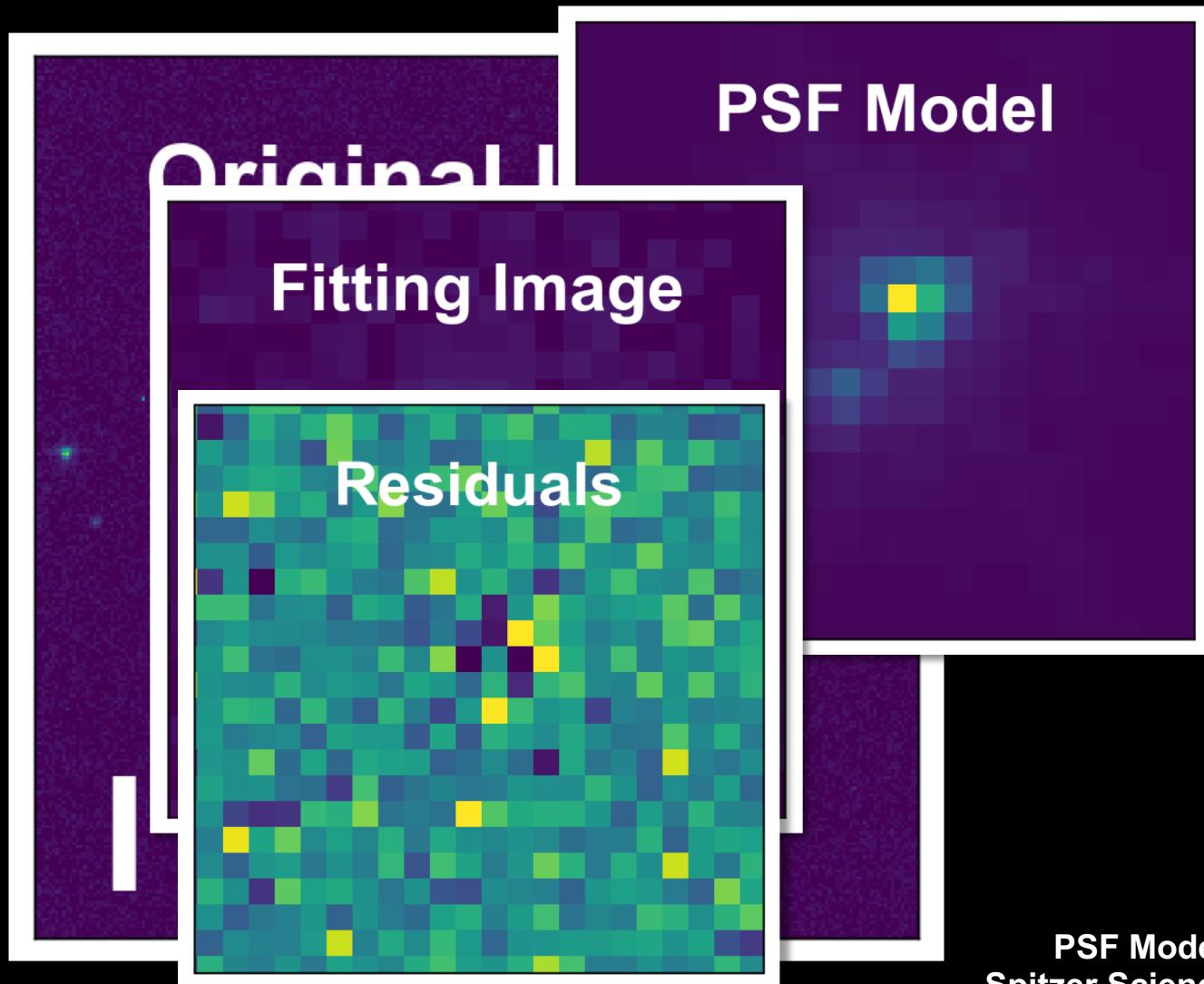


- Automation



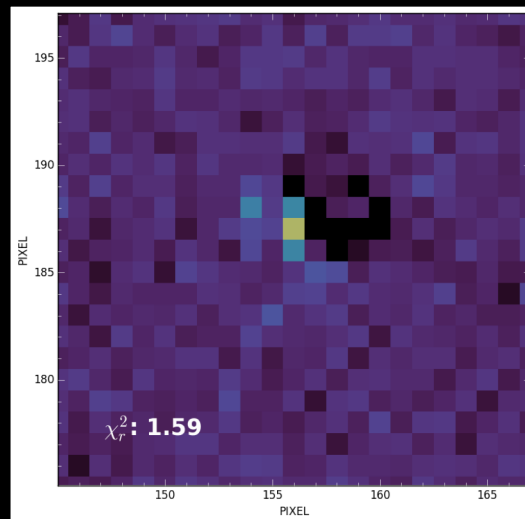
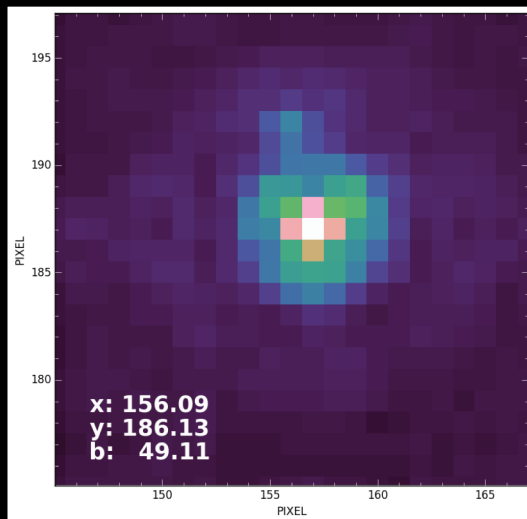
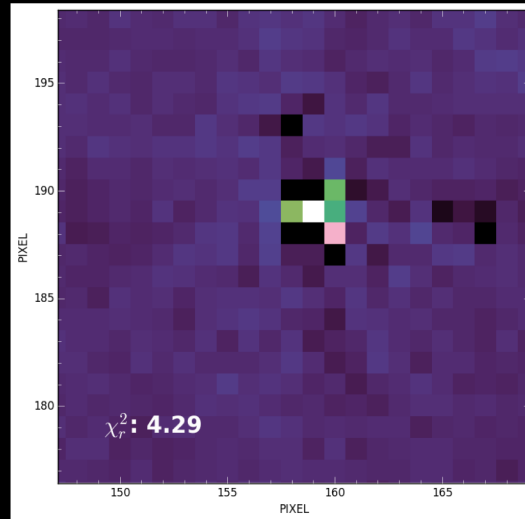
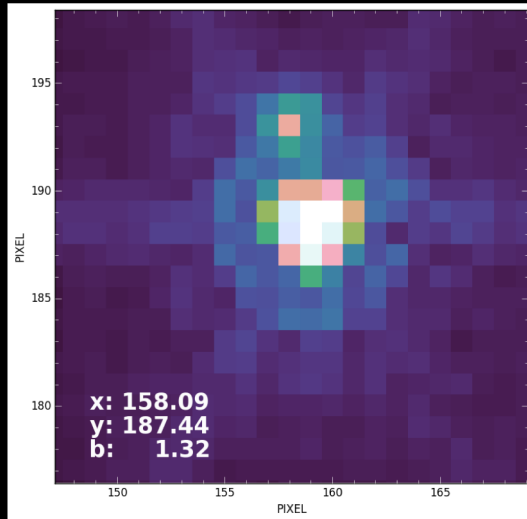
Rogelio Bernal Andreo

Example Pipeline Flow



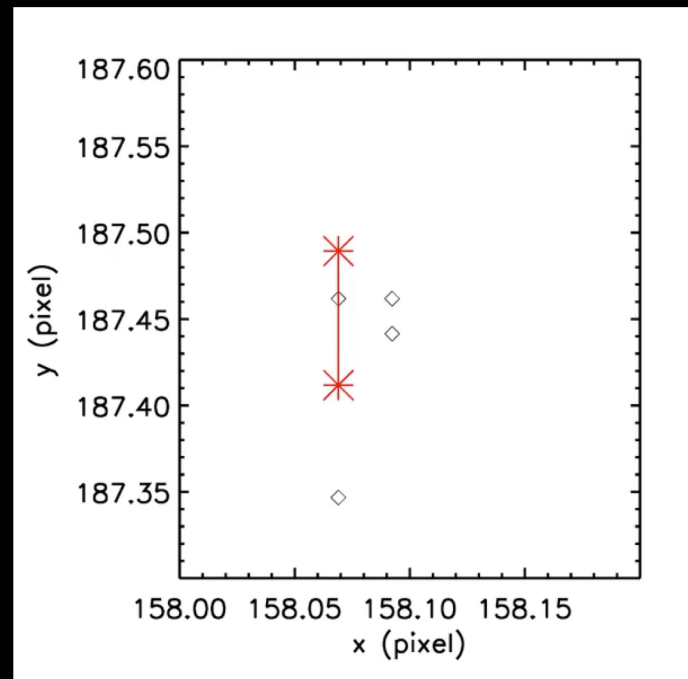
PSF Models from
Spitzer Science Team
described in Hoffman 05

Image-Specific MCMC Fit



Model Parameters:

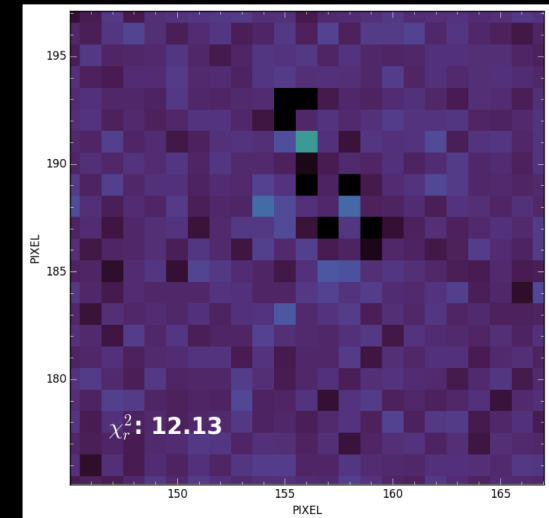
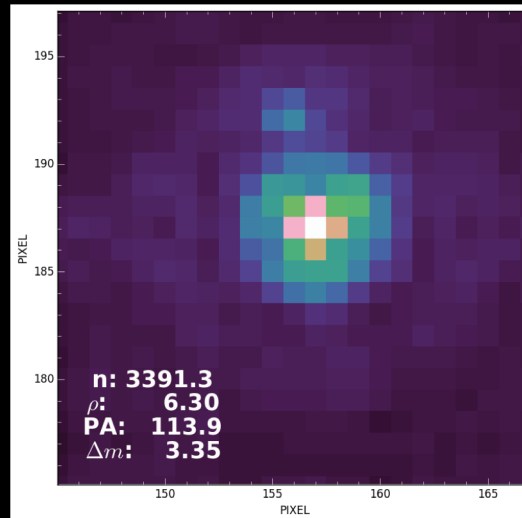
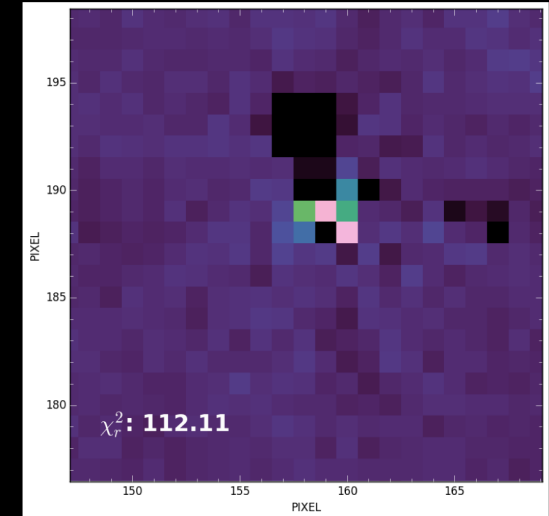
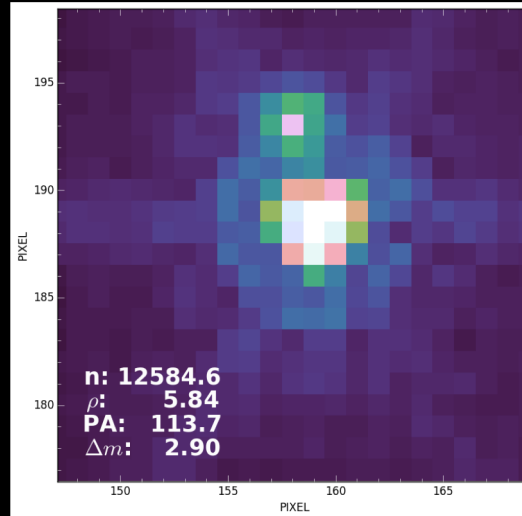
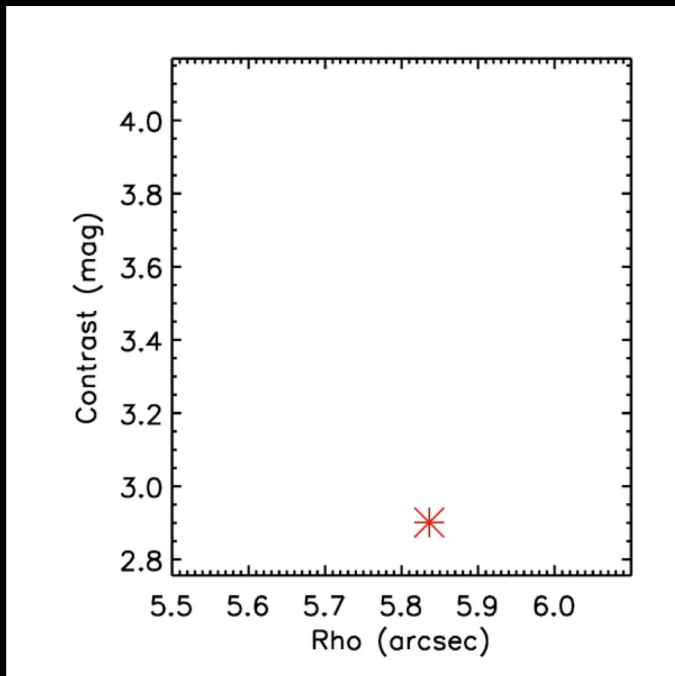
- x-pixel position (x)
- y-pixel position (y)
- Background (b)



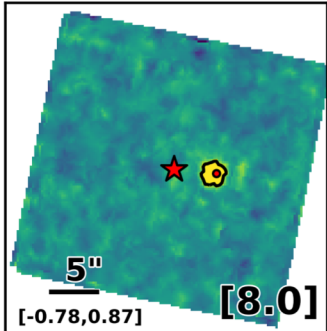
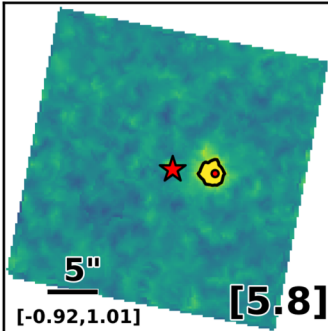
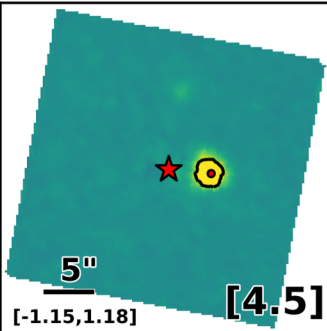
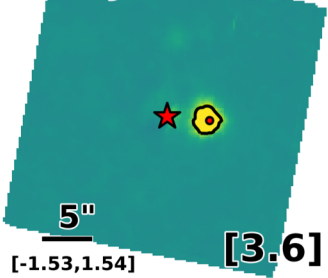
System-Specific MCMC Fit

Model Parameters:

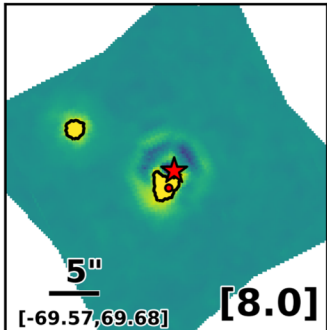
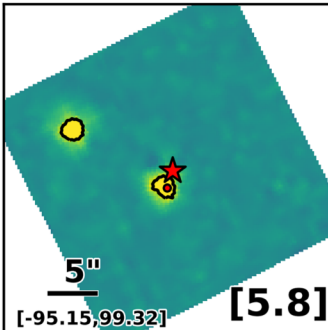
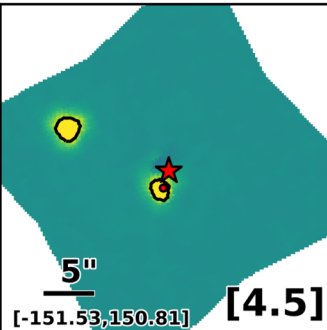
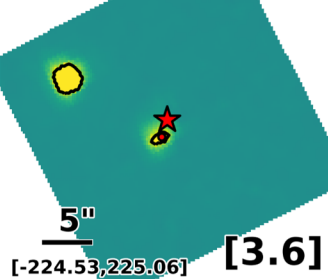
- Primary Flux (n)
- Projected separation (ρ)
- Position Angle (P.A.)
- Contrast (Δm)



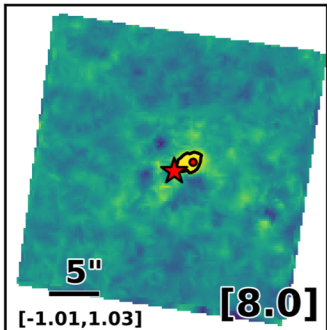
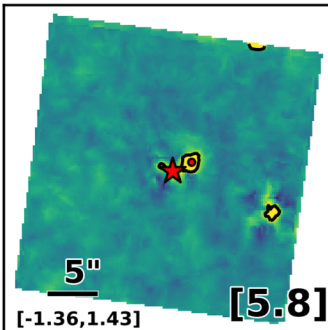
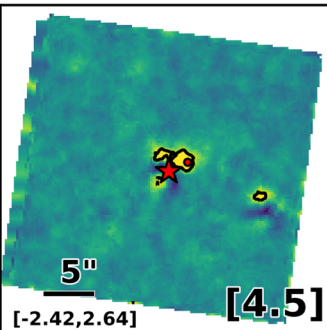
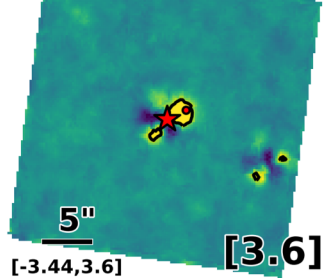
[SCH]0359+2009



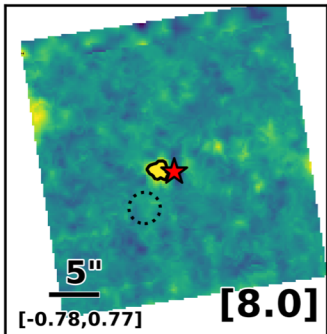
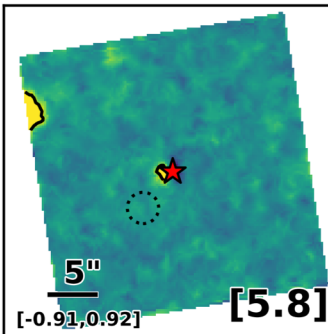
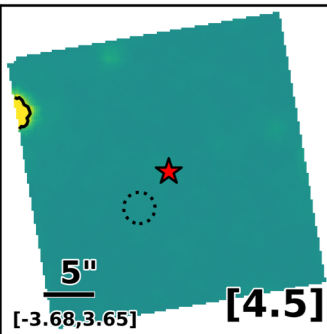
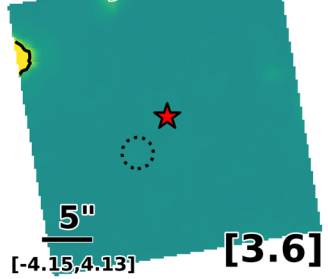
Sz 41



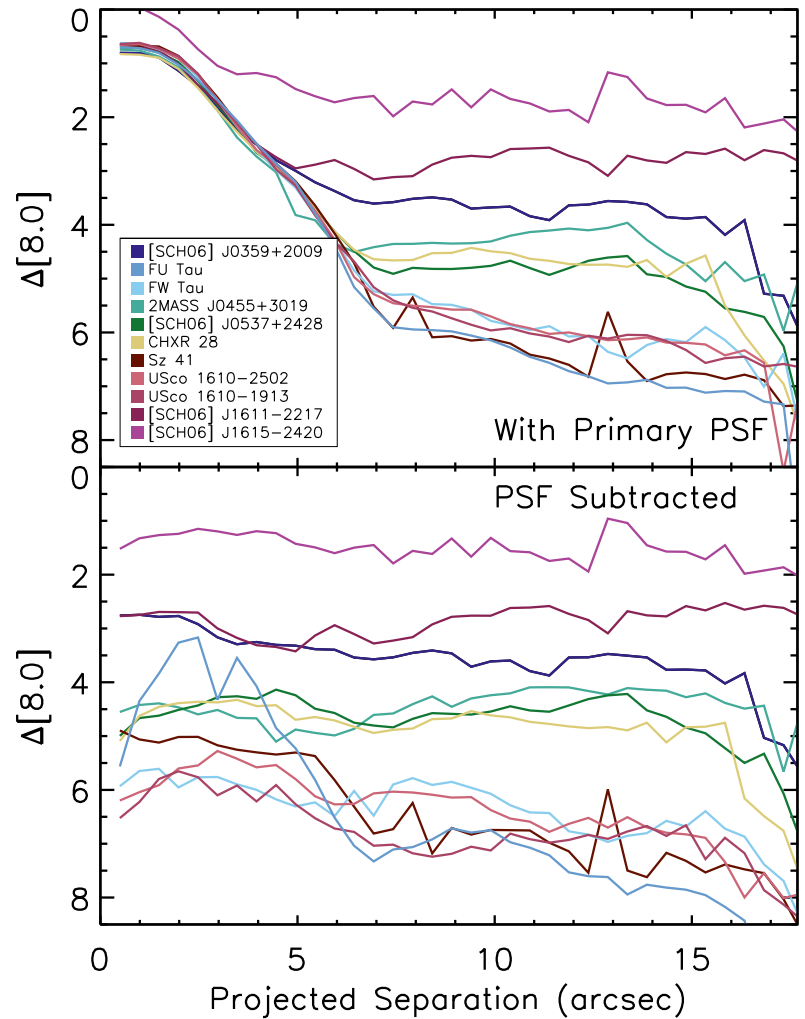
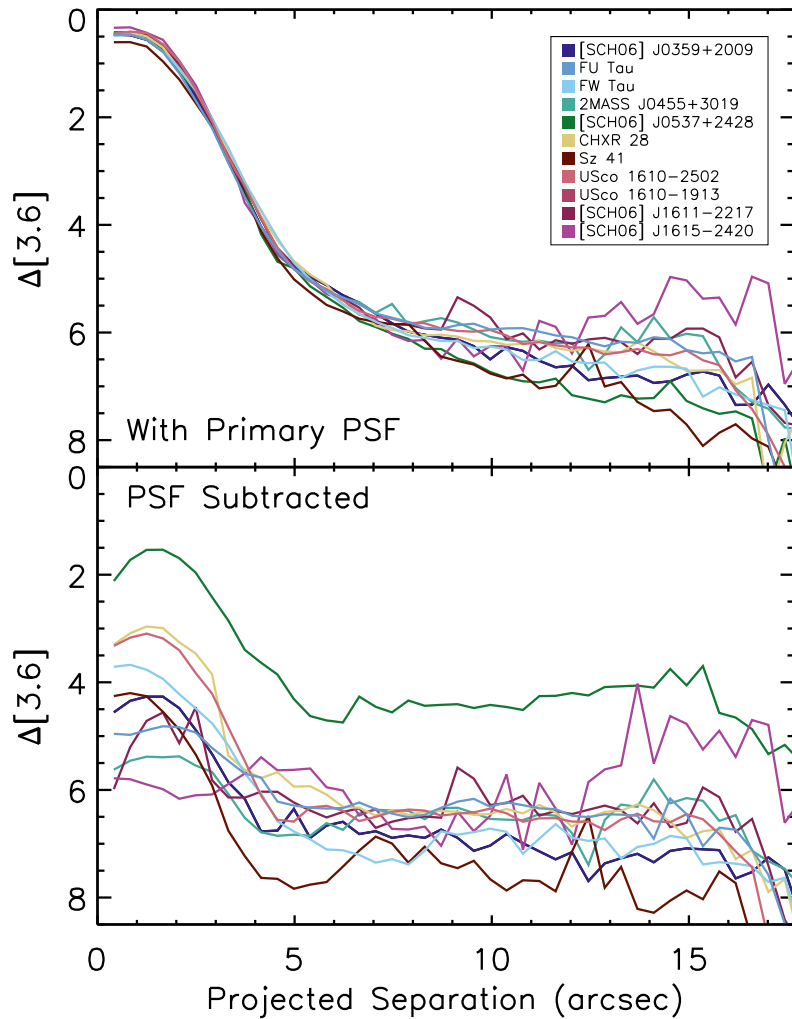
FW Tau



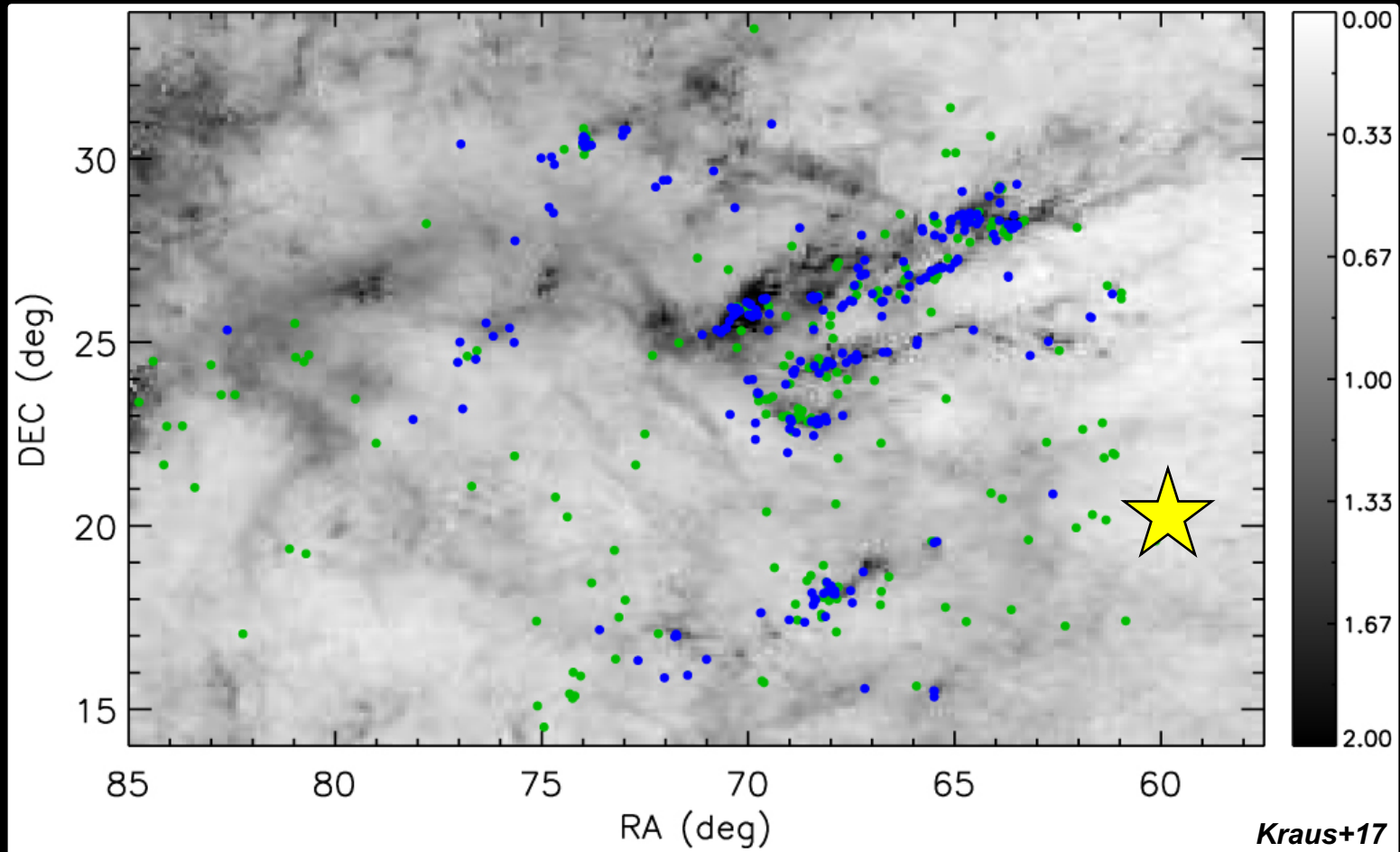
[SCH]1615-2420



Detection Limits

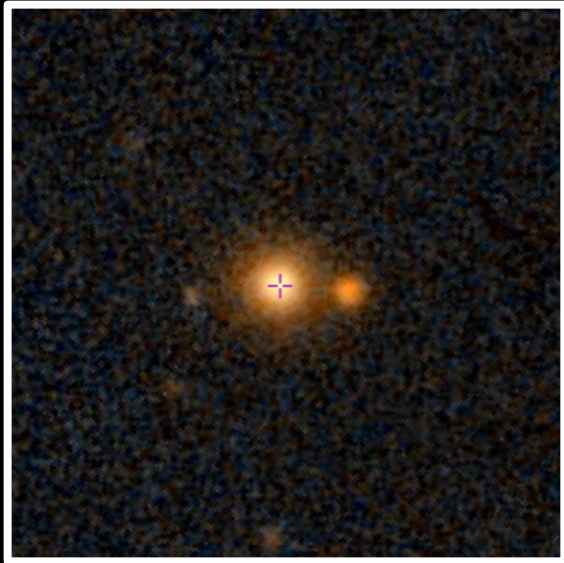


[SCH06] J0359+2009



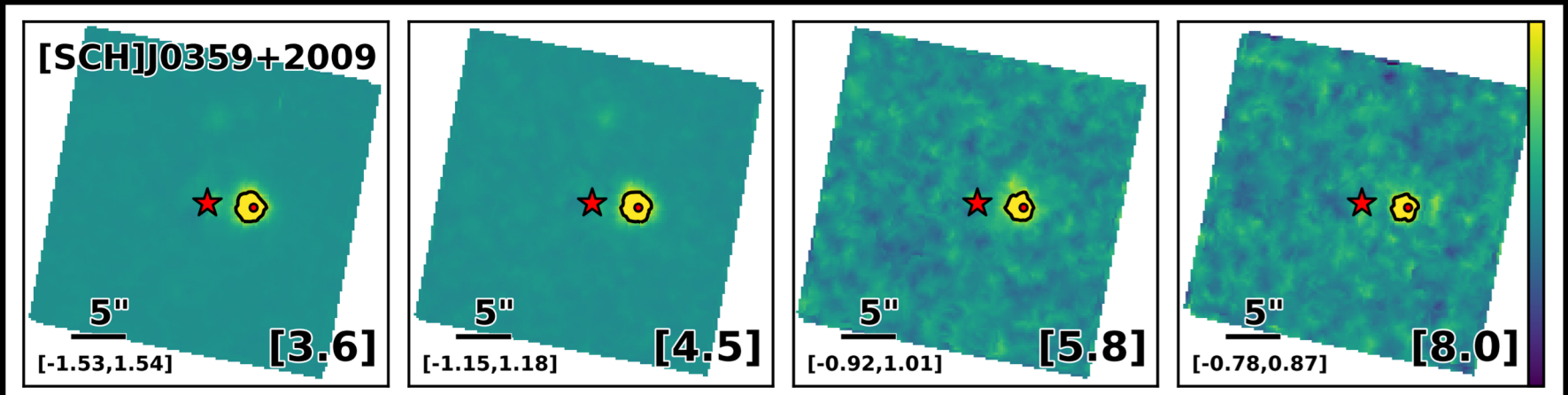
Member of older, distributed Taurus population (Slesnick+06)

[SCH06] J0359+2009

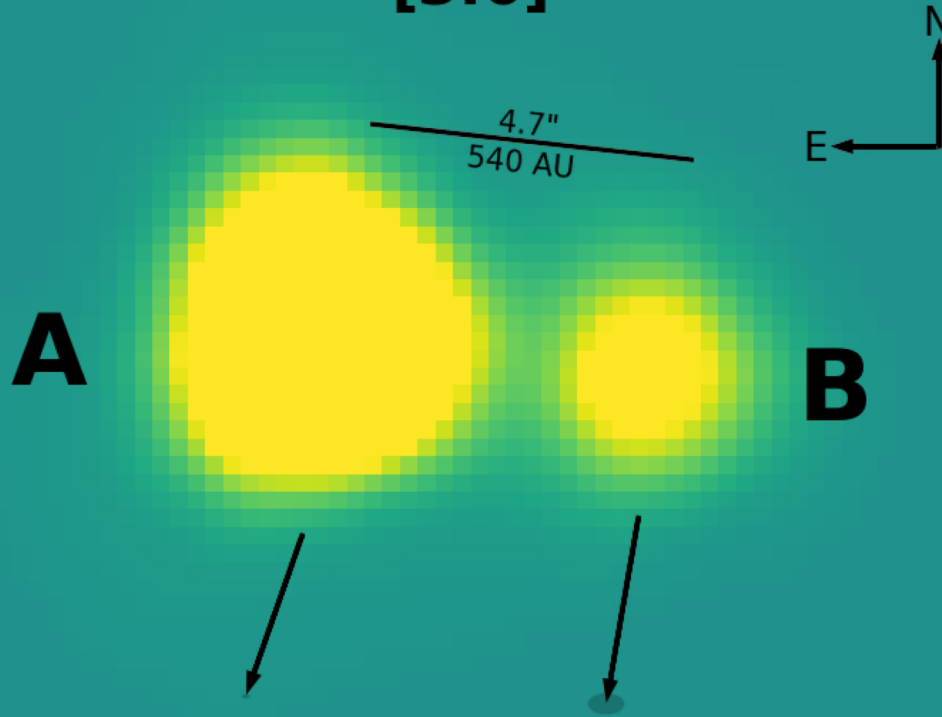


PS1

- Candidate companions at 4.66" and 5.95" (Kraus & Hillenbrand 2012)
- Inner companion detected with $[3.6]-[8.0] = 0.96 \pm 0.05$ mag
- Outer candidate companion not detected

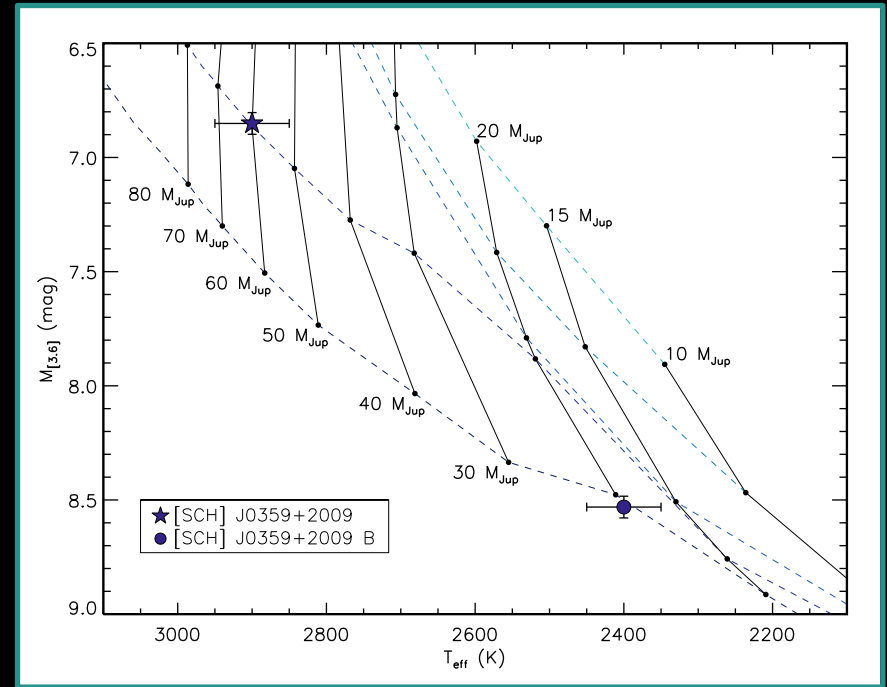
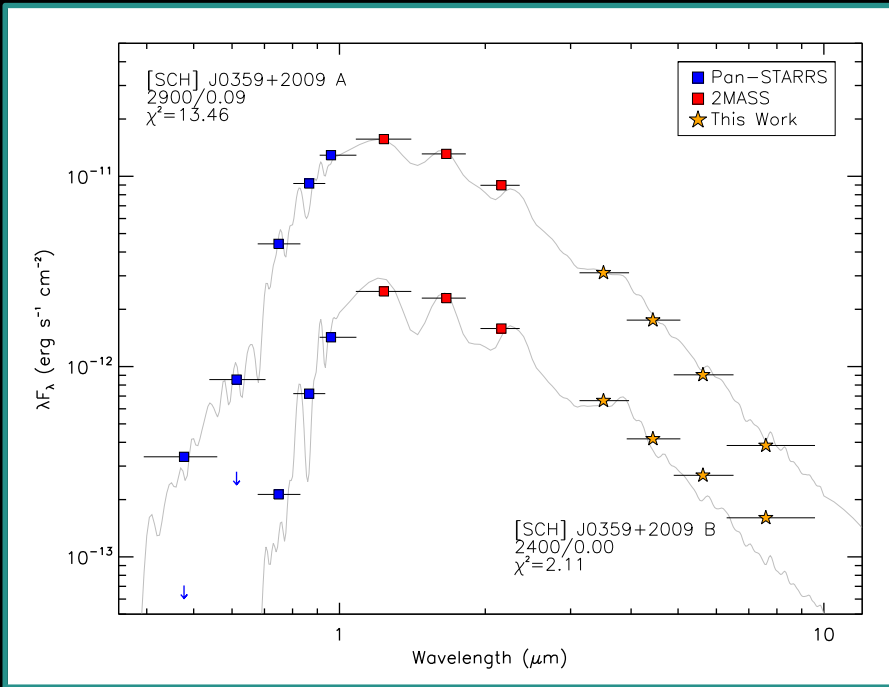


[SCH06] J0359+2009 [3.6]



$(\mu_\alpha, \mu_\delta, \pi)_A = (4.95 \text{ mas/yr}, -14.14 \text{ mas/yr}, 8.49 \text{ mas})$
 $(\mu_\alpha, \mu_\delta, \pi)_B = (2.85 \text{ mas/yr}, -16.49 \text{ mas/yr}, 7.27 \text{ mas})$

**Gaia DR2 parallax and proper motion measurements
consistent with Taurus membership**

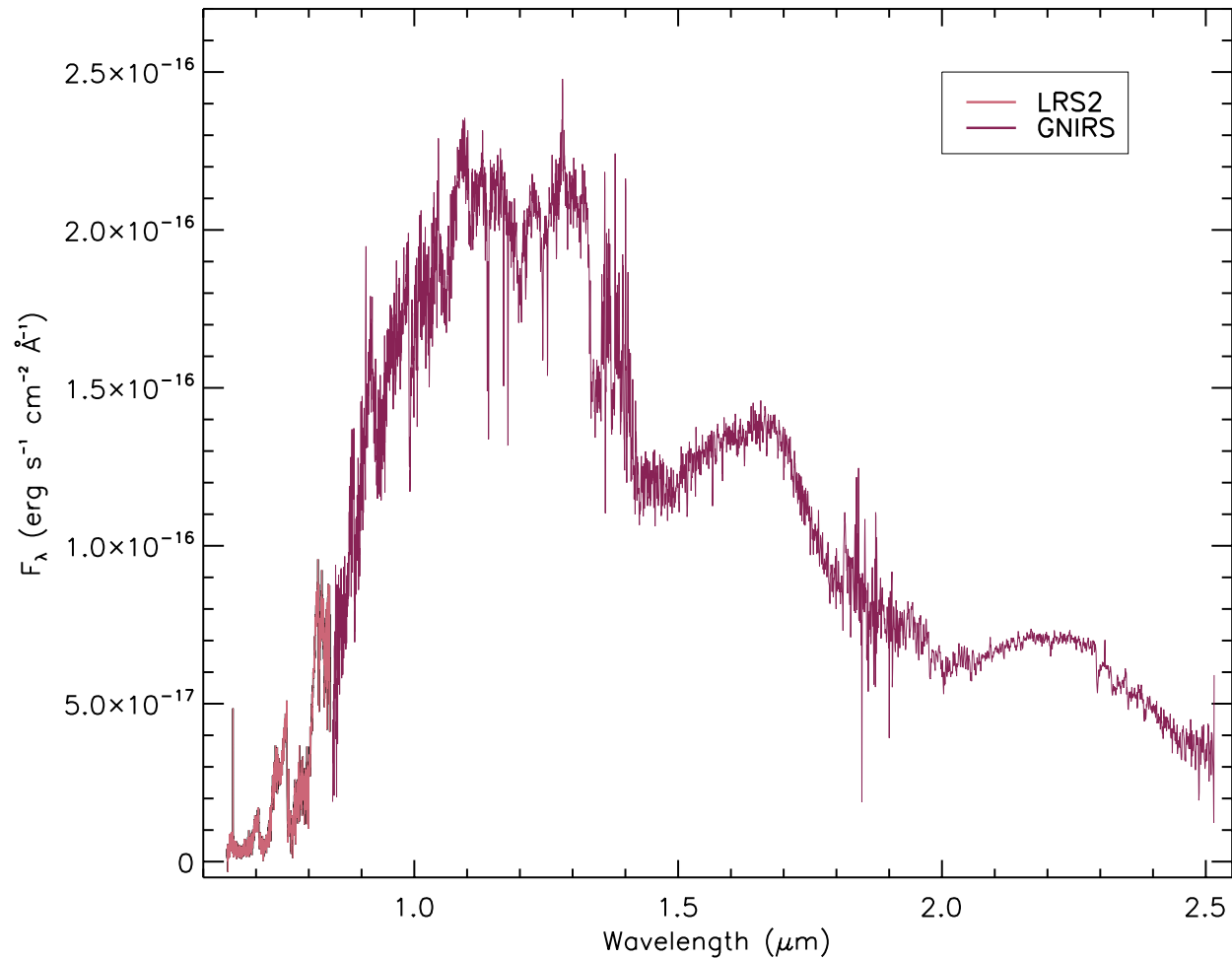


Martinez & Kraus (2019)

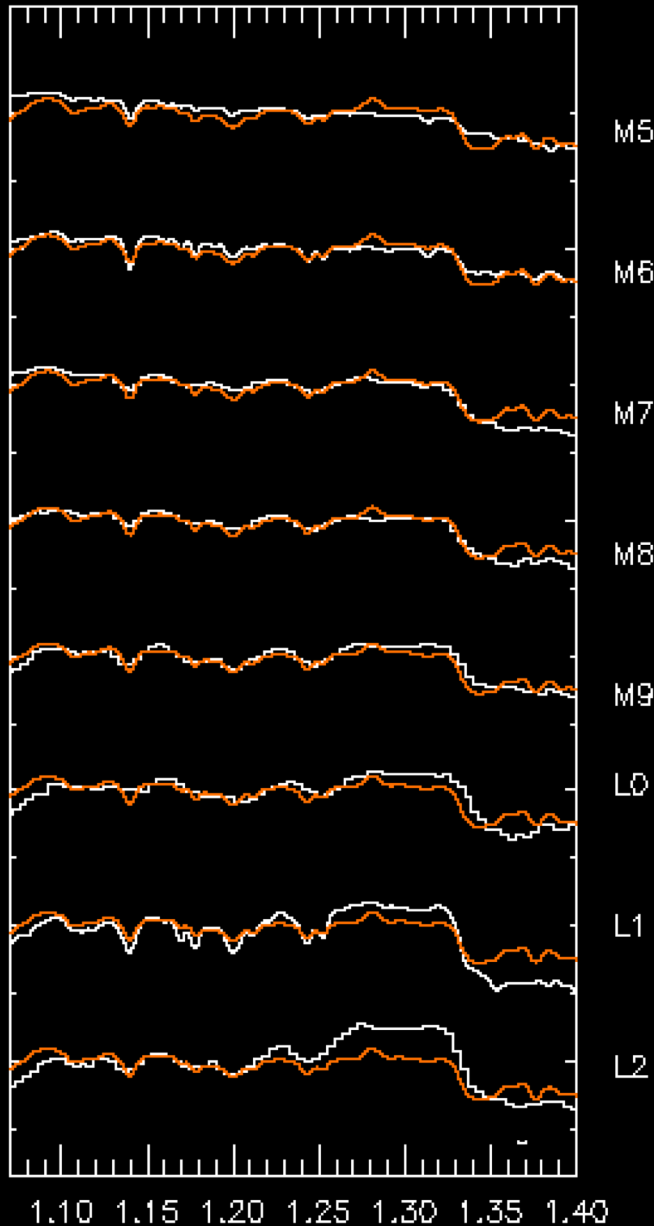
[SCH06] J0359+2009 A: $M = 60 \pm 10 M_{\text{Jup}}$

[SCH06] J0359+2009 B: $M = 20 \pm 5 M_{\text{Jup}}$

Spectroscopic Follow-Up: HET/LRS2 and GN-GNIRS

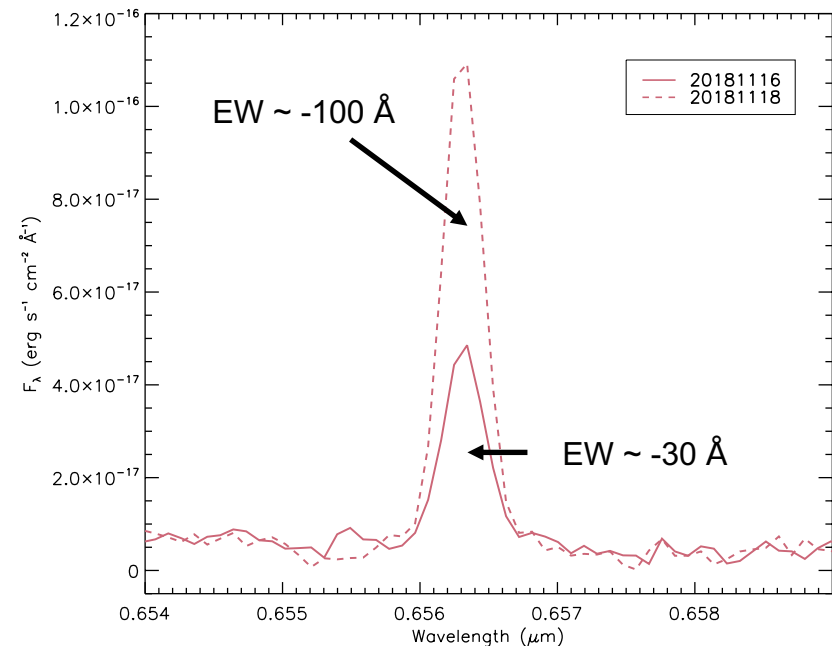


J-band visual classification



Allers & Liu (2013)
NIR Classification
Sp Ty: M9 ± 1
Gravity: Intermediate

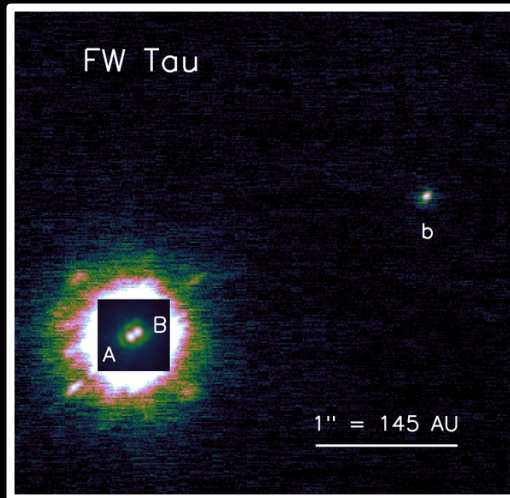
H α variability



Summary

- **Wide-orbit companions challenge both star and planet formation scenarios**
- **Developed pipeline to search for more of these systems**
- **Identifying candidate systems for ground-based and future space-based follow-up**
- **Stage is set to embark on systematic search for wide companions in archival *Spitzer* images**

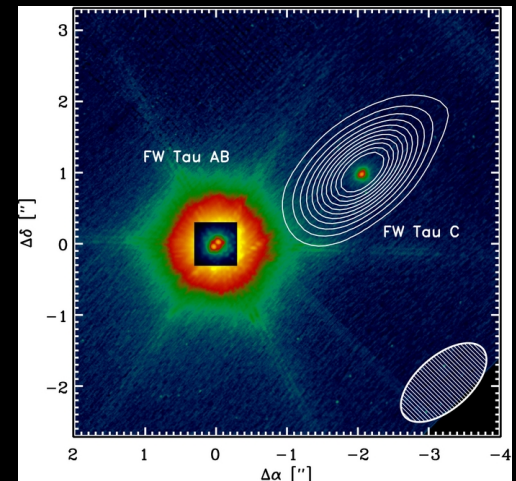
The FW Tau System



Kraus et al. 2014

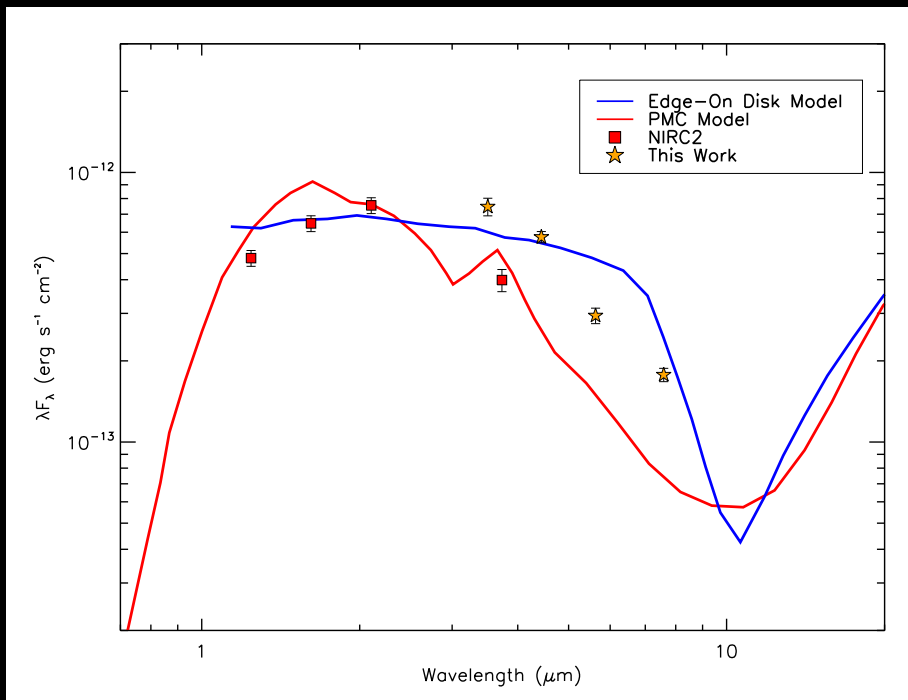
- **Primary is close binary**
- **Companion confirmed to be co-moving**
- **Near-infrared luminosity suggests companion mass $\sim 10 M_{\text{Jup}}$**

- **Radio observations detected emission only associated with companion**
- **Estimated dust mass of $1-2 M_{\oplus}$**
- **Disk dynamics indicate heavier companion mass $\sim 100 M_{\text{Jup}}$ (Wu & Sheehan 17)**

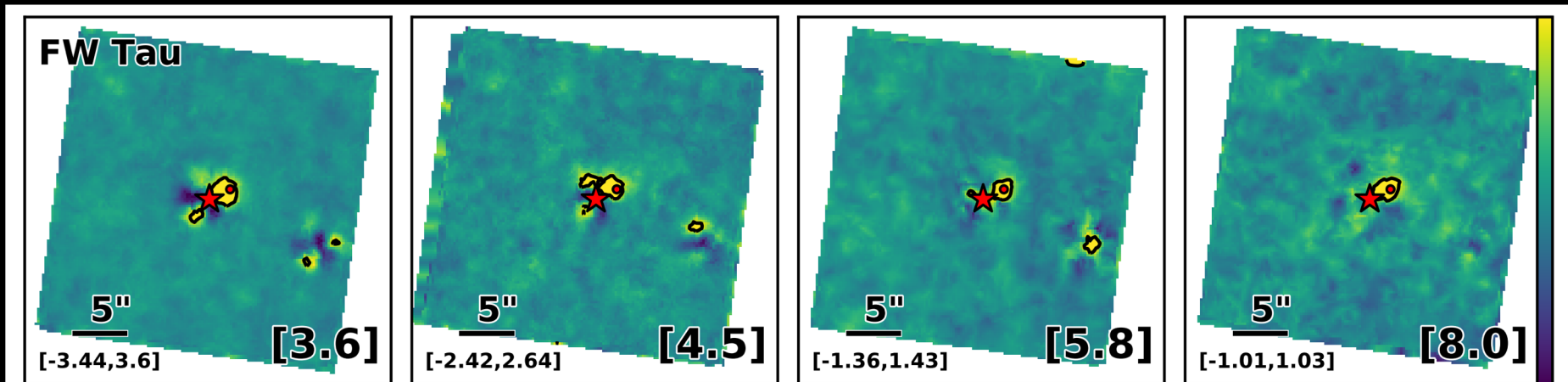


Kraus et al. 2015

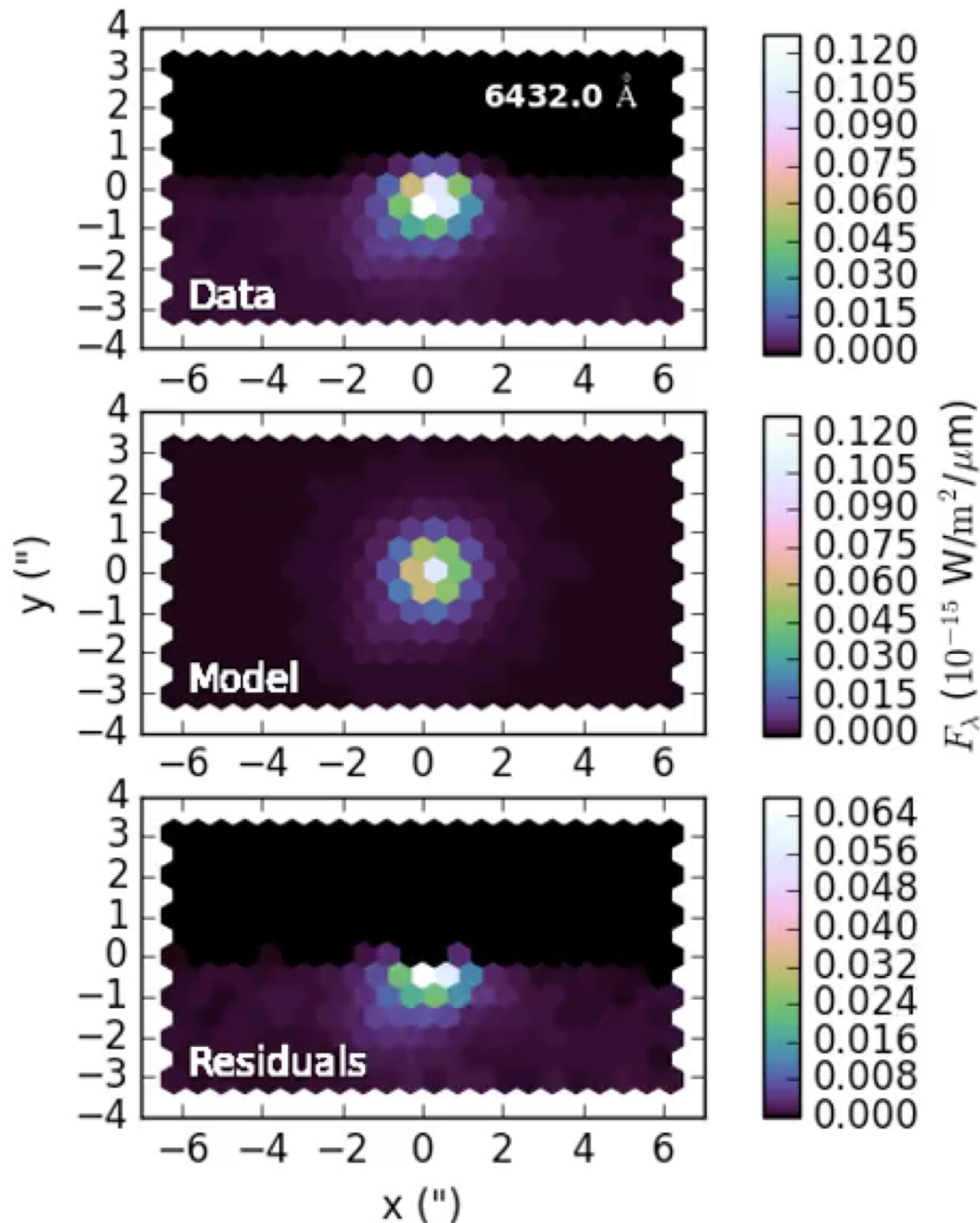
The FW Tau System



- Wide companion resolved; infrared excess confirmed
- Brightness of companion consistent with edge-on disk
- SED shape more coincident with PMC



Spectroscopic Follow-Up: HET/LRS2



- Seeing-limited fiber-fed integral field spectrograph
- 12" X 6" FoV
- Red arm: 6430Å to 10560Å
- Determine optical spectral type of FW Tau's wide companion and measure absolute accretion rates