Synthesizing Accretion and Circumplanetary Disk Properties of a Wide Orbit Planet with HST and JWST

Claire Finley

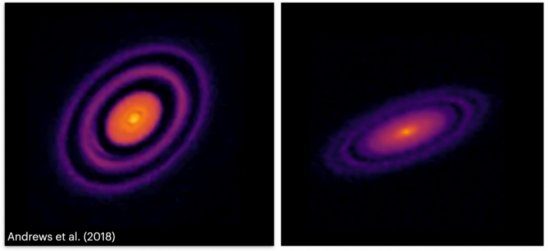
The University of Texas at Austin, University of California Santa Barbara

Collaborators: **Brendan Bowler,** Ya-Lin Wu, Yuhiko Aoyama, William Best, Ian Czekala, Catherine Espaillat, Katherine Follette, Adam Kraus, Raquel Martinez, Connor Robinson, Quang Tran, Kimberley Ward-Duong, Yifan Zhou

Giant planets grow by accreting mass from a circumplanetary disk, regardless of formation history

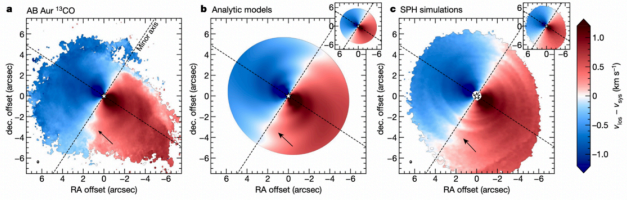
Core accretion

e.g. Pollack et al. (1996), Lambrechts & Johansen (2012)



Gravitational/disk instability

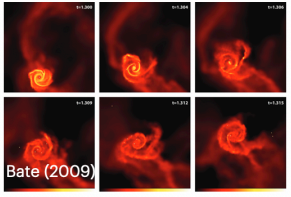
e.g. Boss (1997), Kratter & Lodato (2018)



Speedie et al. (2024)

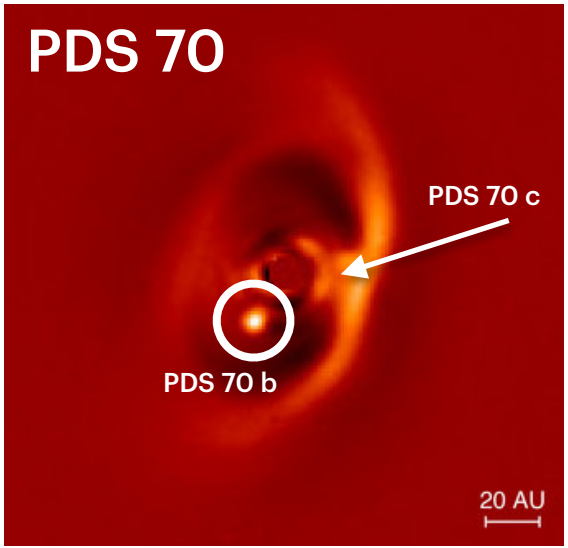
Filament/core fragmentation

e.g. Bate (2009), Offner et al. (2023)

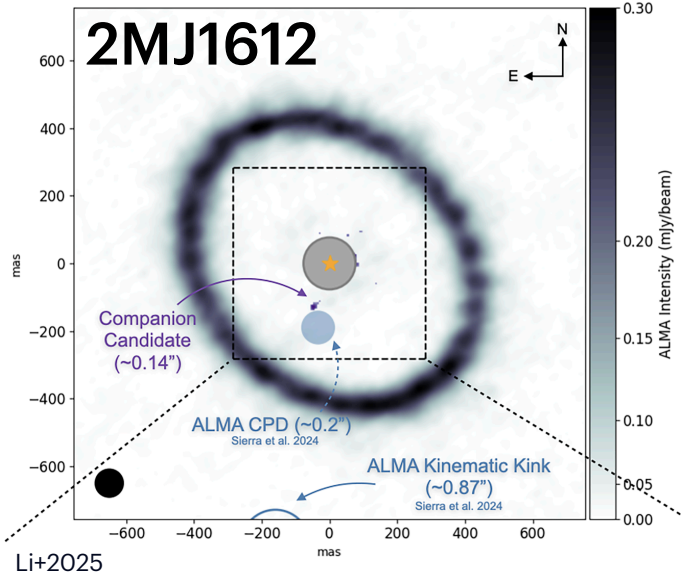


Mass transfer is facilitated by a circumplanetary disk

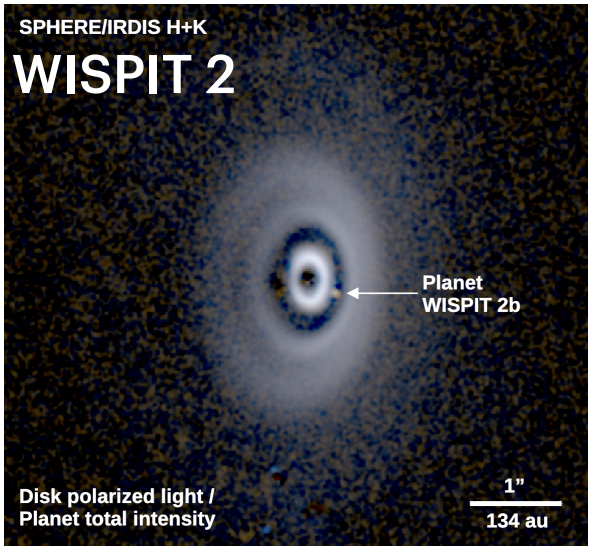
Accreting protoplanets are windows into mass transfer during planet formation



Credit: ESO/A. Müller, MPIA
Keppler+2018, Haffert+2019

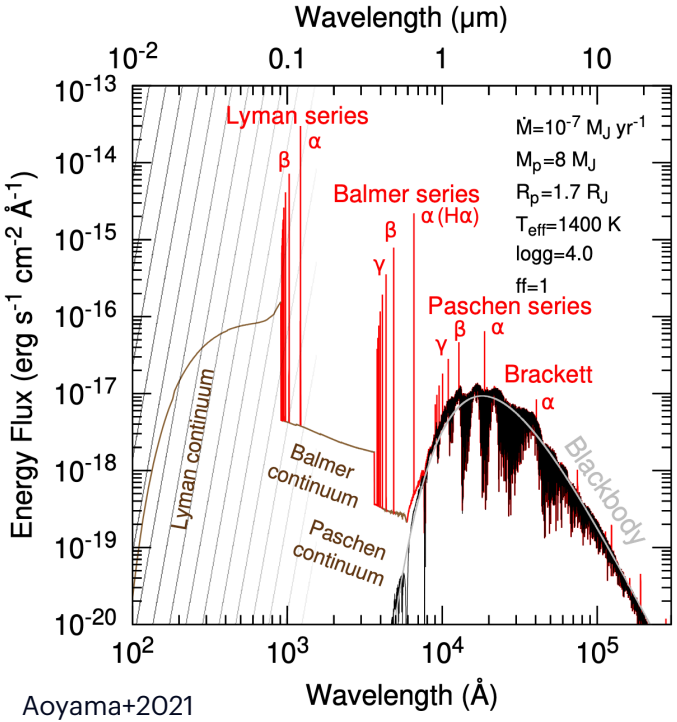


Li+2025

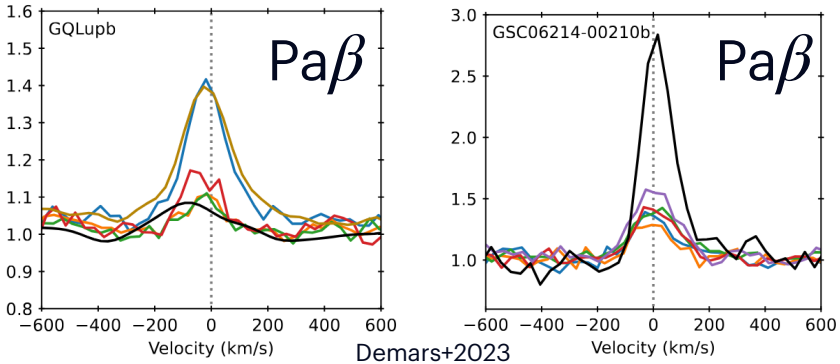


van Capelleveen+2025
Close+2025

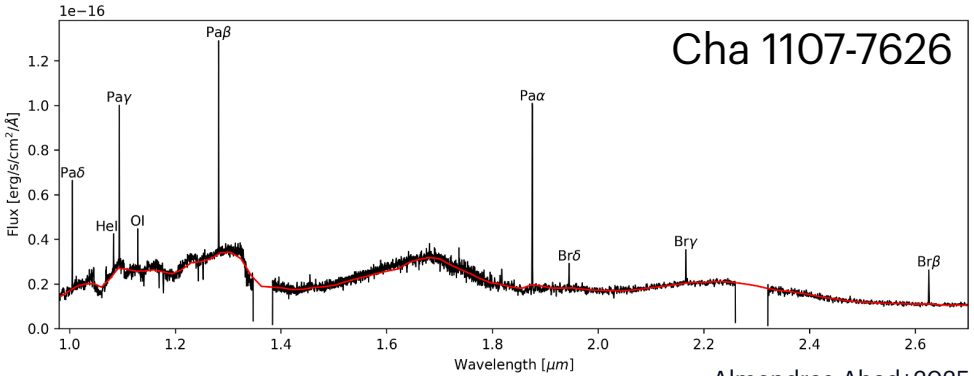
Accretion is traced by UV continuum excess and hydrogen emission lines



Aoyama+2021
(model spectrum)



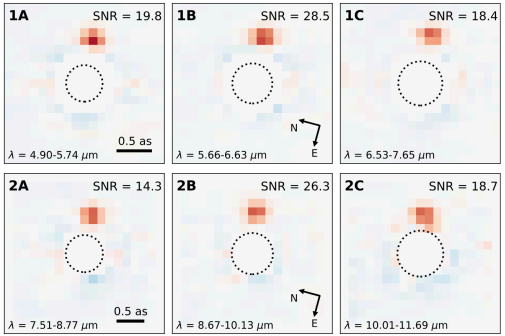
Demars+2023

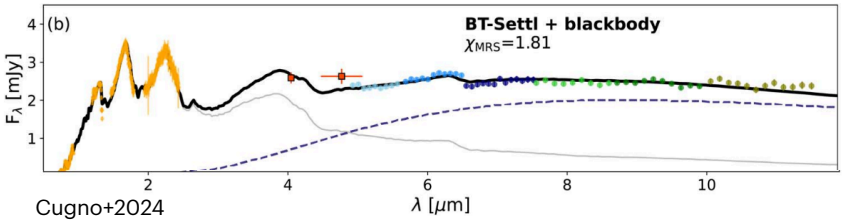


Almendros-Abad+2025

Mid-IR excess offers a way to study warm dust in circumplanetary disks

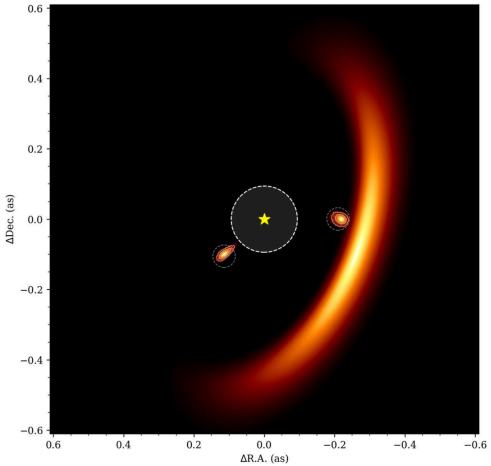
Brown dwarf GQ Lup B

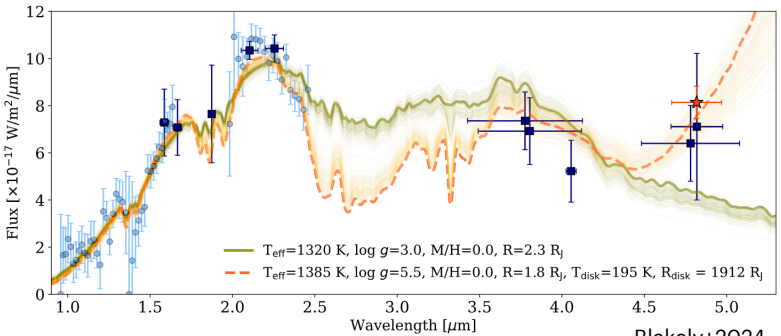




Cugno+2024

Protoplanets PDS 70 b and c





Blakely+2024

SR 12 c is a young, accreting, planetary-mass companion

System properties

Orbital separation: ~1200 AU

Age: ~2 Myr

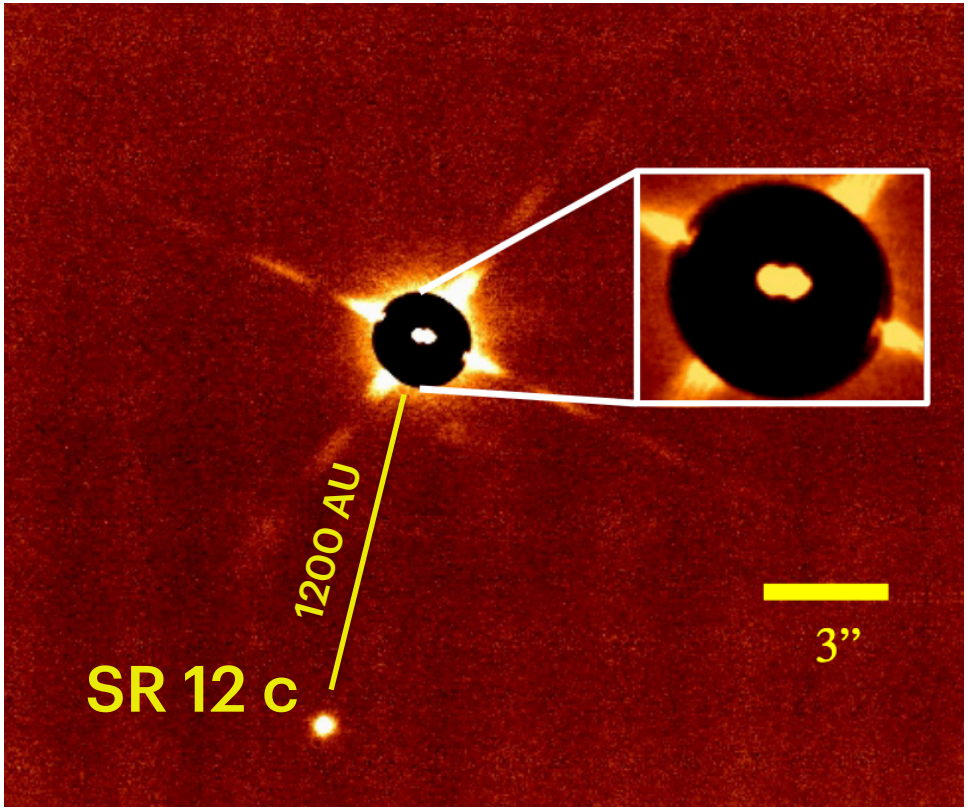
Location: ρ Oph cloud

M_p: 11±3 M_{Jup}

Planet SpT: L0±1

M_*: ~1.0 and 0.5 $M_\odot$

Kuzuhara+2011 Ortiz-León+2017, Wu+2022, Santamaría-Miranda+2018, Bowler+2014, Wilking+2005, Pecault & Mamajek (2013)



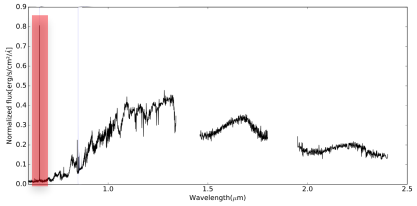
Kuzuhara et al. (2011)

Previous imaging and spectroscopy of SR 12 c

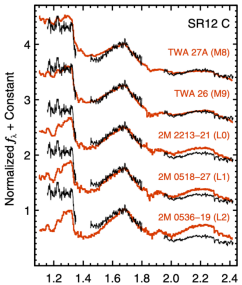
UV

MIR

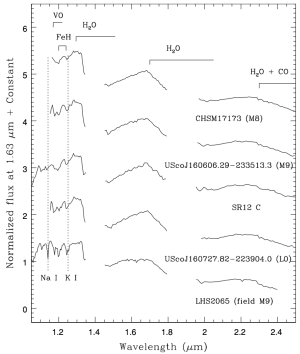
Previous imaging and spectroscopy of SR 12 c



VLT/X-shooter
Santamaría-Miranda+2018

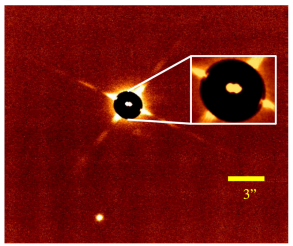


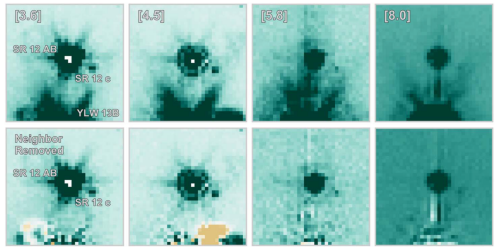
IRTF/SpeX
Bowler+2014



Subaru/CISCO
Kuzuhara+2011

IRSF/Sirius
Kuzuhara+2011





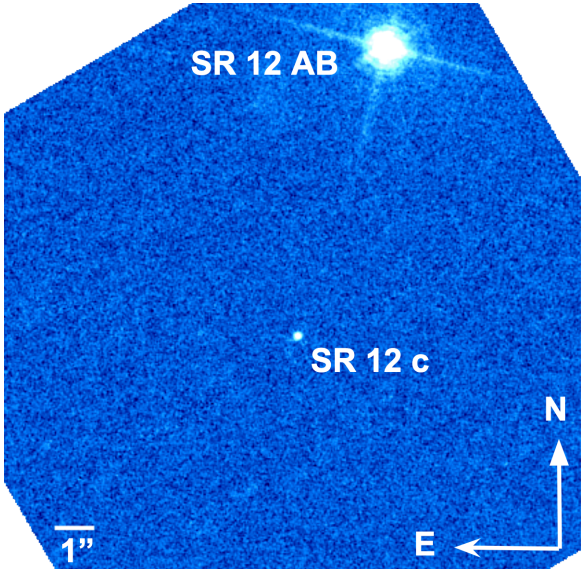
Spitzer/IRAC
Martinez+2022

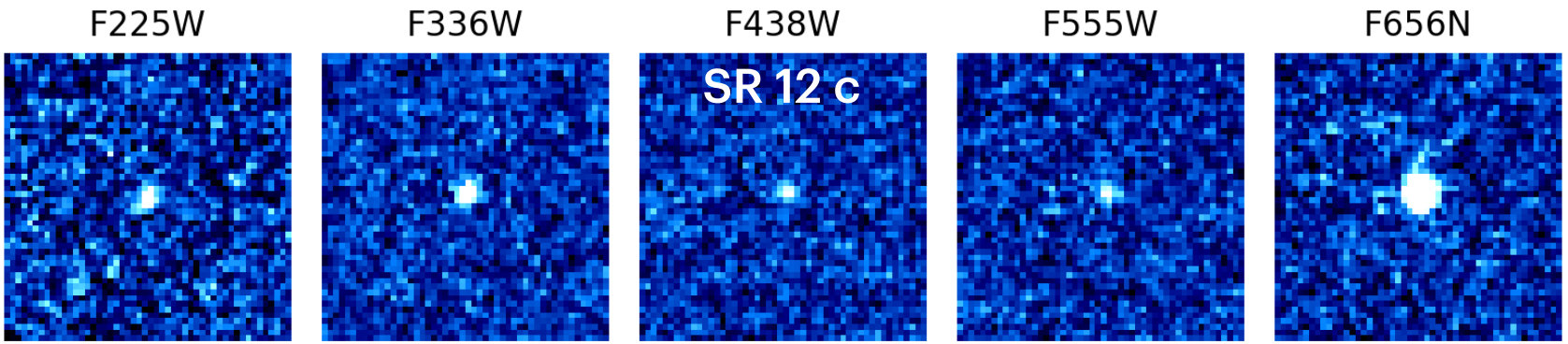
UV

MIR

New HST/WFC3 imaging from 2200-6600 Å shows continuum and emission line accretion signatures

Finley+(in prep.)

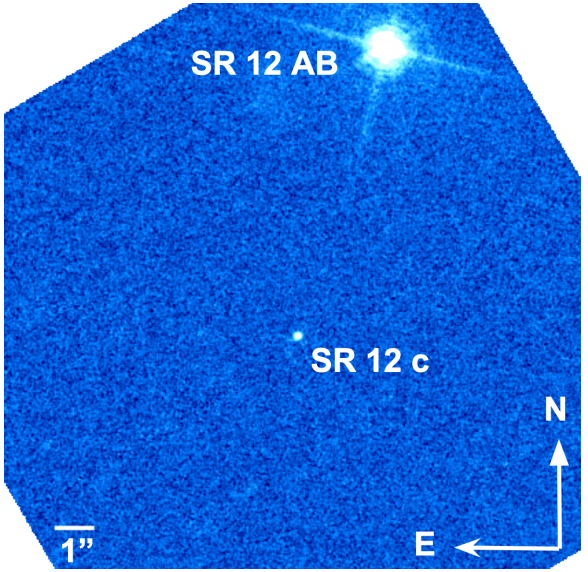


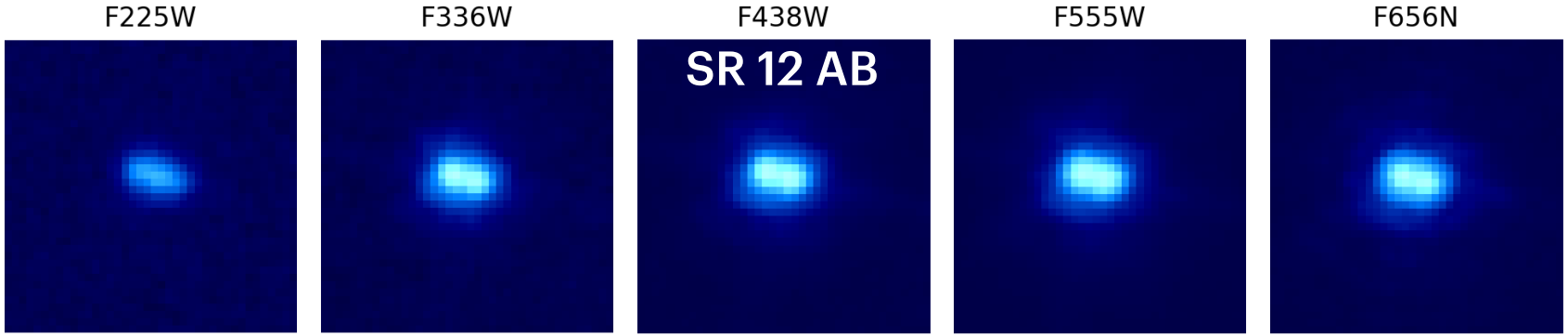


GO 16203

New HST/WFC3 imaging from 2200-6600 Å shows continuum and emission line accretion signatures

Finley+(in prep.)

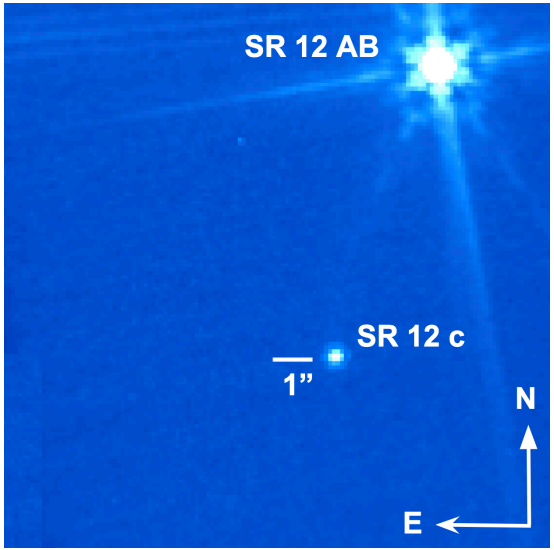




GO 16203

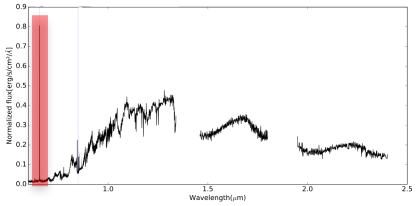
New JWST/MIRI imaging from 5.6-21 μm shows thermal excess consistent with a CPD

Wu, *Finley*+(in prep.)

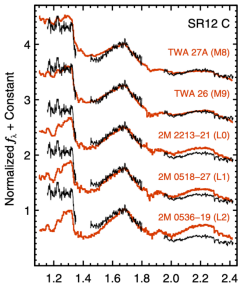


GO 2311

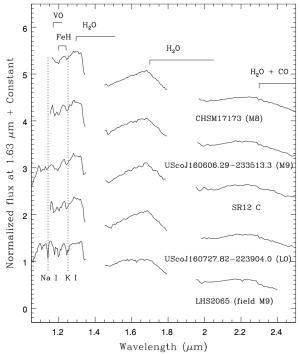
Previous imaging and spectroscopy of SR 12 c



VLT/X-shooter
Santamaría-Miranda+2018

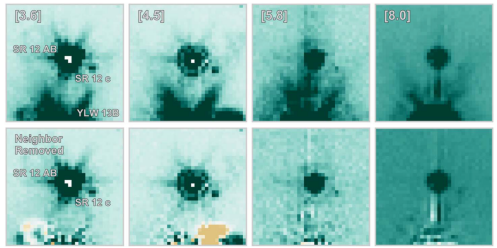


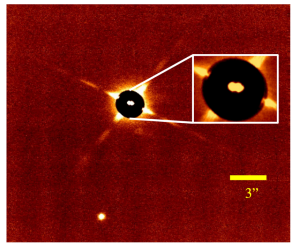
IRTF/SpeX
Bowler+2014



Subaru/CISCO
Kuzuhara+2011

IRSF/Sirius
Kuzuhara+2011





Spitzer/IRAC
Martinez+2022

UV

MIR

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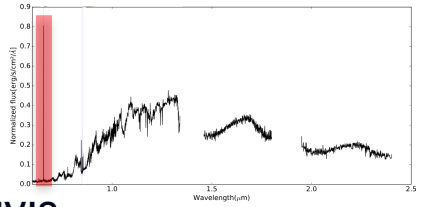
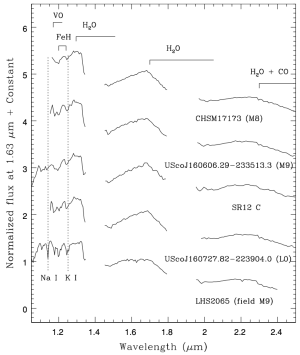
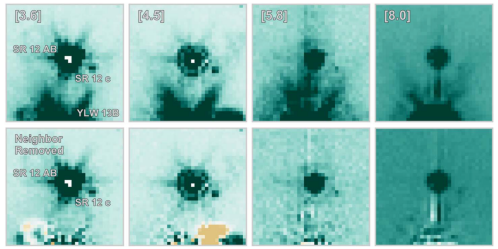


HST/WFC3-UVIS
Finley+(in prep)

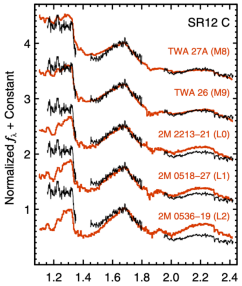


IRTF/SpeX
Bowler+2014



IRSF/Sirius
Kuzuhara+2011

VLT/X-shooter
Santamaría-Miranda+2018



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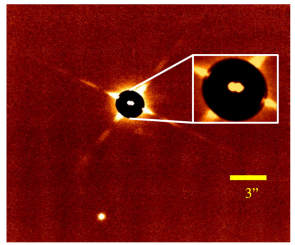
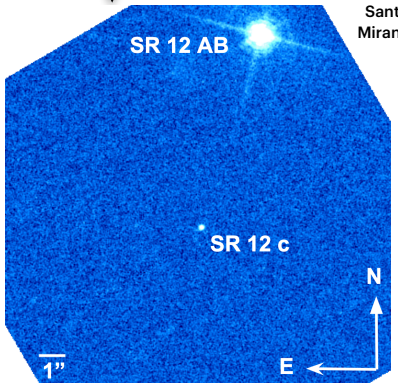
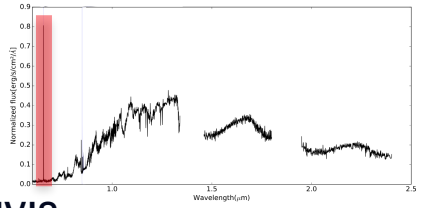


Spitzer/IRAC
Martinez+2022

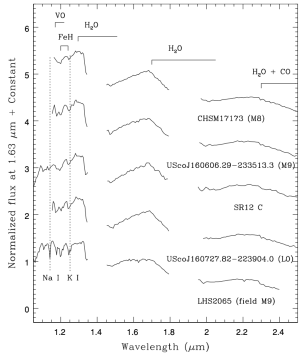


MIR

Previous imaging and spectroscopy of SR 12 c



HST/WFC3-UVIS
Finley+(in prep)



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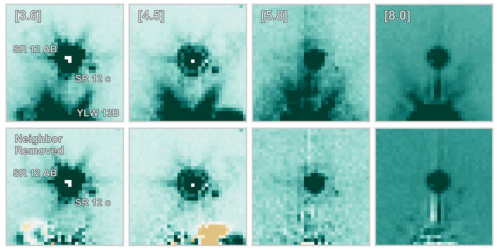

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JWST/MIRI
Wu, **Finley**+(in prep)

VLT/X-shooter
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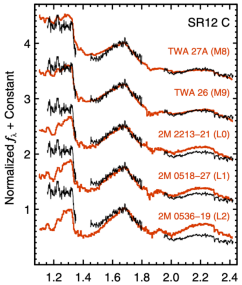

Subaru/CISCO
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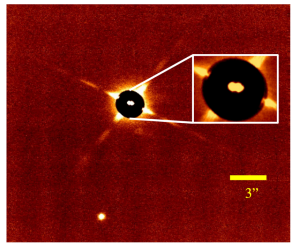
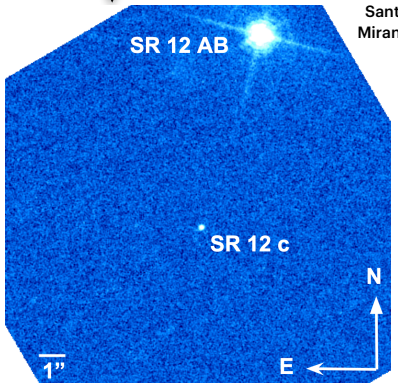
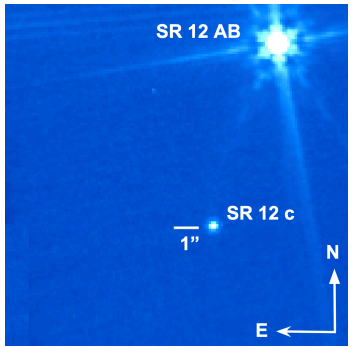
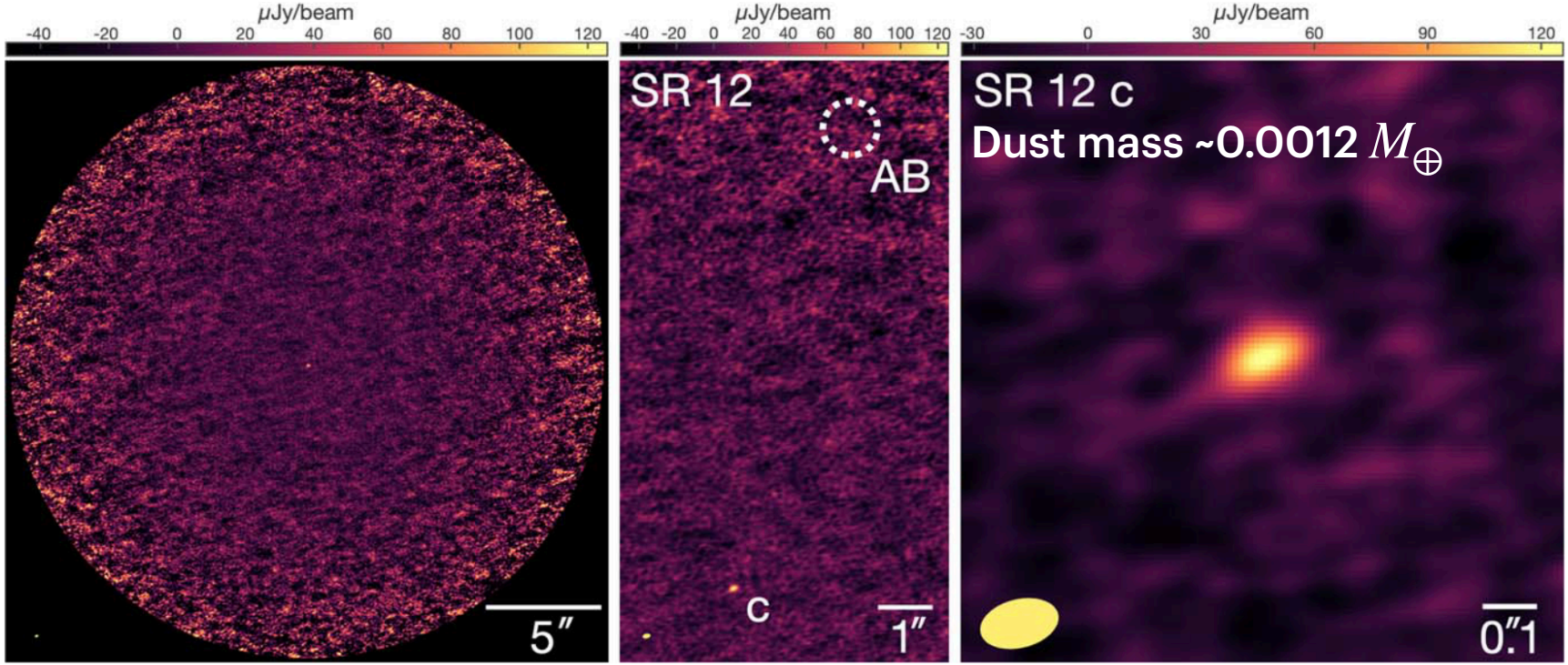


Spitzer/IRAC
Martinez+ 2022



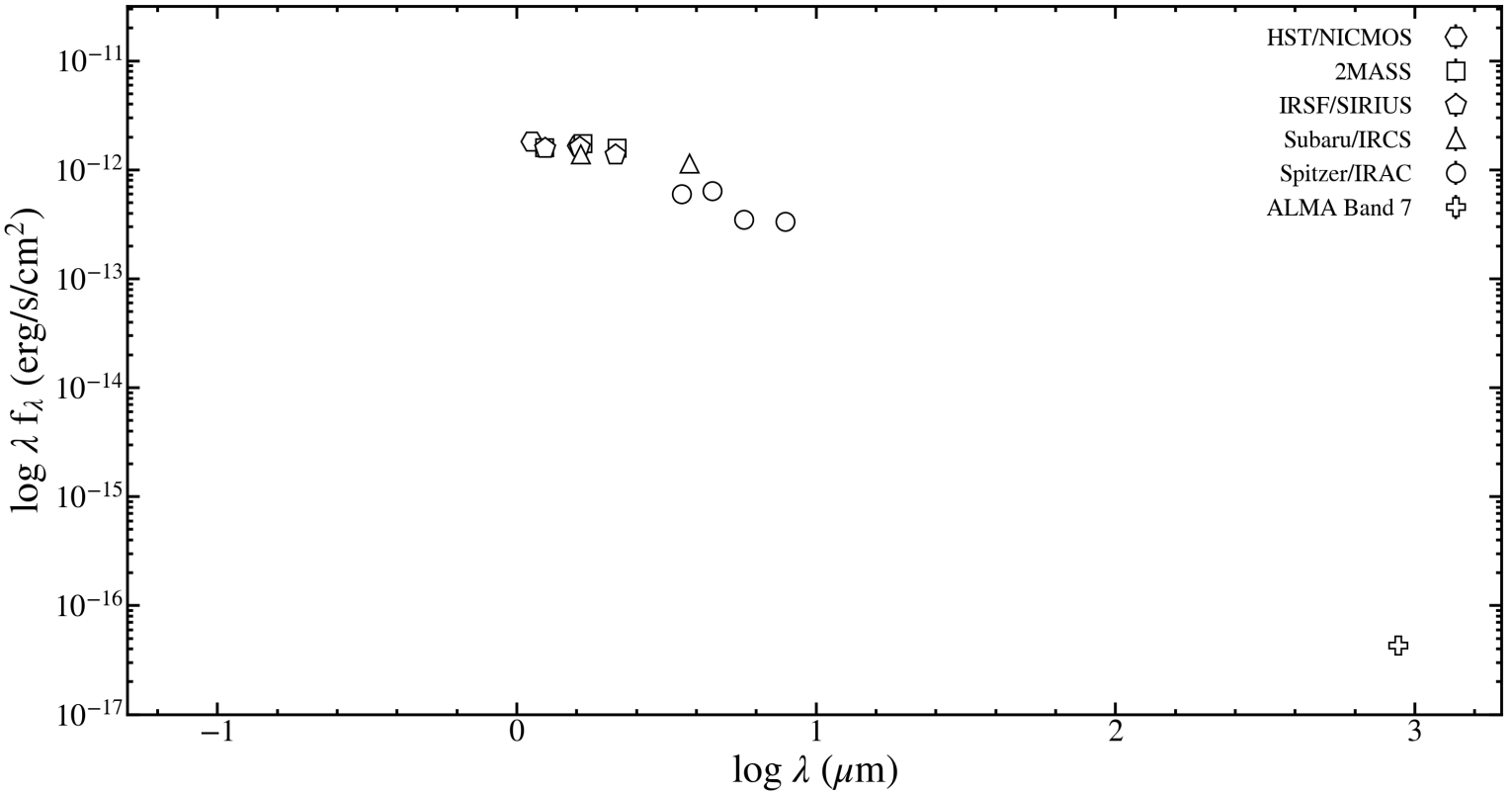


ALMA detection of the CPD surrounding SR 12 c



Wu+2022

The UV through sub-mm SED of SR 12 c



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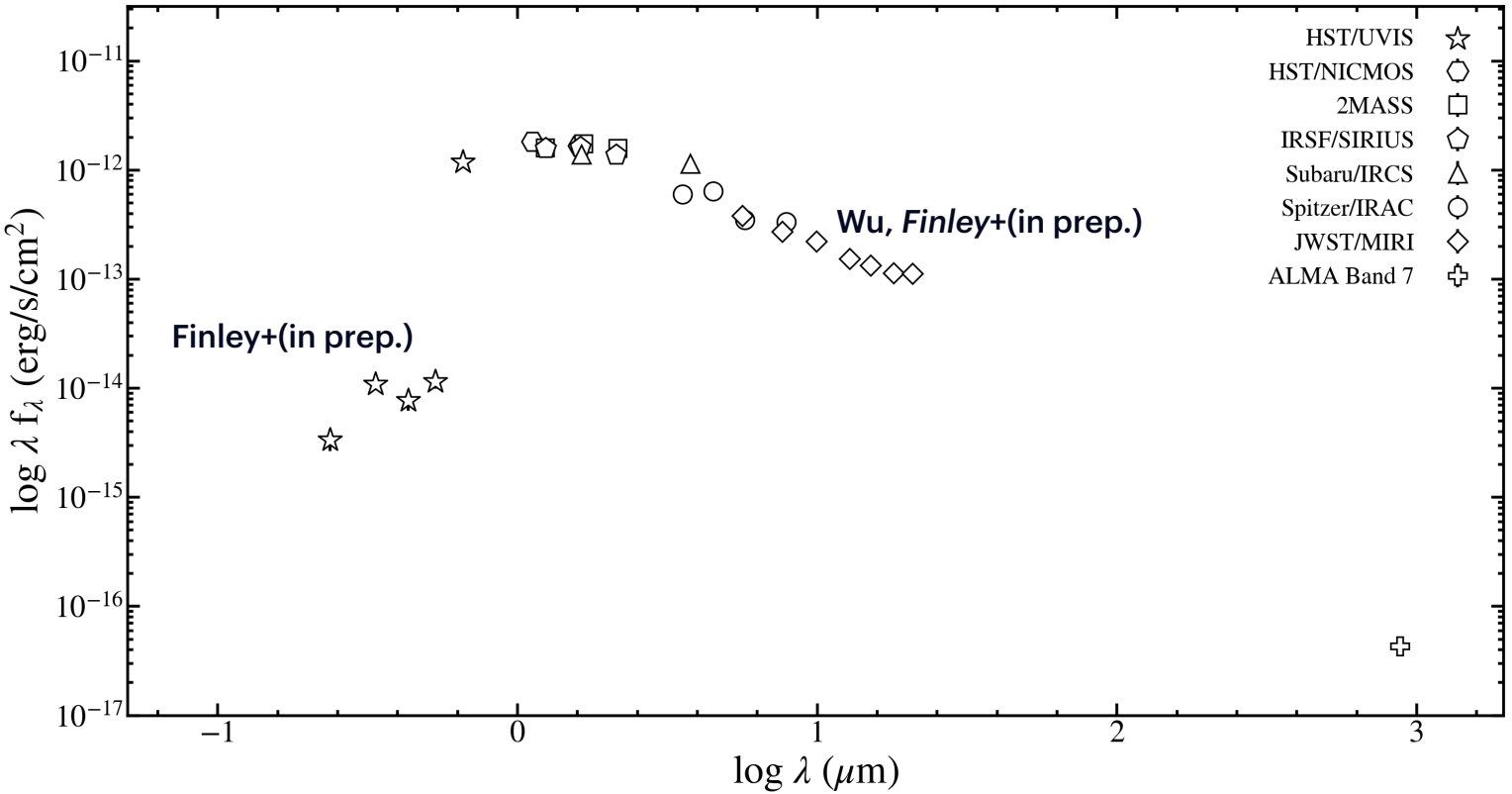

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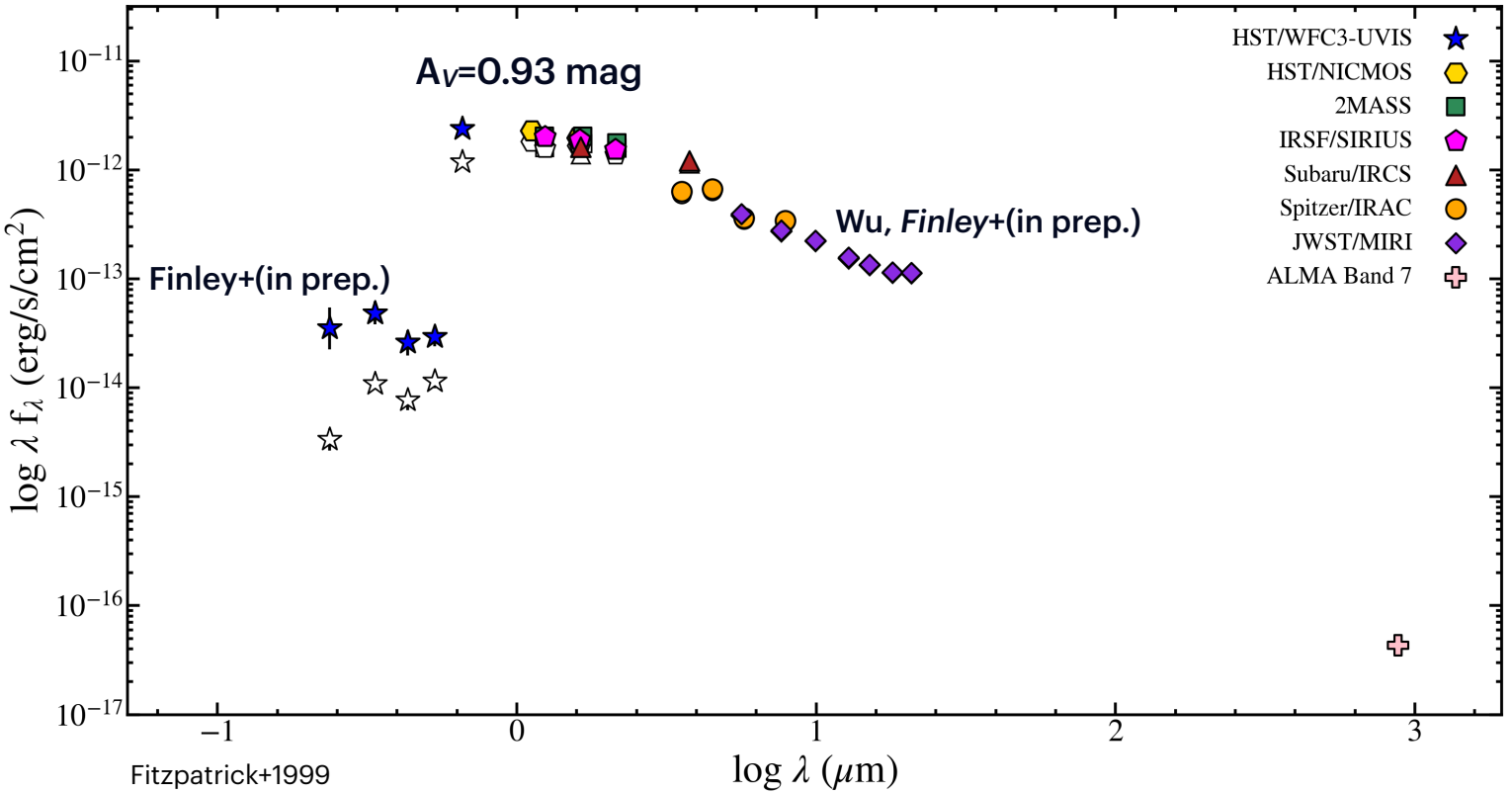

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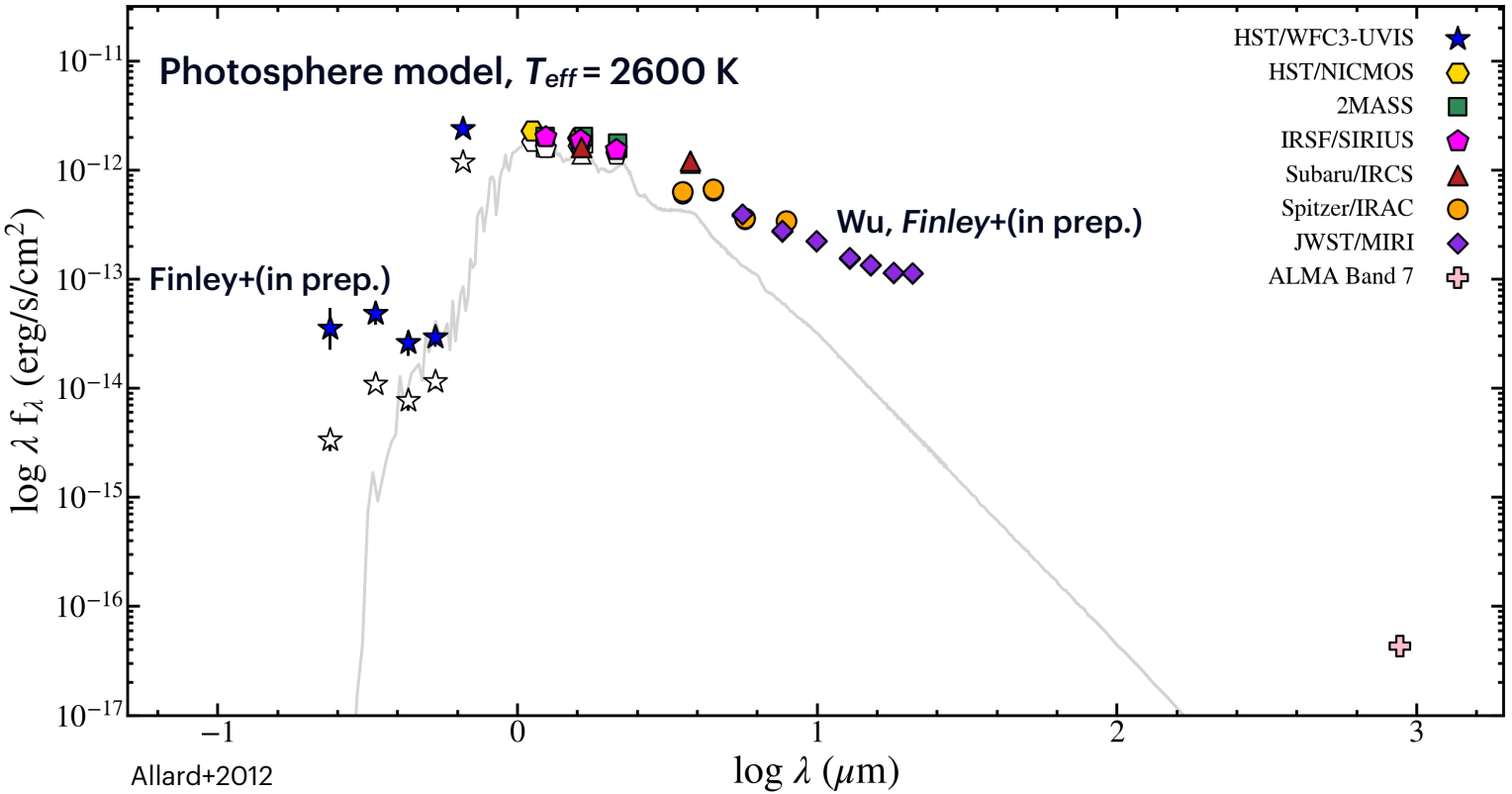
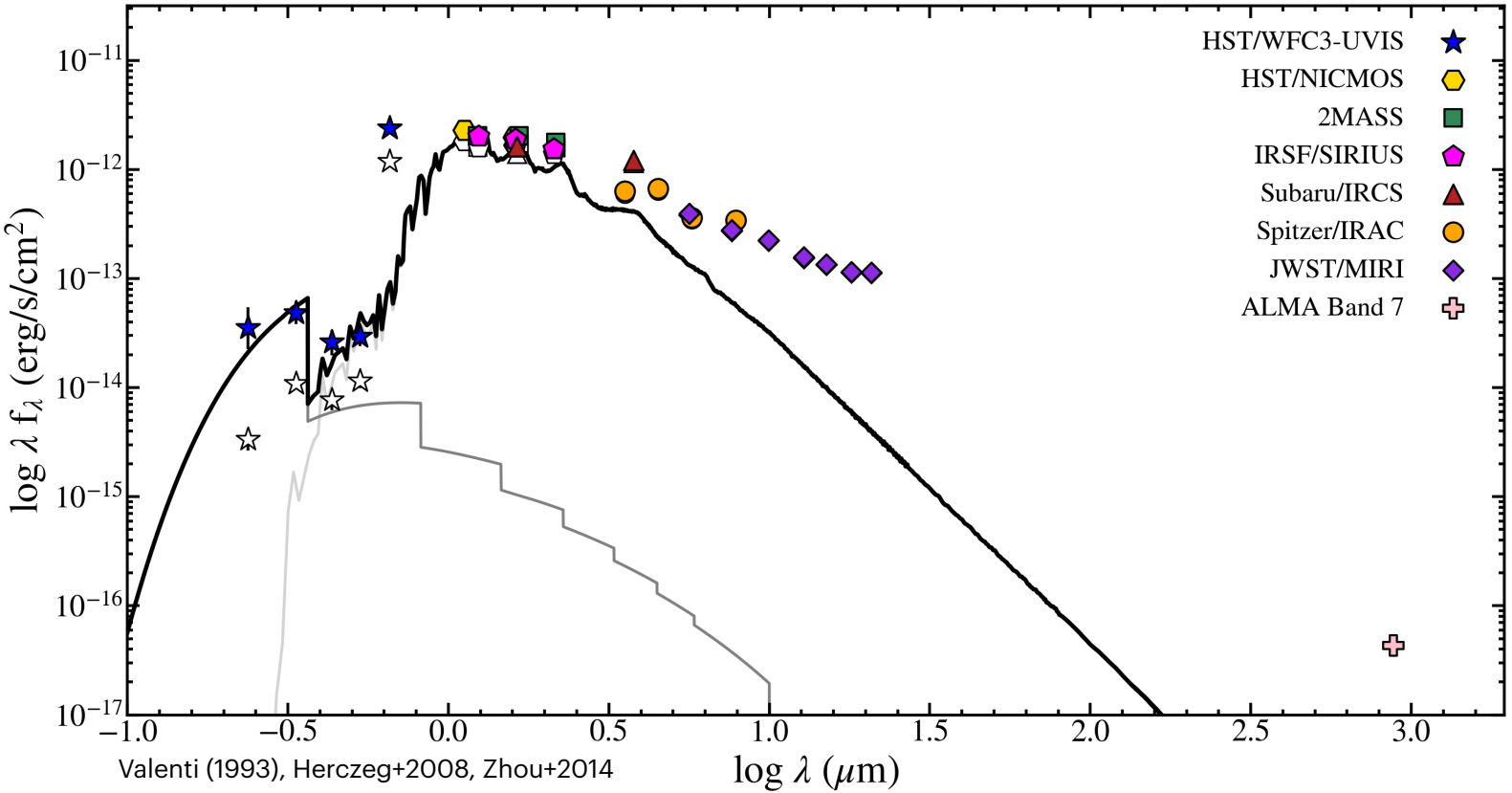
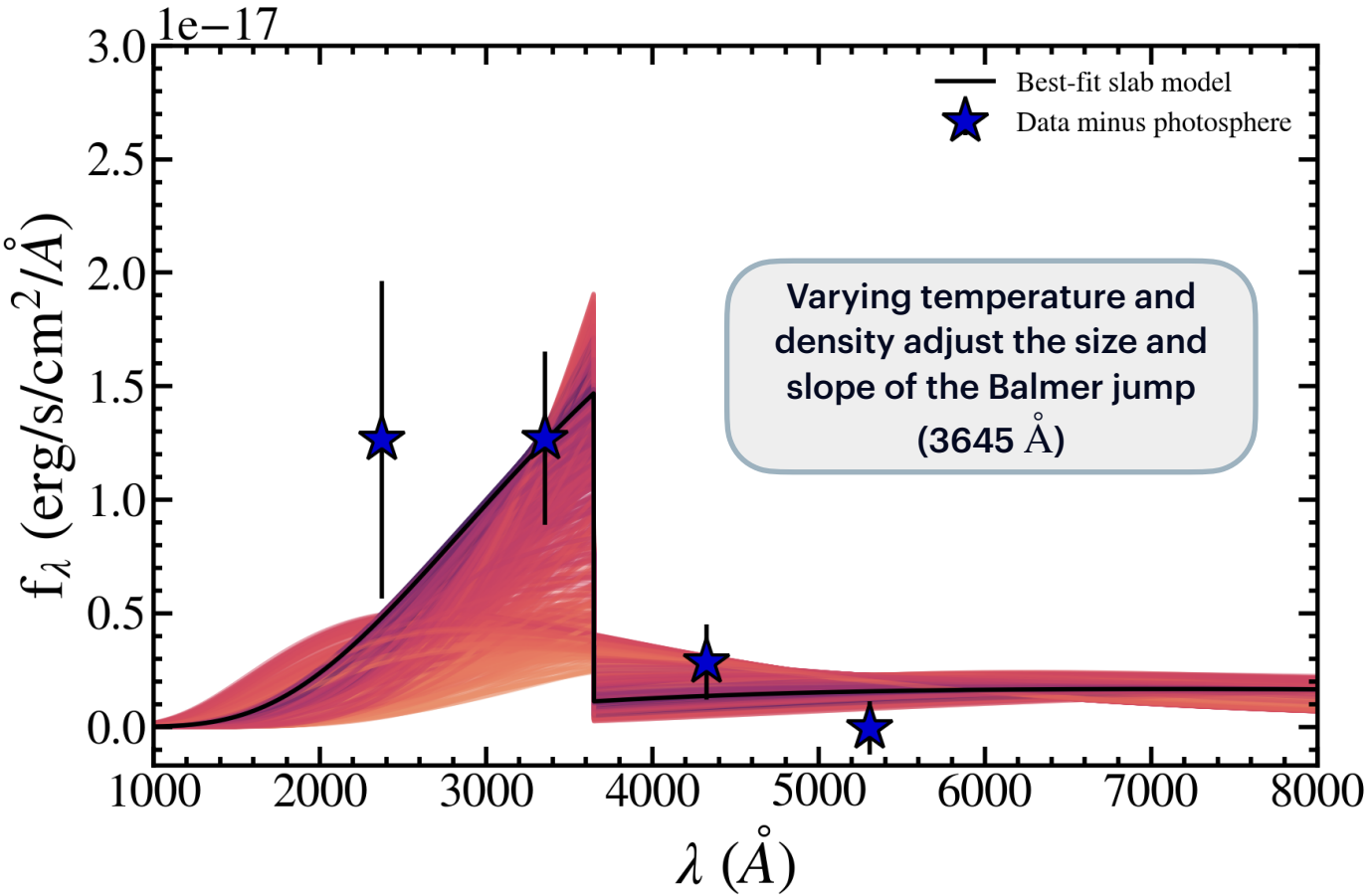


Hydrogen slab models quantify accretion properties



Fitting hydrogen slab models to the Balmer break



From UV excess to mass accretion rate

Continuum accretion luminosity ($L_\odot$)		*Hα line accretion luminosity ($L_\odot$)*		*Total accretion luminosity ($L_\odot$)*		*Mass accretion rate ($M_\odot\ yr^{-1}$)*
1.8×10^{-5}	+	3.8×10^{-6}	=	2.2×10^{-5}	→	1.4×10^{-11}

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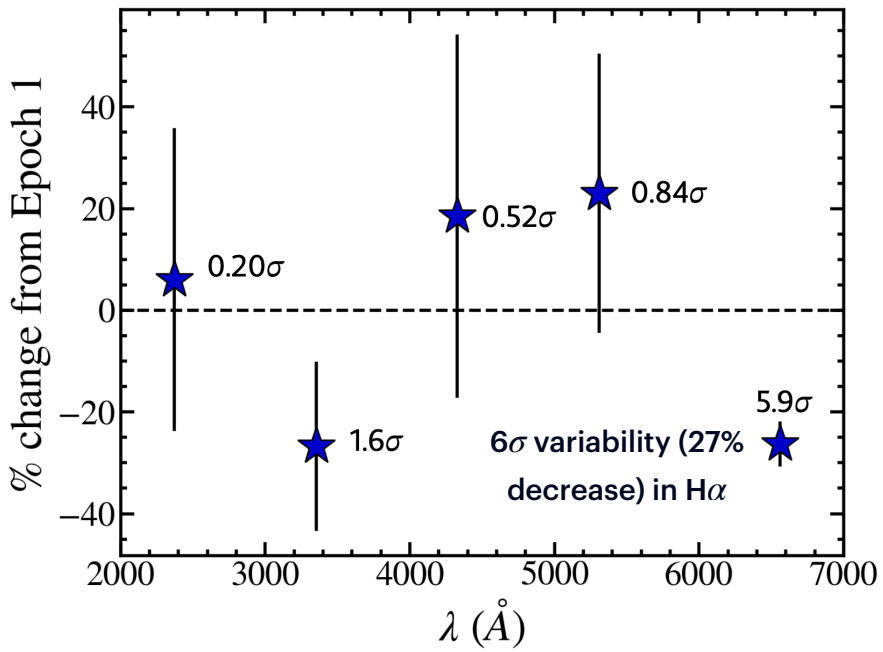
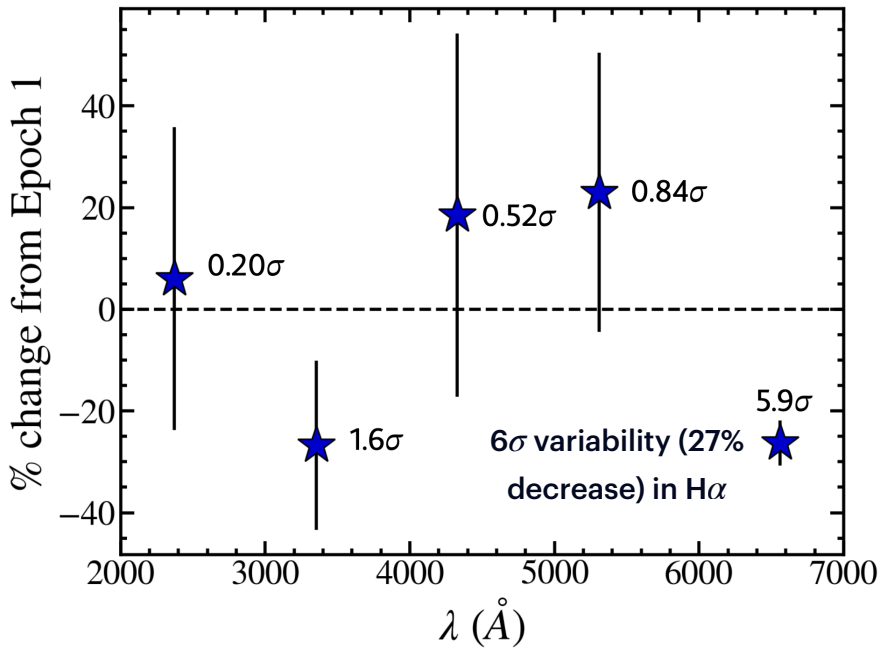
1.8×10^{-5}	+	3.8×10^{-6}	=	2.2×10^{-5}	→	1.4×10^{-11}

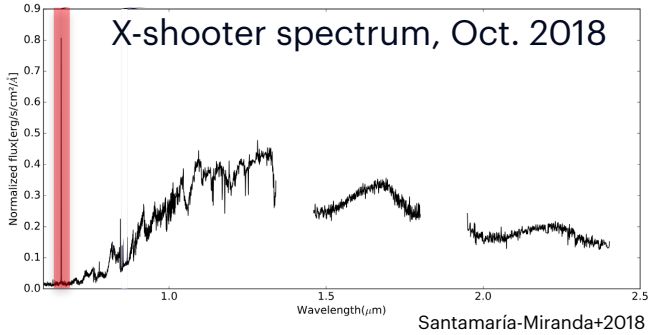
Over the next Myr, at this rate, it will only accrete another 0.01 M_{Jup}—SR 12 c formed all 11 M_{Jup} in just 2 Myr

Accretion variability implies dynamic mass transfer



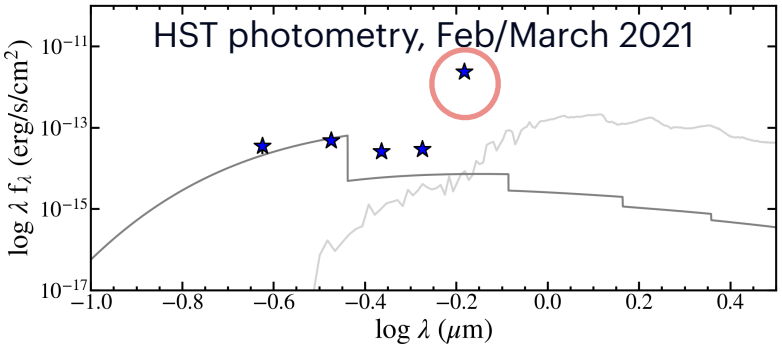
Accretion variability implies dynamic mass transfer



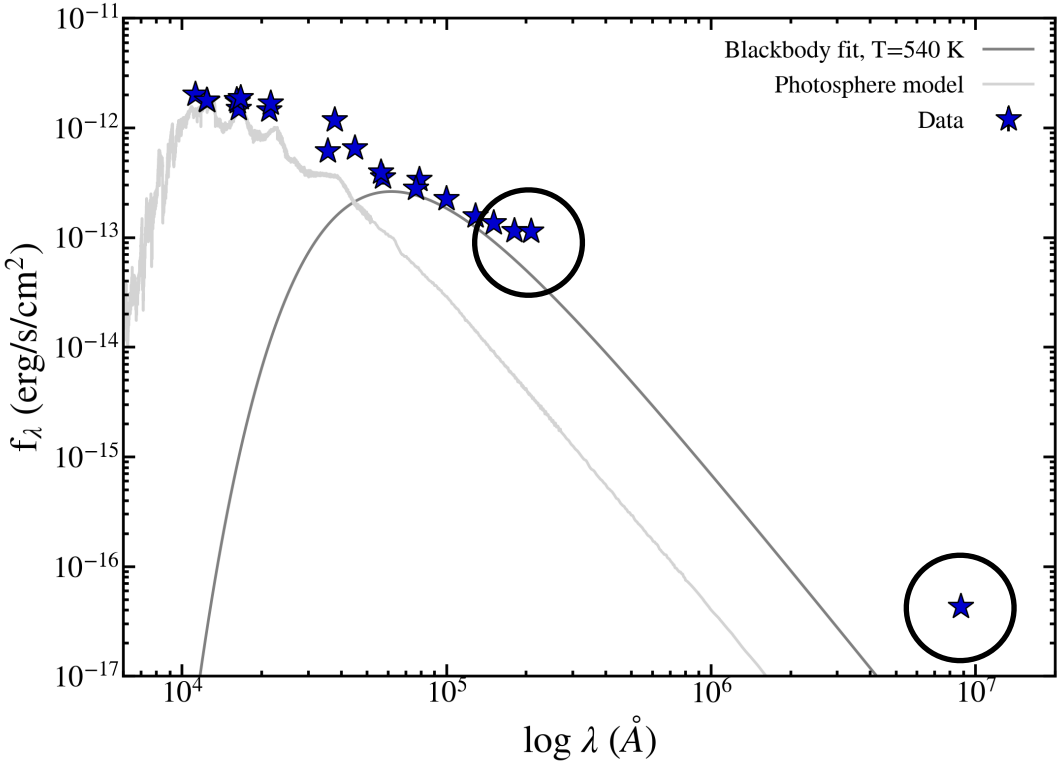


Santamaría-Miranda+2018

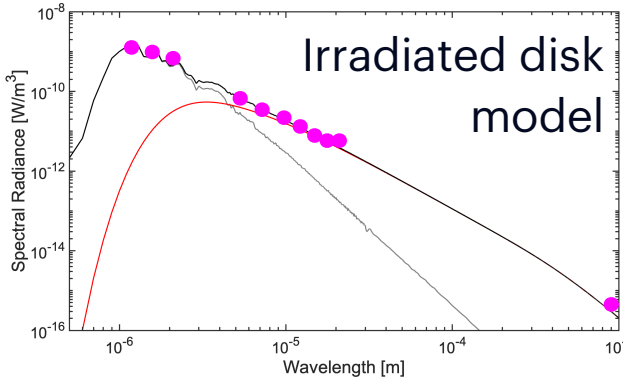
90% decrease in Hα flux over 4 years

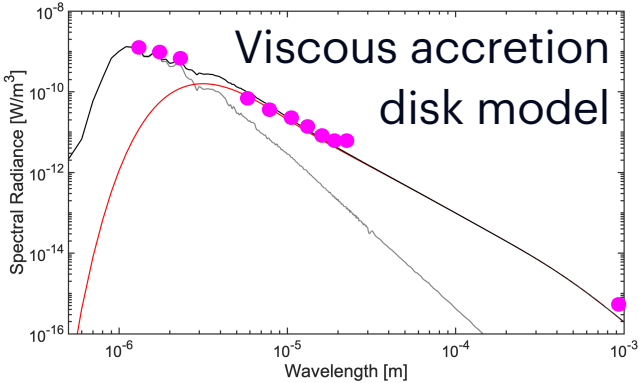


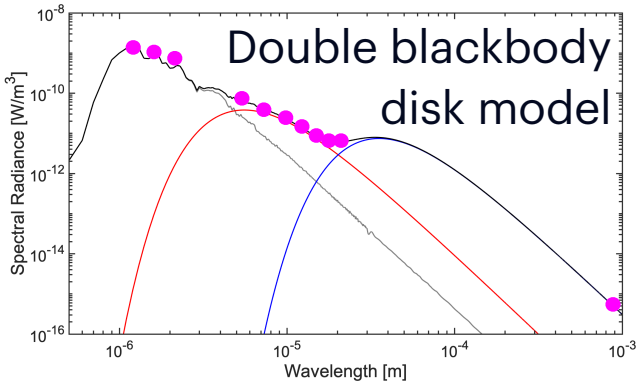
A single blackbody provides a poor fit to the mid-IR excess



More realistic analytical models improve the fit to the CPD emission







Wu, *Finley*+(in prep.)

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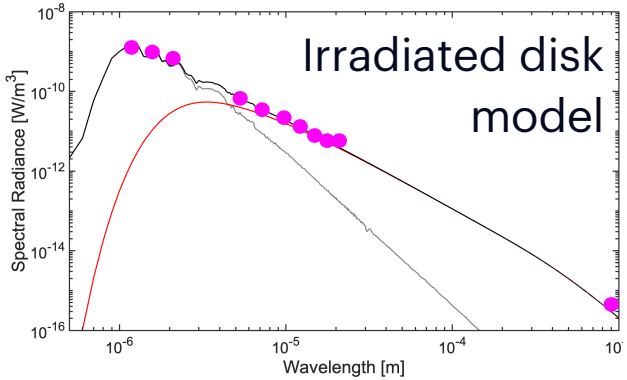
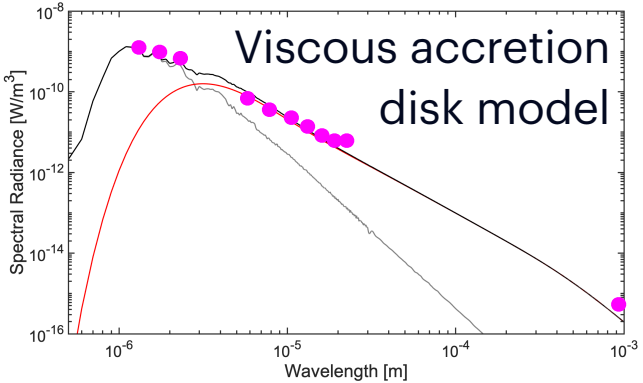
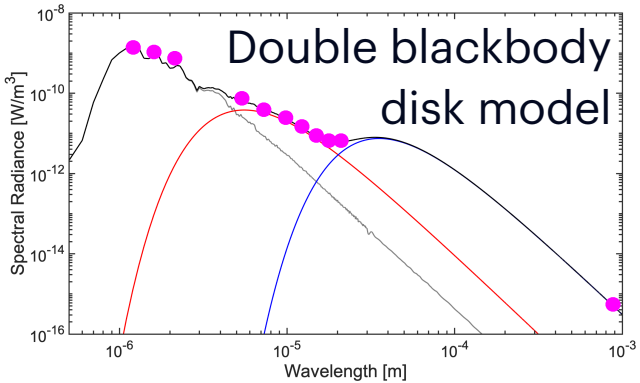


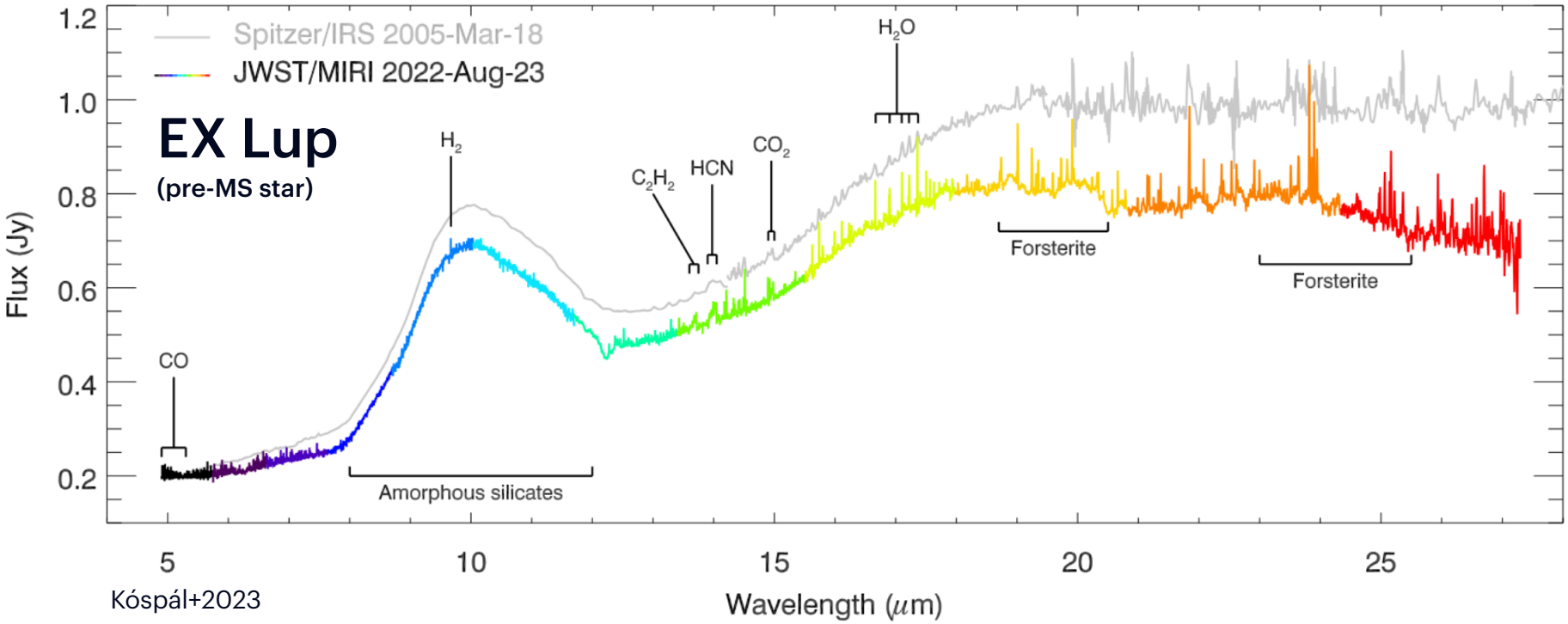




Wu, *Finley*+(in prep.)

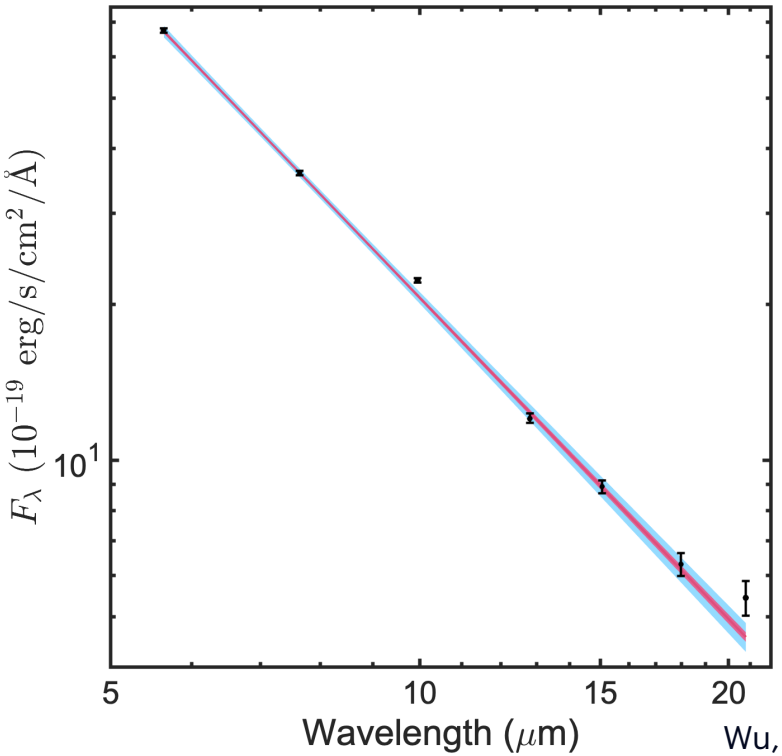
All three models imply a characteristic outer radius of ~1000-2000 R_{Jup}

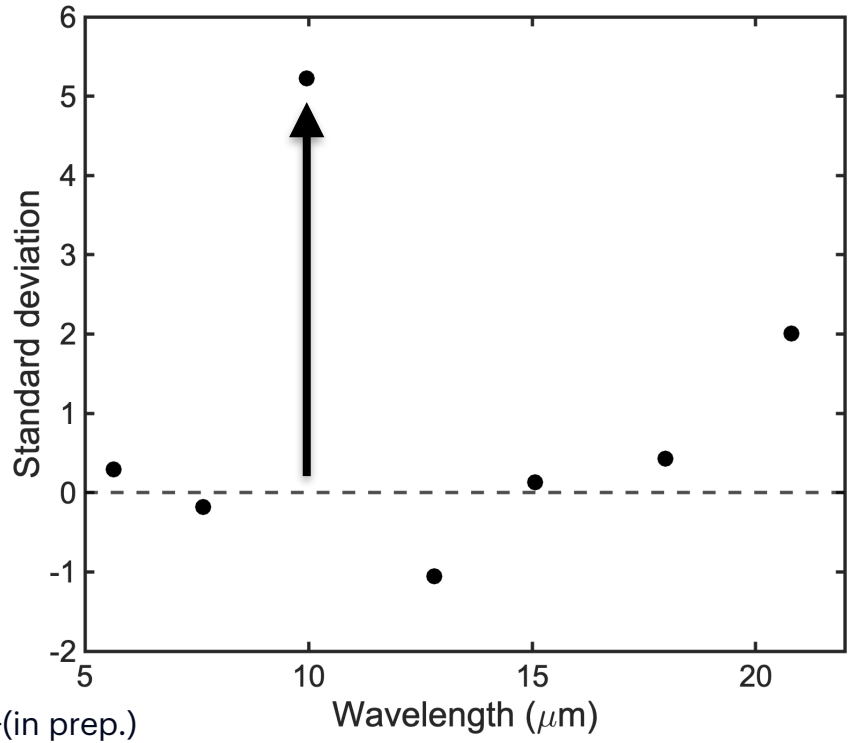
The 10 μm silicate feature traces dust evolution in disks



Kóspál+2023

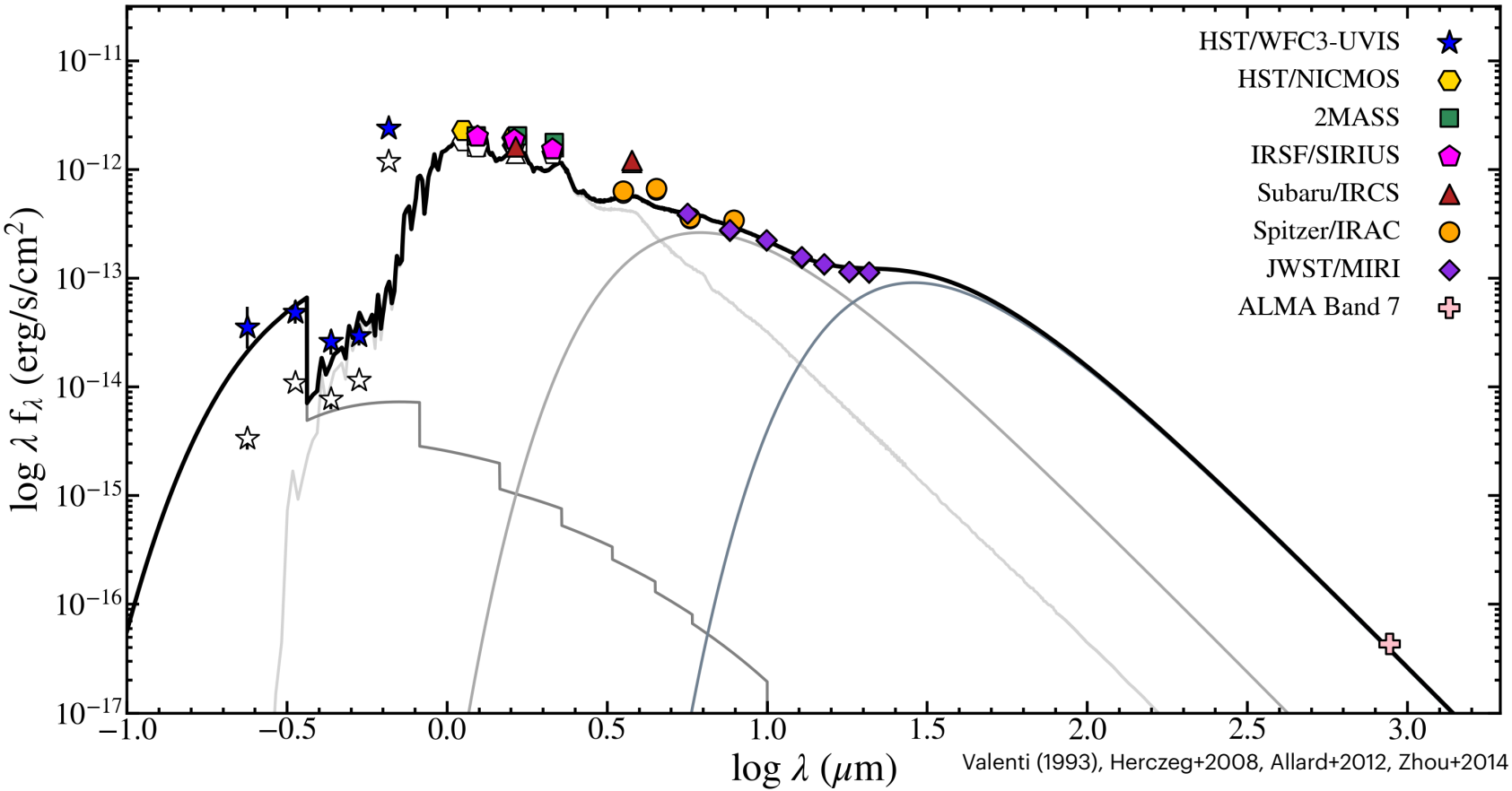
SR 12 c displays mild 10 μm silicate emission, indicating dust grain processing has occurred





Wu, *Finley*+(in prep.)

Jointly modeling accretion, photosphere, and CPD emission



Valenti (1993), Herczeg+2008, Allard+2012, Zhou+2014

Summary

- Circumplanetary disk properties and evolution trace how giant planets grow

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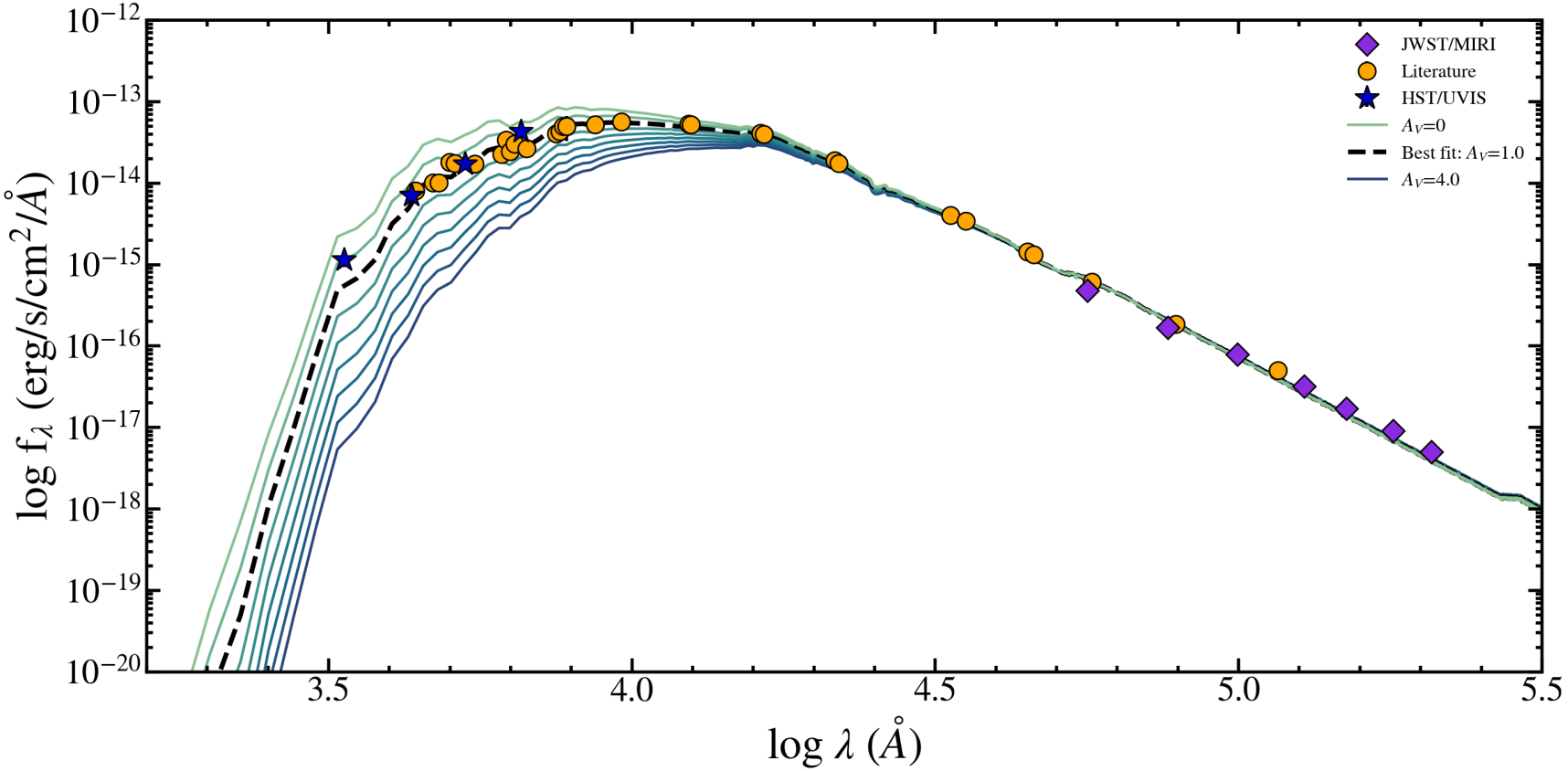
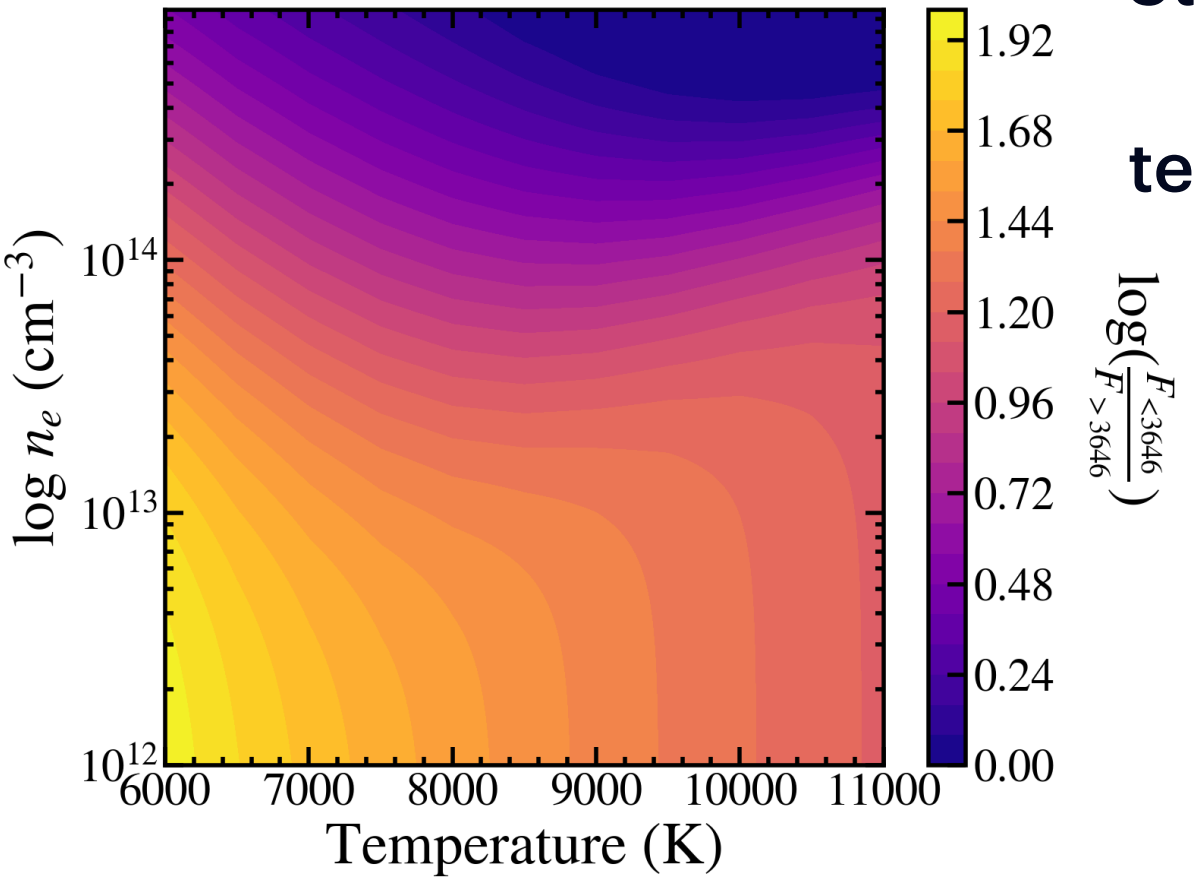
Supplemental slides

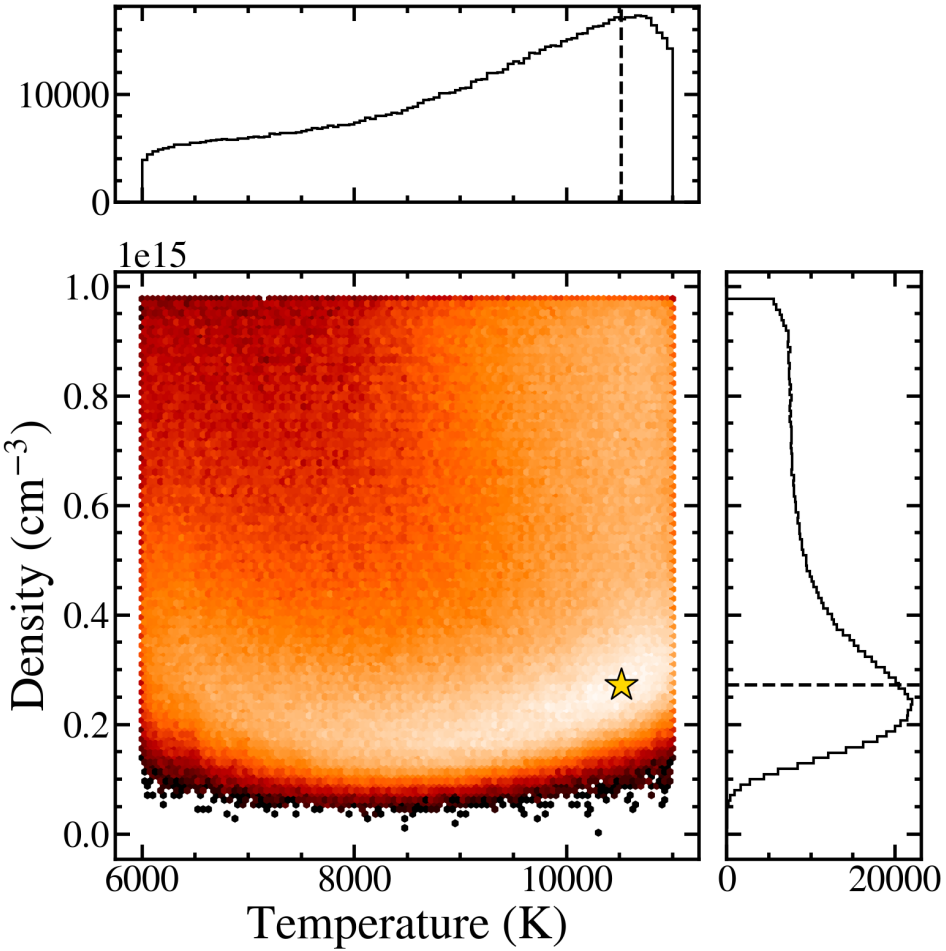
Extinction is estimated using the host binary



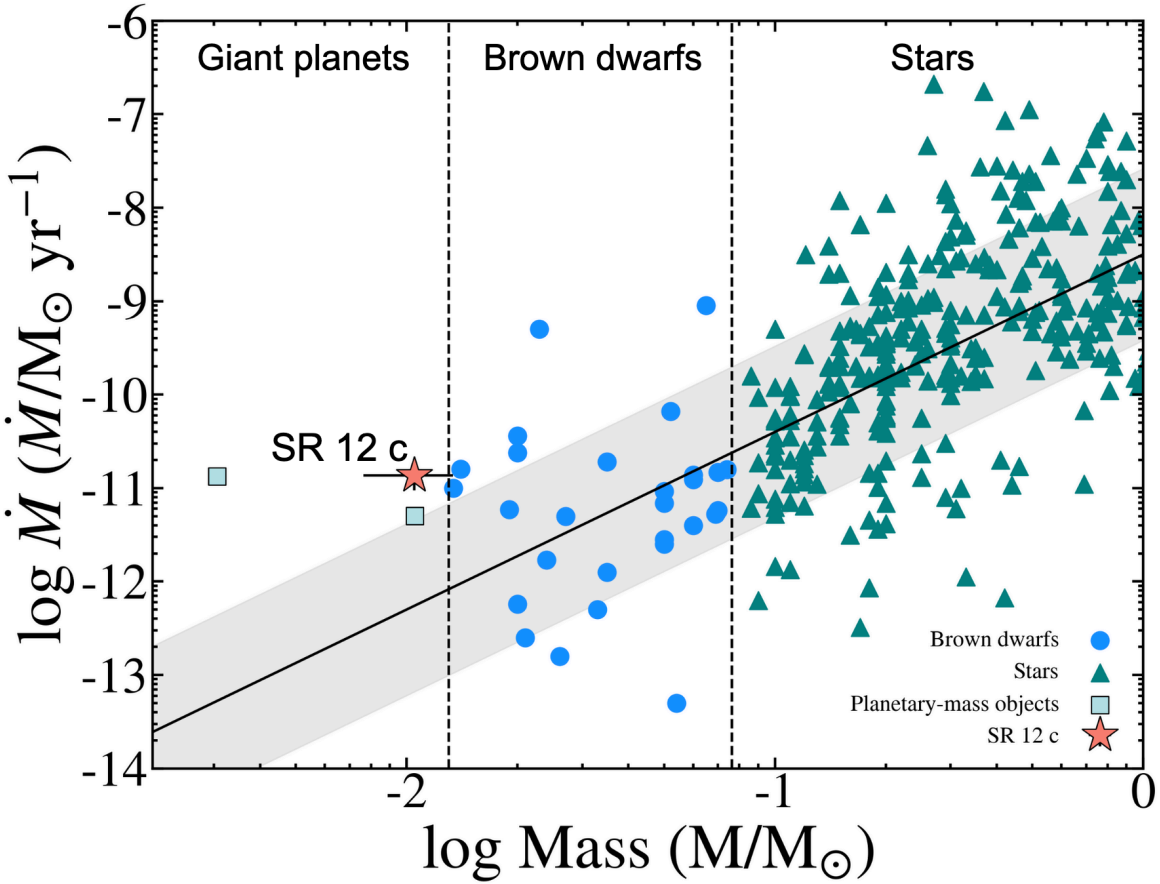
Strength of the Balmer jump with varying temperate and density



MCMC posterior corner plot

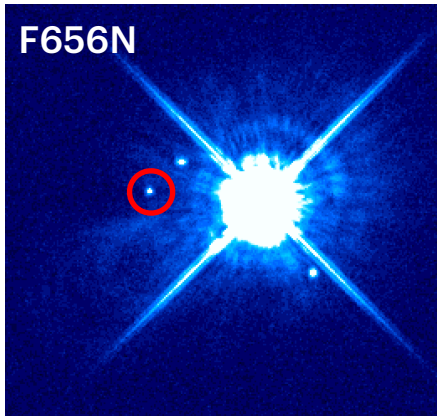


We may be able to predict formation using accretion



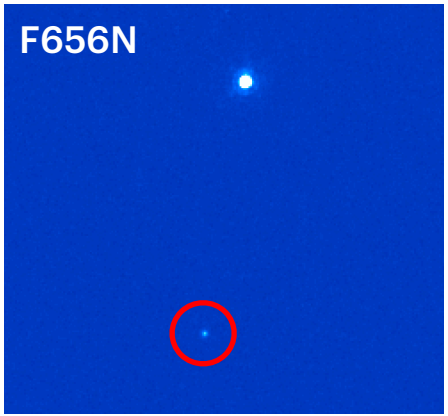
The rest of this program will double the current census of PMC continuum accretion studies

CT Cha b



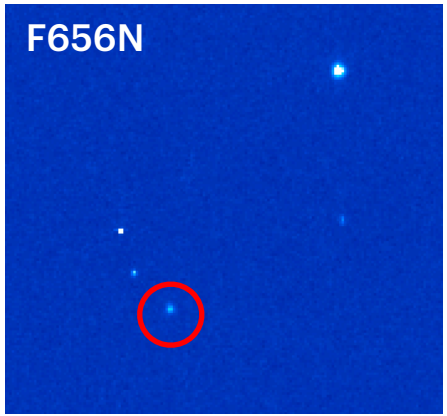
M=17±5 M_{Jup}

FU Tau b



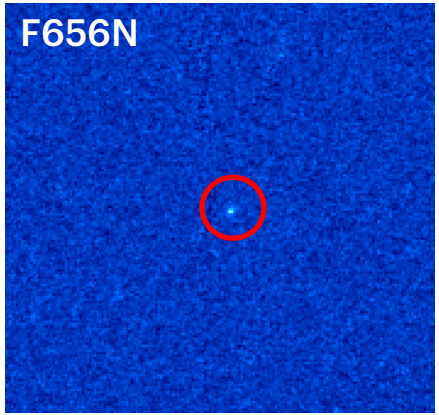
M=19±4 M_{Jup}

SCH06-J0359+2009 b



M=15±1 M_{Jup}

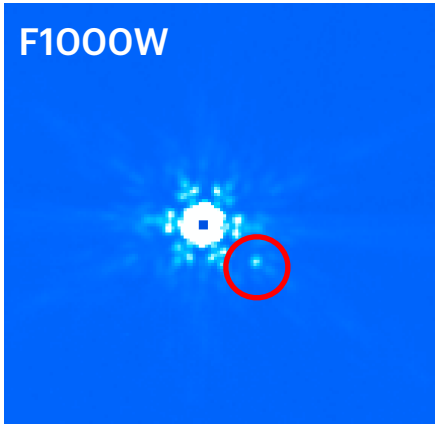
OTS-44 (free floating)



M~12 M_{Jup}

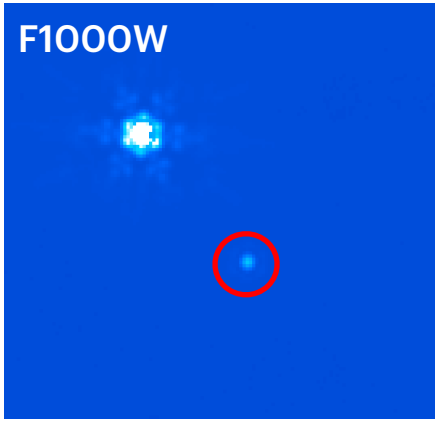
With this program we will ~double the sample of observed CPDs

DH Tau b



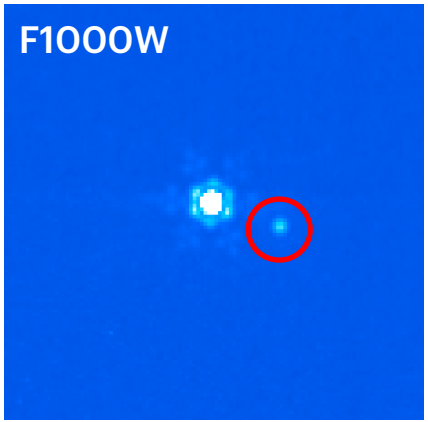
M=11±3 M_{Jup}

FU Tau b



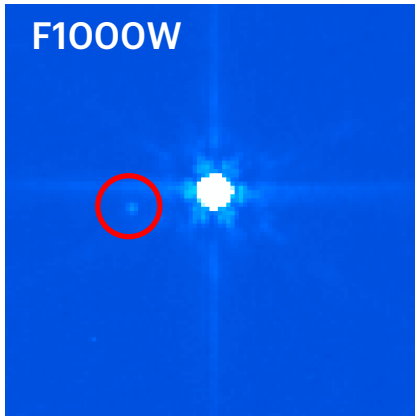
M=19±4 M_{Jup}

GSC 06214-00210 b



M=14±2 M_{Jup}

1RXS1609 b



M=12±2 M_{Jup}