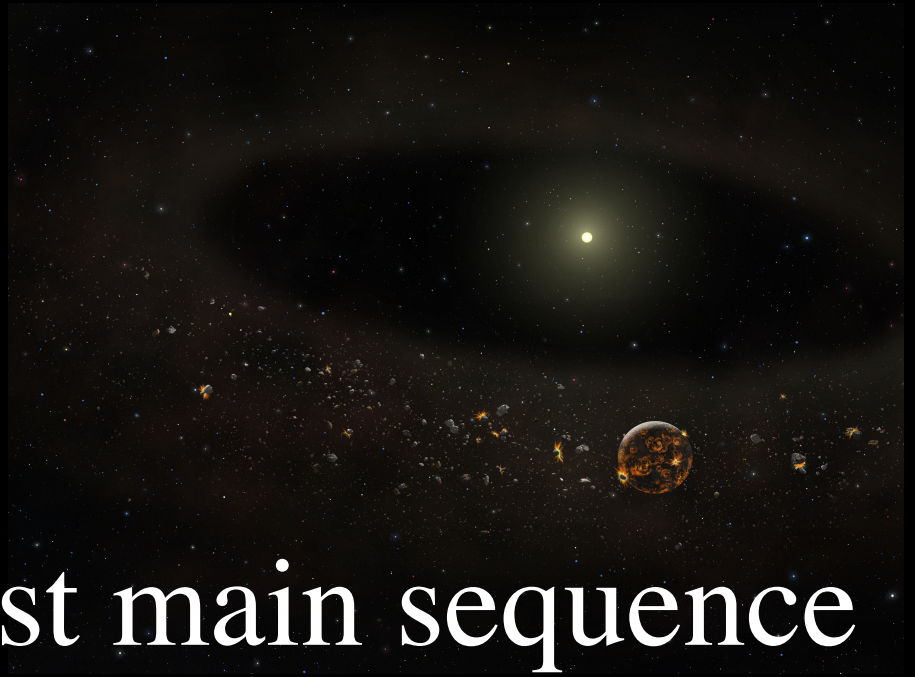


What are the dustiest main sequence stars telling us about planetary systems?

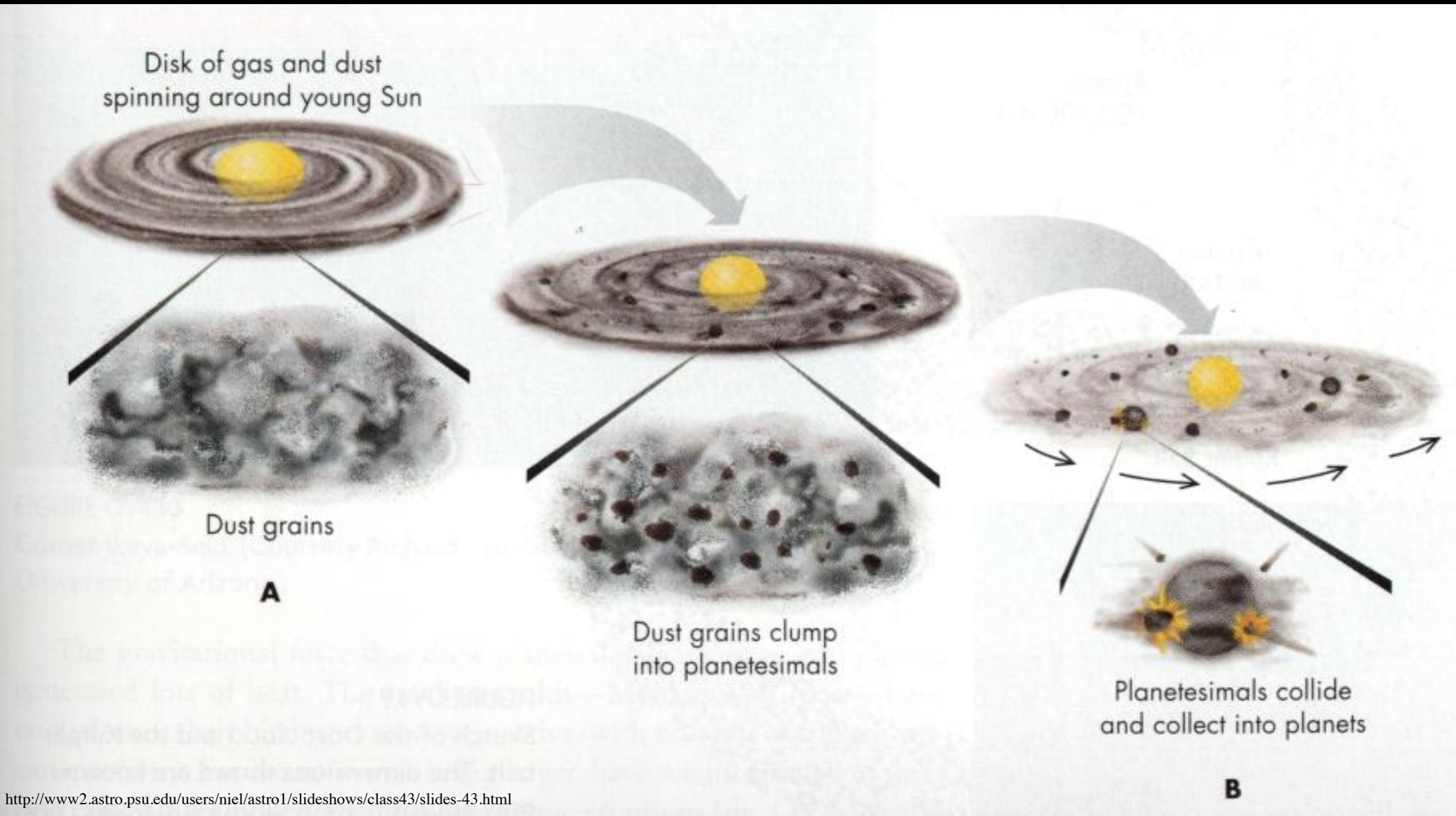
Dr. Carl Melis

Associate Research Scientist

UC San Diego Center for Astrophysics and Space Sciences

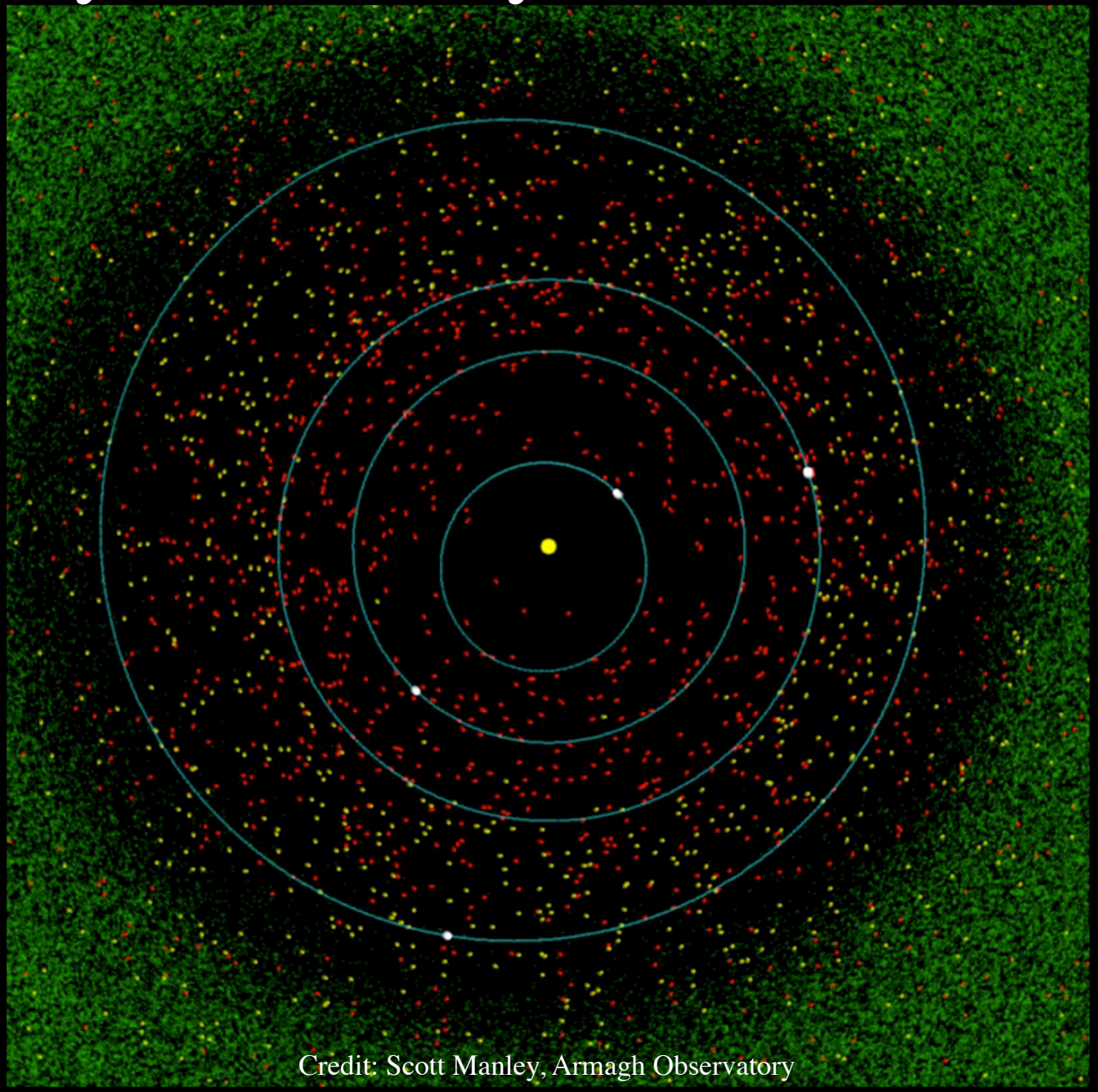
Image Credit: Gemini Observatory/Lynette Cook + NASA/David A. Hardy

Planetary System Formation Review



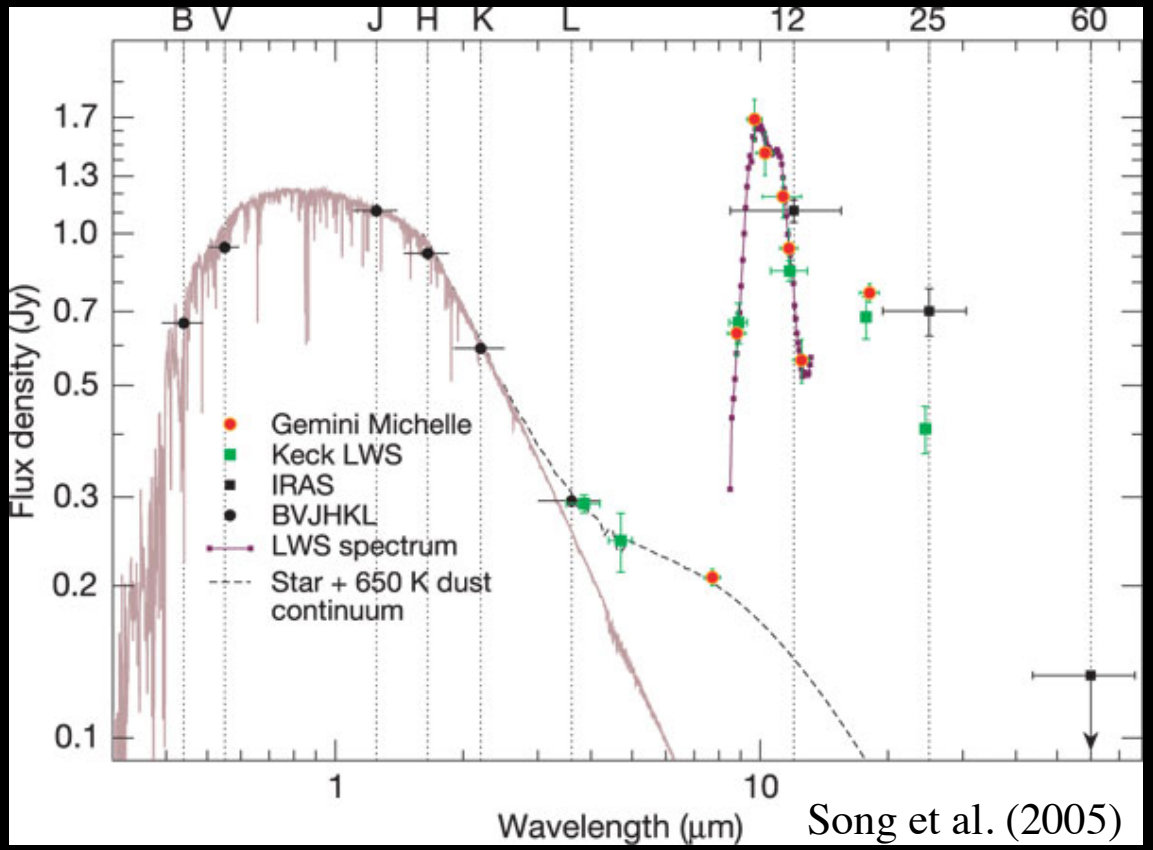
http://www2.astro.psu.edu/users/niel/astro1/slideshows/class43/slides-43.html

Planetary systems are dynamic!



Credit: Scott Manley, Armagh Observatory

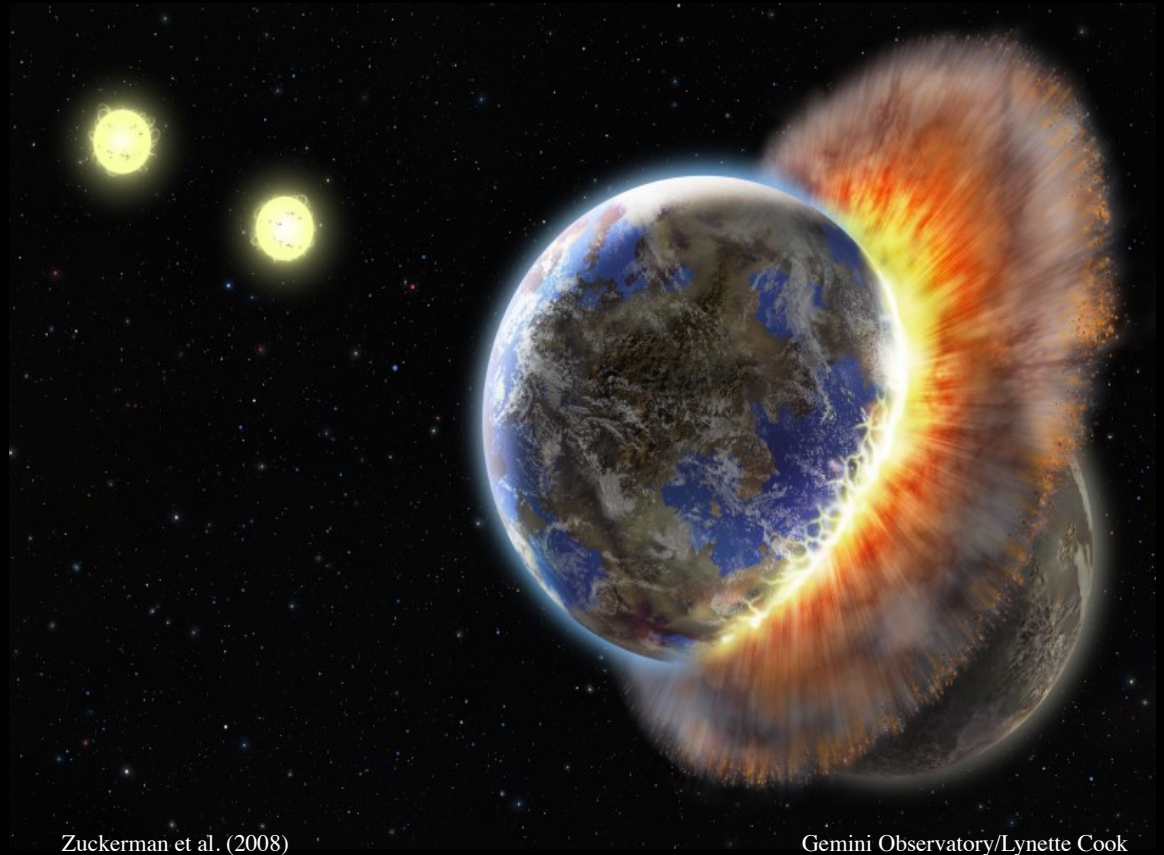
Signatures of Rocky Planet Formation/Evolution



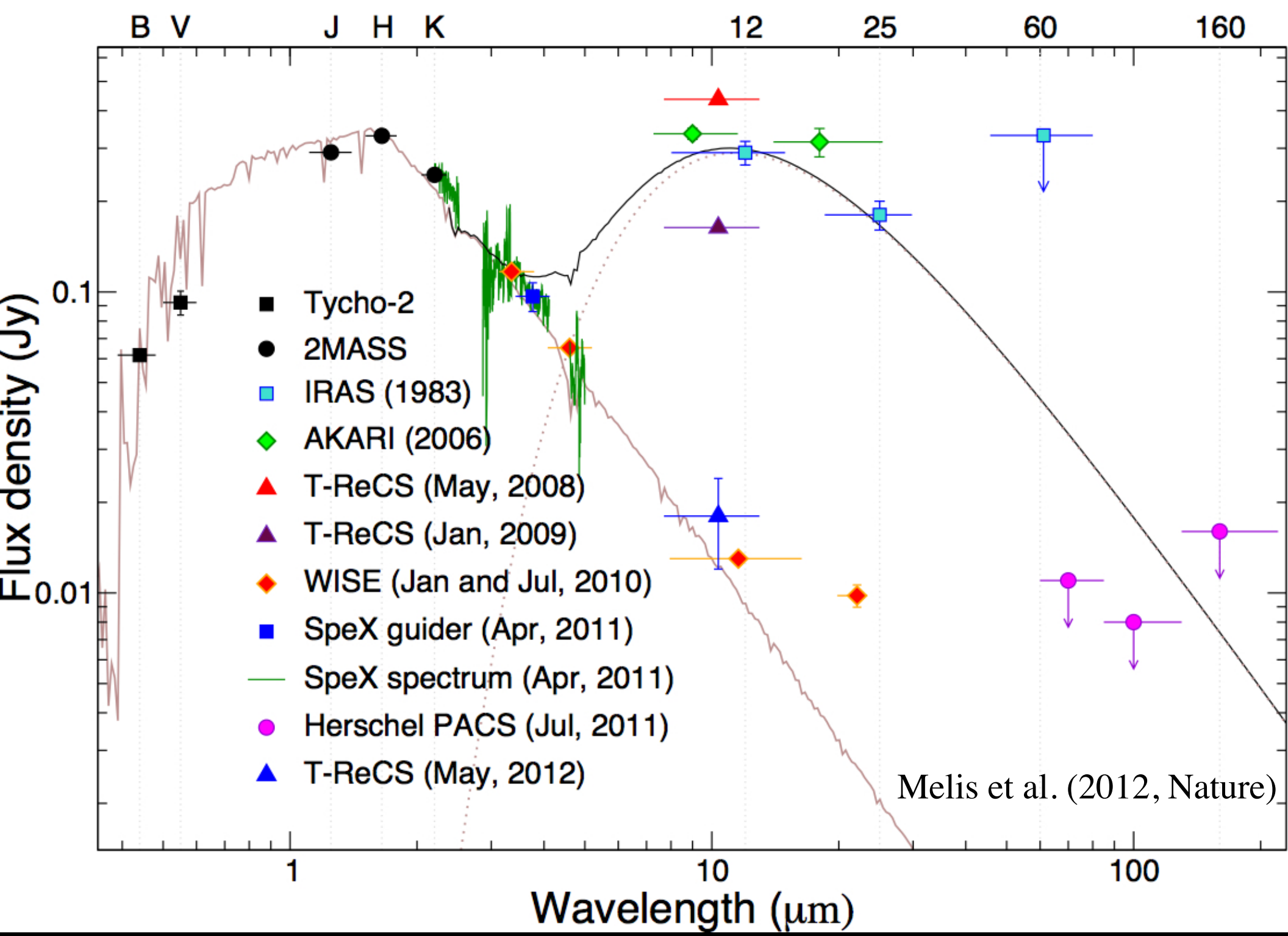
Song et al. (2005)

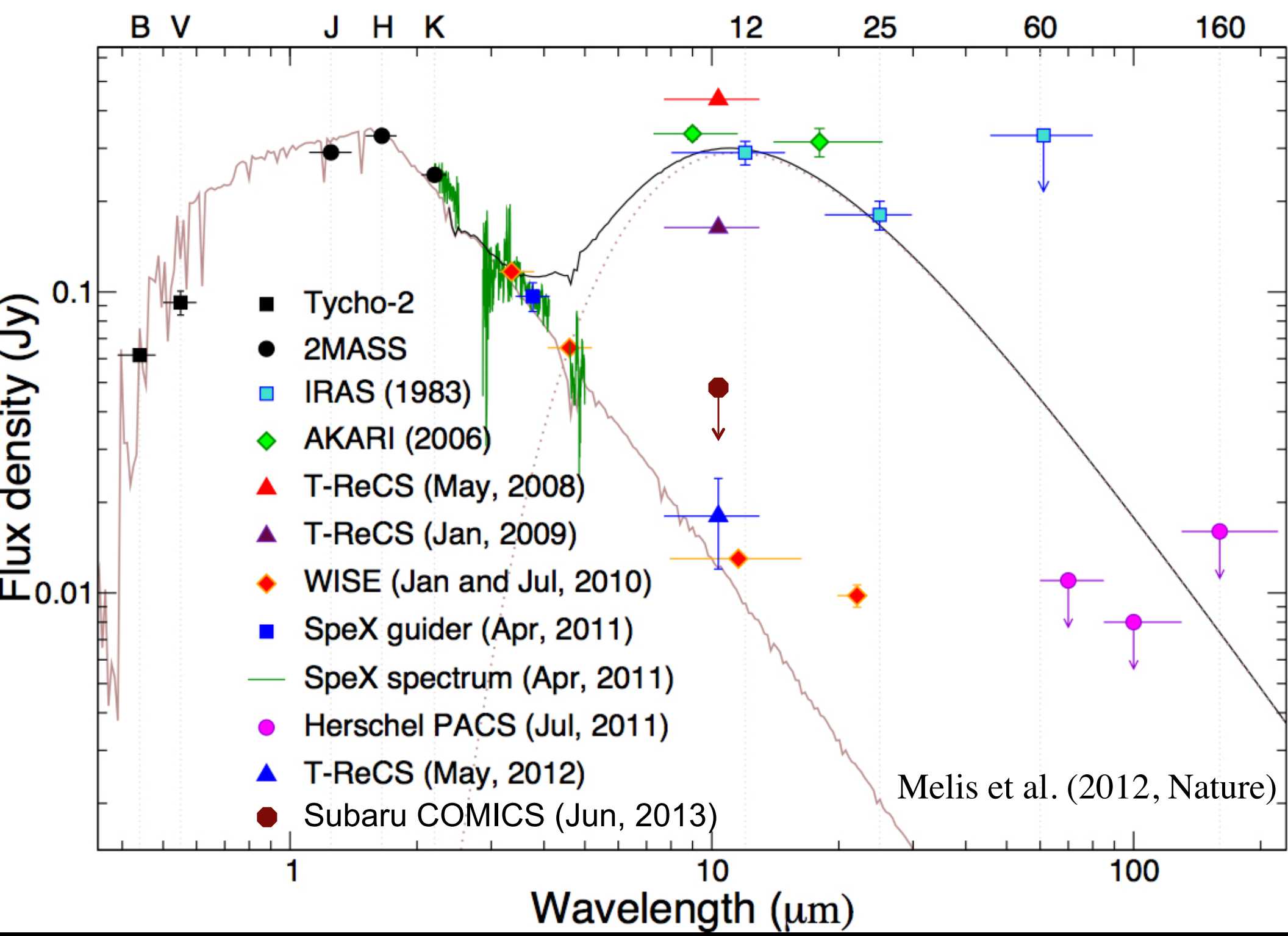
BD+20 307: one million times dustier than the Sun's zodiacal cloud.

Signatures of Rocky Planet Formation/Evolution



BD+20 307: one million times dustier than the Sun's zodiacal cloud.


B V J H K 12 25 60 160
Flux density (Jy)
0.1
0.01
Tycho-2
2MASS
IRAS (1983)
AKARI (2006)
T-ReCS (May, 2008)
T-ReCS (Jan, 2009)
WISE (Jan and Jul, 2010)
SpeX guider (Apr, 2011)
SpeX spectrum (Apr, 2011)
Herschel PACS (Jul, 2011)
T-ReCS (May, 2012)
Melis et al. (2012, Nature)
1
10
100
Wavelength (μm)


B V J H K 12 25 60 160
Flux density (Jy)
0.1
0.01
Tycho-2
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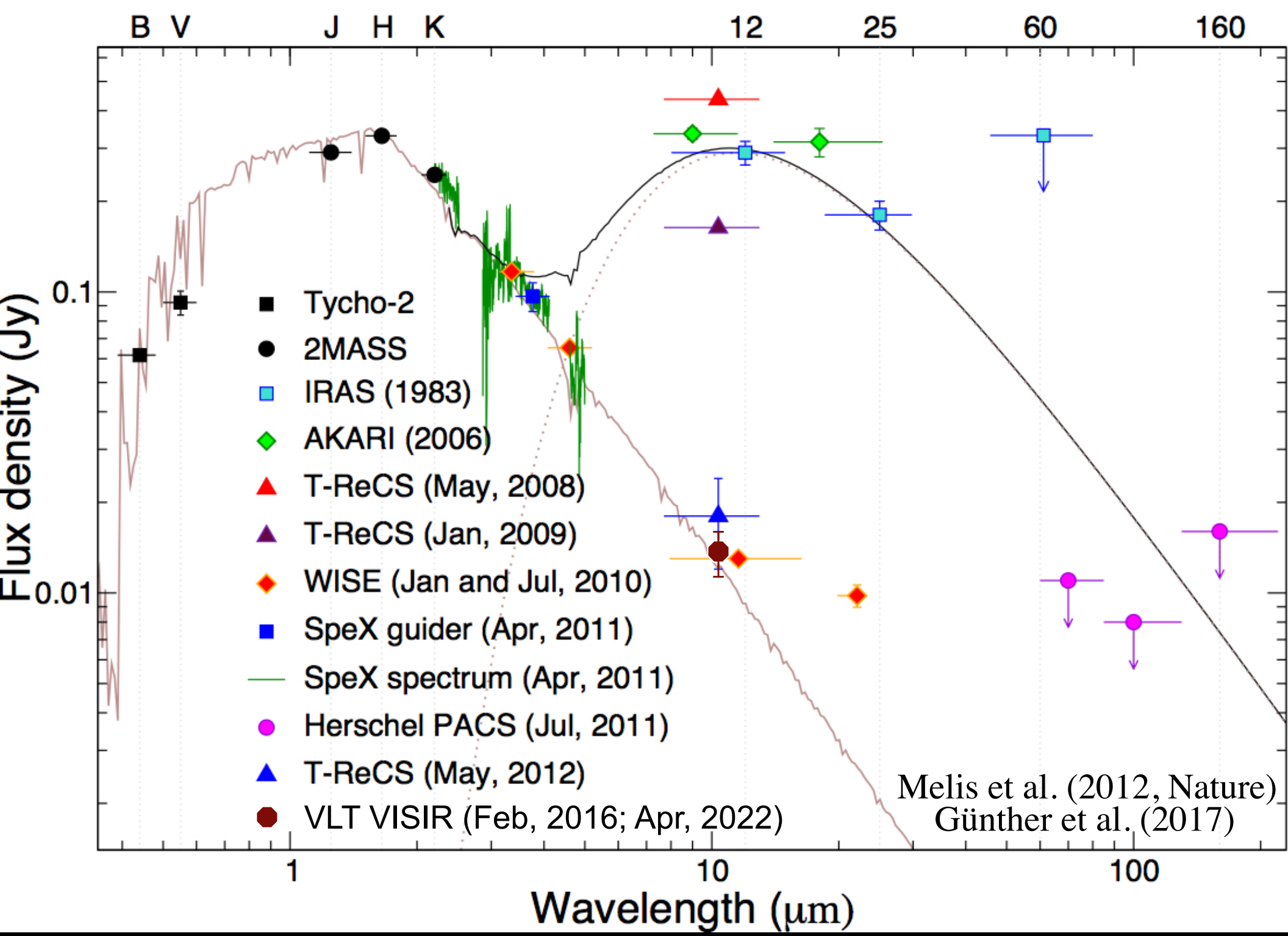
Subaru COMICS (Jun, 2013)
Melis et al. (2012, Nature)
1
10
100
Wavelength (μm)


B V
J H K
12
25
60
160
Flux density (Jy)
0.1
0.01
Tycho-2
2MASS
IRAS (1983)
AKARI (2006)
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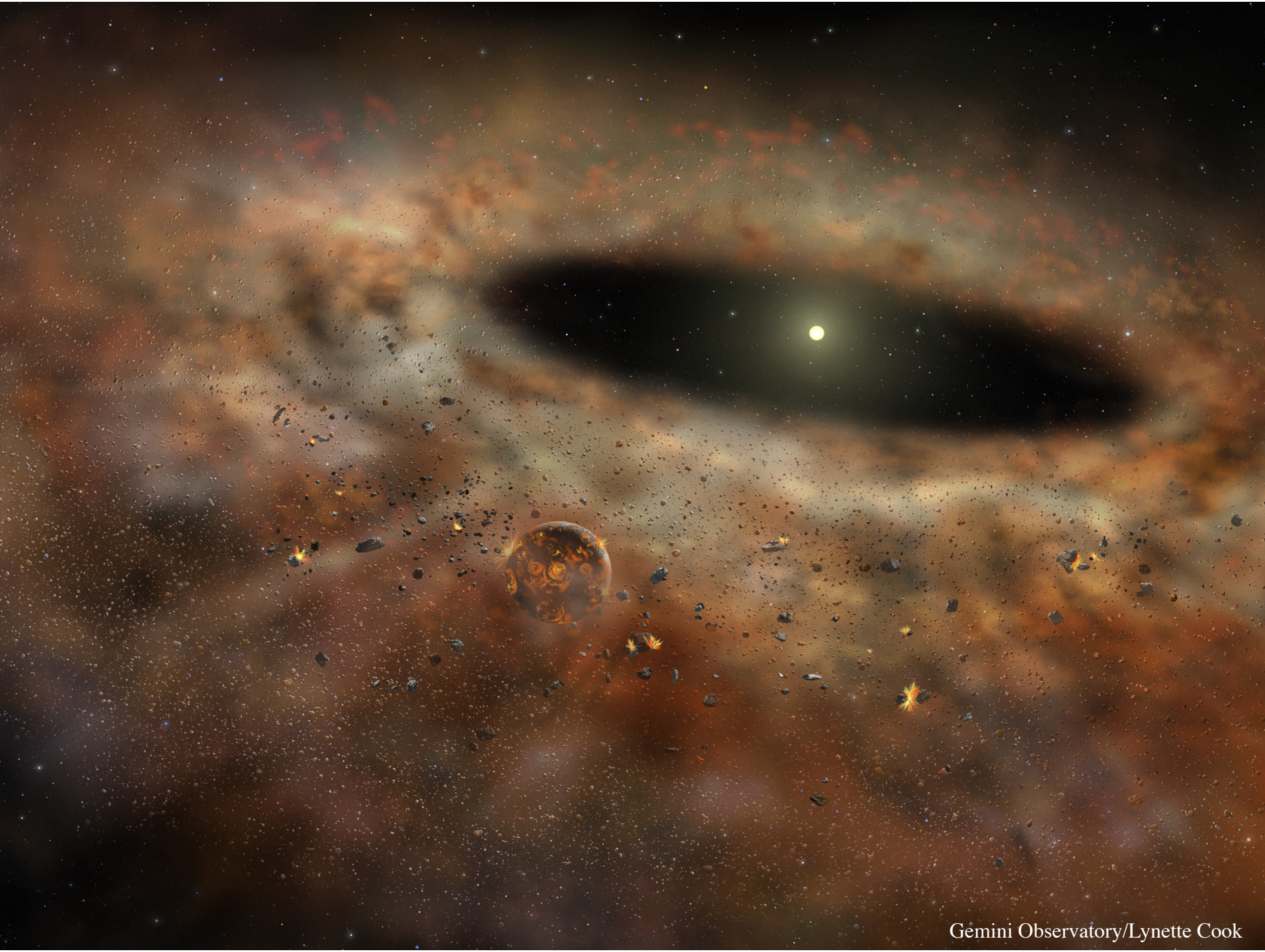
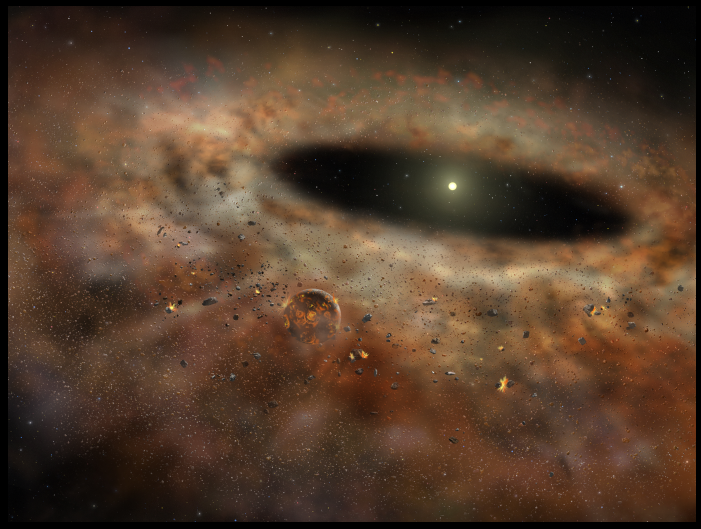
T-ReCS (Jan, 2009)
WISE (Jan and Jul, 2010)
SpeX guider (Apr, 2011)
SpeX spectrum (Apr, 2011)
Herschel PACS (Jul, 2011)
T-ReCS (May, 2012)
VLT VISIR (Feb, 2016; Apr, 2022)
Melis et al. (2012, Nature)
Günther et al. (2017)
1
10
100
Wavelength (μm)


Gemini Observatory/Lynette Cook


Where did it go?
Gemini Observatory/Lynette Cook

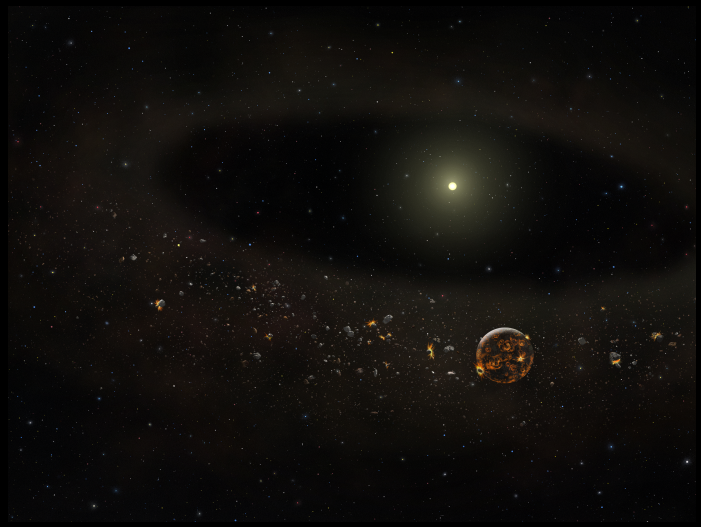
Disk Parameters



Pre-2009 Epoch

- $T_{dust} \approx 450$ K; $R_{dust} \approx 0.4$ AU
- $L_{IR}/L_* \approx 11\%$
- $M_{dust} > 5 \times 10^{21}$ g

Post-2009 Epoch

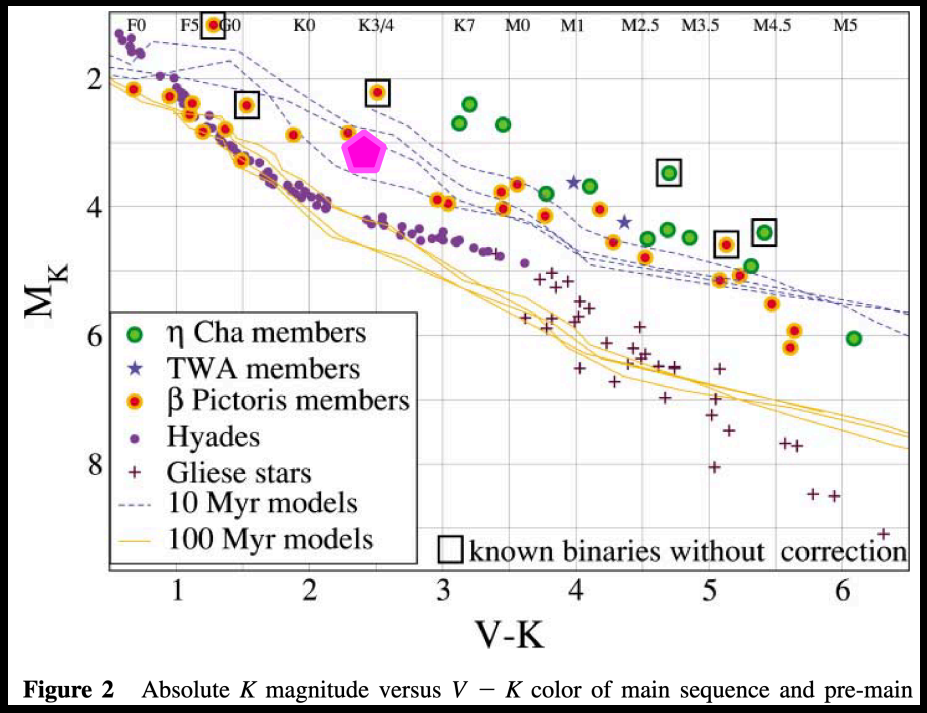


- $T_{dust} \sim 200$ K; $R_{dust} \sim 2$ AU
- $L_{IR}/L_* \approx 0.1\%$
- $M_{dust} > 10^{21}$ g
- $L_{IR}/L_* < 0.05\%$ for any remaining 450 K dust.

$\Rightarrow$ Grains with radius up to ~1mm must be removed from 0.4 AU ($L_{IR}/L_* \propto a^{-1/2}$).

What about the star?

TYC 8241 2652 1 itself is pretty normal for its age and spectral type.



Zuckerman & Song (2004)

Figure 2 Absolute K magnitude versus $V - K$ color of main sequence and pre-main

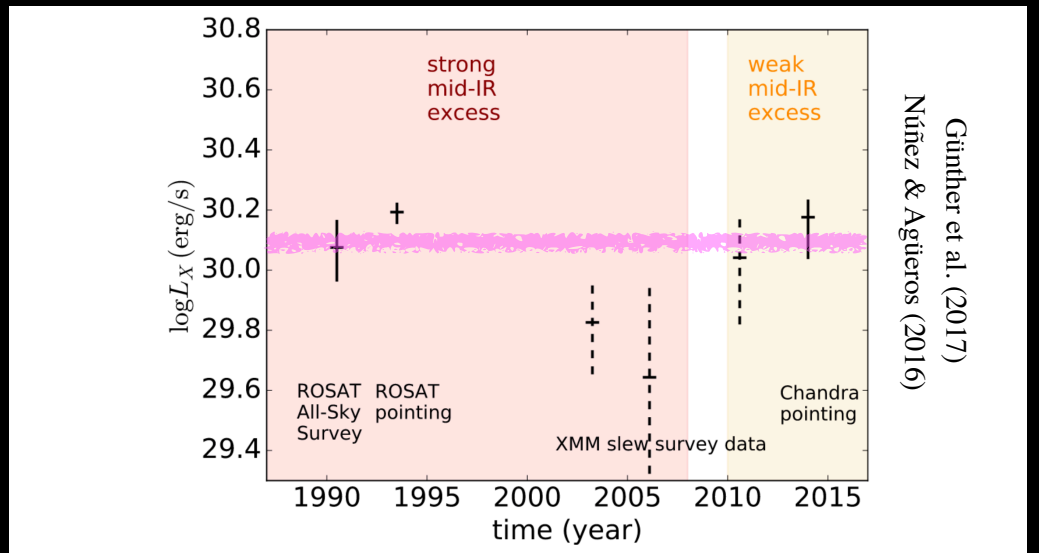
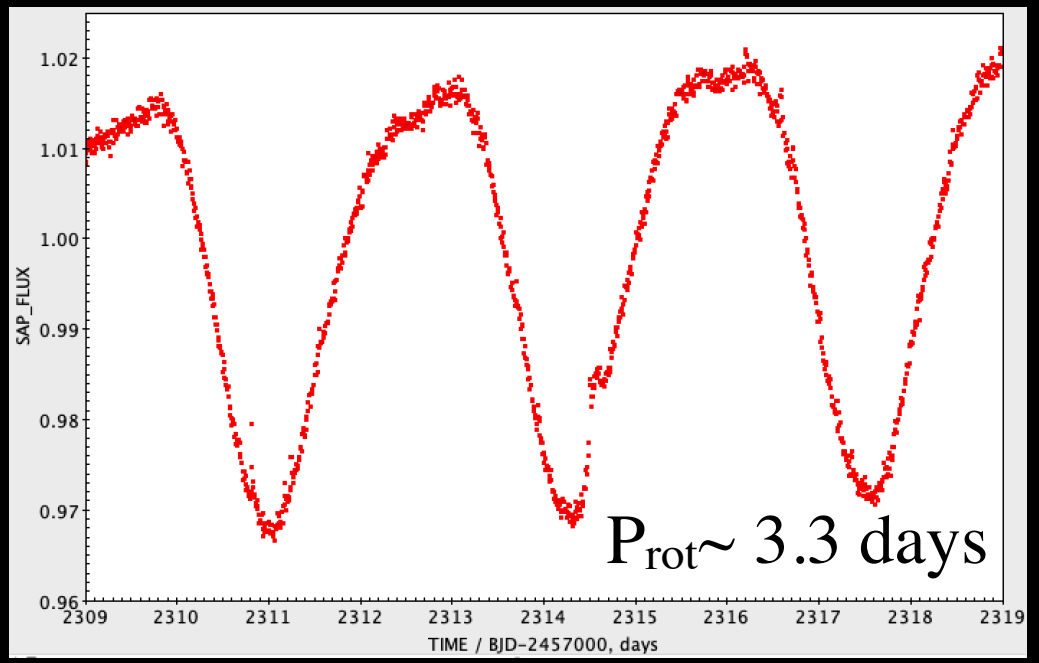
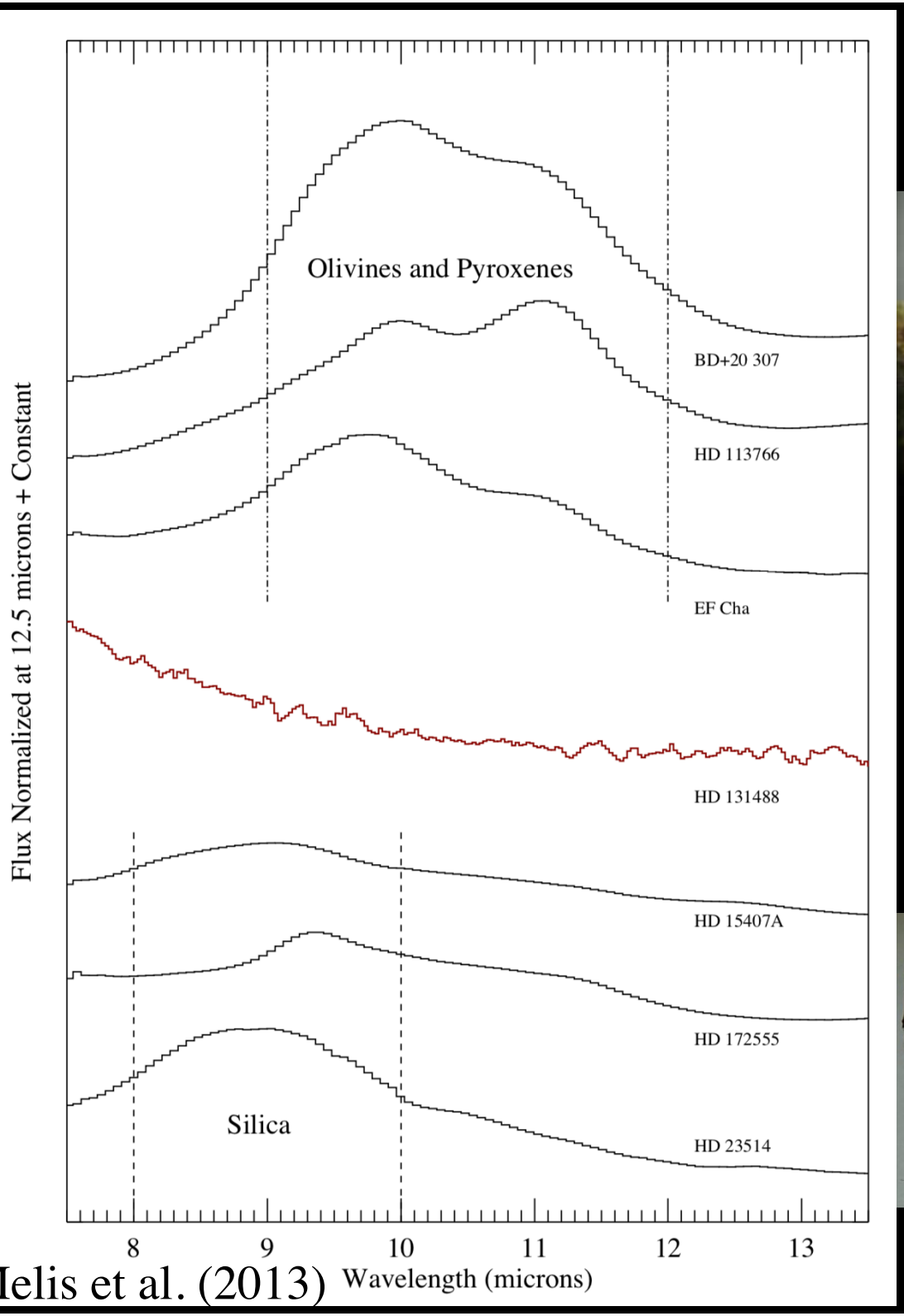


Fig. 2. Observed X-ray luminosity of TYC 8241 2652 1 is constant



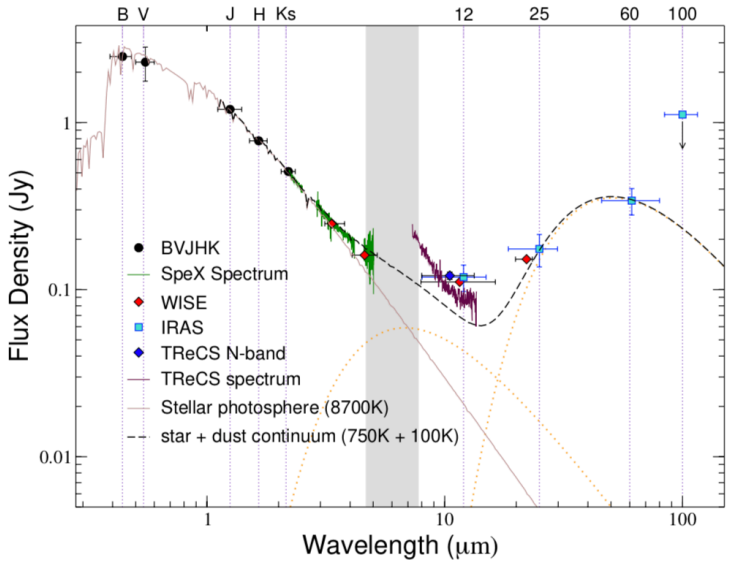
Alien Dust



Melis et al. (2013)

?

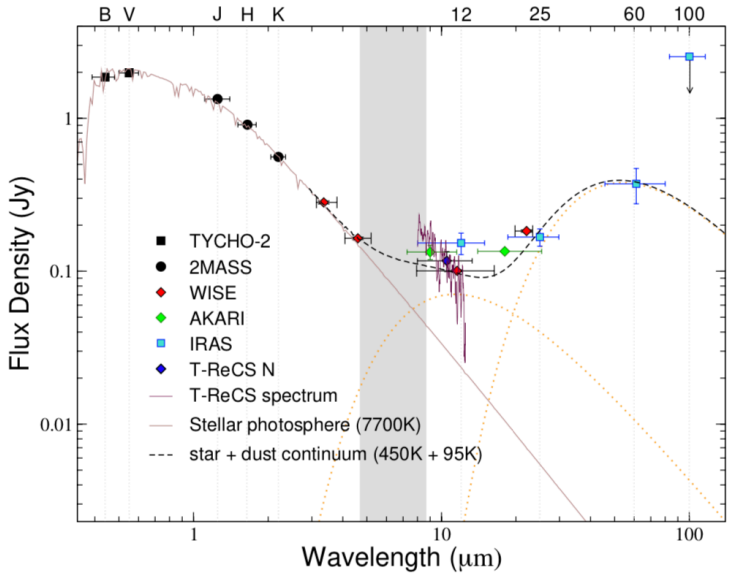
Alien Dust: host planetary systems

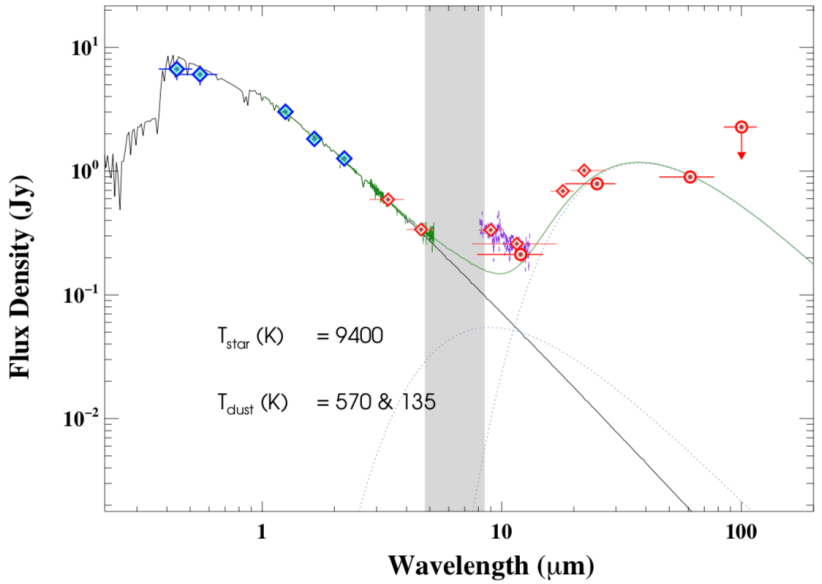


~5-20 Myr old

Melis et al. (2013)

Lisse et al. (2017)





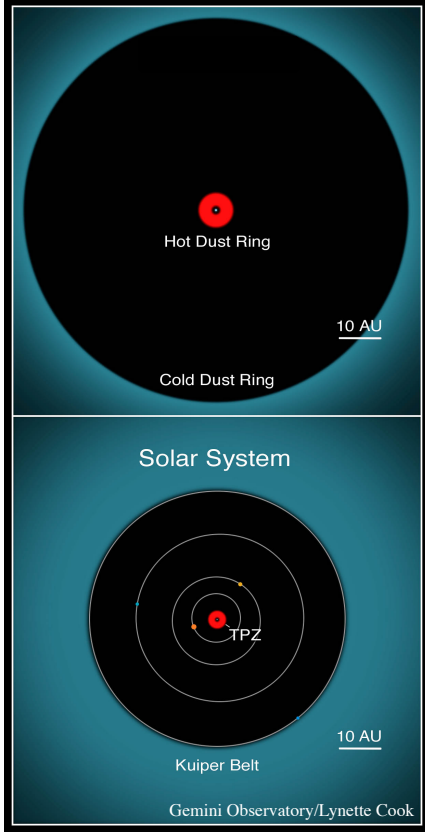
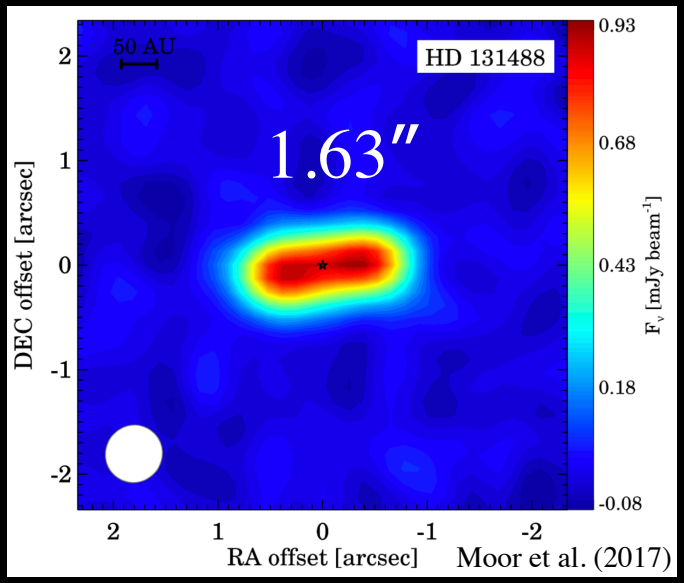
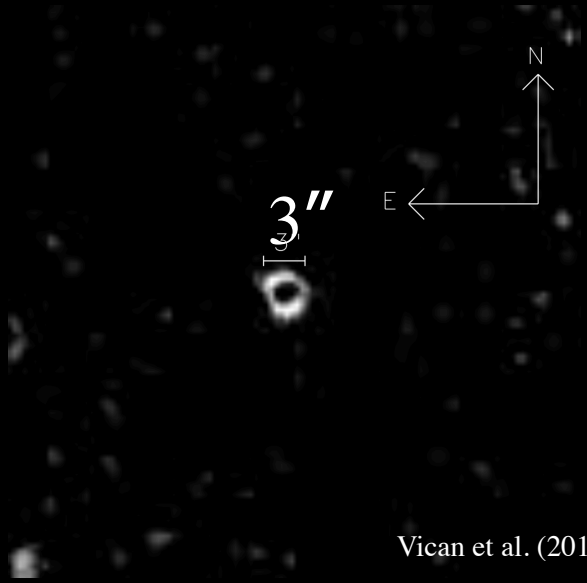
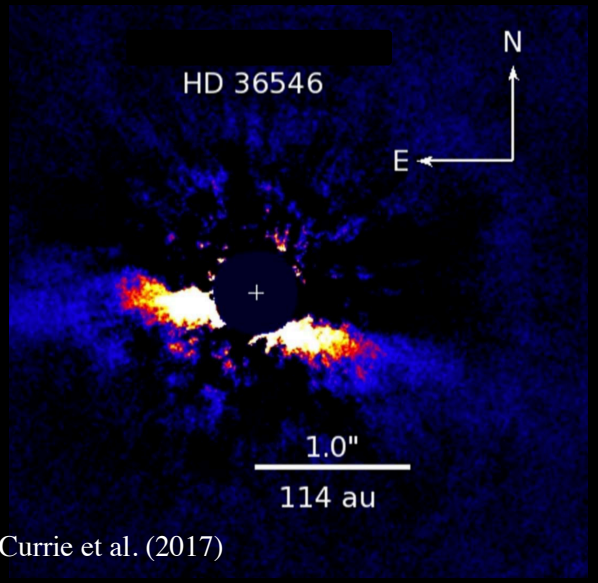


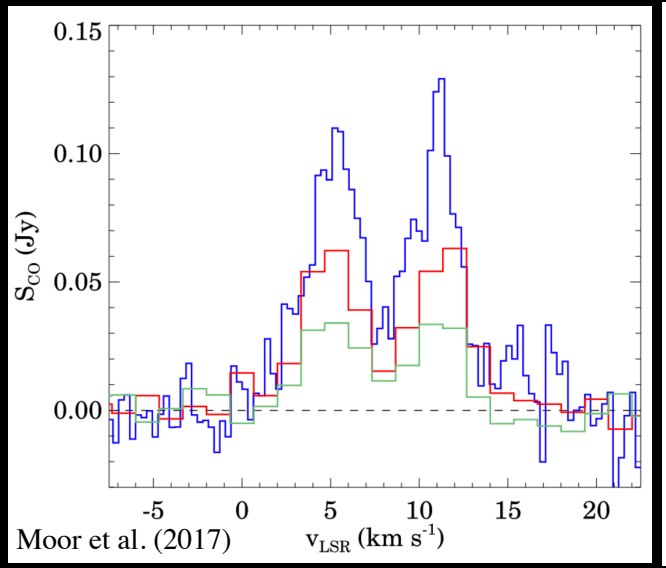
Figure 2: Spectral energy distributions for HD 131488 (top), HD 121191 (bottom left), and HD 36546 (bottom right). All three stars exhibit excess emission longward of 5 μm that turns over

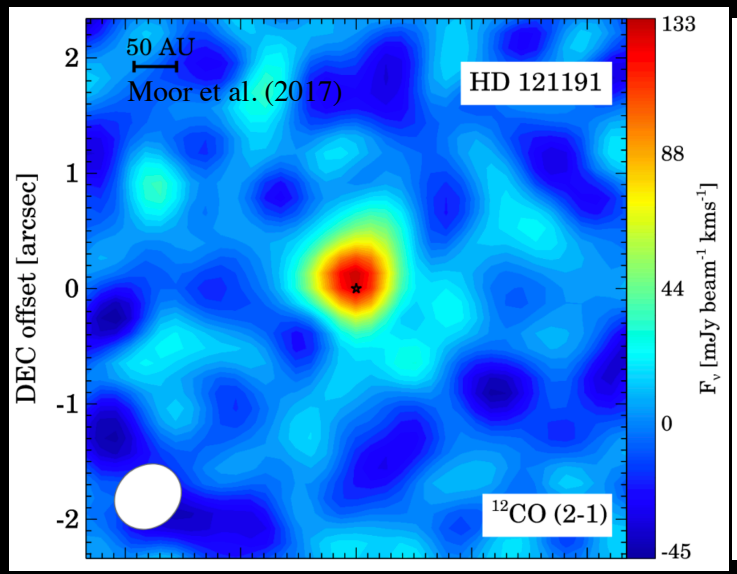
Alien Dust: host planetary systems

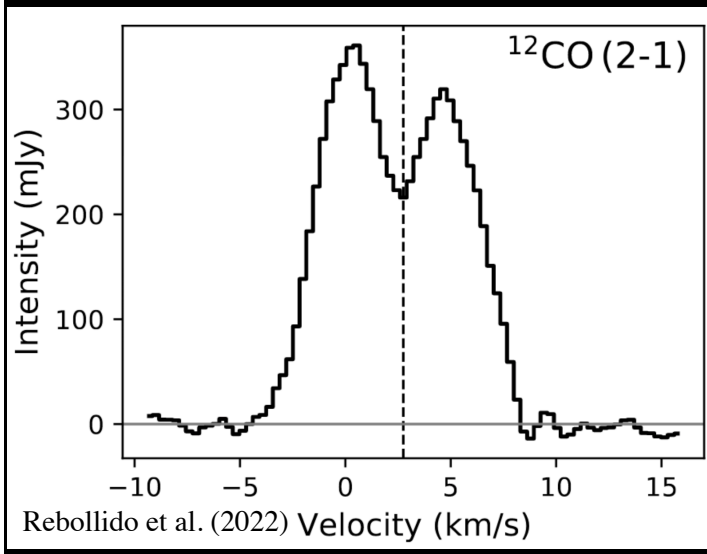












Alien Dust: just a bunch of comets?

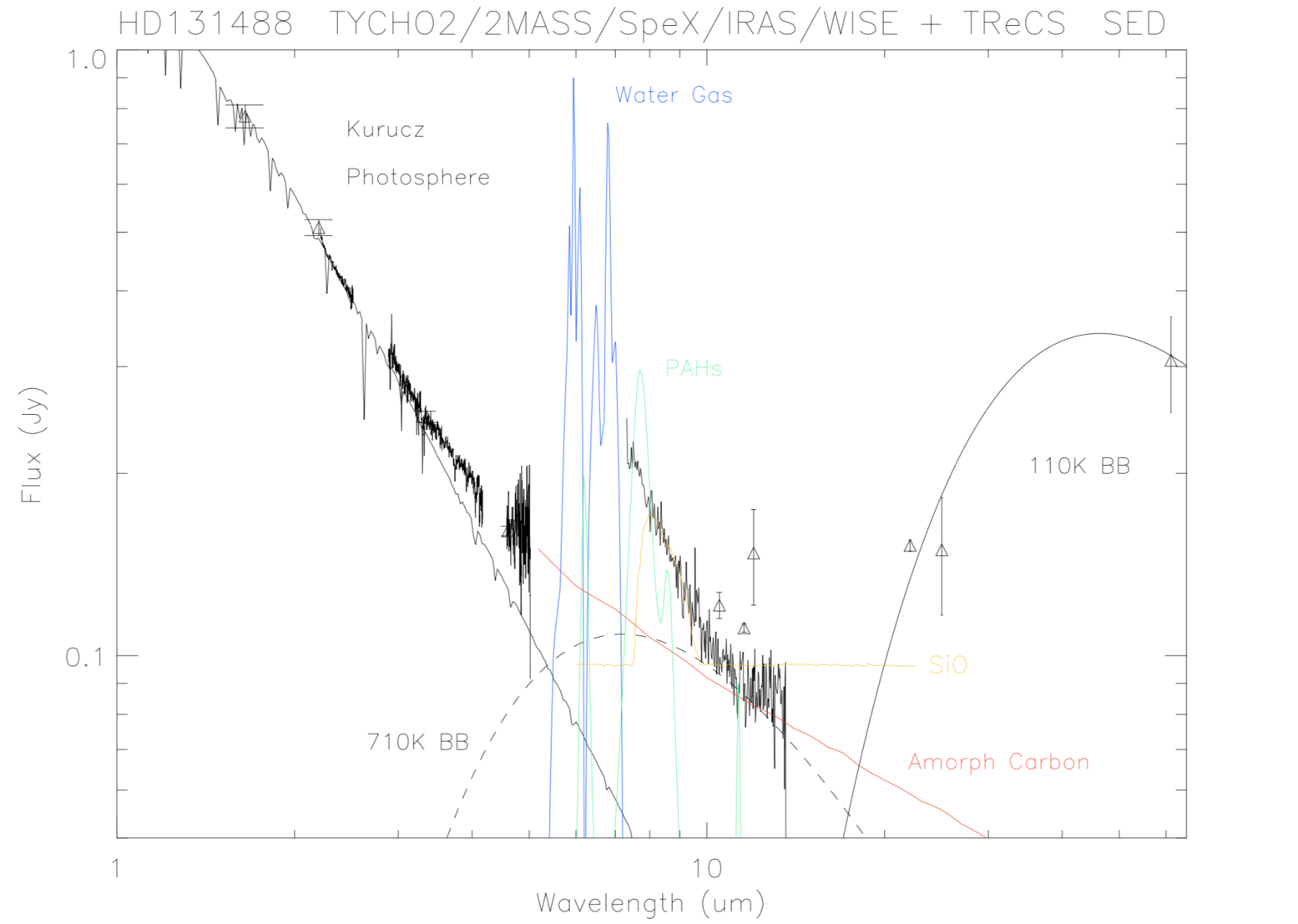
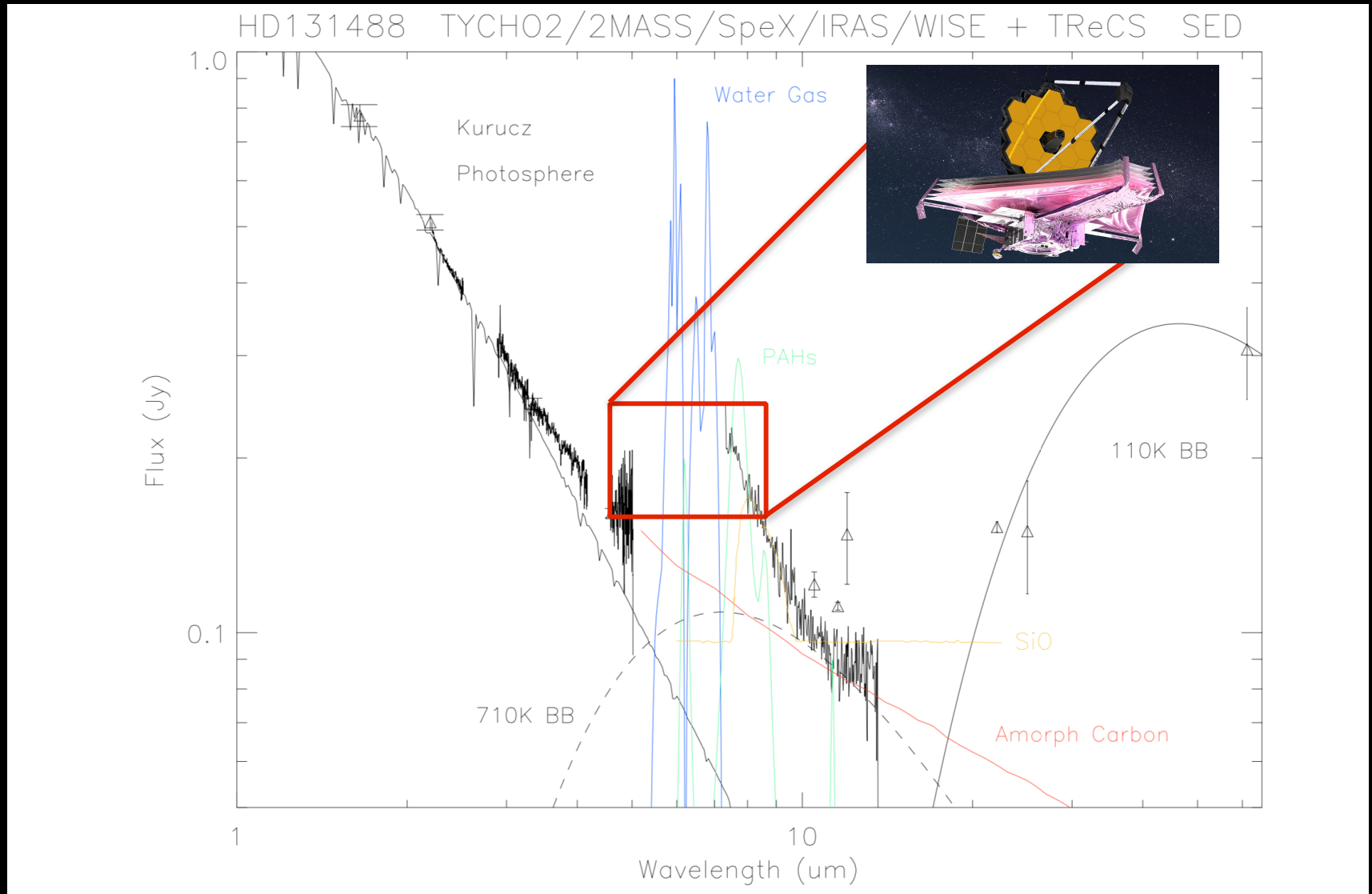


Figure 4: An alternative model to explain the unusual mid-infrared spectral feature seen in HD 131488 (and similarly HD 121191 and HD 36546) as described in Lisse et al. (2017) and Melis et al. (2013). In this model the dust is produced by dynamically hot comet-like bodies colliding

Alien Dust: just a bunch of comets?



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Alien Dust: …or something truly strange?

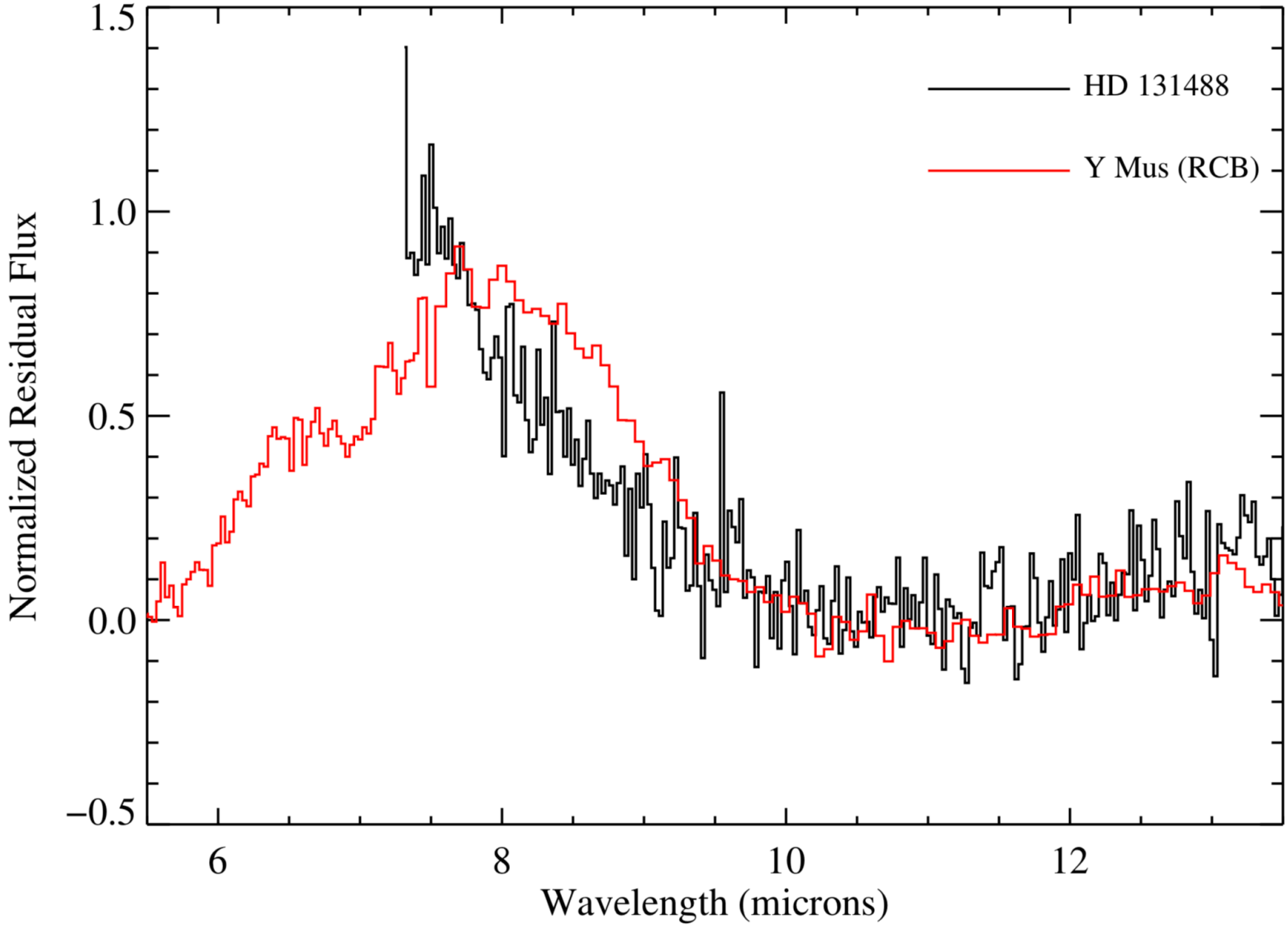
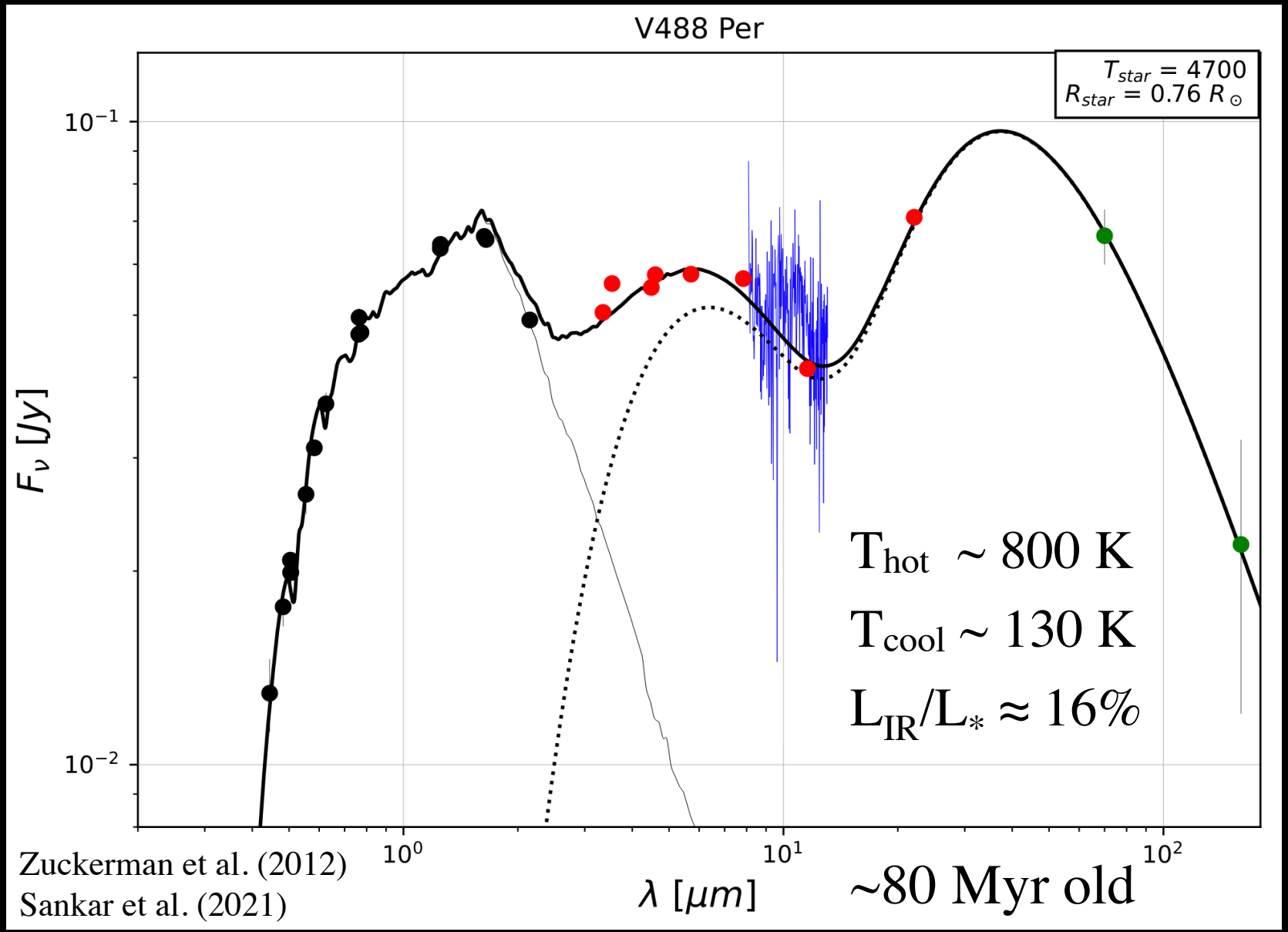
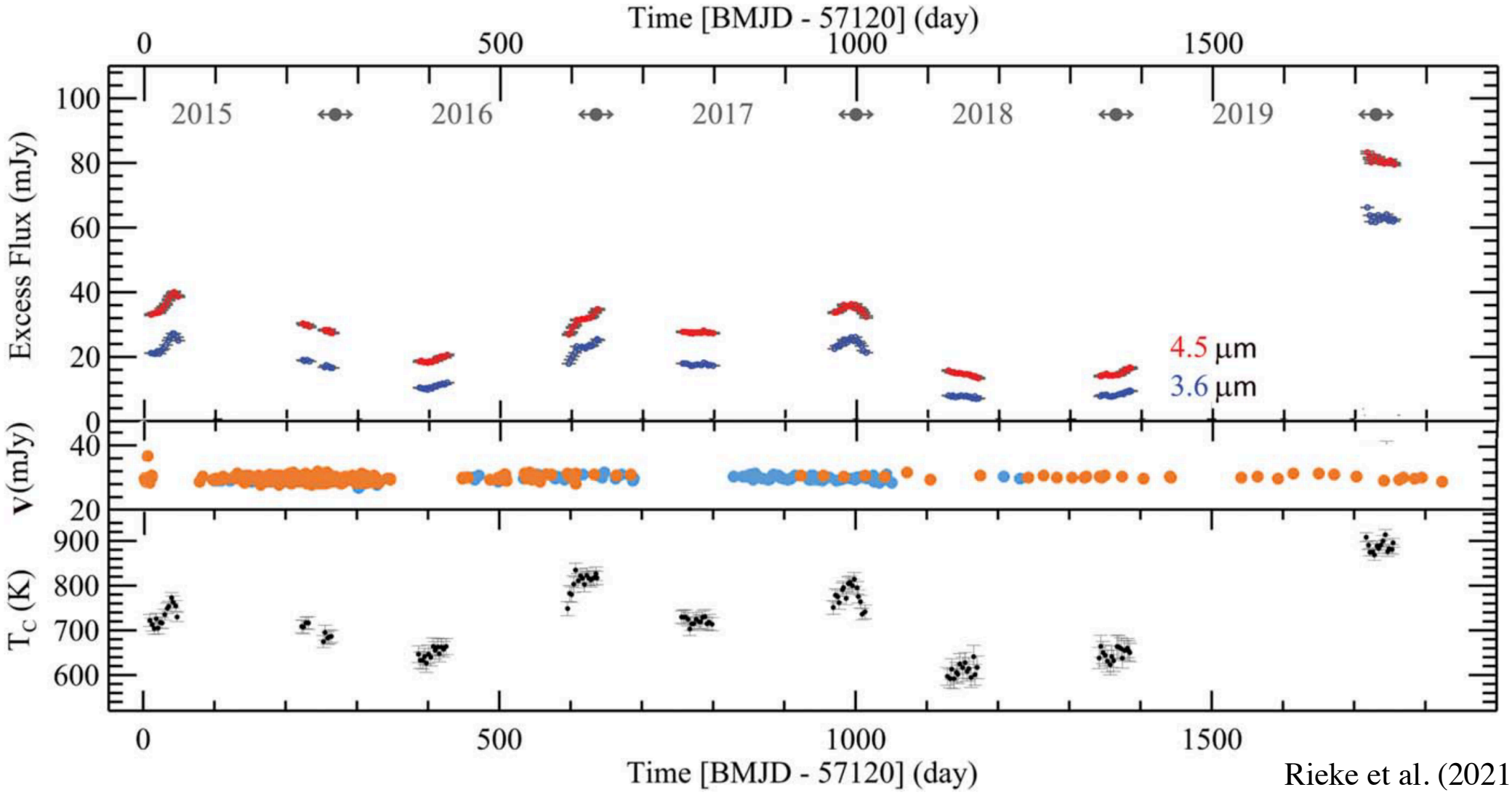


Figure 3: Mid-infrared spectra for HD 131488 and the RCB star Y Mus (García-Hernández et al. 2011ab, 2013). Dust and stellar continuum emission are subtracted from each spectrum, then the

The dustiest main sequence star known



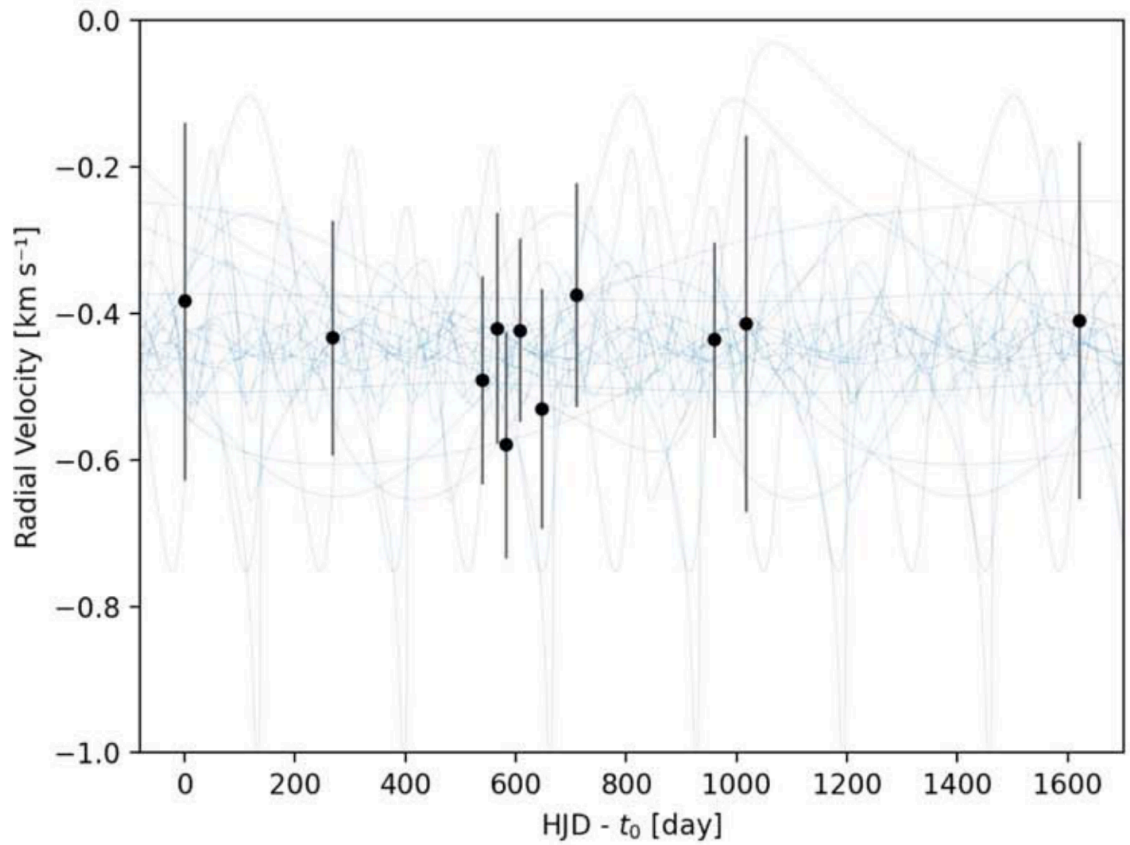
V488 Per: also variable in the IR

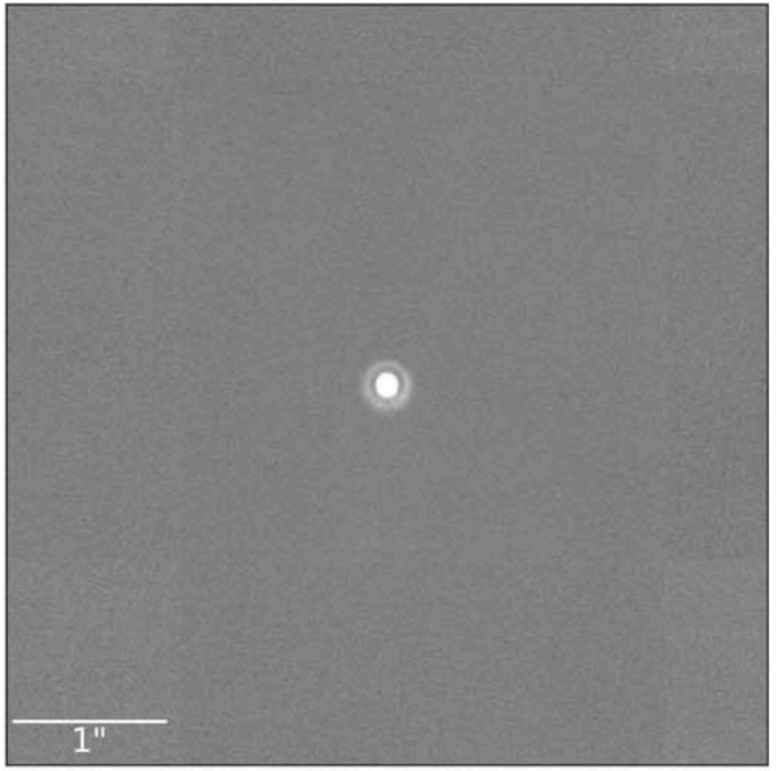


Rieke et al. (2021)

V488 Per: why so dusty? and variable?

Is it a companion stirring an asteroid belt?





Sankar et al. (2021)

V488 Per: why so dusty? and variable?

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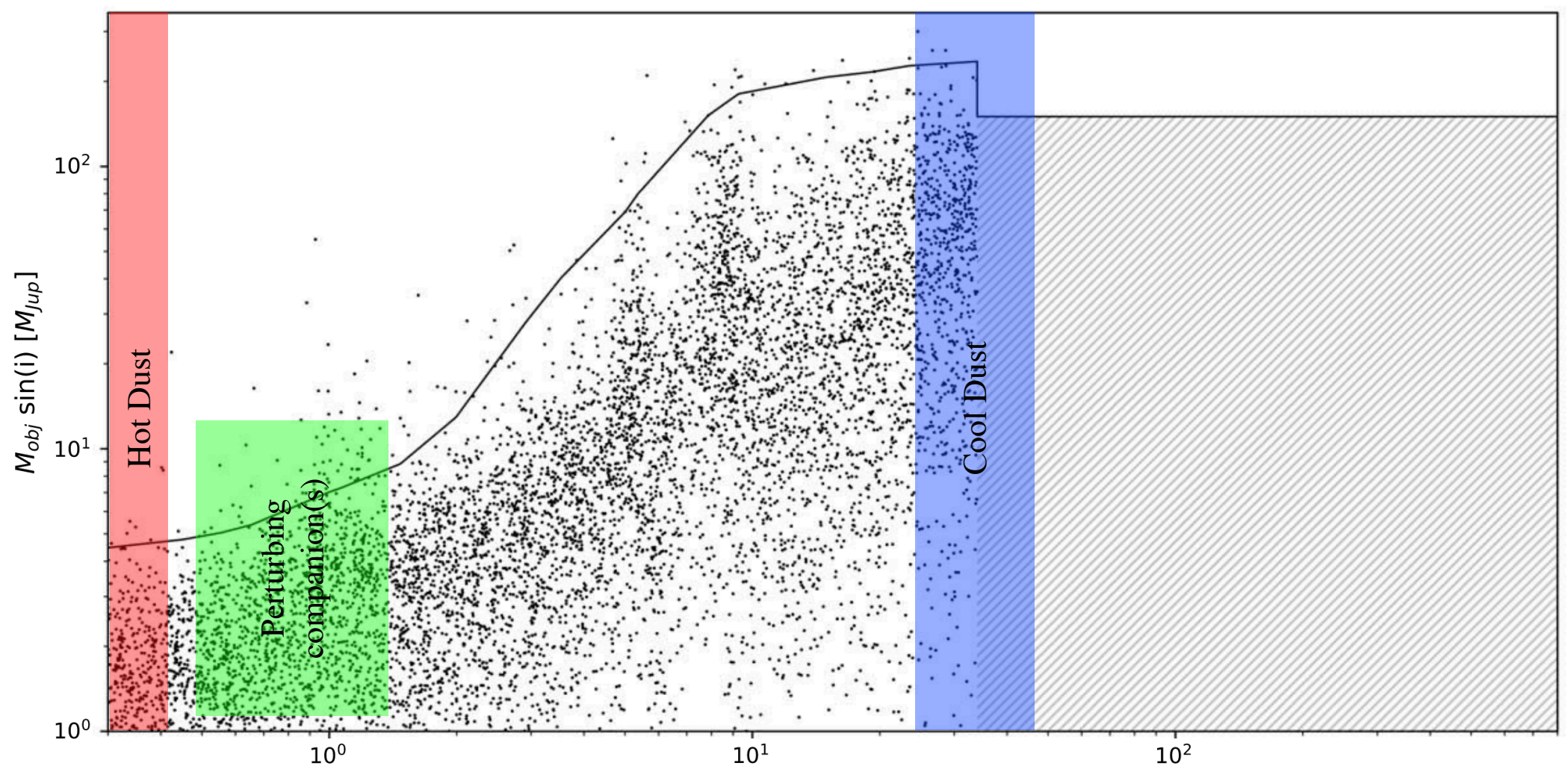
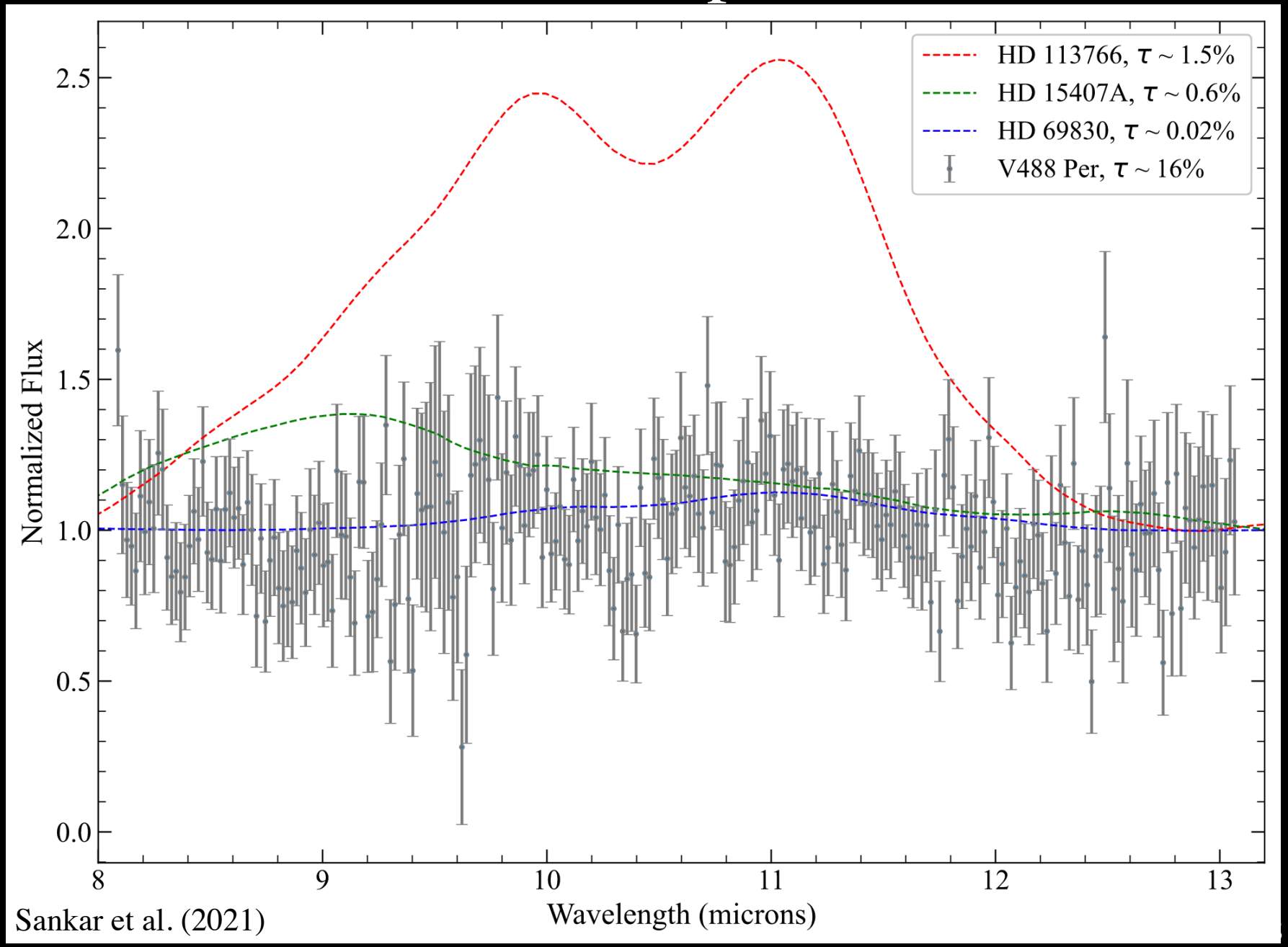


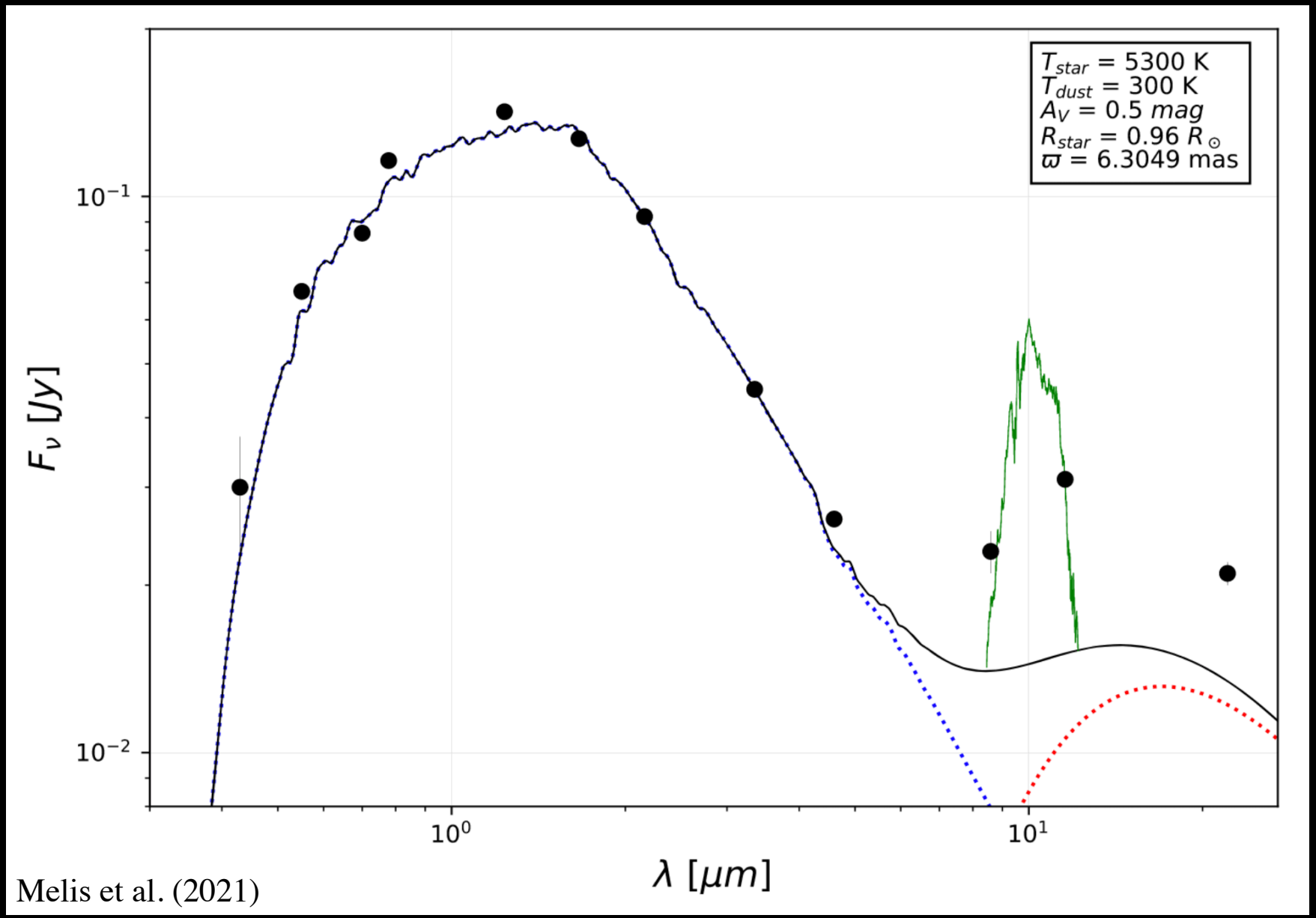
Sankar et al. (2021); Rieke et al. (2021)

V488 Per: but no mid-IR spectral feature?



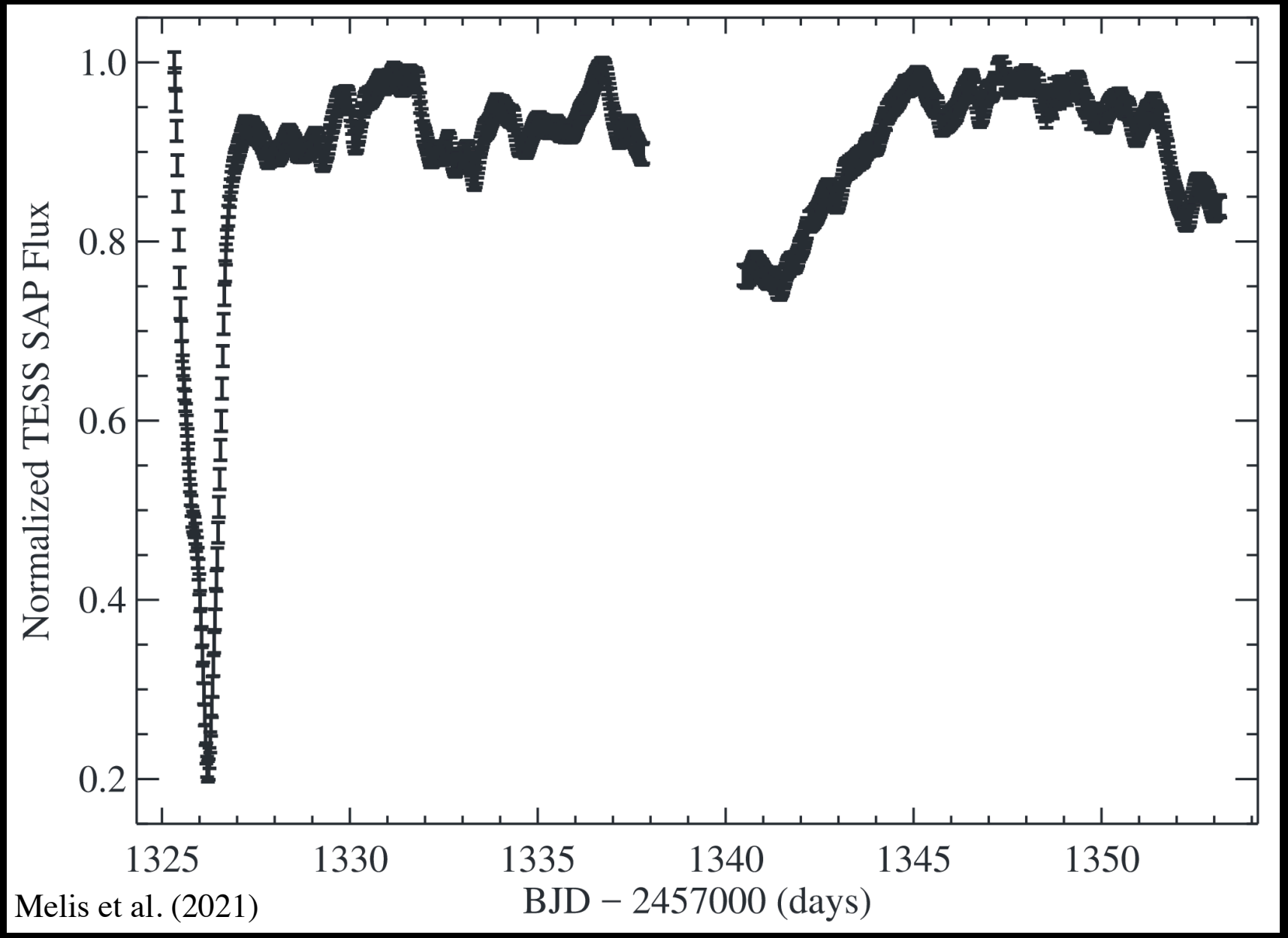
Sankar et al. (2021)

TYC 8830 410 1: dusty

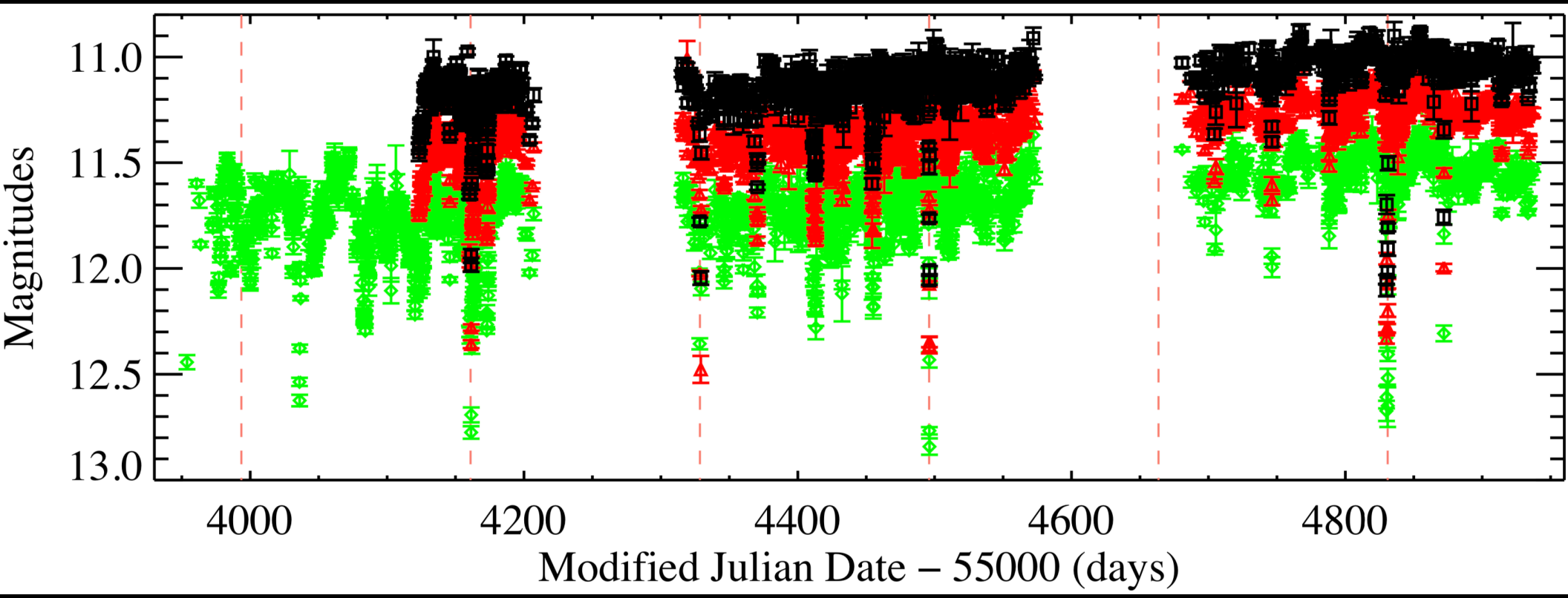


Melis et al. (2021)

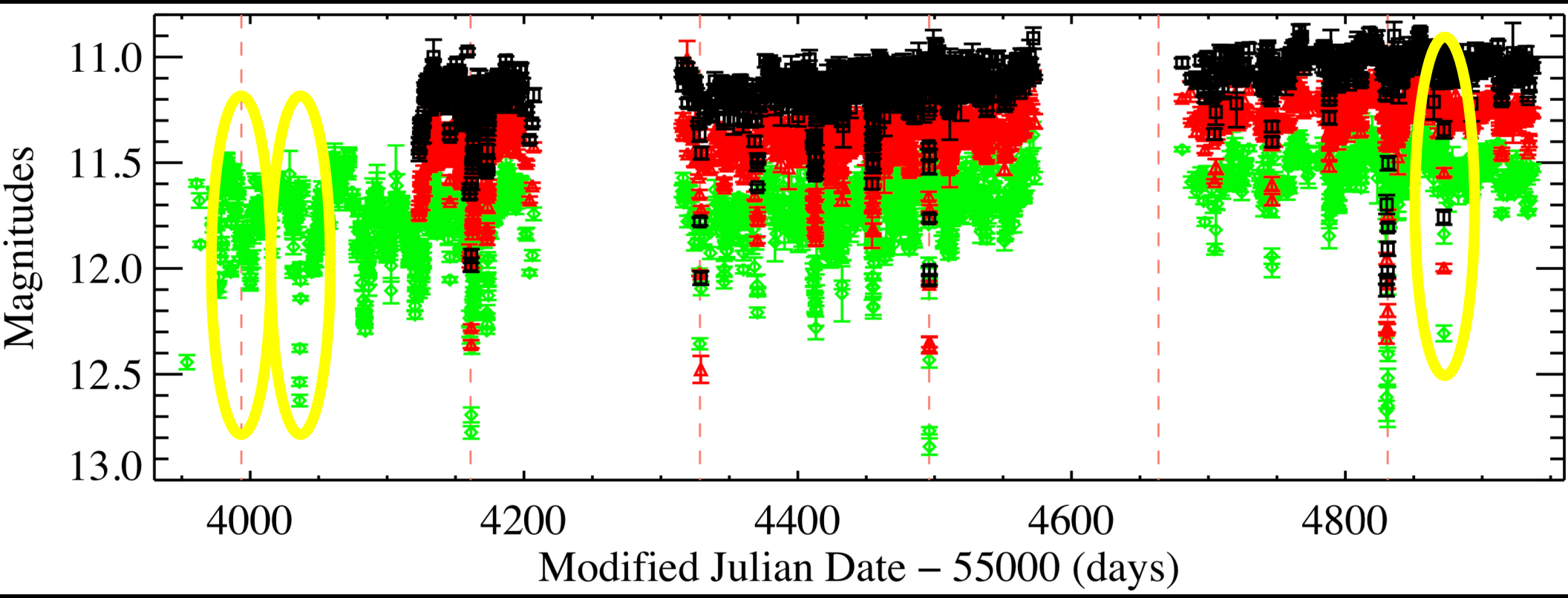
TYC 8830 410 1: dusty dipper



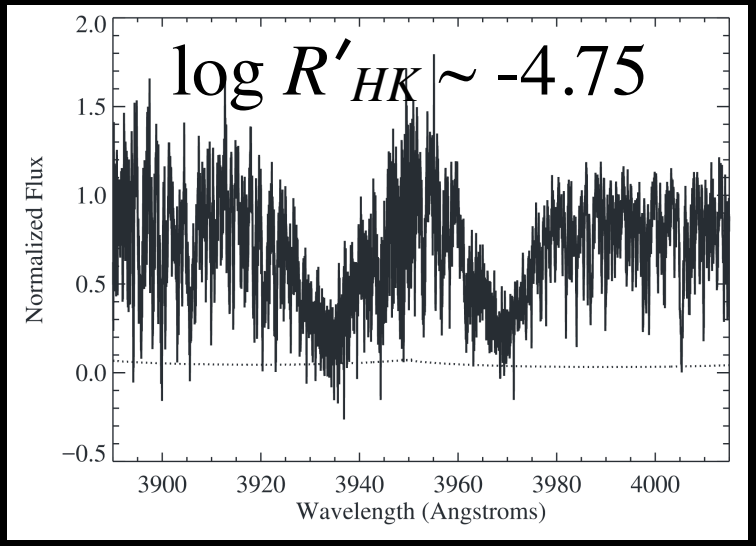
TYC 8830 410 1: dusty dipper



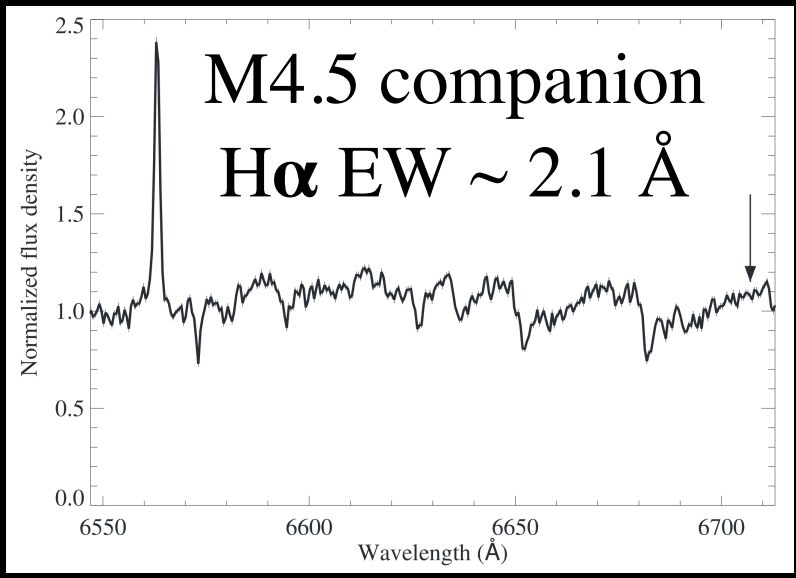
TYC 8830 410 1: dusty dipper

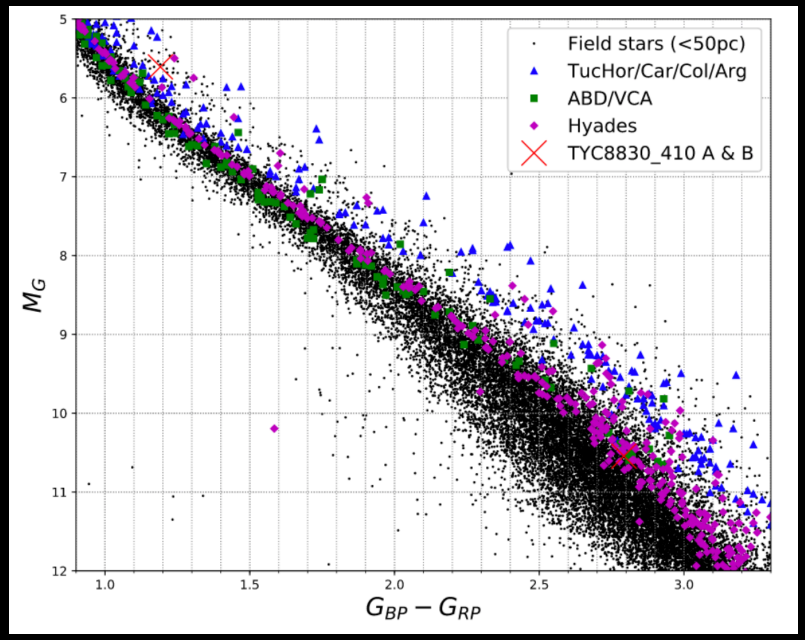


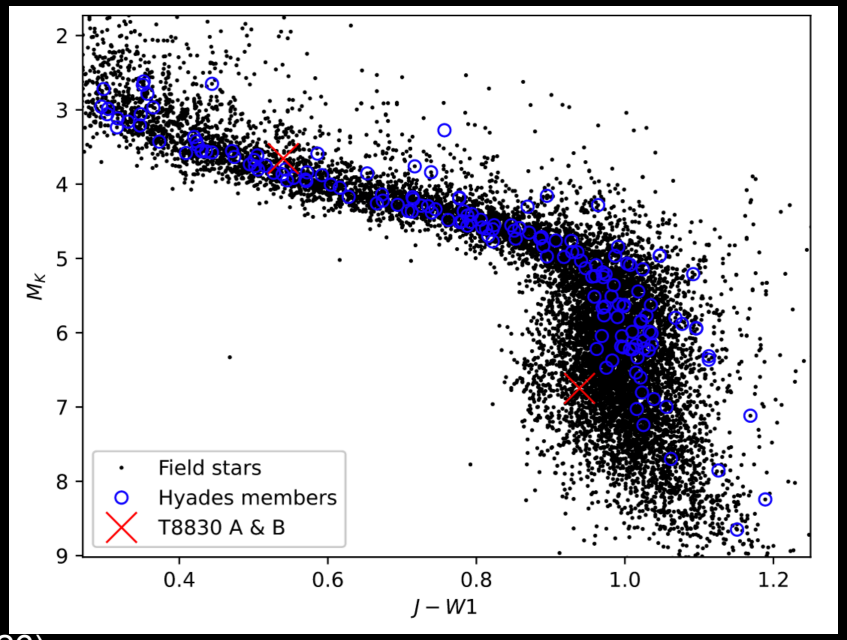
TYC 8830 410 1: dusty old dipper



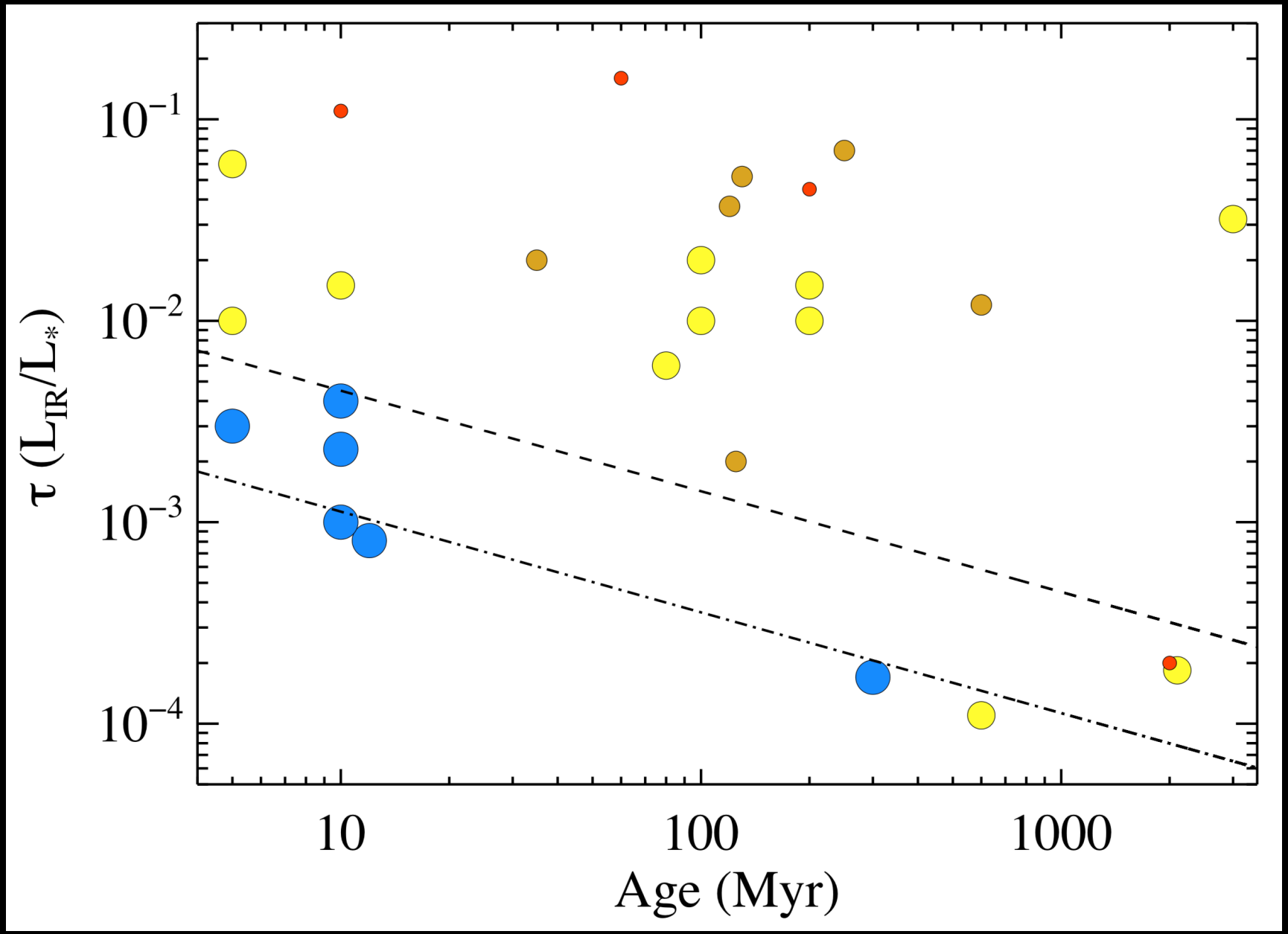
300-600 Myr old!



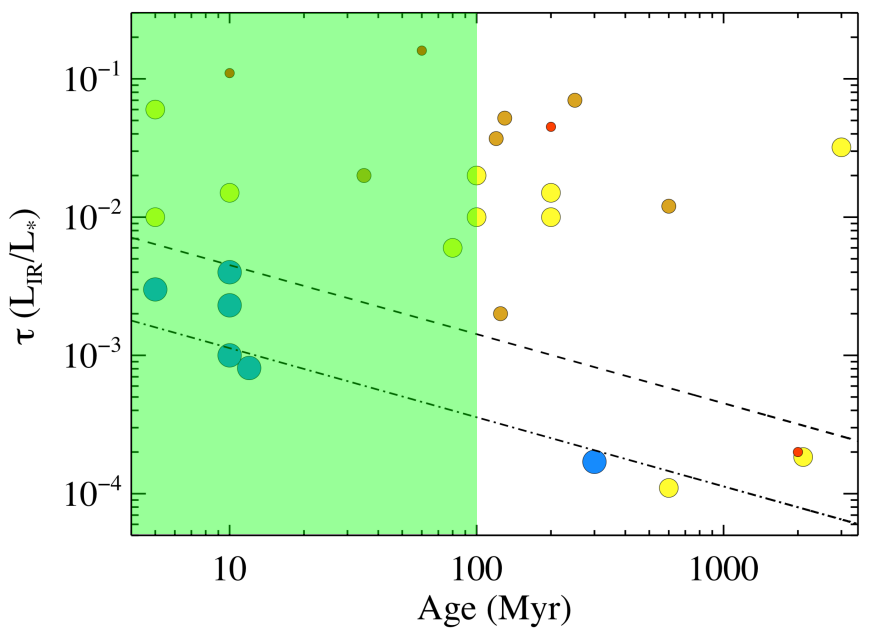




The Dustiest Main Sequence Stars



Youngins: planet formation?




Gemini Observatory/Lynette Cook

Giant-impact formation events should occur at ages <~100 Myr (Hartmann & Davis 1975; Genda et al. 2015; Levison et al. 2015).

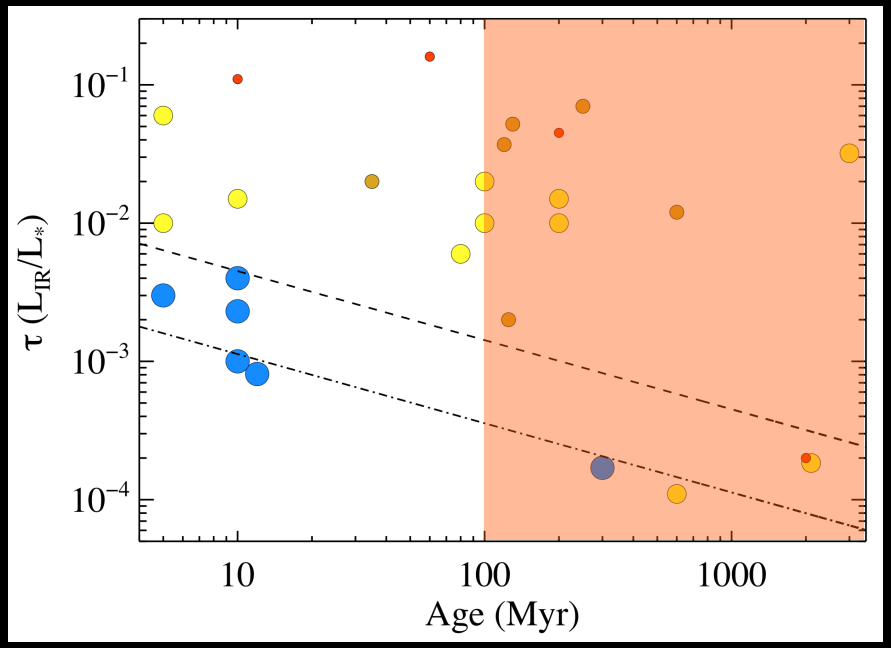
- ~0.5% of FGK stars in the 10-100 Myr age range have extreme quantities of warm dust (Balog et al. 2009; Melis et al. 2010).

- But there should be ~1 Earth-like planet for every FGK star! (Petigura & Marcy 2013; Burke et al. 2015).

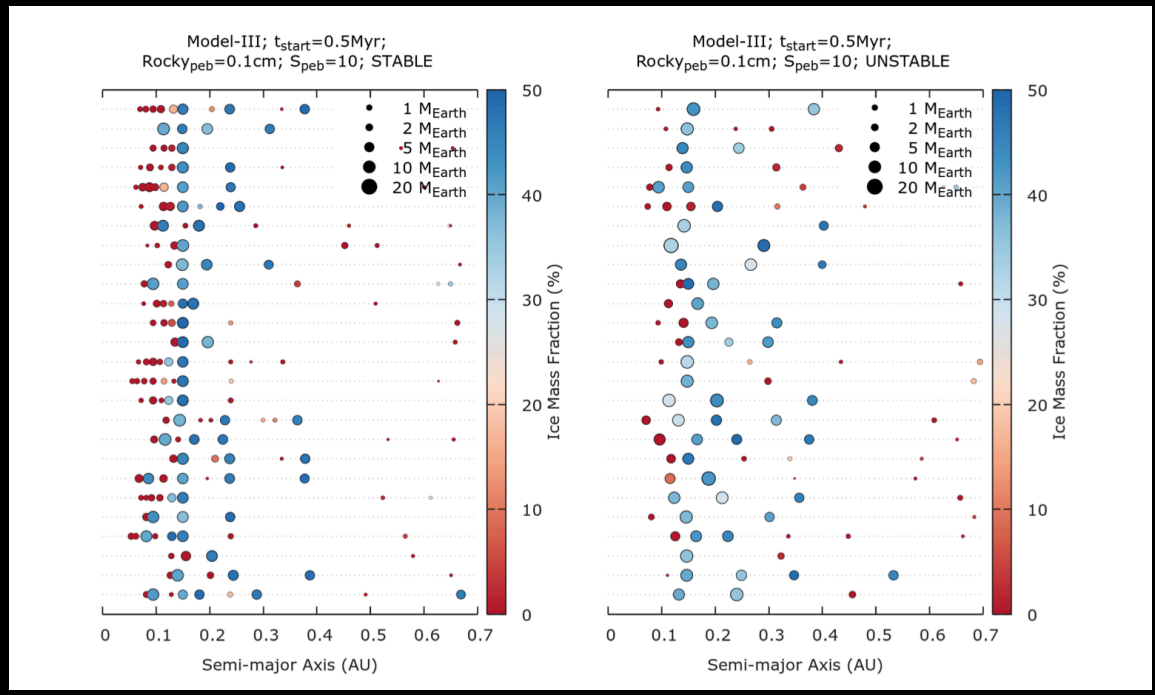
Where are all the dusty stars?

Perhaps some process acts to remove dust effectively (Najita, Kenyon, et al.).

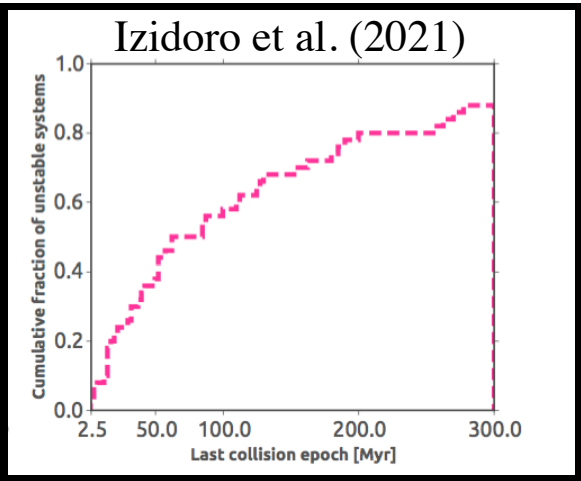
Older and old: instabilities?



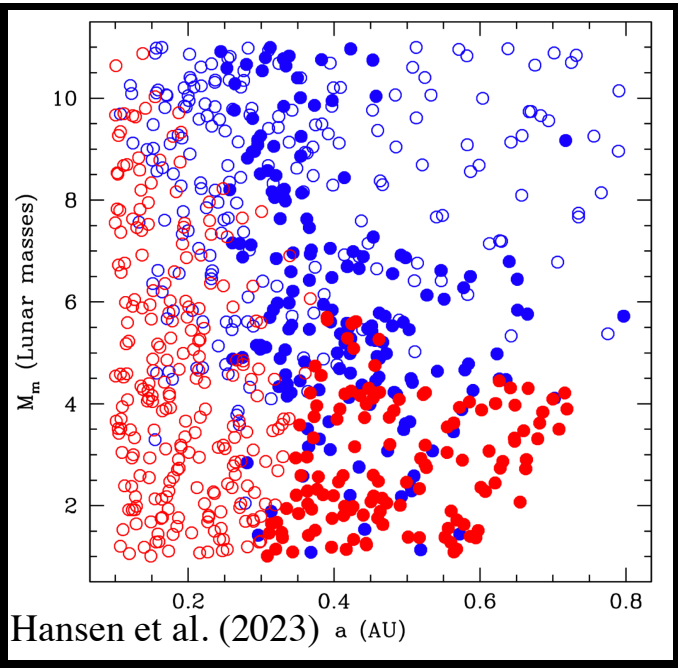
Tight-packed inner planetary systems



Izidoro et al. (2021)



Exomoons

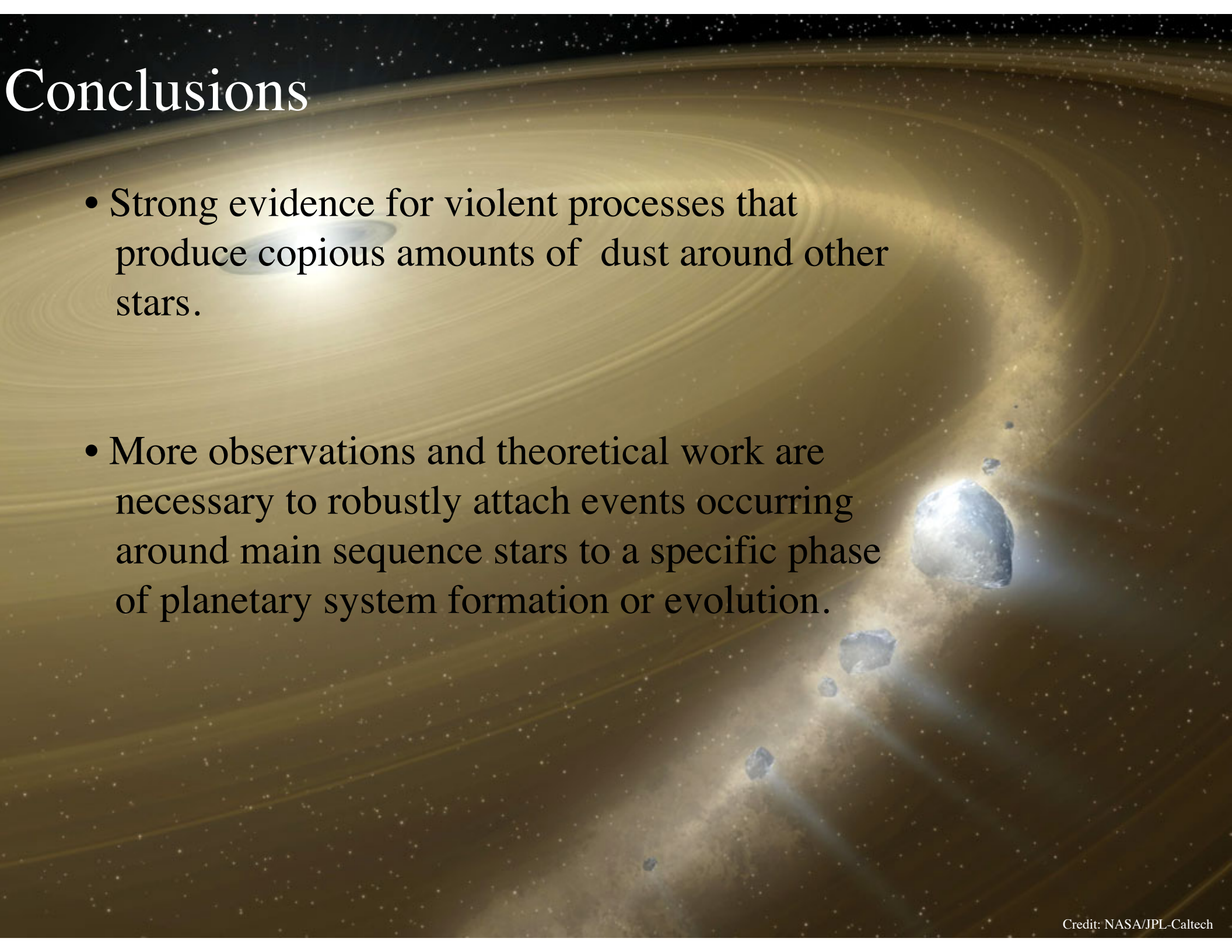


Hansen et al. (2023)

Conclusions

- Strong evidence for violent processes that produce copious amounts of dust around other stars.

- More observations and theoretical work are necessary to robustly attach events occurring around main sequence stars to a specific phase of planetary system formation or evolution.



Credit: NASA/JPL-Caltech