Tracking Debris Disks in the β Pictoris Moving Group

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We need 3 Critical Things

- Well-defined membership
- Consistent physical properties of the disks
- Consistent observations of scattered light and thermal emission

The β Pictoris Moving Group

- Based on the work of many, co-eval stars to β Pictoris have been discovered in local space (Barrado y Navascues et al., 1999b; Zuckerman et al. 2001a; Schlieder et al., 2012; see Malo et al., 2013 for add'l references)
- At least 39 bona fide members with reliable parallaxes, up to dozens more candidates which are primarily M stars (Moor et al. 2013; Malo et al., 2013; Reidel et al., 2014)
- A commonly named non-member, **HD 15115** (Debes et al., 2009; Malo et al., 2013)

Traits of the BPMG

- U:-10.94 km/s, V:-16.25 km/s, W:-9.27 km/s d=9-73 pc
- Age ~22 Myr (i.e. Binks & Jeffries, 2013; Mamajek & Bell, in prep.)
- Members defined through obvious signs of youth, common galactic motions, distances, and sky positions
- Completeness and how well defined? Many candidates, only few "bona fides"

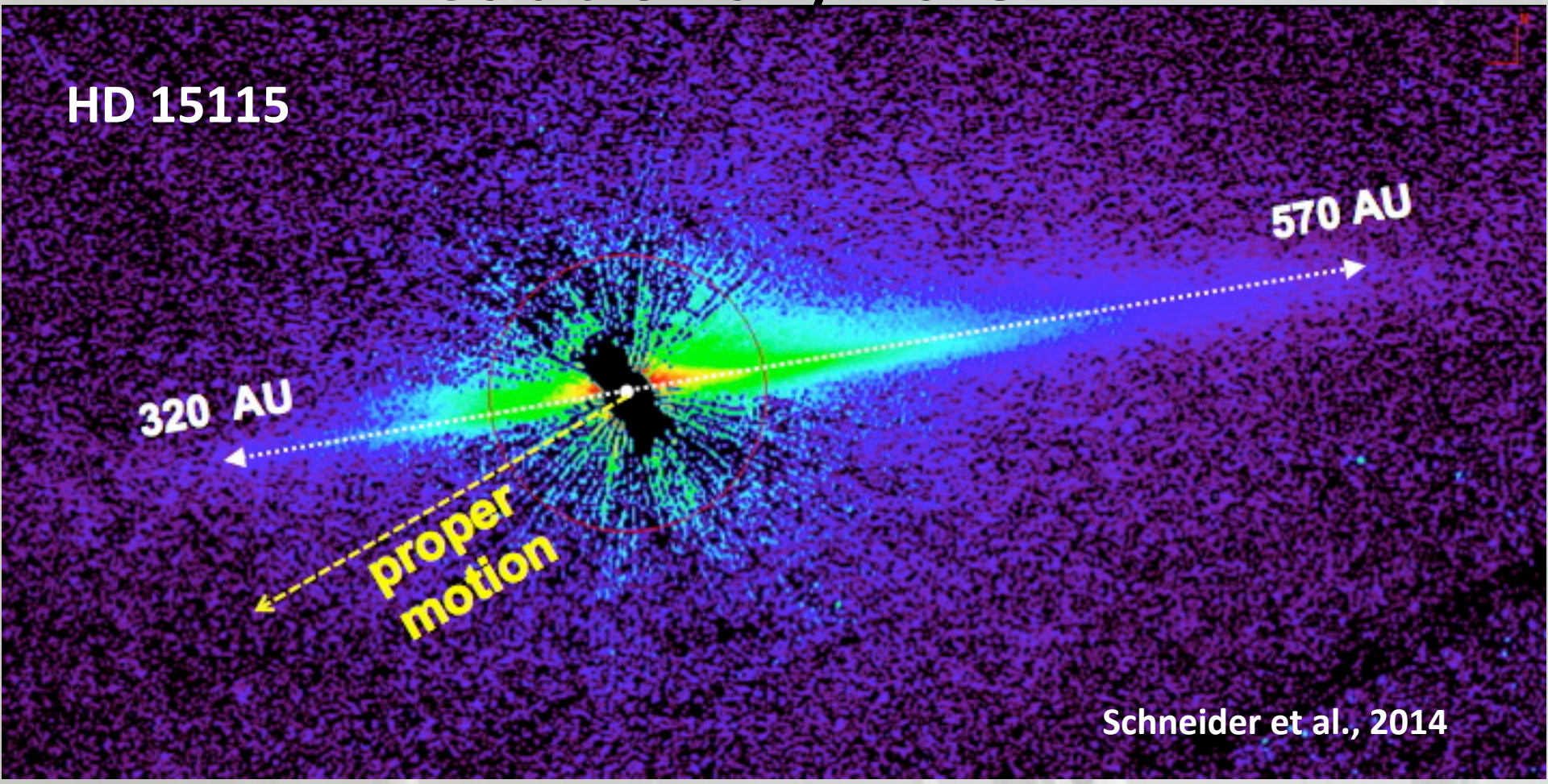
Name	SpT	Dist (pc)
HIP 560 (HR 9)	F2IV	39
HIP 10679	G2V	27
HIP 10680	F5V	35
HIP 11152	M3Ve	29
HIP 11437AB (AG Tri)	K8+M0	40
HIP 12545AB	K6Ve(sb1)	42
HIP 21547 (51 Eri)	F0V	29
GJ 3305AB	M0.5+:	29
HIP 23200	M0Ve	26
HIP 23309	M0.5kee	27
HIP 25486 (HR 1817)	F7	27
HIP 27321 (β Pic)	A5V	19
J0608-2753	M8.5e	31
HIP 29964 (AO Men)	K4Ve	39
HIP 5015	M1V	23
TWA 22AB	M6Ve+M6Ve	18

Name	SpT	Dist (pc)
HIP 76629AB (V343 Nor)	K0V+(M4.5+:)	39
HIP 79881 (HR 6070)	A0	41
HIP 84586ABC (V824 Ara)	(G5IV+K0IV)+M3Ve	31
HIP 86598 (HD 160305)***	F9V	72
HIP 88399AB (HD 164249)	F5V+M4V	48
HIP 88726AB (HR 6749+6750)	A5V+A5V	42
HIP 89829***	G5V	73
HIP 92024ABC (HR 7012)	A7+(K7V+:)	29
HIP 92680 (PZ Tel)	G9IV	51
HIP 95261AB (η Tel)	A0Vn+M7	48
HIP 95270 (HD 181327)	F5.5	52
HIP 99273	F5V	52
HIP 102141AB (AT Mic)	M4Ve+M4Ve	11
HIP 102409 (AU Mic)	M1Ve	10
HIP 103311	F8V*	46
HIP 112312AB	M4IVe	23

Malo et al., 2013 and refs therein;
IR excesses from Rebull et al., 2008; McDonald et al., 2012
Patel et al., 2013;Riviere-Marichalar et al., 2014

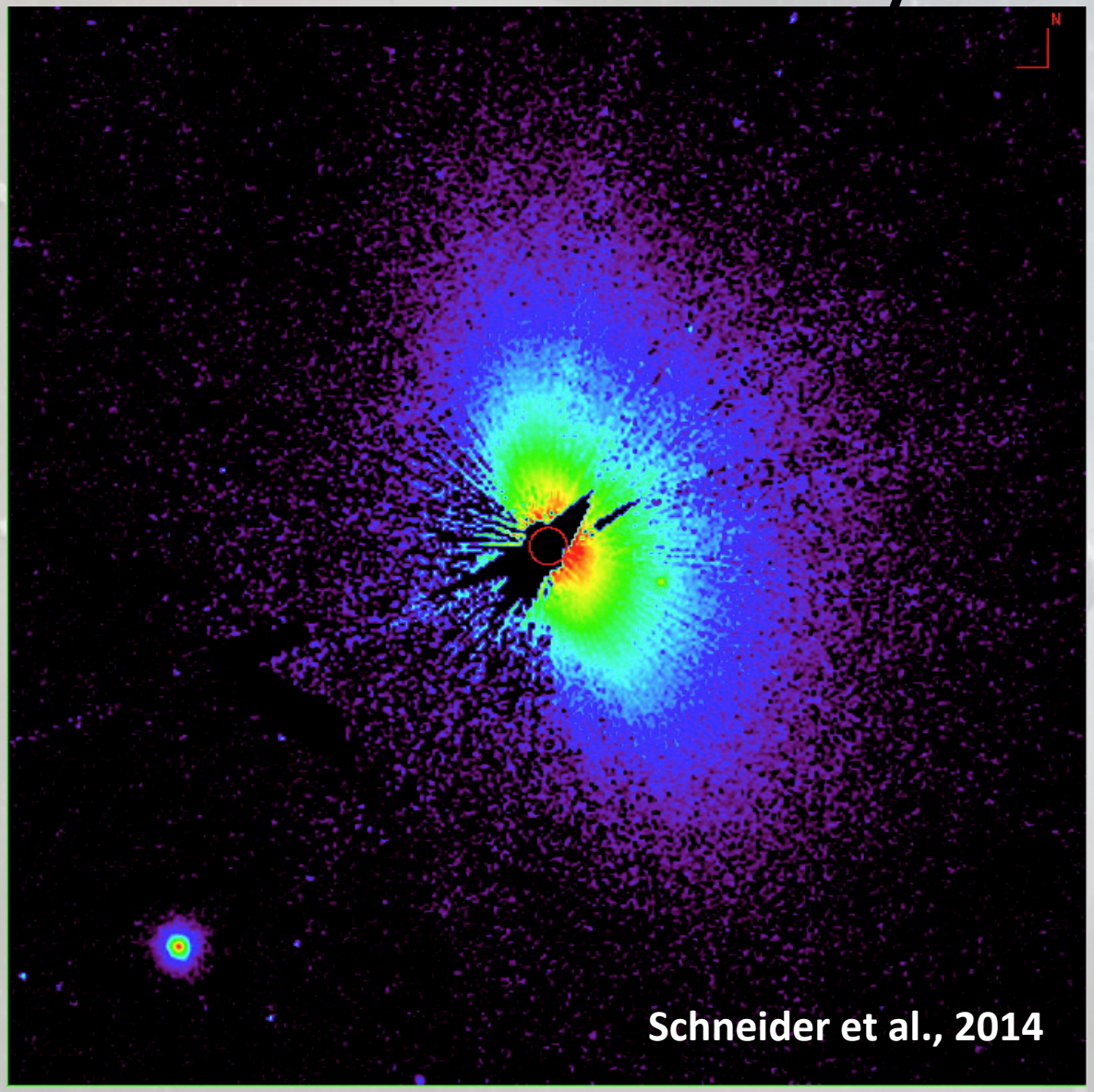
***WISE Candidates

Cautionary Tale--1



first seen by Kalas et al., 2005, BPMG by Moor et al., 2006
Traceback puts it far from main BPMG (Debes et al., 2009)
Banyan calculations favor Columba membership (Malo et al., 2013)

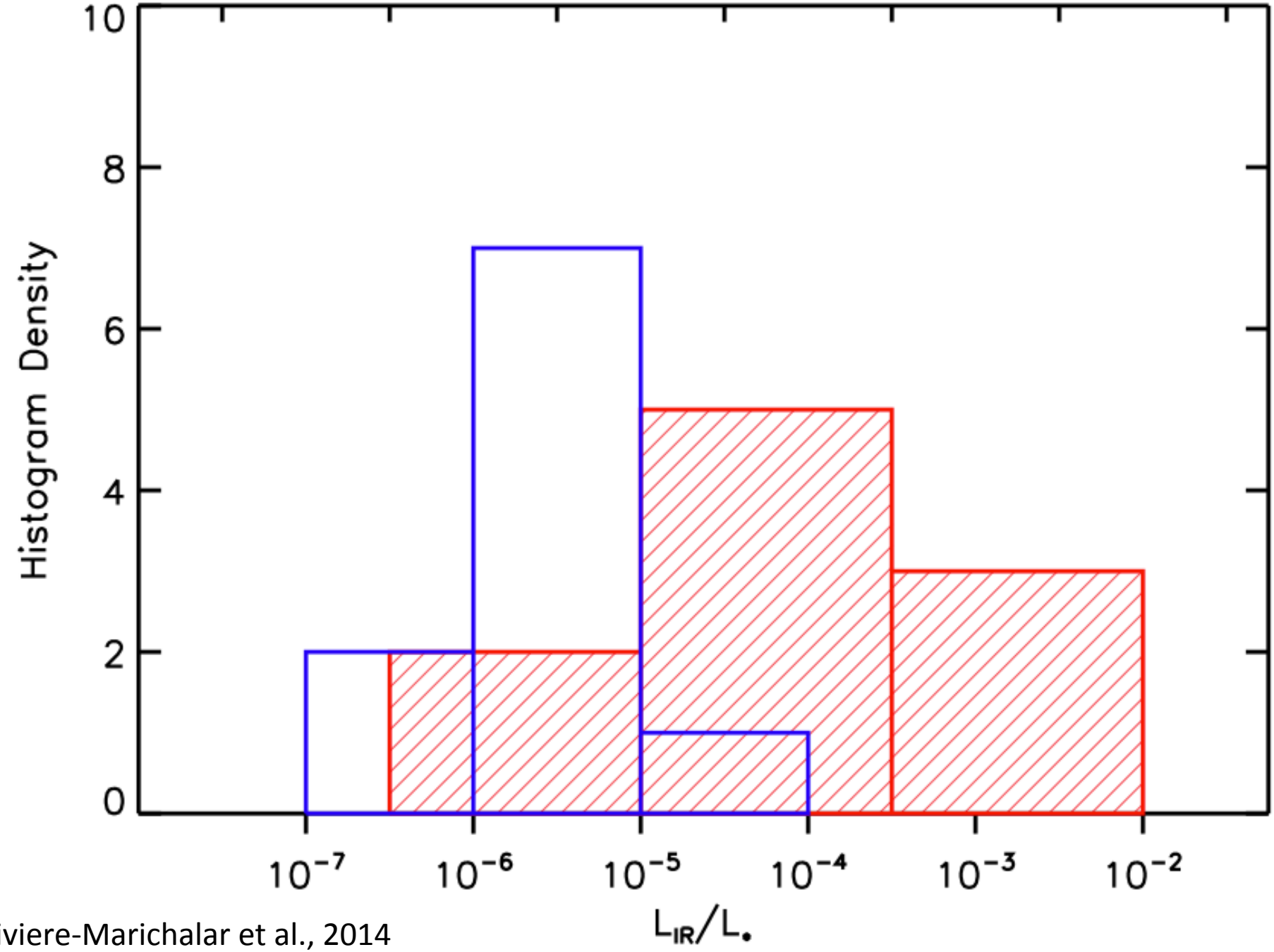
Cautionary Tale--2



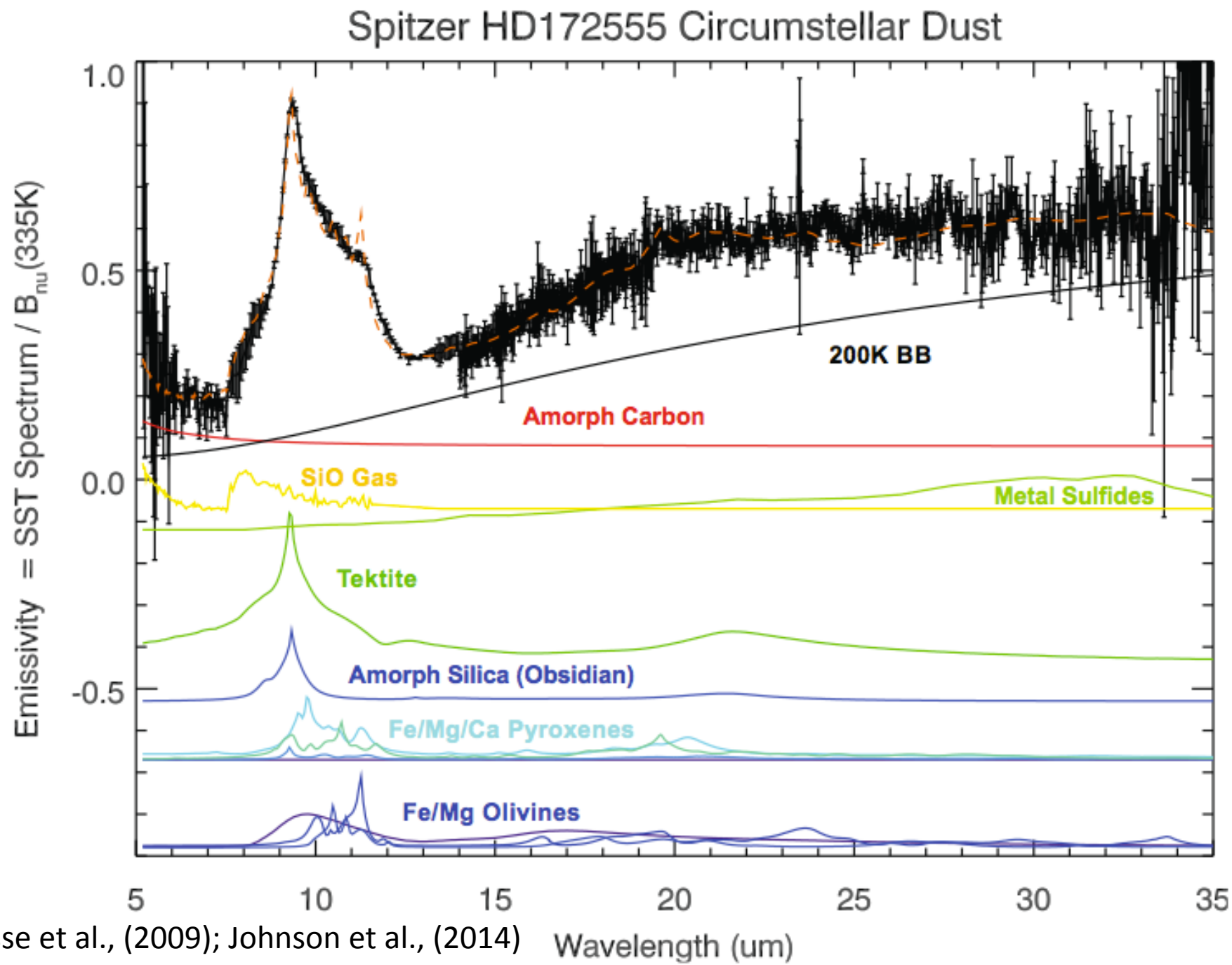
- First discovered by Kalas et al. (2007b)
- Claimed BPMG member by Moor et al. (2011) based on rv, kinematics, and youth indicators
- BANYAN online tool disputes this probability (88% field??)

Quick Stats from IR

- 14/32 Systems have detected disks (12 secure, two candidates)
- 13/22 are earlier than M type
- 1/10 are later than M0
- Median $L_{IR}/L_{*} = 8x10^{-4}$
- Min $L_{IR}/L_{*}=2.3x10^{-5}$ (HIP21547)
- Max= $2.3x10^{-3}$ (HD 181327)

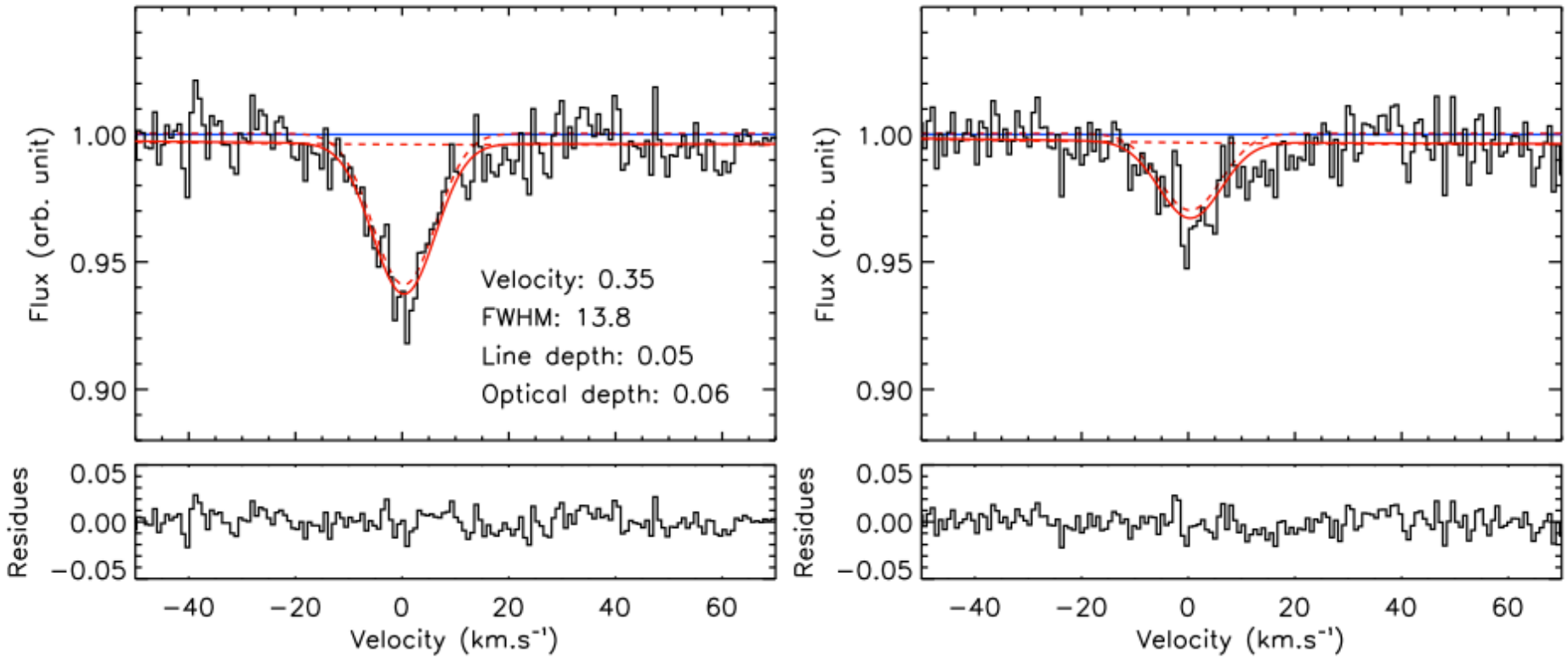


Riviere-Marichalar et al., 2014



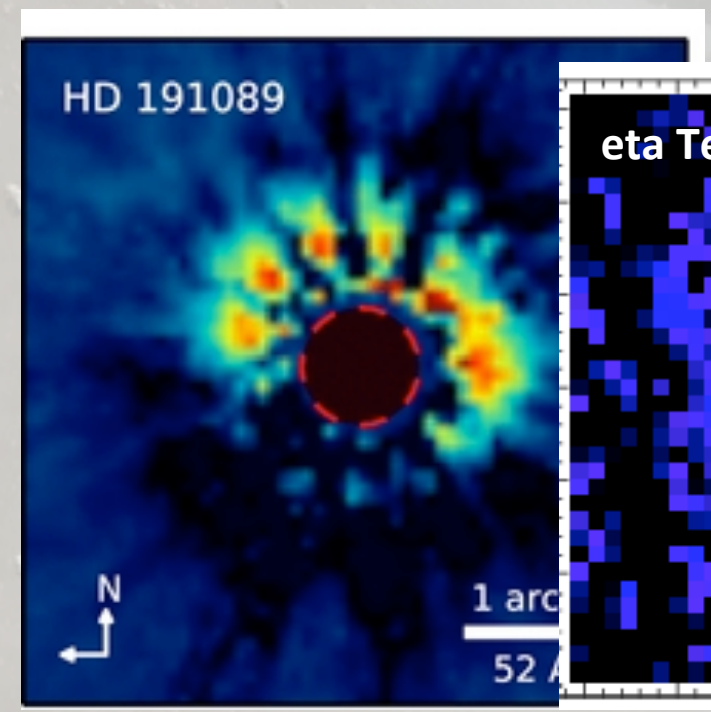
Lisse et al., (2009); Johnson et al., (2014)

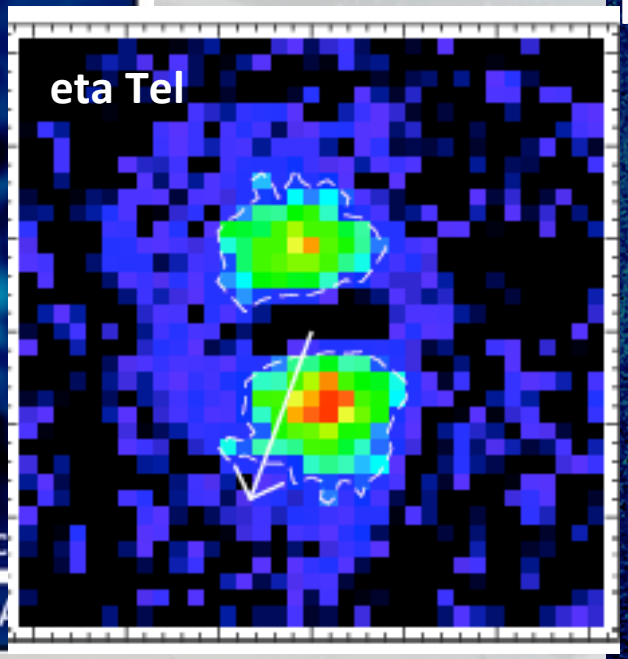
HD 172555--FEBs

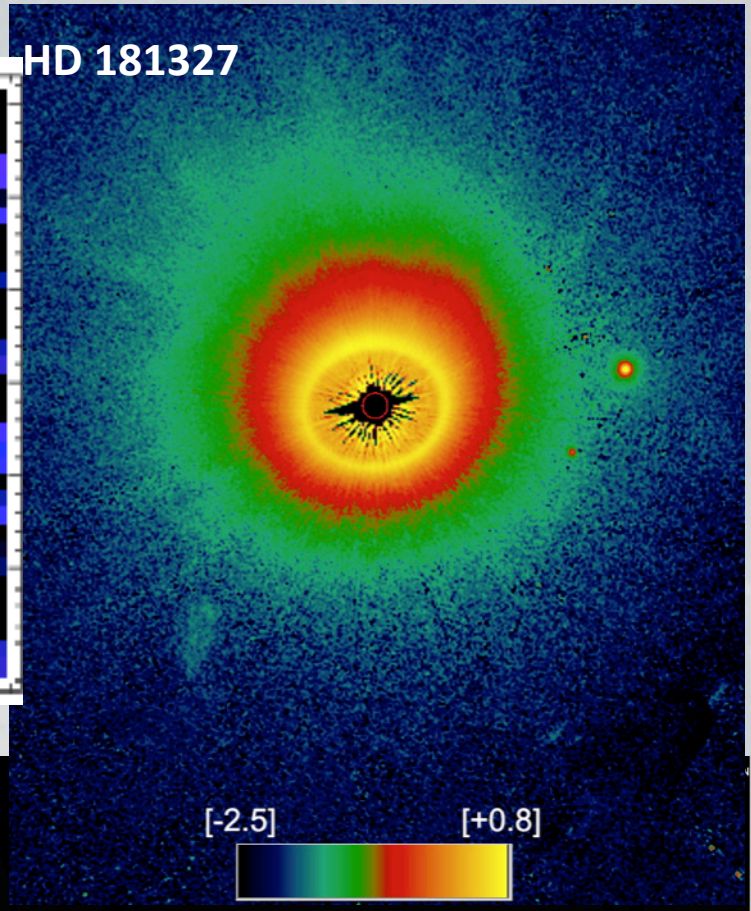


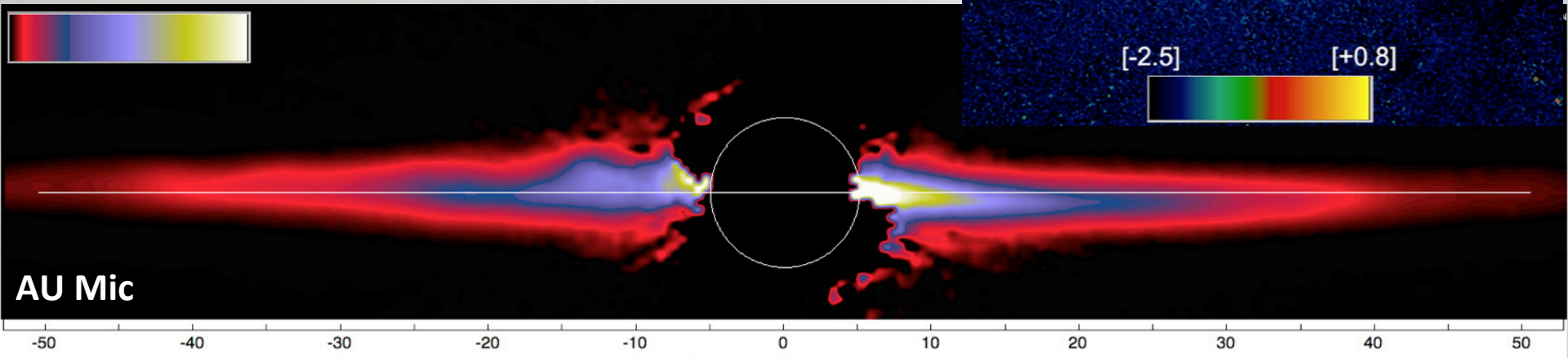
Kiefer et al., 2014

Resolved Disks

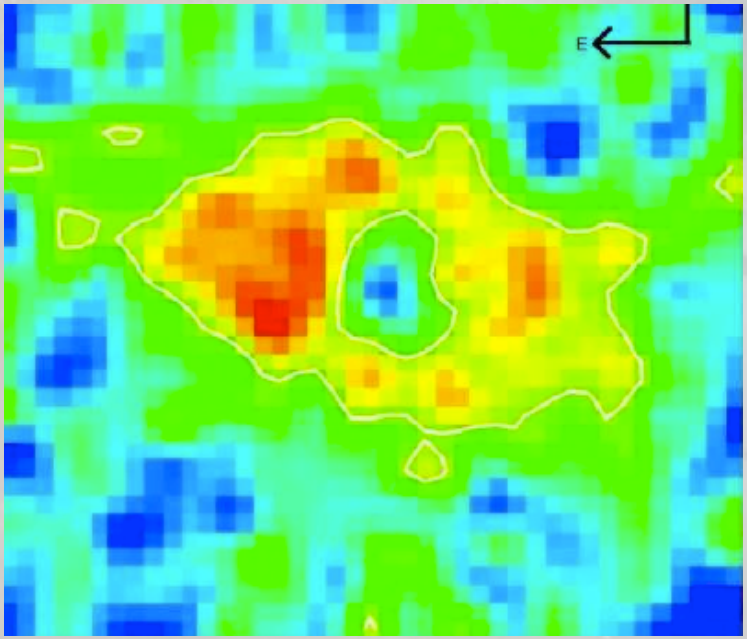






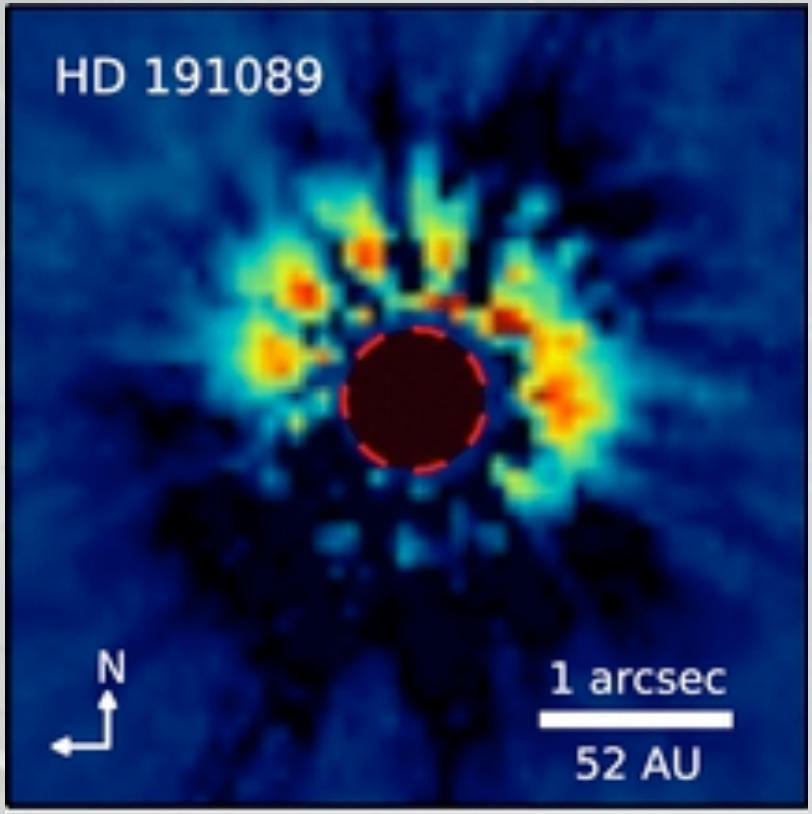


18.3 μm T-ReCs



Churcher et al., 2011

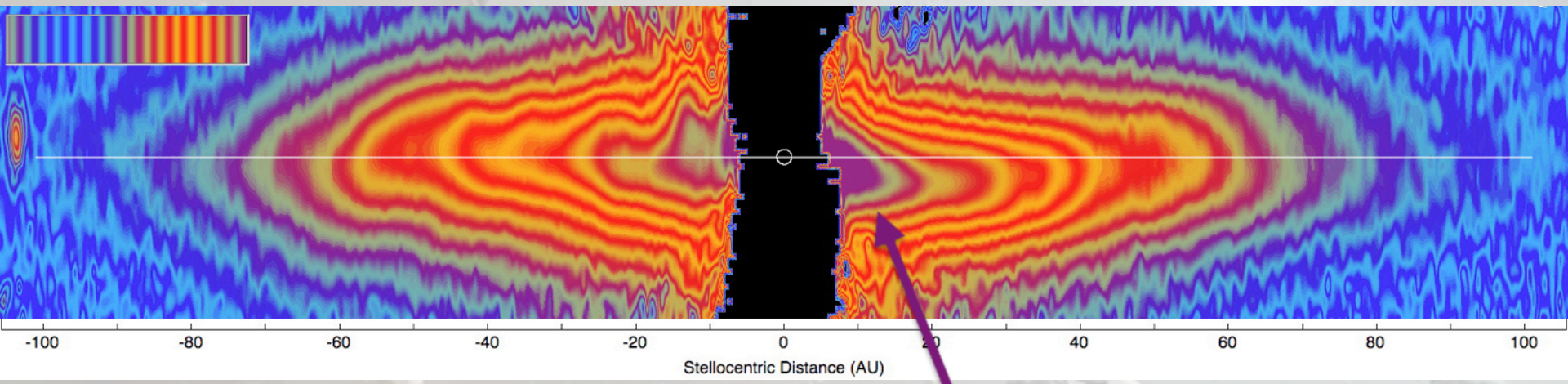
1.1 μm NICMOS/ALICE



Soummer et al., 2014

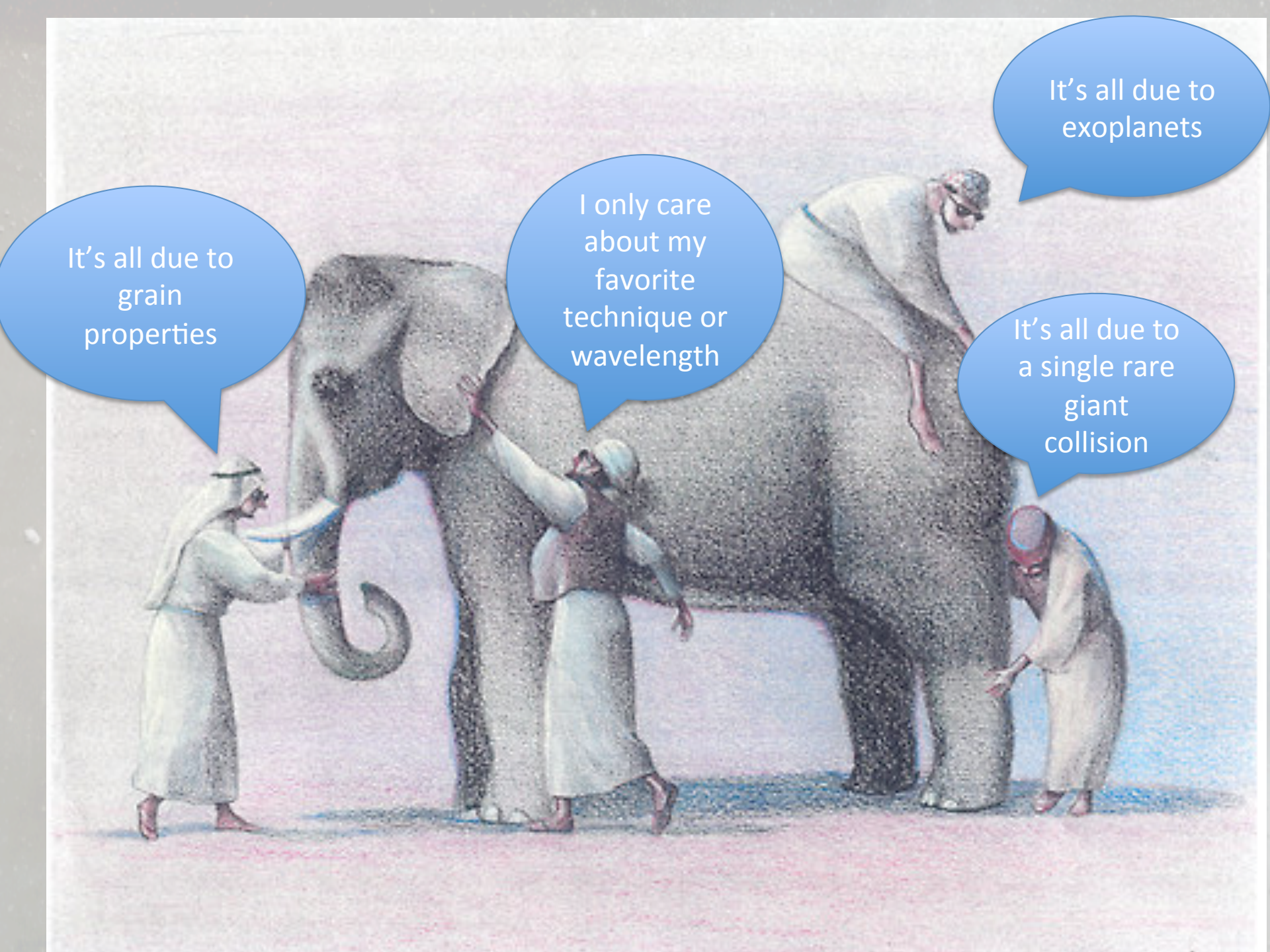
AU Mic

- Blue colors in scattered light, polarization studies imply icy porous grains (Graham et al., 2007)
- Birth ring at ~35-45 AU (Strubbe & Chiang, 2006; Augereau & Beust 2006)

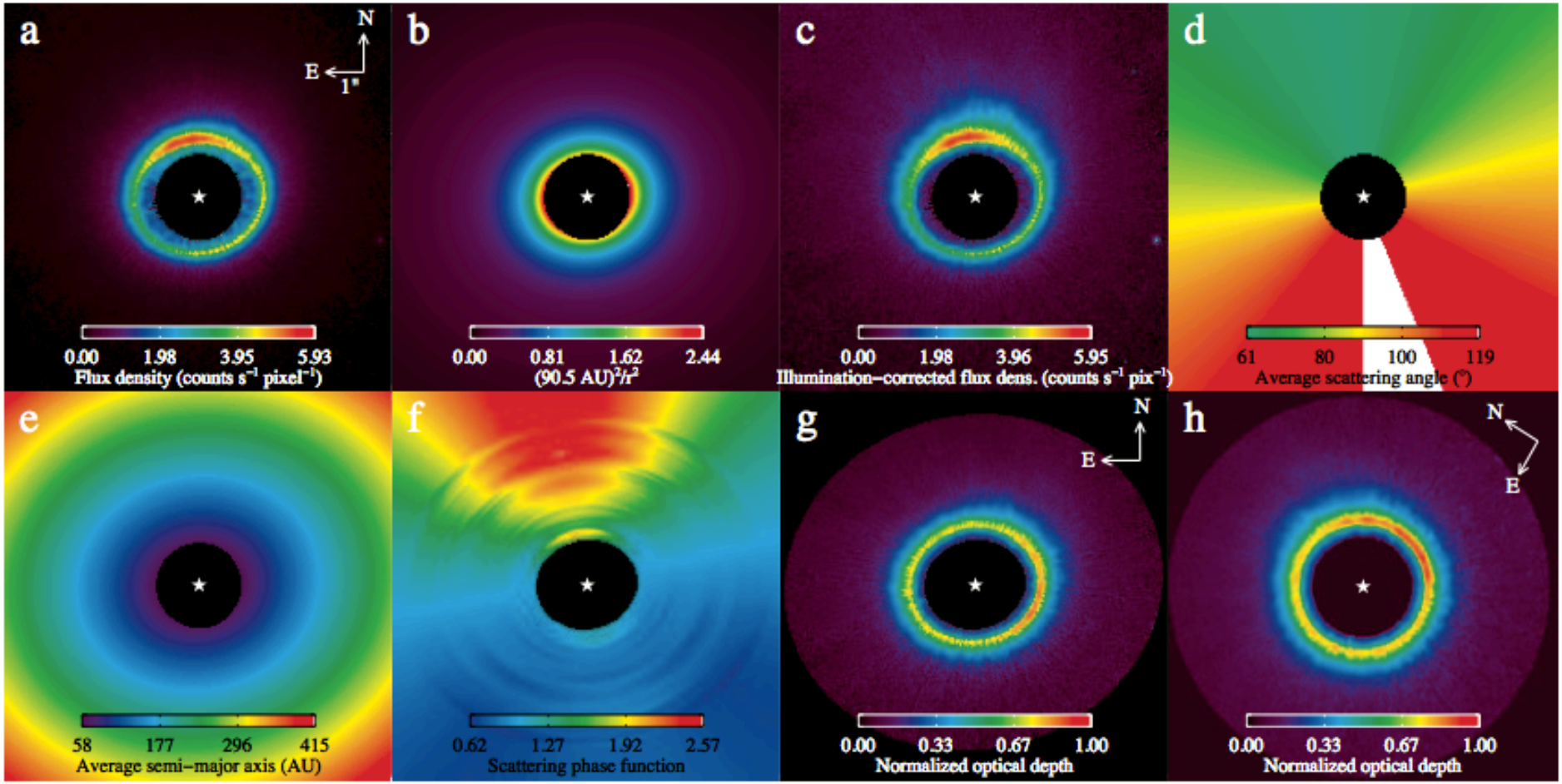


Schneider et al., 2014

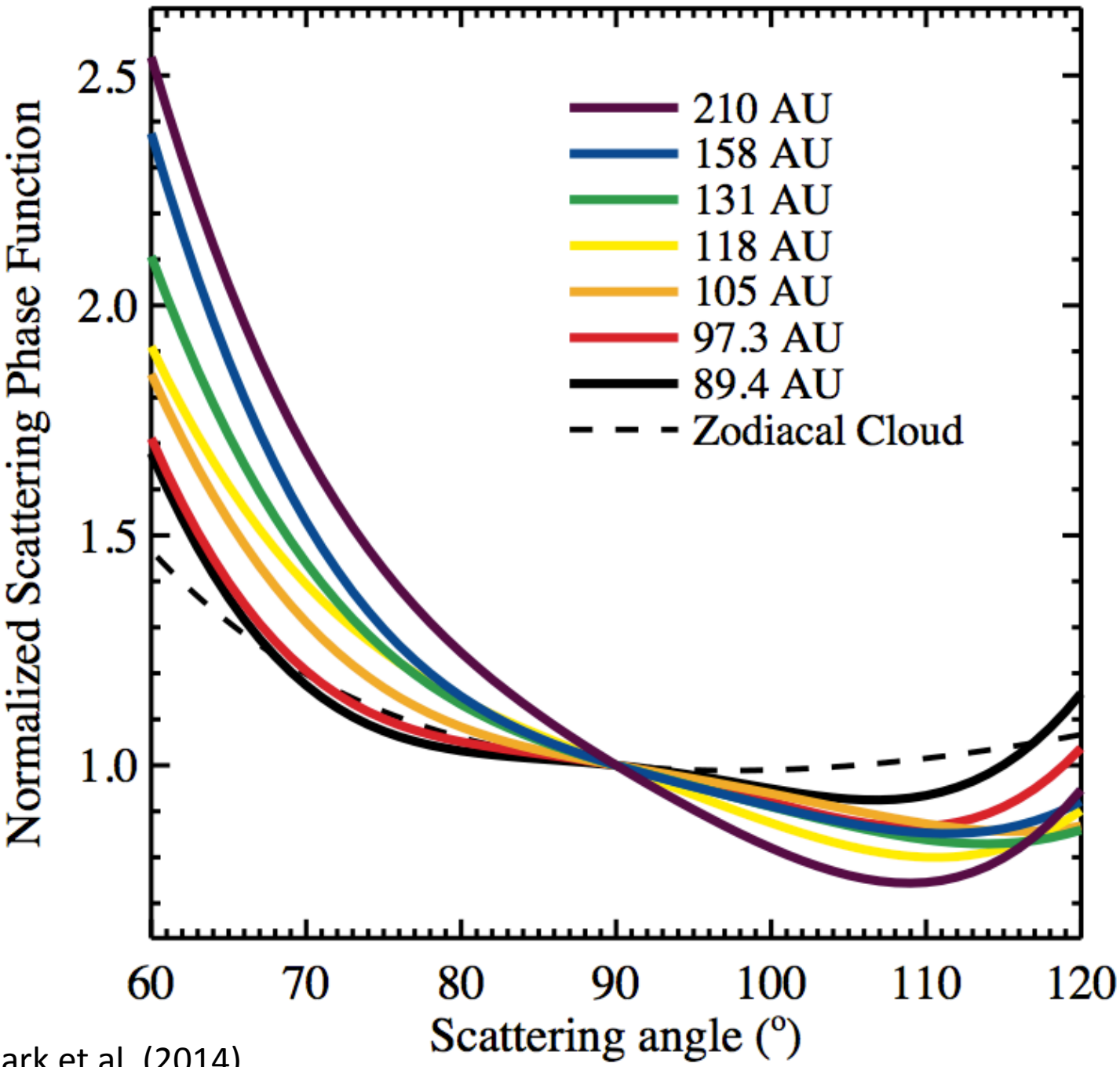
WARP!!


It's all due to grain properties
I only care about my favorite technique or wavelength
It's all due to exoplanets
It's all due to a single rare giant collision

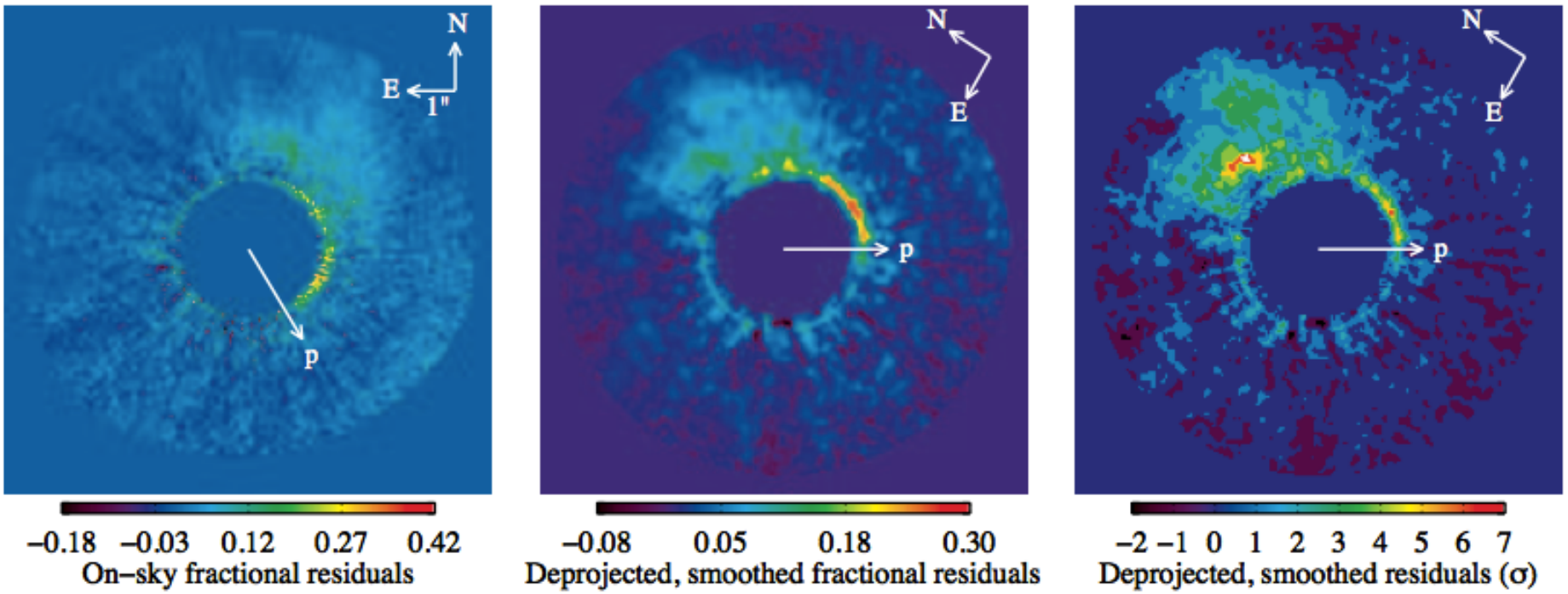
HD 181327



Stark et al. (2014)

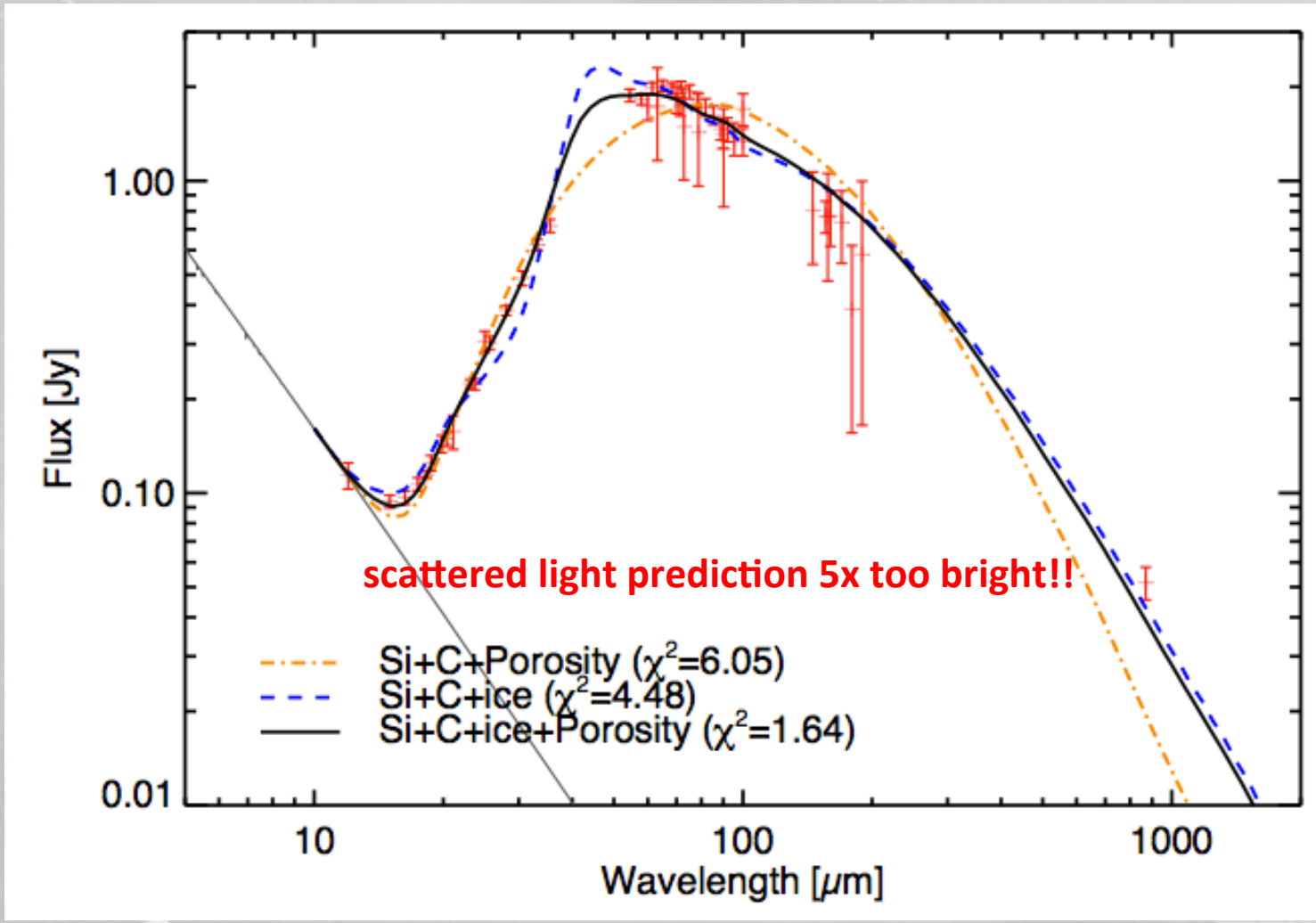


Stark et al. (2014)



Stark et al. (2014)

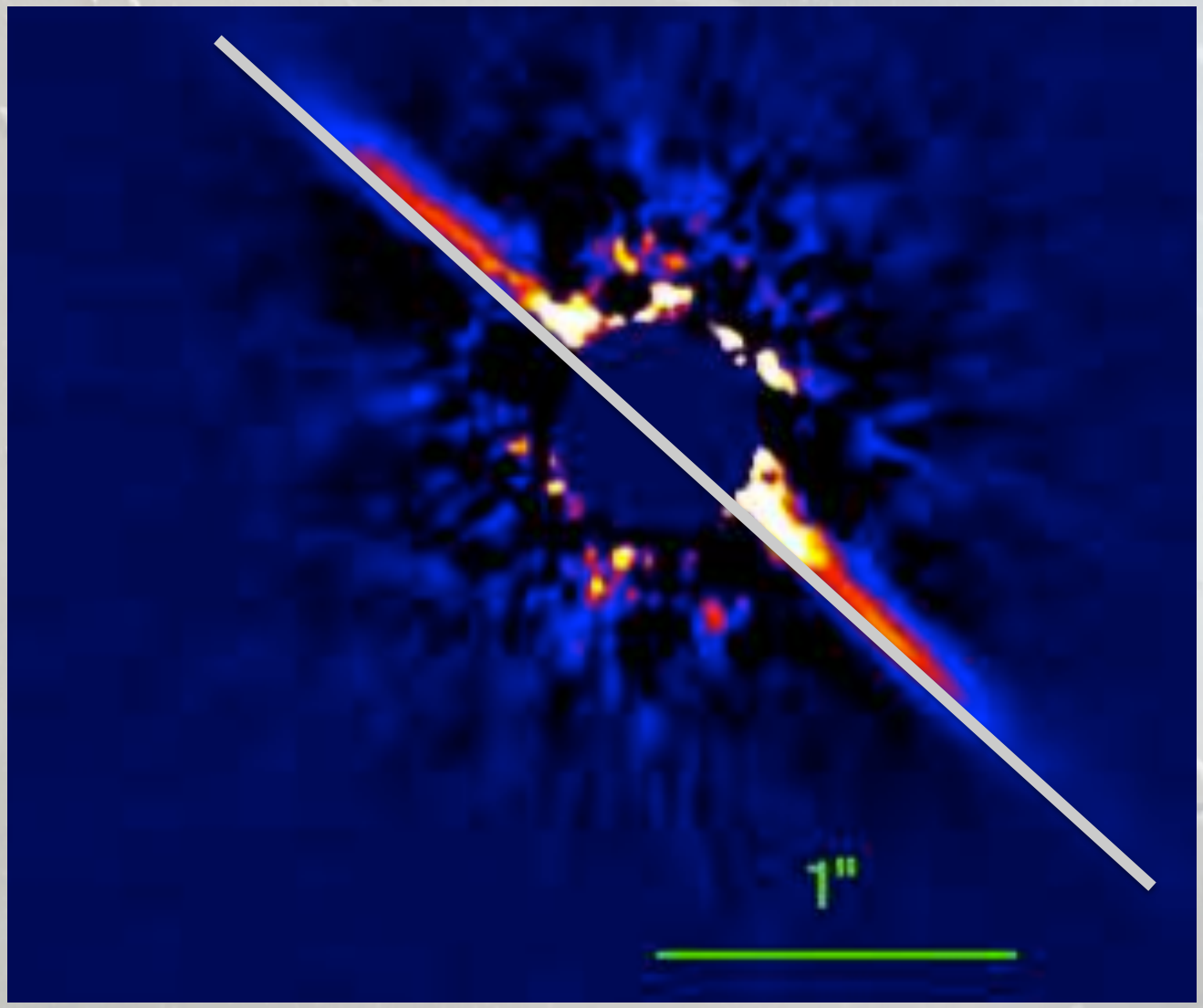
HD 181327 Composition?



Lebreton et al. (2011)

See talk by Rodigas

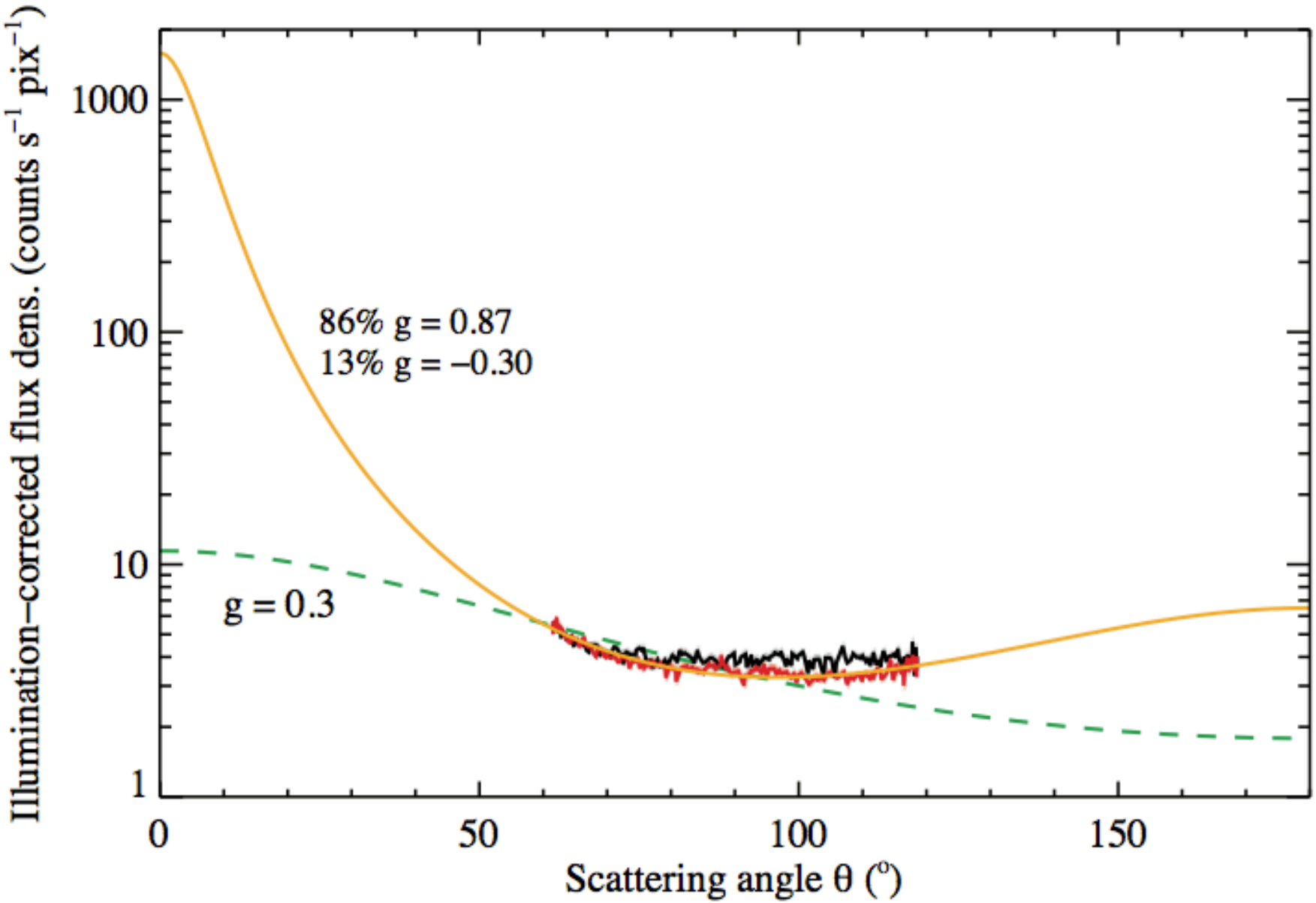
The debris disk phase function



Rodigas et al., (2012)
Currie et al. (2012)

Two-component
Phase function:

90% g=0.95
10% g=-0.1



Stark et al. (2014)

The 3 Critical Points

- We need the "foundational" BPMG members in order to extract useful conclusions
- A few disks in the BPMG are extremely well studied, while some need more investigation (GPI, SPHERE, HST?)
- Better disentangling of grain properties (**empirical phase function{!!},** multi-wavelength studies, spatially resolved scattered and thermal studies, polarization)