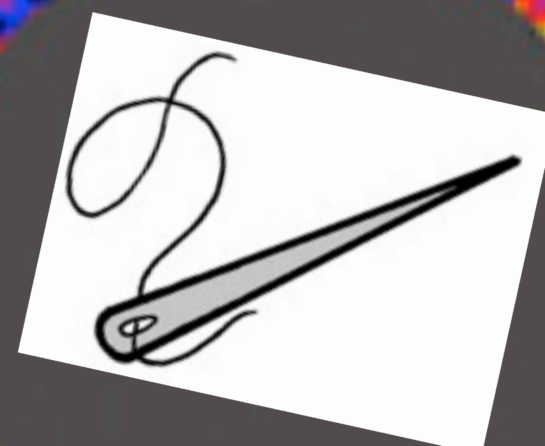
The ~~Blue~~ Gray Needle: LBT AO Imaging of the HD 15115 Debris Disk



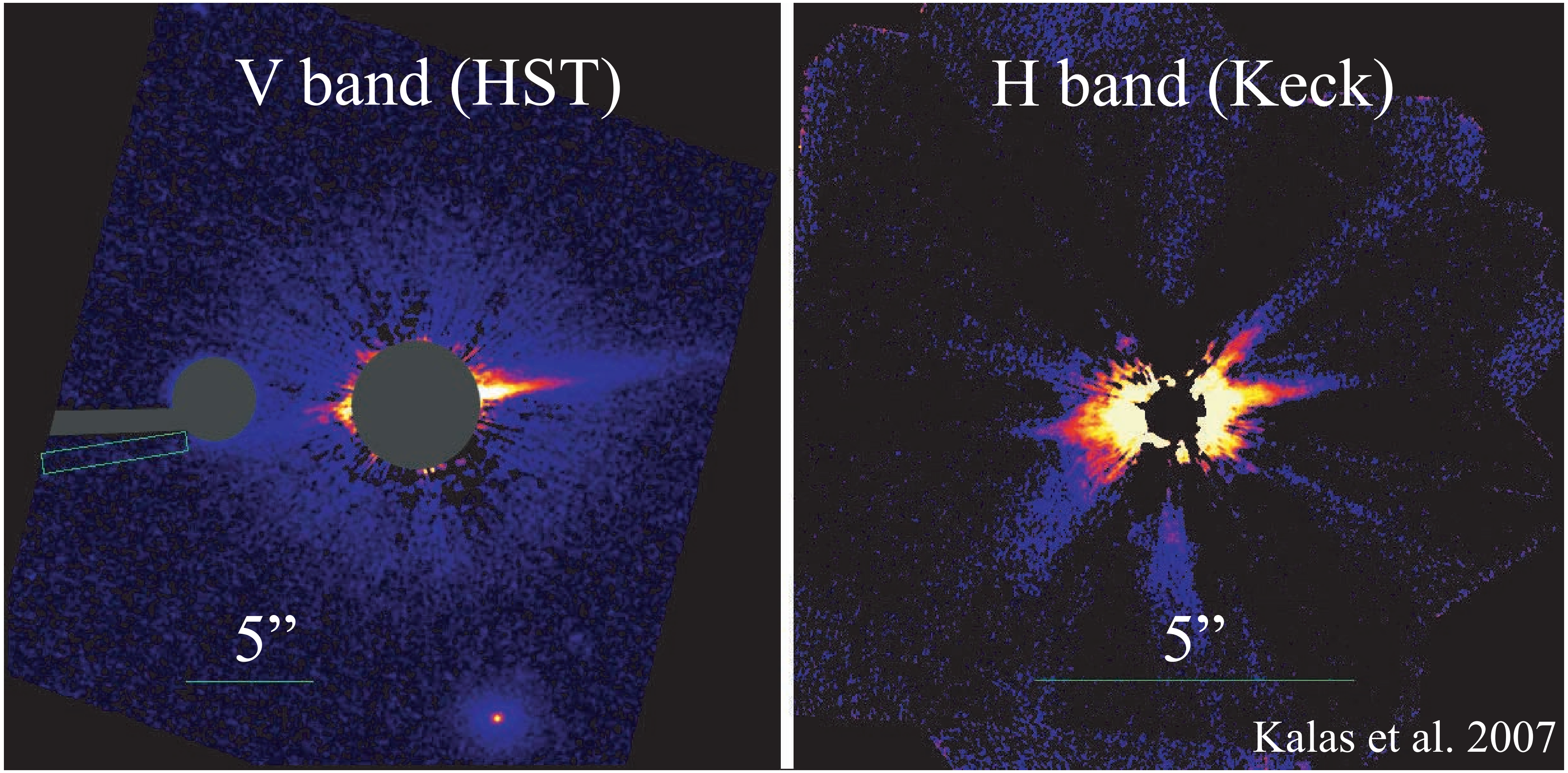
Timothy J. Rodigas

+ Phil Hinz, Andy Skemer, Kate Su, Glenn Schneider, Laird Close, Vanessa Bailey, Thayne Currie & 48 Co-authors…

University of Arizona/LBTO/INAF

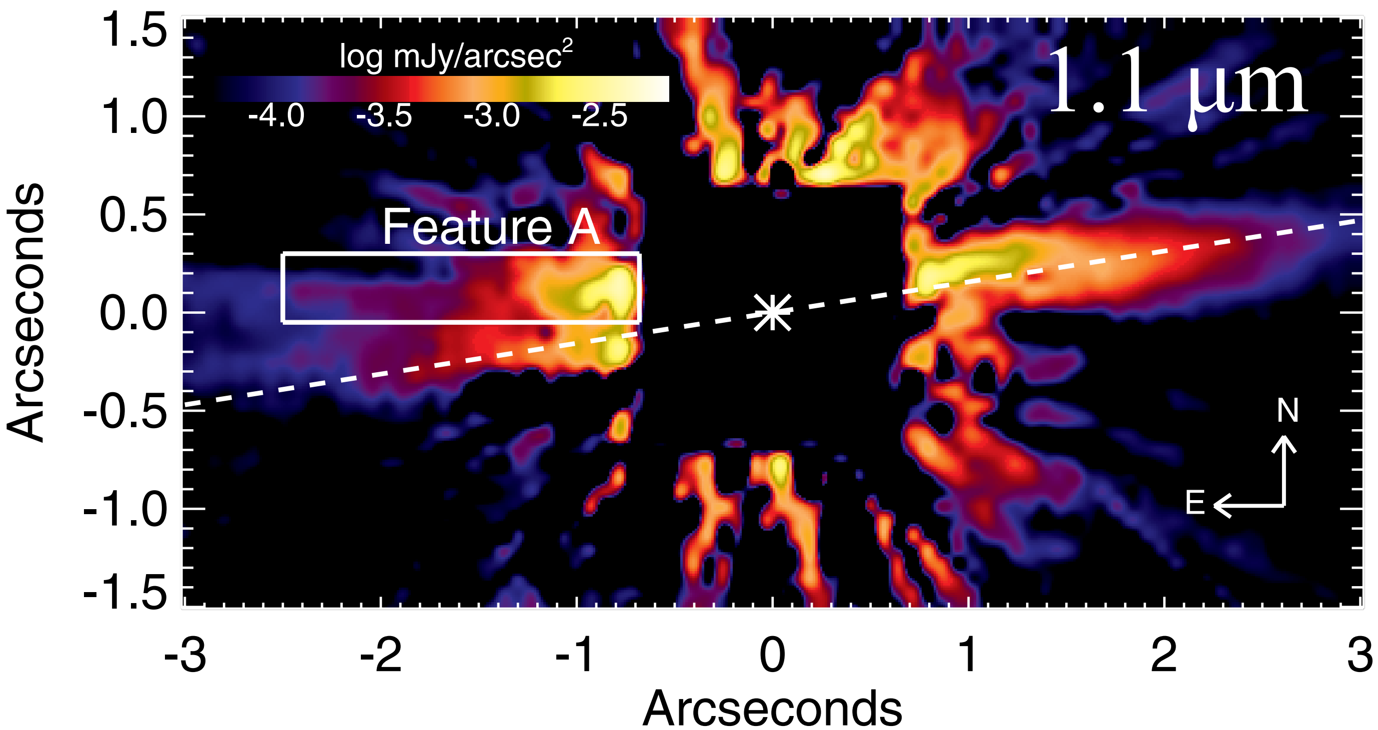
Rodigas et al. 2012 (ApJ)

HD 15115's debris disk

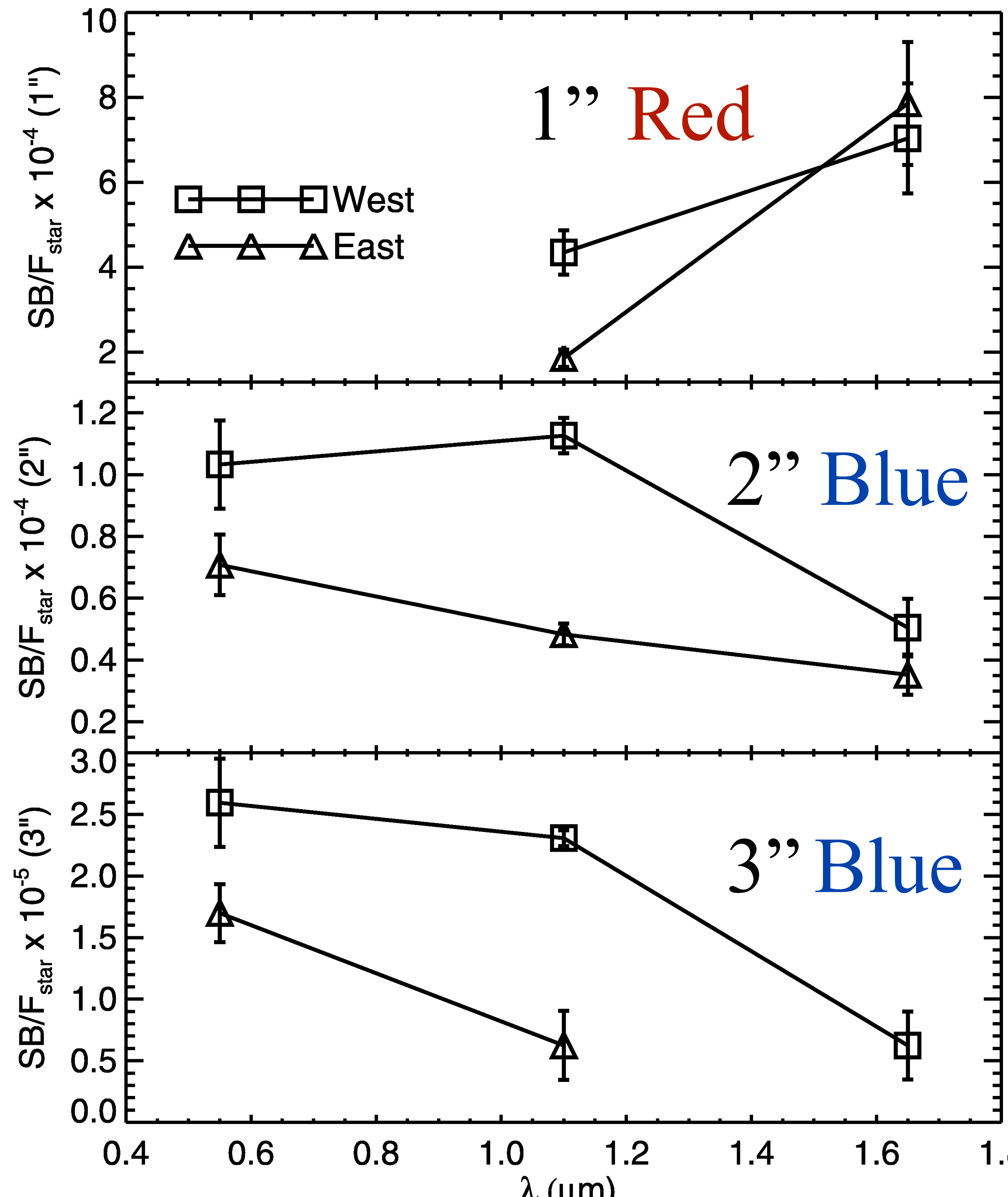


- High fractional luminosity disk (5x10^-4; Moor et al. 2006)
- Very asymmetric
- Dynamical interactions with ISM to south-east? (Debes et al. 2008)
- BLUE colors (V-H) → small dust grains (< ~ 1 μm?) (Kalas et al. 2007, Debes et al. 2008)

Is the disk really that blue/asymmetric?



Debes et al. 2008

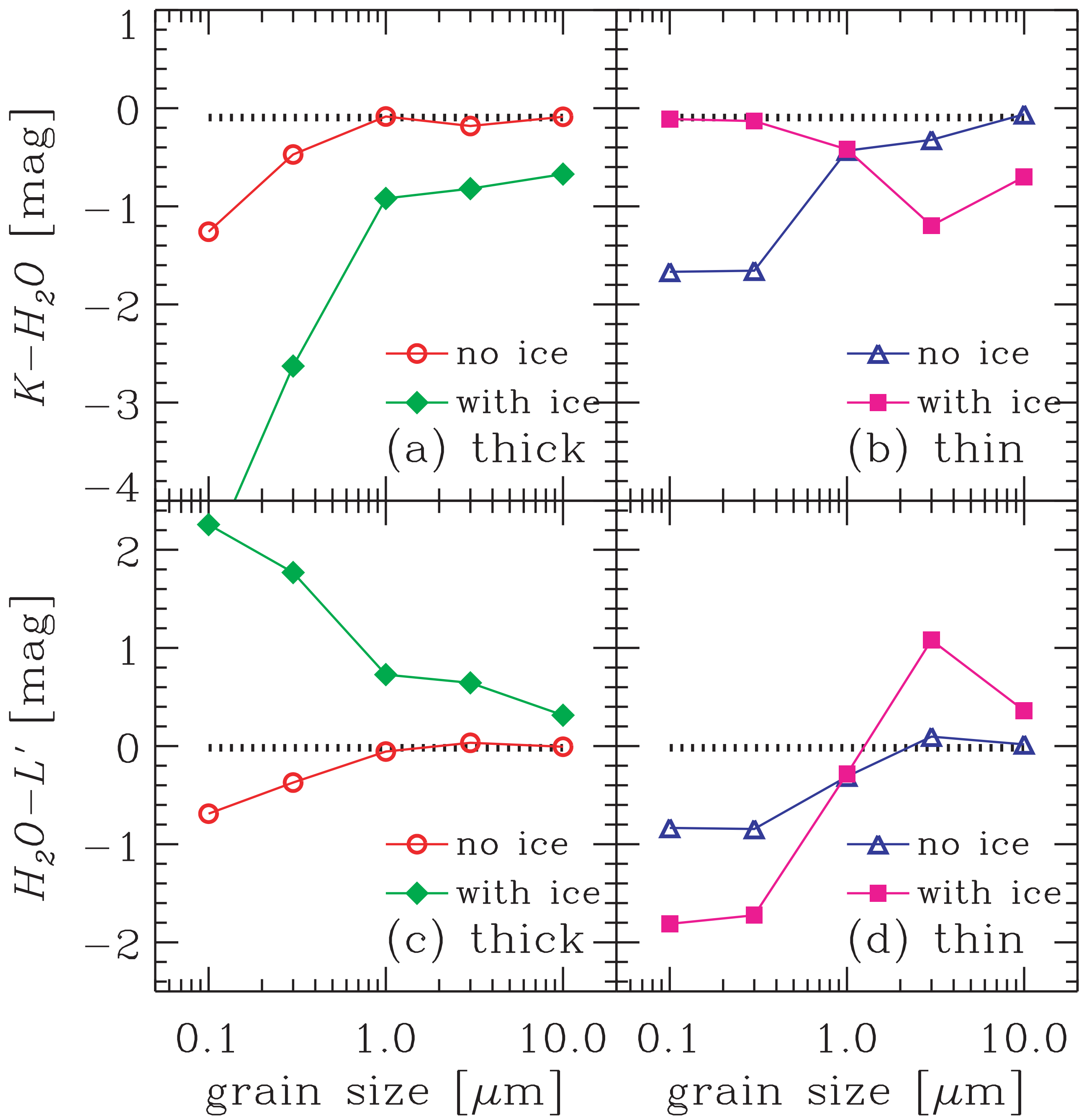


Red inside 1"?

↓

Favorable for NIR imaging

λ > 2 μm imaging: what it gets you

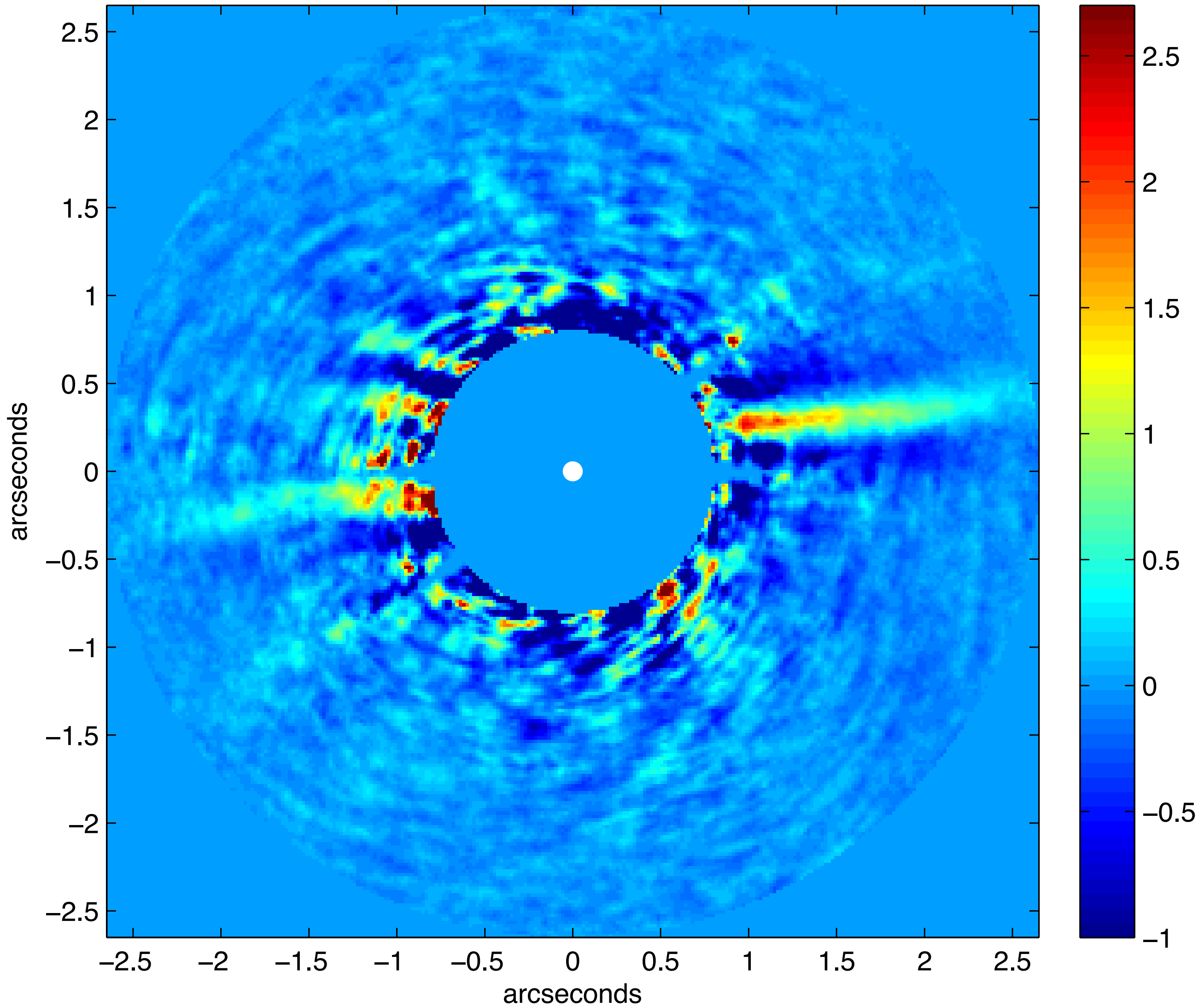


Inoue et al. 2008

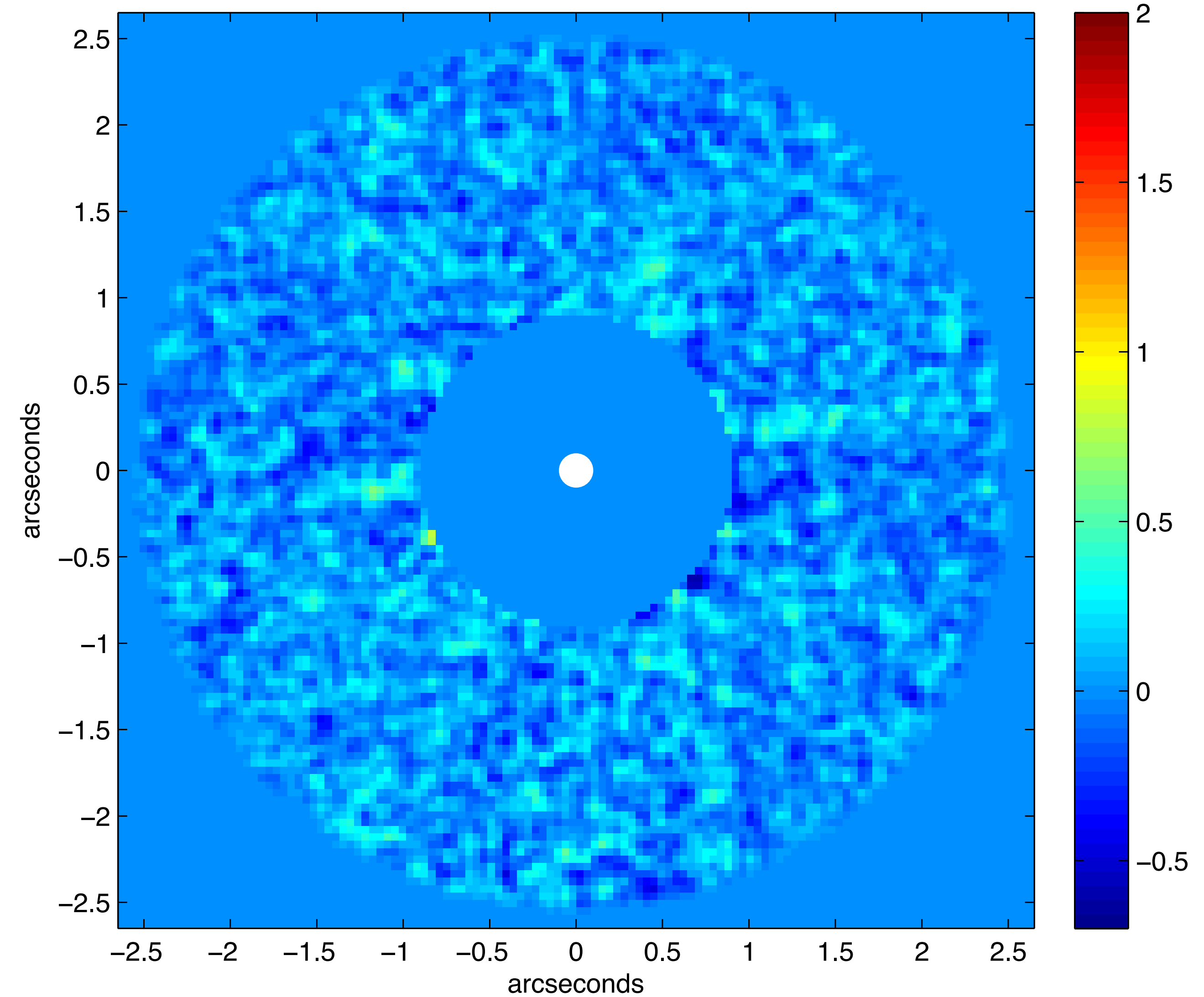
- constrain dust grain size (esp. large grains)
- inform on geometry (large grains also asymmetric?)
- with 3 μm image, constrain water ice fraction (Inoue et al. 2008, Honda et al. 2009)
- probe for Jupiter-mass planets
- higher Strehl → higher S/N closer to star

Observations with LBT AO: new Ks and L' images

2.15 μm (PISCES)



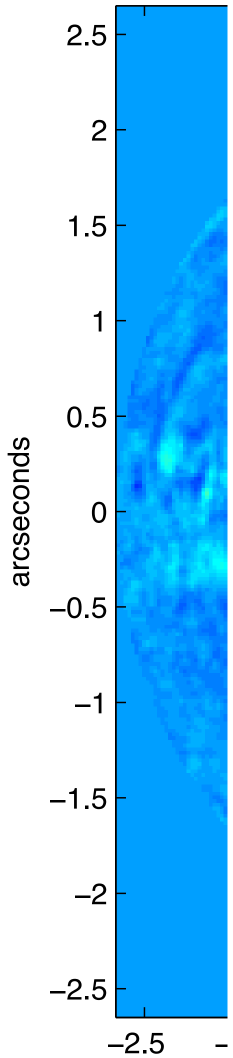
3.8 μm (LBTI/LMIRCam)

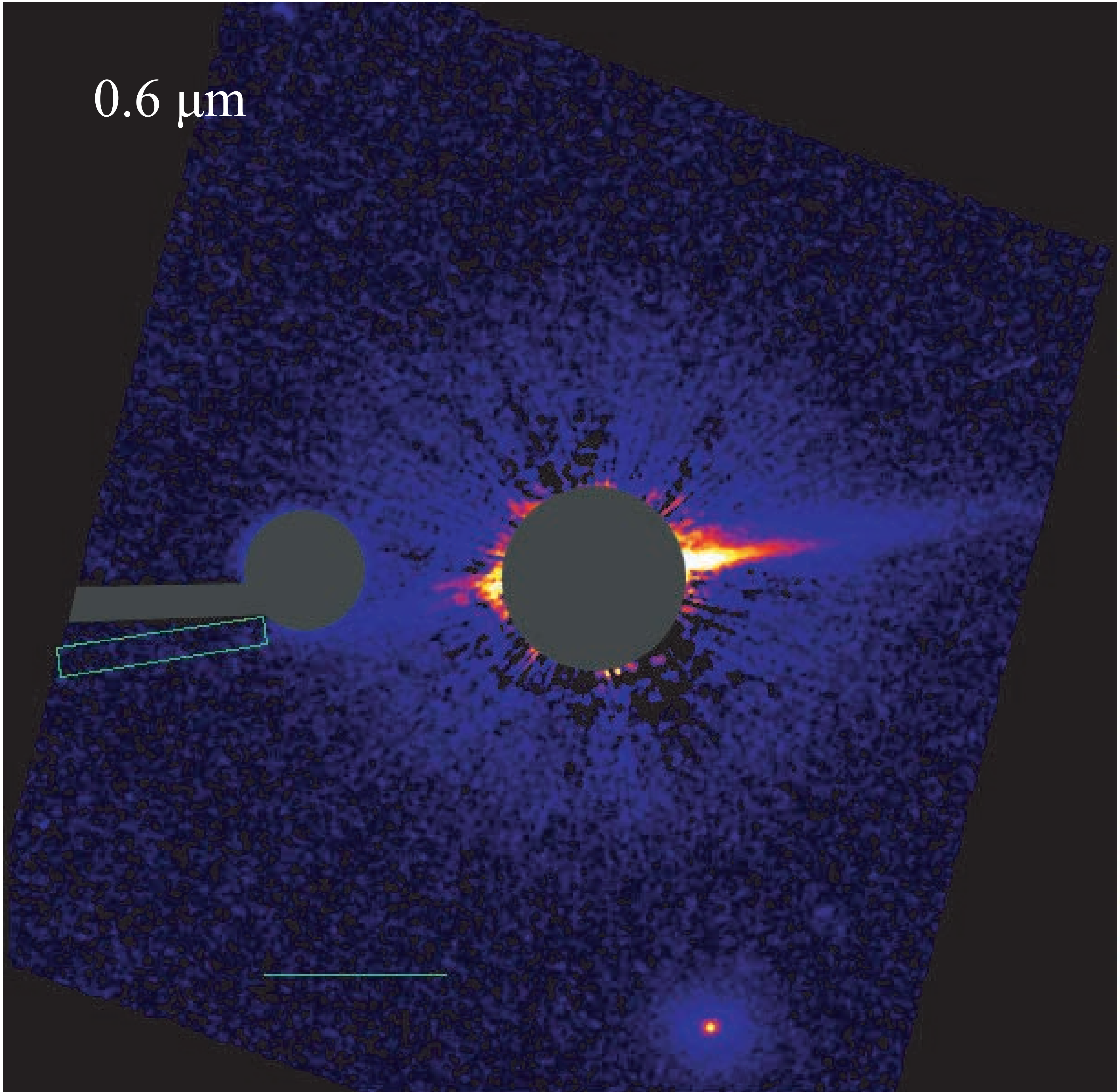


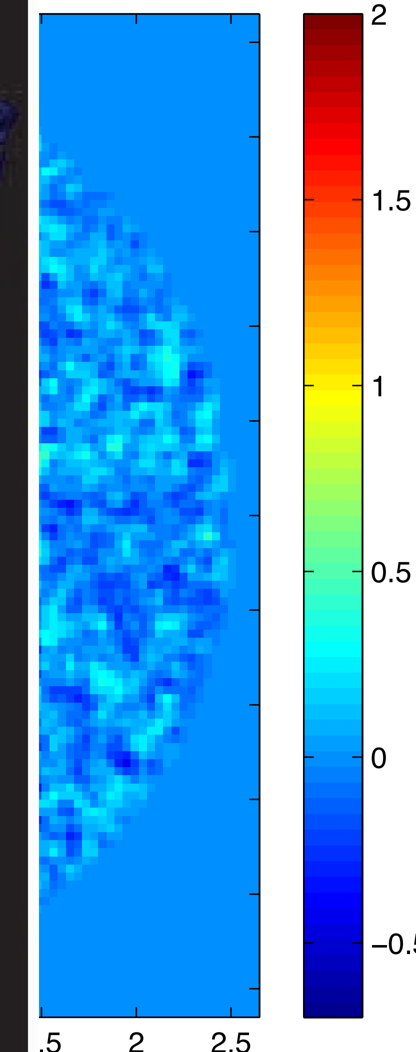
The disk is morphologically different between 2 & 4 μm, and between 0.5-1 & 2-4 μm

Obs … images

n)



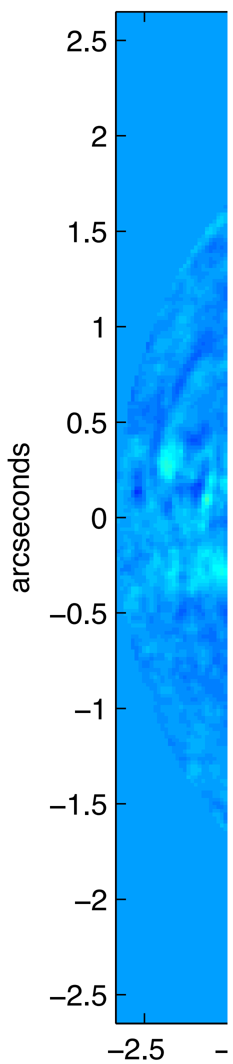


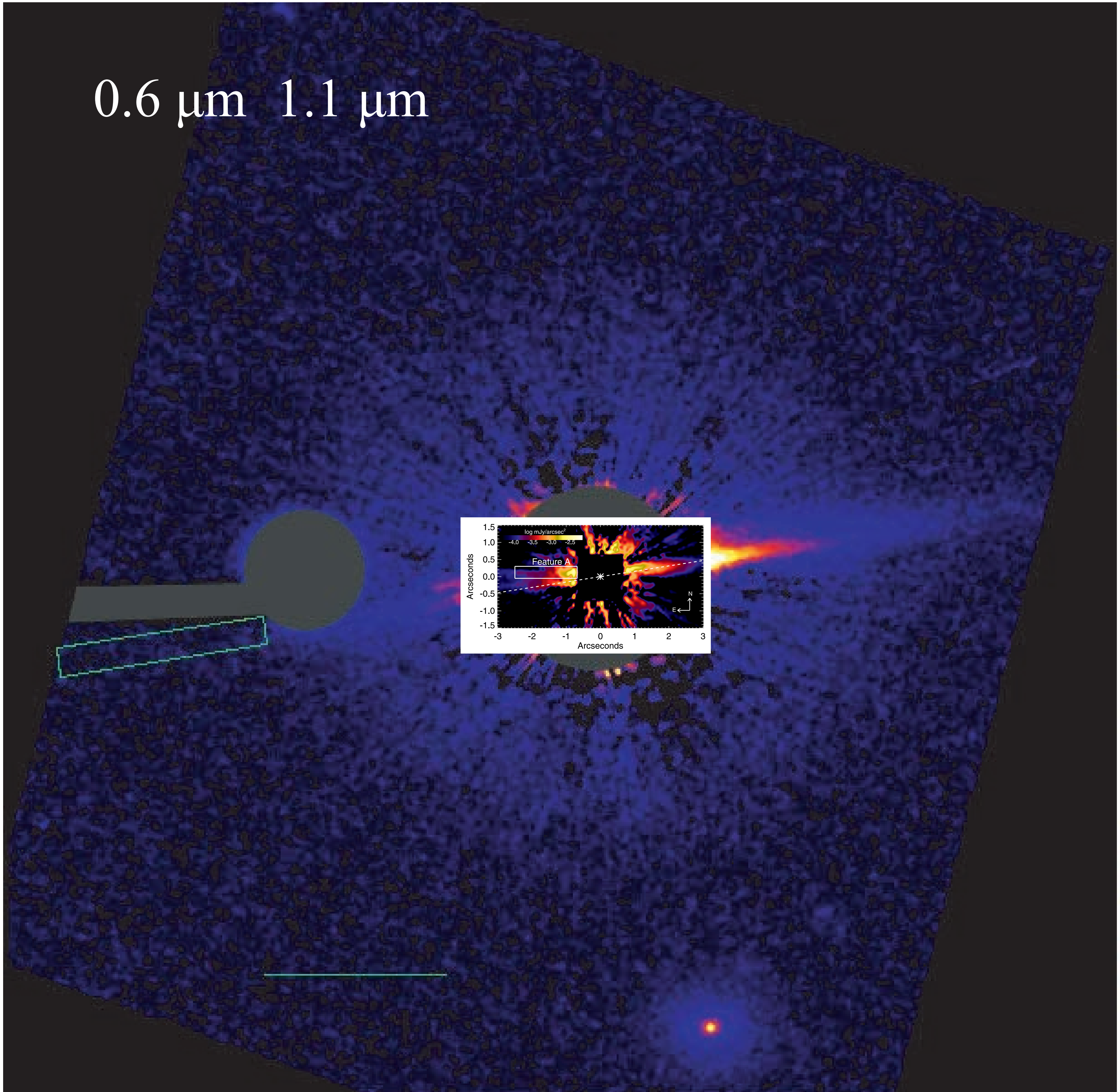


Tl … m,

ar

Obs … images





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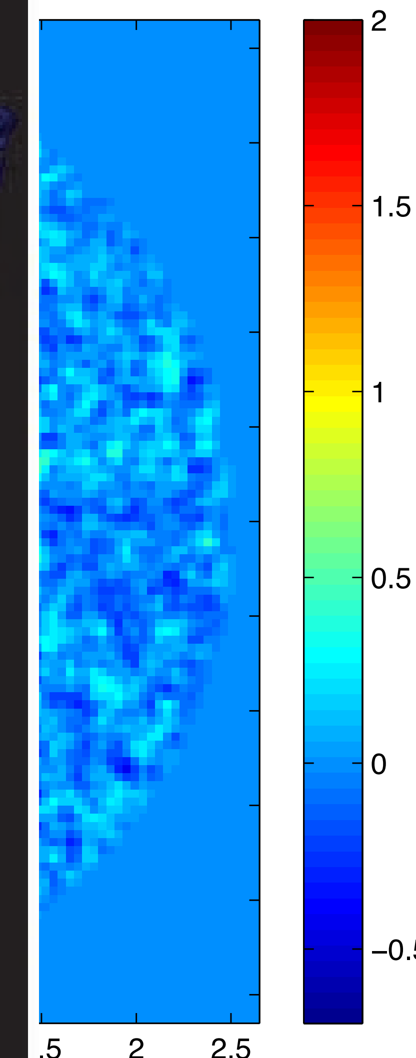

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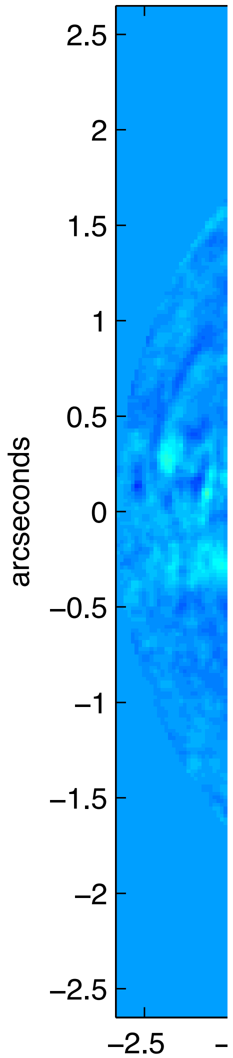

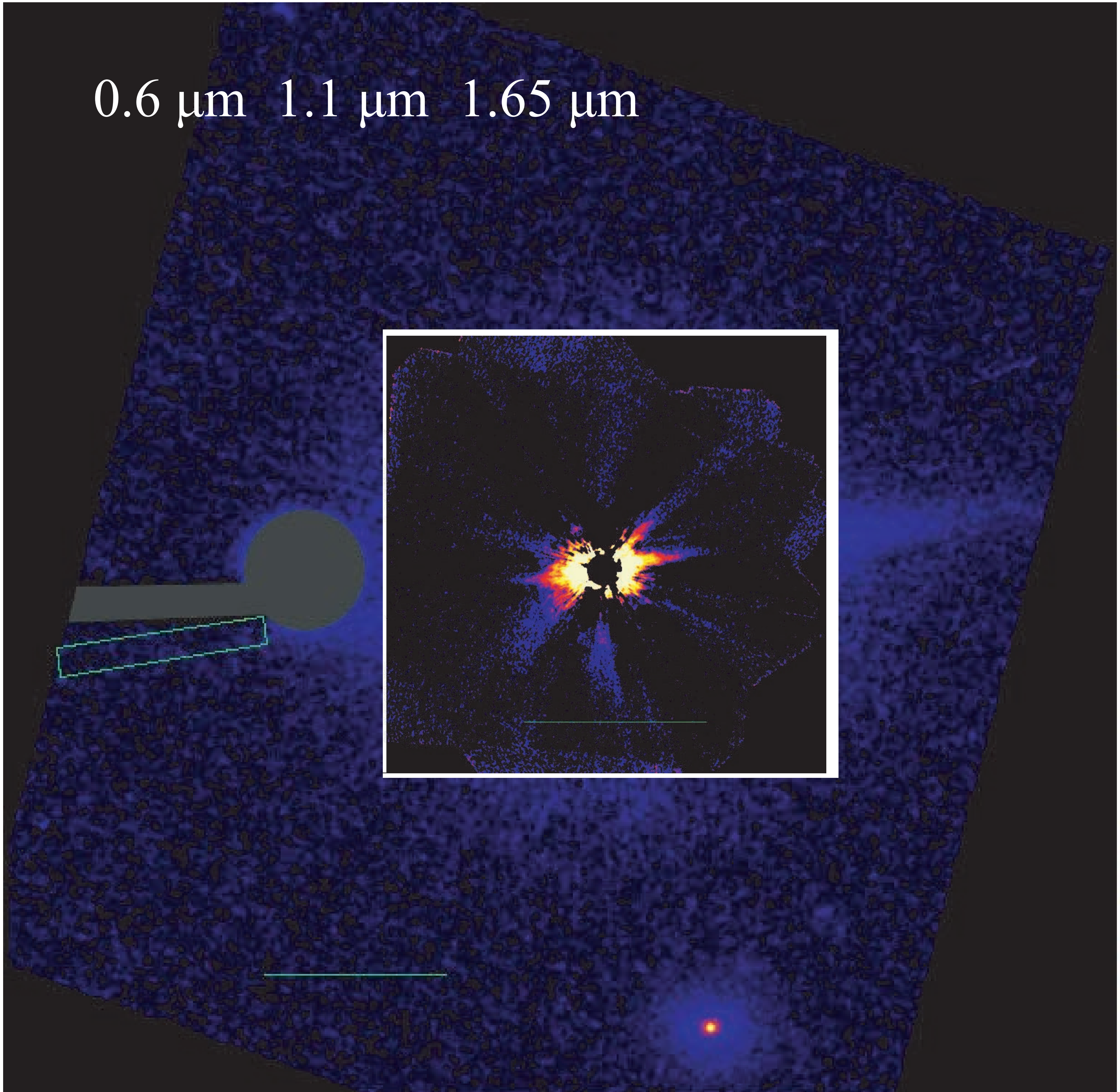

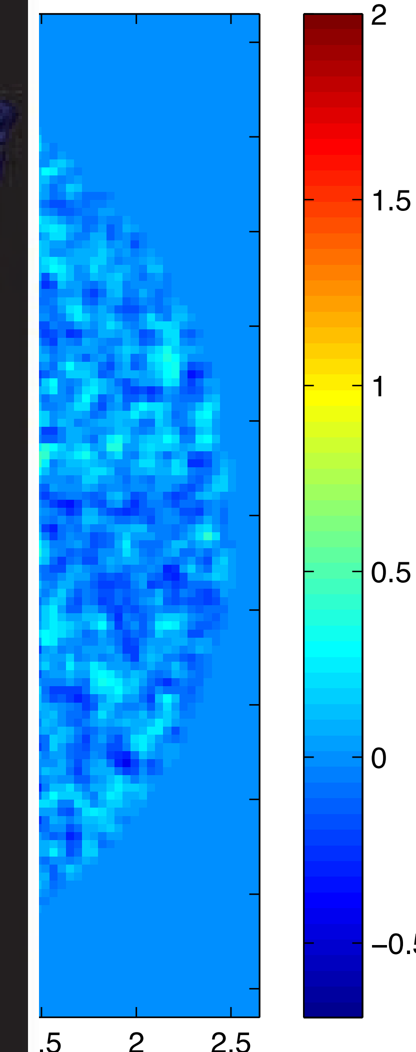

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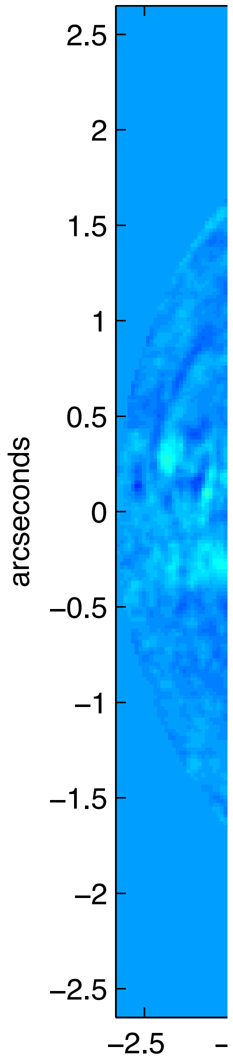

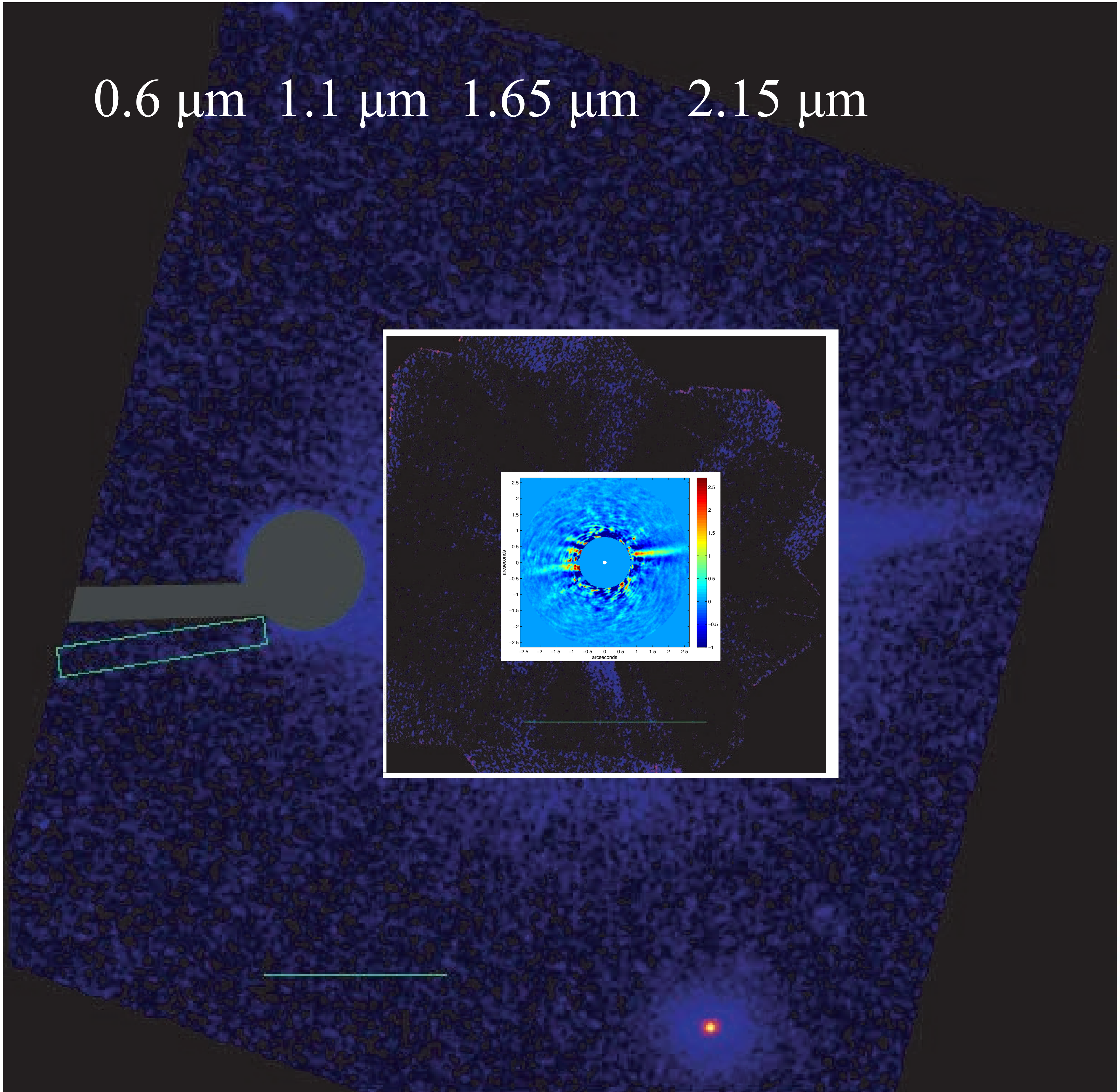

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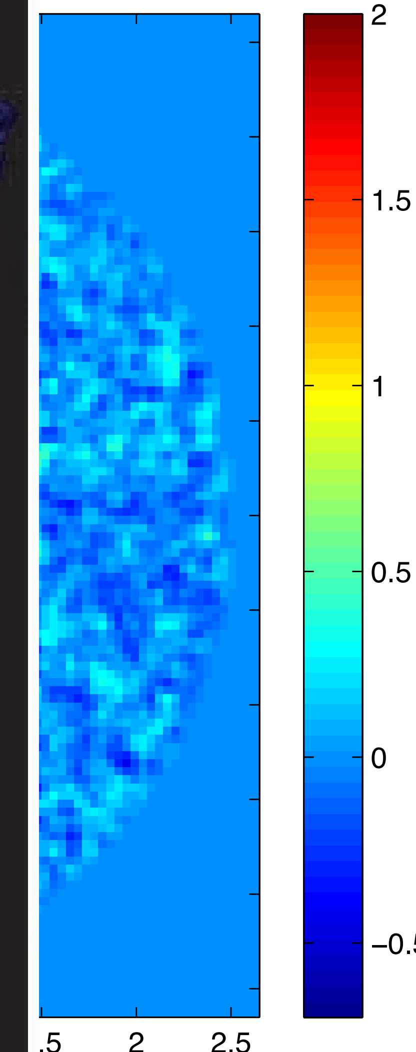

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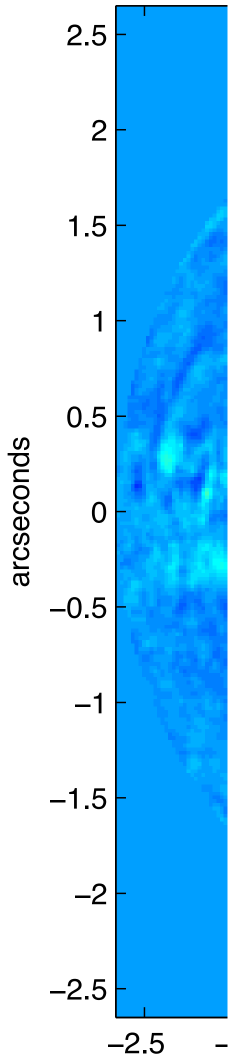
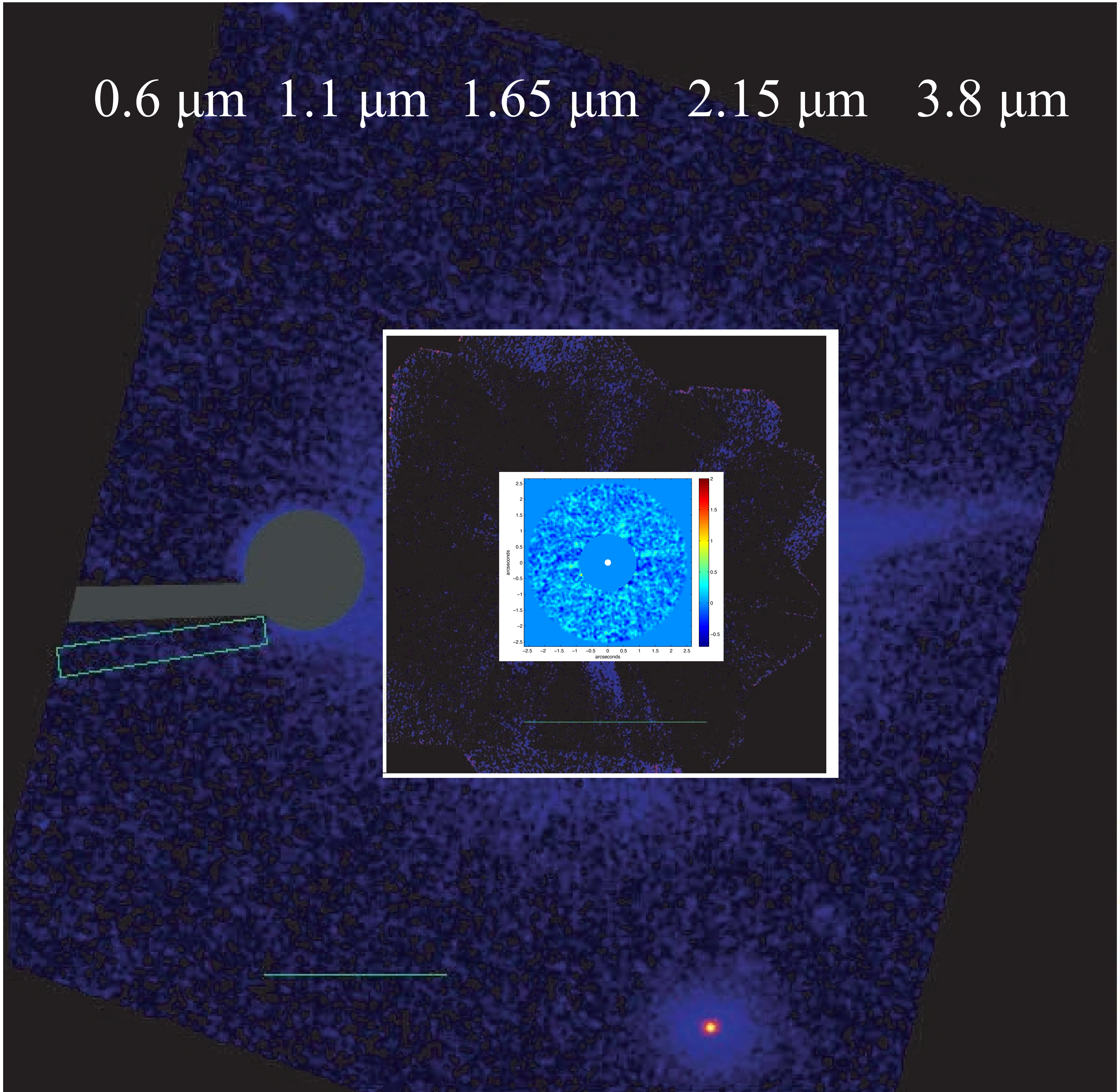
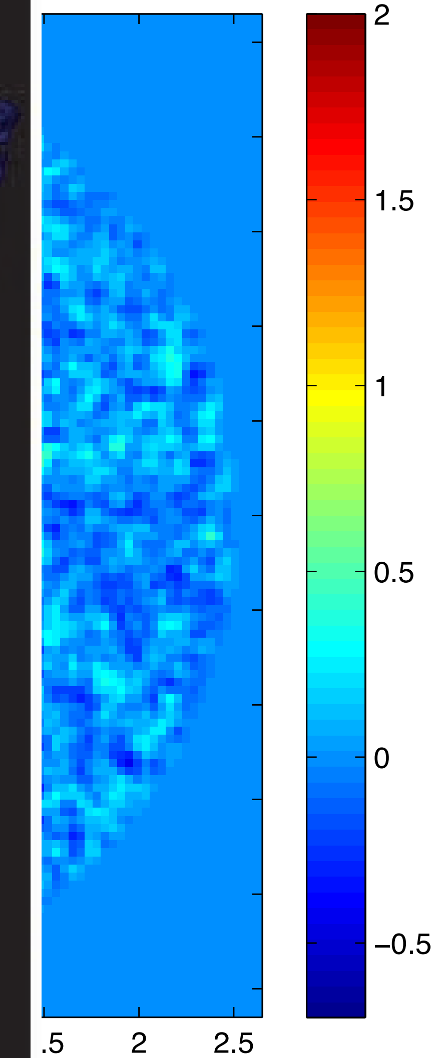


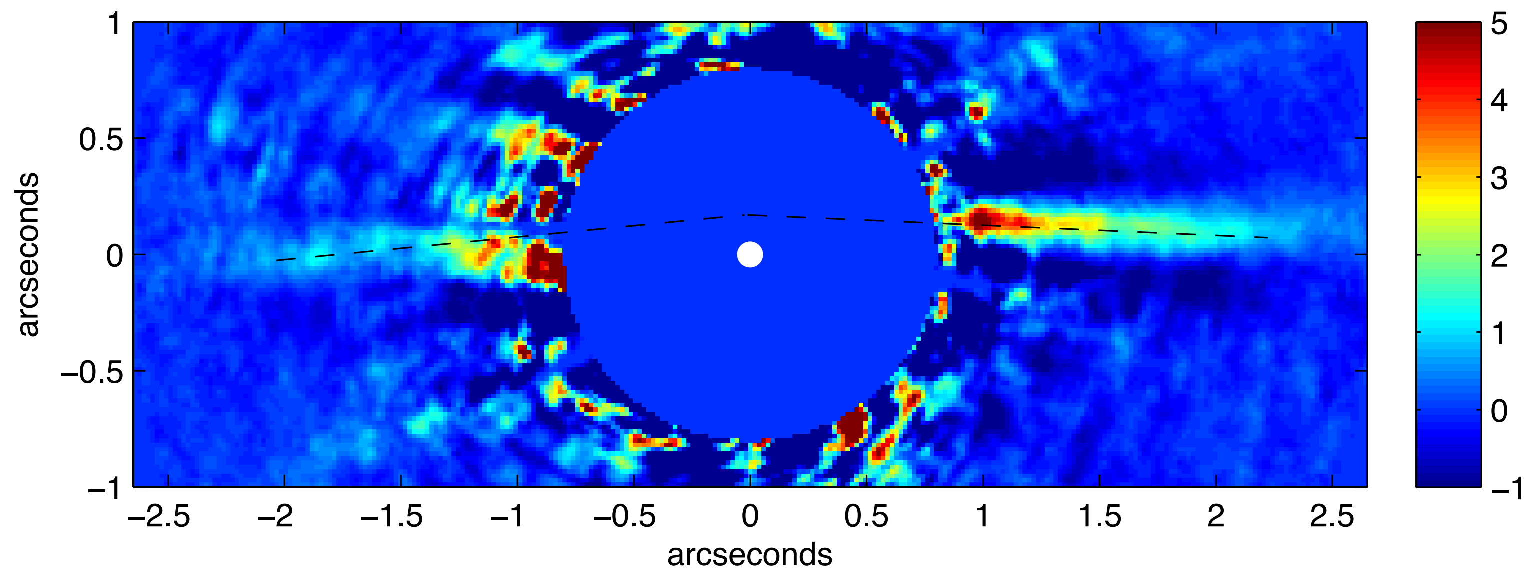




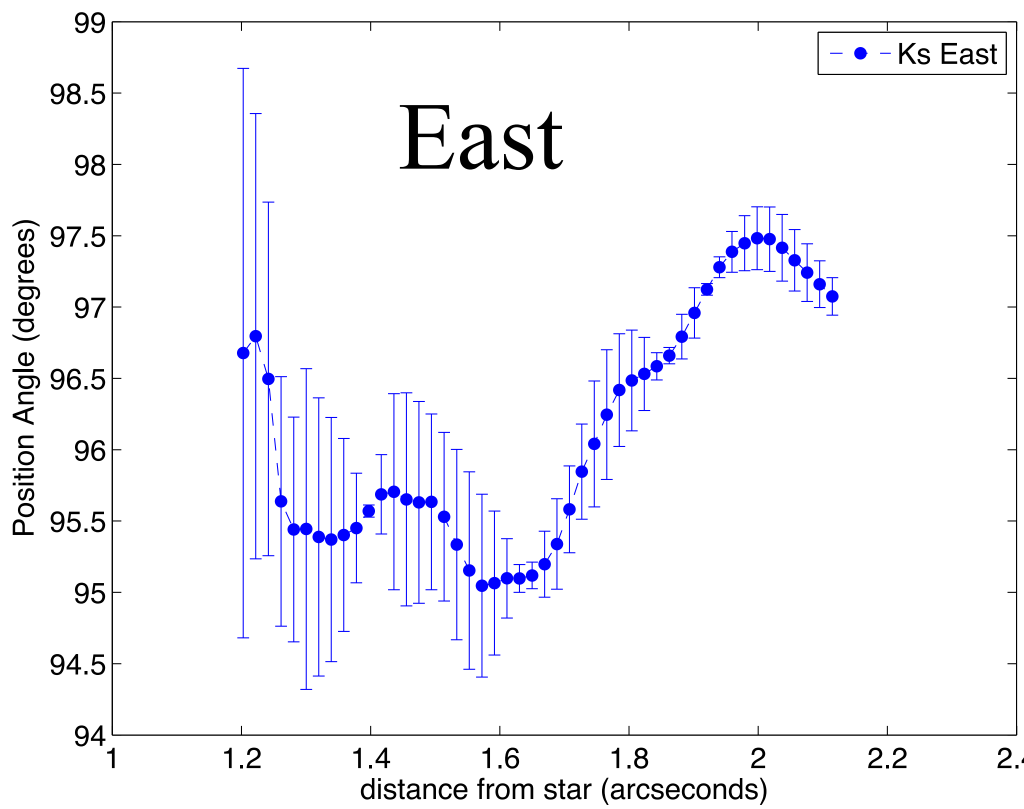
Tl … .m,

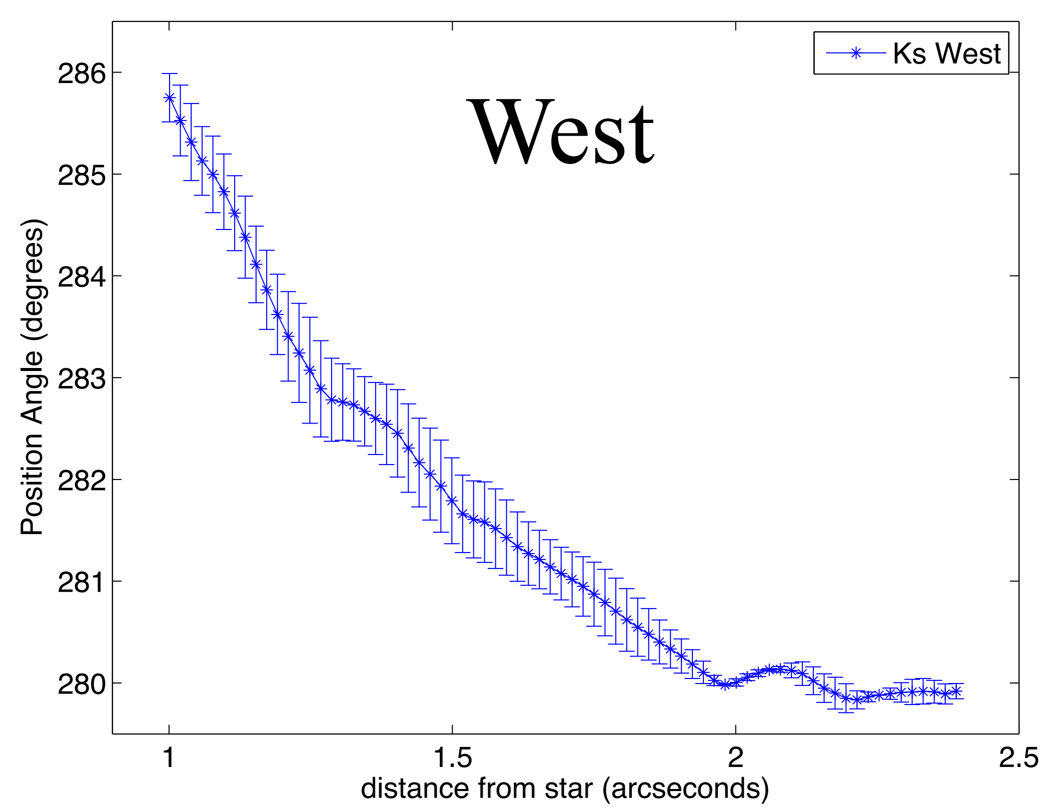
ar

Disk Morphology: an apparent bow-shape



Disk Position Angle vs. distance from star



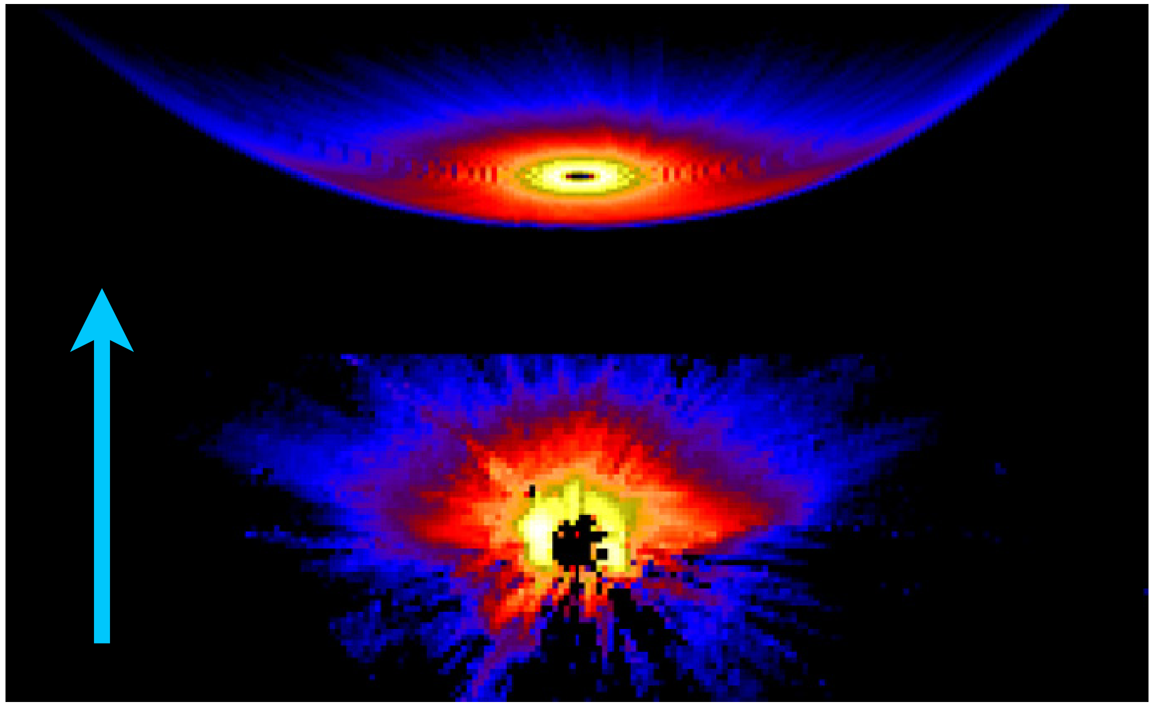


The PA for an un-bowed edge-on disk should remain ~constant

Can ISM interactions explain the bow?

Can ISM interactions explain the bow?

HD 61005 (“the moth”)



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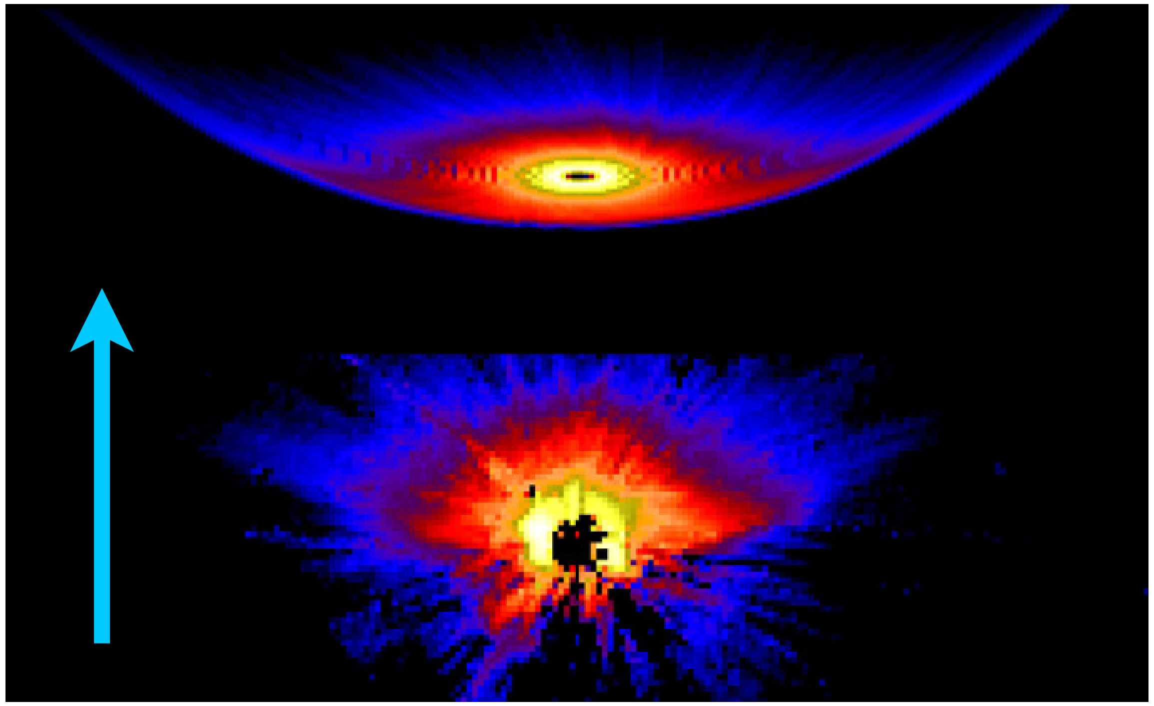

For the moth, yes

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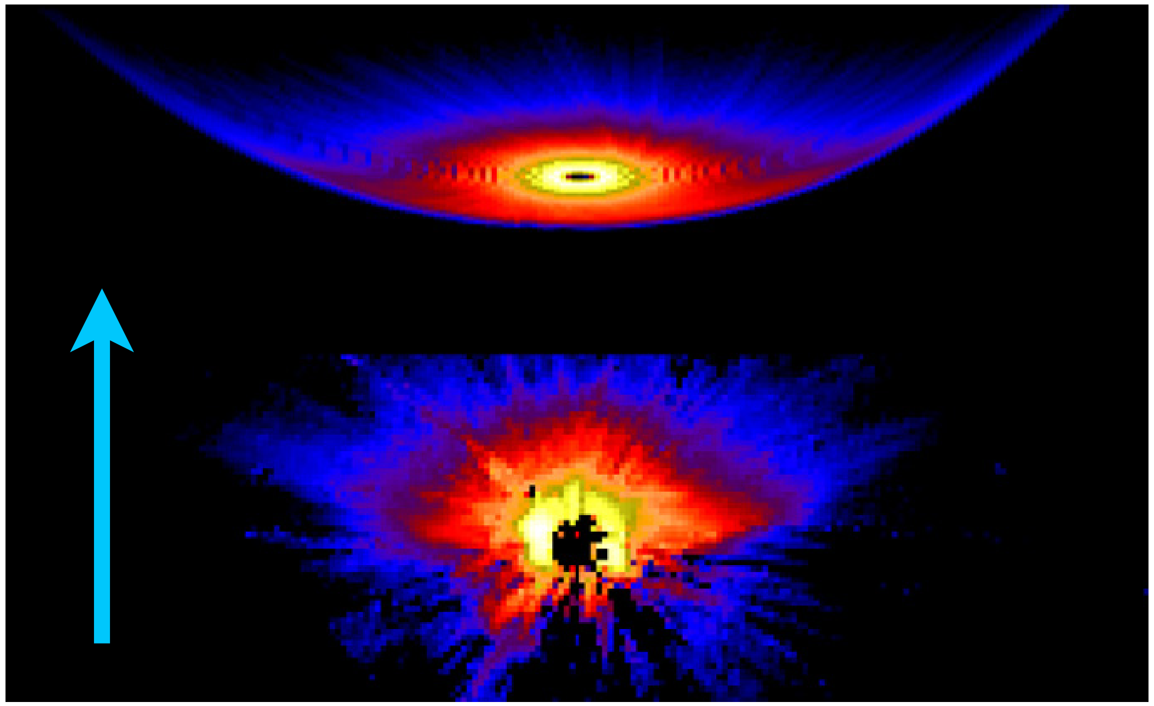

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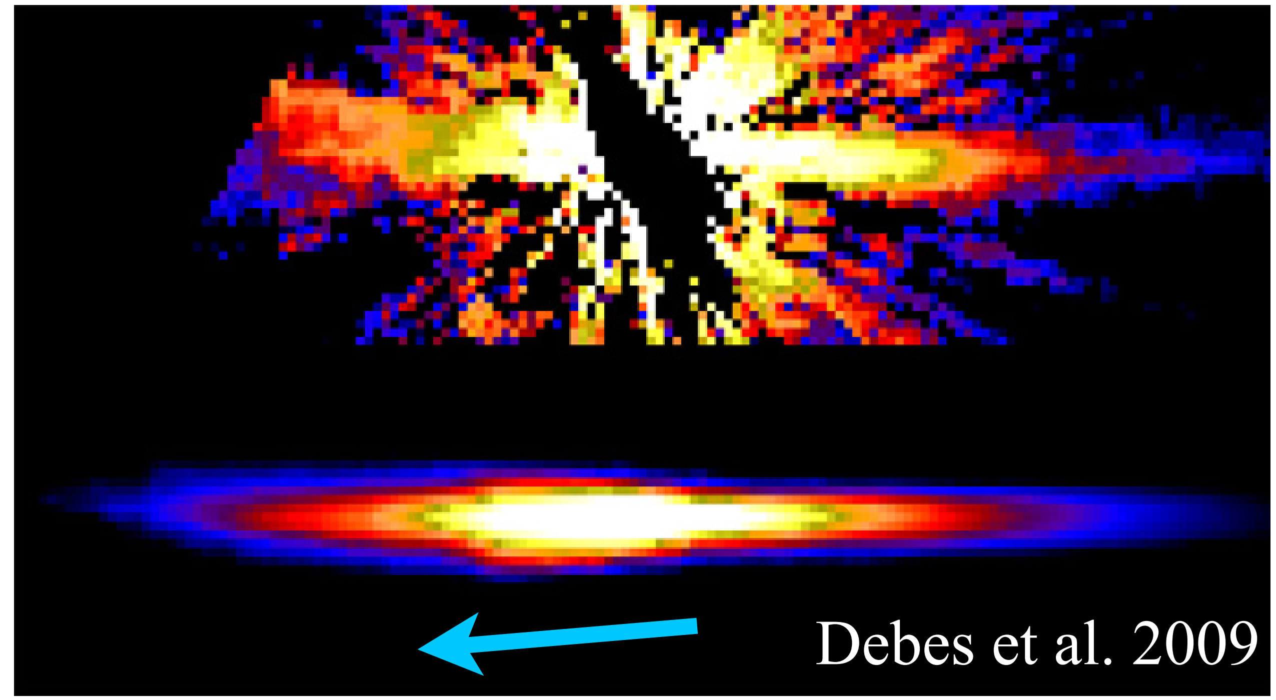
HD 15115



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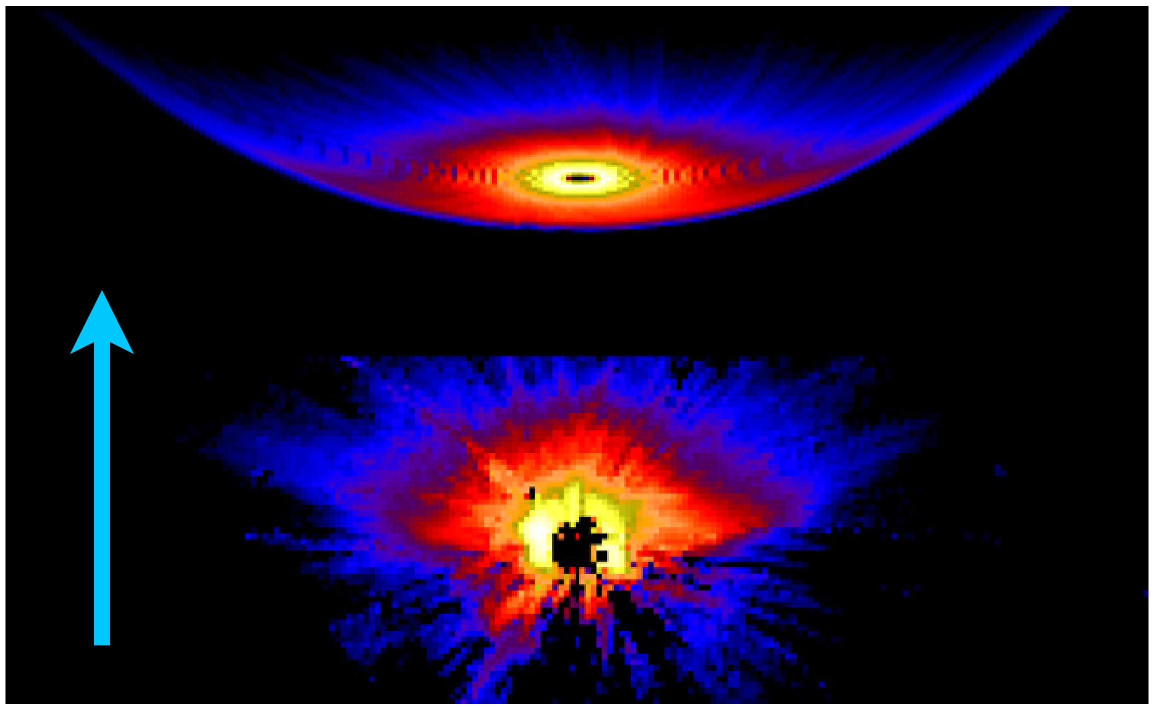

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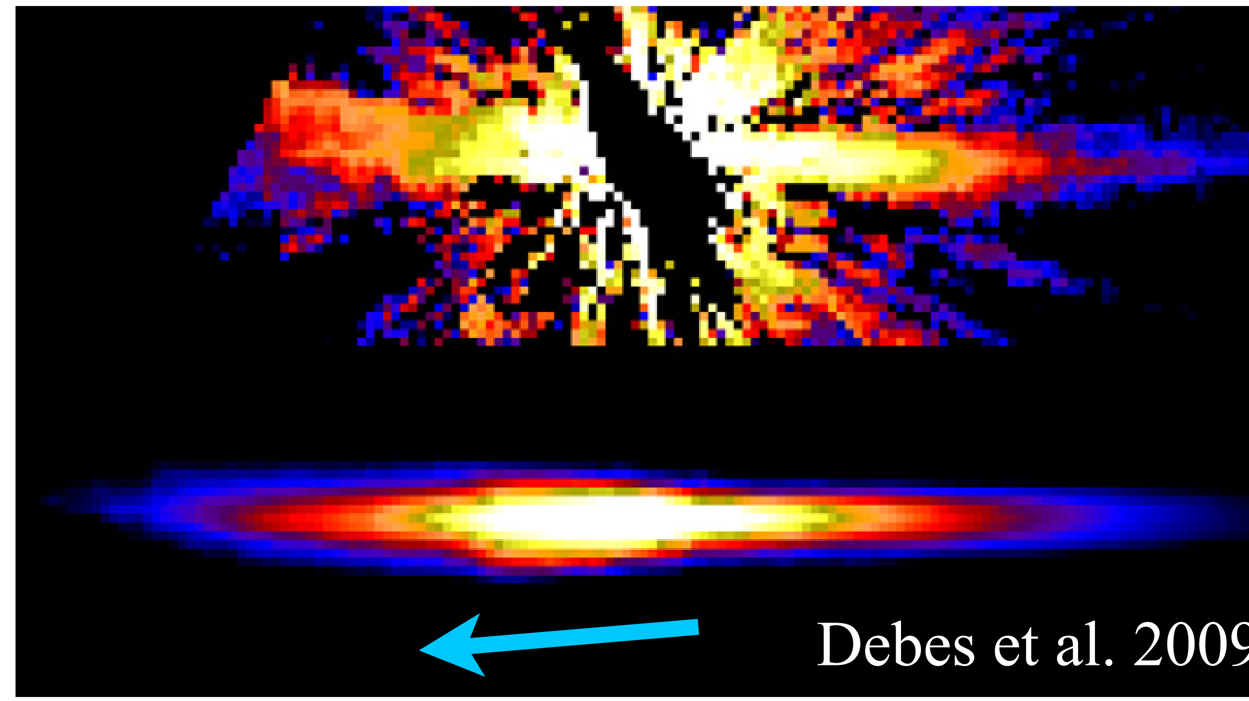
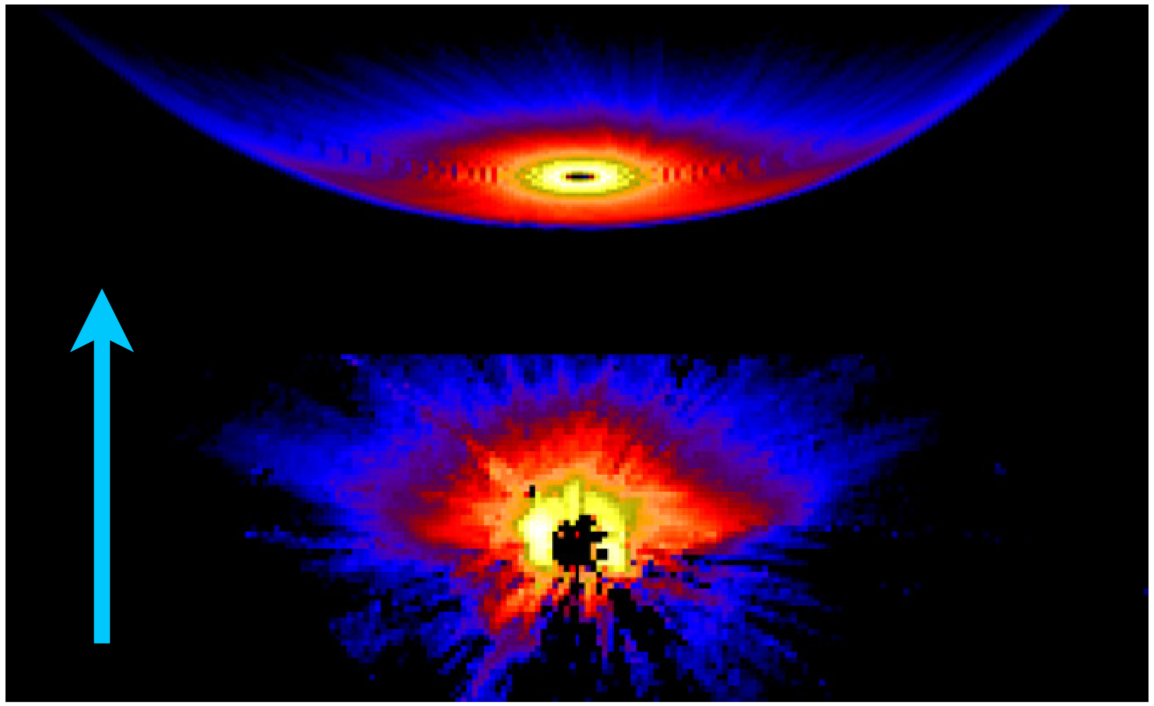
HD 15115



For HD 15115, unlikely

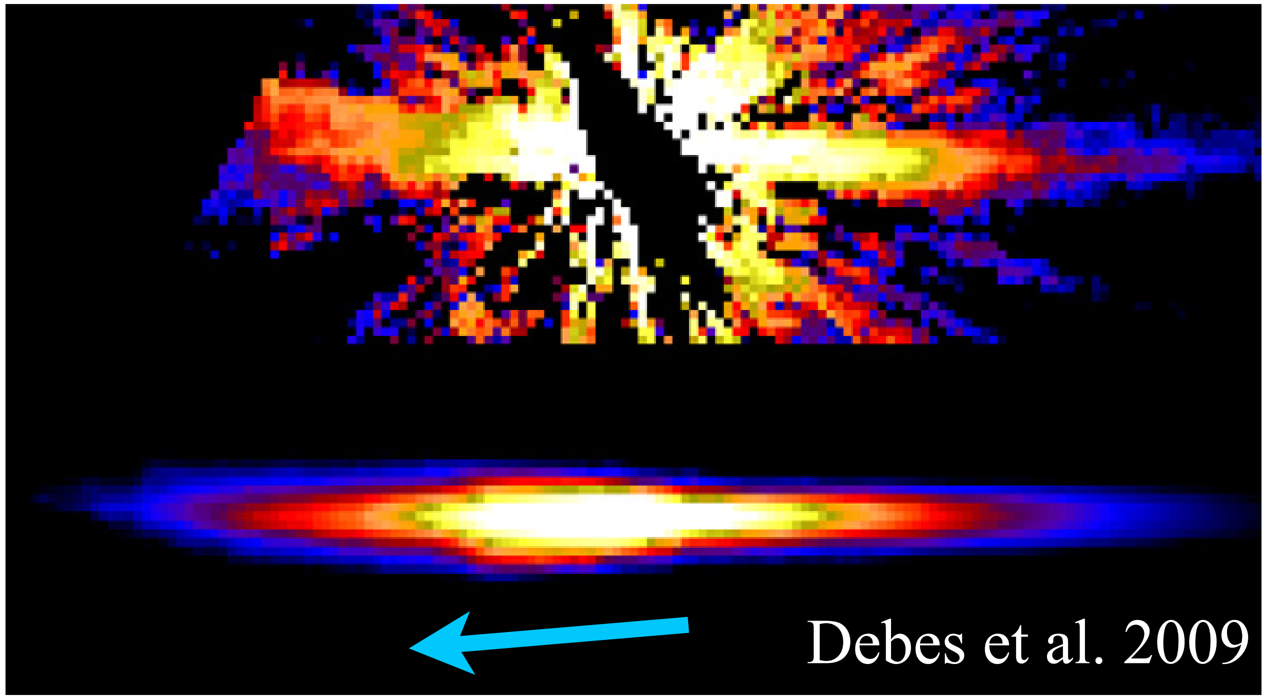
Can ISM interactions explain the bow?

HD 61005 ("the moth")



For the moth, yes

HD 15115



For HD 15115, unlikely

...But is good candidate to explain east-west asymmetry

Just viewing geometry?

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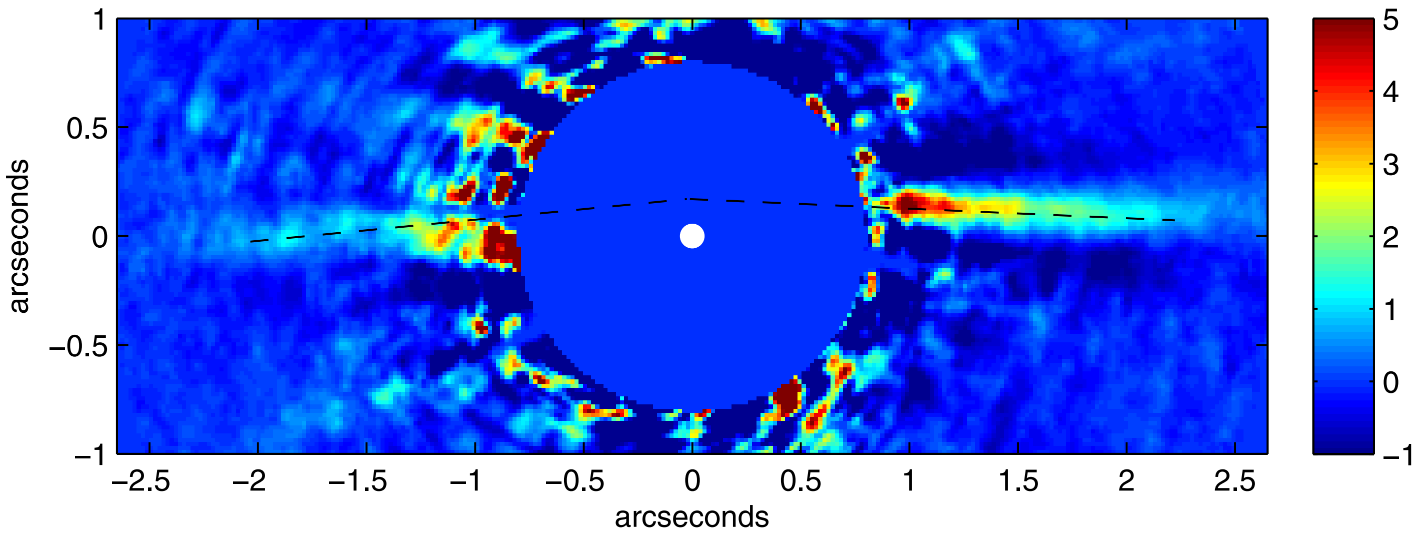
Real



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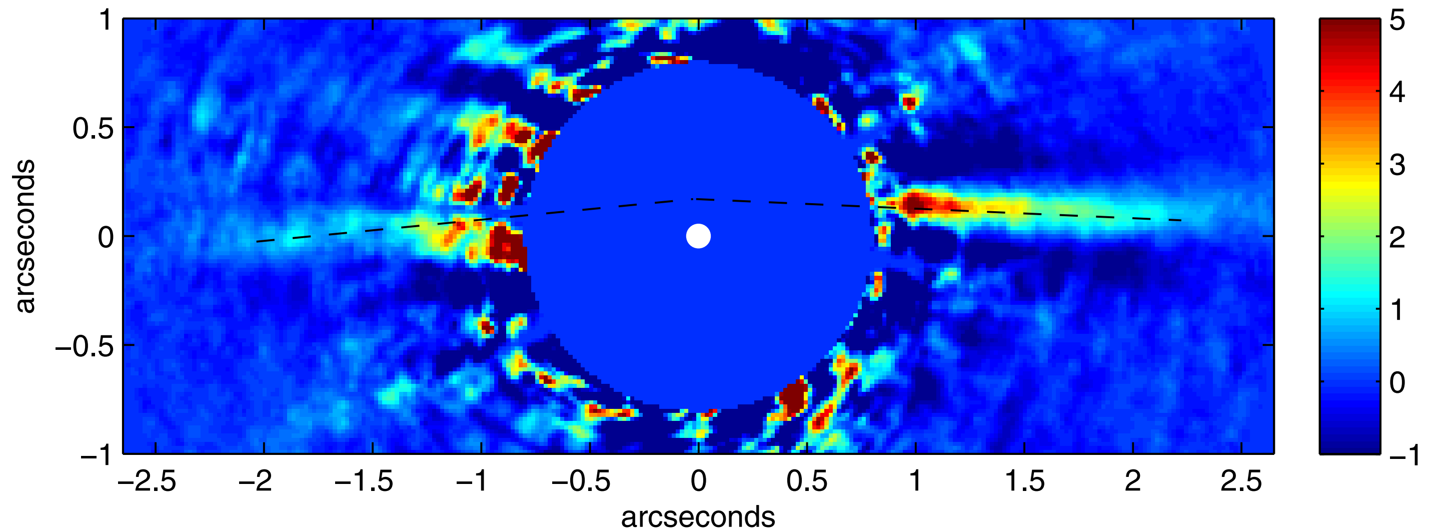
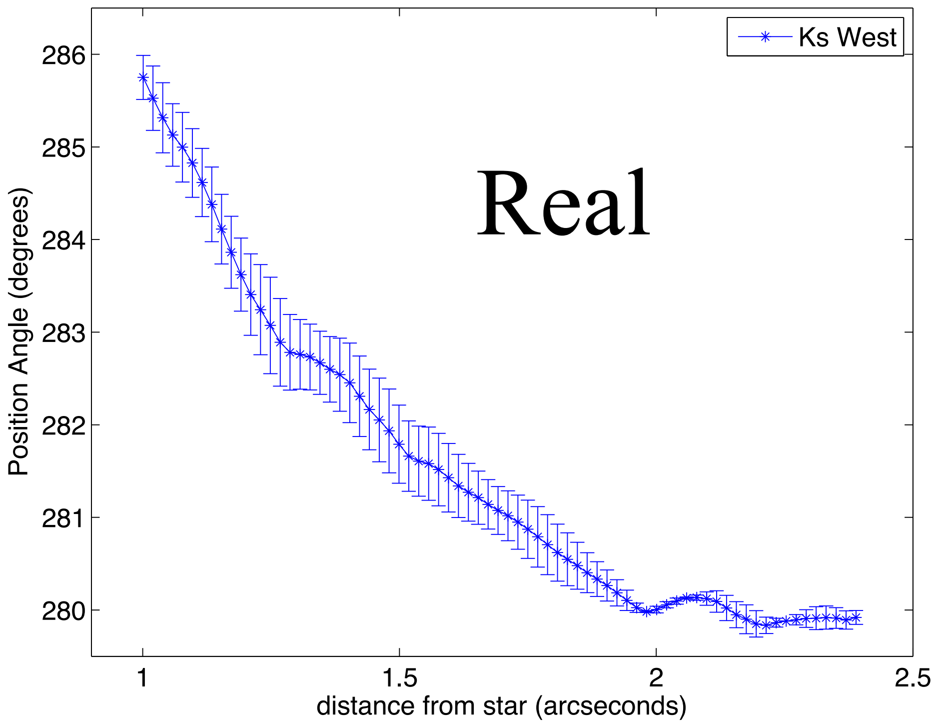


PA vs. radius



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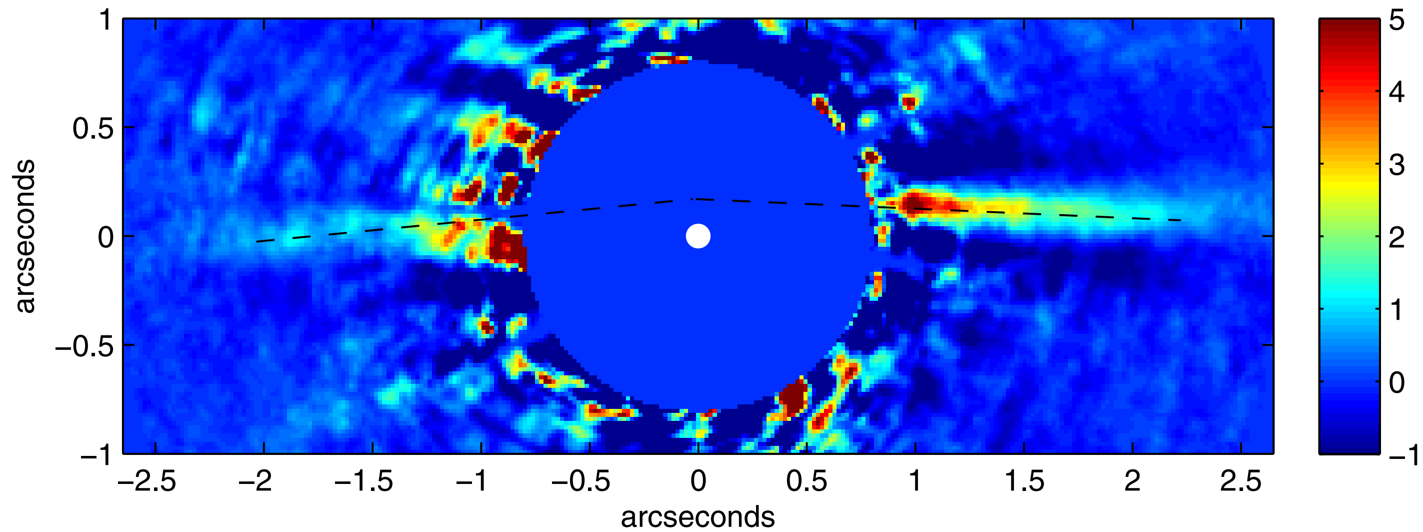

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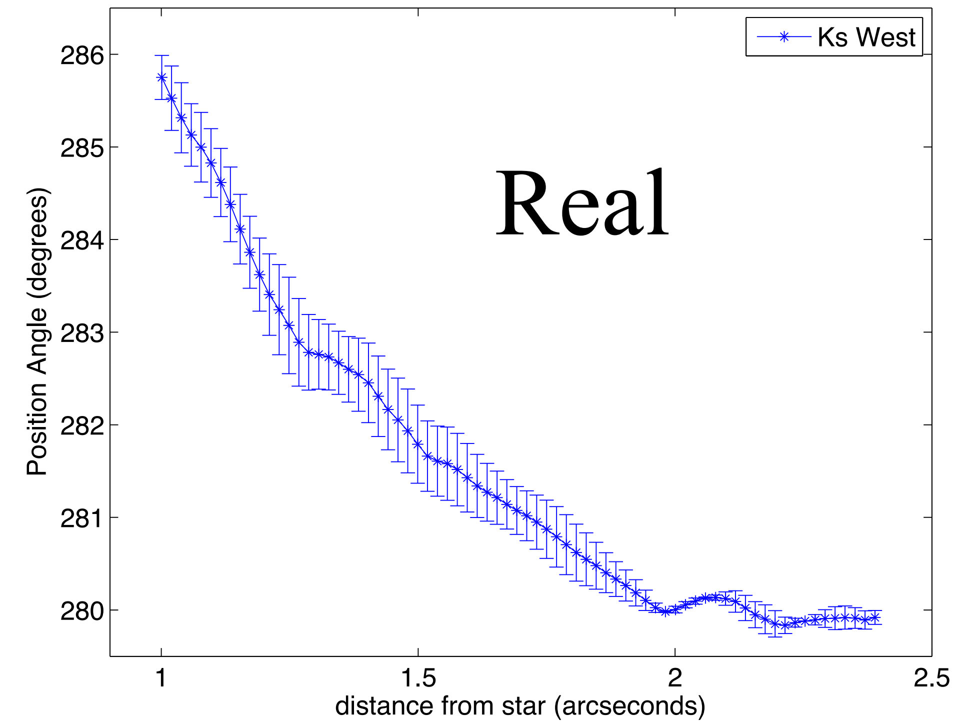
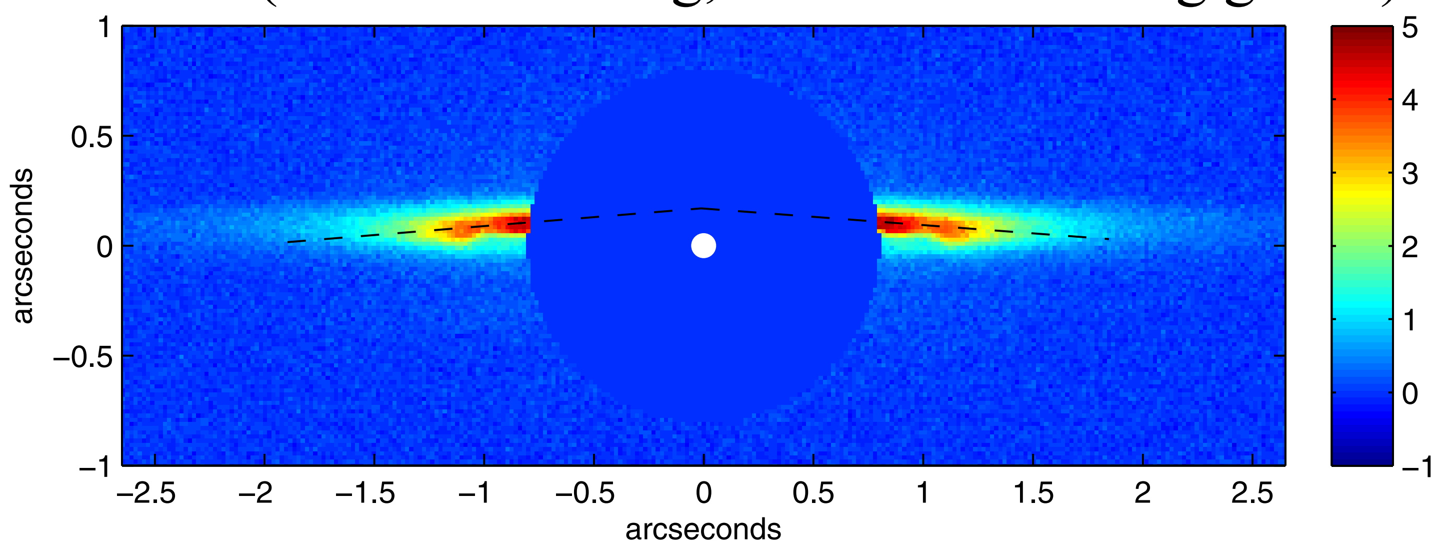


Model (87° inclined ring, forward-scattering grains)



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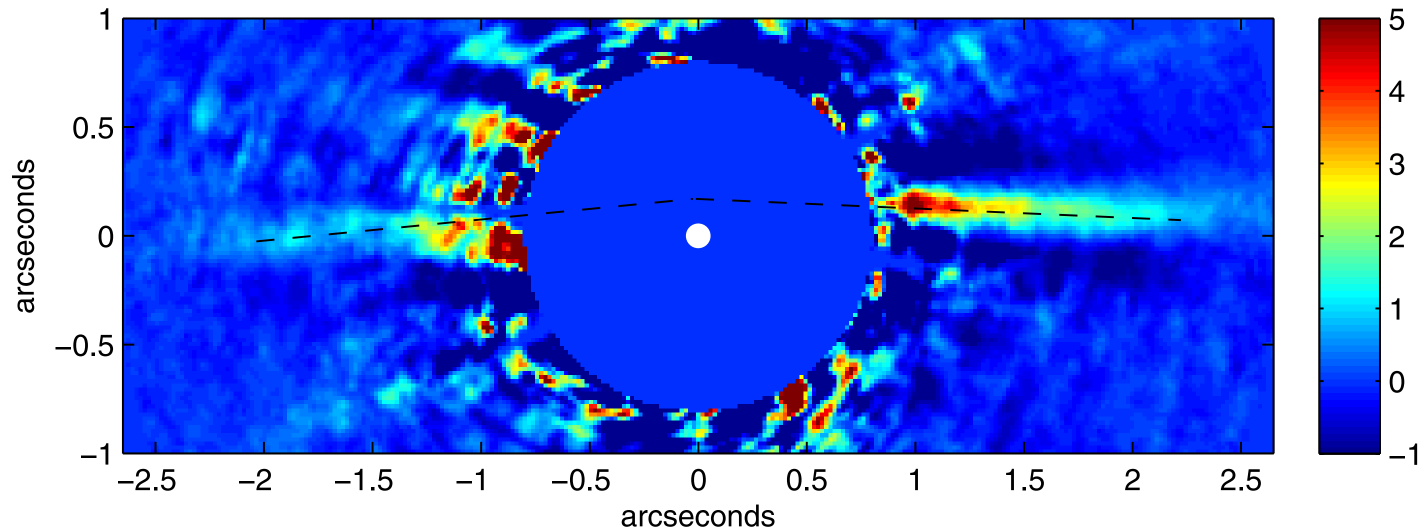

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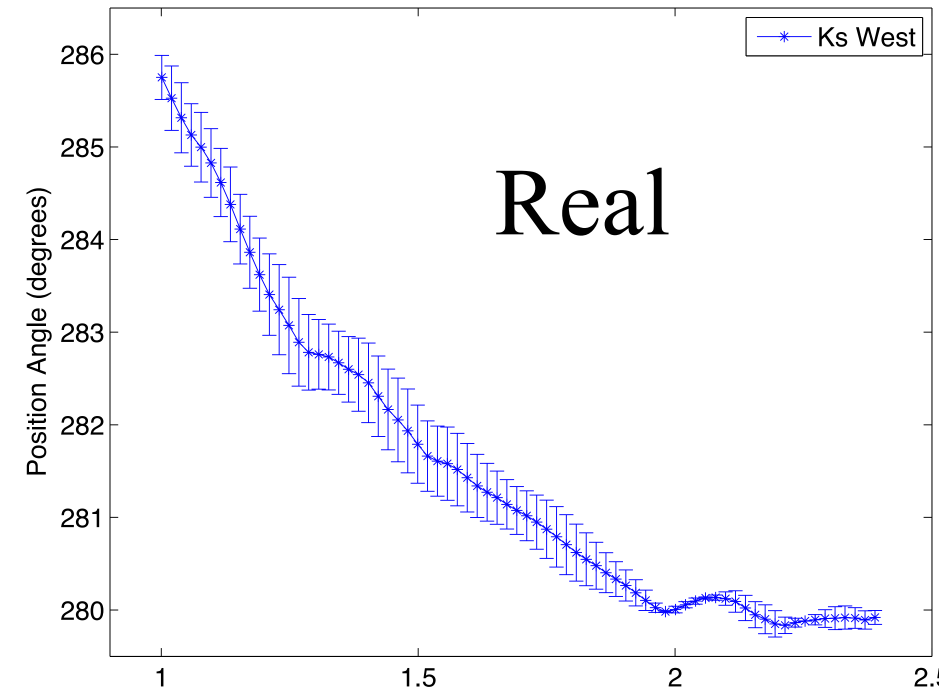

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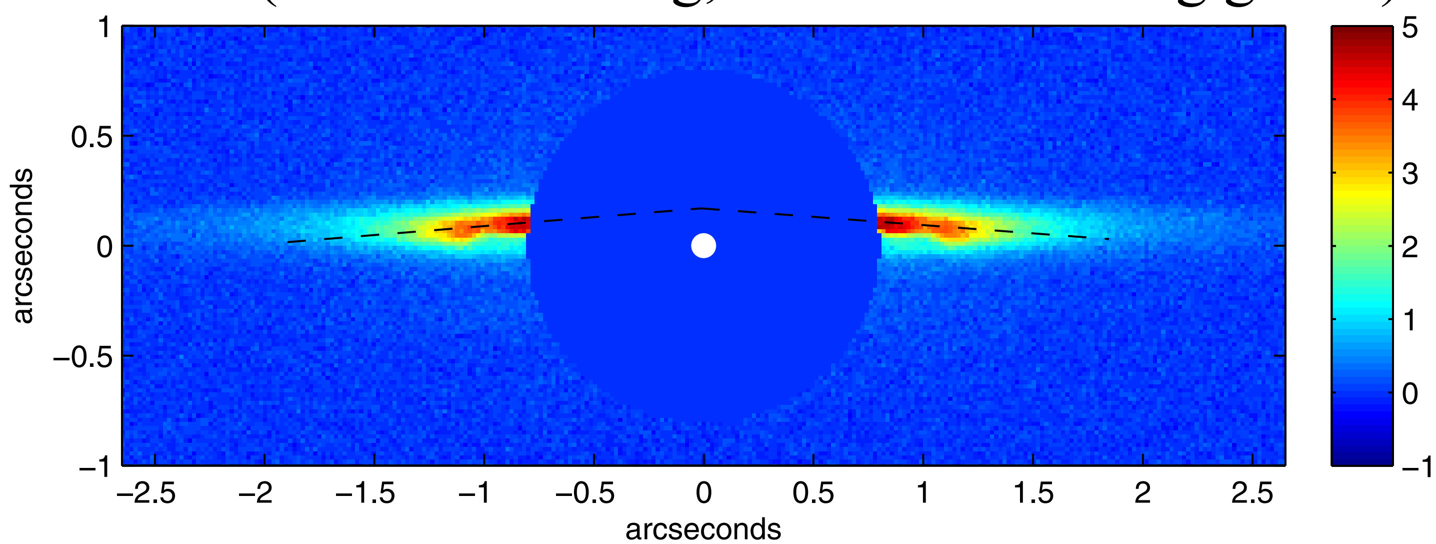

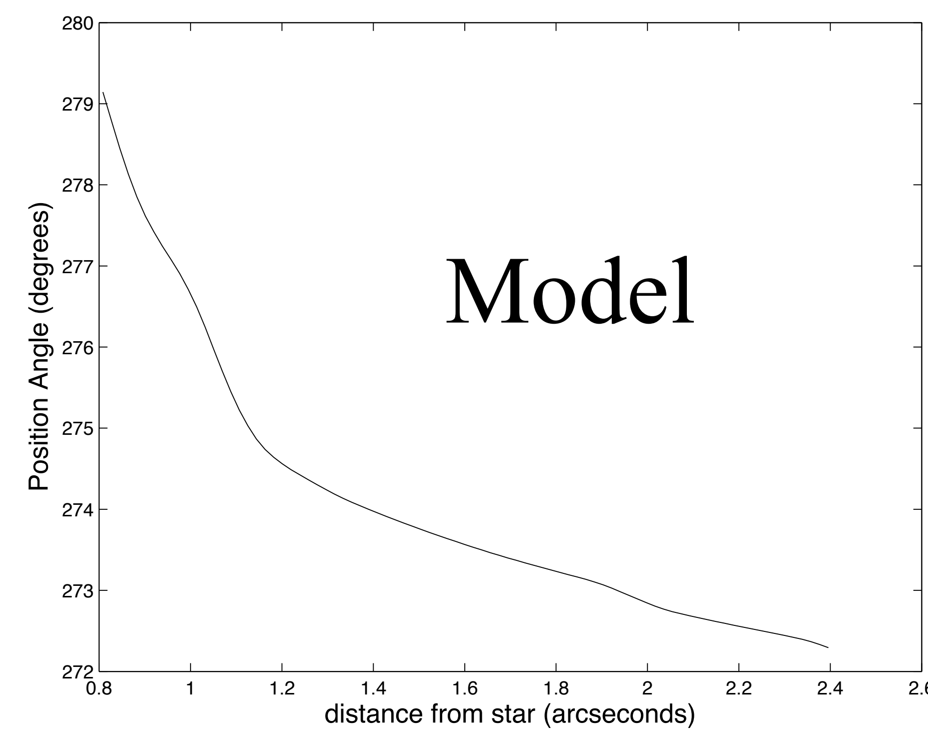

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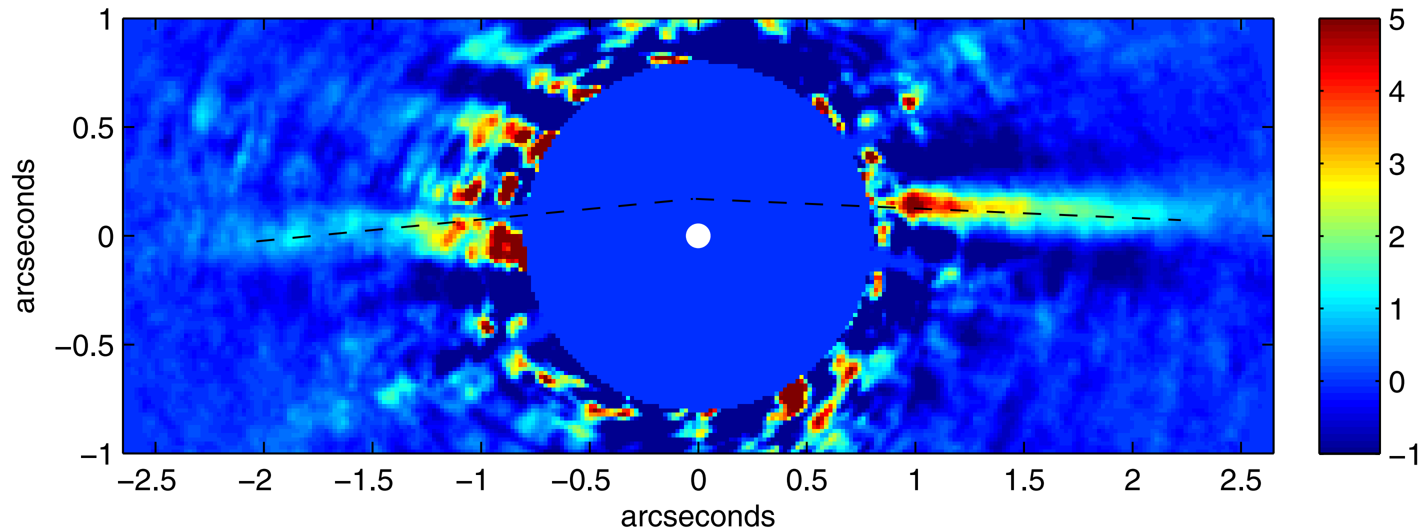

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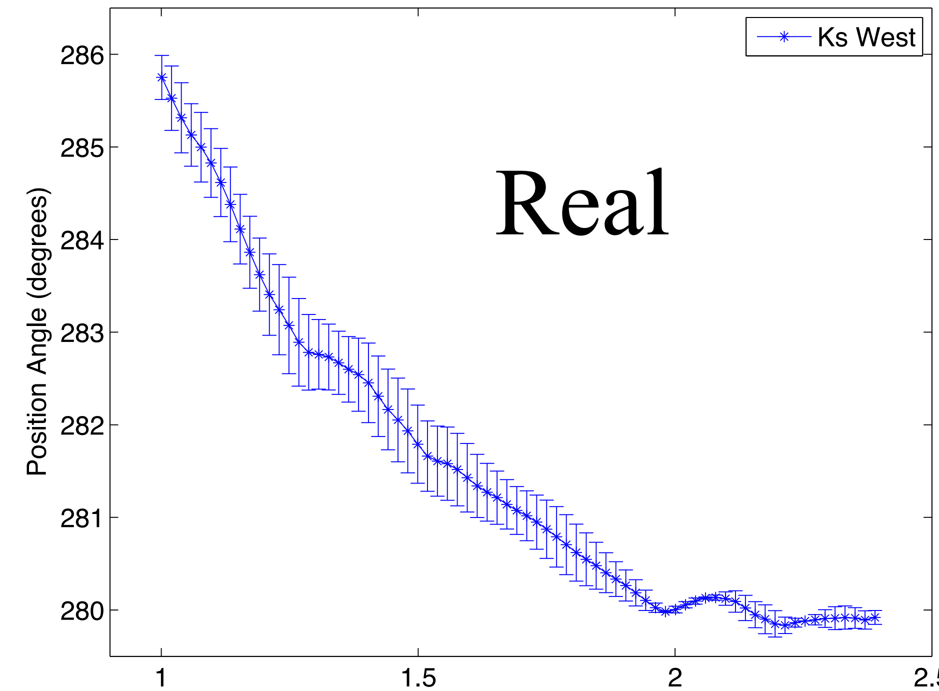

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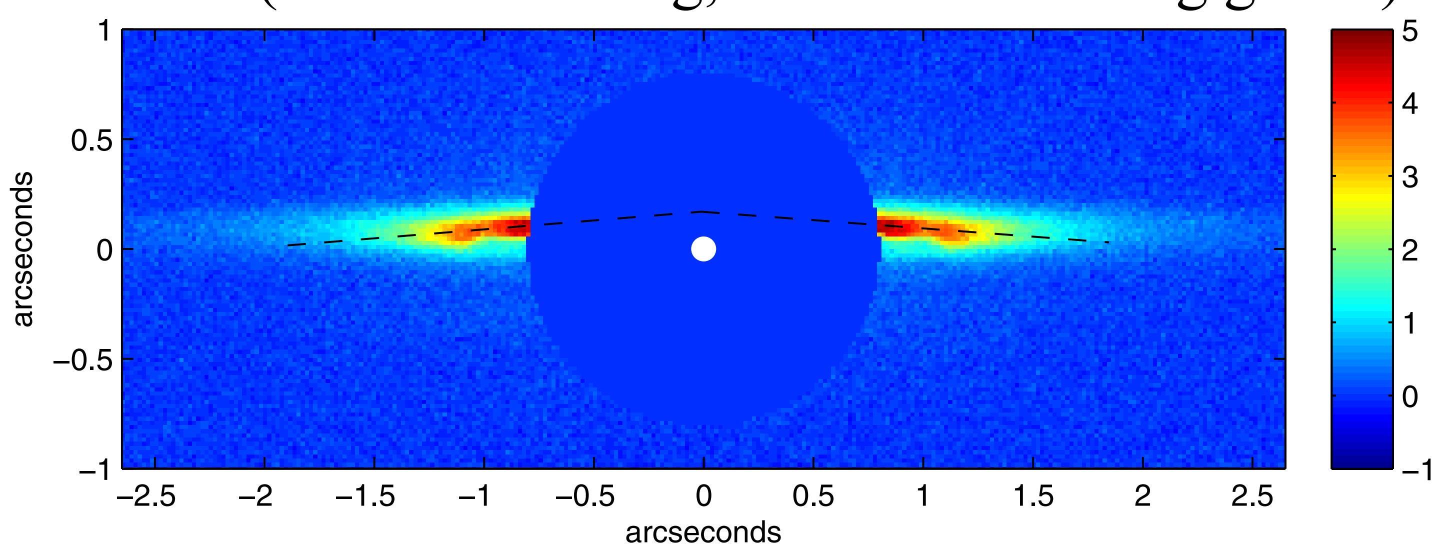
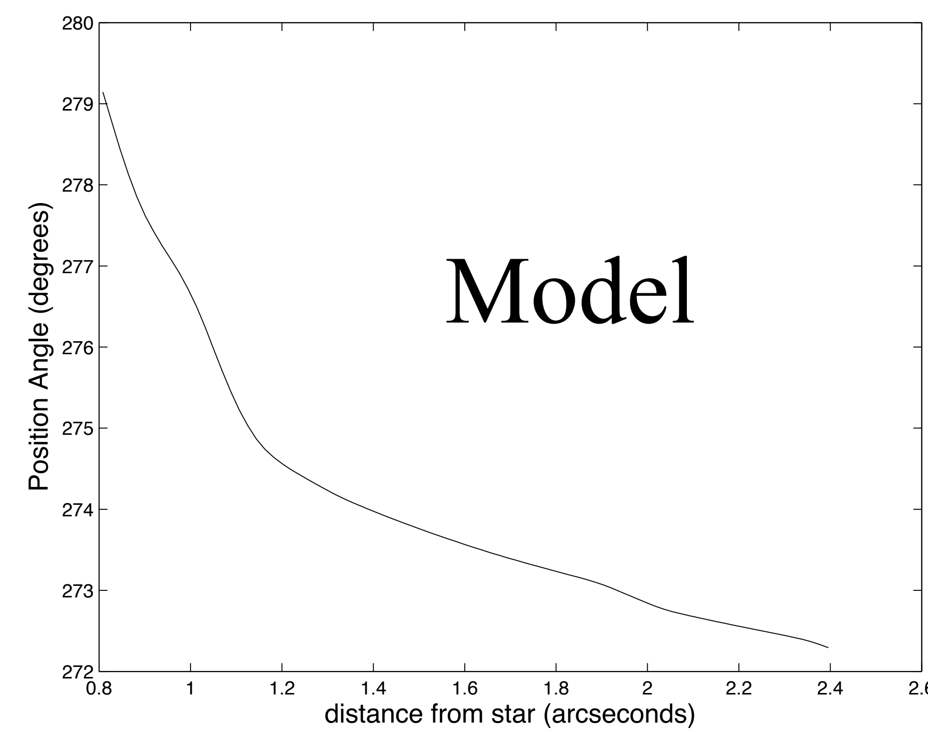
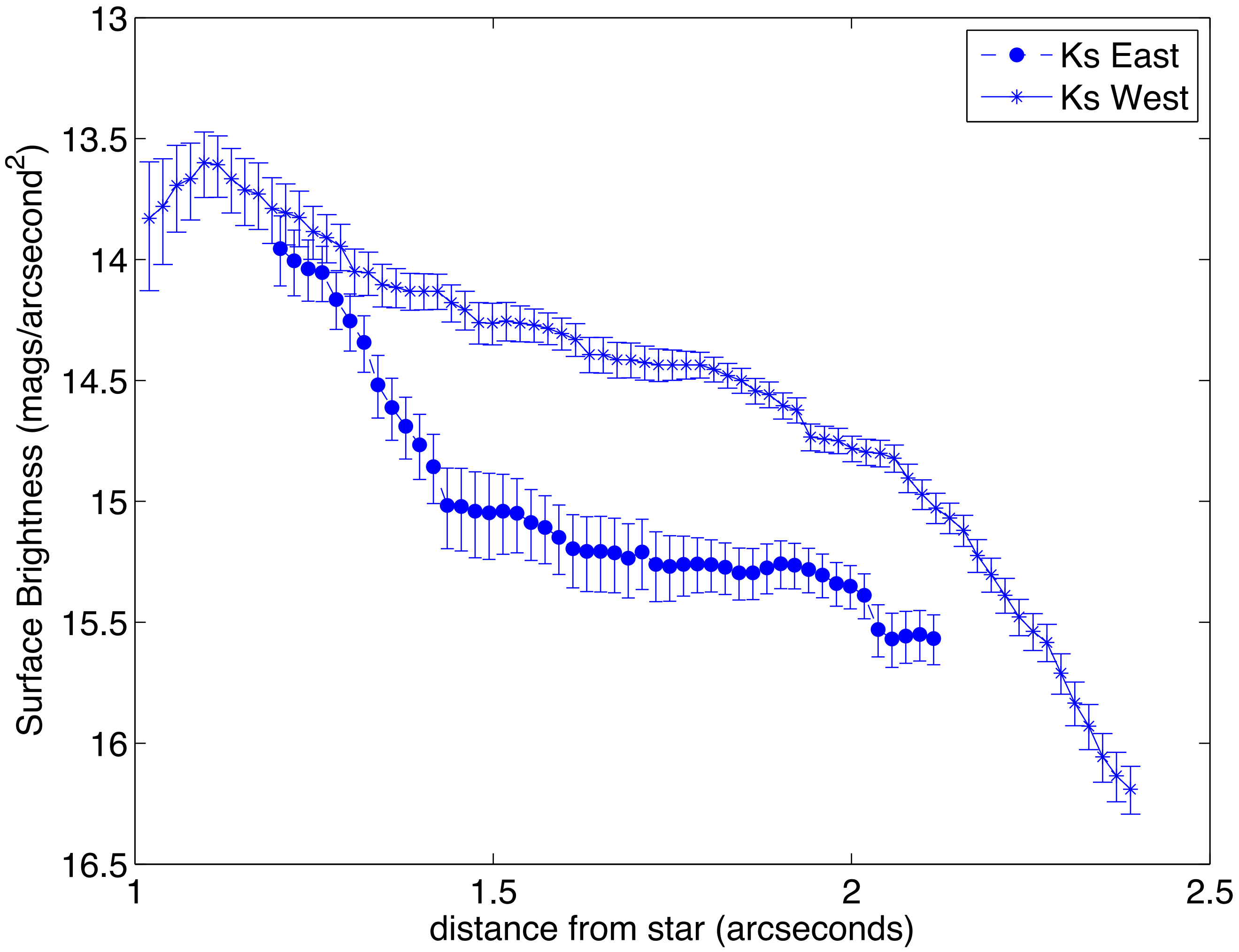




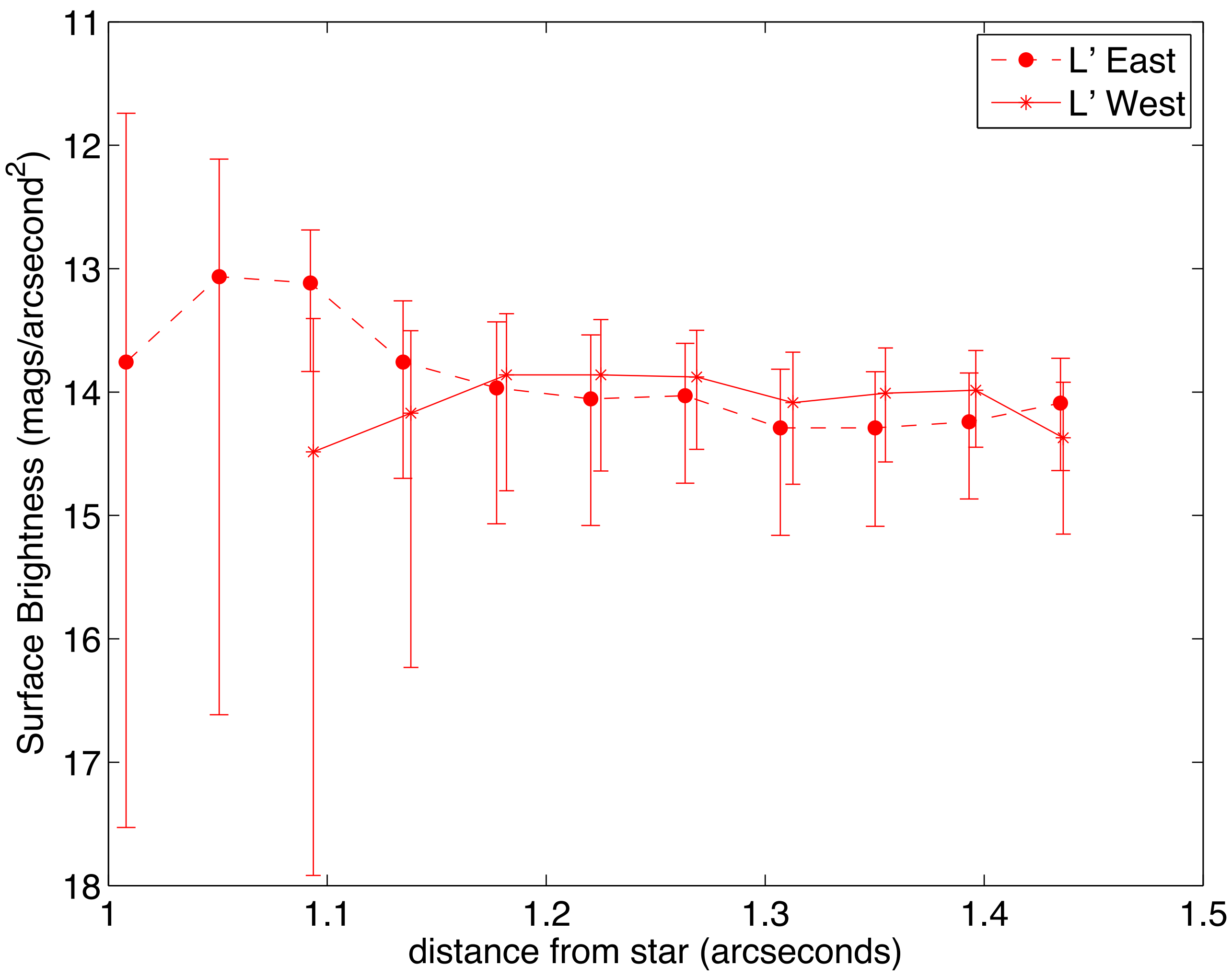
Model reproduces PA well
(though not unique)

Surface Brightness Profiles

2.15 µm



3.8 µm



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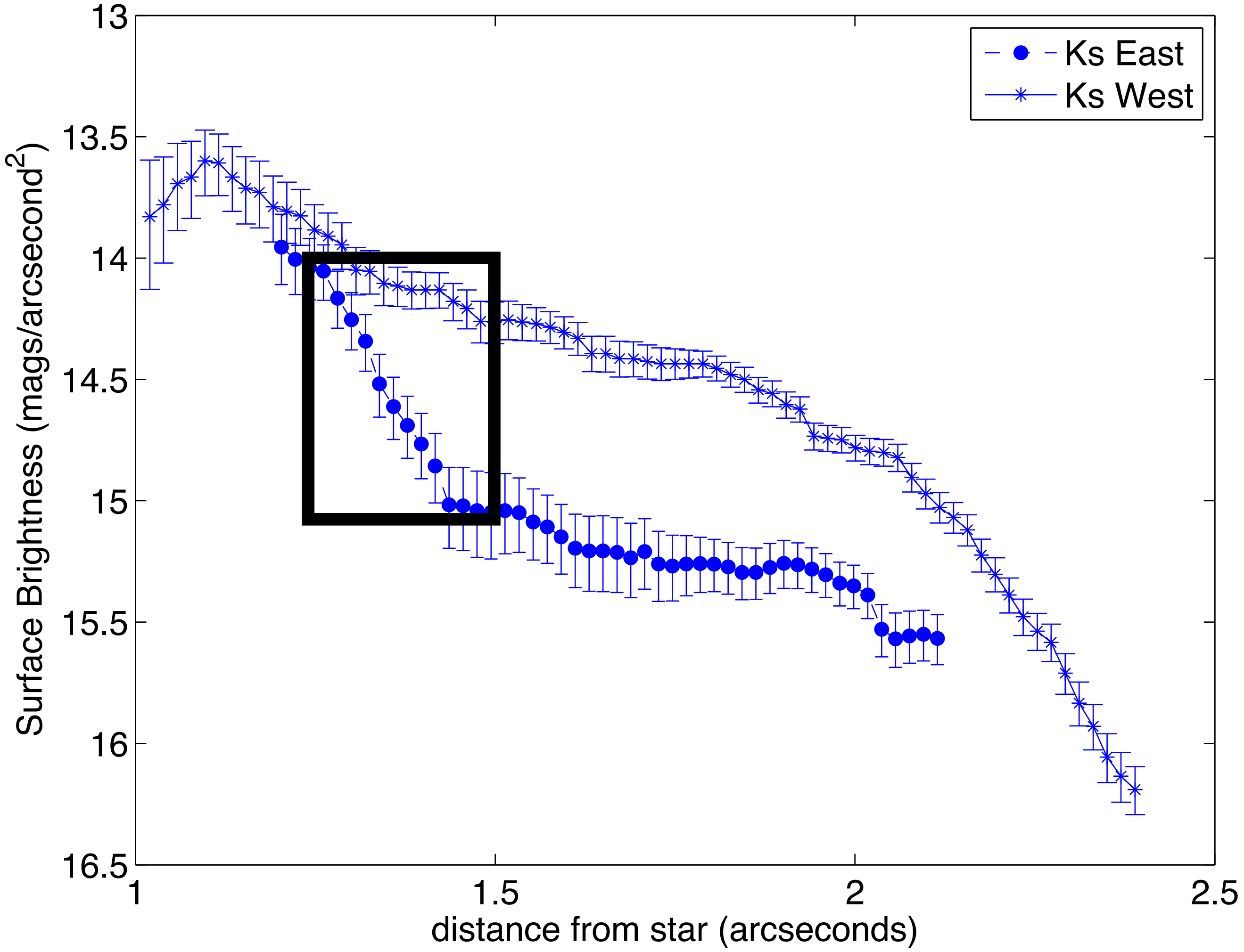

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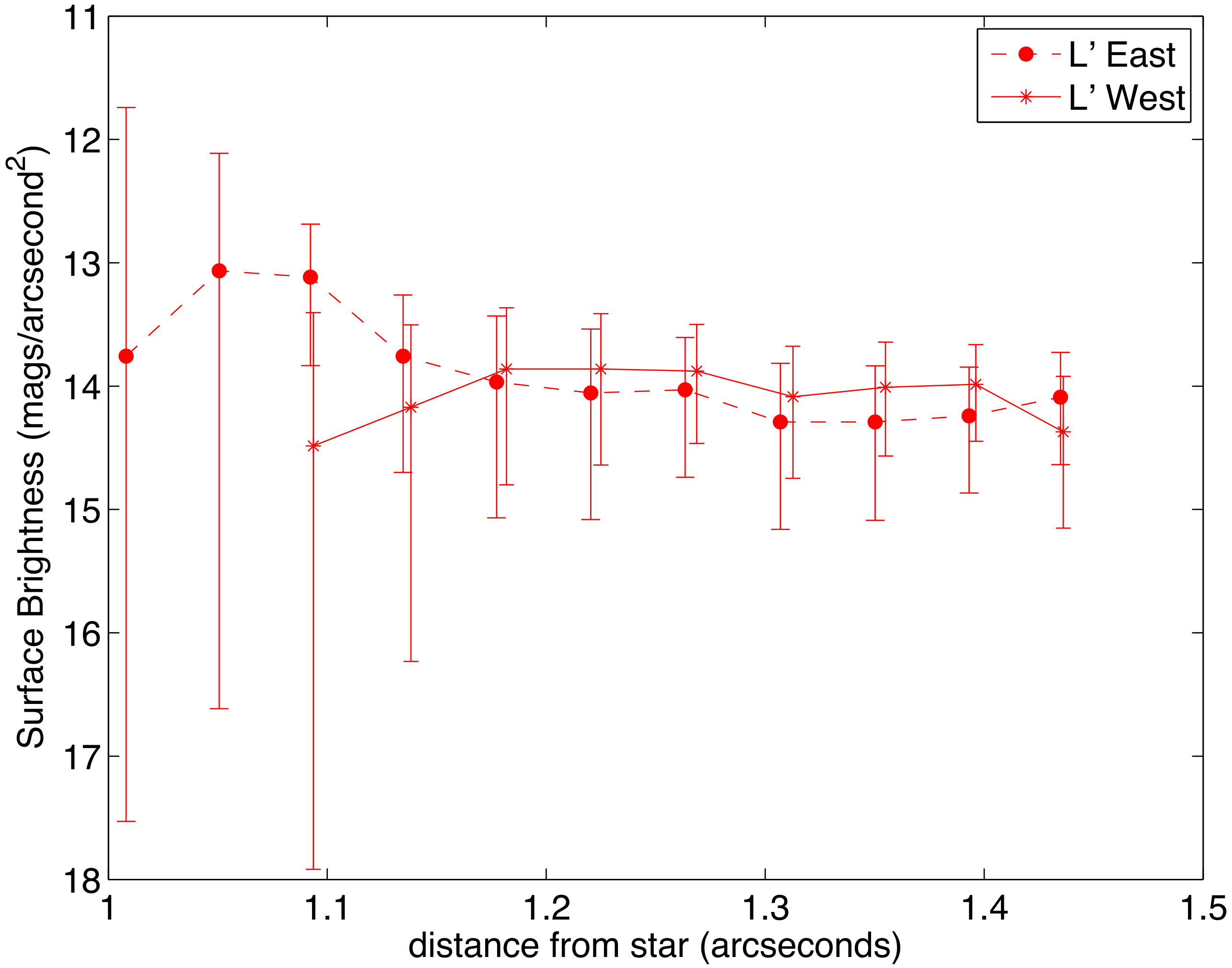

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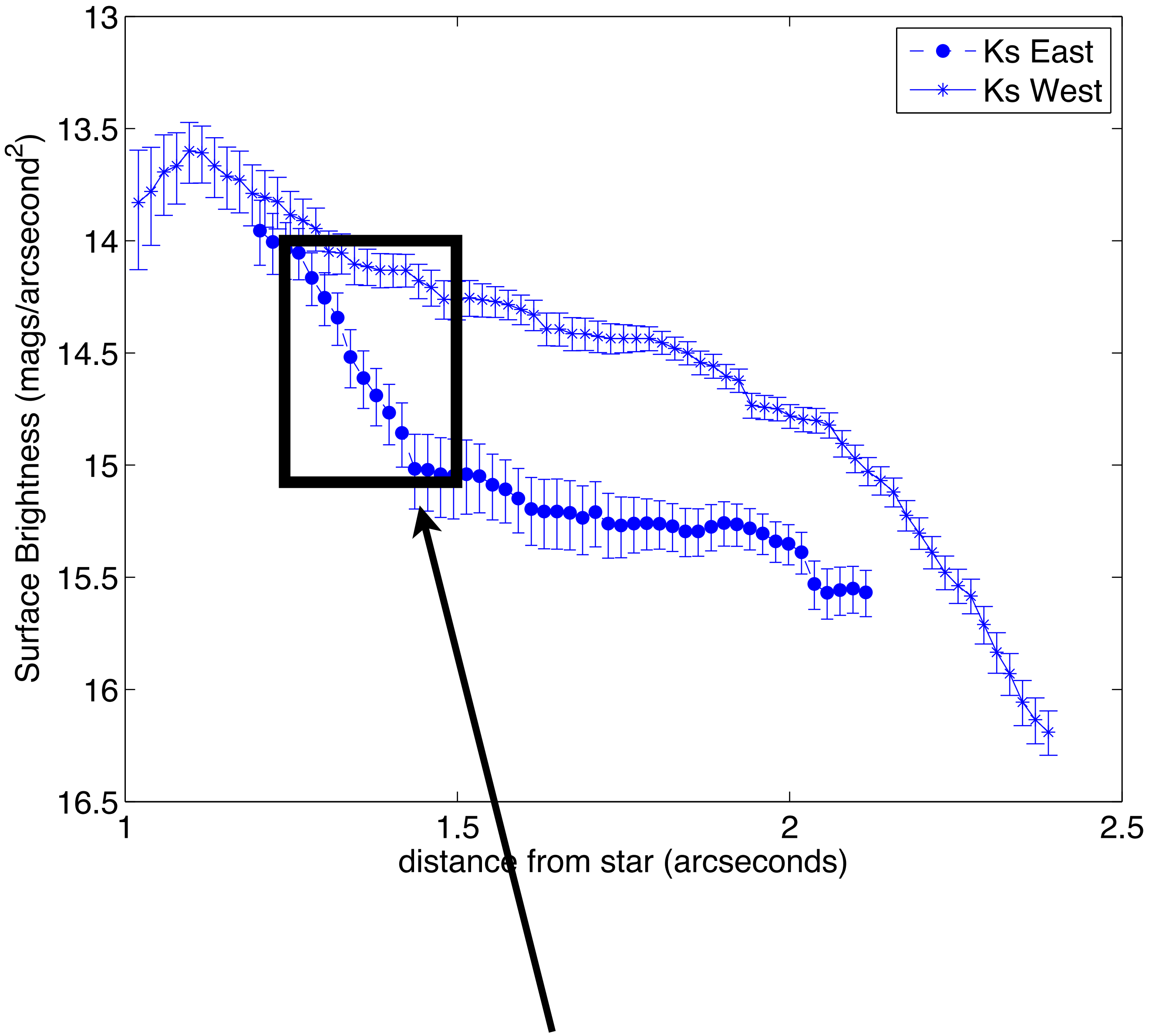
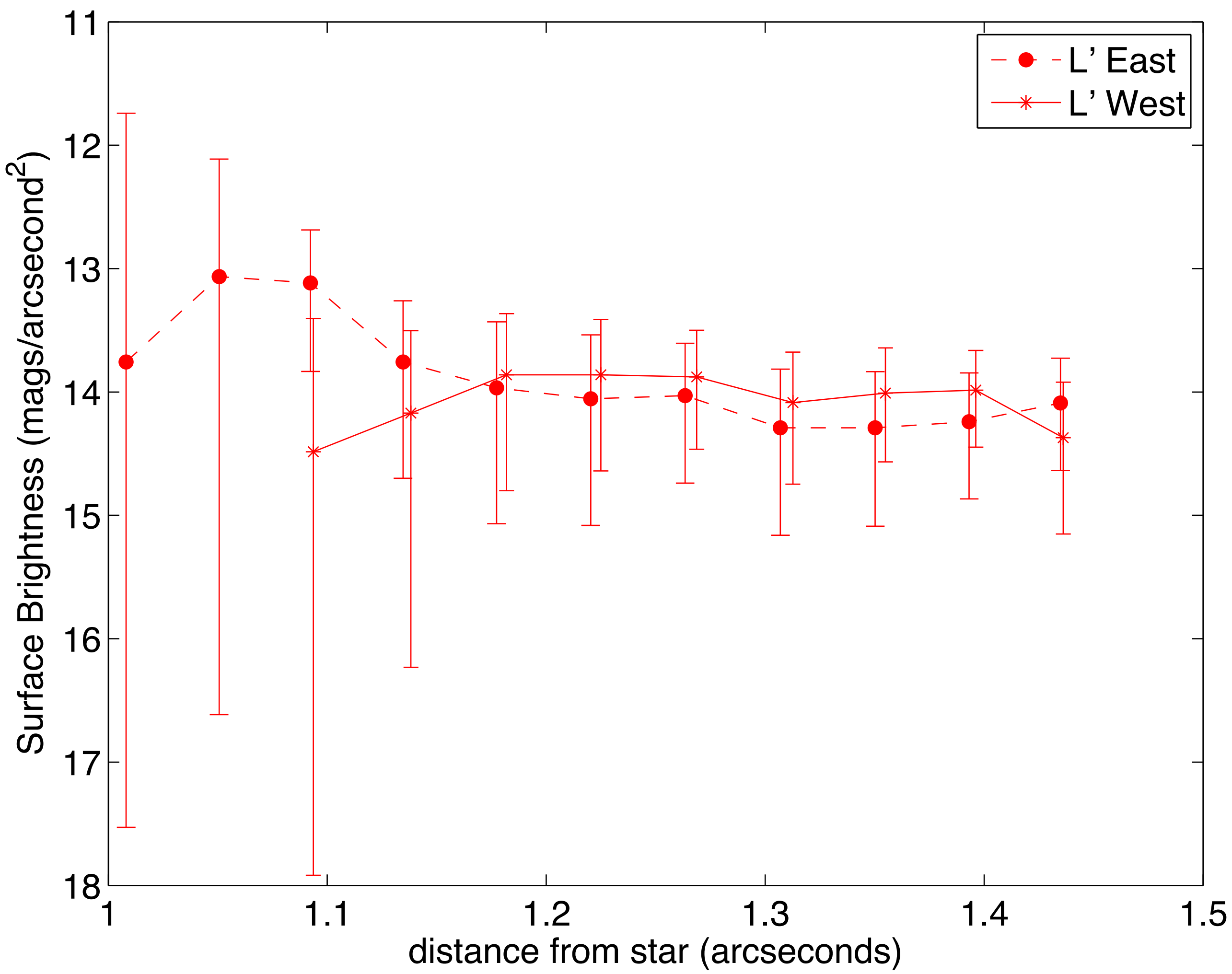


West brighter than East

3.8 µm



Rodigas/NCAD/July 20, 2012

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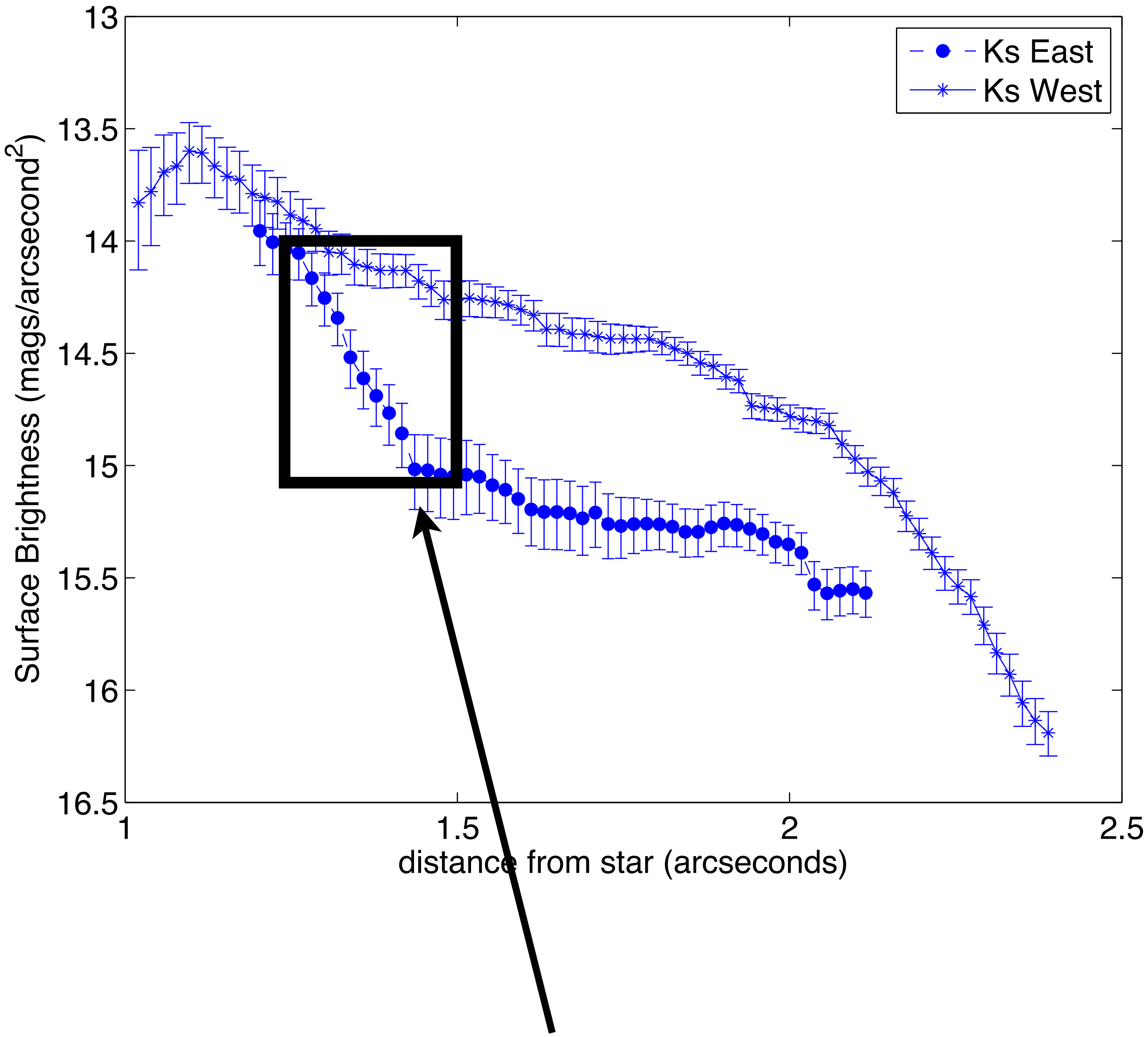

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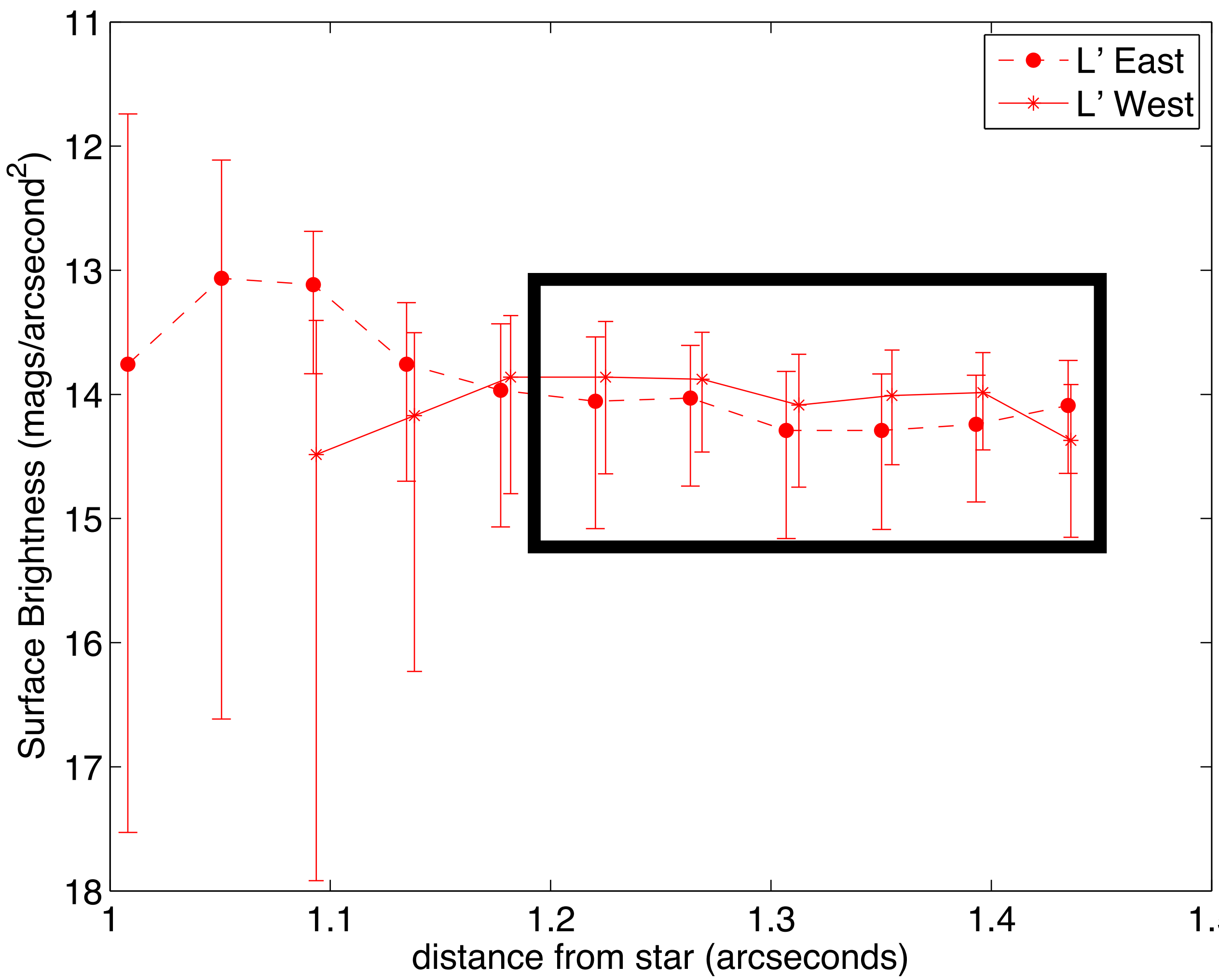

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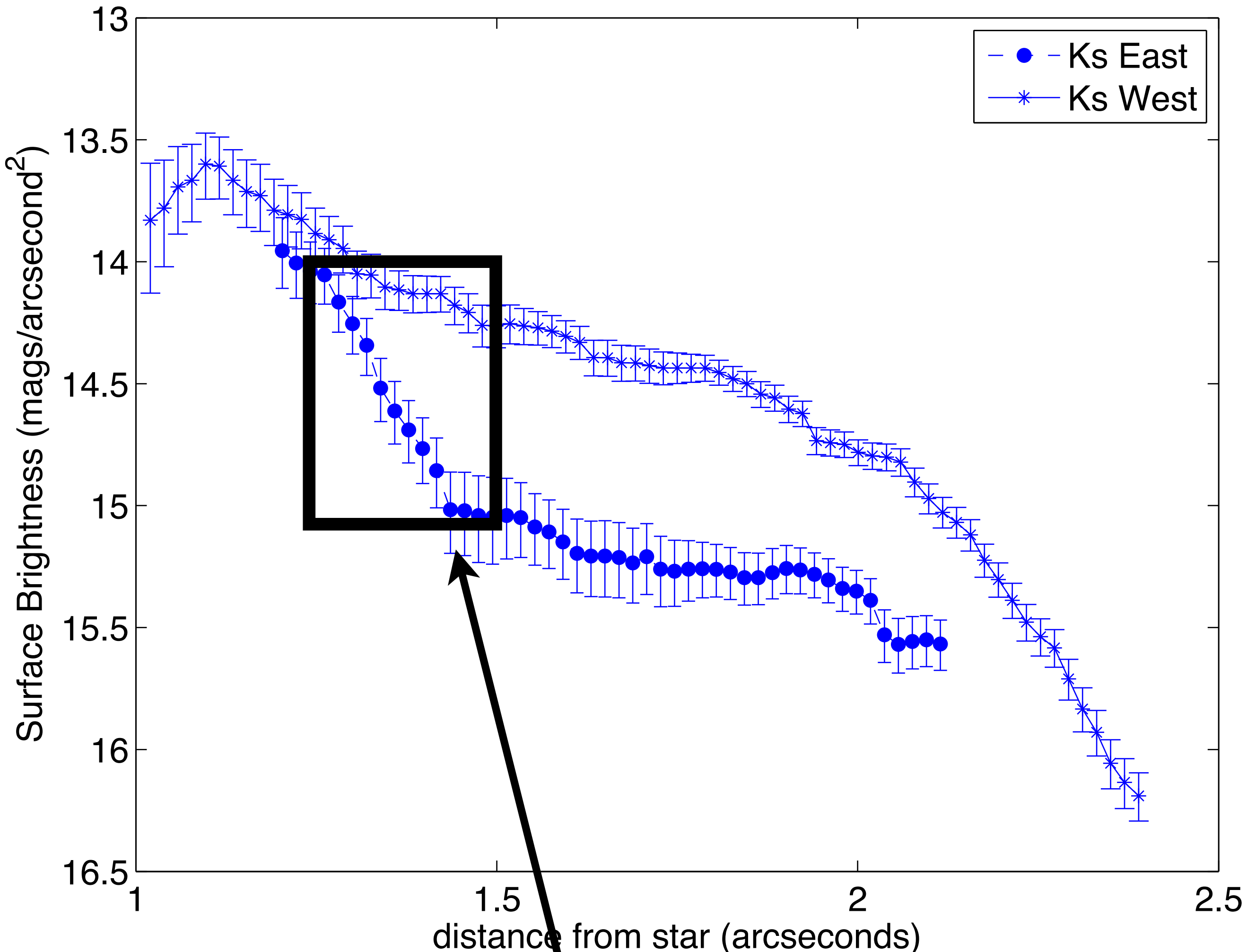

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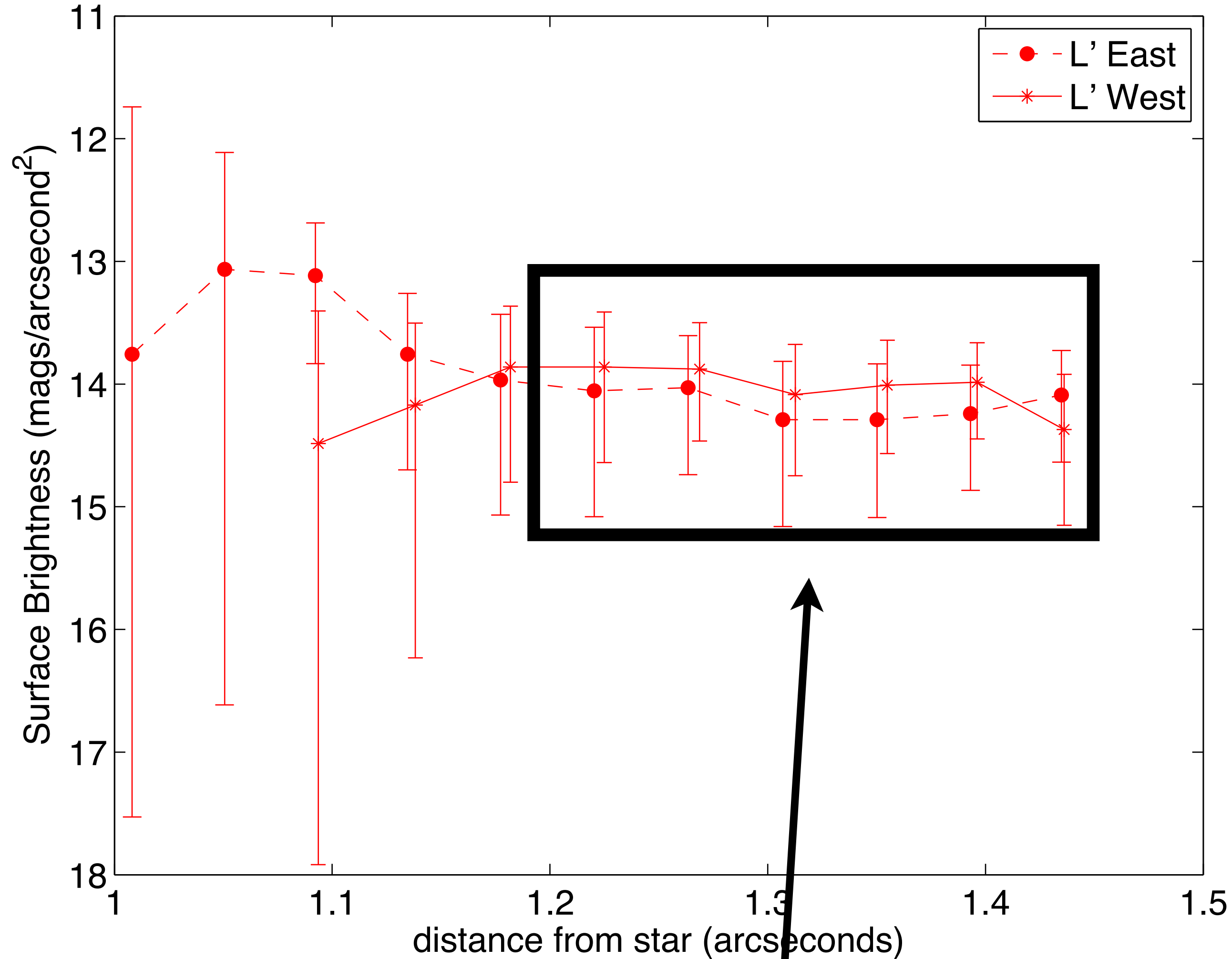
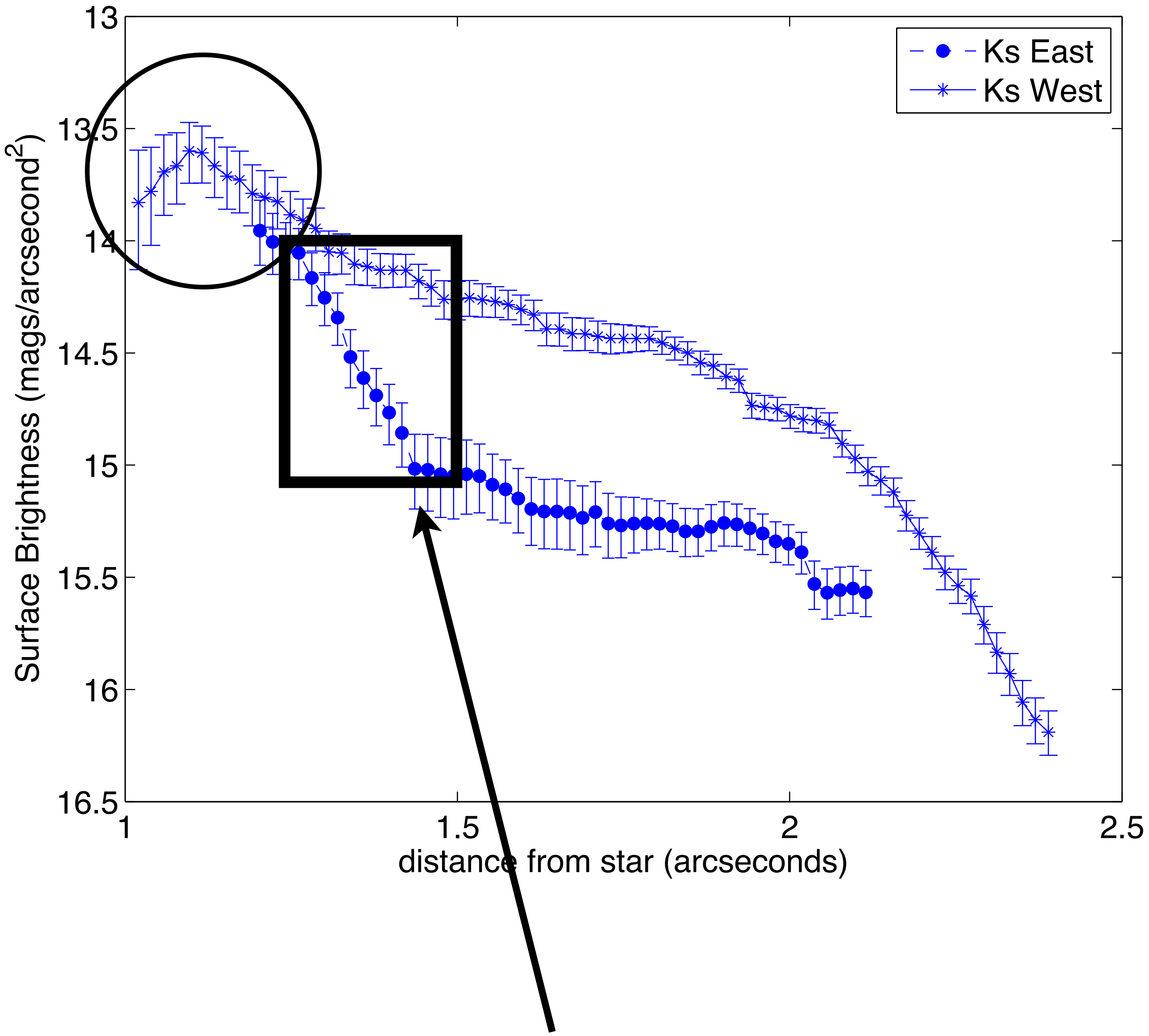


~ equal

Surface Brightness Profiles

2.15 μm



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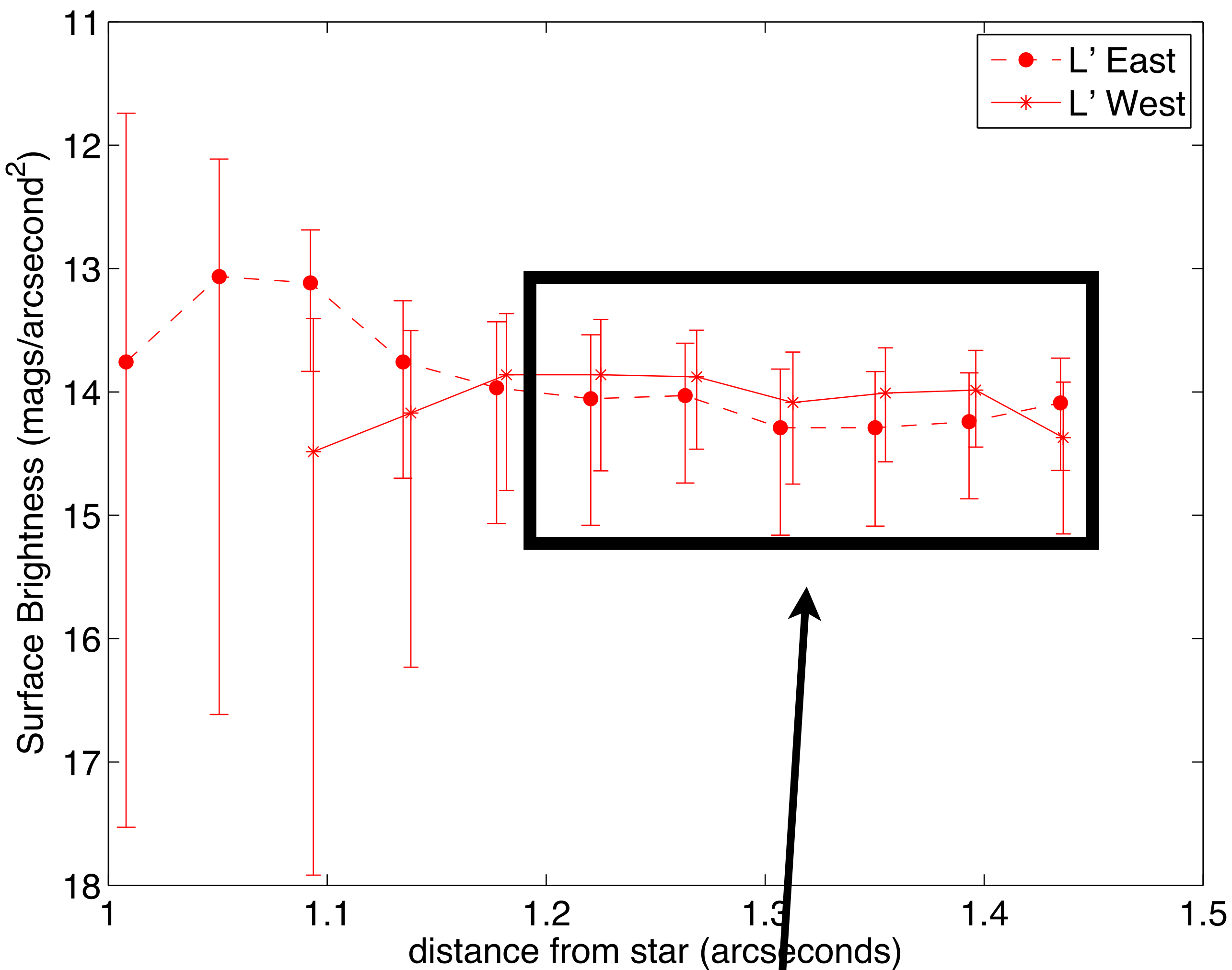
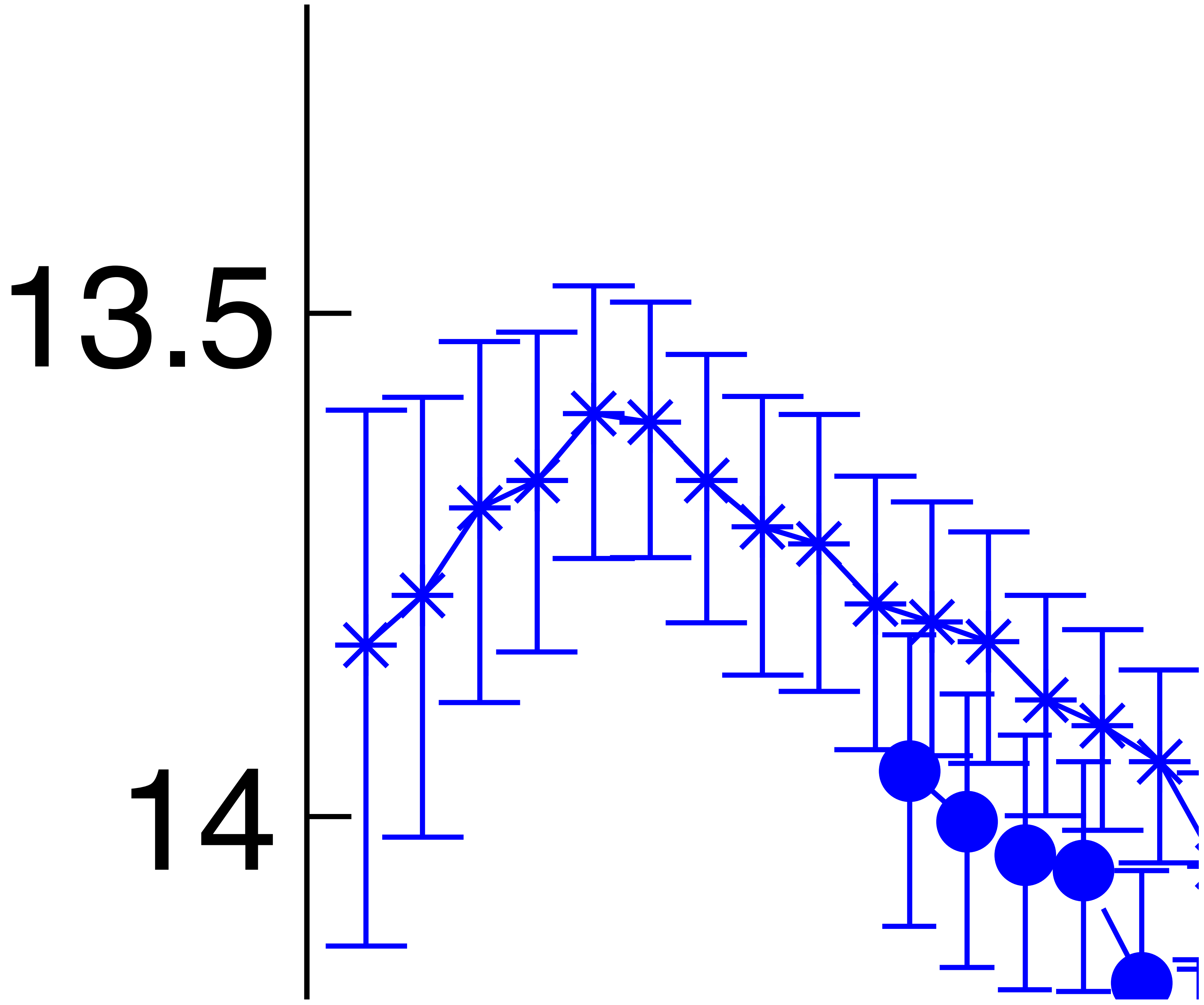


~ equal

A SB drop-off?



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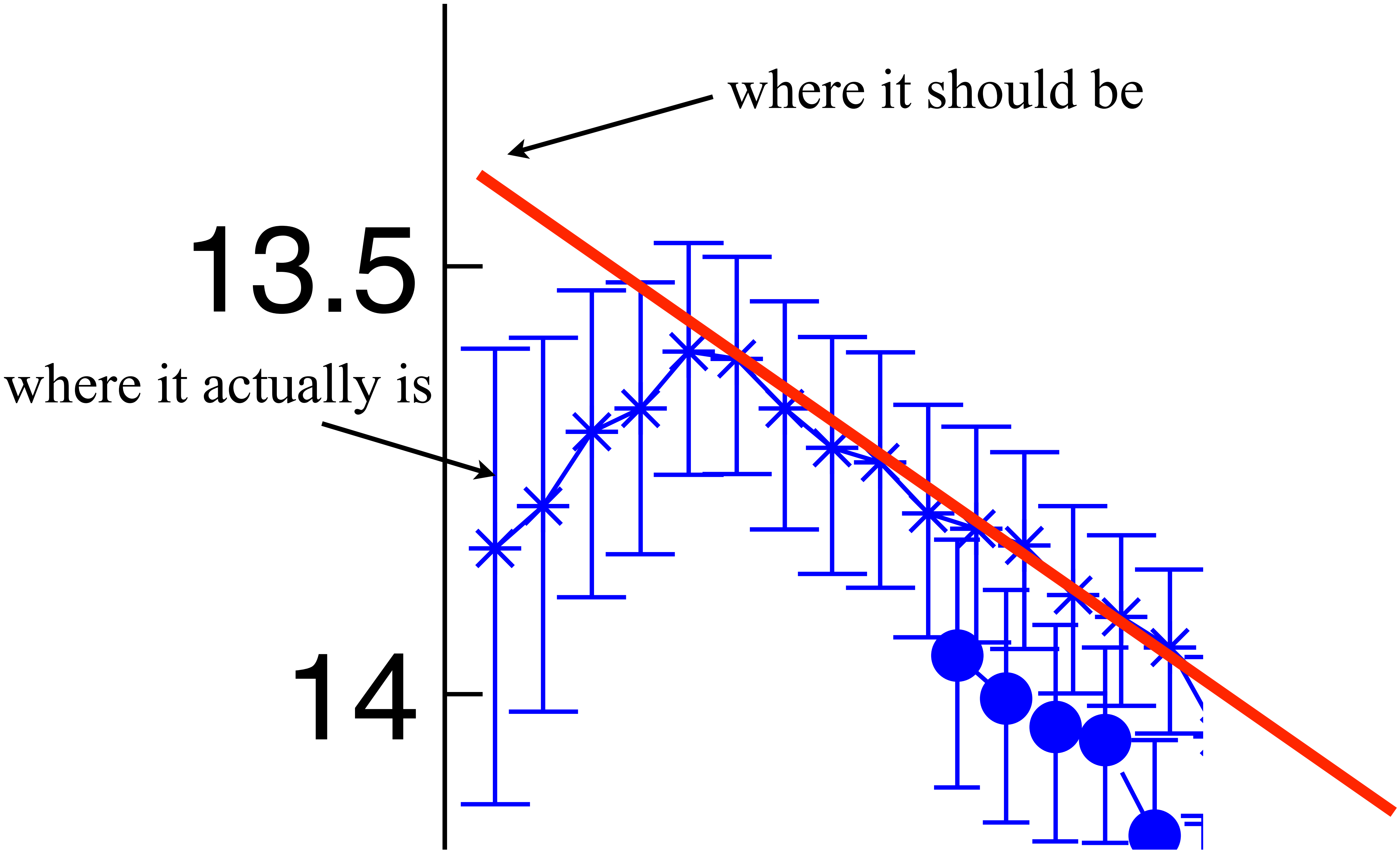

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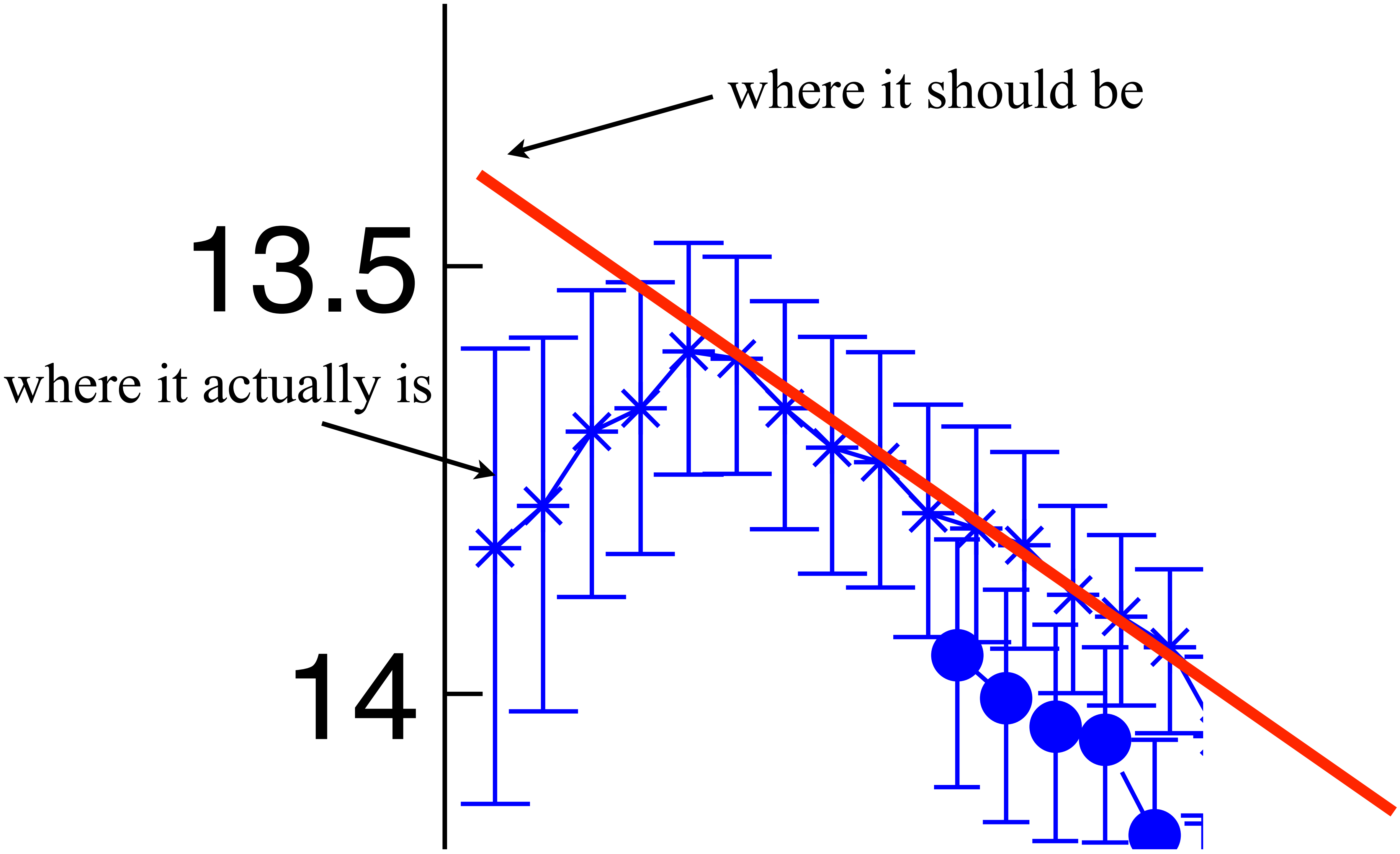
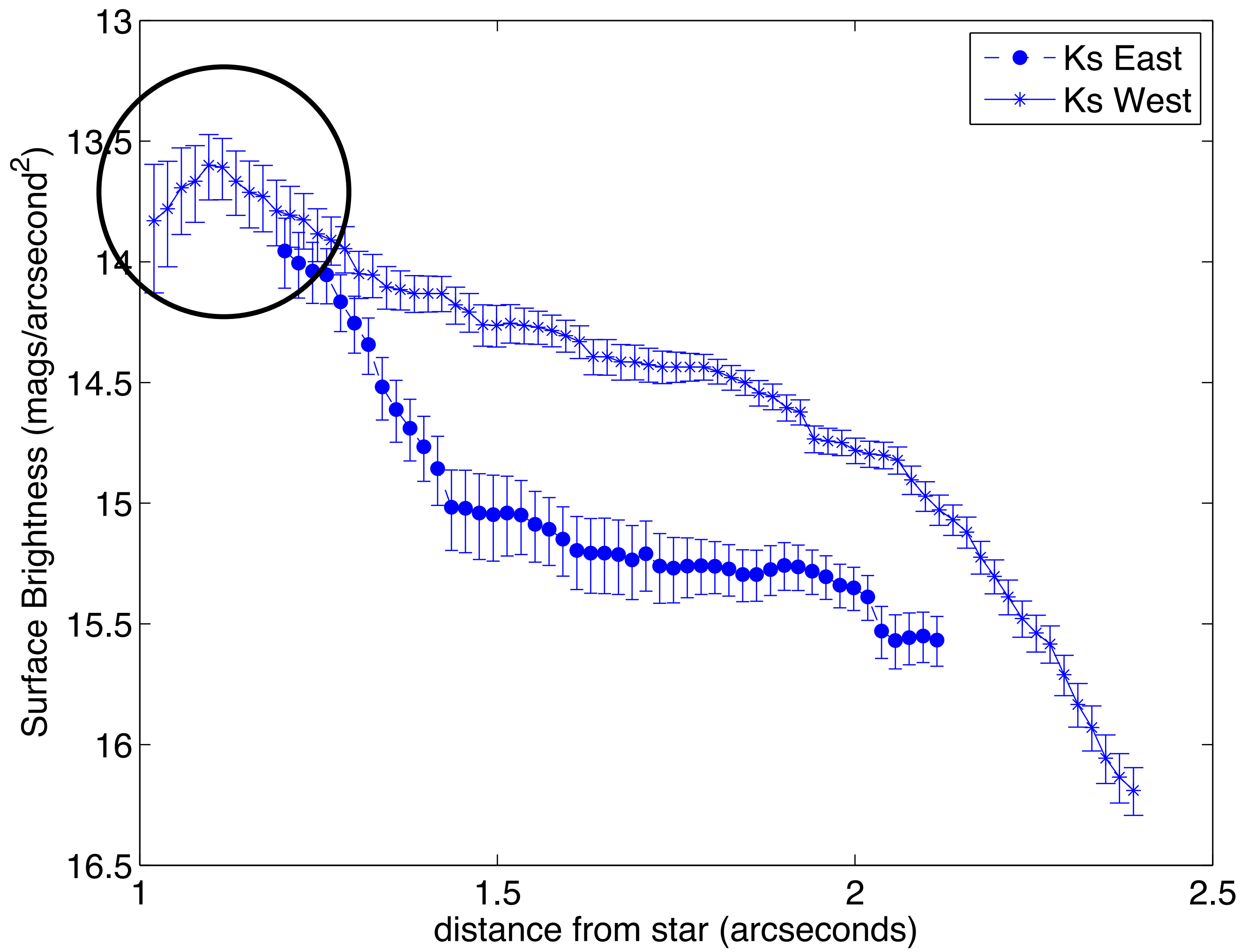


Low-SNR evidence for a gap!

Evidence for a disk gap?

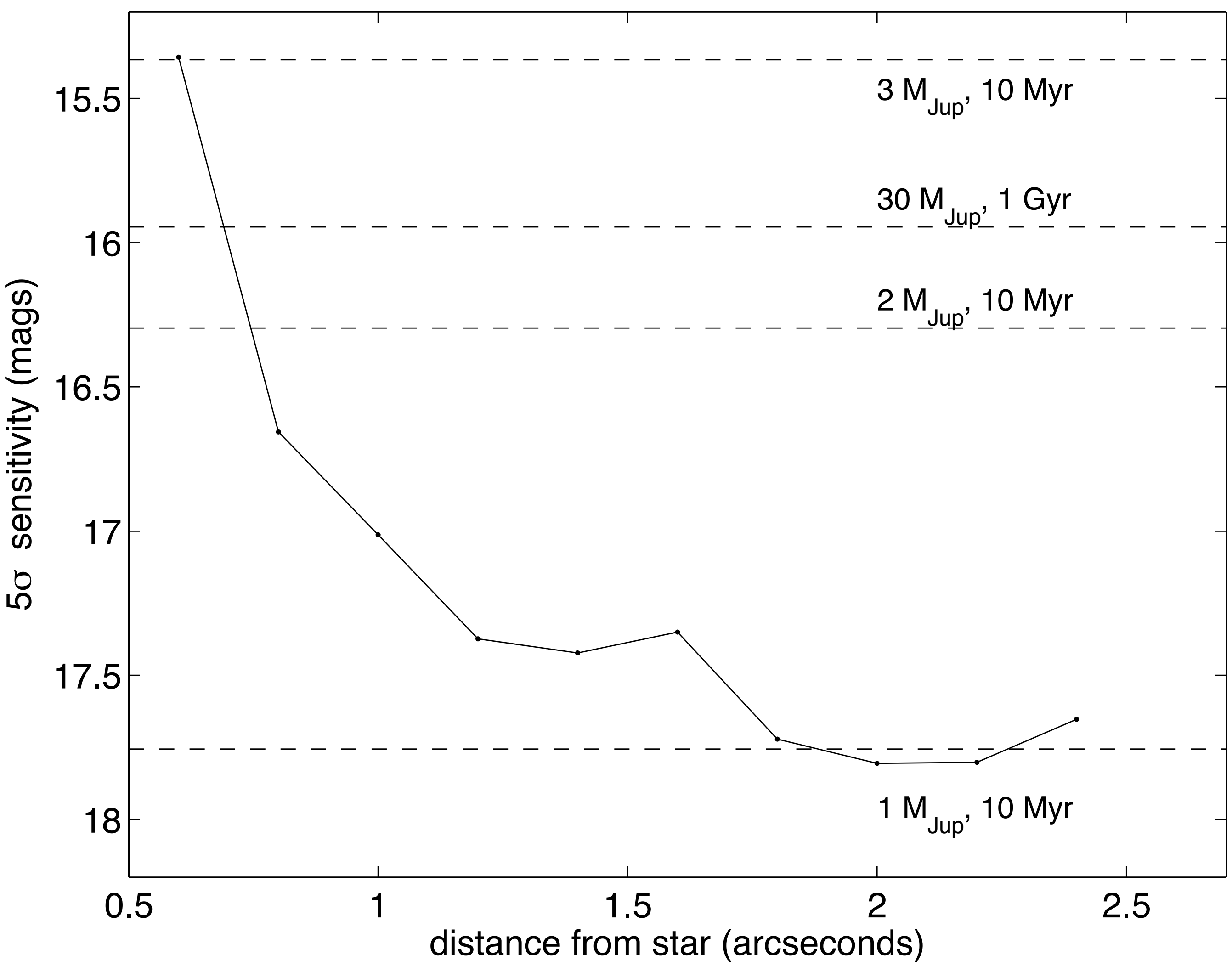
- For an edge-on debris disk, the SB should increase closer to the star
- A flattening/drop-off would then indicate a deficit in reflecting material (ie, less/no dust)
- SED suggests a two-component disk, with a gap near 1” (45 AU) (Moor et al. 2011b)

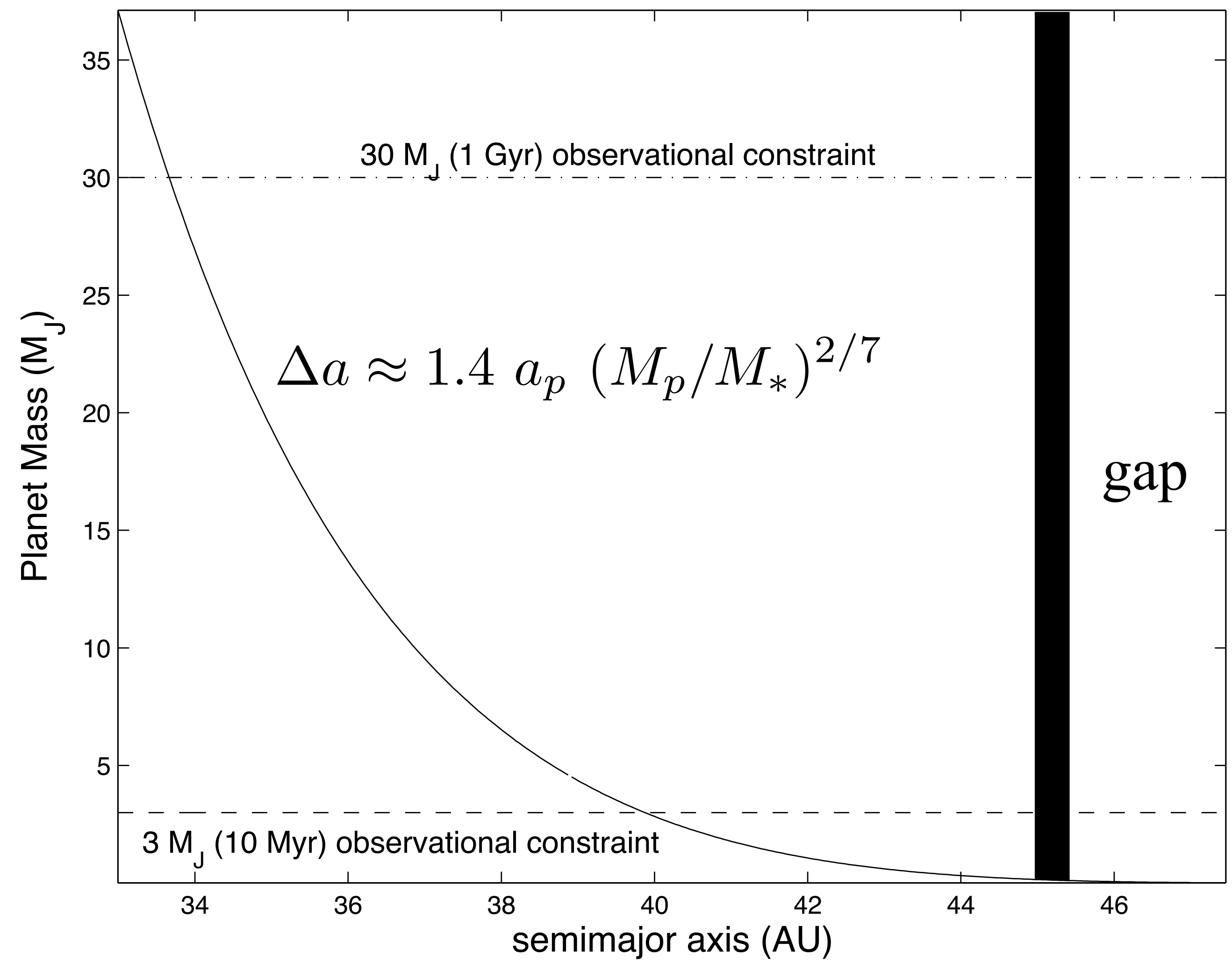


SED + observations pointing to a gap near 45 AU

Limits on a potential planet inside the gap

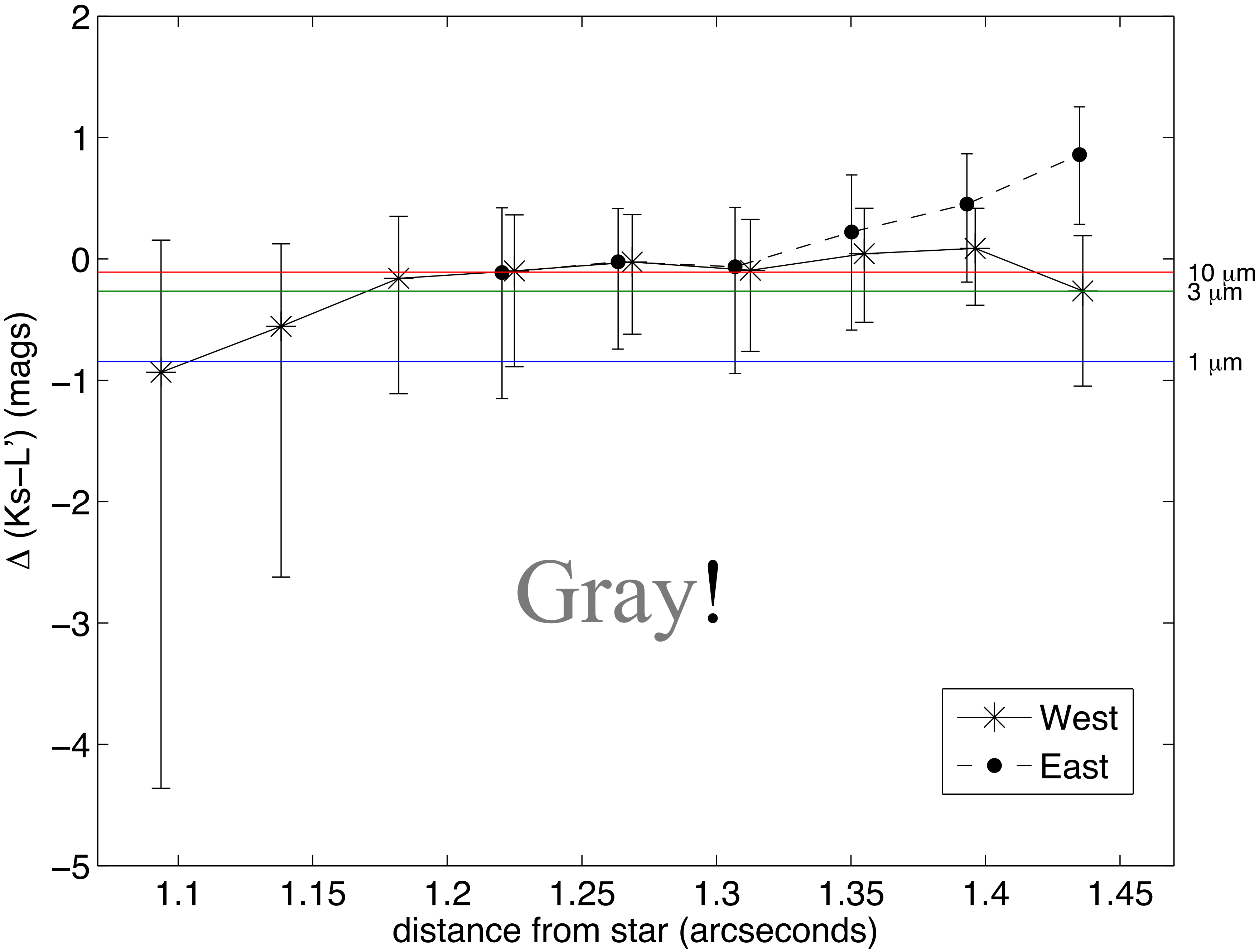
- Can use well-known chaotic zone equation to set limit on planet mass vs. semimajor axis
- Combine this with our observational constraints on planets in the system to set stringent limits





Planet constrained to ~ 3-30 M_J and ~ 34-45 AU orbit

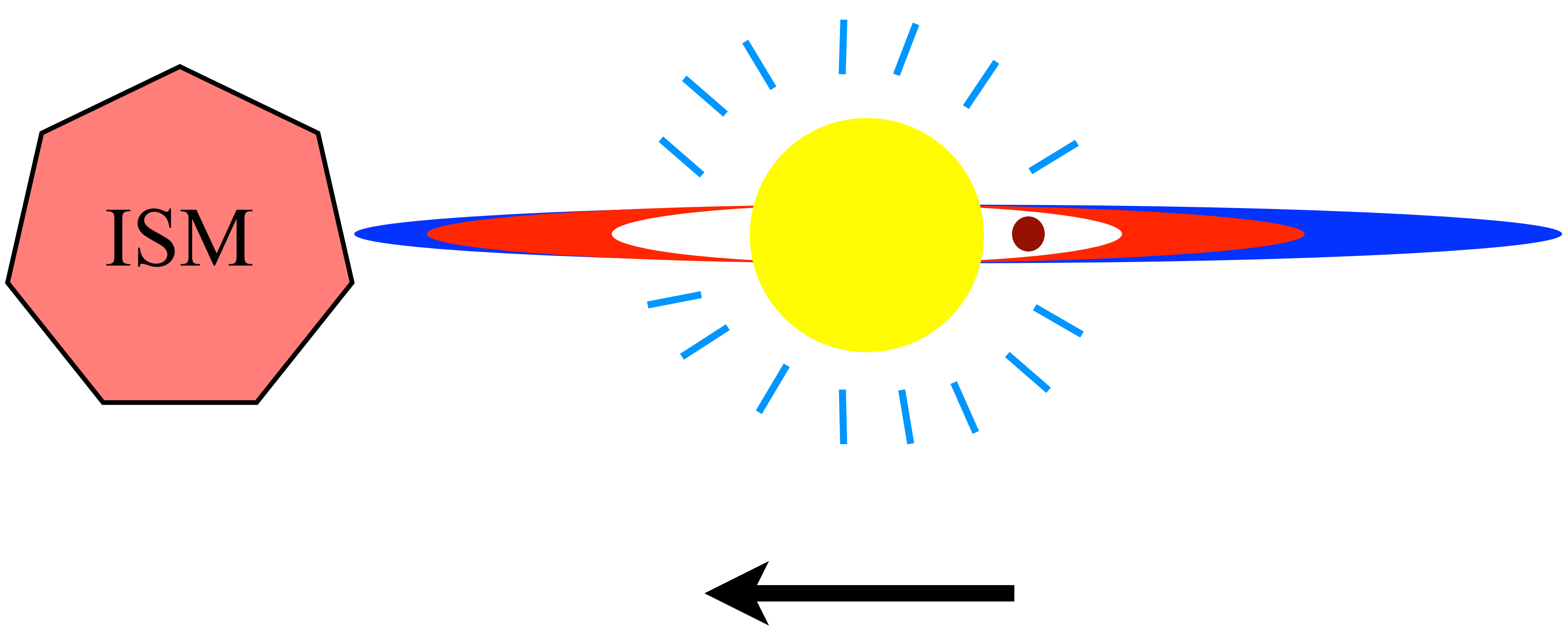
Does the disk contain large grains?



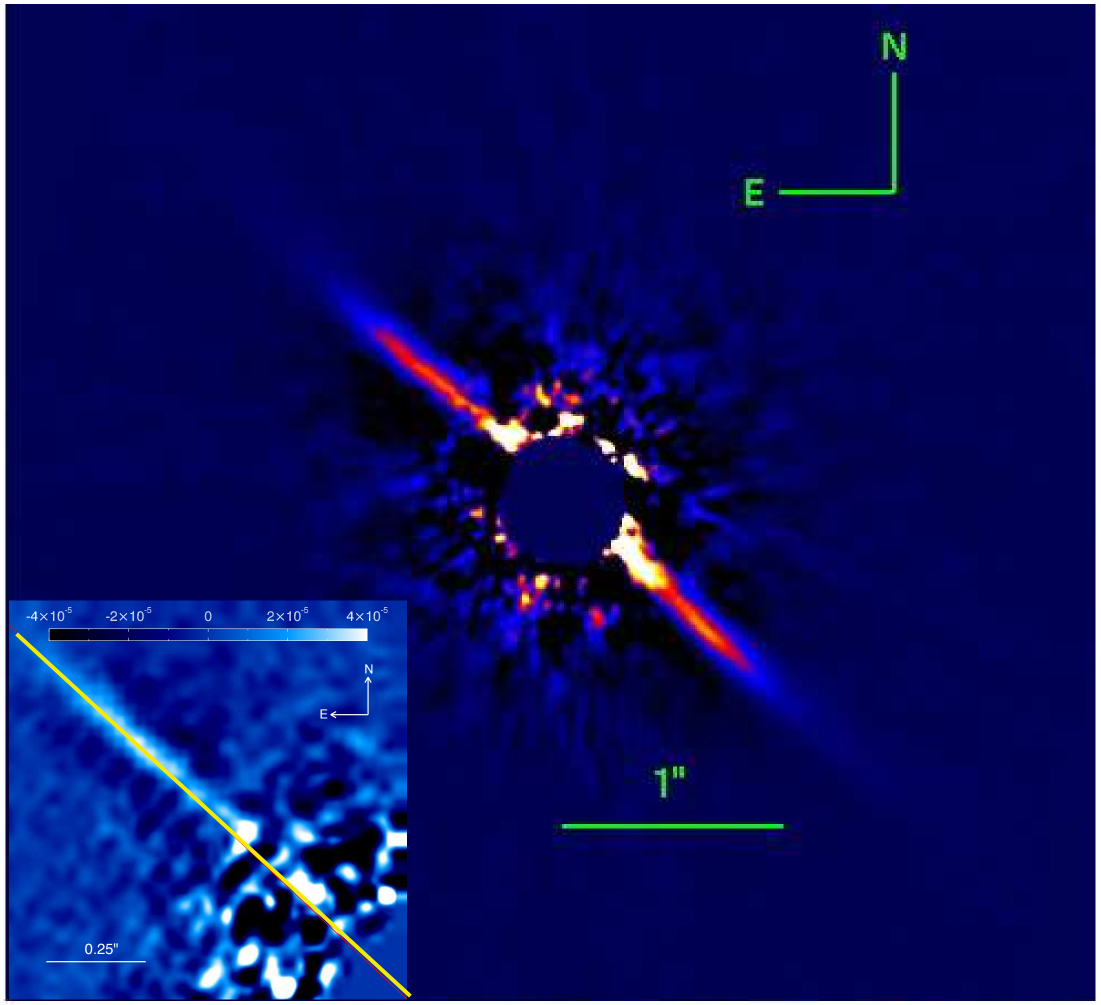
The disk is ~**gray**, contains 1-10 μm grains, and shows evidence for the west side containing smaller grains than the east

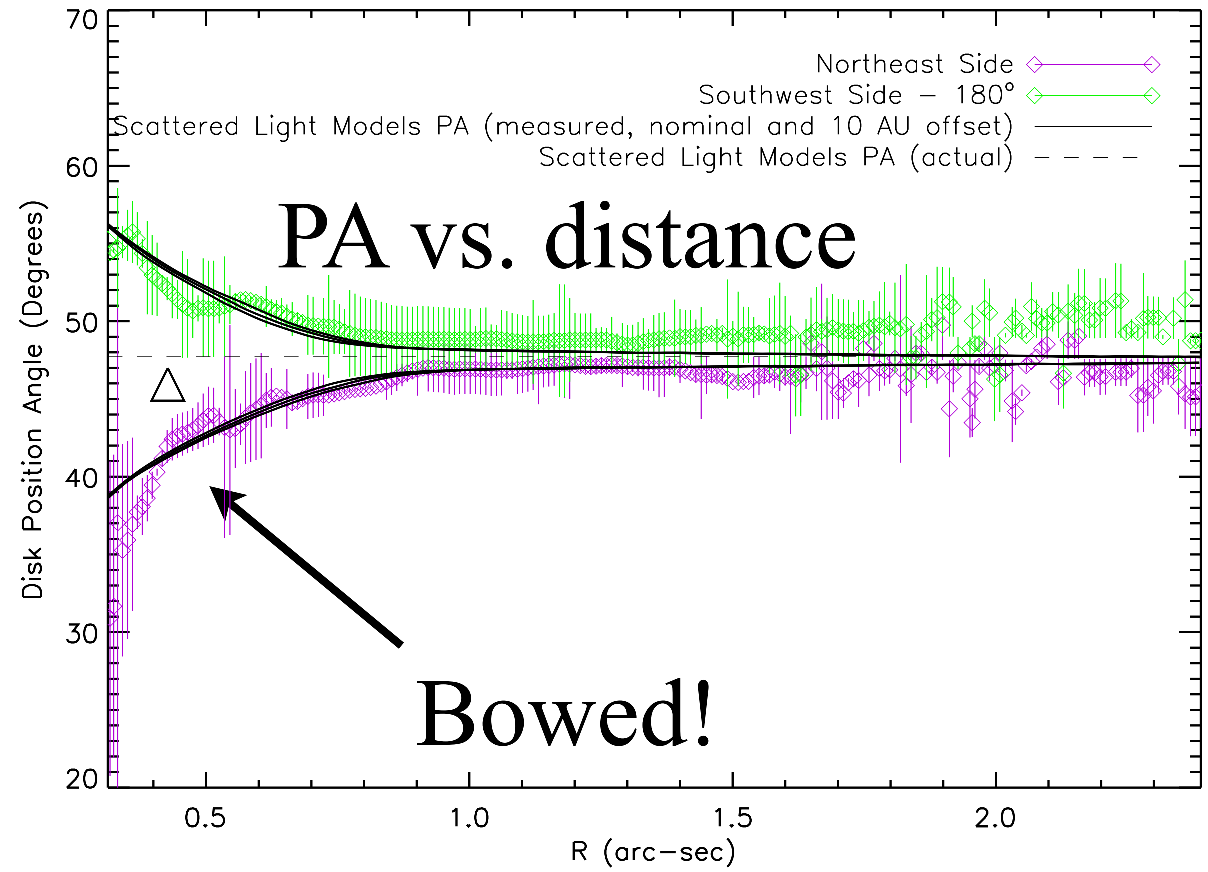
Putting it all together

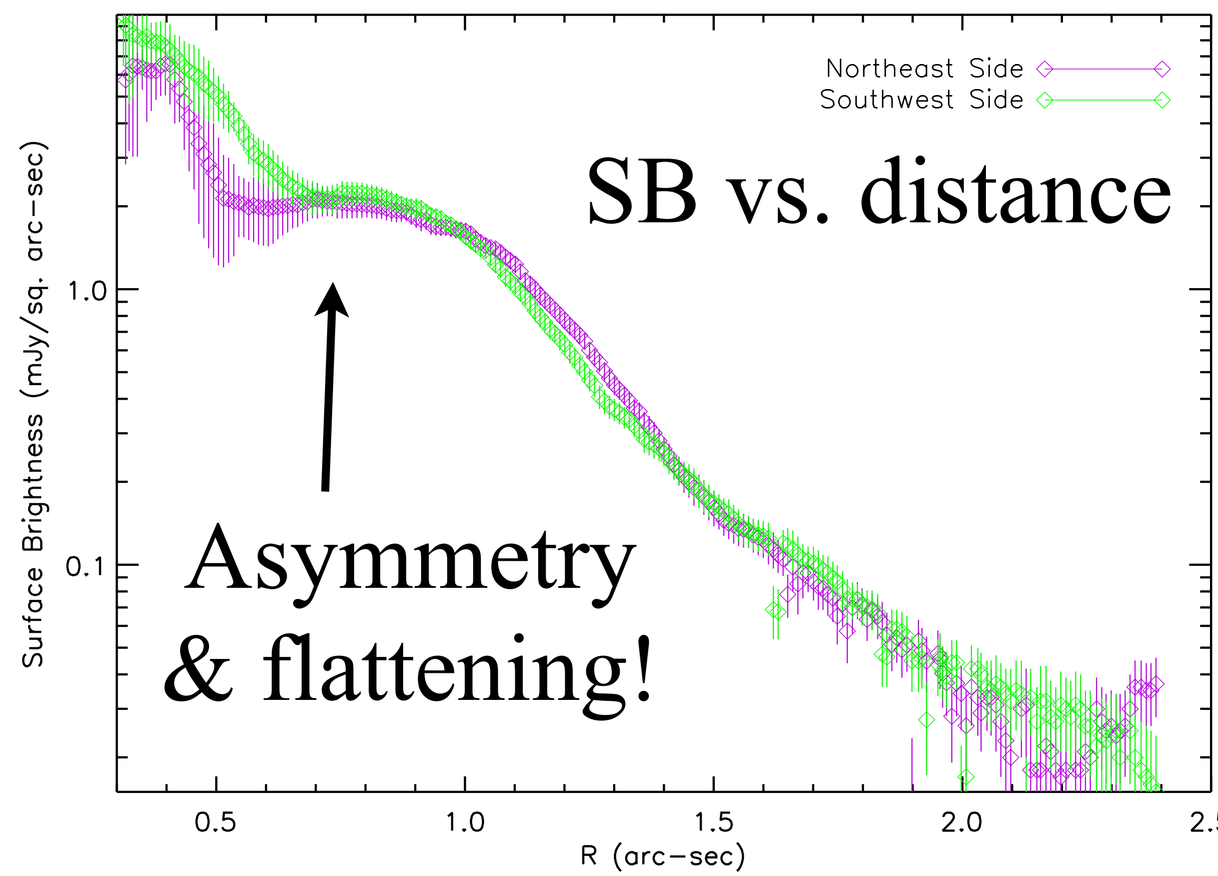
- HD 15115's debris disk consists of both small and large grains
- Its color changes from blue to gray/red closer to the star
- The disk may have a gap near 45 AU, potentially containing a planet (but none were detected)
- The east side of the disk is probably being dynamically affected by the ISM, leaving only large grains on this side
- The system is dynamically complex, and should be imaged/modeled again in the future



A brief note on HD 32297...







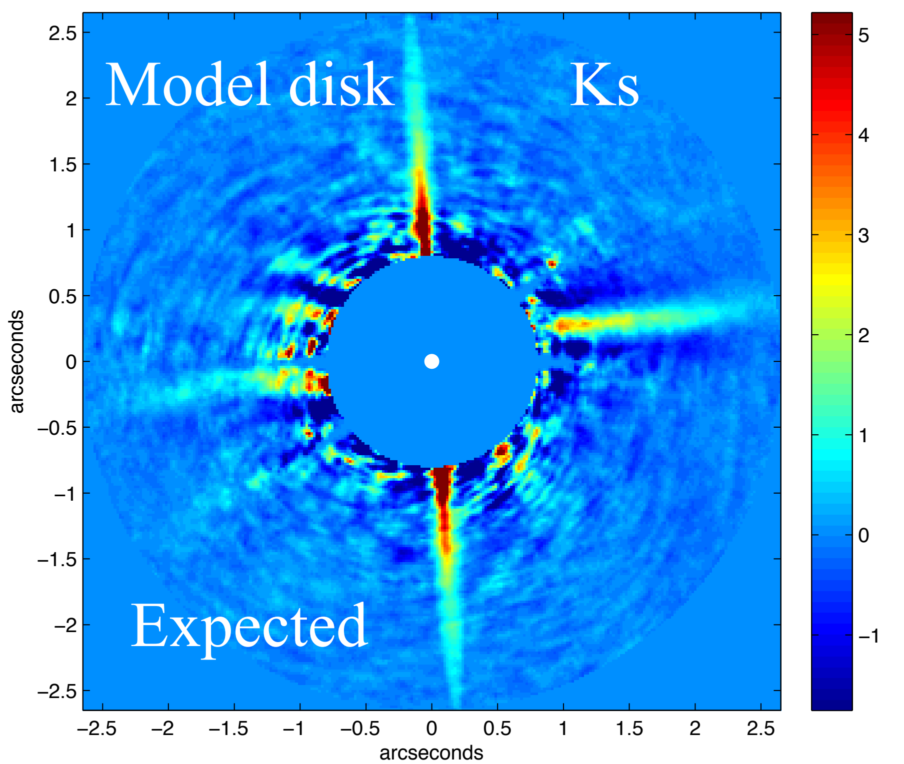
See Currie et al. 2012 (+ Rodigas, Debes, Kuchner…) & Boccaletti et al. 2012 for more details

Looking ahead

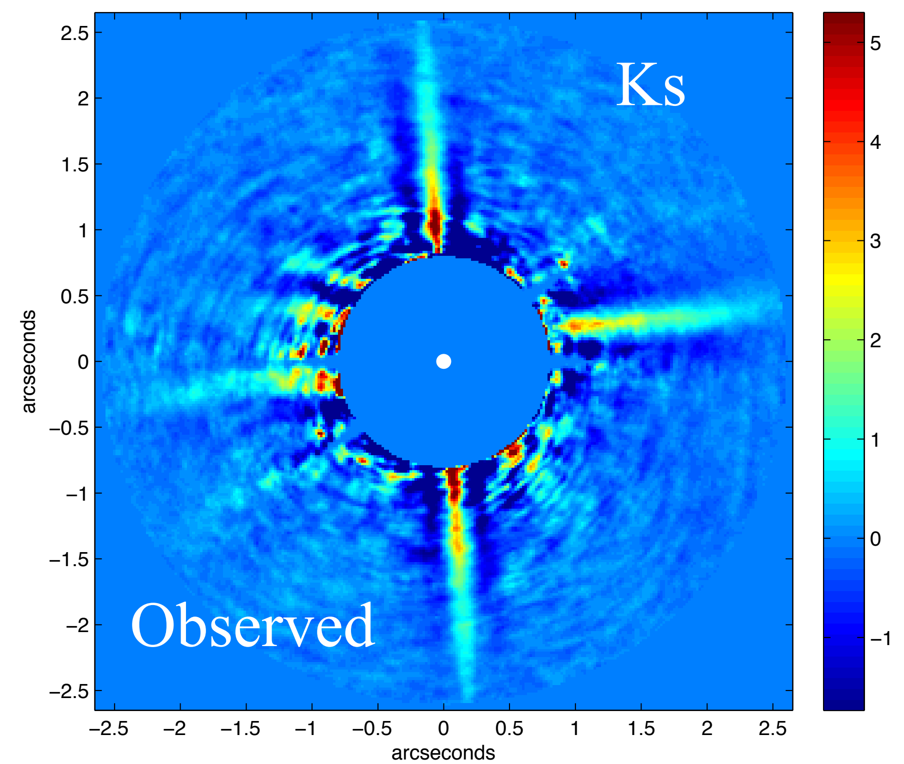
- Ultimately want to directly detect light from another Earth
- Learn about other Earths indirectly--by studying the circumstellar environments in which they formed (disk gaps, grain sizes, gas giant planets)
- The LBT is pushing us closer

Back-up slides

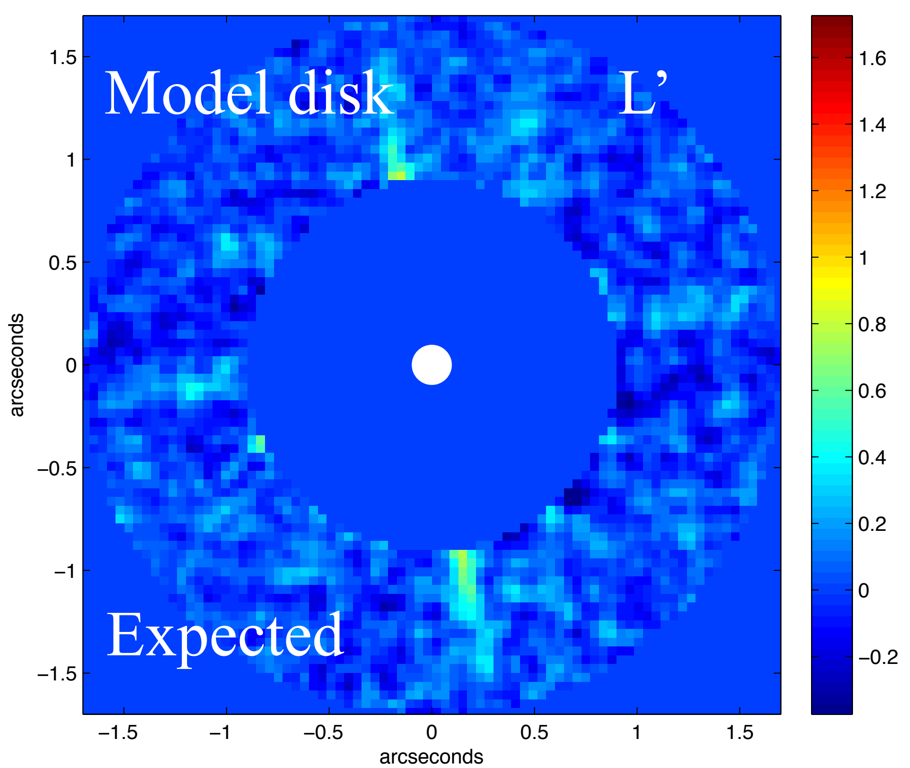
Proof of concept

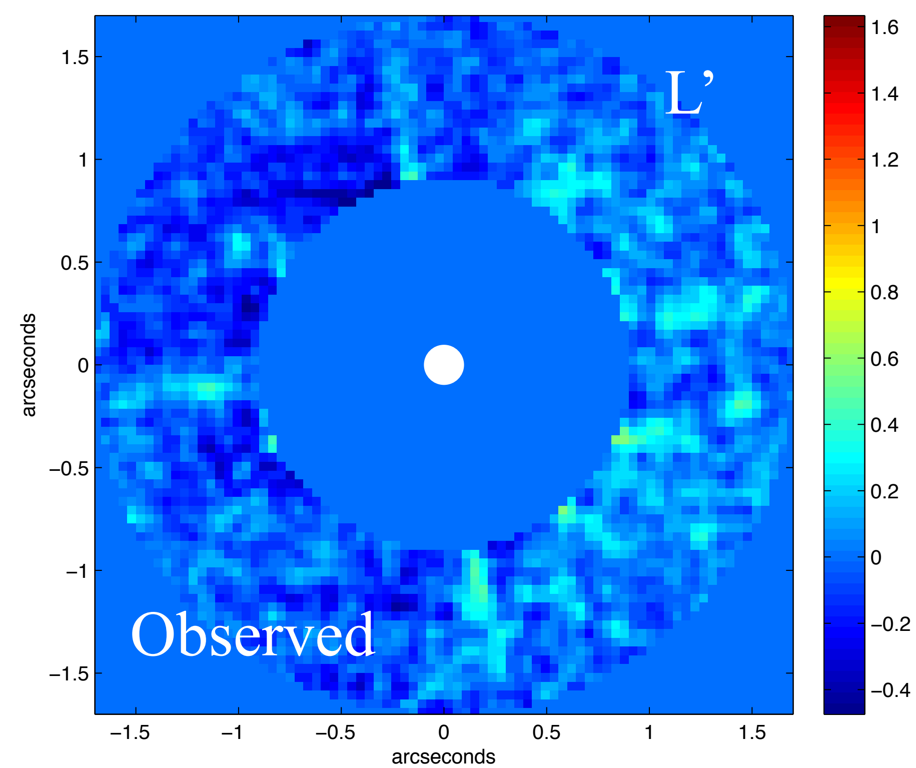


(a)



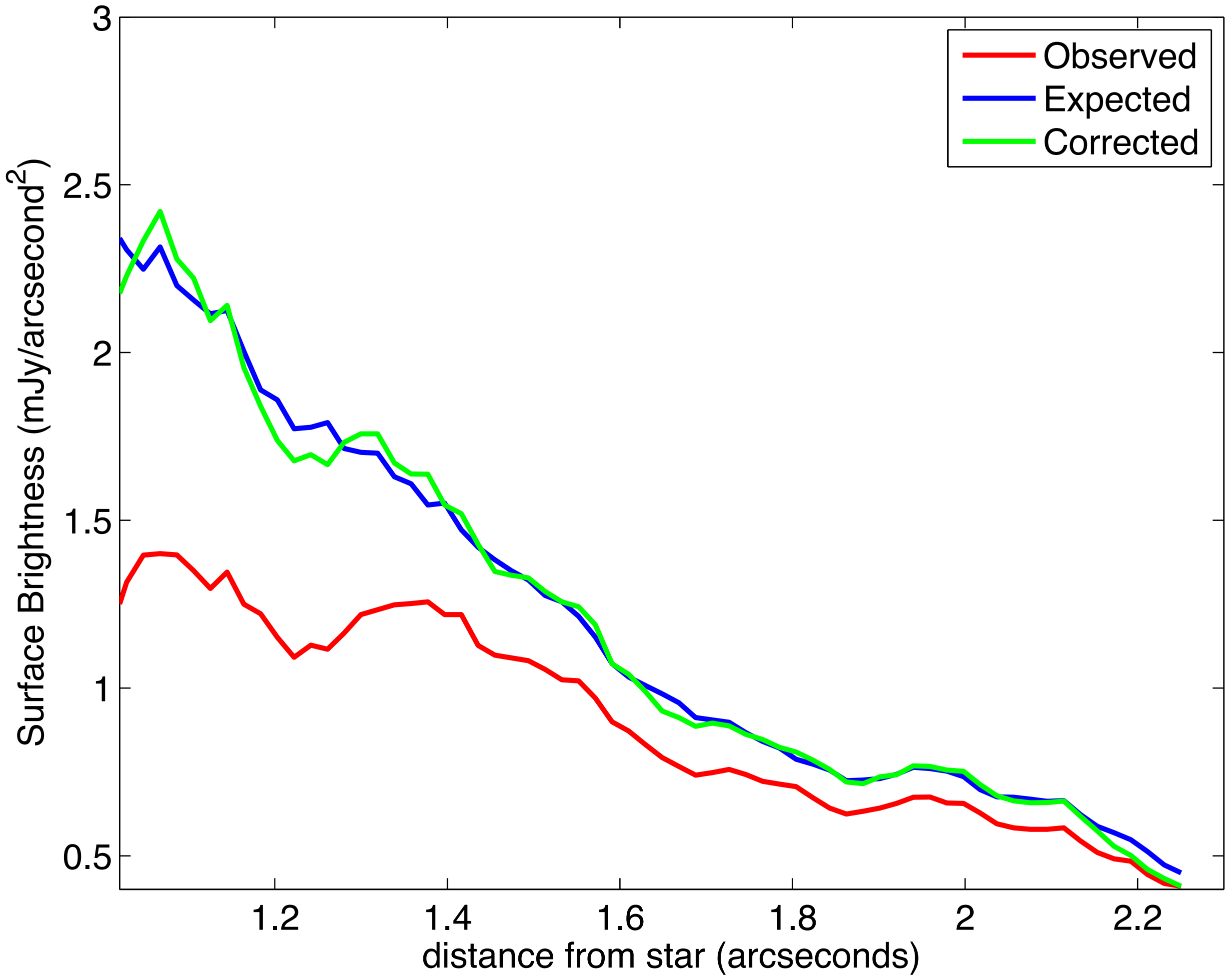
(b)



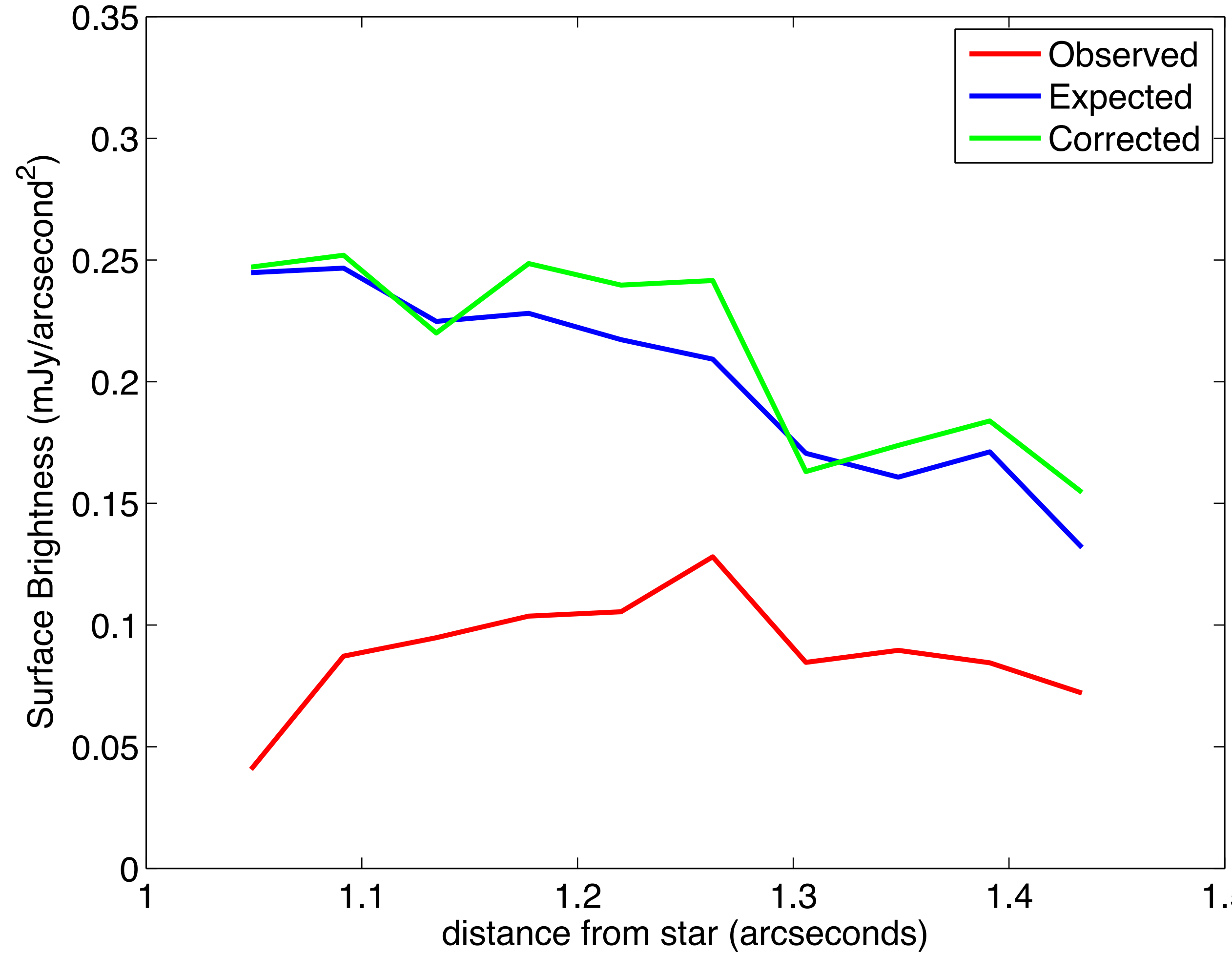


Correcting for self-subtraction

2.15 μm

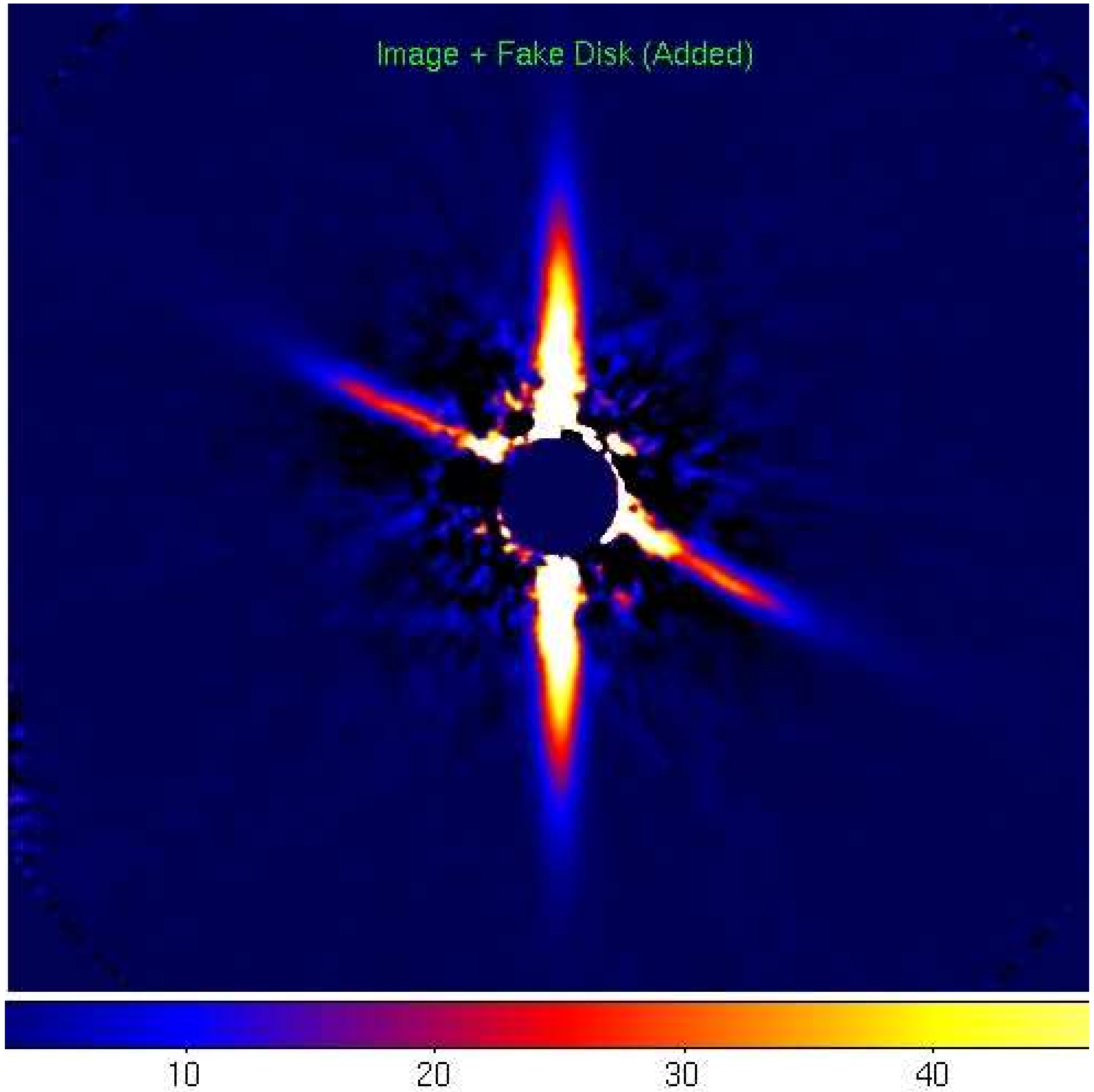


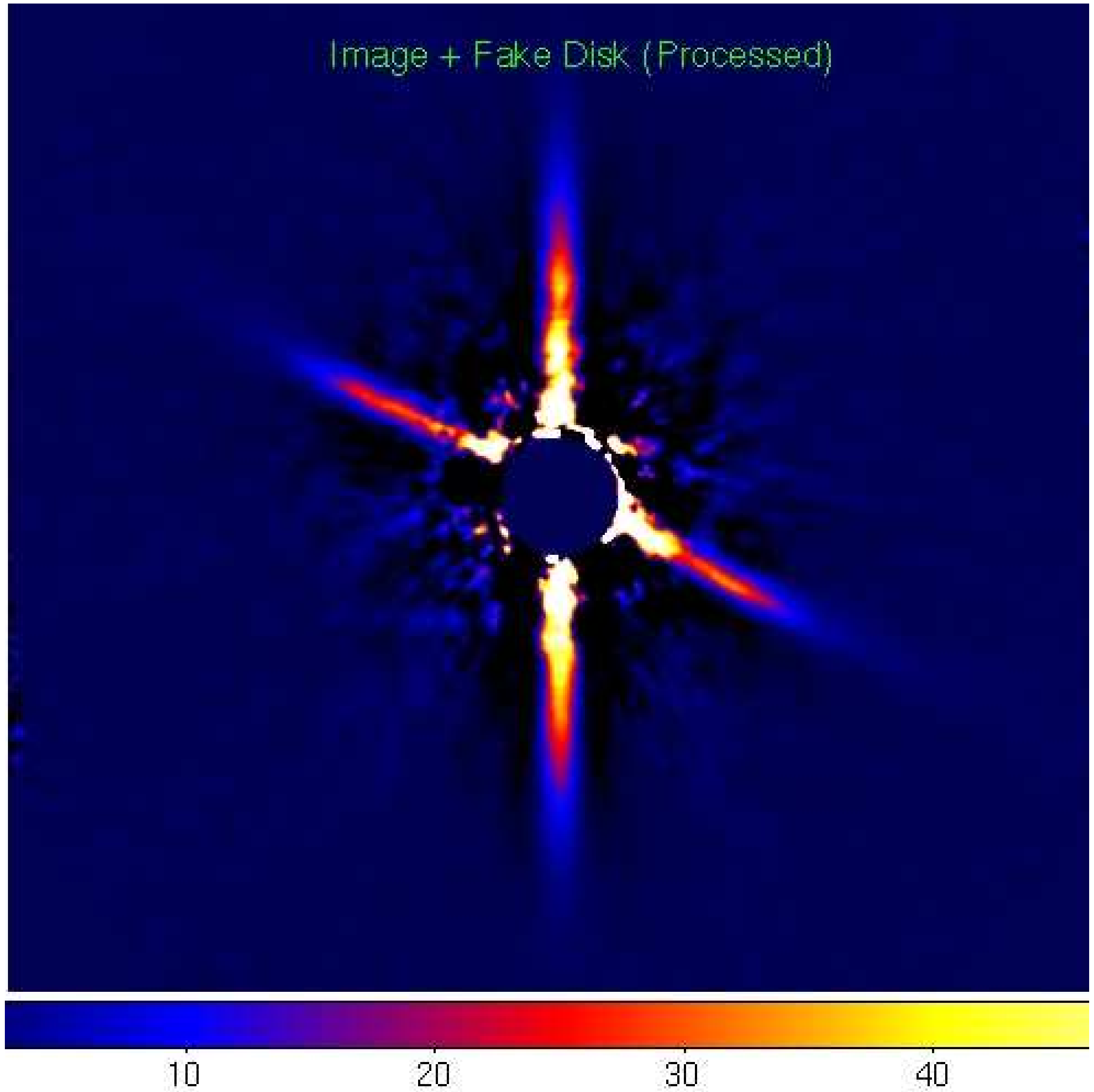
3.8 μm



The drop-off in SB is *not* an effect from the data reduction

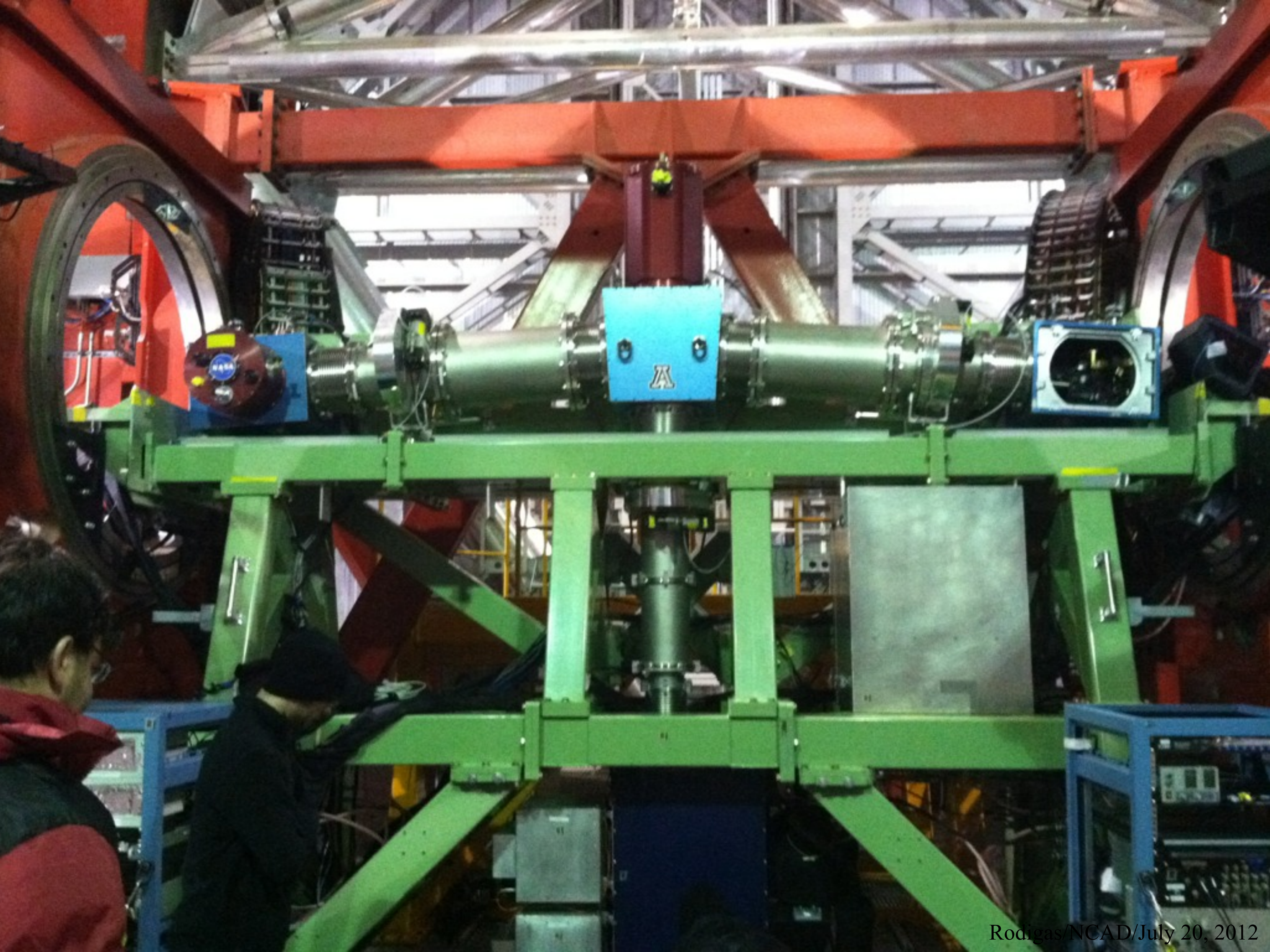
Proof of concept





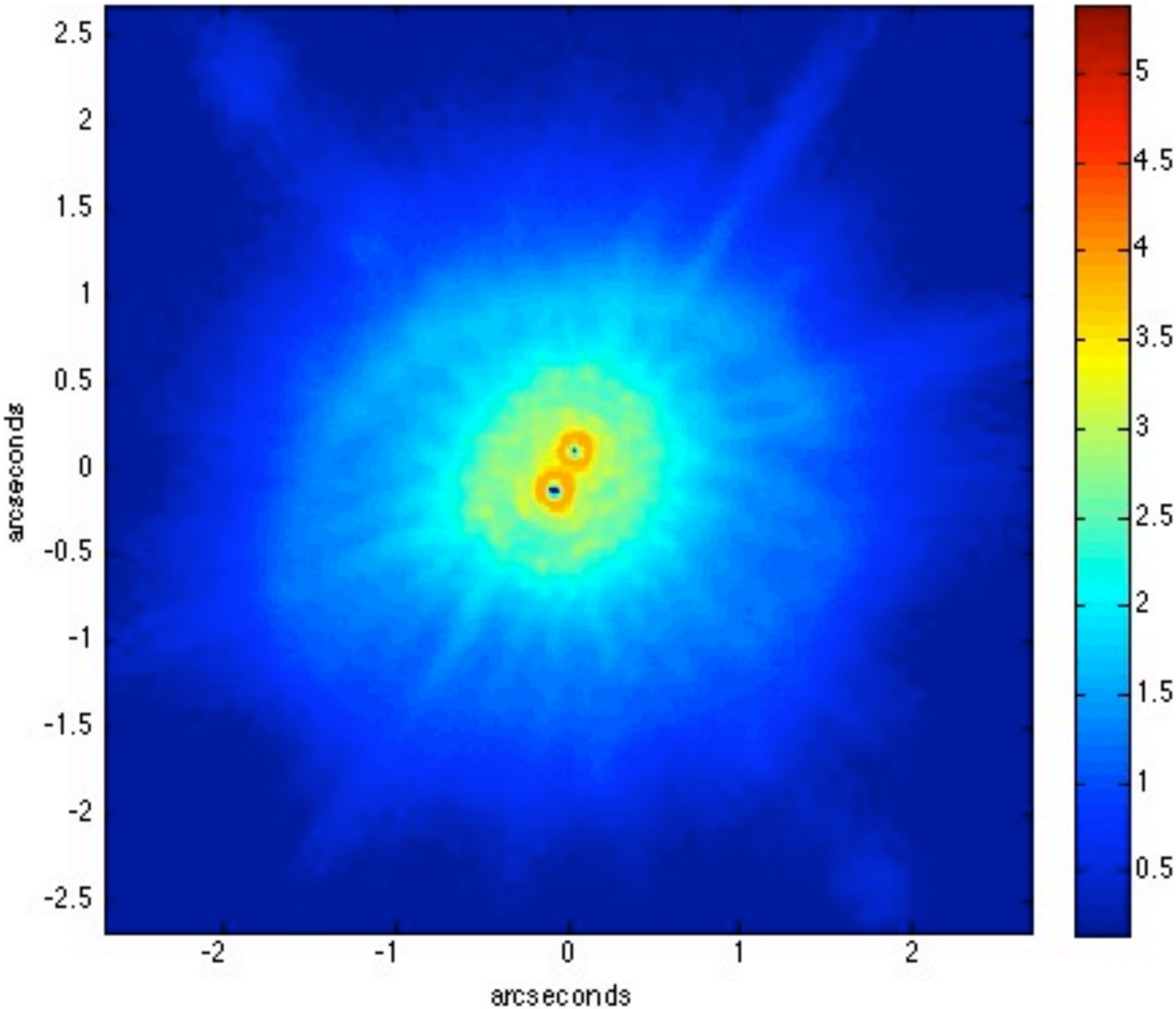
The need for LBT AO

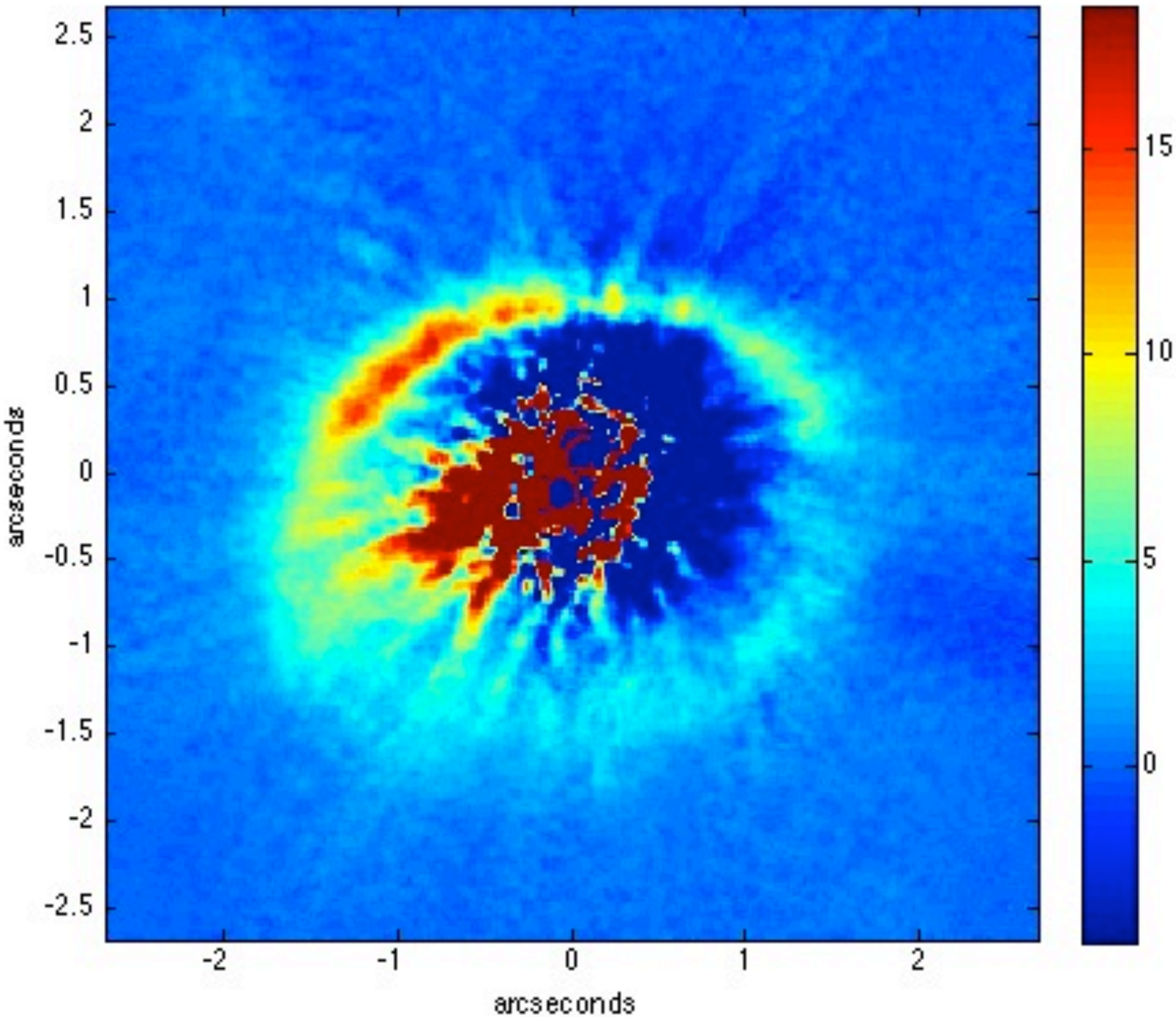
- Sky is bright at $\lambda > 2$ μm
- Thermal noise becomes important
- Need large aperture + precise AO
- At the LBT (and MMT, and soon Magellan), the secondary *is* the adaptive mirror!



Rodigas/NCAD/July 20, 2012

Talk about high Strehl...





2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
arcseconds
-2
-1
0
1
2
arcseconds
15
10
5
0