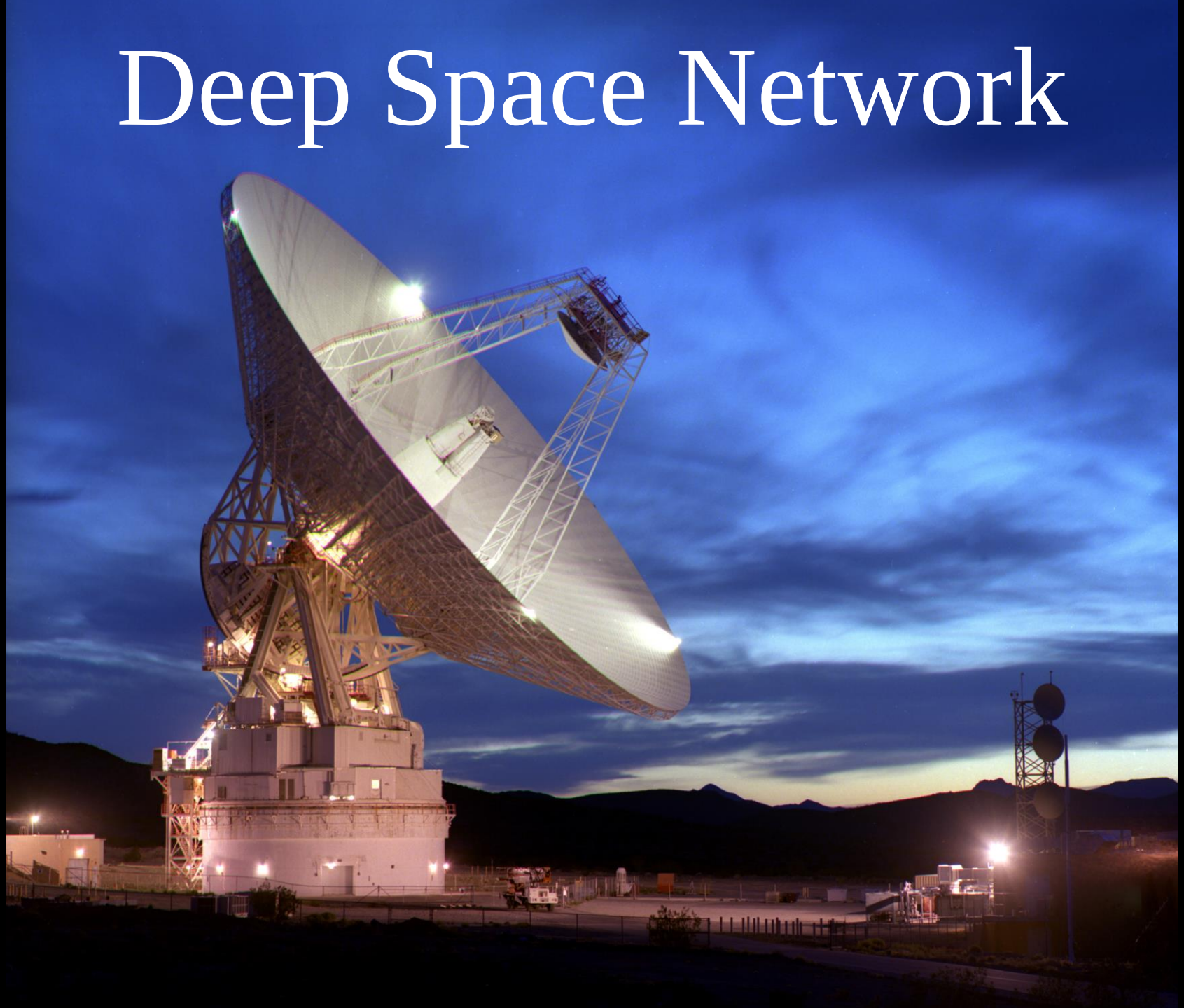
Jet Propulsion Laboratory, California Institute of Technology

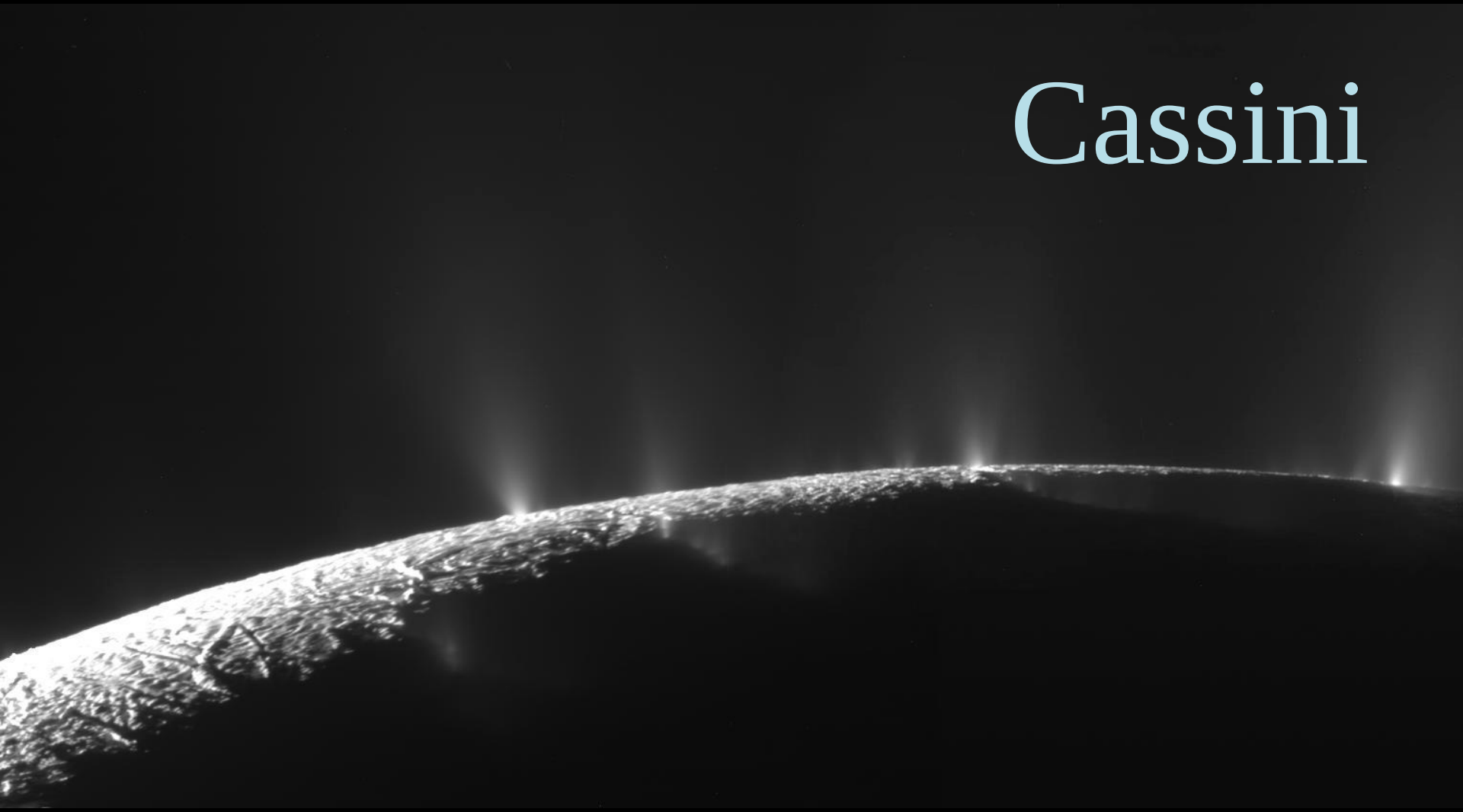
www.jpl.nasa.gov

Deep Space Network



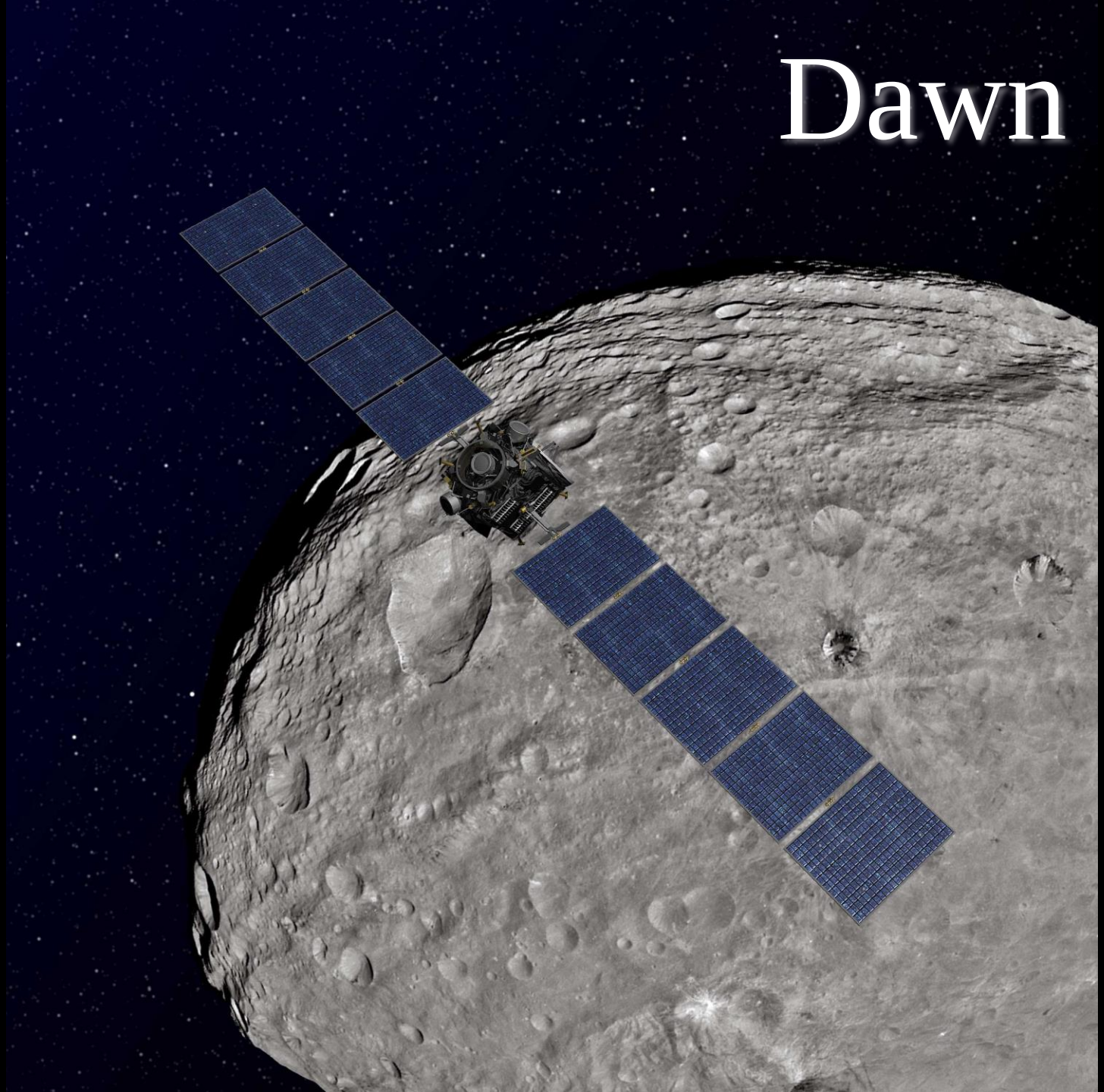
Mars Rovers

National Aeronautics and Space Administration



National Aeronautics and Space Administration

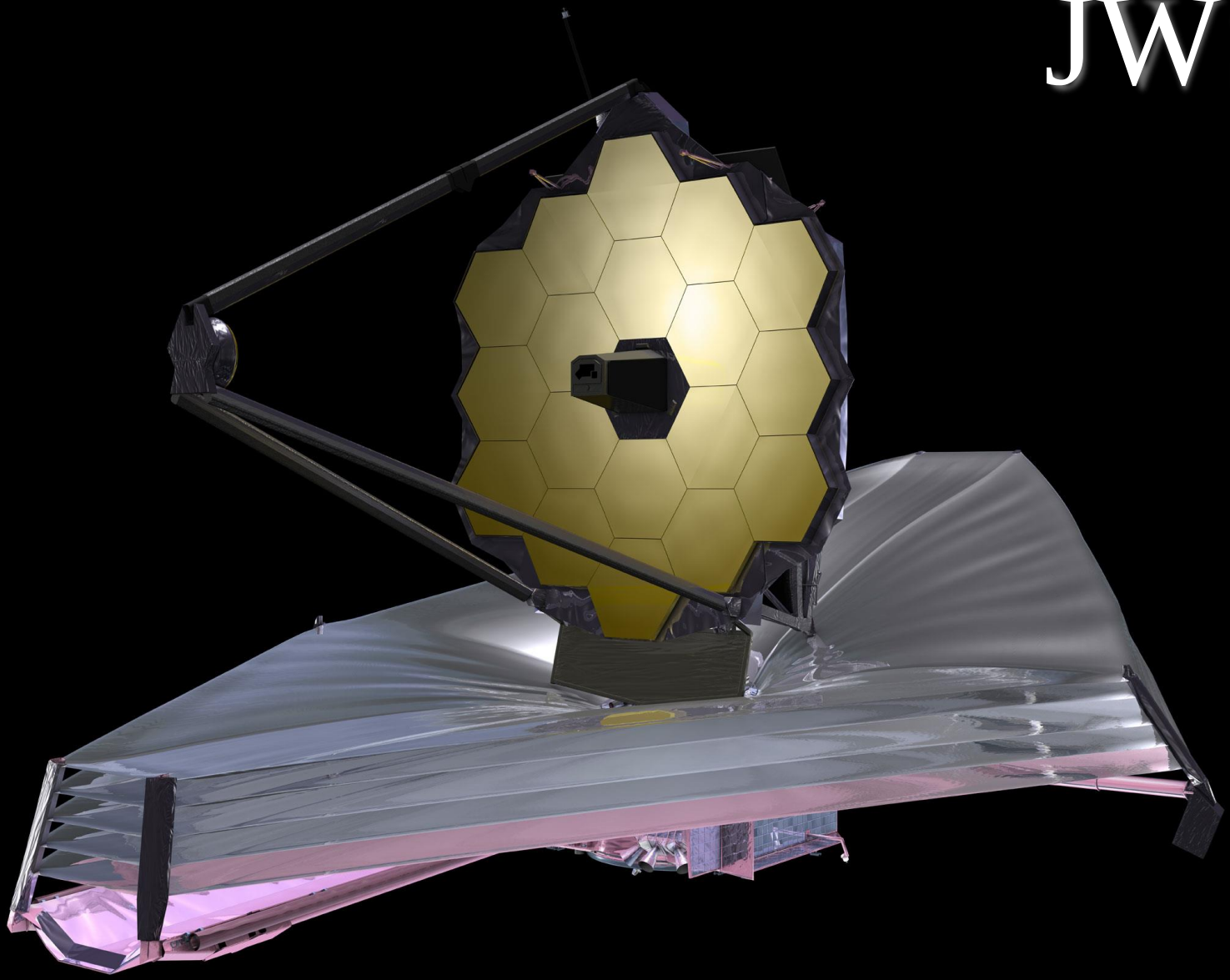
Dawn



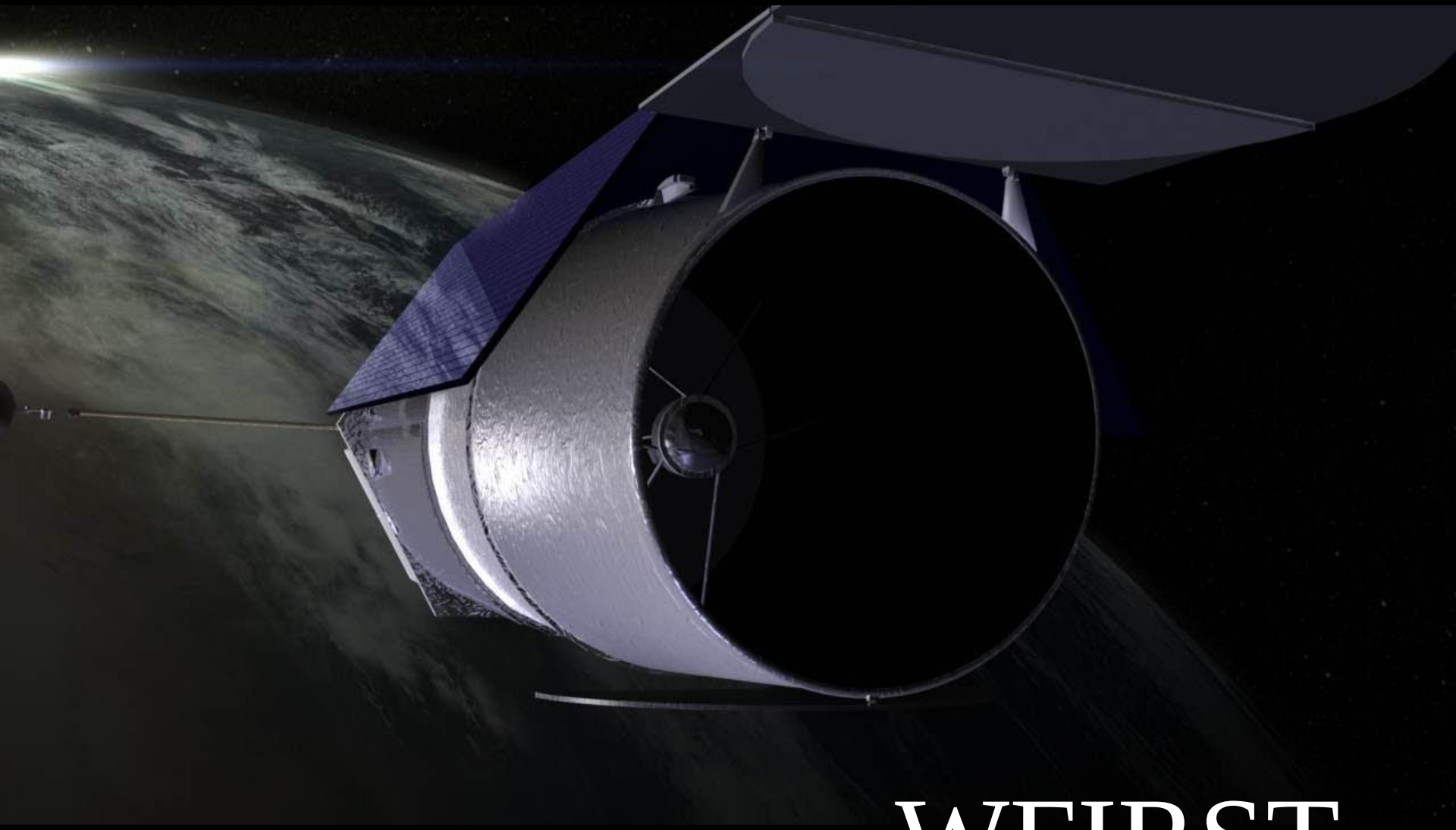
NASA/JPL-Caltech


Juno
NASA

JWST



NASA

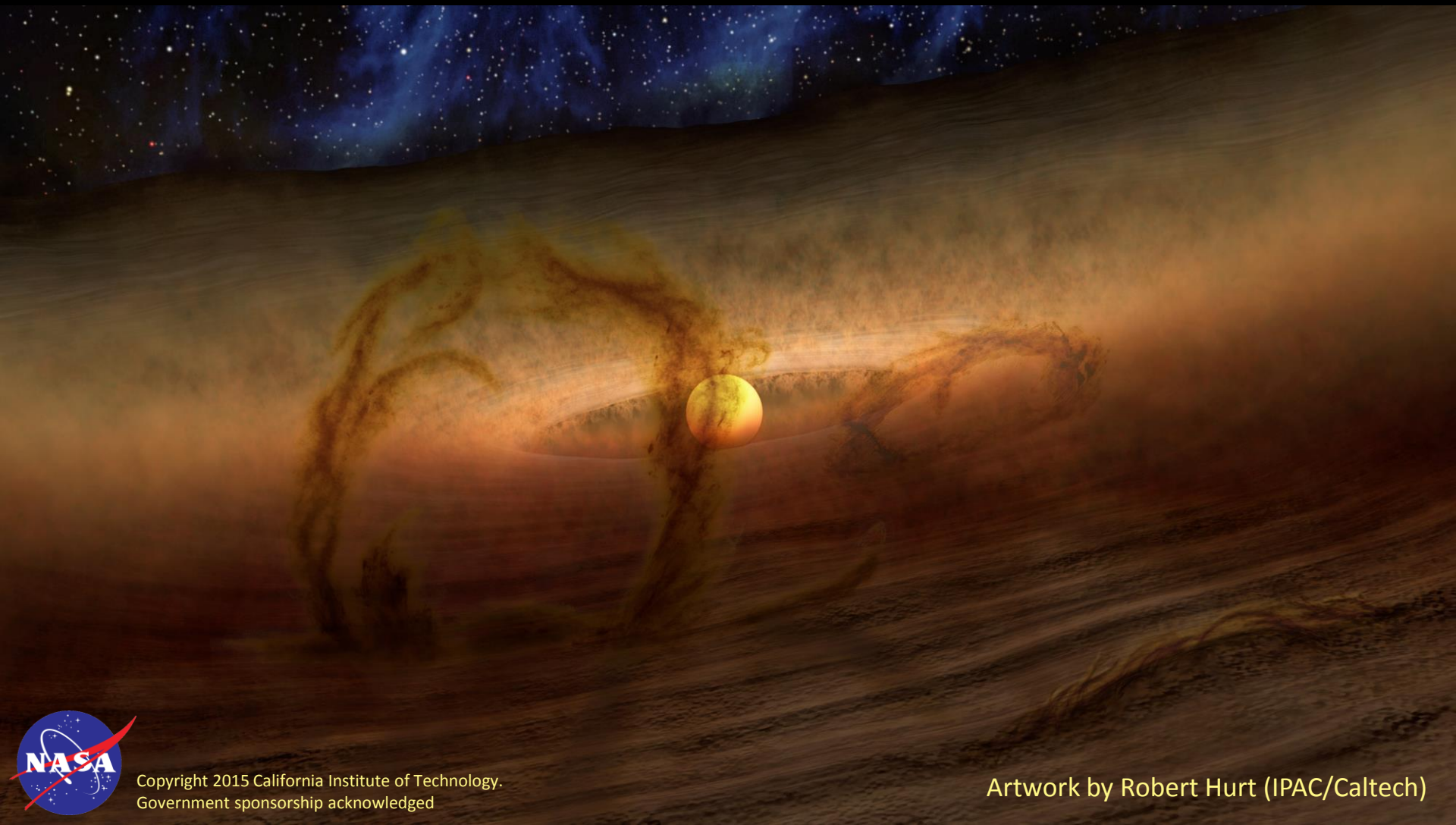


WFIRST

NASA

Protostellar Disks' Restless Atmospheres

Neal Turner (JPL/Caltech) with S. Hirose, C. Dullemond, M. Benisty



Artwork by Robert Hurt (IPAC/Caltech)

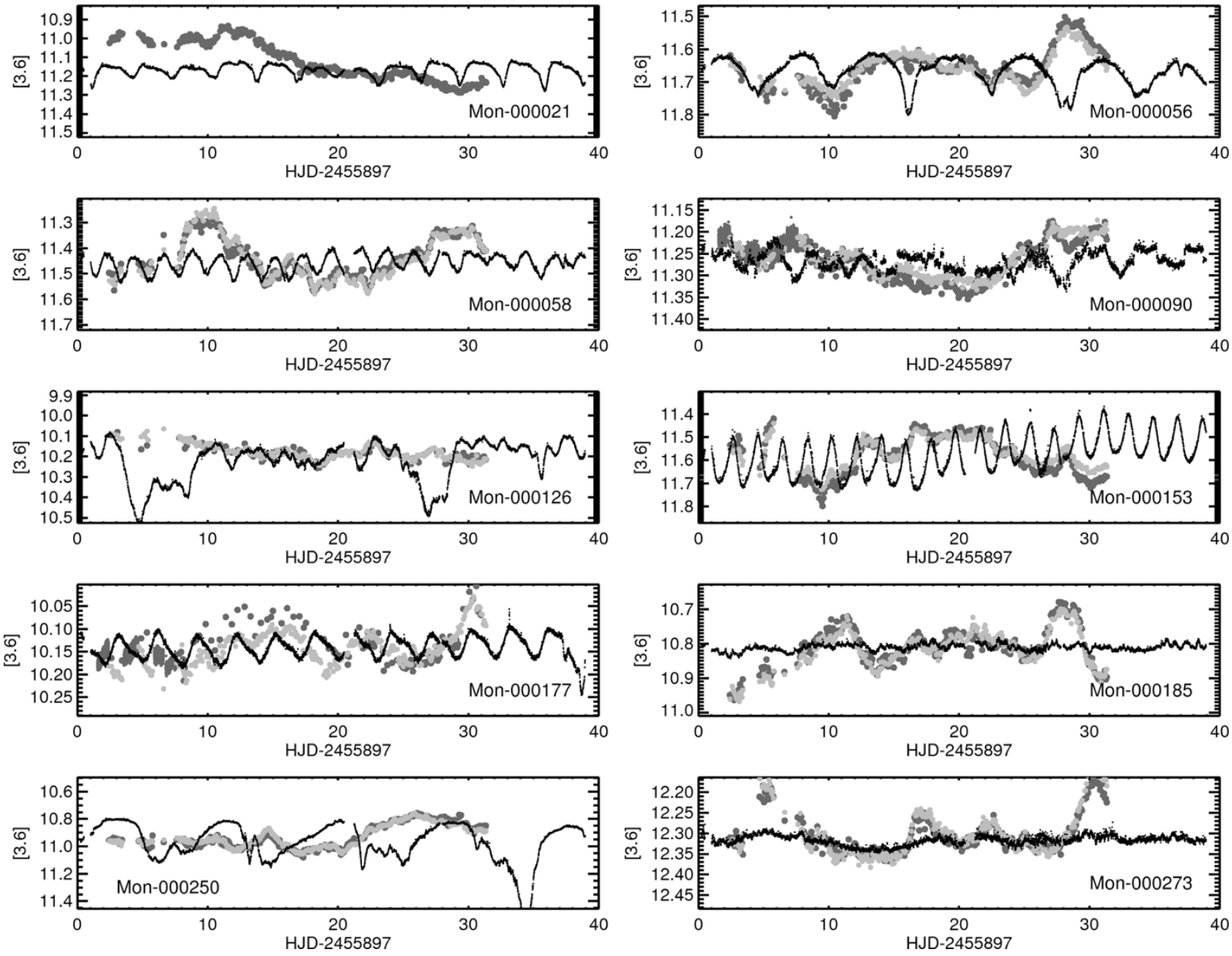
Spitzer

National Aeronautics and Space Administration

CoRoT (ESA)

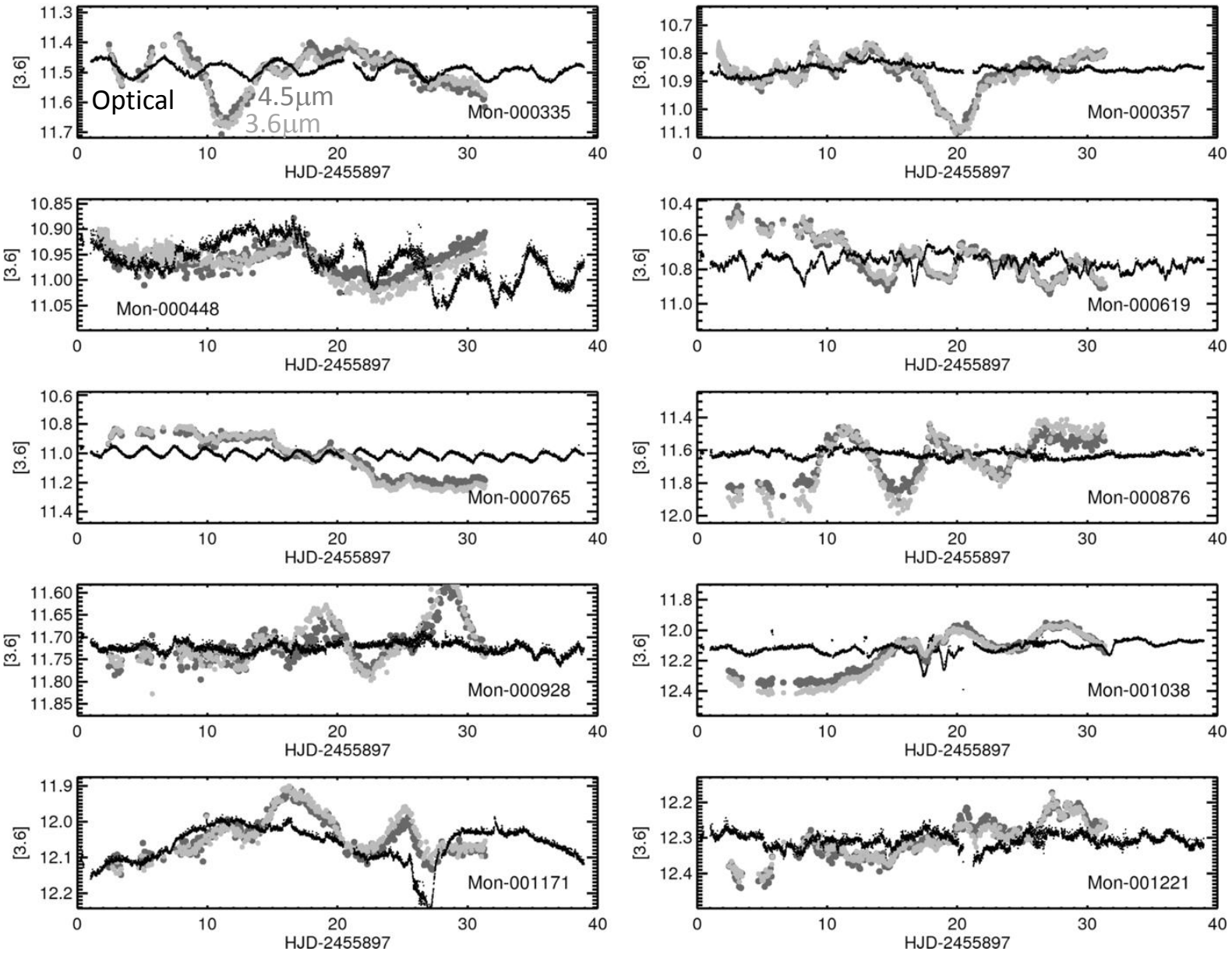
CNES & European Space Agency

Uncorrelated Optical & IR Changes



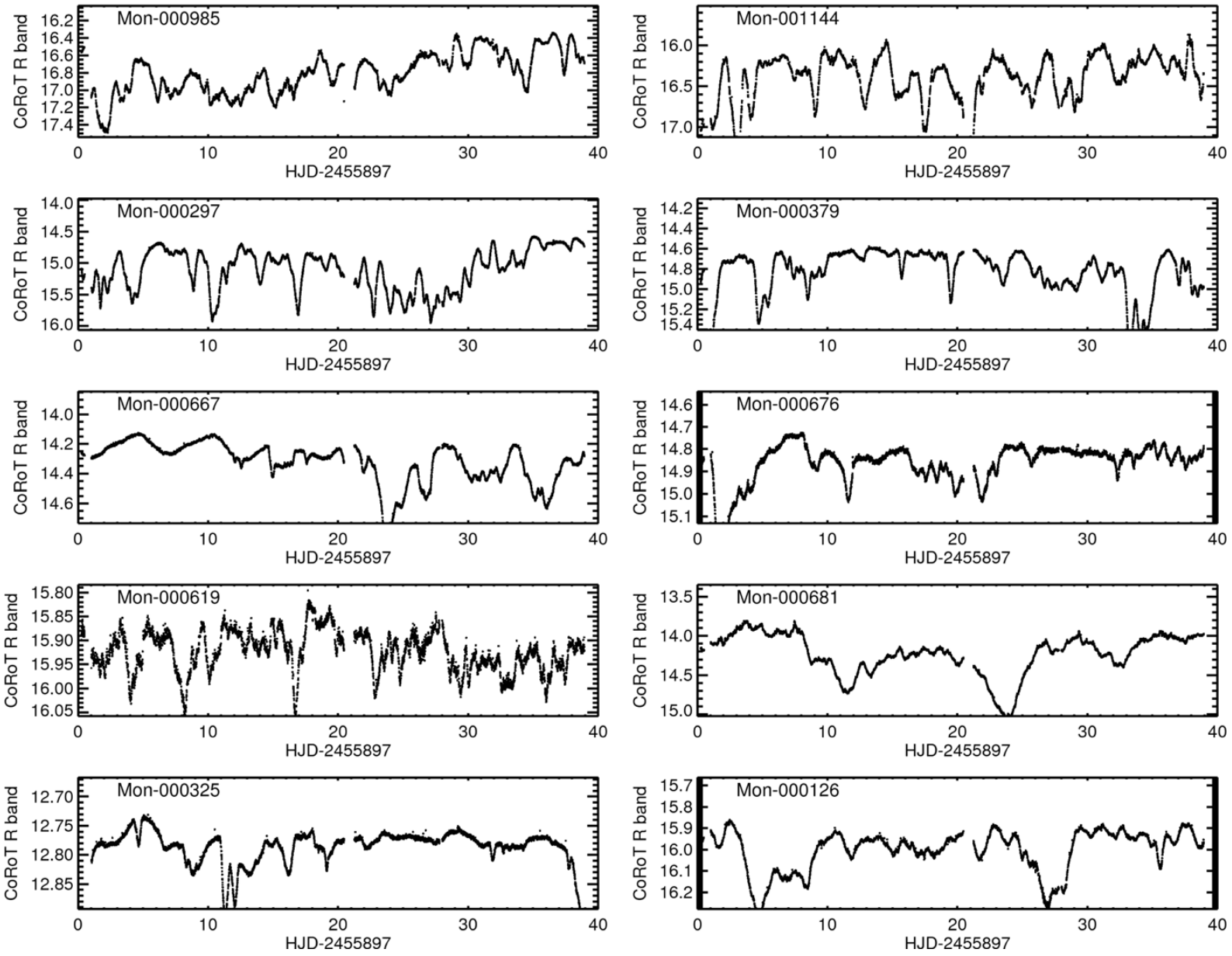
A. M. Cody et al. 2014

Uncorrelated Optical & IR Changes



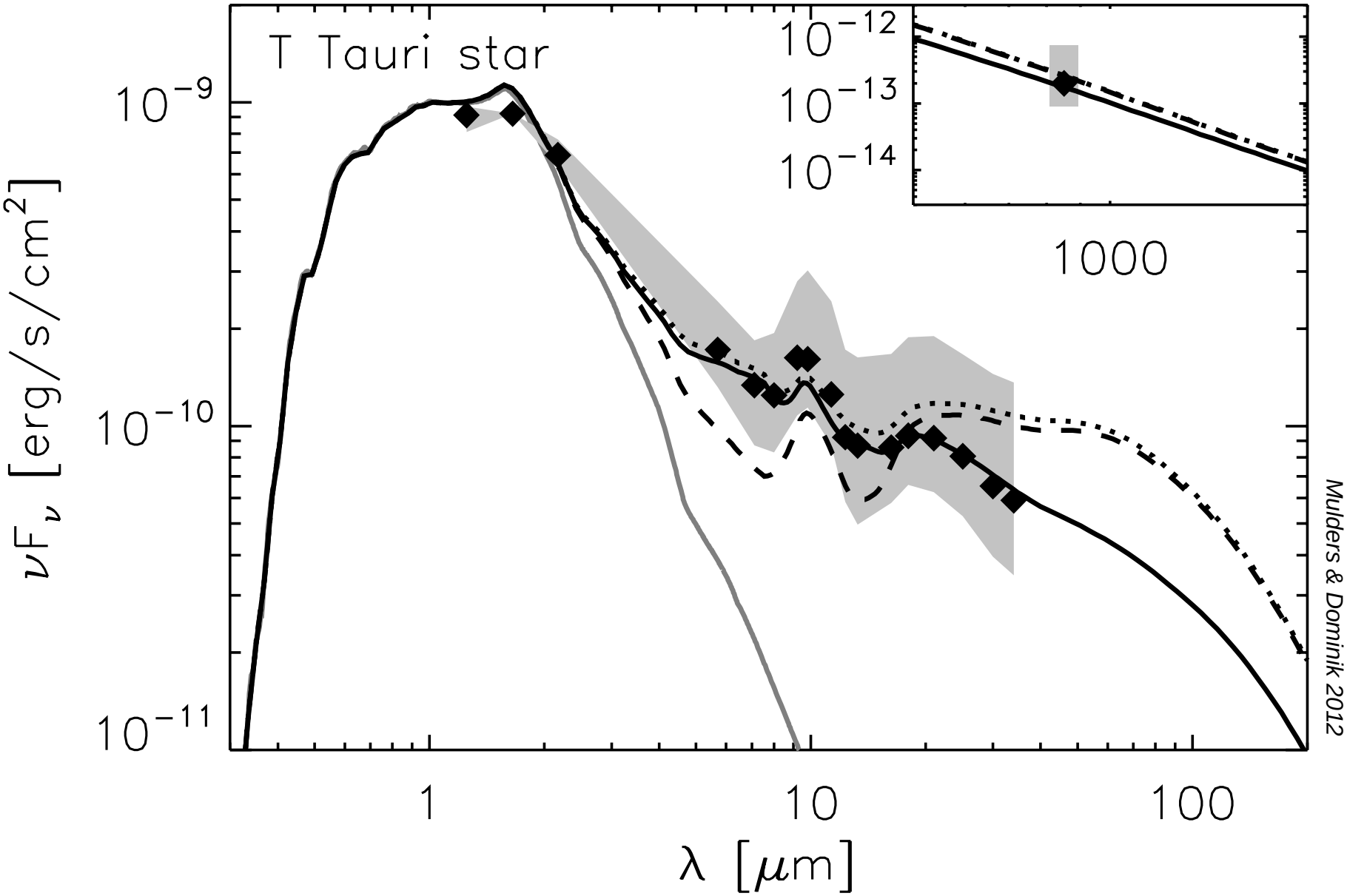
A. M. Cody et al. 2014

Erratic Dips Due to Variable Extinction

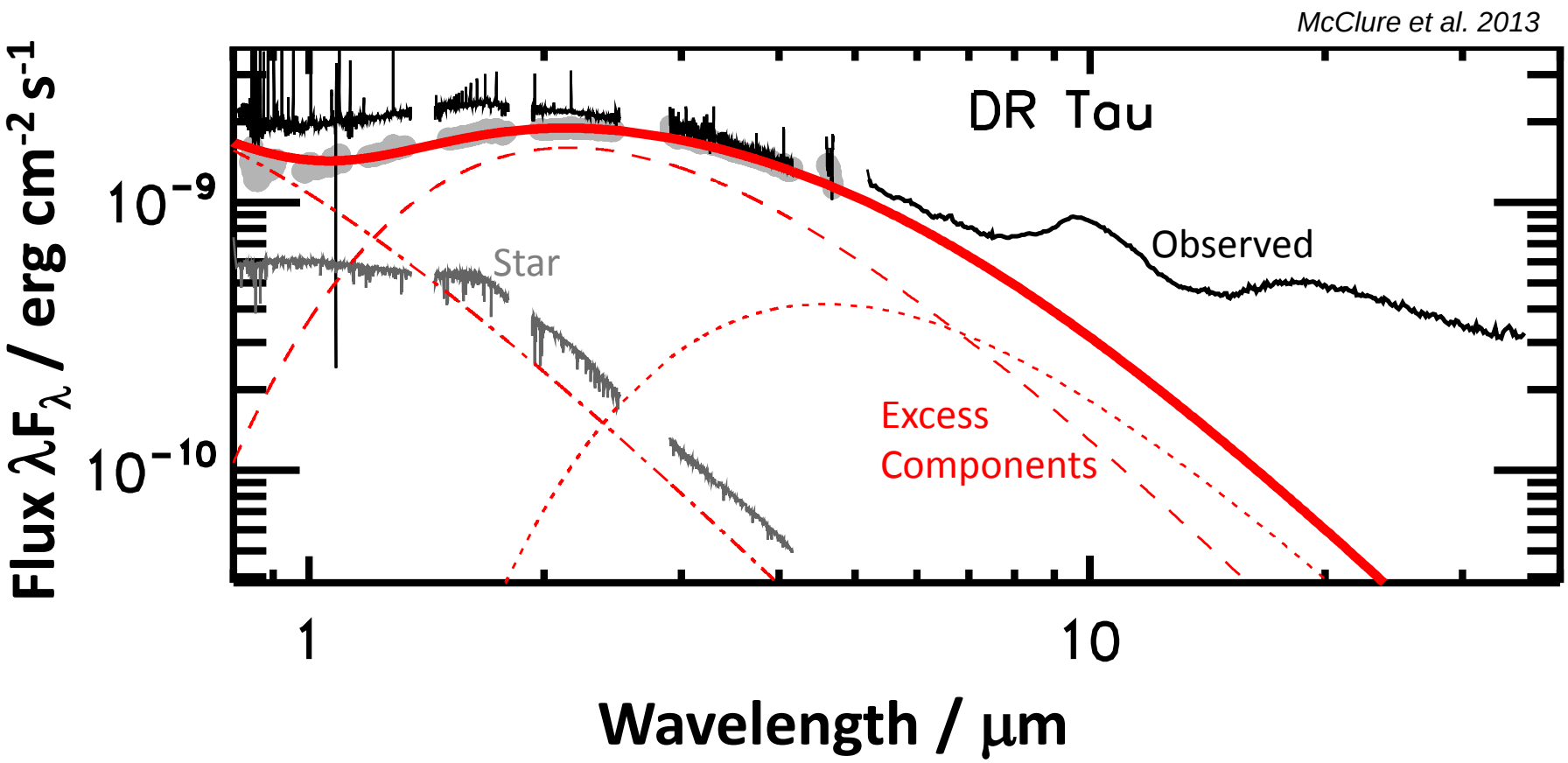


A. M. Cody et al. 2014

Median CTTS Has NIR Excess Too Large



NIR Excess has $T \sim T_{subl}$ and L up to $0.17 L_*$!



Outline

1. Magnetic fields support an extended disk atmosphere,
1. Which absorbs enough starlight to cause the IR excess.
1. Fluctuating fields yield big-enough brightness changes.
1. The atmosphere can intermittently obscure the star.

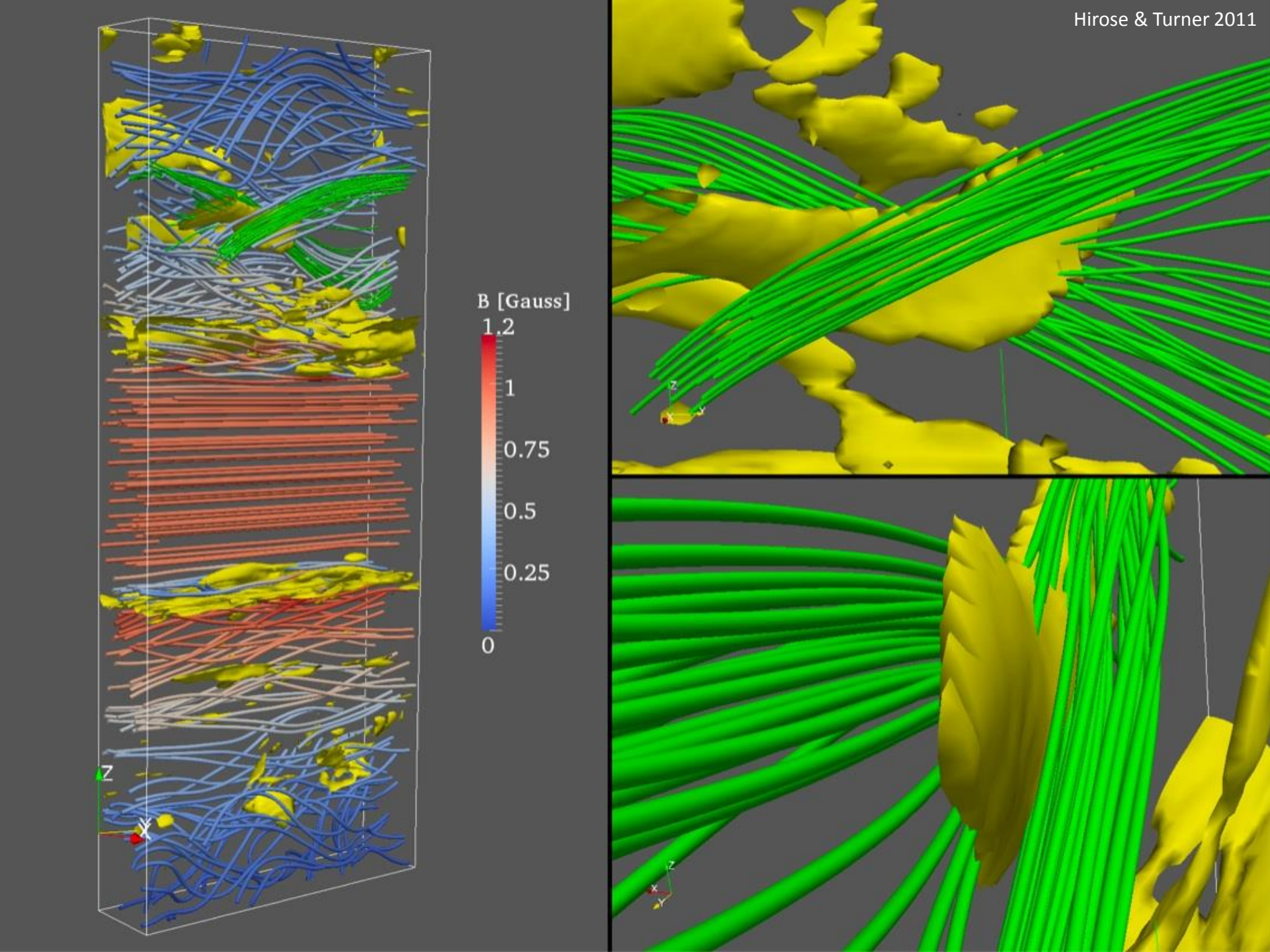
Outline

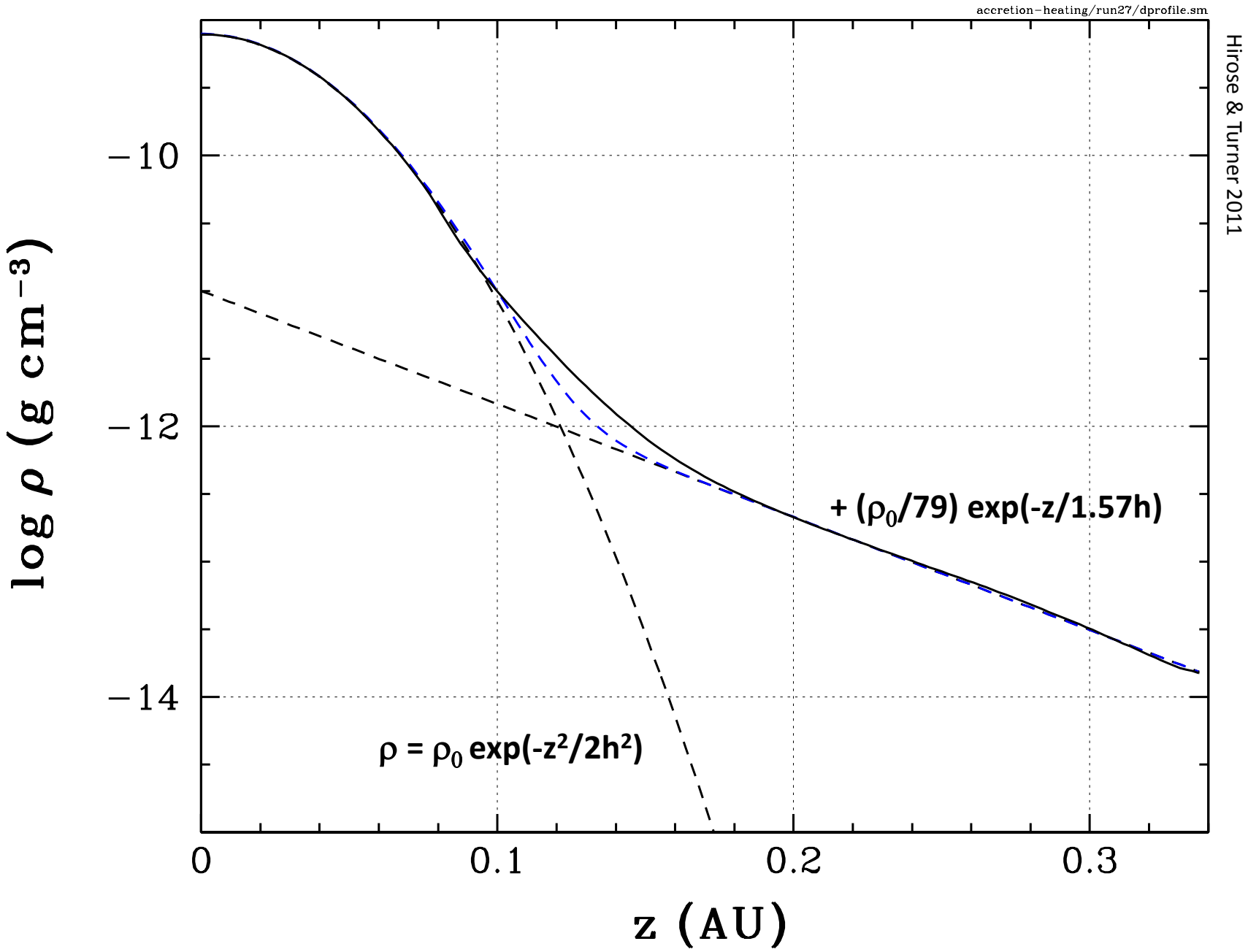
1. **Magnetic fields support an extended disk atmosphere,**

1. **Which absorbs enough starlight to cause the IR excess.**

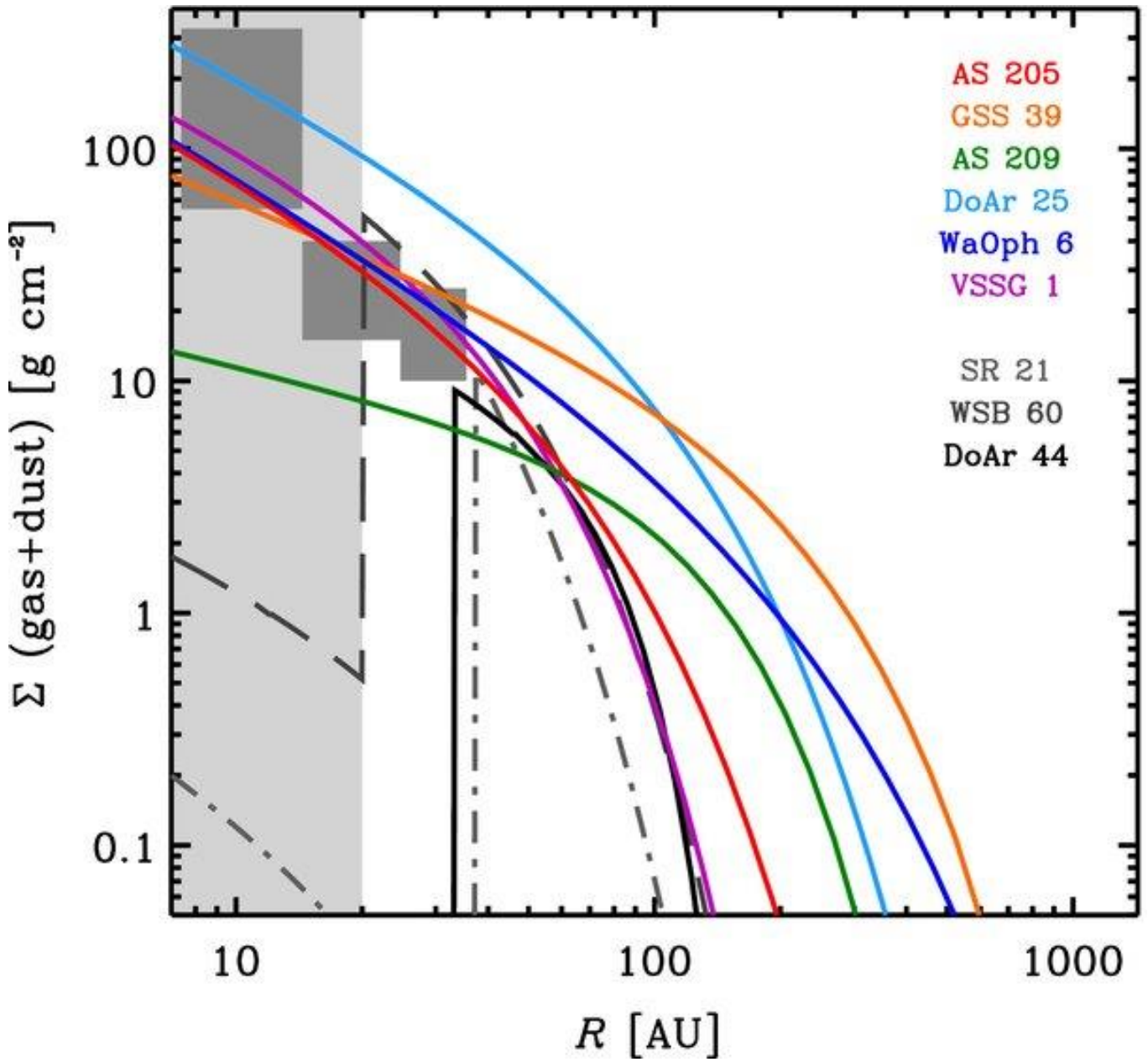
1. **Fluctuating fields yield big-enough brightness changes.**

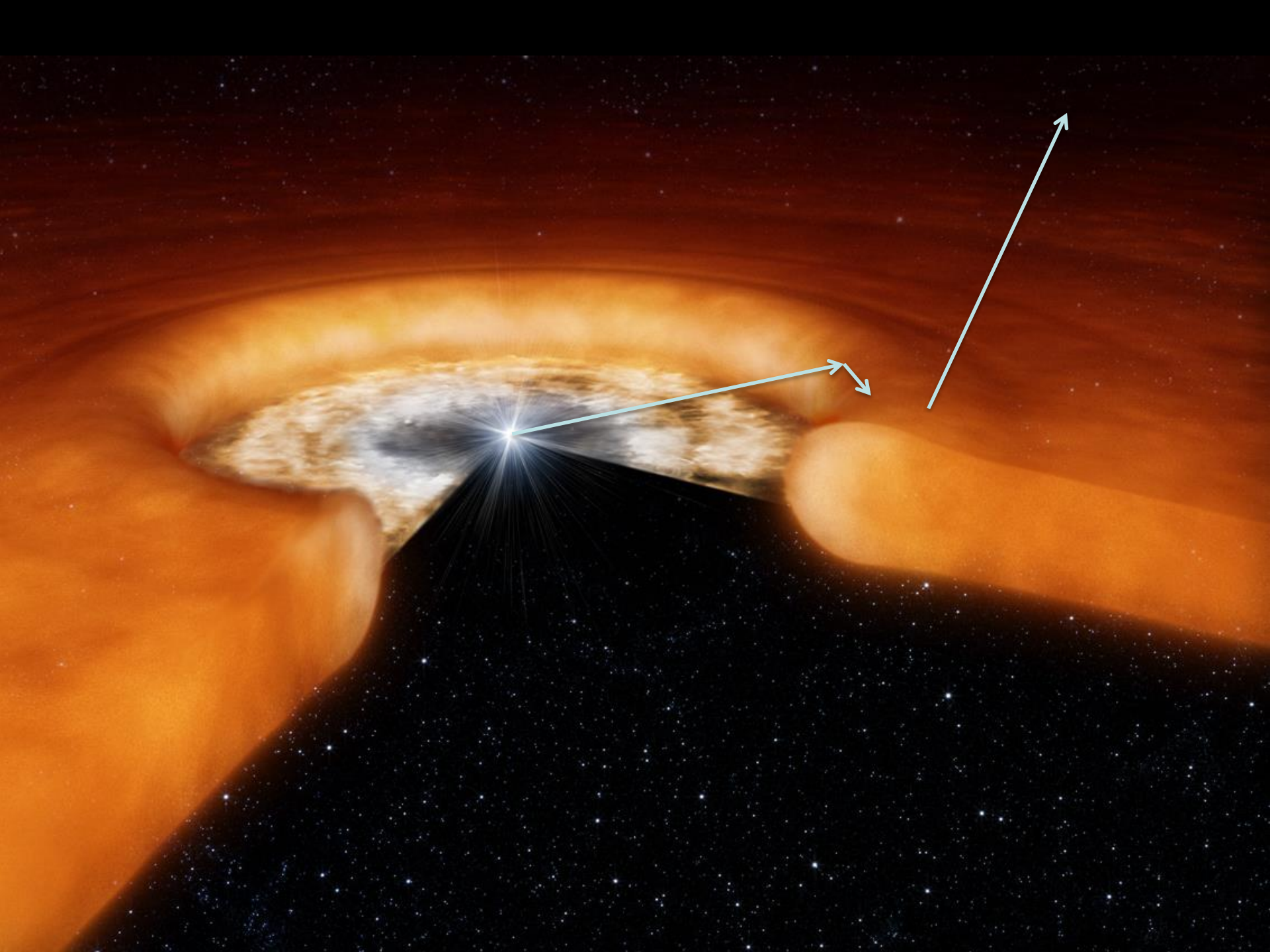
1. **The atmosphere can intermittently obscure the star.**


B [Gauss]
1.2
1
0.75
0.5
0.25
0
Z
Y
Hirose & Turner 2011


accretion−heating/run27/dprofile.sm
Hirose & Turner 2011
log ρ (g cm−3)
−10
−12
−14
0
0.1
0.2
0.3
z (AU)
+ (ρ0/79) exp(-z/1.57h)
ρ = ρ0 exp(-z2/2h2)

Andrews et al. 2009





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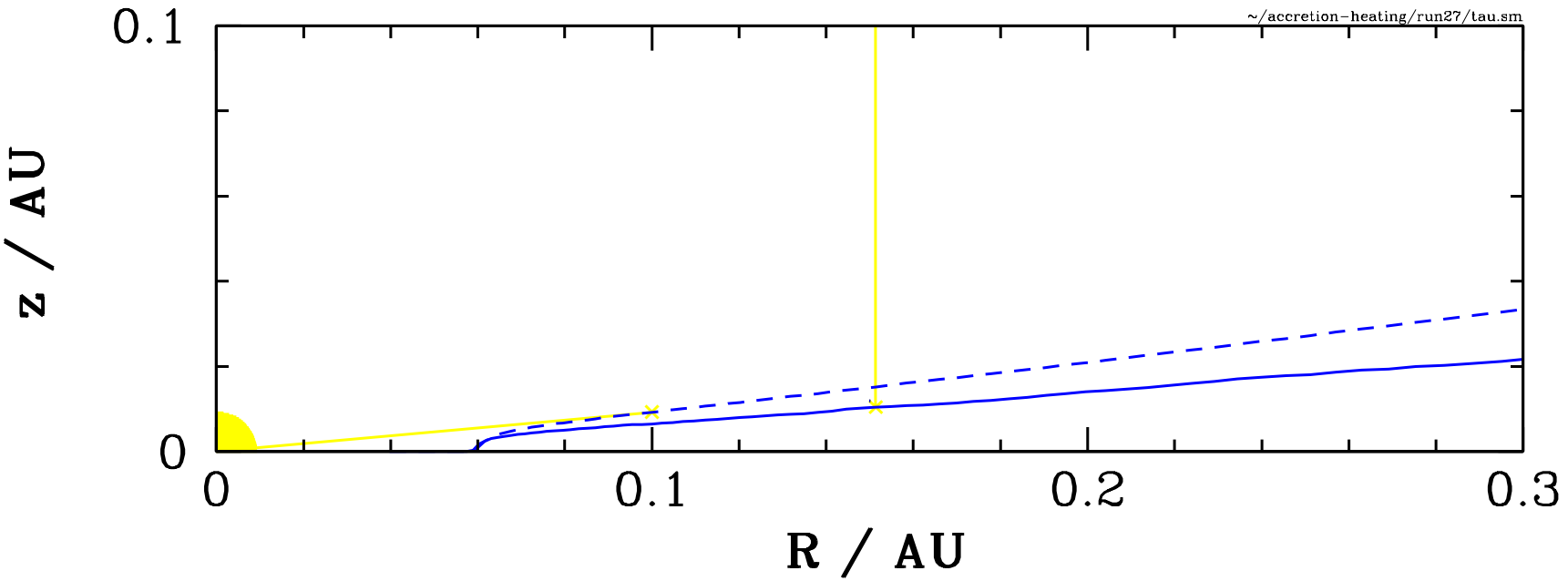
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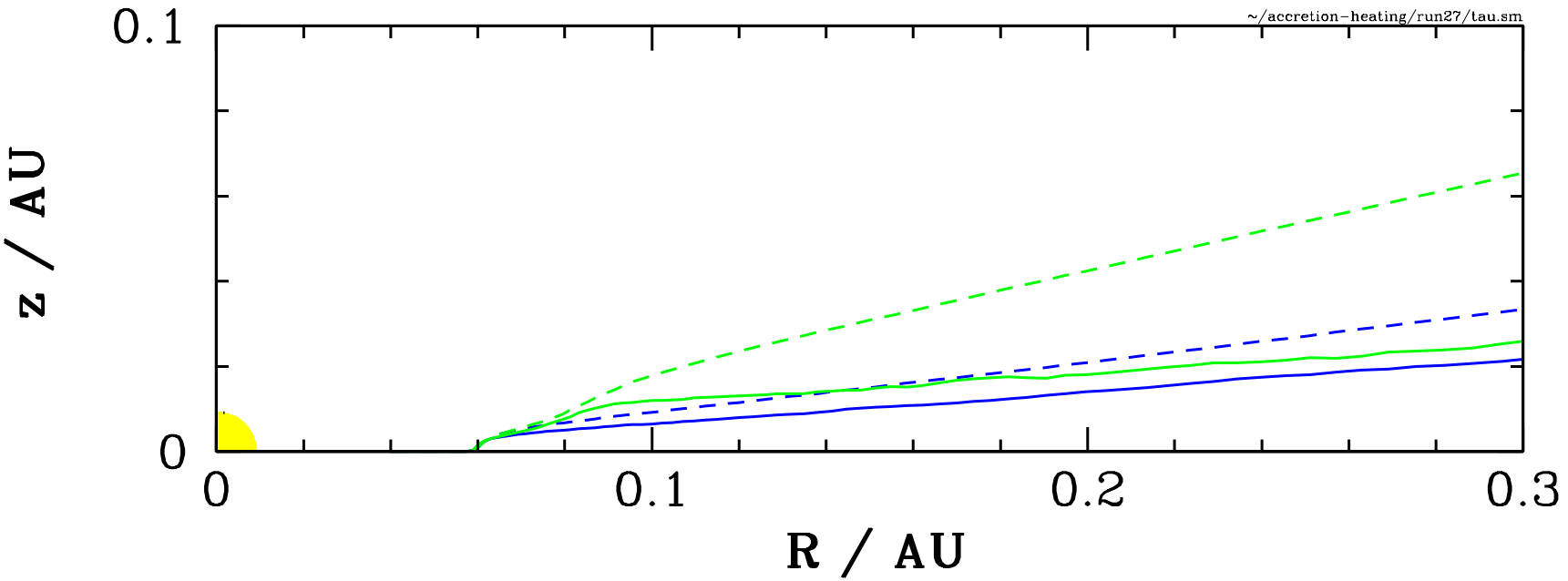
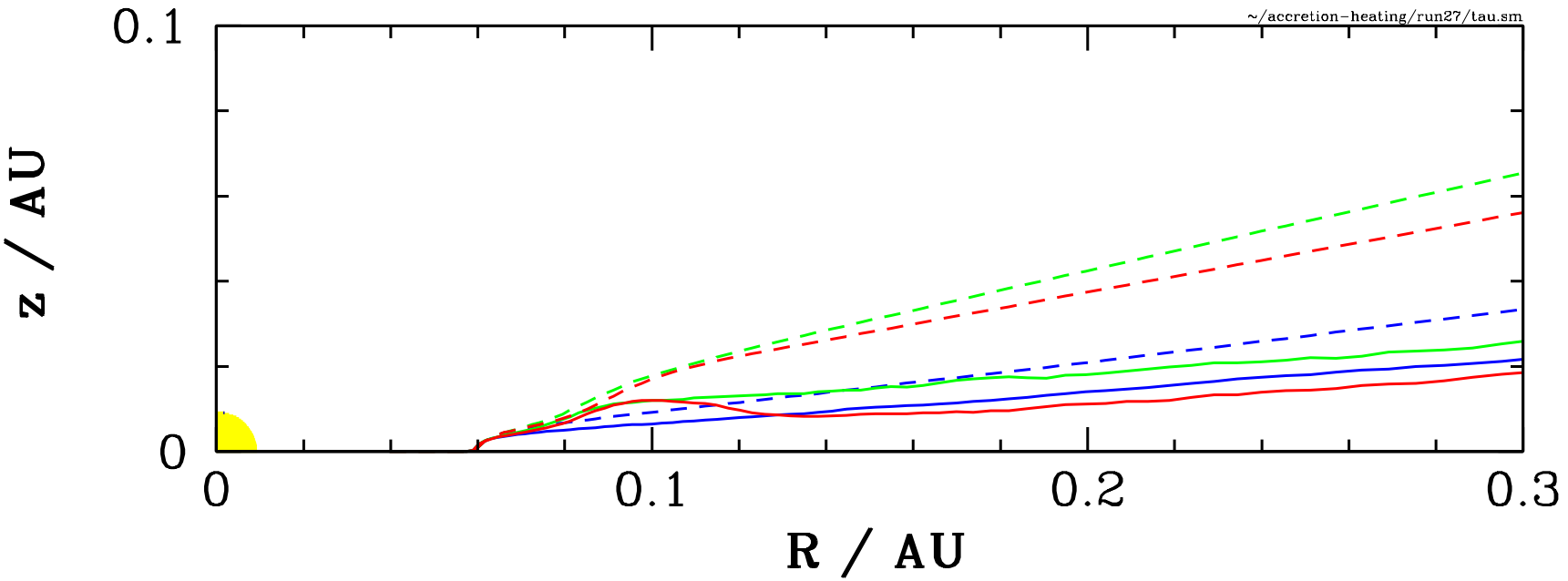
0.1
0
z / AU
0
0.1
0.2
0.3
R / AU


~/accretion-heating/run27/tau.sm
0.1
0
z / AU
0
0.1
0.2
0.3
R / AU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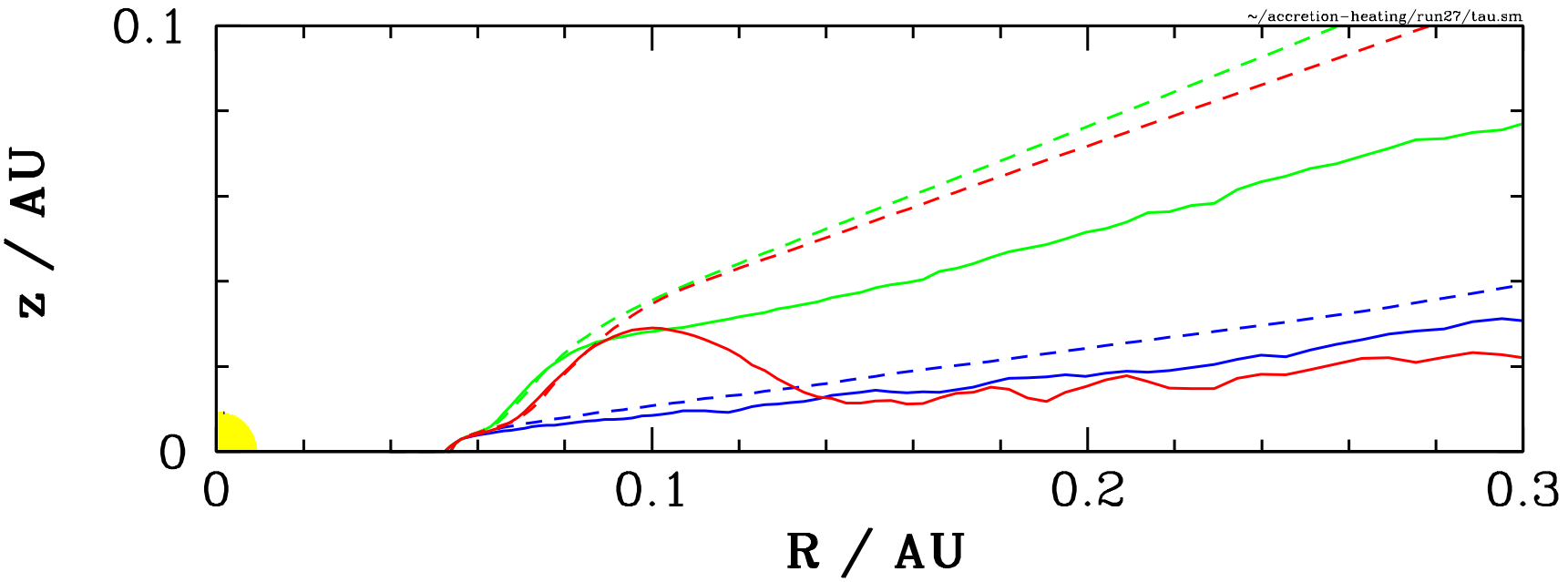
0.1
0
z / AU
0
0.1
0.2
0.3
R / AU


~/accretion-heating/run27/tau.sm
0.1
0
z / AU
0
0.1
0.2
0.3
R / AU

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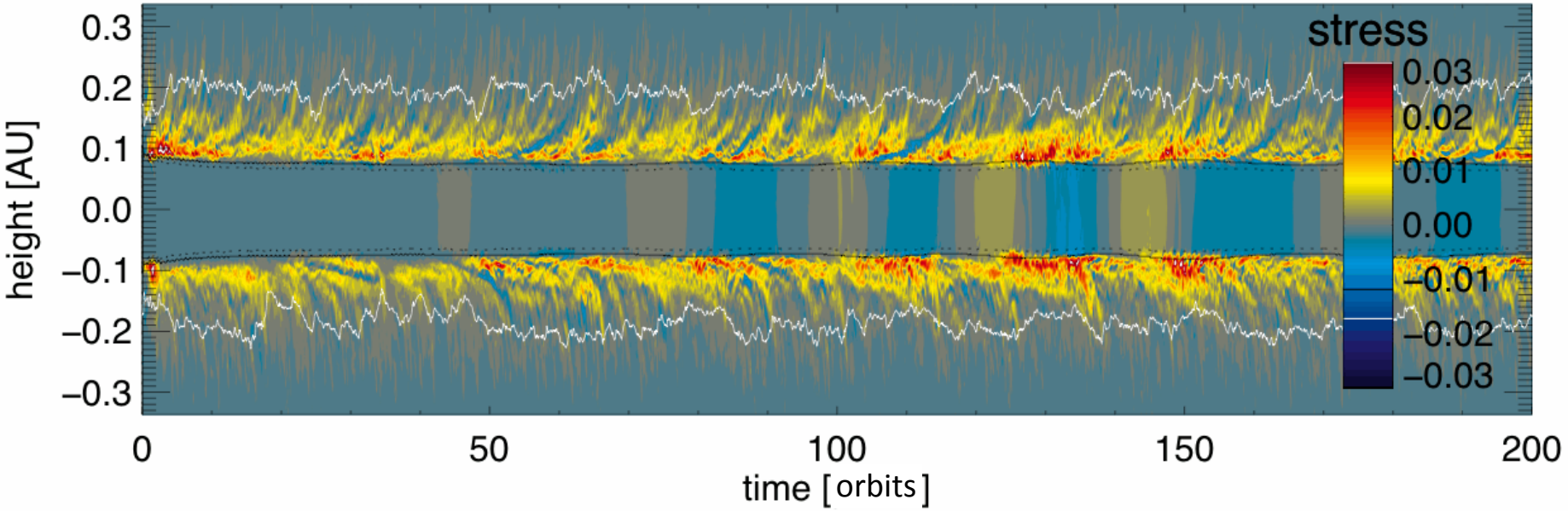
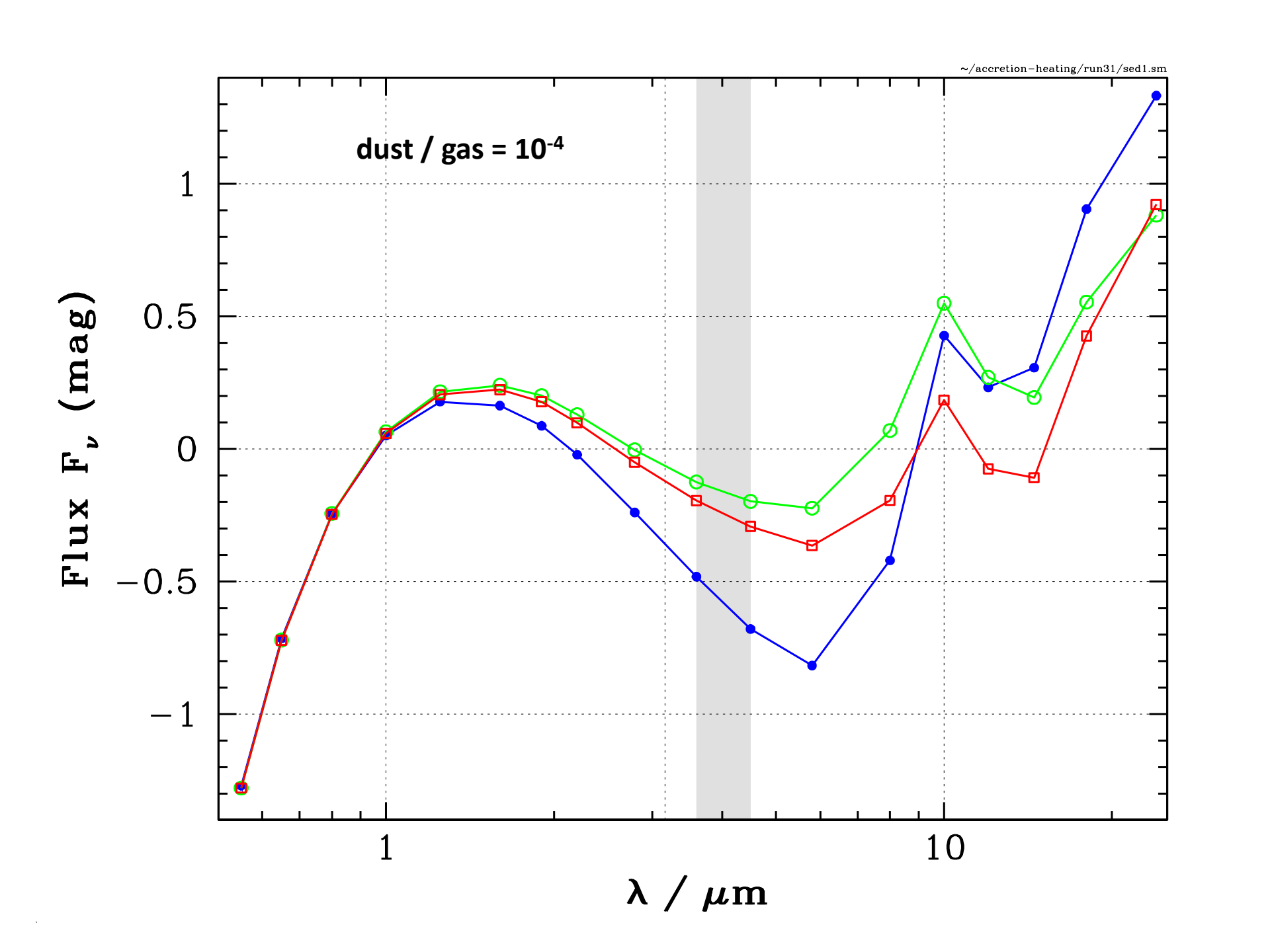
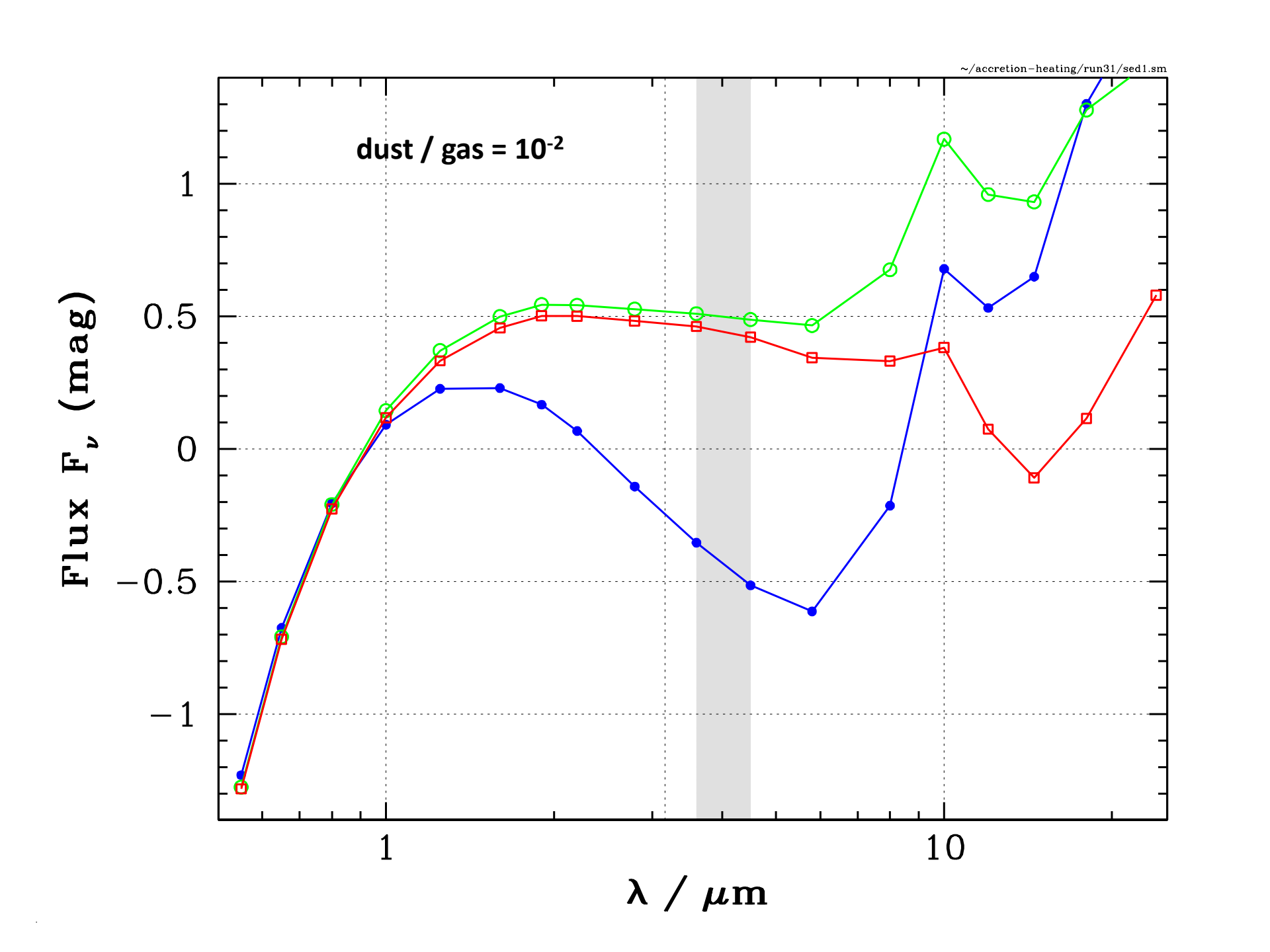


Hirose & Turner 2011


~/accretion-heating/run31/sed1.sm
dust / gas = 10-4
1
0.5
0
−0.5
−1
Flux Fν (mag)
1
10
λ / μm


~/accretion-heating/run31/sed1.sm
dust / gas = 10-2
1
0.5
0
−0.5
−1
Flux Fν (mag)
1
10
λ / μm

Outline

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1. Which absorbs enough starlight to cause the IR excess.
1. Fluctuating fields yield big-enough brightness changes.
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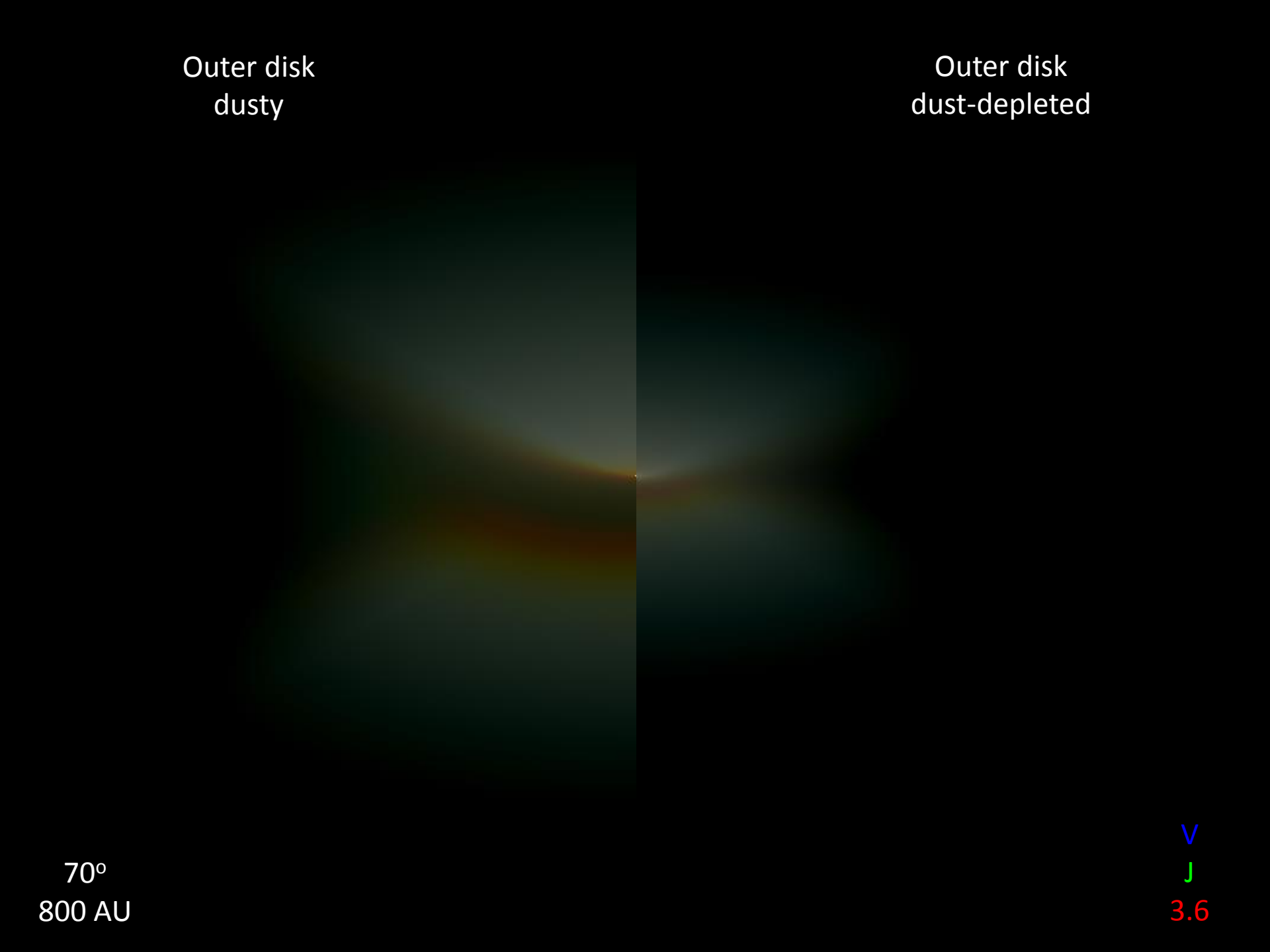
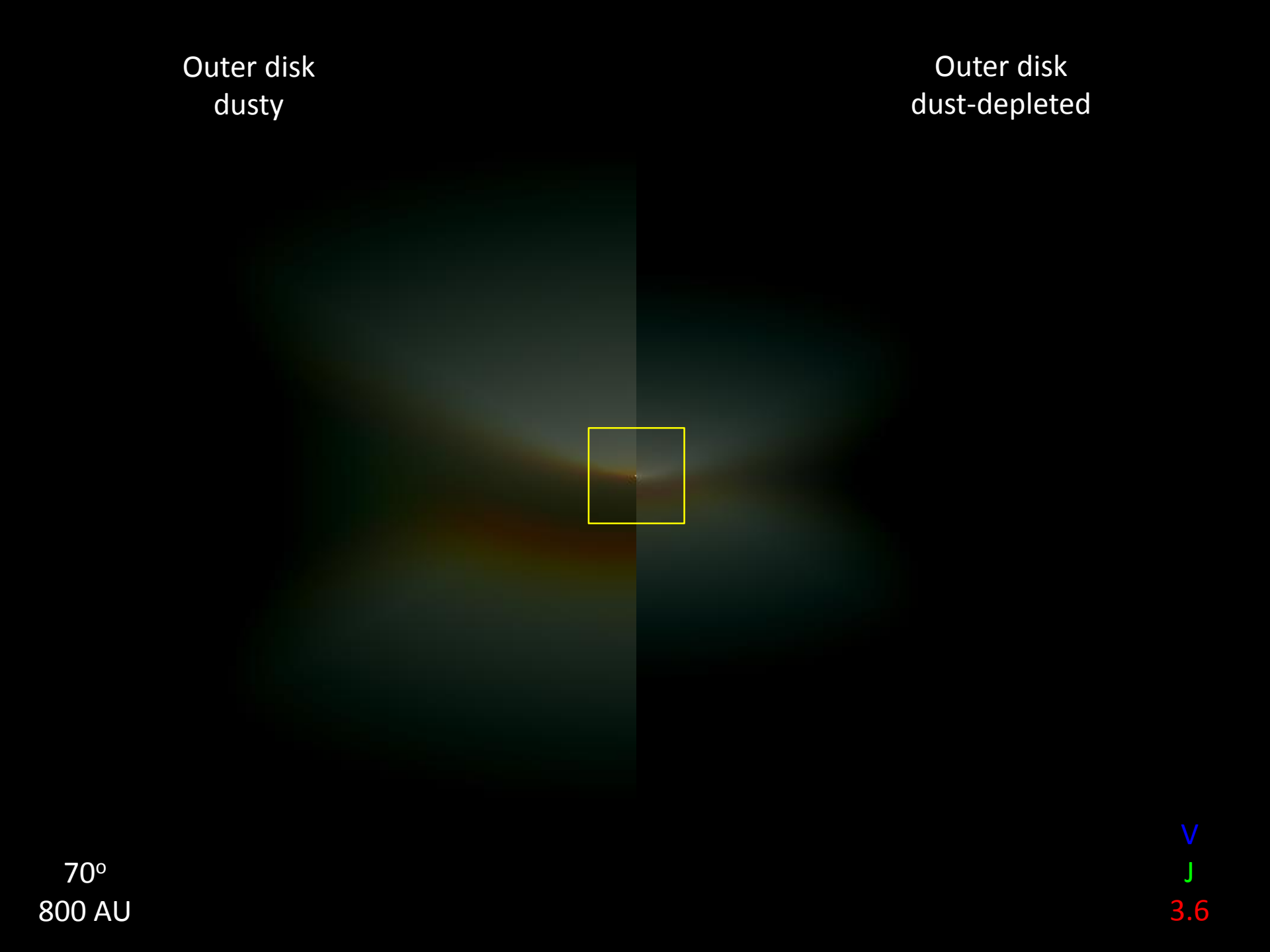
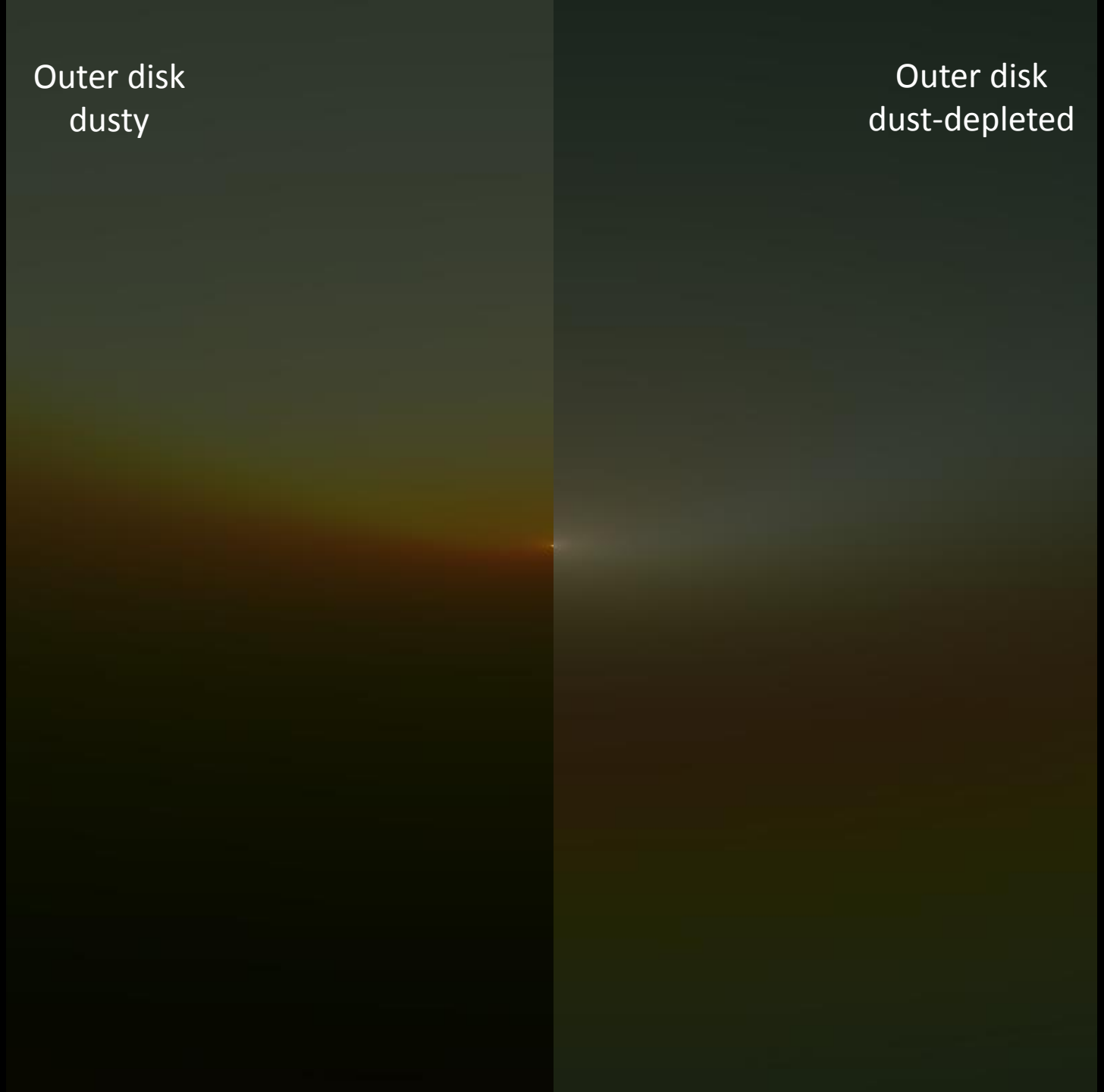
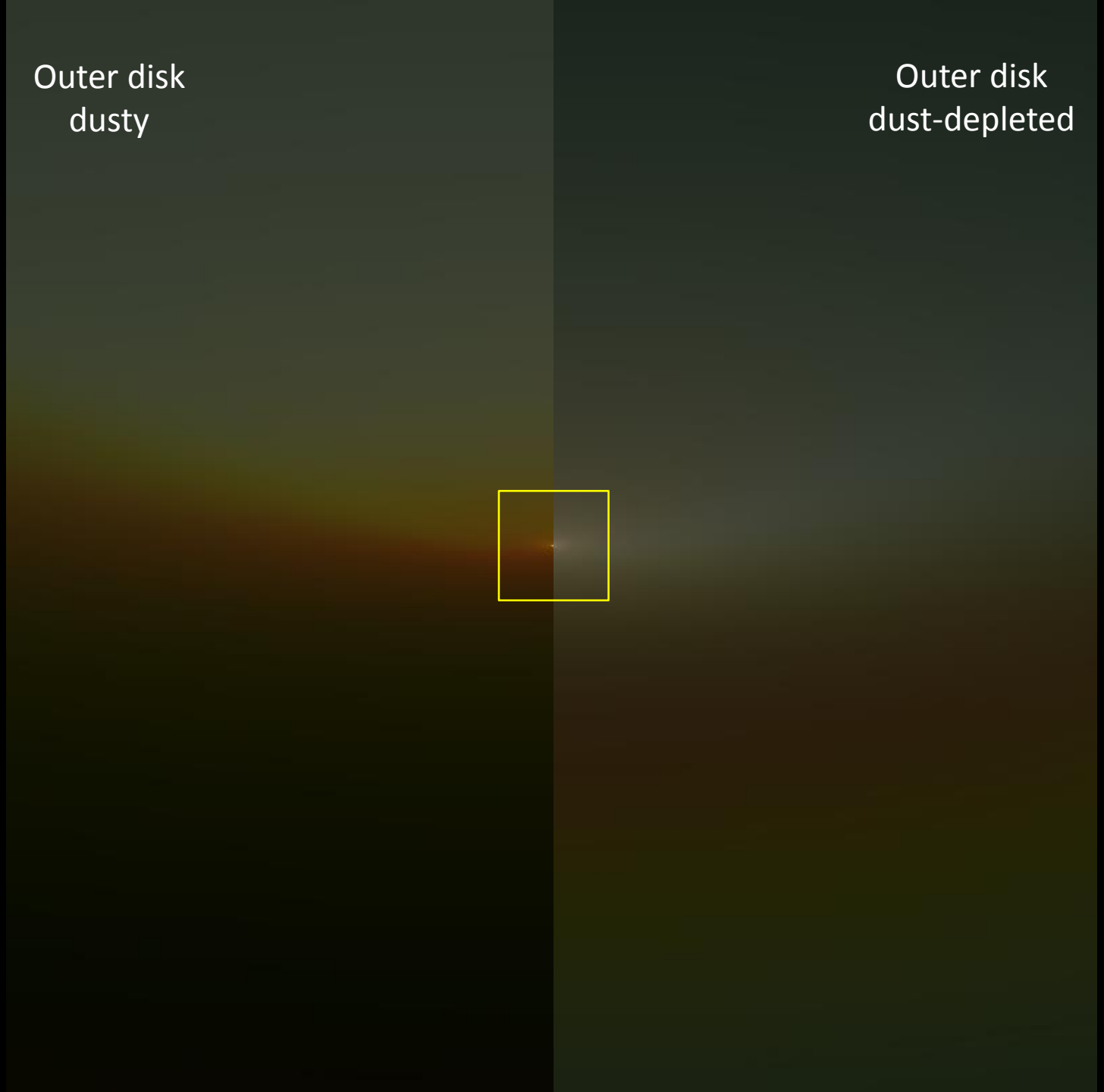
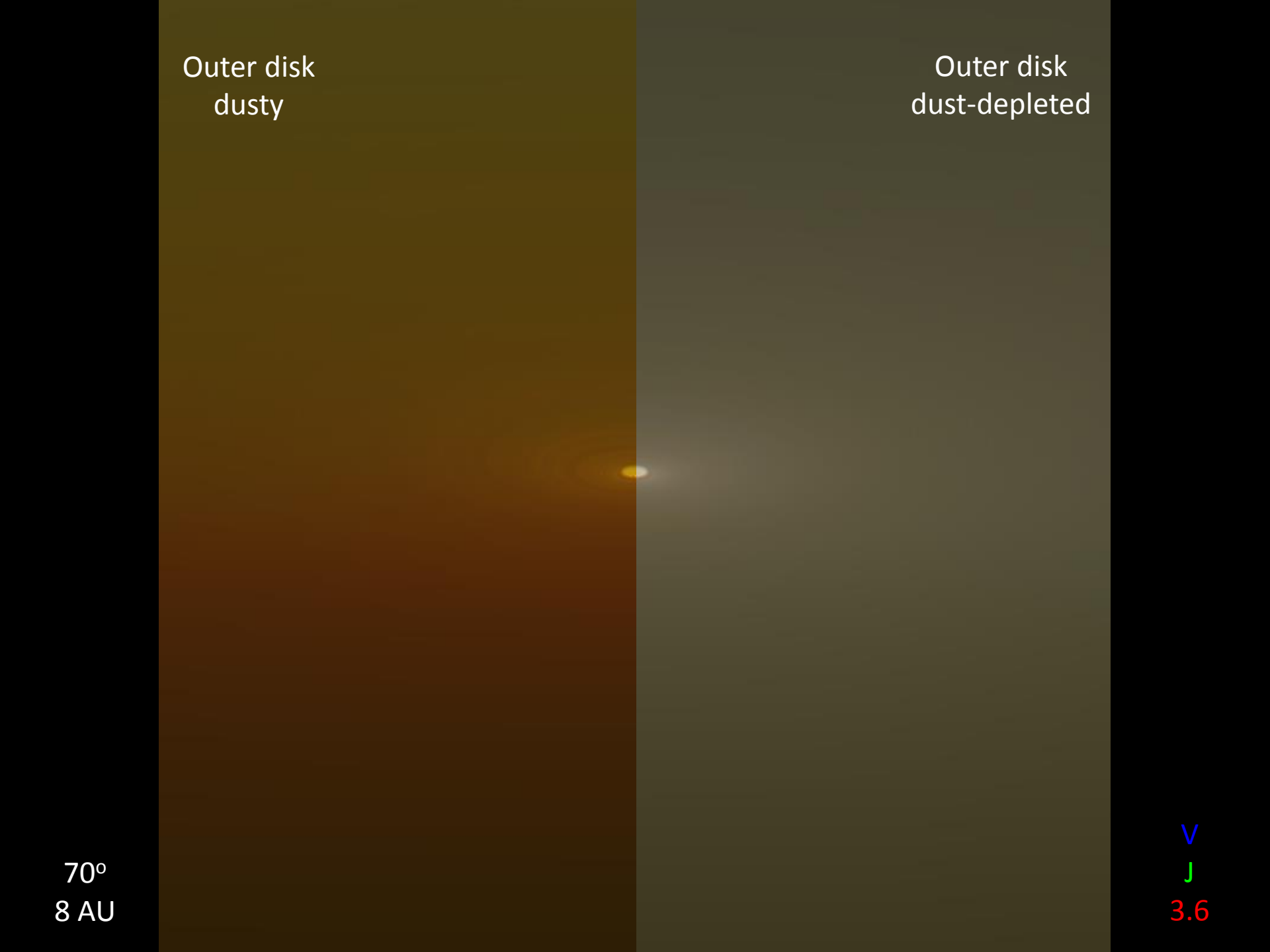
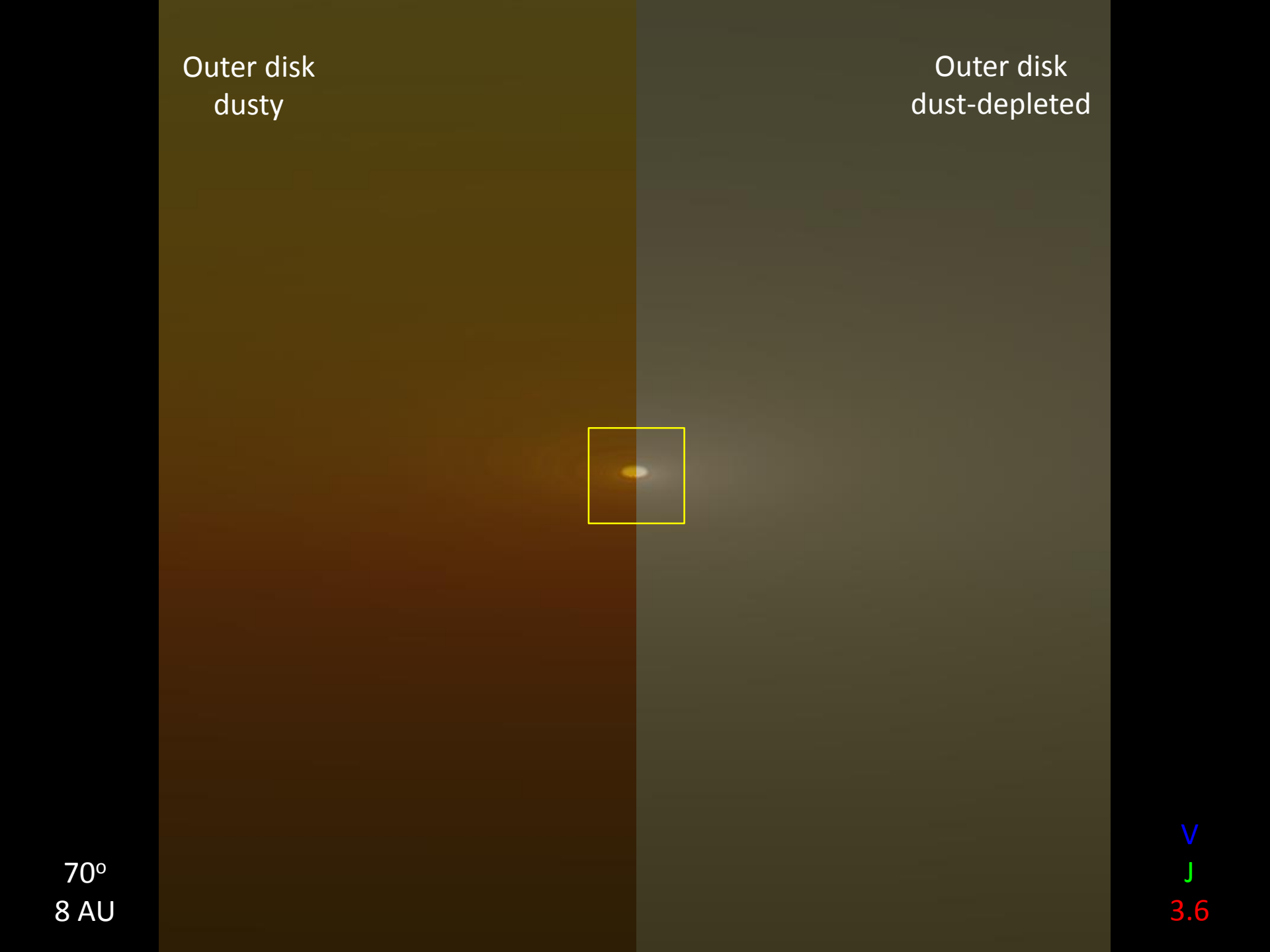

Outer disk
dusty
Outer disk
dust-depleted
70°
800 AU
V
J
3.6

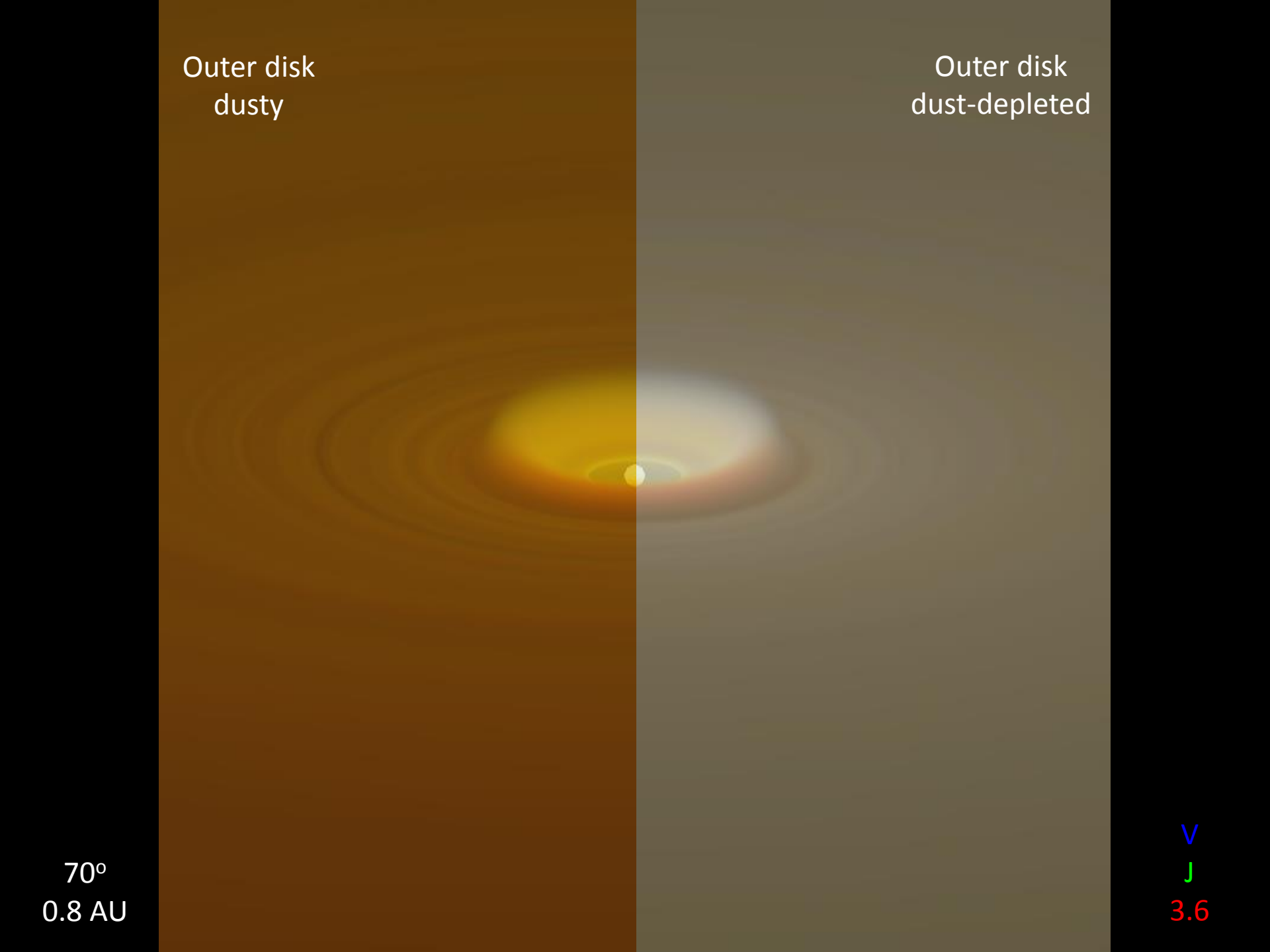

Outer disk
dusty
Outer disk
dust-depleted
70°
800 AU
V
J
3.6

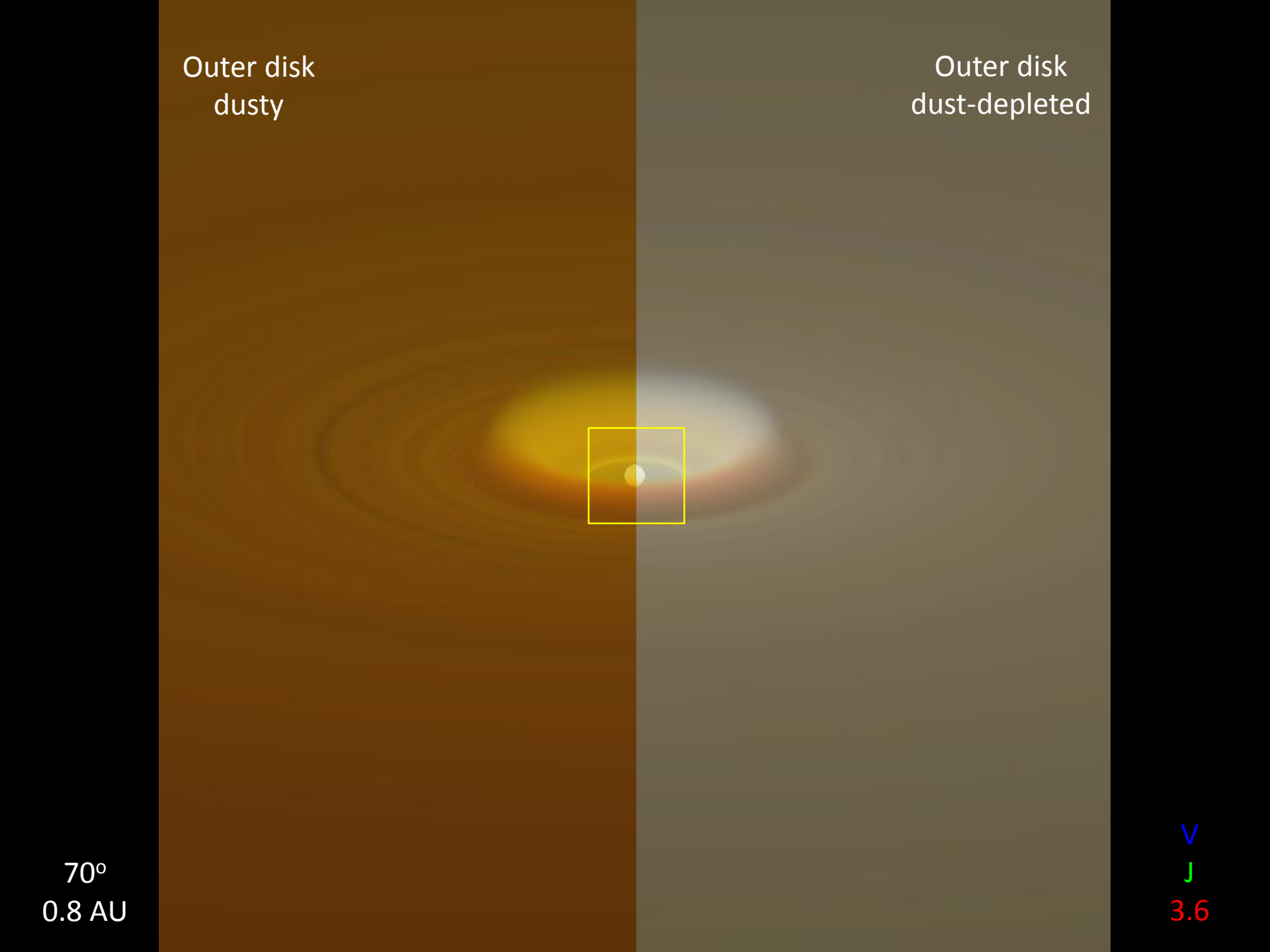

Outer disk
dusty
Outer disk
dust-depleted
70°
80 AU
V
J
3.6

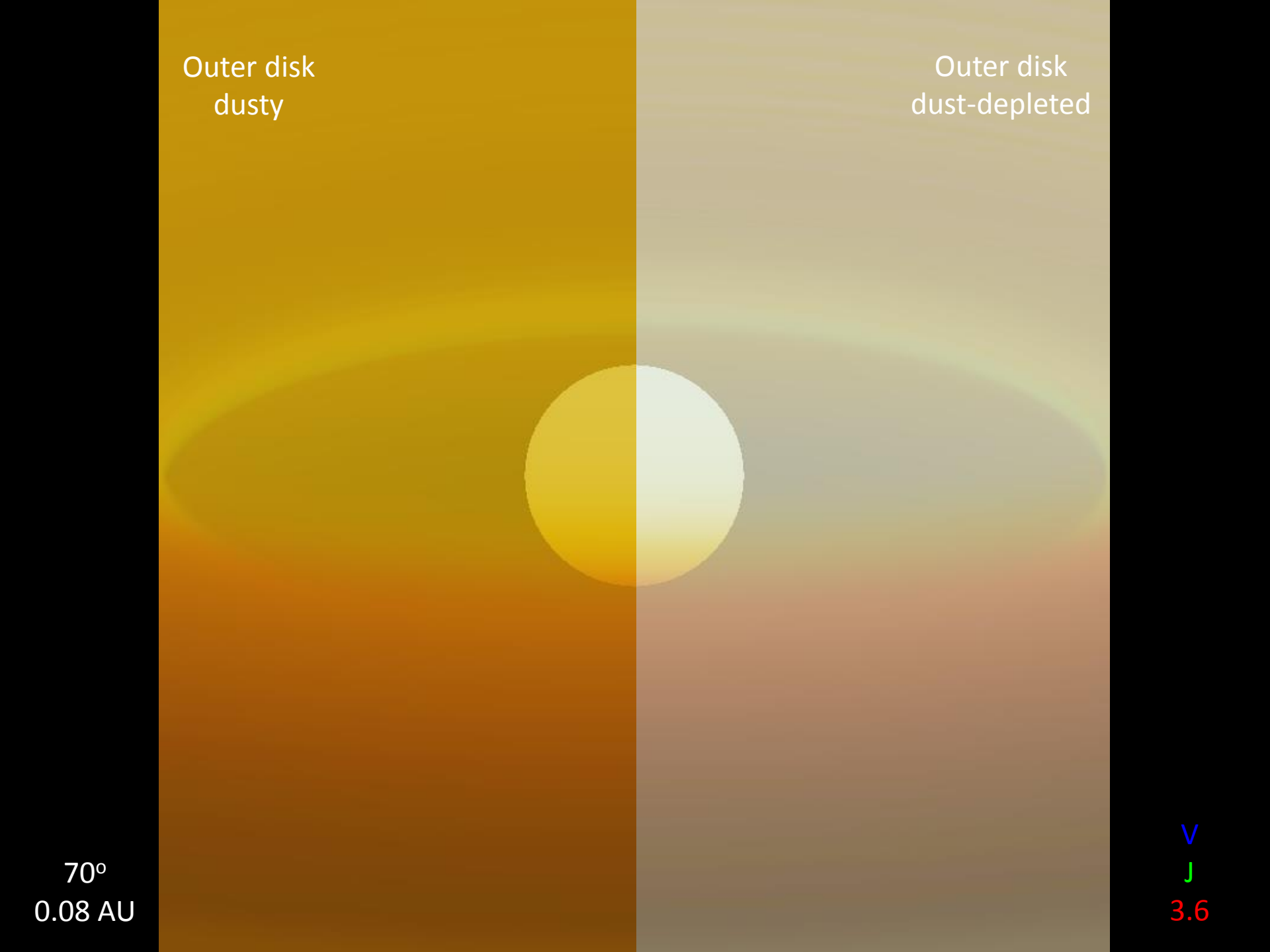

Outer disk
dusty
Outer disk
dust-depleted
70°
80 AU
V
J
3.6

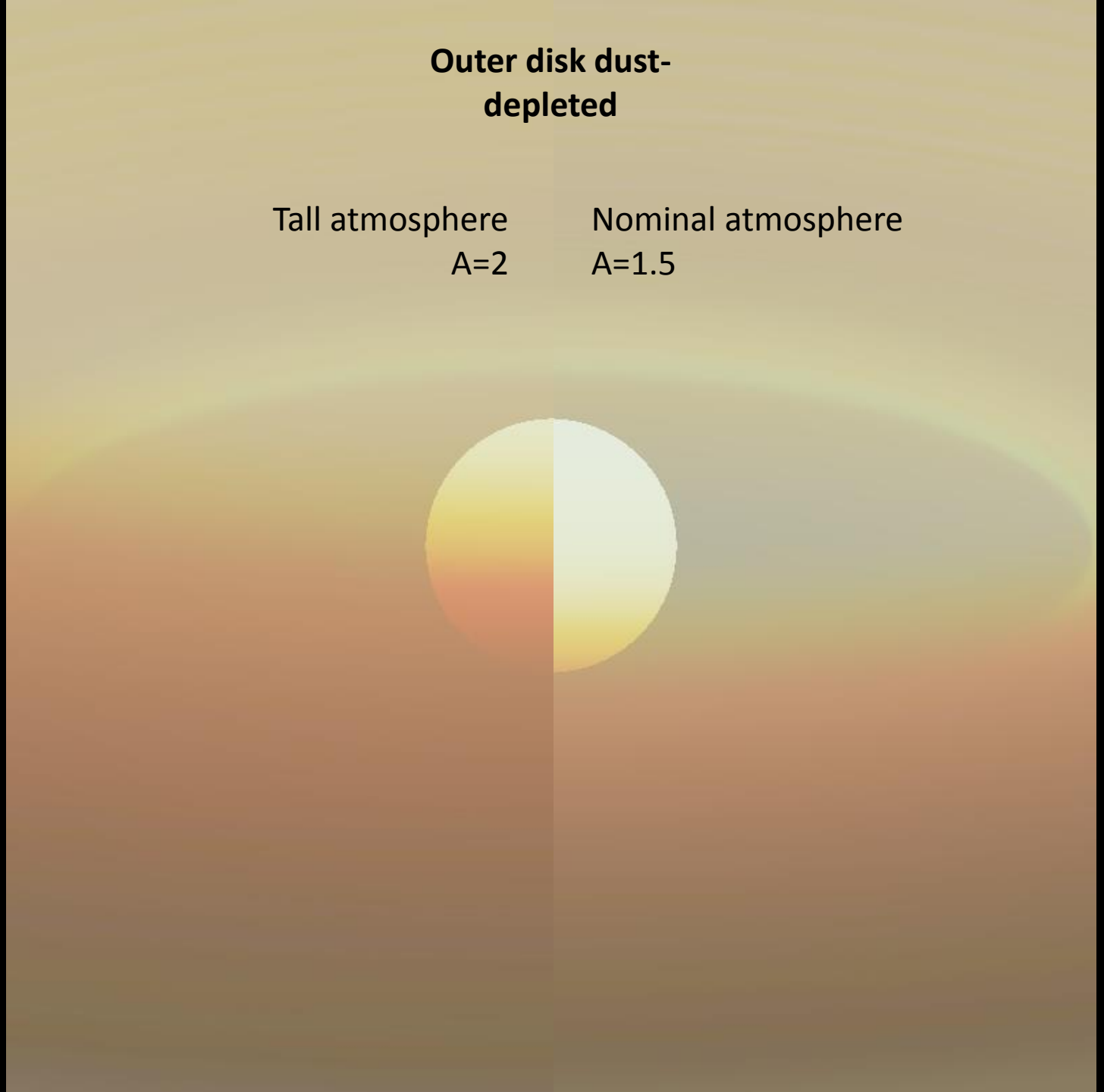

Outer disk
dusty
Outer disk
dust-depleted
70°
8 AU
V
J
3.6


Outer disk
dusty
Outer disk
dust-depleted
70°
8 AU
V
J
3.6


Outer disk
dusty
Outer disk
dust-depleted
70°
0.8 AU
V
J
3.6


Outer disk
dusty
Outer disk
dust-depleted
70°
0.8 AU
V
J
3.6


Outer disk
dusty
Outer disk
dust-depleted
70°
0.08 AU
V
J
3.6


Outer disk dust-depleted
Tall atmosphere
A=2
Nominal atmosphere
A=1.5
70°
0.08 AU
V
J
3.6

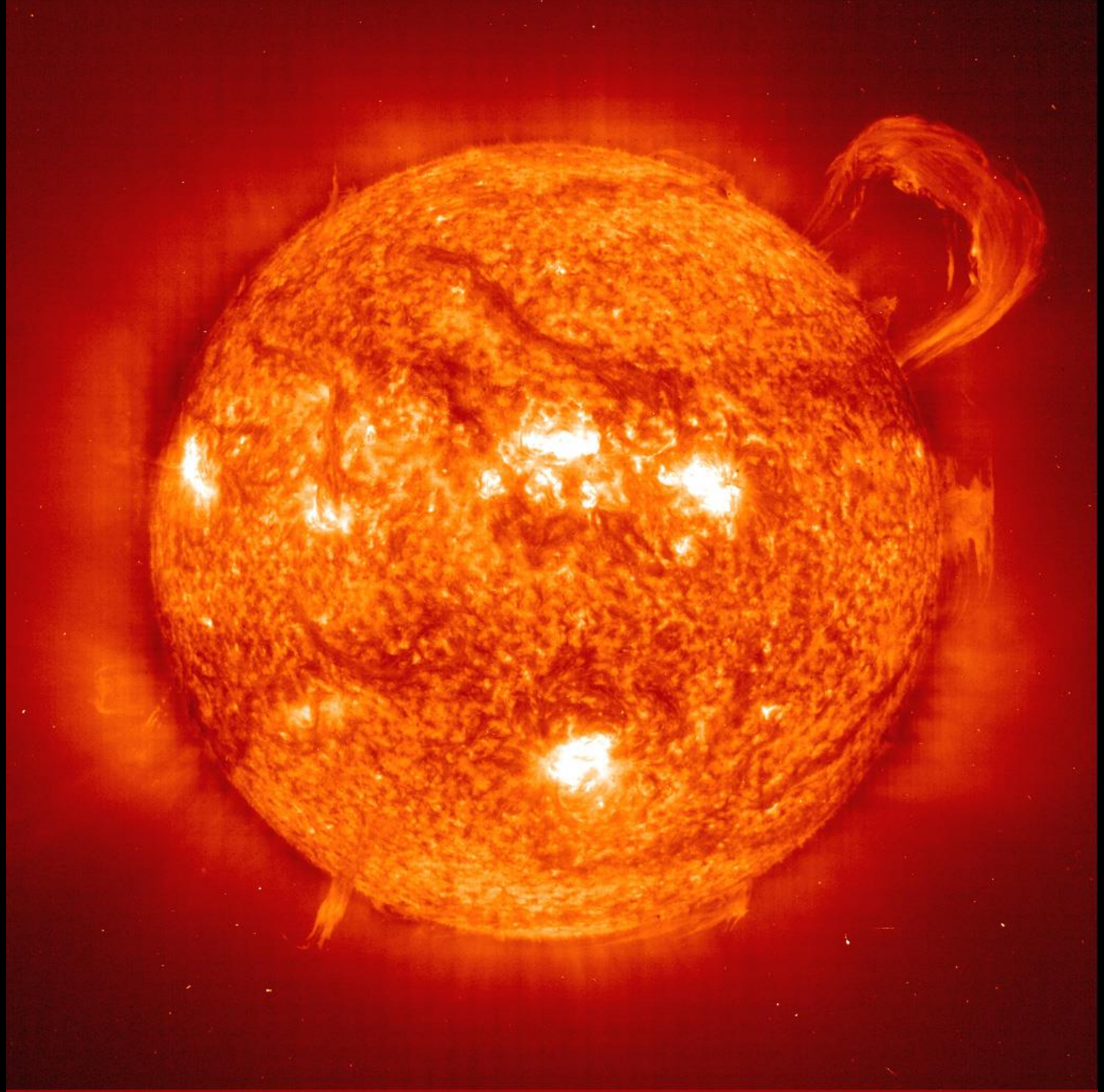
Outer disk dust-depleted

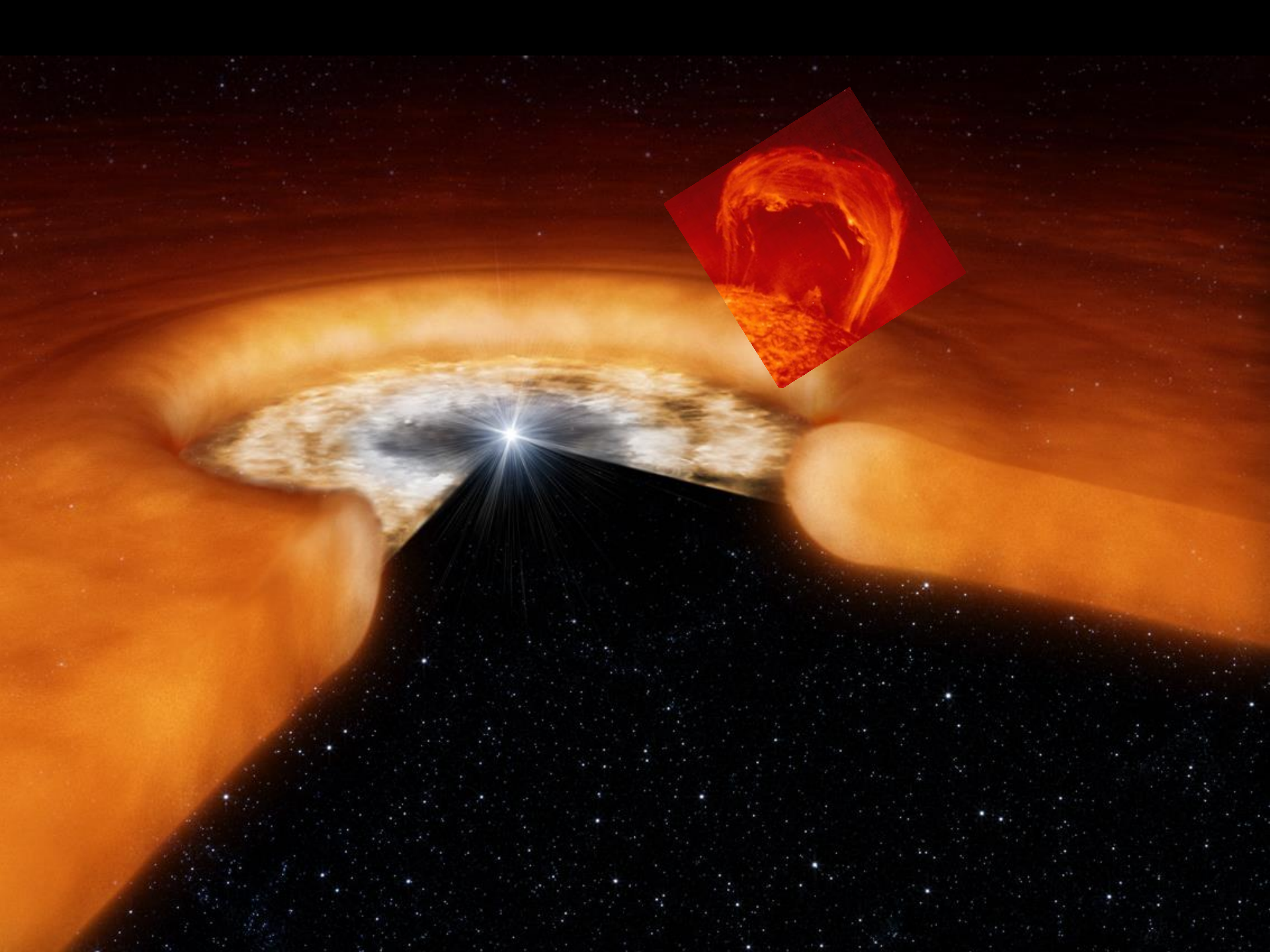
Tall atmosphere
A=2

75°
0.08 AU

V
J
3.6

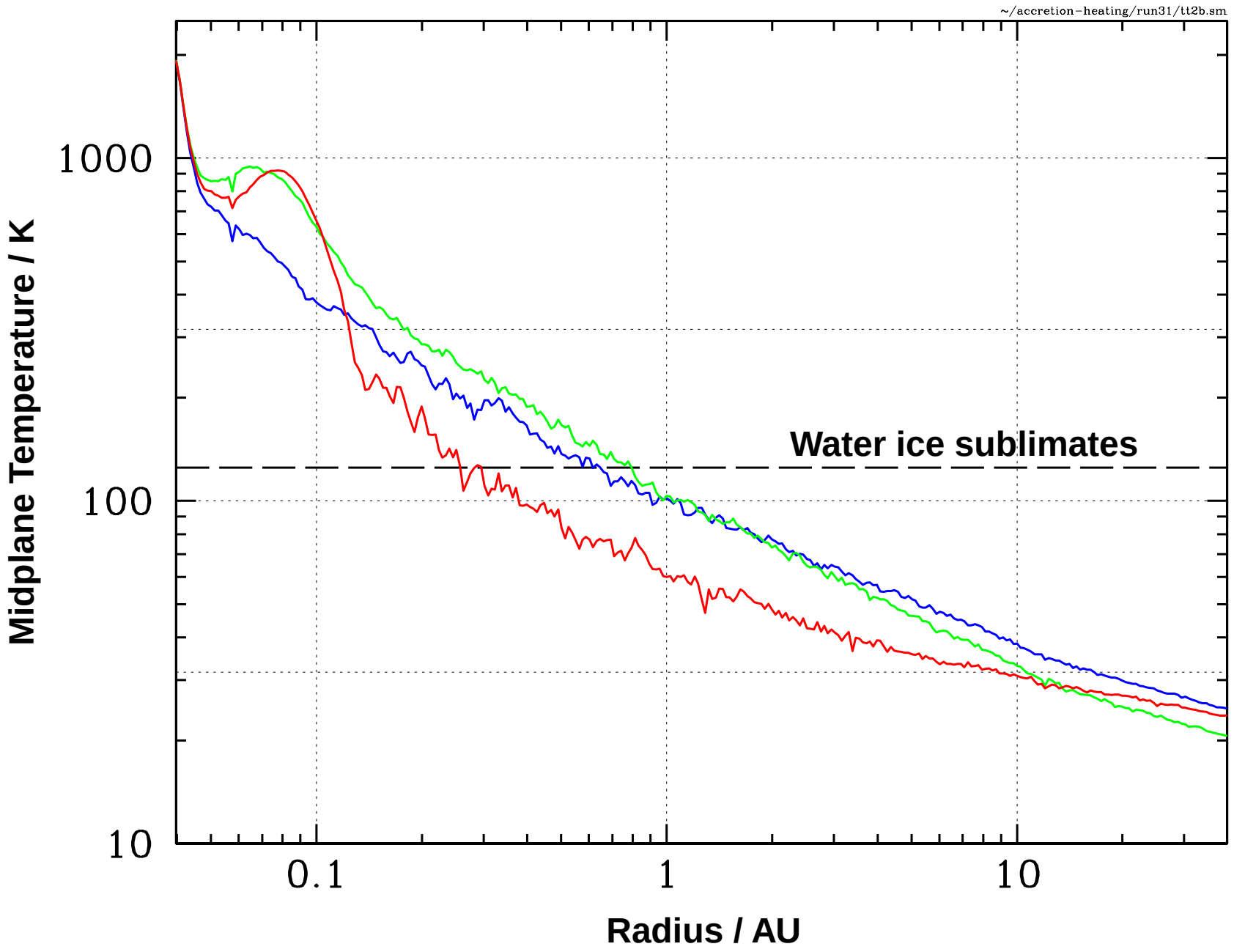
Summary





1. Magnetic fields support an extended disk atmosphere.
2. The atmosphere absorbs enough starlight to cause the IR excess.
3. Fluctuating fields yield brightness changes with amplitudes like those observed.
4. The atmosphere can intermittently obscure the star in systems seen near edge-on, if dust has settled in the disks' outer reaches.

What does it all mean?


~/accretion-heating/run31/tt2b.sm
1000
100
10
0.1
1
10
Midplane Temperature / K
Radius / AU
Water ice sublimates

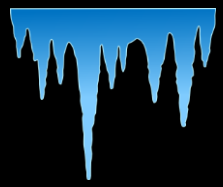
1. Most young stars with disks vary in the infrared, some because of starspots and accretion variability.

1. Cases with the optical steady while the IR varies are hard to understand unless the disk's surface moves.

1. Such movements naturally arise in a magnetized disk atmosphere.

1. The atmosphere casts time-varying shadows.

2. The shadows move the snow line in and out.



http://flickr.com/photos/jeffstewartphotos