Hunting for Extrasolar Planets using the MMT

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Huachuca Astronomy Club, 21 November 2008

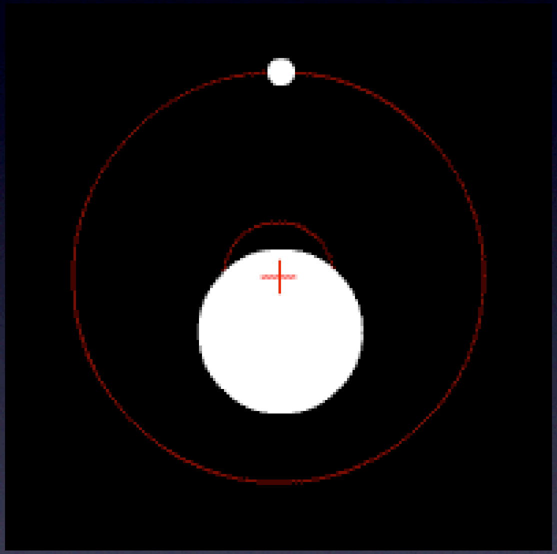
Are there other worlds in the Universe?

The first ones found...

...in 1992, but around a PULSAR!

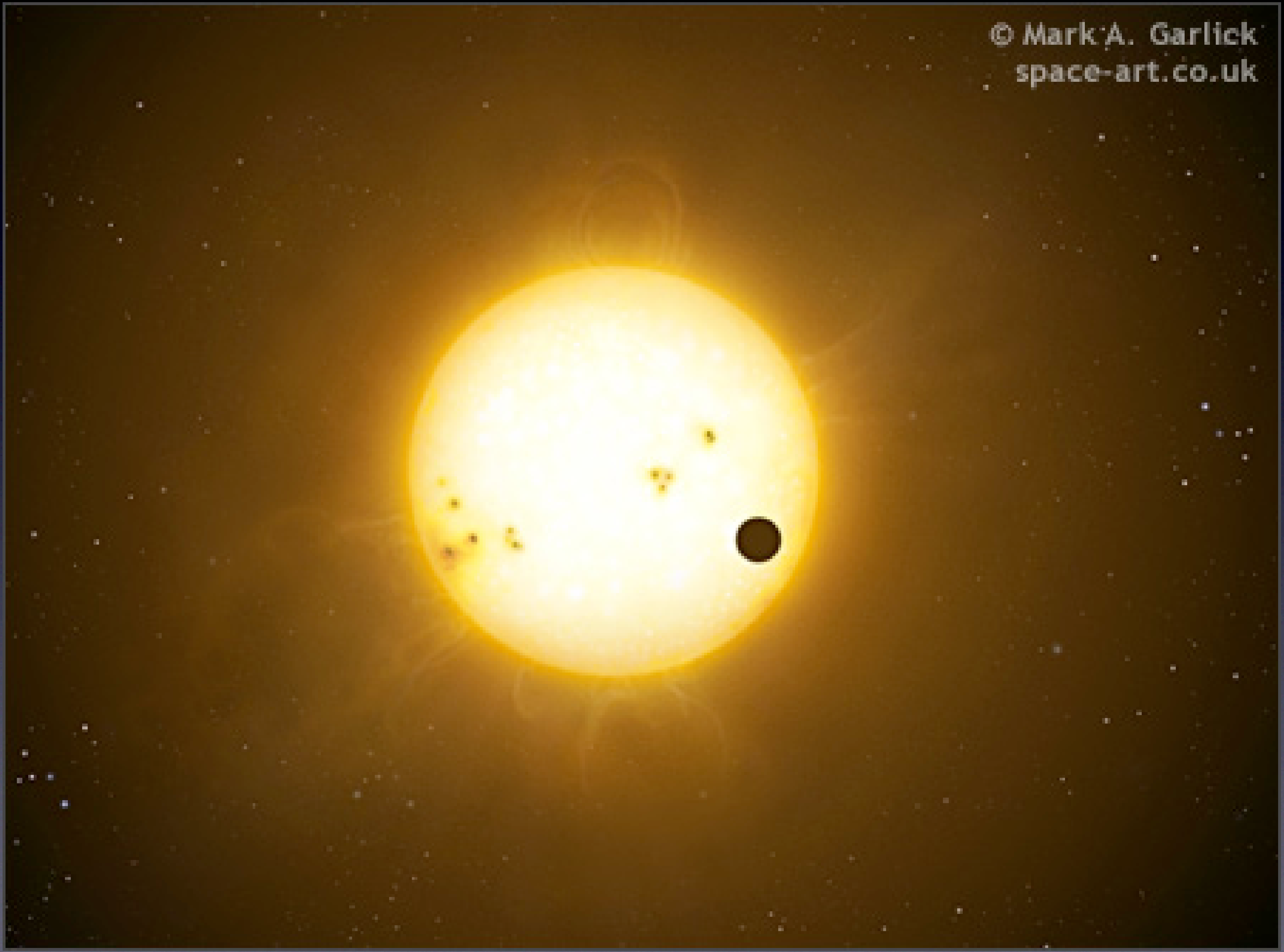
Indirectly Detecting Planets

- ~300 planetary systems indirectly detected by radial velocity reflex motion
- CANNOT see the planet - only its influence on the parent star



Zhatt

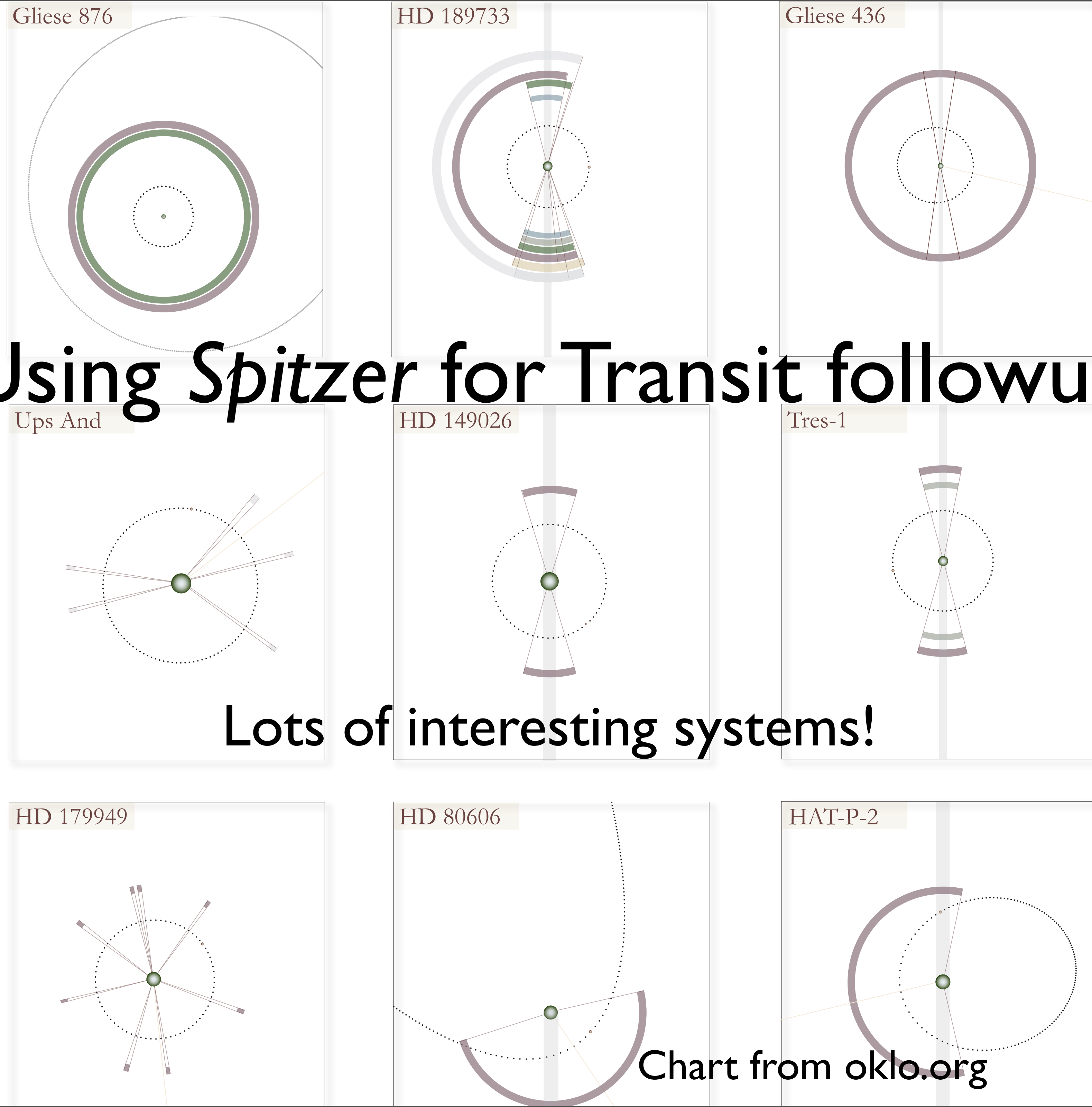
Transits



Transits

- Primary transits give star/planet ratio
- Follow-up radial velocity confirms them
- Don't need big telescope for this!
- In space, CoRoT and Kepler

Using *Spitzer* for Transit followup



Lots of interesting systems!

Chart from oklo.org

Detecting Planets

- Radial Velocity technique leads the way!
- Transits are catching up though......
- Others are microlensing, astrometry

Why not Direct Imaging?

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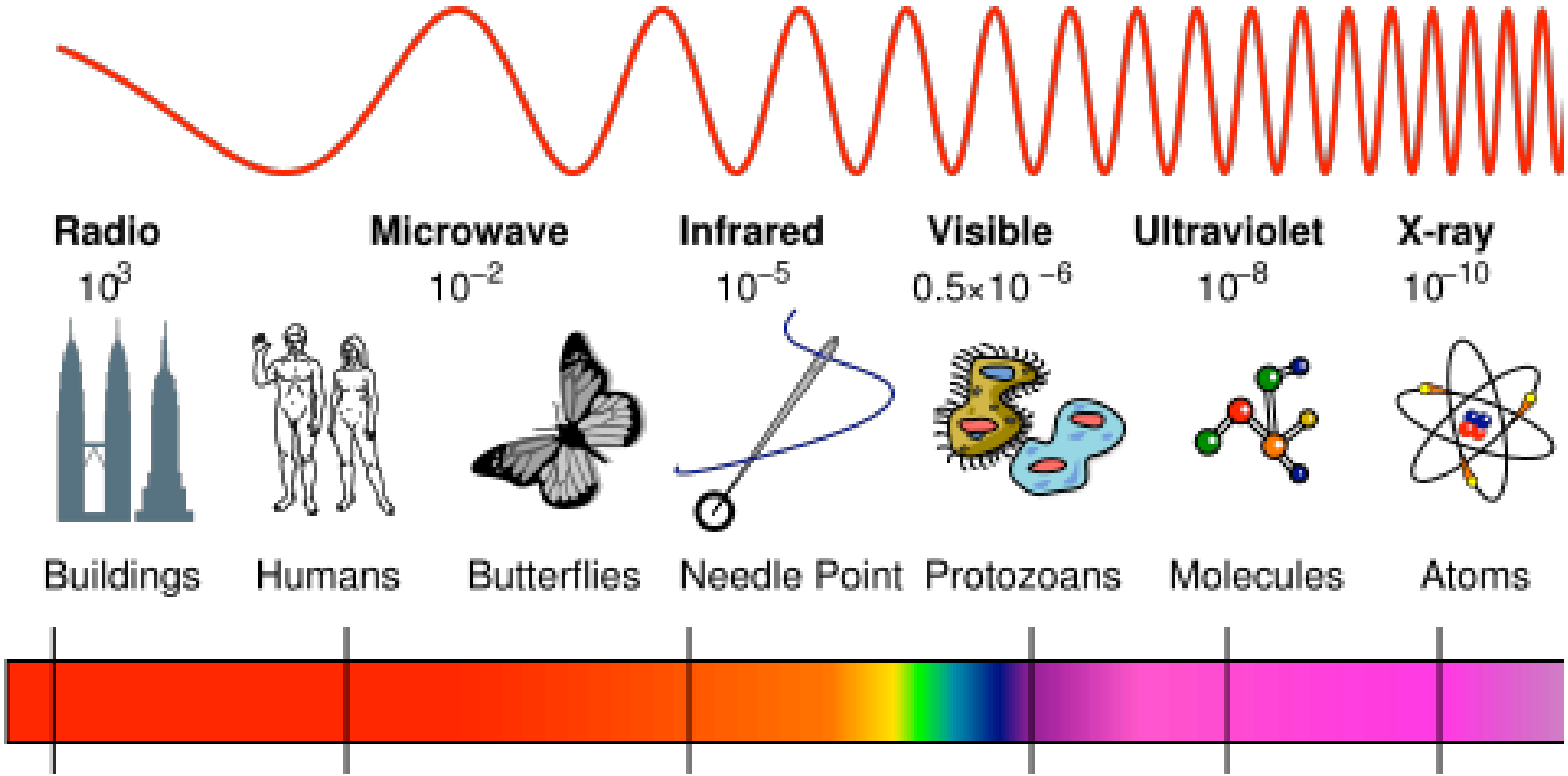
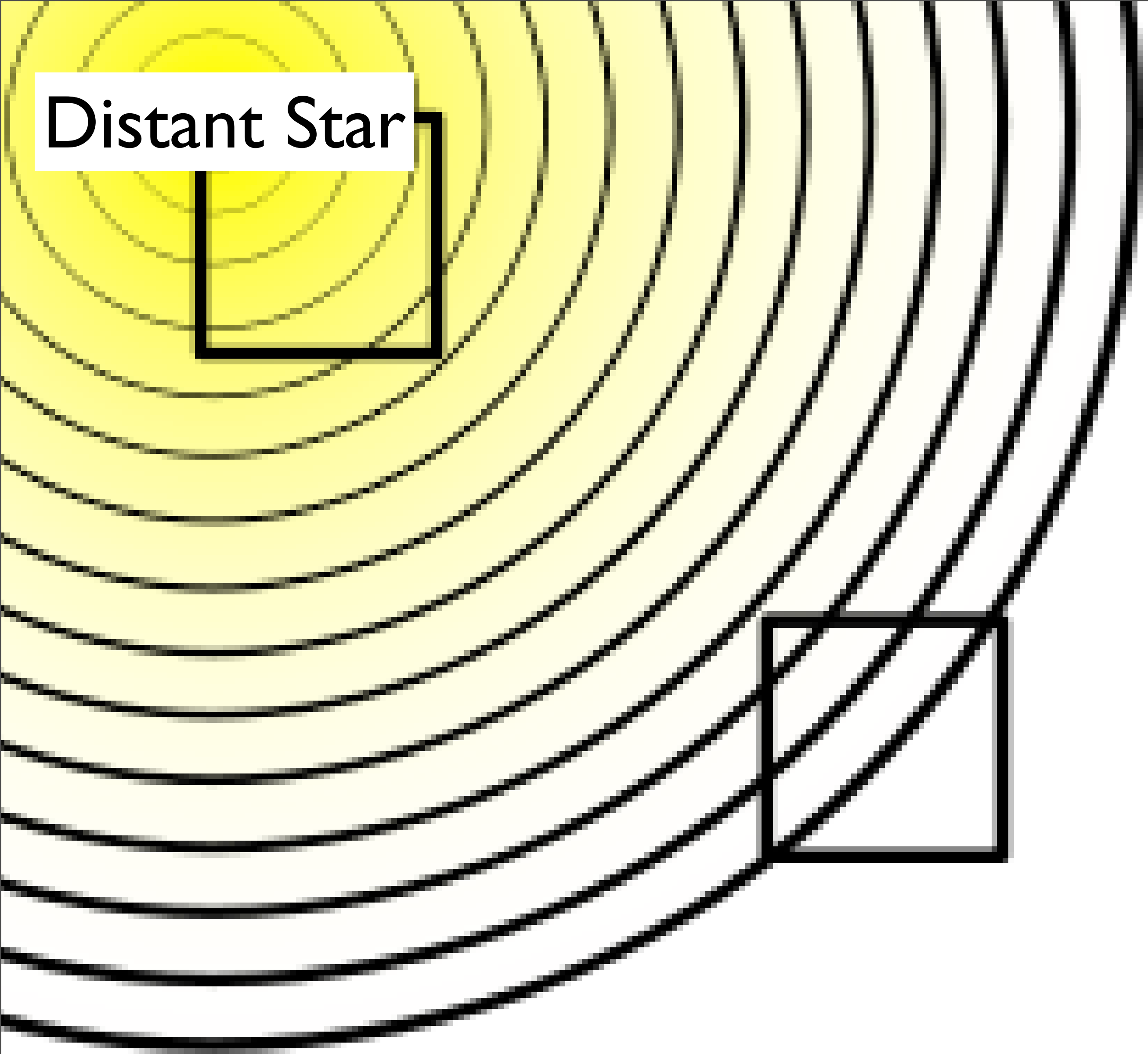
Why not Direct Imaging?

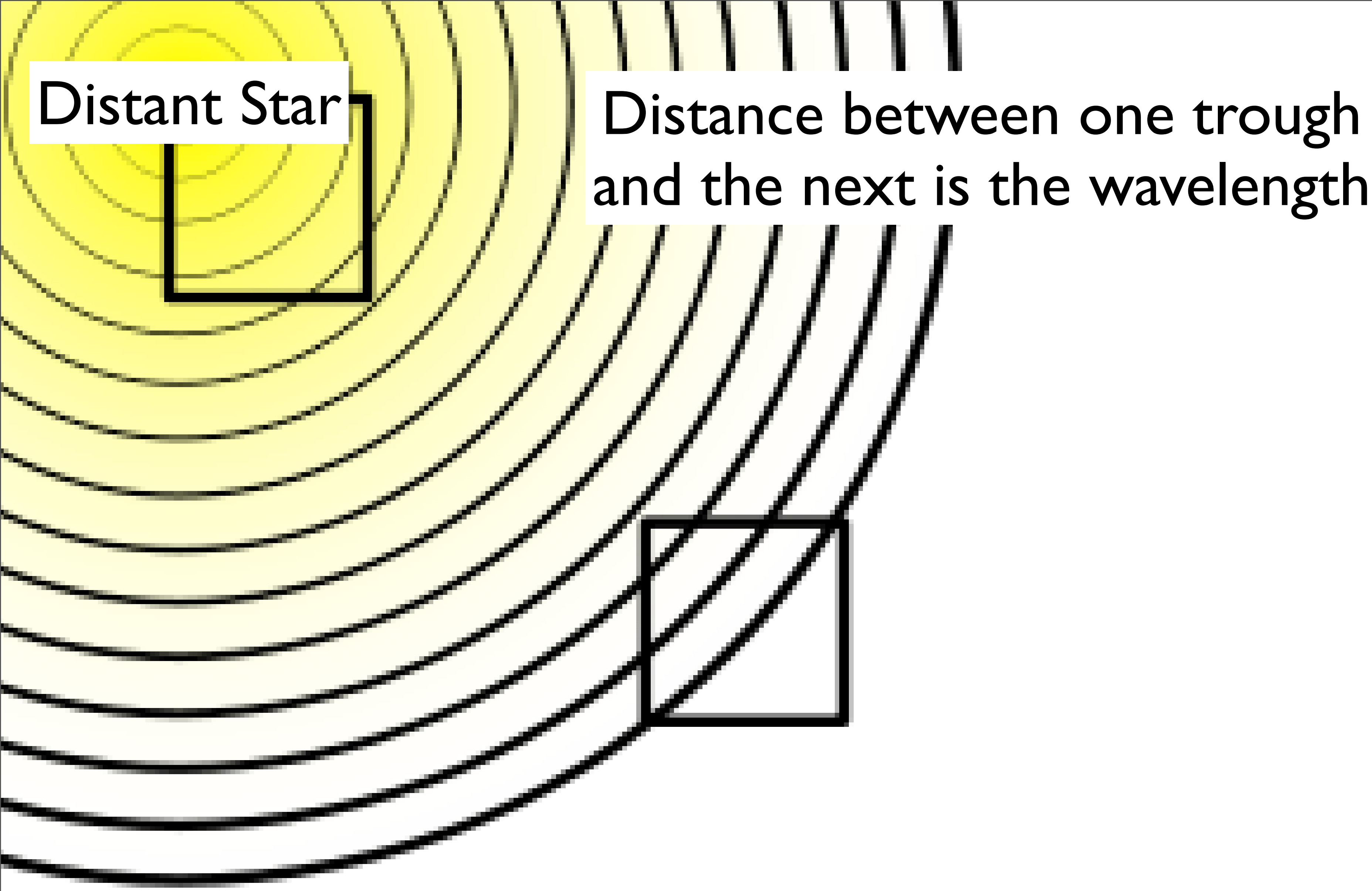
- 20 years ago, astronomers assumed other planetary systems would be like ours
- We assumed that direct imaging would see a planet first
- Because these extrasolar planet systems look VERY DIFFERENT compared to ours, Radial Velocity and Transits are detecting them first!

How we see things

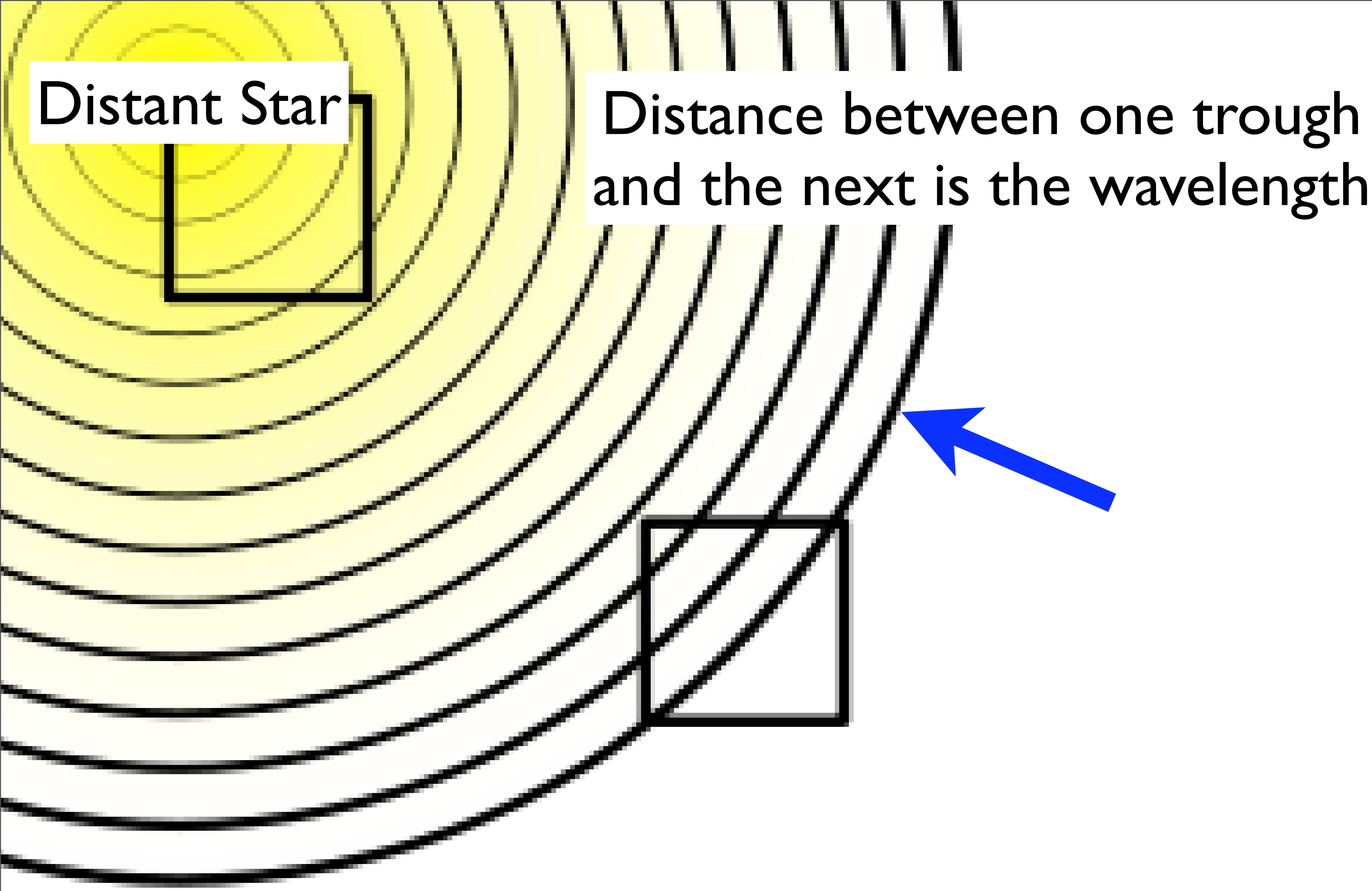




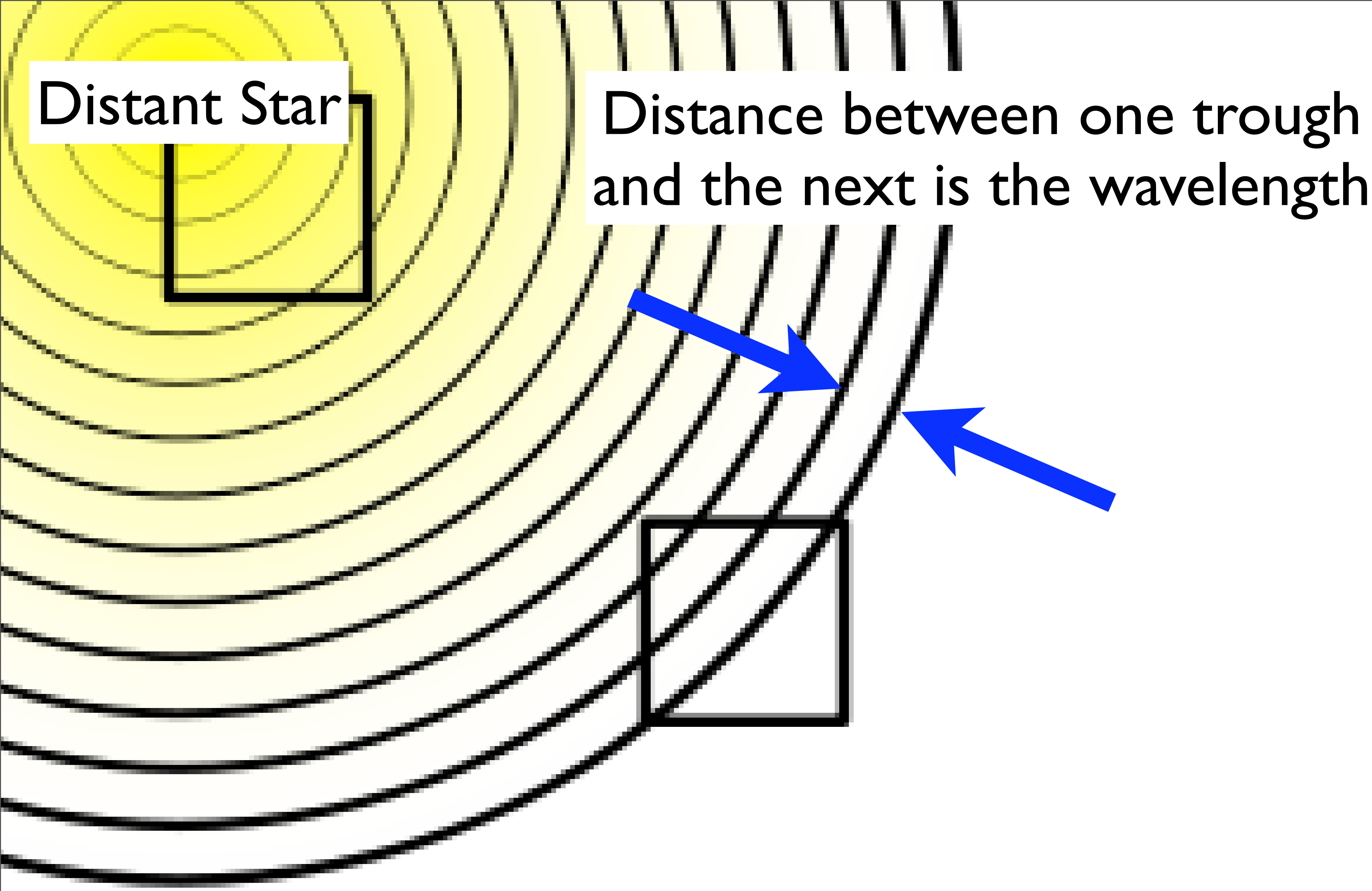
Light as a series of waves



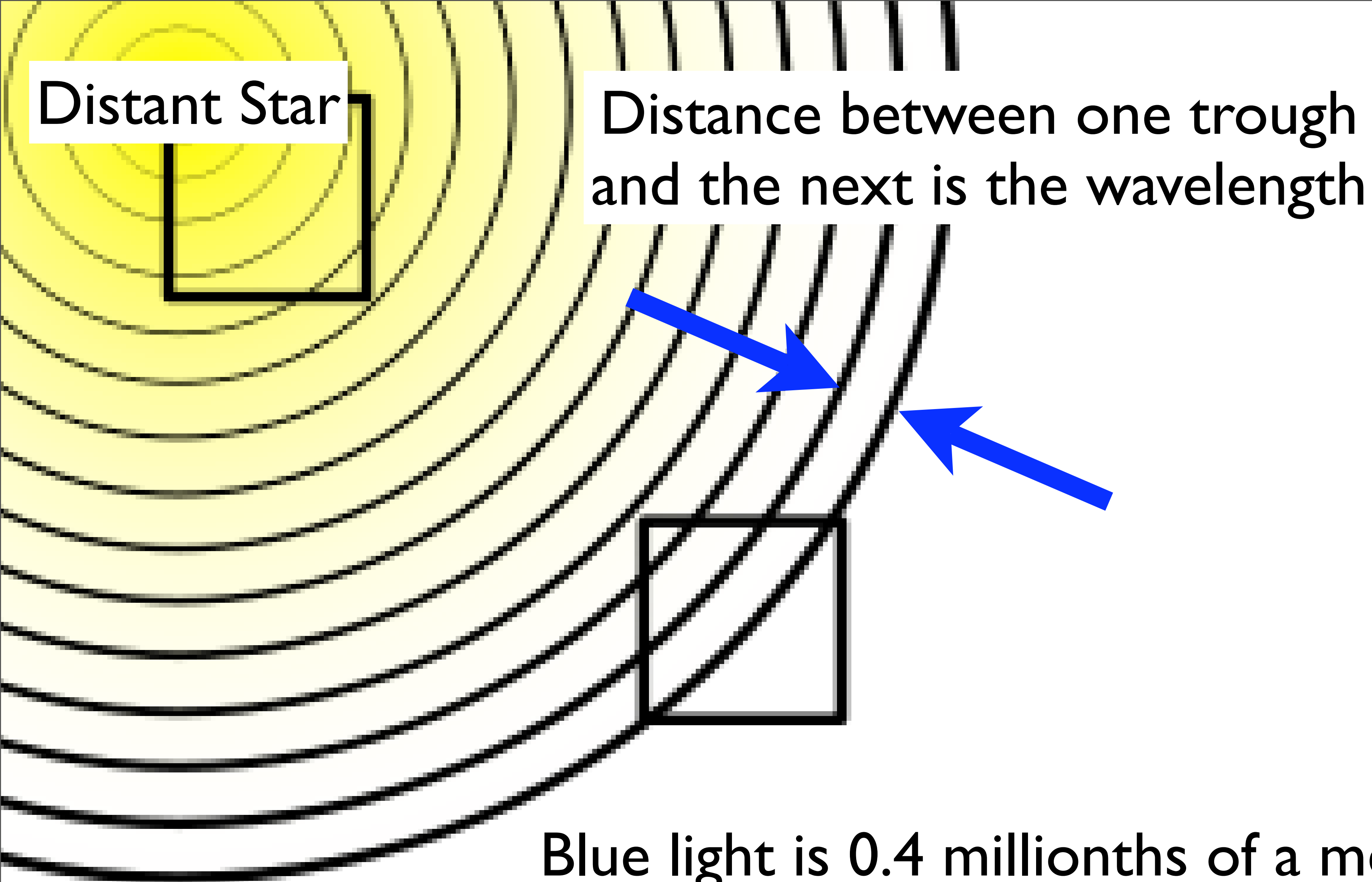
Light as a series of waves



Light as a series of waves

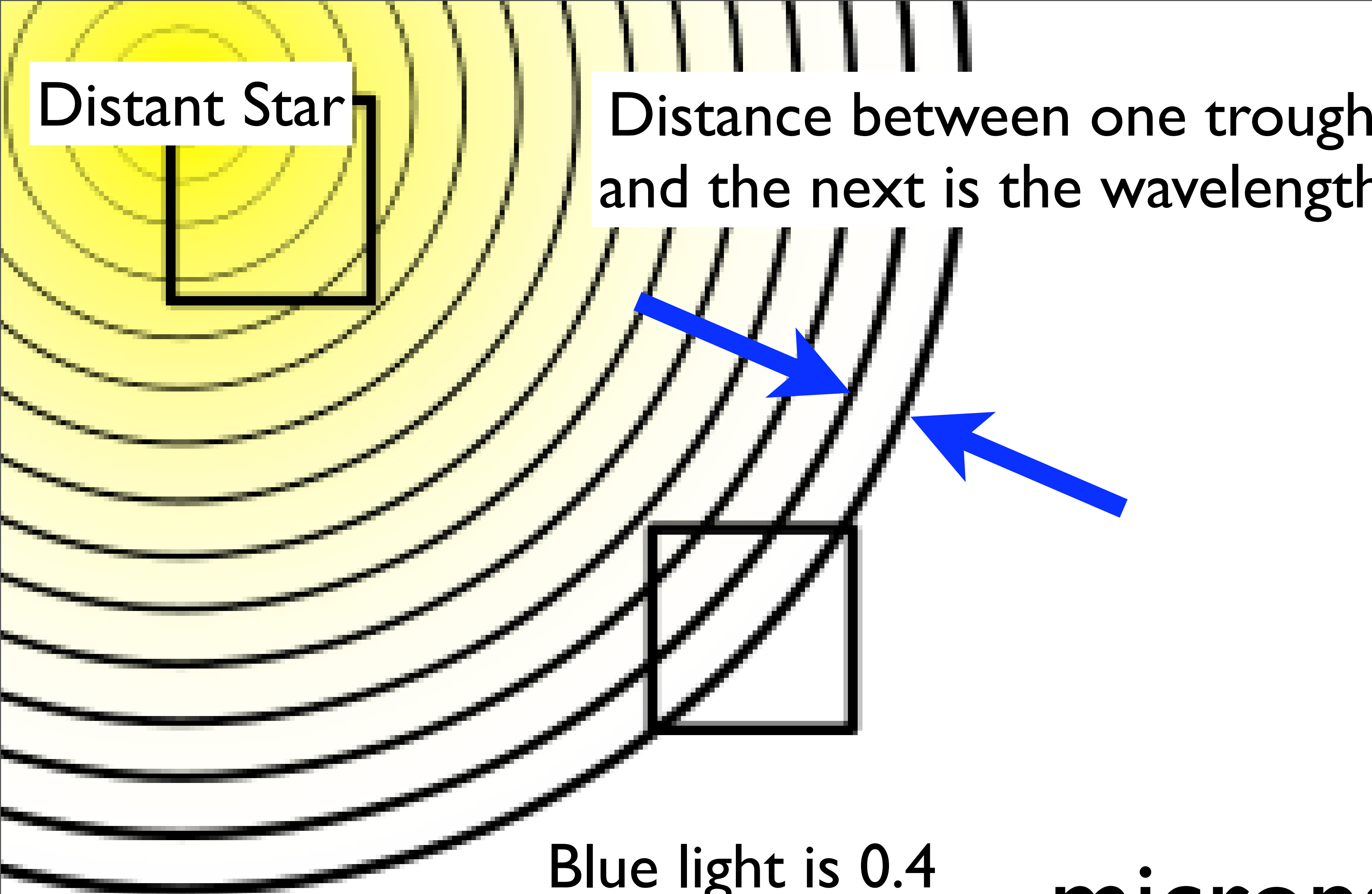


Light as a series of waves



Blue light is 0.4 millionths of a meter
Red light is 0.8 millionths of a meter

Light as a series of waves

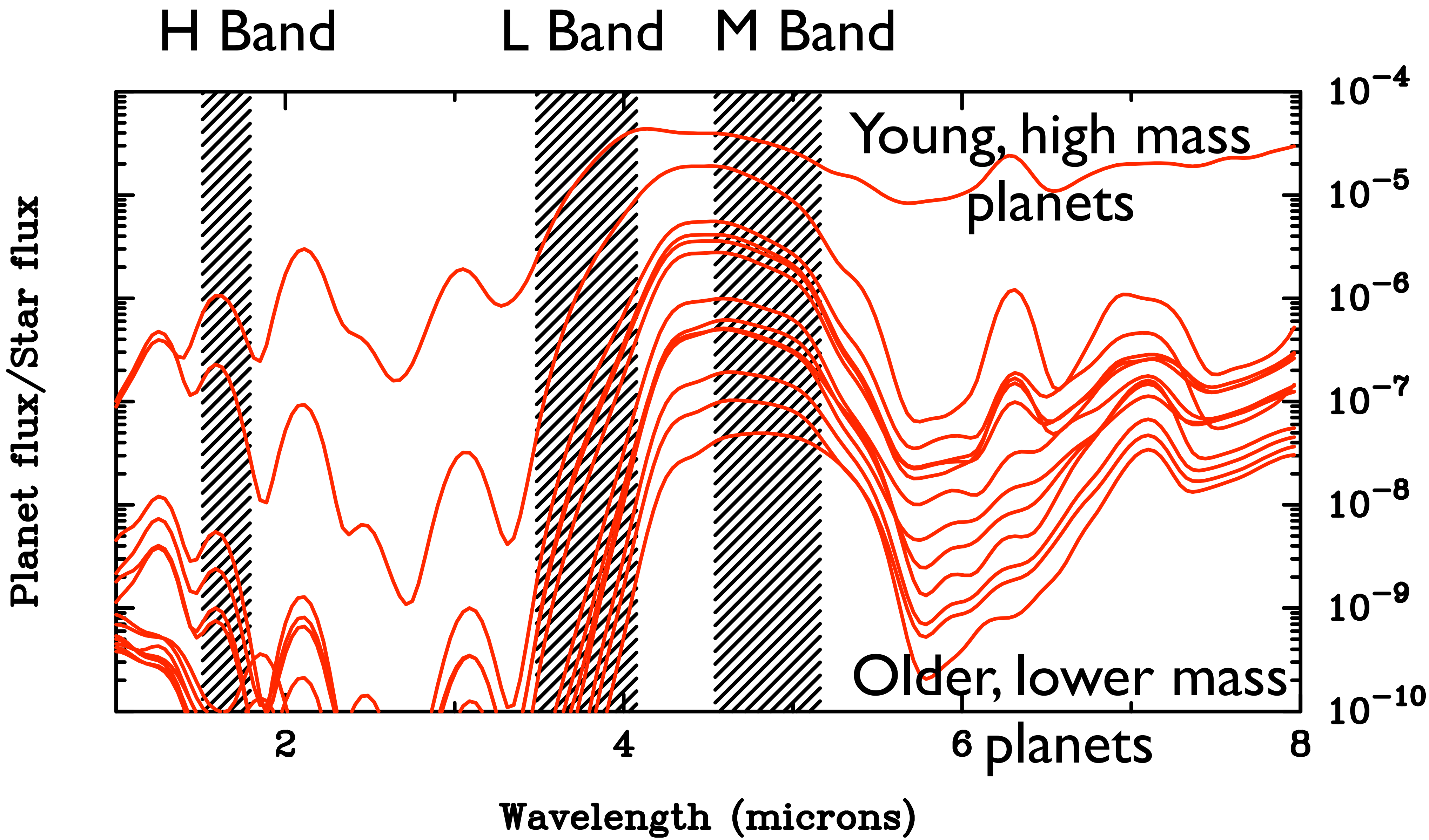


Blue light is 0.4
Red light is 0.8

microns

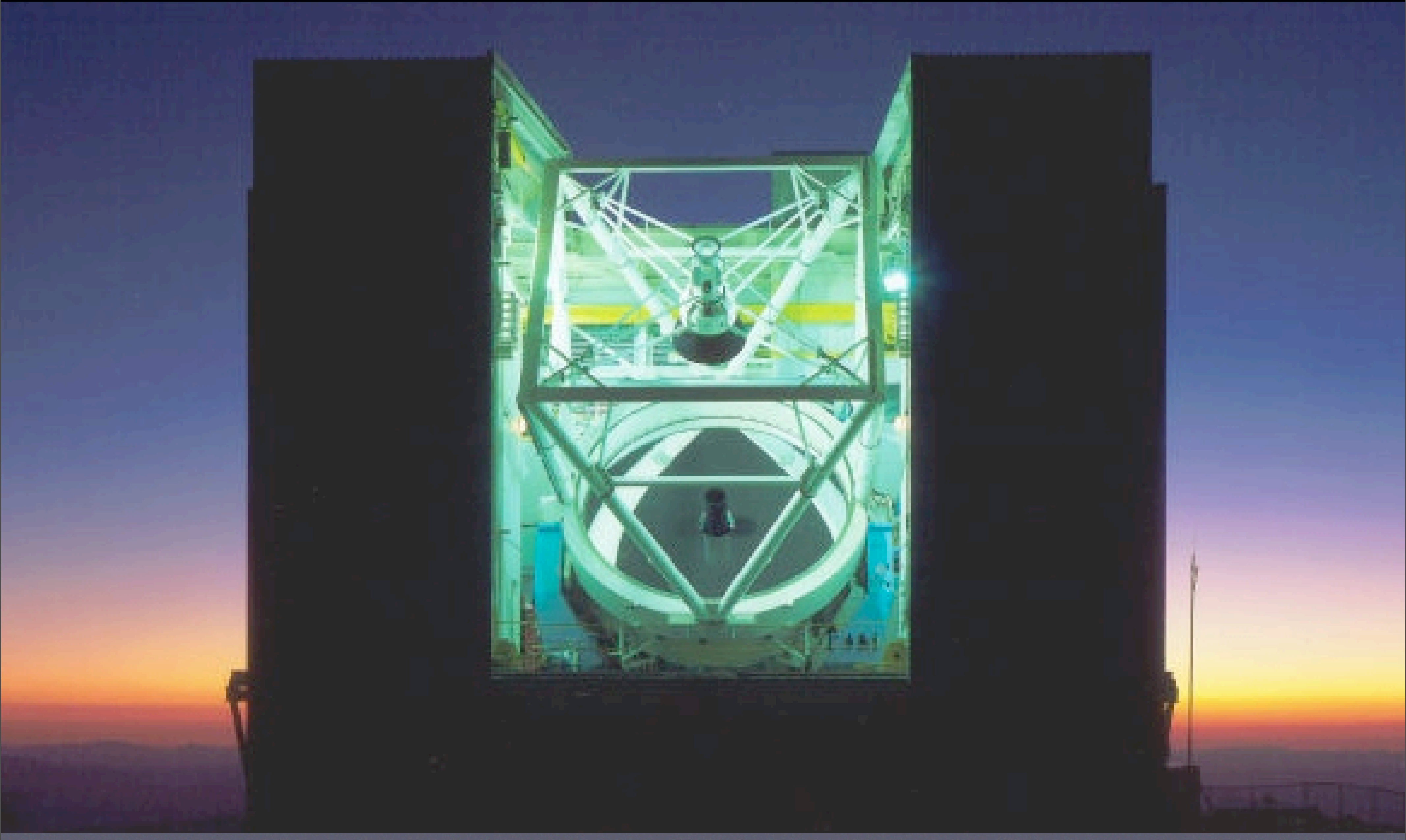
Light as a series of waves

Where do planets glow?

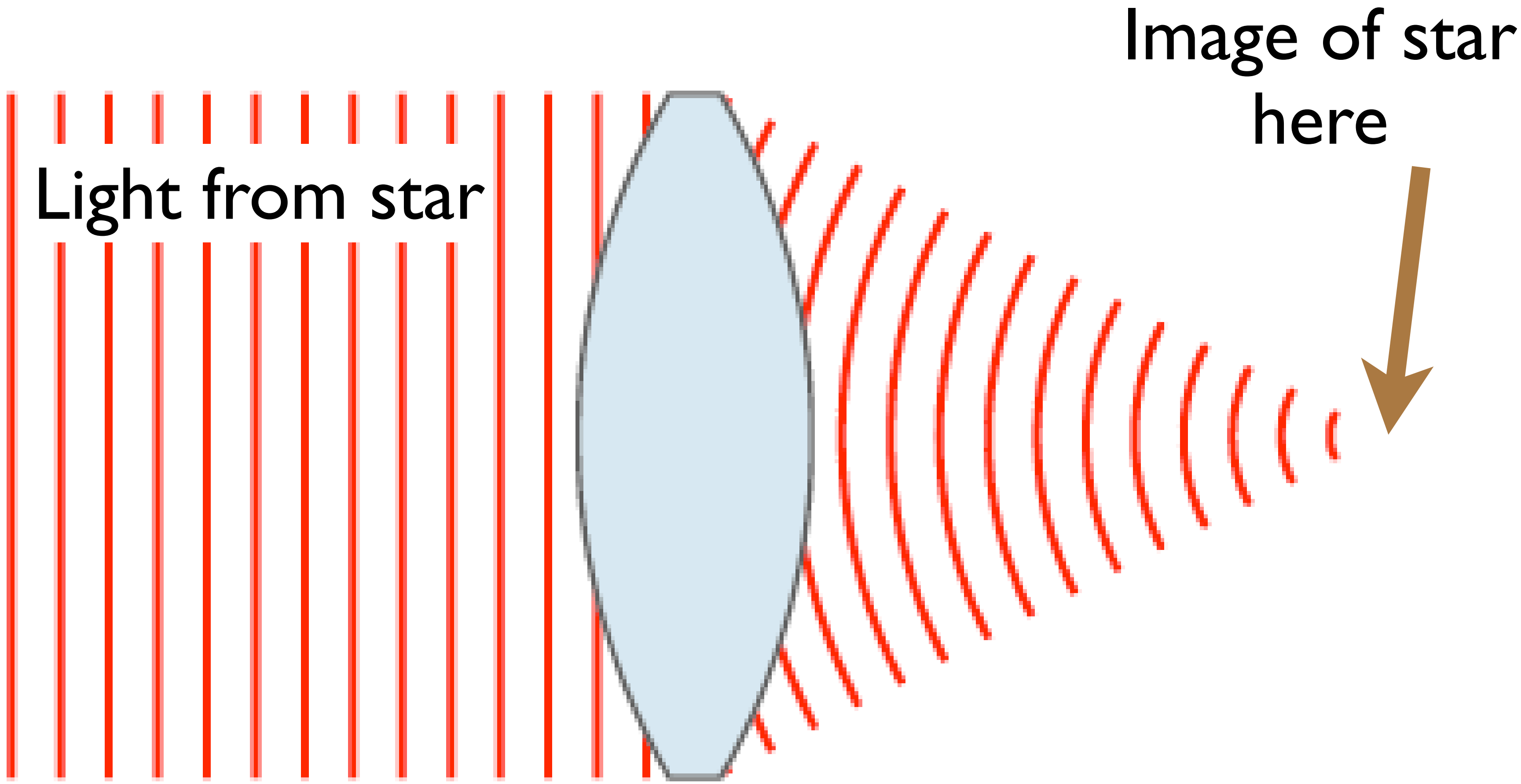


Adapted from Burrows, Sudarsky and Hubeny 2004

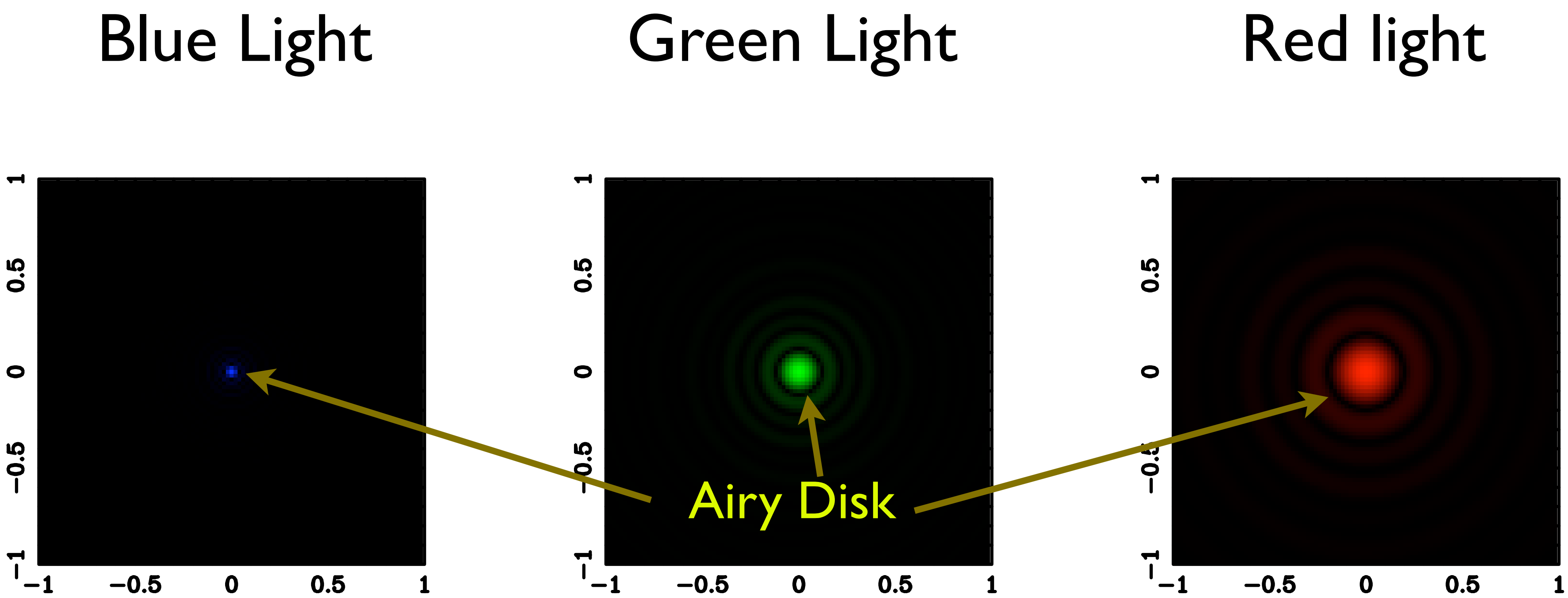
MMTO 6.5m Telescope



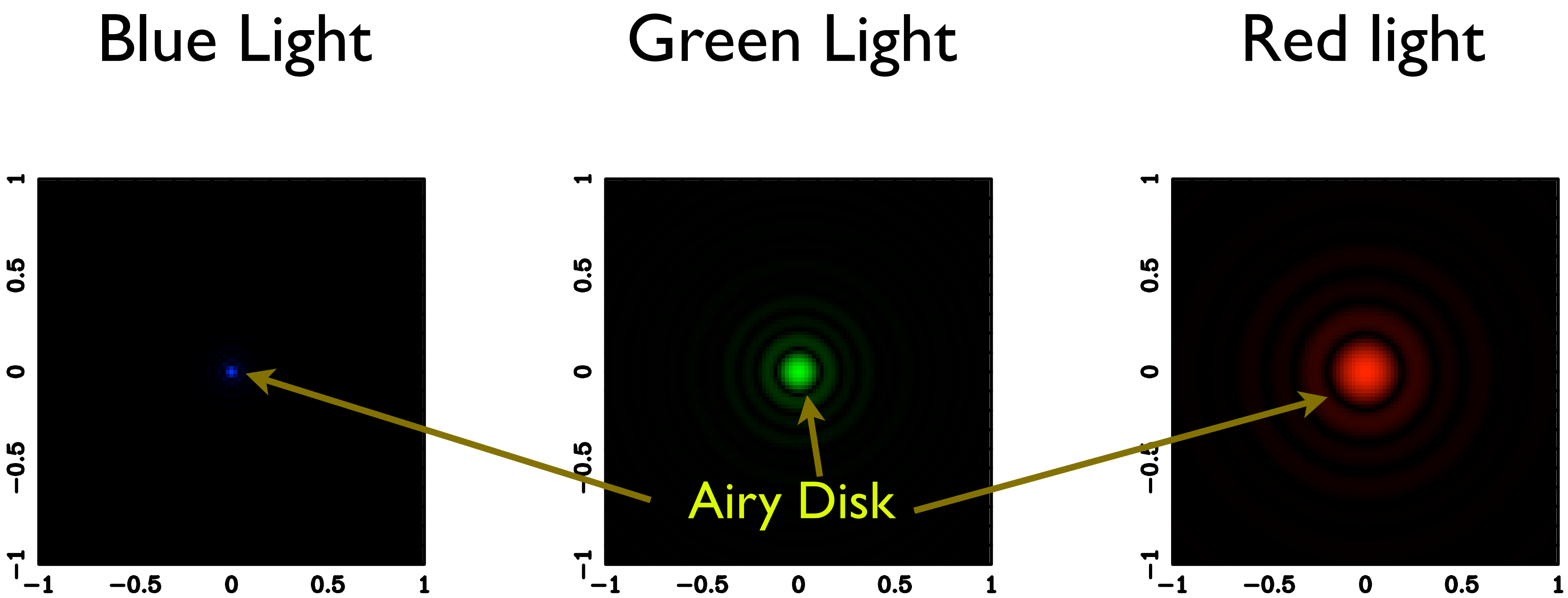
Focusing light



Not-so-point sources

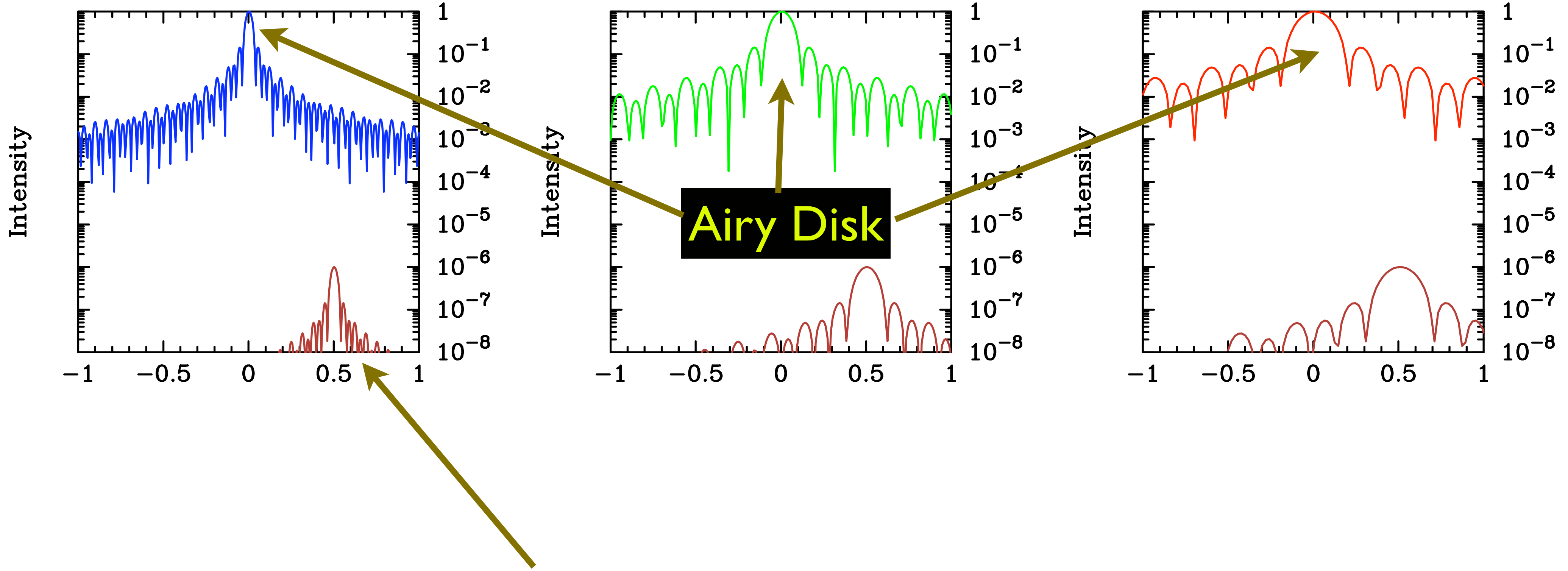


Not-so-point sources

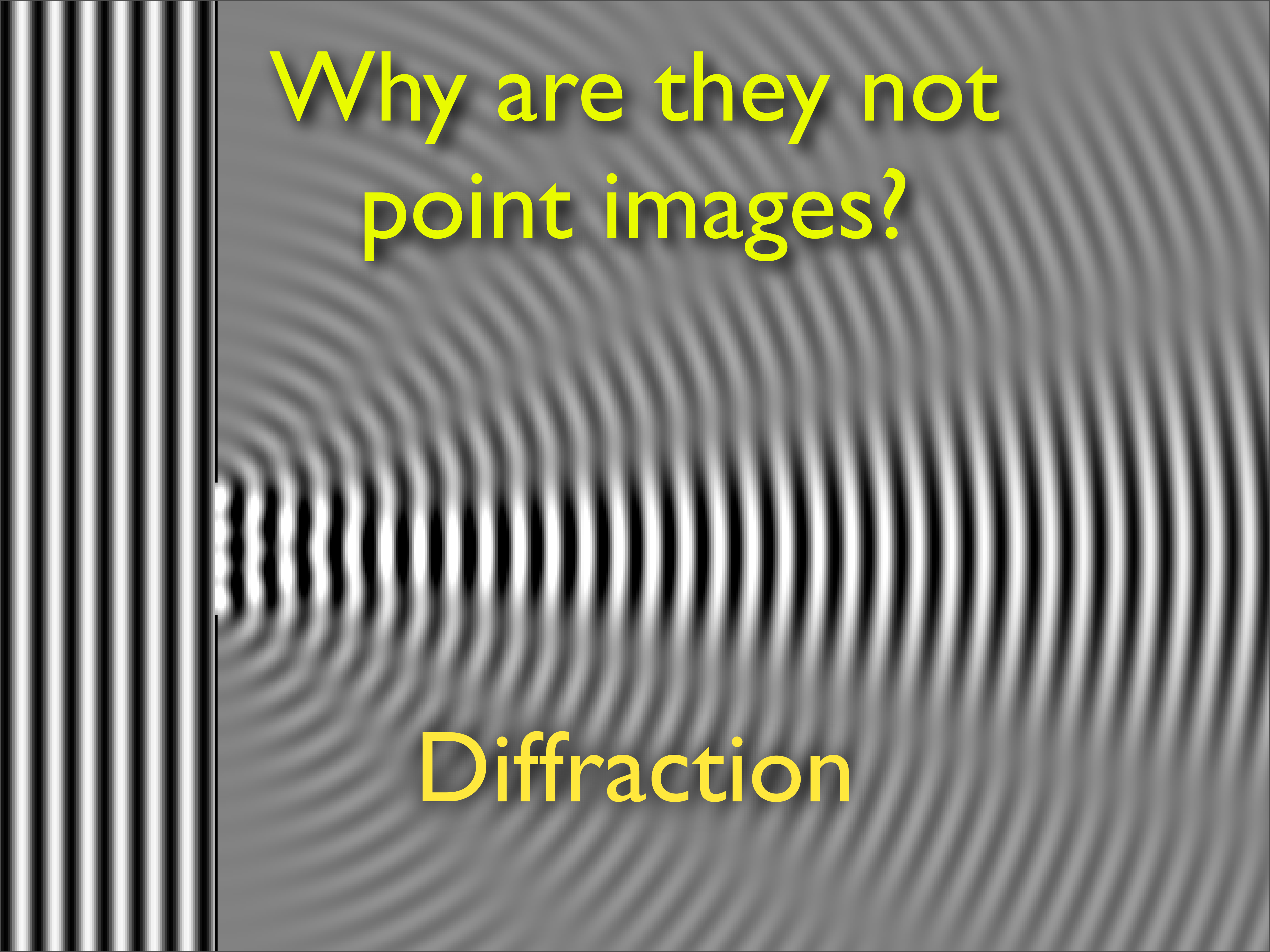


This is called
DIFFRACTION LIMITED IMAGING

Not-so-point sources



Planet a million times fainter at 0.5 arcsec
Corresponds to Jupiter around a star 30 light years away

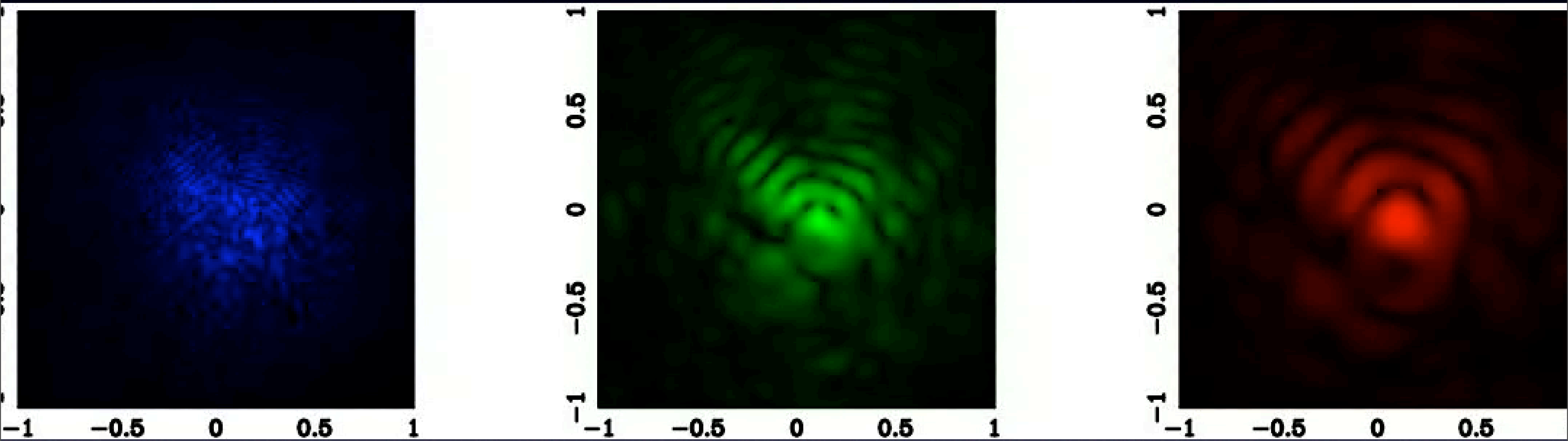

Why are they not point images?
Diffraction

But wait! It gets tougher...

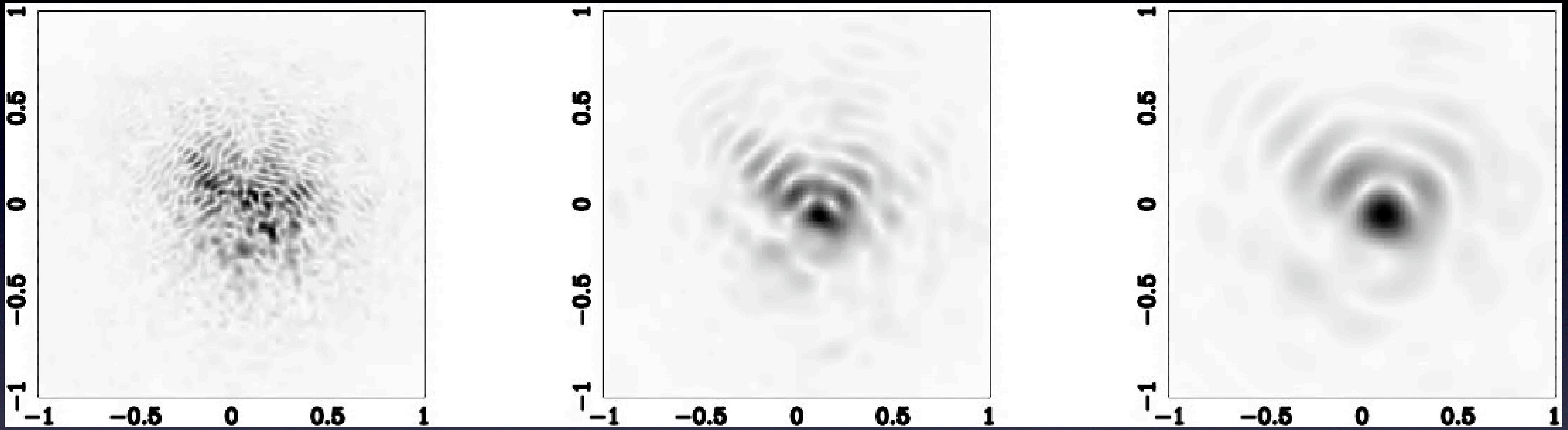
But wait! It gets tougher...

- When we use telescopes on the ground, we rarely see diffraction limited images

Turbulent Atmosphere



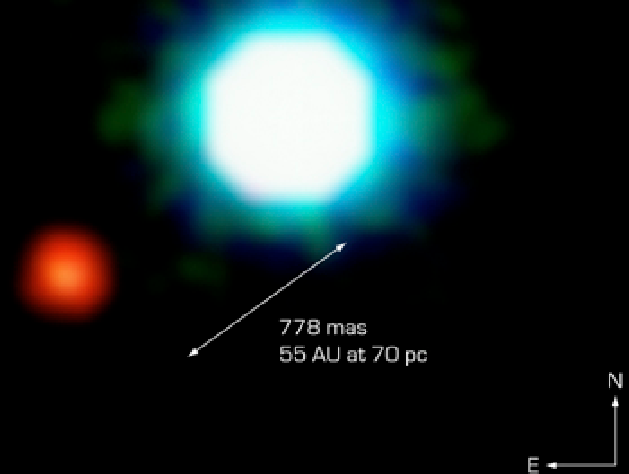
Turbulent Atmosphere



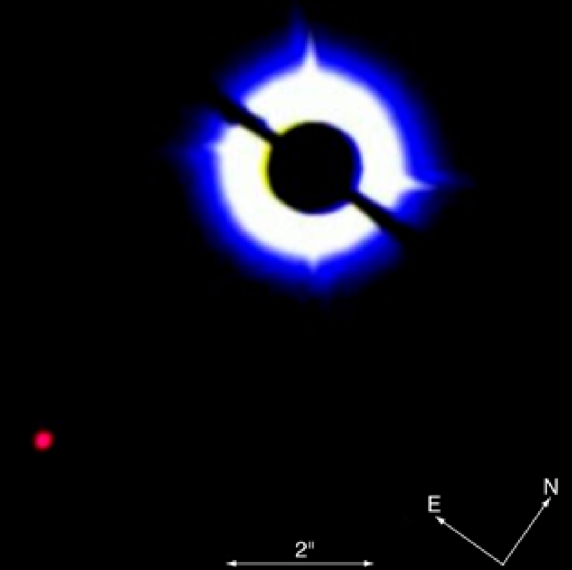
What we'd *like* to see...

Credit: G.Bacon, NASA and ESA

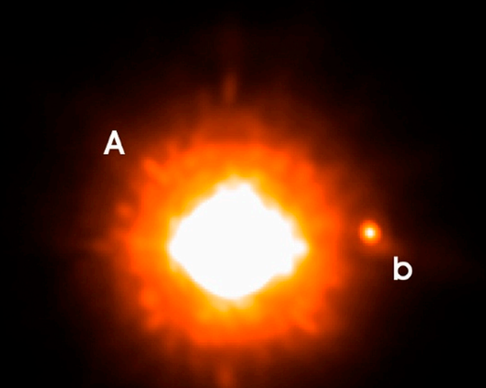
2M1207b
Confirmed planetary mass companion to a Brown Dwarf



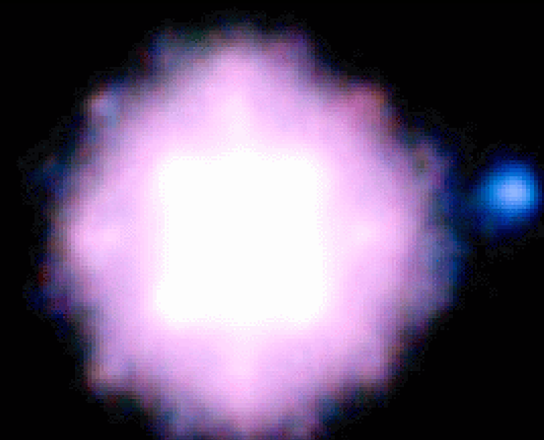
AB Pic b



...but what we *really* see



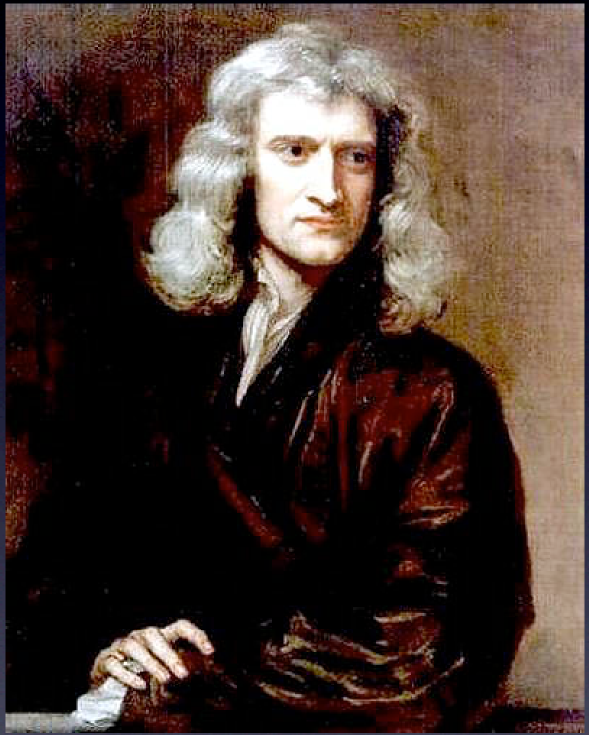
GQ Lup b



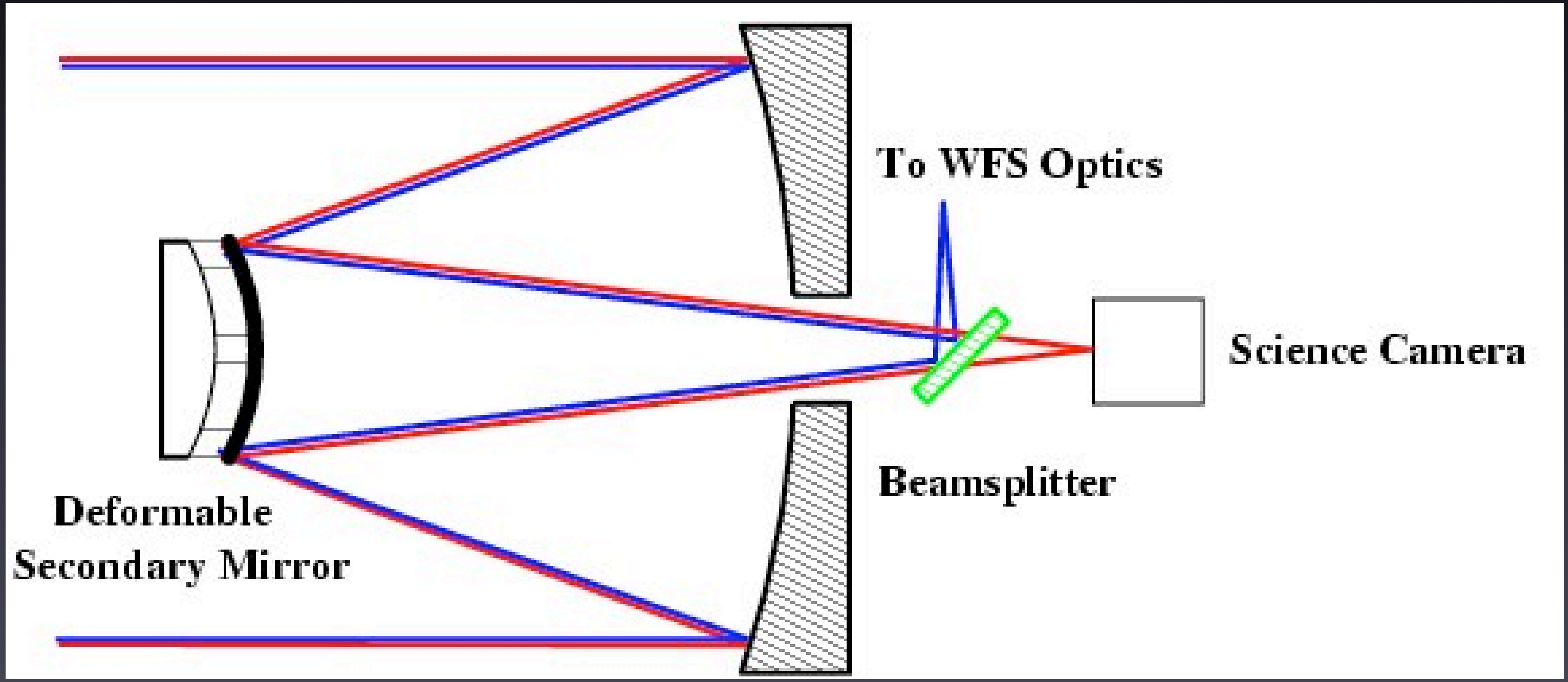
SCR 1845 b

‘Seeing’ is the problem

“Telescopes … cannot be so formed as to take away that confusion of the Rays which arises from the Tremors of the Atmosphere. The only Remedy is a most serene and quiet Air, such as may perhaps be found on the tops of the highest Mountains above the grosser Clouds.” (Isaac Newton, 1730)



Remove the effects of the atmosphere with ADAPTIVE OPTICS!



Deformable Secondary Mirror

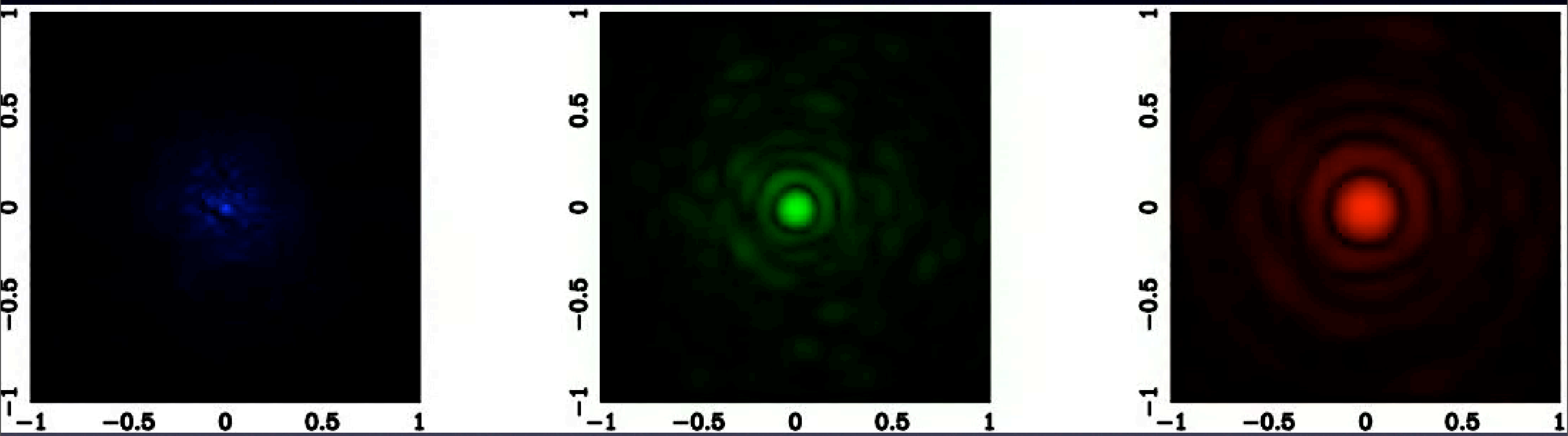
Great for thermal infrared

2mm thick by 640 mm diameter

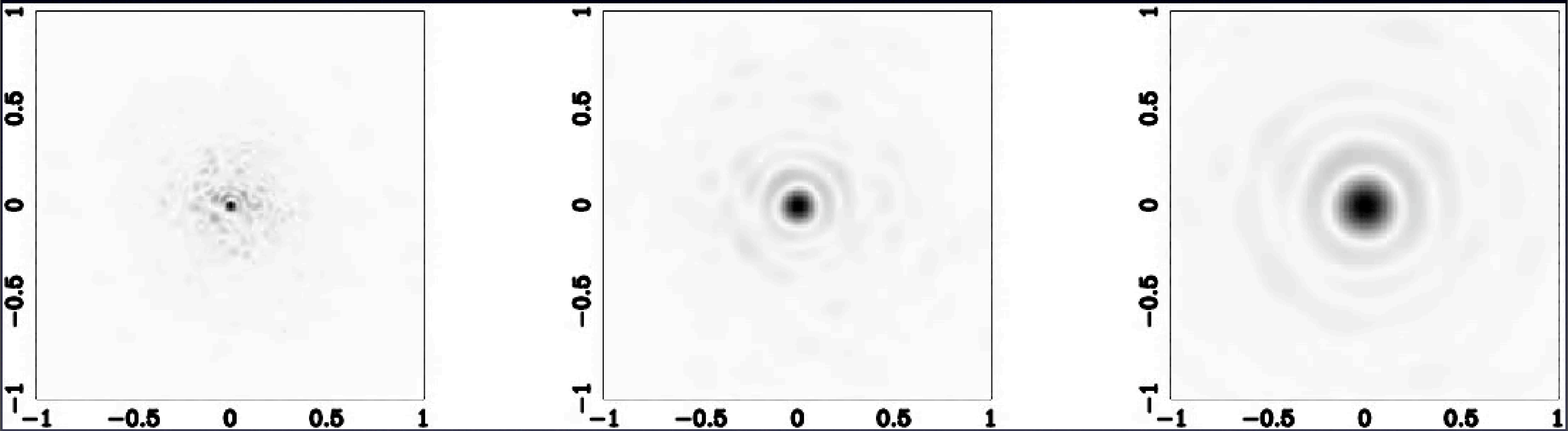
336 voice coil actuators

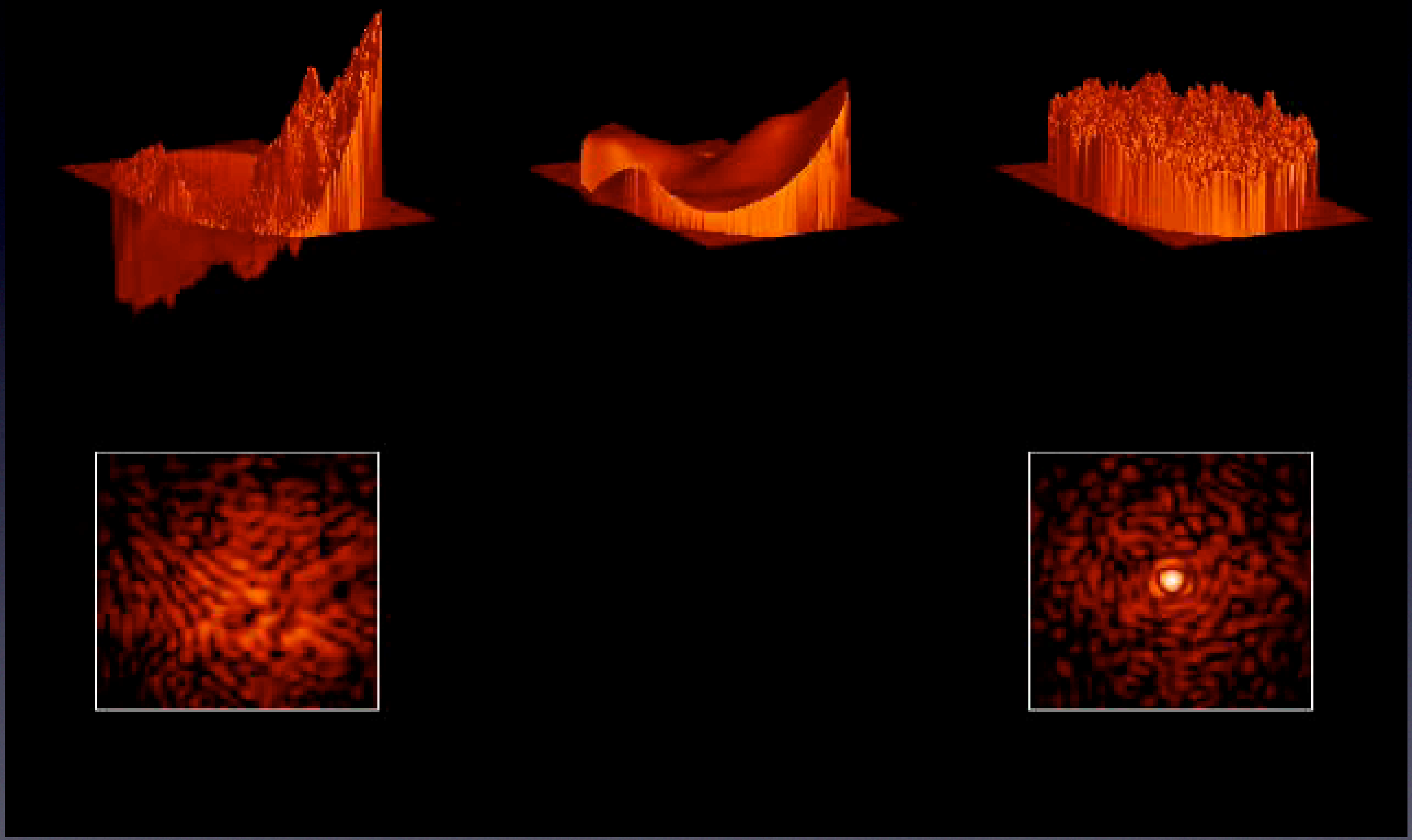
Undersized pupil
for IR observations
(effective D=6.35m)

AO correction
- the longer the wavelength, the more stable star's image



AO correction
- the longer the wavelength, the more stable the PSF



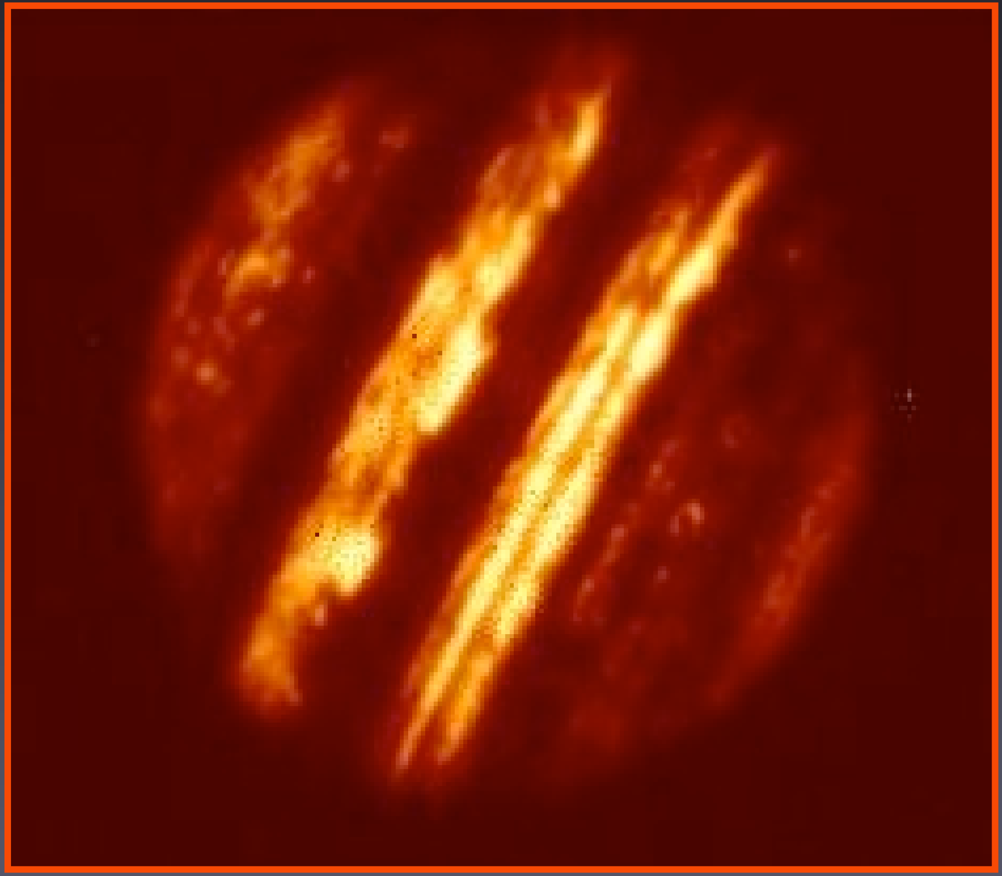


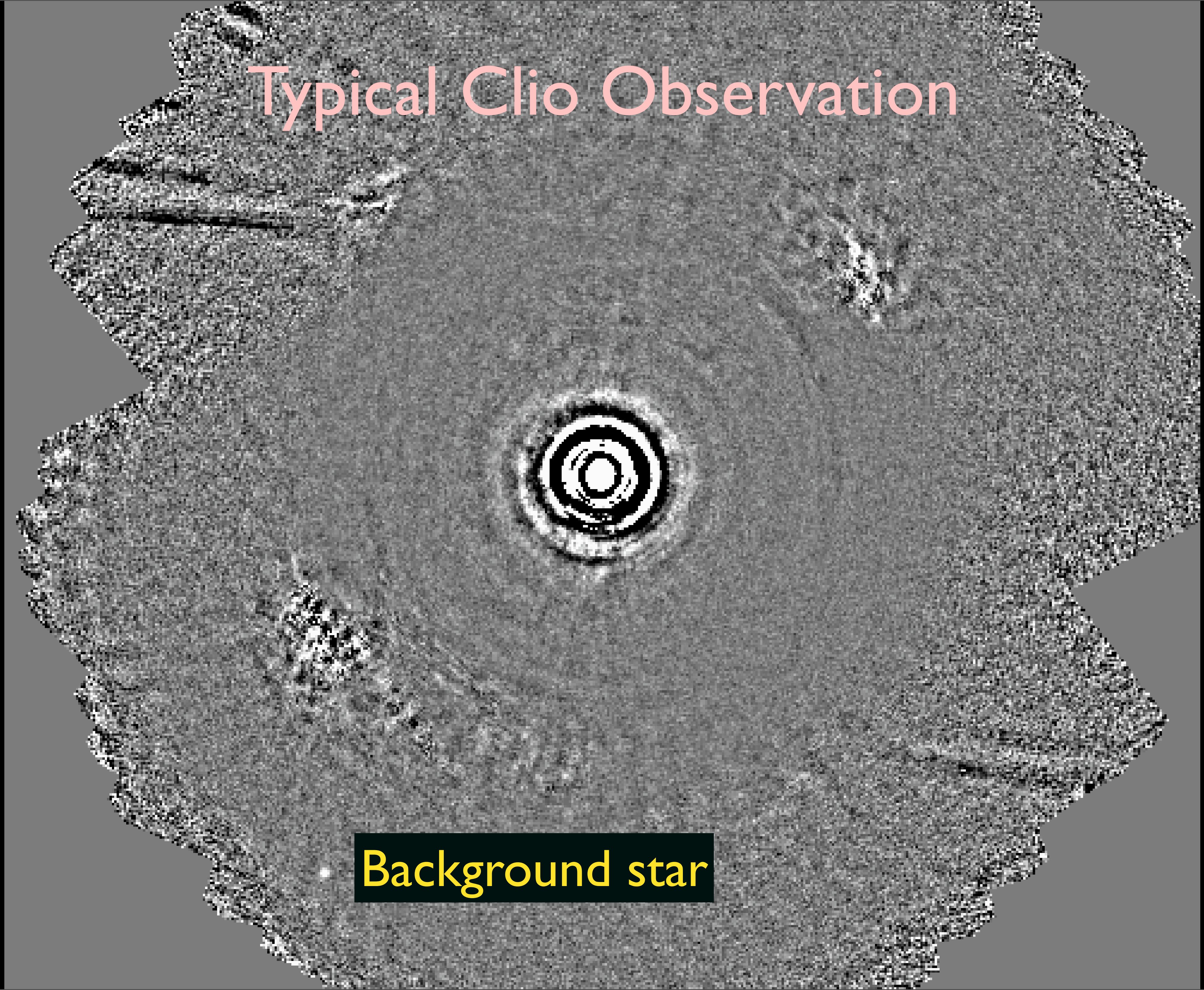
The Lyot Project http://lyot.org/

Thermal Imaging with Clio

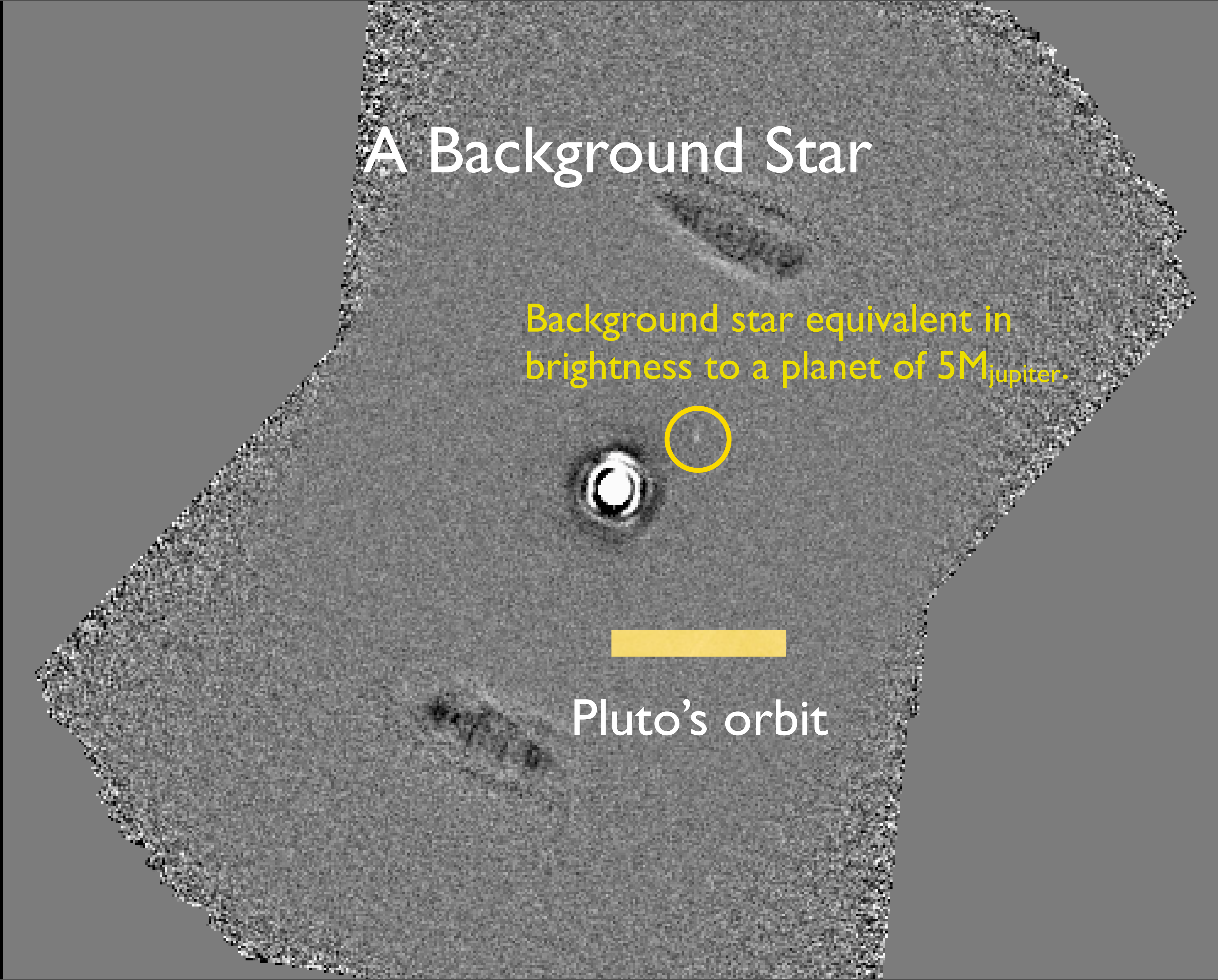
Built by Prof. Phil Hinz

- 3 to 5 micron imaging camera/coronagraph

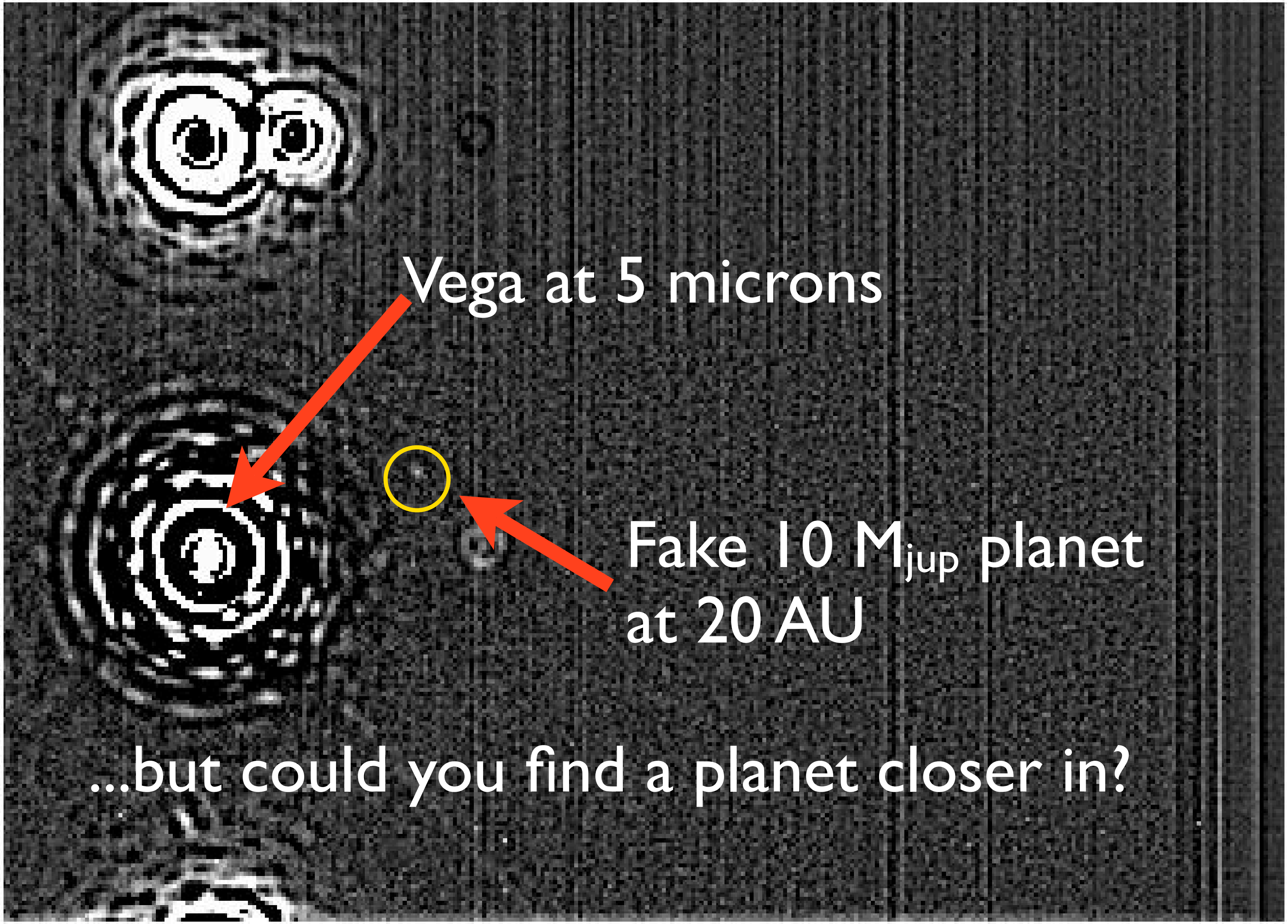



Typical Clio Observation
Background star

A Background Star



Diffraction Effects



Why does Image Subtraction not work?

- Two images taken about 20 minutes apart are not identical
- Quasi-static ‘speckles’ are present in all images

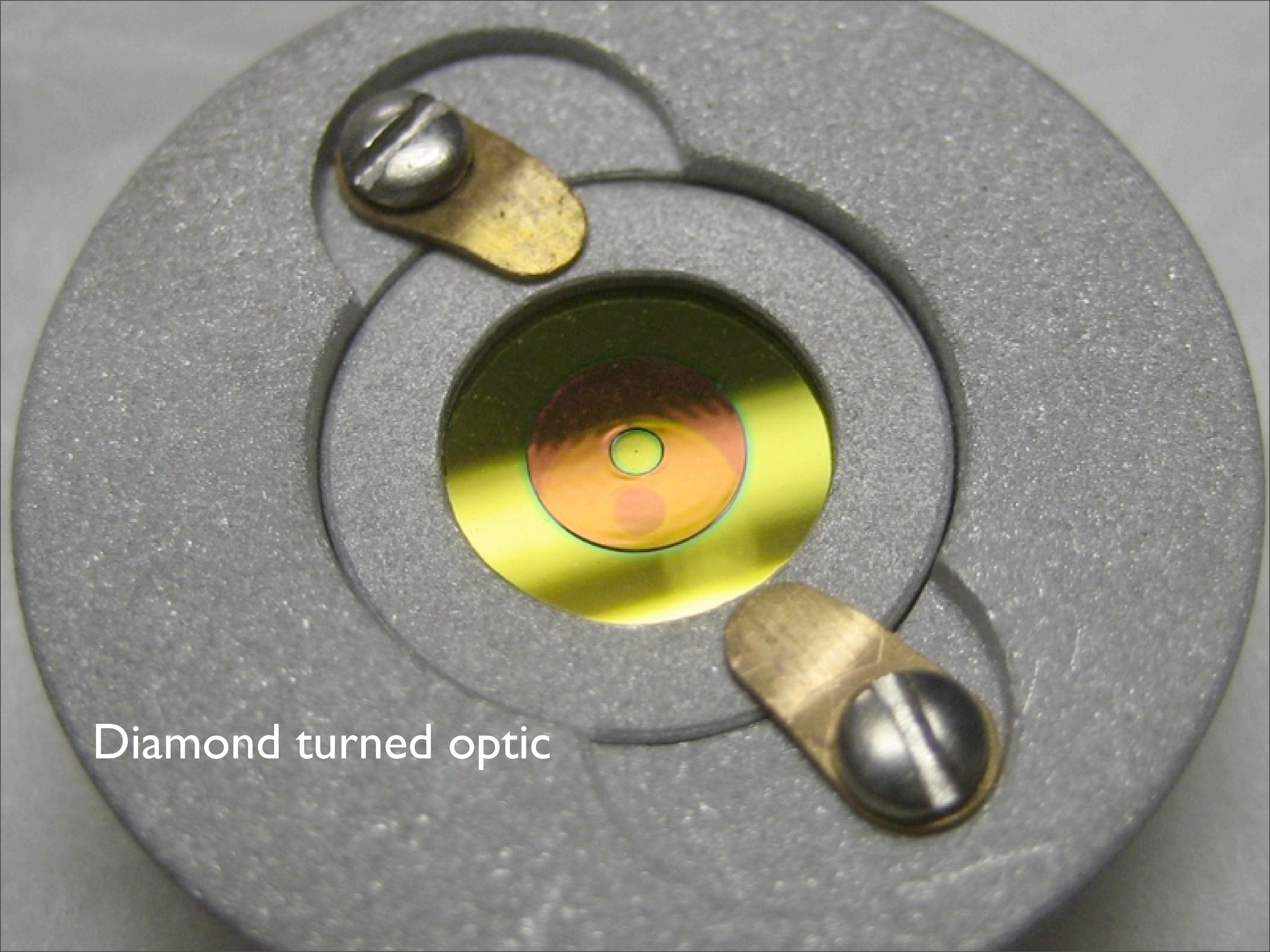
But wait! It gets ***even*** tougher...

Coronagraph

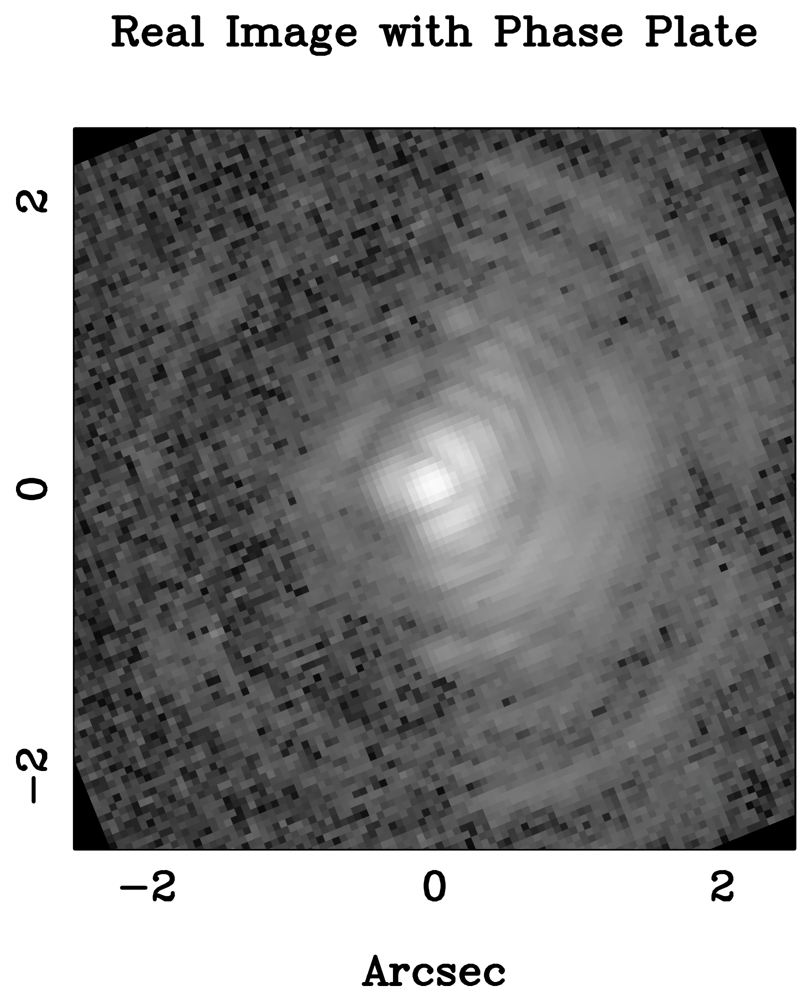
- ‘Looking at the Sun’s Corona’
- Invented by Bernard Lyot

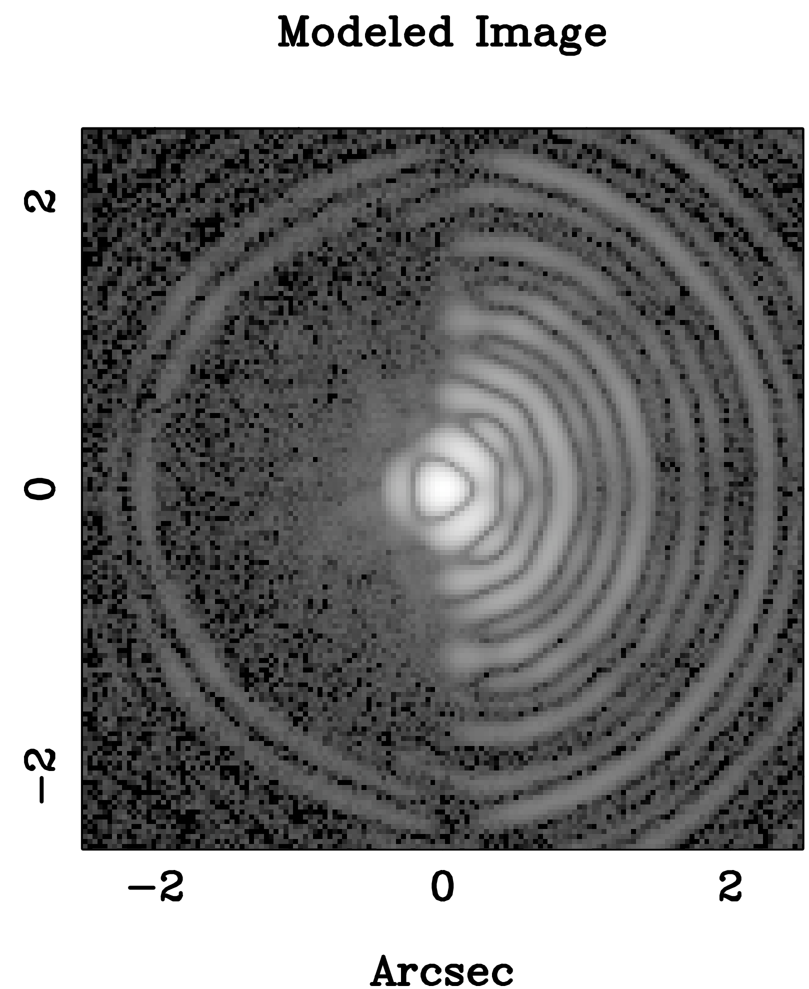
Coronagraphy

- “Cover the star with your thumb!”
- Removing diffraction from star whilst letting planet light through


Diamond turned optic

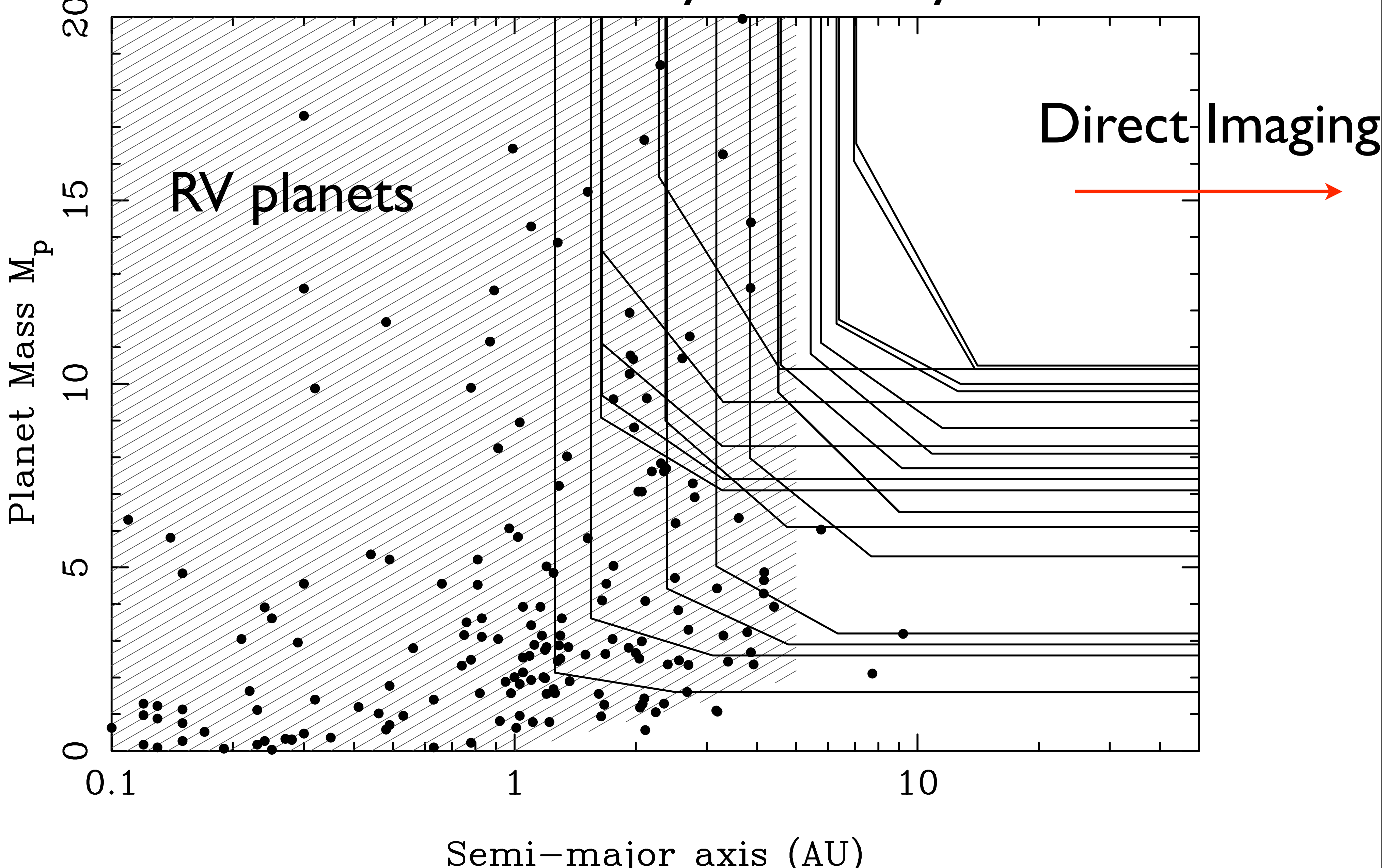
It works...



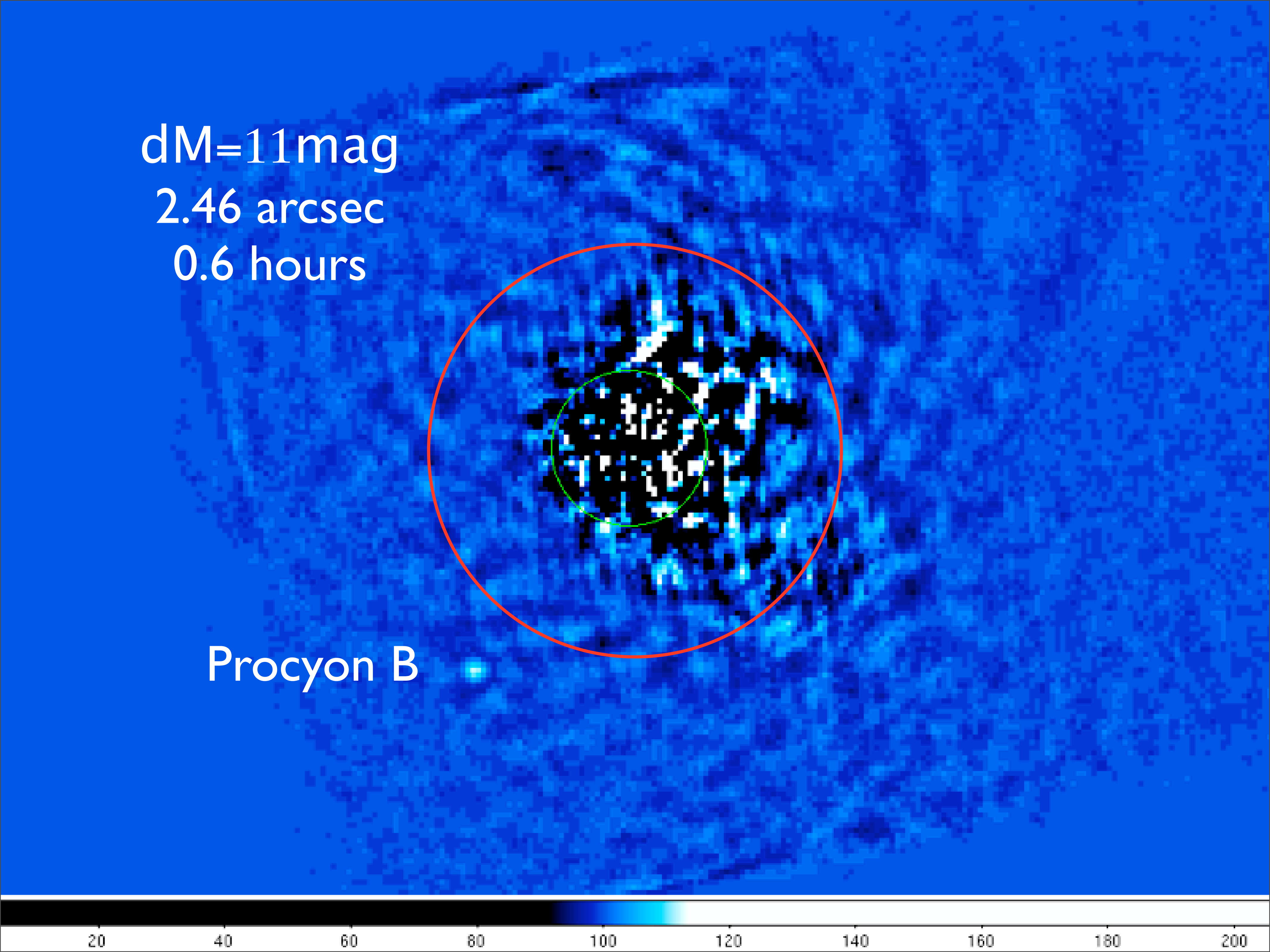


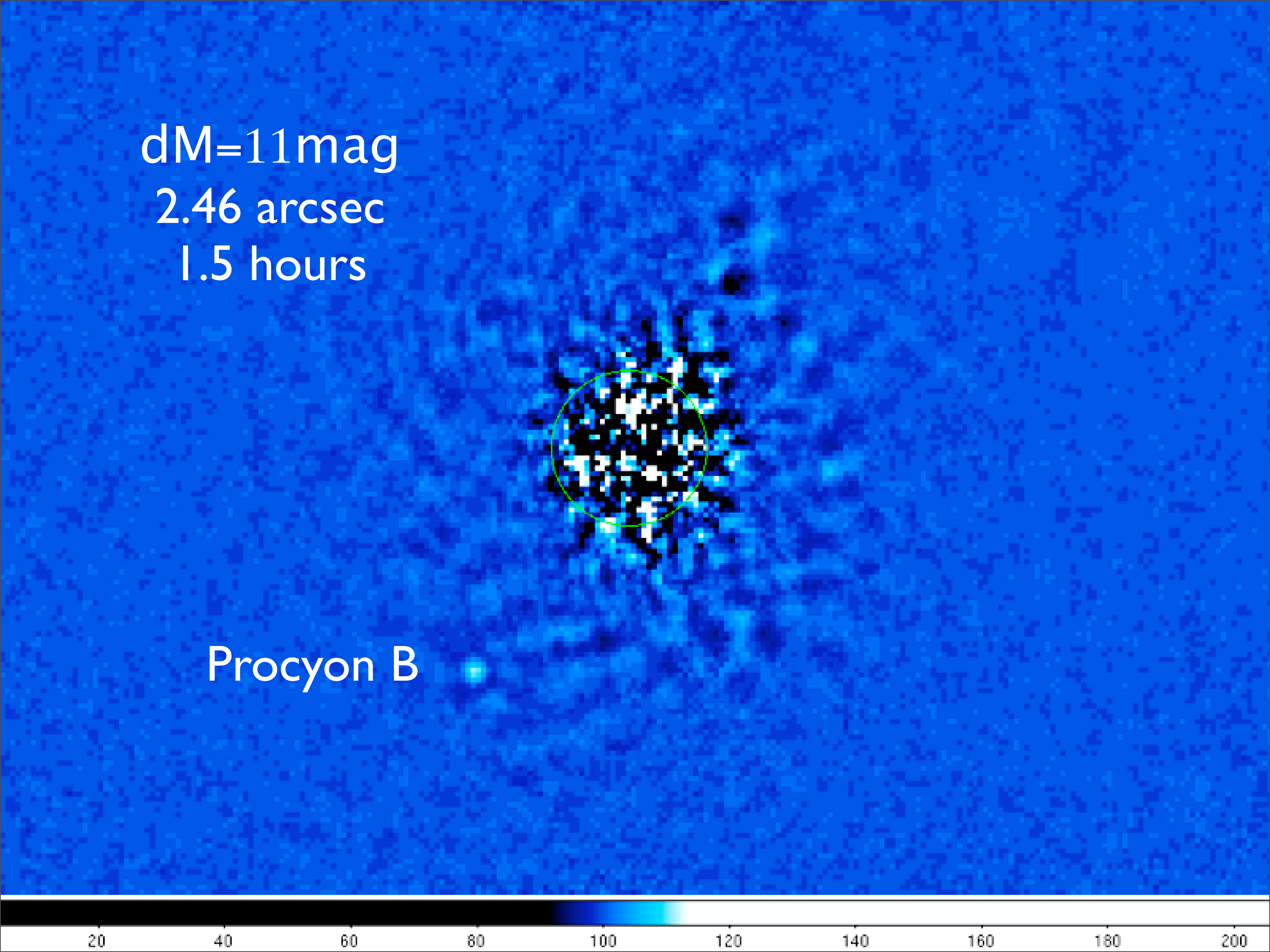
April/May 2006

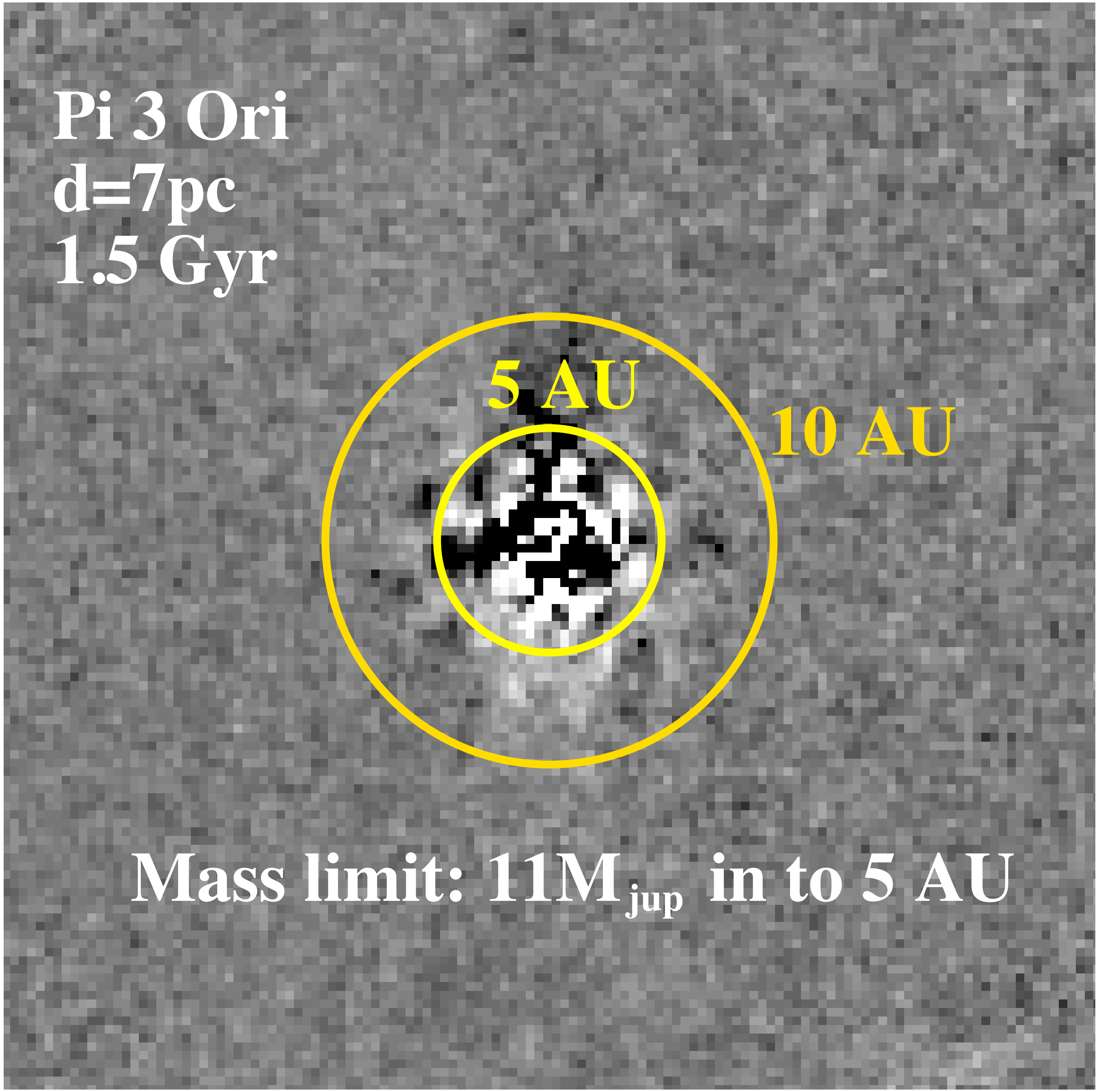
Ice Line Survey Sensitivity



- Play animation


dM=11mag
2.46 arcsec
0.6 hours
Procyon B
20
40
60
80
100
120
140
160
180
200

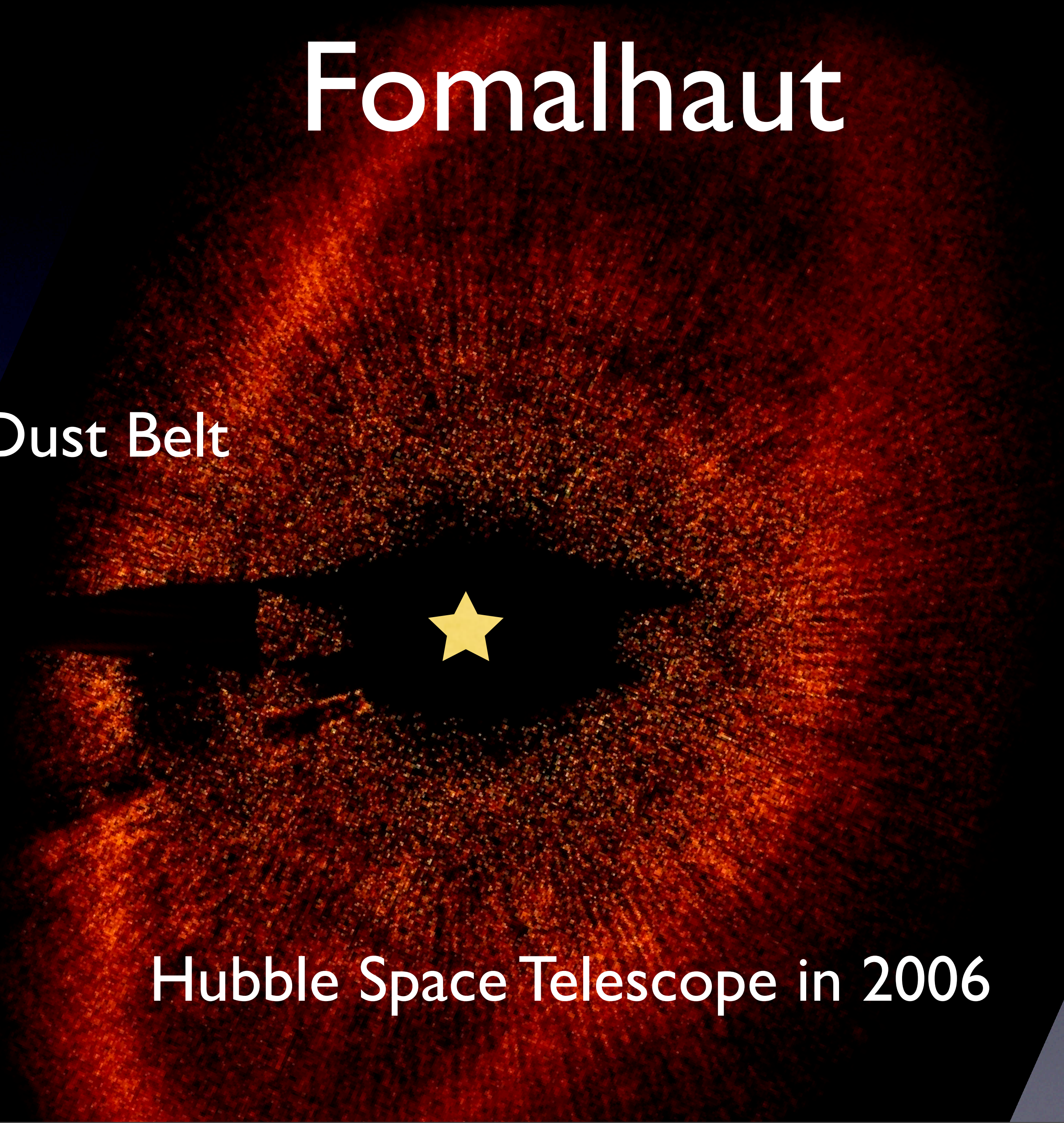

dM=11mag
2.46 arcsec
1.5 hours
Procyon B
20
40
60
80
100
120
140
160
180
200


Pi 3 Ori
d=7pc
1.5 Gyr
5 AU
10 AU
Mass limit: 11M jup in to 5 AU

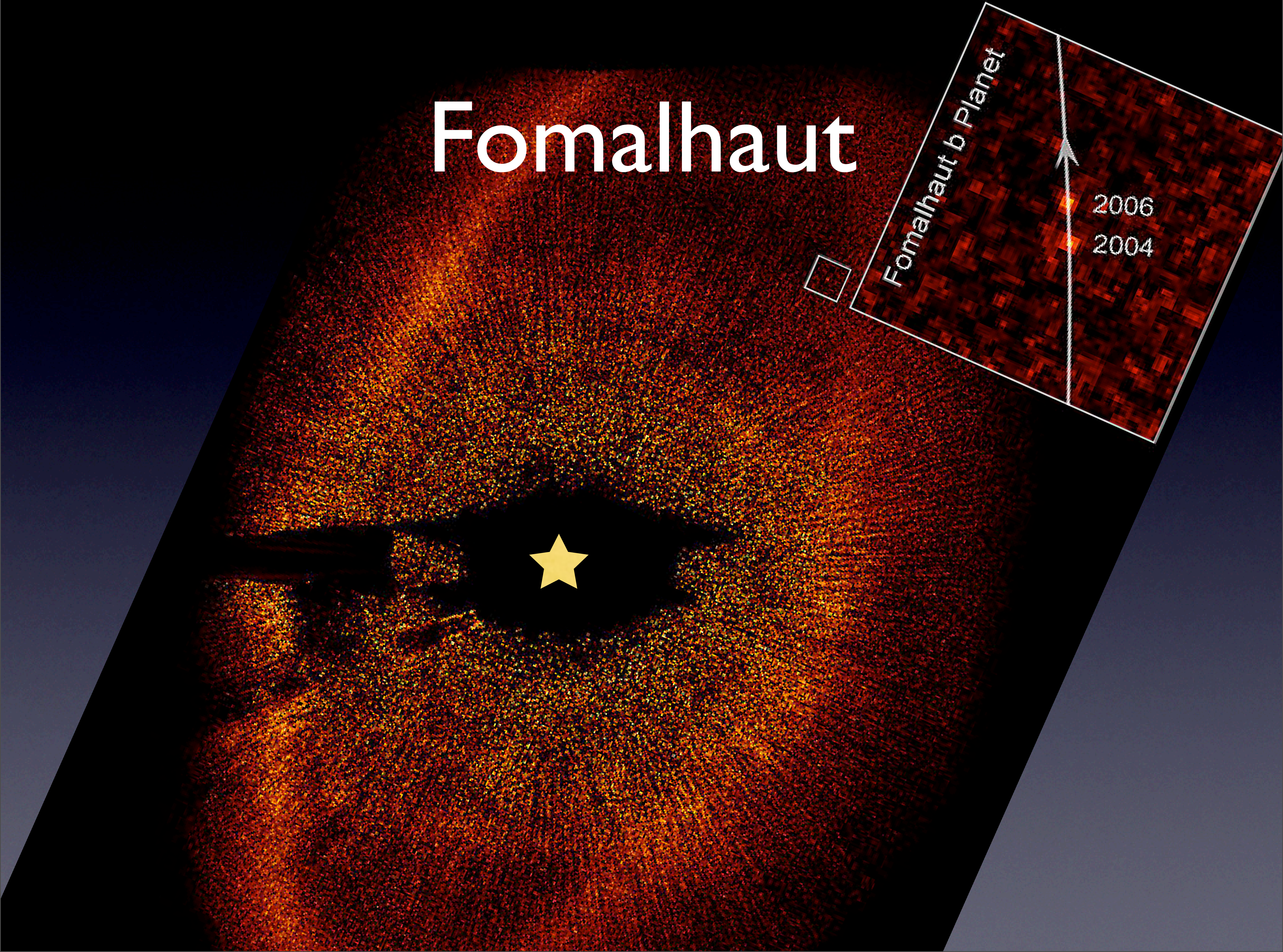
Conclusions

- Thermal imaging is sensitive enough (assuming models are close to reality...)
- No planets so far... but watch this space!
- 8 stars out of 25 observed, no planet candidates

Fomalhaut

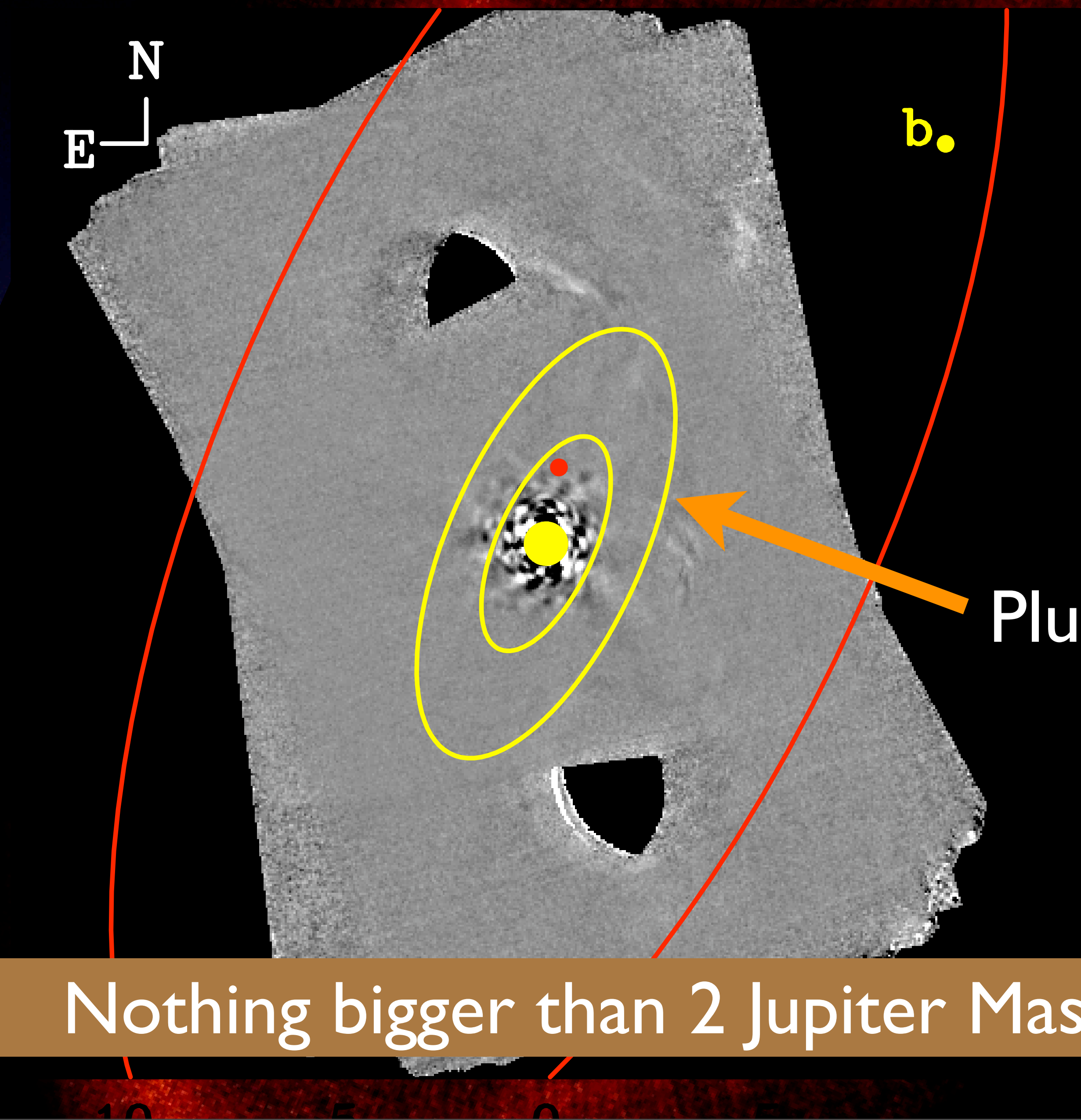


Fomalhaut



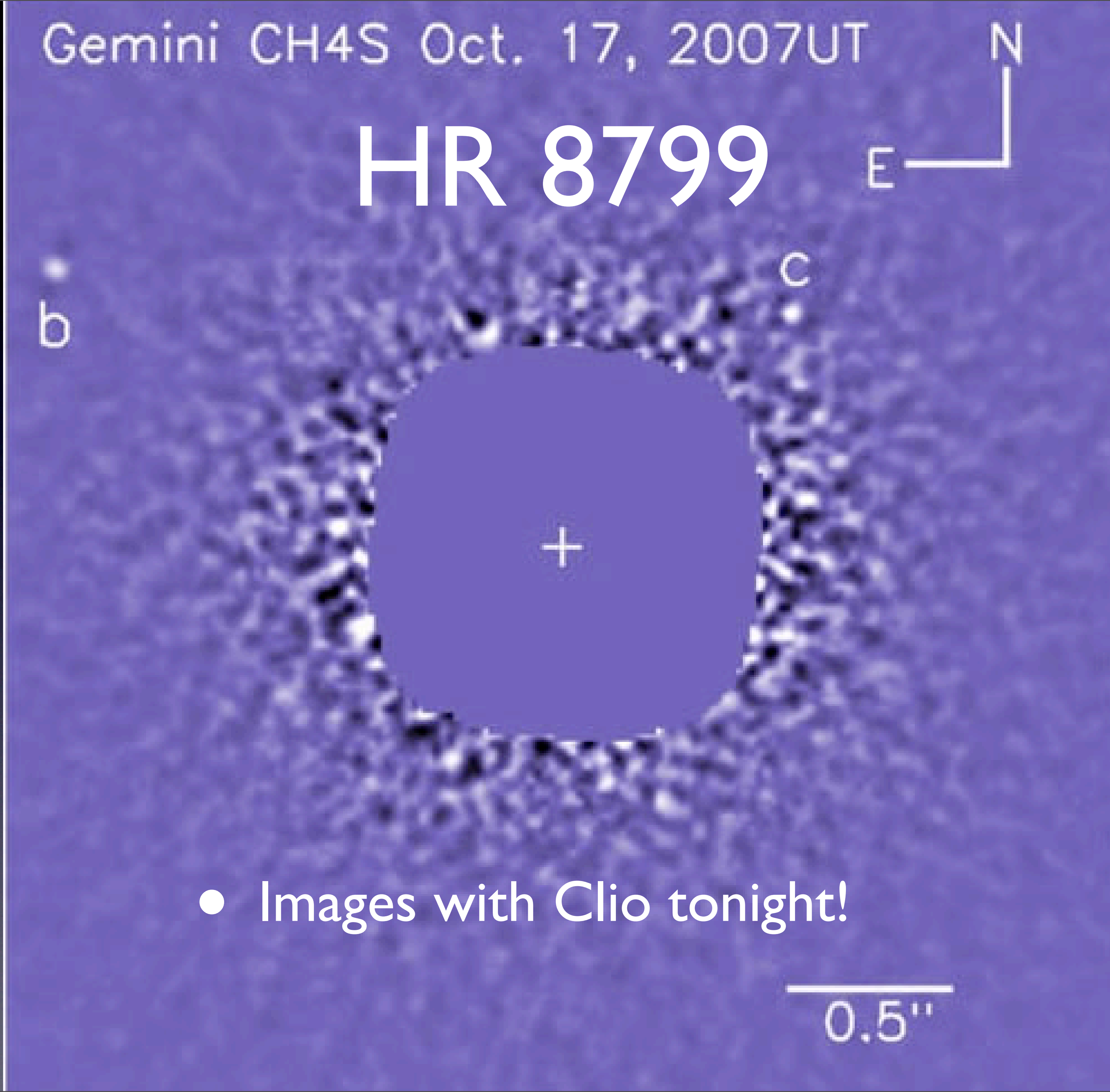
Clio at MMT
Dec 2006

Fomalhaut



Nothing bigger than 2 Jupiter Masses

HR 8799



- Images with Clio tonight!

Beta Pic

lures

btained be-
with NaCo.
× 14 lenslet
e CONICA
s. Saturated
ration times
s (NDIT) of
e applied in
noval. Non-
f the stellar
calibration.
r (transmis-

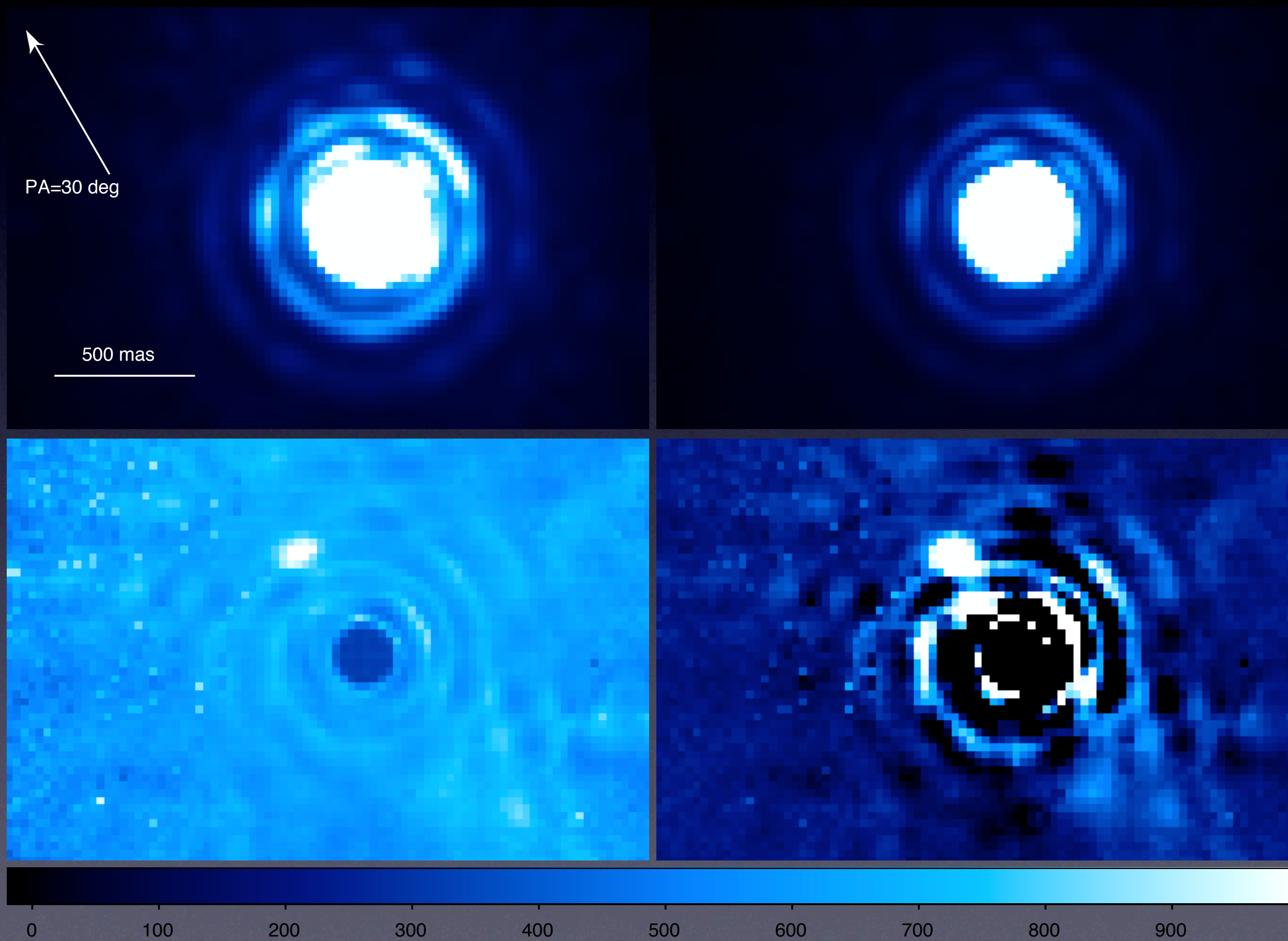


Fig. 1. β Pic and HR 2435 recentered and saturated L' images (top left and top right, respectively) in data set A. Below are the divided (bottom

Thanks for listening!