Detecting ExtraSolar Planets: A Survey of Methods and Results

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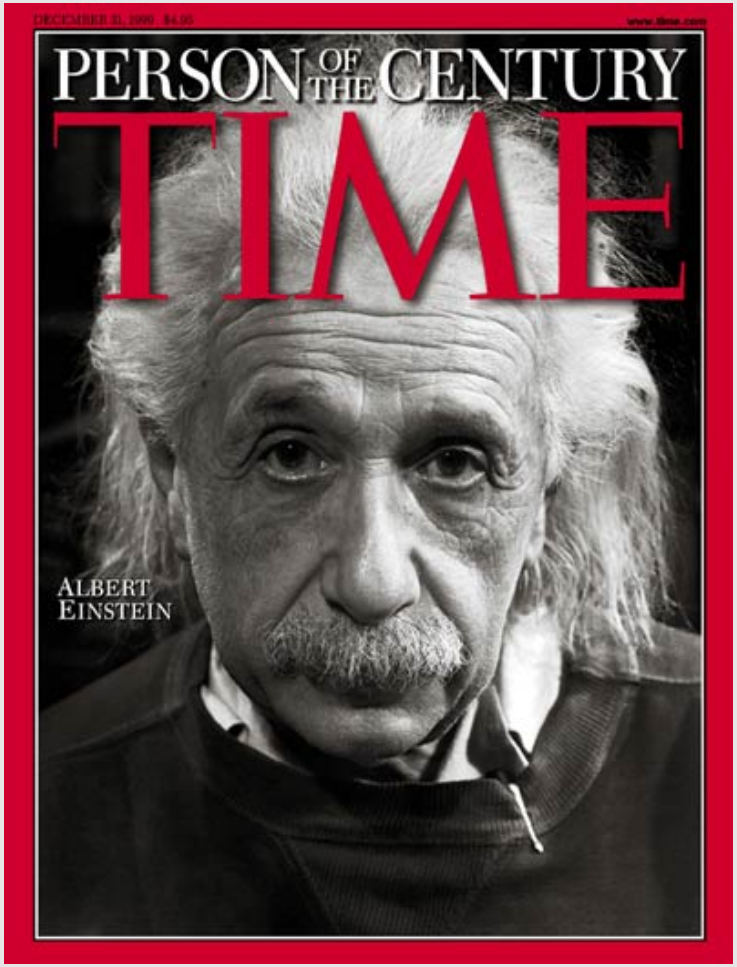
2007 May 26

NJAA
Voorhees State Park, High Bridge NJ

http://www.princeton.edu/∼rvdb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www.time.com
PERSON OF THE CENTURY
TIME
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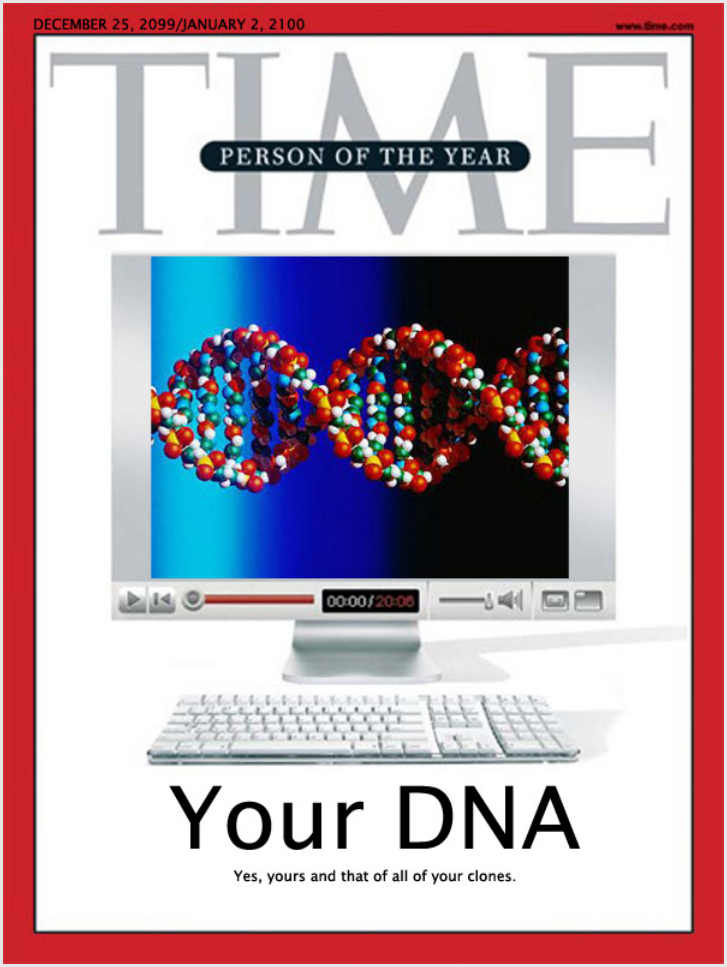
DECEMBER 25, 2099/JANUARY 2, 2100
www.time.com
TIME
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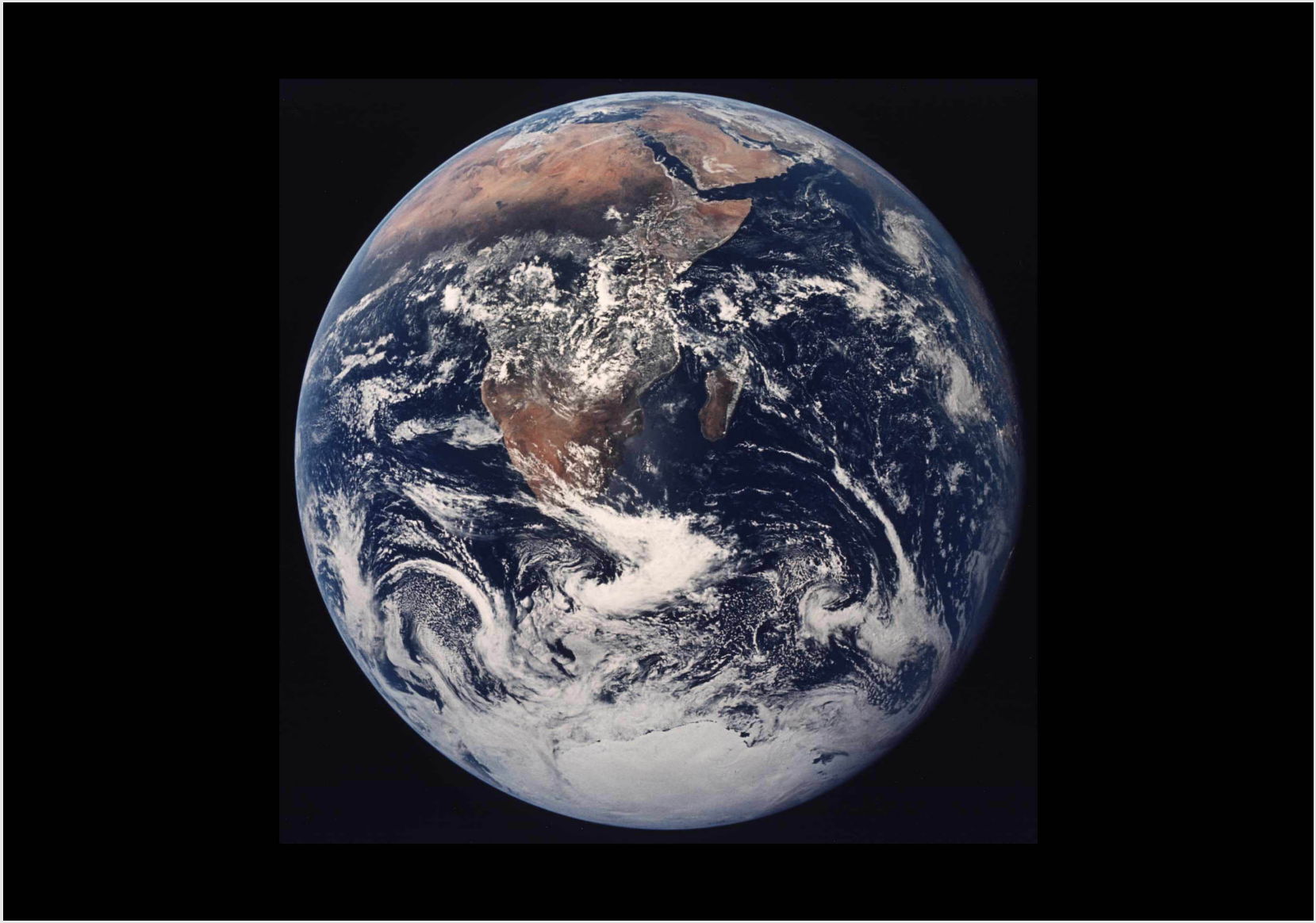
Your DNA
Yes, yours and that of all of your clones.

Are We Alone?



Indirect Detection Methods

209 planets found so far

Wobble Methods

Radial Velocity.

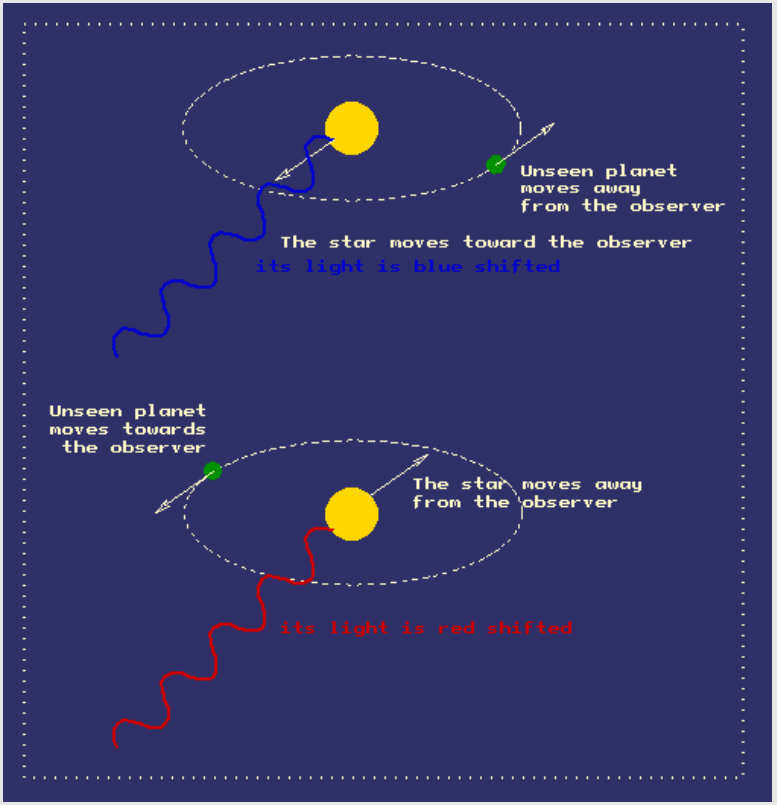
For edge-on systems.

Measure periodic doppler shift.

Astrometry.

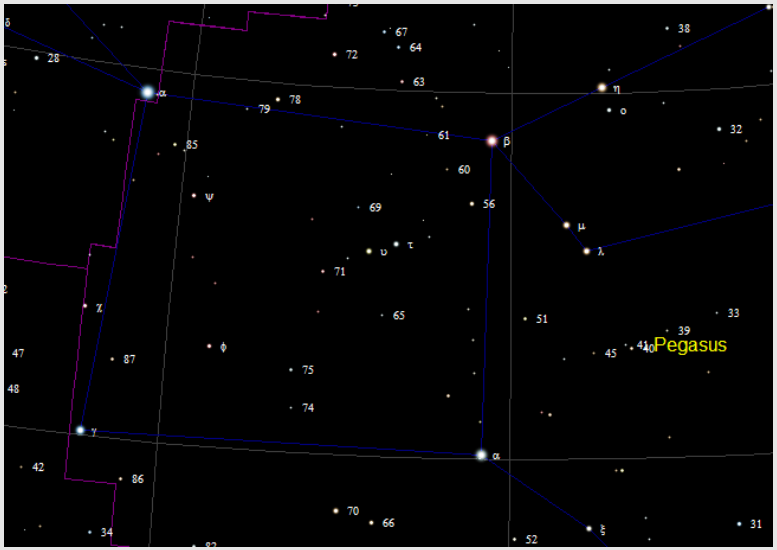
Best for face-on systems.

Measure circular wobble against background stars.



First Discovery: 51 Pegasi b

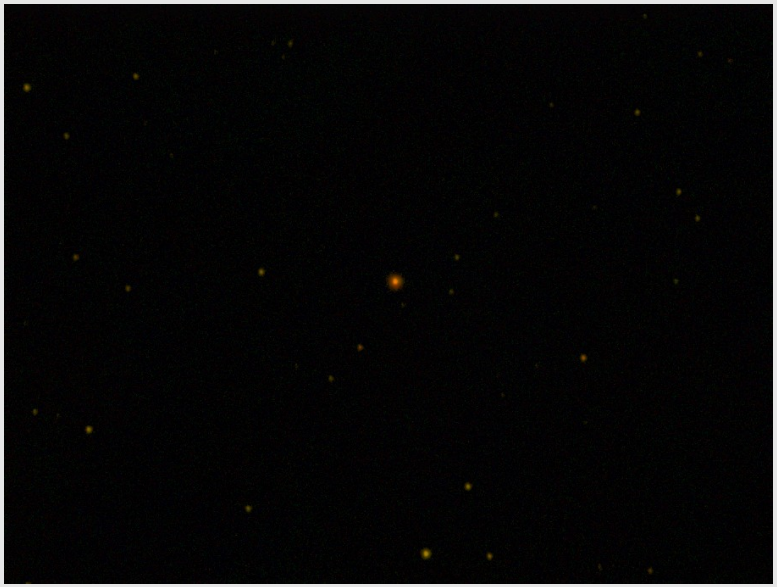
- Mayor and Queloz (1995)
- Mag. 5.5 main sequence star
- Detected by *radial velocity* method
- Velocity difference: 70 m/s $= 160$ mph
- Period: 4.2 days
- Separation: 0.05 AU
- Angular separation: 0.0035 arcseconds
- Mass: $> 0.47 M_{\text{J}}$
- Hot Jupiter



Notable Recent Discovery: Gliese 581c

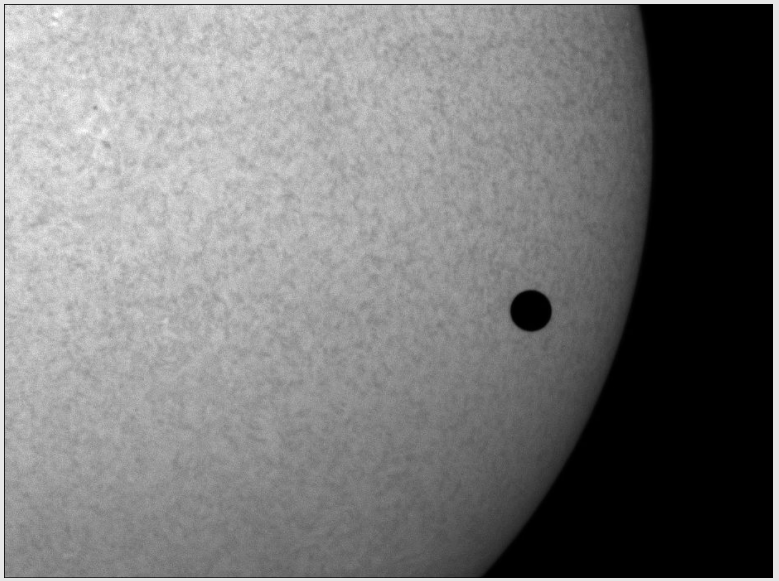
Possibly Terrestrial

- Mag. 10.5 red dwarf
- Detected by radial velocity method
- Period: 13 days
- Separation: 0.07 AU
- Angular Separation: 0.012 arcseconds
- Mass: $> 5M_{\mathsf{E}}$

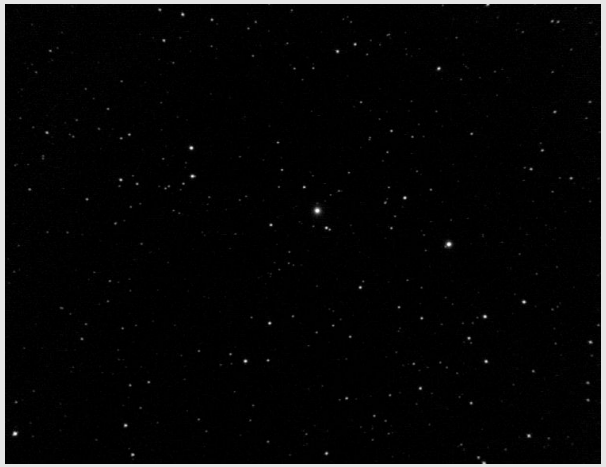


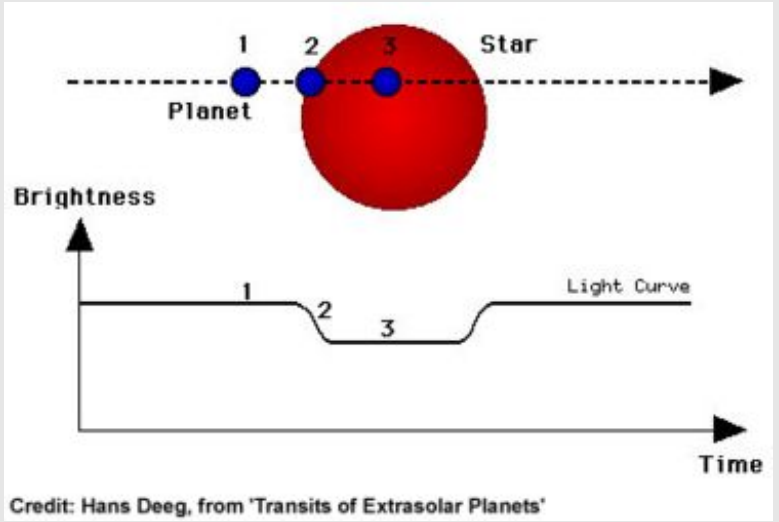
Transit Method

- HD209458b confirmed both via RV and transit.
- Period: 3.5 days
- Separation: 0.045 AU (0.001 arcsecs)
- Radius: $1.3R_{\mathrm{J}}$
- Intensity Dip: $\sim 1.7\%$
- Venus Dip $= 0.01\%$, Jupiter Dip: 1%
- Kepler and Corot



Venus Transit (R.J. Vanderbei)

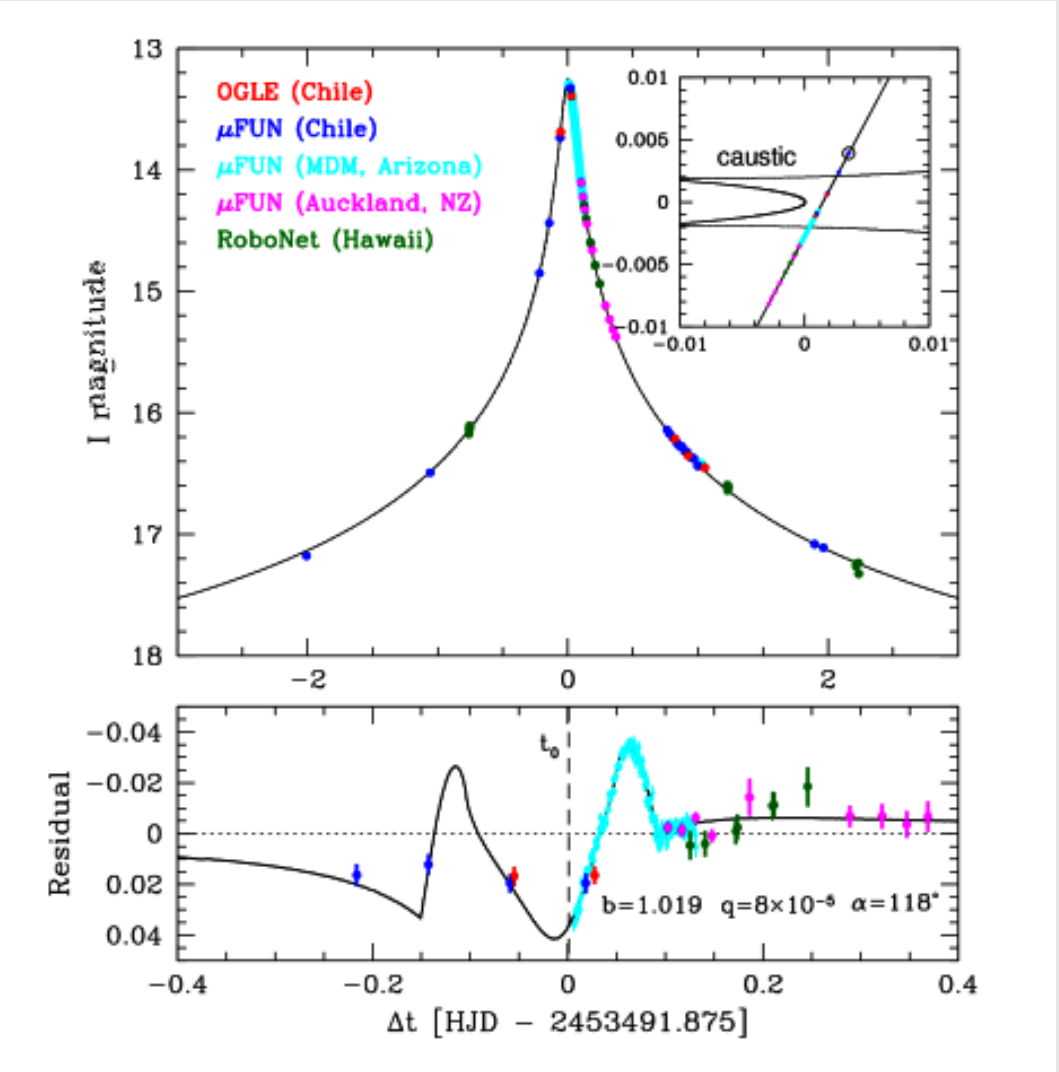




Credit: Hans Deeg, from 'Transits of Extrasolar Planets'

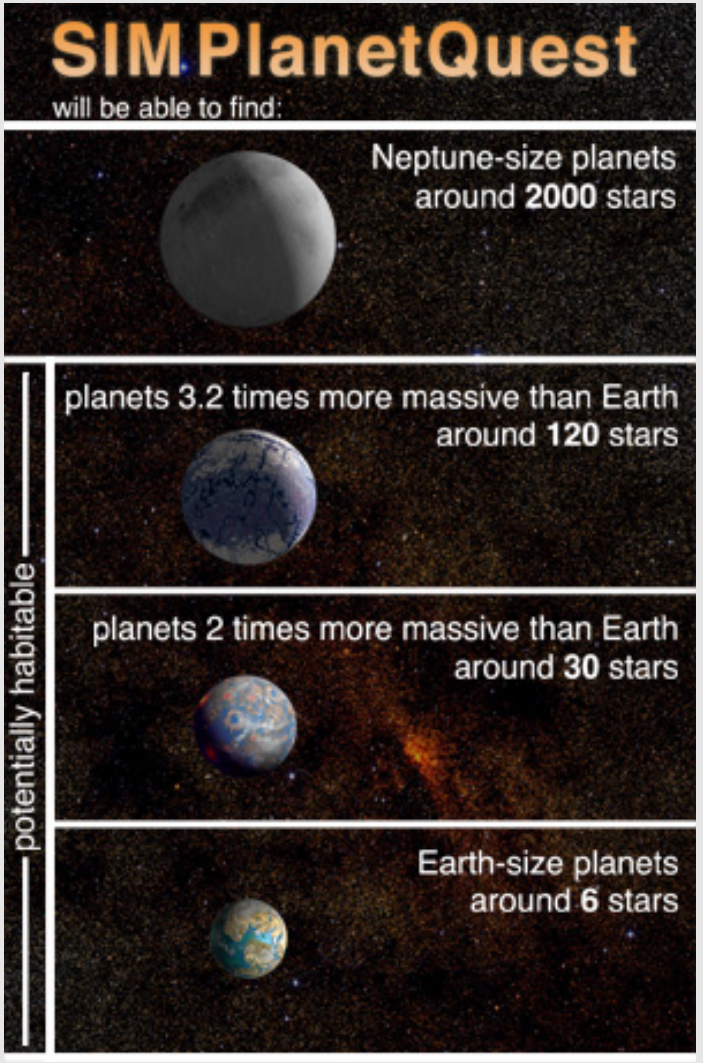
Gravitational Lensing (OGLE)

8 discoveries.



Astrometry

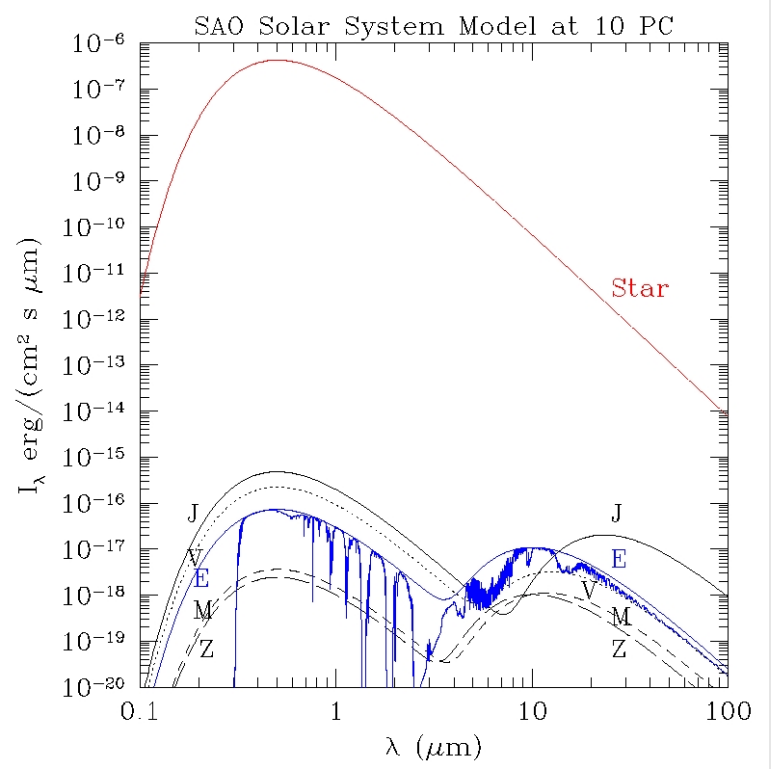
- *Space Interferometry Mission (SIM)*
- Wobbles as small as 0.000001 arcsecs (the thickness of a nickel viewed from the distance of the moon).
- Mission Cancelled



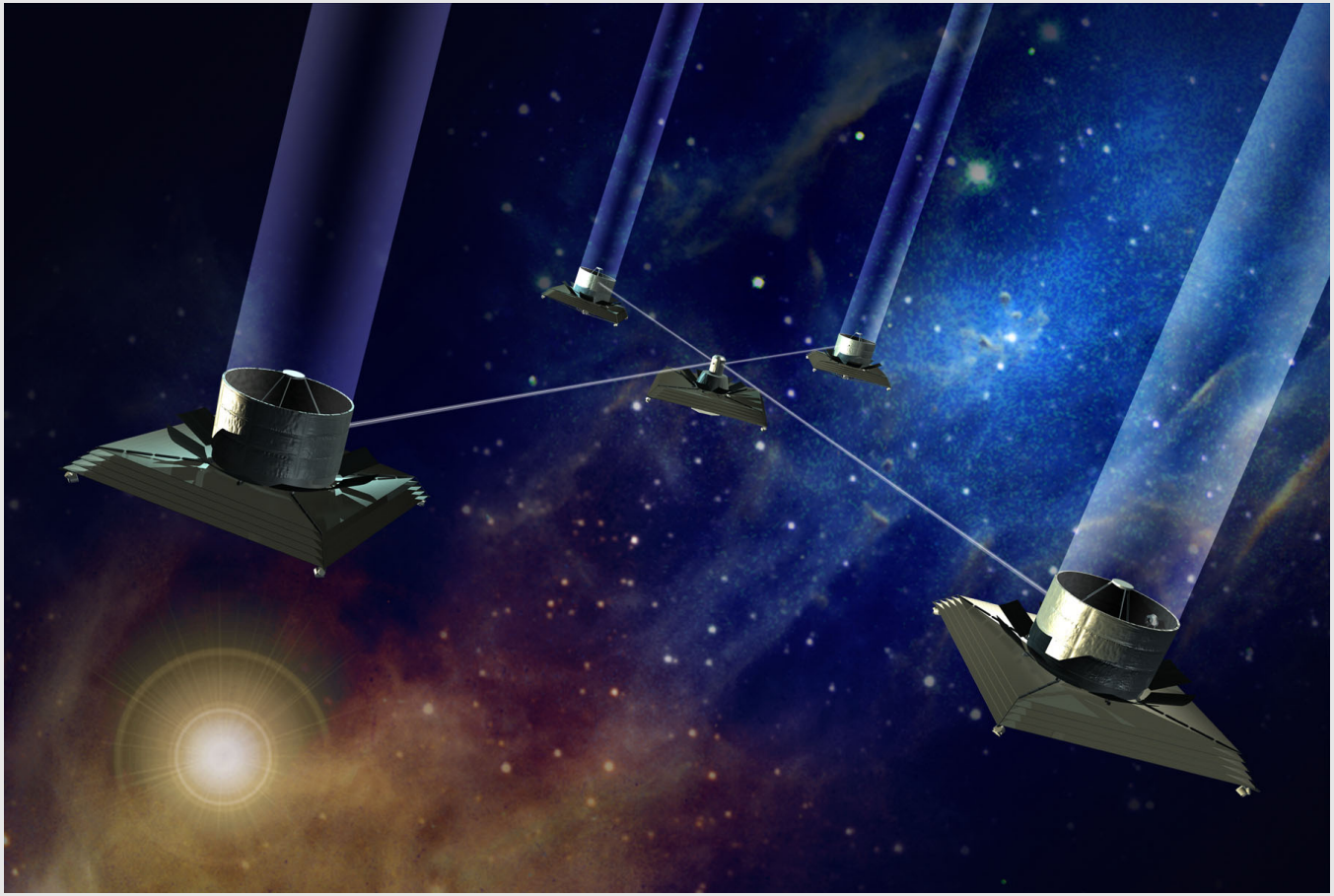
Direct Detection

Why It's Hard

- *Bright Star/Faint Planet:* In visible light, our Sun is 10^{10} times brighter than Earth. That's 25 mags.
- *Close to Each Other:* A planet at 1 AU from a star at 10 parsecs can appear at most 0.1 arcseconds in separation.
- *Far from Us:* There are less than 100 Sun-like stars within 10 parsecs.

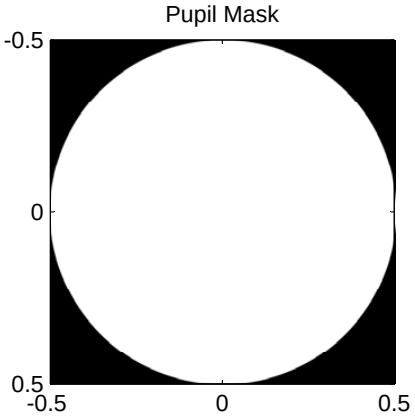


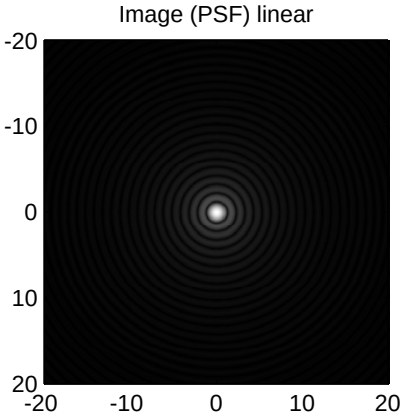
Space-Based IR Interferometer (TPF-I)

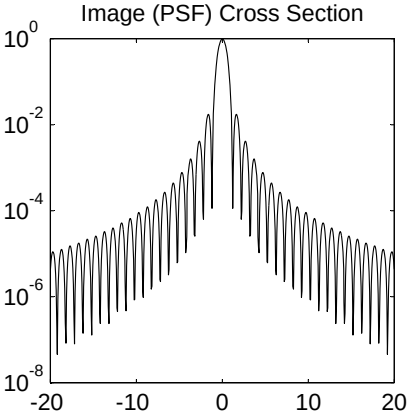


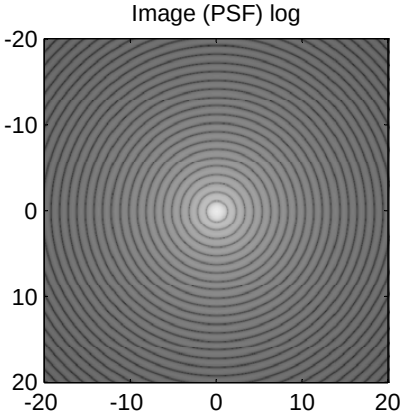
Telescope w/ Unobstructed Aperture

Doesn't Work! Requires an aperture measured in kilometers to mitigate diffraction effects.

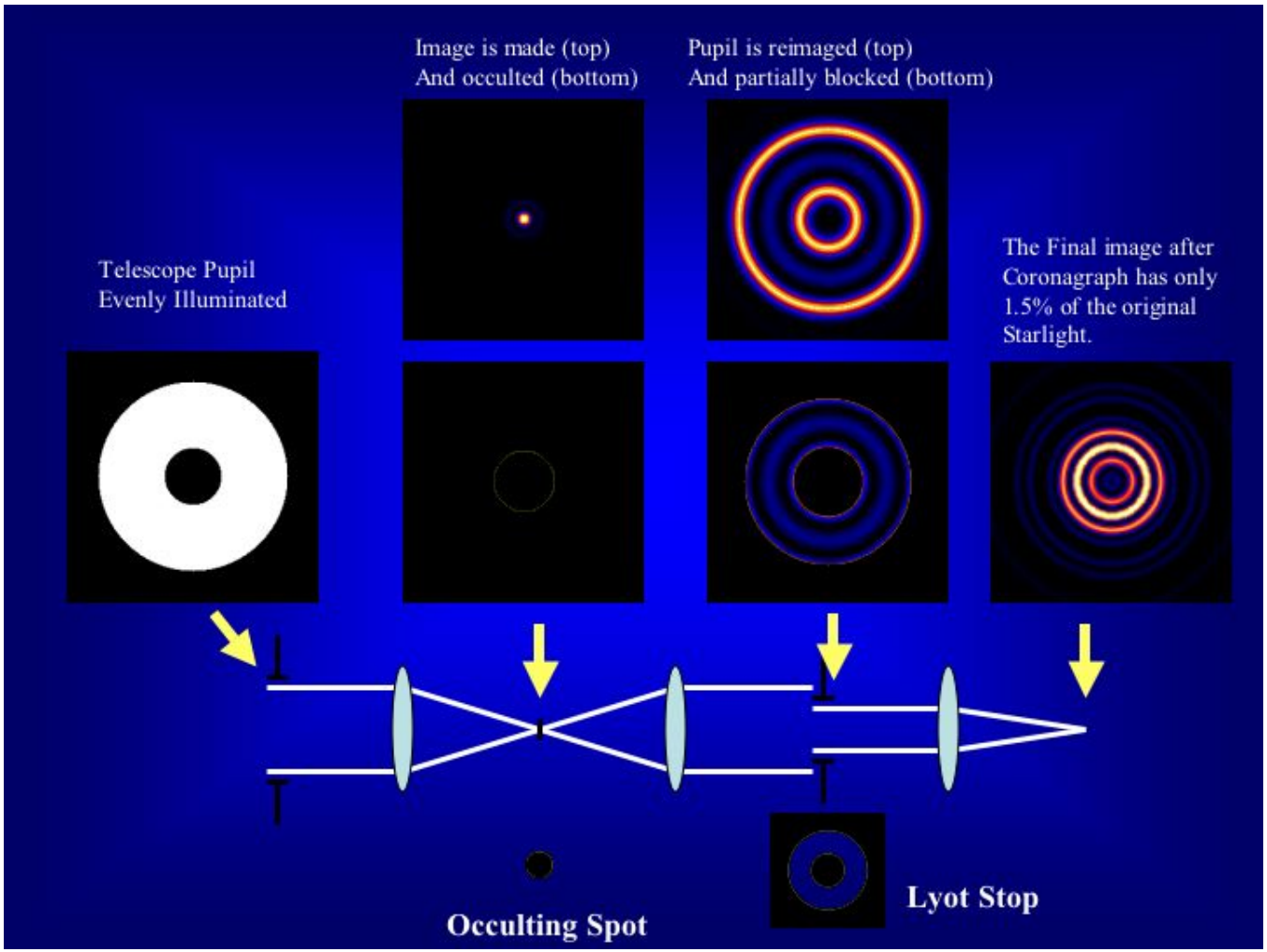








Lyot Coronagraph (TPF-C)



Apodized Pupil Coronagraph (Unmanufacturable)

Apodized pupil

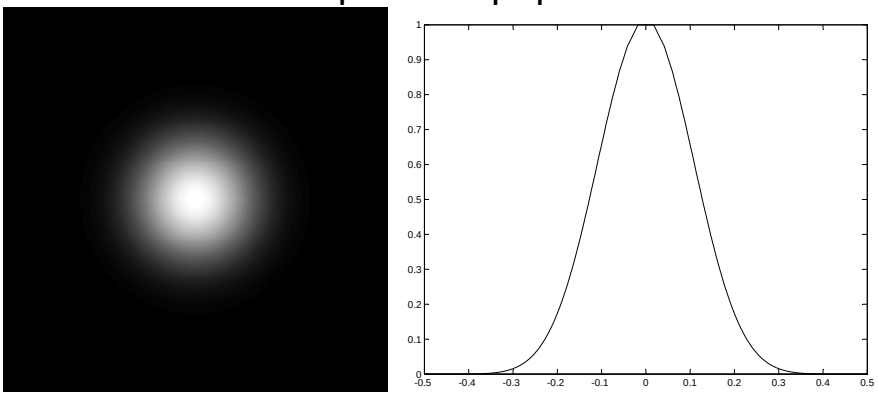
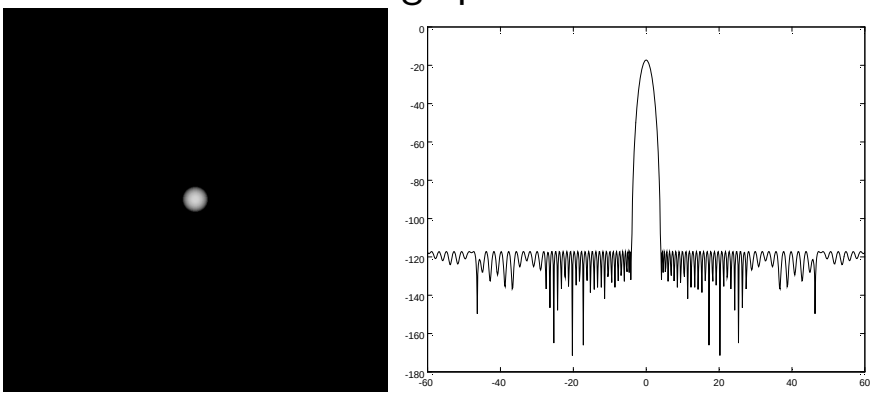
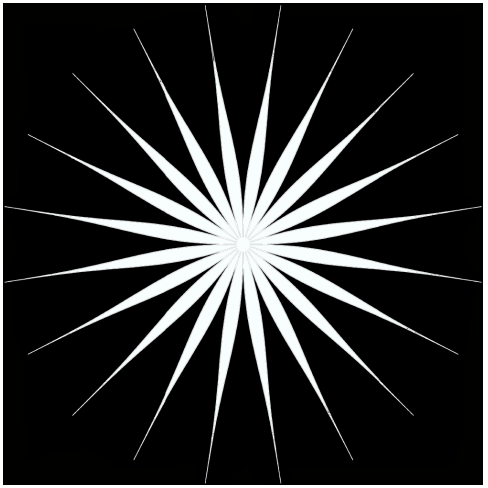


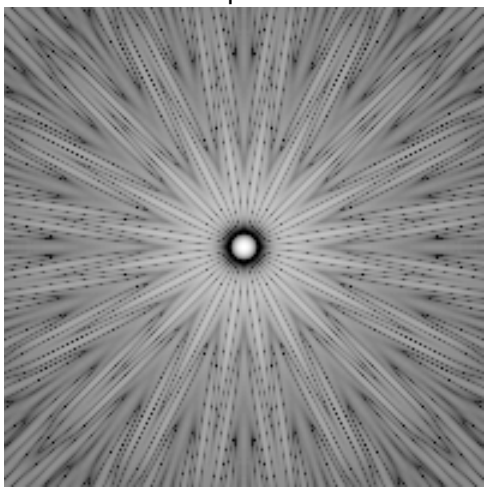
Image plane



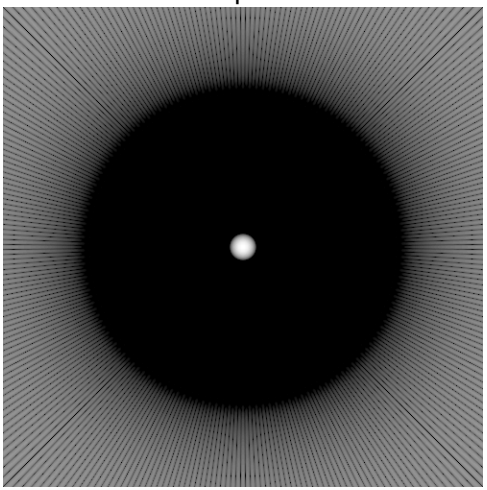
Shaped Pupil Coronagraph (TPF-C)



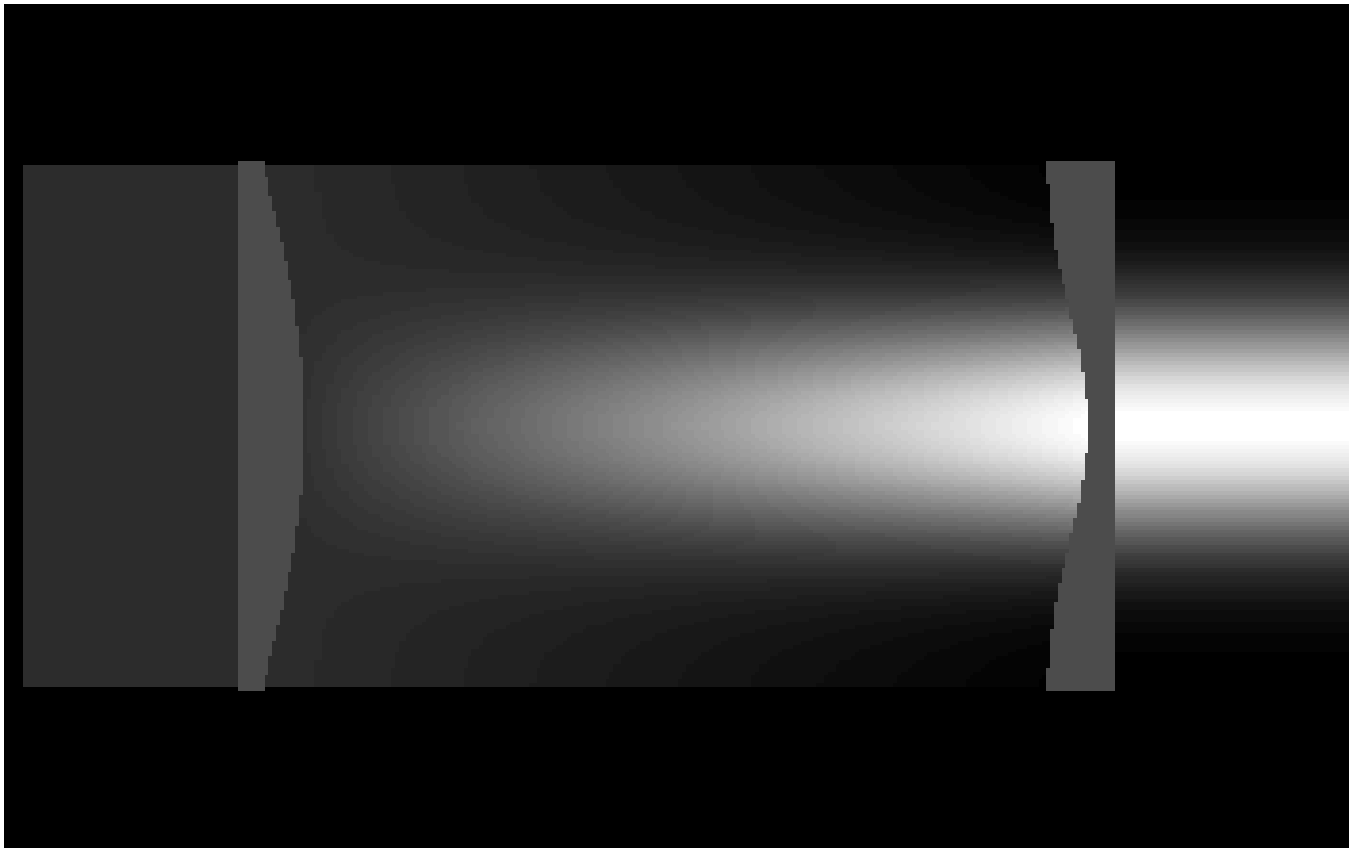
20 petals



150 petals



Pupil Mapping (TPF-C)

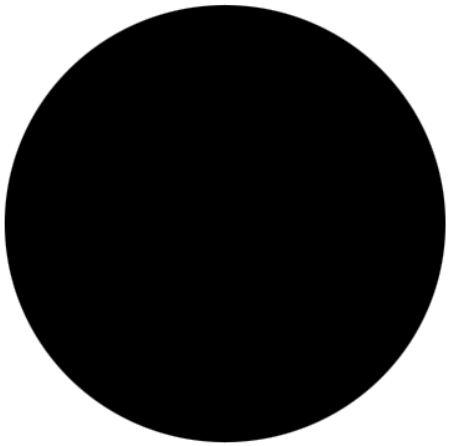


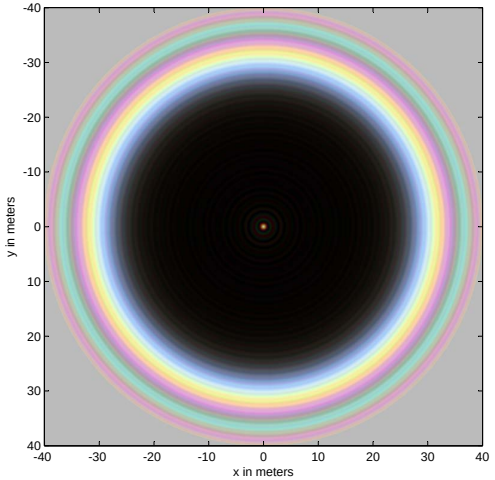
All above methods require optics of extraordinary quality: $1/10,000$ wave precision.

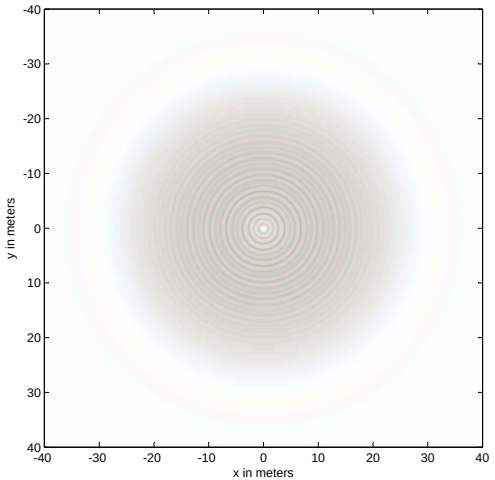
Space-based Occulter (TPF-O)

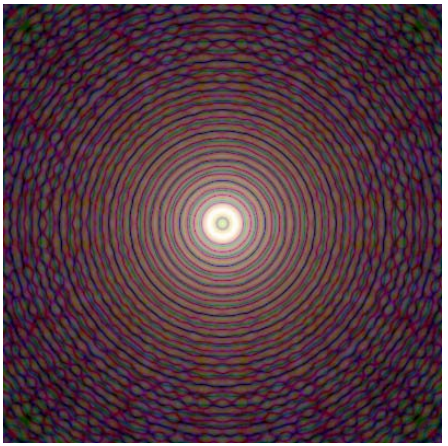
Telescope Aperture: 4m, Occulter Diameter: 50m, Occulter Distance: $72,000$km

Plain External Occulter (Doesn't Work!)

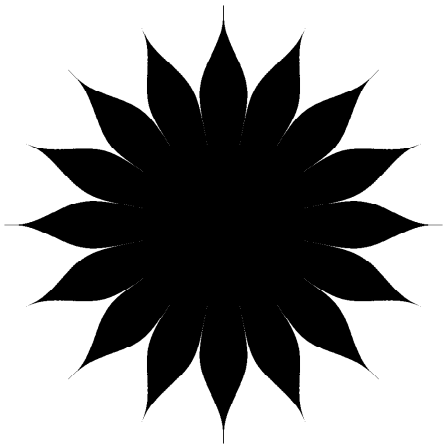


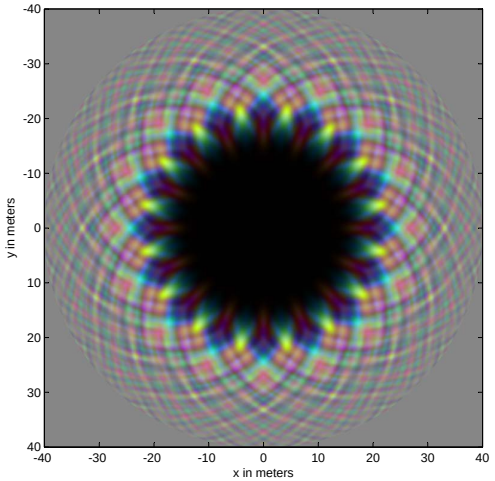


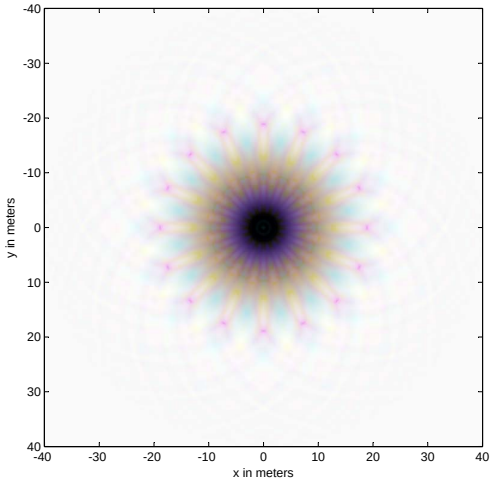


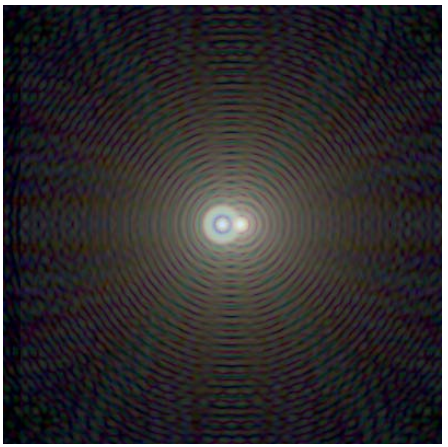


Shaped Occulter

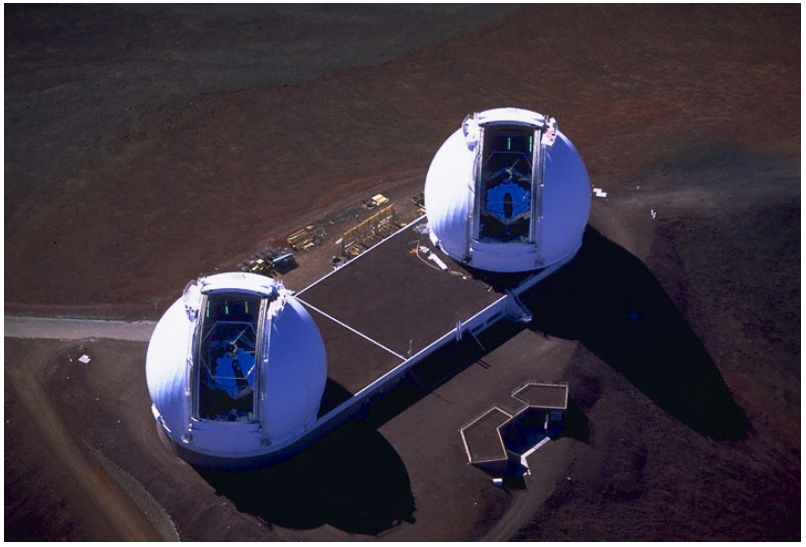








Ground-Based Possibilities



- Atmospheric *seeing* limits resolution to about 1 arcsec.
- Large aperture with adaptive optics.
- Interferometry.