New Worlds Imager

Webster Cash
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New Worlds Imager

An Alternative to TPF

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Alan Stern	Southwest Research Institute – Boulder
Steve Kilston	Ball Aerospace
Erik Wilkinson	
Mike Leiber	
Jim Leitch	
Jon Arenberg	Northrop Grumman
Ron Polidan	
Chuck Lillie	
Willard Simmons	MIT

and growing…

Exo-Planets

- Exo-planets are the planets that circle stars other than our Sun.

- There are probably 10,000 exo-planets within 10pc (30 light years) of the Earth.

Are Any Habitable??

Are Any Occupied???

To Be Human Is to Want to Know

Some Poetry (?)

Certain knowledge of

a destination

could

drive future generations

to cross

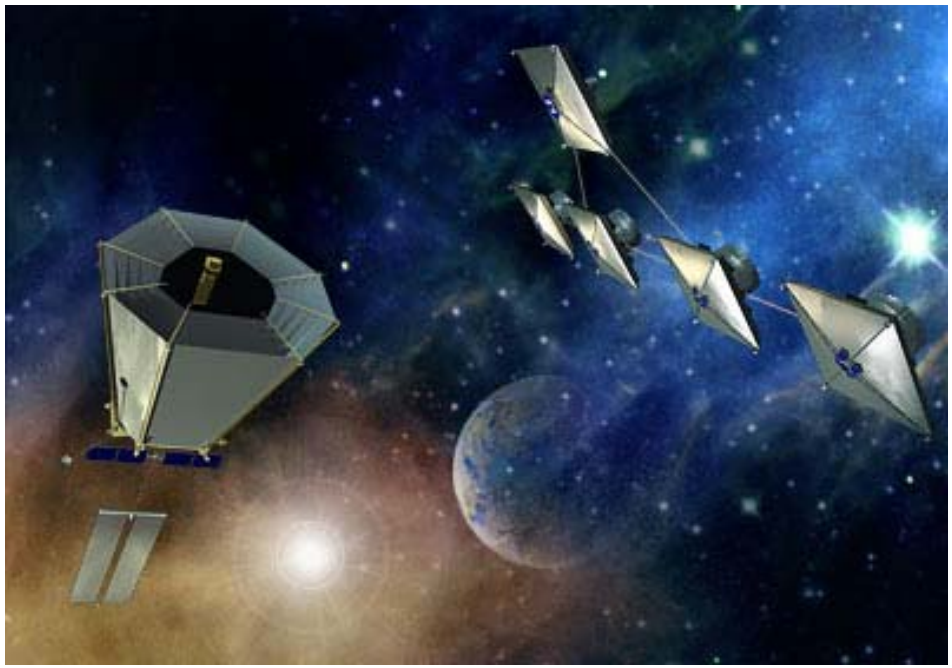
the awful gulf of interstellar space.

The Problem with Exo-Planet Studies

- Planets are lost in the glare of parent star.
- The Earth as viewed from light years is 10 billion times fainter than the Sun.

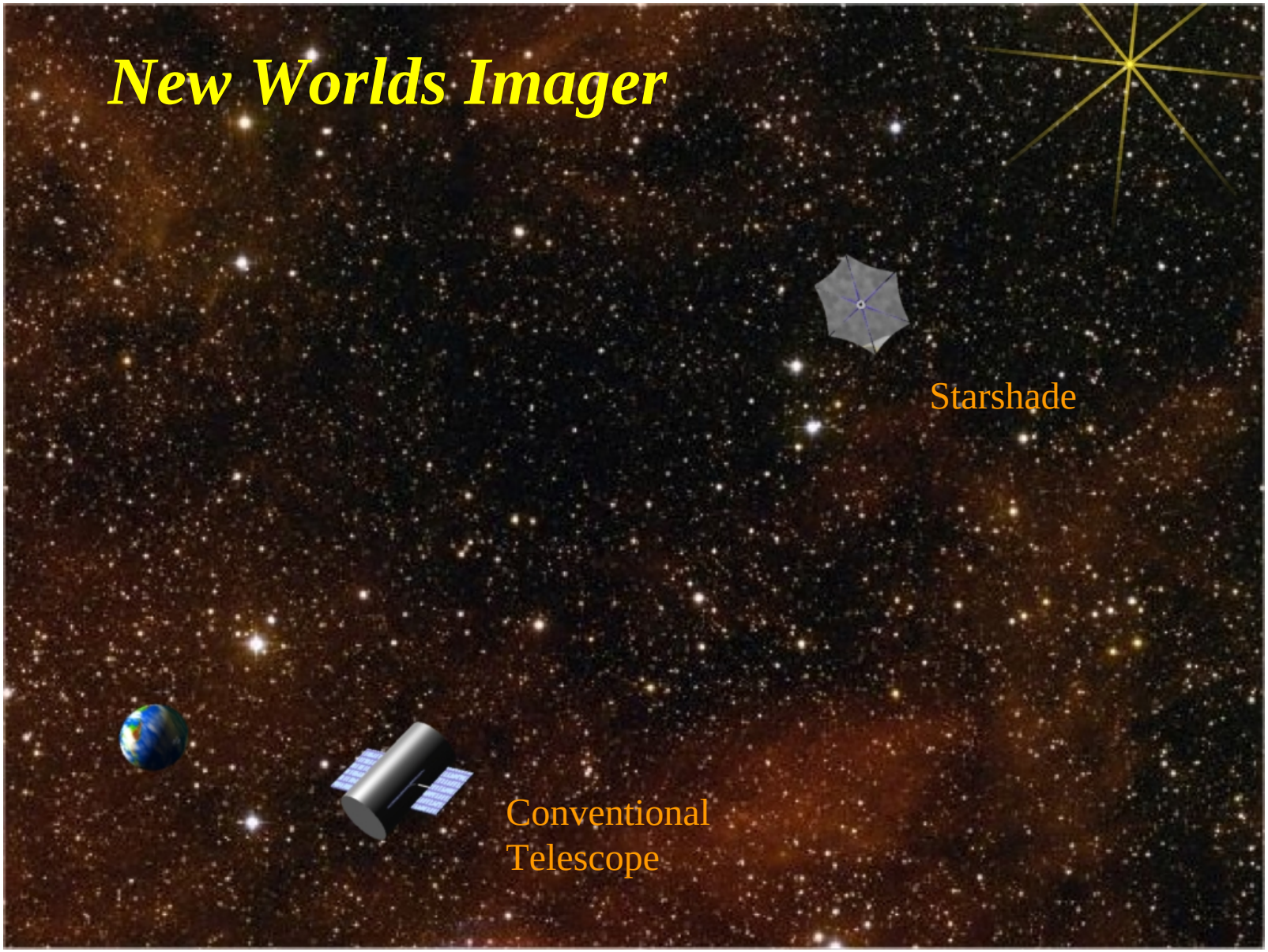
Terrestrial Planet Finder

- Telescopes must be PERFECT to suppress scatter:
  λ/5000 surface,
  99.999% reflection uniformity



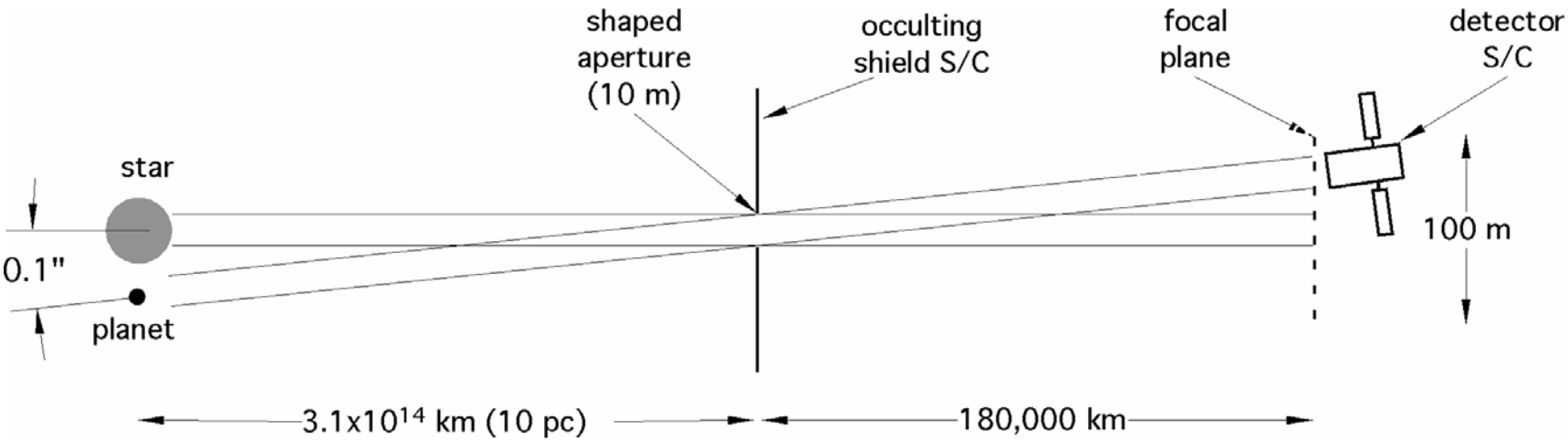
- TPF is *very* difficult

- Is there any easier way?


New Worlds Imager
Starshade
Conventional
Telescope

A Pinhole Camera Meets The Requirements:

- Perfect Transmission
- No Phase Errors
- Scatter only from edges – can be very low
- Diffraction Issues Remain

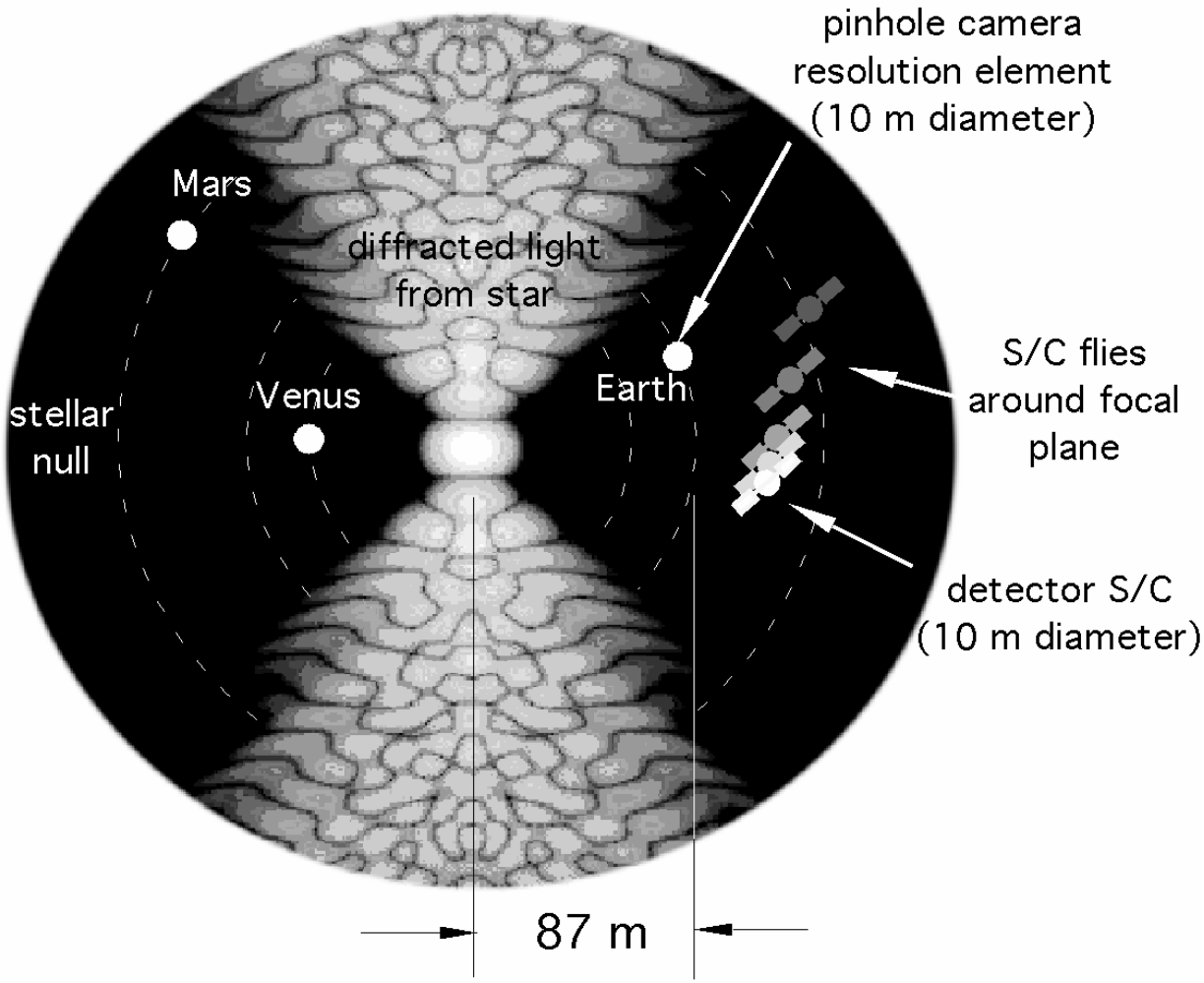


Large Distance Set by 0.01 arcsec requirement

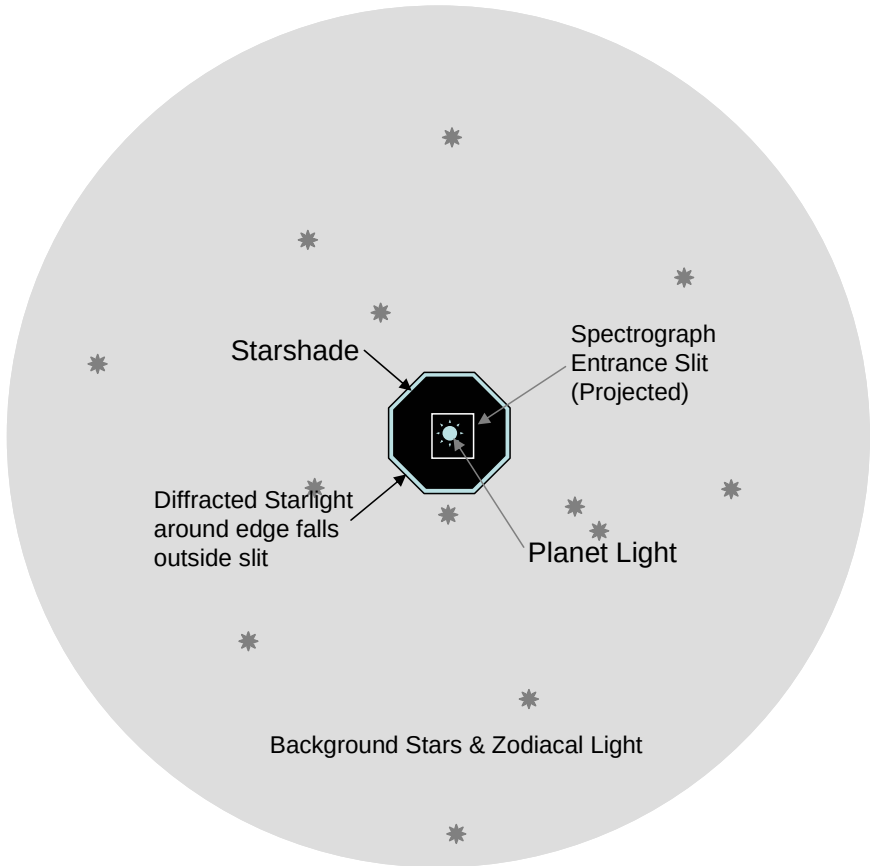
diffraction: $\lambda/D = .01'' \rightarrow D = 10m$ @500nm

geometric: $F = D/\tan(.01'') = 180{,}000km$

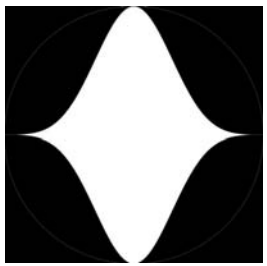
Focal Plane

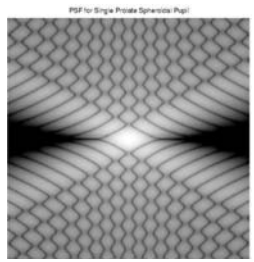

pinhole camera
resolution element
(10 m diameter)
Mars
diffracted light
from star
Venus
Earth
stellar
null
S/C flies
around focal
plane
detector S/C
(10 m diameter)
87 m

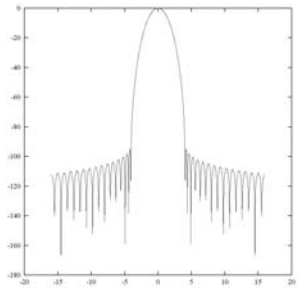
View Back Toward Starshade

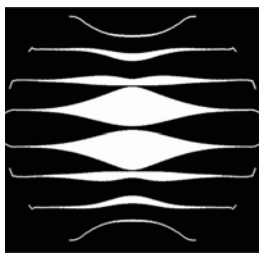


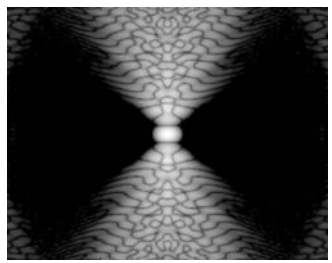
Starshade Aperture Shapes

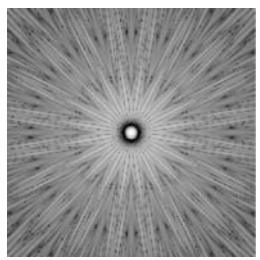


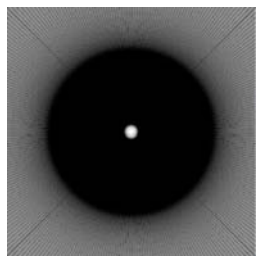




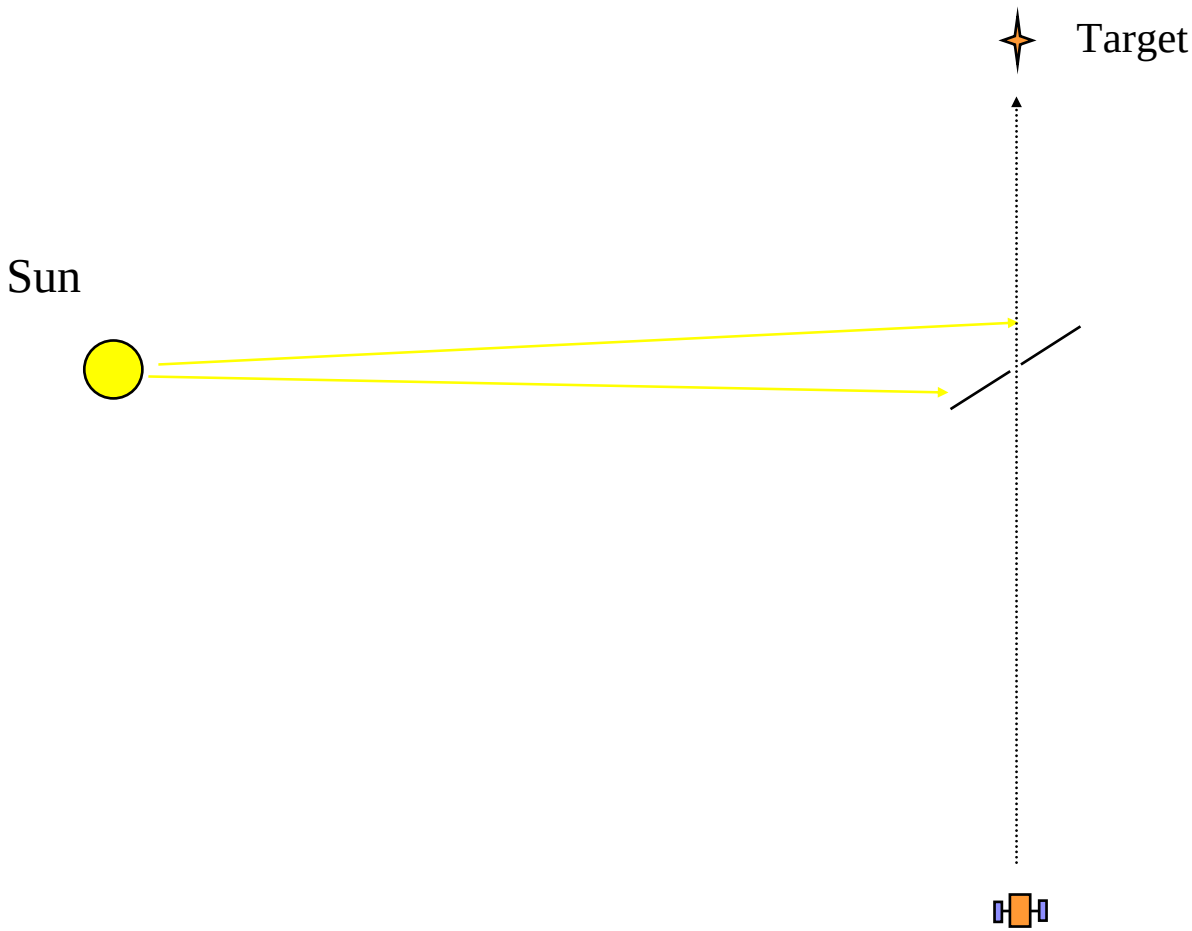




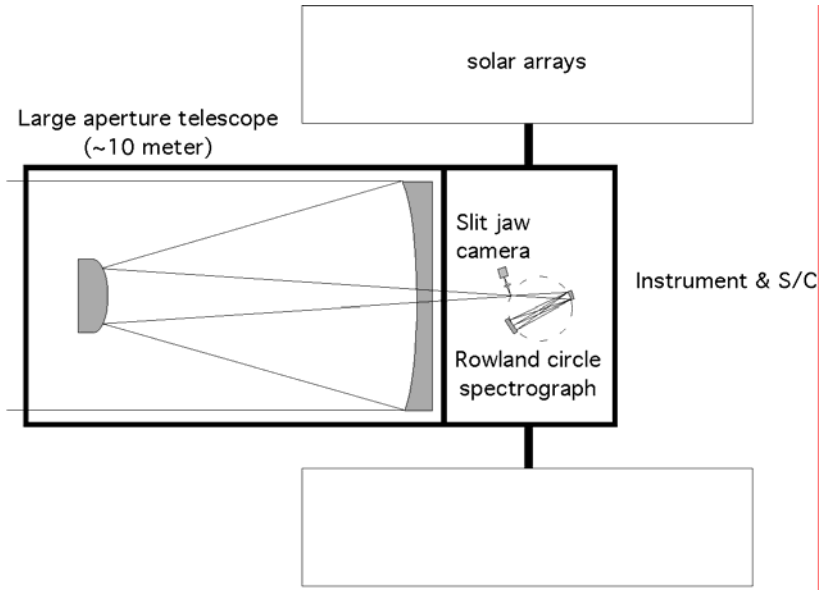




View Dark Side of Starshade



"Standard" Observatory Views Starshade



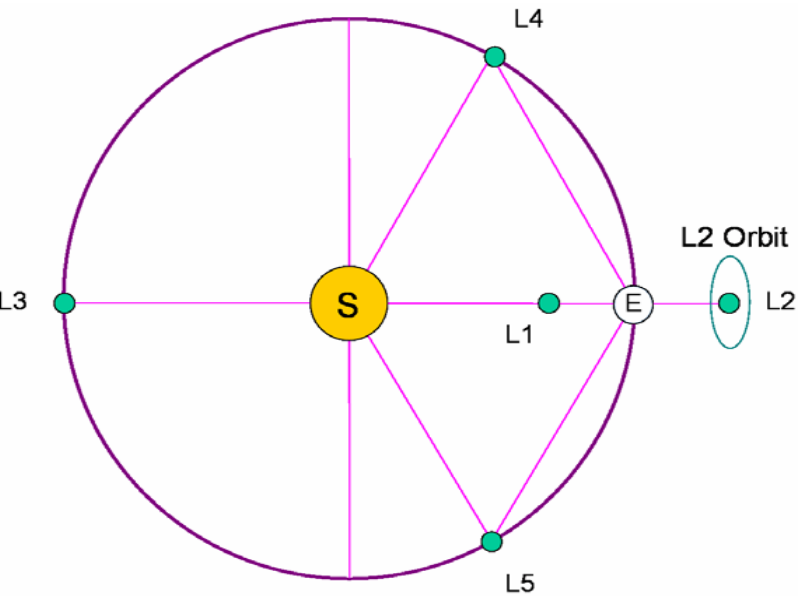
~1" resolution or somewhat better
(not necessarily diffraction limited)
High efficiency, low noise spectrograph (e.g. COS)

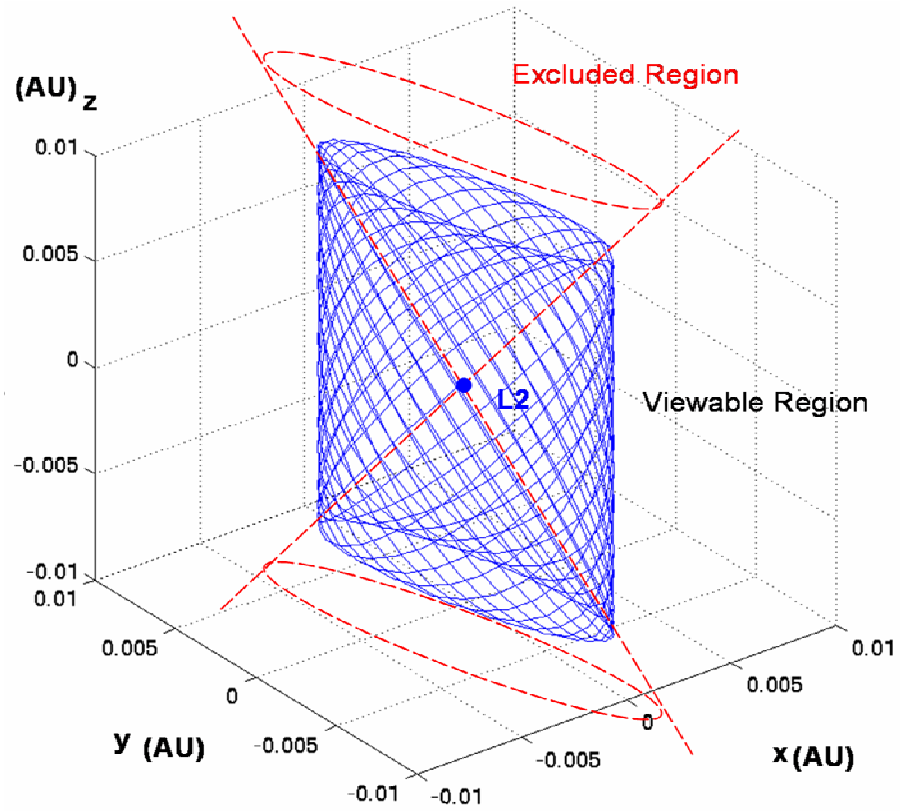
Reduces Noise Almost to Zero

		Detector Noise (counts)		
Diameter (m)	Required integration time (days) to get 100,000 counts	MCP_{glass}	MCP_{Si}	CCD
1	28	363	15	604800
5	1.1	15	0.6	24192
10	.3	4	0.1	6070
15	.1	2	0.06	2700
20	.07	1	0.04	1512

Assumptions: Fλ~3e-9 photons/cm2/sec/Å for Earth at 10pc, system efficiency ~0.35, λ=5000Å.
Background calculations done using MCPglass=0.5 counts/cm^2/sec, MCPsilicon=0.02 counts/cm^2/sec,
CCD=1e- read noise and readout every 20 minutes, and a 0.03x1 mm resolution element with 0.010 mm pixels.

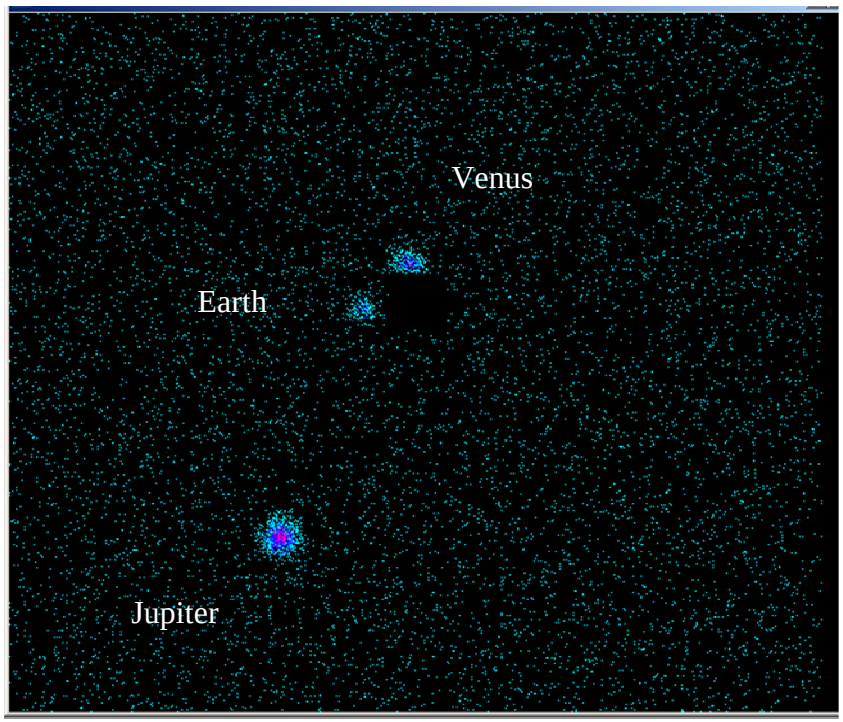
Orbital Considerations Need Study



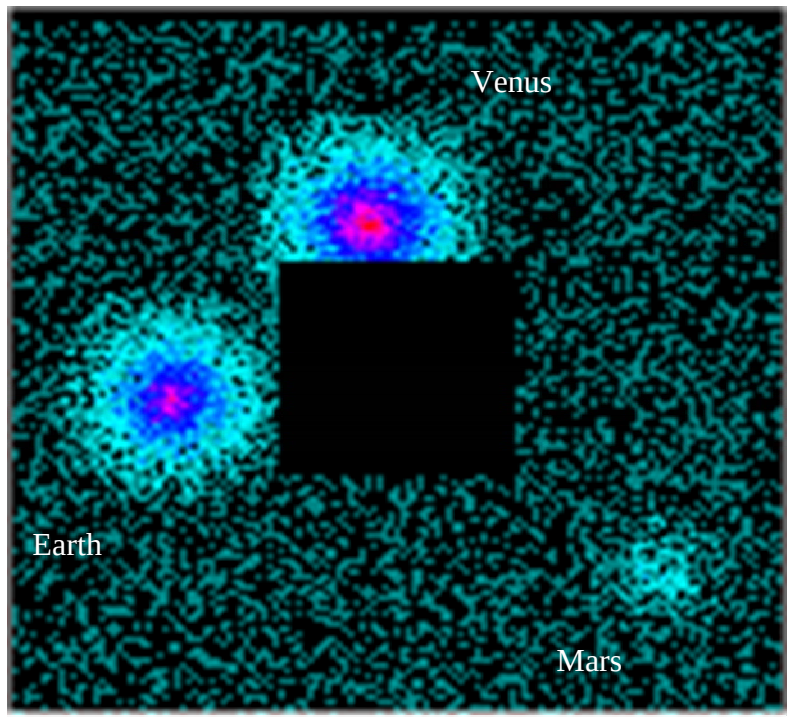


Planet Finding Mode

Solar System at 10pc



Survey to 7AU

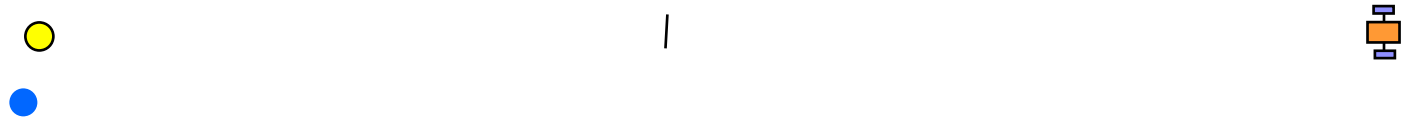


Survey Habitable Zone

Inverse Pinhole

Occulter

Pinspeck



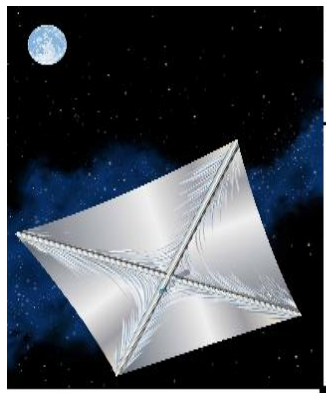
- Smaller Starshade
  - Create null zone, image around occulter
- 10m shade, 1m diffraction limited telescope and 20,000km separation would work
- Observe entire planetary system at once
- Highly affordable. Could build today

Predecessors

http://umbras.org/

Starkman showed that starlight could be reduced by 10,000x.

BOSS



Spokesperson: Glenn Starkman

Organization: CWRU

Phone: (216)368-3660

Email: gds6@po.cwru.edu

URL: http://boss.phys.cwru.edu

Collaborators: Caltech, JPL, L'Garde, Lockheed-Martin

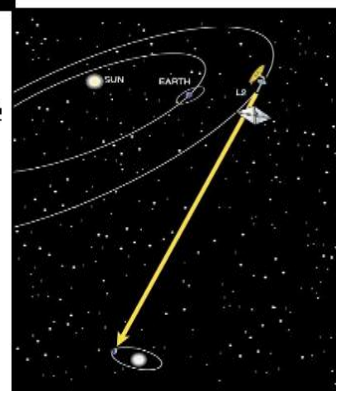
Funding: JPL, IPAC, NSF

MISSION CONCEPT:

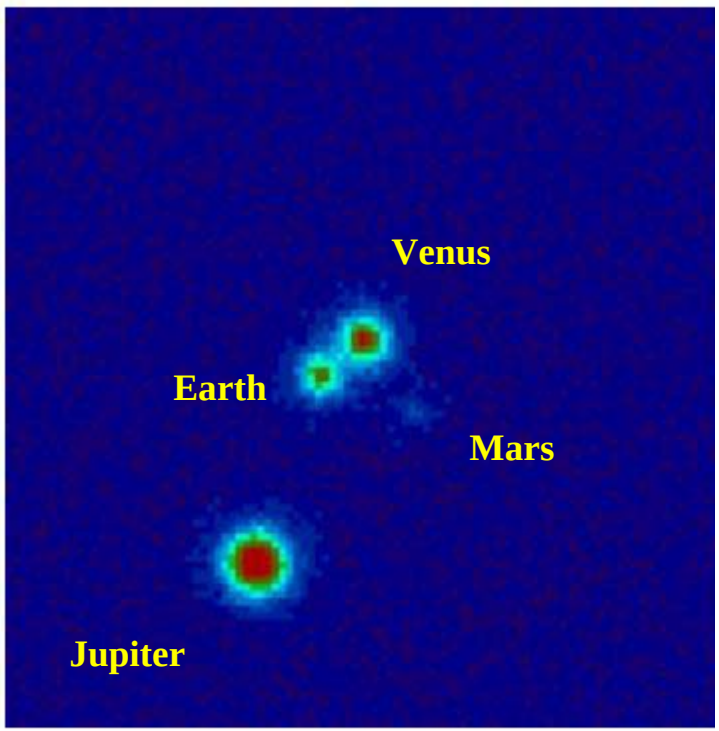
Deploy a large occulting satellite with a space telescope at L2

Occult nearby stars to discover and image planets

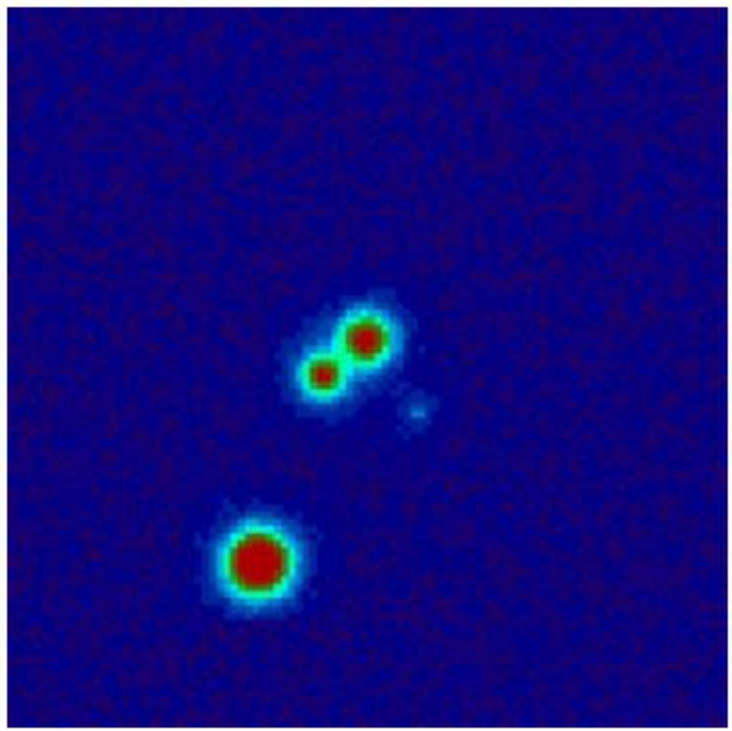
Do ultra-high resolution imaging of target sources



Pinspeck with 1m Telescope

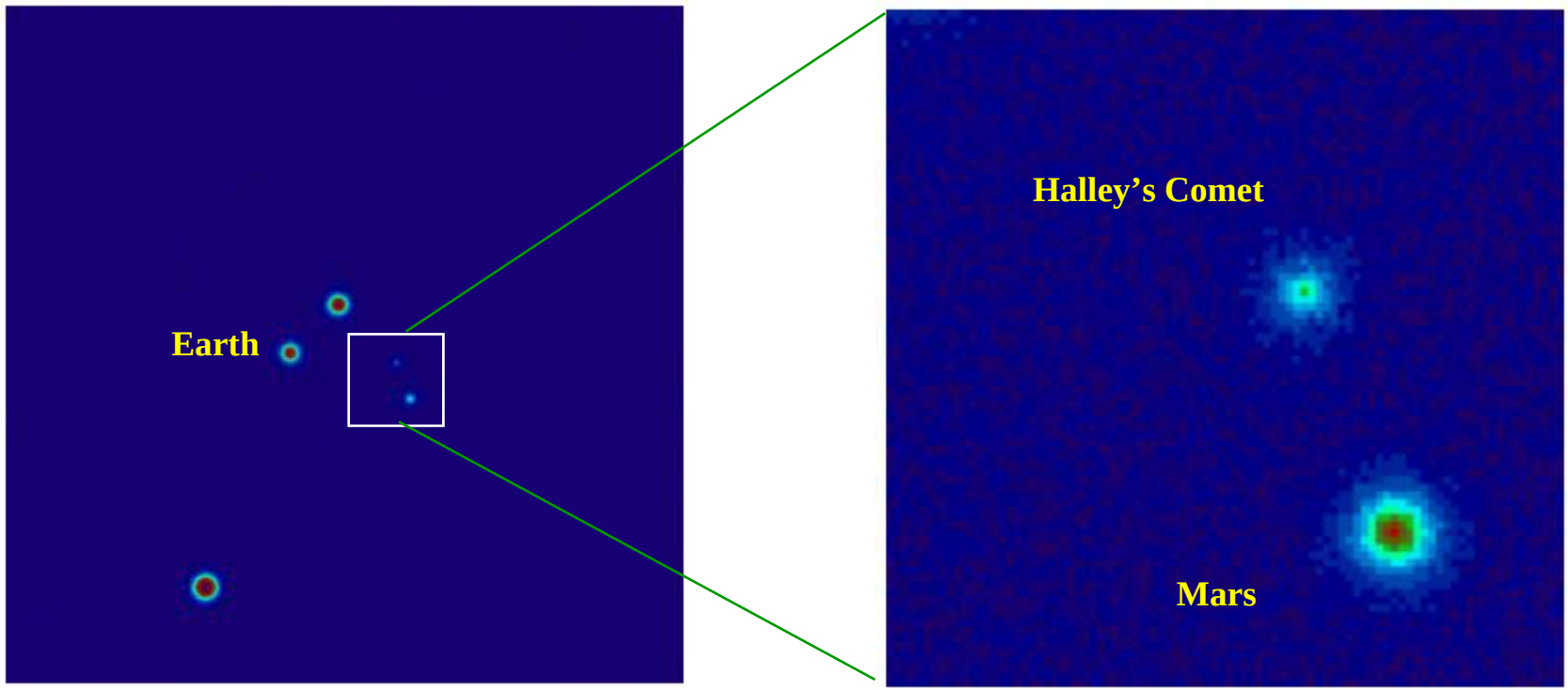


50,000 seconds

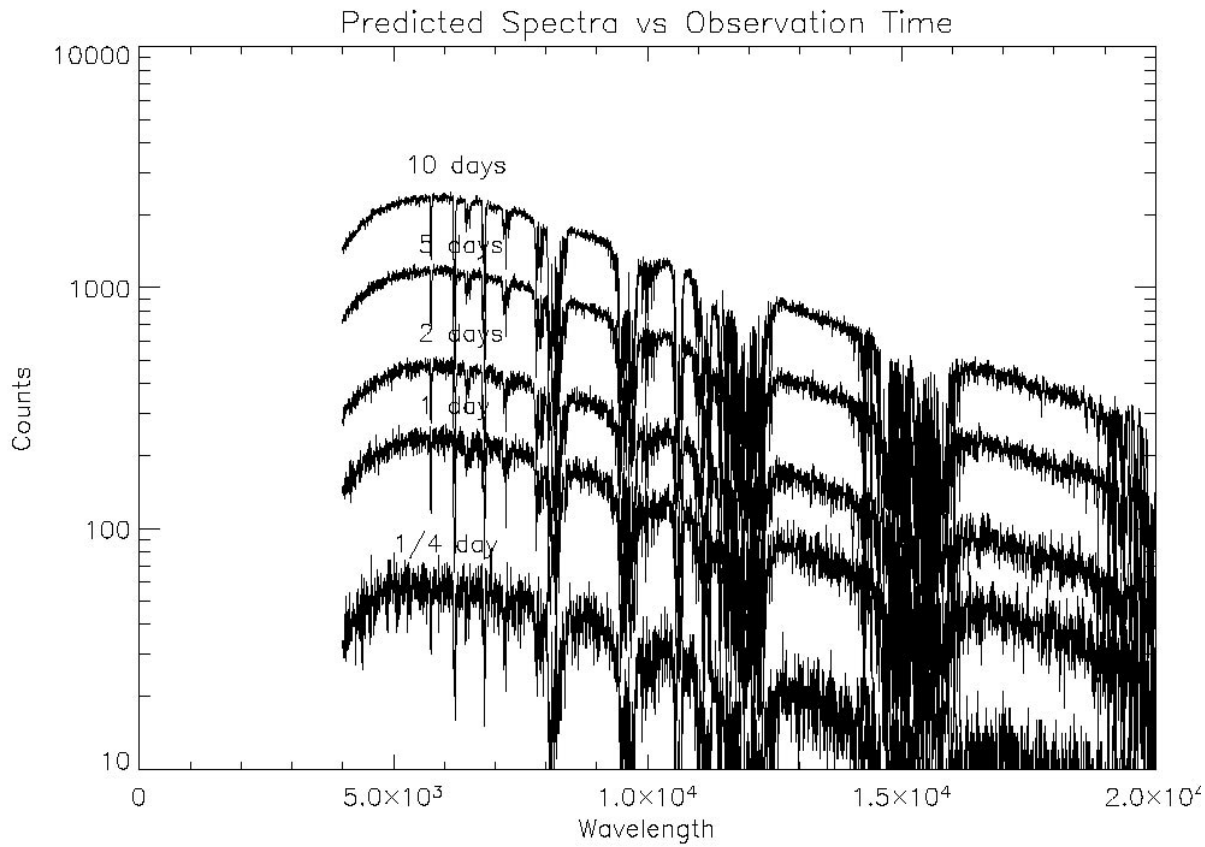


400,000 seconds

Pinspeck with 8m Telescope



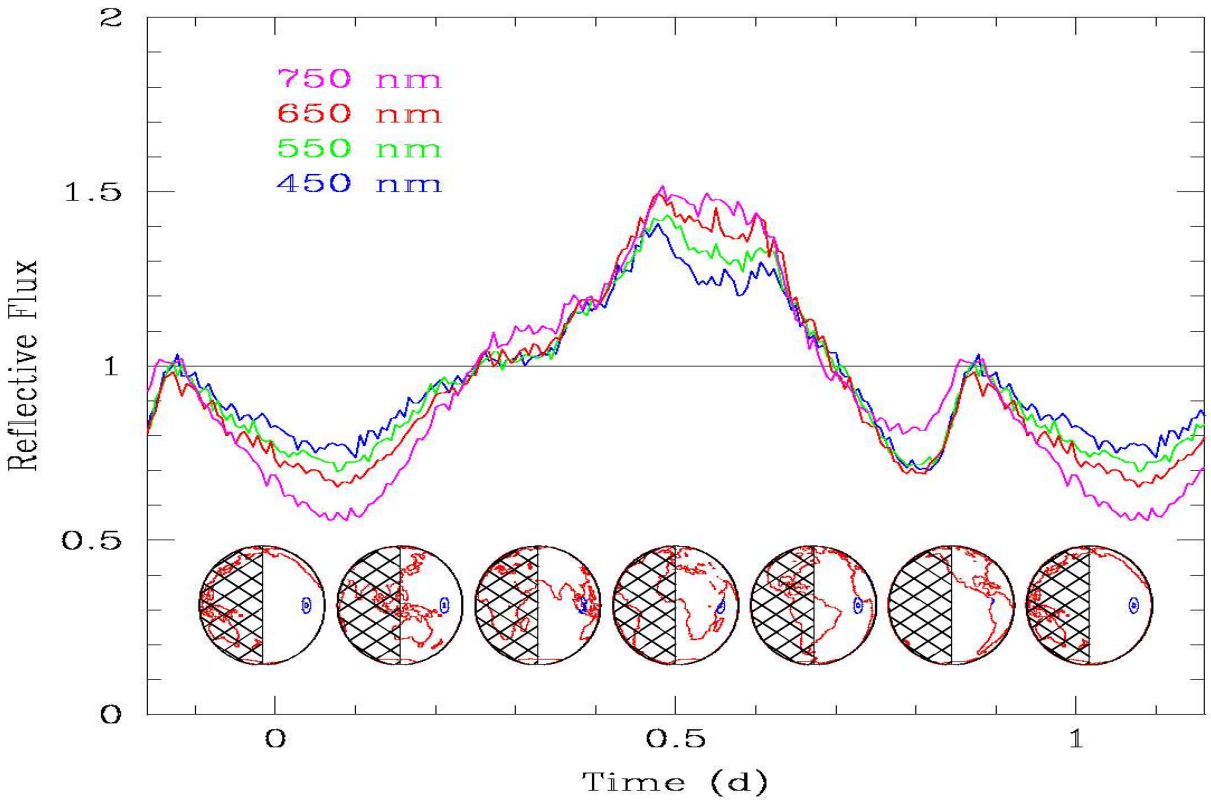
Simulated Data
Earth at 10pc



Spectroscopic Biomarkers

Water	Necessary for habitability
Oxygen	Free oxygen results only from active plant life
Ozone	Results from free oxygen
Nitrous Oxide	Another gas produced by living organisms
Methane	Life indicator if oxygen also present
Vegetation	Red edge of vegetation at 750nm

Photometry



Photometric Imaging is Possible!

Pale Blue Planet Mission

PBP Requirements

100km Resolution at 10pc is 0.06 micro-arcseconds

Interferometer requires a 1500km baseline
And the same collecting area as Keck Telescope in Hawaii
(10 meter diameter)

We can do this right now if we have the will.

The "Freeway Mission"

From the movie Contact.
Dr Arroway gets a brief glimpse of this alien landscape.

Freeway Requirements

300m resolution at 10 parsecs = 0.02 nano-arcseconds

500,000km baseline

Huge collecting area – one square kilometer

Right now this is impossibly expensive,

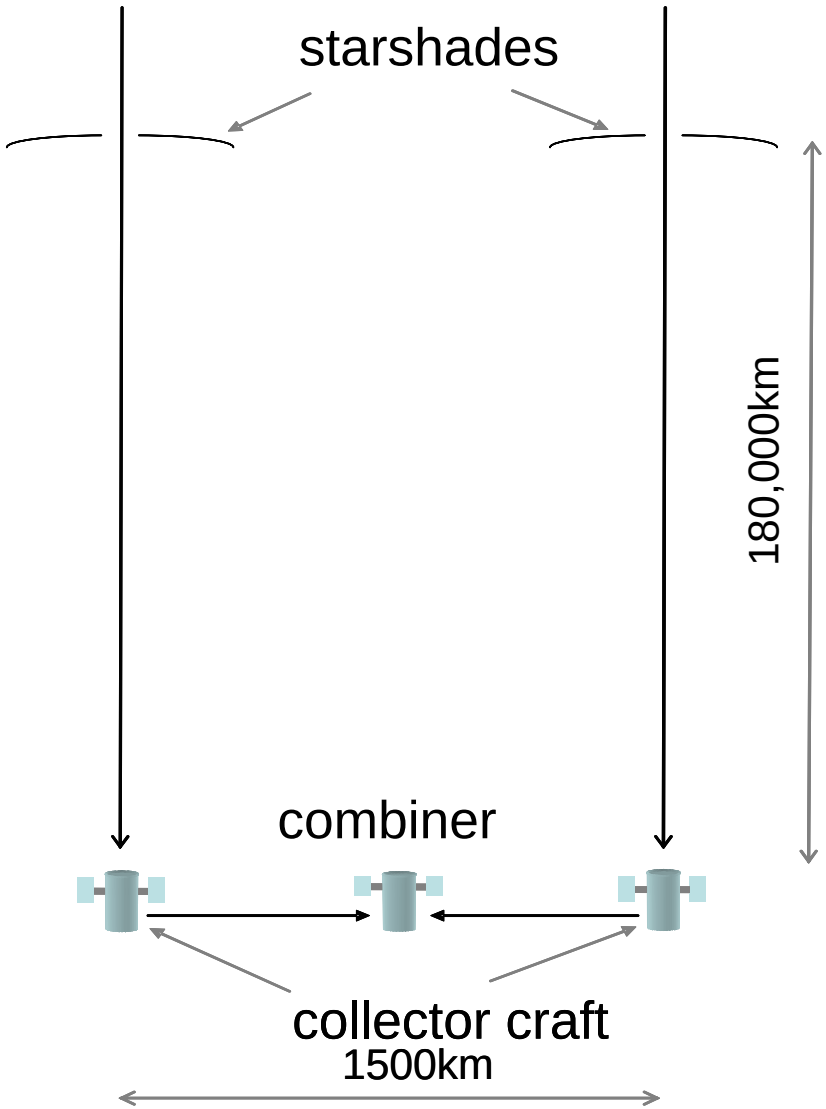
but not necessarily tomorrow

The New Worlds Imager

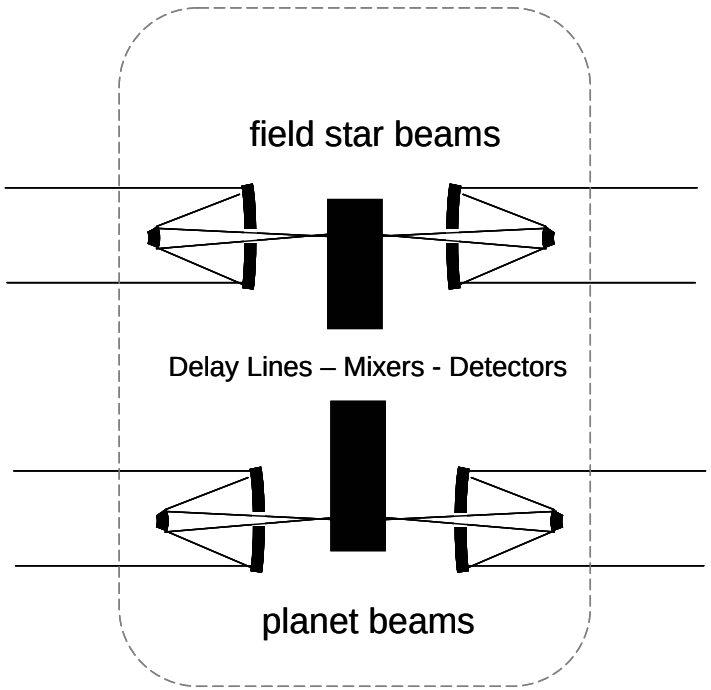
Earth at 200km resolution. Oceans, continents and clouds are visible.

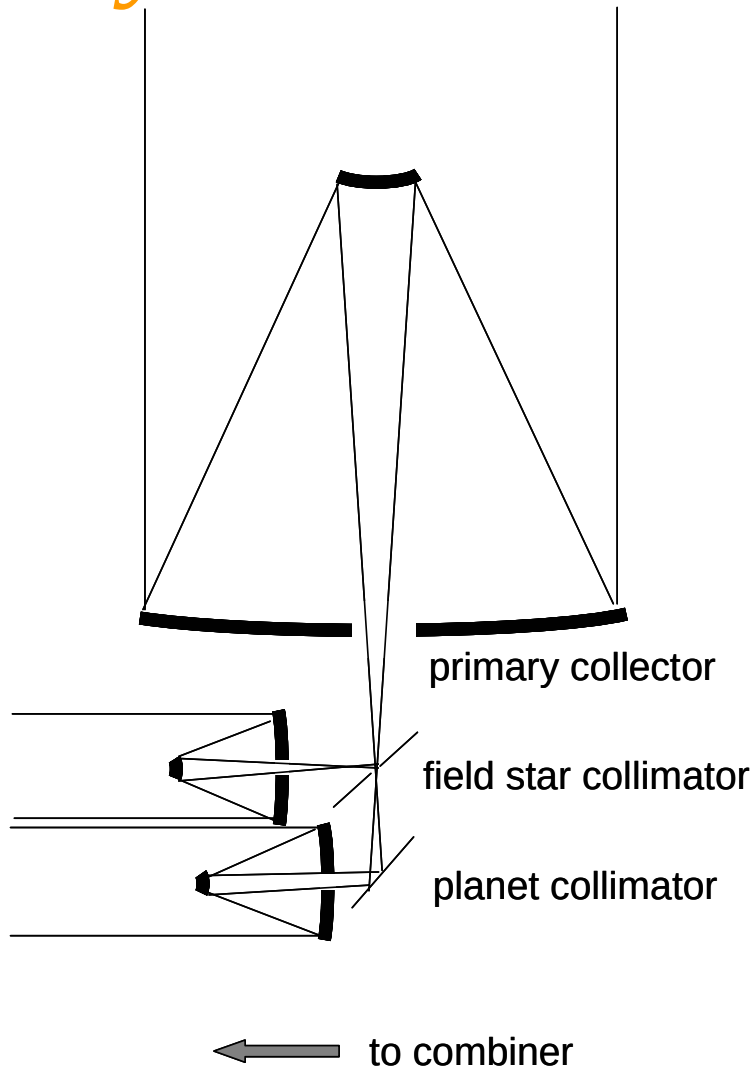
A simulated exo-planet at 500 km resolution.

NWI Concept

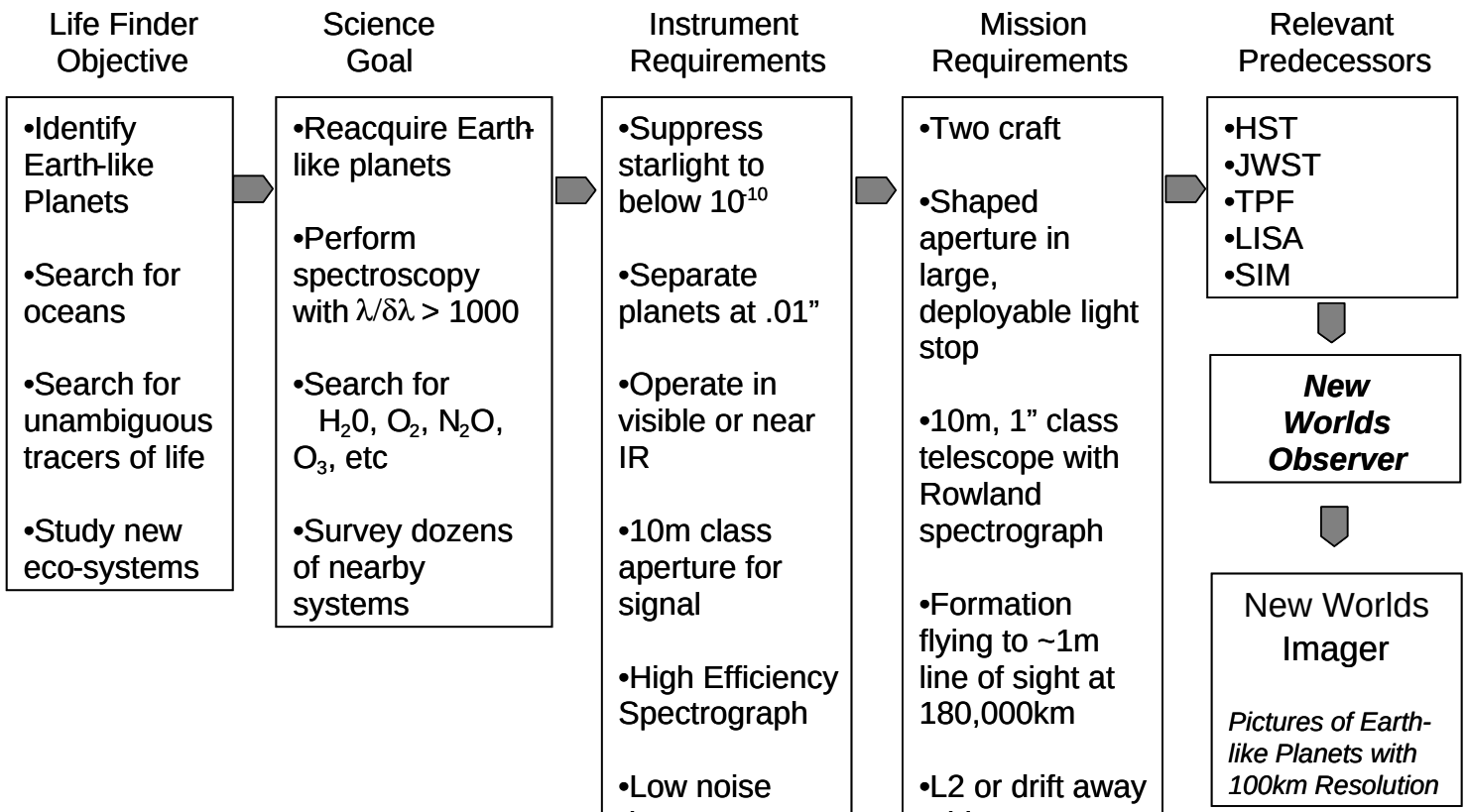


Holding the Array





Fits Into NASA Planning



New Worlds Observer Roadmap

- Pinspecks vs Pinholes
- Minimize Size (and hence cost)
- Deployment of Starshade
- Orbit Tradeoff
- Formation Flying
- Telescope Design
- Simulations and Limitations

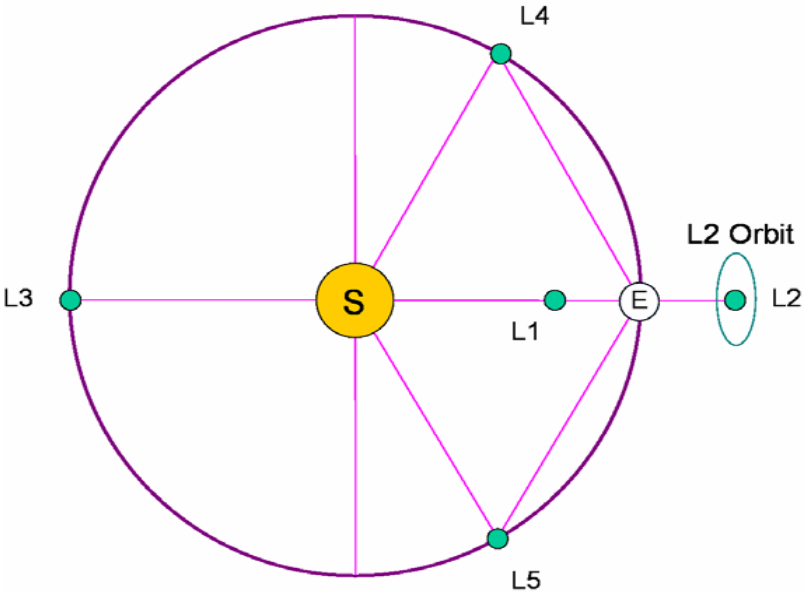
New Worlds Imager Roadmap

- Formation Flying Requirements
- Interferometer Design
- Image Formation
- Pathlength Nulling
- Simulations

N.B. NWI is very challenging, but it's the first true planet imaging architecture for which we can write specifications that are not ridiculously difficult.

Size Minimization

- Pinspeck if at all possible
- Diffraction dominates signal but drops with size of starshade.
- I have five mathematicians working on the problem. (N.B. Mathematicians are not used to working on deadlines!)



Orbital Analysis

At L4, L5 or any Sun-centered orbit, it takes .001N continuous thrust to keep a 1000kg craft in alignment.

Milli-Newton thrusters are now available, and a few square meters of solar panels can power it.

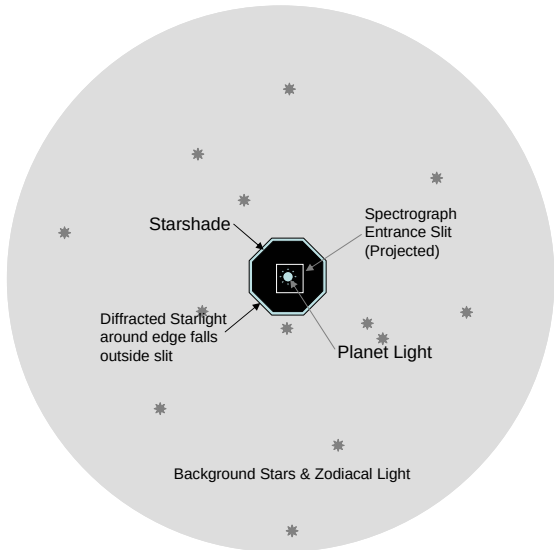
These thrusters can move the starshade to the next target in a day or two. 50 planetary systems per year.

Formation Flying

1W laser can be seen at 200,000km.

Can track relative to back ground stars.

Craft need to be designed to find each other and align against sky.

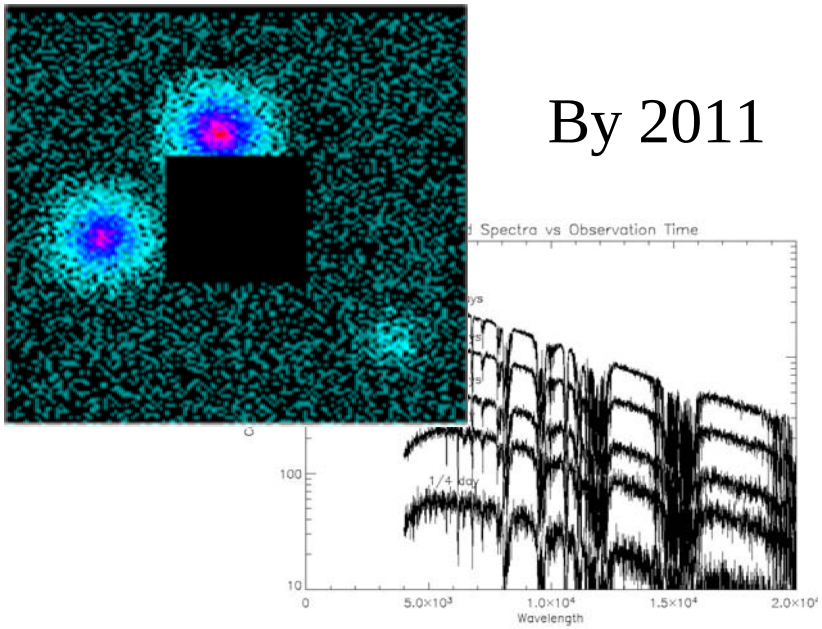


NIAC: They Bring Good Things To Life

- Press Interest
  - Publicity Crucial to Shifting Opinions
- Industry Interest
  - Northrop Grumman Putting in Resources
- Government Interest
  - White Paper Put Us in NASA Roadmap
  - Goddard Studying This as Alternative
    - TPF Off-ramp?

Conclusion

By 2011



- Needs *Thorough* Study
- If No Major Problems Emerge, then…
- We have an exo-planet observatory concept that can be implemented with today's technology
- Biggest Problem may be political

By 2018