New Worlds Observer Occulter Performance

TPF/Darwin Conference
Amy S. Lo
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Jonathan Arenberg
Webster Cash
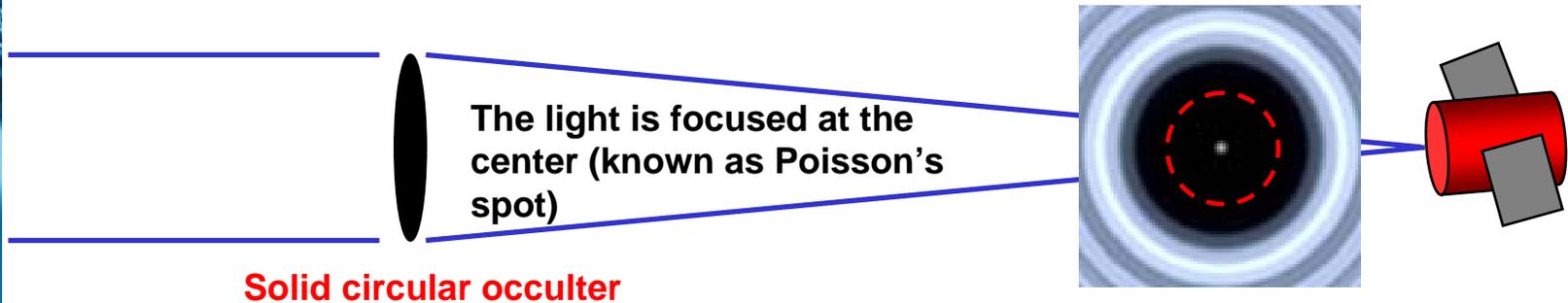**Chuck Lillie**

What is New Worlds Observer?

External Occulter + **"Generic" Space Telescope** = **Find Terrestrial Planet**

This Talk: **How does NWO work? What's the Advantage?**
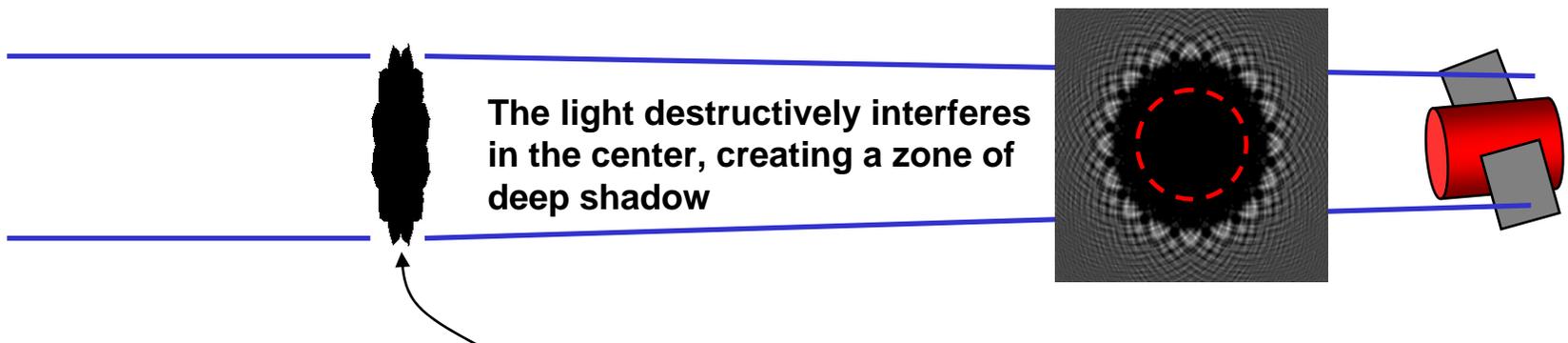
New Worlds Occulter Operates in the Fresnel Regime

Diffraction around a solid circle

Telescope flies in the shadow

The light is focused at the center (known as Poisson's spot)

Solid circular occulter

http://daugerresearch.com/fresnel/PoissonAragoStory.shtml

Diffraction around an "apodized" occulter

The light destructively interferes in the center, creating a zone of deep shadow

Special petals shaped to cause destructive interference in the optical near field
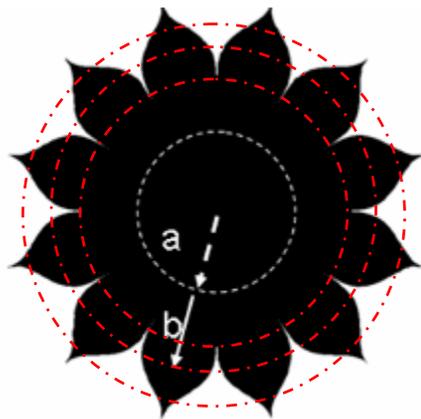
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NWO Is Buildable

- **Apodized Occulter**

  Webster Cash's Hypergaussian function

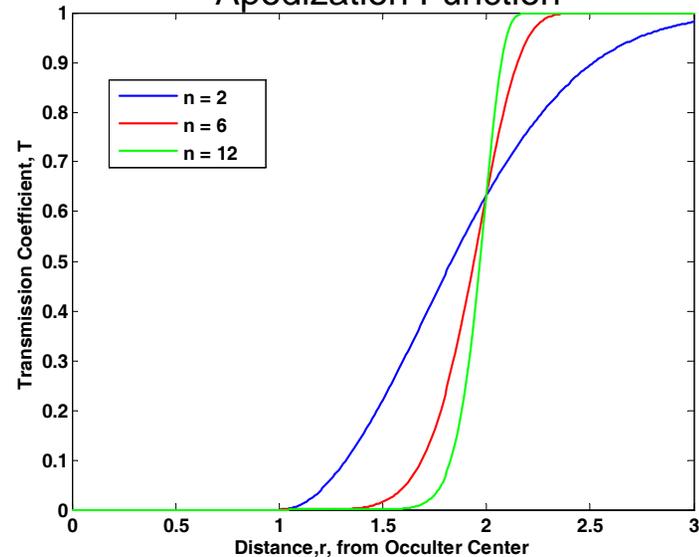 $$T = \exp\left(-\left[\frac{r-a}{b}\right]^n \right)$$
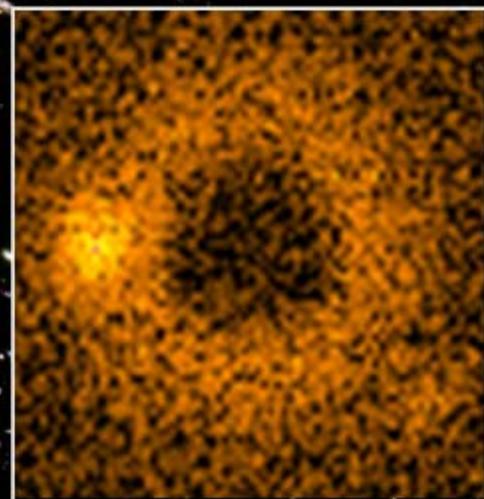
- **Binary Apodization**

Azimuthal sum of fraction of opaque to transparent area conforms to apodization function

Telescope Flies in Occulter's Shadow

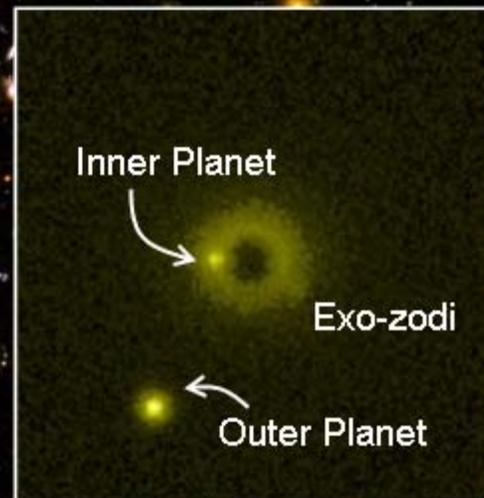- **Occulters blocks on-axis star light**
- **Telescope looks at off-axis star light to observe companion**
- **The occulter shadow is very black**
  - Capable of creating 10^{-10} or better contrast suppression
- **Occulter size is generally 10's of meters**
- **Occulter and Telescope separation is 10,000's of km**

planet

Target Star

NWO Occulter

Telescope

A13882_040
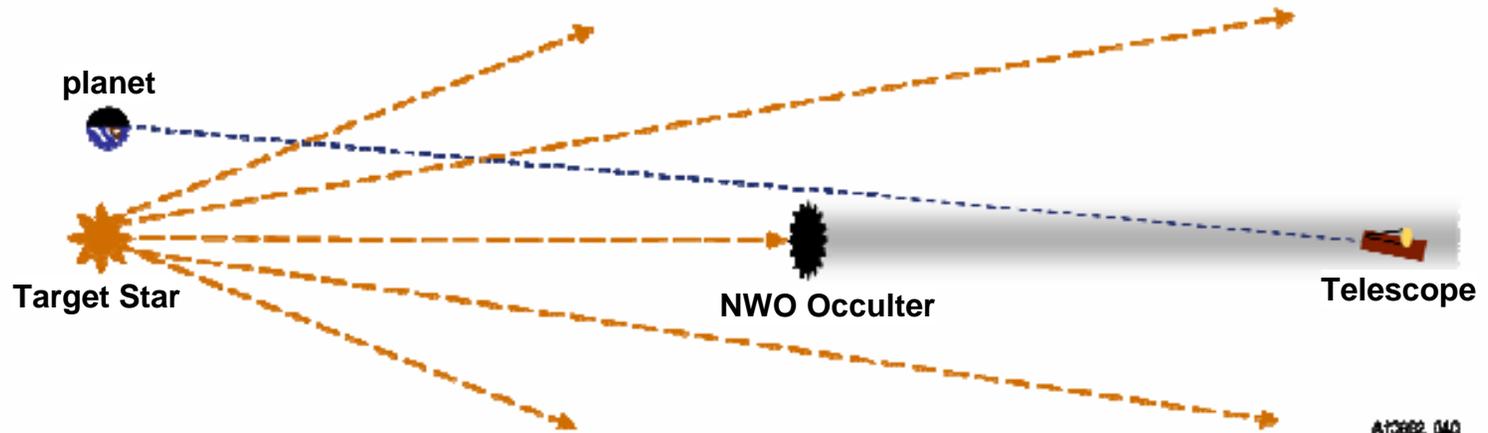
Survey Occulter

Deep Look Occulter

Inner Planet

Exo-zodi

Outer Planet

Useful Throughput

- **Basis for comparison between occulter and coronagraphs**

"Useful Throughput" =
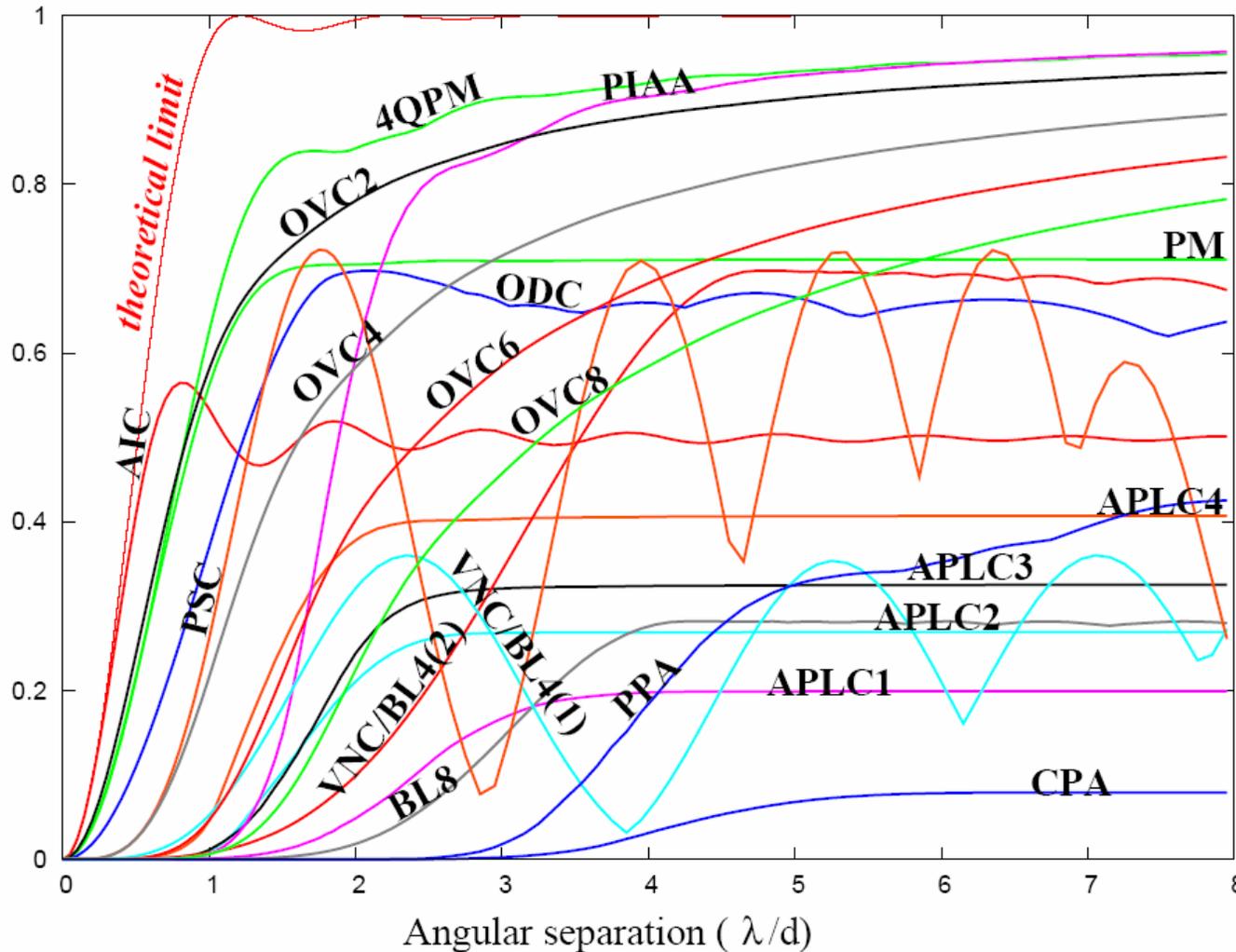$$\dfrac{\displaystyle\sum_{n} F_p}{\displaystyle\sum_{N} F_p}$$

Where

n = pixels in bold black area, where flux from star equals flux from planet
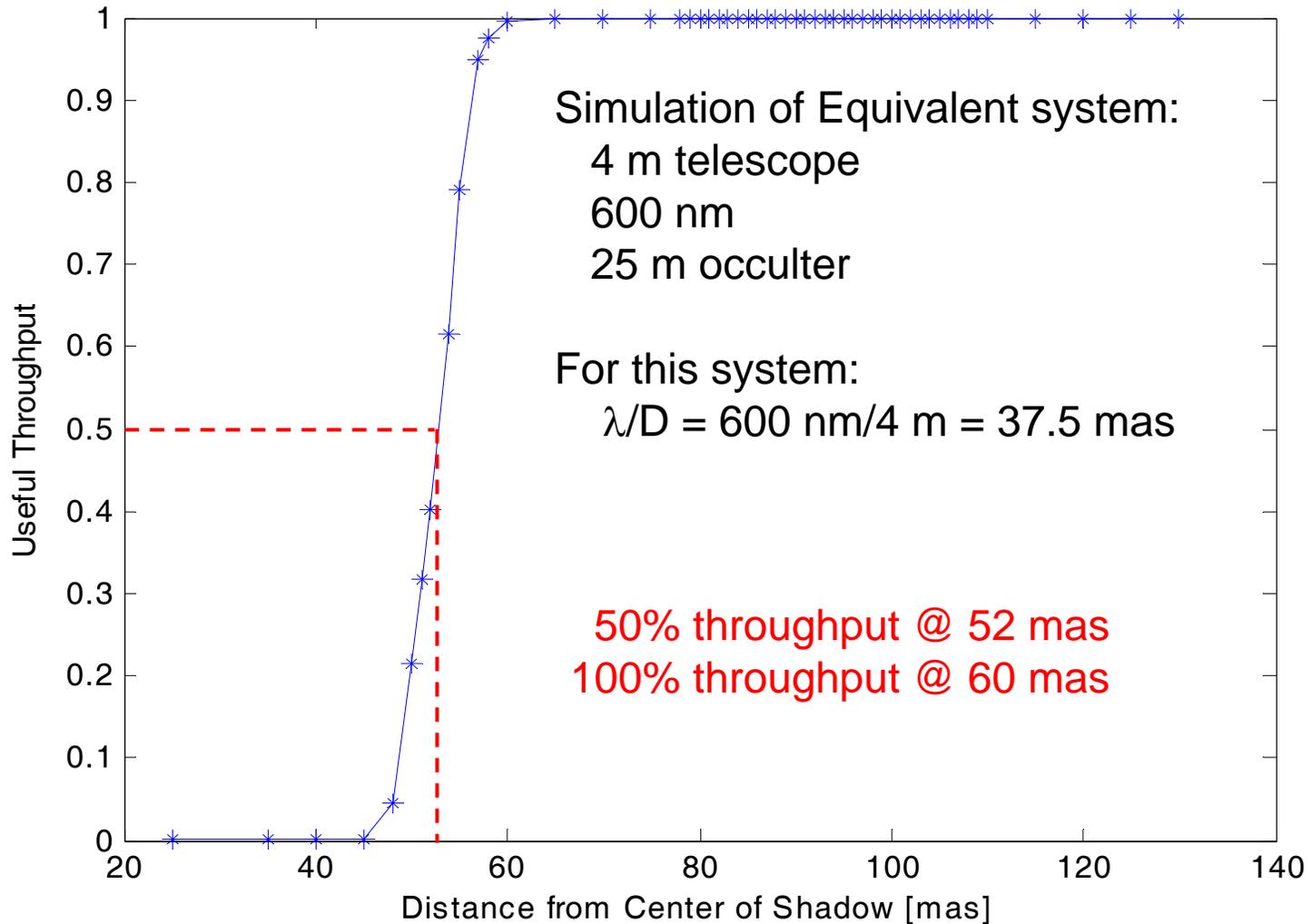
N = all pixels with planet light

Guyon et al. 2006
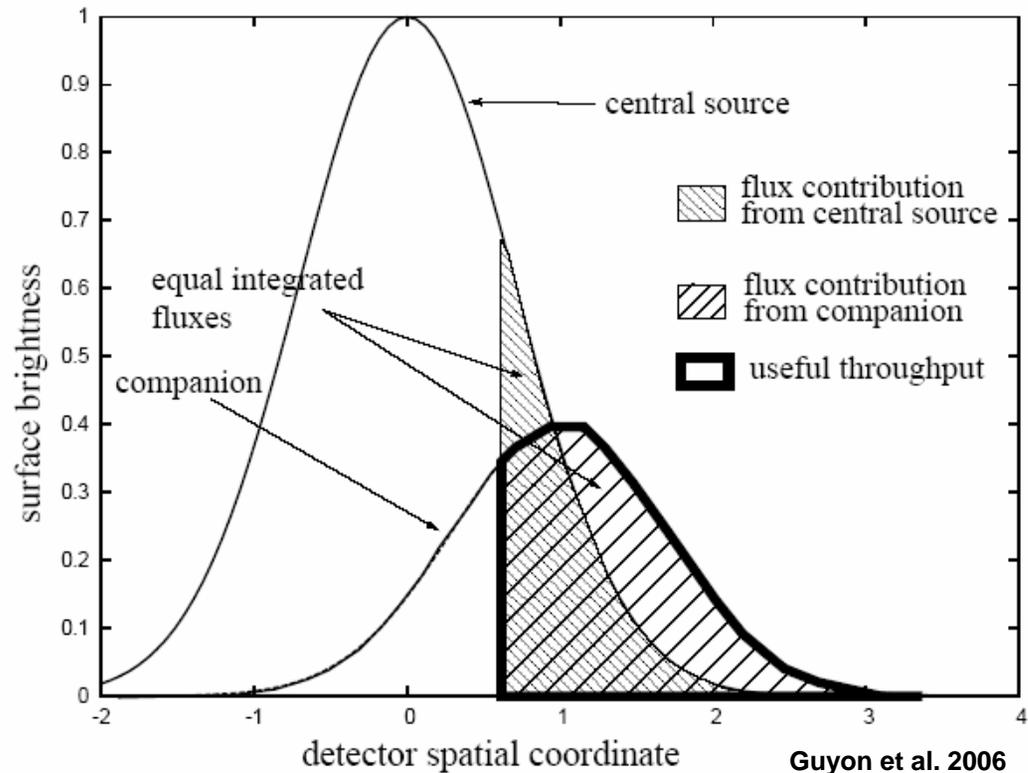
Coronagraph Throughput

Point source / Peak throughput

O. Guyon 2006

NWO Useful Throughput Reaches 1

Simulation of Equivalent system:
   4 m telescope
   600 nm
   25 m occulter

For this system:
   $\lambda/D = 600$ nm/4 m $= 37.5$ mas

50% throughput @ 52 mas
100% throughput @ 60 mas

Useful Throughput

Distance from Center of Shadow [mas]

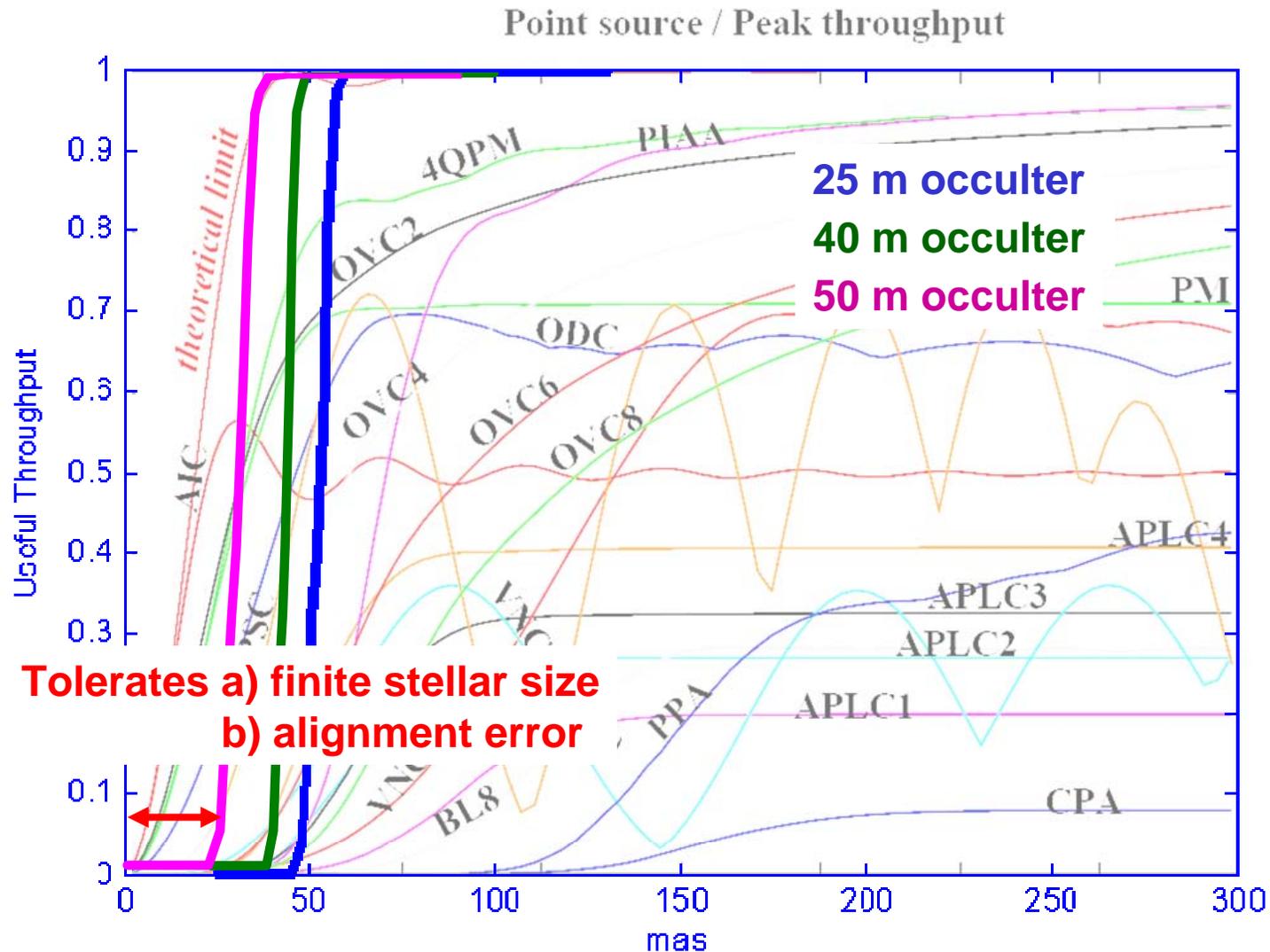**NORTHROP GRUMMAN**

NWO Has High Throughput

Point source / Peak throughput
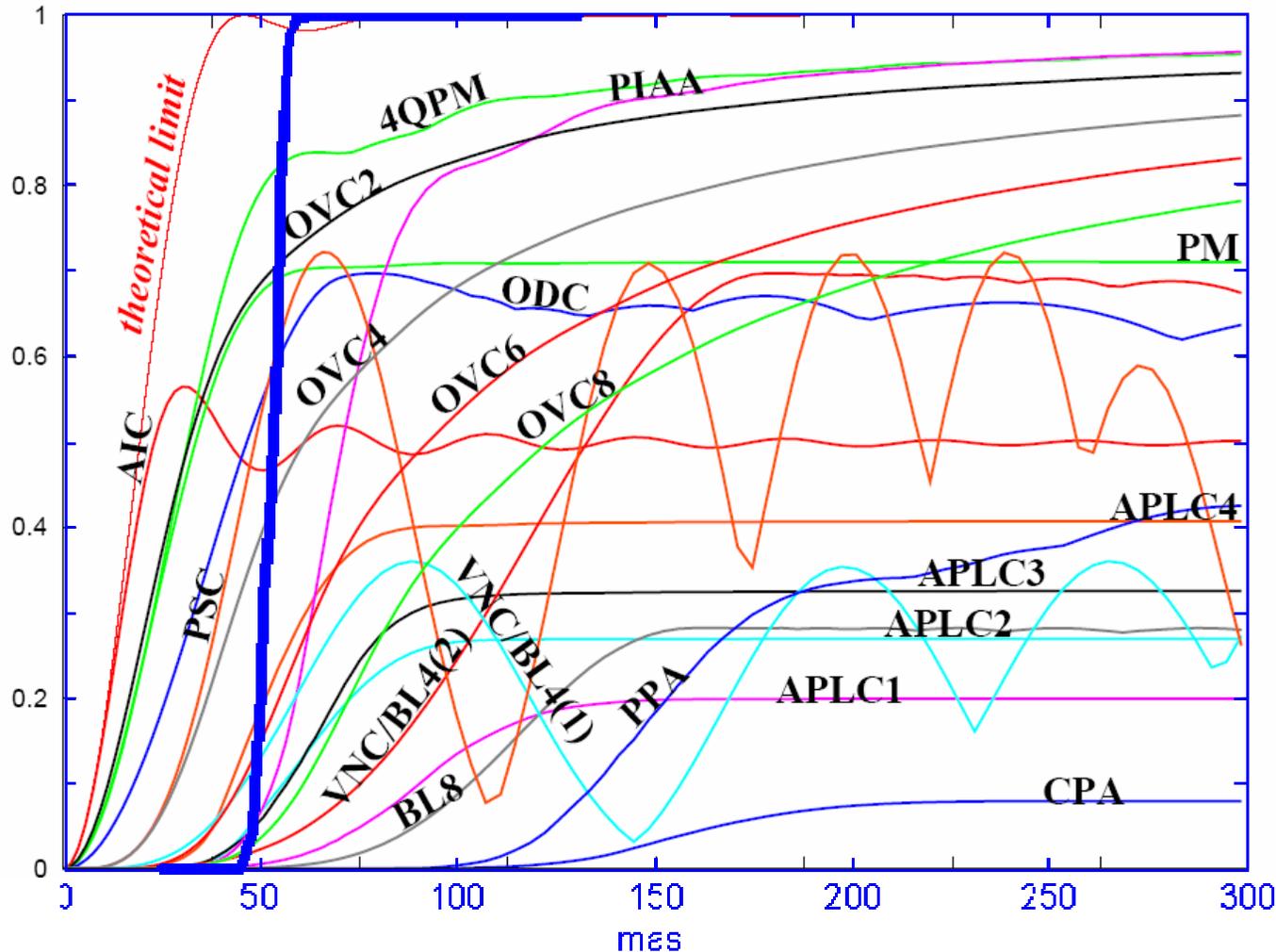
Occulter throughput reaches 1, higher than any other method

Transformed using λ = 600 nm and D = 4 m

Coming Soon… Different Occulters

Point source / Peak throughput

25 m occulter
40 m occulter
50 m occulter

Tolerates a) finite stellar size
b) alignment error

IWA = occulter radius/telescope separation

Experimental Results from Webster Cash

- **Experimental test occulter set up at CU (35 mm occulter)**
- **Piped sunlight through a pinhole, down a dark, 45 m tunnel**
- **Measured shadow depth (irradiance) with scanning photometer**
- **Measured 3x10^{-7} contrast suppression *in air***
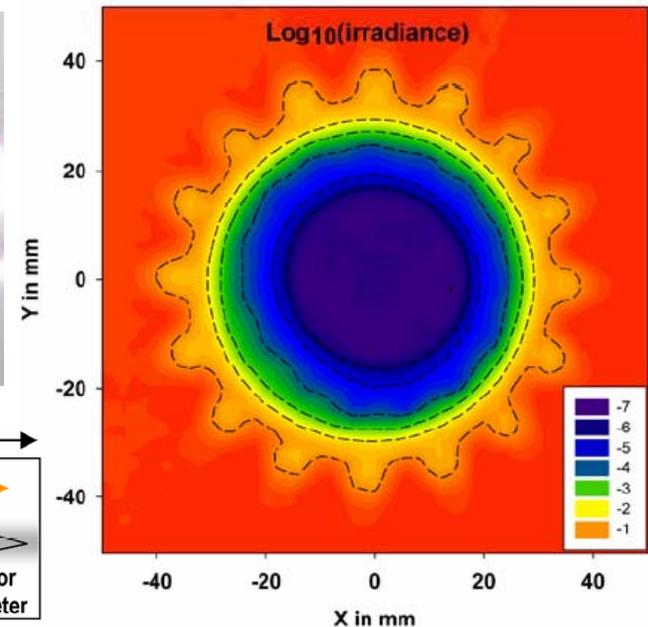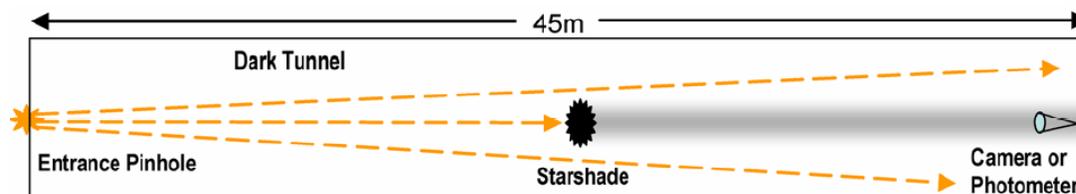
Conclusion and Future Work

- **Conclusions**
  - NWO achieves throughput = 1
    - Less starlight enters the telescope to allow maximum throughput
    - Better throughput than any coronagraph
  - NWO can be built to the necessary IWA
    - Different sized occulters have different IWA
    - Insensitive to telescope aperture size
- **Future Work**
  - More occulter useful throughput data
  - Finer mesh optical simulation for better fidelity
  - Laboratory occulter test in vacuum

Please come see Tiffany Glassman's NWO poster

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