New Worlds Observer Occulter Performance

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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

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

Solid circular occulter

Telescope flies in the shadow

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
**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

  ![Diagram](image)
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
Useful Throughput

- Basis for comparison between occulter and coronagraphs

“Useful Throughput” = \[ \frac{\sum_{p} F_p}{\sum_{N} F_p} \]

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

Guyon et al. 2006
Coronagraph Throughput

Point source / Peak throughput

Angular separation (λ/d)

Coronagraph Throughput

O. Guyon
2006
NWO Useful Throughput Reaches 1

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

For this system:
\( \lambda/D = 600 \text{ nm}/4 \text{ m} = 37.5 \text{ mas} \)

50% throughput @ 52 mas
100% throughput @ 60 mas
NWO Has High Throughput

Point source / Peak throughput

Transformed using $\lambda = 600$ nm and $D = 4$ m

Occulter throughput reaches 1, higher than any other method
Coming Soon... Different Occulters

Point source / Peak throughput

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 $3 \times 10^{-7}$ 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