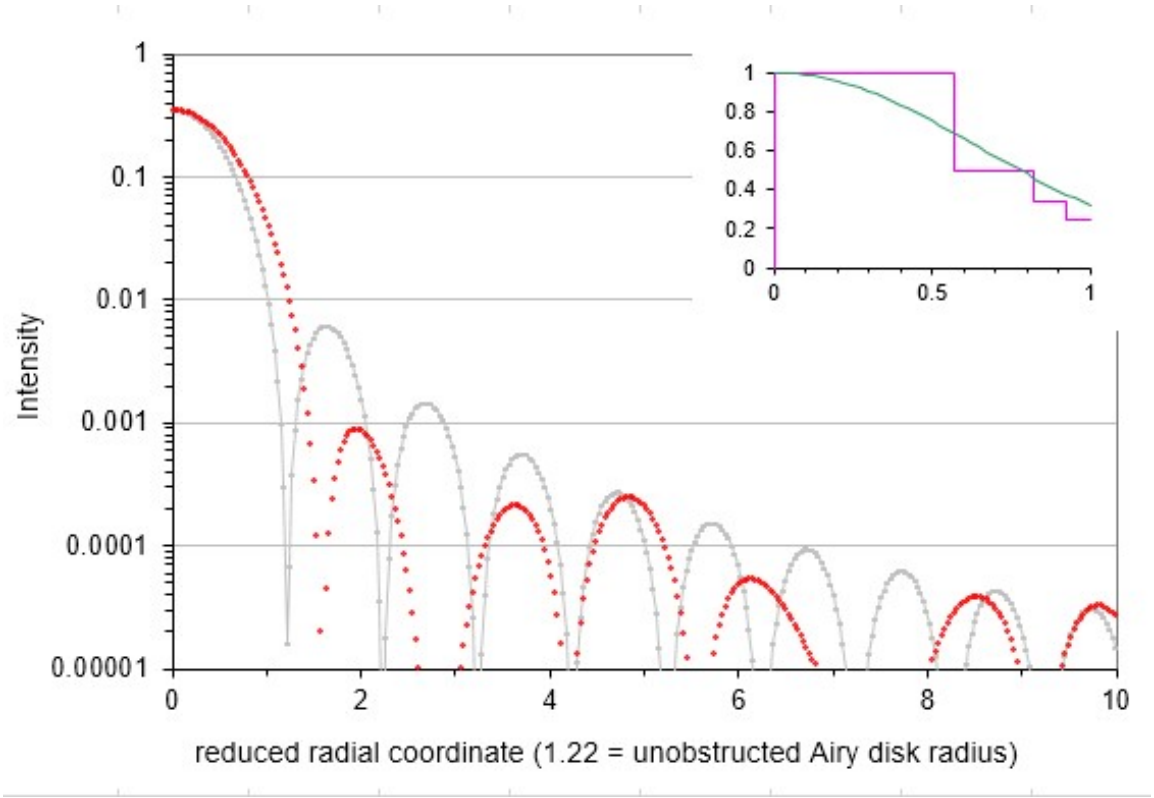
Amateur one-dimensional apodizing masks

By Dick Suiter & Emmanuele Sordini (www.bloomingstars.com)

An apodizer is an aperture mask used to shape the diffraction behavior. It cannot lessen diffraction, but shove it around like a kid rearranging vegetables on a plate.

This is a 20-in two dimensional apodizer made of window screen

2D mask:



From ApodizeTut.xlsx
Under TM tab at
www.bay-astronomers.org

12% improvement
in EER(1.22)

Works kind of so-so, can only vary the radii and number of zones. Can't vary the transmissivity of the screen.

Double-star photography needs the apodization only along a line, however!

I will concentrate on 1D apodizers that are easy to build for an amateur. Lots more elaborate apodizers have been built or envisioned by professionals, but those are theoretical devices or apodizers designed to be fitted to coronagraphs (devices with intermediate foci and blocking).

My collaborator is Emmanuele Sordini, an astrophotographer who lives in the Italian Alps. I have never met him. He did the maskmaking and photography, I did the theory and library reading.

Photographing unequal double stars can be quite difficult. A magnitude difference of 5 magnitudes is a factor of 100 in raw brightness. The dim star is caught in the glare of the bright star, and the separation is quite small.

Sirius A and its white dwarf companion Sirius B is separated by 11 arcseconds (nearly the maximum) and the difference in magnitude is 9.9 (factor of 9100). See how an unmasked C11 images it…

Uneven double stars

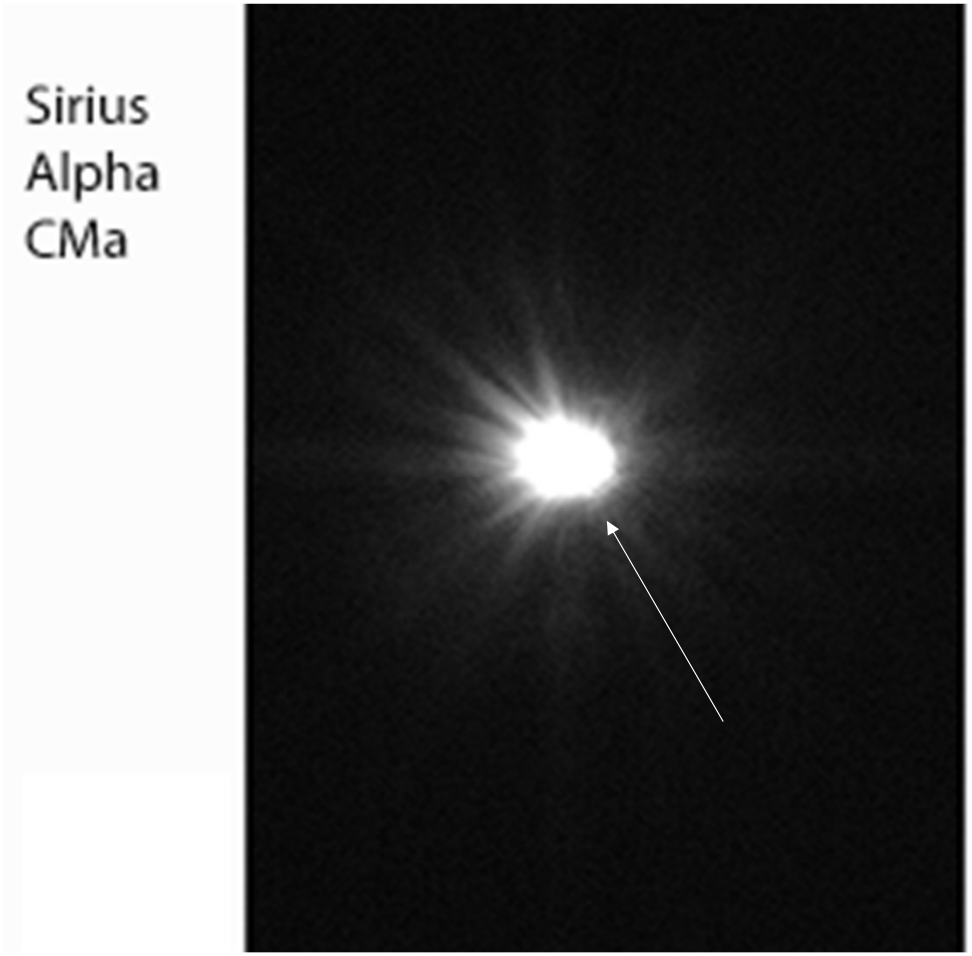


photo by E. Sordini

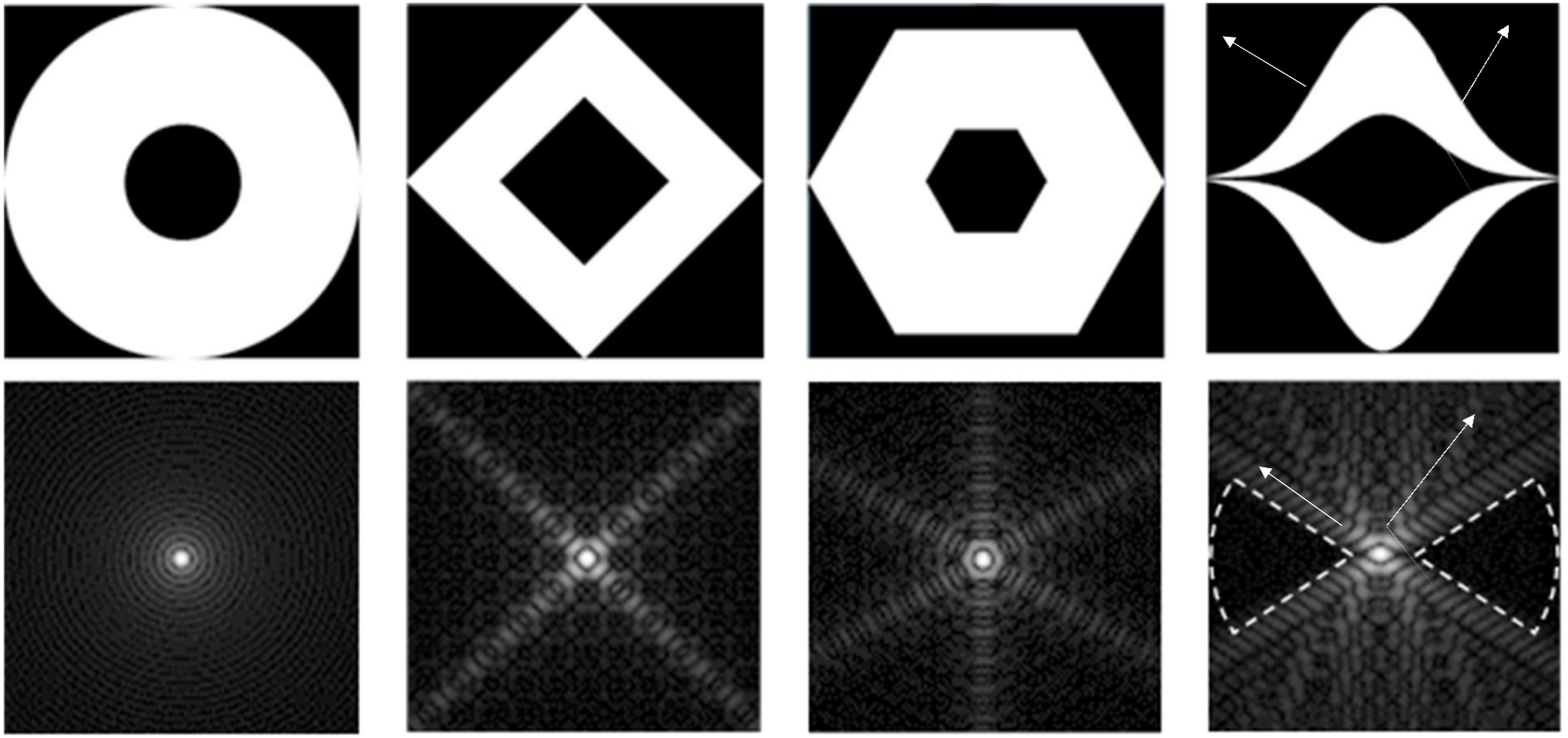
This is without a mask.

See how the white-dwarf companion is buried in the diffraction and scattering of Sirius A.

Maybe it’s this spike and maybe it’s not.

What can be done about this?
FFT modeled masks…

No mask | square or diamond | hex | Gaussian



Inflection point is maximum slope

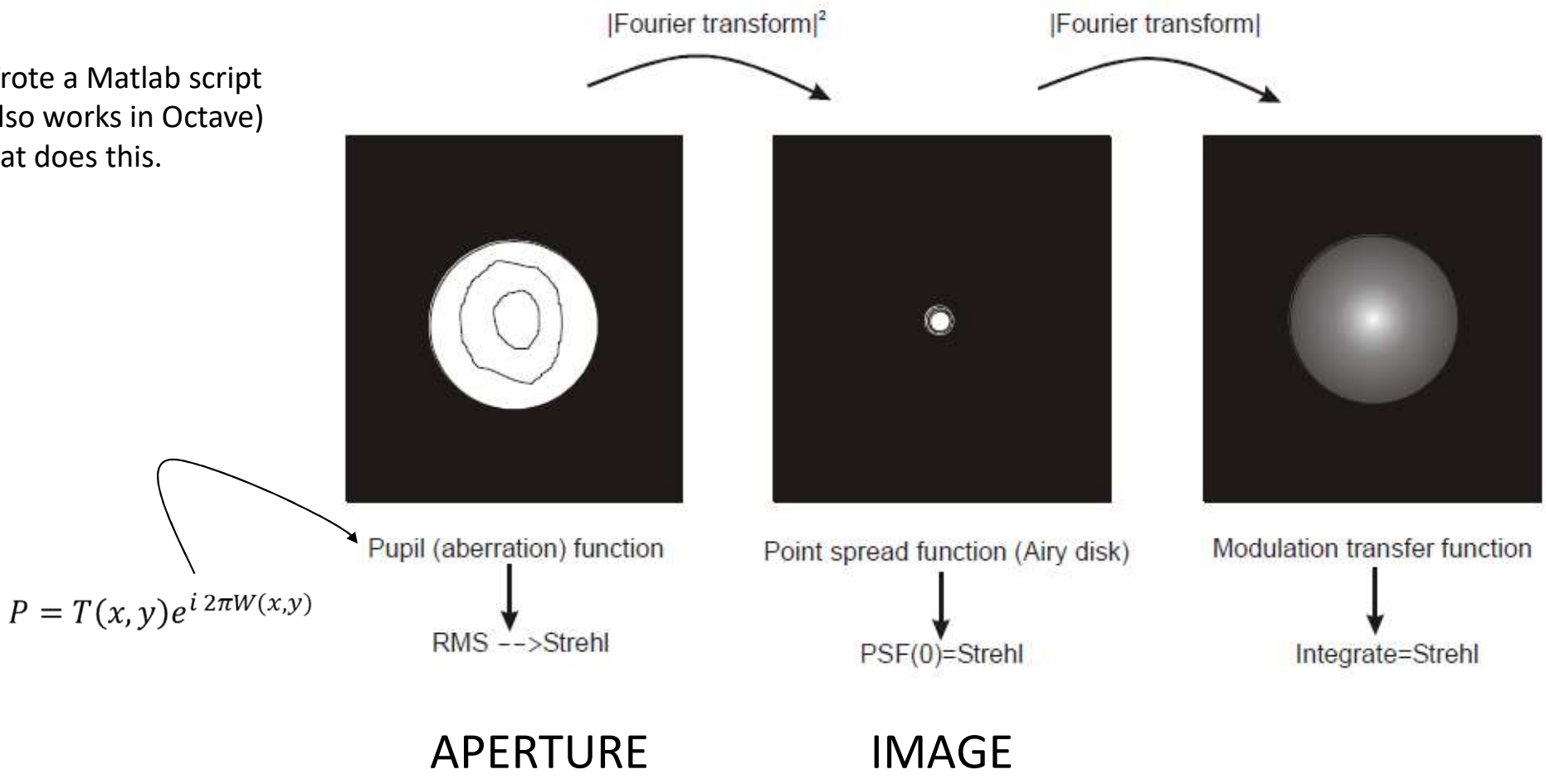
Important: Secondary must also be covered with mini-apodizer

Note extreme darkness!

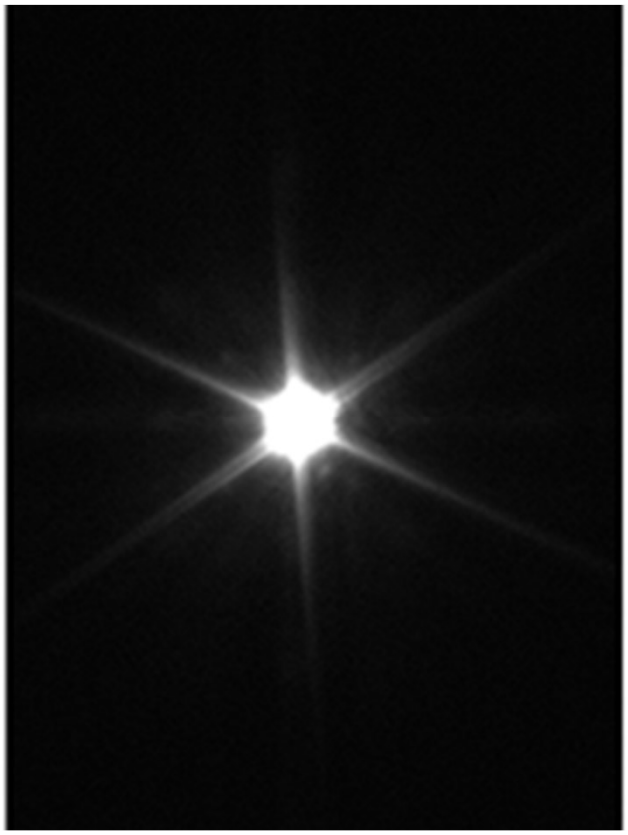
Contrast is stretched

The way these modeled images were calculated

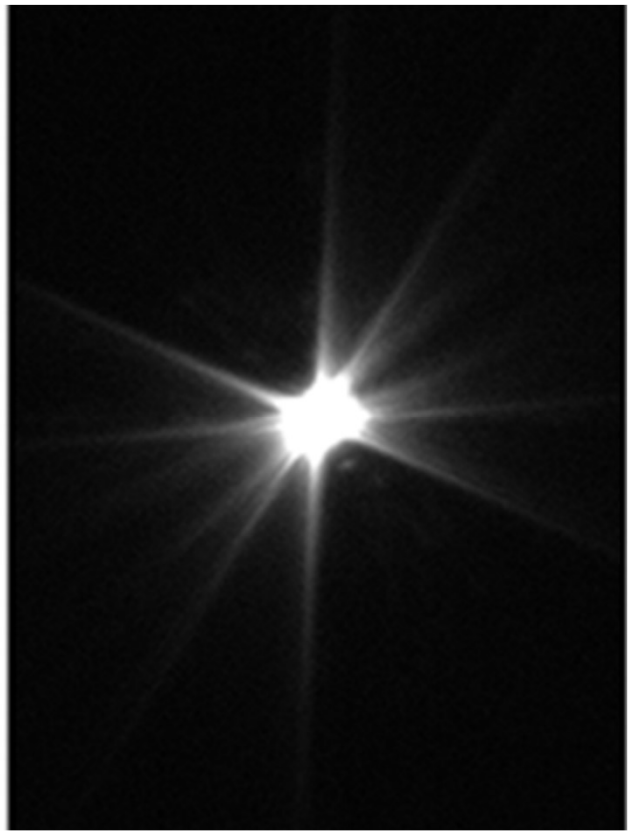
Wrote a Matlab script (also works in Octave) that does this.



Hex



Gaussian



Sirius A/B with aperture masks

Separation current to imaging is ~11 arcsec, but nearly 10 magnitudes different!

The hex mask is not a ‘designed’ apodizer, but acts similarly

photos by E. Sordini

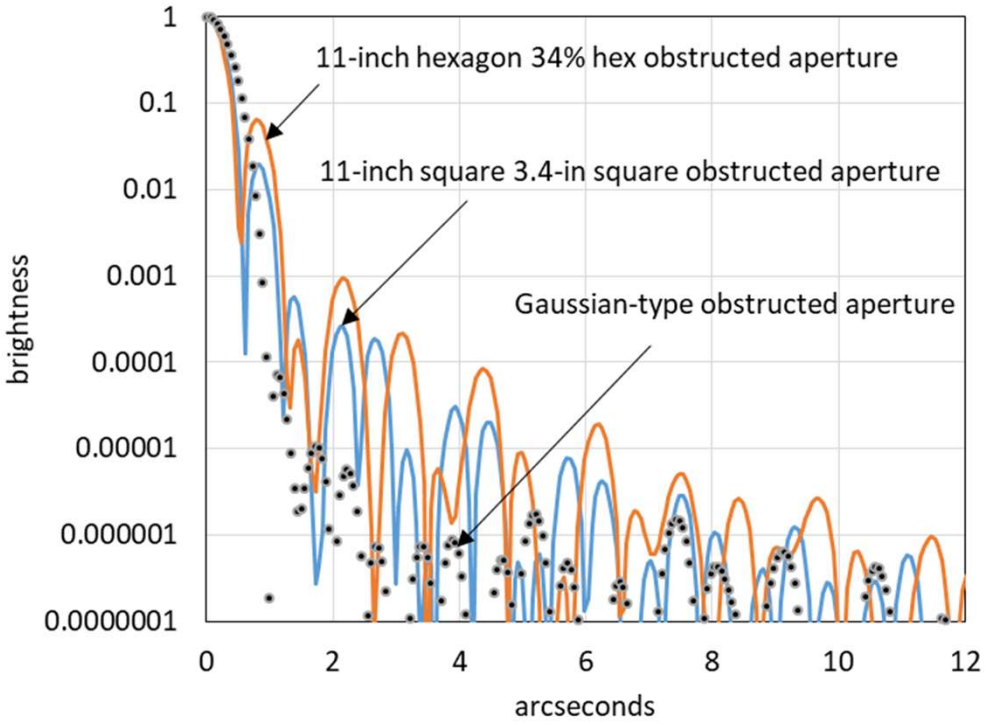
Best kind of instruments -- those w/o other diffracting structures in the optical path (spider vanes, clips, dirt, etc.):

- Refractors
- Maksutov-Cassegrains
- Schmidt-Cassegrains – an 11-inch Celestron is what Emmanuele uses

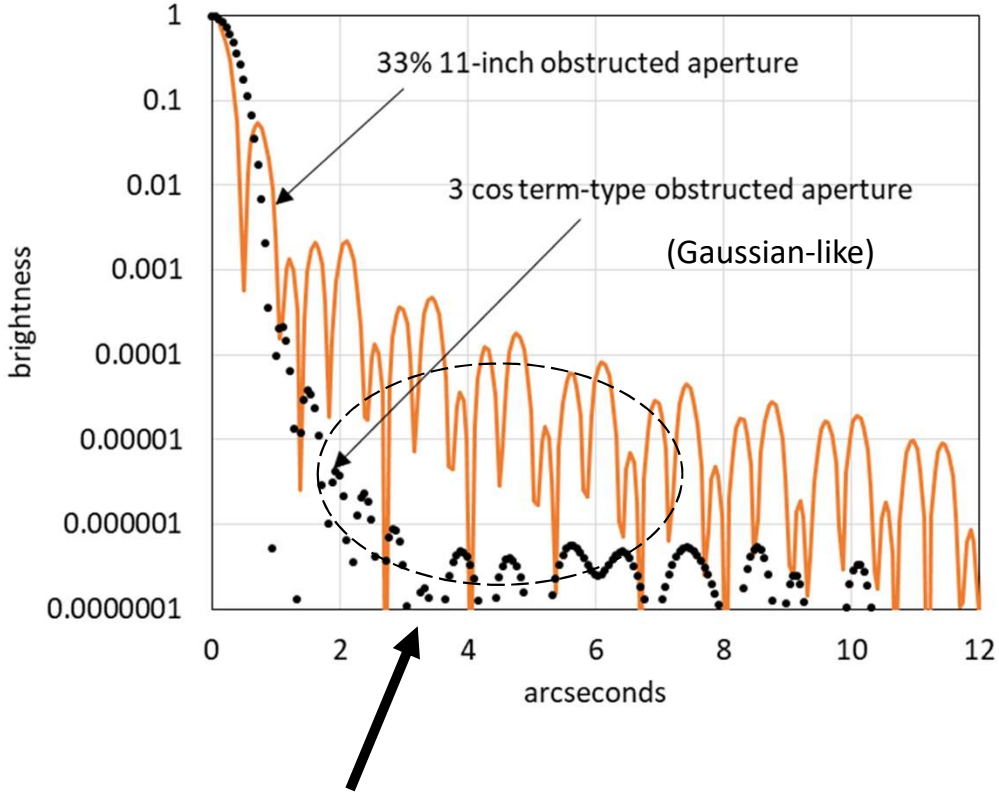
- Can, in principle, use a 4-vaned spider as long as you are careful to orient it along the angles of inflection. But must be able to rotate the whole tube easily

Drawing a line across the most favorable angle and plotting from the middle

Comparison of apodized apertures



Best apodized compared to no mask

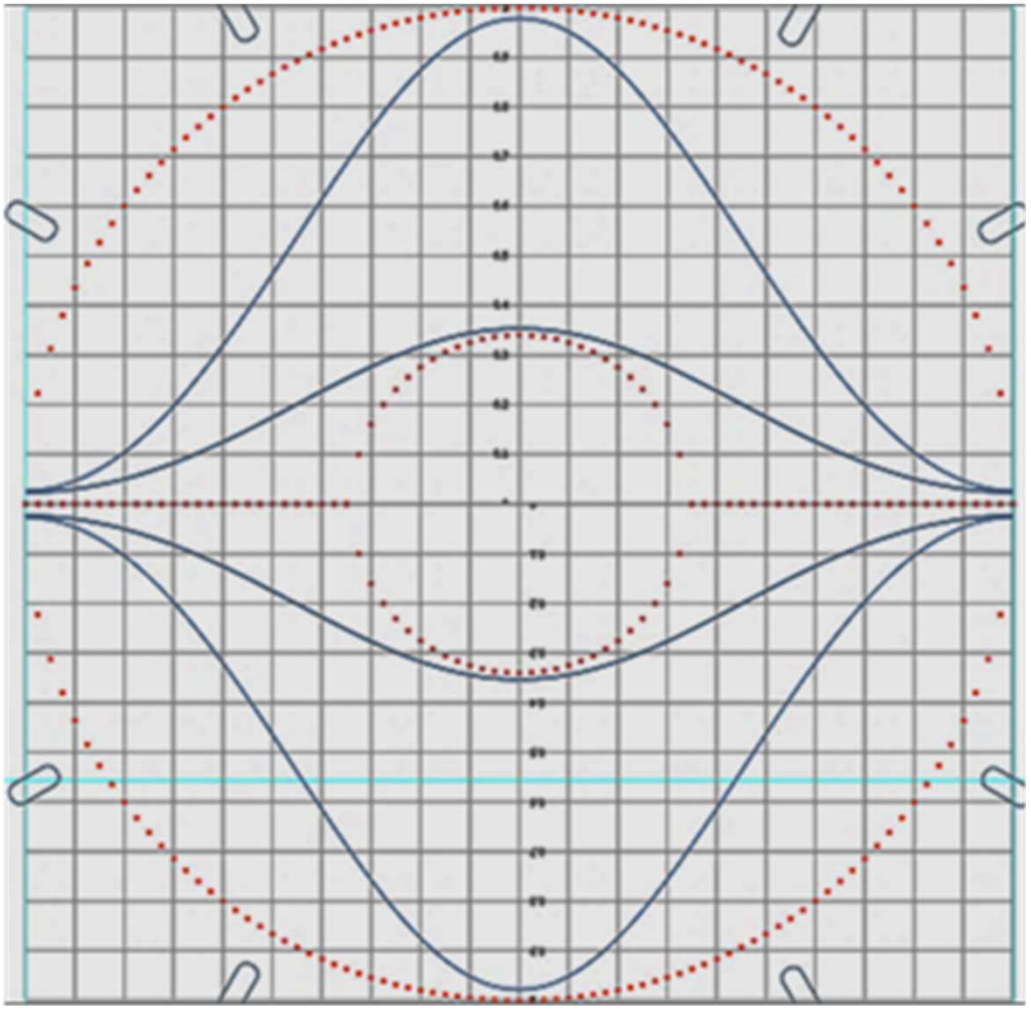


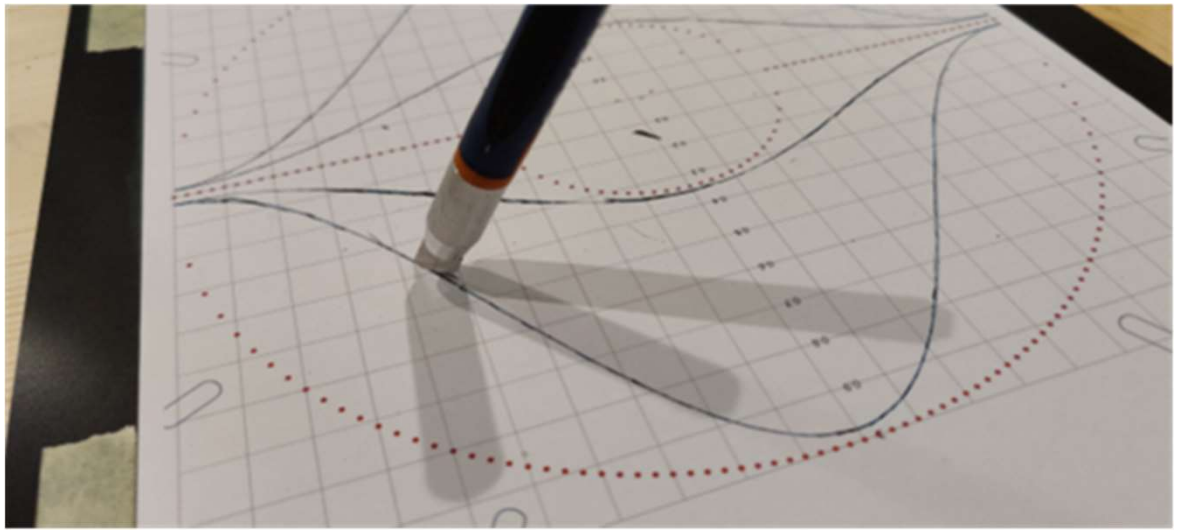
Sweet spot

HOW ARE THESE MADE?

START WITH A TEMPLATE PRINTED ON PAPER

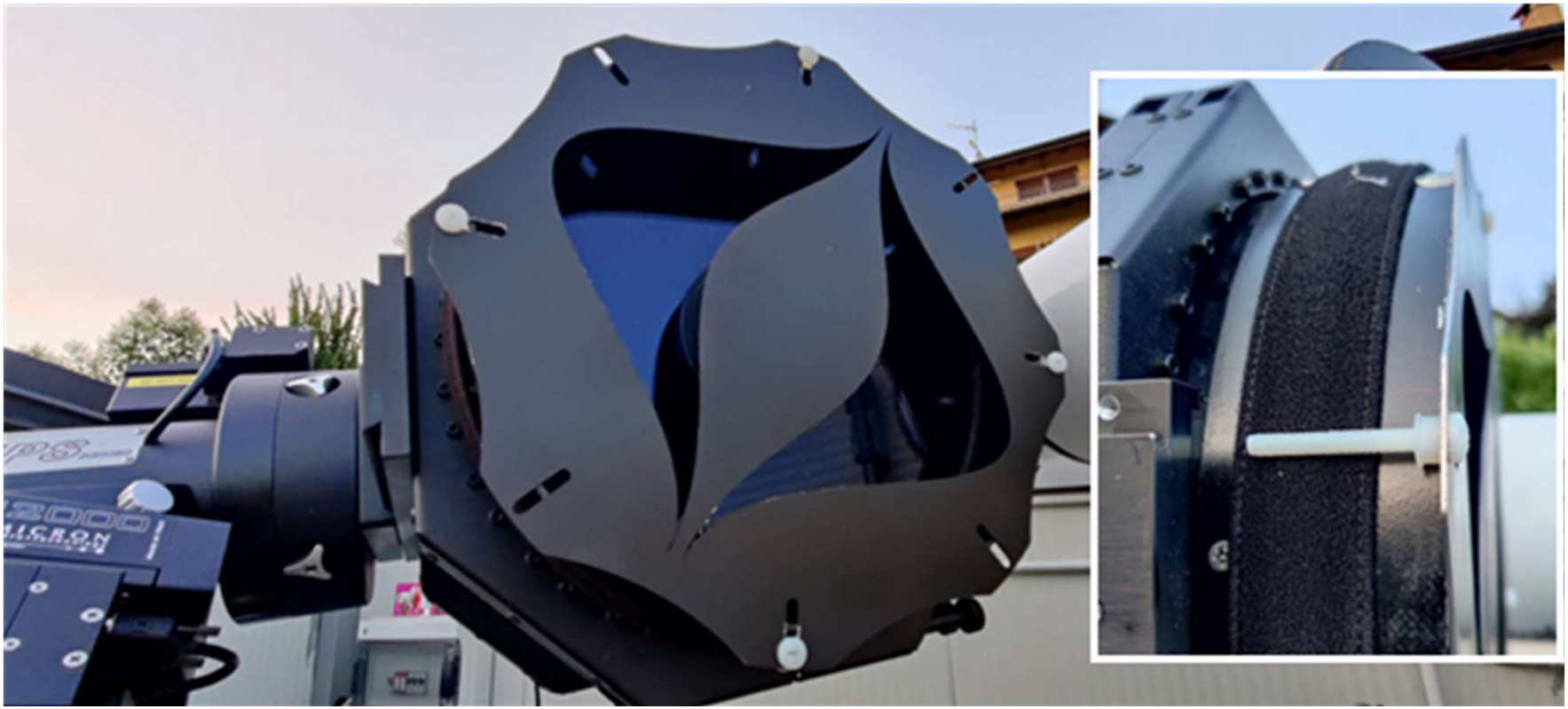
Gaussian curves elevated a bit to provide a ‘backbone’ and shrunk a little to stay away from the edge.





Paste the template to black foamboard and carefully cut it out. Sand the edges.

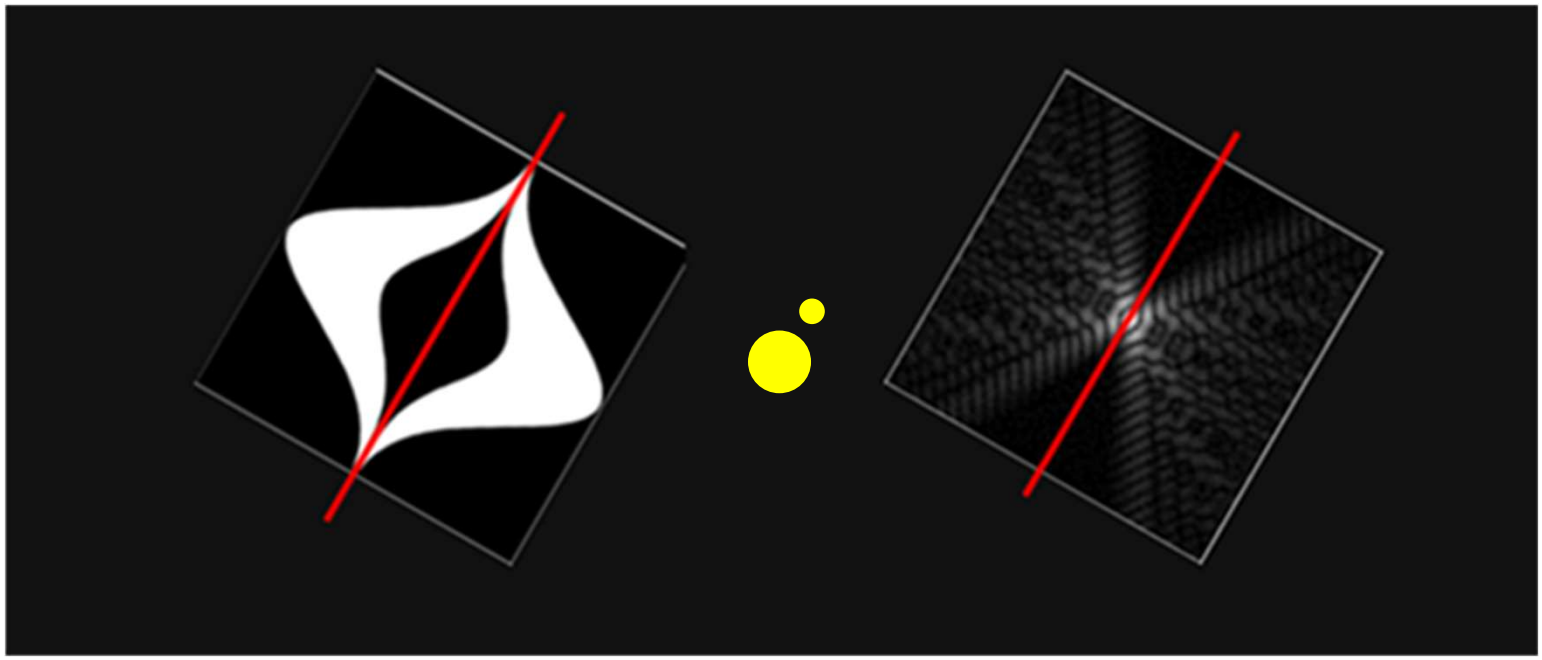
Or, cut it out of metal with a computer-guided laser/plasma



photos by E. Sordini

The mask ready for use

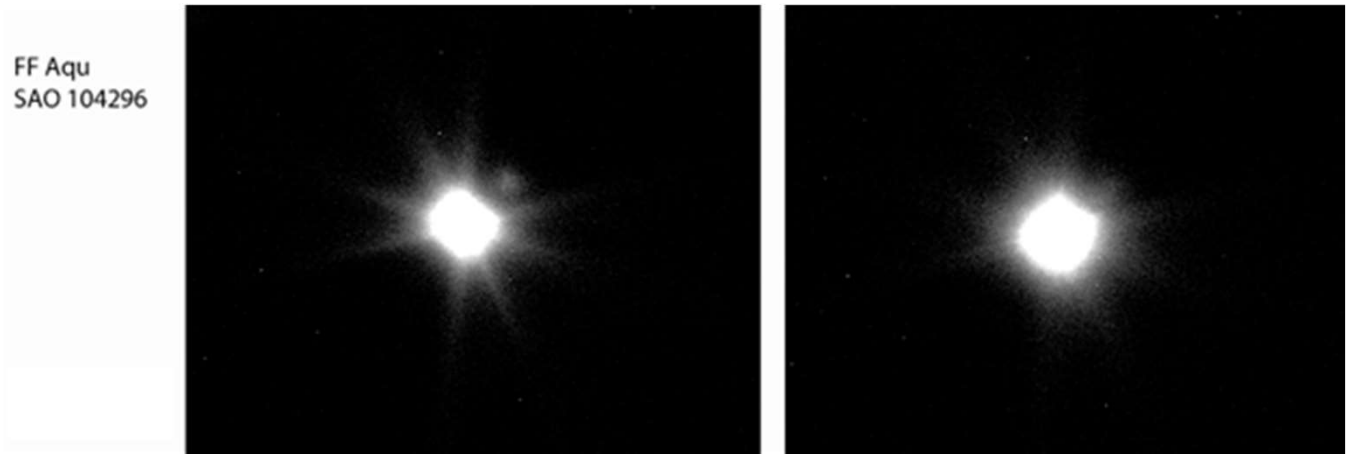
Turn the mask in the direction of the B star



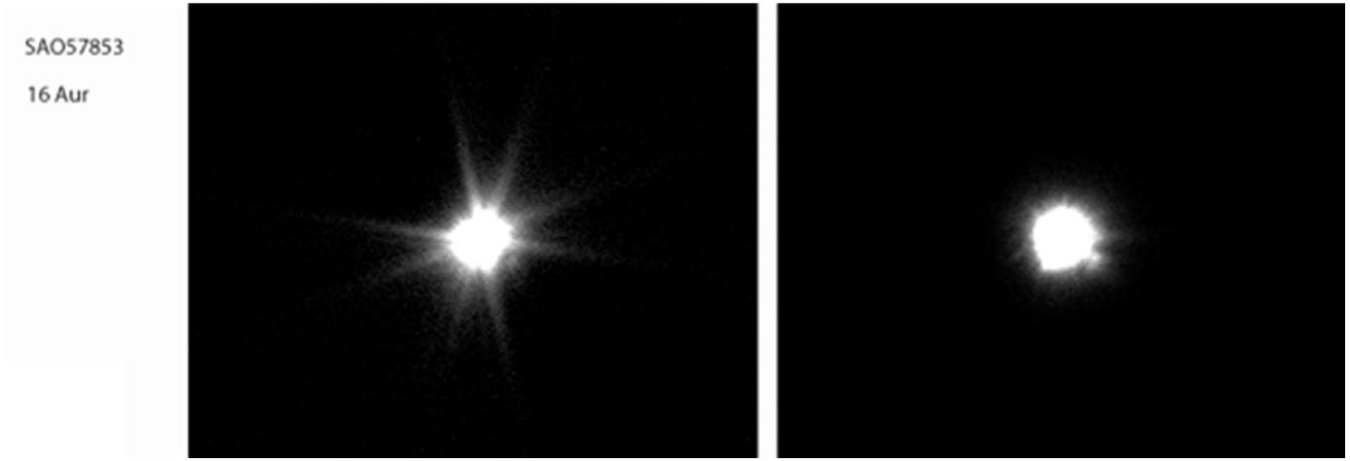
From "*Stelle Doppie*" (www.stelledoppie.it)

SAO number¤	designation¤	Name¤	WDS Data¤	Pos Angle¤	Sep (sec)¤	Mag 1¤	Mag 2¤	Δ Mag¤
151881¤	α CMa¤	Sirius¤	(2020)¤	66¤	11.3¤	-1.47¤	8.44¤	9.91¤
104296¤	FF Aql¤	--¤	(2015)¤	145¤	7¤	5.44v¤	10.12¤	4.68v¤
57853¤	16 Aur¤	--¤	(2002)¤	55¤	4.1¤	4.8¤	10.6¤	5.8¤
79294¤	δ Gem¤	Wasat¤	(2018)¤	229¤	5.5¤	3.55¤	8.18¤	4.63¤

THESE MASKS DON'T WORK ALL THE TIME



Both of these are with the mask

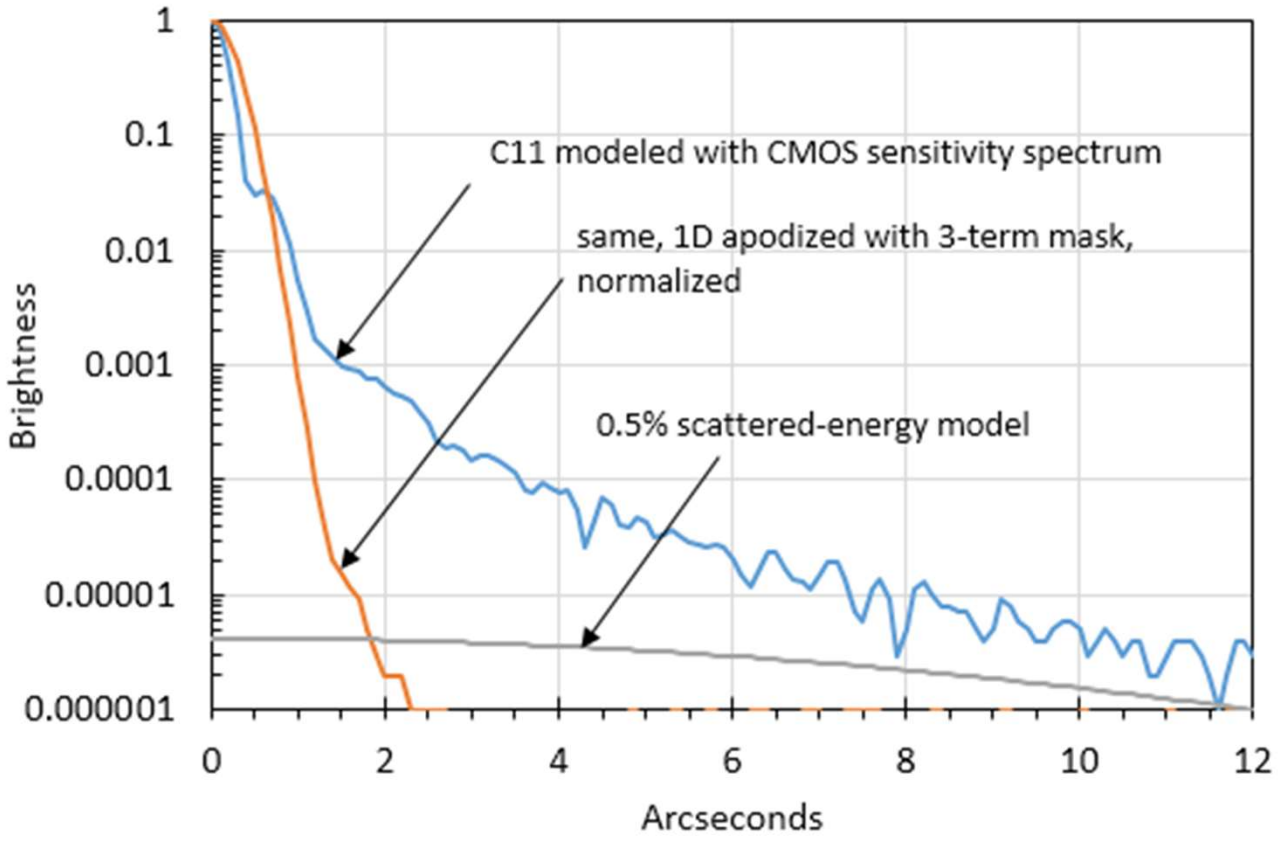


The one on the left is with the mask, the other is without

photos by E. Sordini

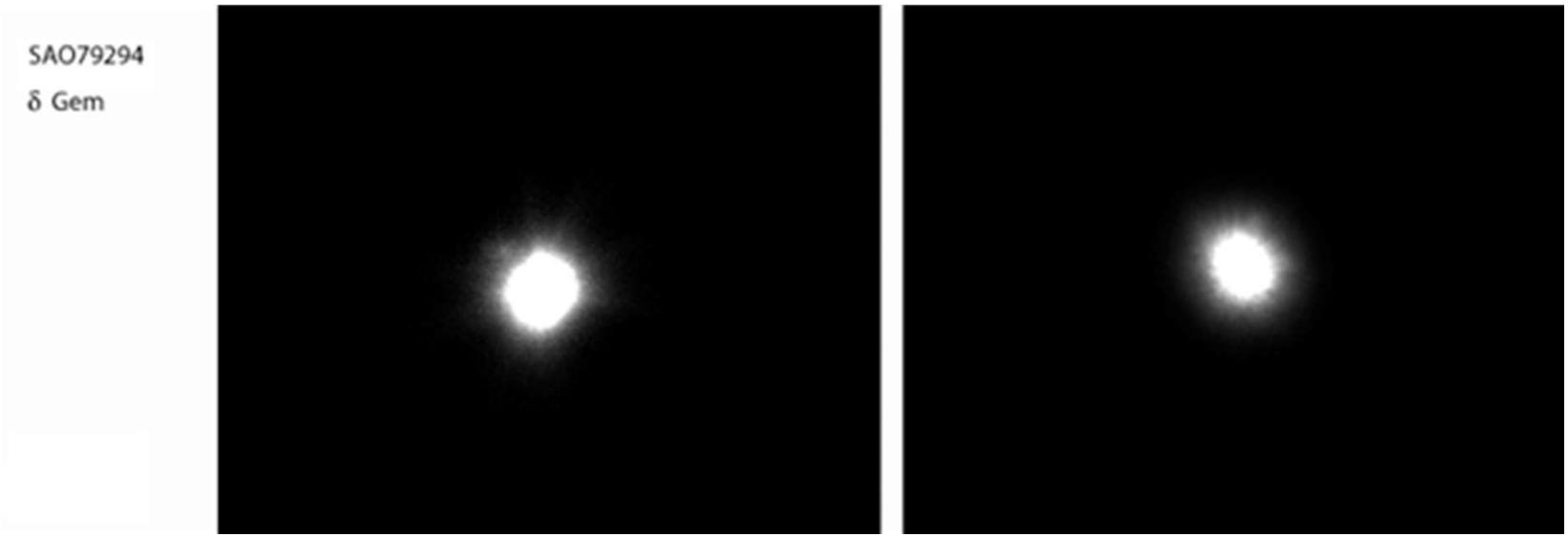
Scattered light creeps in

Multispectral ZEMAX model



When everything goes right

photos by E. Sordini



With mask

Without mask

CONCLUSIONS

-- The 1D apodizer works well if resolution is not a consideration and bright star is not too dim
-- The hex apodizer also works if Δm is not too large
-- Both can be easily made. Perhaps hex is easier, but holding the mini-hex over the secondary can be a problem (balsa stick backbone?)
-- Make sure your optics are clean and the sky is not hazy

Questions?

References

1. R. W. Argyle (ed.), Patrick Moore's Practical Astronomy Series, *Observing and Measuring Visual Double Stars*, Second Edition, DOI: 10.1007/978-1-4614-3945-5, Springer, New York 2012
2. P. Jacquinot & B. Roissen-Dossier, "Apodisation" (UK spelling) *Progress in Optics, Vol III*, ed. by E. Wolf, North Holland 1964.
3. Donald Loveland, E. Foley, R. Genet, N. Zimmerman, D. Rowe, R. Harshaw, and J. Ray, "Detecting Faint Secondary Stars with Shaped Aperture Masks," Vol. 12 No. 3 Journal of Double Star Observations, March 2016
4. Edward Leo Foley, *A Rotating Aperture Mask for Small Telescopes*, Thesis, California Polytechnic State University, San Luis Obispo, 2019.
5. N. Jeremy Kasdin, R.J. Vanderbei, M.G. Littman, D.N. Spergel, "Optimal Asymmetric Apodizations and Shaped Pupils for Planet Finding Coronagraphy," arXiv:astro-ph/0404388 v1 20 Apr 2004.