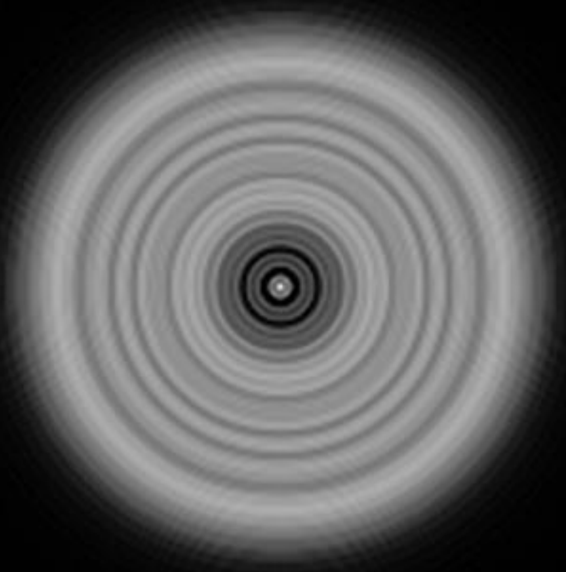
intrafocal



extrafocal

STAR TESTING

A powerful, free method for optics evaluation

U.A.I. Sun-Moon-Planets Meeting September 27-28, 2025

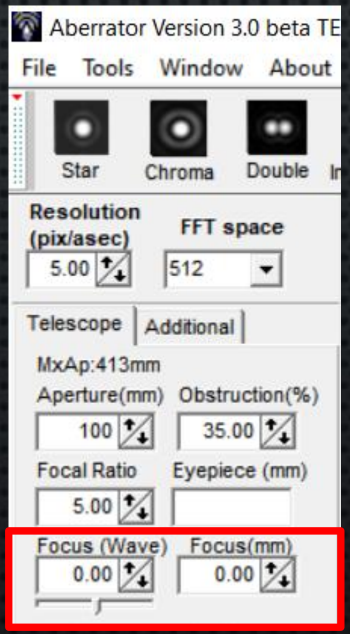
Italy

Vincenzo della Vecchia

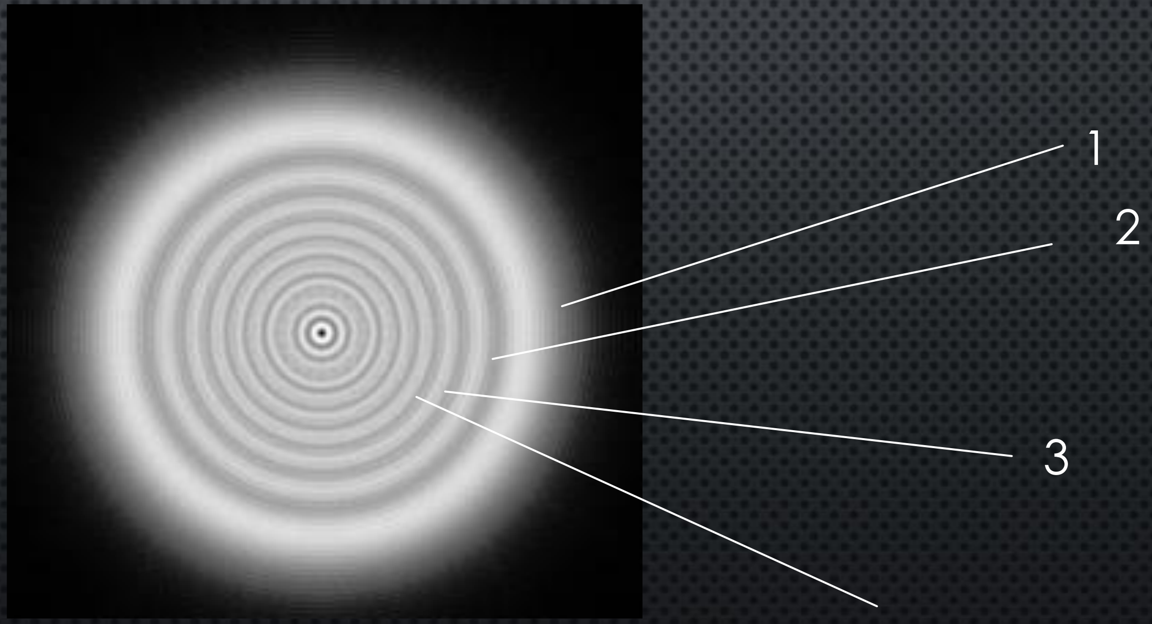
DEFOCUS: HOW IS IT MEASURED?

- *Expressing defocus in millimeters is not convenient because telescopes with different f/ratios have different defocused patterns values for the same focuser travel.*

- *It's much better to use interference waves (Fresnel rings). Just count the bright (or dark) rings*



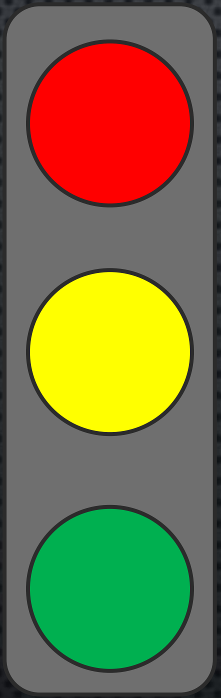
We easily estimate defocus with Aberrator. An f/4 instrument needs only 0.35 mm of travel for 5 waves of defocus. For an f/20, 8.7 mm are required!



10 (waves) of defocus 0% obstruction

TEST CONDITIONS (1/2)

Different defocus values highlight different aberrations.

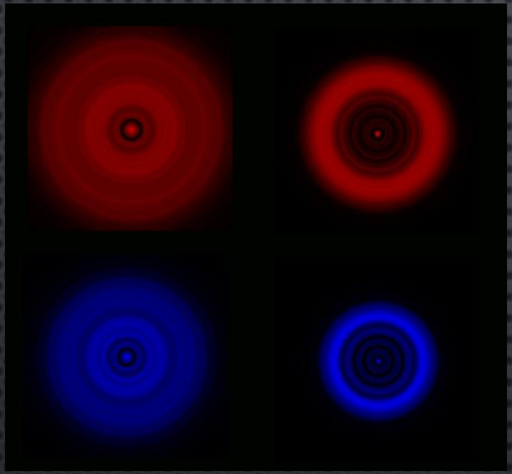


- ***5 waves***: *a very severe test for SA and deformations. No optics are perfect when observed at this defocus!*
- ***10-15 waves***: *most aberrations are clearly visible (coma, astigmatism, spherical, roughness)*
- ***20-30+ waves***: *indicated only for zonal errors and especially TDE (Turned Down Edge). At these defocus values, all other aberrations are very diluted and barely noticeable*

TEST CONDITIONS (2/2)

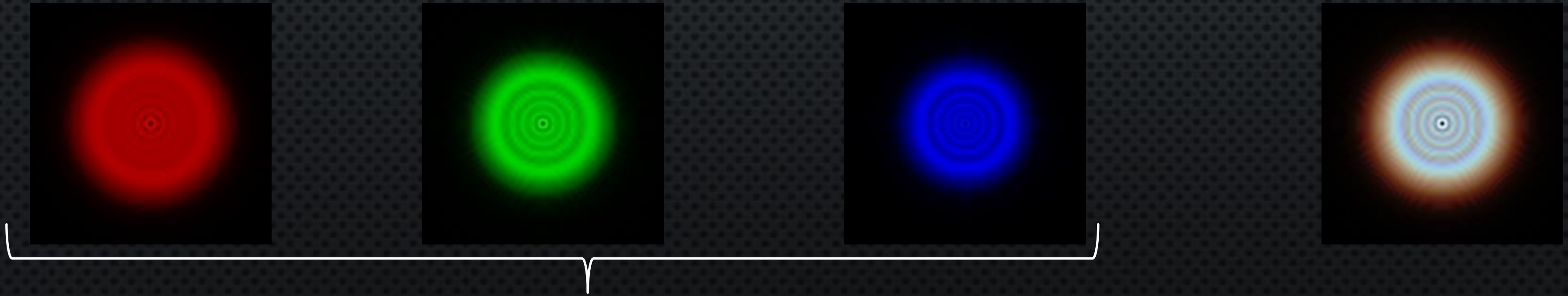
- *The telescope must be acclimated to avoid disturbance from heat 'waves.' This includes the observer's body heat.*
- *Turbulence is less evident because it is averaged over the surface of the defocused star. Nevertheless, it's better avoid nights with very poor seeing.*
- *It's advisable to cut incoming light with a filter, green or even blue if the seeing is good, infrared if there's turbulence.* ***In IR, the test is more forgiving!***
- *Do not use Barlow lenses, diagonals, focal reducers, etc unless you specifically want to test these devices. The errors of everything on the optical train will sum on the focal plane.*
- *Defocus as little as possible for maximum sensitivity, unless specifically looking for TDE or zonal errors.*

INFLUENCE OF WAVELENGTH (ALSO FOR REFLECTORS)



- *In both cases, the defocus is 5 lambda and with 0.4λ (4/10) of Spherical Aberration, but…*
- *In red light, the error is 650*0.4=260 nm, in blue light it's 400*0.4=160 nm!*
- *In other words, when testing optics with R/IR and B filters, the same wavefront error in nm **will be greater in blue** in terms of fraction of wave*
- *By testing in green light we obtain results comparable to those on the optical bench*

R *G* *B* *White light*



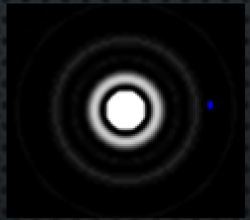
Same defocus (5 waves)

WHAT QUALITY TO EXPECT FROM ONE'S TELESCOPE

¼ wave P-V = 1/14 RMS
@550 nm
Spherical aberration
COMPLETE FORM of Rayleigh criterion

→ **Conventional** ***diffraction limit***

Aberrations are 'contained' within the Airy disk, which is the smallest detail detectable by the telescope and thus invisible



For high-resolution work, it is more important to have well-corrected optics

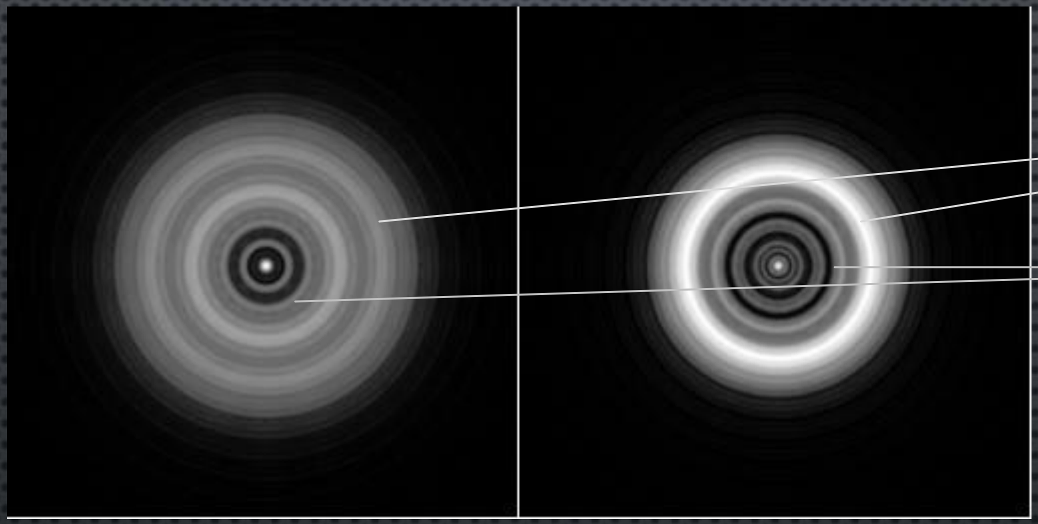
THE MAIN ABERRATIONS

All aberrations presented below (except TDE) result in a Strehl ratio of 0.80, thus making the instrument just above «diffraction limited».
In order of severity (error to achieve S.R.=0.8) we can classify the main aberrations as follows:

Spherical Aberration (S.A.) 0.25 λ
Astigmatism 0.37 λ
Coma 0.42 λ
Turned Down Edge (TDE)

A well-executed test reveals almost <u>all</u> aberrations (including those external to the optics like heat waves and turbulence)

MAIN ABERRATIONS: SPHERICAL (1/2)



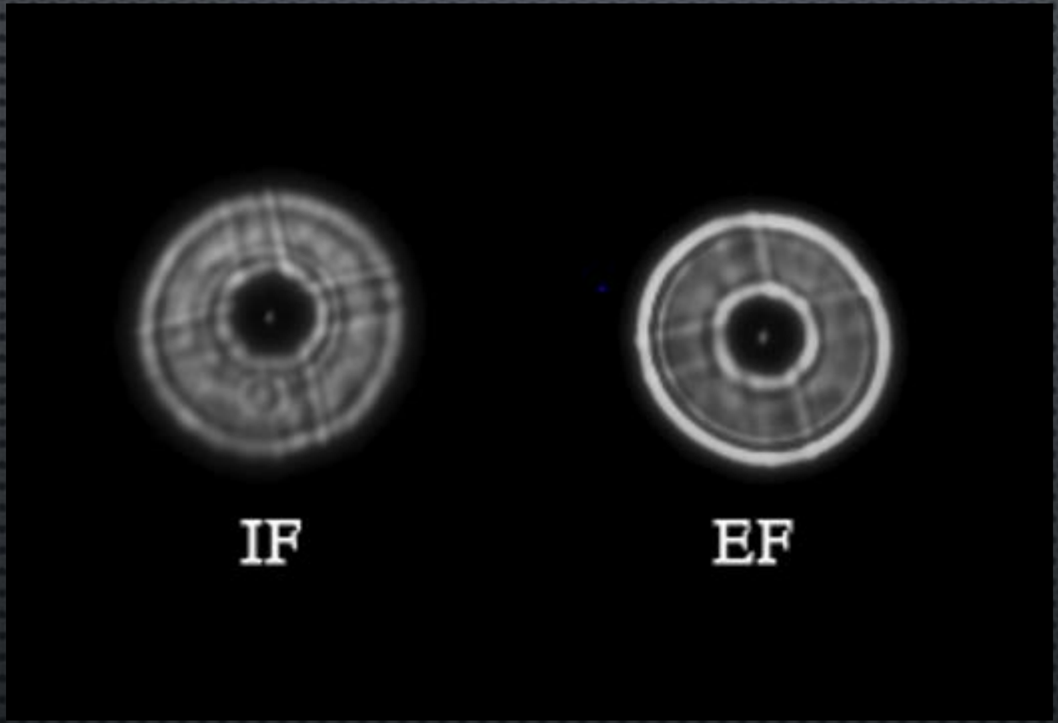
¼ lambda S.A. 5 lambda defocus

- ❑ Do NOT pay too much attention to the different sizes of the secondary mirror's shadow on either side of focus, especially for instruments with corrector lenses (Maksutov, Maksutov-Cassegrain etc)

- ❑ Instead, look at the light distribution on the two outer and inner rings (for obstructed instruments)

- ❑ If the snap test is accurate at high magnifications, do not worry too much

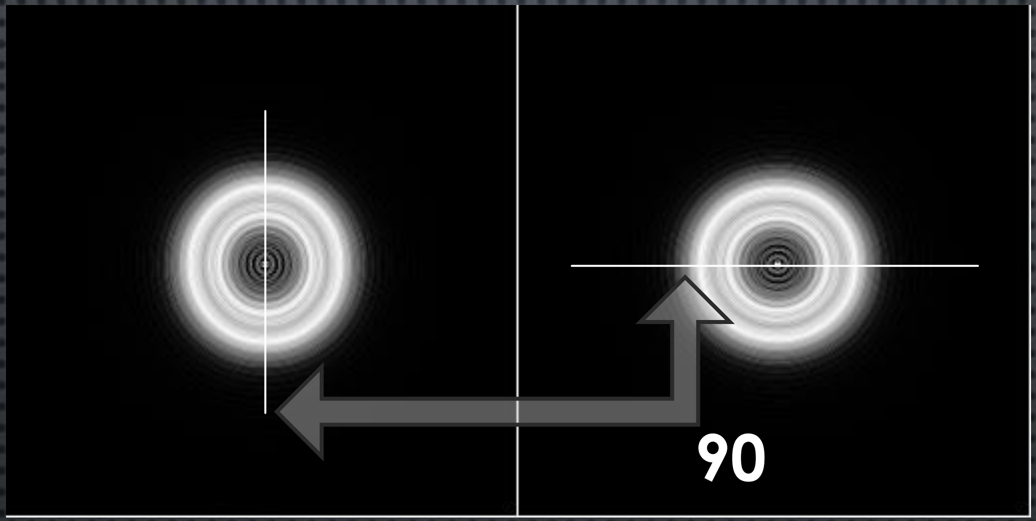
MAIN ABERRATIONS: SPHERICAL (2/2)



20 lambda defocus, G filter

This f4.5 Newton, tested with a G filter, exhibits visible spherical aberration, despite the secondary shadows being very similar in size. A fair degree of astigmatism is also present. Roddier's test showed the optics to be just diffraction-limited.

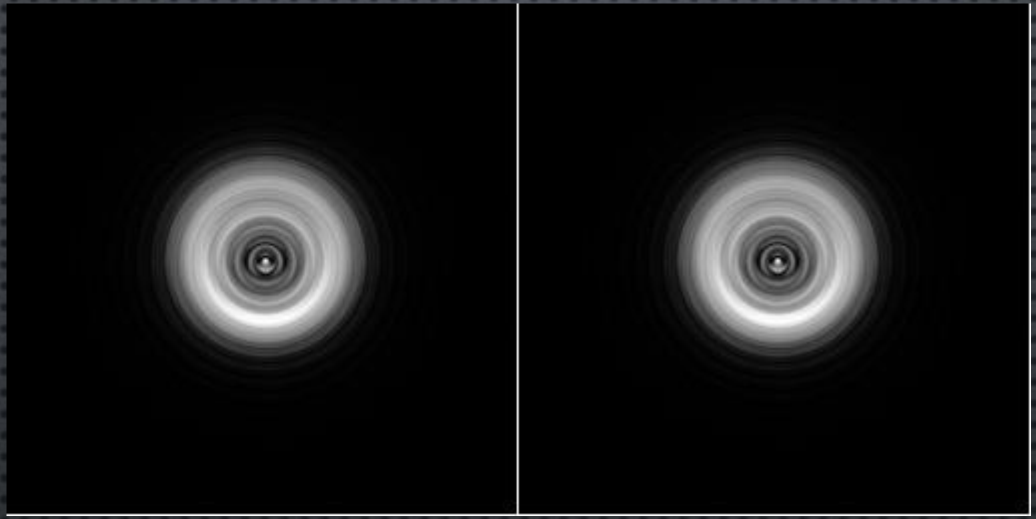
MAIN ABERRATIONS: ASTIGMATISM



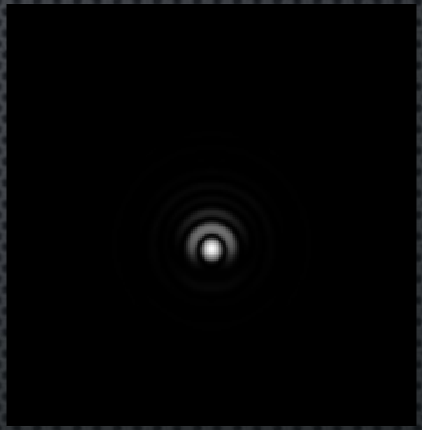
1/2.7 (0.37) lambda astigmatism. 10 lambda defocus

- If astigmatism changes from horizon to zenith, it is likely caused by primary mirror deformation: in this case, by placing a finger near the focus, the direction of one of the ellipse's axes will be <u>along the vertical.</u>
- Rotate the mirrors (or the focuser!) separately, checking if the astigmatic ellipse rotates accordingly
- In Newtonians, if one axis of the ellipse is aligned with the major axis of the flat mirror, then the latter is likely the astigmatic element

MAIN ABERRATIONS: COMA



1/2.4 (0.42) lambda of coma. 5 lambda defocus

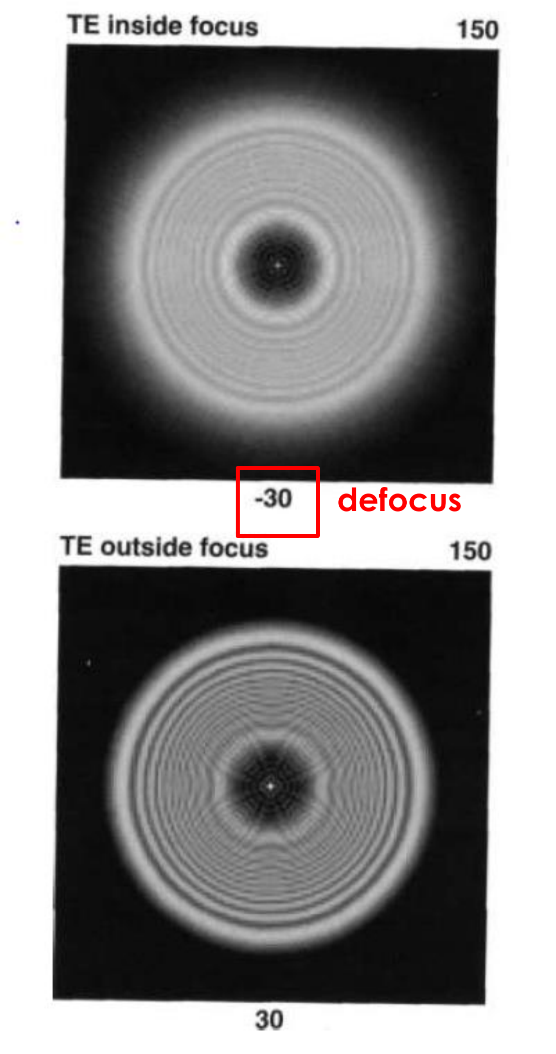


At focus

Move the star with collimation knobs in this direction for fine collimation

- ❑ Coma promptly arises in case of diasalignments, helping in diagnosis
- ❑ Fine collimation is best done with a star <u>at focus</u>
- ❑ It's a symmetrical aberration when star testing is concerned, meaning it doesn't change from one side to the other of the focus

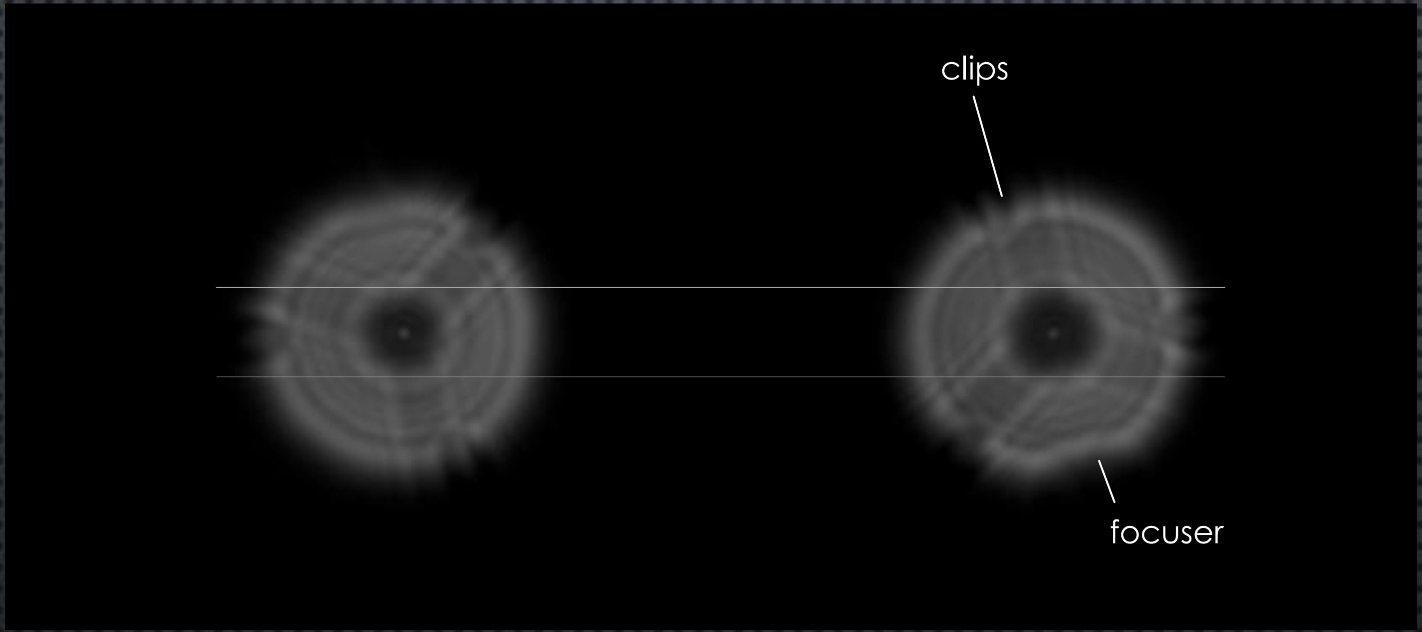
MAIN ABERRATIONS: THE TURNED EDGE



0.67 lambda of TDE
from Suiter, *Star testing astronomical telescopes*

- One must especially look at <u>the intrafocal image</u> (above in the adjacent image) which appears undefined and 'hairy'
- Defocus by at least 20 waves
- Particularly detrimental to planetary images because reflected light can remain within the disk, reducing contrast.
- It can be cured by masking the edge

THE PERFECT STAR TEST



The secondary shadows size are not perfectly identical

25 cm f/5 Parabolic - Carl Zambuto
IR685 nm filter - 14 lambda defocus

ADVANTAGES AND LIMITATIONS OF THE STAR TEST

- **It's free**! You only need an eyepiece/digital sensor and a clear night with no abysmal seeing
- It's very accurate (1/10 P-V wave) on a real star, even more so on an optical bench. Since almost no telescope is so well corrected, the intra- and extra-focal figures will almost never be identical
- Optical performance tests included with telescopes can be unaccurate (sometimes intentionally...), **the star test never lies!**
- Experience is needed to disentangle the various aberrations that almost always appear together
- By its nature, it's a qualitative test, even if the magnitude of the error can be estimated
- The required degree of correction depends on the telescope's use. For visual observation alone, more tolerance is acceptable; for high-resolution digital imaging across the entire accessible spectrum, criteria must be more severe

«A defocused star tells you everything»

V. DELLA VECCHIA

FOR THE LAZY ONES....

- Send your instrument's star test to v.dellavecchia@uai.it
- It will be published onwww.vincenzodellavecchia.it and commented

BIBLIOGRAPHY

- H. Suiter, *Star testing astronomical telescopes*
- J. Sidgwick*, Amateur astronomers handbook*
- Amateur telescope optics website *https://www.telescope-optics.net/*
- Mel Bartels website *https://www.bbastrodesigns.com/*

THANK YOU FOR YOUR ATTENTION