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SkyWave

Alignment of Cassegrain type of Telescopes with at Least One Spherical Mirror

SCT, CDK, iDK, …

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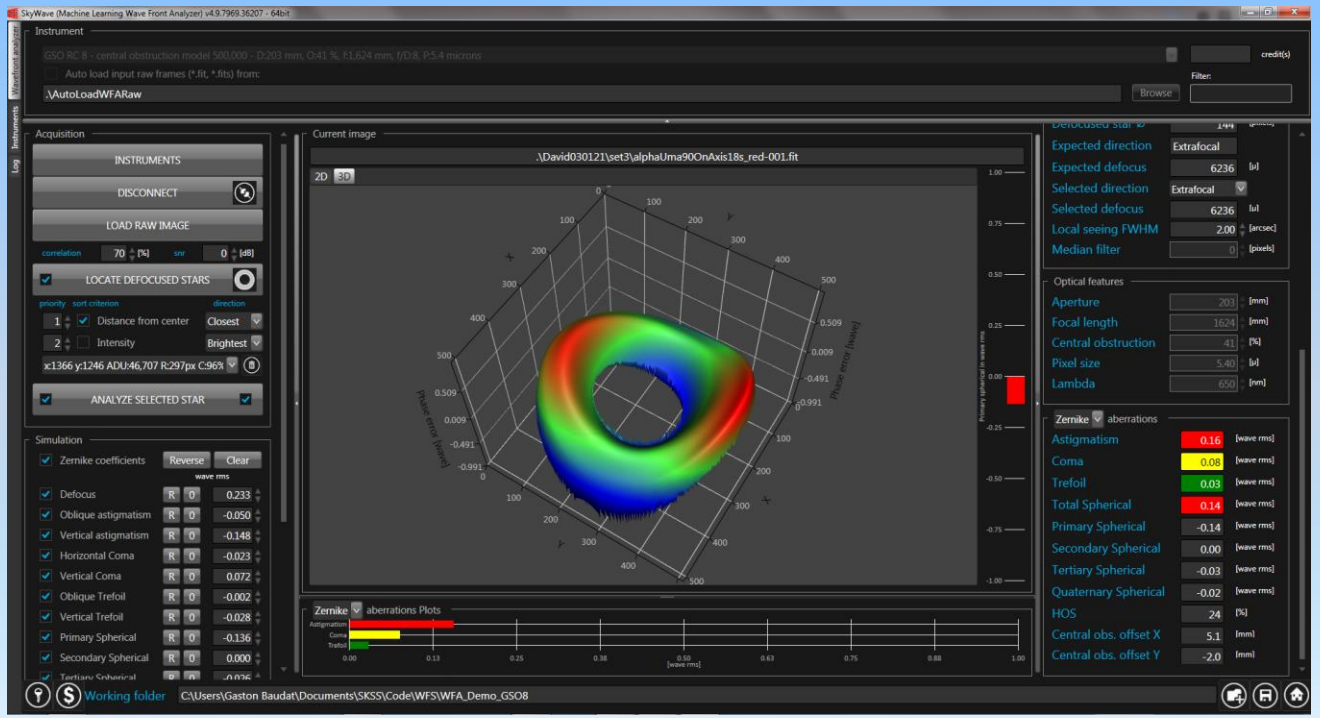
SkyWave (SKW)

SKW engine uses our patent pending AI based wavefront sensing technology. The wavefront and related aberrations are determined from a single defocused star even under seeing limited conditions.



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Goal & Content

- This presentation describes how to align with SKW the mirrors of Cassegrain type of telescopes having at least one spherical mirror, such as SCT, CDK, iDK, ...

- First some basic concepts and definitions are discussed then an example using a 8" SCT is presented.

- Telescope optical alignment is made of two distinct parts:

1. Alignment of the mirror optical axes. Both axes need to be superimposed. Defined as congruence in this presentation.

2. Setting the correct distance between both mirror vertices. Defined as spacing in this presentation.

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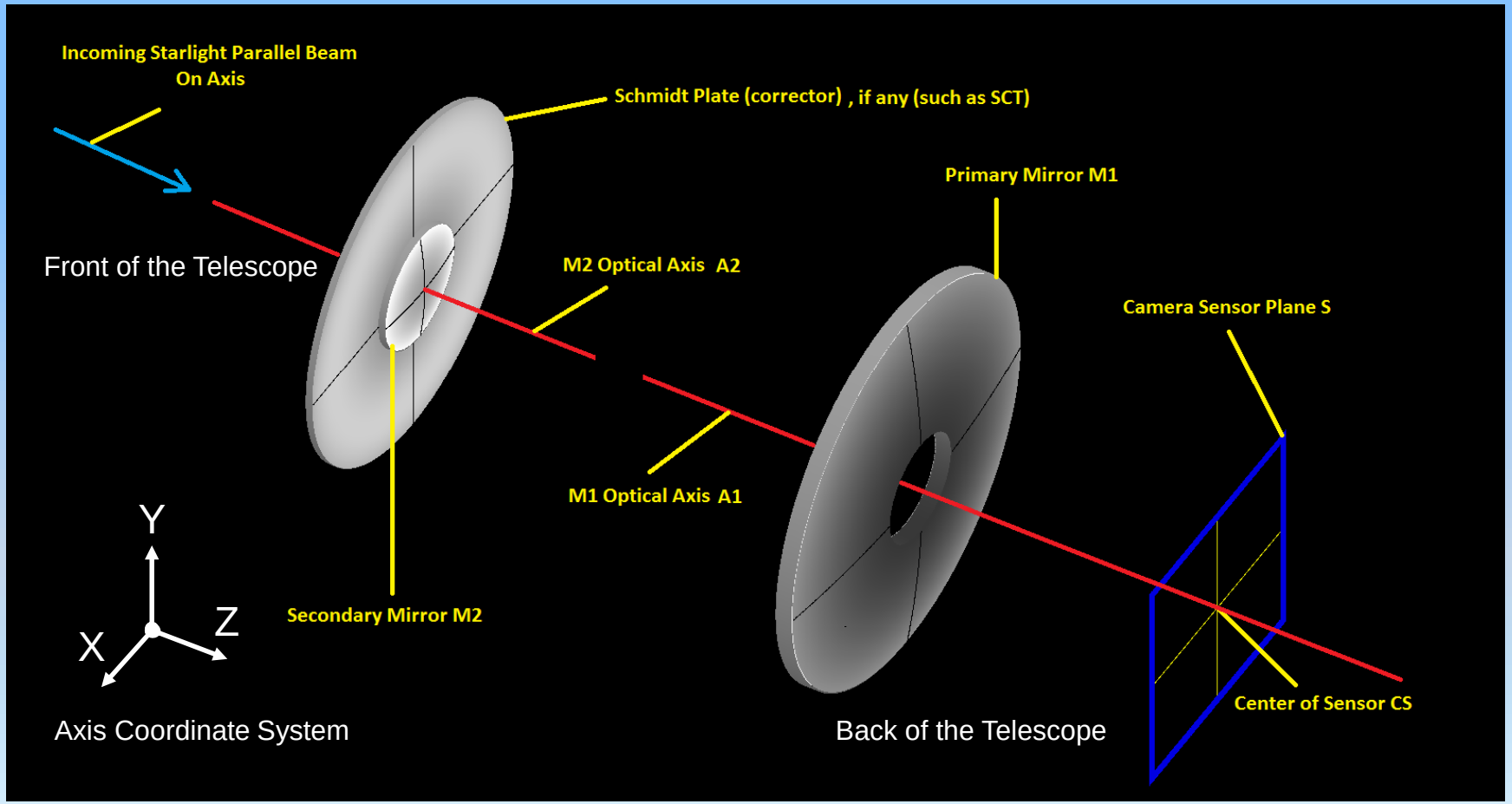
Some Definitions



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Part 1: Congruence

- The goal is to superimpose both optical axes A1 and A2 to make them congruent.
- A1 is the reference axis. For a spherical mirror it is any axis going through the mirror and passing by its center of curvature, for an aspherical mirror it is its unique axis of revolution.
- By definition a star is on-axis when its incoming beam is parallel to A1, even if its image is not located at CS.
- When the axes are congruent the star image on the sensor plane is the telescope's optical center (OC) location.
- In practice, when the axes are congruent, we can reasonably assume that OC is close enough to CS such the scope native off-axis coma, if any, can be easily neglected in the alignment process.

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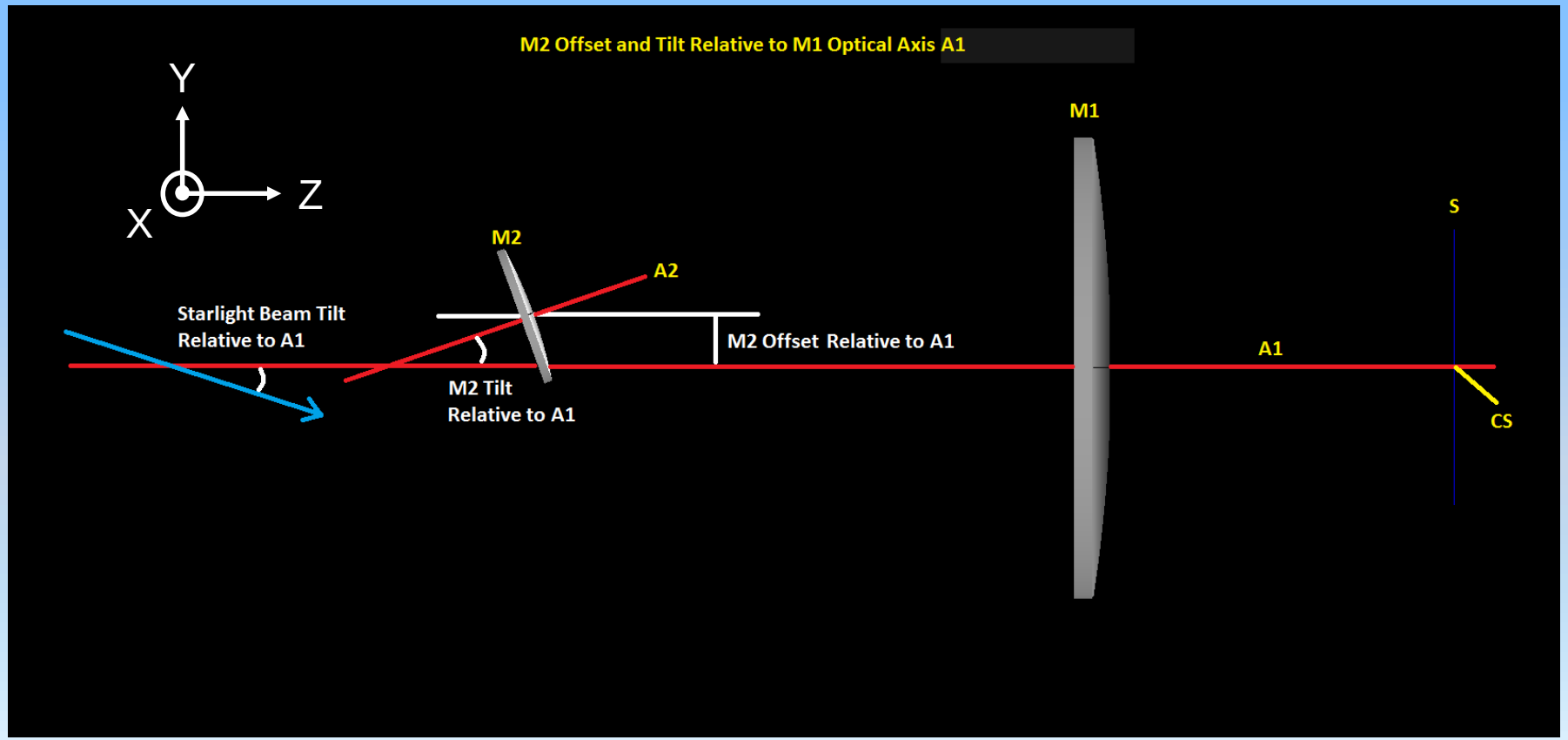
Congruence
Degrees of freedom

In general a mis-aligned A2 exhibits, relative to A1, offsets and tilts in 2 directions X & Y for a total of 4 degrees of freedom. Spacing omitted (Z).



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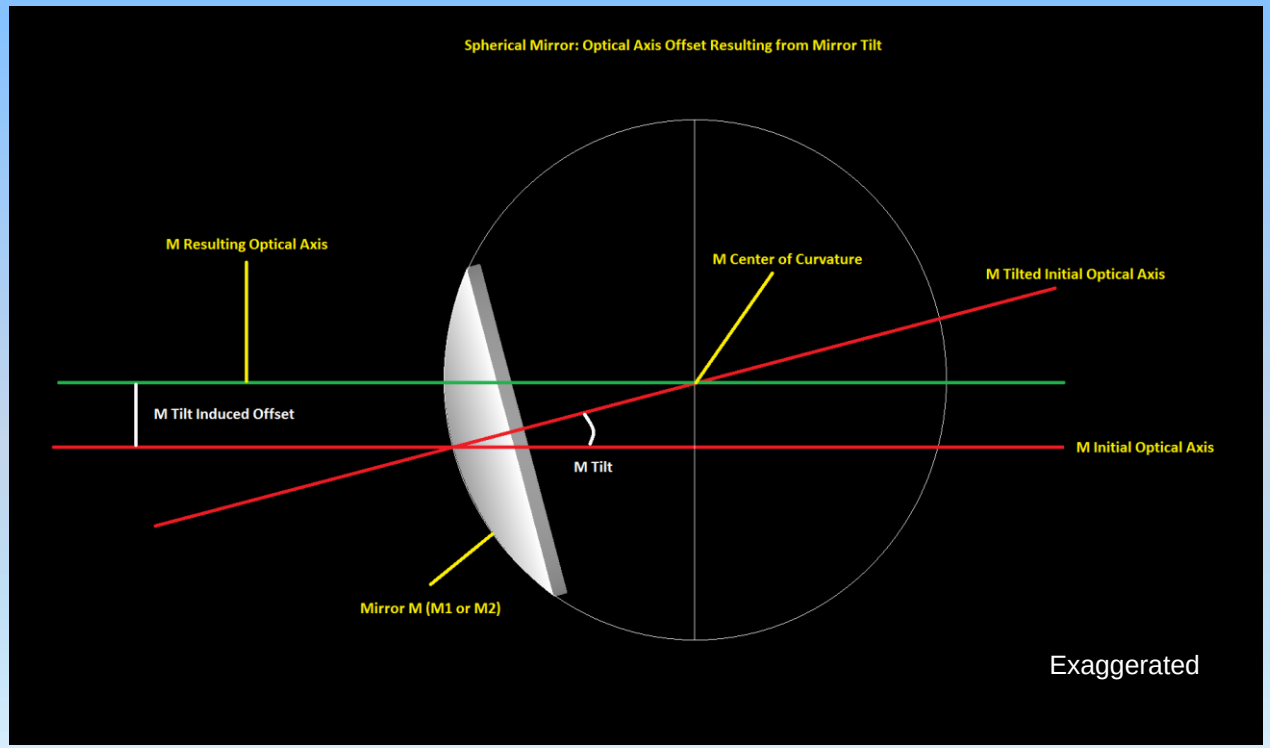
Congruence
Spherical Mirrors

Any axis going through a spherical mirror and passing by its center of curvature is an optical axis, tilts translate to offsets. For scopes with at least one spherical mirror A2 exhibits, relative to A1, offsets only. Extreme tilts may still lead to optical vignetting.



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Congruence
Coma Driven Alignment

- SCT, CDK, iDK, … scopes have at least one spherical mirror, either the primary or the secondary, or both.
- M2 tilt/tip adjustments are enough for reaching congruence.
- 3rd order coma is the relevant figure of merit to be used here.
- Any aligned telescope exhibits off-axis coma only. Conversely the lack of congruence leads to on-axis coma, still there is no alignment induced astigmatism with spherical mirrors.
- When a star located at the OC, near the CS in practice, is coma free A1 and A2 are congruent.
- Alignment induced coma away from CS grows much faster than the scope native one. After alignment, some off-axis coma & astigmatism may still exist, depending on the optics.

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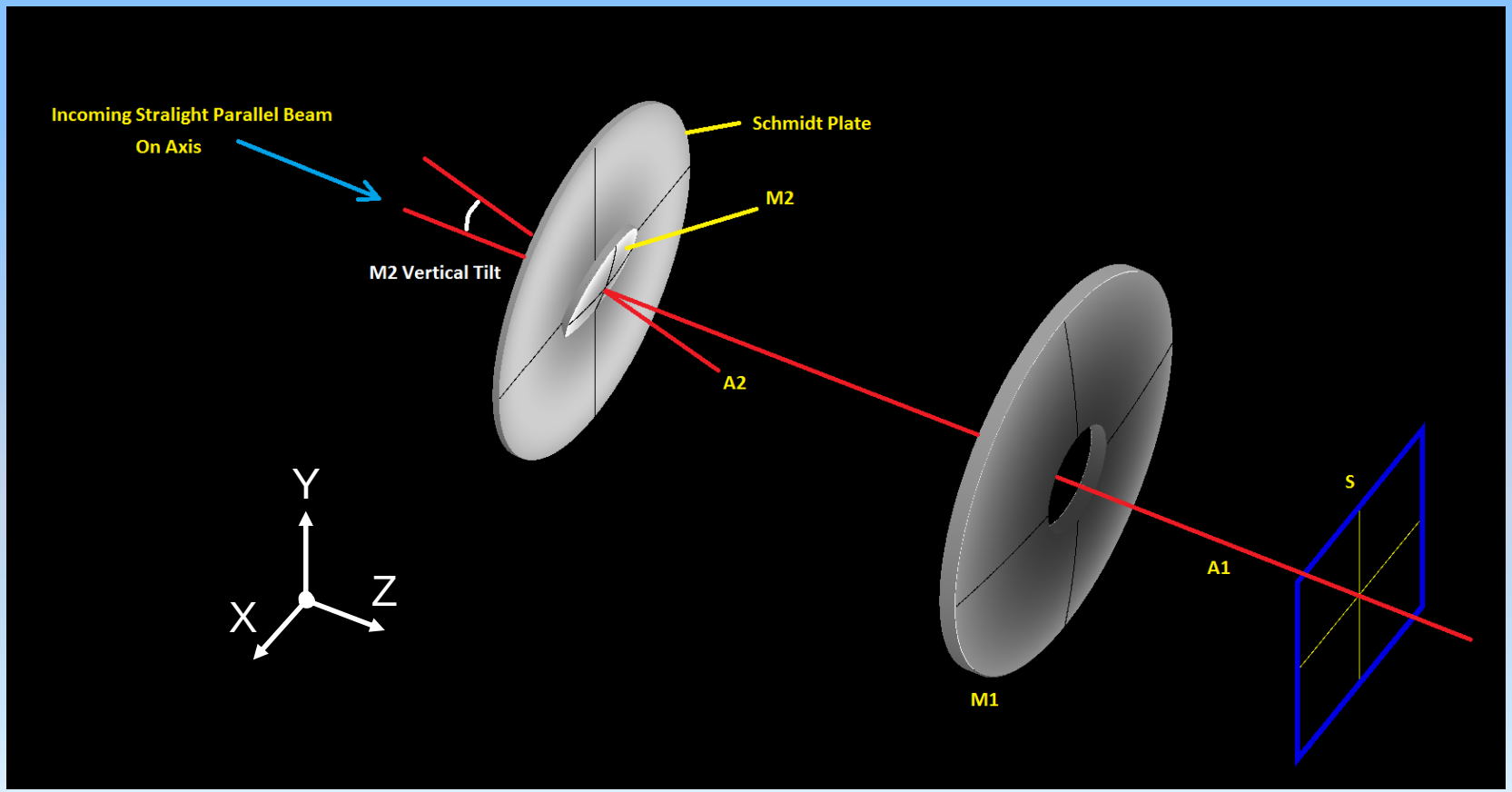
Congruence
Example with a 8” SCT

Also valid for any scope with spherical mirror(s)

In this example A2 is tilted forward by 0.1°, or 1.74mm, away from the top of the Schmidt plate. Not at scale in the figure.



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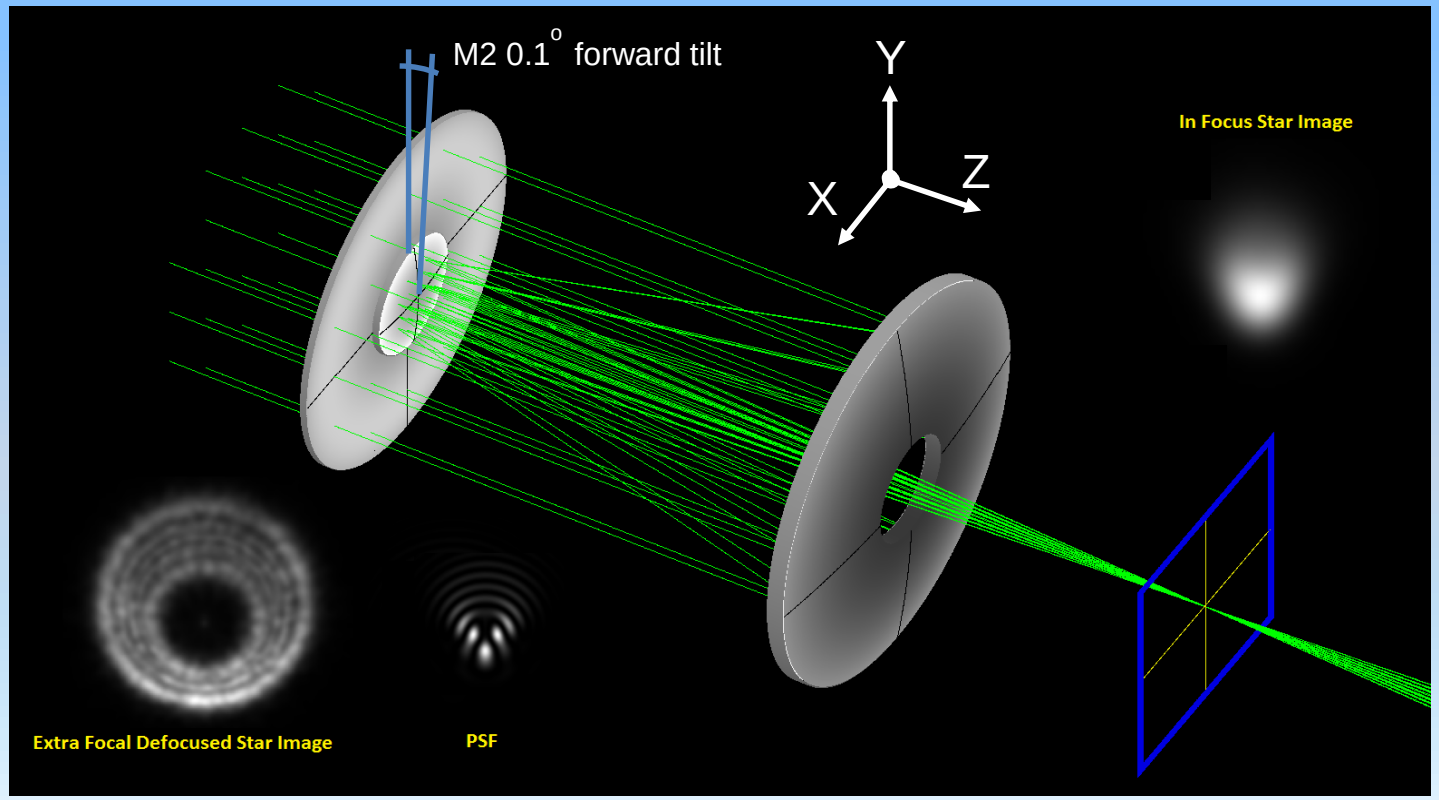
Congruence
SCT mis-alignment aberrations

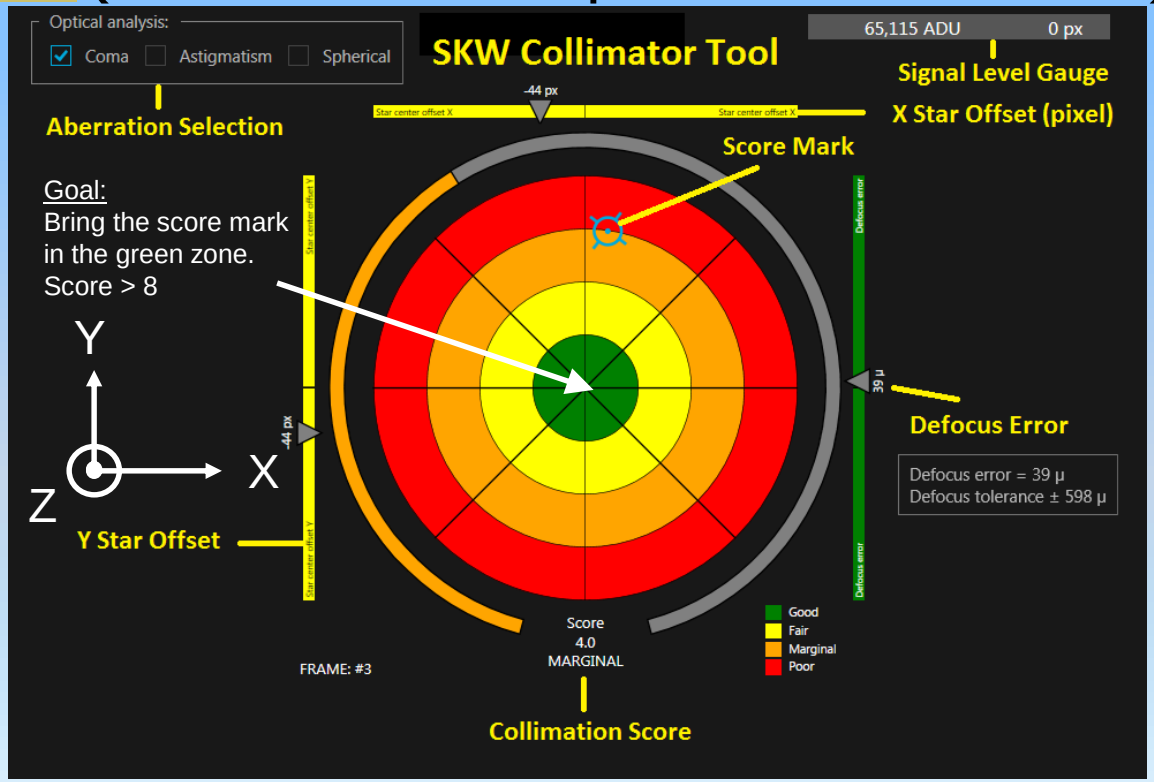
The star at CS is overwhelming dominated by alignment induced coma, here 0.2 wave rms. Scope off axis native coma is negligible. There is no alignment induced astigmatism. Off-axis native astigmatism may exist since the star at CS is off-axis here.



Congruence
Alignment using SKW

The SKW features a tool named collimator for alignment which displays a score mark inside a target. Coma only should be selected. The mark is oriented toward the point where M2 is the most tilted forward (in this SCT example the +Y direction).

SKW collimator provides angular information in relation with the axis coordinate system used in this presentation.



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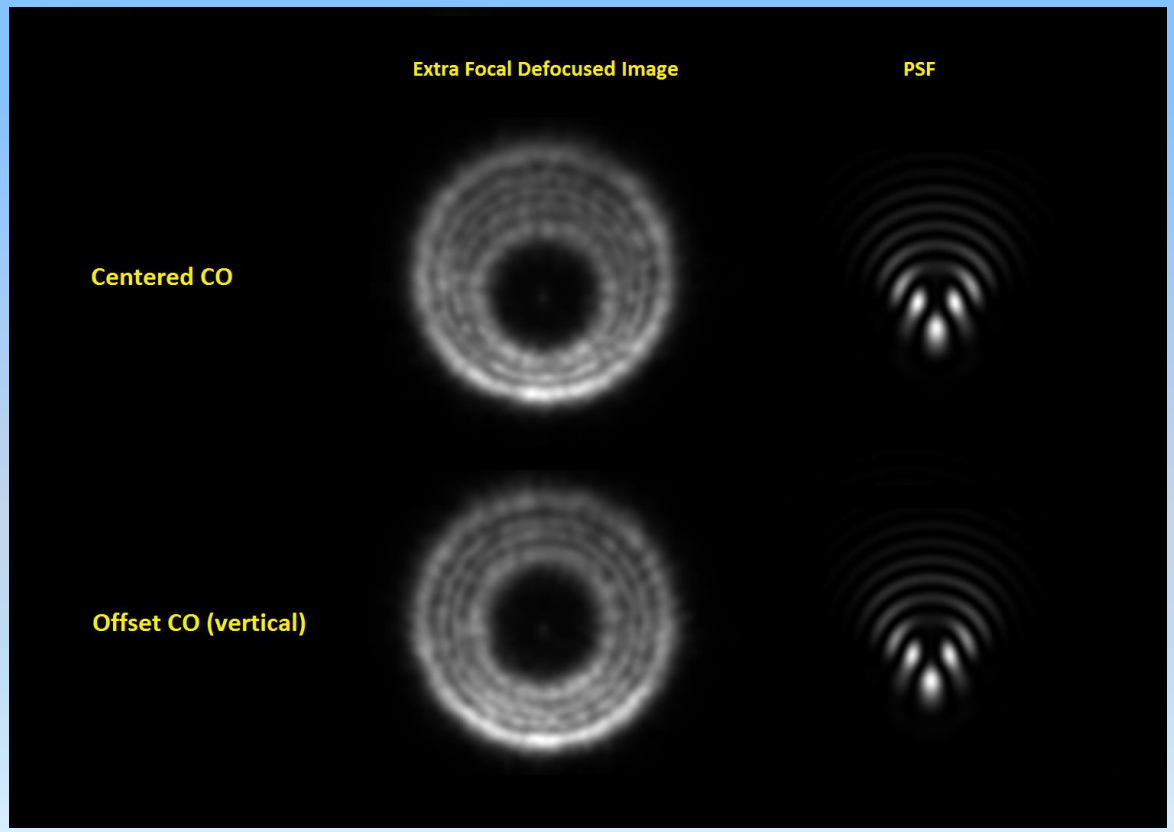
Congruence
Effect of Central Obstruction Offsets

The defocused star image is strongly affected by any M2 central obstruction (CO) offset for any reason, while the in-focus image is not. SKW provides quantitative aberrations independently of such offset.



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Part 2: Spacing

- The goal is to set the distance **d** between both mirror vertices to its optimal value **d0**.
- Departure from **d0** leads to mainly primary spherical aberration and defocus. The telescope focal plane moves.
- For most telescope optical design prescriptions, the spherical aberration increases quite slowly with **d**.
- Therefore, a large primary spherical aberration may very well be related to the scope optics itself not its alignment.
- Since SKW retrieves and uses the wavefront data, the spherical aberration is computed independently of any other aberrations, such as coma.

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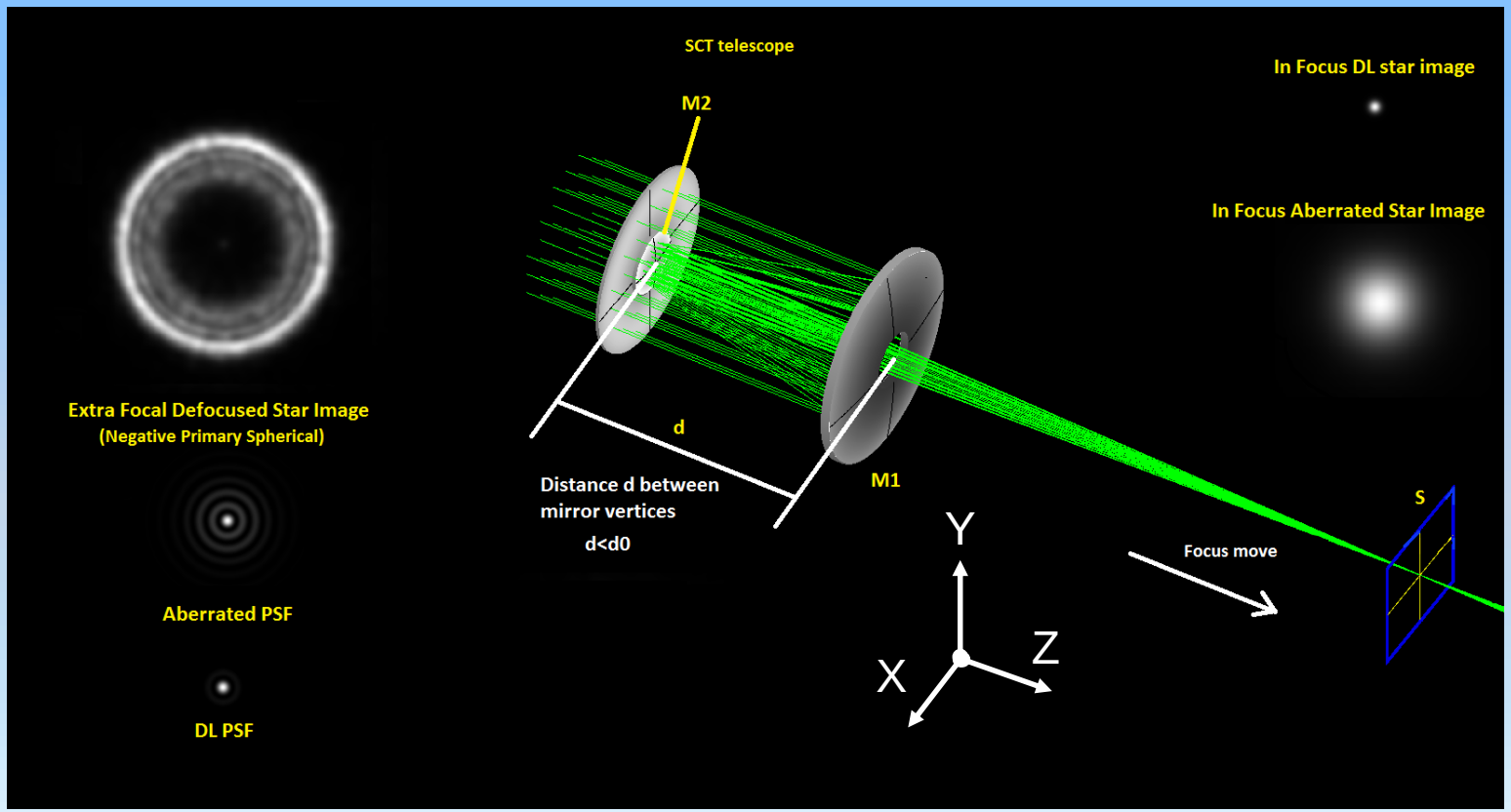
Spacing
Example with a 8” SCT

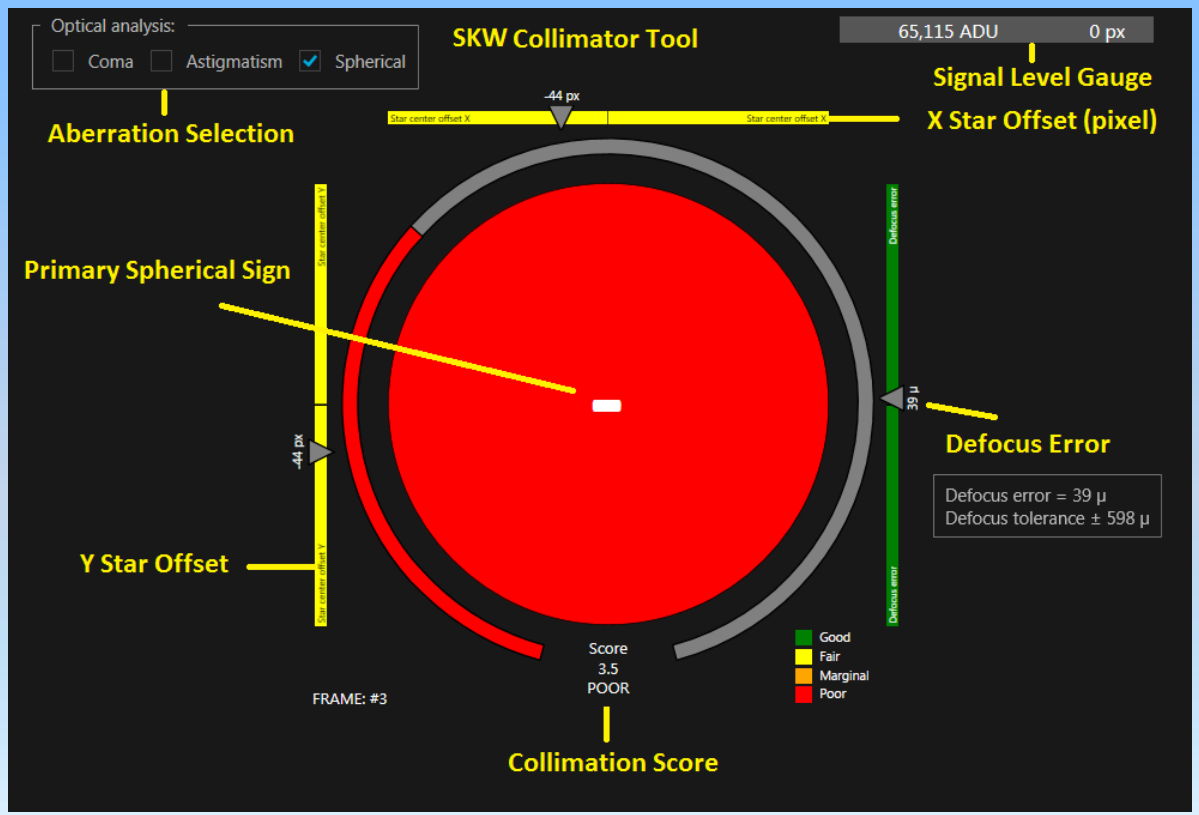
Also valid for any scope with spherical mirror(s)

In this example **d<d0** by -11mm leading to -0.3 wave rms of negative primary spherical aberration.
The focus shifts forward by 469mm with this SCT optical design.



Spacing
SKW Collimator Tool

The SKW collimator tool displays the score and the sign of the primary spherical aberration. Spherical only should be selected. A negative sign implies that **d<d0**, a positive one that **d>d0**.



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Conclusions

- SKW determines wavefront and related aberrations from a single defocused star image even under seeing limited conditions. This allows for an accurate and fast quantitative optical alignment of telescopes.

- Score goal ≥ 8, the green zone. Rules when using SKW collimator and the M2 alignment (collimation) screws:

  1. Congruence using **coma only** (see axis coordinate system)

Pull M2 at the position indicated by the SKW score mark angular direction.

  2. Spacing using **spherical only**

Increase the mirrors spacing if the SKW spherical aberration sign is negative, decrease it if positive.

Astronomy

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Thank you!