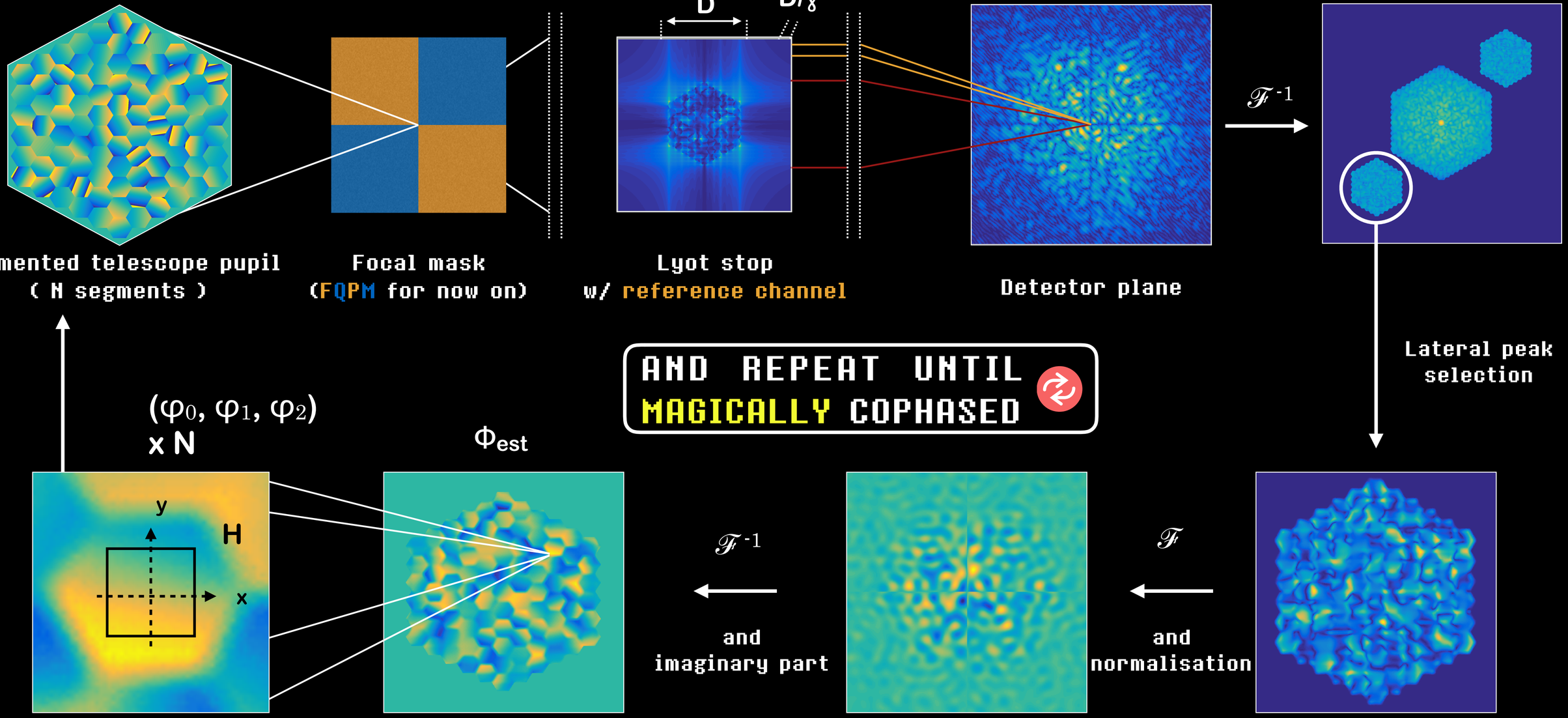
The SCC-PS - How does it work ?

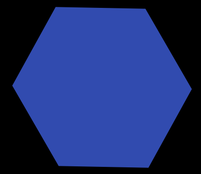


SCC-PS : Janin-Potiron et al. (2016)

SCC : Baudoz et al. (2006) ; Galicher et al. (2008)

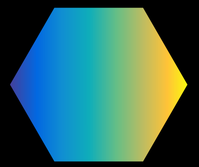
The SCC-PS - Piston, tip and tilt retrieval

Piston



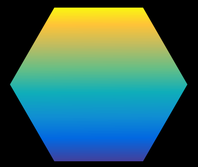
$$\varphi_0 = \iint_H \phi_{est} dxdy$$

Tip

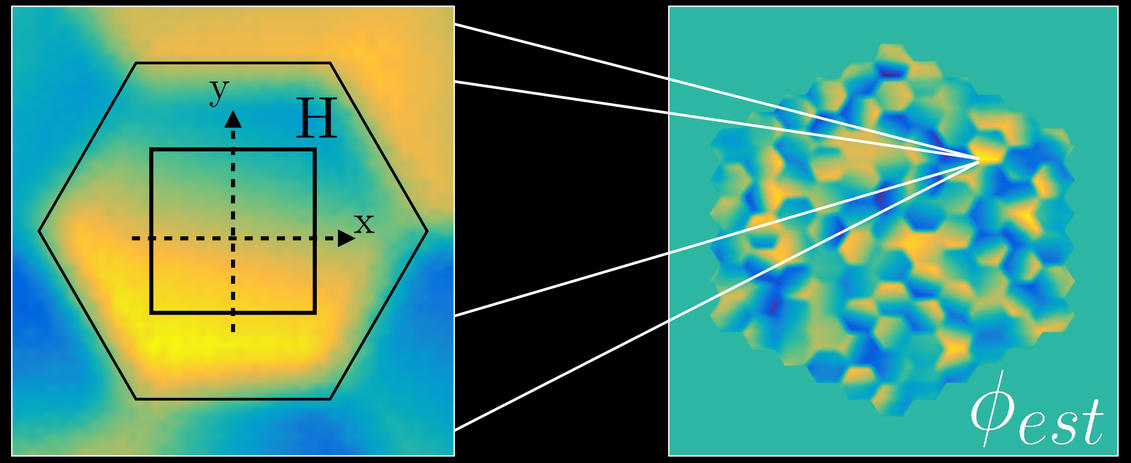


$$\varphi_1 = \iint_H \nabla_x(\phi_{est}) dxdy$$

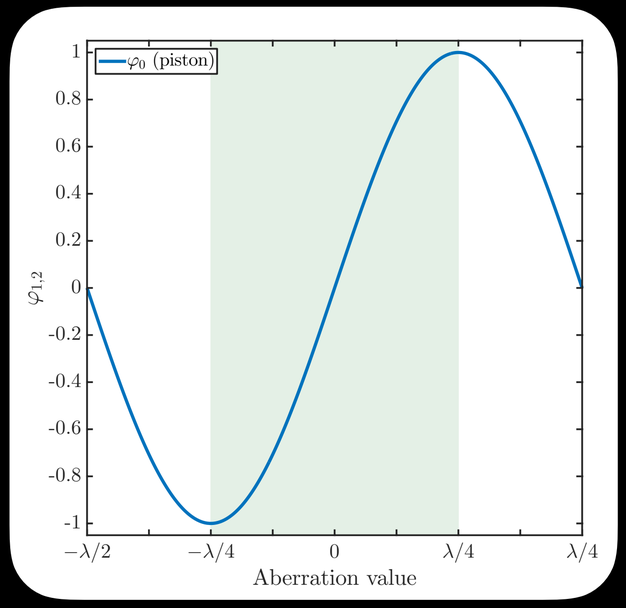
Tilt



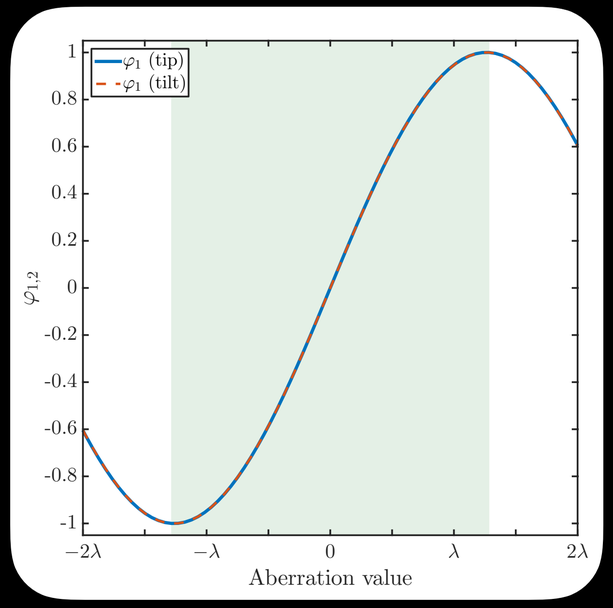
$$\varphi_2 = \iint_H \nabla_y(\phi_{est}) dxdy$$



$$S \propto \sin\left[2\pi(p + tx + Ty)/\lambda\right] * \bullet_{\text{ref}}$$



Piston response curve



Tip-tilt response curve

Capture range = bijective zone where the measurement is unambiguous

Janin-Potiron et al. (2016)

The SCC-PS - Closed-loop cophasing

- The estimated values of PISTON, TIP and TILT are retrieved from the inversion of the linear system

$$[p_{est}, t_{est}, T_{est}] = \left(M^{-1} \times [\varphi_0, \varphi_1, \varphi_2]\right)^T$$

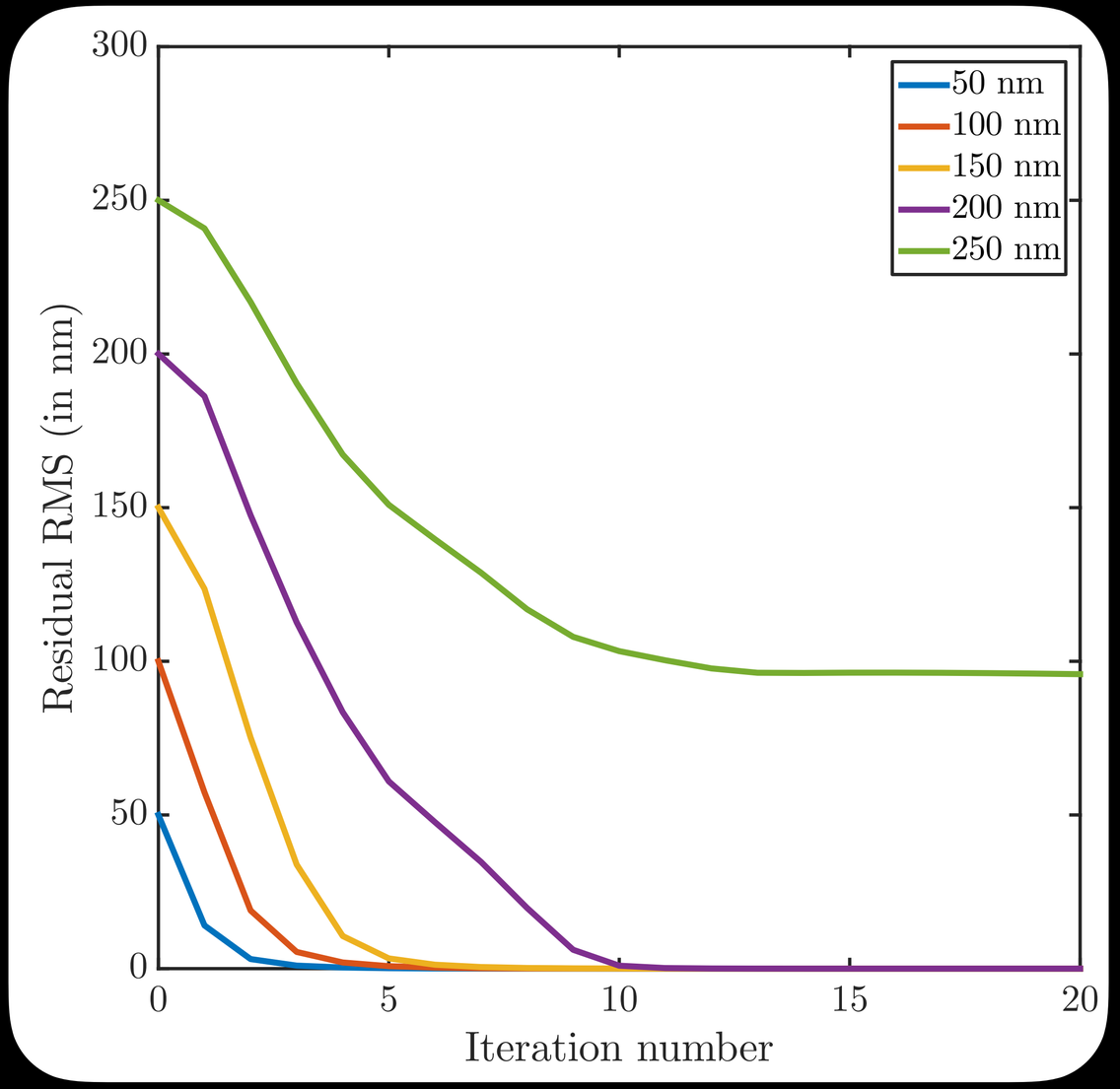
- Once calculated, these values are applied as a correction to the current PISTON, TIP and TILT positions

$$[p_{n+1}, t_{n+1}, T_{n+1}] = [p_n, t_n, T_n] - [p_{est}, t_{est}, T_{est}]$$

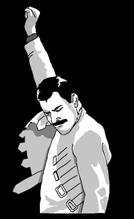
- The quality of the correction is assessed by measuring the residual standard deviation on the mirror

$$\sigma = \sqrt{\mathrm{var}(\mathbf{p}) + \mathrm{var}(\mathbf{t}) + \mathrm{var}(\mathbf{T}) + \mathbb{E}[t]^2 + \mathbb{E}[T]^2}$$

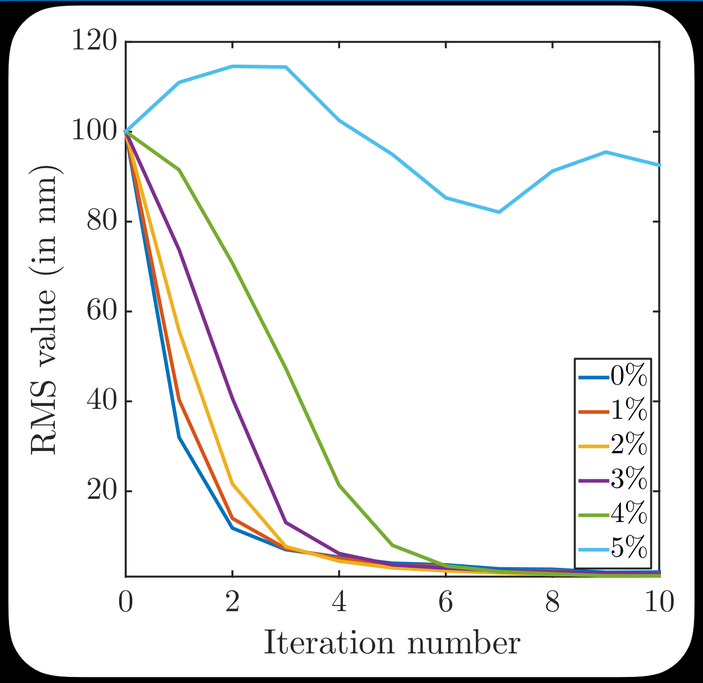
Janin-Potiron et al. (2017)



PISTON + TIP-TILT CONVERGENCE



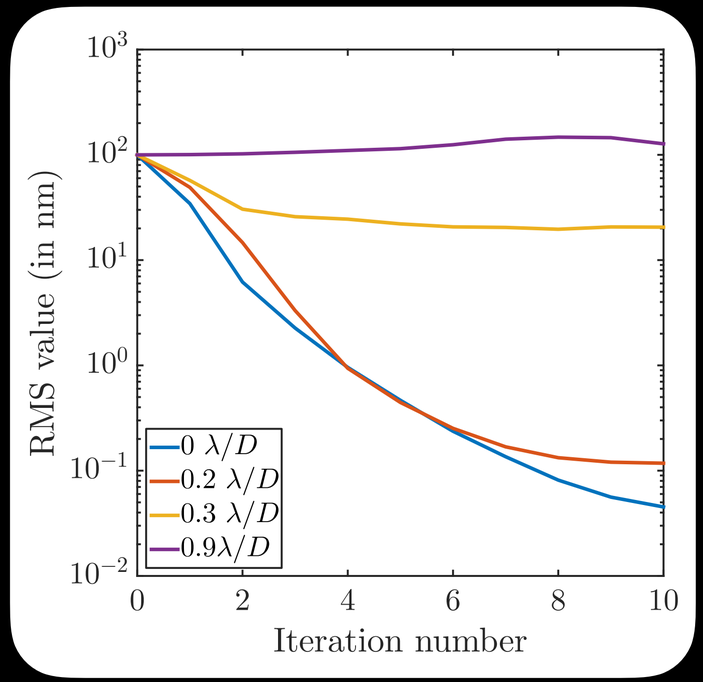
The SCC-PS - Misalignment and magnitude sensitivity



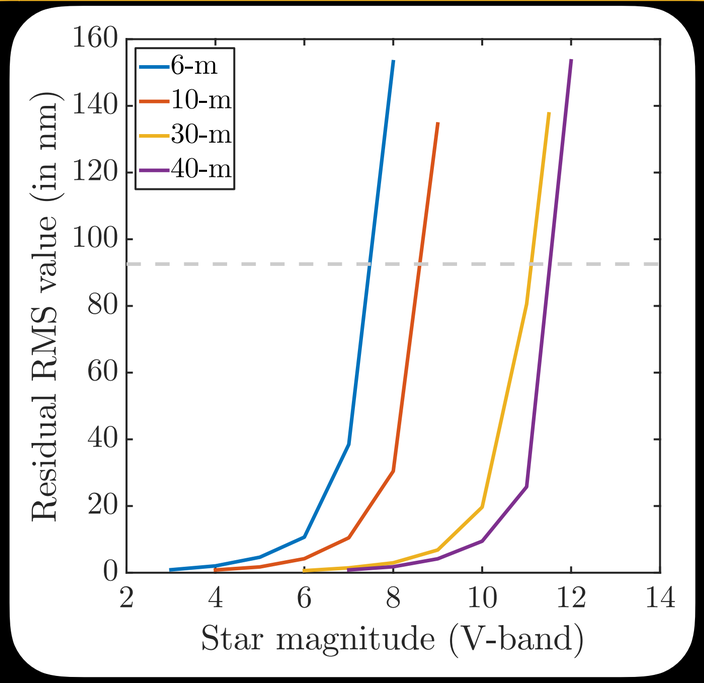
Analysis zone displacement

- In the predicted range for the JWST pupil displacement (~ 3 - 4 %, Bos et al. 2011)
- More restrictive with increasing number of segments

- Displacement simulated with global tip-tilt on the pupil
- In the achievable range already obtained on optical bench (Mas et al., 2012)



Focal mask displacement



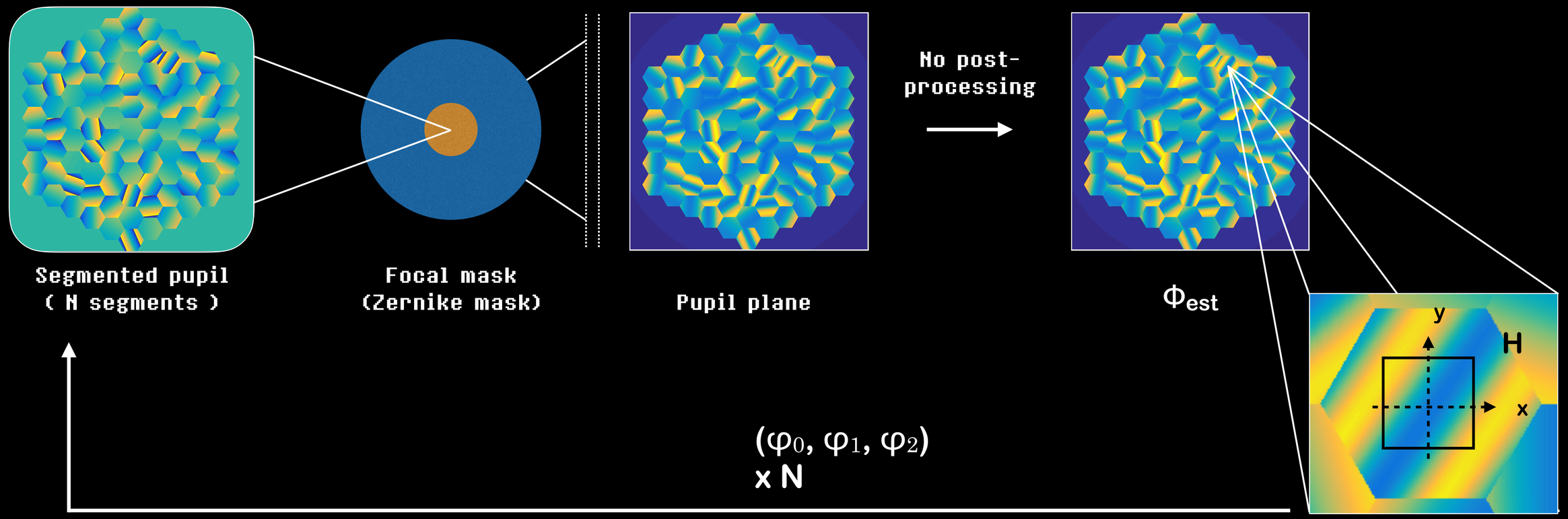
Magnitude sensitivity

- Depends on the signal-to-noise ratio on each individual segment
- Limiting stellar magnitude lower than with other sensors (Pinna et al. 2008, Surdej et al. 2010)

Janin-Potiron et al. (2016)

The ZELDA - Phasing Sensor

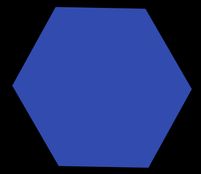
The ZELDA-PS - How does it work ?



AND REPEAT UNTIL
MAGICALLY COPHASED

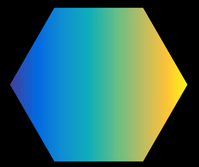
The ZELDA-PS - Piston, tip and tilt retrieval

Piston



$$\varphi_0 = \iint_H \phi_{est} dxdy$$

Tip



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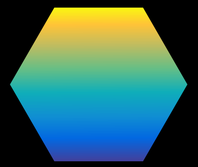
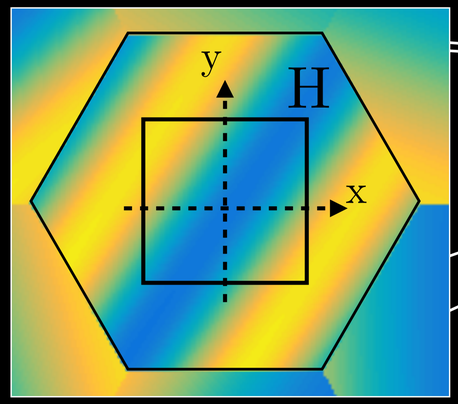
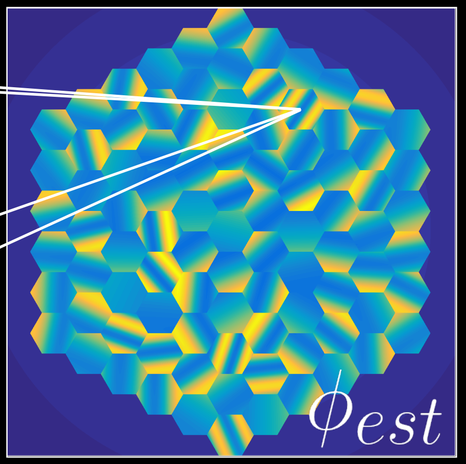
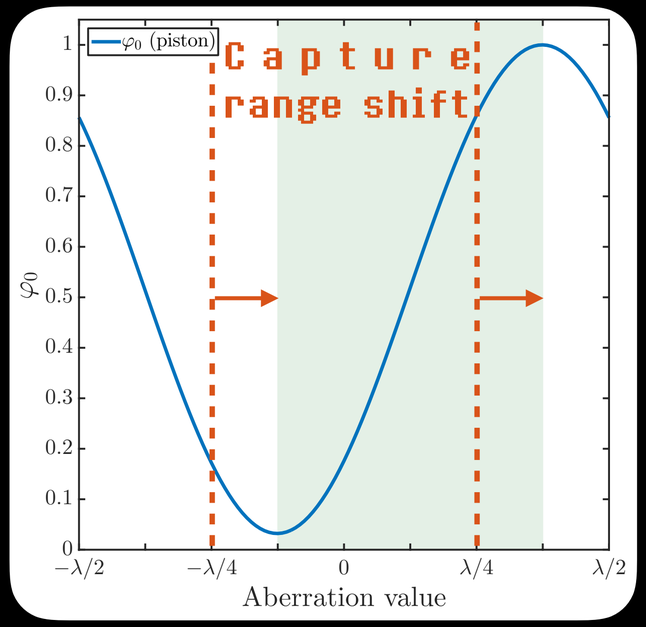
Tilt

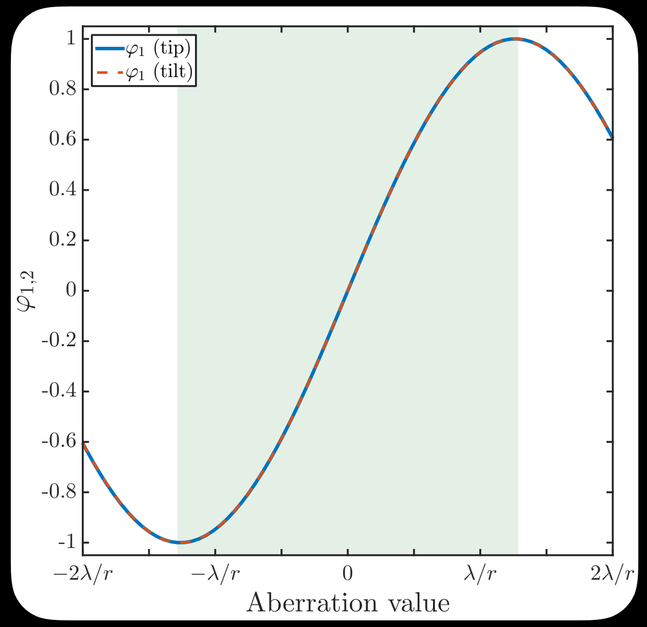


$$\varphi_2 = \iint_H \nabla_y(\phi_{est}) dxdy$$









$$\varphi_0(p_n, t_n, T_n) = 2\sqrt{2}Pb\mathcal{H}^2 \sin\left(\frac{2\pi p_n}{\lambda} - \phi_0\right) \operatorname{sinc}\left(\frac{\pi \mathcal{H} t_n}{\lambda}\right) \times \operatorname{sinc}\left(\frac{\pi \mathcal{H} T_n}{\lambda}\right) + \mathcal{H}^2\left(P^2 + 2b^2\right)$$

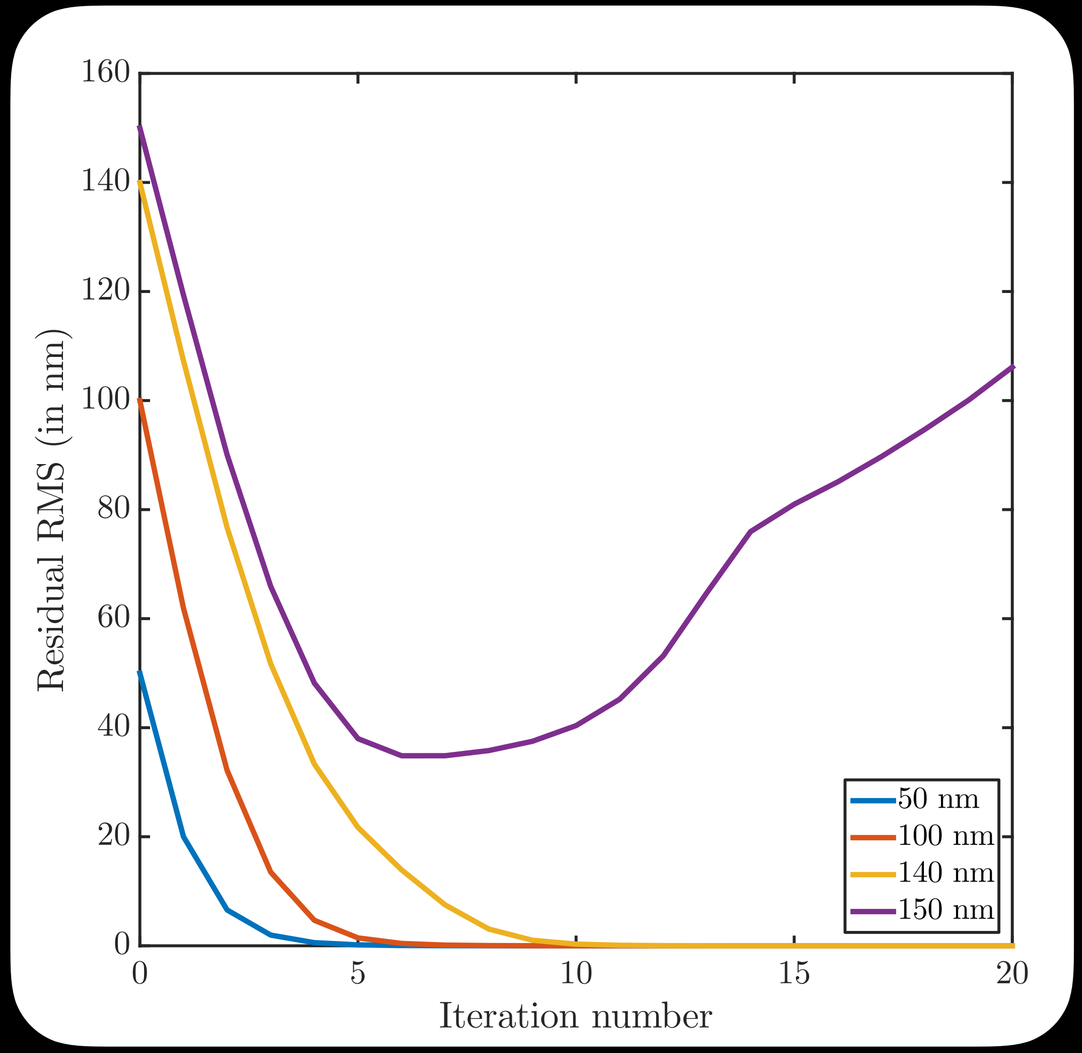
$$\varphi_1(p_n, t_n, T_n) = 4\sqrt{2}Pb\mathcal{H} \cos\left(\frac{2\pi p_n}{\lambda} - \phi_0\right) \times \sin\left(\frac{\pi \mathcal{H} t_n}{\lambda}\right) \operatorname{sinc}\left(\frac{\pi \mathcal{H} T_n}{\lambda}\right)$$

$$\varphi_2(p_n, t_n, T_n) = 2\sqrt{2}Pb\mathcal{H} \cos\left(\frac{2\pi p_n}{\lambda} - \phi_0\right) \times \operatorname{sinc}\left(\frac{\pi \mathcal{H} t_n}{\lambda}\right) \sin\left(\frac{\pi \mathcal{H} T_n}{\lambda}\right)$$

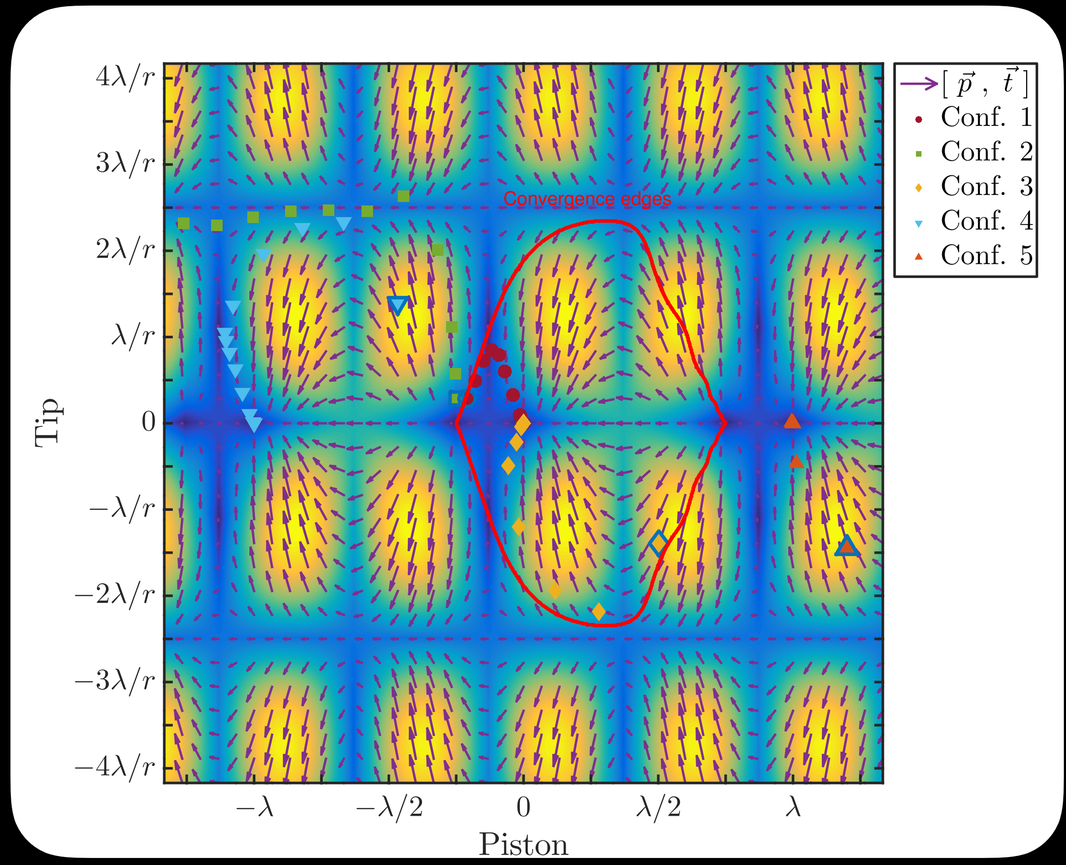
Janin-Potiron et al. (2017)

The ZELDA-PS - Closed-loop cophasing

PISTON + TIP-TILT CONVERGENCE



PISTON + TIP THEORETICAL CONVERGENCE



Prediction of the convergence by calculating gradient norm and direction

$$\begin{cases} \vec{\Delta} = \vec{\varphi_0} + \vec{\varphi_1} \\ ||\Delta|| = \varphi_0^2 + \varphi_1^2 \end{cases}$$

Janin-Potiron et al. (2017)

The ZELDA-PS - Closed-loop cophasing

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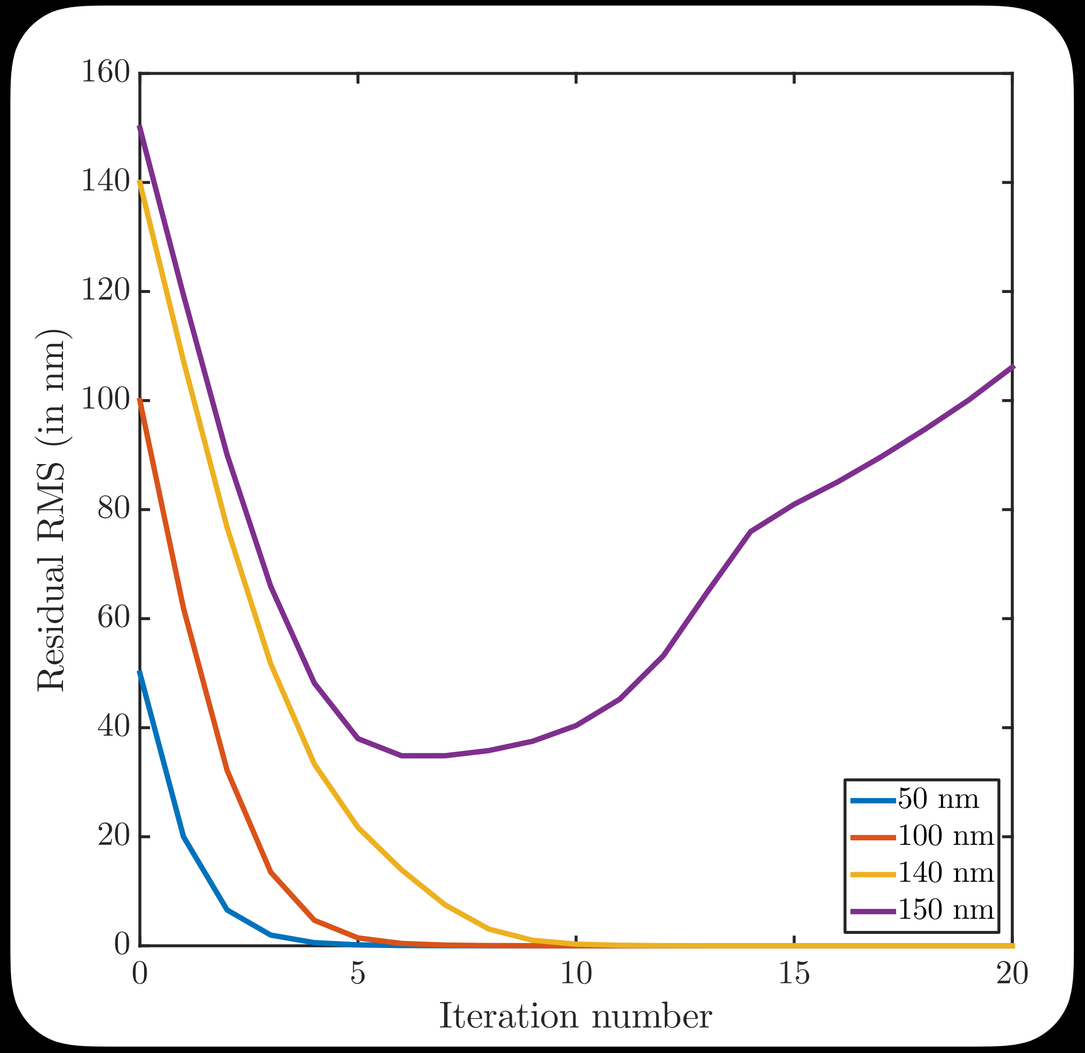
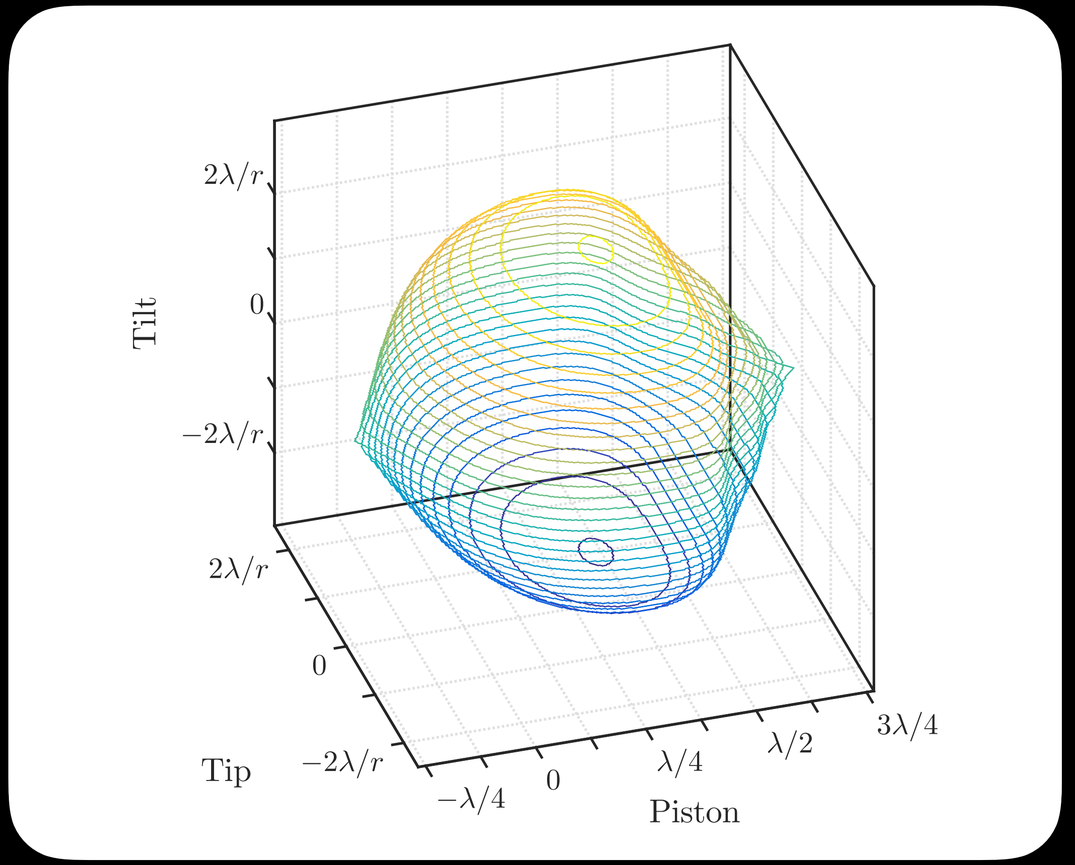


PISTON + TIP-TILT THEORETICAL CONVERGENCE



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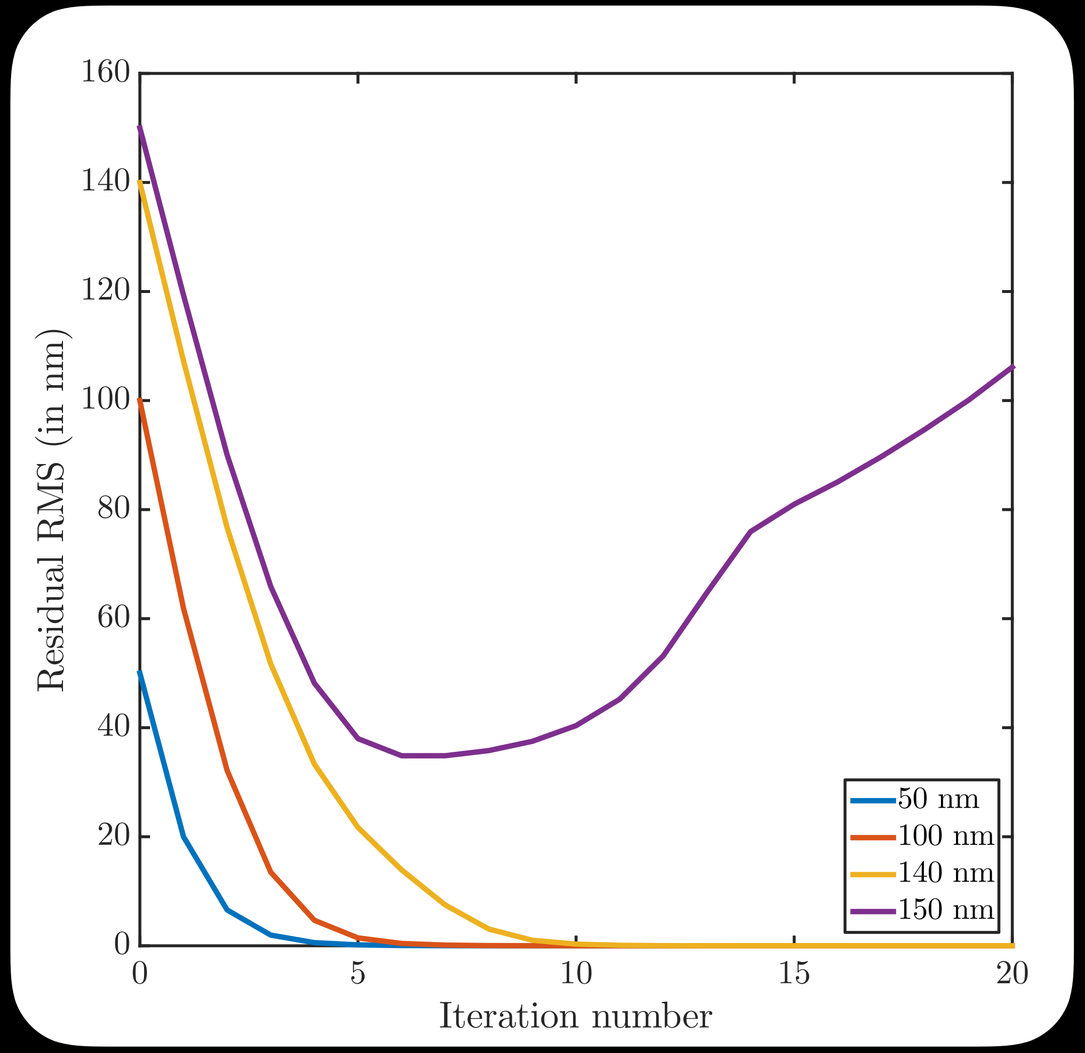

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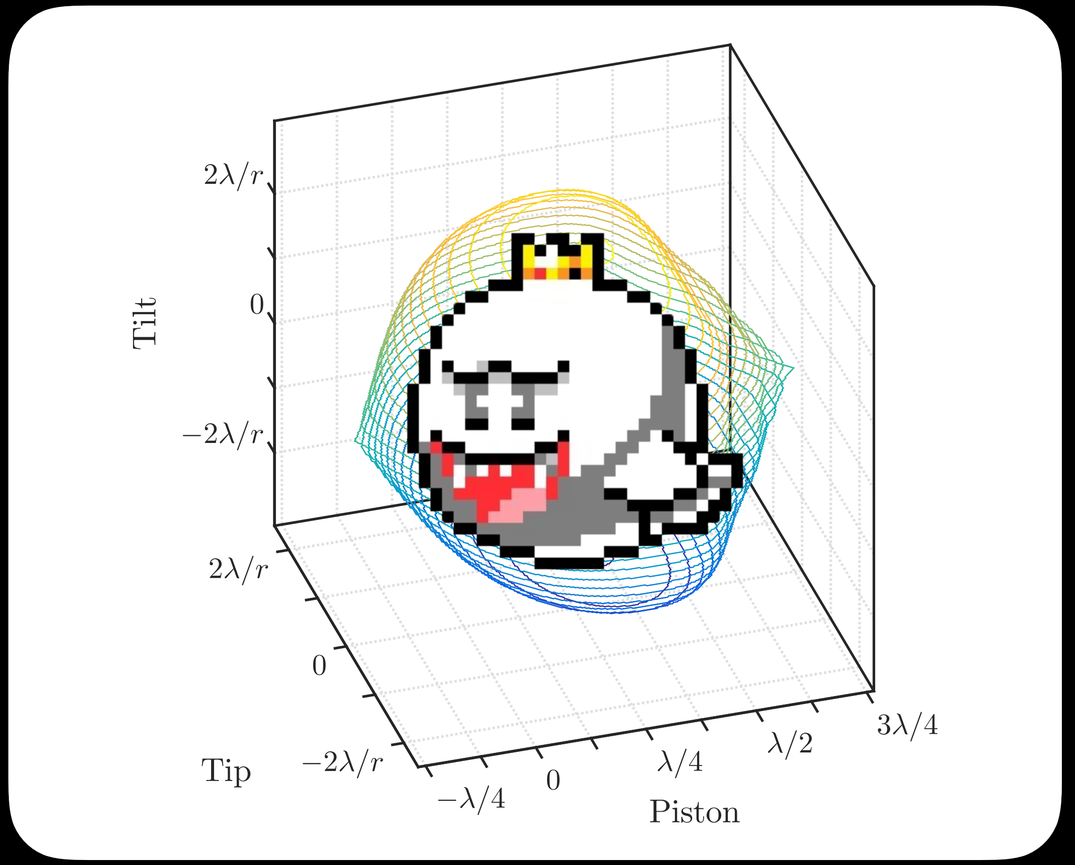

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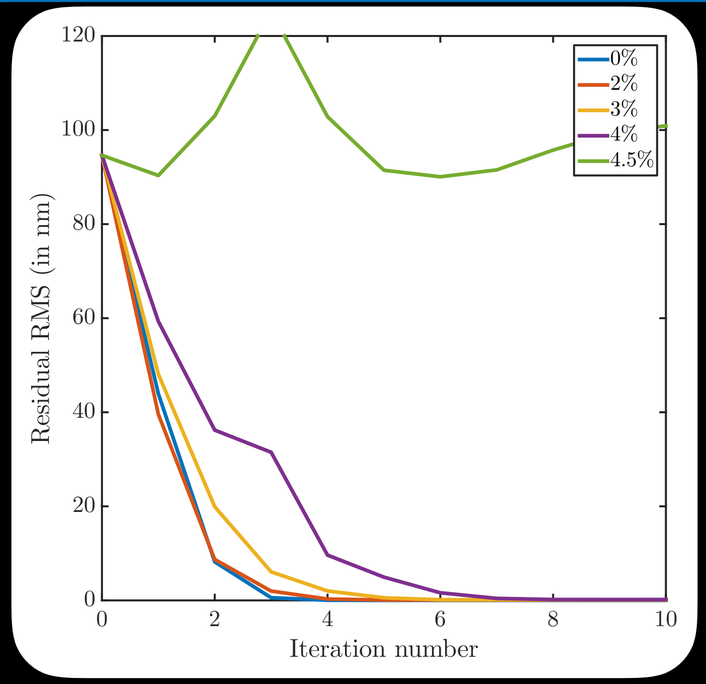
The ZELDA-PS - Misalignment and magnitude sensitivity



Analysis zone displacement

- In the predicted range for the JWST pupil displacement (~ 3 - 4 %, Bos et al. 2011)
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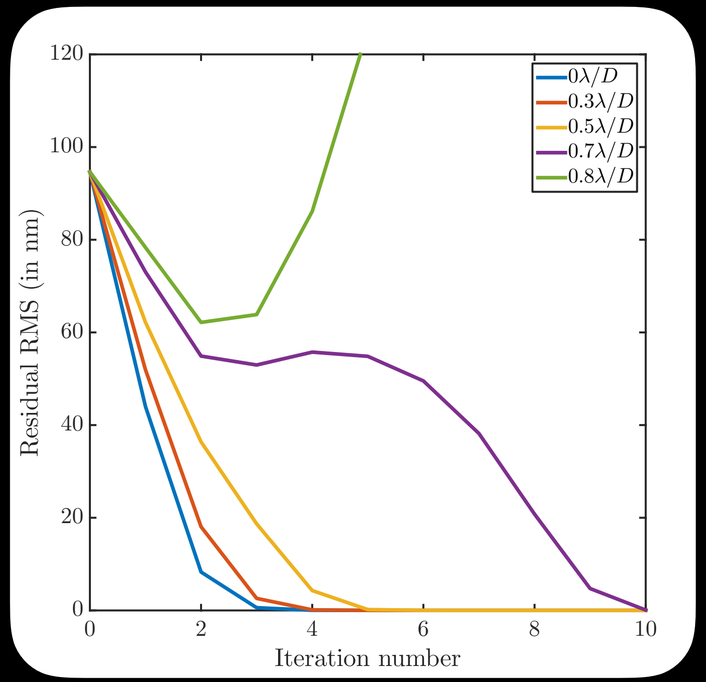
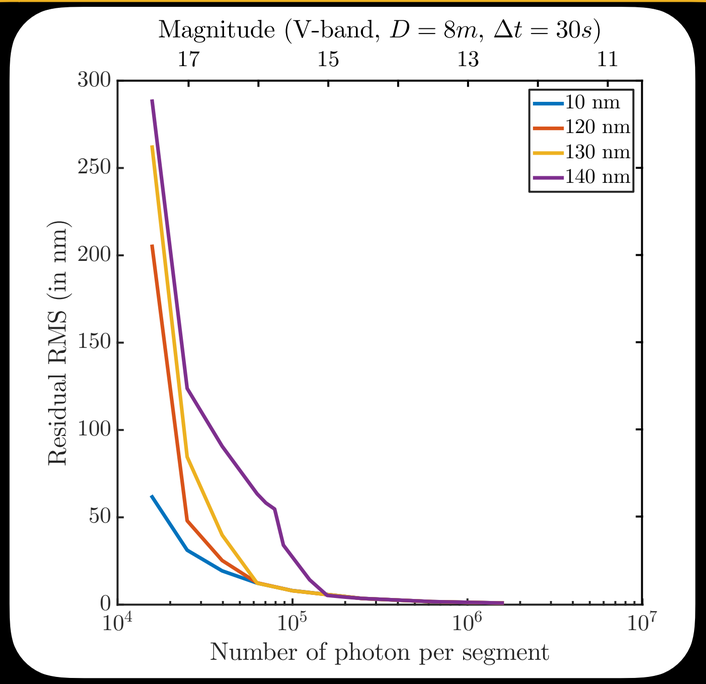


Focal mask displacement

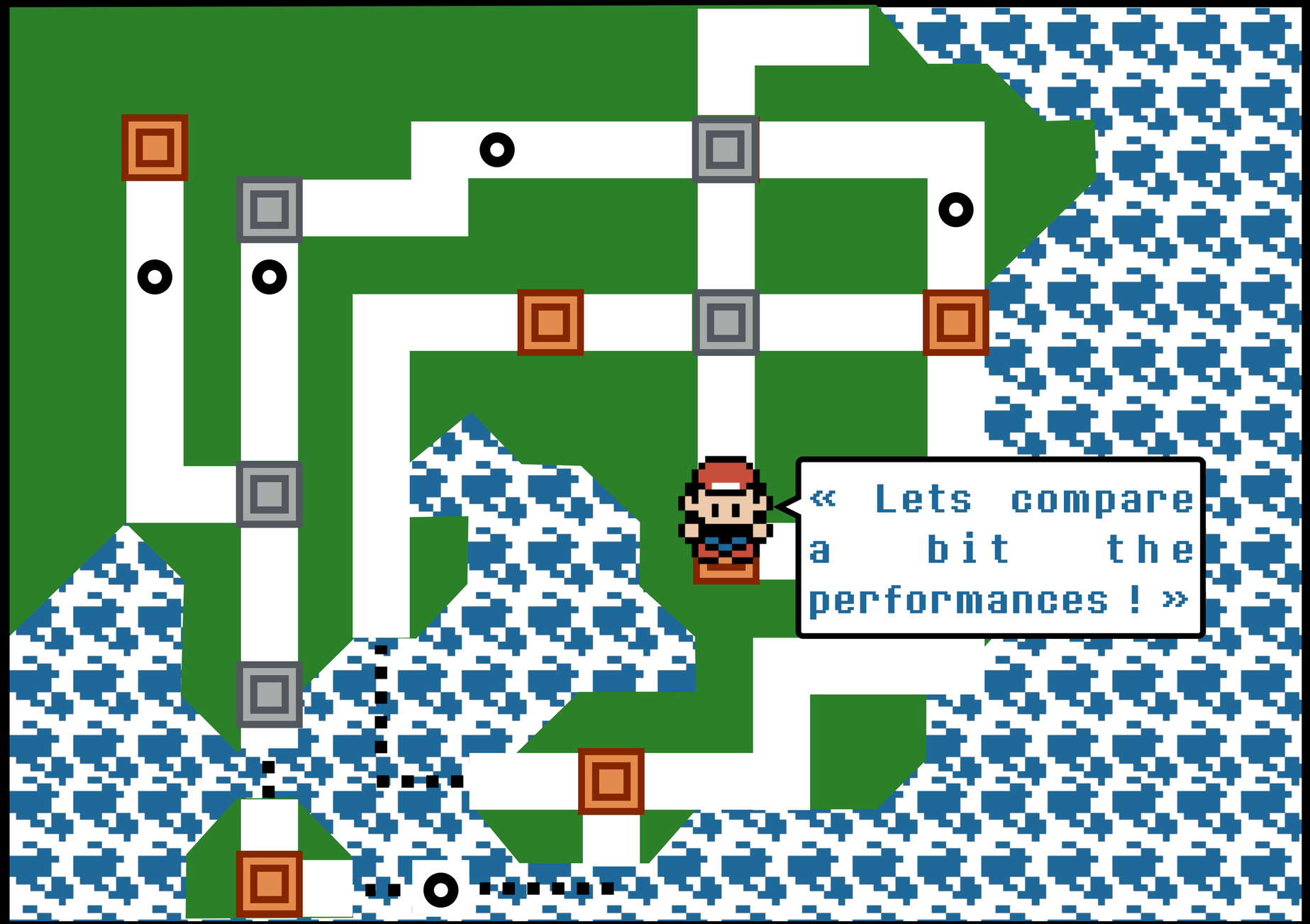


Magnitude sensitivity

- Median of the RMS residual after 20 iterations is measured
- The results are consistent with other phasing sensors (Pinna et al. 2008, Surdej et al. 2010)

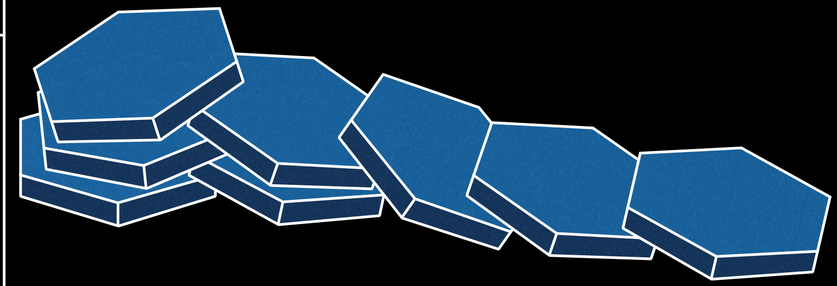
Janin-Potiron et al. (2017)

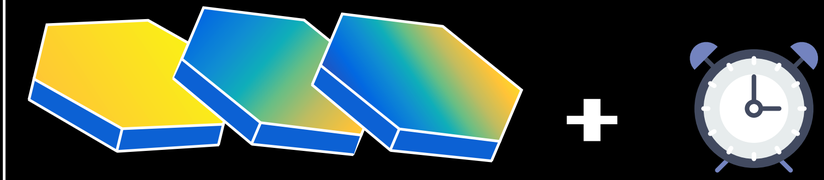
Comparison summary between SCC-PS and ZELDA-PS

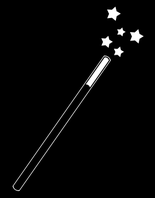


Comparison summary between SCC-PS and ZELDA-PS

	SCC-PS	ZELDA-PS
Works with a large number of segments	✓	✓
Simultaneously measure and correct for piston, tip and tilt + real time control	✓	✓
Can operate using the science image	✓	STOP
Moderate complexity of the system	✓	✓
Works with high magnitude targets	YIELD	✓
Has the optimal capture range	✓	YIELD







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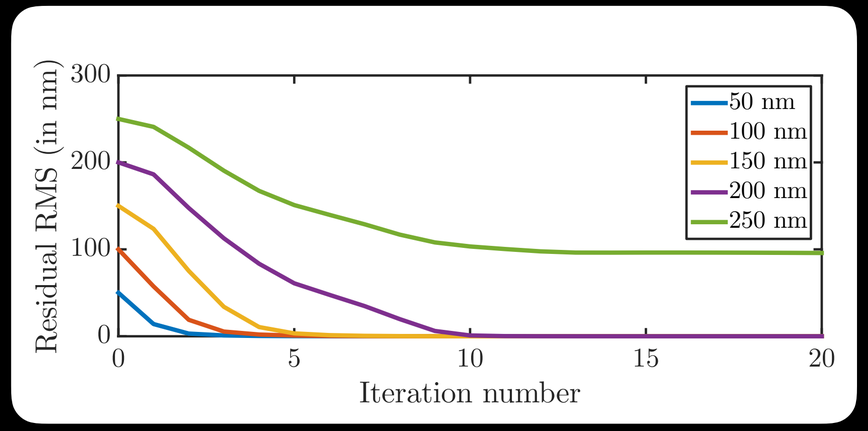
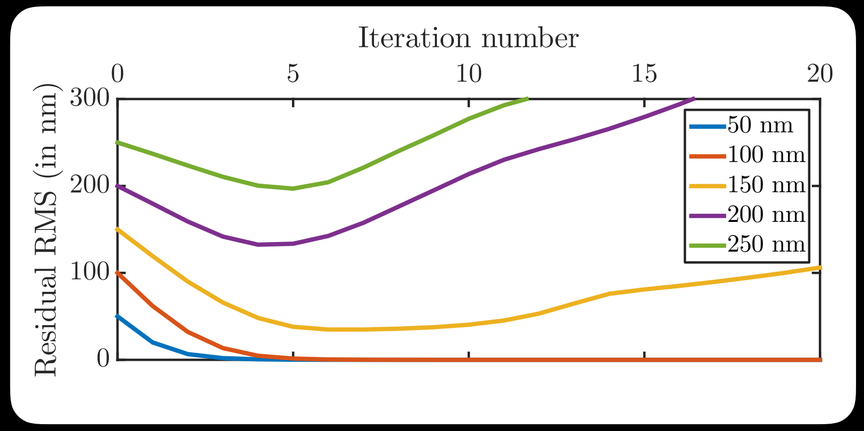


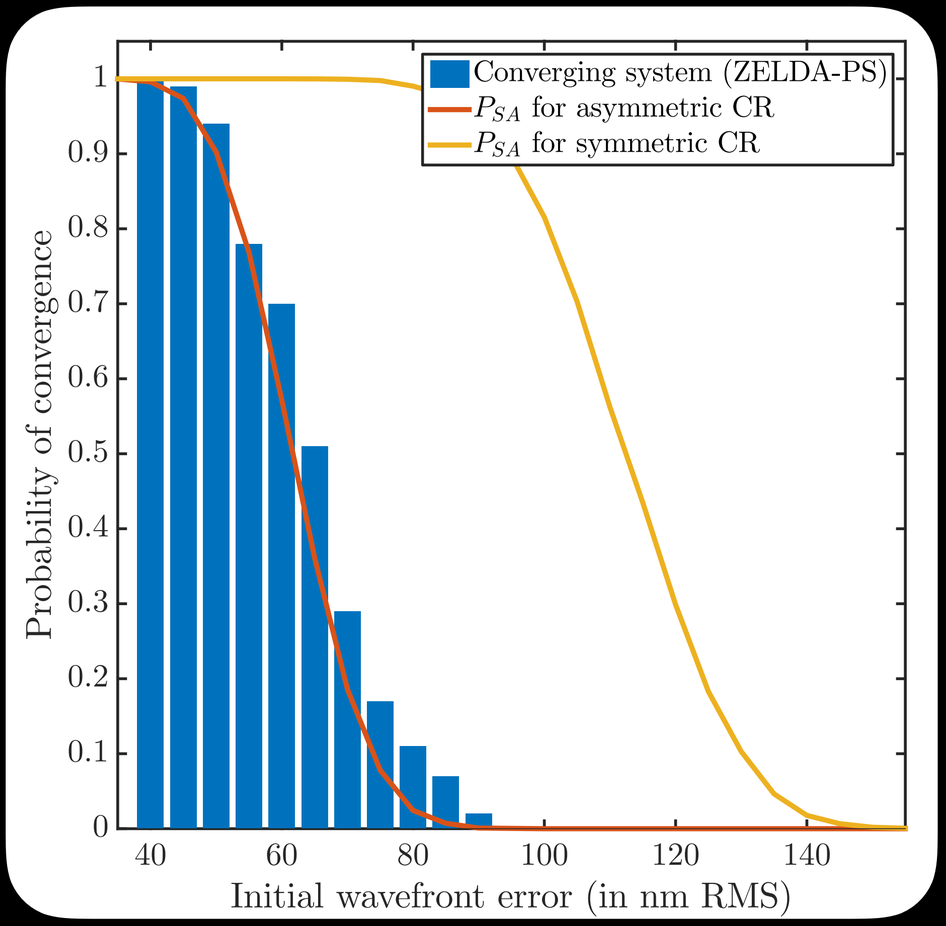
Piston & tip-tilt - SCC-PS



Piston & tip-tilt - ZELDA-PS

Properties and improvements of the cophasing systems

Properties and improvements - Statistical approach of the cophasing



$$\mathbb{P}_{SA}(\sigma^2_{pupil}, a, b) = \int_{(\mathbb{R})^N} \mathbb{1}\left\{ \bigcap_{n=1}^{N} a < p_n - \mathbb{E}[\mathbf{p}] < b \right\} \times \prod_{n=1}^{N} f_P(p_n \mid 0, \sigma_p^2)\,(\mathrm{d}p_1 \cdots \mathrm{d}p_n \cdots \mathrm{d}p_N)$$

- In piston only, the outcome of the converging can be analytically calculated

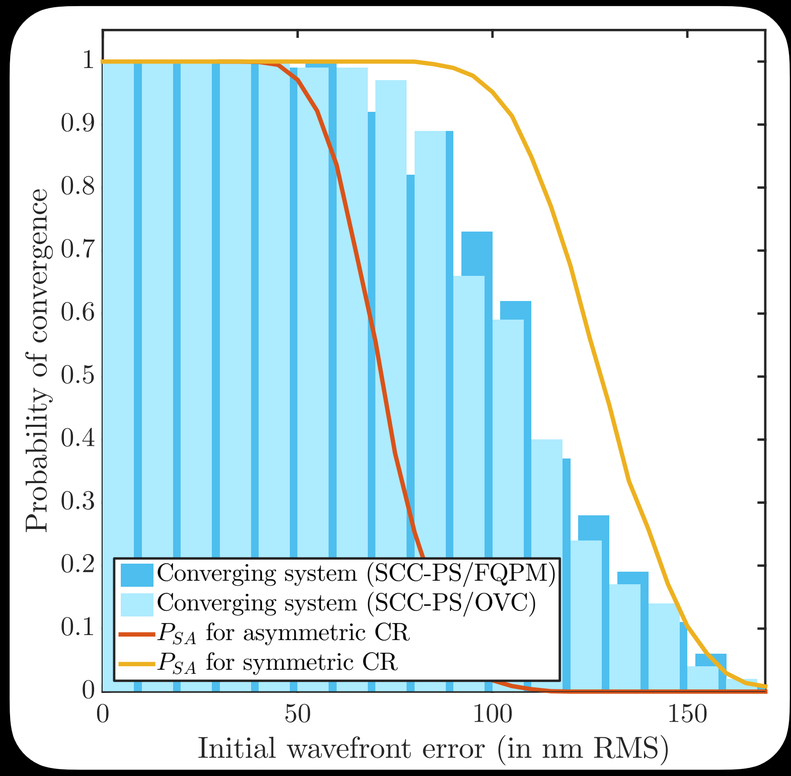
- The probability of the convergence depends on four parameters

The level of initial aberrations

The probability density function of the piston errors

The number of segments composing the pupil

The capture range boundaries

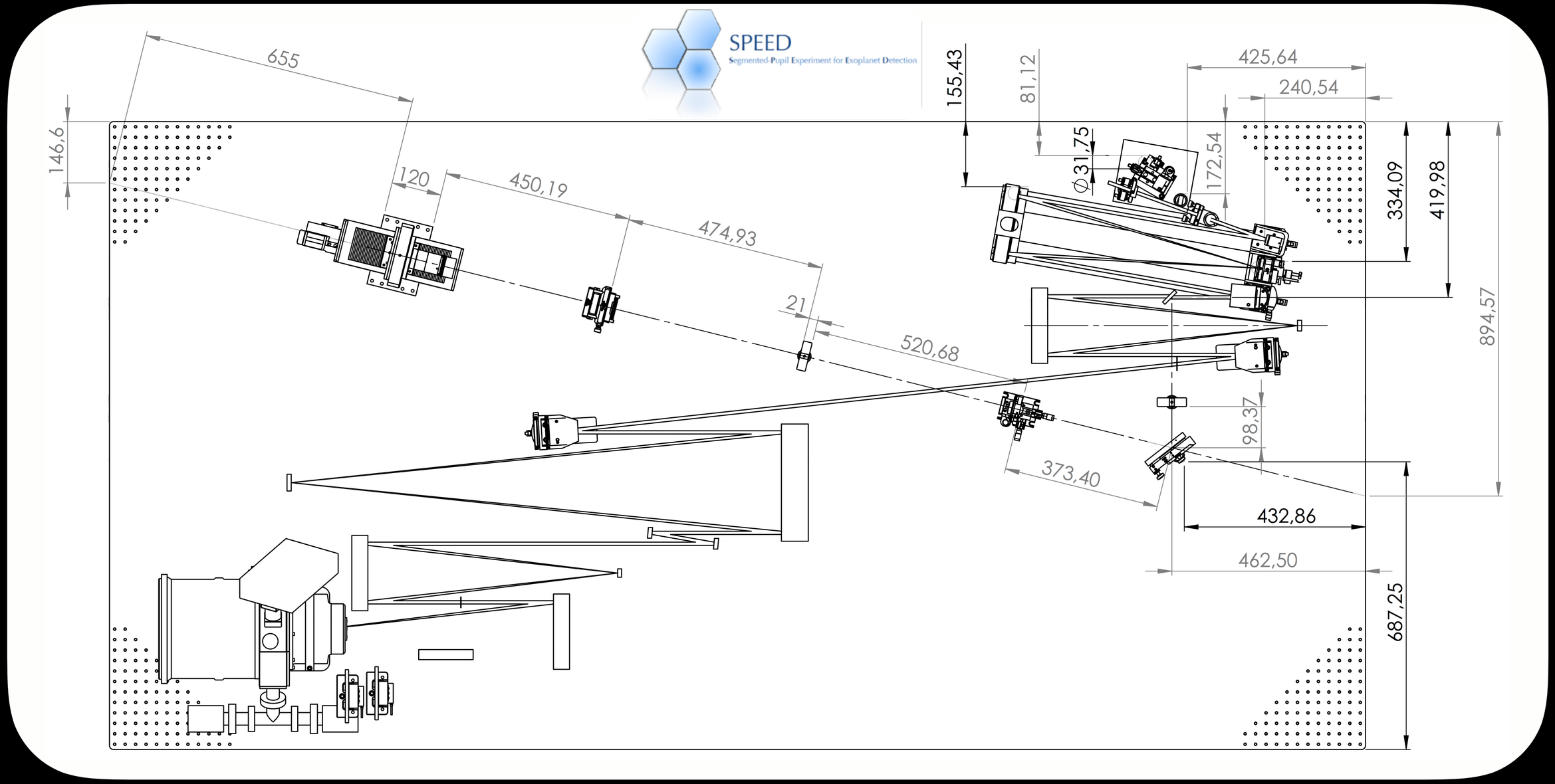


Janin-Potiron et al. (2017)

M. Postnikova (M2 internship, 2017)

Real life implementation

Real life implementation - The SPEED bench



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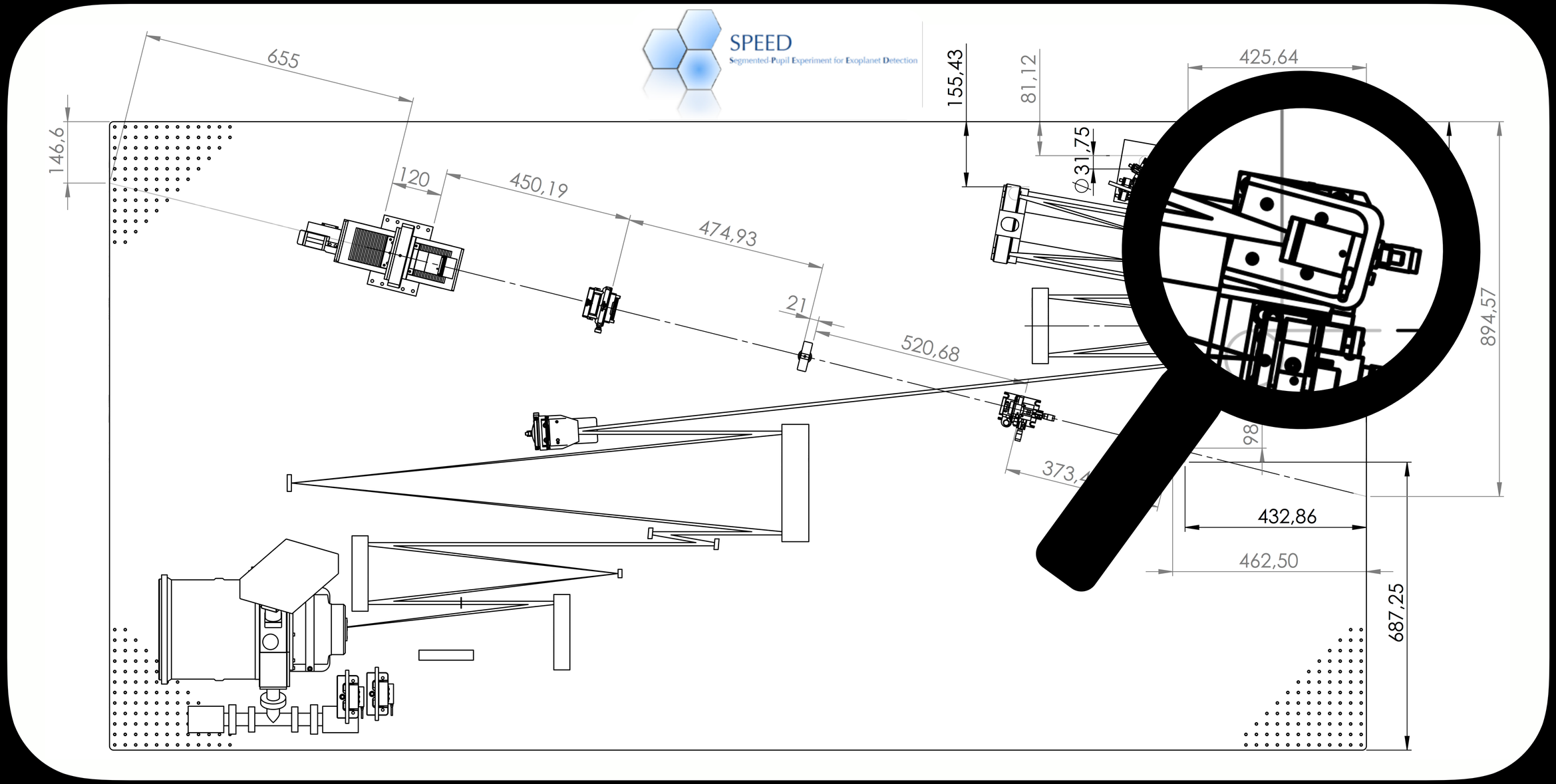
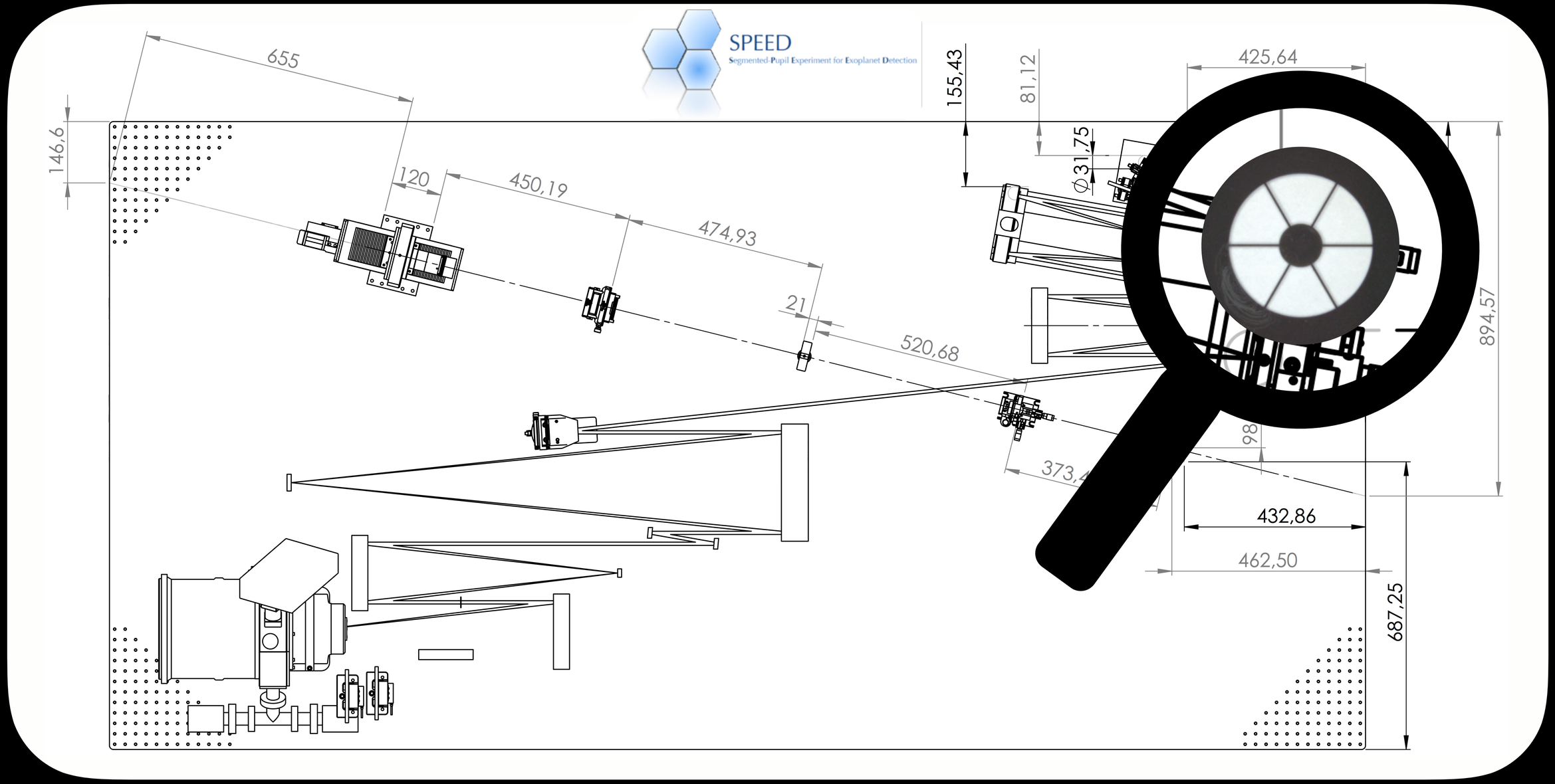


Plan : J. Dejonghe, C. Gouvret

Real life implementation - The SPEED bench



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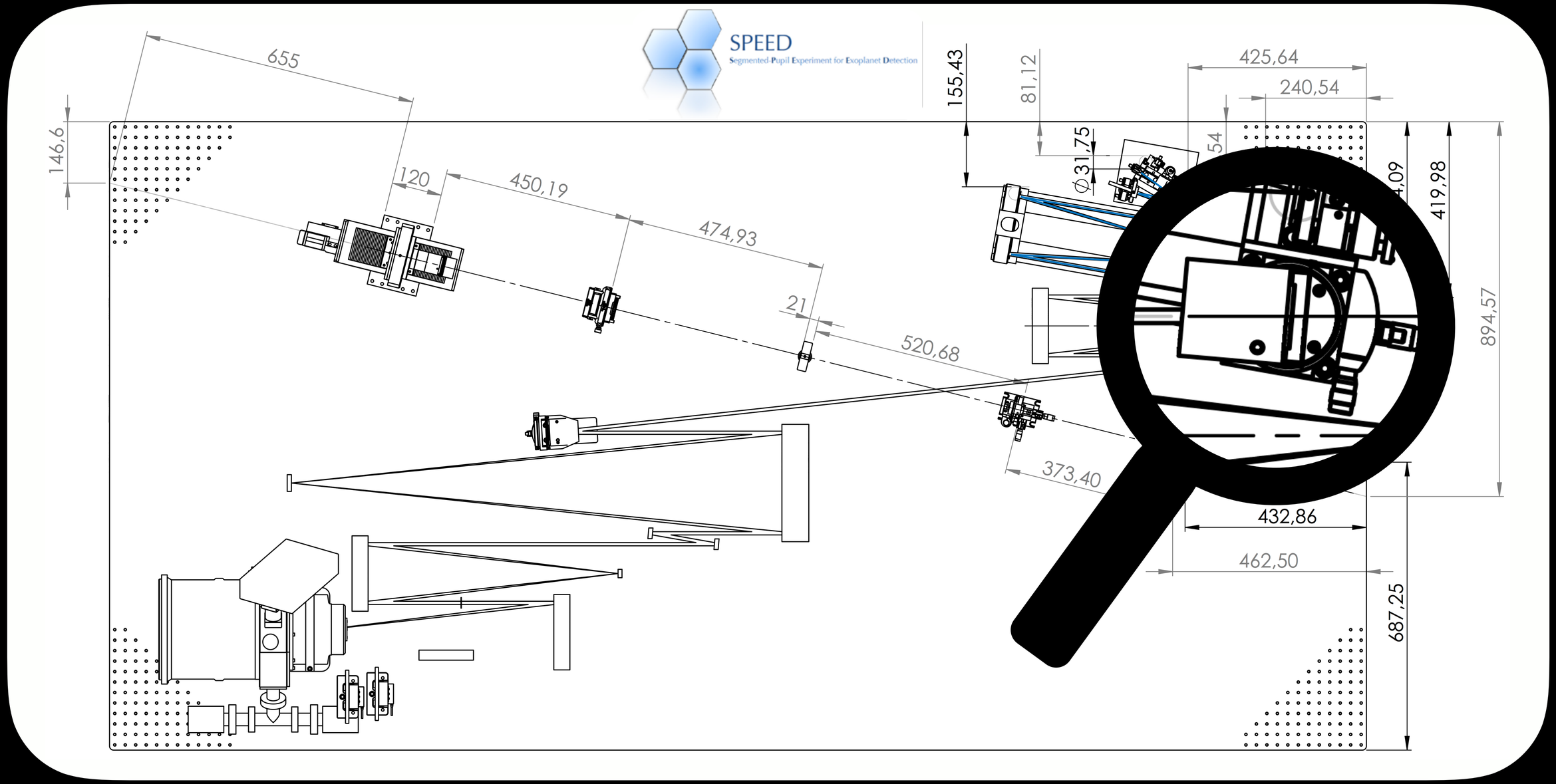

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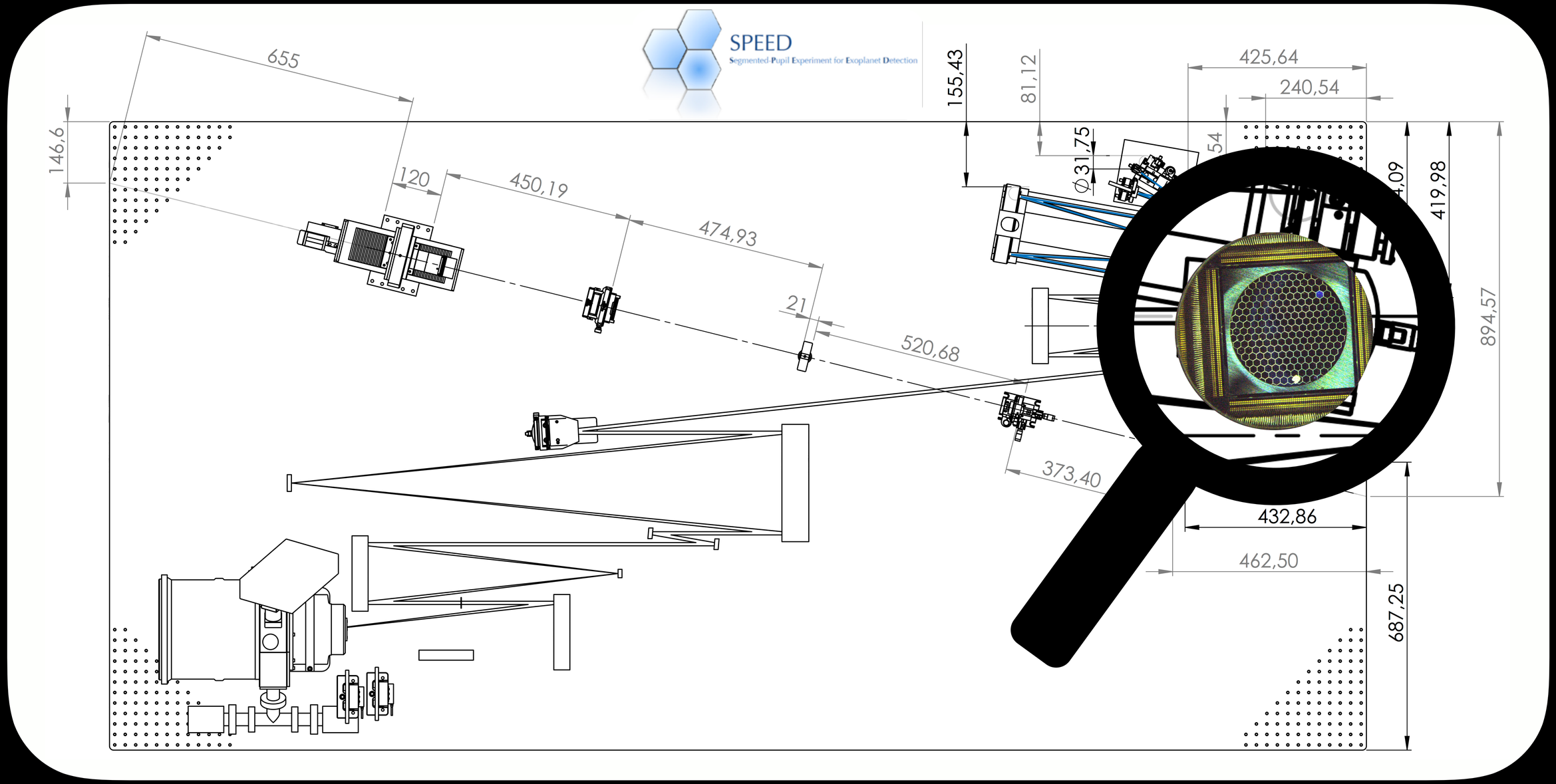

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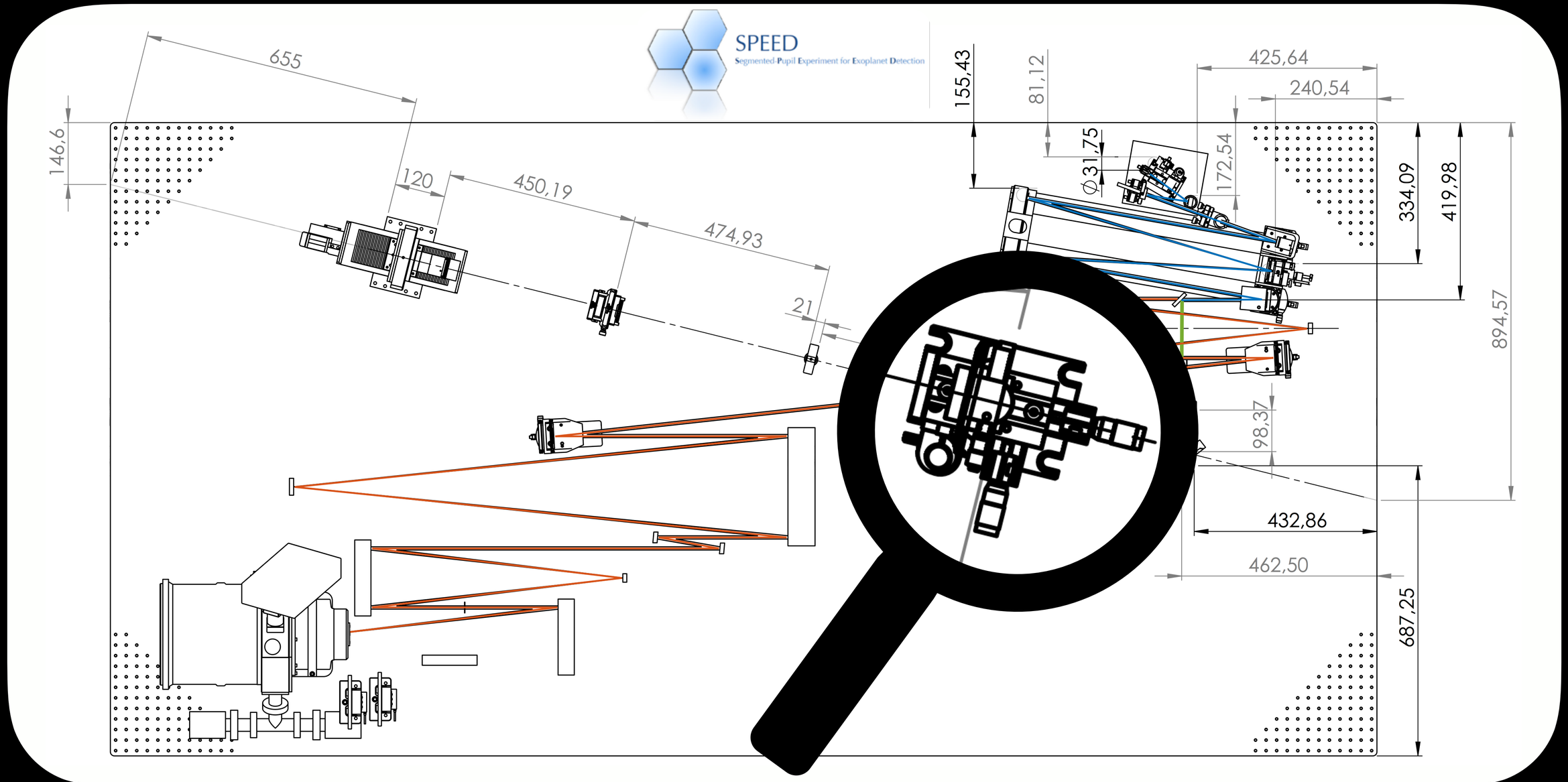

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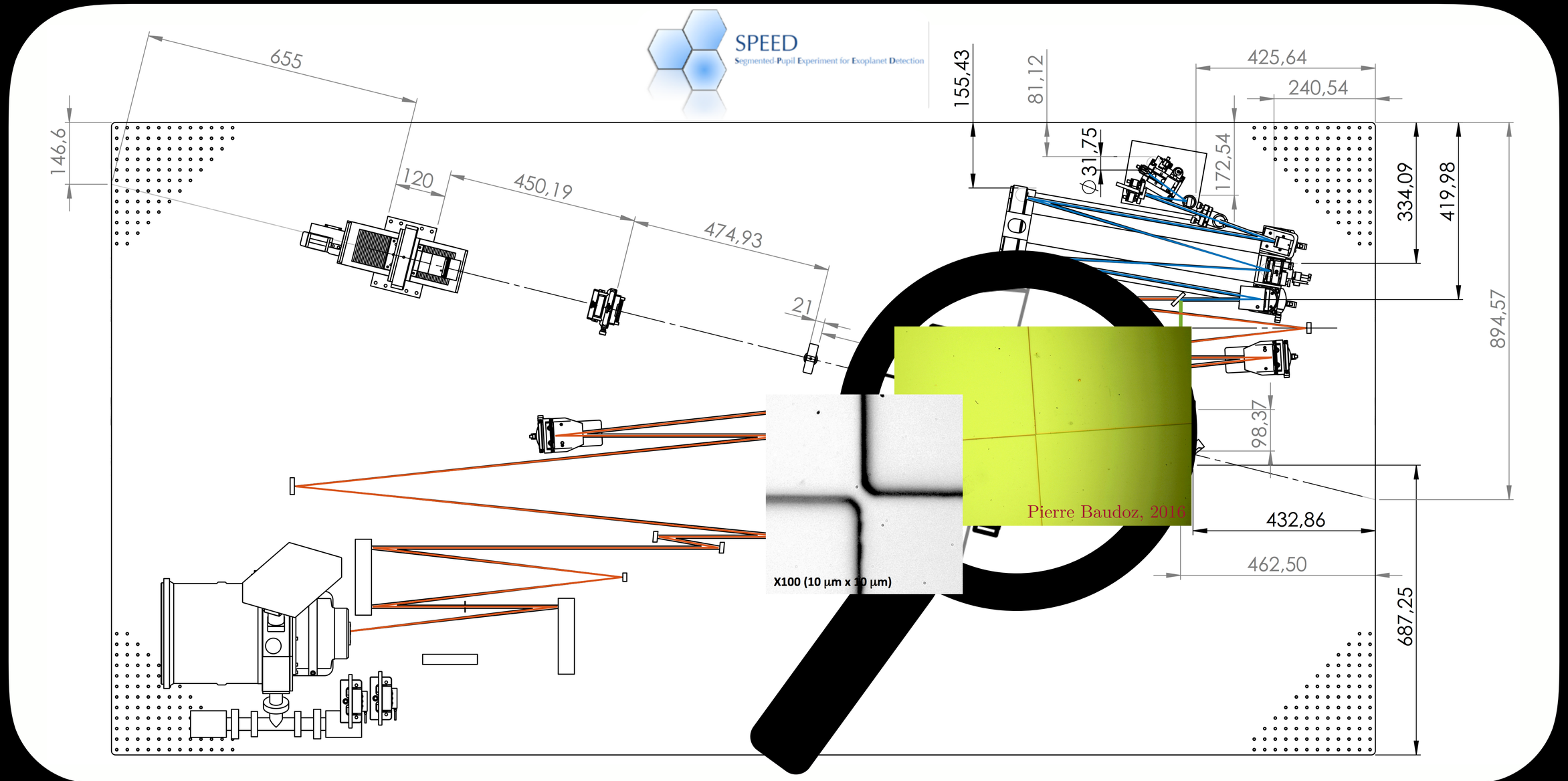

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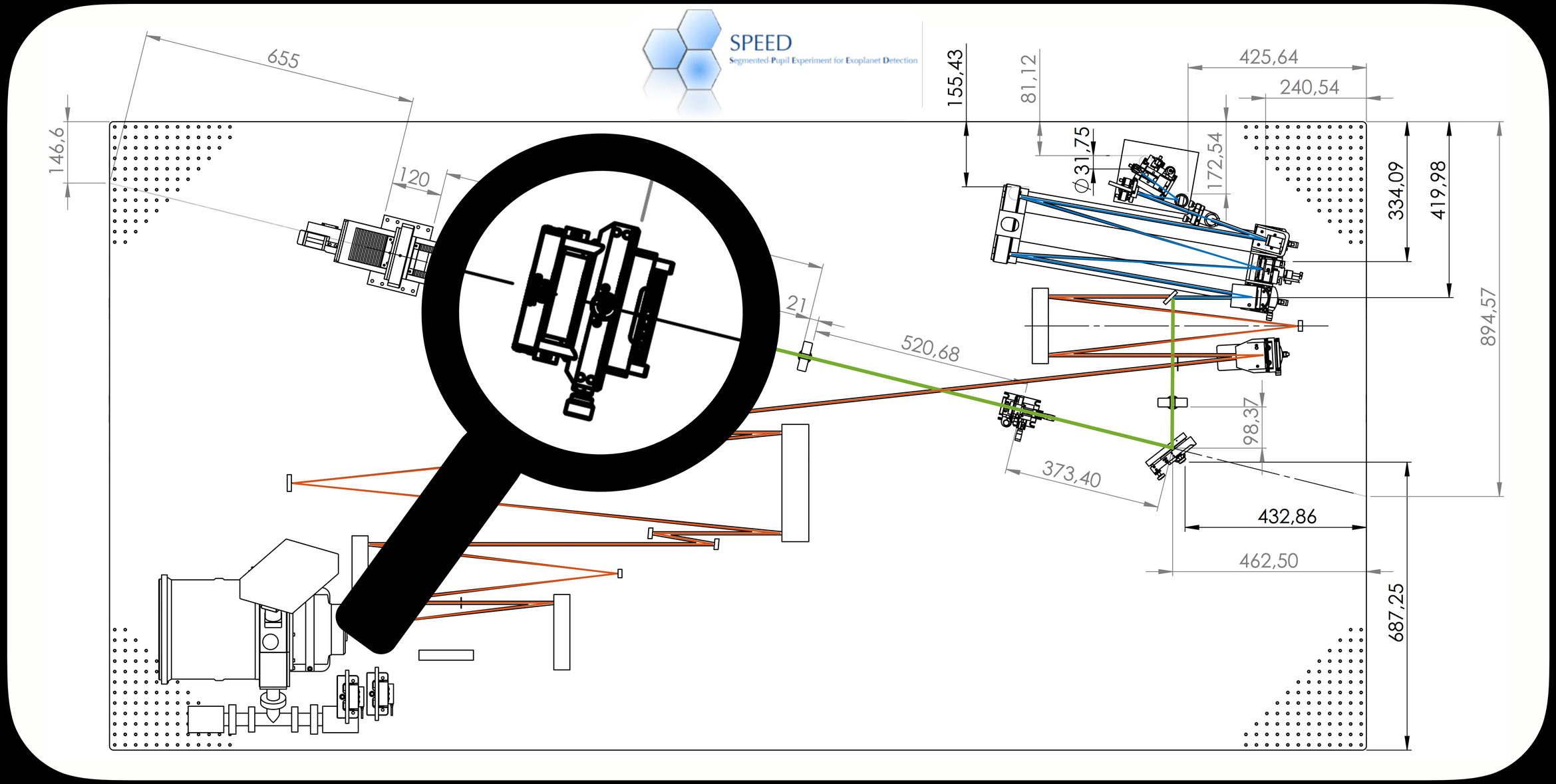
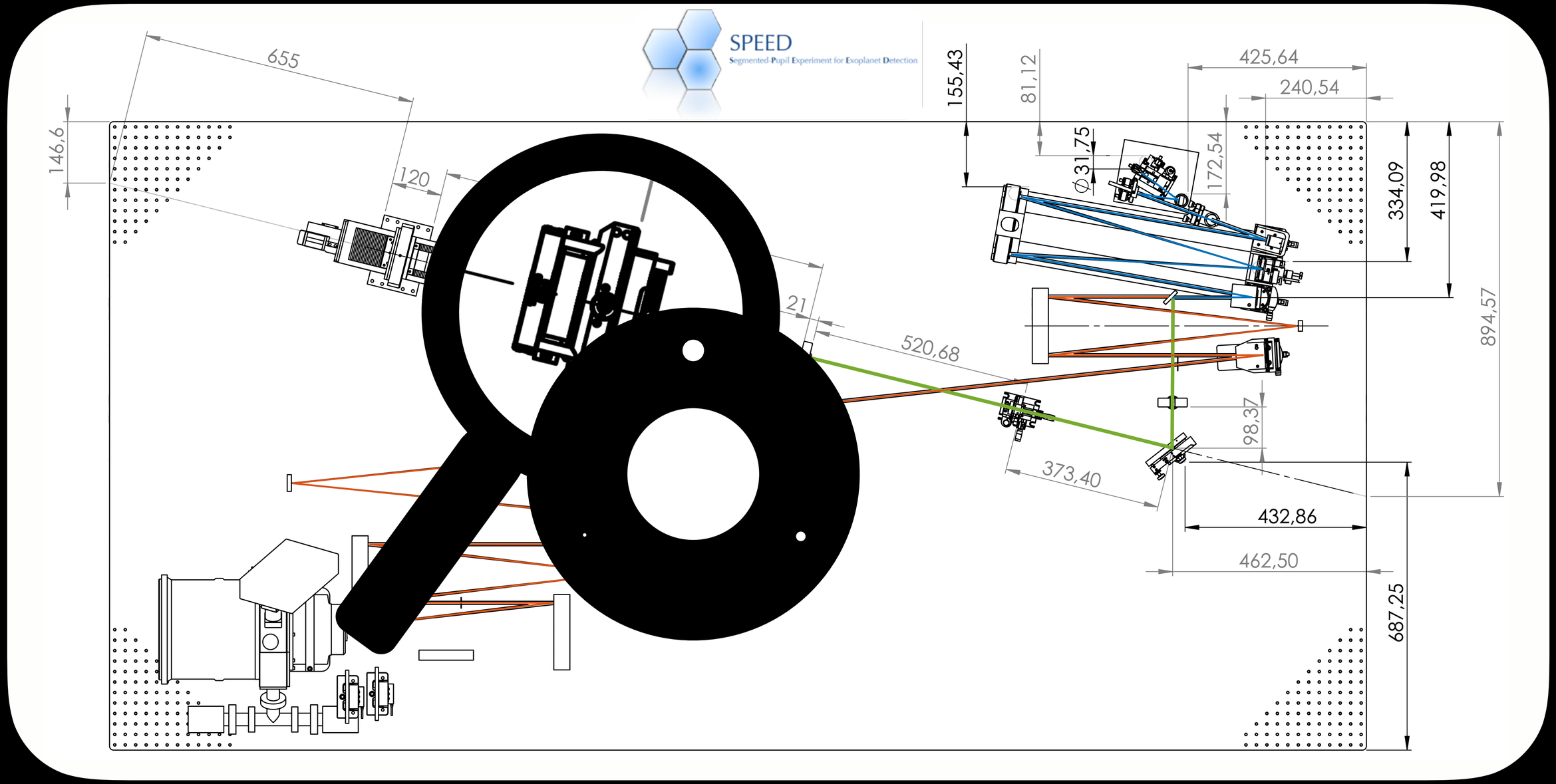
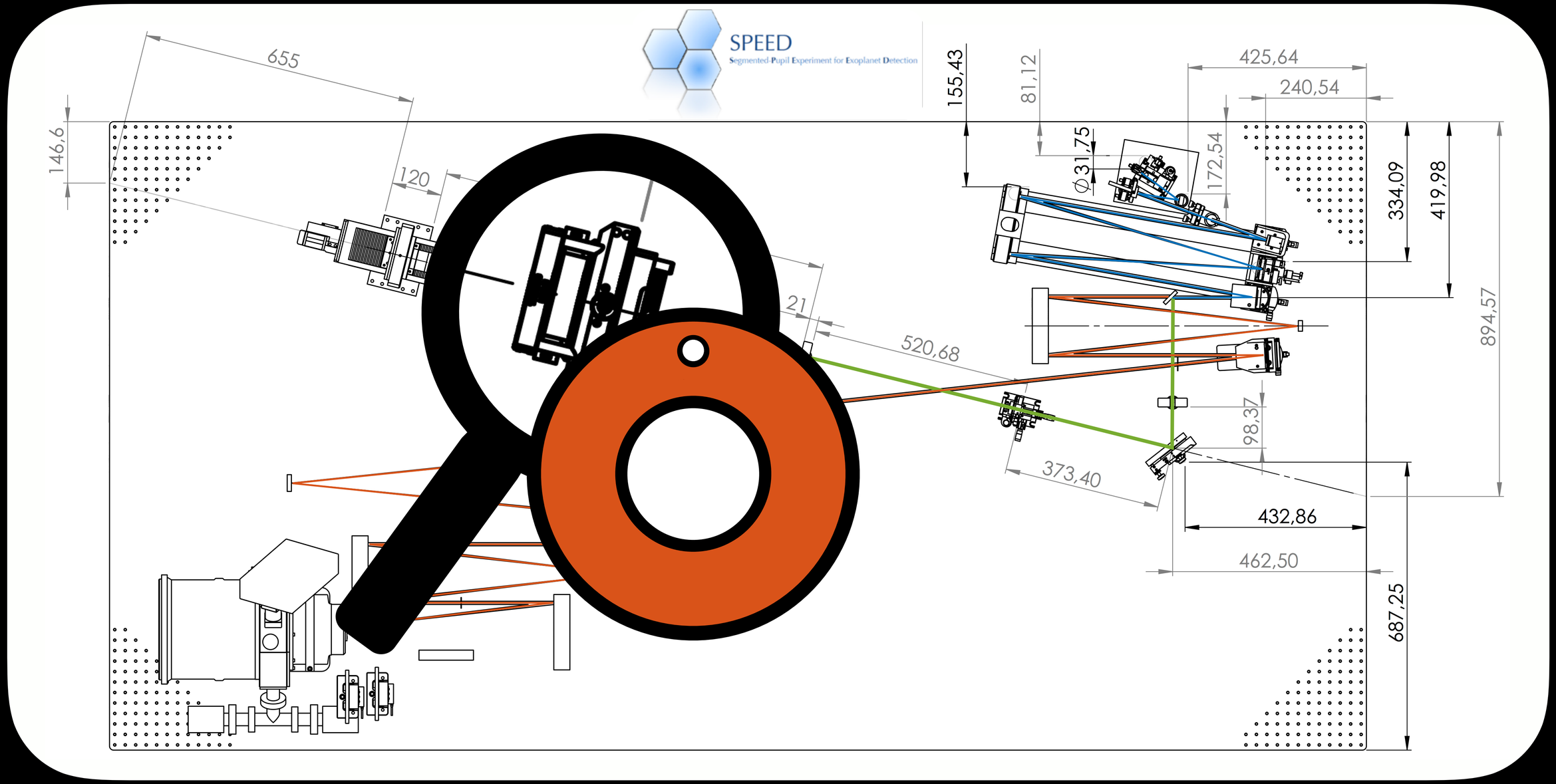


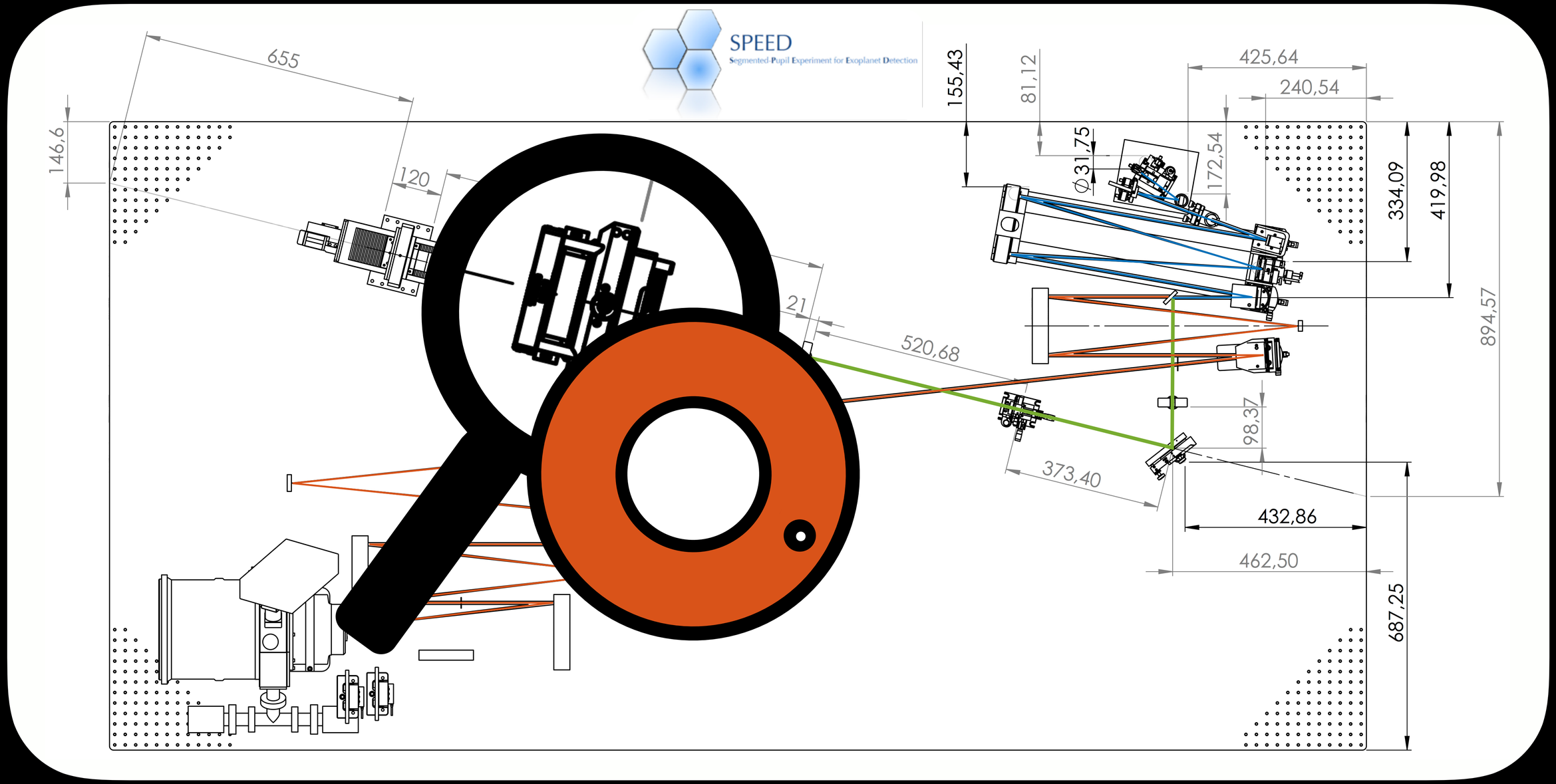
Real life implementation - The SPEED bench



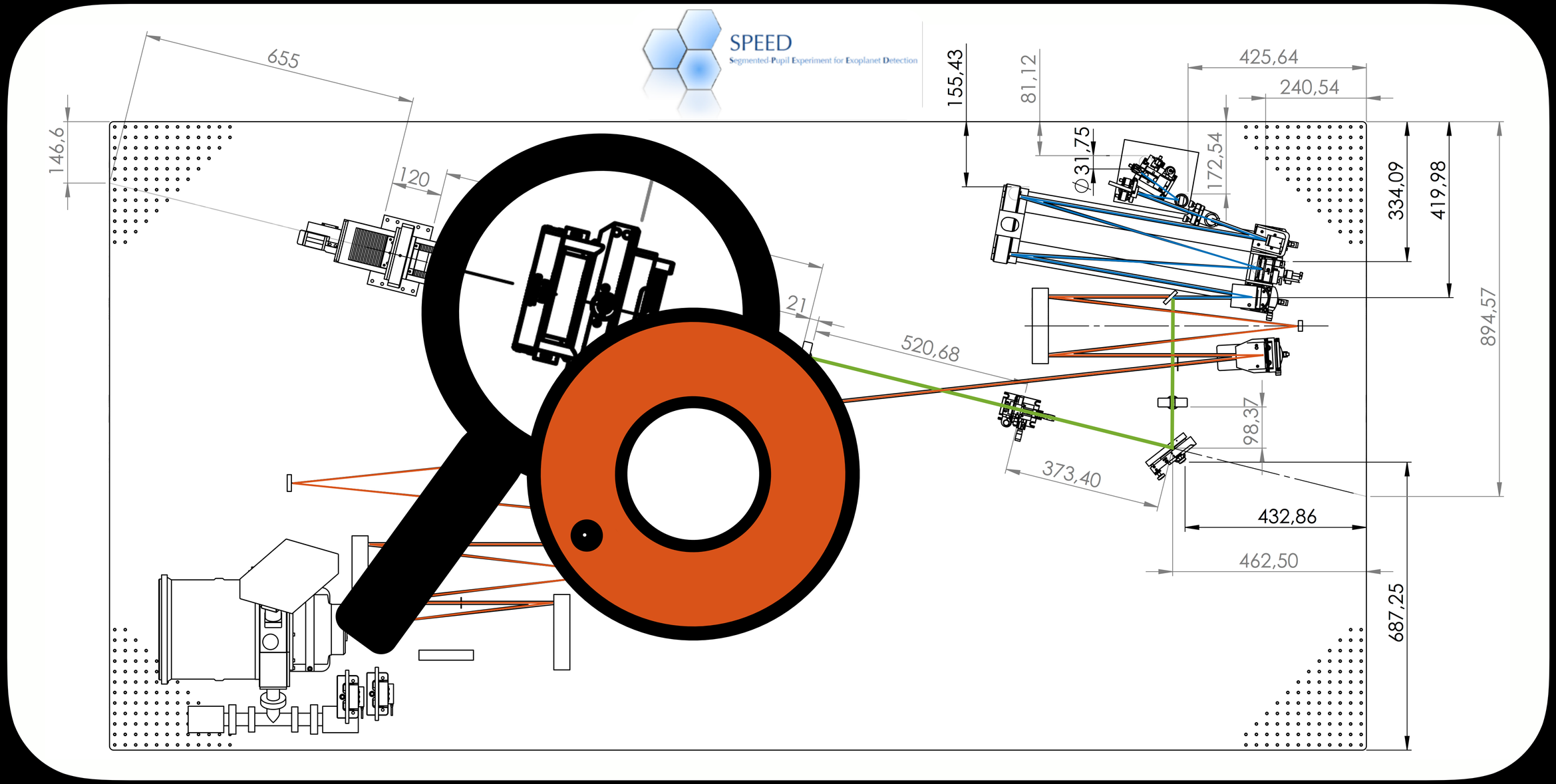
Real life implementation - The SPEED bench



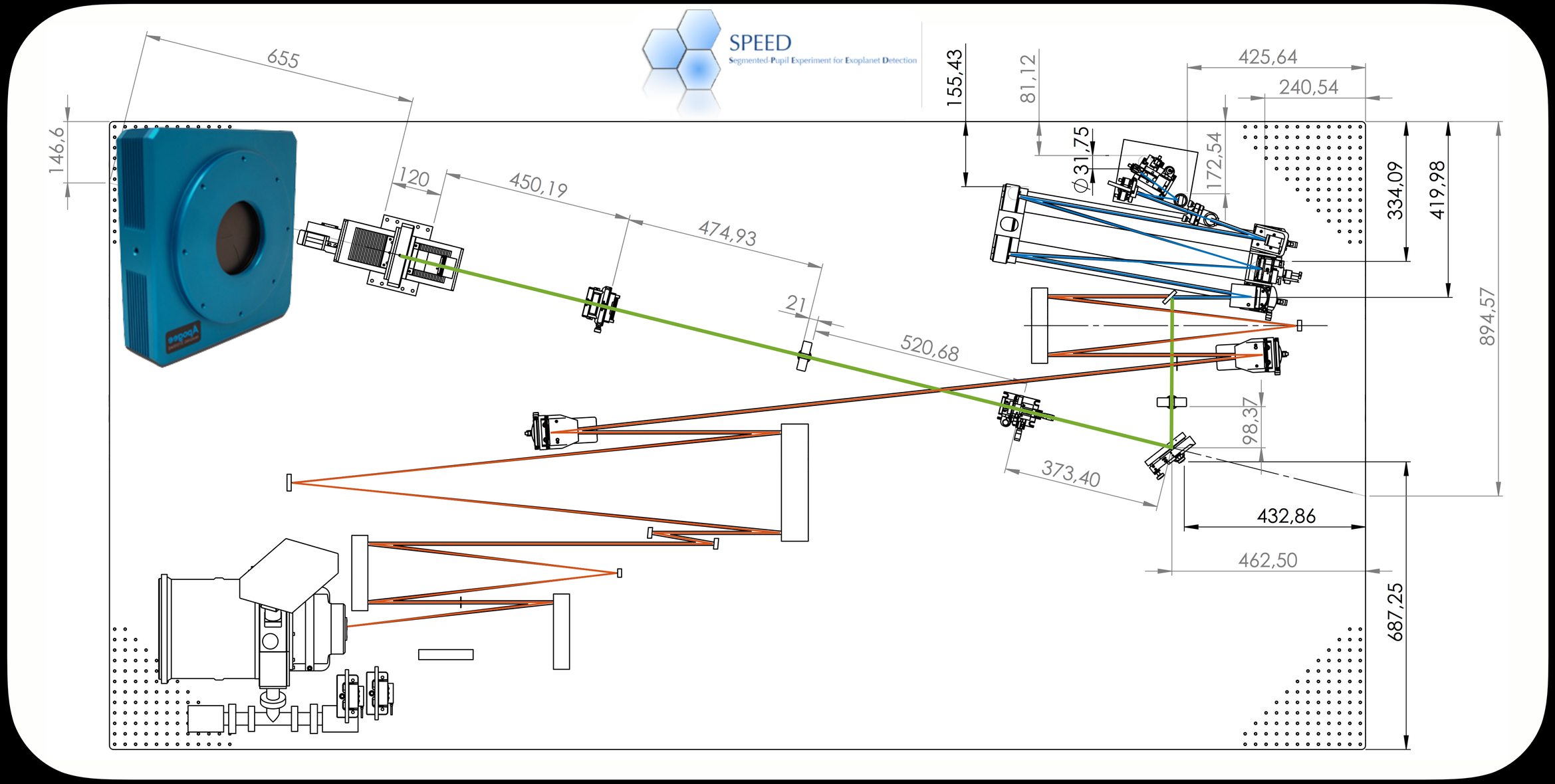
Real life implementation - The SPEED bench



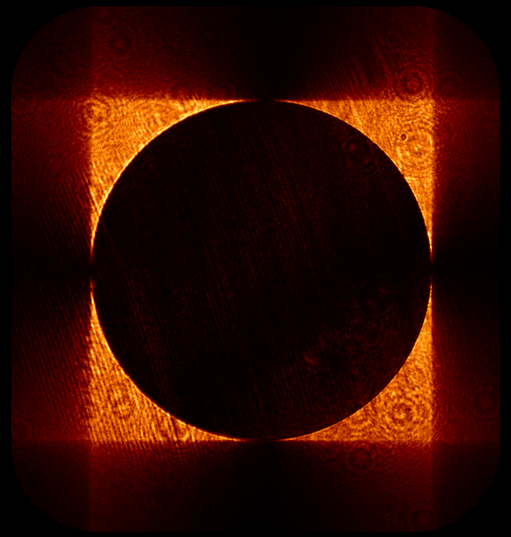
Real life implementation - The SPEED bench

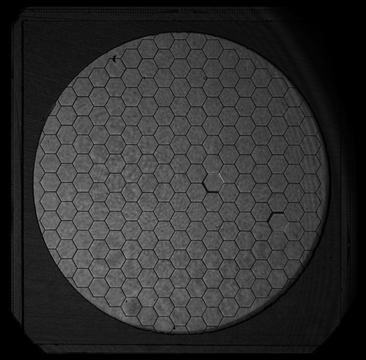


Real life implementation - The SPEED bench

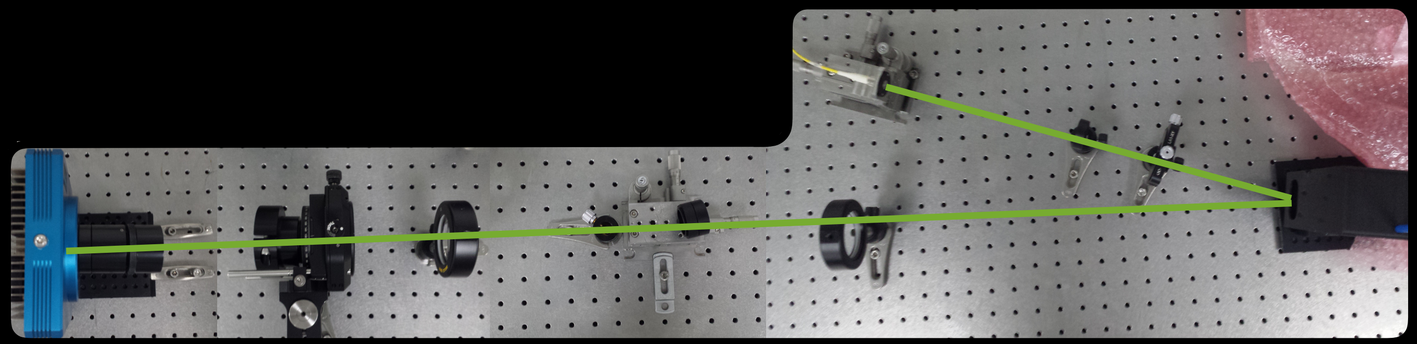


Real life implementation - The SPEED visible path integration

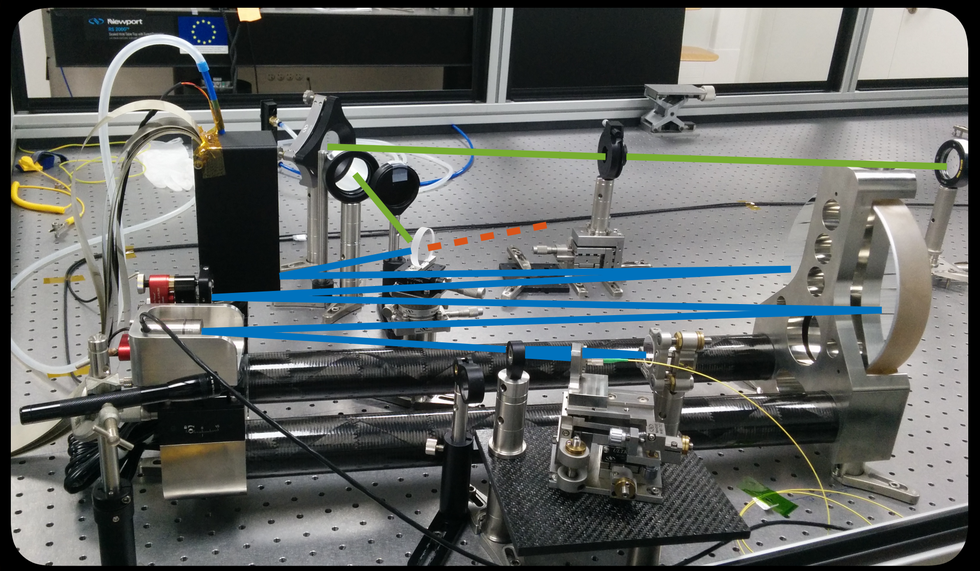


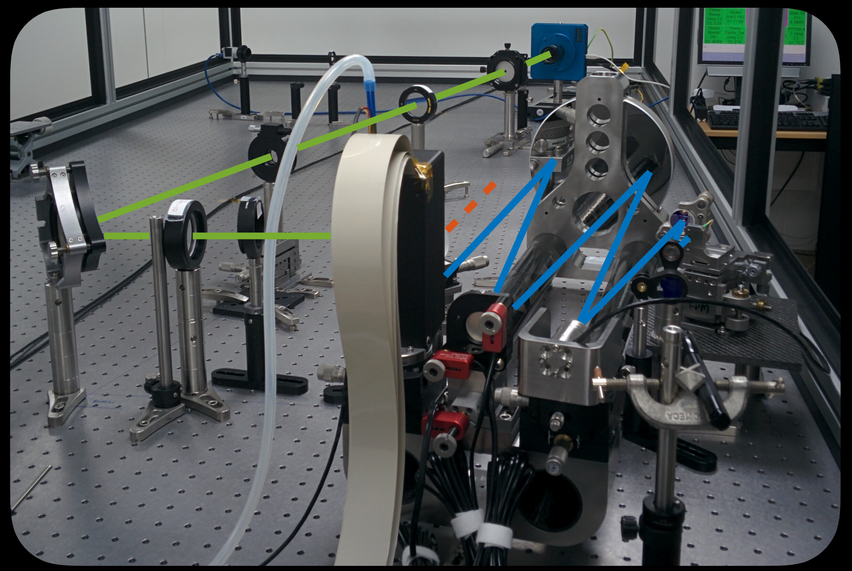


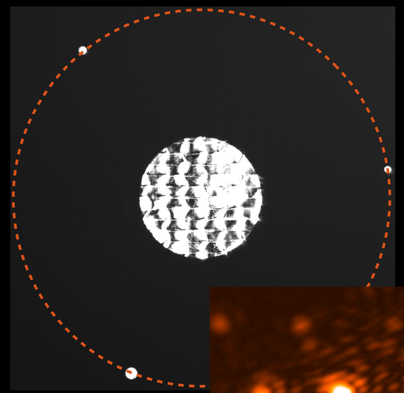
SCC-PS test bench

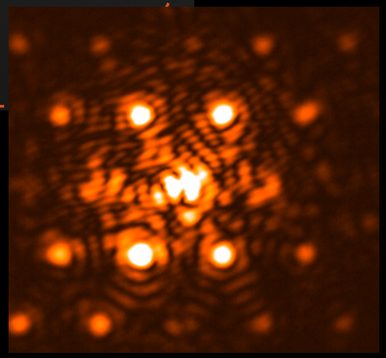


SPEED visible path



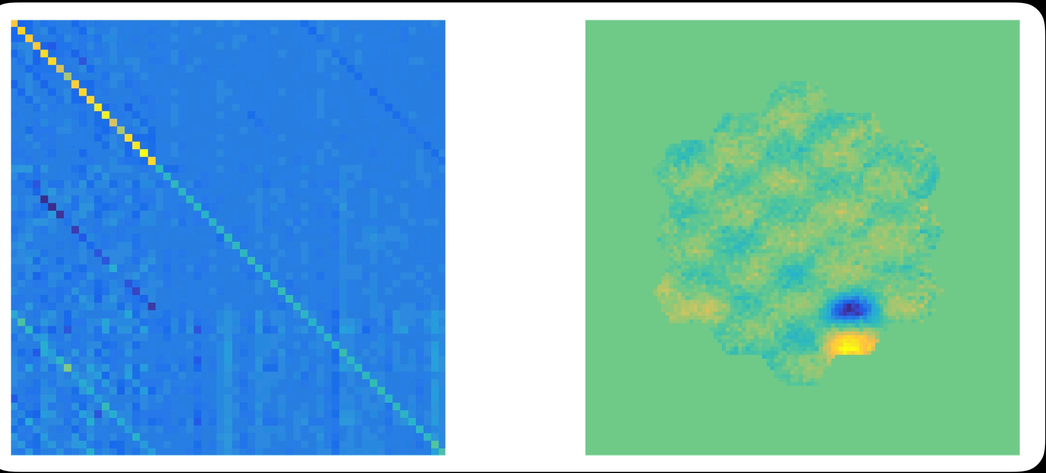


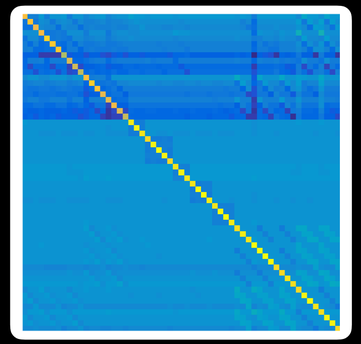




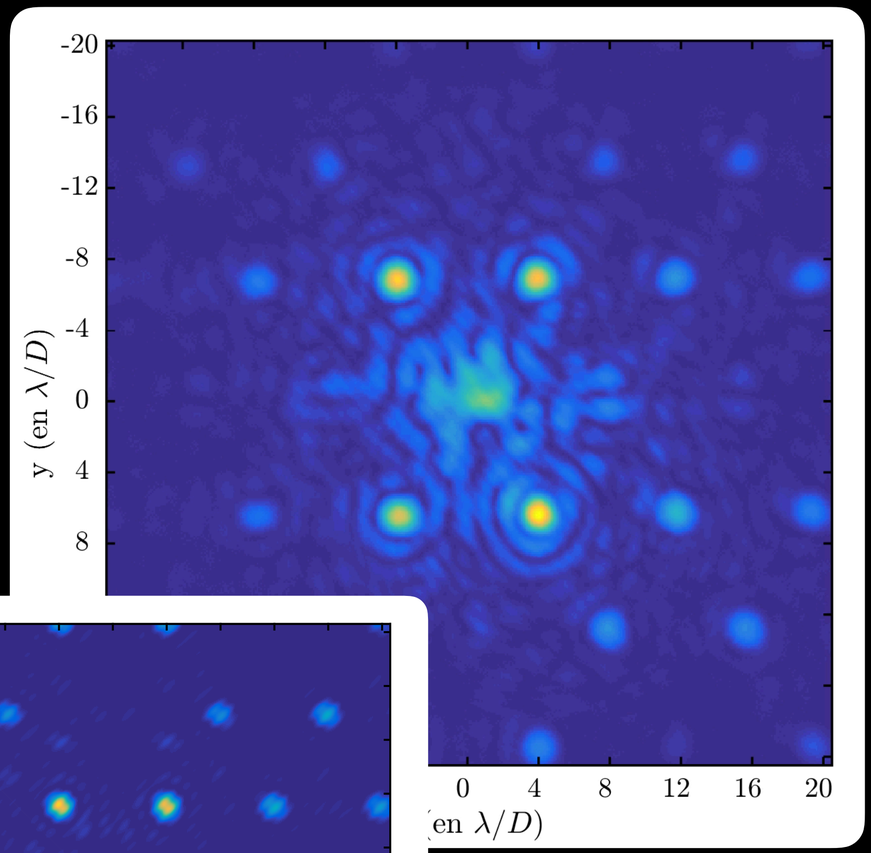
Real life implementation - The preliminary results

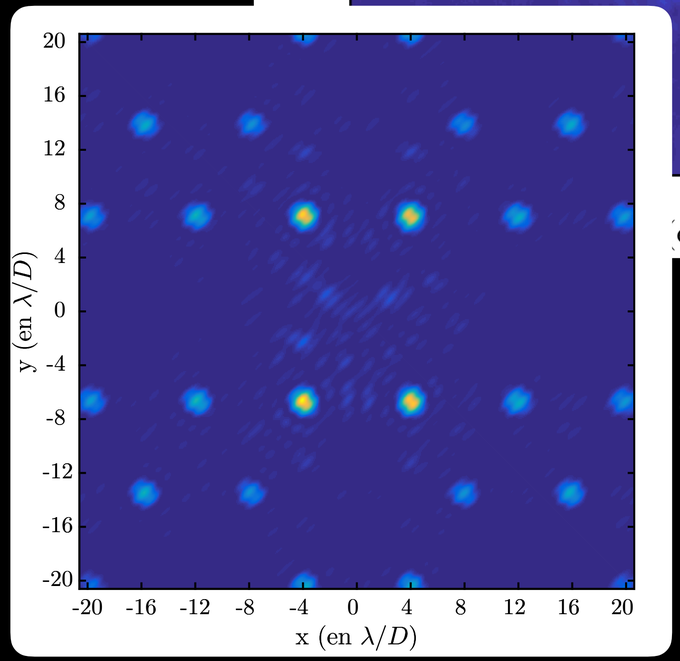
- Visual assessment of the SCC-PS behavior by poking each segment in piston on a M=2 pupil
- Measurement of the phase estimation and matrix calibration construction





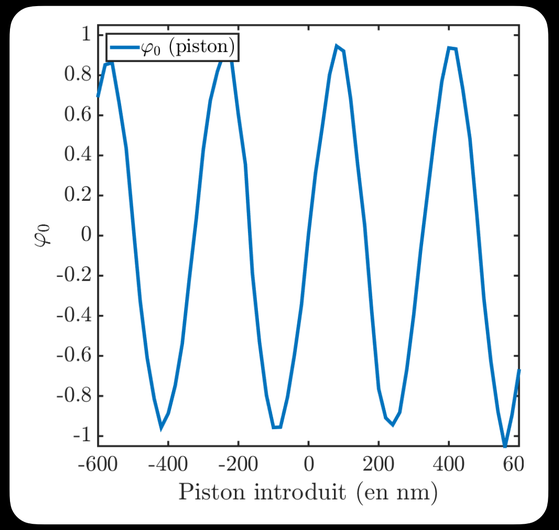
- Comparison with the calibration matrix obtained earlier in simulations

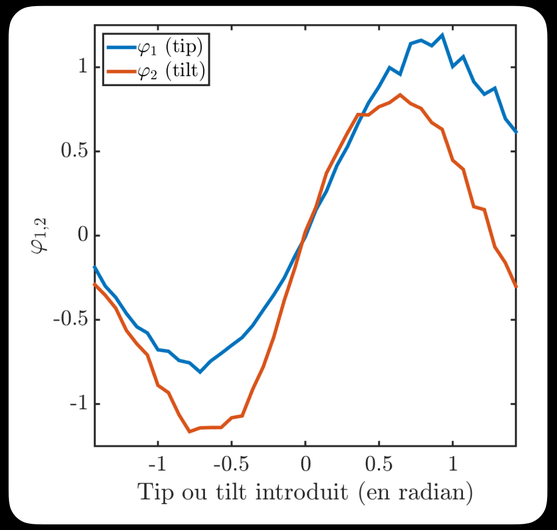




- Comparison with a simulated PSF with phase error measured on bench

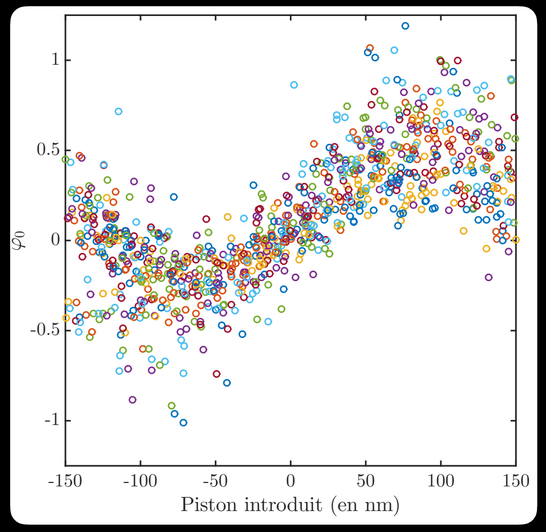
Real life implementation - The preliminary results



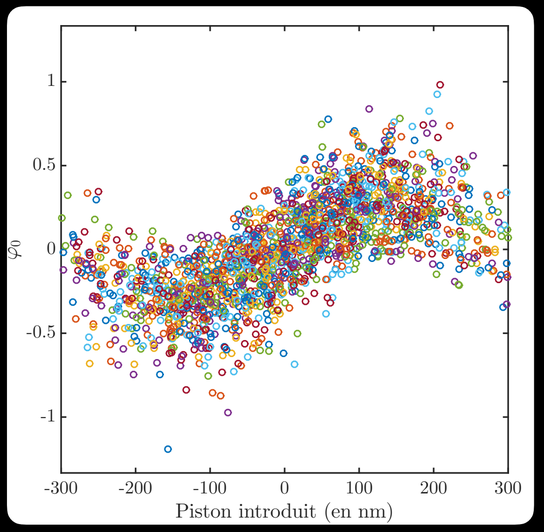


- Measurement of the piston and tip-tilt response curves
- The theoretical capture range is retrieved for piston with CR~160 nm
- The theoretical capture range is retrieved for tip-tilt with CR~1.20 mrad for a H=r/3 zone

- Estimation of φ_0 for a hundred random configuration of piston
- A dispersion is visible on the bench measurement
- The same process has been repeated in simulations with the same parameters

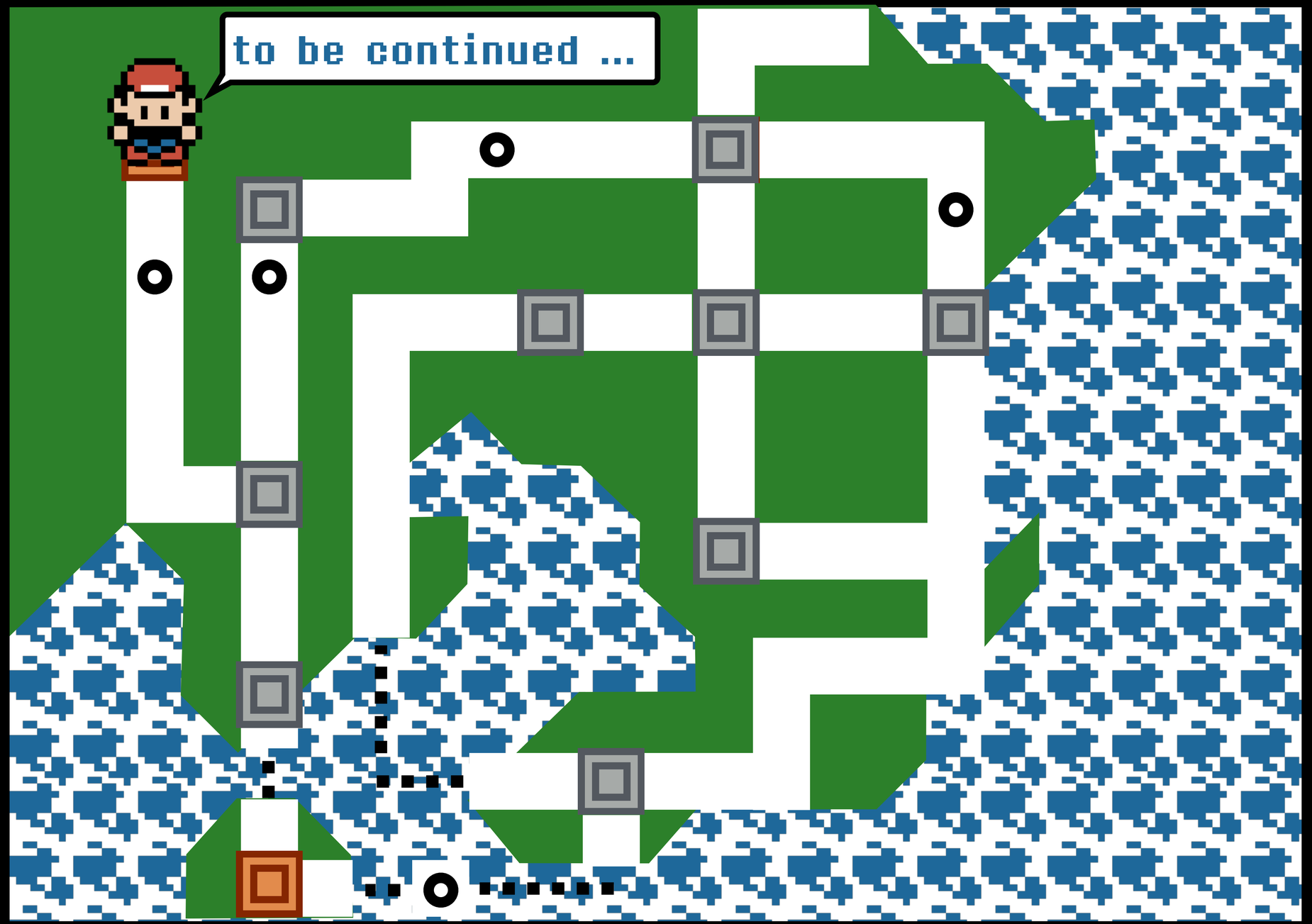


On bench



Simulation

Conclusion



Perspectives

Develop new masks for the SCC-PS

Try already existing or develop new one to cleverly redistribute the energy in the Lyot plane.

Developing the no calibration matrix mode for ZELDA

Gain of time when considering large mirrors with high N. Pseudo-synthetic matrices also possible.

Improve the cophasing package

Add turbulence, spiders, adaptive secondary, NCPA, etc.

Validation of the SCC-PS in polychromatic light

The SCC has been successfully used in polychromatic light, does the SCC-PS scale up ?

Implement the SCC-PS on the SPEED bench

Top 1 priority right now ! First results have been presented in this thesis, but the closed-loop remain to be … CLOSED !