

The release of a faster ITM

SCAR AAA 7th workshop 2023, Longyearbyen, Svalbard, Norway

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Fondazione C. Fillietroz-ONLUS

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Electronic upgrades: one box per functionality

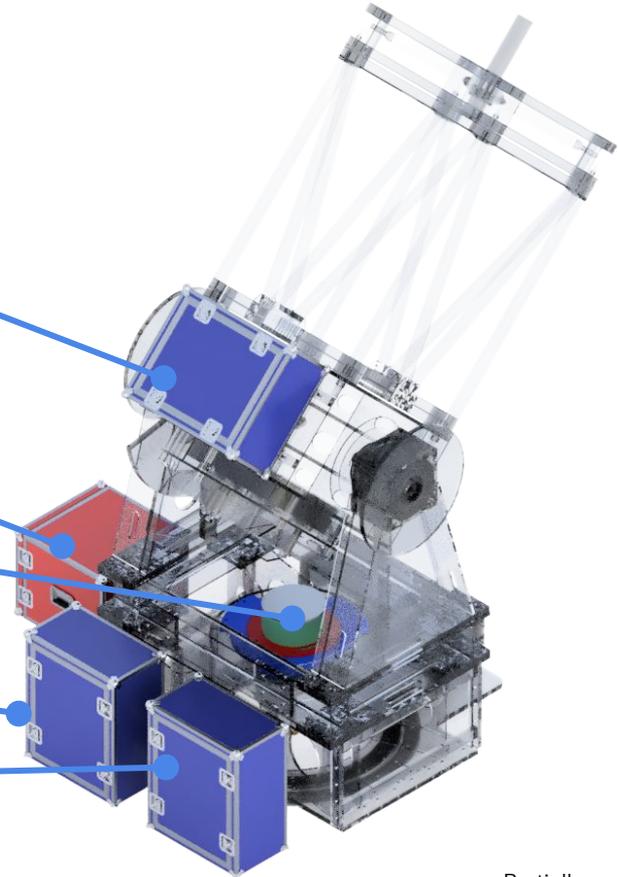
Box Control: manages mount and focus movements

Box Motor: drives the axis motors in closed loop with encoders

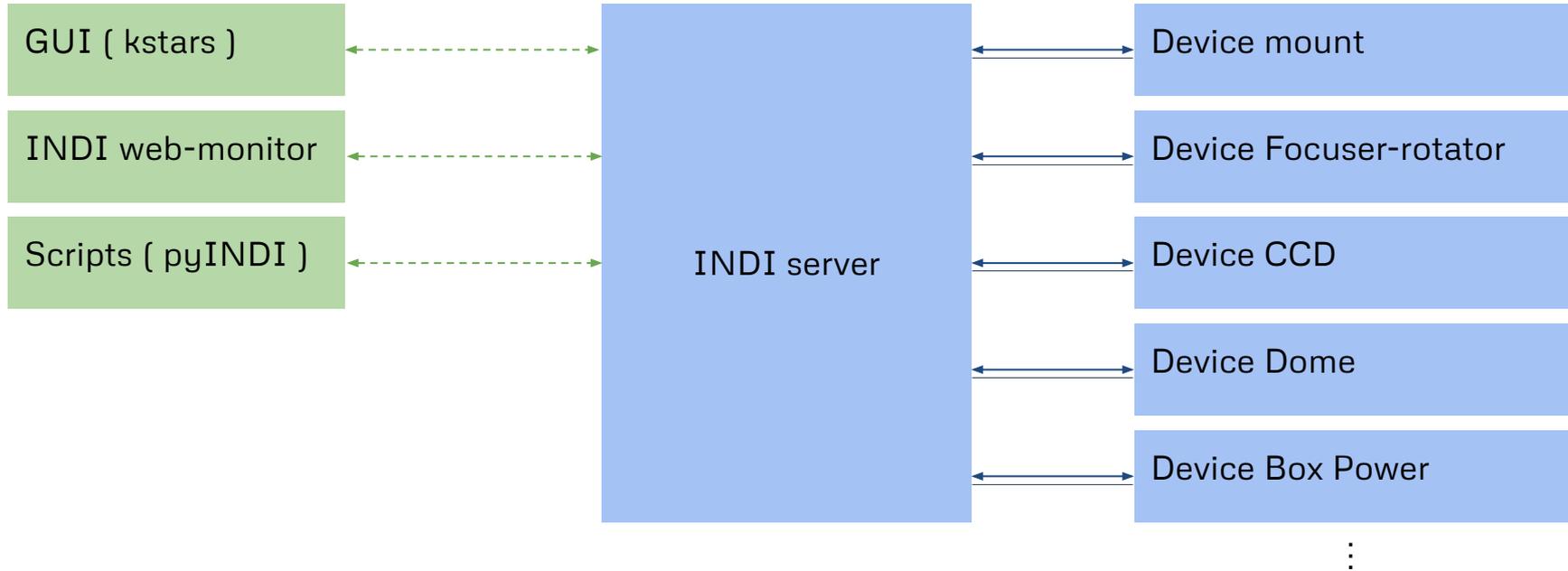
Slip-ring: derotates 400V power and LAN

Box Web: manages the telescope LAN

Box Power: distributes electrical power to the boxes



SW upgrades: INDI architecture



XML over TCP-IP

XML over IPC (Inter Process Communication)

INDI White Paper: <http://www.clearskuinstitute.com/INDI/INDI.pdf>



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SW upgrades: pyINDI@OAVdA architecture

- Pure python INDI-protocol implementation
- AsyncIO based
- MMT Observatory repository (focused on monitoring via web)
- Our repository (forked) focuses on schedule observation automation:
 - Flat-field acquisition
 - Best focus procedure
 - Mount goto
 - CCD acquisition
 - Autoguide loop

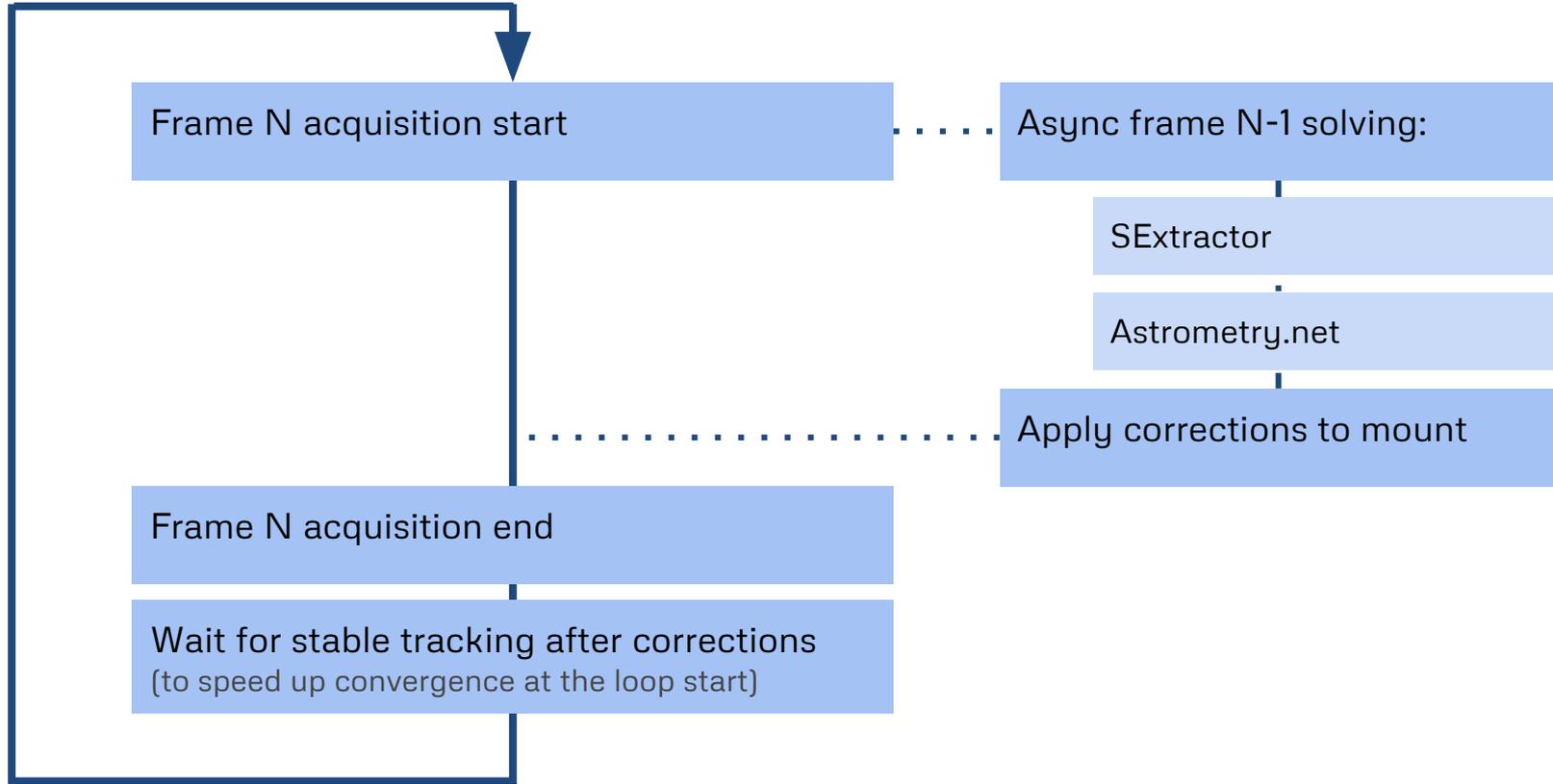
<https://github.com/MMTObservatory/pyINDI>

<https://github.com/stefano-sartor/pyINDI>

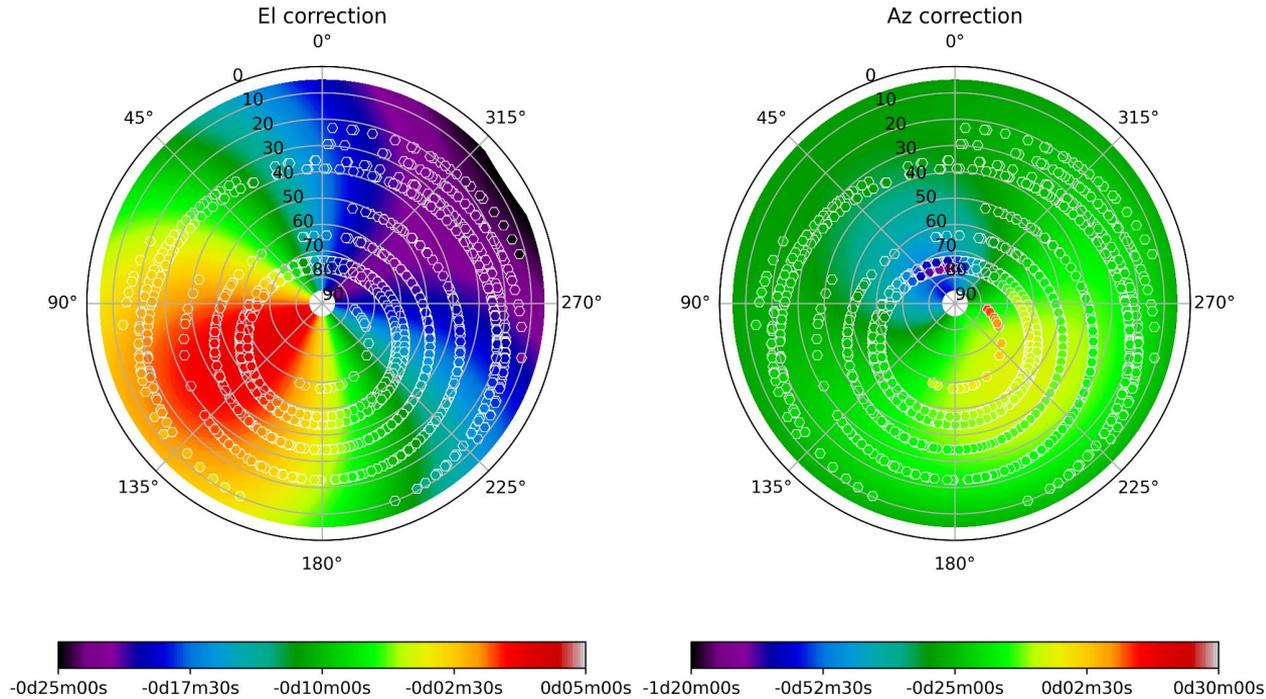


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SW upgrades: Autoguide loop using science frames



Pointing Model: Analytical approach WholeSky (ALMA*)



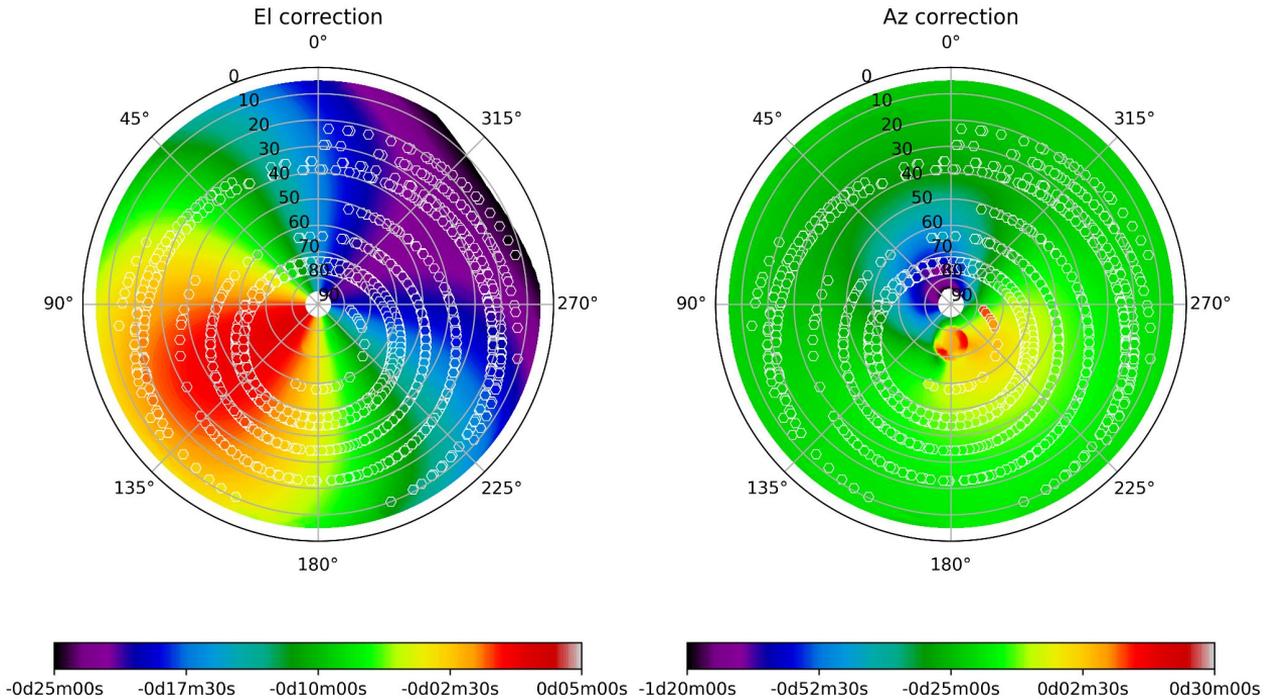
$$\delta Az = A_1 + A_2 \sin(El) + A_3 \cos(El) + A_4 \sin(El) \sin(Az) + A_5 \sin(El) \cos(Az)$$

$$\delta El = E_1 + E_2 \cot(El) + E_3 \cos(El) + E_4 \cos(Az) + E_5 \sin(Az)$$

*ALMA Memo #366, A Telescope Pointing Algorithm for ALMA, J. G. Mangum, 04/30/2001



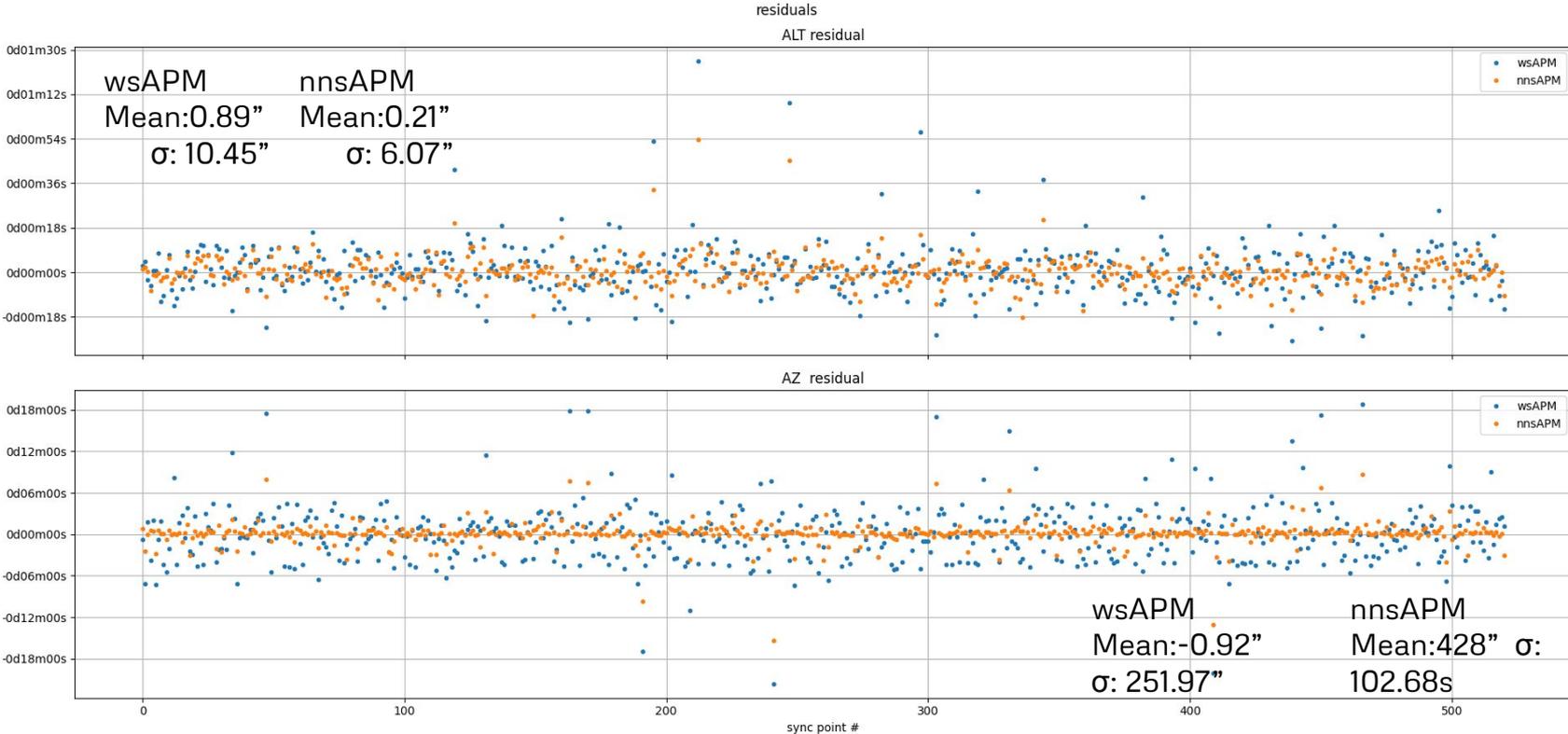
Pointing Model: Analytical approach NN-Segmented (ALMA*)



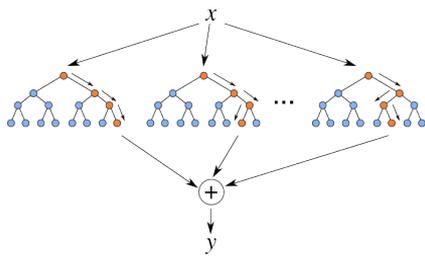
$$\nabla [\Delta Az, \Delta Alt] \left\{ \begin{array}{l} \delta Az = A_1 + A_2 \sin(El) + A_3 \cos(El) + A_4 \sin(El) \sin(Az) + A_5 \sin(El) \cos(Az) \\ \delta El = E_1 + E_2 \cot(El) + E_3 \cos(El) + E_4 \cos(Az) + E_5 \sin(Az) \end{array} \right.$$

*ALMA Memo #366,A Telescope Pointing Algorithm for ALMA,J. G. Mangum, 04/30/2001

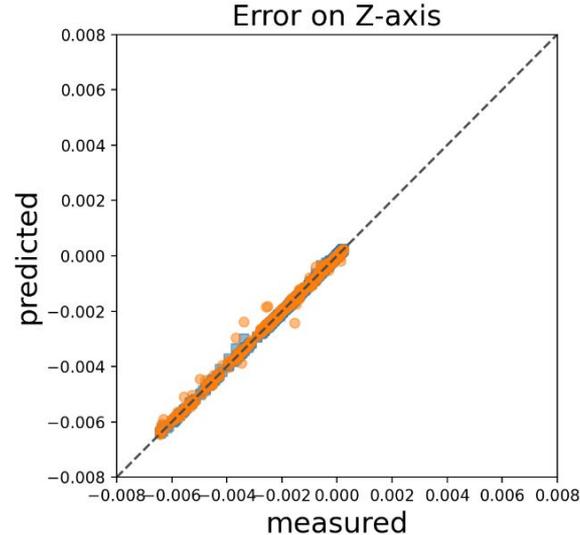
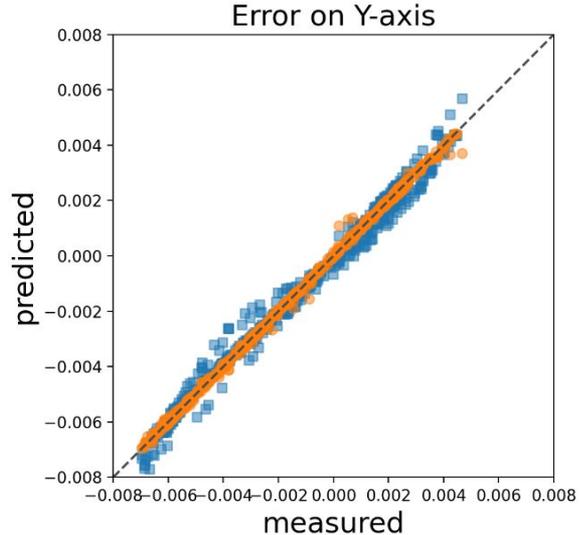
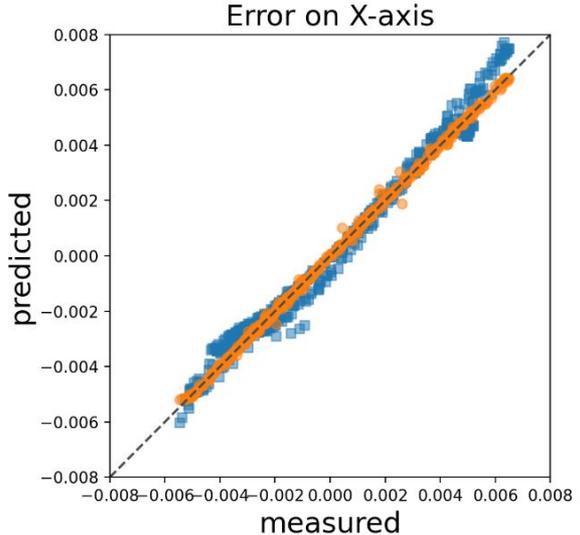
Pointing Model: Analytical approach residuals



Pointing Model: AI approach - RF



Pointing error prediction results



■ Analytical model ● Random Forest (n=200)



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Observations: Scheduling

For each TESS Object of Interest (TOI) the following constraints, which must be valid during all the transit duration, are checked:

- astronomical night
- Moon separation ≥ 45 deg
- Sun separation ≥ 60
- Elevation ≥ 20 deg
- Elevation ≤ 82 deg
- Transit depth ≥ 4 mmag
- Transit duration ≤ 5 hours
- Star mag ≤ 12.5
- At least 5 stars in the field with similar magnitude (± 0.5 mag)

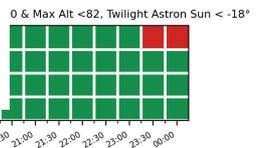
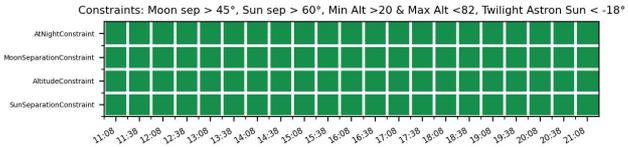
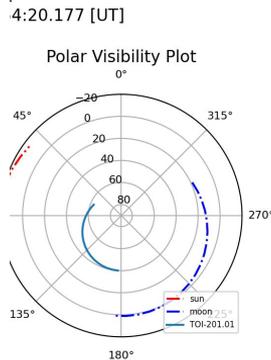
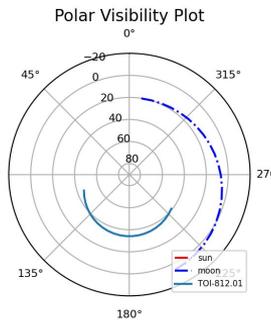
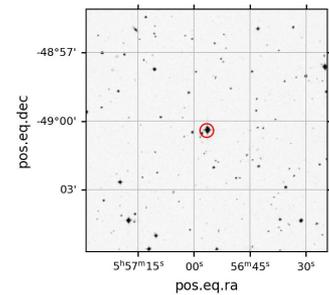
Overlapping scheduled TOIs are manually handled



Observations: Scheduling

TOI-812.01
transit 2023-06-27 16:23:34.276 [UT]

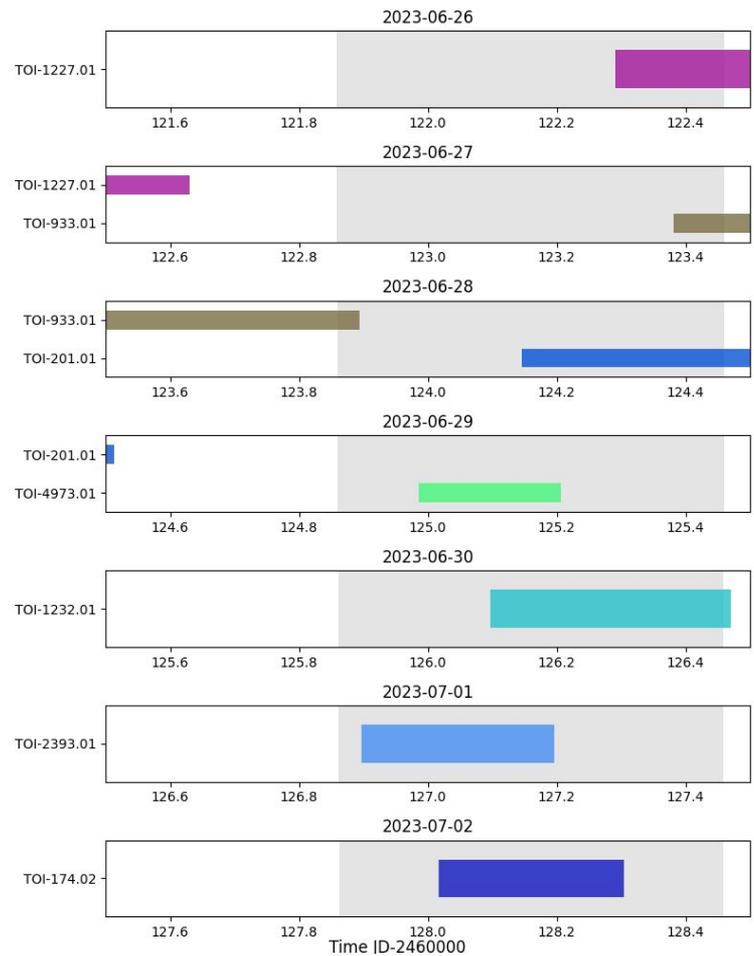
05h56m56.56s -49d00m25.02s



Constraints: Moon sep > 45°, Sun sep > 60°, Min Alt > 20 & Max Alt < 82, Twilight Astron Sun < -18°

Time on 2023-06-27 UTC TOI-812.01
 2023-06-27 11:08:50.476 [UT] JD2460122.96447 Observation start (2 hours pre transit ingress)
 2023-06-27 16:23:34.276 [UT] JD2460123.18304 Mid Transit
 2023-06-27 21:38:18.076 [UT] JD2460123.40160 Observation stop (2 hours post transit egress)
 6.49 [h] transit duration
 10.96 Mag Tess
 8.64 [mmag] Depth

Time on 2023-06-28 UTC TOI-201.01
 2023-06-28 15:30:16.577 [UT] JD2460124.14603 Observation start (2 hours pre transit ingress)
 2023-06-28 19:54:20.177 [UT] JD2460124.32940 Mid Transit
 2023-06-29 00:18:23.777 [UT] JD2460124.51278 Observation stop (2 hours post transit egress)
 4.80 [h] transit duration
 8.58 Mag Tess
 7.35 [mmag] Depth



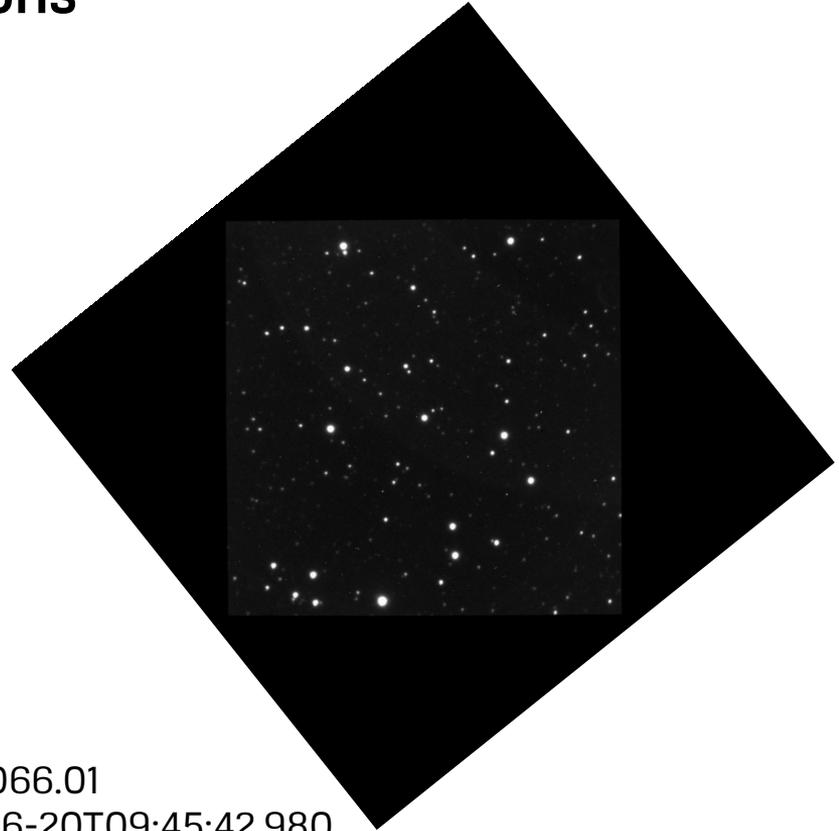
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Observations: Image Acquisitions



TOI_3066.01
2023-06-20T09:45:42.980
Exptime: 60
Binning: 4x4

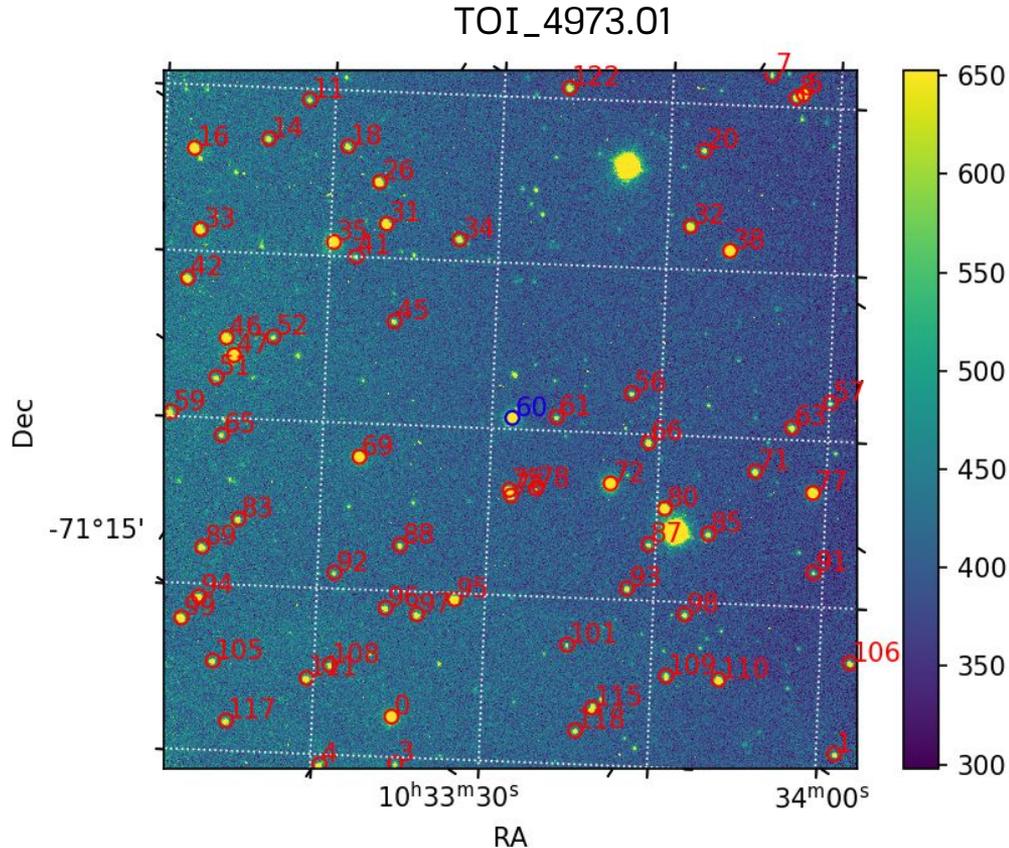


TOI_3066.01
2023-06-20T09:45:42.980
Equivalent exptime: 360 (6*60)
Binning: 4x4



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Observations: FOV solving and indexing



Astrometry.net **solve field** ran
after acquisition

SExtractor **source extraction**

Source filtering on flux and
FWHM, object shapes

Matching indexes on all
images on WCS and proximity

Target identification

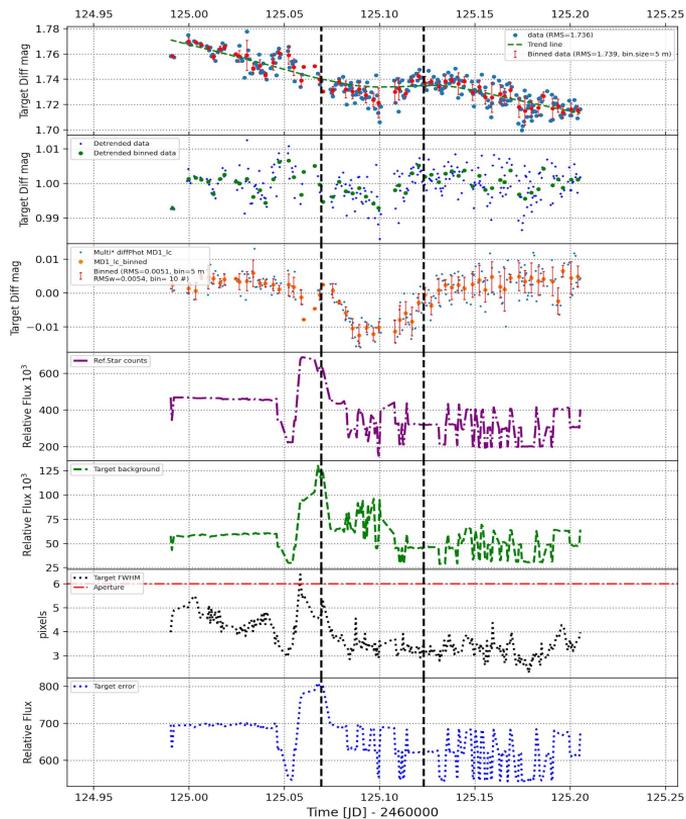


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Observations: Photometry

TOI_4973.01 on UT 2023-06-29 14:18:38.186
ITM@Dome C (75S-123E) (R, aper. radius=6 px - 4.1",exp.time=60s)



Δ magnitude

Detrended data

Quality checks

Ref. Star counts

Target background

Target FWHM and
best aperture

Target error

Single Star Photometry

Aperture photometry for all sources; local background computation + annulus

Differential photometry:
 Δ magnitude =
(Targ. - Reference Star)

Find **best aperture** based on a minimum-RMS for the target light curve

Reference Star selected from the sample

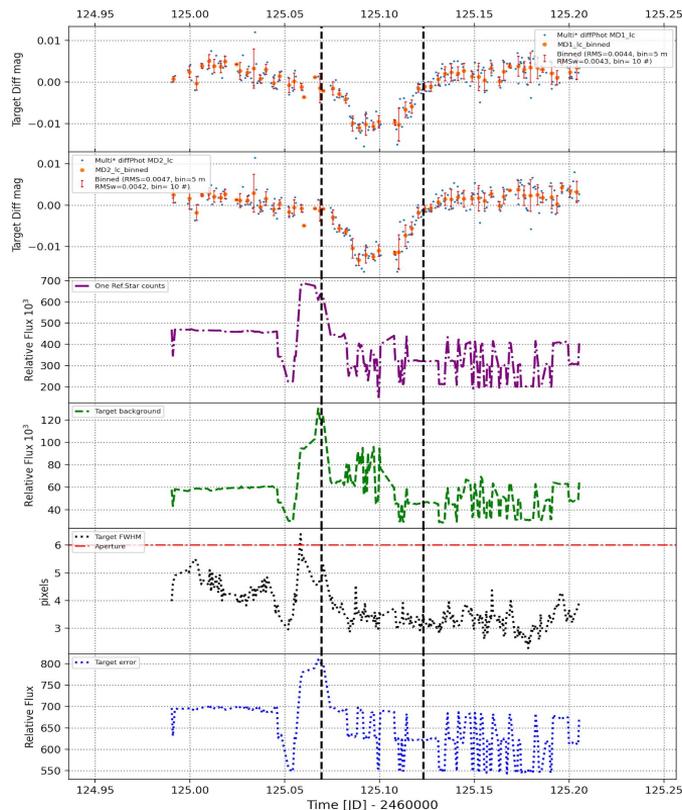


Partially supported by



Observations: Photometry

TOI_4973.01 on UT 2023-06-29 14:18:38.186
ITM@Dome C (75S-123E) (R, aper. radius=6 px - 4.1",exp.time=60s)



Model
Differential 1

Model
Differential 2

Quality checks

MD1 Photometry

Photometric light curves **using all stars** detected in the field

Differential photometry between target and all stars:
 $\Delta \text{magnitude}(i) = \text{Targ.} - \text{Reference Star}(i)$

Reference stars are the **subset which minimizes the RMS** of the differential light curve of the **target**

Find best aperture

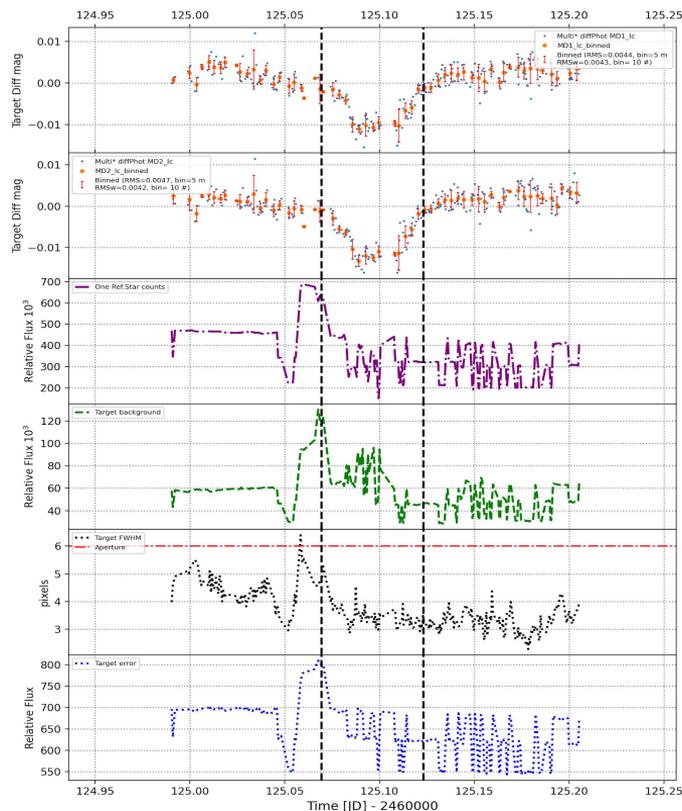
Burke et al. 2006
Giacobbe et al. 2012

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Observations: Photometry

TOI_4973.01 on UT 2023-06-29 14:18:38.186
ITM@Dome C (75S-123E) (R, aper. radius=6 px - 4.1",exp.time=60s)



Model
Differential 1

Model
Differential 2

Quality checks

MD2 Photometry

Photometric light curves **using all stars** detected in the field

Differential photometry between target and all stars:
 $\Delta \text{magnitude}(i) = \text{Targ.} - \text{Reference Star}(i)$

Reference stars are the **subset which minimizes the RMS** of the differential light curve of **each potential reference star**

Find best aperture

Burke et al. 2006
Giacobbe et al. 2012

Partially supported by



Observations: Photometry

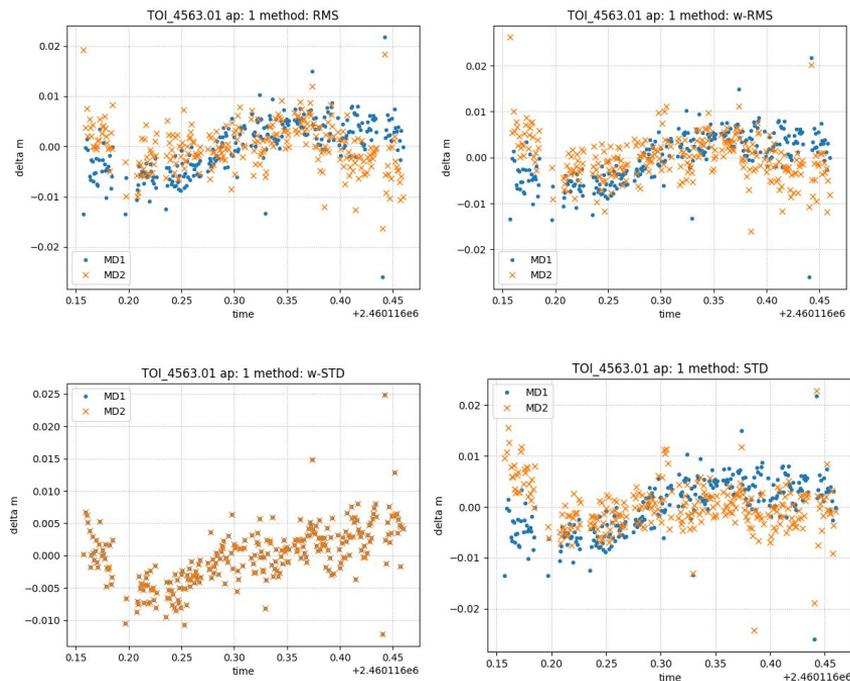
How to quantify dispersion in light curves?

Best aperture is the one which **minimizes the dispersion** in the lightcurve of the target

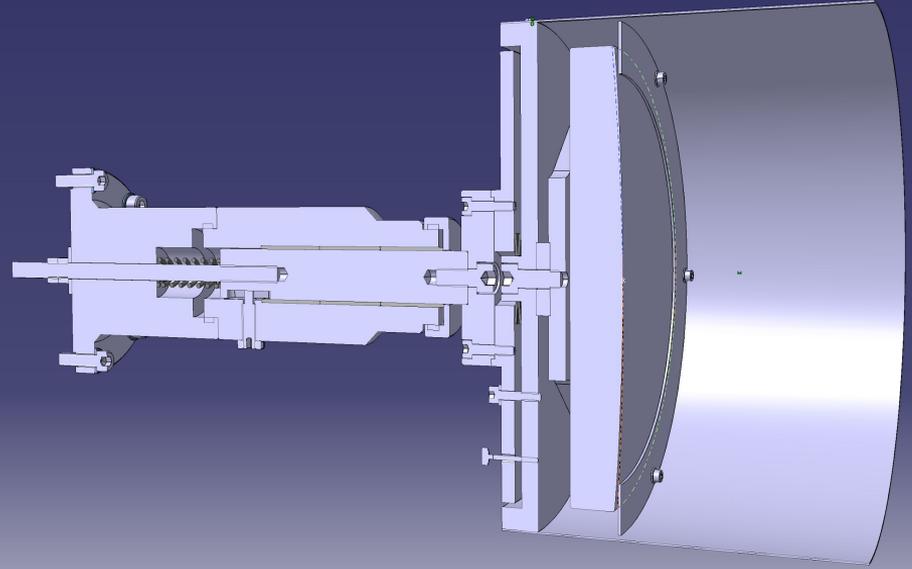
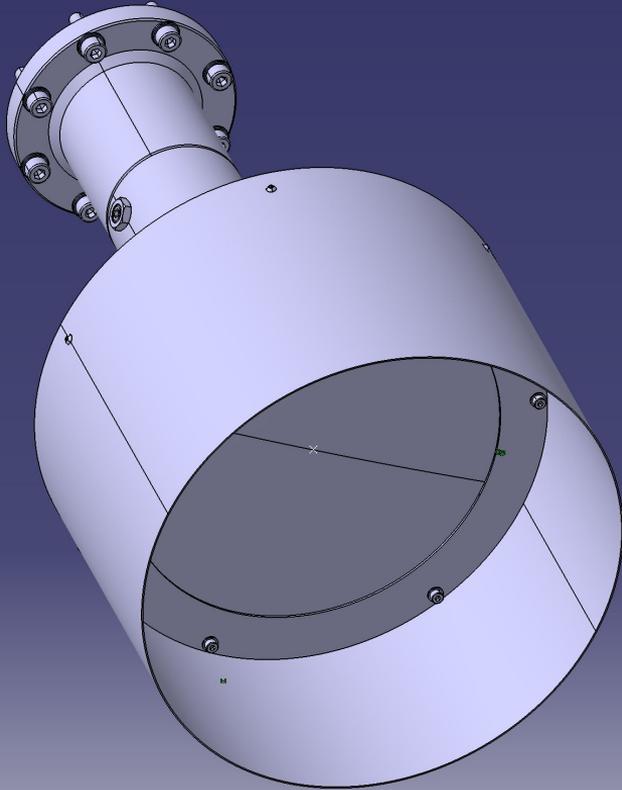
Four methods to quantify this dispersion:

- RMS: Root mean squared
- RMS-w: Root mean squared with a moving window
- STD: Standard Deviation
- STD-w: Standard Deviation with a moving window

Pipeline computes light curves for all these four methods (for MD1 and MD2 model), **case by case investigation** to choose the most relevant light curve



New Optical Scheme: M2 mechanical support

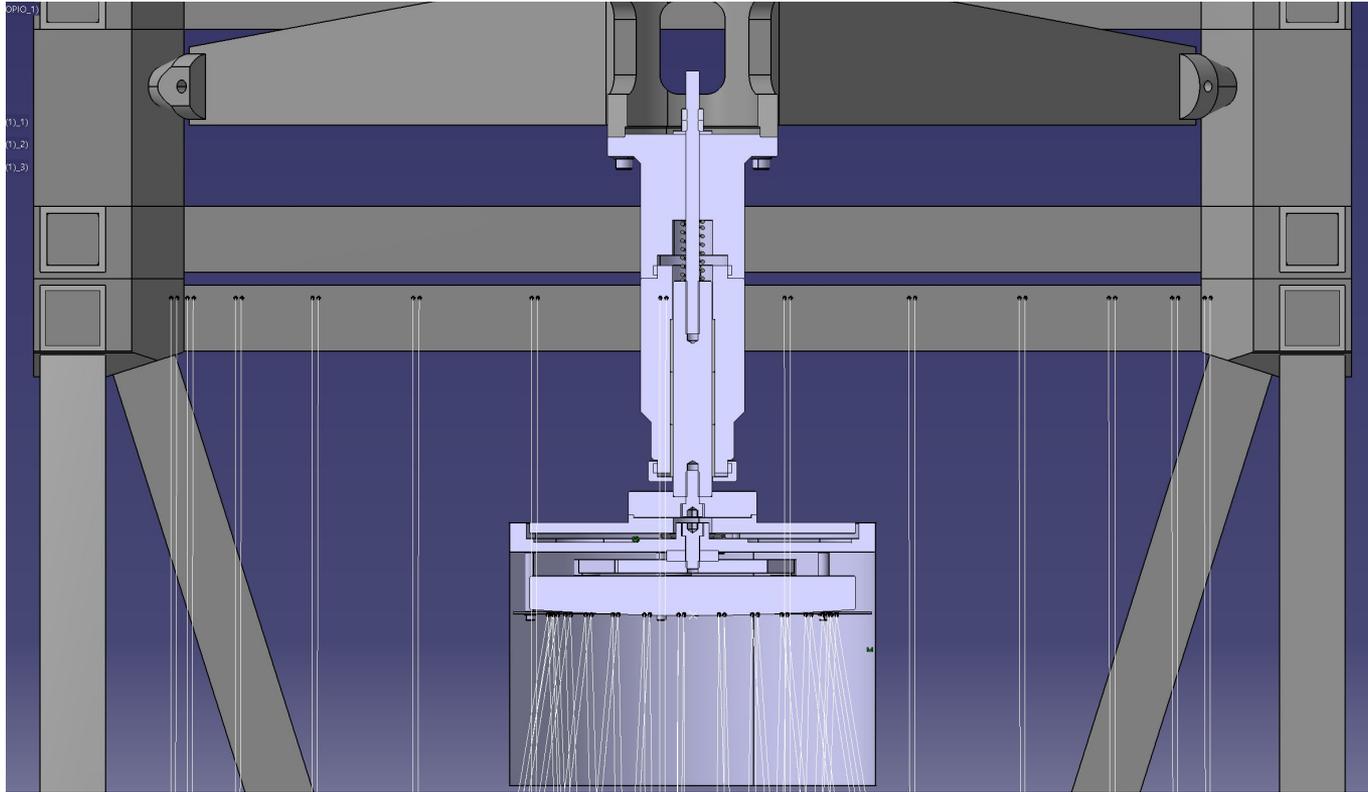


Secondary mirror
Vertex radius: 1697.697 mm
Conic constant: -2.78
Diameter: 250 mm
Substrate: Fused Quartz
Coating: near-infrared optimized Silver

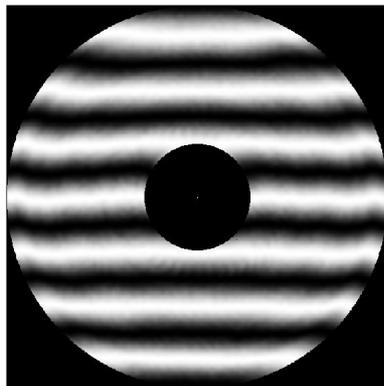
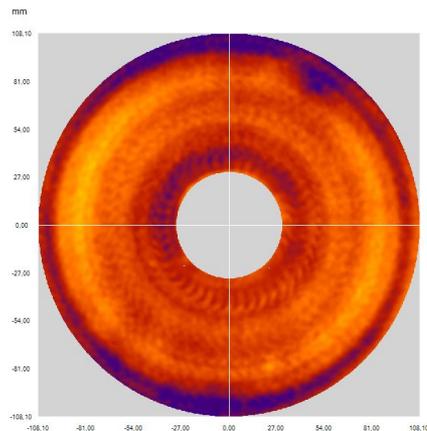
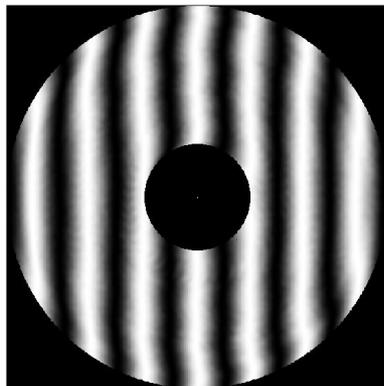


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New Optical Scheme: M2 mechanical support



New Optical Scheme: M2 interferogram



PV: 0.168 wv @ 632.8 nm

RMS: 0.028 wv @ 632.8 nm

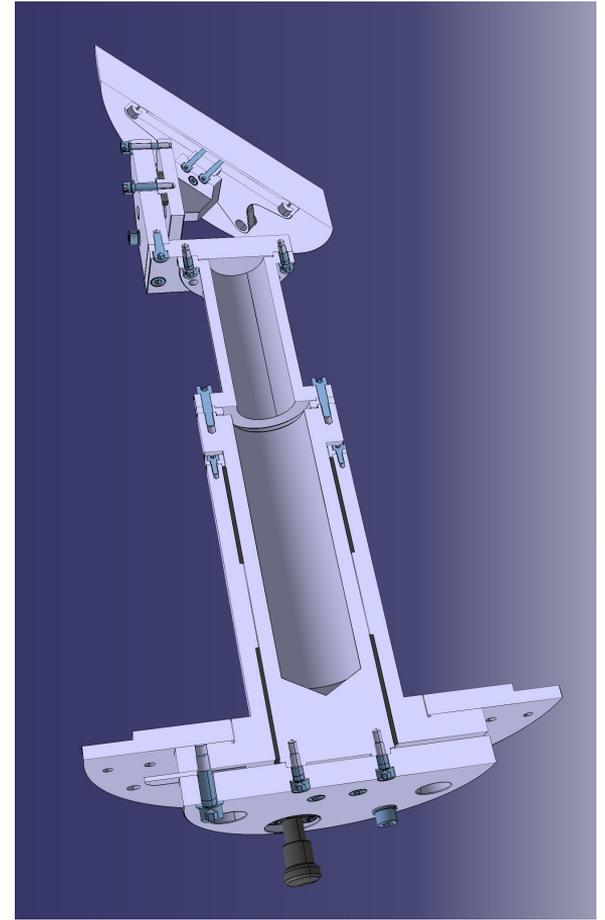
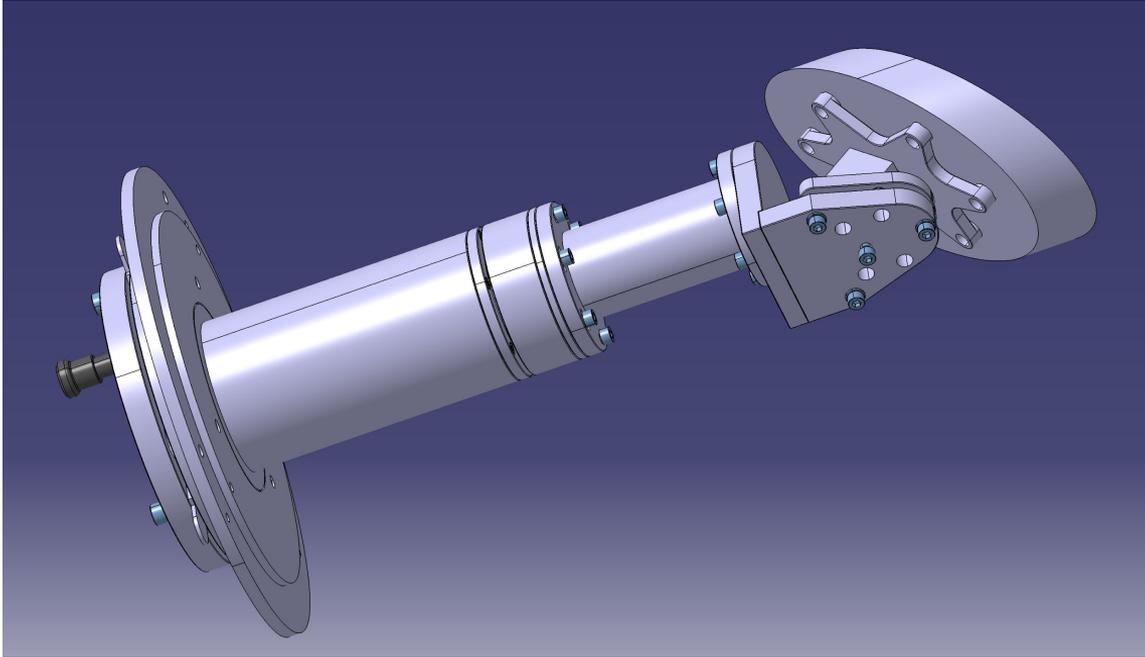
Strehl ratio: 0.969

Excellent work ASA!

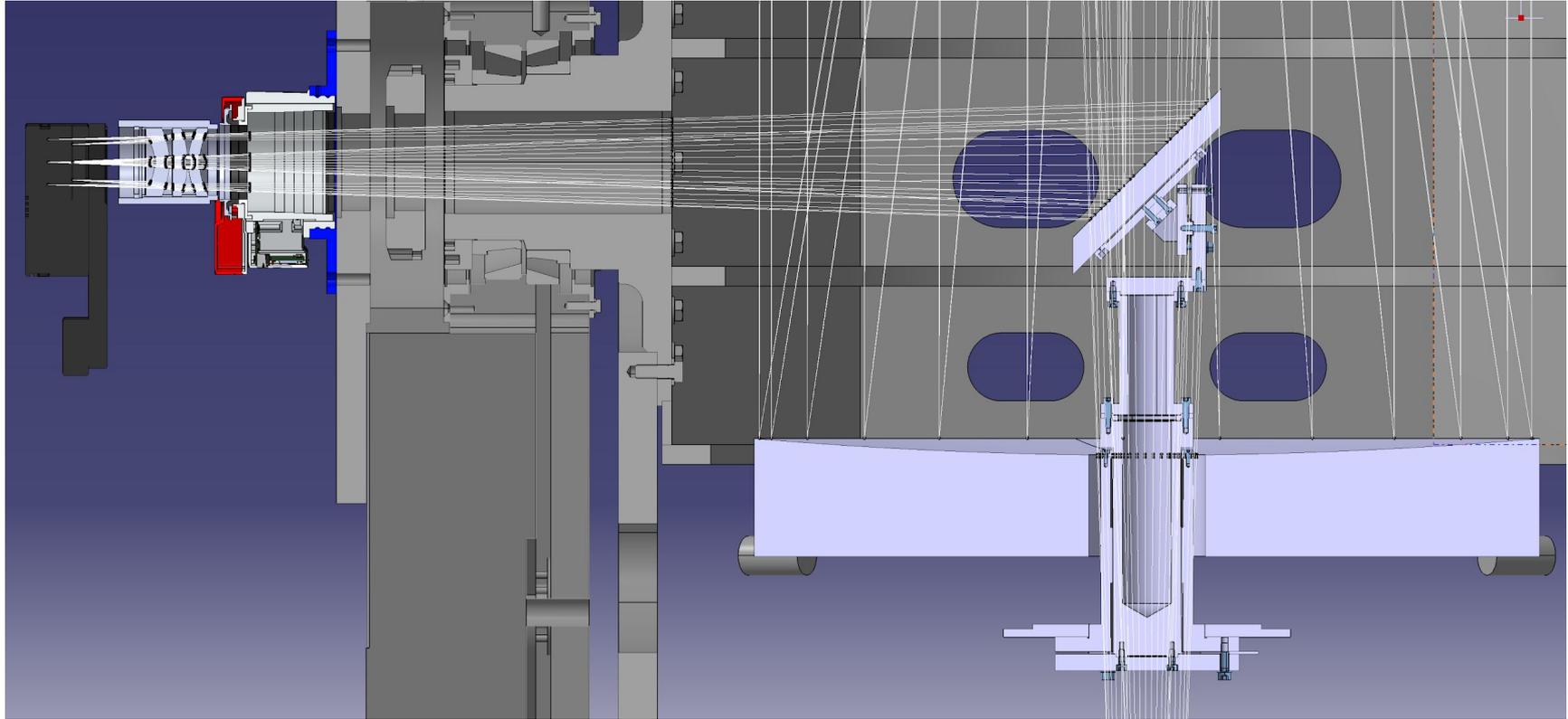


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New Optical Scheme: M3

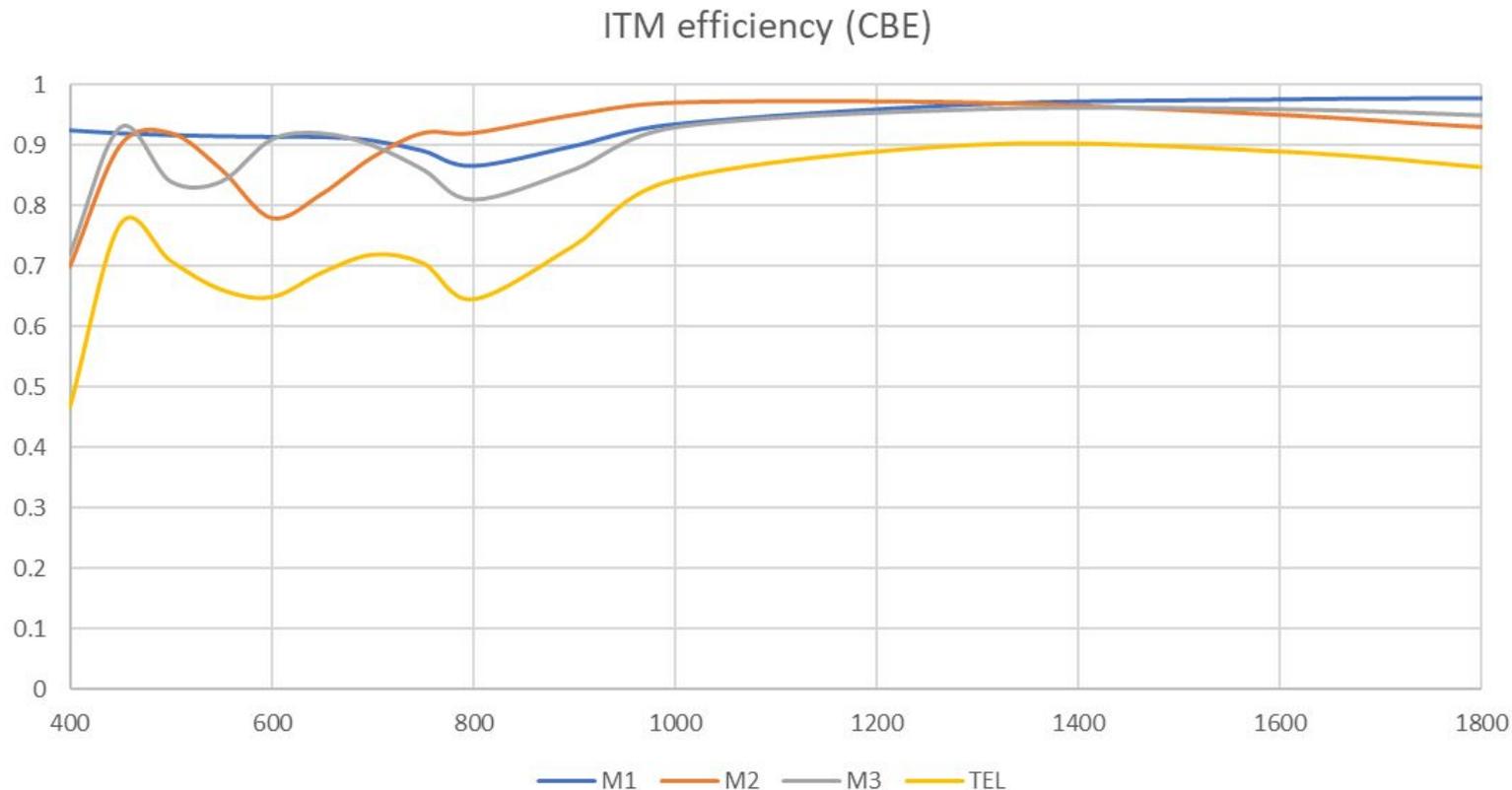


New Optical Scheme: M3



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New Optical Scheme: M2-M3 mirror's coating



Partially supported by



New Optical Scheme: Spot Diagram

Configuration: RC

Telescope focal length: 9600 mm (F/12)

Unvignetted FOV: 22 arcmin diameter

Wavelength: UV-Visible-Infrared (300 nm - 10 μ m)

Scale plate: 21.5 arcsec/mm

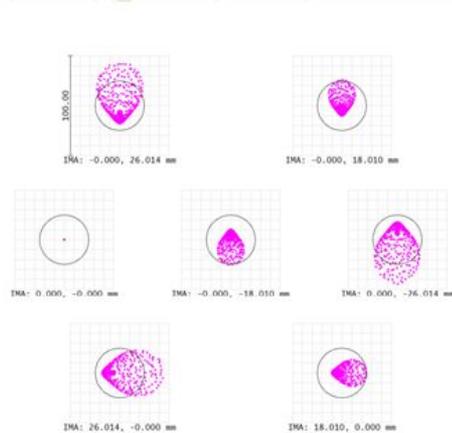
Configuration: RC + 0.75X focal reducer

Telescope focal length: 7613 mm (F/9.5)

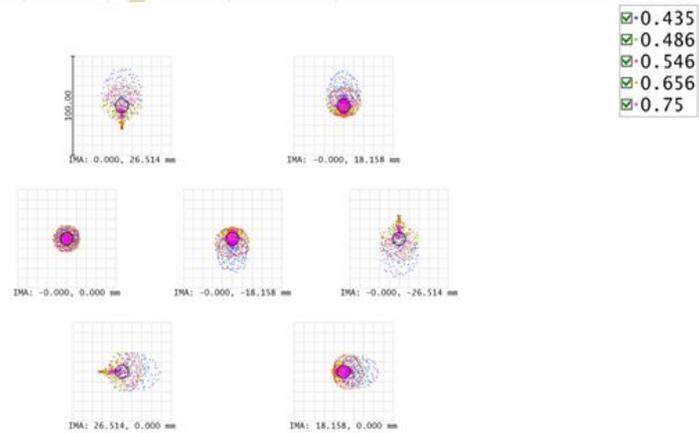
Unvignetted FOV: 18 arcmin diameter

Wavelength: Visible (435 - 750 nm)

Scale plate: 27.1 arcsec/mm



1.7



0.435
0.486
0.546
0.656
0.75

Surface: IMA

Spot Diagram

08-Sep-23
Units are μ m. Airy Radius: 24.89 μ m. Legend items refer to Wavelengths
Field : 1 2 3 4 5 6 7
RMS radius : 18.486 10.006 0.127 10.093 18.372 18.456 9.997
CEO radius : 42.514 25.882 0.259 25.142 44.577 44.025 24.881
Scale bar : 100 Reference : Centroid

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Ansys Zemax OpticStudio 2023

IRAIT_F12_70mm-longer-BFL.zos
Configuration 1 of 3

Surface: IMA

Spot Diagram

08-Sep-23
Units are μ m. Airy Radius: 6.344 μ m. Legend items refer to Wavelengths
Field : 1 2 3 4 5 6 7
RMS radius : 15.041 9.695 6.588 9.629 15.010 15.012 9.725
CEO radius : 37.573 34.943 14.271 34.154 38.946 38.881 35.133
Scale bar : 100 Reference : Centroid

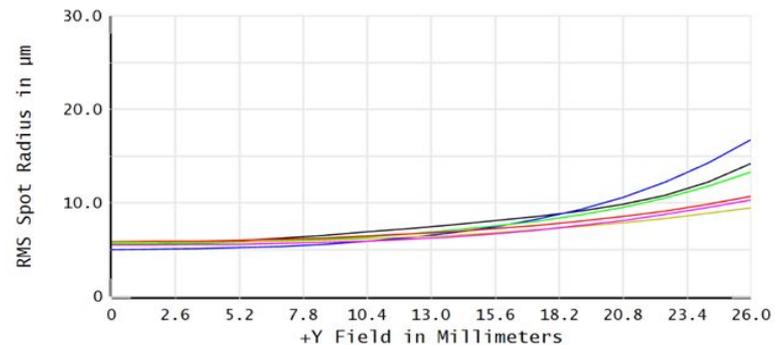
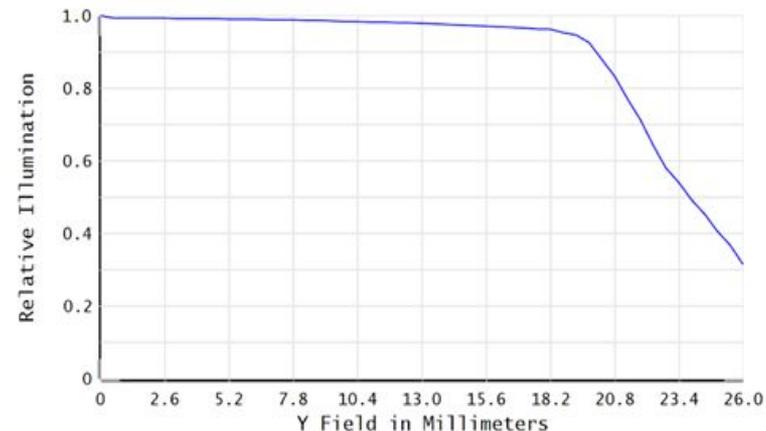
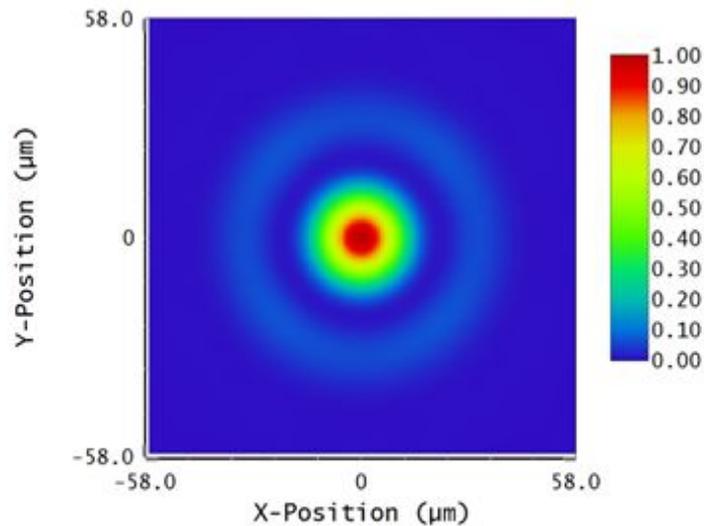
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Ansys Zemax OpticStudio 2023

IRAIT_F12_70mm-longer-BFL.zos
Configuration 3 of 3

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New Optical Scheme: PSF and RMS spot radius



Polychromatic FFT PSF

08-Sep-23
 1.5000 to 1.8000 μm at 0.00, 0.00 mm.
 Side 1s 115.20 μm .
 Surface: Image
 Reference Coordinates: 0.00000F+00. 0.00000F+00

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 p.spano@optical-design.it
 Ansys Zemax OpticStudio 2023
 IRAIT_F12_70mm-longer-BFL_B.zos
 Configuration 1 of 3

PSF on-axis
 RC at NIR (H-band)

— Poly — 0.4350 — 0.4860 — 0.5460 — 0.6560 — 0.7500



New Optical Scheme: Focuser



- Crayford style focuser with 40 ball bearings, specially designed for very high load capacity (up to 10 kgs) with no flexure
- Low profile design with only 65mm thickness (91mm with internal flange).
- 35mm focuser travel with an incredible resolution of 0.04 microns per step!



New Optical Scheme: Rotator



- Low profile rotator - 23mm of body thickness
- 1 arc second resolution per step
- 76.3mm of free aperture
- Specially designed full aluminum case, for rotating heavy cameras and accessories without any flexure
- M81 threaded



Thanks!

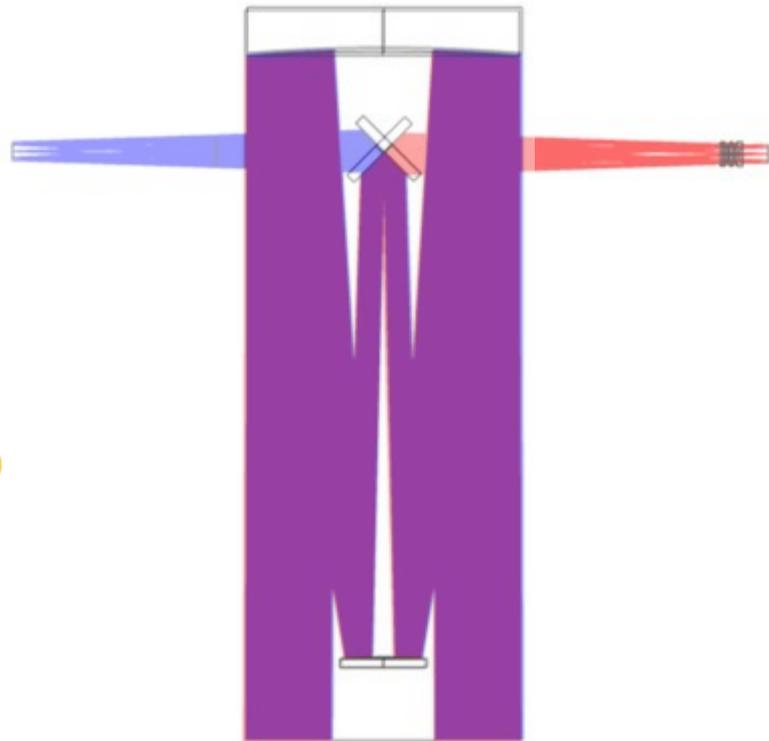
Any questions?

You can find me at:

direttore@oavda.it

www.oavda.it

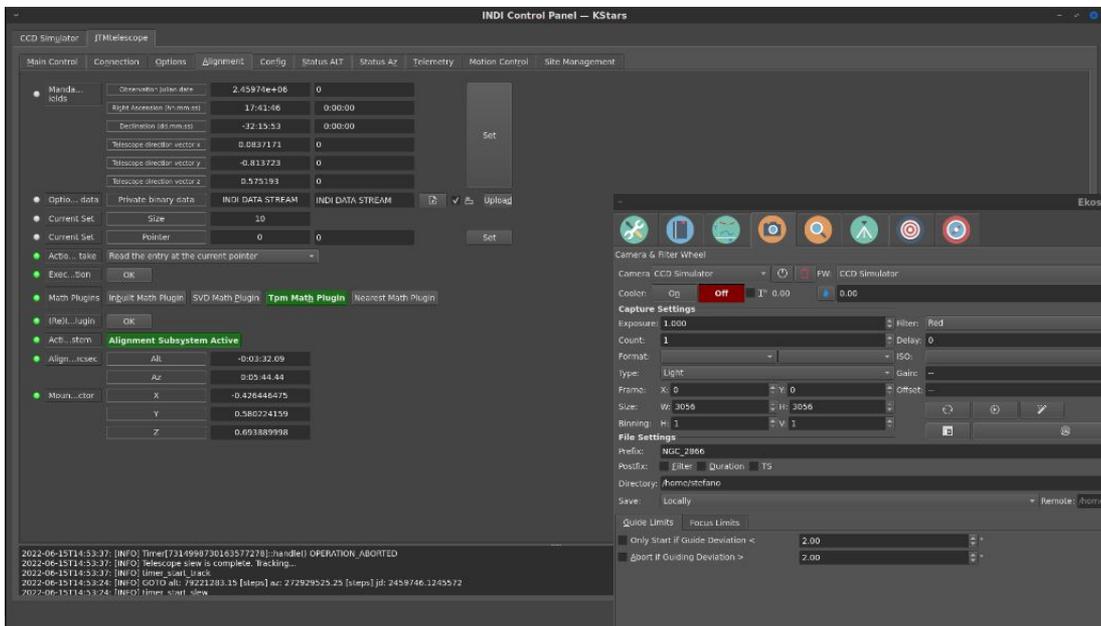
+39(0)165-770050



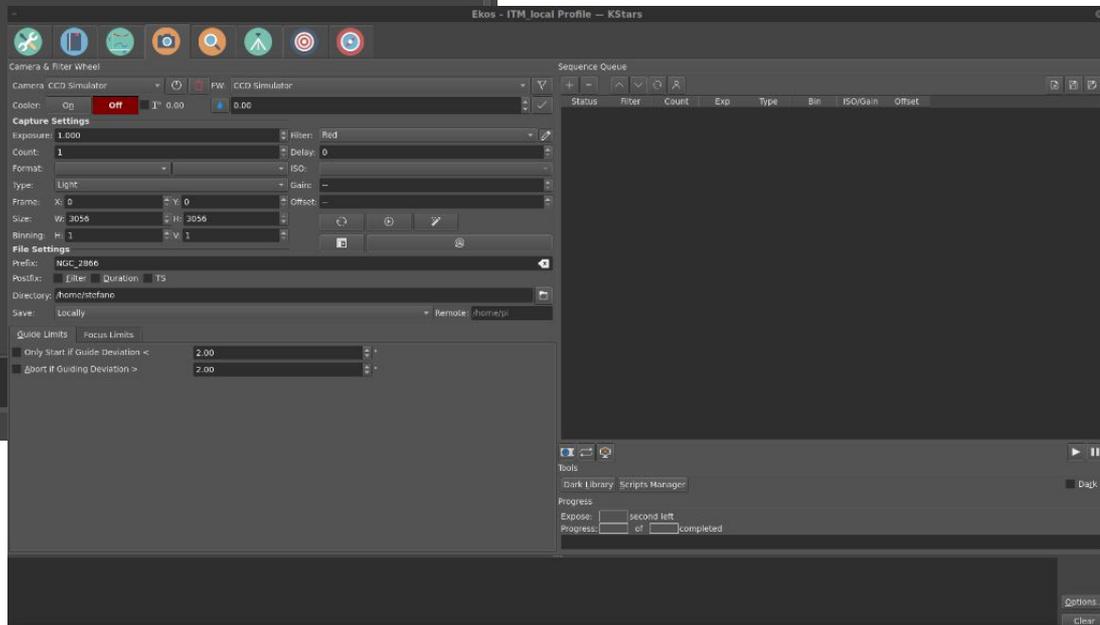
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Software upgrades: INDI-Ekos-Kstars



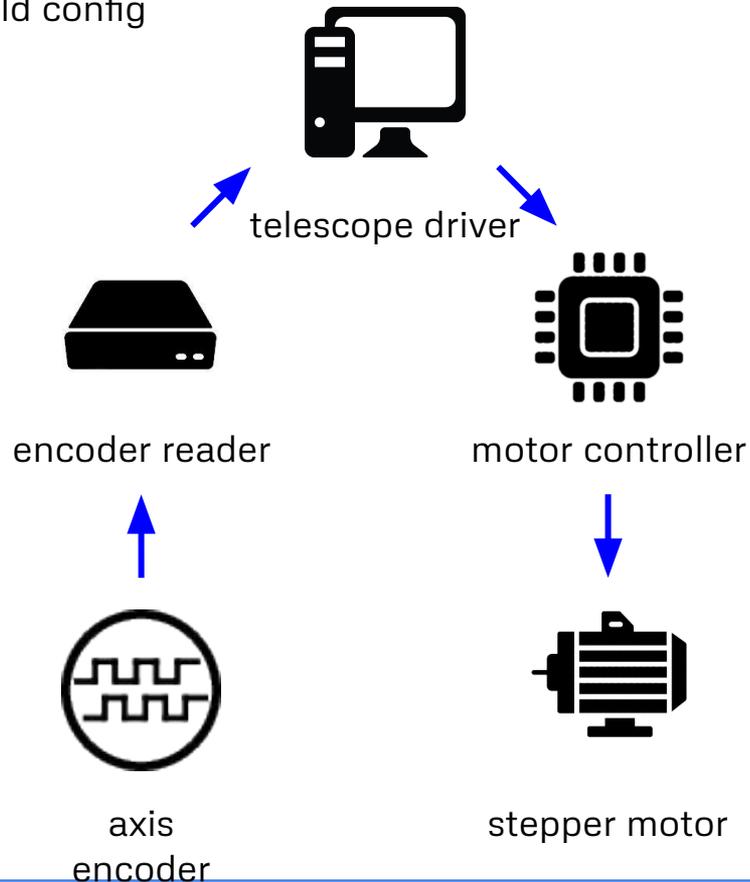
Full featured GUI



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Software upgrades: Encoder closed loop

old config



new config

