Evaluating and optimizing performances of a small telescope

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What are we talking about

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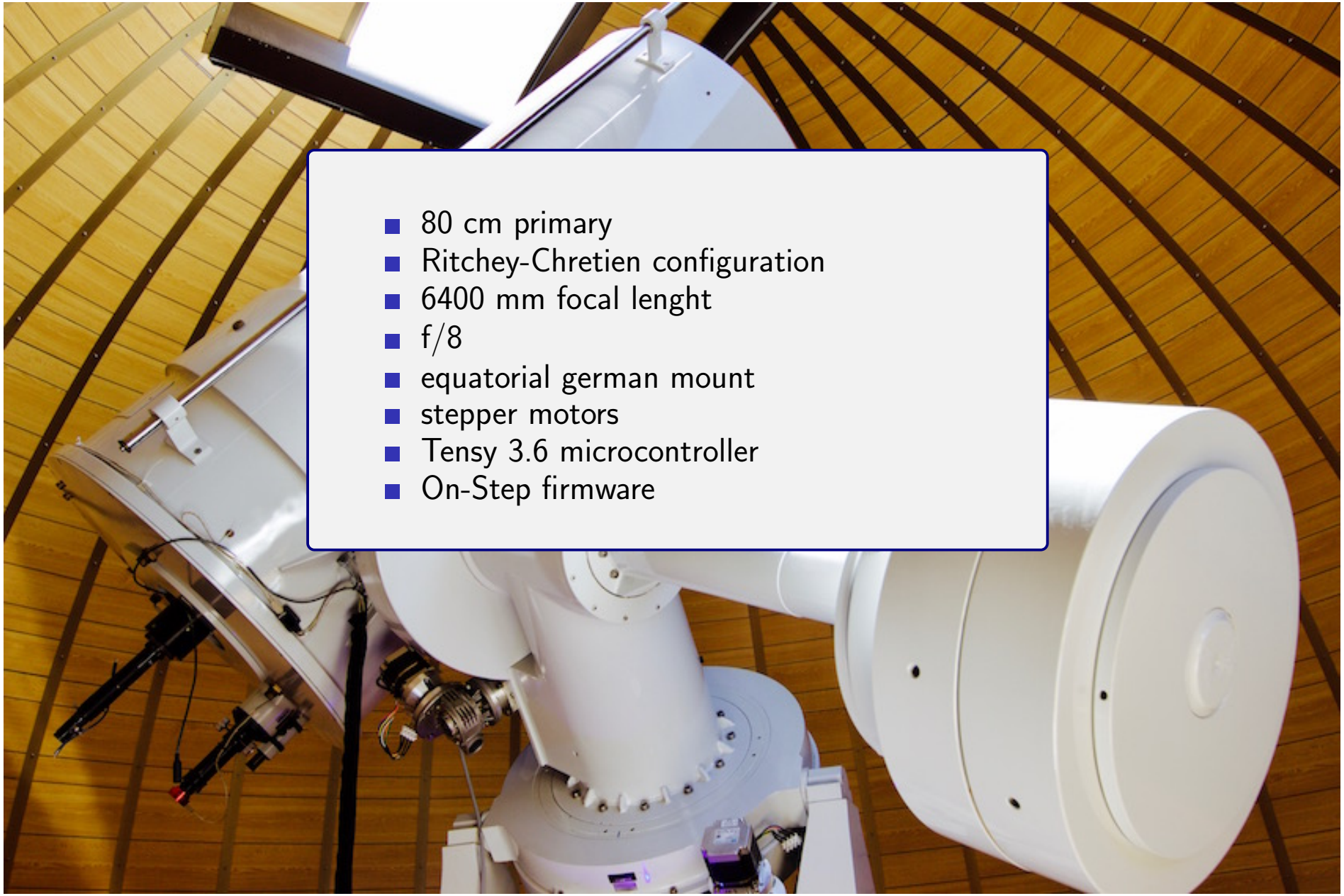

- 80 cm primary
- Ritchey-Chretien configuration
- 6400 mm focal lenght
- f/8
- equatorial german mount
- stepper motors
- Tensy 3.6 microcontroller
- On-Step firmware

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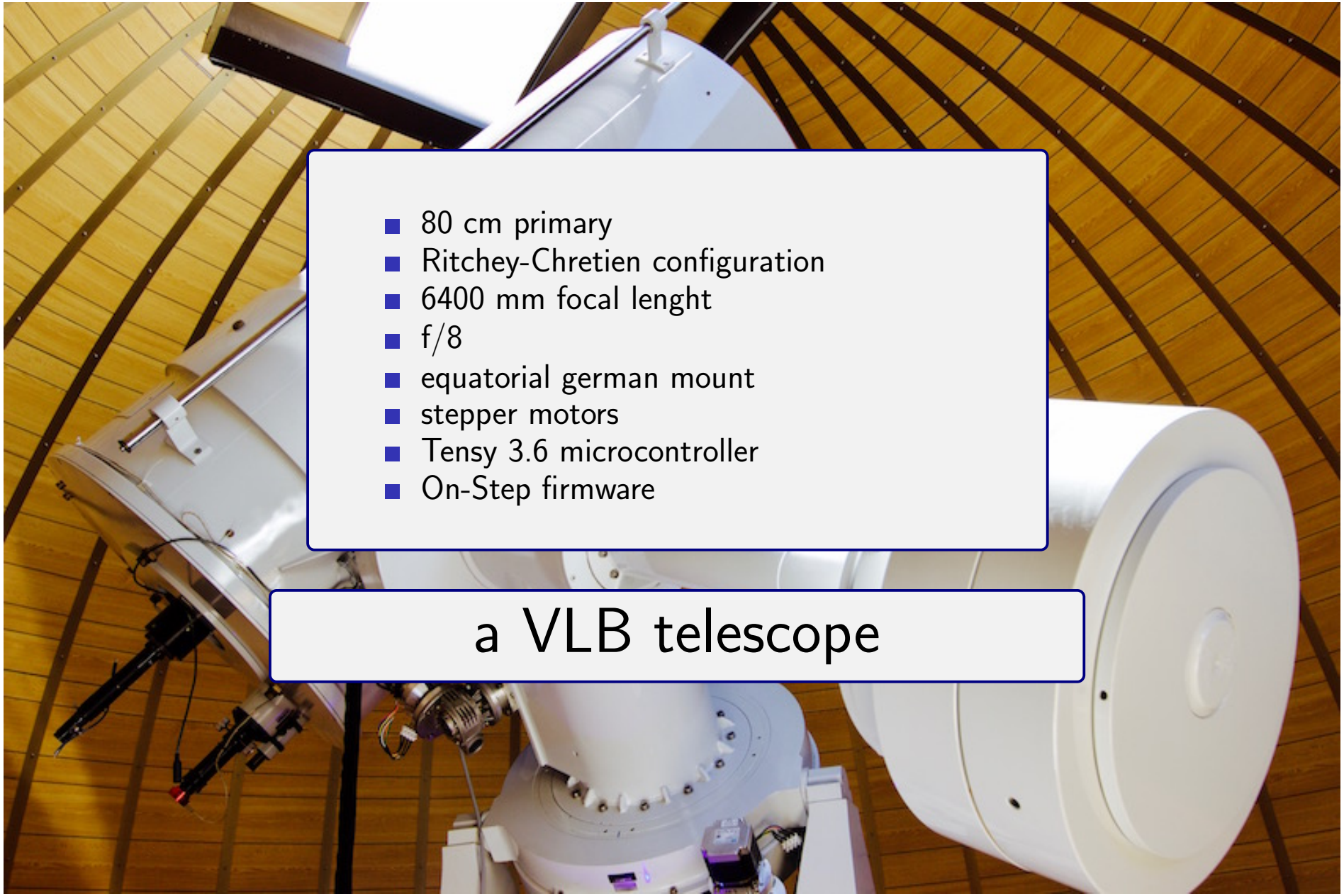

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a VLB telescope

Tracking drift

Dataset 1:

- 41 images from HD73710
- Field center: RA $= 8^h40^m22^s$, DEC $= 19°40'11''$
- Image size: 1536×1024
- Scale: 0.46 arcsec/pixel
- Average interval: 18.65 s
- Total time: 746 s
- Total drift: 77 pixels
- Total drift: 35.55 arcsec
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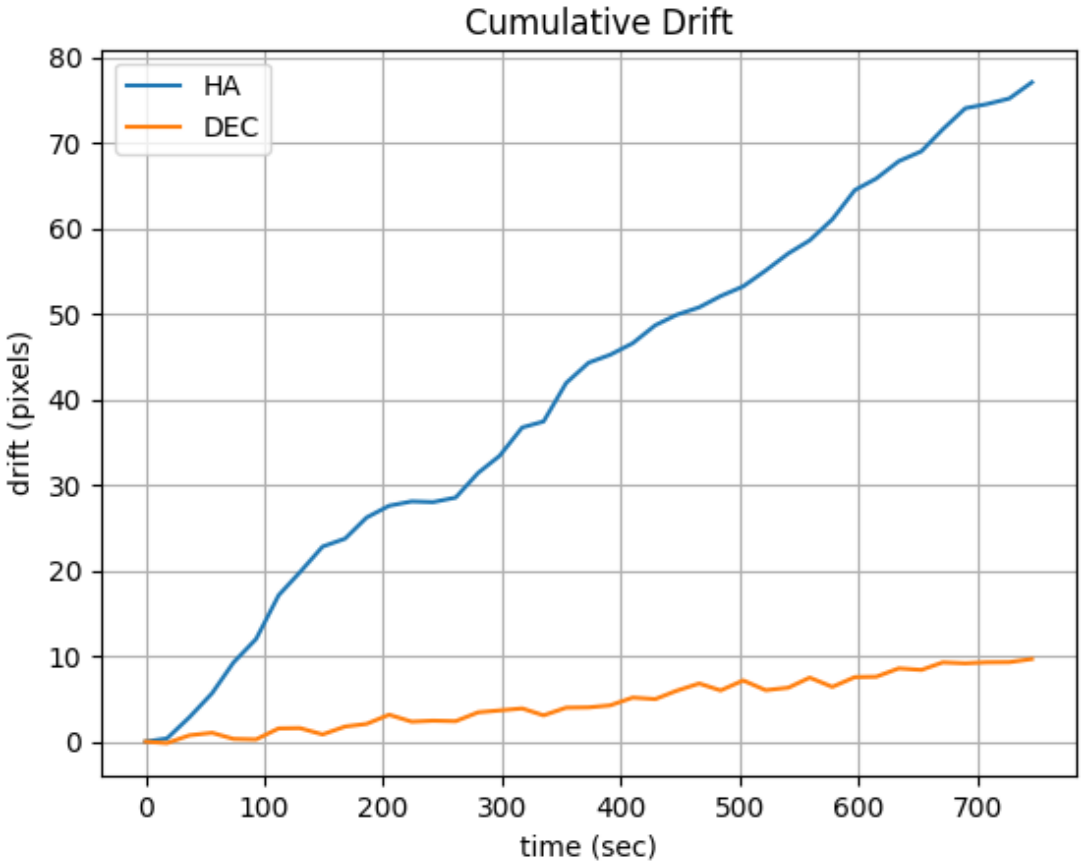

Tracking frequency adjustment

- The On-Step firmware allows adjustment of the tracking frequency
- We decreased the tracking frequency in steps to an optimal value

Tracking drift - optimized frequency

Dataset 2:

- 81 images from HD73710
- Field center: RA $= 8^h40^m22^s$, DEC $= 19°40'07''$
- Image size: 1536×1024
- Scale: 0.46 arcsec/pixel
- Average interval: 18.73 s
- Total time: 1499 s
- Total drift: 14.25 pixels
- Total drift: 6.56 arcsec
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Tracking drift - optimized frequency

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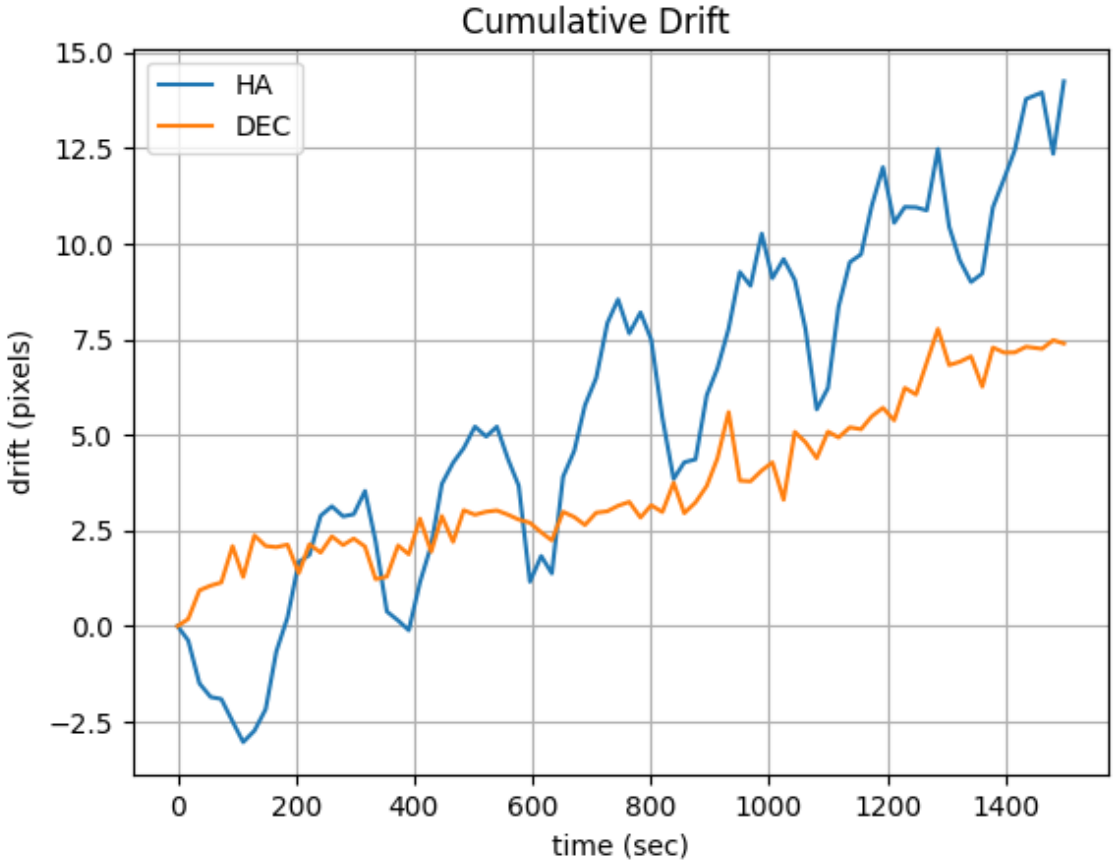
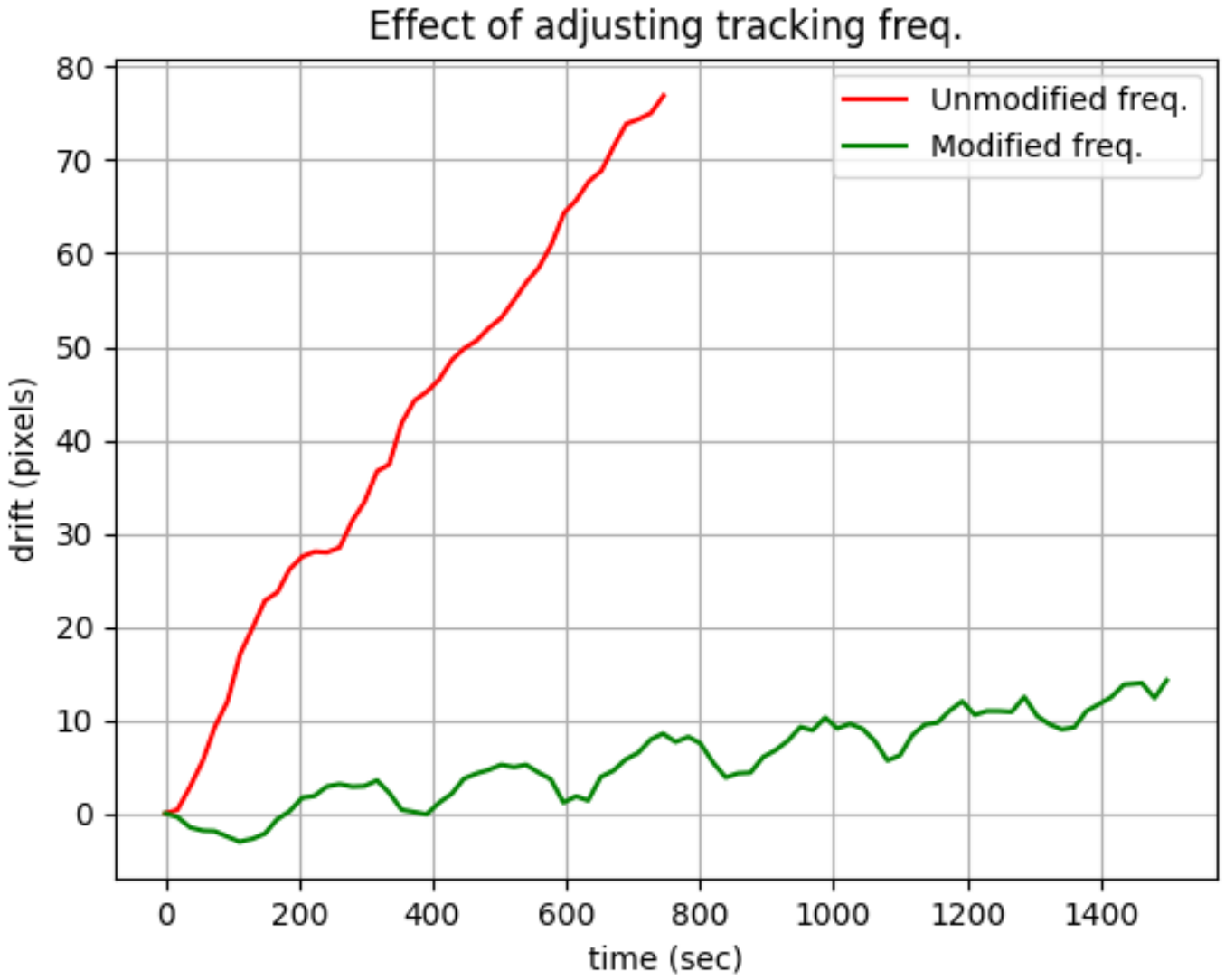
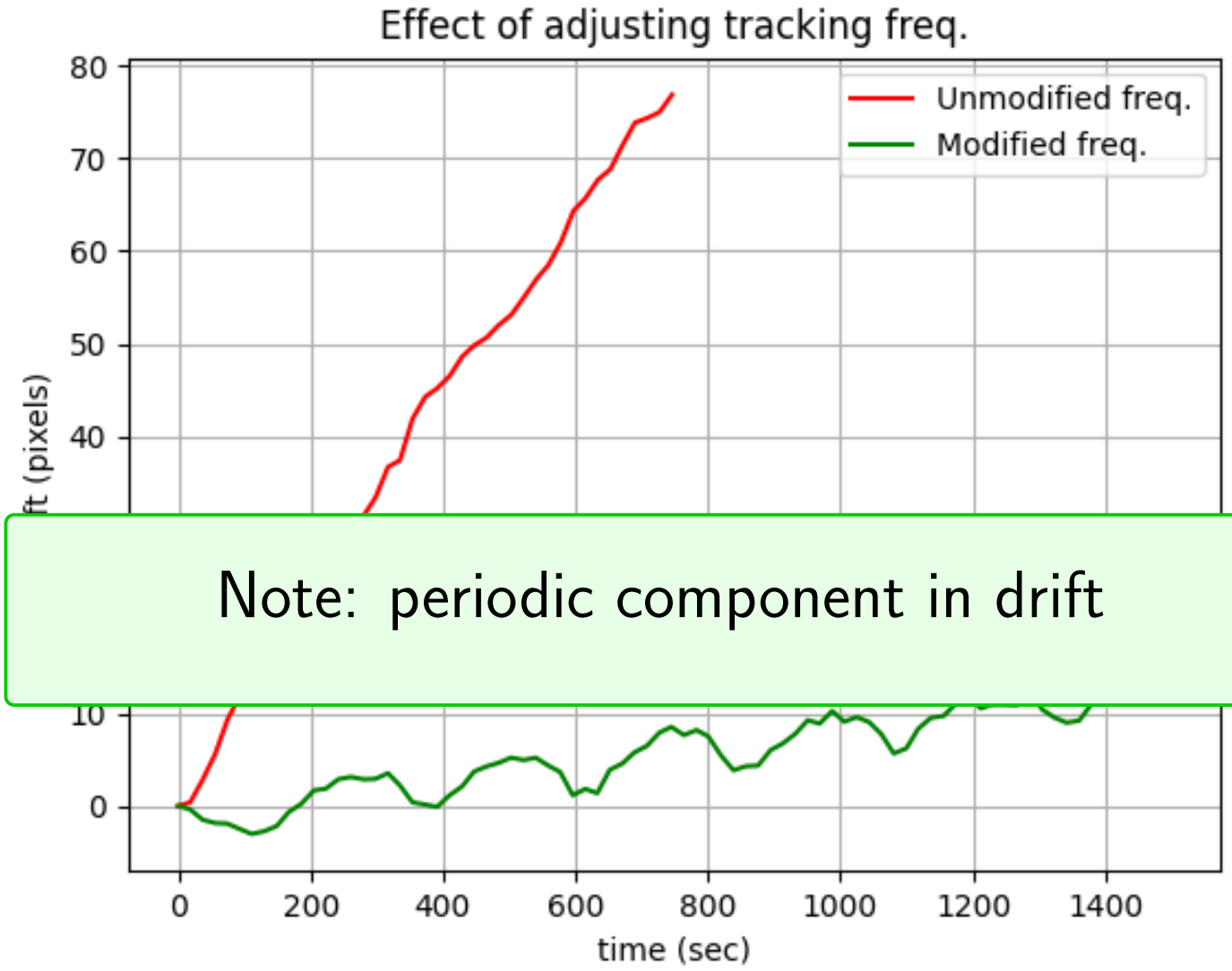


Tracking drift - HA comparison



Tracking error reduction factor: 13.34

Tracking drift - HA comparison

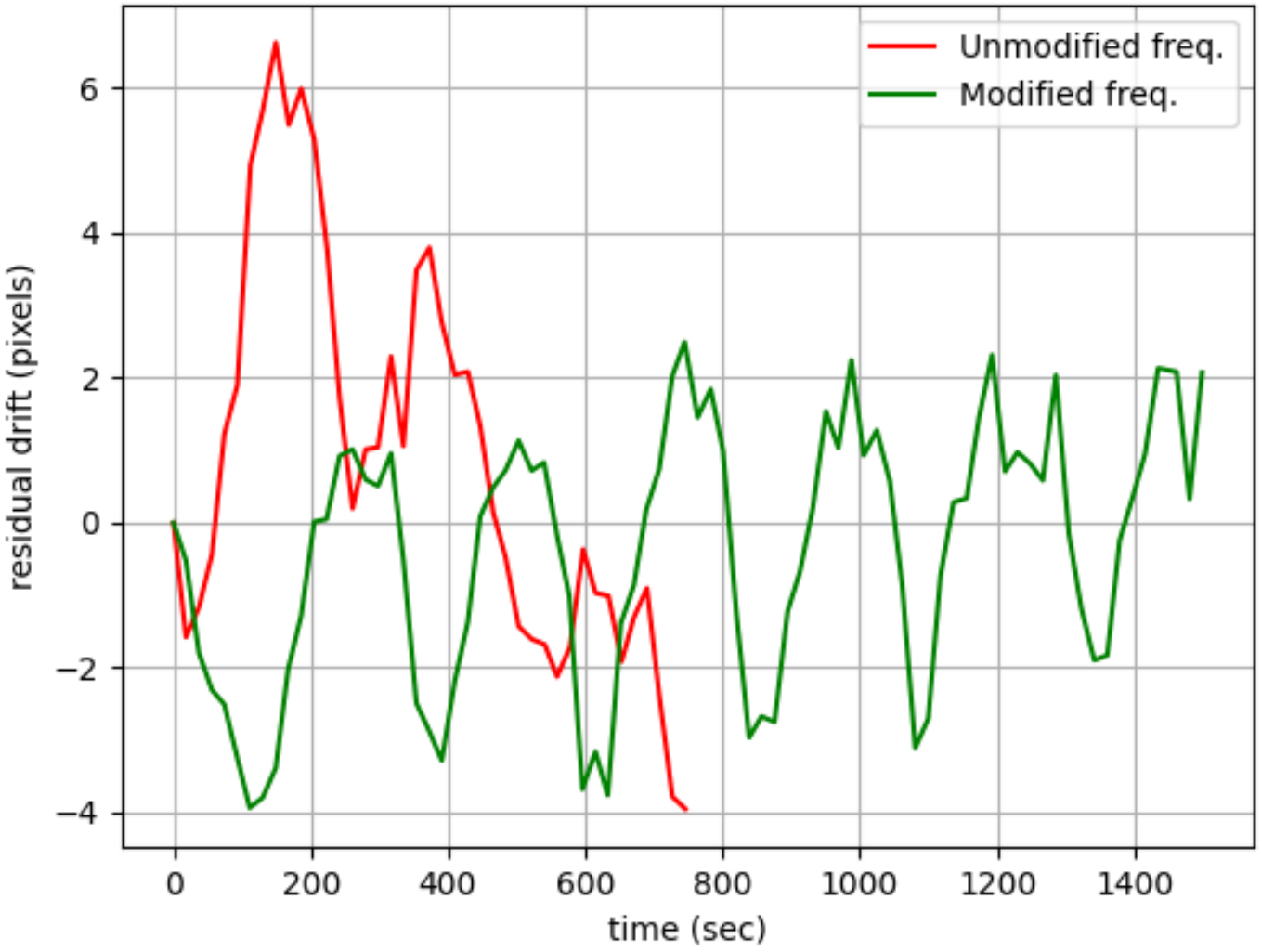


Note: periodic component in drift

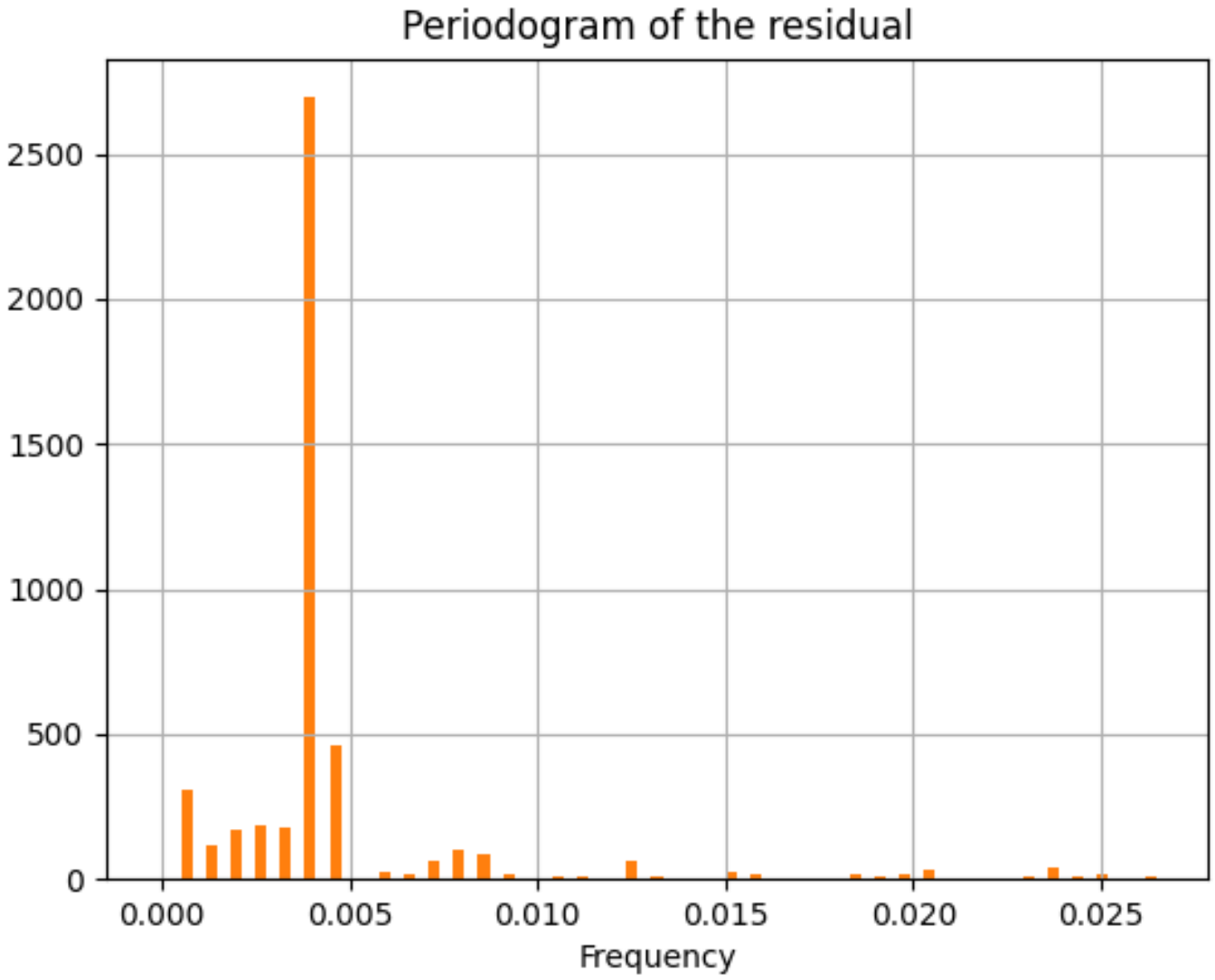
Tracking error reduction factor: 13.34

Tracking drift - Periodic component

Residual drift after removing the linear component



Tracking drift - Periodic component



- Highest peak period = 252.95 s $\Rightarrow$ 3794 arcsec ($\sim$ 3600 arcsec)

Tracking drift - Next improvements

- Sample errors at different telescope positions
- Refine tracking frequency adjustment
- Verify repeatability of periodic component phase
  - Use a lookup table to remove the periodic component

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We tested a commercial app for telescope modeling with with poor success

More work on that could be profitable

Active guiding

Guiding on scientific images

- suitable for sequences of short-exposure images
- happens to fit the main research activity at OPC

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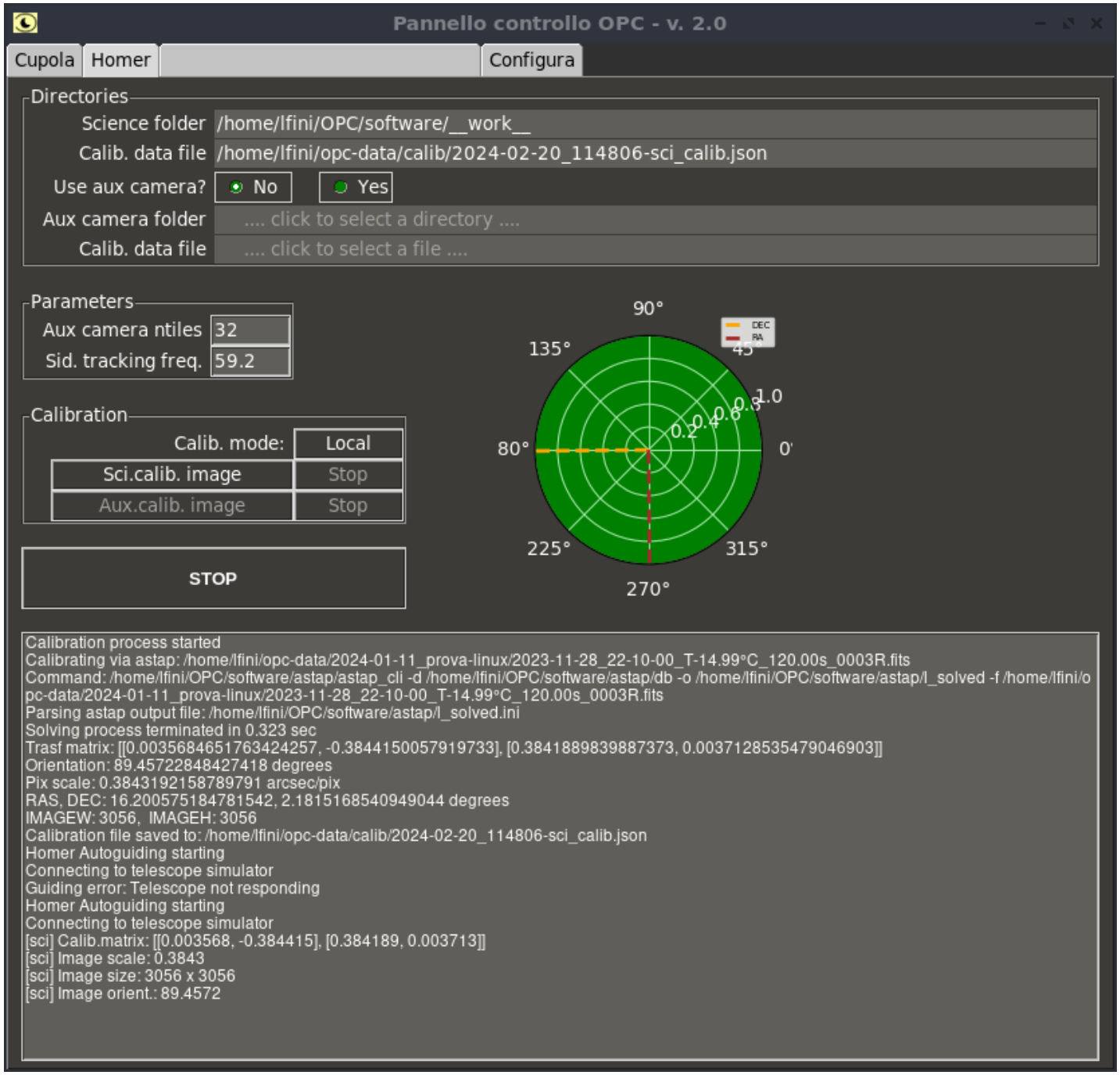
HOMER: a python GUI based program

- measures image shift between successive frames during observation
  - uses the *donuts* python package
- adjusts telescope pointing to compensate for drift
  - uses a python client for the LX200-like OnStep protocol
- Idea and first implementation by L.Naponiello

Homer in action



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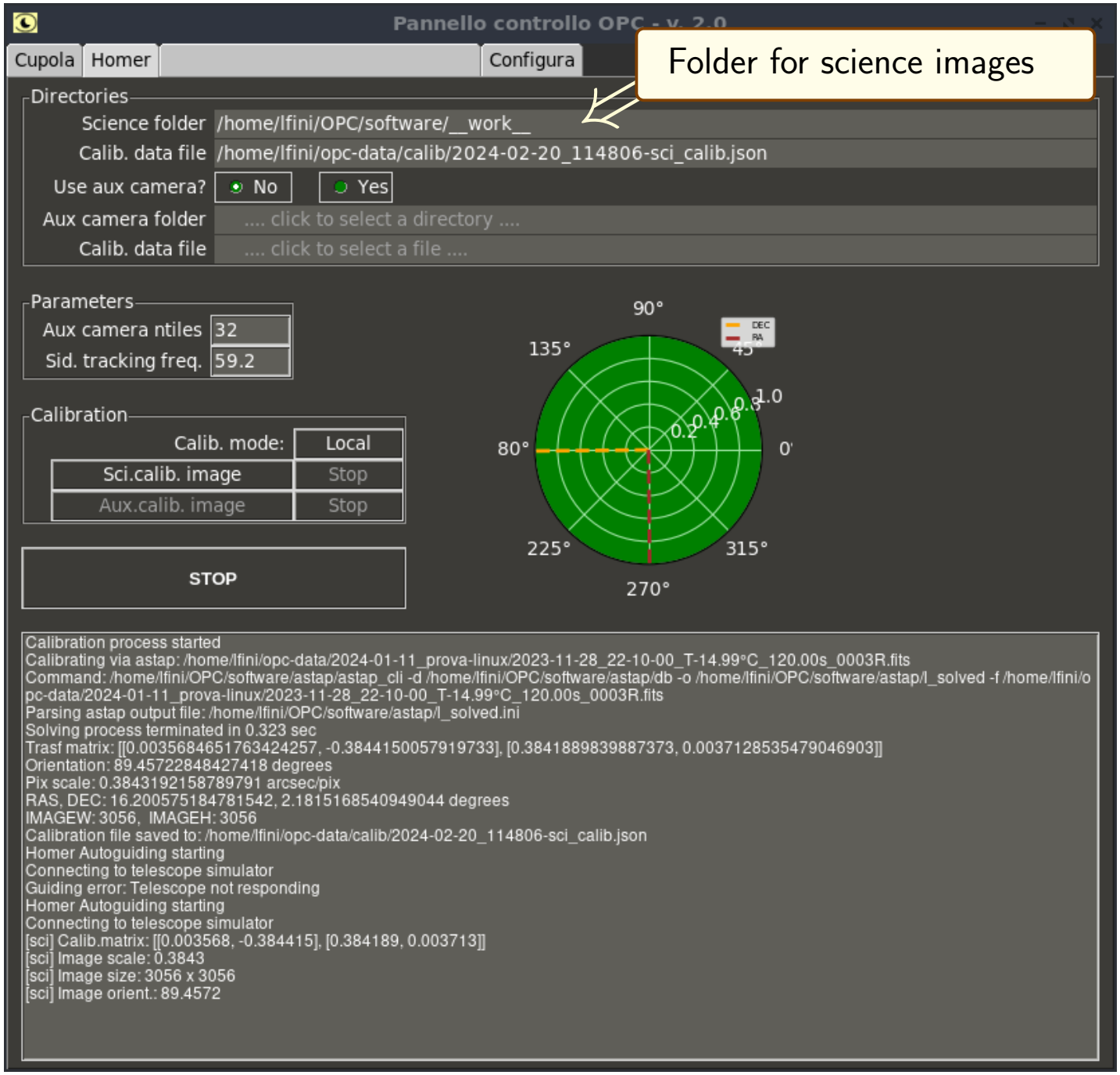

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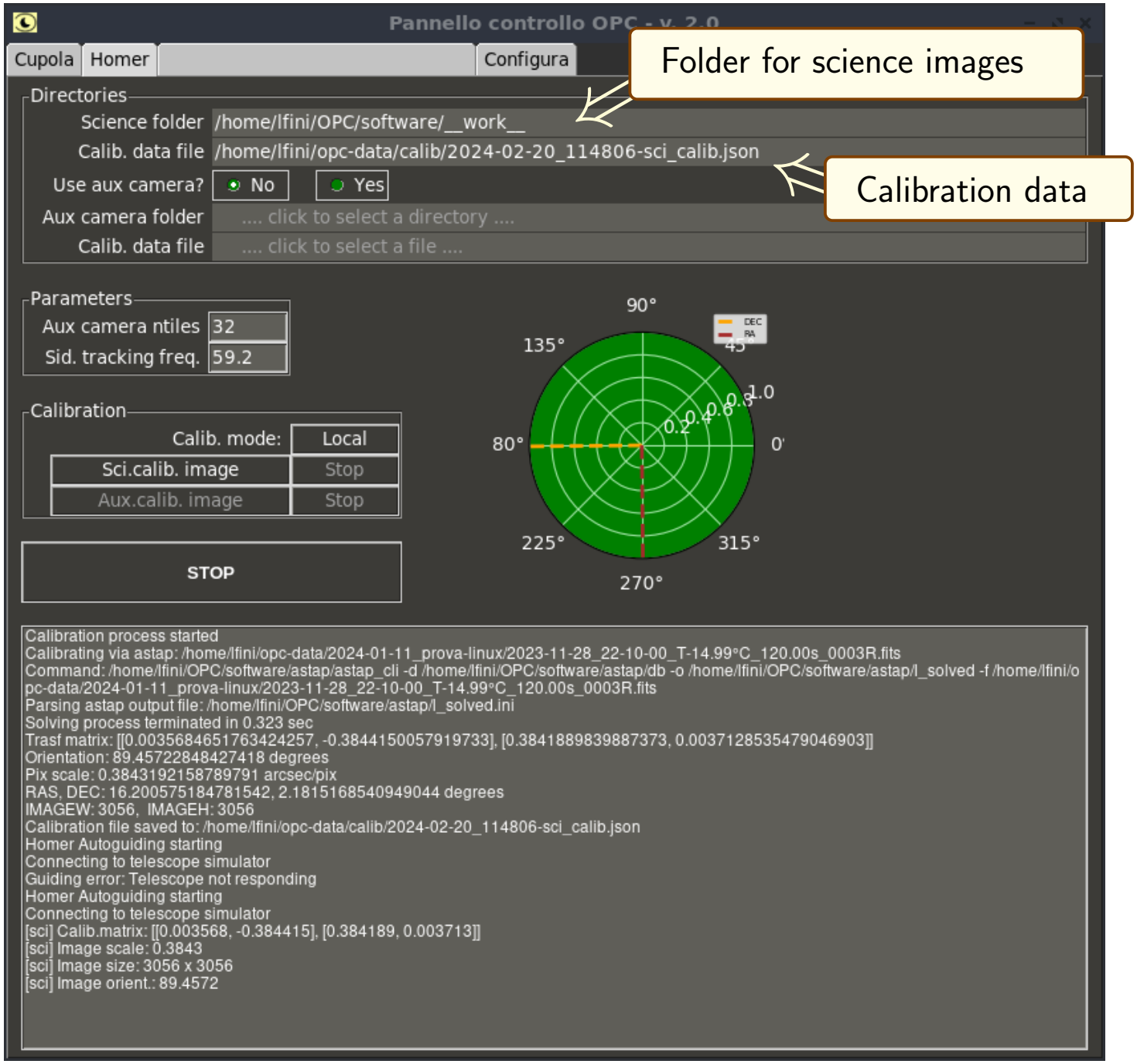

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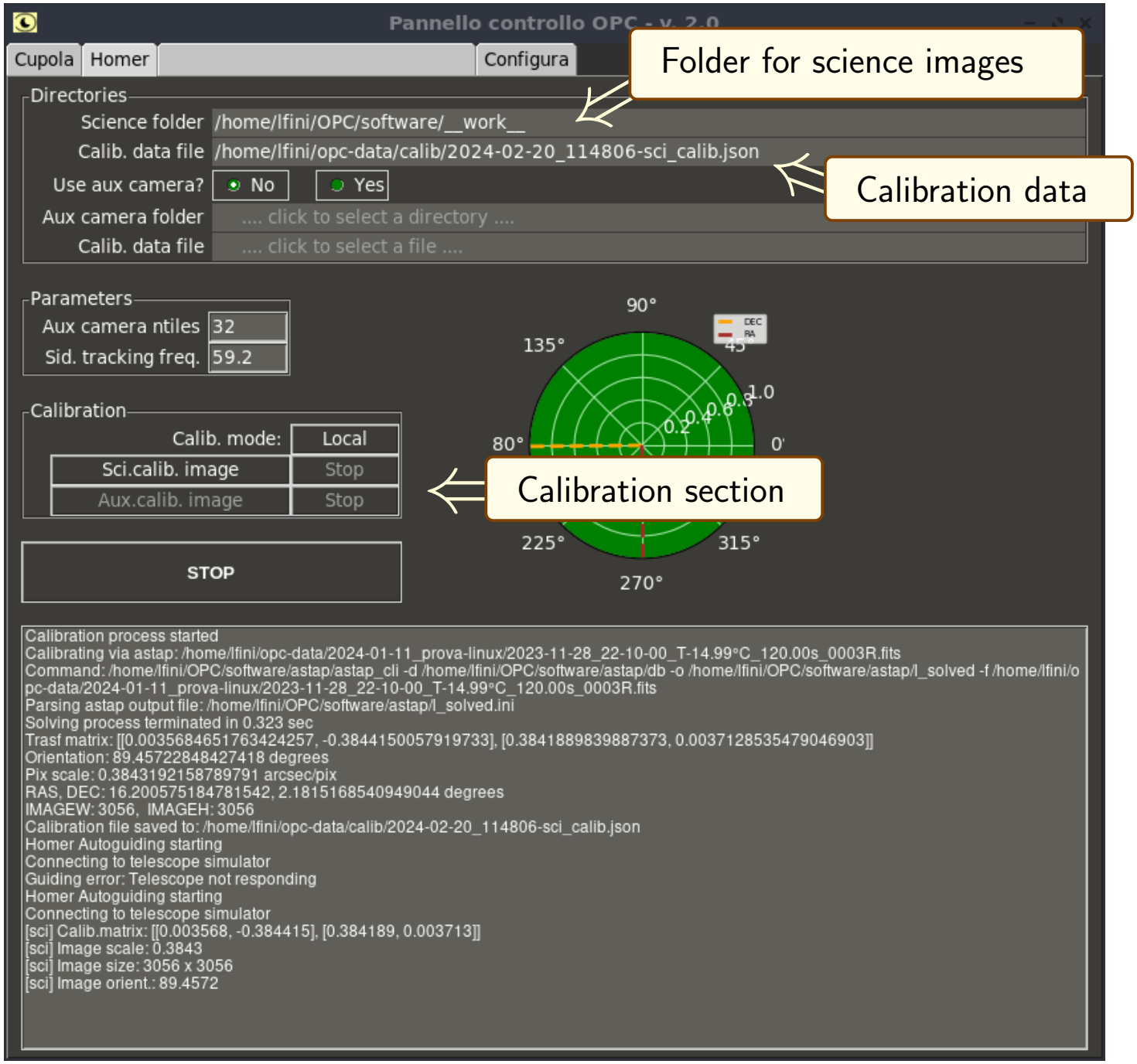

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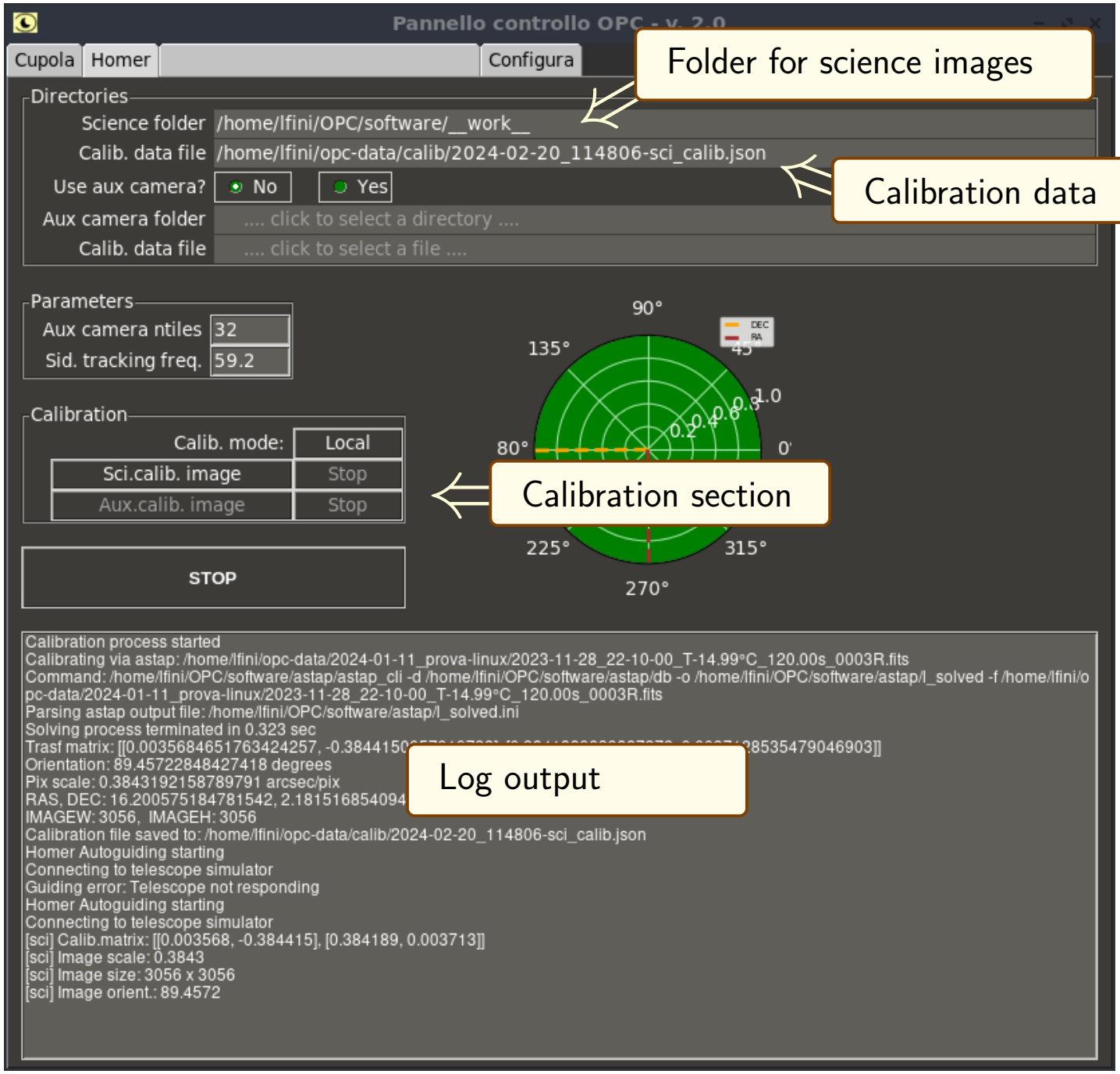

Homer: how it works

1. Calibration:
   - Uses either a local plate solving program[1] or *Astrometry.net* network based API to compute the trasformation matrix `pixel-pos` $\rightarrow$ `sky-pos` from the first science image.
2. A loop is started with *Homer* waiting for new images
3. When a new image is detected:
   - Computes the pixel shift with respect to the first image
   - Converts shift from pixels to sky coordinates using calibration data
   - Sends the adjust command to telescope
4. *Homer* can optionally use another source of images (e.g.: from a guide camera) to repeat the adjustment process in the interval between two science images

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1) We are currently using *astap*: `https://www.hnsky.org/astap`

Homer log data as diagnostic tool

Dataset 3:

- 12 images from M77
- Field center: RA $= 2^h42^m47^s$, DEC $= 0°0'57''$
- Image size: 3056×3056
- Scale: 0.384 arcsec/pixel
- Average interval: 75 s
- Total time: 825 s
- Total drift: 24.5 pixels
- Total drift: 9.4 arcsec
- HA linear coefficient: 0.02

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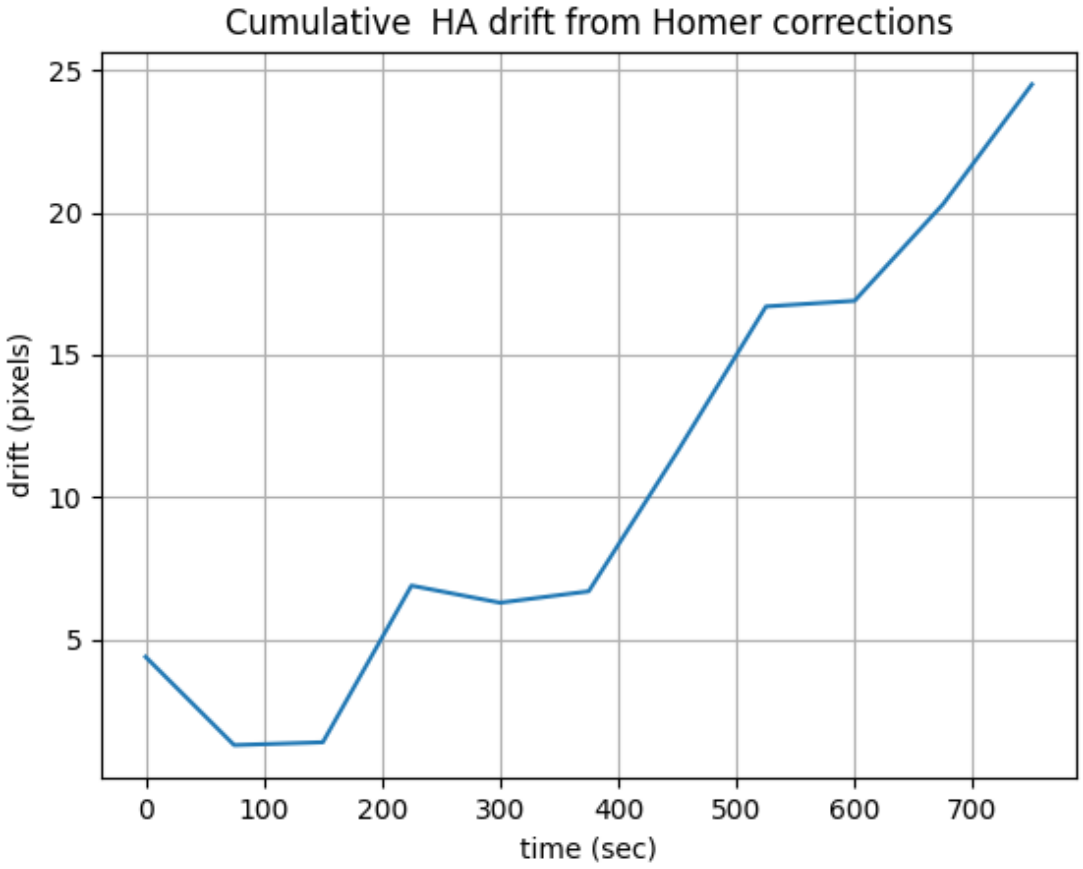

Tools for the trade

- **cross_correlation_shift**

  Function from `image_registration` astropy package
  Uses cross-correlation and a 2nd order taylor expansion to measure the offset between two images
  Given two images, calculates the amount image2 is offset from image1 to sub-pixel accuracy using 2nd order taylor expansion.

- **DONUTS**

  A Science Frame Autoguiding Algorithm with Sub-Pixel Precision, Capable of Guiding on Defocused Stars.
  It was designed to calculate guide corrections from a series of science images and recentre telescope pointing between each exposure.

Contributors

- Lorenzo Betti
- Alfredo Biagini
- Luca Fini
- Luca Naponiello
- Vladimiro Noce
- Ruggero Stanga

Thank You