

Evaluating and optimizing performances of a small telescope

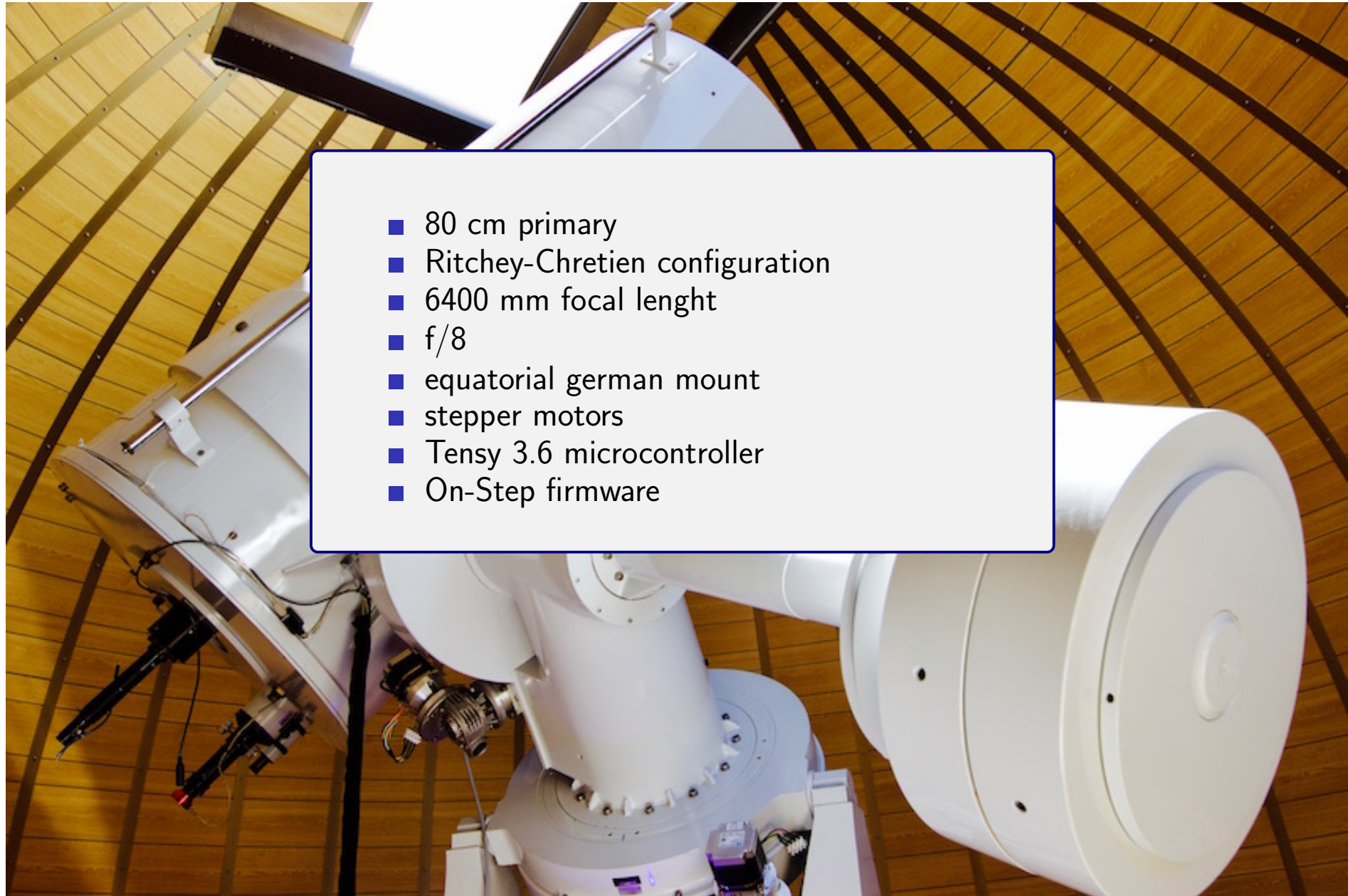
Luca Fini

INAF - Osservatorio Astrofisico di Arcetri and OPC

What are we talking about



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

a VLB telescope

Tracking drift

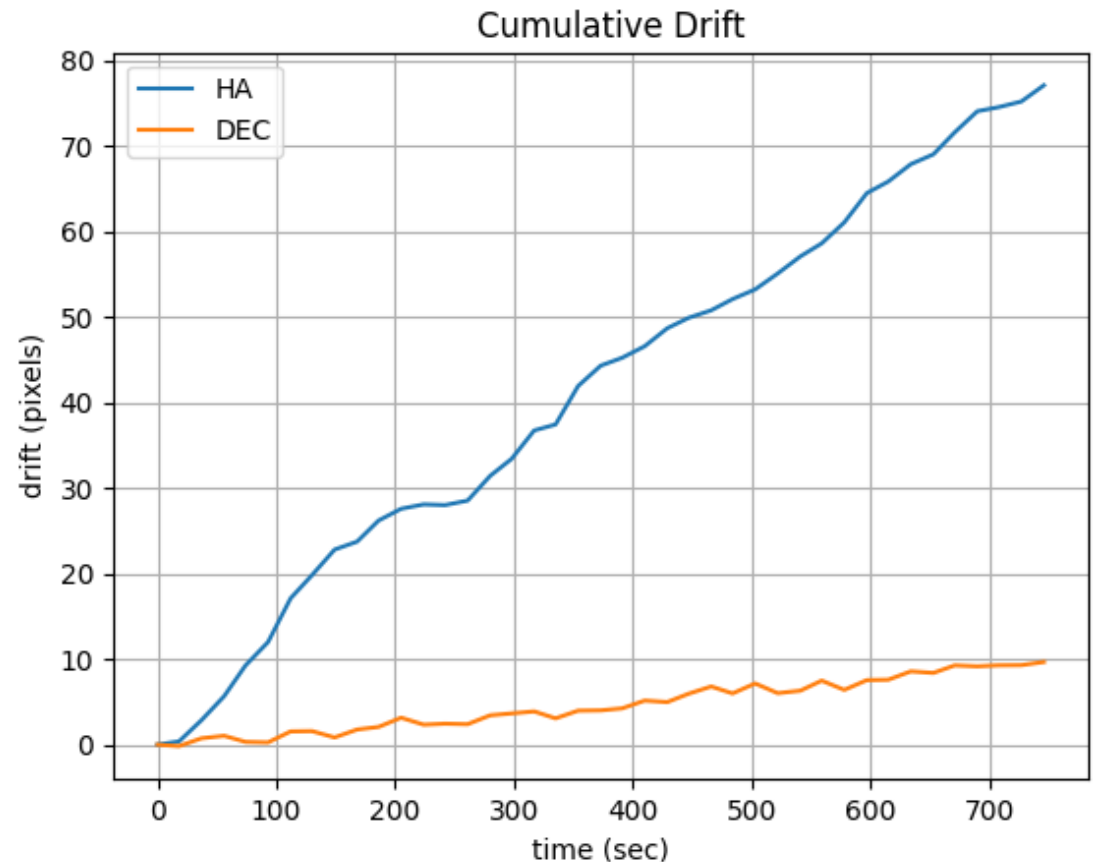
Dataset 1:

- 41 images from HD73710
- Field center: RA = $8^h40^m22^s$, DEC = $19^\circ40'11''$
- 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
- HA linear coefficient: 0.1084

Tracking drift

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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

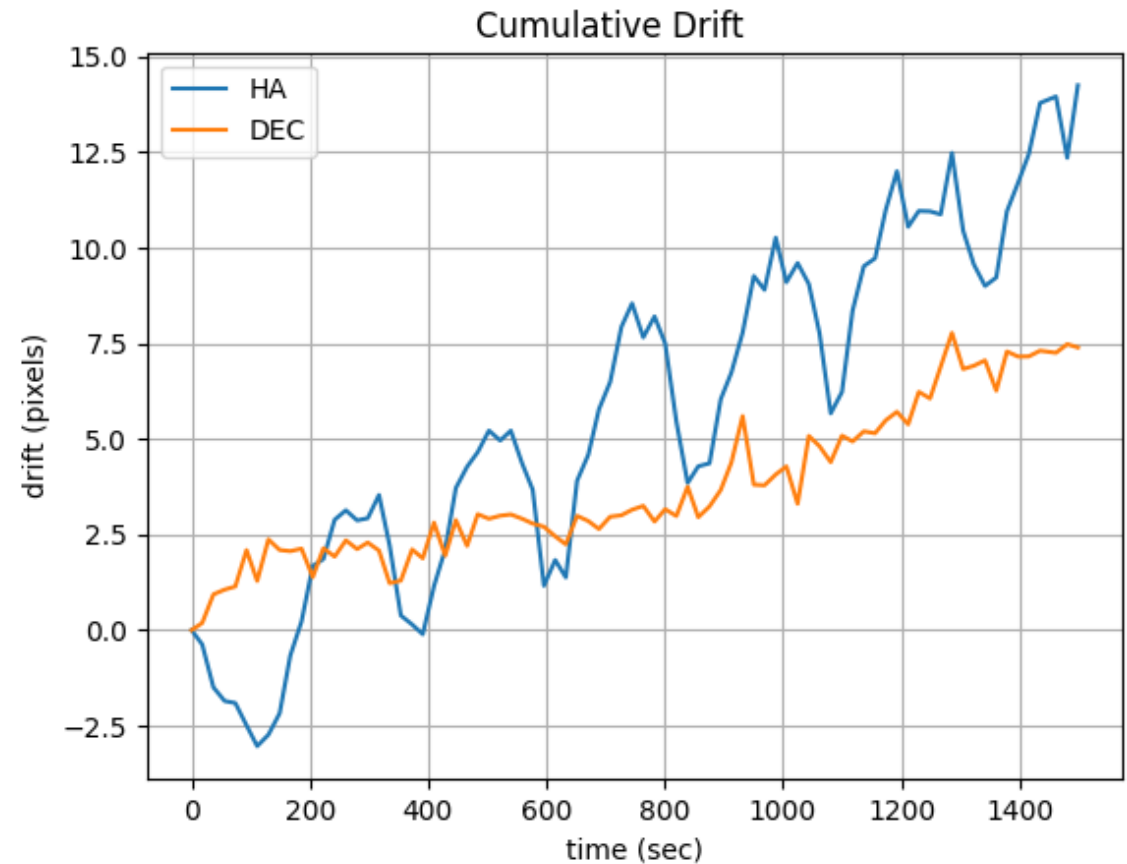
Dataset 2:

- 81 images from HD73710
- Field center: RA = $8^h40^m22^s$, DEC = $19^\circ40'07''$
- 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
- HA linear coefficient: 0.008

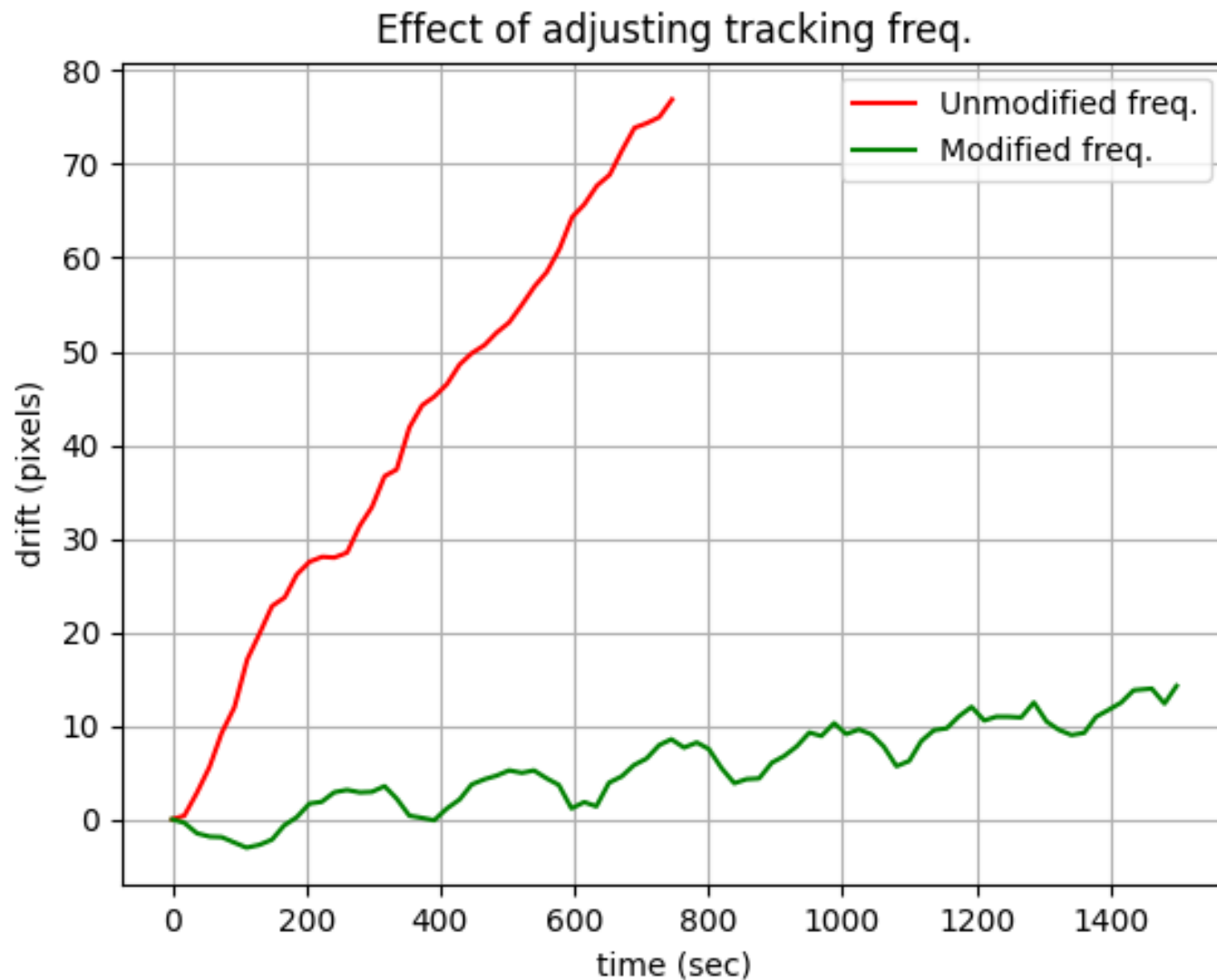
Tracking drift - optimized frequency

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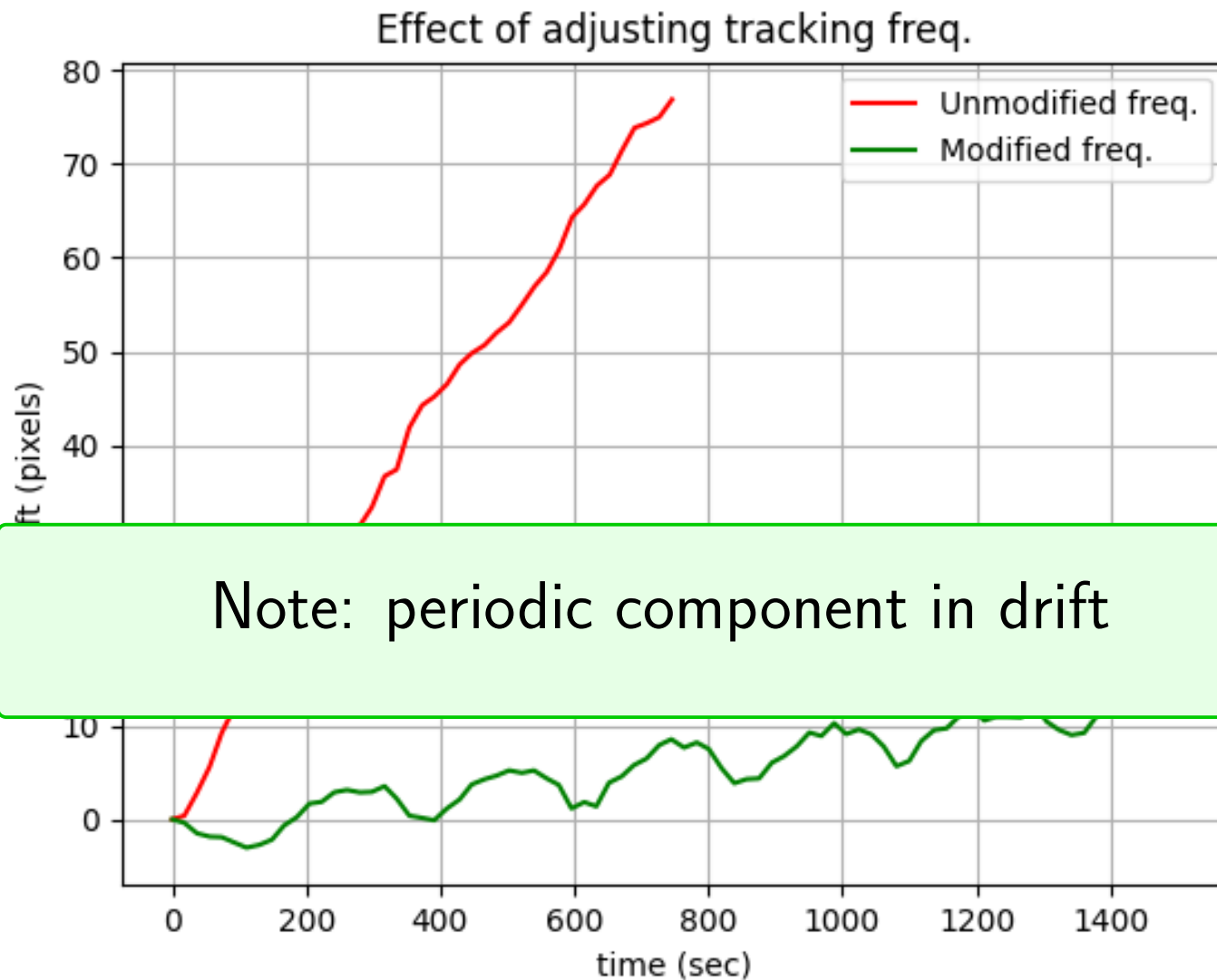


Tracking drift - HA comparison



Tracking error reduction factor: 13.34

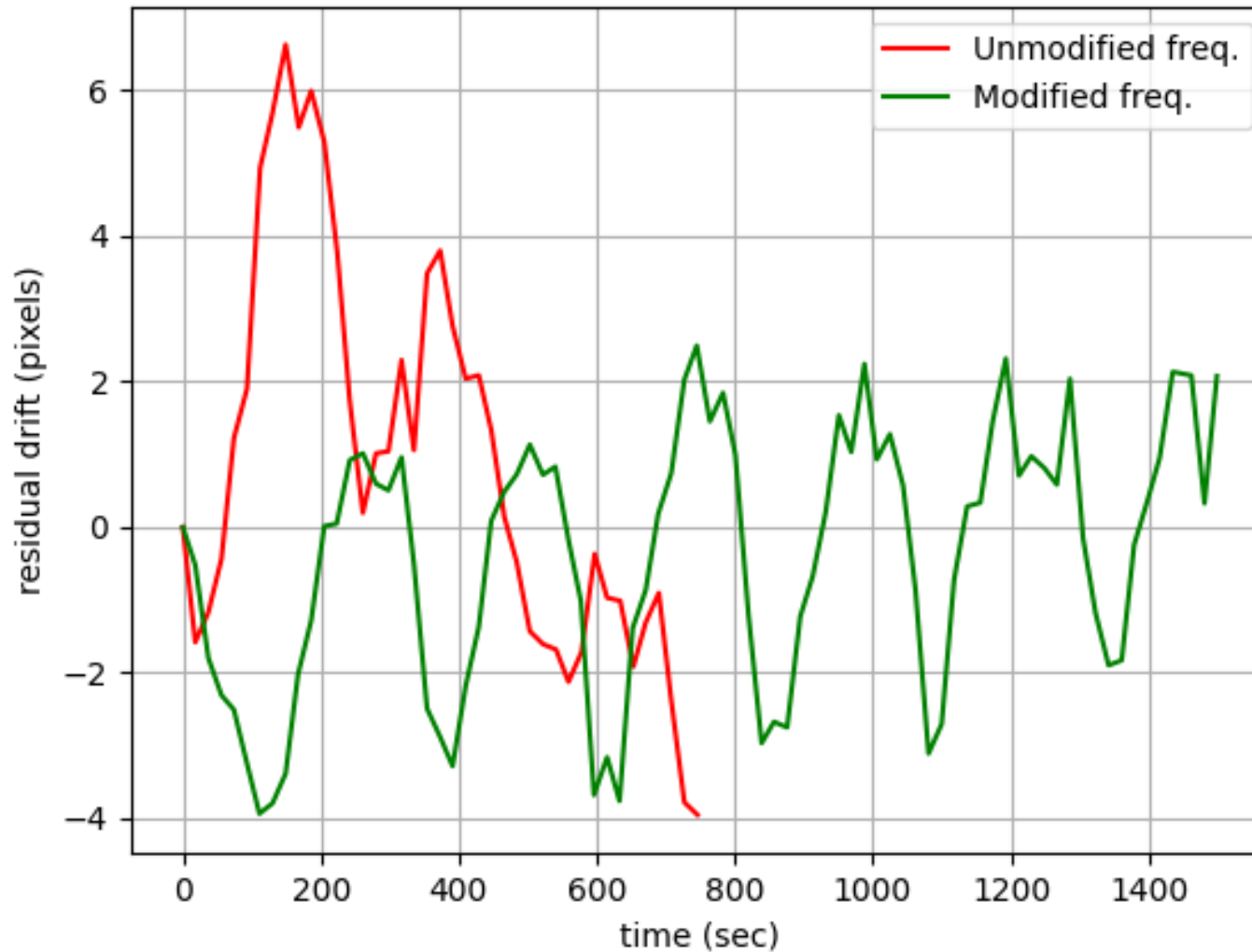
Tracking drift - HA comparison



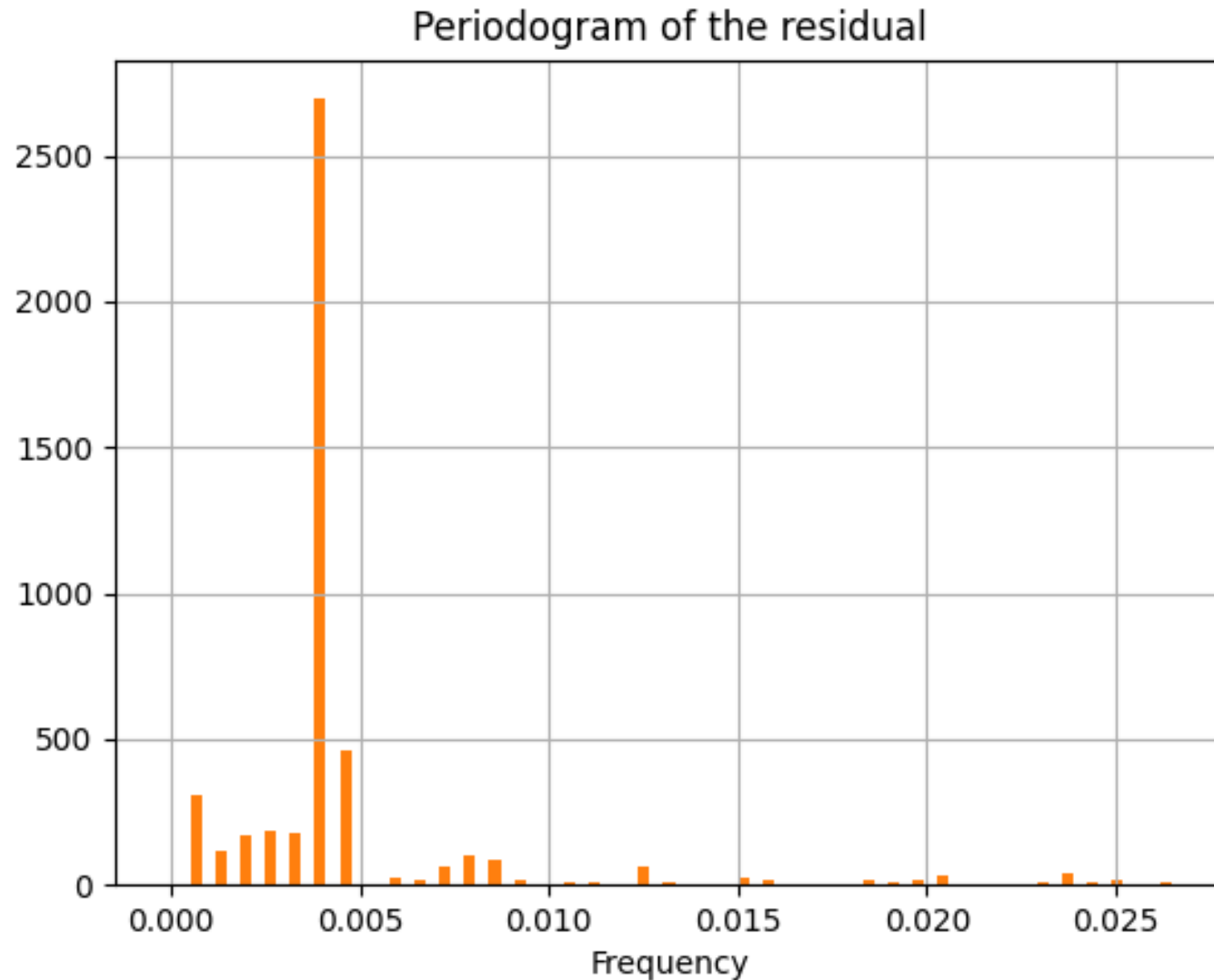
Tracking error reduction factor: 13.34

Tracking drift - Periodic component

Residual drift after removing the linear component



Tracking drift - Periodic component



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

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

Pannello controllo OPC - v. 2.0

Cupola Homer Configura

Directories

Science folder /home/lfini/OPC/software/_work_
Calib. data file /home/lfini/opc-data/calib/2024-02-20_114806-sci_calib.json
Use aux camera? No Yes
Aux camera folder click to select a directory
Calib. data file click to select a file

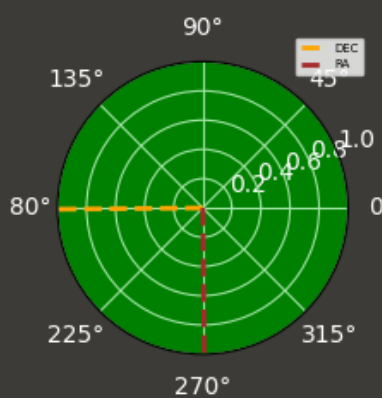
Parameters

Aux camera ntiles 32
Sid. tracking freq. 59.2

Calibration

Calib. mode:	Local
Sci.calib. image	Stop
Aux.calib. image	Stop

STOP



Calibration process started
Calibrating via astap: /home/lfini/opc-data/2024-01-11_prova-linux/2023-11-28_22-10-00_T-14.99°C_120.00s_0003R.fits
Command: /home/lfini/OPC/software/astap/astap_cli -d /home/lfini/OPC/software/astap/db -o /home/lfini/OPC/software/astap/l_solved -f /home/lfini/opc-data/2024-01-11_prova-linux/2023-11-28_22-10-00_T-14.99°C_120.00s_0003R.fits
Parsing astap output file: /home/lfini/OPC/software/astap/l_solved.ini
Solving process terminated in 0.323 sec
Trasf matrix: [[0.0035684651763424257, -0.3844150057919733], [0.3841889839887373, 0.0037128535479046903]]
Orientation: 89.45722848427418 degrees
Pix scale: 0.3843192158789791 arcsec/pix
RAS, DEC: 16.200575184781542, 2.1815168540949044 degrees
IMAGEW: 3056, IMAGEH: 3056
Calibration file saved to: /home/lfini/opc-data/calib/2024-02-20_114806-sci_calib.json
Homer Autoguiding starting
Connecting to telescope simulator
Guiding error: Telescope not responding
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[sci] Calib.matrix: [[0.003568, -0.384415], [0.384189, 0.003713]]
[sci] Image scale: 0.3843
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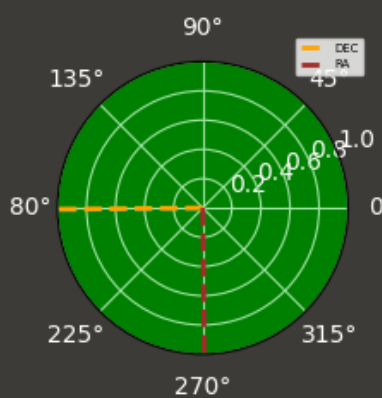
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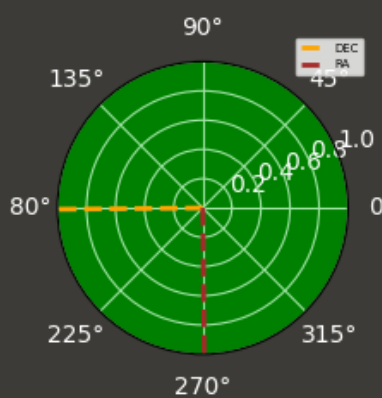
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Folder for science images

Calibration data

Homer in action

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Calibration section

Folder for science images

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Homer in action

The screenshot displays the 'Pannello controllo OPC - v. 2.0' interface. It is divided into several sections:

- Directories:** Includes fields for 'Science folder' (pointed to by 'Folder for science images'), 'Calib. data file' (pointed to by 'Calibration data'), 'Use aux camera?' (set to No), 'Aux camera folder', and another 'Calib. data file'.
- Parameters:** Includes 'Aux camera ntiles' (32) and 'Sid. tracking freq.' (59.2).
- Calibration:** Includes a table for 'Calib. mode' (Local), 'Sci.calib. image' (Stop), and 'Aux.calib. image' (Stop). A 'STOP' button is located below this section.
- Calibration section:** A circular diagram with radial lines and concentric circles, labeled with angles (90°, 135°, 80°, 225°, 270°, 315°, 0') and values (0.2, 0.4, 0.6, 0.8, 1.0). It is pointed to by 'Calibration section'.
- Log output:** A text window at the bottom (pointed to by 'Log output') showing the calibration process details, including the command used, parsing of the output file, solving process, and the resulting calibration matrix and image parameters.

Folder for science images

Calibration data

Calibration section

Log output

Homer: how it works

- 1 Calibration:
 - Uses either a local plate solving program¹ or *Astrometry.net* network based API to compute the transformation 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

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

Homer log data as diagnostic tool

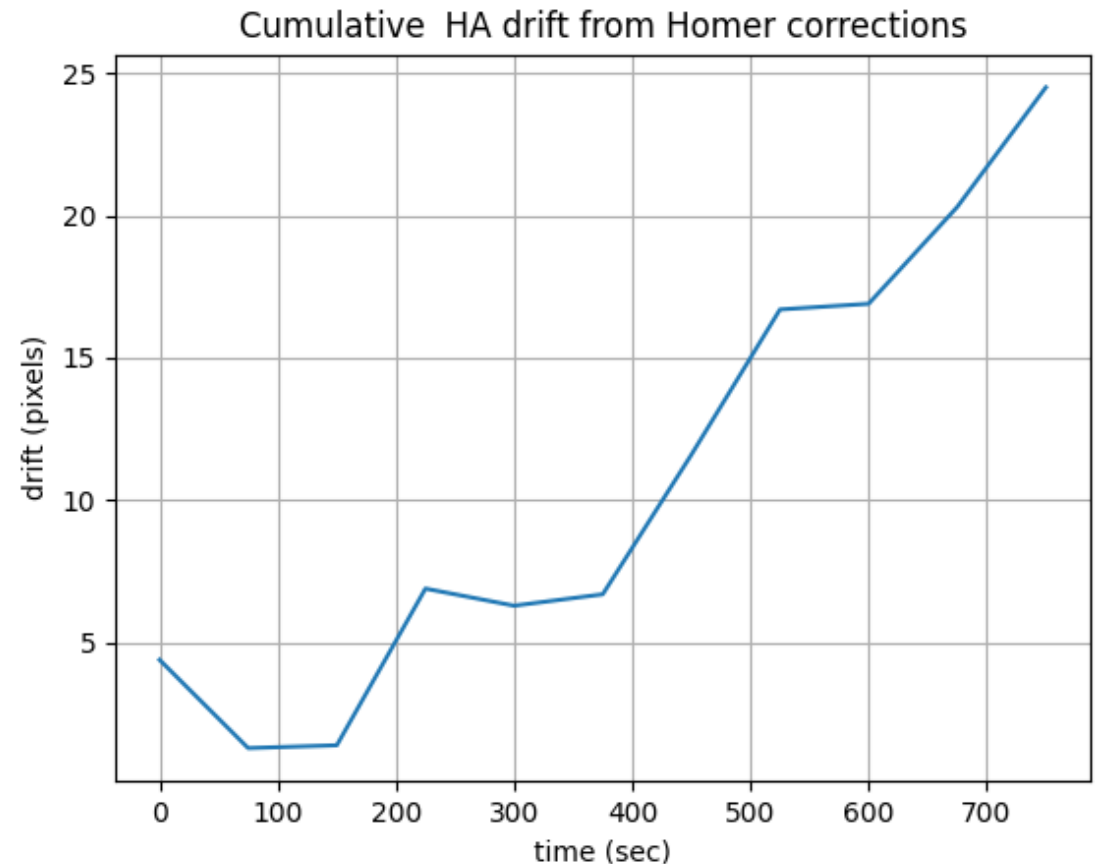
Dataset 3:

- 12 images from M77
- Field center: RA = $2^h42^m47^s$, DEC = $0^\circ0'57''$
- 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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■ **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