LEIBNIZ-INSTITUT FÜR ASTROPHYSIK POTSDAM

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GREGOR: AO Manual

Document No. **GRE-KIS-MAN-0019**

Version: **1**

Date: **17.5.2022**

Signatures & Approval

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Change Log				
Vers.	Date	Author	Description of Changes	Sect./Para.
1	19.5.22	L. Kleint	copied and adapted Thomas' manual-en.tex	

Contents

1 Scope

This document explains the AO at GREGOR.

2 Changes from February 2021

- in order to lock on the pinhole pattern, a new camera setting with longer integration time can be used (see Sect. 6.3)
- if the AO GUI cannot connect to the AO server within 30 sec, the AO server process is killed and the GUI terminates. A waiting period of 3 min is required before starting the AO GUI again (which then starts the server).

3 General

- the diffraction limit can only be reached for seeing better than 1" (r_0=10 cm), the Adaptive Optics (AO) needs good conditions, too! Stable operation is possible for seeing better than 2" seeing (r_0 = 5 cm), also depending on the target.
- Observing without AO at GREGOR is useless! Only with the AO the optics aberrations are corrected, without AO your data will have issues!
- it is strictly forbidden to touch any optics (including motorized stages) between (and including) M12 and the WFS !!
- Problems? Please write a ticket or contact Thomas Berkefeld (phone ++49-761-3198166) email: berke@leibniz-kis.de. Problems can almost always be solved, but only if they are reported.

4 Switching on the Hardware

Only the high voltage (HV) amplifier for the deformable mirror (DM) and the tip-tilt mirror (TT) needs to switched on/off every day (see Fig. 1). Please make sure that the HV amplifier is switched on BEFORE starting the AO software.
The other components must stay powered on continuously. If switched off or in case of a power failure, call berke.

- 2x HV power supply: max output voltage +/- 240V
- wavefront sensor (WFS) camera
- COSM-bus (at the left of the AO-rack), power cycle requires reinitialization (homing) of the WFS-motors.
- GAOS control computer (at the bottom of the AO-rack).

Fig. 1: *GREGOR AO control cabinet. The arrow points to the switch that the assistant shall operate.*

5 Starting the Software

The GREGOR-AO software is started by double-clicking the *AO-GUI* icon on the desktop of the flight stations. If the AO server is already running, the GUI comes up immediately, otherwise it takes about 20 seconds.

6 Use of the GREGOR-AO software

The main menu is on the upper left, the upper center displays status data and the upper right shows an image of the wavefront sensor (WFS) camera (164 subapertures) (Fig. 2).
The two circles on the lower right resemble the tiptilt mirror and the deformable mirror (DM, 256 actuators). The stroke of the actuators is colour-coded like the visual spectrum (red = maximum negative stroke, white = zero stroke, blue = maximum positive stroke)
As default, the WFS camera shows a field of 12.8” of solar structure in each subaperture. If this is not the case, most likely a field stop needs to be moved into the F3 focus (with the GREGOR GUI). The maximum intensity should be kept between 80-90%, using the radio buttons in the main menu (below *ND filter wheel*, 10 possible settings). The present calibration and reference positions that are used during the calibration and reference measurement can be shown using the button below *Show Positions*. Subapertures used for correction are marked green, unused subapertures are marked red, the reference subaperture is marked yellow.
Operations that take longer than two seconds display a green writing in the submenu or the motor window. The GUI is not blocked, but the user should wait until the end of the operation and the green writing disappears.

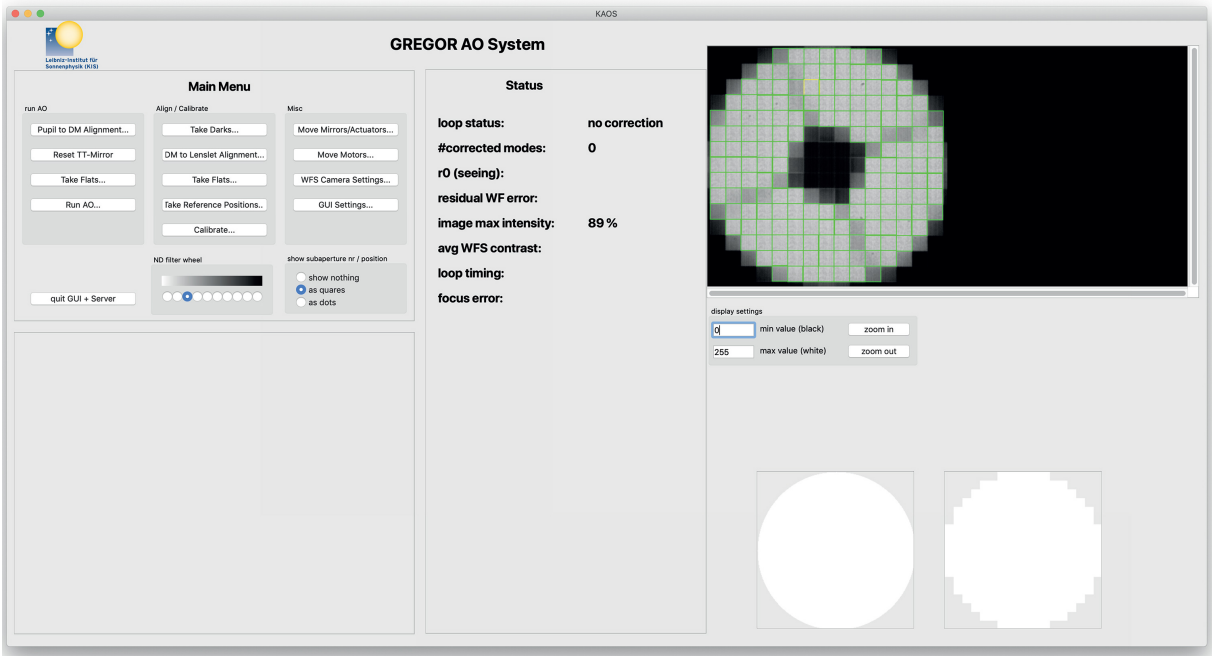


Fig. 2: *GREGOR-AO GUI showing flat mirrors and a 12.8" field of the sun on the WFS-camera*

6.1 AO observation

For doing a normal AO-assisted observation, the steps listed below *Run AO* need to be executed. The green squares must be completely within the illuminated subaperture areas, otherwise a flatfield and a reference measurement must be made (via *take Flats...* and *Take Reference Positions...*, but call Thomas before doing this).

6.1.1 *Pupil to DM alignment...*

Pupil to DM alignment... activates the measurement of the subaperture intensities. M11 gets tilted until the pupil is illuminated symmetrically (symmetric subaperture illumination), i.e. the beam is centered on the DM. Since the flatfield has not been taken yet, the pupil alignment might show a very slight error in illumination which is ok. Image 3 shows a shifted pupil, in Fig. 2 the pupil is aligned. In low light conditions the pupil alingment procedure is not active. When moving the F3 focus wheel, the pupil to DM alignment get misaligned for a short time, but the pupil is centered on the DM again within 30 sec after the F3 wheel movement has ended).
back to main menu activates the main menu again and moves the field stop into the WFS again.

6.1.2 *Reset TT Mirror*

Reset TT Mirror ramps the tip-tilt mirror in order to set it to a defined position. The accuracy / reproducibility is better than one arcsecond on sky.

6.1.3 *Take Flats...*

Take Flats... activates the submenu for the measurement of flatfields. Now the flatfield motion of the telescope has to be switched on manually. Pressing *take flats* starts the actual flatfield measurement (takes about one minute). When finished, stop the telescope flatfield motion in

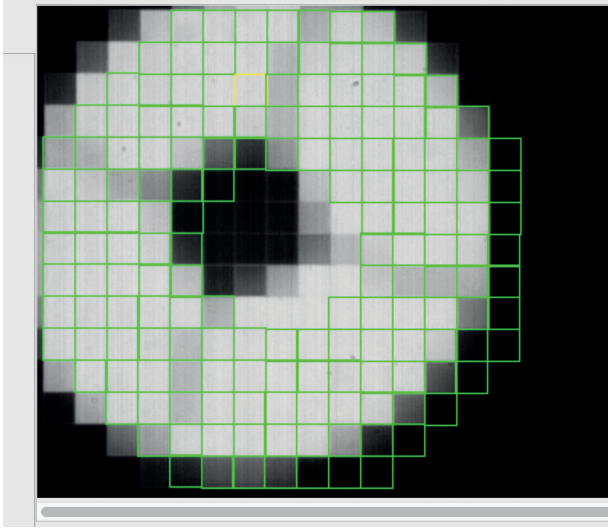


Fig. 3: *shifted pupil*

the GREGOR GUI. *back to main menu* activates the main menu again. Flatfields should be taken as often as possible, especially after derotator changes.

6.1.4 *run AO...*

run AO finally activates the submenu for the closed loop AO correction (see Fig. 4). The realtime AO control loop starts processing but without starting any actual correction. Modal offsets are now applied to the DM. To the right of the WFS image the correlation functions are now displayed. In order to see the current status quickly, the most important parameters such as number of corrected modes, r0 etc are shown in the status table to the right of the main menu. In two tables situated below the status table, the properties of each suberture and each mode / degree of freedom are displayed, respectively. The upper table (subaperture data) shows for each subaperture the residual current shift-x/y, residual time-averaged shift-x/y, subaperture counts and contrast. The lower table (mode data) shows for each mode the mode name, current residual wavefront error (*reserr*), time-averaged total wavefront error (including DM shape, *totalerr*), the (time)-RMS residual wavefront error (without static errors), the (time)-RMS total wavefront error (without static errors) and the current modal gains. The ratio between the (time)-RMS residual wavefront error and the (time)-RMS total wavefront error resembles the factor by which the AO corrects the dynamic errors of the respective mode. Wavefront errors are in units of radian RMS at 500 nm (80 nm RMS).
The following prerequisites must be met for AO working conditions:

- pupil centered on the DM
- DM aligned to lenslet. This should be checked once a week by the assistant, see section 6.2
- valid / recent flatfield. Flatfields should be taken as often as possible
- decent seeing, whatever this means (also depends on the solar target). The average subaperture contrast as displayed in the status table should be above 2.5%. All correlation functions should have a distinctive peak and a round shape. Examples of good and bad correlation functions are shown in the appendix.

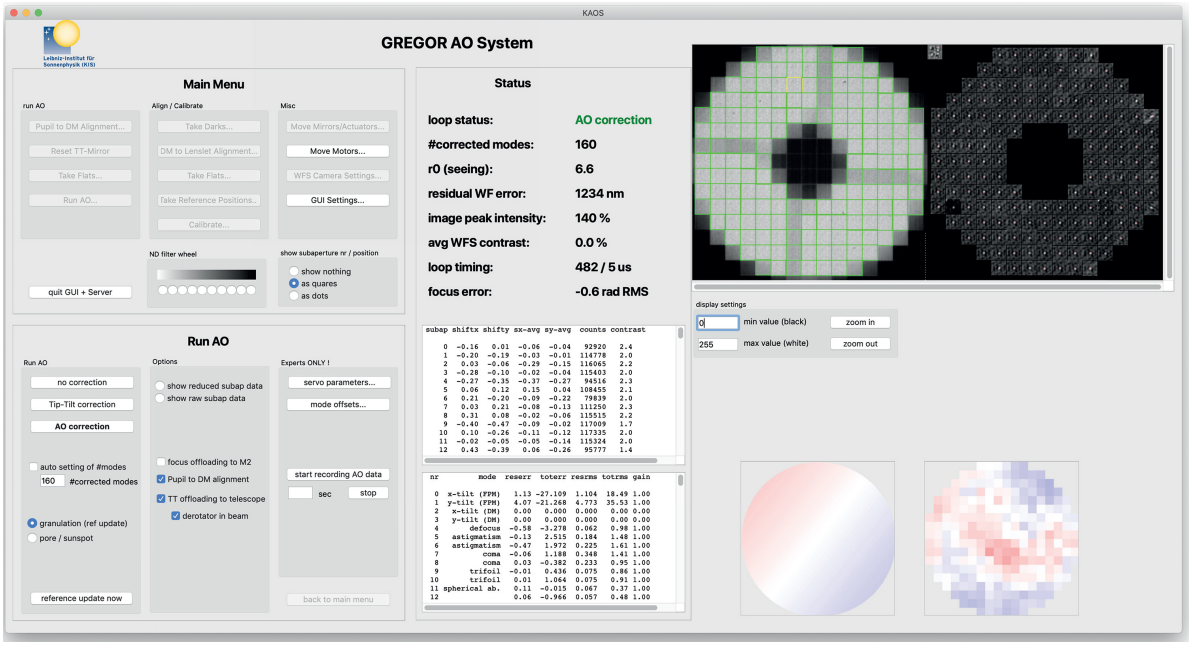


Fig. 4: *KAOS-screen with activated Run AO - submenu*

- the telescope must be roughly in focus, according to the M2 focus table on the wall of the observing room. An appropriate focus can also be set automatically in the telescope GUI. The current focus error as seen by the AO is shown in the status table.
- the maximum intensity level should be set to about 90%, as shown in the status table.

The most important buttons in the *run AO...* subemenu are those in the left column (labeled *Run AO*) for switching on/off the correction, updating the reference and setting the number of corrected modes.

- *no correction*: switch off the correction
- *TipTilt correction*: switch to tiptilt correction (correlation tracker mode)
- *AO correction*: switch on the AO correction (blurring compensation)
- *update reference now*: takes a new reference image, must be done after every repointing of the telescope before starting the TT or AO correction. If the correction is already on, an update of the reference image is enforced.
- *auto setting of modes*, (default: enabled): if disabled, the *#corrected nmodes* is used, if enabled, the AO sets the number of corrected modes depending on the seeing conditions and the target (pore / granulation buttons below).
- *pore / sunspot or granulation* (default: granulation): when observing a pore or sunspot, due to the better contrast, more modes can be corrected for the same seeing conditions. When observing granulation, the reference image is updated at least once per minute to account for changes of the solar surface structure. When observing a pore / sunspot the reference image is not updated.

The center column of the *run AO...* submenu provides the following options:

- *show original data / show reduced data*: *show reduced data* helps to show artefacts that require a new flatfield.
- *focus offloading to M2* (default: disabled): if enabled the average focus error which the DM has to correct is offloaded to M2. This only works for stable operation of the AO locked on a solar target, i.e. reasonable seeing. Do NOT use when locked on an F2 or F3 target / pinhole etc. Do NOT keep it on all the time to avoid constantly sending small motions to the hexapod. If |focus error| > 3, then enable the offloading for ~ 60 s, which will reduce it to below ± 1.
- *pupil to DM alignment* (default: enabled): uses the subaperture intensity distribution to keep the beam centered on the DM (same as the corresponding button in the main menu). Since a proper illumination of the DM and the WFS camera is very important, the pupil to DM alignment should always be on.
- *TT offloading to telescope* (default: disabled): offloads the average tip-tilt error of the TT mirror to the telescope by moving it slowly. Since the direction depends on the derotator, *derotator in beam* (default: disabled) has to be checked when the derotator is in the beam.

For locking on non solar structures (=internal targets like F2 or F3 air force target, grids, pinholes etc),

- set the target to *pore / sunspot*
- disable *focus offlading to M2* and *TT offlaoding to telescope*

The special options on the right column of the AO submenu are for specialists only.

- *servo parameters...* opens a window to control the servo parameters, display modal power spectra / time series etc. NOT to be used by the average user !!
- *mode offsets...* opens a window to control the modal offsets (see Fig. 5) up to spherical aberration.

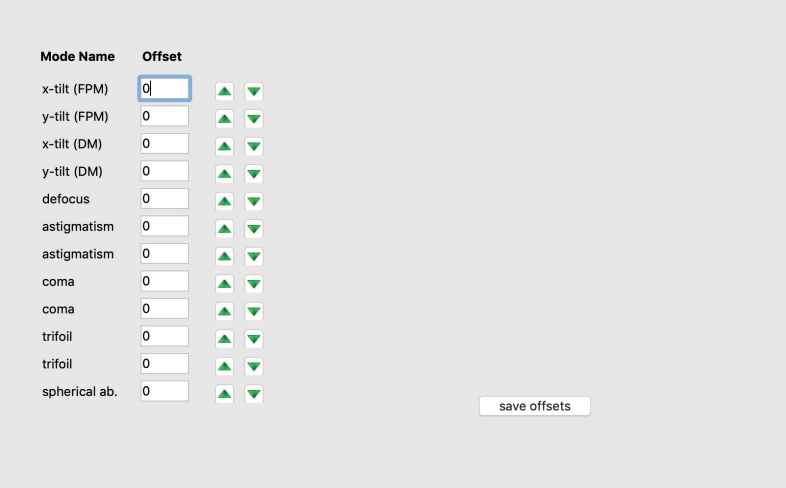


Fig. 5: *window to control modal offsets*

The mode numbering is the same as in the mode table display. Units are radian RMS at 500nm (80nm RMS) wavefront. The offset can be entered directly for the respective mode,

alternatively, the arrows increase or decrease the offset in steps of 0.1 radian. *save offsets* stores them on disk. They will be applied automatically whenever the AO is in *run AO* mode.

- *start recording AO data* records AO internal data at full AO loop frequency. NOT to be used by the average user !! Furthermore, the current actuator voltages can be stored (*save actuator values*, press only for saving the flat DM actuator voltages when locking the AO on the CT target or the CT pinhole).

back to main menu finally stops the AO control loop, sets the modal offsets to zero and closes the *run AO...* submenu.

6.2 *DM to Lenslet Alignment...*

activates the submenu to check the alignment between lenslet and DM. The small F3 pinhole is moved into the beam. Then 4x4 actuators are ramped continuously (see Fig. 7), and the response of four subapertures are recorded, out of which the alignment parameters (Lenslet shifted x/y wrt to DM, lenslet rotated wrt to DM and lenslet scaled wrt DM) are calculated. During normal AO calibration only the xy shift values are important, the rotation / scaling alignment has been done during the mechanical WFS installation.

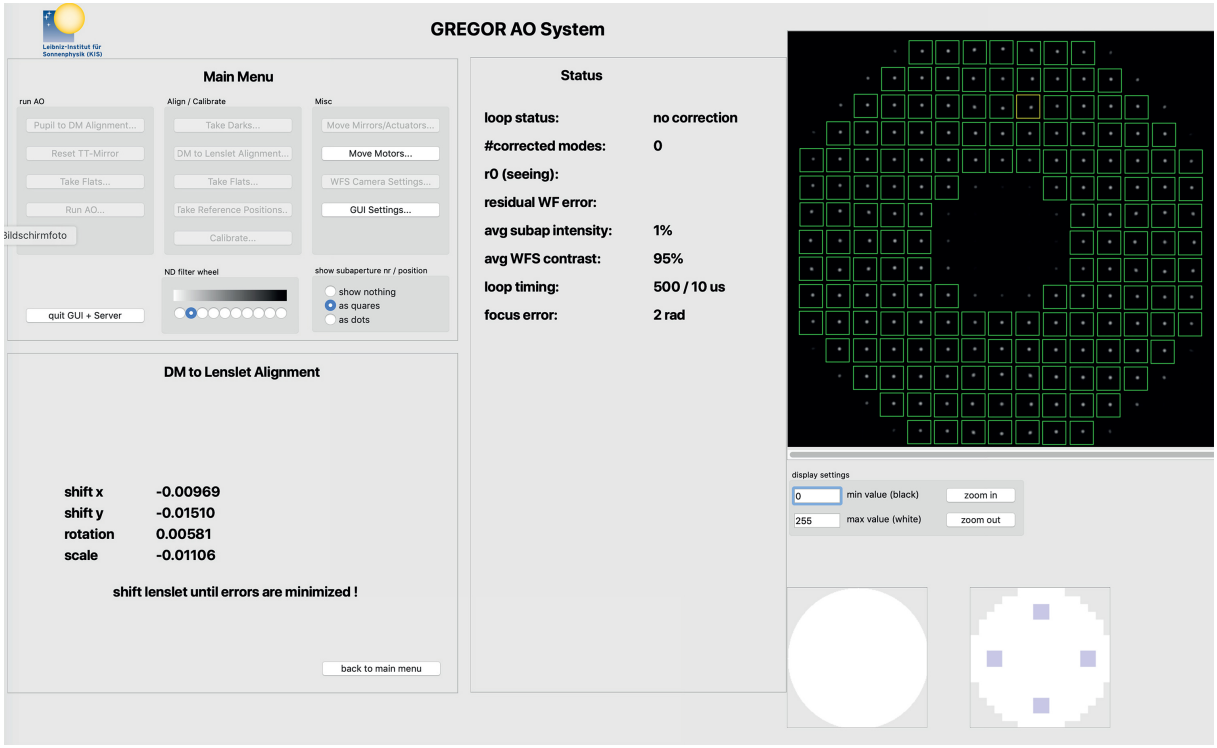


Fig. 6: *poking 4x4 actuators,*

On average, the absolute of the xy shifts should be below 0.01 for each axis. If one of the axes shows an average value of larger than +-0.04, then contact Thomas Berkefeld.
This check should be done once per week and after each exchange of the 900 / 650 beam splitters.
back to main menu stops the actuator movement and returns to the main menu.

6.3 *Camera Settings*

This submenu allows to change the setting of the WFS camera. Do not change the exposure time, frame rate or gain individually, but change the predefined settings. The first setting is used for normal / solar operation, the second is intended for low light operation, e.g. when locking on the pinhole pattern. Changing the camera setting also changes the corresponding servo parameters of the AO control loop.

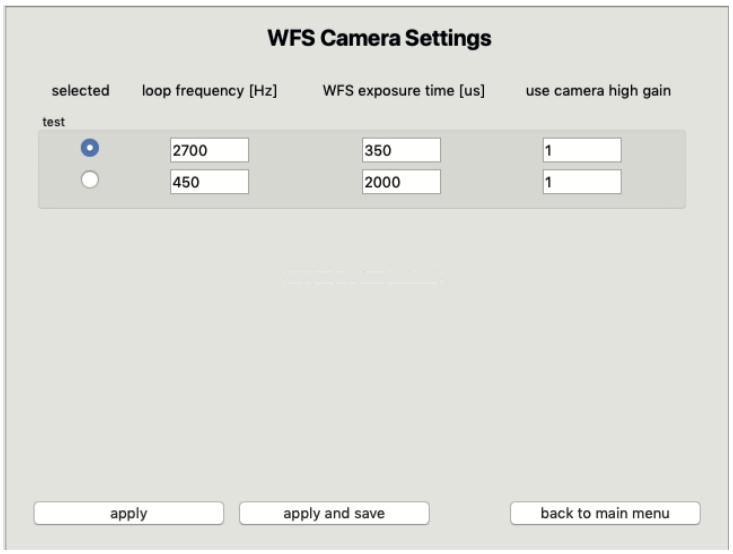
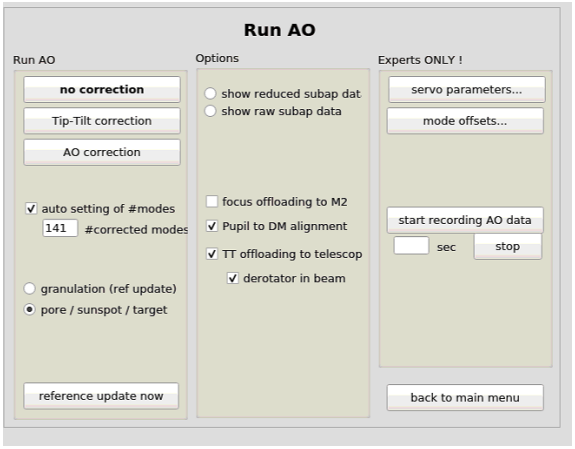


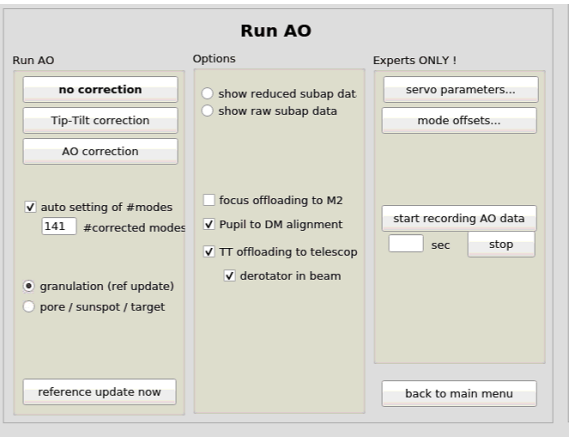
Fig. 7: *camera settings for normal operation (first setting) and low light operation (second setting)*

6.4 Correct settings of checkboxes

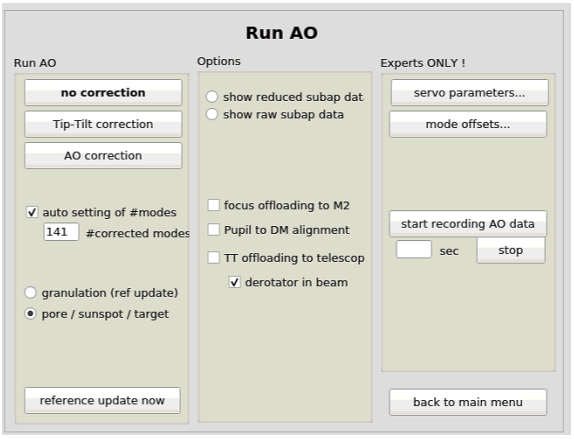
Figure 8 shows different settings of checkboxes and explains when a given setting should be used. The pupil to DM alignment should always be on, except for small pinhole and pinhole array.



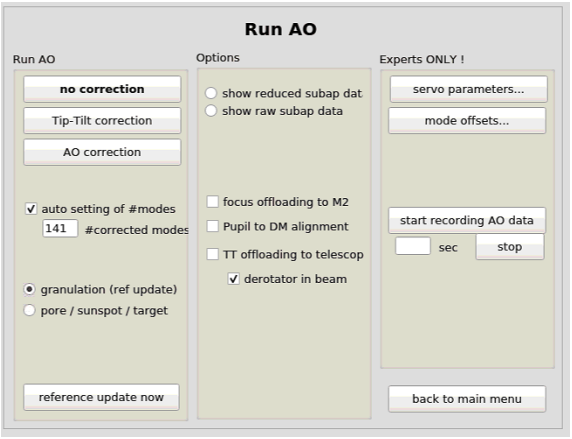
(a) *Standard observation of a sunspot or a pore with the derotator in the beam.*



(b) *Standard observation of granulation with the derotator in the beam.*



(c) *Target calibrations. TT offloading needs to be unchecked! Pupil to DM alignment can be checked (better) or unchecked (ok, if calibrations are done fast, meaning minutes).*



(d) *This setting does not make sense and should not be used.*

Fig. 8: *Examples of different settings of AO checkboxes*

6.5 Examples of GUI displays

This section shows a few examples of what to look for or what can go wrong.

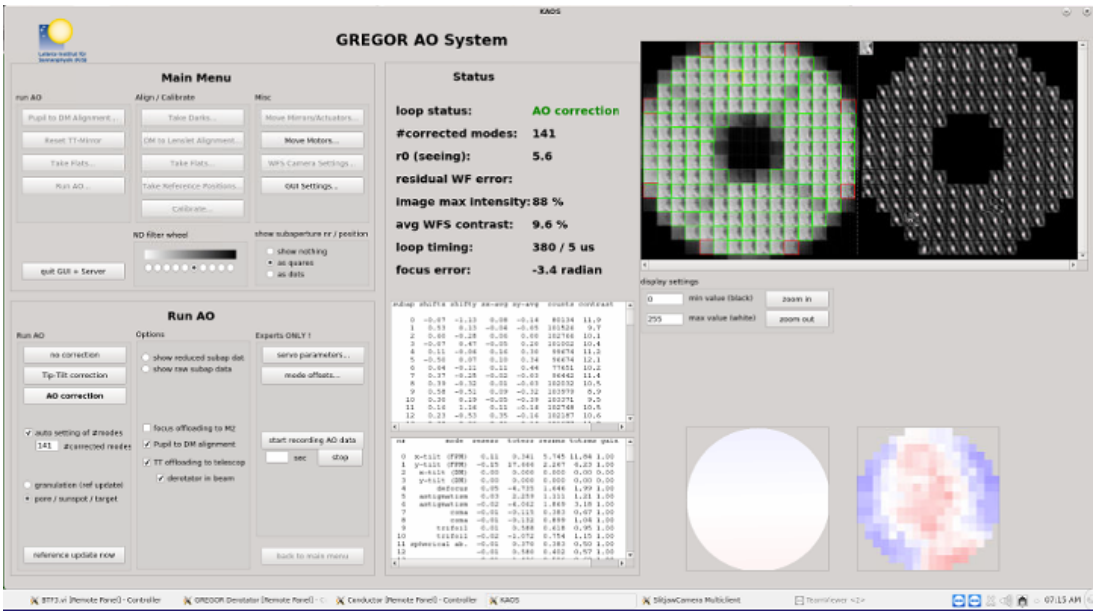


Fig. 9: *Example of a bad AO state: The sunspot is just at the edge of the field of view, making the correlation functions elongated (=bad). Also, the focus error is high (-3.4 rad), which is also visible as the blue ring in the bottom right DM display. Here, one should center the sunspot better plus switch on focus offloading to M2.*

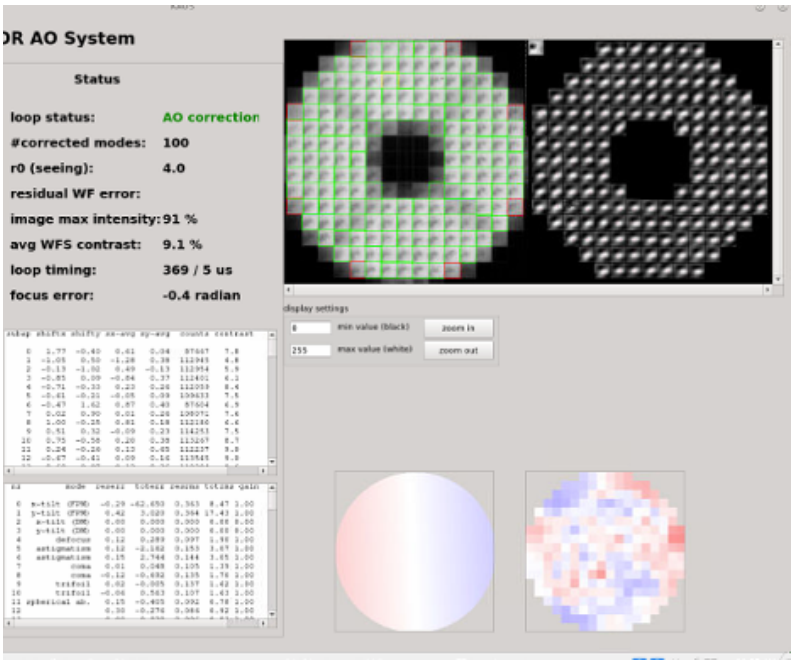


Fig. 10: *Example of a normal AO observation, however during bad seeing. The number of corrected modes was automatically lowered to 100. The focus looks fine, which is also visible because the DM on the bottom right shows colors without any large-scale structure.*

7 Errors

7.1 Network Problems

The following errors might be due to network problems:

- sun find center script (conductor) does not connect to AO ⇒ restart AO software should most likely fix the problem.
- run AO: tip-tilt offloading does not work. If it offloads to the wrong direction, it is not a network problem but the derotator checkbox is set wrong.
- M11 (pupil guiding) does not work: The pupil guiding needs a minimum of light, so using the small pinhole will not work. Likewise, too much much light does not work either.

If it still does not work, ask Olivier Grassin (phone -331)

7.2 AO does not lock

If the AO does not lock on solar surface structures, then try to lock on the air force target first. If it locks on the target but not on the solar surface structure,

- the focus might be wrong. Check if M3 is set to the right focus wrt the derotator being in/out, then check whether M2 is at the approx correct focus.
- the correlation functions are bad (see images 11, 12 and 13 in the appendix for good, fair and bad correlation functions. Bad correlation functions typically come from bad seeing or a flatfield that is too old. Anyway, try to take a new flatfield.

If the AO does not lock on the air force target

- is the HV electronics switched on?
- is the light level correct?

If it still does not work, check the pupil to DM alignment (section 6.2).
If nothing helps, contact Thomas Berkefeld or write a ticket.

8 Appendix

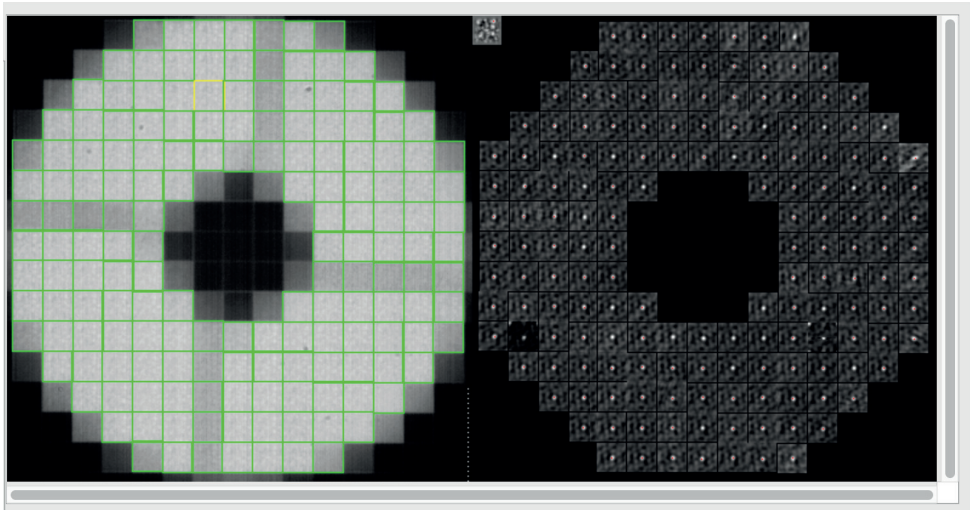


Fig. 11: *good correlation functions*

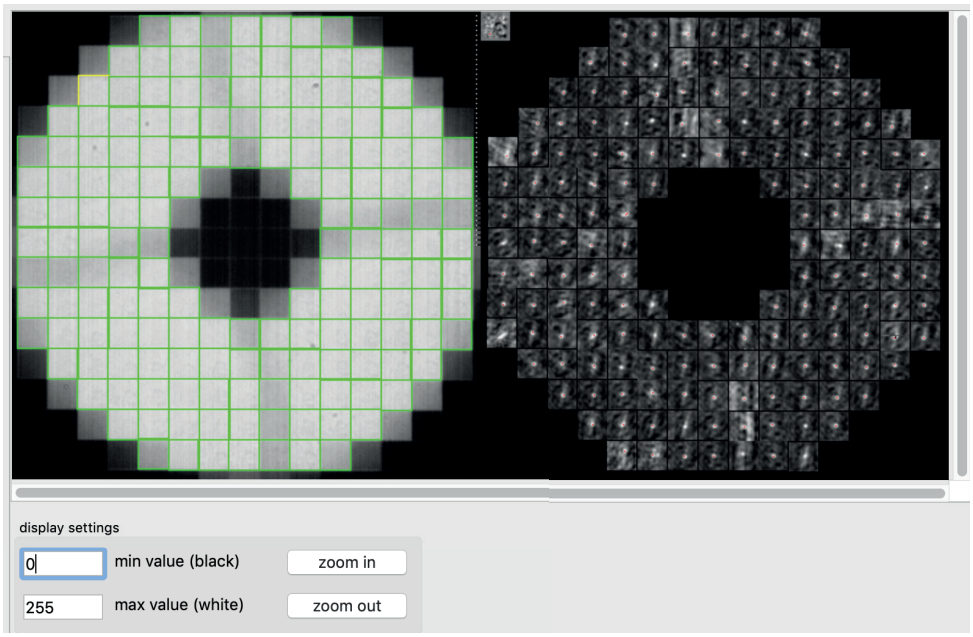


Fig. 12: *fair correlation functions. Also, the spider is visible on the right, meaning that the flatfield may be too old.*

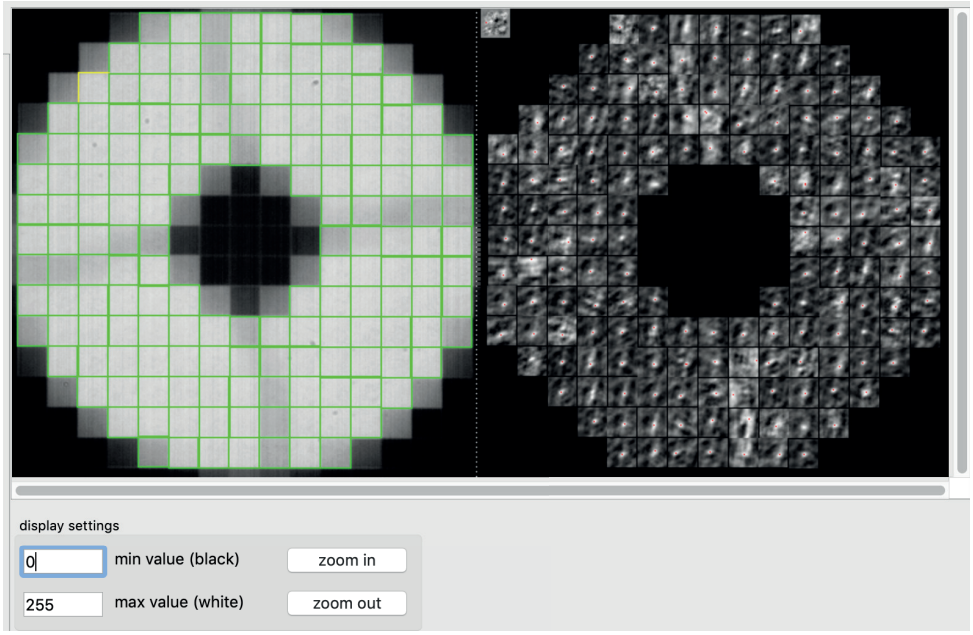


Fig. 13: *bad correlation functions*