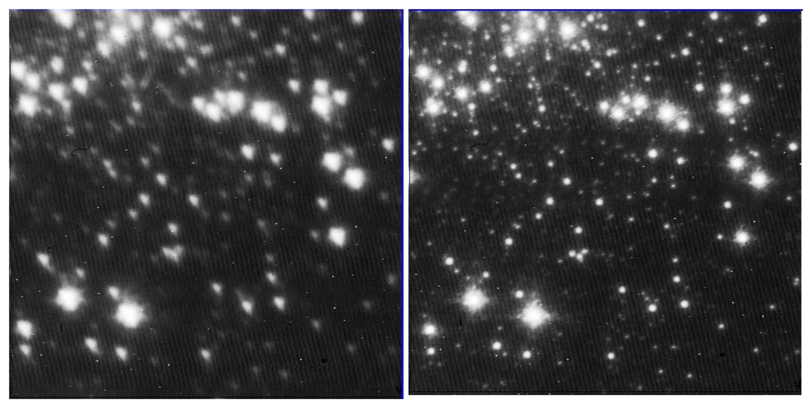

On-sky performance of the tip-tilt correction system for GLAS using an EMCCD camera

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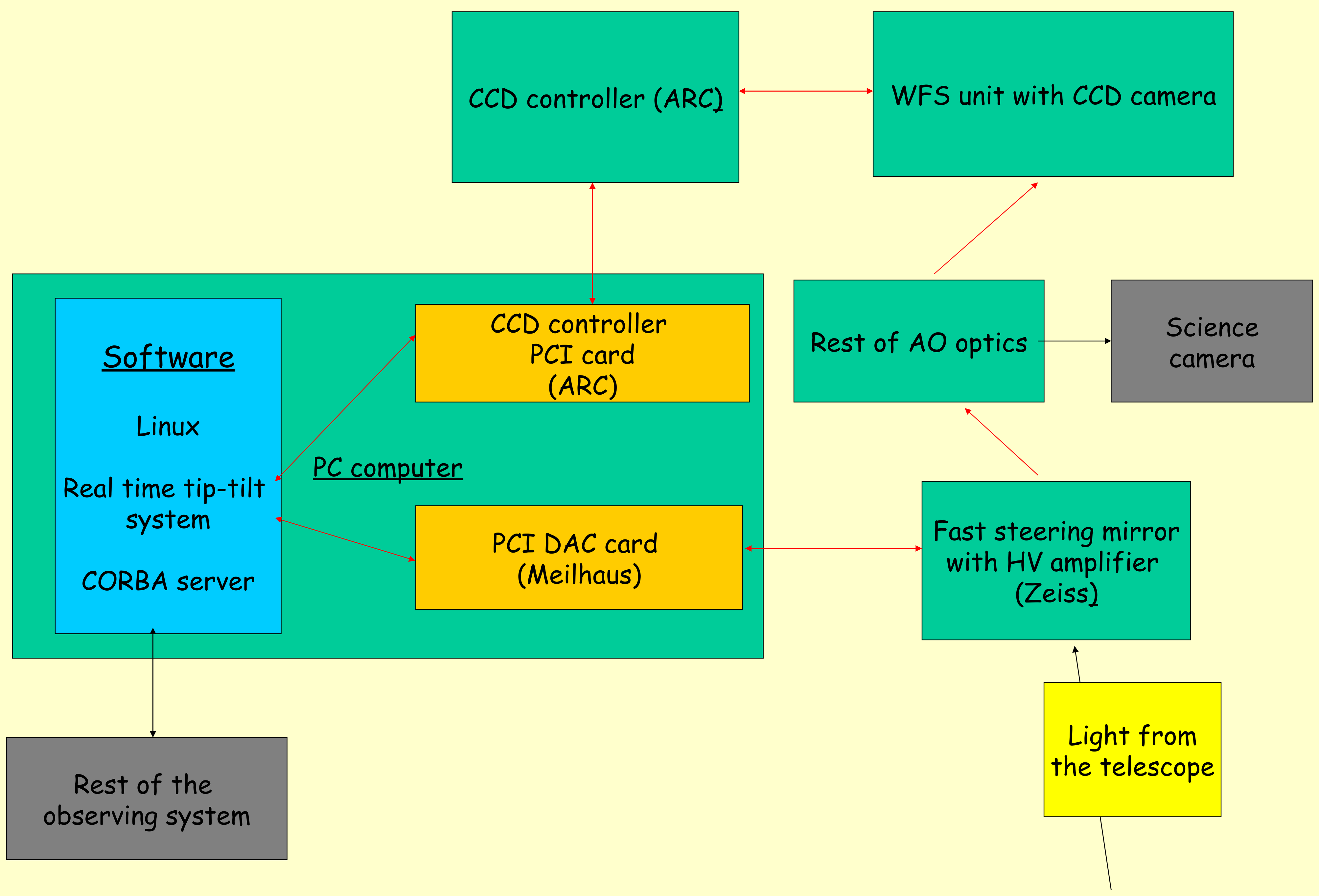
Adaptive optics systems based on laser guide stars still need a natural guide star (NGS) to correct for the image motion caused by the atmosphere and by imperfect telescope tracking. The ability to properly compensate for this motion using a faint NGS is critical to achieve large sky coverage. For the laser guide system (GLAS) on the 4.2 m William Herschel Telescope we designed and tested in the laboratory and on-sky a tip-tilt correction system based on a PC running Linux and an EMCCD technology camera. The control software allows selection of different centroiding algorithms and loop control methods as well as the control parameters. Parameter analysis has been performed using tip-tilt only correction before the laser commissioning and the selected sets of parameters were then used during commissioning of the laser guide star system. We have established the SNR of the guide star as a function of magnitude, depending on the image sampling frequency and on the dichroic used in the optical system; achieving a measurable improvement using full AO correction with NGSes down to magnitude range R=16.5 to R=18. A minimum SNR of about 10 was established to be necessary for a useful correction. The system was used to produce 0.16 arcsecond images in H band using bright NGS and laser correction during GLAS commissioning runs.

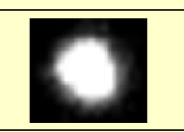
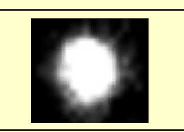
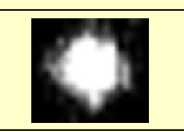
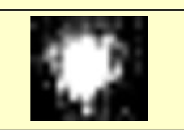
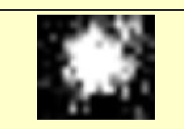
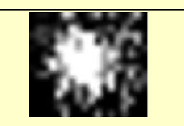
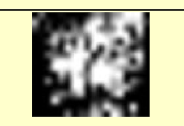
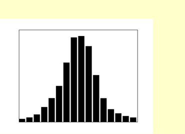
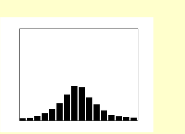
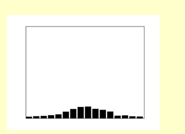
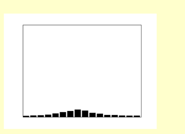
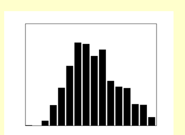
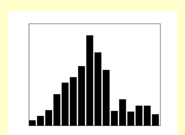
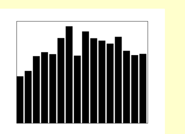
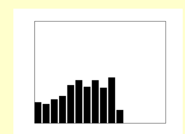
System diagram



System properties

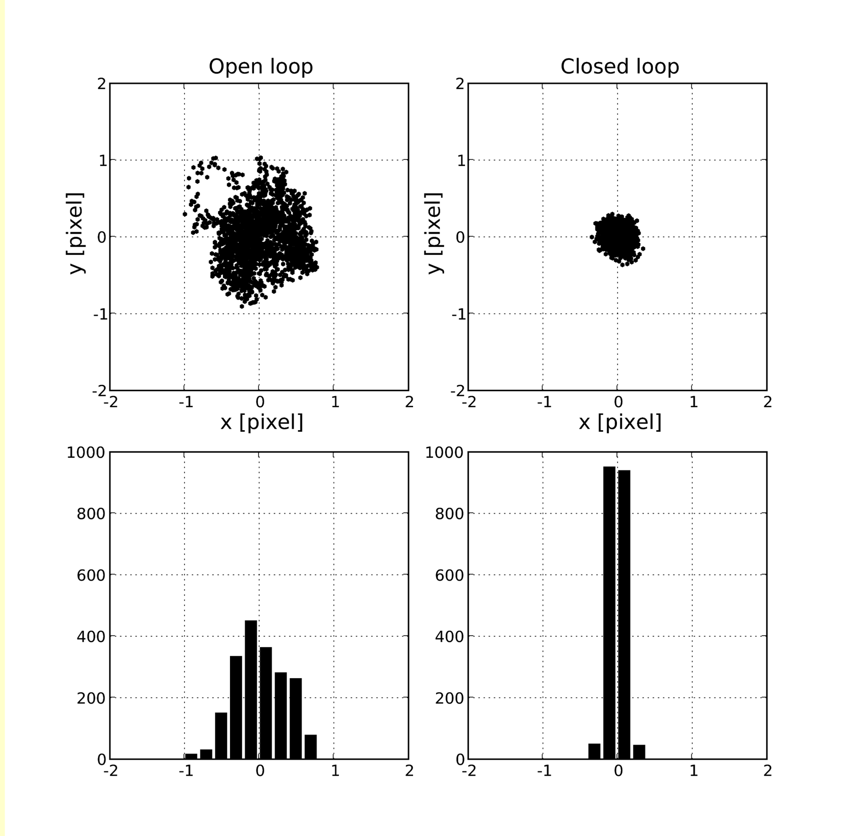
- Framing rates up tp 328 Hz.
- Readout modes 8x10, 16x18, 32x34, 88x80 pixels
- Centroiding: thresholded weighted
- Background determination: separate background lines in the images, IIR filtering
- Control loop: PID, optional Kalman filtering of centroids
- Offload to the telescope control system autoguider to prevent FSM saturation

Performance of the EMCCD WFS camera

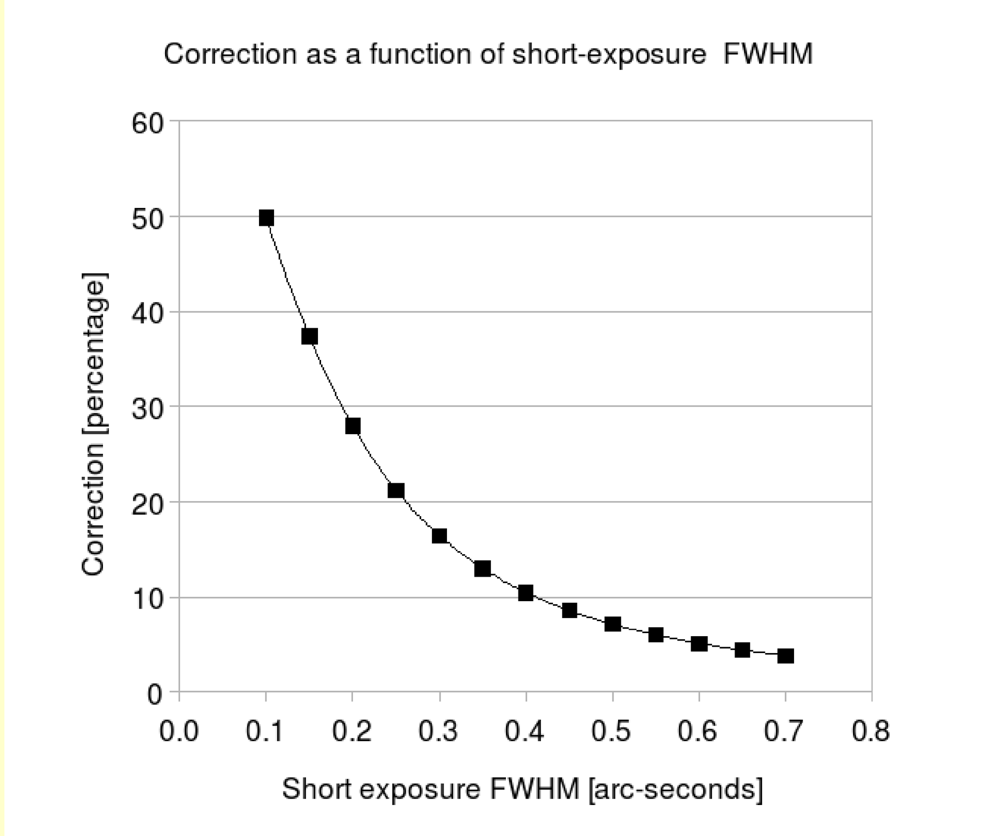
Mag	11.0	12.1	13.3	14.1	15.0	15.5	16.2	16.9
SNR	123	77	27	19	11	10	5	3
Image								
Profile								

NG stars of different magnitudes. Each star is shown with the V magnitude, the SNR, an example image and a star profile, projected onto the x axis. The scale of the profile is linear. The scale of the profile graph is smaller by a factor of 40 for last four fainter guide stars. The exposure time was 10 ms. Stars after V=13.3 were partially clouded.

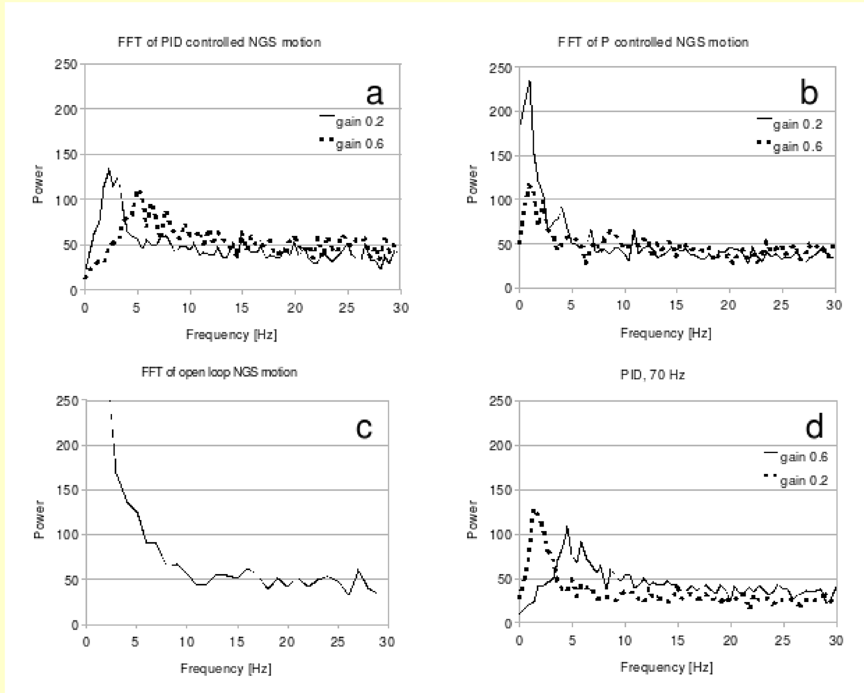
On sky correction



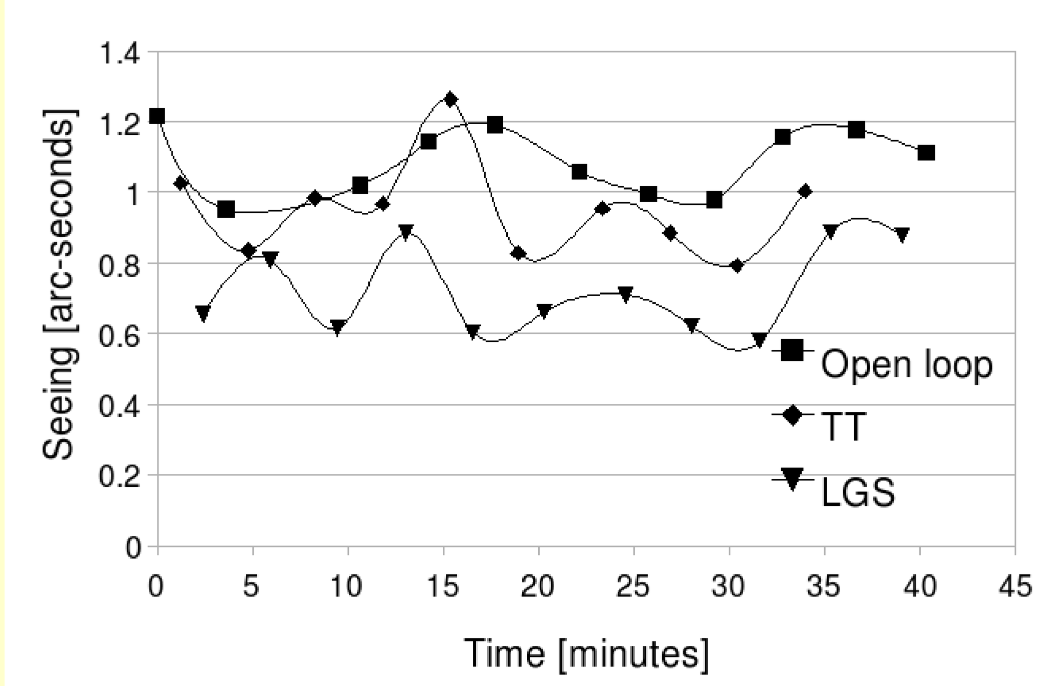
Coordinates of the guide star under open and closed loop conditions for a magnitude 9 guide star at 200 Hz framing rate. In the closed loop a proportional control loop method with the gain set to 0.6 was used. The FWHM of the open loop distribution was 0.21 arcsecs and 0.06 arcsecs for closed loop. The sequence of spots was recorded during 10 seconds of real time.



Calculated amount of correction in percentage of the long-exposure FWHM as a function of short-exposure FWHM, assuming that without correction the FWHM of the NGS centroid position distribution is 0.21 arcsecs and the tip-tilt corrected centroid position distribution has a FWHM of 0.06 arcsecs.



Frequency spectrum of the NGS movement in one dimension under different conditions. a) PID control, loop frequency 100 Hz, I=0.6, D=0.6; b) Proportional control, loop frequency 100 Hz; c) Open loop; d) PID, loop frequency 70 Hz. The proportional control does not suppress low frequency motion as well as PID, however, it seems to be less prone to overshoot, which adds some high frequency content to the spectrum. Even low-gain PID has a very good suppression of low frequencies. To keep all graphs within the same scale, the open loop curve had to be clipped. The missing points have values 698 and 291.



Time sequence of measured PSFs during the observing run in H band using a NGS with SNR=89 and framing rate 100 Hz. Different control loop gains are used in the closed loop situations. Except for high gains using a proportional algorithm there is a correction by up to a factor of 2 even at the rather bad seeing of 1.0 – 1.2 arcsecs. Tip-tilt only correction varies from none to slight, which is expected given the conditions. Note that the lines connecting the markers are just to guide the eye.

Under good seeing conditions the best correction of LGS + NGS was to 0.16 arcsecs from 0.4 arcsecs – see the images on the top of the poster.
Even using 18 mag NGS and a framing rate of 20 Hz a correction from 0.6 to 0.4 arcsecs was observed.

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