PALM Low Order Wavefront Sensor

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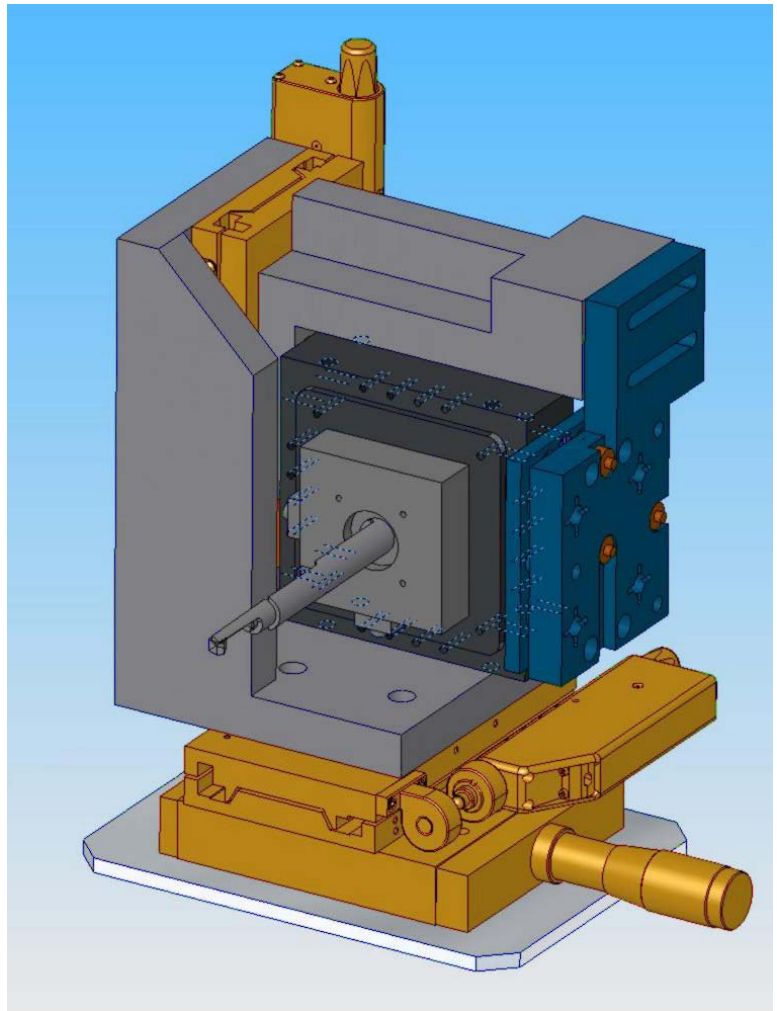
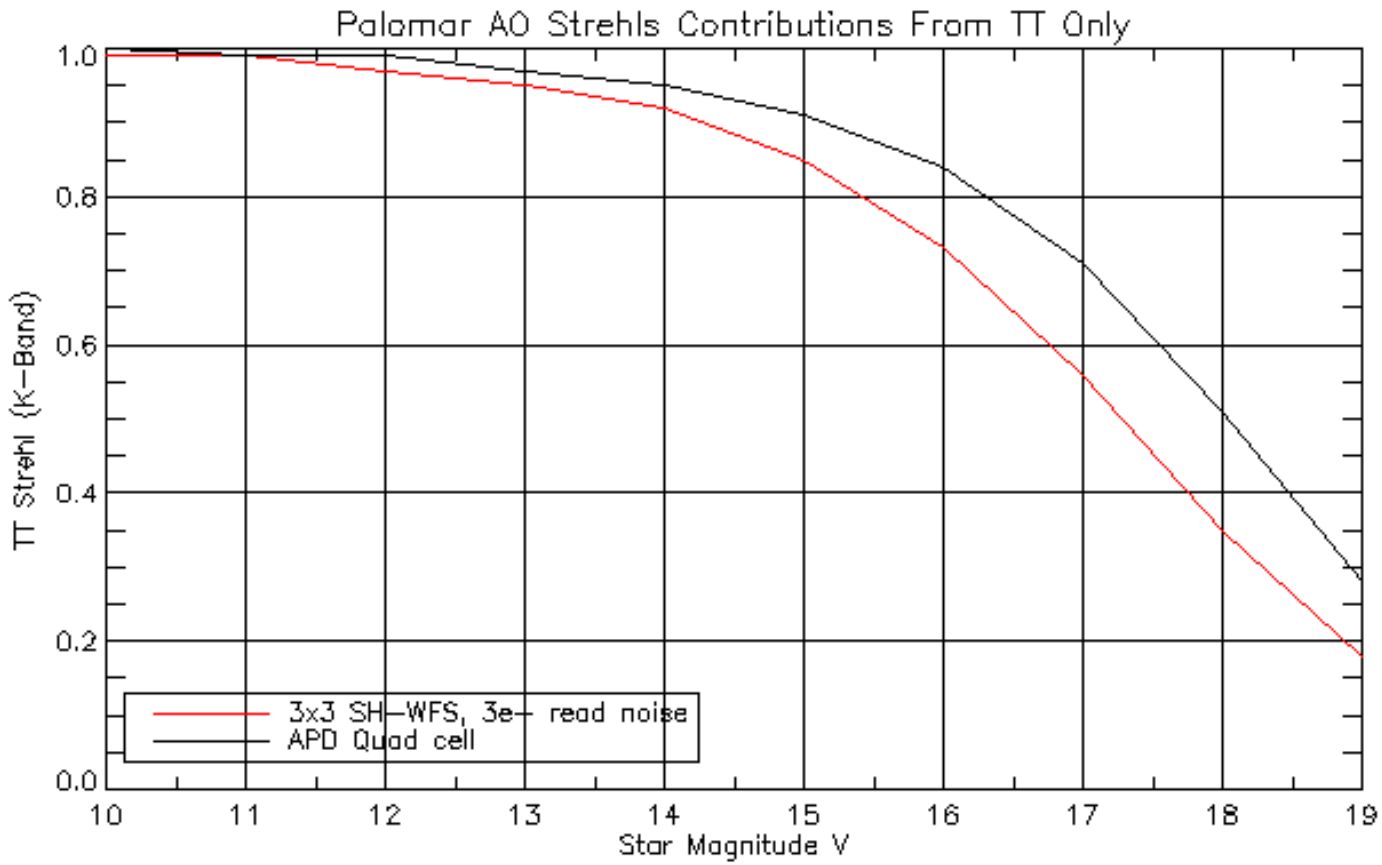
November 17, 2006

PALM LGS Low Order WFS (LOWFS)

- SciMeasure camera with E2V CCD-39
- S-H WFS, 3x3 subaps
- Each subap 6x6 pixels, binned on-chip to 2x2
- Currently used on NGS to measure and feedback to the AO system tip/tilt and focus
- Motorized stages give access to a 2 arcmin field
- Originally designed to fit into a space constrained by the Palomar Tomograph (MGSU)



Predicted Performance



- 3x3 S-H WFS was chosen instead of APD so that tip/tilt, focus and astigmatism could all be measured with one sensor
- There is 0.75 magnitude loss in sensitivity for 3x3 S-H compared to the APD

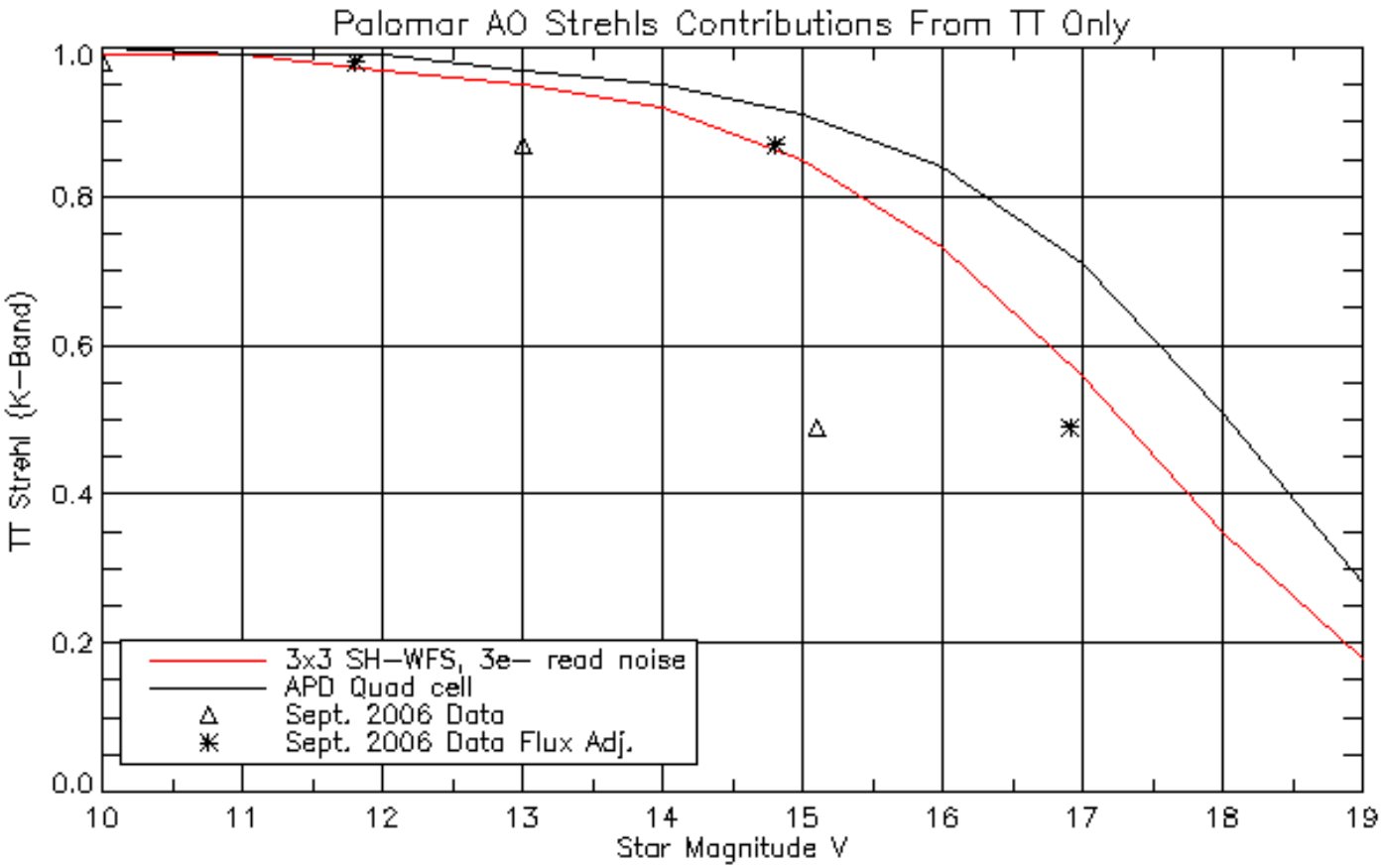
LOWFS Flux

- While taking data to characterize the sensitivity of the LOWFS, we noticed that the measured flux levels were lower than we expected for a given star magnitude.
- By comparing the flux levels in the LOWFS to both the predicted values and the values in the HOWFS for a given star magnitude, we found that the LOWFS is missing 73.5% of the expected flux.
- If we take this flux loss into account, the predicted flux values from the error budget agree very well with the measured values from several stars

V Mag	10.09	12.22	13	16.11	12.98
Frame Rate	500	200	50	50	200
Avg Subap Flux (DN/subap)	2320	1446	217	64	459
Predicted Subap Flux from Original Error Budget	8781	5508	822	238	1727
Predicted Subap Flux from Error Budget Modified for Flux Loss	2327	1461	218	63	458

Measured and Predicted Subaperture Flux for 5 different stars

LOWFS Performance



- Data represent observed tip/tilt degradation on 3 stars from Sept 06
- The value of the measured strehl contributions due to tip/tilt are also in excellent agreement once the loss is taken into account

Possible Causes of Flux Loss - Electronic

- Binning/Readout
  - Compare un-binned data to binned data
- Camera Gain and Read Noise
  - Photon transfer curves
  - Data was taken by adjusting the light output of the white light stimulus from 0 to 100% in 1% increments.
- Digitization
  - Bit histograms to verify all bits get turned on
- Camera Control Electronics
  - Test camera with alternate electronics

Photon Transfer Curves

- Photon transfer curves are a way to characterize the noise properties of a CCD using the statistical properties of photon noise
  - Specifically, where

    M = mean counts V = variance

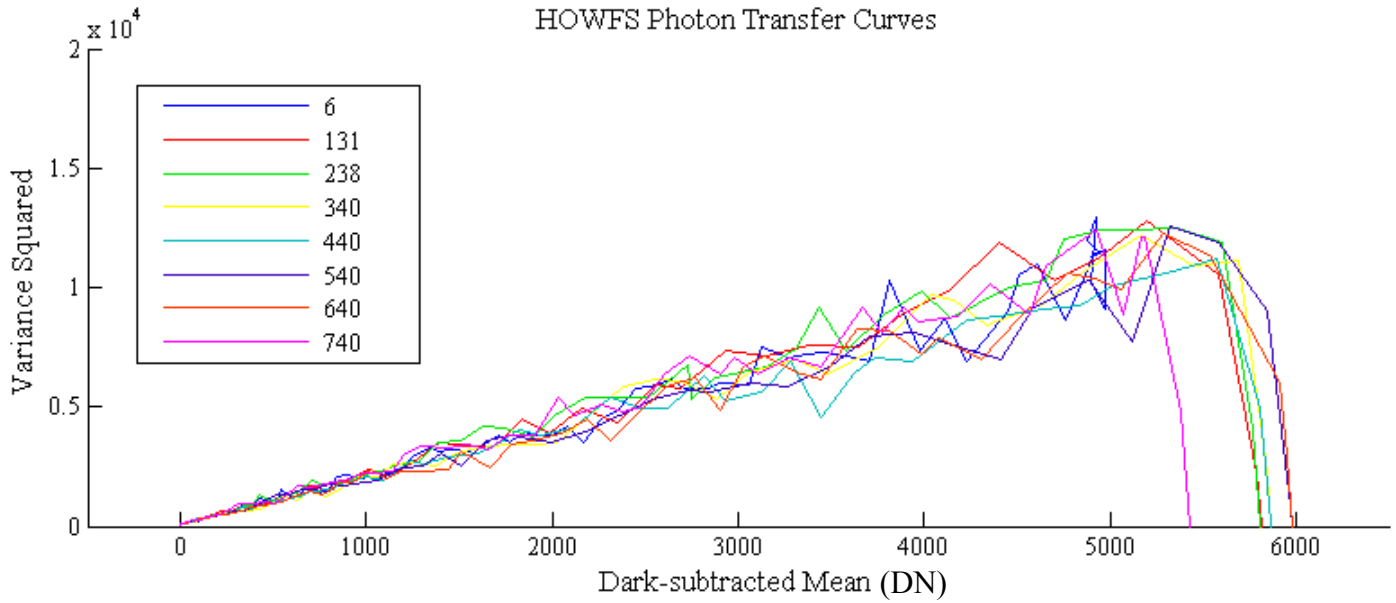
    G = CCD gain X = input signal

    $M = G*X$

    And $V = \sigma^2 = G^2*X$ (for photon/shot noise)

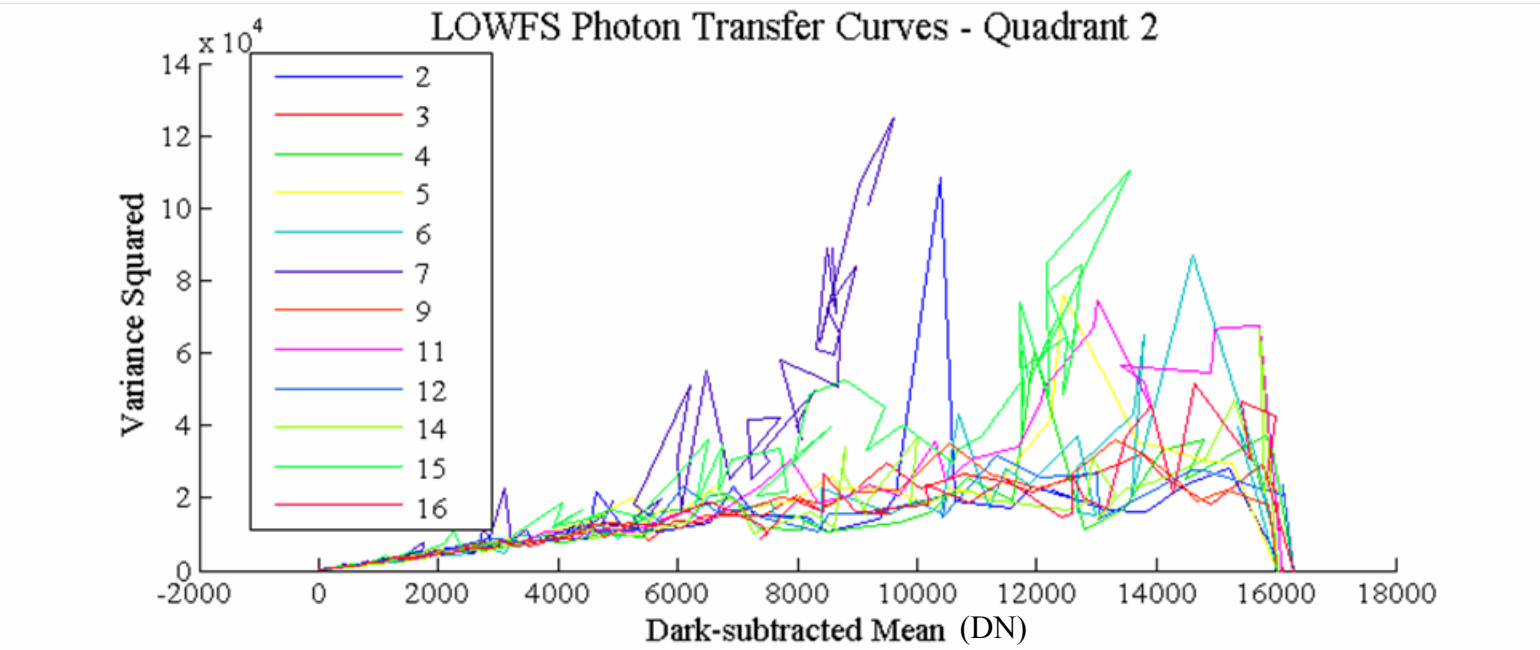
    So, $V = G*M$
- To get these statistics, we used the mean and standard deviation for each pixel over about 100 frames for each light level
- The high order WFS (HOWFS) was also tested for comparison

HOWFS Photon Transfer Curves



- A few curves for individual HOWFS pixels. All HOWFS curves appear to be very similar
- Fitting a line to the mean values less than 4000:
  - Avg Slope = Camera Gain = 2.14 ± 0.14(DN/e-)
- This varies slightly from our expected value of 2.5 (DN/e-)
- The read noise can be estimated from the value of the curve at 0 counts: 4.2 ± 1.8 (e-)

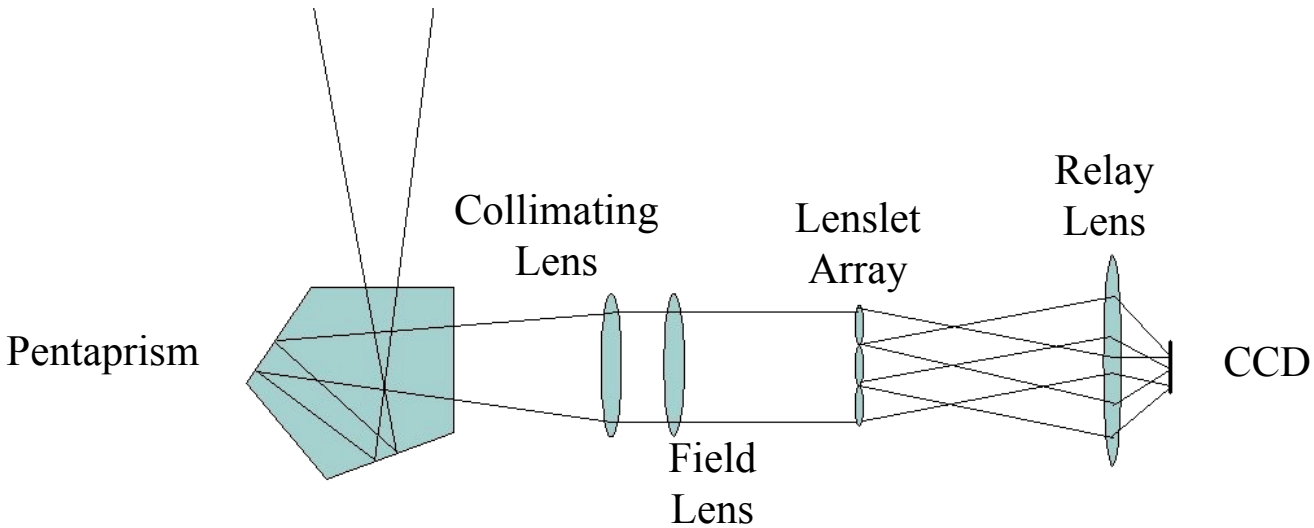
LOWFS Photon Transfer Curves



- These are the curves for all the fully illuminated pixels in the second quadrant.
- Fitting a line to the mean values less than 6000:
  - Avg Slope = Camera Gain = 2.15 ± 0.15(DN/e-)
- This varies slightly from our expected value of 2.5 (DN/e-)
- The read noise can be estimated from the value of the curve at 0 counts: 5.2 ± 2 (e-)

Possible Causes of Flux Loss - Optical

- Vignetting
  - Beam appears to be centered in optics, but more investigation is necessary
- Coatings
  - Manufacturer coating specifications suggest this is not the issue
- Dust
  - Optics appear to be clean



Schematic of LOWFS optics (not to scale)

Current Status

- LOWFS system currently works well, despite flux loss
- Tip/tilt and focus control have been used successfully in LGS observations
- 1.8 magnitude loss limits our NGS tip/tilt stars to ~16th magnitude
- We will continue investigating causes for flux loss

Future LOWFS Plans

- PALM LGS
  - Find and remedy cause of flux loss
  - Investigate anomalies in photon transfer curves
  - Modify optical path to the LOWFS in order to better access full 2 arcmin field

- PALM3000 upgrade
  - Prototyping visible pyramid sensor for low order correction (2007)
  - Develop NIR low order WFS