

Blind Offset Reconstruction with Palomar LGS-AO

A. Bouchez
v1.0; 9/25/09

Introduction

The low-order wavefront sensor (LOWFS) provides tip/tilt and focus control when using the Palomar LGS-AO system. The LOWFS is a 3x3 subaperture Shack-Hartmann sensor, which patrols the focal plane behind a 589nm-reflective dichroic on two motorized linear stages identified as `lowfs_x` (parallel to the AO bench surface) and `lowfs_y` (perpendicular to the bench surface). When the tip/tilt loop is closed on the LOWFS and for a given target-guidestar separation, the mechanical location of LOWFS defines the apparent position of the target in the science camera focal plane. Blind offsets can therefore be reconstructed by converting the LOWFS motor offsets to angular offsets on the sky. Note however that flexure of the AO bench and optics not in the common path to the LOWFS and science instrument will add a small additional offset which grows with time, at an approximate rate of 1-2 milliarcseconds per minute (see CIN #616). Also, large offsets (>10 arcseconds) may be affected by differing distortions in the LOWFS and science camera focal planes, not included in this model.

Calibration

On August 11, 2009 UT, we observed binary star WDS18428+5938 with the LGS-AO system to calibrate the LOWFS stage motion ($V_1=9.11$, $V_2=9.96$, $sep=11.818$ arcseconds, $PA=177.35^\circ$ at the time of observation). With the 589 nm reflective dichroic installed, the brighter component was centered on the HOWFS field stop and the tip/tilt and high order control loops were locked on the HOWFS. Each component was then acquired in turn with the LOWFS, adjusting the LOWFS stages until the measured centroid was near zero, and the stage position in microns recorded. This procedure was repeated at 3 different Cassegrain ring angles.

The difference between LOWFS stage positions at each Cassegrain ring angle was then fit with the following model which allows for misalignment between the LOWFS stage axes,

$$s[\Delta x \quad \Delta y] \begin{bmatrix} -\sin(c + \theta_x) & \cos(c + \theta_x) \\ \sin(c + \theta_y) & -\cos(c + \theta_y) \end{bmatrix} = [\Delta RA \quad \Delta Dec]$$

where s is the platescale in arcseconds per micron, Δx and Δy are the LOWFS stage position differences between stars, c is the Cassegrain ring angle, and θ_x and θ_y are the apparent angle from celestial north to the stage axes (positive clockwise). The best-fit model parameters are shown in Table 1. The resulting RMS error in fitting the binary separation vector is 0.0148 arcseconds. Note however that since only one binary was observed, any error in the assumed binary star parameters is not reflected in this result.

Table 1: Best-fit model parameters

Parameter	Value
s [arcsec μm^{-1}]	2.564×10^{-3}
θ_x [deg]	-56.79
θ_y [deg]	33.31

Data Extraction

LOWFS and star selector mirror (SSM) motor positions for a list of observing times (eg. SWIFT 'times.YYMMDD' files) can be retrieved using the following script on the computer 'harbor':

```
> ssh aouser@harbor.palomar.caltech.edu
    (password on post-it above monitor).
> cd swift
scp or sftp your 'times' file to this directory
> idl
IDL> SWIFT_TELEM, 'times.090806', 'telem.090806'
```

Verification

We plan to repeat the LOWFS calibration experiment using a different binary star during the October 9, 2009 UT LGS-AO observing night. We will also verify this LOWFS position model by observing a bright (V~11) tip/tilt star with PHARO, offsetting it to several positions around the field, and recentering the frames based on the extracted LOWFS motor positions.