FIVE YEARS OF STELLAR POSITION MEASUREMENTS WITH THE MKIII OPTICAL INTERFEROMETER

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Abstract. Using the north-south and east-south astrometric baselines of the MKIII optical interferometer on Mt. Wilson (each about 12 meters in length), we measured the positions of eleven FK5 stars with an accuracy of about 10 milliarcseconds (mas) in declination and 20 mas in right ascension.

1. Astrometry with the MKIII on Mt. Wilson

This instrument (Shao et al. 1988), jointly operated by the Center for Advanced Space Sensing of the Naval Research Laboratory and by the U.S. Naval Observatory since 1988, features two astrometric baselines 12 m in length and oriented north–south and east-south, of which one at a time can be used. High–precision siderostats, mounted on massive concrete piers located in air–conditioned huts, pick up star light and feed it into vacuum pipes leading to a temperature–controlled laboratory. Here, the geometrical delay d is compensated by evacuated delay lines and the two beams are combined at a beam splitter. The fringe pattern is scanned by modulating the delay with a triangle wave, using piezo-activated mirrors. At the same time, these mirrors are used in a closed loop to track the fringe motion, induced by turbulence in the atmosphere, in a wide–band channel. Three additional 25 to 40 nm narrow–band channels are centered at 500, 550 and 800 nm.

On a typical night, some 100 to 200 scans are obtained on a list of about 12 stars, which are distributed uniformly over part of the sky. The complex visibility is coherently averaged in 200 ms intervals for each scan. In order to correct for delay variations introduced by the refractive index fluctuations of the atmosphere, we calculate as an estimate of the true delay $d = d_{\rm red} - D(d_{\rm blue} - d_{\rm red})$ (with the dry-air dispersion $D = (n_{\rm red} - 1)/(n_{\rm blue} - n_{\rm red})$ and n=refractive index) using the delays (the product of the fringe phase and the filter wavelength) measured in the red and blue channels. Only delays of data points obtained while tracking the zeroth–order fringe are averaged over the length of the scan ($\sim$75 s). The fringe identification is accomplished by using the relative phase relationships of the data points in the four channels.

The fundamental equation relating the measured delays to the star positions $\mathbf{S}_i$, $d_i = \mathbf{B}\mathbf{S}_i + C$ with the baseline vector $\mathbf{B}$ and the delay constant C (the difference in length between the north (or east) arm and the south arm of the interferometer), is solved in two steps. First, the coordinates X, Y, and Z, of the baseline vector and C are fitted to the delay data, assuming that the time dependence of the first three is negligible (but see below). By injecting a white light beam into the system, which is reflected off by cornercubes attached to the rear of the siderostat mirrors, any time dependence of C can be accounted for by monitoring the position of the white

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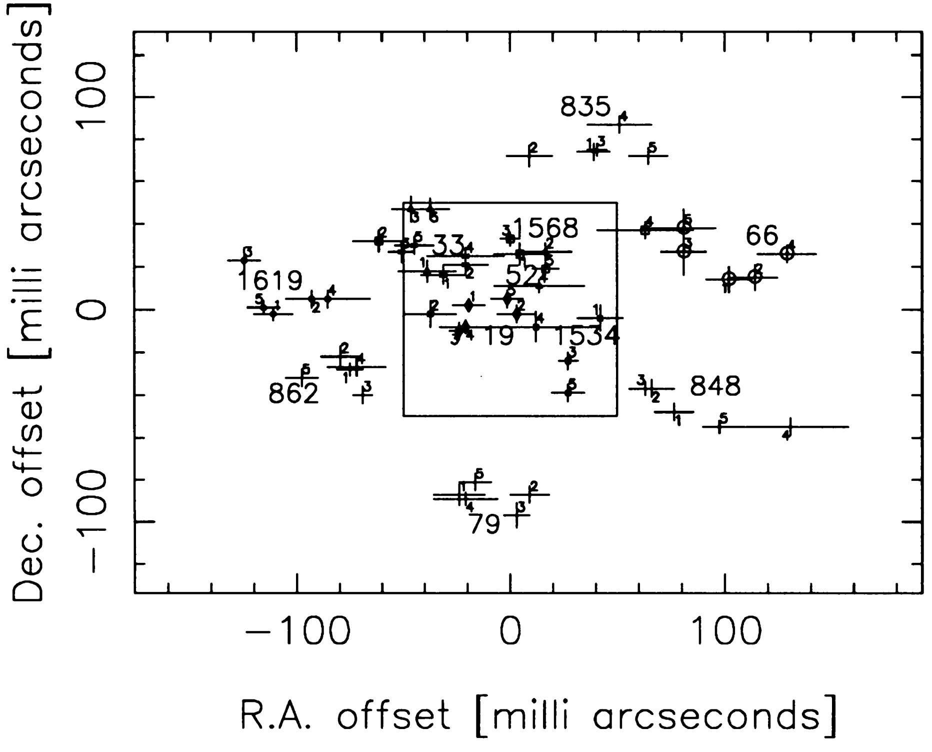
light fringe pattern. Second, residual delay variations are modelled with offsets of the star positions from the FK5 position.

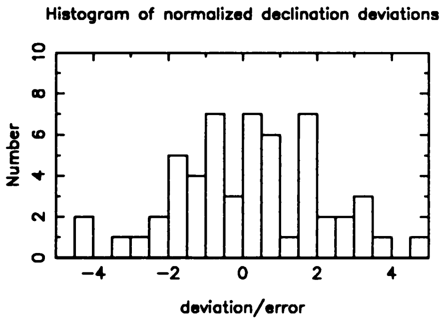
2. Results

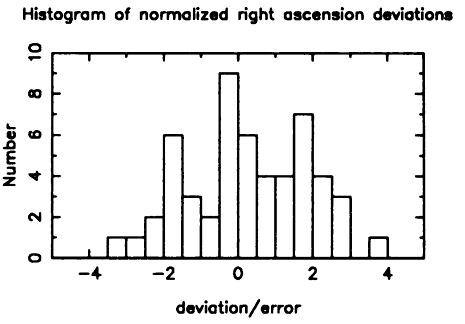
Preliminary results from five observing sessions between 1988 and 1992 (each session lasting 4 to 10 days) indicate formal accuracies in the determination of stellar positions (per session by simultaneous solution for all observed baselines) of about 5 mas in declination and 10 mas in right ascension. The following figure shows the offsets of the FK5 star positions for each session. The error box shows the FK5 positional accuracy of about 50 mas.



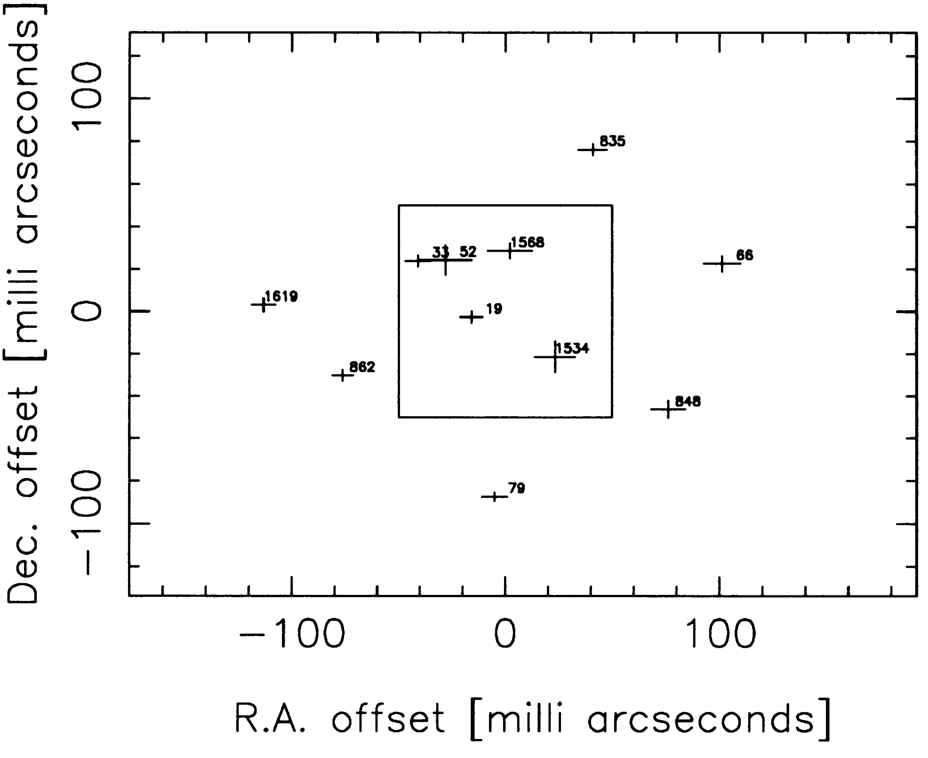
An error analysis, as shown in the histograms of the normalized deviations of the positional offsets from a weighted average position, indicates that systematic errors are not completely under control. For example, no C-monitoring was available in July 1989. In addition, systematic residual delay deviations from the fits occur regularly, affecting especially star positions based on smaller hour angle coverage. We attribute these effects to the fact that only delay constant metrology rather than a full array metrology is available to monitor thermal drifts. However, most of the positional deviations are less than 2 standard error bars and factors of order 2 were applied to the formal errors leading to a reduced χ^2 of unity for each star.

With these scaled errors, the mean stellar positions of all five sessions are plotted.





Accuracies are now in the range from 5 to 10 mas. (Errors in right ascension are larger since the north-south baseline is more sensitive to declination offsets and the east-south baseline was observed less frequently.)



References

Shao, M., Colavita, M.M., Hines, B.E., Staelin, D.H., Hutter, D.J., Johnston, K.J., Mozurkewich, D., Simon, R.S., Hershey, J.L., Hughes, J.A., and Kaplan, G.H.: 1988, *Astron. Astrophys.* **193**, 357.