CHARA TECHNICAL REPORT

No. 58 2 JANUARY 1998

Binary Astronomy Accuracy with Two Telescopes

W. G. BAGNUOLO

1. INTRODUCTION

The first two telescopes of the CHARA Array will provide a mostly North-South separation of some 34 meters. Although this is inadequate in a 'snapshot' mode, a significant amount of U- plane coverage can be obtained during a night from the trajectories of the stars across the sky. As we will see, the UV coverage is most favorable for stars with declinations from 40° through 70°, although stars with dec = -20° can still be observed. The UV coverage can be translated into models for the position angle, separation, and magnitude differences (δm) of the binaries. For a given error in measured V^2, a series of 'measurements' during a night can be simulated, and the locus of computed best fitting measurements can be found. In particular, the errors in the binary star position (secondary relative to primary) can be determined. Ideally, we would like to minimize this at least down to the level comparable with speckle (on a larger baseline). Stars of about 2 milli-arcsecond (mas)separation can be well measured with the 34 m first baseline. By analogy with speckle, we would like errors in position to be about 2% (i.e. roughly 1° in position angle A and 2% in separation. This corresponds to 0.04 mas in x and y or 40 μas.

In this Technical Report, we first discuss the UV coverage for stars of different declinations and then the resulting astrometric errors for a target binary star under a number of conditions, such as declination, σ_V^2, Δm. It turns out in particular that the accuracy deteriorates significantly for stars south of de = +=10.

2. UV COVERAGE

Figure 1 shows the UV coverage for the first two CHARA telescopes for four declinations: -10°,+10°, +40°, and +70°. Note that the maximum projected separation is 34 m. The points indicate 'observations' made at 3000 s (50 min) intervals. (Observations are made only when the star is within 60° of the zenith.) Figure 2 shows the visibility results of observations for a binary star with equal components and a separation of 2 mas each in the x,y directions (or a separation of ρ = 2.828 mas and θ = 45°.) During a simulated night, the binary is observed at different projected angles, and the separation of the stars is resolved at the longest projected baselines (resulting in zero visibility). The stars were assumed to both have diameters of 0.1 mas in this case and a bandwidth of 10 nm per

[1]Center for High Angular Resolution Astronomy, Georgia State University, Atlanta GA 30303-3083
TEL: (404) 651-2932, FAX: (404) 651-1389, FTP: ftp.chara.gsu.edu, WWW: http://www.chara.gsu.edu

channel (i.e. there is basically no effect from blurring from a wide bandwidth). The wave band was centered at 650 nm. Figure 2 shows the results of 100 simulated 'nights' with errors of $\sigma_{V^2} = 0.03$.

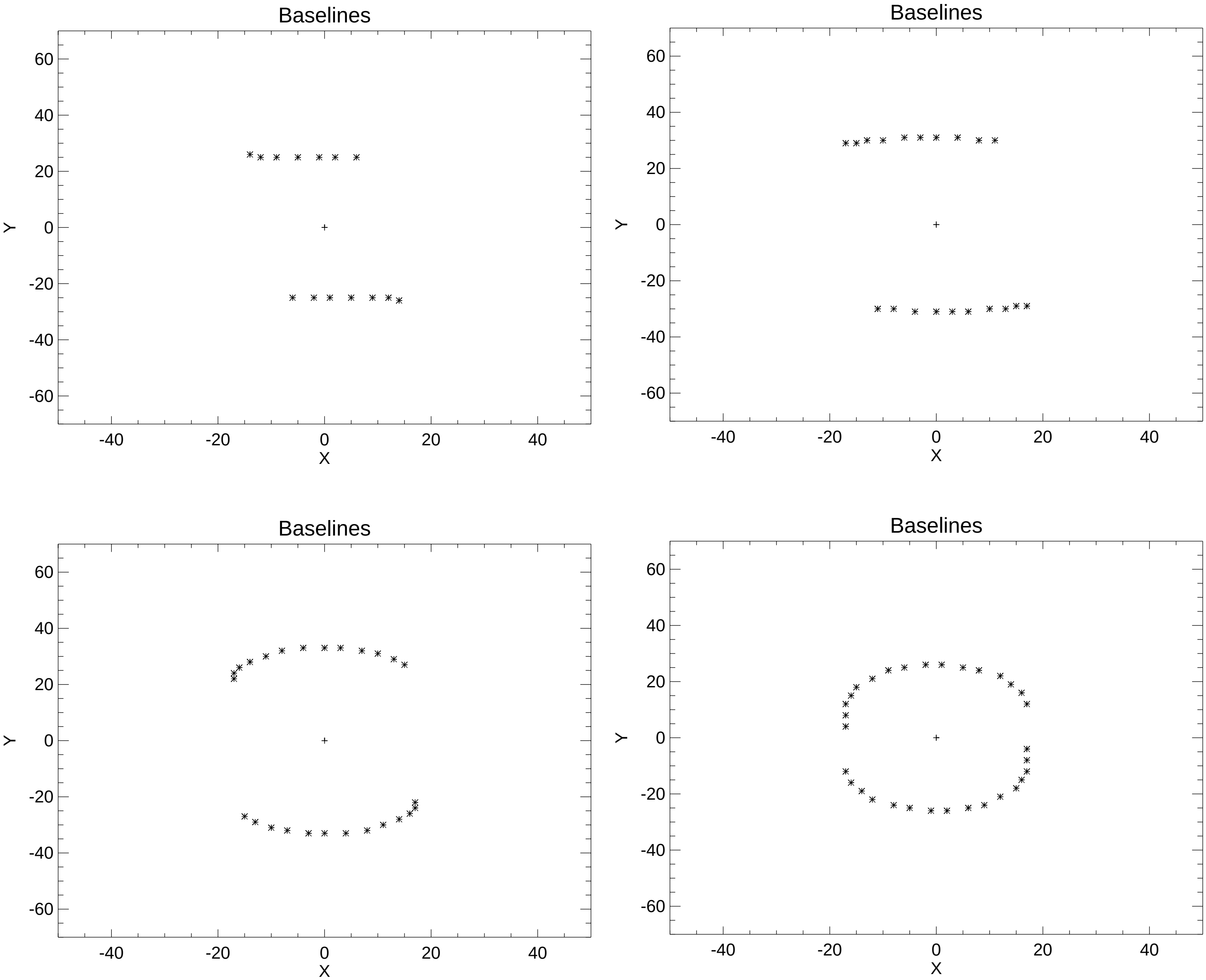
The visibility 'observations' can be processed to provide an estimate of the separations in coordinates x and y, as well as Δm. The algorithm used was "Curfit" modified from a standard IDL routine, based originally on the nonlinear least-squares fit program of Bevington (1969). Figure 3 shows the results for runs of 100 trials for the four declinations.

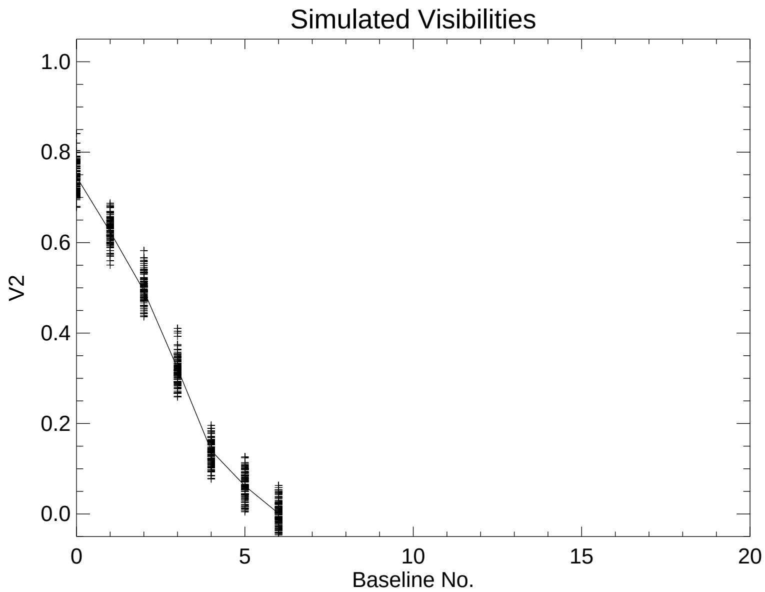
Figure 4 shows a summary of a number of simulations in terms of trends in the errors. The dec = +40 and $\sigma_{V^2} = 0.03$ cases are assumed. The top of Figure 4 shows the position errors as a function of declination. In general the results get much worse for declinations south of +10°. Therefore, all else being equal, we should probably not include stars in these declinations for initial measurements. The bottom left shows that errors increase as a function of magnitude difference, as one would expect. Finally, the bottom right shows that errors increase with star diameter, as the stars are just starting to be resolved at 1 mas diameters, degrading the visibilities.

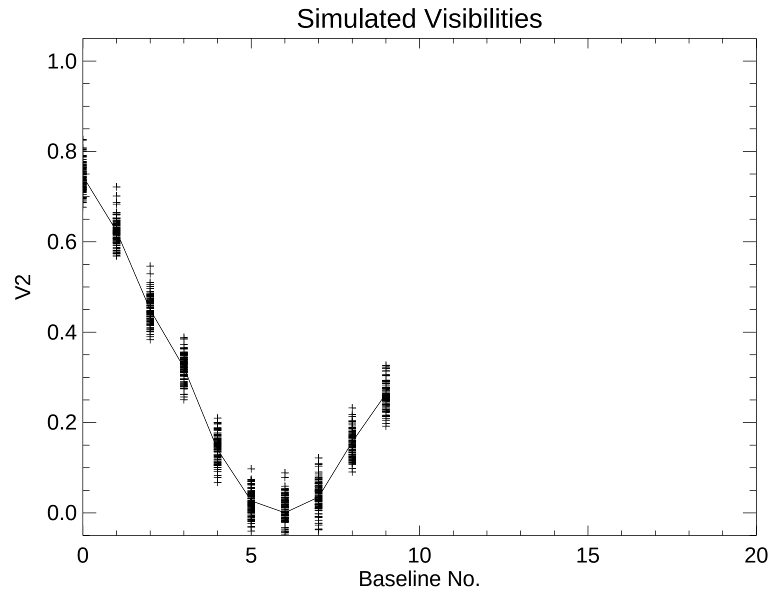
3. CONCLUSIONS

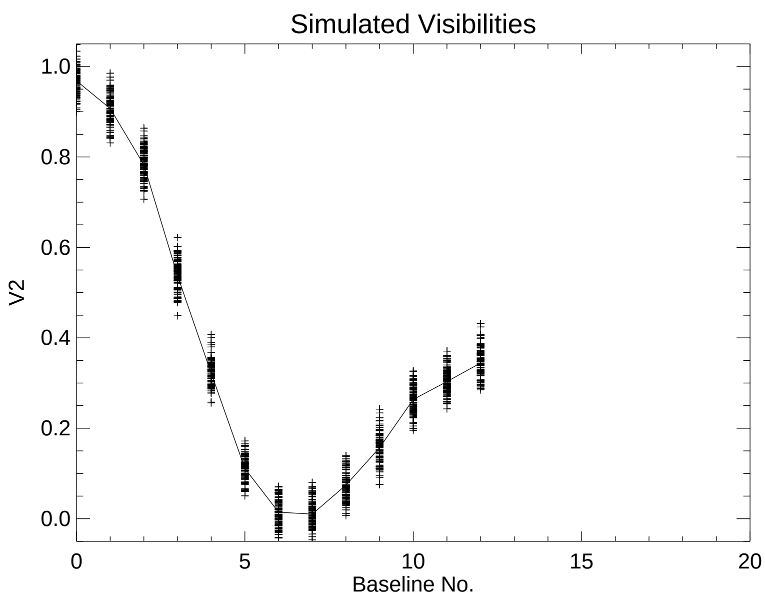
Results form the interferometer can be obtained of the same (relative) quality as speckle if the basic V^2 errors are kept down to below 0.03, which should happen under reasonably good conditions. Errors significantly increase for: $\sigma_{V^2} > 0.03$, $Dec < +10$, $\Delta m > 1.5$, and, stellar diameter > 1 mas. Additional simulations have also shown that the errors go up significantly if the star has a significantly smaller separation than 2.0 mas. The star is then not resolved to first null at any projected baseline during a night. Additional simulations were also done with the same 2.82 mas separation but different position angles with no significant changes in overall position errors with this baseline.

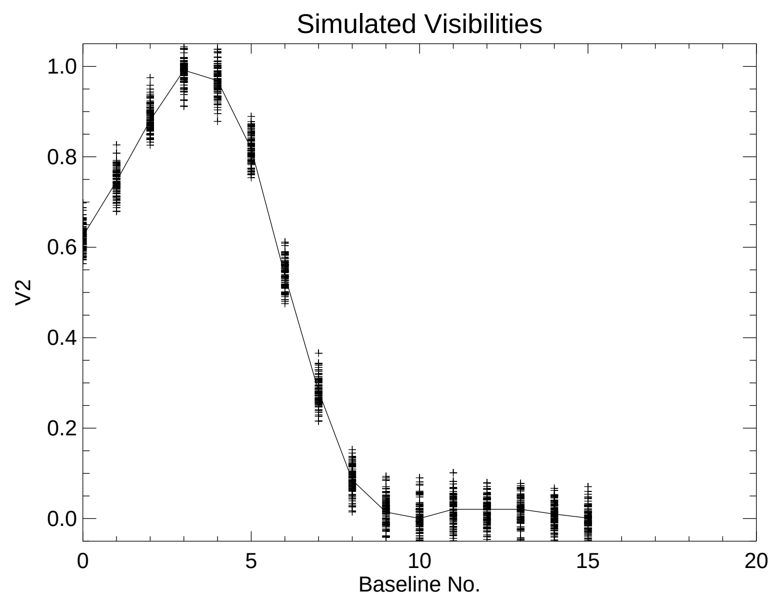
An additional potential complication is the movement of the stars during (say) an 8-hour observation interval. This would have to be taken into account in final orbit fitting.

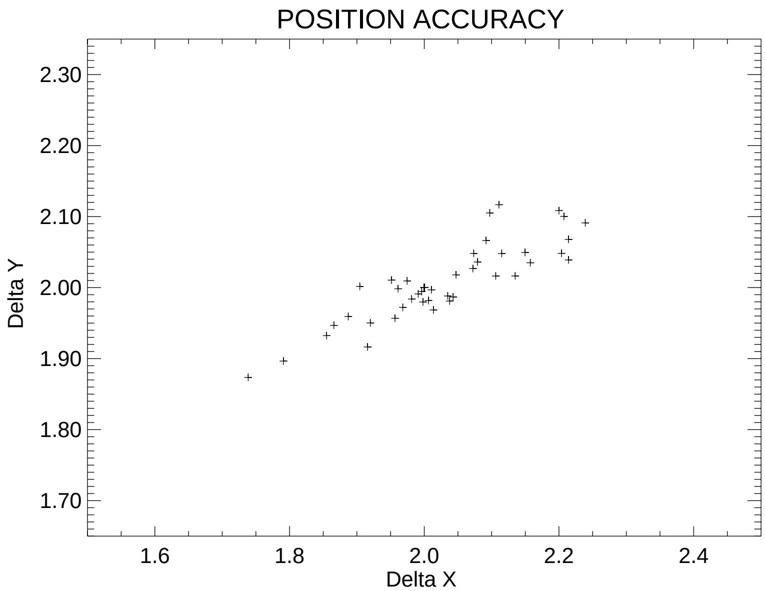

Baselines
Y
X
Baselines
Y
X
Baselines
Y
X
Baselines
Y
X

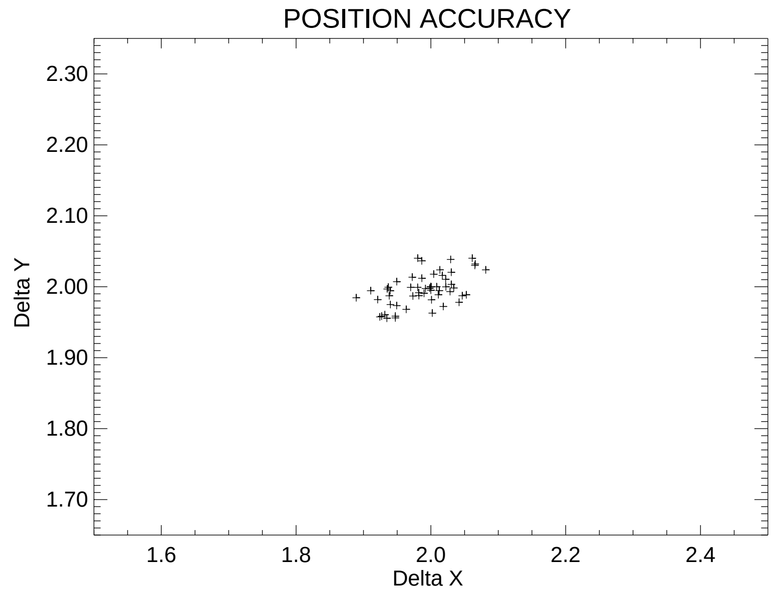

Simulated Visibilities
V2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Baseline No.

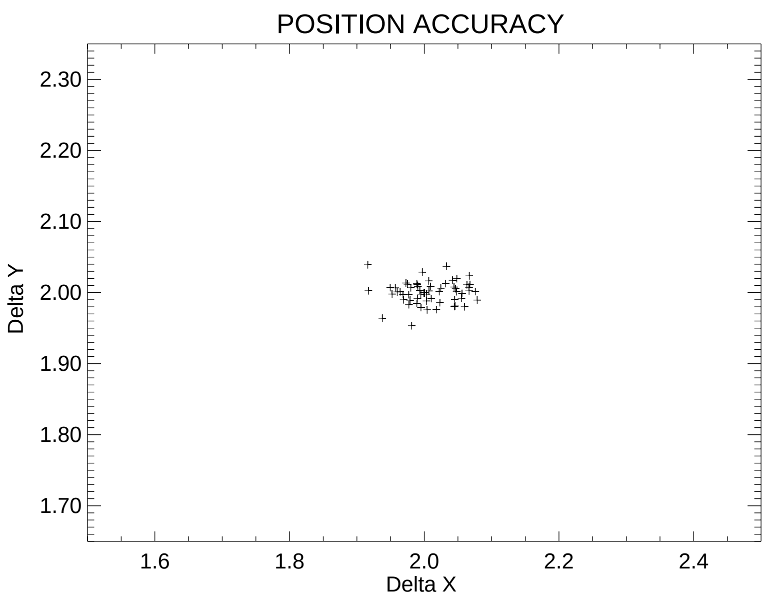

Simulated Visibilities
V2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Baseline No.

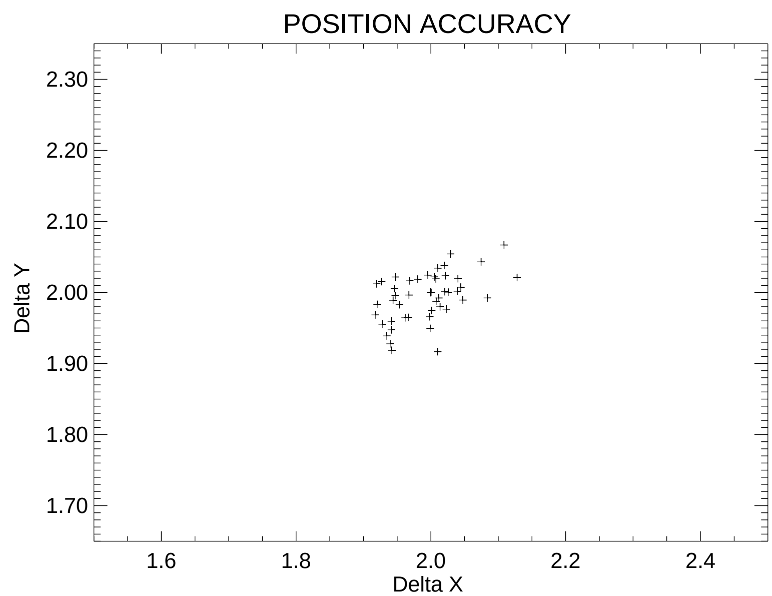

Simulated Visibilities
V2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Baseline No.

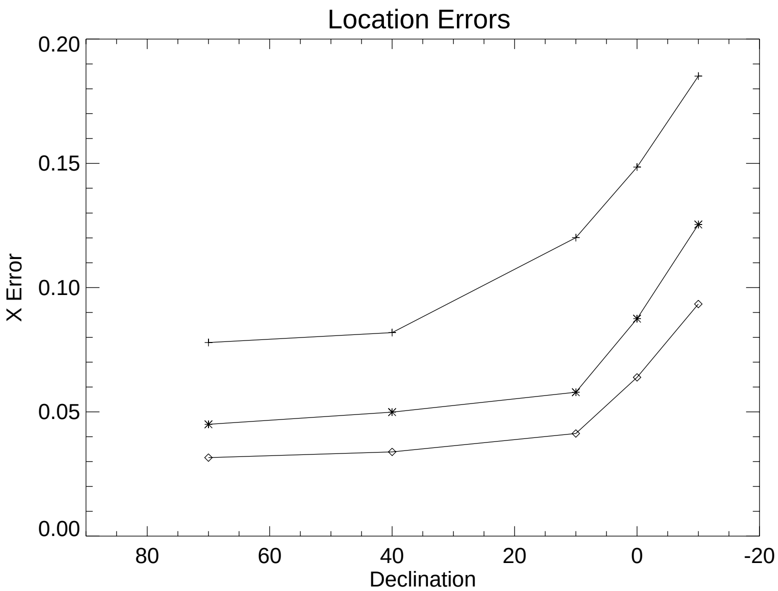

Simulated Visibilities
V2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
Baseline No.

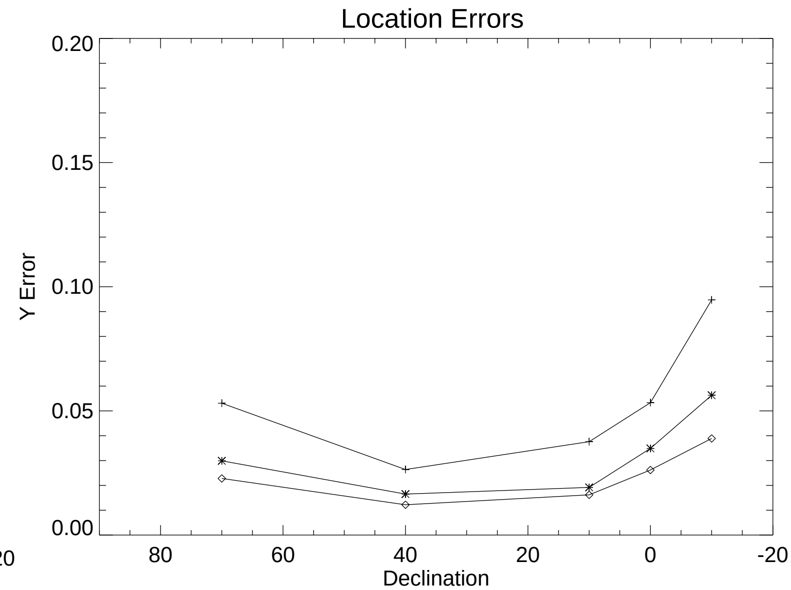

POSITION ACCURACY
2.30
2.20
2.10
2.00
1.90
1.80
1.70
Delta Y
1.6
1.8
2.0
2.2
2.4
Delta X

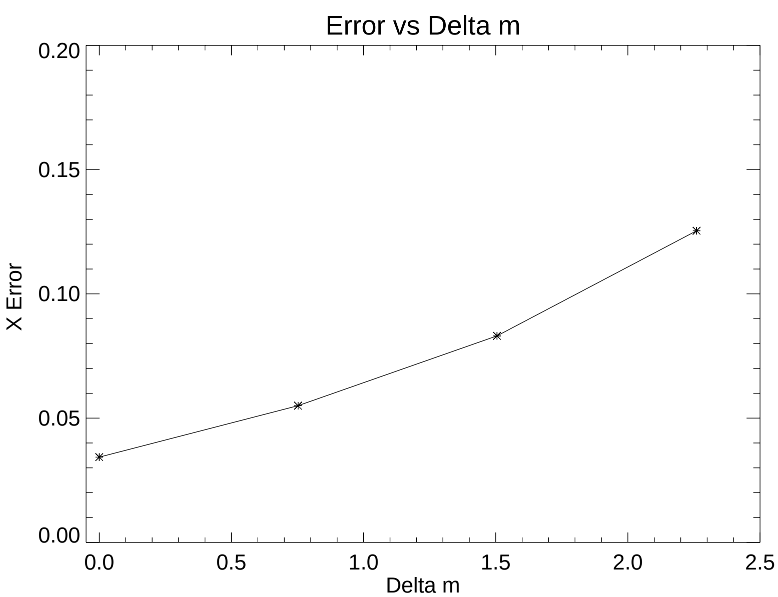

POSITION ACCURACY
2.30
2.20
2.10
2.00
1.90
1.80
1.70
Delta Y
1.6
1.8
2.0
2.2
2.4
Delta X

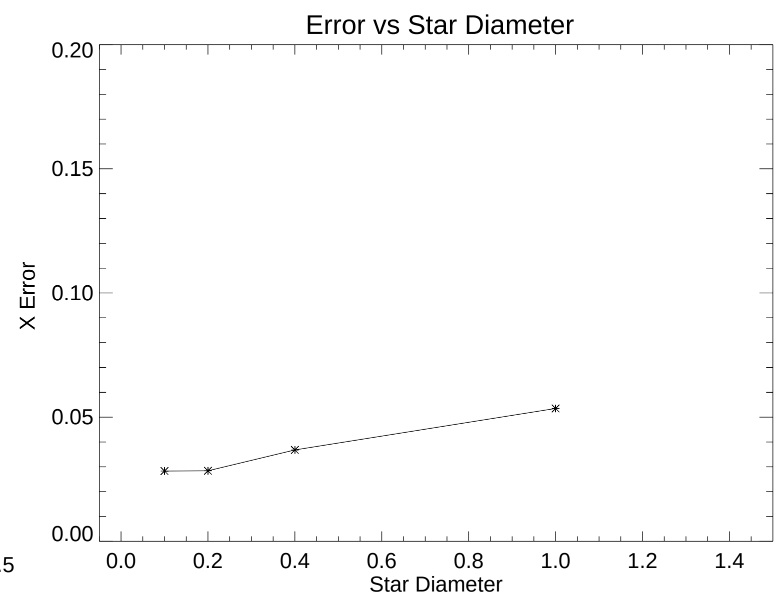

POSITION ACCURACY
2.30
2.20
2.10
2.00
1.90
1.80
1.70
Delta Y
1.6
1.8
2.0
2.2
2.4
Delta X


POSITION ACCURACY
2.30
2.20
2.10
2.00
1.90
1.80
1.70
Delta Y
1.6
1.8
2.0
2.2
2.4
Delta X


Location Errors
X Error
0.20
0.15
0.10
0.05
0.00
80
60
40
20
0
-20
Declination


Location Errors
Y Error
0.20
0.15
0.10
0.05
0.00
80
60
40
20
0
-20
Declination


Error vs Delta m
X Error
0.20
0.15
0.10
0.05
0.00
0.0
0.5
1.0
1.5
2.0
2.5
Delta m


Error vs Star Diameter
X Error
0.20
0.15
0.10
0.05
0.00
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Star Diameter