CHARA TECHNICAL REPORT

NO. 11 15 FEB 1995

Interferometer Layouts on Mount Wilson

WILLIAM BAGNUOLO, WILLIAM HARTKOPF, & STEPHEN RIDGWAY

1. INTRODUCTION

It is almost axiomatic that no interferometer site is perfect. Sites with very good seeing usually have terrain that is pretty useless for good $U-V$ plane coverage for an interferometer. (For example, sites located on a sharp peak or long ridge.) In this report we consider a site on Mt. Wilson which has a number of obvious limitations on telescope locations, both from the basic terrain and the existing buildings, such as the huge 100-inch telescope dome. We examine a number of potential three-leg, distorted Y-shaped configurations for both 5- and 7-telescope arrays. A routine has been developed to pick site locations to optimize $U-V$ plane coverage for an array. The basic conclusion is that the best Mt. Wilson layouts are only slightly inferior to the best unobstructed Y-shaped arrays in their $U-V$ coverage and the resulting image quality of reconstructed images.

2. THE MOUNT WILSON SITE

Mt. Wilson is one of the best known sites for astronomy. As a prime example of a coastal site with a cold-current inversion layer, it should have excellent seeing, inferior only to island sites that are also above the inversion layer (Walker, M.F. 1986, in *Identification, Optimization, and Protection of Optical Telescopes*, ed. R.L. Millis et al., Lowell Obs., p. 128). In fact, the site has been successfully used for interferometry since 1919. "Seeing lore" has it that on some occasions the seeing has been as good as $r_\circ \approx 50\,\mathrm{cm}$. A detailed comparison of the seeing at this and other candidate sites will be presented in a separate Technical Report.

As might be expected, though, the site presents an uneven appearance and is populated by a number of existing structures, notably the 100-inch dome. Figure 1 is a three-dimensional plot of the Mt. Wilson Observatory site. Proposed sites for a 7-telescope array are denoted by 100 ft high 'spikes' (as is the array center), and the location of the 100-inch dome is denoted by a small dome. Due to topography and other site constraints, the most likely site has three 'legs' centered on a site on the plateau area about 45 m from the 100-inch dome. The azimuth directions of the legs are approximately $48^\circ\!.5$, $171^\circ\!.5$, and $279^\circ\!.6$ respectively. The permitted locations for the telescopes are: LEG 1 (NE): r = 91–220 (end), LEG 2 (S): r = 120–140 or 190–200 (end), LEG 3 (W) r = 25–45 106–180 (end). One additional

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

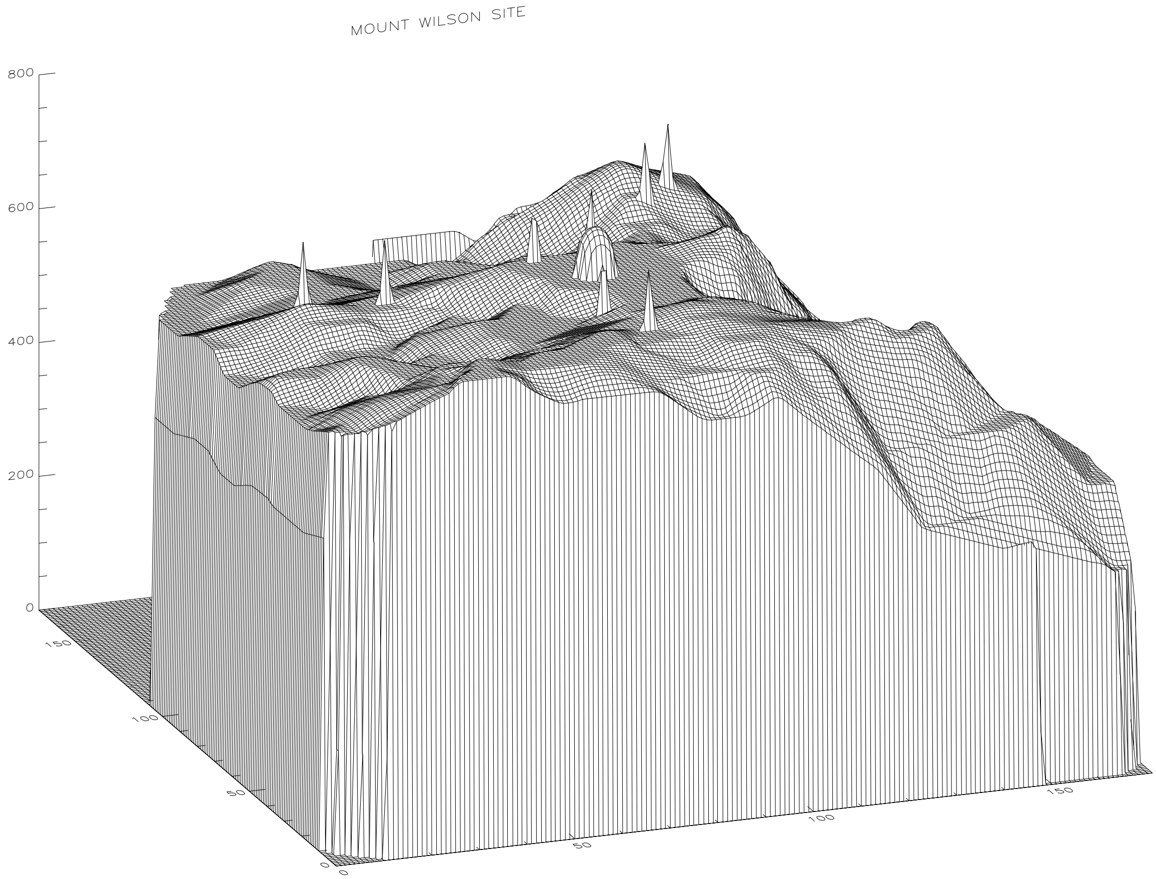

FIGURE 1. Mount Wilson site with optimum 7-telescope configuration.

possibility that produced good $U-V$ plane coverage was to have one telescope close (10 m away) to the combining house on the West leg. This has been currently ruled out by possibile obscuration and seeing degradation from that building and from the 100-inch dome.

3. U-V PLANE COVERAGE FOR BEST TELESCOPE LAYOUTS

A method described in the 1994 CHARA Proposal was used to find optimal arrays in terms of the best $U-V$ plane coverage. It may be summarized as follows:

- For five and seven telescopes the coverage of an array was calculated for latitude 34°, a limit of 40° elevation, and for an object declination of 20°.
- The Y arrays were defined by axes going out from the central combining house at position angles shown in Figure 2. (These axes are at approximately 48°.5, 171°.5, and 279°.6.) For comparision, we also considered an "unobstructed" array with axes at 0° (North), 120° (East), and 240° (West). For each run the initial three telescopes are located at the ends of the legs. Additional telescope positions are chosen at random in cyclic order so that the fourth telescope is added on the North line, the fifth on the East line, and so on.

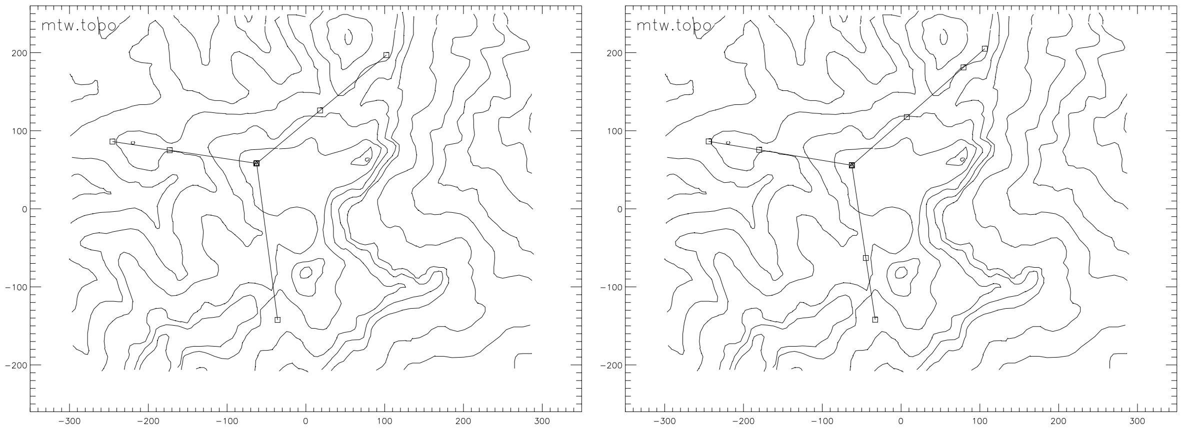

FIGURE 2. Mount Wilson site with optimum "restricted" 5- and 7-telescope configurations.

- For a given set of telescope positions, the $U-V$ plane coverage is calculated at intervals of 50 hour angle locations from the maximum to minimum hour angles consistent with the 40° elevation limit. The points in the $U-V$ plane are *quantized* to the nearest grid points of a 32×32 pixel grid in which the maximum $U-V$ plane separation of 354 m corresponds to a radius of ten pixels (35 m/pixel). Thus, points within a distance of about 20 m from the $U-V$ plane trajectories are "covered". (One pixel covers an area equal to that of a circle of 20 m radius.)
- Points in the $U-V$ plane were weighted linearly with distance, from a weight of 2.0 at r=30 m to a weight of 1.0 at r=200 m. Points with r<30 m or r>200 m were given zero weight. (Very short baselines can be observed with conventional masking / speckle techniques.)
- The iterative optimization process for an initial array configuration is a grid search with a single step in radius for each telescope moved successively. The initial step size was 50 m and was reduced by a factor of 0.7 after each cycle. The search was terminated when the step size dropped below 1 m.

Table 1 shows the results of this optimization, listing the coverage for the array configuration schemes that were considered. Note that for the 5-telescope case the configurations with two telescopes in the W leg (denoted by 2,1,2) were generally better than those with two telescopes in the S leg. Note that removing the local site restrictions, but keeping the general directions of the Mt Wilson Y improved the coverage very little. Finally, note that the best restricted Mt. Wilson sites are only slightly worse in $U-V$ coverage than the 'standard' unrestricted Y sites with legs at azimuths 0°, 120°, and 240°. Figure 2 shows the locations of the best restricted Mt. Wilson Y configurations. Note that the 7-telescope case is very close to being the 5-telescope array with two telescopes added. (Table 1 shows a significant increase in $U-V$ coverage with seven telescopes.) Thus, one advantage of this initial 5-telescope configuration is that it is readily expandable with little sacrifice in $U-V$ coverage.

Figure 3 (left) shows the $U-V$ plane coverage with the best 5-telescope restricted and unrestricted Mt. Wilson Y arrays versus the best unrestricted 'classical' Y. Note that although the coverage percentages are close, the 'classical' Y and unrestricted Mt. Wilson Y appear somewhat qualitatively better than the restricted Mt. Wilson Y.

TABLE 1. $U - V$ Coverage with Mt. Wilson and unrestricted Y configurations.

N_{tel}	N_{tel}/leg	Configuration	Restrictions	Weighted Coverage	Comments
5	2,2,1	Std. Y	No	0.607	Unsuited for Mt. Wilson
		MtW Y	No	0.577	Telescope near 100-in dome
		MtW Y	Yes	0.562	Site OK
	2,1,2	MtW Y	No	0.604	Telescope near combining house
		MtW Y	Yes	0.585	Site OK
7	3,2,2	Std. Y	No	0.845	Unsuited for Mt. Wilson
		MtW Y	Yes	0.829	Site OK
		MtW Y	No	0.831	Near NE telescope in bad location

FIGURE 3. $U - V$ coverage with optimum 5-telescope configurations. Left: restricted Mt. Wilson Y, Center: unrestricted Mt. Wilson Y. Right: unrestricted classical Y. The outer circle represents a 354 m separation, as in the original CHARA Y.

Figure 4 shows a similar comparision with three 7-telescope arrays. Note that the overall coverage is qualitatively better than in the case of the 5-telescope arrays.

4. COMPARISON OF RECONSTRUCTED IMAGES

In the section above, we have seen that in terms of the criterion of a weighted coverage, the restricted Mt. Wilson Y arrays are only slightly inferior to the unrestricted Y arrays. Another comparison is to carry the process one step further and to use the arrays' $U - V$ plane coverages to reconstruct a sample image and to see if there is any significant loss of image quality with the restricted Mt. Wilson Y case.

The $U - V$ plane coverages have been translated into reconstructed images via a procedure described in the CHARA 1994 Proposal. Basically, an interpolation is made of the complex visibilities in the $U - V$ plane for each of the arrays. The result is then Fourier-Transformed to produce an image. Although this method is not quite as good as CLEAN, it has the advantage of being a quick diagnostic of potential imaging for various site locations. Figure 5 shows a reconstruction of a fairly difficult object based on a model for the star 29 CMa. The model includes a binary (low spatial frequency components) with resolved components with both tidal distortion and limb-darkening (high frequency components). The input

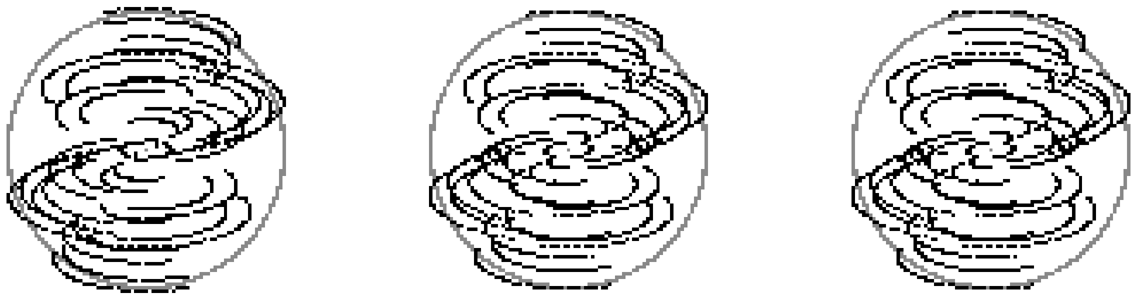

FIGURE 4. $U - V$ coverage with optimum 7-telescope configurations. Left: restricted Mt. Wilson Y, Center: unrestriced Mt. Wilson Y. Right: unrestricted classical Y.

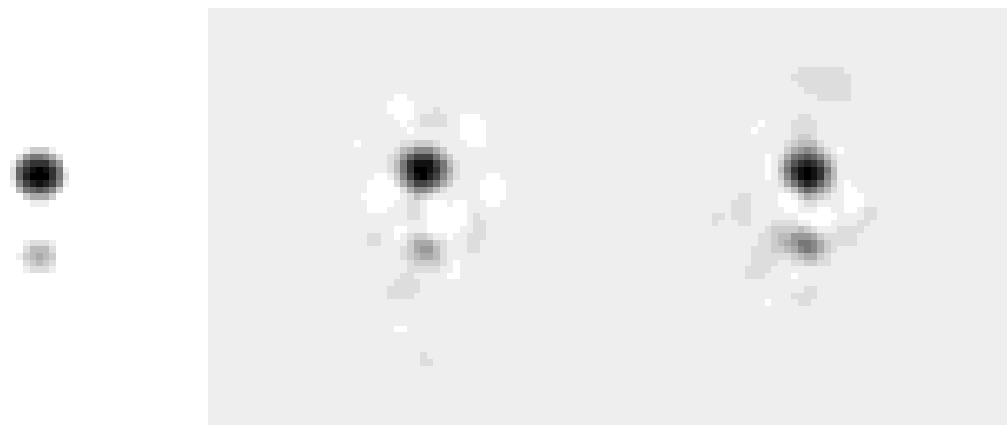

FIGURE 5. Imaging with optimum 5-telescope configurations. Left to Right: input object (29 CMa model), "image" with restricted Mt. Wilson Y, "image" with unrestricted classical Y.

image is at left. The other two images are those reconstructed from "observations" made with the coverages of the restricted Mt. Wilson Y and the unrestricted CHARA Y (see Figure 3). As can be seen in this figure, the final image qualities are pretty similar, which suggests that little is lost by using the Mt. Wilson site instead of an unrestricted site.

5. CONCLUSION

We have shown that adequate $U - V$ plane coverages can be obtained at the Mt. Wilson site with only a slight degradation in coverage compared to the CHARA unrestricted Y configuration. One optimum configuration in particular has the advantage of being upgradable from 5 to 7 telescopes by simply adding two telescopes without reconfiguring the first five telescopes. However, due to the irregularities of the terrain and the trees, a good survey must be done at the site to see if the telescopes can really be located where the models suggest. (And if so, how much "aquaducting" must we build to convey the light.)