CHARA Technical Report

No. 49 10 July 1997

Expanding (U,V)-Plane Coverage with Outriggers

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1. INTRODUCTION

CHARA Technical Report No. 46 addresses the use of additional 1-m aperture telescopes to enhance the (U,V)-plane coverage in comparison with that provided by the currently funded five-telescope array. The report shows that the CHARA Array begins to take on the character of a true imaging array at the six or seven-telescope level and concludes that our originally proposed seven-telescope array provides the optimum scientific return following a $3M increase over the present budget.

Another possible improvement to the standard CHARA Array based upon fixed, 1-meter telescopes is to emphasize imaging of brighter objects by adding three or more "outrigger" telescopes of 50-cm aperture. Under mediocre conditions in the visual little would be lost in terms of a magnitude limit. Subapertures as large 17 to 21 cm could be used, or even the whole 50 cm aperture in some cases. However, there would be a loss of limiting magnitude of at least 0.7 magnitude under conditions of very good seeing in the visual band. In the K-band, this would also be the case. According to theory, the apertures 'RSS', which is why 3-m equivalent capability is claimed for 1-m outriggers on the 10-m Keck telescopes. This assumes, of course, that the noise is mostly photon noise.

2. COSTS OF OUTRIGGER TELESCOPES

Cost is the crucial element in terms of whether this idea should even be considered. The old "rule of thumb" was that telescope costs scaled as about the 2.6 power of the diameter. More recently, with the advent of less expensive structures and more expensive drive/control/communication systems, this law has shown signs of flattening out.

According to a recent conversation with CHARA's telescope designer Larry Barr, the cost of telescopes can be broken down as follows. First, it would cost roughly half as much to design half-scale CHARA telescopes as it did to design standard 1-m CHARA telescopes. This is probably a conservative estimate, as there are many structural elements in the CAD program that would simply scale by half. At any rate, according to Mr. Barr, it would take several man-weeks to go through the blueprints to see where the modifications would take place. Some of the modifications would be to take advantage of the smaller size to

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simplify the design. The mirror cell would only require a 9-point wiffle-tree, for example. The cost for this re-design phase would be roughly $70K, to be amortized over three or more telescopes.

Secondly, the structural cost ($256K for the 1-m telescopes) would scale as approximately the square of the aperture, or about $64K for the 0.5-m telescopes. Thirdly, the mirror cost would scale roughly as the *cube* of the diameter, according to conversations with Gene Fair (of Fair Optical) as well as with our telescope optics vendor, Telescope Engineering Company. The cost of the primary/secondary optics would then decrease from about $70K to only $9K. Fourth, the cost of the motors, drive system, and computer would decrease only slightly. Another cost would be software (which depends on whether we have bought the source code or not). A rough (optimistic) estimate would be about $25K. Finally, the shelter cost would go down as roughly the cube of the size. (The telescope could fit inside an 8-foot amateur-sized dome, at an estimated cost of about $15K.)

To sum up, the overall telescope cost for the 50-cm telescopes would be about $136K each for three telescopes, or $409K for the set. This is actually less than the cost of a single extra "full-size" telescope ($479, using the same cost estimates). A cost comparison is given in Table 1.

TABLE 1. Comparative telescope costs.

Component	1-m Tel. Cost	0.5-m Tel. Cost
Design	140/5	70/3
Structure	256	64
P+S Mirrors	70	9
Motors, etc.	30	25
Shelter	120	15
Total	$479K	$136K

It should be noted that to the telescope cost must be added the 'downstream' system costs of additional lightpipes and OPLE carts and beam-combining optics. (This cost could be small if an arrangement is made for the outrigger telescopes to use existing lightpipes and OPLEs, but then part of the (U,V)-plane coverage improvement will be lost.)

One of the main advantages of small outrigger telescopes is that they can be more readily relocated compared to the standard 1-m Array telescopes. It may even be worth proliferating telescopes using the same light pipes, like SUSI to insure flexibility of coverage, especially for larger stars than the 2 milli-arcsec images considered in Technical Report No. 46. The existing array is not well optimized for stars of this size class.

To improve imaging for larger diameter stars we need to change the criterion for selecting (U,V)-plane coverage. The program can be modified to assume a 110-m cutoff for maximum baselines that 'count', instead of 346-m. Using this criterion creates a different (U,V)-plane coverage map for the location of a sixth telescope. Basicially, the best arrays favor clustering close (but not too close) to existing telescopes. One such choice is given by locating the sixth telescope about 70 m north of the current telescope S2. Simulations employing this configuration for the NRP star example considered in Technical Report No. 46 produce a better image than the six-telescope array selected for best general (U,V)-plane coverage. In fact, the image and is roughly as good as the previous seven telescope array. This demonstrates the advantage of being able to tune the array configuration to best meet the spatial frequency structural needs of the object to be imaged. Although the original proposal for the CHARA Array had a limited ability to relocate the three outermost telescopes to provide a second more compact configuration, it is more feasible to attempt a more generally configurable array using smaller aperture "outriggers" than is afforded by our present 1-m telescopes.

3. CONCLUSIONS

An alternative to providing additional (U,V)-plane coverage through the addition of one or two 1-m telescopes is to proliferate 50-cm telescopes. The cost of three such telescopes is estimated to be less than that of a single 1-m telescope. Additional costs would be in the OPLE carts and lightpipes, and auxiliary beam-combining optics. Alternatively, the small telescope could share lightpipes.

The advantages of outrigger telescopes appear to be:

1. a less expensive way of obtaining more (U,V)-plane coverage from more telescopes,
2. flexibility in observing many more objects, such as larger stars, by moving the telescopes, or even proliferating them.

The disadvantages are:

1. magnitude limit disadvantage under good seeing,
2. more system complexity, including more design work on combining optics.