Wide-Field Designs for Off-Axis Telescopes: Application to the Optics of CCAT-prime.

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The advantages of using off-axis optical designs for radio telescopes have been recognized for many years. These include the absence of aperture blocking, which lowers the side-lobe level, and a large reduction in multi-path reflections, which greatly improves spectral baselines. In addition, two-mirror designs meeting the Mizuguchi-Dragone criterion have good polarization properties. For applications requiring a large field of view and a reasonably flat focal plane, the crossed-Dragone configuration (upper part of Fig. 1) is particularly advantageous [1].

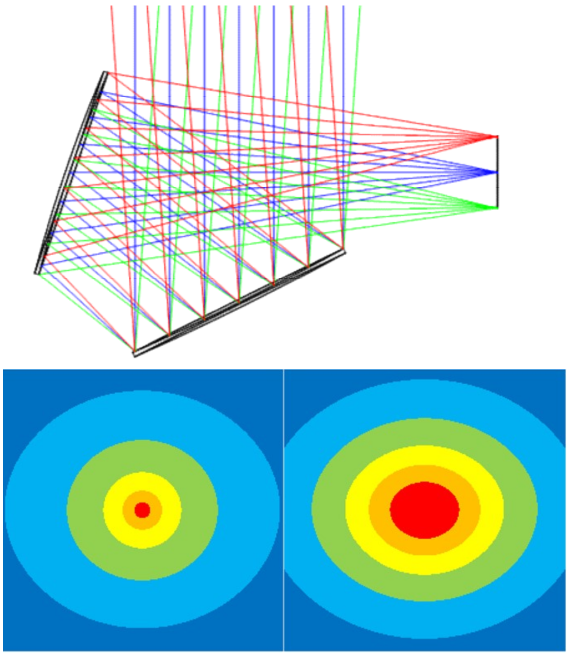

Fig. 1. Upper: Crossed-Dragone f/2.5 configuration with a 6m aperture and an 8-degree diameter field of view. Lower: Contours of 80% Strehl ratio in the focal plane (8deg x 8deg) at (blue to red) 75, 150, 300, 600 and 1500 GHz. Left: classical design. Right: with correction for coma aberrations.

These designs are however still based on the classical Cassegrain telescope, e.g. the primary and secondary reflectors are, respectively, segments of a paraboloid and of a hyperboloid. We describe here how a small modification to the shapes of the mirrors, analogous to the Ritchey-Chrétien design long used for optical telescopes, can greatly increase the field of view, especially at high frequencies.

The dominant aberration in such optical systems is usually coma and this can be corrected by adding higher-order terms to one mirror and compensating for them in the other. Dragone [2] did in fact set out the principles for making such a correction as long ago as 1983, but this option does not seem to have been widely adopted, perhaps because it was expressed in a purely analytical form. With modern optical design packages, however, the relevant optimization is relatively straight-forward to achieve. Practical ways of doing this, along with some of the pit-falls to be avoided, will be explained in the presentation.

This approach has been applied to the optics of CCAT-prime [3]. The lower part of Fig. 1 illustrates the very large increase in the useable field of view that is achieved in the sub-mm wavebands. This improvement is gained without significant sacrifice of the other aspects of the optical performance, although there are some modest penalties in terms of manufacturing the reflectors.

The presentation will include a general description of the CCAT-prime telescope design (which has also been adopted for the Simons Observatory CMB Large-Aperture Telescope) as well as a brief discussion of other designs and applications of the coma-correction approach.

References

[1] M. D. Niemack. "Designs for a large-aperture telescope to map the CMB 10X faster," *Applied Optics*, vol. 55, no. 7, pp. 1688–1696, 2016.

[2] Dragone, C., "First-Order Correction of Aberrations in Cassegrainian and Gregorian Antennas", *IEEE, Antennas Propagat.*, Vol. 31, 764-775, (1983)

[3] S. C. Parshley et al., "The optical design of the six-meter CCAT-prime and Simons Observatory telescopes", *SPIE Conference Series,* vol. 10700E..41P, 2018.

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