Center for Astrophysics

Harvard College Observatory
Smithsonian Astrophysical Observatory

TECHNICAL MEMORANDUM

MEMO #35

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To: Files

From: Paul Ho

Subject: Concerning a Chopping Secondary

In designing the optics of the telescopes, one of the decisions will be whether the subreflector will be used for sky chopping. The impact of such a decision is basically cost. A chopping secondary will be more expensive in three ways: (1) the subreflector must be able to withstand rapid motions, (2) the feed legs or quadrupods must be stiff enough and strong enough for the additional weight, and (3) the additional costs for the drive system to nutate the subreflector. With regards to engineering, such a system is not novel or difficult. Adequate systems have already been designed, with the most likely one for our purposes being the one designed by Arizona and to be adopted by Chicago for CSO. With regards to motions of the subreflector, it will do well to remember that full translation and rotation of the secondary will be required in any event to point and focus the beam under gravitational and thermal distortions.

As there is clear dissension as to whether chopping at the secondary or at the tertiary or later is the best option, I will discuss here the merits of a chopping secondary.

(1). Historically, chopping at the tertiary or at the focal plane was the first method to be tried in order to reject sky and other background noise fluctuations that overwhelm the astronomical signals. Low and Rieke (1974) give a short discussion to this subject in *Method of Experimental Physics, Volume 12, Part A, p.444*. Wobbling or nutating the secondary is a superior technique simply because the two beams that are formed are more nearly matched the closer you get to the primary and the more nearly identical parts of the primary and secondary are used. Wobbling of the primary would be even better except for the fact that the primary is too heavy to move at the rate of 10 Hz or thereabouts in order to compensate for atmospheric fluctuations.

(2). A chopping secondary is difficult if the subreflector must be large for example because of the focal ratio or the diameter of the primary. In low frequency radio telescopes, for example, the subreflectors are so large that they cannot be wobbled at the required rate. However, for the SMA telescopes, and because of the availability of carbon fiber technology, the weight can be reduced to the order of 10 lbs (design weight for the CSO subreflector as proposed by Chicago). The total weight including the driver for the chopping motion, cables, mounting plate, and focusing mechanisms, can be held to about 100 lbs. This can be supported by the usual quadrupods of standard designs.

(3). Experience at operating telescopes is valuable to look at. A chopping secondary is now operating on the IRTF, UKIRT, CFHT, JCMT, KAO, IRAM 30m, NRAO 12m, and planned on the SMT and the CSO. Hildebrand of Chicago has built and used a rotating blade chopper and a rocking mirror tertiary at Cerro Tololo and at Mt. Lemmon. He claims that whenever these systems were replaced by well-designed chopping secondaries, the improvement in signal-to-noise has been "dramatic". In fact, the CSO which was built without a chopping secondary will soon be outfitted with one to be funded by NSF through Hilebrand's group.

(4). Scientifically, the rationale for a chopping secondary is exceedingly clear. What you are after is the best sensitivity for continuum sources. Chopping at the secondary will give you better signal to noise. This means you can locate a pointing source faster and you can reach fainter sources. We already know that the atmophere will be difficult, and that the number of strong sources is small. The design must allow for the best technique to be employed. This technique is the chopping secondary.

(5). Operationally, the rationale for a chopping secondary is also exceedingly clear. If offered a chopping secondary, no telescope will refuse it. The only consideration is one of cost. Studies by Heinrich Foltz concurs that chopping at the tertiary will not be as good as wobbling the secondary. For the SMA, useful work will be done in the single dish mode for calibrations as well for zero-spacing information. Anyone who has worked under difficult atmospheric conditions (and at submm wavelengths, the best night will be lousy by the usual mm wavelength standards), knows that spectral baselines will be difficult and detection of continuum sources will be difficult. Weak and wide extragalactic lines are not going to be a piece of cake.

Design considerations. In any event, there should be no obstacle to a chopping secondary in the design. For example, the quadrupods must be designed to support the weight of such a system. The optics must be such that a chopping secondary can be used. For the chopping secondary, a good initial design would be the Arizona design by Nagel, Davison, Ray and Martin. This should be available from them. In addition, the Chicago group has added a rotating platform so that chopping can be in an arbitrary direction. This is certainly most desirable especially for holding the reference position to fixed relative celestial coordinates. The design of the chopping secondary has to take into account of chopping speed (f) versus the beam throw (θ). A common figure of merit, θf^2, should be maximized. The design should also look into the choice of the f-ratio, since this will impact on off-axis aberrations and astigmatism, which will influence how far the beam can be thrown in a chopping motion. The distortions at the focal plane will be of interest especially if array receivers are used in the future.

Recommendations. My recommendation is that a cost analysis and a design analysis should be made for a chopping secondary. This analysis should be made before deciding on the optics of the system.