Memorandum
Gemini 8m Telescopes Project

To: Rick M.
From: Doug S.
Date: October 5, 1994
Re: Tolerance on Chop Timing
cc: Matt M., Fred G.

I have examined in detail your MathCAD model of the effect of chopping noise on the SNR of 10 µm imaging. My main concern with your model is that it isn't clear to me how the predicted 1% drop in SNR due to chopping noise applies to "real" performance (i.e., what is the science implication?). I have therefore tried to redefine the solution in terms of simply remaining sky background limited during chop cycles in this memo. Fred has also made some estimates of allowable noise in the context of nodding over 10 sec cycles (he found that the integration time drift must be <<100 µs) but my understanding is that you need a numerical spec on chop timing stability that is not explicitly covered in Fred's estimates. In order to better define the allowable chopping noise (and hopefully not totally confuse the issue...) I propose we set the chopping noise spec such that any object-sky pair must be background not chopping noise limited. To form this spec set the basic equations,

$$c_1 = (S+B)t$$

$$c_2 = Bt$$

where c_1 is the total signal (source + background) accumulated during time t and c_2 is the background signal accumulated while chopping off source. Assume B >> dark current and B >> (read noise)^2. Using standard error propagation,

$$\sigma_{c_1}^2 = \sigma_S^2 t^2 + \sigma_B^2 t^2 + (S+B)\sigma_t^2$$

$$\sigma_{c_2}^2 = \sigma_B^2 t^2 + \sigma_t^2 B^2 .$$

Then for x defined to be the net signal $c_1 - c_2$, we have $\sigma_x^2 = \sigma_{c_1}^2 + \sigma_{c_2}^2$. Using $\sigma_S^2 = S$ and $\sigma_B^2 = B$ and assuming a faint source so S << B, inserting the above expressions in the equation for σ_x^2 and rearranging yields,

$$\sigma_x^2 = 2Bt^2 + 2B^2\sigma_t^2 .$$

The uncertainty on the net signal x is therefore expressed as a term due to natural sky noise ($2Bt^2$) and one due to chopping noise ($2B2\sigma_t^2$) of characteristic rms σ_t. The condition requiring chopping noise to be less than sky noise is then

$$2Bt^2 > 2B^2\sigma_t^2$$

or

$$\sigma_t < \frac{t}{\sqrt{B}}.$$

Now use the smallest t possible for the Gemini chopper (chopping at 10 Hz so t = 50 ms) and select a filter yielding 50% full well in this integration time of 25 x 10^6 e^- (which incidentally is close to a broad band N filter for the Gemini mid-IR camera). This yields a maximum allowable chopping noise of 10 µs. My understanding is that Matt has also calculated a chop noise spec based upon a ~3 hr observation of a faint source which I think is in the same "ball park" as my 10 µs value (need to check this). Does this approach sound reasonable to you?.