J-MAPS Technical Memorandum 09-08

Centroiding Error as a Function of Flat Field and Dark Current Variability

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ABSTRACT

In order to ensure single milliarcsecond (mas) precision astrometry for J-MAPS, the sources of centroiding error must be understood for different spectral types, magnitudes, and exposure lengths. Of particular importance are J-MAPS guide stars and quasars. We examine the effect of variability of dark current on the centroiding error of the detector.

1. Methodology

The dark current analysis consisted of two steps. Similar to how variability in the flat field is applied, expected dark rates are generated for each pixel using Gaussian noise with a mean value of 1 electron per second per pixel and a sigma varying from 0 to 0.4. Then, this dark rate map was multiplied by the exposure time of the simulation to produce the dark map. A Poisson distribution with a lambda equal to the expected dark count, generated by the original Gaussian, multiplied by the exposure time, is then used to generate the electron count for each pixel. Variability in dark current refers to the sigma of the Gaussian distribution used in generating the expected dark current rate. To test the range of responses, the centroiding error resulting from variability over the dark current was calculated for a 9^{th} magnitude F5 with an exposure time of 0.2s, a 12^{th} magnitude F5 with an exposure time of 20s, a 14^{th} magnitude F5 with an exposure time of 20s, and a 16^{th} magnitude M6 with an exposure time of 500s to mimic imaging a 16^{th} magnitude quasar. Quasars typically have extended point spread functions (PSFs), and the M6 PSF is the most extended of available spectral types. Again, for each case, 250 simulations are performed and the mean of the centroiding error is recorded.

The relationship between the total centroiding error and the dark current variability is defined by the following linear equation:

$$TotalError^2 = a^2 \times varibility^2 + b^2 \tag{1}$$

Because Equation 1 is linear, $b^2 = Floor^2$ and is the y-intercept of a linear regression, and a^2 is the slope of the linear regression.

02s 9 mag F9 counts= 6475.45507812

04counts= 12950.9101562

counts= 25901.8203125

0.2 9th F5 0.000646 0.0142

Table 2: X-Centroiding Error per Percent Variability Over Dark Current

Exposure Time (s)	Mag	Spectral Type	Equation 1 Fit Paramter a (mas/percent)	Equation 1 Parameter b (Error Floor) (mas)
0.2	9^{th}	F5	0.000646	0.0142
20	12^{th}	F5	0.00998	0.227
20	14^{th}	F5	0.0472	1.08
500	15.35	M5	0.208	4.68
500	15.35	G5	0.176	4.01

Note: The Total X-Centroiding Error was modeled with Equation 1.

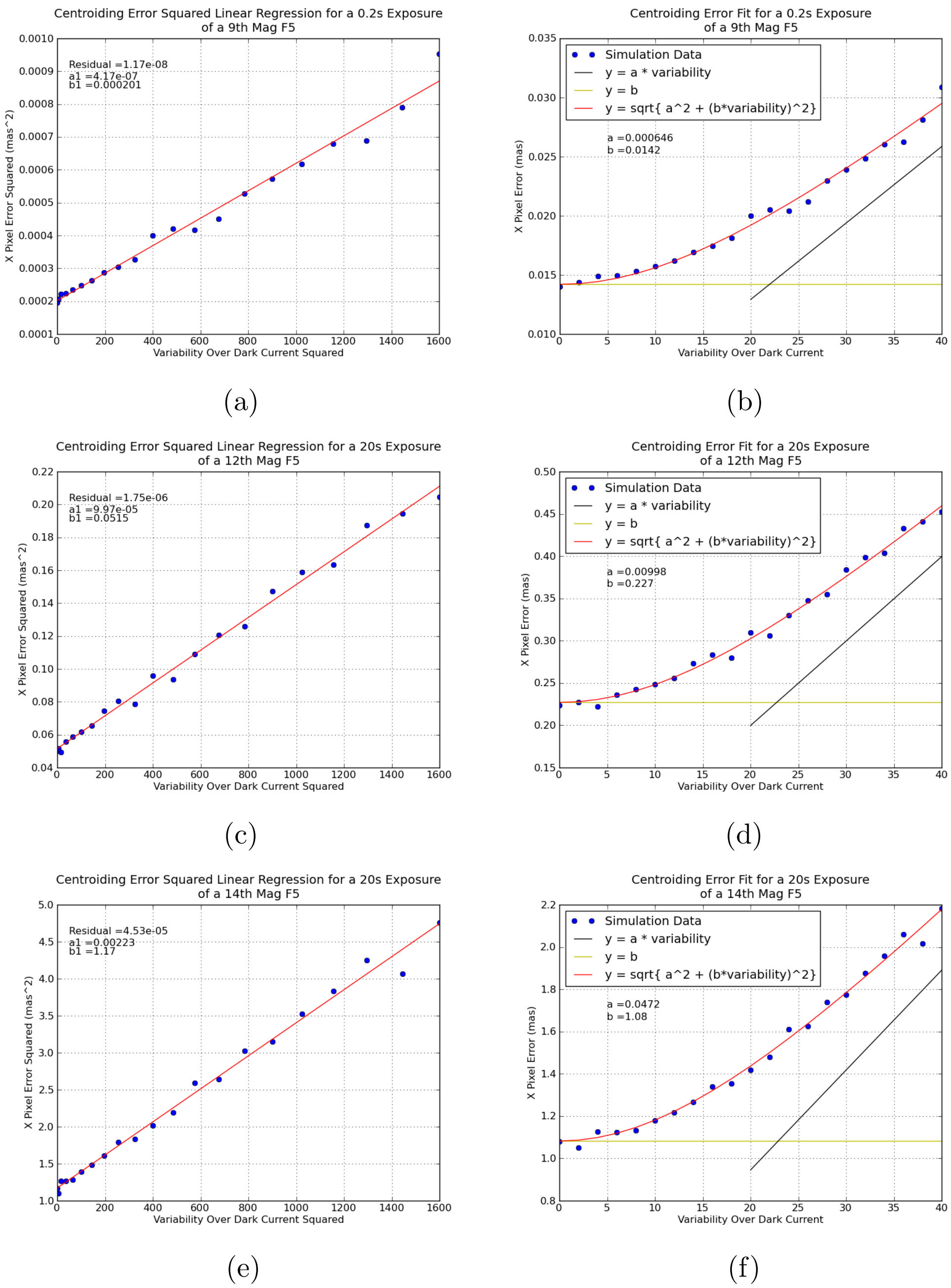
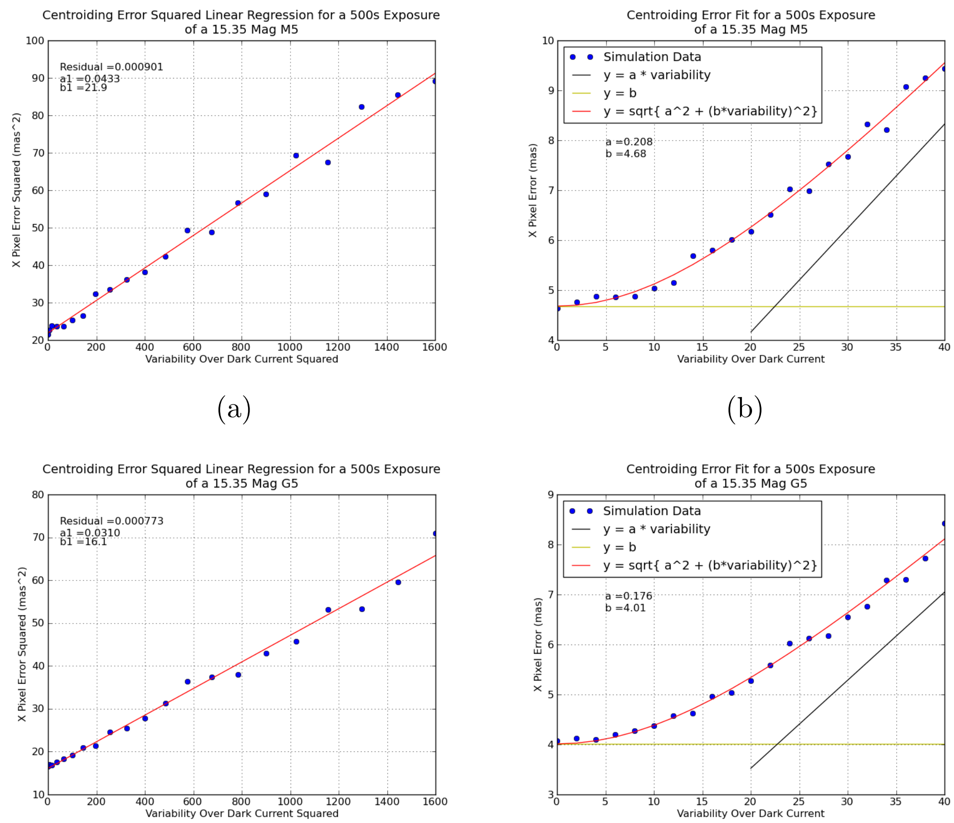


Figure 4: Centroiding Error as a Function of Variability Over the Dark Current for an F5

In Figure 4(a), we show the X centroiding error squared as a function of dark current variability squared, from which we derive the equation fit parameters to use in Figure 4(b) for a 0.2s exposure of a 9^{th} magnitude F5. In Figures 4(b)-(c), we show the same for a 20s exposure of a 12^{th} magnitude F5, and in Figures 4(e)-(f), we show the same for a 20s exposure of a 14th magnitude F5.



(c) (d)

Figure 5: Centroiding Error as a Function of Variability Over the Dark Current for an M5 and a G5

In Figure 5(a), we show the X centroiding error squared as a function of dark current variability squared, from which we derive the equation fit parameters to use in Figure 5(b), for a 500s exposure of a 15.35 magnitude M5. In (c)-(d), we show the same for a 500s exposure of a 15.35 magnitude G5.