Cylindrical approximation to the MMT's focal surface for Binospec

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1 Adopted Cylindrical Approximation

The mask active area is 8 by 15 arcminutes for each Binospec channel. The long direction of the mask is along the Y direction. The optical axis of the telescope is the Z axis, with the positive direction further from the secondary mirror. The cylindrical approximation to the mask bends the mask in a cylinder about the X axis, and tilts the cylinder by 0.72° about the Y axis. The center of the mask is at (X,Y,Z) = (2.214, 0.000, -0.02275). The vertex of the MMT's focal surface is at (0.000, 0.000, 0.000)

Table 1. Summary specifications of slit mask

Parameter	Value
X offset of mask center from optical axis	2.214 inches (56.236 mm)
Z offset of mask center from focal surface vertex (Z along optical axis)	-0.02275 inches (0.578 mm)
Tilt of mask about Y axis	0.72°
Cylindrical radius (curved along Y axis)	166.603 inches (4231.72 mm)
Active area of mask for slitlets	±1.58 inches (40.1 mm) X ±2.96 inches (75.2 mm) Y

With this cylindrical approximation, the worst defocus is 0.0054 inches (0.137 mm). The MMT focal plane scale is ~0.167 mm/arcsecond at f/5.28, so the image diameter corresponding to the worst defocus is 0.026 mm or 0.16 arcseconds. Table 2 shows the difference between the sag of the cylindrical approximation to the actual focal surface. Although the worst defocus can be decreased by 0.001 inch by slightly changing the tilt, we have elected to keep the mask axes perpendicular to the chief ray and collimator axis to keep the mask images symmetric across the mask.

Table 2. Comparison of the cylindrical approximation to the actual focal surface

Comparison of tilted cylindrical approximation to actual MMT spectroscopic focal surface								6/23/2014
All dimensions in inches								
The cylinder approximation is a tipped cylinder (curvature along Y, tipped around Y axis								
Cylinder Approximation to Focal Surface						**Focal Surface Conic**		
Tilt about	**X offset**	**Radius**	**Z offset**	**Conic**		**Radius**	**Conic**	
Y axis (deg)			**(focus)**	**constant**		**of curvature**	**constant**	
0.720	2.214	-166.603	-0.02275	0.000		-134.01575	-665.000	
Tilt in radians								
0.01257								
X	**Y**	**Z cylinder**	**X rot**	**Y rot**	**Z rot**	**R**	**Z conic**	**Difference**
0.6340	0.0000	0.00000	0.6339	0.0000	-0.00289	0.6339	-0.00149	-0.00140
1.4240	0.0000	0.00000	1.4239	0.0000	-0.01282	1.4239	-0.00743	-0.00539
2.2140	0.0000	0.00000	2.2138	0.0000	-0.02275	2.2138	-0.01752	-0.00522
3.0040	0.0000	0.00000	3.0038	0.0000	-0.03267	3.0038	-0.03124	-0.00143
3.7940	0.0000	0.00000	3.7937	0.0000	-0.04260	3.7937	-0.04799	0.00539
0.6340	1.4800	-0.00657	0.6339	1.4800	-0.00946	1.6100	-0.00945	-0.00001
1.4240	1.4800	-0.00657	1.4238	1.4800	-0.01939	2.0537	-0.01517	-0.00423
2.2140	1.4800	-0.00657	2.2137	1.4800	-0.02932	2.6629	-0.02492	-0.00440
3.0040	1.4800	-0.00657	3.0037	1.4800	-0.03925	3.3485	-0.03821	-0.00103
3.7940	1.4800	-0.00657	3.7936	1.4800	-0.04917	4.0721	-0.05451	0.00533
0.6340	2.3680	-0.01683	0.6337	2.3680	-0.01972	2.4513	-0.02130	0.00158
1.4240	2.3860	-0.01709	1.4237	2.3860	-0.02990	2.7785	-0.02700	-0.00291
2.2140	2.3680	-0.01683	2.2136	2.3680	-0.03957	3.2415	-0.03599	-0.00358
3.0040	2.3680	-0.01683	3.0036	2.3680	-0.04950	3.8248	-0.04870	-0.00080
3.7940	2.3680	-0.01683	3.7935	2.3680	-0.05943	4.4719	-0.06435	0.00492
0.6340	2.9600	-0.02630	0.6336	2.9600	-0.02919	3.0271	-0.03170	0.00251
1.4240	2.9600	-0.02630	1.4236	2.9600	-0.03911	3.2845	-0.03688	-0.00223
2.2140	2.9600	-0.02630	2.2135	2.9600	-0.04904	3.6961	-0.04578	-0.00326
3.0040	2.9600	-0.02630	3.0034	2.9600	-0.05897	4.2169	-0.05801	-0.00096
3.7940	2.9600	-0.02630	3.7934	2.9600	-0.06889	4.8116	-0.07313	0.00423
							average diff	-0.00064
							max diff	0.00539
							min diff	-0.00539
							delta diff	0.01078
guide star area (center)								
0.6340	3.8800	-0.04519	0.6334	3.8800	-0.04807	3.9314	-0.05118	0.00310
1.4240	3.8800	-0.04519	1.4233	3.8800	-0.05800	4.1328	-0.05597	-0.00204
2.2140	3.8800	-0.04519	2.2133	3.8800	-0.06793	4.4669	-0.06422	-0.00370
3.0040	3.8800	-0.04519	3.0032	3.8800	-0.07786	4.9065	-0.07564	-0.00221
3.7940	3.8800	-0.04519	3.7931	3.8800	-0.08778	5.4261	-0.08985	0.00207

2 Images from slit mask surfaces

If the best mask images are to be produced by the collimator, we should optimize the mask curvature for the collimator optics, not the telescope optics. Table 2 optimizes the curvature for the telescope optics. However, as we show below, the collimator images with the Table 2

approximation are about as good as optimization for the collimator optics. Therefore we can obtain good mask transmission and good mask imaging.

I used a standalone model of the collimator with a paraxial camera to compare the images from the nominal focal surface and two cylindrical approximations. The stop is on the grating, and the aperture is "float by stop size". One cylindrical approximation is the R=-166.603 inches derived above, and the other is a best-fit for the collimator (not telescope) with R=-210.484 inches. The differences are small enough that the R=-166.603 inches radius cylindrical approximation is adopted. The results are shown in Figure 1 through Figure 3.

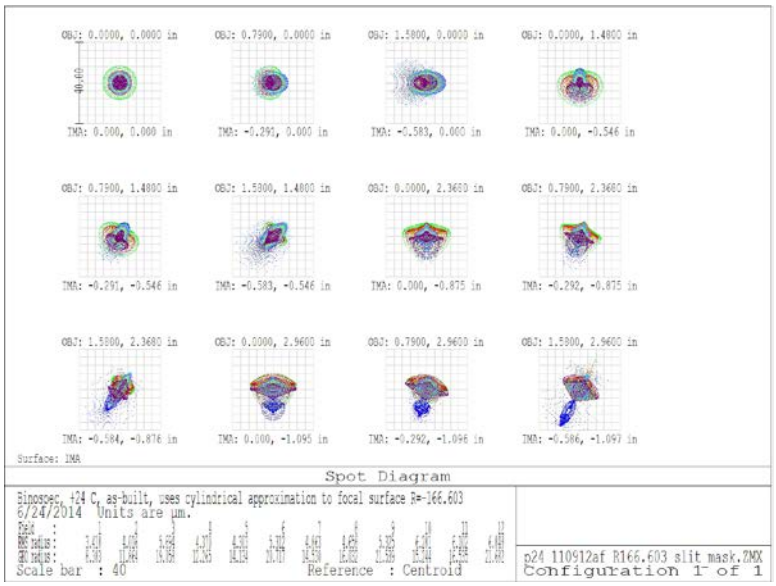

Figure 1. Images from R=-166.603 inch cylindrical approximation to the focal surface. The model uses the collimator with a paraxial camera. The entrance aperture is "float by stop size".

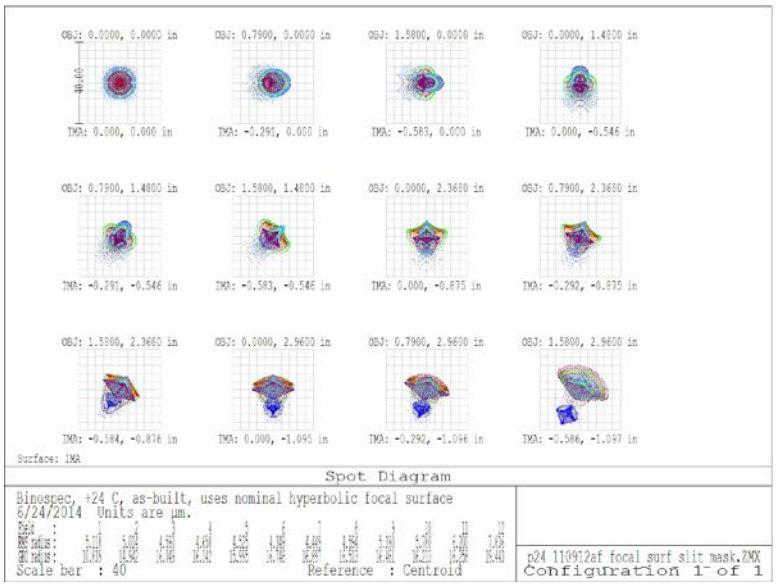

Figure 2. Images from the nominal hyperbolic focal surface. The model uses the collimator with a paraxial camera. The entrance aperture is "float by stop size".

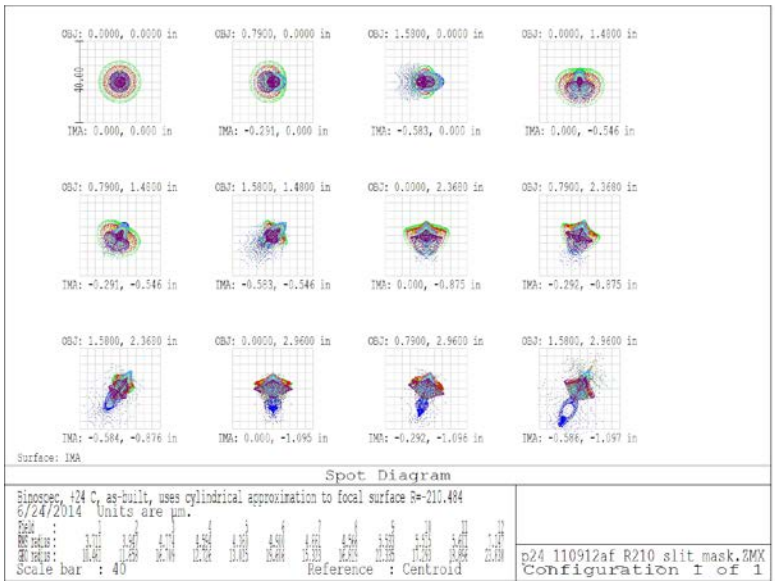

Figure 3. Images from R=-210.484 inch best-fit cylindrical approximation to the focal surface. The model uses the collimator with a paraxial camera. The entrance aperture is "float by stop size".

3 Geometry for cutting slit masks

The adopted mask has R=-166.603 inches and is tilted at 0.72°=0.012566 radians. The mask segments are centered at $(X_c,Y_c)=(\pm 2.214, 0)$ inches. To convert to flat coordinates to cut the slit mask (X_m,Y_m) we apply the following corrections. All trig functions are in radians. The formula for Y simply calculates the length along the arc (θ*R). Both corrections are small.

$$Xm = \frac{(X - Xc)}{\cos(0.012566)} = 1.000079 * (X - Xc)$$

$$Ym = 166.603 * \arcsin(\frac{Y}{166.603})$$