THE ONE METRE INITIATIVE (OMI) AND THE CANADA FRANCE HAWAII TELESCOPE (CFHT) WIDE-FIELD COMPARITIVE CAPABILITIES

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Abstract. The One Metre Initiative (OMI) is a wide-field telescope (5 degrees²) designed to be an extremely efficient imaging platform. The OMI is compared to the CFHT Megacam; Canada's premier wide field instrument in terms of throughput and wide-field imaging performance. The OMI will be the only large étendue (ΩA) instrument in the world offering a seamless (continuous) image due to its monolithic CCD sensor.

1 Introduction

The performance of a wide field imaging telescope has several key parameters that determines its overall performance. These include the field size, aperture, download times, filter change times, CCD imager topology (monolithic vs. mosaic), seeing and telescope overhead (position to position time, etc.). We will show that the OMI can outperform the CFHT for objects brighter than mag=23.5 for a 5 degrees² FOV (r′, s/n = 5). The comparison assumes similar filter transmission, mirror reflectivity and lens transmission. Both the CFHT and the OMI use the u′, g′, r′, i′, z′ filter set. In addition the OMI will employ an ultra wide-band, 420-870 nm filter reaching 0.65 magnitude deeper when compared to the r′ filter, useful for rapid detection when this is the overriding requirement. A monolithic image sensor will give the OMI a distinct advantage when compared to other large étendue telescopes.

2 CFHT

The CFHT Megacam covers a FOV of 0.90 degrees² (0.96º X 0.94º) with a clear aperture of 3.6 meters and a central obstruction of 1.5 meters (17.5% areal obstruction). The CCD imaging array uses thirty-six 2048 x 4612 sensors arranged in a 4 x 9 pattern. The mosaic has 3 X 9 gap grid with 15″/12″ gaps between the sensors with two 85″ connector gaps. Thus a dithering movement is required to fill in the gaps. The download overhead is 40 seconds and filter change times are on the order of 90 seconds. Typically an overlap is required to join the fields (~10%, 0.1deg, 5% per side) for wider area surveys.

3 OMI

The OMI covers a FOV of 4.97 degrees² (2.23º X 2.23º) with a clear aperture 1.016 meters and a central obstruction of 0.42 meters (17% areal obstruction) The CCD image sensor is monolithic with a 10560 x 10580 array, thus no gaps. Download times are on the order of 1.4s and filter change times are smaller than 10 seconds. The OMI has less than 6% vignetting on the extreme edge of the field (corners). The monolithic image sensor offers a much simpler calibration and geometric correction, and removes the need for dithering with more consistent QE throughout the array and 100% fill factor. Although the OMI captures 10X less light per unit time than the CFHT the overall throughput (area/unit time) can be much higher for objects brighter than magnitude 24 due to the CFHT's large overheads. Indeed, due to the OMI's larger FOV it has an extra efficiency gain because a smaller percentage of the image area is committed to overlap.

4 CFHT and OMI Comparison

The CFHT and the OMI key parameters (see Table 1) highlight the important differences. In terms of imaging efficiency, the important overhead differences are download times (40s vs. 1.4s), filter change (90s vs. 10s) and a mosaic array vs. a monolithic sensor. For m<23.5 (r′, s/n=5) the OMI can outperform the CFHT, as shown in Figure 1, for a 5 degrees² FOV. Although the CFHT has over 10X the light gathering capability of the OMI its overheads reduce the efficiency. For dimmer objects, the OMI performs at 30% the rate of the CFHT. For multicolor imaging the CFHT's 90s filter change times are significantly longer than the OMI's change times of 10s as seen in Figure 2. Figure 3 shows the OMI/CFHT relative efficiency for different s/n from magnitude 22 to 26 (r′), the relative efficiency diminishes with larger s/n but tops out at ~35% for a s/n ≥ 10. The OMI is seeing limited, with expected seeing of 1.25″ FWHM. With similar seeing to the CFHT (0.8″ FWHM) the OMI could almost match it even at very faint magnitudes for 5 deegrees² FOV, as can be seen in Figure 1 and 2. The OMI will be located at 400 m altitude and will have a cosmic ray flux ¼[1] that of the CFHT at 4200 m.

Table 1. OMI and CFHT parameters

	CFHT	OMI
Aperture (m)	3.6	1.016
Obstruction (m)	1.5	0.42
Effective Area (m²)	8.4	0.81
FOV (degrees²)	0.90	4.97
Download times (s)	40	1.4
Array topology	4 x 9	monolithic
Filter change time	90	10
Read noise (e-)	4	14
PSF (arcsec/pixel)	0.187	0.76
QE 500 nm (%)	85	94
Dark noise (e-/pix/hr)	~1	~1
Sky Brightness v (mag/arsec²)	21.4	21.82
Seeing (mean FWHM)	0.80	1.25
Altitude (m)	4200	400

Table 2. OMI and CFHT comparative cycle times for 5 deg² FOV for a mag=23, s/n=5 with a filter change

Magnitude r′	CFHT (0.85″)	OMI (1.25″)	Notes
Single Frame Exposure (s)	9.4	123	
Download (s)	40	1.4	
Equivalent FOV (frames)	6	1	For a 5 deg², includes overlap
Move to next frame (s)	5	5	
Filter change (s) (effective)	90 (50)	10 (8.4)	Parallel with download
Total cycle time (s)	376	138	

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[1] Based on data from Steve Kliewer (http://www2.slac.stanford.edu/vvc/cosmicrays/tourstop3.html)

Figure 1. OMI vs. CFHT relative efficiency for a 5 degrees² FOV and varying seeing

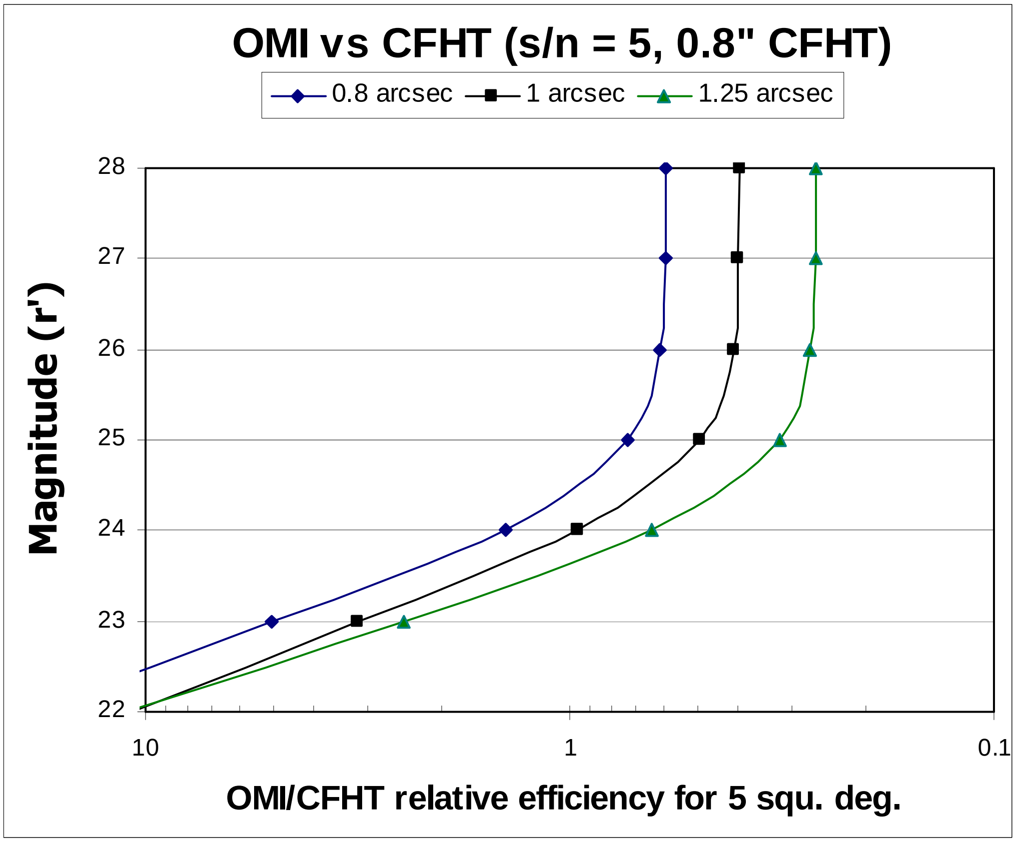


Figure 2. OMI vs. CFHT relative efficiency for a 5 degrees² FOV in g′, r′, i′ with varying seeing

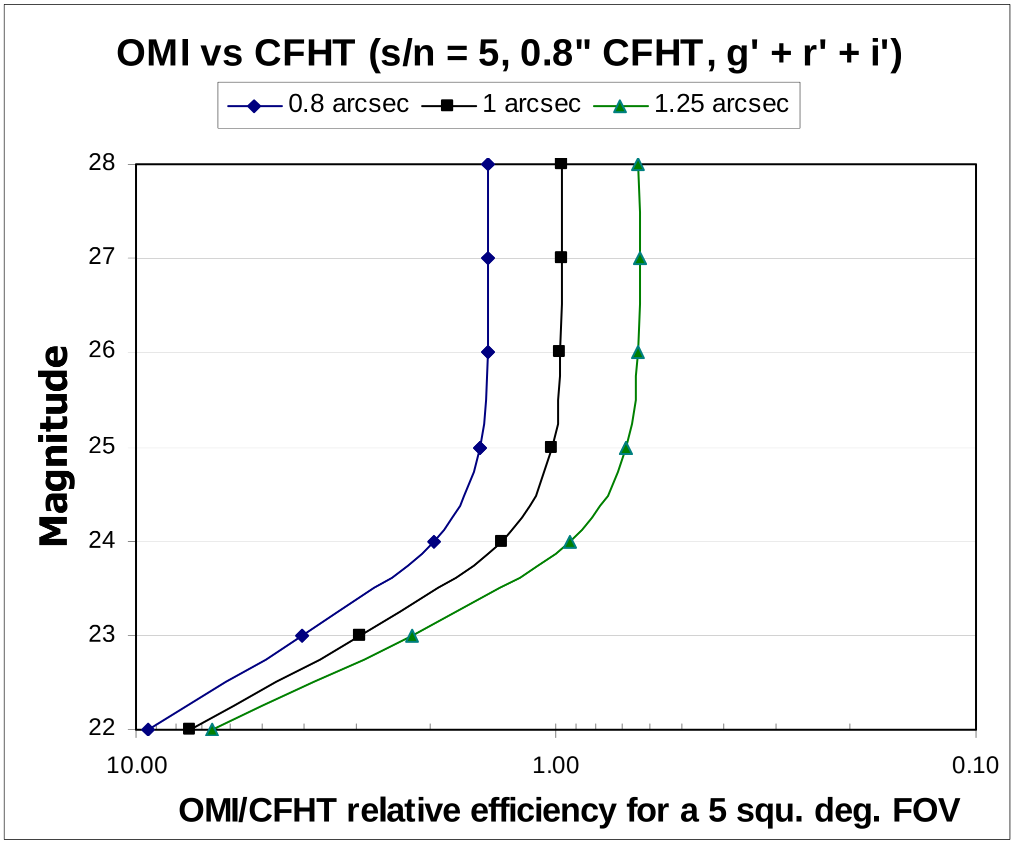
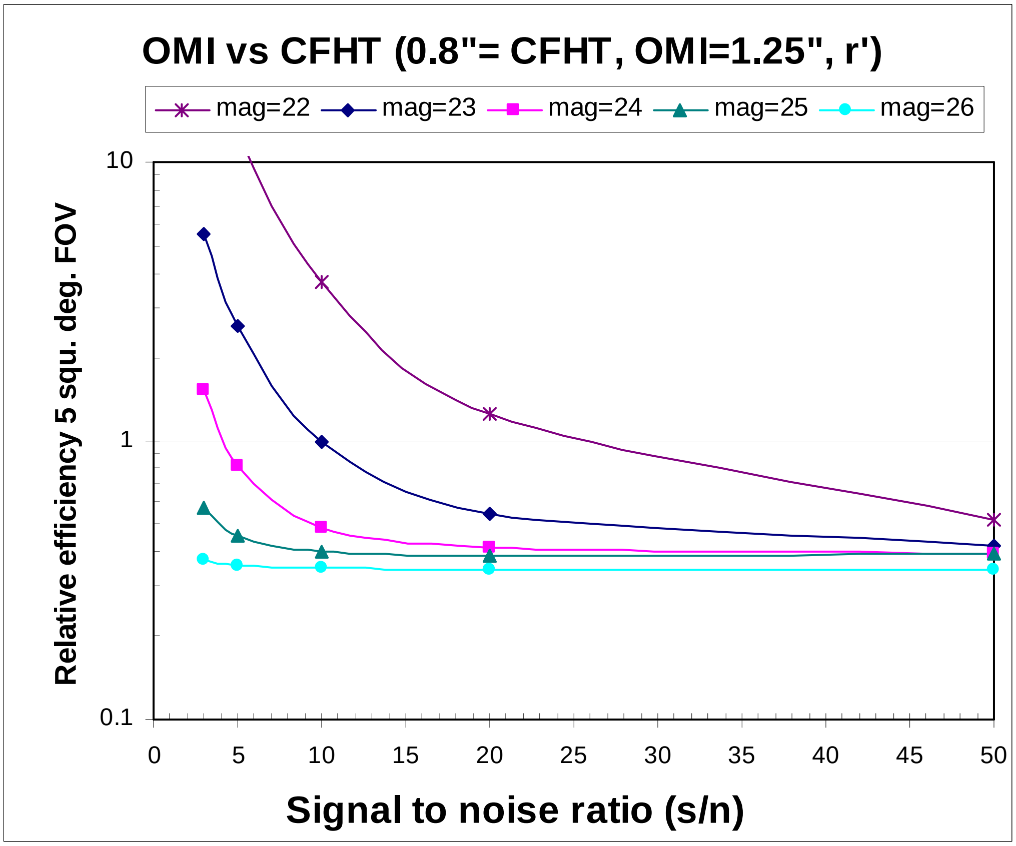


Figure 3. OMI/CFHT relative efficiency for 5 degrees² FOV with for a given s/n and limiting magnitude



5 Sky Coverage

The example given here is centered on M31, m=23 (g′, r′, i′) with a s/n = 5 and a 6º x 6º FOV with 0.2º overlap (0.1º/side) between the fields. The image requires nine OMI frames to accomplish this task which could be achieved in about 1½ hours. Similarly the CFHT would take about four hours for the same field size and require about 54 frames to cover this FOV to assure sufficient overlap between the frames (0.1º); some efficiency is lost in the overlap. Table 3 shows the sky coverage for an 8 hour period for non-overlapping and over-lapping coverage 4.97/4.41 deg² and 0.90/0.49 deg² respectively for the OMI and CFHT.

Table 3. Sky coverage in degrees² comparison for s/n=5 for an 8 hour period, includes download times and overlap (1.25″ OMI and 0.85″ CFHT FWHM) but does not include moving the telescope to the next position

Non-overlapping				Overlapping (0.1º, 0.05º/side)	
Magnitude r′	OMI	CFHT		OMI	CFHT
	(deg²)	(deg²)		(deg²)	(deg²)
22	4800	610		4250	331
23	1300	540		900	294
24	200	350		165	190
25	34	110		27	59
26	4.97	22		4.97	11
27	-	3		-	2

Figure 4. 6º X 6º degrees FOV centered on M31. The OMI would need 1½ hours (9 frames) total in the g', r', i' band (1.25" FWHM) to mag=23 with s/n=5. Similarly the CFHT would take ~4 hours (54 frames) (0.85" FWHM) to image the same size field in the g′, r′, i′

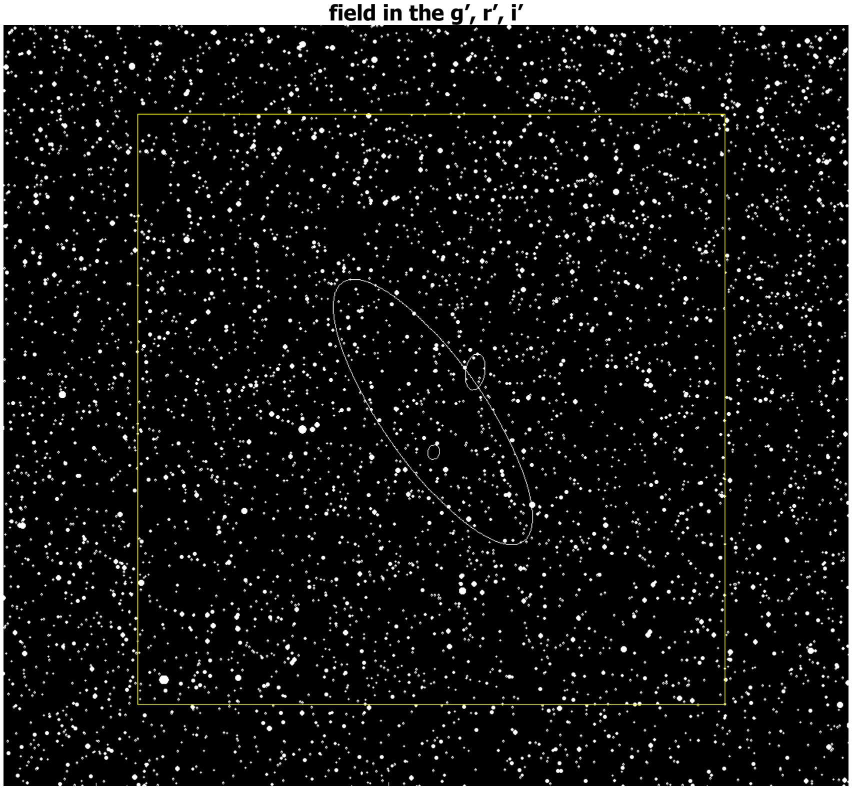
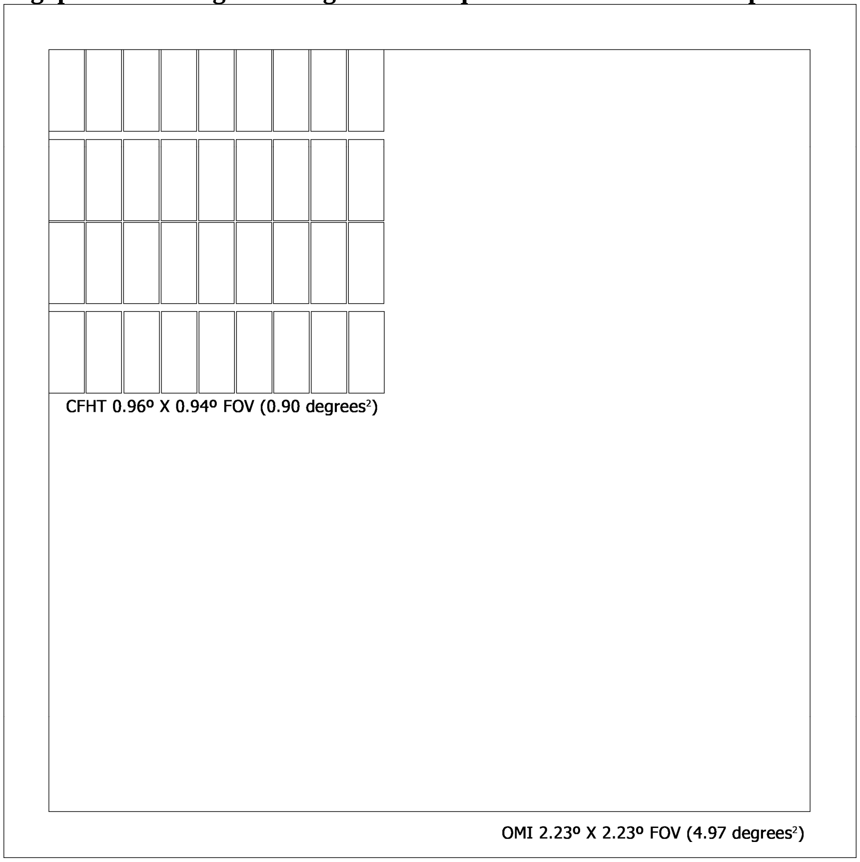


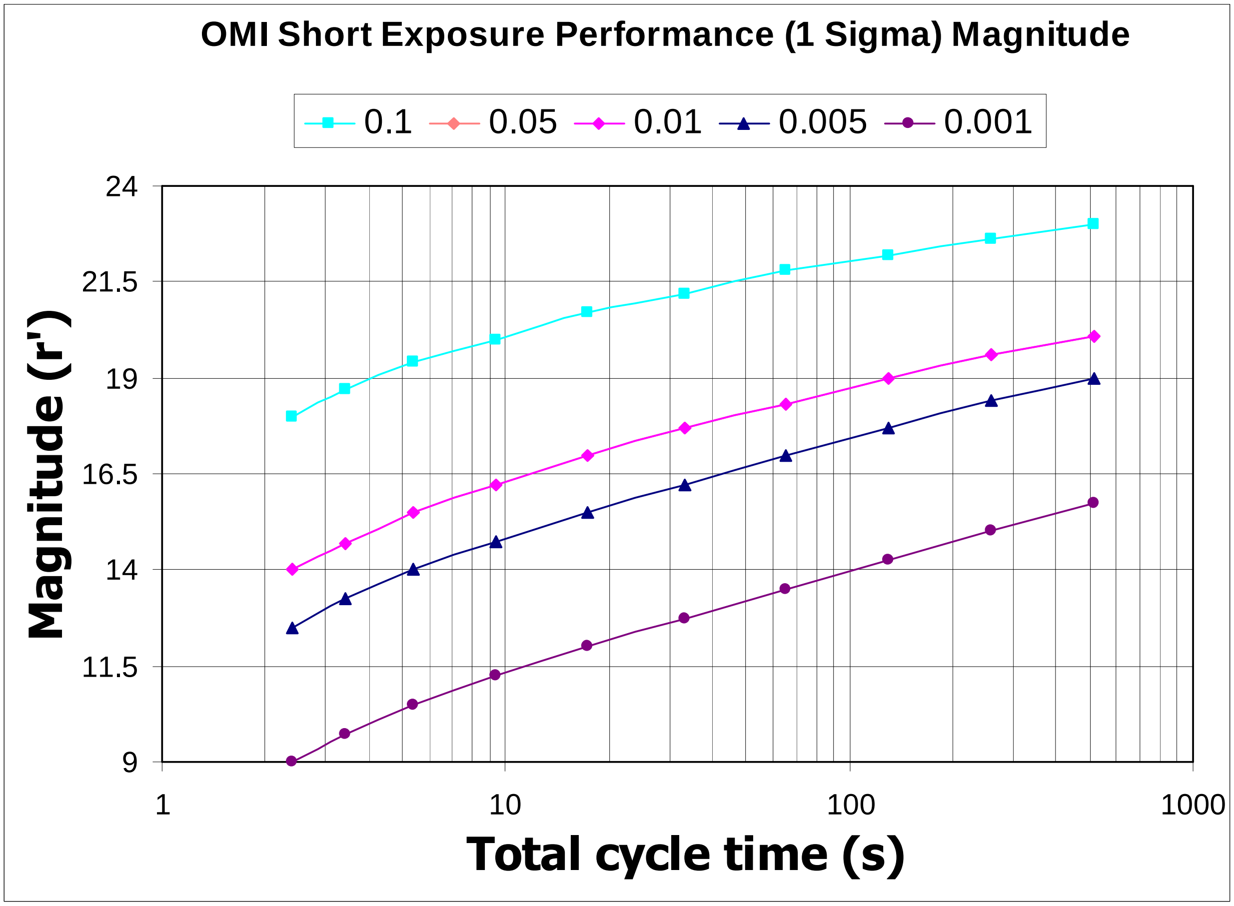
Figure 5. The OMI FOV (4.97 deg²) is 5.5X the CFHT FOV (0.90 deg²). A monolithic sensor offers seamless images and higher yields, i.e. no gaps or dithering. The larger FOV requires less waste in overlap and telescope movements.



6 OMI wide-field rapid frame astronomy

The OMI can download the entire 5 degrees² in less than two seconds. Phenomena such as red dwarf flares, slowly varying pulsars, GRB's and unusual objects could be studied with the OMI. The OMI is capable of short exposure times on the order 0.1 second with an accuracy of 0.3% thus suitable for bright star photometry.

Figure 6. OMI Short exposure performance for 1σ magnitude



7 OMI Monolithic imaging sensor and other advantages

Amongst the large étendue (ΩA) instruments the OMI is the **ONLY** wide-field telescope in the world with a monolithic image sensor, offering continuous coverage and thus no gaps. Table 4 lists some key advantages of the OMI.

Table 4. OMI performance advantages

		Notes
Field of view (degrees²)	5	
Download times (seconds)	<2	
Imager topology	Monolithic	Continuous coverage, no gaps or dithering
Filter change times (seconds)	<10	
Total capital cost ($ USD)	~$2 million	

8 Legacy support etc.

The OMI can support legacy surveys such as the SDSS, CFHT LS, POSSI/II etc. The example given here (CFHT) is simply for a comparative analysis to give a reference point as to the OMI's potential capabilities.

9 Conclusion

Discoveries such as SNe, KBO, NEO, SNe light echo's, Exoplanets etc. are directly related to square degrees per unit time and the depth. The OMI, a more compact and efficient telescope than the CFHT, with its extremely wide field of view, high system efficiency (low total cycle time) can image more square degrees per unit time than the CFHT. The cross-over is about magnitude 23.5 for s/n of 5, after which the CFHT overheads have less effect on efficiency. Even then, the OMI operates at about 30% the throughput of the CFHT. A seamless monolithic FOV offering continuous coverage with no gaps is highly desirable for certain areas of research. In addition the OMI offers the capability to do rapid variation astronomy (transient). The OMI will be a valuable addition to Canada's ability for wide field imaging especially considering the extremely modest total capital investment of ~$2 million USD.

Errata: My previous article (December 2008 #139 issue) omitted the altitude difference of the CFHT. This has now been corrected.