Annual Report on CCD Imaging at the OAN

Alan Watson, Michael Richer,
Arturo Godínez, and Teresa García

August 2004

1 Introduction

This is a report on the state of CCDs, small telescopes, and filter wheels of the OAN. It is based on measurements performed between 23 and 30 August 2004. We have published similar reports every year since 2000 [1, 2, 3, 4].

We are grateful to Francisco Murillo, Benjamín Martínez, Enrique Colorado, and Eduardo López for their help during this run, for their efficiency and good humor in the face of so many instrument changes and, especially, for their efforts to get the Marconi CCD working.

2 Measurements

2.1 CCD Characteristics

We characterized the SITe1, SITe3, Thomson, and Marconi CCDs.

Table 1 shows the gain and read noise for each CCD. We report these figures for both gain modes of the SITe1 and SITe3 CCDs and both amplifiers of the Marconi CCD. We measured read noises and gains using pairs of bias and flat field exposures and the findgain task in IRAF. The read noises are effective read noises, and as such include contributions from amplifier read noise, quantization noise, and spurious charge. Note the anomalously high read noise for the SITe1 in mode 1 when used at 1×1; this appears to be real and repeatable.

Table 2 shows the linearity for each CCD determined from graduated flats.

Table 3 shows the CCD operating temperatures and dark currents (per physical pixel).

Table 4 shops the read times (the time to read a full frame to the CCD control computer) and Table 5 shows the write speed (the speed at which data is transfered from the CCD control computer to the analysis computer).

Table 1: CCD Electronic Characteristics

CCD	Mode	Binning	Gain	Read noise
SITe1	1	1×1	4.97 e^-	33.1 e^-
		2×2		12.7 e^-
		4×4		16.8 e^-
	4	1×1	1.28 e^-	8.8 e^-
		2×2		8.2 e^-
		4×4		13.6 e^-
SITe3	1	1×1	5.00 e^-	9.8 e^-
		2×2		16.6 e^-
		4×4		27.8 e^-
	4	1×1	1.19 e^-	11.0 e^-
		2×2		15.3 e^-
		4×4		25.8 e^-
Thomson	1	1×1	1.97 e^-	7.7 e^-
		2×2		6.8 e^-
		4×4		7.9 e^-
	4	1×1	0.51 e^-	4.9 e^-
		2×2		5.7 e^-
		4×4		6.8 e^-
Marconi	left	1×1	1.73 e^-	4.4 e^-
		2×2		5.3 e^-
		4×4		8.0 e^-
	right	1×1	1.80 e^-	4.5 e^-
		2×2		5.3 e^-
		4×4		7.9 e^-

Table 2: CCD Linearity

CCD	Mode	Non-linearity
SITe1	1	$< 1\%$
	4	$< 1\%$
SITe3	1	$< 1\%$
	4	$< 1\%$
Thomson	1	3%
	4	$< 1\%$
Marconi	left	$< 1\%$ below 55k; $> 1\%$ above 55k
	right	$< 1\%$ below 60k

Table 3: CCD Operating Temperatures and Dark Currents

CCD	Temperature	Dark Current
SITe1	-88 C to -84 C	8.1 $e^-/$h
SITe3	-97 C	1.3 $e^-/$h
Thomson	-93 C	?.? $e^-/$h
Marconi	-120 C	?.? $e^-/$h

Table 4: CCD Read Times

CCD	Gain mode	Binning	Read Time
SITe1	1	1×1	10 s
		2×2	5 s
		4×4	5 s
	4	1×1	17 s
		2×2	7 s
		4×4	5 s
SITe3	1	1×1	32 s
		2×2	12 s
		4×4	6 s
	4	1×1	59 s
		2×2	18 s
		4×4	8 s
Thomson	1	1×1	116 s
		2×2	36 s
		4×4	15 s
	4	1×1	220 s
		2×2	62 s
		4×4	22 s
Marconi	left	1×1	14 s
		2×2	7 s
		4×4	? s
	right	1×1	14 s
		2×2	7 s
		4×4	? s

Table 5: CCD Write Speeds

Controller	Telescope	Write speed
PMIS	84-cm	4.0 MB/s
PMIS	1.5-m	0.5 MB/s
Voodoo	1.5-m	>2.0 MB/s

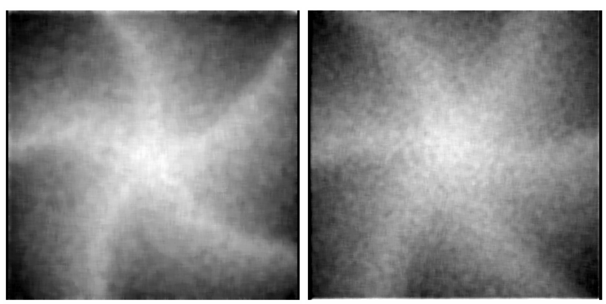

Figure 1: The shutter errors for the SITe1 (left) and Marconi (right).

Table 6: CCD Shutter Errors

CCD	Telescope	Center	Corner
SITe1	84-cm	55 ms	35 ms
	1.5-m	30 ms	0 ms
SITe3	84-cm	80 ms	50 ms
Marconi	1.5-m	20 ms	0 ms

2.2 Shutter Errors

Figure 1 and Table 6 show the shutter error (the additional exposure time above that requested) for the SITe1 and Marconi. These were calculated by comparing a single n-second flat-field exposure with n 1-second flat-field exposures. The pattern of the SITe3 are similar to that of the SITe1.

The variations are as expected for five- and six-bladed iris shutters with travel times of 10–15 ms. However, in the case of the SITe1 and SITe3 at the 84-cm there are significant pedestals of 35 and 50 ms, which are presumably the result of time errors on the part of the CCD control system. These pedestals do not appear to be present at the 1.5-m, although we do not have complete data.

2.3 Fringes

Figure 2 and Table 7 show long exposures in I (unfortunately, at full moon) taken to investigate fringing. The fringes are 1% peak-to-valley in the SITe3 and about 3% peak-to-valley in I in the Marconi.

The SITe1 shows no evidence for fringing in I.

In previous years we have determined that the Thomson suffers from severe fringing in I and in narrowband filters longward of 6000 Å and moderate fringing in R.

2.4 Zero Points

Table 8 shows the zero points for various broadband and narrowband filters. For broadband filters the zero point is the number of electrons per second expected from a star with a Vega-mag of 0 at 1 airmass. For the narrowband filters, the zero point is the number of electrons per second expected for a star with an AB-mag of 0 at 1 airmass.

The zero points for the Thomson on the 84-cm were actually measured with Sophia and the $UBVRI1$ fitlers, but have been scaled to no focal reducer and the $UBVRI3$ filters using the ratio of the SITe3 zero-points in these configurations.

2.5 Sky Brightnesses

Table 9 shows the sky brightnesses at 3 days past quarter moon (for the Mexman filters).

2.6 Transmissions

Table 10 shows the transmissions of the focal reducers and Ruca polarizing filters in $UBVRI$. The transmittances of the polarizing filters were measured using an unpolarized standard.

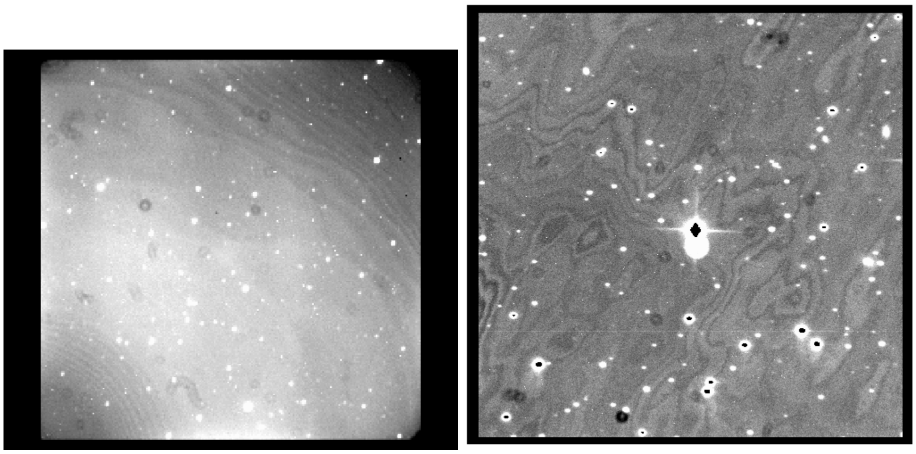

Figure 2: Deep I image with the SITe3 (left) and Marconi (right).

Table 7: CCD Fringe Peak-to-Valley Amplitude in I

CCD	Amplitude
SITe1	0%
SITe3	1%
Marconi	3%

Table 8: Zero Points

Telescope	Filter	SITe1	SITe3	Thomson	Marconi
84-cm	$U3$	2.57×10^8	2.01×10^8	1.36×10^8	
	$B3$	1.20×10^9	8.49×10^8	1.40×10^9	
	$V3$	1.61×10^9	1.45×10^9	1.54×10^9	
	$R3$	1.52×10^9	1.44×10^9	1.39×10^9	
	$I3$	1.28×10^9	1.29×10^9	9.06×10^8	
	3727	1.71×10^7	1.28×10^7		
	5007	9.31×10^7	8.27×10^7		
	6563	1.59×10^7	1.53×10^7		
	6726	7.88×10^7	7.56×10^7		
1.5-m	$U2$	5.98×10^8	4.83×10^8		1.06×10^9
	$B2$	2.19×10^9	1.68×10^9		4.05×10^9
	$V2$	3.60×10^9	3.28×10^9		4.18×10^9
	$R2$	4.43×10^9	4.31×10^9		4.57×10^9
	$I2$	3.54×10^9	3.62×10^9		3.06×10^9
	II 3727	9.62×10^7	7.20×10^7		2.32×10^8
	II 4363	2.31×10^7	1.59×10^7		4.24×10^8
	II 4861	2.65×10^8	2.06×10^7		3.22×10^8
	II 5007	3.03×10^8	2.66×10^8		3.50×10^8
	II 5876	3.39×10^8	3.16×10^8		3.66×10^8
	II 6563	3.29×10^7	3.36×10^7		3.43×10^7
	II 6730	3.52×10^8	3.31×10^8		3.45×10^8
	I 9069	4.00×10^7	4.19×10^7		2.89×10^7

Table 9: Sky Brightnesses

Filter	Sky Brightness^a
$U3$	19.7^b
$B3$	20.1^b
$V3$	20.0^b
$R3$	20.0^b
$I3$	18.7^b
3727	20.8^c
5007	20.3^c
6563	20.1^c
6726	20.3^c

^{a} mag arcsec^2
^{b} Vega mag
^{c} AB mag

2.7 Sophia

Sophia is a renovated focal reducer for the 84-cm and 2.1-m[6].

The magnification is about $\times 2.35$. The scale changes radially by about 2% from the center to the edge of the field. We did not notice evidence for significant aberrations.

The field diameter at 50% vignetting is about 13.5 arcmin, and outside this the vignetting becomes very severe. The unvignetted region is only about 4 arcmin in diameter.

There appears to be some sort of a ghost in the center of the field, but its effect on sky flats is only 1–2%.

The transmission is awful in U (10%), poor in B and I (44% and 55%), and acceptable in V and R (69% and 75%).

Using night-sky flats and correcting for geometric distortion, we were able to obtain photometry in V with a scatter of 0.01–0.02 mag over the whole field. Night sky flats are quite feasible; a 90-second exposure with the SITe3 CCD in VRI at full moon gives about 10,000 e^-/pixel.

However, when observing a bright PN in the wider 5007 filter of series I, we noticed a 15% difference from the center to the edge. This might be the result of vignetting of the converging beam on the filter bandpass.

3 Comments

3.1 Telescope Reflectivities

The 1.5-m is slightly better than in 2002, with the zero-points being about 15% higher in U and and marginally higher in $BVRI$. It is in much better state than in 2001, with the zero-points being 50% higher in U, 30% higher in B, and 20% higher in VRI. A similar pattern is seen at the 84-cm. Both telescopes have fresh coatings for the tests two years ago, had year-old coatings last year, and had fresh coatings this year.

These measurements are in agreement what we have learned in previous years. The combined reflectivity drops by about 20% in the red and 50% in the blue over the course of a year.

3.2 SITe1 and SITe3 CCDs

The anomalously high read noise of 30 about e^- the SITe1 in gain mode 1 when binned 1×1 is worrying, and is perplexing given that the read noise is normal when binned 2×2 and 4×4.

Other than that, there is little new to report here. Both CCDs are good, although the SITe1 is slightly better in U (more efficient) and I (no detectable fringing).

3.3 Thomson CCD

Just about the only niche for the Thomson is in B and V. It has poor QE in U and fringes badly in R and I. Mode 1 is non-linear.

3.4 Marconi CCD

We spent several nights becoming familiar with the new Marconi CCD. We confirm the high efficiency in the U and B compared to the other CCDs (see Figure 3), low read-noise, and good linearity. The only problem is the tendency to fringe in I.

The Marconi is driven by the Voodoo software rather than PMIS. After some problems, we managed to figure out a relatively efficient modus operandi. This is documented separately[5].

The Marconi can currently be mounted only on the Ruca. The guider at the 1.5 meter is centered and focused at RA = 52, Dec = 29, and focus = 3360.

The Marconi has two output amplifiers and can be read using either or both. To simplify reductions, we recommend reading with only one, and we have configured the software to use the right amplifier only by default.

We tried to measure the dark current from six half-hour dark exposures. However, the resulting mean dark image is dominated by small changes in the bias structure at the level of $\pm$2 DN. Any contribution from the dark appears to be less than a few e^{-}/pix/h.

3.5 Shutter Errors

These shutter errors have important implications for standard stars. If you place a star at the center of the CCD and ask for a 1 second exposure, you will actually take a 1.055 second exposure with the SITe1 at the 84-cm, a 1.080 second exposure with the SITe3 at the 84-cm, a 1.030 second exposure with the SITe3 at the 1.5-m, and a 1.020 second exposure with the Marconi at the 84-cm. Thus, your photometry will be systematically wrong by 5.5%, 8%, 3%, and 2%.

To get 1% photometry, we recommend taking standard star exposures that are no shorter than 10 seconds at the 84-cm and 3 seconds at the 1.5-m. Indeed, it may well be worth deriving the shutter shading on each run; simply compare the difference between a single 10-second dome flat and ten 1-second dome flats.

3.6 Sophia

Sophia appears to be quite capable of accurate broad-band photometry over large fields, but narrowband photometry appears to suffer large errors.

Table 10: Transmissions

	U	B	V	R	I
Focal Reducers					
Ruca – blue	0.79	0.83	0.86	0.86	0.86
Ruca – red	0.42	0.72	0.81	0.82	0.82
Sophia	0.088	0.44	0.69	0.75	0.55
Polarizing Filters					
Ruca	0.22	0.28	0.28	0.22	0.37

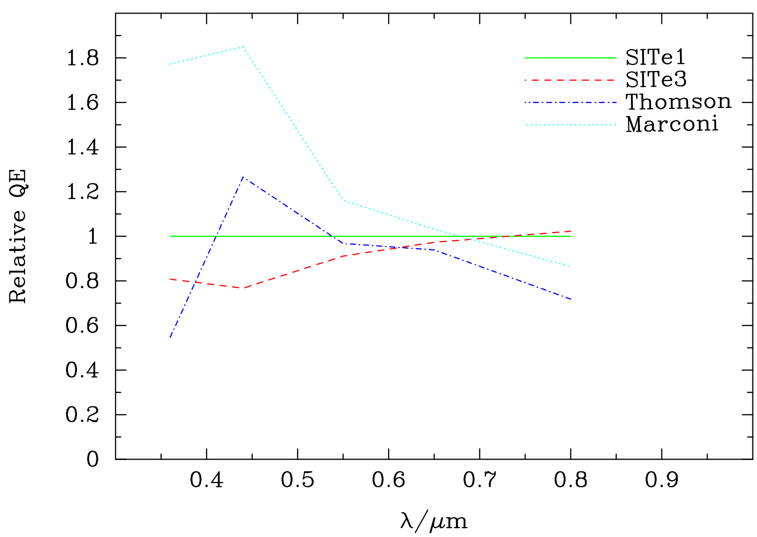

Figure 3: Relative QE of the SITe1, SITe3, Thomson, and Marconi CCDs.

References

[1] "Reporte de la temporada de ingeniería del 13-18 de septiembre de 2000", Michael Richer, Alan Watson & Henri Plana, 20 September 2000.

[2] "Las respuestas fotométricas de los CCDs", Michael Richer & Alan Watson, 11 February 2002.

[3] "Reporte de caracterización de los CCDs y de los telescopios de 1.5m y 84cm", Michael Richer, Alan Watson, Simon Kemp, & Sandra Ayala, 9 January 2003.

[4] "Reporte de caracterización de los CCDs y de los telescopios de 1.5m y 84cm", Sandra Ayala, Michael Richer, Alan Watson, & Simon Kemp, 6 January 2004.

[5] "Operating the Marconi CCD", Alan Watson, Enrique Colorado, Michael Richer, Teresa García, & Arturo Godínez.

[6] "Sophia: Sistema Óptico Para Hacer Imágenes de campo Amplio", E. Colorado, F. Quiroz, J.M. Muriilo, A. Córdova, J. Valdez, L. Gutiérrez, M.A. Moreno, & E. Luna.