

# LATEST NEWS ON INSTRUMENTATION

## Multi-Object Spectrography

As everyone inside CFHT knows, this is one of the three main present development areas suggested by SAC, one of the so-called three legs.

As an interim development, a contract has been issued with B. Fort, Observatoire de Toulouse, for an upgrading of the Observatoire de Marseille focal reducer. It will be commissioned in early May in the PUMA mode, and is expected in general use by September 1st. Inter alia, this means a lot of software development for the CFHT relevant group.

Concerning the new generation M.O.S., a number of early milestones have been reached:

- October 1st — Detailed Specifications sent by CFH
- November 1st — Letters of Intent received from the prospective builders:

*"A very faint Object Spectrograph with multi slit capability for the prime focus of CFHT".*

L. Vigroux and G. Lemaître.

*"Proposition Française pour le M.O.S."*

Y. Georgelin.

*"Canadian Letter of Intent"*

D. Crampton.

- November 18th, 19th — Group of Experts meeting in Waimea (D. Crampton, Y. Georgelin, A. Stockton, G. Monnet, D. Salmon).

A bi-national development of the Instrument has been decided, with D. Crampton as Principal Investigator and Y. Georgelin as Co-P.I. The general concept is that of a folded mounting incorporating an easily accessible central hole for modular field environments, a multi-object spectrograph (MOS) on one side, a sub arc second imaging spectrograph (SIS) on the other side. End of the feasibility study is scheduled for February 1st and it is expected that a formal contract could be issued soon after.

In parallel a French group (G. Lemaître, J.P. Picat, L. Vigroux) is looking at a YAG laser drilling machine for the making of optical quality PUMA masks. A final offer will be in hand soon.

## CFHT CCD's

At this time, six CCD's have been commissioned for astronomical use (see Table 1). The highlights of the CCD development include:

- improved performance of RCA3 for the UV Prime Spectrograph
- acquisition of a 'flat' double density RCA chip, RCA4, which is still bonded to its support glass
- acquisition of two commercially available (Texas Instruments and Thomson) low noise CCD's
- commissioning of the UV coated TH1 with optimum preflash procedures.

The expected quantum efficiencies are listed in Table 1.

device name	array size	pixel ( $\mu$ )	area mm	noise electrons	qe			Note
					400nm	500nm	700nm	
RCA1	320x512	30	9.8x15.6	78	50	75	70	UBC dewar
RCA2	640x1024	15	9.8x15.6	45	60	93	70	rms surface $\pm 35\mu\text{m}$
RCA3	320x512	30	9.8x15.6	50	50	75	70	mini cryostat (UV)
RCA4	640x1024	15	9.8x15.6	55	50	75	70	flat, glass support
TH1	384x576	23	8.8x13.2	12	25?	30	45	special preflash
VTI1	390x584	22	8.6x12.8	12	40	45	55	many 'traps'

At the summit, the CCD's are controlled by the HP1000F computers with a new display, the IVAS (from International Imaging Systems), which provides 1024x1024 resolution. A major project is now in progress to upgrade the Data Acquisition Computers as well as to provide a preprocessing environment for the observer. The new computers will include standard architecture, networking, window environments and operating systems, which have a great potential for growth and flexible use.

The Waimea Data Reduction Facility provides an environment for full pre-processing of CCD data and auxiliary evaluation of engineering and commissioning data for each device. Most of the processing is done with the IRAF version 2.5, which includes the 'CCDRED' package from NOAO as well as procedures developed in house. Each CCD is commissioned on the telescope with a 1-3 night observing run in which the performance of the device in the observing environment (cabling, software, etc.) is examined. Standard fields are observed to derive 'typical' calibration coefficients. The commissioning data is pre-processed in the nominal way, and the data are examined to test for unusual processing problems or spurious effects. Nominal calibration coefficients are presented in Table 2. This table contains the extinction coefficient,  $\alpha$ , a color term,  $\beta$ , and the zero point,  $\gamma$ , which is defined as the magnitude corresponding to a detected flux of 1 electron/second at the detector for an object with color = 0.0 observed at an airmass = 1.0. Each coefficient can change from night to night and run to run, where it is anticipated that the color term should be the most stable. However, these coefficients also will vary depending upon the number, quality and type of standards observed due to external errors in the standards photometry. Typically the internal measuring errors are less than 0.02 mag.

By far, the RCA4 coefficients appear the most reliable, as they were determined during an excellent 3 night run. The  $\sigma$ 's given are for a typical calibration solution. Notice that the B filter exhibits a strong color term for each chip. This is primarily due to the mismatch of the B filter to the 'standard' system. The filters themselves are degrading and a new set including a better B filter has been ordered from Barr Associates. Note that the V, R and I zero points do not differ significantly in relative QE. Unfortunately engineering data in the blue is nonexistent for RCA2, but there is some marginal evidence that the U and

B response of RCA2 is slightly better than for RCA4. As is seen in Table 2, the calibrations are still not complete.

**Table 2: Extinction and Transformation Coefficients for CFHT CCD's.**

Coeff.	RCA1 F/8	RCA1 F/4	RCA2 F/8	RCA2 F/4	RCA4 F/4	VT11 F/4	TH1 F/4
elect/ADCU	28.6	28.6	11.6	11.6	5.7	2.9	7
Rn \ elect	75	75	51	51	61	13	14
$\alpha_u$	0.26				0.35	0.15	0.25
$\beta_u$	0.12				0.03	0.15	-0.20
$\gamma_u$	23.43				22.93	22.05	22.90
$\alpha_b$	0.15	0.17			0.20	0.14	0.19
$\beta_b$	0.21	0.21			0.20	0.25	0.22
$\gamma_b$	26.18	26.05	26.2		26.09	25.50	25.15
$\alpha_v$	0.11	0.13	0.12		0.13	0.09	0.13
$\beta_v$	-0.05	-0.06	-0.04*		-0.02	-0.04	-0.03
$\gamma_v$	26.00	25.85	25.90		25.90	25.25	25.30
$\alpha_r$				0.04	0.09	0.05	
$\beta_r$				-0.11*	-0.04	-0.08	
$\gamma_r$				25.72	25.68	25.47	
$\alpha_i$	0.04	0.03	0.04		0.08	0.01	
$\beta_i$	-0.01	-0.02	0.00		-0.08	-0.05	
$\gamma_i$	24.95	24.94	25.10		25.10	24.50	
$\sigma$	0.02	0.02	0.03	0.03		0.06	0.04

M[std] = -2.5 log [counts (elect/sec)] -  $\alpha * \chi + \beta * color + \gamma$

U color term in (U-B)  
 B color term in (B-V)  
 V color term in (B-V)  
 R color term in (V-R)  
 I color term in (V-I)  
 \*V color term in (V-I)  
 \*R color term in (R-I)

So, to quote a famous phrase, "Which chip IS right for you?" The RCA1 chip, with 30mm pixels has been superceded by the two double density RCA CCD's, RCA2 and RCA4. The double density CCD's have 15  $\mu$ m pixels, and offer the same sky coverage as RCA1 but at twice the resolution. RCA2 was acquired from the manufacturer during the final months of CCD production at RCA. The support glass was removed from RCA2, and an anti-reflection coating was applied in an attempt to improve the blue response. However, the gain in QE is small. The chip has a 'wrinkled' appearance caused by the relaxation of the thin silicon wafer after the removal of the support glass. The ripple produces a variation in the focus across the chip which is most noticeable at F/2, and can be detected at F/4 (Prime Focus) in good seeing. At F/8 the variation is seen only in exquisite seeing. RCA2 offers a slight advantage over RCA4 in that it is less susceptible to fringing and has a slightly lower read noise. RCA4 is flat and fringing is most noticeable in one corner of the device, however the level is low there (<5%). Care must be taken with either CCD to obtain adequate frames for fringing removal in the R and I bandpasses. Both chips require a small preflash (300 electrons) to overcome the charge skimming problem inherent in the double density architecture. The chips have very high QE in the B through R bandpasses, have excellent transfer efficiency and large full well capacity (110,000 electrons per pixel). Note that the full well capacity of the serial ('horizontal') register is in excess of 500,000 electrons, so binning in a variety of configurations is possible.

For broad band imaging work, the RCA CCD's have no competition. The QE is high, and the sky brightness easily dominates the read noise. Programs that require a non-variable PSF across the field are best accomplished with RCA4. Applications where a field small in angular diameter is being studied, with susceptibility to slight fringing effects are better done with RCA2. Any project done in a fast beam (eg.,

spectroscopy with the Herzberg Spectrograph) requires RCA4 if the flux is sufficient.

The lack of commercially available low noise CCD's has a serious impact on projects involving low flux levels such as faint object spectroscopy and extremely narrow band imaging. Two CCD's were acquired: a virtual phase Texas Instruments' CCD, VT11, and a Thomson CCD, TH1. Both chips are thick: the type of chip available now since thinning processes greatly reduce yield. VT11 is very uniform in response, with low noise and ease of use. However the chip has 100 or more 'traps' scattered randomly across its face. Each trap is followed by a number of pixels depleted in charge. The number of pixels and amount of depletion vary across the chip and are non-linear functions of exposure time and exposure level. Although it is possible to use the device for some programs, the pre-processing is not straightforward and therefore the chip will be decommissioned.

TH1 has been coated with a UV enhancing film to improve the QE in the blue. This coating is extremely thin (a few angstroms) and provides excellent image quality in the blue, where before the coating was applied the chip was essentially 'dead'. The chip requires a complex, double preflash that was incorporated into the software in October, making the procedure transparent to the user. The read noise, with preflash, is 14 electrons. The CCD pixels are larger (22  $\mu$ m) than RCA2 or RCA4 pixels, and the device covers less area on the sky. The chip is suitable for low noise applications, but it must be kept in mind for the expected signal-to-noise ratio that the quantum efficiencies of thick chips are much lower than for the RCA devices.

The RCA3 CCD is a device devoted to spectroscopy with the UV Prime spectrograph. The dewar is a 'mini-cryostat' from CEA that fits in the beam of the instrument. The CCD is now controlled through the CCD interface unit (from Photometrics) by the HP1000 software. The implementation of this chip by coupling the CFHT equipment to the CEA camera head is an important step in providing new devices to the CFH astronomical community.

The future development of the CCD program will be to continue the commissioning of CCD's with large format and improved performance, as the devices become commercially available. The laboratory test facilities allow us to commission such devices, fully optimized, in a short period of time. As mentioned above, improvements to the summit observing environment are in progress and this system will favorably impact the CCD observers. The revised CFHT CCD User's manual is available to scheduled observers and can be made available on request from the support astronomer.

C. Christian

## Imagerie par segmentation pupillaire à F/8

L'analyse des résultats obtenus avec l'expérience préliminaire installée au foyer coudé a été poursuivie (voir bulletin No. 17). Ils ont fait l'objet de deux présentations, d'une part au 27<sup>ème</sup> colloque d'astrophysique de Liège "Observational astrophysics with high precision data" et d'autre part à l'école d'été de Santa Cruz, "Instrumentation for ground-based optical astronomy." En outre un article a été accepté par Astronomy and Astrophysics.