First Light of AquEYE

This report covers the activity carried out from the 20th to the 28th of June 2007, at the 182cm telescope of Asiago Cima Ekar by a team composed by Claudia Facchinetti, Enrico Giro, Giampiero Naletto, Tommaso Occhipinti, Enrico Verroi, Paolo Zoccarato.
Great technical help was provided by Venerio Chiomento, Gigi Lessio and Luciano Traverso.
Wojciech Makowiecki (a guest from Krakow University, Poland) put its informatics skill at our disposal for several conversions from Linux to Windows and viceversa.

After calibration in the optical laboratory, Aqueye was brought to the 182cm of Cima Ekar the 20th of June, 2007. It was mounted on the AFOSC spectrograph (still on the floor), and its entrance pinhole (3 arcsec diameter) aligned with the optical axis by using the AFOSC CCD camera as intermediate reference (see Figure 1).

Figure 1 - Left: Giampiero Naletto, Gigi Lessio and Enrico Verroi ponder on the situation. Right: Enrico Giro kisses goodbye to his beloved exit lens of AFOSC.

Finally, AFOSC + AqueEYE were mounted at the telescope (see Figure 2). It was a surprisingly easy operation.

Figure 2 - AFOSC + AquEYE mounted at the telescope.

As with any other instrument we built, at least one mistake had to be done: AquEYE was supposed to be mounted at 45° from the orientation seen in
Figure 2! The correct orientation had been determined both for mechanical reasons of clearance below the main mirror cell and for optical (and more important) considerations: at 45°, the spiders of the secondary mirror support would nicely be aligned with the edges of the inner pyramid. It was decided not to correct that mistake in this occasion, due to the essentially engineering nature of the run (the telescope itself was in the course of a major overhauling of the control system).
The following night (summer solstice!) the first stars were acquired see (Figure 3, Figure 4).

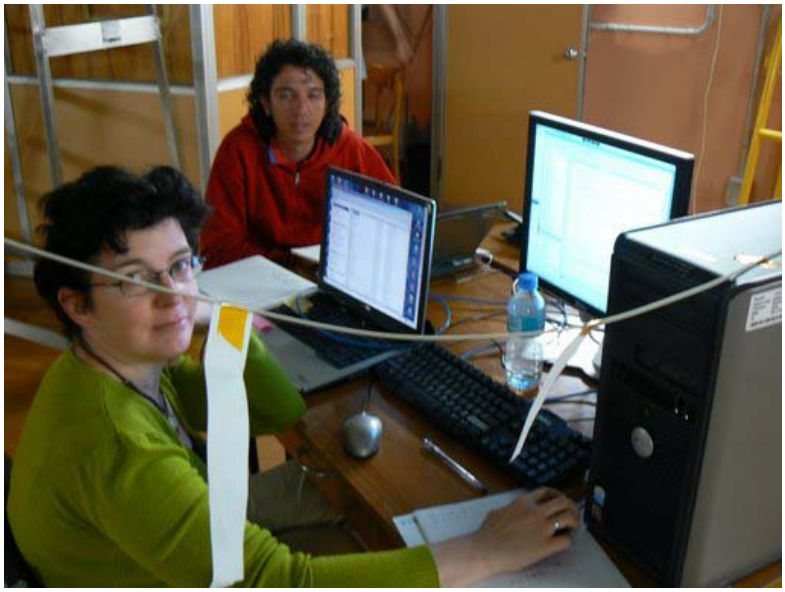

Figure 3- Claudia Facchinetti and Tommaso Occhipinti driving the acquisitions through hanging cables.

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5----rollover:  19074  ch-Hit: 1-  39289  diff_e:39286.686115  diff_g:39370.078740  time: 0.999979828850 - 1.000030380725
5----rollover:  19074  ch-Hit: 7-  40165  diff_e:40162.640212  diff_g:40322.580645  time: 0.999996948825 - 1.000038625450
5----rollover:  19074  ch-Hit: 5-  39415  diff_e:39412.756485  diff_g:39525.691700  time: 0.999992912250 - 1.000018575500
5----rollover:  19074  ch-Hit: 3-  39784  diff_e:39782.066533  diff_g:39840.637450  time: 0.999988271350 - 1.000011566900
5----rollover:  19074  ch-Hit: 7-  39895  diff_e:39895.376246  diff_g:40000.000000  time: 0.999990781375 - 1.000029194625
EOF on Caen1290_5.bin
6----rollover:  19074  ch-Hit: 5-  39446  diff_e:39445.541007  diff_g:39525.691700  time: 0.999990361275 - 1.000030211625
6----rollover:  19074  ch-Hit: 7-  39722  diff_e:39719.832895  diff_g:39840.637450  time: 0.999990881775 - 1.000031325600
6----rollover:  19074  ch-Hit: 1-  39489  diff_e:39488.123948  diff_g:39525.691700  time: 0.999952076975 - 1.000000137125
6----rollover:  19073  ch-Hit: 3-  40088  diff_e:40088.046745  diff_g:40160.642570  time: 0.999989047775 - 1.000010400850
6----rollover:  19074  ch-Hit: 5-  39604  diff_e:39602.952453  diff_g:39682.539683  time: 0.999976223875 - 1.000004234050
6----rollover:  19073  ch-Hit: 7-  40000  diff_e:40000.720778  diff_g:40160.642570  time: 0.999967737525 - 1.000013306475
EOF on Caen1290_6.bin
7----rollover:  19074  ch-Hit: 7-  39607  diff_e:39606.526148  diff_g:39682.539683  time: 0.999994979325 - 1.000025270475
7----rollover:  19074  ch-Hit: 3-  39808  diff_e:39807.360484  diff_g:39840.637450  time: 0.999979744750 - 1.000026466125
7----rollover:  19075  ch-Hit: 1-  39384  diff_e:39381.489151  diff_g:39525.691700  time: 0.999989053925 - 1.000011465400
7----rollover:  19075  ch-Hit: 5-  39503  diff_e:39500.071201  diff_g:39525.691700  time: 0.999999967825 - 1.000025951925
7----rollover:  19074  ch-Hit: 7-  39639  diff_e:39638.994214  diff_g:39682.539683  time: 0.999983380200 - 1.000025416450
EOF on Caen1290_7.bin
8----rollover:  19074  ch-Hit: 7-  40104  diff_e:40102.168611  diff_g:40160.642570  time: 0.999984385650 - 1.000018655725
8----rollover:  19075  ch-Hit: 3-  39872  diff_e:39869.706444  diff_g:40000.000000  time: 0.999993454100 - 1.000031563600
8----rollover:  19075  ch-Hit: 7-  39864  diff_e:39861.355909  diff_g:40000.000000  time: 0.999998242125 - 1.000032559125
8----rollover:  19074  ch-Hit: 5-  39174  diff_e:39171.869166  diff_g:39215.686275  time: 0.999988820725 - 1.000027920175
```

Figure 4 - The stream of photons form an unknown star. The arrival time of each photon in each of the 4 channels (here numbered 1,3,5,7 for reasons that only Claudia and Tommaso could explain) is time tagged by the internal clock, whose ticks happen every 25 (±1.1) picoseconds. Claudia and Tommaso did a great job of disentangling the time roll-overs due to the limited number of bits available for tagging inside the CAEN board.

Tests and observations resumed from the 26th to the 28th, with the telescope still not fully operational, and thanks to Venerio Chiomento and Luciano Traverso, two most skilled night assistants who substituted a pletora of still missing software instructions and circuitry with their magic fingers. There was enough time to make the system much more professional, with all

electronics attached to the telescope and computers moved to the control room via a 20-m long fiber (Figure 5).

Figure 5 - Tommaso Occhipinti and Wojciech Makowiecki in the control room cleaning residual bugs.

The weather was not certainly not cooperative, but we had several holes between clouds that allowed to observe 5th mag stars, the variables AM Her (found in a very low state), SS Cyg and the night sky (well seen above the dark counts, see Figure 6, Figure 7, Figure 8).

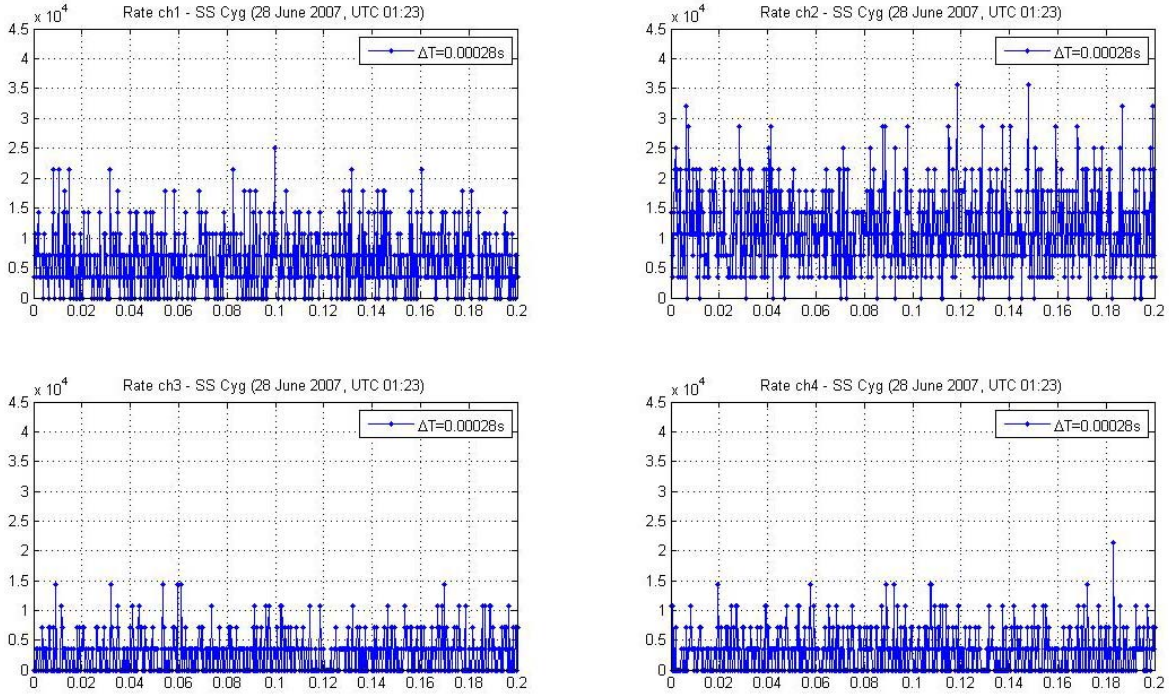

Figure 6 - A short string (0.2 s) of counts from SS Cyg. In this figure, the counts have been binned over 280 microseconds.

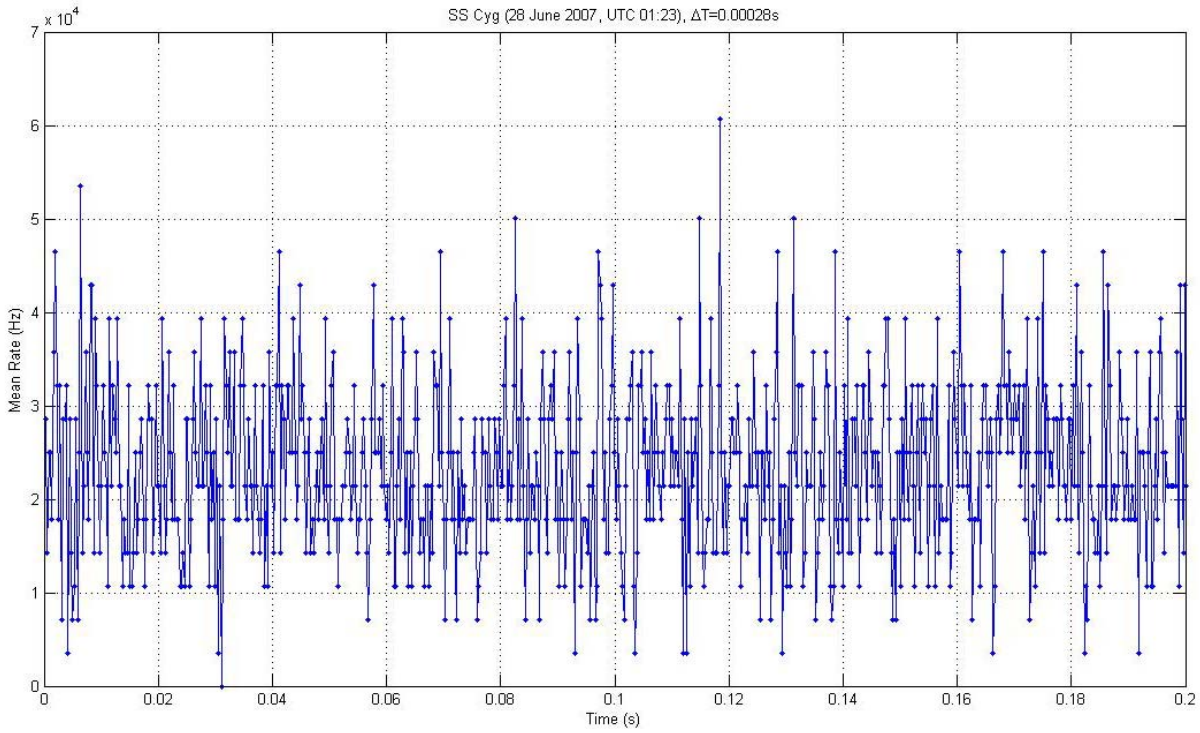

Figure 7 - The sum of the 4 channels, again binned over 280 microseconds.

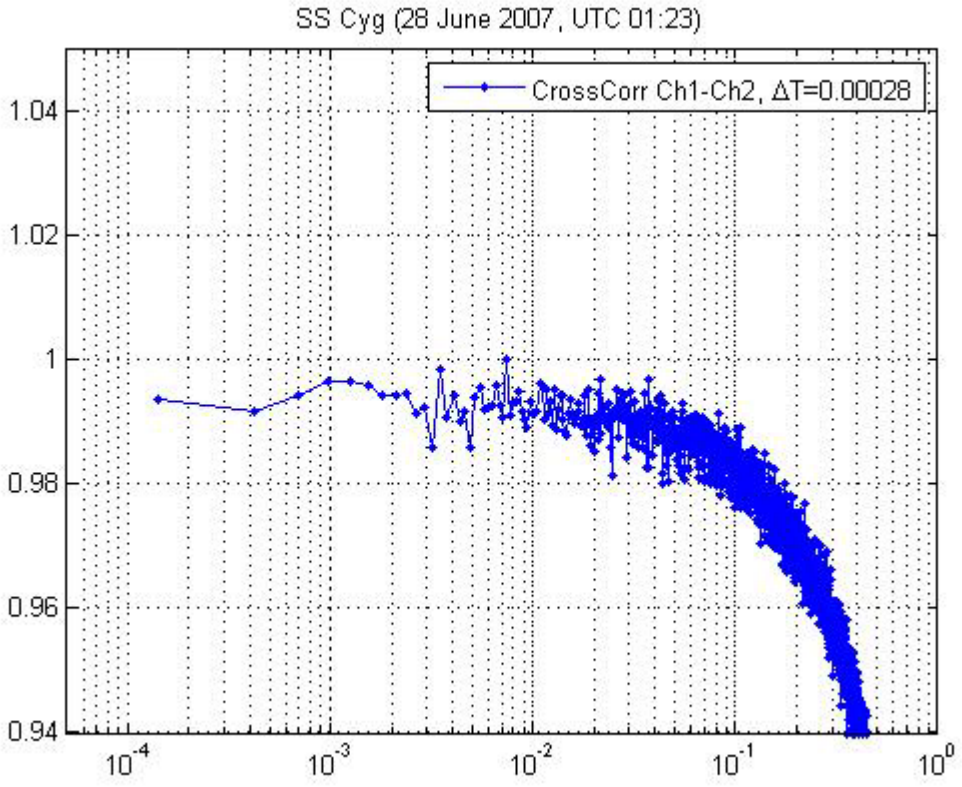

Figure 8 - The cross-correlation of channel 1 against channel 2.

Few engineering considerations are warranted here.

The system performed flawlessly, enduring temperatures as low as 4 C (amazing indeed for the 26th of June!) and humidity as high as 90%.
Saturation in each channel happened around 1 MHz count rates, but ways to raise it were promptly identified. Today, after some improvement to the software, each channel can count to up 4 MHz.
At the lower end, dark is well below the night sky, but some more adjustment can still be made.

What's next in preparation for the August 9 to 14 run?
AquEYE is back in the optical laboratory for 45° rotation and further alignment.
One of the 4 SPADs, showing a higher dark count rate, will be substituted with a new one kindly provided by MPD.
A high precision Rubidium external clock is being characterized in Cagliari. The Cima Ekar site has been surveyed to determine the best position of a GPS antenna. We then expect to have soon a first class UTC timing system.
Astronomer-friendly software is being written.
So, wait for more!

Acknowledgment

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References

AquEYE has been described in several places, see for instance:

G. Naletto, C. Barbieri, T. Occhipinti, F. Tamburini, S. Billotta, S. Cocuzza, D. Dravins, 2007, *Very fast photon counting photometers for astronomical applications: from QuantEYE to AquEYE*, SPIE Conference 6853A on Photon Counting Applications, 19 April 2007, Prague, Czech Republic

C. Barbieri, S. Billotta, P. Bolli, G. Bonanno, A. Di Paola, C. Facchinetti, E. Giro,S. Marchi, G. Naletto, T. Occhipinti, C. Pernechele, E. Sain, M. Zaccariotto, P. Zoccarato, 2007, *Status of AQUEYE, the fast multichannel photometer for the 182cm telescope at Cima Ekar*, Mem. SAIt