Report on the ESO Workshop

Detectors for Astronomy 2009

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In the 1980s and 1990s, the developments in sensitivity, size, and effective image quality of semiconductor detectors progressed faster and with lower cost than any equivalent increase in the geometrical light-collecting power of optical/infrared telescopes could have achieved. Now, in the era of Extra Large Telescopes, where light-collecting power is again increasing and ever more sophisticated space-borne instruments are in preparation, the growing maturity of detectors still forms an important cornerstone of these large investments. The recent workshop brought together many of the world's leading detector developers, producers and users, as well as astronomers, to exchange ideas, questions and solutions with the aim of enabling detector systems to optimally support the exciting astronomy projects of the future.

Figure 1. The DfA2009 participants facing a snow-cold sky outside the Max-Planck-Institut für Extraterrestrische Physik in Garching, where the workshop was held.

After the workshops in 1991, 1993, 1996, 1999 (all in Garching), 2002 (in Hawaii) and 2005 (in Taormina, Italy), the seventh workshop in the series Detectors for Astronomy (DfA2009) returned to the ESO Headquarters in Garching. During the course of almost two decades, the title and scope of these workshops have evolved somewhat, but the emphasis has changed little. For the first time, the number of participants exceeded the capacity of the ESO auditorium, and the workshop was kindly hosted by the Max-Planck-Institut für Extraterrestrische Physik (MPE). During three full days and two half days, the 185 participants were presented with around 60 talks and 40 posters. In terms of attendance, this places DfA2009 in the top 10th percentile of the ~ 100 workshops held at ESO–Garching since ESO Headquarters was established there in 1980.

The approximately 50 % increase in attendance since DfA2005 signals the growing importance that the astronomical detector community assigns to these meetings. In fact, from the beginning, their format has been very special, in that they have brought together: (a) research laboratories, where much of the fundamental understanding and concepts are developed; (b) detector manufacturers, who run their own R&D programmes, but also cast research results into recipes for serial production and marketing; and (c) detector engineers at observatories, who are trying to deliver the best possible performance to astronomical users. Obviously, there are large overlaps in the expertise of these groups. This is the basis for a common understanding. But it is remarkable that the professional knowledge of none of the groups is a simple superset of any of the other two. Therefore, everyone can benefit and learn from everyone else. This makes such encounters extremely productive.

An additional thrill results from the fact that detectors, while indolently destroying photons after millions and billions of years of travel, do their utmost to preserve the information carried by the photons. After the detector electronics and software have assembled the detected signals, it is the very first moment that humans can reflect on these "messages" from very far away. Nothing gets closer to feeling the pulse of the Universe than the light-detection process. For this reason, the DfA workshops try to also include some scientific reports from observational experiments that are particularly dependent on the excellence of detectors. This time, cataclysmic variables observed at high temporal or spatial resolution, the quest for the identification of dark matter and energy, solar physics, the search for killer asteroids, cosmic shear, the use of supernovae as the accelerometers of the Universe, stellar diameter measurements from lunar occultations, the detection of TNT in high security areas, delay-time based 3D imaging, and many more, served to illustrate the difference between excellent and good detectors. Some of the forthcoming, or planned, advanced world-class facility observatories were also presented. It was interesting to see that such projects are now often proactive in identifying and securing the detectors they require. This planning especially applies to wavefront sensors for adaptive optics, but also to the development of curved detectors that would enable much better optical designs than a flat detector with a field-flattening lens.

Size, quantum efficiency and controllers

Back in 1991, the central questions (D'Odorico et al., 1991) concerned the maximum size of available charge coupled devices (CCDs), their UV-blue quantum efficiency, and the architecture and performance of controllers. These three topics, addressed from the DfA2009 perspective, are treated in the following, necessarily short, summary. During the eighteen years now covered by the DfA series, the scope of the workshops has long been extended to include

Figure 2. The 32 participants in the ESO Mini-Workshop on Large-size CCDs held at ESO Garching 18–19 June 1991. Twelve of them also attended DfA2009.

infrared (IR) arrays as well, the sizes of which have meanwhile grown, from the standpoint of the early 1990s, to unimaginable dimensions. For CCDs, from the first marketing of 2k × 2k chips (15-μm pixels) announced in 1991, the progress in size has been more moderate with 4k × 4k devices (also with 15-μm pixels) still being the largest thinned, backside-illuminated square formats readily found in the catalogues of all manufacturers. But results of successful on-sky tests obtained with a 111-million pixel detector were presented. Rather than in size, the growth has often been more in the diversity of chips, which in many cases can be further customised to match specific applications.

After the introduction of backside illumination and improved anti-reflection coatings, UV-blue sensitivity has long been very satisfactory. In the very near IR, CCDs and IR CMOS (complementary metal oxide semiconductor) technology are now competing: Deep-depletion technology permits thicker and thicker silicon devices to be used so that even at wavelengths close to 1 μm, where silicon is starting to become transparent, CCDs can detect up to 50 % of the light. Thick silicon also greatly reduces fringing, but at the price of increased sensitivity to particle radiation, and the point spread function needs careful attention. In this same wavelength region, IR CMOS detectors even achieve quantum efficiencies of 90 % or more. Their higher read noise and cost still prevent their usage at shorter wavelengths, but the rate of progress continues to be high.

The limits in space-borne projects on mass, volume, and power consumption are bringing about a paradigm shift from conventional controllers to ASICs (Application-Specific Integrated Circuits), which can often be mounted back-to-back with the sensor they are commanding. During the most recent Hubble repair mission, a conventional CCD controller of the Advanced Camera for Surveys was actually replaced with an ASIC originally developed for IR detectors. In a ground-based context, a number of talks also elaborated on the virtues of ASICs. But, as was also shown, conventional dedicated or general-purpose controllers can still offer some advantages if their bulkiness is not an issue. It will be interesting to see when custom-developed ASICs will become affordable.

A dream of many a detector physicist, engineer and astronomer is the noise-free detector. Electron-multiplying CCDs, avalanche photodiodes, and other technologies are coming ever closer to this ideal. Dead times, excess noise factors, and dynamic range still present challenges, but already permit routine application in specialised areas, most notably wavefront-sensing with laser and natural guide stars. Frame rates well above 1 kHz and the ability to discriminate between 100, 101 or 102 photon events were described. For scientific applications with very long exposure times, extremely low dark currents are of similar importance as low read noise and a "world-record" low value was reported.

Quite a few talks touched upon the optimisation of detectors under astronomical operating conditions; some were actually dedicated to this topic, mostly in conjunction with IR detectors. In the CCD domain, a major component was also the increased understanding of very low-level effects, such as pixel-size variations, e.g., as a function of proximity to the edge of the chip or of signal level, and the modelling of the interaction between light and silicon, including fringing. A concern for CCDs and CMOS devices alike is the coupling between charge in neighbouring pixels, so that any serious characterisation of detectors must include illumination with point sources. Optimisation is also one of the big challenges for large detector mosaics — now measuring up to more than 1 gigapixel, given the need to achieve much lower budgets for mass, power dissipation, etc. Several impressive examples were presented in great detail.

The level of precision, with which chemical and electrical profiles can be engineered and operated at sub-pixel dimensions, and the complexity of infra-pixel electronics (for CMOS devices) are stunning. So is their reproducibility from device to device as well as over millions of pixels. The much improved cleanroom technology has not only led to progress in these areas, but has given the term "chip cosmetics" a new meaning. Improved production yields lead to lower costs per pixel, but also permit larger devices to be made, so that the revenues of manufacturers do not suffer.

All in all, the talks and posters presented in less than one week may have been based on well over 1000 personyears of highly specialised work — a compression factor of order 10^5! Numerous discussions during coffee breaks, two well-attended poster sessions, demonstrations of ESO's New General detector Controller (NGC), OCam, the Bonn shutter and TeePee, a nice welcome reception on Monday, and dinner at a Bavarian restaurant in Garching completed a very rich programme. Many participants commented explicitly on the openness with which authors also talked about the problems they had encountered. This was stated to be a very positive contrast to other major conferences. There was particular praise for the Broadband Introductory Course on Detector Technologies, run by James Beletic and Markus Loose.

In view of the high rate of progress in the very dynamic field of astronomical detectors, the DfA2009 proceedings will be published on the workshop web pages only[1]. At the time when this *Messenger* report appears, all presentations and some of the first papers will be available.

Acknowledgements

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References

D'Odorico, S. et al. 1991, The Messenger, 65, 43

Links

[1] http://www.eso.org/sci/meetings/dfa2009/program.html

3D Movie Featuring ESO's Paranal Observatory

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The production companies parallax raumprojektion and fact&film have produced a unique 3D documentary about ESO's Very Large Telescope (VLT), in close cooperation with ESO, as part of its International Year of Astronomy 2009 activities. The film, *The EYE 3D — Life and Research on Cerro Paranal*, stars the young scientist and ESOcast host Dr J, aka Joe Liske. In June 2009, a German film crew, who specialise in making 3D movies, accompanied Dr J on a trip from ESO Headquarters in Garching to the landscapes of the Atacama Desert in the north of Chile, home of the VLT.

Along with stunning views of the telescopes and clear explanations of how such a technical masterpiece functions, the movie also follows the lives of people at Paranal: astronomers, engineers, physicists and technicians, showing just how everyone's work at the VLT contributes to the cutting-edge research about the Universe. The movie is aimed at a broad audience, from schoolchildren to science scholars. Its extraordinary 3D technique gives viewers a real sense of being at the centre of the action, taking them on virtual tours inside the telescope domes, or for a walk in the desert with Dr J.

The film was co-financed by the film subsidy agencies of the German federal states of Baden-Württemberg and Bremen, several charitable and public organisations and ESO. It has been appointed a Special Project of the International Year of Astronomy.

The EYE 3D, directed by Nikolai Vialkowitsch, had its world premiere on Wednesday, 28 October 2009, at the Film Festival in Biberach, Germany and is showing in 3D theatres across Germany, and later this year all over Europe. An international version in English language is available, and further translations in other European languages are in production.

More information at www.eso.org/public/events/special-evt/theeye/index.html.

Credit: parallax raumprojektion/ESO

Dr Joe Liske in the Atacama Desert in the movie *The EYE 3D*.