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OmegaCAM at the VLT Survey Telescope

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Abstract. We present the status of the VLT Survey Telescope (VST) and OmegaCAM projects. VST is a 2.6m telescope which will be integrated in the ESO-VLT environment at Paranal and will be equipped with a $16k \times 16k$ CCD camera (OmegaCAM) covering 1 square degree with a resolution of 0.21 arcsec/pix. The main scope of this observing facility is the selection of targets for VLT science. It is expected that VST+OmegaCAM will become operational in spring 2004.

Key words. Instrumentation: detectors – Surveys

1. Introduction

The VLT Survey Telescope (VST) is a 2.6m telescope with a corrected field of view of over 1 square degree which is built by Capodimonte Astronomical Observatory (OAC) and, thanks to the collaboration with the European Southern Observatory (ESO), will be located at Cerro Paranal (Chile).

The telescope will be equipped with a huge CCD imaging camera, OmegaCAM, that with 16k×16k pixels will cover the field of view of the VST almost entirely. OmegaCAM is built by a consortium of Institutes in the Netherlands, Germany and Italy in collaboration with ESO.

The main scope of the VST–OmegaCAM observing facility is to perform surveys in support of VLT science. The expected products are large, homogeneous multi-colour catalogs of astronomical sources which will be used for the selection of targets for spectroscopic follow-up. Also, because of the large field of view, this facility will give a unique opportunity to search rare or extreme astronomical objects.

According to the current plan, it is expected that the VST will be installed in Paranal at the end of 2003, whereas OmegaCAM will follow a few months later.

2. The VLT Survey Telescope

The scientific motivations, the technical feasibility and the financial opportunities to build the VST were finalized in 1997 with the signature of a Memorandum of Understanding (MoU) between OAC and ESO (Arnaboldi et al. 1998). Based on the MoU, OAC has to design and build the telescope whereas ESO has the responsibility of the dome construction and of the telescope operation.

The VST telescope has a 2.61m primary mirror, a f/5.5 focal ratio and covers a very large field of view (1.47° diagonal) with a high resolution (0.21"/pix). It has been designed with a high image quality (80% of the enclose energy in two pixels over the entire field of view) and is optimized for observation in the optical window, from U to I bands (0.320-1.014 nm). It can be operated with two different optical configurations: with a two lens camera corrector or otherwise, for observations at large zenithal distances, with the combination of an Atmospheric Dispersion Corrector (ADC) plus a different lens. In the latter case however the accessible spectral range is cutoff shorter than 0.365 nm.

The telescope has an Alt-Az mounting which allows a high mechanical stiffness and a compact overall structure (Fig.1). VST is equipped with active optics (Mancini et al. 2001): the primary mirror is supported by 84 axial pads, distributed on four concentric rings, and 24 lateral pads. The secondary mirror is also actively controlled to compensate thermal and gravitational structure deformation. The Adapter/Rotator includes a sensing and guiding arm that provides the telescope guiding and on-line wavefront analysis. However with OmegaCAM in operation these data will be provided by dedicated auxiliary CCDs (cf. Sec.3).

The VST control system is based on the main concept used by ESO for the VLT design (Schipani & Mancini 2001; Schipani et al. 2001). This allows to maximize the use of VLT standard components and software. In turn this choice simplifies the VST maintenance and assure a smooth integration of the VST in the VLT operation environment. Further details can be found at *http://twg.na.astro.it/vst/vst_homepage_twg.html*.

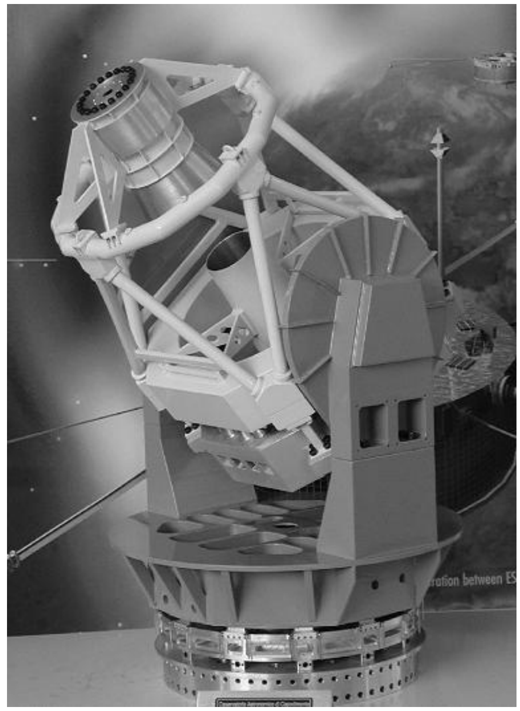

Fig. 1. A model of the VLT Survey Telescope.

The VST project faced a very difficult situation in early May 2002. The primary mirror after delivery to ESO in Jena (Germany) and while in transit to Chile was accidentally destroyed. Thanks to the prompt reaction of OAC, ESO and the mirror manufacturer (LZOS, Moscow), a contract for the delivery of a replica of the 2.6m mirror was signed only few week later. It is expected that the new mirror will be delivered at the end of 2003 with a minor impact on the telescope schedule.

At the time of writing the mechanical components of the telescope are being integrated in a dedicated facility located in Scafati (Salerno, Italy). In mid 2003 the

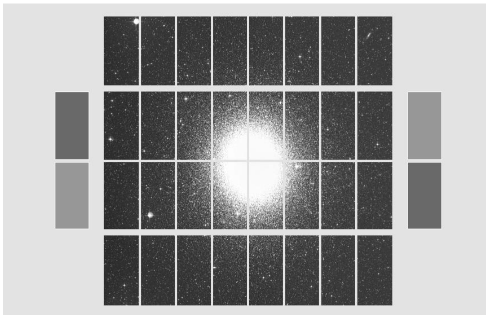

Fig. 2. Layout of the CCD mosaic in OmegaCAM

telescope will be sent to Chile where it will be installed and is expected to become operational in April 2004.

Meanwhile, the telescope enclosure has been designed by ESO and construction is in progress. The precise location of the dome is between the UT3 and UT4 units of VLT (see map at *http://www.eso.org/instruments/)*. Being upstream of the VLT units with respect to the prevalent wind direction, VST will fully exploit the exceptional quality of the Paranal observing site.

3. OmegaCAM

The heart of OmegaCAM is the CCD mosaic (Fig. 2), being built at ESO by a team lead by O. Iwert. The 'science array' consists of 32 thinned, low-noise ($5e^-$) 3-edge buttable 2×4k Marconi (now E2V) 44-82 devices, for a total area of 16384×16384 15μm pixels. Paving 26×26 cm of the VST focal plane, the science array covers a sky area of 1x1 degree at 0.21 arcsec/pixel.

Aside the science array are placed four 'auxiliary CCDs'. Two of these are used for auto-guiding and the other two for online image analysis. The whole detector system is mounted behind a large, curved dewar window (the final optical element in the VST design) and is cooled using a 40-l Nitrogen cryostat. Readout of the full mosaic takes 45s, and is accomplished by two FIERA controllers (a third FIERA takes care of the auxiliary CCDs).

In front of the dewar window sits the filter exchange mechanism, and above that the shutter. Both components have to fit into a design space of a mere 16cm between the dewar window and the VST's Shack-Hartmann unit. The housing provides the mechanical link between the telescope flange and the detector/cryostat system.

Figure 3 gives a section view of the final design that foresees a cylindrical housing with a spoke-like rib structure to support the axisymmetrical loads at the Cassegrain focus. The filters are stored in two magazines which can move up and down, at either side of the focal plane. High precision filter positioning ensures that intensity variations in the flat fields due to optical imperfections in the filters (dust grains, etc) are less than 0.1%. More details on the mechanics can be found in Nicklas et al. (1998).

The exposure shutter (Reif et al. 2002) is one of the key units of OmegaCAM. It consists of two carbon fiber blades which open and close the light path. These movements are controlled such that each individual CCD pixel is illuminated for an identical time, even if the blades are still accelerating. Tests show that even for an exposure time as short as 0.1 second, deviations from a homogeneous exposure are below $\pm 0.3\%$ over the whole field of view.

All instrument functions (filter exchange, shutter, detector readout, as well as monitoring the instrument state) are controlled in software. The programming environment is defined and provided by ESO through the releases of the VLT Common Software which has to be used as the basis for design and development. The partitioning of the OmegaCAM Instrument Software (OmegaCAM INS) into software subsystems also follows the VLT standards. Nevertheless there were several challenges peculiar to OmegaCAM.

The *Autoguiding Software* and *Image Analysis* modules normally belong to the Telescope Control Software. In the case of

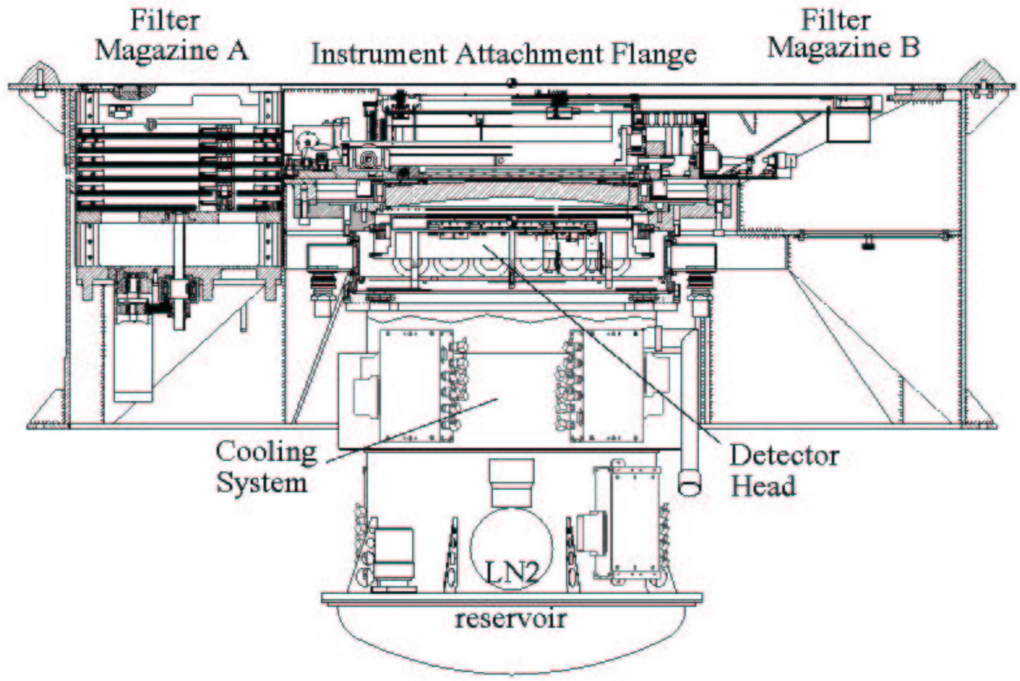

Fig. 3. OmegaCAM section view

OmegaCAM it was necessary to move these functionalities to the INS because during normal operations the VST guiding arm will not be used, as it would vignet the science array. A new software algorithm was developed to extract optical aberration coefficients from the out-of-focus images recorded on the Image Analysis CCDs. On the detector software side, particular attention had to be paid to the coordination of the readouts by the different FIERA's, and to the efficient storage of the data on disk (Baruffolo et al. 2002).

The primary filter set of OmegaCAM will include the Sloan u', g', r', i' and z' filters. In addition, there will be Johnson B and V filters for stellar work and for cross-calibrating the photometric systems, a stromgren v filter, an Hα filter consisting of 4 segments with redshifts of up to 10000km/sec, and a segmented ugri filter for efficient photometric monitoring of the sky. The procurement of large format filters of the required size turned into a challenging task. Only one manufacturer (the French company SAGEM) could make an offer for producing the primary set of filters without resorting to a segmented design, which would have created vignetting shadows on the detector array. Rather than using colored glass—barely available in the required size—the filter passband is generated by means of multiple layer coating of up to 5 surfaces in a sandwich of three plates. The expected throughputs of the Sloan filters are very high (Fig. 4). On the other side, to better match the standard filter definition, B and V filters will be made of four segments. All these filters have already been ordered and will be available at the beginning of VST operation.

The amount of data produced by OmegaCAM will be truly huge. We estimate that there will be over 15 Terabyte of raw data per year. This raw data volume contains roughly 5 Terabyte of calibration

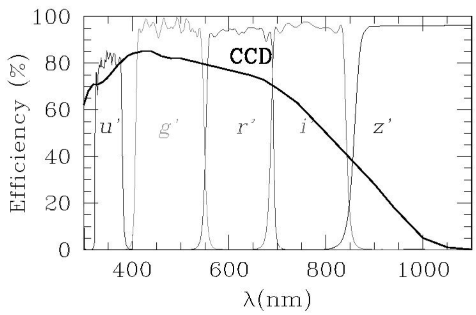

Fig. 4. OmegaCAM filter transmission compared with the CCD efficiency curve.

data and 10 Terabyte of raw science data. Data processing will produce another 10 Terabyte of reduced science data and will result, with about 100000 astronomical objects per OmegaCAM field, enormous catalogues. To efficiently handle this data volume the data acquisition, calibrations and the pipeline reductions are strictly procedurized. ESO will operate the instrument in service mode, optimizing the observing programme to ambient conditions, and routinely taking calibration data. After consideration of a number of scientific cases, four standard observing modes, have been identified:

- *Dither* has offsets matching the maximum gap between CCDs, ∼400 pixels (5.6mm). This mode is intended for complete coverage of the gaps in the focal plane.
- *Jitter* has offsets matching the smallest gaps in CCDs ∼5 pixels. This mode optimizes the homogeneity of the context map and will be used when the wide gaps are not disturbing, but instead a well-mapped smoothly varying PSF is required.
- *Stare* allows reobserving one fixed pointing position multiple times.
- *SSO* is the mode for observing Solar System Objects, which requires non-sidereal tracking.

The observing modes and strategies are fully integrated with the data reduction software being developed by the OmegaCAM consortium. ESO users will be provided with the output of the image pipeline, run in Garching, on the data contained in a single OB. The nominal photometric accuracy of this pipeline will be ±0.05 mag. The nominal accuracy for the astrometry is ±0.1 arcsec rms over the entire field of view.
The OmegaCAM consortium will deliver software modules that ESO will integrate into the image pipeline. In addition, a project has been set up among european wide-field imaging groups to provide a 'wide-field imaging survey system' that will combine pipeline processing of image data with archiving and data mining tools. Further details can be found on *http://www.astro-wise.org*, and in Valentijn & Kuijken (2002).
The OmegaCAM project is now well into the manufacturing phase. Most of the CCDs have been delivered and tested; most of the mechanics exists and is ready to be integrated; instrument control and data analysis software is being coded. Extensive tests in Europe are foreseen for the second half of 2003, and the camera should see first light early in 2004.

4. Science with VST – OmegaCAM

The performance of VST+OmegaCAM can be predicted with great confidence based on the ESO experience with the WFI at the 2.2m ESO/MPI telescope It is expected that for a star of 25 mag observed in good sky conditions through the V filter, a S/N=5 over the PSF area can be gathered in just 20 min (cf. *http://www.astro.rug.nl/∼omegacam/etc/etc.html*).
VST+OmegaCAM is a survey facility for the ESO community. It will be mainly dedicated to ESO public surveys though there will be room also for individual research programs. However a significant fraction of the observing time will be reserved to the

Institutes which devoted their financial and human resources to build the instruments. In particular, the Italian community, after the investments in the construction of VST and the partnership in the OmegaCAM consortium, will have reserved access to 20-25 % of the VST+OmegaCAM observing time distributed over the 10 years of the expected instrument lifetime. This gives a unique opportunity for scientific projects requiring large and/or long term sky surveys.
Observations at VST will be performed in service mode only. This assures an optimal use of the telescope time and also some saving on the cost of operation. On the other side, because of the huge data size the transfer through network appears not viable with the present technology. Therefore, there appears to be a problem for program requiring prompt access to the data, for instance for the rapid detection and follow-up of variable objects. Among the possible solutions which are being explored, the more effective seems that of the installation in Chile of a dedicated computer where individual research groups can install and run their own detection software. . This implies a significant investment in hardware, software and manpower and may require a synergy of research groups working of different topics.
An important add-on of VST + OmegaCAM is the environment where it will be operated. This is not only because Paranal is one of the best worldwide astronomical site, and for the overwhelming possibilities offered by the VLT instrumentation for follow-up of selected sources, but also for the opportunity to perform coordinated optical and infrared surveys which will materialize when VISTA, the 4m infrared telescope being built by KU institutes, will also became available at Paranal (*http://www.vista.aa.Ku/*).

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