Part I

Introduction
The biggest mysteries in cosmology today concern the nature of the "dark matter" and the "dark energy". Together, they dominate the energy budget of the universe, yet we know little about the underlying physics.

Dark matter manifests itself through its gravity: analysis of the gravitational fields of galaxies and clusters using such diverse probes as the orbits of stars and gas clouds, the deflection of light, and the pressure equilibrium of hot X-ray emitting haloes, consistently reveal that there is much more matter present than what we can observe directly in stars and gas. Moreover, the physics of nucleosynthesis in the hot Big Bang predicts that no more than four percent of the present energy density of the universe can be in the form of "ordinary" baryonic matter.

Dark energy is required in order to explain observations of the anisotropy of the Cosmic Background Radiation, and the flux-redshift relation of distant supernovae, both of which indicate that the expansion rate of the universe is not slowing down under its own gravity, as had been expected, but it is instead accelerating. The pressure that drives this expansion can be described as a cosmological constant term in Einstein’s equation of general relativity, or as a kind of vacuum energy.

In this thesis we focus on dark matter. While the baryonic matter is known, it is composed of ordinary atoms that are found in the stars, the planets, and everything which surrounds us, the non-baryonic matter remains unknown. New particles such as neutrino, neutralino, wimps or axion, have been introduced by physicists and can be used to explain the composition of the non-baryonic matter but direct detection experiments have been unsuccessful until now. It has been proved that the neutrino exists (Cowan et al., 1956), but it is too light to explain the total mass of the non-baryonic matter in the universe. The neutralino, the wimps and the axions are still hypothetical particles. In this thesis, we will not discuss the nature of dark matter, we will instead concentrate our effort on locating and quantifying it.

After a brief summary in Section 1.1 of few major discoveries which have convinced the astronomical community that the majority of the matter in the universe is dark, we
introduce in Section 1.2 the basics of gravitational lensing which is one of the main ways to reveal the presence of the dark matter. We derive in this section the tools that are necessary to realize the weak gravitational lensing studies carried out in the second part of this thesis. In section 1.3 we present the Very Large Telescope Survey Telescope - OmegaCAM (VST-OmegaCAM) system. VST-OmegaCAM is a new wide field imager that will be installed on Paranal and it will be used to realize wide field surveys in the near future. This instrument will provide the necessary data to study the dark matter presence at different scales of the universe. The section about the VST-OmegaCAM instrument is an introduction to the first part of this thesis which summarizes the work that has been done to characterize the OmegaCAM CCDs.

### 1.1 Brief History of the Dark Matter

#### 1.1.1 Cluster of Galaxies

The concept of dark matter appeared for the first time in a paper published by Zwicky in 1933. During the estimate of the total mass of the Coma cluster, a discrepancy between the dynamical and luminous mass was found (Zwicky, 1933). After having measured surprisingly high radial velocities of eight galaxies in the Coma cluster, Zwicky applied the virial theorem to relate the velocity of the galaxies to the dynamical mass of the cluster. To estimate the luminous mass of the Coma cluster, Zwicky used the mass-to-light ratio (M/L) for each galaxy which composes the cluster (Zwicky, 1937b). The estimate of the mass, using the virial theorem, turns out to be much larger than the mass obtained using luminous information. In 1936, Smith performed similar work on the Virgo cluster and confirmed Zwicky’s results. To explain the missing mass, Smith wrote in his conclusions that a considerable quantity of mass has to be present between galaxies (Smith, 1936). These striking discoveries had limited impact at that time because the expansion of the universe monopolized the attention of the astronomical community.

With imaging X-ray telescopes that have been made available in space, such as the Einstein Observatory, EXOSAT or ROSAT satellites, it has been possible to compute very precisely the total dynamical mass of nearby galaxy clusters (e.g., Coma, A 2256, Perseus, A 2163). The analyses carried out on these X-ray data, showed that a large amount of non-luminous matter is present in the central regions of the clusters and that between galaxies, huge quantities of ionized gases are present (Eyles et al., 1991; Arnaud et al., 1992; Briel et al., 1992; Miyaji et al., 1993; Henry et al., 1993).

#### 1.1.2 Galaxies

The problem of missing mass appeared also with the work of Vera Rubin et al. who decided to study the spiral galaxies in the neighborhood of the milky way (Rubin and Ford, 1970; Rubin et al., 1980). Their results showed that the rotation speed of the luminous objects in all galaxies increases, as anticipated, when the distance from the center to the periphery of the galaxy increases, and that, against all expectations, the rotation speed remains constant up to the optical edge of the galaxies while this speed was supposed to decrease. Rubin et al. concluded that such results can be explained only if a significant halo of non-luminous mass surrounds the optical galaxies. Later in 1985, Van Albada et al. carried out a similar study on optical data and radio measurements
1.1: Brief History of the Dark Matter

of neutral hydrogen gas (H I) of the galaxy NGC 3198 (van Albada et al., 1985). The extended rotation curve of NGC 3198 showed that the rotational speed of H I also does not decline at larger radii. The difference between the rotation curve expected from the stellar disk and the observed rotation curve can be explained by the presence of dark matter. At least four times more dark matter than the luminous matter is required to explain the observations.

Another approach, used to explain the mass discrepancy problem in galaxies, consists of introducing an alternative theory of gravity, the Modified Newtonian Dynamics (MOND) theory. In 1983, Milgrom modified the Newton's second law by changing the acceleration, \( a \), in \( F = ma \), to \( a^2/a_0 \) when the accelerations due to gravitational forces become very small (Milgrom, 1983; Sanders, 1986). The change in the Newton's second law leads consequently to the prediction of the flat rotation curves at the outer distances from the center of the galaxies. Several studies have shown that the rotation curves can be described correctly by the MOND theory (Sanders and Verheijen, 1998, for example), and de facto, there is no longer a reason to introduce dark matter in order to explain the shape of the rotation curves of galaxies.

1.1.3 Cosmic Microwave Background

The Big Bang theory was at first difficult for the scientists to accept. The idea that the universe has an origin in time and that it is expanding ever since was unrealistic. In the beginning of the last century, only the principle of a static universe was admitted. It is only after the discovery of the relic radiation of the Big Bang in 1964, that the Big Bang theory started to gain acceptance. In 1948, Gamow, Alpher and Herman predicted that the hot Big Bang would produce a background radiation and because of the process of the expansion of the universe, this background radiation would be observable nowadays in the microwave wavelength range, the Cosmic Microwave Background (CMB). The assumptions of Gamow et al. were confirmed by Wilson and Penzias in 1964 who measured a puzzling source of noise in the microwave part of the spectrum while they were performing tests on a new radio antenna. In addition to the predictions mentioned above, small fluctuations in the temperature of the CMB radiation were anticipated. These fluctuations were finally detected in 1990 in the data from the Cosmic Background Explorer (COBE) satellite and refined later by the results obtained from the analysis of the data taken by the Wilkinson Microwave Anisotropy Probe (WMAP) satellite. The latter experiment provides high accuracy measurements of many cosmological parameters supporting the "Concordance Model" of cosmology, the flat Lambda-Cold Dark Matter (\( \Lambda - \text{CDM} \)) model (Spergel et al., 2006). From the CMB measurements and the 2dFGRS power spectrum, the cosmological parameters of the flat \( \Lambda - \text{CDM} \) model are estimated with a very good accuracy. Sánchez et al. deduced a matter density parameter of \( \Omega_m = 0.237 \pm 0.02 \), a baryon density parameter of \( \Omega_b = 0.041 \pm 0.002 \), a dark energy density parameter of \( \Omega_\Lambda = 0.763 \pm 0.02 \) and a Hubble constant of \( H_0 = 74 \pm 2 \text{ km s}^{-1} \text{ Mpc}^{-1} \) (Sánchez et al., 2006).

From the concordance model, we deduce that 95.9% of the universe is composed of an unknown form of matter and energy. Until now the nature of the dark energy remains unknown. At present we are certain only about the fact that the dark energy generates a force which is responsible for the accelerating expansion of the universe. The matter present in the universe, 23.7%, is mainly composed of non-baryonic matter, 19.6%. The
rest is composed of baryonic matter, of which only a rough percent is visible.

### 1.2 Gravitational Lensing

#### 1.2.1 Introduction

During the first half of the XX century, only isolated articles have been published in the gravitational lensing discipline. The first time gravitational lensing tools have been applied successfully was during the eclipse of the sun in May 29, 1919 (Dyson et al., 1920). This experiment has proven that the predictions based on the theory of the general relativity are correct. The light paths of stars, passing close to our sun, are bent by the gravitational potential that the sun produces. Later in 1936, Einstein has presented in an article the basics of the theory of gravitational lensing produced by stars (Einstein, 1936). This theory introduces possible multiple images of the source objects and the amplification of light. In 1937, Zwicky has extended Einstein’s work on the gravitational lensing by stars to galaxies (Zwicky, 1937a; Zwicky, 1937c). But it is only after the 60’s that the gravitational lensing field was really extended with a theoretical discussion published by Refsdal, followed by Barnothy et al. and others (Refsdal, 1964; Barnothy and Barnothy, 1972). It is in 1979 that the first observation of multiply imaged quasar event 0957+561 has been made by Walsh et al. (Walsh et al., 1979). In 1985 a new major discovery has been made by Mellier et al. in the cluster of galaxies Abell 370 (Mellier, 1988). A giant arc structure is observed in their images, which is in fact a distorted galaxy positioned in the background of the cluster. Since then the development of the gravitational lensing field has continued and become one of the major tools of present-day cosmology.

#### 1.2.2 Basic Principles of Gravitational Lensing

**Lens Equations**

As explained above, the light paths from luminous sources are deflected when they pass close to a gravitational potential, also called a lens, produced by a massive object. As a consequence, the images of the sources are shifted, magnified and distorted by the gravitational lens when they reach the observers see Figure 1.1. We introduce here the basic equations of the gravitational lensing theory. For details on this theory, the reader is referred to the book by Schneider et al (1992). The equations for a single lens event can be deduced from Figure 1.1. We have,

\[
\vec{\theta}_E D_{OS} = \vec{\theta}_S D_{OS} + \vec{\alpha}(\vec{\theta}_E) D_{LS}
\]  

(1.1)

where \(\vec{\theta}_E\) and \(\vec{\theta}_S\) are the angular positions of the image and the source, respectively. \(D_{OS}\) corresponds to the angular-diameter distance between the observer and the source and \(D_{LS}\) is the angular-diameter distance between the lens and the source. \(\vec{\alpha}(\vec{\theta}_E)\) is the deflection angle, which is the sum of the deflections produced by the different elements of the lens,
\[ \vec{\alpha}(\vec{\theta}_E) = \frac{4G}{c^2} D_{OL} \int \Sigma(\vec{\theta}_E) \frac{\vec{\theta}_E - \vec{\theta}}{|\vec{\theta}_E - \vec{\theta}|^2} d^2\theta \quad (1.2) \]

where \( \Sigma(\vec{\theta}_E) \) is the surface mass density of the lens, \( G \) is the gravitational constant and \( c \) is the speed of the light.

Figure 1.1: Geometrical construction of a typical gravitational lensing event (Blandford and Kochanek, 2004). An observer in \( O \) sees the object \( S \) in location \( E \) because of the light ray deflection produced by the lensing mass \( L \). \( \alpha \) corresponds to the bending angle produced by the lens \( L \). Depending on the position and mass of the lens with respect to the source, the image \( E \) will be weakly or strongly distorted and magnified by the factor \( \mu \) defined in Equation (1.4).

**Magnification Matrix**

The differentiation of Equation (1.1) leads to an expression for the deformation of very small bundles of light by a gravitational field. The distortion is given by the Jacobian matrix, \( \overline{A} \). Each element of \( \overline{A} \) can be expressed using three terms, the convergence, \( \kappa \), and the shear coefficients, \( \gamma_1 \) and \( \gamma_2 \). The convergence corresponds to the magnification isotropic component of the distortion matrix \( \overline{A} \) and the shear coefficients to the anisotropic deformation, respectively. Differentiating Equation (1.1) with respect to \( \theta_S \) leads to:

\[ \overline{A} = \frac{\partial \vec{\theta}_E}{\partial \theta_S} = \begin{pmatrix} 1 - \kappa - \gamma_1 & -\gamma_2 \\ -\gamma_2 & 1 - \kappa + \gamma_1 \end{pmatrix} \quad (1.3) \]
where the convergence, $\kappa$, is defined as $\kappa = \Sigma(\theta_E)/\Sigma_{critical}$. $\Sigma_{critical}$ is the critical surface mass density (Fort and Mellier, 1994).

From the distortion matrix, $\overline{A}$, we deduce the magnification of an image, $\mu$ by,

$$\mu = \frac{1}{\text{det}(\overline{A})} = \frac{1}{(1 - \kappa)^2 - \gamma_1^2 - \gamma_2^2}$$  \hspace{1cm} (1.4)

### Micro, Strong, and Weak Lensing

Based on the equations above, we can distinguish between three different regimes, microlensing, strong gravitational lensing and weak gravitational lensing.

- **Microlensing.**

  Microlensing events are produced by compact objects with a mass typically within $10^{-6} M_{\odot}$ to $10^6 M_{\odot}$ (Wambsganss, 2005). The splitting of the image is not observable without instruments with micro-arcsecond resolution. Such instruments are not available with the nowadays technology. Nevertheless, it is possible to measure the magnification that a compact lens can produce, if the observer, the lens object and the source object are aligned correctly. Since either the observer, the lens or the source has a motion, the magnification will vary as a function of time (Paczynski, 1986). Equation (1.4) becomes,

$$\mu(t) = \frac{u(t)^2 + 2}{u(t)\sqrt{u(t)^2 + 4}}, \text{ with } u(t) = \sqrt{a^2 + b^2t^2}$$  \hspace{1cm} (1.5)

where $a$ and $b$ are two dimensionless free parameters. See for example Figure 1.2 where Equation (1.5) has been fitted to the data.

Microlensing analyses are well suited for example, to study compact objects such as MAssive Compact Halo Objects (MACHOs), which are possible candidates to explain the missing baryonic dark matter. These compact objects act as lens on stars in the Milky Way, in M31 (Andromeda galaxy) and in the LMC/SMC (Large and Small Magellanic Cloud). For more details on this subject, we refer the reader, for example, to the thesis of J. De Jong, *Microlensing In Andromeda*.

- **Strong Gravitational Lensing**

  Strong gravitational lensing events are observed when the lenses have a mass larger than $10^6 M_{\odot}$. Galaxies with a solar mass of about $10^{11-12} M_{\odot}$ and cluster of galaxies with a solar mass of the order of $10^{14} M_{\odot}$ are very good candidates to produce strong lensing events. With $\Sigma(\theta_E)/\Sigma_{critical} > 1$, these objects fulfill the necessary conditions to produce multiple images and giant arcs of objects positioned, correctly in their background. Abell 2218 is a very nice example of strong lensing by a cluster of galaxies, see Figure 1.3.

Strong gravitational lensing events are used in cosmology to give, for example, accurate constraints on the potential and mass distribution of the lenses on small scales. They can also be used as gravitational telescopes. The images of distant and
1.2: **Gravitational Lensing**

Far faint source objects are strongly magnified, which makes their study possible. Such analyses are often impossible in other circumstances. Objects at high redshift are too faint to be observed. From strong lensing it is also possible to study the cosmological parameters of the universe and the Hubble constant (Wambsganss, 1998).

- **Weak Gravitational Lensing**

In the case of the weak lensing regime, we have $\kappa << 1$ and $\sqrt{\gamma_1^2 + \gamma_2^2} << 1$. In this regime, the magnification is too faint and the distortion of the objects images is too small to be observed directly. We resort instead to statistical analyses to study the weak distortions and extract from them the general properties of the lenses. Weak lensing analyses applied to clusters of galaxies permit to estimate the mass distribution of the galaxies. These weak lensing analyses allow also for the studies of the galaxies dark matter halos, the halos shapes and maximum radius. Finally, the statistical study of the ellipticity distribution of distant galaxies, distorted...
slightly by a large scale structure, can provide information about the geometry of the universe and the properties of the dark matter density power spectrum (van Waerbeke and Mellier, 2005).

1.2.3 Aims of Current Gravitational Lensing Programs

Gravitational lensing became in less than 20 years a mature discipline providing powerful tools for cosmological studies. A large number of articles has been published over the last twenty years, employing gravitational lensing tools to measure the Hubble constant, to estimate cosmological parameters, to study microlensing events, mass distributions of clusters of galaxies, dark matter haloes of galaxies and high redshift lensed galaxies. These studies require new programs and bigger instruments to describe better the history of the structure formation of the universe, the properties of the large scale structures which compose the cosmos, and the distribution of the dark matter at large scale as well as in the galaxies. In the case of cosmological weak gravitational lensing analyses for example, it is commonly admitted that the majority of present day results are given with precisions that are not better than 10% - 30%. The very small amplitude of the distortion signals that are present in the shape of the galaxies means that gravitational lensing analyses require both, a huge number of galaxies and a high images quality. To achieve a high images quality, optical instruments have to be used at a high altitude where the image quality (seeing) can be very good. In addition, optical defects have to be minimized, which means that the quality of the CCD detectors has to be excellent (high quantum efficiency, very low noise, good linearity, very few cosmetic defects and an excellent charge transfer efficiency) and the CCD controller has to produce very little noise. The imposed requirements allow for reducing the point spread function in the images and hence, for estimating with a better precision the distortions in the galaxies. These surveys can be carried out by systems such as the CFHT - MEGACAM or the Very Large Telescope Survey Telescope (VST) - OmegaCAM system. The OmegaCAM camera, consists of 32 + 4 CCDs which are mounted in a mosaic to cover the focal plan of the VST. CCDs are electronic devices made of mosaics of pixels (2k × 4k for the OmegaCAM CCDs). Each pixel is a small squared surface of several micrometers size made of silicon and sensitive to light from ultra violet to near infrared wavelengths (see Chapter 2 for more detail). With the Very Large Telescope Survey Telescope and the OmegaCAM high quality wide field camera, surveys that current gravitational lensing studies require will be carried out e.g. the Kilo Degree Survey (KiDS) a 1500 square degree survey in 4 bands (Kuijken et al. in preparation). Unfortunately, wide field survey systems do not provide perfect images. As mentioned previously, the distortions we are looking for in the image of the galaxies are generally very small, particularly in the cases of weak gravitational lensing analyses. If specific care is not taken, the extraction of the distortions will be strongly affected by electronic noise, optical defects, atmospheric disturbances, possible micro vibrations of the telescope during the acquisition and/or focusing problems. Specific methodologies have been developed to compensate for these defects, two of them will be used in this thesis, the Kaiser, Squires and Broadhurst (KSB) method and the shapelets method (see Chapters 5 and 6). The shapelets method, still under development, is a very promising alternative to standard methods such as the KSB based techniques. The shapelets method is theoretically more accurate than the other techniques and has already proved reliable on simulated images. The KSB and shapelets
methods will be used during the data reduction of the KiDS images. The system which will produce these data is introduced in the next sections.

1.3 The Very Large Telescope Survey Telescope - OmegaCAM System.

The Very Large Telescope (VLT) Survey Telescope - OmegaCAM system is composed of a 2.6 meters Ritchey-Cretien telescope on which an optical and near infrared wide field camera (OmegaCAM) will be permanently mounted. It will be located on Cerro Paranal in Chile, close to the VLT and it should be operational in 2007. This system has been designed to carry out large homogeneous multi-color imaging surveys suitable for VLT following and also to perform stand-alone survey projects. The VLT Survey Telescope - OmegaCAM system has been designed to perform wide extragalactic surveys, narrow band imaging surveys, multi-color surveys, exoplanets searches, study of milky way objects, nearby galaxies, extragalactic and intra cluster planetary nebulae (PNs), weak and micro lensing phenomena, high red shift supernovae and active galactic nuclei (AGN) and quasars researches.

1.3.1 The VLT Survey Telescope

The European Southern Observatory (ESO) and the Italian National Institute of Astrophysics (INAF) decided to develop in collaboration an alt-az telescope of 2.6 m aperture dedicated to wide field imaging, the VLT Survey Telescope (VST) telescope (see Figure 1.4). It is a modified Ritchey-Chretien telescope F/5.5 that has a primary and secondary mirror actively controlled to compensate for the gravitational and thermal deformation of the structure. The optical system has a corrected Field of View (FoV) of 1.46 degrees diameter, at the focal plane, the full non vignetted field represents a diameter of 372 mm. An additional Atmospheric Dispersion Corrector (ADC) is available for observations at large distances from the zenith or at blue wavelengths (Capaccioli et al., 2003).

1.3.2 The OmegaCAM Camera

An international consortium, consisting of NOVA (The Netherlands), the Universitäts Sternwarte München, Göttingen and Bonn (Germany) and the INAF (Italy), has been founded to finance and build an optical 16k × 16k Charge Coupled Devices (CCDs) camera (Kuijken et al., 2002). The detector has been designed and built by the ESO Optical Detector Team (ODT) (Iwert et al., 2006) while the consortium has been in charge of developing the software to control and operate the instrument. The consortium has also developed a pipeline to reduce and calibrate the massive data output that OmegaCAM will produce.

This camera consists of 32 + 4 2k by 4k E2V 44-82-1-A57 CCDs from the manufacturer E2V. These CCDs are mounted in the detector head on a CCD mosaic plate made of aluminum (see Figure 1.5). This CCD mosaic plate is fixed to a cooling system using nitrogen liquid (called dewar) to maintain the CCDs at cryogenic temperatures (-120 C). All the temperature sensors are connected to PULPO2. PULPO2 is an electronic unit which monitors and controls the temperature, the pressure and the shutter of a
The mosaic of 4 x 8 thinned 44-82 CCDs has a total area of 16384 × 16408 pixels (256 × 258 mm). The orientation of the CCDs follows the arrangement Left-Left, Right-Right (see Figure 1.6). In Figure 1.6, we see the output register pointing to the left in the first two columns of CCDs and in columns three and four all the output registers.
Figure 1.5: The mosaic filled with 8 by 4 mechanical sample CCDs. Courtesy European Southern Observatory, http://www.eso.org/).

are oriented to the right. Because of mechanical constraints, gaps are necessary between the light sensitive areas of the CCDs. Between two sensitive areas oriented left-left or right-right, a distance of 5.61 mm is necessary. Between two long edges of two sensitive areas, a distance of 1.5 mm is needed. Finally we have a distance of 0.82 mm between the two short edges of two sensitive areas, positioned in the middle of the mosaic. This configuration yields a mosaic with a filling factor of about 95%. The mosaic covers 1 x 1 square degree of the VST field of view and samples correctly the images even if the seeing is very good (0.4 - 0.5 arc second). Each pixel is a squared area of 15\( \mu \)m by 15\( \mu \)m which represents a resolution of 0.21 arc-second per pixel.

1.3.3 Standard Filters

The standard Sloan u' g' r' i' z' filters have been selected. Each filter is mounted in one of the two filter magazines and has a dimension of 370 x 292 mm.

Johnson B and V filters, mainly for stellar work, are also present as well as a set of narrow band filters such as Halpha at redshifts up to 8000 km/s. Finally, a composite filter u', g', r', i' in four quadrants can be used for a rapid photometric calibration and the monitoring of the atmospheric conditions. More details about the filters can be found in the article "OmegaCAM - Technical Design and Performance" (Nicklas et al., 2002).

1.3.4 The OmegaCAM Shutter

A high precision slit type shutter has been developed at the Sternwarte of the University of Bonn (Reif et al., 2004) for the OmegaCAM camera. This photometric shutter has an aperture size of 370 x 292 mm and two rest positions for two blades (see Figure 1.7). The frame is made of aluminum while the two blades consist of carbon fiber. The blade travel time is about 0.9 seconds. The minimum exposure time is about 1 milli-second with an accuracy of about 0.3 milli-seconds. This shutter has a symmetric design with no preferred direction of movement. The blade, which covers the CCDs, moves to the free
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Figure 1.6: Schematic view of the CCDs position in the mosaic as well as the distances between sensitive areas. The gray rectangles on the edge of the sensitive area correspond to the output register. They are situated on the left in columns 1 and 2 and on the right in columns 3 and 4.

Figure 1.7: The OmegaCAM shutter, the laptop shows the position of the aperture (370 × 292mm). Courtesy Astronomical Institutes of the University of Bonn, www.astro.uni-bonn.de/~ccd/shutters/).

rest position to start an exposure. The second blade moves from the other rest position to the front of the CCDs to end the exposure. For two consecutive exposures, the blades will move from left to right and then from right to left. The shutter has been designed and tested to perform more than one million operations without failure.

The detector system, the shutter, the two magazines loaded with filters and the filter exchange mechanism are mounted on the VST telescope with the help of the attachment flange which interfaces the OmegaCAM instrument and the telescope (see Figure 1.8).
1.3.5 OmegaCAM Instrument Software

To acquire data, the CCD mosaic, the filters, the shutter, the guide CCDs, the image analysis CCDs, the temperature sensors, the cryostat-cooling controller, etc. have to work in a coordinated manner. It is the role of the OmegaCAM Instrument Software (INS), to control and operate the instrument. The OmegaCAM Instrument Software consists of the Instrument Control Software (ICS), which controls the hardware, the Detector Control Software (DCS), which checks all parameters, the Auto-Guiding software (AG), which controls the guiding system and sends parameters to the Telescope Control Software (TCS). In addition the software also contains the Image Analysis software (IA), which analyzes the telescope aberrations measured by the IA CCDs and transfers to the TCS the necessary information in order to compensate the defects by controlling actively the primary and secondary mirror (Kuijken et al., 2004a). Finally, the OmegaCAM software contains also the Observation Software (OS), which coordinates the instrument and the telescope and controls the transfer of the data to the archive. Detailed information about the OmegaCAM Instrument Software can be found in the article "Advanced Telescope and Instrumentation Control Software" (Baruffolo et al., 2002).

1.3.6 AstroWISE

OmegaCAM will produce between 50 and 150 Gbytes of raw imaging data per night, including the calibration images and science images, this means between 15 and 45 Tera bytes per year. After the reduction of these data, each observed sky field is expected to produce a catalog of about hundred thousand objects with their characteristics. The database produced in this way can reach between 3 and 5 Tera bytes per year. To
handle different observing modes, the calibrations, to transform the raw data into astrometrically and photometrically calibrated images and to archive the huge amount of wide-field imaging data, a complete data processing and handily infrastructure has been built, AstroWISE (Valentijn and Kuijken, 2004; Valentijn and Verdoes Keijn, 2006). The software and the hardware infrastructure are the result of the collaboration between NOVA/Kapteyn Astronomical Institute -co-ordinator of the consortium-, Groningen (The Netherlands); The Osservatorio Astronomico di Capodimonte, Napoli (Italy); Terapix, Institut d’Astrophysique de Paris (France) and the Universität-Sternwarte München (Germany). AstroWISE provides a database driven environment which is distributed over different physical locations, maintaining a single unity through internet connections. This system uses Oracle-10g with SQL and Python for the interface between the users and the database.

1.4 Outline of this Thesis

The European Southern Observatory (ESO), which is in charge of building and operating the VST - OmegaCAM system, had to perform tests on the pre-selected 42V 44-82 1-57 CCDs before mounting them inside the Camera. The CCDs have to fulfill baseline requirements to be accepted for the mosaic. This task was given to the Optical Detector Team (ODT) at ESO Garching which has the facilities to carry out such a large scale operation. This activity required extra manpower for the Optical Detector Team during the period of tests. The first part of this thesis is the result of 2.5 years with the ESO ODT in Garching. We present in this first part the characteristics of the 32 science CCDs which are mounted in the OmegaCAM camera. They have been selected out of 57 science grade CCDs. This first part discusses also two innovative techniques to improve the characterization of the conversion factor and the charge transfer efficiency of a CCD. The second part of the thesis has been carried out at the Kapteyn Institute in Groningen. The research performed in this second part concerns dark matter and gravitational lensing. We have developed two pipelines based on methodologies which will be applied to the OmegaCAM images for weak gravitational lensing analyses (galaxy-galaxy lensing and cosmic shear analyses). This work has been carried out as a preparation for the VST-OmegaCAM data reduction.

Chapter 2 is devoted to the results that we obtained from the tests sequence of the 32 OmegaCAM CCDs. After a brief description of the main characteristics of the 44-82-1-A57 42V CCDs, we present the system which has been used to test all devices, as well as the different updates that have been made since 1996, the year when the new ESO test bench was built. Furthermore we give an overview of the software that has been developed to control all devices of the test bench, and to analyze the output data. Finally the results are analyzed for the quantum efficiency, the photo response non-uniformity, the readout noise, the conversion factor, the linearity, the dark current, the charge transfer efficiency and the cosmetic defects.

In Chapter 3 we describe an efficient and time-saving computation method to calculate the conversion factor of a CCD using Time Delay Integration (TDI) images. In this chapter we briefly summarize the purpose of TDI images in the actual CCD test
procedure and review the photon transfer method. Next, we explain how to modify the standard photon transfer method for handling TDI images in order to produce a photon transfer curve, from which, we deduce the conversion factor. Two techniques are tested using either one or two TDI images, respectively. The results are discussed and compared to those obtained with the variance method used in the tests of the OmegaCAM CCDs.

In Chapter 4 we present a new method to estimate the charge transfer efficiency (CTE). After recalling the definition of the CTE and the standard extended pixel edge response (EPER) method for computing the CTE parameter, we demonstrate how the CTE can affect the variance of the signal and the conversion factor. Based on this work, we develop a model to extract the vertical (horizontal) CTE from flat field images and then we test this technique on both simulated and real data. Finally, a comparison of the new technique, the standard EPER method and the $^{55}$Fe technique (radio active source) is performed, using real data, and the results are discussed.

In chapter 5 we perform a galaxy-galaxy lensing study on 50 uncorrelated VLT Fors1 field images. The main characteristics of galaxy halos situated at the average redshift of $z = 0.5$ are estimated using $6 \times 6$ minutes exposures with the I-band filter. Two models of galaxy halos are compared, namely the singular isothermal sphere profile and the Navarro, Frenk and White (NFW) model.

In chapter 6 we repeat the cosmic shear calculation performed by Maoli et al. (2001) to test a new method for Point Spread Function (PSF) correction and ellipticity estimate of galaxies. Two pipelines, one based on the conventional Kaiser, Squires and Broadhurst method and a new one based on the shapelets technique have been developed to correct the PSF and compute the cosmic shear signal. An extensive comparison is carried out between the output data of the two pipelines to validate the data reduction software based on the shapelets formalism. The shapelets pipeline has already proved reliable on simulated data (Kuijken, 2006), and here we also prove that the shapelets formalism can be applied to real data to carry out successfully weak gravitational lensing analyses.
CHAPTER 1: REVEALING DARK MATTER FROM WIDE FIELD IMAGING