The PAU Camera

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Abstract

The PAU (Physics of the Accelerated Universe) Collaboration aims to carry out a world-class experiment to investigate Dark Energy. For that purpose, it will build a large field-of-view camera with which to conduct a large area survey. The main idea is to develop a camera that can image in many narrow band filters to be able to sample adequately the spectral energy distribution of all objects in the field and in particular of galaxies. We would thus be able to infer the galaxies redshifts. We are currently designing a camera for the prime focus of the William Herschel Telescope with its current corrector. We envisage the construction of a larger camera for a potential facility providing an even larger field of view.

Introduction

The spectral energy distribution (SED) of astronomical object provides information about their nature and properties. For galaxies, the spectral features in their SEDs allow us to measure their redshifts and properties such as their stellar mass, the age of their stellar populations, their metallicities, and their dust content. In order to study and properly sample the SED of a galaxy one needs to measure it with sufficient spectral resolution. Normally this is achieved with spectrographs. Cosmological studies require the study of large volumes sampling many galaxies out to large redshifts and faint limits. However, the multiplexing capabilities and the depth reached by spectrographs do not always allow these cosmological and evolutionary studies. Moreover, many cosmological applications do not require the resolution delivered by spectrographs. Another viable approach is to sample the galaxies SEDs with less resolution using narrow band filters photometry. This is the technique chosen for the PAU survey.

The PAU collaboration is building a large field of view camera equipped with ~40 narrow band filters in order to perform a large area survey for cosmological studies. The idea is to use ~100 Å wide filters between 4500 Å and 8500 Å complemented by a set of broad band filters to sample the galaxies SED to obtain accurate photometric redshifts.

The PAU Camera

The PAU Camera (PAUCam) is being designed to be placed at the prime focus of the William Herschel Telescope (WHT) sited at the Observatorio del Roque de los Muchachos (La Palma, Canary Islands, Spain). The primary mirror of the WHT has a diameter of 4.2 m and it shape is an f/2.5 paraboloid. For instruments to be placed at the prime focus there is a three lens optical corrector and an atmospheric adaptive corrector that delivers an unvignetted field of view of 40 arcmin diameter. The field-of-view is vignetted 50% at a radius of 30 arcmin. The effective focal length is of 11,737 mm equivalent to a scale in the focal plane of 17.57 arcsec/mm.

The basic idea of the PAUCam design is to achieve a system delivering a large field-of-view that can image in many narrow band filters. Extensive simulations suggest that the best compromise to achieve our scientific goals is to use a set of ~40 narrow band filters of approximately 100 Å width covering the wavelength range from 4500 to 8500 Å and complemented by a set of broad band filters.

The field of view of the WHT prime focus sets the physical size of our camera. We want to cover the whole field of view which implies a focal plane of ~20cm diameter. Narrow band filters of this size are hard and expensive to manufacture. Moreover such a number of filters make it impossible to have a system of filter wheels hosting them all. We would thus need frequent filter changes which implies operational risks and expenses. We have opted instead for a system of small filters of the same size of the detectors that will be placed on segmented trays just in front of them. In order to avoid vignetting and obscuration due to the filter tray and not to lose area coverage of the focal plane, we need to place our filters as close as possible to the detectors. Having more filters than CCDs implies a system of moving trays that need to work with very tight tolerances on a vacuum and cryogenic environment. For simplicity we would like the minimum number of filter trays. However, for full wavelength coverage, that is observing in all filters, without vignetting, we only have the central 8 CCDs available and therefore need at least 5 trays for our 40 filters (figure 1). The filters sharing a filter tray need to be parfocal. In addition, we need to image in broad band filters. So, our design includes now 10 filter trays inside the cryostat that are moved from their parking position in a jukebox-like tower to their position in front of the detectors and vice versa. This is one of the most challenging and innovative components of PAUCam.

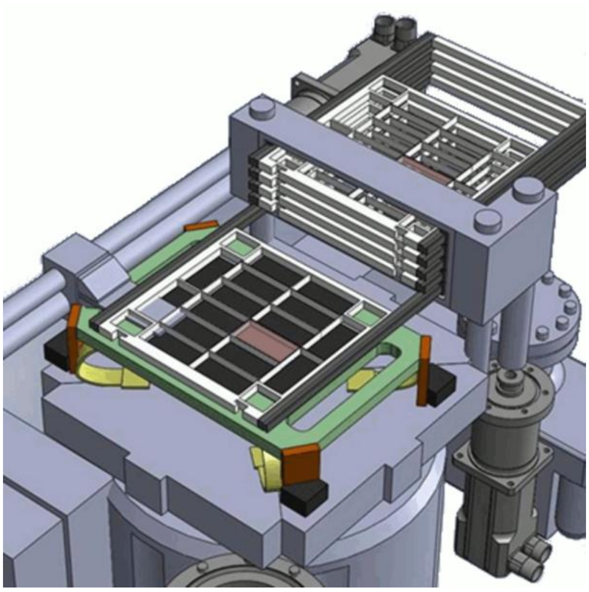

Figure 1: Preliminary design of PAUCam showing the filter tray system.

We want to cover the focal plane with CCD detectors as compactly placed as possible. Tiling flexibility, area loss due to CCD mountings and cost have made us chose 2k x 4k pixel detectors of 15 μm size. With them, it is possible to cover the unvignetted field of view with 8 CCDs and the whole 60 arcmin focal plane with 18. The pixel scale is of 0.26 arcsec/pix. In order to cover as much as possible the objects SEDs and reach high redshifts, we want our detectors to have the widest coverage in wavelength. Therefore, we are interested in thick CCDs with good quantum efficiency in the red. The CCD distribution is shown in figure 2, where it can be seen that we completely sample the focal plane available.

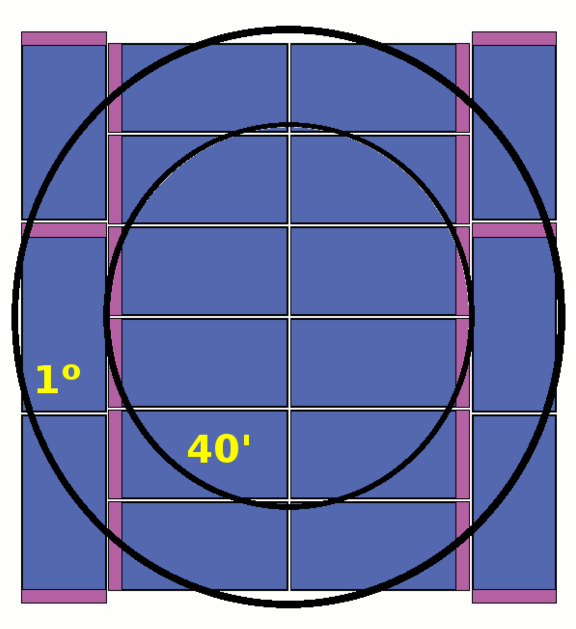

Figure 2: CCD distribution optimized by the prime focus of the WHT.

The camera cooling system is based on liquid nitrogen that flows to a heat exchanger boiler in thermal contact with the cold plate. Its flow, and thus the heat exchange, is regulated by a valve controlled by a PID monitoring the CCD temperatures. The CCDs will be kept at ~170 K with the thermal homogeneity being achieved by means of the cold plate. Our thermal models indicate that we can keep the whole focal plane CCDs within a temperature difference of 3 degrees.

Our science requirements imposes constraints on the allowed read-out noise that cannot be larger than $5e^-$. The camera electronics system is based in the Monsoon system, developed by NOAO.

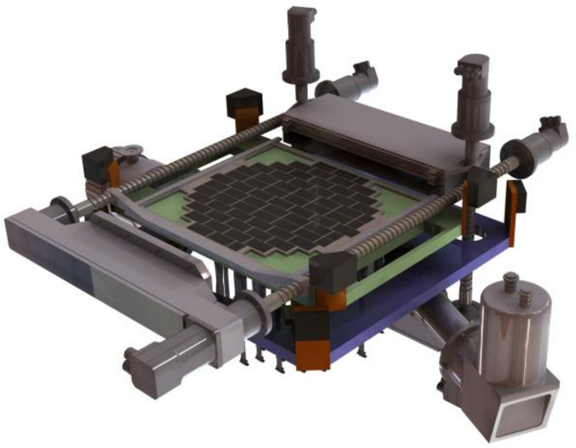

Figure 3: Large field-of-view camera sketch with 64 CCDs of 2k x 4k and 6 of 2k x 2k to cover a focal plane diameter of 40 cm.

The future

The PAUCam is designed and will be built for the WHT prime focus with its current corrector. However, the design is flexible enough that it may be possible to install it in another wide focal plane. The engineering solutions can also be applied to a larger camera if funding and a suitable larger field of view becomes available in the future (figure 3).

Summary

We are in the process of designing the PAU Camera. It is expected to be mounted at the WHT prime focus in approximately two years. PAUCam at the WHT will be the most powerful wide area imaging capability at La Palma. It will be able to image in 40 narrow band filters and also standard broad band filters. Its wavelength resolution will allow to sample the spectral energy distribution of all objects observed in its large field of view.