An Atmospheric Cerenkov Telescope Simulation System

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1 ABSTRACT

A detailed numerical procedure has been developed to simulate the mechanical configurations and optical properties of Imaging Atmospheric Cerenkov Telescope systems. To test these procedures a few existing ACT arrays are simulated. First results from these simulations are presented.

2 INTRODUCTION

During the last two decades or so the Atmospheric Cerenkov Imaging Technique (IACT) has developed rapidly, thus opening up the very high energy (VHE, 0.1 TeV to 10 TeV) gamma ray astronomical particle band and has led to the detection and detailed studies of very large number of astrophysical sources that emit electromagnetic particle radiation in these energies. Examples of Cerenkov imaging telescopes are (i) the Whipple Observatory, (ii) the MAGIC telescope system, (ii) the VERITAS telescopes, (iv) the HESS I and HESS II telescopes. This branch of astronomy is yet to grow further with the commissioning of the Cerenkov Telescope Array (CTA).

Before the advent of the Cerenkov imaging technique, several experimental groups around the world made attempts to detect celestial VHE gamma ray sources using the traditional (presently somewhat obsolete) Wavefront Sampling Technique. Unlike the Cerenkov Imaging Technique that uses stereoscopic imaging of the particle showers initiated by the celestial VHE gamma rays and also the background cosmic ray particles, the wavefront sampling technique just attempts to collect the Cerenkov photons using large mirrors and tries to distinguish between photon initiated and hadron initiated showers using somewhat loosely defined characteristics, such as the shape of the lateral distribution of the Cerenkov photons, or the Cerenkov photon pulse profile etc. This resulted in poor signal-to-noise ratios.

In the 1980s a simple computer procedure was developed at TIFR, Mumbai just to calculate the lateral distribution of the Cerenkov photons emitted by soft (electro-magnetic) cascades in the atmosphere. This Monte Carlo procedure was based on the soft cascade program developed by (Late) R H Vatcha. The Cerenkov photon emission routines (mostly analytical) were added to the soft cascade procedure.

Later, the Cerenkov emission routines were rewritten completely to follow individual Cerenkov photons along their path together with other im-
provements.

Since the Wavefront Sampling is presently almost out of fashion, one feels the need to develop numerical simulation procedures for the Cerenkov Imaging Technique. In the present we try to give some preliminary results from such an endeavour.

3 THE DETECTOR SYSTEMS

The details of the HAGAR telescope are available elsewhere [SHU]. This array employs the traditional wave-front sampling technique. This system consists of seven clusters of mirrors arranged in the form of a hexagon with side 50 meters. Each cluster consists of seven mirrors (each having a diameter of 0.9 meters and a focal ratio \(f/d\) equal to 1).

The details of the HESS I IACT telescope system are given in [BER03]. Briefly, the HESS I system consists of four individual imaging telescopes arranged in the form of a square having sides of 120 meters. Each telescope consists of 382 spherical mirror facets. All the facets have the same diameter equal to 60cm. The focal length of each facet is 15m. The 382 mirror facets are arranged in the form of a panel with a small central hole. The HESS I telescopes are located at a site in Namibia at an altitude of 1800m above the mean sea-level.

The light reflected by the telescope mirror (having a total reflector area \(108m^2\)) is focused onto a camera consisting of 960 pixels. Each pixel consists of a photo-multiplier tube (PMT, ) having a diameter equal to . A Winston Cone placed at the face of each PMT facilitates efficient light collection. The 960 PMTs are grouped into PMT DRAWERS (4X4). Thus, there are a total of 60 DRAWERS in the camera. The photo-cathode is a bi-alkali one with a peak quantum efficiency of 24% at 340nm wavelength. The camera is placed at a distance of 15m from the reflector, i.e. at its focus.

4 THE SIMULATION SYSTEM

The numerical simulations are carried out using a hybrid technique consisting of both analytical and Monte Carlo (based on random numbers). Random numbers are used wherever necessary. The simulation codes are written largely using the FORTRAN 90/95 language (the GNU GFORTRAN com-
piler is used for this purpose). Details of the simulation procedures are available elsewhere (the author, in preparation). In the following we give a very brief outline of the same.

The present simulation system consists of two major components. One part of the system deals with the simulation of the Cerenkov telescope arrays (the complete mechanical, optical and electronic aspects). This part has been developed recently. The other part of the simulation code deals with the simulations of the Extensive Air Showers (EAS) which are the sources that emit the Cerenkov photons. The EAS are initiated by the Very High Energy (VHE) gamma rays from the Celestial objects and also (at the same time much more numerous) Cosmic particle radiation (mainly protons and other heavier nuclei) that constitute the unwanted (for this type of work) background.

For the simulations of Extensive Air Showers (EAS) we do not use CORSIKA, but a home-grown software. The electro-magnetic (soft) cascade program is essentially that developed by R. H. Vatcha [VAT] and the hadronic part is essentially that developed at TIFR. The Cerenkov photon emission procedures were added by the present author alongwith others at TIFR in the 1980s [BSA82], [RAO88], [SIN95] and later developed further by the present author. The main shower simulation procedures have also been significantly modified.

5 RESULTS of SIMULATIONS

In Fig.1 we present the simulated profile of a single large parabolic mirror (diameter 10 m). In Fig.2 we present the simulated profile of a single Atmospheric Cerenkov Telescope (this telescope consists of seven parabolic mirrors, each having a diameter equal to 0.9 meters). This type of telescopes are being used in the Indian HAGAR experiment situated at Leh in the western Himalayas. The HESS I Imaging Atmospheric Telescope System is in operation since in Namibia at an altitude of. The HESS I System consists of four Imaging telescopes, each one having an effective area of 108 m². Each of the four HESS I telescope mirror consists of 382 mirror facets (each having diameter 60 cm). Each HESS I mirror may be thought of as consisting of six large sectors, each sector looking like an inverted triangle. In Fig.3 we present the simulated image of a single telescope.

Fig.4 shows the simulated profile of the HESS I camera. The camera
Figure 1: A Single Large (10 m) Mirror.

Figure 2: The HAGAR telescope looking 20 deg. Zenith.
Figure 3: One of the four (12 meter) HESS I Telescopes.

consists of 960 PMTs. Fig.5 shows the camera positioned at the focus of the telescope.

6 DISCUSSIONS and CONCLUSION

There are certain small inaccuracies in the present calculations. These have to be removed. It is possible to improve the procedures by including finer details. Hopefully we will be able to present more advanced work in this direction.

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Figure 4: The HESS I CAMERA (consisting of 960 PMTs).

Figure 5: The HESS I mirror with the camera at its focus.
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