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Study of geomagnetic effects in the data collected by HESS-II

Summary of work :

The last, most energetic window for astronomical investigation was recently opened up by the H.E.S.S. collaboration in the Very High Energy (VHE) gamma-ray domain, a breakthrough that was recognized by the award of the Descartes Prize for 2006. VHE astronomy traces the sites of particle acceleration in the Universe, even in dense environments, and provides an unique view of the central engine of fascinating objects such as the Active Galactic Nuclei, Pulsars, Supernova Remnants and Microquasars.

The H.E.S.S. experiment is an array of four Atmospheric Cherenkov Telescopes (ACT) of 107 m^2 each, located in the Khomas Highlands, Namibia, and equipped with fast camera comprising 960 individual photomultiplier pixels. H.E.S.S. achievements include the first VHE scan of the inner parts of the Galaxy[1][2] (Fig. 1), which revealed a harvest of new sources belonging to the categories of shell-type supernovae remnants (SNR), pulsar wind nebulae (PWN), star forming regions and binary systems. Some of these sources, called "dark accelerators", have no known counterparts in other energy domains, thus strengthening the discovery capabilities of VHE astronomy. Key results also include the first VHE image ever produced from a SNR[3], which showed strong correlations between X-ray and VHE features, the detection of diffuse gamma-ray emission around the Galactic Centre[4], the detection of VHE orbital modulation in a binary system[5] and low constraints on the diffuse intergalactic infra-red background obtained from the observation of distant active galactic nuclei[6], as well as the first observation of a starburst galaxy[7].

After the successful opening of the energy domain above 100 Gigaelectronvolts (GeV), H.E.S.S. has been completed by a 28 m diameter telescope, which has been inaugurated in September 2012 and is now concentrating on the lower energy domain, between 10 and 100 GeV. This domain remains almost unexplored although key physics results are expected in this region. Amongst the challenges needed to beat the night sky background in this region and to make signal extraction possible, the question of the reconstruction of gamma-ray events though recorded

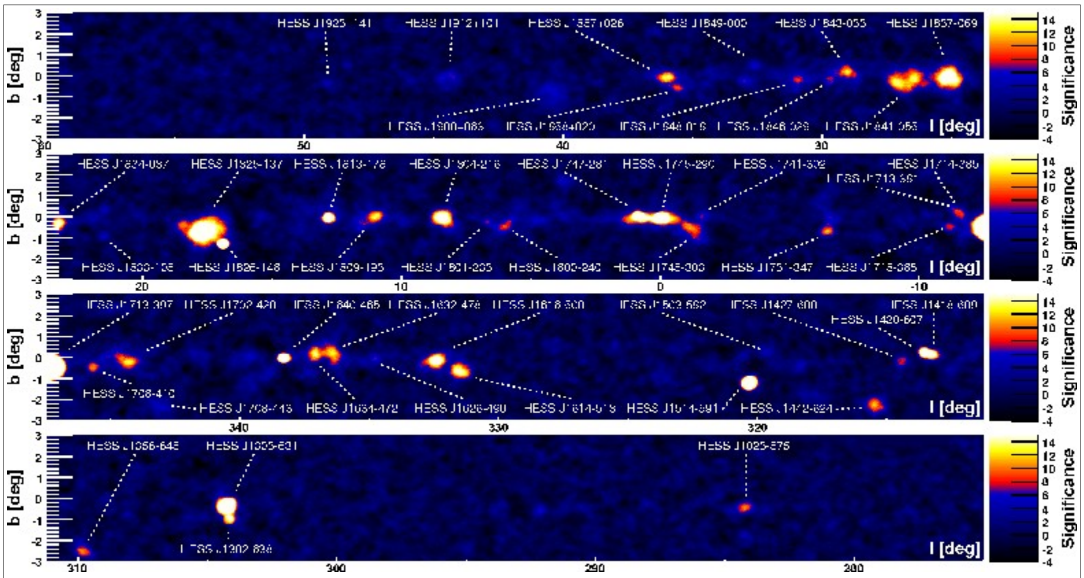

Figure 1: Galactic Plane as seen by HESS. From [2].

atmospheric shower images is very central. Existing reconstruction techniques based on simple geometric assumptions indeed become quickly ineffective as the energy decreases.

One of the most powerful reconstruction technique applied in HESS[8] (the *Model Analysis*) is based by the log-likelihood comparison of the actual, raw images, with a precalculated model, and is particularly suited for analysis of low energy showers, because is does not rely on image cleaning an exploits the full available information.

At low energy however, the geomagnetic field influences the development of atmospheric showers by separating apart positively and negatively charged particles. This induces a larger spread of the shower in the direction orthogonal to the magnetic field. Several authors studied the effect of the magnetic field on the image shape in Atmospheric Cherenkov Telescopes, both on the theoretical level and on the experimental one (e.g. [9], [10]):

- The interaction of the field and the cascade electrons produces a broadening of the atmospheric Cherenkov light image resulting in a reduction in the density of light sampled by the telescope; so the energy threshold for the telescope increases.
- Images are slightly distorted and rotated compared to shower developed in the absence of field; this effect induces a systematic bias in the direction estimation and results into inhomogeneities in the background level. The effect on image shapes is illustrated in Fig. 2.

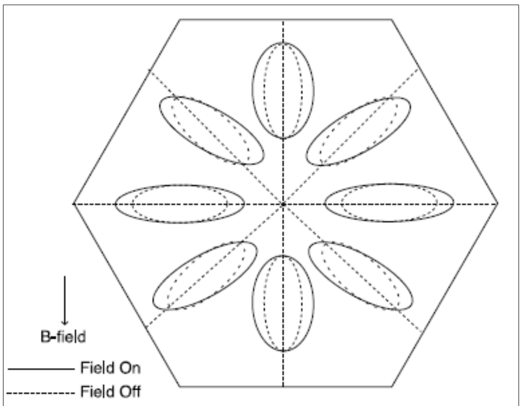

Figure 2: The effects of the geomagnetic field on the shape and orientation of images of VHE gamma rays. From [9]

This effect can be in principle fully reproduced using simulation, distortion to the images could be in principle incorporated into the Model Analysis: actual images in the camera will be compared to rotated and distorted model images, thus solving the reconstruction systematics. This approach is expected to be more efficient than an *a-posteriori* correction of reconstructed parameters as it would not only correct for image rotation, but also for distortions and wrong energy estimation.

The proposed work would consist in:

- Characterization of the distortion effect induced by the geomagnetic field using existing simulation software
- Estimation of the effect on the energy and angular resolution of the instrument
- Correction of that effect by proper transformation of the precalculated images used in the reconstruction algorithm
- Test on existing HESS-I and HESS-II data.

Possible follow-up:

This work is an essential part toward an efficient analysis technique for HESS-II. It will allow the applicant to get used to the simulation and analysis framework of HESS, and can therefore be a perfect preparation for a PhD work inside the HESS collaboration. Possible thesis subjects that would largely benefit from this work could be the search for diffuse emission across the Galactic Plane at ~ 100 GeV as well as study of galactic binary systems or supernova remnants.

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