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Spot Size of 17m-Diameter MACE Reflector in Presence of Surface Inaccuracies

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Abstract The MACE (for Major Atmospheric Cerenkov Experiment), an imaging cerenkov telescope for gamma-ray astronomy investigations in the sub-TeV energy bracket, plans to use a 17 m-diameter high quality reflecter mounted with a high definition imaging camera in its focal plane. The spot size of the MACE has been estimated for, both, on- and off-axis cases, considering an ideal mirror surface. The effect on this spot-size due to surface smoothness errors has been investigated.

Keywords : Atmospheric Cerenkov Radiation, Gamma Rays, Graded Focal Length , Spot Size

1 Introduction

The exploration of gamma-ray (γ) astronomy in the energy range between $\sim$ 20-200 GeV has not been possible due to limitations of the detection area of current satellite-based gamma-ray telescopes and the higher threshold energy of ground-based atmospheric cerenkov experiments. There is a strong physics motivation behind studying this largely unexplored window in a detailed way. A few of the important problems which can be addressed are:

(I) Investigations of spectral evolution of EGRET sources (including γ-ray pulsars and active galaxies like BL-objects) above tens of GeV energy range.
(II) Understanding the nature of unidentified EGRET objects.
(III) Learning about galaxy-evolution in early epocks of the universe.
(IV) Searching for high-energy spectral tails in cosmic gamma bursts.

A proper exploitation of the 10's GeV γ-ray spectral window requires detectors with very large collection areas, a requirement made realisable using very large reflector telescopes like the MAGIC [1], which incorporate (a) a large cerenkov light collection areas, red-extended spectral response ($\lambda \sim 300 - 600$ nm) and (b) a high resolution imaging camera comprising light collection with a high quantum efficiency.

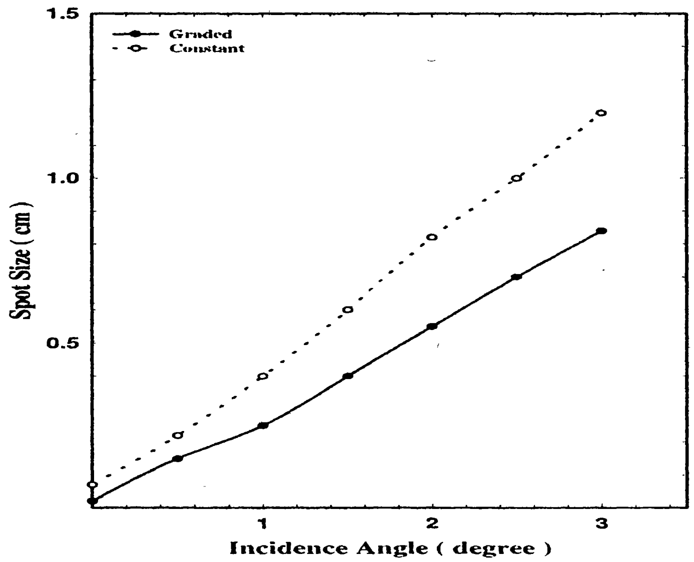

Figure 1: Plot of the spot size as the function of Incidence Angle for two differnnt cases; (i) Constant focal length and (ii) graded focal length of the mirror facets.

Some groups such as STACEE [2] and CELESTE [3] are using solar power plants as sub-TeV air Cerenkov detectors. Their main advantage is the ready availability of a large reflector system. But, their expected performance seems to be far from optimal due to limited angular range, the non-ideal optics and the large time spread of the signals as a result of the extended geometry.

2 Stereo MACE

Our group is presently building the imaging gamma-ray telescope stereo-MACE as a major component of the GRACE, gamma-ray astronomy facility, set up at Mt. Abu, Rajasthan, India [4]. Like the MAGIC, the MACE will deploy multi-facetted 17m light collector, placed on alt-azimuth mounts, provided with two axes steerability. The mirror-facets are diamond-turned Al alloy plates, each 2304 cm^2 in area, and backed up with Al honecombs for structural rigidity. Four mirror facets are placed side by side on a 1m $\times$ 1m Al panel, again provided with Al honecombs for mechanical rigidity. The mirror facets have focal lengths varying between 17.06 - 18.16 m in a graded manner, as we move from the centre to the edge of the light collector. The surface smoothness of the mirror facets is specified to be better than 10 nm.

There are certain limitations that prevent the diameter of a single telescope to be increased well beyond that of the current telescope [5]. Based on general scaling factors in technical design, the cost of increasing the reflector area would be proportional to more than the third power of the diameter. Also there are optical problems: for a telescope with more than 17 m diameter the images are blurred to such an extent that γ/hadron seperation power deteriorates strongly [6].

This paper describes simulation results obtained on the expected optical quality (spot-size) of the over all light collector in presence of surface inaccuracies (rms value $\sim$ 10nm)

3 Simulation Results

The spot size of the MACE has been estimated for, both, on- and off-axis for the interesting two cases of constant and graded focal length for the individual spherical facets. In the latter case, the grading increases as we go out from the light collector centre to its rim. The results depicted in Fig. 1 clearly demonstrate the advantage of the graded focal length configuration over the constant focal length case. This is reflected by the improvement in the spot size in the former case.

The simulations for the spot size analysis have been carried out for an ideal mirror surface. But, in actual practice, the mirror facets have inaccuracies which fall in two categories: (I) a short-term surface inaccuracy and (II) a long-term profile inaccuracy. In the second iterative excerise, the consequence of the expected mirror surface inaccuracy on the spot size have been investigated. This analysis assumes a lot of significance for a MACE like systems as the imaging camera pixel resolution is as small as 0.1^0.

The simulations were carried out using a ray-tracing programme. The mirror surface inaccuracy has been incorporated using a Gausion distribution. Various degrees of surface inaccuracy ranging from a σ value of 5 nm to 10^4 nm, have been considered. The fall-out of the surface inaccuracy on the spot size remains almost unperturbed upto the surface inaccuracy value of few hundred nm. So, the reflector will behave almost as an ideal one upto this limit of surface distortion. The impact of the inaccuracy on the spot size above this limit becomes quite significant Fig. 2. The results establish that surface inaccuracy upto few hundred nm are tolerable and the spot size remains well within the MACE imaging camera

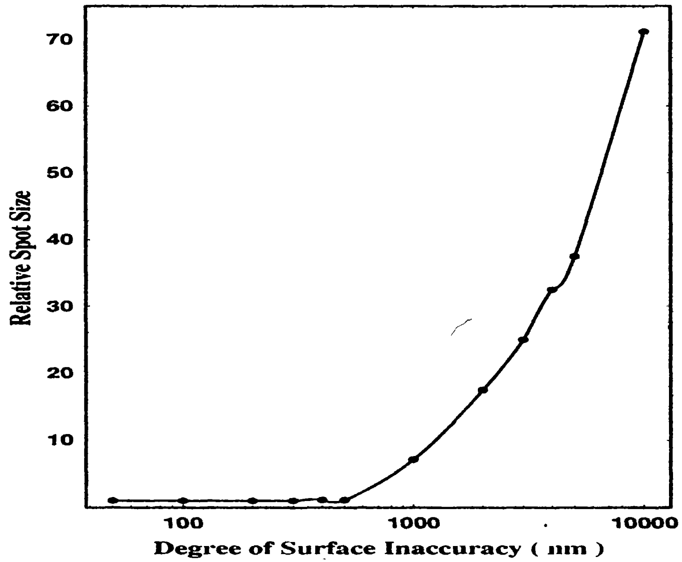

Figure 2: Plot of the normalised spot size as a function of the surface inaccuracy, the normalization factor being the spot size of an ideal reflector.

pixel resolution of $\sim 0.1^0$. We are presently investigating the effect of profile inaccuracy on the spot-size.

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