All Sky Camera for CTA Site characterization

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Abstract. The All Sky Camera (ASC) for CTA Site characterization is an automated optical instrument providing optical observation of the night sky conditions above the future Cherenkov Telescope Array observatory. It provides the basic sky condition analysis like cloud coverage, cloud position, nightsky background in visible light wave range and basic raw photometry. The result will serve for further Monte Carlo design studies and calculations. The ASC and additional auxiliary instruments (e.g. Ceilometer) will provide input data for smart scheduler during the standard measurement procedure of the CTA observatory.

1 Introduction

The Cherenkov Telescope Array (CTA) [1] will be the next generation of gamma-ray astronomy ground-based observatory for very-high energies. With more than 100 telescopes located in the northern and southern hemispheres, CTA will become the world's largest and most sensitive high-energy gamma-ray observatory. The atmosphere has to be monitored during the observation as the measurement process is strongly sensitive to the current atmospheric condition. There will be a complex program for atmospheric monitoring running within the observatory to study real-time atmospheric parameters to allow eventual changes of the measurement schedules or for correcting the measured data and analysis. The ASC is an instrument for the site characterization during the pre-production and deployment phase and serve for the dynamic scheduler of the CTA observatory during the standard observation.

2 Analysis of clouds above the observatory

The main task of the instrument is the analysis of the clouds on the sky over the CTA observatories before and during the measurement period. The goal is to monitor the clouds condition, changes and a local behavior of the atmosphere in term of cloudiness during the nights. The CTA observatory selected two potential sites for CTA north and south observatory. Both sites were very well investigated and described in the meaning of cloud coverage during the CTA site search campaign. The comparison of the CTA candidate sites was carried out during the period of 2011 - 2015 [2]. The data for the campaign could be used e.g. for the estimation of the cloud-free nights. The cloud-free night could be defined as a night with the cloudiness of the sky (or cloud fraction cf - fraction of the sky covered with the clouds) less than 20% during the whole night. The limit of the cloud-free sky - less 20% of the sky was set as the CTA clear sky criteria during the site search campaign. The comparison is shown in the figure 1. Vertical axis represent the cloudy/clear nights, where 0 means completely covered sky during the whole night, and 1 means completely clear sky during the whole night with respect to the CTA definition. The whole data set of both sites represents 457(red color)/439(blue color) analyzed nights. SITE_1 (red color) shows better sky condition in terms of clear sky comparing to the second one. We do not present the location of the site, it is just a comparison of both future CTA observatories and the cloud condition of the particular site is one of the criteria of the quality of CTA sites. The CTA criteria could be also changed. The figure 2 shows the number of good quality nights with respect to the cloud fraction criteria cf. If assumed the scenario with the cloud fraction e.g. 50 (50% of the sky is covered with the clouds) the total number of good quality nights could significantly increase with respect to the CTA cf criteria (see fig. 2). The result depicts the expected percentage of nights without observation (number of fully covered nights) and nights without any observation losses (completely clear nights).

3 Site characterization

3.1 Clouds cover

The CTA north and south sites were chosen to host new CTA observatory. The average cloud coverage was measured and analyzed [3, 4] during the CTA site search campaign at both locations. The next step of the site characterization is a deep study of the night sky condition with respect to seasonal variations, local anomaly, and standard

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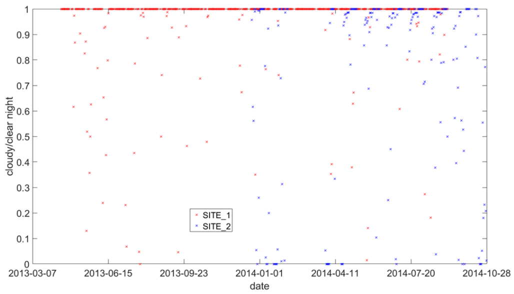

Figure 1. The comparison of cloudless night of CTA sites. 0/1 - fully covered/clear sky during the whole night.

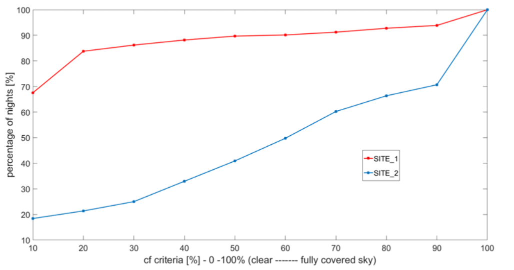

Figure 2. The fraction of fully clear/covered nights as a function of cf (cloud fraction) criteria of CTA sites.

nature of the clouds above the observatory. We installed a new generation of ASC in 10/2015 at CTA north and 11/2015 at CTA south site. The new generation of the camera contains additional CCD cooling system and photometric Johnsons filters comparing to the first ASC generation dedicated for the site search campaign. The resolution of the CCD chip of the camera (Moravian Instruments G2-4000) is 2056 × 2062 pixels, the angular resolution is 0, 1° and the lens f number is 2.8 (Sigma 4.5/2.8 EX DC). We observe stars up to 7 star magnitude in zenith with 30 sec. exposure time typically. The figure 3 shows the result of cloud analysis. The green/red circles show detected/not-detected (covered by cloud) stars. The figure represents three subsequent images. The clouds are visible and the red arrows show the estimated cloud movement direction. Further analysis will focus on new method that should consist in estimating the cloud movement direction using a set of previous analyzed clouds maps. The method should be able to determine the location and the time of clouds and predict if the target source will be observable or not, providing input to the scheduler.

3.2 Star photometry

The new generation of the ASC contains 5 position filter wheel for 1.25” threaded cells with BVR Johnsons filter installed. The Johnsons BVR filter allows us to measure the flux from the known stars and compare the signal with the catalog for different wave range. TYCHO2 star catalog is used (for the astrometry and clouds analysis) for the star photometry. The comparison of the flux measured

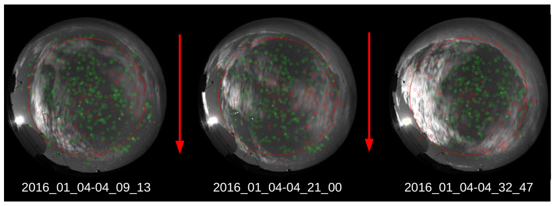

Figure 3. Cloud analysis of three subsequent images during one cloudy night. The green/red circles represent detected/not-detected stars. The clouds are also visible due to the moon in the field of view (the moon light is scattered from the clouds). The clouds are moving top-down direction (red arrows). The direction was estimated by observer.

by ASC and TYCHO2 value could be used for the RAW estimation of the integral atmospheric attenuation in the direction to the observed star as shown in figure 4. The red dashed curve represents the theoretical extinction of the source for different zenithal angle. It is the zenithal atmospheric brightness - extinction at zenithal angle. The dots with different colors (one color per one star at different zenithal angle) depict the differences between the measured star flux (using ASC) and the catalog value of individual analyzed stars. The cloud-free nights were selected for this analysis only. The offset of the theoretical (catalog) and measured magnitudes is caused by the attenuation of the ASC optics (namely vignetting) and its non-homogeneous spectral transmission of the ASC lens across the FoV. Higher is the zenith angle, greater is the difference (figure 4). To mitigate the offset caused by the optical elements a local catalog will be generated for particular site, especially during the long term site characterization campaign. Thus the final analysis for routine observation will be independent of a star catalog and spectral correction.

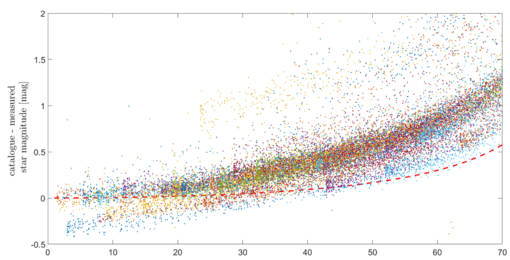

Figure 4. The result from a set of 300 clear sky images. The dashed red curve represents a zenithal atmospheric brightness. The color points represent the differences between signal measured (in magnitudes) by the ASC and the star catalog value for different zenithal angles (one star - one color).

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