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Selection of astrophysical/astronomical/solar sites at the Argentina East Andes range taking into account atmospheric components

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Abstract

In the present work we analyze sites in the Argentinian high Andes mountains as possible places for astrophysical/astronomical/solar observatories. They are located at: San Antonio de los Cobres (SAC) and El Leoncito/CASLEO region: sites 1 and 2. We consider the following atmospheric components that affect, in different and specific wavelength ranges, the detection of photons of astronomical/astro physical/solar origin: ozone, microscopic particles, precipitable water and clouds. We also determined the atmospheric radiative transmittance in a day near the summer solstice at noon, in order to confirm the clearness of the sky in the proposed sites at SAC and El Leoncito. Consequently, all the collected and analyzed data in the present work, indicate that the proposed sites are very promising to host astrophysical/astronomical/solar observatories. Some atmospheric components, like aerosols, play a significant role in the attenuation of light (Cherencov and/or fluorescence) detected in cosmic rays (particles or gamma photons) astrophysical observatories, while others, like ozone have to be considered in astronomical/solar light detection.

Keywords: Astrophysical; Astronomical; Solar: sites; Argentina-Andes: atmospheric components

1. Introduction

Astrophysical and astronomical observatories have very demanding requirements on the clear sky conditions and those devoted to the search of astroparticles (ultra-high energy photons and particles) have additional needs in terms of available flat space and an adequate altitude (to be able to detect the maximum development of the cosmic ray showers) for their considered sites.

Astrophysical/astronomical/solar facilities, involve big projects (frequently carried out by giant international collaborations) with special requirements on site selection for their construction. For these kind of facilities, an

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important scientific constraint is to have good quality atmospheric conditions given by the clearness of the atmosphere. Different atmospheric components that contribute to reduce atmospheric transmittance are analyzed in this work for sites in the Argentinian Andean regions, selected in the framework of the site selection process of the Cherencov Telescope Array (CTA) Astroparticle Physics Project. But the results about their atmospheric conditions are of interest also for other astrophysical and astronomical (including solar) applications.

Astroparticle Physics is a relatively new transdisciplinary field of physics, a product of the interaction between particle and nuclear physics, astronomy and cosmology. There is a widespread conception that in the last decade this field of research has become a mature astronomical discipline Hinton et al. (2013). A pillar and strategic topic of its research is high energy messengers (charged particles, neutrinos, gamma rays) and it is apparent that most of the corresponding research projects have been or will be implemented within international collaborations, as has been the case for the Pierre Auger and CTA projects (see Abraham et al., 2004; Aab et al., 2015a; Actis, 2011).

The reconstruction of gamma rays showers is based, for CTA Project, on Cherencov light detection. Moving through the atmosphere at speeds higher than the phase speed of light in air, secondary charged particles (such as electrons and positrons) of the cascade originated by the primary astroparticle, emit a beam of bluish light, known as Cherenkov light. In the last decades, general reviews on the subject show the evolution of the ideas about Cherenkov light detection and the fundamental discoveries (see for example Cawley and Weeks (1996), Ong (1998), Catanese and Weeks (1999), Hinton and Hofmann (2009), Hillas (1985) and Hillas, 2013).

For near vertical showers, this Cherenkov light illuminates a circle with a diameter of hundred of meters on the ground. This light can be captured with optical devices and used to image the shower. Reconstructing the shower axis in space and tracing it back onto the sky, the celestial origin of the cosmic gamma ray is determined.

The Pierre Auger is a hybrid project: composed of surface and fluorescence (SD and FD) detectors, to register both the lateral distribution of the shower at ground level and the shower development across the atmosphere. The latter is detected by the FD system. It registers the fluorescence photons emitted during the passage of the cosmic ray shower through the atmosphere.

Although the Extensive Air showers are common to both, the Pierre Auger Observatory and CTA are different systems of detection, because they observe different energies and phenomena produced at different parts of the atmosphere: fluorescence emission has time scales of microseconds, and depends mainly on the presence of N_2 and water vapor, Cherenkov light is produced in time scales of nanoseconds and depends on the air density in the effective collection area, which is determined by the angle of emission; for gamma photons in the energy range of interest for CTA, the maximum of the shower is between 8 and 12 km asl (with an air density of 200–300 g cm^{-2}), while for high energy particles in the energy range of interest for Auger, this maximum is at about 1.4 km asl, that is almost ground level at the Auger Observatory.

In spite of the differences, the study of the atmosphere for both systems is devoted to the same parameters, with small differences in the requirements.

The Argentina (East) Andes mountains have geographical and climatic (meteorological and solar radiation) conditions that are, in principle, very adequate for the placement of astrophysical/astronomical observatories and Solar facilities. In particular, the Pierre Auger Observatory of ultra-high energy cosmic rays (http://www.auger.org), is located in Pampa Amarilla, a large plateau at about 1400 m asl, near Malargüe city, Province of Mendoza. It consists of about 1700 Surface Detectors (SD) distributed in a ground surface of 30 km×40 km, plus 27 atmospheric Fluorescence Detectors (FD), 24 telescopes in 4 buildings and three high altitude telescopes (the HEAT project), overlooking the array, which observe the longitudinal cosmic ray shower development by detecting the fluorescence light produced by the de-excitation of the atmospheric nitrogen from its excited state originated in its interaction with the charged particles of the shower. The surface detection is based on the Cherenkov light produced when high velocity particles (traveling at speeds higher than the speed of light in the water) interact with the water in the tanks, with time scales of nanoseconds. The Fluorescence Detectors at Auger look for the Nitrogen fluorescence which presents a spectrum partially in the UV and partially in the visible, at a particular line of 337 nm, and a time scale of production of microseconds. The shower maximum is reached between 2 and 8 km asl for a shower with 10^{19} eV, depending on the type and the inclination angle of the primary particle. The FD telescopes of the Pierre Auger Observatory oversee the sky between 0.7 km and 12.5 km above ground level (at about 1.4 km asl), at a distance of 20 km.

The energy for the SD functioning, data collection and transmission is provided by photovoltaic panels. The whole system has been working for more than a decade, showing a good behavior. The FD detectors function connected to the power line, that in all cases was installed especially for this purpose (for details see Aab et al., 2015a,b).

When a large astrophysical/astronomical observatory is proposed to be built for the detection of light, coming from astronomical sources or originated by showers of astroparticles (high energy photons and particles), a detailed search for the best places in the world is undertaken and the clearness of the sky is usually a main condition to be addressed. An essential feature of the CTA, when considering the site selection, is their lack of shelters. Whereas a typical optical telescope is protected from extreme weather by a dome the CTA telescopes are always exposed to the environment. The choice of lack of shelter has been made because of cost. This fact explains the necessity of many of the