A Site Evaluation Campaign for a Ground Based Atmospheric Cherenkov Telescope in Romania

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Abstract

Around the world, several scientific projects share the interest of a global network of small Cherenkov telescopes for monitoring observations of the brightest blazars - the DW ARF network. A small, ground based, imaging atmospheric Cherenkov telescope of last generation is intended to be installed and operated in Romania as a component of the DW ARF network. To prepare the construction of the observatory, two support projects have been initiated. Within the framework of these projects, we have assessed a number of possible sites where to settle the observatory. In this paper we submit a brief report on the general characteristics of the best four sites selected after the local infrastructure, the nearby facilities and the social impact criteria have been applied.

Keywords: site testing, gamma-ray Cherenkov telescopes, very high energy gamma rays

1. Introduction

The best way to detect very high-energy (VHE) $\gamma$-rays (100 GeV $< E < 100$ TeV), of cosmic origin, from the ground is by imaging the Cherenkov light produced by the secondary particles once the $\gamma$-rays interact within the atmosphere. This method employs elaborate instruments, as the ground based Imaging Atmospheric Cherenkov Telescopes (IACTs) \cite{1}. The major IACT experiments currently in operation, MAGIC \cite{2}, VERITAS \cite{3}, H.E.S.S. \cite{4}, and CANGAROO-III \cite{5} have shown us an immense potential for scientific discoveries with significant consequences for astrophysics, cosmology and particle physics. A new era of outstanding precision will begin with the future Cherenkov Telescope Array (CTA) - the next generation of highly automated telescopes for gamma-ray astrophysics \cite{6}.

The number of known VHE $\gamma$-ray sources has exponentially grown and is presently more than 100 \cite{7}. Some of them belong to the category of Active Galactic Nuclei (AGNs). It is inferred that AGNs have large luminosities, beamed emission and their energy source is the release of gravitational energy from an accretion disk surrounding a super-massive black hole \cite{8}. Particularly interesting for the VHE $\gamma$-ray community are the blazars, a sub-class of AGNs whose relativistic plasma outflows (jets) point towards the observer. So far, more than 10 AGNs have been detected in the VHE $\gamma$-ray window and most of them are blazars. One distinctive feature of blazars is the strong variability of their VHE emission. It ranges from years down to minutes scales \cite{9}. The study of this variability may help us better understand the central engine of AGNs, the particle acceleration within their plasma jets, and the propagation of these jets. Long-term monitoring observations of the blazars and maybe some other sources will provide the VHE $\gamma$-ray astronomy of the future years with data of paramount importance for solving these problems.

The major IACT experiments are presently performing observations at their sensitivity limit or in multi-wavelength campaigns for most of their operation time. If monitoring observations take place (see MAGIC \cite{10}), the amount of time assigned is, by far, not sufficient.

Under these circumstances and due to the importance of the observational data, a global network of several small Cherenkov telescopes was proposed to be operated in a coordinated way for long-term monitoring observations of the brightest blazars - the DW ARF (Dedicated Worldwide AGN Research Facility) Network \cite{11}. This network will have to be distributed around the globe for 24/7 monitoring, preferably with temporal overlap and redundancy to account for weather and duty cycle constraints, as well as for muon background reduction. The prototype telescope of this network is the former HEGRA CT3 telescope, located at the Roque de los Muchachos on the Canary Island of La Palma, completely refurbished with an enlarged mirror area and a robotic design \cite{12}.

The DW ARF type telescopes have smaller reflectors (total surface $\approx 10 \text{ m}^2$) than the largest ones (MAGIC, HESS $> 100 \text{ m}^2$) and this limits the observations to the brightest VHE
gamma-ray sources at a few hundred GeV energy threshold, still acceptable for monitoring purposes.

So far, around the world, several scientific projects share the interest of the DW ARF network in monitoring observations of the brightest blazars. Since 2005, the Whipple telescope located on Mt. Hopkins in Arizona, USA has been used for nightly monitoring observations and since 2007 it was decided that Whipple observations will dovetail with those of the DW ARF telescope [12]. The TACTIC telescope situated on Mt. Abu, India is also dedicated to long-term monitoring observations and it can be operated within the DW ARF network [13]. Two of the former HEGRA air Cherenkov telescopes will be refurbished, installed and operated as the OMEGA project on the Volcano Sierra Negra in the state of Puebla, Mexico [14]. The main scientific goal of OMEGA is testing at very high altitude (≈ 4100 m.a.s.l.) its ability to detect the Cherenkov light from the air showers generated by VHE γ-rays. However, OMEGA will be also used for monitoring observations of the brightest blazars and to follow up candidate HAWC [15] sources. The Star Base Utah will be a stereoscopic system of two telescopes located close to Salt Lake City, USA [16]. After the Cherenkov cameras will be completed, the system will be used for monitoring observations, as well. CROATEA is proposed to be a small IACT system based on two ex-HEGRA telescopes, located near the Adriatic coast in Croatia [17]. CROATEA will serve as a test telescope for new photodetectors and as an observatory devoted to known AGNs.

To join the international efforts on understanding the physics of VHE γ-rays, a small, ground based, imaging atmospheric Cherenkov telescope of last generation is intended to be installed and operated in Romania as a component of the DW ARF network.

2. The Romanian Cherenkov telescope

On the initiative of the Institute of Space Sciences at Bucharest-Magurele, a consortium has been established in order to prepare the construction, in Romania, of an observatory for VHE γ-ray studies. The observatory will employ, at the beginning, a small, ground-based, last generation, Cherenkov telescope. Upgrades and developments are possible in the future.

The major scientific goals to be accomplished are: to work in synergy with gamma-ray telescopes around the world for long term monitoring observations of the brightest blazars and eventually other VHE γ-ray sources, to perform broadband multi-wavelength observations in collaboration with other observatories, to participate in multi-messenger observations of γ-rays and neutrinos with neutrino observatories and last but not the least, to exploit its great educational potential for the students interested in the field.

To prepare the construction of the observatory, two support projects have been initiated. The first one is focused on building a dedicated instrument to measure the level of the background light of night sky (LONS) [18]. Within the framework of the second project, a site testing campaign has started at the end of 2007.

3. General criteria for site assessment

During this campaign, we have assessed all the places where middle altitude meteorological stations from the Romanian national network have been in operation over the last ten years. A time range of ten years is usually considered appropriate when general, long-term tendencies are looked for in meteorological data sets. Subsequently, taking into consideration technical, economical and social selection criteria (section III.b and III.c), we generated a short list of four locations (Table 1 and Figure 1). However, this is not the list of final choice. An upgraded version will be produced when the future in-situ light pollution measurements will be completed.

A statistical data analysis of the standard meteorological parameters (air temperature, humidity, air pressure, wind speed) was performed on the ten years data from the national meteorological database for the sites on the short list. The results will be published in a future paper.

In this paper, we submit a brief report on the general characteristics of the sites included on the present short list, from the point of view of the local infrastructure, the nearby facilities and the social impact.

| Site          | Latitude | Longitude | Altitude [m] |
|--------------|----------|-----------|--------------|
| Baisoara     | 46° 32’ 08” N | 23° 18’ 37” E | 1357         |
| Rosia Montana | 46° 19’ 03” N | 23° 08’ 21” E | 1198         |
| Semenic      | 45° 10’ 53” N | 22° 03’ 21” E | 1432         |
| Ceahlau      | 46° 58’ 39” N | 25° 57’ 00” E | 1897         |

Table 1: The latitude, the longitude and the altitude of the sites on the present short list, for the settlement of a Cherenkov telescope in Romania.

Figure 1: The four candidate sites on the present short list, for the settlement of a Cherenkov telescope in Romania.
All the astronomical telescopes are designed and operated in close relation with the local conditions. The site has a significant influence on the good quality of the future astronomical data as well as on the scientific productivity of the observatory, over its lifetime. The characteristics of the site affect the cost and ease of construction and operation. There is also an impact on the activities of management, technical support, and personnel recruiting. Therefore, the selection of a site is always a critical issue.

No requirements are created for a site in the form of limits for certain parameters, as there are generally no hard cut-offs beyond which a site becomes unsuitable. Instead, the scientific teams measure the technical properties of the sites with the highest accuracy and longest temporal baseline possible. These parameters are subsequently balanced against each other using a methodology developed during the course of the site testing process [19].

IACTs are mainly used as astronomical instruments, observing in the near UV bands (UVB and UVA) and the visible part of the electromagnetic spectrum (the wavelength range of Cherenkov light photons goes roughly from 300 to 600 nm [21]). Most of the criteria that apply to the selection of the sites hosting astronomical telescopes operating in this wavelength range, also apply to the sites hosting IACTs. A review of these criteria follows below.

3.1. Physical criteria

a) the site should be located at moderate to high altitudes (1000 - 2500 m), if possible, above the inversion layer [21]; it is under consideration if exceeding the altitudes of ≈ 3000 m can be beneficial or not to an IACT [14].

b) the site with the lowest possible value of geomagnetic field (GF) should be selected in order to minimize the influence of this parameter on the observatory performance [22].

c) the site should be characterized by good atmospheric transparency (minimization of Rayleigh and Mie scattering). This happens when there is a low cloud coverage, a low amount of dust in the air and a low level of chemical pollution,

d) the site should be characterized by a low level of humidity. High humidity can produce severe damages to electronics and it can increase the absorption of the Cherenkov light in the blue,

e) low speed winds are required for the site as moderate speed winds can put the electronic camera in oscillation and high speed winds can damage the large mirror of the telescope,

f) the temperatures at the site should be moderate and preferably free from ice (protection of mirrors) and snow (reduced level of albedo radiation),

g) the site should be characterized by a low level of natural (e.g. aurora borealis) or man-made light pollution,

h) the atmospheric turbulence above the site should be low (stable atmosphere) in order to enable a maximum response for highly inclined showers [23]. However, IACTs are less influenced than the optical ground based telescopes by the turbulences in the Earth’s atmosphere, because the objects under study are VHE γ-ray induced air showers and the fluctuations in the shower development are considerably higher than the effects of wavefront distortions [24].

3.2. Technical criteria

a) the site should be one of good geological and geotechnical conditions (seismic activity, mechanical properties of the soil, vibration transmission properties),

b) the site should have good access roads for transportation purposes,

c) the site should offer a large enough area for the installation and the safe operation of the telescope and the associated equipment and buildings,

d) electricity and water supplies should be available on site.

3.3. Economical and social criteria

a) the construction and operation costs associated to the site should be under the available budget,

b) the site should allow for land ownership or eventually the rent paid should be as low as possible,

c) the travel costs to the site should be low,

d) the labor force availability and the economic impact of building the telescope (new jobs on the market) should be considered,

e) the cultural, the archeological, the environmental and the land use potential restrictions have to be considered,

f) the reasonable proximity of the site to academic centers is desirable.

Based on the above considerations, when site selection programs are underway, systematic site-to-site comparisons are carried out and the site that best fits the above criteria is selected.

4. The selected sites

4.1. Baisoara

The site is located in the region of Transilvania, the Cluj County. There is a modernized, paved road, 18 km long, connecting the site to the local county road. The closest major cities are Cluj-Napoca (≈ 60 km, ≈ 318,000 inhabitants) and Turda (≈ 55 km, ≈ 60,000 inhabitants). The closest bus station is 18 km away, in the village of Baisoara and this is also the place where basic supplies can be purchased. The closest hospital is located in Turda. Cluj-Napoca harbors the closest railway station and the closest airport (domestic and international connections). Rental car services are available in Cluj-Napoca. In Figure 2 we show the road map of the area.

Electricity and water supply are available on the premises. The communications services are provided by a national operator (cellular phone and internet). Major universities with Physics and/or Mathematics departments in the region are located in the following cities: Cluj-Napoca, Targu Mures (≈ 160 km), Baia Mare (≈ 200 km) Oradea (≈ 200 km), Alba Iulia (≈ 220 km) and Sibiu (≈ 220 km). Offices and laboratories associated to the observatory may be operated in Cluj-Napoca.
4.2. Rosia Montana

The site is located in the region of Transylvania, the Alba County. There is a 1.5 km paved road that connects the site to the national road from the city of Abrud (≈ 14 km). The closest major city is Alba-Iulia (≈ 80 km, ≠ 67,000 inhabitants). The closest bus station and the closest hospital are located in Abrud. The closest railway station is located in the city of Zlatna (≈ 50 km). The city of Cluj-Napoca (≈ 133 km) harbors the closest airport (same connections as for Baisoara). Rental car services are available in Cluj-Napoca. In Figure 3 we show the road map of the area.

Electricity, water supply and sewage are available on site. The communications services are provided by two national operators (regular and cellular phone, and internet). The site at Rosia Montana is not very far away from the site at Baisora, so the same considerations apply in what concerns the major nearby universities. The site is not placed inside a reservation area, but the Apuseni National Park is located in the neighborhood. A medium level of chemical air pollution is generated by an open-air copper pit. This level can increase in the future if an envisaged gold exploitation will become operational. The level of light pollution is presently not very high. The ruins of the Roman stronghold Alburnus Maior are located not far away from the site, but the settlement of the observatory will not assume excavations in the archeological restricted area. No other cultural restrictions may apply.

4.3. Semenic

The site is located in the region of Banat, the Caras-Severin County. There is a modernized, paved road, 50 km long, connecting the site with the closest major city - Resita (≈ 84,000 inhabitants). The closest bus station, railway station and hospital are located 45 km away, in the city of Caransebes. The closest airport (domestic connections only) is also located in Caransebes. The closest international airport is located in the city of Timisoara (≈ 160 km). In Figure 4 we show the road map of the area.

Electricity and water supply are available on premises. The communications services are provided by a national operator (cellular phone and internet). Major technical universities in the region are located in the following cities: Resita, Timisoara and Arad (≈ 200 km). Offices and laboratories associated to the observatory may be operated in Timisoara, the major educational center of the region. The site is placed inside the Semenic National Park in an area where the level of the chemical pollution is very low. The meteorological station whose database was used for analysis is located in the proximity of a skiing resort. Therefore, in what concerns the level of light pollution, the same considerations apply as in the case of Baisoara. No archeological, cultural or social restrictions may impede on the
4.4. Ceahlau

The site is located in the region of Moldova, the Neamt County. The closest major city is Piatra Neamt (~96 km, 110,000 inhabitants). The closest bus station is in Durau (~16 km). The closest hospital and railway station are located in the city of Bicaz (~66 km). The closest airport is located in the city of Bicaz (~155 km, domestic and international connections). Rental car services are also available in Bacau. In Figure 5 we show the road map of the area.

Electricity and water supply are available on site. The communications services are provided by the national operator (cellular phone and internet). Major universities with Physics and/or Mathematics departments in the region are located in Bacau and Iasi (~227 km). Offices and laboratories associated to the observatory may be operated in Iasi, the major educational center of the region. The site is placed inside the Ceahlau National Park. No chemical hazards can be identified in the area, but a medium level of light pollution is to be expected as a result of tourist activity. The darkest place in the region where to settle the telescope will be identified after in-situ light pollution measurements. No archeological, cultural or social restrictions may impede on the settlement of the observatory.

5. Conclusions

A consortium has been established to prepare the construction, in Romania, of a small, ground-based, last generation, Cherenkov telescope. The site testing campaign has started looking upon all places where middle altitude meteorological stations from the national network have been in operation over the last ten years. After local infrastructure, nearby facilities and social impact assessment criteria have been applied, four sites have been selected (Baisoara, Rosia Montana, Semenic, Ceahlau). All of them benefit of good local infrastructure and facilities. No archeological, cultural or social restrictions may impede on the settlement of the observatory at any of these sites. The level of chemical pollution is low. For a further refinement of the selection procedure future, in-situ light pollution measurements will be carried out. If none of these selected sites and their surrounding areas have a sufficiently low light background, the list of “four” will be upgraded with other, more isolated locations. The final choice in what concerns the site where to settle the future Romanian gamma-ray observatory will be made after all the tests presently underway will be completed.

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