ICRC'07 Mérida, México

HAWC @ Mexico

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Abstract: HAWC is a next generation large area water Cerenkov observatory for mapping and monitoring the high energy γ-ray sky at around 1 TeV. To achieve optimum sensitivity HAWC requires an area $\gtrsim (150\ \mathrm{m})^2$ at an altitude higher than 4000 m. Mexico is proposing locating the HAWC observatory inside the Parque Nacional Pico de Orizaba, benefiting of the altitude and latitude of the zone together with the physical and scientific infrastructure developed around the Large Millimeter Telescope.

From MILAGRO to HAWC

HAWC, the High Altitude Water Cerenkov experiment, is a proposed water Cerenkov observatory for high energy γ-ray astronomy. Water Cerenkov detectors like MILAGRO and HAWC function as wide field monitors of photons of energies $\sim$ 1 TeV, operating continuously -day and night- without interruptions due to weather conditions. Their field of view extends up to 45° from the zenith, allowing them to make a shallow survey of more than 7 sr every sidereal day. The continuous accumulation of homogeneous data permits a deep exposure of over 50% of the sky after a few years of operation. The principle of these detectors has been demonstrated with the successful 8 years of operation of MILAGRO in New Mexico, at an altitude of 2650 m, and its detection of the Crab, Mrk 421 and the extended emission from the Cygnus region [1, 2]. MILAGRO has also acted as a gamma-ray burst (GRB) monitor, setting physically constraining upper limits for bursts like GRB 010921.

The knowledge and resources are already available to build a detector more than an order of magnitude more sensitive than MILAGRO at a reasonable cost (below 10 MUSD). The science case for such an instrument, HAWC, include mapping and continuous monitoring of the TeV sky; the study of the Galactic interstellar medium, together with the properties of cosmic rays throughout the Milky Way; the study of extended emission from Galactic nebulae; the persistent and transient emission active galaxies; monitoring prompt emission and searching high energy afterglows of gamma-ray bursts; cosmological pair attenuation and the intergalactic infrared background. HAWC can also be used for studying the Sun, searching for dark matter and for γ-ray emission coincident in location or time with neutrinos registered by IceCube.

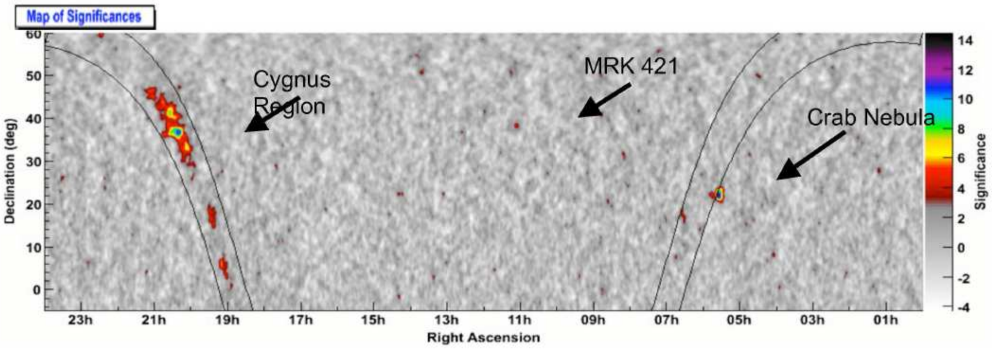

Figure 1: The MILAGRO view of the high energy γ-ray sky, showing the Crab nebula, Mrk 421 and diffuse emission along the Galactic plane. The extended emission in the Cygnus region is the most prominent map in this TeV map.

Two basic conditions are needed to achieve a more sensitive water Cerenkov detector: a higher site and a larger area detector. Further improvements can be made in the design of the detector. Under these considerations HAWC is conceived to have a $150\,\mathrm{m} \times 150\,\mathrm{m} = 22,500\mathrm{m}^2$ detection area at an altitude above 4000 m with respect to sea level. The detector will incorporate a single layer of 900 photomultipliers at a depth of 4 m with respect to the surface of water, arranged in a grid of 30×30 cells of 5 m side, each one optically isolated from the others. This arrangement allows a straightforward rejection of atmospheric muons together with an effective hadron-photon discrimination. HAWC will be able to achieve 5σ detections of the Crab nebula in single transits and fluxes down to 50 mCrab after 1 year.

In April 2006 a group of astrophysicists and high energy physicists held a workshop on high energy astrophysics at Tonantzintla[1] and as a decided to jointly support installing HAWC in Mexico. This group has since worked on site and design studies, a funding proposal submitted to CONACyT in May 2007 and the environmental impact declaration submitted to SEMARNAT in early June 2007.

The Sierra Negra site

Suitable sites above 4000 meters are not easy to find. The experiment requirements demand a flat area of about $200\ \mathrm{m} \times 200\ \mathrm{m}$ above 4000 m altitude, manageable weather conditions for human builders and operators, the availability of about 120 000 m^3 of water and of support infrastructure, namely an access road, electricity and internet. Two locations have been studied as potential HAWC sites: Sierra Negra in Mexico and Tibet in China. The Sierra Negra volcano is the site of the Large Millimeter Telescope / Gran Telescopio Milimétrico (LMT/GTM), the largest scientific project ever in Mexico [4]. LMT/GTM is a 50 m antenna for millimeter wave astronomy located at the top of Sierra Negra -also known as Tliltepetl- at 4600 m. The development of this site for the LMT/GTM project started in 1997 with the construction of a road and includes the installation of a power line and optical fiber link to the Internet, both already functional.

Sierra Negra is inside the Parque Nacional Pico de Orizaba, named after the volcano Pico de Orizaba, or Citlaltepelt, the highest mountain in Mexico with 5610 m. The National Park has an extension of 197.5 km^2 and comprises both Citlaltepetl and Sierra Negra, whose summits are at a distance of 7 km. The valley between these two strato-volcanoes is at some 4000 m altitude. We selected as the site for HAWC a relatively flat area at the base of Sierra Negra, which has an area of about 90 000 m^2 comprised within $\pm 10\,m$ altitude. We performed a topographic survey of a favorable location for HAWC, which had an area of about (210 m)^2, a mean altitude of 4099 m and a slope of 5°. Making the HAWC pond requires moving

1. http://www.inaoep.mx/∼alberto/taae/

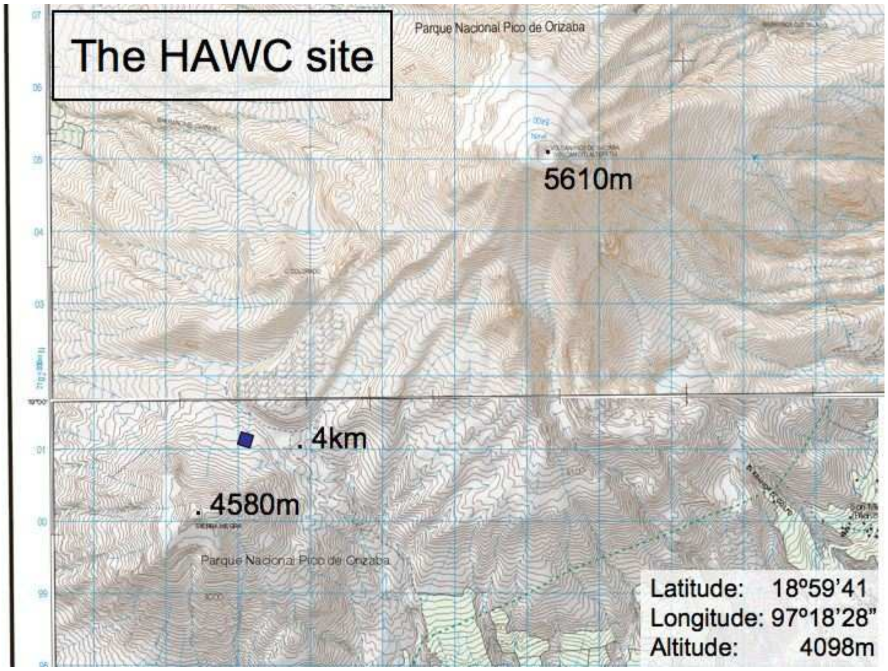

Figure 2: The location of HAWC inside the Parque Nacional Pico de Orizaba. The summits of Sierra Negra and Citlaltepetl are marked with black dots and the altitude. The site for HAWC is marked by the blue square just 1 km North of the top of Sierra Negra. The grid in light blue denotes Universal Transverse Mercator coordinates (UTM) with a 1 km spacing. The geographical coordinates at the bottom right are for the HAWC site. The underlying maps are from INEGI - http://www.inegi.gob.mx

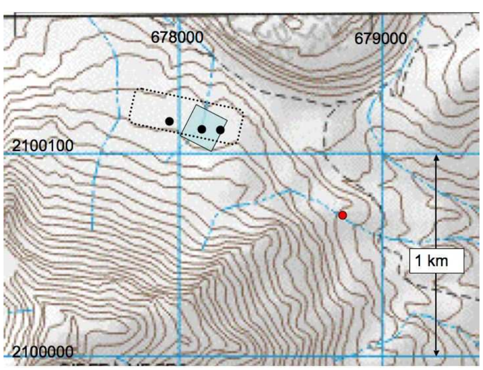

Figure 3: Zoom on the HAWC site. The blue square denotes a (172 m)^2 area inside the topographic survey. In practice HAWC can be located anywhere inside the dotted rectangle which covers $\gtrsim 90\ 000\,\mathrm{m}^2$. Altitude contour levels have steps of 20 m and the blue grid spacing of 1 km. The red dot at the right marks the nearest point to the LMT/GTM road and electricity post. The underlying map is from INEGI - http://www.inegi.gob.mx

$\gtrsim 60\ 000\ \mathrm{m}^3$ of soil, which is eased by the softness of the terrain. The site is at $\lesssim 1\ \mathrm{km}$ from the nearest point to the LMT road and power line, from where access, electricity and Internet can be extended to HAWC with very little cost and effort.

Water for HAWC

One of the most challenging aspects of this proposal is the acquisition of water in a reasonable period, of the order of six months. The national park is located in the limits between the Mexican states of Puebla and Veracrúz, in a transition zone from a high altitude dry region (Puebla) to low altitude wet region influenced by the Gulf of Mexico (Veracrúz). The precipitation in the park is important, amounting to 1000 mm per year, with a very marked seasonal modulation: 83% of the precipitation is received in the six months between 1$^{\mathrm{st}}$ of May and 31$^{\mathrm{st}}$ of October.

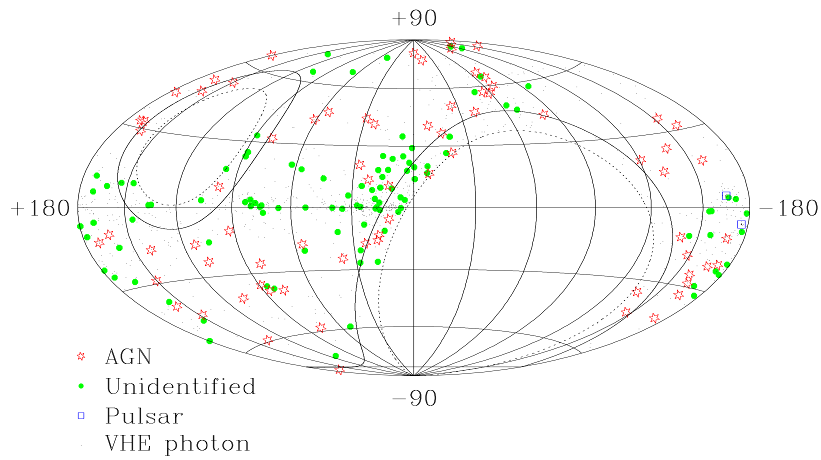

Figure 4: The high energy γ-ray sky as viewed from Sierra Negra. The solid lines represent points transiting $35°$ from zenith, while the dot lines span to $45°$. Show are EGRET sources and $E > 10$ GeV photons.

We performed geoelectrical studies in the zone between Citlaltepetl and Sierra Negra some 80 meters below the HAWC site, which showed the presence of water flows running some 100 m to 150 m underground along the structure of a former glacier. These studies have defined the most promising location for a water extraction well. We are currently working on an exploratory well at this location. Complementary water studies were made using a tridimensional model of the region to find natural nozzles where water converges during precipitation. One point identified through these studies corresponds to the convergence of precipitation falling in a physical area of just under 10^6 m^2. A concrete trap and pipe system can be used to capture and transport water from this point to the HAWC site. This method will be used only if the extraction well does not supply enough water.

HAWC astrophysics at Sierra Negra

Located at Sierra Negra HAWC will benefit from much more than just the altitude of the site. The survey sky coverage is a function of geographical latitude $\propto \cos(b)$ such that HAWC at a latitude of 19°N can cover 8.4 sr, gaining 17% more sky relative to the 7.2 sr reachable from the MILAGRO site. As shown in figure 4 there is a much more important coverage of the Galactic plane, even grazing the Galactic Center at a zenith angle of $46°$.

The operations of HAWC will be handled through the Consorcio Sierra Negra which groups almost ten scientific experiments in the site, including the largest single dish millimeter telescope in the world (LMT/GTM), the 5 m antenna of the RT5 solar radio telescope, a solar neutron telescope (TNS), two atmospheric Cerenkov telescopes, a cosmic ray surface detector array and fluorescence telescope. HAWC will form part of an unique multiwavelength multidisciplinary scientific complex able to perform combined studies of astrophysical sources (LMT + ACTs), the high energy emission from the Sun (RT5 + TNS) and cross calibrated cosmic and γ-ray atmospheric events. Sierra Negra offers HAWC not only a site with the required infrastructure but also with extraordinary synergy and the support of forty scientists with experience in astrophysics, solar and high energy physics.

References

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