Populations of High Energy Sources in Galaxies
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Ground Based Gamma-Ray Astronomy

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Abstract. The field of ground based gamma-ray astronomy has seen rapid growth over the past thirty years with the development of the Imaging Atmospheric Cherenkov Technique to search for Very High Energy (VHE; E > 100 GeV) gamma radiation. This growth continues with the construction of four third generation telescope systems in Namibia, Australia, La Palma and the USA. These systems will search for VHE gamma radiation from such objects as AGN, SNRs, microquasars, dark matter and the galactic centre.

Keywords. TeV, gamma ray, IACT, AGN, SNR.

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1. Imaging Atmospheric Cherenkov Technique

This paper provides a brief overview of the field of ground-based gamma-ray astronomy. In the first section, the technique will be described, and in the second section a selection of recent results will be summarised.

Upon striking the earth's atmosphere, a high-energy gamma ray initiates a relativistic cascade of electromagnetic particles known as an Extensive Air Shower (EAS). These particles produce Cherenkov radiation which may be detected on the ground using arrays of PMTs mounted in the focal plane of a large reflector. As the Cherenkov radiation produced is extremely faint, this can only be done on clear moonless nights, resulting in a duty cycle of ∼10 %. Due to the almost overwhelming hadronic background, a highly efficient rejection technique is required. This can be achieved as gamma-ray induced EAS produce small compact images whereas hadronic images are large and irregular. A parameterisation of the size and shape of the image (Hillas (1985)) allows discrimination between these images, with a background rejection of ∼98 % and a signal acceptance of ∼30 %.

Local muons produce images very similar to low energy (<200 GeV) gamma rays. These can be discriminated against using multiple telescopes with a large (∼100 m) baseline operating with a coincidence trigger, as local muons only affect single (or adjacent) telescopes. Coupled with a large mirror area, this allows a reduction of the system's energy threshold to ∼100 GeV and results in arc minute resolution and an energy resolution close to 15 %. This technique, known as stereoscopy, is being employed by the four large ground based gamma-ray astronomy groups. These are CANGAROO-III (the Japanese-Australian collaboration sited in Woomera, Australia: Kubo *et al.* (2004)), HESS (the largely German-French collaboration sited in Namibia: (Benbow & Hess Collaboration (2005)), MAGIC (the German-Spanish-Italian collaboration sited in La Palma: Lorenz & MAGIC Collaboration (2005)) and VERITAS (the North American-European collaboration located in Arizona: Weekes (2003)). This new generation of telescopes is already producing spectacular new science results and has pushed the number of detected VHE sources beyond thirty (see Ong (2005) for details).

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2. Recent Results

The number of VHE gamma-ray source categories has risen to six in the past year. To date eleven AGN, twelve SNRs (six shell type and six plerionic) a binary pulsar, a microquasar, and possible detection of diffuse emission have been reported. There are also reports of three unidentified sources raising the possibility of a new family of dark emitters, although previously unidentified sources were subsequently associated with SNRs using deep Integral exposures and archival ASCA data.

Recently the SNR RX J1713.7-3946 was mapped in VHE gamma rays at one arc-minute resolution; this degree of resolution is unprecedented at any gamma-ray energy. VHE emission was found to correlate strongly with x-ray emission, which coupled with the hard spectrum, lent the first convincing evidence of SNRs as a source of cosmic rays (Berge *et al.* (2005)). The binary pulsar PSR B1259-63 which was observed near periastron, was the first VHE galactic variable to be detected (Beilicke *et al.* (2004)). VHE emission was detected from the vicinity of the galactic center - although the spectrum of this source has been measured (Hinton & Aharonian (2005)), it is not yet clear whether it is associated with the radio source SgrA*, or with at least one supernova remnant also in the field of view. As many as twelve sources, many extended, have been discovered using sky survey observations along the galactic plane (Funk & Lemiere (2005)). Many of these sources have firm SNR or EGRET unidentified associations, although there are some with no known association whatsoever. Future multiwavelength campaigns should result in the identification of these objects. The microquasar LS 5039 was detected at TeV energies (Aharonian *et al.* (2005)), leading to the exciting possibility of studying relativistic jets, similar to those produced by AGN, in our own galaxy. A selection of AGN, all but one blazars, has been detected. Multiwavelength campaigns have shed new light on AGN emission mechanisms, with both x-ray correlated and orphan TeV flares reported (Krawczynski *et al.* (2004)). These observations will help distinguish between hadronic and leptonic emission models. The detection of AGN at higher and higher redshifts has put new constraints on the optical/infra-red extra galactic (EBL) background, with recent observations suggesting this background may be less dense than previously thought. See Quinn (2005) for a more complete description of recent AGN observations.

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