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Gamma astronomy with ARGO-YBJ

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Summary. — ARGO-YBJ, an extensive air shower detector located at Yangbajing (Tibet, China) at 4300 m a.s.l., is made by a full coverage carpet plus a guard ring ($\sim 6700\,\text{m}^2$) of resistive plate chambers. Its structure, and the high altitude allow exhaustive studies of γ astronomy with energy range in the TeV region. In this paper some of the ARGO-YBJ results in γ astronomy are discussed. In particular the TeV emissions of the blazar Mrk 421, the analysis of its last two flares and the comparison with Cherenkov telescopes results are presented.

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1. – The ARGO-YBJ detector

ARGO-YBJ is a modular detector, the basic unit is the *cluster* ($5.7 \times 7.6\,\text{m}^2$), made up of 12 RPCs. The central full coverage carpet (constituted by 130 clusters with an active area of 93%) is enclosed by a sampling guard ring of 23 additional clusters to reach a total active surface of $\sim 6700\,\text{m}^2$. The experiment works with an energy threshold of $\sim$ 300 GeVs recording all the events triggering at least 20 pads in the central carpet within a coincidence window of 420 ns corresponding to a trigger rate of $\sim$ 3.6 kHz. The hit arrival time, and spatial coordinates are used to reconstruct the shower core position, and the arrival direction of the primary particle [1, 2].

2. – Gamma astronomy results

One of the most important sources analyzed by ARGO-YBJ was the Crab Nebula that is observed since 2007 November, for a total of $\sim$ 800 days with a statistical significance of 14 standard deviations (s.d.). The energy spectrum follows a power law $\mathrm{d}N/\mathrm{d}E = kE^{-\alpha}$, where k, and α have been estimated simulating a source following the Crab path. The best fit gives $k = (3.0 \pm 0.3) \times 10^{-11}$, and $\alpha = -2.59 \pm 0.09$ in agreement with the observations of other detectors, such as Tibet AS-γ [3], and the Cherenkov telescopes H.E.S.S. [4], and MAGIC [5].

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The source MGRO J1908+06, discovered by the Milagro detector in 2007, has been observed for about 3 years by ARGO-YBJ at energies above $\sim 1\,\text{TeV}$. The integrated signal has a statistical significance of ~ 5.4 s.d. and the obtained energy spectrum is $\mathrm{d}N/\mathrm{d}E = (2.2 \pm 0.4) \times 10^{-13}(E/7\,\text{TeV})^{-2.3\pm0.3}\gamma\text{cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}$. The flux measured by us, in agreement with Milagro results, is ~ 3 times larger than what observed by H.E.S.S., that also estimated a smaller size for the emission region. These disagreements are still unclear. They can be due to the morphology of the source or to the contamination of other extended sources lying near the object observed by H.E.S.S. since ARGO-YBJ and Milagro have a worse angular resolution and integrate the signal over a larger area.

Mrk 421 is an active blazar with frequent major outbursts in X-ray, and γ-ray bands lasting several months, and accompanied by many rapid flares with timescales from tens of minutes to several days. Its spectral energy density shows two humps like all Active Galactic Nuclei. The X-ray hump is commonly attributed to the synchrotron radiation from relativistic $e^{\pm}$ within the jet. The γ-ray hump could be due to the inverse Compton scattering of the synchrotron (SSC model) or external γ (EC model) by the same population of relativistic e^{-} [6]. Other models invoking hadronic processes are discussed in [7]. Long-term monitoring of ARGO-YBJ shows a good correlation between the X- and γ-ray emission indicating that they may have a common origin as assumed in the SSC model [8]. In 2008 Mrk 421 entered a very active phase showing two strong episodes on June 3-8, and on June 9-15. The integral flux measured in the first flare by ARGO-YBJ, above $1\,\text{TeV}$, is ~ 3.5 times larger than the Crab one and ~ 1.5 times higher than what observed by the Cherenkov telescope VERITAS. This disagreement can be attributed to the non-coincidence of the data-taking periods of the two detectors (the difference in longitude is $\sim 160°$) and to the small timescale of the source variability. Furthermore VERITAS data refer to June 6 while the ARGO-YBJ ones are integrated over 3 days, from June 4 to 6. The integral flux measured above $1\,\text{TeV}$ during the second flare is ~ 6 Crab units, and the statistical significance 3.8 s.d. There are not Cherenkov data about the second flare because the moonlight hampered the telescopes measurements, and the light curve of γ-rays detected by ARGO-YBJ is consistent with X-rays satellites ones. The spectrum obtained is $\mathrm{d}N/\mathrm{d}E = (3.2 \pm 1.0) \times 10^{-11}(E/2.5\,\text{TeV})^{-2.1\pm0.7}e^{-\tau(E)}\gamma\text{cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}$, and it is larger than predicted in [9], while it is consistent with that measured by the Whipple Cherenkov telescope during 2000/2001 observing season for a flare of comparable intensity [10]. The last flare of Mrk421 occurred on 2010 February 16-18. The flux measured by ARGO-YBJ is larger than 3 Crab units with a peak higher than 10 Crab on February 16th. The significance is 6 s.d., and similar results have been obtained by VERITAS, reported in Atel #2443.

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