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Concept of a Global Network of Cherenkov Telescopes and first joint observations of H·E·S·S· and MAGIC

D. Horns,[1] F. Goebel,[2] D. Mazin,[2] G. Rowell,[3] R.M. Wagner,[2] and S. Wagner[4] for the H·E·S·S·* and MAGIC♦ collaborations

1 Institut für Astronomie und Astrophysik, Universität Tübingen, D-72076 Tübingen, Germany
2 Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München, Germany
3 Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg, Germany
4 Landessternwarte Heidelberg, D-69117 Heidelberg, Germany

* http://www.mpi-hd.mpg.de/hess/
♦ http://wwwmagic.mppmu.mpg.de/

Abstract

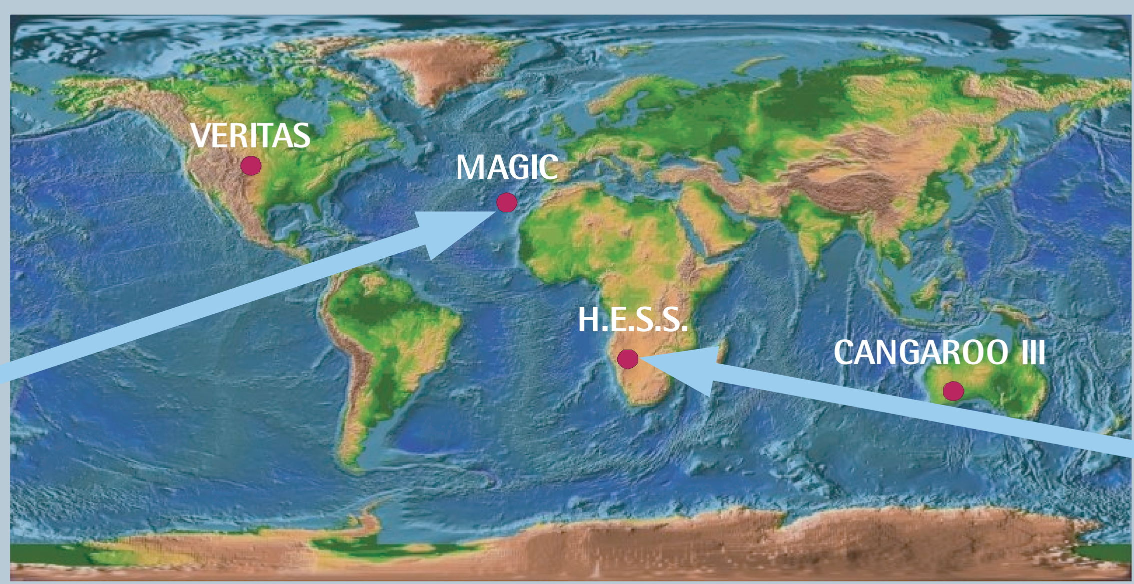
The current generation of Cherenkov telescopes covers a wide range of longitudes (137°E to 110°W) making continuous observations of transient sources possible. Given the close match in longitude of the MAGIC (17.9°W) and H.E.S.S. (16°E) sites, simultaneous observations at greatly differing zenith angles are also feasible. The measurable energy range can thus be extended beyond what is accessible to individual instruments. The planning and coordination of world-wide observations is challenging and requires close interaction between the different collaborations. The potential of a Global Network of Cherenkov Telescopes (GNCT) campaigns for improving energy and temporal coverage of different observations and objects is discussed. The GNCT is of great importance to study broad energy band spectral behaviour mainly of transient objects but also of steady sources. As a proof of concept, first tentative results on simultaneous data taken with the MAGIC and HESS telescopes on Mkn 421 are presented.

MAGIC

The 17 m diameter MAGIC telescope is located on the Canary Island of La Palma (28°30'N, 17°53'W) at an altitude of 2200 m a.s.l. MAGIC is currently a stand-alone instrument with a second telescope under construction. Owing to its novel technologies and large mirror area, and its fine granulated camera with high quantum efficiency PMTs, MAGIC was designed to detect VHE gamma-rays of energies down to 30 GeV [1]. Its sensitivity permits the detection of signals from Crab-like sources within a few minutes. MAGIC started regular observations in August 2004.

H.E.S.S.

The High Energy Stereoscopic System (H.E.S.S.) is located in Namibia (23°16'S, 16°30'E). It consists of 4 identical 13 m diameter Cherenkov telescopes with 107 m^2 tessellated and automatically adjustable glass mirror facets [2]. The energy threshold achieved for observations close to the zenith is around 100 GeV with an angular resolution of better than 0.1° for individual events. For large zenith angles the threshold energy increases to 1.2 TeV at 60° zenith angle.

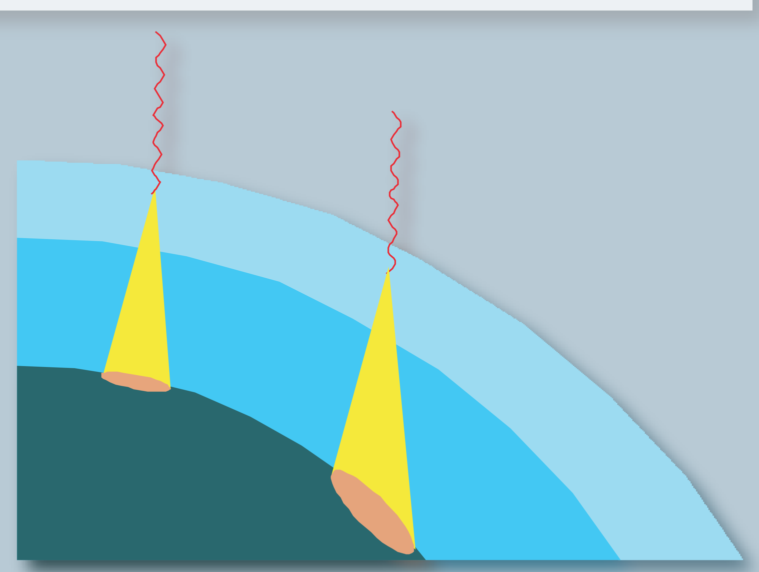


Simultaneous observations with MAGIC and H.E.S.S.

- Unique combination of two detectors at similar longitude and very different latitudes
- Simultaneous small and large zenith angle observations for sources within a wide band of declinations with declinations -45° < δ < 45°.
- Good candidates so far:

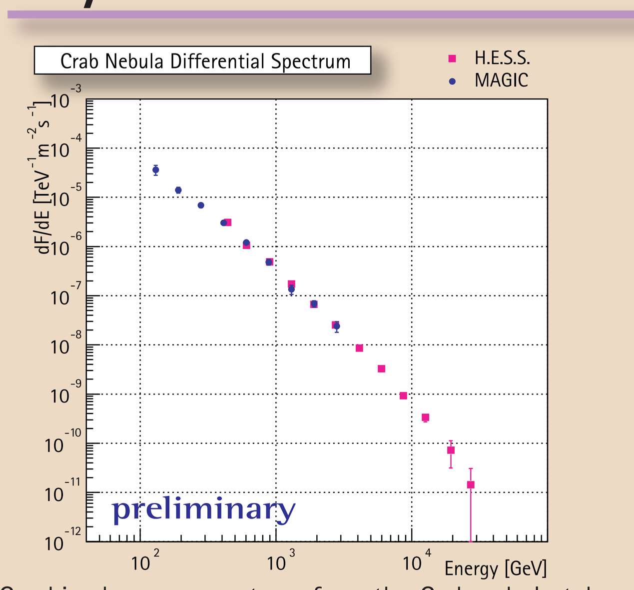
Mkn 421	δ = +38°12'32''	LS 5039	δ = -14°50'54''
Mkn 501	δ = +39°45'37''	1ES1218+304	δ = +30°10'37''
PKS 2155-304	δ = -30°13'32''	1ES1101-232	δ = -23°29'31''
H1426+428	δ = +42°40'21''	H2356-309	δ = -30°37'37''
M87	δ = +12°23'29''		

- Bright sources (F> 1 Crab): Good determination of the spectrum from 30 GeV up to 30 TeV within a few hours of observation
- Follow time variability and spectral evolution over 3 decades of energy



For two observatories at different latitudes, the showers will be observed under different inclination angles. For larger inclination angles, the Cherenkov light illuminates a larger patch on the ground, thus increasing the collection area at the expense of a higher energy threshold as the Cherenkov photon density is reduced accordingly

Physics Goal I: Combined energy spectrum of the Crab nebula

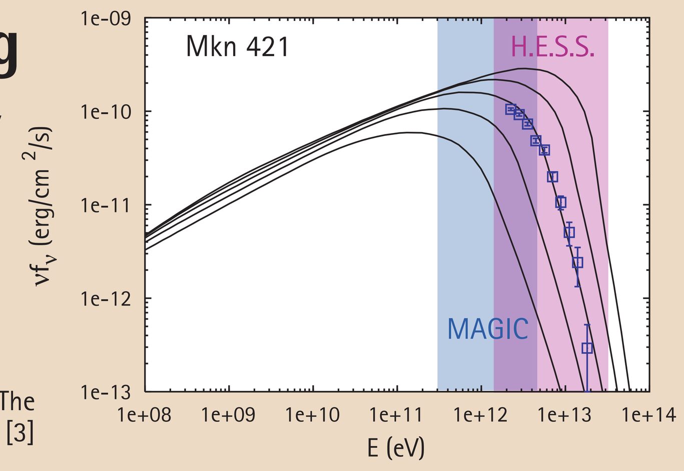


Combined energy spectrum from the Crab nebula taken around culmination. The Crab nebula has a declination of 22°. Therefore the respective energy thresholds differ by a factor of 4, which allows a considerable overlap of the energy spectra.

- The Crab nebula is considered a standard candle since it emits a strong constant flux of GeV-TeV γ-rays.
- Allows good cross calibration with considerable overlap in energy range
- Observations of H.E.S.S. at zenith angles ~45° for 10 hrs in 2003/2004
- Observations of MAGIC at zenith angles ~15° for 12 hrs in 2004/2005
- Good agreement indicates small systematic uncertainties of independent detector calibration

Physics Goal II: TeV Blazars – Catching rapid broadband variability

- Strong sources of Gamma-rays (F_{flare}>1 Crab)
- Flux and spectral variability < 1 hour
- Best candidates Mkn 421(z=0.031) and Mkn 501 (z=0.034)
- Unique view of acceleration/cooling during flares

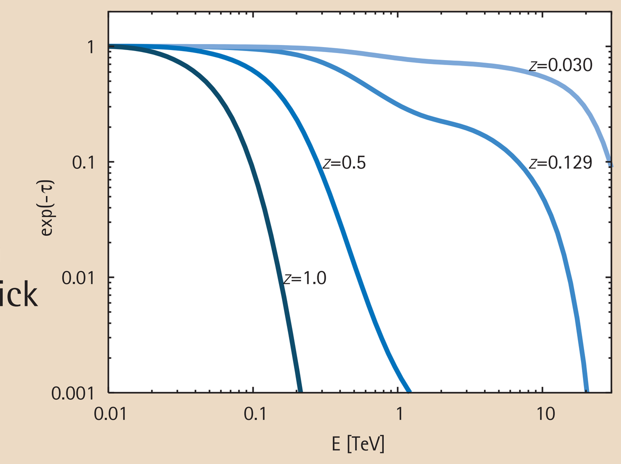


Example of the expected broad band variability for Mkn 421. The measured spectrum has been measured by H.E.S.S. [3]

Physics Goal III: Measuring the optical depth due to pair creation processes on Optical/Near IR extragalactic background light (EBL)

$$\gamma_{EBL} + \gamma_{TeV} \rightarrow e^+ + e^-$$

- $Flux_{observed} = Flux_{intrinsic} \times \exp(-\tau)$, τ optical depth
- Sample transition: Optically thin -> optically thick
- Need:
  a) Reasonably strong absorption and
  b) intrinsically hard sources
- Best candidate (so far): H1426+428 (z=0.129)



Attenuation factor exp(-τ) for sources at four different redshifts: z=0.30 (as Mkn 421, Mkn 501), z=0.129 (as H1426), z=0.5, and z=1.0 as a function of energy of GeV-TeV photons. The energy spectrum and the transition from optical thin to thick due to absorption on the extragalactic background light is well sampled by combined MAGIC/H.E.S.S. observations. The spectral distribution of the EBL is assumed as in [4]

Physics Goal IV: Morphology of extended sources at different energies

- Many Galactic sources are extended [5]
- Extension and morphology is expected to change with energy
- Energy dependent morphology important to understand transport and energy loss mechanism
- Coordinated (not necessarily simultaneous) measurements at different energy ranges more efficient by combining low and high elevation data

Concept of Global Network of Cherenkov Telescopes (GNCT)

With the installation of the four major Cherenkov telescope facilities (CANGAROO III, H.E.S.S., MAGIC, VERITAS), global networking of these telescope facilities is becoming feasible. Different physics questions could motivate different type of observations: While the North-South connection between the telescope facilities can be used for the simultaneous observations of variable sources, the West-East connection allows one to overcome the long gaps in time coverage by performing follow-up observations. The planning and coordination of world-wide observations is challenging and requires close and fast interaction between the different collaborations. Currently the MAGIC and the H.E.S.S. collaborations are organizing a well defined joint observation strategy including fast mutual information exchange on target of opportunity sources. The future GNCT aims to plan and coordinate joint observations of all four telescopes.

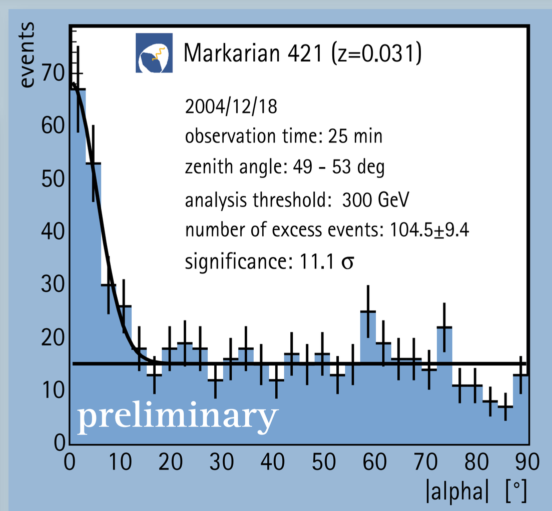
Mkn 421: 2004 joint observations

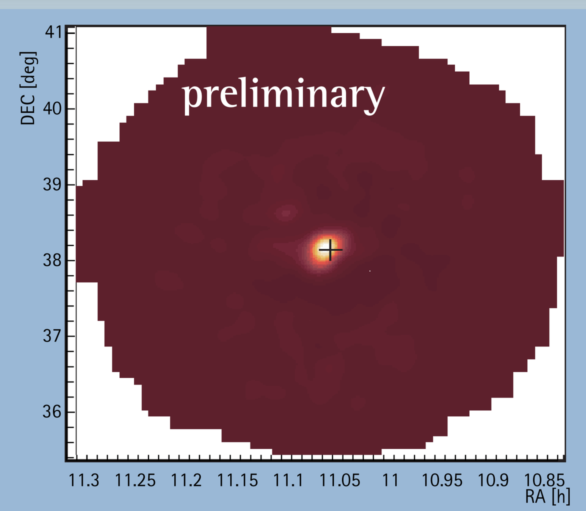
Triggered by an increased activity observed in the X-ray band and by the VERITAS collaboration (H.Krawczynski, priv. comm.) on 2004 December 14, the H.E.S.S. and MAGIC collaborations agreed to perform joint observations of the flaring Mkn 421. Due to weather conditions common observations were performed on two nights only (December 18 and 19). Moreover, due to observational constrains (like zenith angle and dark time), the common observational window was only open for 30 minutes on each night. The joint data sample of Mkn 421 encompasses 1 h:

H.E.S.S.: zenith angle range = 65-67 degrees, good weather conditions
MAGIC: zenith angle range = 47-54 degrees, good weather conditions

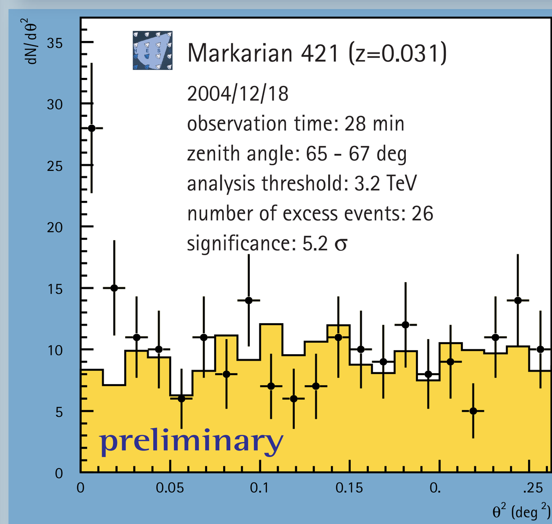
Additionally to these joint observations more data of the Mkn421 flare taken by the two experiments without time overlap. The H.E.S.S. measurements comprise 0.5h, z.a. = 67° (2004/12/16), the MAGIC data comprise 2.5h, z.a. = 8-30 degrees (2004/12/18-19).

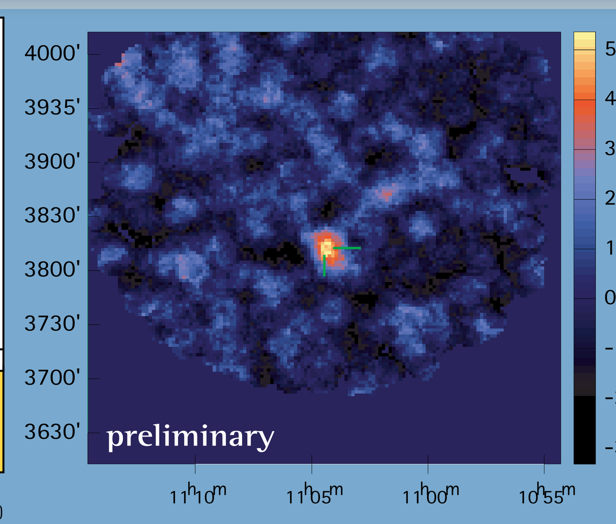
The clear detections and reasonable number of photons collected in the different energy bands are encouraging given the comparably low flux state of the source and the non-optimal zenith angles of the observation.



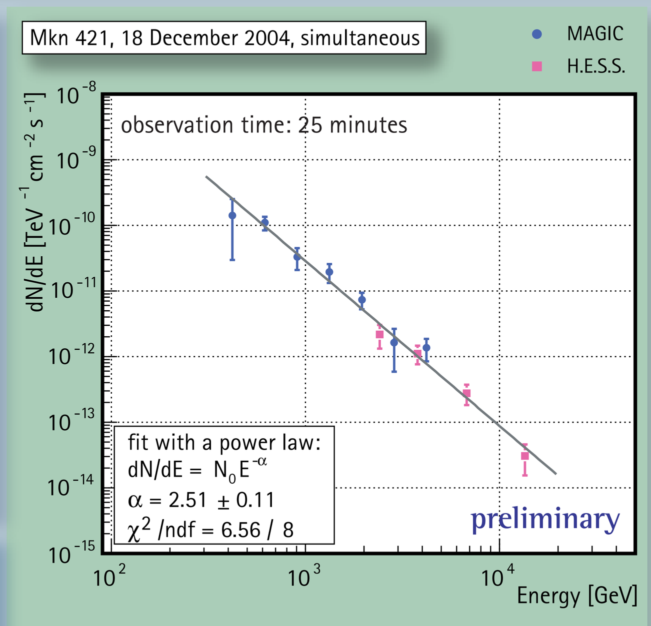


MAGIC results. In the left plot, the ALPHA distribution after cuts of the Mkn 421 simultaneous data set from 2004/12/18 (25 min) is shown. In the right figure, the sky map of reconstructed incoming direction of the gamma candidates for this data sample is presented. The sky map is smoothed using the angular resolution of 0.1°. The black cross indicates the actual position of the blazar Mkn 421.





HESS results. In the left plot, the distribution of arrival directions with respect to the position of Mkn 421 is shown. A clear detection above an energy threshold of 3.2 TeV within 28 minutes of observation time is seen. The right frame shows the significance sky map in the field of view covered during that observation. Again, a clear excess at the position of Mkn 421 in celestial coordinates is seen.



Differential energy spectrum of Mkn 421, 2004/12/18, using data from H.E.S.S. and MAGIC. The data have been analyzed independently by both experiments yielding consistent flux values in the overlap region. The combined spectrum can be described by a power law $dN/dE = N_0 E^{-\alpha}$, with the spectral index α=2.5±0.1.

References: [1] R. Mirzoyan, this conference [2] W. Hofmann et al., this conference [3] F. Aharonian et al., A&A 437 (2005) 95-99 [4] J. Primack, AIP Conf. Series Vol. 745, 23-33 (2005) [5] F. Aharonian et al., Science 307 (2005) L17-L20

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