

ABSTRACT - The MAGIC telescopes performed a deep observation of the central region of the Perseus galaxy cluster in stereoscopic mode between October 2009 and February 2011. The nearly 90 hours of data taken represent the deepest observation of a cluster of galaxies at Very High Energies (VHE) ever. The survey resulted in the detection of VHE gamma-ray emission from its central galaxy NGC 1275 as well as from the head-tail radio galaxy IC 310 which represents the first head-tail galaxy that is shown to emit at VHE. Its spectrum results to be very flat and strong hints of variability are seen in the MAGIC data. In addition, the deep survey will also allow for the first time to put constraints on emission models predicting VHE gamma-rays from cosmic ray (CR) acceleration in the cluster and to put limits on Dark Matter (DM) annihilation and decay scenarios. In this poster we report the latest MAGIC results concerning these topics.

The MAGIC telescopes

The Major Atmospheric Gamma Imaging Cherenkov (MAGIC) experiment consists of two 17 meter Imaging Air Cherenkov Telescopes (IACTs) located at the Canary Island of La Palma (28°N, 18°W), 2200 meters a.s.l.. The MAGIC telescopes are currently the largest existing IACTs. Since the end of 2009 the telescopes are working together in stereoscopic mode which ensures an excellent sensitivity of <1% of Crab Nebula flux above 200 GeV in 50 hours of observation [1].



Fig 1 – The MAGIC telescopes.

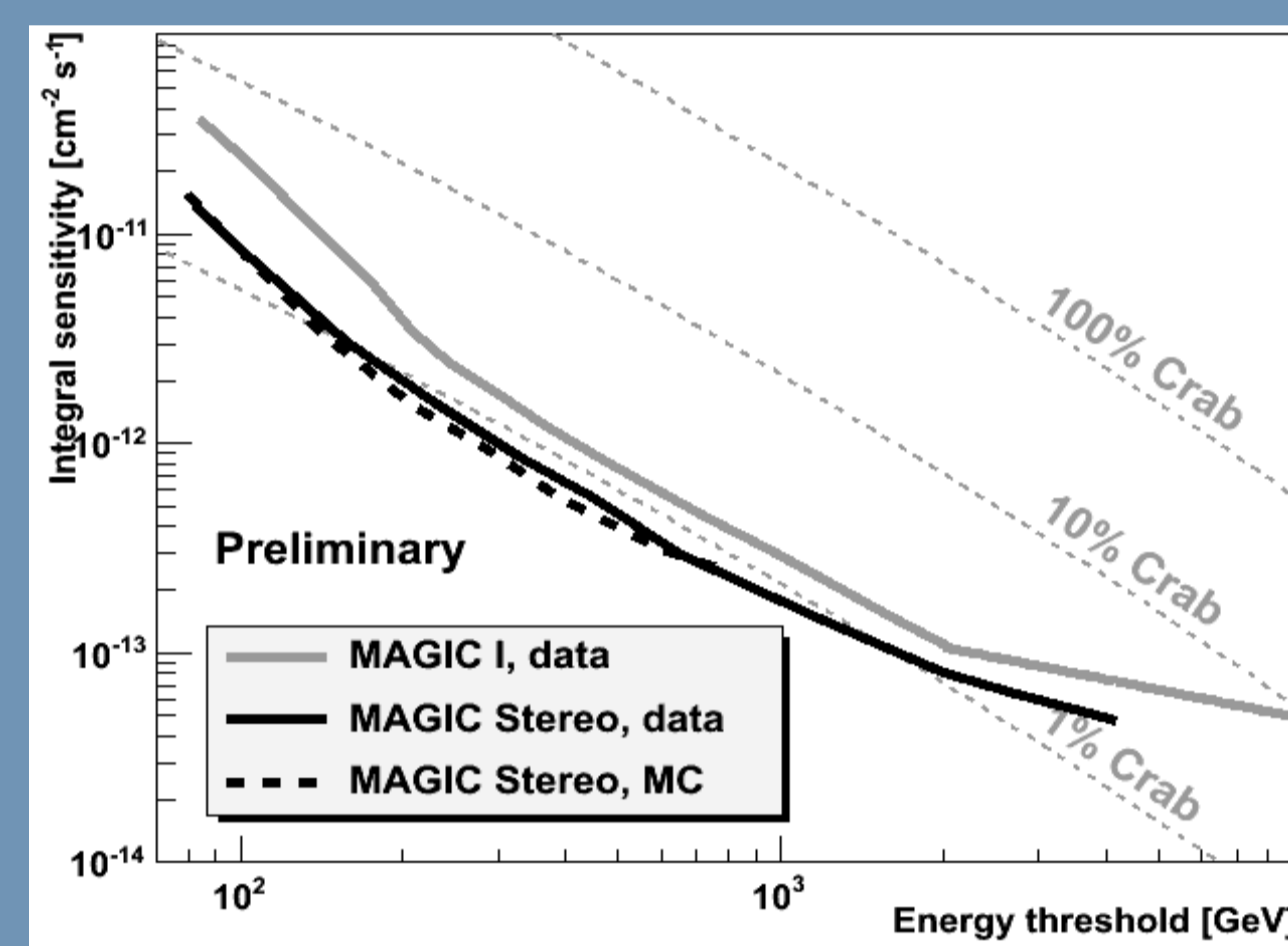


Fig 2 – The MAGIC sensitivity curve.

Perseus cluster at VHE

The Perseus cluster is an interesting target for VHE gamma-ray observations. There are different physics processes that could contribute to a VHE signal:

- ✓ emission from the central giant radio galaxy NGC 1275
- ✓ emission from two head-tail galaxies, IC 310 and NGC 1265
- ✓ emission from hadronic interaction of CRs with the inter-cluster medium
- ✓ emission from hypothetical DM WIMP annihilations

The MAGIC experiment conducted the deepest survey ever made in VHE of the Perseus cluster, collecting data in both single telescope mode (~25 hr of MAGIC-I observations, between November 2008 and December 2008) and stereoscopic mode (~90 hr of observations between October 2009 and February 2011).

These observations resulted in the detection of VHE emission from IC 310 [2] and NGC 1275 (Atel #2916).

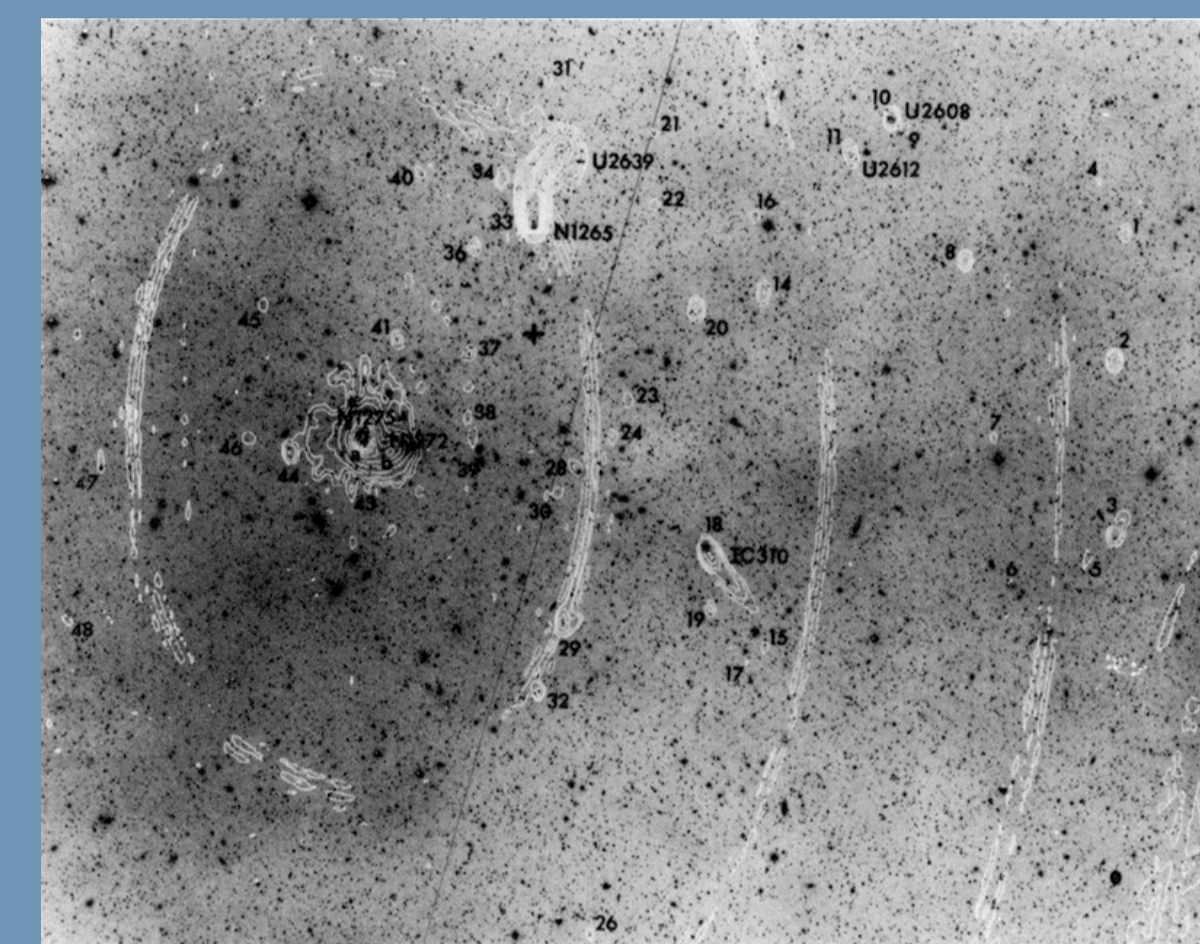


Fig 3 – Radio map of the Perseus cluster of galaxies [3].

MAGIC-I observation of the Perseus cluster and constraints on the CRs induced VHE emission

The Perseus galaxy cluster was observed by the MAGIC-I telescope for a total effective time of 24.4 hr during November and December 2008. No significant excess was found in the data [4]. The integral flux upper limits were compared to the simulated flux of the gamma-ray emission from decaying neutral pions that result from hadronic CR interactions with the ambient gas in the Perseus cluster [5], allowing to constrain the average cosmic ray-to-thermal pressure to <4% for the cluster core region and to <8% for the entire cluster. The large amount of data collected with the MAGIC system (~90 hr) and its improved performance, will allow us to probe the CR models. Results are under preparation.

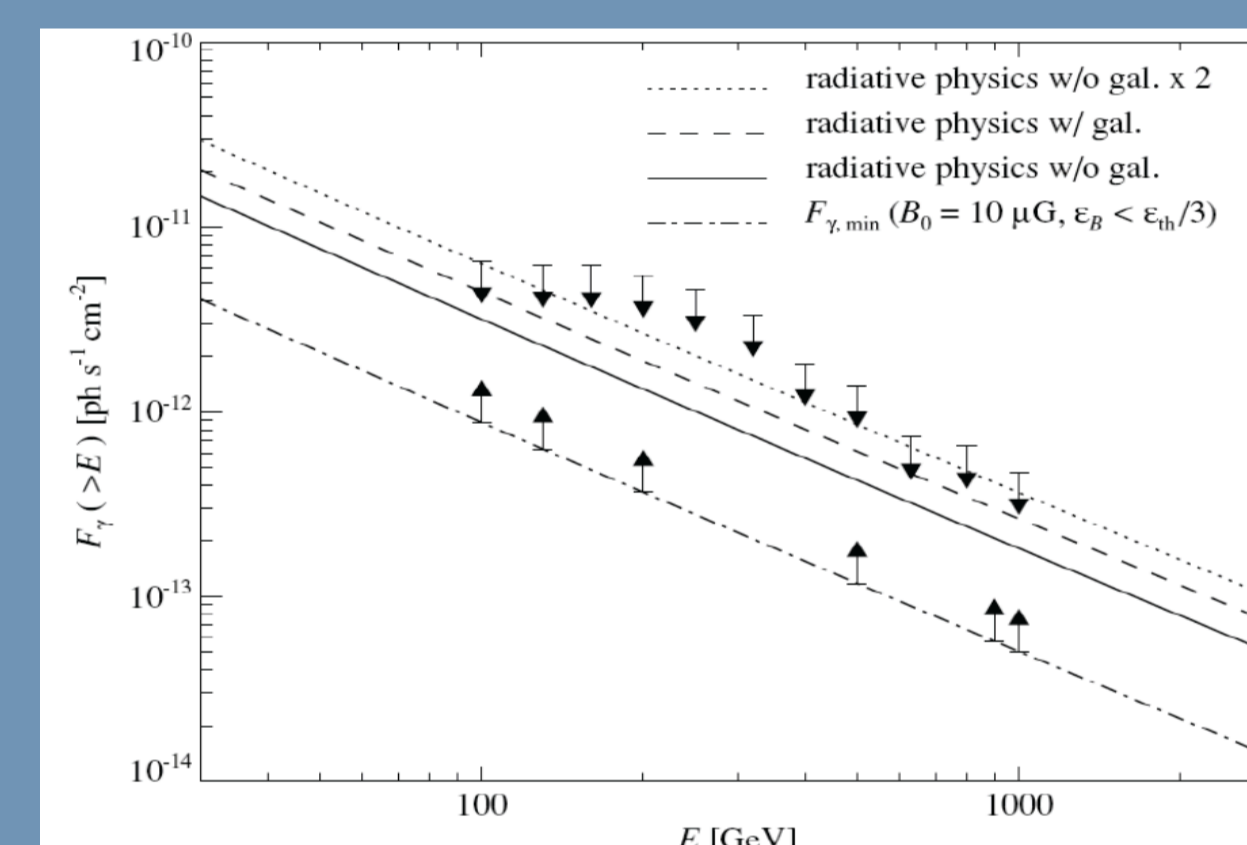


Fig 4 - Integral flux upper limits (upper arrows) compared with simulated Perseus gamma-ray integrated spectra [5]. The minimum flux estimated for the hadronic model of the Perseus radio mini-halo (dash-dotted with lower arrows) is also shown.

Discovery of VHE emission from IC 310 by MAGIC

IC 310 (redshift $z=0.019$) is a head-tail radio galaxy located in the Perseus cluster, 0.6° (~1 Mpc) from the cluster's central galaxy, NGC 1275.

The LAT instrument on board the Fermi satellite has detected IC 310 [6] with 5 (3) photons > 30 GeV (> 100 GeV). The source was also detected at VHE by MAGIC (both in mono and stereo data) [2]. The observations revealed

- ✓ a flat spectral energy distribution (SED) between 150 GeV and 7 TeV

- ✓ a differential spectrum well fitted ($\chi^2/n_{\text{dof}} = 2.3/4$) by a single power-law

$$dN/dE = (1.1 \pm 0.2) \times 10^{-12} (E/\text{TeV})^{-2.00 \pm 0.14} [\text{cm}^{-2} \text{s}^{-1} \text{TeV}^{-1}]$$

- ✓ a mean gamma-ray flux above 300 GeV of $(3.1 \pm 0.5) \times 10^{-12} [\text{cm}^{-2} \text{s}^{-1}]$, corresponding to $(2.5 \pm 0.4)\%$ Crab Units (C.U.)

- ✓ a hint of variability on a one-year time scale (from the comparison with the upper limit achieved from the 2008 mono data (<1.9% C.U.))

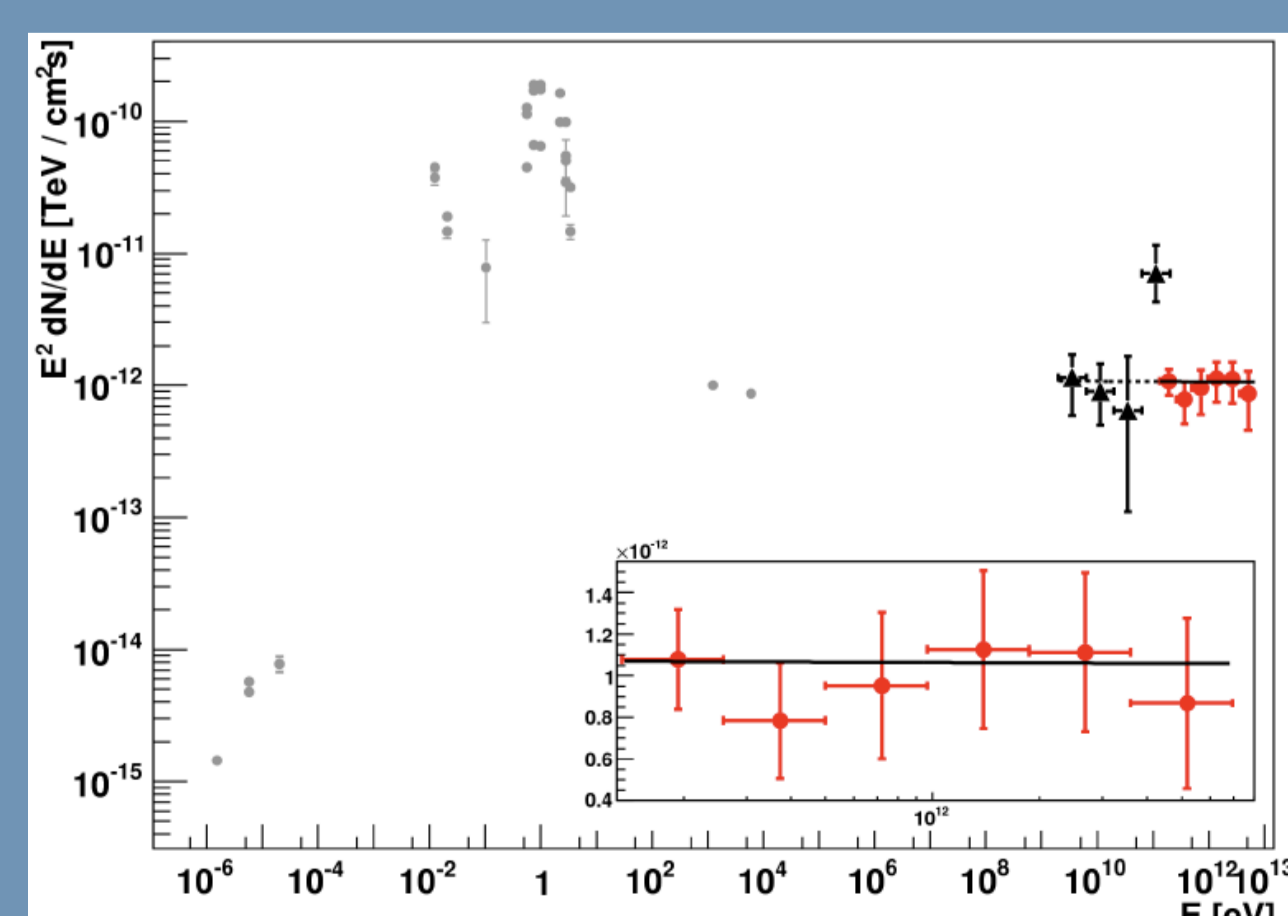


Fig 5 - SED of IC 310 obtained with 20.6 h of MAGIC stereo data (red circles). The black triangles show the flux measurements from the first two years of operation of Fermi-LAT. Archival X-ray, optical, IR and radio data obtained from the NED database are shown with grey dots. The solid line shows a power law fit to the MAGIC data, and the dotted line is its extrapolation to the GeV energies.

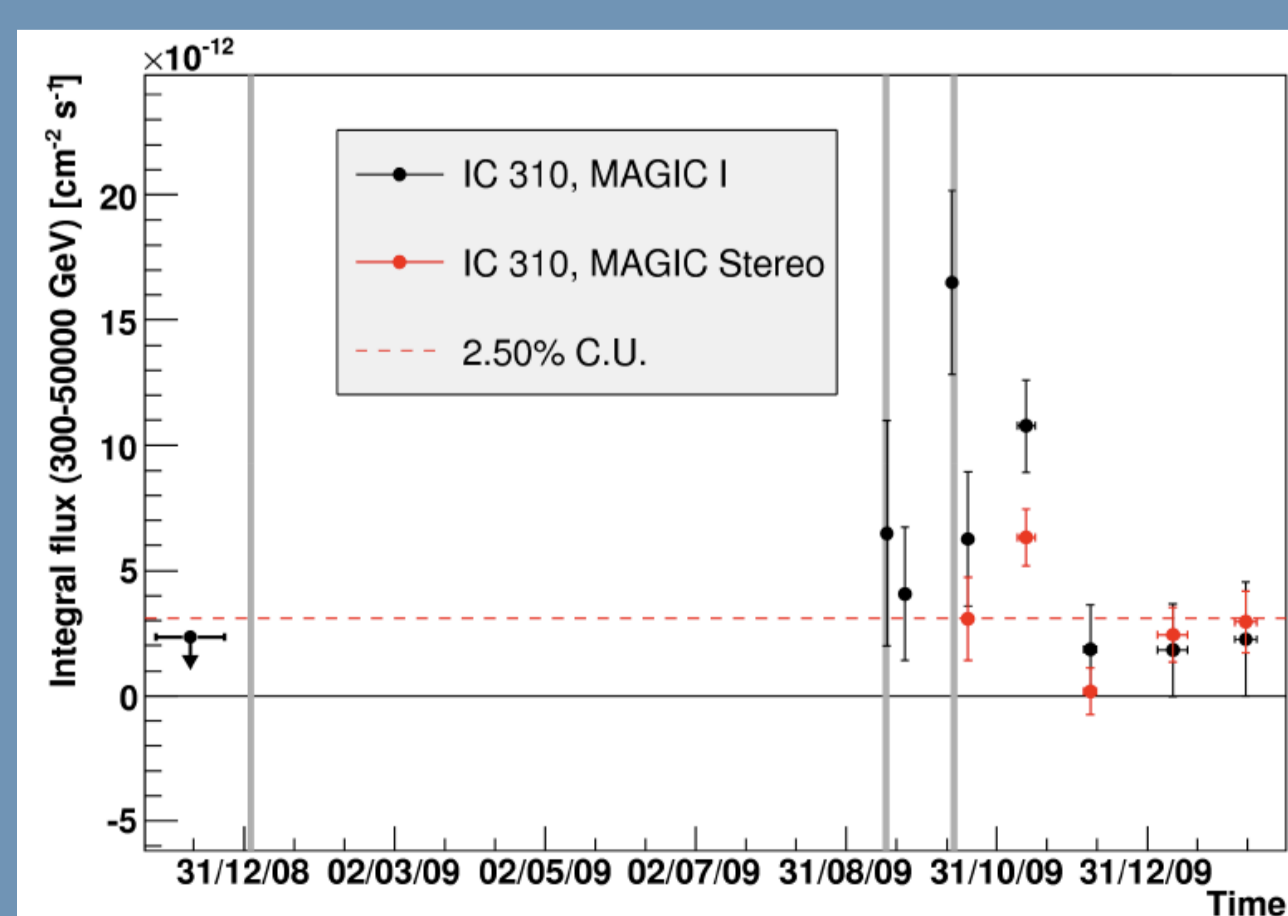


Fig 6 - Light curve (in 10-day bins) of the gamma-ray emission >300 GeV obtained with the mono (black) and the stereo (red) MAGIC data. The black square with an arrow is the upper limit on the emission in November-December 2008. Vertical grey lines show the arrival times of >100 GeV photons from the Fermi-LAT instrument. The horizontal dashed line is a flux level of 2.5% C.U..

Discovery of VHE emission from NGC 1275 by MAGIC

The central cluster radio galaxy NGC 1275 has been detected at VHE by the MAGIC telescopes during the survey carried out between August 2010 and February 2011 (Atel #2916), resulting in a soft spectrum and a preliminary mean gamma-ray flux above 150 GeV of ~1.5% C.U.. The spectrum of the source and its light curve will be published in an upcoming paper (in preparation).

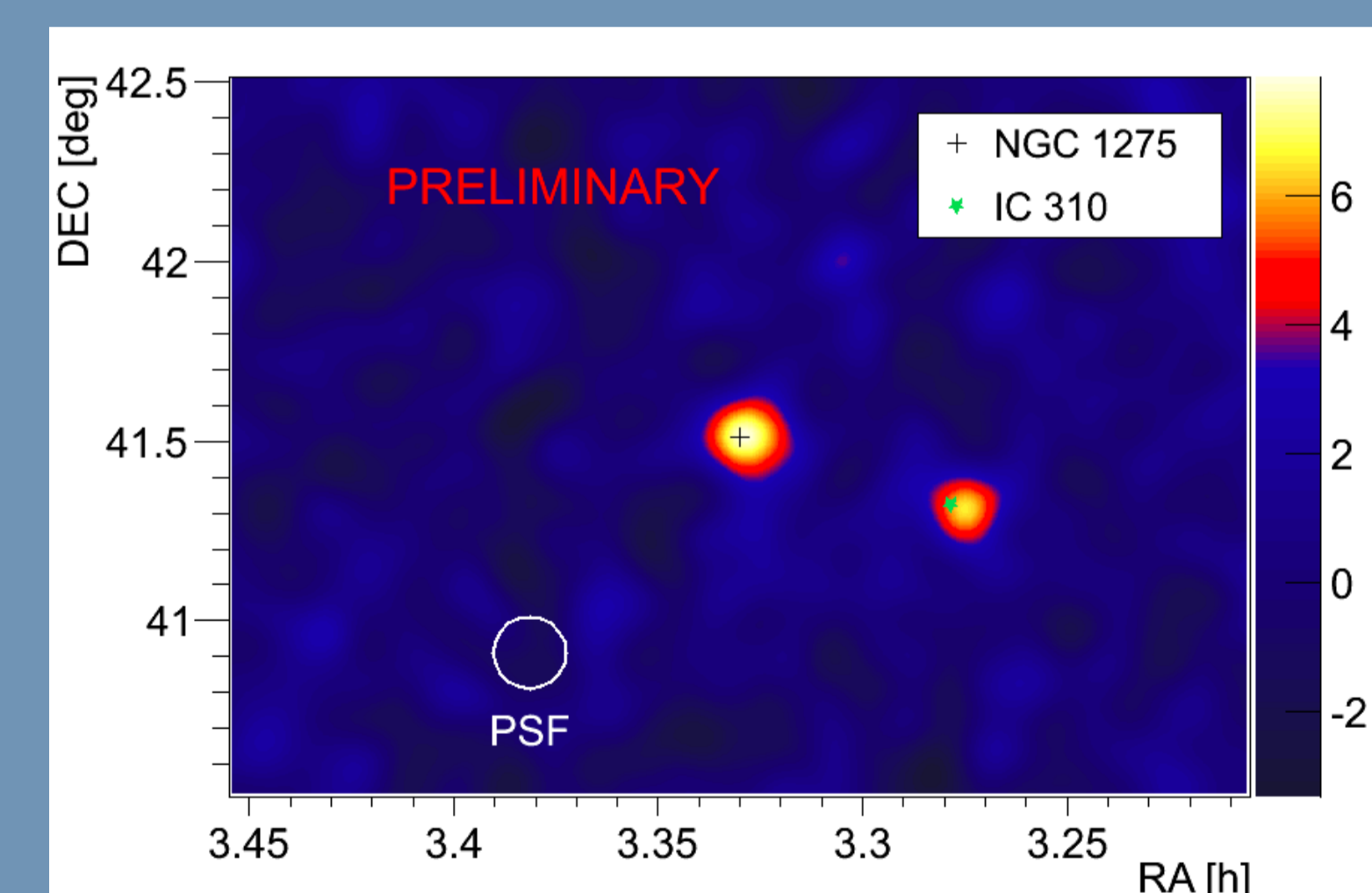


Fig 7 - Significance skymap above 150 GeV of the Perseus cluster region. For this map the overall MAGIC stereo data (nearly 90 hr) have been used. NGC 1275 is clearly detected at the center of the cluster. Also IC 310 is visible at VHE.

References: [1] Colin et al. 2009, in Proc. 31st ICRC (Lodz) (arXiv:0907.0960) [2] Aleksić et al. 2010, ApJL, 723, L207 [3] Gisler, G. R., and G. K. Miley, 1979, Astron. Astrophys. 76, 109 [4] Aleksić et al. 2010, ApJ, 710, 634 [5] Pinzke & Pfrommer 2010, MNRAS, 409, 449 [6] Neronov, A., Semikoz, D. & Vovk, I., 2010, A&A, 519, L6

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