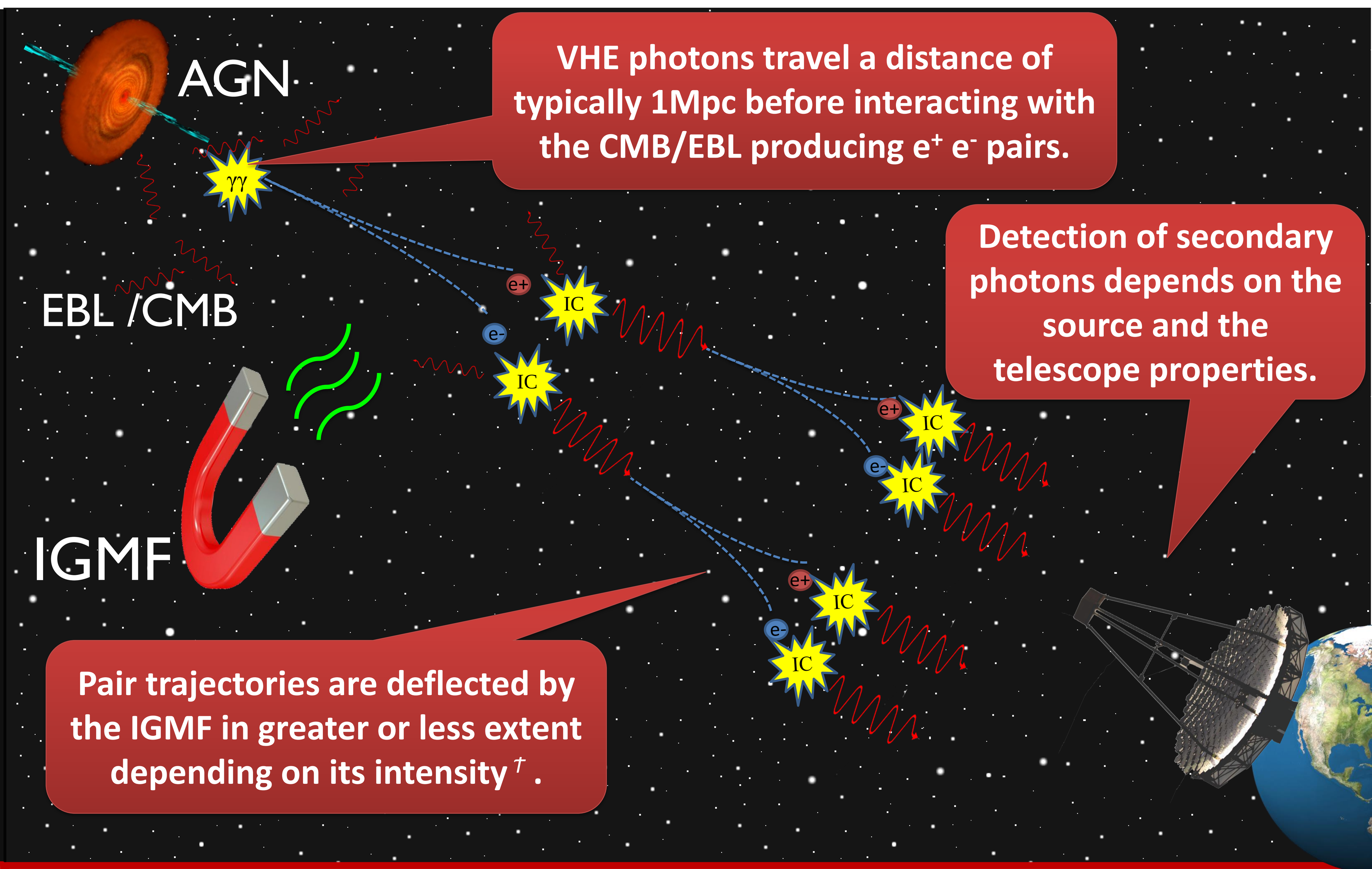
Detecting extended gamma-ray emission with the next generation Cherenkov telescopes

Fernandez Alonso M.[1], Supanitsky A.D. [1], Rovero A.C.[1]

[1]Instituto de Astronomía y Física del Espacio (IAFE, CONICET-UBA), Argentina

Very high energy (VHE > 100 GeV) gamma rays coming from blazars can produce pairs when interacting with the Extragalactic Background Light (EBL) and the Cosmic Microwave Background, generating an electromagnetic cascade. Depending on the Intergalactic Magnetic Field (IGMF) intensity, this cascade may result in an extended isotropic emission of photons around the source (halo), or in a broadening of the emission beam. The detection of these effects might lead to important constrains on both the IGMF intensity and the EBL density, quantities of great relevance in cosmological models. Using a Monte Carlo program, we simulate electromagnetic cascades for different values of the IGMF intensities and coming from a source similar to 1ES0229+200, a blazar with hard spectrum at redshift z=0.14, which is an ideal distance for potentially observing the effect. Motivated by the existence of a real future Cherenkov telescope system, the Cherenkov Telescope Array, we assume a simplified model of response for such a system to develop a method for testing the feasibility of detection of extended emission around a given source.

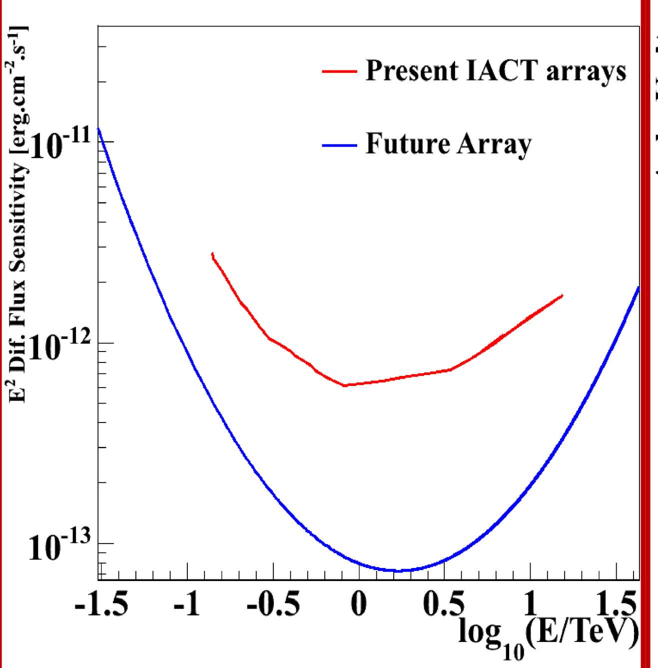


Telescope features

Future generation Cherenkov telescope arrays will have better sensitivity and angular resolution than present Imaging Atmospheric Cherenkov telescopes (IACT) like VERITAS, H.E.S.S. and MAGIC. We use the next simplified model of the telescope features†† to emulate its possible response.

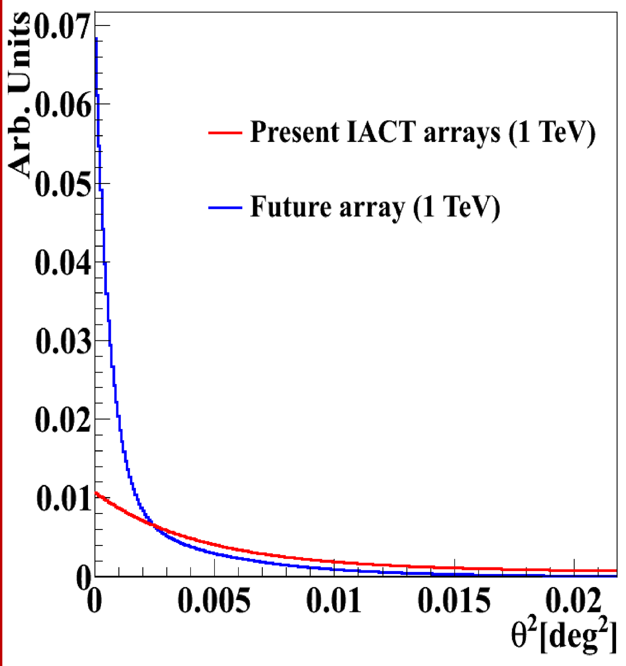
SENSITIVITY

$$S(E) = -13.1 - 0.33\,\log(E/TeV) + 0.72\,\log^2(E/TeV)$$



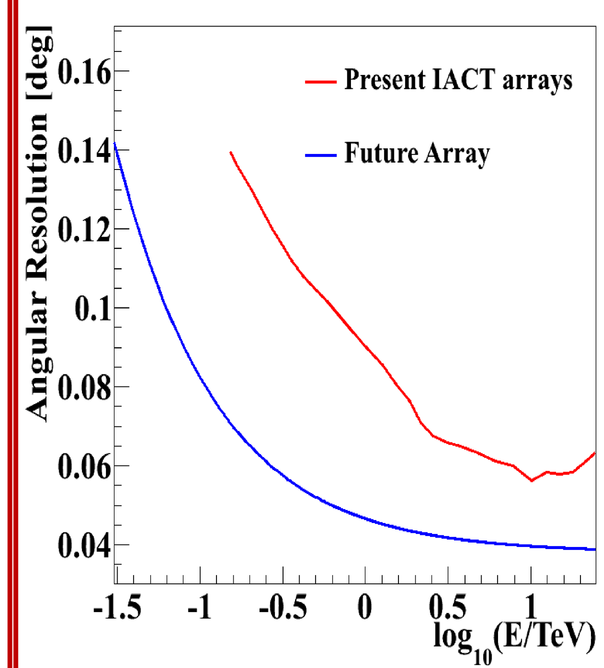
PSF

$$P(\theta^2) = \exp\left(\frac{-\theta^2}{2\sigma_1}\right) + C\,\exp\left(\frac{-\theta^2}{2\sigma_2}\right)$$



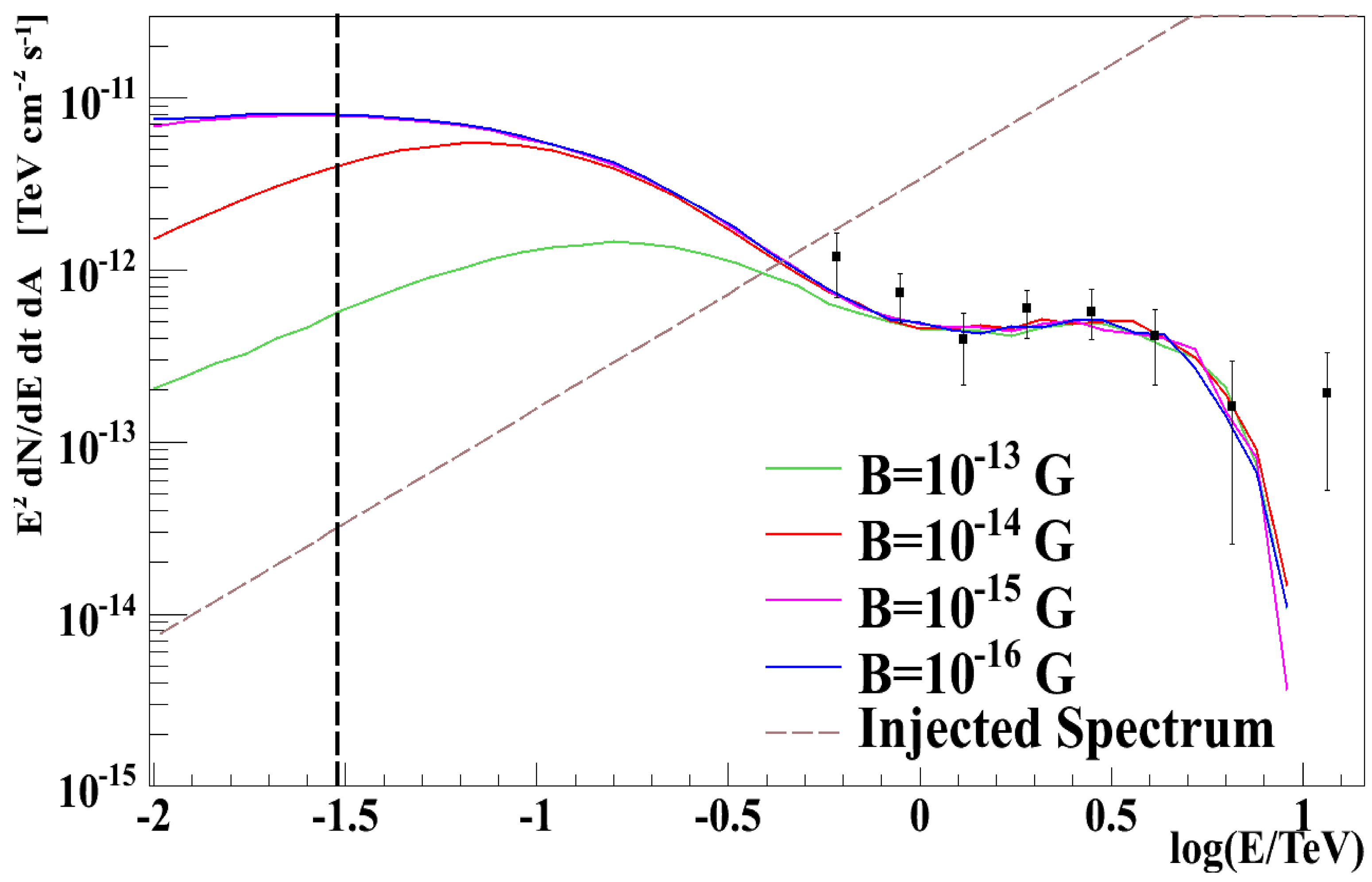
ANGULAR RESOLUTION

$$\psi(E) = \exp\left(\frac{-\log(E/TeV) + 2.9}{0.61}\right) + 0.038$$



Simulation

We simulate Intergalactic cascades (Elmag†††) under different IGMF scenarios and study the angular (θ^2) and spectral distribution (SED) of photons reaching the Earth. We consider an input energy spectrum following a power law with index Γ=2/3 and adjust it to match VHE flux observations from the Blazar 1ES0229+200 (black dots in the plot).

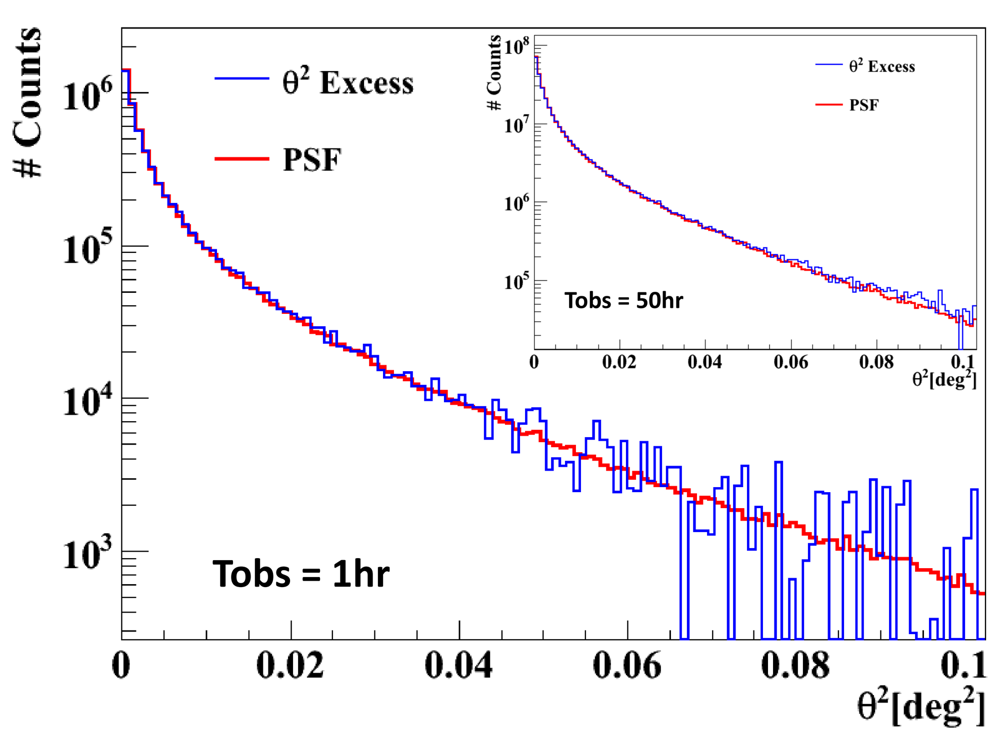


Above E=30 GeV (black-dashed) SEDs for IGMF weaker than 10^{-15} G start to be indistinguishable. → In this regime, IGMF effects should still be appreciable in the θ^2 distributions.

Method

We consider the case **B=10^{-16} G** to calculate the θ^2 excess distribution for a given observation time (T_{obs}) and compare it with the telescope PSF. We calculate the **cosmic ray background** using the telescope **effective area** and **sensitivity**.

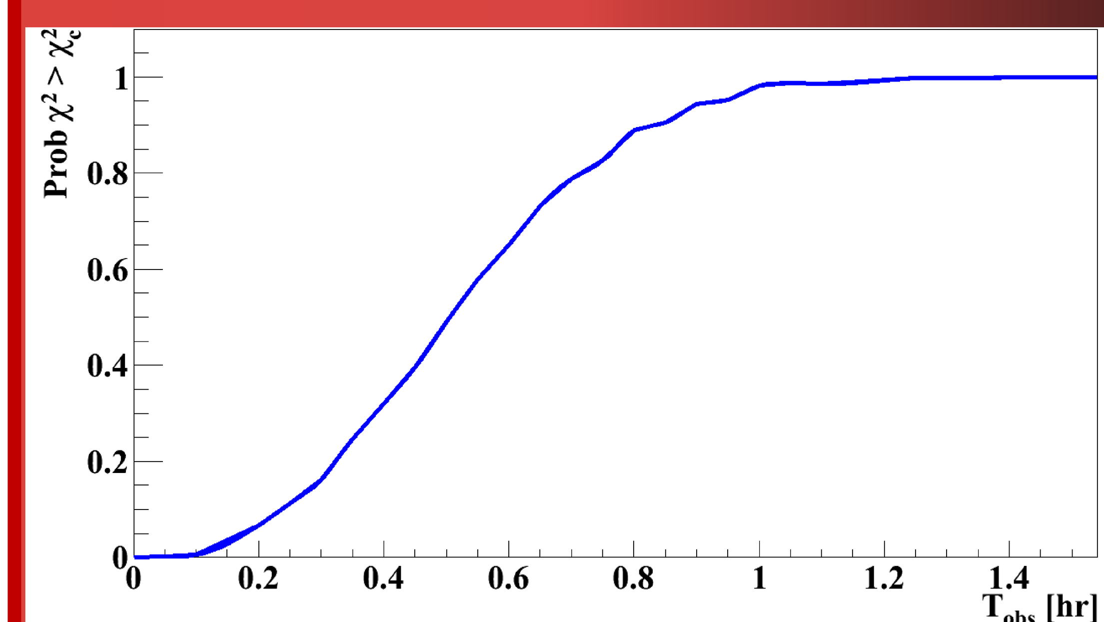
1. Obtain θ^2 distribution from simulation and add cosmic ray background including fluctuations
2. Substract background in "wobble" mode to obtain θ^2 excess
3. Use χ^2 test to compare θ^2 excess to PSF
4. Repeat the process for N samples



$$\chi^2 = \sum_{bin} \frac{(N_{excess} - N_{PSF})^2}{\sigma(N_{excess})} = \sum_{bin} \frac{(N_{excess} - N_{PSF})^2}{N_{SIM} + N_{OFF} + \frac{1}{3} N_{OFF}}$$

Preliminary results

From the χ^2 test results we calculate the probability of rejecting the null hypothesis (IGMF=0) considering the fraction of samples that overpass the rejection threshold (set to 99% C.L). In other words, this probability tells **how likely** it is to **detect** extended emission with the telescope array for a given observation time. It is probable that the optimistic proyection of this results comes from an **overestimation** of the telescope capabilities.



We developed a **method** to test the **power of detecting** extended emission with future Cherenkov telescopes. The method is specially useful in **weak IGMF** scenarios where SEDs are indistinguishable in the HE-VHE range. The method can be applied to different sources at various redshifts.

References

† Aharonian, F. A.; et al. Astrophysical Journal, Part 2 - Letters, vol. 423, no. 1, p. L5-L8.
†† *Charbonnier, A.* Monthly Notices of the Royal Astronomical Society, Volume 418, Issue 3, pp. 1526-1556.
††† *Kachelrieß, M.; et al. Computer Physics Communications, Volume 183, Issue 4, p. 1036-1043.*