Simulations of Cherenkov Telescope Array observations to locate the γ-ray emission zone in jetted narrow-line Seyfert-1 galaxies

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cherenkov telescope array

ABSTRACT

Determining the location of the γ-ray emitting region in jetted sources is one of the currently open issues that can be efficiently addressed by future observations with the Cherenkov Telescope Array (CTA). For transients/flaring events (time-scales of ~1 day or shorter) CTA will be at least two orders of magnitude more sensitive with respect to Fermi-LAT in the overlapping energy range above 25 GeV, thus providing an unprecedented opportunity to investigate flaring γ-ray emitting narrow-line Seyfert 1 galaxies (γ-NLS1). We simulated the spectra of the most promising sources, SBS 0846+513, PMN J0948+0022, and PKS 1502+036, by adopting a detailed treatment of γ-γ absorption in the radiation fields of the broad-line region (BLR) as a function of the location of the γ-ray emission region with parameters inferred from observational constraints. We find that, due to the energy range extent and its sensitivity, CTA is particularly well suited to locate the γ-ray emitting region in γ-NLS1. In particular CTA will be able not only to distinguish whether the γ-ray emitting region is located inside or outside the BLR, but also where inside the BLR it may be.

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INTRODUCTION

Narrow-Line Seyfert 1 galaxies (NLS1s) are a subclass of active galactic nuclei (AGN) located at the lower end of the line-width distribution for the Seyfert 1 population. γ-ray emitting narrow-line Seyfert 1 (γ-NLS1) galaxies are thought to harbour relatively low-mass black holes (10^6-10^8 $M_{\odot}$) accreting close to the Eddington limit. In Romano et al. (2018) we considered the prospects for observations of γ-NLS1 as a class of sources to investigate with the Cherenkov Telescope Array (CTA) since the detection in the VHE regime would provide important clues on the location of the emitting region. Here (also see Romano et al. 2020) we only examine three sources that were considered good candidates for a perspective CTA detection in Romano et al. (2018), SBS 0846+513, PMN J0948+0022, and PKS 1502+036.

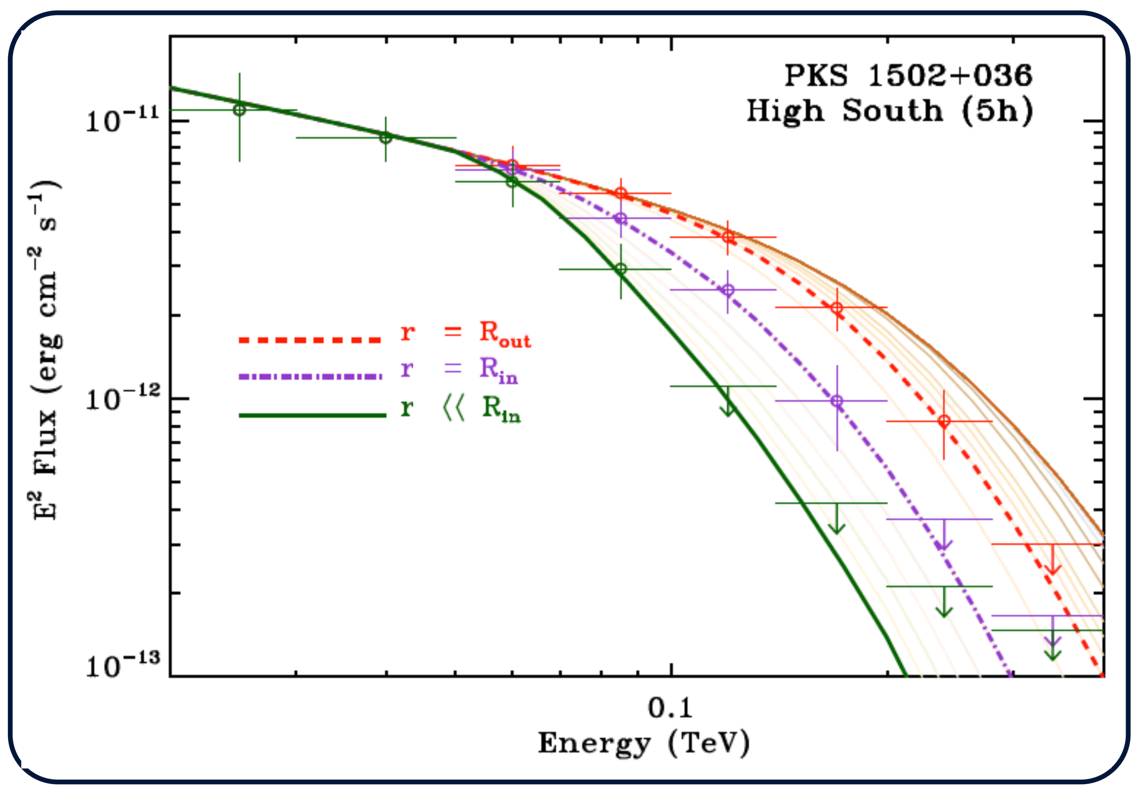

Fig. 1: Input models (curves) for PKS 1502+036 in the high flux state (as observed by Fermi) as a function of the location r of the γ-ray emission region. The points are the CTA simulations for the Southern CTA site (5h exposure).

METHODS

We simulate the spectra of SBS 0846+513, PMN J0948+0022, and PKS 1502+036, by adopting more realistic broad-line region (BLR) absorption models than those adopted in Romano et al. (2018) with a detailed treatment of γ-γ absorption in the radiation fields of the BLR of these NLS1s as a function of the location of the γ-ray emission region as proposed by Böttcher & Els (2016, 2018). We produced a grid of models accounting for γ-γ absorption in the BLR as a function of the location of the γ-ray emission region (curves in Figs. 1 and 2). The absorption is derived self-consistently from the shape of the spectral energy distribution (SED) in the framework of a single-zone leptonic external Compton BLR (EC-BLR) model for the γ-ray emission of flat-spectrum radio quasar (FSRQ) blazars.

In selected energy ranges we first used the task *ctobssim* within *ctools* (Knödlseder et al. 2016) to create event lists based on the input models, and then *ctlike* to fit a power law with a maximum-likelihood model fitting. We performed sets of 100 statistically independent realizations. When the source was not detected, we calculated 95 per cent confidence level upper limits on fluxes from the distribution of the simulated fluxes. We simulated each model using both fixed energy ranges (Fig. 1) and, to optimise the sensitivity yield, by using a dynamical energy binning (Fig. 2).

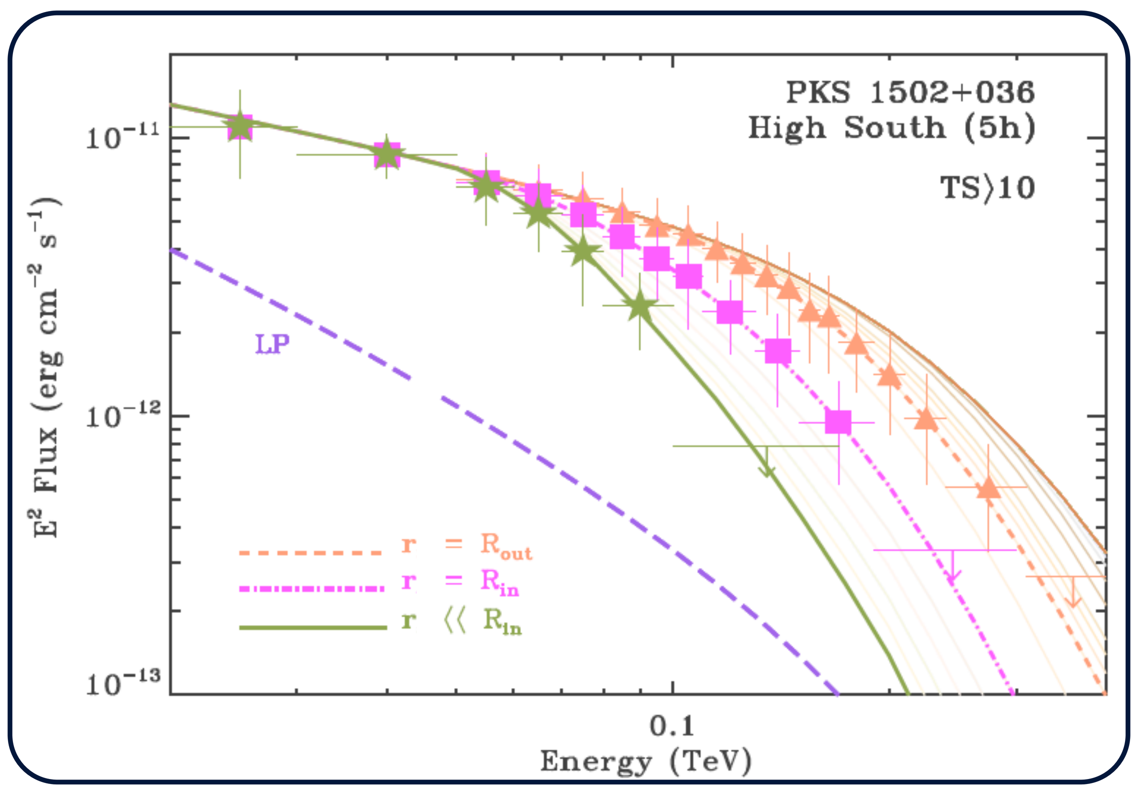

Fig. 2: Same as Fig. 1, but with the CTA simulations obtained by adopting a dynamical binning ensuring a TS>10 in each bin. The violet long dashed curve is the extrapolation of the 4FGL log-parabola fits scaled to the same Fermi flux.

RESULTS

We find that CTA will be able not only to distinguish whether the γ-ray emitting region is located inside or outside the BLR, but also where inside the BLR it may be. Furthermore, the adoption of a dynamical binning for the energy will improve our chances of discriminating between competing models while simultaneously providing a better chance to study in detail the curvature of the spectrum.

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