Bjet_MCMC: A new tool to fit the broadband SEDs of blazars

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Abstract

Multiwavelength observations are now the norm for studying blazars' various states of activity, classifying them, and determining possible underlying physical processes driving their emission. Broadband emission models became unavoidable tools for testing emission scenarios and setting values to physical quantities such as the magnetic field strength, Doppler factor, or shape of the particle distribution of the emission zone(s). We announce here the first public release of a new tool, `Bjet_MCMC`, that can automatically fit broadband spectral energy distributions (SEDs) of blazars. The complete code is available on GitHub and allows testing leptonic synchrotron self-Compton models (SSC), with or without external inverse-Compton processes from the thermal environment of supermassive black holes (accretion disk and broad line region). The code is designed to be user-friendly and computationally efficient. It contains a core written in C++ and a fully parallelized SED fitting method. The original multi-SSC zones model of `Bjet` is also available on GitHub but is not included in the MCMC fitting process at the moment.

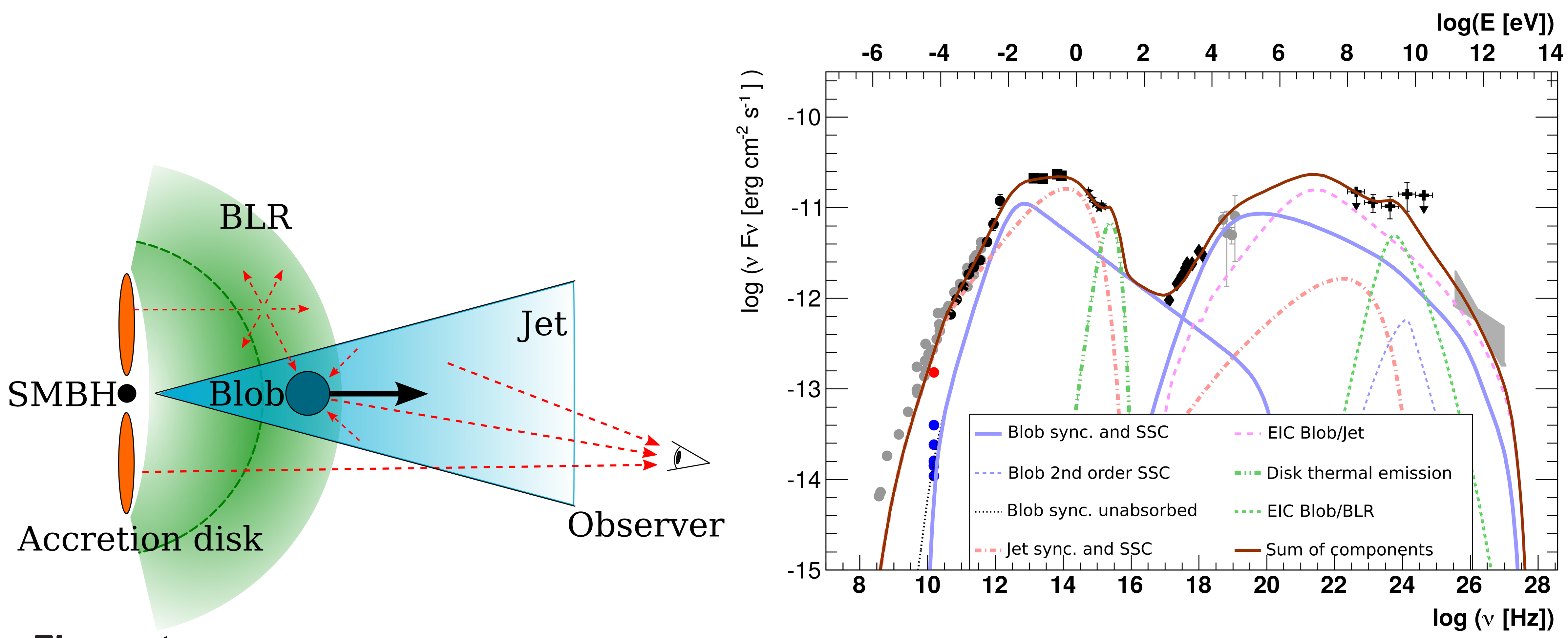

Figure 1: *Left: Scheme of the `Bjet` model, dashed lines show the considered radiative transfers. Right: Example of an application of the `Bjet` model on the SED of the blazar AP Librae [5].*

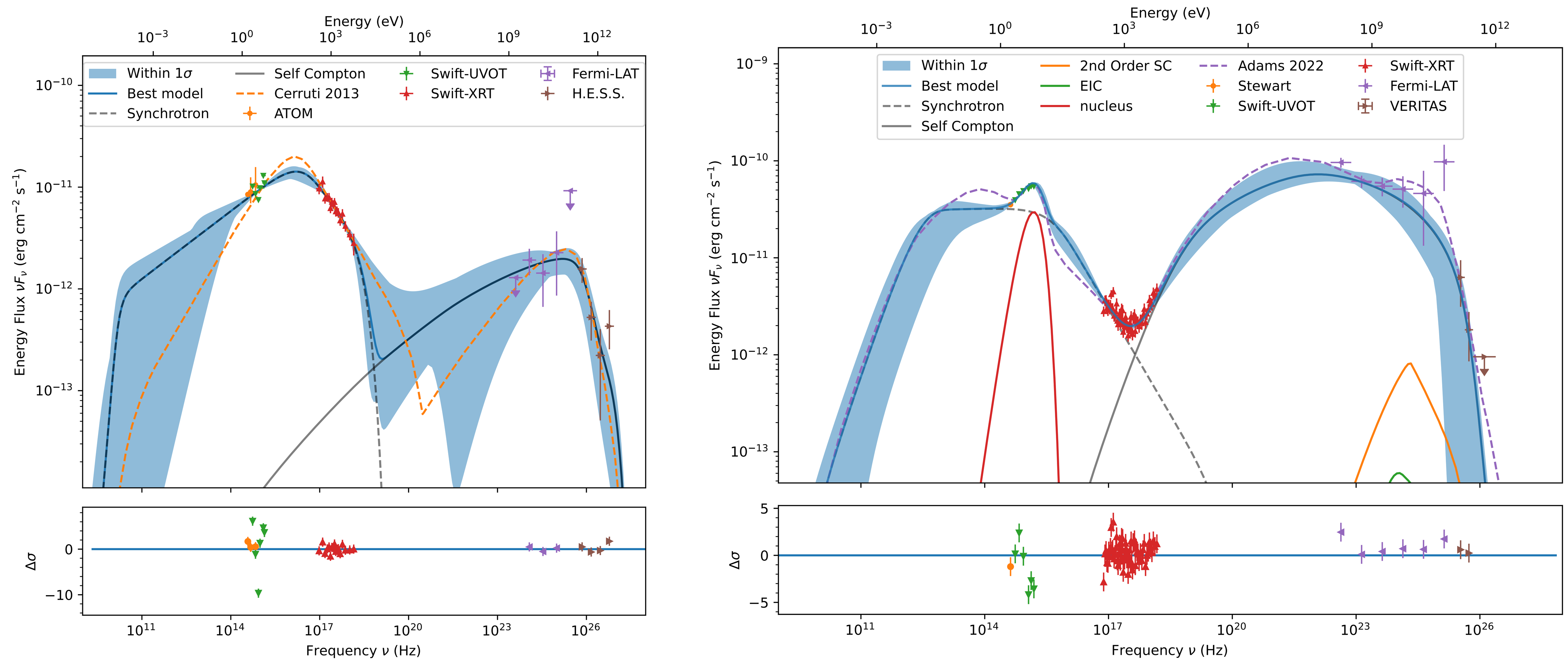

Figure 2: *Results of `Bjet_MCMC` on the SED fit of the blazars 1RXS J101015.9-311909 (left, one-zone pure SSC) and PKS 1222+216 (right, one-zone SSC + thermal EIC). The SED data points have been shared by the authors of [1, 3], while their model lines have been manually digitized from the original papers.*

Table 1: *Best fit and parameter comparison for 1RXS J101015.9-311909.*

Parameter	Cerruti et al. 2013		`Bjet_MCMC`	
	Best Value	1σ Range	Best Value	1σ Range
δ	96.83	32.07–99.53	83.8	35.8 – 100
$N_e^{(1)}$ [cm^{-3}]	undefined	undefined	4.24×10^3	2.18×10^2 – 1.0×10^6
n_1	2.0	fixed	2.56	2.31 – 2.74
n_2	4.0	fixed	3.75	3.25 – 4.24
γ_{min}	100	fixed	9.22	1.00 – 1.49×10^4
γ_{max}	5×10^6	fixed	1.99×10^6	2.57×10^5 – 9.99×10^7
γ_{break}	5.31×10^4	$(3.48–13.15)\times10^4$	2.13×10^5	2.40×10^4 – 3.93×10^5
B [G]	0.015	$(0.51 - 4.089)\times10^{-2}$	1.71×10^{-3}	7.92×10^{-4} – 1.42×10^{-1}
R [cm]	1.3×10^{16}	$(0.49–11.57)\times10^{16}$	1.40×10^{17}	1.71×10^{15} – 2.21×10^{17}
$\chi^2_{\rm red}$ total	260.6/27 = 9.65		187.1/24= 7.80	
$\chi^2_{\rm red}$ X-ray – γ-ray	18.6/18 = 1.04		14.4/15= 0.96	

Validation of `Bjet_MCMC` on two blazars

As a validation test, we used Bjet_MCMC on the broadband SEDs of two blazars. We applied a one-zone pure SSC model on the HBL 1RXS J101015.9-311909 and a one-zone SSC + thermal EIC on the FSRQ PKS 1222+216 (see Figure 2). For both cases, we used 100 walkers with 5000 steps each and a burning phase of 200 steps. The results look satisfactory with better χ^2 achieved compared to previous SED fits [1, 3]. Due to a lack of room, only the parameter comparison with the model of [3] is shown in this poster. The official paper of the release of `Bjet_MCMC` has been submitted to ApJ and is available on ArXiV [6].

General information

`Bjet` is a leptonic multi-SSC zones model developed by [5] that has shown its capability in modeling various types of blazars (HBLs, IBLs, LBLs, FSRQs) and a radiogalaxy candidate [1, 2, 7, 10]. The main purpose of the project `Bjet_MCMC` is to provide this tool to the scientific community through an open GitHub project.[a] Users can have access to the full `Bjet` code and perform one-zone or multi-zones modeling. A scheme of `Bjet` geometry (not to scale) and an example of its application on a broadband SED are shown in Figure 1. The main radiative processes and formulas used in the code are described in [5, 8].

As SSC models are notorious for being challenging for standard χ^2 minimization methods, we used a Markov-Chain Monte-Carlo (MCMC) fitting method through the `emcee` package [4]. Only the one-zone SSC model (with or without a thermal nucleus) can be used with the MCMC method.

Our probability function is based on the χ^2 value of the model on all considered SED spectral points as $\ln P = -\chi^2/2$. From the posterior probability distribution, the solutions within 1σ confidence level have $\chi^2 < \chi^2_{\rm min} + \Delta\chi^2$ [9], where $\chi^2_{\rm min}$ is our best solution and $\Delta\chi^2 = \chi^2_{\rm ppf}(0.682, k)$. k is the number of free parameters in our model that can range from 1 to 13.

Acknowledgments

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[a]`https://github.com/Ohervet/Bjet_MCMC`