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Radio-gamma-ray response in blazars as a signature of adiabatic blob expansion

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Multi-wavelength light curves in long-term campaigns show that, for several blazars, the radio emission occurs with a significant delay with respect to the γ-ray band, with timescales ranging from weeks to years. Such observational evidence has long been a matter of debate and is usually interpreted as a signature of the γ-ray emission originating upstream in the jet, with the emitting region becoming radio transparent at larger scales. We show, by means of self-consistent numerical modelling, that the adiabatic expansion of a relativistic blob can explain these delays, reproducing lags compatible with the observed timescales. We use the JetSeT framework to reproduce the numerical modelling of the radiative and accelerative processes, reproducing the temporal evolution of a single blob, from the initial flaring activity and the subsequent expansion, following the spectral evolution and the corresponding light curves, investigating the relations among the observed parameters, rise time, delay, and decay time, and we identify the link with physical parameters. We find that, when adiabatic expansion is active, lags due to the shift of the synchrotron frequency occur. The corresponding time lags have an offset equal to the distance in time between the flaring onset and the beginning of the expansion, whilst the rising and decaying timescales depend on the velocity of the expansion and on the time required for the source to exhibit a synchrotron self-absorption frequency below the relevant radio spectral window. We derive an inter-band response function, embedding the parameters mentioned above, and we investigate the effects of the competition between radiative and adiabatic cooling timescales on the response. We apply the response function to long-term radio and γ−ray light curves of Mrk 421, Mrk 501, and 3C 273, finding satisfactory agreement on the long-term behaviour, and we use a Monte Carlo Markov Chain approach to estimate some relevant physical parameters. We discuss applications of the presented analysis to polarisation measurements and to jet collimation profile kinematics. The collimation profiles observed in radio images agree with the prediction from our model.

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