One decade of multiwavelength variability of the blazar PKS 2155-304

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The variability of BL Lac objects is an important tool to probe the mechanism at play in the jet and the link between the jet and the accretion disk. We have studied the multiwavelength variability of PKS 2155-304 (z=0.116) with almost 10 years of optical, X-ray and gamma-rays data [1]. The variability as a function of the energy presents a double bump behaviour. In optical and X-ray, the flux time-series follow a log-normal process. An intriguing hint for a periodicity of about approximately 700 days is found in the optical and in the high energy (100 MeV $< E <$ 300 GeV) range. To explain these observational findings, a time-dependent, synchrotron self-Compton model is used which reproduces the energy-dependent variability and provides an explanation as to why the periodicity cannot be detected in X-ray and above 100 GeV.

1 Introduction and data sets

Variability of blazars is one of the tools to study the mechanisms responsible for their electromagnetic emission. To this purpose, a lot of studies were made on eruptive, fast and often dramatic events which undoubtedly help to constrain the physic of the jet. Nevertheless, long term light-curves and studies of the stochastic processes are still barely present in the literature. Since different classes of electromagnetic models - leptonic or hadronic - predict different patterns of variability, such long term studies are of paramount importance to distinguish them. PKS2155-304 (z=0.116) is the most observed blazars at TeV energies in the southern sky and a bright γ-ray source. As for most of objects if its kind, it is variable at all wavelengths.

Log-Normal behaviour in γ-ray was reported by [2] and periodicity at optical and *Fermi*-LAT energies in several publications.
Data from almost a decade taken on PKS 2155-304 were gathered from optical to TeV energies. At γ-ray energies, *Fermi*-LAT and H.E.S.S. data were extracted from [2].
X-ray observations from *RXTE*, *Swift*/XRT and *XMM*-Newton spanning over more that 8 years were analysed and SMARTS [3] optical data, in the J,R, V and B bands, were also used.
Light-curves in different energy ranges - 3 in X-ray, 2 in *Fermi*-LAT range and 1 in H.E.S.S. range, were computed to study the properties of the variability of this well-known object.

2 Observational results

To probe the stochastic properties of the data sets, we used two different tools : The fractional variability $F_{\rm var}$ [4] and the Lomb Scargle periodogram (LSP) [5, 6].

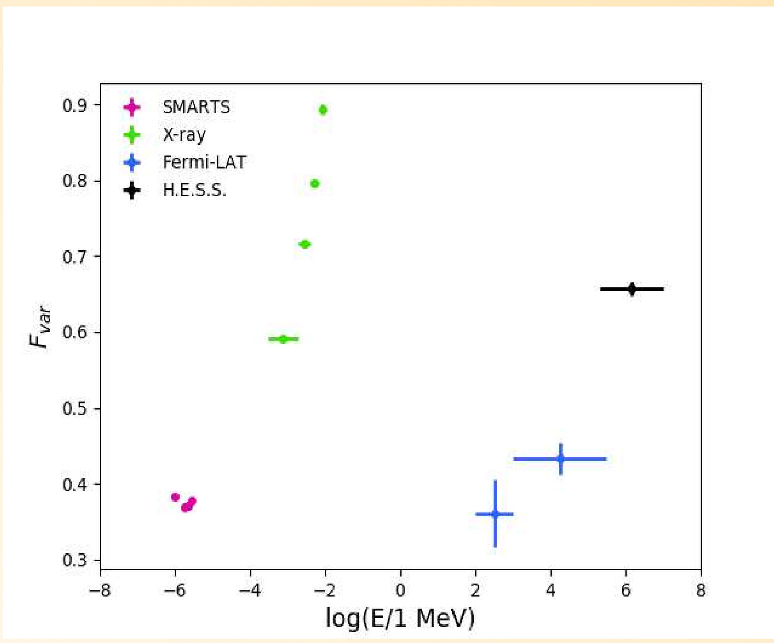

Fig 1. $F_{\rm var}$ as a function of the energy for PKS 2155-304.

Fig 1. gives $F_{\rm var}$ as a function of the energy. Optical and *Fermi*-LAT energy range show less variability than in X-ray and TeV range. Such a bimodal behaviour was already been reported for this object on shorter time scale [7] and for other blazars such as Mrk 421.

In optical and *Fermi*-LAT energy range (Fig. 2), a clear periodicity was found. In optical, depending on the band, the periodicity range from 715 to 733 days. *Fermi*-LAT light-curve presents a periodicity of 685±9 days

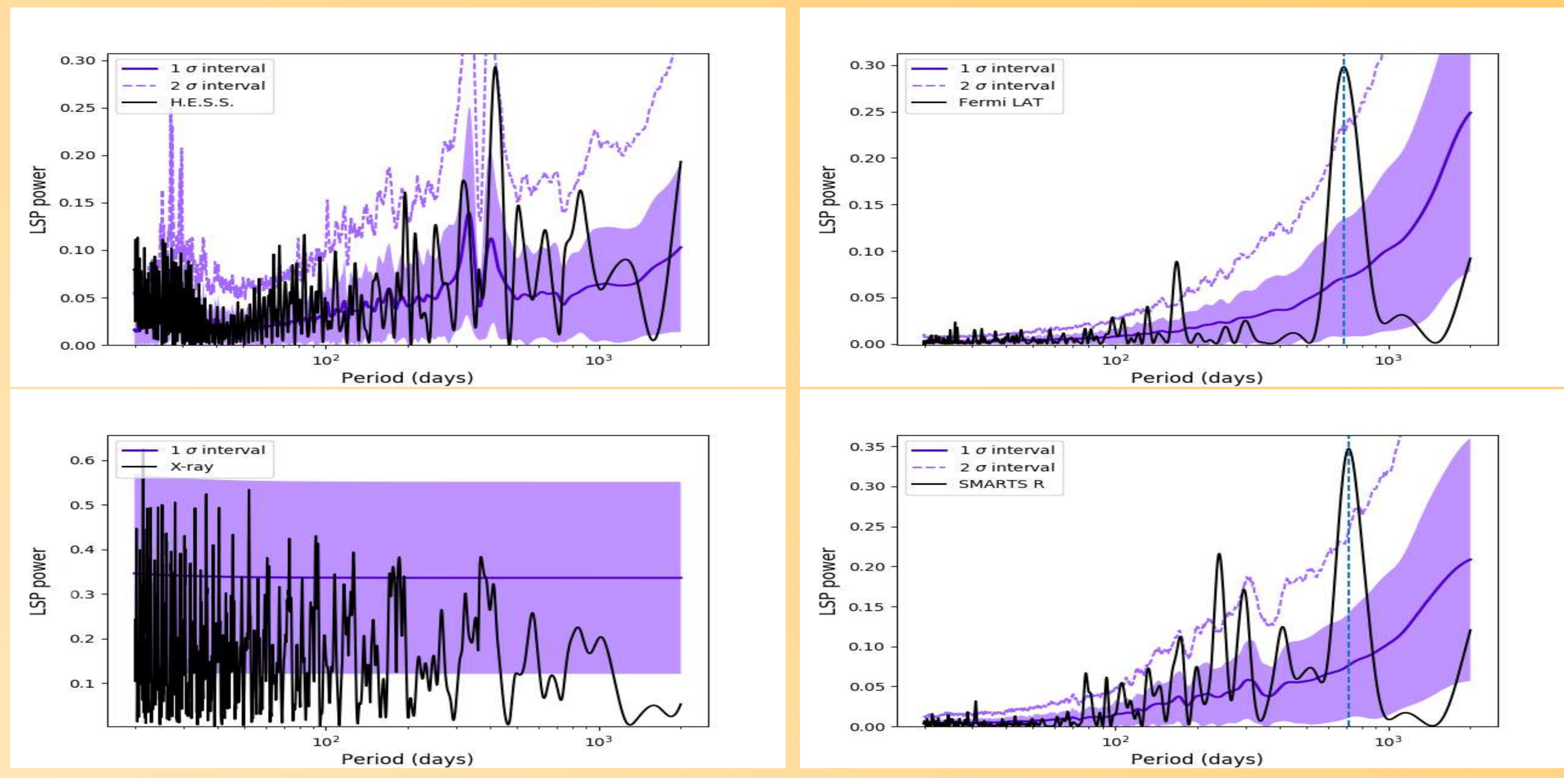

Fig 2. Lomb Scargle periodogram for the R band of SMARTS, X-ray light curve, *Fermi*-LAT data and the H.E.S.S. data.

Such periodicity has been found by several authors with somehow different periods highlighting the difficulties of such a study (see [8] for a review).

3 Simulations and results

We aim to reproduce the stochastic properties of the light-curve with a simple SSC model. The used SSC model is a one-zone model with a constant B-field and uniform electron distribution. The model is time-dependent and at each step the Fokker-Planck equation with losses due to Synchrotron and inverse-Compton cooling is solved. Fresh electrons are injected and the electron distribution is described by a power-law with exponential cut-off. We considered two components of the variability :

- Stochastic component : The value of the exponential cut-off varies in time following a flicker noise with an index of $\beta = 1$
- Deterministic component : Periodicity is included in the simulation by varying the Doppler factor.

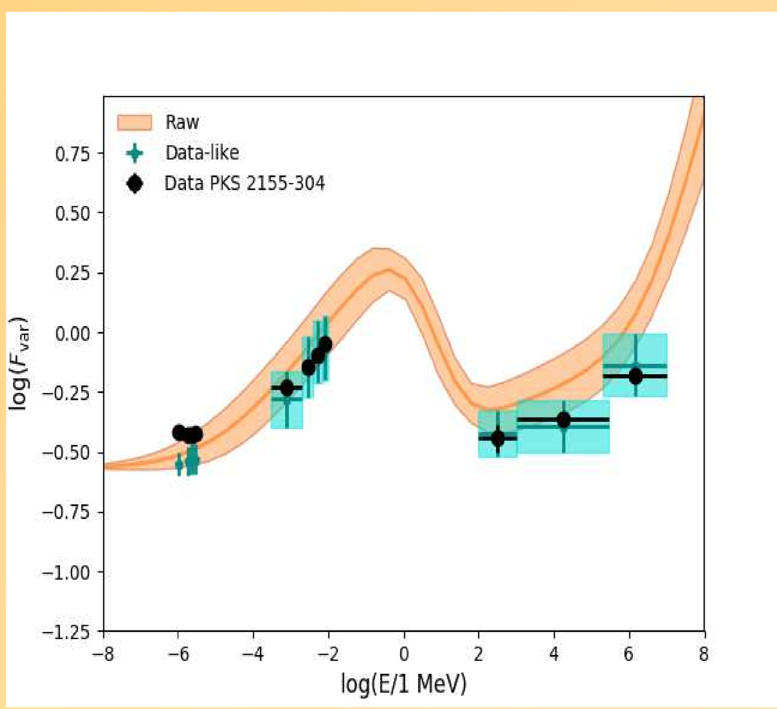

Fig 3. Simulated $F_{\rm var}$ - corrected and not corrected instrumental effects. Data are shown in black.

We performed 200 simulations covering a 10 years period with a 9.5 minutes binning (in the observer rest frame) were performed. Instrumental effects were taken into account by applying the same time binning and windowing to produce the simulated light-curves.

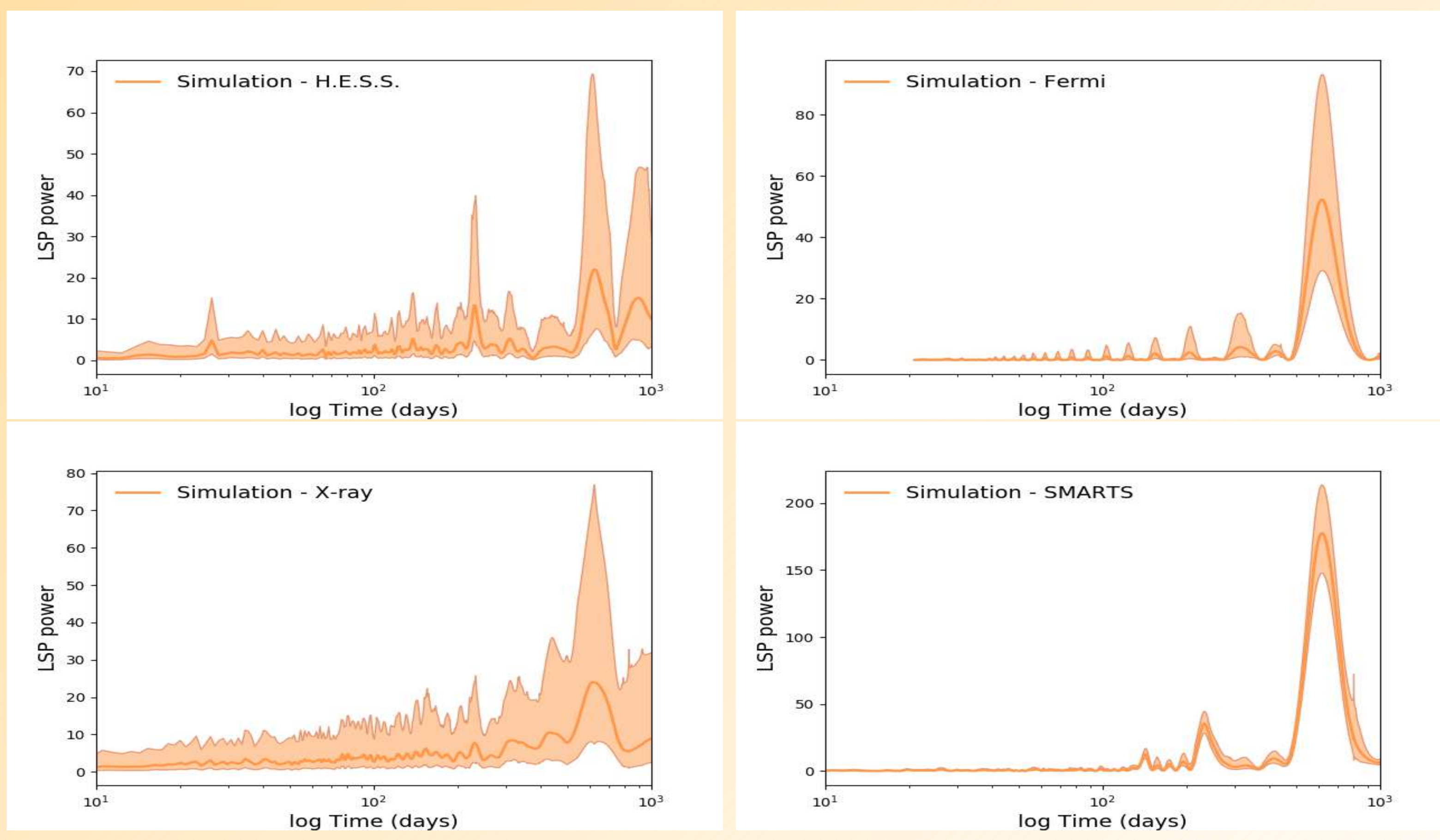

Fig 4. LSP of the simulated light-curves in the same energy ranges than Fig. 2.

The results of the simulations are shown in Fig. 3 and 4. The behaviour of $F_{\rm var}$ is well reproduced except in optical. Periodicity in optical and *Fermi*-LAT range, while present, is sub-dominant with respect to the high variability in the X-ray and TeV ranges.

4 Conclusions

- A simple time-dependent SSC model is able to reproduce the long-term energy dependent variability of PKS 2155-304
- The cut-off energy of the electrons is changed following a stochastic process and a deterministic process to reproduce the periodicity.
- The tantalizing hint of periodicity in the optical and GeV range is not detected in the X-ray and TeV range, consistently with the high degree of variability in these ranges.

References

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