Report MAXI J1820+070 project

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1 Introduction about MAXI J1920+070

MAXI J1920+070 is a low mass transient x-ray binary system, with a black hole as a compact object (Abe et al., 2022). It is most commonly studied in the field of x-ray spectral timing, because of it's 2018 outburst and decay and subsequent reflare in 2019 (Marco et al., 2021 & Shaw et al., 2021). In this project however, the flux spectrum of the source will be studied and subsequently a spectrum of the source's jet will be modeled by combining a calculated self-absorbed synchrotron spectrum with a monte-carlo simulation of the self-synchrotron inverse compton upscattering of these local synchrotron photons.

1.1 Model set-up

For this project a jet divided into 10 slices, spaced evenly in $log^{10}(z)$ space is assumed. As input parameters of the model we use a plasma moving with a Lorentz factor of $\Gamma = 3$ (Zdziarski, Tetarenko, and Sikora, 2022), containing a power-law of electrons with a power-law index of 2.44 (Abe et al., 2022). An initial magnetic field, used for calculating the synchrotron spectrum, of $B = 10^{8.5}G$ was used, as this gave the best match with our data. Other parameters we used are a mass of $8.48M_{\odot}$ (Torres et al., 2020) and a distance to earth of $2.96 \cdot 10^3 pc$ (Atri et al., 2020).

1.2 Data source

As MAXI J1920+070 is mainly studied in the x-ray regime, radio spectra of the source are quite scarcely available. The best data source that the model created in this project tries to simulate is the plot seen in figure 8.

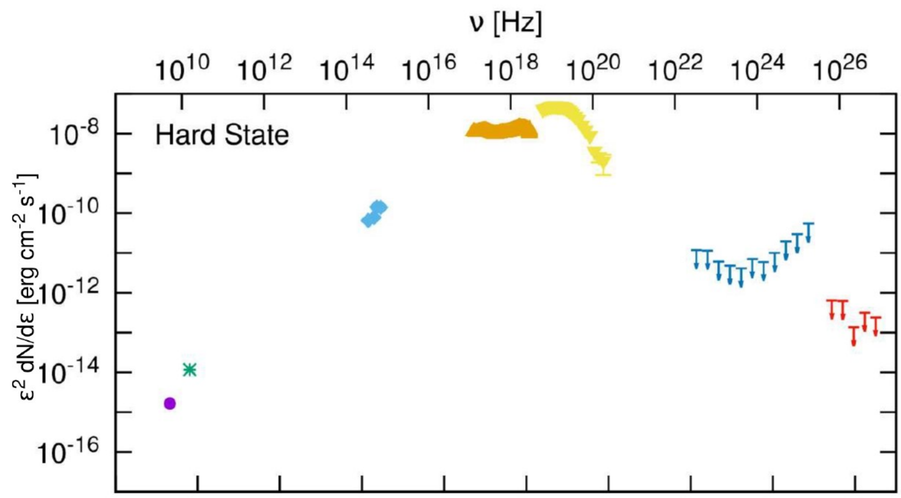

Figure 1: νF_{ν} spectrum obtained from Abe et al., 2022

2 Figures

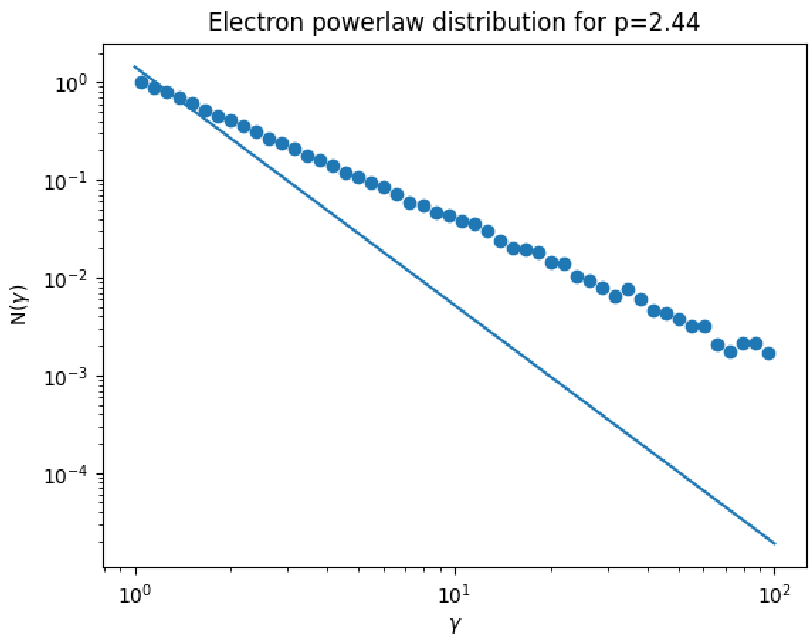

Figure 2: Drawn electron velocity distribution vs. analytical solution

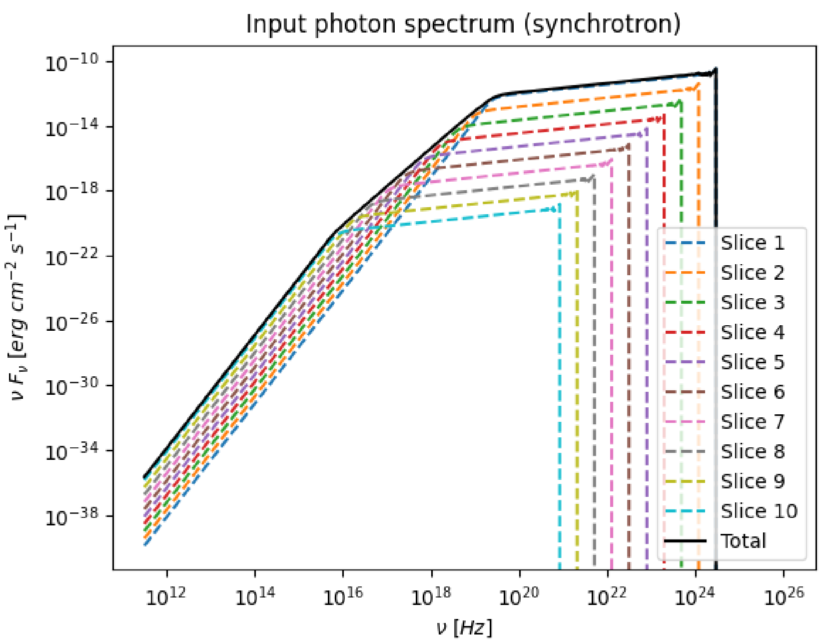

Figure 3: Input synchrotron photon spectrum νF_ν.

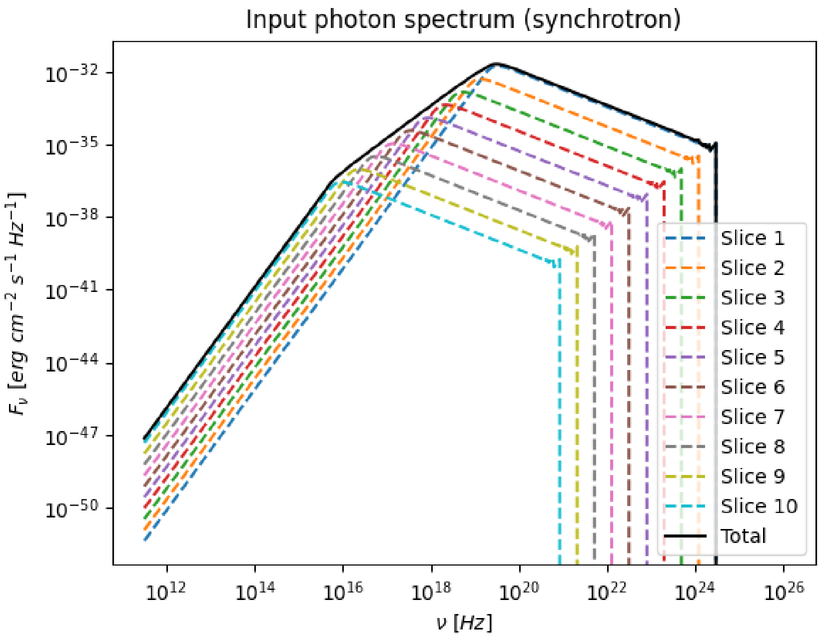

Figure 4: Input synchrotron photon spectrum F_ν.

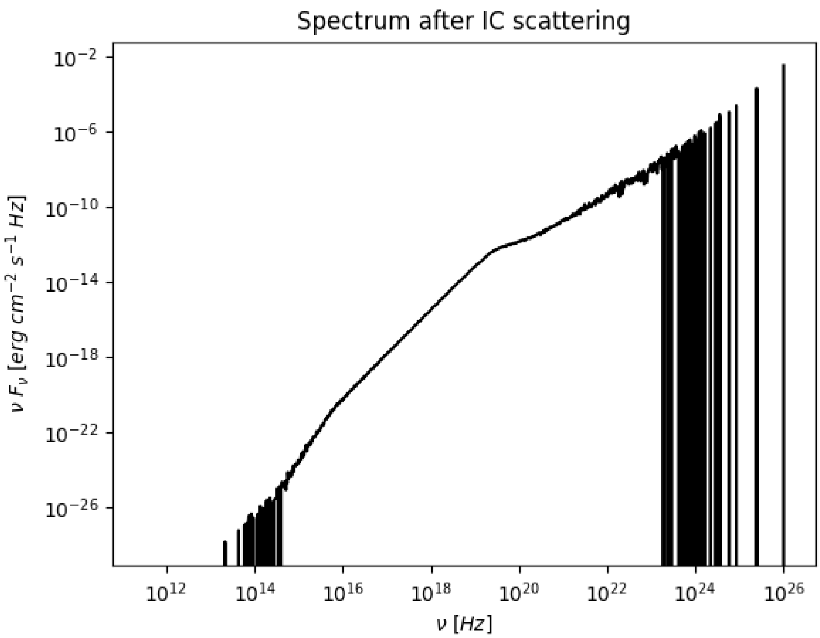

Figure 5: νF_ν spectrum after inverse Compton scattering.

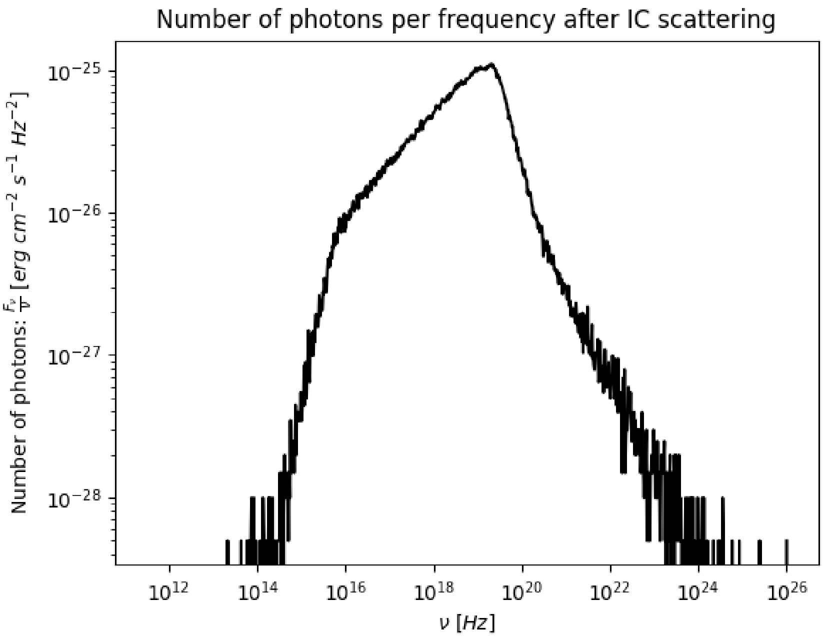

Figure 6: Number of photons per frequency after inverse Compton scattering.

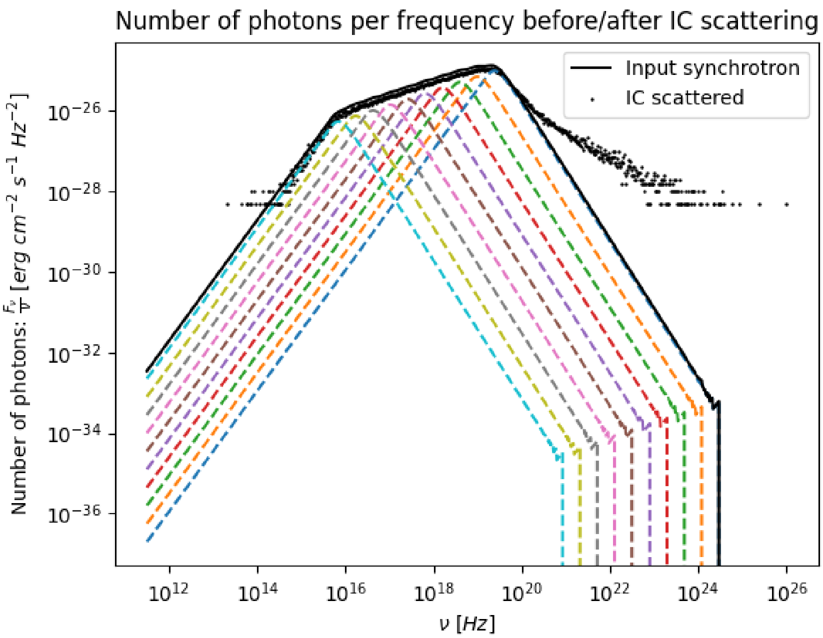

Figure 7: Number of photons per frequency both before and after inverse Compton scattering.

3 Verification

3.1 Comparison to observed data

We compare our model to the data as seen in figure 8. The are a few points of comparison. The first one is the frequency ν at which the intensity drops off. In both figure 8 and figure 3, we see that it drops off at roughly $\nu = 10^{19} Hz$. The second point of comparison is the height of this peak. The intensity in the data peaks around $10^{-8} ergcm^{-2}s^{-1}$, just like the intensity in our model peaks at $10^{-8} ergcm^{-2}s^{-1}$ (see figure 5).

3.2 Synchrotron power

The expected synchrotron radiation power follows from equation 1. Using values of $\gamma = 3$, $\beta = 1$, and filling in the constants, the value for $P_{synchro}$ can be calculated for different values of U_b or B^2. This value can then be compared to the value seen in figure 3.

In figure 3, we can see that the power at ν_{SSA} is roughly 10^{-8}. Using the initial value of $B = 10^4 G$ (Zdziarski, Tetarenko, and Sikora, 2022), the value for the synchrotron power is indeed also roughly 10^{-8}. However, in the model, we used an initial value of $B = 10^{8.5} G$ in order to let the model correspond to the observed data seen in figure 8.

$$P_{synchro} = \frac{4}{3}\sigma_T U_b \gamma^2 \beta^2 c. \tag{1}$$

3.3 Synchrotron input spectrum for inverse compton

For our model to produce significant results, we need a properly normalized synchrotron photomn distribution, from which we draw random photons that we subsqeuently use for our monte carlo simulation. In figure 7 can be seen that the photons drawn from the photon probability match relatively well with out input synchrotron spectrum and that there is some upscattering happening at the higher frequencies.

3.4 Electron power-law

As mentioned in subsection 1.1 we used a power-law of electrons as our input for the inverse compton upscattering of the local synchrotron photons. This power law is given by:

$$N_\gamma \propto \gamma^{-p}. \tag{2}$$

We modeled this power-law, normalized it and subsequently turned it into a probability distribution function (pdf) from which we draw the electron velocities. In figure 2 the result of the drawing of these electrons is plotted against the analytical solution for the powerlaw pdf of electron velocities. As can be seen in the figure, our drawn velocities do not perfectly follow the analytical distribution. The power-law index seems to be off by a factor of 0.5. However, this should not affect our spectrum very significantly, as most velocities drawn will be drawn at the lower velocities, which seem to match the analytical solution relatively well.

3.5 Radio vs X-ray luminosity

As discussed in the lectures, X-ray binaries have a "built in" radio/X-ray coupling. This relation, see eqaution 3, should thus also show up in our model. This can be checked by calculating the luminosity in both the radio as the X-ray band and check if this relation (3) holds. However, in our model, we only see X-ray data, as the frequency is too high for radio. We can however check the modelled X-ray luminosity with the expected value of $L_x \sim 10^{34}$.

In our model, the value for the luminosity at $\nu = 10^{19} Hz$ is equal to the observed νF_ν (see figure 3) times $4\pi D^2$, resulting in $L_x \sim 10^{32}$. This thus matches the observed data relatively well.

$$L_R \propto L_x^{0.55-0.7}. \tag{3}$$

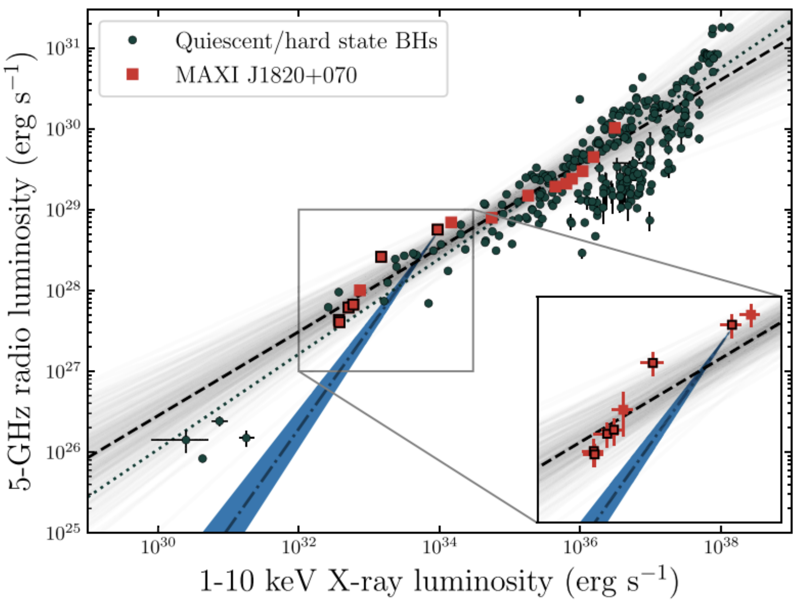

Figure 8: Plot for Radio/X-ray correlation verification from Shaw et al., 2021

References

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