EA MAXIJ 1820+070

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1 Description

Calculate the self-absorbed cyclo-synchrotron and SSC within the corona, as well as inverse Compton up-scattering of the disk blackbody. For the cyclo-synchrotron part you will need to use a modified expression for the emissivity that accounts for sub-relativistic cyclotron emission, please see section 4.2 in the BHjet paper loaded on the final project module.

2 Introduction

MAXI J1820+070is a low mass x-ray binary system. During 2018 multiple outbursts were detected in the hard state Bright et al. (2020); Atri et al. (2020). It is hypothesized that emission in the hard state is dominated by the corona and generates a non-thermal X-ray spectrum Bright et al. (2020). Our interest is in the corona of the black hole during the hard state, we model and verify the cyclo/synchroton emission, synchroton self-Compton scattering and inverse self-Compton of the black-body into the corona.

3 Cyclotron and Synchroton

Our process is similar for both Cyclotron and Synchroton emission. Following our work from assignments 3 and 5 in the class we treat the corona as a spherical blob at constant size. We calculate a constant magnetic field and verify a $\frac{1}{r}$ dependence as if the corona was growing radially outwards.
From equipartition we assume $U_e = U_b$ to calculate the C and $\hat{C}$ constants. Our equations to evaluate the constants are given in equation 1.

$$\begin{aligned} \hat{C} &= \frac{U_e}{\int E^{-p+1} dE} \\ C &= \frac{\hat{C}}{m_e c^2} \\ U_e &= \frac{\eta L_{edd}}{4\pi R^2 v} \\ U_b &= \frac{B^2}{8\pi} \end{aligned} \tag{1}$$

Where η and v are free parameters of efficiency and electron velocity respectively. Thanks to Ben and Leon we know that for a Maxwell-Juttner distribution in the corona, the power law approximates as p=4. We use C, $\hat{C}$ and the magnetic field to evaluate the source function in terms of the emission $_v$ and absorption coefficient α_ν.

$$S_v = \frac{n_\nu}{\alpha_\nu} \tag{2}$$

B (G)	$1.6 \cdot 10^6$
M ($M_\odot$)	9.2
η	0.15
γ_{max}	1000

Table 1: Table of free Parameters from literature

Where α_ν is the absorption coefficient defined in chapter 6 of Rybicki & Lightman (1986), We apply this absorption coefficient in both the cyclotron and synchroton spectrum, subsections 3.1 and 3.2 have expressions for their respective emission coefficients. The intensity I_ν and flux $F_\nu$measured at earth is given by equation 3. We assume the corona is spherical and at the base of jet therefore we calculate the intensity and flux for one slice at the base of the jet.

$$
\begin{aligned}
I_\nu &= S_\nu(1-e^{-\tau}) \\
F_\nu &= I_\nu(\frac{R}{D}^2)
\end{aligned}
\tag{3}
$$

We apply this to both the cyclotron emission and synchroton emission to plot a flat jet spectrum.

3.1 Cyclotron Emission

Beginning with the non-radiative emission, cyclotron emission comes from the gyration of charged particles around a magnetic field Rybicki & Lightman (1986). We treat the corona as the base of the jet in the hard state, and charged particles enter the system through this base. The spectrum model follows the steps in the BHjet paper Lucchini et al. (2022) in the frame of the corona. To account for relativistic and non-relativistic effects we define an electron distribution $N\gamma$ in terms of non-dimensional momentum (ρ), see Lucchini et al. (2022); Katarzyński et al. (2006)

$$
\begin{aligned}
N(\gamma) &= N(\rho)\frac{d\rho}{d\gamma} \\
\gamma(\rho) &= \sqrt{\rho^2+1}
\end{aligned}
\tag{4}
$$

$$
N(\rho) = N_o\rho^2 e^{\frac{-\gamma(\rho)}{\theta}} \tag{5}
$$

Where $N(\rho)$ is the Maxwell–Juttner distribution and $\theta = \frac{K_b T}{m_e c}$ is the dimensionless thermal temperature of the electrons Lucchini et al. (2022). The total cyclotron emissivity is given by Lucchini et al. (2022) as

$$
j_c(\nu) = \int_{\gamma_{min}}^{\gamma_{max}} N(\gamma) j_c(v,\gamma)\, d\gamma \tag{6}
$$

Where $j_c(\nu,\ \gamma)$ is the emissivity per particle with Lorentz factor γ Lucchini et al. (2022).

3.2 Synchroton Self Absorption

Synchroton emission comes from the radiation produced by relativistic particles in a magnetic field. We assume the corona is an isotropic source of this radiation. The emission of photons falls between the characteristic frequency regime as:

$$
\nu_c = \frac{3\gamma^2}{4\pi}\omega_g \sin(\alpha) = 4.3\cdot 10^6 B\gamma^2 Hz \tag{7}
$$

Where B is the magnetic field strength in Gauss Rybicki & Lightman (1986), We calculate a minimum and maximum characteristic frequency in terms of $\gamma_{min} = 2$ and $\gamma_{max} = 1000$. Initially we wished to follow the steps in Lucchini et al. (2022) to calculate synchroton emissivity and absorption but had errors deriving the integrals. We therefore follow assignment 5 and calculate the synchroton spectrum as one slice of the jet for p=4. Thanks to Ben and Leon for the advice. The procedure to calculate the spectrum is outlined in section 3. Following chapter 6 and equation 6.36 in Rybicki & Lightman (1986) to calculate the total emission for arbitrary p indices.

4 SSC

5 Inverse Compton

6 Verification

1. Flux and number density
2. Ue = Ub
3. compton y
4. SSA peak
5. constant tau, wont see Compton hump
6. constant magnetic field from literature does the corona grow
7. corona is jet v = 0.89c
8. assumed gamma max =1000
9. gamma squared is off

7 Conclusion

References

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Lucchini, M., Ceccobello, C., Markoff, S., et al. 2022, , 517, 5853, doi: 10.1093/mnras/stac2904

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