STMS Report - Michael Gabler (COST-STSM-ECOST-STSM-MP1304-300814-047763)

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1 Purpose

The aim of this visit was to complete the coupling of the two independent code pieces of a newly developed code that computes the emission processes in the magnetosphere of magnetars [Gabler 2014a, Gabler 2014b]. The two parts, radiation transport of photons and calculation of particle momenta, were developed by M.Gabler and P. Cerdá-Durán, respectively. Both parts have been developed during the last 2 years when M.Gabler has worked as a PostDoc in Valencia (2011-2013) and they separately work satisfactory. The visit of M.Gabler to Valencia was essential at this stage of the code development. Once the code is ready for application we can make important contributions to explain the spectra of quiescent (non-bursting) magnetars and to the understanding of quasi-periodic oscillations observed in giant flares of magnetars.

2 Work carried out

In the beginning of the stay we found that the major problem to run the combined Monte-Carlo/Particle-in-a-Line code MCMaMa is the use of appropriate initial data. Because of numerical issues we cannot follow how the pair cascade develops from the very beginning, i.e. lifting particles from the surface of the star that initiate the pair cascade. The problem hereby is the high multiplicity of the newly created plasma. It is numerically difficult to follow the pair creation because of the low number of primary particles that have to be followed compared to the high number of secondaries, the circuit may shut down (numerically). We thus agreed to start with an educated guess for the initial data according to previous work by [Beloborodov 2013]. We follow [Beloborodov 2013] to set up the initial data of a simplified particle distribution in the magnetosphere. The simplest approximation to the real electron-positron flow with a broad momentum distribution in the magnetosphere is done with a water bag model. In the latter model, the particle species are separated in momentum space and the particle of the slower species with the highest momentum is just a bit slower than the slowest particle of the higher-momentum species. The momentum distribution is then given by $f = 1.0/(p_+ + p_-)$, where p_+ and p_- are the upper and lower end of the momentum distribution allowed. By prescribing a multiplicity of the plasma close to the star, the interaction with the radiation field determines the

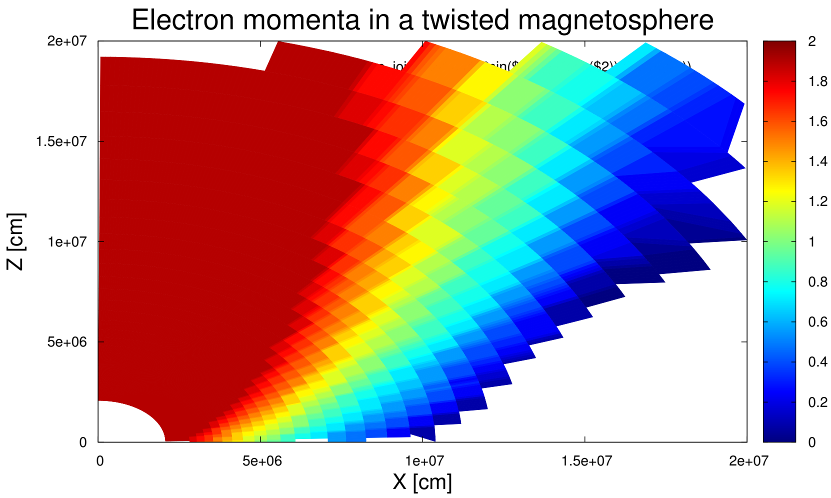

Figure 1: The logarithmic momenta $p = \gamma\beta$ of the electrons in the near magnetosphere between $2 \times r_{\rm star} < r < 20 \times r_{\rm star}$. Close to the equator the particles are decelerated by the interaction with the radiation.

momentum distribution along a given field line. The calculation of this initial guess was done by M.Gabler.

During the setting up of this initial data we also noticed that we have to change our numerical approach to calculate the interaction between the photons and the particles. We first wanted to include the scattering of the particles (electrons and positrons) in a probabilistic way. However, in some regions of the magnetosphere the interaction will be so strong that the medium becomes almost opaque for the particles. We thus had to include an approach to average over the possible scatterings between particles and photons. Within our code, this can be done easily, because we already computed the probability of a particles with a certain momentum to get scattered to other momenta. We simply need to integrate over the momentum change weighted with the corresponding probability and we obtain the change of momentum due to the possible scattering processes. This part of the project was carried out by P. Cerdá-Durán.

3 Main results

We have set up the initial data appropriately and can now start to do the first production runs with the code. Additionally we have adopted the code to be able to cope with the strong interaction between particles and photons in certain parts of the magnetosphere. The code is now ready for performing first coupled simulations of the resonant cyclotron process around magnetars. In Fig. 1 we plot the logarithm of the momenta $p = \gamma\beta$, of the electrons in the near magnetosphere. Here, γ and β are the Lorenz factor and the velocity of the

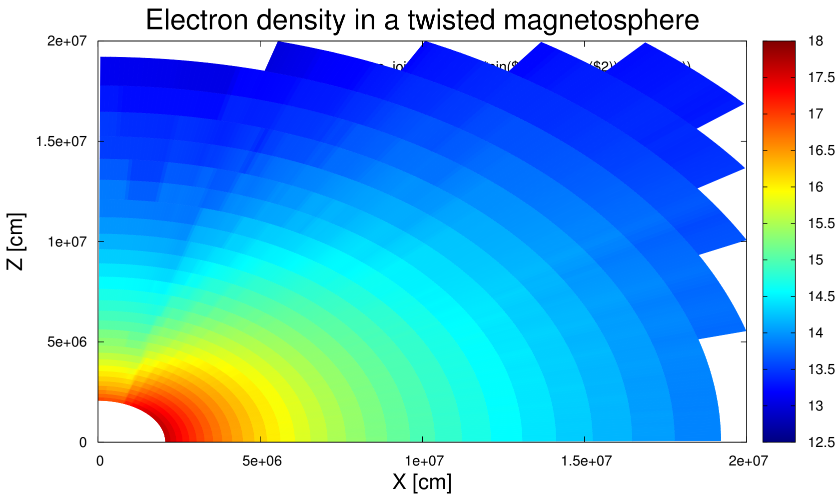

Figure 2: The logarithmic number density of the electrons in the near magnetosphere between $2 \times r_{\rm star} < r < 20 \times r_{\rm star}$.

electrons, respectively. The particles clearly are decelerated by the interaction with the radiation due to resonant cyclotron scattering.

For illustration we plot also the logarithm of the electron number density (per volume) in Fig. 2. The number of particles per length along magnetic field lines stays constant.

4 Future collaboration

After passing a phase during which we have to test the code, we will continue to work in close collaboration to use the code for the production of first scientific results with this new numerical tool. We further intend to extend the code by including more physics like pair annihilation or photon splitting. This will be done naturally in collaboration, because M.Gabler is the author of the Monte-Carlo radiation transport part of the code while P. Cerdá-Durán is more committed to the Particle-in-a-Line part.

5 Publications

We intend to use the code for a number of publications in the future. However, there is no immediate article to be published very soon, because we still have to pass a phase of intense code testing.

6 Comments

We would like to thank COST for making this stay possible through the STMS action.

References

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