Research Networking Programmes

Short Visit Grant ☒ or Exchange Visit Grant ☐

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title: Models for electrical discharges in extraterrestrial atmospheres

Application Reference N°: 6918

1) Purpose of the visit

Brown dwarfs are astronomical objects that are somehow halfway between giant planets and small stars. Their mass is not enough to sustain hydrogen fusion and therefore they have relatively low temperatures of around 1000 K. On the other hand, unlike planets, they are not hosted by an active star so they do not receive as much ionizing radiation. It is therefore a puzzle that their X-ray emissions show the characteristics of a magnetically active corona [1], thus impliying a significant degree of ionization in their atmospheres. Neither thermal ionization nor incoming UV radiation can explain the required level of ionization.

Since recent models of brown dwarf atmospheres predict a significant concentration of dust particles [2], a possible mechanism of ionization would consist in the charging of the dust grains followed by electron multiplication in the high electric field, eventually leading to a mechanism similar to terrestrial lightning [1]. As on Earth, these discharges would be presumably initiated by electron avalanches and then streamer discharges.

In this scientific exchange within the TEA-IS network we aim to apply existing models of streamer discharges to brown dwarf

atmospheres. The purpose is to investigate the conditions under which electrical discharges in the dust clouds of a brown dwarf produce the levels of ionization required to explain the observations mentioned above.

2) Description of the work carried out during the visit

In May, during a previous visit to Granada by C. Stark, from St. Andrews University, we used the Boltzmann solver BOLSIG+ [3] to obtain the electron transport parameters and ionization rates under the gas composition predicted by the DRIFT-PHOENIX model of brown dwarf atmospheres. We also built a simplified model of electron capture by dust particles. With this model we started to investigate the extinction of discharges by the presence of dust.

In our visit to St. Andrews that we report here we implemented the transport parameters and reaction rates into the ARCoS code for the simulation of streamers [4, 5].

3) Description of the main results obtained

We thus obtained preliminary simulations of a streamer developing in a brown dwarf atmosphere. We also extended the simplified dust-extinction model to incorporate pre-existing charging of the dust grains due to some radiation field.

4) Future collaboration with host institution (if applicable)

Once we have set up the tool and the parameters fixed by atmospheric models, we plan now to investigate the influence of the background electron density on the propagation of a streamer in a brown dwarf. We will look for a maximum density above which streamers do not exist. This density in turn will give us an absolute maximum of the ionization level that can be created by electrical discharges.

5) **Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)***

We plan to publish one or preferentially two articles resulting from this collaboration: one will deal with the properties of streamers in brown dwarf atmospheres; the other will contain results from the simplified model of discharge extinction by dust.

6) Other comments (if any)

References:
[1] C. Helling, M. Jardine, and F. Mokler, Astrophys. J. 737, 38 (2011), 1105.4409.
[2] C.Helling, M.Dehn, P.Woitke, and P.H.Hauschildt, Astrophys. J. Lett. 675, L105 (2008), 0801.3733.
[3] G. J. M. Hagelaar and L. C. Pitchford, Plasma Sour. Sci. Technol. 14, 722 (2005).
[4] A. Luque, V. Ratushnaya, and U. Ebert, J. Phys. D 41, 234005 (2008), 0804.3539.
[5] A. Luque and U. Ebert, J. Comput. Phys. 231, 904 (2012).