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Influence of self-gravity on the equilibrium structures of magnetized tori

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Abstract. We present some results obtained with a toy model developed in Trova *et al.* 2016 used to study the influence of the self-gravity on the equilibrium configurations of magnetized rotating self-gravitating gaseous tori, in the context of gaseous/dusty tori surrounding supermassive black holes in galactic nuclei. While the central black hole dominates the gravitational field and it remains electrically neutral, the surrounding material has a non-negligible self-gravitational effect on the torus structure. The vertical and radial structures of the torus are influenced by the balance between the gravitational and the magnetic force. By comparison with a previous work without self-gravity (Slany *et al.* 2016), we show that the conditions of existence of these configurations can change.

Keywords. gravitation – magnetic fields –methods: numerical.

1. Introduction

The equilibrium structures of dusty tori present in active galactiv nuclei are influenced by the self-gravitational field of the torus. Due to the large distance from the central source, frequently a massive black hole, the self-gravitational field of these tori has to be taken into account. Equilibrium figures of rotating self-gravitating fluids have been described in great detail since decades under various assumptions (Masuda *et al.* 1998, Otani *et al.* 2009). Here, the rotating torus, modelled by a perfect fluid with barotropic equation of state and with some net electric charge spread through the fluid, is embedded in a spherical gravitational and dipolar magnetic field. The existence of these structures is possible for certain values of the model parameters, such as the rotation law, the polytropic index, the magnetic field and the self-gravity intensity.

2. Conditions of existence of equilibrium stuctures

The torus equilibrium is governed by the Euler equation (Landau & Lifshitz 1987, equation (2.3)), which can be integrated and rewritten as the Bernouilli's equation:

$$aH + d_t\Psi_{\rm Sg} + \Psi_c + b\phi + e\mathcal{M} = c, \tag{2.1}$$

where H, Ψ_{Sg}, Ψ_c, Φ, $\mathcal{M}$ are, respectively, the enthalpy, the self-gravitational potential of the torus, the gravitational potential of the central mass, the centrifugal and the "magnetic" potential (linked to the dipolar field due to the central mass). The constants a, b, c, d_t, and e, are linked to physical parameters (the angular momentum, strength of the magnetic field...) and to the geometry of the torus. The conditions of integrability give insight on the rotation of the fluid and on the charge density. By setting these two parameters, we can find the conditions of existence of the equilibrium solutions. Working

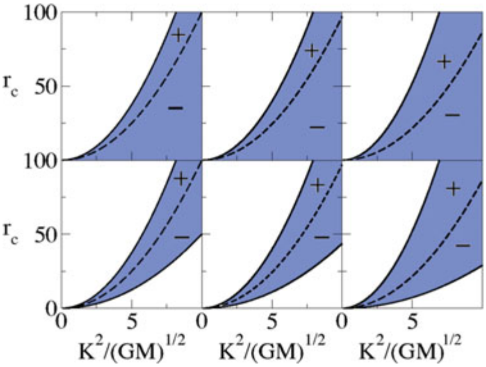

Figure 1. Representation of conditions of existence: from the left to the right, $d_t = 0, 0.1, 0.5$. The x-axis represents the constant b and the y-axis the maximum of pressure r_c.

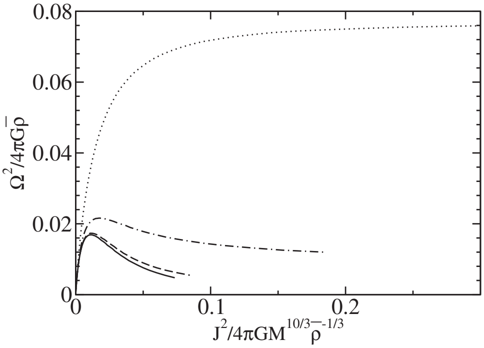

Figure 2. One-ring sequences for various values of $d_t = 0$ (full line), 0.01 (dashed line), 0.1 (dot-dashed line), 0.5 (point line).

with a constant angular momentum rotation and two different charge distributions (given by Slany *et al.* 2016), we obtain, from Equation 2.1, the conditions for three mass ratios (Figure 1). The colored region represents values for which we have a solution. The $+(-)$ region corresponds to positively(negatively) charged tori. In Figure 2, we show the impact of the value of d_t on the one ring sequence (as shown in Hachisu 1986, for self-gravitating tori only).

3. Conclusion

We have found that the self gravity has a direct impact on the conditions of existence of a magnetized self-gravitating torus. The range of possible solutions increases with the value of d_t. This result can also been found on the one-ring sequence presented in Figure 2. Moreover, for the same parameters, the tori can be positively or negatively charged in function of d_t. In Trova *et al.* 2016, we also showed that the morphologies of the solution, meaning the shape and the density profile, can be impacted by the self-gravity.

Acknowledgments

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