Stellar magnetic equilibria and their stability

Andreas Reisenegger[1*], Laura Becerra[2,3], Juan Alejandro Valdivia[4,5], Mikhail Gusakov[6]

[1]Departamento de Física, Universidad Metropolitana de Ciencias de la Educación, José Pedro Alessandri 774, Ñuñoa, Santiago.
[2]Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Macul, Santiago.
[3]Escuela de Física, Universidad Industrial de Santander, A.A 678, 680002, Bucaramanga, Colombia (present address).
[4]Departamento de Física, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Ñuñoa, Santiago, Chile.
[5]Centro para el Desarrollo de la Nanociencia y Nanotecnología, CEDENNA, Santiago, Chile.
[6]Ioffe Institute, 26 Politekhnicheskaya Street, St Petersburg 194021, Russia.

* andreas.reisenegger@umce.cl

Abstract

In the efforts to harness nuclear fusion energy for peaceful human use, magnetic fields are often used to confine the hot, dense plasma. This is not necessary in stars, in which the plasma is confined by gravity. However, stellar magnetic fields can still play an important role in the observational appearance of stars and in the transport of angular momentum through their interiors. In some cases, as in the solar envelope, stellar magnetic fields are very dynamic and constantly regenerated by dynamos. In other cases, particularly in massive hydrogen-burning stars, white dwarfs, and neutron stars, they appear to be long-lived “fossils” in a stable magnetic equilibrium state.

In this talk, I will show analytical arguments and numerical simulation results to discuss the physical ingredients likely required for such magnetic equilibria and their stability. First, to hold a stable magnetic field, the matter inside a star needs to be stably stratified, which can be achieved either by an entropy gradient (in massive non-degenerate stars and white dwarfs) or by a composition gradient (in neutron stars). Furthermore, even if this condition is satisfied, the simplest possible magnetic field configurations (purely toroidal or purely poloidal) appear to be unstable, so a combination of mutually stabilizing toroidal and poloidal fields appears to be the simplest stable field configuration [1], but more complex geometries are possible and may well arise in real stars [2].

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