Local dynamo in stars beyond the Sun: Study for a K0V star

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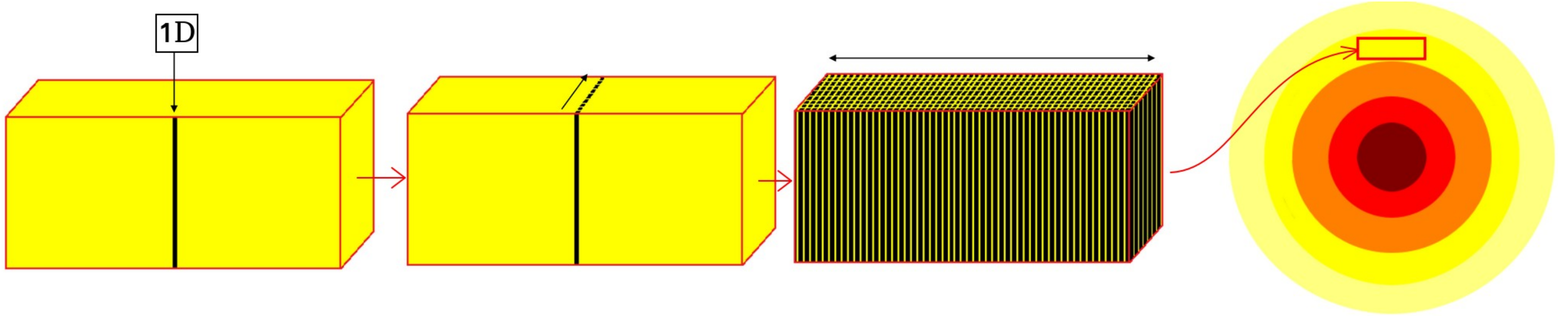
We present the first results of application of the MANCHA3D code (Felipe 2010; Khomenko et al. 2017, 2018) to a K0V cool star. Initially we run the code solving purely hydrodynamic equations until the stationary convection is reached. Then we produce the magnetic field generation and amplification by Biermann's battery seed and local dynamo. We find values around 100 Gauss for the amplified saturated magnetic field, similar to those found in Khomenko et al. (2017) for the solar case.

Context

Although it is not easy to measure due to technical limitations, it is accepted knowledge that there is magnetic field in the quiet regions of the Sun. The mean value of this field in the photosphere has been measured in the range 50-200 Gauss (Khomenko et al. 2005; Danilovic et al 2010; Shchukina & Trujillo Bueno 2011). This basal magnetic field is almost independent from the solar cycle and the magnetic field in the active regions (Trujillo Bueno et al. 2004), thus, it cannot be explained with the same mechanisms as the high-scale magnetic field of the Sun. One of the usually proposed origin to this phenomenon is the combined action of a seed of magnetic field and its amplification by small-scale dynamo. Through several simulations, it has been proved that this local dynamo can enhance the seed till saturation values similar to those found in the observations (Vögler & Schüssler 2007; Rempel 2014; Khomenko et al. 2017).
While this has been widely explored in the Sun, there is still not many hydrodynamical 3D models of other cool stars (Beeck et al. 2013a, b; Magic et al. 2013a, b) and even less that include the magnetic fields (Beeck et al. 2015a, b).
In this work we show the preliminary results for the saturated magnetic field of a K0V star simulated with the MANCHA3D code.

Description of the work

1. *First, we produce a 1D stellar model (the initial temperature and density structure) using the grey atmosphere approximation modified by mixing length theory. Then, we fill the three-dimensional box-in-a-star with this 1D model, and introduce a perturbation into the density to obtain a seed for convection. With this, we have the initial snapshot to star the simulation.*

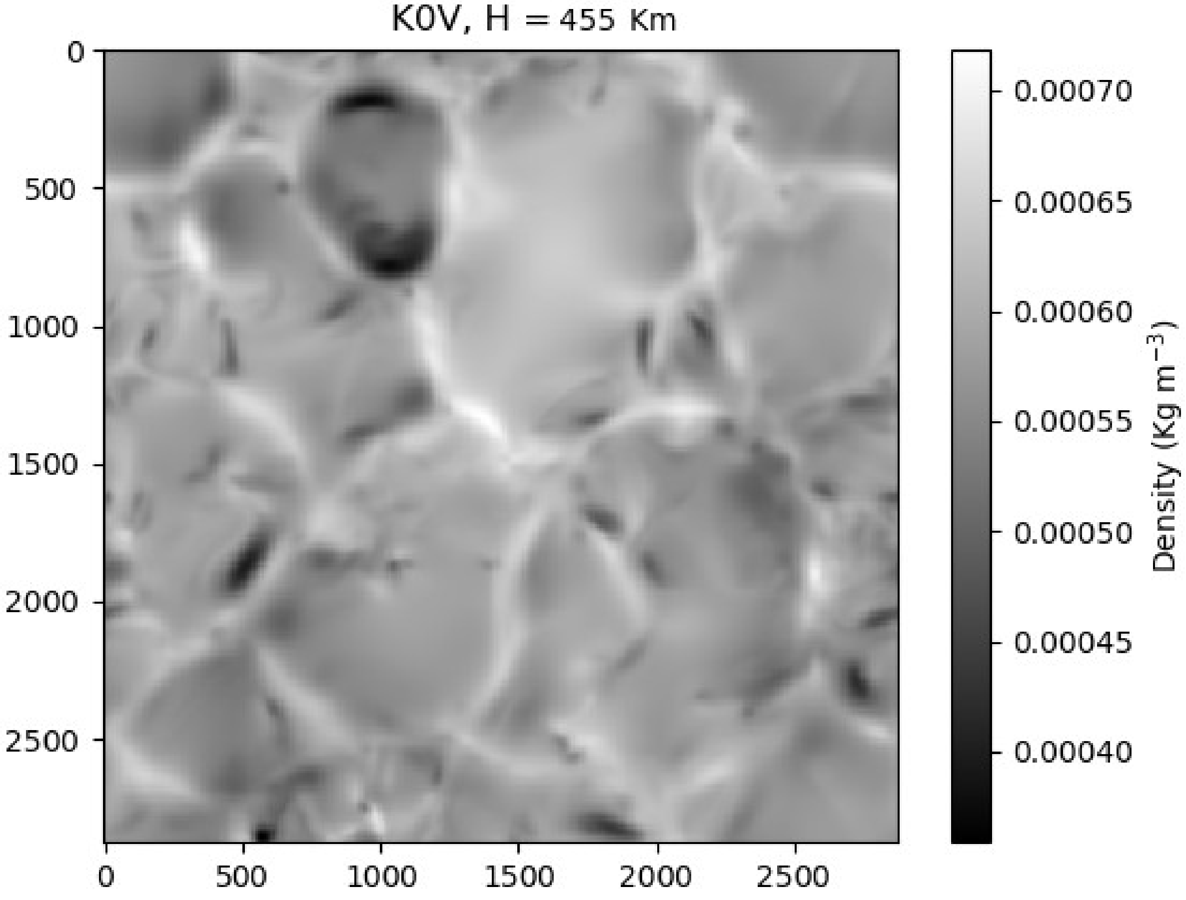


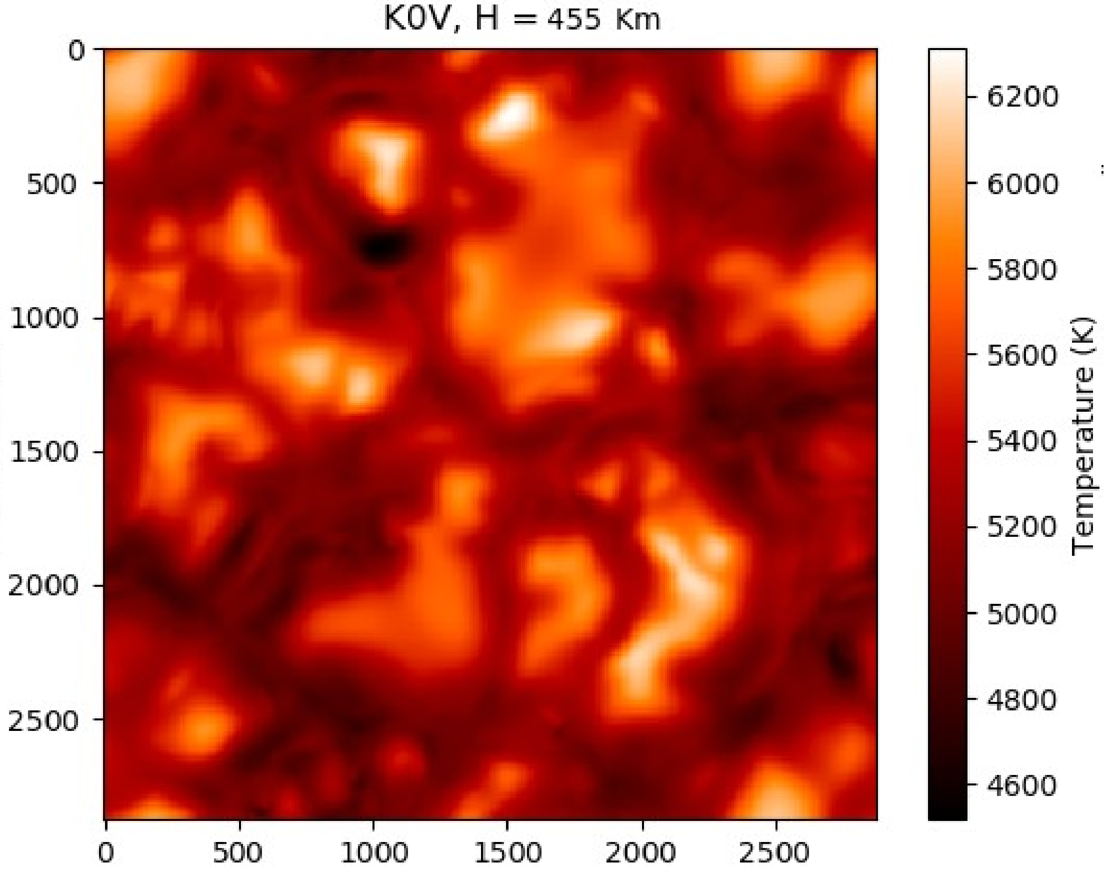
2. *We use the MANCHA3D code to solve the realistic hydrodynamical equations that governs the dynamics of stellar plasma and produce convection in the domain.*

3. *We add Biermann's battery term to the induction equation to produce a seed for the magnetic field, which is then enhanced by the local dynamo action. We leave the simulation running for enough stellar time to reach the saturation of the magnetic field.*

Results: Convection

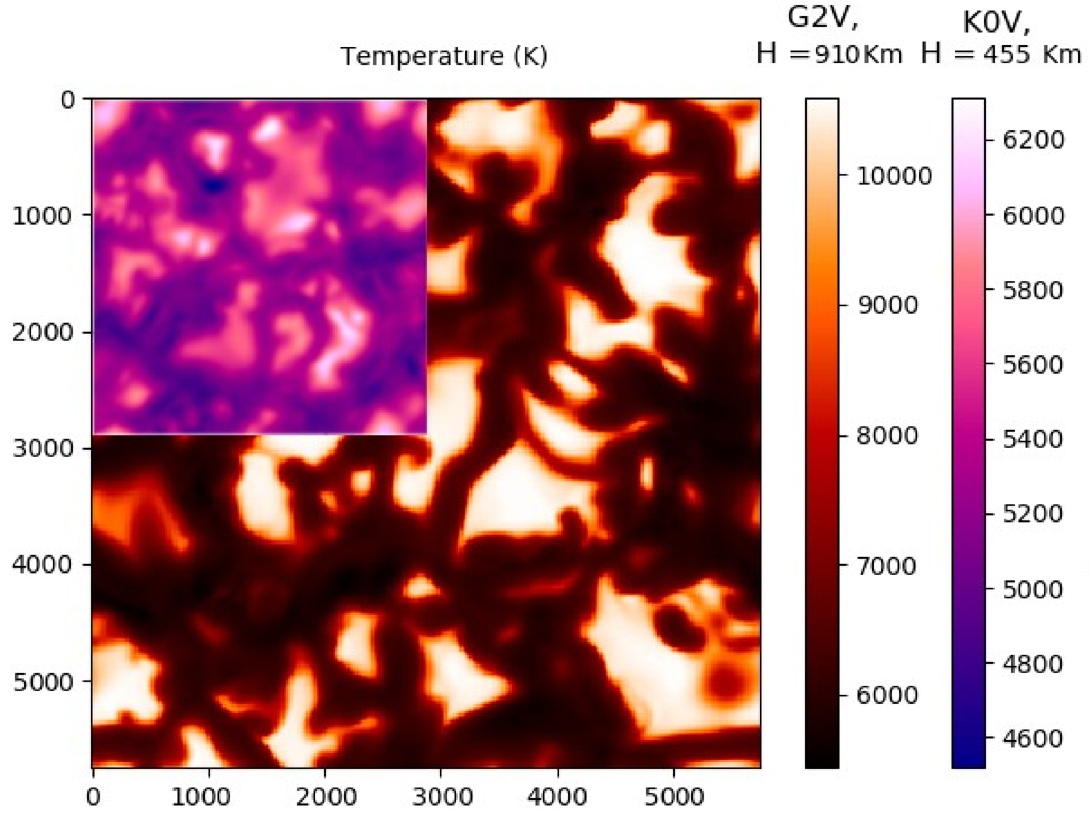
Horizontal cut at height 455 km (around τ = 1) for a snapshot with developed convection in the K0V star. Density in Kg/m³ (left) and temperature in K (right). Horizontal size and height of the domain: 2880x2880 km, 784 km

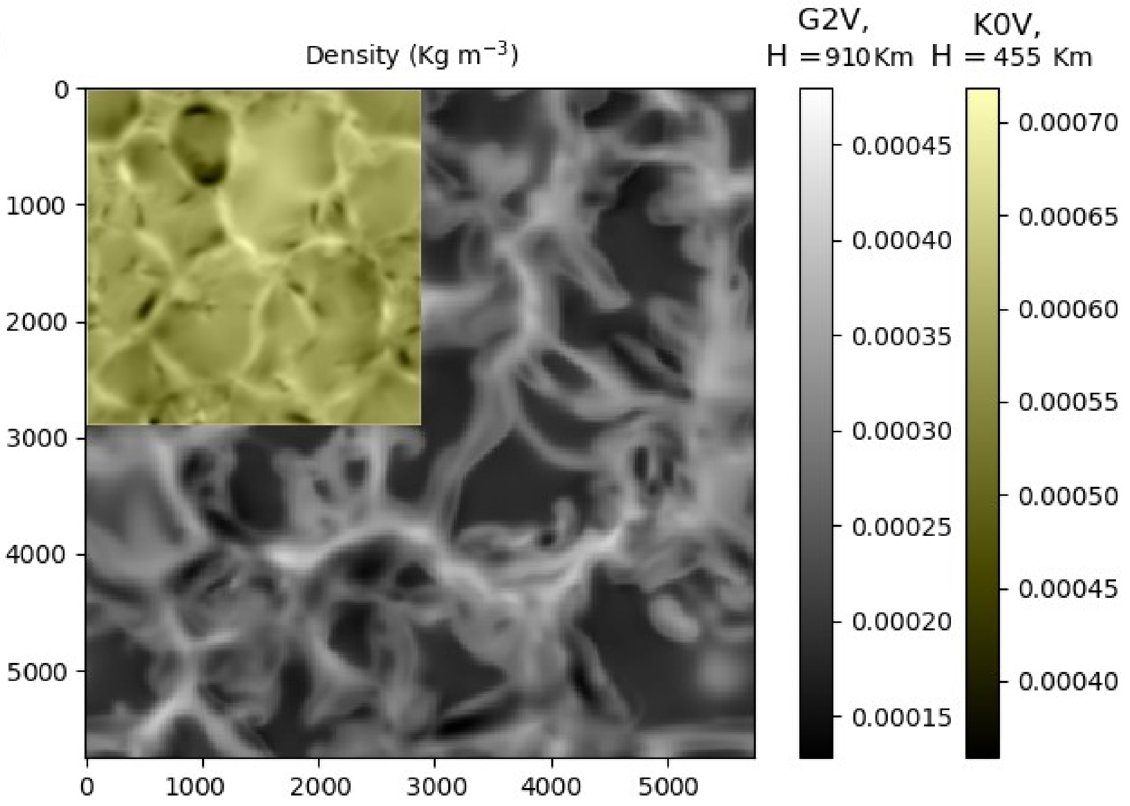




Results: Convection

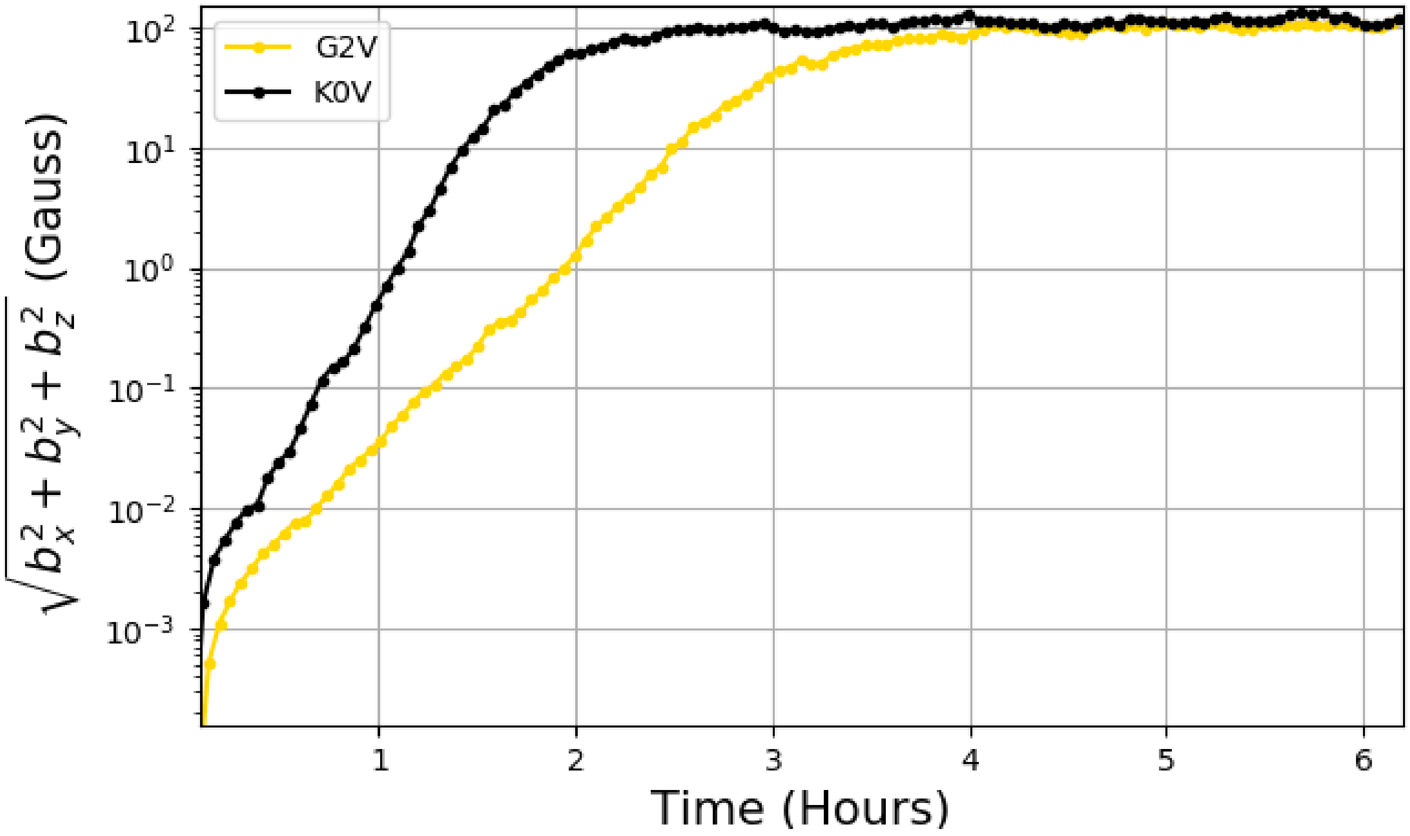
Comparison of the previous horizontal cut of the K0V snapshot (with changed color scale) with the solar case, also at height around τ = 1. In general, the K0V star shows smaller granular cells and lower temperature contrast than the Sun. Horizontal size and height of the solar domain: 5760x5760 km, 1568 km





Results: Magnetic field

Mean value of the modulus of the magnetic field on the surface at height around τ = 1 for the K0V star versus time after the introduction of the Biermann's battery term into the equations. The solar case is also plotted for comparison. The field is amplified from ~10^{-7} Gauss till ~100 Gauss in less than 3 hours for the K0V star, faster than the Sun.



Impact and prospects for the future

- *Magnetohydrodynamical simulations of a K0V star show values for the mean basal magnetic field similar to the solar case.*
- *These simulations also show different properties of the granulation for the K0V star respect to the Sun, in terms of size and contrast.*
- *We plan to analyze further the data for the K0V star: Compare the statistics of the granulation with that found by other authors (Beeck 2014; Magic 2014).*
- *We plan to do the same for other cases in a range from F to M stars. We will check if all the stars have similar saturation values for the mean magnetic field and try to discern if this is caused by an effect produced by the Prandtl regime or if it's something physical.*