Living Around Active Stars
Proceedings IAU Symposium No. 328, 2016
D. Nandy, A. Valio & P. Petit, eds.

doi:10.1017/S1743921317003799

Modelling coronal electron density and temperature profiles based on solar magnetic field observations

J. M. Rodríguez Gómez[1], L. E. Antunes Vieira[1], A. Dal Lago[1], J. Palacios[2], L. A. Balmaceda[3] and T. Stekel[1]

[1]National Institute for Space Research (INPE), Avenida dos Astronautas-12227-010, São José dos Campos-SP, Brazil
email: jenny.gomez@inpe.br

[2]Departamento de Física y Matemáticas, Universidad de Alcalá University Campus, Sciences Building, P.O. 28871, Alcalá de Henares, Spain

[3]Instituto de Ciencias Astronómicas de la Tierra y el Espacio, ICATE-CONICET, Avda. de España Sur 1512, J5402DSP, San Juan, Argentina.

Abstract. The density and temperature profiles in the solar corona are complex to describe, the observational diagnostics is not easy. Here we present a physics-based model to reconstruct the evolution of the electron density and temperature in the solar corona based on the configuration of the magnetic field imprinted on the solar surface. The structure of the coronal magnetic field is estimated from Potential Field Source Surface (PFSS) based on magnetic field from both observational synoptic charts and a magnetic flux transport model. We use an emission model based on the ionization equilibrium and coronal abundances from CHIANTI atomic database 8.0. The preliminary results are discussed in details.

Keywords. Sun: magnetic fields, corona.

1. Introduction

The coronal electromagnetic emission provides important information about the dynamics and the characteristics of the solar corona and it is spatial and temporal variability. However, the determination of the plasma parameters, such as the electron density and temperature is difficult because the electromagnetic emission is affected due to the distribution is along the line of sight. Here we present a physical model to reconstruct the electron density and temperature profiles through the solar corona based on the configuration of the magnetic field. In particular, we study the evolution of the electron density and temperature during the two last solar cycles. For this purpose, we use magnetic field from synoptic charts of MDI/SOHO and HMI/SDO instruments.

2. Approach

In order to model electron density and temperature profiles in the solar corona, we used solar surface magnetic field from the surface flux model of Schrijver (2001). The surface flux model was updated each six hours. A diffusion model, the evolution of active regions and the transport process at the solar photosphere were considered. The magnetic field components B_r, B_θ, B_ϕ in each magnetic field line were obtained from PFSS (Schrijver & De Rosa (2003)). They were used to build the density and temperature profiles. The electron density (N) and temperature (T) profiles are described using the

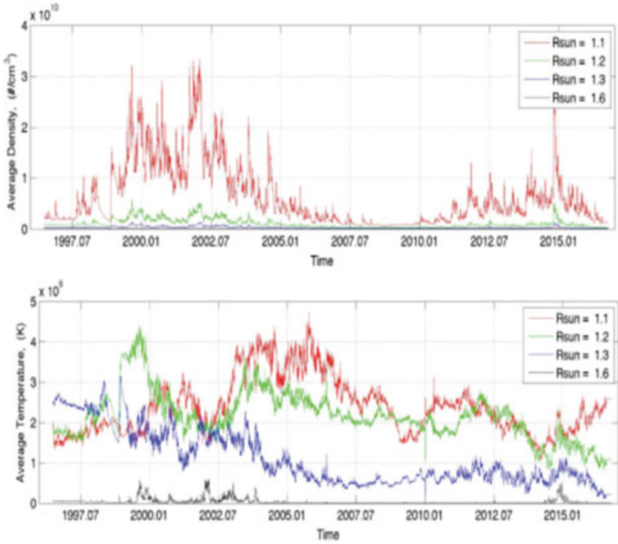

Figure 1. Upper panel: Temperature profile in different layers through the solar corona. Lower panel: Average density profile at different heights in the solar atmosphere.

following expressions:

$$N = N_o\,(B)^{\gamma} \tag{2.1}$$

$$T = T_o\,(B)^{b-1}\,e^{-\left(\frac{B}{a}\right)^{(b-1)}} \tag{2.2}$$

Temperature profile is based on the Weibull distribution function. Where a, b and γ are proportional coefficients, the magnitude of the magnetic field corresponds to $B = \sqrt{B_r^2 + B_\theta^2 + B_\phi)^2}$, N_o and T_o are the background density and temperature. We use an emission model based on the solar reference spectra. It is built using ionization equilibrium model Mazzotta *et al.* (1998) and the coronal abundances from Meyer (1985) at the central wavelength. The contribution function $G(\lambda, T)$, from CHIANTI atomic database 8.0 (Del Zanna *et al.* (2000)) is yielded. The emission at a specific wavelength is calculated in each voxel and integrated line-of-sight. This emission is compared to observational data from TIMED/SORCE and it provides the performance of our model.

3. Variability of the electron density and temperature during the solar cycle 23 and 24

The density and temperature profiles were obtained from the solar cycle 23 to 24 in different layers through the solar corona ($Rsun$ = 1.1 , 1.2, 1.3 and 1.6 $R_\odot$) are shown in Fig. 1. In this case we use the guess parameters: $\gamma = 1.9992$, $a = 2$, $b = 6$, $N_o = 294692000\ cm^{-3}$, $T_o = 9 \times 10^6$ K, to obtain the density and temperature profiles.

4. Discussion

The temperature profiles show differences during solar cycles 23 and 24 at different heights in the solar corona (lower panel in Fig. 1) due to the relationship with the structure of the coronal magnetic field. The average temperature profile (Fig. 2) is in agreement with the trend of some features in the solar atmosphere shown in Fontenla *et al.* (2011).

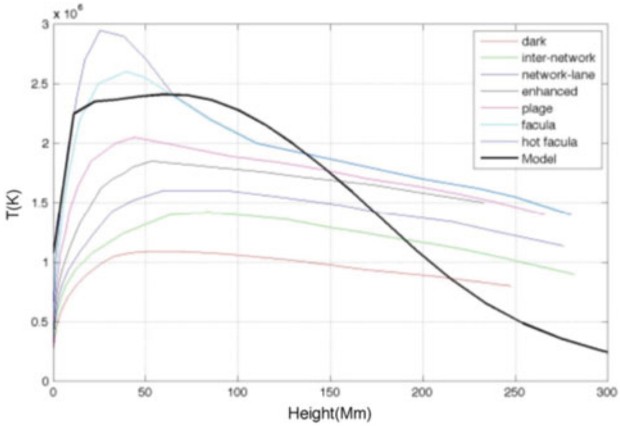

Figure 2. Average temperature profiles in all considered layers from our model (black line). Temperature profiles from Fontenla *et al.* (2011); in coloured lines, average temperature profiles from different structures of the solar photosphere are displayed.

The density profiles are related to magnetic flux variations over the solar cycles (upper panel in Fig. 1). This is the starting point for the study of long-term properties in the solar corona. In the next steps we will use the optimization algorithm to fit the model parameters.

5. Acknowledgements

The Authors want to acknowledge C. Schrijver and M. de Rosa. We would like to thank SOHO/MDI, SDO/HMI Data Science and Teams and the Chianti atomic database 8.0. This work is partially supported by CNPq/Brazil under the grant agreement no. 140779/2015-9 and no. 304209/2014-7. JP acknowledges UAH travel grant for visiting INPE and MINECO project no. AYA2013-47735-P.

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https://doi.org/10.1017/S1743921317003799 Published online by Cambridge University Press