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Mass Loading of Quiescent Prominences

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Abstract. From April through June 2011 a multi-spectral observing campaign of quiescent prominences was made. Observations were carried out in EUV by SDO/AIA, in soft X-rays by XRT on Hinode and in Hα by horizontal spectrographs of the Ondřejov observatory. In this work the masses of selected prominences, observed on May 18 and April 19, were determined in order to test the method and our semi-automatic computer code.

1. Introduction

Heinzel et al. (2008) proposed a method to estimate the optical thickness of prominence continua from observations of EUV coronal lines with wavelengths below 912 Å (head of the hydrogen Lyman continuum) and in soft X rays. Then using the theoretical work of Anzer & Heinzel (2005) the total mass of the prominences can be computed from the maps of the optical thickness. In this work we present the total masses of two prominences calculated using our new semi-automatic code.

2. Method

Asymmetry of the coronal emissivity along the line of sight is expressed by parameter α defining the fraction of the coronal emission along the line of sigh behind the prominence (α=0.5 for a symmetrical corona). Assuming that outside the prominence (in both surrounding cavity and corona) the EUV line intensities are similar to those of X-rays (except of a multiplicative factor) while at each prominence position the EUV radiation is lowered compared to X-rays by the absorption, the optical thickness τ_λ of the prominence plasma at wavelength λ below 912 Å can be calculated (after Heinzel et al. (2008)):

$$\tau_\lambda = -\ln\left(1 - \frac{1-r'}{\alpha}\right), \tag{1}$$

where r' is the ratio between the EUV and X-ray intensity where EUV intensities are fitted to those of X-rays in the cavity and corona. The α parameter is estimated from observations in two EUV channels 193 Å and 211 Å; the ratio of values of the optical thickness τ_{193} and τ_{211} estimated from observations using Eq. (1) for a correct α should be equal to the ratio of theoretical values calculated using the following formula:

$$\tau_\lambda = N(\mathrm{H})\ \{(1-i\,)\,\sigma_\mathrm{H}(\lambda) + r_\mathrm{He}\ [(1-j_1-j_2)\ \sigma_\mathrm{HeI}(\lambda) + j_1\,\sigma_\mathrm{HeII}(\lambda)]\}\ , \qquad (2)$$

where i, j_1 and j_2 are the ionization degrees of hydrogen and singly and double ionized helium, respectively, σ's are the cross-sections of ionization, r_He is the solar abundance of helium equal to 0.1 and N(H) is the column density of hydrogen. The ratio is not very sensitive to ionization degrees and reaches always value round 0.8. Ionization degree of hydrogen can be estimated from Hα intensities using the relation between logarithms of optical thickness $\tau_\mathrm{o}(\mathrm{H}\alpha)$ and Hα integral intensity estimated by Heinzel et al. (1994) and relation between hydrogen ionization degree and $\tau_\mathrm{o}(\mathrm{H}\alpha)$ derived from NLTE calculations of Anzer & Heinzel (2005). Column mass m of the prominence plasma consisting of hydrogen and helium is then calculated as

$$m = N(\mathrm{H})\ (m_\mathrm{H} + r_\mathrm{He}\,m_\mathrm{He})\ , \qquad (3)$$

where m_H and m_He are the masses of hydrogen and helium atoms, respectively. Then integrating the column mass over the whole prominence area the total mass is obtained. Ionization degrees of helium are estimated using comparison of the total mass estimated from 193 Å channel and from additional AIA channel 335 Å. Radiation at 335 Å is not absorbed by double ionized helium, thus the ratio τ_{335}/τ_{211} is rather sensitive to ionization degrees of helium.

3. Results and conclusions

We estimated the total masses 4.3×10^{10} and 1.8×10^{12} kg for prominences of April 19 and May 18, 2011, respectively. Mass of the first small and diffuse prominence is one order of magnitude lower than values estimated by Gilbert et al. (2005), mass of the second one, bright and well pronounced, is somewhat higher than results of Gilbert et al. (2005). Ionization degree of hydrogen 0.7 – 0.8 is rather high as we are able to estimate only its average values along the line of sight using the relations derived for isothermal NLTE models at the temperature 8 000 K made by Heinzel et al. (1994) and Anzer & Heinzel (2005). Ionization degrees of helium are within the ranges given by Labrosse & Gouttebroze (2004). These results indicate, that the method and our code are working properly.

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