Total mass of several quiescent prominences estimated from multi-wavelength observations

P. Schwartz[1,2], P. Heinzel[2], F. Fárník[2], P. Kotrč[2], Yu. A. Kupryakov[3], E. E. DeLuca[4], L. Golub[4]

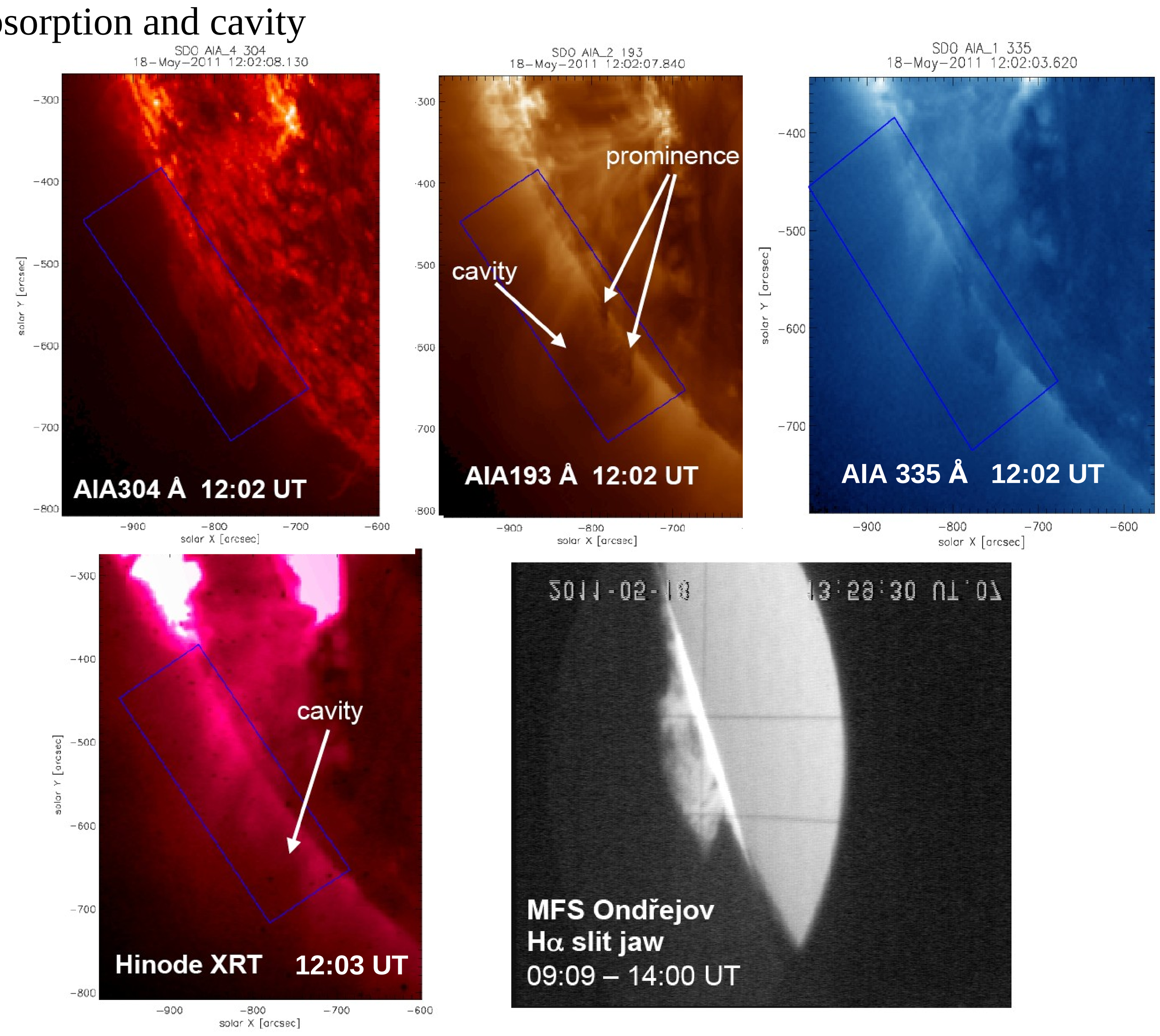
[1]Astronomical Institute, Slovak Academy of Sciences; [2]Astronomical Institute, Academy of Sciences of the Czech Republic; [3]Sternberg Astronomical Institute, Russia; [4]CfA, Cambridge, MA, USA

Introduction

From May through June 2011 a multi-spectral observing campaign of quiescent prominences took place. Observations were carried out in EUV by AIA/SDO, in soft X-rays by XRT on Hinode and in the Hα and CaII H lines by two horizontal spectrographs at the Ondřejov observatory. The maps of the total optical thickness of prominence plasma in hydrogen and helium resonance continua were computed using the spectroscopic method developed in Heinzel et al. (2008). It is based on two mechanisms responsible for a depression of the coronal radiation below 912 Å at the prominence location: absorption by the prominence plasma by hydrogen (HI) and possibly also by helium (HeI and HeII) resonance continua and the so-called emissivity blocking which is the lack of coronal EUV emissivity in volume occupied by the prominence itself and the surrounding cavity. While for the X-ray radiation there is only the blocking, absorption is negligible (Anzer et al. 2007). Using the theoretical work of Anzer&Heinzel (2005) and following Heinzel et al. (2008), the hydrogen column density was derived from the optical thickness at 195 Å. Finally, the total mass of the prominences was computed by integrating the hydrogen and helium column mass throughout the whole prominence area. Our aim is to make a statistics of the total masses of quiescent solar prominences. The masses of six selected prominences, observed between 19 April and 18 May 2011, were calculated and were compared with masses of CME's generated by eruptive prominences on limb to estimate contribution of prominence to mass of CME.

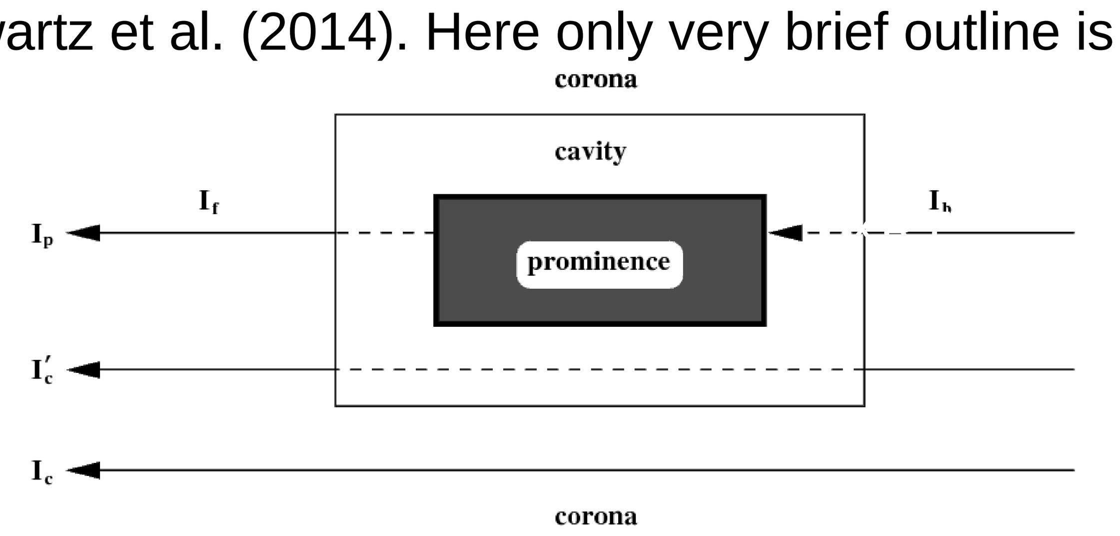
Observations

Example of observations – 18 May 2011 – a big prominence with nice absorption and cavity



Method

The detailed description of the method is to be published soon in Schwartz et al. (2014). Here only very brief outline is given.



I_p is the intensity of the EUV line with $\lambda \leq 912$ Å observed at the prominence location, decreased by both absorption and blocking. $I_b = \alpha\, I_{cp}$ and $I_f = (1-\alpha)\, I_{cp}$, where I_{cp} is I_p for X-rays (no absorption). α is the parameter of asymmetrical distribution of the coronal emission ($\alpha = 0.5$ for symmetrical corona). If outside the prominence I_c(XRT) and I_c(EUV) are similar (except for a multiplicative factor) :

$$I_p = I_f + I_b\, e^{-\tau} \qquad I_{cp} = I_f + I_b \qquad r' = \frac{I_p}{I_{cp}} \qquad (1)$$

Then τ at wavelength below 912 Å can be calculated from the formula (Heinzel et al. 2008):

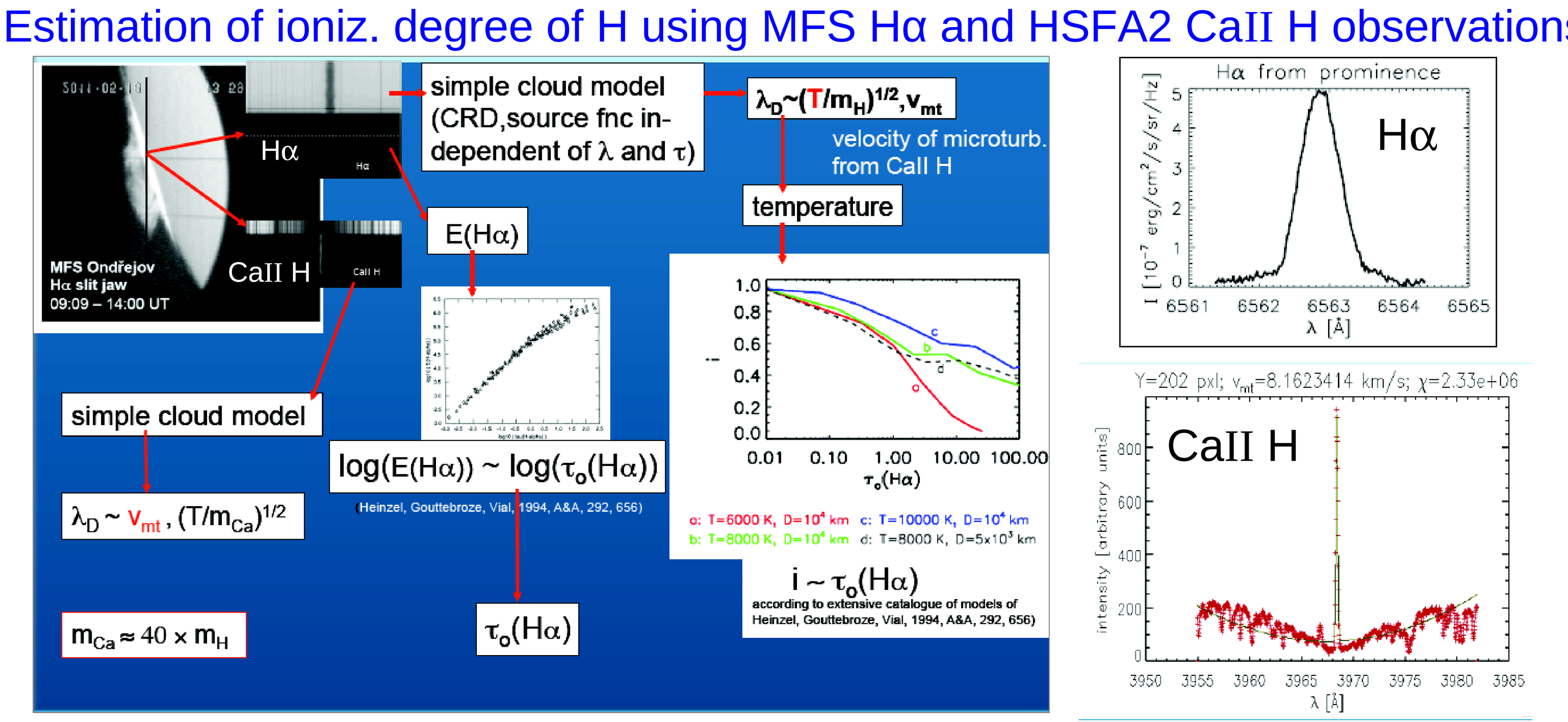
$$\tau = -\ln\left(\frac{r'}{\alpha} - \beta\right), \text{ where } \beta = (1-\alpha)/\alpha \qquad (2)$$

The α parameter is estimated from a comparison of ratios of τ_λ obtained from the observations in two channels with the theoretical τ_λ ratios. For $\lambda \leq 227$Å τ_λ is computed using following formula (Anzer&Heinzel 2005):

$$\tau_\lambda = N(\mathrm{H})\,\{(1-i)\,\sigma_{\mathrm{H}}(\lambda) + r_{\mathrm{He}}\,[(1-j_1-j_2)\,\sigma_{\mathrm{HeI}}(\lambda) + j_1\,\sigma_{\mathrm{HeII}}(\lambda)]\}\,, \qquad (3)$$

where i, j_1 and j_2 are ionisation degrees of hydrogen, neutral and singly ionised helium and for helium abundance r_{He} according to hydrogen common solar value of 0.1 is adopted.

Estimation of ioniz. degree of H using MFS Hα and HSFA2 CaII H observations



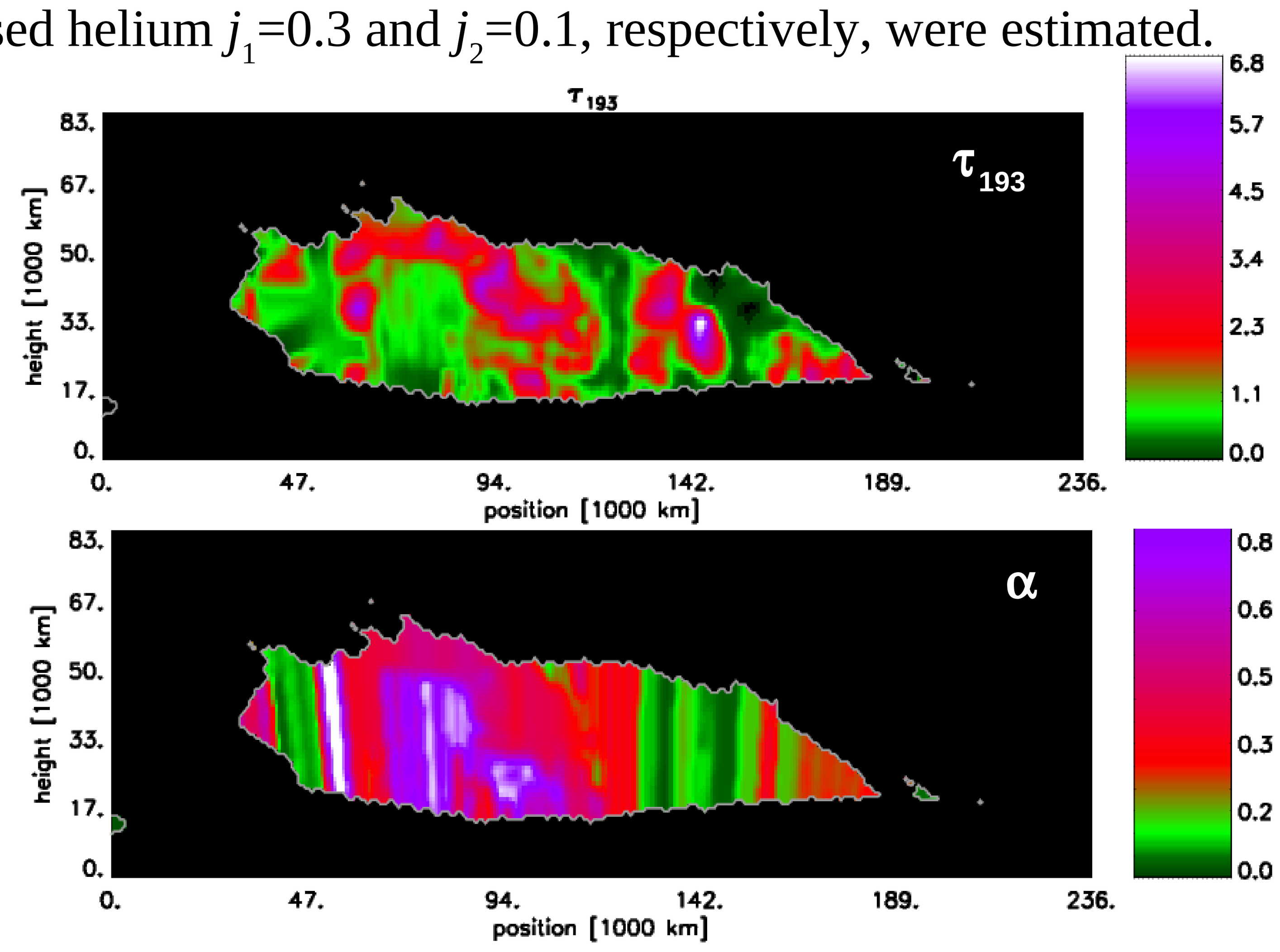
From τ_λ maps the hydrogen column density is calculated using formula (3).

Column mass: $m = N(\mathrm{H})\,(m_{\mathrm{H}} + r_{\mathrm{He}}\, m_{\mathrm{He}})$

The total mass of prominence: $M = \int_{PA} m\, dS$, where PA is a prominence area fixed according to AIA 304 A image. Unique for whole prominence area values of ionisation degrees j_1 and j_2 are estimated from comparing of masses estimated from AIA observations in 193 Å and 335 Å channels.

Results

The τ_{193} and α maps for prominence of May 18 2011. Map of ionisation degree i of hydrogen was constructed from Hα spectral observation and values of i range from 0.61 to 0.88. Values of ionisation degrees of neutral and singly ionised helium j_1=0.3 and j_2=0.1, respectively, were estimated.



The τ_{193} and α maps for other five prominences are similar to these shown here.

CONCLUSIONS: Values of the total mass of the six studied prominences range from 2.9×10^{11} to 1.7×10^{12} kg. Burkepile et al. (2004) estimated masses of CMS's associated with eruptive prominences on limb ranging from values comparable to our prominence masses up to values one order of magnitude higher what is in agreement with statement of Low (1996).

Acknowledgements. This work was supported by grant VEGA 2/0108/12 of the Science Grant Agency and by project No. APVV-0816-11 of the Slovak Research and Development Agency.

REFERENCES

Anzer, U., & Heinzel, P. 2005, ApJ, 622, 714
Anzer, U., Heinzel, P., & Fárník, F. 2007, Sol. Phys., 242, 43
Burkepile et al. 2004, J. Geophys. Res., 109, 3103
Heinzel, P., et al. 2008, ApJ, 686, 1383
Low, B.C. 1996, Sol. Phys., 167, 217
Schwartz, P. et al. 2014, A&A, submitted