COST
Short Term Scientific Missions

Action number: MP1104 – Polarization as a tool to study the Solar System and beyond

Applicants: Alessandro Bemporad and Lucia Abbo

Home Institution: INAF-Osservatorio Astrofisico di Torino (OATo), Turin, Italy

Contact Scientist: Prof. Dr. Javier Trujillo Bueno

Host Institution: Instituto de Astrofisica de Canarias (IAC), Tenerife, Spain

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Scientific Report

During this short term scientific mission (STSM) at the Instituto de Astrofisica de Canarias (Tenerife, Spain), the applicants continued their collaboration with Dr. Luca Belluzzi. The collaboration started last July thanks to another STSM within the COST action. The main target of this first mission was to implement a forward modeling routine for the simulation of the expected Hanle effect in the FeXIV 530.3 nm spectral line, in order to define and organize spectropolarimetric observational campaigns at the CoMP telescope with the Lyot-filter developed by the OATo Team for this spectral line.

We started our analysis by developing a FORTRAN routine able to produce 3D boxes of distribution coronal physical quantities to be used as input files to the routines already developed by Dr. Roberto Casini and Dr. Philip Judge (HAO-UCAR) for the computation of synthetic emission in the FeXIV 530.3 nm spectral line. To this end, we modified the routine *dipole.f* (and produced the corresponding IDL version *dipole.pro*): this routine first of all assumes the existence of a magnetic dipole at the center of the Sun and computes the vector magnetic field in the 3D space starting from the analytic expression of the magnetic dipole scalar potential $\Psi(r) = m \cdot r / (4\pi r^3)$ for a magnetic moment m; the vector magnetic field B is then given by $B = -\nabla\Psi$. Second, the routine fills a region of the corona with a density inside a magnetic field flux-tube, in order to simulate a realistic shape of a magnetic loop arcade. The plasma density is distributed with a double Gaussian profile, decaying as one moves out of the loop central axis and out of the central longitude where the loop is located. In these first attempts the magnetic dipole was placed at the center of the Sun with its axis aligned with the Sun's polar axis, hence the artificial loop we produced was symmetric about the equatorial plane.

For the first runs performed during this mission we assumed the loop to be located on the plane of the sky with a longitudinal (FWHM) extension of about 7°, while the vertical extension of the loop was set by assuming a thickness of the shell of dipole scalar potential equal to 5% of the value assumed. The electron density at the center of the loop was set to the value of $n_e = 10^9$ cm^{-3} (e.g. Ugarte-Urra et al. 2005); moreover we also added out of the loop an electron density profile from the literature, decaying with altitude with a power law along the streamer boundaries: $n_e(r)=(\frac{1736.9}{r^{13.72}} + \frac{27.3}{r^{4.2}} + \frac{4.6}{r^2})$ x10^5 cm^{-3} (Antonucci et al. 2006); with values of about 2 10^8 cm^{-3} at the base and about 10^5 cm^{-3} at 3 R_{sun}.

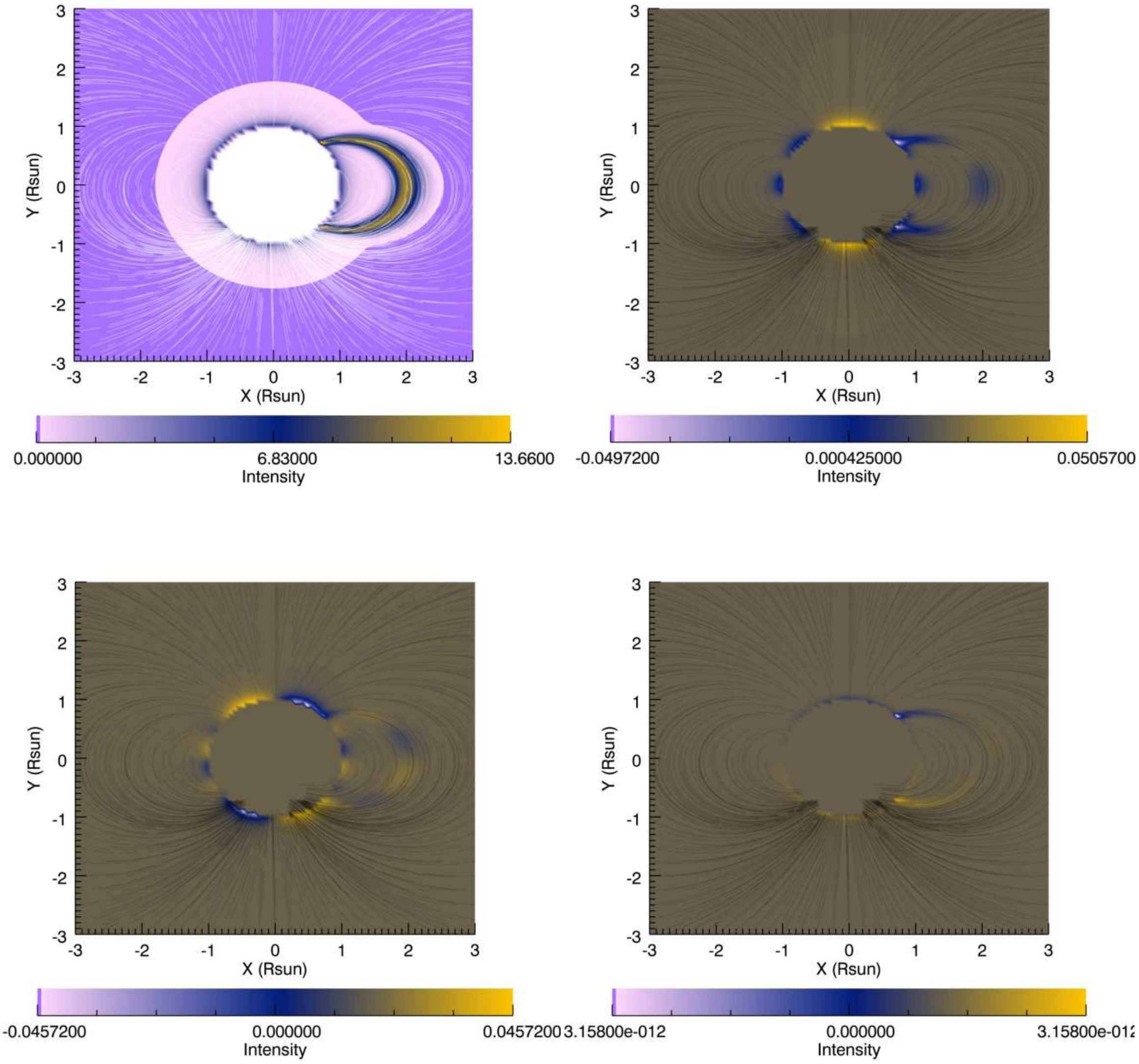

Figure 1, top left: the distribution of plasma density in the loop and the relative orientation of dipolar magnetic field plotted on the plane of the sky. The following 3 panels show the corresponding absolute variations of Stokes Q (top right), Stokes U (bottom left) and Stokes V (bottom right) computed for the FeXIV 503.3nm spectral line.

Preliminary results we obtained for the FeXIV 530.3nm line are shown in Figure 1 for the four components of the Stokes vector: I (top left), Q (top right), U (bottom left) and V(bottom right). Looking at these data we discovered that the relative intensity of Q, U and V components is very small if compared with the total unpolarized intensity I, making its detection really hard. In particular, Figure 2 shows the two quantities $P = (Q^2 + U^2)^{1/2}/I$ and $\vartheta = atan(U/Q)$ which represent the total linear polarization P, and the rotation of the polarization vector, ϑ; in this Figure the signal from surrounding corona has been masked, for visualization purposes. Figure 2 (top) clearly shows that the total linear polarizarion is hardly larger than 1%, making its possible detection with observations really hard.

In order to better investigate the possible origins of this low signal of polarized component, we made a first attempt with a second run where the collisional excitation of Fe^{13+} ions was neglected. Results (figure 2, bottom panel) show that in this second run the expected linear polarization signal P (bottom left) is much larger relative to the total intensity with respect to the previous run (up to 15%), while the polarization angle ϑ (bottom right) is unchanged; nevertheless the total intensity of the line (Stokes I) is much smaller, by a factor ~13. These results can be interpreted as follows: because the FeXIV 530.3 nm is a forbidden line, the collisional excitation is dominant over the radiative excitation, hence if we assume that no collisional excitation occurs the absolute intensity is strongly reduced, as observed. On the other hand, only the emission from radiatively excited atoms is polarized, while the collisional component is unpolarized, hence by neglecting the collisional excitation we maximize the polarization signal.

Another test we carried out was to decrease the electron density in the loop, so to decrease the impact of collisional excitation. Also in this case, for the same physical reasons explained above, the intensity of the radiation emitted by the loop is much lower than in the first run, but a significantly higher degree of linear polarization is obtained. Although the lower value of the electron density assumed for this run is not realistic, as well as the non-collisional limit previously considered, these tests allowed us to appreciate the strong sensitivity of the results to the collisional processes. Hence, from this preliminary analysis we conclude that the As expected, a correct estimate of the electron density in the coronal structure under investigation, and of the rate of collisional excitation of Fe^{13+} ions are therefore crucial for our purposes.

Hence, from this preliminary analysis we conclude that the correct estimate of the rate of collisional excitation of Fe^{13+} ions is crucial for our purposes.

During this short term mission the applicants also gave two informal talks to the group at IAC titled "Electro-optical Spectro-polarimeter for Ground- and Space-based Solar Coronagraphy" (by A. Bemporad), where the activities of OATo Group for past and future spectropolarimetric measurements on ground-based telescopes in the FeXIV green line were described, and "Spectral line intensities measured by SOHO/UVCS" (by L. Abbo) where the brightest UV spectral lines observed in the off-limb corona and their possible use for specropolarimetric measurements of coronal magnetic field were discussed.

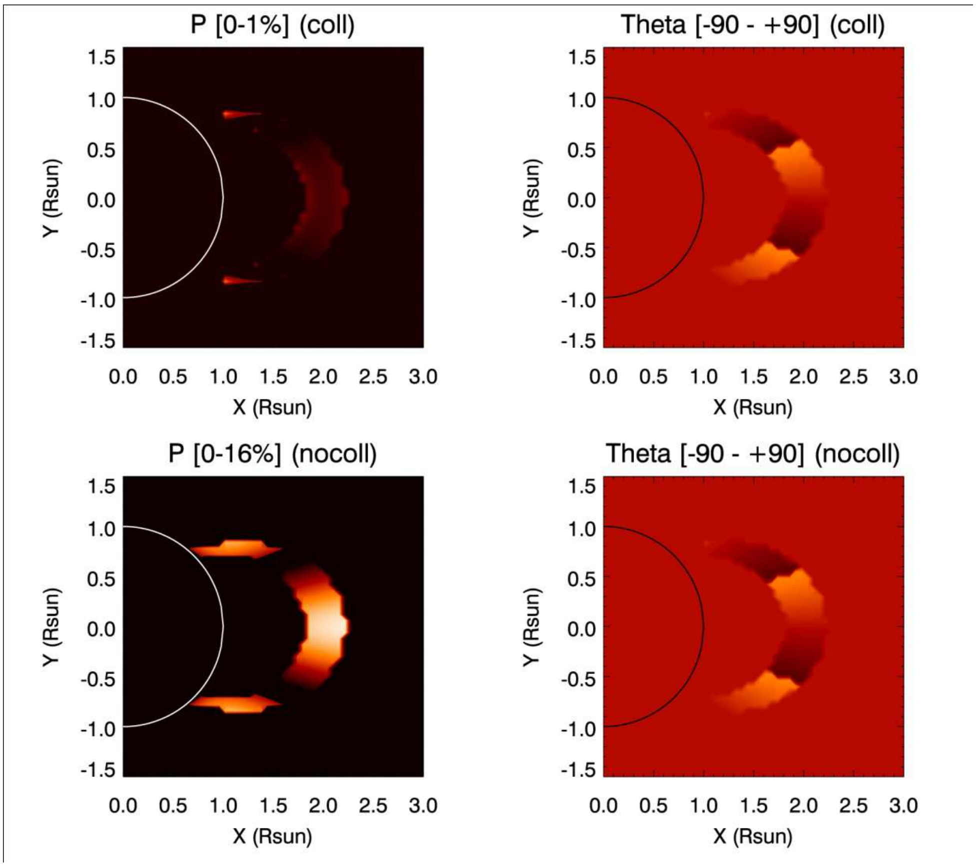

Figure 2, top: percentage of total polarization (left, color scale from 0 to 1%) and polarization angle (right, color scale from -90° to +90°) in the first case considered, i.e. with both radiative and collisional excitation processes. Bottom: the same quantities resulting after the second run, when the collisional excitation has been neglected.

References

Antonucci, E., Abbo, L., and Telloni, D., ApJ, 643, 1239, 2006

Ugarte-Urra, I., et al., A&A, 439 (1), 351