Solar corona from SolO/Metis and SOHO/LASCO: observations and comparison with MAS code simulations

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Background

Coronal mass ejections (CMEs) consist of clouds of high-density magnetised plasma that emerge from the Sun and propagate first in the solar corona, the outermost layer of the solar atmosphere, and then in the interplanetary medium. CME events are the most important drivers of the Space Weather, producing solar storms that can have severe technological impacts on Earth. One open question in the study of these phenomena is understanding how their origin and initial evolution is influenced by modifications of the pre-existing coronal magnetic configuration. For the purpose of this work, we considered total (tB) and polarised (pB) visible-light brightness datasets of the solar corona acquired by three space-based coronagraphs: Metis (on board the Solar Orbiter, SolO [1],[2]), LASCO-C2 (on board the SOlar and Heliospheric Observatory, SOHO), and SECCHI/COR2 (on board the Solar TErrestrial RElations Observatory – Ahead, STEREO-A). We analysed data images from December 2021 to March 2022 and compared the solar corona as seen in the changing field of view of the three instruments. We aim at comparing the coronagraphic data with simulations by the Predictive Science Inc. group using the MAS (Magnetohydrodynamic Algorithm outside a Sphere) model, in particular focusing on the possible discrepancies between the magnetic field topology obtained by the MAS model and that derived from the visible-light images before the onset of CME events, in order to investigate how such differences in the magnetic configurations can be correlated with the subsequent evolution of the CMEs.

Data set & analysis

We retrieved data images from Metis (SolO), SECCHI/COR2 (STEREO-A) and LASCO/C2 (SOHO) between December 1, 2021 and March 31, 2022. We focused on this time window because Solar Orbiter entered its nominal mission phase. Furthermore, SolO first perihelion occurred about at the end of March 2022. Metis acquires images in both total (tB) and polarised (pB) visible light in the wavelength range 580-640 nm, with plate scale of 10 arcsec/pix and variable temporal resolution, depending on the Solar Orbiter Observing Program. Metis and SECCHI/COR2 pB images were calibrated to physical units. Calibrated LASCO/C2 tB data were reduced in order to remove the contribution coming from the dust-scattered F-corona and isolate the electron-scattered K-corona. In particular, we rejected all the corrupted images and then we subtracted from all valid images a monthly minimum background, thus retrieving the structures of the inner K-corona [3]. We masked the images of the three instruments to remove the regions close to the inner occulter which are more affected by stray light contamination. Then, we rotated and scaled them so that each shared the same angular view of the solar corona. We finally obtained a dataset of about 3500 images per month. ***Table 1*** reports the main characteristics of the analysed data set. ***Figure 1*** shows the positions of the Earth (representative of the SOHO position), SolO, and STEREO-A, as well as SolO's trajectory, in the geocentric-solar-ecliptic system. We stacked together all the processed images to make a side-by-side movie of the solar corona as seen by the three instruments.

Table 1 *Main characteristics - wavelenght ranges (nm), spatial plate scale (arcsec), field of view (°) and temporal resolutions (s) - reported for SolO/Metis, LASCO/C2, and SECCHI/COR2*

Properties	SolO/Metis	LASCO/C2	SECCHI/COR2
Wavelenght range	580 – 640 nm (VL)	540 – 640 nm (VL)	650 – 750 nm (VL)
	121.6 ± 10 nm (UV)		
Spatial Plate Scale	10 arcsec (VL)	11.4 arcsec (VL)	14.7 arcsec (VL)
	20 arcsec (UV)		
Field of View	1.6° - 3.4°	0.4° - 1.7°	0.7° - 4.0 °
Temporal resolution	1 – 450 s (VL)	60 s	11 s
	1 – 30 min (UV)		

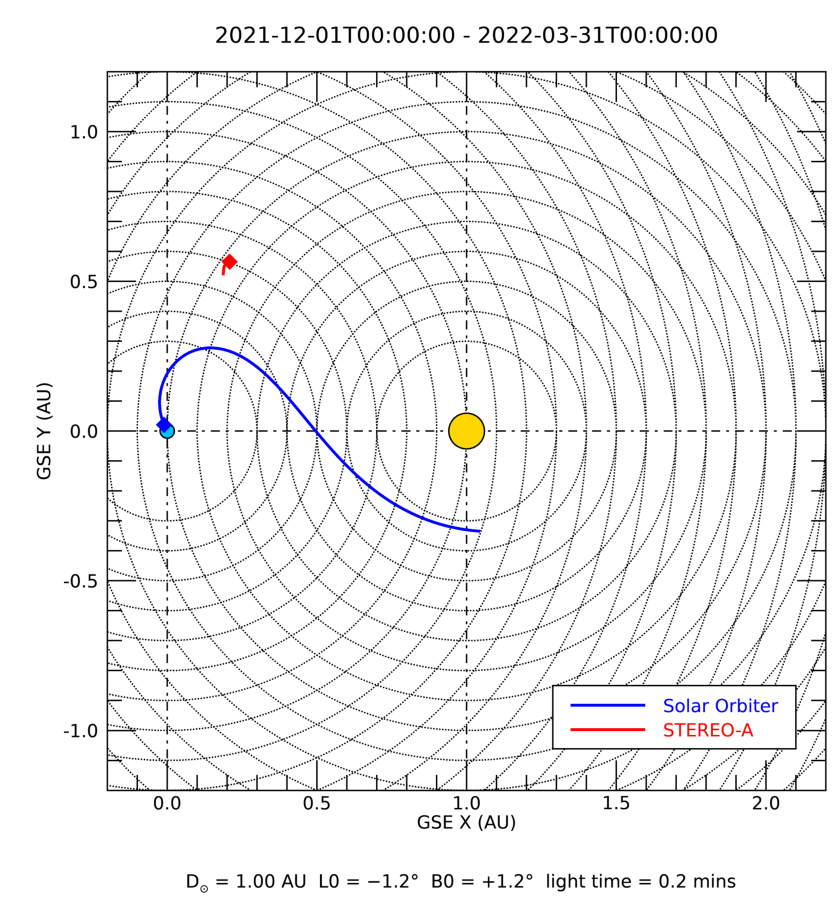


Figure 1 *SolO (blue), STEREO-A (red), and Earth (cyan, corresponding also to SOHO) positions in the geocentric-solar-ecliptic (GSE) system. Axis are in AU units. The SolO trajectory between 2021-12-01 and 2022-03-31 is also shown (blue line).*

Multi-view of solar corona

Starting from the processed data images, we performed a side by side movie showing the changes and evolution of the K-corona structures as they pass into the field of views of the three coronagraphs (SolO/Metis, LASCO/C2, and SECCHI/COR2), due to the solar rotation and/or spacecraft orbital motions, in the time window 2021-12-01 to 2022-03-31 (***Figure 2***).

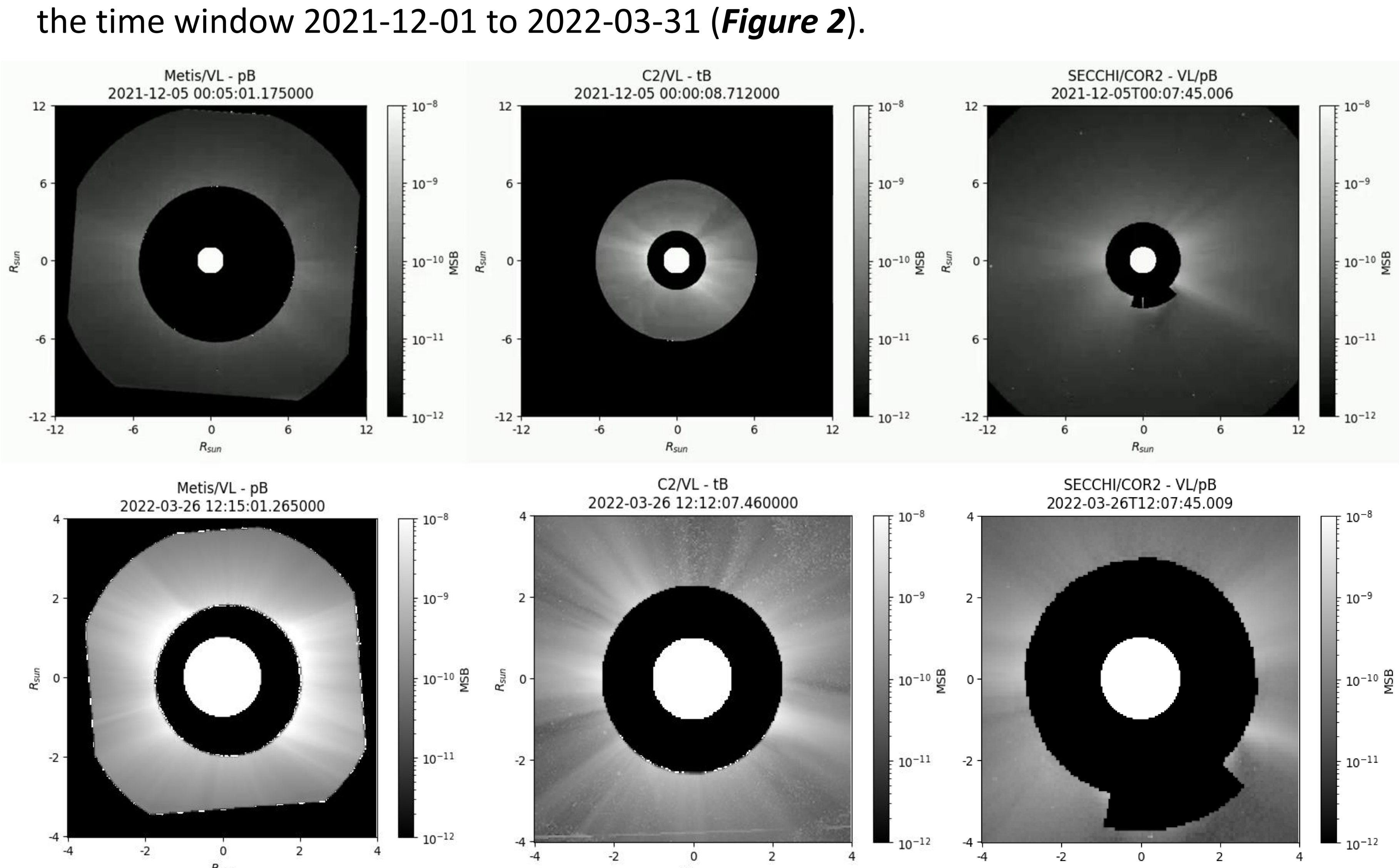
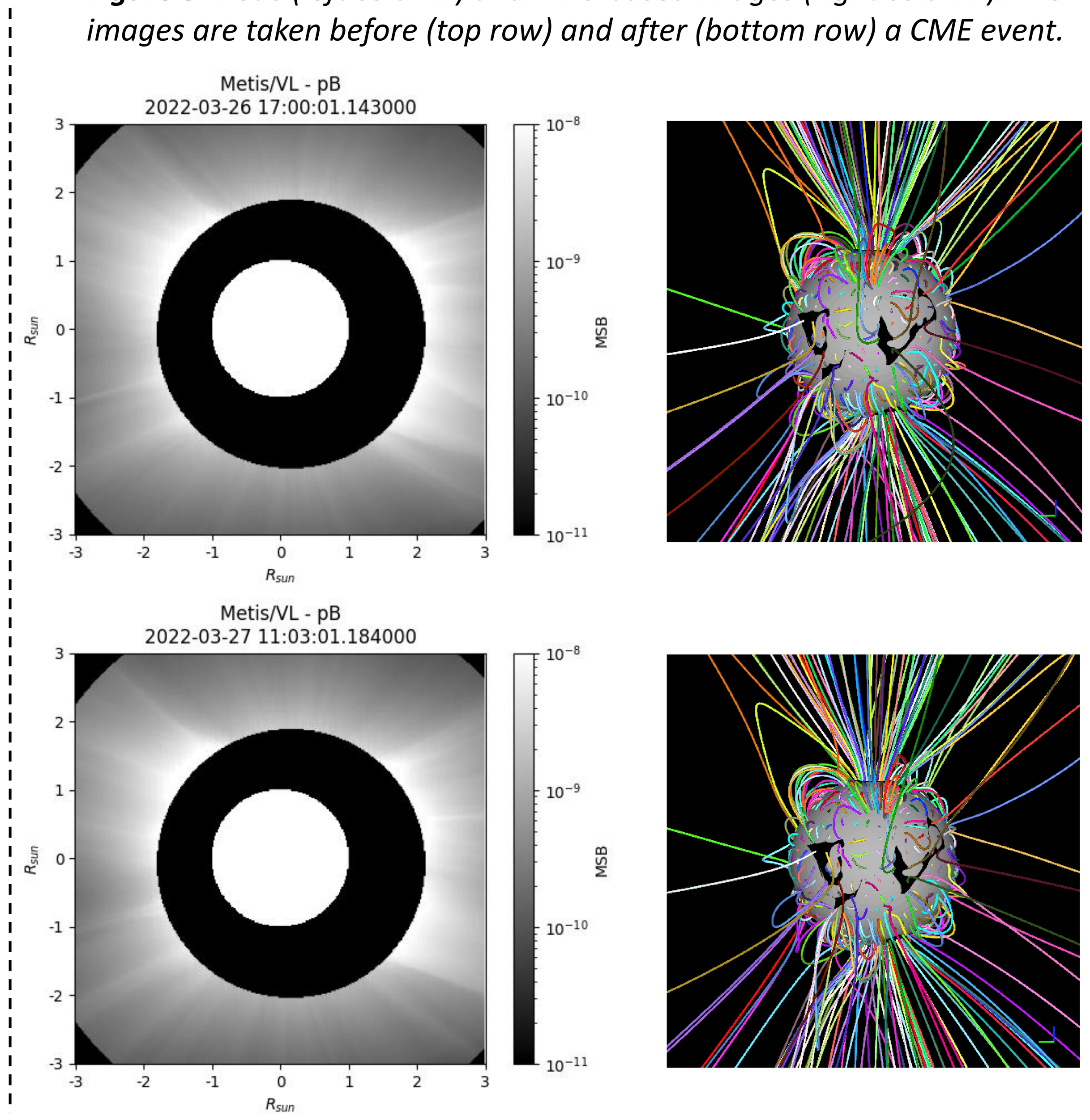


Figure 2 *Frames from the movie: (Top) From left to right: Metis/VL pB image, C2/VL tB reduced image and SECCHI/COR2 VL/pB image are shown. Here data images are shown in heliocentric cartesian coordinates (HCC), from -12 R_{sun} to 12 R_{sun}. Colorbar is logarithmic (from 10^{-12} to 10^{-8} B_{sun}), thus enhancing the coronal streamers. (Bottom) same as top, but here the HCC spans from - 4 R_{sun} to 4 R_{sun}, to enhance the inner corona.*

Goals and future work

Figure 3 *Metis (left column) and MAS-based images (right column). The images are taken before (top row) and after (bottom row) a CME event.*



The electron-scattered component of the coronal visible light (K-corona) as seen in coronagraphic images is an efficient tracer of the coronal magnetic-field structure. Furthermore, the magnetic field lines can be also extrapolated through simulations based on the MAS model, giving the potential configuration of the magnetic field (***Figure 3***). We aim at performing a close comparison of the pB/tB images and the magnetic field obtained from the model (before and after CME events) in order to study how possible differences between the two are related to the CME onset and evolution. In addition, we also aim at studying the overall magnetic configuration of the corona and its long-term evolution as seen by the three different view points.

References

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