Investigating the Coronal Magnetic Field from the Type-II Solar Radio Burst event on 2 May 2013

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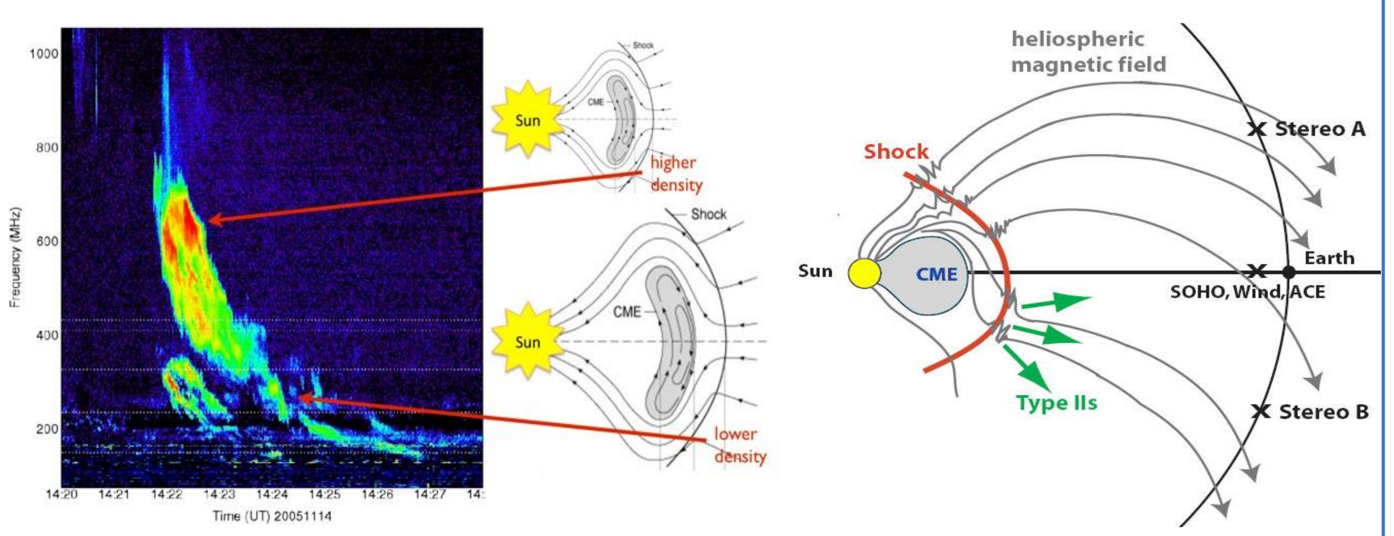
Abstract

- We studied the characteristics of the Type-II solar radio burst event that occurred on 2 May 2013 through combined space observations from SOHO and STEREO, in parallel with the ground-based observation from the DARO-CALLISTO station in Germany.
- The type-II burst frequency range was 25 – 180 MHz and it was preceded by a group of Type-III radio bursts related to a solar flare event from the same active region (NOAA AR 1731).
- We calculated the density jump [*X*] and the Alfven Mach number [Ma] by applying the Rankin–Hugoniot relations on the clear band-splitting of the type-II burst. By using the 4-fold Newkirk electron density model we could convert the plasma frequency of the type-II burst into height [R] in terms of solar radii. Then we calculated the shock speed [Vs], the Alfven speed [Va], and the coronal magnetic field strength [B] at heights ranging between 1.961 – 1.988 R_s.
- The accompanied partial-halo (W= 344° from SOHO) CME event was detected by STEREO-A, STEREO-B, and SOHO with linear speeds 518 $km.s^{-1}$, 429 $km.s^{-1}$, and 671 $km.s^{-1}$, respectively. And we traced the evolution of the event via the height-time profile.
- We found a common behavior in Vs, Va, and B dependencies with R at the height ~ 1.975 (more info in the *conclusion* section).

Introduction

The coronal shocks from the Sun can produce a major impact on the space weather and human beings, so it is essential to study their properties for a better forecasting. In the frequency-time plane, a type-II solar radio burst shows a drift from high to low frequency with a drift rate of 0.5 MHz/s [1] with decreasing values at longer wavelengths [2]. It is worth to mention that the metric type-II bursts occur in the solar corona at heights from 1.1 to 2 solar radii [1] and they often occur as two emission bands, fundamental (F) and harmonic (H), with a frequency ratio ≈ 1:2 [3].

The drift from high to low frequency is mostly due to the decrease in electron density with increasing distance in the solar corona , and it is interpreted as the radio signature of a collision-less MHD shock wave generated in the tenuous solar corona [4]. In some situations, either the H band or both of the F and H bands are split into two sub-bands, upper band [U] and lower band [L], with a separation in frequency usually smaller than that between the F and H bands. The band-splitting feature is attributed to the radio emission originating in the corona ahead (upstream) and behind (downstream) the associated MHD shock front [5]. The radio emission is caused by the conversion of plasma waves excited by electrons accelerated at MHD shocks propagating through the solar corona [6].



In this work, we apply the band-split method to the metric type-II radio burst to study the characteristics of the shock responsible for producing the type-II radio burst via combined observations involving multi-wavelength EUV data from satellites and the radio dynamic spectrum from a ground-based station. Besides, we got the coronal and photospheric magnetic fields and we compared our results of the shock speed with the direct measurements from space.

Data Analysis and Methods

We obtained the type-II burst data from the CALLISTO Spectrometer Network and applied the density model to calculate the characteristics of the type-II radio burst and the coronal magnetic field strength by implementing the band-splitting method. Then we traced the associated CME event by using the databases of SOHO and STEREO to get the height-time profile for the CME from different perspectives as well as its initial speed and compared it with the shock speed inferred from the type-II radio burst analysis. Then we estimated the coronal magnetic field strength [B] using this relation: $B = 5.1 \times 10^{-5} \times f_{UFB} \times V_a$

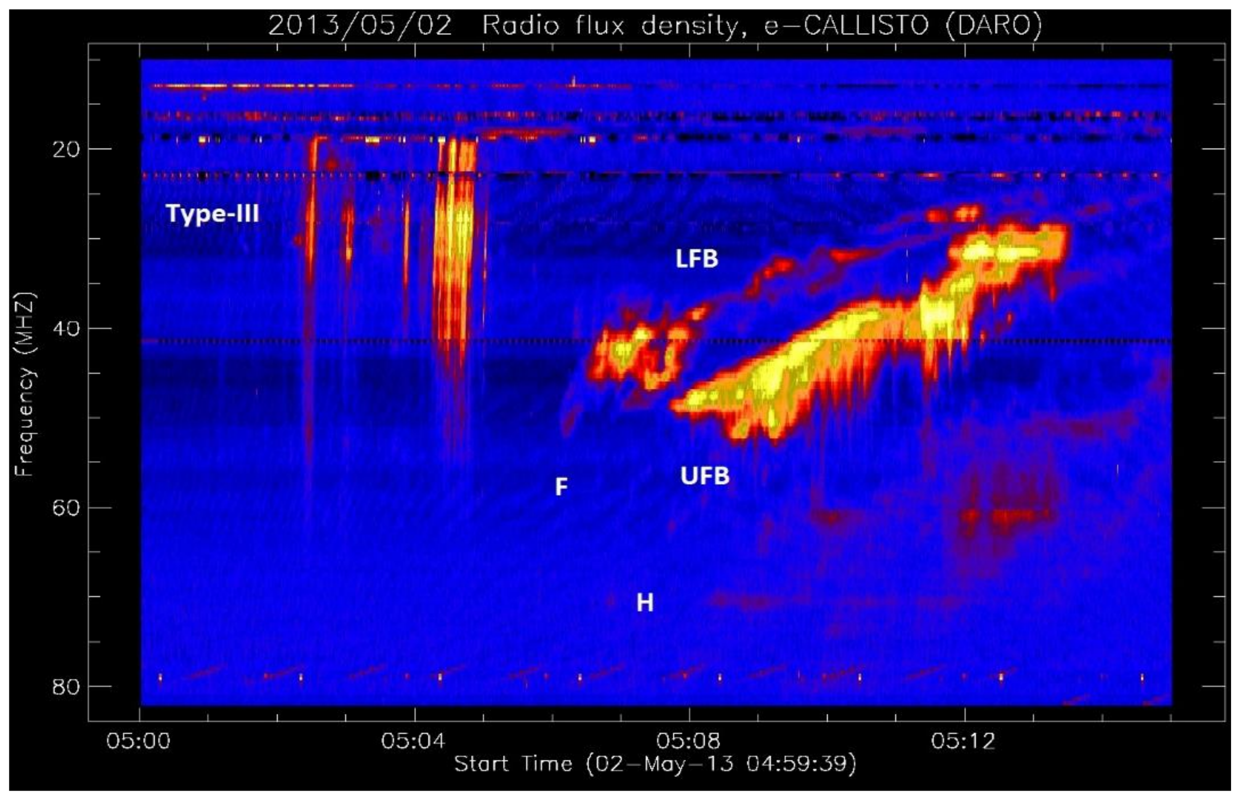


Fig.1 Spectrum of the type-II radio burst recorded on 2 May 2013 at 05:06 – 05:22 UT by the DARO-CALLISTO station at Germany.

The CME occurred on the location N10W28 and there was an evidence of a Solar Flare (04:58 UT; M1.1) associated with the type-II burst. The CME erupted around 05:24 UT and was preceded by an M-class flare. The CME was detected by STEREO/SECCHI (COR2 Ahead) and SOHO/LASCO (C2 + C3) at 05:24 UT, and by (COR2 Behind) at 05:54 UT.

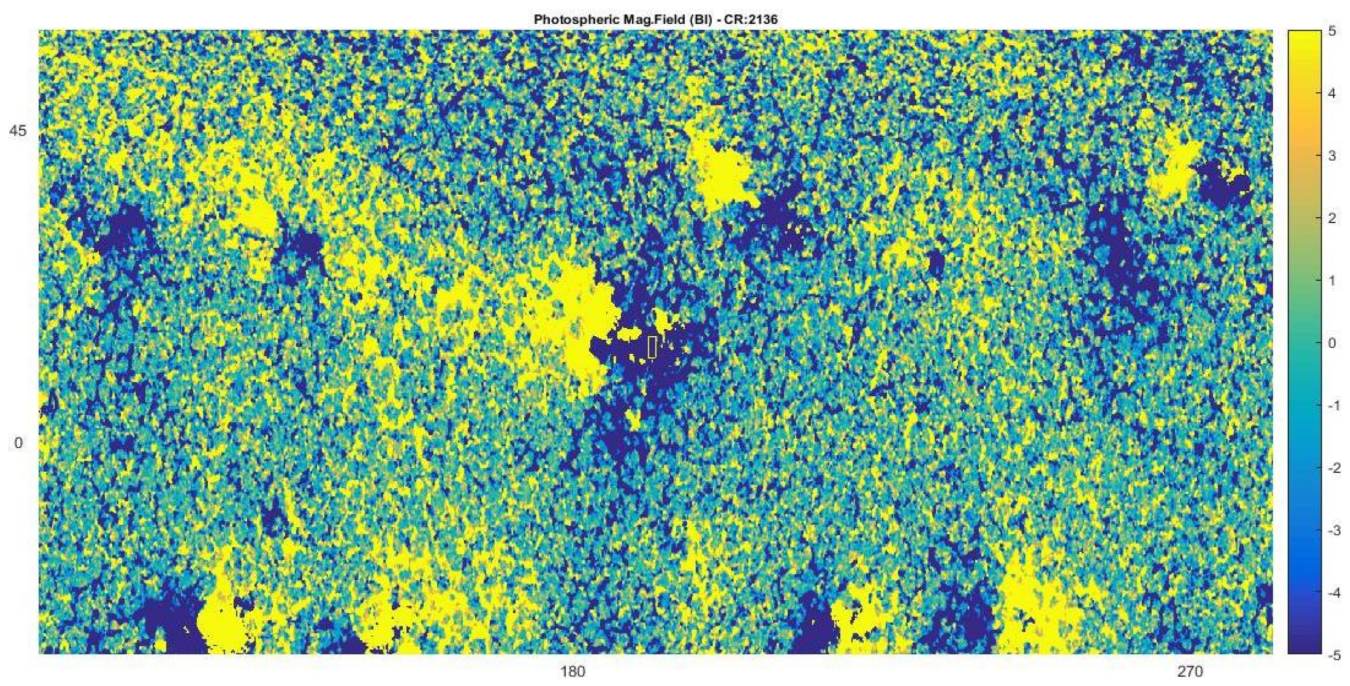


Fig.2 The synoptic map of the CR 2136 obtained from the HMI onboard the SDO satellite. The photospheric magnetic fields at the event's location were found to be 260.43 G and -391.38 G for the north and south polarities, respectively.

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Results

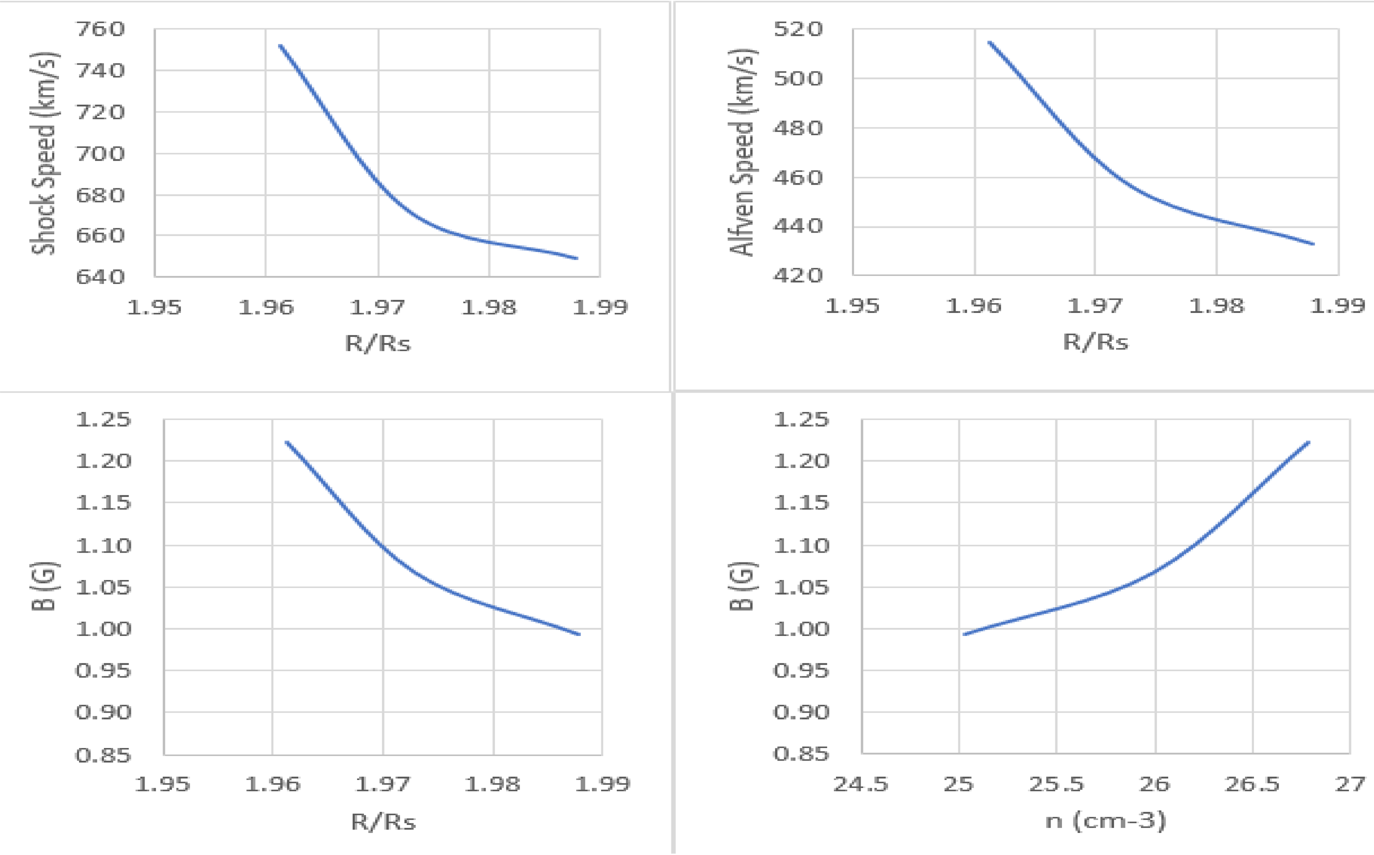

Fig.3 The variations of the shock speed, Alfven speed, and coronal magnetic field strength with the height, and also *B* with electron density.

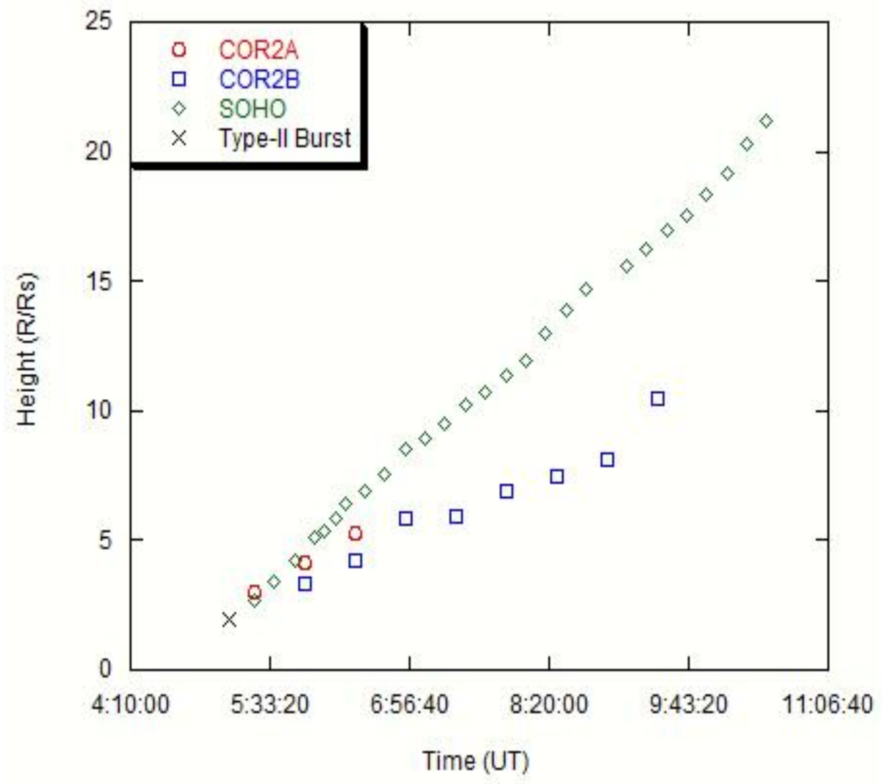

Fig.4 Tracing the evolution of the associated CME using STEREO, SOHO, and CALLISTO.

Conclusion

Table 1 The characteristics of the type-II radio burst, and they are comparable with previous studies.

Time (UT)	f_p (MHz)	R/Rs 4×N	V_s (km/s)	M_a	V_A (km/s)	X	BDW	B (G)
05:08:46	46.58	1.961	752.10	1.46	514.64	1.575	0.244	1.223
05:08:58	45.89	1.972	671.47	1.47	456.14	1.587	0.255	1.068
05:09:14	45.03	1.988	648.88	1.50	432.59	1.619	0.260	0.993

- In Fig.3, we found that the shock speed, Alfven speed, and the coronal magnetic field decrease steeply with height until reaching ~1.975 Rs, then the decreasing became moderate. The same behavior was also reflected on the coronal magnetic field where its value increased slightly with electron density until reaching ~ 1 G at a density ~ 25.8 × 10^6 cm^{-3} the slope became steeper.
- The reason may be due to the *Aerodynamic Drag effect* where the relatively high density of lower corona impedes the shock motion and when the shock cross this boundary its motion become more stable and uniform. For the coronal magnetic field strength, recalling the relatively high electron density at lower corona, the magnetic field increase slightly with electron density and this slight increase may refer to the electrons act like a shield or opaque to the magnetic field, until crossing that boundary and the corona become more transparent to the magnetic field lines.
- The shock speed that deduced from the type-II radio burst is in consistence with the measured speed of the CME in the FOV of STEREO-Ahead, STEREO-Behind, and SOHO.

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