Source Region of the Decameter–Hectometric Type II Radio Burst: Shock–Streamer Interaction Region

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Abstract. D–H type II radio bursts are widely thought to be caused by the coronal mass ejections (CMEs). However, it is still unclear where the exact source of the type IIIs on the shock surface is. We identify the source regions of the decameter–hectometric (D–H) type IIIs based on imaging observations from SOHO/LASCO and the radio dynamic spectrum from Wind/Waves. The analysis of two well–observed events suggests that the sources of these two events are located in the interaction regions between shocks and streamers, and that the shocks are enhanced significantly in these regions.

1 Introduction

Type II radio bursts, especially in the decameter–hectometric (D–H) and kilometer (km) wavelength range, are thought to be caused by the electron beam accelerated by CME–driven shocks [e.g. Sheeley et al. 1983, Reiner et al. 1998, Bale et al. 1999]. Assuming that the type II radio burst was excited at the shock front, the speed of the shock could be obtained from the observed frequency drift rate of the type II radio burst based on a coronal–density model [e.g. Vršnak et al. 2001, Kopalswany and Kaiser 2002, Vršnak et al. 2002, Reiner, Kaiser, and Bougeret 2003, Vršnak, Magdalenic, and Zlobec 2004]. This method is widely used to study and forecast the propagation of shocks [e.g. Dryer and Smart, 1982, Smith and Dryer, 1994, Fry et al. 2003, Reiner, Kaiser, and Bougeret 2007, Shen et al. 2007].

2 Method

In this work, the source region of the D–H type II radio burst is obtained from the combined analysis of the Wind/Waves and SOHO/LASCO observations. The detailed method is described as follows:
i) Previous results suggest that type II radio bursts especially in the D–H and longer wavelength range are caused by the CME–driven shocks [Reiner et al. 1998, Bale et al. 1999]. Recently, Vourlidas et al. 2003 and Ontiveros and Vourlidas 2009 found that shocks could be directly observed in coronagraph images. We use SOHO/LASCO–C2 observations to identify the position of the shock front, called $S_{\text{shock}}$ hereafter. It is thought to be the possible source region of type II bursts.

ii) The fundamental frequency of a type II burst is related to the background electron density by Priest 1982:

$$N_e = \left( \frac{f_{\text{fund}}(H\alpha)}{8.98 \times 10^3} \right)^2 \text{cm}^{-3}.$$ (1)

Therefore, the electron density of the source regions of the type II could be obtained from the radio burst dynamic spectrum. Using the pb_inverter.pro procedure in Solar Software (SSW), the polarized–brightness observations from SOHO/LASCO could be used to get the background electron density distribution. The pb_inverter.pro procedure uses the pb inversion derivation obtained by van de Hulst 1950. A polynomial fit of the form $r^{-n}$ is applied to the pb image for a single position angle to get the electron density distribution (see the introduction of the ‘pb_inverter.pro’ in the SSW). Thus, the possible regions, called as $S_p$, which can generate the type II radio bursts at the observed frequency range at the time of shock observed, can be determined. In addition, considering a 2% uncertainty in the brightness observations (Vourlidas, 2012, private communicate), a 2% uncertainty in the obtained electron density was applied to find the $S_p$.

iii) The overlap region of the shock front ($S_{\text{shock}}$) and the derived density region ($S_p$) is defined as the source region of the type II radio burst.

Based on the method described above, to determine the source region of a D–H type II radio burst, we need the polarized–brightness image and the direct imaging observations of the shock from SOHO/LASCO and the D–H type II radio–burst observation from Wind/Waves. Thus, we select events based on the following criteria:

i) A clear type II radio burst was recorded by Wind/Waves.

ii) The burst was caused by a limb CME with clear shock signatures in the LASCO–C2 field of view. We require limb CMEs because the polarized–brightness image represents the background coronal–density distribution near the plane of the sky, and the shock driven by a limb CME should have the most clear signatures in coronagraph.

Conforming to these two criteria, two well–observed events were found for study in this article.

3 7 March 2011 Event

Figure 1 shows the SOHO/LASCO observations before and after the onset of this CME. On 7 March 2011, a limb CME originating from N24W59 was first observed by SOHO/LASCO–C2 at 20:00 UT. The orange * symbols in panel (b) of Figure 1 show the possible front positions of this CME at 20:00 UT. Using the GCS model [Thernisien, Howard, and Vourlidas 2006, Thernisien, Vourlidas, and Howard, 2004, Thernisien 2011], Shen et al. 2012 obtained the speed of this CME as 2115 ± 136 km s$^{-1}$ in the three–dimensional space. This is a very fast CME with a speed much faster than the local Alfvén speed, and therefore LASCO–C2 only captured three images of the CME. We can expect that this CME drove a shock when it propagated in the corona.

Seen from panel (c) and (d) in Figure 1 obvious shock signatures ahead of the main body of the CME could be identified. The orange * symbols in panel (c) and (d) of Figure 1 mark the shock front at two instants of time. As we described in Section 2, the shock front, $S_{\text{shock}}$, is thought to be the possible source region of the associated type II radio burst.

Figure 2 shows the Wind/Waves observations from 7 March 2011 19:50 UT to 21:00 UT. From Figure 2, we observe a clear type II radio burst at 20:12 UT which could be identified. The vertical dotted–dashed white lines in Figure 2 indicate the times of the shock recorded by SOHO/LASCO–C2. Seen from this figure, the signature of the type II radio burst at 20:12 UT is very weak. Near 20:22 UT, this type II radio burst became stronger, and lasted for about ten minutes. The white asterisks show the minimum and maximum fundamental frequency of this D–H type II radio burst at the time of 20:24 UT, which are 4.6 and 7.4 MHz corresponding to the electron density of 2.6 × 10$^5$ cm$^{-3}$ and 6.8 × 10$^5$ cm$^{-3}$, respectively, based on Equation (1).

Figure 3 shows the background electron–density distribution obtained from the polarized image at 08:58 UT. The white regions in Figure 3 are caused by the point source region of type II radio burst. The white + symbols in Figure 3 show the boundary of the point source region indicated in red. The type II radio burst near 20:24 UT were probably generated from these region.

The position of $S_{\text{shock}}$ based on coronagraph observations is overplotted with yellow + on Figure 3. As we discussed in Section 2, the source region of a type II radio burst is the overlap region between the $S_{\text{shock}}$ and $S_p$. For this event at 7 March 2011 20:24 UT, the source region is located in the region indicated by the blue rectangle.

The white + symbols in Figure 3 show the boundary of the streamer, which is determined from the SOHO/LASCO image before the onset of the CME as indicated by the green + in Figure 1(a). It is found that the source of this type II radio burst is located at the shock–streamer interaction region. This result suggests that the type II radio burst at the D–H frequency range might also originate from the shock–streamer interaction region, similar to the metric type II radio bursts Cho et al. 2007, 2008.

In addition, at 20:12 UT, the shock was also very clear
4 9 May 2011 event

This CME burst from the east limb of the solar disk. SOHO/LASCO–C2 observed it since 21:24 UT. It was a fast limb CME with a projected speed of 1318 km s\(^{-1}\). Figure 4 shows the SOHO/LASCO observations before and after the onset of this CME. It is found that the shock structure ahead of the CME could be well observed and identified at 21:24 UT, 21:36 UT and 21:48 UT based on SOHO/LASCO–C2 observations. The orange \(\ast\) symbols in panels (b) – (d) show the shock front at three instants of time, which are defined as \(S_{\text{shock}}\).

A D–H type II radio burst associated with this CME is shown in Figure 5. It started at \(\approx 21:15\) UT. At 21:24 UT, the type II radio burst was very weak and is difficult to identify. The half of the frequency of its harmonic component, which varied from 2.5 MHz to 3.3 MHz, is used as the fundamental frequency. After 21:24 UT, the strength of this D–H type II increased. This radio burst reached its strongest phase near 21:48 UT. At 21:36 UT, the fundamental frequency varied from 1.9 MHz to 2.7 MHz.

Figure 6 shows the electron–density distribution, which is derived from the polarized–brightness image recorded at 14:58 UT. The regions of \(S_{\rho}\) at 21:24 UT and 21:36 UT are indicated by the red color in panels (a) and (b), respectively. Similar to Figure 4, the yellow \(\ast\) symbols indicate \(S_{\text{shock}}\).

The source regions of this type II event at the two instants of time were located in the regions enclosed by the blue rectangles in Figure 6.

The white + symbols in Figure 6 show the boundary of
the streamer as same as the green + in Figure 4(a). It is found that the source regions of this event at different time also located in the shock–streamer interaction regions. It confirms the conclusion that the shock–streamer interaction region might be the source region of a D–H type II radio burst. Seen from the Figure 4(b) and (c), it is found that the interaction between the shock and the streamer may start near 21:24 UT. After that, the shock further interacted with the streamer. During this phase, the observed D–H type II radio burst enhanced continuously as shown in Figure 5. Thus, the increase of the intensity of this radio burst was probably caused by the enhancement of the shock during its interaction with the streamer.

5 Conclusion

In this work, the source regions of two well–observed D–H type II radio bursts are checked based on SOHO/LASCO–C2 and Wind/Waves observations. It is found that the source regions of these two D–H type II radio bursts probably located in the shock–streamer interaction regions, which is the same as the source regions of metric type II radio bursts [Cho et al., 2007, 2008, 2011]. In addition, by analyzing the intensity variation of these two D–H type II radio bursts, we suggest that the shocks were enhanced during their interaction with the streamer. Such enhancement of shocks would increase the intensity of the radio bursts.

These results indicate that the shock–streamer interaction region could also be one of the main source region of the D–H type II radio burst. It should be noted that the background density in a streamer (or the flank of a shock) is quite different from that near the nose of a shock. Thus, to calculate the shock speed based on the frequency drift rate of type II radio burst, a detailed analysis of where a radio burst is generated from should be done first.

As we described in Section 2, the background density obtained from the SOHO/LASCO polarized–brightness image is an important factor in our method. Unfortunately, there is only one polarized image taken each day in each telescope for most period of the SOHO mission. Solar eruptions, especially the large CMEs, would significantly influence the background density. Thus, we choose only the events in which no large CME events occurred between the time of the polarized–brightness image recorded and the type II radio burst. In addition, clear type II radio–burst observations and clear shock signatures in SOHO/LASCO observations are needed in this method. Combined with these selection criteria, the number of events could be studied is limited. In a future work, the method developed by Hayes, Vourlidas, and Howard [2001] could be used to obtain the background electron density based on the total–brightness images, and more events could be studied.

It should be noted that only projection observations were used in this work. Recently, some methods were developed to obtain the CME’s parameters [e.g. Thernisien, Howard, and Vourlidas, 2006; 2007], background electron density in the corona [e.g. Frazin et al., 2010] and the streamer structure [e.g. Morgan and Habbal, 2010] in three–dimensional space. Thus, the three–dimensional source region of the radio burst could be further checked by applying various...
three-dimensional models.

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