The Sun’s hot and magnetized corona acts as a reservoir for the onset of solar eruptions, the spiraling solar wind stream, and their interaction with the planetary magnetic fields constituting a planet’s space weather. One of the fundamental physical processes of the magnetic field in the solar corona, which causes localized heating, leads eruptions, and provides the kinetic energy for the propulsion of the plasma, is known as magnetic reconnection. In the first instance, the magnetic reconnection is defined as the self-reorganization and relaxation of the complex and twisted magnetic fields in the solar corona that leads to the liberation of stored magnetic energy in the constituent plasma due to the direct dissipation of the electric current (e.g., Priest & Forbes 2007; Yamada et al. 2010; Priest 2014, and references cited there). In the solar corona, the magnetic reconnection is one of the major mechanisms to heat it locally, and to trigger various types of eruptive phenomena and localized plasma dynamics (e.g., Parker 1988; Cargill & Klimchuk 2004; Shibata & Magara 2011; Jess et al. 2014; Klimchuk 2015; Xue et al. 2016; Van Doorsselaere et al. 2020, and references cited there). It is also responsible for the different types of small-scale activities and physical processes in the solar atmosphere such as small-scale Ellerman bombs (e.g., Nelson et al. 2013; Peter et al. 2014; Tian et al. 2016, and references cited there), small to large scale solar jets (e.g., Yokoyama & Shibata 1995; Innes et al. 1997; Sterling et al. 2015; Srivastava et al. 2018, and references cited there), ultraviolet and extreme ultraviolet transients (e.g., Tian et al. 2014), solar flares (e.g., Masuda et al. 1994; Shibata & Magara 2011; Su et al. 2013; Forbes et al. 2018, and references cited there), large-scale filament/prominence eruptions (e.g., Li et al. 2016; Xue et al. 2016), coronal mass ejections (e.g., Savage et al. 2010), etc. Magnetic reconnection may also be driven by the external eruptions, flux emergence, etc. van Driel-Gesztelyi et al. (2014) have observed that magnetic reconnection can be driven by the expansion of a coronal mass ejection, and it reconnects with a nearby active region. The erupting fluxrope undergoes an interchange magnetic reconnection with the oppositely directed magnetic field, and it is responsible for the eruption. It is similar to the breakout model of the corona (e.g., Antiochos et al. 1999; Cohen et al. 2010). The reconnection favored emerging flux may also be responsible for the triggering of the filament eruption and the associated CME (e.g., Feynman & Martin 1995; Chen & Shibata 2000; Okamoto et al. 2009). Magnetic reconnection has wide physical implications for the Sun’s atmosphere, planetary magnetospheres, the heliosphere, and in many other astrophysical objects, e.g., active galactic nuclei, pulsars, etc., as well as for laboratory plasma (Hesse & Cassak 2020). However, there are several outstanding issues associated with magnetic reconnection, which are still under debate despite remarkable progress in their study over the last three decades both in the frame-work of theory and observations. A few scientific issues include determining the geometry of the reconnection region, the properties and dynamics of the current sheet, magnetic field configuration and formation of the X-point, the exact estimation of the reconnection rate, the physical process and role of resistive instabilities in the reconnection region, and the quantification of resistivity/magnetic diffusivity (e.g., Priest & Forbes 2007;
Yamada et al. 2010; Hesse & Cassak 2020; Mishra et al. 2020; Pezzi et al. 2021, and references cited there).

Magnetic reconnection also invokes the breaking and reconfiguration of the oppositely directed magnetic field lines in the resistive plasma in which they collapse on the X-point and the associated current sheet in the localized solar atmosphere (Priest & Forbes 1986; Birn et al. 2005). In a spontaneous magnetic reconnection, current sheet dynamics may be associated with MHD instabilities, e.g., the resistive tearing mode instability (Shibata et al. 1995; Shibata & Tanuma 2001; Vekstein 2017). Another stable magnetostatic configuration of the current sheet could also be developed in the large-scale solar corona where some external perturbations may trigger a forced magnetic reconnection (Srivastava et al. 2019). Using the spaceborne data from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO), Srivastava et al. (2019) first found observational evidence of the forced reconnection at a considerably high rate, which occurred locally in the solar corona. The observed forced reconnection was generated in the large-scale corona when two oppositely directed magnetic field lines forming an X-point and associated current sheet were perturbed by an external disturbance generated by the motion of a cool solar prominence. This type of reconnection has only been reported in theory (Jain et al. 2005) and has never been directly observed in the Sun’s large-scale corona. Before this, Jess et al. (2010) observed a microflare activity driven by the forced magnetic reconnection, which they termed as its indirect signature in the solar chromosphere. Recently, Mészárosová & Gömöry (2020) have reported the evolution of sausage waves in the magnetic structures and their role in enabling a forced reconnection in the vicinity of the solar corona.

As seen in the above example, in general, the current sheet may undergo the process of forced reconnection by some external perturbations generated by oscillatory processes, the evolution of pulses, coalescence and tearing mode instabilities, etc. (e.g., Vekstein & Jain 1998; Jain et al. 2005; Vekstein 2017; Potter et al. 2019, and references cited there). There has been a significant development in the theory of forced magnetic reconnection in a variety of magnetized plasma configurations over the last three decades (e.g., Hahm & Kulsrud 1985; Vekstein & Jain 1998; Browning et al. 2001; Birn et al. 2005; Jain et al. 2005; Beidler et al. 2017; Potter et al. 2019; Srivastava et al. 2019, and references cited there). Typically for the solar corona, the forced reconnection was studied by Jain et al. (2005) as one of the primary candidates for its heating. They have simulated the forced reconnection when a sheared force-free field is perturbed by the slow pulse-like disturbances that generate a series of heating events similar to nanoflare heating. Vekstein & Jain (1998) have studied earlier the forced reconnection in a force-free magnetic field in a current sheet due to a tearing mode instability, which could mimic the physical scenario of solar coronal heating. Potter et al. (2019) have modeled a force-free current sheet in the solar corona that allows multiple magnetic islands to be formed and coalesce in order to release the energy rapidly. Recently, using the data-driven MHD modeling, Srivastava et al. (2019) also showed that even without much development of the typical physical conditions for reconnection, a magnetic explosion may forcibly and rapidly occur in a current sheet due to an external velocity perturbation in order to liberate energy and to heat the localized solar corona. There are simple manifestations in many previous reports that some perturbations may lead a driven magnetic reconnection (Birn et al. 2005), however, the forced reconnection possesses some specific physical properties that were not observed earlier. The plasma heating in a forced reconnection may be provided by the ongoing external driving and internal reconnection both, provided the timescale of the driver and the reconnection match each other (Jain et al. 2005).

In the forced reconnection, even if the likely conditions are not present in the localized corona, inflows may be driven by external perturbations, and there will be an obvious time lag between plasma inflows and outflows (Srivastava et al. 2019). The current sheet can appear obviously in an MHD stable magnetic configuration in the localized corona in response to some external perturbation, and this further leads to a forced magnetic reconnection (Vekstein 2017). The smaller resistivity may also trigger reconnection over the stable current sheet under the influence of external perturbations (Vekstein 2017; Srivastava et al. 2019). Recent observations clearly demonstrated some of these specific physical properties of a forced reconnection, although further observations and modeling of this physical phenomenon are required (Potter et al. 2019; Mészárosóvá & Gömöry 2020; Khabarova et al. 2021).

In the present paper, using multiwavelength observations of the solar corona from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) from 2019 December 30, we observe a cool prominence driven forced reconnection in a dynamical X-point in the off-limb solar corona, and thereafter its responses in the form of the hot plasma flows and the formation of coronal jet-like dynamics in its surroundings. The dynamical nature of the prominence is governed by the eruption of a localized hot segment of the prominence initially, which further perturbs the overlying magnetic field configuration. Overall, this plasma dynamics triggers the expansion of the cool prominence system that further stretches the overlying coronal magnetic field lines and pushes them into the reconnection region. This dynamical process stretches and expands the overlying coronal field lines, and causes the onset of inflows and subsequently the forced magnetic reconnection in the overlying solar corona. In Section 2, we present the observational data and their analysis. The observational results are depicted in Section 3. The discussion and conclusions are outlined in the last section.

2. Observational Data and Analyses

We analyze the multitemperature temporal image data from the AIA on board the SDO as observed on 2019 December 30. AIA consists of seven extreme ultraviolet (94, 131, 171, 193, 211, 304, and 335 Å), two ultraviolet (1600 and 1700 Å) and one visible (4500 Å) full disk imager with 1.5 spatial resolution per two pixels. The pixel size of the image data is 0.6, while the cadence is 12 s. We use 94, 131, 171, 193, 211, 304, and 335 Å temporal image data of AIA in the present analysis. We have selected ≈ 2 hour multifilter/temperature time-series data starting from 09:20 UT on 2019 December 30 to observe a prominence system at the northeastern limb and the overlying complex loop system. We choose a particular area with a 400” by 350” field of view (Figure 1(a)) ranging from −650” to −1050” in the East–West direction and 400” to 750” in the North–South direction. The basic calibration and normalization of the data were performed by using the SolarSoft IDL routine “aia_prep.pro.”

We use five channels of SDO/AIA observations (304, 171, 211, 193, and 131 Å) to analyze the dynamics of the prominence and overlying coronal structures (Figure 1). The transition region (TR)/ upper chromospheric emission at 304 Å is dominated by the He II
lines formed between $(5–8) \times 10^{4}$ K, and show the existence of cool plasma. The inner coronal emission at 171 Å is formed around $(6–8) \times 10^{5}$ K to exhibit the appearance of the inner coronal plasma. In the present study, the prominence dynamics and associated flows are observed at 304 Å. The forced reconnection region, the formation of the associated X-point and the dynamical current sheet, and the overlying coronal magnetoplasmoid system are best seen in the 171 Å emission. The coronal magnetic field lines and their dynamics are collectively visible at 211, 193, and 131 Å, which are the high-temperature filters of SDO/AIA. The composite images are constructed by combining AIA 304 Å and 171 Å (Figure 1 right column), and AIA 131, 193, and 211 Å (Figure 1 left column) to observe the behavior of cooler prominence plasma, the dynamics of coronal plasma, and the overall dynamics of the forced reconnection region and its surroundings. The AIA 193 Å images are also used to show initially the evolution of the eruption of some hot components of the prominence plasma configuration (Figure 2) that further triggers the expansion of the cool prominence system to force the reconnection in the overlying large-scale solar corona. Figures 1–5 depict all such analyses and the related results, which will be described in detail in Section 3. The schematic is also displayed in Figure 3 to describe the overall dynamical scenario associated with the forced reconnection event driven by the expanding cool prominence system, and the stretching of the overlying coronal field lines that go further into the reconnection region.

In order to understand thermal structures of the forced reconnection region and associated plasma dynamics, we obtain the Differential Emission Measure (DEM). We map the DEM by using six different temperature AIA filters, i.e., 131, 171, 193, 211, 94, and 335 Å as observed by SDO. We do not use the cool and optically thick 304 Å filter to examine only the relative contributions of the high-temperature plasma on the total emission as captured by different hot AIA filters. We have used the method of Hannah & Kontar (2012) to measure the differential emission from the heated prominence material, and also to demonstrate its dynamics, the surrounding magnetic field, and the reconnection region. The present estimation is based on an automated method, which gives a regularized DEM as a function of temperature ($T$). In order to obtain the inversion, we implement a zeroth-order regularization in the temperature range of $\log T(K) = 5.0$ to $\log T(K) = 7.5$ over a total of twenty-six temperatures at $\Delta \log T(K) = 0.1$ intervals. For the selected six hot AIA filters, we compute the DEM for the region of interest (ROI) in the selected temperature bins, which is displayed in Figure 4. The dynamics of the forced reconnection region and the associated hot plasma outflows, as well as the formation of the hot coronal jet-like structure in the vicinity, are observed in the temperature range of $\log T(K) = 6.0–7.2$. The detailed results related to the DEM analyses and their physical implications are described in Figure 6 and Section 3.

3. Observational Results

The dynamics of the large-scale magnetic field and frozen-in plasma is seen in the northeast part of the off-limb corona from 09:20 UT to 10:38 UT on 2019 December 30 (Figure 1, rightmost panel). The off-limb region consists of a cool prominence system
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Figure 2. Left panel: multwavelength imaging observations of SDO/AIA 193 Å (top), 131 Å (middle), and 304 Å (bottom) wave bands demonstrate the dynamical nature of the localized hot plasma segment of the prominence system, the overlying magnetic fields embedded in the hot coronal plasma, the below-lying cool prominence system, and the overlying reconnection region in the large-scale off-limb corona. The top left panels show that a hot plasma segment is erupted and trapped within the overlying magnetic domain. The AIA 193 Å images show the expansion of the hot plasma segment and the overlying magnetic field configuration. Top right panel: a slit “P1” has been taken of the 193 Å (top left panel) image at 09:46 UT along the expansion of the localized hot plasma segment and overlying magnetic structures. The corresponding distance—time map along “P1” estimates the kinematics of the hot plasma segment (~21 km s\(^{-1}\)) and overlying magnetic field (~27 km s\(^{-1}\)). Middle left panel: the AIA 131 Å image determines the evolution of the same overlying magnetic field embedded in the hot coronal plasma lying just above the cool prominence. A slit “P2” has been taken along the expansion of these field lines to deduce the velocity in the 131 Å data. Bottom right panel: it is seen in the corresponding distance—time map in 131 Å along “P2” that the coronal field lines move with a speed of ~28 km s\(^{-1}\). This speed almost resembles that observed in the 193 Å wave band. Bottom left panel: the AIA 304 Å images show the expansion and upward motion of the entire cool prominence system just below the overlying stretched coronal magnetic field configuration (top and middle left panels).

(Figure 1, right column, 09:20:09 UT). The small localized prominence chunk (reddish-brown) at the rightmost part is confined below an overlying diffused coronal loop system (green). A set of large-scale coronal field lines is also present at the rightmost part of this region; however, their upper ends are diffused in the overlying corona. The prominence footpoints appear to be active and bright in the higher temperature emissions, also (Figure 1, left column, 09:20:09 UT). This qualitatively suggests that some localized flux emergence and related heating is enveloping the prominence footpoints, and later makes some parts of them eruptive. We, therefore, observe that the hot component of the plasma present at the active footpoints-pillars of a prominence is mostly visible at a coronal temperature in AIA 193 Å and AIA 211 Å (Figures 2 and 1). This plasma structure starts to lift up at ~09:24 UT and causes the overlying prominence associated magnetic field to expand upward. The eruptive prominence further stretches the overlying coronal magnetic field lines that then undergo the forced reconnection (the 10:04:09 UT image in the left column of Figure 1). We have used the running difference image of AIA 193 Å to observe the dynamical behavior of the hot plasma segment of the prominence system (its one low-lying active footpoint) and its possible kinematical trajectory (Figure 2, top right panel). Later, it is trapped and fades away within the overlying magnetic domain. Figure 2 shows the height—time diagram along the path P1 (top right panel). It elucidates the eruption of the heated plasma segment of the prominence system and the overlying coronal magnetic fields. The eruption of the prominence’s heated plasma segment follows a parabolic trajectory, which indicates a failed eruption of it. Some internal localized and small-scale reconnections may be responsible for its eruption, while it fades and is trapped at the later stage due to the overlying magnetic fields. This plasma structure moves upward initially at a speed of 21 km s\(^{-1}\) (the top right panel of Figure 2), and further destabilizes and expands the entire prominence system. The eruptive prominence further stretches the overlying coronal magnetic field lines. These stretched overlying magnetic field lines embedded in the hot plasma move up just above the prominence with a speed of 27–28 km s\(^{-1}\) (the top right and bottom panels of Figure 2). These field lines are also visible in the higher temperature filter of AIA 131 Å (10 MK; the left middle panels of Figure 2). A path “P2” has been taken along the expansion of the overlying coronal field lines. We found that the hot plasma embedded in these stretched overlying coronal magnetic fields accelerates toward the X-point with a velocity of 27–28 km s\(^{-1}\) (Figure 2, lower right panel). It is comparable with the scenario observed in the AIA 193 Å filter. The cool prominence plasma just moves behind it upward toward the reconnection region. It is seen that another set of large-scale coronal field lines is also present at the leftmost part of the observed magnetoplasma system in the given field of view,
however, their upper end is also diffused in the overlying corona (Figure 1, right column, 09:20:09 UT).

To mimic the physical scenario and dynamics of the different magnetic structures in the off-limb corona, we draw a schematic to emphasize the erupting prominence, the overlying coronal magnetic fields, the onset of the forced magnetic reconnection, and the associated plasma dynamics (Figure 3). It describes the observations vis-à-vis the dynamical evolution and overall configuration of the magnetic system containing a prominence, its activation, and dynamics of the overlying large-scale magnetic fields of the diffused corona (green and blue lines; top panel). The green lines depict the large-scale coronal magnetic field lines lying just above the prominence system. The prominence associated with cool plasma lies just below this set of coronal magnetic field lines (i.e., green lines). The whole prominence is bound by the low-lying arcades (yellow arcs) crossing across its pillars/footpoints. One hot segment of the prominence (the middle one among the orange-colored prominence pillars) lifts up and triggers the expansion of the entire prominence system and subsequently stretches the overlying coronal magnetic field lines (top right panel, green lines). It forcibly reconnects with the overlying diffused large-scale coronal magnetic field lines (blue lines). The onset of the forced reconnection is shown in the bottom left panel, which is accompanied by the bidirectional multitemperature plasma flows in the eastward and westward magnetic channels. The overlying regions above the reconnection point also open up into the overlying diffused corona, which enables the hot plasma flows in the upward direction, also. The bottom right panel mimics the onset of the post-reconnection scenario, where the plasma flows in the eastward magnetic channel and further interacts and reconnects with another localized prominence segment, its overlying fields (loop/arcade), and open field lines to trigger the jet-like eruptions. The overlying magnetic field breaks and disappears after the eruption of the jets. The overall physical scenario depicted by this schematic is clearly observed and described in greater detail in Figures 1–2 and Figures 4–5.

As explained above in the schematic, the magnetic complexity of the system is much larger in the present observational baseline (Figures 1–2). The cool prominence system is embedded in the overlying large-scale coronal magnetic field configurations (Figure 1, right column, 09:20:09 and 09:46:09 UT). It is initially unstable due to the localized eruption of the hot plasma segment of the prominence system (Figures 1–2). This process further triggers the expansion of the entire cool prominence system that further stretches the overlying coronal magnetic fields and enables them to be transported into the forced reconnection region in the off-limb corona.

Figure 4 shows distance–time measurements (i) along the path S1 (right panel), which estimates the kinematics of the inflowing plasma toward the reconnection point, and (ii) along a curved path S2 (right panel), on which the bidirectional plasma channeling takes place during the forced reconnection once the magnetic reorganization takes place. These measurements are respectively displayed as distance–time maps in 171 Å running difference and 304 Å images (left panel). Above, the temporal variation of the emissions from the reconnection region (white dashed box in the right panel), as recorded by various AIA channels, has been plotted. The distance–time
map along S1 shows that plasma associated with the prominence system moves in the upward direction at 09:28 UT with a speed of 24 km s\(^{-1}\). At almost the same time, less dense plasma moves inward from the top with an average speed of 7 km s\(^{-1}\). This north–south motion of the field lines into a reconnection region occurs during 09:28 UT–09:48 UT. It should be noted that this is a projected scenario of the motion. Also the bidirecional north–south motion of the magnetoplasmatic system is significantly different in speed here because the upward motion of the coronal plasma is forced by a prominence system from the inward direction. This feature is itself different from the normal reconnection process, and is very typical of a forced magnetic reconnection (Srivastava et al. 2019). The reconnection takes place around \(\approx 09:48\) UT due to the forced plasma inflows as seen from the north (top)– south (bottom) in the two-dimensional projection. Thereafter, the reorganization/reorientation of the magnetic field also takes place in the East–West directions (Figure 1 and the animations associated with Figures 1 and 5).

After the forced reconnection, the rightmost magnetic field domain is locally closed and the rightmost small prominence segment is trapped within it (Figures 2–4). It is also seen that the upper part of this magnetic domain is an open channel (the red and pink arrows in top right panel of Figure 5). In the difference image (bottom right panel of Figure 5) of 171 Å, it is also clearly observed that well after the forced reconnection (10:18 UT–10:38 UT), the east–west magnetic domains are completely separated and the newly configured rightmost (westward) magnetic configuration/domain exhibits a cusp-like structure. Meanwhile, the leftmost (eastward) magnetic domain now constitutes a separate plasma channel whose one end is going further eastward over the leftmost prominence segment where later the jet-like eruption is formed (Figure 5, top right and bottom right panels). Its upper end is curved and going up as an open magnetic channel in the overlying diffused corona (the pink arrows in Figure 5, top right and bottom right panels). These two magnetic channels open up, respectively, as a separator between the eastward and westward newly configured magnetic field domains after the commencement of the forced reconnection and the reorganization/reorganization of the magnetic fields took place.

The analysis of the distance–time map created along the curved path “S2” (Figure 4, left bottom panel) shows that, as soon as the inflow of two opposite magnetoplasma threads north–south undergo the forced reconnection at \(\approx 9:48\) UT, the east–west reorientation of the magnetic fields starts creating a bidirectional channeling of the plasma at 09:53 UT, which is traced by its cool components (shown by red arrows in the right panel of Figure 4). We have drawn two vertical lines (green and white) to indicate the initiation time of the inflow and outflow along slits “S1” and “S2”, respectively. The northward–southward inflow starts when the heated plasma segment of the prominence system starts to lift up (09:24 UT) and destabilizes and expands the entire cool prominence system toward the X-point from the regions below. Once these dynamics are developed along the north–south direction, the inflow of the plasma also starts (09:28 UT) along slit “S1” in the north–south direction. The forced reconnection begins at \(\approx 09:48\) UT.
After the onset of the forced reconnection, the plasma outflow is initiated along the curved path in the east–west direction along the slit “S2”. Their respective outflow speeds in the right (westward) and left (eastward) directions are 37 km s\(^{-1}\) and 28 km s\(^{-1}\), respectively. The time lag of \(\approx 20\) minutes between the initiation of inflows and outflows is the characteristic observable of the forced reconnection (Srivastava et al. 2019). The estimated outflow speeds are the projected minimum speed, and their values depend upon the local magnetic field strength and plasma density in the reconnection region. Because the forced reconnection region involves the bulky prominence and overlying coronal magnetic fields, and due to its larger density, the outflow speeds must be significantly lower than the characteristic Alfv\’en speed in the inner corona (Innes et al. 2012; Mishra & Srivastava 2019; Srivastava et al. 2019).

As mentioned above, two magnetoplasma channels reconfigure/reorient in both the eastward and westward directions after the reconnection, whose one end opens up in the overlying diffused corona. Therefore, along the slit “S1” there are traces (projected along the slit “S1”) of the upward outflows of the coronal plasma with speeds of 22 and 19 km s\(^{-1}\) that are also seen (Figure 4, left middle panel). This complex plasma motion is observed during the forced reconnection process. The normalized intensities as captured by the various AIA filters for the reconnection region are plotted in Figure 4, left top panel, which clearly shows that the emission in different filters, even those sensitive to the high-temperature plasma (e.g., 131, 094, and 335 Å) peaks during the time of the forced reconnection at 09:48 UT. After the gradual progress of the reconnection, these emissions subside except in few AIA channels (e.g., 335, 094, and 171 Å) because some traces of the hot plasma also flow along the upward open magnetic channels well after the reconnection.

After the commencement of the forced reconnection, the DEM map at \(\log T_e = 7.2\) on 10.04 UT (Figure 6, top right panel) shows the existence of hot plasma along the eastward and westward magnetic channels, propelling down toward the limb. It should be noted that multitemperature plasma is created, and prominence material is also heated up to some extent to the transition region inner coronal (log \(T_e = 5.9–6.0\)) temperature. The evolution of the temperature at the reconnection site is shown in the bottom panel of Figure 6. It is evident that most of the emissions from the reconnection region come from the plasma at approximately \(\log T_e = 6.4\), while its quarter fraction comes from the plasma at \(\log T_e = 7.2\). The hot
plasma mixed with the cool traces of the prominence, as well as the plasma maintained at the typical coronal temperature flow toward the eastward magnetic channel (Figure 6 top panels, and Figure 5).

Figure 5 (right panel) and the DEM maps in Figure 6 (middle panels) show that after the reconnection, the plasma outflows took place in the eastward direction toward the leftmost localized prominence system as seen in the field of view (Figures 1–5; the animations associated with Figures 1 and 5). The multitemperature plasma, which consists of some flowing prominence threads and their magnetic fields too, hurls toward this prominence and compresses this region. Reconnection between the prominence and the overlying magnetic fields takes place and the base and spire of a coronal jet-like structure builds up (Figure 5, top right and bottom right panels). The distance–time diagram in Figure 5 as well the animations (associated with Figures 1 and 5) clearly show that the base of the jet-like structure evolves during 10:24 UT–10:38 UT through a prominence–prominence interaction and a prominence–loop (overlying arcade field) interaction (Kumar et al. 2010; Li et al. 2016). Subsequent reconnection takes place, and thereafter hot plasma is ejected multiple times along the spire or open magnetic channel (black-dashed line in the right bottom panel of Figure 5) with a high speed ranging from 178 to 183 km s\(^{-1}\) (Figure 5, bottom left panel). DEM maps (Figure 6, middle panels) also show the formation of a hot jet-like spire at the leftmost region through which the multitemperature plasma (log \(T_e = 6.0–7.2\)) is propelled into the higher atmosphere. This jet-like propulsion is found to be highly impulsive with the triggering of a high-speed plasma multiple times. The emissions in various AIA channels at the base region/lower segment of this jet-like structure show that they peak multiple times whenever the plasma is propelled through the jet’s spire (Figure 5, top left panel). This indicates that multiple episodic reconnections occur at the base of this jet-like structure during prominence–prominence/loop interaction when multitemperature plasma as well as the traces of the prominence are propelled from the forced reconnection region to this particular region. After the formation of the jet, the overlying magnetic channel disappears in the overlying corona (Figures 1 and 3; the schematic in Figure 3).

Figure 6. Top and middle panels: DEM maps at different temperatures of log \(T_e = 5.9, 6.0,\) and 7.2 at (i) 10:04 UT when the forced reconnection is gradually progressing, (ii) 10:38 UT when the responses in the post-reconnection phase have been observed in the form of multitemperature plasma flows and the onset of a jet-like eruption. Bottom panel: the DEM vs. temperature plot from the forced reconnection region.
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4. Discussion and Conclusions

In this paper, we investigate the observational signature of the prominence driven forced reconnection in the off-limb large-scale corona. The eruptive prominence acts as an external driver to trigger the expansion and stretching of the overlying coronal magnetic field lines that undergo the forced magnetic reconnection with an overlying set of coronal magnetic field lines inflowing toward the reconnection region from the top in the off-limb corona. The direct observational manifestation of the forced reconnection, externally driven by a prominence, is given by Srivastava et al. (2019). However, they did not observe a large temperature evolution at the site of the forced reconnection due to the fact that partially ionized, dense, and collision dominated prominence plasma might consume the liberated energy (Chen & Ding 2006). Another point was that they observed the nonfailing quiescent loop system far off-limb in the structured corona, where magnetic complexes were not much present. However, in the present case, the magnetic complexity was more predominant, with a cool prominence system and stretched and expanding coronal magnetic field lines that rise up near the limb to drive the forced reconnection with the overlying loop system. Moreover, in a 2D projection, the inflows appear to be squeezing into the reconnection region from the north–south direction, and after the reconnection the new east–west magnetic configuration/channel is generated and separated. This process creates a complex pattern of the outflowing plasma both in the upward direction along the open magnetic channel above the reconnection region, as well as in the downward direction toward the footpoints of the eastward and westward separated magnetic channels. Later, the multitemperature plasma carries prominence threads along with it toward the footpoint of the eastward magnetic channel, which further causes the prominence–prominence interaction and prominence–loop interaction to generate a coronal jet-like structure (Kumar et al. 2010; Li et al. 2016).

It is interesting to note that hot plasma flows appear through the eastward magnetic channel over a length of $\approx$10$^7$ km after the reconnection (Figure 6). The erupted prominence material is also channeled through the same set of magnetic field lines. It is seen in the present observational baseline that the embedded core prominence material and outer peripheral coronal magnetic fields/loop system directly interact with the overlying inflowing typical loop system within the reconnection region. The stretching and expansion of the peripheral coronal magnetic field lines due to the eruption of the prominence from below further triggers the inflows and subsequent forced magnetic reconnection. However, the outflowing plasma consists of the mixture of multitemperature hot plasma and the remaining bulky prominence threads/materials. Prominence material does not directly absorb the generated energy at the reconnection site, and the coronal plasma is directly heated to the range of the temperature (i.e., $\log T_e = 6.0-7.2$) at the reconnection site. This physical effect is well demonstrated collectively in form of the elevation of the normalized intensities of various AIA channels, as shown in Figure 4, the DEM maps in the top panel of Figure 6, and the DEM versus temperature plot in the bottom panel of Figure 6.

van Driel-Gesztelyi et al. (2014) have observed the magnetic reconnection by an eruption of a filament and the expansion of its magnetic field in the corona. Similarly, Feynman & Martin (1995), Chen & Shibata (2000), and Okamoto et al. (2009) have observed that an emerging flux reconnects with the overlying coronal magnetic field and is responsible for the large-scale eruptions. These above-mentioned observations belong to the category of spontaneous reconnection. In such findings, the expansion of the eruptive field lines associated with the flux emergence directly reconnect themselves with the overlying coronal magnetic fields to lead the magnetic reconnection. However, in the forced reconnection scenario, an additional step has basically evolved, which is seen also in the present observational study. An external perturbation (e.g., an eruption, waves, the release of photospheric magnetic field shearing, etc.) may disturb or force the surrounding field lines to reconnect with the overlying or nearby oppositely directed magnetic fields (Srivastava et al. 2019; Mészárossová & Gömöry 2020). The dynamic nature of the Sun may support such externally driven reconnections more often along with their related physical scenario at different spatio-temporal scales (e.g., Nakariakov et al. 2016; Jelínek et al. 2017; Srivastava et al. 2019; Mészárossová & Gömöry 2020). In the present paper, we provide an observational scenario for the forced reconnection that occurs off the limb into the solar corona. It is driven by the eruption of a cool prominence system and the overlying/peripheral expanding and stretched coronal field lines. These magnetic structures are further jointly transported into the reconnection region and reconnect with the opposite coronal fields flowing inward from the top regions of the off-limb corona. The notable outcome of such a reconnection is the heating, as well as the formation of hot and cool plasma motions in both the downward as well as the upward directions from the reconnection site. Some secondary dynamical plasma processes, e.g., the formation of the jet-like structure in the vicinity, are also seen at later times in the same magnetic domain. Therefore, we establish the facts that such a reconnection is forced and affects severely the localized coronal regions both in terms of energetics as well as plasma dynamics. Such a physical phenomenon should be examined in detail while we study the dynamical solar coronal/eruptive regions.

As we are well aware, the concept of forced reconnection is established in analytical theory and numerical modeling for a variety of plasmas, including solar and astrophysical plasmas (e.g., Hahm & Kulsrud 1985; Vekstein & Jain 1998; Browning et al. 2001; Birn et al. 2005; Jain et al. 2005; Yamada et al. 2010; Beidler et al. 2017; Vekstein 2017; Potter et al. 2019, references cited there). Recently, Srivastava et al. (2019) have first presented the fact that, even in the presence of a smaller amount of resistivity, the efficient forcing from an external driver implemented in the vicinity of an X-point, can trigger reconnection at a reasonable rate. They have also observed a similar phenomenon in the large-scale solar corona directly. However, more stringent modeling of the complex magnetic field configuration that mimics the observed conditions (e.g., as seen in the present observations), which includes the role of the external drivers associated with the realistic eruptive conditions (e.g., a cool prominence eruption in the present case), and quantifies the heating and dynamical motions, are necessary (Figures 1–5). After the claim of the first direct detection of the observational signature of a forced reconnection in the large-scale solar corona by Srivastava et al. (2019), this is another remarkable case that depicts a complex magnetoplasma environment in the localized solar corona where forced reconnection took place, caused by the eruption of a cool
prominence system, resulting in a significant evolution in temperature and plasma dynamics in the solar corona. In conclusion, these meaningful multwavelength observations provide the signature of a prominence driven forced reconnection, and demonstrate its role in heating the corona locally, and also in generating the hot plasma flows and jet-like motions. However, more observations and refined data-driven modeling of the forced reconnection should be performed, and its potential role in the heating and dynamics of the solar corona must be explored and established in the light of such novel observational findings.

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