List of Figures

Figure 1.1 Solar structure (Chandra 2006). .................................................3
Figure 1.2 A picture of a typical sunspot (from www.google.com) ..........5
Figure 1.3 Solar cycles (courtesy: HATHAWAY/NASA /MSFC 2009/07) ........................................................................................................7
Figure 1.4 Main components of the Sun-Earth system. Photons, particles and plasma flow from the Sun, their variations driven by dynamo action in the convection zone that produces sunspots and bright active regions. Photons from the Sun’s surface and atmosphere reach the Earth’s surface and atmosphere while the magnetosphere intercepts the particles and plasma. Eruptive events such as coronal mass ejections (shown emerging from the Sun’s atmosphere into the solar wind) perturb the magnetosphere, allowing energetic particles to penetrate Earth’s atmosphere in the Polar Regions (where the field lines are anchored) (Adapted from Lean, 2008) ..........10

Figure 1.5 SOHO/LASCO image (with an EIT 195 image superposed) obtained on 2001 December, 20 showing the three-part structure of a CME above the southwest limb (Gopalswamy et al., 2006) ..........13

Figure 1.6 A time sequence of Solar Maximum Mission coronagraph images showing a coronal mass ejection on August 18, 1980, (from Hundhausen, 1999) ........................................................................................................15
Figure 1.7 The Structure of solar eruptions (Forbes, 2000) .................37
**Figure 1.8** Schematic diagram of a disrupted magnetic field that forms in an eruptive process. Catastrophic loss of equilibrium, occurring in a magnetic configuration including a flux rope, stretches the closed magnetic field and creates a Kopp-Pneuman-type structure (taken from Lin, J., 2004). Upper part: sketch of the flux rope/CME model of Lin and Forbes (2000), showing the eruption of the flux rope, the current sheet formed behind it and the post flare/CME loops below, as well as the inflows and outflows associated with reconnection. Lower part: enlarged view of the post flare/CME loops (from Forbes and Acton, 1996).

**Figure 2.1** Solar radio spectrum observed in the frequency range of 25–2500 MHz (from Hiraiso Solar Radio Observatory, NICT, Japan, [http://hirweb.nict.go.jp](http://hirweb.nict.go.jp)).

**Figure 2.2** Different types of radio bursts associated with solar flares. (Adapted from Hiraiso Solar Observatory).

**Figure 2.3** A scheme of the different kinds of electromagnetic radiation emitted from flares. (Adapted from Svestka, 1975).

**Figure 2.4** Typical curves of the flare time development at different wavelengths: 3 km (100 KHz), 100 m (3 MHz), 1.5 m (200 MHz), 10 cm (3000 MHz), 1 cm (30 GHz), 6563 Å (Hα), 300-1500 Å (UV), 2-12 Å, <1.2 Å (>10 KeV), <0.25 Å (>50 KeV), and <0.06 Å (>200 KeV). (Adapted from Svestka, 1975).

**Figure 3.1** Histogram showing the speed distribution of 367 DH CMEs. The average and median speed is 1048 km/s and 943 km/s respectively.
Figure 3.2  Histogram showing the width distribution of 367 DH CMEs. The last bin in the histogram shows halo CMEs whose width is 360 degree, this bin has been divided by 10 just to bring it to scale..........................69

Figure 3.3  Variation of annual average width of DH CMEs......................70
Figure 3.4  Variation of annual average speed of DH CMEs......................70
Figure 3.5  Histogram showing the distribution of the acceleration. A clear bias towards events with deceleration is obvious.................................71
Figure 3.6  Most of annual average width lies in the range 70-90° and annual average speed in the range 800-1400 km/s...........................................72
Figure 3.7  Annual variation of mean sunspot number and the number of DH CMEs................................................................................73

Figure 4.1  Speed distribution of type IV bursts associated CMEs, observed during 1996-2007.................................................................80
Figure 4.2  Duration of 13 moving type IV bursts observed during 1996-2007.........................................................................................81
Figure 4.3  Ending frequency of 13 moving type IV bursts observed during 1996-2007.................................................................81
Figure 4.4  Annual variation of mean sunspot number and the number of type IV radio bursts. Red line exhibits mean sunspot number divided by ten and blue line represents number of type IV bursts.................................83
Figure 4.5  Annual variation of total number of solar flares and the number of type IV radio burst Red line exhibits total number of solar flares divided by hundred and blue line represents number of type IV bursts.................83

Figure 5.1  Distribution of life times of multiple type II radio bursts........107
Figure 5.2  Starting frequency of 42 multiple type II bursts ............108
Figure 5.3  Ending frequency of 42 multiple types II bursts ............109
Figure 5.4  Histogram showing the distribution of bandwidth of 42 multiple types II bursts .................................................................110
Figure 5.5  Distribution of normalized drift rates of type II radio bursts .........................................................................................110
Figure 5.6  The scatter plot of the start frequency of type II bursts and their normalized drift rates .................................................................111
Figure 5.7  Distribution of CMEs velocities and drift velocities of multiple type II radio bursts .................................................................112
Figure 5.8  Speeds of CMEs associated with multiple types II bursts ....113
Figure 5.9  Scatter plot of ending and starting frequencies of 42 multiple types II bursts ........................................................................113
Figure 5.10 Distribution of angular width of CMEs associated with multiple type II bursts .................................................................114
Figure 5.11 Distribution of acceleration of CMEs associated with type II bursts ..............................................................................114