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Radio signatures of particle acceleration in the solar corona

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1 Extended Abstract

The acceleration of charged particles to high energies is a common, though poorly understood, process in natural plasmas. In the astrophysical domain the heliosphere offers particularly favorable conditions for its study because of the proximity of the observer to the acceleration sites and the ensuing possibility to observe radiative signatures with spatial and temporal resolution, and to combine remote sensing observations with in situ measurements. Although candidate processes such as shock waves, magnetic reconnection and turbulence involve much smaller spatial and temporal scales than accessible to observations, multi-instrument observations reveal an increasing number of constraints.

Radio emission is generated at the Sun and in the interplanetary medium by non thermal electrons, through a variety of processes: incoherent gyrosynchrotron emission of mildly relativistic electrons (hundreds of keV to some MeV) in strong magnetic fields, collective emission processes of electrostatic waves that subsequently couple to escaping electromagnetic waves. Cyclotron maser emission was also proposed at times, and discarded at others, just to come up again when unusual types of intense radio emission challenged our overall understanding. The interest of radio emission in the study of particle acceleration at the Sun is that it shows processes in the dilute corona, where collisional emission mechanisms such as bremsstrahlung at X-ray wavelengths are inefficient, and that collective radio emission is a very sensitive tracer of non thermal electrons and their propagation.

The original diagnostic contributions of radio observations include

- the identification of electron acceleration in the non-flaring corona, and possibly in quiet regions of the lower atmosphere;
- the tracking of electron beams in the corona and resulting evidence on the acceleration regions in solar flares;
- the prime evidence for shock waves in eruptive solar events, with the possibility to remotely determine shock parameters;
- the evidence for time-extended electron acceleration in eruptive solar events that persists well beyond the impulsive flare phase.

The talk will start with a short overview on these observations and then discuss in more detail the last two subjects:

1. While the radio emission of shock waves was identified in the corona since the early years of solar radio observations, recent numerical simulations and detailed spectrographic and imaging observations have brought new insight into the spectral structure of the radio emission and its relation with the shock geometry and the compression ratio at coronal shock fronts. I will attempt to review relevant work and the conclusions that we can draw on the parameters of shock waves in the corona, and will compare them with other diagnostics of coronal shock waves.
2. Radio emission in the aftermath of coronal mass ejections (CMEs), so-called type IV bursts, are the oldest known signature of particle acceleration in eruptive processes after the impulsive flare phase. Much work has been done over decades to understand their relationship with the flare process, coronal shock waves, and CMEs. I will review our present understanding and explore if there is a relationship between these radio emissions and the recent discovery, by FERMI/LAT, of long-lasting radiative signatures of relativistic protons in the solar atmosphere.

The upcoming Solar Orbiter and Solar Probe missions will focus the interest of a broad scientific community onto the investigation of solar-heliospheric relationships, and energetic particles will be an important part of this. Radio diagnostics from space and ground have an important role in this research because of their sensitivity to energetic electrons in an extended region of the corona.

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