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On the Radio Signatures Associated with the Development of Coronal Mass Ejections

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Abstract. The methods of radioastronomy are in important observational tool to explore magnetic energy releases in the solar corona. When combined with the useful diagnostics provided by observations in other wavelengths, namely with data from space missions such as Yohkoh, SOHO, and more recently RHESSI, these datasets allow us to track the progression of solar eruptive events from the low corona into the interplanetary medium. One of the most dramatic forms of solar activity, coronal mass ejections (CMEs) encompass a large range of spatial scales in a question of a few minutes. These go from the very small like current sheets, to small like active regions, to the very big like trans-equatorial loops and the transient seen in white light images (with angular extents in excess of 100 degrees for some events). Hence, in order to understand the CME phenomenon, its origin, and early development, we need a set of observations able to image the whole Sun with time cadences of the order of the second. Radio observations can do that presently. Multifrequency radio observations of the solar corona in the metric domain provide diagnostics of a wide variety of phenomena that occur in association CMEs. Radio imaging instruments can follow the processes leading to CME initiation, follow the expansion of the CME in the low corona, both on disk, and above the solar limb, and as such make the link with coronagraphic data. The characteristic signatures of the many CME related phenomena go from thermal emission of the eruptive cavity in the low corona, to direct imaging of the CME loops from synchrotron emission, to radio continua and shock associated emissions, recent progress on the understanding of the early development of CMEs, and on the coronal restructuring in the aftermath of the mass ejection, based on solar radio imaging from the Nancay Radioheliograph, is reviewed here.

Keywords. Sun: coronal mass ejections (CMEs)

Discussion

Jie Zhang: Given the high cadence of radio observation in the inner corona, can you see the acceleration or velocity change of the CME in the inner corona?

Maia: We are limited by resolution of the instrument. Above $\sim 1.5\ R_\odot$ the velocity seems to be the same as in LASCO C2. Below that there could be some acceleration but I can not estimate it reliably.

Yousef: If you have acceleration of electrons at the top of the loop coming down you get X-ray emission at the 2 footpoints of the loop. Is this the case in radio event you have shown?

Maia: I don't have X-ray emission available for these events. But the bursts are due to the plasma emission mechanism, that is, we are seeing only a slice in density.

Gopalswamy: 1. What is the nature of the intense radio emission at the place where the synchrotron loop connects to? May I suggest that it is the reconnection region from which non thermal electrons are injected?
2. In that case, the loop should be the same as the traditional moving type IV burst.

Maia: 1. Maybe. The origin of the electrons is not clear.
2. Yes, the CME radio loops are one of the categories of the traditional moving type IV burst.

Schwenn: Comment to the question about backward extrapolation. It works only for limb CMEs. If it comes from disk center, you will be off by several minutes. Careful! Also, the apparent lateral loop expansion could be due to a projection effect of a non-limb CME.

Maia: Yes, that is right. Extrapolating CMEs to the limb only makes sense for very fast CMEs (2000Km/s means $1R_\odot$ in about 6min); or for the ones you are sure that are very close to the limb. I agree also that "lateral" expansions must take care about projection effects. In the event presented (Nov 6, 1997), it is a "true" expansion because we see that the small loop systems which disappear are affected at the time the CME flanks reach them - For this event it's not simply a large structure emerging from behind the limb. In general Dr. Schwenn is right, it is more likely that we would be seeing projection effects.

Ruffolo: I'd like to ask more about the dangers of extrapolation. When we study solar energetic particles, from very fast CMEs, we want to compare with a CME lift-off time, which we extrapolate from LASCO C2 and C3. How bad is the timing error, and can radio people give us a more accurate time?

Maia: On average it's probable not very important but for a particular event you can be in error for something like 30min for these fast events ($\sim$1000Km/s). It depends greatly on the height of the first image. I found events whose velocity higher than $5R_\odot$ is about 70% less than in the low corona. And there is also the problem of knowing the longitude of the CME source.

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