RADIOASTRONOMY

FADING OF THE CONTINUUM OF NOISE STORMS IN THE DECAMETER RANGE RELATED TO CME

E.A. Isaeva

Institute of Radio astronomy of NAS of Ukraine, *isaevaode@gmail.com*

ABSTRACT.   In this paper, we studied the incomprehensible fading of a continuum of noise storms and type IV continual bursts in the decameter range, coinciding in time with coronal mass ejections (CMEs) for solar proton events (SPE). A comparative analysis showed that about 60% of the CMEs are accompanied by the fading of the continuum of noise storms and type IV continual bursts in the range of 25-30 MHz. It is shown that the fading of the continuum of a noise storm associated with a CME is distinguished by the intensity and duration of fading, as well as the width of the fading band and the frequency at which the maximum fading depth is observed. Moreover, detailed studies have shown that, against the background of a general decline in the radiation flux, a fine temporal structure at adjacent frequencies remains. This may indicate that the radiation is shielded by an external region in the path of radiation propagation. It can be a cold and dense cloud of the CME itself or absorption in the ionosphere. Absorption at low frequencies in the Earth's ionosphere is quite possible, since the x-ray and ultraviolet radiation of the flare can cause additional short-term ionization. In this regard, studies have been conducted on the relationship of the fading of the continuum of noise storms with x-ray flares. A comparative analysis showed that there is a fairly strong relationship between the integral flux and the effective duration of x-ray flares with the integral flux and the effective duration of the decrease in the continuum of noise storms, respectively. Moreover, the relationship between the effective durations is slightly higher, where the correlation coefficient between the studied values is ≈ 0.71. It was also shown that short-term impulse fading is associated with impulse x-ray flares, and long-term with gradual long-term x-ray flares. It was noted above that absorption can also occur in the body of the CME itself, therefore, the relationship between the parameters for lowering the continuum of noise storms at a given frequency and the speed of the CME was investigated. A comparative analysis showed that there is a fairly strong relationship between the maximum fading depth and the CME speed, where the correlation coefficient between the studied values is ≈ 0.65.

АНОТАЦІЯ. У даній роботі досліджені незрозумілі завмирання континууму шумових бур і континуальних сплесків IV типу в декаметровом діапазоні, які збігаються у часі з корональними викидами маси (КВМ) для сонячних протонних подій (СПП). Порівняльний аналіз показав, що близько 60% КВМ супровод-

жуються завмиранням континууму шумових бур і континуальних сплесків IV типу в діапазоні 25-30 МГц. Показано, що завмирання континууму шумових бур, пов'язані з КВМ, відрізняються інтенсивністю і тривалістю завмирання, а також шириною смуги завмирання і частотою на якій спостерігається максимальна глибина завмирання. Більш того, детальні дослідження показали, що на тлі загального спаду потоку радіовипромінювання зберігається тонка тимчасова структура на сусідніх частотах. Це може вказувати на те, що випромінювання екранується зовнішньої областю на шляху поширення випромінювання. Це може бути холодна і щільна хмара самого КВМ або ж поглинання в іоносфері. Поглинання на низьких частотах в іоносфері Землі цілком можливо, так як рентгенівське і ультрафіолетове випромінювання спалаху може викликати додаткову короткочасну іонізацію. У зв'язку з цим були проведені дослідження зв'язку завмирання континууму шумових бур з рентгенівськими спалахами. Порівняльний аналіз показав, що існує досить сильний зв'язок інтегрального потоку і ефективної тривалості рентгенівських спалахів з інтегральним потоком і ефективною тривалістю зниження континууму шумових бур, відповідно. Причому, зв'язок між ефективними длительностями трохи вище, де коефіцієнт кореляції між досліджуваними величинами ≈ 0.71. Також було показано, що короткочасні імпульсні завмирання пов'язані з імпульсними рентгенівськими спалахами, а тривалі з поступовими тривалими рентгенівськими спалахами. Вище зазначалося, що поглинання може відбуватися і в тілі самого КВМ, тому бул досліджен зв'язок між параметрами зниження континууму шумових бур на даній частоті і швидкістю КВМ. Порівняльний аналіз показав, що існує досить сильний зв'язок між максимальною глибиною завмирання і швидкістю КВМ, де коефіцієнт кореляції між досліджуваними величинами ≈ 0.65.

Keywords: speed of the CME, fading continuum of noise storms, integral flux.

1. Introduction

The interest in coronal mass ejections is due to their high geoeffectiveness.

Broadband studies in the radio range showed that most of the CME formation events are accompanied by sporadic phenomena in the radio range (about 80% of the total number of cases). In 50% of cases, the phenomena in the radio band

preceding the registration of the CME are broadband. At the same time, it was shown that CMEs that are not accompanied by broadband phenomena in the radio range are ejections with a small angular width <40° and an average ejections velocity of not more than 700 km/s.

A generalization of the observational data in the radio range indicates that at the stage of CME formation in the meter-decameter bands, an increase in the continuum of noise storms with characteristic quasiperiodic oscillations is observed until the noise storms completely fade before the CME exit (Durasova et al., 1999, 2002). In the centimeter-decimeter ranges, at the stage of the CME formation, an increase in the microwave radiation intensity is observed, as well as powerful bursts of the GRF type with characteristic temporal fluctuations in the flux intensity with periods > 20 minutes, and short-period fluctuations in the flux intensity are observed immediately before the CME output, for 10-15 minutes with periods ranging from 6-22 seconds (Grechnev, 2003; Fridman & Sheiner, 2008).

It should also be noted that there is a strong connection between CMEs and broadband continual type IV bursts. It was shown in (Isaeva & Tsap, 2017) that there is a strong relationship between the CME velocity and the integral flux of microwave bursts (μ-bursts) for proton events. Moreover, the relationship between the speed of the CME and the integral flux of type IV continual bursts largely depends on the frequency of the continual radio burst. With a decrease in the frequency of radio emission of continual bursts, the relationship between the CME velocity and the integral flux of continual bursts sharply decreases and is practically absent already in the meter-decameter wavelength ranges.

2. Initial data and research results

The studied sample contains 112 solar proton events (SPE) for the period from 24-11-2000 to 23-07-2016 years, accompanied by CME. Of 112 CME events, 67 ($\approx$ 60%) were accompanied by the fading of a continuum of noise storms and type IV continual bursts in the decameter range at frequencies of 25-30 MHz.

For analysis, we used original recordings of the dynamic spectrums in the range of 25-180 MHz with Solar Radio Spectrograph (SRS) (http://www.ngdc.noaa.gov/stp/ space-weather/solar-data/solar-features/solar-radio/rstn-spectral/), CME data (SOHO/LASCO CME CATALOG), list of proton events (ftp://ftp.swpc.noaa.gov/pub/indices/ SPE.txt), original recordings of the x-ray radiation of the Sun in the range of 1-8 Å and the intensity of the proton flux I_p with an energy of E_p >1-100 MeV according to GOES (https://sat-dat.ngdc.noaa.gov/sem/goes/data/ new_avg/).

A comparative analysis showed that fading of noise storms is characterized by the frequency band width Δf, maximum intensity (depth) F_{max}, duration d and frequency f_{max} at which the maximum fading depth is observed. For most events, fading noise storms are observed in a narrow frequency band Δf from 125 kHz to 2 MHz. For most events, the maximum intensity (depth) of fading F_{max} is observed in the frequency region $f_{max} \approx 27$ MHz. In Figures 1 a) and b) show examples of the attenuation of the continuum of noise storms and type IV continual bursts at fixed frequencies taken from the original recordings of the dynamic
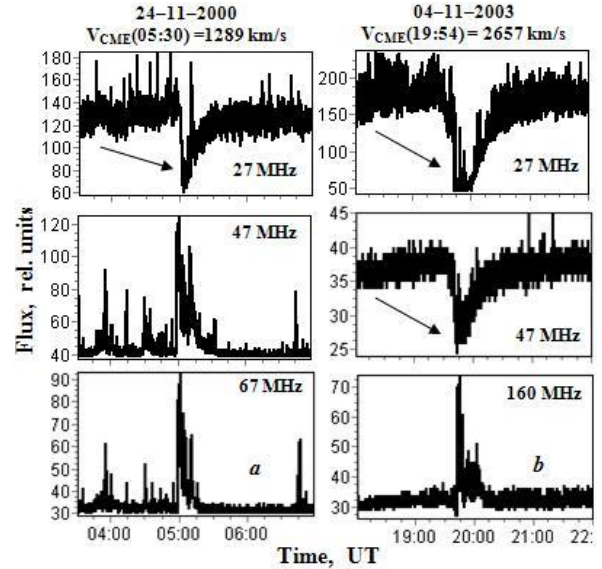

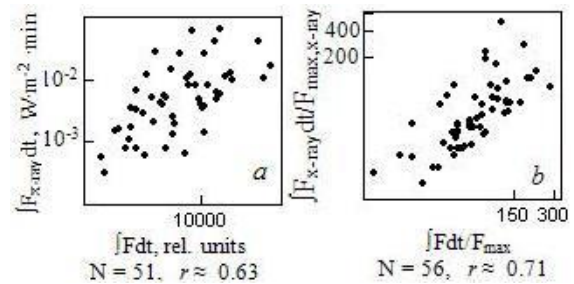Figure 1: Examples of fading of a continuum of noise storms and continual bursts associated with a CME.

Figure 2: The relationship between the parameters of the fading continuum of noise storms and the parameters of x-ray bursts.

spectrum from Solar Radio Spectrograph. The effect of fading noise storms is shown by black arrows. Above the figures, the date, time of registration and speed of the CME are indicated. It was noted above that for most events, the effect of fading noise storms is observed in a narrow frequency band Δf from 125 kHz to 2 MHz. However, for some events, fading can be observed in the band 40-60 MHz, for example, as for the event 04-11-2003 (see Figure 1 b).

It is interesting that, against the background of a general decrease in the flux, the fine temporal structure is preserved (it can be seen from a comparison with the fine temporal structure at neighboring frequencies in Figure 1). This may indicate that the radiation is shielded by an external region in the path of radiation propagation. It can be a cold and dense cloud of the CME itself or absorption in the ionosphere. Absorption at low frequencies in the Earth's ionosphere is quite possible, since the x-ray and ultraviolet radiation of flares can cause additional short-term ionization. In connection with these, studies were conducted of the relationship between the parameters of fading noise storms at a frequency of 26.875 MHz and the parameters of x-ray bursts in the range of 1–8 Å.

A comparative analysis that there is a fairly strong relationship between the integral flux of lowering the continuum of noise storms $\int Fdt$ and the integral flux of x-ray bursts $\int F_{x\text{-}}$

$_{ray}dt$ (see Figure 2 a), as well as between the effective duration of the decrease in the continuum of noise storms $\int Fdt/F_{max}$ and the effective duration of x-ray bursts $\int F_{x\text{-}ray}dt/F_{max,\text{x-ray}}$ (see Figure 2 b). Moreover, the relationship between $\int Fdt/F_{max}$ and $F_{x\text{-}ray}dt/F_{max,\text{x-ray}}$ is much higher, where the correlation coefficient r between the studied values is ≈ 0.71. Additional studies have shown that there is a definite relationship between the duration of fading noise storms d and the duration of x-ray bursts and continual microwave bursts. It was also shown that short-term impulse fading is associated with impulse x-ray flares, and long-term with gradual long-term x-ray flares.
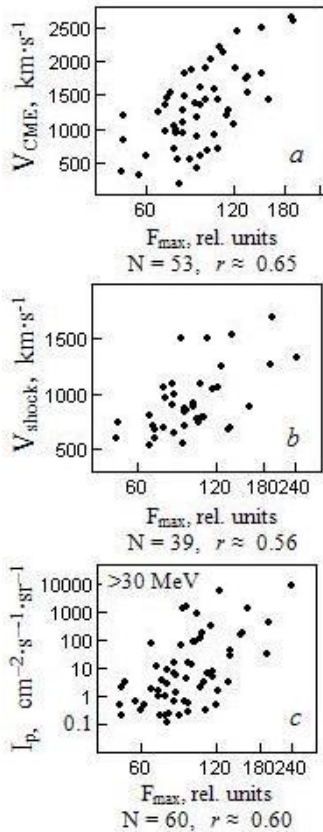

Figure 3: Relation of the intensity of the fading of the continuum of noise storms to the CME speed V_{CME}, the shock wave velocity V_{shock}, and the proton flux intensity I_p.

It was noted above that absorption at low frequencies can also occur in the body of the CME itself. In this regard, studies have been conducted on the relationship between the parameters of fading noise storms and the speed of the CME V_{CME}. A comparative analysis showed that the strongest relationship is observed between the CME speed V_{CME} and the maximum fading intensity (depth) F_{max}, where the correlation coefficient r between the studied values is ≈ 0.65 (see Figure 3 a). In this paper, we are talking about solar proton events, which, as you know, are often accompanied not only by proton fluxes, but also by coronal shock waves (CSW). A comparative analysis showed that there is a definite relationship between the fading intensity of noise storms F_{max} and the velocity of coronal shock waves V_{shock} (see Figure 3 b), where the correlation coefficient r between the studied values is ≈ 0.56. It should also be noted that

there is a fairly strong relationship between the fading depth of noise storms and the proton flux intensity I_p with an energy of $E_p > 30$ MeV (see Figure 3 c).

3. Discussion of the results

It is known that for thermal braking radiation in the CME body or in the ionosphere, the decrease in intensity should be broadband toward low frequencies. And in this case, for most events, the decline in intensity occurs in a narrow band, decreasing not only at higher frequencies, but also at lower frequencies. In this regard, this effect cannot be associated with absorption in the CME body or in the ionosphere.

A possible alternative explanation, according to V.F. Melnikov, there may be the following effect. Usually, short-term decreases in the intensity of meter radio emission in type IV bursts are associated with a breakdown of the cone instability, which is the cause of the continual coherent radiation. The failure is caused by the injection of a new portion of energetic electrons that fill the loss cone, i.e., lead to a sharp decrease in the transverse anisotropy of the electrons trapped in the magnetic trap. Perhaps this effect works in this case. But here, too, there is a certain problem associated with narrowband. Why is the fading band so narrow? Indeed, despite the fact that radio emission in type IV bursts is coherent, i.e., locally narrow-band, a broadband of meter-decameter radiation is generally observed. This is due to the large extent and longitudinal heterogeneity of the trap (magnetic loop). The way out of the contradiction can be this: the instability breaks down only in a relatively small quasihomogeneous part of the trap, while radiation continues to be generated in other parts of the trap.

References

Durasova M. Fridman V., Sheiner O.: 1999, in *Proc. 9th European Miting on Solar Phisics* (ESA,SP-448, December 1999), 972.

Durasova M., Fridman V., Sheiner O.: 2002, in *Proc. SOLSPA* (ESA SP-477, February 2002), 373.

Fridman V., Sheiner O.: 2008, *Solnechno-zemnaya fizika*, № 12, **1**, 79.

Grechnev V: 2003, *Astrophys. J.*, **588**, 1163.

Isaeva E., Tsap Yu.: 2017, *Odessa Astron. Publ.*, **30**, 222.

Sheiner O., Fridman V.: 2005, *Cambrige University Press*, 233.

Sheiner O., Fridman V.: 2005, *Cambrige University Press*, 235.