Proceedings of the Research Institute of Atmospherics,
Nagoya University, vol. 26 (1979)

SUDDEN DECREASE OF MICROWAVE SOLAR RADIO EMISSION

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Abstract

Total flux observations on the microwave solar radio emission sometimes show depressions after bursts or without bursts. These, classified as 'post burst decrease' or 'absorption', are gradual phenomena and the duration is usually more than an hour. In contrast to these phenomena, the authors found two sudden decreases of the total flux just before the bursts of July 21, 1978 and September 7-8, 1978. The durations were shorter than 10 minutes. The observational results are given which were obtained by four microwave polarimeters and two interferometers at Toyokawa. A preliminary interpretation is also given for the event of September 7-8, 1978 using the data of optical, soft X-ray and meter-wave observations.

1. Introduction

Sometimes the total flux of microwave solar radio emission decreases below the quiet level. This phenomena was first found by Covington & Dodson (1953) in the record of the total flux at 2800 MHz at Algonquin Radio Observatory. This event was a post burst decrease. Hα observation at McMath-Hulbert Observatory showed that the dark filament covered the part of the active region at that time.

In 1959, post burst decrease was also observed at Toyokawa

Observatory (Tanaka & Kakinuma, 1960). This event was observed by four polarimeters at frequencies of 9400, 3750, 2000 and 1000 MHz. One-dimensional distributions of the intensity and polarized component were also obtained at 9400 and 4000 MHz. As a result, it was found that the polarized S-component disappeared temporarily. Hα image obtained at Tokyo Astronomical Observatory showed that the dark surge covered only the part of the flare and not the sunspot (Kakinuma & Hiei, 1960). Polarized S-component, however, originates over the sunspot where the magnetic field is strong. Therefore, they concluded that the polarized S-component was absorbed by surge-like material, which covered the most part of the active region. They assumed the physical parameters of the surge-like material and showed that it is optically thick at microwave frequency and is thin at Hα.

Yurovskii (1969) observed the Sun by the RT-22 telescope at Crimean Astrophysical Observatory in 1967 and found that 'negative bursts' are frequently observed at 10 cm, and also found that the decrease of the flux density can precede or follow the impulsive burst. Covington (1969) identified an isolated 'absorption'. Furthermore, Covington (1973) reported the 'negative precursor' associated with the movement of the dark filament before the flare. As this event, however, is superposed on a gradual rise and fall event, it also might have been the decay phase of the gradual rise and fall event (Svestka, 1976). Sawyer (1977a) analyzed the same event. She also studied the relation between negative bursts and absoptions using the microwave data at Algonquin and Penticton and Hα at Sacrament Peak (Sawyer, 1977b). She expected to see a different phase of ejection (or infall) in Hα than at radio frequencies. She also calculated the optical depth of the overlying matter at microwave frequencies and at Hα using the model of Poland et al. (1971).

The burst type of 'absorption' is given for the decrease of total flux (Instruction Manual for Monthly Report, 1975), but in this paper we use the morphological term 'negative burst'.

At Toyokawa, the total flux and polarization observations of the Sun at four microwave frequencies have been carried out regularly. The interferometric observations at two frequencies have also been carried out. Since November 30, 1959, many negative bursts have been observed at Toyokawa. Recently, two distinct depressions of total flux with short duration were observed just before the burst. In this paper, we first summarize the characteristics of the negative bursts observed at Toyokawa between 1959 and 1977. Next, we show the observational results of the two distinct events in 1978.

2. Observations and data

The polarimetric observations of the Sun at 9400, 3750, 2000, and 1000 MHz have been carried out from sunrise to sunset every day. One-dimensional distributions of the intensity and polarization of the Sun at 9400 and 3750 MHz have been also observed by two sets of interferometers. Observational results are published in 'Monthly Report of the Solar Radio Emission (Toyokawa)'.

In 1977, new sets of polarimeters started to operate and the parallel observations have been carried out since then (Torii et al, 1979). Outputs are recorded by chart recorders, and are also digitized and stored on a magnetic tape by a small computer. The sampling interval is 0.1 second. Therefore the detailed analysis became possible. This data acquisition system is described in Shibasaki et al. (1979). The event of July 21, 1978 was also observed by the interferometer at 3750 MHz, but the event of September 7-8, 1978 was not observed because it occured out of the observing time.

3. Characteristics of negative bursts

Since November 30, 1959, when the negative burst was first observed at Toyokawa, post burst decreases and isolated negative bursts are sometimes observed. According to the Monthly Reports up to December 1977, 31 negative bursts were observed. Out of the 31 events, post burst decrease were 10 and isolated negative bursts were 14. In the rest of the events, simple or complex types of bursts were superposed on the negative bursts. Nineteen events were also observed by interferometers and the source positions were determined. Mean duration of the events was 112 minutes at 3750 MHz, and the maximum was 280 minutes and the minimum was 21 minutes. The frequency spectra of the depressed flux of 19 events out of the 31 events have maxima at 3750 MHz. Nine events have maxima at 9400 MHz. Figure 1 shows the mean profile of the frequency spectrum, in which each spectrum of the negative burst is normalized at 3750 MHz.

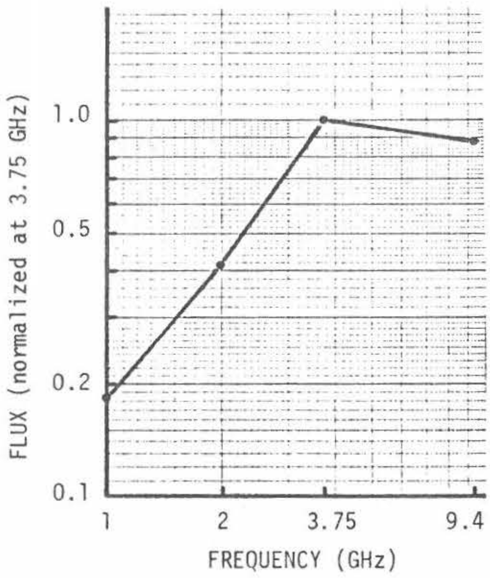

Figure 1. Mean spectrum of 31 negative bursts observed at Toyokawa between 1959 and 1977. Each spectrum is normalized at 3750 MHz.

4. The event of July 21, 1978

The time profile of this event is shown in figure 2. This event was observed by two sets of polarimeters at four frequencies and the interferometer at 3750 MHz. The enhancement at 9400 MHz was so weak that we cannot recognize this event by the interferometer at 9400 MHz. This event started at 0112.5 UT at 2000 and 1000 MHz with sudden decrease, and it reached minimum at 0113.9 UT. Since then, the fluxes increased. At the same time, the enhancement of 3750 MHz started. Positive maxima were at 0114.9 UT at 2000 and 1000 MHz and 0115.1 UT at 3750 MHz. The flux at 3750 MHz decreased gradually, but the flux at 2000 and 1000 MHz decreased suddenly and became negative again. The second minimum was at 0115.7 UT. The whole of this event was within 5 minutes and it differs from the mean duration of usual negative events which was described in the previous section. Moreover, the depression was not seen at 9400 and 3750 MHz, and the enhancement was very small at 9400 MHz. The frequency spectra of the depressed flux are shown in figure 3. It also differs from the mean spectrum. This

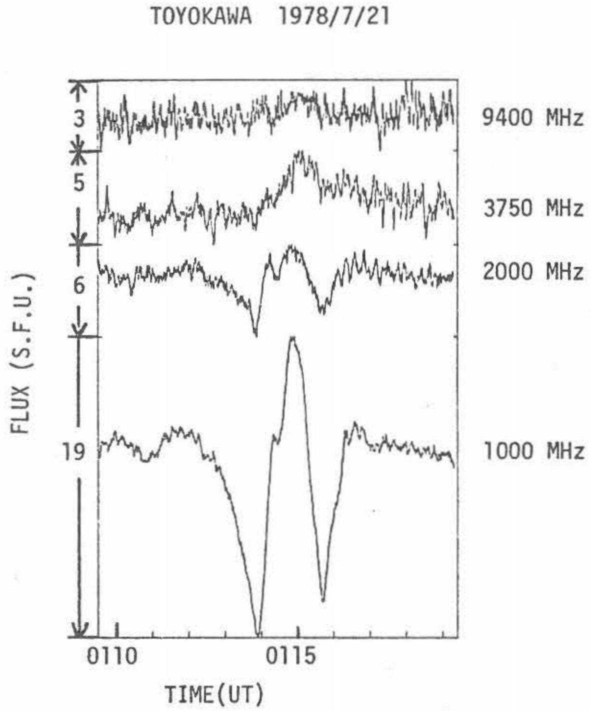

Figure 2. Time profiles of the event on July 21, 1978.

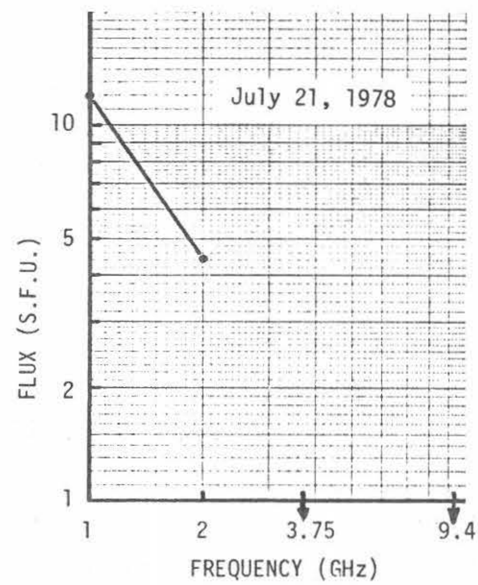

Figure 3. Frequency spectrum of the depressed flux value at the first minimum of the event on July 21, 1978.

type of frequency spectrum was not found in the 31 events. The time profiles of the event suggest that the simple type of burst might be superposed on one negative burst. In this case, the depressed value were larger at 2000 and 1000 MHz much from that shown in figure 3, however, the characteristic of the spectral profile would not change. The enhancement at 3750 MHz was also observed in the one-dimensional drift scan observations by the interferometer and it was found that this event occurred in McMath region 15403. The position of the negative part was not observed, however, it can be assumed from the time coincidence that the negative event occurred at the same position. This region appeared on July 8 on the east limb and caused several great bursts afterwards. The flux of the S-component at 9400 MHz exceeded that at 3750 MHz, and the polarization degree was high (10 percent at 9400 MHz) at around the central meridian passage. The activity was very high. At the time when the event occurred, this region was on the west limb. Figure 4 shows the drift scan curves which were taken at 0257 UT and the map which was taken at 0312 UT on the same day. Soft X-ray observations by GOES (SGD, 1978) show that a small enhancement (start 0109 UT, Peak 0116 UT) corresponds to this event. Optical observations were not carried out during this event (SGD, 1978).

A similar event was found in the record of August 30, 1957. The duration of the whole event was 5 minutes. It was classified as a complex type of event. The frequency spectrum of the negative part has a maximum at 9400 MHz, and it differs from that on July 21, 1978.

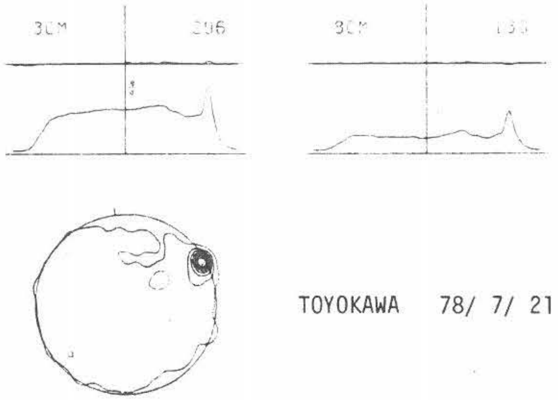

Figure 4. One-dimensional intensity and polarization distributions at 9400 and 3750 MHz, and the radioheliogram at 9400 MHz on July 21, 1978. The one-dimensional distributions were obtained at around 0257 UT and the heliogram was obtained at around 0312 UT.

5. The event of September 7—8, 1978

The event of September 7-8, 1978 is shown in figure 6. Several small bursts including grudual rise and fall event occurred successively on this day: the end of this event is not clear. The duration of the main part of this event is about 20 minutes. The precursor started at 2330 UT on September 7, and lasted 10 minutes. There were several spikes in the precursor at 1000 MHz. At 2340 UT, sudden decrease of total flux started and lasted 10 minutes. This decrease was not so sudden as that of July 21, 1978, but the duration is shorter than the 31 negative bursts in section 3. After the decrease, enhancement lasted 10 minutes with maximum at 2352.5 UT. The post-burst levels at 2000 and 1000 MHz were lower than the pre-burst levels. The enhancements at 9400 and 3750 MHz had no clear maxima and cotinued gradually to the next burst. This event occurred out of the observational time of the interferometers: we could not find the position at microwave frequencies. This event was also observed at Penticton, Canada at 2700 MHz (SGD, 1978). The time profile of this event is shown in figure 5. The frequency spectrum of the depressed fluxes using the data of Toyokawa and Penticton is shown in figure 7. The spectral profile is similar to the mean profile of the 31 events, and has a peak at 3750 MHz. The results of observations other than microwaves are also shown in figure 6. Sudden disappearence of a dark filament at S25W15 was reported in the Monthly Bulletin of the Tokyo Astronomical Observatory (1978). An importance-2F flare was also reported at the same position. This region was McMath 15518 and was spotless on that day. According to

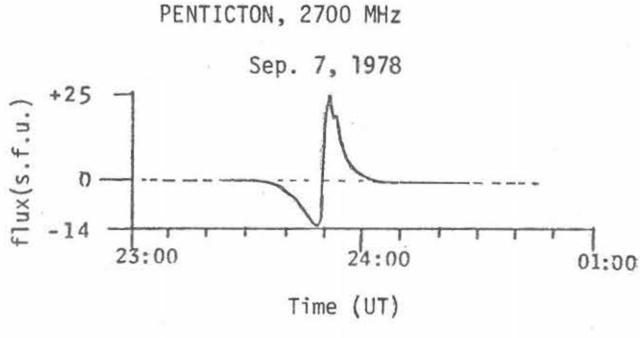

Figure 5. Time profile of the event on September 7-8, 1978 obtained at D.R.A.O. Penticton B.C. Canada (SGD, 1978).

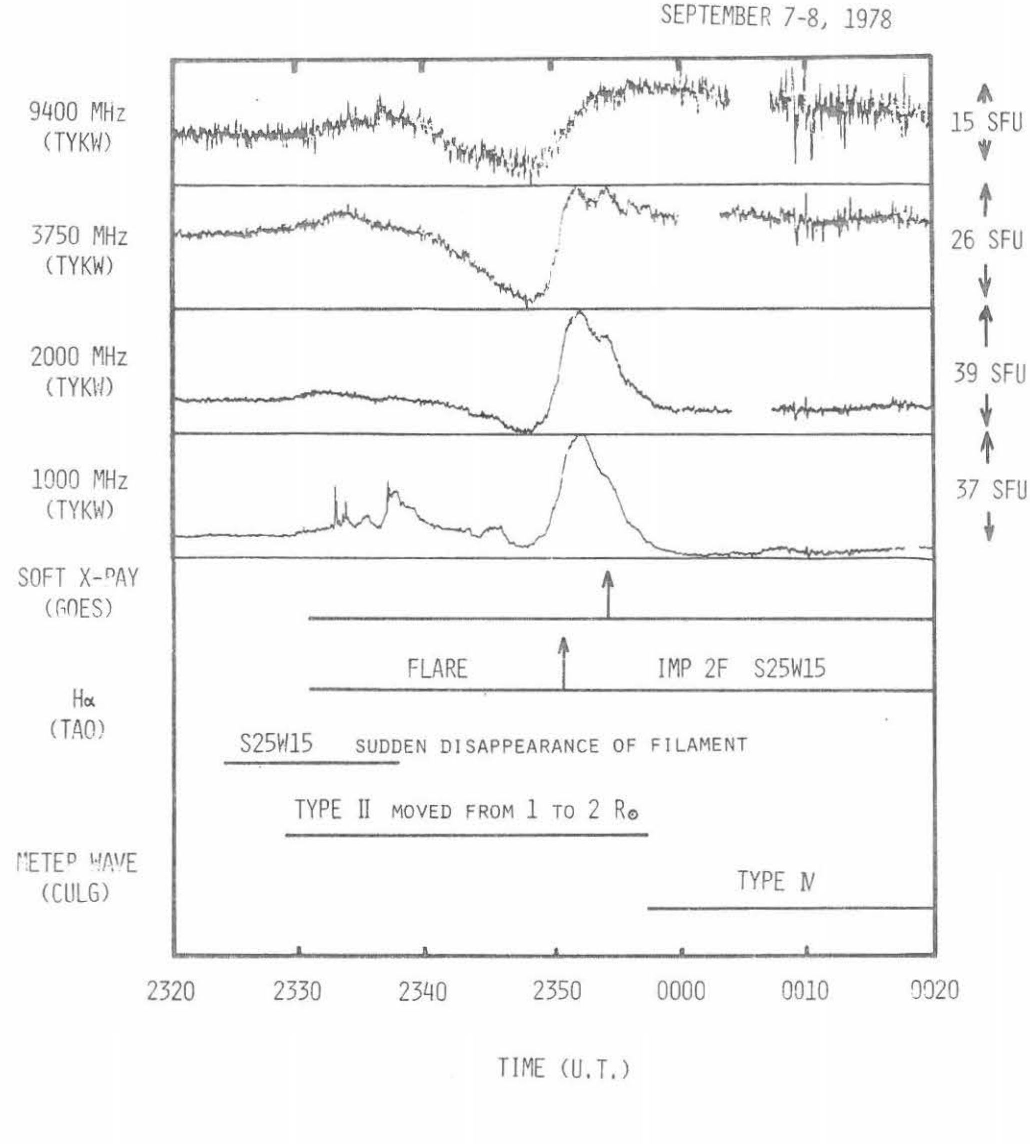

Figure 6. Time profiles of the event on September 7-8, 1978. Soft X-ray data are from GOES (SGD, 1978). Hα data (flare and dark filament) are from Tokyo Astronomical Observatory (Monthly Bulletin on Solar Phenomena, 1978). Meterwave data are from Culgoora Solar Observatory (SGD, 1978).

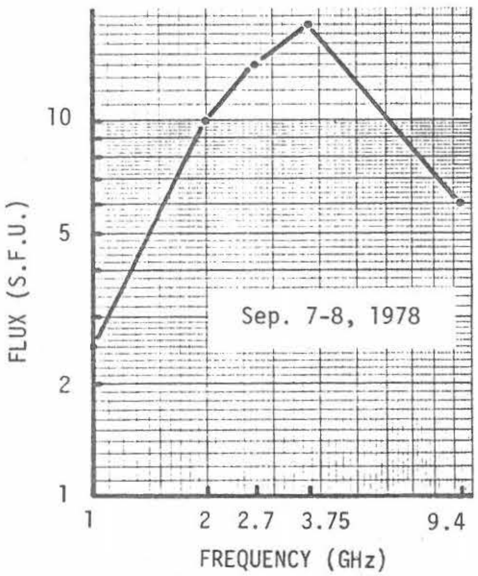

Figure 7. Frequency Spectrum of the depressed flux value of the event of September 7-8, 1978.

Dodson and Hedeman (1970), flares that occur in old regions without sunspots are quite generally preceded by filament motion. The event we are dealing with corresponds to this type of event. Soft X-ray observations by GOES (SGD, 1978) showed that the enhancement started at 2331 UT and reached maximum at 2354 UT. The start is at the same time with the optical flare. The complex sources were observed at metric wavelength with the Culgoora radioheliograph (SGD, 1978). A type II source moved outwards from 1 to 2 solar radii at position angle of 0° between 2329 UT and 2357 UT. Also a type IV source was observed at the central distance of 0.6 solar radius and the position angle of 240° between 2357 UT and 0043 UT. The 9400 MHz radio map at 0303 UT and the one-dimensional intensity and polarization distributions at 9400 and 3750 MHz are shown in figure 8. This figure shows that there is no strong S-component at the McMath region 15518. Two strong S-components are associated with the McMath regions 15508 and 15509 near the 15518. In the one-dimensional distributions, these two components are superposed. The fluxes of these components are 44 s.f.u. at 9400 MHz and 57 s.f.u. at 3750 MHz.

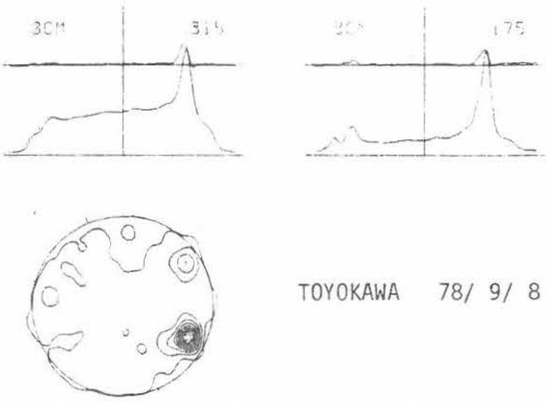

Figure 8. One-dimensional intensity and polarization distribution at 9400 and 3750 MHz, and radioheliogram at 9400 MHz on September 8, 1978. The one-dimensional distributions were obtained at around 0248 UT and the heliogram was obtained at around 0303 UT.

6. Summary and discussion

6-1. The Event of July 21, 1978

There were no other observations on this event except for the soft X-ray. This type of event was reported only on August 30, 1957. The characteristics of this event are as follows:

1) The duration is very short (5 minutes).
2) A simple type of burst occurred in the middle of the depressic
3) The frequency spectrum of the depressed flux has a maximum at 1000 MHz. There were no depressions at 9400 and 3750 MHz.

6-2. The Event of September 7-8, 1978

This event was observed at various spectral regions of the electro-magnetic wave: soft X-ray, Hα, microwave and meter wave. All the data are summarized in figure 5. The characteristics of this event are as follows:

1) The duration of the main part of this event was about 20 minutes, and the negative part was 10 minutes.
2) The negative part was preceded by a positive precursor 10

minutes earlier.

3) The spectrum of the decreased flux has a peak around 3750 MHz and it is similar to the mean profile of the 31 events.
4) The dark filament disappeared at the McMath region 15518 just before the onset of the depression. This region was spotless and the S-component was very small.
5) Depression of S-component is assumed to have occurred at McMath region 15508 and/or 15509.
6) The type II source was visible before the onset of the microwave burst and five minutes after the onset of sudden disappearance of filament.

Negative bursts can be interpreted in terms of 1) a temporal decrease of the S-component emission itself, or 2) an absorption of the S-component emission by overlying matter. We will discuss these two cases.

In the case 1), changes of electron density, electron temperature or magnetic field structure of the active region result in the diminution of the S-component emission. For example the decrease of electron temperature causes the diminishing of the S-component emission, when the S-component is optically thick. On the other hand, when the S-component is optically thin, the increase of electron temperature and/or the decrease of electron density causes a negative burst. A change of magnetic-field structure in an active region will influence the gyroresonance emission of the S-component. If the magnetic field strength in the corona is diminished by this change and the gyroresonance layer goes down to the lower atmosphere of the Sun, the strong S-component in the corona disappears. The frequency spectrum of the diminished part of the S-component emission will be similar to that of the gyroresonance-effective S-component emissions. The sudden disappearance of the dark filament observed just before the negative burst of September 7-8, 1978 suggests that the magnetic-field structure changed temporarily. The duration of the negative burst depends on the time scale of the change of physical parameters.

In the case 2), the frequency spectrum is determined by the optical depth of the matter. The fact that the frequency spectrum of the negative part is similar to that of S-components, indicates that the matter is optically thick at microwave frequencies. According to the calculations by Kakinuma and Hiei (1960) and by Sawyer (1977b), this matter is optically thin at Hα. In the event of September 7-8, 1978, the matter ejected by the filament disappearance seems to have the same nature as this matter. The fact that a type II event preceded the negative burst suggests the association of the type II-generating shock wave with the matter ejection.

As yet we have not enough data to decide which of the two mechanisms really works. If we can see the tenuous matter in the corona by a high space-time resolution heliograph at microwave frequencies, we will be able to solve this problem.

The event of July 21, 1978 is quite different in spectrum and duration from other negative bursts. Therefore we cannot directly adopt the above mentioned interpretations. This type of event is very rare and there is no other observations except for soft X-ray. It is necessary before a full discussion of this type of events to observe more events at various spectral regions of the electromagnetic waves simultaneously.

Acknowledgement

We would like to thank Messrs. Y. Tsukiji, S. Kobayashi, N. Yoshimi, S. Takata, and Miss A. Hara of the Toyokawa Observatory for their contribution to observations and data reductions. Thanks are also due to Dr. Victor L. Badillo for sending us multifrequency record of the Manila Observatory for the event of July 21, 1978.

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