ACADEMY OF SCIENCES OF THE USSR
RADIOTECHNICAL INSTITUTE

Preprint

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Presented to
IAGA Commission V Scientific Sessions
IAGA General Assembly, Madrid, September
1969

MOSCOW

OBSERVATIONS OF INTERPLANETARY PLASMA DISTURBANCES NEAR VENUS ON BOARD SPACECRAFTS VENERA-4 AND VENERA-6

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Interplanetary plasma and magnetic field disturbances were observed simultaneously on October 18, 1967 with charged particle traps and magnetometer aboard the Venera-4 when the spacecraft was approaching the Venus. Preliminary results of Venera-4 plasma measurements were reported earlier [1].

Plasma flux variation near Venus were also detected on board spacecraft Venera-6 by means of the charged particle trap[1].

These observations together with data on interplanctary plasma disturbances obtained near Venus on October 19, 1967 from american spacecraft Mariner-5 [2] enable one to conclude with more certainty then before that solar wind disturbances near Venus exist always and are not due to inhomogenities of interplanetary plasma which occured accasionaly near Venus on October 18, 1967 when the Venera-4 was approaching the planet. In this paper are given the corrected results

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1) The charged particle trap was also installed on board of the spacecraft Venera-5 which descended in the Venus atmosphere on May 16, 1969. According to schedule of flight of Venera-5, however, the sampling rate of measurements results, delivered to the input of the telemetrie system at the near-planetary part of trajectory was much lower then it was at the Venera-6, therefore we use here only the Venera-6 data.

of plasma measurements from the Venera-4 and preliminary results of plasma measurements on board Venera-6 near the planet. The brief discussion af all available data is also given.

I. The experimental data

There must be noted some features of the results of the positive ion fluxes measurements on board of Venera-4 to explain presented now their corrected results.

The measurements were made by means of two plane positive particle traps of integral type; the angle between their collectors was equal 60° and the ions of energy $E < 50$ ev were retarded. The net current of both collectors was measured [1]. The traps of this type are known [3] to give no possibility of precise determining a component measured collector currents due to photoemission from the trap electrodes. But for the near-planetary part of trajectory we managed to determine it by following method using the independent measurement data obtained by the american spacecraft Mariner-5.

If at some part of trajectory the trap orientation relative to the Sun remains unchanged then the photoemission current is also constant and all collector current changes are due only to variations of the positive ion flux reaching the collector. If this case at some moment the ion flux is known from independet measurements then photoemissive component of the collector current can be determined and excluded from the reading of the traps (from net current) on the whole part of trajectory on which the trap orientation relative to the Sun does not change.

For the purpose of excluding the photoemissive component of the traps collectors current when Venera-4 was close to the planet we used the data on solar wind ion fluxes obtained with the modulation type ion trap aboard the Mariner-5 by the group of the Massachusetts Institute of Technology on October 18, 1967 (when Venera-4 was approaching the planet).

This data were kindly provided to us by professor A.Lazarus. When the near-planetary run of the Venus-4 measurements began the Mariner-5 was 240000 km farther from the Sun than was soviet spacecraft and its longitude in the ecliptic plane was 0,22° less. Bearing in mind the Mariner-5 solar wind bulk velocity determination one must conclude that the same values of the solar wind fluxes should be observed by Venera-4 by 14 minutes later [4] (if one supposes that the value of the solar wind flux has not changed during this interval of 14 minutes). In this case the ion component of the traps collector current can be determined at the beginning of the near--planetary run of measurements and the measured collector current and its ion component difference enable us to determine the photoemissive component of the current. As during the whole near-planetary part of the Venera-4 trajectory the traps orientation with respect to the Sun was stable, the photoemissive component could be excluded from the traps readings from the whole this part of trajectory.

Fig.1 shows the changes of the solar wind ion fluxes as Venera-4 was approaching the planet; in this case the effect of photoemission by above mentioned method and the solar plasma ion velocity was supposed to be directed radially outward from the Sun during the whole near-planetary part of trajectory.

One can see that at the distance of $\sim$ 25000 km from the center of the planet the disturbance of the solar wind fluxes begins and the disturbed region is of complicated structure and spread over $\sim$ 15000 km. In disturbed region the maximum ion flux values are $\sim$ 4 times as high as undisturbed ones (i.e. at the beginning of the near-planetary run of measurements).

The precize value of the photoelectron contribution to the collectoe current of the trap aboard Venera-6 is not possible to determine without additional independent data. But as far as during the whole near-planetary run of measurements the trap orientation with respect to the Sun remains constant the photoemissive component of the collector current is also constant. Therefore, without knowledge of the precise value of N_0 - solar wind ion flux at the beginning of the near-planetary run in the undisturbed region, the absolute values of ΔN_i - the changes of registered ion fluxes in the disturbed region relative to N_0 - can be determined accurately enough. Fig.2 presents measured from Venera-6 ΔN_i values. At distances from the center of the planet $R < 32000$ km the sampling rate of trape readings was low and the the small available amount of measurements indicate the marked decrease of N_i when Venera-6 approaching the planet. The plot of Fig.2 shows that detected by Venera-6 increase of N_i values began at the distance of $\sim$ 36000 km from the planet center; the comparison of ΔN_i values of Fig.1, and of Fig.2 indicate that measured by Venera-4 and Venera-6 close to the planet changes of N_i - values are comparable.

2. Discussion

It was supposed in [1] (as well as in [2]) that detected near Venus plasma and magnetic field disturbances are collisionless shock wave which occurs when fluxes of magnetized solar plasma are flowing round the planet. As the authors of [1] did not know the characteristics of the Venus daytime ionosphere (since Venera-4 could provide information only on nighttime ionosphere of the planet) they considered probable that solar wind disturbances can occur as a result of conductivity of the inner part of the planet. Now we share completely the opinion of the authors of [2] that the cause of disturbances of solar wind flowing around the Venus is the conductivity of the daytime planet ionosphere.

The shock wave front location was evaluated in [1] using the gas dynamics relation in which the sound velocity was substituted by Alfven velocity.

Fig.3 gives a number of shock wave front locations calculated with the same relation for various M - Mach numbers corresponding to different solar wind parameters. The parts of Venera-4 and Venera-6 trajectories are also given; the crosses indicate the beginnins of observed disturbances. The same curve containes the points which indicate the Mariner-5 entry in the disturbed zone (point "a") and escape (point "b") (from data presented in [2]).

It should be noted that above-mentioned Mach numbers were in the range of 4,5 to 5 when Venera-4 and Mariner-5 were approaching the Venus; M=10 corresponds to quite rarely occuring combination of solar wind characteristics.

From Fig.3 one can see that all four marked points are more or less near the calculated shock wave front locations. On the Venera-6 which descended as well as the Venera-4 in the nightside part of the planetary atmosphere but farther from the terminator, the detection of plasma disturbances begun at greater distances from the planet. This supports the assumption that the disturbance is a shock wave.

The width of collisionless shock wave front in accordance, with theory [5] have to be somewhat more than the ion cyclotron radius ρ_i (for solar wind $\rho_i \sim 500$ km). One can see on Fig.1 and Fig.2 that this condition is fulfiled for the outer boundaries of sudden risings of plasma fluxes. This again supports the shock wave hypothesis.

It should be noted, however, that from the Venera-6 data the outer boundary of disturbance lays more close to the planet than the point of intersection of Venera-6 trajectory with calculated shock wave front (which is at the distance of R $\sim$ 43000 km for M=5 and R $\sim$ 39000 km for M=10). From observational data of Mariner-5 [2] one can conclude that the outer boundary of disturbed region at the entry of the spacecraft in this region (point(a) on Fig 3) corresponds to the shock wave front with M=5 and at the way out (point (b) on Fig.3) to one with M=2 although the Mach number for undisturbed solar wind seems to be in both cases about 5.

This gives impression that relation of gas dynamics concerning the shock wave front location fit to the observational data obtained near the Venus not very well and it cause us to abstain from categorical statement that the observed disturbances are namely the shock waves.

Some difficulties arise with the explanation of substantial ($\sim$ 4 times) increase of the ion fluxes beyond the disturbance front observed by Venera-4 (Fig.1). In part this increase may be related to the change of the particle flux direction and the increase of isotropy of their motion. As a results traps orientation becomes more favourable and their current rises for a given flux value (it must be recalled that the graph of Fig.1 is plotted on the assumption that at all near-planetary part of the spacecraft trajectory the ions move radially from the Sun).

However, the evaluations of this effect (based on analogy with the observations made beyond the shock wave front near the Earth) reveal that it can not create such significant (~ 4 times) increase of measured fluxes and therefore some vagueness remains.

In the paper [4] the results of magnetic measurements made aboard Venera-4 at the near-planetary part of trajectory are compared with simultaneous measurements from Mariner-5 (the above-mentioned time delay of ~14 minutes is taken account). The magnetic field changes in the disturbed zone near the planet had several features of those in the undisturbed region (although in the disturbed zone the magnetic field variations were considerably more intensive). It can be supposed that the same is true for plasma also (the variations of which in the disturbed zone are quite synchronous with the magnetic field variations, see [1]). It can not be ruled out that this can give additional explanation to the observed by Venera-4 ion fluxes increase at the front of disturbance. Unfortunately the plasma measurement results of Mariner-5 which are in our disposal are averaged over considerably greater time intervals than the data on magnetic measurements of Mariner-5 used in [4]. This deprive us of possibility of making sufficiently detailed comparison of the simultaneous plasma measurements aboard Venera-4 and Mariner-5.

If during the motion of the spacecraft after crossing the shock wave front the undisturbed wind characteristics were changing this could cause the motion of the front with a velocity, which was greater than the velocity of the spacecraft and the twofold crossing of the disturbance front; this can give one of the explanations of the observed complicated structure of the disturbed plasma region (Fig.1).

3. Conclusion

The results can be summarized briefly as the following:

1. Each time when the spacecrafts instrumented for detection of solar wind positive ions approached the Venus the disturbances of ion fluxes were observed.

2. From the results of plasma measurements one can see, that the outer boundaries of this disturbances are located approximately in accordance with the locations of the shock wave front calculated with use of the gas dynamics relation; however the discrepancy of the observed locations of these boundaries with calculated ones cause us to be careful with the identification of the observed disturbances with the shock waves.

3. The significant increase of ion fluxes observed by Venera-4 and Venera-6 near the disturbance front need additional explanations; in part they may be explained by changes of ion motion direction beyond the disturbance front or (and) by simultaneous increase of undisturbed flux. The observed complicated structure of disturbed zone may be related to twofold crossing of the disturbance front (if it moves with velocity higher than the spacecrafts one).

Aknowlegments

The authors express their sincere thanks to professor A. Lazarus and associates of the group of the Massachusetts Institute of Technology for providing unpublished Mariner-5 plasma measurement results including those for October 18, 1967.

We also thank the authors of [4], for providing their paper before its publication.

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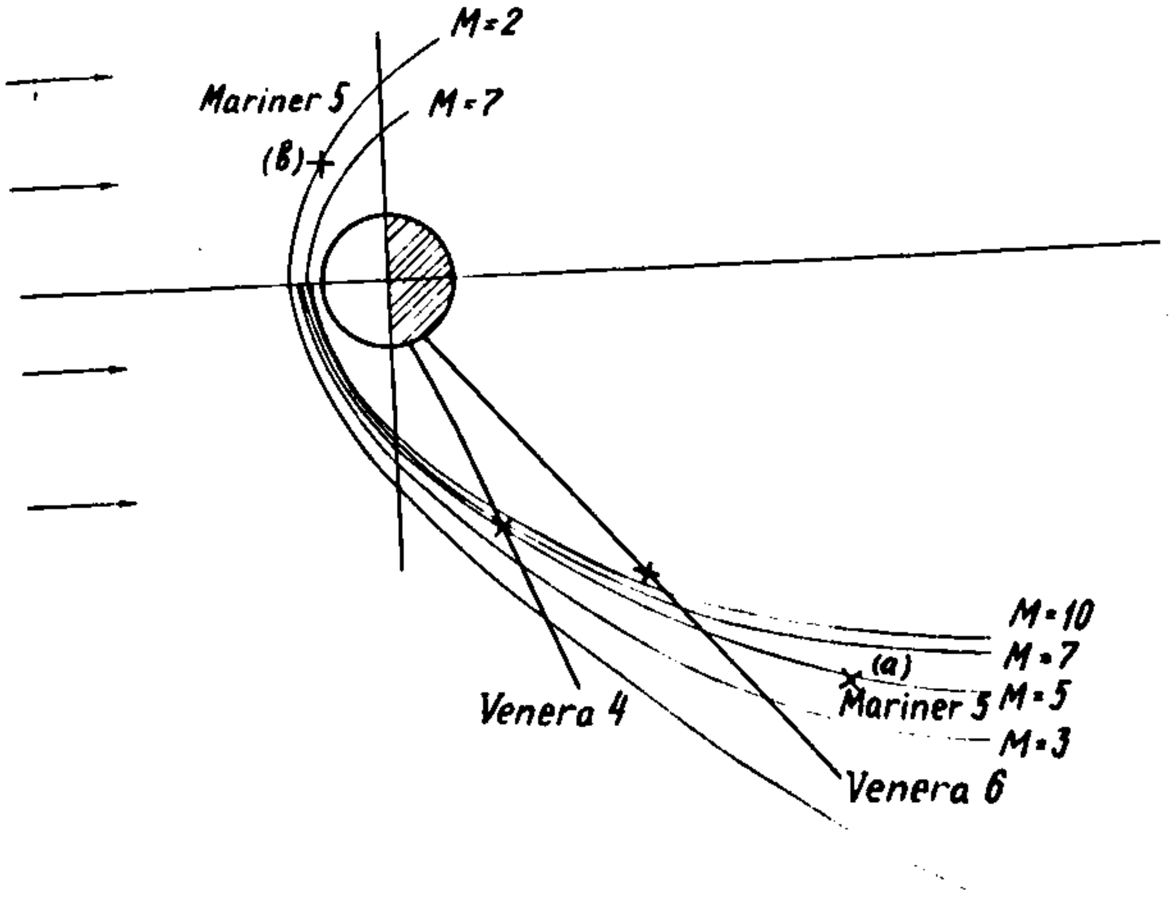
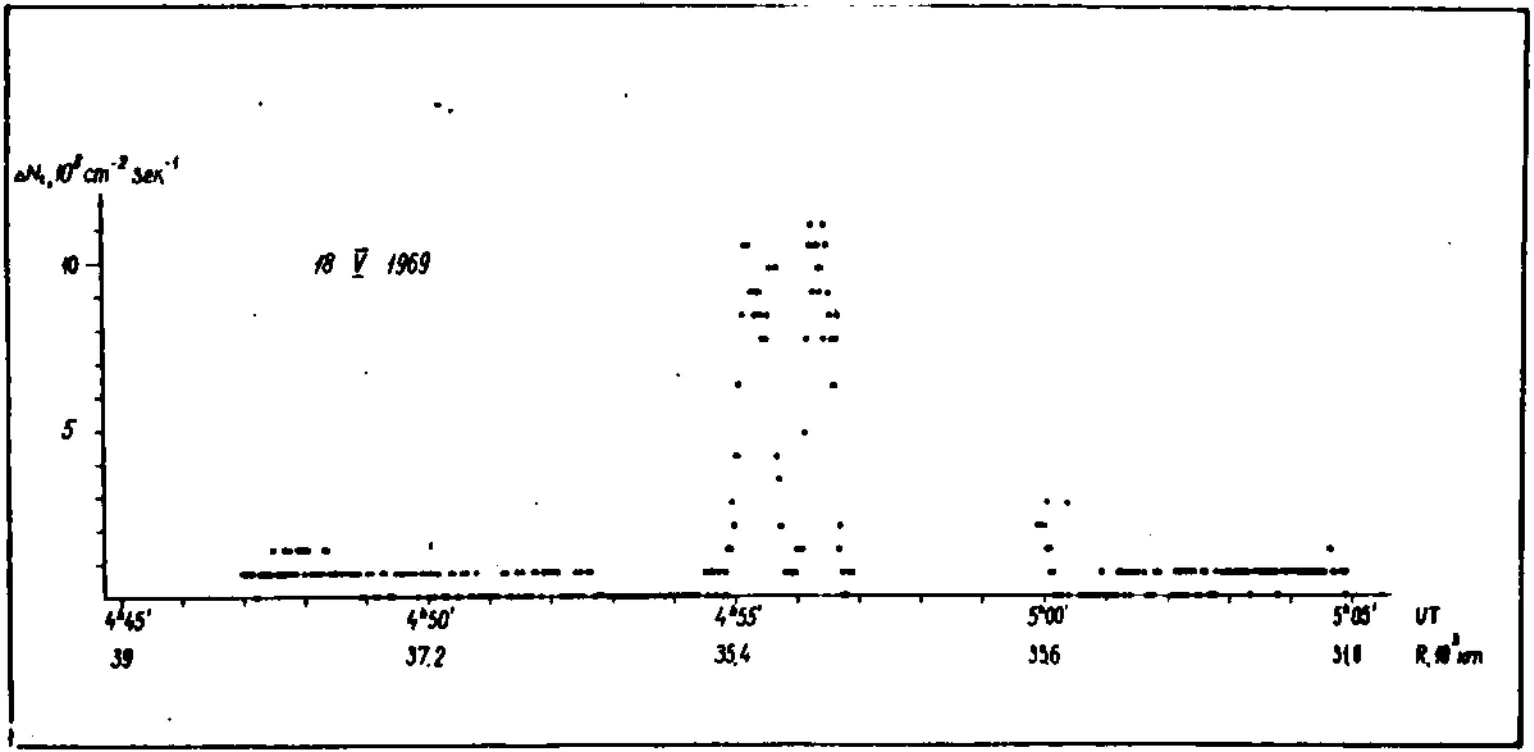


Fig. 1


ΔN, 10^3 cm^{-2} sek^{-1}
10
5
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4h45'
4h50'
4h55'
5h00'
5h05'
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39
37.2
35.4

Fig. 2

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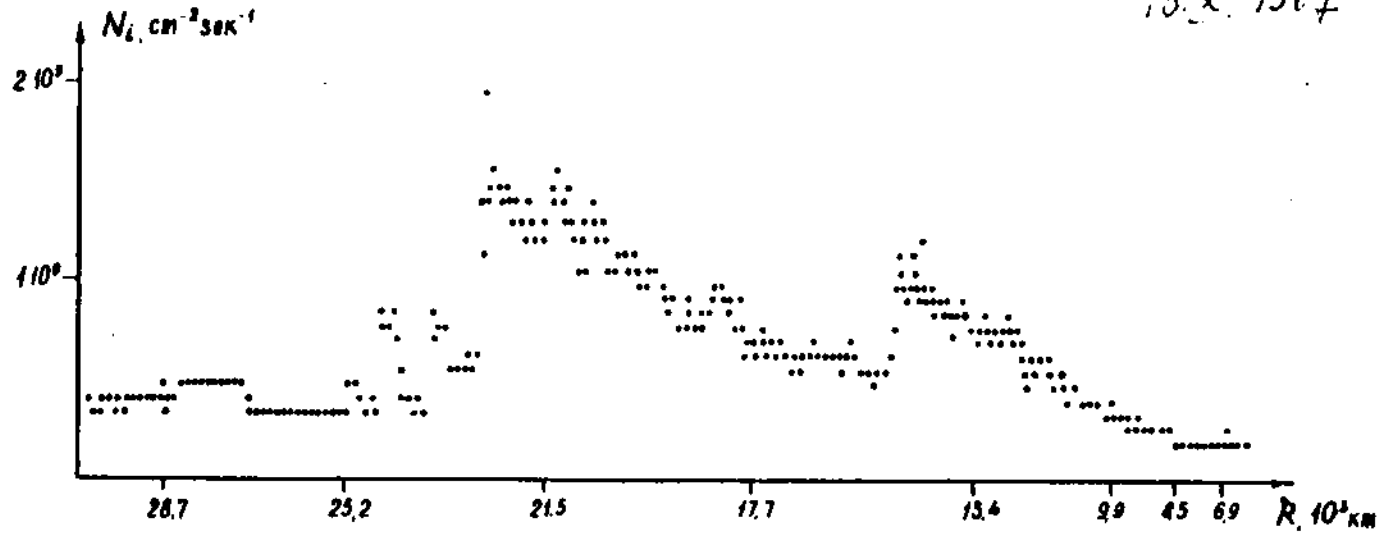

Fig. 3