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# Determining the characteristics of halo coronal mass ejections

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## 1. Introduction

Halo CMEs represent the three-dimensional moving structures, located out of the plane of the sky (Howard *et al.* 1982, St. Cyr *et al.* 2000). At that one halo CMEs move toward the Earth (frontside Halo CMEs), other - away from the Earth, St. Cyr *et al.* (2000). Frontside halo CMEs play the special role in phenomena, associated with space weather, Crosby (2001). The largest geomagnetic storms are caused by influencing such CMEs on the magnetosphere of the Earth (Webb *et al.* 2000, St. Cyr *et al.* 2000). Using the images of halo CMEs in the field of view of a coronagraph it is possible to determine only their apparent characteristics in the plane of the sky. But in this case it is difficult define its important parameters such as directions of movement, angular sizes in various sections of CME, position of the CME "center" or of its front, velocities of CME elements along directions which are not located in the plane of the sky. Without these parameters it is impossible to find the mass of CME, it's kinetic and potential energy. In the present work the methods are offered and approved allowing the estimation of the listed above halo CMEs parameters, which are determined with difficulty.

## 2. Results

($a$) The model of a halo coronal mass ejection as homogeneous relatively dense spherical shell surrounding the less dense cavity has been considered. Using this halo CME model, the relations have been obtained for determining the main parameters of full halo CMEs (at fixed instants), such as CME angular size ($2\alpha$), positions of the CME center ($R_C$) and leading edge (front) $R_F$, velocities of the CME front ($V_F$) and ($V_{FE}$). The first velocity is directed along CME's axis and the second velocity directed along the Sun - Earth axis.The obtained relations allow to find a full halo CME parameters on a displacement value $\Delta R$ of the image halo CME relative to the solar disk center, of radius CME $R_{CME}$, and angular position of the CME source $\beta$ with respect to the Sun - Earth axis. At that radius of an outer CME shell $R_{CME}$ is determined directly from the image of the Halo CME in the plane of the sky. The method of determining of Halo CME parameters with the help of the obtained relations has most precision for $\beta > 10$ deg.

($b$) The intensity of a Thomson scattering of photosphere radiation on model CME "electrons" is calculated. The results of such calculations are compared to brightness distribution in observed halo CMEs in the field of view SOHO LASCO coronagraphs C2, C3. At that the calibrated Level 1 data were used. The electron concentrations are determined in the shell of a CME for some observed halo CMEs.

($c$) The method of determining of parameters of halo CMEs was tested for an estimation of parameters of two groups of full halo CMEs, observed in the field of view LASCO coronagraphs during 1997 - 2002. Halo CMEs from the first group are connected with relatively strong solar flares (21 events), and halo CMEs from the second group are associated with eruptive filaments outside of the sites of strong flares (7 events). A positive correlation between $\Delta R$ and angular position (relatively the Sun - Earth axis) of flare ($\beta_F$) or eruptive filament ($\beta_P$) on a visual solar surface is revealed. It gives the basis to assume, that the angular position of the halo CME source $\beta$ close to $\beta_F$ or $\beta_P$. At the same time using of the obtained relations (item (a)) for an estimating of parameters 28 observable halo CME under the assumption, that $\beta$=$\beta_F$ or $\beta_P$ has given in the next result: for all studied events it was not possible to obtain realistic values of halo CMEs parameters. It is possible that this result indicates discordance between positions of sources a halo CME and flares or eruptive filaments, which are related with the halo CMEs. Not excepting such opportunity, we, nevertheless, have suggested that the main reason of the obtained result is the deflection of a trajectory CME from the radial direction within distances of up to (2.5-3)$R_0$ ($R_0$ is the solar radius). The improved method of an estimation of parameters a halo CME with allowance for of this effect is offered. This method has allowed to estimate the angle sizes of 28 halo CMEs with an accuracy of (30-40)%. The conclusion is made, that the most of a LASCO C3 full halo CMEs have the rather major angular sizes $\beta > 60$ deg.

($d$) The positive correlation between the angular sizes limb CMEs (i.e are detected CMEs, the axes which one are situated near to the plane of the sky) and angular sizes of eruptive filaments (prominences), related to these CMEs and also located near to a solar limb. This dependence was used for determining of the angular sizes of 7 full halo CMEs related with eruption of filaments on the visual disk of the Sun. The obtained angular sizes Halo CMEs have confirmed our conclusion (item (c)), that Halo CMEs, observable in the field of view of the LASCO C3 coronagraph, have the rather major angular sizes (60 - 140) deg.

($e$) The dependencies of front velocity of the model halo CME in a direction of the axis the Sun - Earth ($V_{FE}$) from its angular size ($2\alpha$) and position of its source on a visual surface of the Sun ($\beta$) are calculated. These dependencies were compared to dependencies of transit velocity of interplanetary shock waves (ISW), obtained both with the help of calculations, and under the observational data, and also of interplanetary coronal mass ejections (ICME) (using observations), from value $\beta$. Is found, that the transit velocities ISW and ICME depend on positions of their sources on the Sun ($\beta$) more weakly, than CME's velocity $V_{FE}$ on $\beta$ from relation, obtained by as. The interpretation is given to this phenomenon.

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