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Model of building the images of the moving coronal mass ejections for the muon hodoscope's information matrices

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1. THE PROBLEM SET UP FOR THE MOVING CORONAL MASS EJECTIONS IMAGE DEVELOPMENT

$Y_0(c(Tk),i,j)$ - Initial Coronal mass ejection (CME) image functions on the Aperture of muon hodoscope (AMH) information matrices

$c(Tk)$ - Parametes vector of the system Sun-CME-Earth-AMH (S-CME-E+AMH),

$$i,j=0,1,...,N_f-1,\ T,\ k=0,1,2,...$$

$W(Tk,i,j)$ - Measurements' error matrix, $N(0,\sigma^2)$

$Y(Tk,i,j)$ - Initial CME image observations on the AMH information matrices

$$Y(Tk,i,j)= Y_0(c(Tk),i,j)+W(Tk,i,j),\ i,j=0,1,...,N_f-1,\ T,\ k=0,1,2,...$$

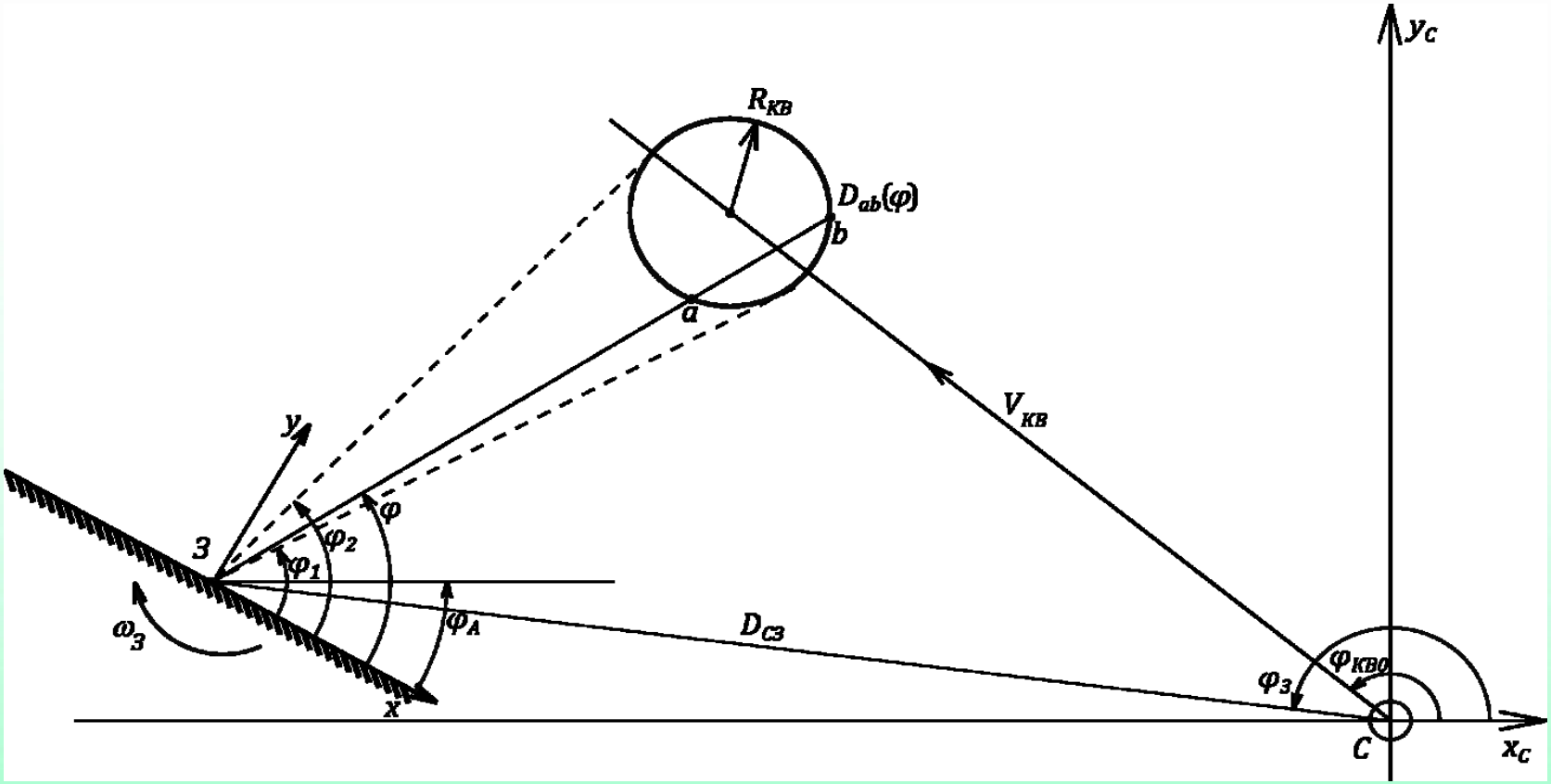
Building the CME image model - components:

1. $Y_0(c(Tk),i,j)$ 2. $W(Tk,i,j)$ 3. $Y(Tk,i,j)$

Applience of the CME image model:

1. algorithms' development;
2. the problem of Forbush effect recognition;
3. the problem of the CME parameters estimation;
4. the estimation of the algorithms' errors by using statistical modelling

2. SCHEME OF THE S-CME-E-AMH SYSTEM MOTION



CME coordinates: $x_{KB}(Tk) = V_{KB}\cos\varphi_{KB0}\cdot Tk + x_{KB}(0),\quad y_{KB}(Tk) = V_{KB}\sin\varphi_{KB0}\cdot Tk + y_{KB}(0),$

$$x_{KB}(0) = D_{KB0}cos\varphi_{KB0}\; y_{KB}(0) = D_{KB0}\sin\varphi_{KB0}$$

Earth's coordinates: $\varphi_3(Tk) = \omega_{3O}\cdot Tk + \varphi_3(0) x_3(Tk) = D_{C3}\cos\varphi_3\cdot Tk + x_3(0),\quad y_3(Tk) = D_{C3}\sin\varphi_3\cdot Tk + y_3(0),$

$$x_3(0) = D_{C3}cos\varphi_{30},\qquad y_3(0) = D_{C3}\sin\varphi_{30}$$

2. SCHEME OF THE S-CME-E-AMH SYSTEM MOTION (PLAIN VARIANT)

Angle of AMH rotation: $\varphi_A(Tk) = \omega_{3C} Tk + \varphi_A(0)$

Coordinates in the AMH system:

$$dx_0(Tk) = x_{KB}(Tk) - x_3(Tk), \quad dy_0(Tk) = y_{KB}(Tk) - y_3(Tk)$$

$$dx(Tk) = dx_0(Tk)\cos\varphi_A(Tk) + dy_0(Tk)\sin\varphi_A(Tk)$$
$$dy(Tk) = -dx_0(Tk)\sin\varphi_A(Tk) + dy_0(Tk)\cos\varphi_A(Tk)$$

Azimuth angle in the AMH system:

$$0 \le \varphi(i) \le \pi, \quad \varphi(i) = \Delta\varphi(i-1); \quad \Delta\varphi = \pi / N_A$$

S-CME-E-AMH system parameters for Tk

$$c(Tk)^T = (dx(Tk), dy(Tk), R_{KB}(Tk))$$

3. THE MODEL OF THE CME IMAGE BUILDING FOR THE SEQUENCE OF THE MUON HODOSCOPE'S INFORMATION MATRICES

CME density function: $\bar{d}_{KB}(Tk) = R^3_{KB}(0) / R^3_{KB}(Tk)$

Linear CME size function for the angle: $\varphi(i), c(Tk)$

$$D_{ab}(\varphi(i), c(Tk))$$

Relative linear CME size:

$$\bar{D}_{ab}(c(Tk), \varphi(i)) = D_{ab}(c(Tk), \varphi(i)) / 2R_{KB\max}$$

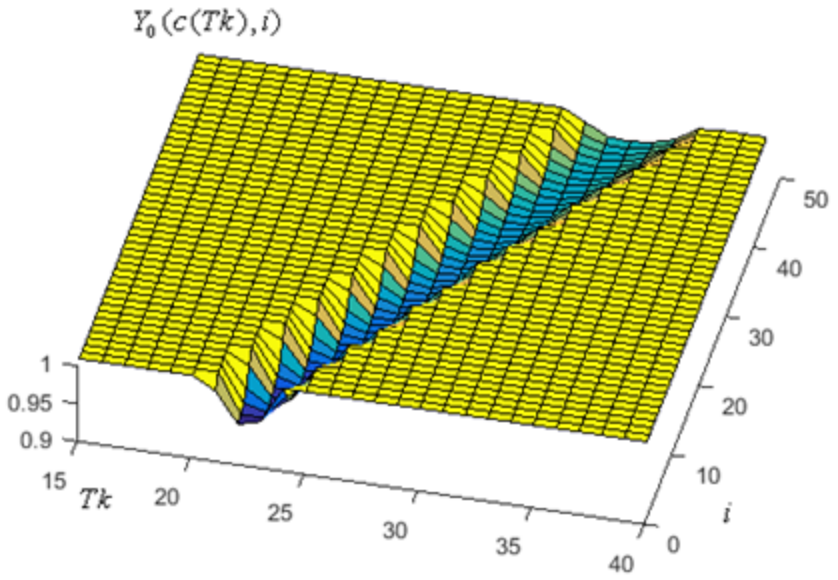
Initial CME images on the AMH:

$$Y_0(c(Tk), \varphi(i)) = \exp(-\alpha_0 \bar{d}_{KB}(Tk) \bar{D}_{ab}(c(Tk), \varphi(i)))$$

CME images models:

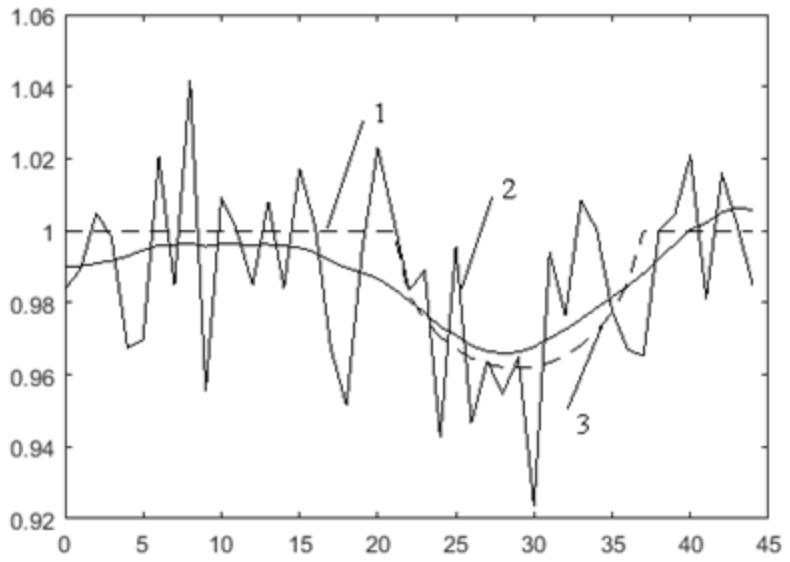
$$Y(Tk,i) = Y_0(c(Tk), \varphi(i)) + W(Tk,i), \quad i = 0,1,\ldots,N_f - 1, \; T, \quad N(0,\sigma^2), \; k = 0,1,2,\ldots$$

4. FORBUSH EFFECTS MODELLING FOR THE SEQUENCE OF THE MUON HODOSCOPE'S INFORMATION MATRICES



sequences of observations of CME image and Forbush-effects : $Y_0(c(Tk),i)$

$k = K_{f1},\ldots,K_{f2}$, $K_{f1} = 15, K_{f2} = 40$, $i = 0,\ldots,N_f - 1$, $N_f = 45$

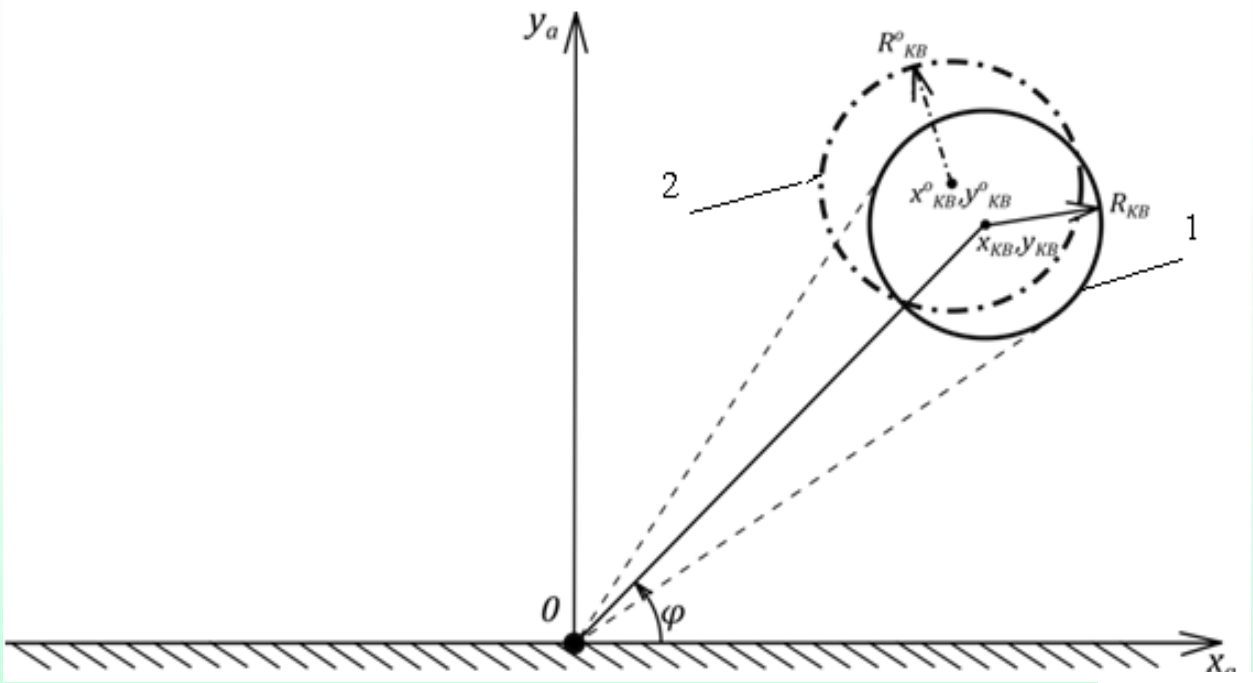


CME images' modelling results with noise:

$Y_0(c(Tk_0),i)$ -1 , $Y(Tk_0,i)$ -2 , filtration result:

$Y^*(Tk_0,i)$ -3, $k_0 = 25$

5. MODELLING OF THE ALGORITHM OF THE CME PARAMETERS ESTIMATION



Initial CME (x_{KB}, y_{KB}, R_{KB}) - 1, estimation of the initial CME $(x^o_{KB}, y^o_{KB}, R^o_{KB})$ - 2

Initial CME image and observations: $Y_0(c(Tk),\varphi(i)) = \exp(-\alpha_0 \bar{d}_{KB}(Tk)\bar{D}_{ab}(c(Tk),\varphi(i))),\ Y(Tk,i)$

The functional and minimization: $S(Y,c) = \sum_{i=0}^{N_A-1} (Y(Tk,i) - Y_0(c(Tk),\varphi(i))^2,\ c \in \bar{C}$

$$c^o \quad \arg\{\min_{c\in\bar{C}} S(Y,c)\}$$

CME parameter's estimation: c^o $(a^o_x(Tk), a^o_y(Tk), R^o_{KB}(Tk))$

The errors estimation by statistical modelling:

$$\sigma_x \approx 1.5\cdot 10^6\,км;\quad \sigma_y \approx 1.5\cdot 10^6\,км;\quad \sigma_{R_{KB}} \approx 2.0\cdot 10^6\,км;$$

Thank you for your attention!