A model for the analysis of the expansion and distortion of the cross-section of MCs in the interplanetary medium

M. A. Hidalgo, T. Nieves-Chinchilla and C. Cid

Departamento de Física, Universidad de Alcalá
Alcalá de Henares, Madrid (Spain)
e-mail: miguel.hidalgo@uah.es

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PHYSICAL ASSUMPTIONS OF THE MODEL

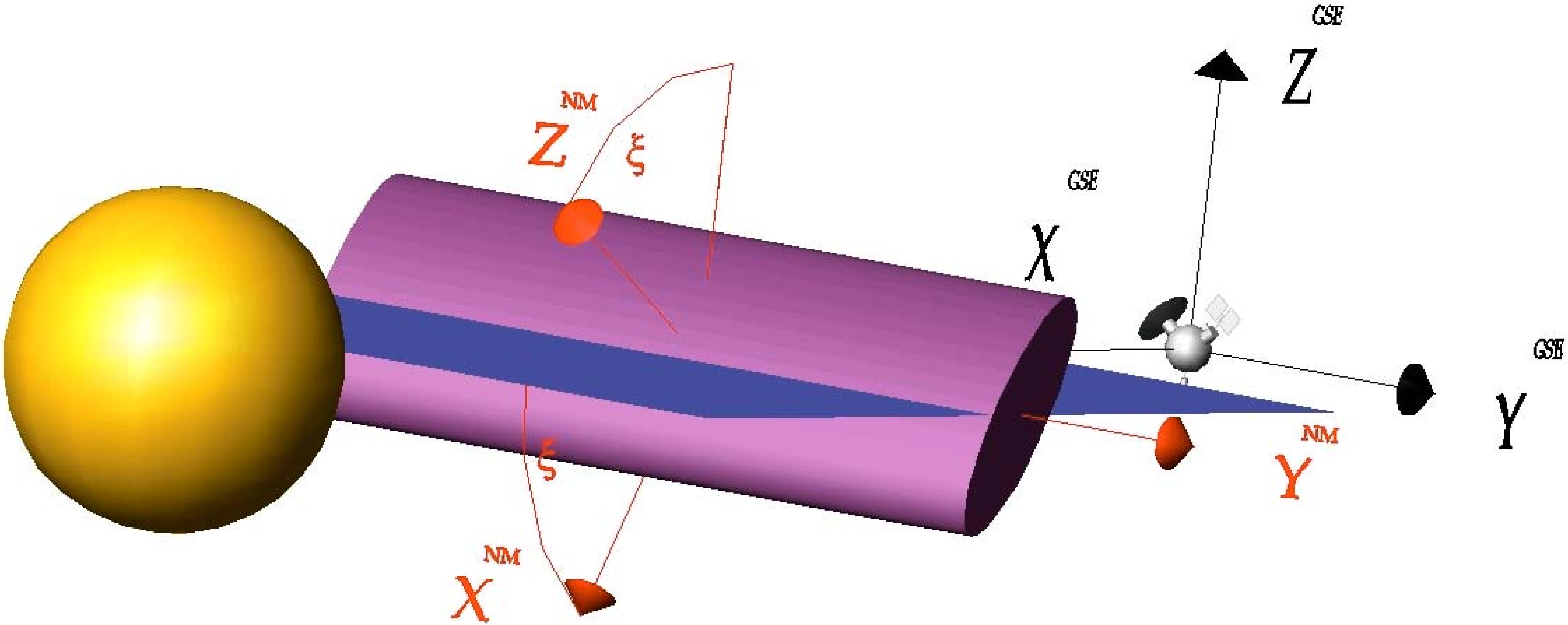
- Cylindrical topology:
  Null radial component of the magnetic field, B_η

- Elliptical cross-section as a first approach to the distortion of the MC in the interplanetary medium

- $|\rho_e| = |\rho_p|$ in every point inside the cloud at any time $\Rightarrow$ we can assume stationary conditions, $\partial(\rho_e + \rho_p)/\partial t = 0$

- Finite (and spatially uniform) normal component of the current density to the cross-section of the cloud, j_η

A scheme of the distorted MC during its movement in the interplanetary medium



MAGNETIC FIELD COMPONENTS OF THE MODEL

$$B_\eta = 0$$

$$B_y = B_y^0 + \mu_0 j_\eta r S \cos\varphi \cosh\eta \qquad (*)$$

$$B_\varphi = - \frac{\mu_0 j_y^0 r \cosh\eta}{\left[\cosh^2\eta - \cos^2\varphi\right]}$$

(*) $S = \sqrt{\sin^2\varphi} \Big/ \sin\varphi$

MAGNETIC FIELD COMPONENTS IN GSE

$$B_x^{GSE} = B_x\left(cos\,\phi\,cos\,\zeta - sin\,\zeta\,sin\,\phi\,sin\,\theta\right) - B_y\,sin\,\phi\,cos\,\theta + B_z\left(cos\,\phi\,sin\,\zeta + cos\,\zeta\,sin\,\phi\,sin\,\theta\right)$$
$$B_y^{GSE} = B_x\left(sin\,\phi\,cos\,\zeta + sin\,\zeta\,cos\,\phi\,sin\,\theta\right) + B_y\,cos\,\phi\,cos\,\theta + B_z\left(sin\,\phi\,sin\,\zeta - cos\,\zeta\,cos\,\phi\,sin\,\theta\right)$$
$$B_z^{GSE} = -B_x\,sin\,\zeta\,cos\,\theta + B_y\,sin\,\theta + B_z\,cos\,\zeta\,cos\,\theta$$

where B_x and B_z is given by the expressions

$$B_x = -B_\varphi\,cosh\,\eta\,sin\,\varphi$$
$$B_z = B_\varphi\,sinh\,\eta\,cos\,\varphi$$

The fits are made using these theoretical GSE components of the magnetic field over the experimental cartesian-GSE magnetic field data (without normalizing)

(The fitting procedure uses a least squares program based on the Marquardt-Levenberg algorithm)

TRAJECTORY OF THE SPACECRAFT

$$r = \sqrt{\left(\frac{x}{cosh\,\eta}\right)^2 + \left(\frac{z}{sinh\,\eta}\right)^2} \quad \text{and} \quad cos\,\varphi = \frac{x}{r\,cos\,h\eta}$$

where

$$x = x_{spacecraft}^{GSE}\left(cos\,\phi\,cos\,\zeta - sin\,\zeta\,sin\,\phi\,sin\,\theta\right) + z_0\,sin\,\zeta\,cos\,\theta$$

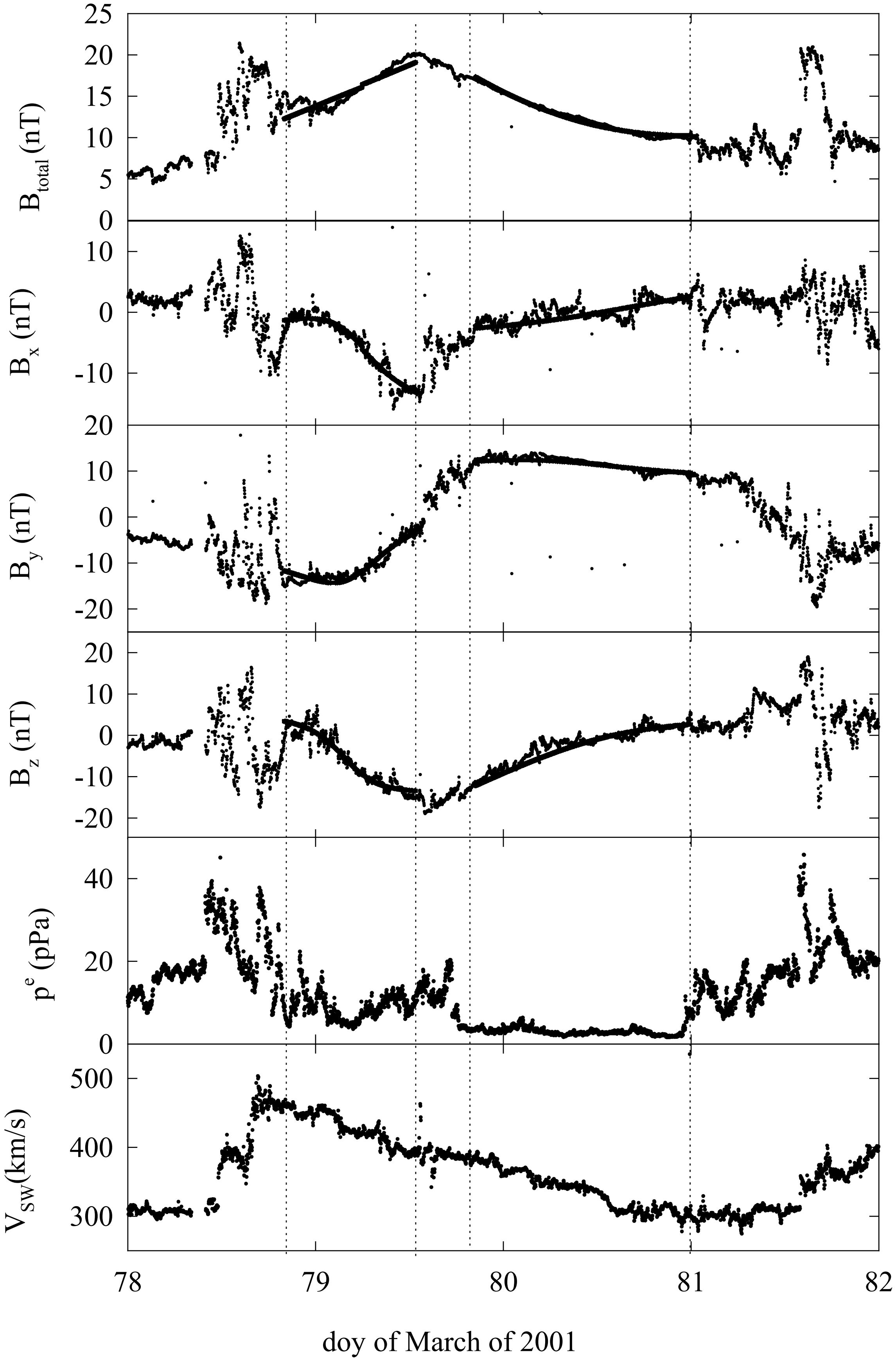
$$z = x_{spacecraft}^{GSE}\left(cos\,\phi\,sin\,\zeta + cos\,\zeta\,sin\,\phi\,sin\,\theta\right) - z_0 cos\,\zeta\,cos\,\theta$$

being $x_{spacecraft}^{GSE} = \bar{v}_{SW}\left(t - t_{in}\right) - x_0$ and $\bar{v}_{SW}$ the mean solar wind velocity at the MC interval and t_{in} the time of the entrance of the spacecraft in it

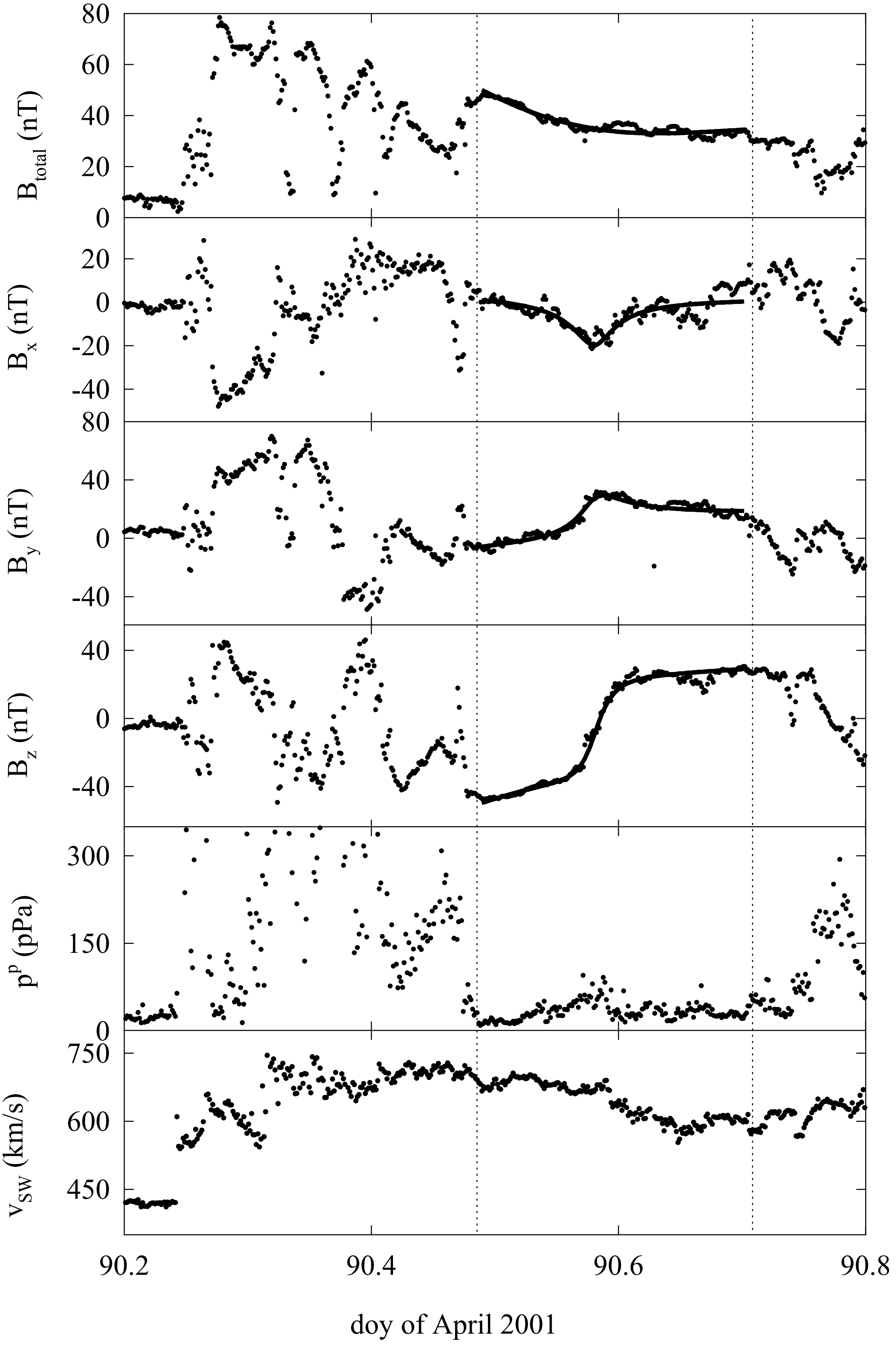
$$x_0 = \frac{\bar{v}_{SW}}{2}\left(t_{out} - t_{in}\right) - z_0 F\,cos\,\theta$$

t_{out} is the departure time of the spacecraft

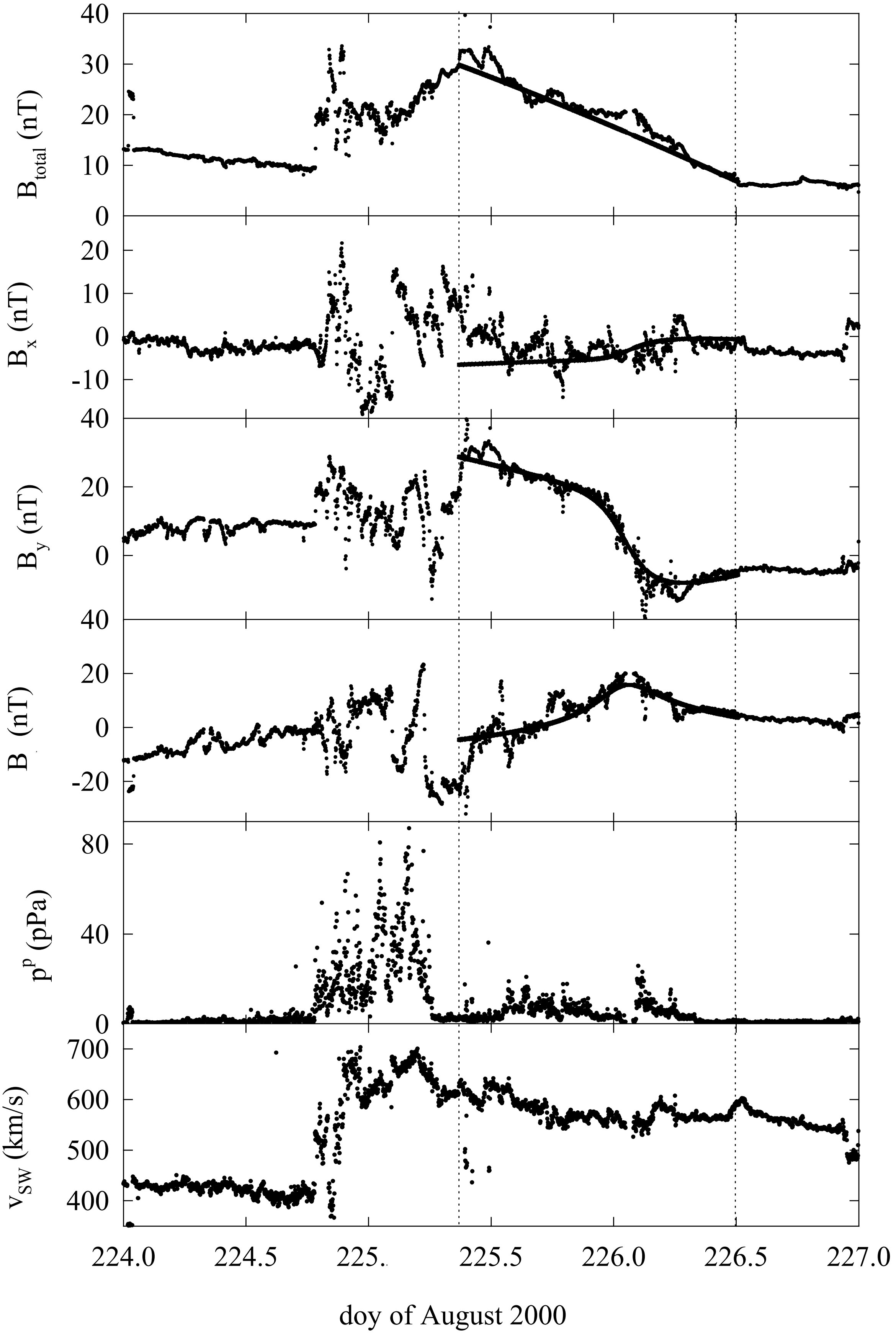
$$F = \frac{cos\,\phi\,sin\,\zeta\,cos\,\zeta + sin\,\phi\,sin\,\theta\left[cosh^2\eta - sin^2\zeta\right]}{cos^2\phi\left[cosh^2\eta - cos^2\zeta\right] + sin^2\phi\,sin^2\theta\left[cosh^2\eta - sin^2\zeta\right] + 2\,sin\,\phi\,cos\,\phi\,sin\,\zeta\,cos\,\xi\,sin\,\theta}$$



B_{total} (nT)
B_x (nT)
B_y (nT)
B_z (nT)
p^e (pPa)
V_{SW}(km/s)
78
79
80
81
82
doy of March of 2001



B_{total} (nT)
B_x (nT)
B_y (nT)
B_z (nT)
p^p (pPa)
v_{SW} (km/s)
90.2
90.4
90.6
90.8
doy of April 2001



B_total (nT)
40
30
20
10
0
B_x (nT)
20
10
0
-10
40
B_y (nT)
20
0
40
B (nT)
20
0
-20
p^p (pPa)
80
40
0
v_SW (km/s)
700
600
500
400
224.0
224.5
225.
225.5
226.0
226.5
227.0
doy of August 2000

PARAMETERS OF THE MODEL

***-Parameters related to the orientation of the cloud*:**

- the latitude, θ
- the longitude, ϕ
- the cross-section orientation, ζ
- z_0 (**)

-Parameter related to plasma current density:

- α
- λ

-Parameter related to the distortion of the MC's cross section (eccentricity):

- η

-Parameter related to the expansion of the MC's cross section:

- t_0

-The axial component of the magnetic field at the axis of the cloud, B_y^0

(**) Maximum approach of the spacecraft to the cloud axis $y_0 = \dfrac{z_0 \cos\theta \cos\phi}{\sqrt{1-\cos^2\theta \sin^2\phi}}$

CURRENT DENSITY COMPONENTS

$$j_\eta = spatially\ \ uniform$$

$$j_y = \frac{sinh\,\eta}{\left[cosh^2\eta - cos^2\varphi\right]} j_y^0$$

$$j_\varphi = \frac{sinh\,\eta\ S\,cos\,\varphi}{\left[cosh^2\eta - cos^2\varphi\right]^{\frac{1}{2}}} j_\eta$$

To introduce the expansion of the cloud we assume

$$j_y^0 = \lambda\left(t_0 - t\right)$$

$$j_\eta = \alpha\left(t_0 - t\right)$$

where t_0 characterizes the expansion of the cloud

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