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THE DRAG-BASED MODEL IN A COMPLEX NUMERICAL ENVIRONMENT

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The Drag-based Model

- The DBM hypothesis – at large heliocentric distances:
  - observational facts: ICME dynamics is solely governed by interaction with solar wind (ambient)
  - the Lorentz force ceases in upper corona, only drag is dominant; net acceleration is

$$a = \cancel{a_L} + \cancel{a_g} + a_d$$

  - collisionless environment – low viscosity and low resistivity:
    - dissipative processes are negligible
    - momentum and energy are transferred by magnetosonic waves
- equation of motion is in a quadratic form (Cargill, 2004):

$$R''(t) = -\gamma(R)\left[R'(t) - w(R)\right]\left|R'(t) - w(R)\right|$$

- parameter γ:

$$\gamma(R) \propto c_d \frac{A\,\rho_{SW}}{M} = \gamma_\infty \frac{w_\infty}{w(R)} \qquad \gamma_\infty := \lim_{R\to\infty} \gamma(R) = \Gamma \times 10^{-7}\ \mathrm{km}^{-1}$$

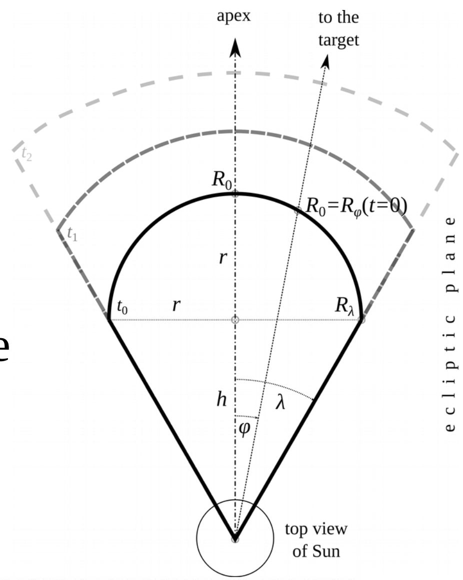
- solar wind speed (unperturbed w_0 + perturbed w_p):

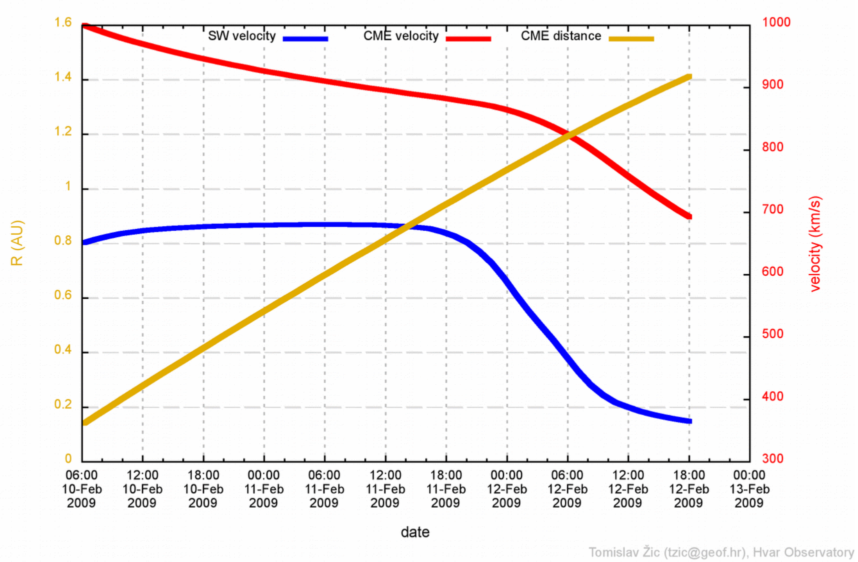
$$w(R) = \begin{cases} w_0(R) + w_p(R), R_1 < R < R_2 \\ w_0(R), otherwise \end{cases} \qquad w_0(R) = w_\infty \left(1 + \frac{k_4/k_2}{R^2} + \frac{k_6/k_2}{R^4}\right)^{-1} \qquad w_\infty = \lim_{R\to\infty} w_0(R)$$

- The DBM: a „tool“ for prediction of ICMEs propagation in the heliosphere
  → primary task for space-weather forecasting

Example of DBM + ENLIL model (http://oh.geof.unizg.hr/~tomislav/DBM-ENLIL/)

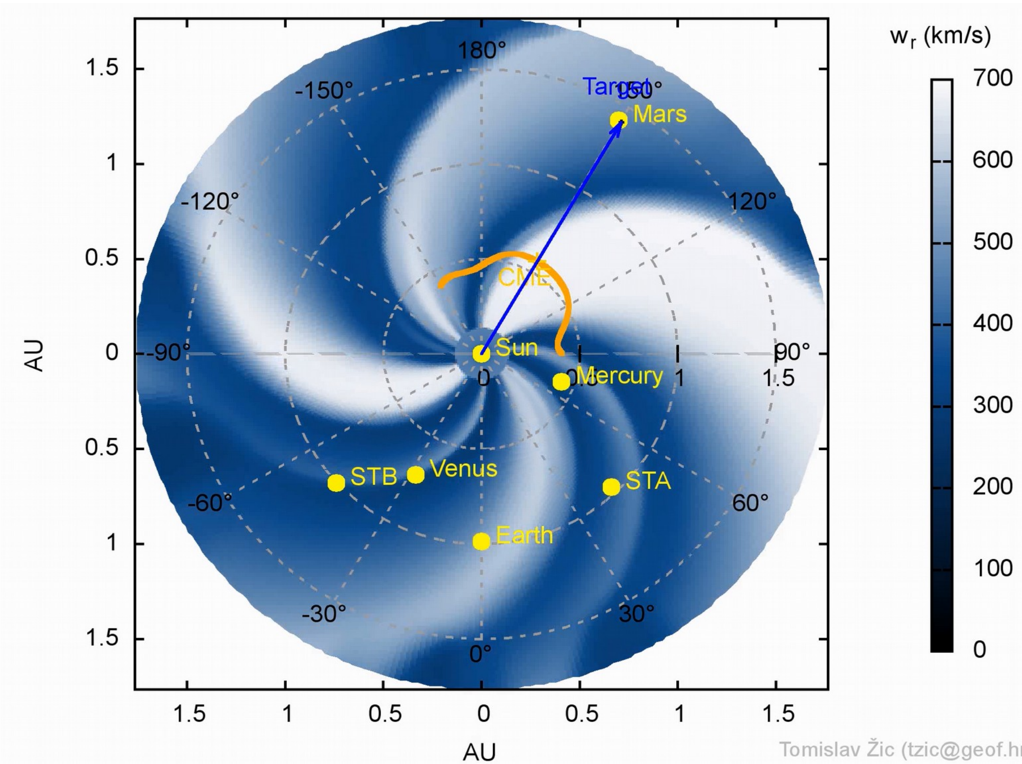
- solar-wind speed and $w(R)$ and parameter $\gamma(R)$ are radially dependent
- CME leading-edge segments propagate independently
- initial cone shape flattens





Propagation of '+ CME' point in geometry plot

$w(R)$, $\gamma(R)$ → CME-edge flattening: $\Gamma = 0.2$, $R_0 = 31\ r_S$, $v_0 = 1000$ km/s, $\lambda = 60°$, $\varphi = 150°$, target: Mars



Cross-section of CME propagation in ecliptic plane

The CME take-off time: February the 10th, 2009 at 06:13 UT

Automatic Fitting (LSF method)

- INPUT: observed ICME dataset: $\{(R_0,v_0),\ldots,(R_N,v_N)\}$
- OUTPUT: DBM parameters $(\Gamma, w_\infty, R_0, v_0)$
- The least-square fitting (LSF):
  - successive variation of DBM parameters → minimal deviation between observed v_i and DBM-calculated speeds $v(R_i)$:

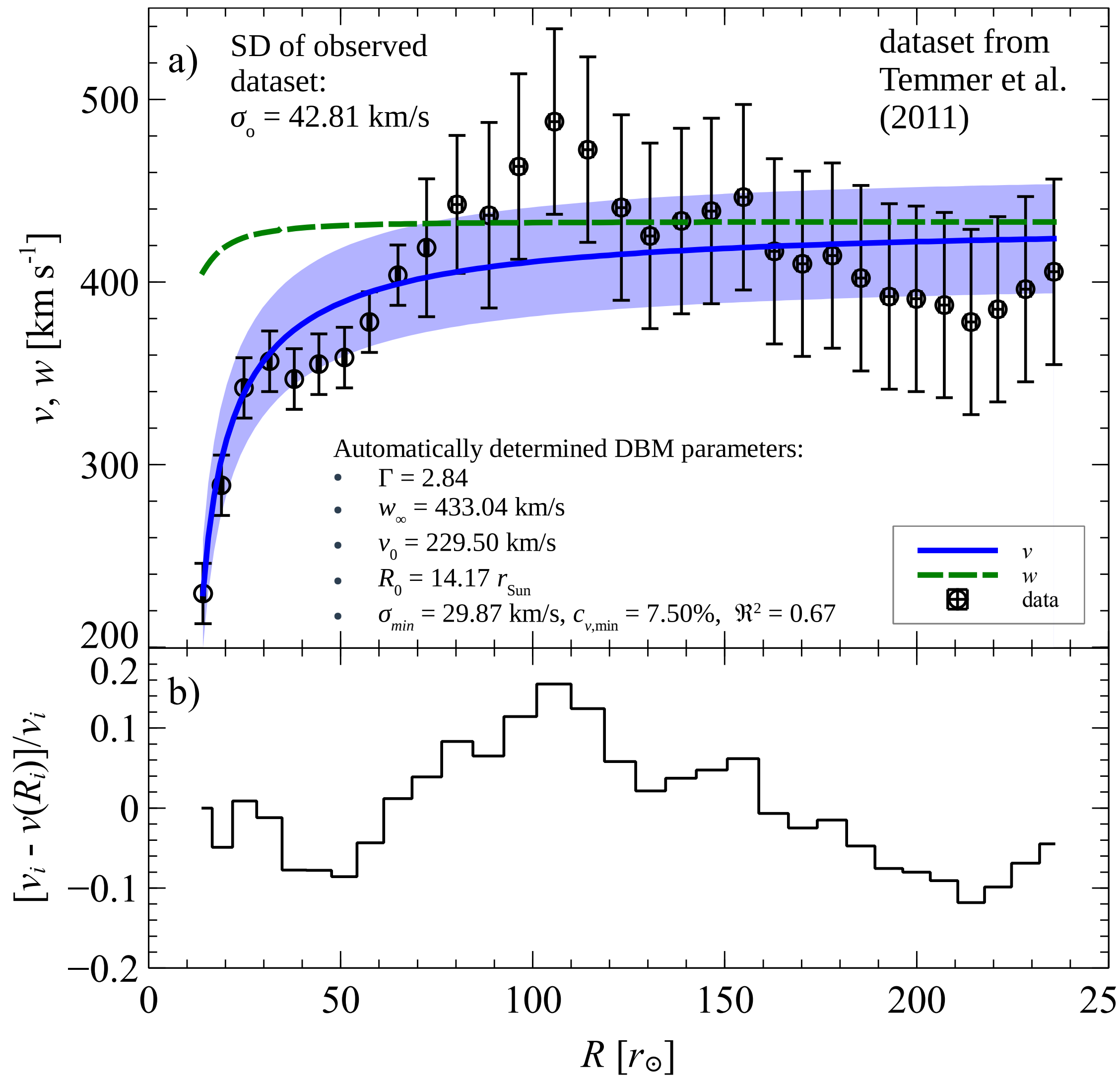
$$\sigma(\Gamma, w_\infty, R_0, v_0) = \sqrt{\frac{1}{(N+1)} \sum_{i=0}^{N} [v_i - v(R_i)]^2}$$

$\rightarrow \sigma_{\min} \rightarrow$

$\rightarrow$ the best $(\Gamma, w_\infty, R_0, v_0)$

- for real-time space-weather forecasting (successive fitting as ICME propagates)

The fitted standard deviation σ_{min} is smaller than the observed σ_o!



Conclusion

- The drag-based model:
  - could be integrated to other advanced numerical codes as ENLIL and EUHFORIA
  - gives an availability for employment in practical and fast online CME prediction tools
- Drawbacks:
  - the magnetic field/Lorentz force is not included in the DBM
  - CME-CME interaction is problematic for calculation
- The LSF method:
  - opens an opportunity for implementation in real-time space-weather forecasting tools and alerting systems for CME impacts on any heliospheric "target" of interest
  - the novel approach: real-time data-driven DBM-parameter optimization improves the accuracy of CME kinematics in the heliosphere
- The current and development DBM versions are available at web-site:

http://www.geof.unizg.hr/~tzic/dbm.html

Acknowledgments

PoKRet

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