Europska Unija
Ulaganje u budućnost
Projekt je sufinancirala Europska Unija iz Europskog socijalnog fonda

SEMINAR: (Space weather research at) The Hvar Observatory

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solar group (5; theory & obs.):

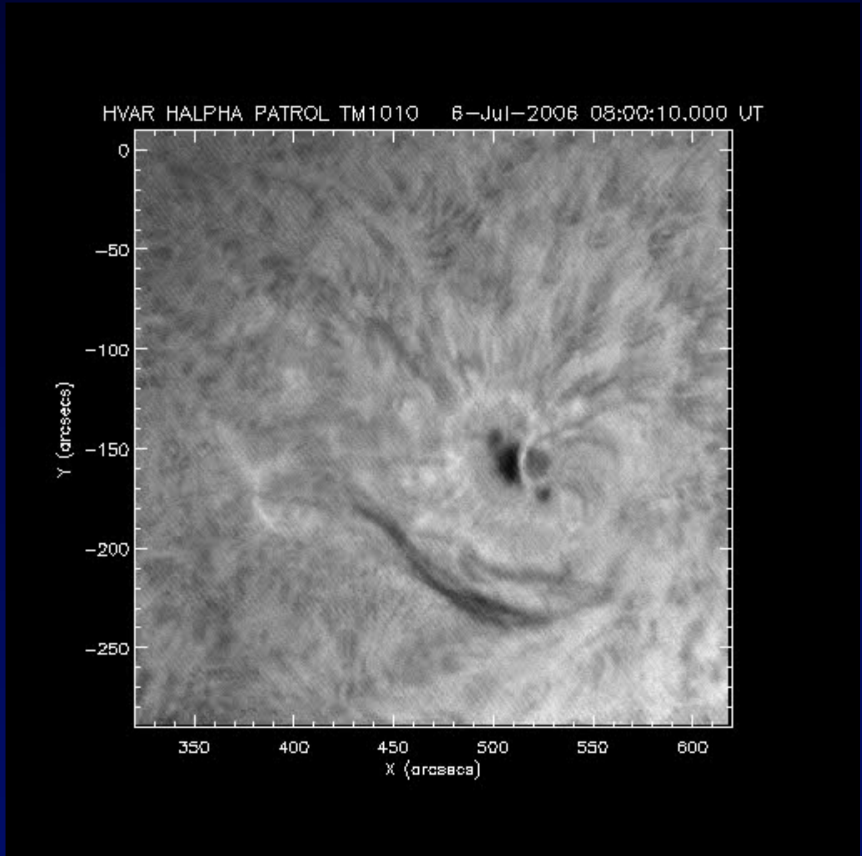
- solar eruptive phenomena
- solar rotation & other large-scale phenomena
- sun-earth connection
  (**space weather**, climate effects, **cosmic rays**)

stellar group (4; obs.):

- variable stars
- Be stars

equip.:

- double solar t.
- 65 cm photometric t.
- 1 m multi-purpose t.


HVAR HALPHA PATROL TM1010 6-Jul-2006 08:00:10.000 UT
Y (arcsecs)
0
-50
-100
-150
-200
-250
350
400
450
500
550
600
X (arcsecs)

US:
GSFC
AFRL
MLSO
NRL
UAH
...

Take-off and propagation of CMEs and ICMEs:

- loss of equilibrium & acceleration (obs./theor.)
- role of reconnection (obs./theor.)
- aerodynamic drag (obs./theor.)
- interplanetary propagation (Drag-Based Model)
- semi-empirical space-weather forecasting

Reconnection:

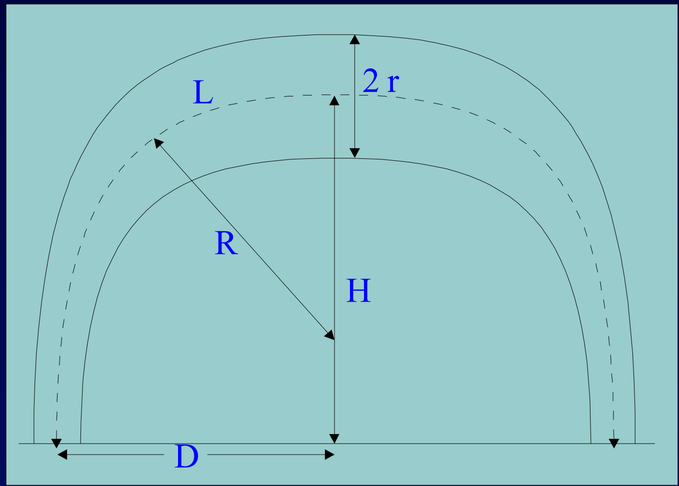
- analytical modeling
- post-CME CSs (obs./theor.)
- role of reconnection in CME acceleration (obs./theor.)
- energy-release scaling in flares (obs.)

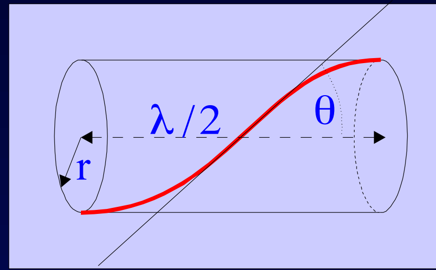
Coronal shock waves:

- formation mechanisms (analyt. modeling)
- origin: flare/CME "?" (obs.: type II, Moreton)

etc.

CMEs - acceleration phase





$$X = \mathrm{tg}\,\theta = B_\phi / B_{//}$$

$$\Phi = l\,X/r, \quad n = \Phi/2\pi$$

$$n = l/\lambda, \quad n = const.$$

$$a = a_\mathrm{L} - g - a_\mathrm{d}$$

$$a_\mathrm{L} = A\,(l/h + l/R - 2l/RX^2) \pm kI/lr$$

$$A = \frac{\mu I^2}{4\pi M} = \frac{B_\phi^2}{\mu\rho l} = \frac{X^2 B_\parallel^2}{\mu\rho l} \approx \frac{v_A^2}{l} = \frac{l}{\tau_A^2} = l\omega^2$$

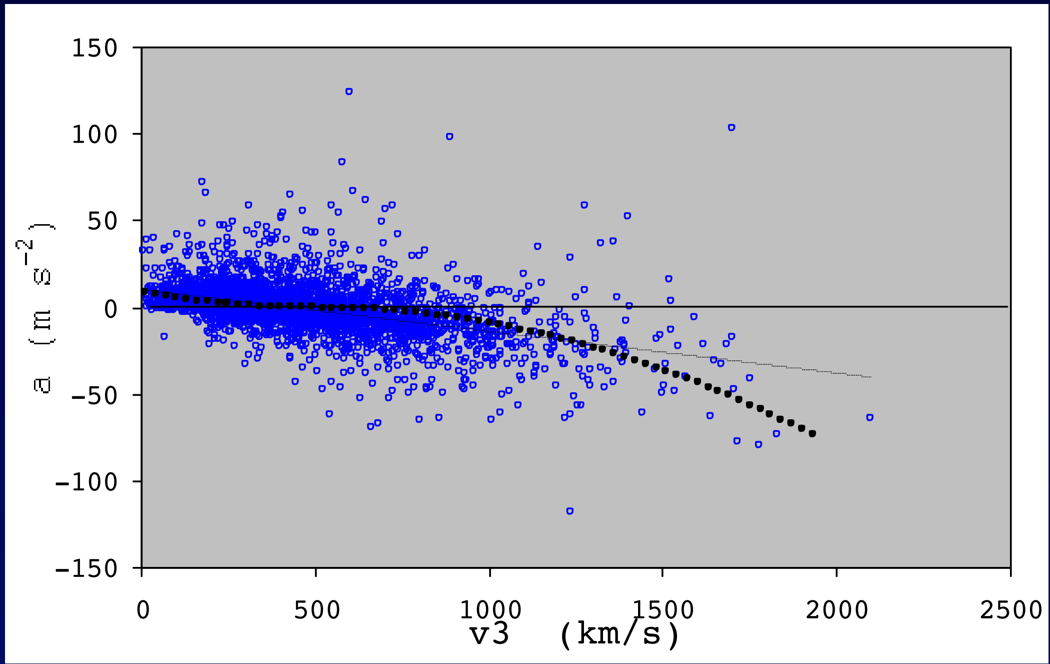
in the absence of reconnection:

$$\Phi_\mathrm{e} = \mathrm{const.} \propto I\,l\,[\ln(8R/r) - 2]$$

$$\Phi_\mathrm{i} = \mathrm{const.} \propto I\,l$$

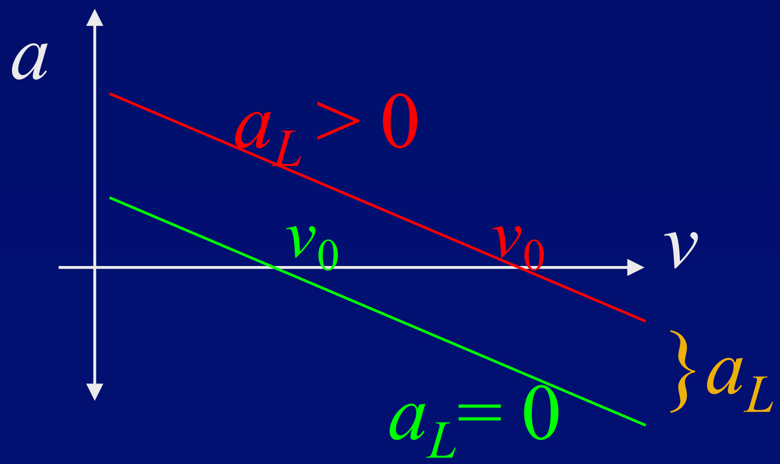
$$\Rightarrow \quad I \propto l^{-1}, \quad r \propto R, \quad X \propto r/l$$

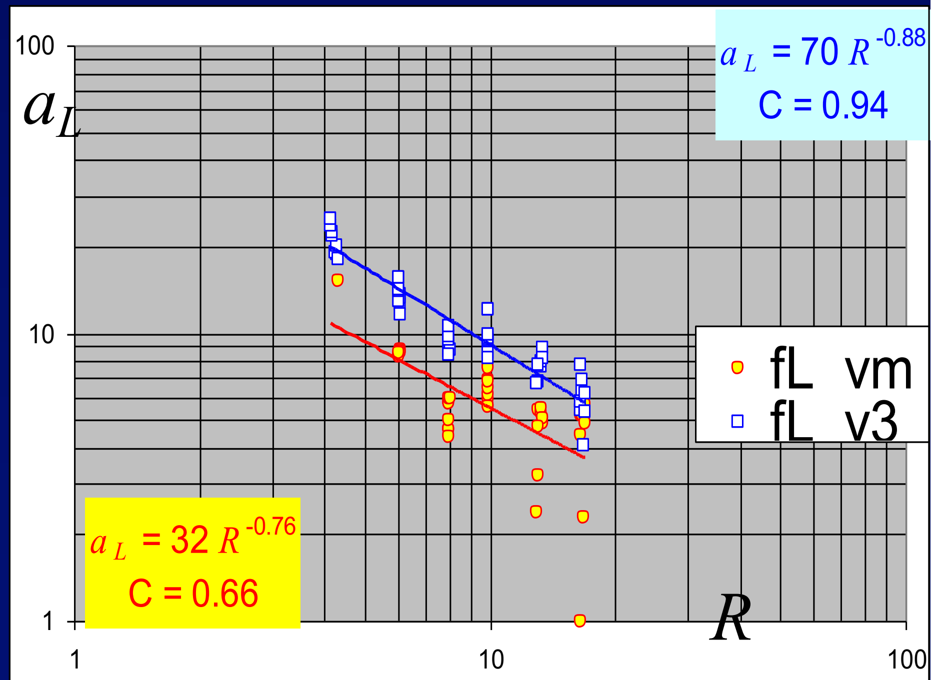
CMEs - propagation phase



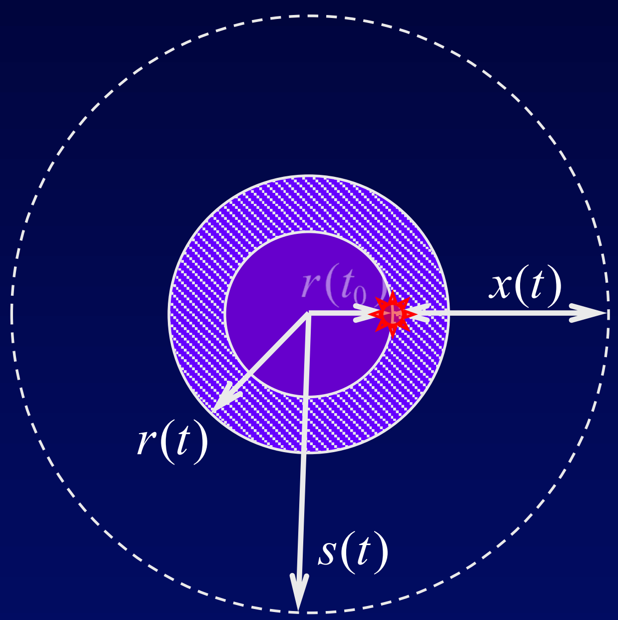
$$v_0\,(a_L > 0) \;>\; v_0\,(a_L = 0)$$

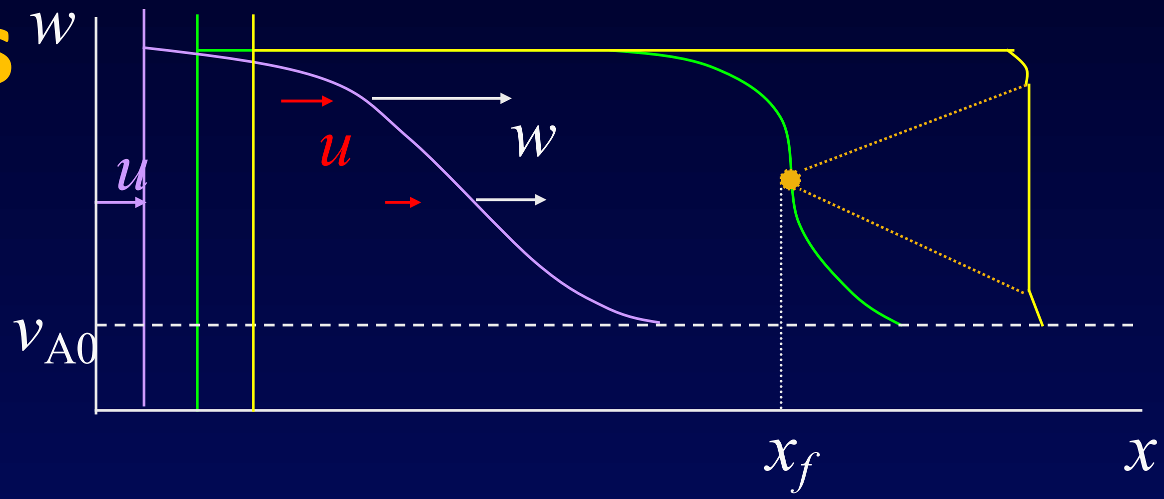
$$a_L = k\,\Delta v_0$$

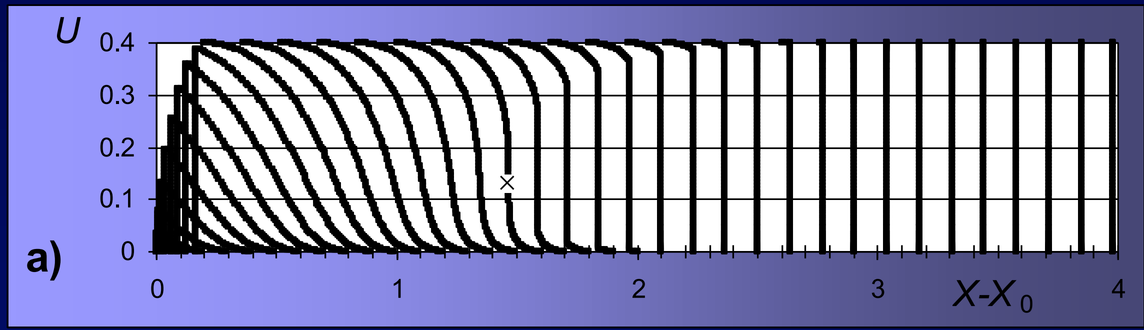


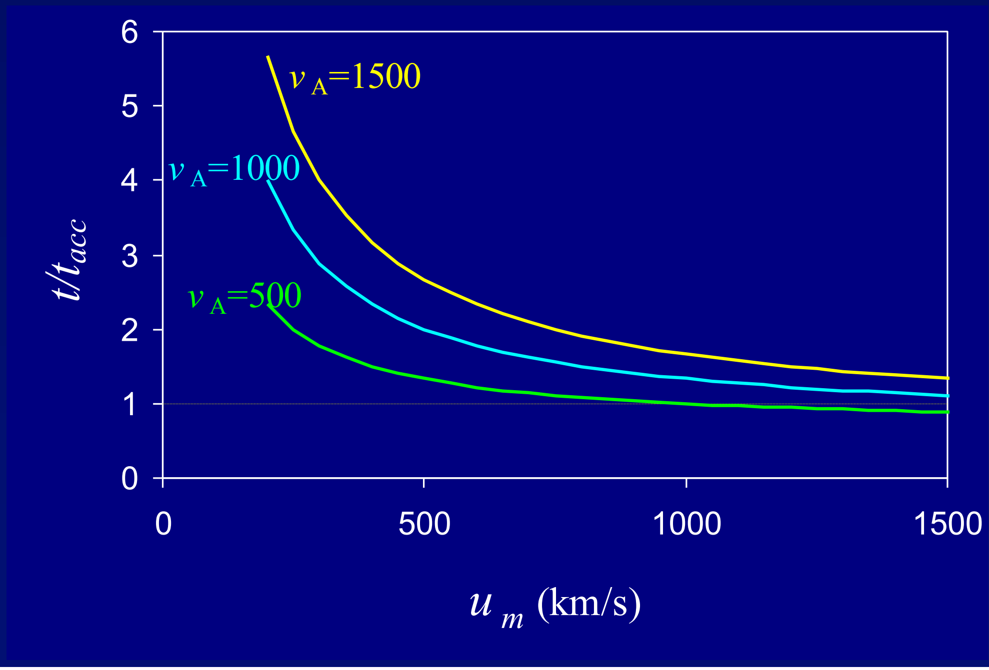


Coronal shocks

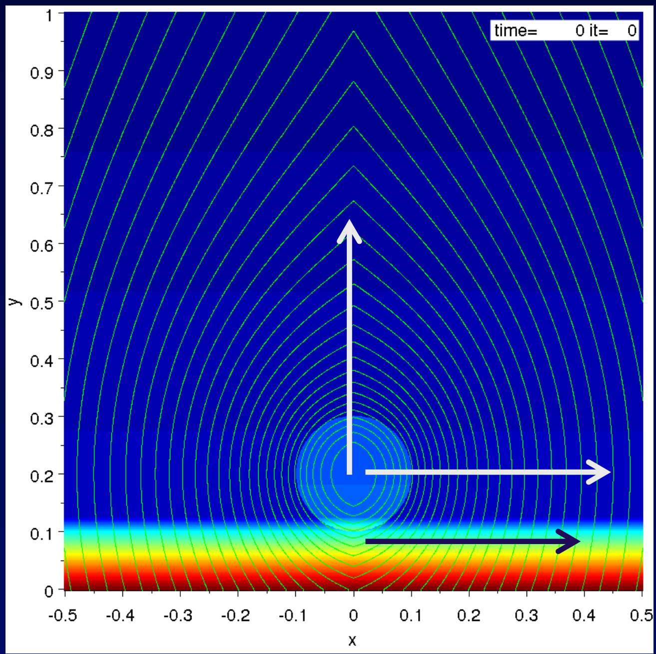


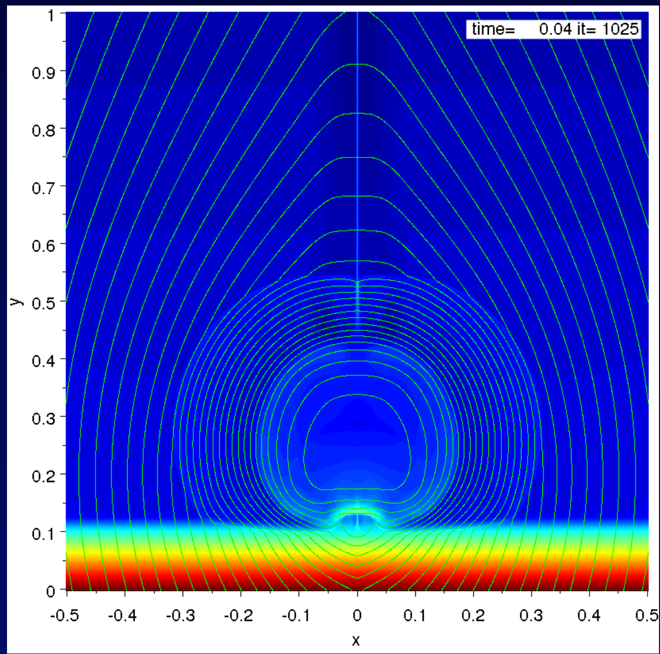


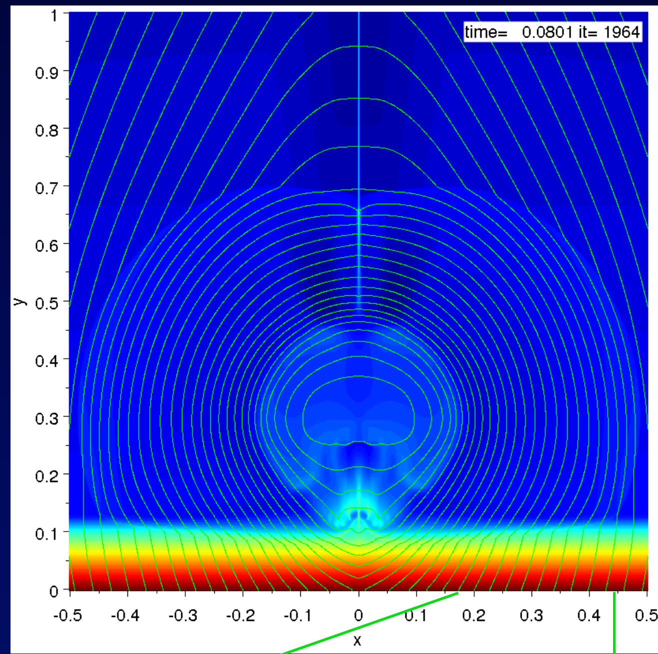


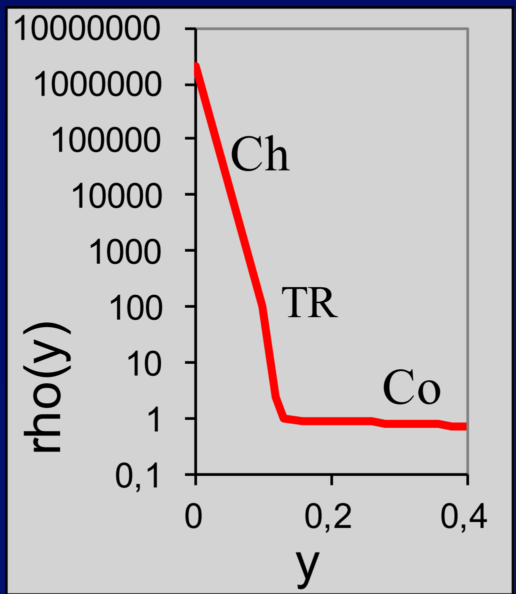


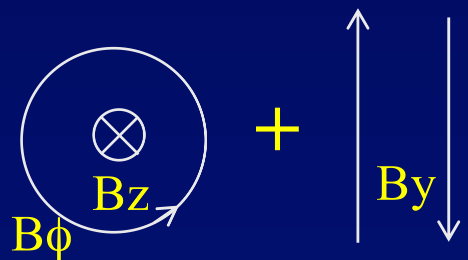
2.5-D MHD simulations: Piston shock

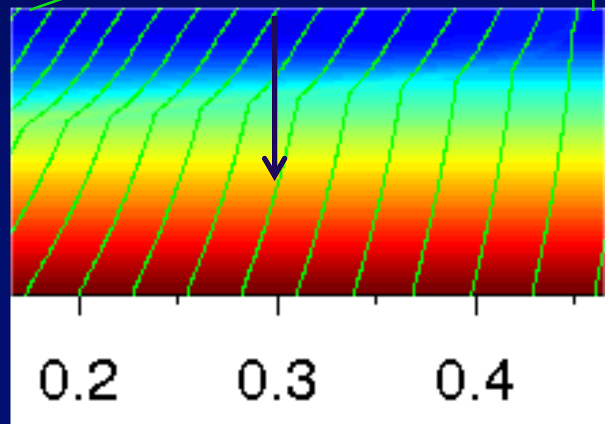


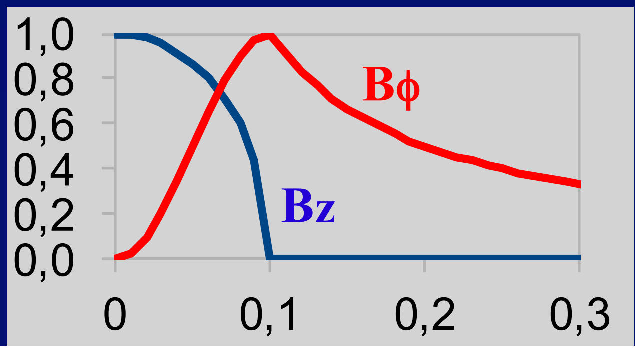






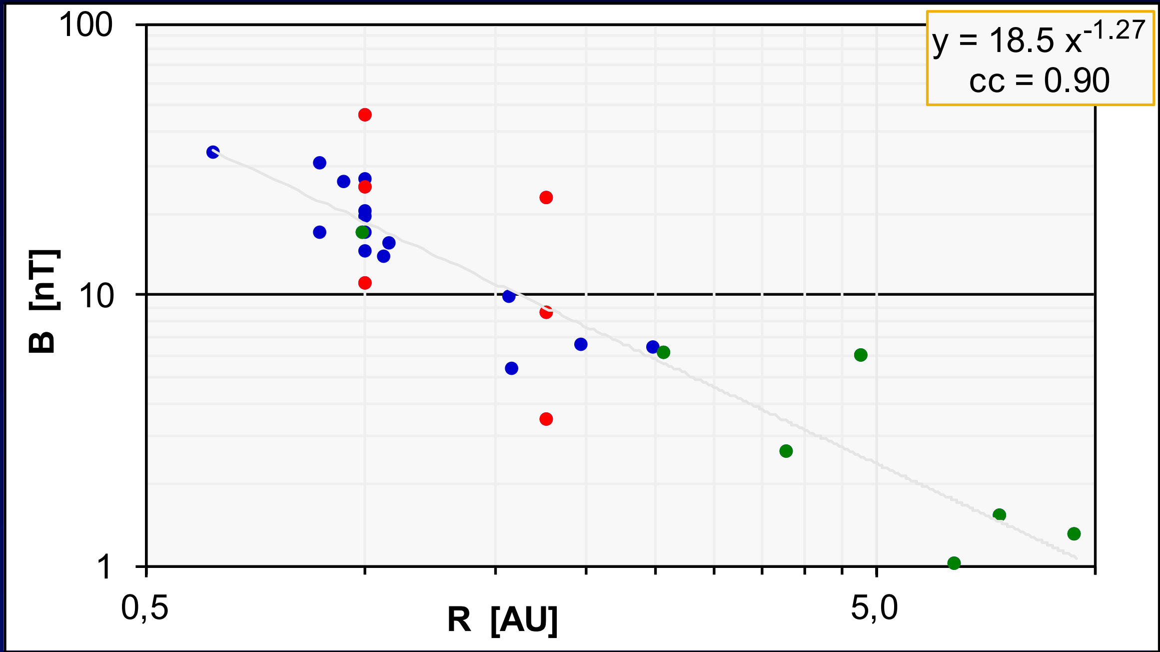






$\beta = 0$

ICMEs - evolution



$B_{||} \sim R^{-1.3}$

expected : $B_{||} \sim R^{-1}$

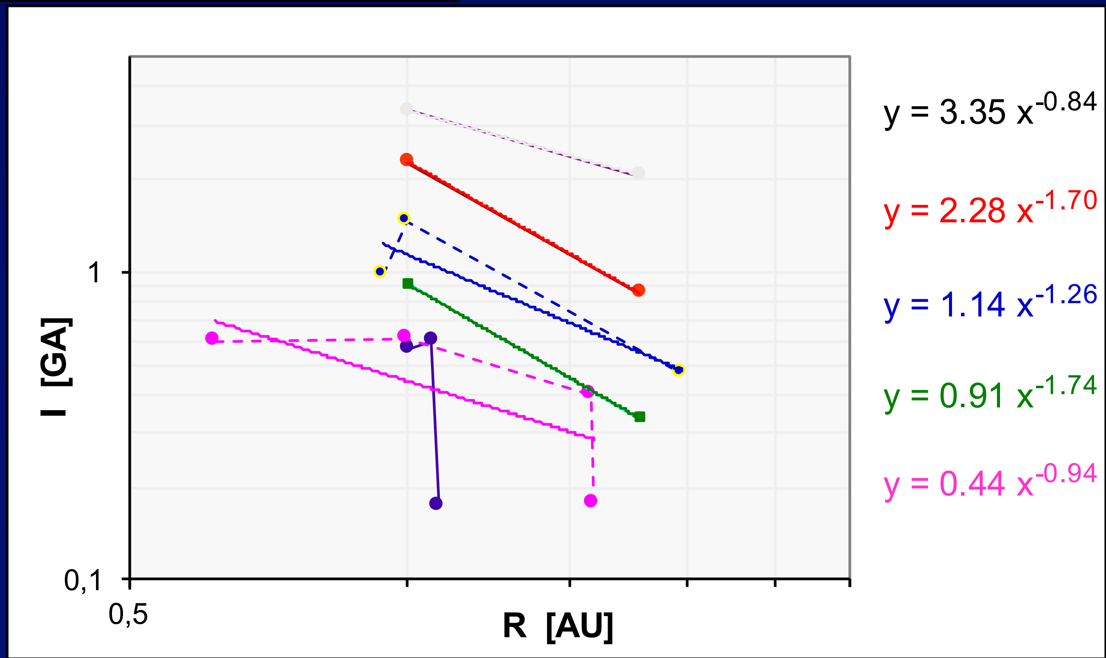
❧ "erosion"

$I_{||} \sim B_{\phi}\, r$

$I_{||} \sim R^{-1.3}$

expected : $I_{||} \sim R^{-1}$

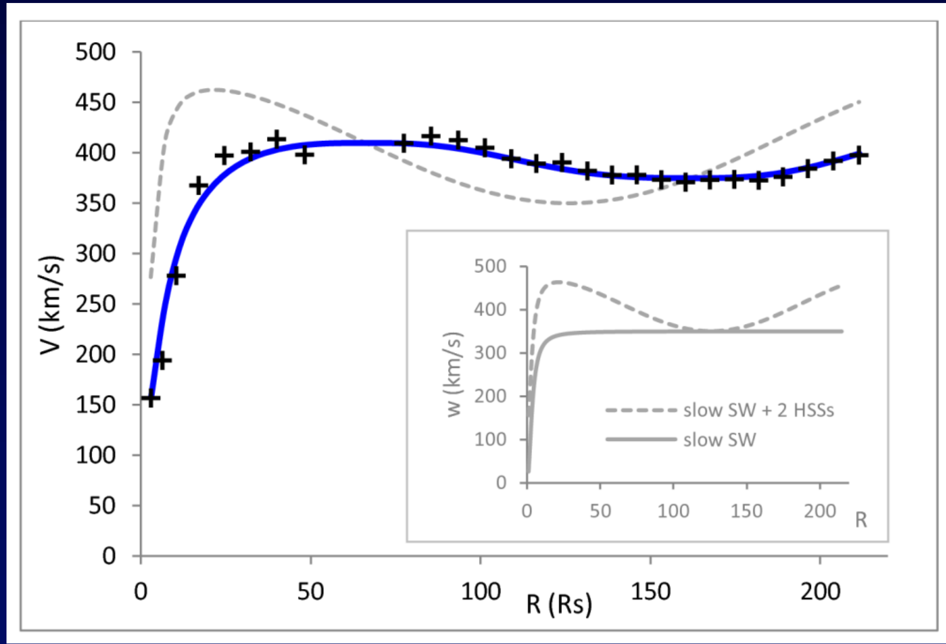
❧ "erosion"

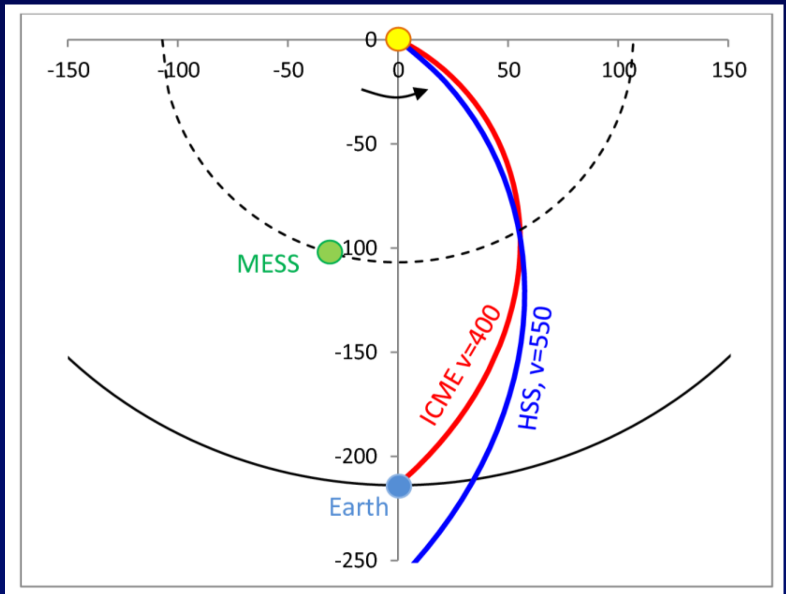


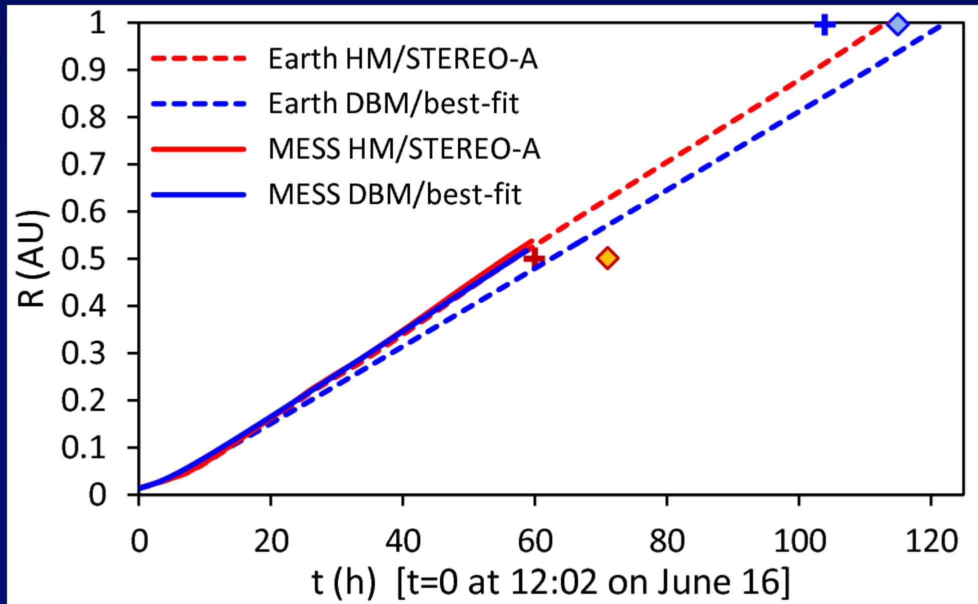
ICMEs – propagation: Drag-Based Model

$$a = -\gamma\,(v-w)\,|v-w|$$

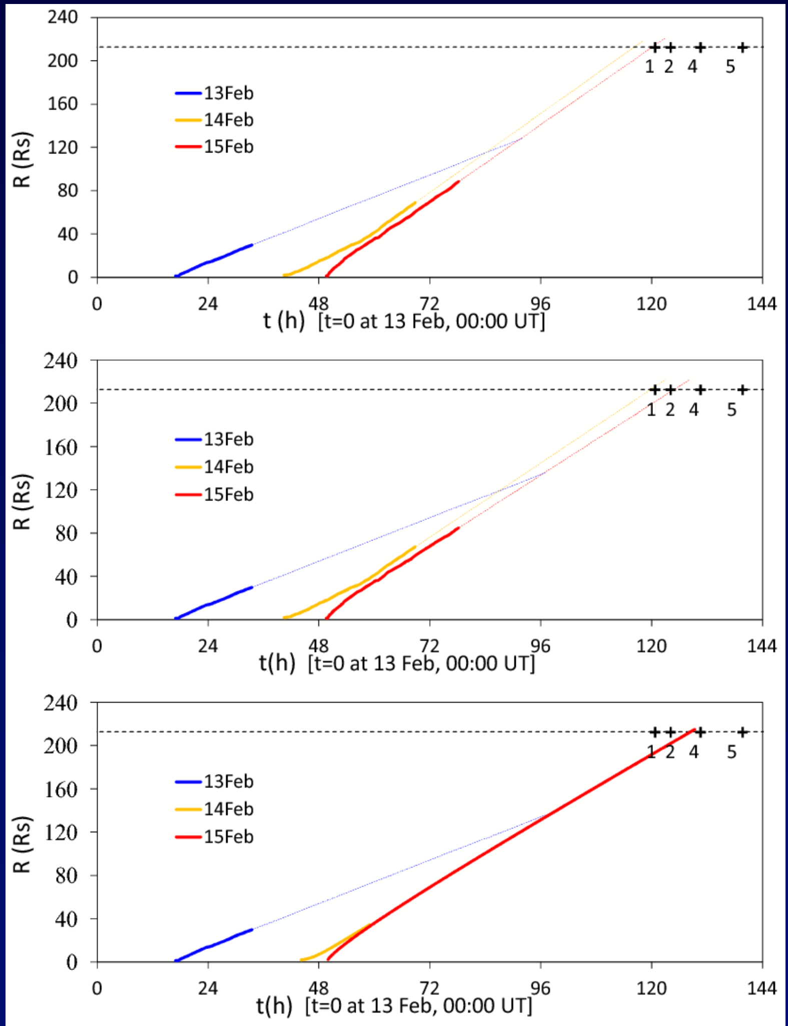
$$[\gamma = c_d A \rho_w / m]$$

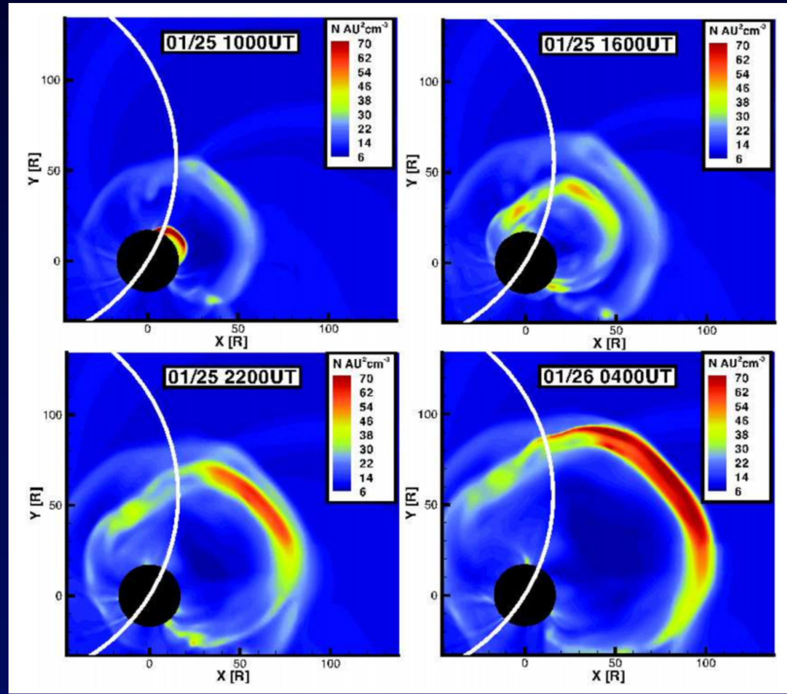


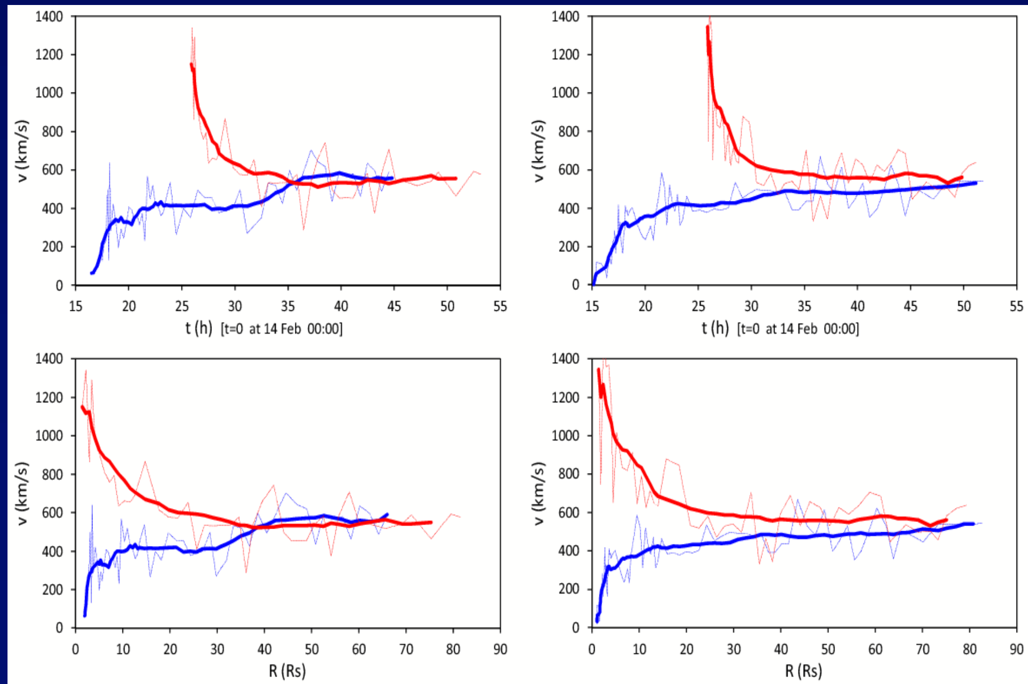




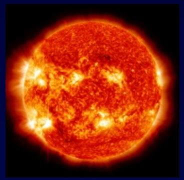
Interacting CMEs





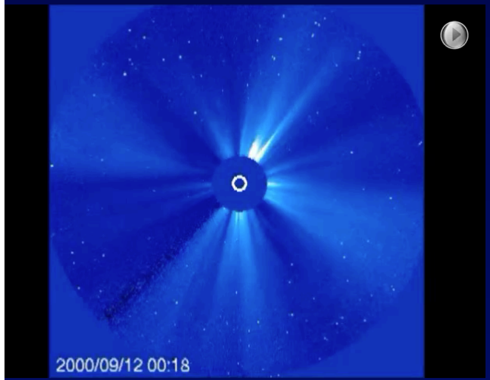


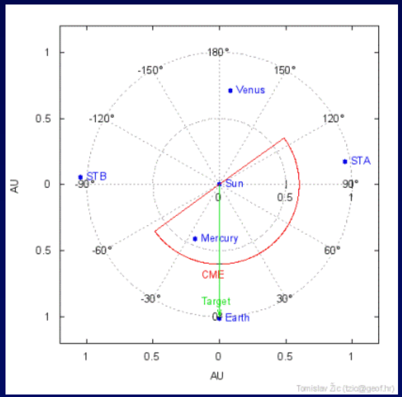
CME space weather effects

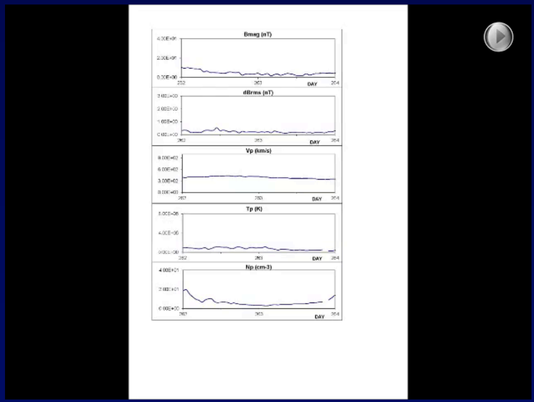


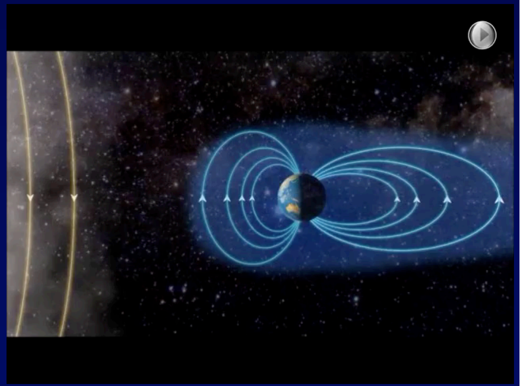
1500 000 km

150 000 000 km







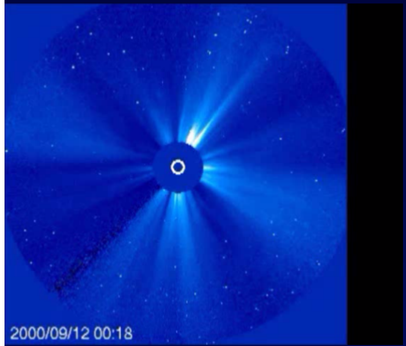


CME detection: Initial conditions → Modeling of CME propagation & evolution → Prediction of ICME arrival and near-Earth properties → Modeling of geomagnetic storms and Forbush decreases

~ 1 day

~ 1 h

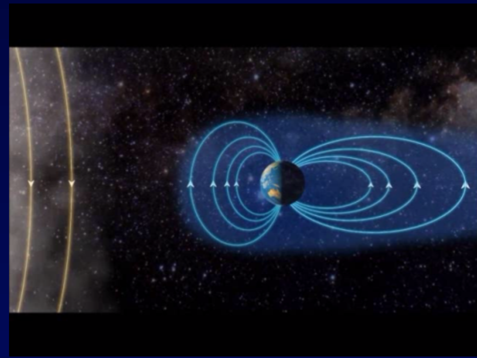
Models for CME space weather effects



Statistical relations

↓

Empirical probabilistic model



CME detection:
Initial conditions

→

Modeling of
geomagnetic storms and
Forbush decreases

~ 1 day

CME Geo-effectiveness Forecast Tool (CGeFT)

Forbush Decrease Forecast Tool (FDFT)

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- Staff
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search...

Home \ Spaceweather tools

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Propagation models

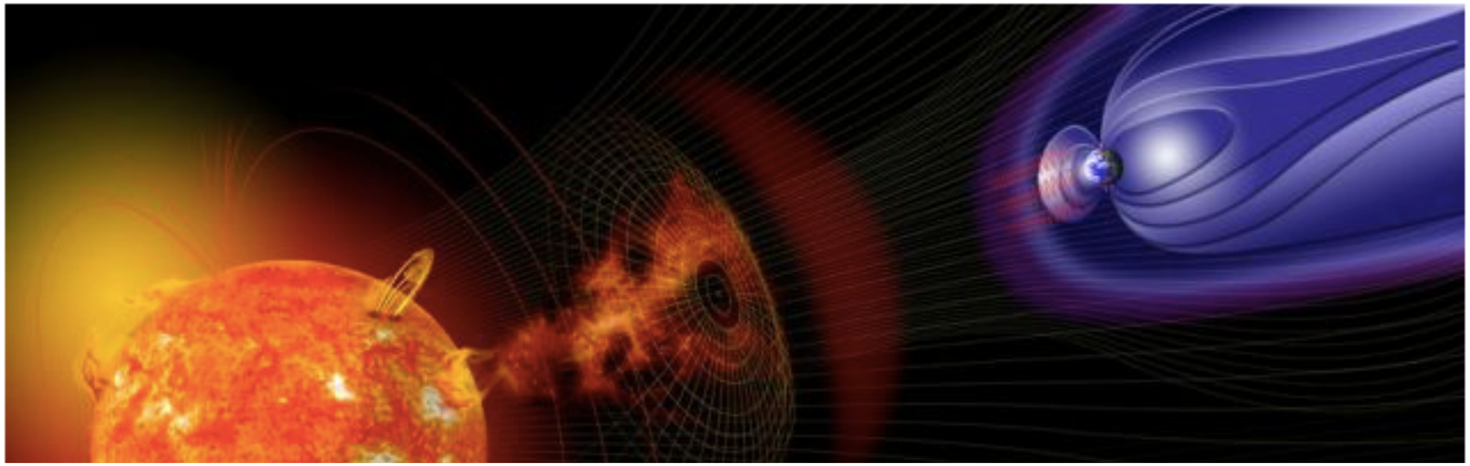
- Forecasting the Arrival of ICMEs at 1 AU: The Drag-Based Model
- Solar wind forecast

Geomagnetic storms

- CME Geo-effectiveness Forecast Tool

Forbush decreases

- Forbush Decrease Forecast Tool



Forecasting the Arrival of ICMEs: The Drag-Based Model

Basic DBM | Advanced DBM | Documentation

CME take-off **date**:	Feb 1 2016
CME take-off **time** (UTC):	18 h 01 min
$\mathbf{R_0}$ - starting radial distance of CME (R_S)	20
$\mathbf{v_0}$ - speed of CME at R_0 (km/s)	1000
$\mathbf{\Gamma}$ - drag parameter (10^{-7} km^{-1})	0.2
w - asymptotic solar wind speed (km/s)	450
$\mathbf{R_{target}}$ - target heliocentric distance (AU)	1

Calculate | Reset!

Drag-Based Model has performed **3015** successful calculations (since 26.12.2012).

Forecasting the Arrival of ICMEs:
The Drag-Based Model

Results | v-R-t plots | CME geometry plot | Documentation

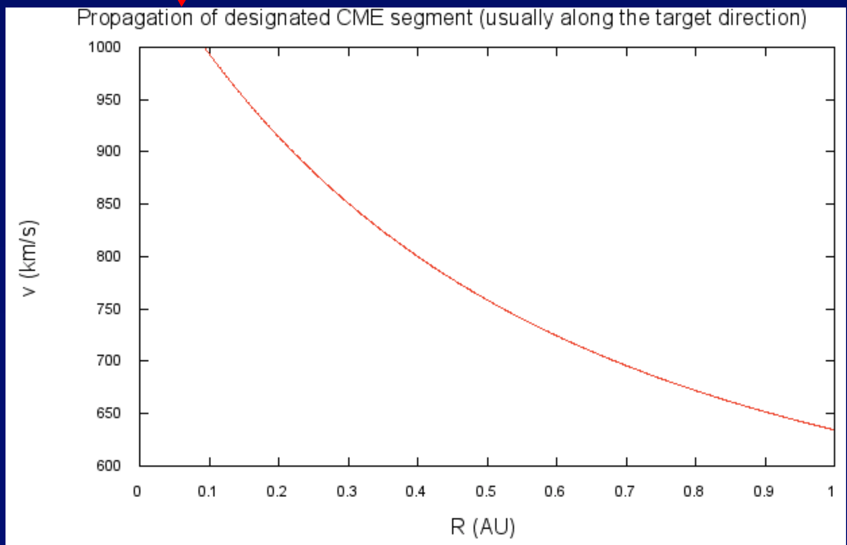
Output:

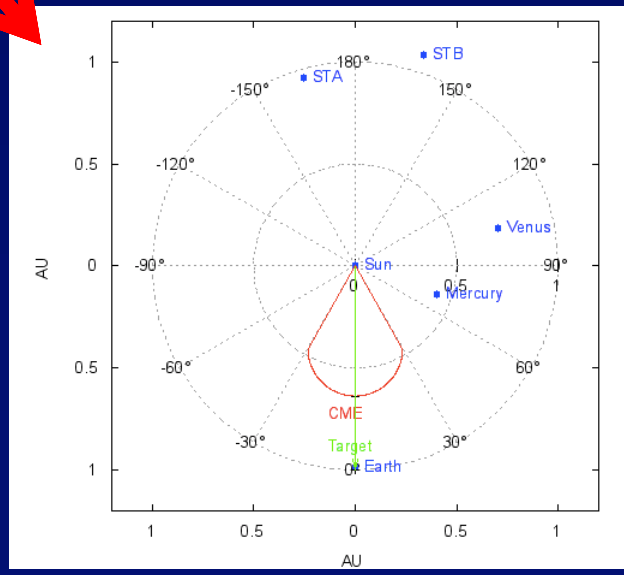
CME arrival at target (date & time): **03.02.2016 at 20h:02min**
Transit time: **49.99** h
Impact speed at target (at 1 AU): **635** km/s

Input parameters:

CME take-off date & time: **01.02.2016 at 18h:03min**

R_0=20 R_S, v_0=1000 km/s, Γ=0.2×10^{-7} km^{-1}, w=450 km/s, R_t=1 AU, Θ=30 deg, ϕ_{target}=0 deg, ϕ_{CME}=0 deg.





CME Geo-effectiveness Forecast Tool (CGeFT)

Model input | Documentation

CME speed, v (in km/s): ? [ ] not available

CME/flare source position radius, R_S (in solar radii): ? [ ] not available

CME apparent width, w: not available

Solar flare x-ray class, f: not available

CME-CME interaction level, i: not available

Calculate Reset!

CME geo-effectiveness forecast tool has performed **265** successful calculations (since 10.3.2014).

Opservatorij Hvar Hvar Observatory IGAM SOLSTEL MESEP HEP

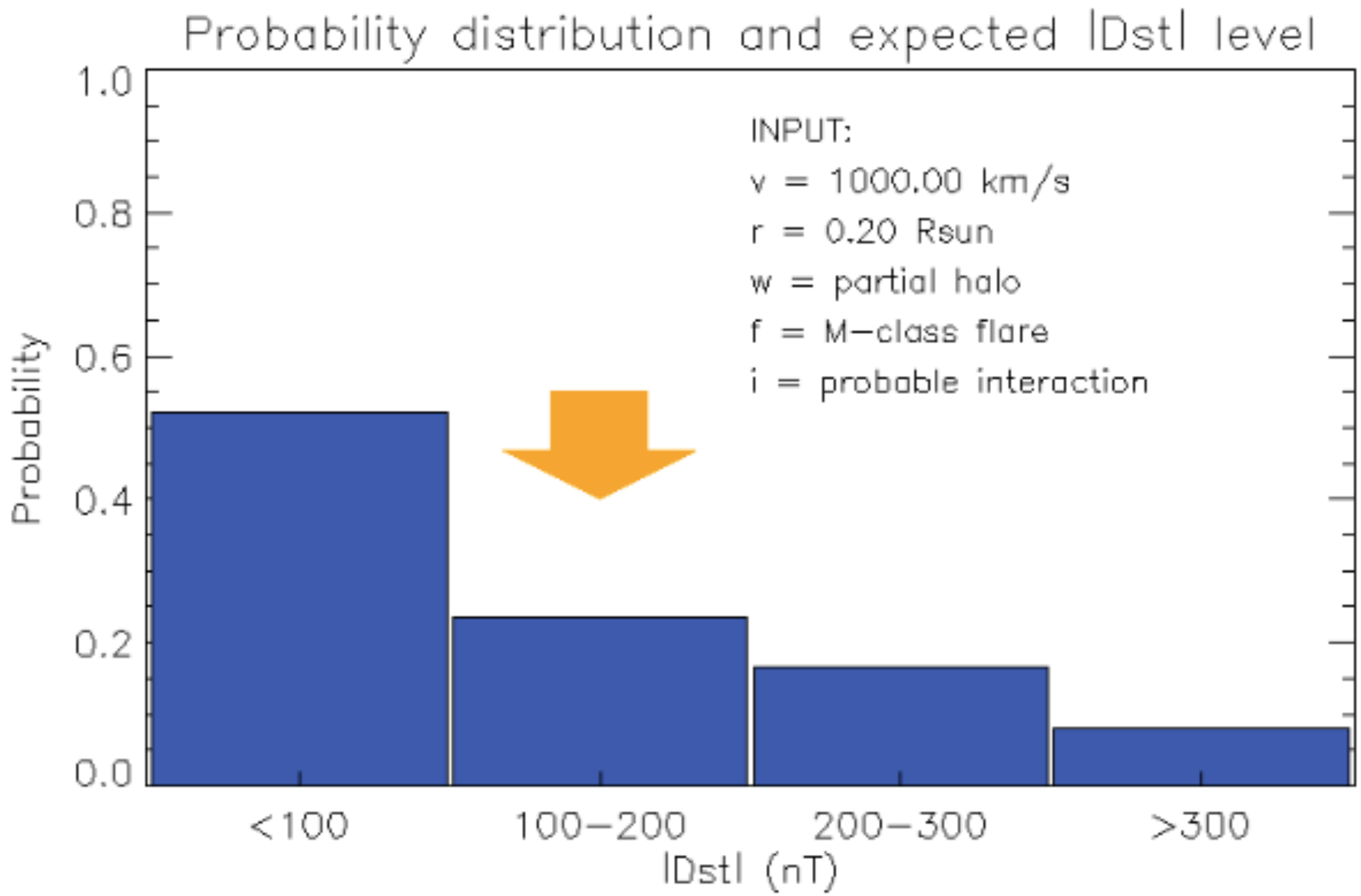
CME Geo-effectiveness Forecast Tool (CGeFT)

Results | Documentation

Output:

Based on the probability distribution for a given CME (blue histogram), the expected |Dst| level calculated by the model is 100 nT < |Dst| < 200 nT (marked by arrow).
Combined probability distribution calculated based on P_v, P_r, P_w, P_f, P_i (see table and table description).

For model calculation details see documentation.



Forbush Decrease Forecast Tool (FDFT)

Model input | Documentation

Initial CME speed, *v* (in km/s): ? — not available

CME/flare source position radius, R_S (in solar radii): ? — not available

CME apparent width, *w* (in degrees): ? — not available

Flare strenght, *f* (in 10^{-7} Wm^{-2}): ? — or select flare x-ray class — not available

CME-CME interaction level, *i*: not available

Calculate | Reset!

Forbush Decrease Forecast Tool has performed **20** successful calculations (since 10.3.2015).

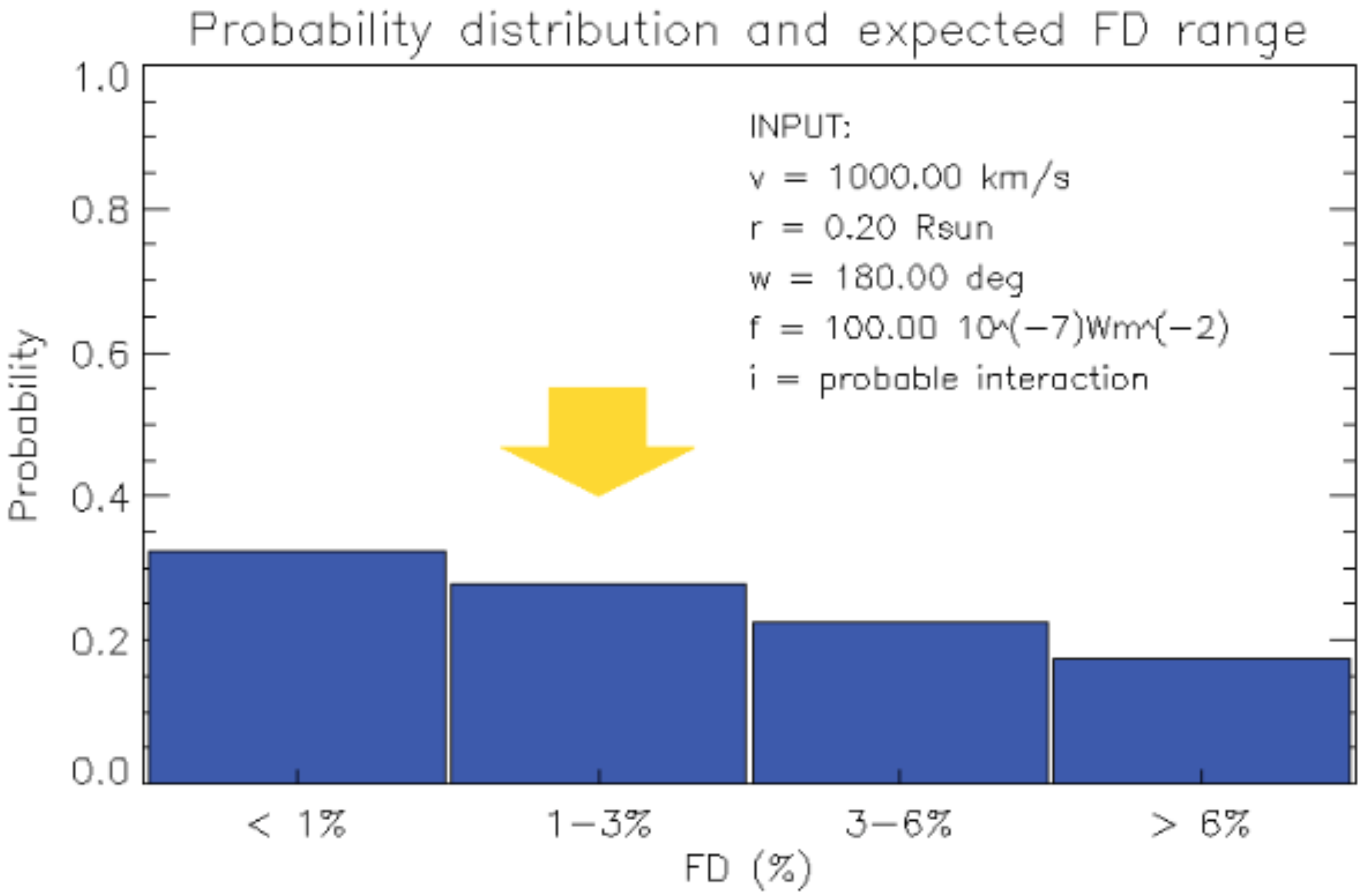
Forbush Decrease Forecast Tool (FDFT)

Results | Documentation

Output:

Based on the probability distribution for a given CME (blue histogram), the expected FD range calculated by the model is 1% < FD < 3% (marked by arrow).
Combined probability distribution calculated based on P_v,P_r,P_w,P_f,P_i (see table and table description).

For model calculation details see documentation.



Thank you

for

your attention