# Parametric functions of the coronal mass ejections properties close to the Sun based on numerical hydrodynamic simulations

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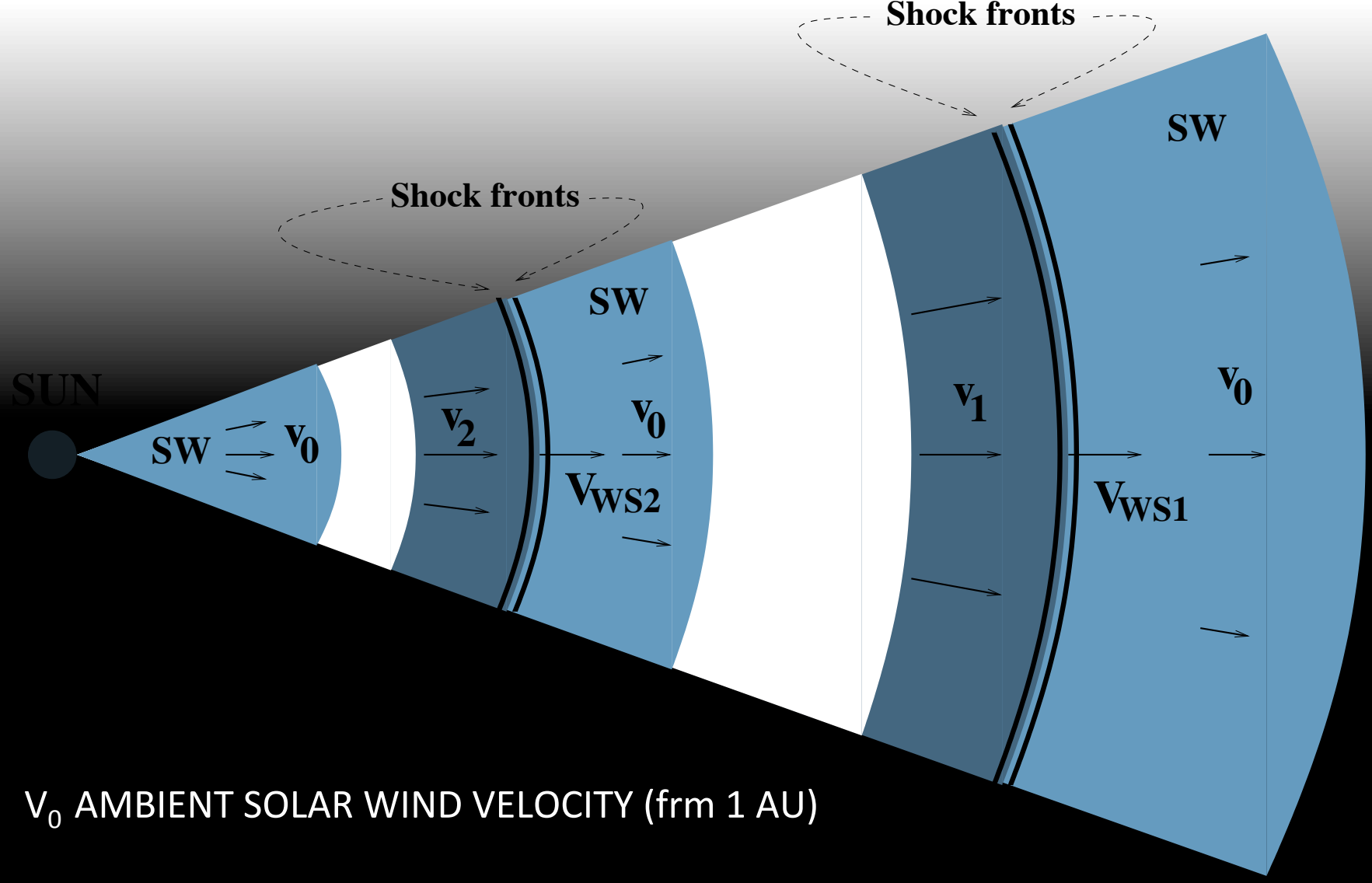



$V_0$ AMBIENT SOLAR WIND VELOCITY (frm 1 AU)

$V_1$ VELOCITY OF THE 1st CME (LEADING EDGE)

$V_2$ VELOCITY OF THE 1st CME (LEADING EDGE)

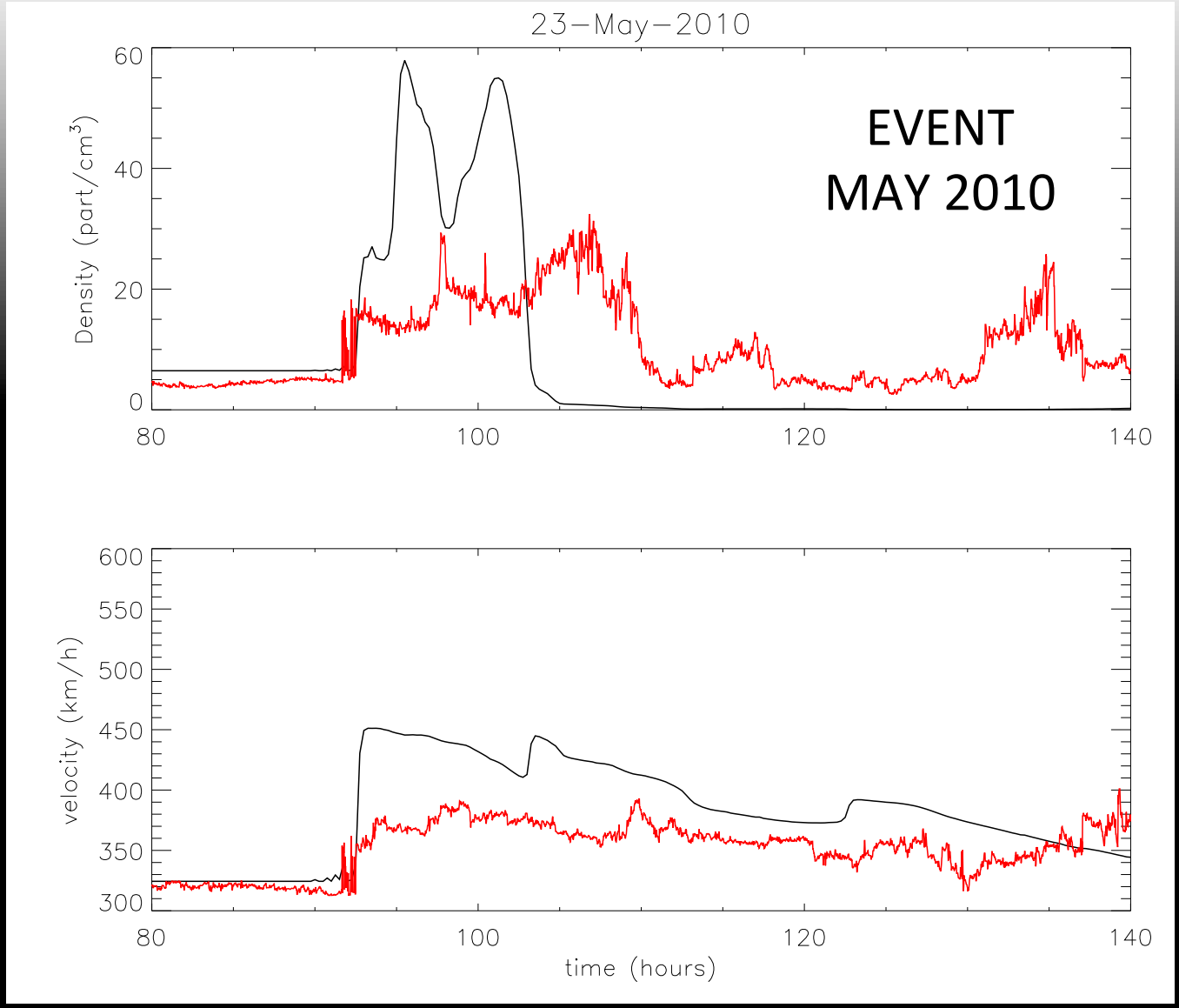
**Niembro et al 2015**

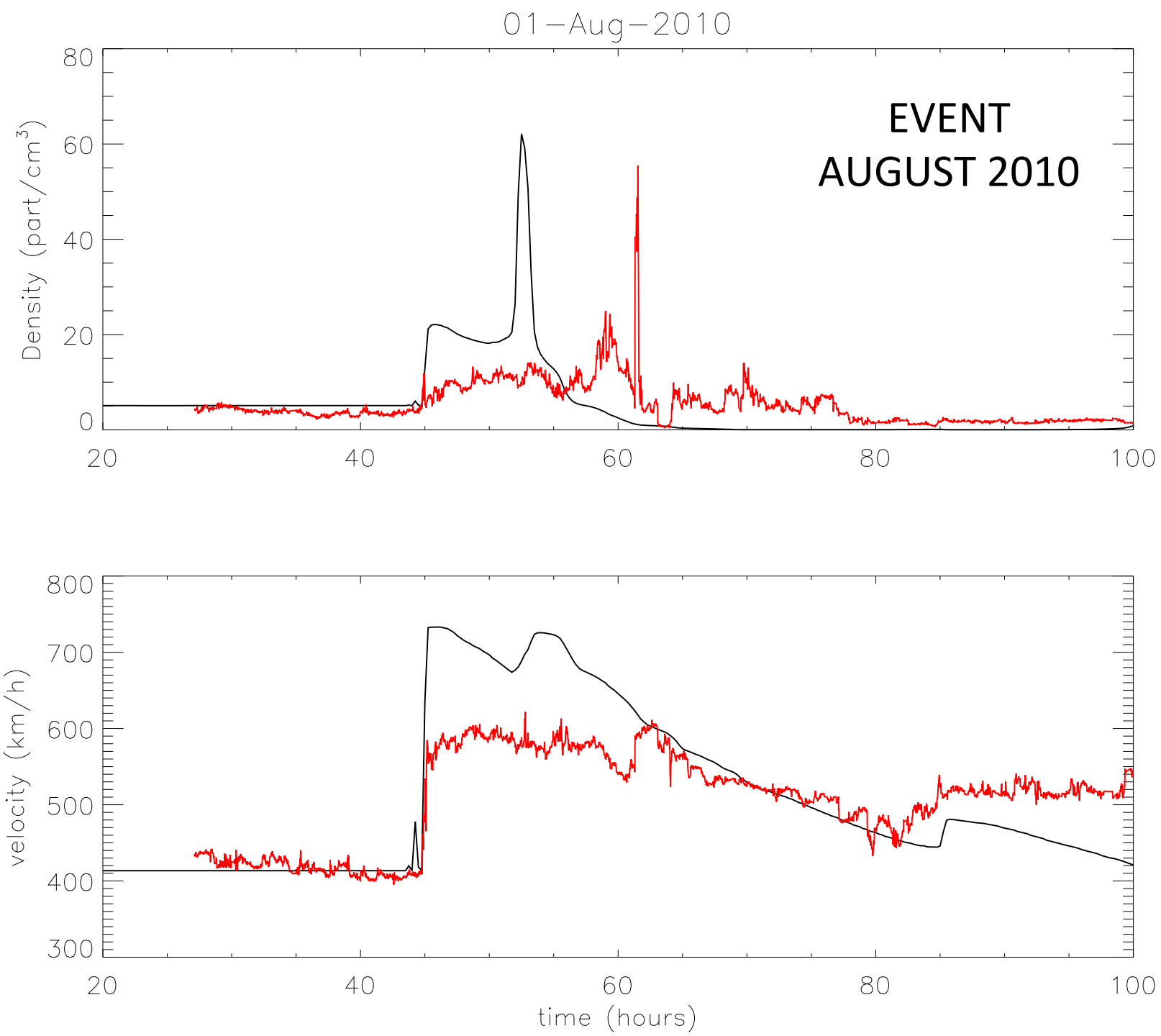
# METHOD

1) We set the initial parameters for:
   CME: velocity, mass loss rate, injection time
   SW: velocity, mass loss rate

2) We obtained profiles of density and velocity as function of time at 1 AU

3) We compared our results with real data at 1 AU


23−May−2010
EVENT
MAY 2010
Density (part/cm$^3$)
60
40
20
0
80
100
120
140
velocity (km/h)
600
550
500
450
400
350
300
80
100
120
140
time (hours)


01−Aug−2010
EVENT
AUGUST 2010
Density (part/cm$^3$)
velocity (km/h)
time (hours)
0
20
40
60
80
100
300
400
500
600
700
800

# FITTING PROBLEMS

Arrival Time +/- 8 hours
Arrival Velocity ++/- 100 km $s^{-1}$
Arrival Density +50 $cm^{-3}$
Compression Region Duration -10 hours
Rarefaction Region Duration -15 hours

# WHY?

- MODEL (1)

- OBSERVATIONS

  CME: velocity, mass loss rate, injection time

  SW: velocity, mass loss rate

The mass loss rate depends on the mass, the solid angle and the injection time

# BACK TO BASICS

- 1 CME
- 1 Dimension
- Change the input set parameters (5)
- FIX 4 and 1 free

## CME

$v = 1330\ km\ s^{-1}$
$m = 1.1\ x\ 10^{13}\ kg$
$n = 1.5\ cm^{-3}$
$Dt = 2\ hr$
$\dot{m} = 1.272\ x\ 10^{-13}\ M_{\odot}\ yr^{-1}$
$\phi = 1.8\ rad$

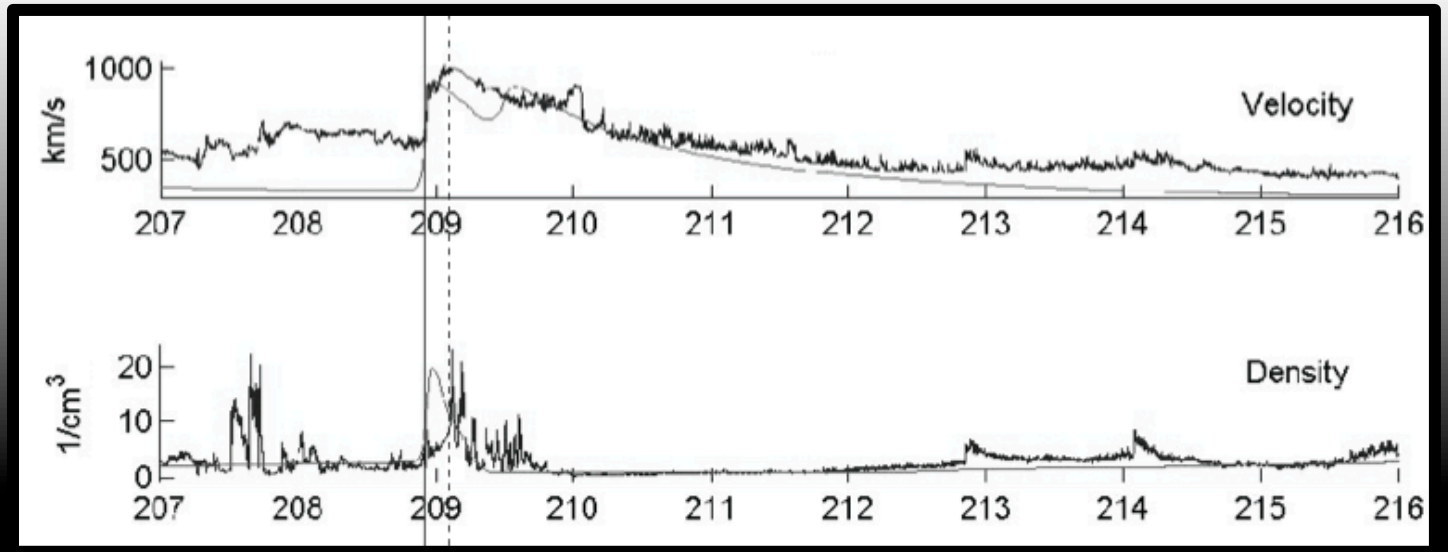
# EVENT
# July 25, 2004

**AMBIENT SOLAR WIND (SW)**

$v_0 = 650\ km\ s^{-1}$
$\dot{m}_0 = 7.26\ x\ 10^{-15}\ M_{\odot}\ yr^{-1}$

VRSNAK ET AL 2010

geofisica UNAM
UNAM POSGRADO
instituto de astronomía unam
CRyA

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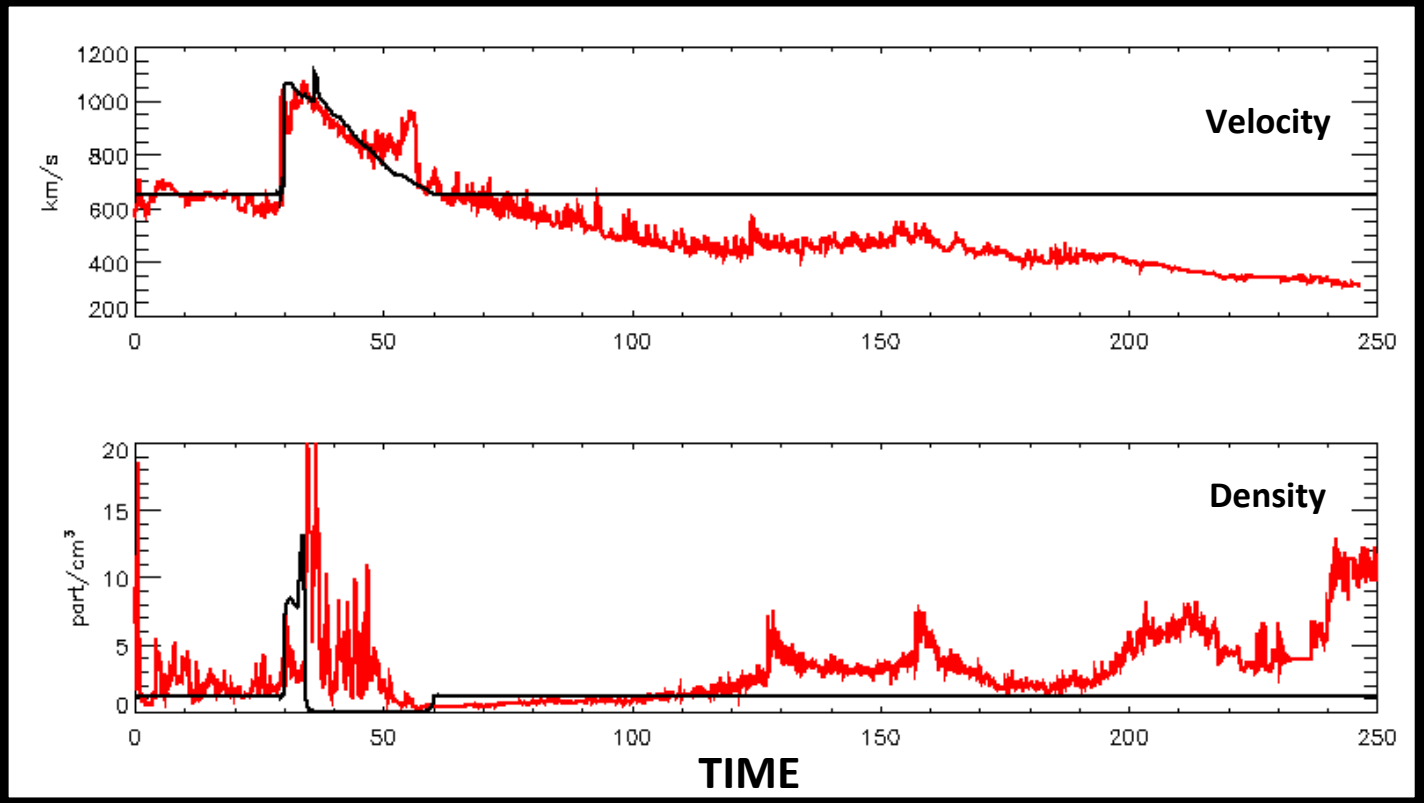
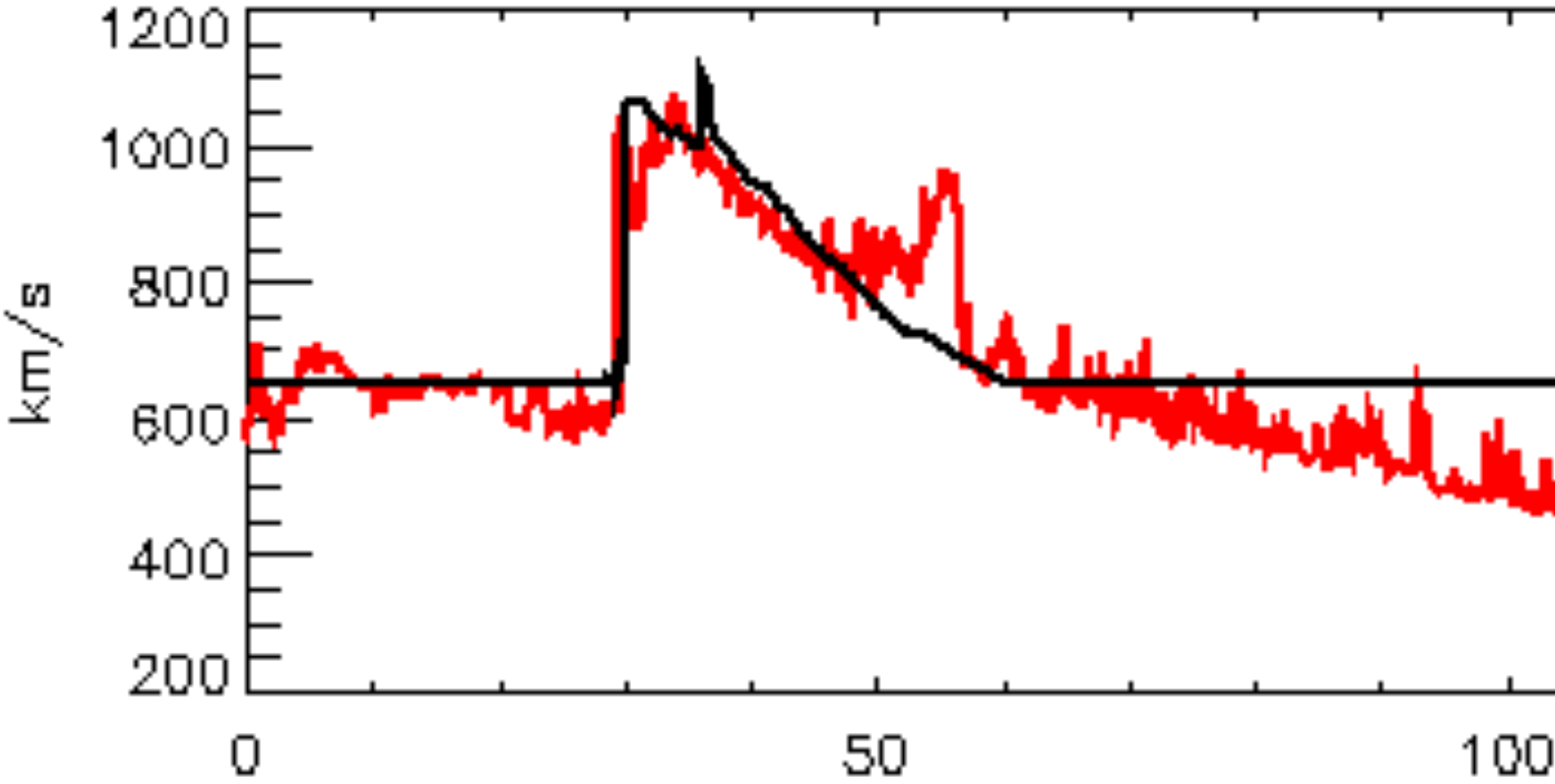
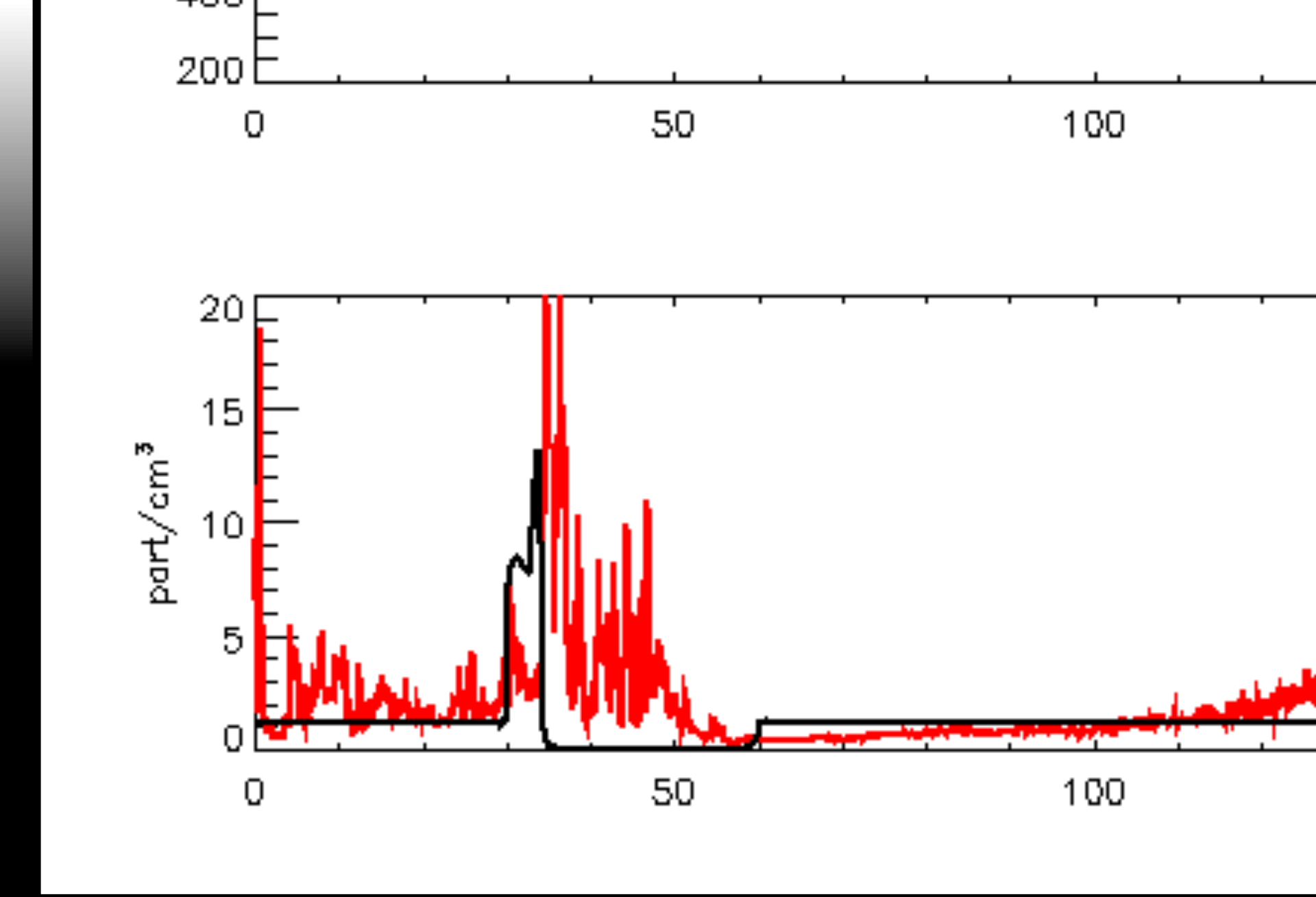
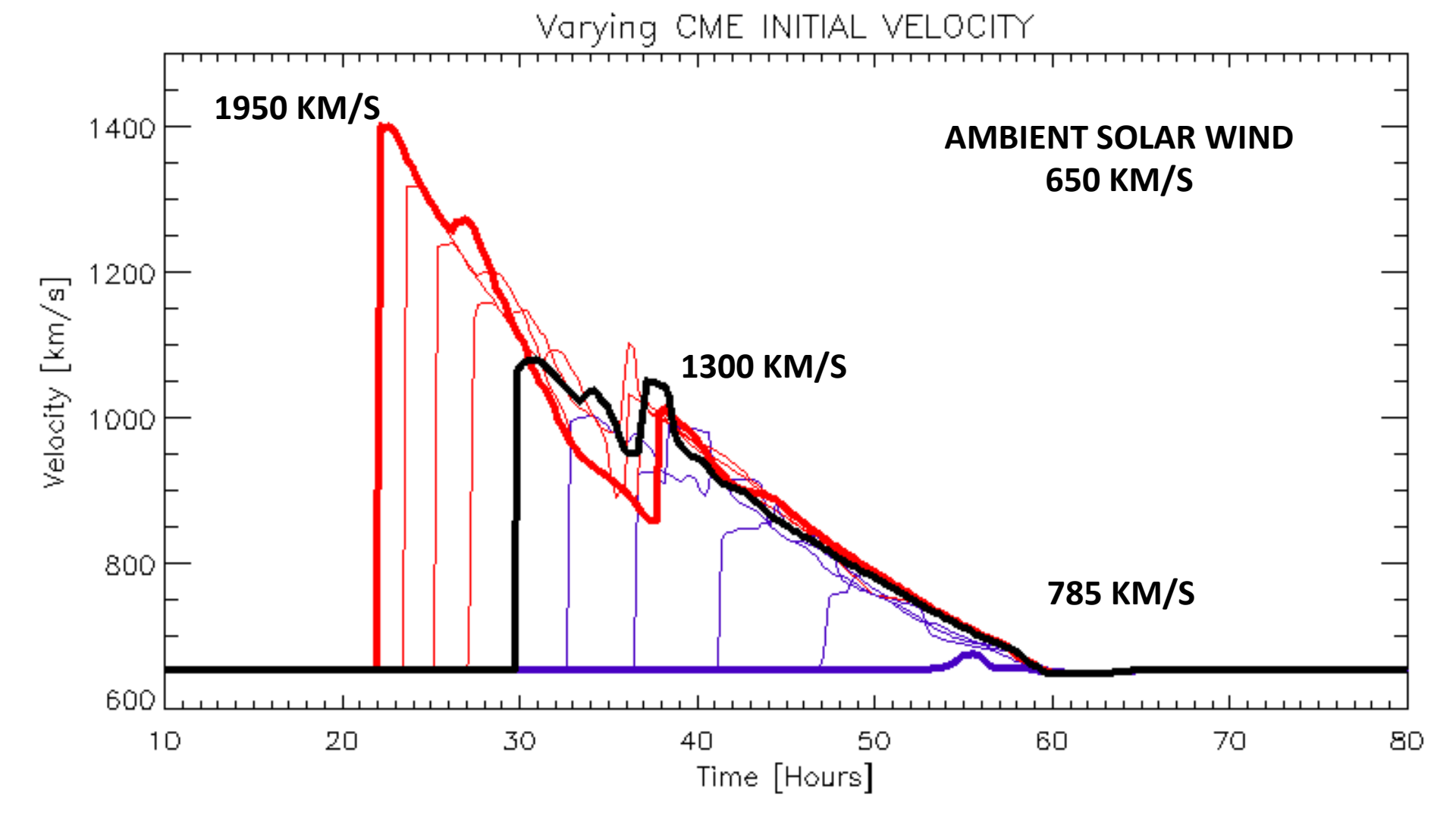


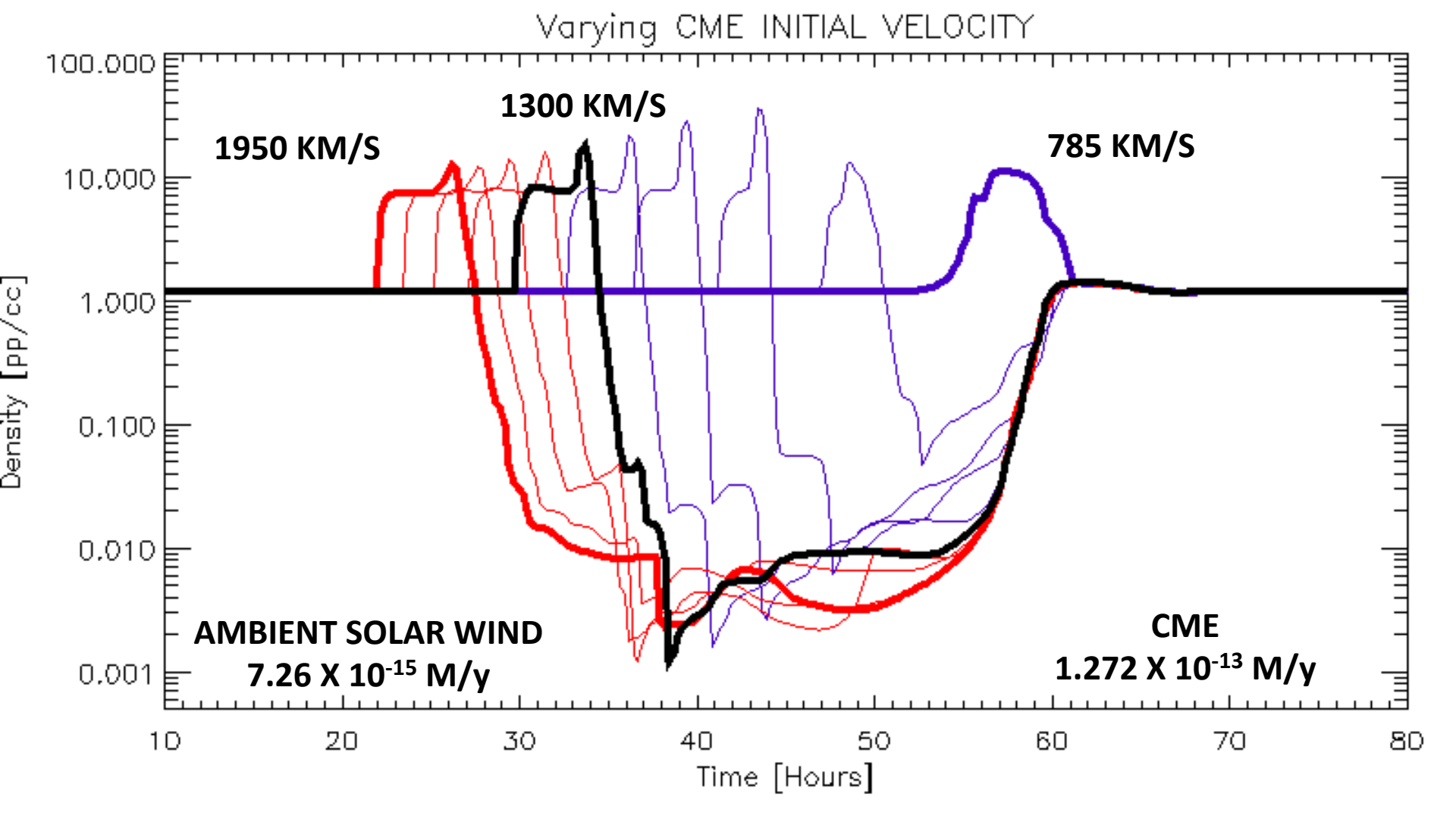

YGUAZÚ


1200
1000
800
600
400
200
km/s
0
50
100

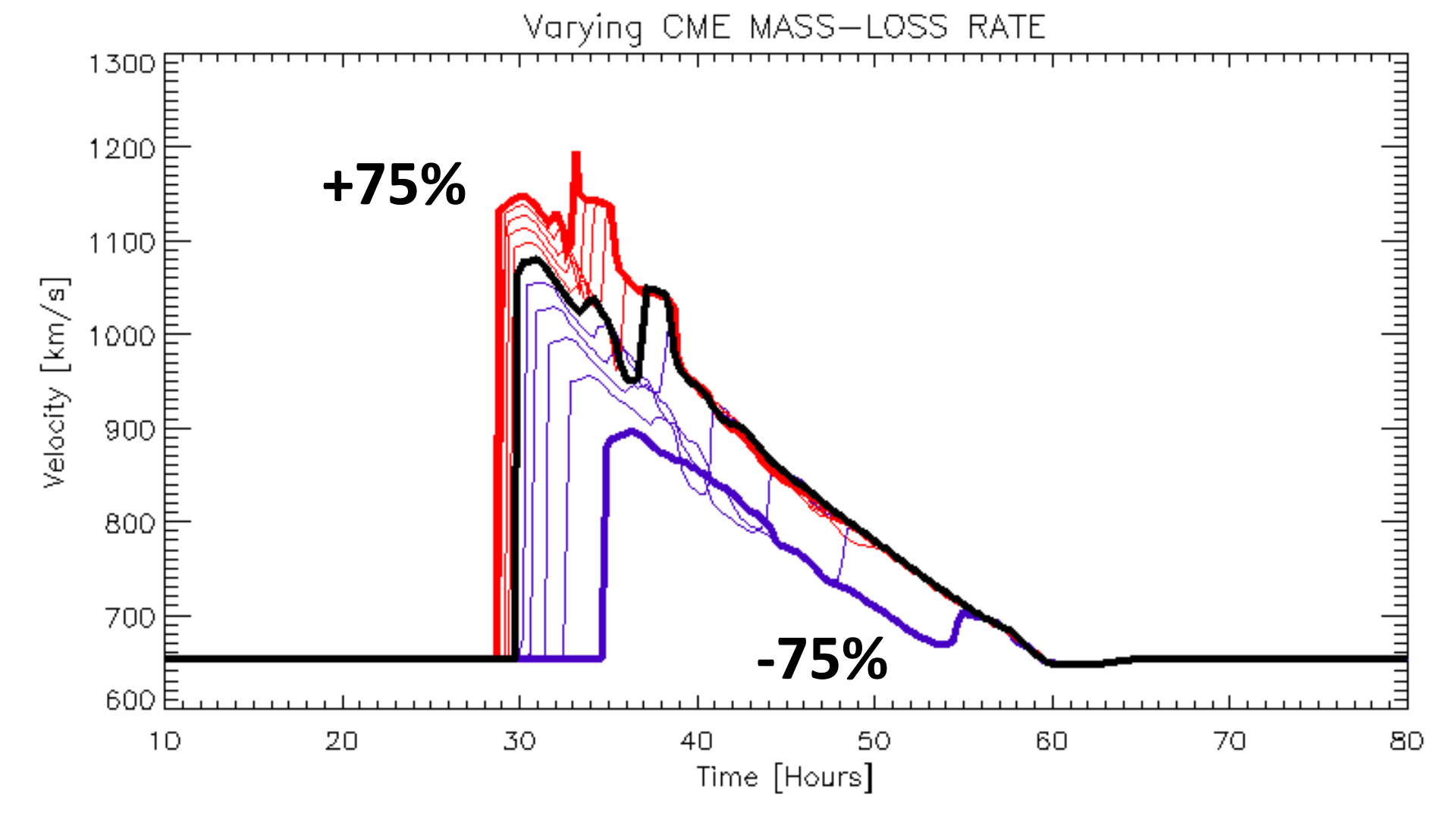

200
0
50
100
20
15
10
5
0
part/cm³
0
50
100

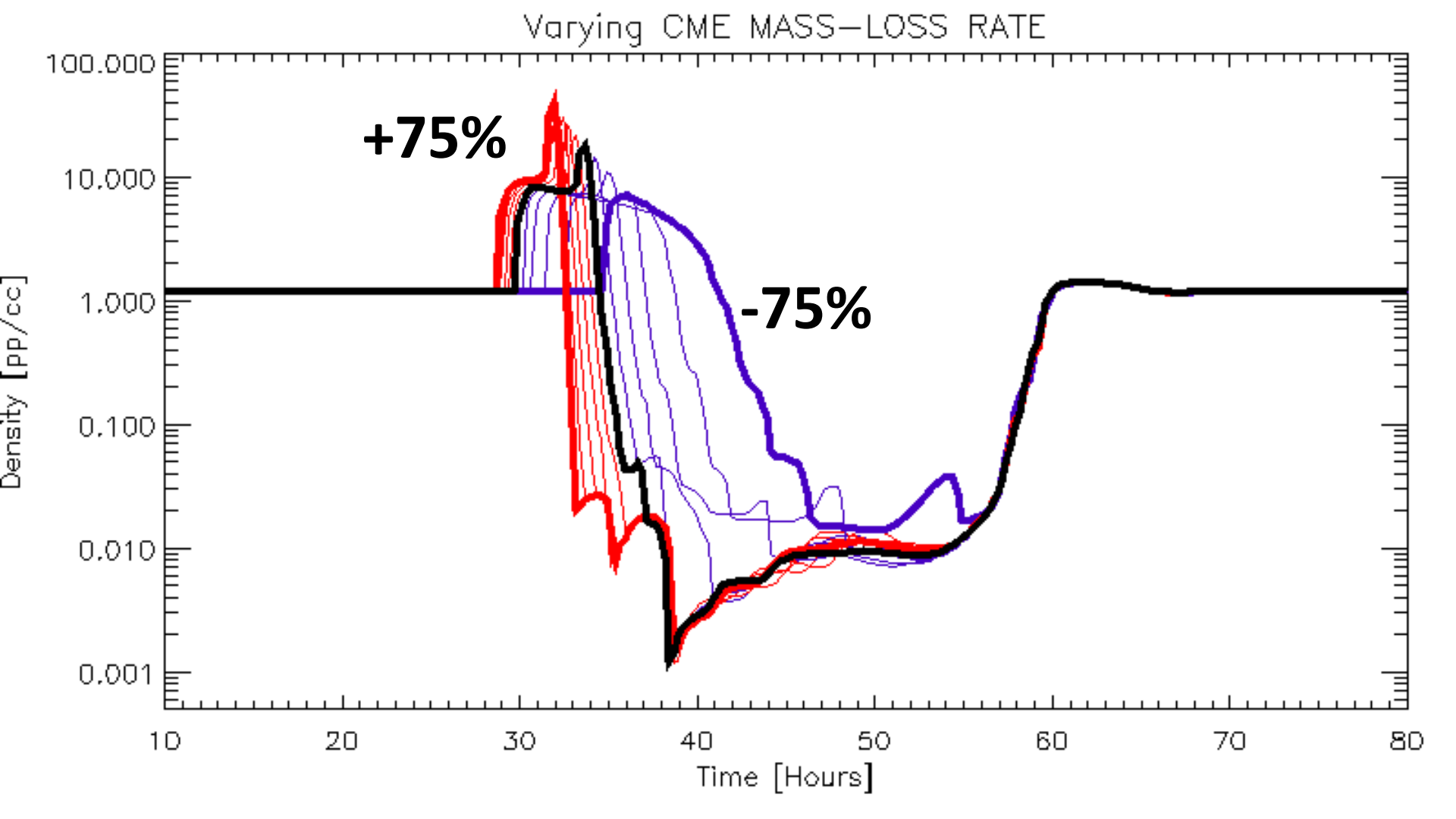
# CHANGING THE VELOCITY OF THE CME


Varying CME INITIAL VELOCITY
1950 KM/S
AMBIENT SOLAR WIND
650 KM/S
1300 KM/S
785 KM/S
Velocity [km/s]
1400
1200
1000
800
600
10
20
30
40
50
60
70
80
Time [Hours]

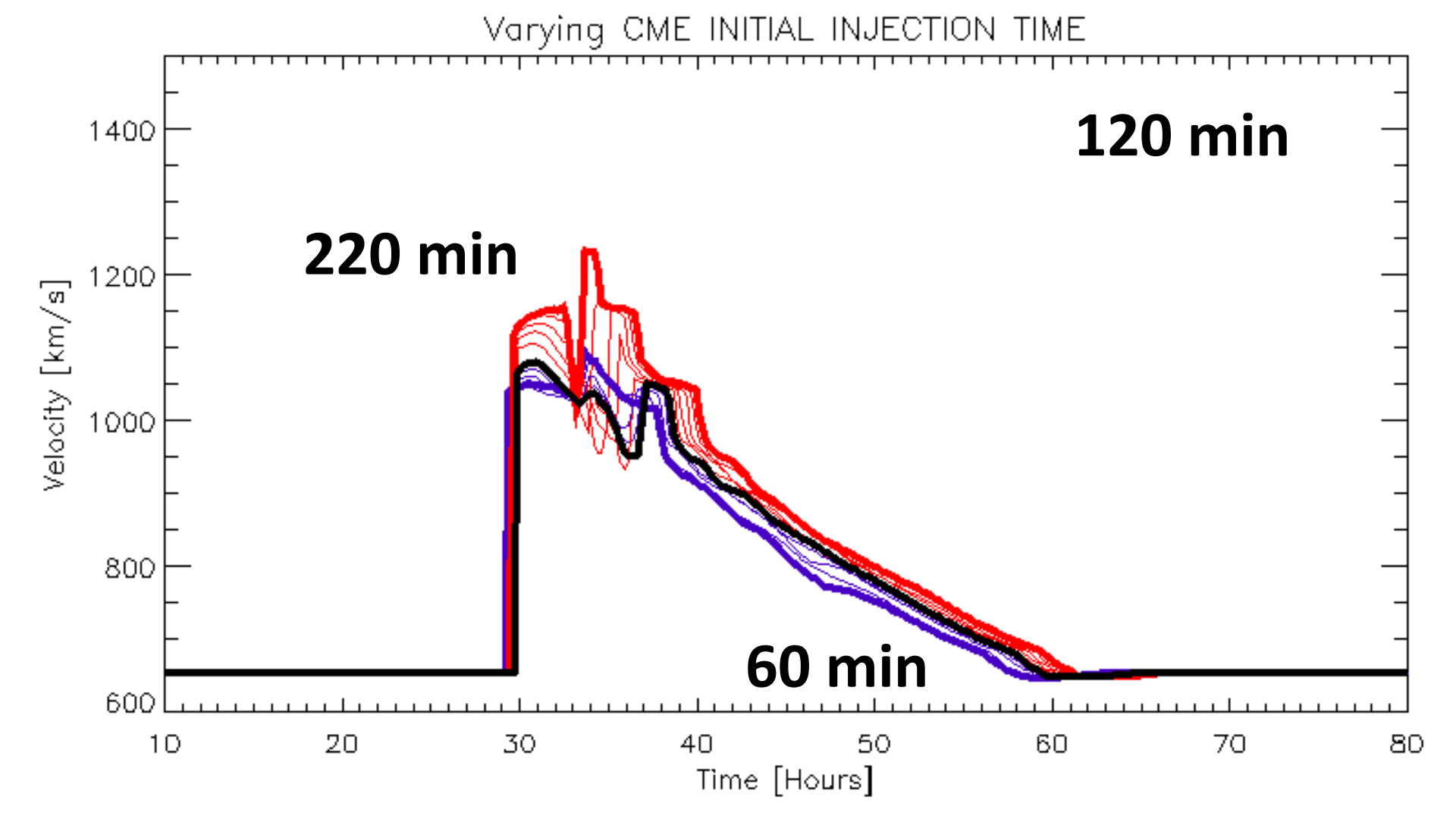

Varying CME INITIAL VELOCITY
100.000
10.000
1.000
0.100
0.010
0.001
Density [pp/cc]
1950 KM/S
1300 KM/S
785 KM/S
AMBIENT SOLAR WIND
7.26 X 10-15 M/y
CME
1.272 X 10-13 M/y
10
20
30
40
50
60
70
80
Time [Hours]

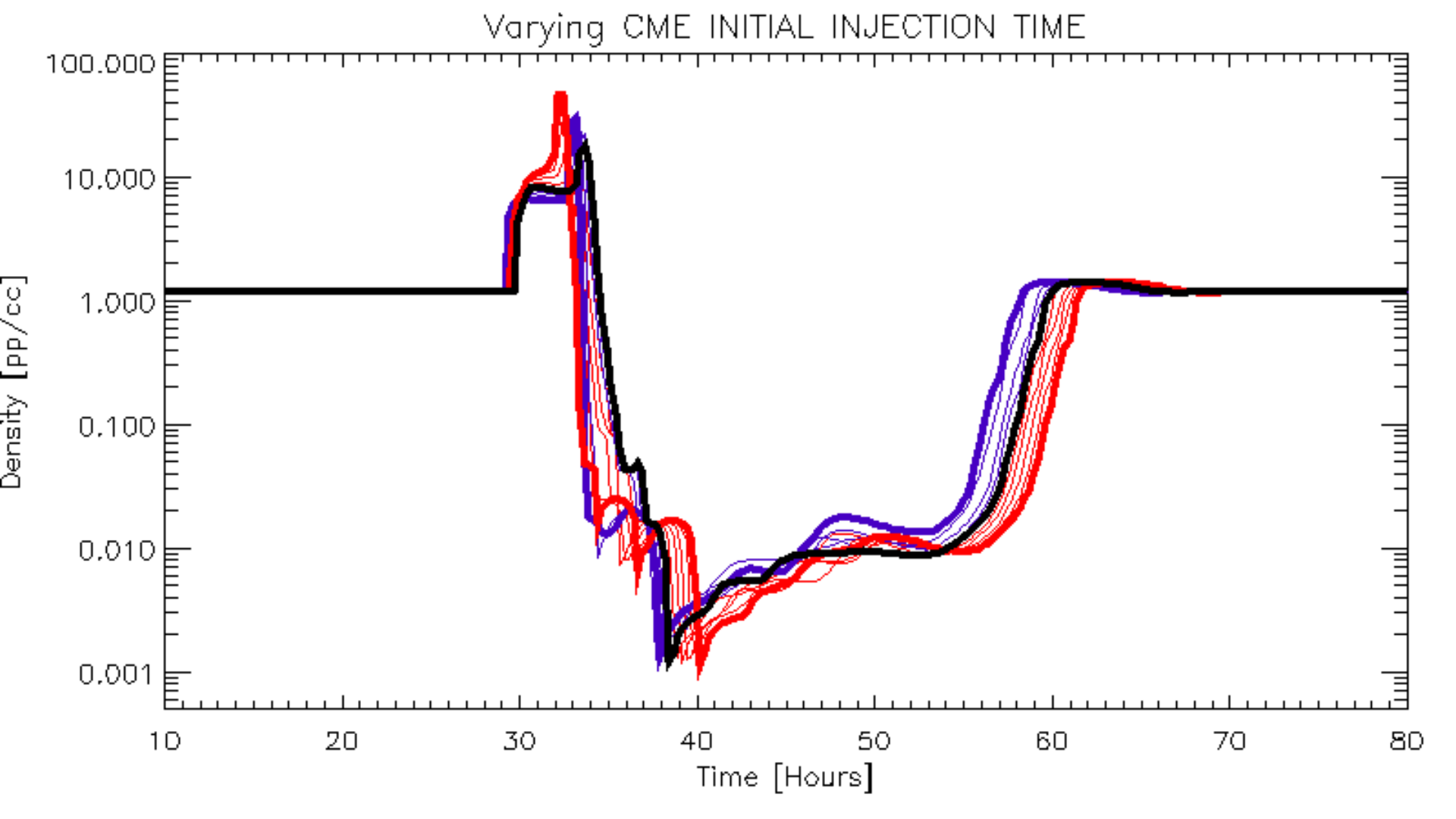
# CHANGING THE MASS LOSS RATE OF THE CME


Varying CME MASS–LOSS RATE
+75%
-75%
Velocity [km/s]
Time [Hours]
1300
1200
1100
1000
900
800
700
600
10
20
30
40
50
60
70
80

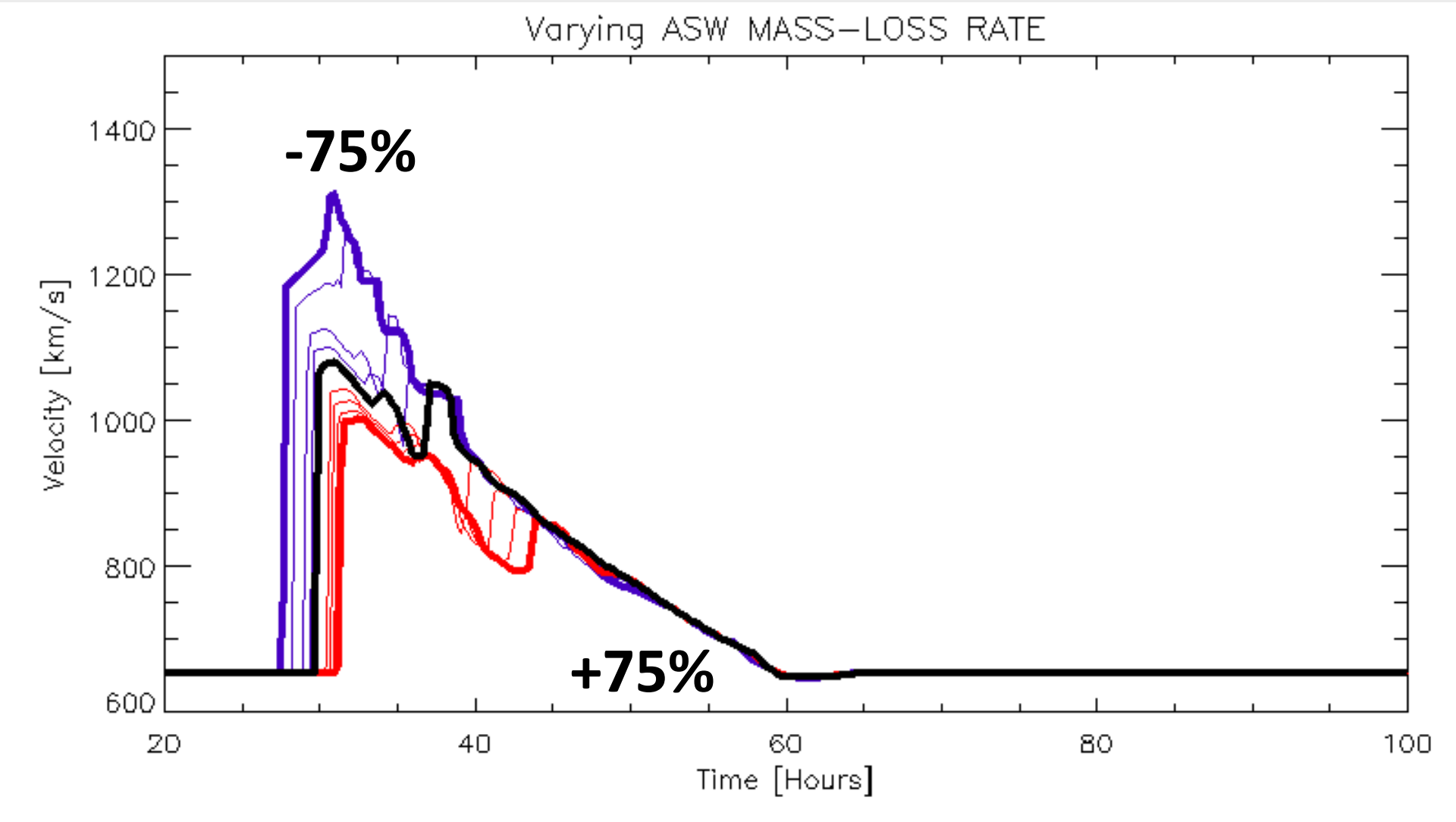

Varying CME MASS-LOSS RATE
+75%
-75%
100.000
10.000
1.000
0.100
0.010
0.001
Density [pp/cc]
10
20
30
40
50
60
70
80
Time [Hours]

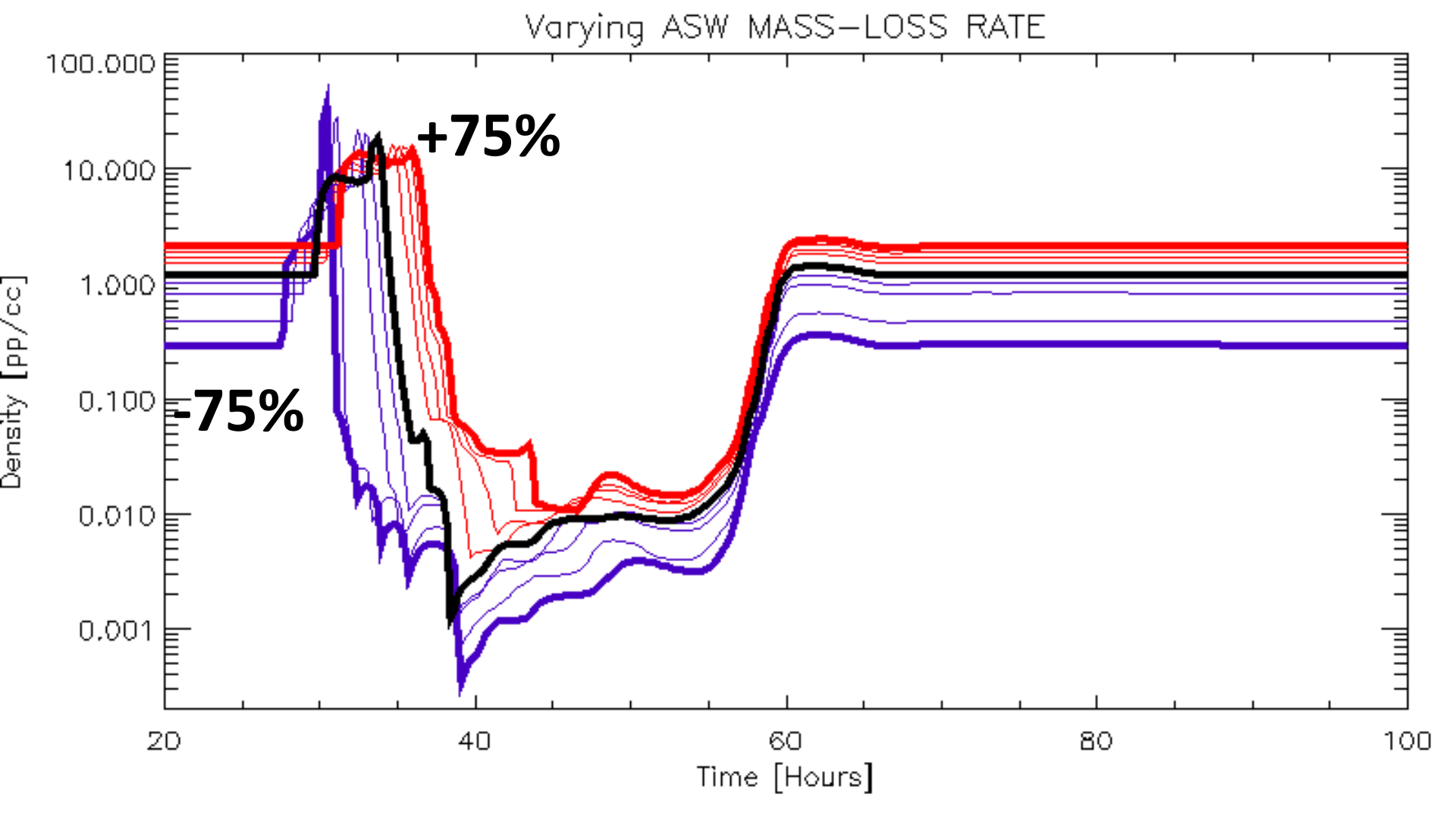
# CHANGING THE INJECTION TIME OF THE CME


Varying CME INITIAL INJECTION TIME
120 min
220 min
60 min
Velocity [km/s]
1400
1200
1000
800
600
10
20
30
40
50
60
70
80
Time [Hours]

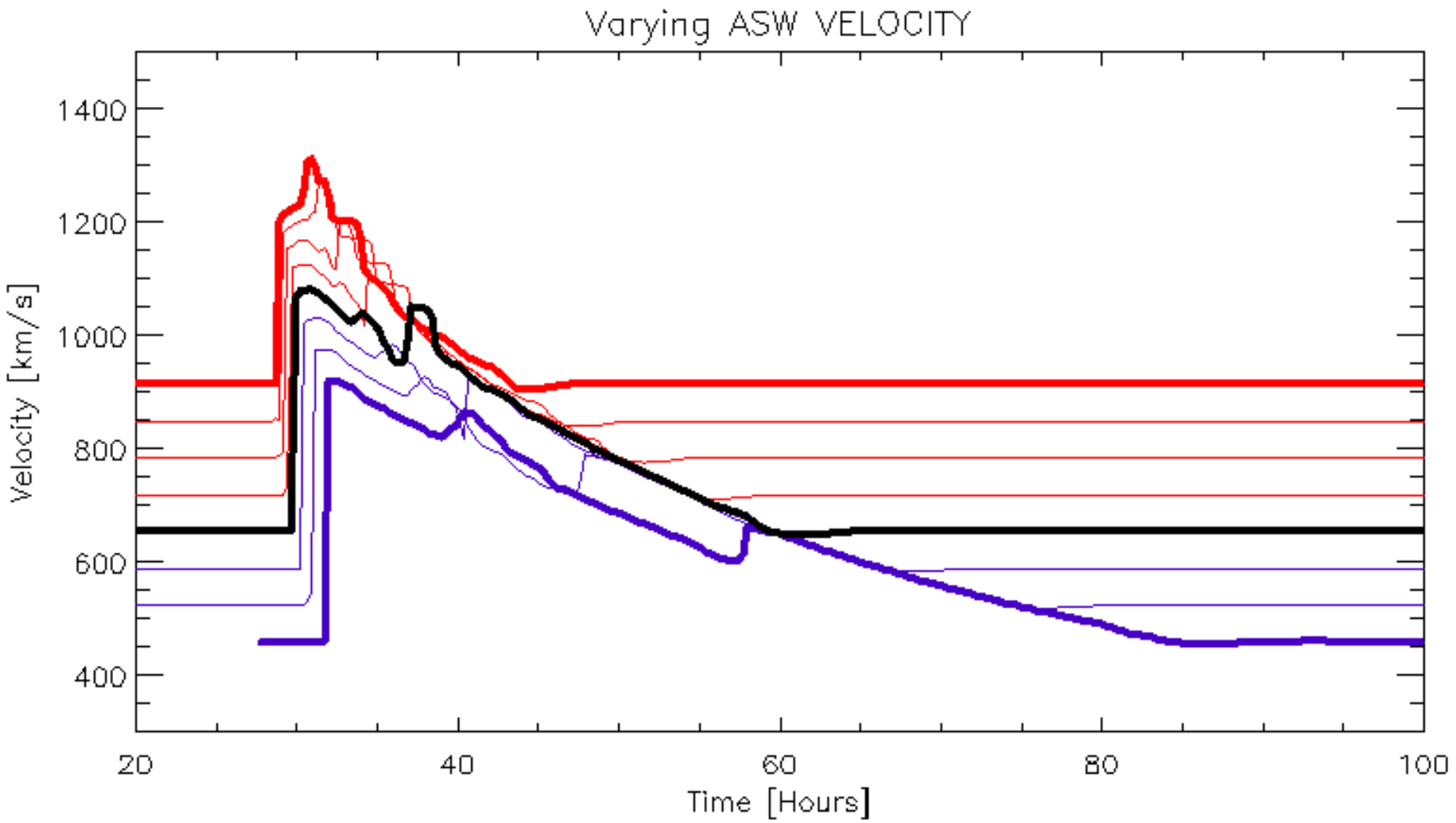

Varying CME INITIAL INJECTION TIME
100.000
10.000
1.000
0.100
0.010
0.001
Density [pp/cc]
10
20
30
40
50
60
70
80
Time [Hours]

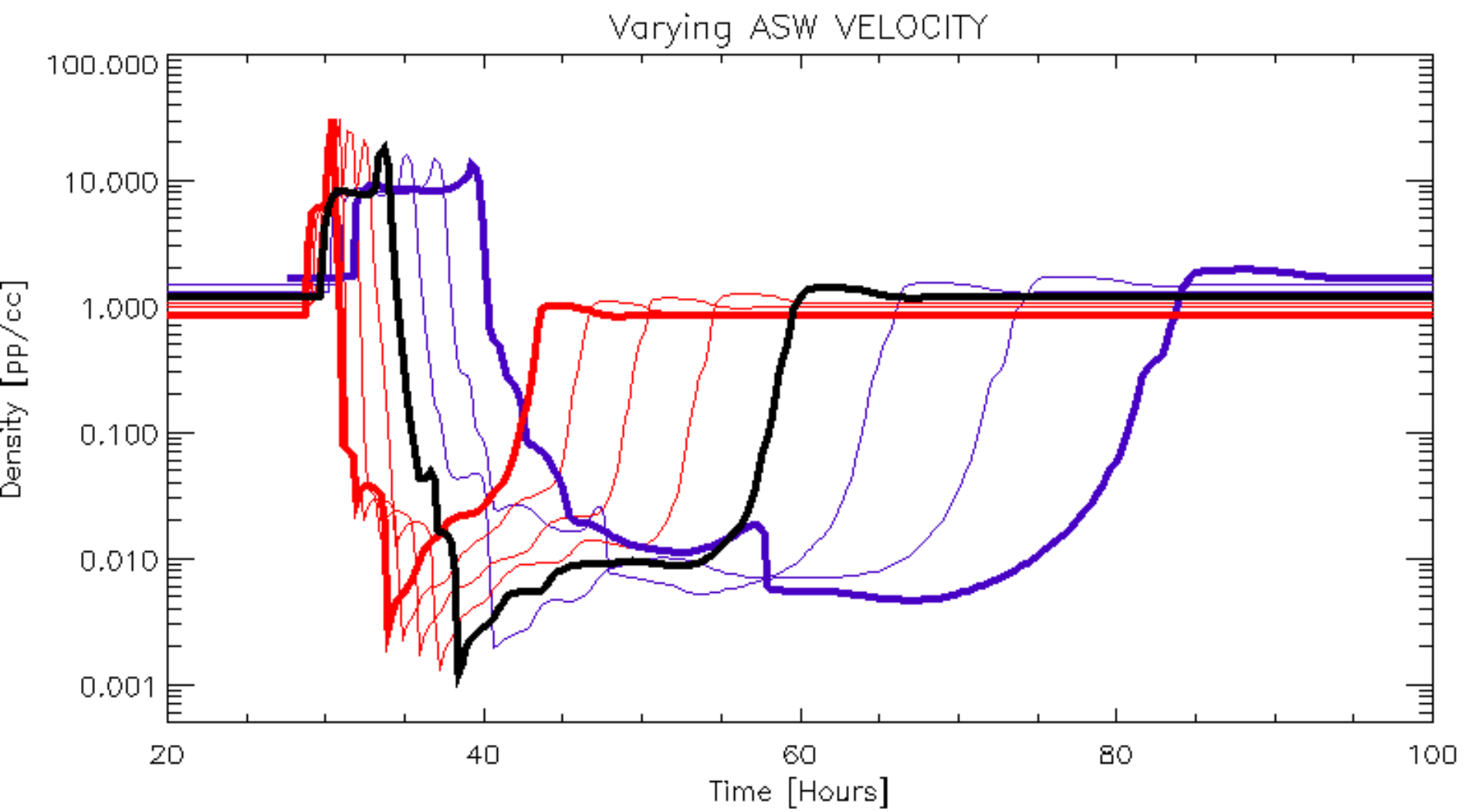
# CHANGING THE MASS LOSS RATE OF THE SW


Varying ASW MASS–LOSS RATE
-75%
+75%
Velocity [km/s]
1400
1200
1000
800
600
20
40
60
80
100
Time [Hours]


Varying ASW MASS-LOSS RATE
100.000
10.000
1.000
0.100
0.010
0.001
Density [pp/cc]
+75%
-75%
20
40
60
80
100
Time [Hours]

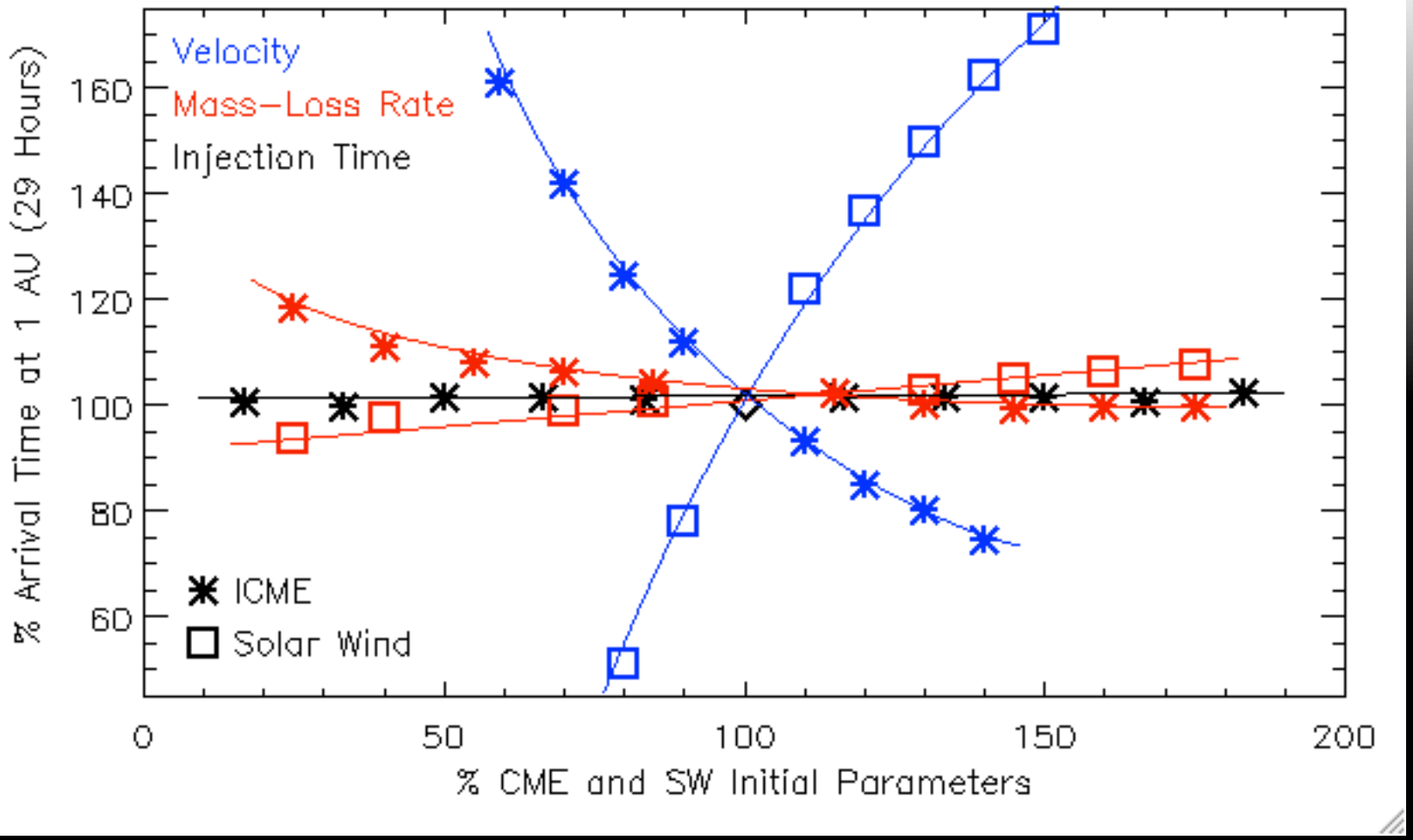
# CHANGING THE VELOCITY OF THE SW

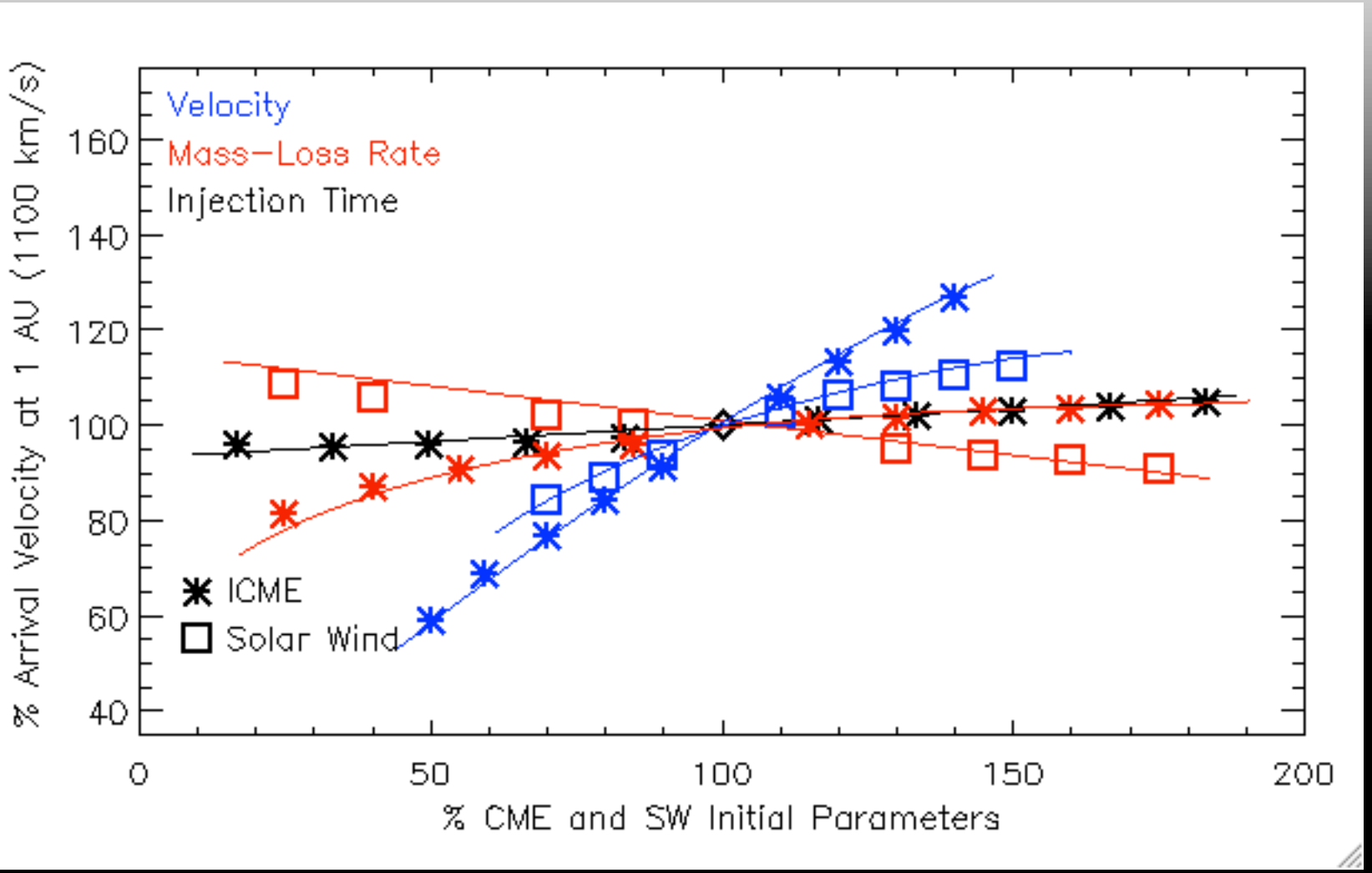

Varying ASW VELOCITY
1400
1200
1000
800
600
400
Velocity [km/s]
20
40
60
80
100
Time [Hours]

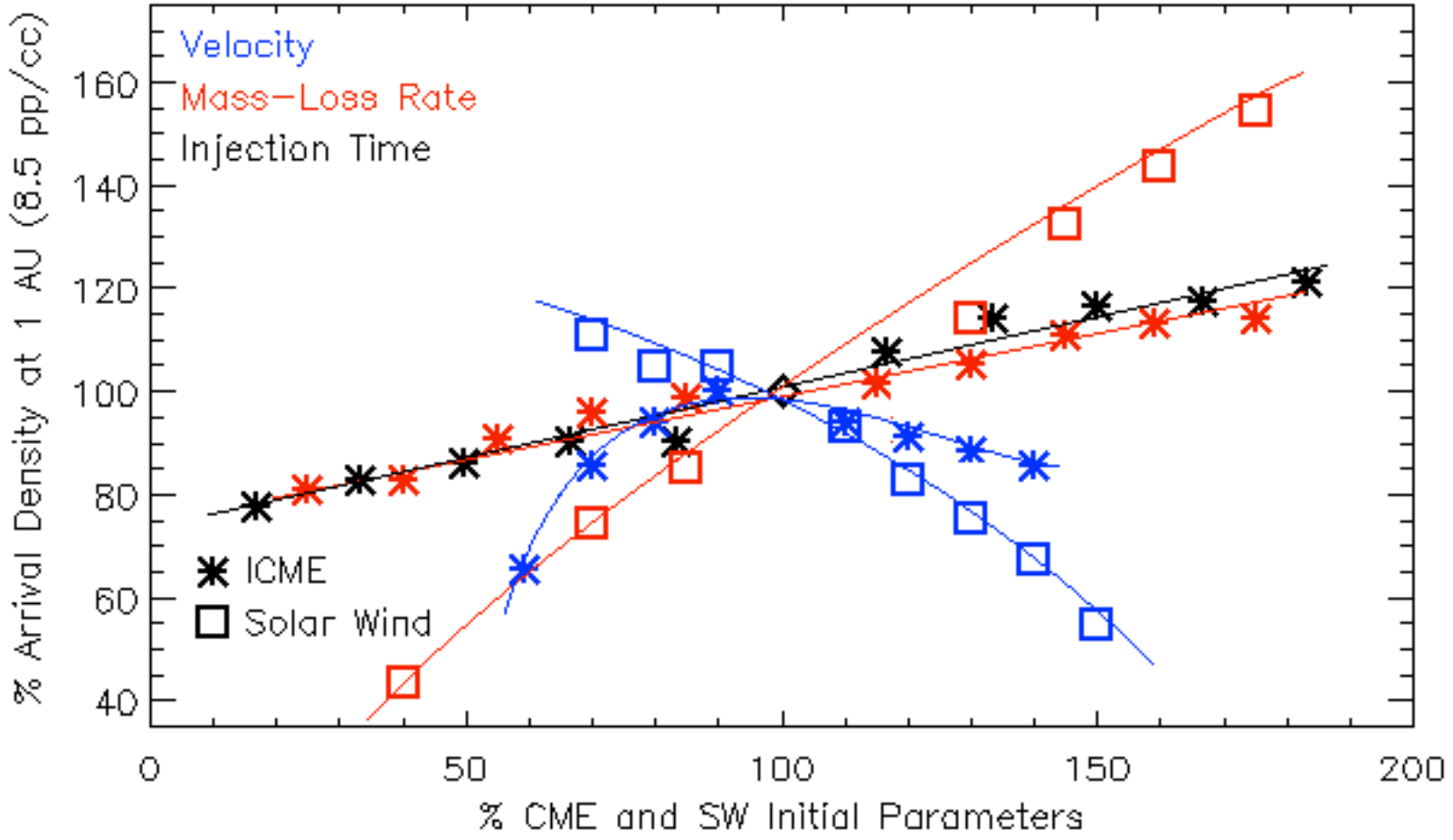

Varying ASW VELOCITY
100.000
10.000
1.000
0.100
0.010
0.001
Density [pp/cc]
20
40
60
80
100
Time [Hours]

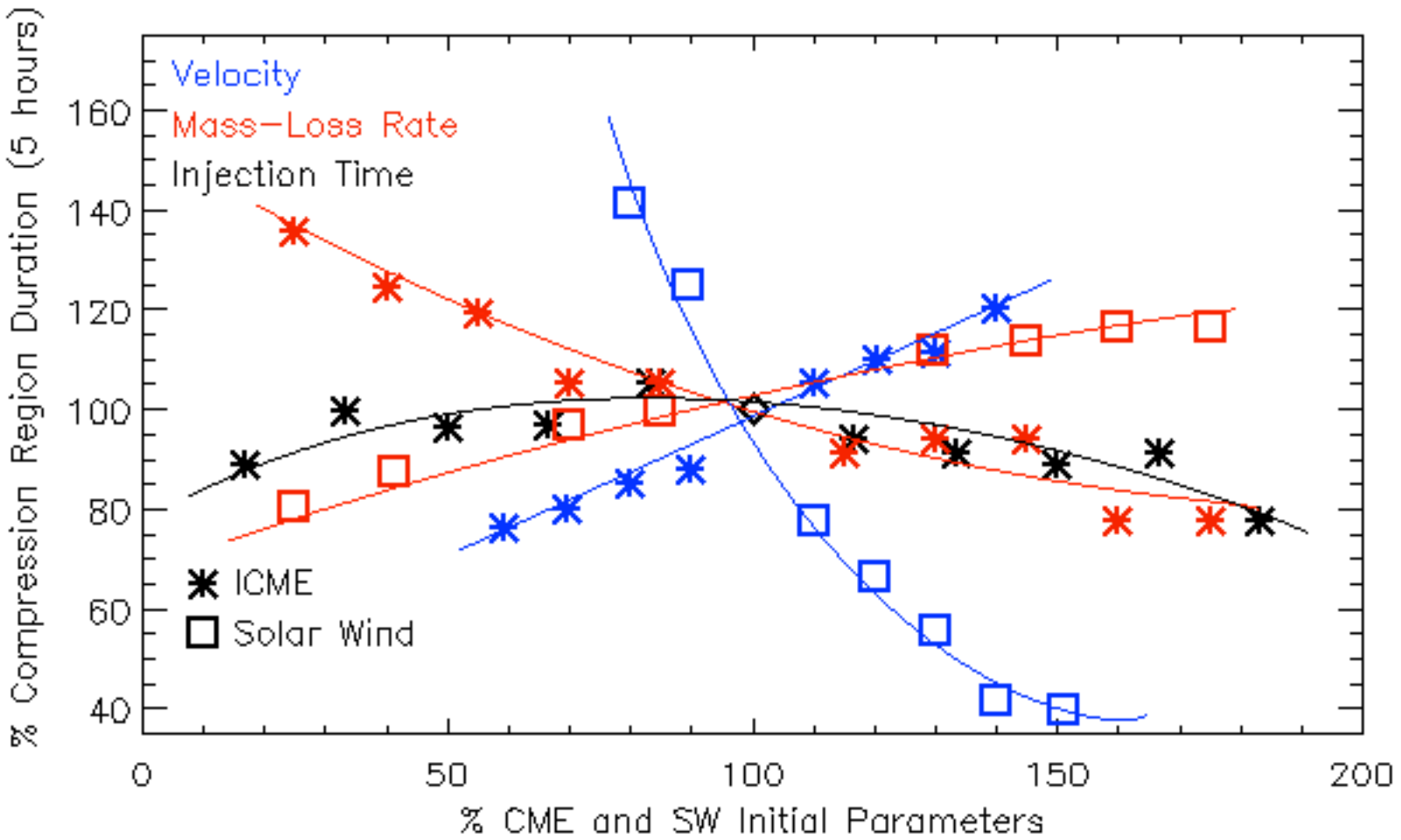
- Arrival Time
- Arrival Velocity
- Arrival Density

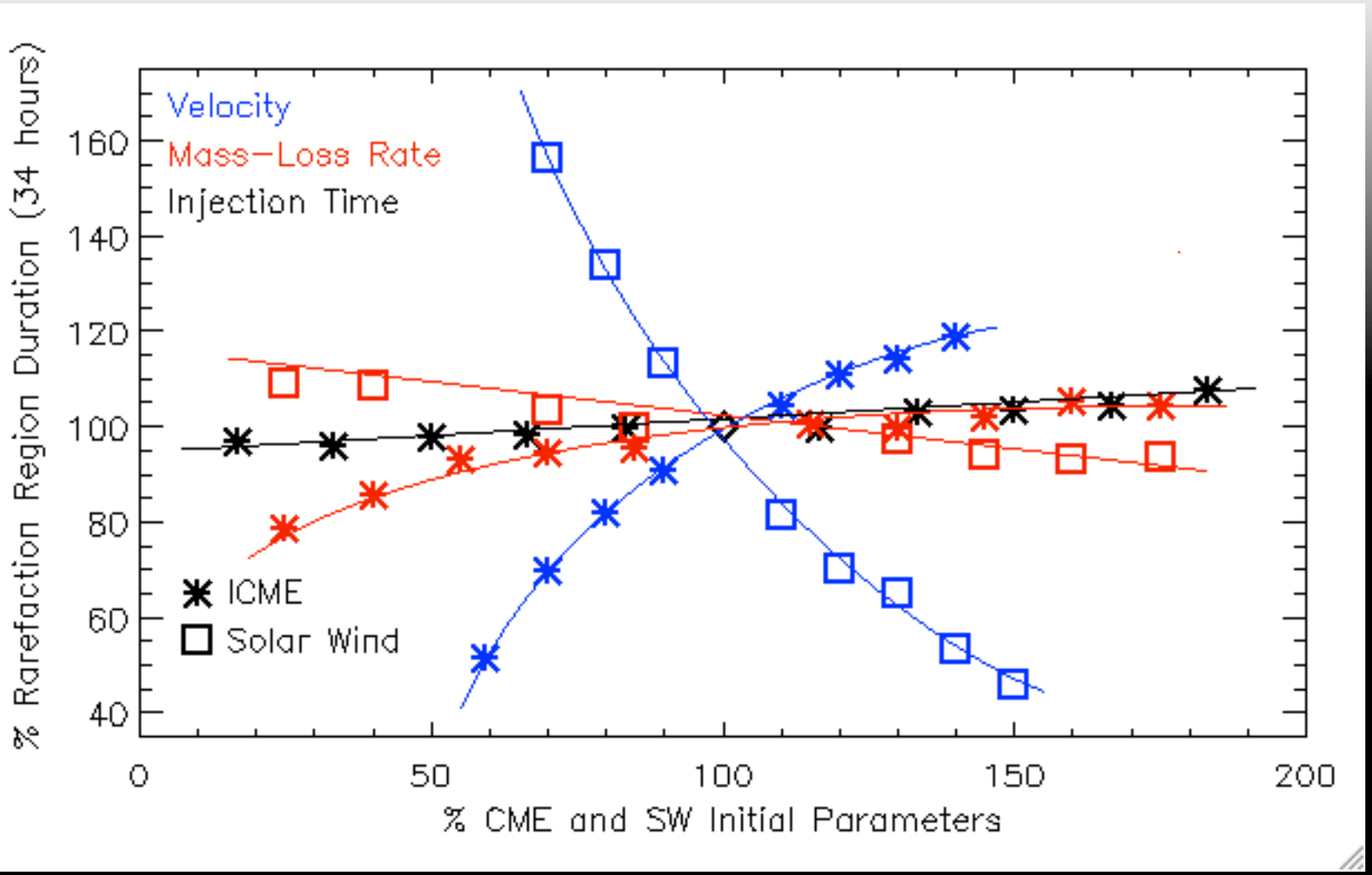
- Duration of the compression region
- Duration of the rarefaction zone


Velocity
Mass-Loss Rate
Injection Time
ICME
Solar Wind
% Arrival Time at 1 AU (29 Hours)
160
140
120
100
80
60
0
50
100
150
200
% CME and SW Initial Parameters


Velocity
Mass-Loss Rate
Injection Time
ICME
Solar Wind
% Arrival Velocity at 1 AU (1100 km/s)
% CME and SW Initial Parameters
40
60
80
100
120
140
160
0
50
100
150
200


Velocity
Mass-Loss Rate
Injection Time
ICME
Solar Wind
% Arrival Density at 1 AU (8.5 pp/cc)
% CME and SW Initial Parameters
40
60
80
100
120
140
160
0
50
100
150
200


Velocity
Mass-Loss Rate
Injection Time
ICME
Solar Wind
% Compression Region Duration (5 hours)
% CME and SW Initial Parameters
40
60
80
100
120
140
160
0
50
100
150
200


Velocity
Mass-Loss Rate
Injection Time
ICME
Solar Wind
% Rarefaction Region Duration (34 hours)
% CME and SW Initial Parameters
40
60
80
100
120
140
160
0
50
100
150
200

# BACK TO THE CME – CME INTERACTION

ADDITIONALLY WE CAN VARY THE AMBIENT SOLAR WIND BETWEEN THE TWO CMES.

FOR THE EVENT OF MAY 2010

**AMBIENT SOLAR WIND**

320 km/s
$2 \times 10^{-14}$ M/y

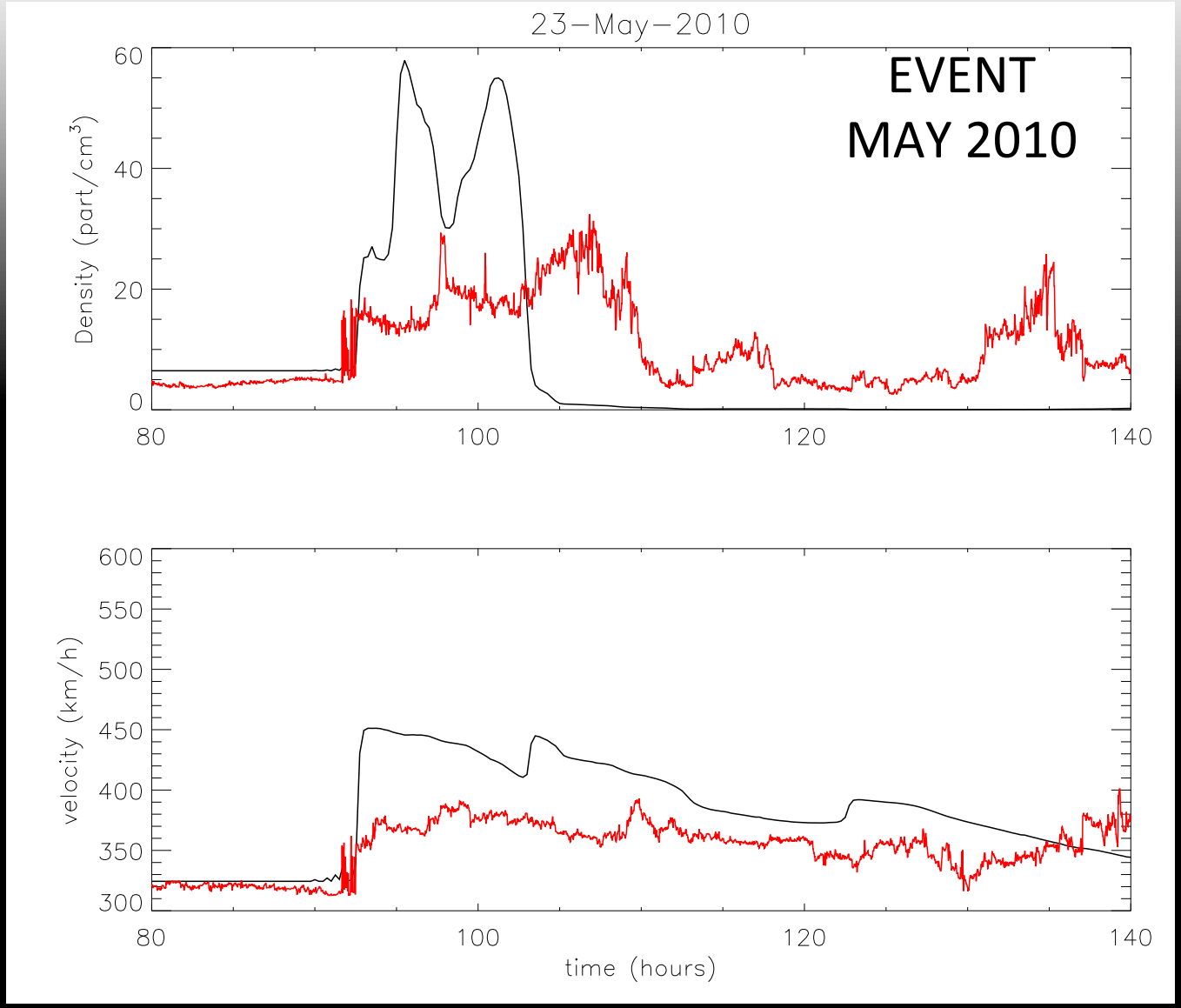
340 km/s
$1.7 \times 10^{-14}$ M/y

**1st CME**

400km/s
$1.5 \times 10^{16}$ g

**2nd CME**

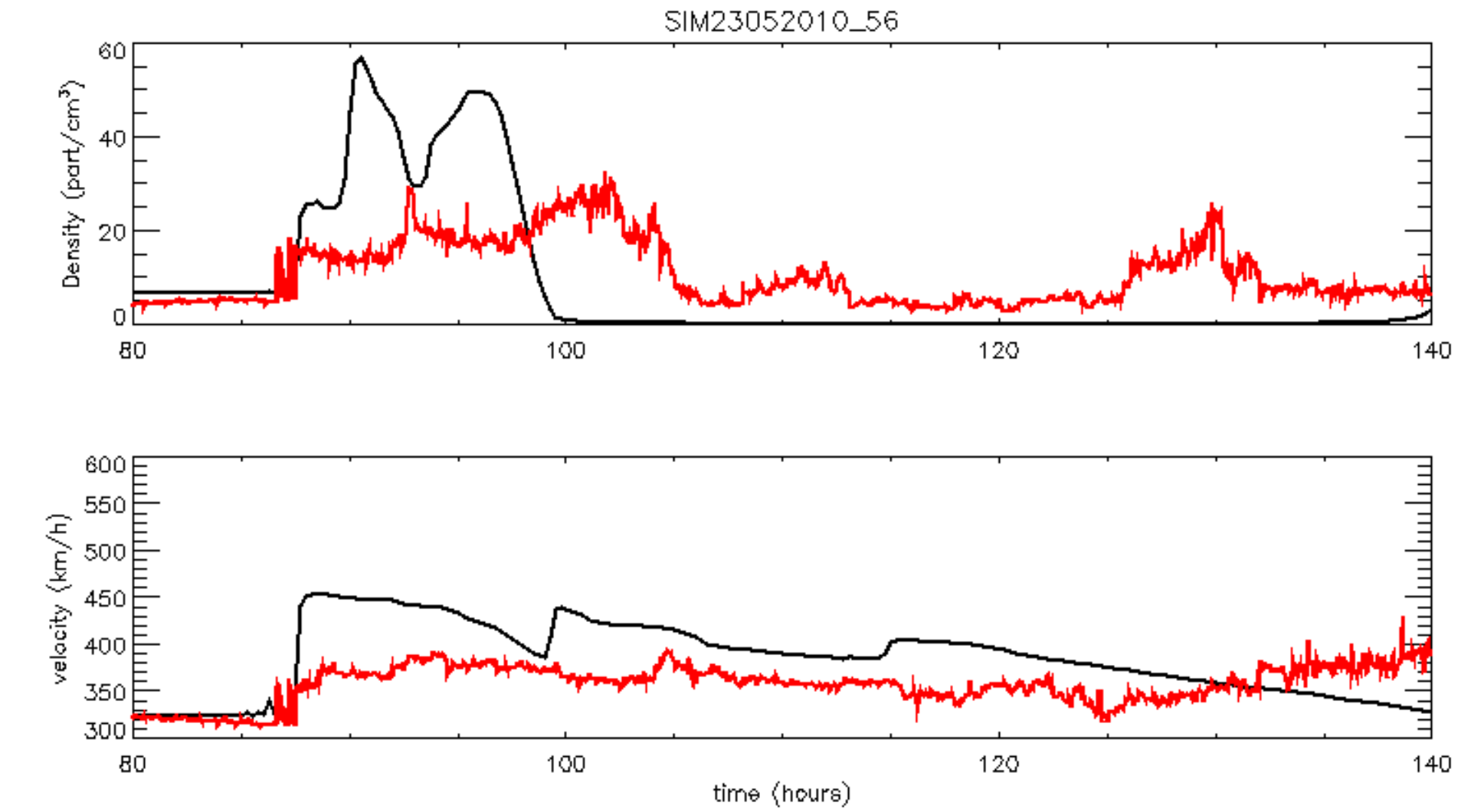
650 km/s
$1.0 \times 10^{16}$ g




**AMBIENT SOLAR WIND**

320 km/s

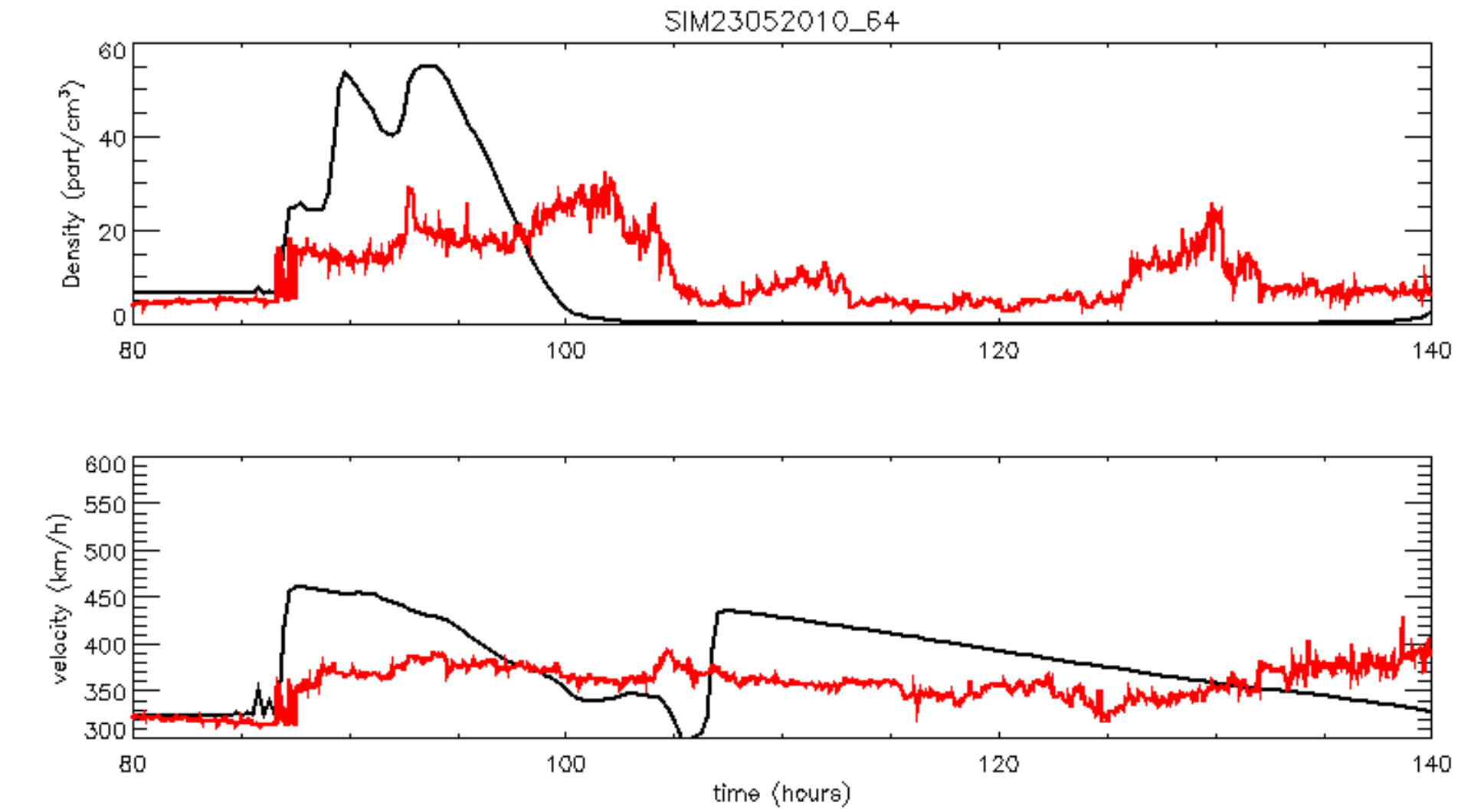
2 x $10^{-14}$ M/y




**AMBIENT SOLAR WIND**

340 km/s

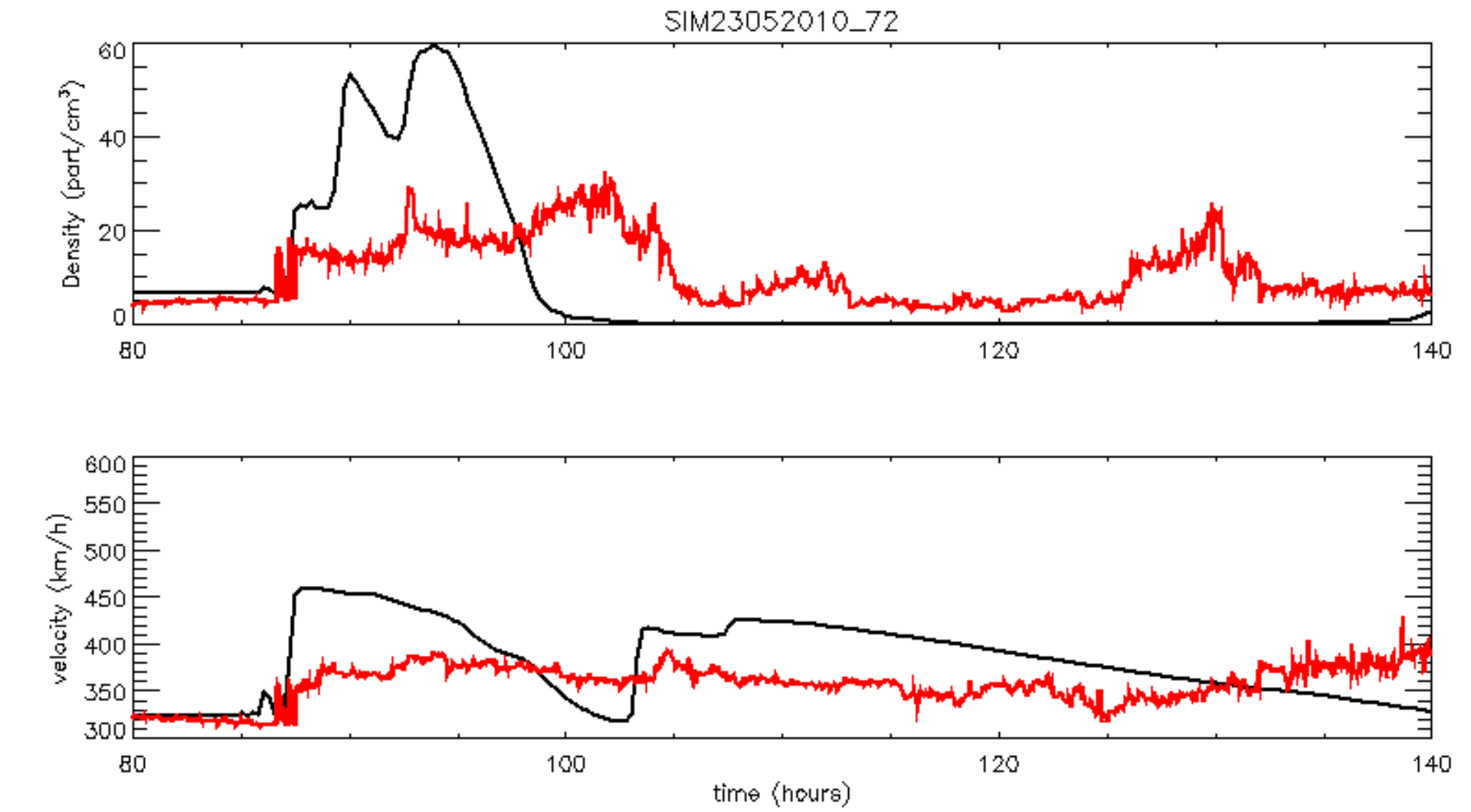
2 x $10^{-14}$ M/y




**AMBIENT SOLAR WIND**

320 km/s

1.7 x $10^{-14}$ M/y




**AMBIENT SOLAR WIND**

340 km/s

1.7 x $10^{-14}$ M/y