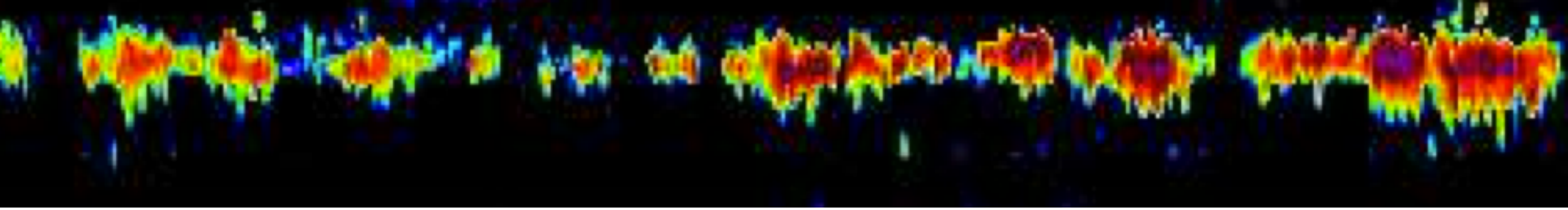


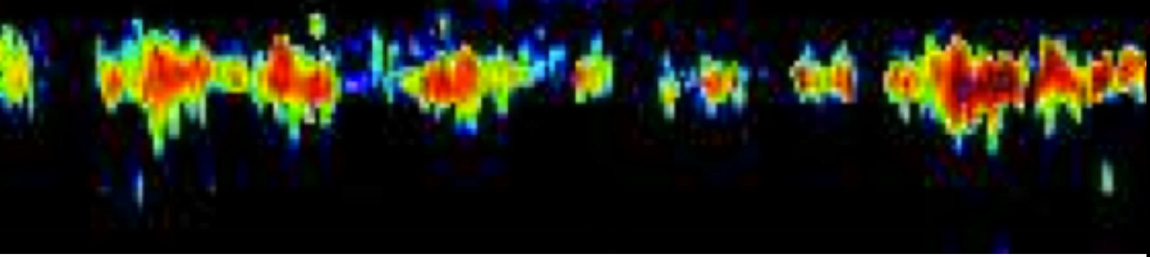
Radio emission before, during and after the interaction between two coronal mass ejections in the interplanetary medium

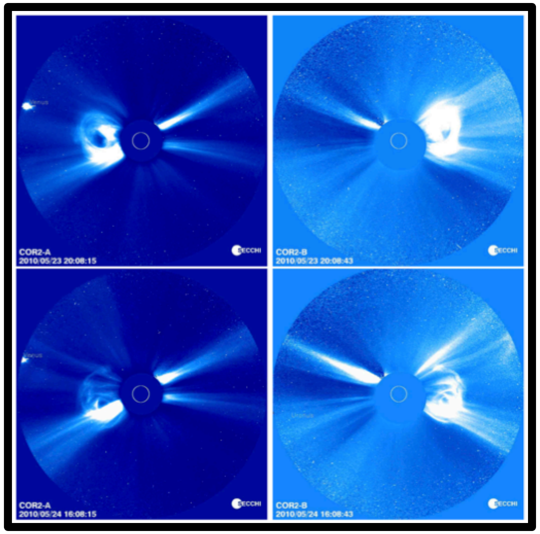
Tatiana Niembro Hernández — Posgrado en Ciencias de la Tierra
Instituto de Geofísica, UNAM

Alejandro Lara Sánchez — Instituto de Geofísica, UNAM

Ricardo González Dominguez — Instituto de Radioastronomía y Astrofísica, UNAM

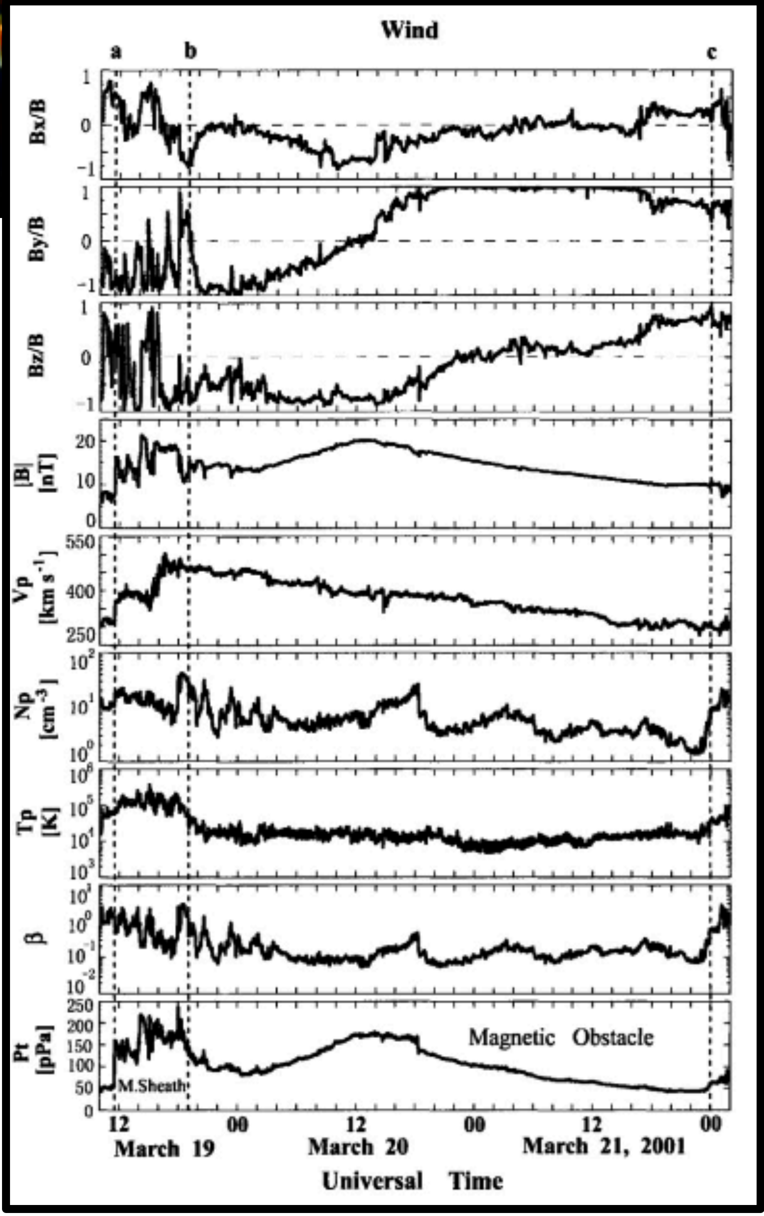
Alejandro Raga — Instituto de Ciencias Nucleares, UNAM

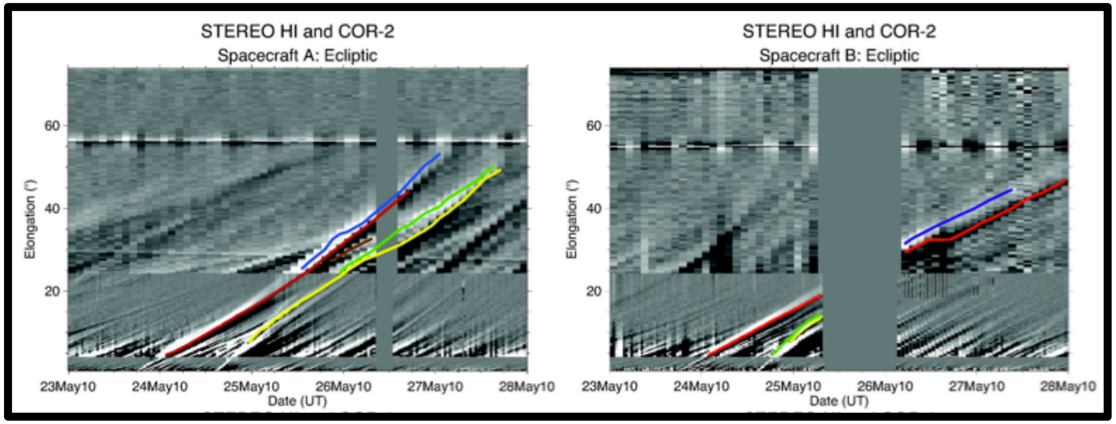


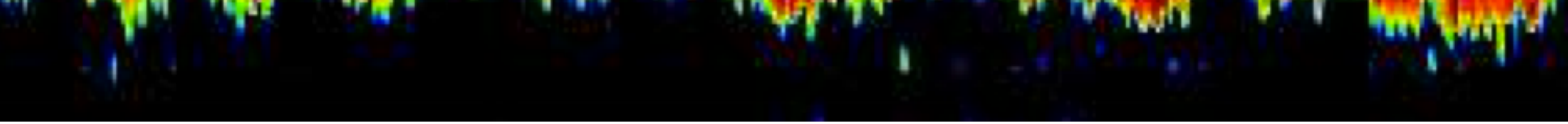


Lugaz et al 2012

Jian et al 2008







ANALITIC MODEL OF ICME – ICME INTERACTION (HYDRODYNAMICALLY)

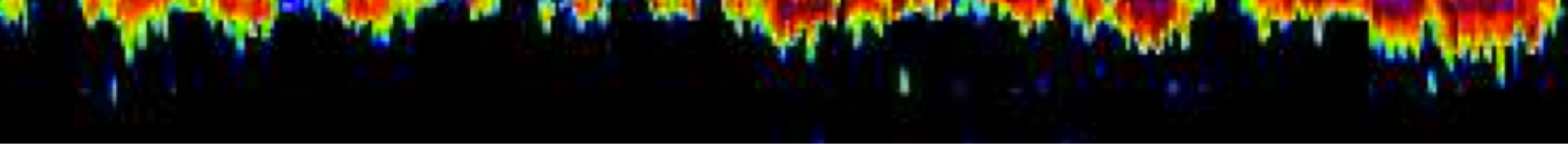
- Predicition of time and distance in which the interaction takes place and a ***merged region*** is formed
- Prediction of arrival time and velocity of the ***merged region*** at 1 AU

NUMERICAL SIMULATION OF ICME – ICME INTERACTION (YGUÁZU-A CODE) (CONSIDERING TERMAL PRESSURE)

- Predicition of time and distance in which the interaction takes place
- Prediction of arrival time and velocity of the ***merged region*** at 1 AU
- Profiles of density and velocity as function of distance at a fixed time
  THE EVOLUTION OF EACH STRUCTURE INVOLVED
- Profiles of density and velocity as function of time at a fixed distance
  COMPARISON WITH IN SITU DATA

RADIO EMISSION

- Searching for signatures in the interplanetary medium related to the ICME-ICME interaction



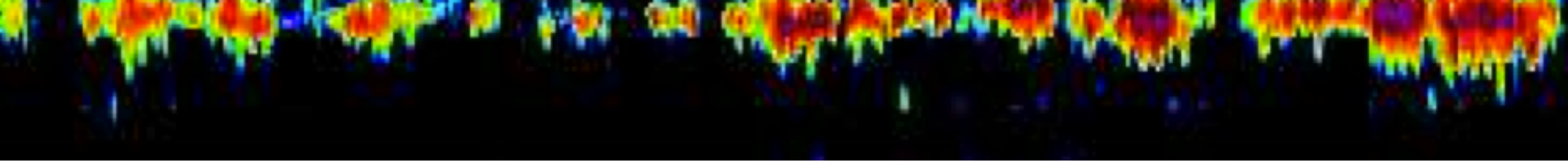
OBSERVED PARAMETERS NEEDED:

VELOCITY OF THE	**CME1** (REMOTE)	**CME2** (REMOTE)	**AMBIENT SOLAR WIND** (IN SITU)
LOSS-MASS RATE OF THE **(MASS / INJECTION TIME)** **SOLID ANGLE**	**CME1** (REMOTE)	**CME2** (REMOTE)	**AMBIENT SOLAR WIND** Wood et al 2002 Cranmer et al 2004

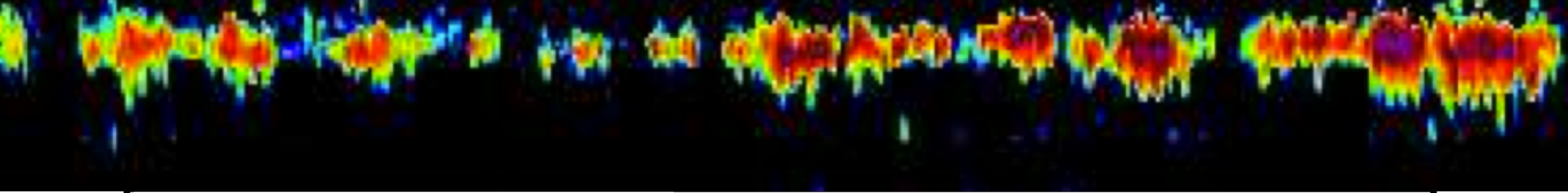
VELOCITY SOLID ANGLE AND MASS

Reported by:

January 24, 2007	Lugaz et al 2008
May 23 2010	Lugaz et al 2012
August 1, 2010	Temmer et al 2012
November 9, 2012	Mishra et al 2014



Parameter	January 24, 2007	May 23, 2010	August 01, 2010	November 09, 2012
Δt_0 [hr]	14.5	17.15	3.73	10.50
Δt_1 [hr]	2.0	2.85	1.1	1.55
Δt_2 [hr]	1.8	3.71	1.0	2.5
m_1 [gr]	4.3×10^{15}	1.5×10^{16}	8.0×10^{15}	4.66×10^{15}
m_2 [gr]	1.6×10^{16}	1.0×10^{16}	3.0×10^{16}	2.27×10^{15}
$\dot{m}_1$ [$M_\odot$ yr^{-1}]	7.21×10^{-14}	3.46×10^{-14}	2.74×10^{-13}	9.04×10^{-14}
$\dot{m}_2$ [$M_\odot$ yr^{-1}]	2.67×10^{-13}	1.32×10^{-14}	7.39×10^{-13}	4.42×10^{-14}
β_1 [^{o}]	42.5	30.0	40.0	45.0
β_2 [^{o}]	45.0	35.0	50.0	35.0
v_0 [km s^{-1}]	310	320	410	300
v_1 [km s^{-1}]	600	400	732	500
v_2 [km s^{-1}]	1350	650	1138	1100

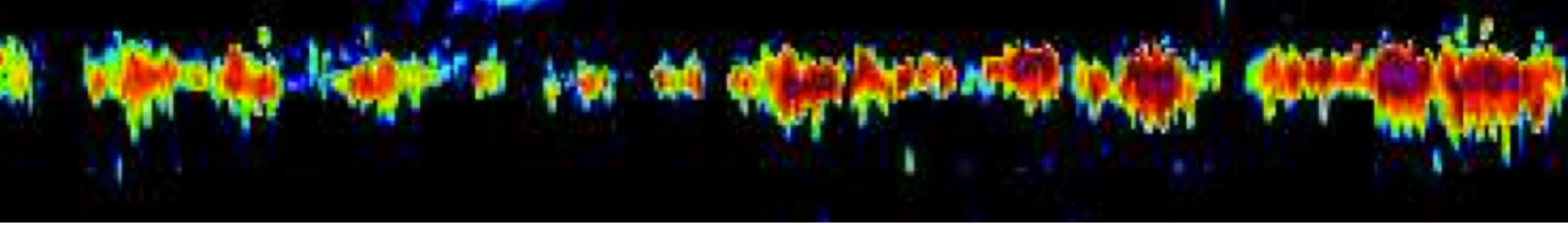


ANALITICAL MODEL RESULTS

Parameter	January 24, 2007	May 23, 2010	August 01, 2010	November 09, 2012
R_{coll} [AU]	0.31	0.69	0.19	0.32
t_{coll} [hr]	29.99	75.08	12.75	34.97
t_{1AU} [hr]	70.34	105.19	53.21	99.23
v_{1AU} [km s^{-1}]	698	427	812	423

OBSERVED DATA

Parameter	January 24, 2007	May 23, 2010	August 01, 2010	November 09, 2012
R_{coll} [AU]	0.45	0.52 - 0.77	0.16	0.16 - 0.46
t_{coll} [hr]	30.48	NA	12.91	19 - 36
t_{1AU} [hr]	105.9	105.5	62.16	96.0
v_{1AU} [km s^{-1}]	716	380	600	450



NUMERICAL SIMULATION

- 2D gasdynamic numerical simulation using a modified version of YGUÁZU- A adaptative grid code originally developed by Raga et al 2000 and modified by González et al 2010.

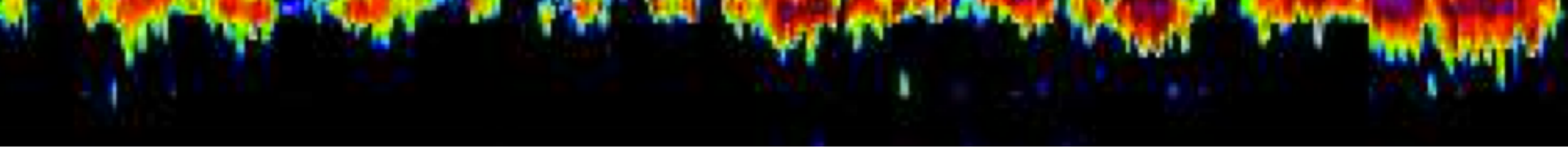
- Integrates hydrodynamic equations accounting for radiative cooling with a set of continuity equations for atomic/ionic species HI, HII, HeI, HeII, CII, CIII, CIV, OI, OII and OIII.

- Abundances: H (0.9), He (0.099), O (0.0007) and C (0.0003)

- <u>Profiles of density and velocity as function of distance</u> at a fixed time

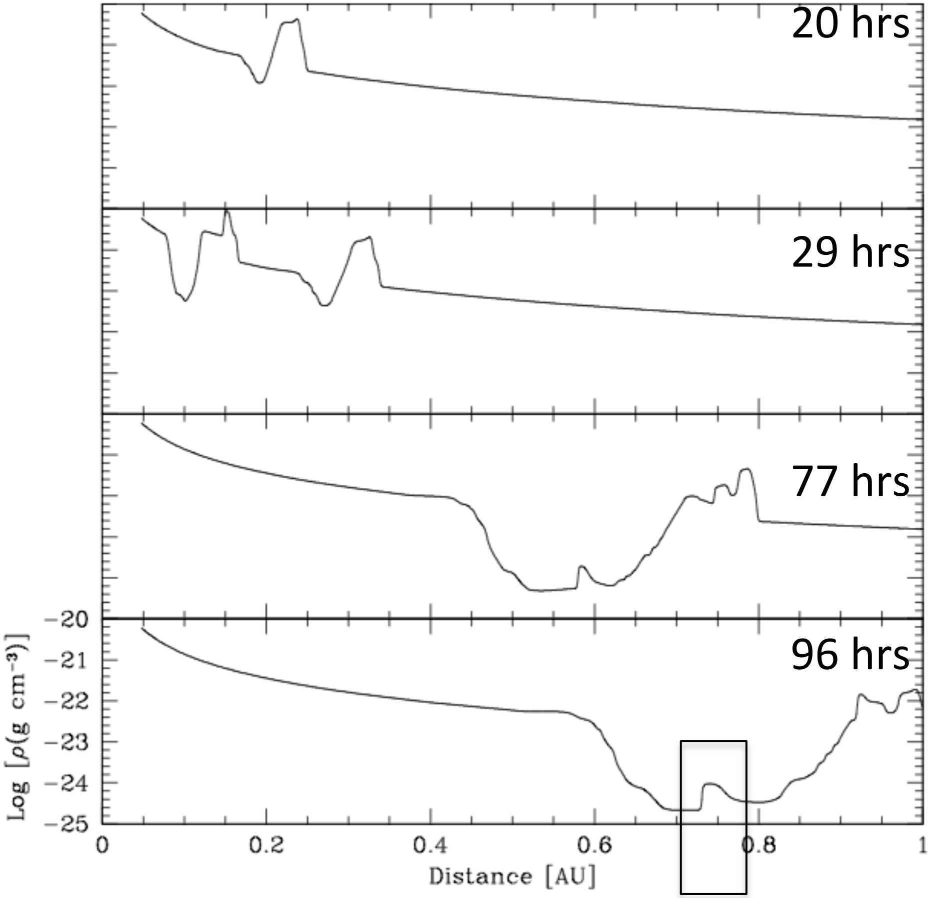
  <u>ALL THE EVOLUTION OF EACH STRUCTURE INVOLVE</u>
- <u>Profiles of density and velocity as function of time</u> at a fixed distance

  <u>COMPARISON WITH IN SITU DATA</u>

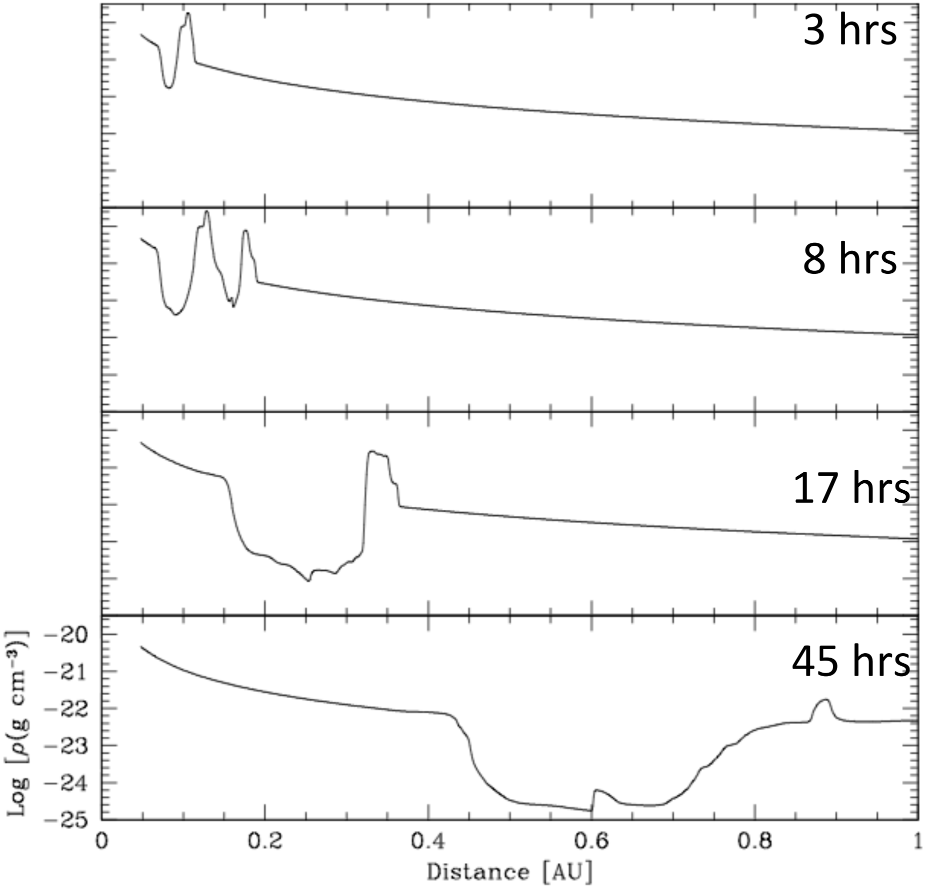


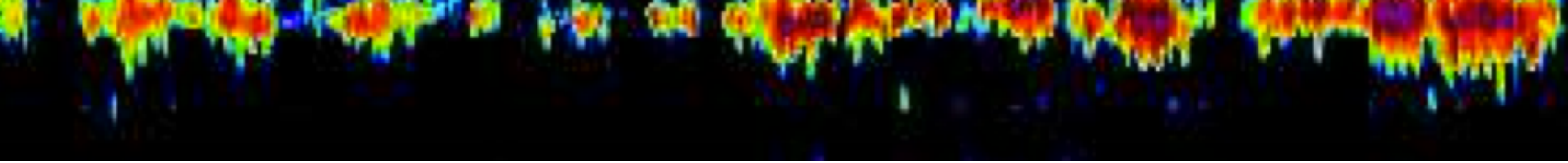
n(r)

May 23, 2010

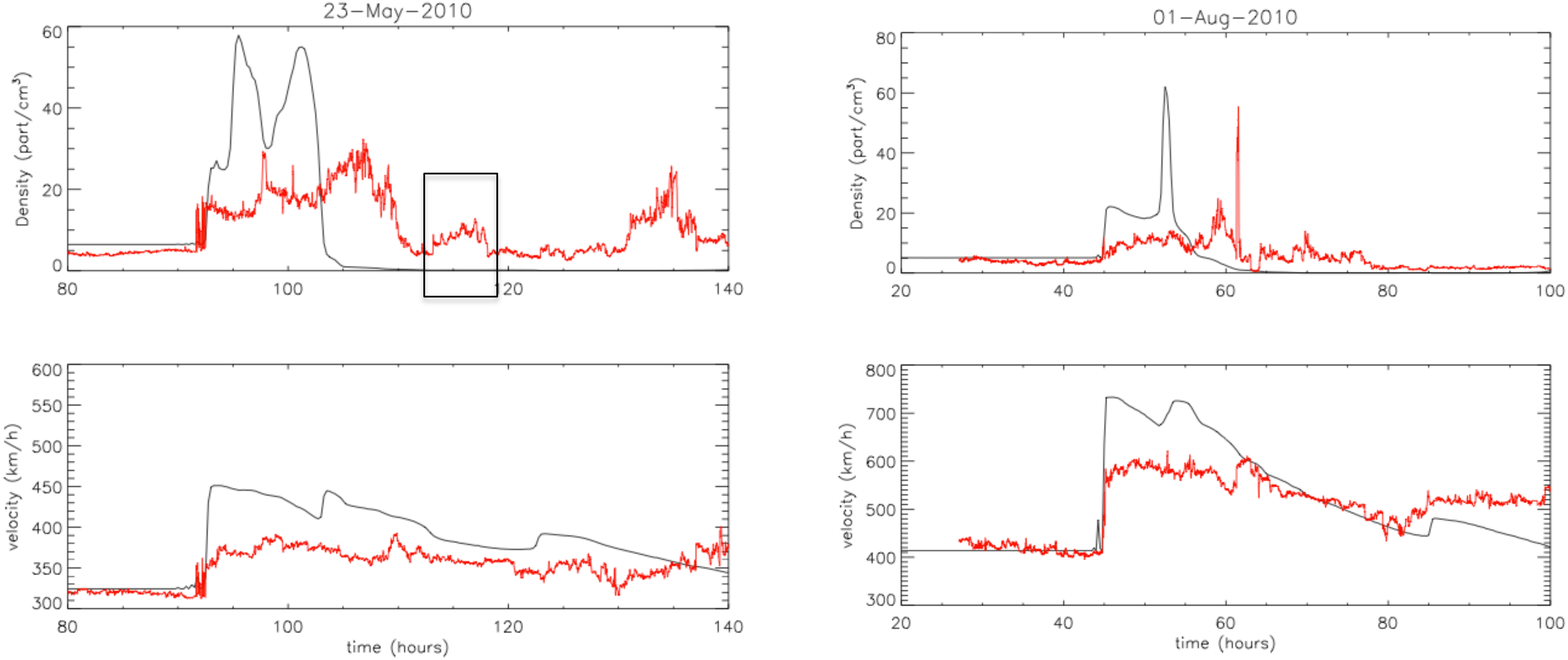


August 1, 2010

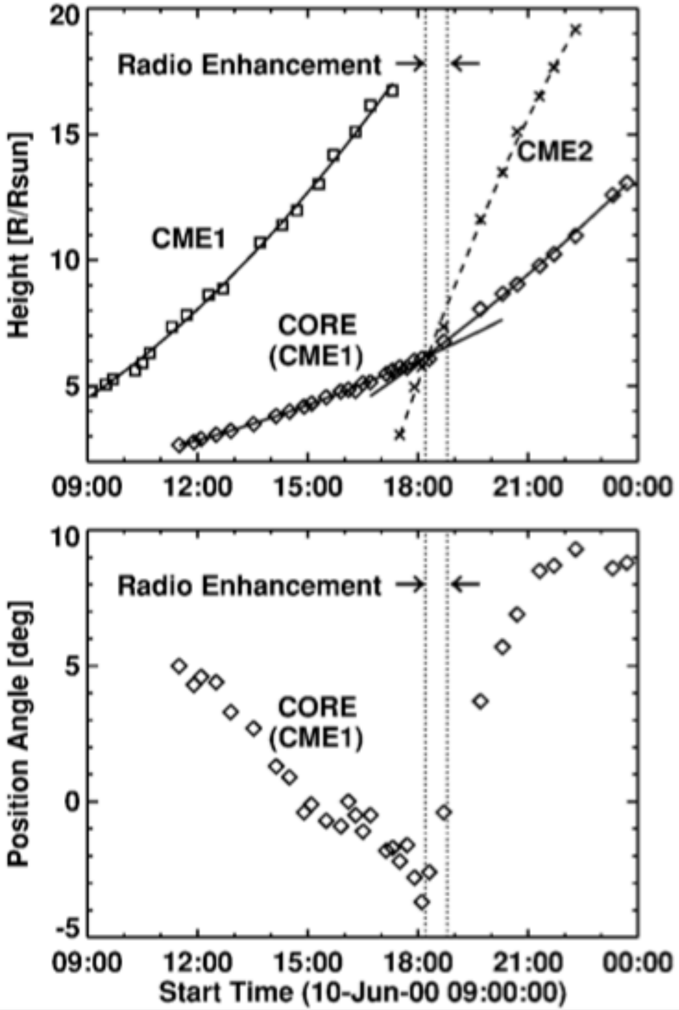


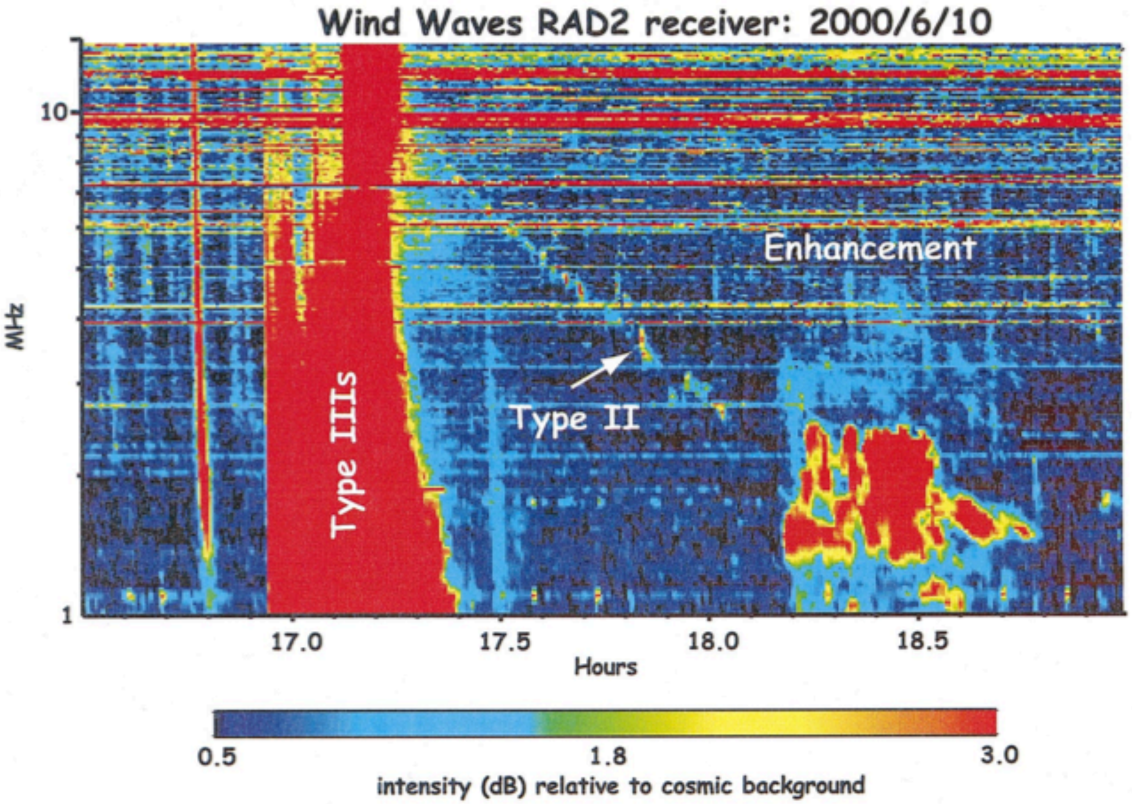


n(t)

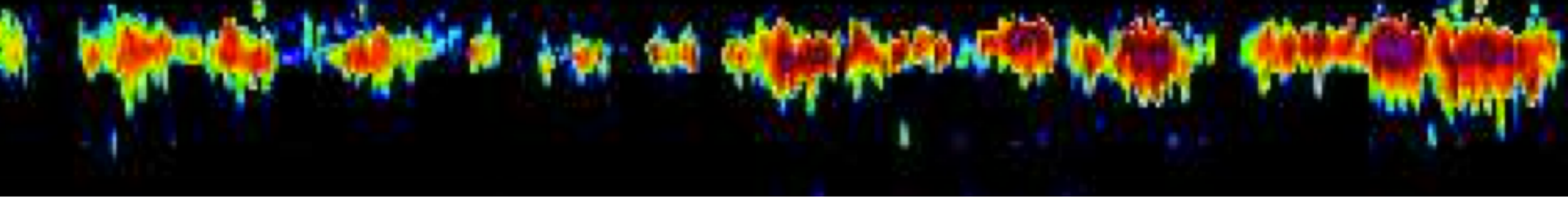

23−May−2010
01−Aug−2010
Density (part/cm^3)
velocity (km/h)
time (hours)
0
20
40
60
80
80
100
120
140
20
40
60
80
100
300
350
400
450
500
550
600
700
800

n(r, t)

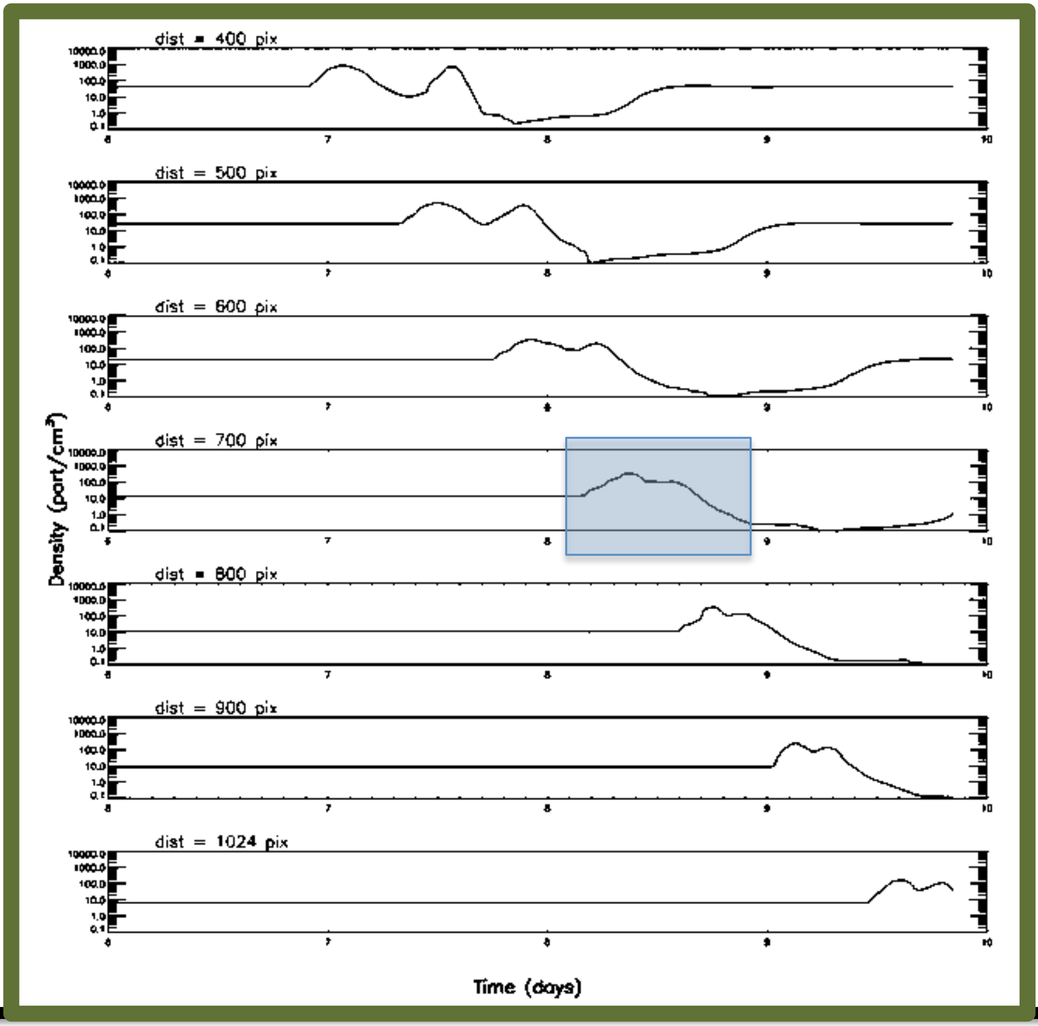




Gopalswamy et al. 2001

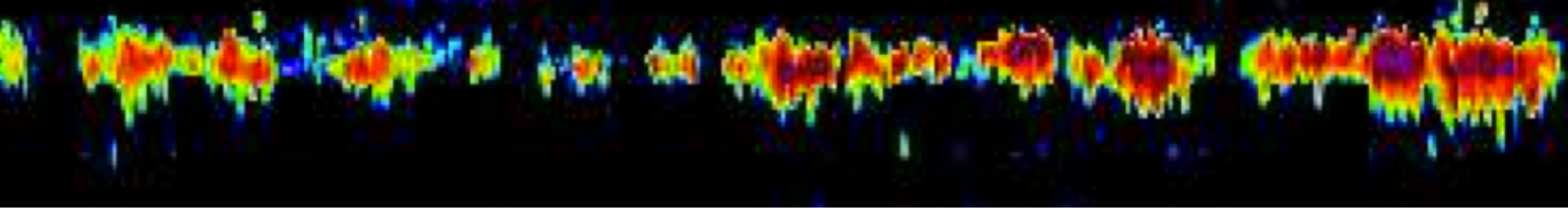


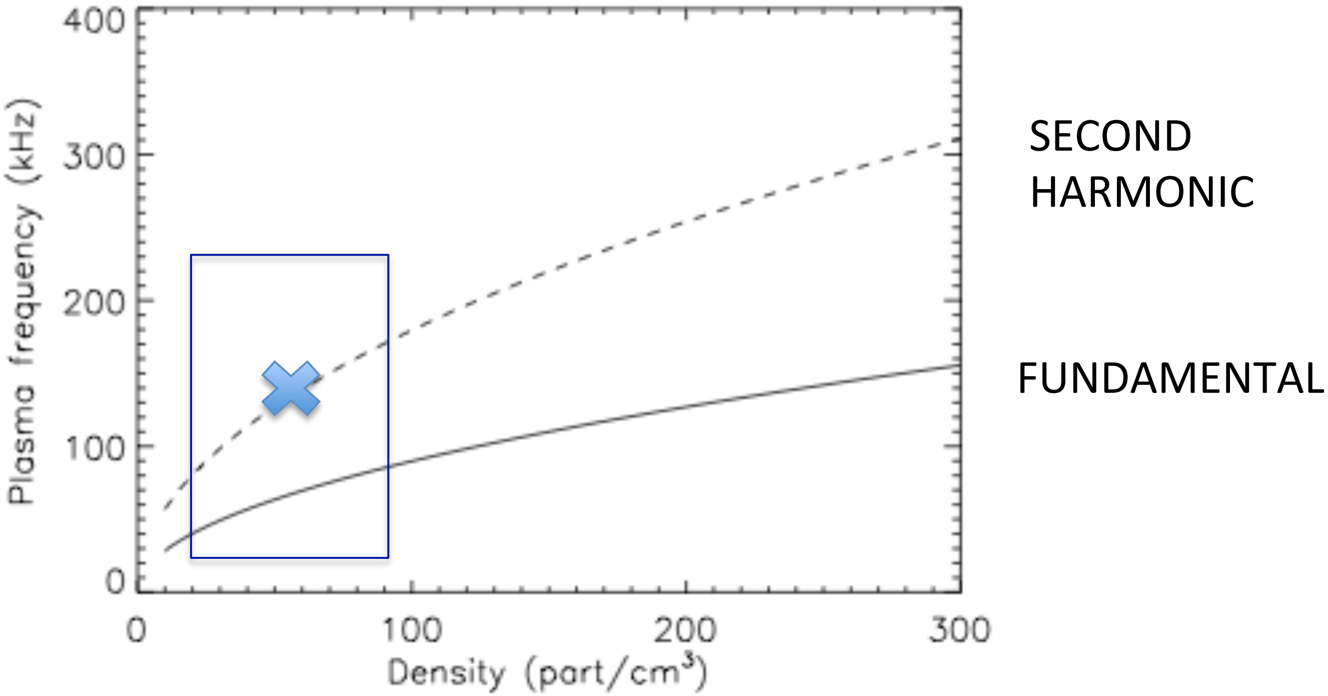
EVENT OF
MAY 2010



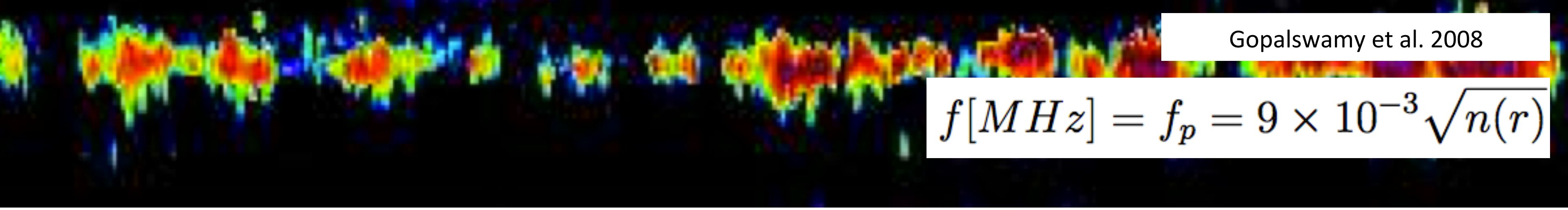
100 to 300

particles per cm^3



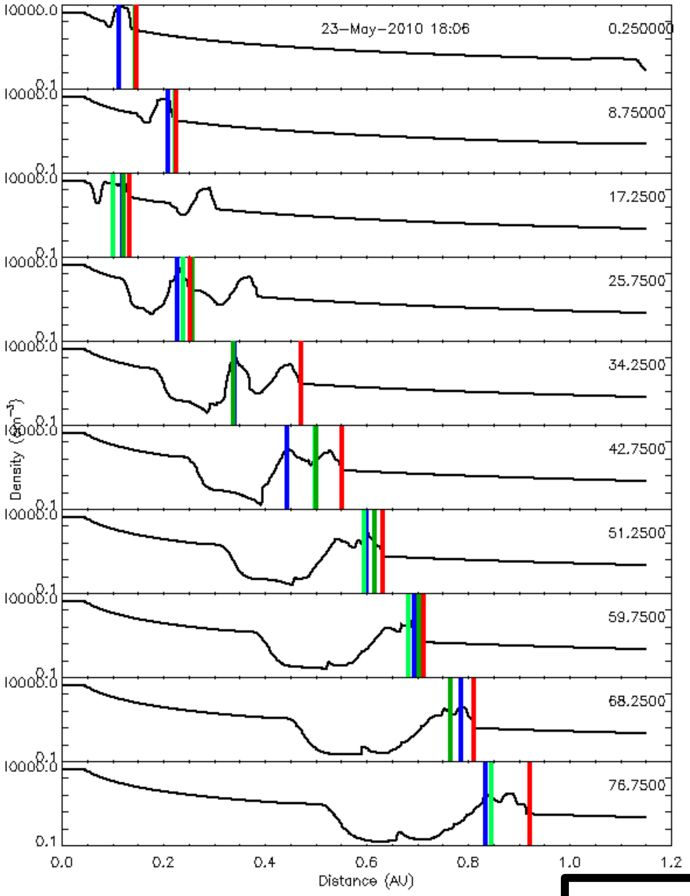


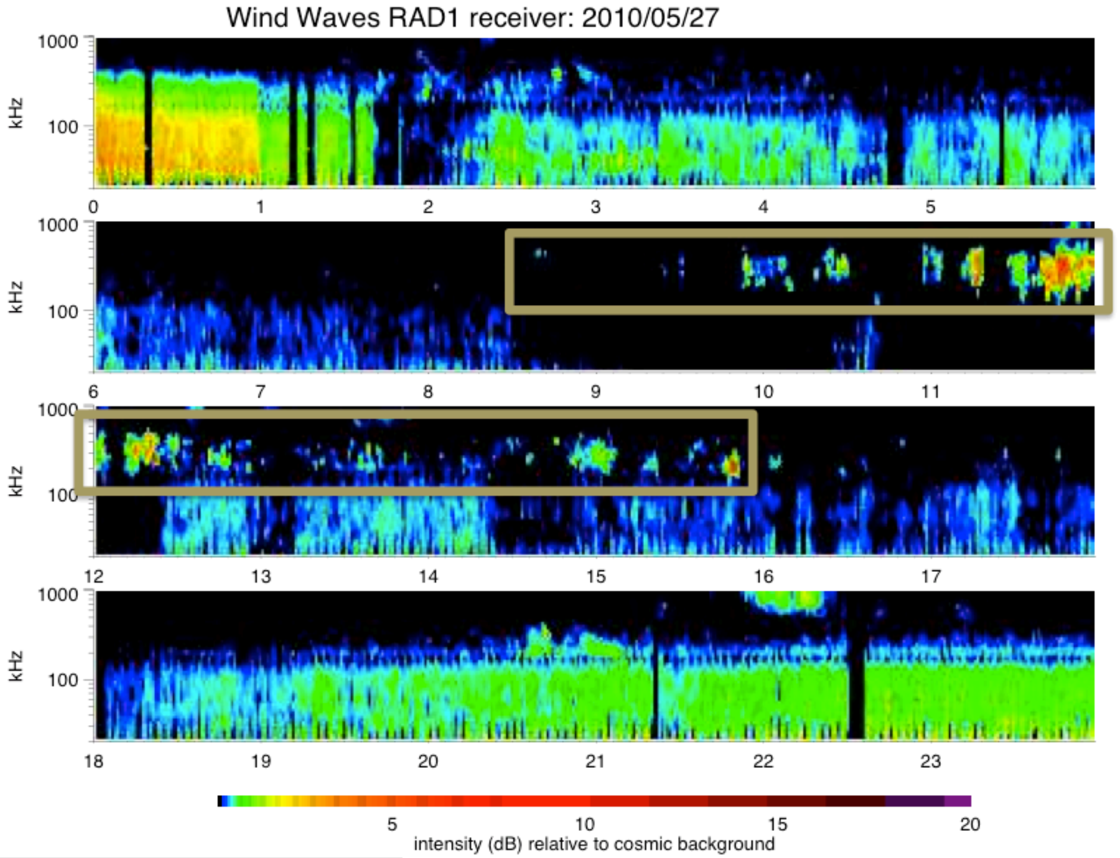
$$f(t) = 9 \times 10^{-3} \sqrt{n(r,t)}$$



Gopalswamy et al. 2008

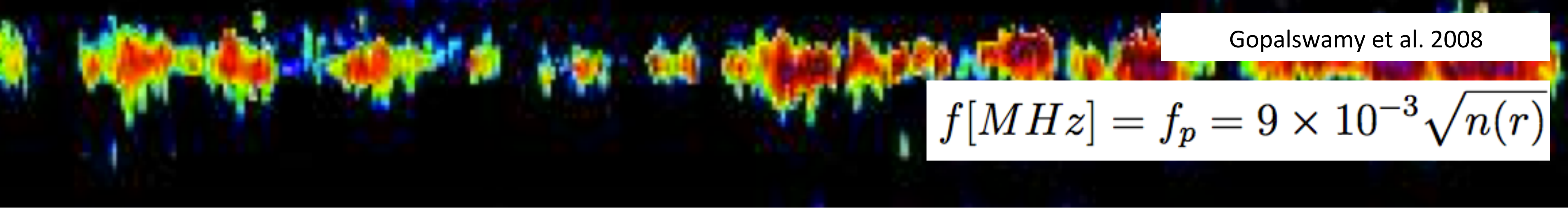
$$f[MHz] = f_p = 9 \times 10^{-3}\sqrt{n(r)}$$





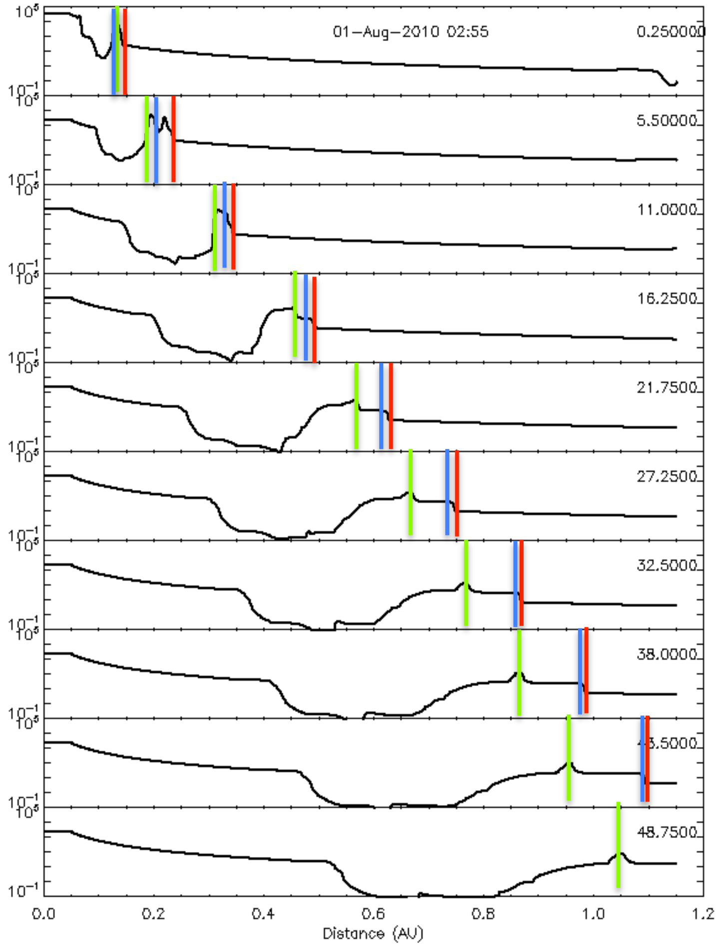
$$\boxed{f(t) = 9 \times 10^{-3} \sqrt{n(r,t)}}$$

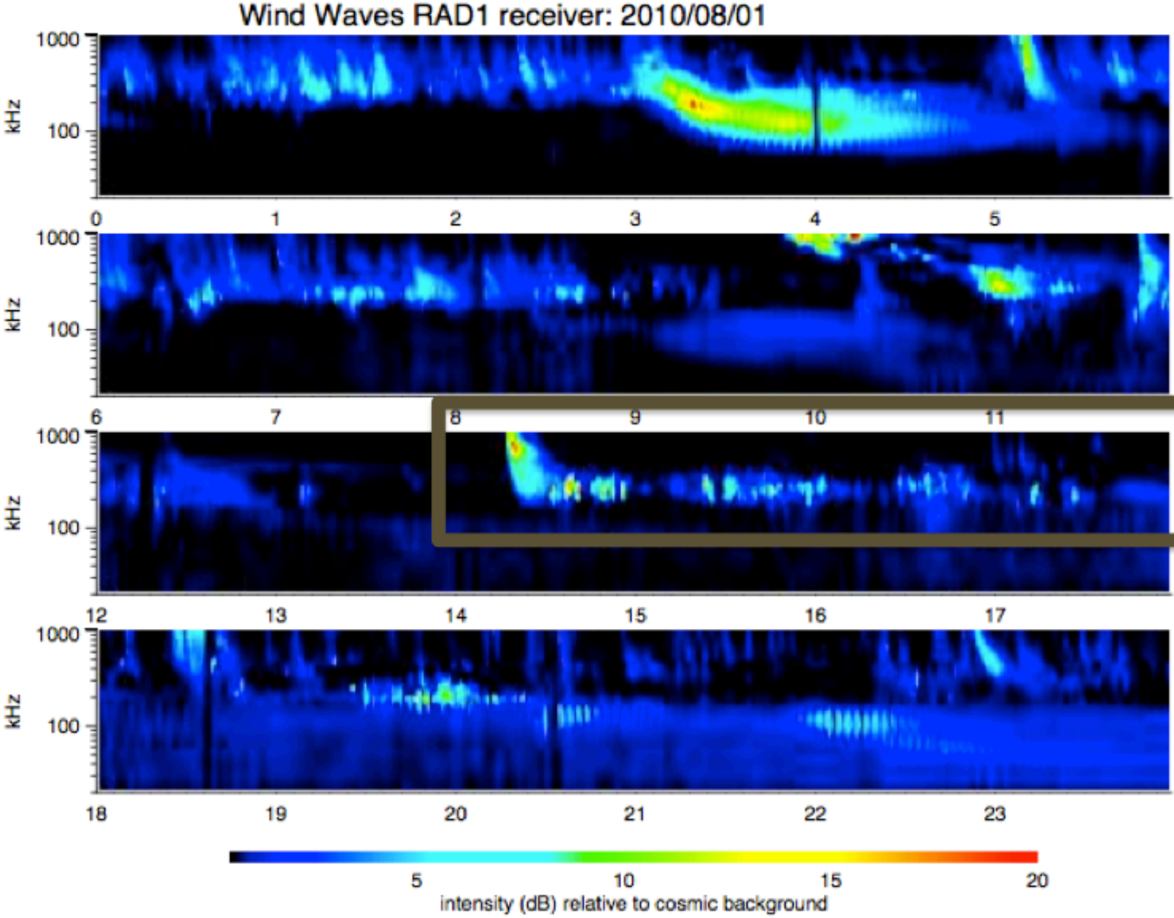
Niembro et al. (in preparation)



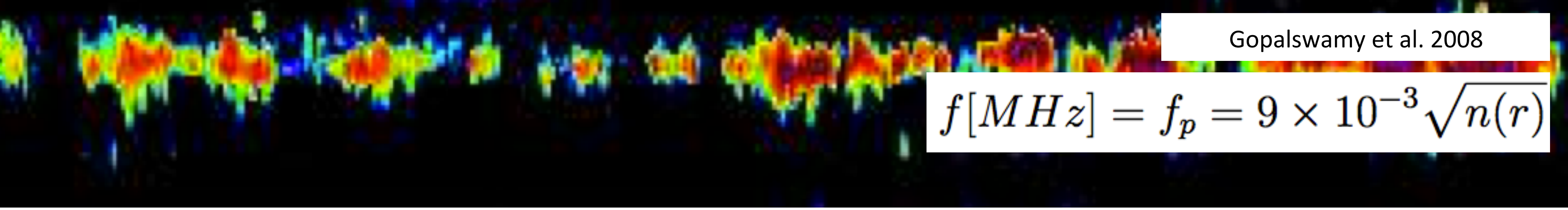
Gopalswamy et al. 2008

$$f[MHz] = f_p = 9 \times 10^{-3}\sqrt{n(r)}$$



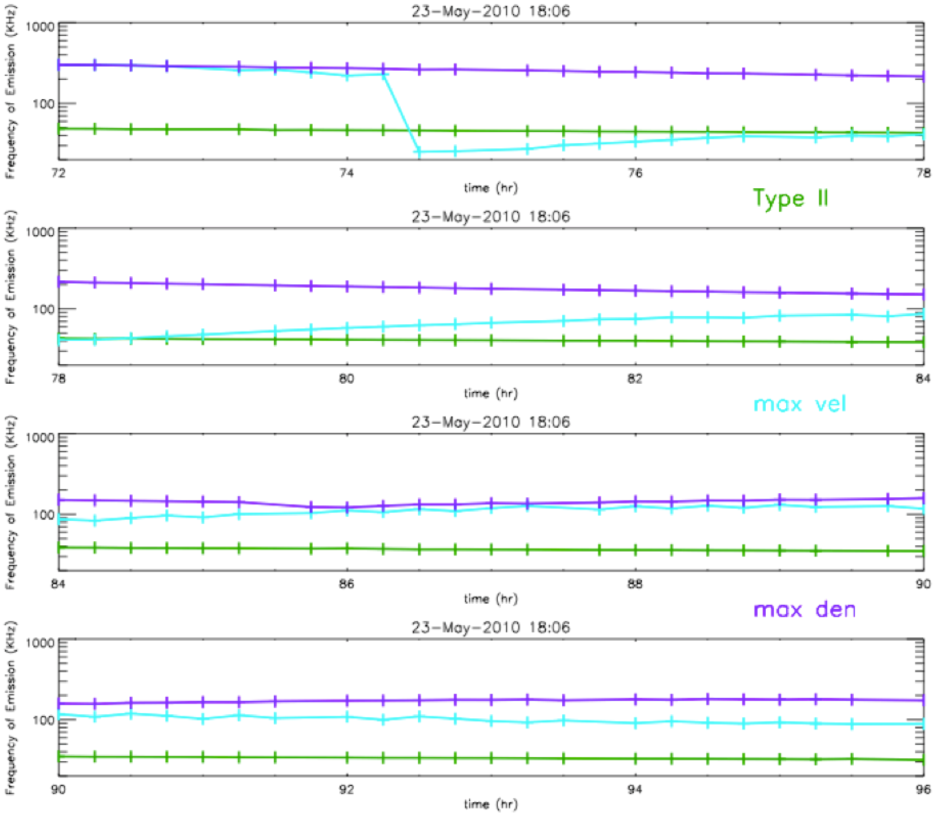


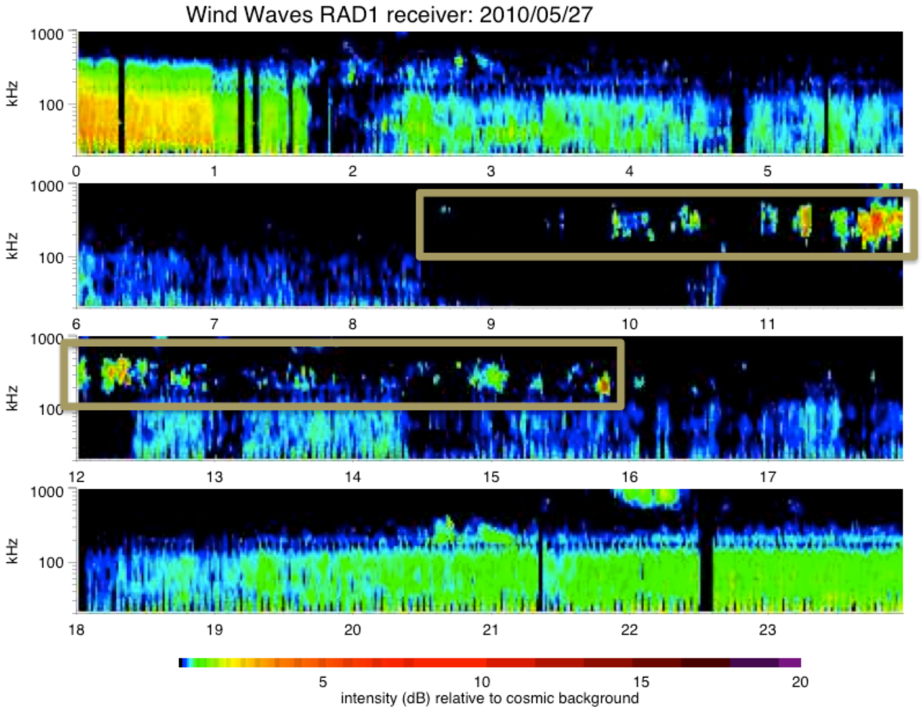
Niembro et al. (in preparation)



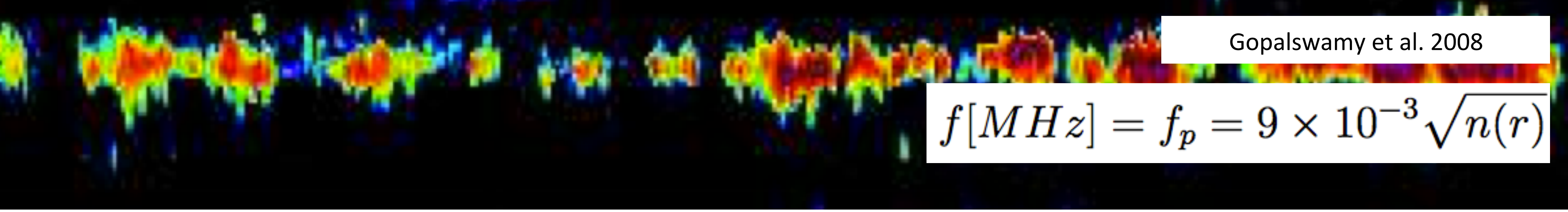
Gopalswamy et al. 2008

$$f[MHz] = f_p = 9 \times 10^{-3}\sqrt{n(r)}$$



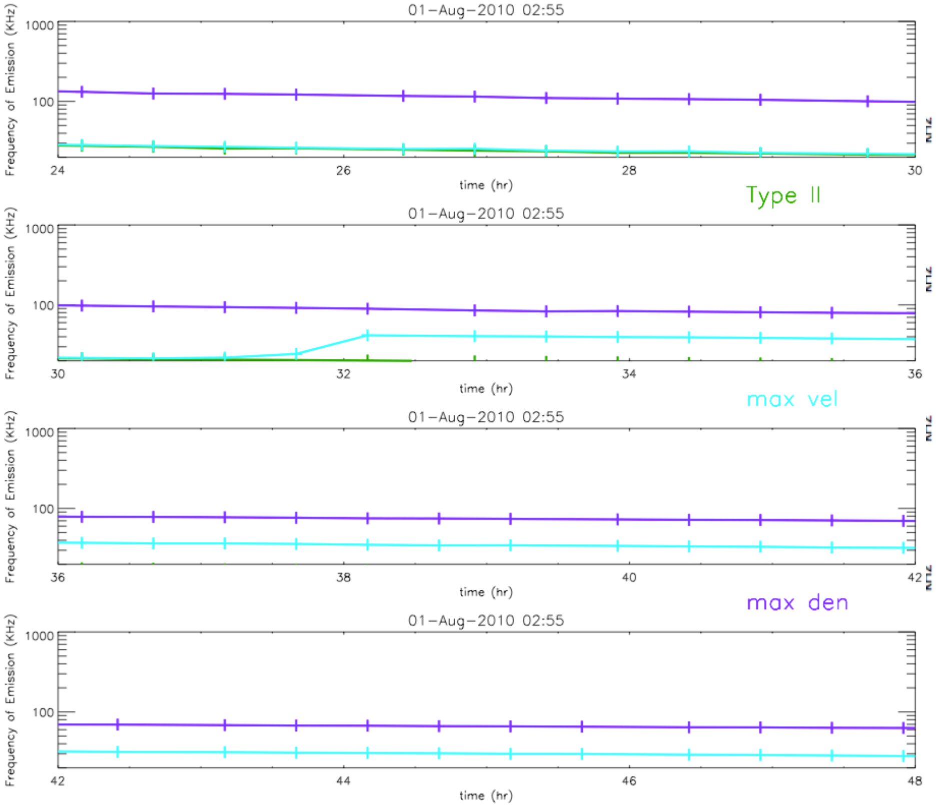


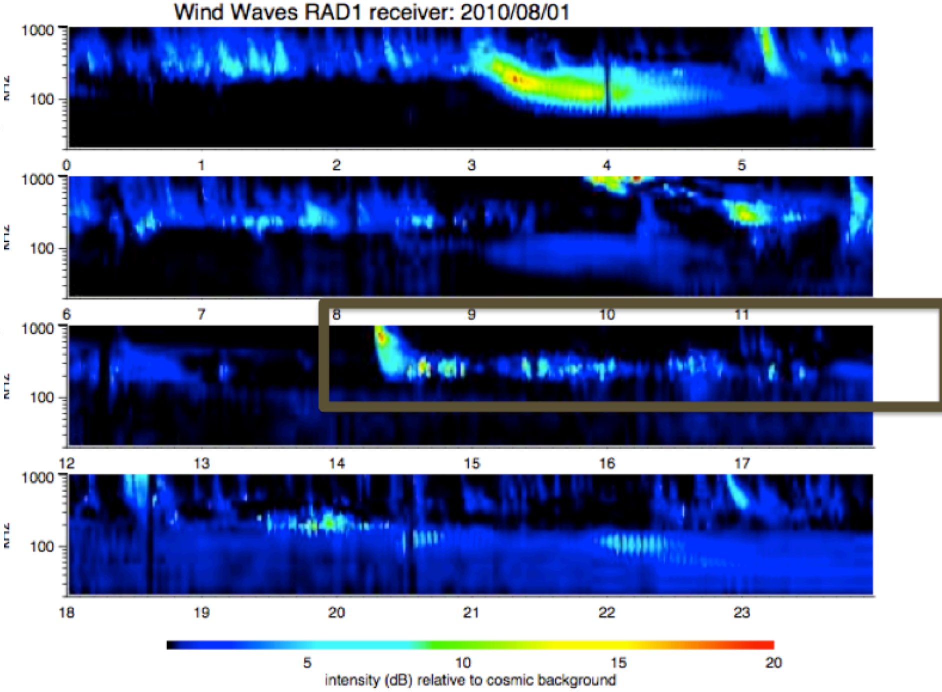
Niembro et al. (in preparation)



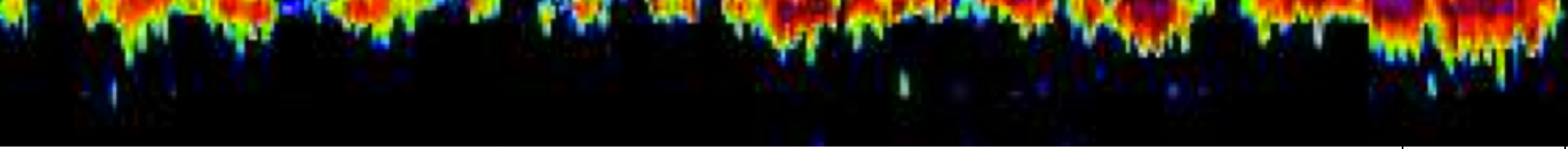
Gopalswamy et al. 2008

$$f[MHz] = f_p = 9 \times 10^{-3}\sqrt{n(r)}$$





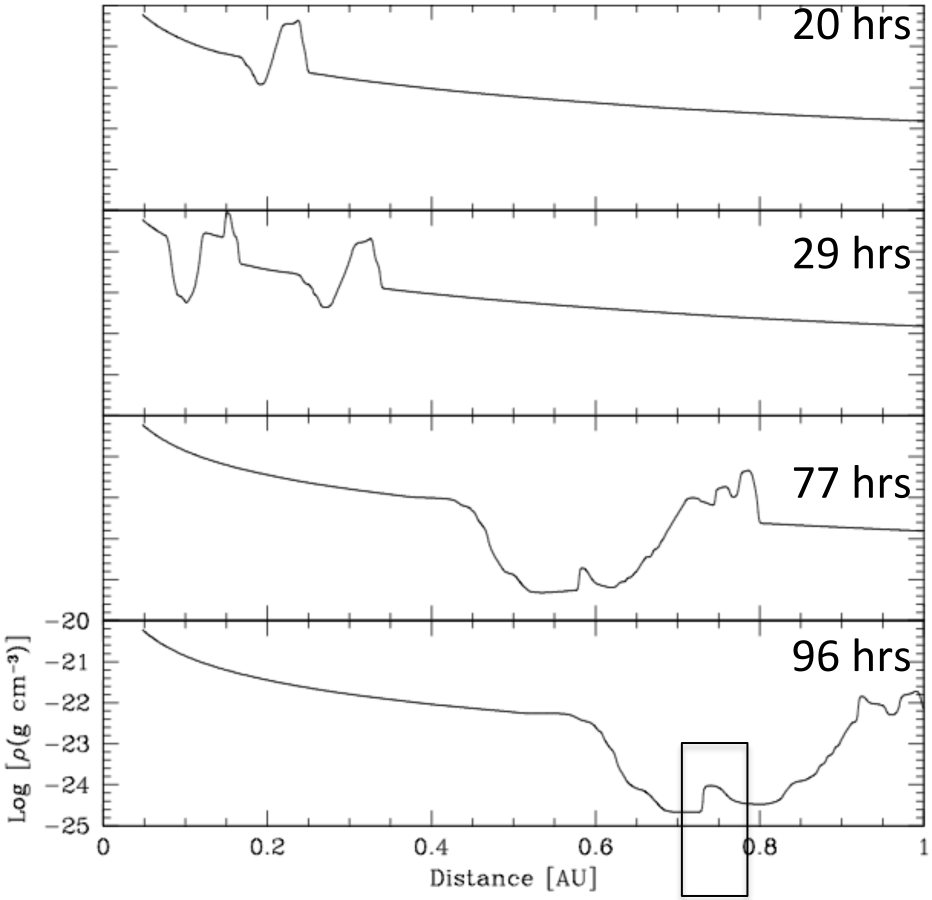
Niembro et al. (in preparation)

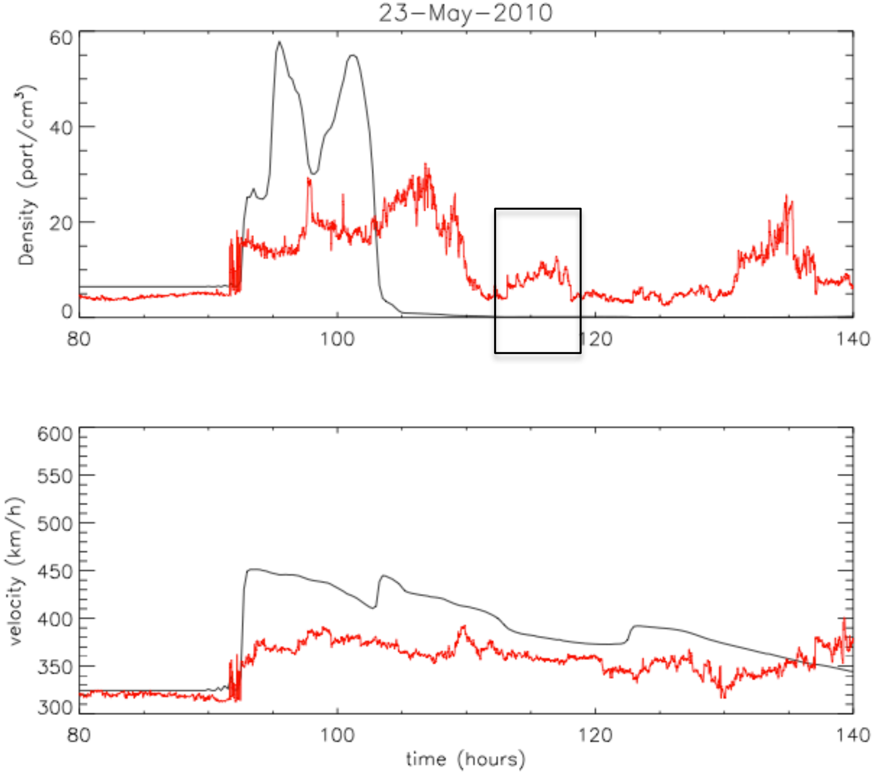


May 23, 2010

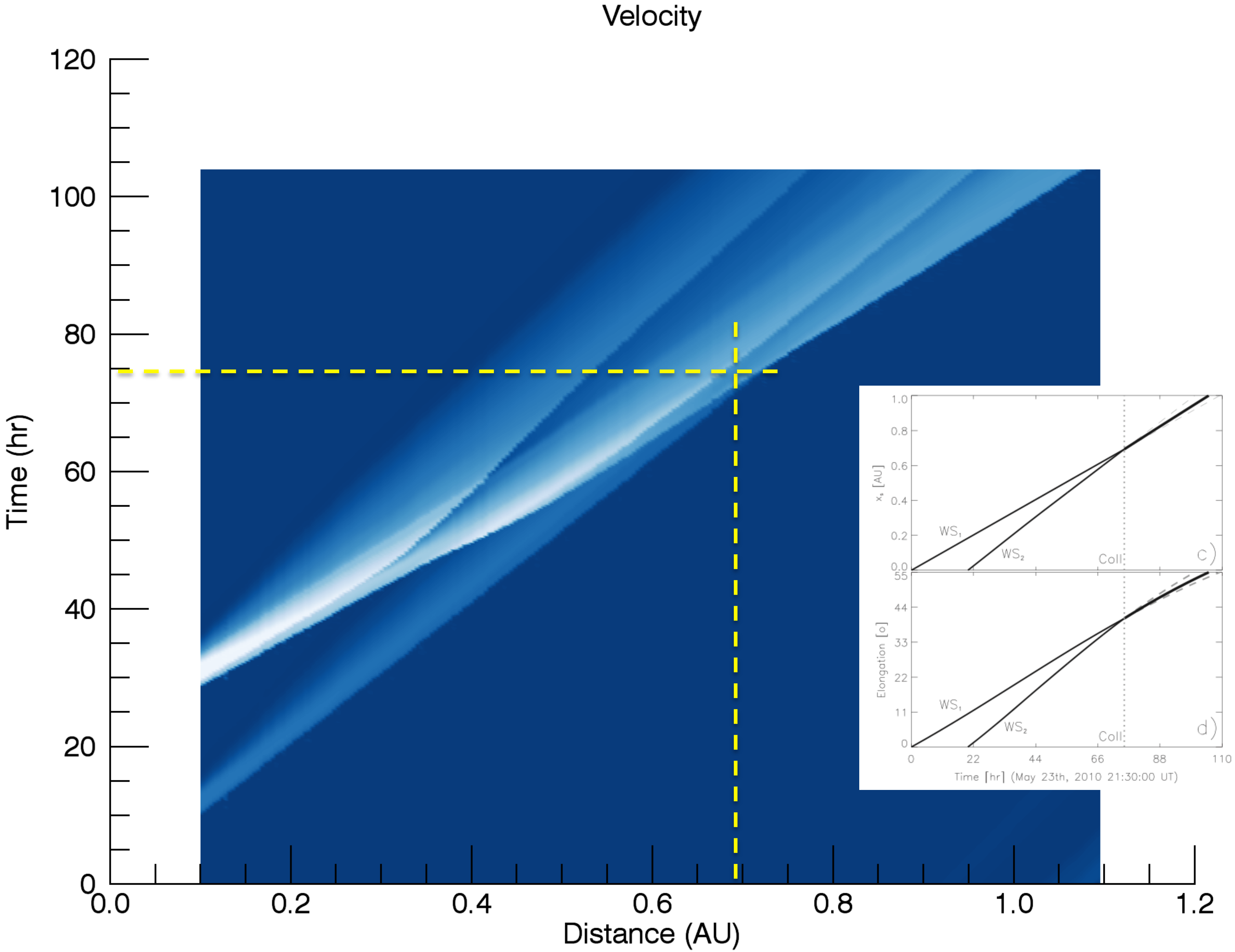
n(r)

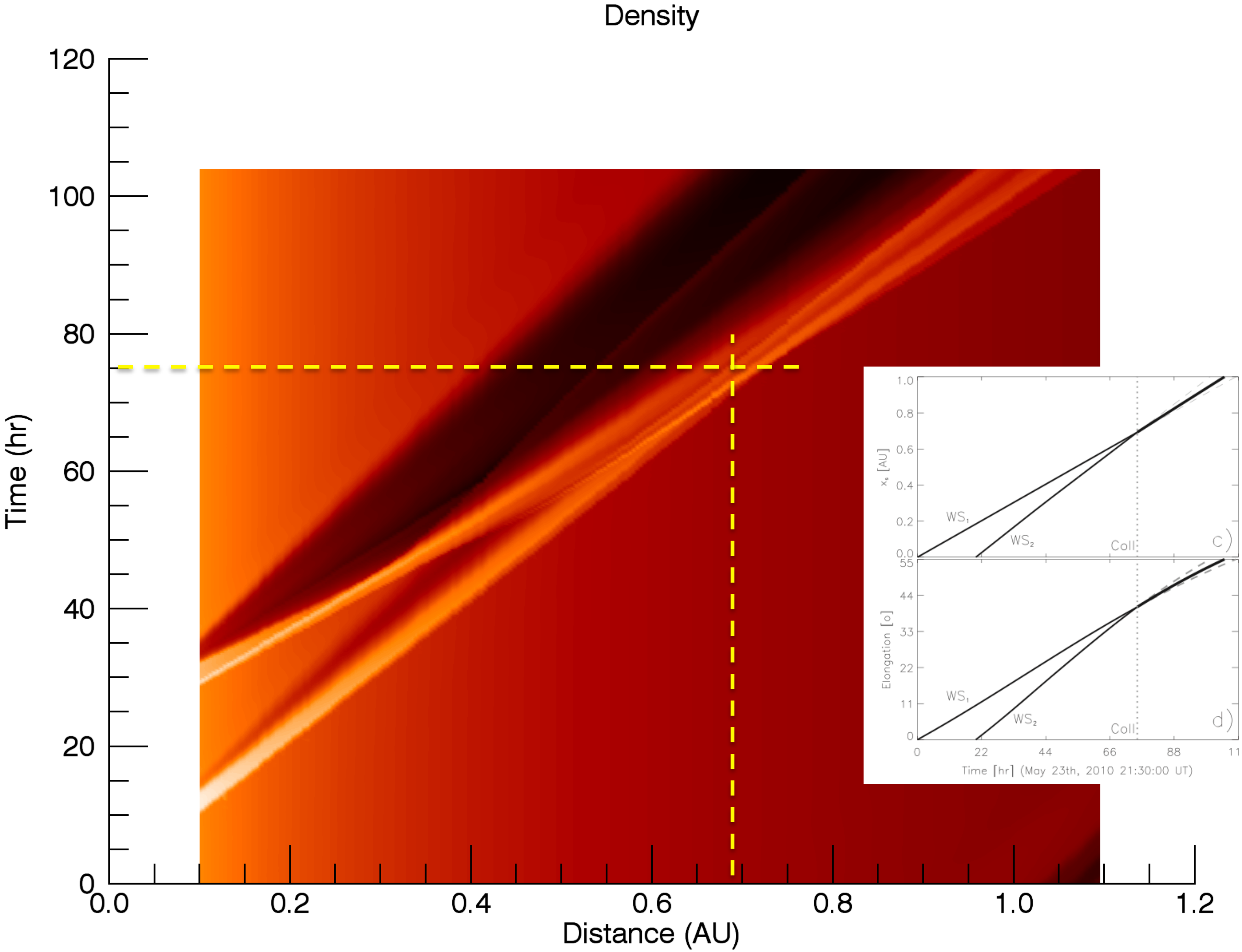
n(t)

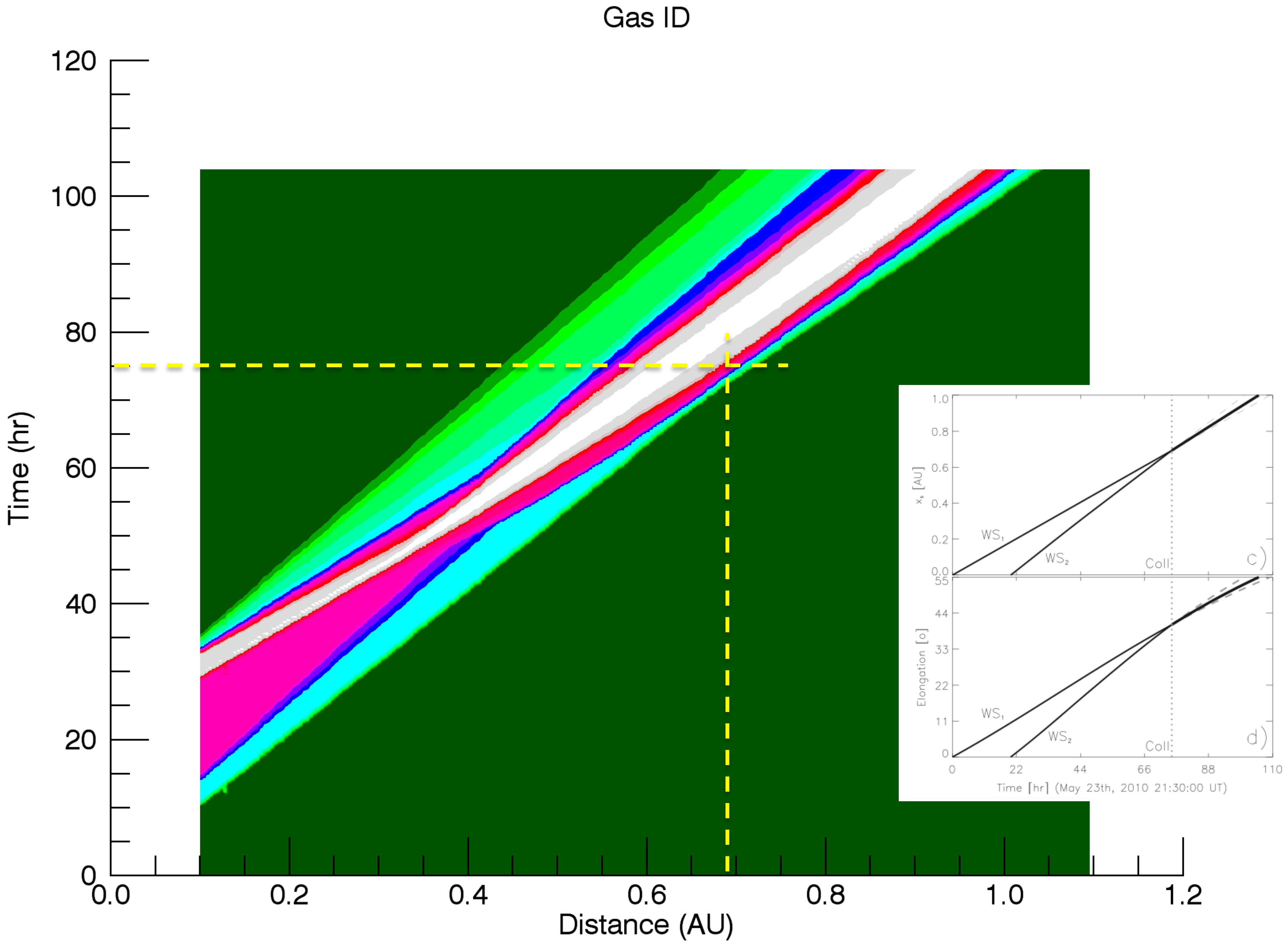


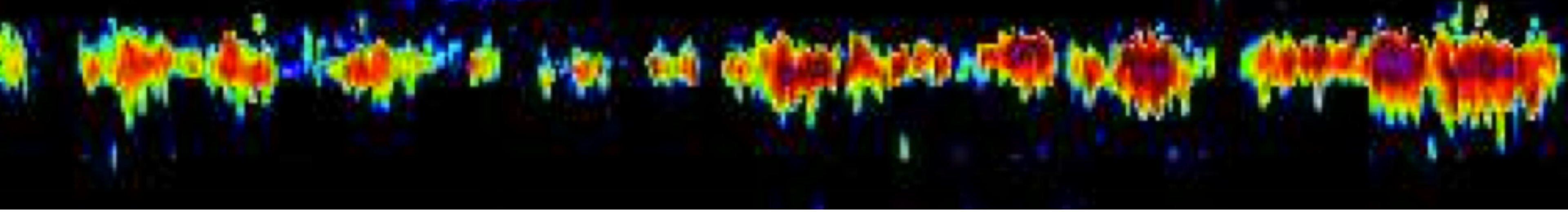


n(r, t)


Velocity
Time (hr)
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Distance (AU)
x_s [AU]
1.0
0.8
0.6
0.4
0.2
0.0
WS_1
WS_2
Coll
c)
Elongation [o]
55
44
33
22
11
0
WS_1
WS_2
Coll
d)
0
22
44
66
88
110
Time [hr] (May 23th, 2010 21:30:00 UT)


Density
Time (hr)
0
20
40
60
80
100
120
Distance (AU)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
x_s [AU]
1.0
0.8
0.6
0.4
0.2
0.0
WS₁
WS₂
Coll
c)
Elongation [o]
55
44
33
22
11
0
WS₁
WS₂
Coll
d)
0
22
44
66
88
110
Time [hr] (May 23th, 2010 21:30:00 UT)


Gas ID
Time (hr)
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Distance (AU)
1.0
0.8
0.6
0.4
0.2
0.0
x_s [AU]
WS_1
WS_2
Coll
c)
55
44
33
22
11
0
Elongation [o]
WS_1
WS_2
Coll
d)
0
22
44
66
88
110
Time [hr] (May 23th, 2010 21:30:00 UT)



CONCLUSIONS

- The analytical model reproduces the general dynamics of the ICME – ICME interaction.
- Our numerical simulation allow us to follow in detail the structures involved in the interaction.
- There are not free parameters in these models.
- Both models predict the time and distance of ICME – ICME interaction as well as the arrival time and velocity.
- The simulation gives the density as function of distance and time allowing us to estimate the possible radio emission associated to the ICME – ICME interaction.
- We have coted the frequency range of the radio emission due to the interaction.