「銀河のダスト」研究会　2009年10月8-10日　大阪産業大学

太陽風3次元構造とダスト粒子軌道の解析

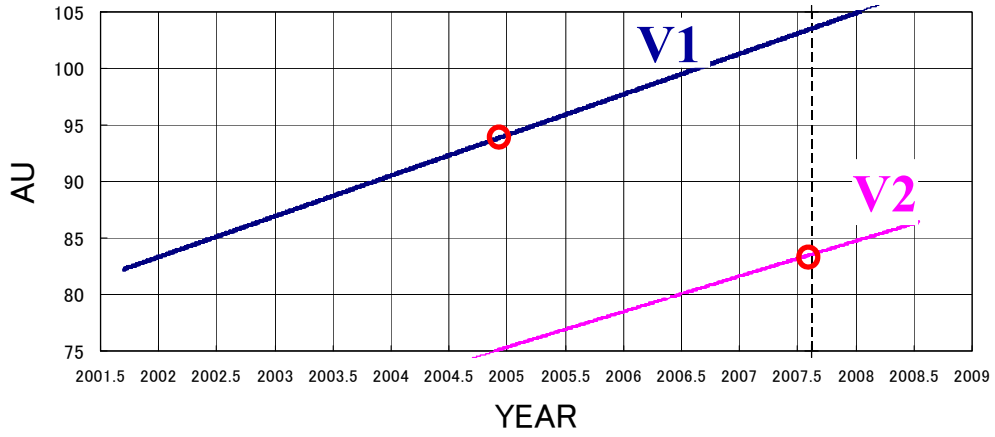
鷲見治一, G. P. Zank, Q. Hu（アラバマ大）
田中高史（九大理）

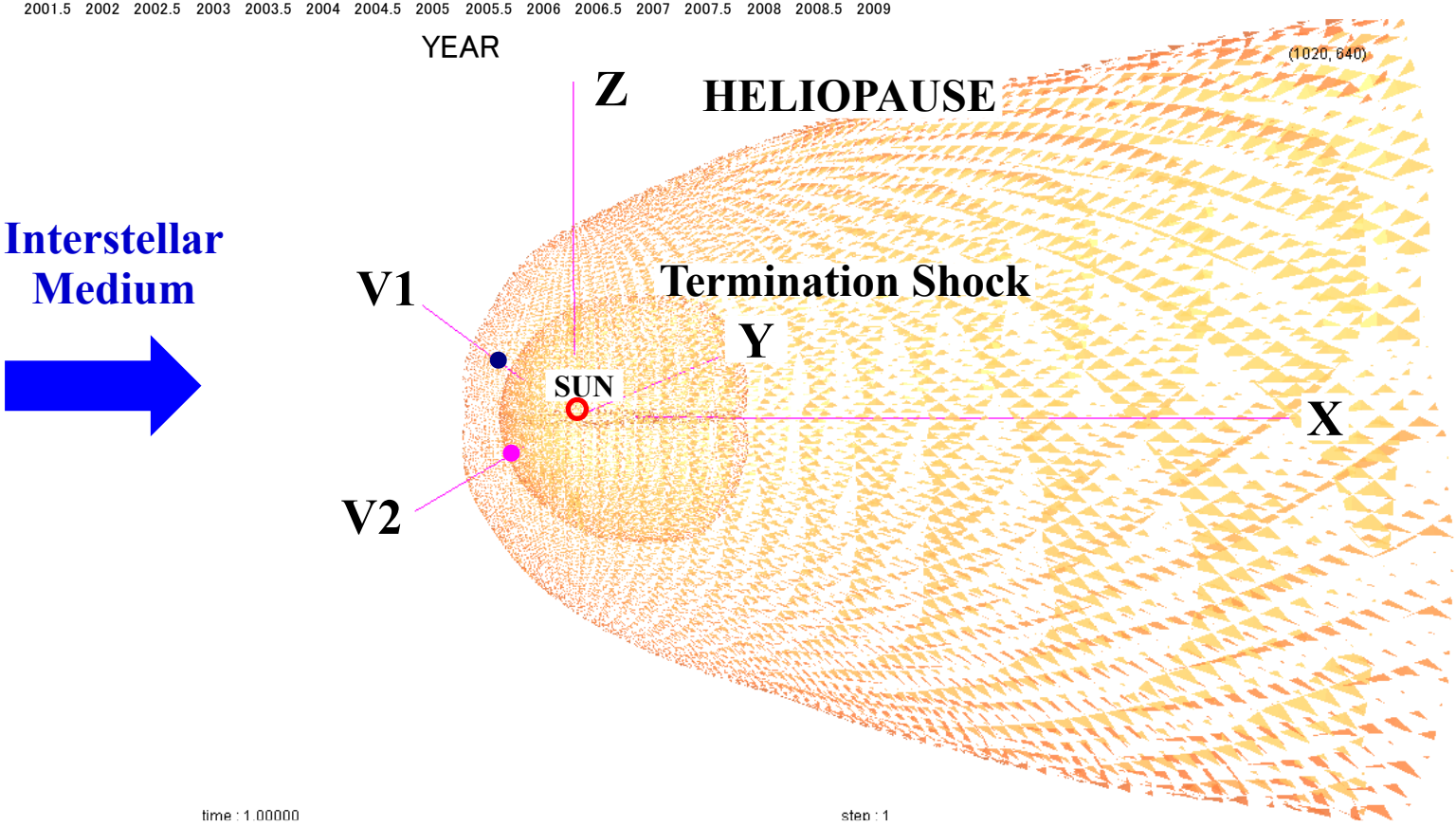
3D MHD + Test Particles

V1-TS crossing: at 94 AU

V2-TS crossing: at 84 AU

Asymmetric structure
Time-varying effect





内容

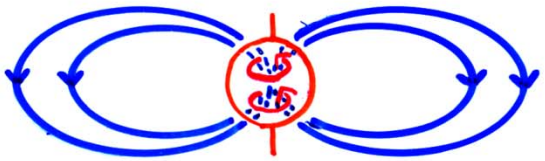
1. 太陽圏、恒星圏（SN1987A、PN）の構造
   ー　MHDシミュレーション

2. 銀河宇宙線、荷電ダスト粒子の太陽圏内部への輸送
   ー　（MHD＋テスト粒子）シミュレーションの準備

3. 太陽圏構造とダイナミックス
   ー　Voyager観測を基礎として

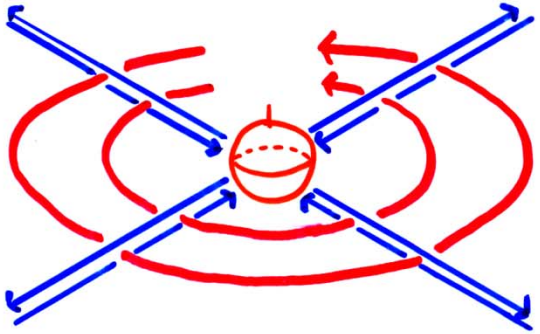
→ : 電流 Current

→ : 磁力線 Magnetic Field Line



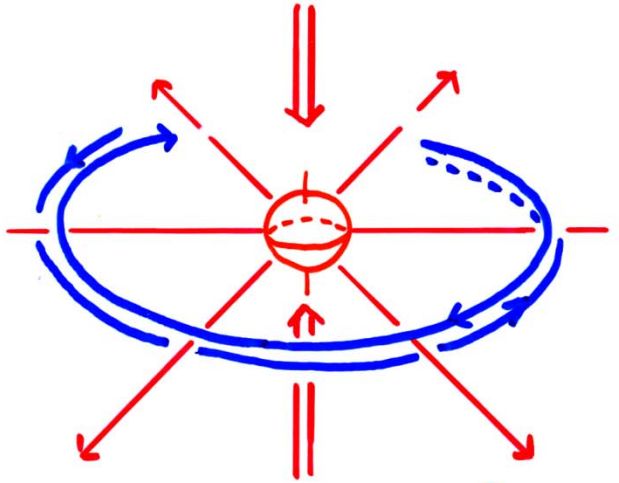
$B_{dipole} \propto r^{-3}$

Poloidal



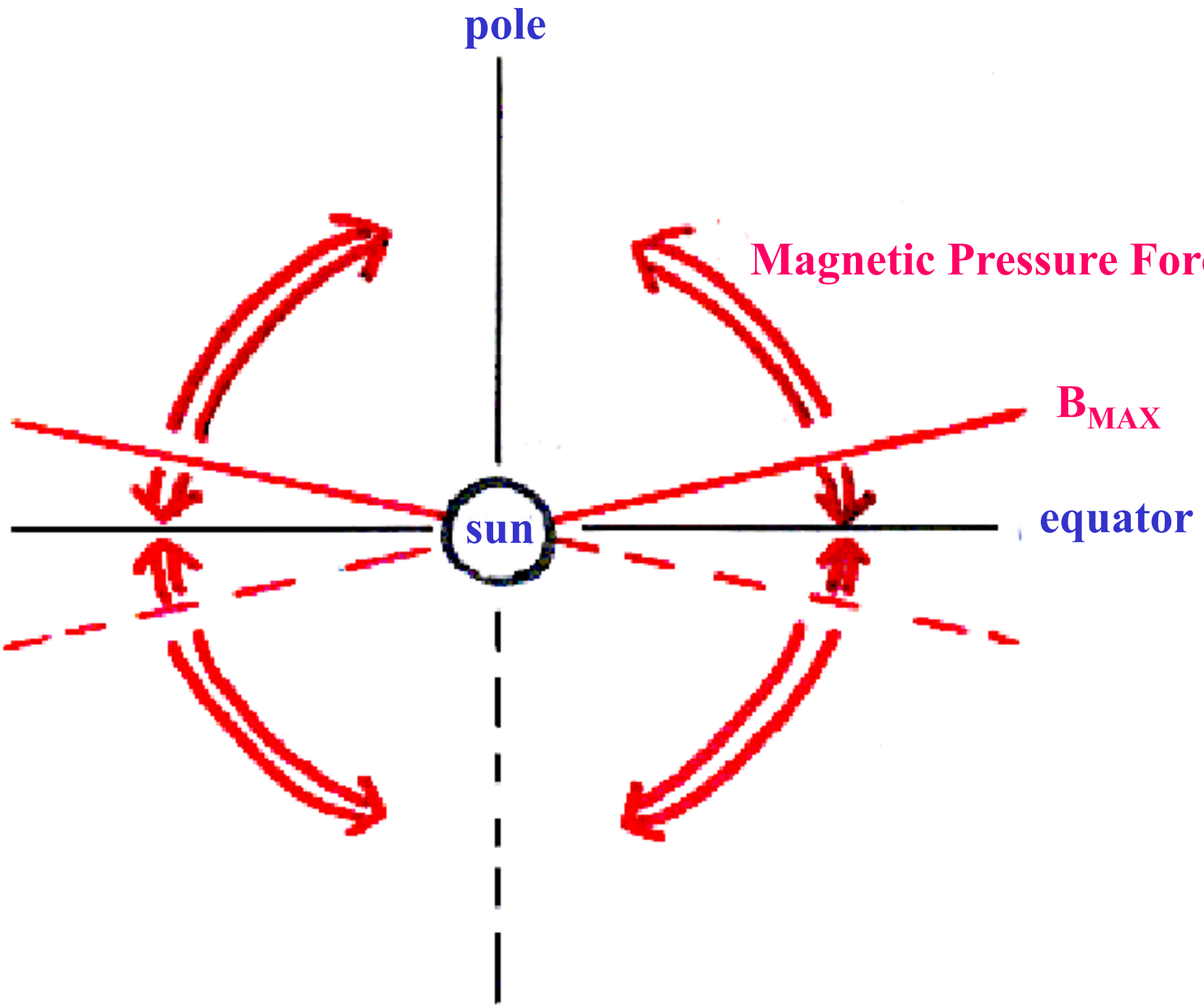
$B_{radial} \propto r^{-2}$

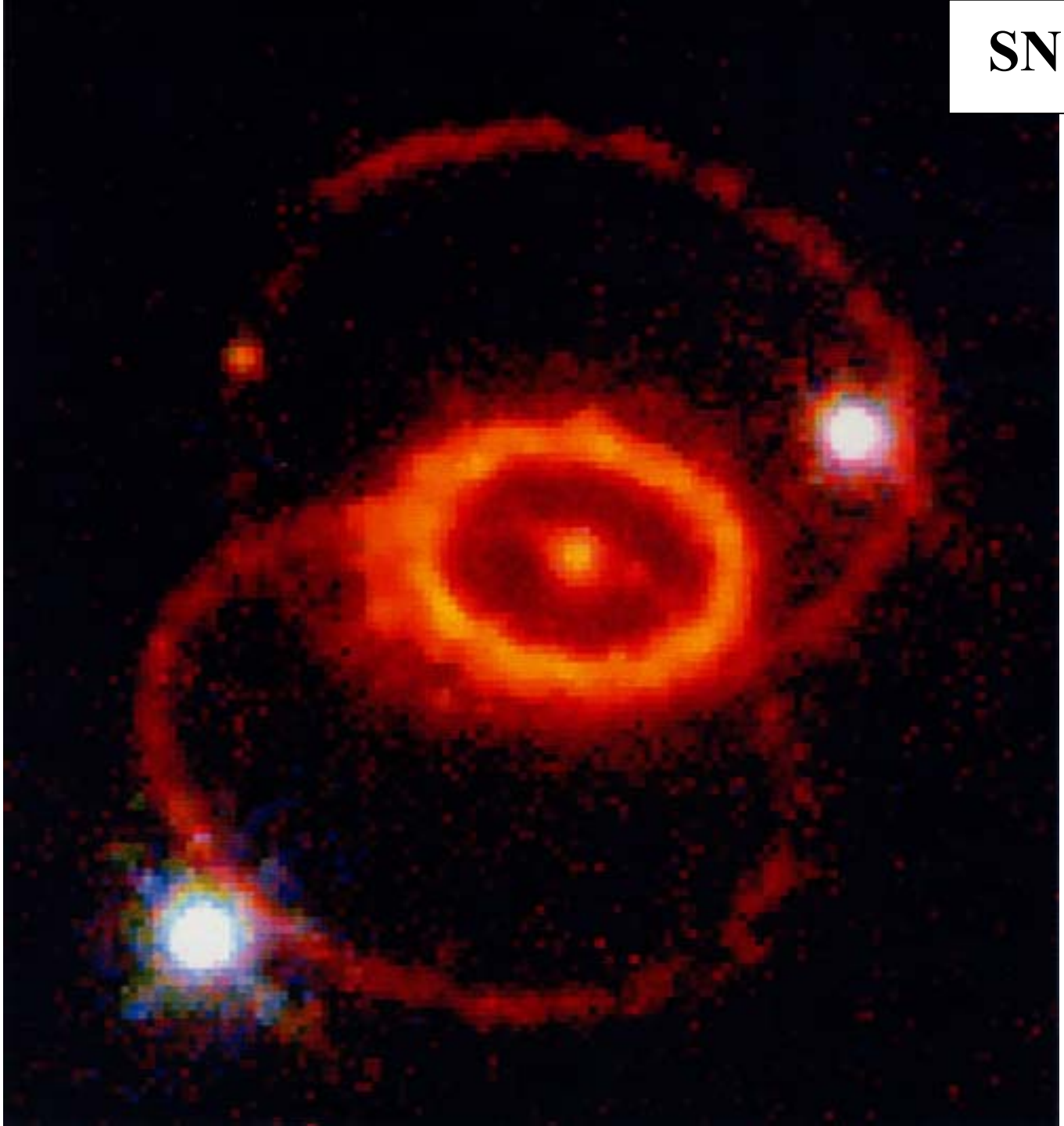
Poloidal

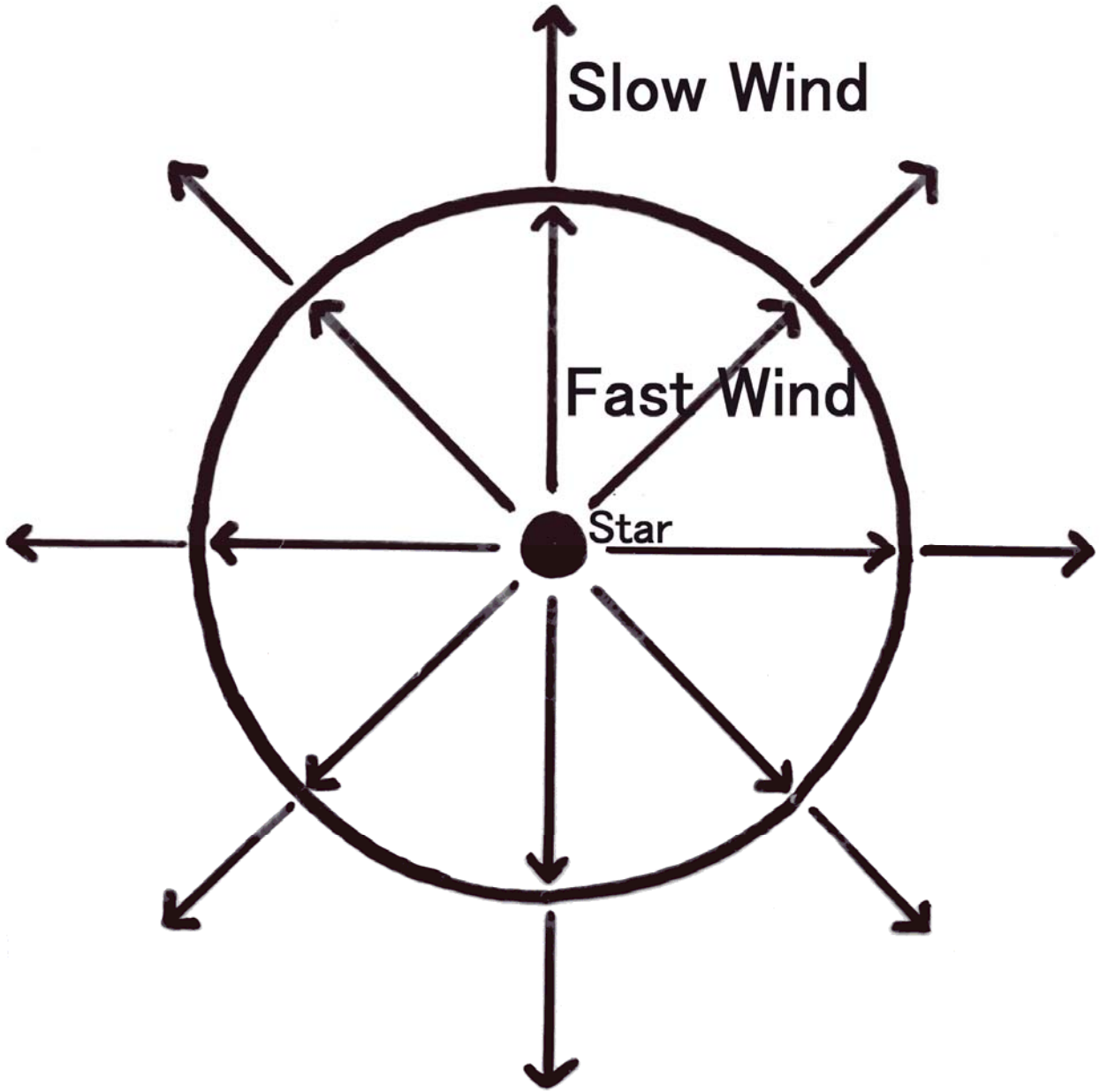


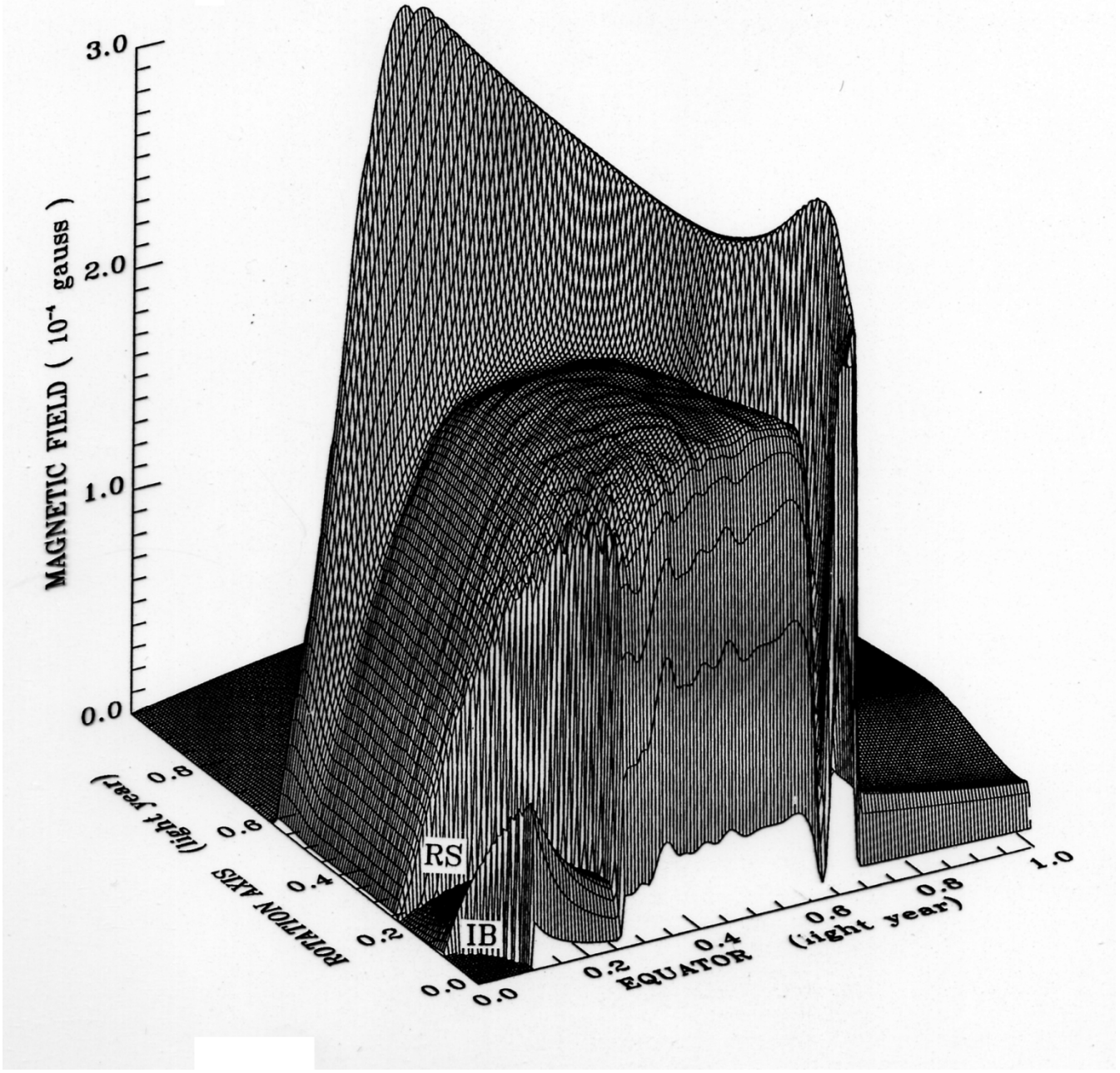
$B_{toroidal} \propto r^{-1}$

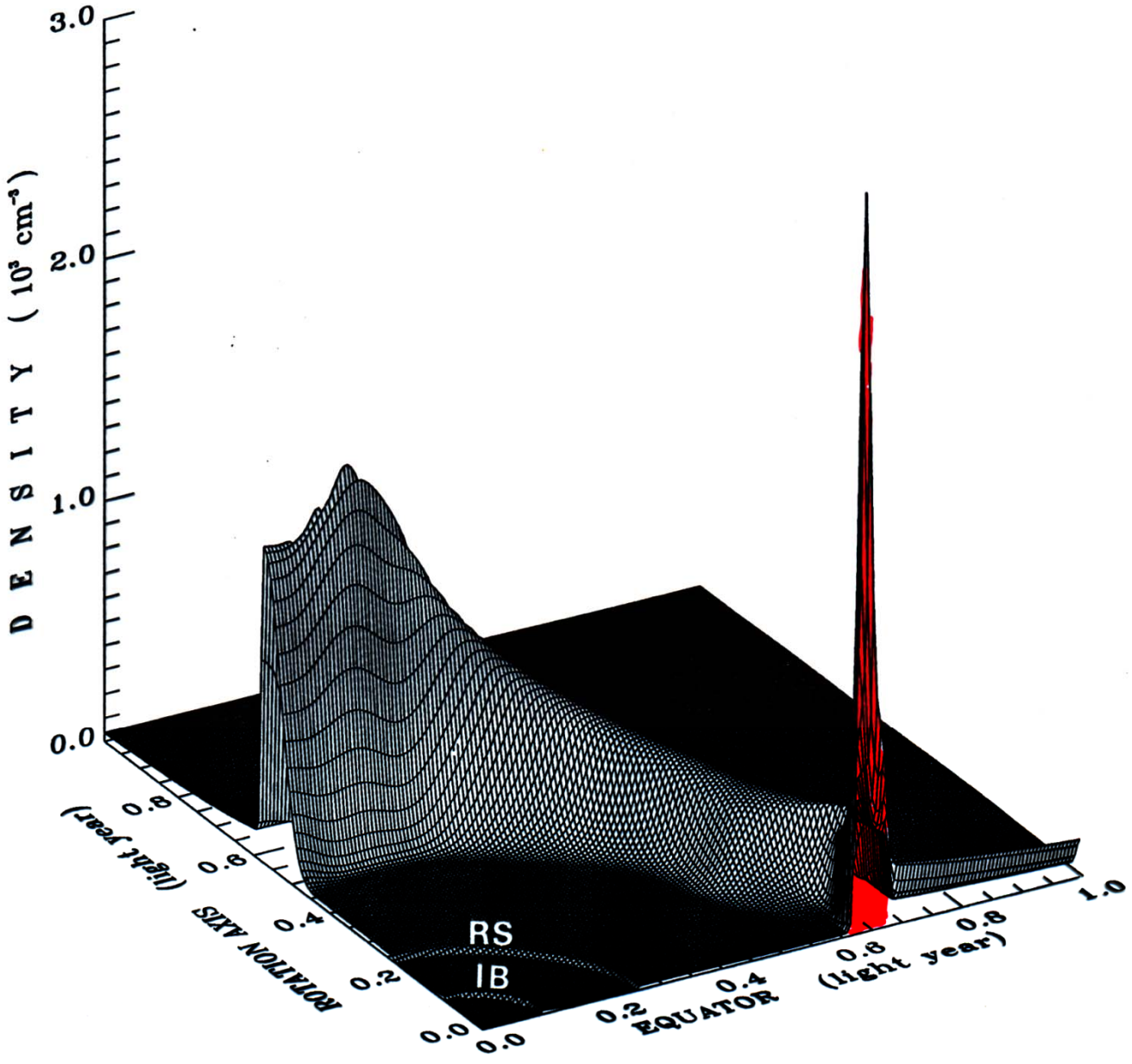
Toroidal

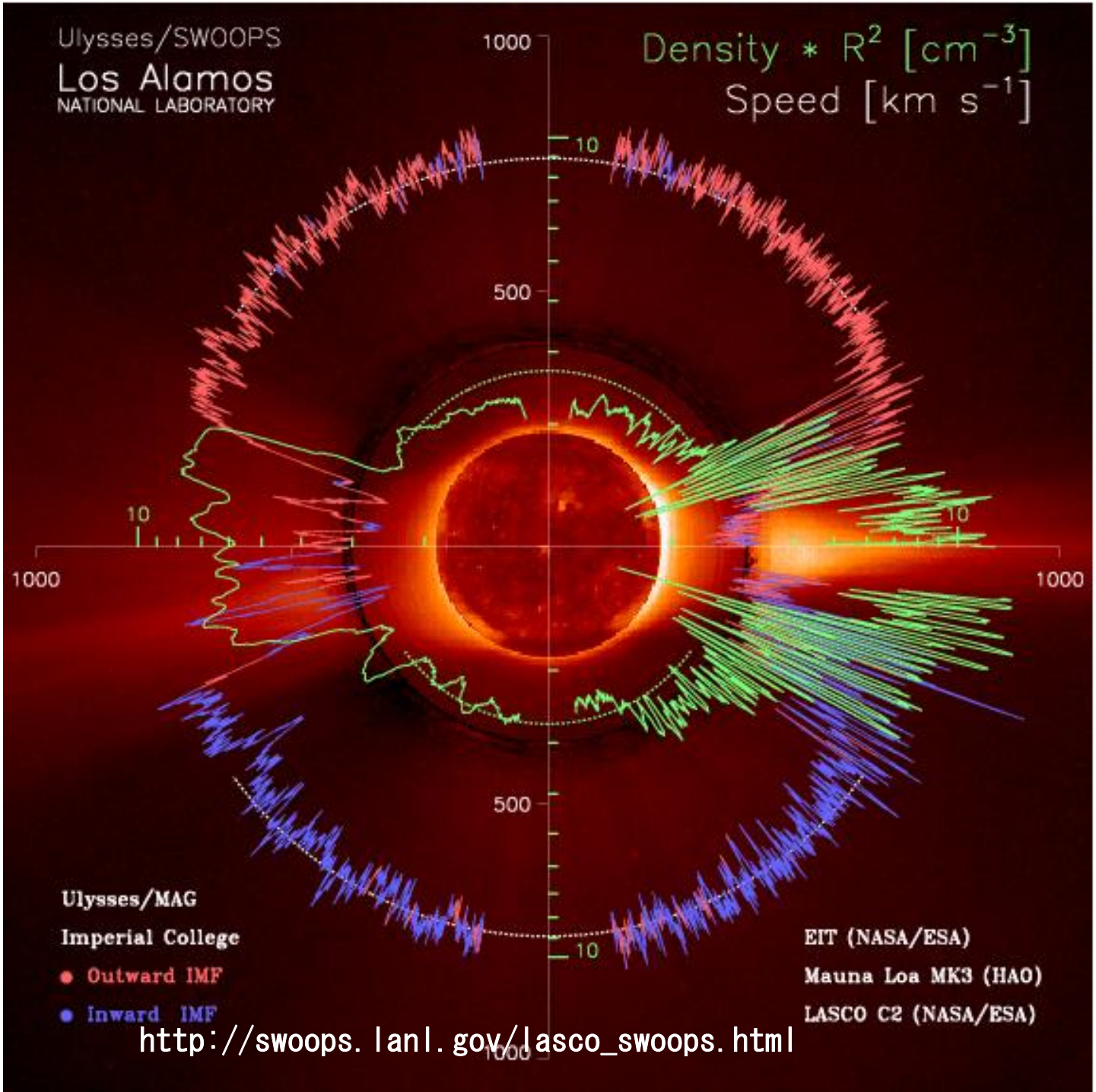

pole
Magnetic Pressure Force
B_{MAX}
sun
equator

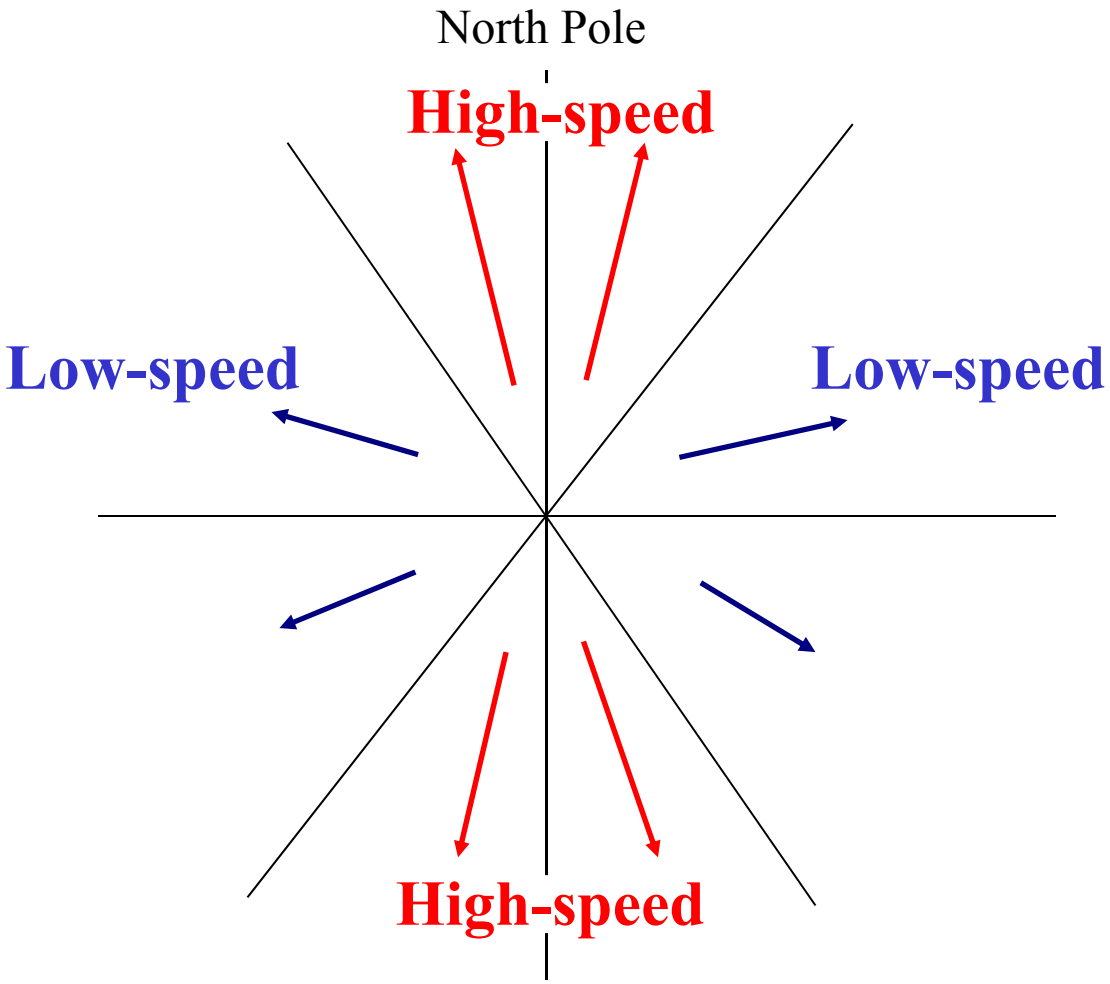

SN1987A

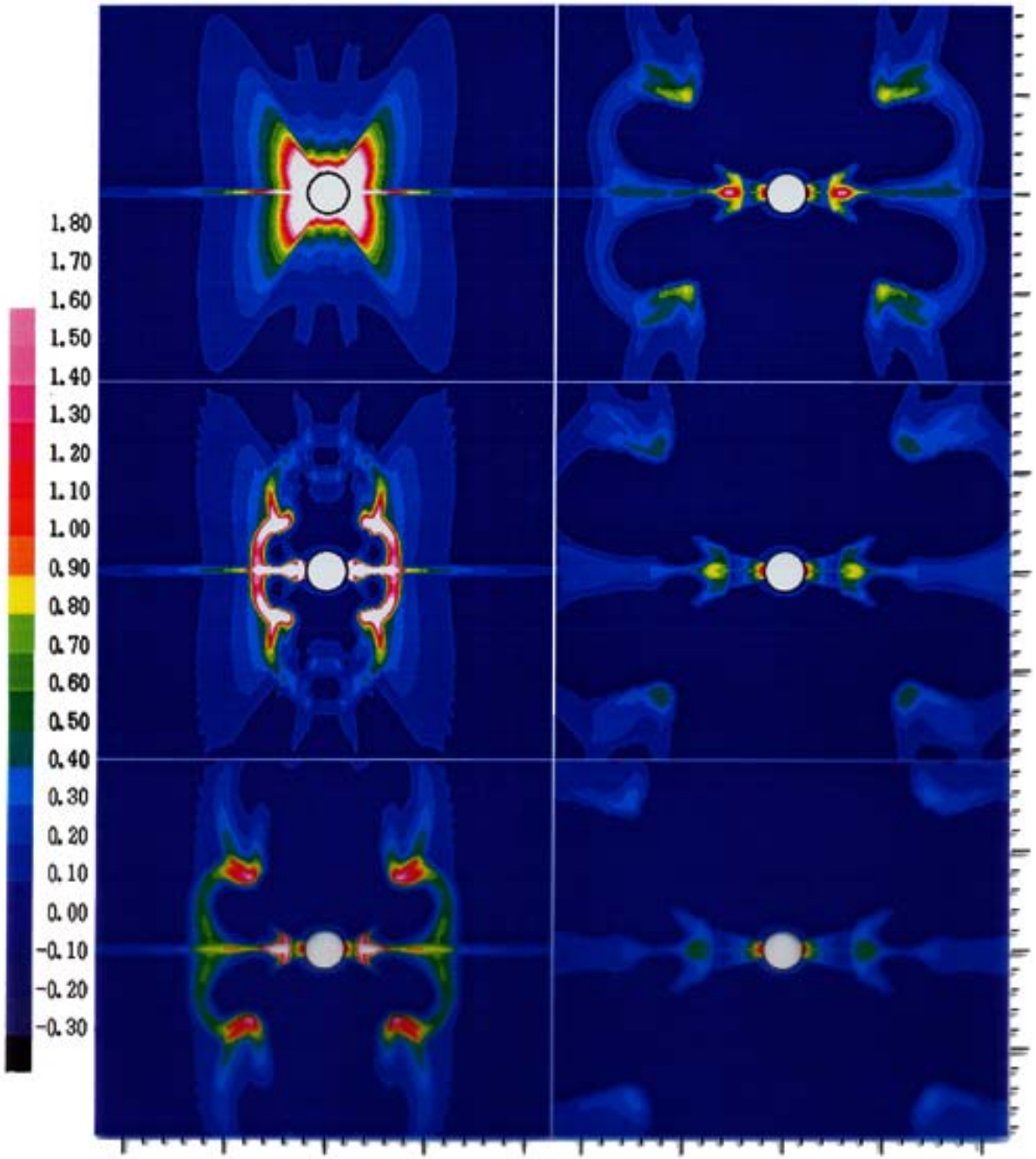

Slow Wind
Fast Wind
Star

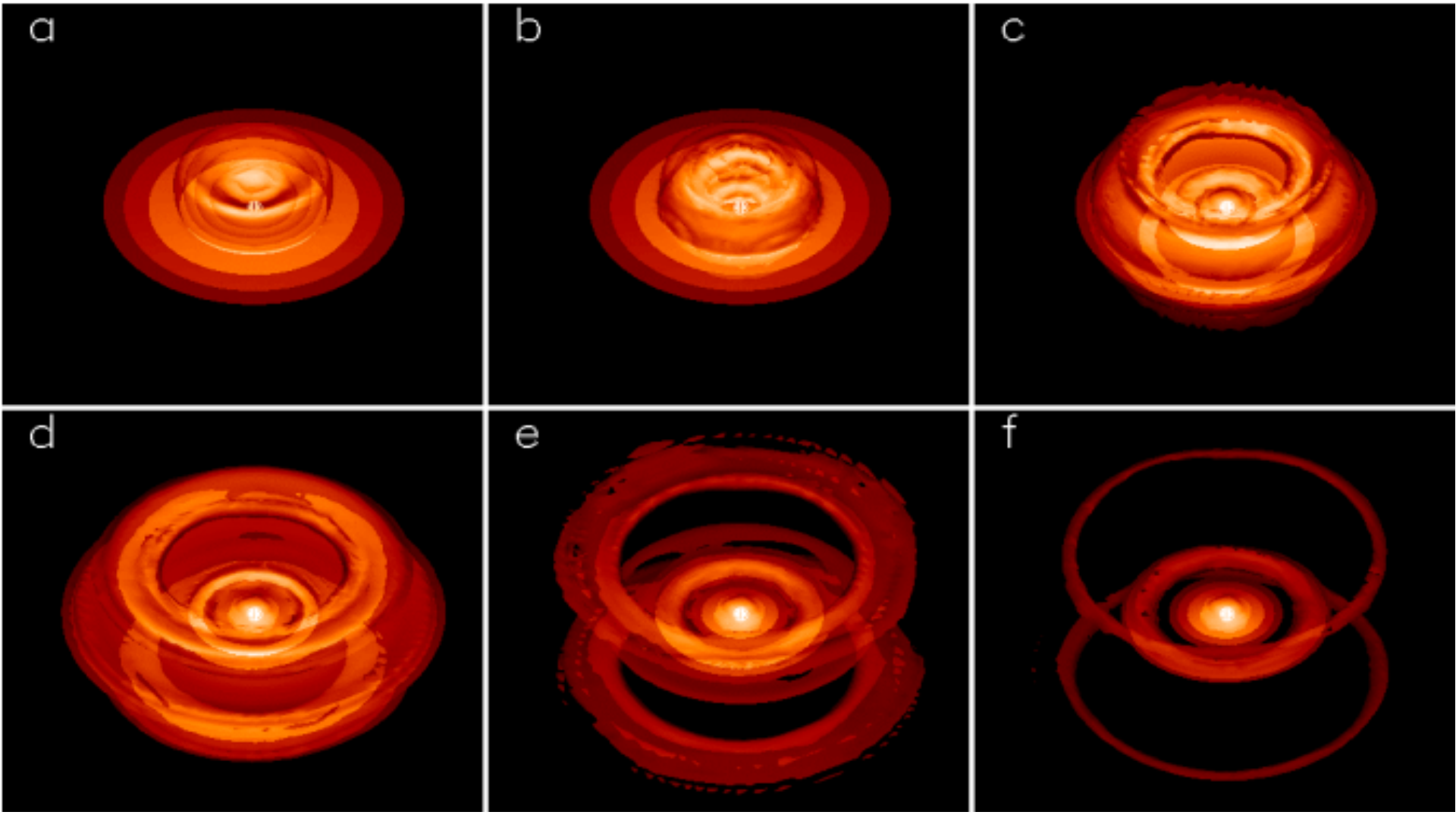

MAGNETIC FIELD (10^{-4} gauss)
3.0
2.0
1.0
0.0
ROTATION AXIS (light year)
0.0
0.2
0.4
0.6
0.8
RS
IB
0.0
0.2
0.4
EQUATOR (light year)
0.6
0.8
1.0


DENSITY (10^3 cm^{-3})
3.0
2.0
1.0
0.0
0.0
0.2
0.4
0.6
0.8
(light year)
ROTATION AXIS
0.0
0.2
0.4
0.6
0.8
1.0
(light year)
EQUATOR
RS
IB

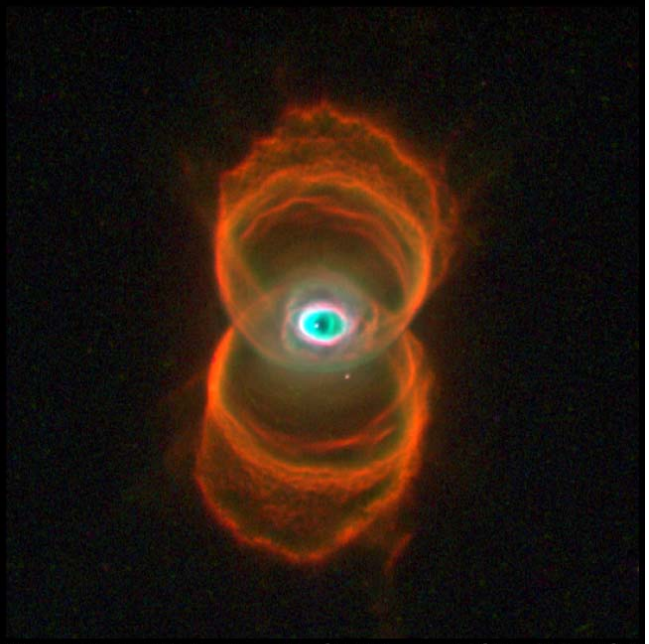

Ulysses/SWOOPS
Los Alamos
NATIONAL LABORATORY
Density * R² [cm⁻³]
Speed [km s⁻¹]
1000
500
10
Ulysses/MAG
Imperial College
Outward IMF
Inward IMF
EIT (NASA/ESA)
Mauna Loa MK3 (HAO)
LASCO C2 (NASA/ESA)
http://swoops.lanl.gov/lasco_swoops.html


North Pole
High-speed
Low-speed
Low-speed
High-speed


1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30



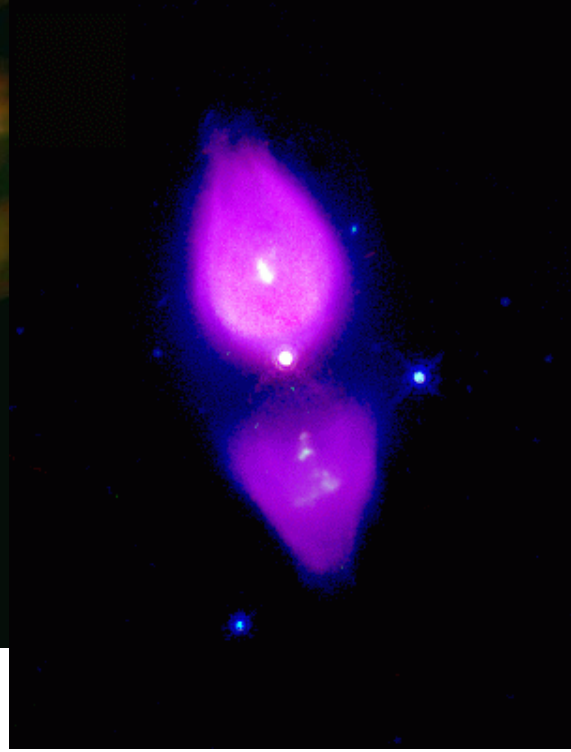
Tanaka &Washimi (Science 2001)

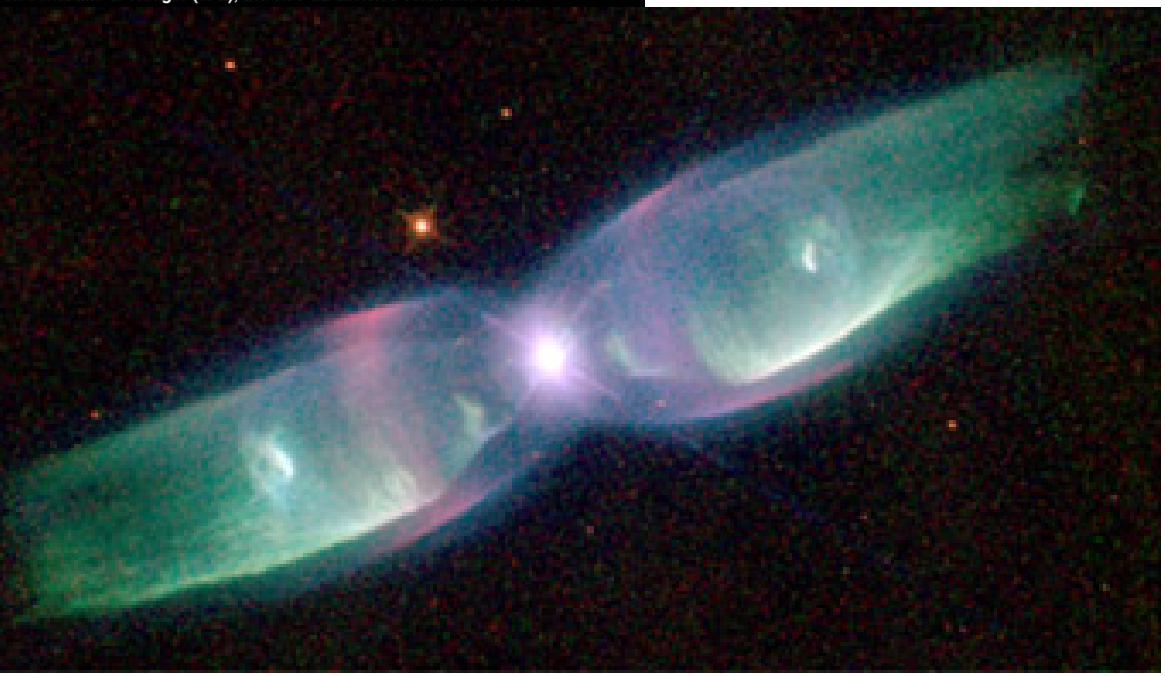


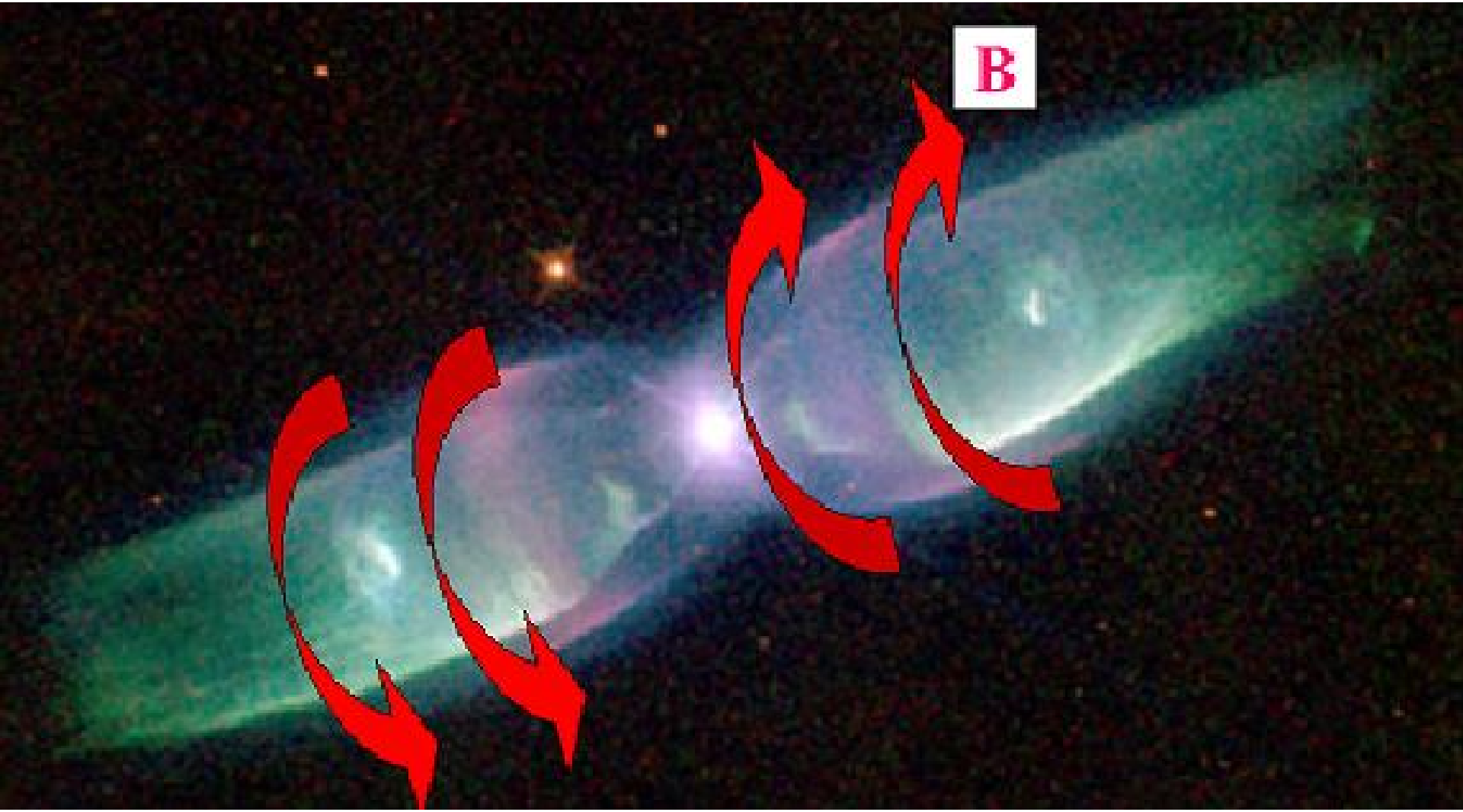
Hourglass Nebula · MyCn18 HST · WFPC2

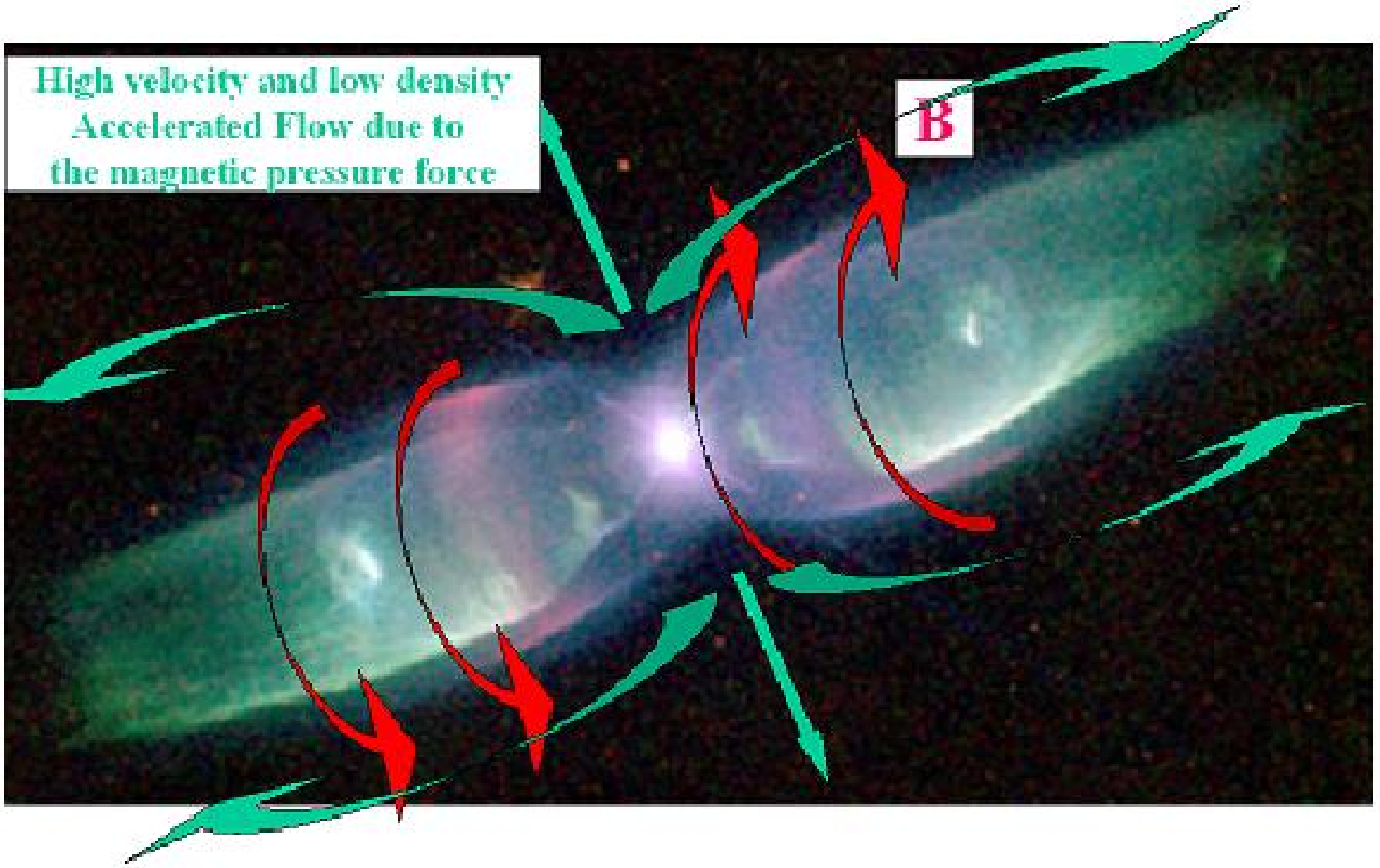
PRC96-07 · ST ScI OPO · January 16, 1996

R. Sahai and J. Trauger (JPL), the WFPC2 Science Team and NASA



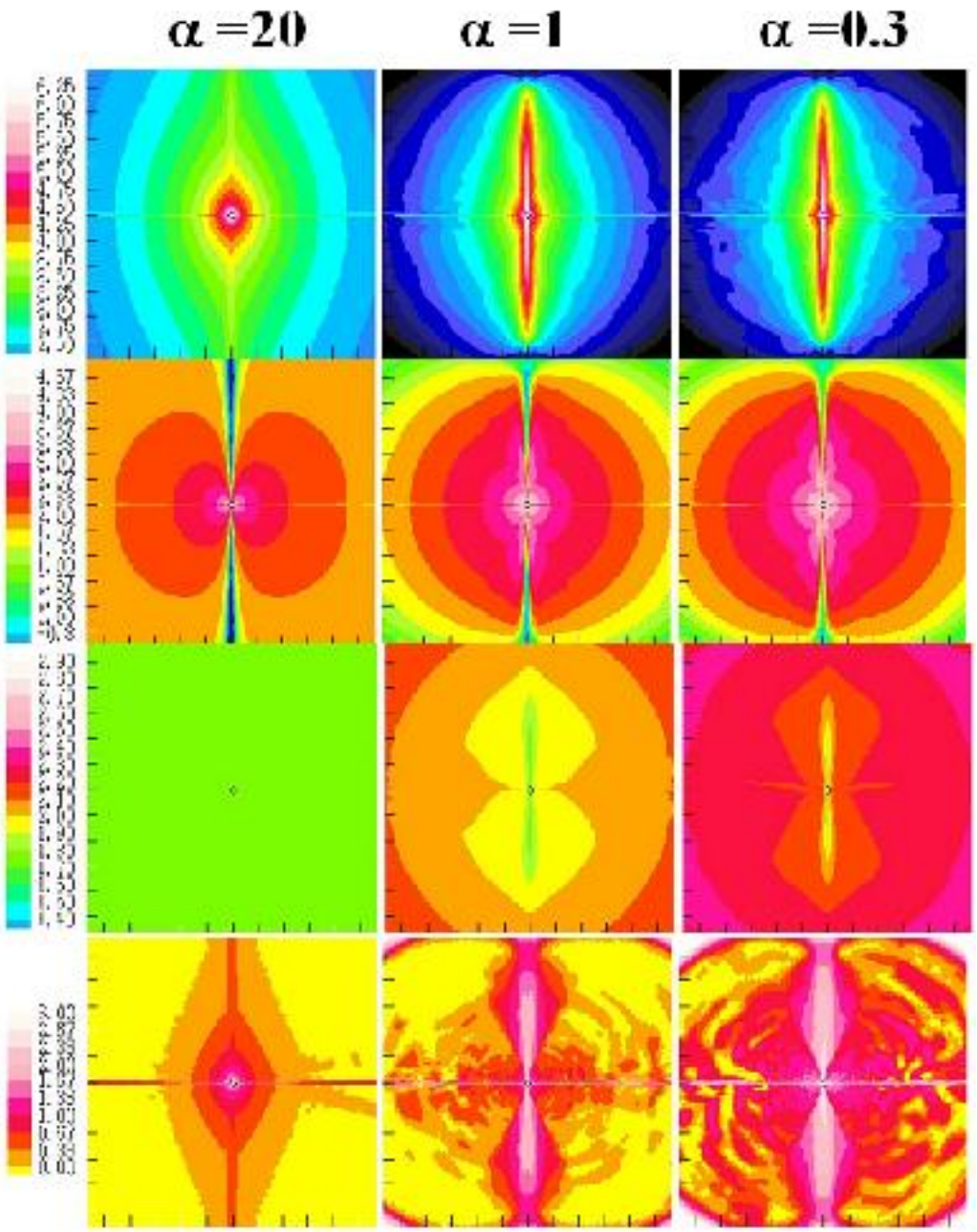


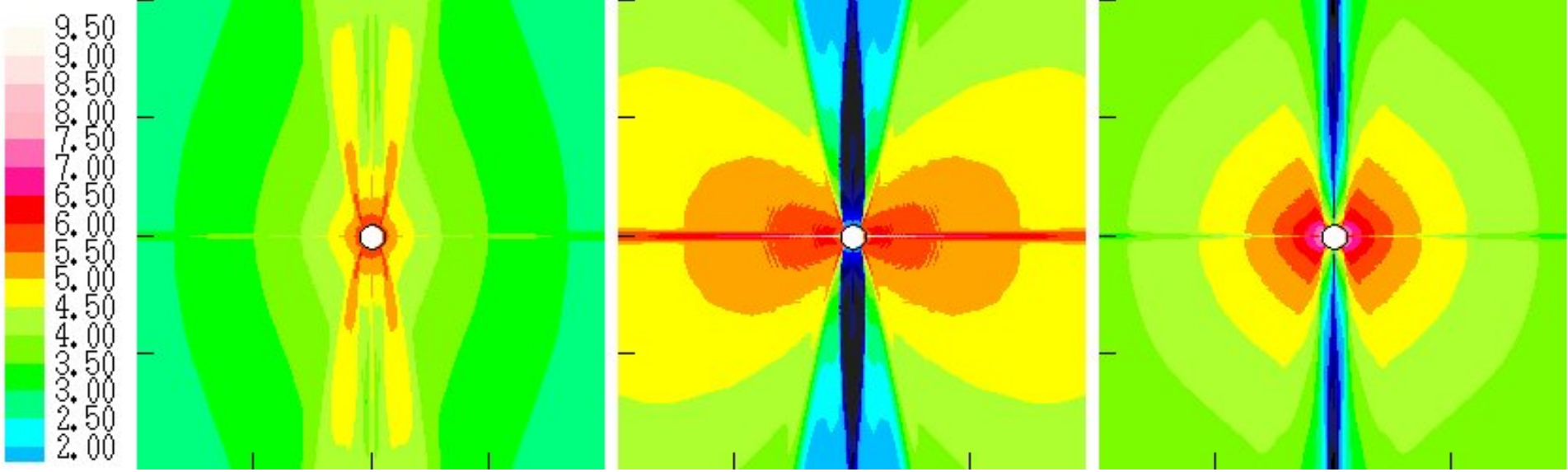

B


High velocity and low density
Accelerated Flow due to
the magnetic pressure force
B

On the Inner Boundary

α = ram-pressure /magnetic-pressure



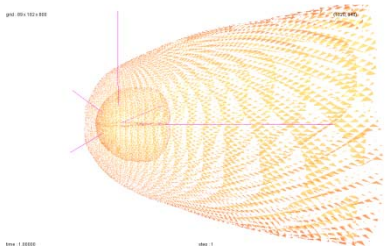


Density **Pram/Pb** **B**

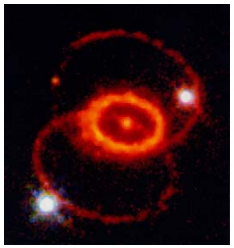
Both the SN1987A progenitors and the AGB star should have magnetic field and the high-speed polar winds

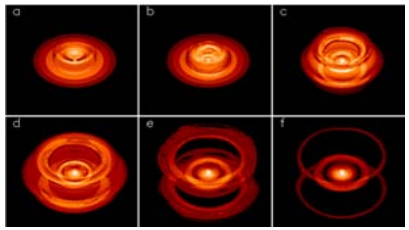
Comparative Outer-Gas Structures

Outer Heliosphere

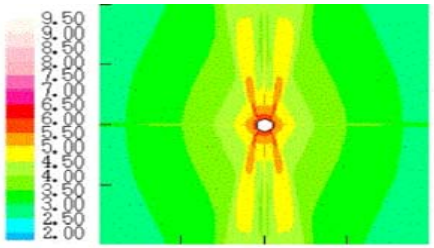


SN1987A Global Structure





Bipolar-Planetary Nebula



Star	Sun	Red and Blue Super-Giants	Asymptotic Giant Blanch
Structure-Type	nose-cone	3-ring	bipolar
Mass of Star	1 M_{sun}	> 8M_{sun}	< 8M_{sun}
Stellar Cycle	22 years	> several 10^3 years	> 10^3 years
Dominant Effects			
ISM & IS-Magnetic Field	Yes	No	No
Time-Varying Stellar-Wind	Yes	Yes (from RSG to BSG)	No
High-Speed Polar Stellar-Wind	Yes	Yes	Yes
Interplanetary Mganetic Field (Nonlinear Effect)	?	Yes	Yes

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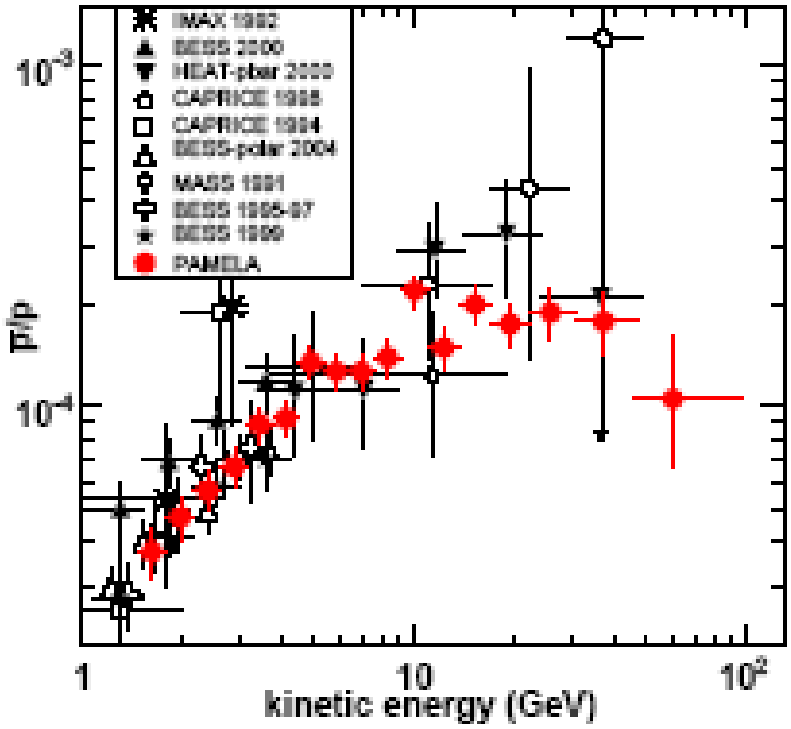


FIG. 4: The antiproton-to-proton flux ratio obtained in this work compared with contemporary measurements [9, 10, 11, 20, 21, 22, 23].

PAMERA Obs.

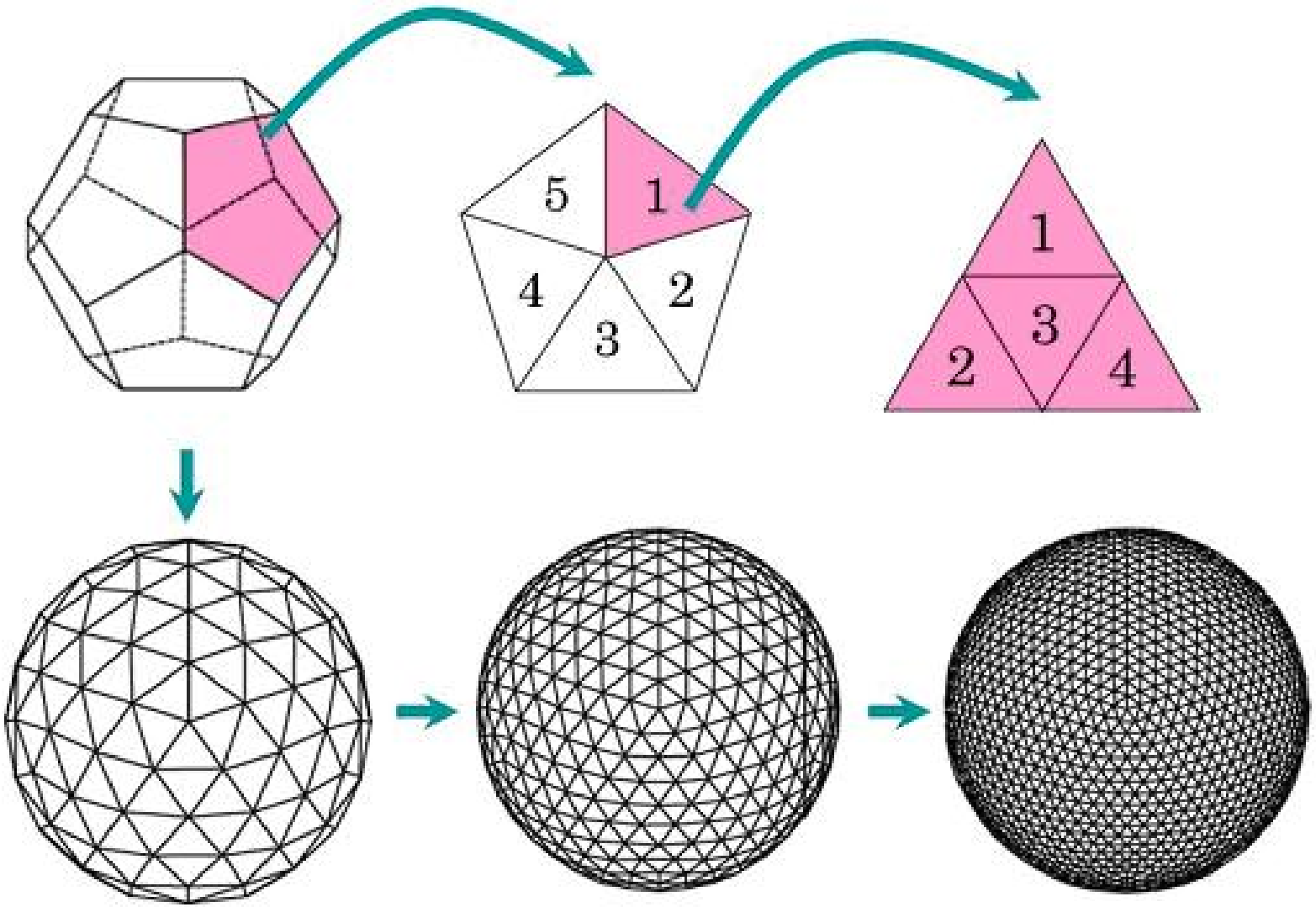
Orbit analysis of 500 GeV proton

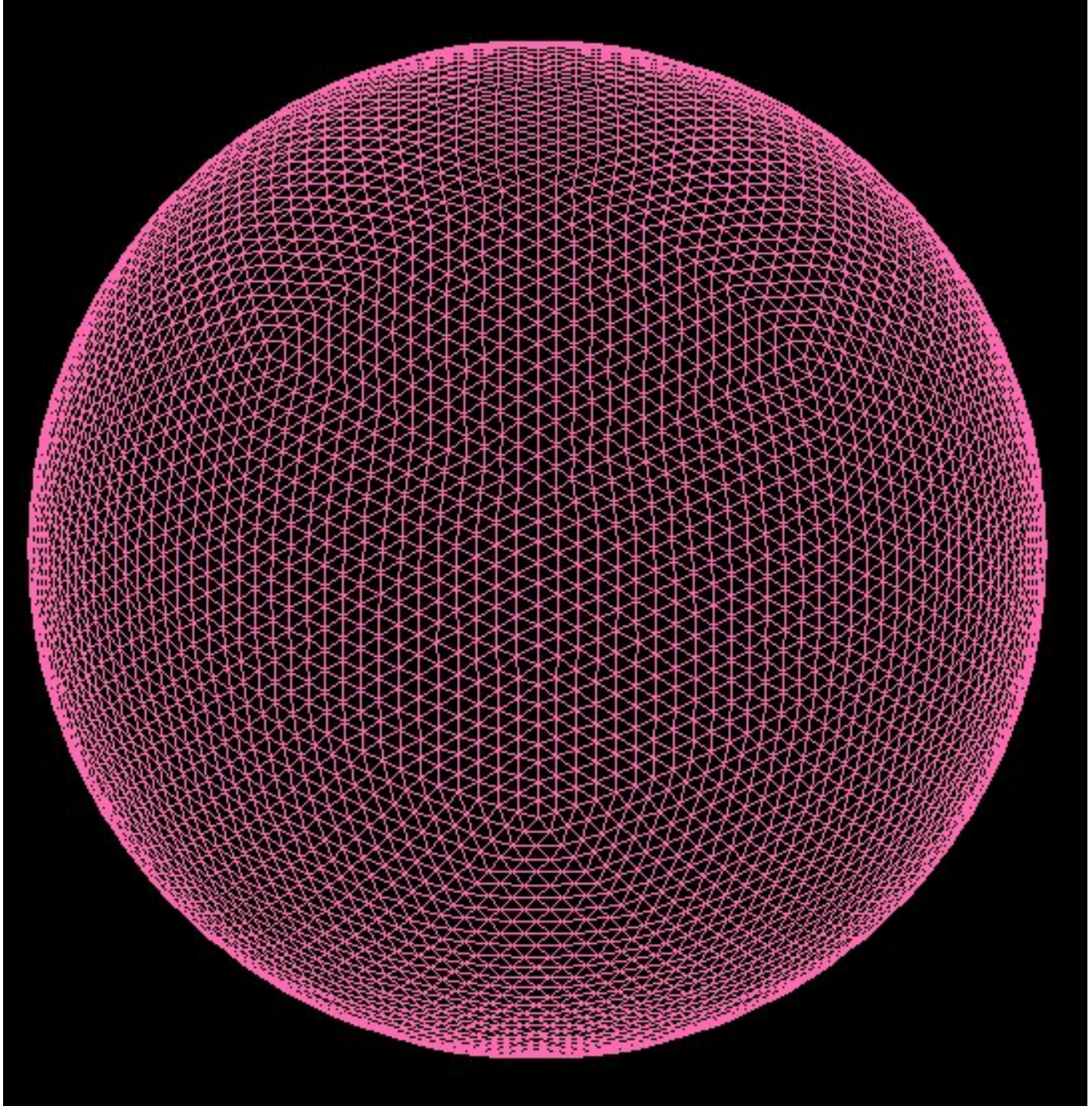
this Larmour radius corresponds
to the dust grain of velocity = 25 km/s,

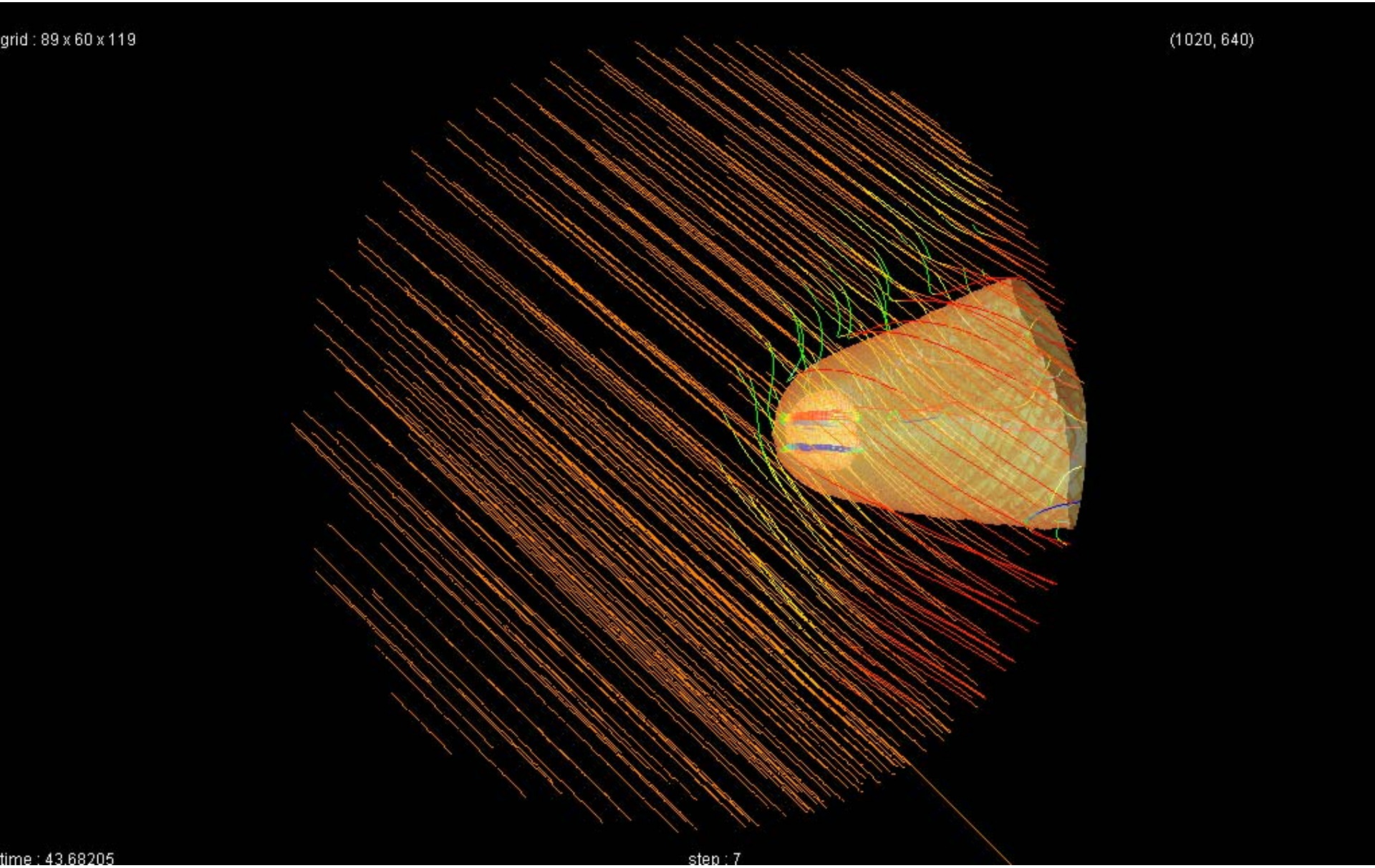
$$(M/Q)_{dust} \sim 10^7 \, (M/Q)_{proton}$$

dust-grain transit time for 1AU moving ~ 70 days

B (μG)	0.33	1.0	3.0
Larmour Radius (AU)	334	111	37
Period (year)	400	133	44.7


5
1
4
2
3
1
2
3
4

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(1020, 640)
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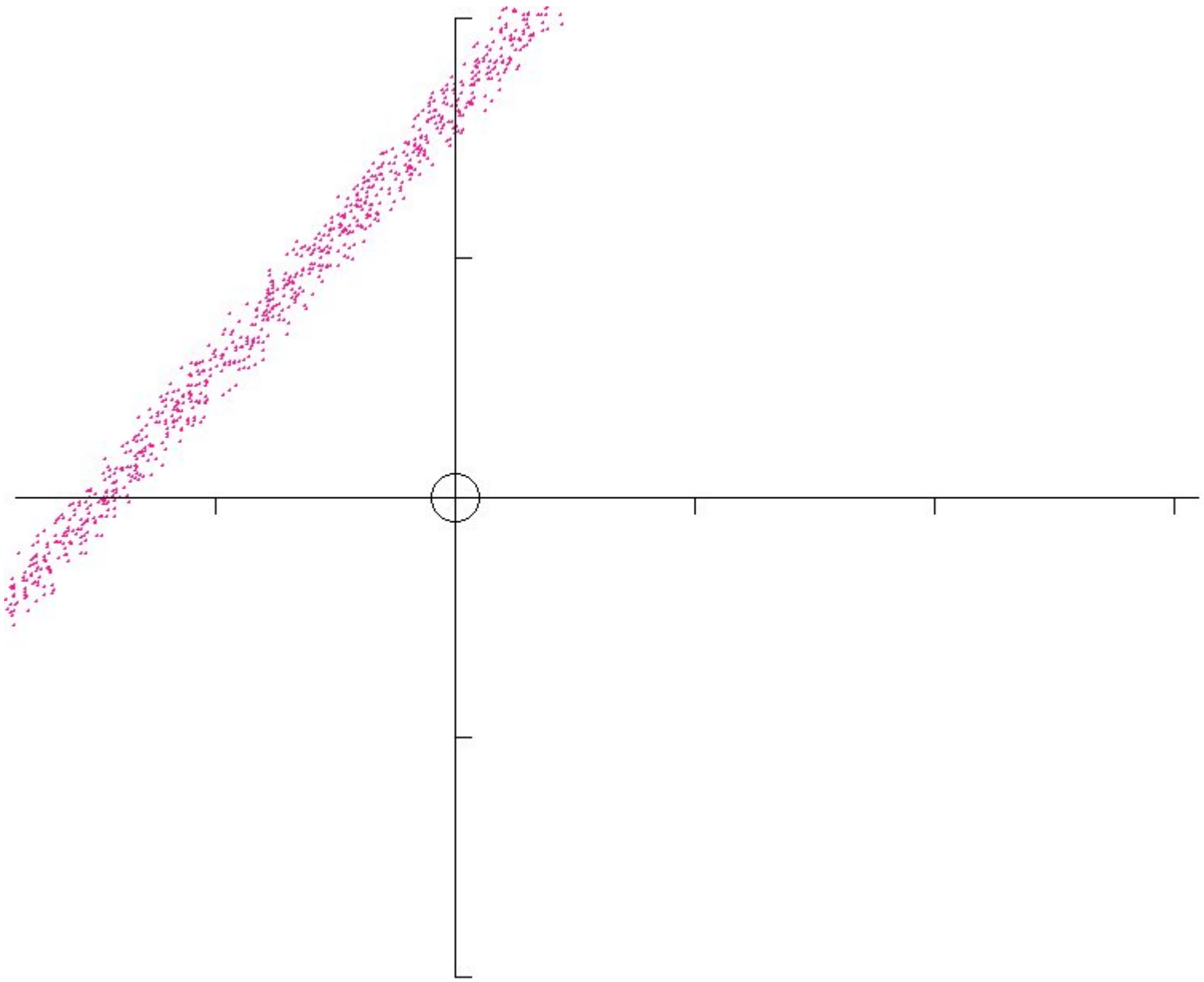
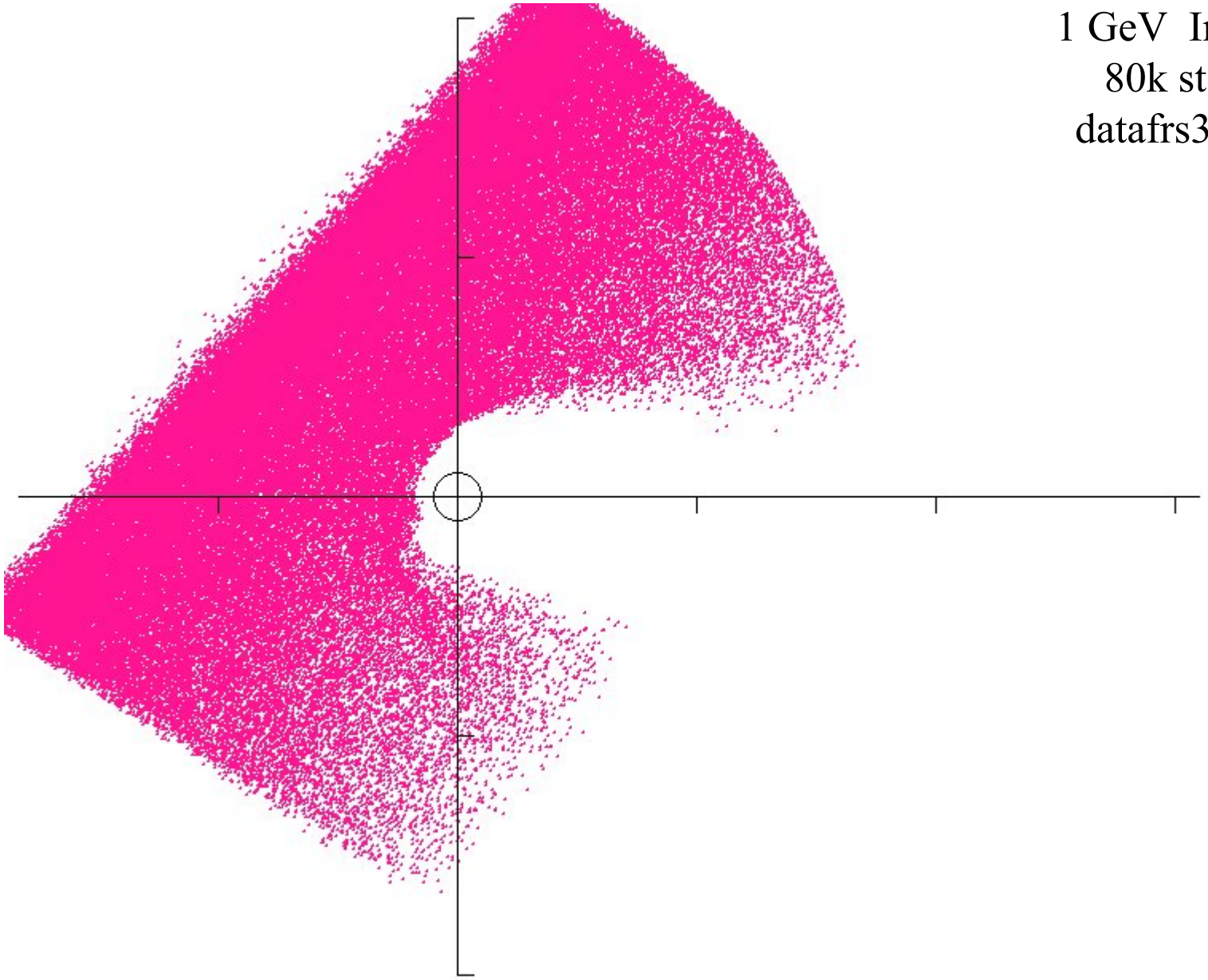
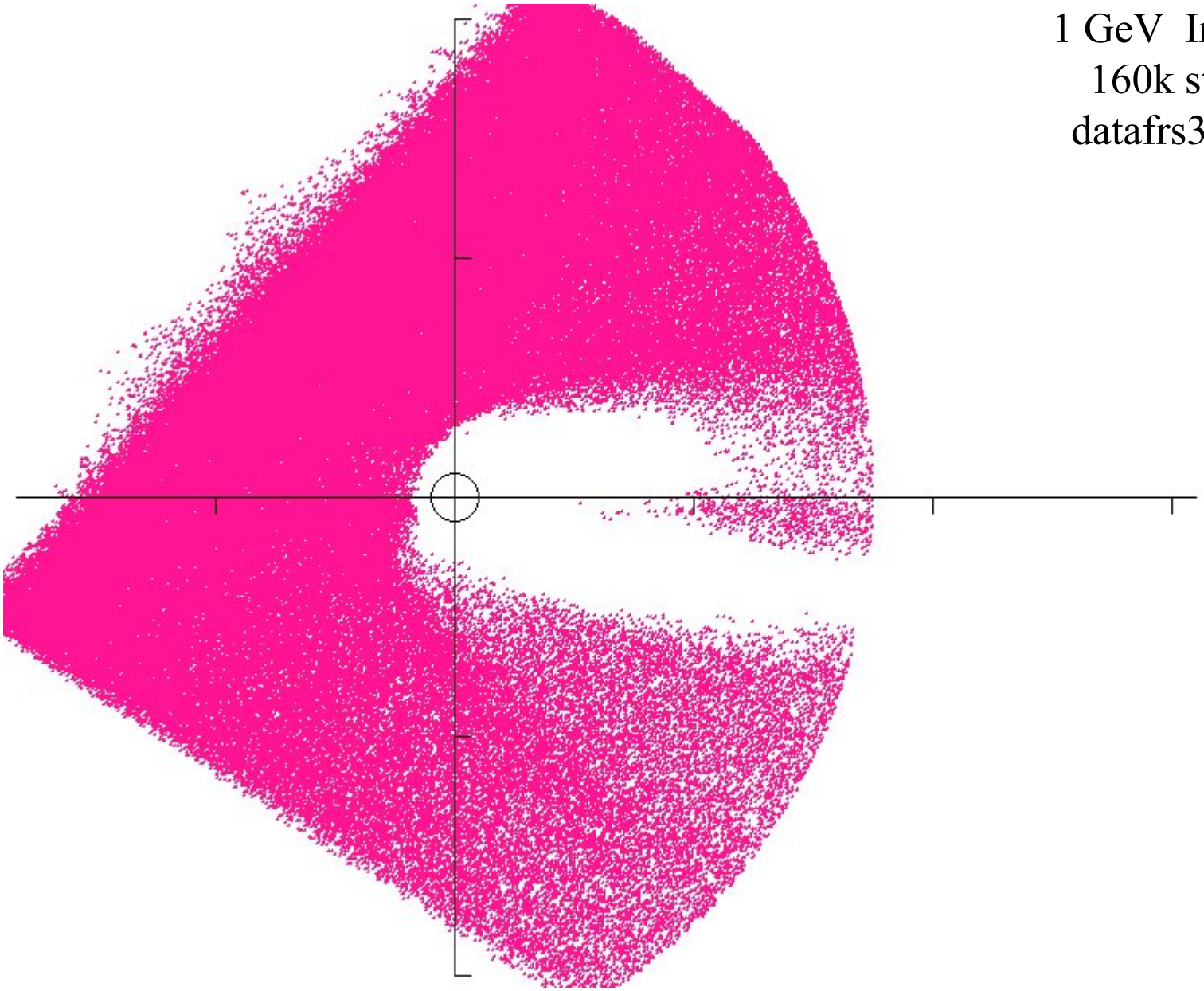
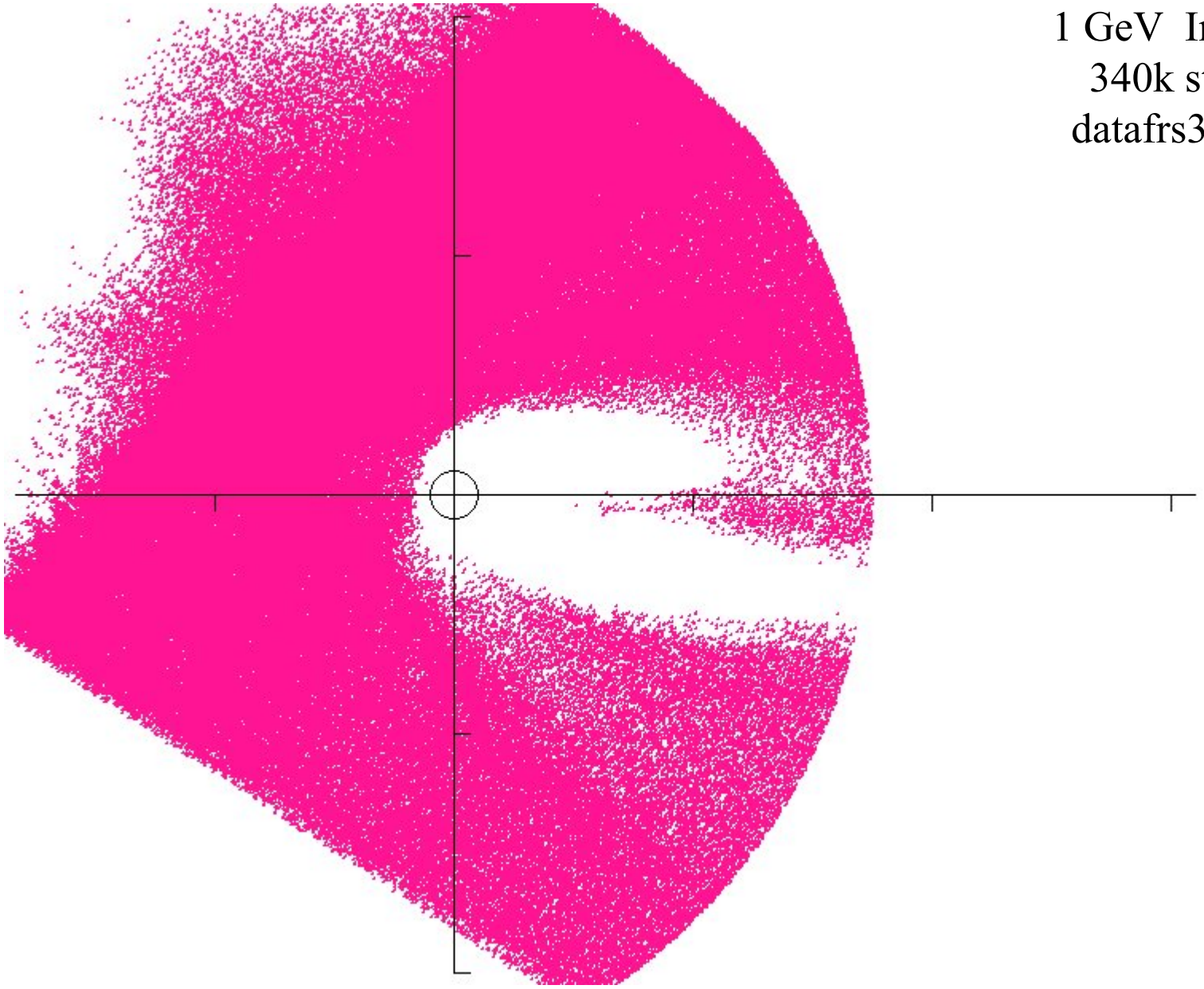
step : 7



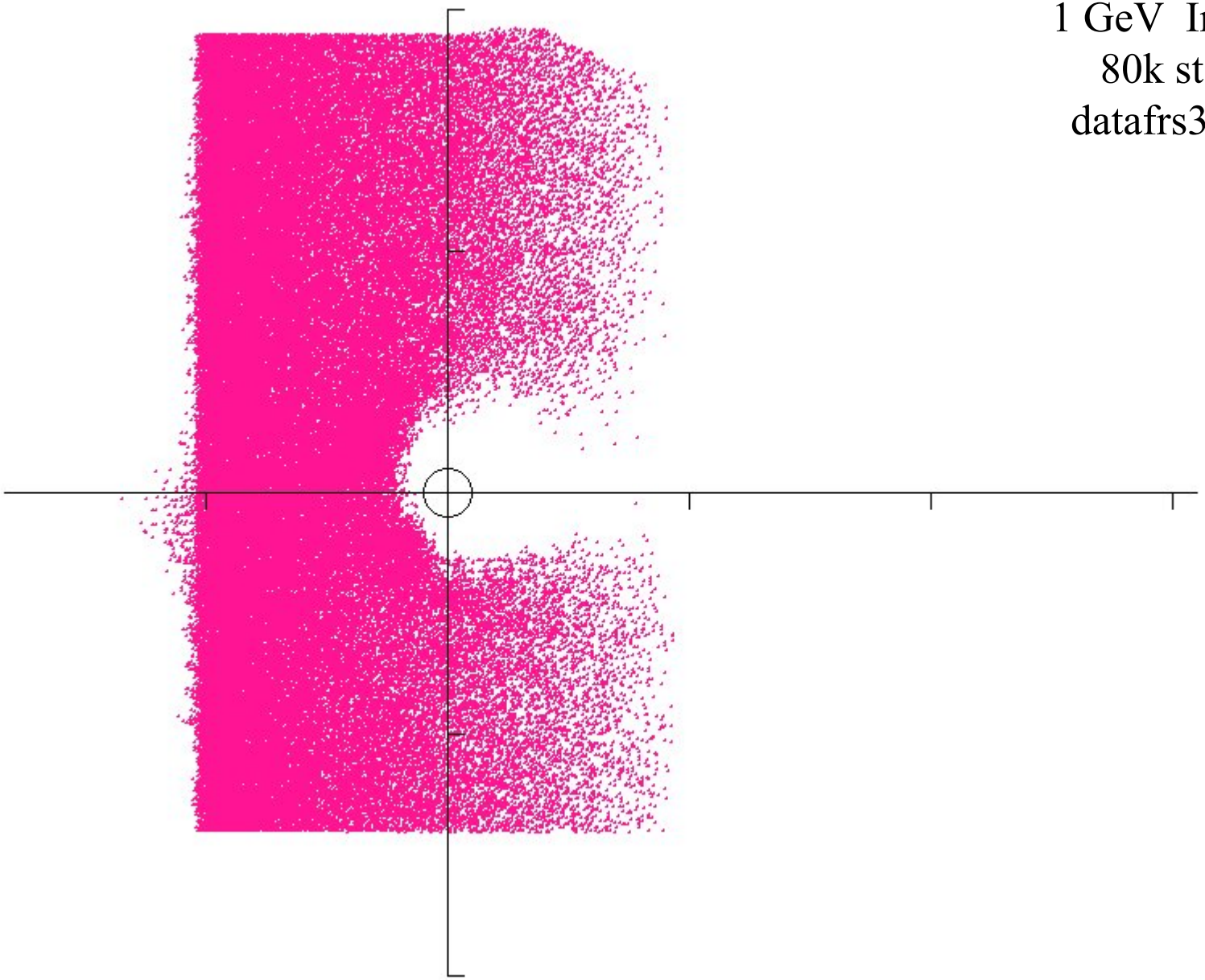

X-Z Plane
1 GeV Inv_B
80k step
datafrs3080


X-Z Plane
1 GeV Inv_B
160k step
datafrs3160

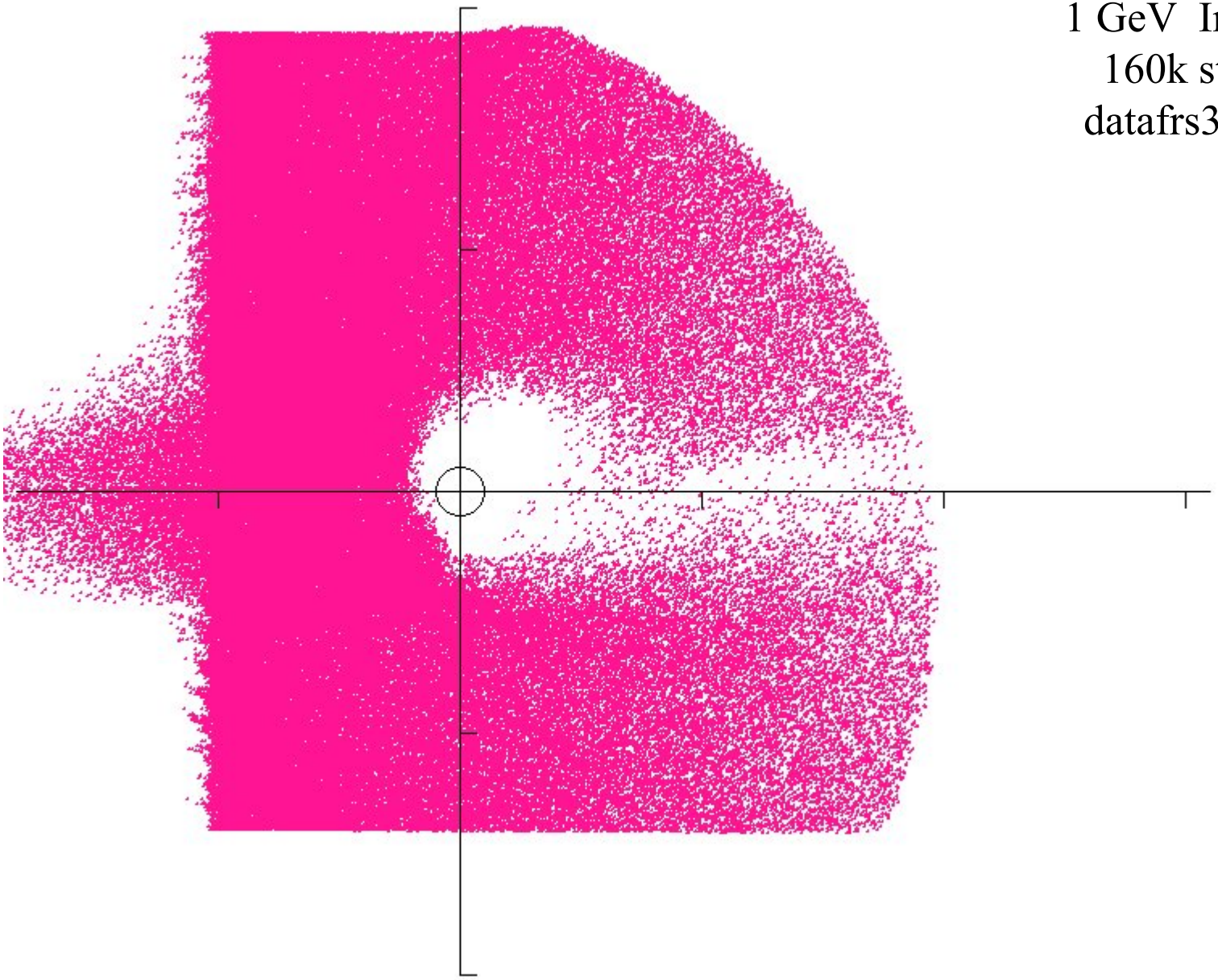
X-Z Plane
1 GeV Inv_B
340k step
datafrs3340

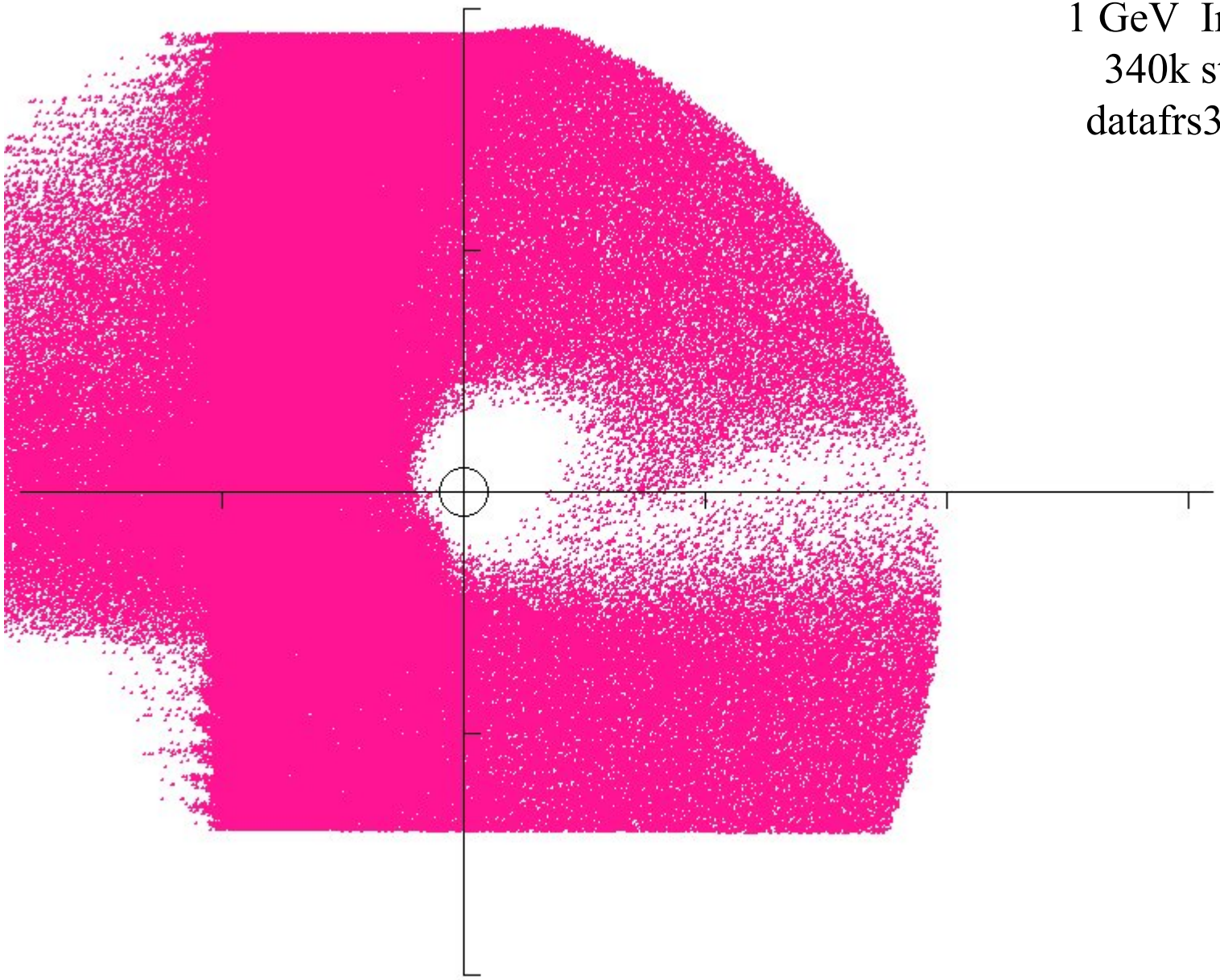


X-Z Plane
1 GeV Inv_B
80k step
datafrs3080

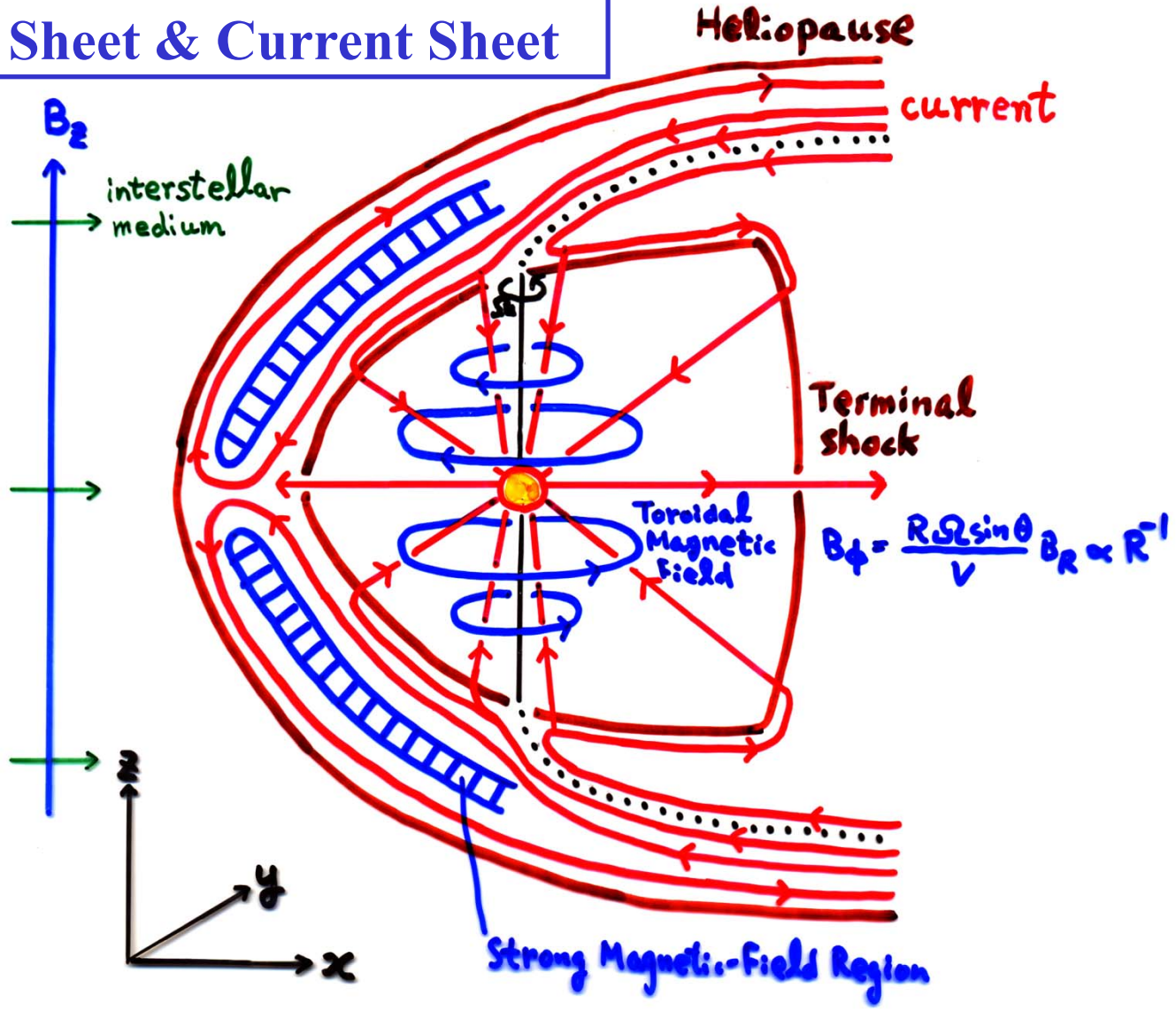


X-Z Plane
1 GeV Inv_B
160k step
datafrs3160

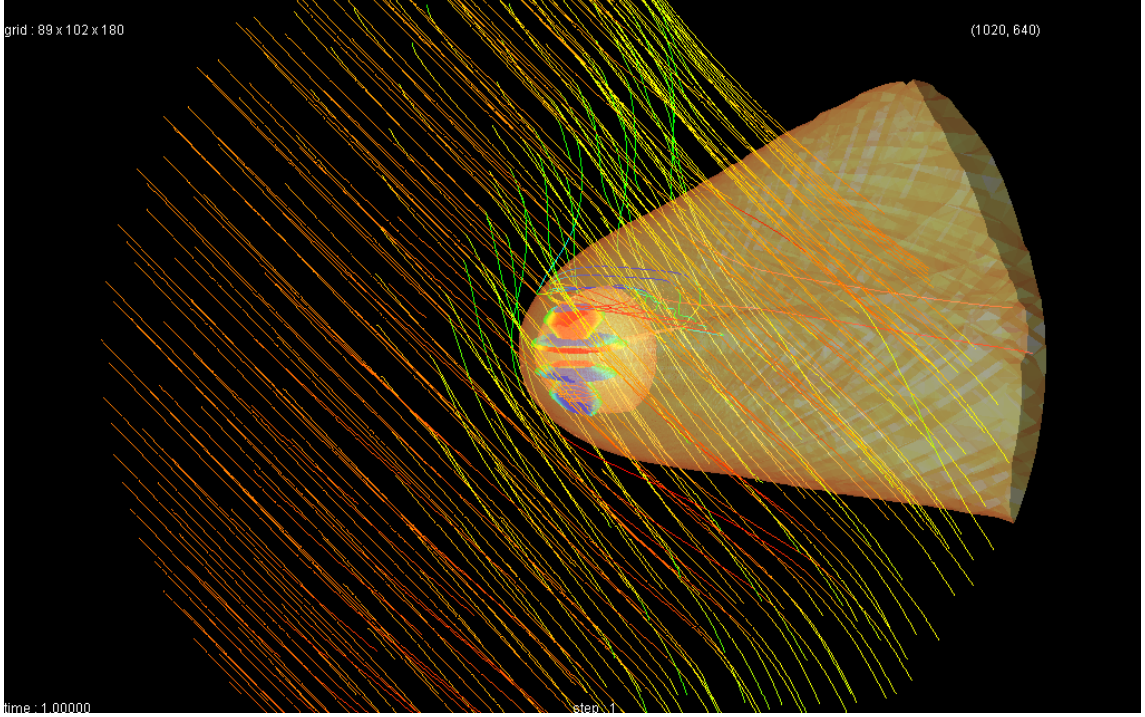



X-Z Plane
1 GeV Inv_B
340k step
datafrs3340

Fine Structure in the heliosheath:
Magnetic Wall
Plasma Sheet & Current Sheet



Washimi & Tanaka 1996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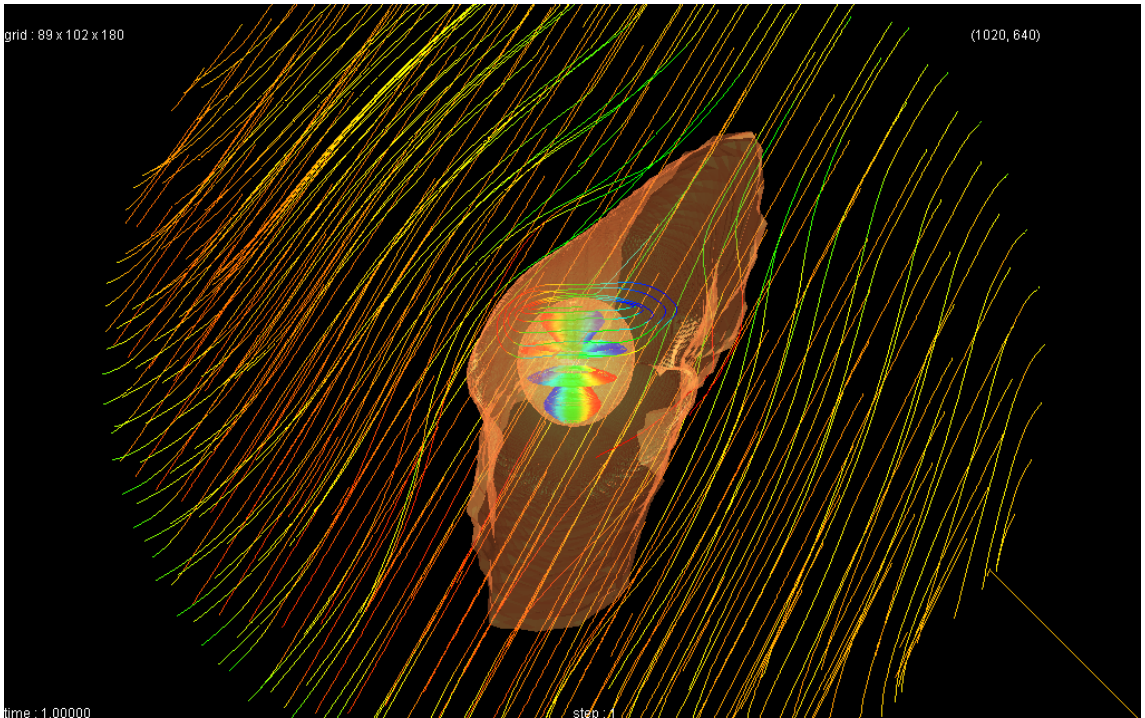
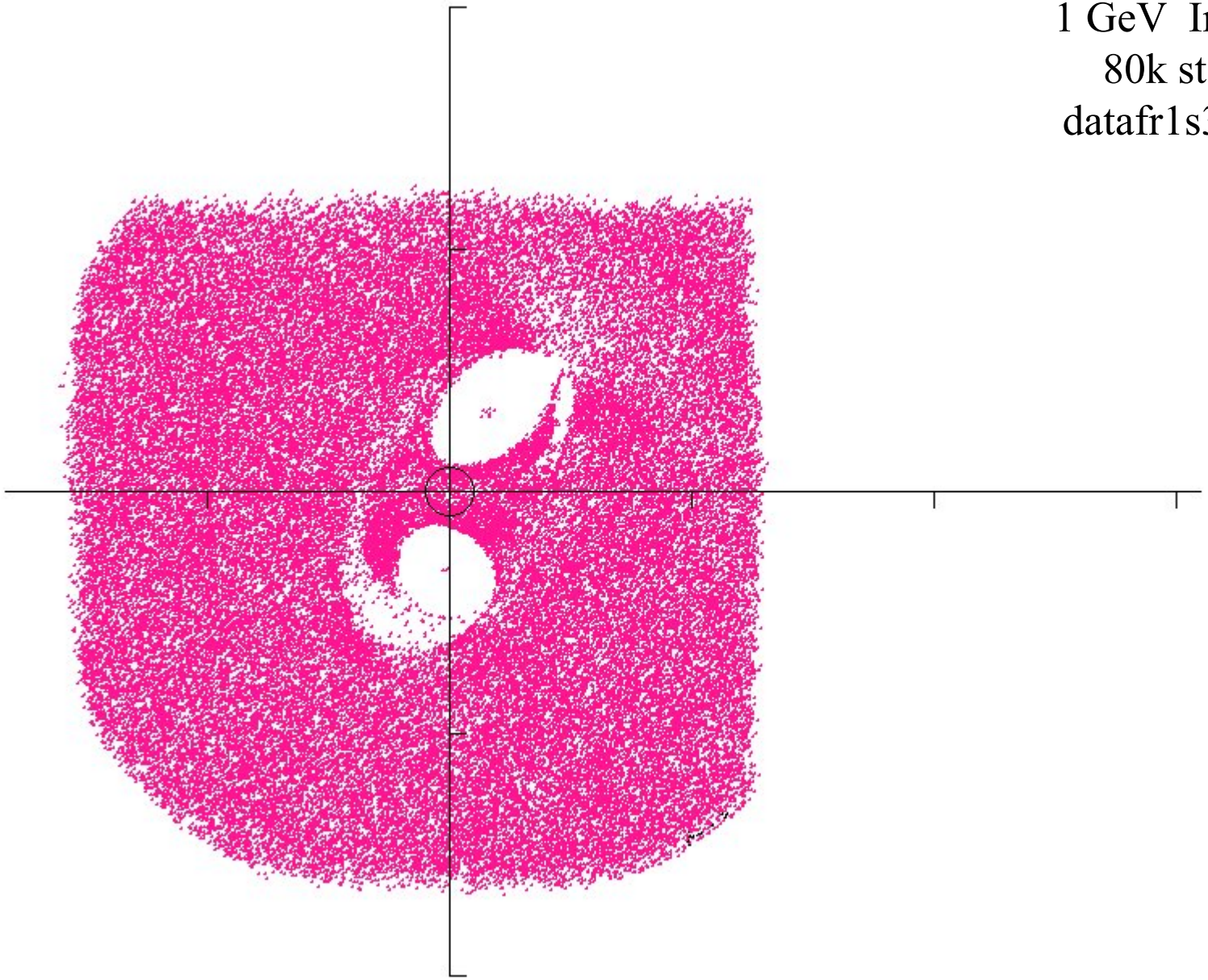
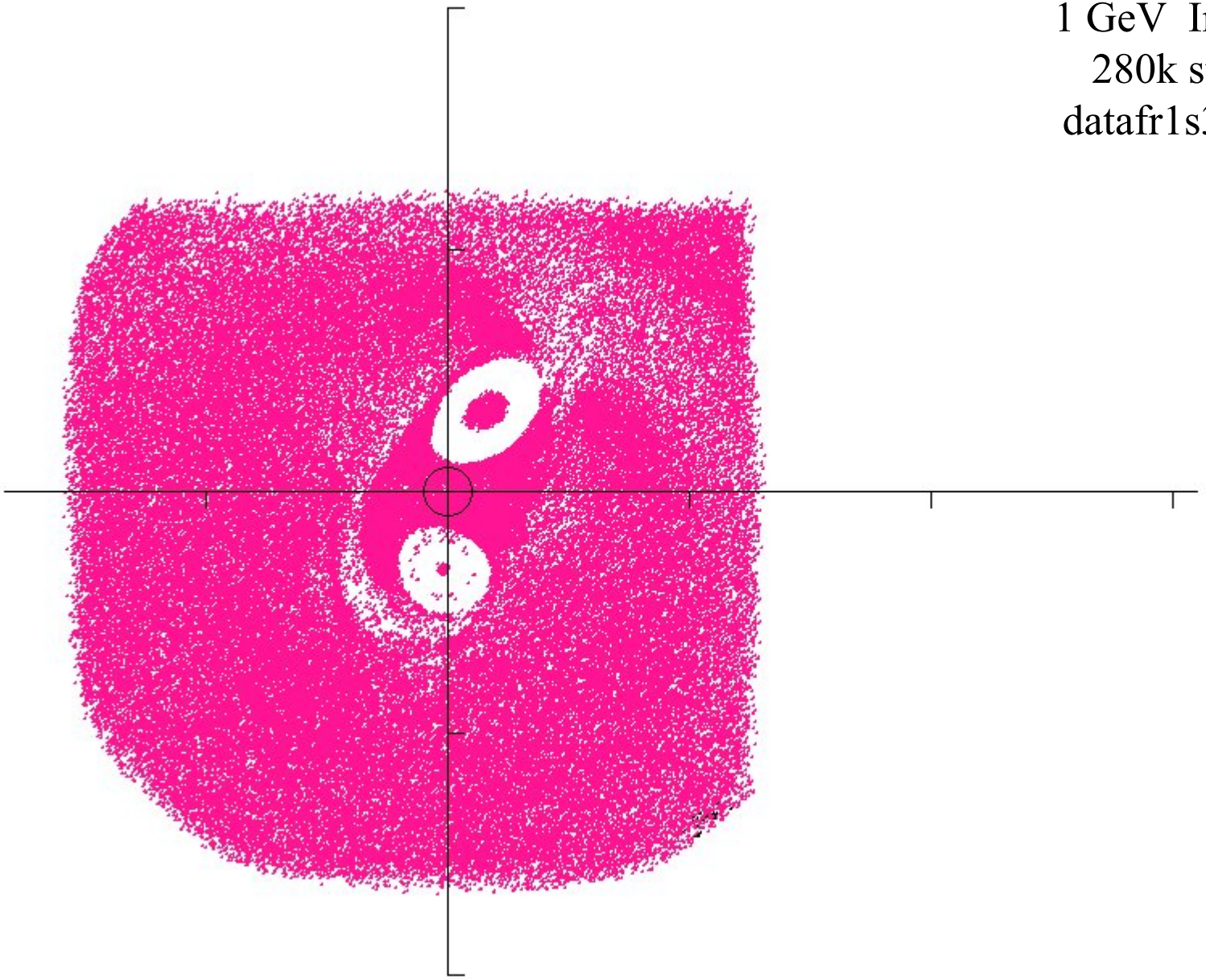
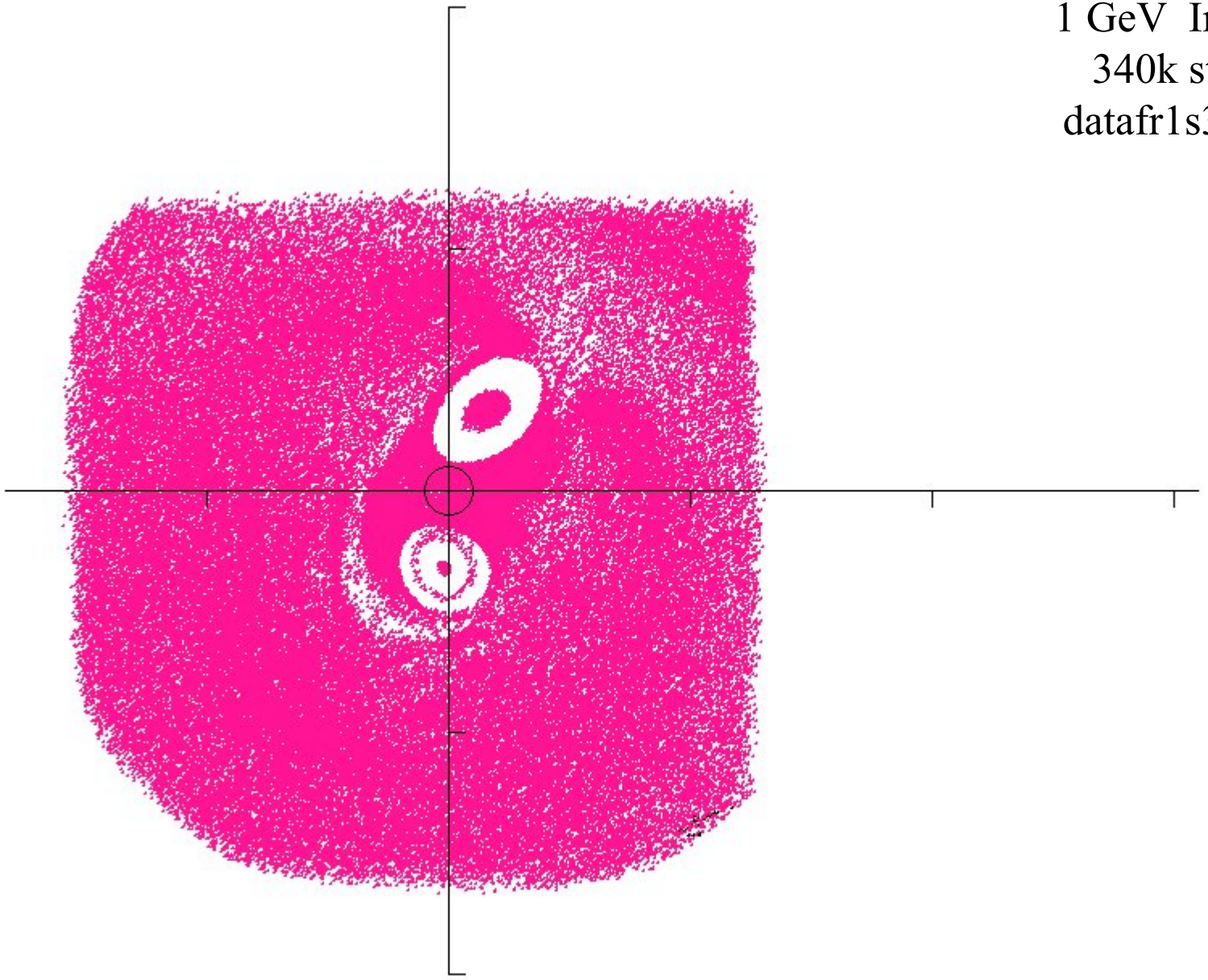
(1020, 640)
time : 1.00000
step : 1


grid : 89 x 102 x 180
(1020, 640)
time : 1.00000
step : 1


Y-Z Plane X=500 AU
1 GeV Inv_B
80k step
datafr1s3080

Y-Z Plane X=500 AU
1 GeV Inv_B
280k step
datafr1s3280




Y-Z Plane X=500 AU
1 GeV Inv_B
340k step
datafr1s3340

内容

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   ー　MHDシミュレーション

2. 銀河宇宙線、荷電ダスト粒子の太陽圏内部への輸送
   ー　（MHD＋テスト粒子）シミュレーションの準備

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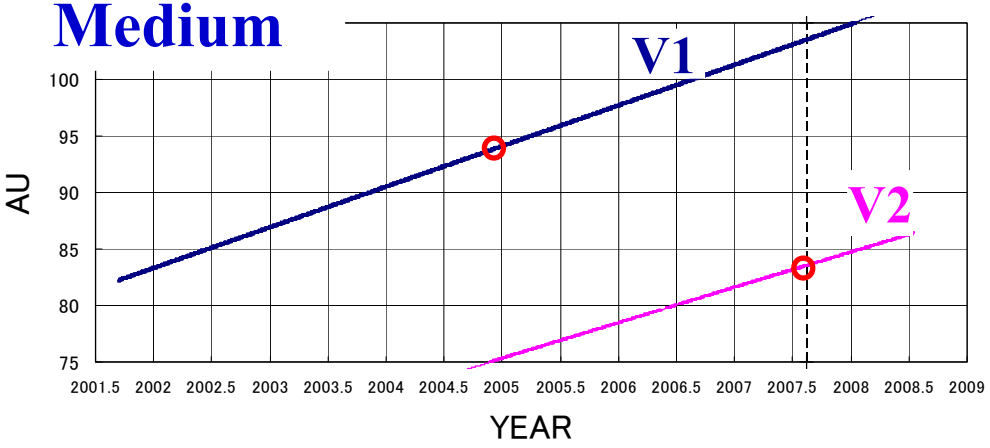
   ー　Voyager観測を基礎として

V1-TS crossing: at 94 AU

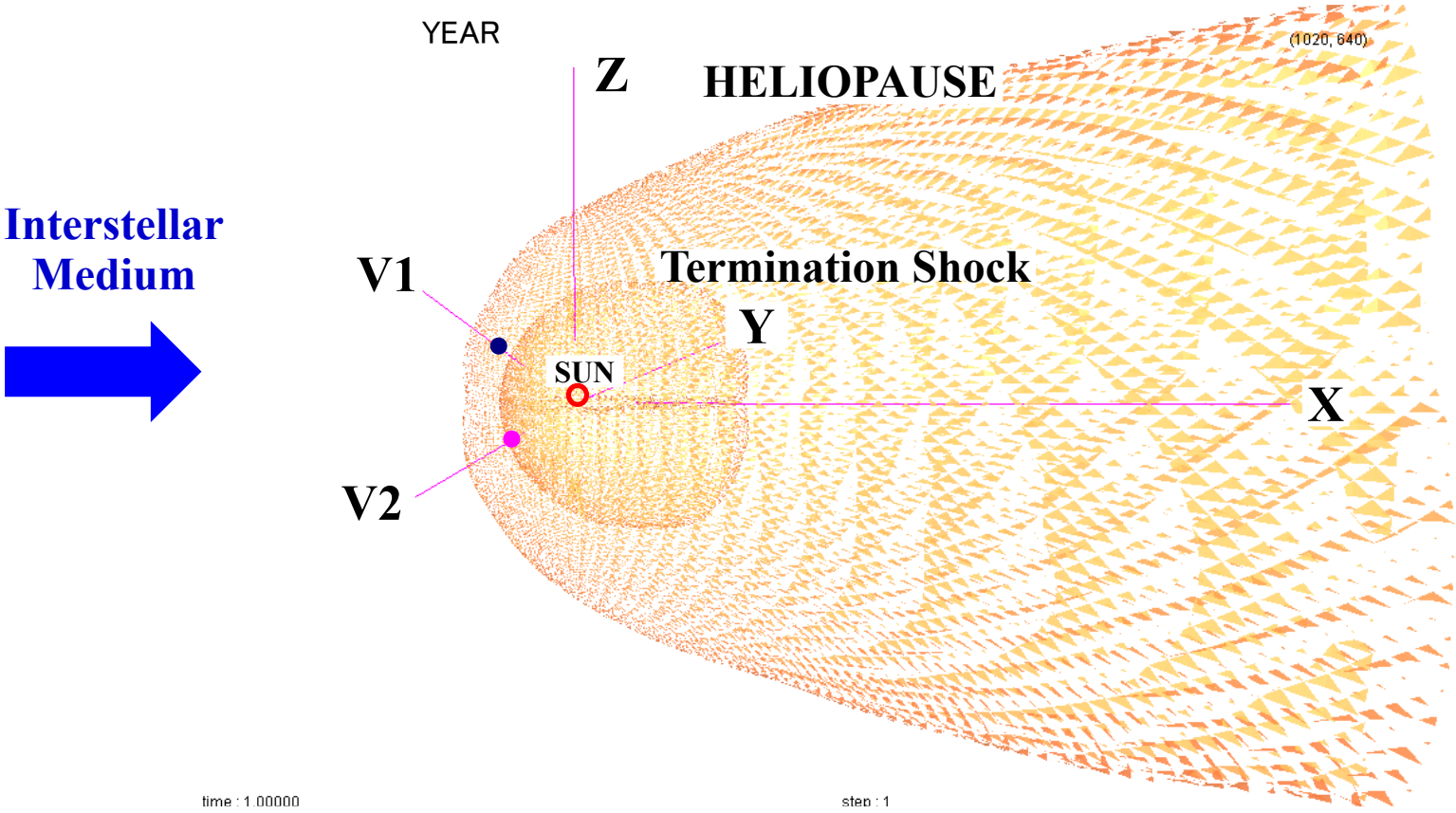
TS crossing: at 84 AU

Interstellar Medium

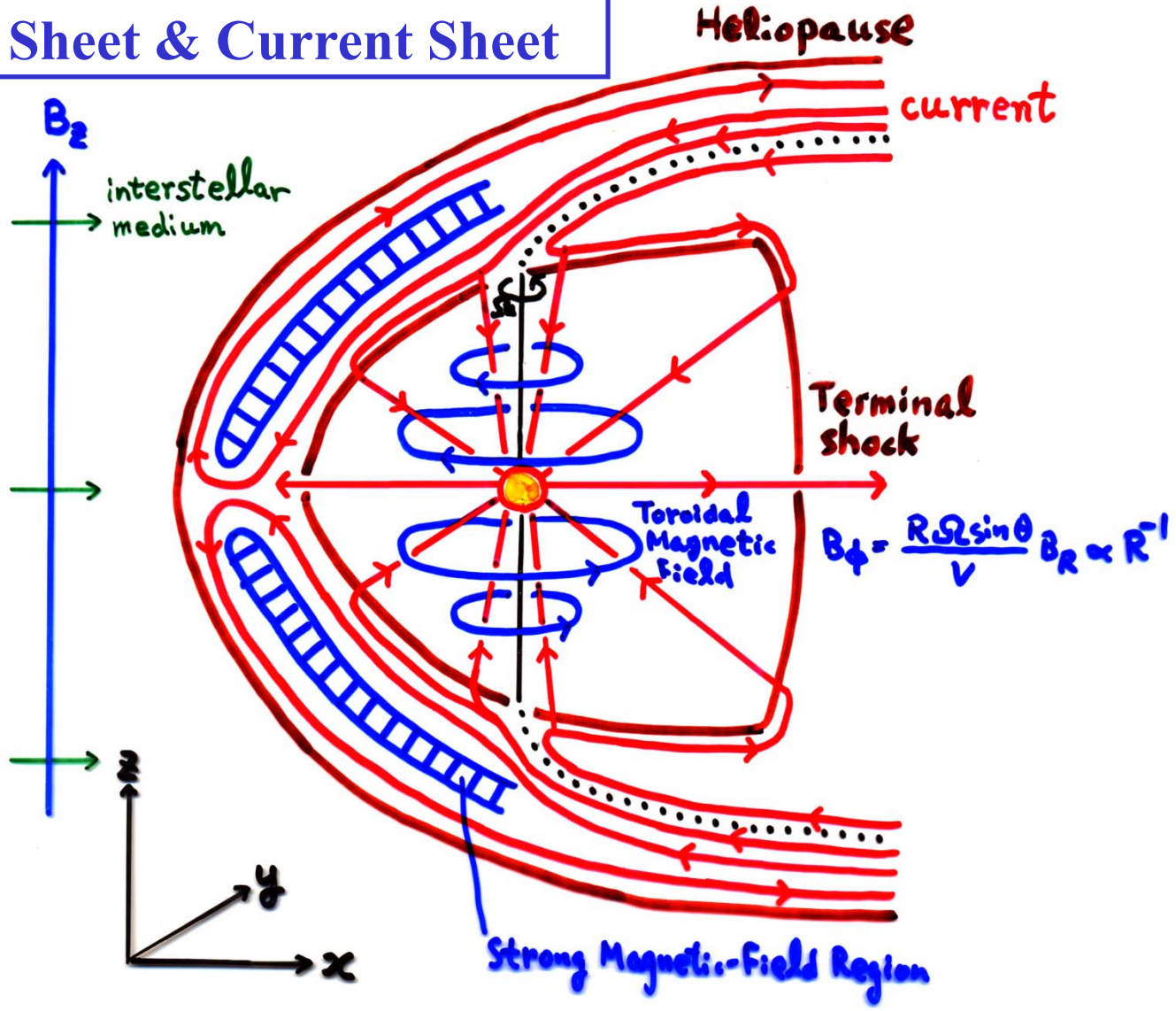


Asymmetric structure
Time-varying effect

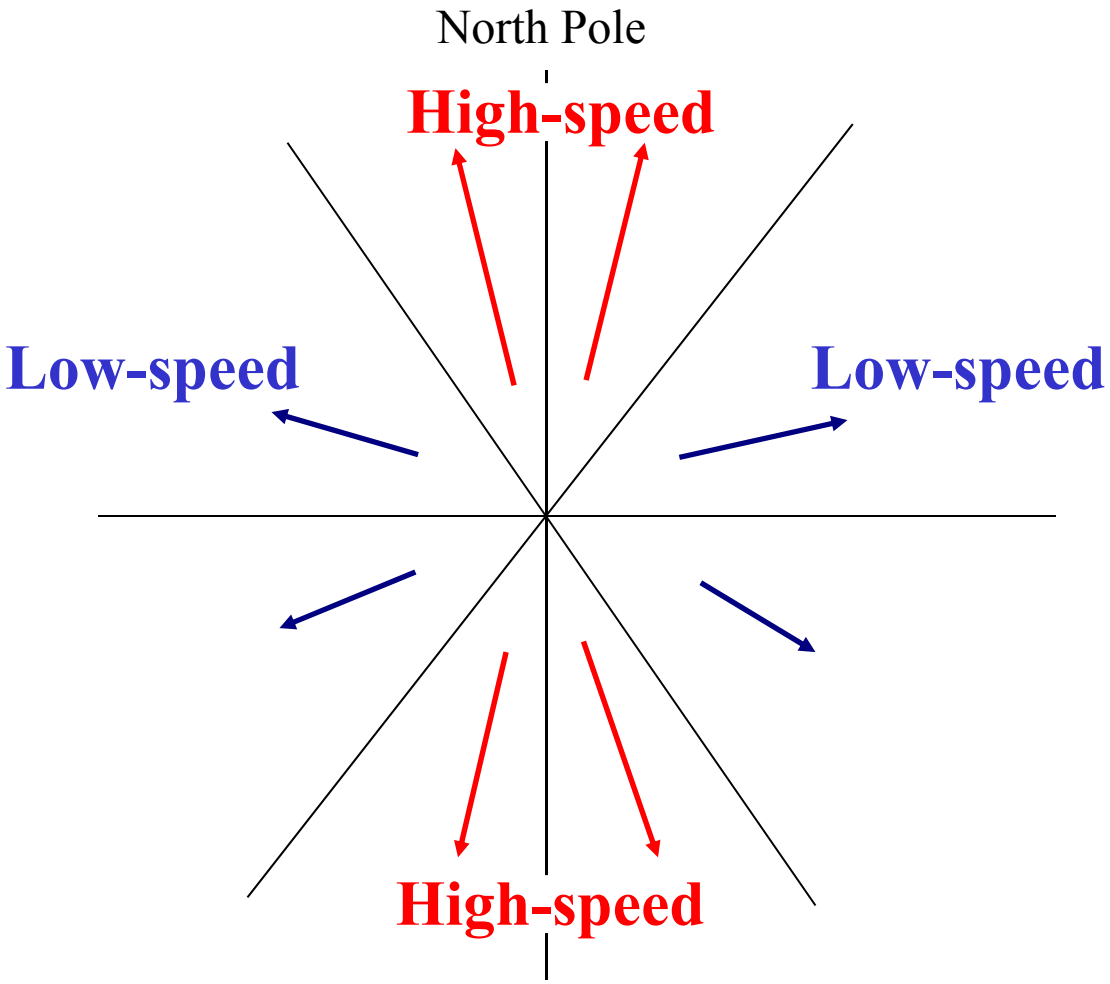
Interstellar Medium



Fine Structure in the heliosheath:
Magnetic Wall
Plasma Sheet & Current Sheet



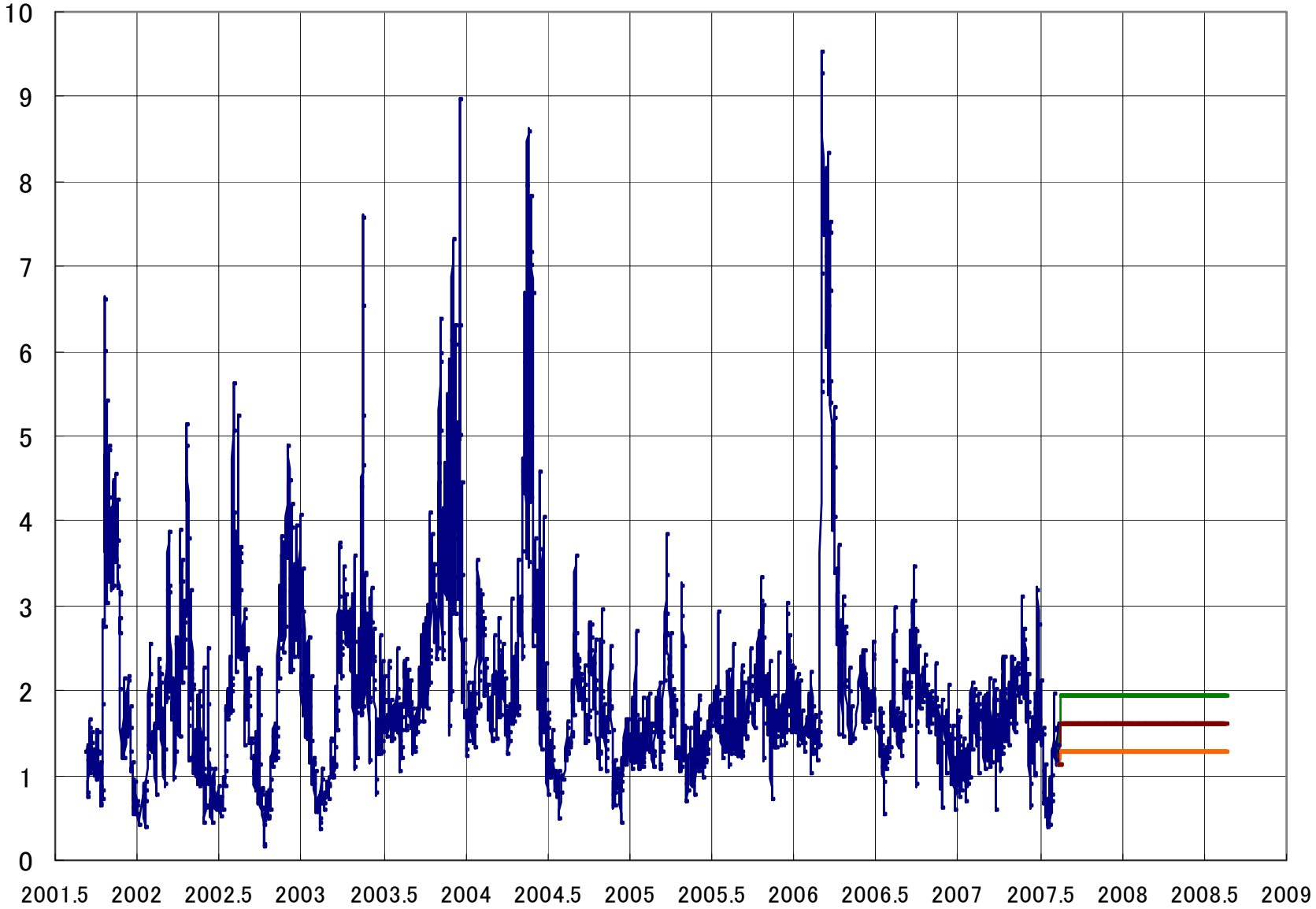
Washimi & Tanaka 1996


North Pole
High-speed
Low-speed
Low-speed
High-speed

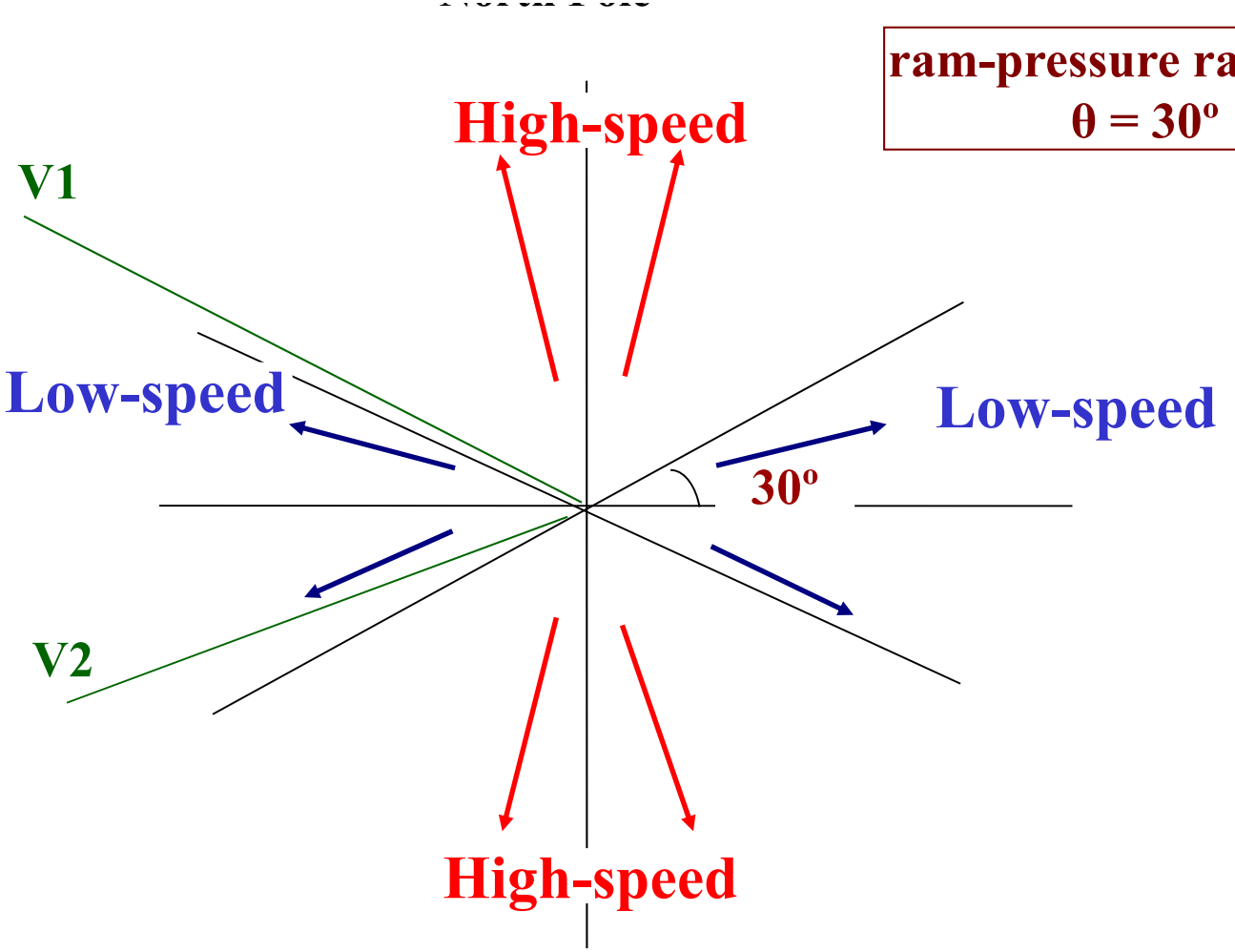
Normalized V2 Obseved Ram-Pressure

Ram-Pressures after Aug 14, 2007 are assumed to be 1.0, 1.25, or 1.5 x Pram0 for forecasting

where Pram0 is ram-pressure when the speed 400km/s and density 5/cc at 1 AU

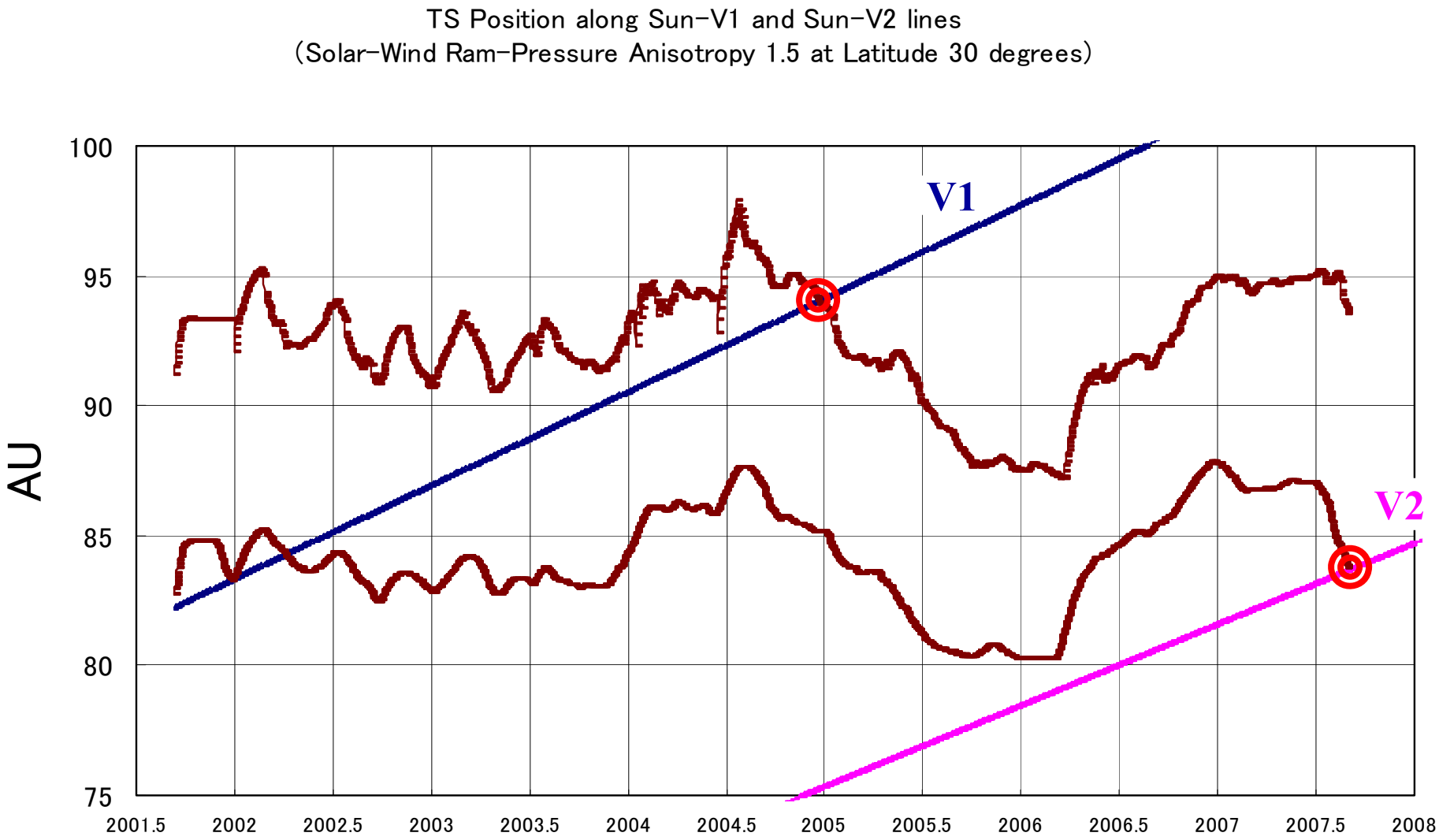


High-speed Polar Wind:
An example which satisfies the V1-TS and V2-TS crossings simultaneously

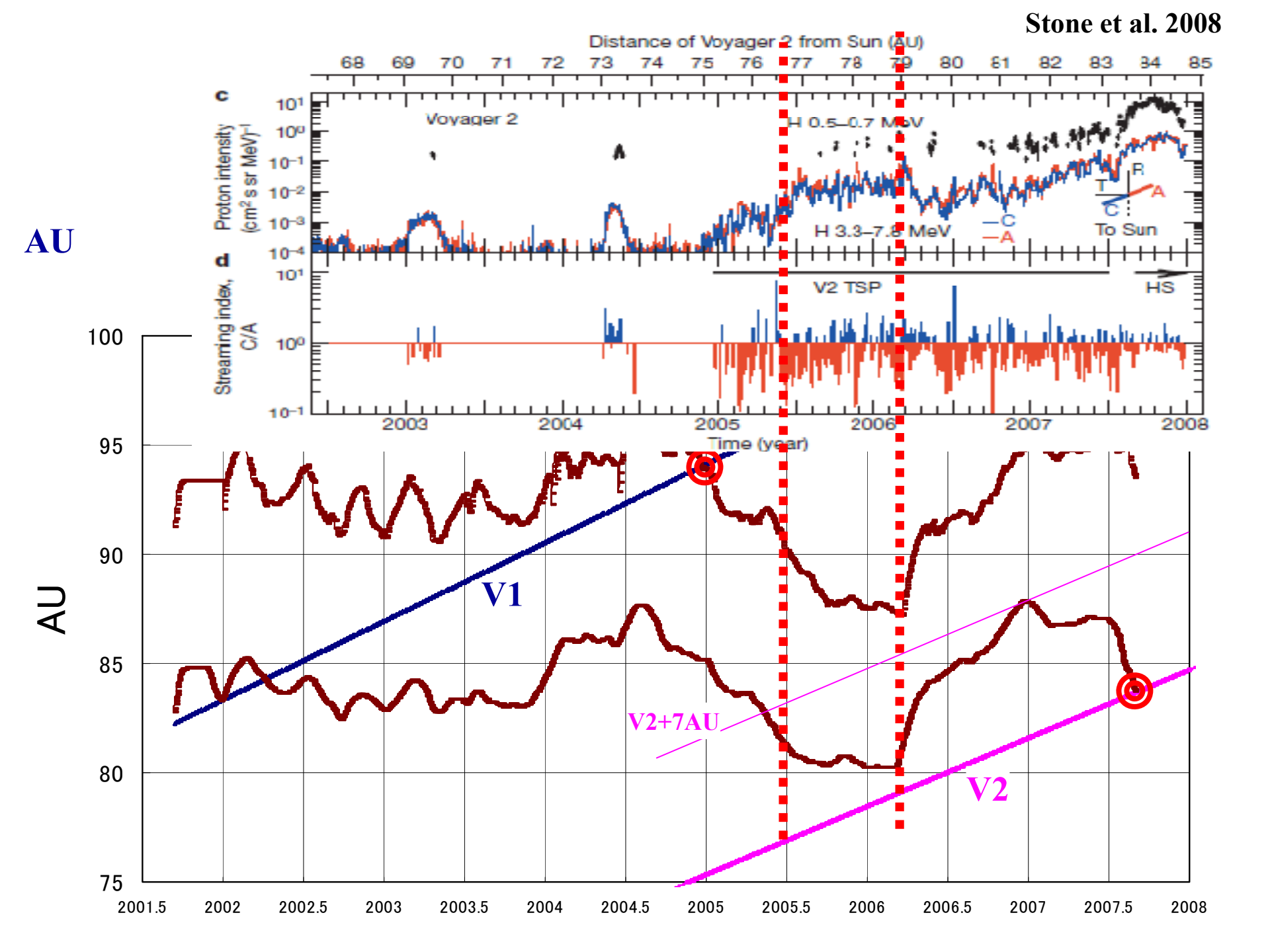


2. MHD Solution

When N_0=5.10/cc at 1AU, and θ_0=30° , both V1 and V2 crossing observed positions are found to be reproduced simultaneously.

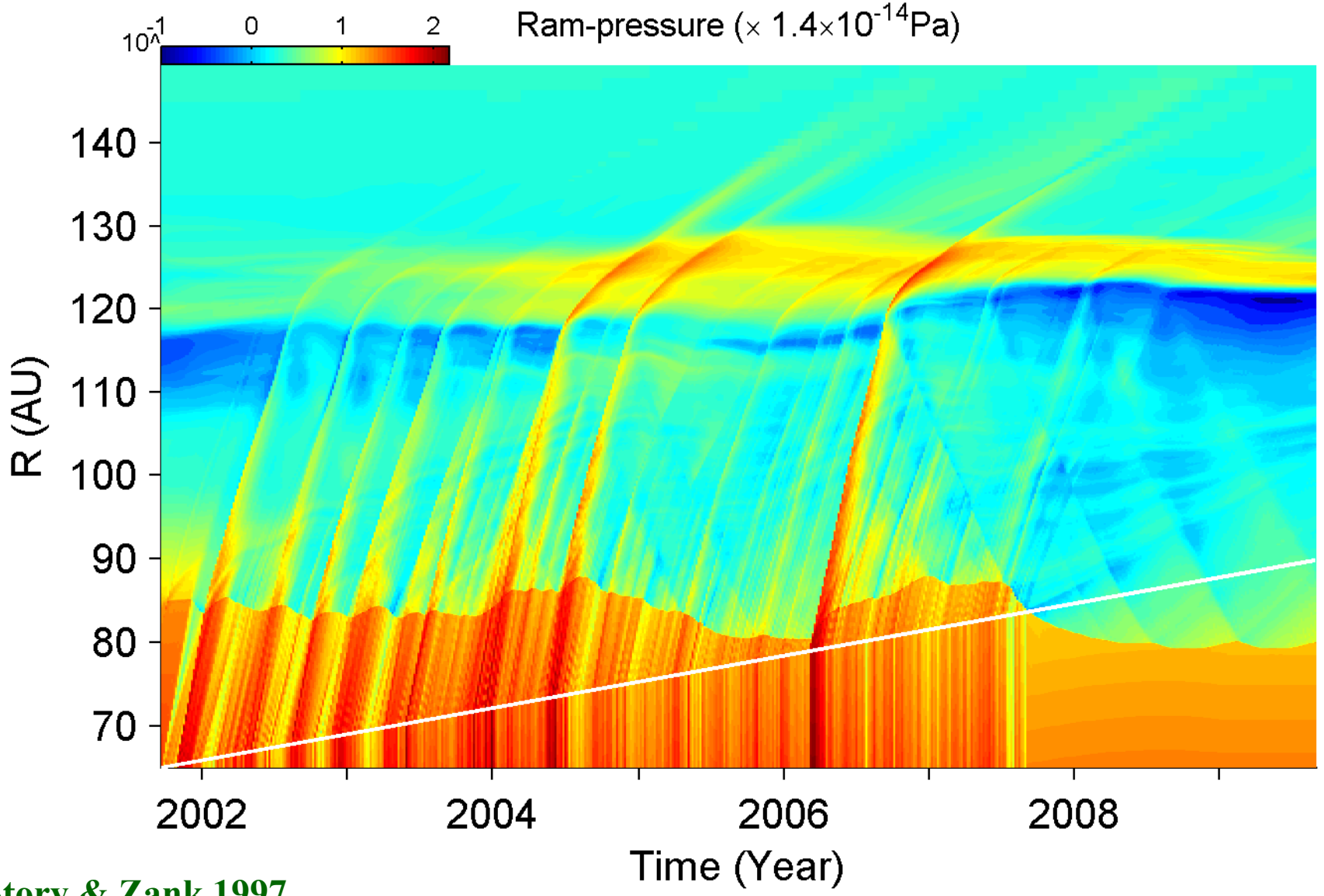


Stone et al. 2008



Magneto-sonic pulse is reflected at the lower boundary of plasma sheet.

When the returned pulse travels back and collides with TS, TS substatially decreses.



Story & Zank 1997

Fast shock (magneto-sonic pulse) is driven downstream of TS

Fig. 5a

Plasma sheet is identified as red-color zone around 120-130 AU.

Below the plasma sheet yellow color zone is identified as magnetic wall.

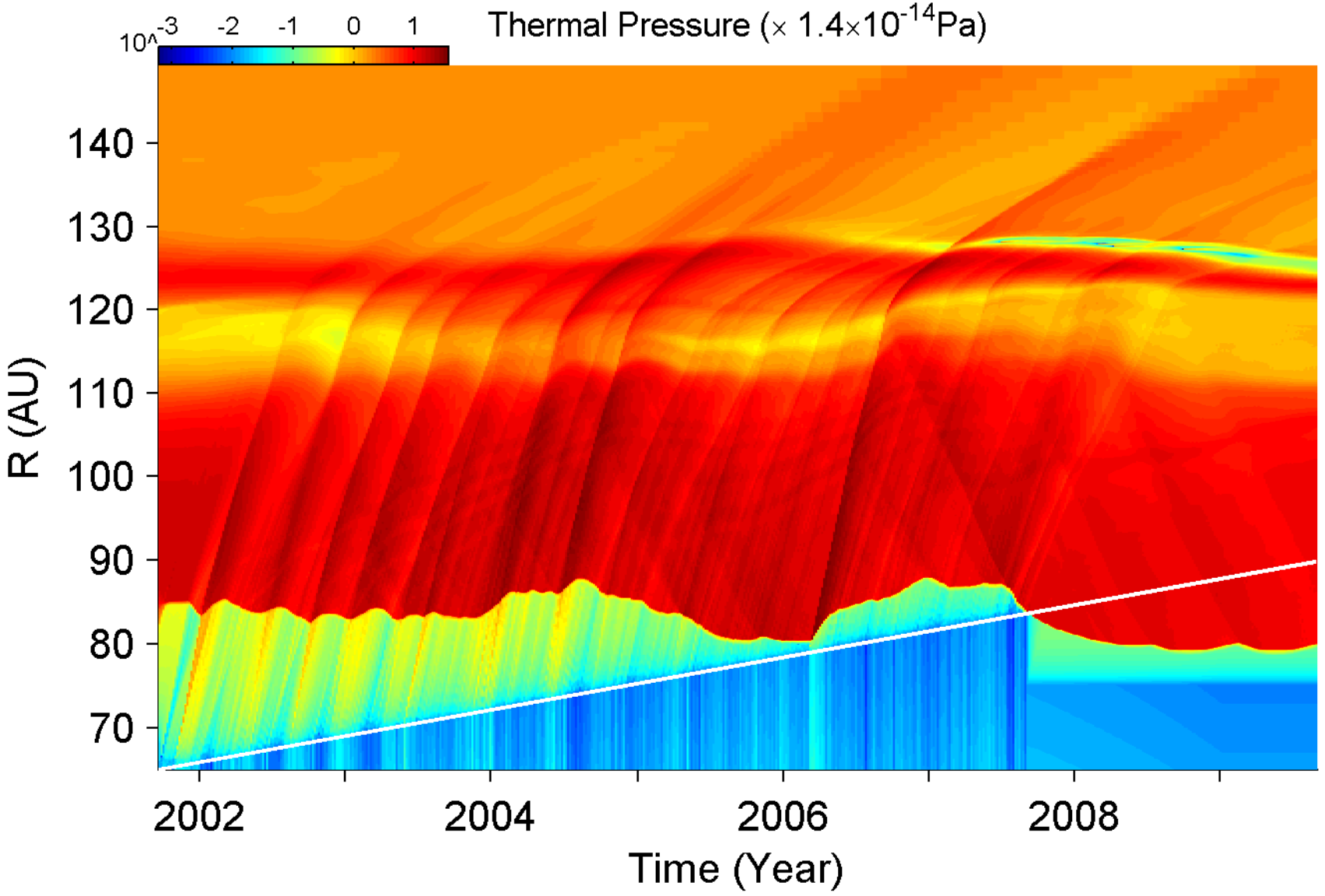


Fig. 5b

Plasma sheet (yellow zone qround 120-130 AU) is identified as yellow zone where heliosheath temperature sharply decreases with the distance from Sun.

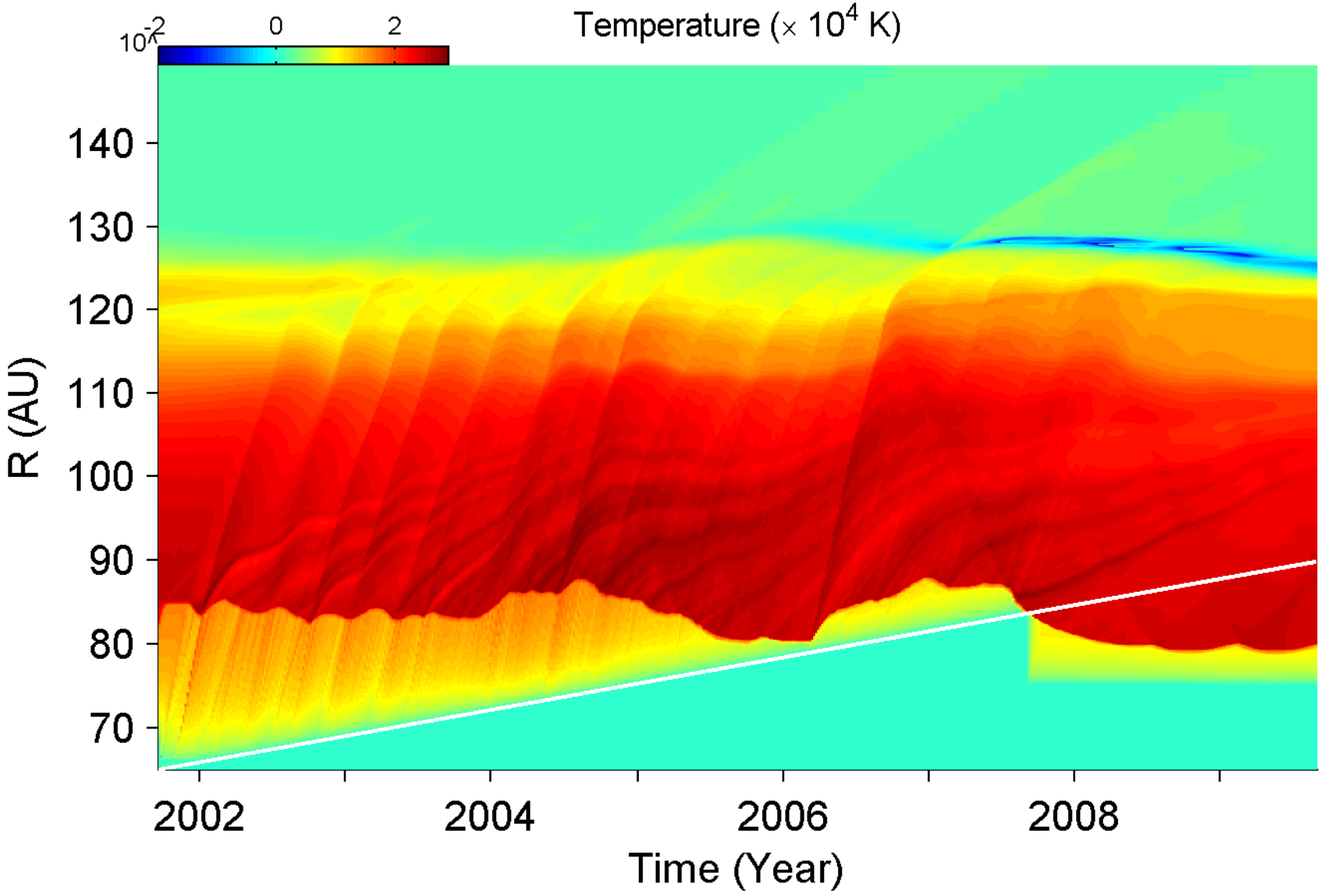


Fig. 5c

Lower boundary of the plasma sheet is identified as yellow line around 120 AU from where plasma density sharply increase.

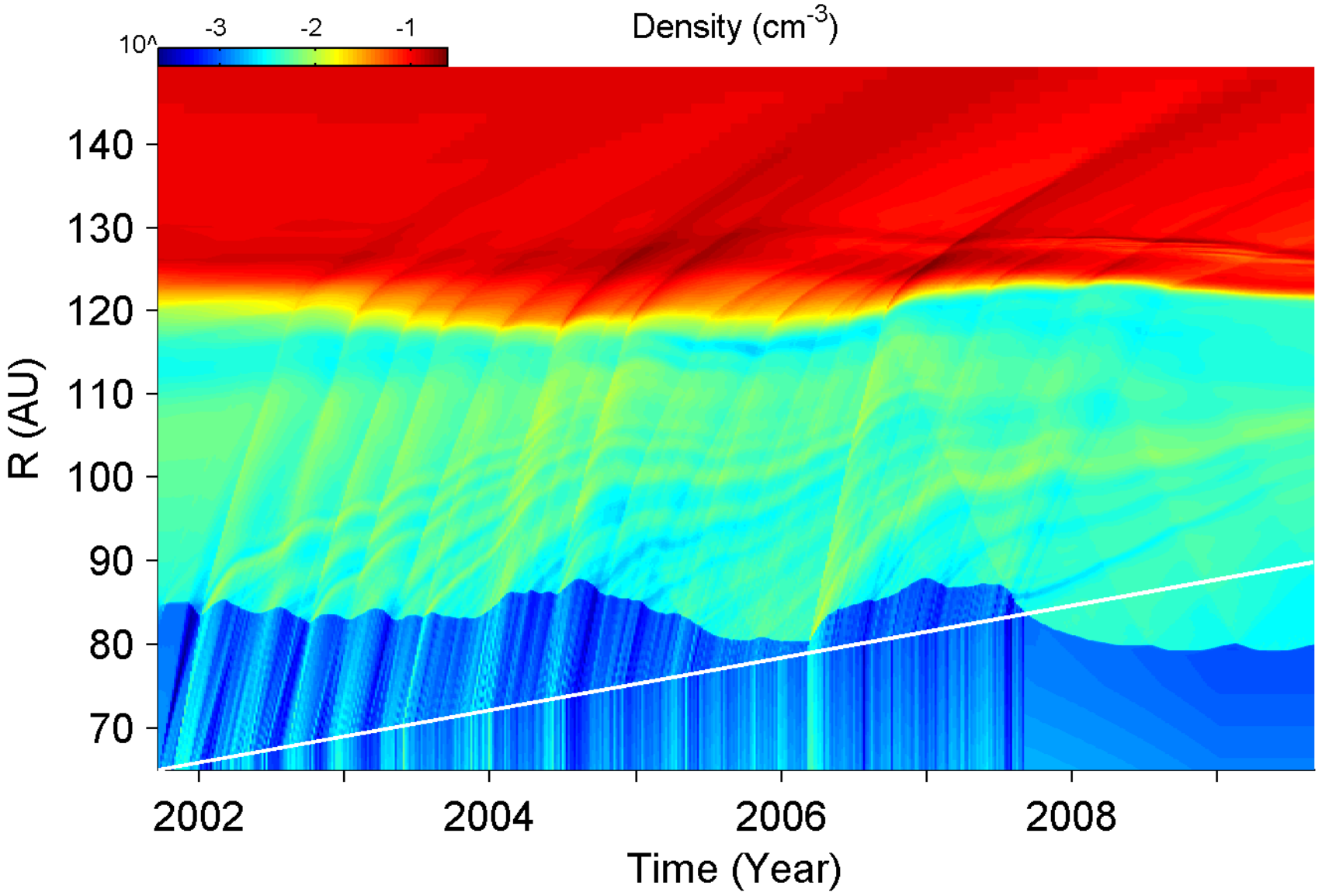


Fig. 5d

Magnetic wall region is identified as dark color where magnetic intensity is maximum in the heliosheath. Yellow line aroud 122 AU is current sheet embedded in plasma sheet.

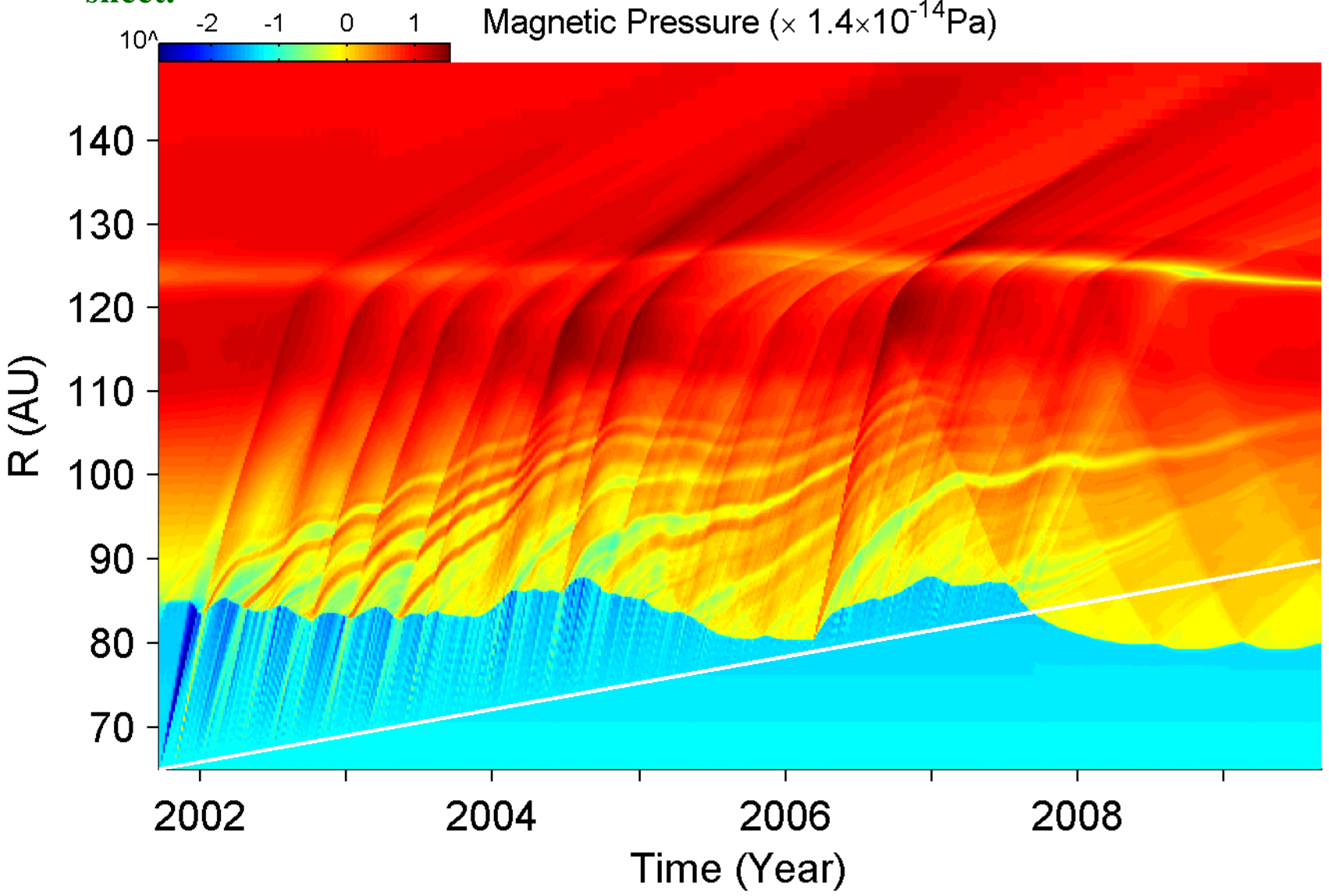


Fig. 5e