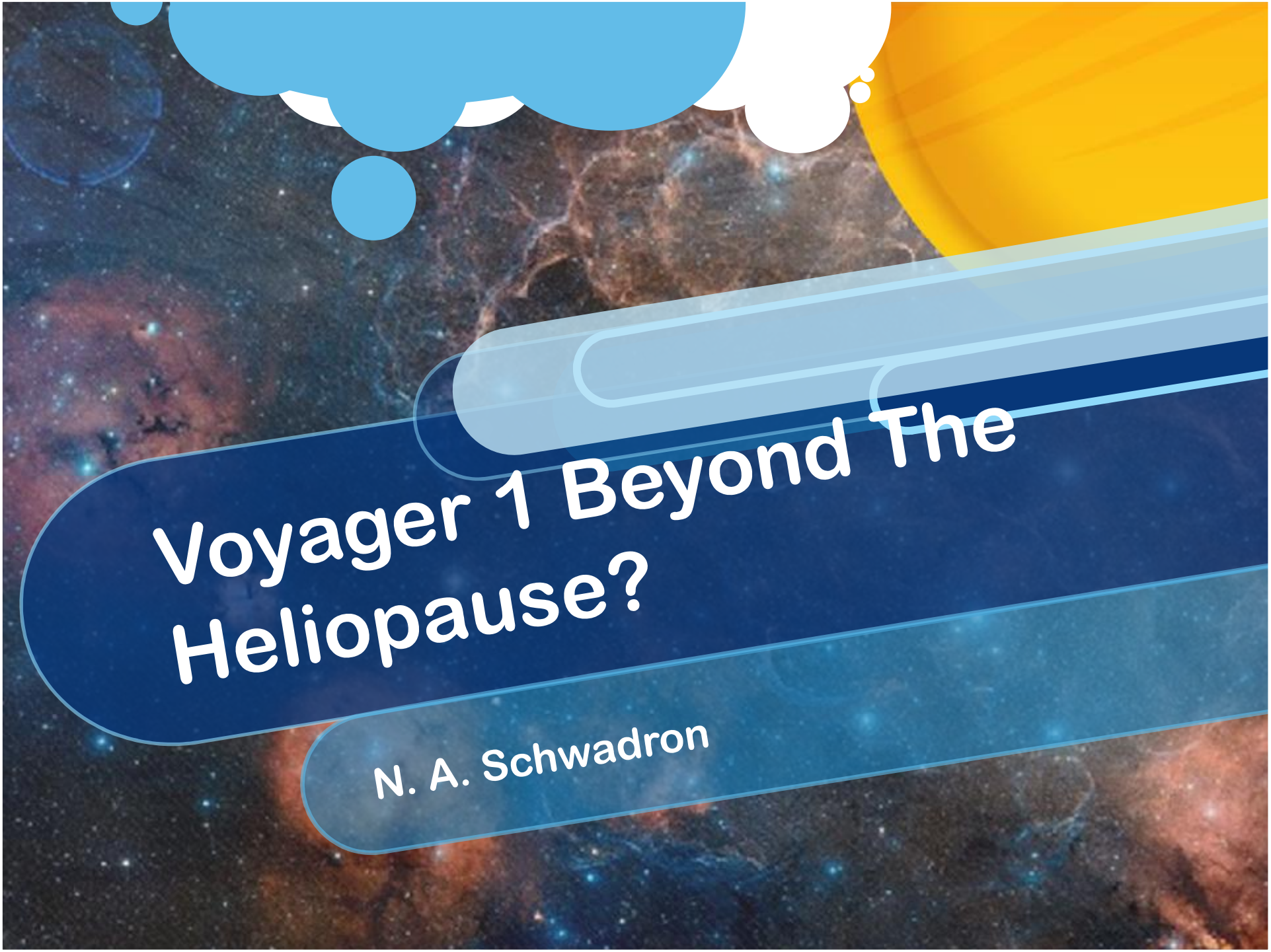
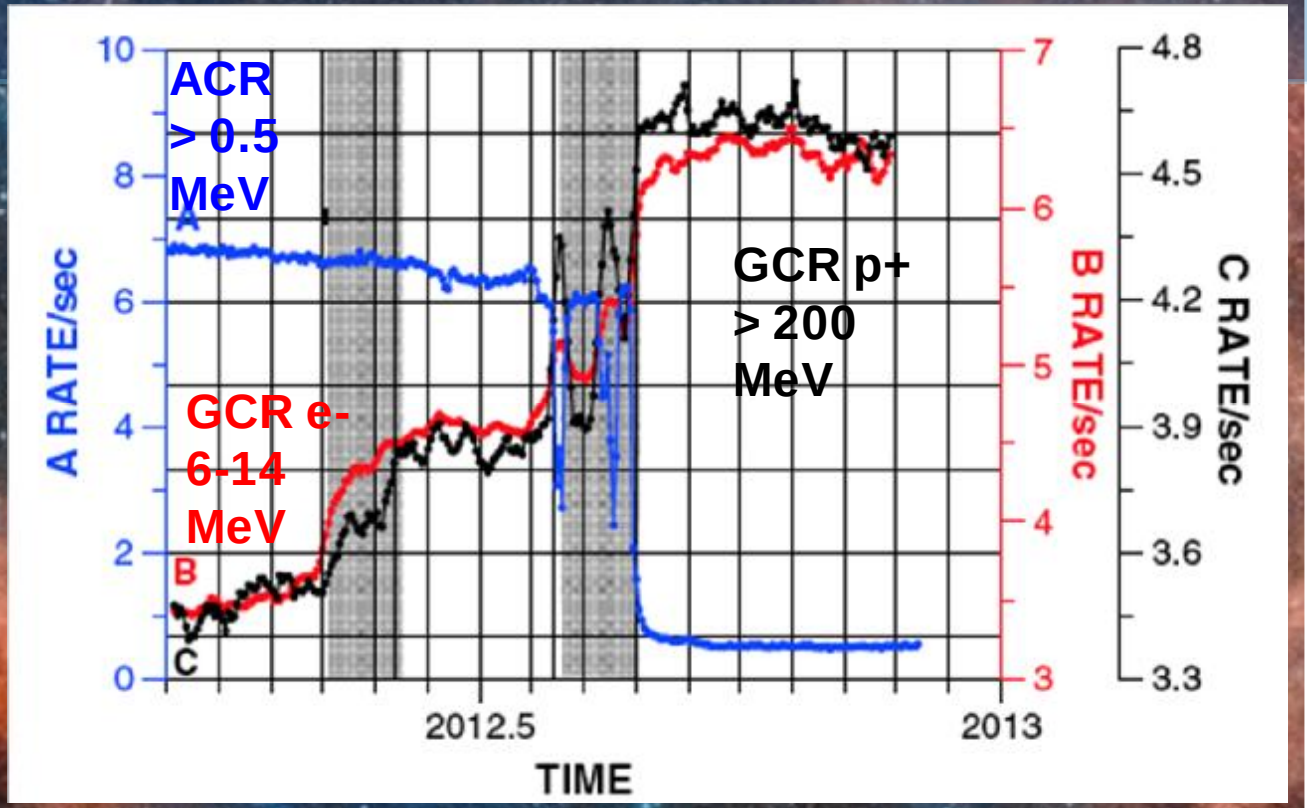

Voyager 1 Beyond The Heliopause?
N. A. Schwadron

Heliocliff

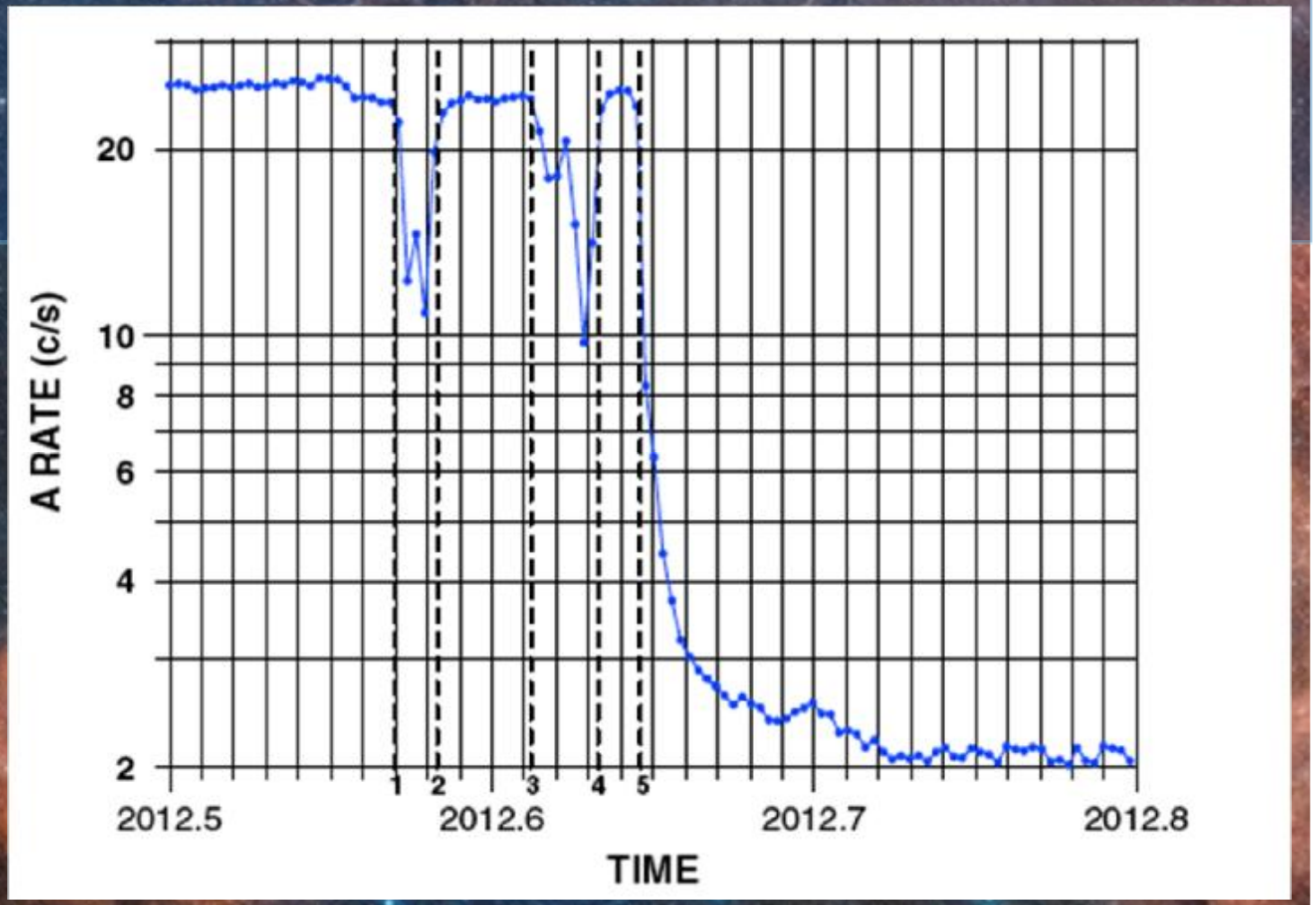
- intensity jumps for both ACR and GCRs
- In 2 weeks ACRs fall to 1%
- GCRs to highest levels since launch (and remained there > 6 months)



Webber & McDonald, GRL, (2013)

Dropout of ACRs and TSPs

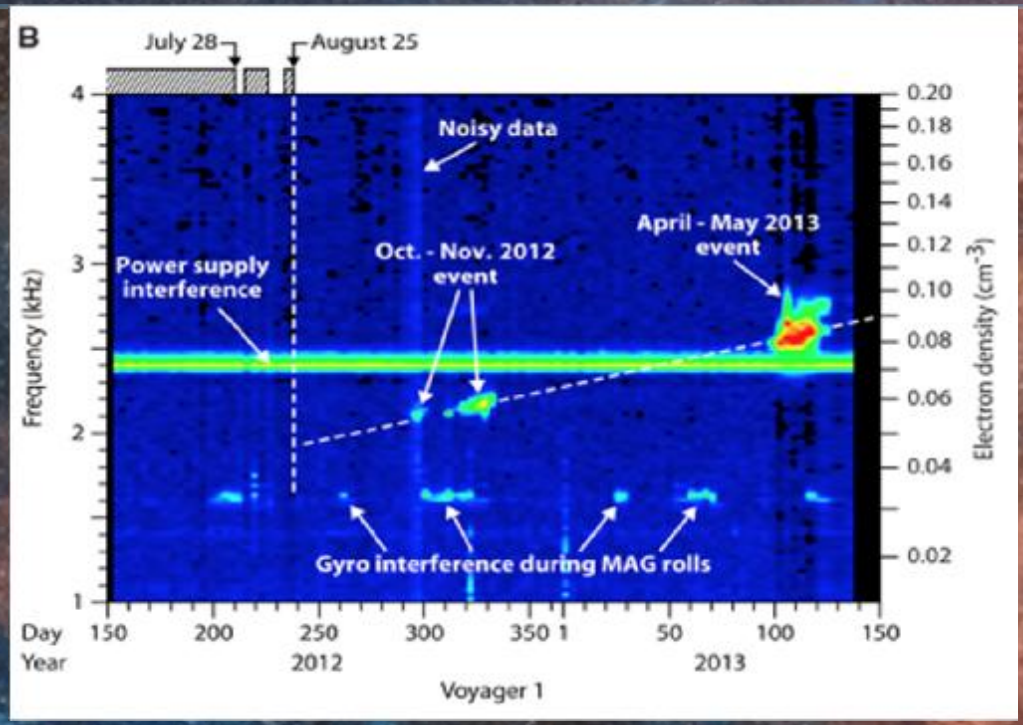
- > 0.5 MeV daily average rate
- Decreases by factors 2-3 in several days



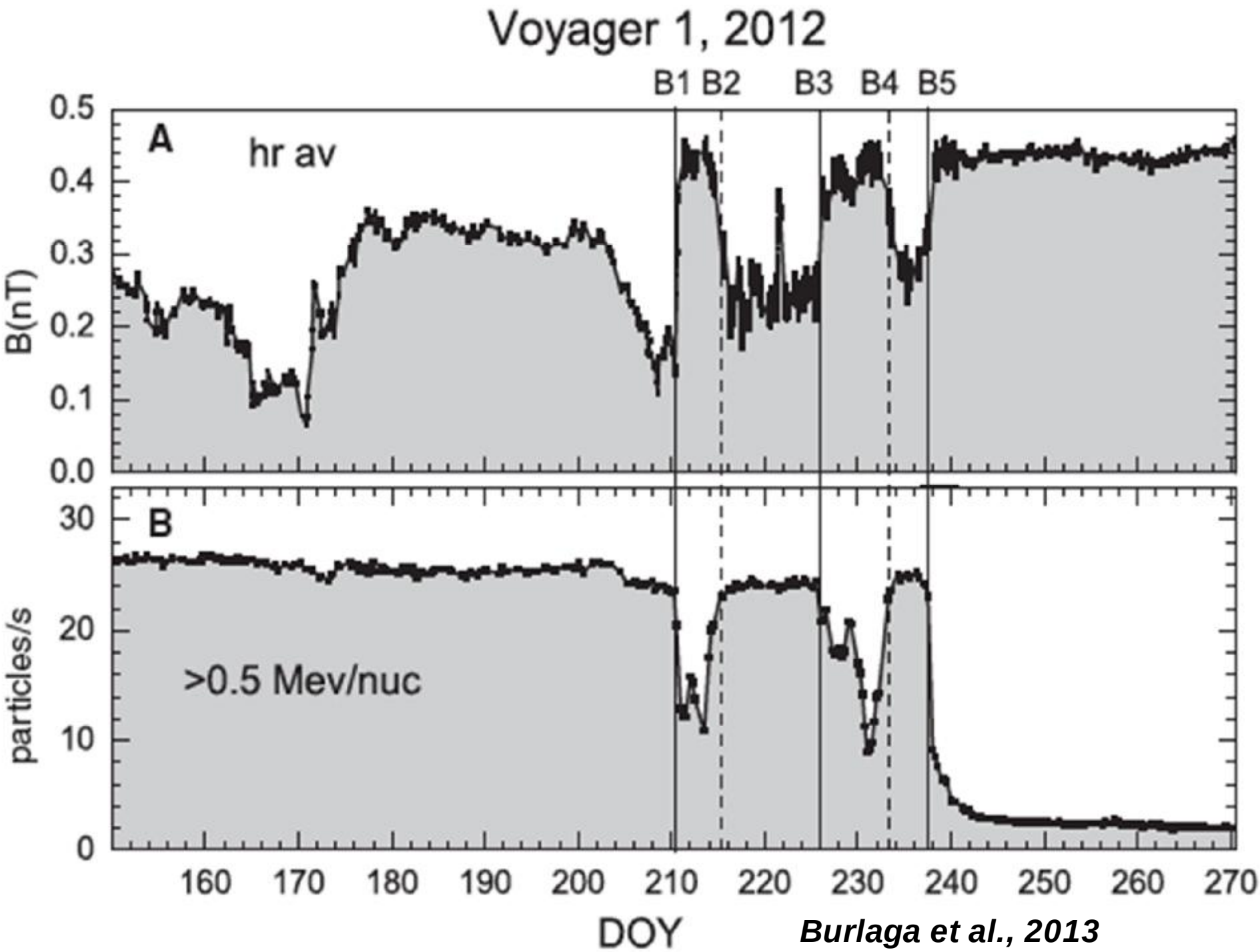
Webber & McDonald, GRL, (2013)

Plasma wave Instrument on Voyager 1

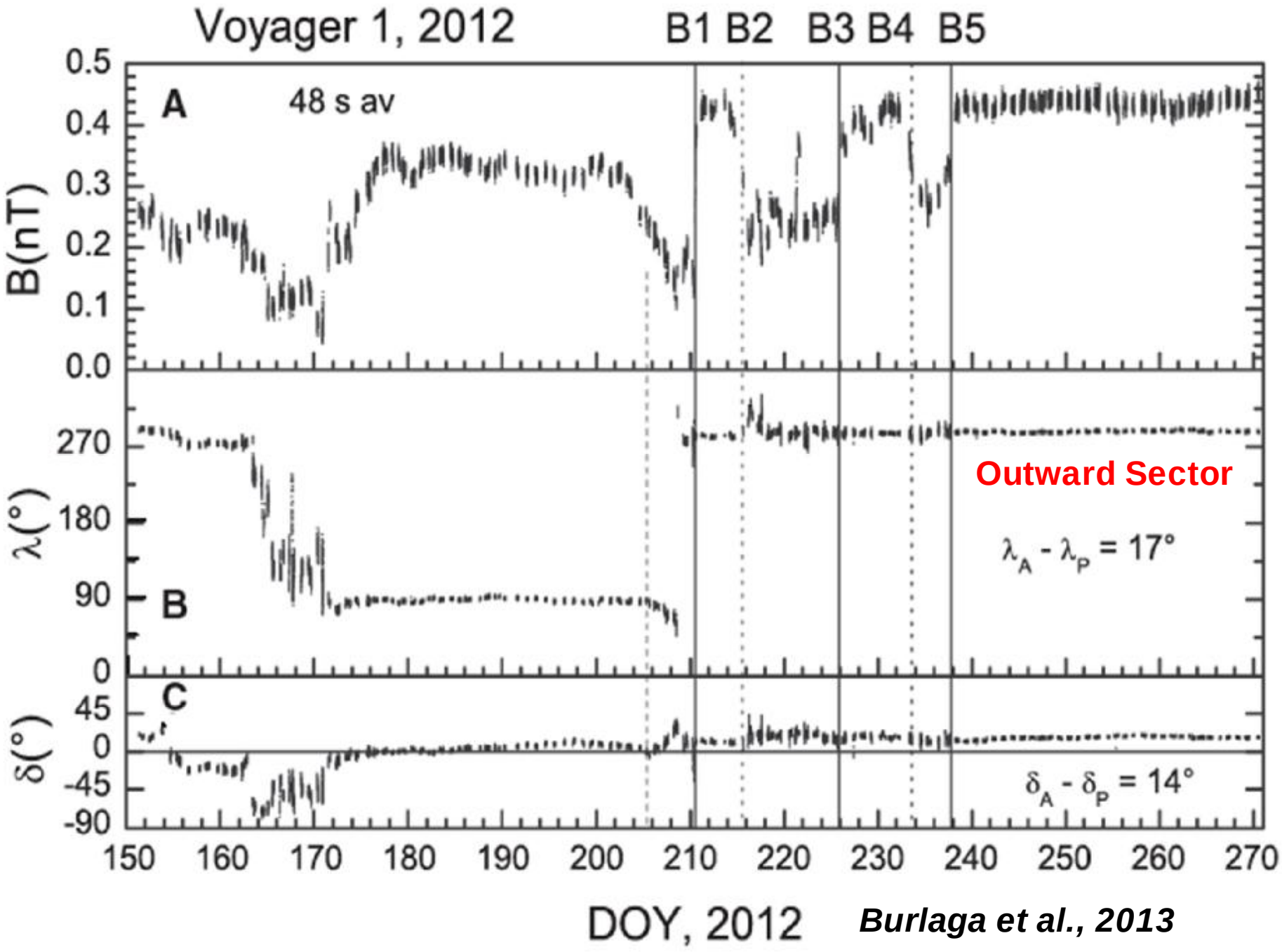
- On April 9, 2013, V1 plasma wave instrument began detecting electron plasma oscillations at a frequency of ~2.6kHz
- Oscillation frequency à electron density 0.08 cm^{-3}
- Inner Heliosheath densities ~ 0.001 cm^{-3}



Gurnett et al., Science, (2013)



Burlaga et al., 2013



Burlaga et al., 2013

Has Voyager 1 Crossed Heliopause

- Loss of ACRs
- Rapid Increase in GCRs
- LISM densities
- BUT magnetic field remains inner heliosheath direction

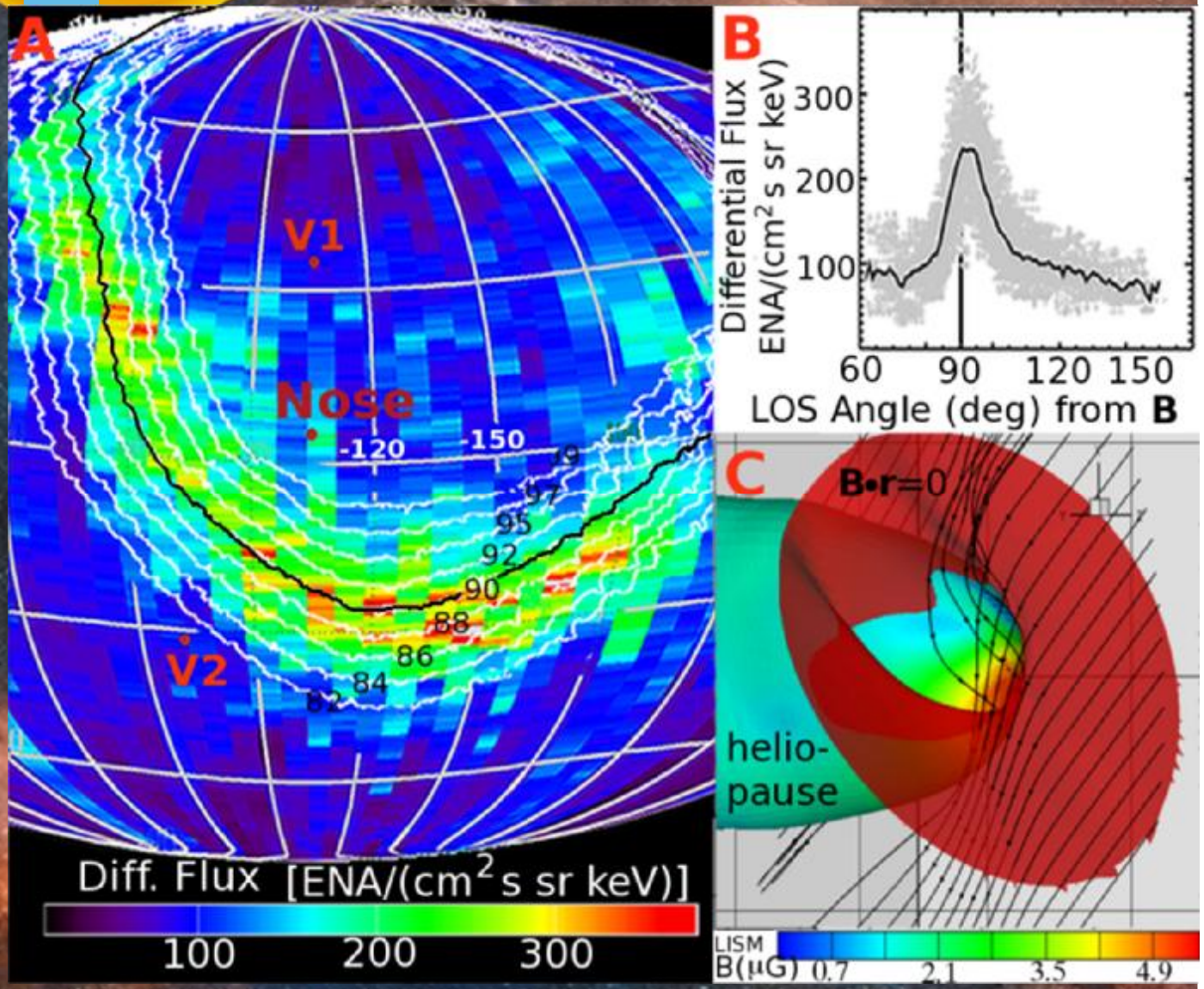
LISM Magnetic Field In Direction of Parker Spiral?

- Probability that magnetic field remains with 2 deg of inner heliosheath direction

0.06%

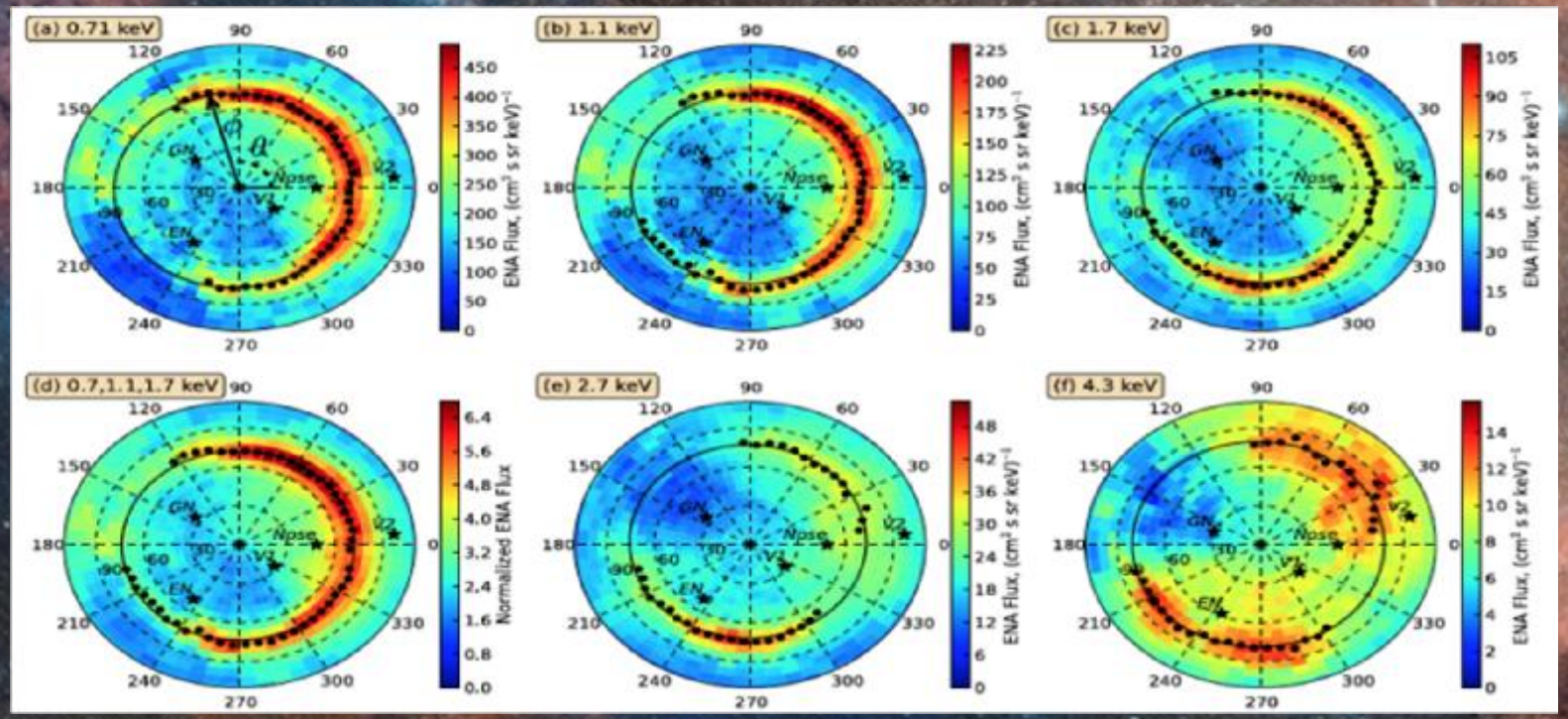
Ribbon Correlates with B•r=0

- A: 1.1 keV Map with contours **B•r** angle from Model 2 and the LOS over 10 AU outside heliopause
- B: Flux as function of LOS angle from **B**
- C: Global structure of heliopause and **B•r**=0 surface

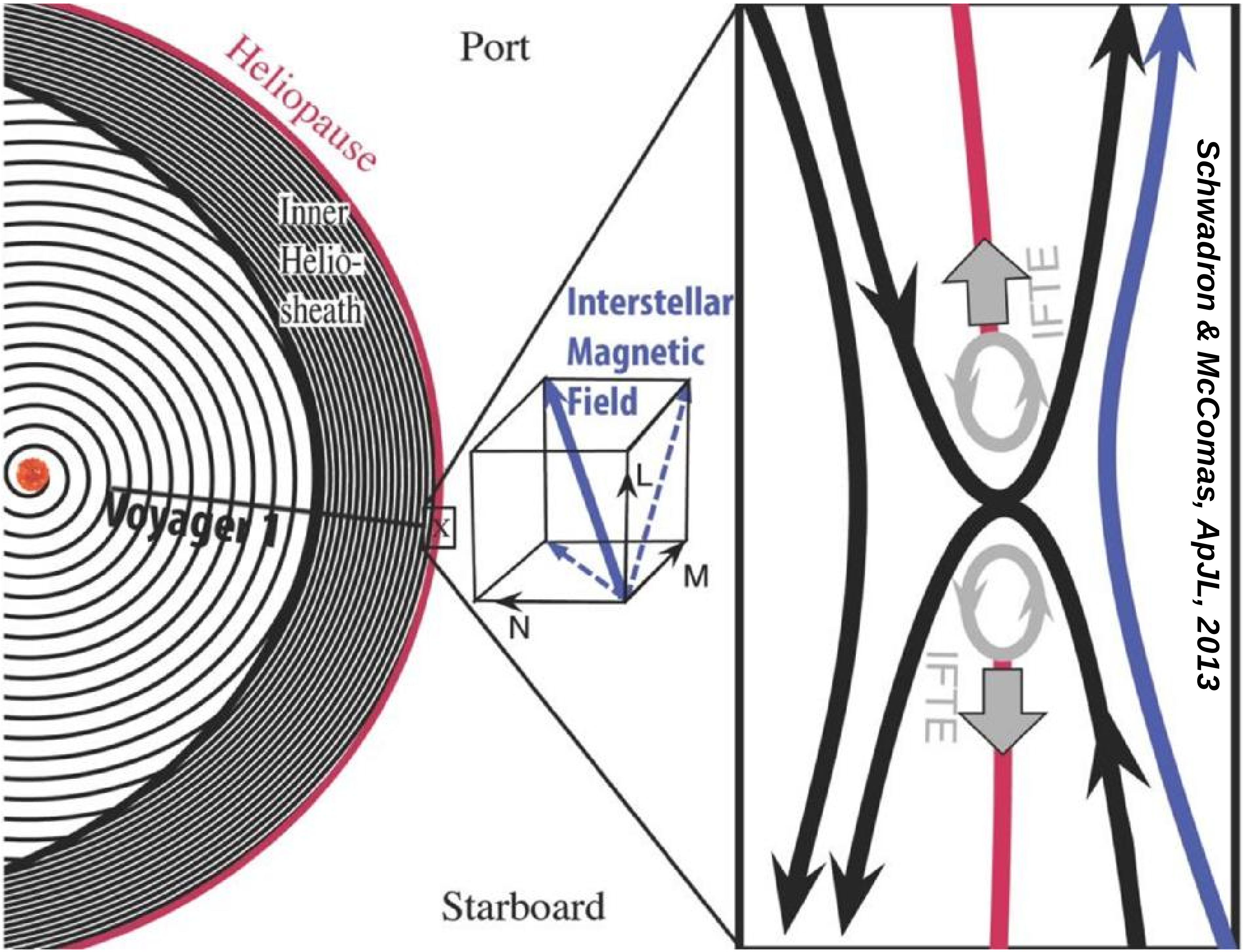


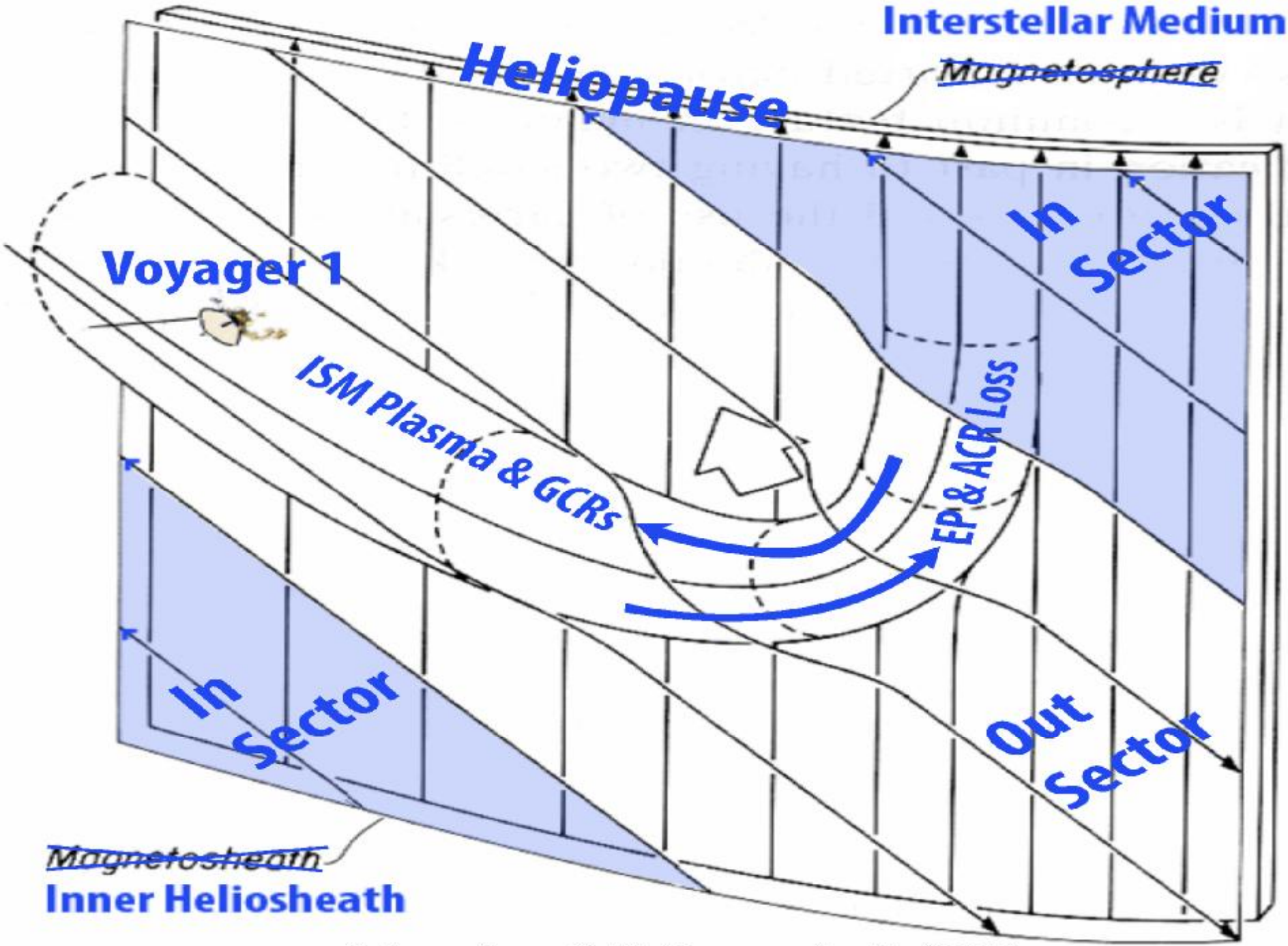
Schwadron et al., *Science*, 2009

Circularity of the IBEX Ribbon



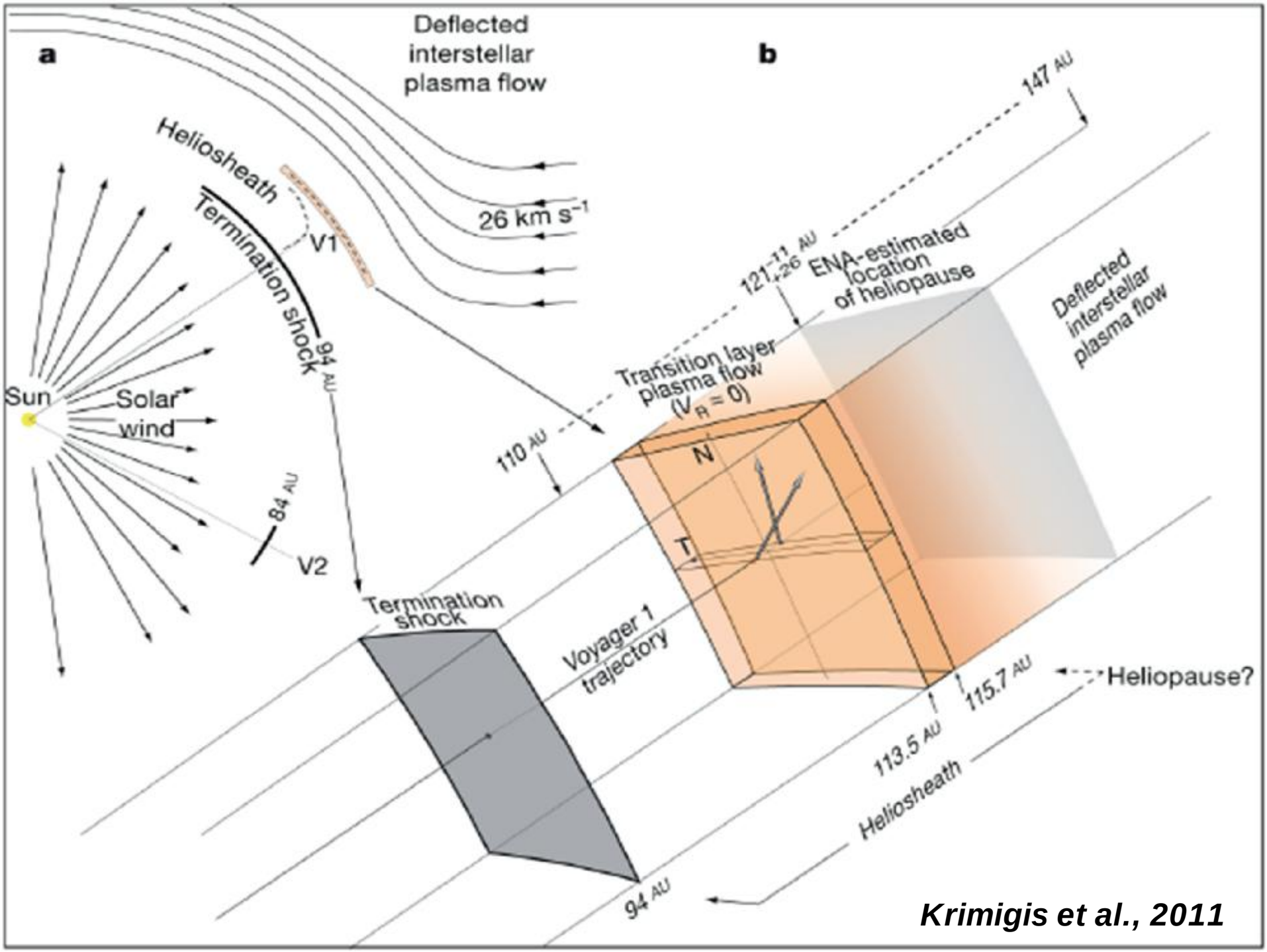
Funsten et al., ApJ, 2013


Port
Heliopause
Inner
Helio-
sheath
Voyager 1
X
Interstellar
Magnetic
Field
L
M
N
Starboard
IFTE
IFTE
Schwadron & McComas, ApJL, 2013

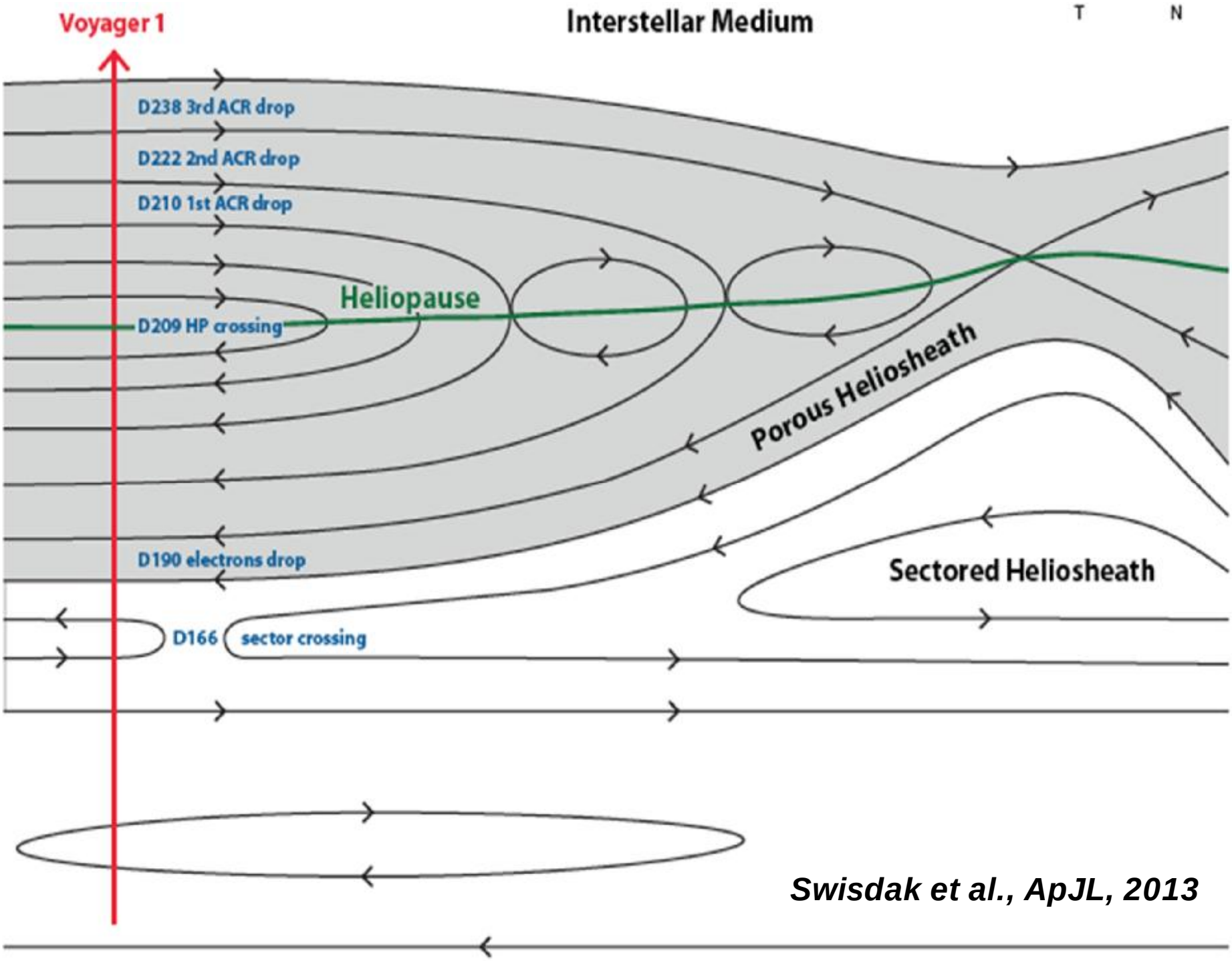


Schwadron & McComas, ApJL, 2013

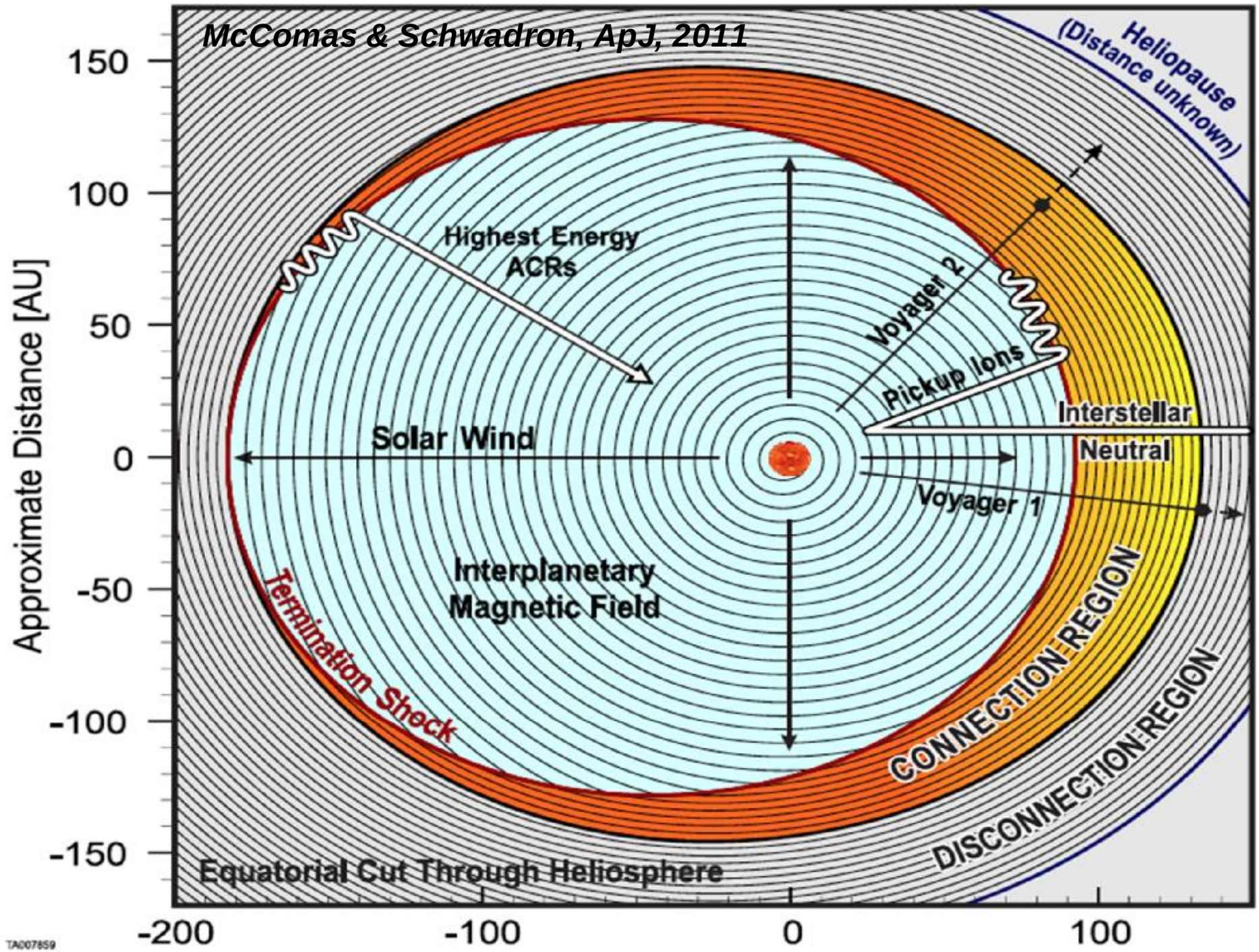
Concept	FTE (near magnetopause)	IFTE (near heliopause)
B_L	Steady Increased strength[1]	Steady (+ inside heliopause) Increased strength
B_N	+/- or -/+ Magnitude of oscillation depends on depth within FTE[1]	Small deviation in azimuthal angle predicted on outskirts of IFTE. Deviation angle increases closer to the interior of IFTE. Sign of deviation depends on location of V1 with respect to IFTE
B_M	Magnitude enhancement[1]	Small deviation in elevation angle on outskirts of IFTE. Deviation angle increases closer to the interior of IFTE. Sign of deviation depends on location of V1 with respect to IFTE.
Plasma	Density enhancement (larger enhancements closer to FTE center)[2]	Density enhancement (larger enhancements closer to IFTE center)
Energetic Particles	Loss of magnetosphere populations[3]	- Loss of Anomalous Cosmic Rays - Increase in Galactic Cosmic Rays
Size	~1 Re[1]	~4 AU
Frequency	~ 8 minutes[1]	~1.4 years
Duration	~1 minute[1]	~2 months

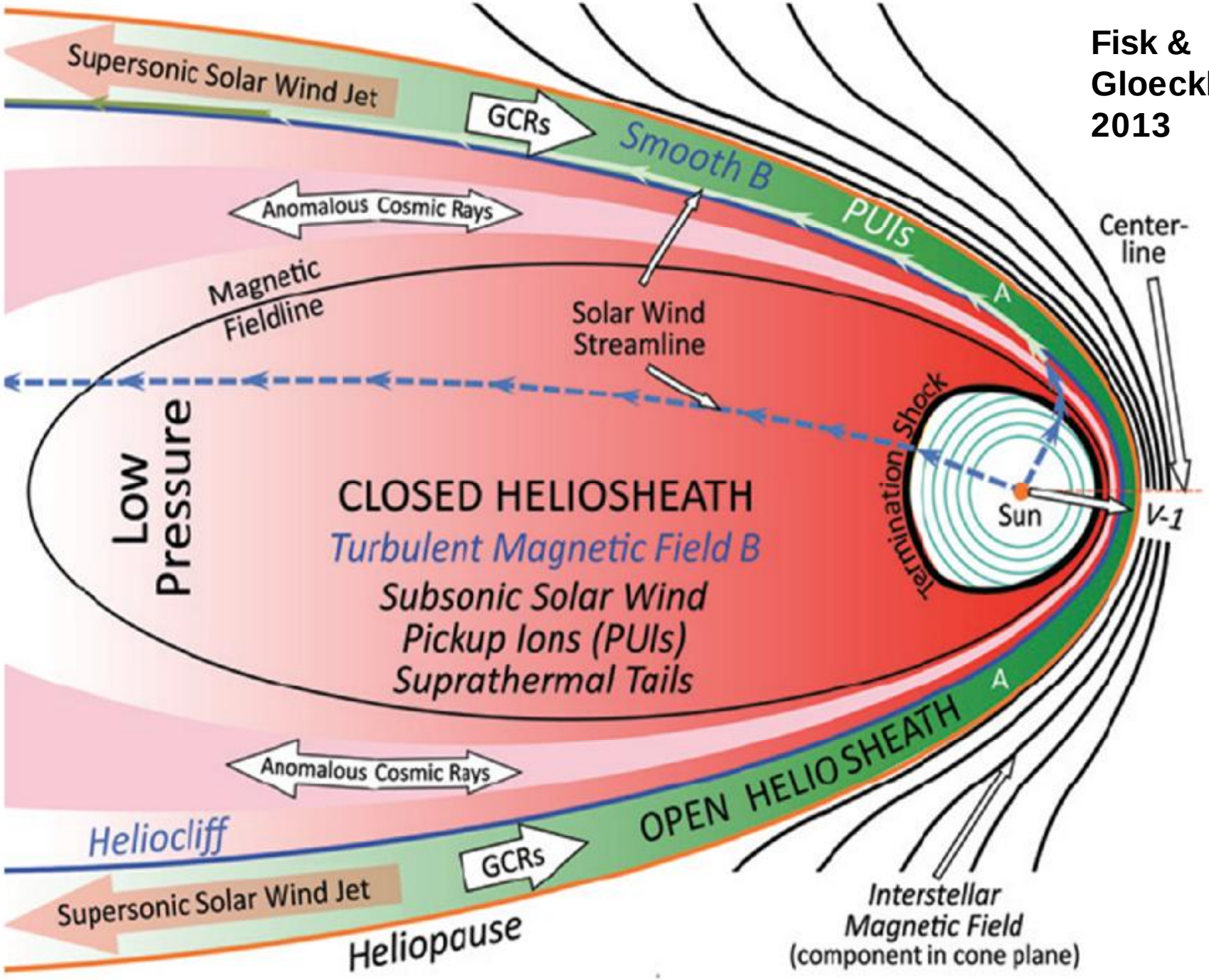


Krimigis et al., 2011

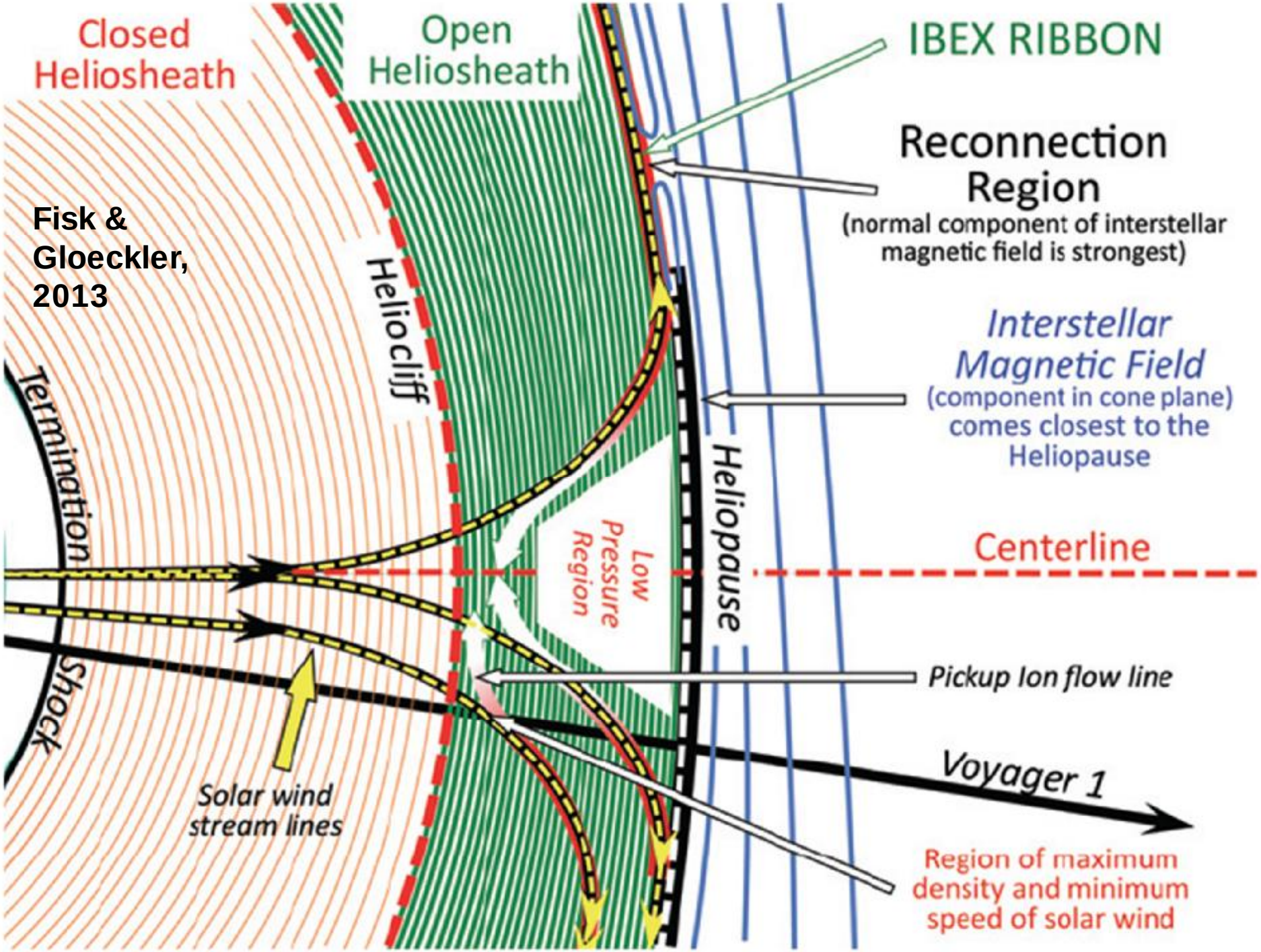


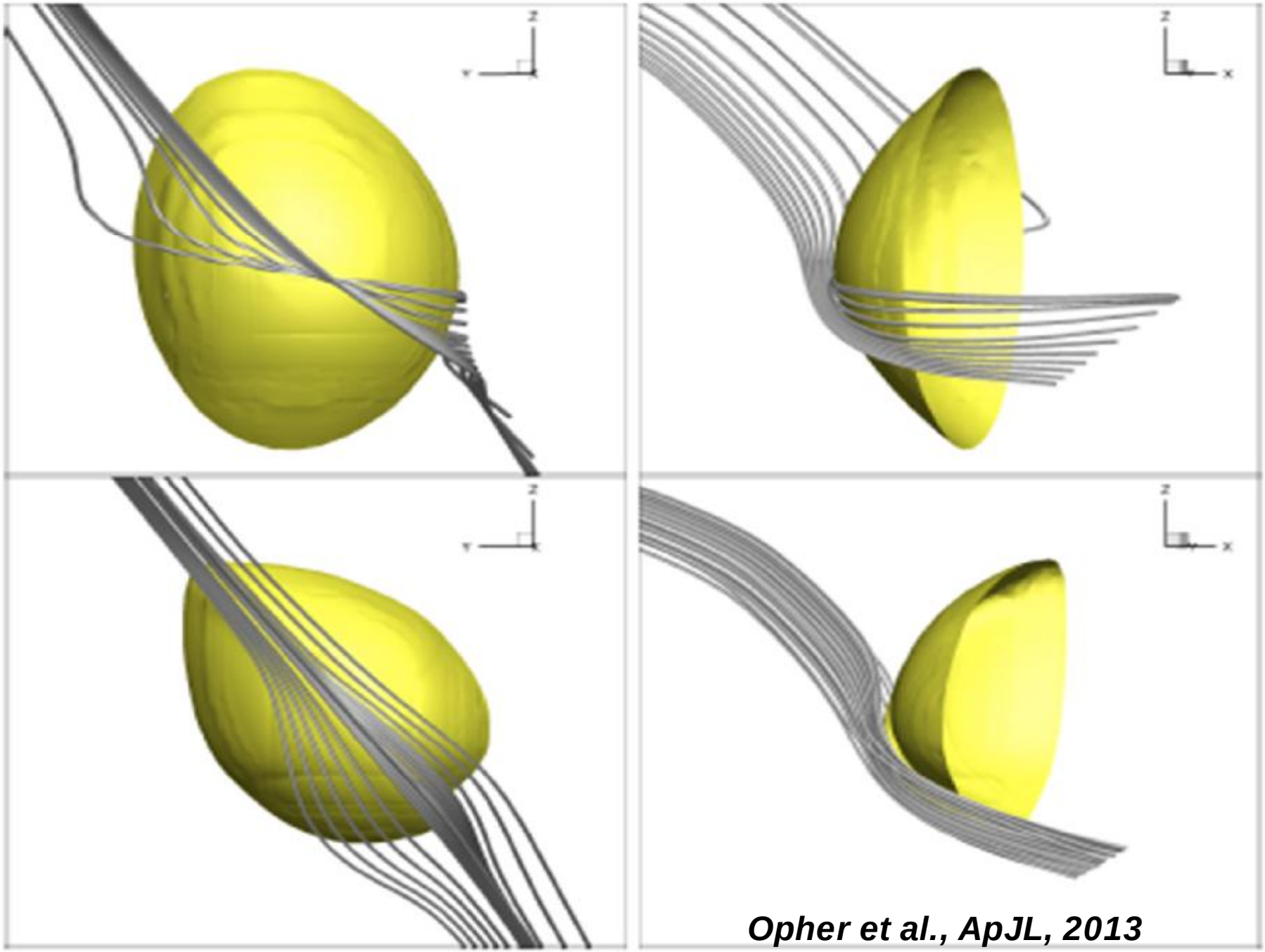
Swisdak et al., ApJL, 2013


McComas & Schwadron, ApJ, 2011
Heliopause
(Distance unknown)
Highest Energy
ACRs
Voyager 2
Pickup Ions
Interstellar
Neutral
Solar Wind
Voyager 1
Interplanetary
Magnetic Field
Termination Shock
CONNECTION REGION
DISCONNECTION REGION
Equatorial Cut Through Heliosphere
Approximate Distance [AU]
150
100
50
0
-50
-100
-150
-200
-100
0
100
TA007859



Fisk & Gloeckler, 2013


Closed Heliosheath
Open Heliosheath
IBEX RIBBON
Reconnection Region
(normal component of interstellar magnetic field is strongest)
Fisk & Gloeckler, 2013
Heliocliff
Interstellar Magnetic Field
(component in cone plane) comes closest to the Heliopause
Termination Shock
Low Pressure Region
Heliopause
Centerline
Pickup Ion flow line
Voyager 1
Solar wind stream lines
Region of maximum density and minimum speed of solar wind



Opher et al., ApJL, 2013

Concept	ACR & EP Depletion	GCR Increase	Inner Hsh Field direction	ISM Plasma Density	Plasma & EP changes at Sector crossing
Zero-radial-speed boundary[5]	Yes	Possibly	Yes	No	No
Porous Boundary[6]	Yes	Yes	No	Yes	No
Disconnection Boundary[7]	Yes	Yes	Yes	No	No
Heliopause Crossing[4]	Yes	Yes	No	Yes	No
IFTE	Yes	Yes	Yes	Yes	Yes

Summary

- ACRs, GCRs, Plasma consistent with Heliopause Crossing
- Magnetic Field persistent
  - Magnetic Reconnection/Flux Transfer?
  - Magnetic Field Draping?
  - Low speed boundary?
  - Porous Heliopause?
  - Open Heliosheath?