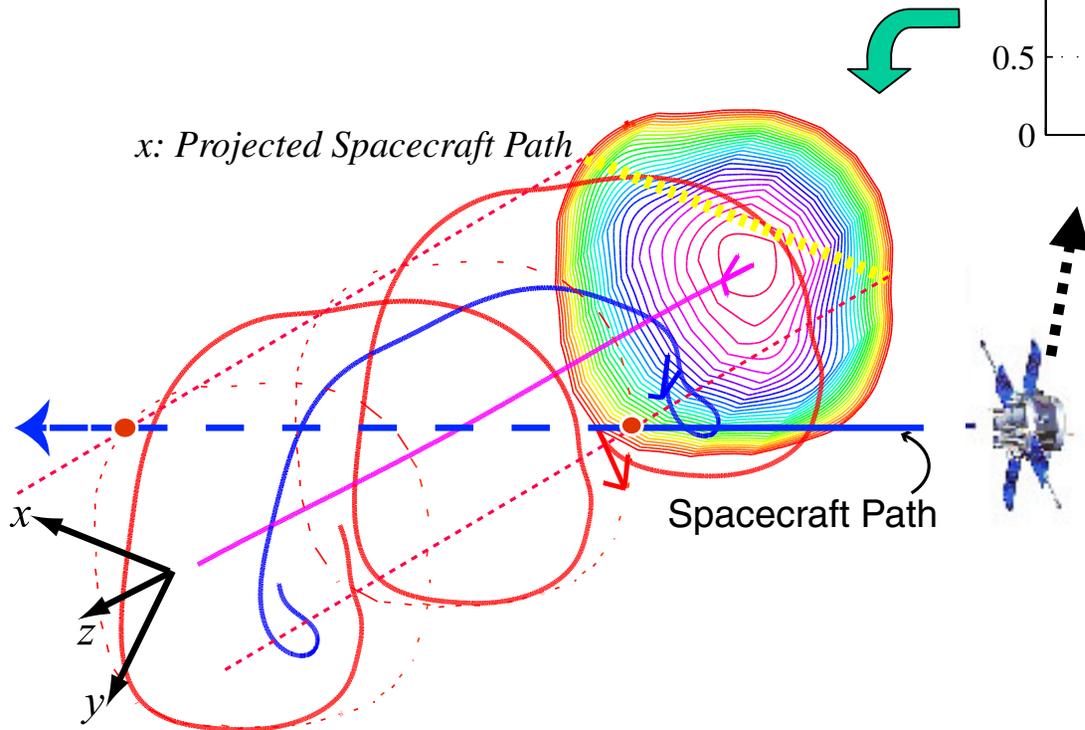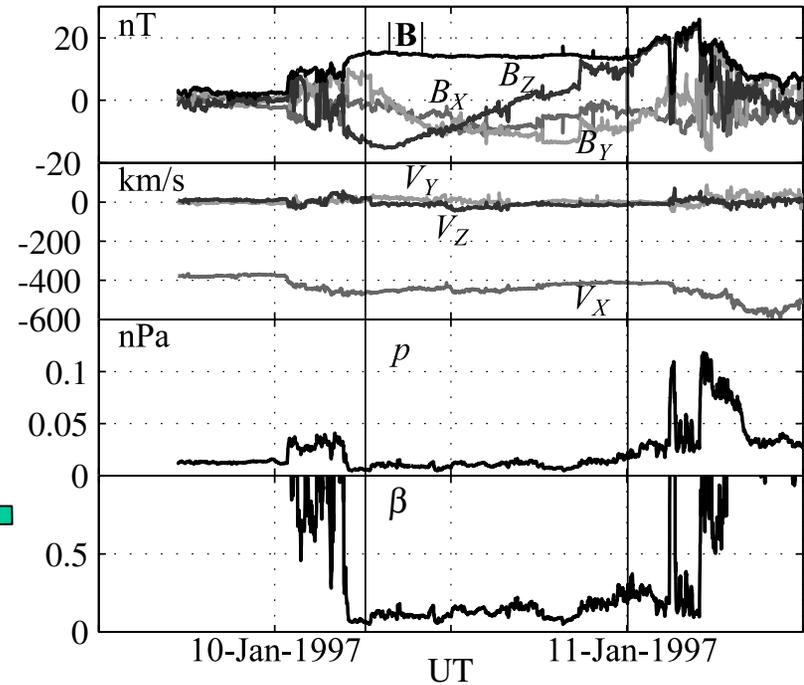# Grad-Shafranov (GS) Reconstruction: A novel technique to derive the cross-sections of magnetic structures in space plasmas from limited spacecraft measurements along a single line.

x: Projected Spacecraft Path

Spacecraft Path

- Features of the GS Reconstruction Technique:
    - Fully 2 ½ D solution (less fitting)
    - Self-consistent theoretical modeling (less subjective)
    - Utilization of simultaneous magnetic and plasma measurements
    - Non-force free
- Limitations:
    - 2D, uncertainty in $\mathbf{z}$ (the quality of $P_t(A)$ fitting, R_f)

$$2D \Rightarrow P_t(A),\ P_t(A) \not\Rightarrow 2D$$

    - Time stationary (quality of the HT frame)
    - Static (evaluating the residual plasma flow)
    - Numerical errors limit the extent in y direction (rule of thumb: $|y| \leq |x|$, $\Delta y \ll \Delta x$)

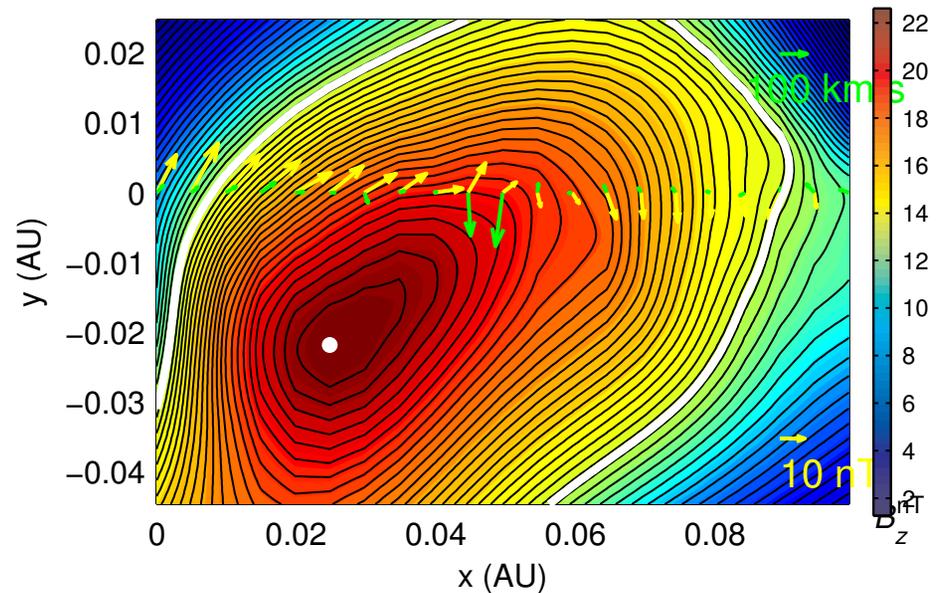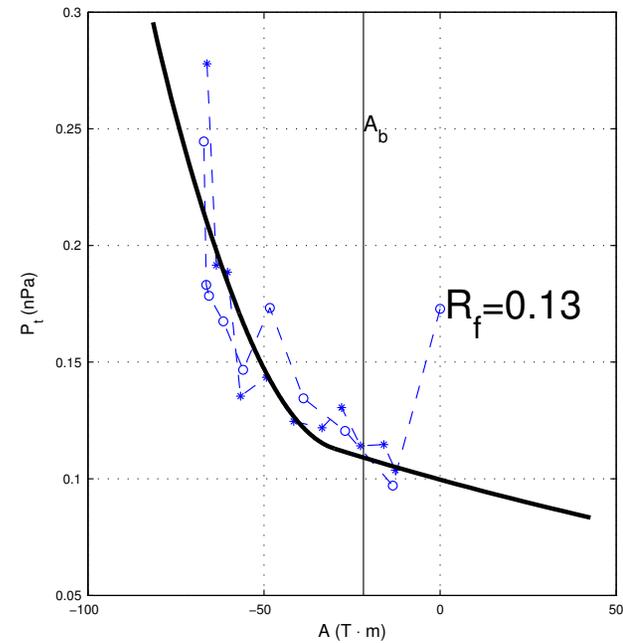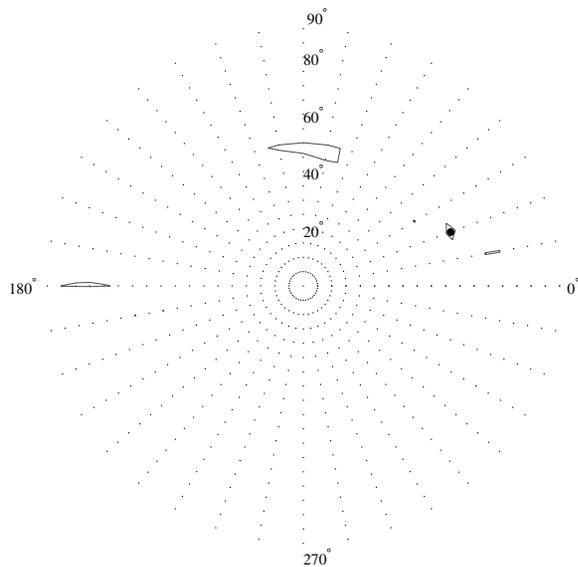# • SHINE Campaign Event: *May 12, 1997* (Wind)
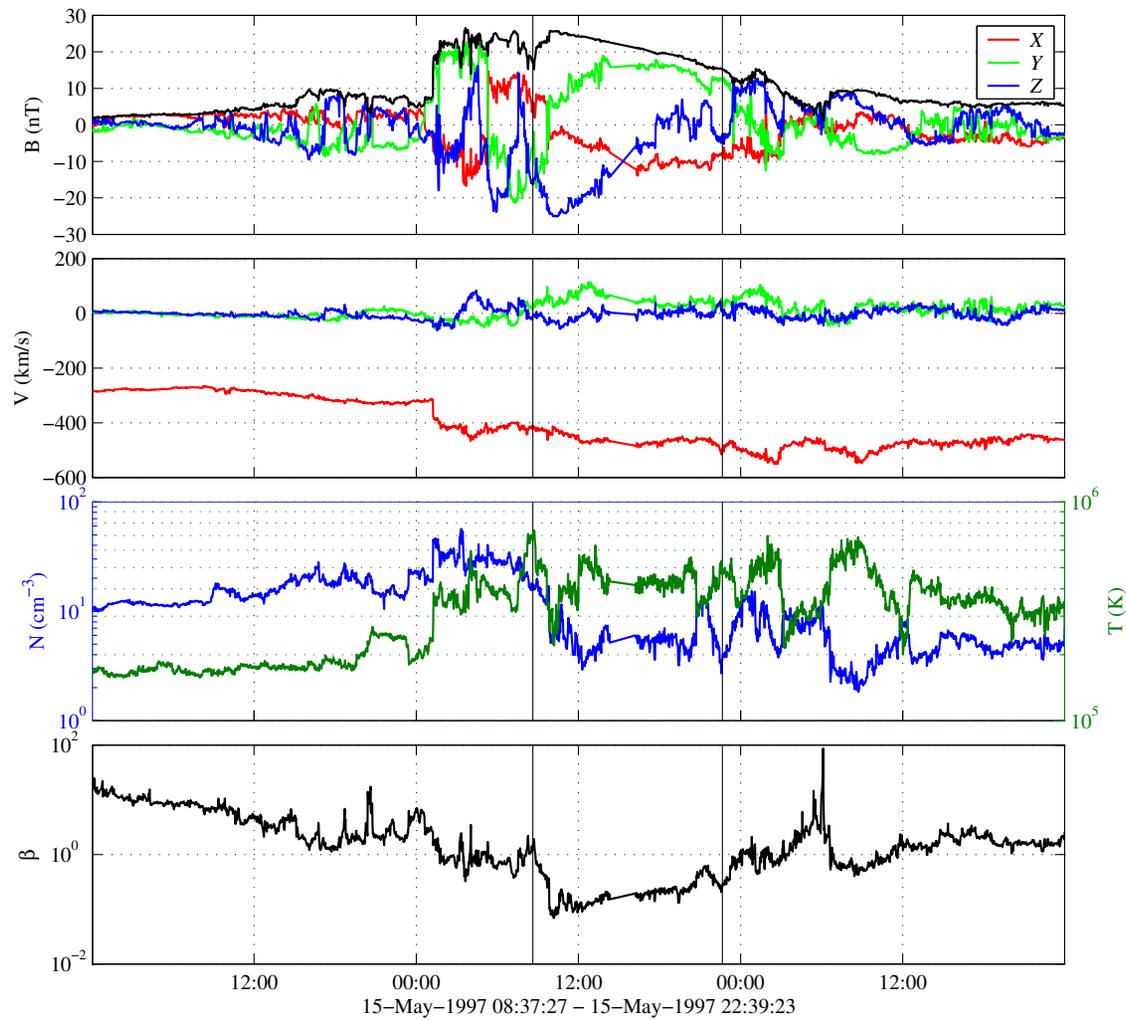
- Cross-section (bottom): transverse field lines and $B_z(x,y)$ in color; yellow (green) arrows are measured transverse magnetic vectors (residual flow velocities)
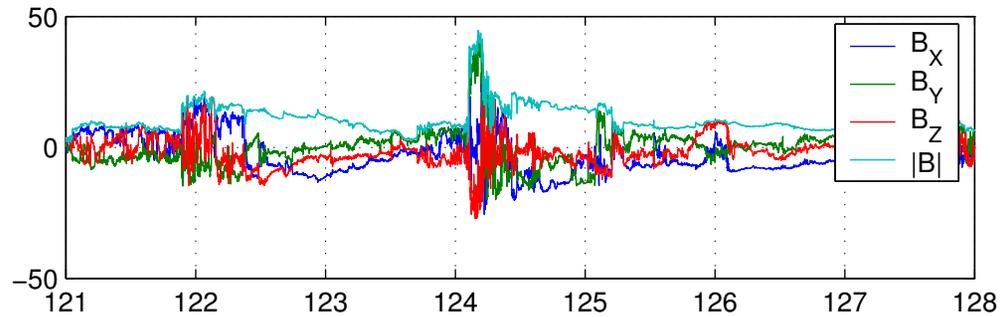
-Typical parameters obtained:

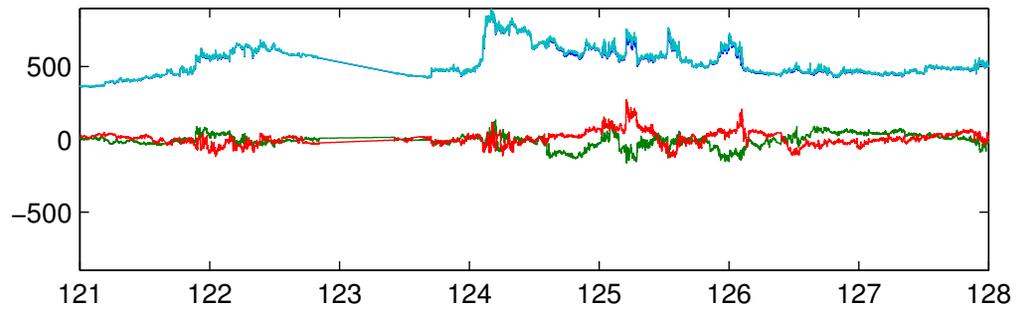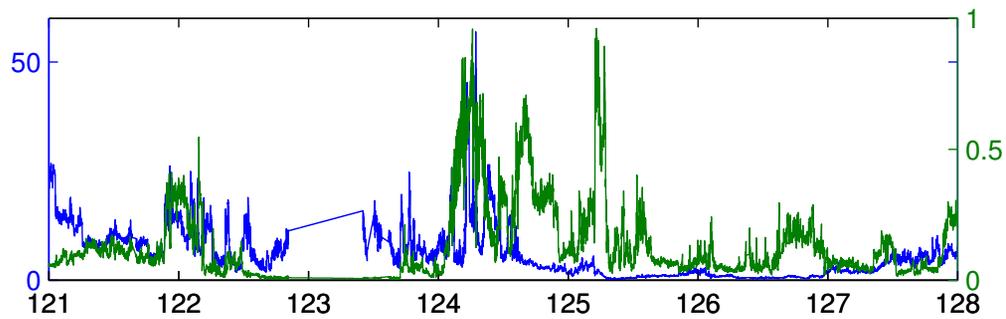| y_0	$B_{z\max}$	$j_{z\max}$	Φz	Iz
AU	nT	$10^{-12} A/m^2$	$10^{12} Wb$	10^8 A
-0.02	23	-6.7	1.9	3.3

and **z**=(136, 326)± (3,6)° GSE

- SHINE Campaign Event: *May 1, 1998* (ACE)

(unsuccessful)

DOY (1998)

ACE/WIND Test

Top panel:

A cross-section is obtained by utilizing ACE data at *y*=0. The WIND path is projected onto the map as the yellow horizontal line.

Bottom panel:

The numerical solutions along that line are compared with real WIND measurements.

WIND position relative to ACE:

$(\Delta x, \Delta y, \Delta z)=(-59, 17, 147) R_E$
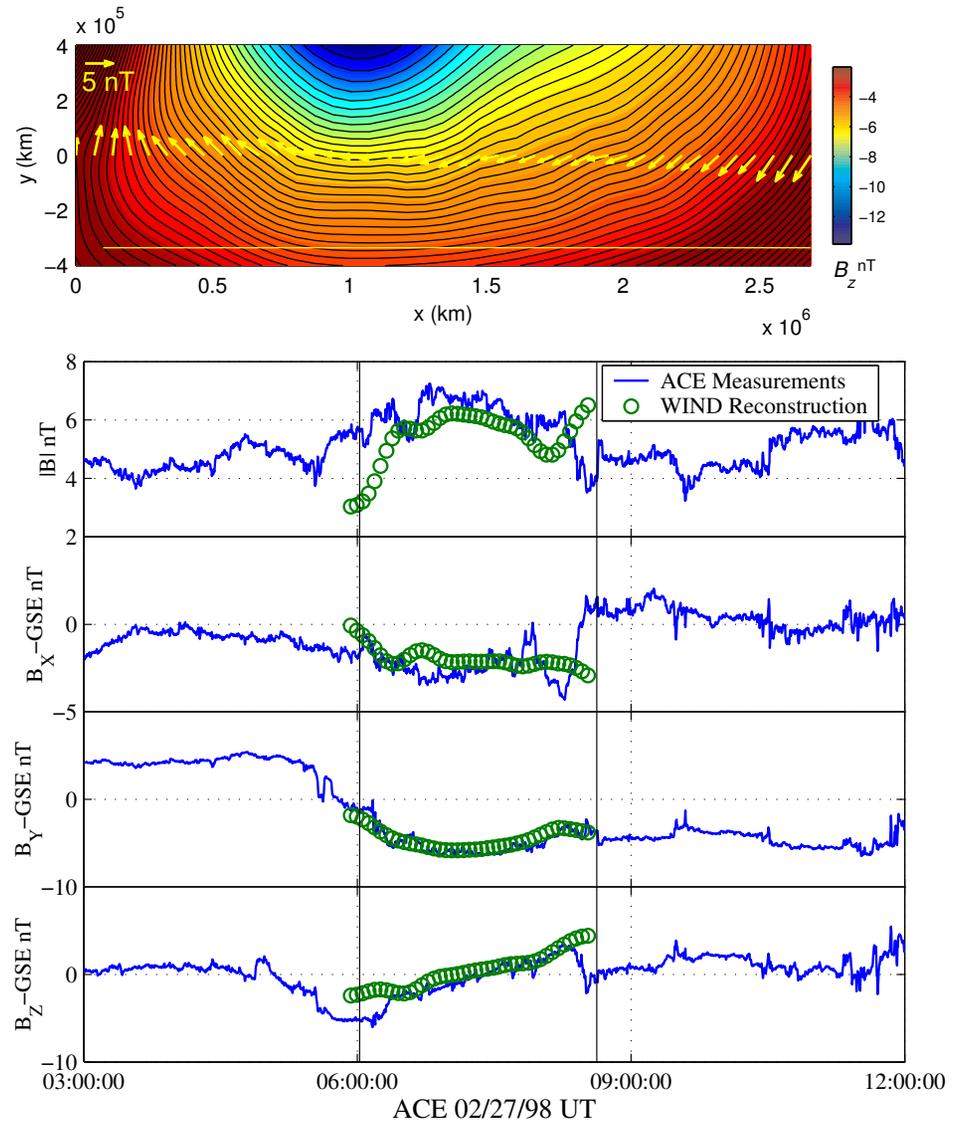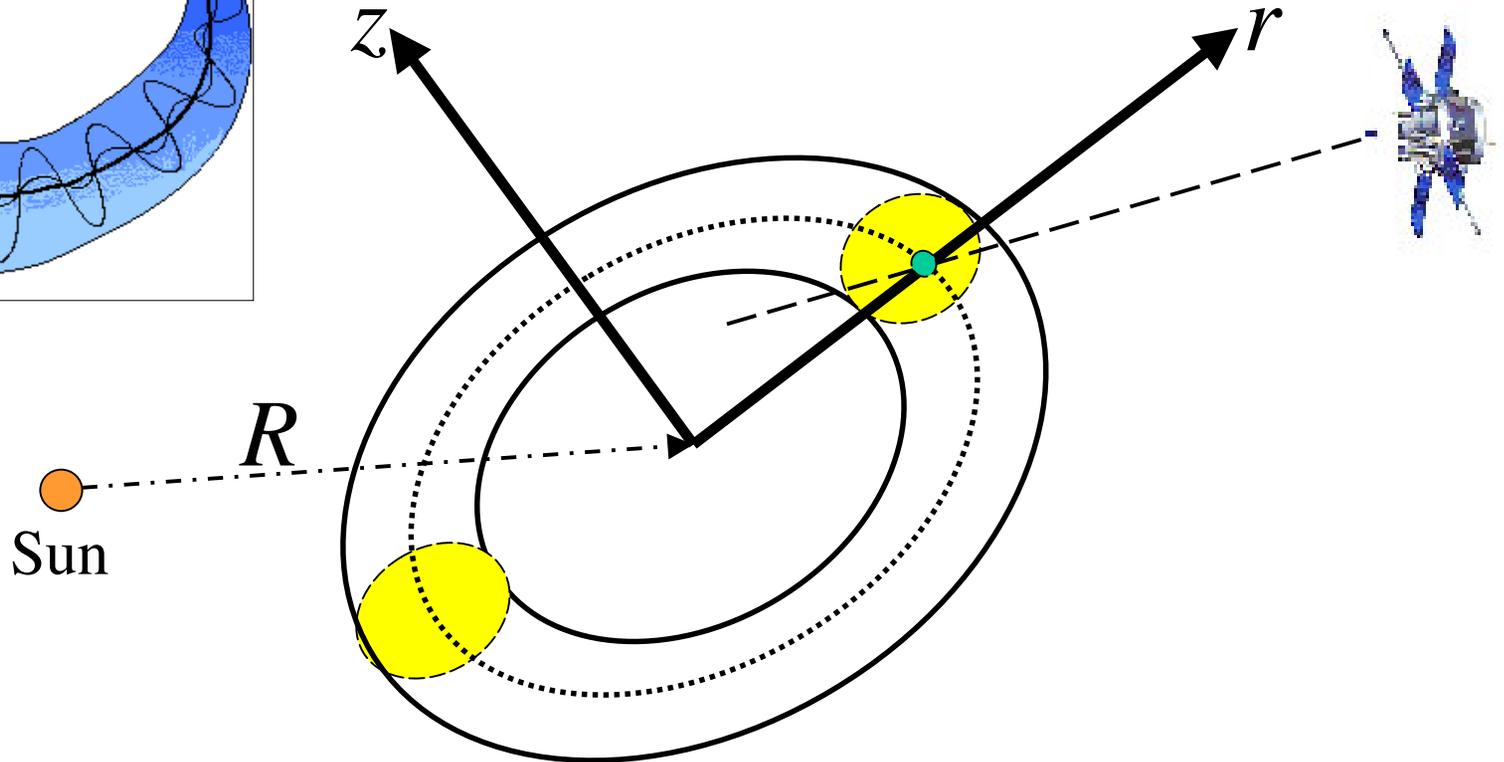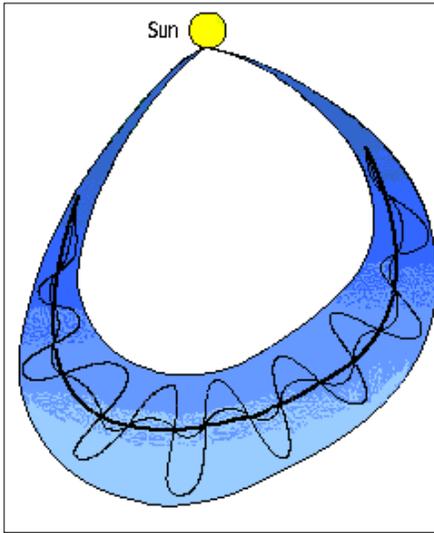

June 24, 1998

ACE position relative to WIND at (0,0,0) is (16, -53, 21) R_E.

A torus of arbitrary cross section?

Sun

z

r

R

Sun

GS equation:
(R. H. Weening, 2000)

$$r\frac{\partial[(1/r)\partial\chi/\partial r]}{\partial r}+\frac{\partial^2\chi}{\partial z^2}=-\mu_0[(2\pi r)^2\frac{dp}{d\chi}+\mu_0 G\frac{dG}{d\chi}]$$

… Fully 3D?