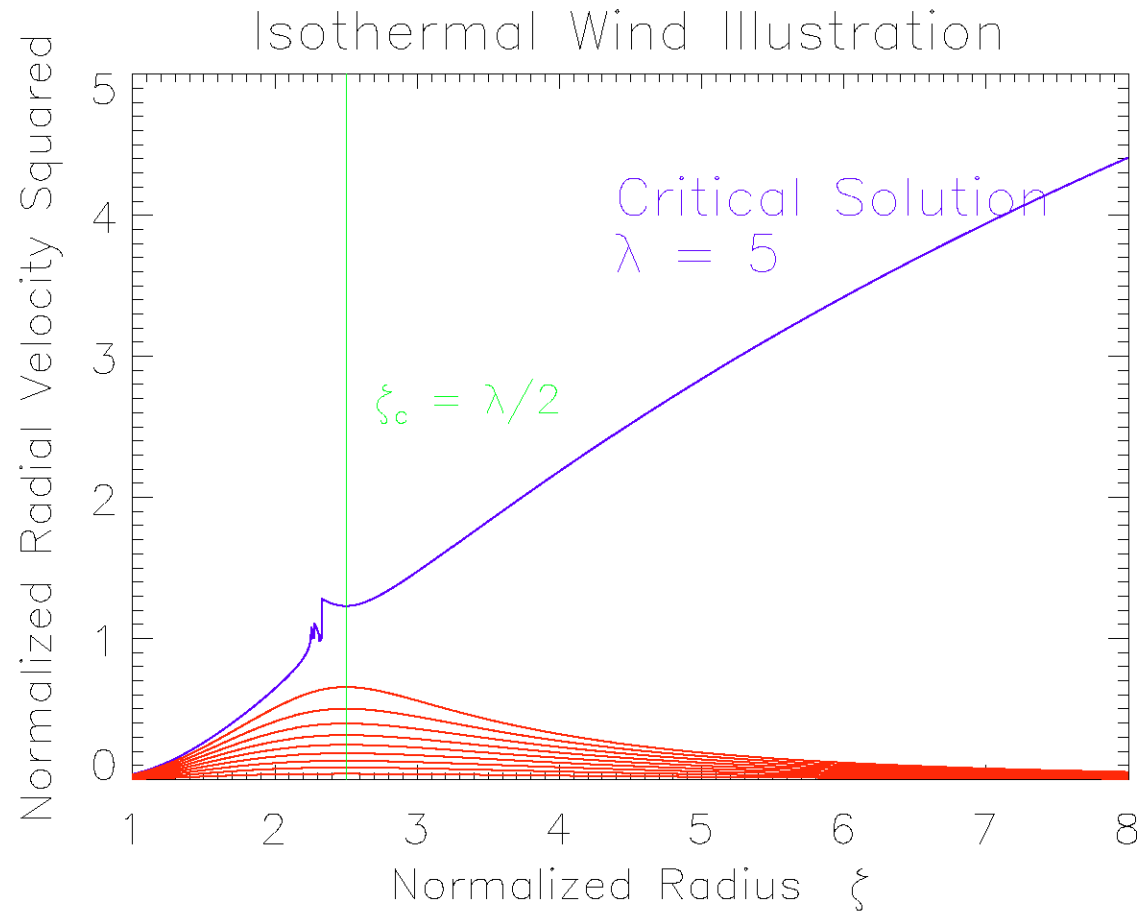
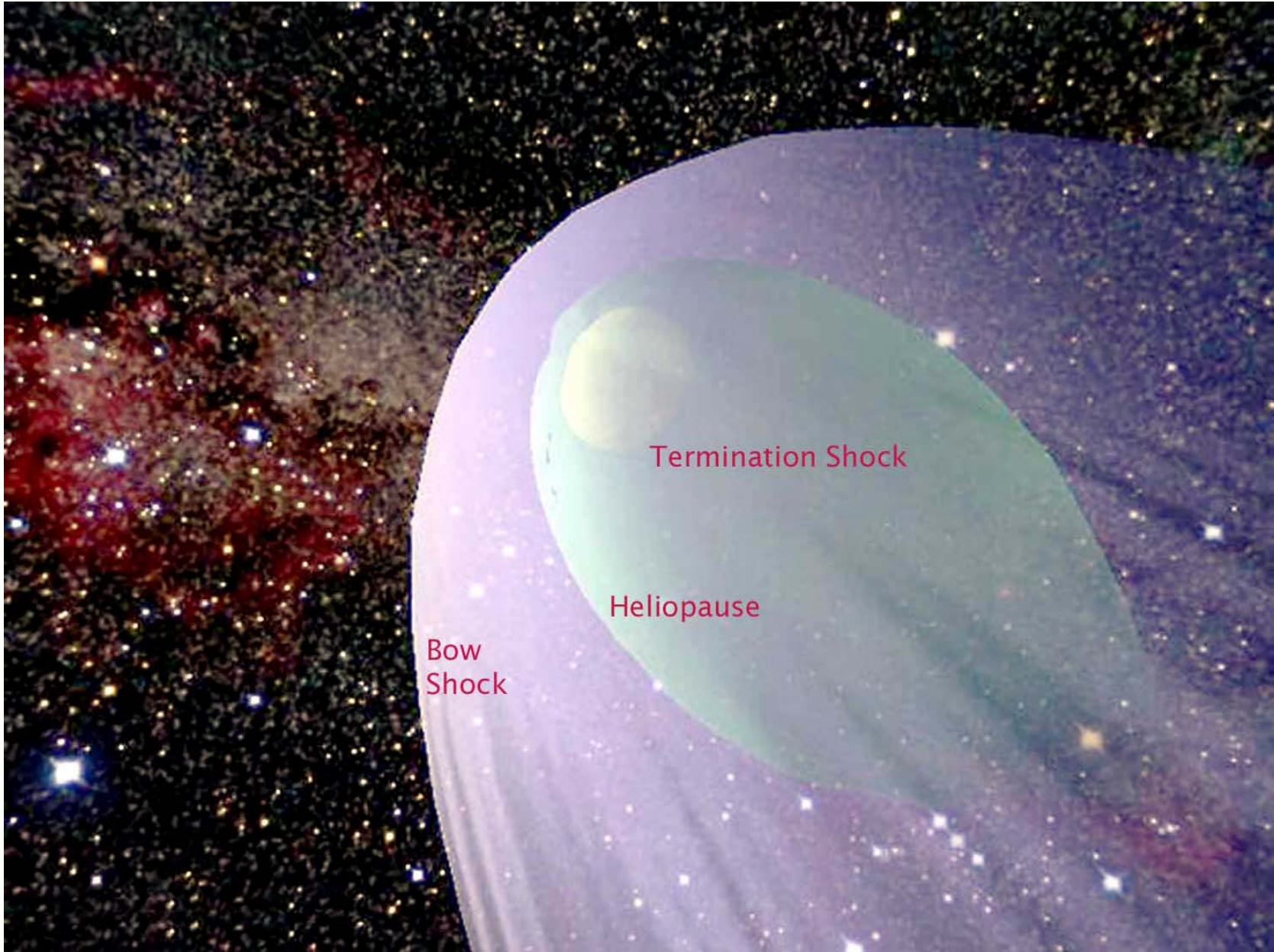


Organization of Lectures

1. Frozen in magnetic field (kinematics).
2. Dynamical Equations
3. Applications and places where breakdown of MHD is important.

Solar Wind

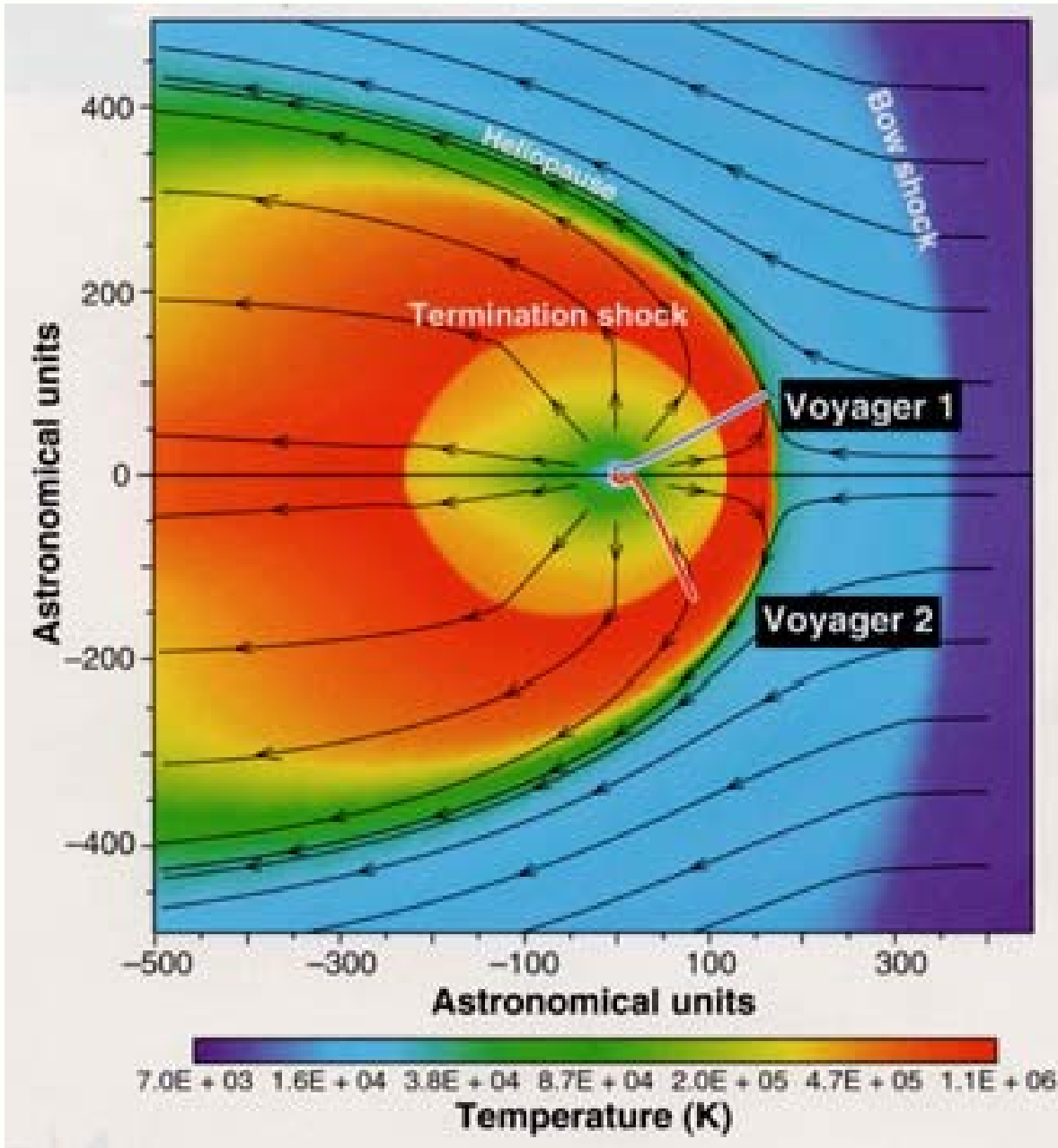




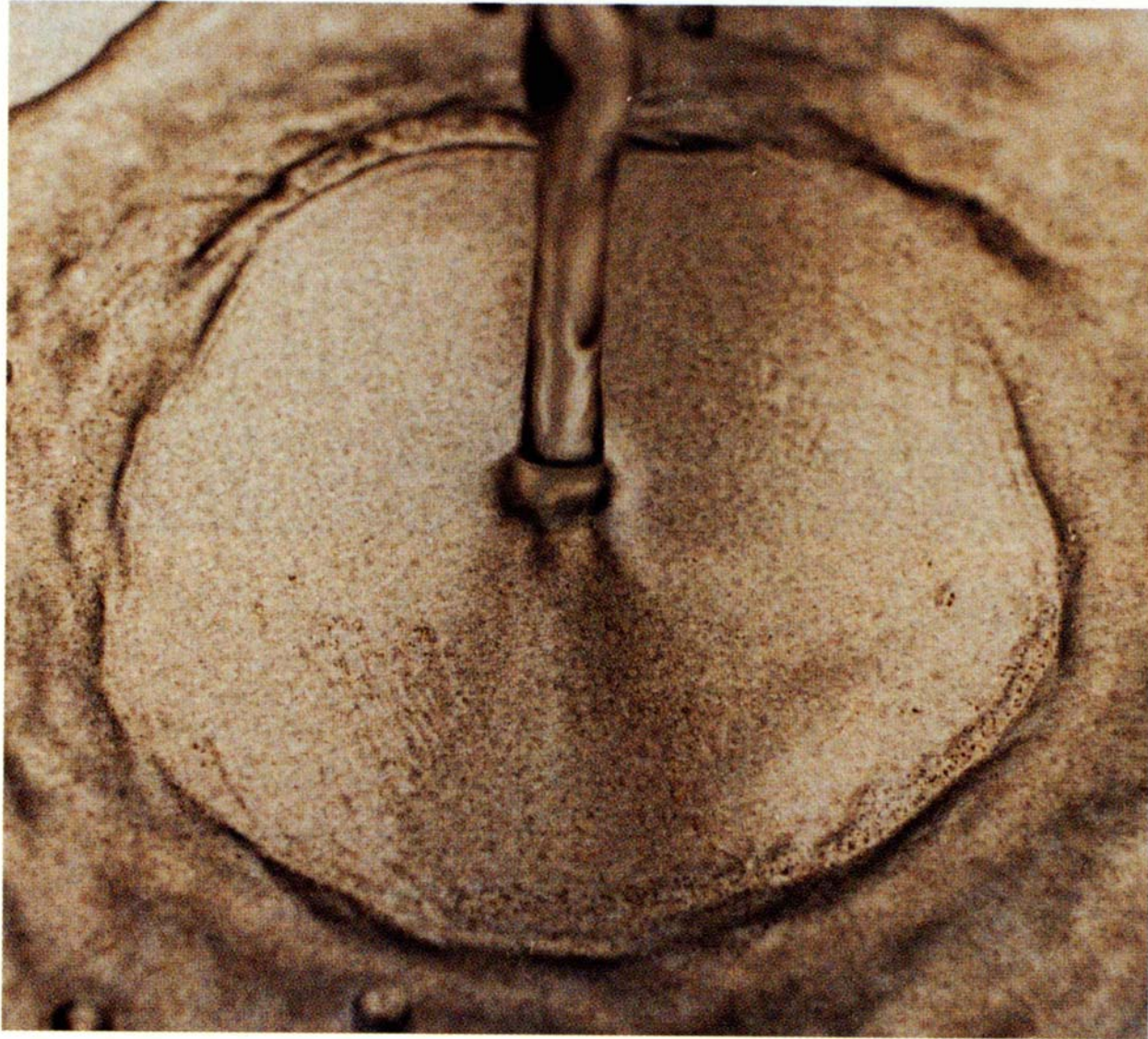
Termination Shock

Heliopause

Bow Shock

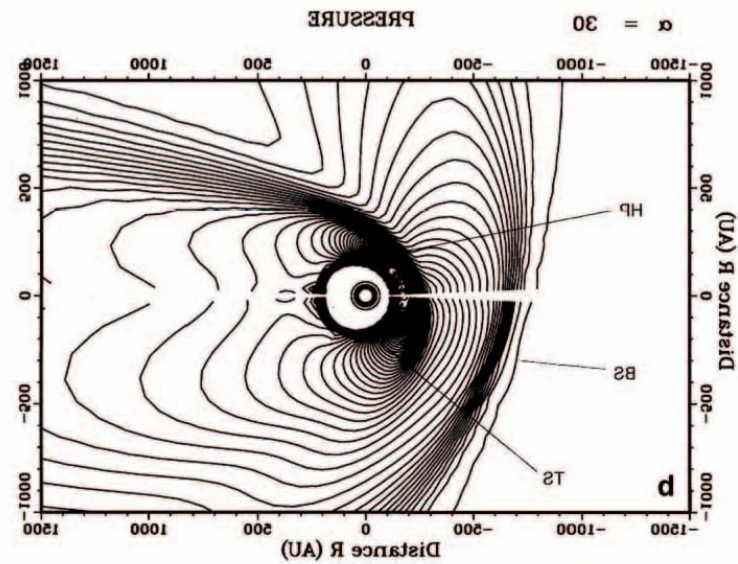


An instructive analog may be seen in a kitchen sink.

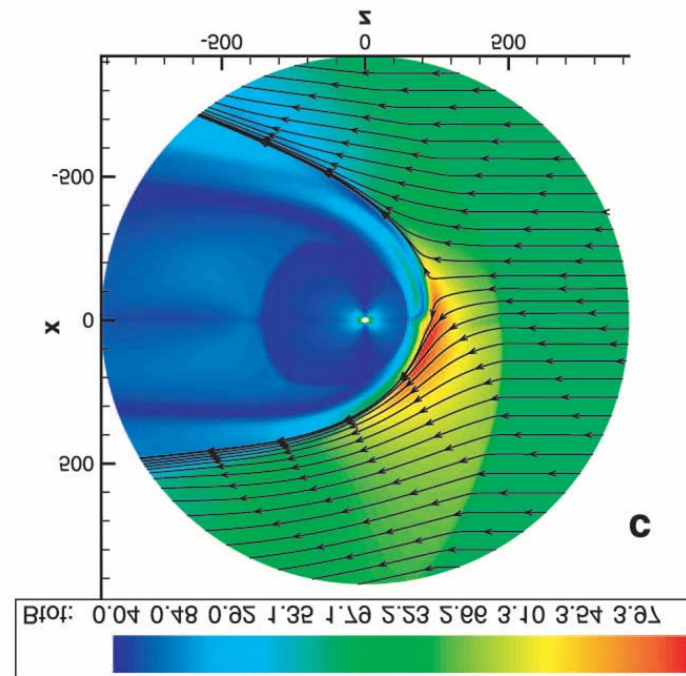


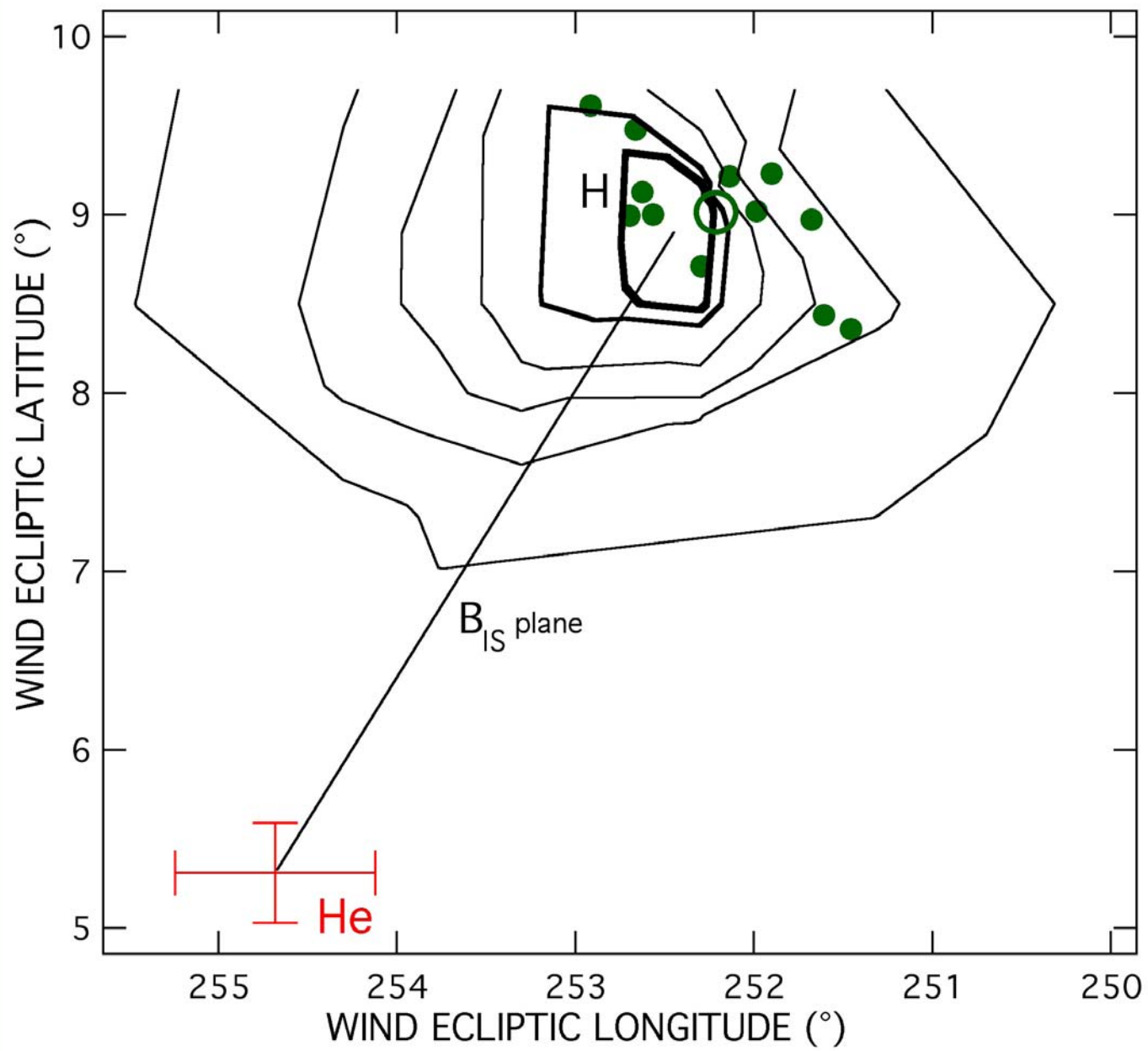
J. R. JOKIPII

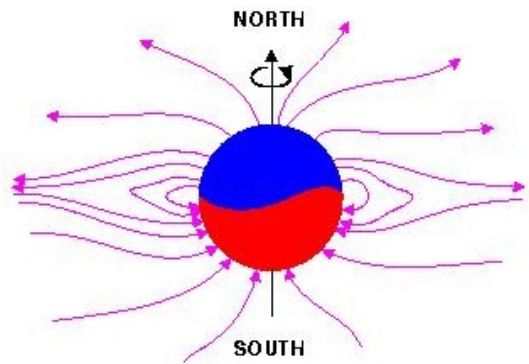
Ratkiewics, et al
(1998)



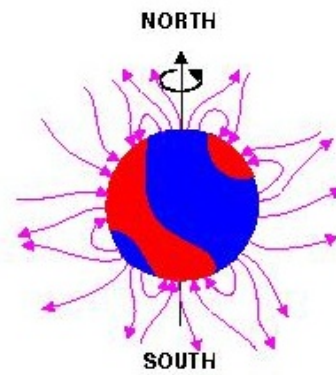
Pogorelov, et al
(2004)



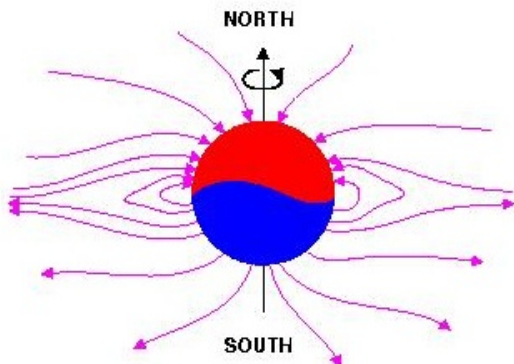




**CORONAL MAGNETIC FIELD LINES AT
SOLAR MINIMUM ACTIVITY**

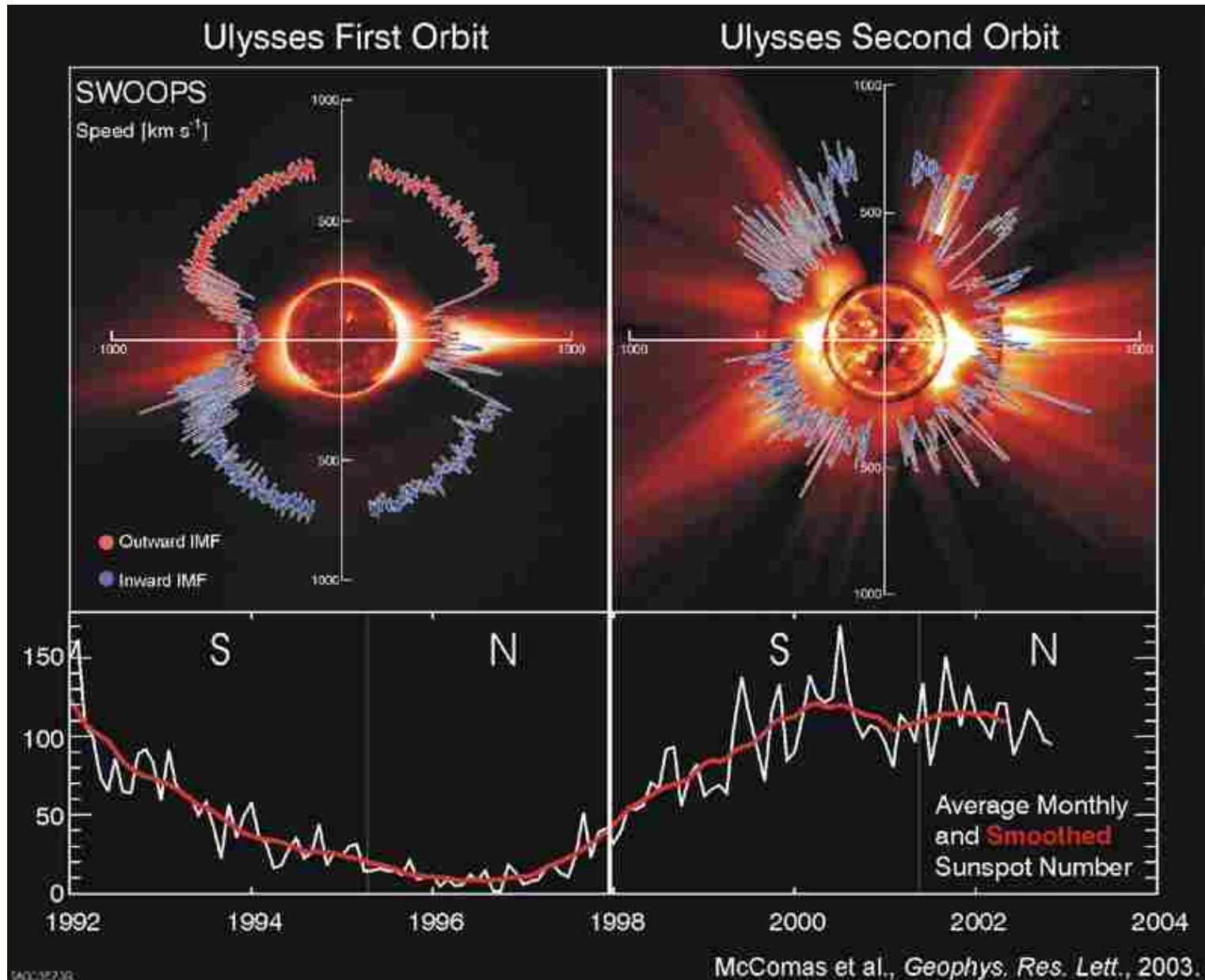


**CORONAL MAGNETIC FIELD LINES AT
SOLAR MAXIMUM ACTIVITY**

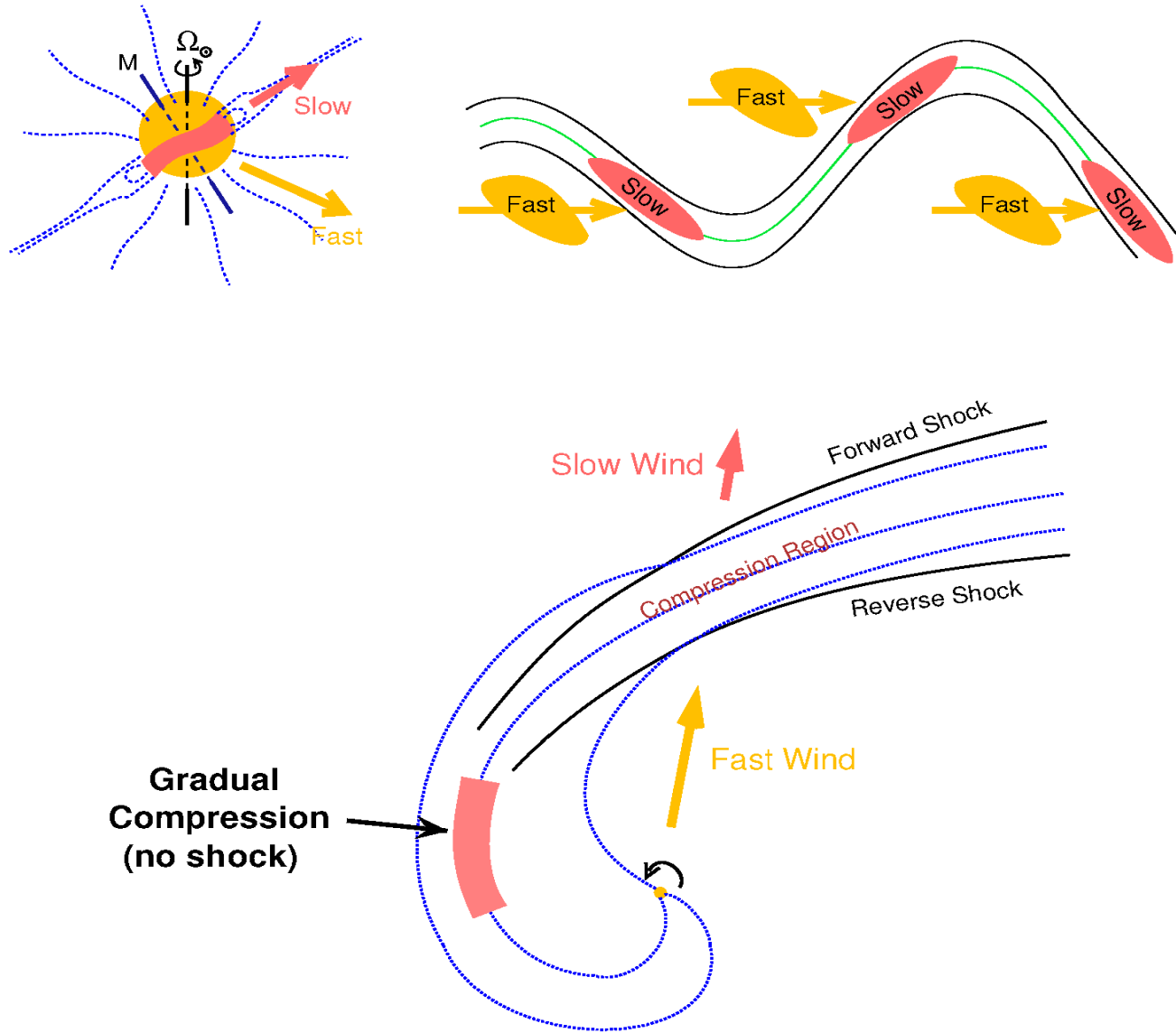


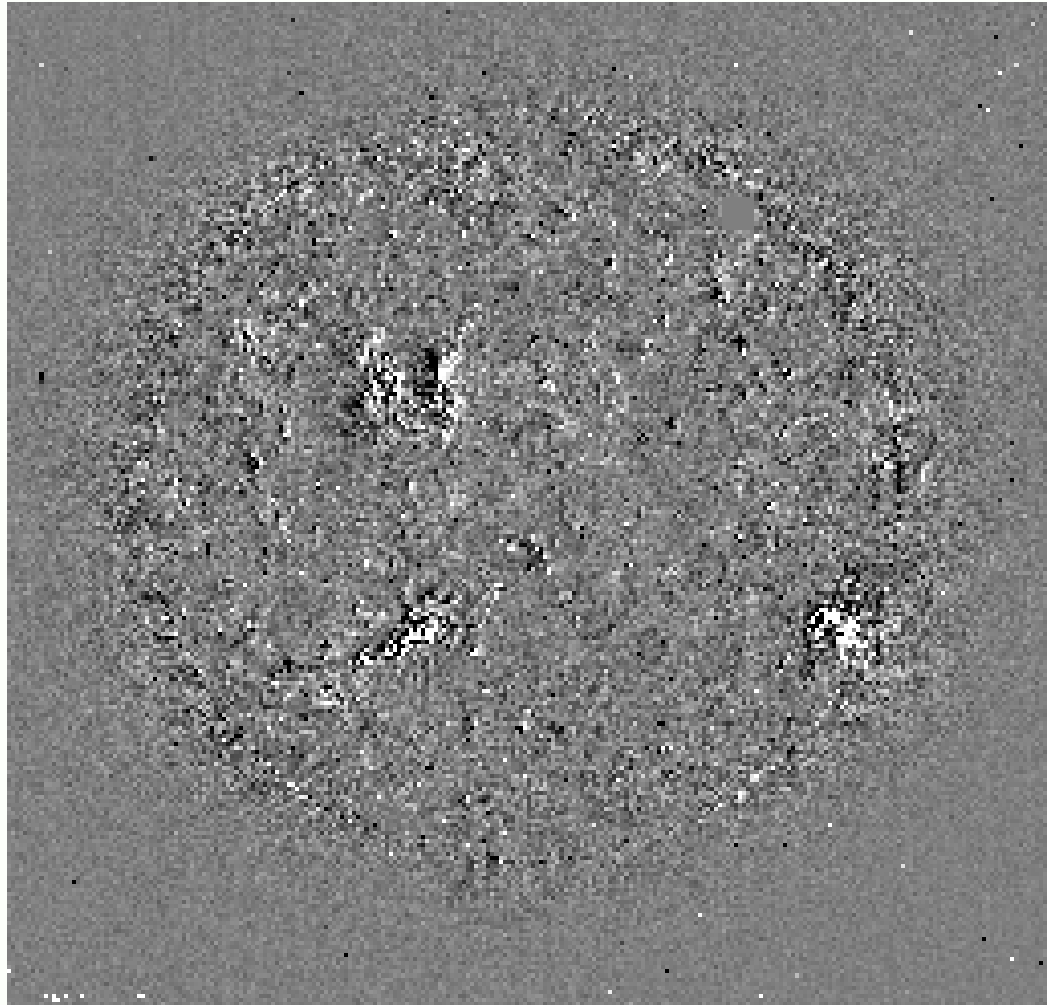
**CORONAL MAGNETIC FIELD LINES AT
NEXT SOLAR MINIMUM**

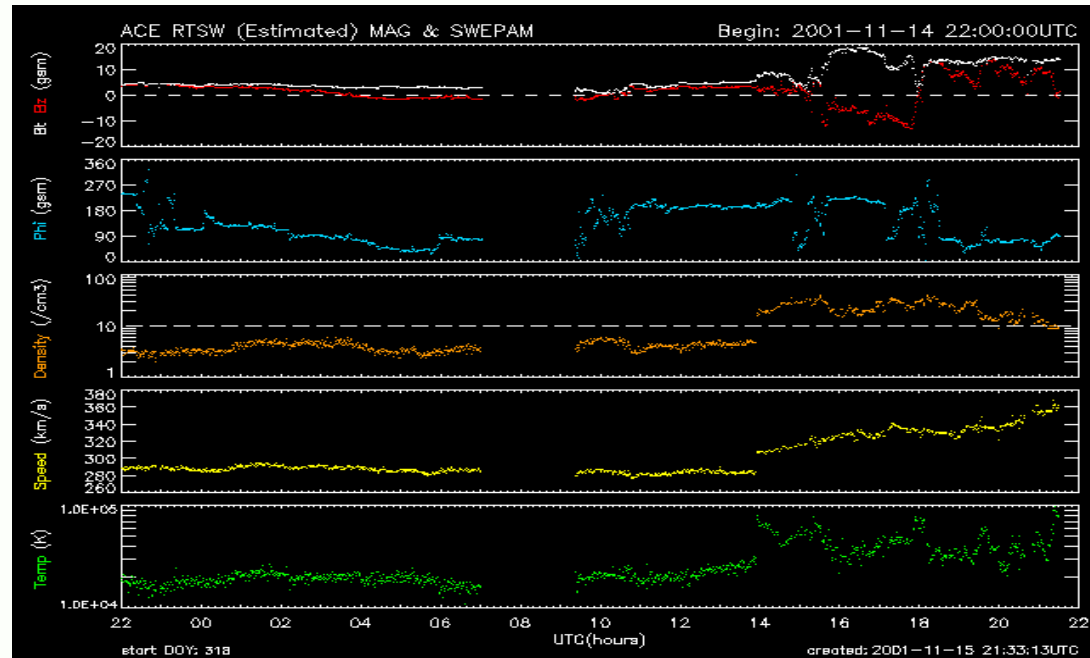
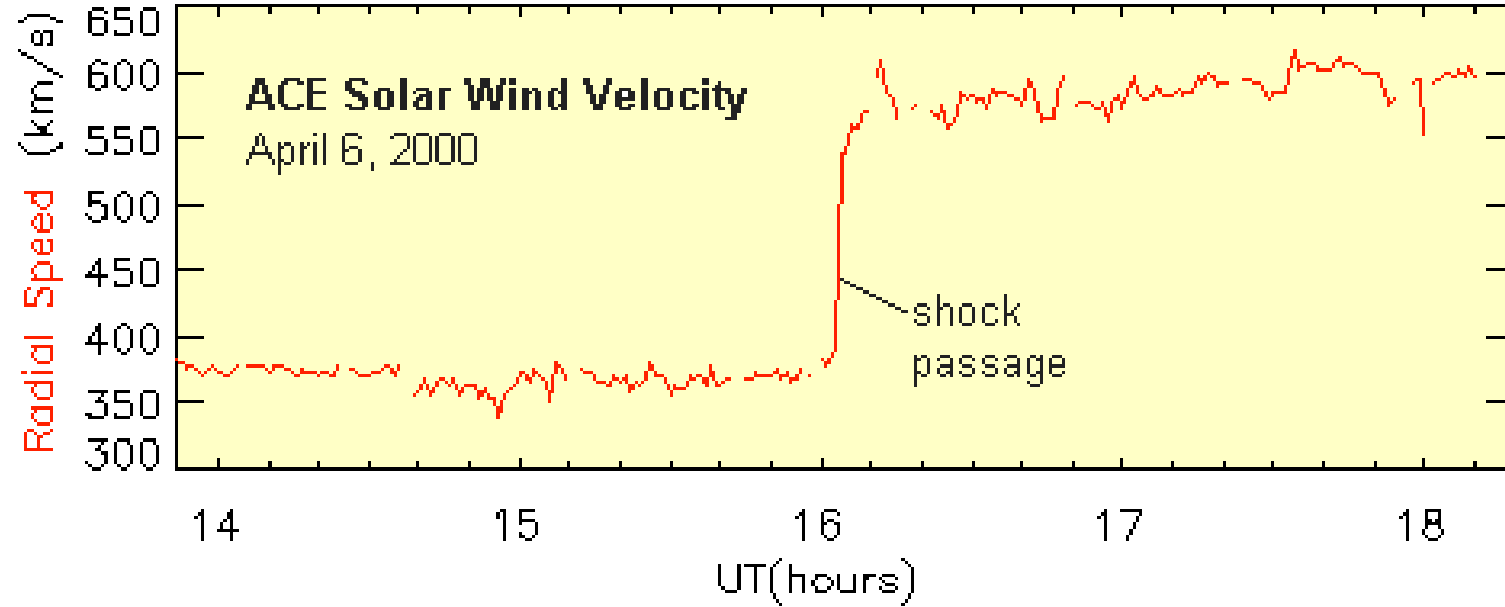
Solar Maximum is more complex.

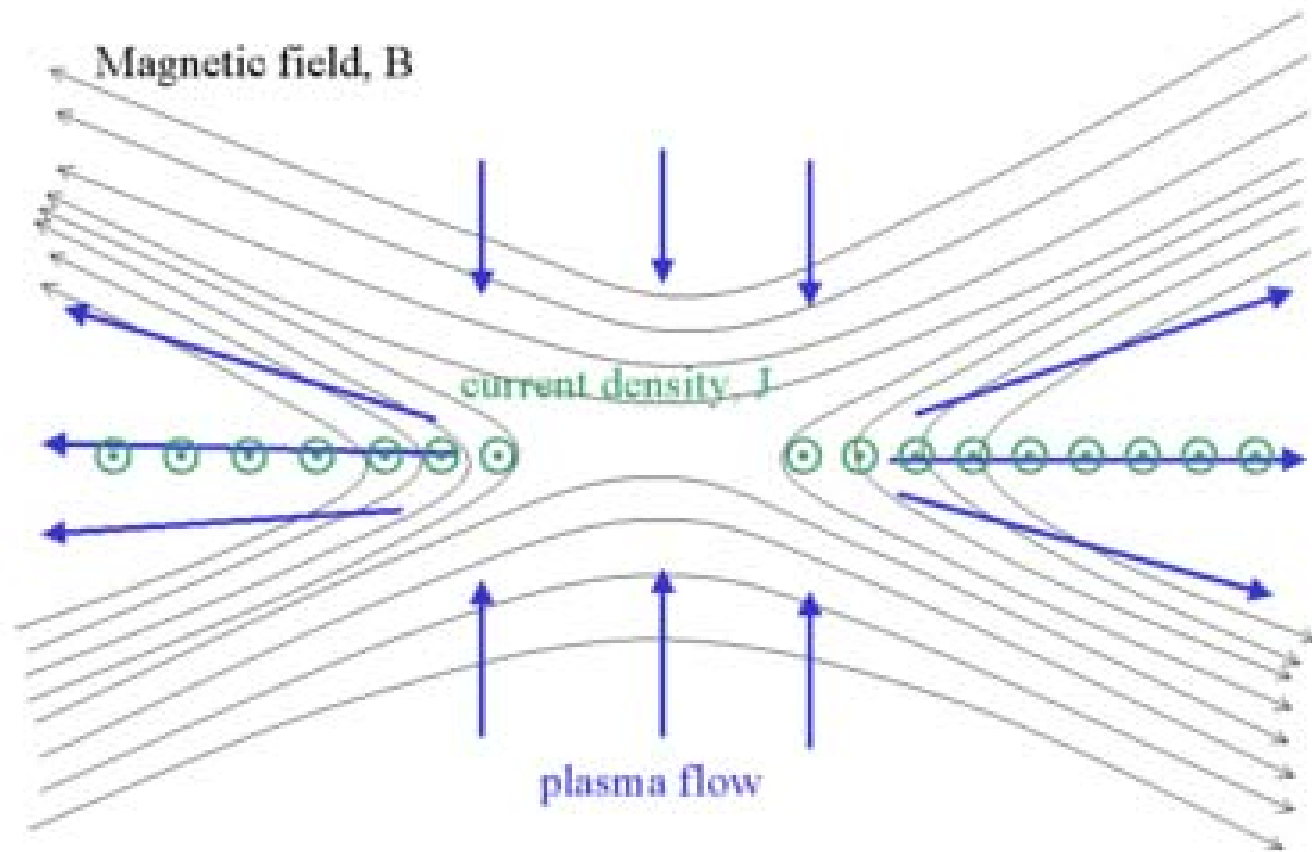


Co-rotating Interaction Regions

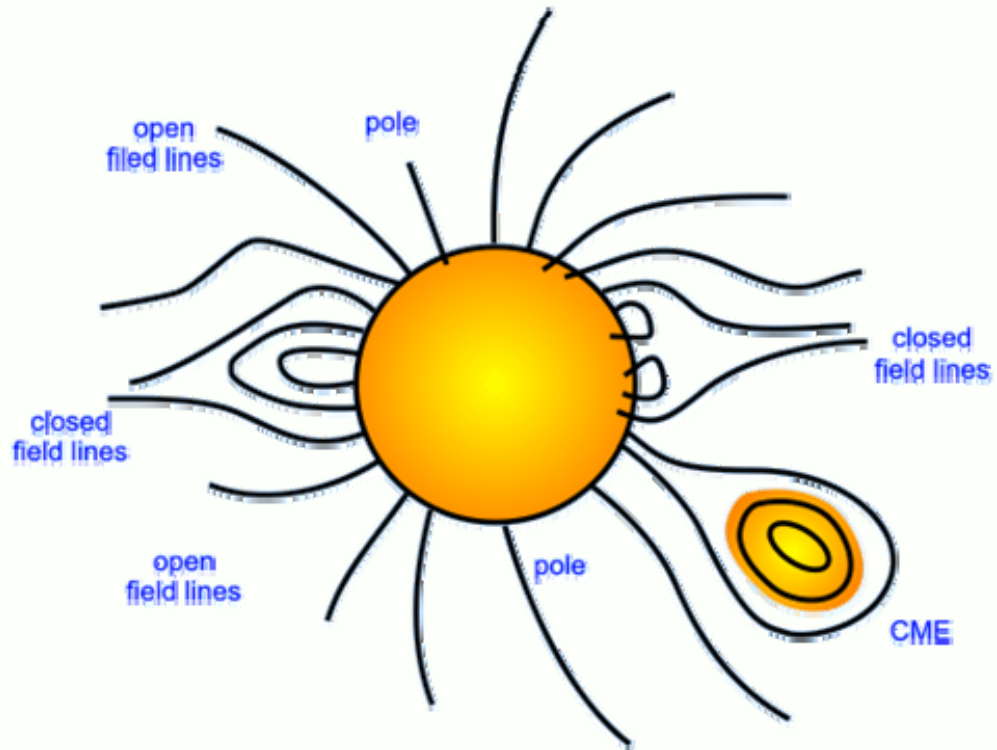












Lecture 3

3-1

dimensionless variables

$$\xi = \frac{r}{r_0}$$

$$\tau = \frac{T}{T_0}$$

$$\psi = \frac{u_{in}^2}{c_s^2}$$

$$\lambda = \frac{GmM_0}{r_0 k T_0}$$

putting into momentum eqn, using continuity

$$\left(1 - \frac{\tau}{\psi}\right) \frac{d\psi}{d\xi} = -2\xi^2 \frac{d}{d\xi} \left(\frac{\tau}{\xi^2}\right) - \frac{2\lambda}{\xi^2}$$

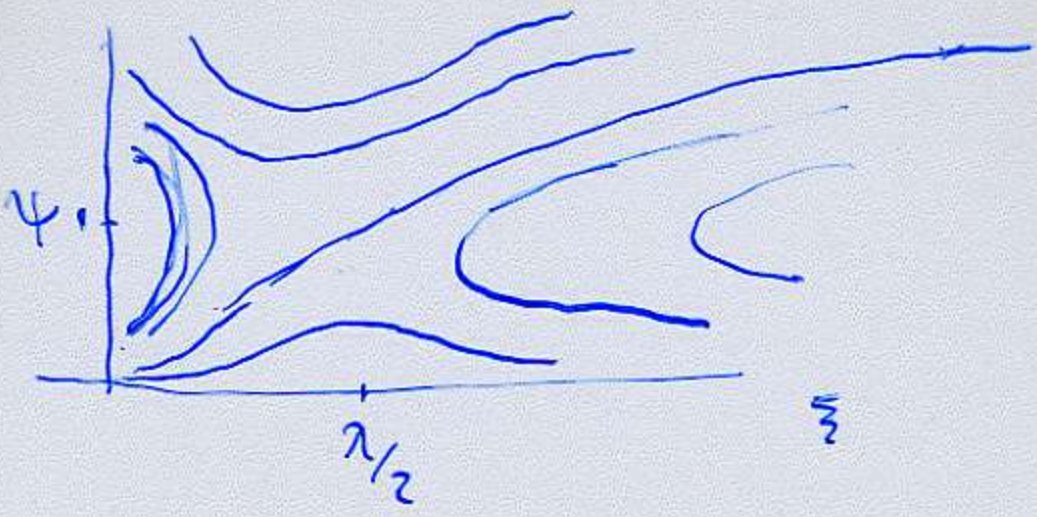
now make isothermal $\Rightarrow \tau = 1$

$$\left(1 - \frac{1}{\psi}\right) \frac{d\psi}{d\xi} = \frac{2}{\xi} \left(2 - \frac{2}{\xi}\right)$$

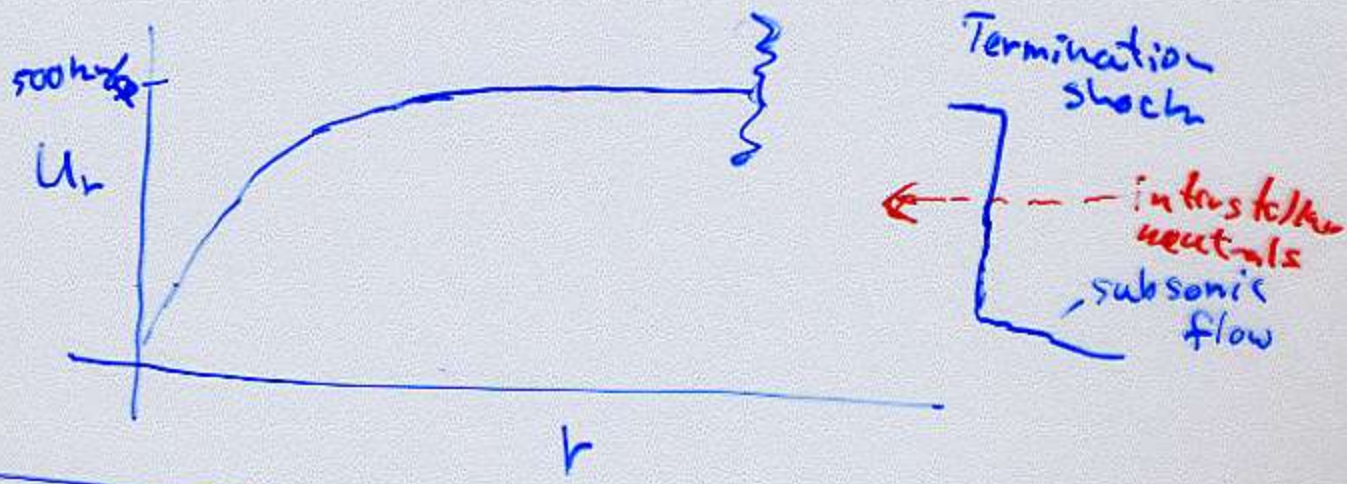
integrate

$$\psi - \ln \psi = 4 \ln \xi + \frac{2\lambda}{\xi} + C$$

$$\frac{d\psi}{d\xi} = \frac{\frac{2}{\xi} \left(2 - \frac{2}{\xi}\right)}{\left(1 - \frac{1}{\psi}\right)}$$



real wind



Ideal MHD is dissipationless.

we can add resistance (finite conductivity)
viscosity

shocks, turbulence (small scale)

reconnection produce large dispersion

but only at small scales

Important dimensionless parameters
Schematically

3-3

$$\rho u \frac{du}{dx} = P + \frac{B^2}{5\pi}$$

$$\frac{n k T}{B^2 / 4\pi} = \beta$$

thermal energy
↓
magnetic energy

if $\beta \gg 1$ thermal energies dominate
 $\beta \ll 1$ magnetic dominates