Solar Wind Origin & Heliospheric Evolution

Tom Holzer

NCAR/HAO

Topics to be Discussed

Remote sensing of the solar wind acceleration region

Extension of the solar wind into the heliosphere

Some relevant physical principles

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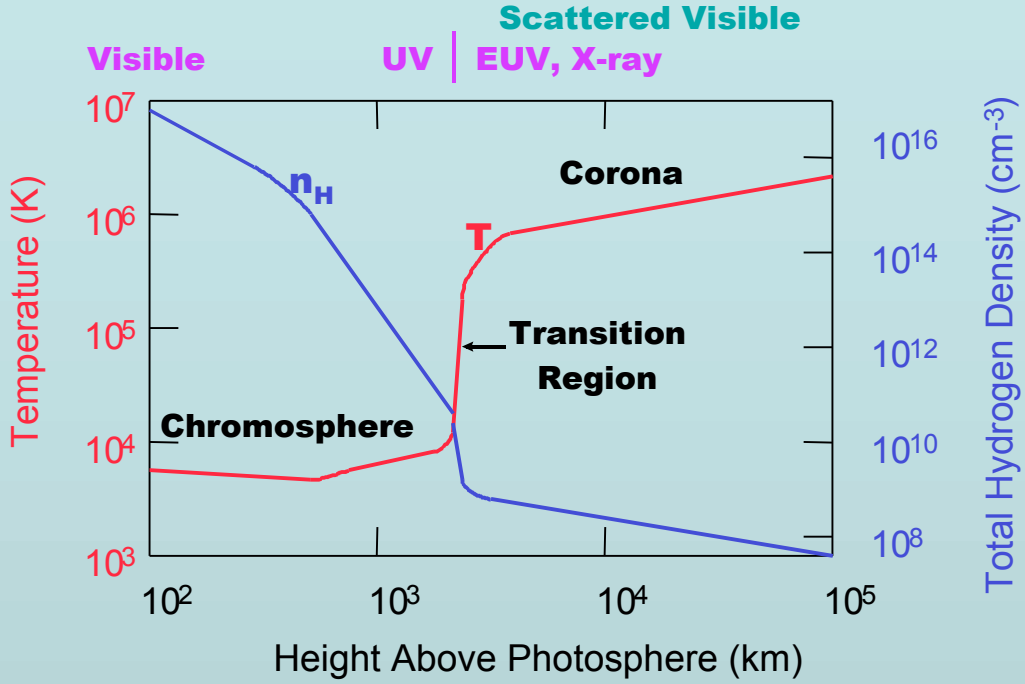
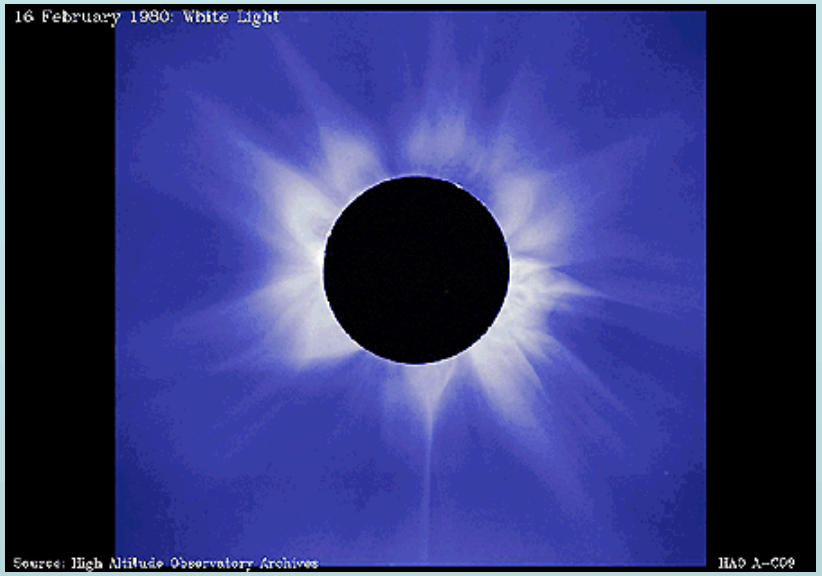
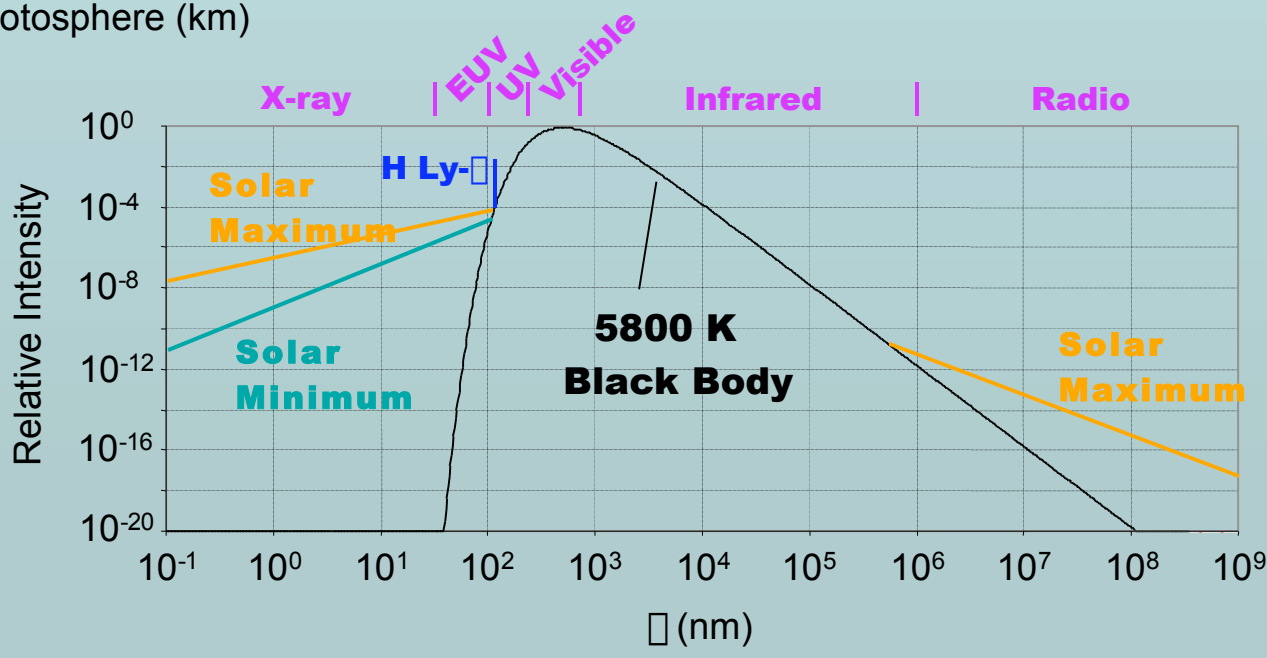
Some relevant physical principles

The Solar Atmosphere



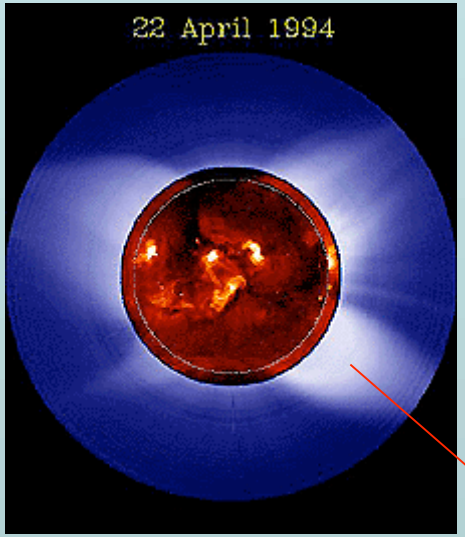


Radiative Output



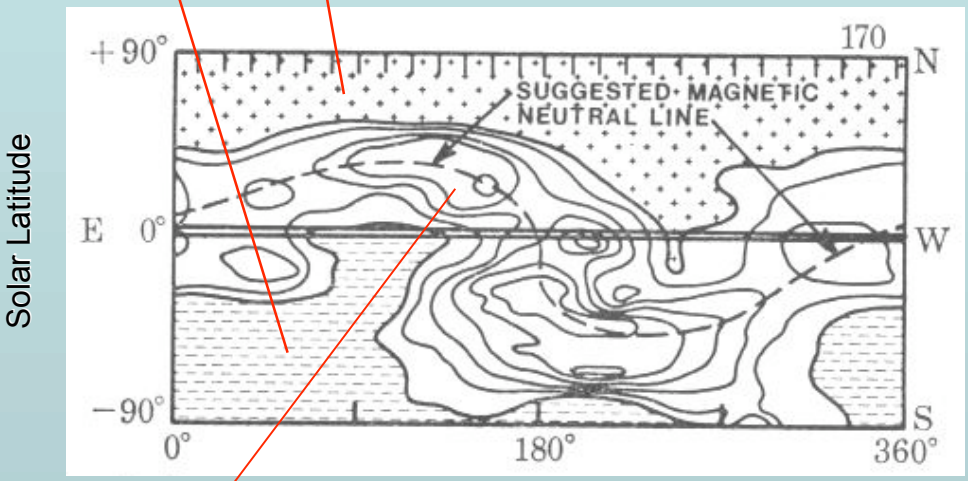
Making a Synoptic Map

Predominant magnetic polarity



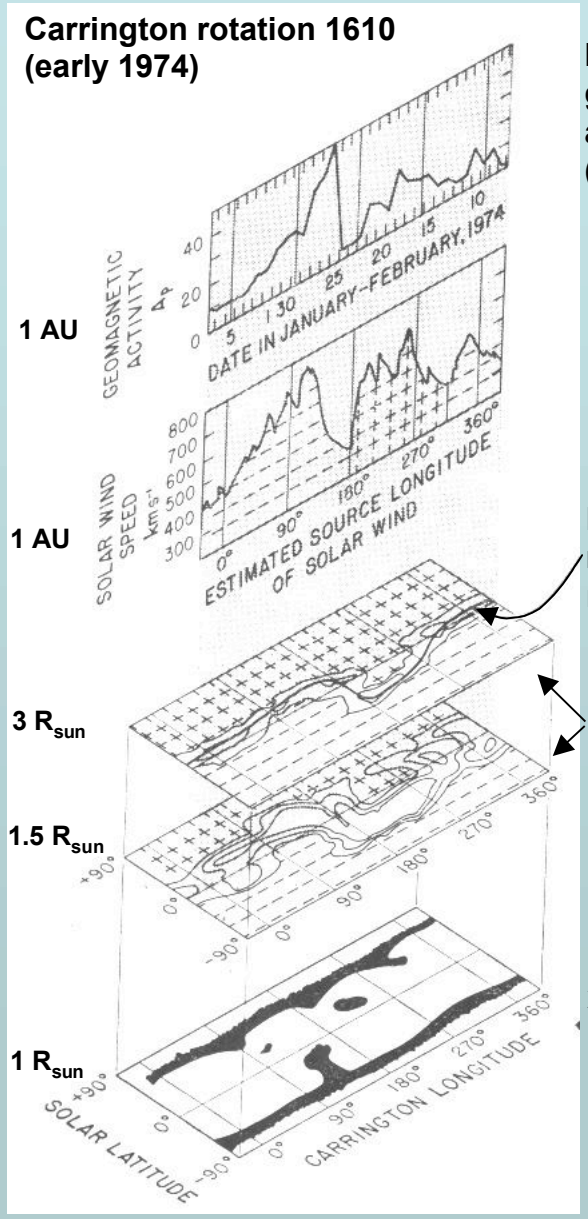
YOHKOH & HAO

Hundhausen, 1980



K-corona in white light (i.e., visible)

Remote Sensing of Solar Wind Origin



Recurrent geomagnetic activity (mapped)

Solar wind speed and magnetic polarity (mapped)

Inferred magnetic neutral line

Coronal polarization brightness

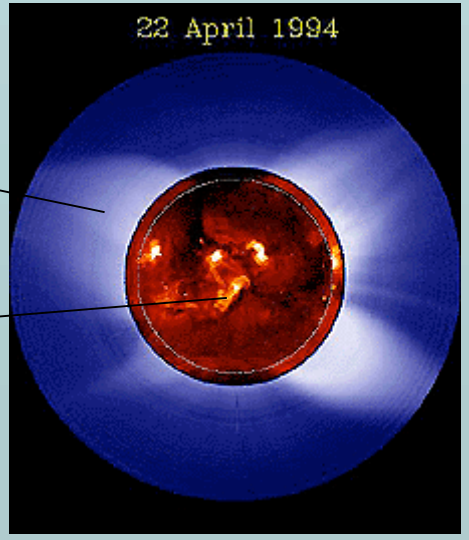
Coronal x-ray emission

Hundhausen, 1980

***In situ* observations: n, u, T, q, B; also geomagnetic activity** *(Neugebauer, Tues. PM)*

← Mapping back to the Sun

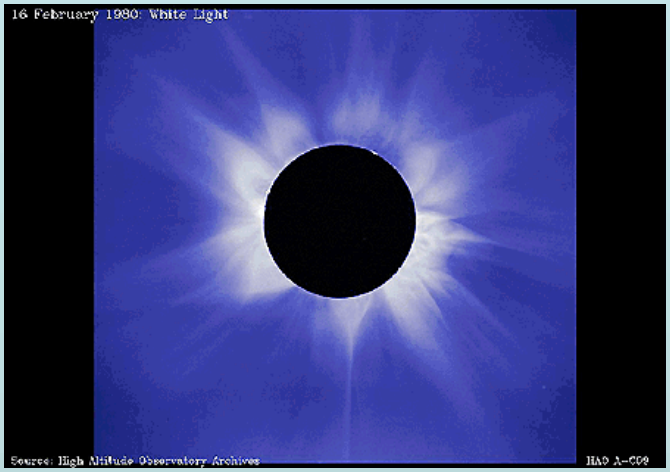
Comparison with disk and limb solar observations (also radio)



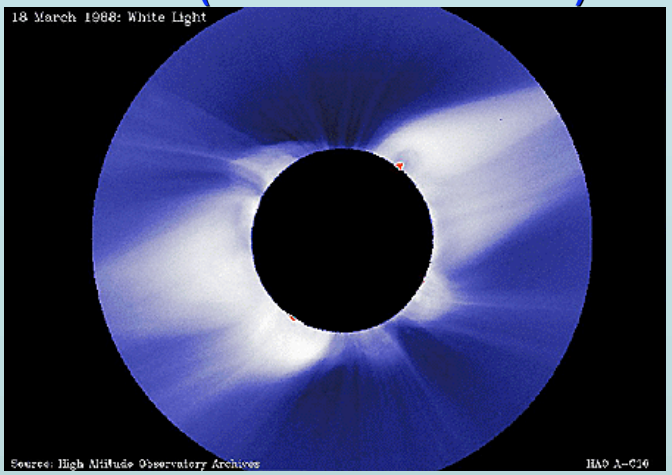
YOHKOH & HAO

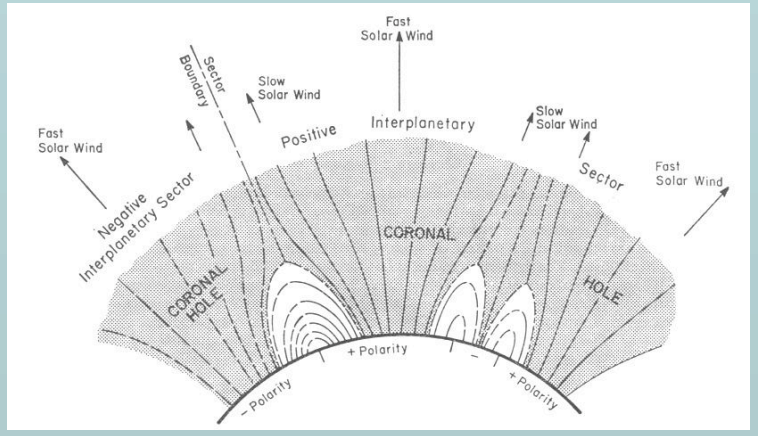
Origin of the Fast and Slow Solar Wind

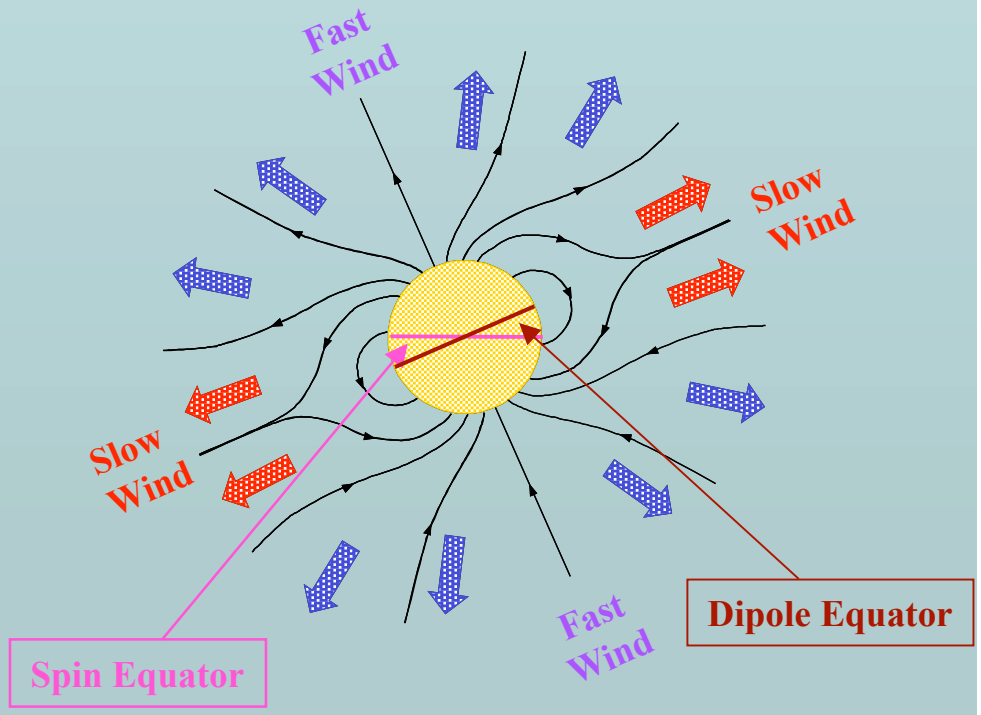
1980 (Solar Maximum)



1988 (After Solar Minimum)







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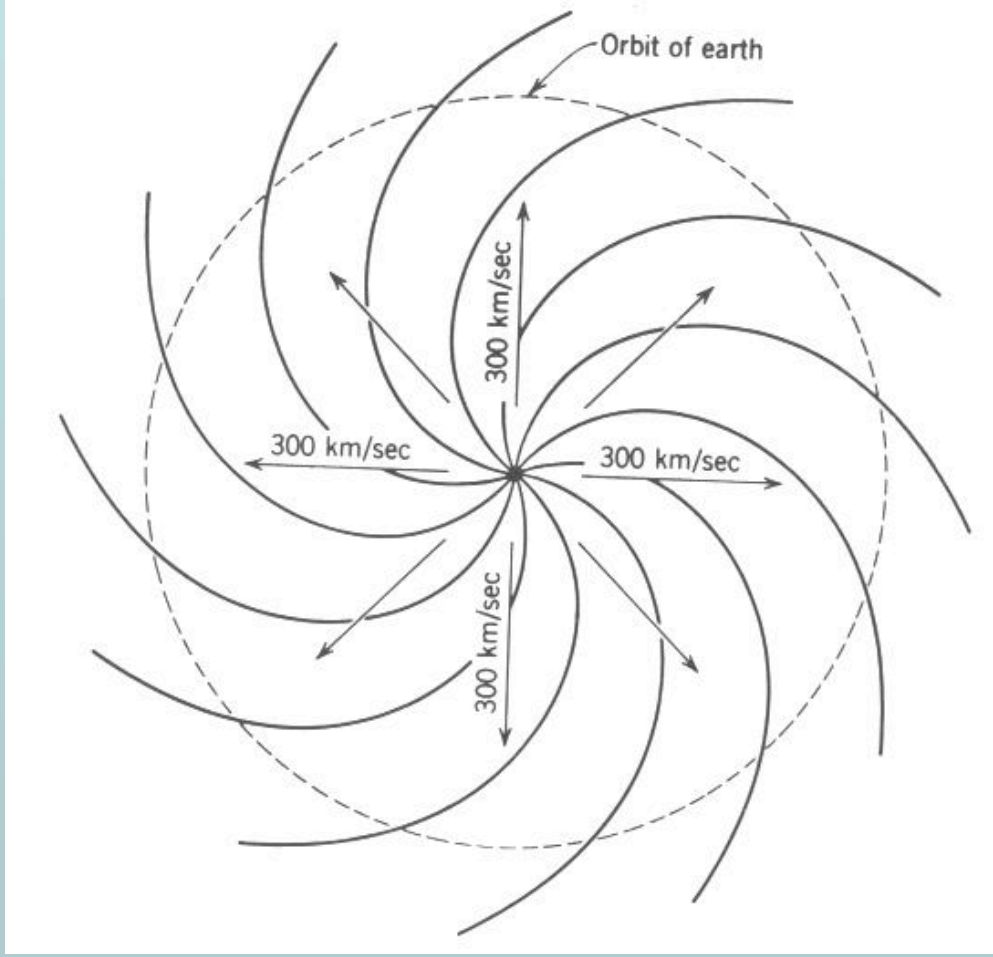
Remote sensing of the solar wind acceleration region

Extension of the solar wind into the heliosphere

Some relevant physical principles

Extension of the Solar Wind into the Heliosphere

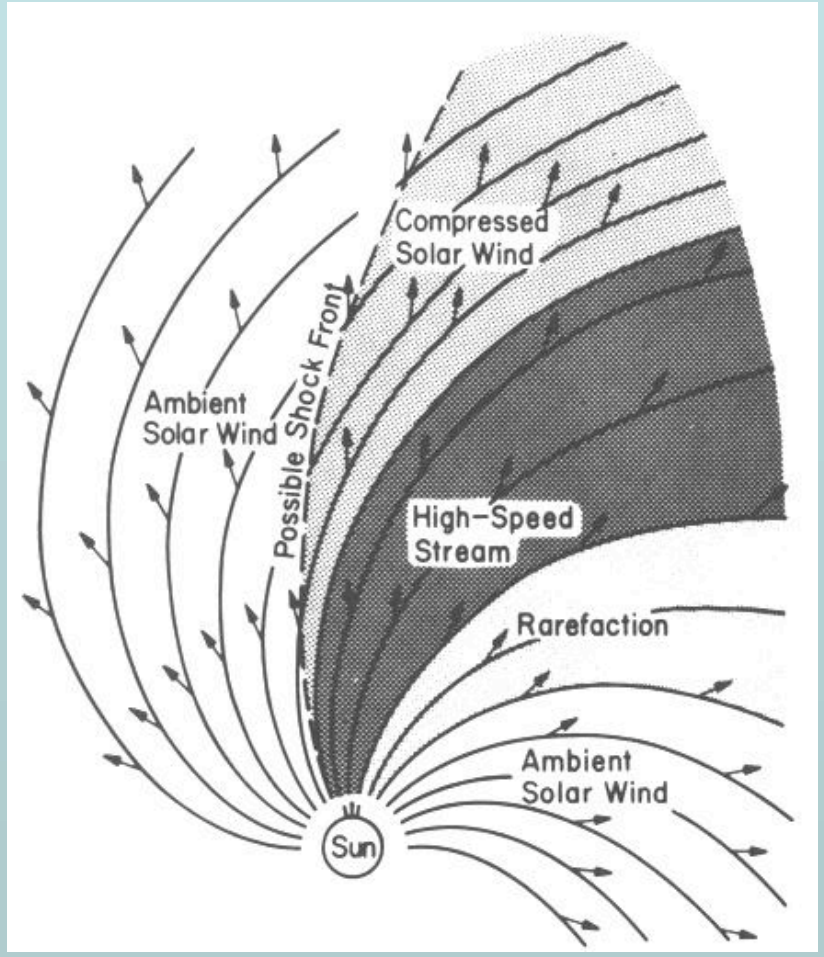
The Interplanetary Magnetic Field



Parker (1963)

Extension of the Solar Wind into the Heliosphere

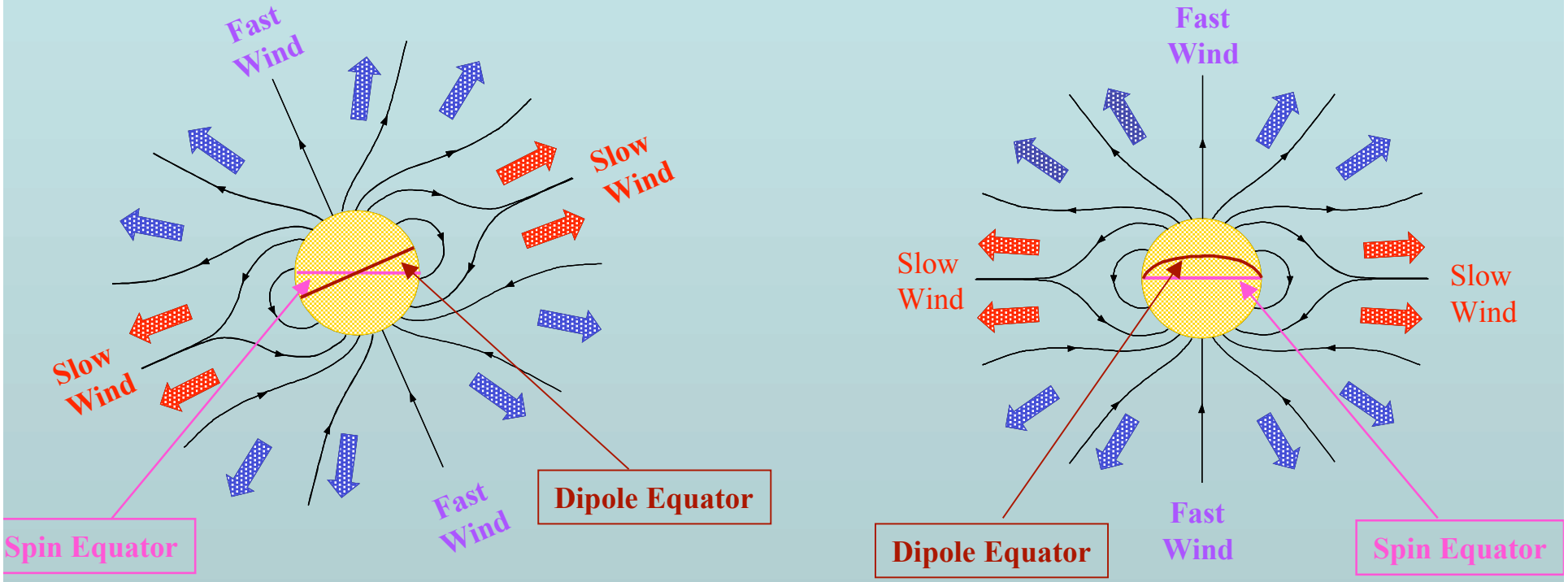
Stream Interactions



Hundhausen (1972)

Extension of the Solar Wind into the Heliosphere

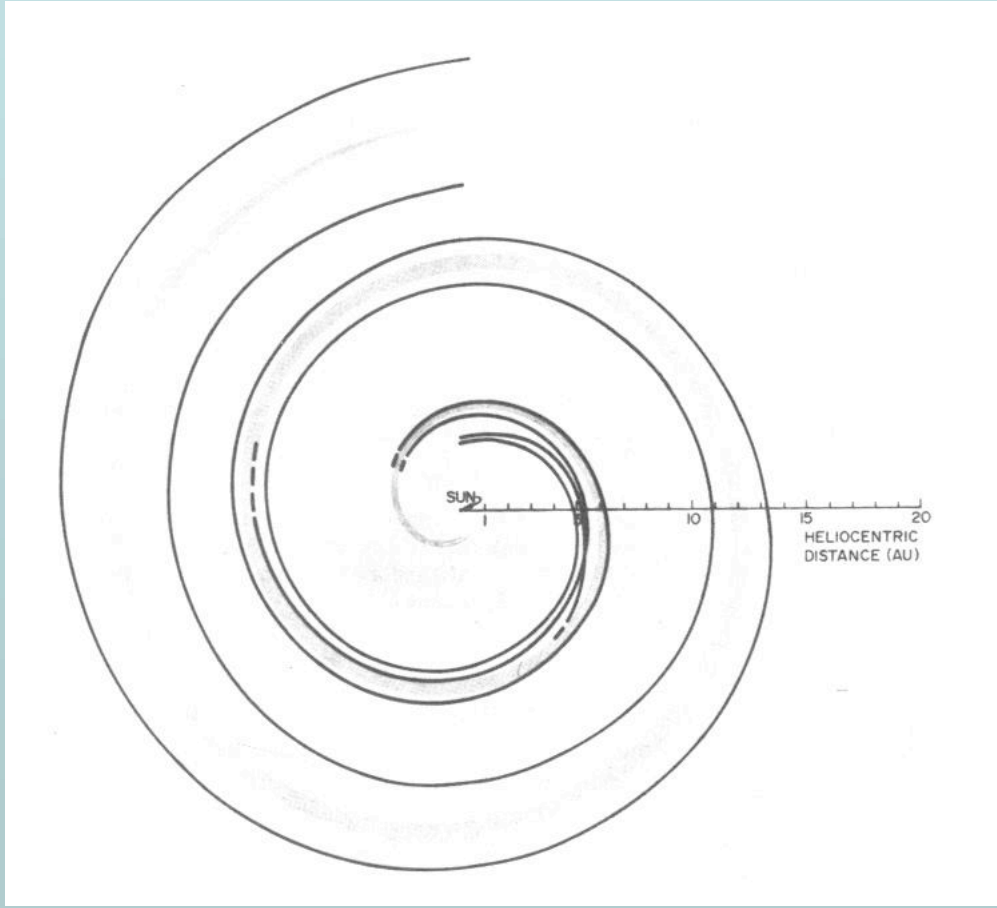
Four-Stream Source



Meridian Planes Separated by 90° in azimuth

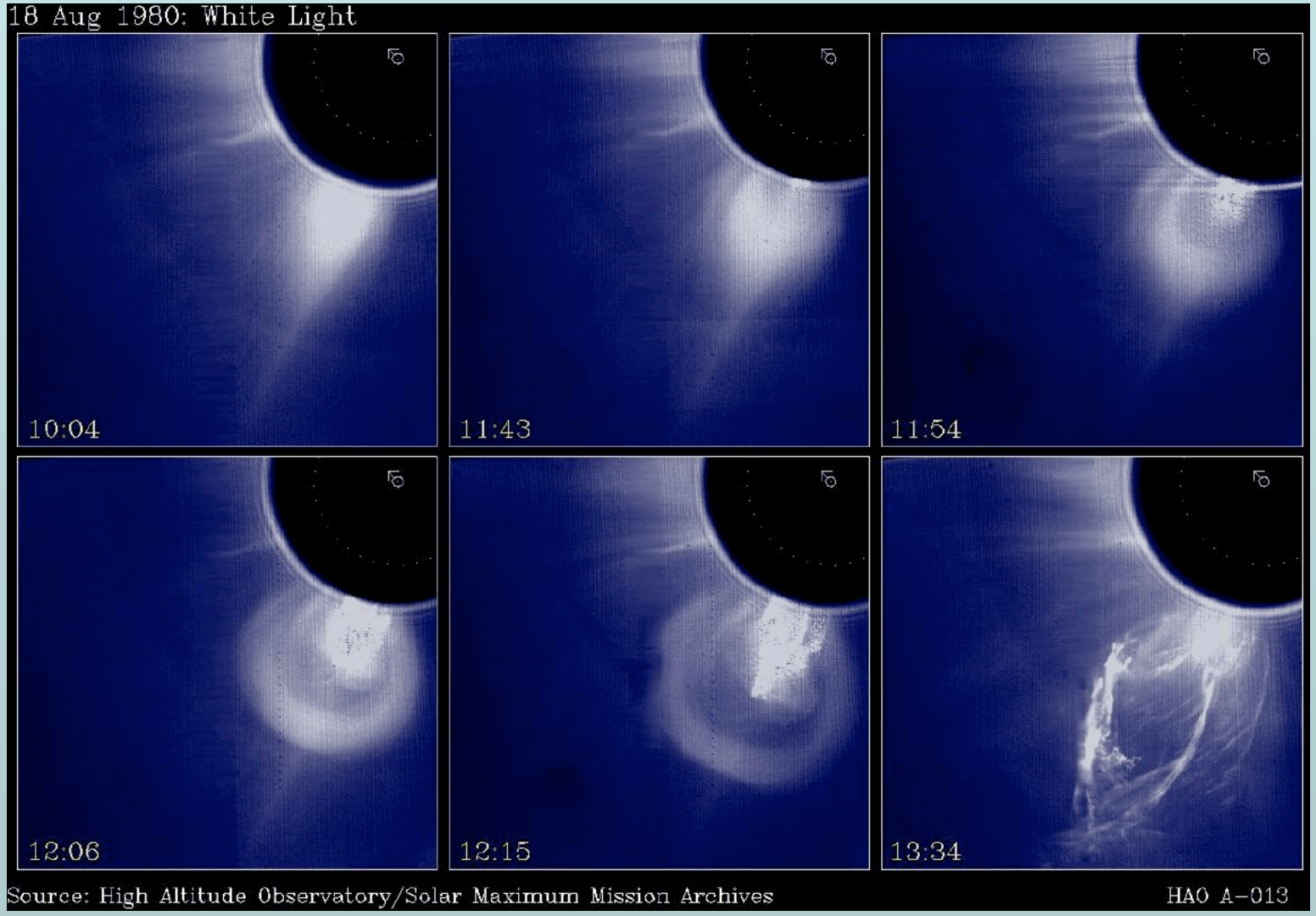
Extension of the Solar Wind into the Heliosphere

Four-Stream Evolution



Hundhausen & Pizzo (1976)

Coronal Mass Ejection



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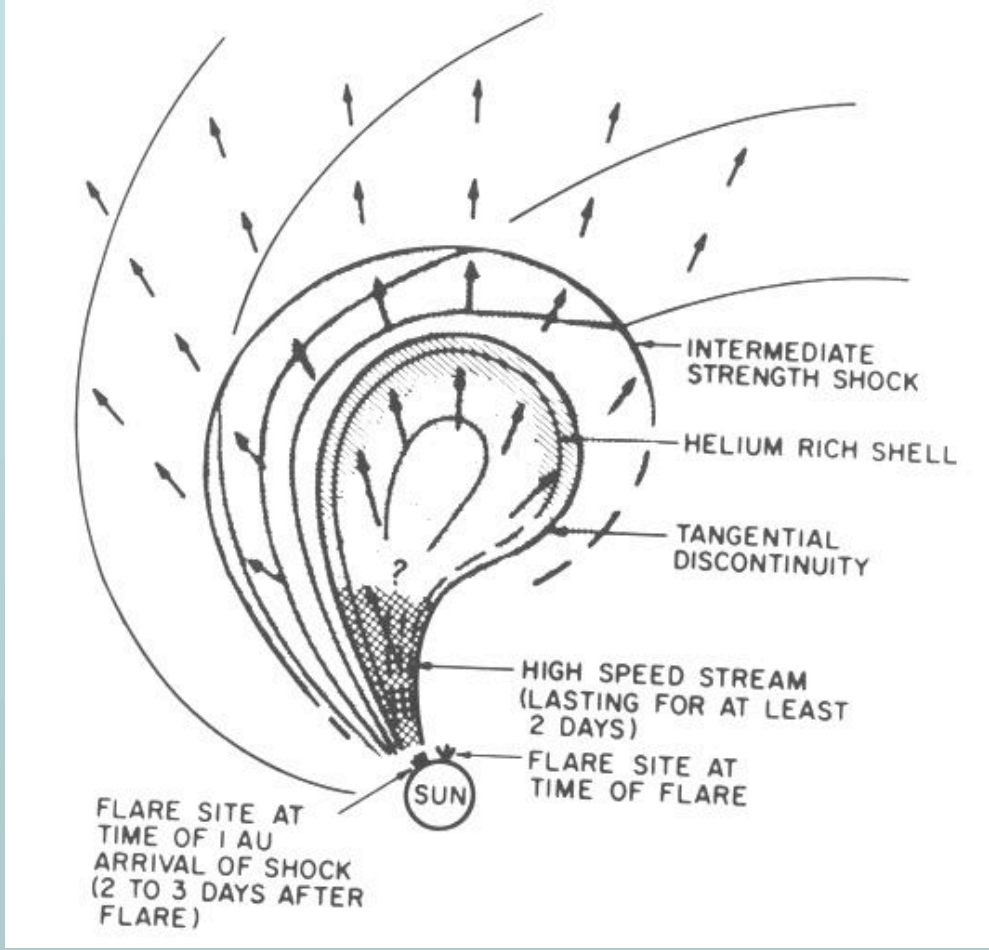
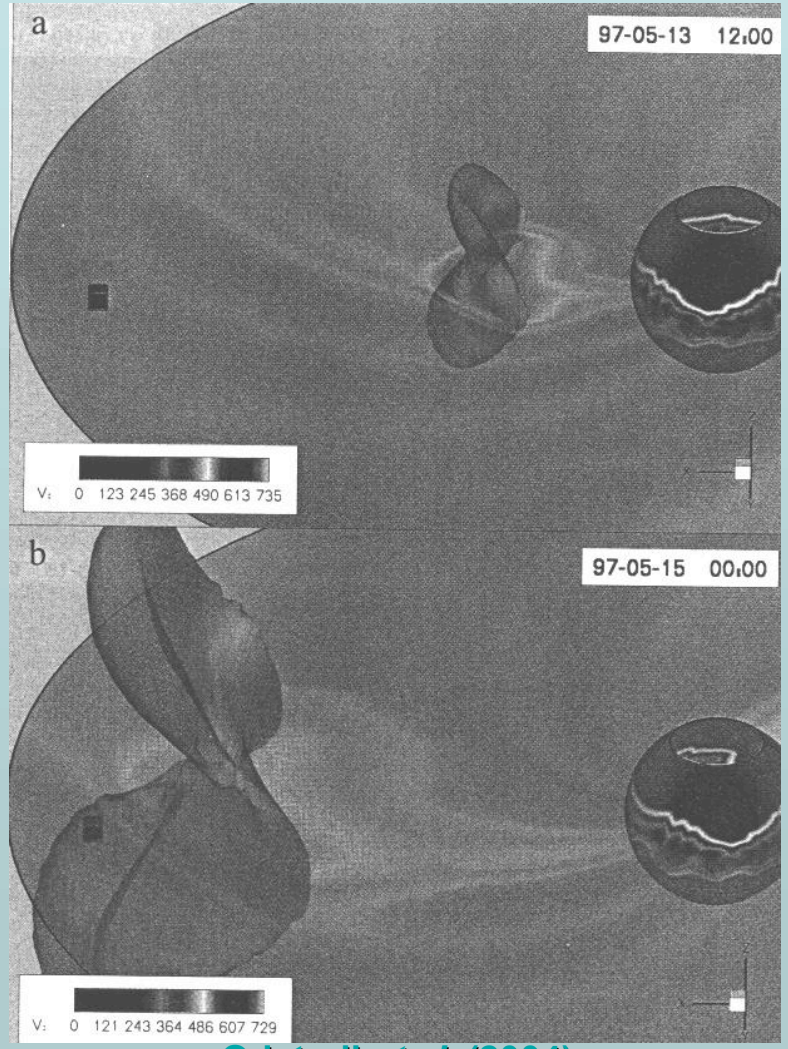
Coronal Mass Ejection



Hundhausen (1972)

Extension of the Solar Wind into the Heliosphere

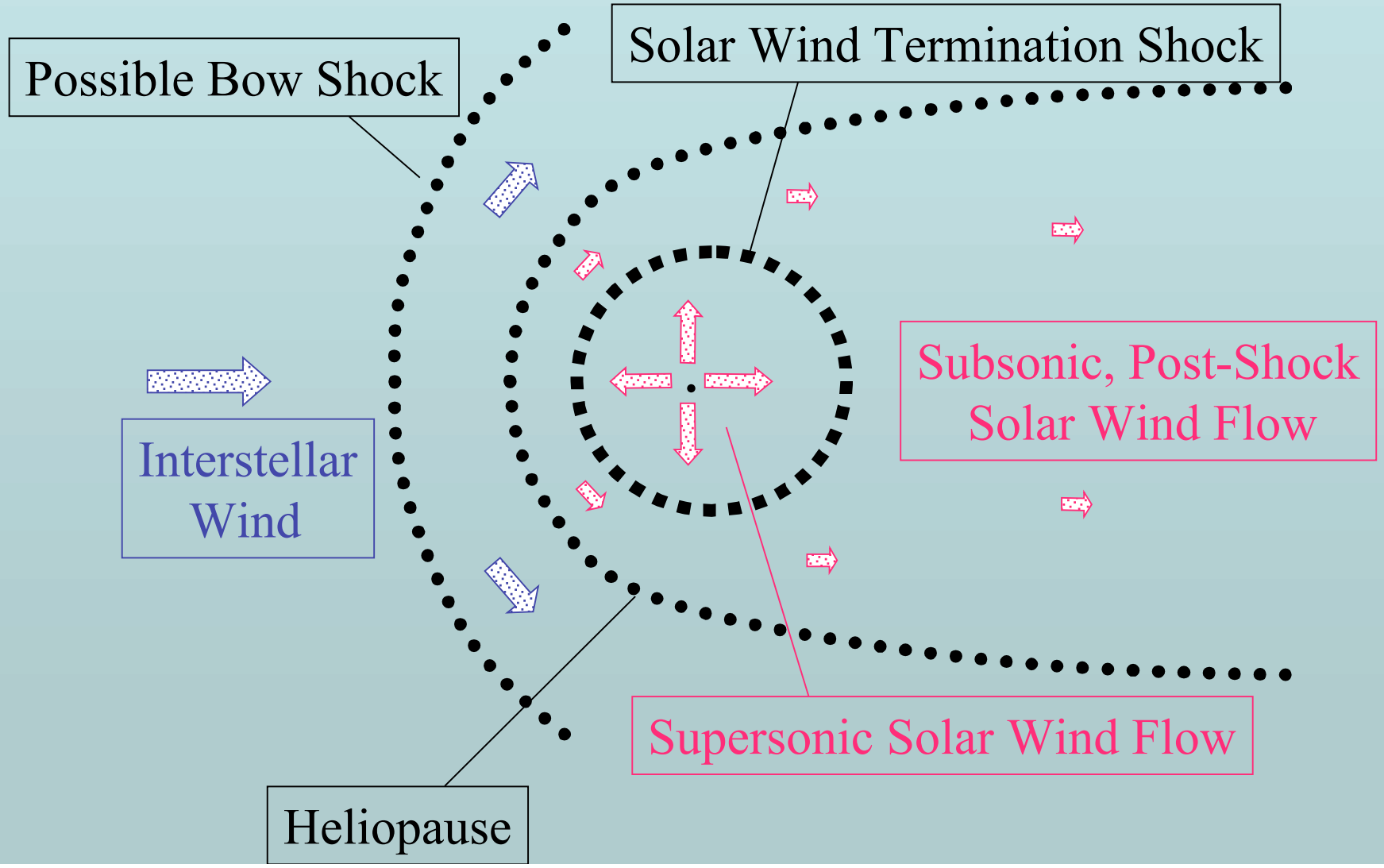
3-D CME Evolution



Odstrcil *et al.* (2004)

Extension of the Solar Wind into the Heliosphere

Interaction with the Interstellar Medium



Topics to be Discussed

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Extension of the solar wind into the heliosphere

Some relevant physical principles

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- Conservation laws for a fluid
- The transonic wind solution
- Chromosphere-corona coupling
- Freezing in of the ionization state
- Potential field extrapolation

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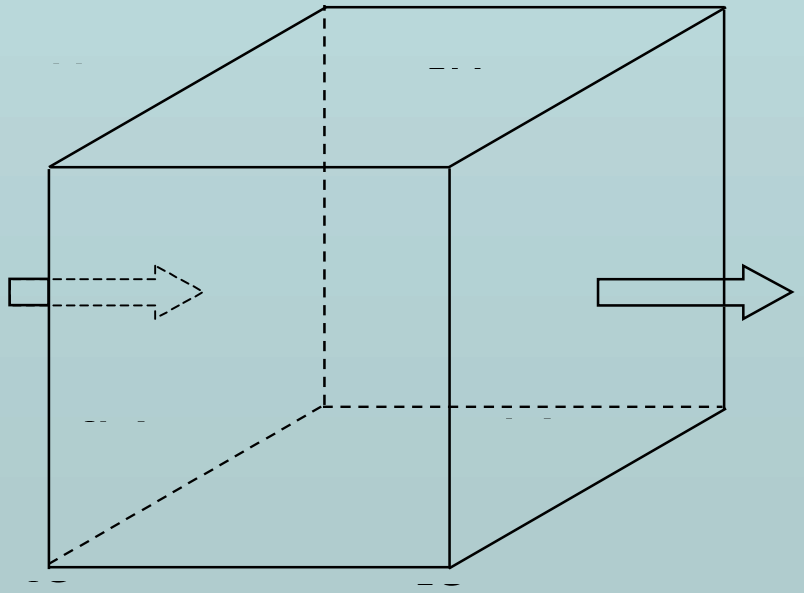
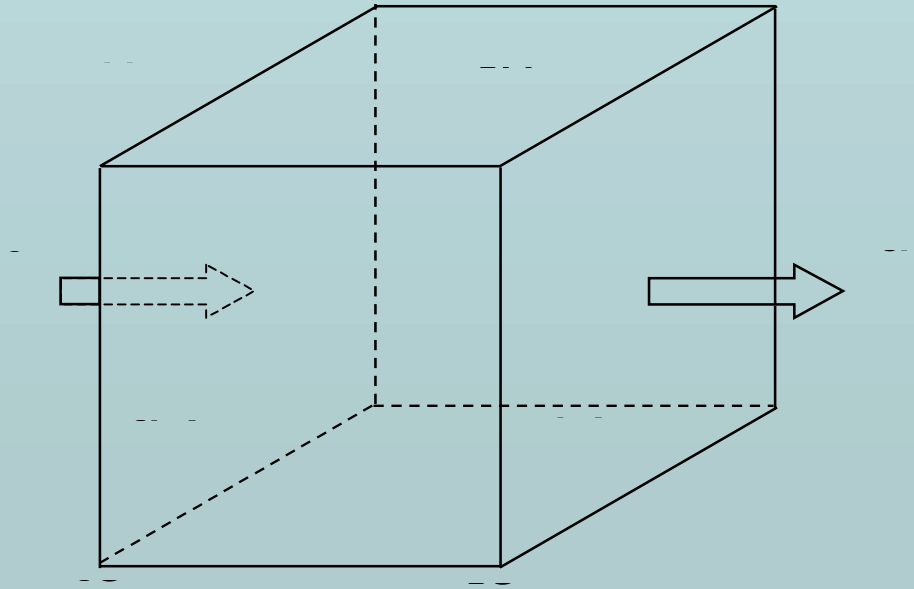
Conservation of Particles



Conservation of Particles and Mass

Particle Conservation with sources and sinks:

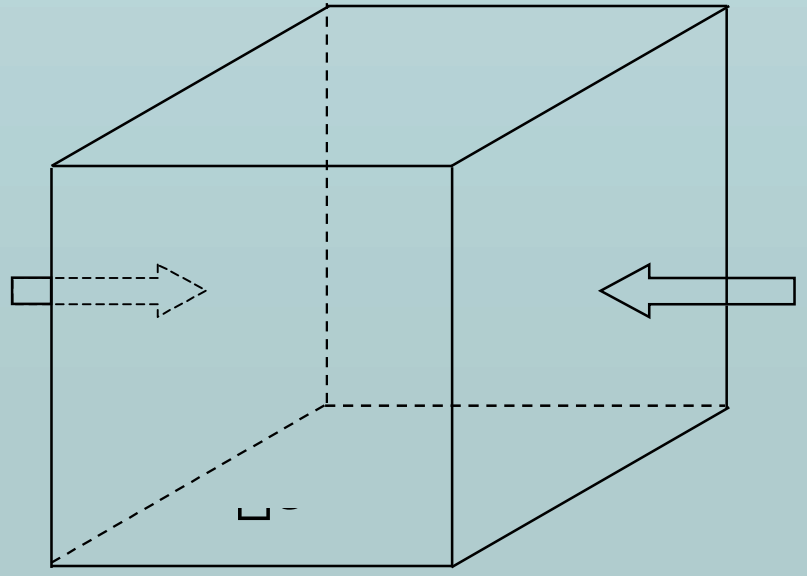
Mass Conservation (no sources or sinks)



Conservation of Momentum

Conservation of Momentum (General Form)

Pressure Gradient Force



Conservation of Momentum and Equation of Motion

Conservation of Momentum

pressure gradient

gravity

waves

total force density

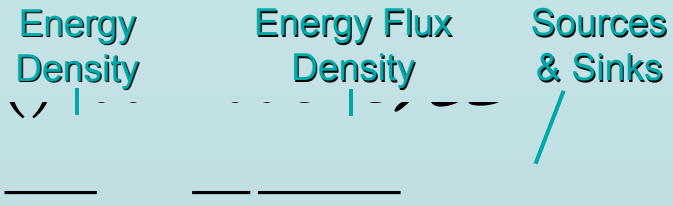
Conservation of Mass

Lorentz

Equation of Motion (without wave or Lorentz forces)

Conservation of Energy

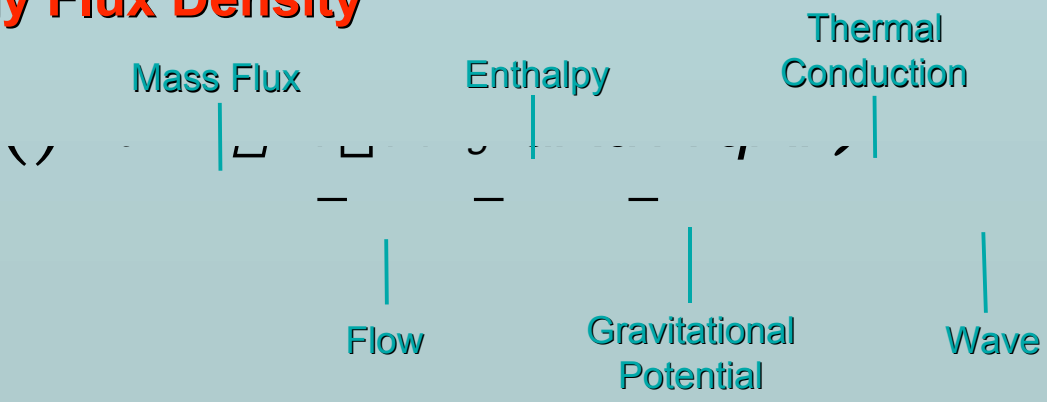
General Form



Source/Sink Term

Energy Density

Energy Flux Density



Topics to be Discussed

Some relevant physical principles

Conservation laws for a fluid

The transonic wind solution

Chromosphere-corona coupling

Freezing in of the ionization state

Potential field extrapolation

The Transonic Wind Solution

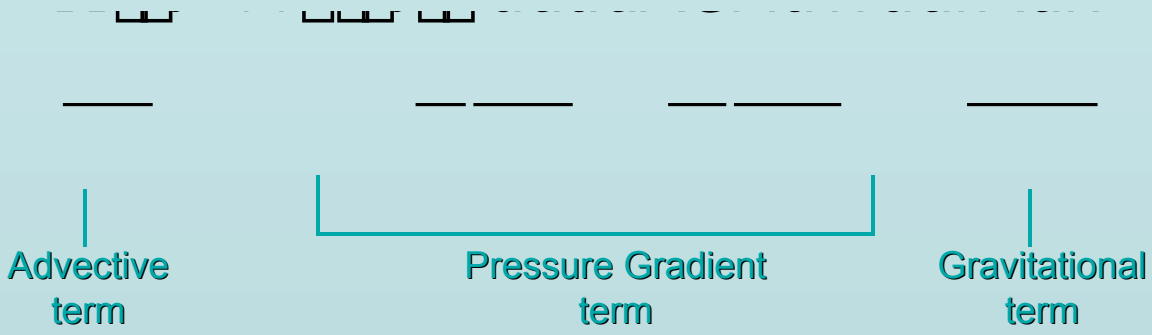
Steady State Equation of Motion (without wave or Lorentz forces)

Steady State Mass Conservation

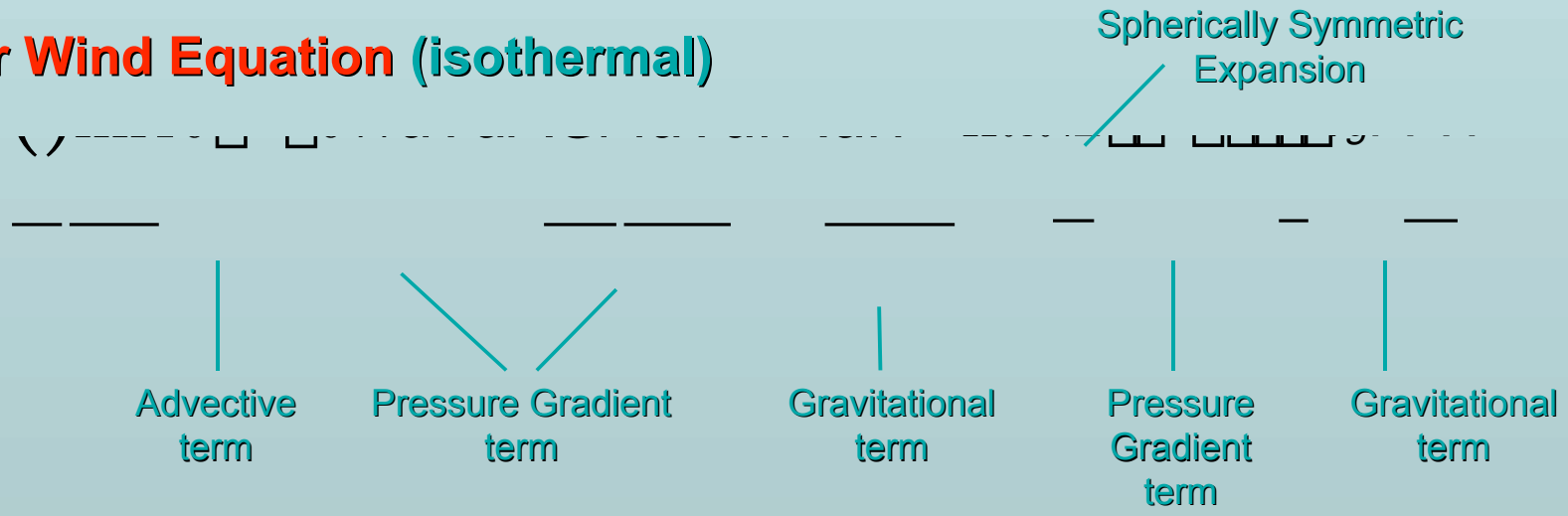
Pressure Gradient Force (isothermal case)

The Transonic Wind Solution

Steady State Equation of Motion (isothermal)

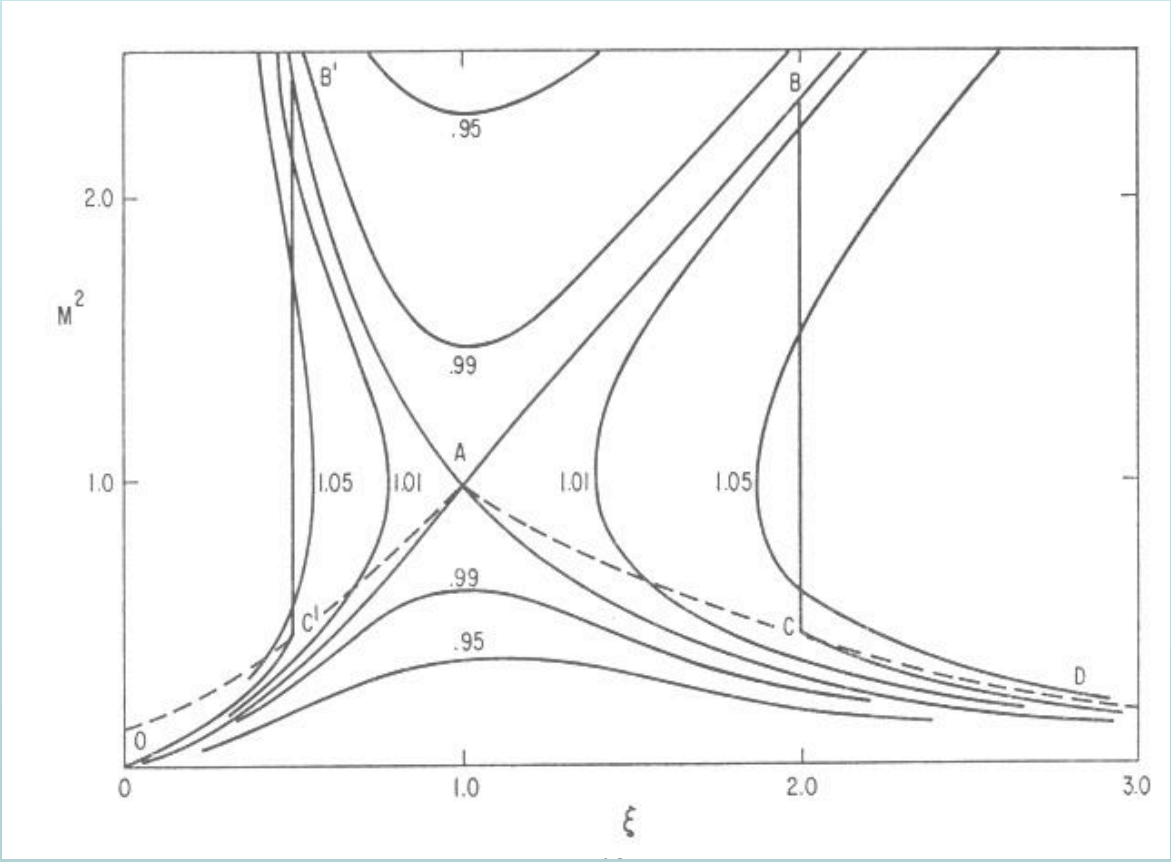


Solar Wind Equation (isothermal)



Critical Radius (isothermal)

The Transonic Wind Solution



Solar Wind Equation

Critical Radius

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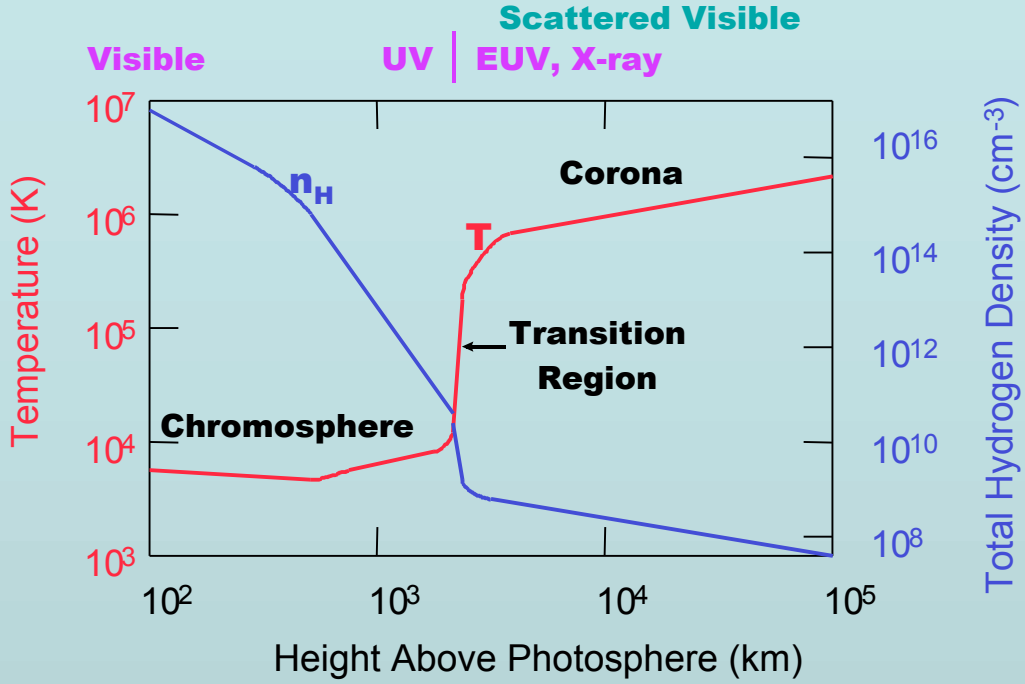
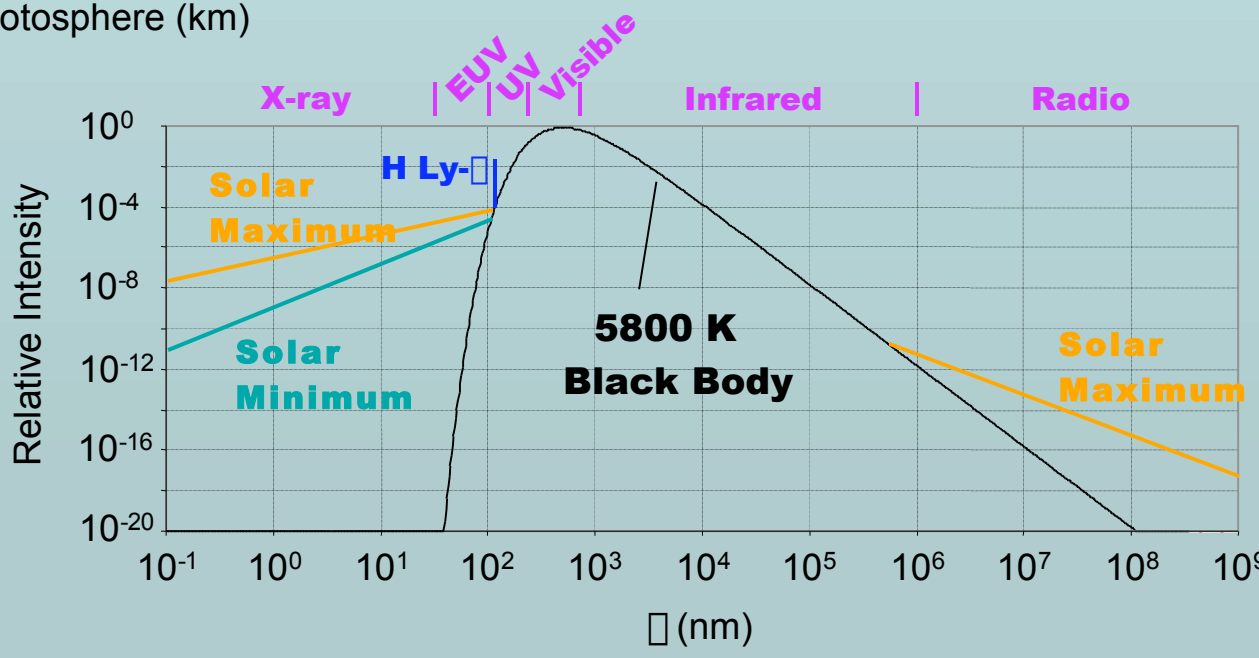


Density and Temperature Structure

Radiative Output



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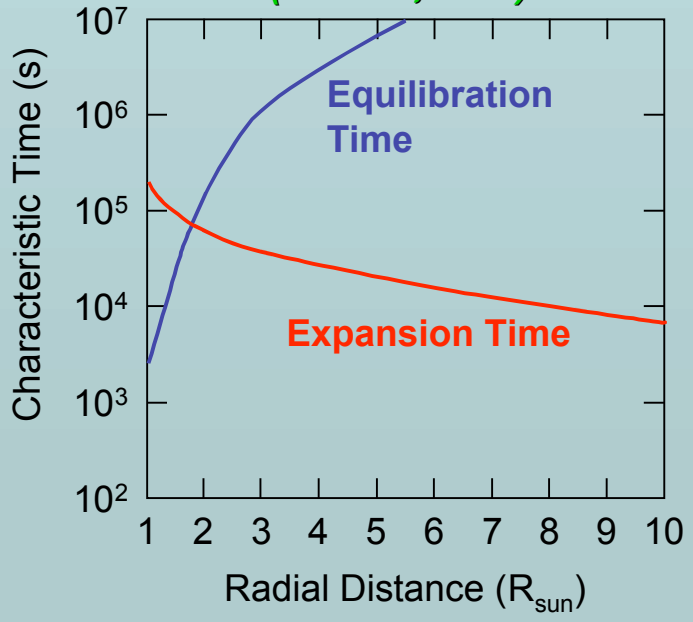
Freezing in of the Ionization State

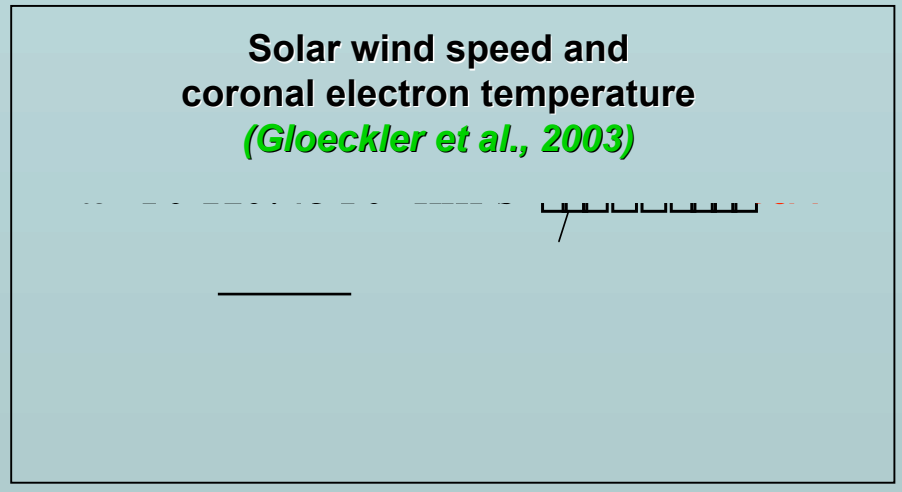
Particle Conservation with sources and sinks:

Temperature Dependence of Sources and Sinks

Freezing in of the ionization state for O^{+6} and O^{+7}
(Owocki, 1982)



Solar wind speed and coronal electron temperature
(Gloeckler et al., 2003)



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Potential Field Extrapolation

Pneuman & Kopp (1971)
Newkirk (1972)

Solid lines: isothermal mhd simulation with dipole lower boundary condition

Dashed lines: potential field source surface model with same b.c.