The Slow Solar Wind

Tom Holzer

NCAR/HAO

Topics to be Discussed

Observational constraints on slow solar wind models

Mass flux, energy flux, and asymptotic flow speed

Physical ingredients for a slow solar wind

Types of slow solar wind models

Interaction of observation and theory

Topics to be Discussed

Observational constraints on slow solar wind models

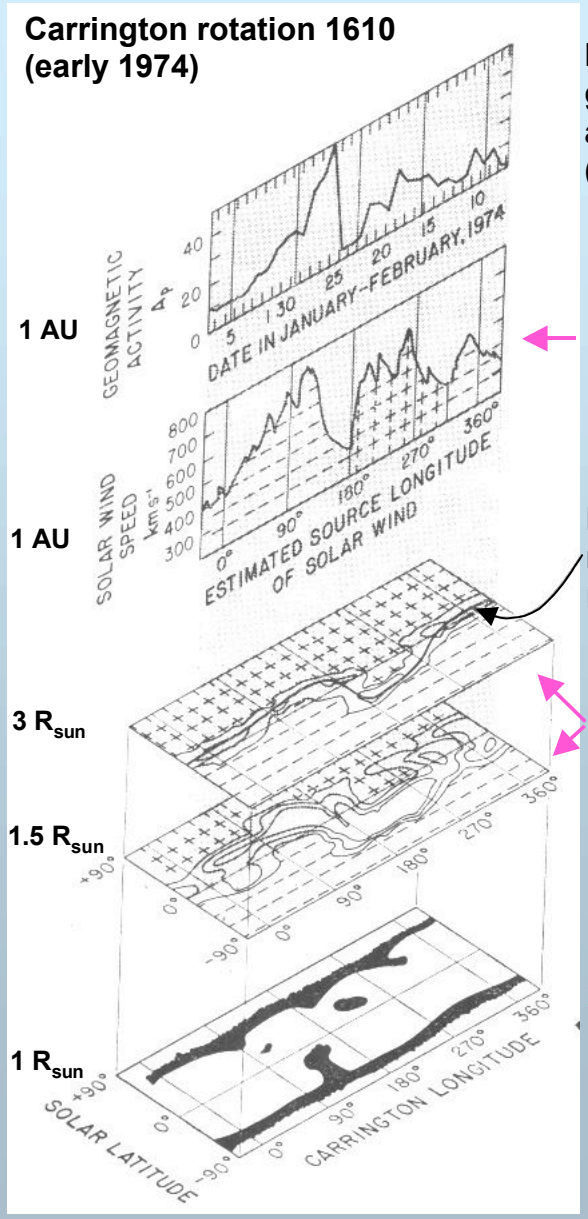
Mass flux, energy flux, and asymptotic flow speed

Physical ingredients for a slow solar wind

Types of slow solar wind models

Interaction of observation and theory

Observational Constraints—1



Recurrent geomagnetic activity (mapped)

Solar wind speed and magnetic polarity (mapped)

Inferred magnetic neutral line

Coronal polarization brightness

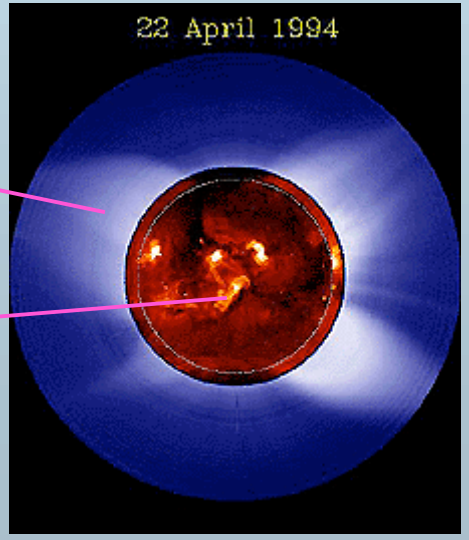
Coronal x-ray emission

Hundhausen, 1980

***In situ* observations: n, u, B, T, q, elemental abundance & ionization state** *(Neugebauer, Tues. PM)*

Mapping back to the Sun

Comparison with disk and limb solar observations (also radio)

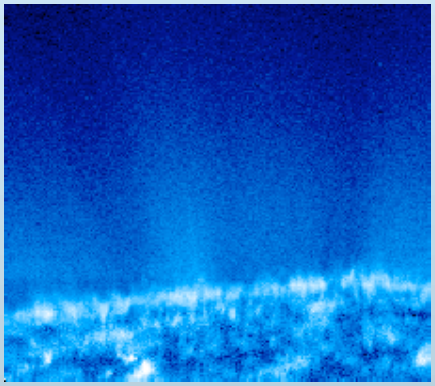


YOHKOH & HAO

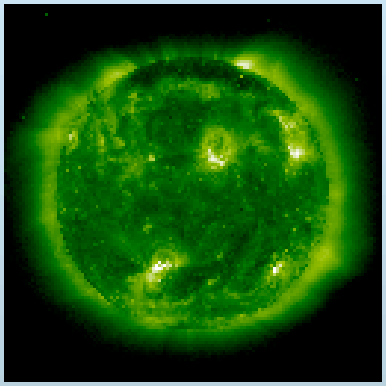
Observational Constraints—2

Off-limb and on-disk spectral and filter observations

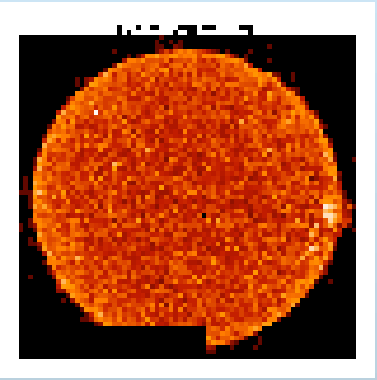
(Feldman, Raymond, Tues. PM)



Mg X: *SOHO/SUMER*

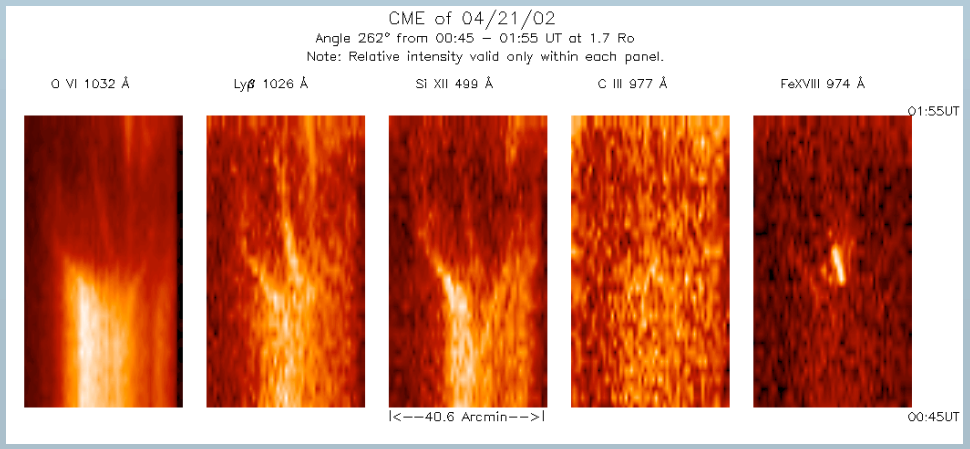


Fe XII: *SOHO/EIT*



O IV: *SOHO/CDS*

SOHO/UVCS
O VI
H I
Si XII
C III
Fe XVIII



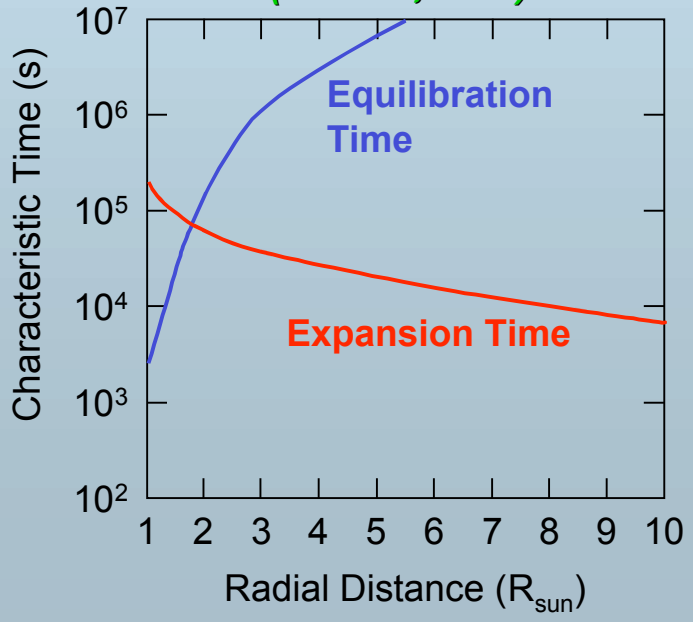
Observational Constraints—3

In situ observations of elemental abundance and ionization state

(Neugebauer, Tues. PM)

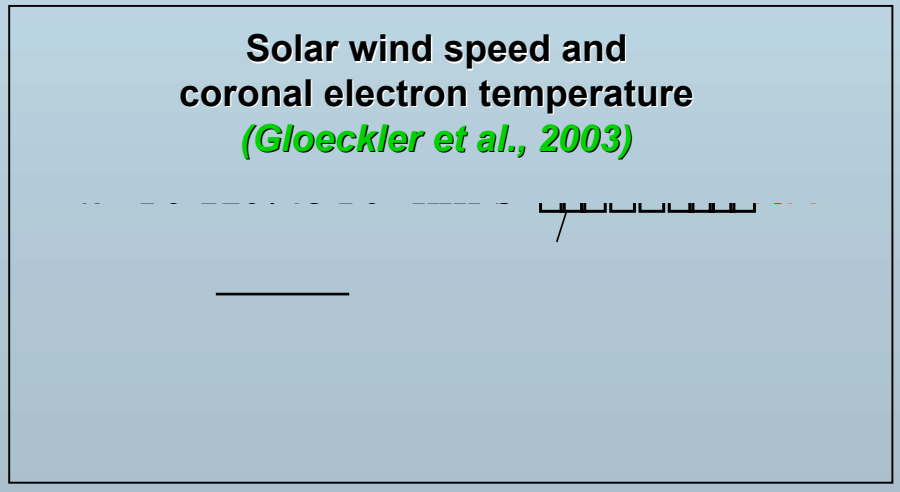
Freezing in of the ionization state for O^{+6} and O^{+7}

(Owocki, 1982)



Solar wind speed and coronal electron temperature

(Gloeckler et al., 2003)



Observational Constraints—4

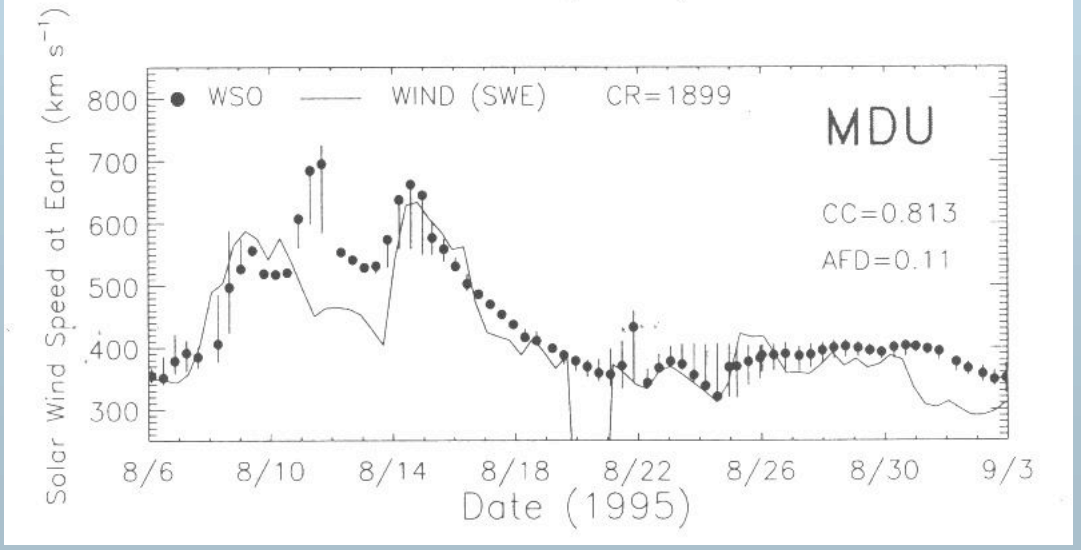
Photospheric magnetic field observations with source-surface, potential-field extrapolation

Wang-Sheeley-Arge (WSA) approach: No talk scheduled

Source Surface Speed

Expansion Factor

Arge & Pizzo (2000)



Topics to be Discussed

Observational constraints on slow solar wind models

Mass flux, energy flux, and asymptotic flow speed

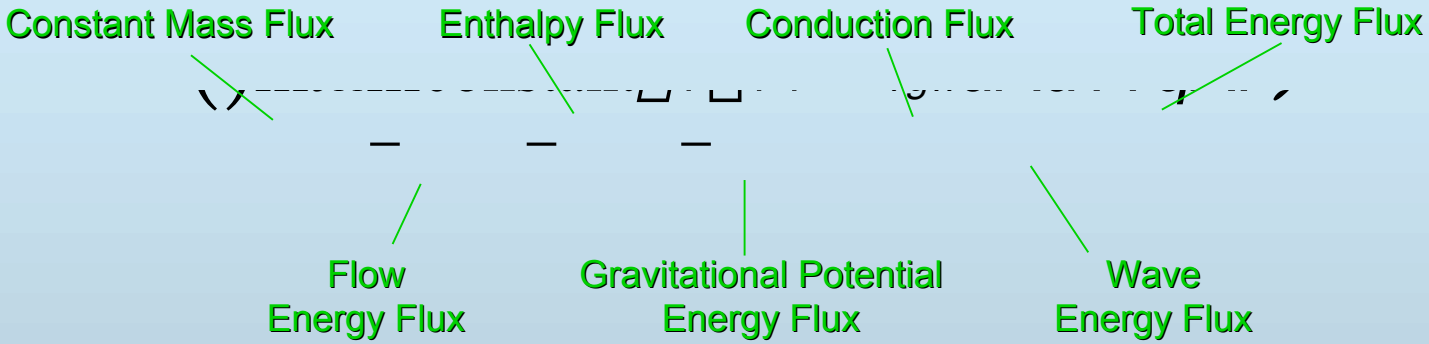
Physical ingredients for a slow solar wind

Types of slow solar wind models

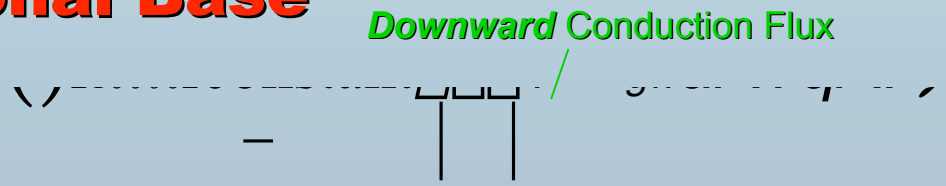
Interaction of observation and theory

Mass Flux, Energy Flux, and Asymptotic Flow Speed—1

Corona/Wind Energy Balance (Steady State)



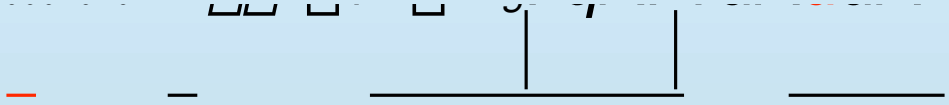
Coronal Base



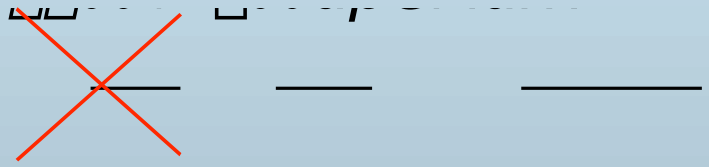
Large Distances

Mass Flux, Energy Flux, and Asymptotic Flow Speed—2

Asymptotic Flow Speed



Subsonic Momentum Balance (Steady State)



Effective Pressure & Gravitational Escape Speed

Mass Flux, Energy Flux, and Asymptotic Flow Speed—3

Critical Point Density

Mass Flux

Mass flux increases with increasing temperature and expansion factor

(Rosner et al., 1976; Hansteen & Leer, 1995)

Chromosphere-corona coupling is crucial

Topics to be Discussed

Observational constraints on slow solar wind models

Mass flux, energy flux, and asymptotic flow speed

Physical ingredients for a slow solar wind

Types of slow solar wind models

Interaction of observation and theory

Physical Ingredients for a Slow Solar Wind

Asymptotic Flow Speed

Subsonic Heating (i.e., increasing T)

Increased mass flux decreased asymptotic flow speed

Subsonic Flow Tube Expansion (increase)

Increased mass flux decreased asymptotic flow speed

Topics to be Discussed

Observational constraints on slow solar wind models

Mass flux, energy flux, and asymptotic flow speed

Physical ingredients for a slow solar wind

Types of slow solar wind models

Interaction of observation and theory

Types of Slow Solar Wind Models

Wind from quasi-steady open magnetic geometries

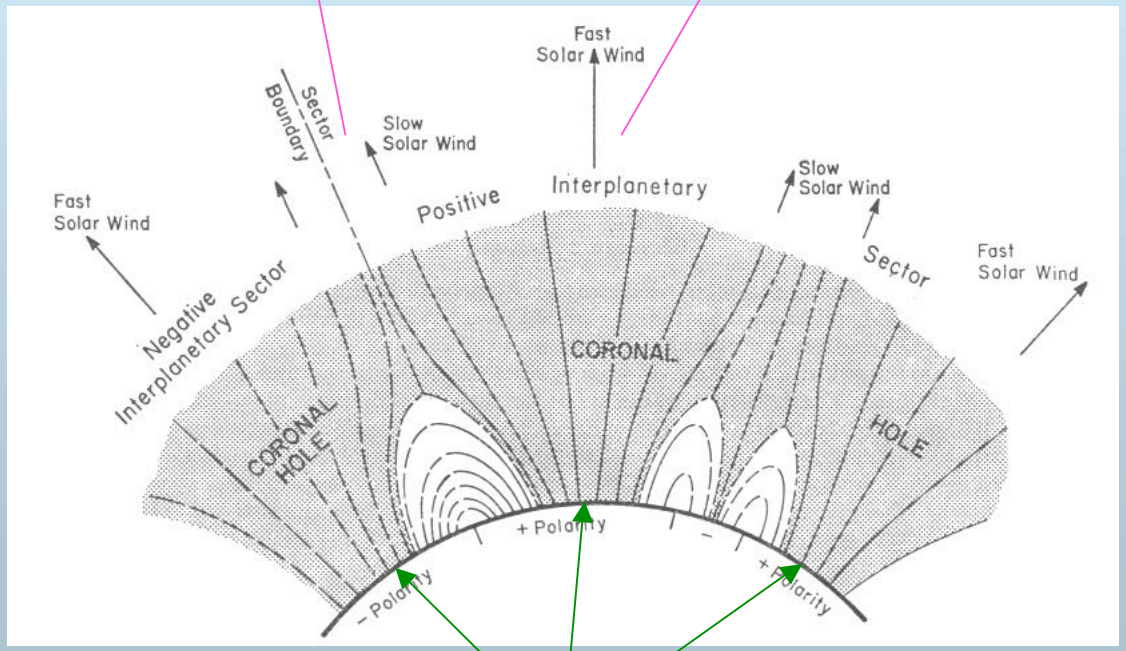
Wind from reconnecting open and closed field lines

Transient ejection of wind from magnetically closed regions

Types of Slow Solar Wind Models

Wind from quasi-steady open magnetic geometries

Ofman (slow wind), Hollweg (fast wind)—Wed. AM)



Hundhausen, 1980

Chromosphere-corona coupling is crucial

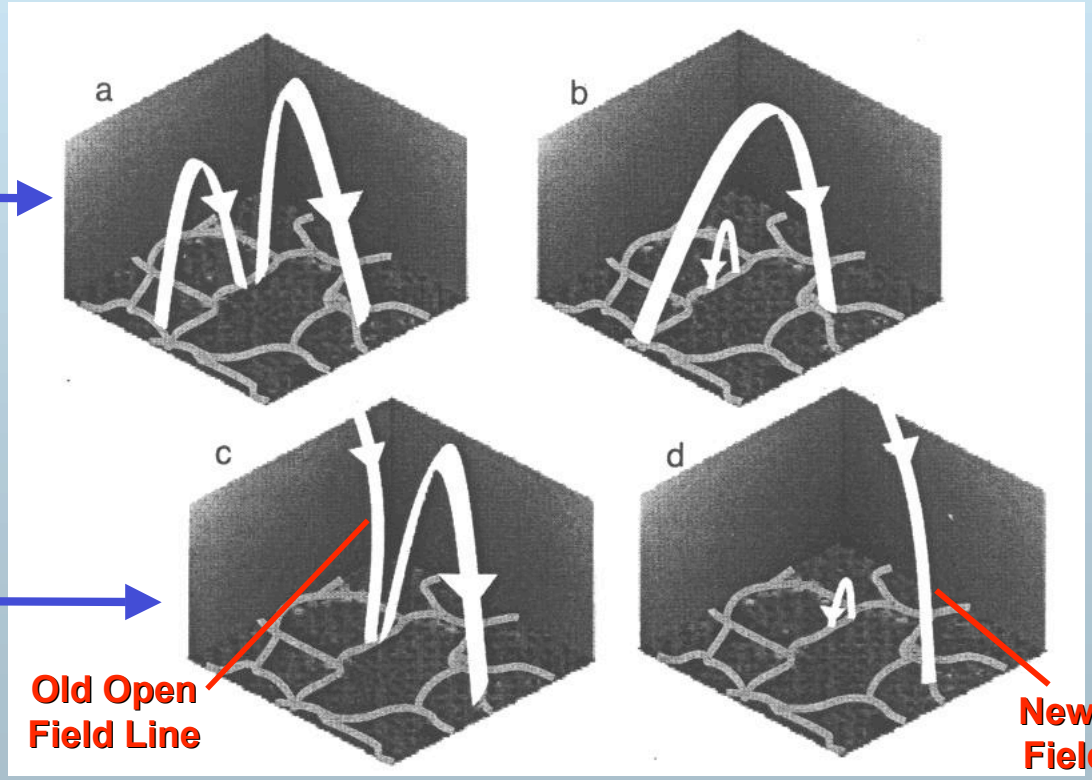
Types of Slow Solar Wind Models

Wind from reconnecting open and closed field lines

No talk scheduled, but ask Len Fisk—Wed. AM

Closed-closed reconnection

Open-closed reconnection

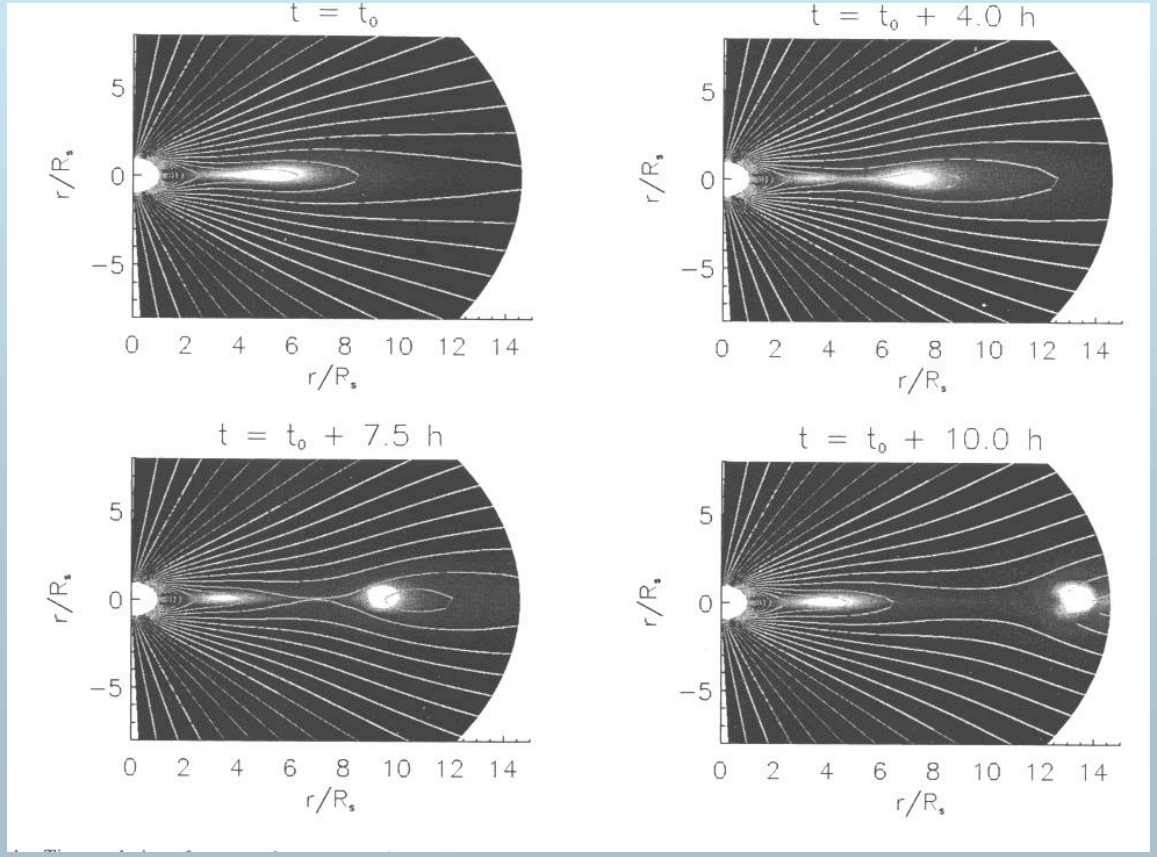


Fisk (2003)

Types of Slow Solar Wind Models

Transient ejection of wind from magnetically closed regions

(Dahlburg, Wed. AM)



Endeve et al., 2003

Topics to be Discussed

Observational constraints on slow solar wind models

Mass flux, energy flux, and asymptotic flow speed

Physical ingredients for a slow solar wind

Types of slow solar wind models

Interaction of observation and theory

Interaction of Observation and Theory

Each theory should be compared with all relevant observations

Each observation should be compared with all relevant theories

Potential Field Extrapolation

Near the streamer, f_{ss} is larger for the PFSS model than for the MHD model

Solid lines: isothermal mhd simulation with dipole lower boundary condition

Pneuman & Kopp (1971)

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

Newkirk (1972)