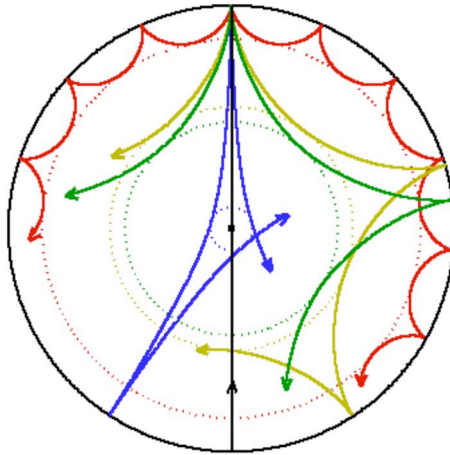


Helioseismology provides observational information on the solar interior...

(see <http://163.180.179.74/~magara/page31/Topics/Seismology/seis2.html>)



Distribution of sound speed (\Rightarrow temperature) in the solar interior

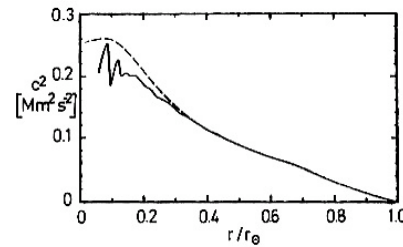
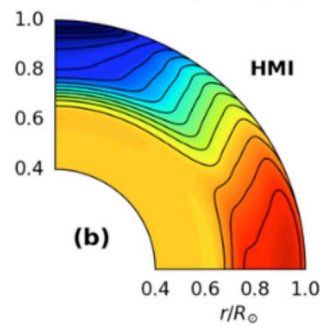
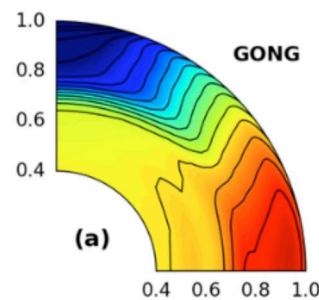


Fig. 5.17. Square of the sound speed in the Sun. *Continuous line*: inversion of the data in Fig. 5.16; *dashed*: theoretical solar model. From Christensen-Dalsgaard et al. (1985)

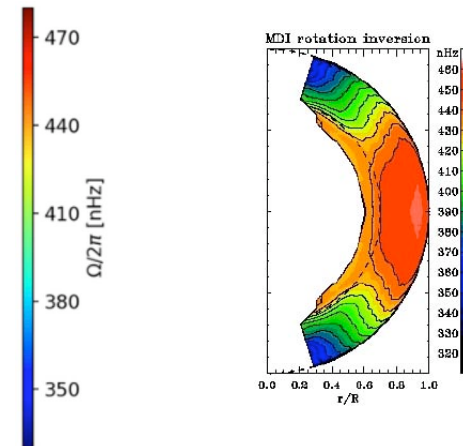
Distribution of angular velocity ($\Rightarrow v_\phi$) in the solar interior



Larson and Schou 2018, HMI



Howe et al. 2005, GONG

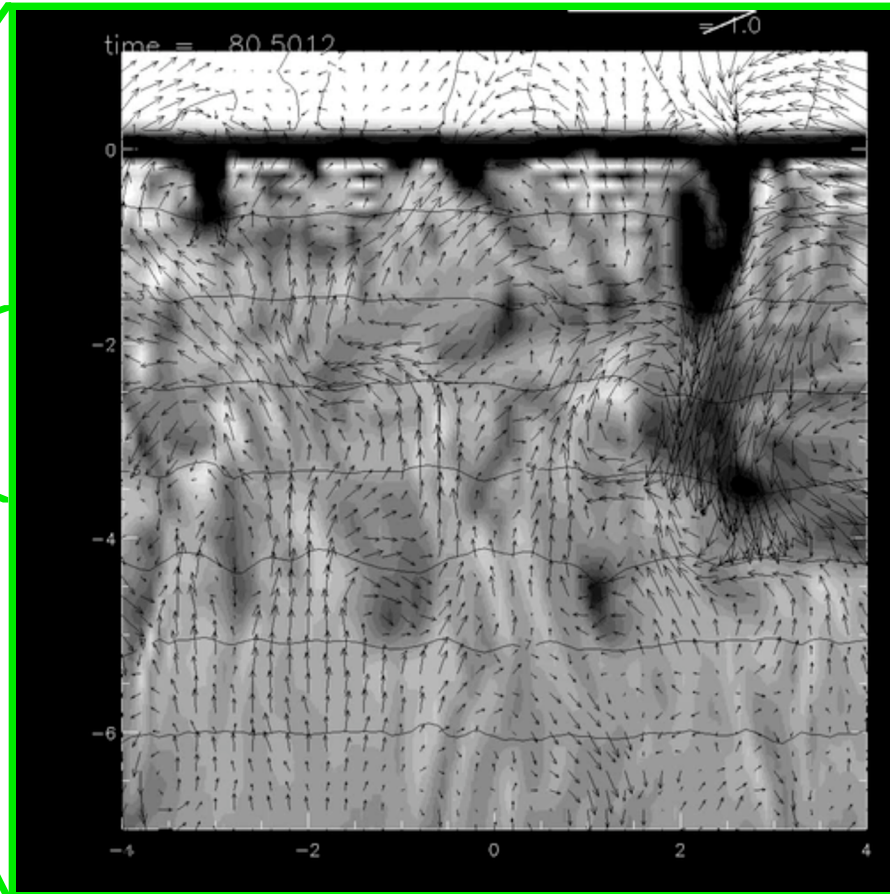
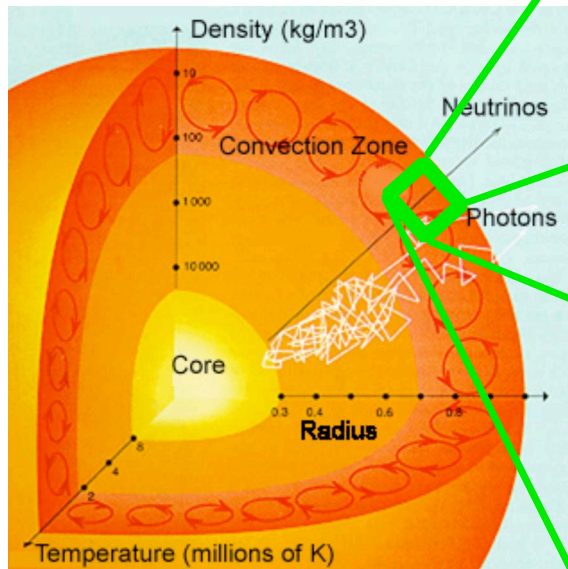


Schou et al. 1998, MDI

Transport of magnetic fields through
the convection zone

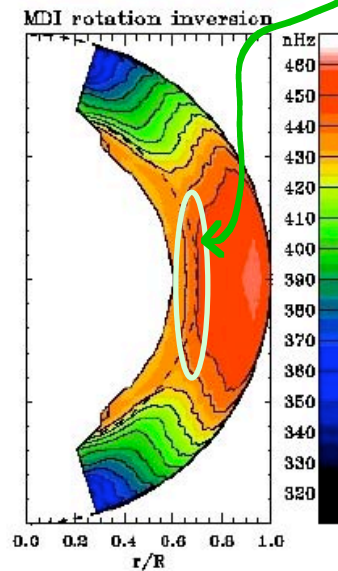
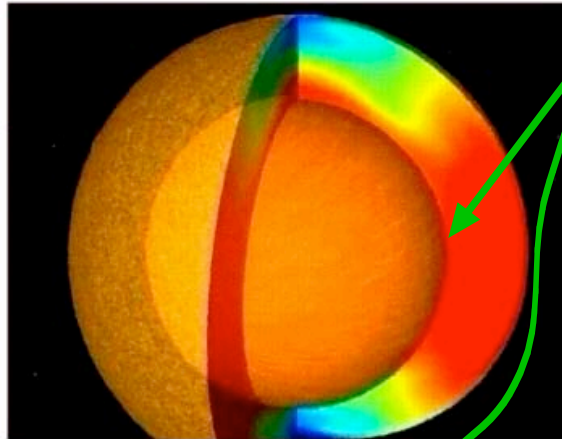
Convective motions...

Mixture of upflows, downflows, circulating flows



Vertical slice of a 3D simulation

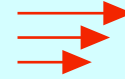
SMFs rise via magnetic buoyancy...



Distribution of angular velocity
in the solar interior

Tachocline (bottom of the convection zone)

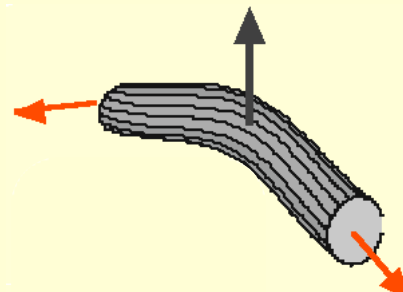
... sharp change of angular velocity => **shear flow**



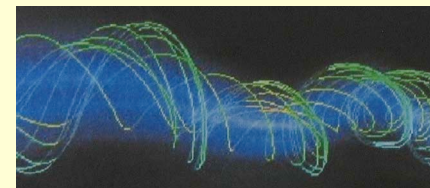
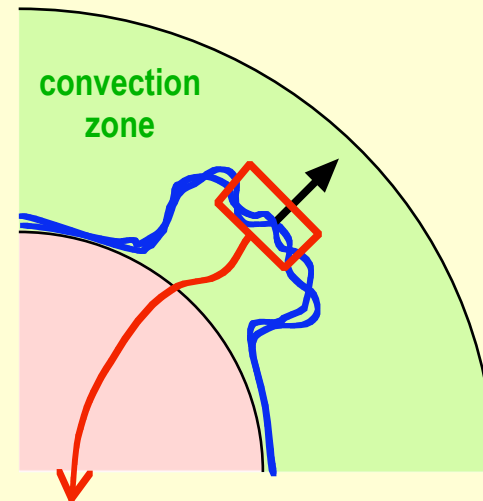
magnetic fields are deformed by the shear flow, which may produce **flux tubes of intense magnetic flux**.



Magnetic buoyancy



mass drains from Ω -part of a flux tube, which enhances the buoyancy of that part.

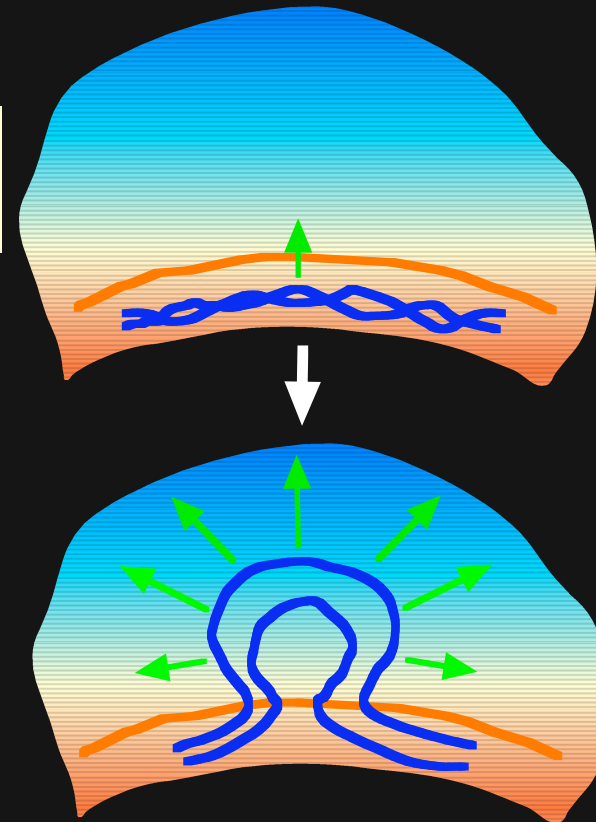
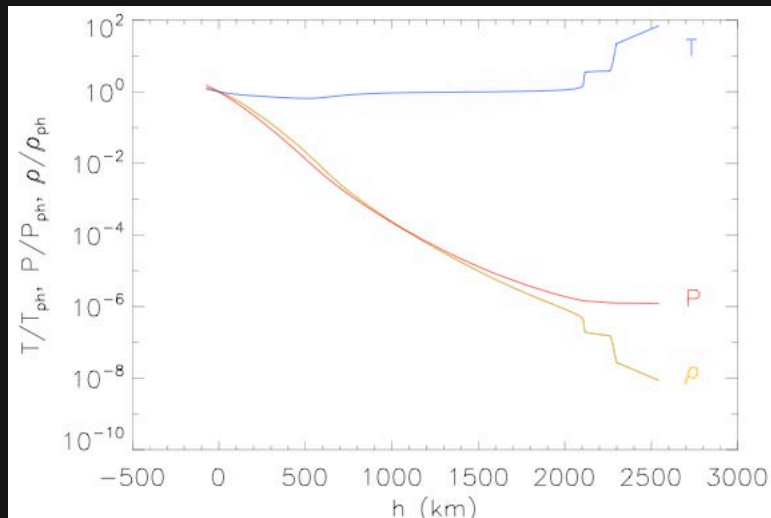


Twisted flux tube

Emergence of magnetic fields into
the solar atmosphere

Flux emergence...

A magnetic flux tube emerges to solar atmosphere and then expands rapidly due to the sharp decrease of gas pressure of a surrounding plasma across solar surface (photosphere).



Photosphere

$P \sim 2 \times 10^5 \text{ dyn/cm}^2$

Chromosphere

$P \sim 1 \times 10^2 \text{ dyn/cm}^2$

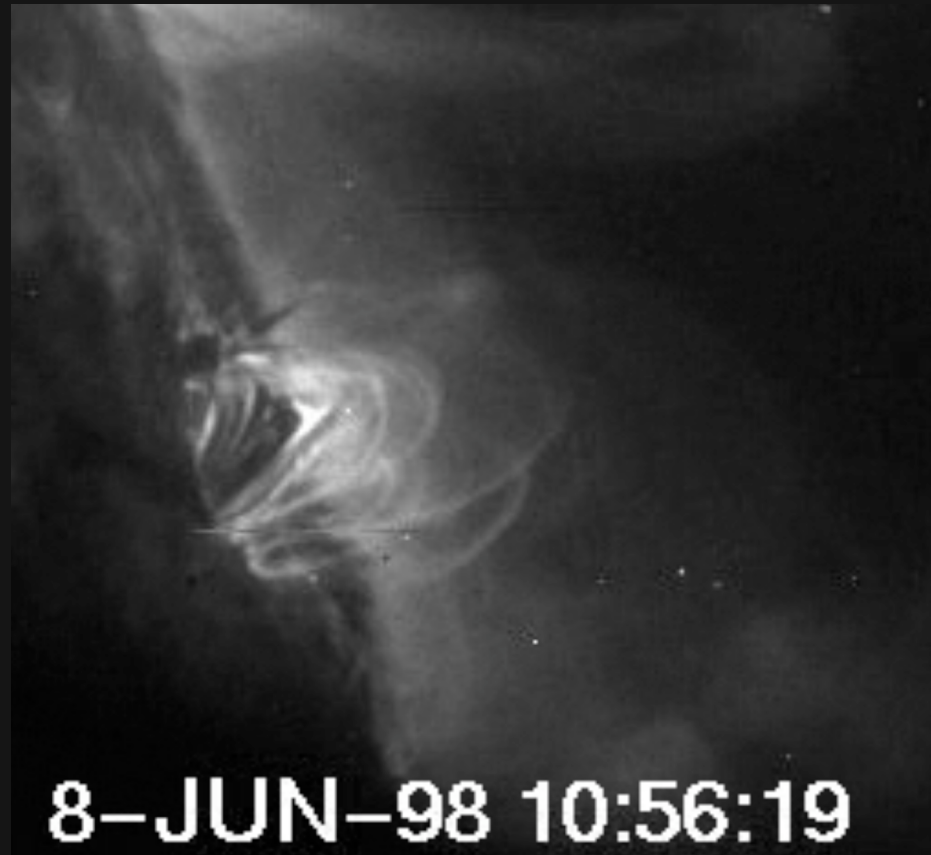
Corona

$P \sim 2 \times 10^{(-2)} \text{ dyn/cm}^2$

840 km
(0.001 R_s)

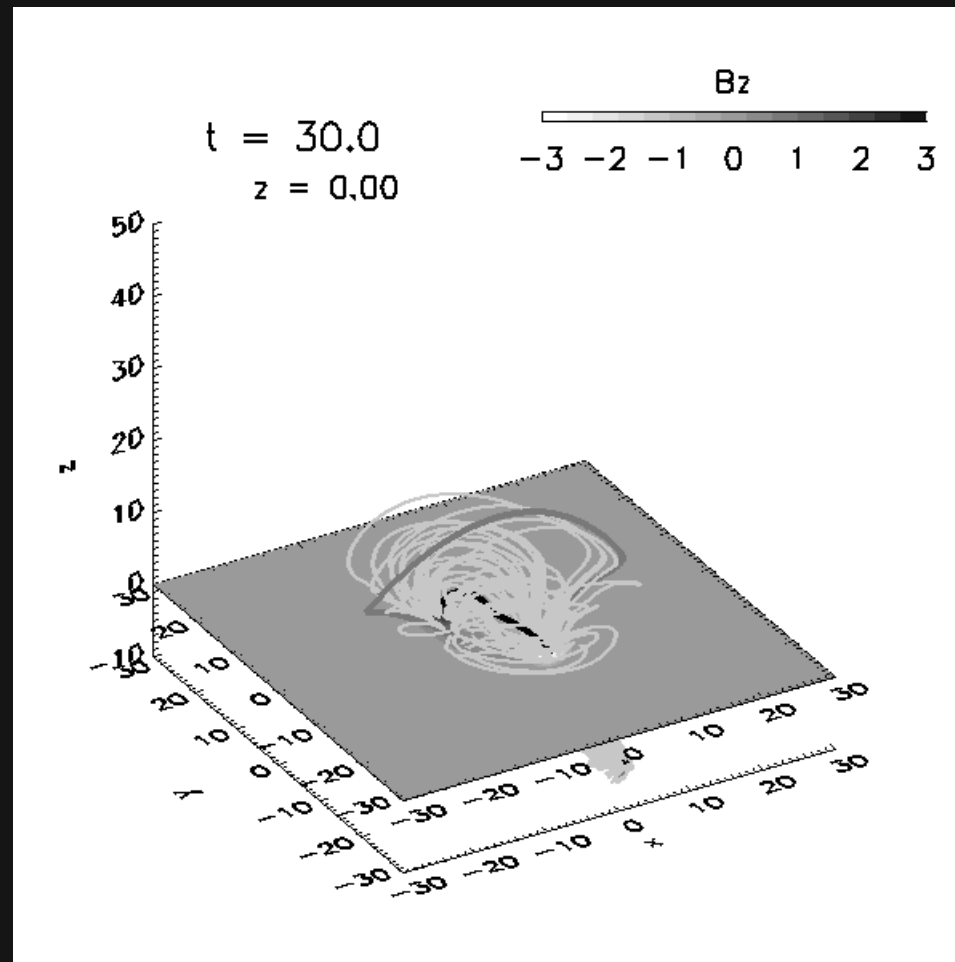
6000 km
(0.01 R_s)

Flux emergence... a very dynamic process (observation)



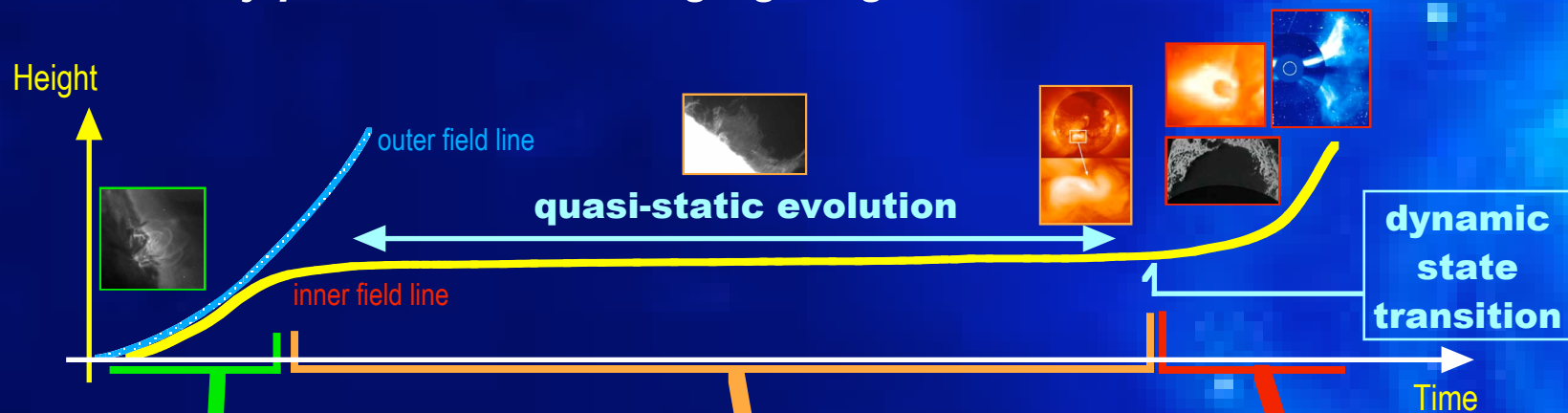
Observed by *TRACE*

Flux emergence... a very dynamic process (simulation)



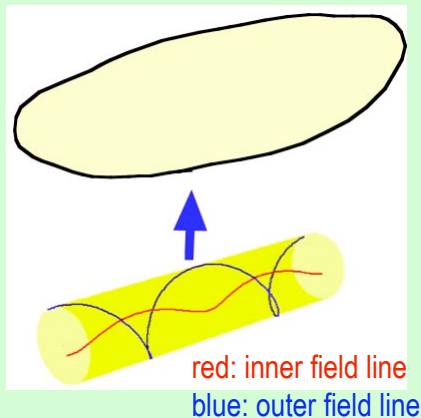
Magara (2004)

Evolutionary phases of an emerging magnetic field



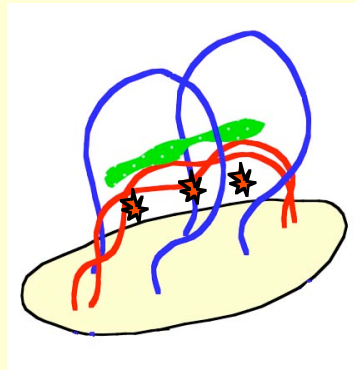
Emergence phase:

Emergence of subsurface magnetic field in a **twisted flux-tube shape**



Formation phase:

Formation of magnetic structure called **flux rope** in the solar corona (**prominence /filament, sigmoid, small-scale flaring events** are observed)



Eruption phase:

Eruption of flux rope toward the interplanetary space (sometimes accompanied by **flare with plasmoid ejection**)

