Nonlinear Evolution of the Magnetic Buoyancy Instability

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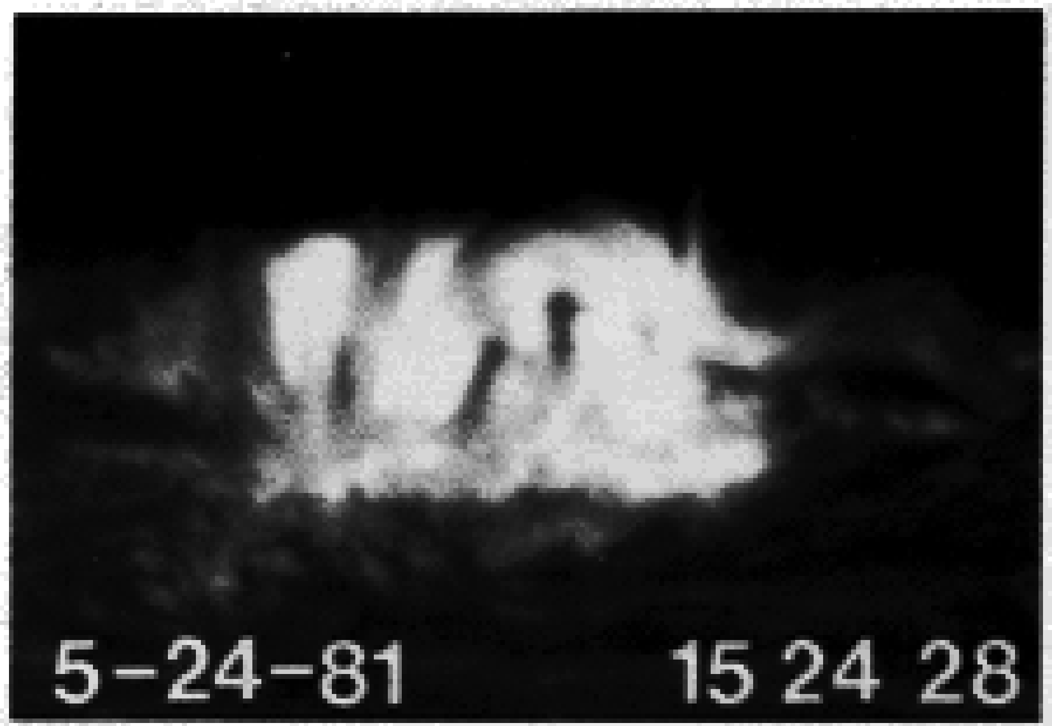
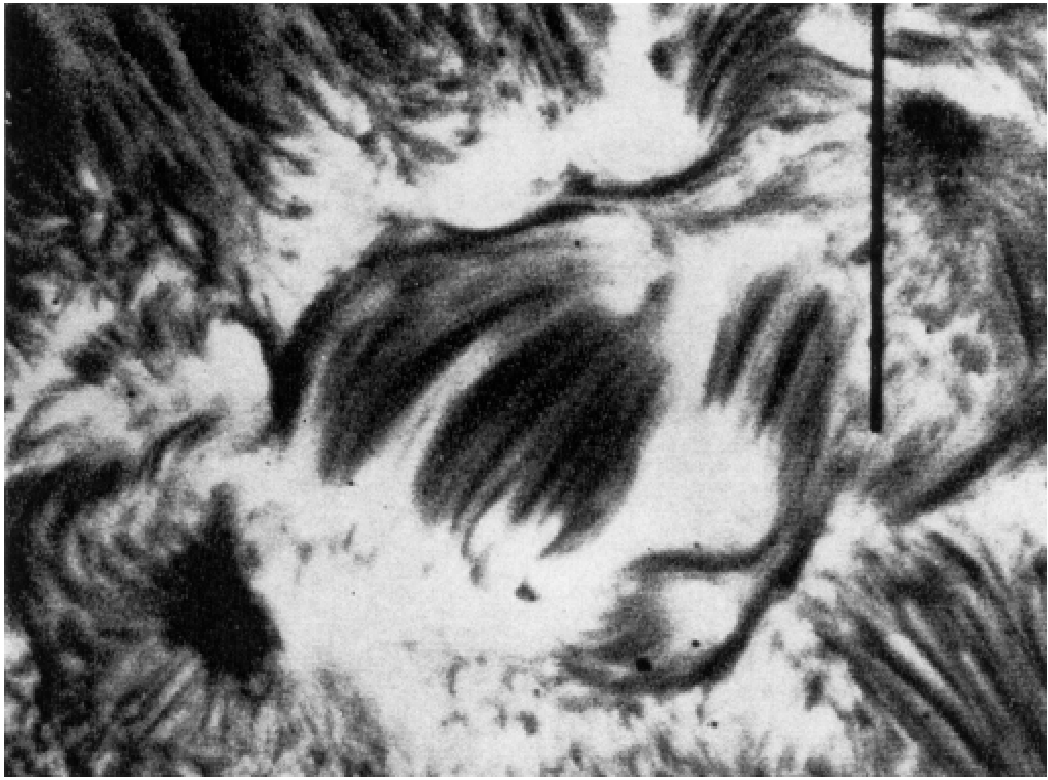
Emerging Flux

Magnetic flux emerges from the solar interior into the atmosphere. In the Chromosphere this emerging flux can be observed like arch filament features.

30,000 km

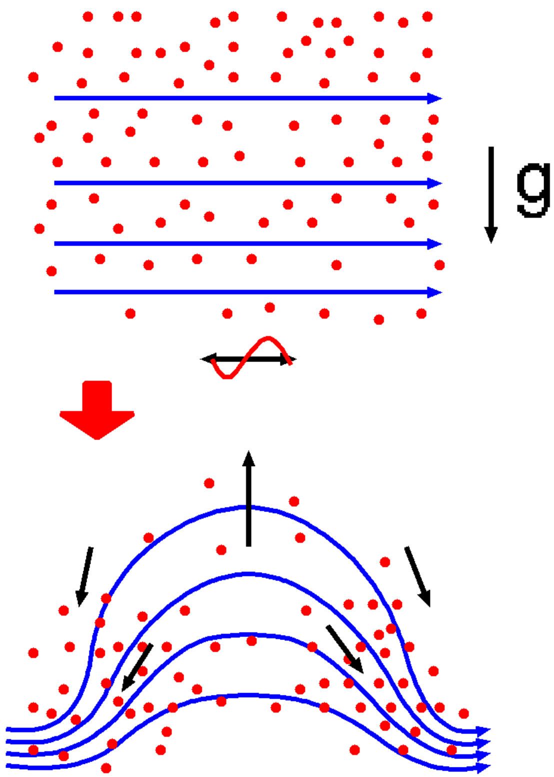


30,000 km

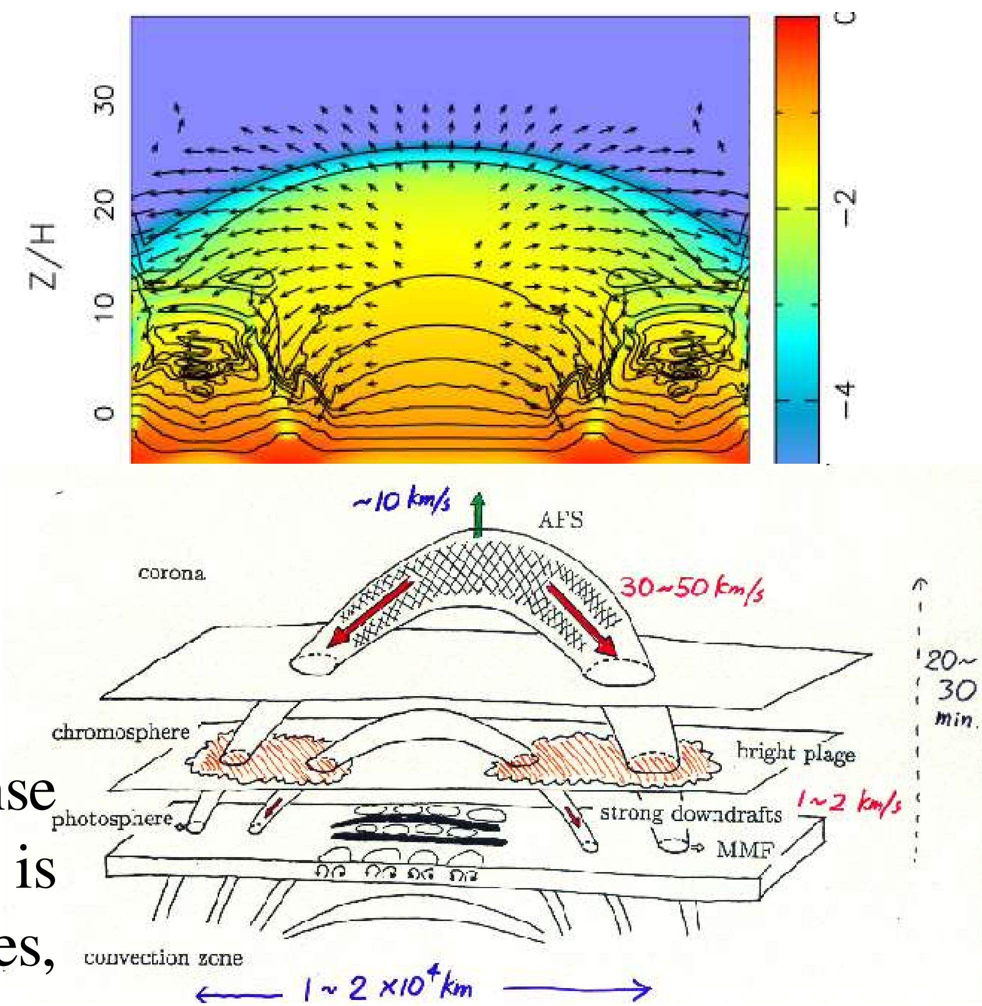


- Size ~ 30,000 km
- Width ~ 20,000km
- Life time ~ 3 days
- Rise Velocity ~ 10-20 km/s

Parker Instability

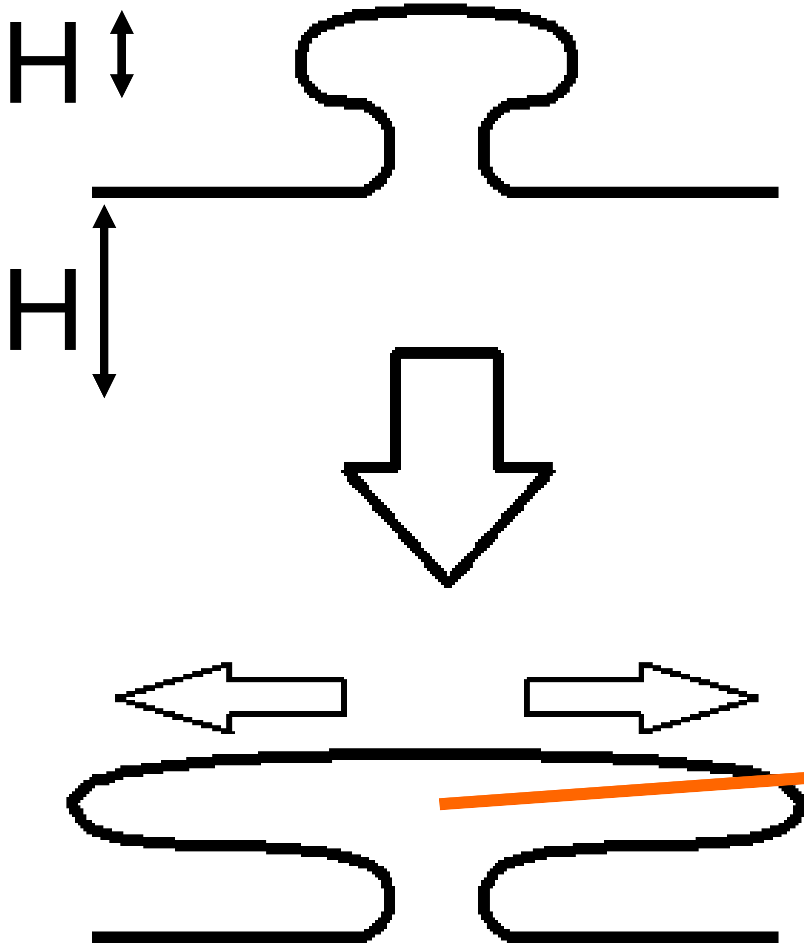


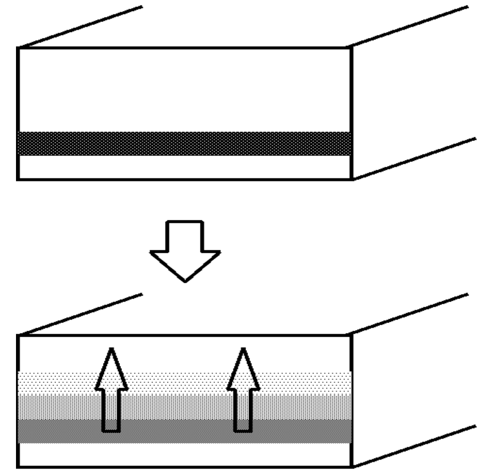
Following the perturbation, dense material above the magnetic flux is driven along the magnetic field lines, creating a net upward force.



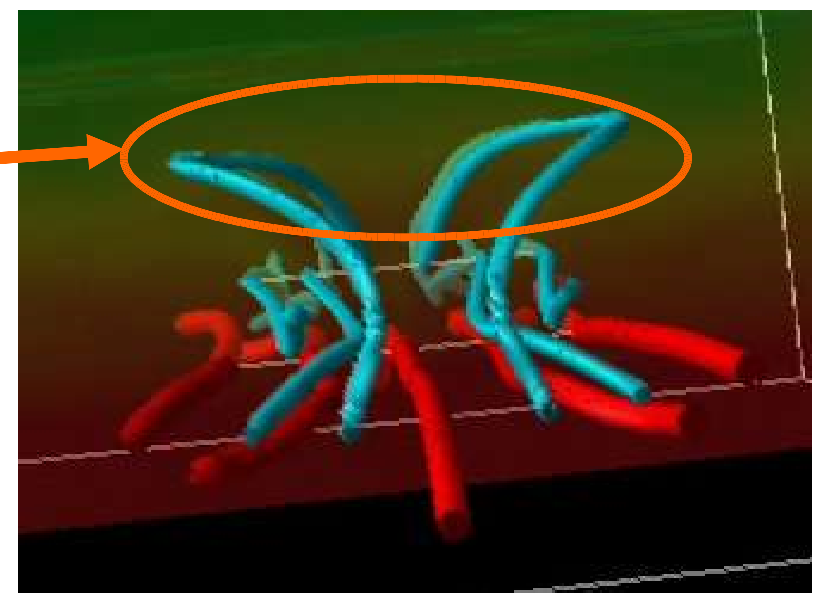
Shibata et al. (1989)

Result of 3D MHD simulation





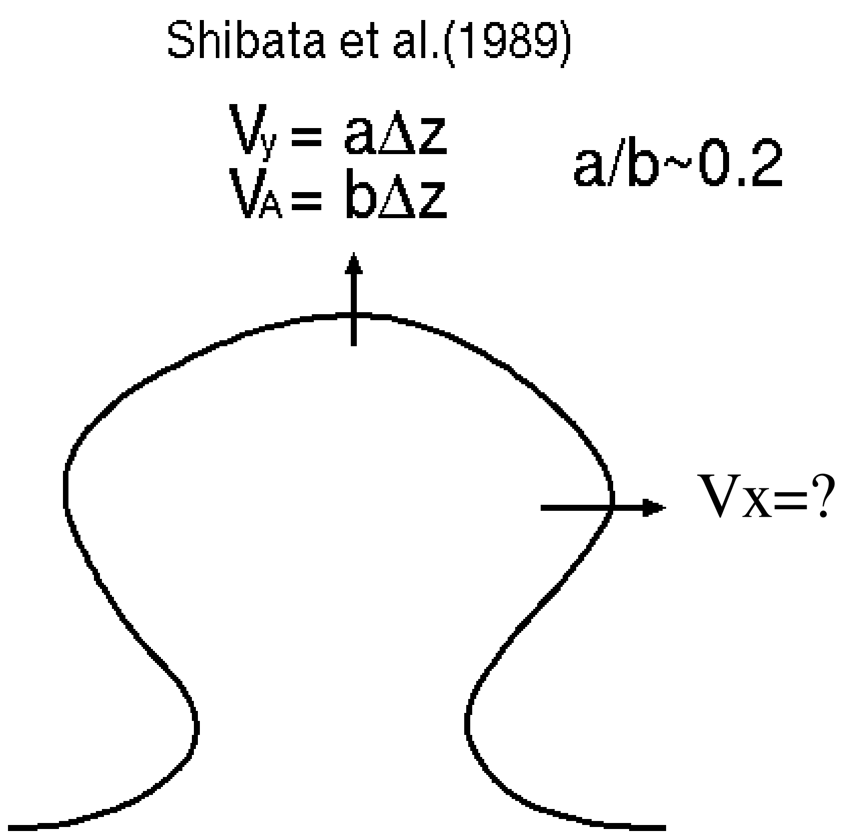
Since the scale height of the photosphere is smaller than the thickness of a magnetic sheet, the gas pressure outside the sheet decreases rapidly.



Nozawa (2005)

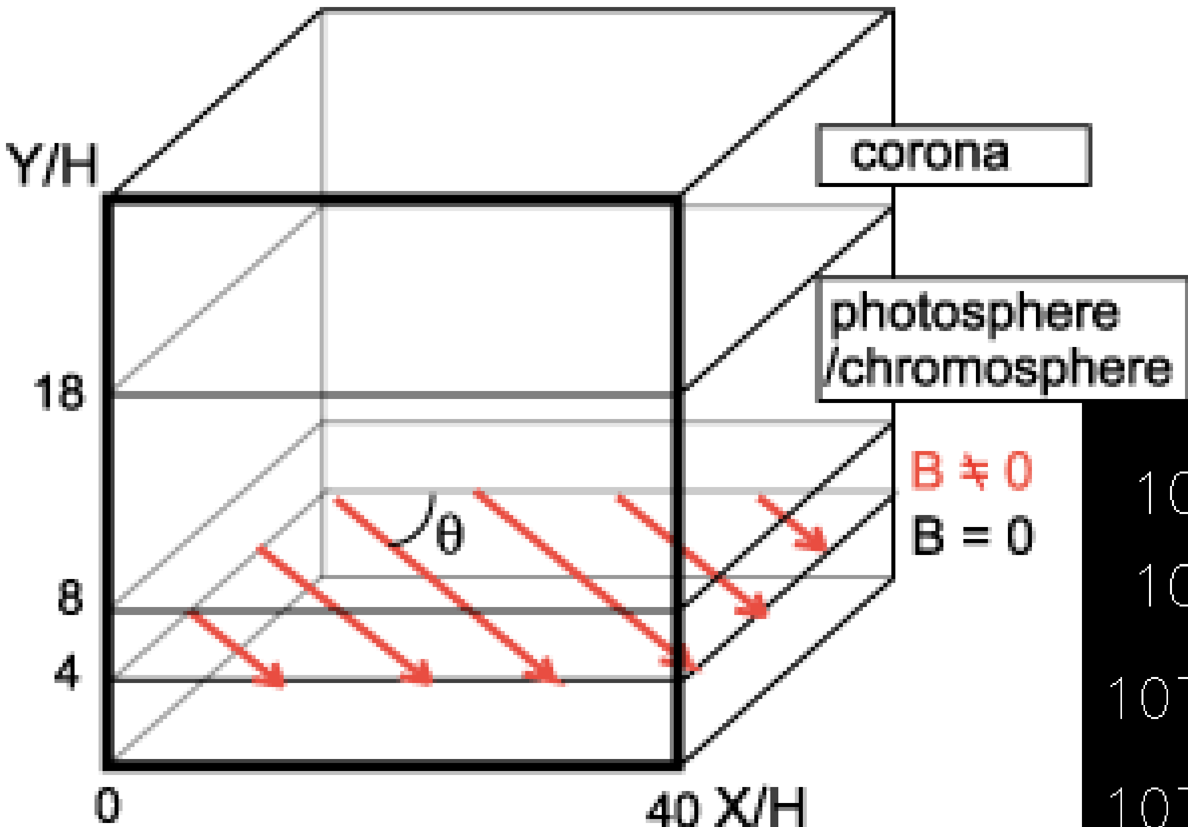
The magnetic flux expands horizontally until the magnetic pressure of the sheet is balanced with the surrounding gas pressure.

Result of 2D MHD simulation

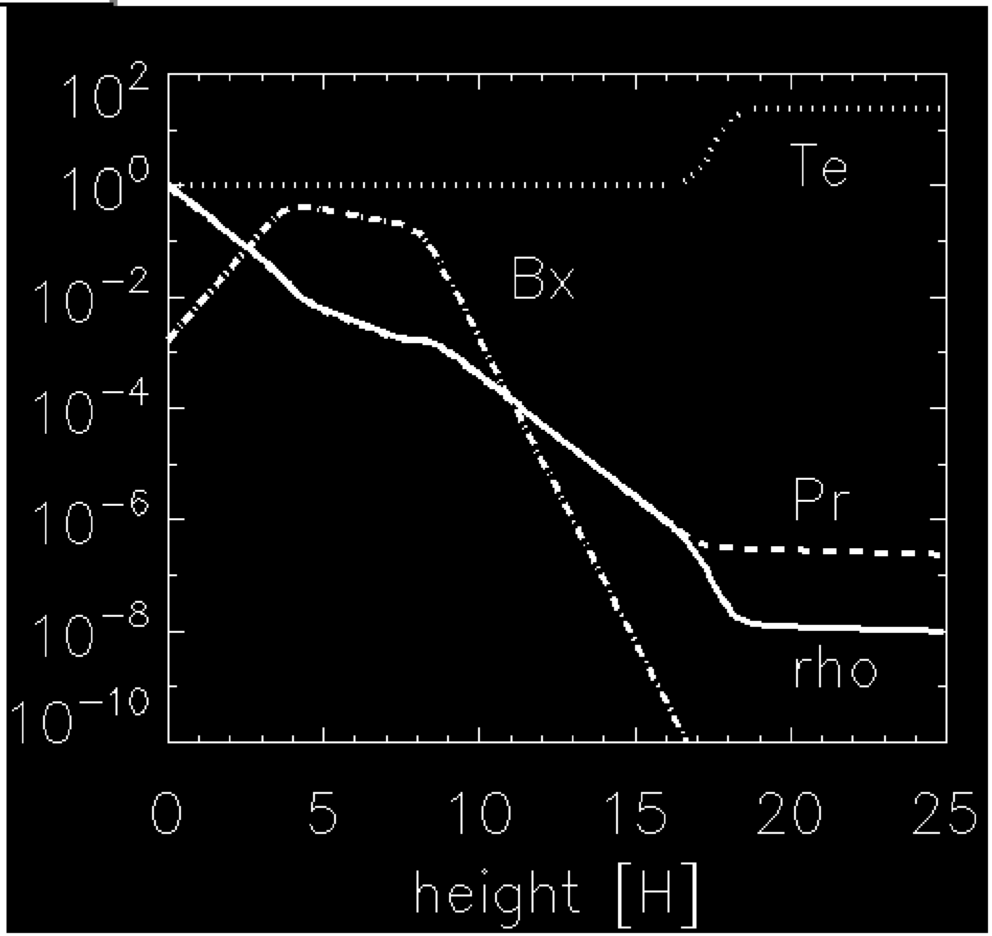


- Vertical expansion speed and Alfven speed are found to be independent of time, being only dependent on height above Photosphere. Their ratio is found to be constant.
- It is of interest to see if this result remains true for a 2.5D MHD simulation, and for different angles of magnetic field direction.
- What determines the horizontal expansion (Vx) is unclear. We are interested in trying to explain this result.

Initial condition

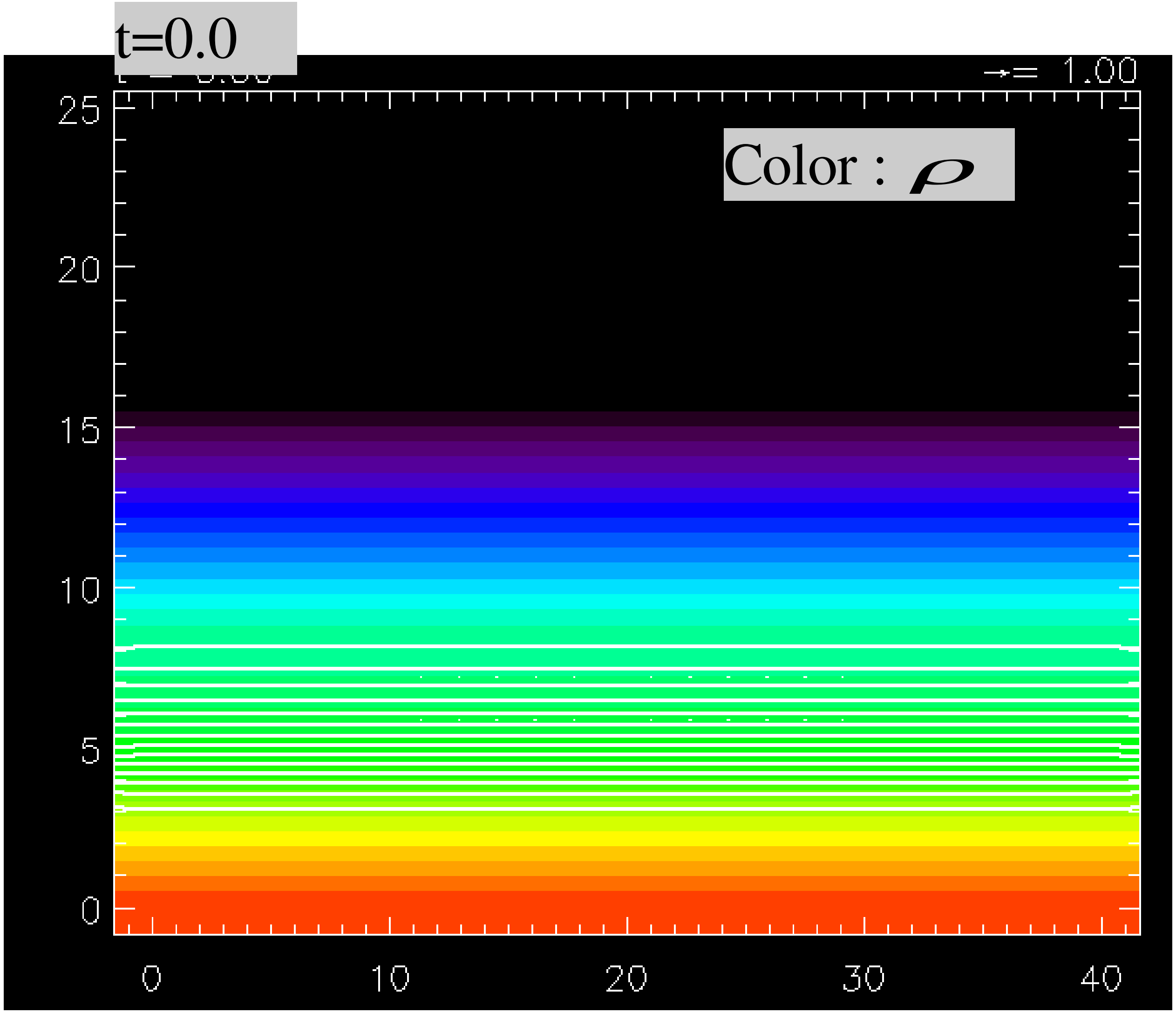


- Plasma beta = 1 (=p_gas/p_mag)



- 2.5-D ideal MHD
- Uniform gravity
- The modified Lax-Wendroff scheme
- The simulation code CANS
- Grid : 108 (x) * 158 (y)

Initial condition



Initial magnetic field

Normalization

Normalized by photospheric values

- Gravitational acceleration $g = \gamma g_{photo}$
- Number density n_{photo}
- Temperature T_{photo}

↓

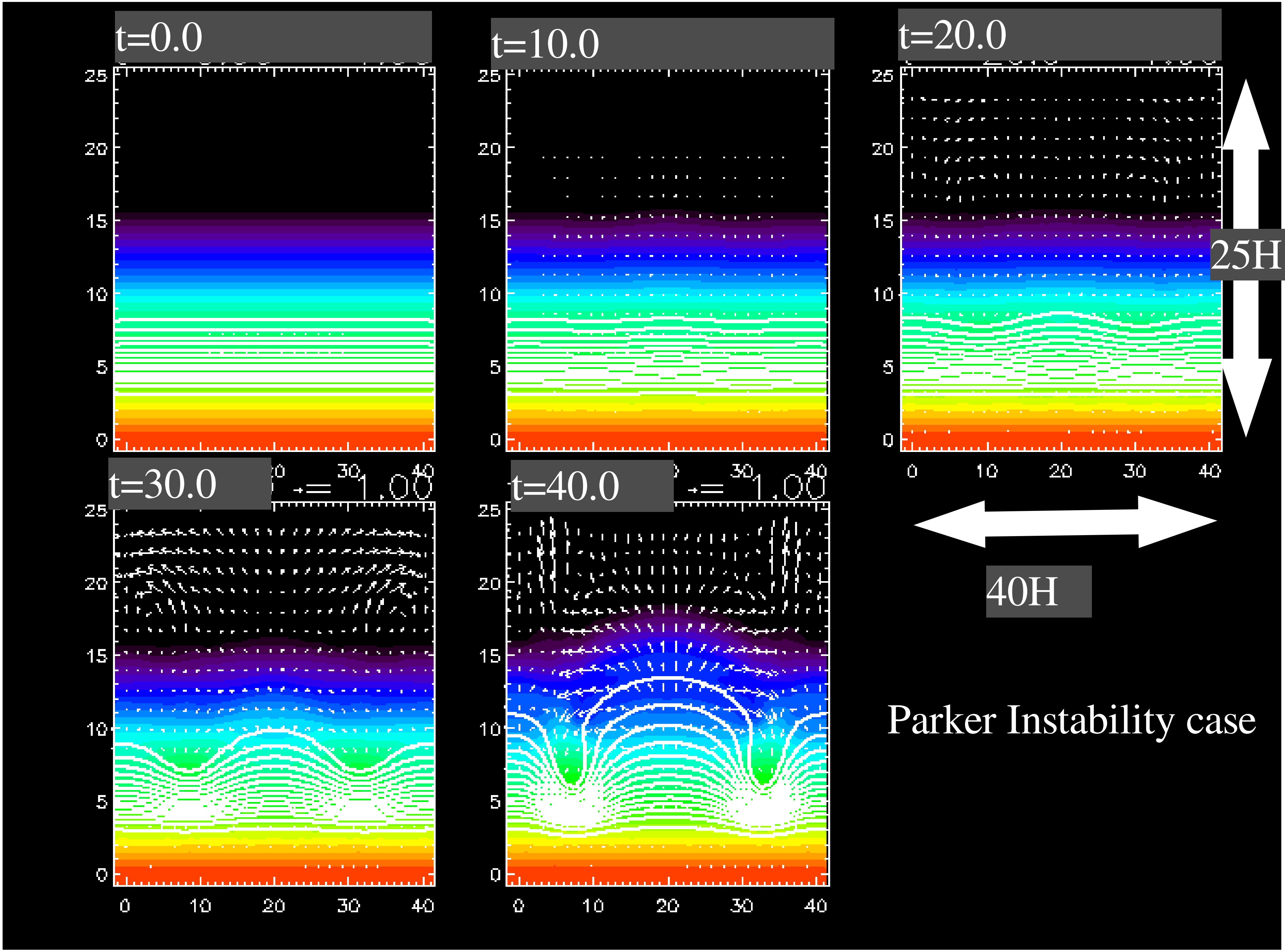
Length unit : Photospheric scale height H ~ 200km
Velocity unit : Photospheric sound speed Cs ~10km/s

Time unit : 20sec

Result

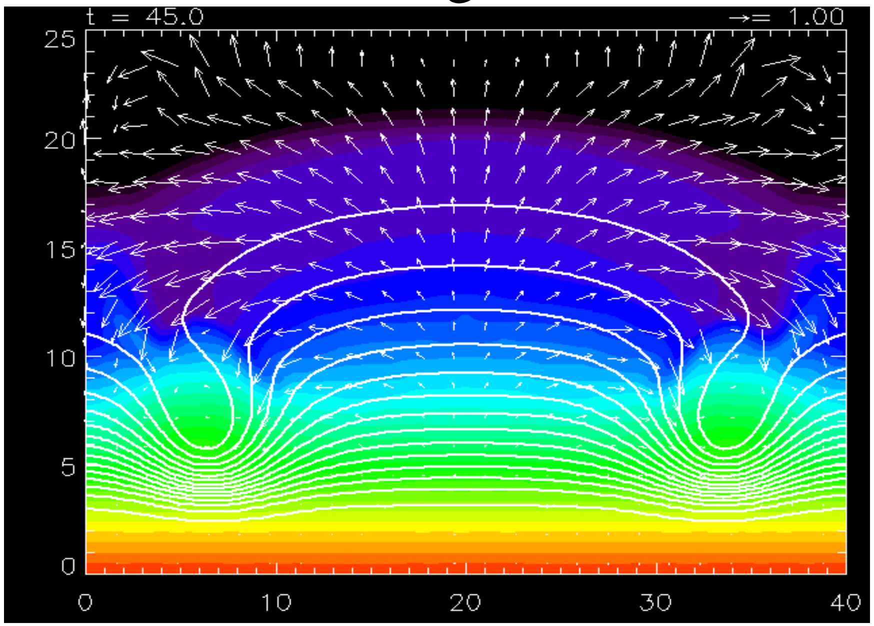
Movie (IDL)

Density profile in a typical case $\theta = 0$

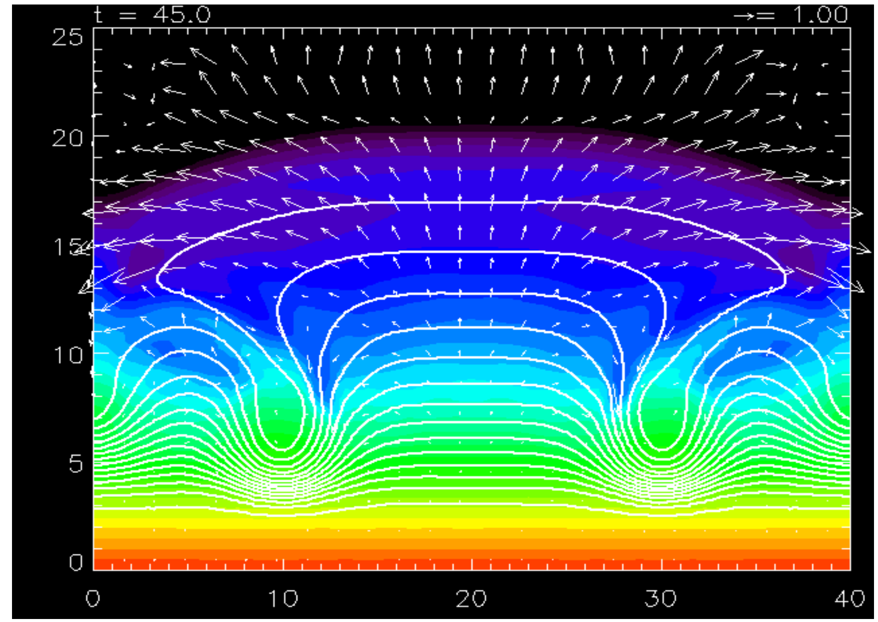


Density Profile for different values of theta

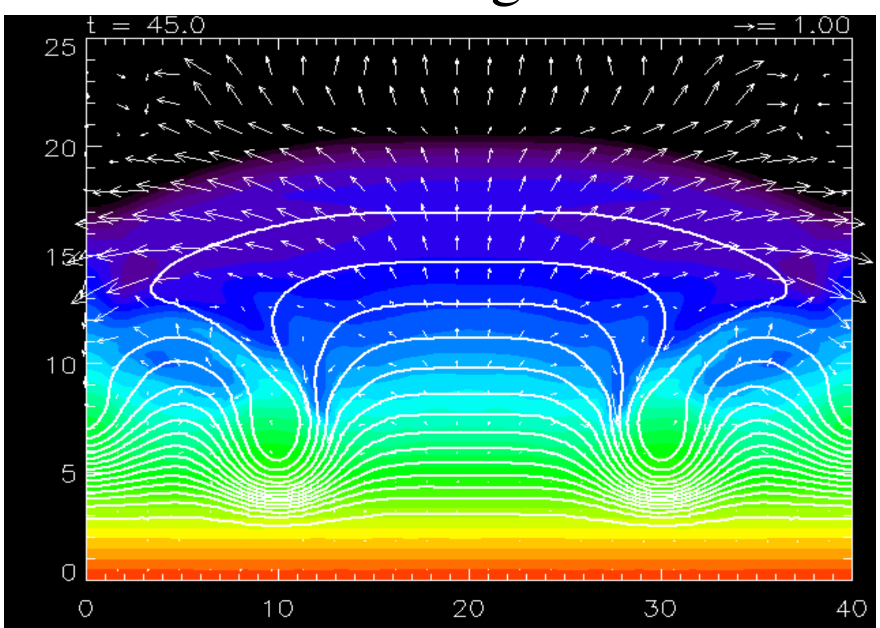
0 degree



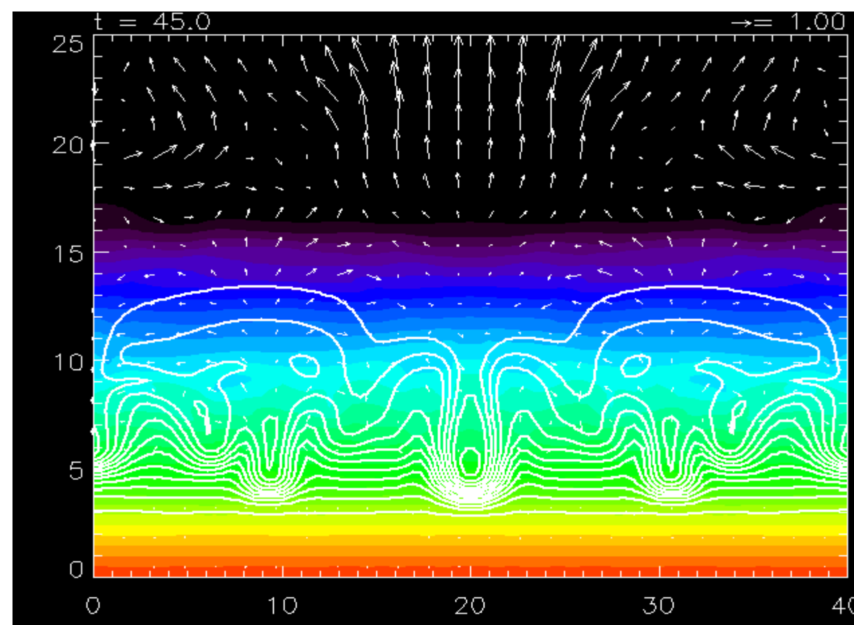
30 degree



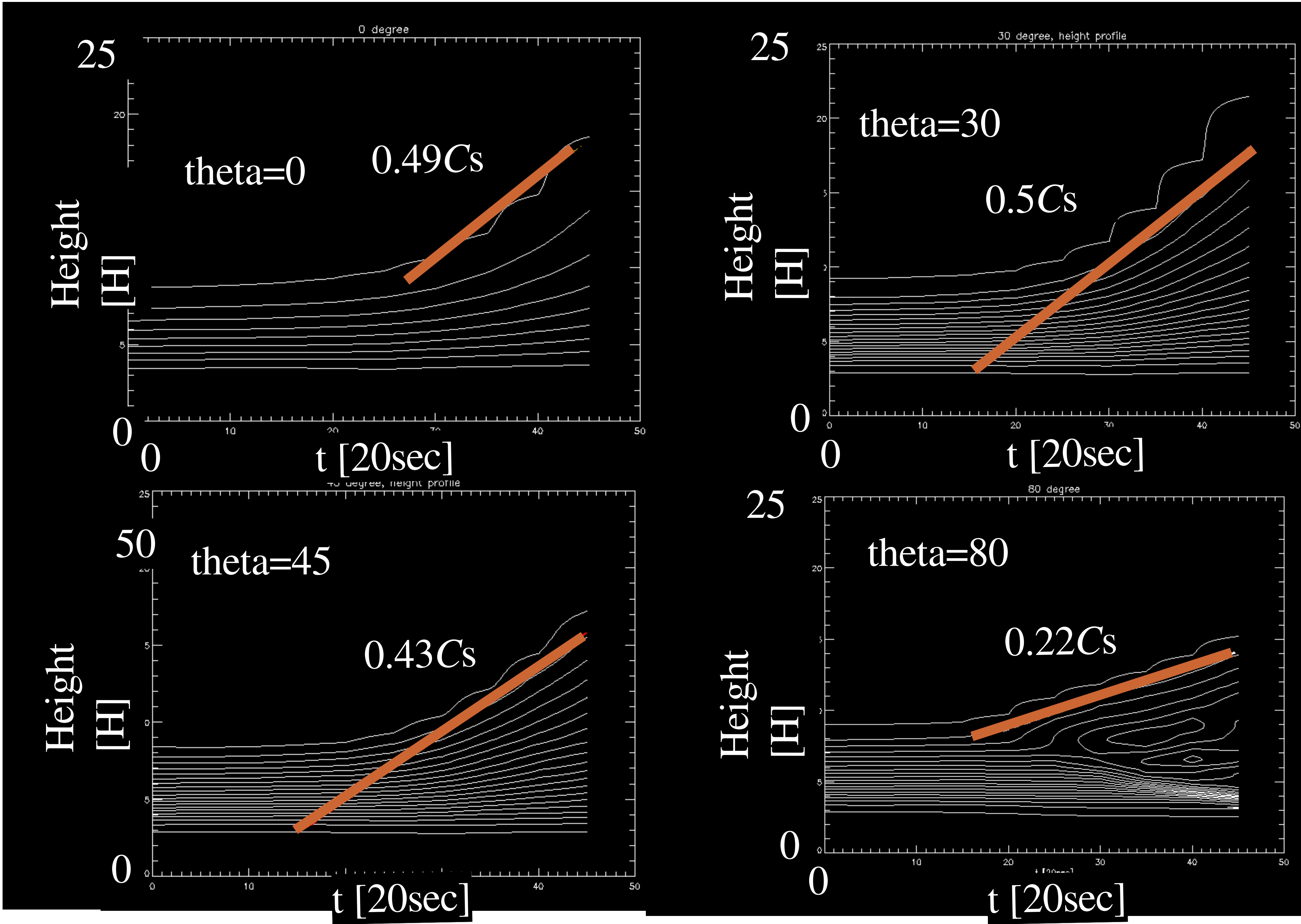
45 degree



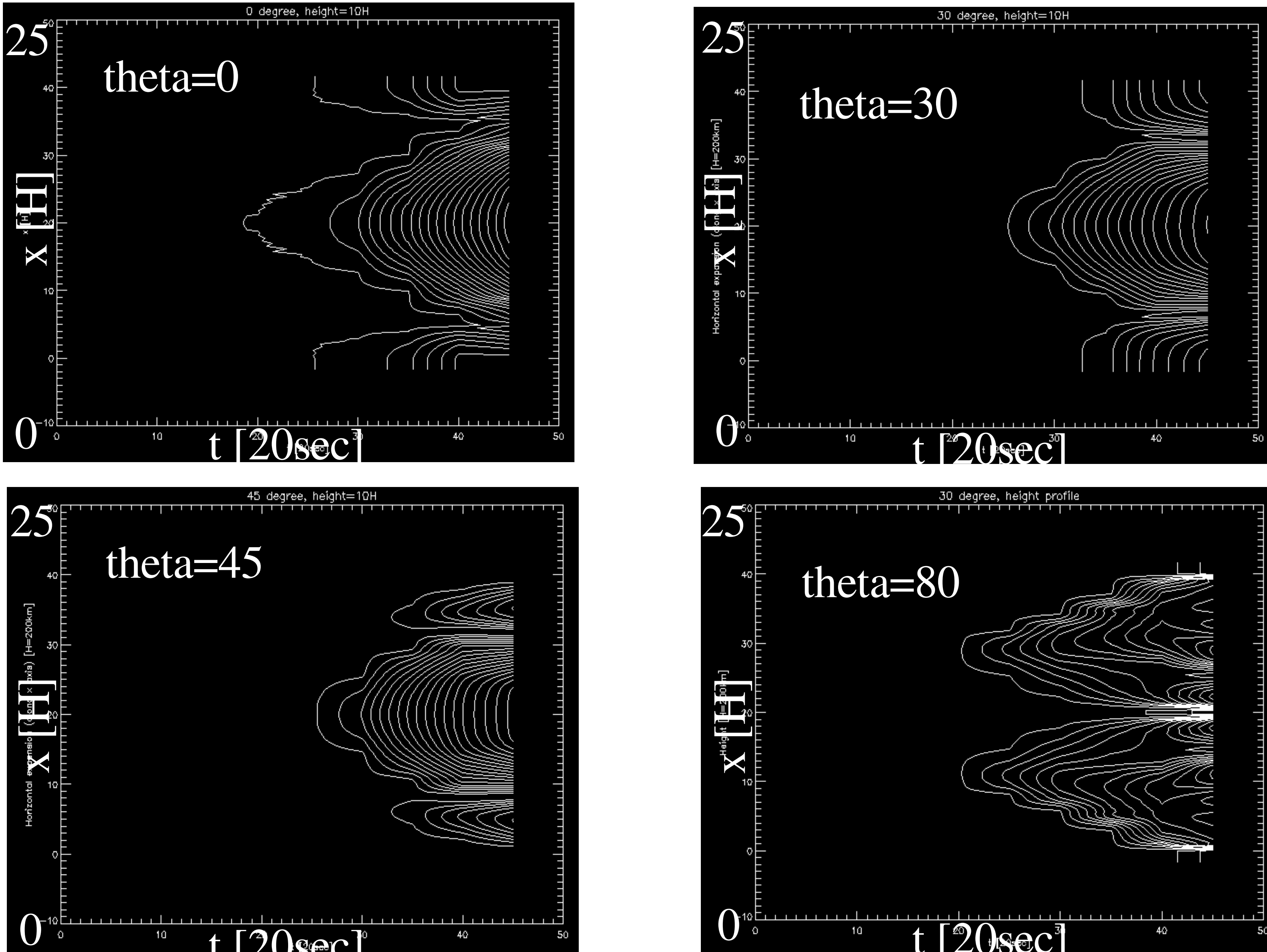
80 degree



Height-Time profile of magnetic field (at center of loop)



Horizontal expansion at a height of 10H



Results

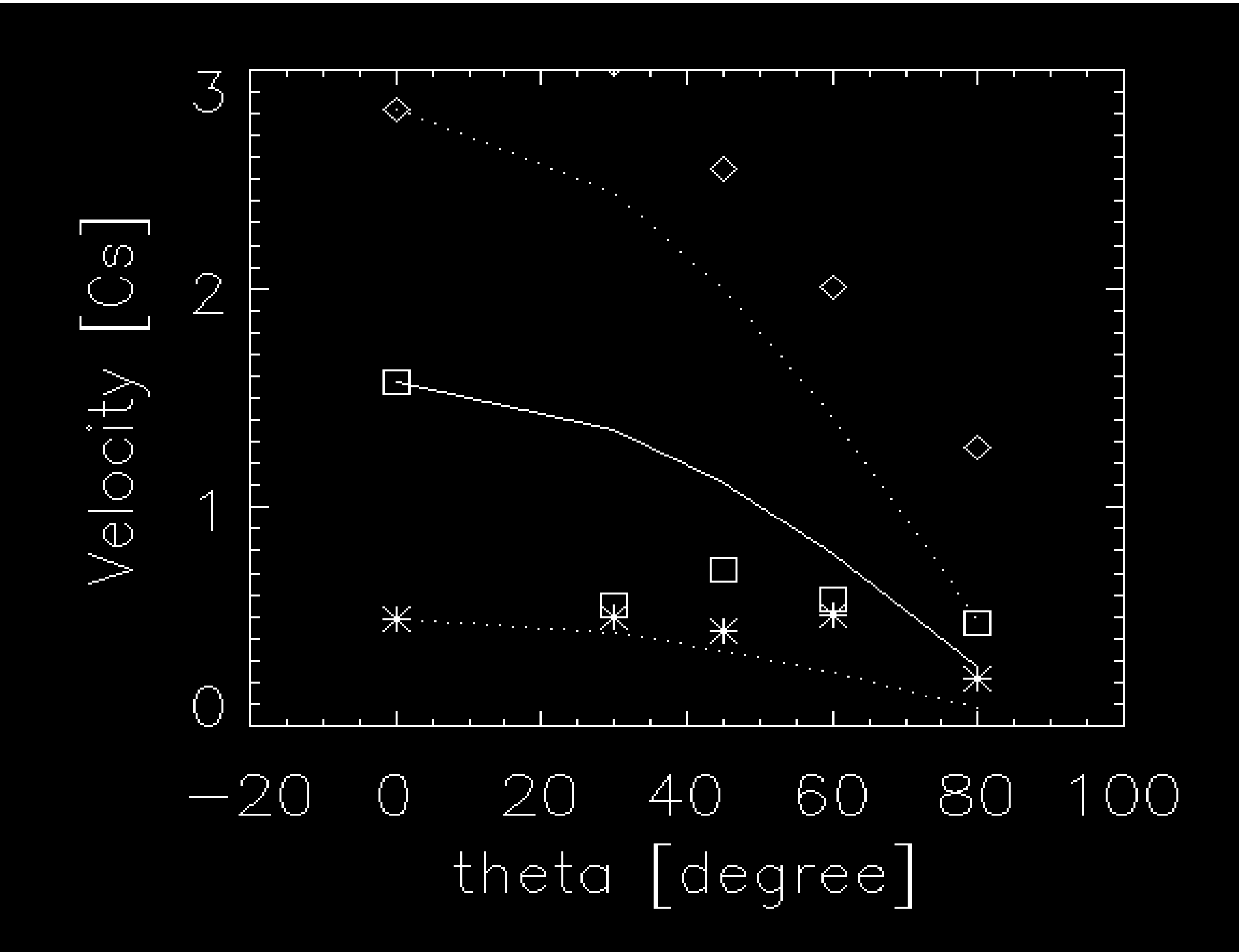
theta	Vx (H) >	Vy (H)	Va
0	0.5(9.2)< 1.57(12.6	0.49	2.82
30	0.5(9.2)< 0.55(13)	0.5	3.03
45	0.71(12)< 1.33(13)	0.43	2.55
60	0.58(10)< 1.34(12)	0.51	2.01
80	0.47(10)< 0.59(**)	0.22	1.27

Velocity : 1 =Cs(photospheric sound speed) = 10km/s

Height : 1 = H (photospheric scale height) = 200km

(** : same loop at different times in its expansion at the loop head)

Velocity variation with angle θ



□ Vx

* Vy

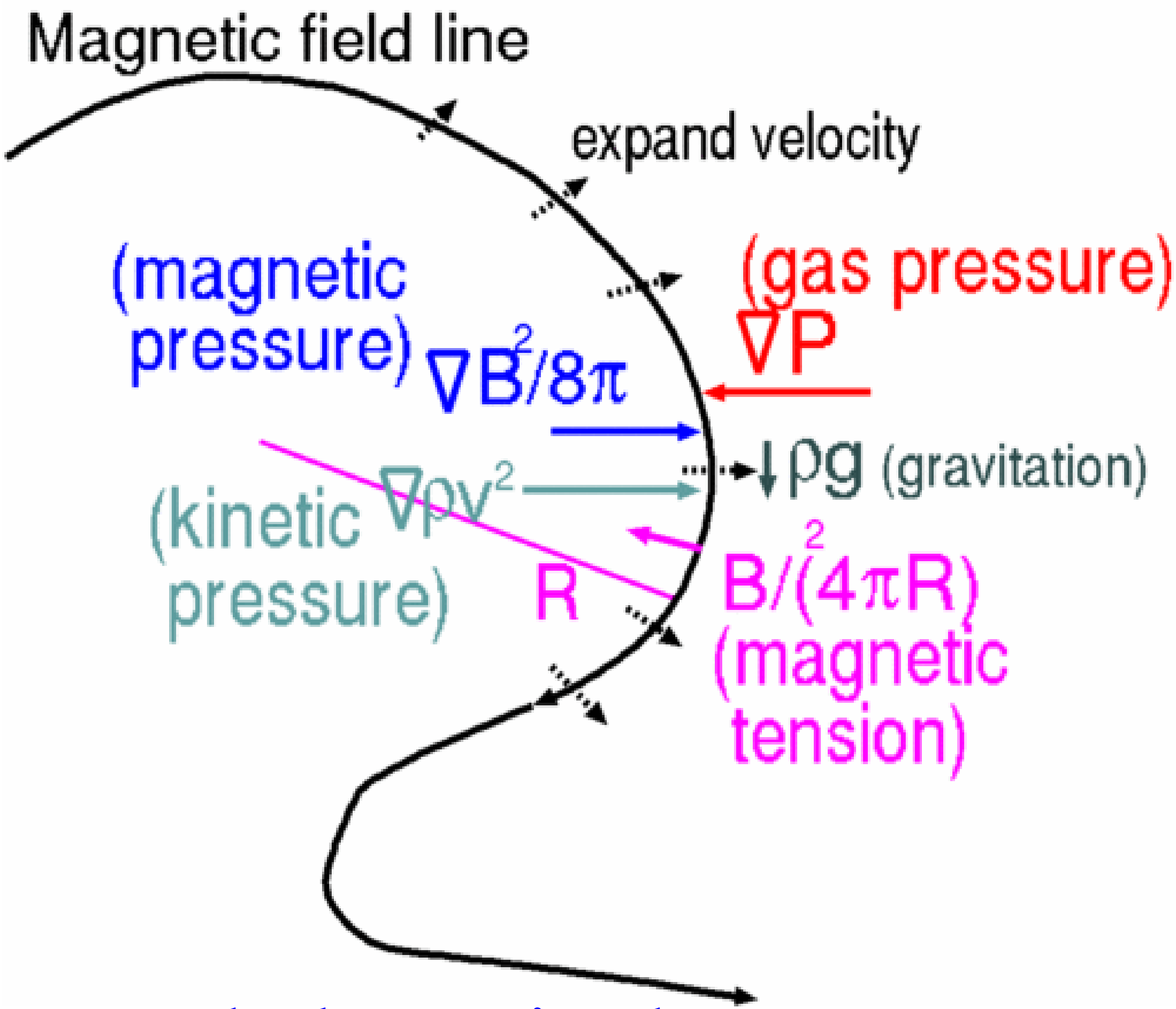
□ Va

Lines:

V_0*cos(theta)

(V_0 = V(theta=0))

Future work



Force balance in the corona