INITIATION AND EVOLUTION OF CORONAL SHOCK WAVES

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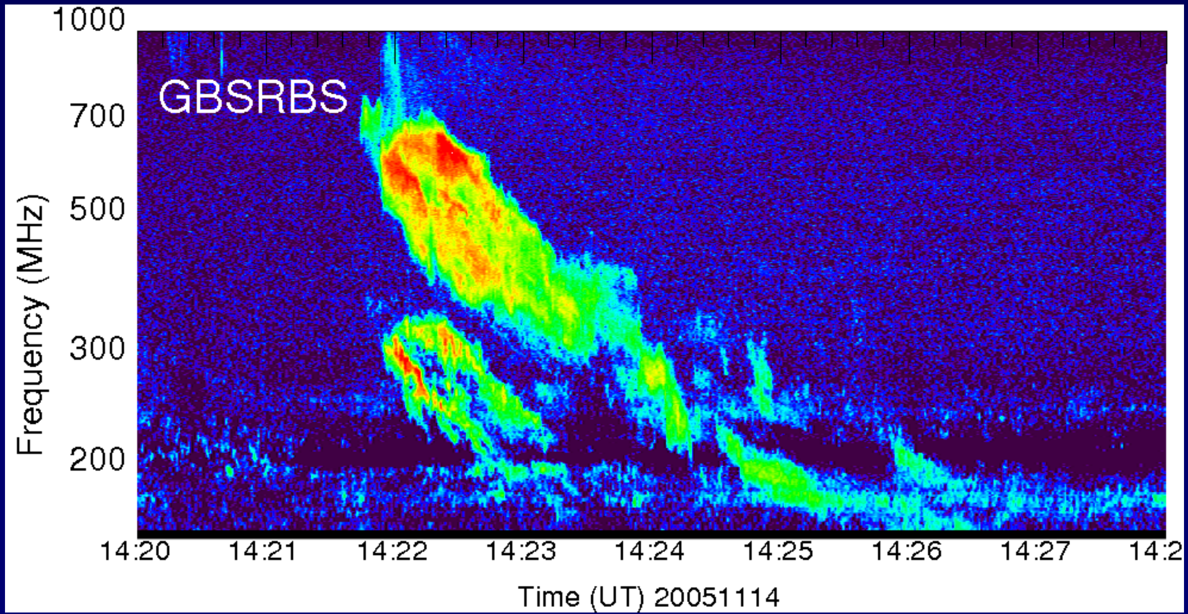
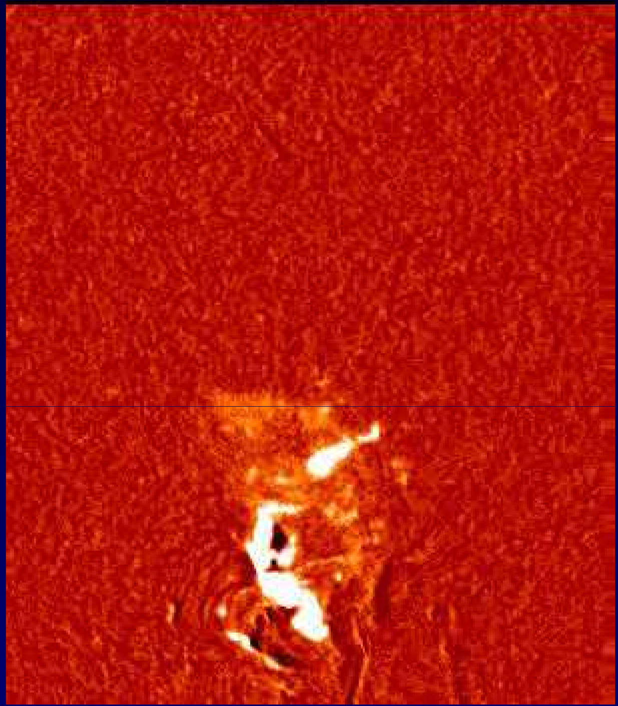
Observational signatures

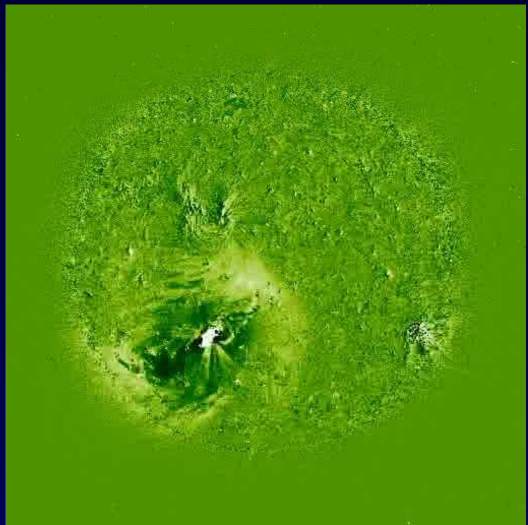
- Type II radio bursts
  (Wild & McCready 1950, *Aust.J.Phys*. 3, 387)
- Moreton waves
  (Moreton & Ramsey 1960, *PASP* 72, 357)



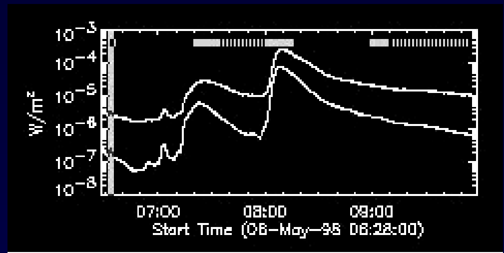


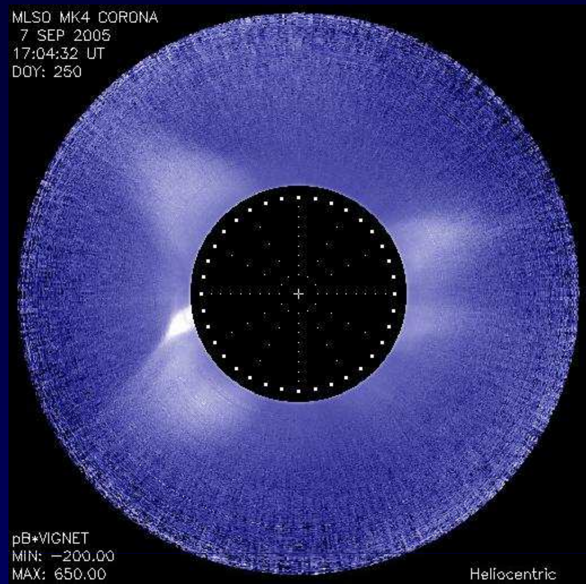
KSO

EUV, SXR, He I, coronograph, radio,...



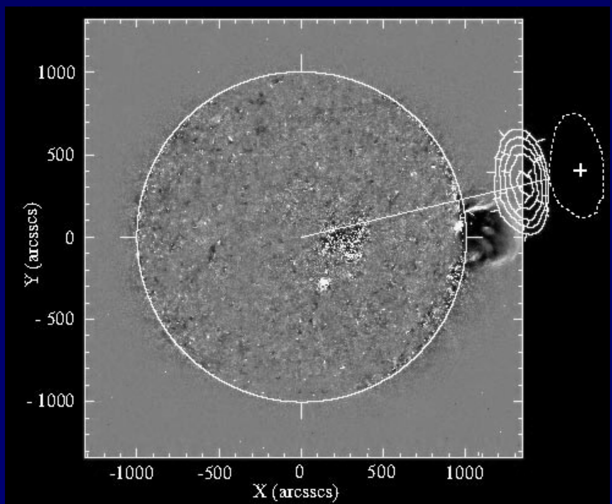
EIT/SoHO

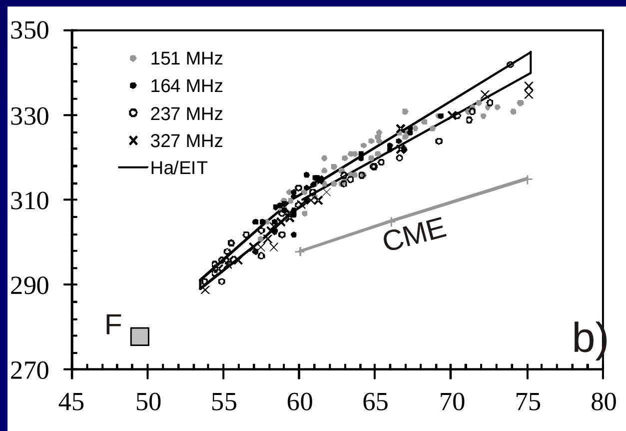




MLSO

NRH





Domain / Signature

in situ

IP
(radio, WL)

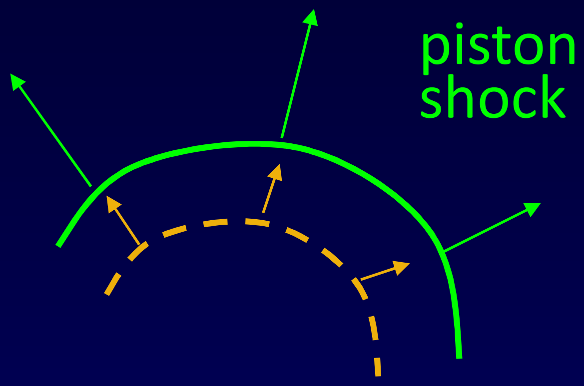
Corona
- radio type II
- WL fronts, streamers

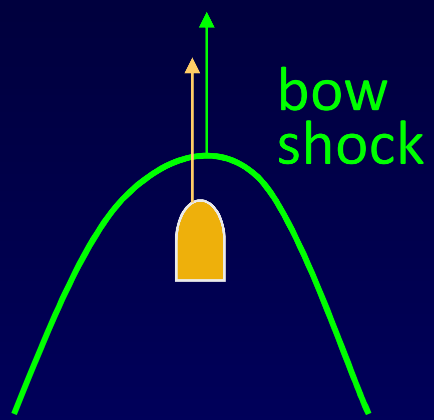
Low Corona (EUV)

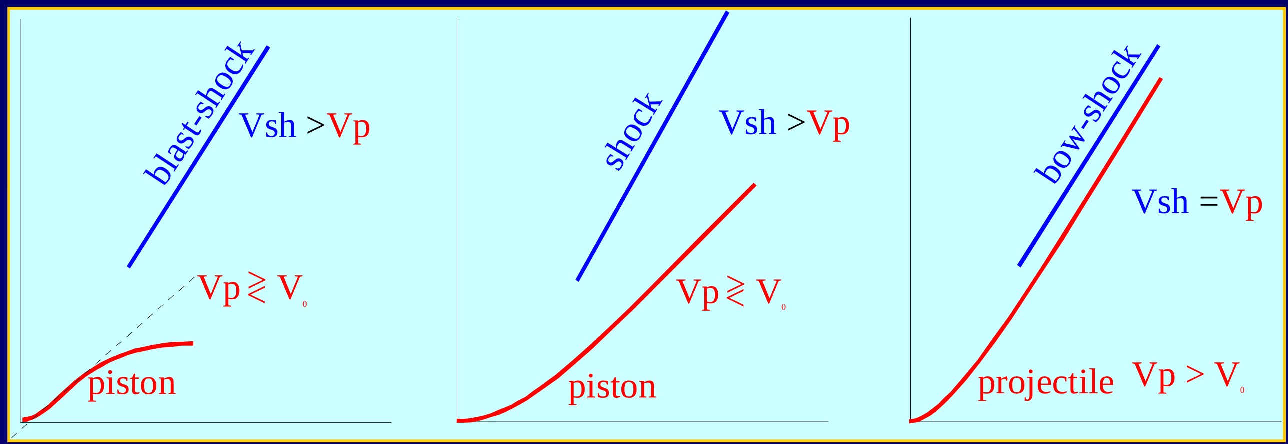
Upper Chromosphere & TR
(Hα, He I, …)
Moreton, disturbed filaments, …

timing, kinematics, intensity, spectral, morphology, …

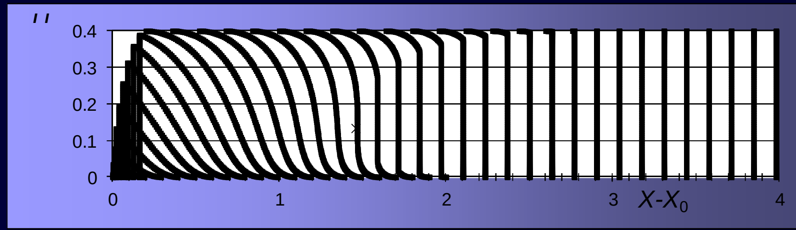
Terminology





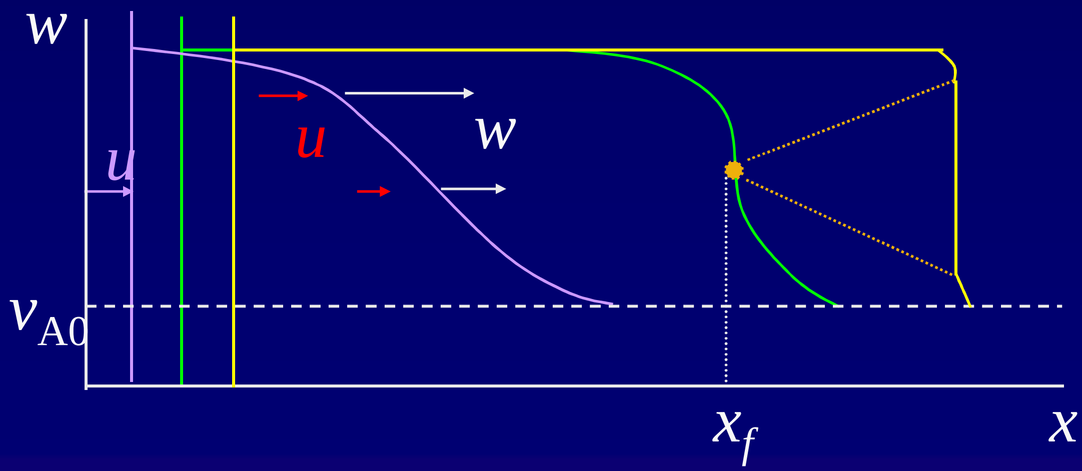


Large-amplitude wave (shock)



- impulsive plasma motion perpendicular to the magnetic field ("strong" acceleration)
- large amplitude wavefront is created
- shock forms after certain time/distance due to the nonlinear evolution of the perturbation (signal velocity depends on the amplitude!)

$$\frac{\partial u}{\partial t} + (v_0 + \tfrac{3}{2}u)\frac{\partial u}{\partial x} = 0$$



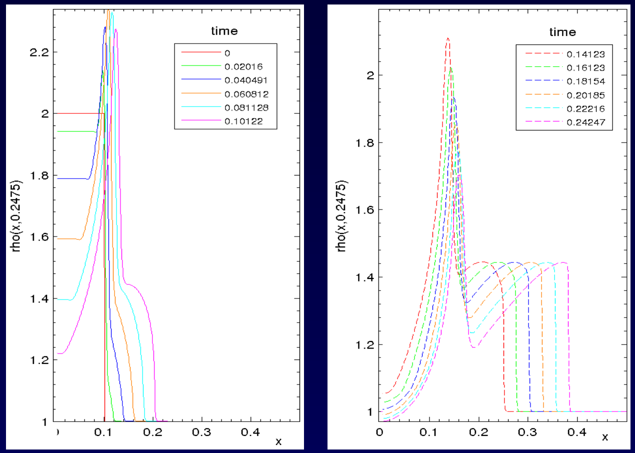
$$w(t) = w_0 + k\,u(t)$$

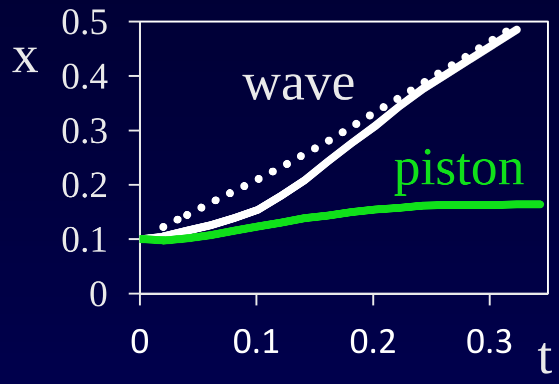
k=4/3, $w_0 = c_{s0}$ at $\beta >> 1$

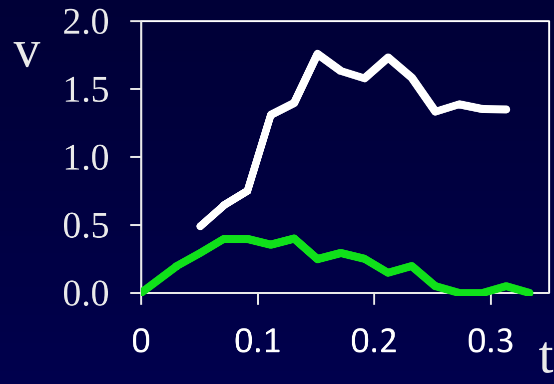
k=3/2, $w_0 = v_{A0}$ at $\beta << 1$

Piston Mechanism (simulations)

1D - planar

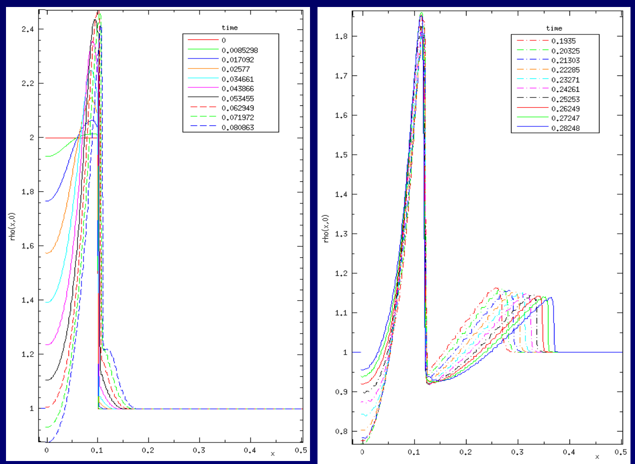


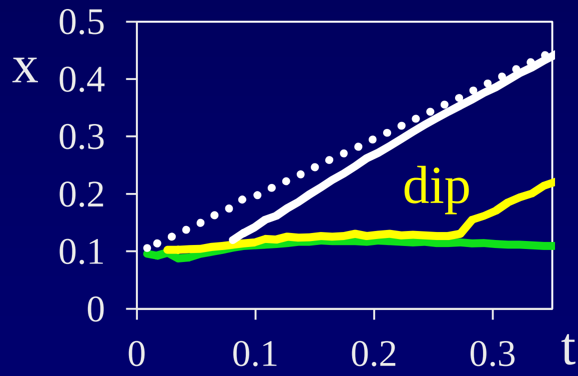


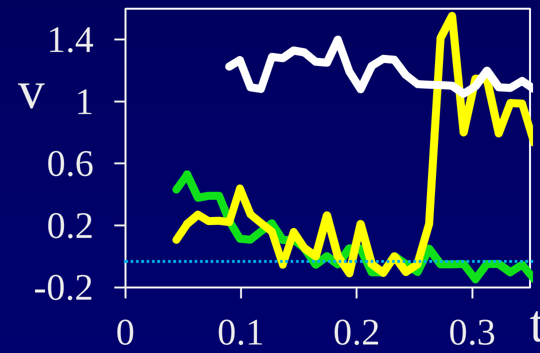


- amplitude growth + steepening → shock formation
- after t~0.15 ~const. amplitude/velocity

2D - cylindrical

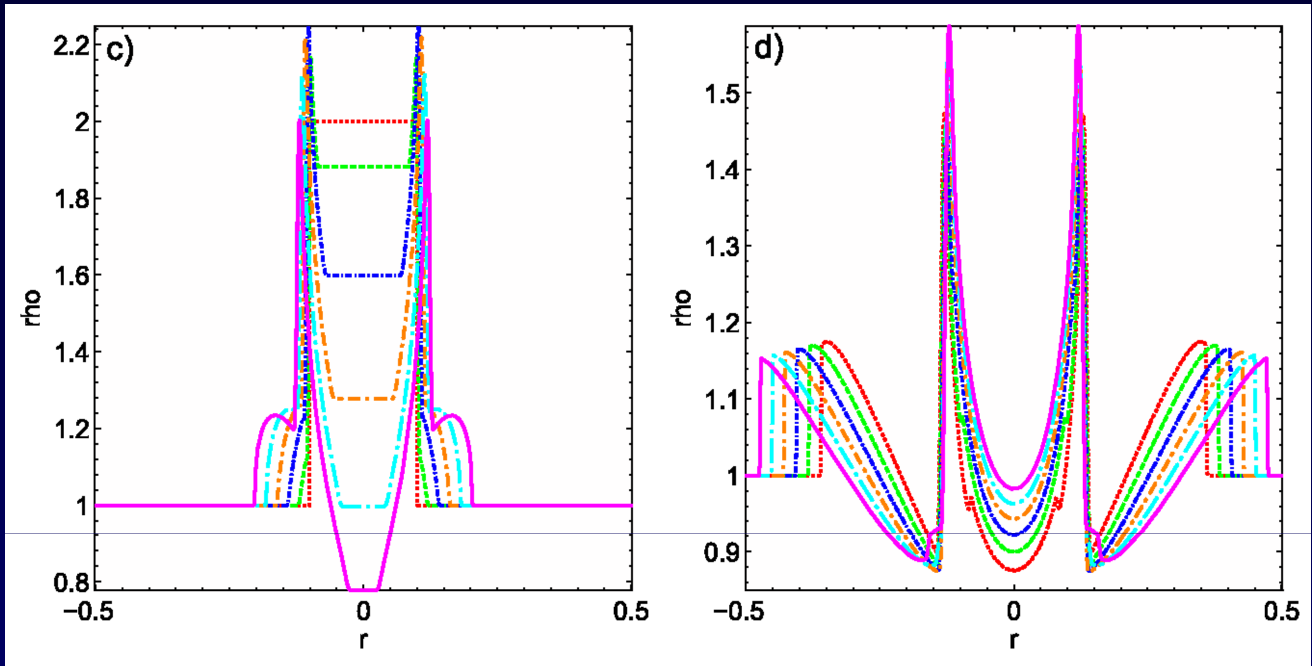


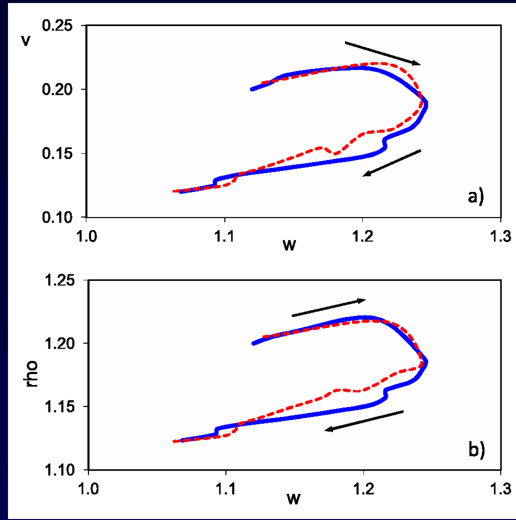




- amplitude growth + steepening → shock formation
- lower amplitude, formation of rarefaction region
- after t~0.08 decreasing amplitude/velocity

Wave evolution (2D)





N. Muhr et al.: On the formation of a coronal disturbance

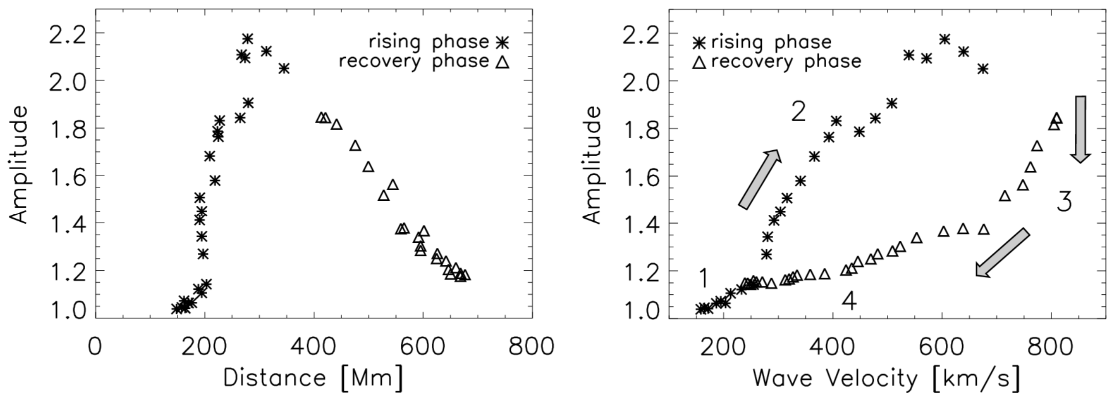
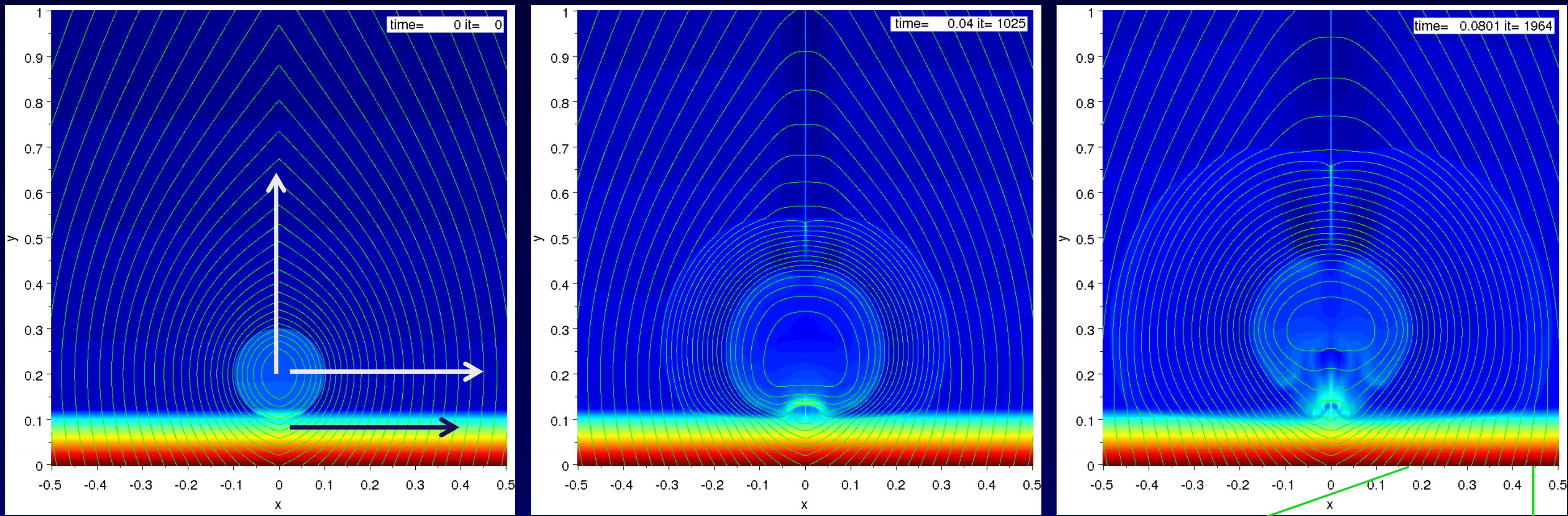
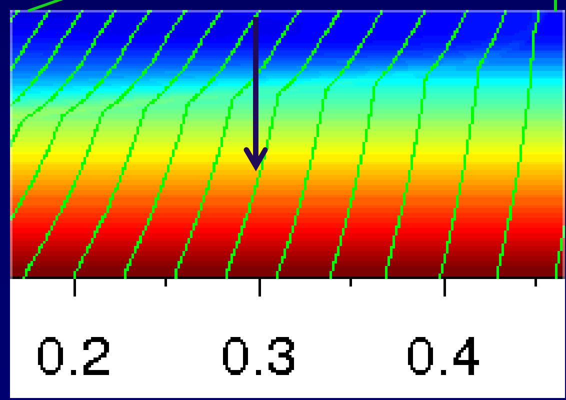
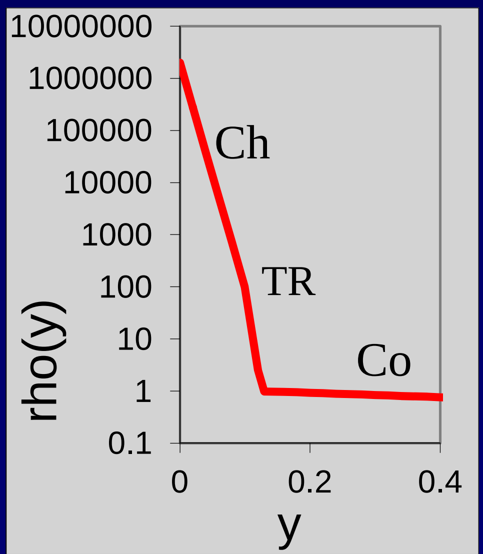


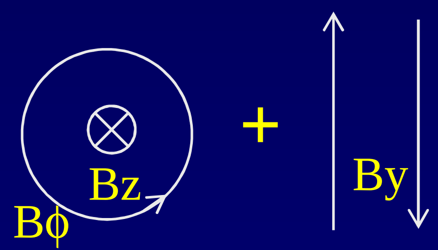
Fig. 10. Amplitude of the perturbation profile against the distance (left) and the velocity (right) of the EUV wave derived from AIA 211Å observations during 01:48 UT-02:12 UT. Arrows indicate the temporal evolution.

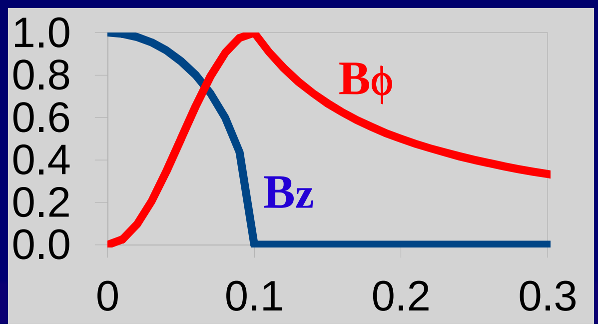
2.5-D MHD simulation





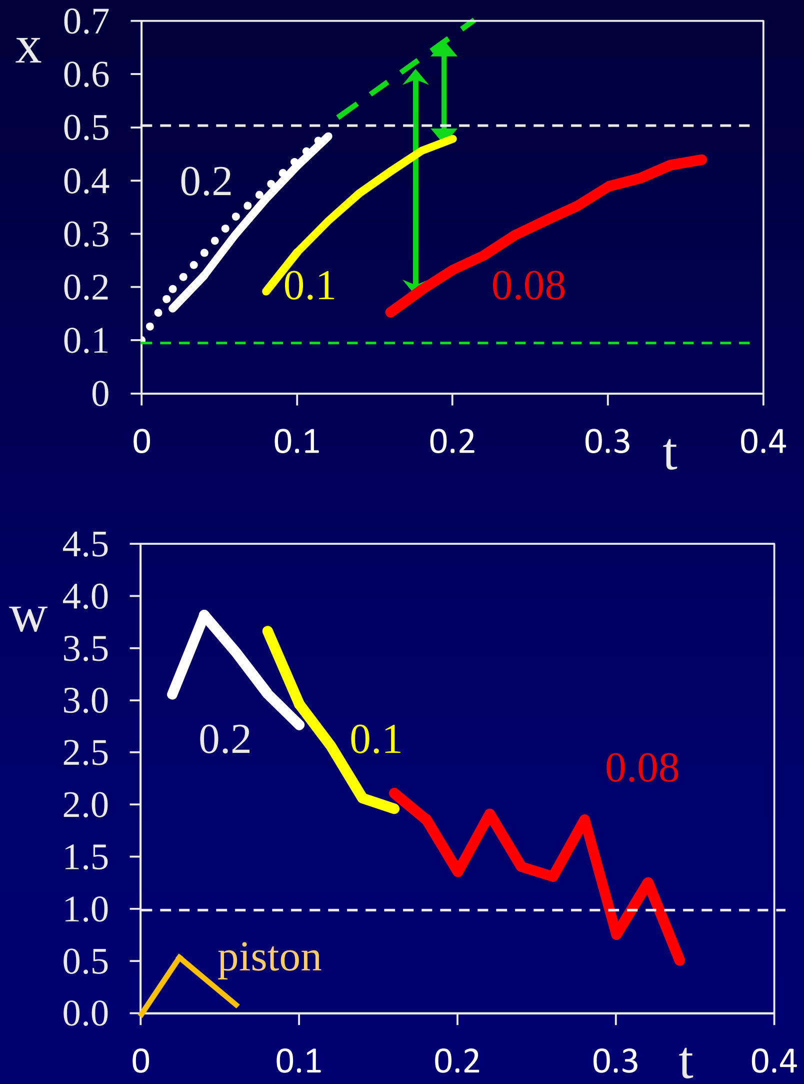


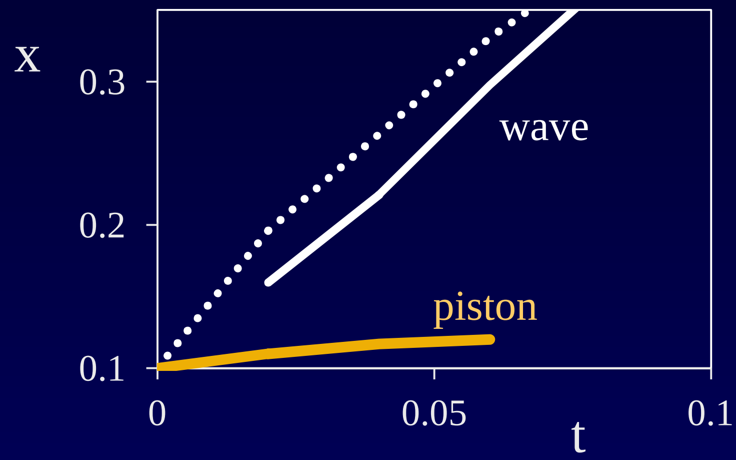




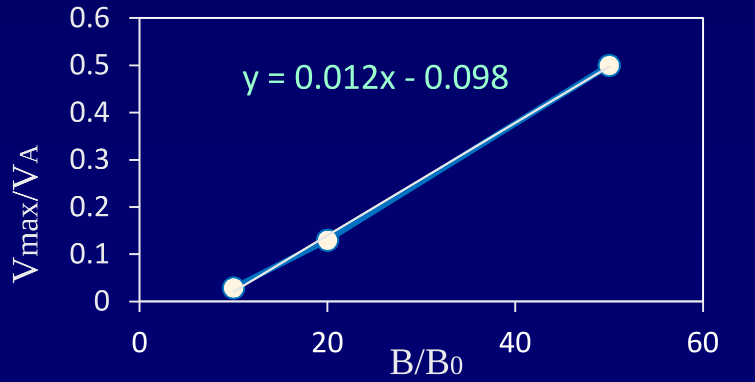
$\beta = 0$

MHD simulation: Corona (horizonatal)





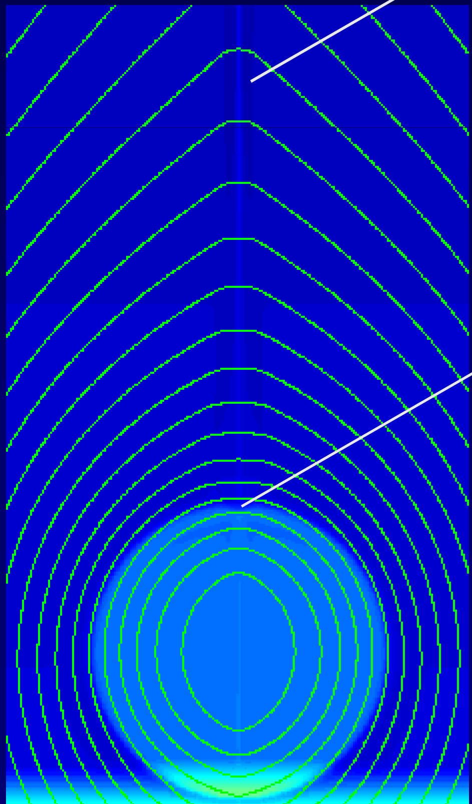
- steepening + ampl. increase → shock
- deceleration; ampl. decrease
- corona/Moreton offset
- corona/Moreton delay

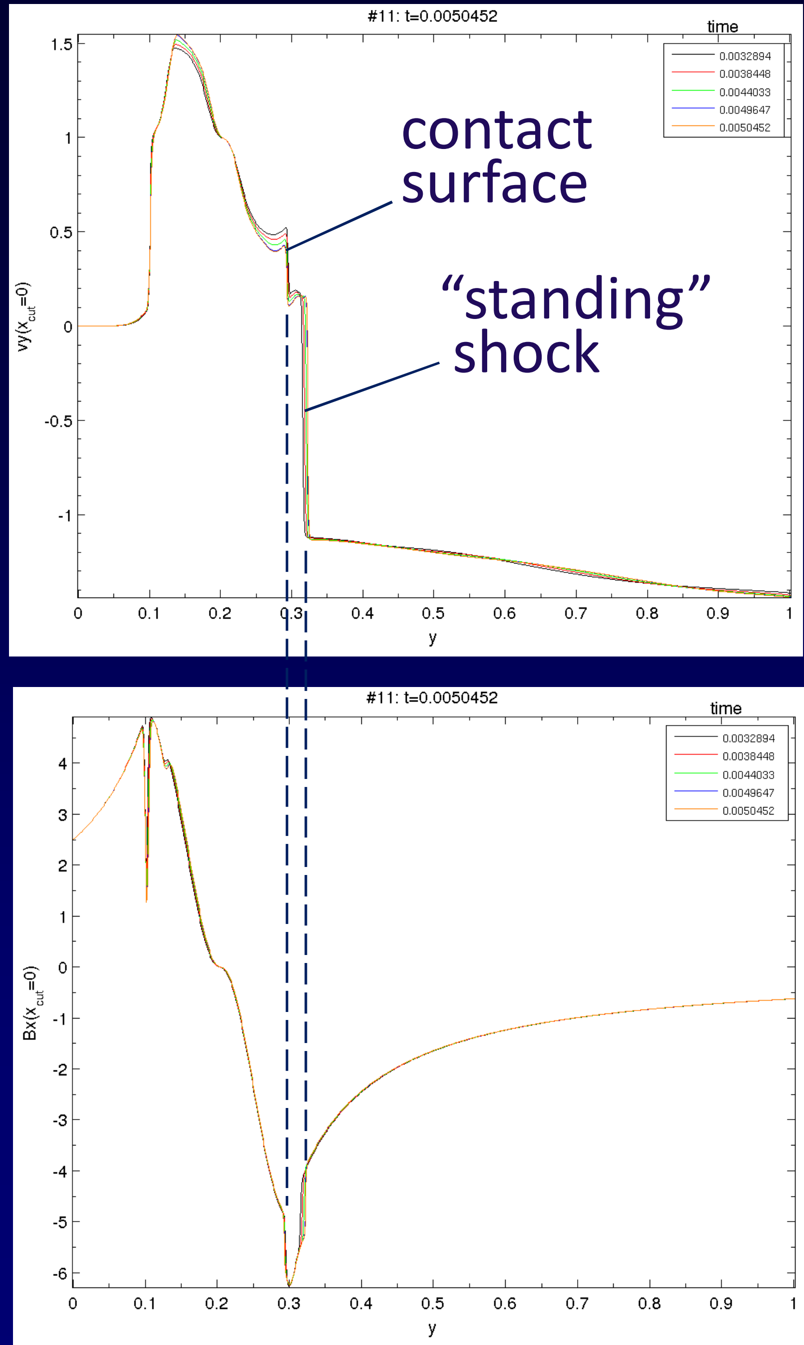


MHD simulation: Corona (above)

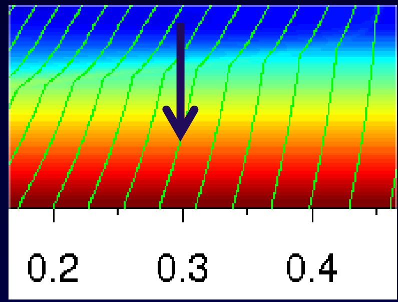
streamer (current sheet)
(reconnection outflow jet)

fast-mode
standing shock

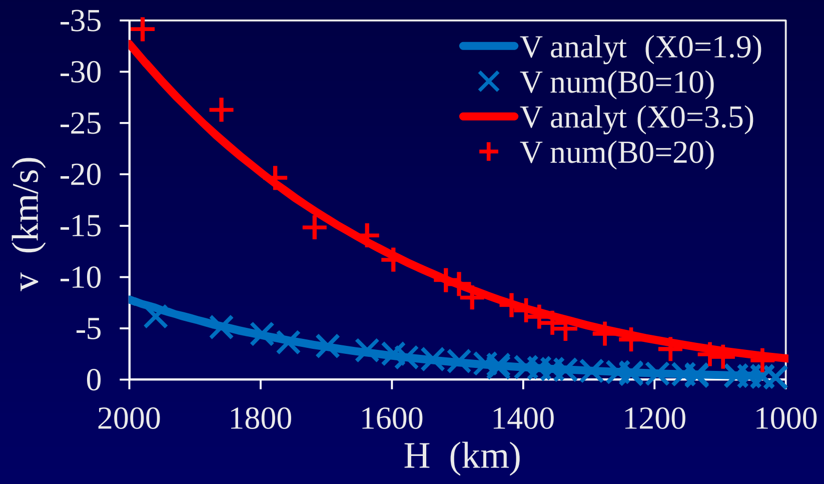


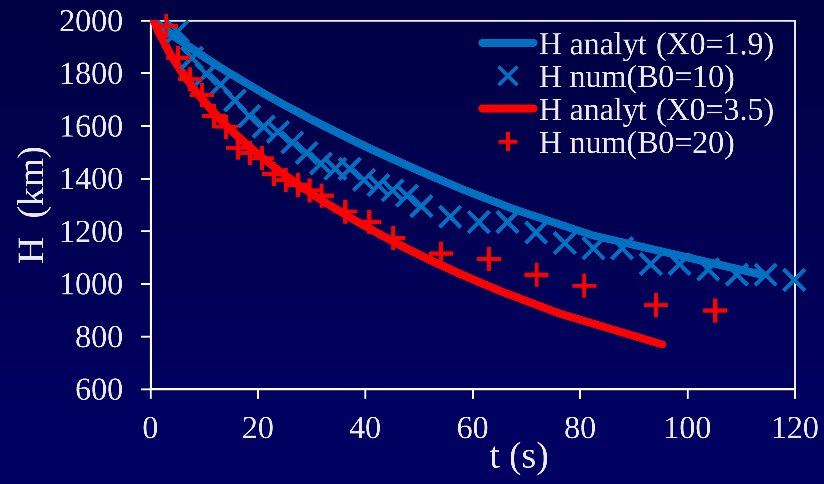


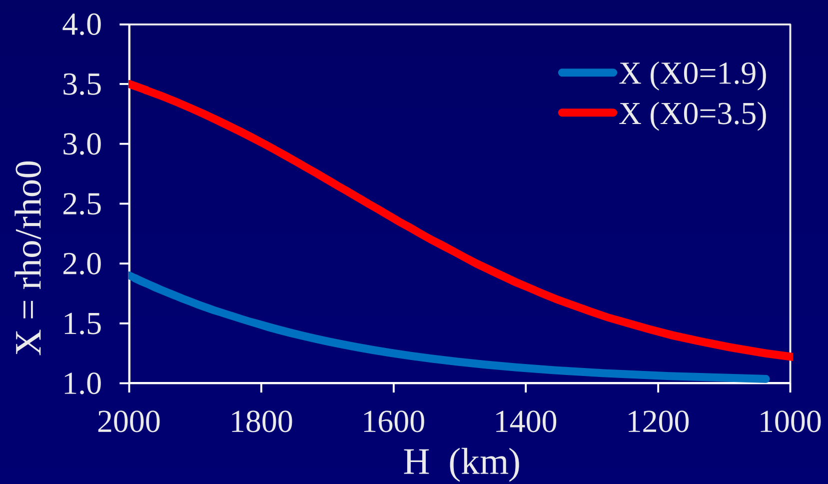
MHD simulation: Moreton wave

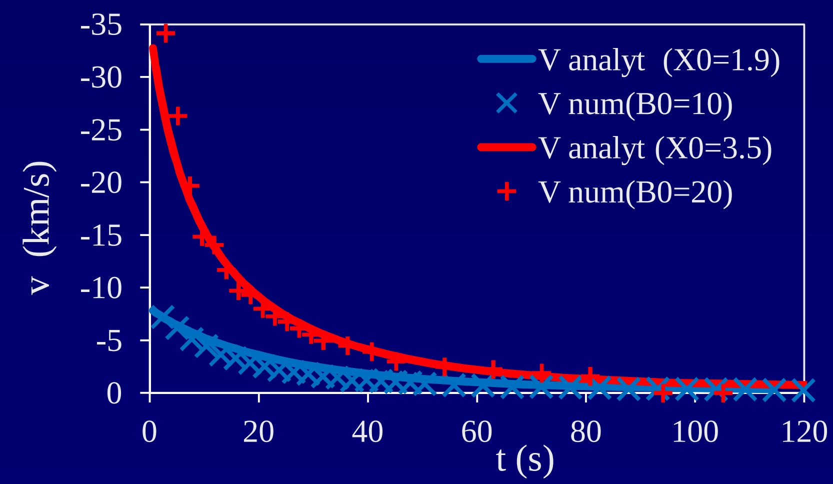


comparison with analytical:
$\rho v^2 w$ = const.;
c_s = 10 km/s = const.









Conclusion

- upward (type II burst) = driven bow/piston shock
- lateral (EUV, HeI, Hα) = temporary piston ("CME overexpansion")
- the time/distance of the shock formation and its amplitude/speed depend strongly on the impulsiveness of the piston
- Moreton wave appears only if shock is sufficiently strong (fast); only the upper chromosphere is affected
- downward propagating chromospheric disturbance is quasi-longitudinal fast-mode shock that can be well approximated by a sound shock
- Moreton wave lags behind the coronal wave due to chromospheric inertia

Thank you

for

your attention