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Seismic studies of solar prominences

Multi-threaded prominence oscillations triggered by a coronal shock wave

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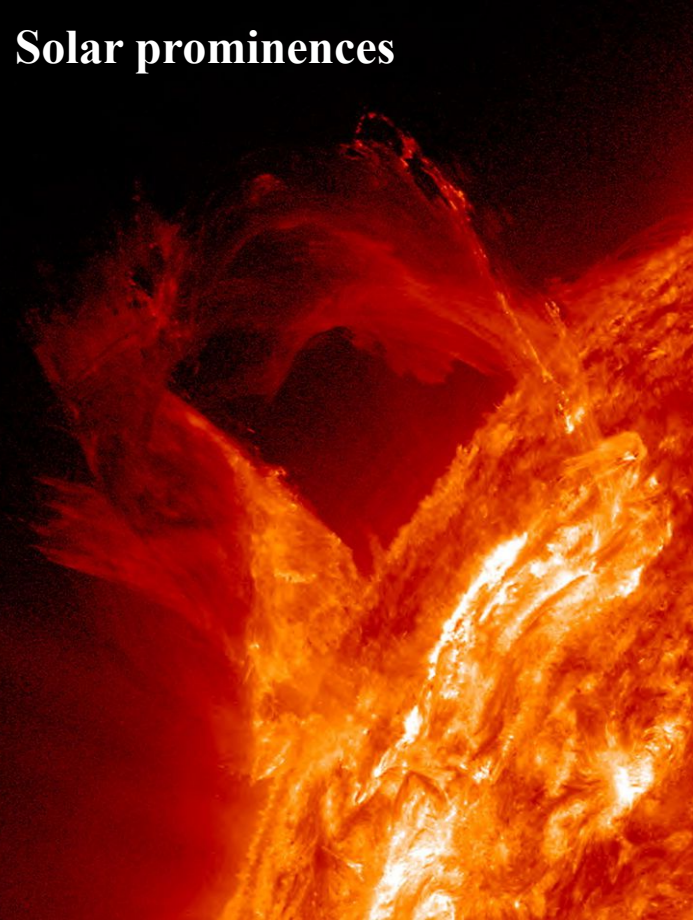
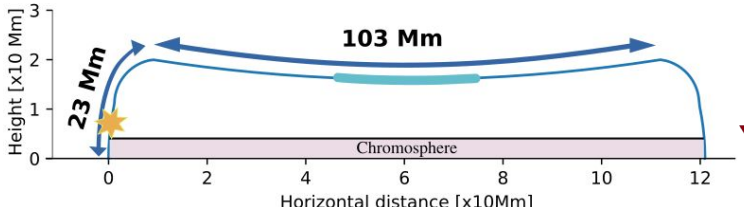
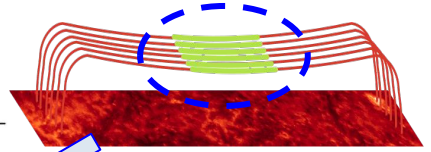
Solar prominences

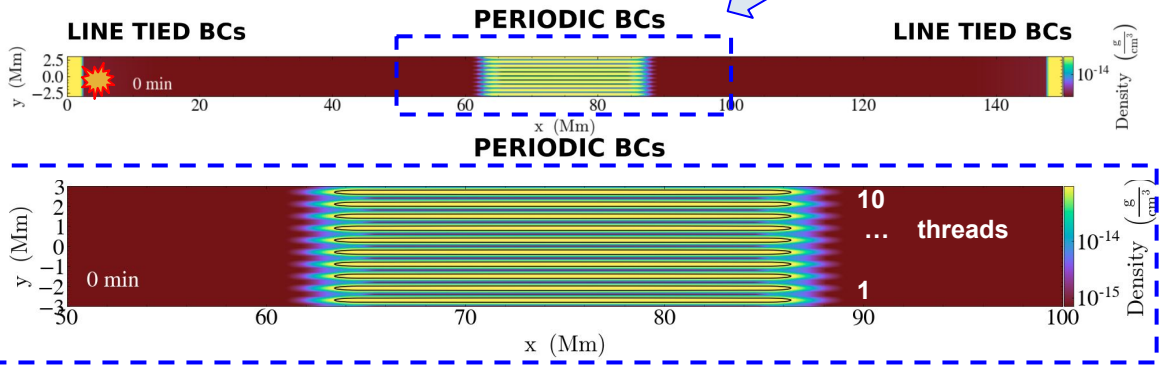


Solar prominence on March 16, 2013. (Image credit: Solar Dynamics Observatory/NASA).

Methods

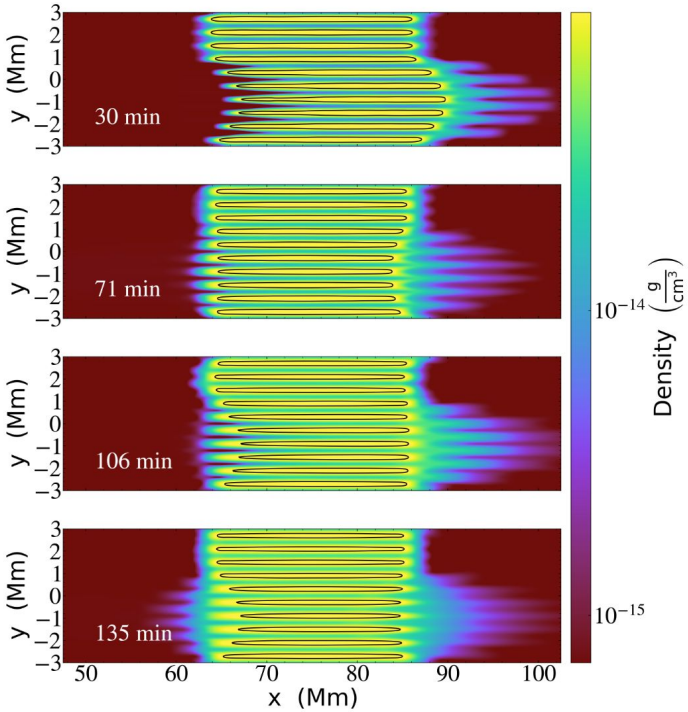




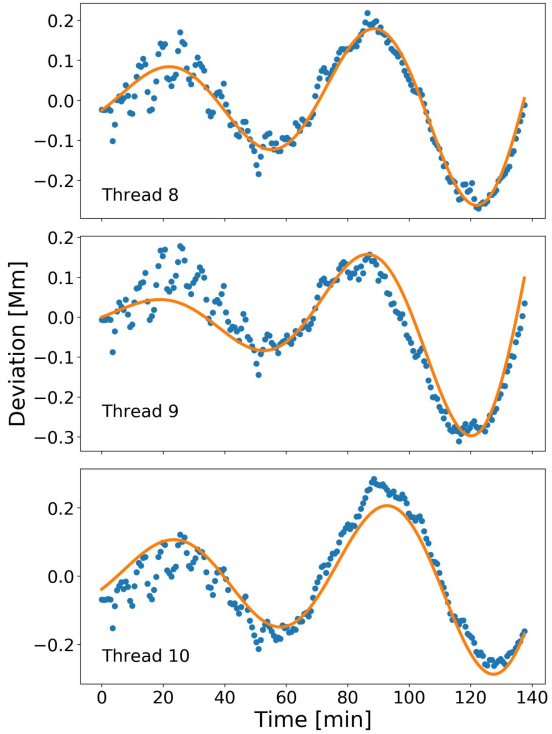


- **2D adiabatic** simulation, MPI-AMRVAC.
- **Stratified atmosphere**.
- Threads - **artificially** created (~23 Mm long and ~230 km wide).
- Resolution of 36 km × 7.5 km.
- Source region at x=4Mm, y=-1Mm.

Longitudinal oscillations



Oscillations with contour lines marking the area with number density higher than $5\times10^{10}cm^{-3}$.

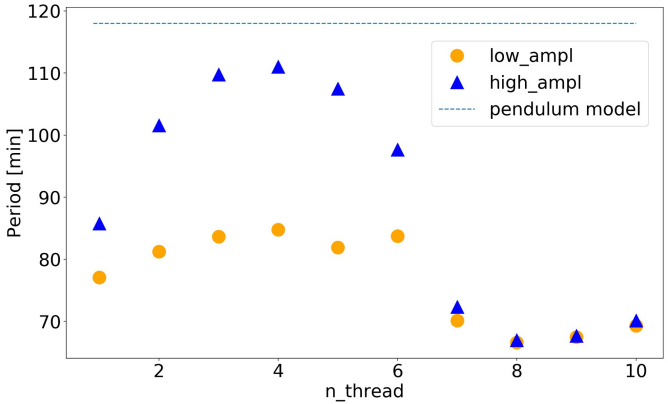


Evolution of the motion of the CM in the *x* direction of threads 8, 9 and 10, in regards to their position at t=0.

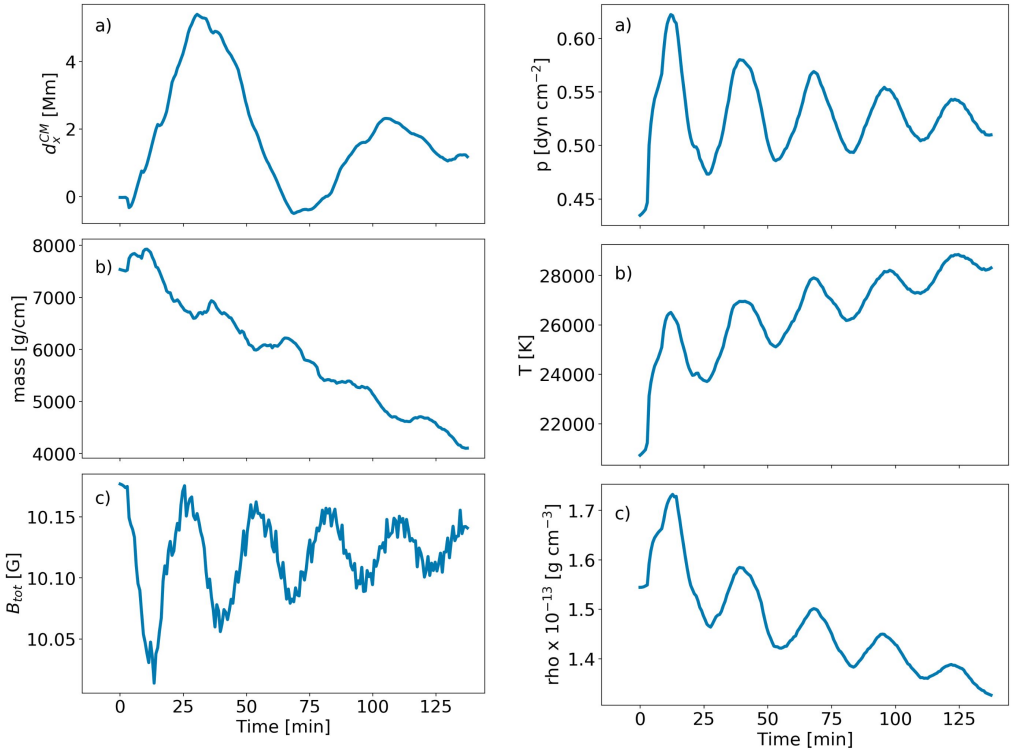
- Longitudinal oscillations:
  - damping of threads 1-7,
  - amplification of threads 8-10.
- Doubling the source amplitude (high_ampl case) - all parameters experience stronger perturbations.

Properties of longitudinal oscillations

- Loss of mass and decrease of the average density.
- Oscillations of the magnetic field in antiphase with pressure and density.
- Increase in the temperature of the threads.
- Periods do not match the analytic pendulum model.



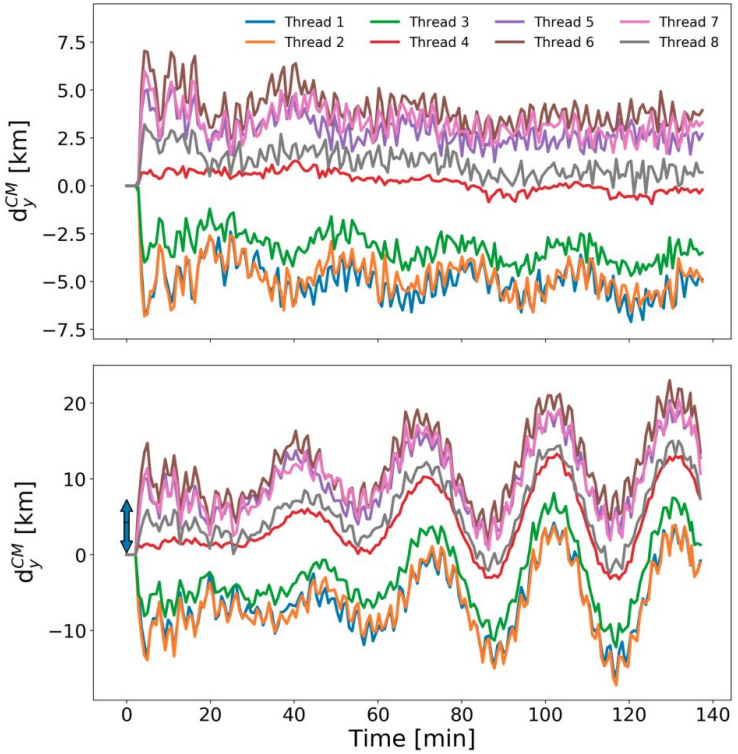
Periods of oscillation of the 10 threads, triggered by sources of different amplitude (low_ and high_ampl cases).



Evolution of the motion of the CM in the *x* direction and the average values of mass, magnetic field, pressure, temperature and density during oscillations of thread 4.

Transverse oscillations

- Amplification of motion in the *y* direction.
- Interchange of energy between longitudinal and transverse motion.
  - Related to the periodic boundary conditions.
- High frequency oscillations in d_y^{CM}, v_y, B_y and B_x parameters.
  - All with a period of 1.5 to 16 min.
  - Coinciding with the periods of magnetoacoustic waves.



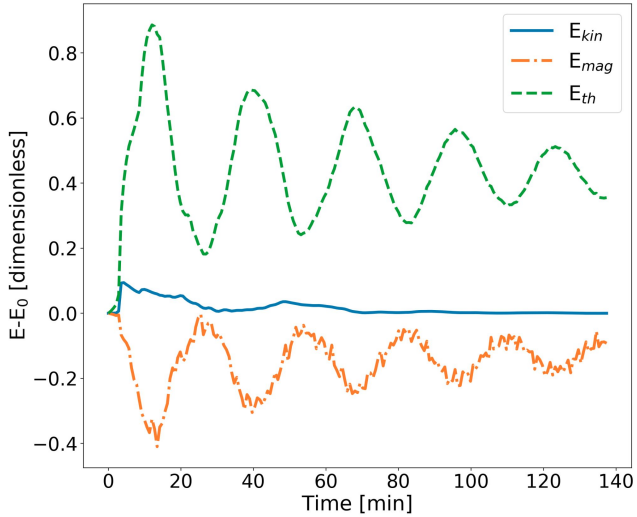
Low_ampl case

High_ampl case

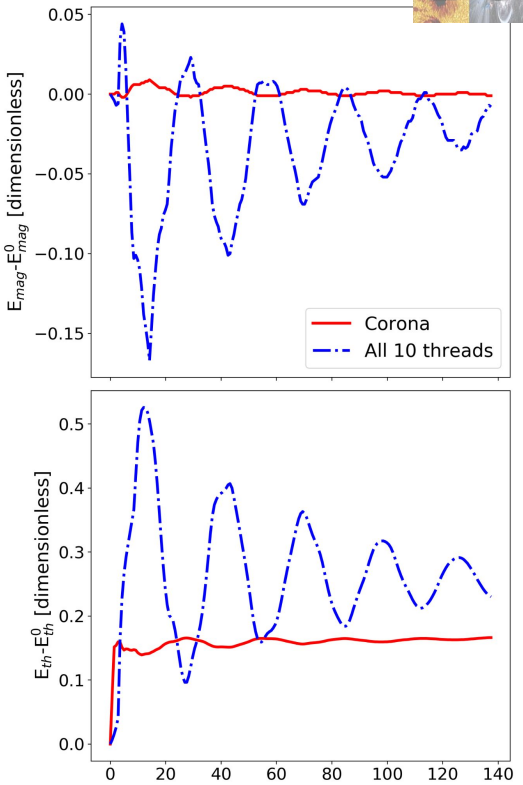
Evolution of motion of the CM in the *y* direction of threads *1-8* in respect to their initial position. The arrow on the bottom plot marks the size of the cell in the *y* direction (7.5 km).

Energy analysis

- Interchange of energy:
  - between the shock wave and the threads
  - between the corona and the 10 threads.



Changes of the average thermal (green dashed line), kinetic (full blue line) and magnetic (dash-dotted orange line) energy of thread *4* with respect to their initial value (after the relaxation phase).



Changes of the average magnetic (top panel) and thermal (bottom panel) energies of all 10 threads and the corona, with respect to their initial value (after the relaxation phase).

Conclusion

- The source and the thread-like prominence structure influence the measured period.
- Repeated reflections and transmissions of the initial shock wave result in numerous interferences of compressional waves propagating within and surrounding the prominence plasma.
  - They contribute to the restoring forces of the oscillation and lead to differences in the attributed damping between various threads.
- Multiple high frequency oscillations represent the propagation of magnetoacoustic waves.
- The damping is linked to the conversion of energy and its exchange with the corona.
- Exchange of energy between different threads and different modes of oscillation is also evident.