Heating and acceleration of the solar wind by low-frequency Alfvén waves

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To understand

The evolution of low-frequency Alfvén waves

Goal

- Comparison of wave propagation for different periods: τ = 1000 s, τ = 1800 s, τ = 4000 s
- Efficiency to accelerate Solar winds.
- Mechanism of heating the Corona

Injected wave

$$v = v_0 \sin(\omega_0 t)$$

$$\omega_0 = 2\pi f \qquad f = 1/\tau$$

$$v_0 = 9 \text{ km s}^{-1}$$

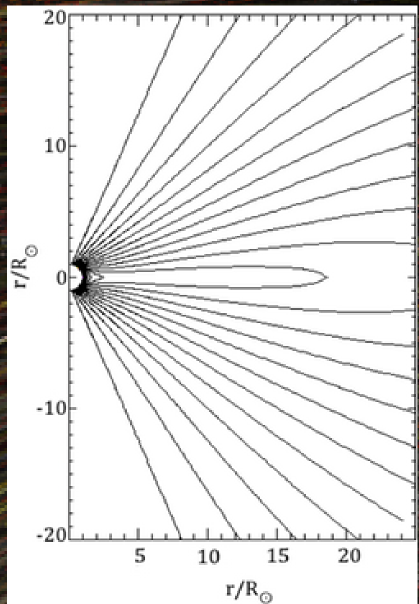
Tools

2.5D numerical MHD model

Background plasma

In the absence of waves, the dipole field is stretched into a helmet streamer by the solar wind.

The wind speeds near the equator are lower than those near the poles due to magnetic configuration



What we Know

Alfvén waves play important role in heating and accelerating of solar wind.

If there are counter-propagating Alfvén waves, Alfvén-wave turbulence evolves. This turbulence influences the energy cascade and the formation of the power spectrum.

Shoda et al. (2018) showed that the solar wind possess a frequency-filtering mechanism with respect to Alfvén waves

Wave evolution of Alfvén wave with different τ at the coronal base

Parametric Decay Instability

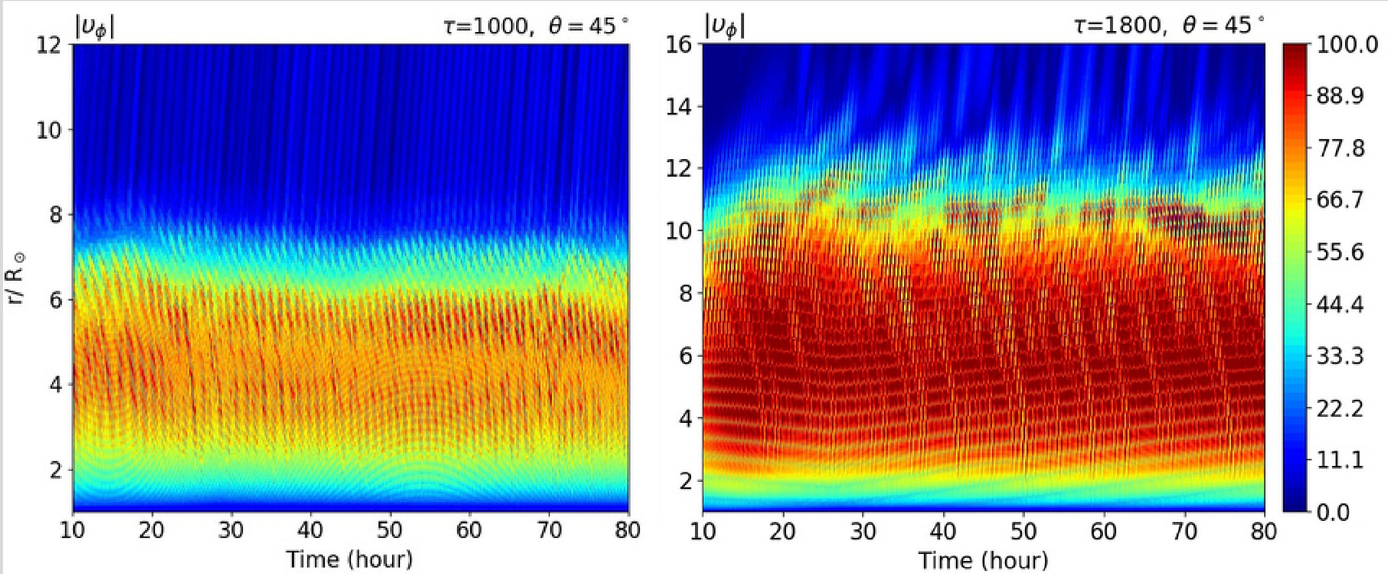
Alfvenic Fluctuation

$$f \geq 10^{-3}\ \mathrm{Hz}$$

This cavity remains fixed in time and becomes wider for longer wave period.

The increased amplitude produced by interaction between the forward and backward propagating modes.

latitude = 45

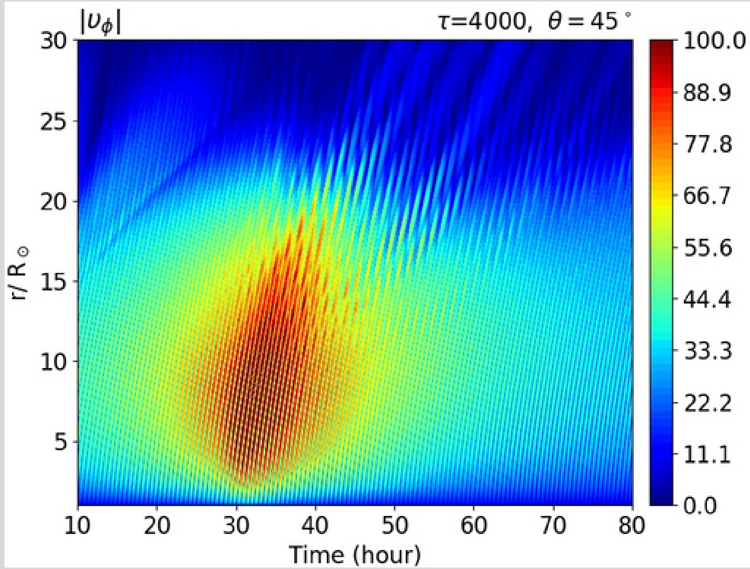


$$f < 10^{-3.5}\ \mathrm{Hz}$$

The width of the cavity changes with time.

The fluctuation amplitude increases near the Sun.

latitude = 45



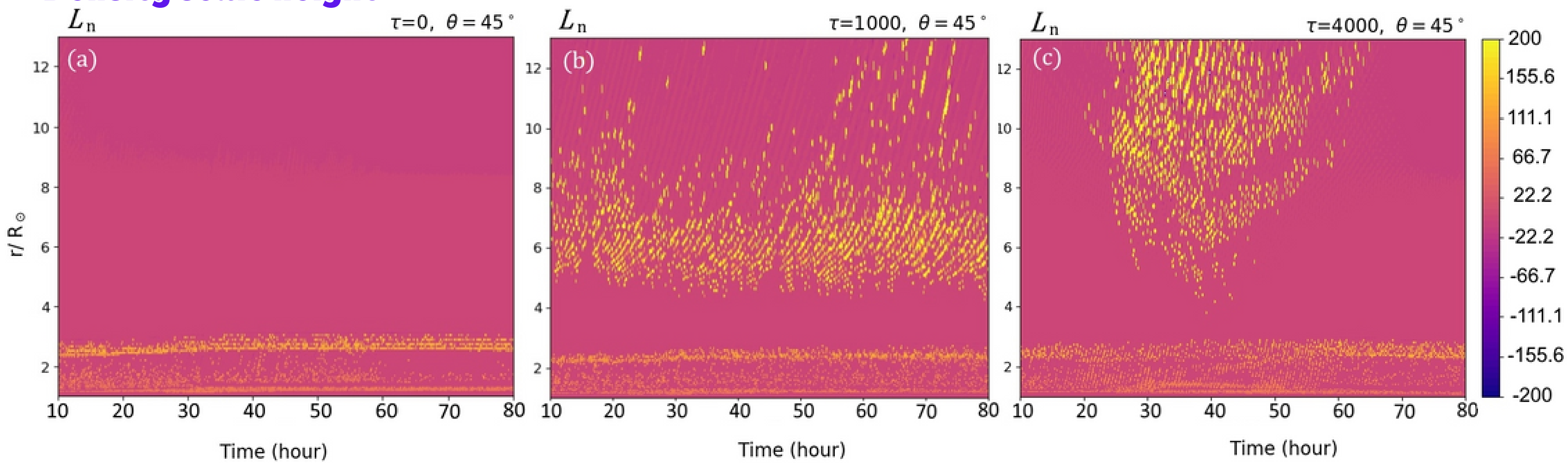
Enhanced wave amplitudes provided by the nonlinear pendermotive effect.

Beyond the threshold radii, the wave amplitudes are small due to conversion of wave energy into kinetic (solar wind acceleration) and thermal (heats up the corona) form.

RESULTS

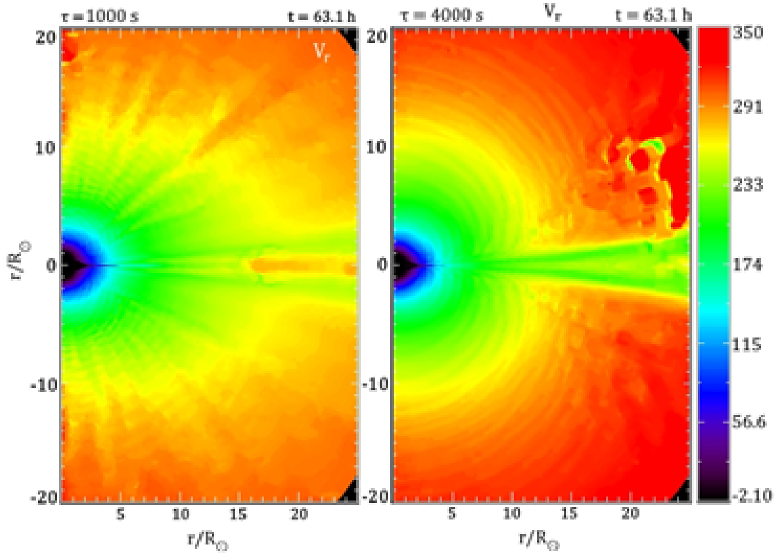
In the radial direction

Density scale height



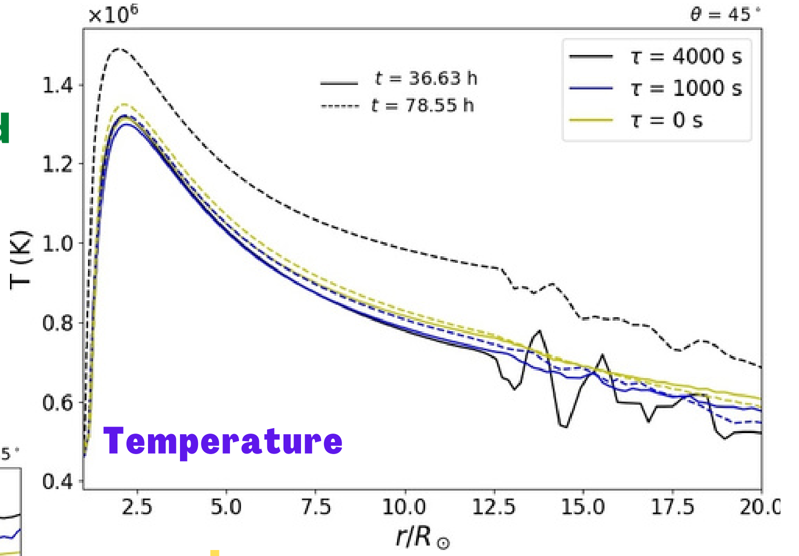
Injected waves change the density scale height that influences the wave propagation.

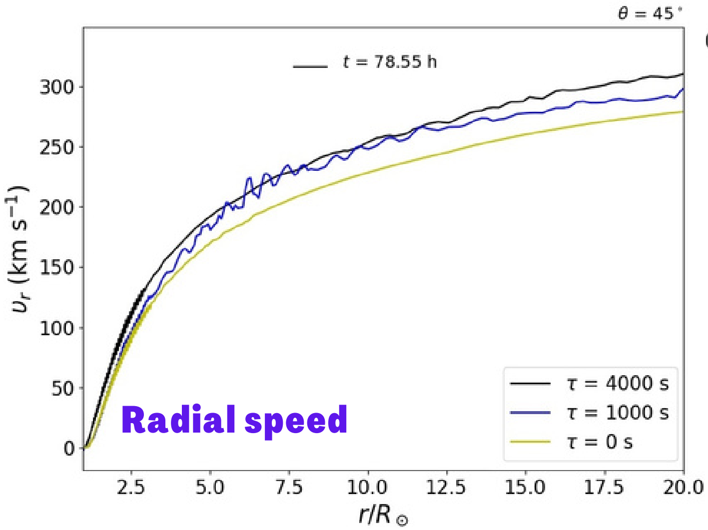
Snapshot of the radial velocity for the two different waves.



Radial velocity is more variable near the equator and higher speed for $\tau = 4000$ s than $\tau = 1000$ s.

When $\tau = 4000$ s, we find enhanced heating of the solar wind plasma more than $\tau = 1000$ s.





Injected waves accelerate the solar wind and speed perturbation decreases with time for $\tau = 4000$ s.

Discussion

The propagation of Alfven waves and their influence on heating and acceleration is determined by the driver frequency.

Low frequency wave:

- Distort the medium and increases the propagation resistant and its energy converts thermal energy more efficient than the kinetic energy.
- More efficient to accelerate the solar wind.
- The strength of the background magnetic field of of the corona slightly reduces.

High frequency wave:

- Wave amplitudes are less affected by the medium and the energy is mainly converted into wind acceleration.
- The strength of the background magnetic field of of the corona slightly increases.

Summary

The frequency of the Alfvenic driver determines:

- The heating and acceleration of the solar wind plasma.
- The nature of the nonlinear wave evolution.

Thanks ...

References

M. Shoda, T. Yokoyama, and T. K. Suzuki, The Astrophysical Journal860(1), 17 (2018)

N. F. Derby Jr, The Astro-physical Journal224, 1013 (1978).