Observation of the Streaming-Kink Instability in the Solar Prominence

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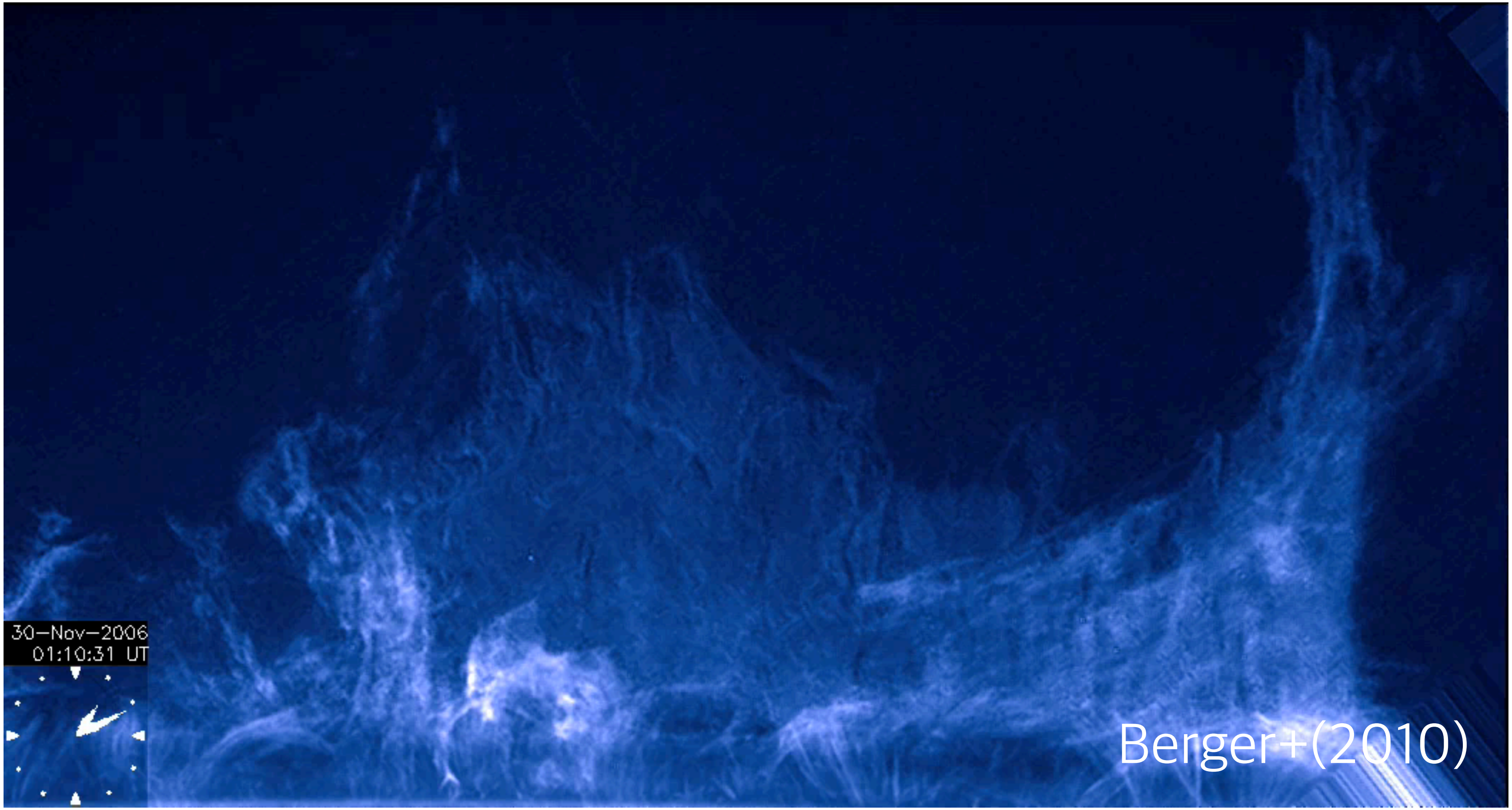
Instabilities in the Sun

- plumes - Reileigh-Taylor Instability (RTI)
- frank of the plume - Kelvin-Helmholtz Instability (KHI)
- frank of the CME ejecta - KHI
- at the interface between an erupting region and the surrounding corona - KHI
- formation of large-scale arch shaped Bubble - Screw Pinch Instability (SPI)



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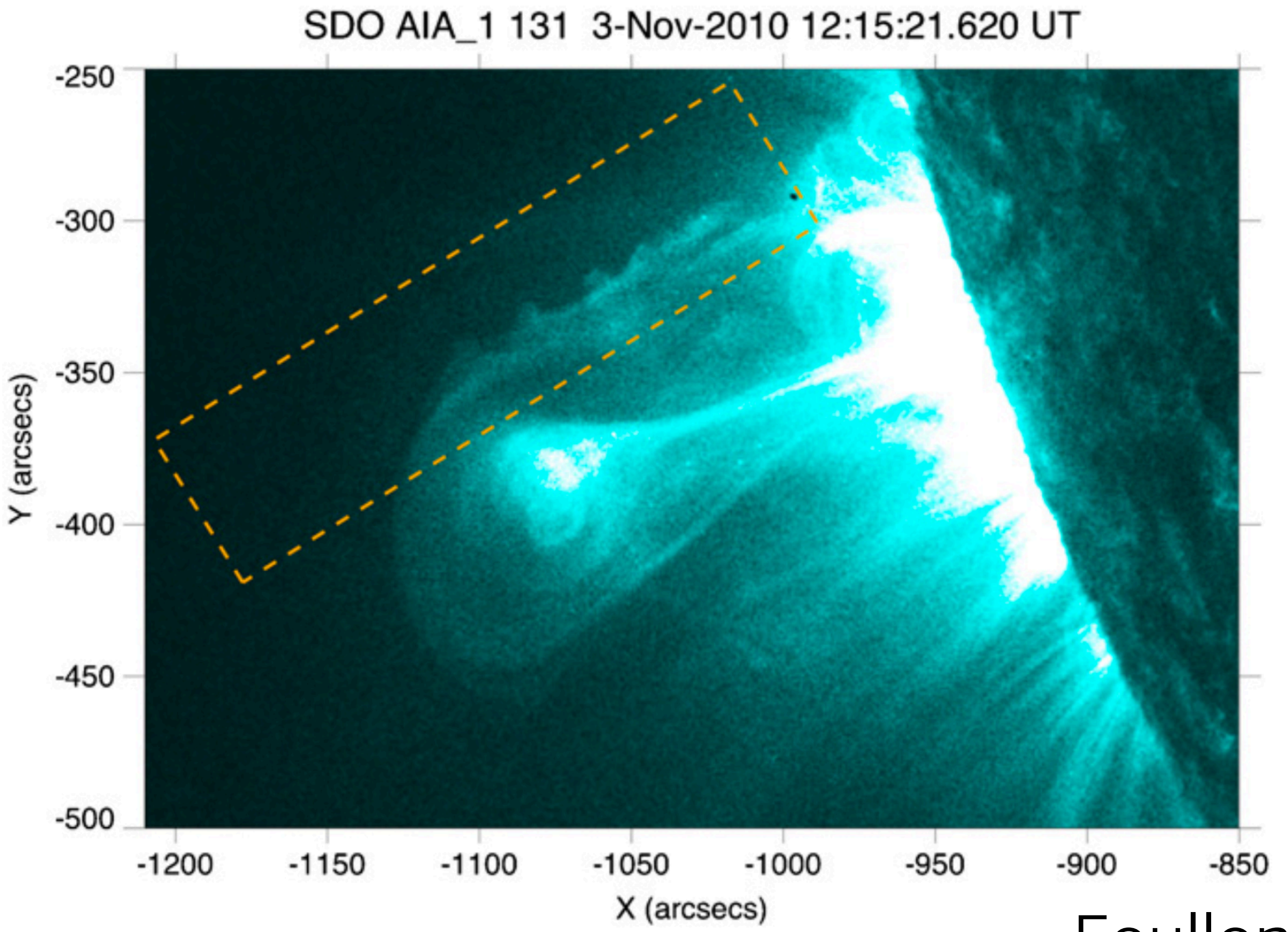

Foullon+(2011)

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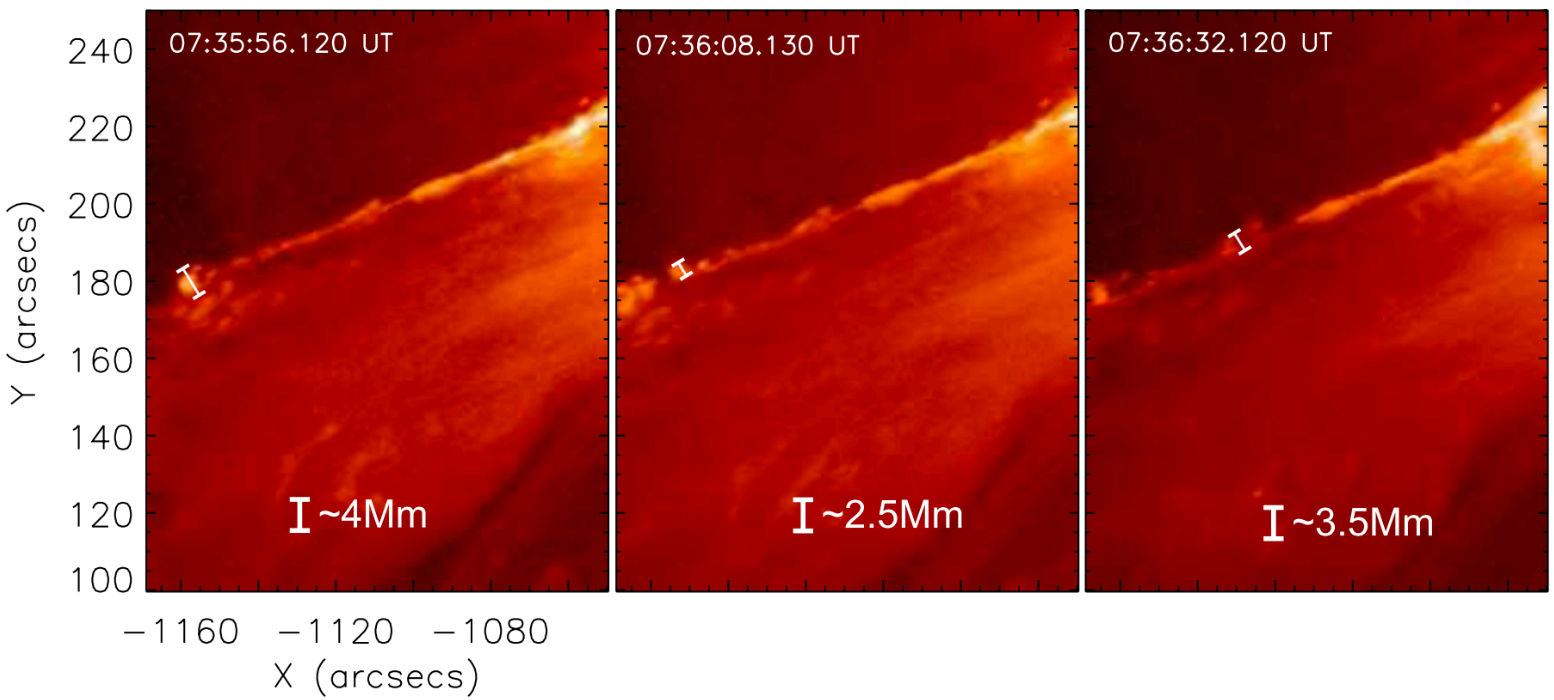

Mostl+(2013)

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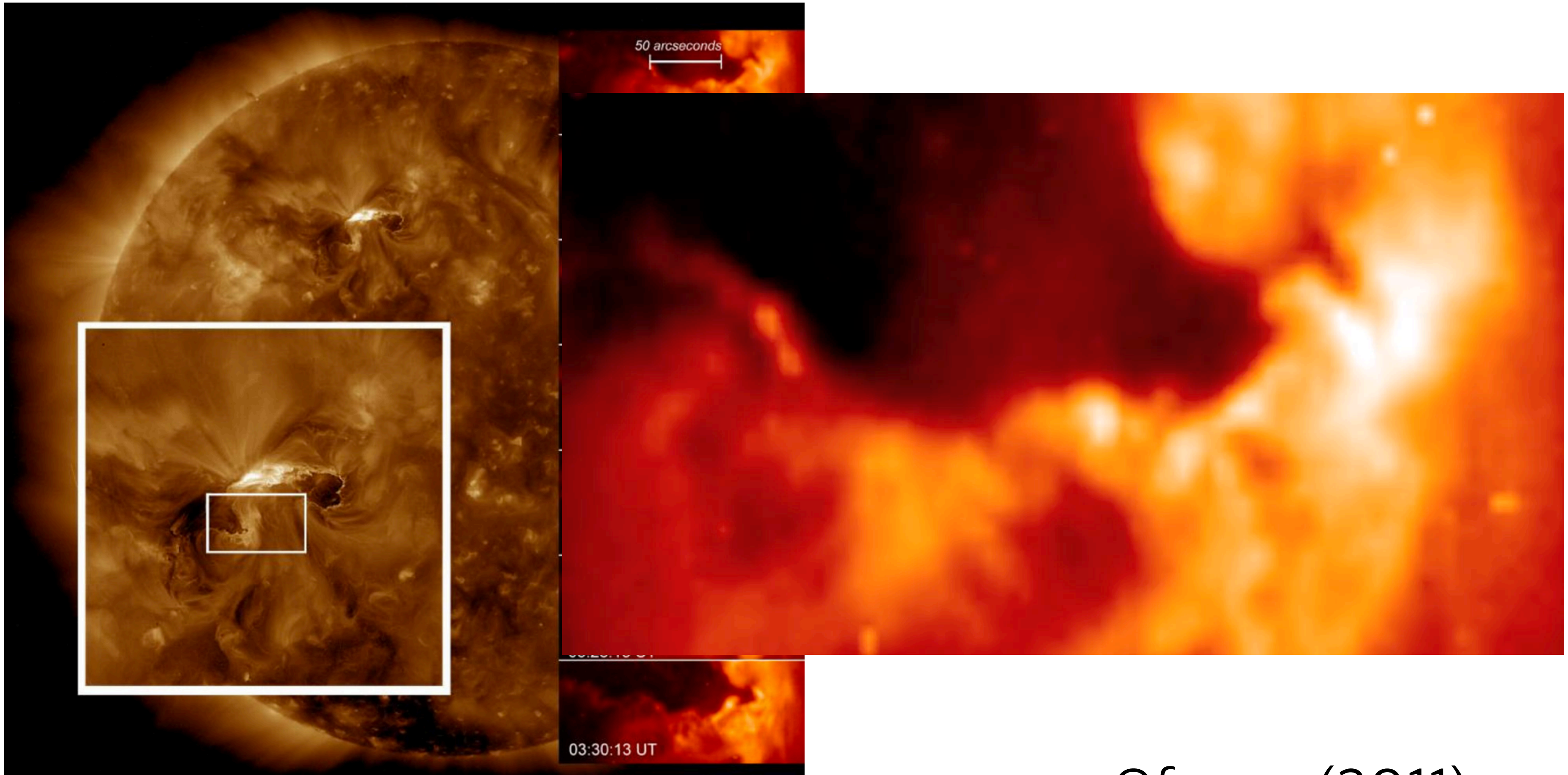
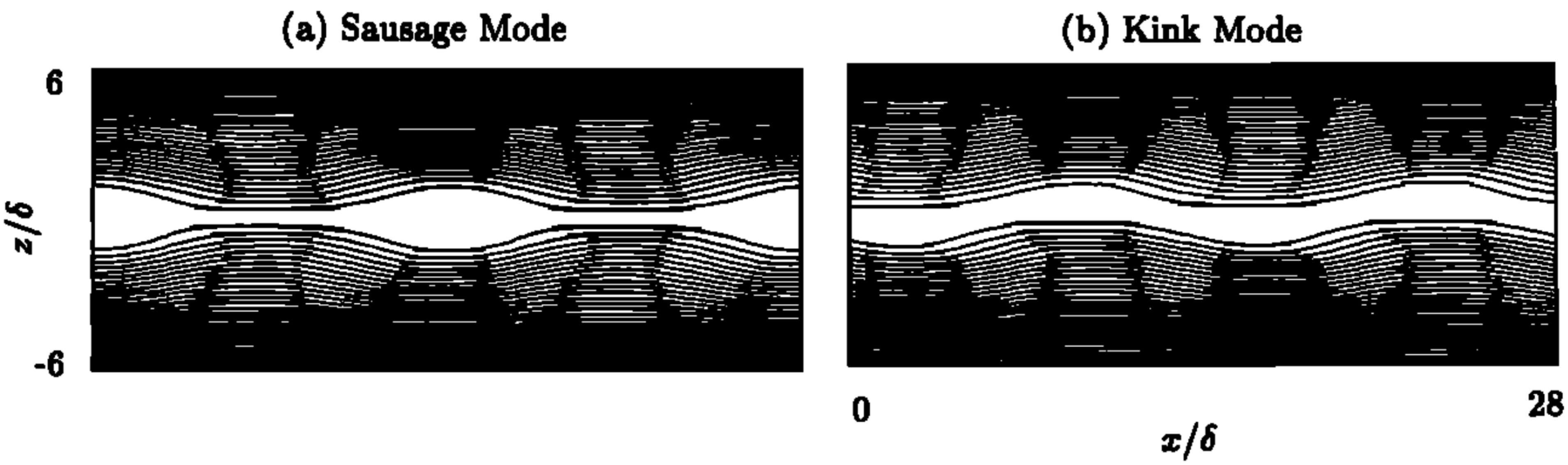


Ofman+(2011)

Streaming Kink Instability (SKI)

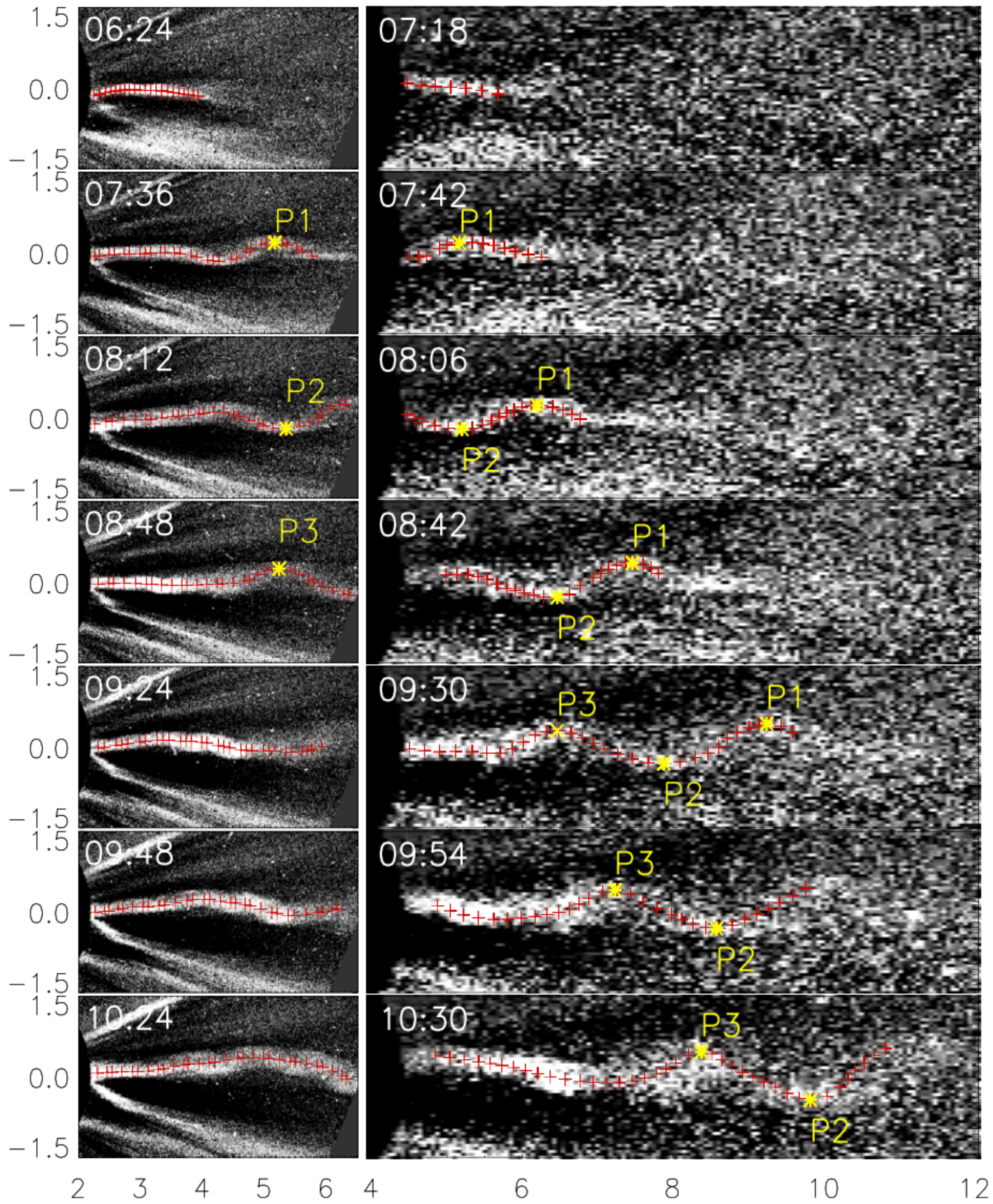
- SKI is similar solution with MHD KHI
- Shear flow → SKI → turbulence or large-scale wavy motion
- SKI has been studied in magnetotail of the earth (Lee+1987)
- Magnetic field (parallel to the flow) suppresses the instability.
- depend on the compressibility, ionization, alfven speed, etc.
- Vortex forms
- Such instability is a very important mechanism for momentum and energy transport and the mixing of fluid



SKI of a Coronal Streamer

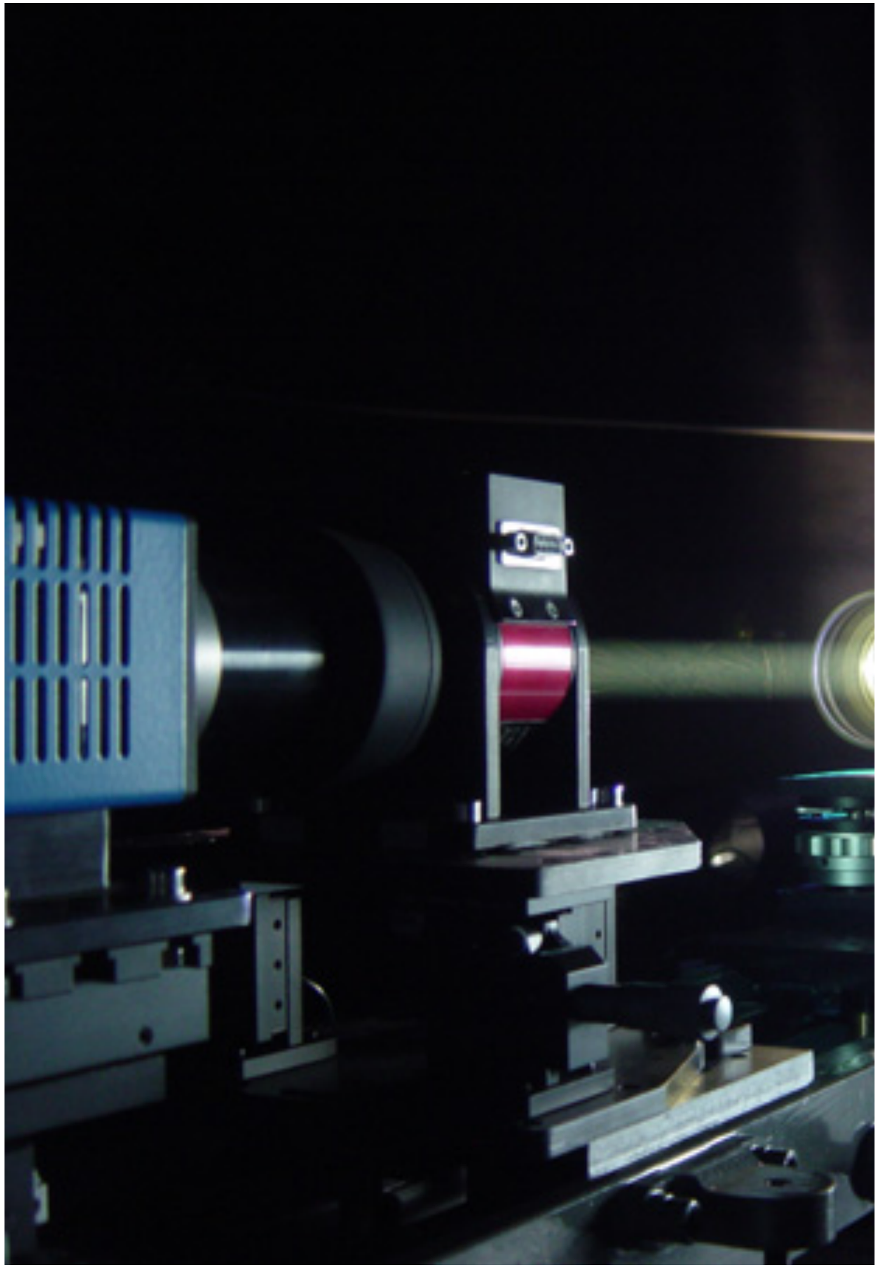
- amplitude of the kink motion is increased without any triggering source

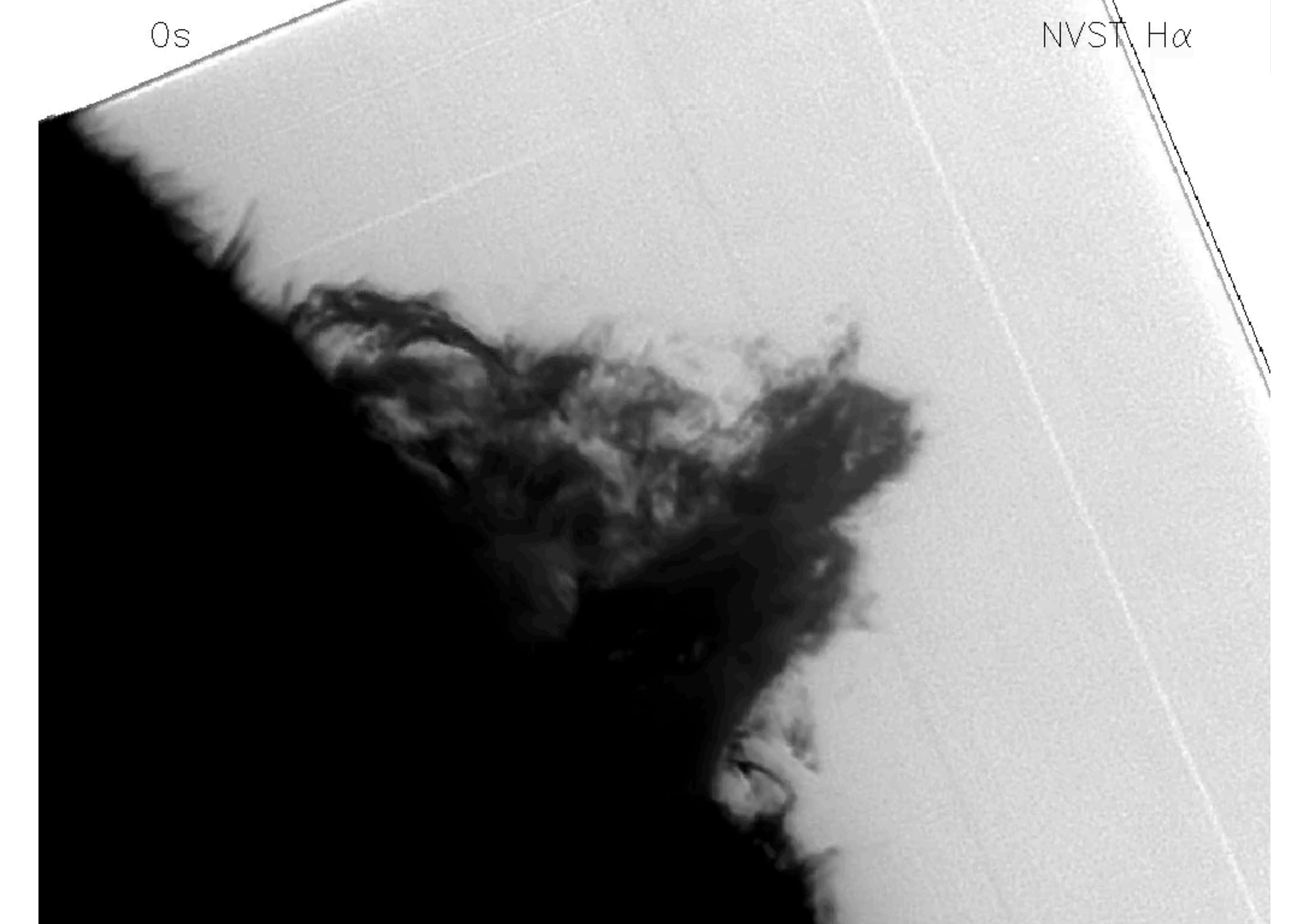
- Feng+(2013) attribute the kink motion of the coronal streamer to the SKI.



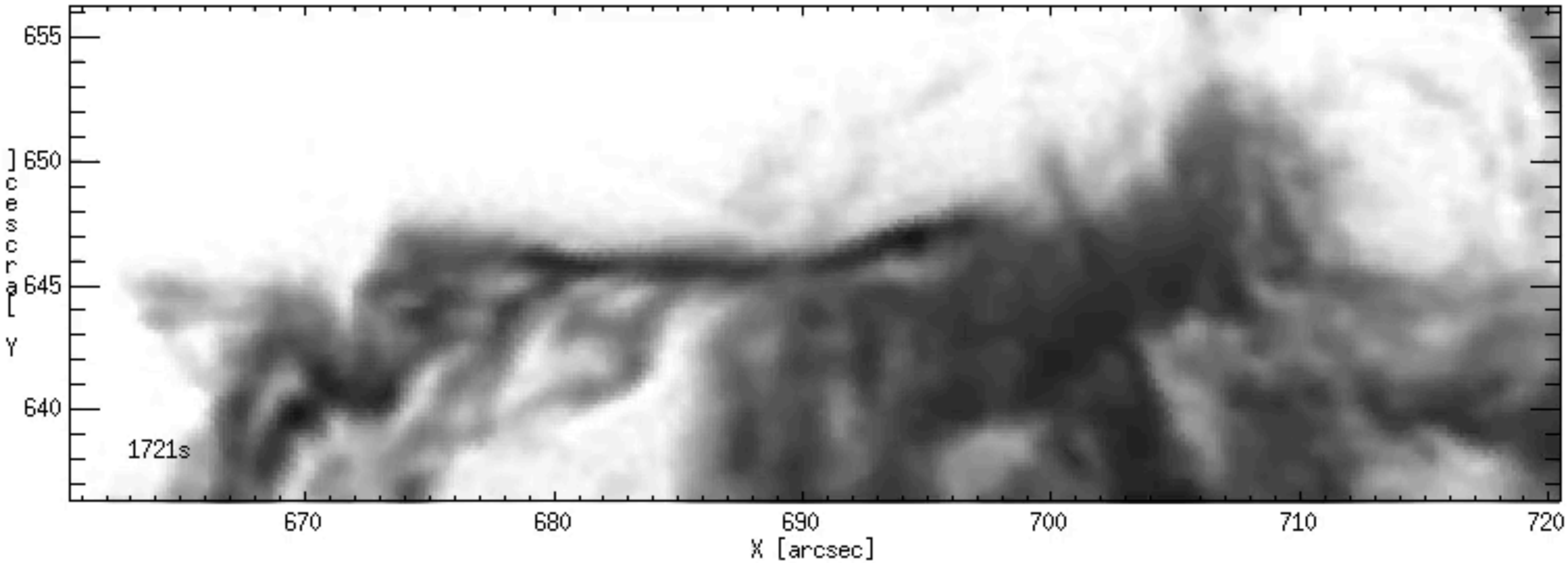
Our Observation

- June 4, 2016
  Limb observation
- 1 meter New Vacuum Solar Telescope
- Ha Tunable Filter :
  0.25A FWHM
  180”X180” FOV
  Lucky Imaging method
- no AO



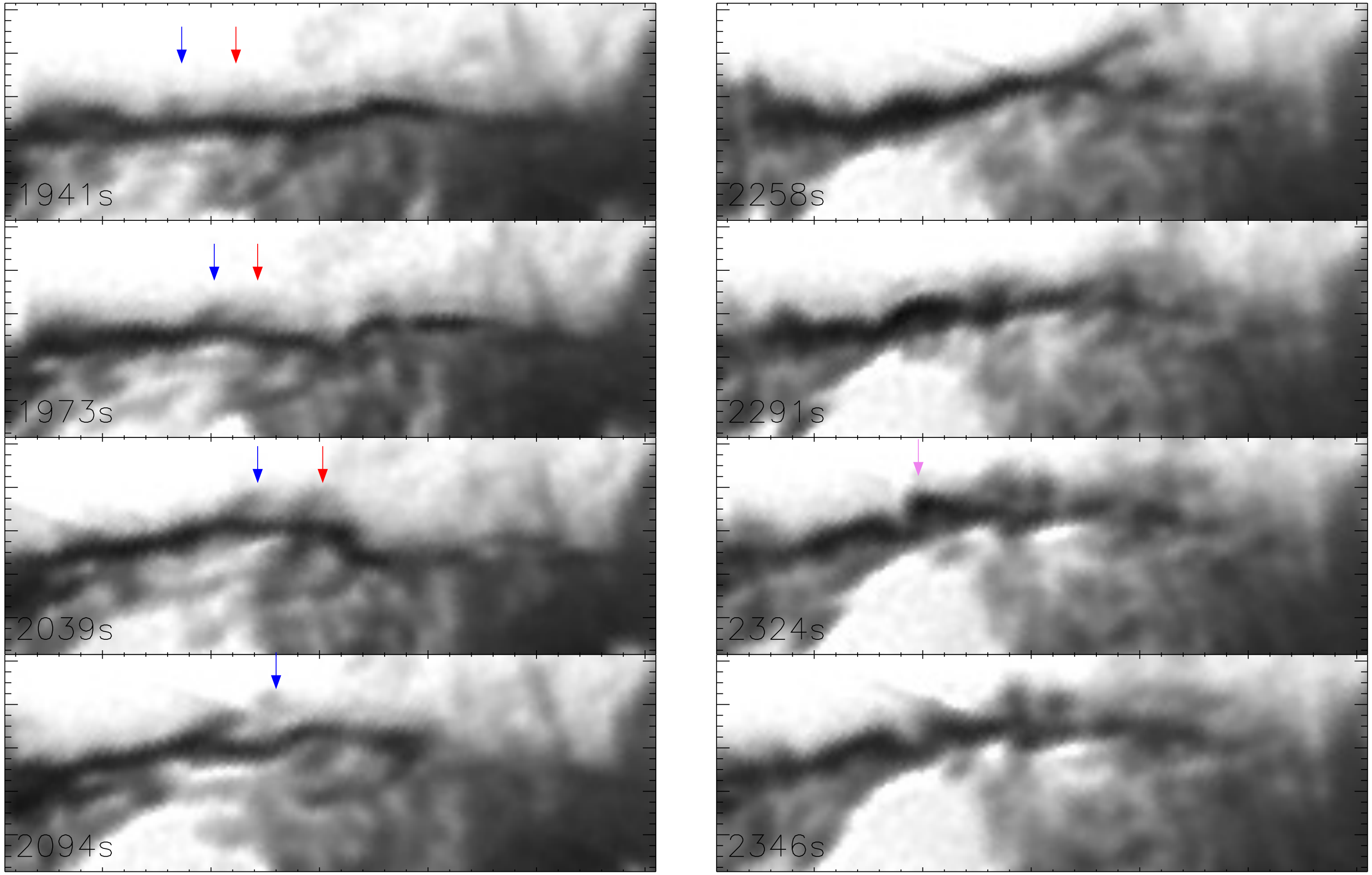

0s
NVST Hα

Observed Flows in the Prominence

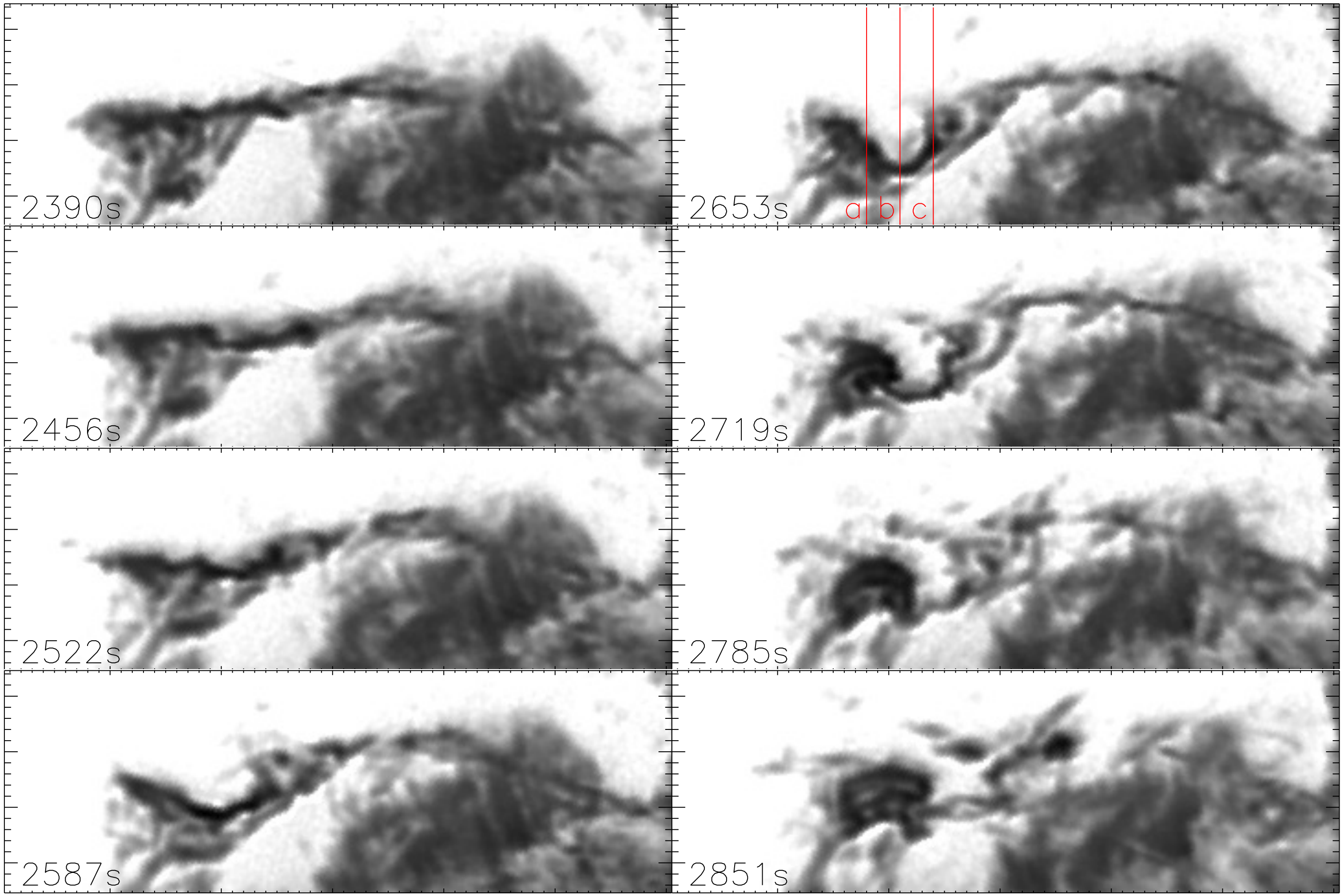


2 asc-size Vortices

- Initially, stream was straight -> wobbled
- τ~36 sec

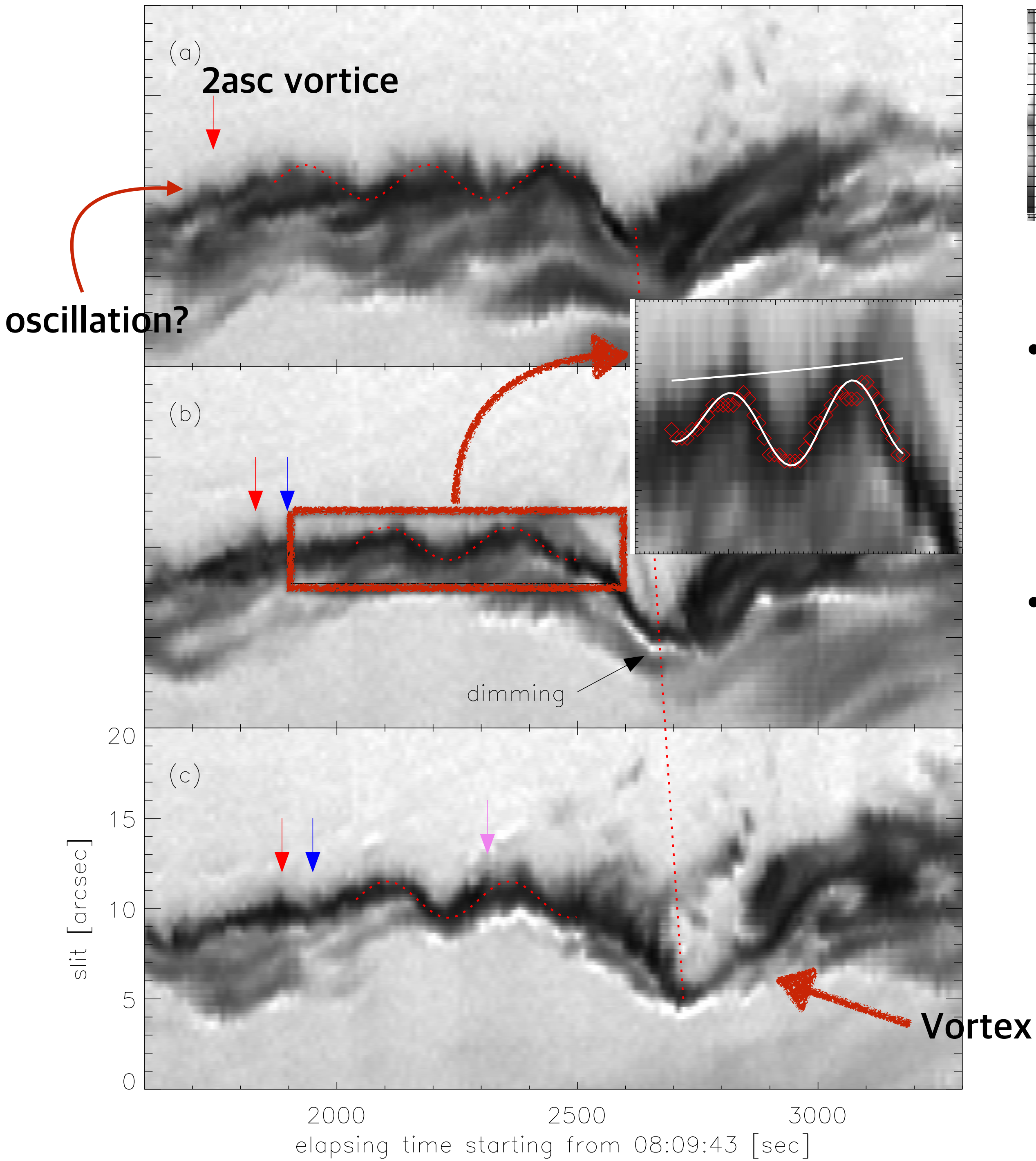


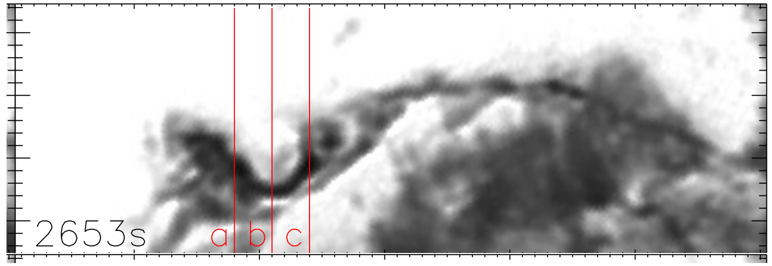
5 asc-size Vortex



- **τ~255 sec**
- **oscillation is observed prior to the formation of vortex**

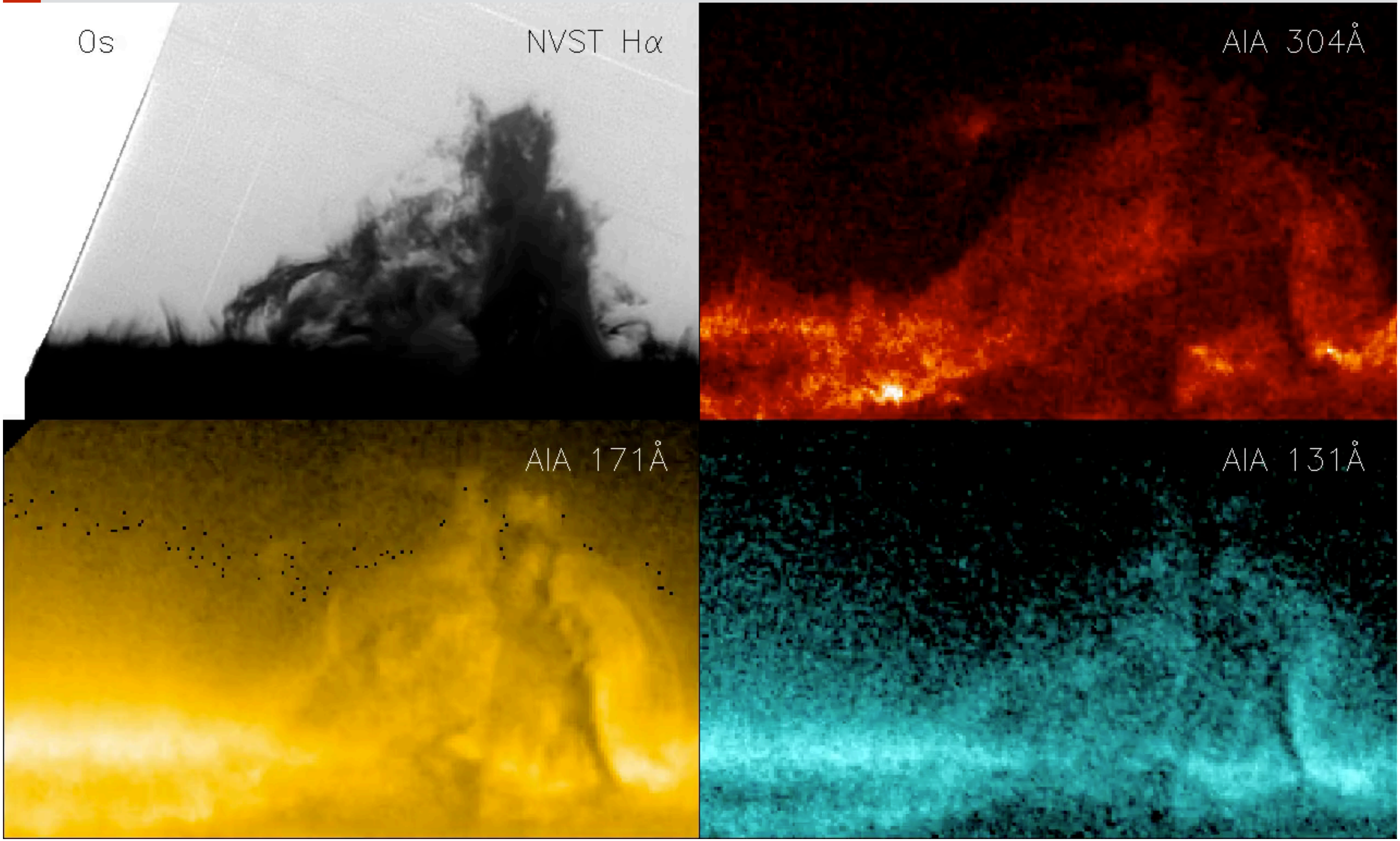
Amplitude Grows!!!





- **255 sec oscillatory pattern prior to the large vortex!**
- **The amplitude increased with time!** **τ_{grow}~972 sec**

Ejection after the vortex destruction

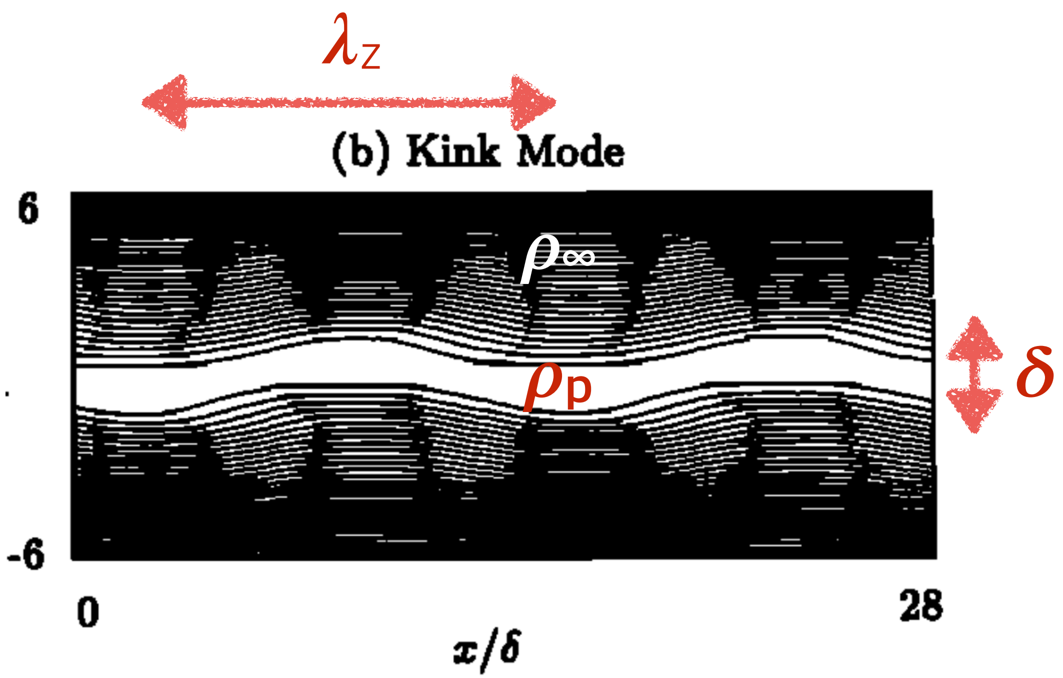


plasma ejection after the vortex → mass transport by the instability

Linearized Solution of the SKI

Table 1: Physical parameters measured in the observation.

Characteristics	Units	Small Vortices	Large Vortex
v_p	$\mathrm{km\,s^{-1}}$	20 – 60	
v_{ph}	$\mathrm{km\,s^{-1}}$	15 – 22	
τ	sec	66, 102	255
τ_{grow}	sec		972
δ	km	808.5	
λ_z	km (″)	1450 (2)	3625 (5)
ρ_p/ρ_∞		10 – 13	



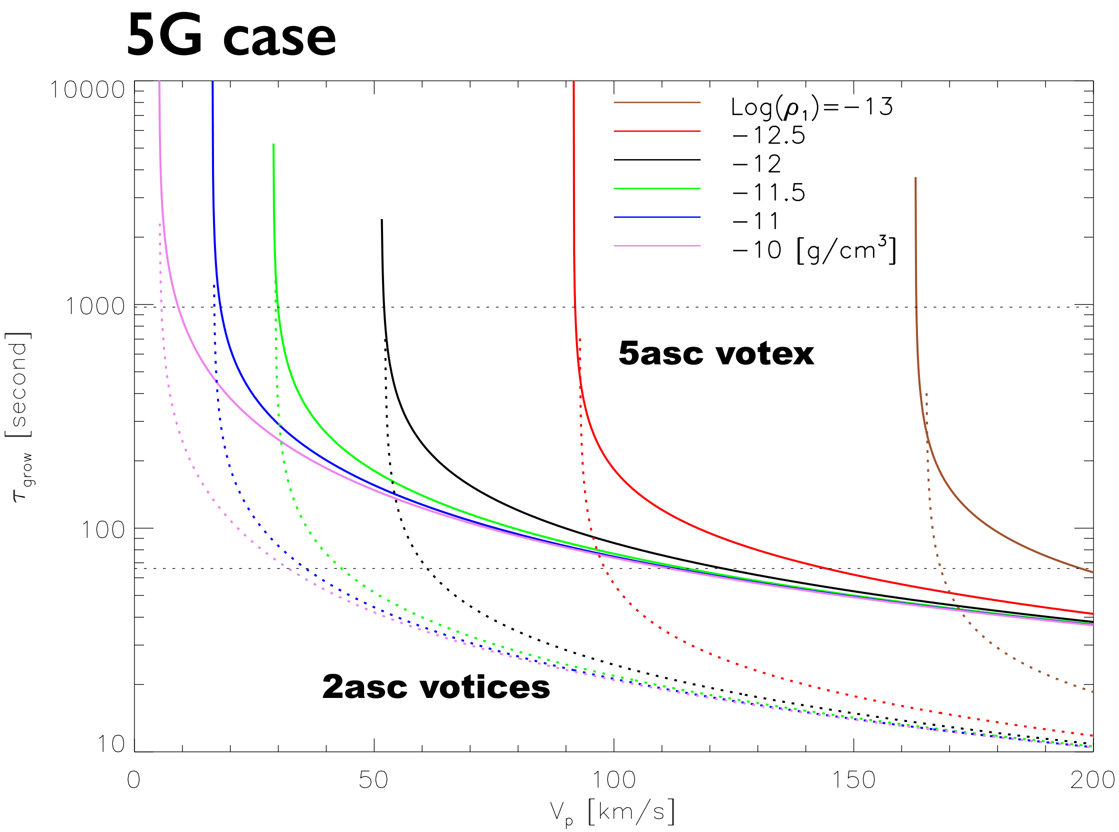
- **SKI of the incompressible fully ionized plasma**

$$\Delta_i = \begin{cases} \text{if } x < -\delta/2 & B_{0x} = B_\infty \quad v_0 = 0 \quad \rho_0 = \rho_\infty \\ \text{if } 0 < x < \delta/2 & B_{0x} = 0 \quad v_0 = v_p \quad \rho_0 = \rho_p \\ \text{if } -\delta/2 < x < 0 & B_{0x} = 0 \quad v_0 = v_p \quad \rho_0 = \rho_p \\ \text{if } \delta/2 < x & B_{0x} = B_\infty \quad v_0 = 0 \quad \rho_0 = \rho_\infty \end{cases}$$

$$\frac{\omega}{k} = \frac{1}{(\rho_p + \rho_\infty) + (\rho_p - \rho_\infty)e^{-2k\delta}} \cdot \{\rho_p v_p (1 + e^{-2k\delta}) \pm [\rho_p \rho_\infty (v_{A\infty}^2 - v_p^2)(1 - e^{-4k\delta}) + \rho_\infty^2 v_{A\infty}^2 (1 - e^{-2k\delta})^2]^{1/2}\},$$

following Lee+(1988)

Linearized Solution of the SKI



- The density may be higher than 10^{-11}-10^{-12} g/cm^3 when we compare with the linearization solution. ($\leftrightarrow 10^{-12} - 10^{-15}$ g/cm^3; Hirayama, 1986; Parenti, 2014)

Summary

- We observed vortex formations in a solar prominence, and we analyze it attributing to the Streaming Kink Instability (SKI).
- 2 asc-size and 5 asc-size vortices were formed as a result of the instabilty, that is the most distinguishable feature SKI.
- The density may be 10^{-11}-10^{-12} g/cm^{-3} (linearization solution)
- We found the plasma ejection from the prominence after destruction of the vortex. (distinguishable from the pre-eruption oscillations)
- Our observation shows the clear connection between the oscillation and the cascade processes such as the formation of the vortex and the plasma ejection.
- Our result shows that the instability is an important mechanism for momentum and energy transport upward in the corona.