Multi-layered Kelvin-Helmholtz Instability in the Solar Corona

Ding Yuan

Email: yuanding@hit.edu.cn

Harbin Institute of Technology, Shenzhen

Collaborator: Yuandeng, Shen, Yu Liu,
Xueshang, Feng, Rony Keppens

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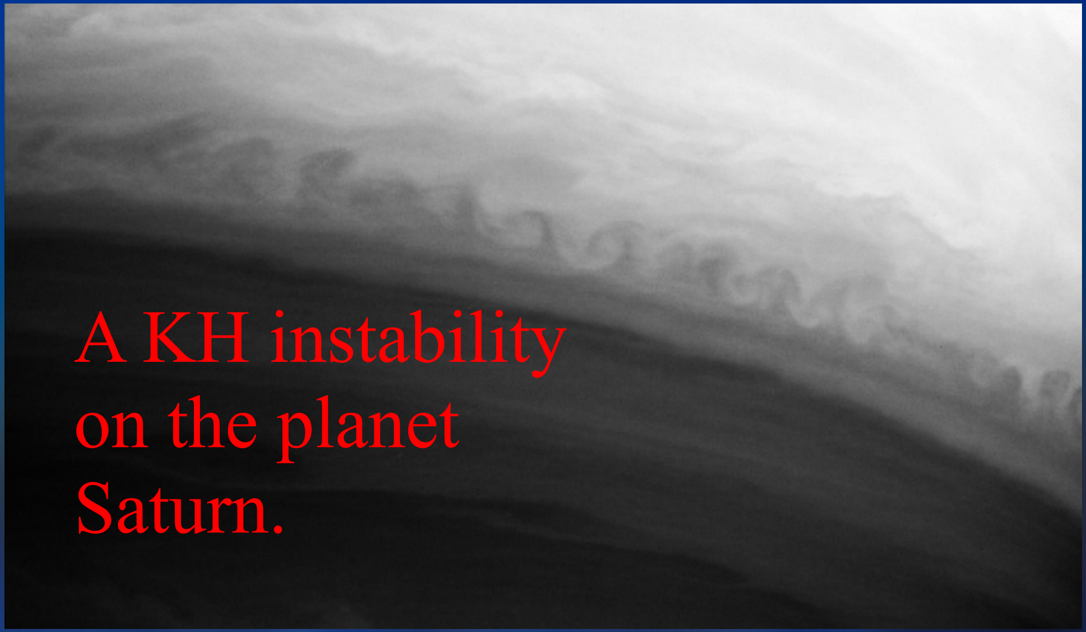
Kelvin Helmholtz Instability

- Convert energy from large-scale to small scales;
- Mix fluid of different properties.
- Dynamic energy to thermal energy

Kelvin Helmholtz Instability



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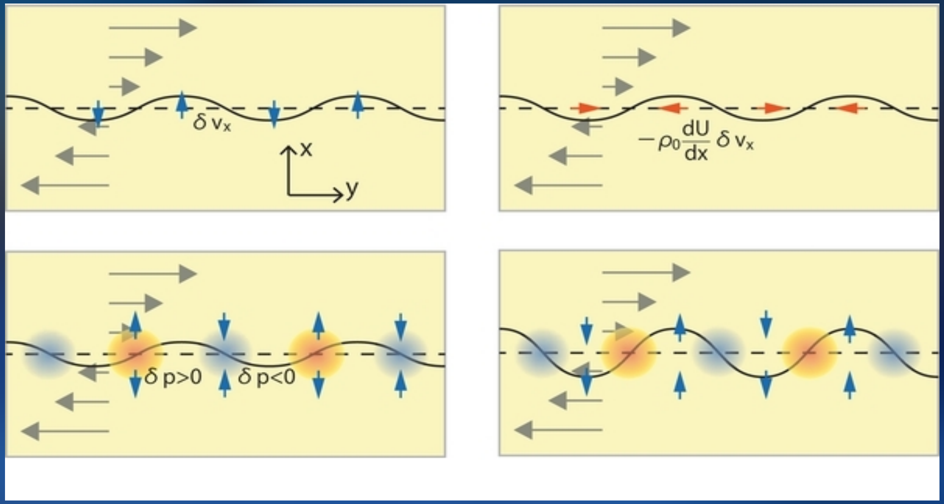
Linear theory on KH instability in magnetized incompressible plasma

Chandrasekhar 1981

Assumptions:
Small-amplitude perturbation
Incompressibility

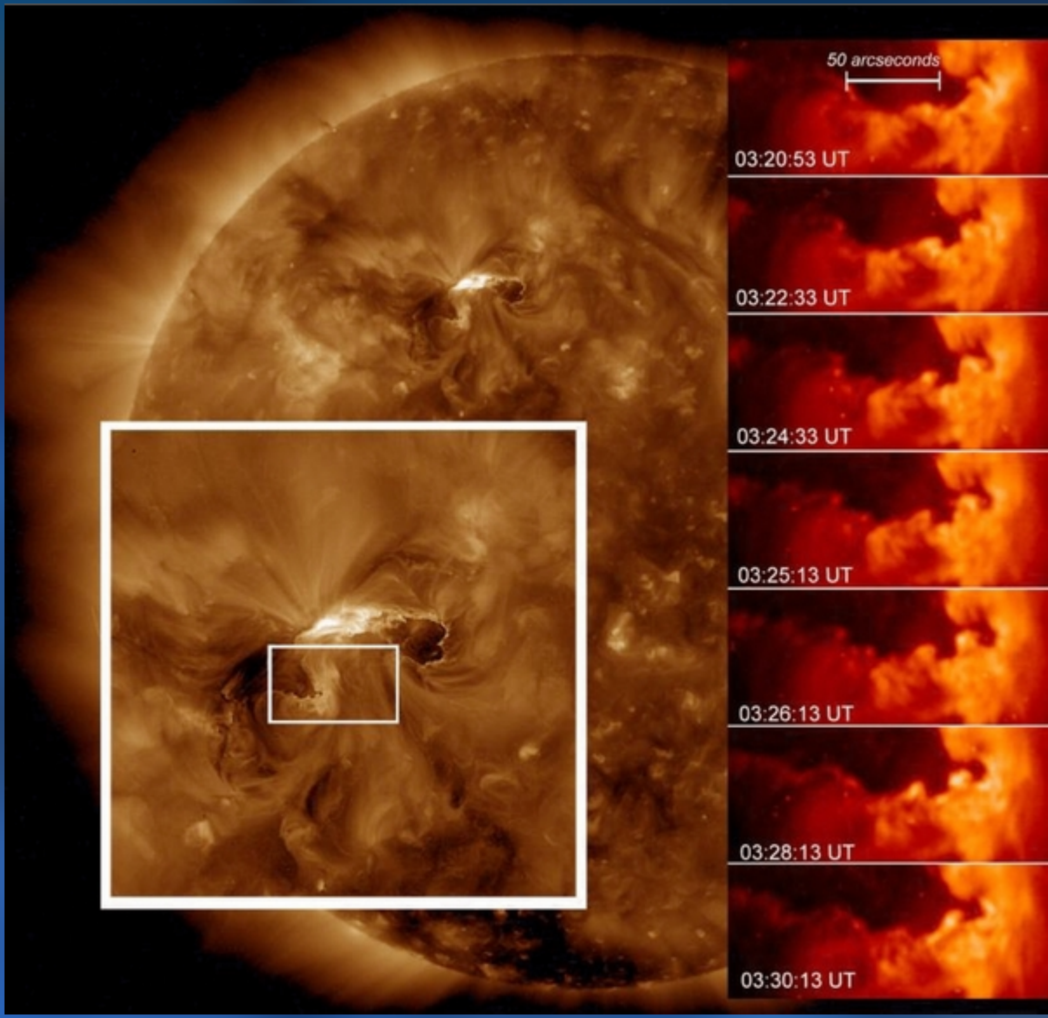


Suzuki et al. 2014 ApJ 787 169

$$\omega = \frac{\mathbf{k}\cdot(\rho_1\mathbf{V}_1+\rho_2\mathbf{V}_2)}{\rho_1+\rho_2} \pm i\sqrt{\rho_1\rho_2\left([\mathbf{k}\cdot(\mathbf{V}_1-\mathbf{V}_2)]^2 - \frac{(\mathbf{k}\cdot\mathbf{B}_1)^2+(\mathbf{k}\cdot\mathbf{B}_2)^2}{4\pi\rho_{12}}\right)}$$

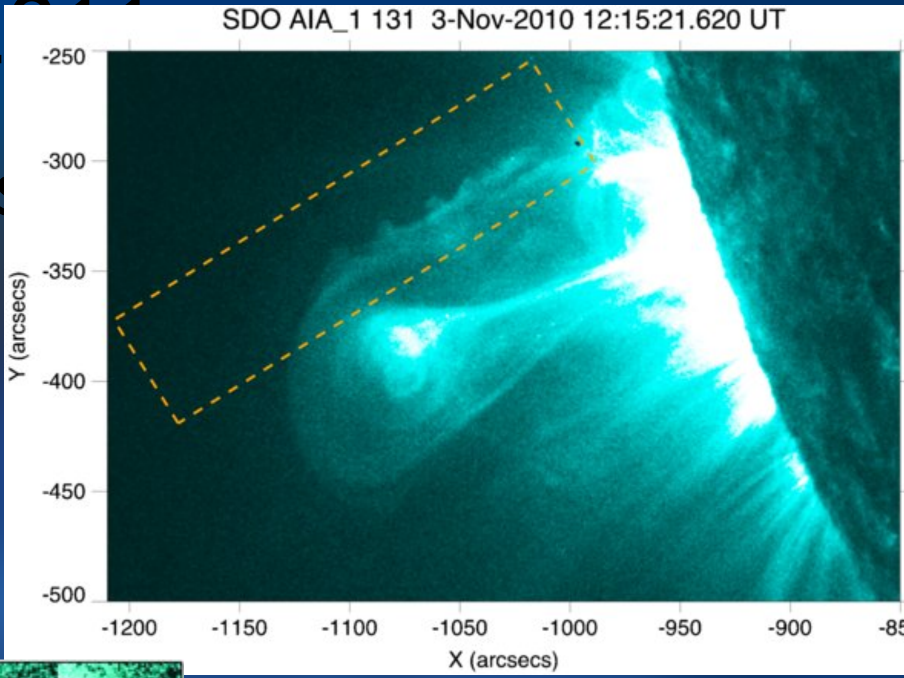
KHI in the solar corona
-Ofman et al. ApJL 2011

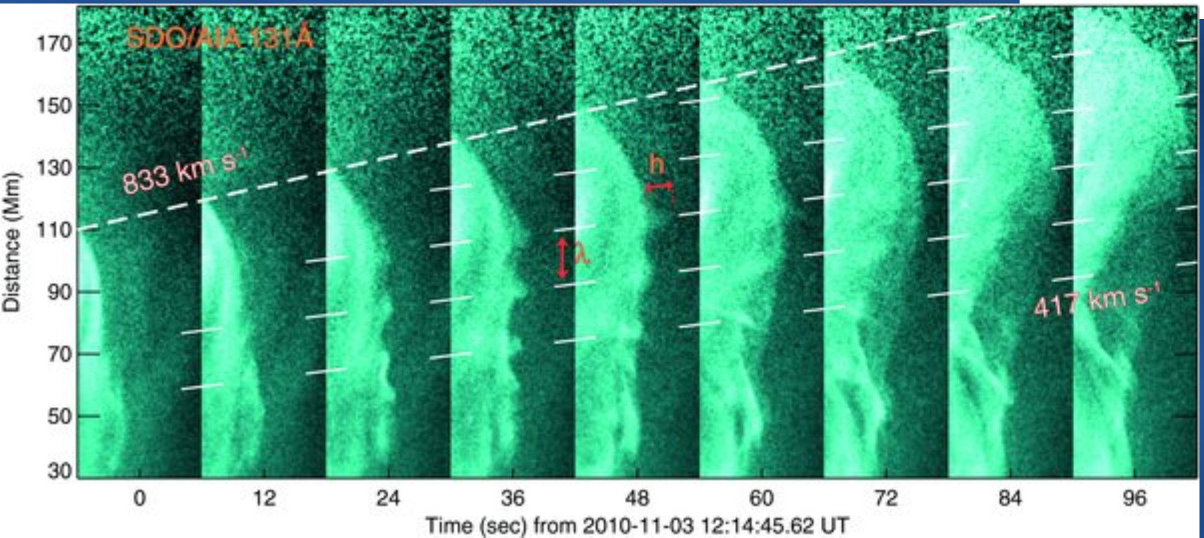
- Series of vortices were formed along the interface between an erupting (dimming) region and the surrounding corona.
- Size: 1- 10 arcsec
- Propagation speed (Sub-sonic): 6-14 km s^{-1}



KHI at a flank of erupting CME
-Foullon et al ApJL 2

- Ejecta speed: ~ 800 km/
- Phase speed: ~ 400 km/s
- Period: ~40 s
- Wavelength: ~18 Mm





KH instability by colliding flow
--Fang et al ApJ 2015, 2016

- Interaction of plasma flows evaporated from loop footpoints;
- Instability against aligned magnetic field

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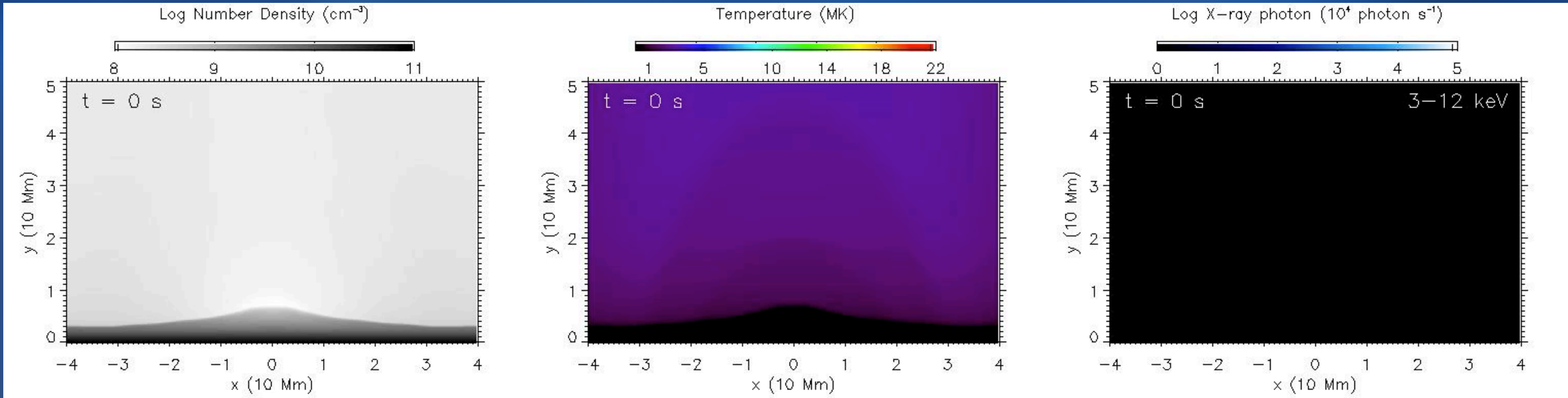

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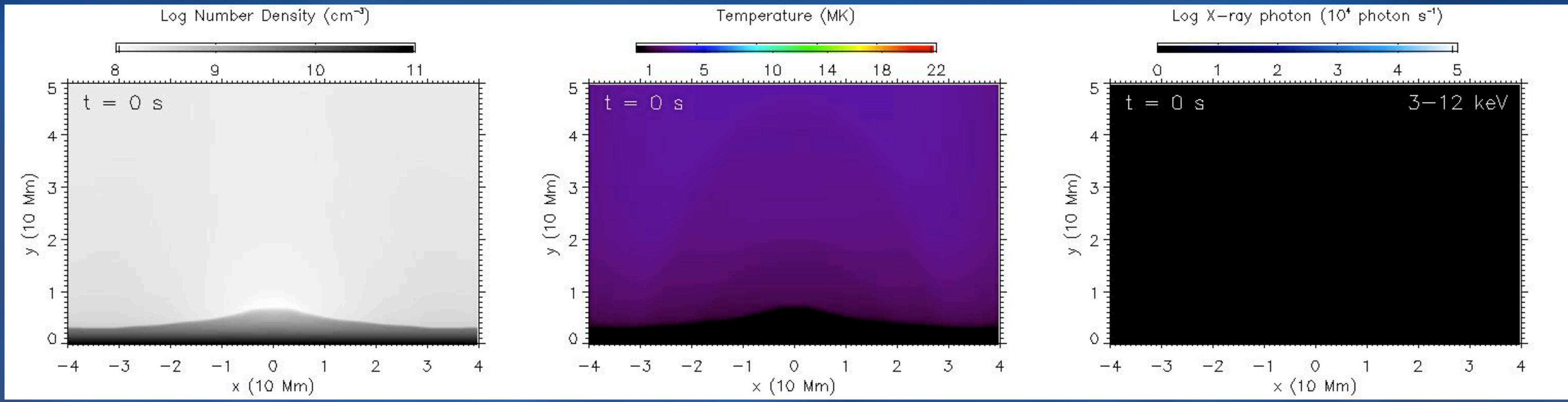
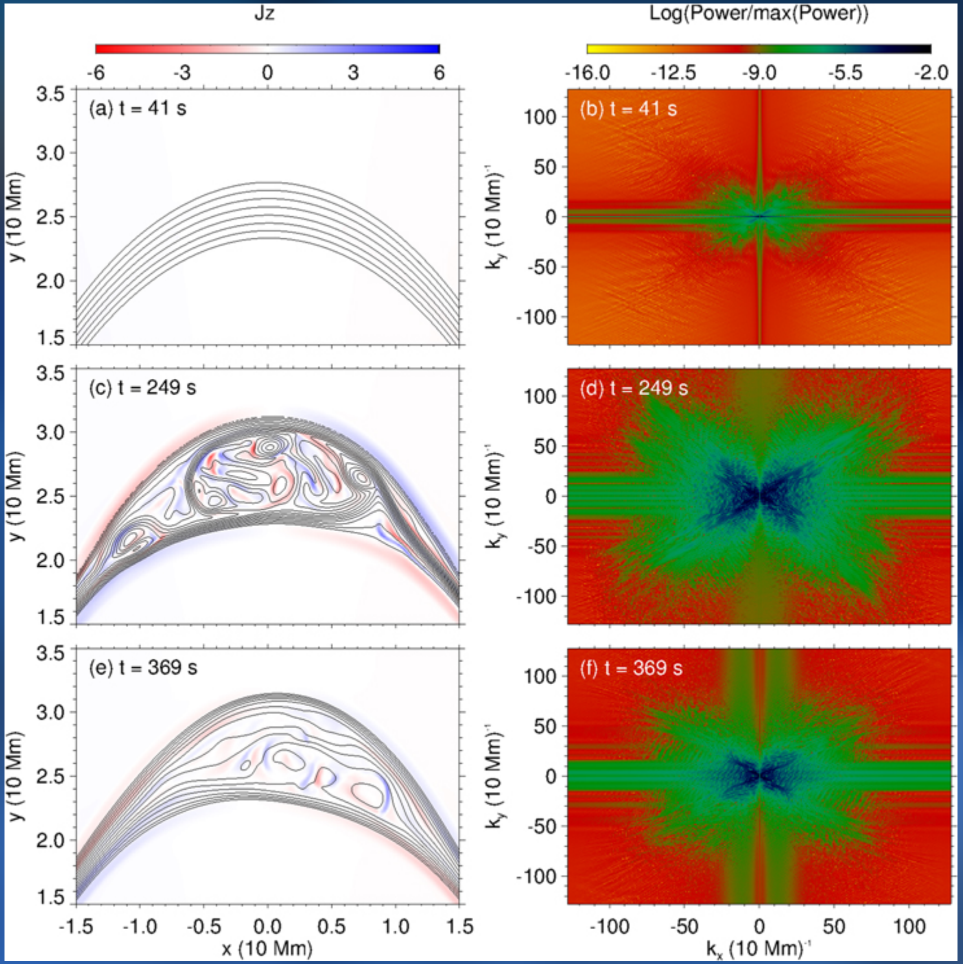


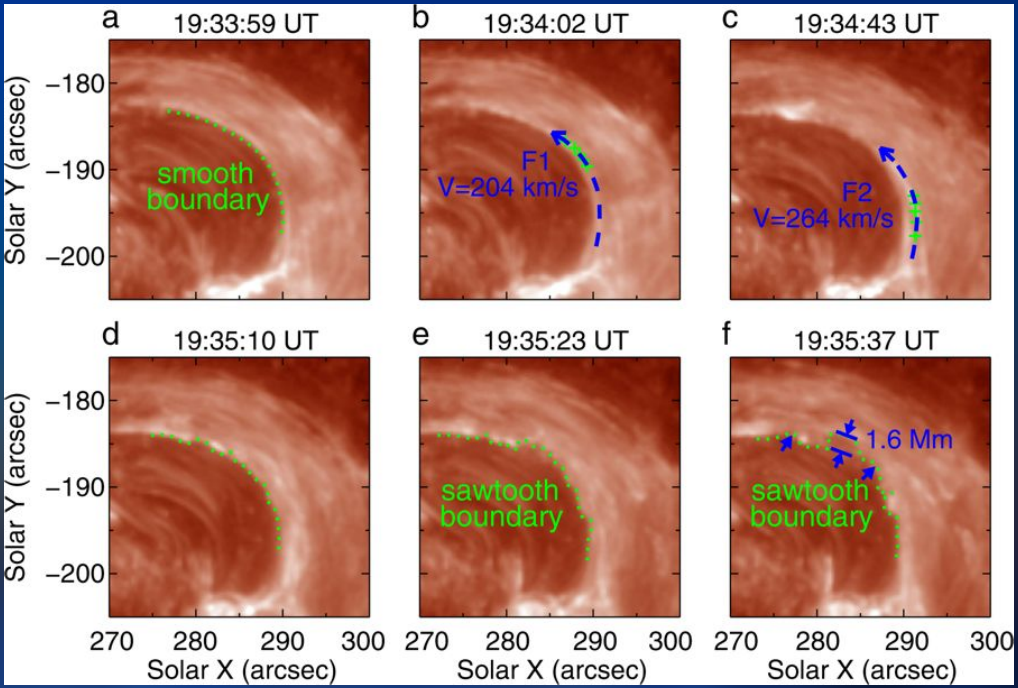
Dissipation by magnetic reconnection
--Fang et al ApJ 2015, 2016

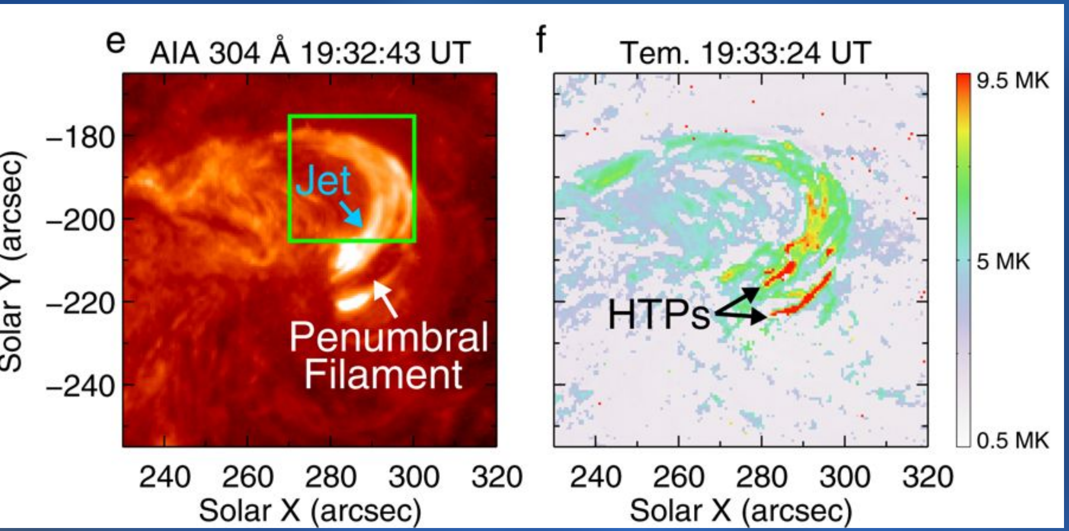
- Magnetic islands formation ;
- Energy dissipation by reconnection.



KHI in a coronal loop

- Signature of heating

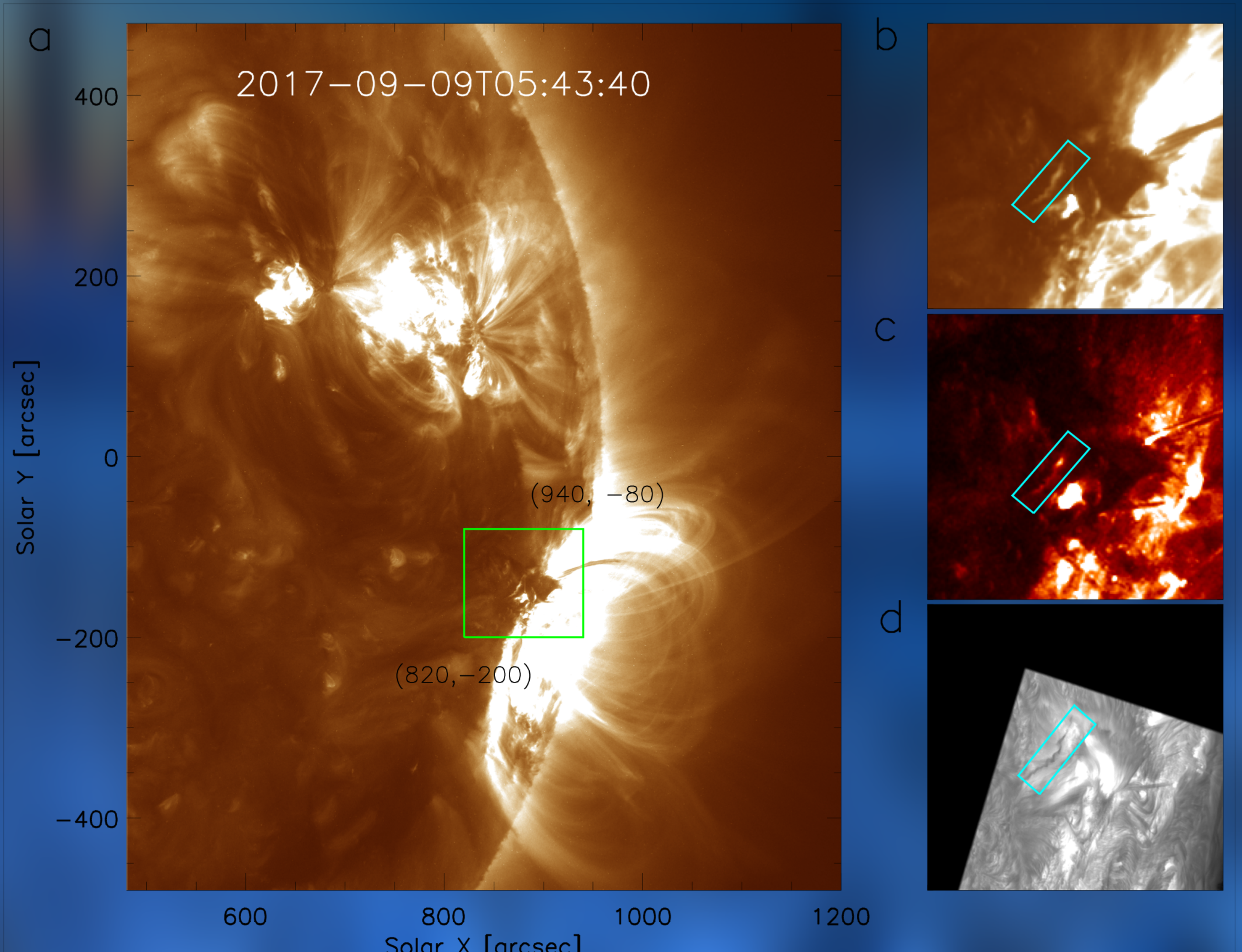




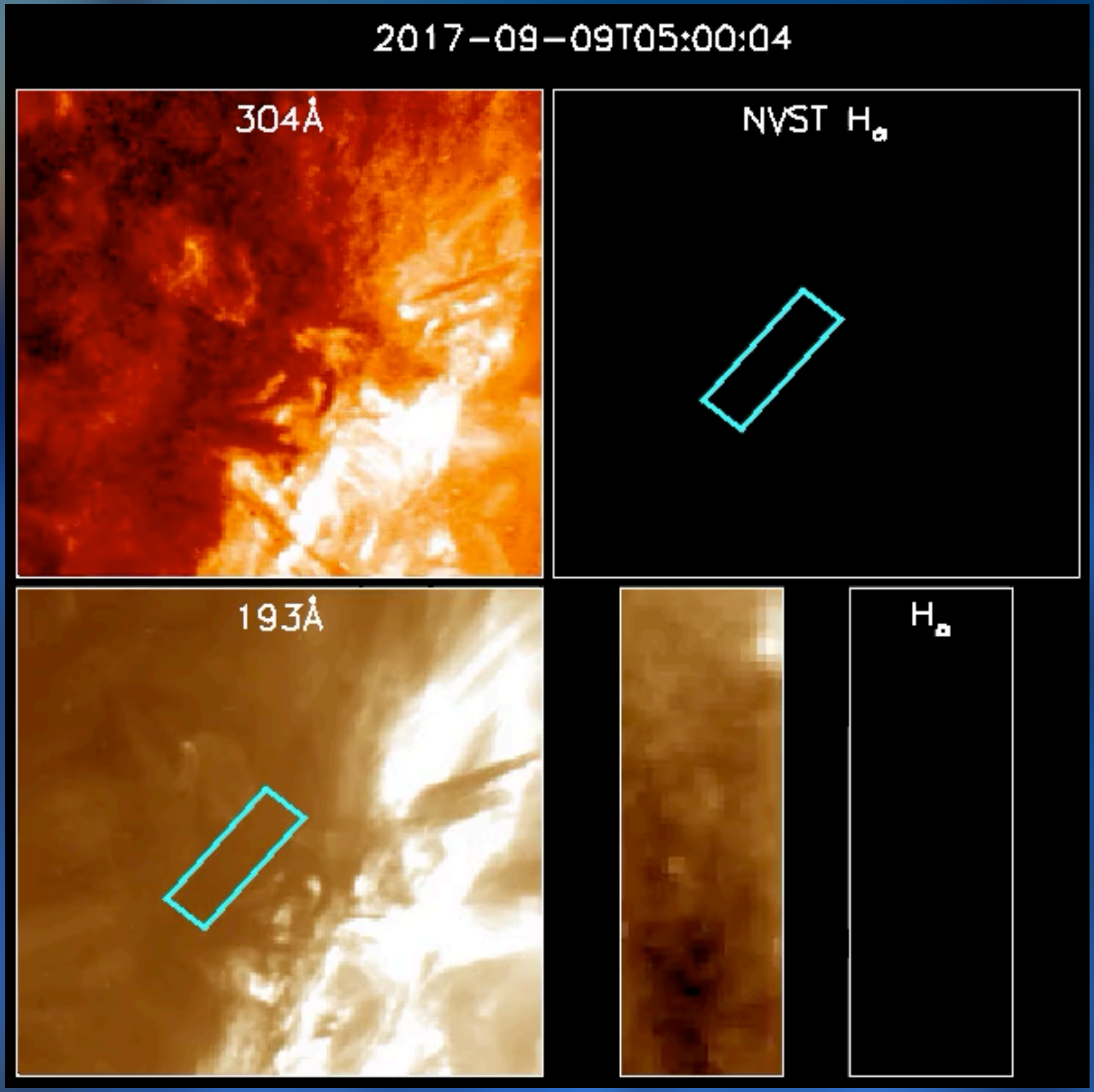
Li, Xiaohong, Sci. Rep. 2018

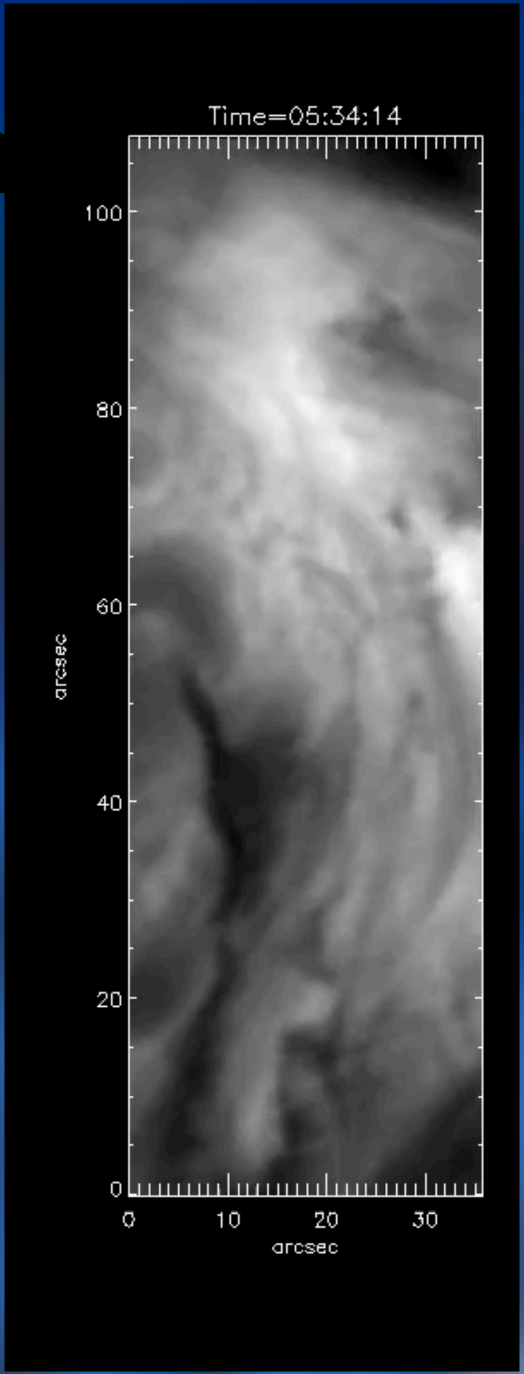
NVST observation

Yuan et al 2019, ApLJ



NVST & AIA observation





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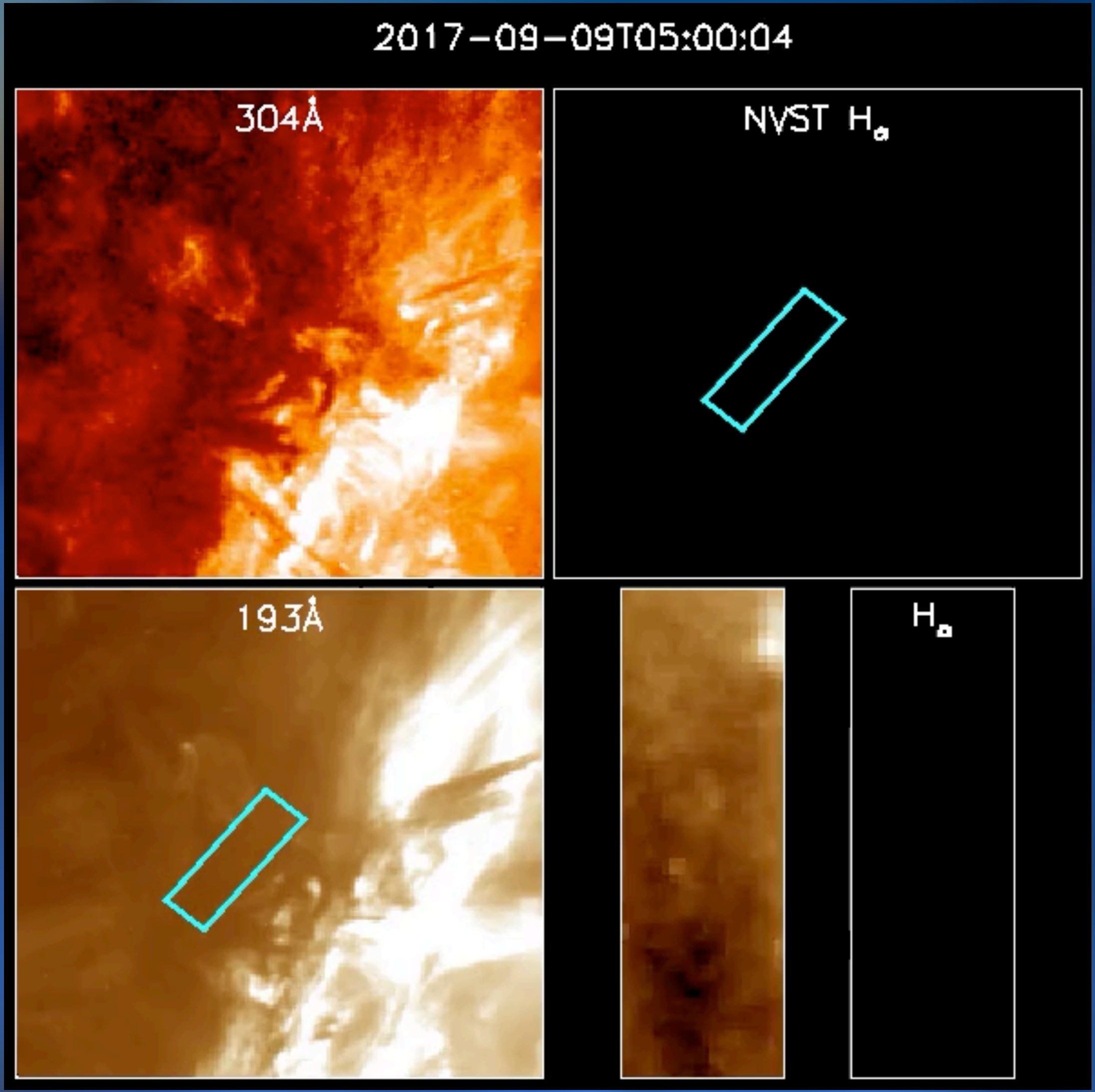

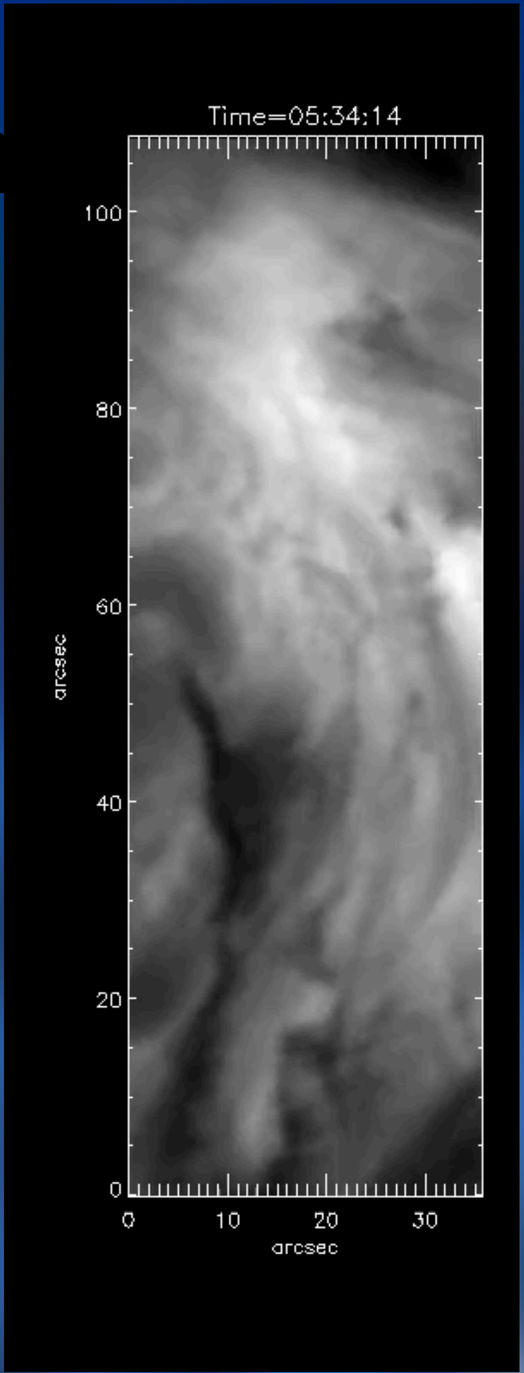

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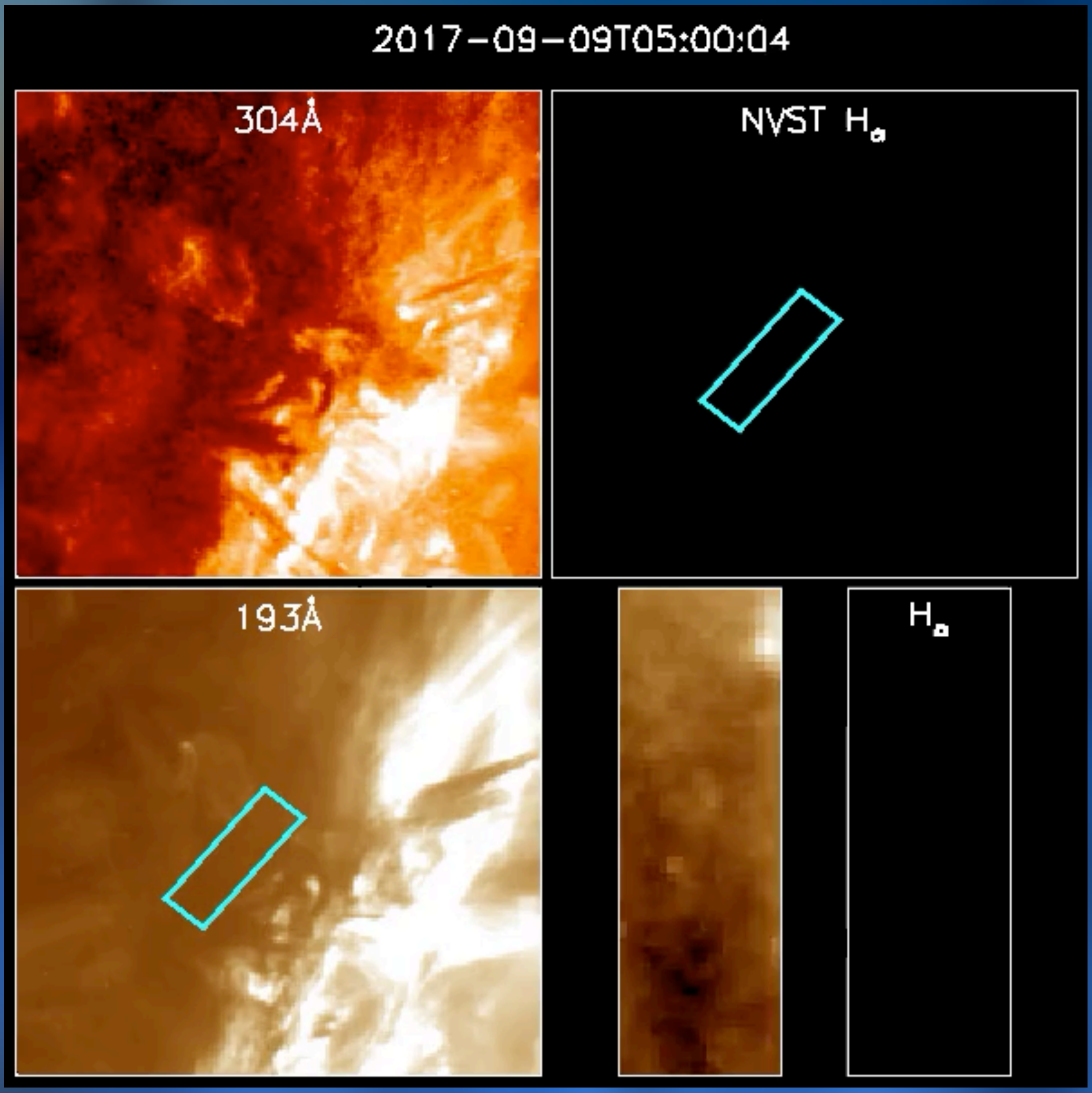

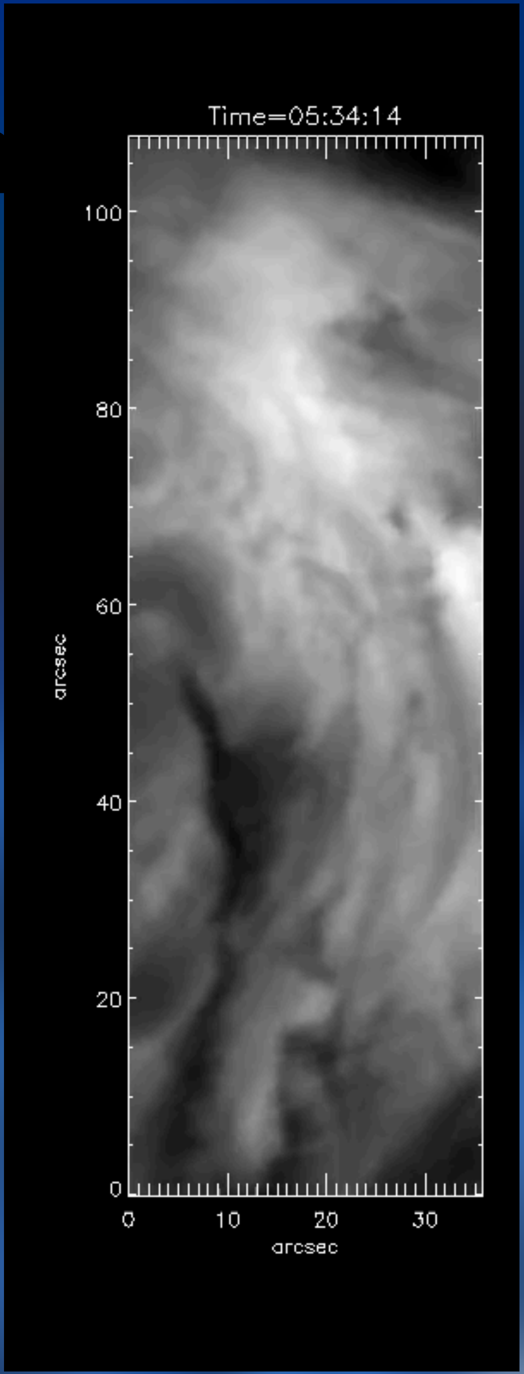

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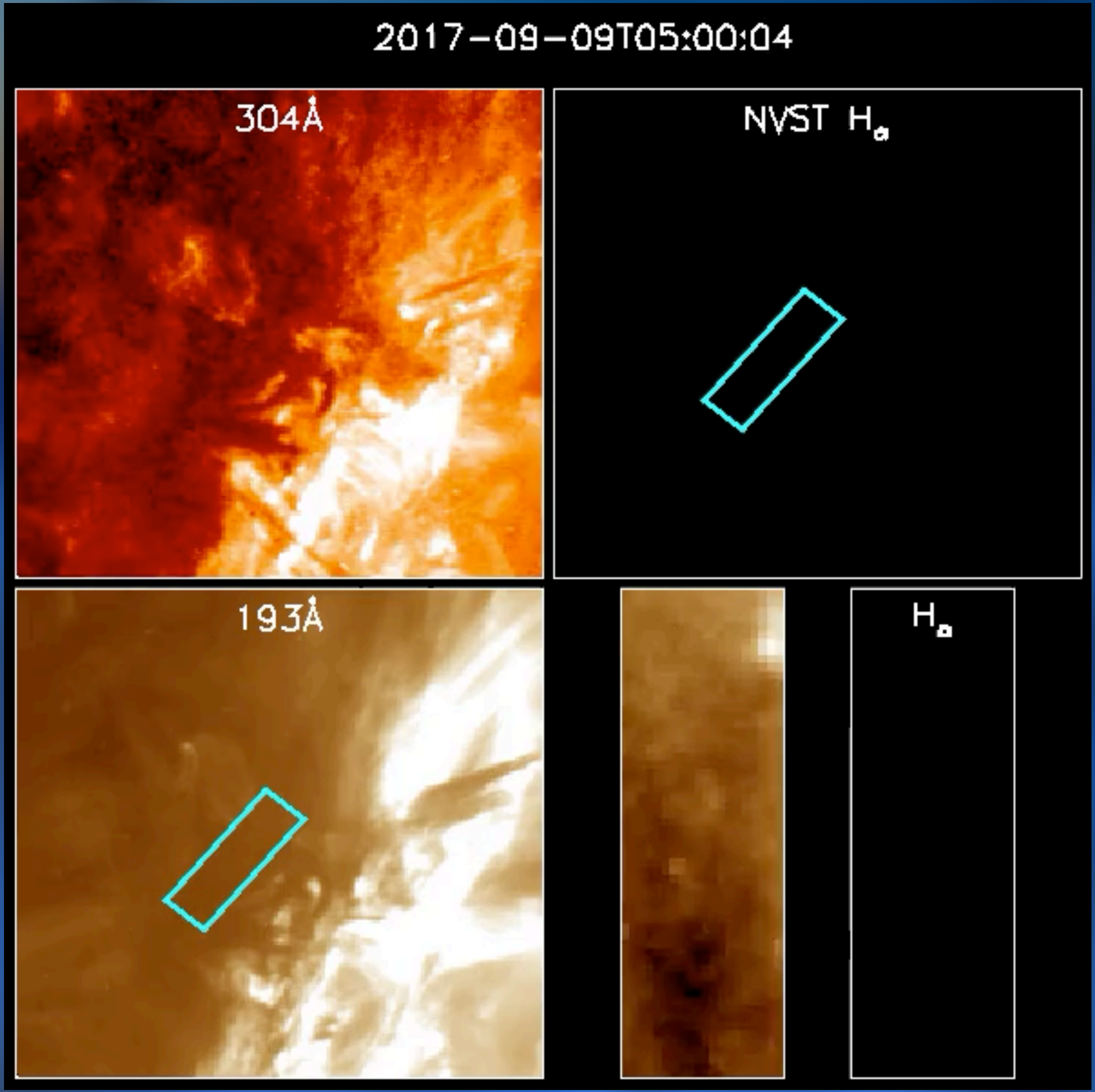
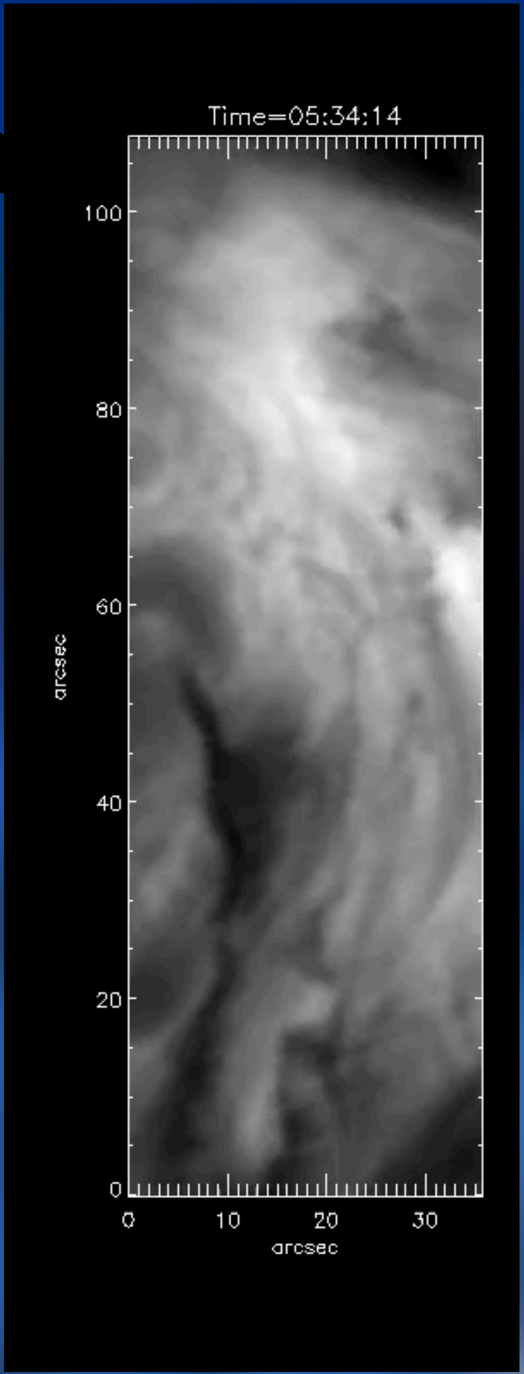
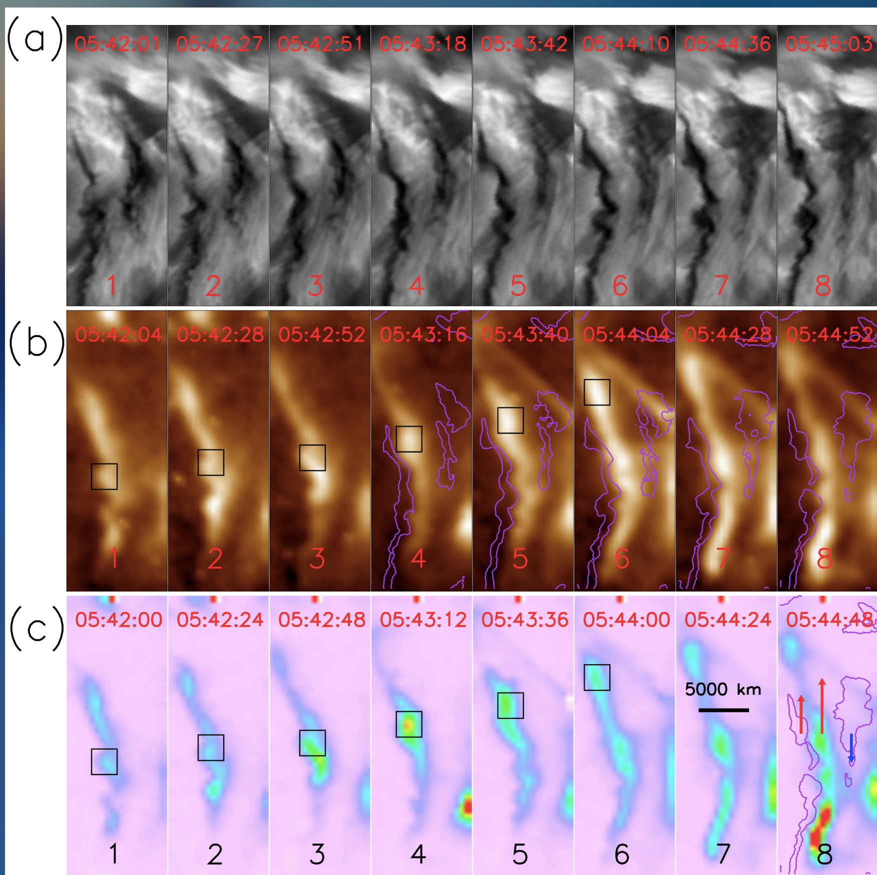




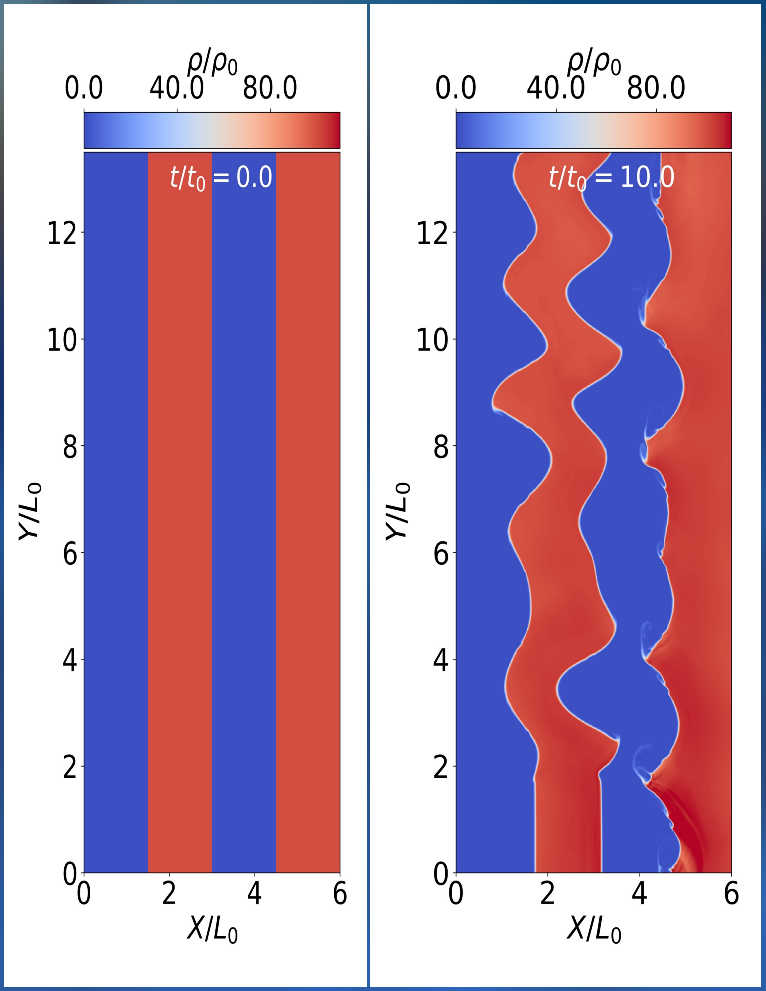
Multi-layers of shearing flow



Yuan et al 2019 ApJL

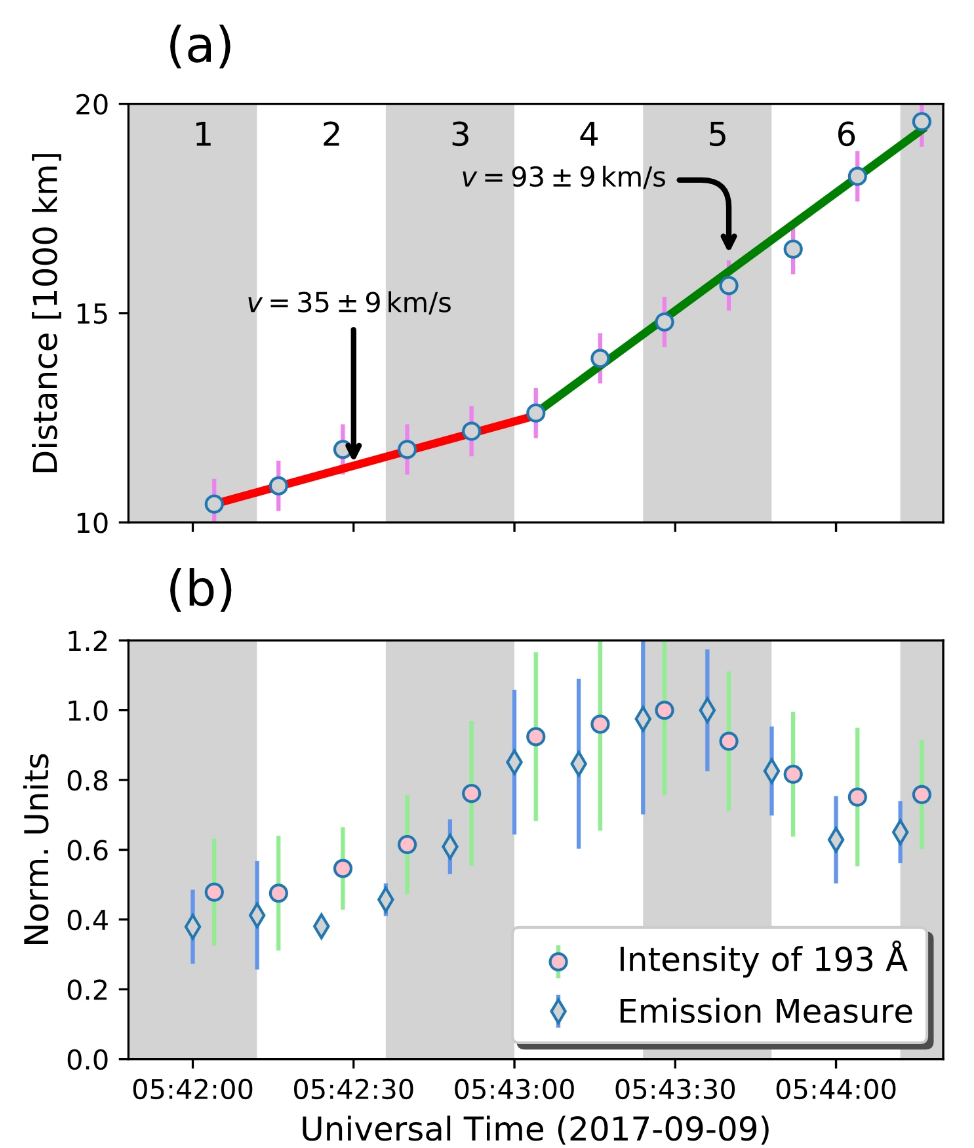
- KH instability develops at two plasma sheets.
- In a single bandpass, one could not observe both
- But they do interact with each other and provide an source of mass & energy.

2D MHD simulations



- Each interface develops KH instability of its own.
- No collective mode at this stage.

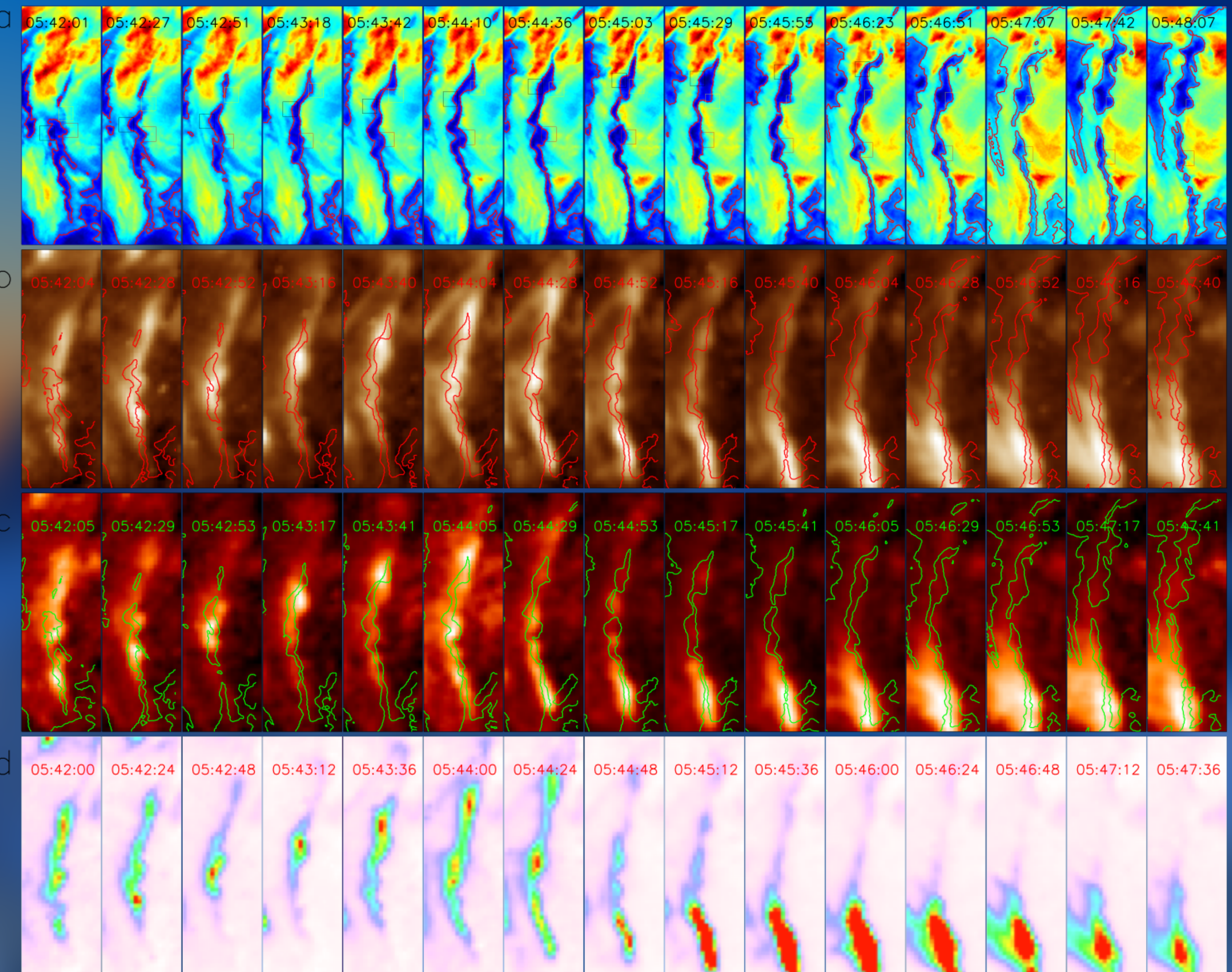
Acceleration & Energy gain



Number Density	Temperature	Energy gain	Wavelength
$5.0^{\pm 1.5} \cdot 10^{10}$ cm $^{-3}$	$1.5^{\pm 0.5} \cdot 10^{6}$ K	$5.0 \cdot 10^{17}$ J, about 100-1000 nanoflare	1~2.5 Mm

Summary

- Observation of Multi-layers of KH instability
- Sudden acceleration could be caused by coalescence of KH vortex.
- Current linear theory is not sufficient to describe the KH instabilities.
- Single narrowband filter observation could easily neglect component with high temperature contrast.
- Transparent or "Vacuum" ambient environment could be a good source of mass and energy.
- This could be found in prominence, coronal loops, spicule, jets, coronal hole etc.



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05:44:10
05:44:36
05:45:03
05:45:29
05:45:55
05:46:23
05:46:51
05:47:07
05:47:42
05:48:07
b
05:42:04
05:42:28
05:42:52
05:43:16
05:43:40
05:44:04
05:44:28
05:44:52
05:45:16
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05:46:04
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05:46:52
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c
05:42:05
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05:42:53
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d
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