Study on the connectivity between the photospheric magnetic fields and their counterparts in the upper atmosphere with Hinode and IRIS

-Sunspot light bridge
-MHD waves

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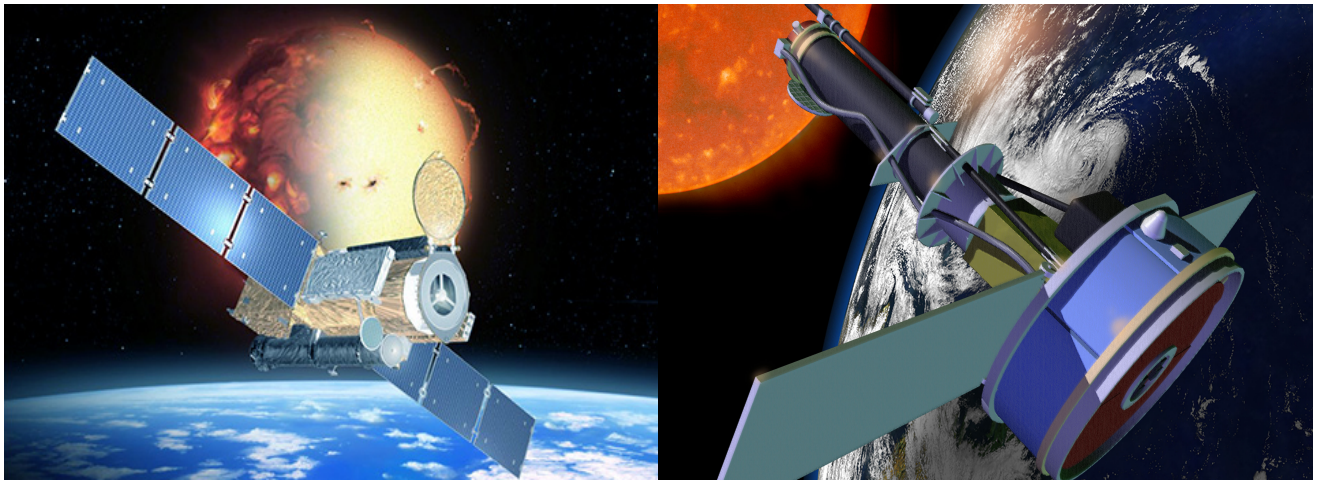


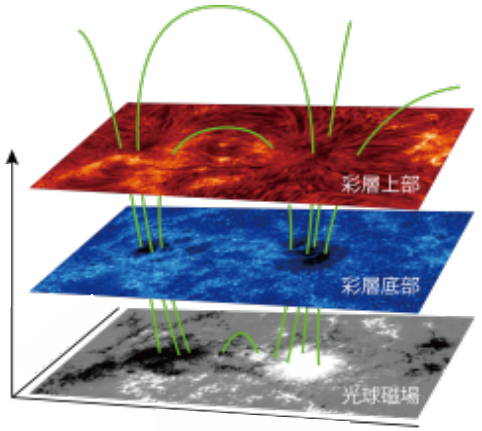
June 17, 2015 Hinode seminar @ ISAS

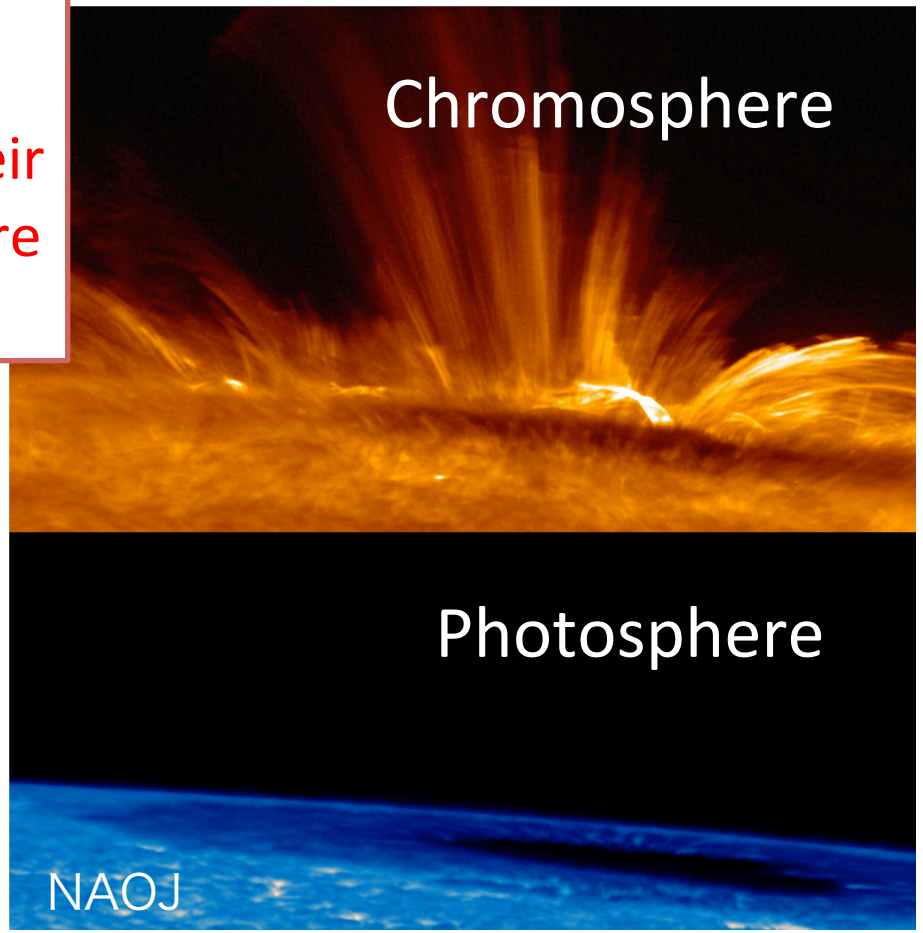
Introduction

Magnetic fields are thought to play a key role in coronal heating problems.

Therefore, connectivity between the photospheric magnetic fields and their counterparts in the upper atmosphere is one of essential information.

The coordination of Hinode observation with IRIS observation makes it possible to understand the connectivity.





Dynamical horizontal magnetic fields in a sunspot light bridge observed with Hinode and IRIS

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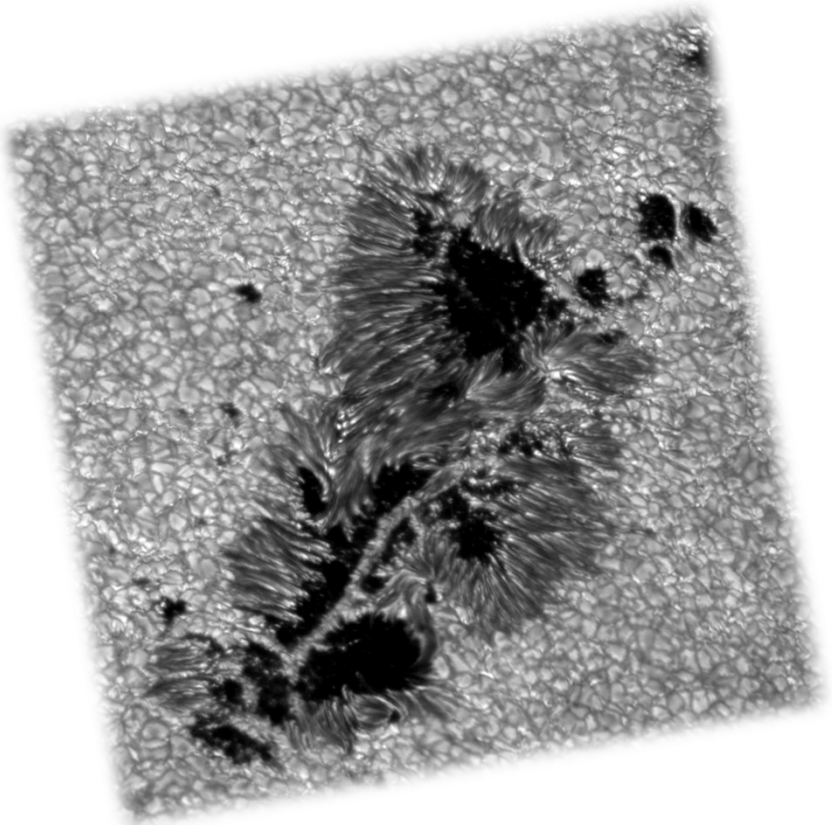
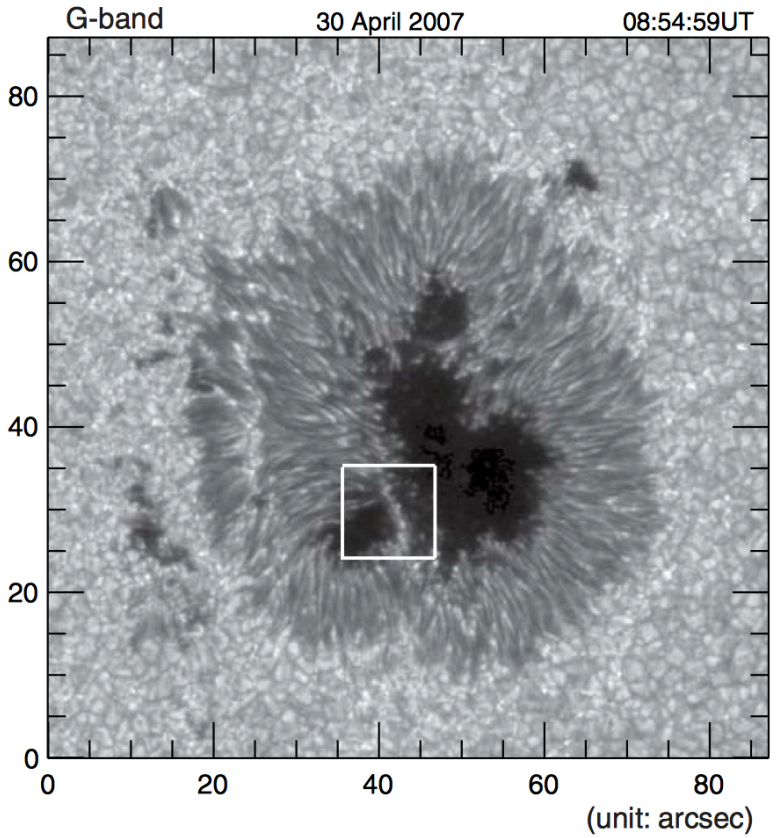


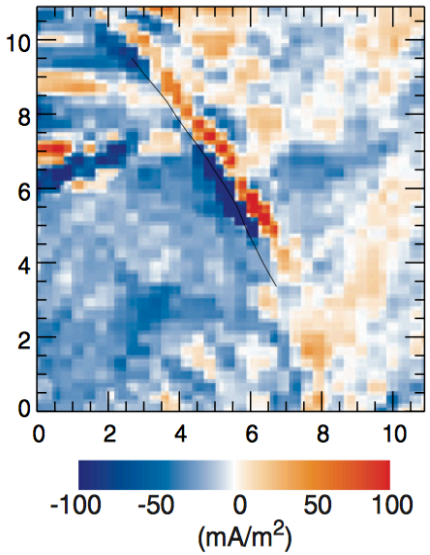
Subject of this study

Emergence of a photospheric horizontal fields and their counterparts

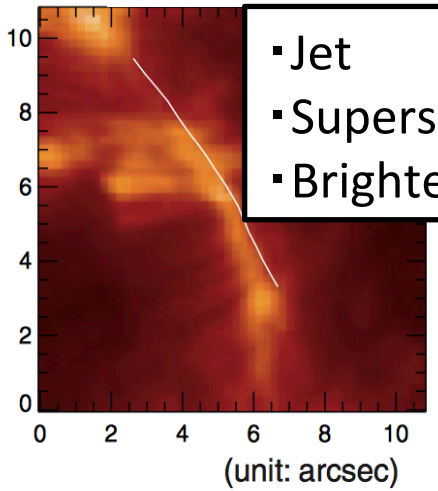
(Shimizu et al. 2009)



Current (J_z)



Ca II H Image



- Jet
- Supersonic flow
- Brightening

Remaining tasks

- Multi wavelength observation

The UV spectral data from the IRIS can be used with simultaneous observations by Hinode/SOT. Counterparts in the upper atmosphere are one of essential information in understanding how upper atmosphere responds to evolution of magnetic field at the low atmosphere.

- Temporal evolution

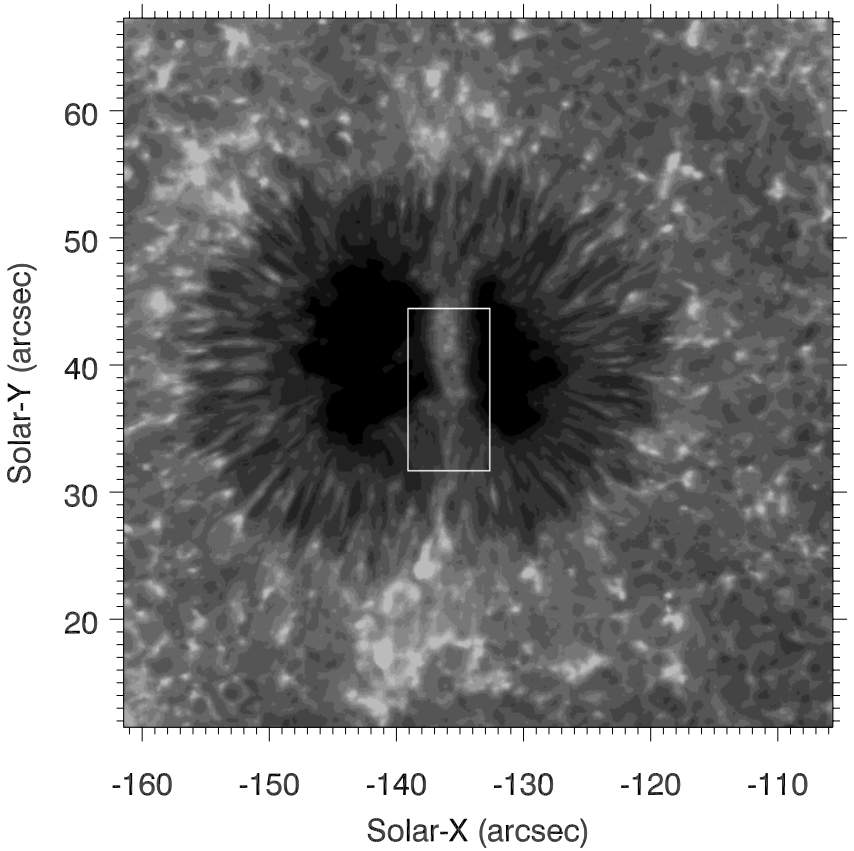
Although there are many observations and studies about LBs, spectro-polarimetric observations provide the evolution of magnetic fields in the cadence longer than a few hours, which is much longer than typical time scale of activities.

Observation

Target: NOAA Active Region 11836

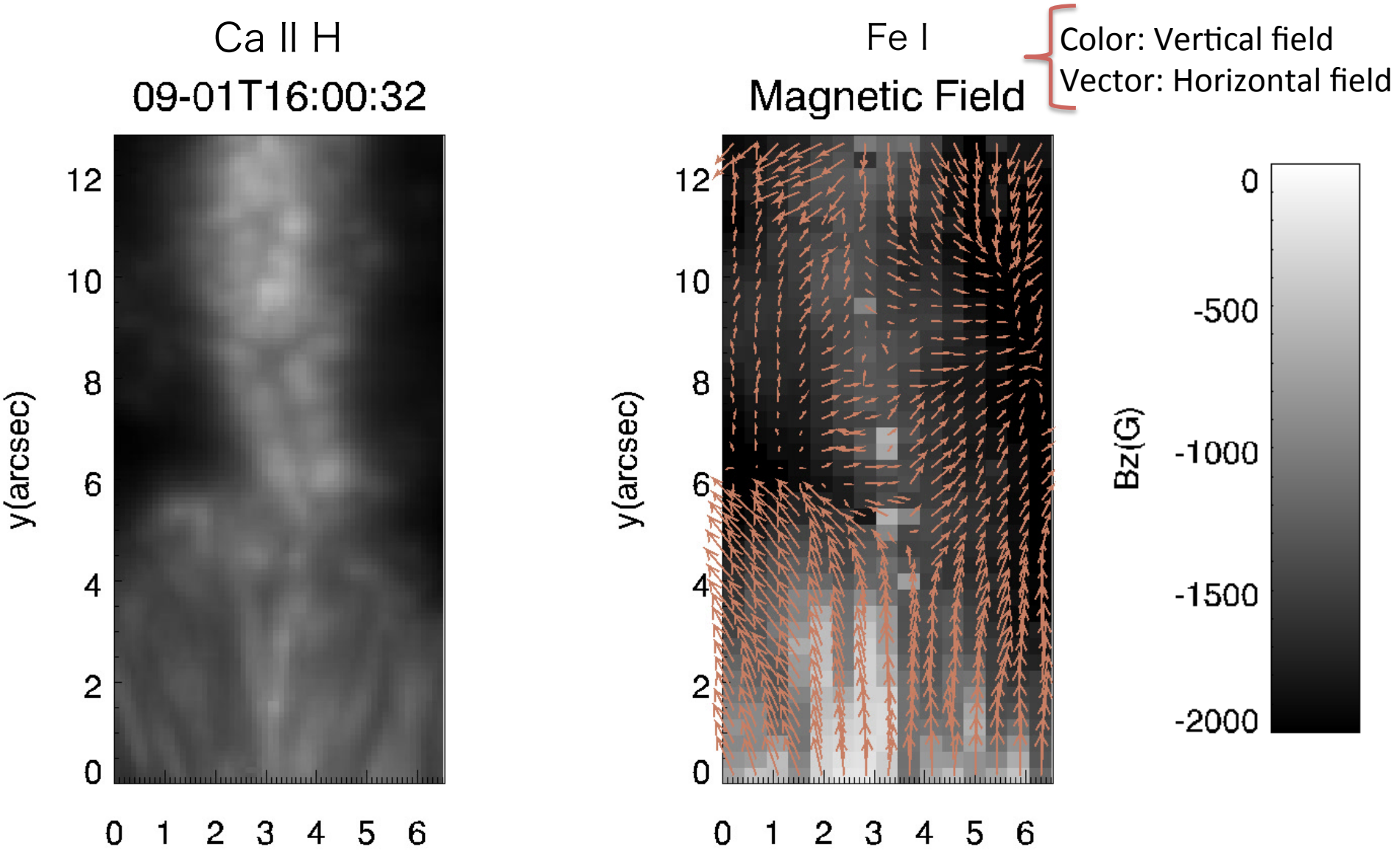
2013/08/31　16:00UT - 18:00UT
→Without horizontal fields

2013/09/01　16:00UT - 18:00UT
→Horizontal fields are emerging

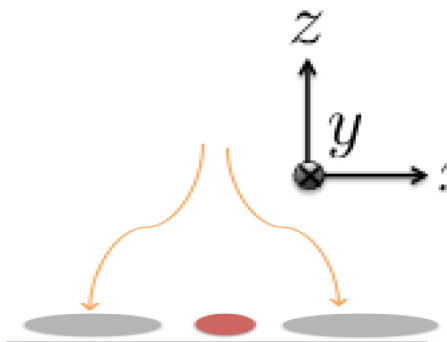


Camera	Filter	Observation method	Cadence
Hinode/FG	Ca II H	Imaging	15 sec
Hinode/SP	Fe I	Slit scan	72 sec
IRIS (SJI)	Mg II k、C II、Si IV	Imaging	12 sec
IRIS (RASTER)	Mg II k、C II、Si IV	Slit scan	3 sec

Temporal evolution of the magnetic fields



Configurations of the magnetic fields

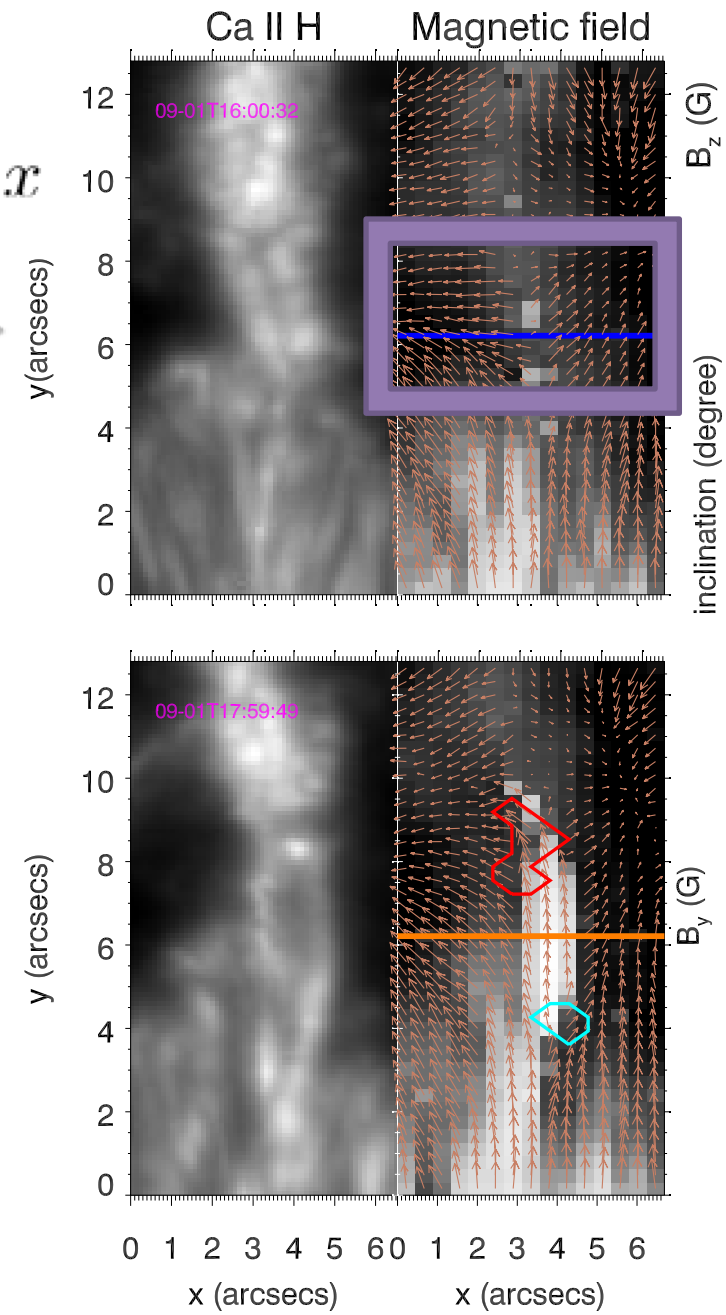


Cusp-like field

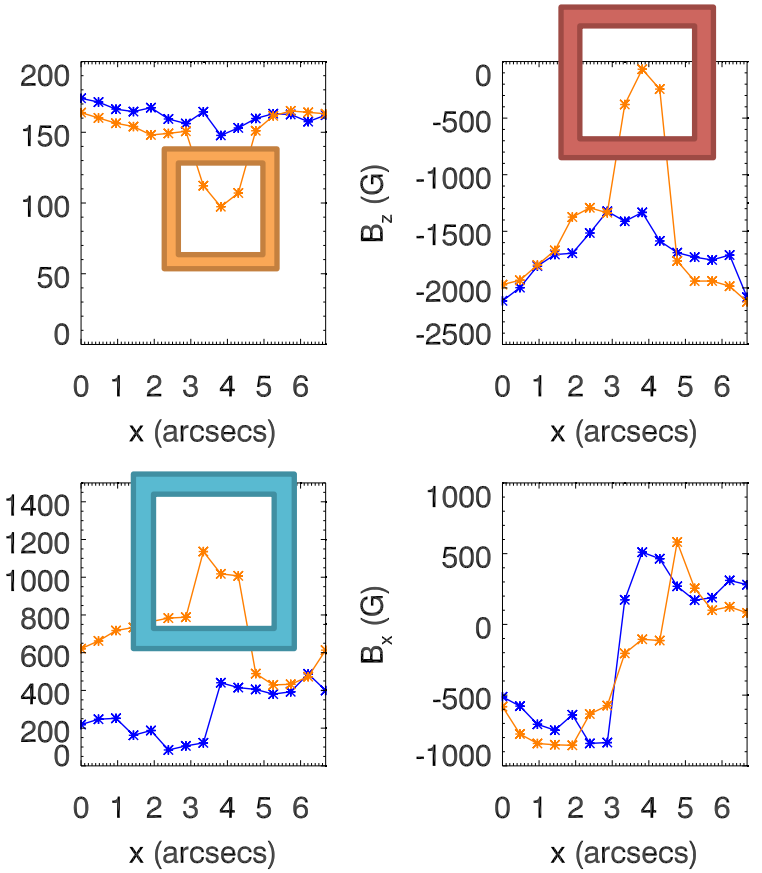
B_z
1300G→100G

B_y
500G→1000G

Inclination
150°→100°

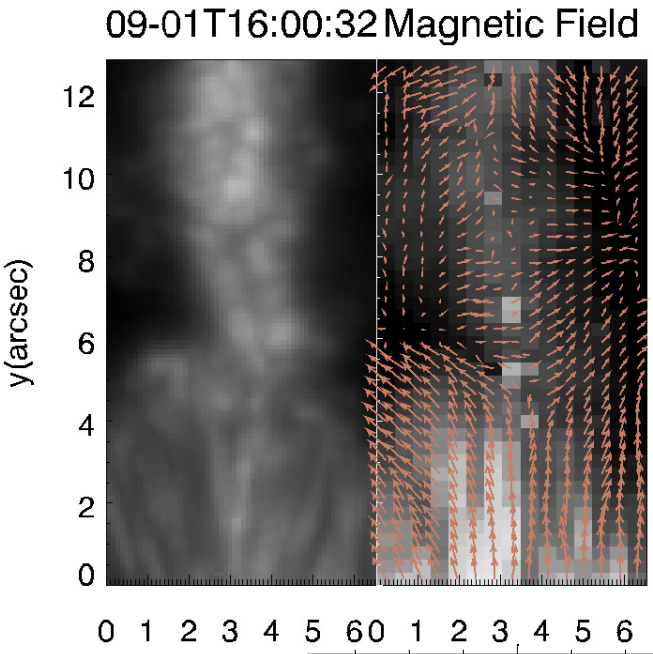


Magnetic fields along
the blue/orange slices
↓

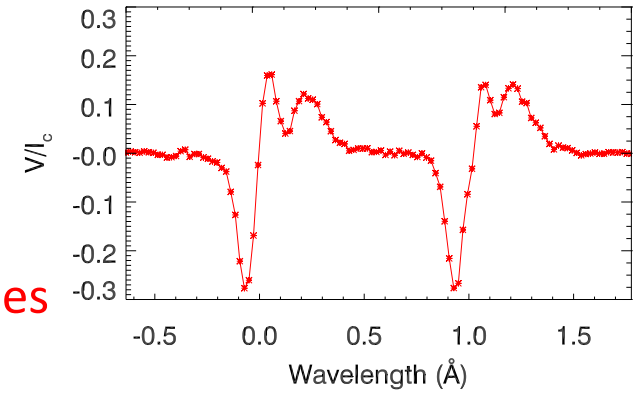


※Milne-Eddington inversion is used.

Morphology of the horizontal fields



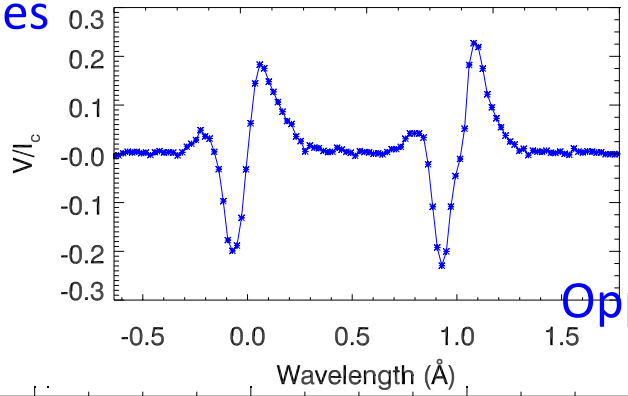
Stokes-V

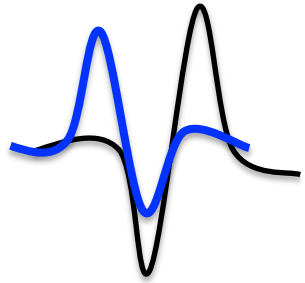


Red patches

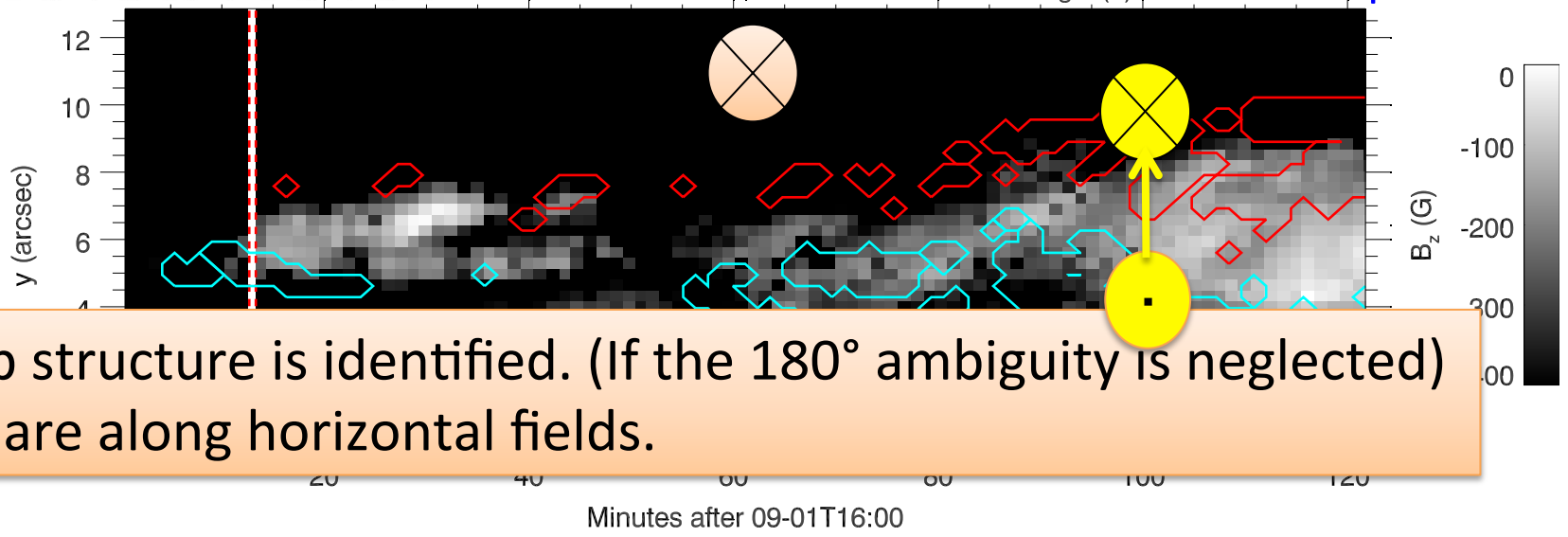
Same polarity
Downflow

Blue patches



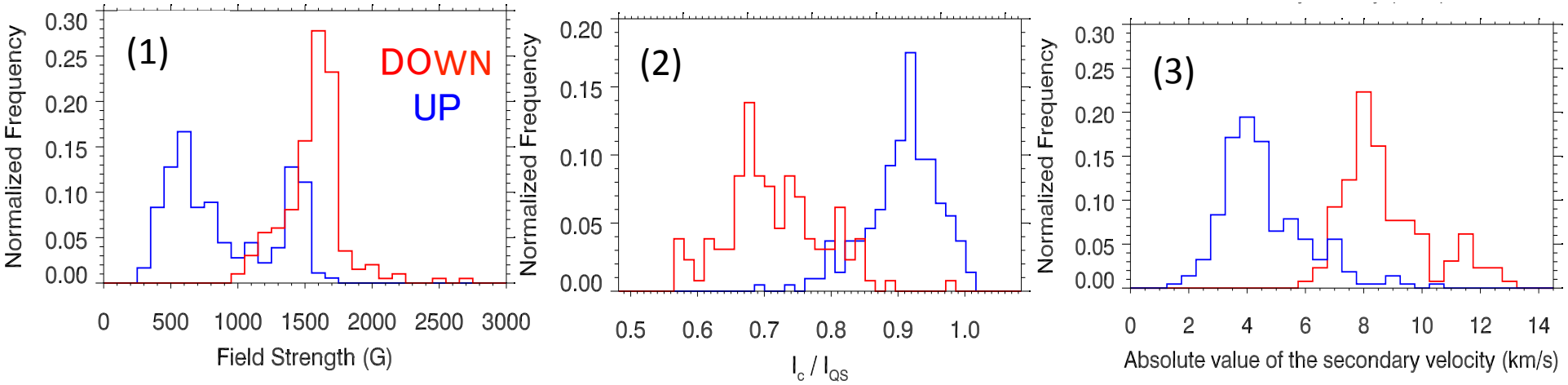


Opposite polarity
Upflow



Ω-loop structure is identified. (If the 180° ambiguity is neglected)
Flows are along horizontal fields.

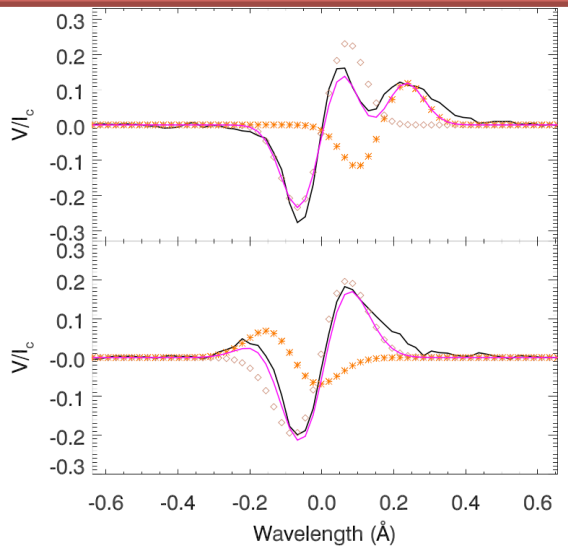
Properties of the up/down patches



(1)	(2)	(3)
$B_{DOWN}>B_{UP}$	$I_{DOWN}<I_{UP}$	$v_{DOWN}>v_{UP}$

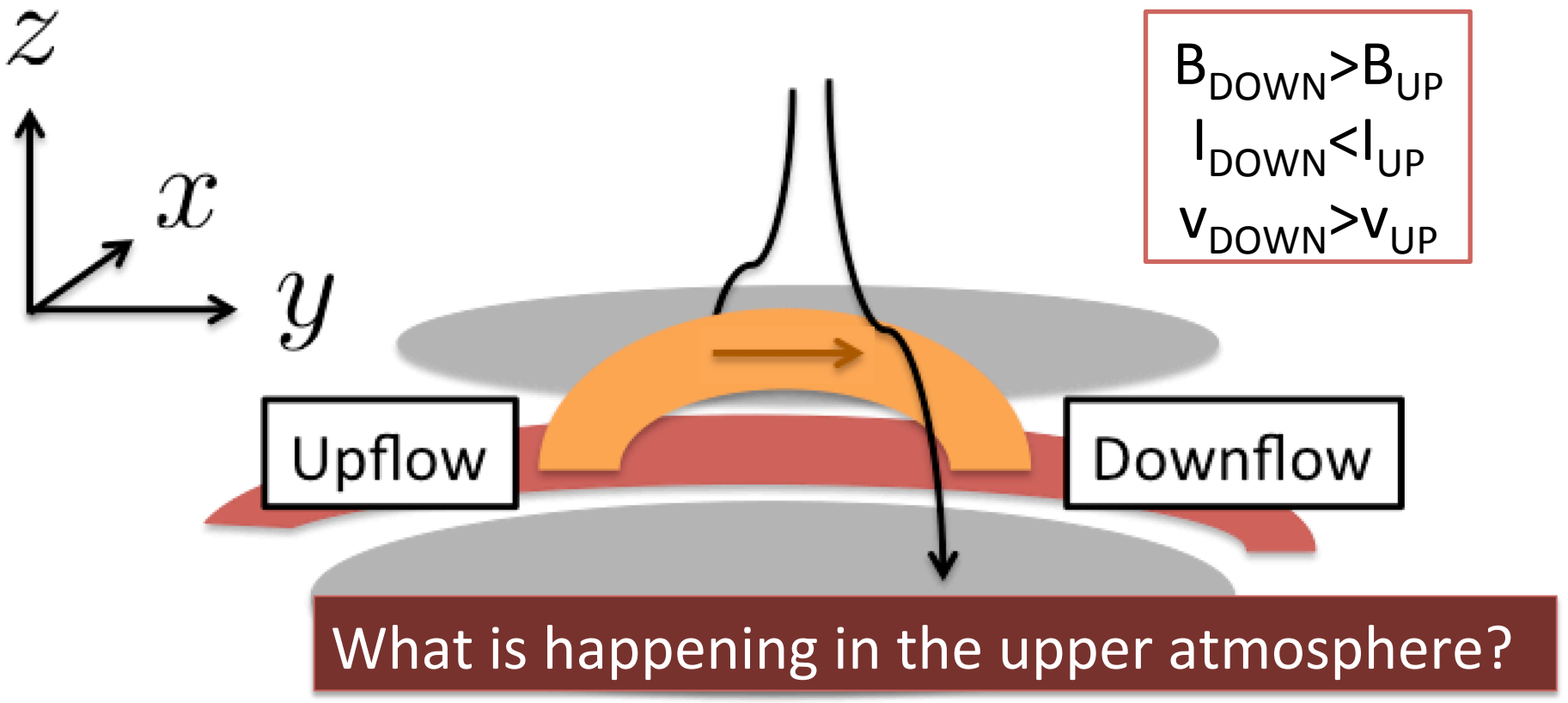
In sunspot area, correlation between field strength and photospheric intensity is reported (Cowling 1953).

Therefore, (2) supports the result of (1).



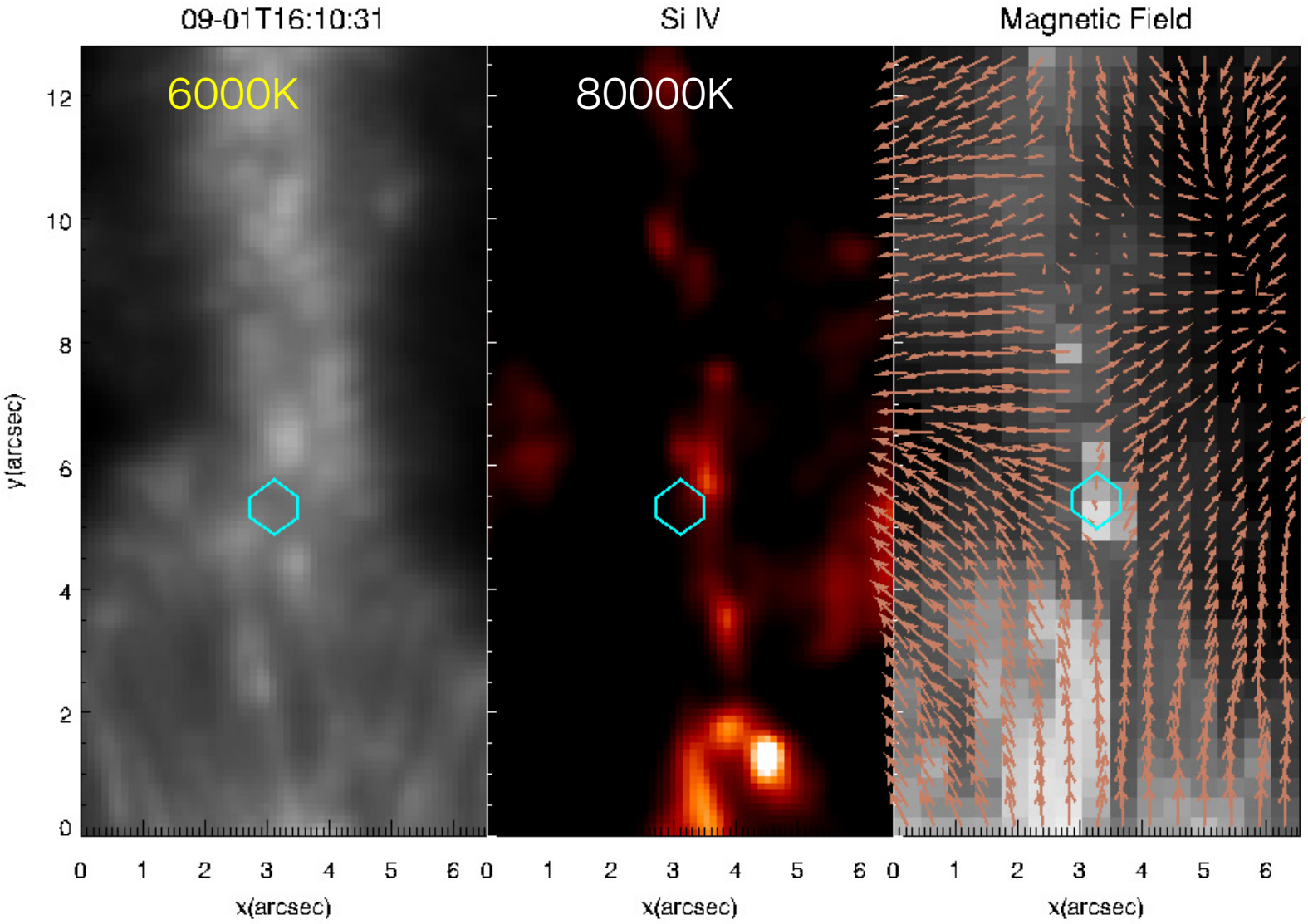
(3) is derived by 2-component fit.

Schematics of the photosphere

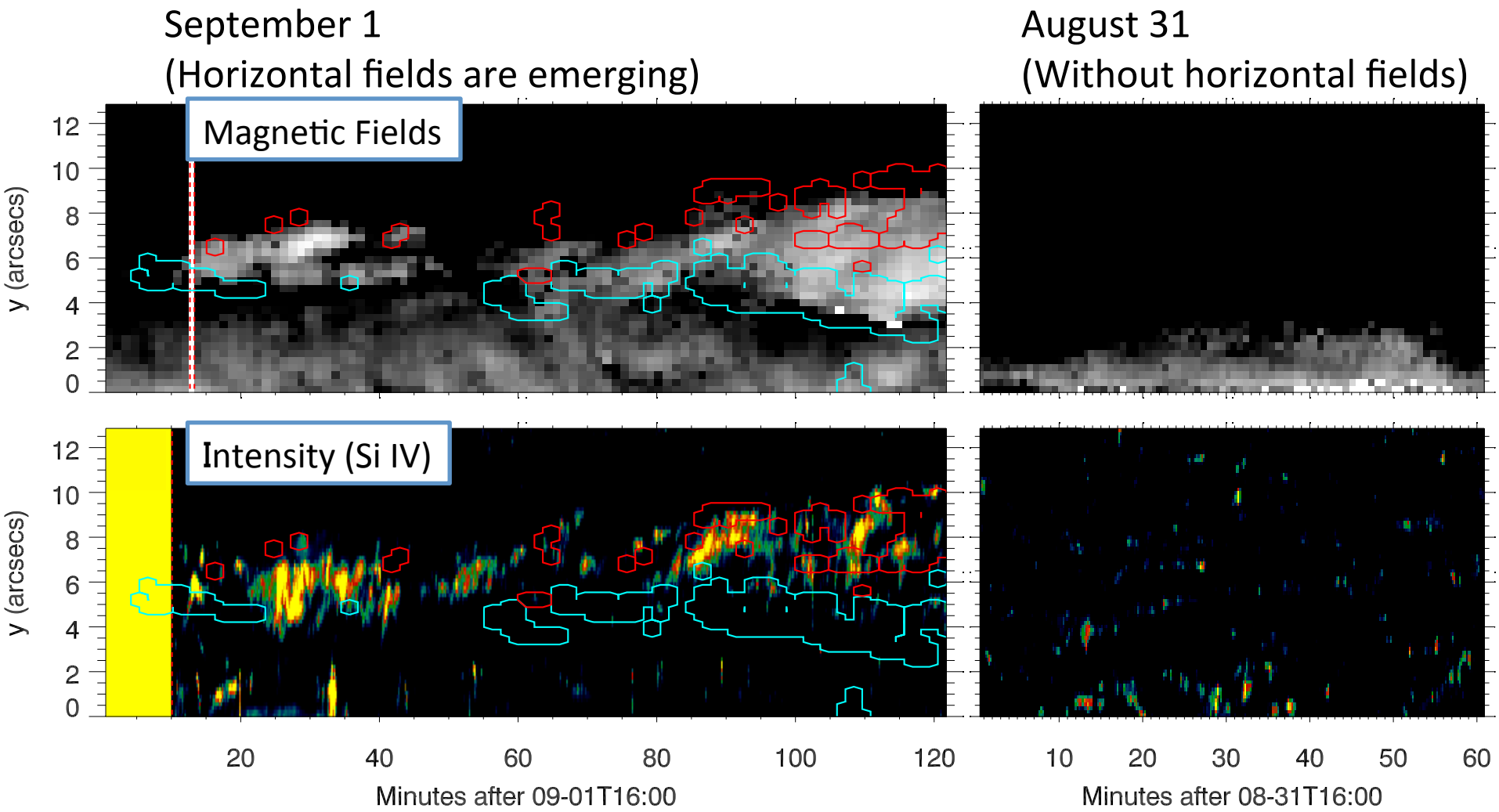


Ω-shaped flux tube emerges from below the cusp-like ambient fields.
Materials are flowed along the horizontal fields.

Activities in the upper atmosphere

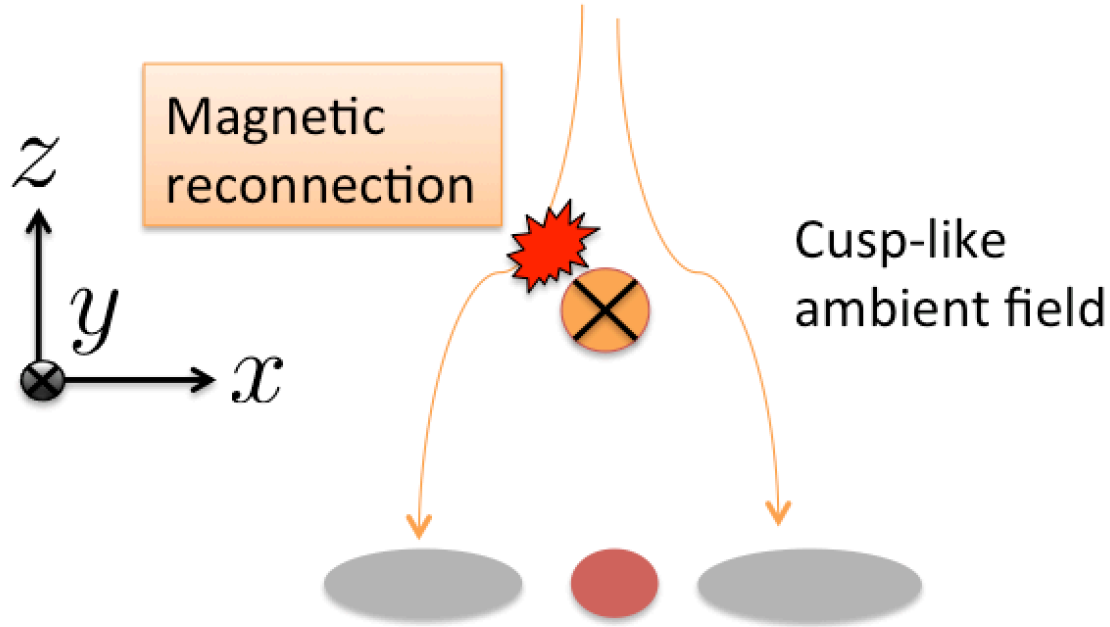


Horizontal fields and brightening



A bright feature can be seen in the LB on September 1. Location of the feature is similar to the photospheric horizontal fields. In contrast, there are neither the bright feature nor the horizontal fields on August 31.

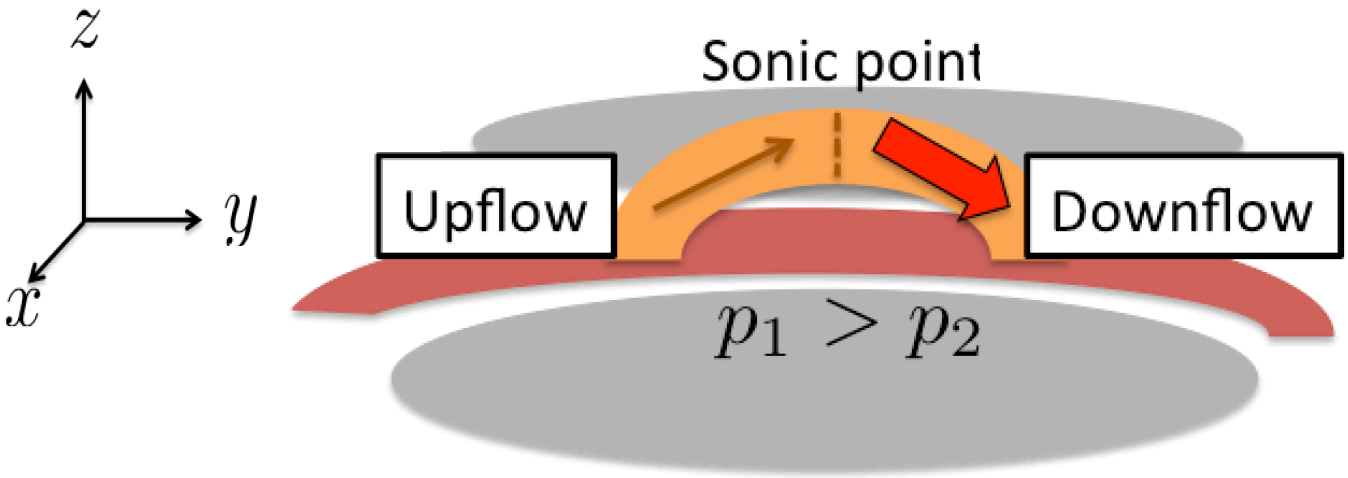
Discussions[1]
Heating mechanisms



When a horizontal flux tube emerges from below the photosphere, the interaction between ambient vertical fields and newly emerging horizontal fields may create current sheets and cause magnetic reconnection.

Discussions[2]

Driving mechanisms of the photospheric flows



$B_{DOWN} > B_{UP}$
$I_{DOWN} < I_{UP}$
$v_{DOWN} > v_{UP}$

$$P_1 + \frac{B_1^2}{2\mu} = P_2 + \frac{B_2^2}{2\mu}$$ (Siphon flow)

These flows can be understood as a consequence of siphon flow mechanism in case of magnetohydrostatic.

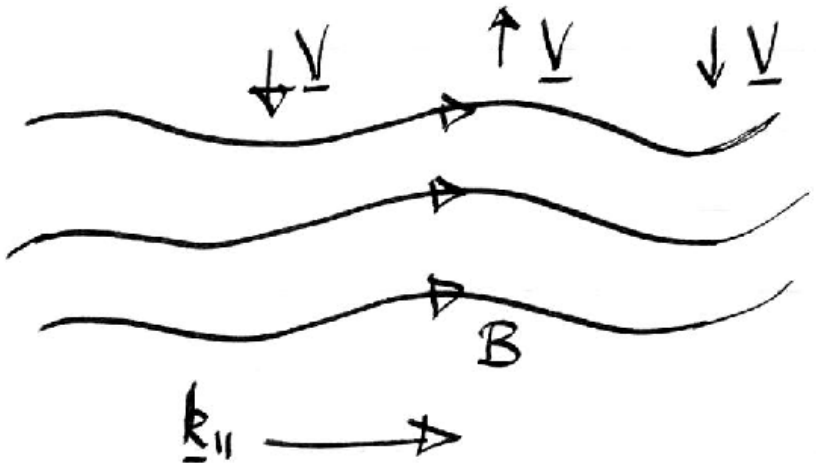
※

There is possibility that convection in inclined magnetic field geometries is a driver.
However, in that case, driver that accelerates the vigorous flows is still to be identified.

Summary

- Observed horizontal fields in a sunspot light bridge have Ω-loop structure.
- Rapid flows are excited along the horizontal fields.
- The horizontal fields influence to heat the solar atmosphere.

Study on dissipating processes of MHD waves with Hinode and IRIS



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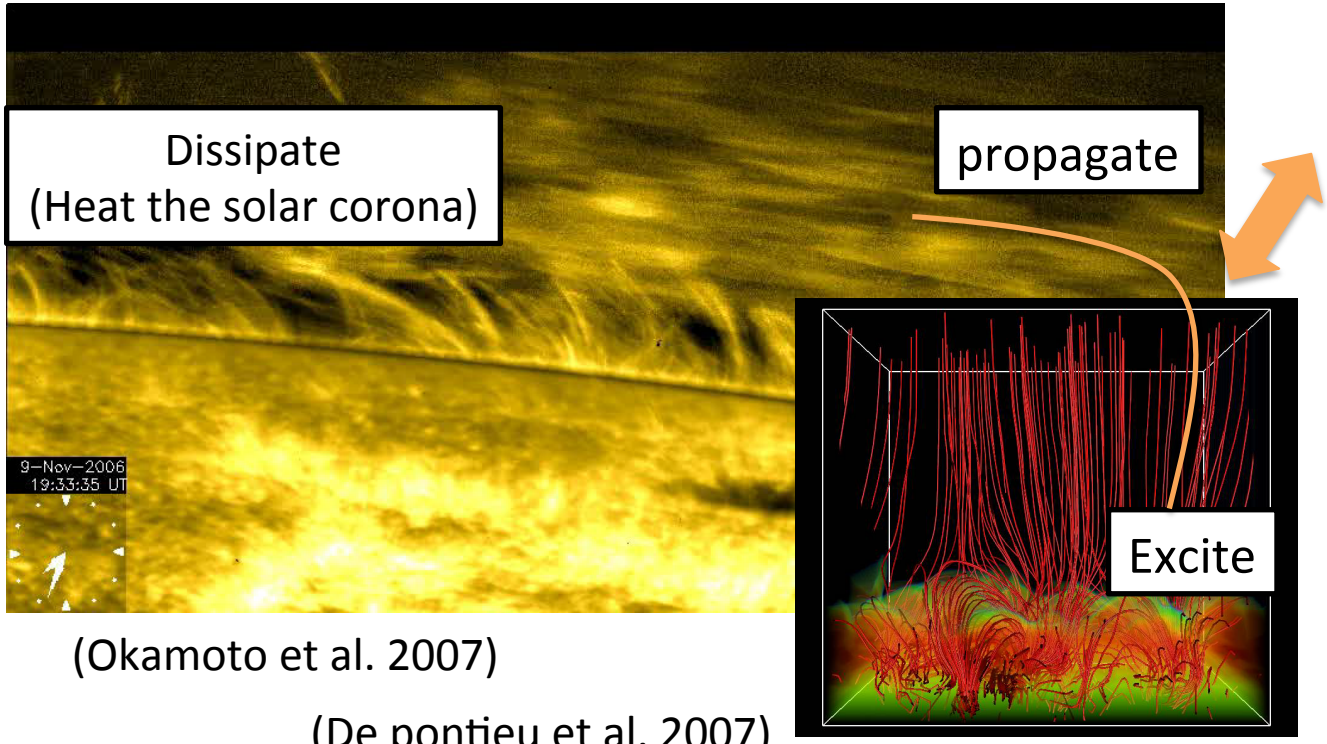
Coronal heating by means of MHD waves



(Okamoto et al. 2007)

(De pontieu et al. 2007)

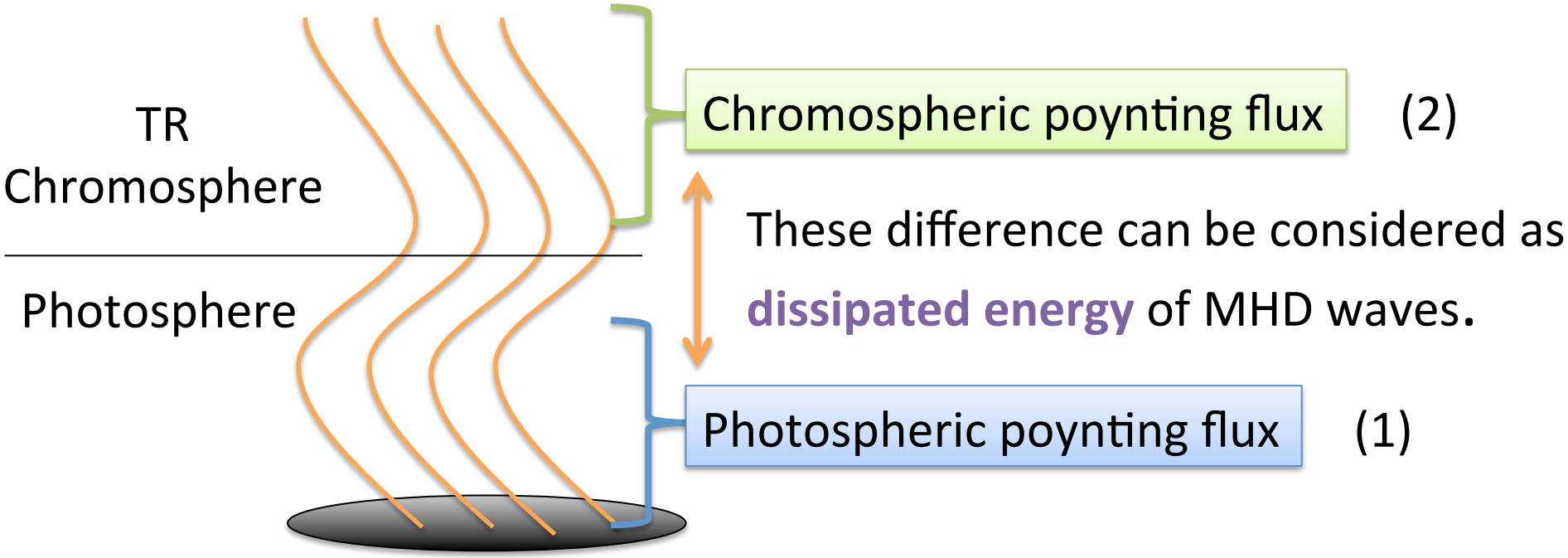
There are many observational studies about MHD waves.
However, study which detects dissipating or exciting processes of MHD waves is very rare.

Moreover, quantiative study with spectro-polarimetric observation will be important in the future. (In anticipation of Solar-C)

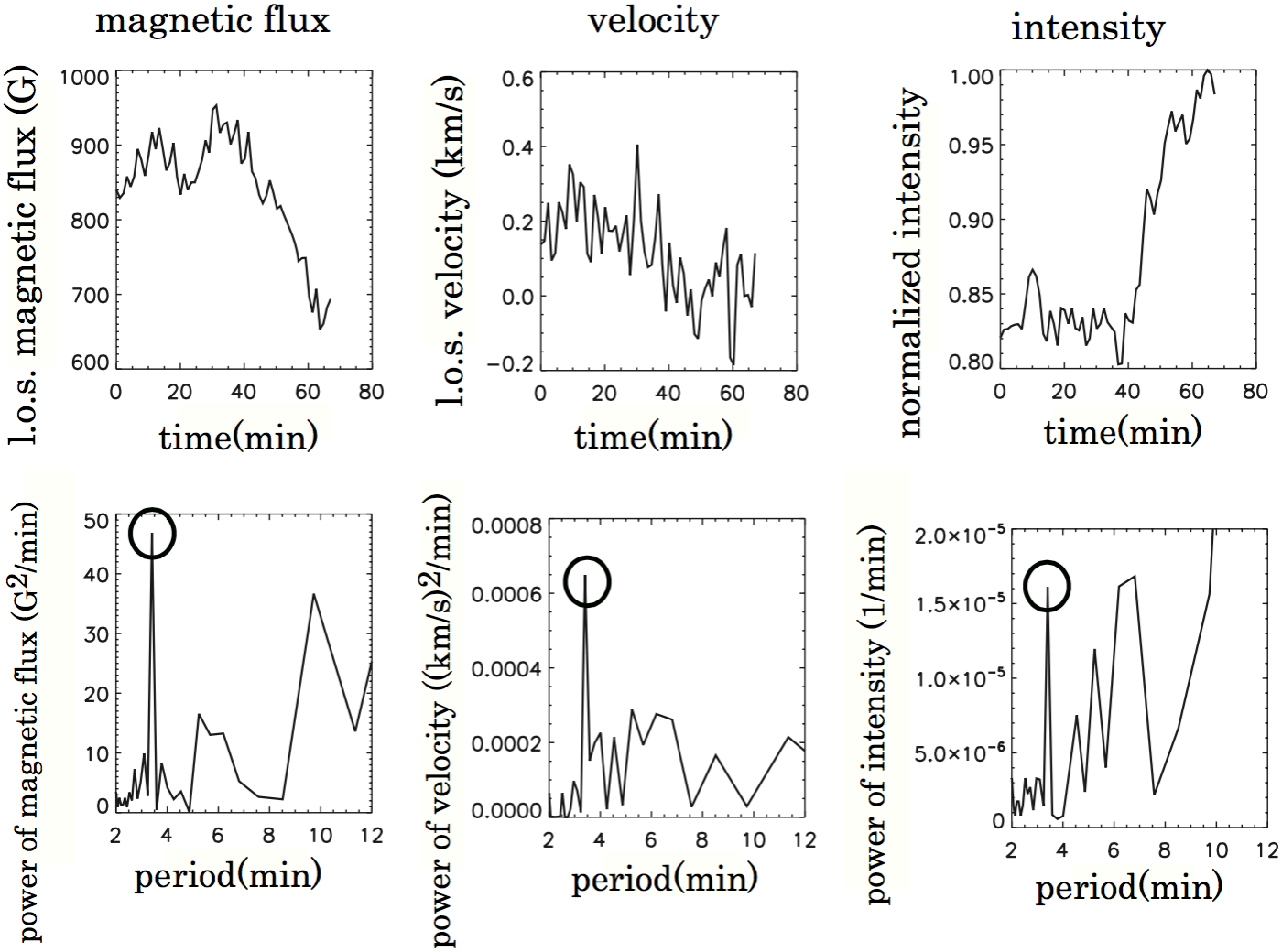
Our idea for estimating the dissipated energy of MHD waves

(1)**SOT/SP** can estimate poynting flux in the photosphere by using techniques developed in previous study (Fujimura&Tsuneta (2009))

(2)With assumption of the magnetic field strength, we can use same techniques to **IRIS** data. (In anticipation of Solar-C)



Review of Fujimura&Tsuneta(2009)



Solar-X:460''
Solar-Y:10''

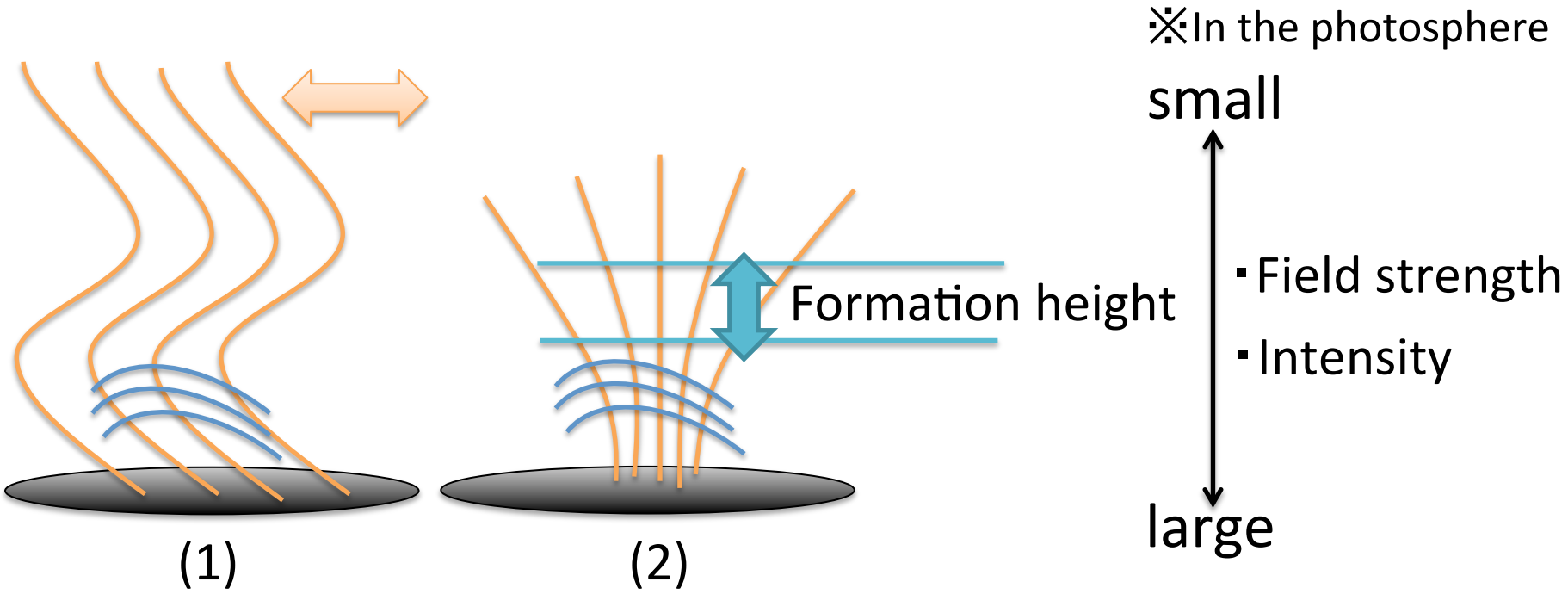
※ They averaged physical parameters of the pixels with strong CP in the ROI.

They mentioned that these small fluctuations with same frequency are products of MHD waves driven by p-mode oscillation.

We should note that there are two possibilities to reproduce these observed aspects

(1)P-mode oscillation excites MHD waves
(Magnetic fields are oscillated)

(2)P-mode oscillation changes the line formation height
(Actually, magnetic fields are not oscillated)

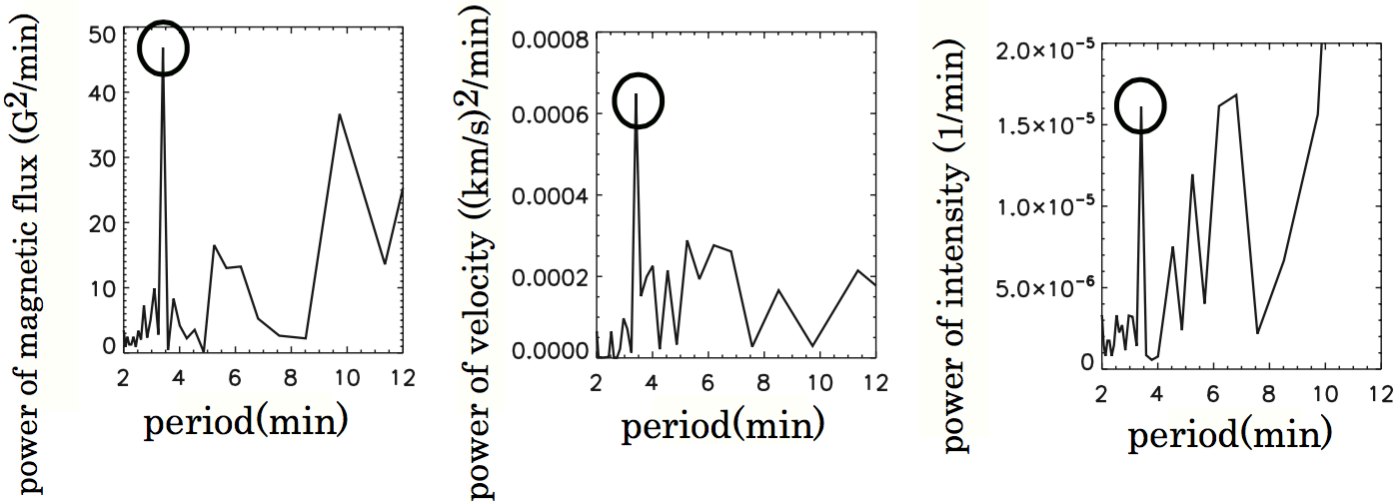


How to distinguish ?

- Phase relation is very important.

If oscillation is caused by opacity effect, phase difference between B and I_c should be 0° .

In previous study, by using inverse Fourier transform only to strong peak, they checked phase relations and derived Poynting flux.



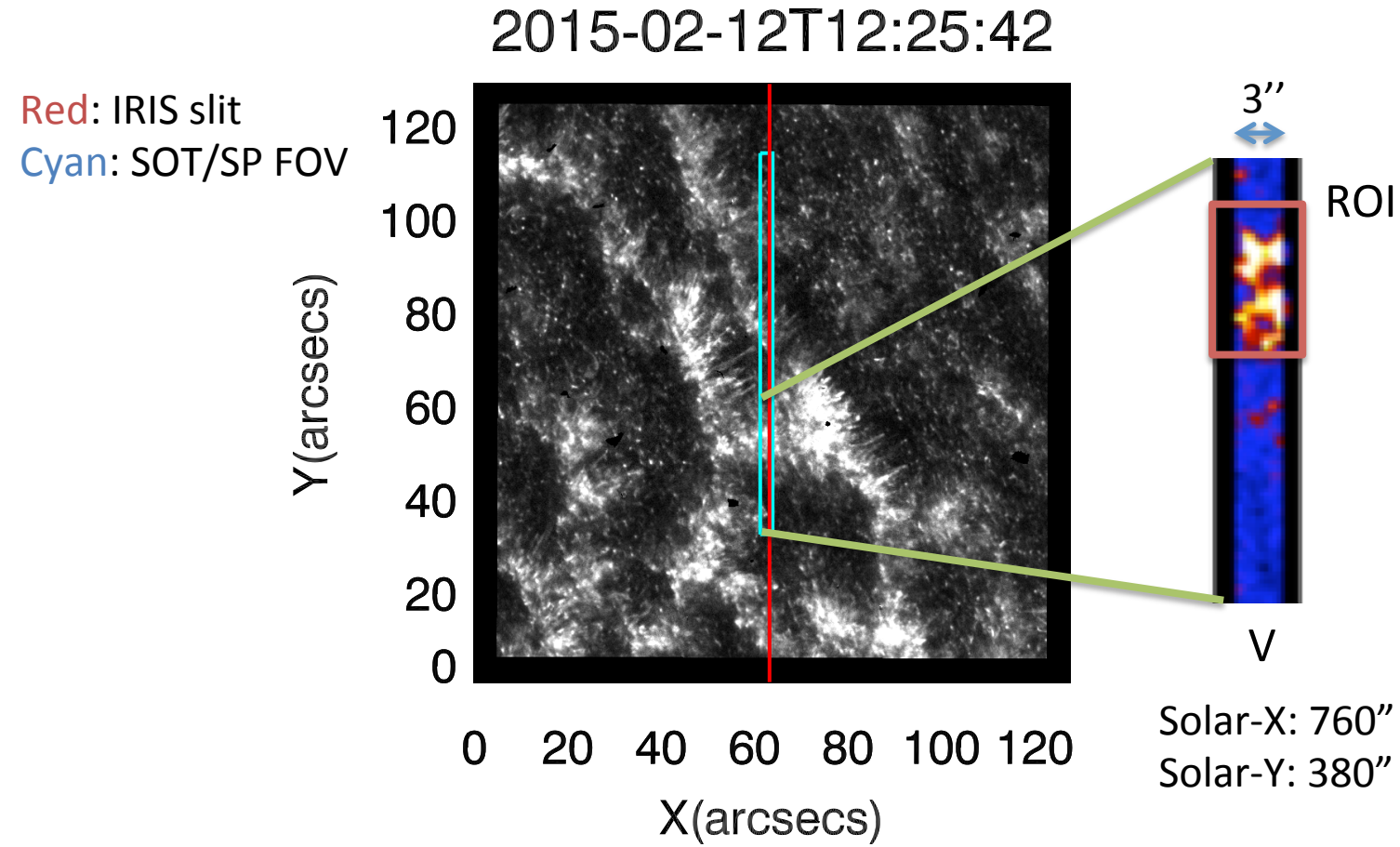
Our opinion

- Phase relation is very important to distinguish between the real oscillation and the apparent oscillation (opacity effect). However, we think that the temporal resolution in previous study (67 sec) is not enough. We need to check that using inverse Fourier transform only to strong peak is reasonable or not.

- Moreover, there are some possibilities that we can obtain new aspects of MHD waves from their waveform.
(ex. Processes of nonlinearization, attenuation etc…)

Therefore, we performed new observation on 2015/02/12 with 21 sec cadence.

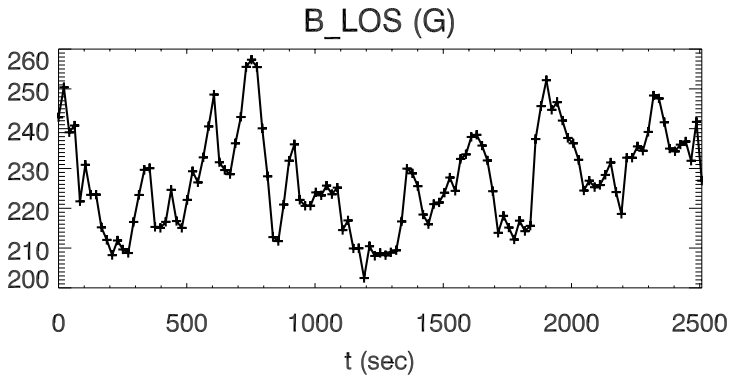
Observations and data analysis

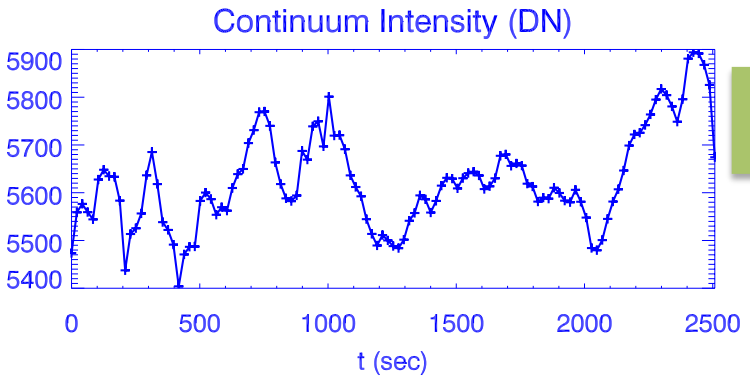


Milne-Eddington inversion is used for deriving physical parameters.
We averaged physical parameters of the pixels with strong CP in the ROI.

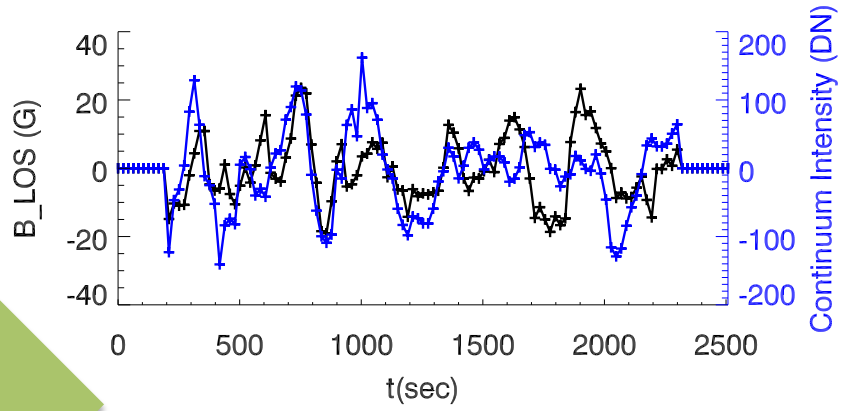
Results

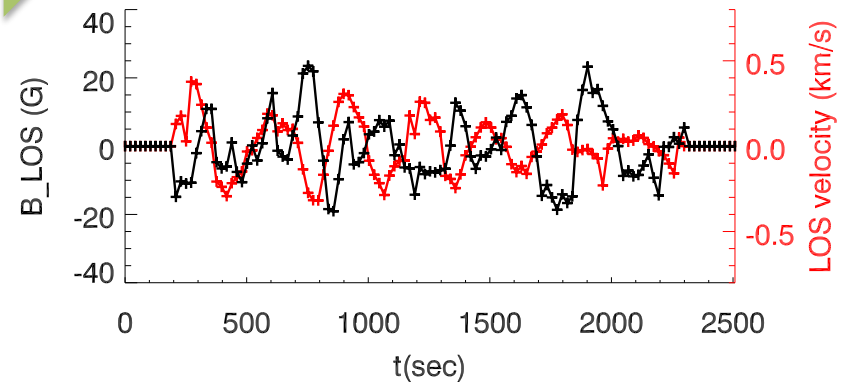
※
We averaged physical parameters of the pixels with strong CP in the ROI.

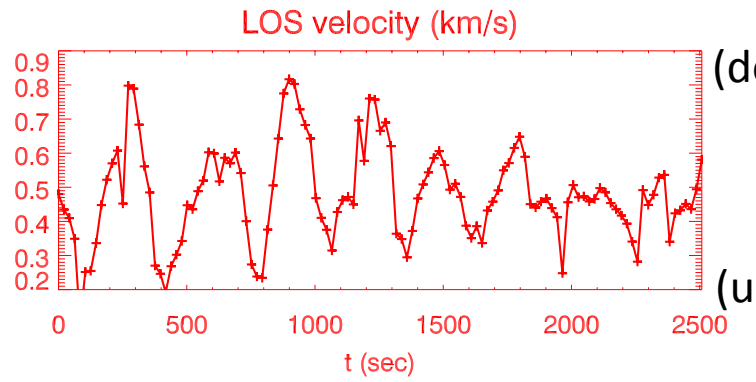




Subtract running average





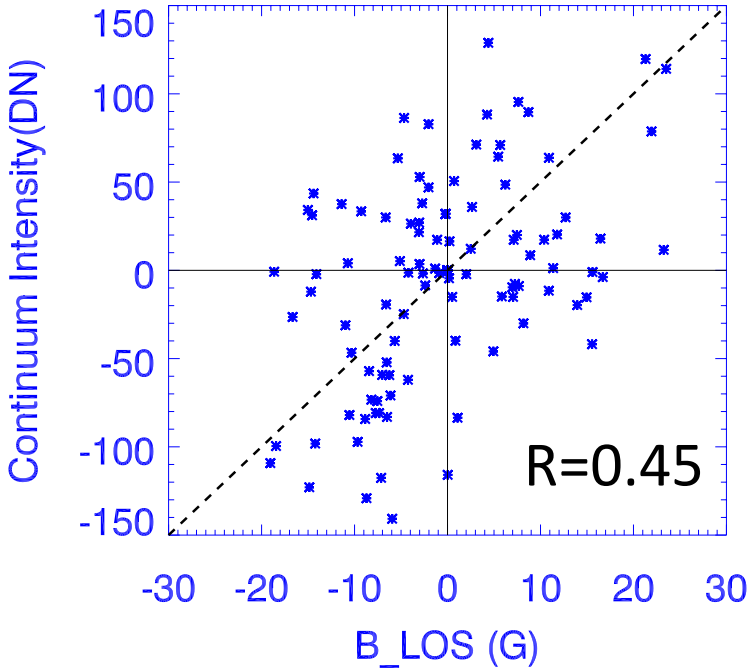


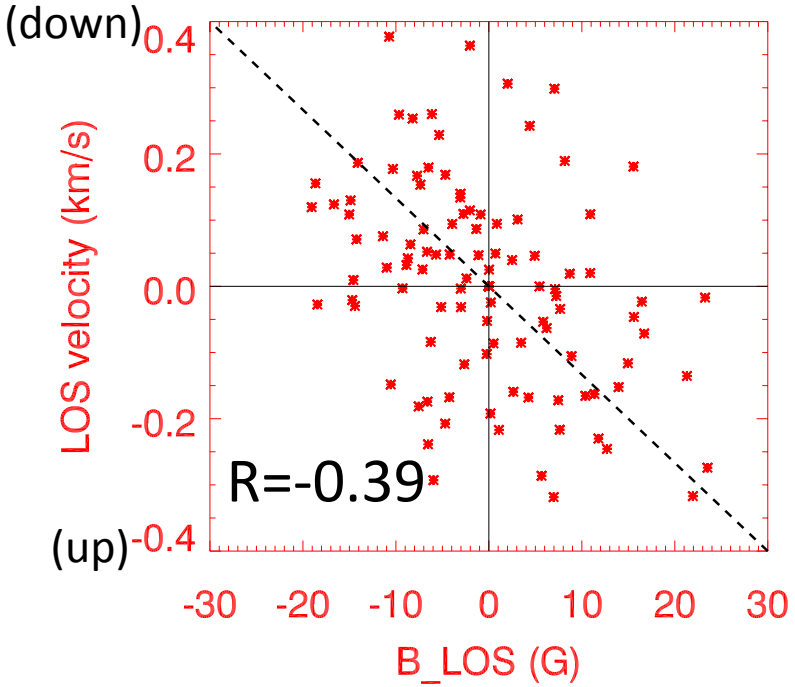
(down)

(up)

- Black:Filling factor × LOS Field strength
- Blue:Continuum Intensity
- Red:LOS velocity

Phase relations





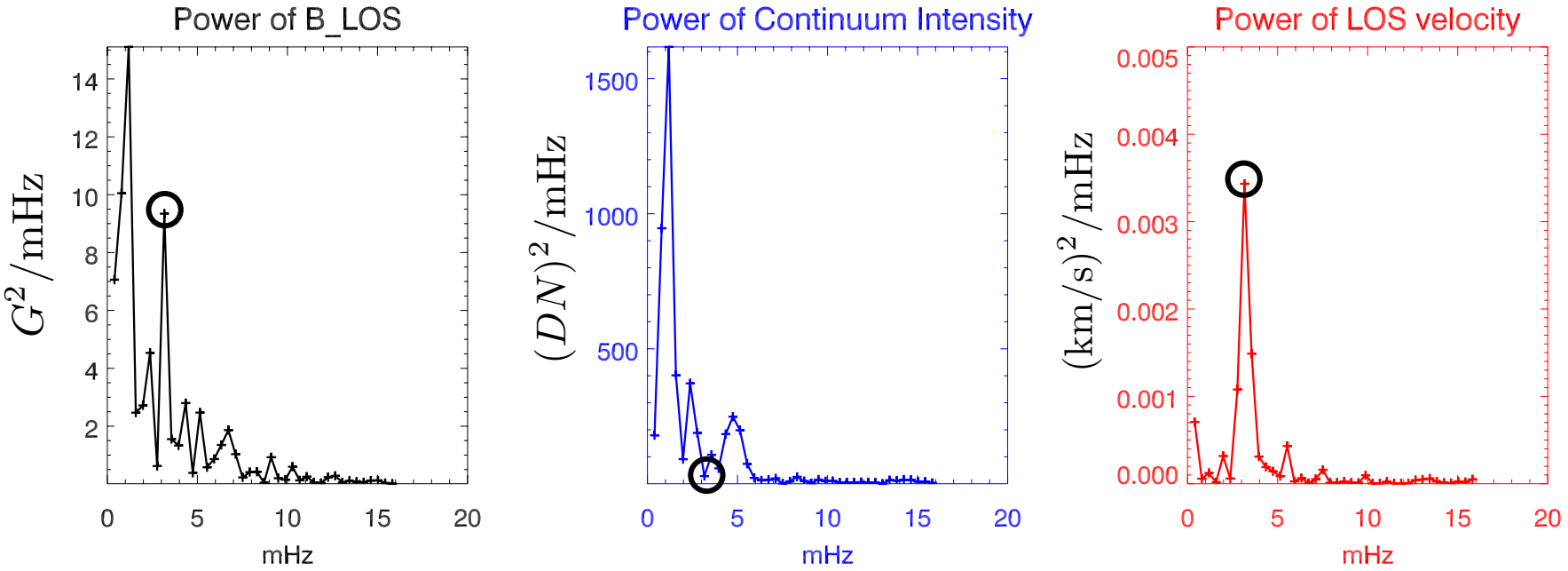
I_c and B_{LOS} correlate positively → consistent to opacity effect

※

Note that the correlation coefficient is not so large.

There are some possibilities that influences of MHD waves are lurking.

Comparison to the previous study



We apply Fourier transform to original profiles in the same way as previous study.

Interestingly, the results show that only B_{LOS} and v_{LOS} have a strong common peak. It means that I_c does not oscillate with same frequency as B_{LOS}, namely, these are **inconsistent to the opacity effect**.

Discussions

- P-mode oscillation does not maintain perfectly constant frequency. Therefore, we think that focusing only to specific frequency as previous study may not be reasonable.

- It is important to distinguish the opacity effect and the real oscillation for estimating dissipated energy of the MHD waves.

Interim summary

- Oscillating signals can be seen in B_{LOS},v_{LOS}, $I_{C.}$

- These phase relations are consistent to opacity effect. This result is different from previous study.

- Focusing only to specific frequency as previous study may not be reasonable.