Alfven waves, Spicules and the partially ionized chromosphere

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Collaborators:
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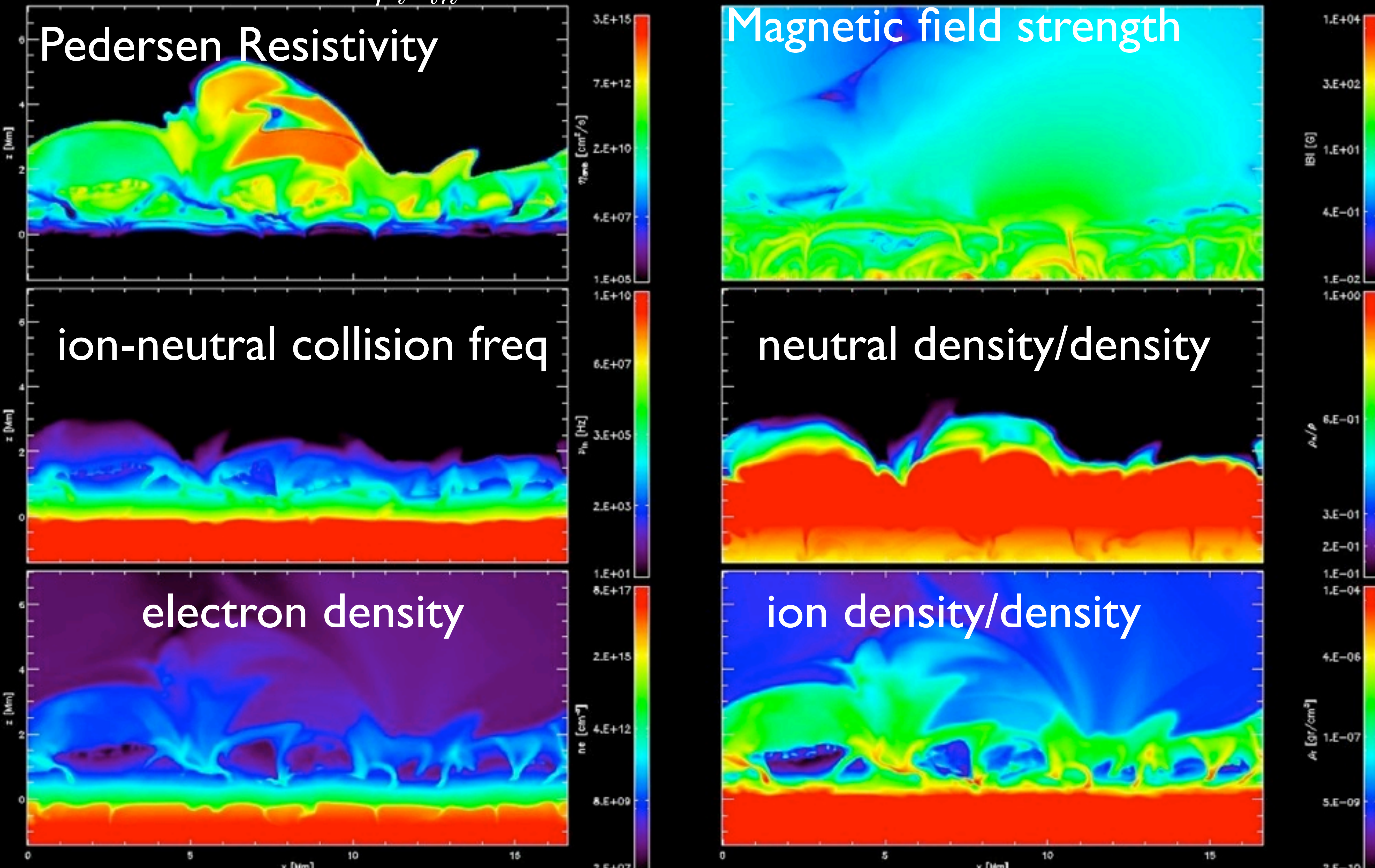
Papers:
Martinez-Sykora, De Pontieu, Hansteen, ApJ, 2012
De Pontieu, et al., ApJL, 2012
Pereira, De Pontieu, Carlsson, submitted to ApJ, 2012
Pereira, De Pontieu, Carlsson, submitted to ApJL, 2012

Pedersen resistivity shows horizontal and vertical variations in chromosphere of 6-7 orders of magnitude for ionization equilibrium calculations

Reminder: $$\eta_A = \frac{(|B|\rho_n/\rho)^2}{\rho_i \nu_{in}}$$



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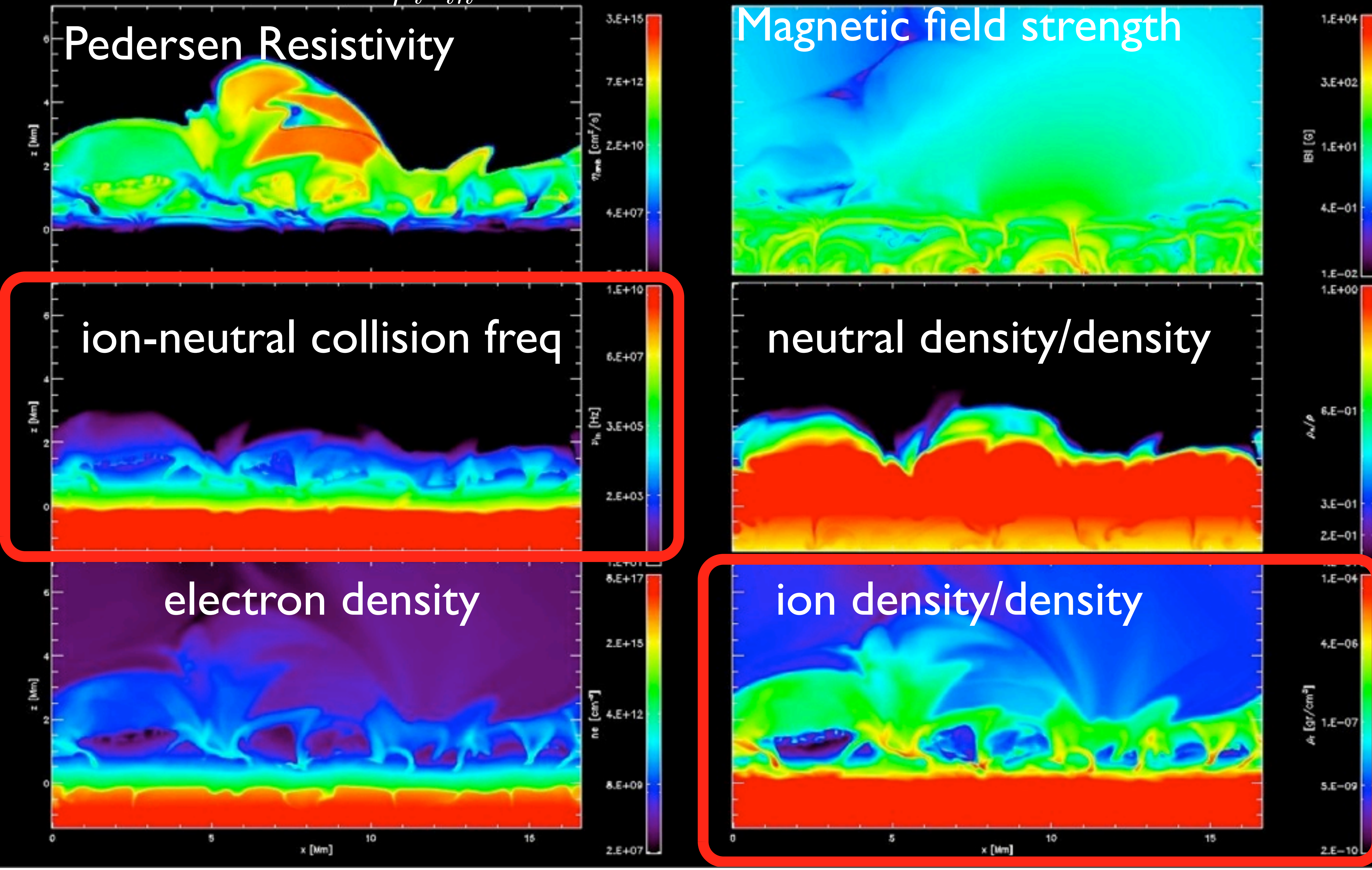
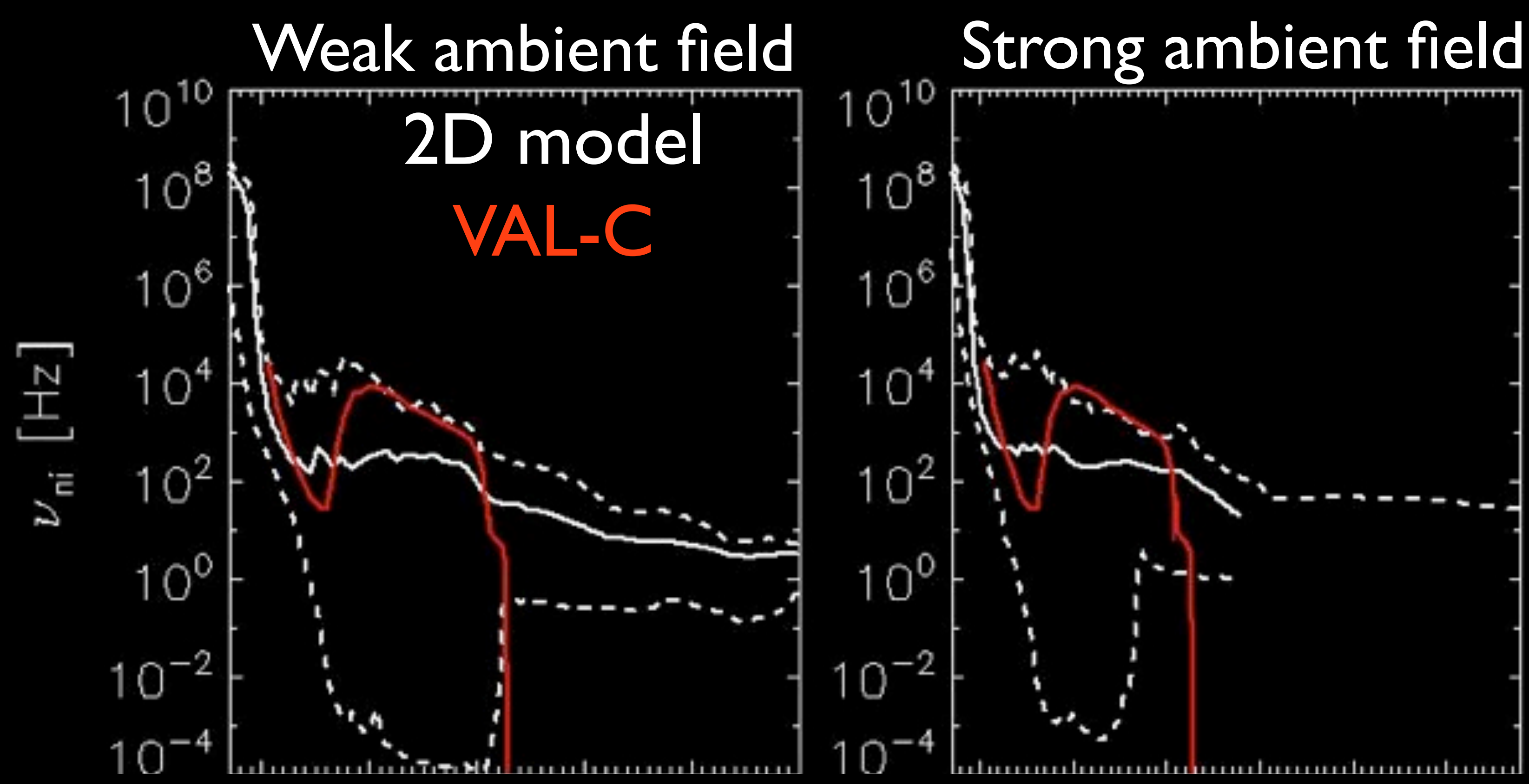


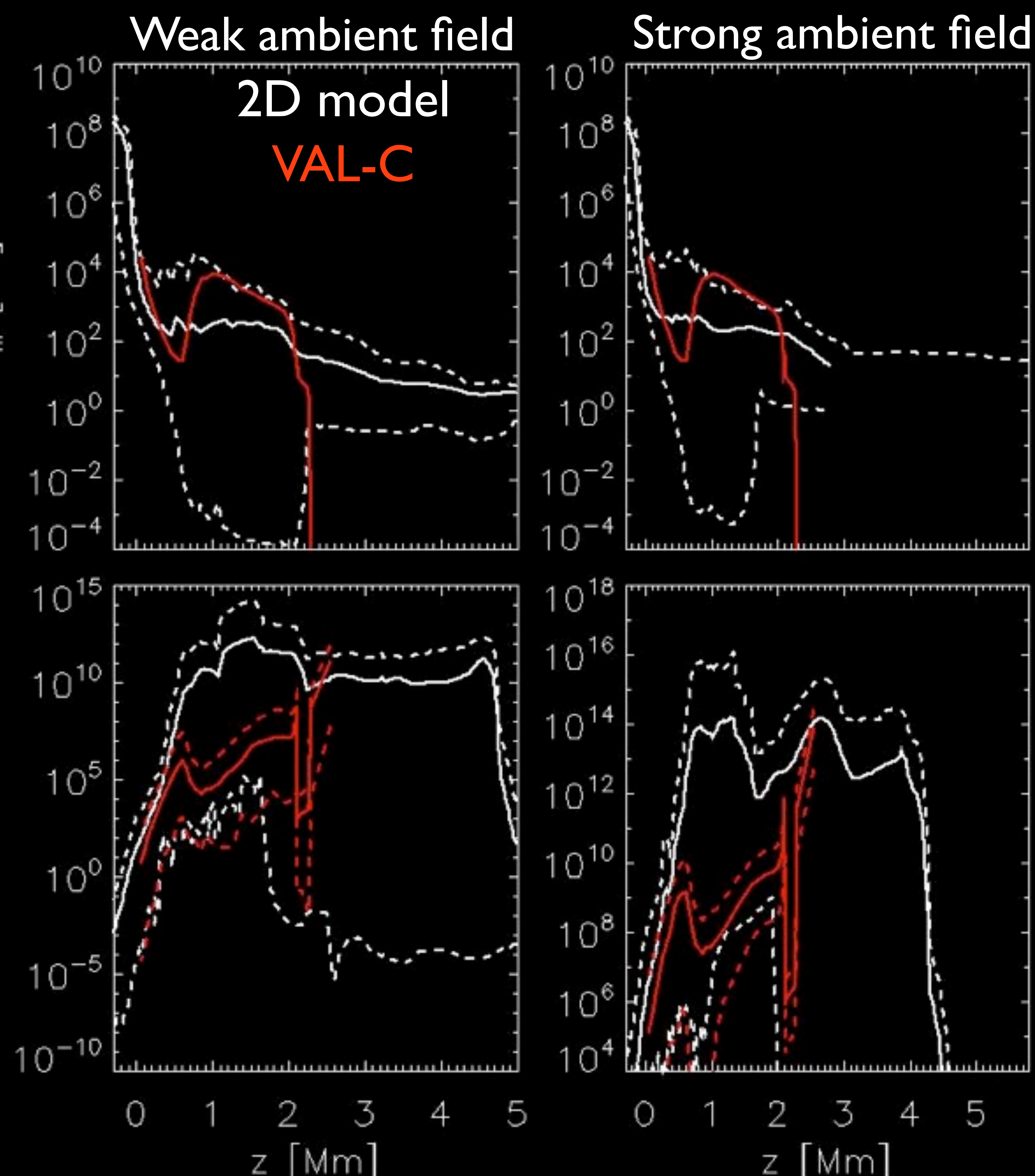
Diffusivities and collision frequencies highly dependent on equation of state: radiative losses and ionization very important



- Strong field case has Pedersen resistivity that is 3 orders of magnitude larger than weak field case.

- Strong variation with height of the ambipolar diffusivity and neutral-ion collision frequency. Very large differences with VAL-C.

Using the VAL/FAL models is not a reliable method of estimating importance in solar atmosphere of various plasma physics effects

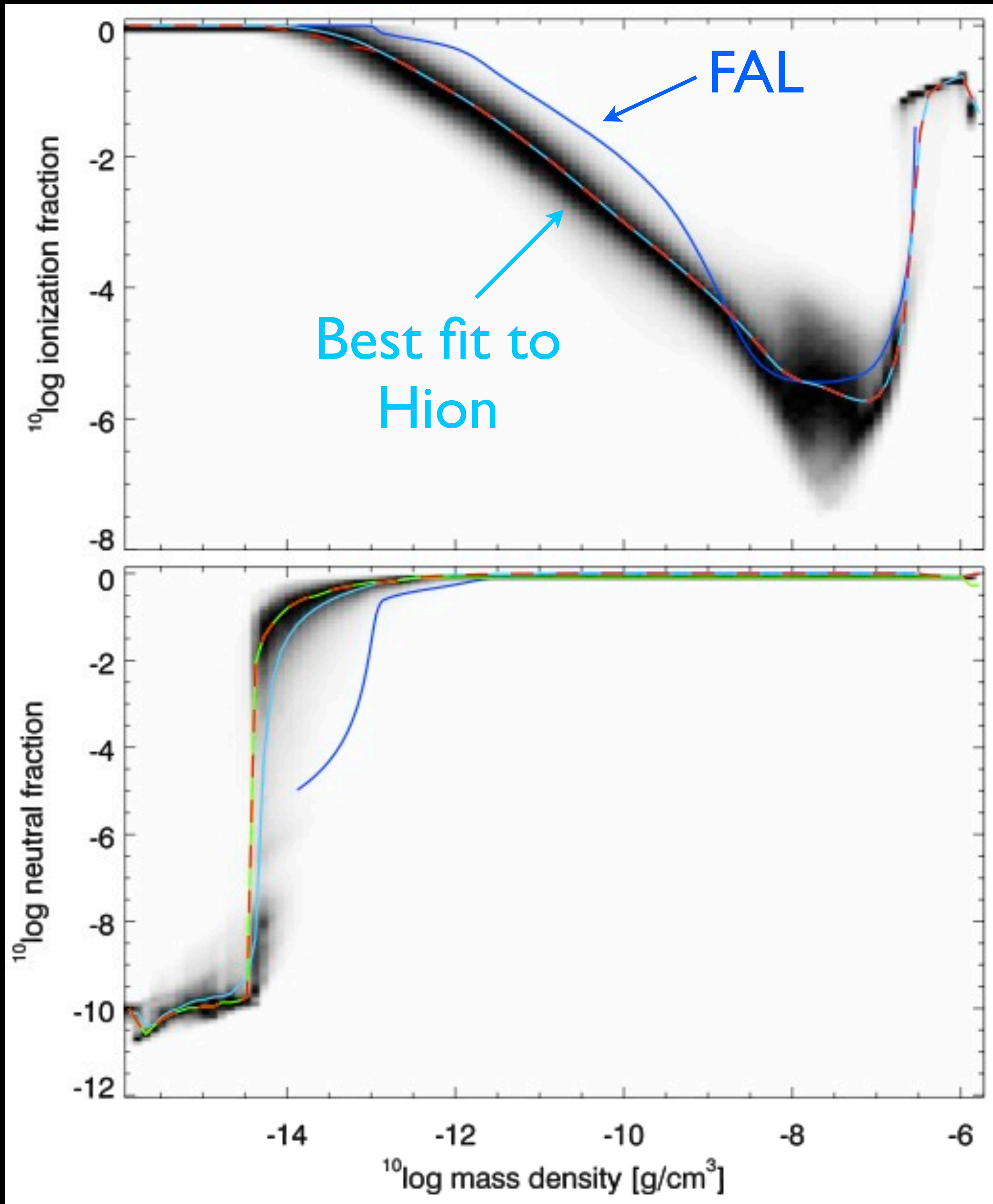


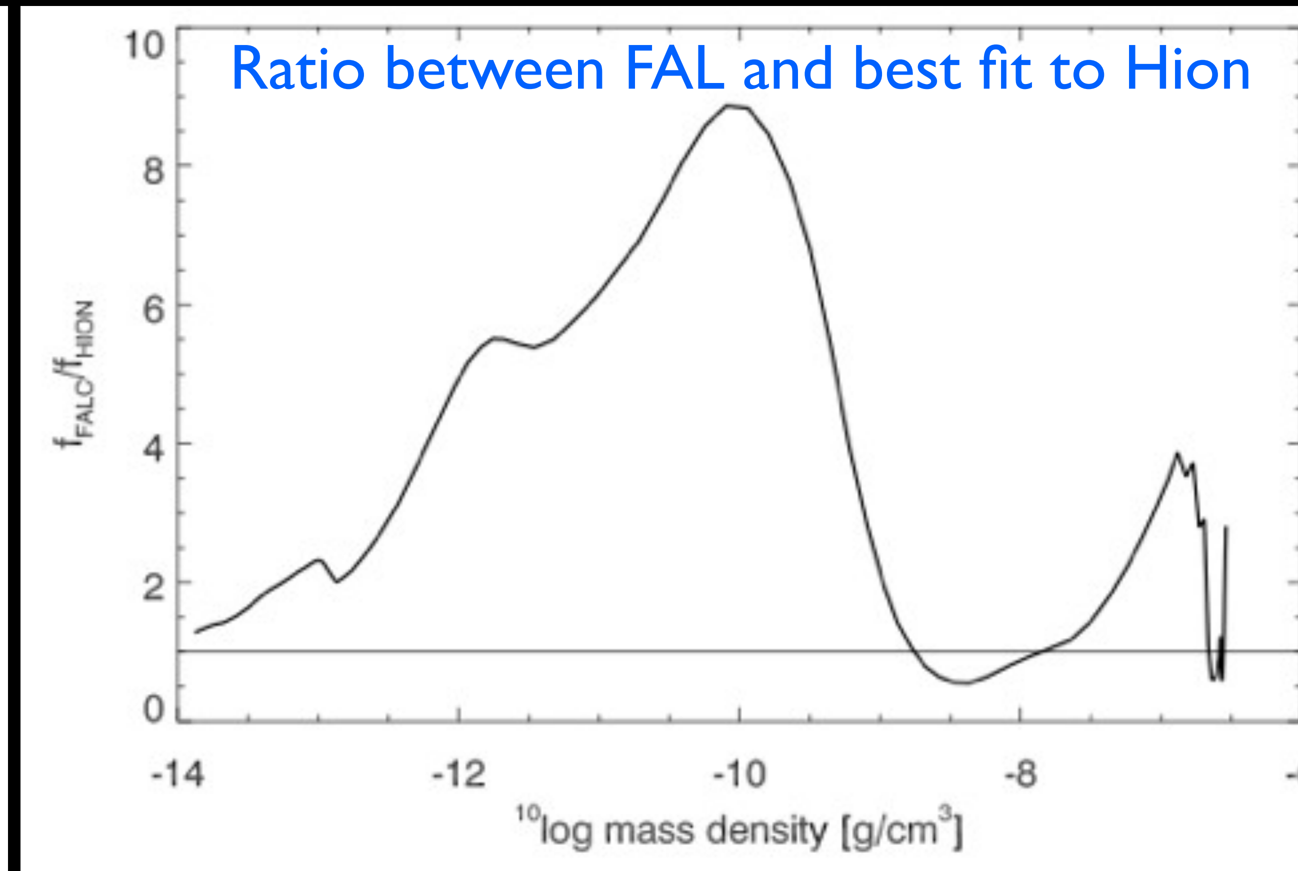
- Strong field case has Pedersen resistivity that is 3 orders of magnitude larger than weak field case.

- Strong variation with height of the ambipolar diffusivity and neutral-ion collision frequency. Very large differences with VAL-C.

- Important to note that the Pedersen resistivity and collision frequency changes several orders of magnitude at the same height in the chromosphere. Very large differences with VAL-C + magnetic field strength.

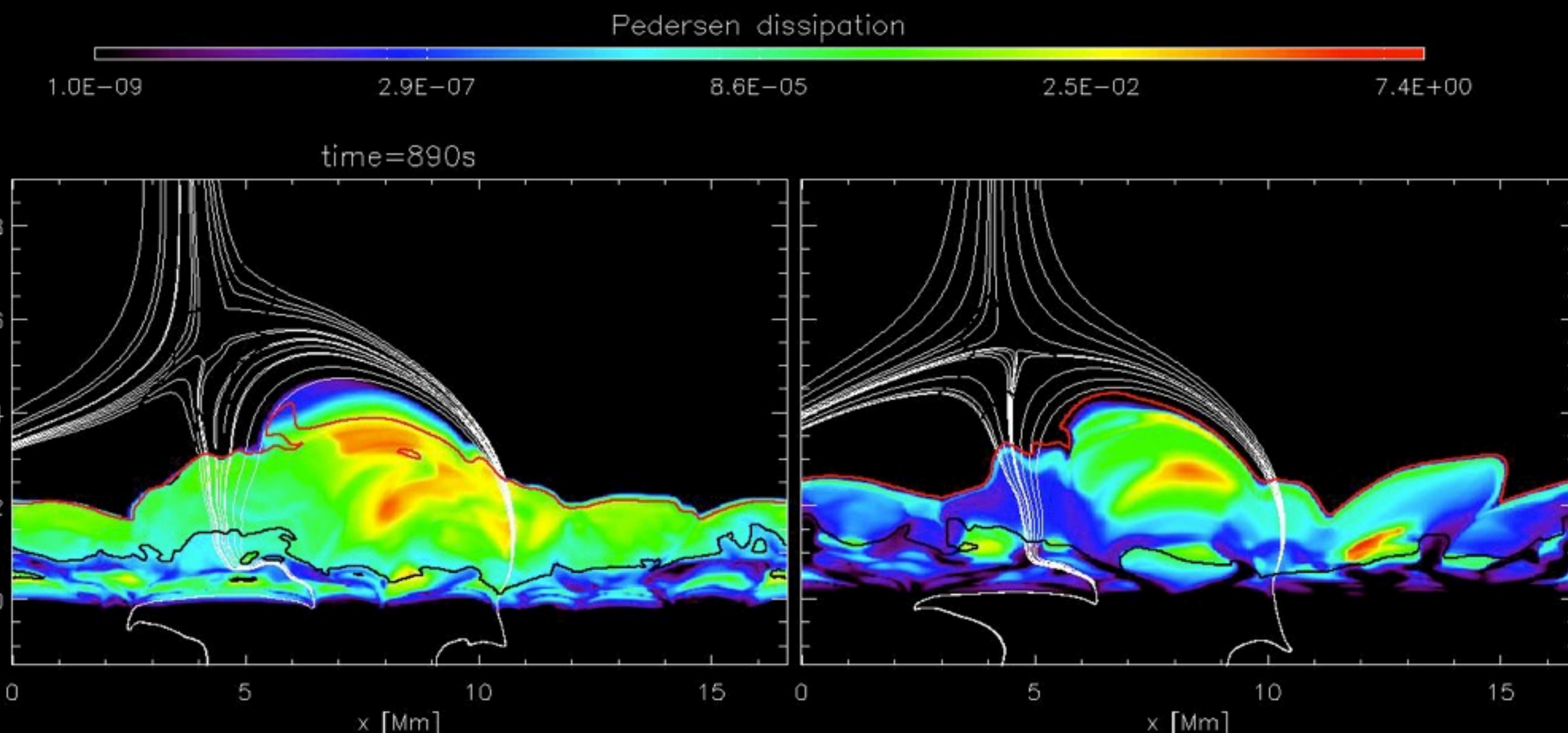
Time dependent H ionization does not remove discrepancy with VAL/FAL





Courtesy Jorrit Leenaarts

Spatial variations still show range of 4-5 orders of magnitude at any one height, even for time dependent hydrogen ionization calculations

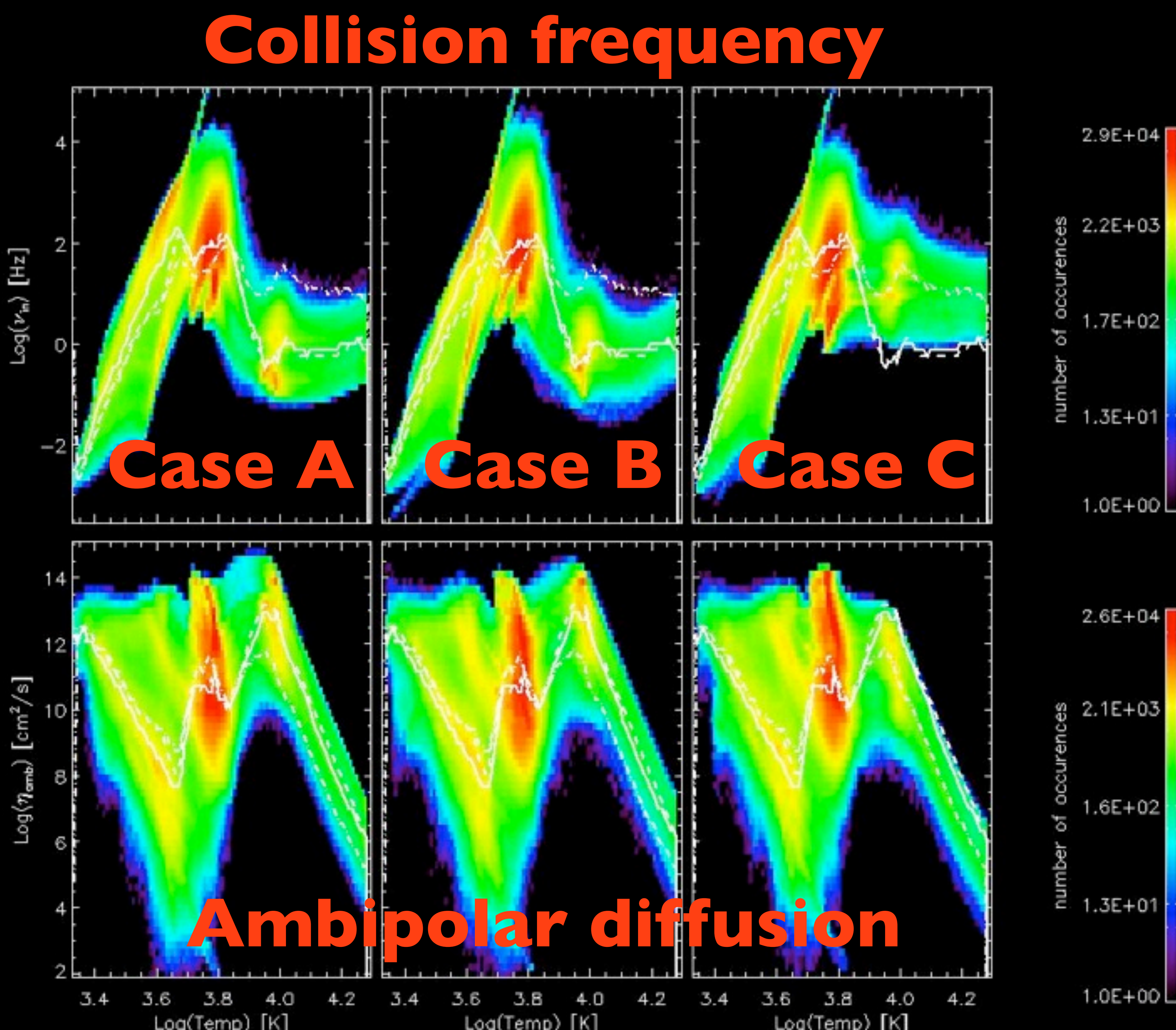


Generalized Ohm's Law
+ H ion

Generalized Ohm's Law

Do we know the atomic physics well enough?

Different formulas for collision frequencies lead to significant uncertainty in Pedersen resistivity



- We calculate the collision frequency using different methods:
- Osterbrock (1961) : case A
- Steiger & Geiss (1989): case B
- Fontenla et al.(1993): case C

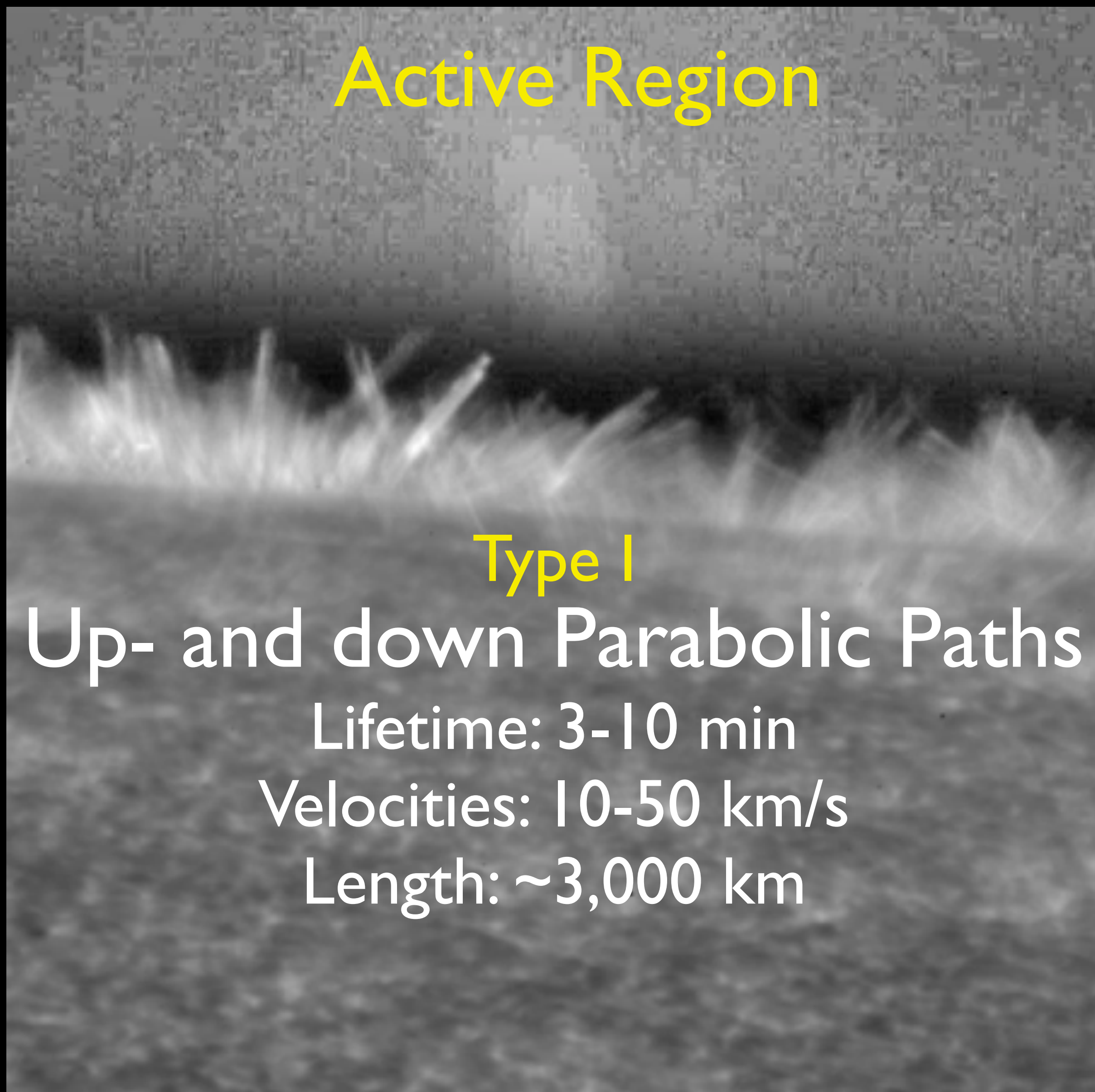
- The range of values of the collision frequency, the mean value, and the dependence with temperature differ considerably between the different methods.

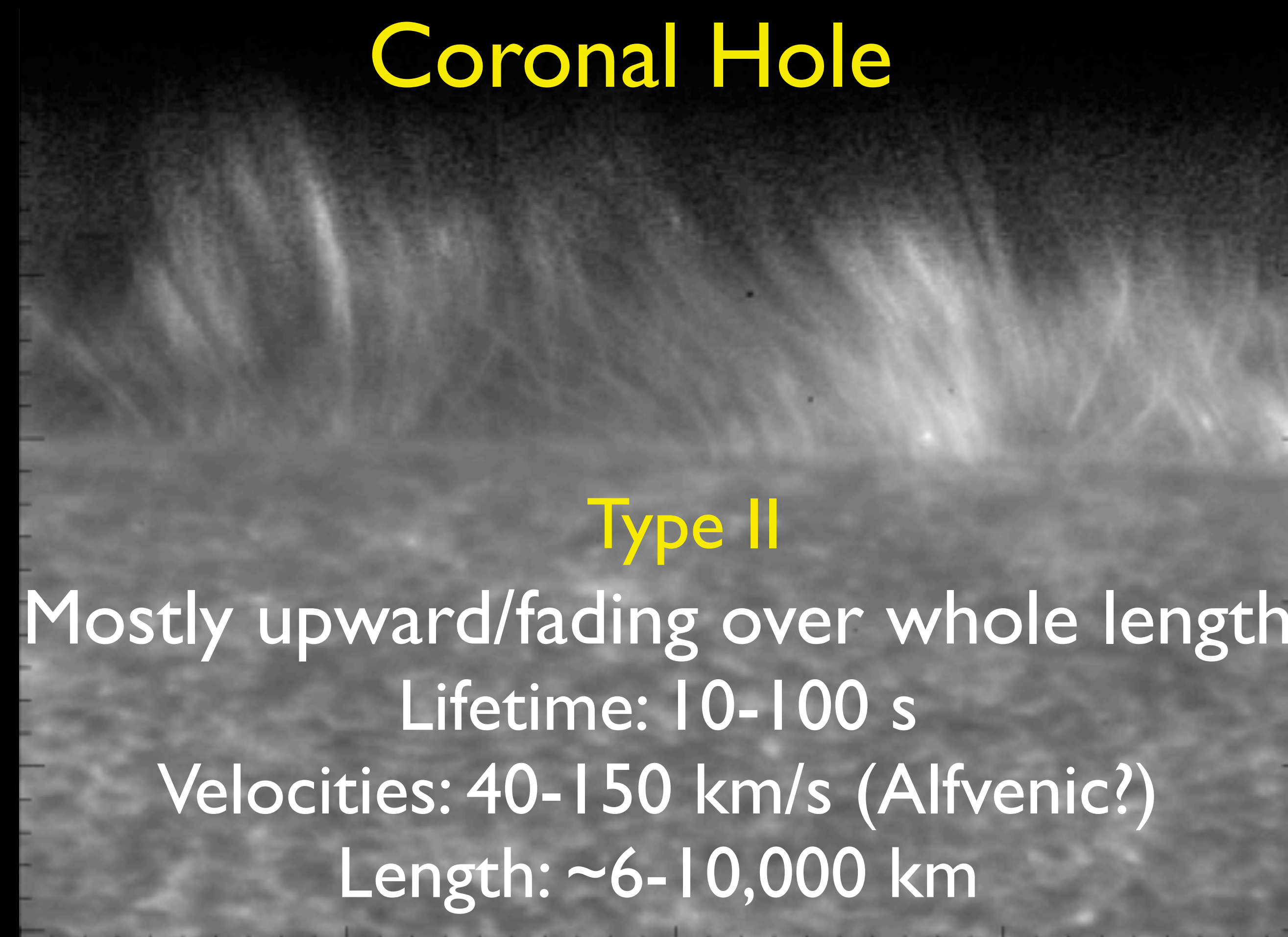
↓

The ambipolar diffusion shows a rather significant uncertainty.

- Note: The axes are in logarithmic scale.

Are there really two types of spicules?



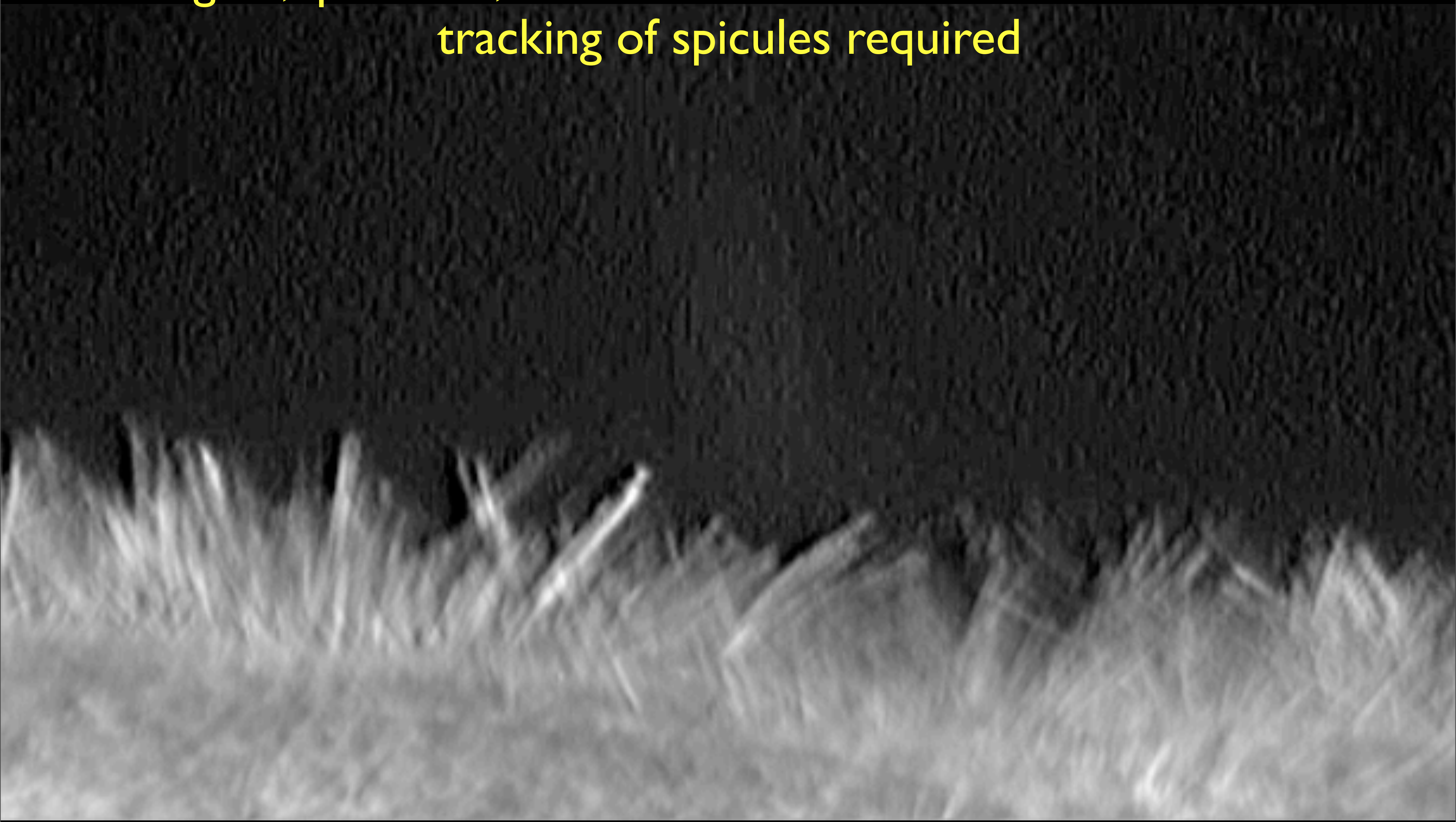


De Pontieu et al. (2007)

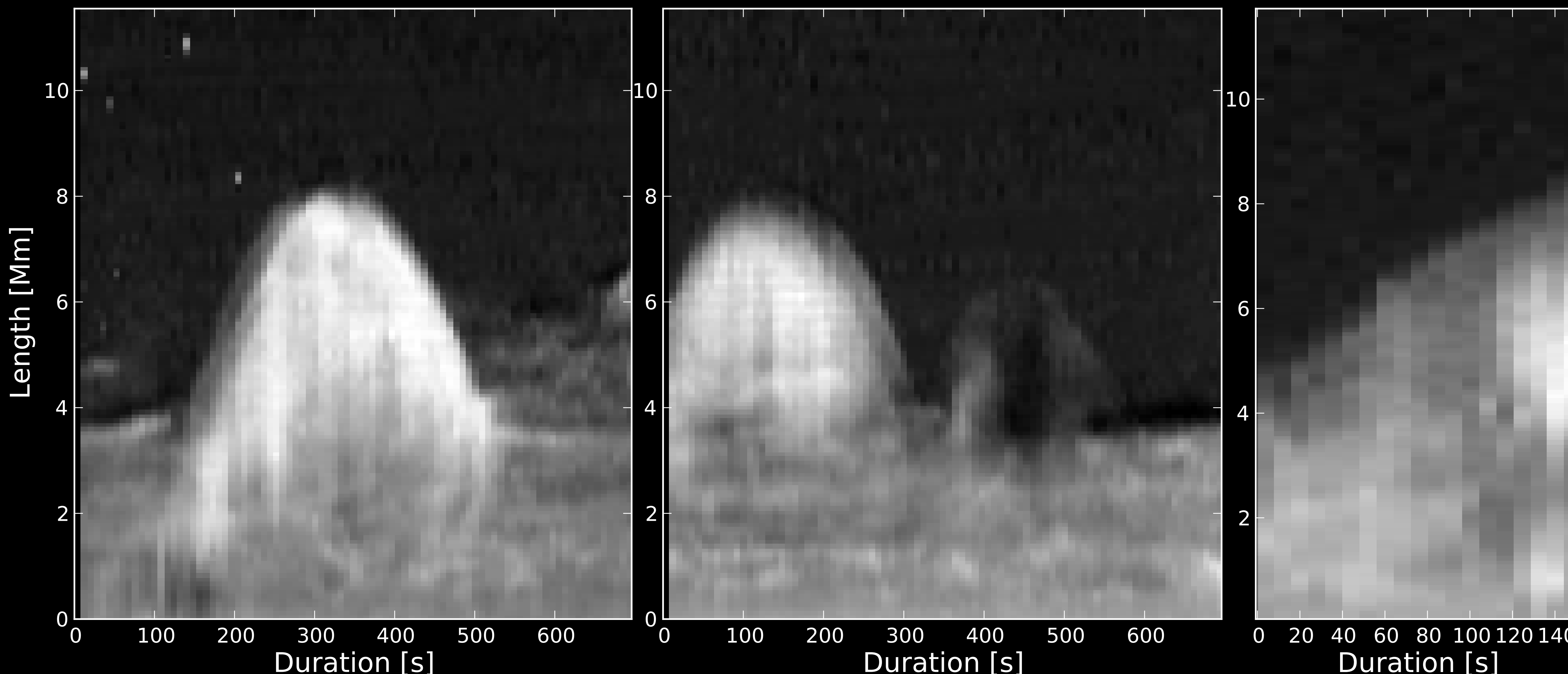
And why do we care?

- Spicule formation not understood
- Spicule properties not well constrained?
- May play significant role in energizing corona/solar wind

To provide meaningful statistical sample for active region, quiet Sun, coronal hole automated detection and tracking of spicules required

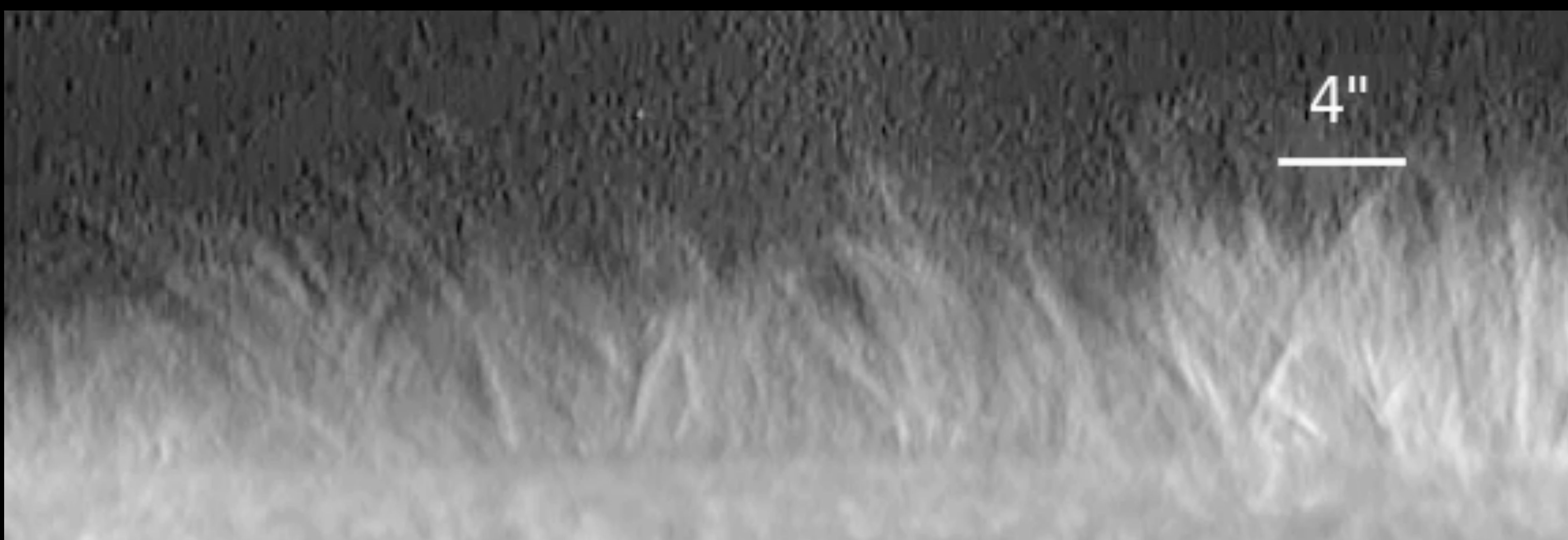


We tracked the temporal and spatial evolution of hundreds of spicules for each type of region



Pereira, De Pontieu, Carlsson, 2012

Spicules around the limb



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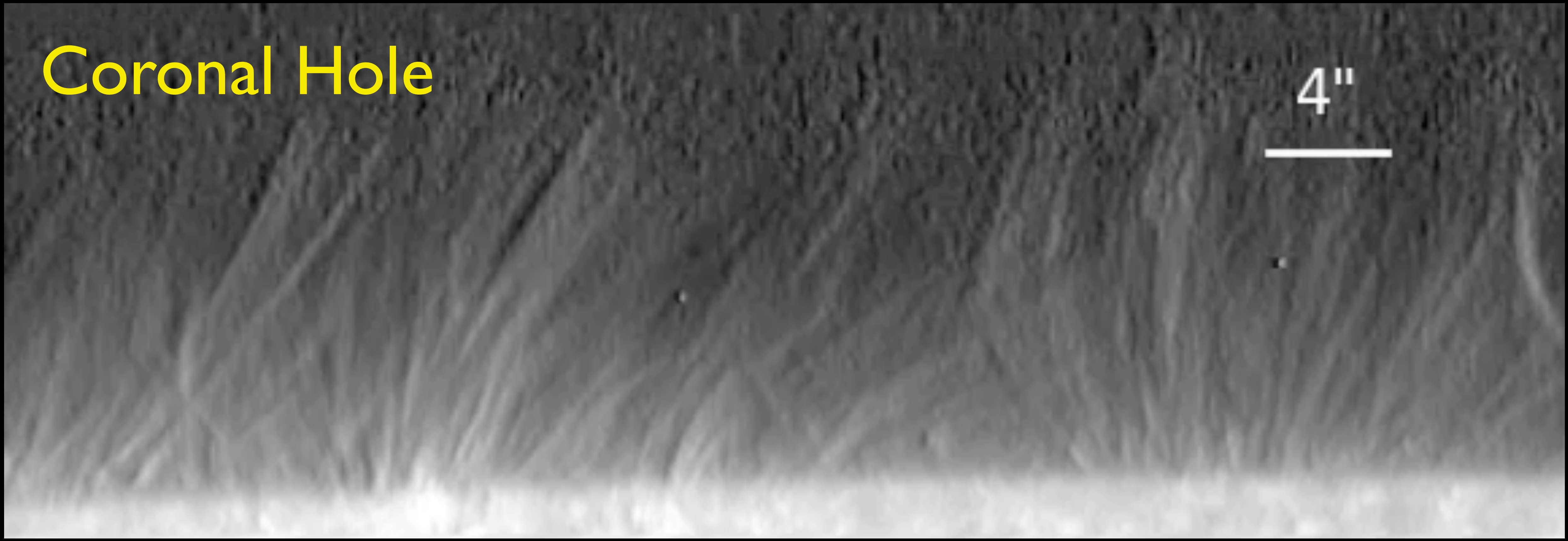

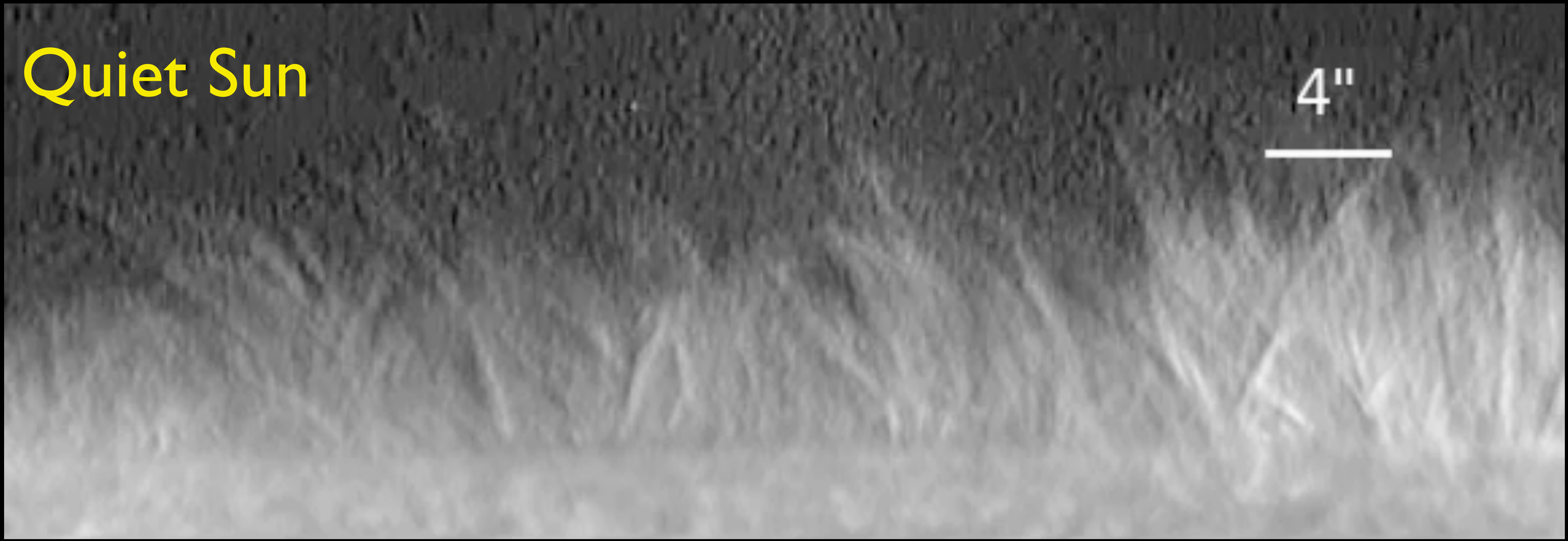

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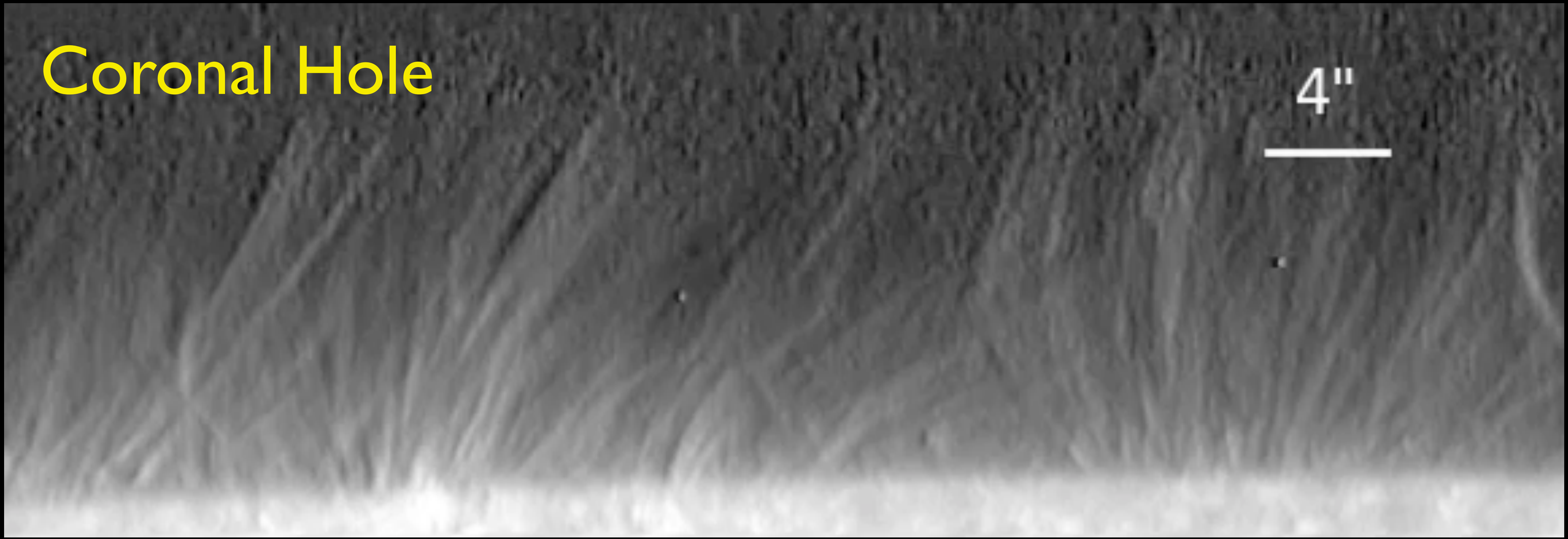

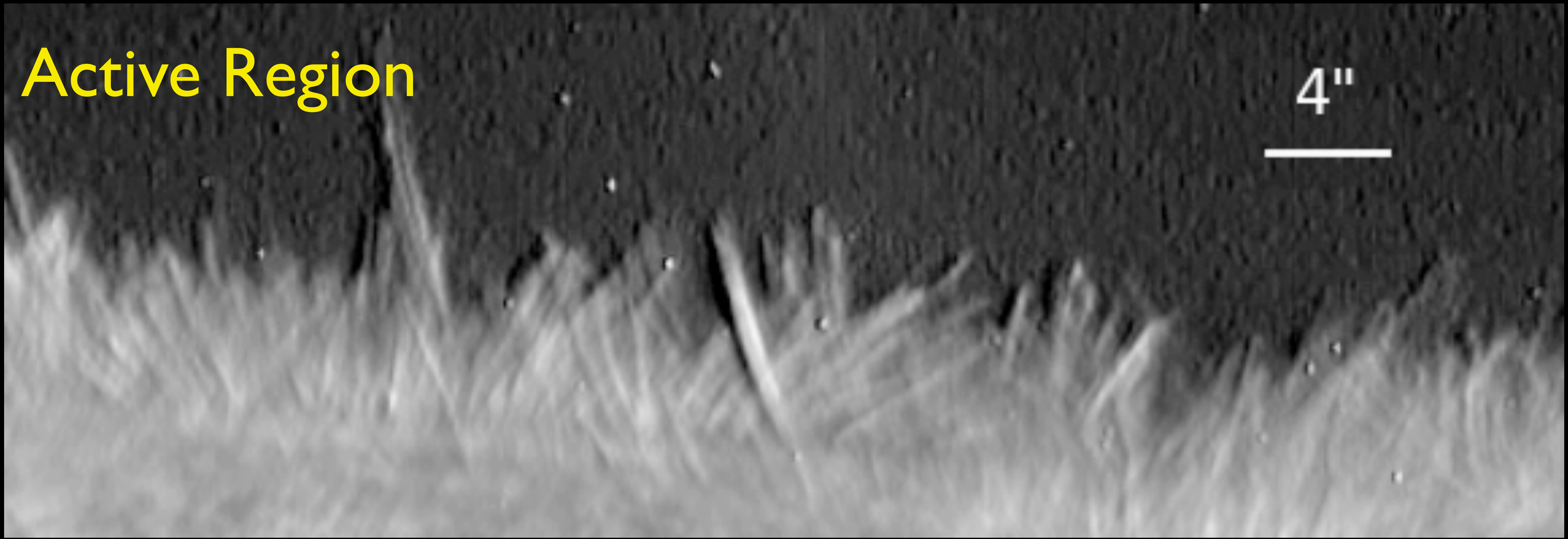

Are there two different types of spicules?

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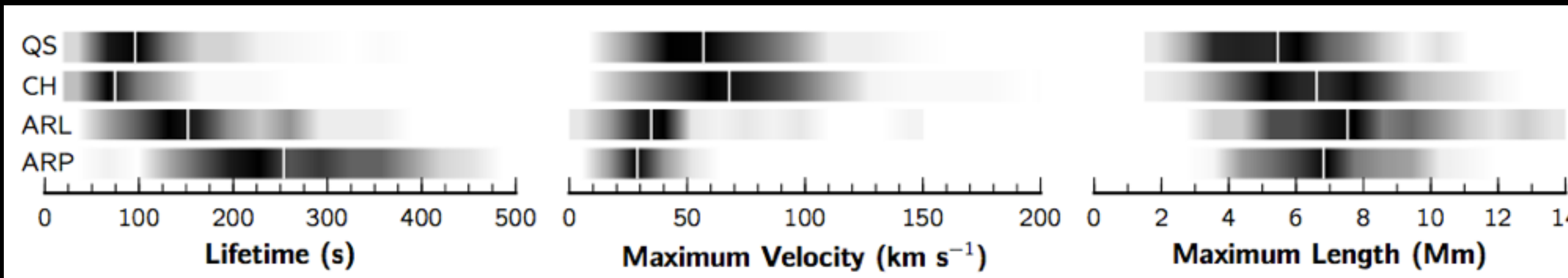

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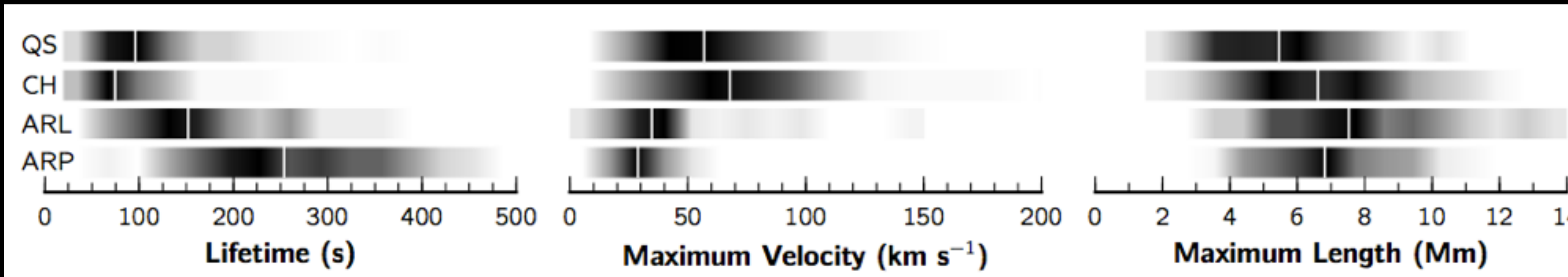

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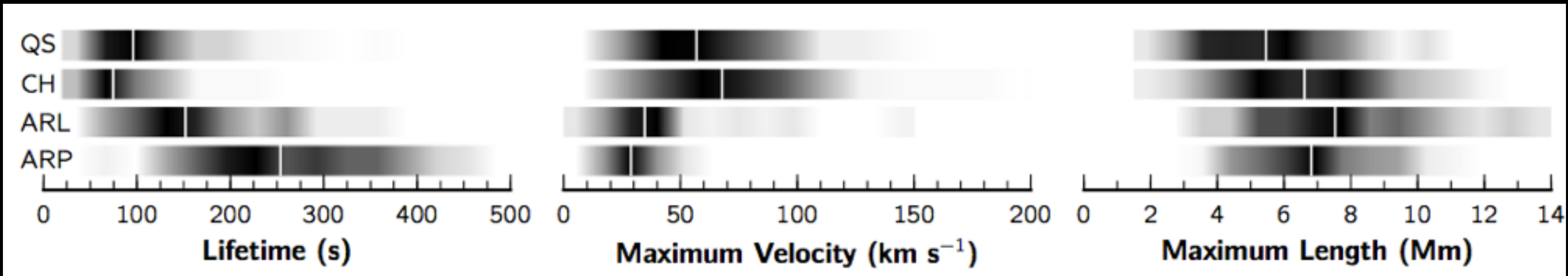

Yes.

Fast (30-100 km/s), short-lived (20-150s) type II dominate in QS, CH
Slower (10-50 km/s), long-lived (100-500s) type I dominate in AR

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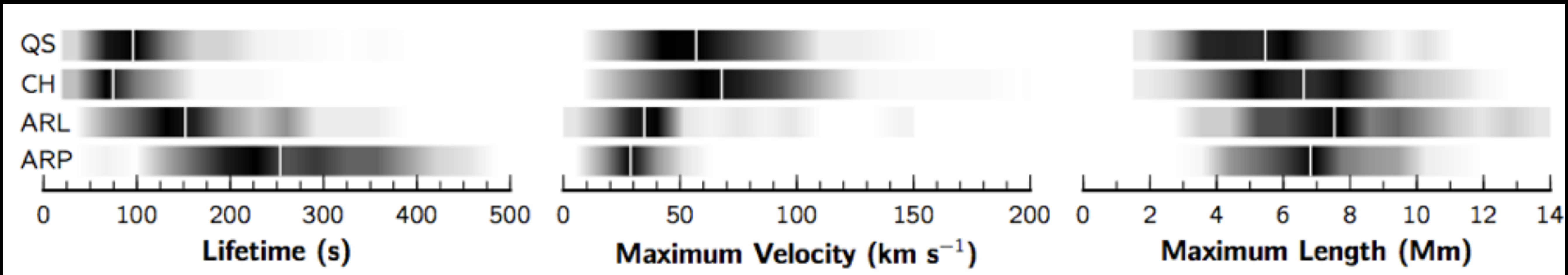

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What are classical spicules (20-30 km/s, 5-10 min)?

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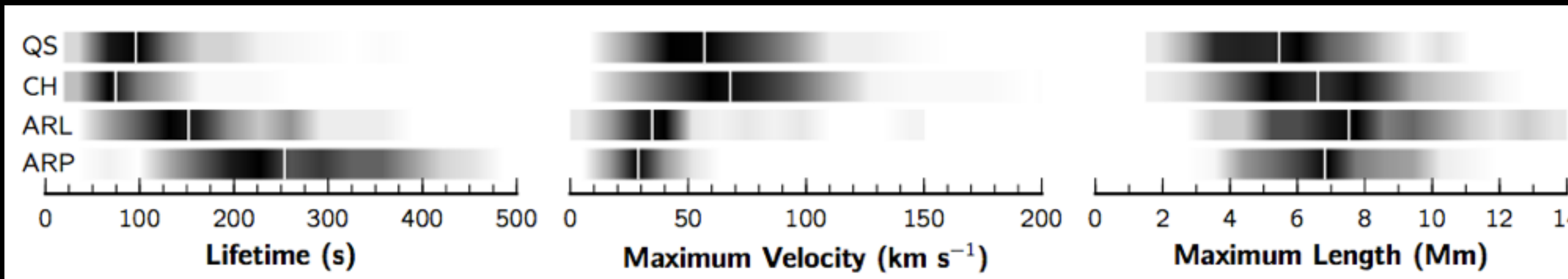

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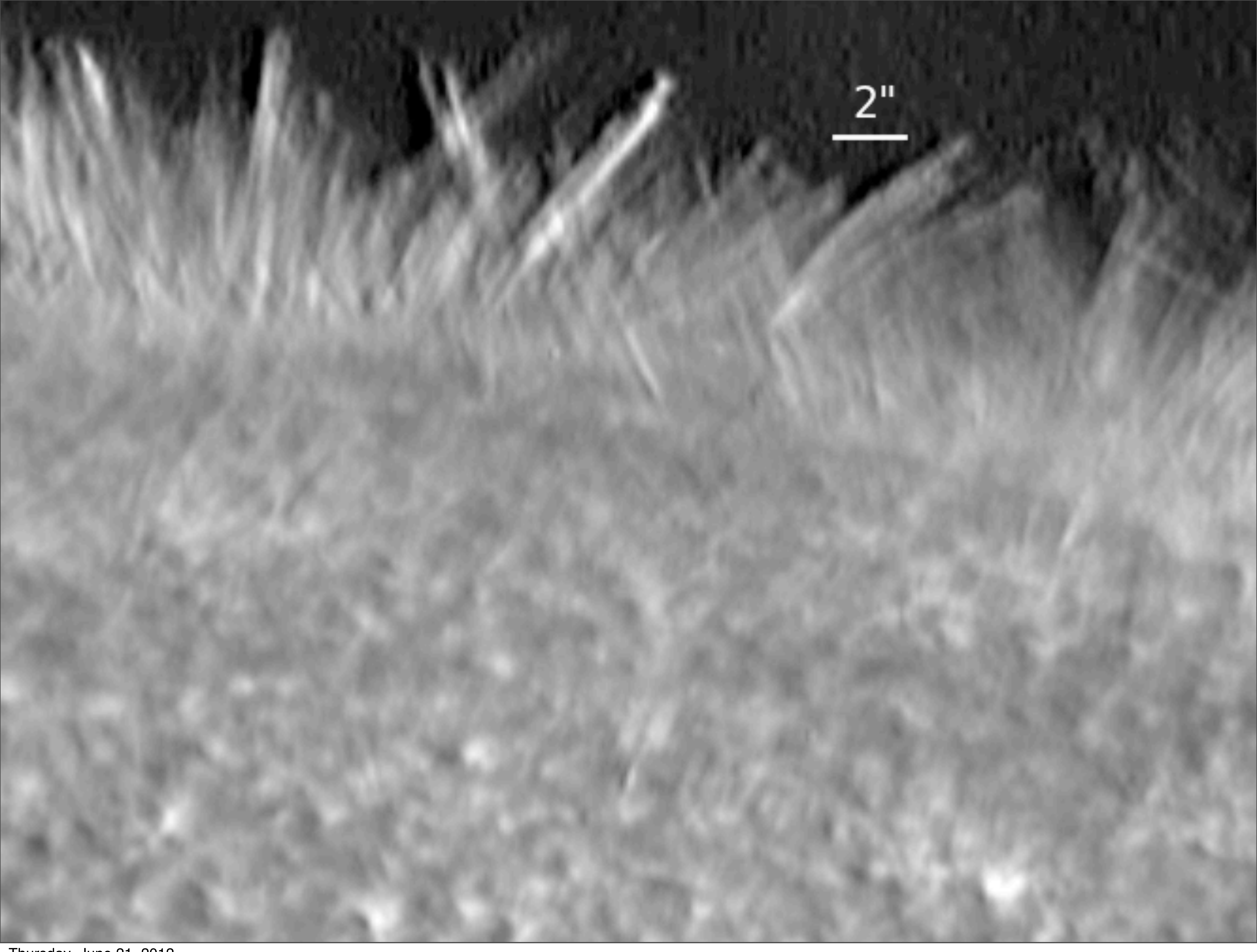
Artefact of (poor) spatio-temporal resolution
(Pereira, De Pontieu, Carlsson, 2012)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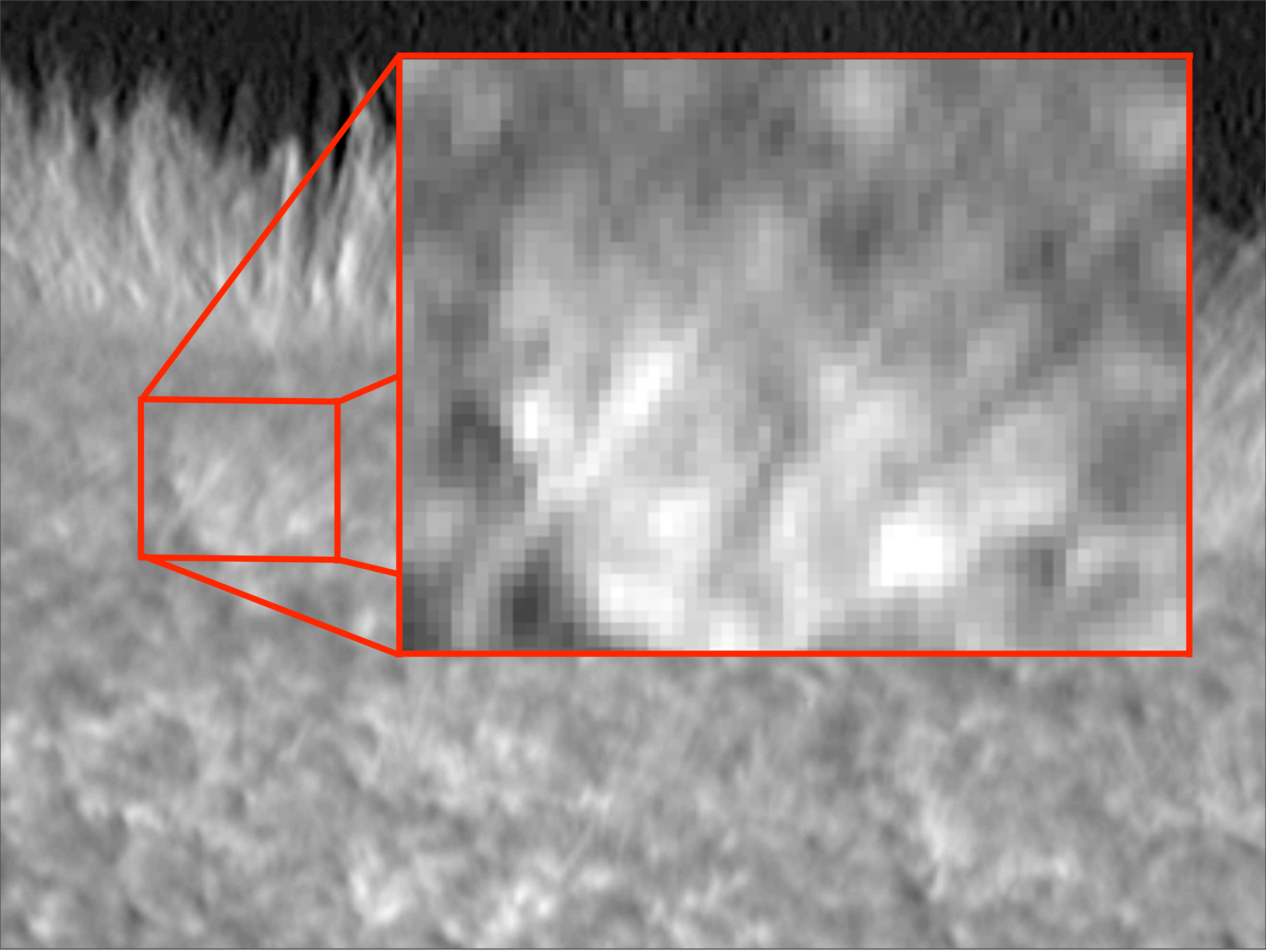
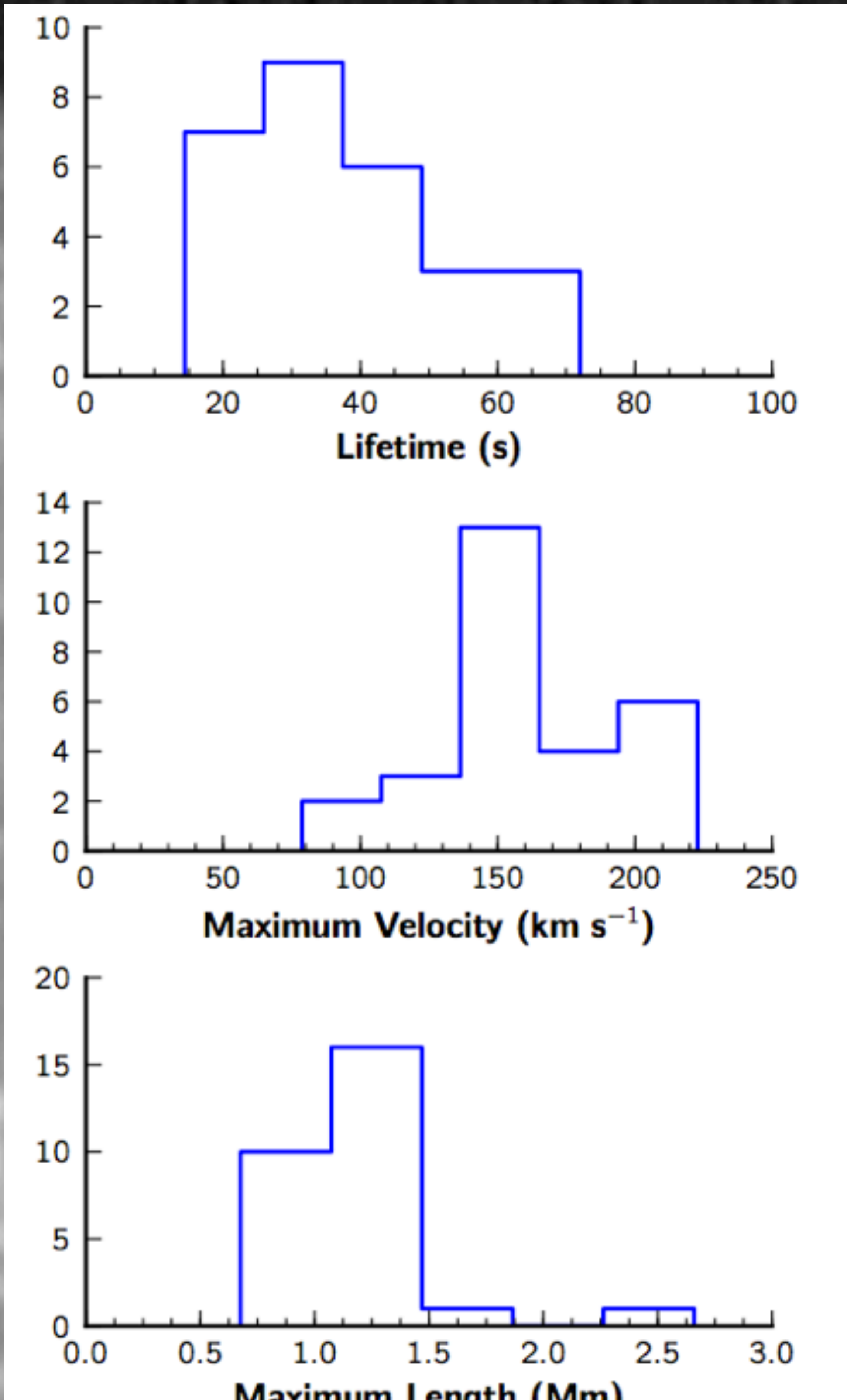
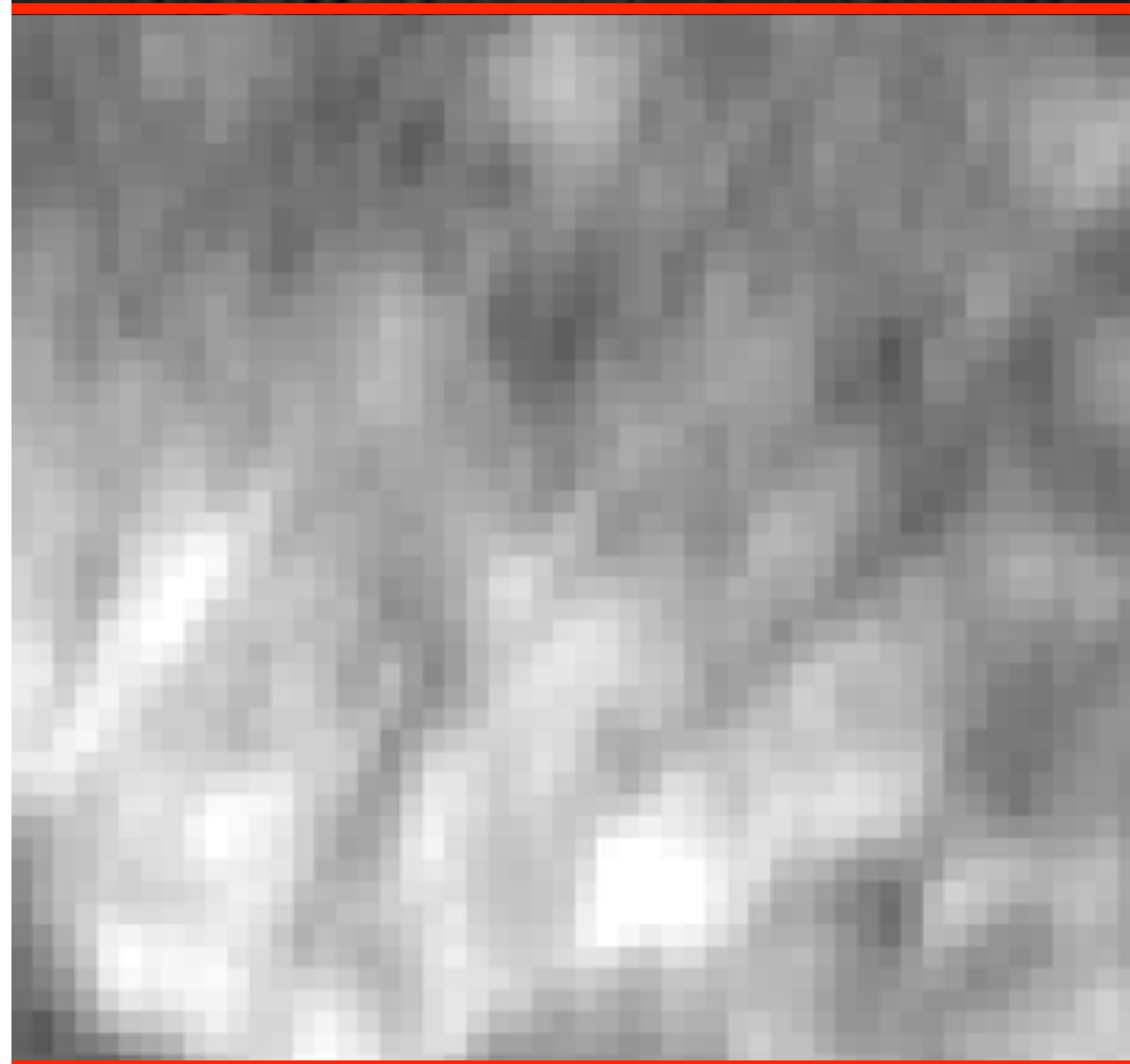




10
8
6
4
2
0
0
20
40
60
80
100
Lifetime (s)
14
12
10
8
6
4
2
0
0
50
100
150
200
250
Maximum Velocity (km s^{-1})
20
15
10
5
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Maximum Length (Mm)



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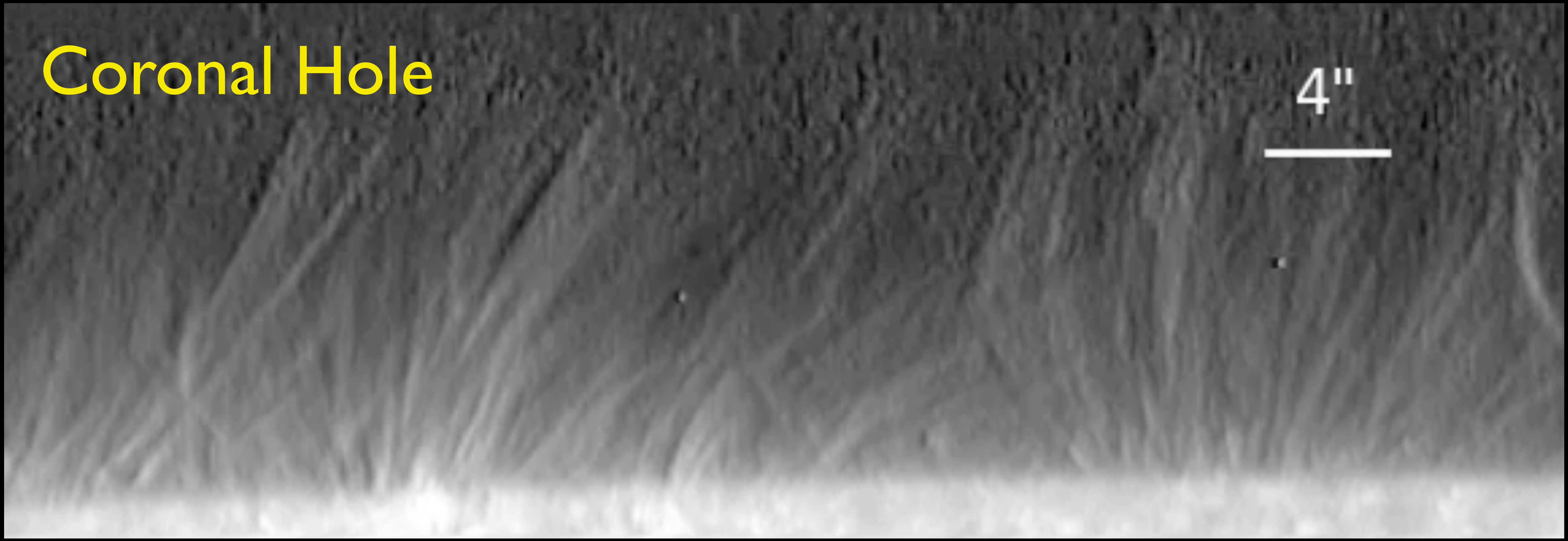
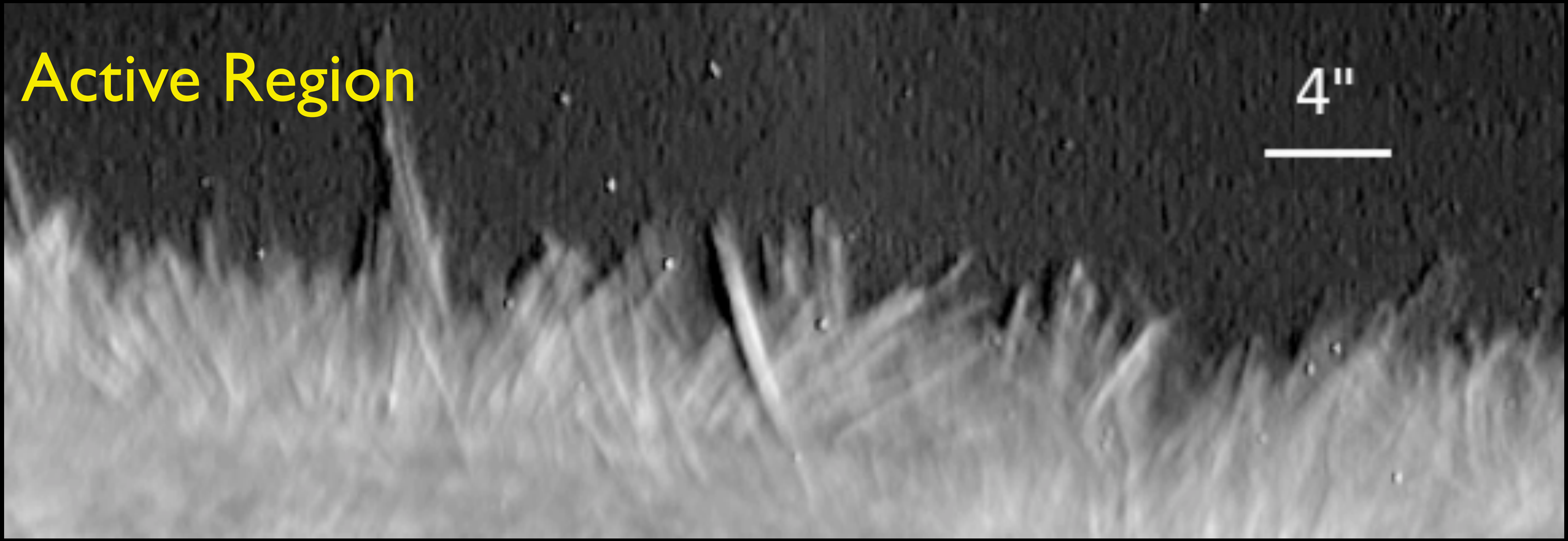
Addressing Zhang et al. (2012)





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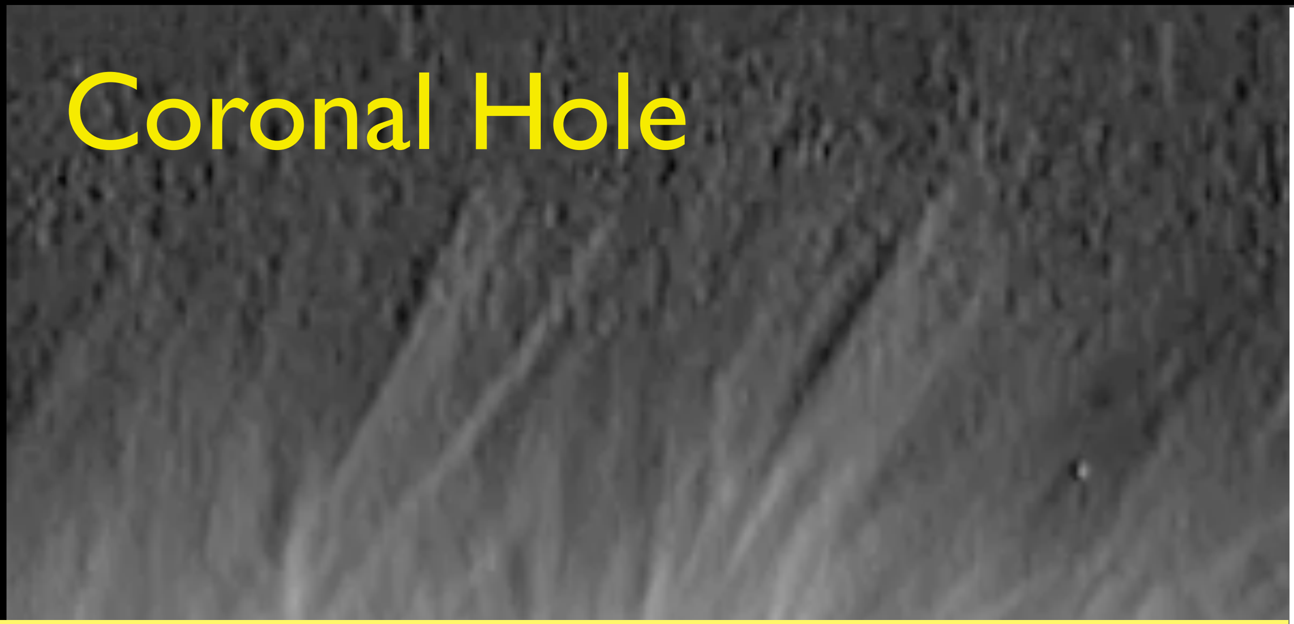
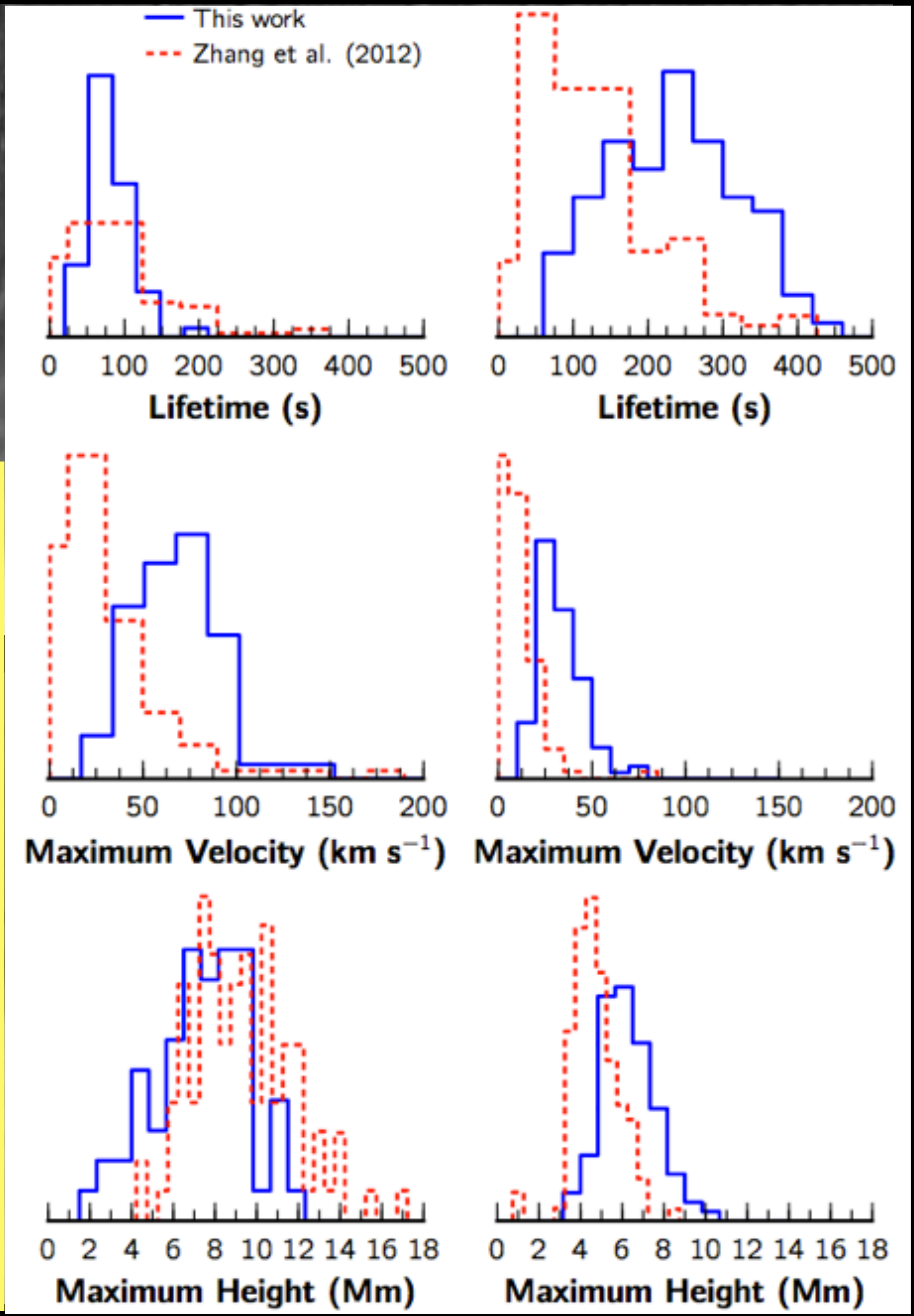
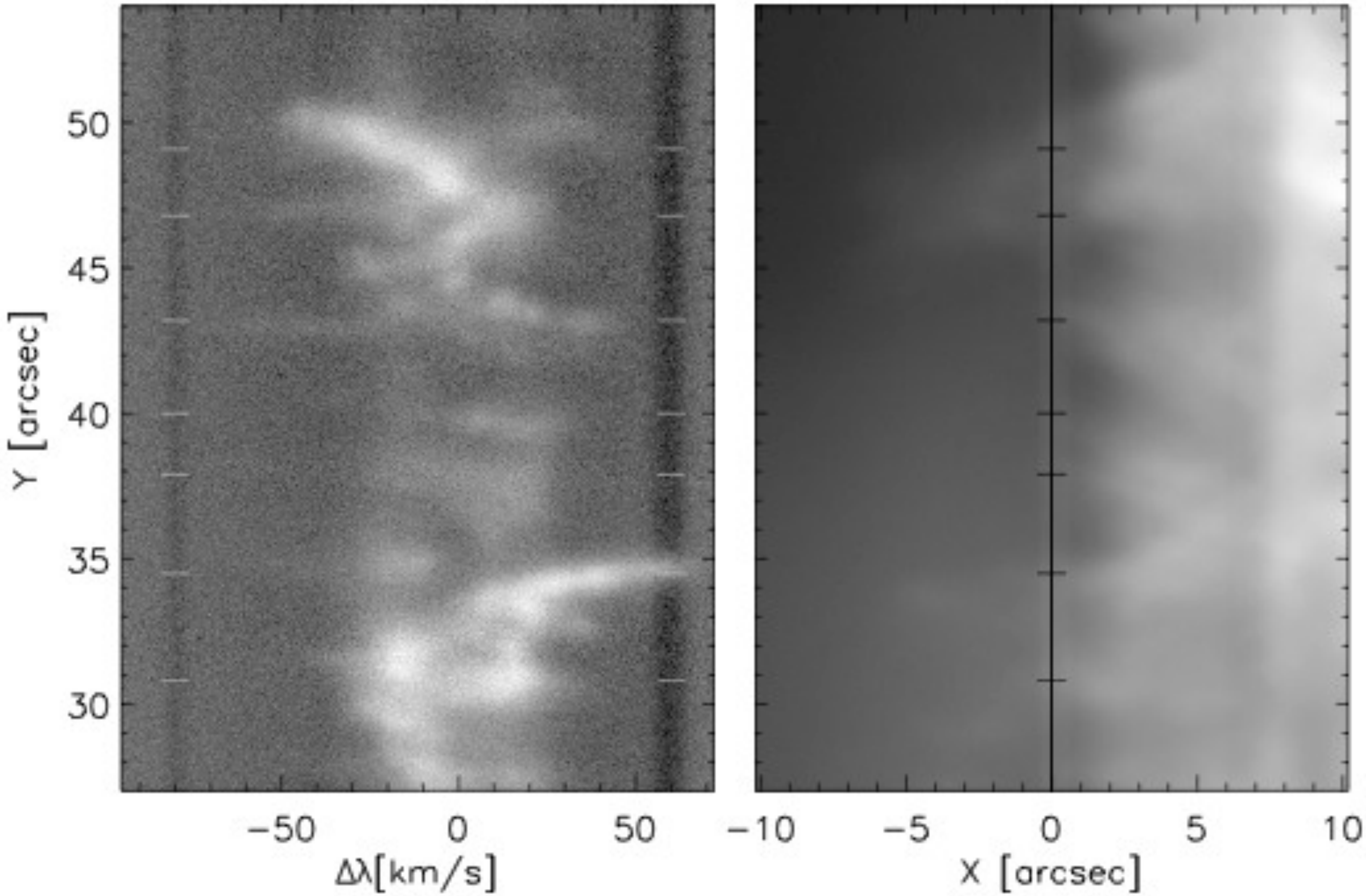


- Z12 and we analyzed identical datasets
- Z12 mislabeled AR dataset as QS
- Z12 claim they see up- and down behavior in CH, visual inspection shows only upward motion, as does our automated tracking
- Z12 claim type II's do not exist because "artefact from not tracking transverse motion", but we do find type II's by tracking transverse motion
- Z12's median lifetime x median maximum velocity does not equal median maximum height...
- Z12 result suspect, maybe caused by not tracking spicules?



Are there torsional motions (Alfven waves) on spicules?



De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

Spicules dominated by three motions: LOS projection of field-aligned upflows, swaying motions and torsional motions

Inclined spectra in spicules indicate red/blueshift pattern across spicule compatible with strong torsional motion of 20-30 km/s

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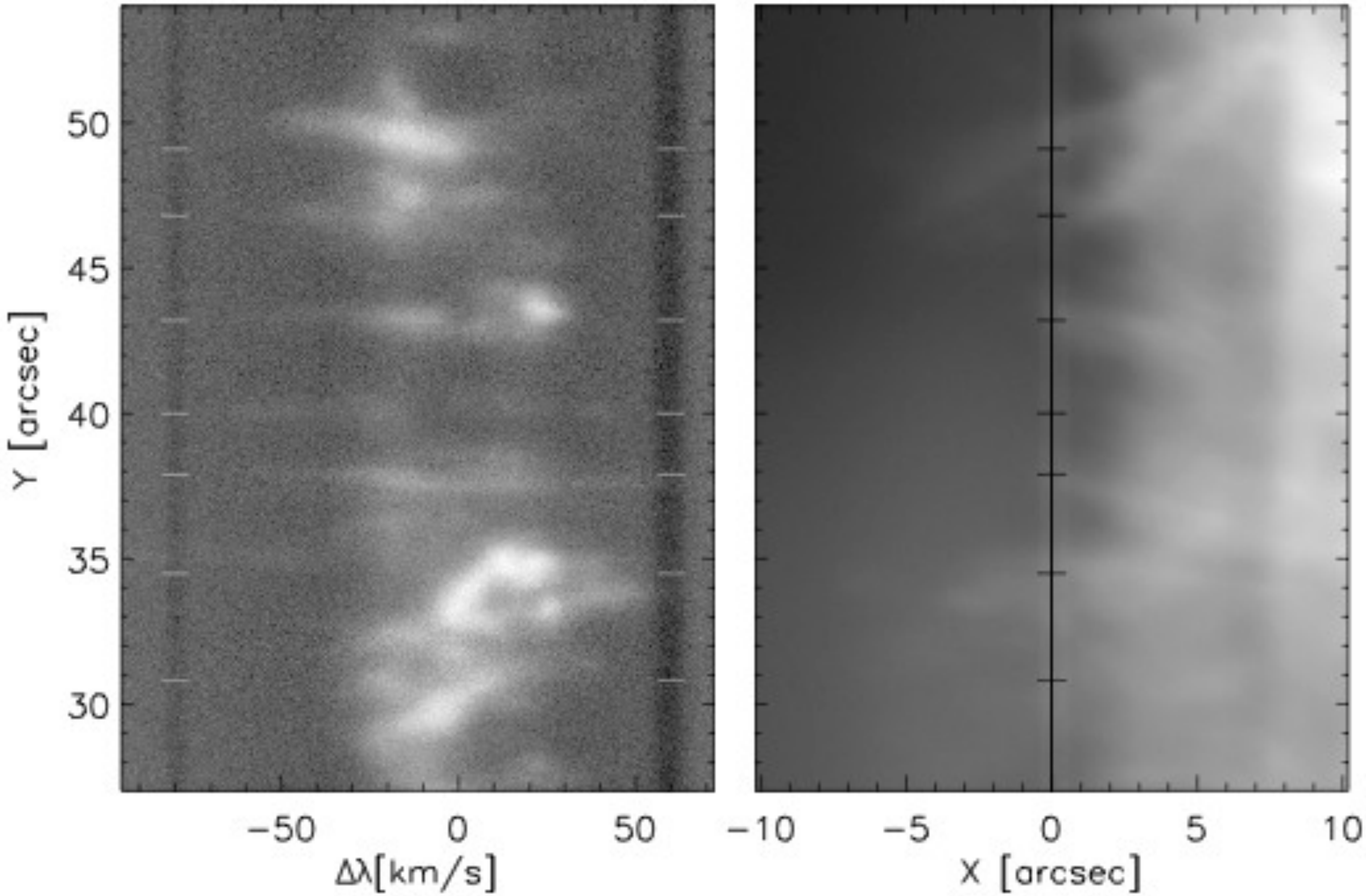

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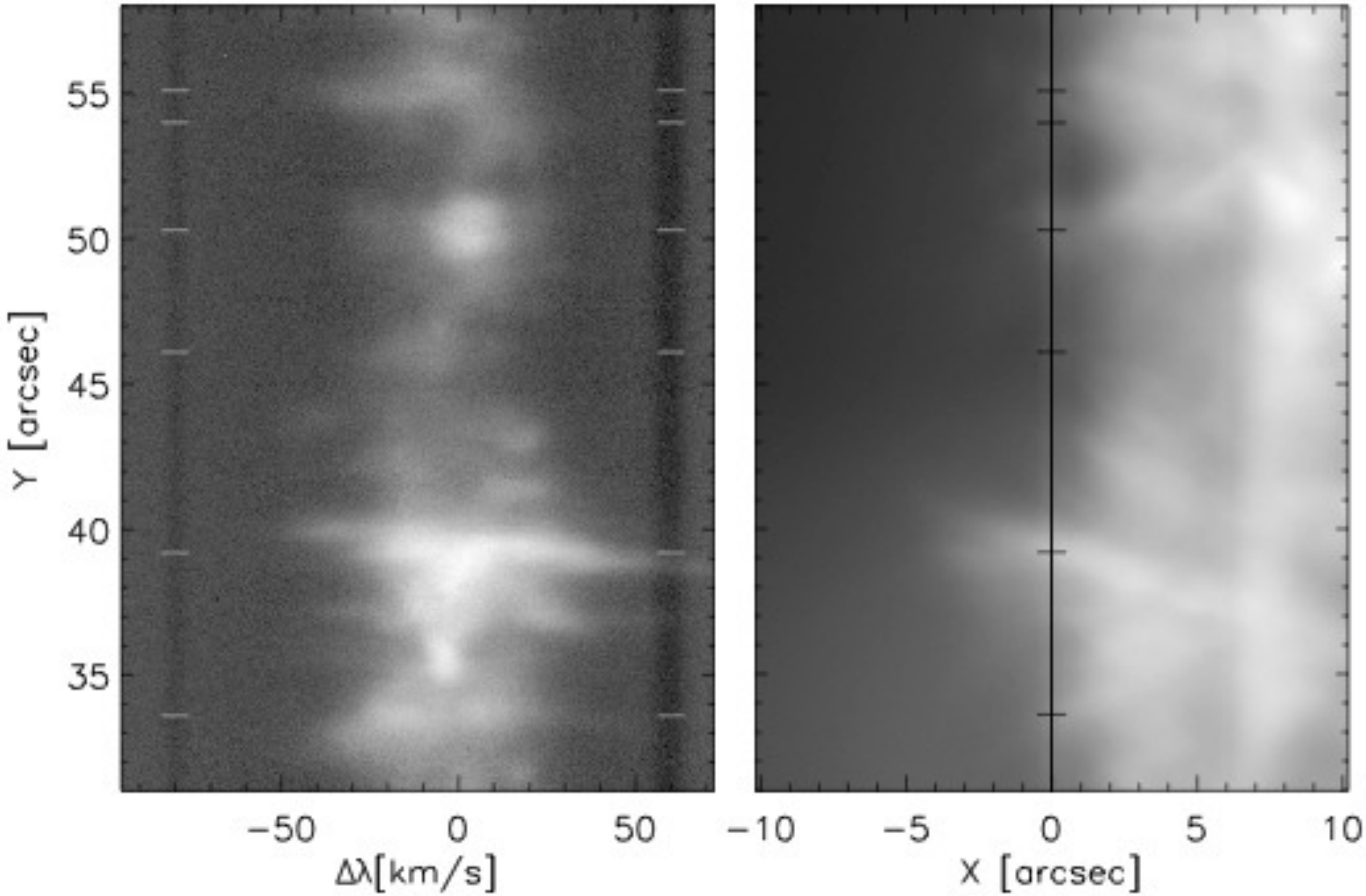

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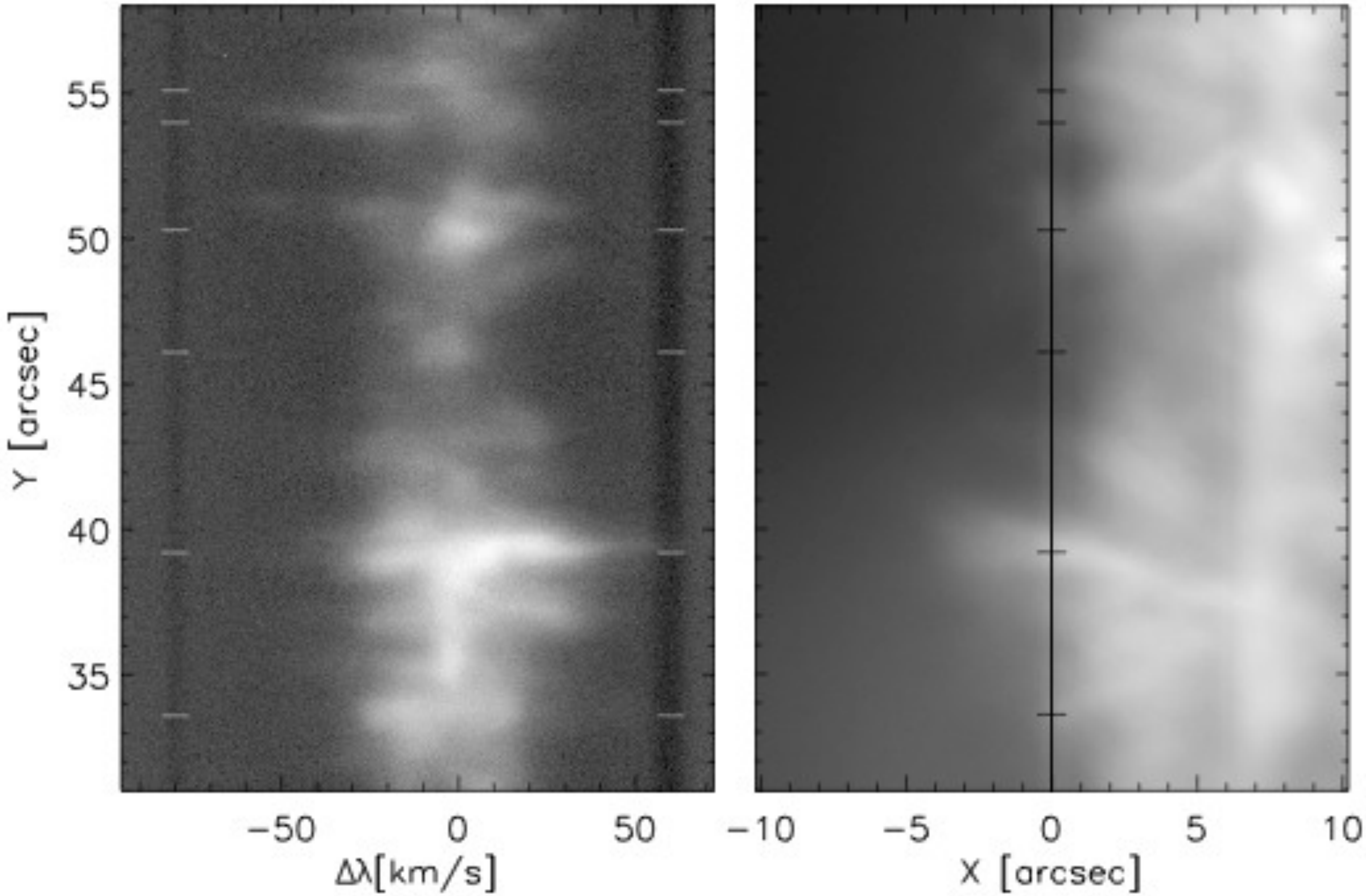

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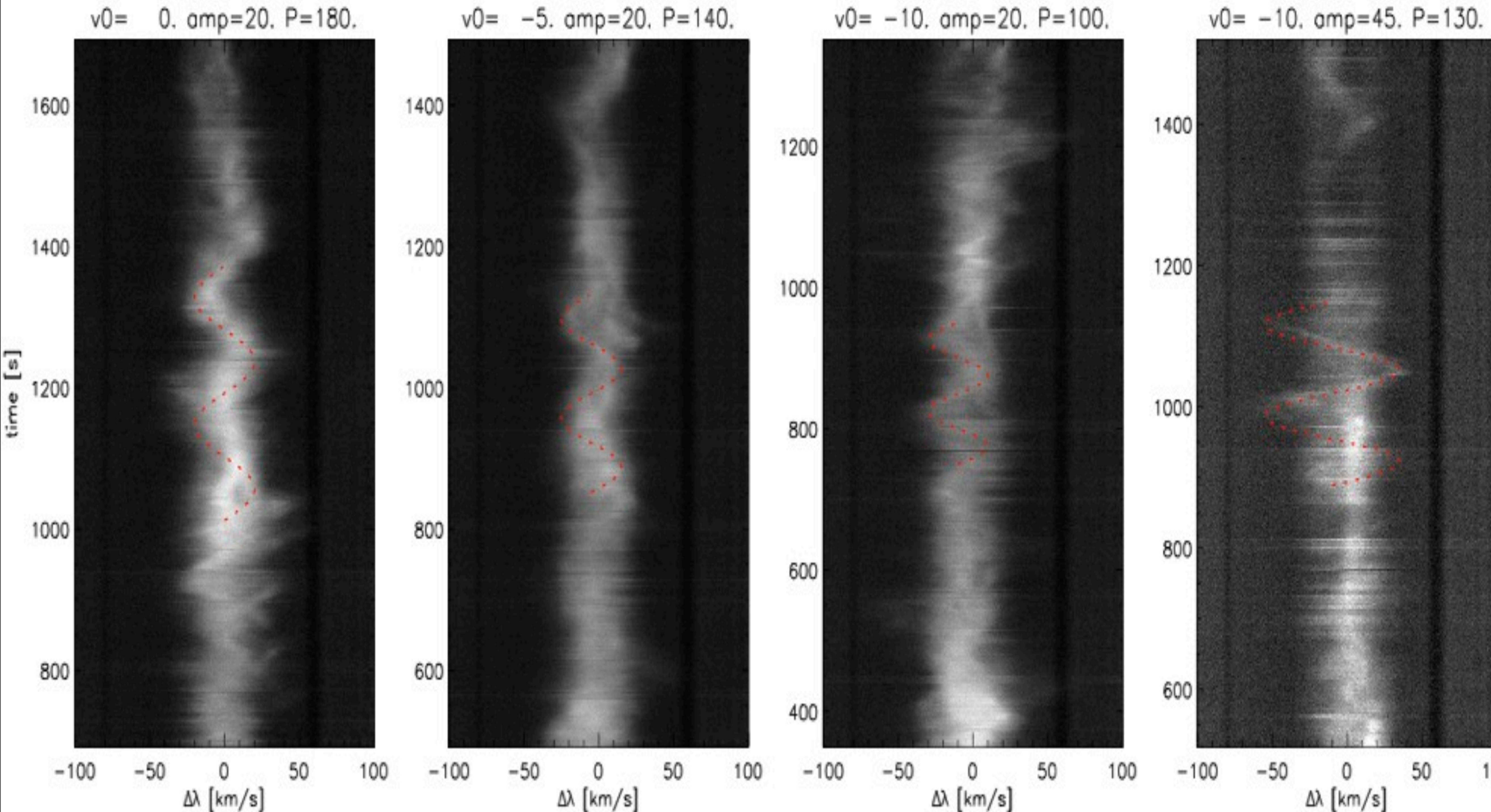
Inclined spectra in spicules indicate red/blueshift pattern across spicule compatible with strong torsional motion of 20-30 km/s

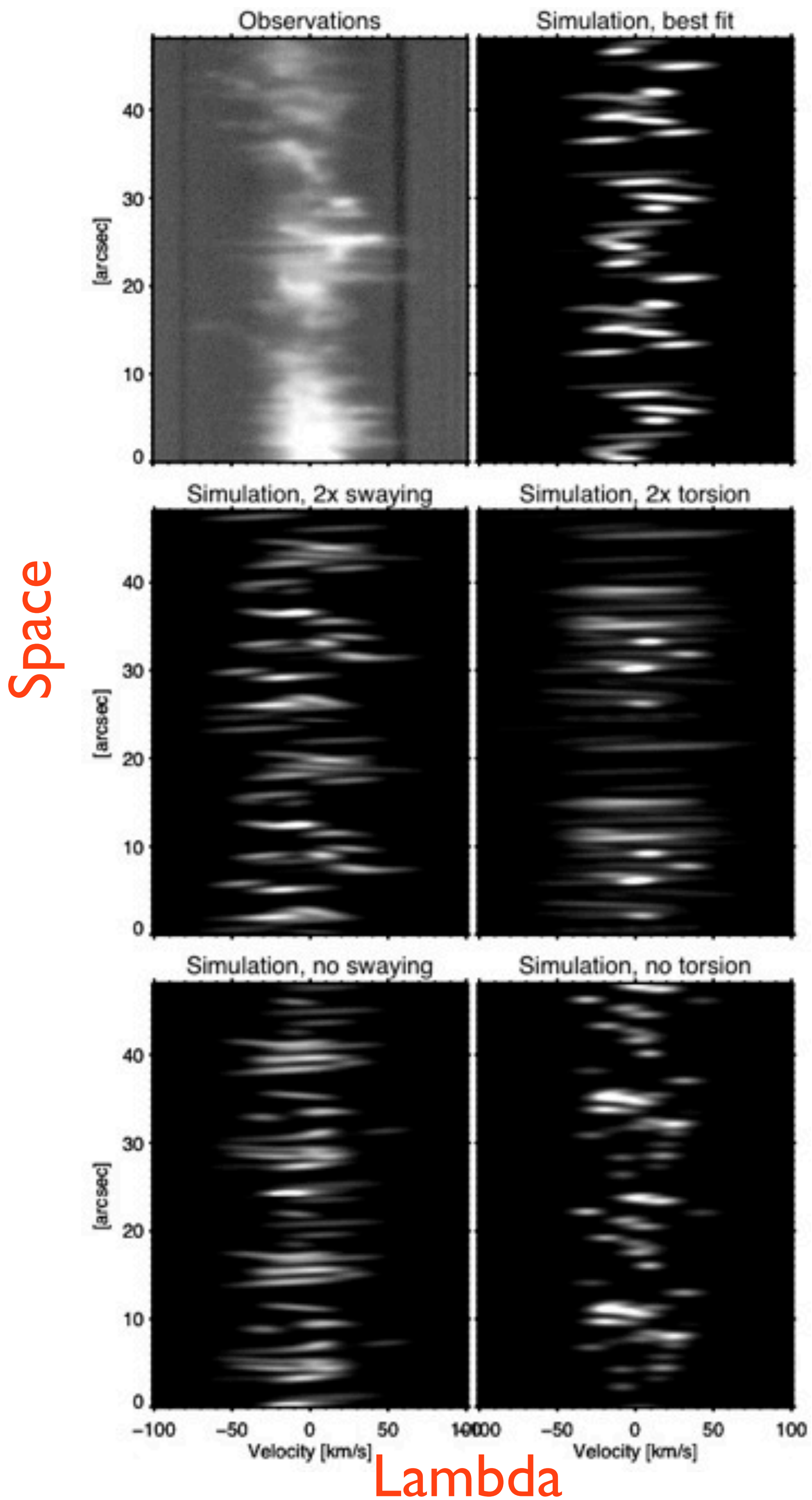
Torsional motions are time-dependent on ~min timescale



De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

Lambda-time plots in one location show lots of wiggles from time-dependent swaying and torsional motions

Monte Carlo simulations constrain parameters well



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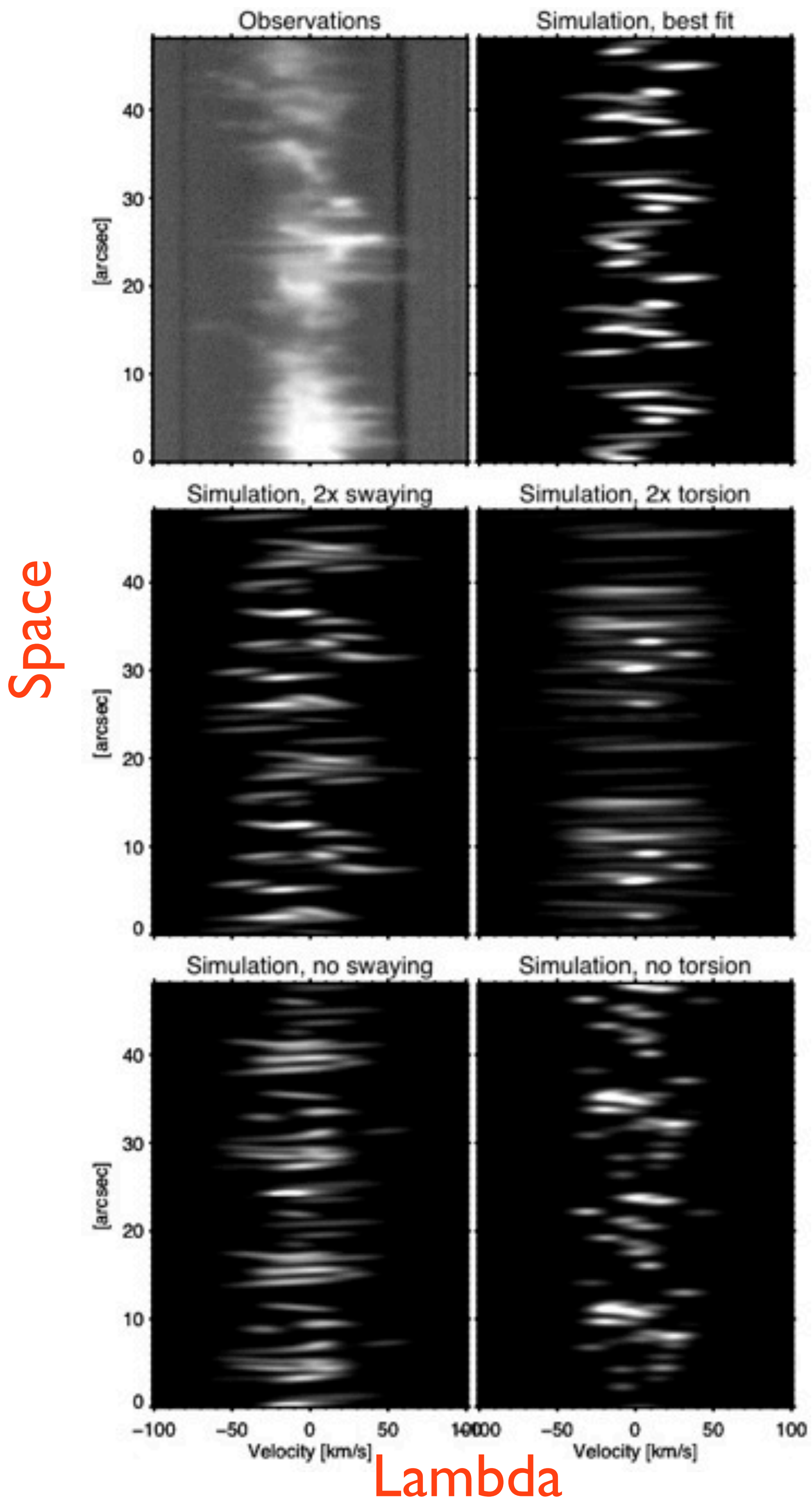

Assume N spicules with:

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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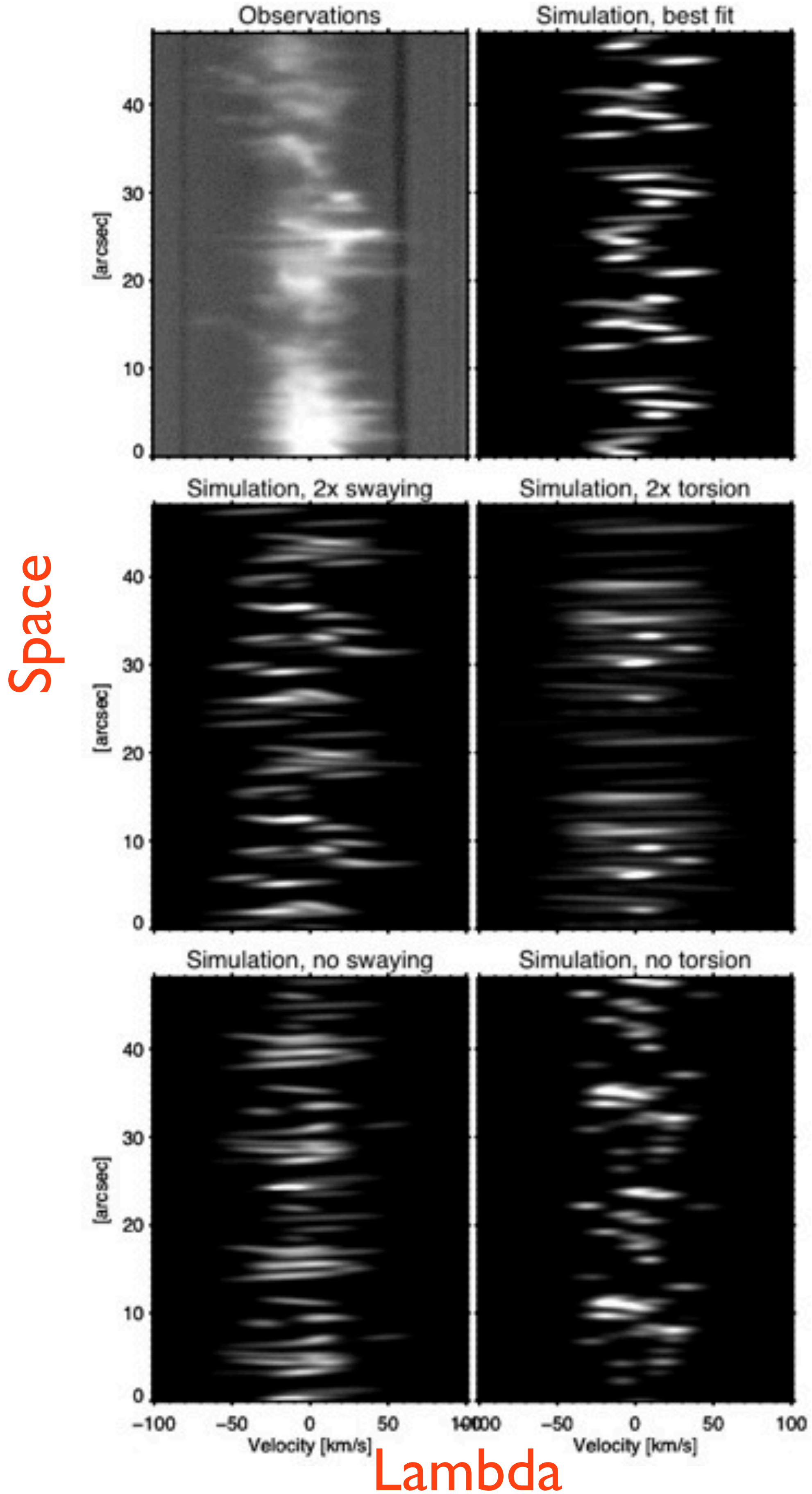

Assume N spicules with:

- upflows from Gaussian ~70 km/s

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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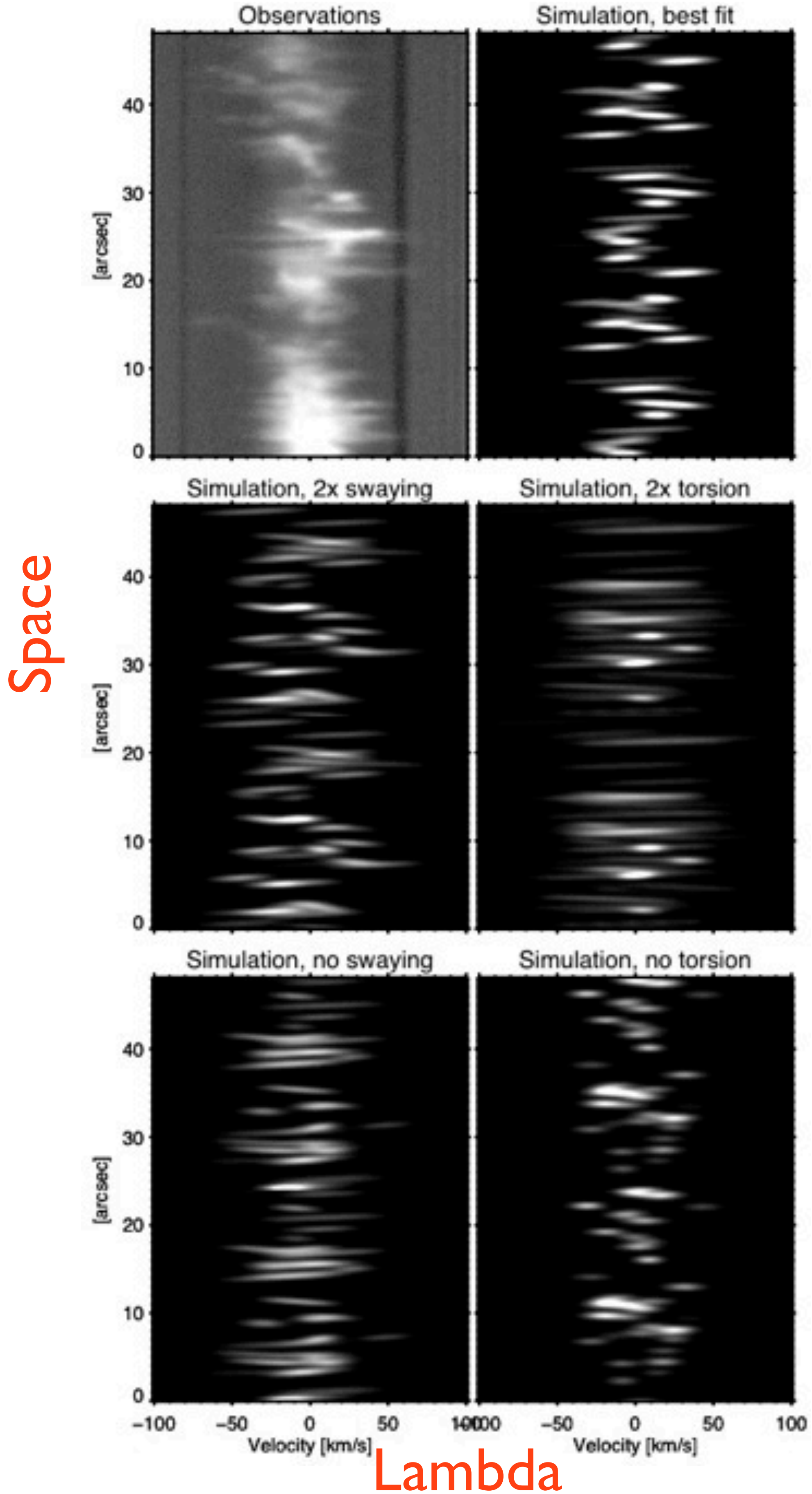

Assume N spicules with:

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De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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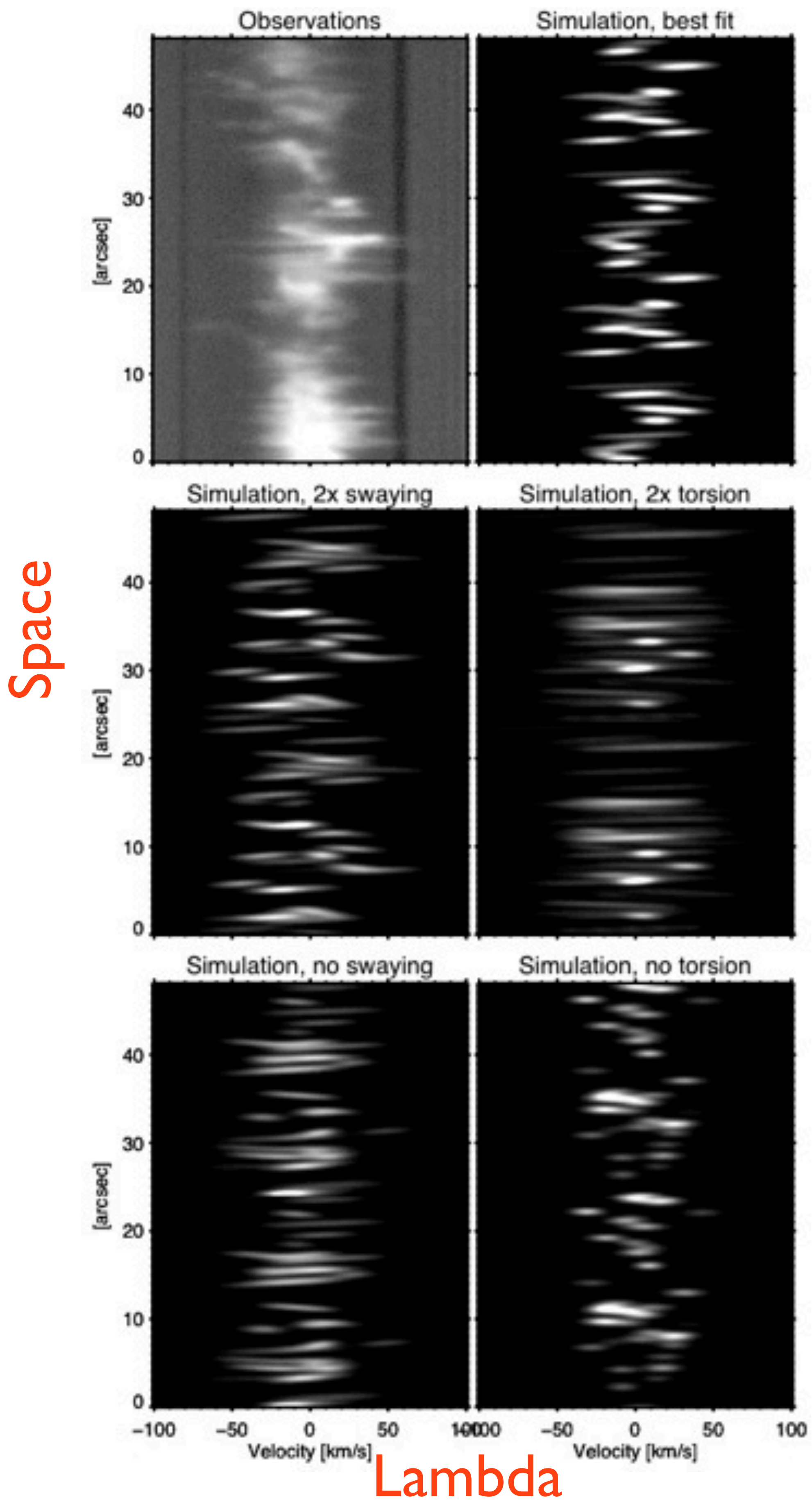

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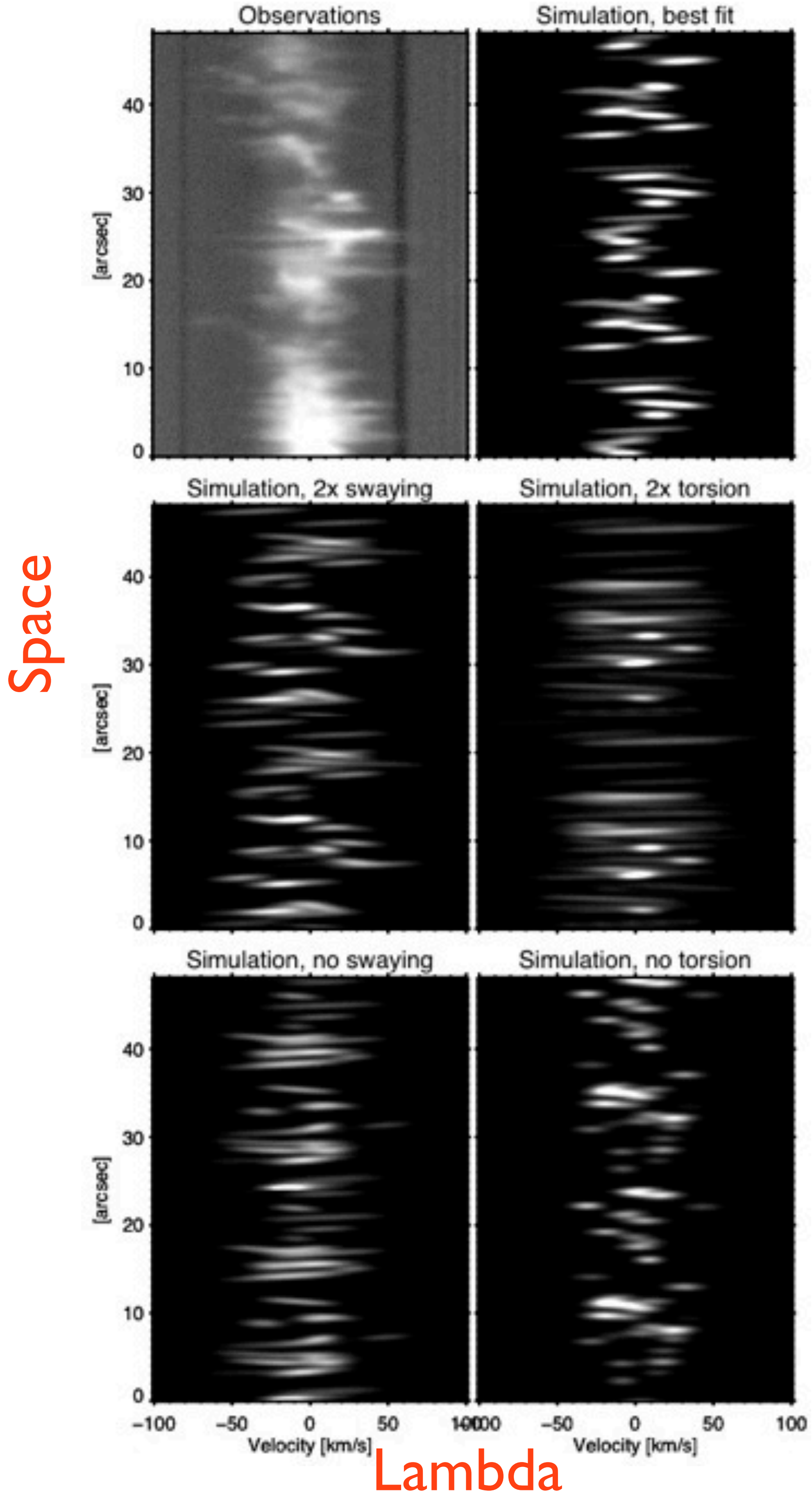

Assume N spicules with:

- upflows from Gaussian ~70 km/s
- swaying motions from Gaussian ~15 km/s
- torsional motions from Gaussian ~30 km/s

- lifetime from Gaussian around 120s

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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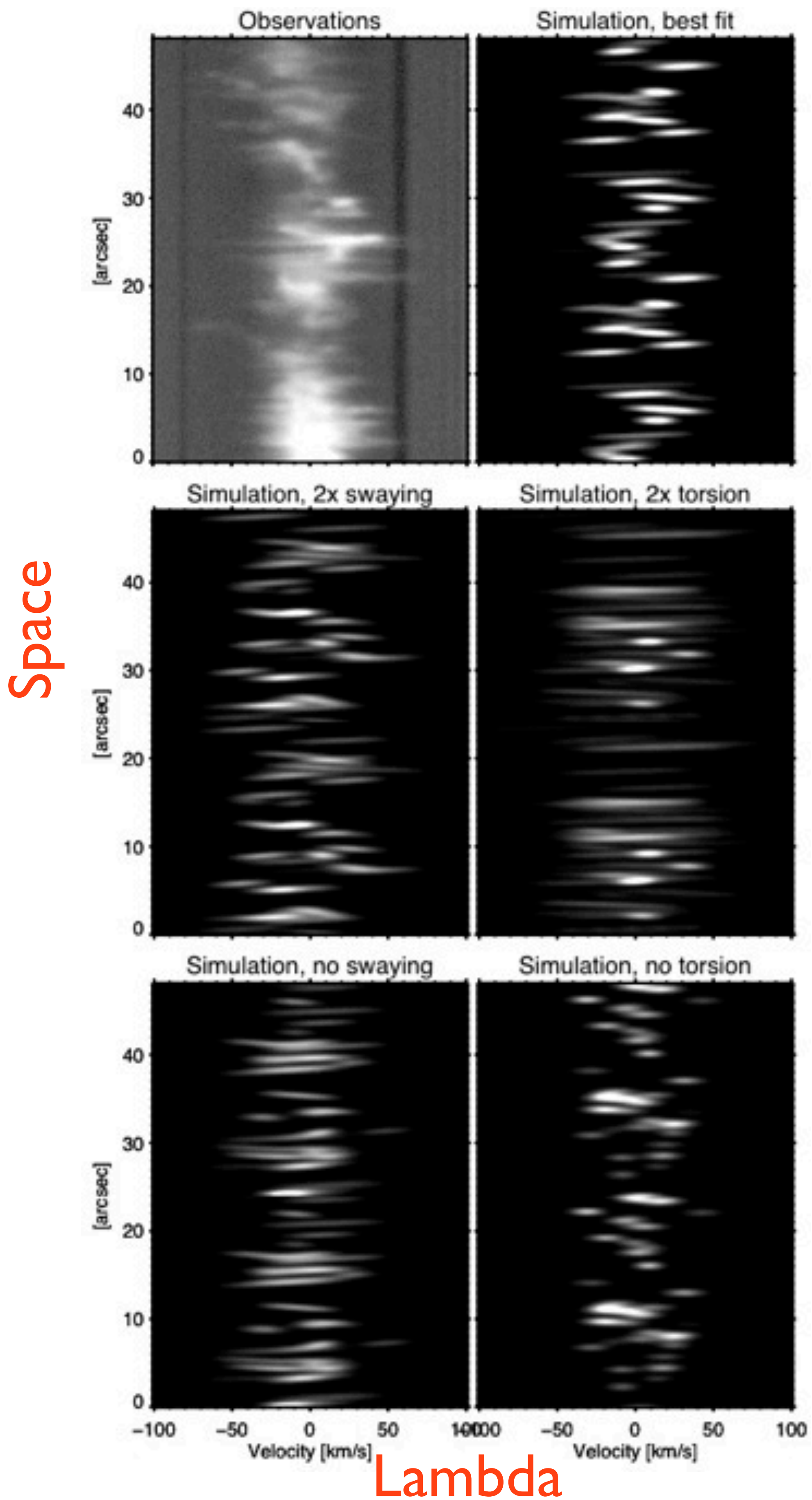

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De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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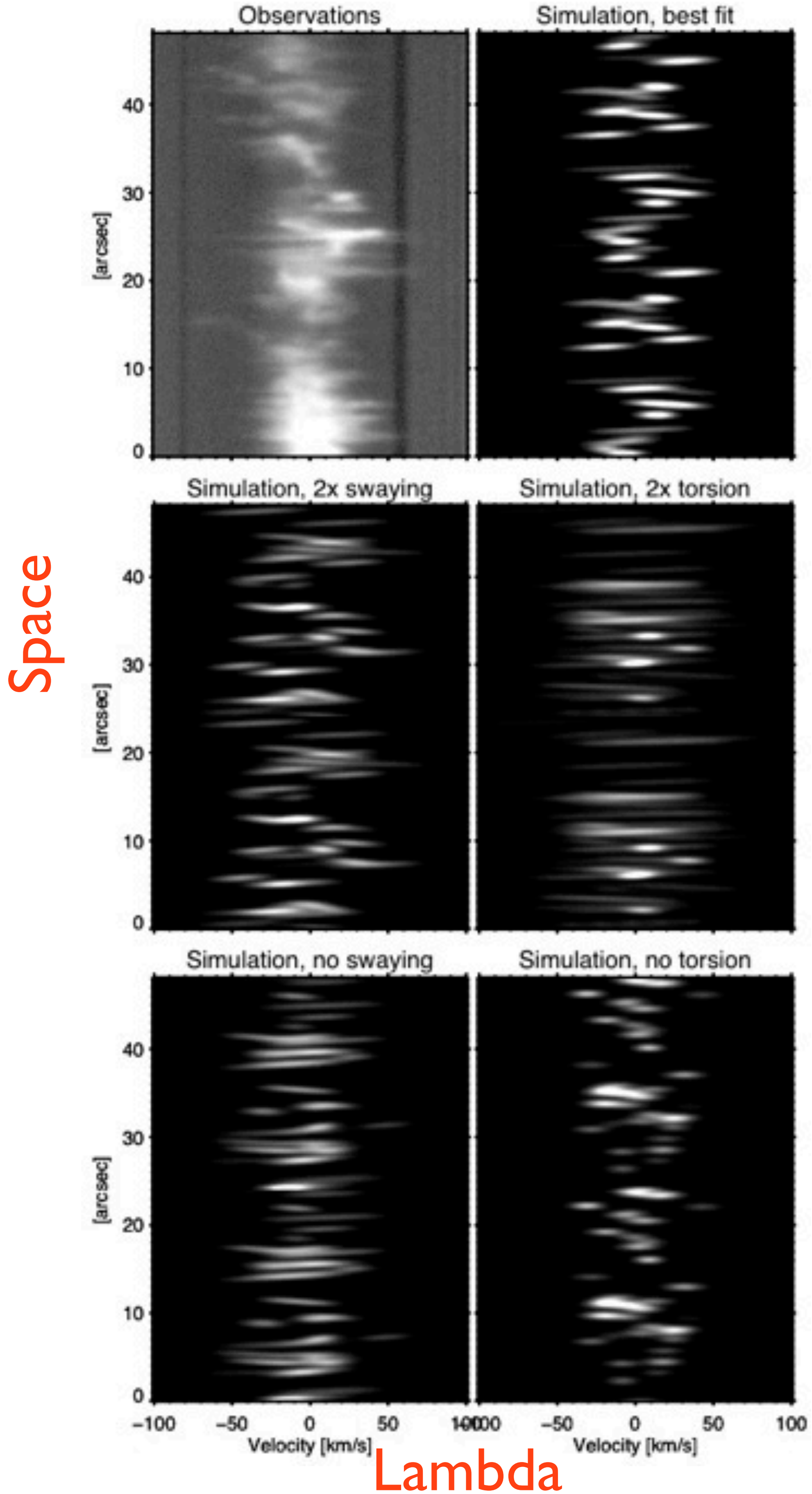

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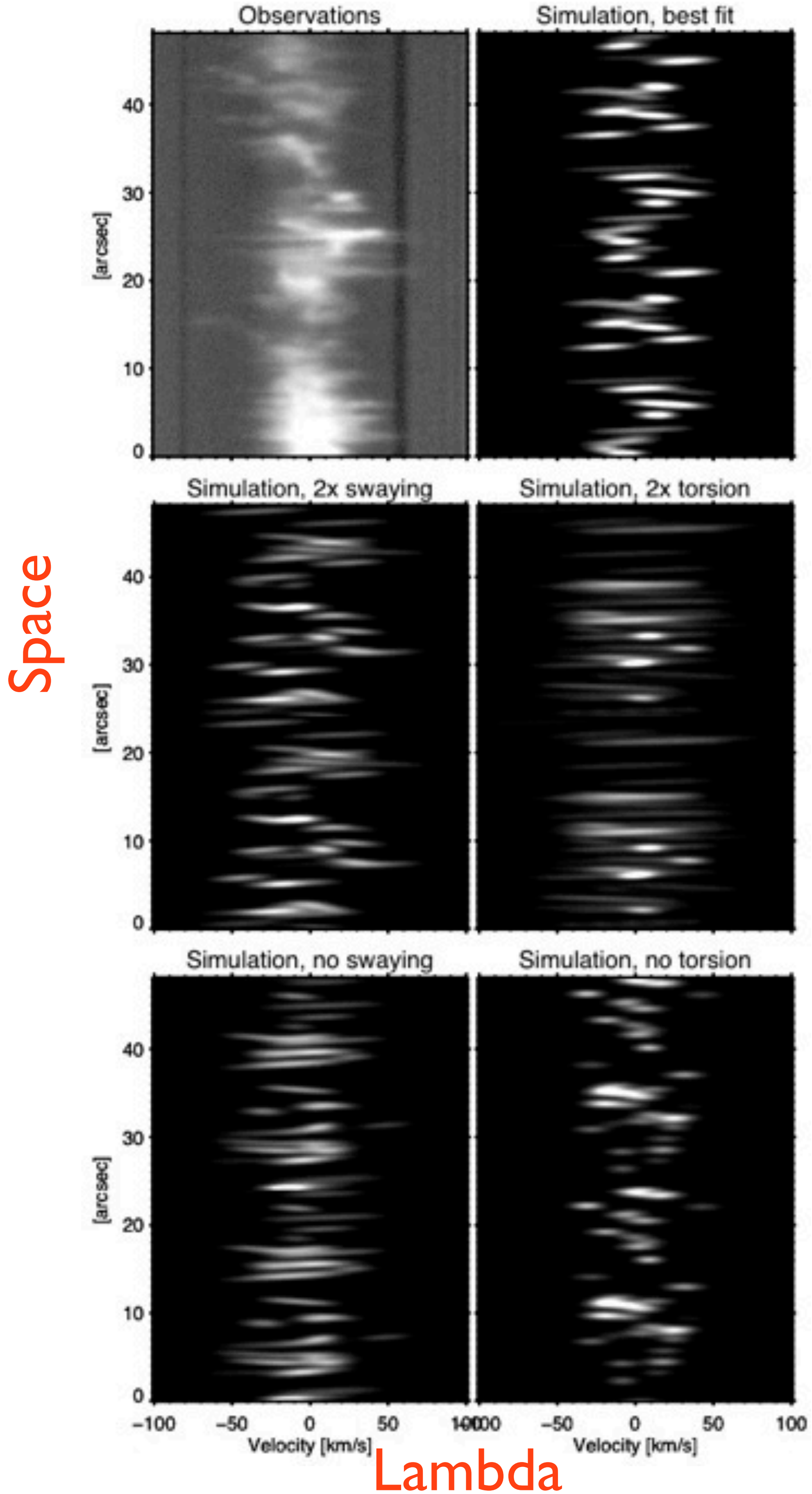

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- wave phase uniform 0-360 deg

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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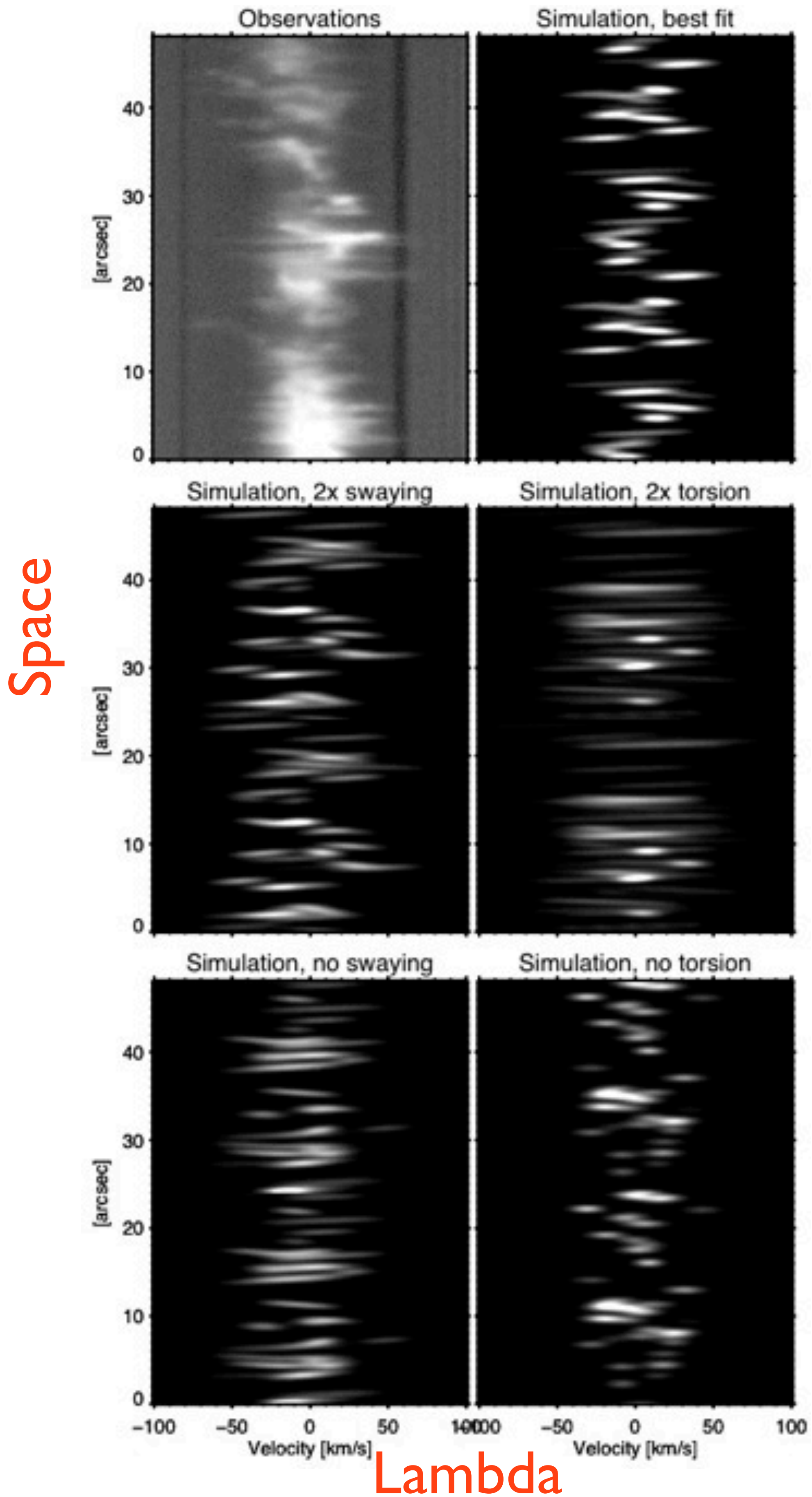

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- wave phase uniform 0-360 deg
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De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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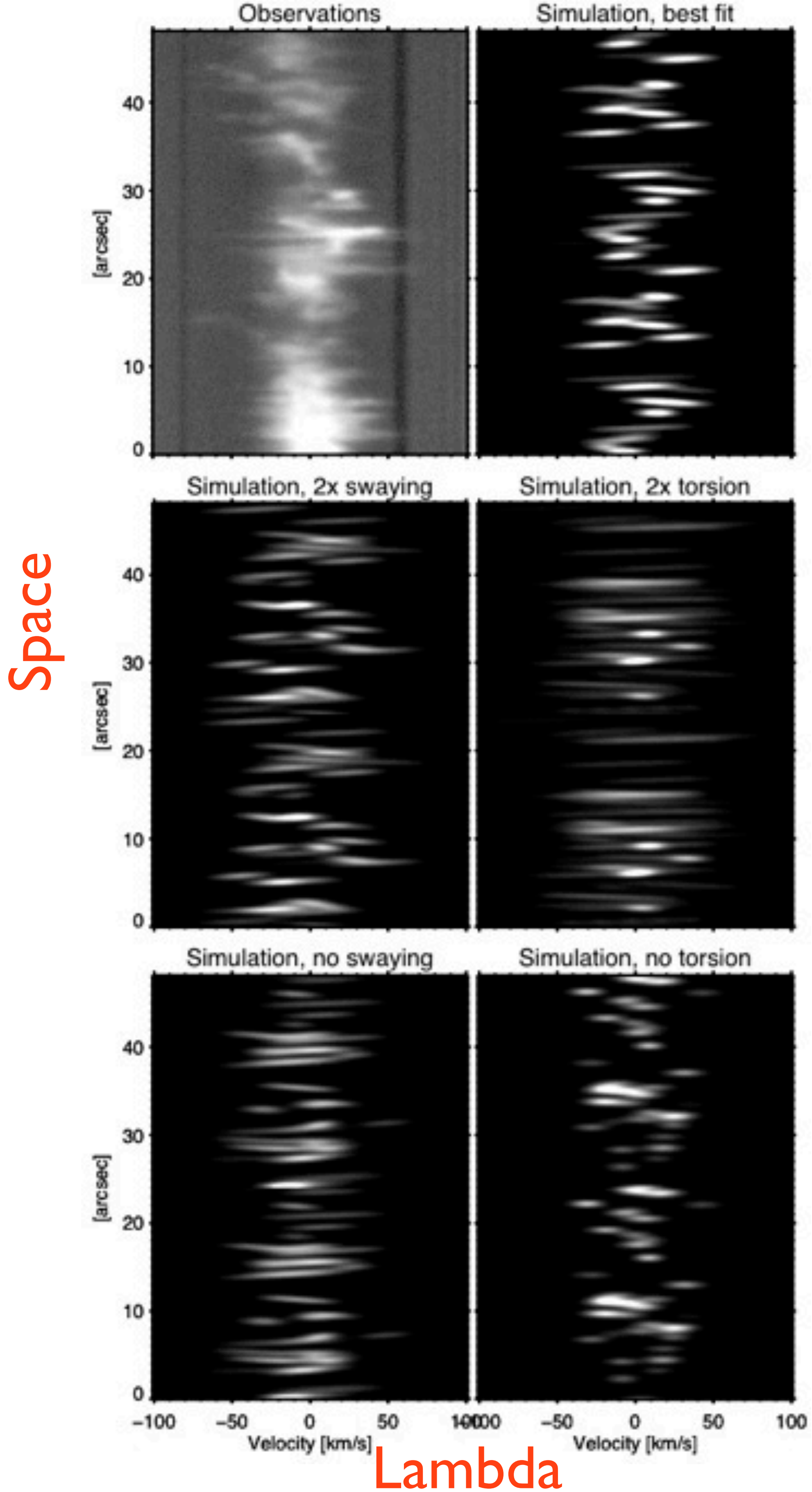

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- azimuth angle from uniform 0-360 deg

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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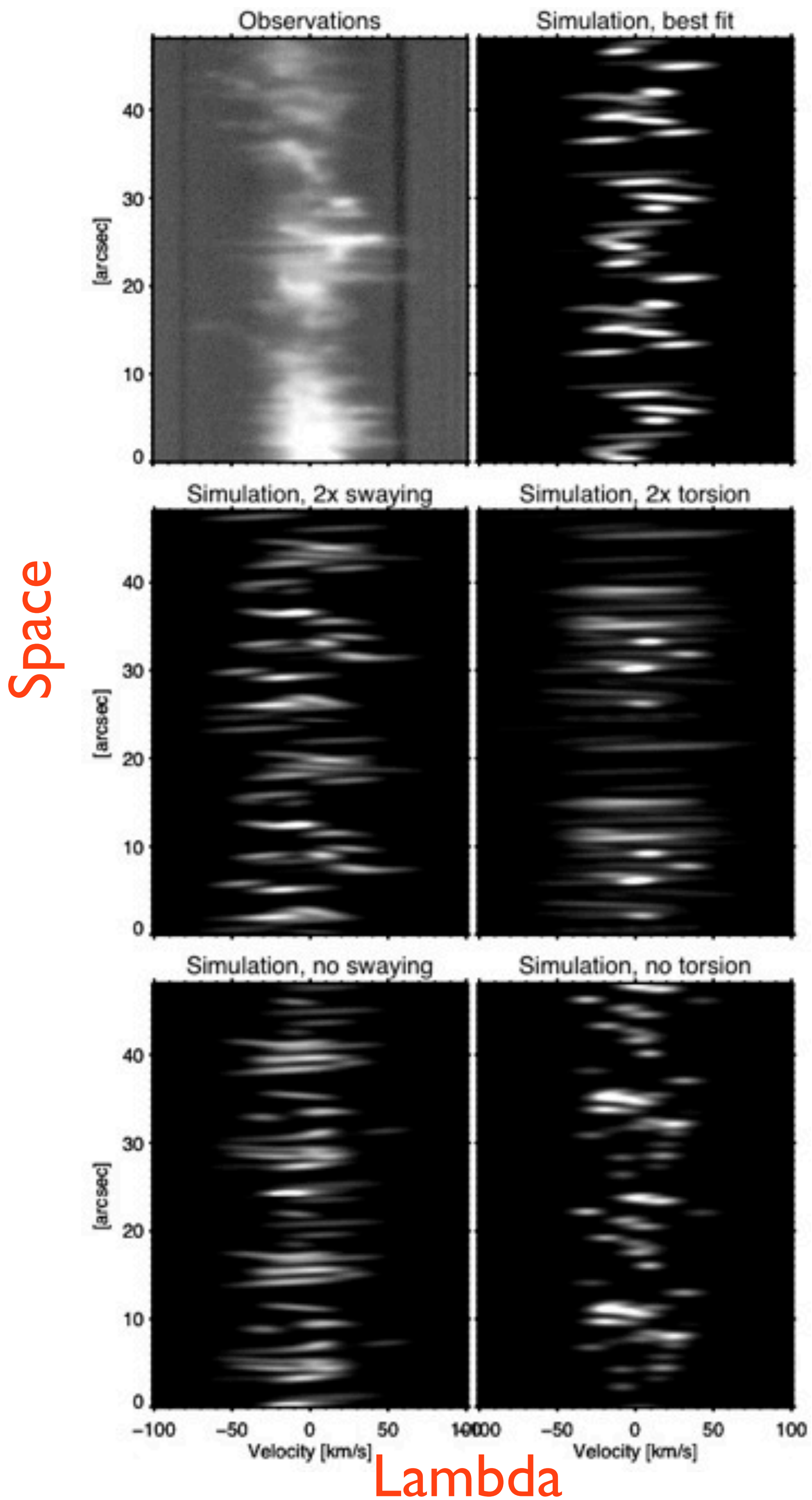

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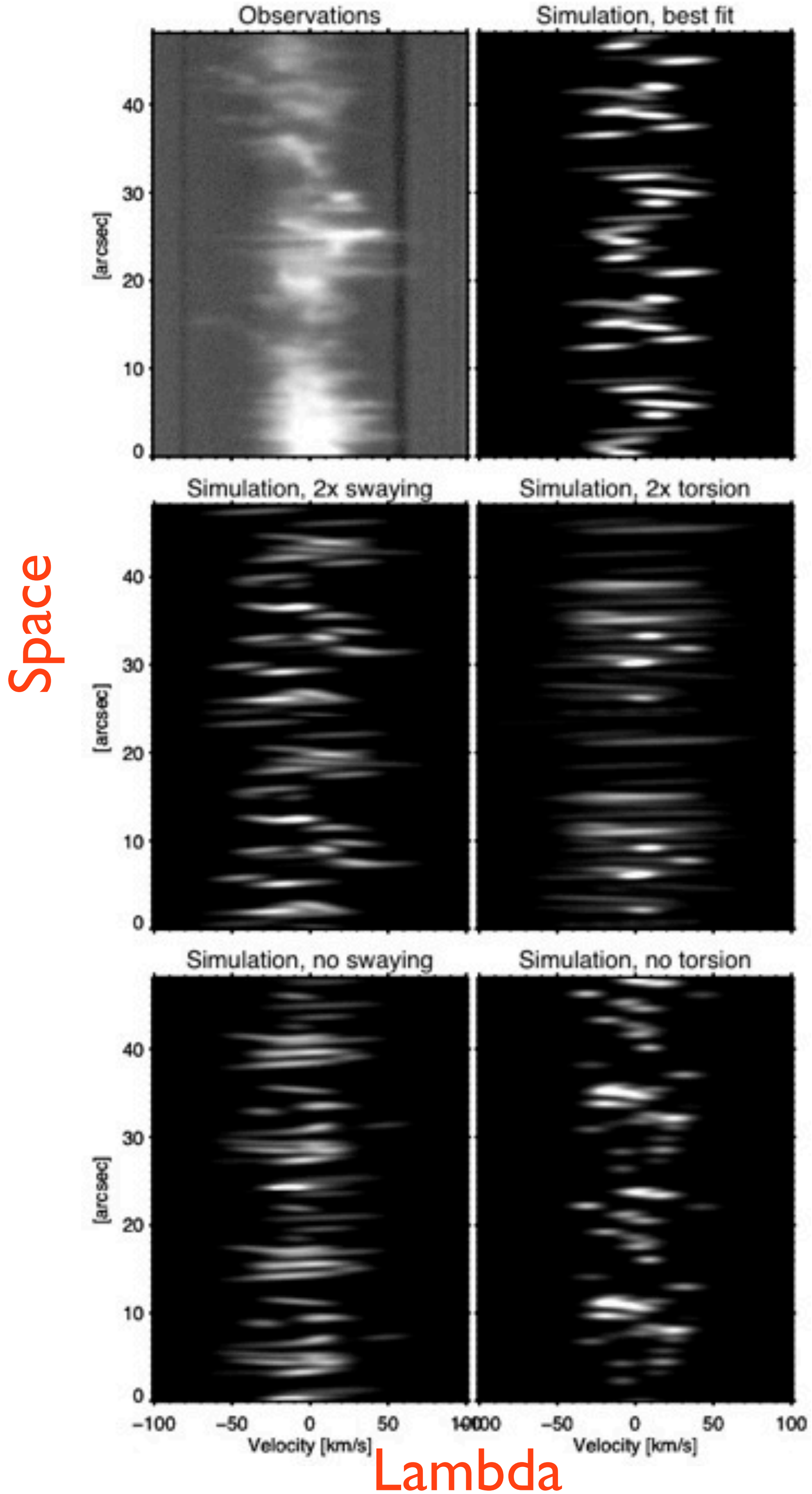

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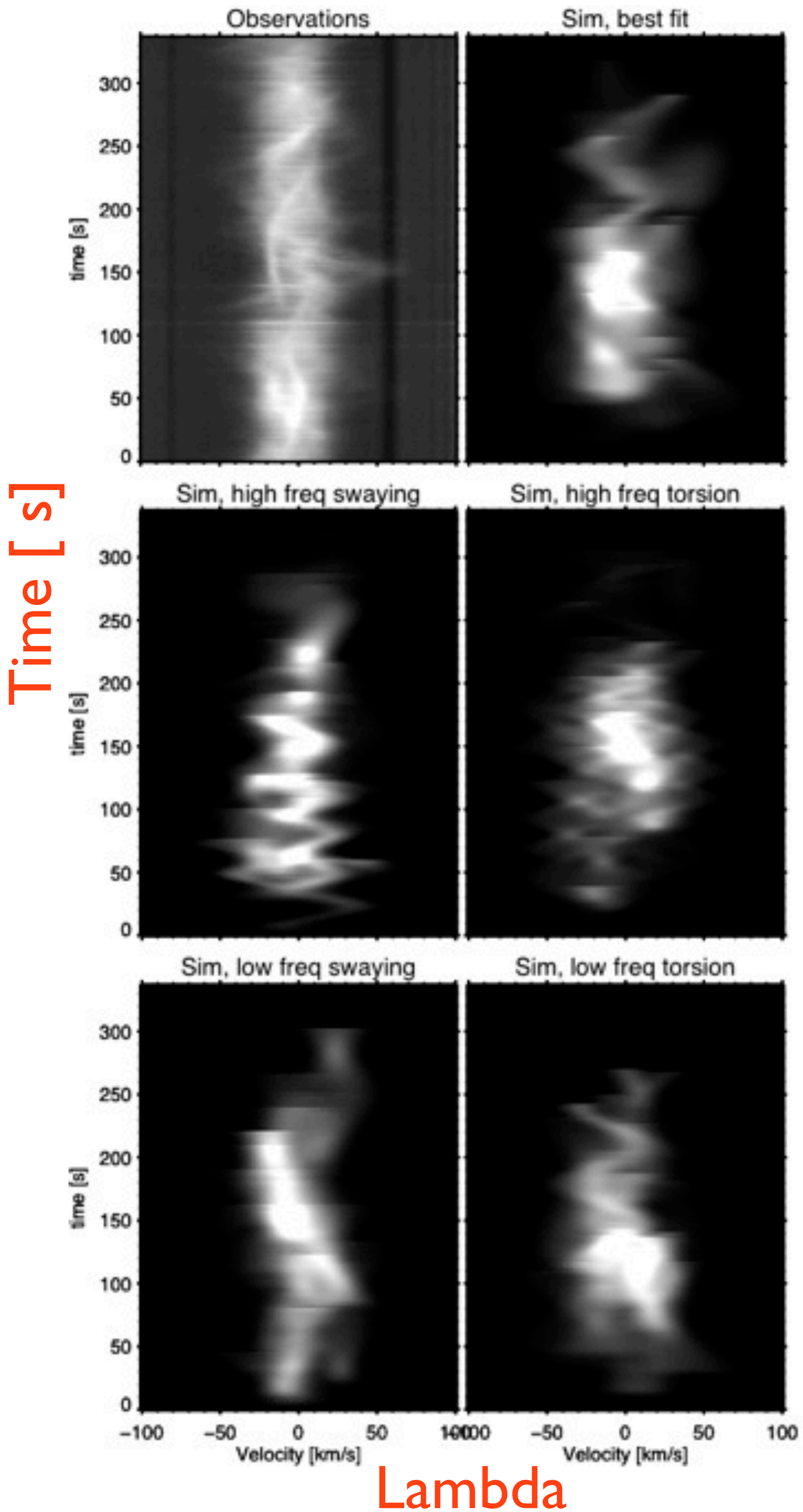
- torsional period from uniform 100-300s

- wave phase uniform 0-360 deg
- inclination from uniform at 20 deg from vertical
- azimuth angle from uniform 0-360 deg

2x swaying: too zig-zagging
2x torsional: too wide in lambda
0x swaying: not enough zig-zagging
0x torsional: not wide enough in lambda

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

Monte Carlo simulations constrain parameters well



Assume N spicules with:
- upflows from Gaussian ~70 km/s
- swaying motions from Gaussian ~15 km/s
- torsional motions from Gaussian ~30 km/s

- lifetime from Gaussian around 120s
- swaying period from uniform 100-300s
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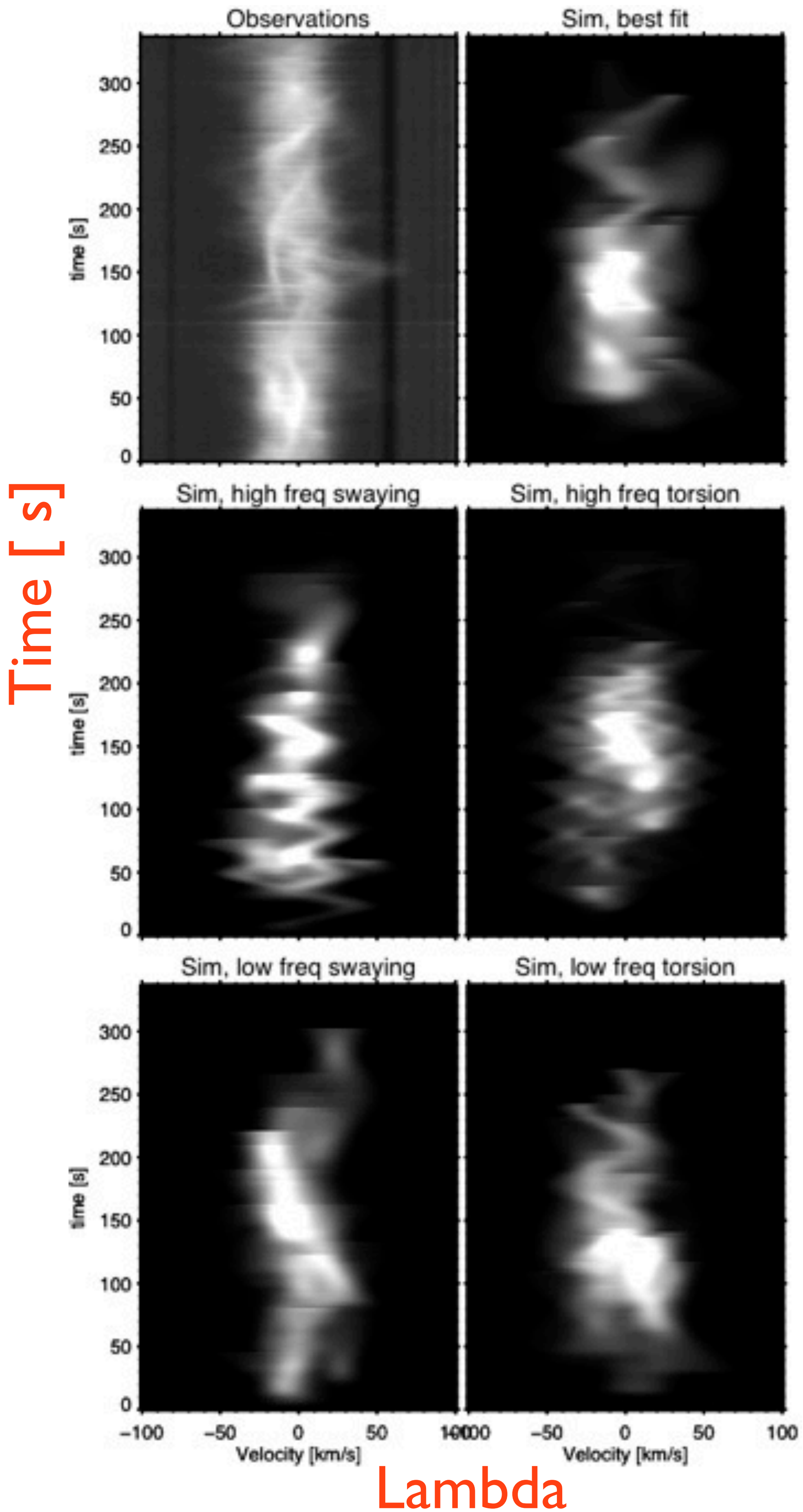

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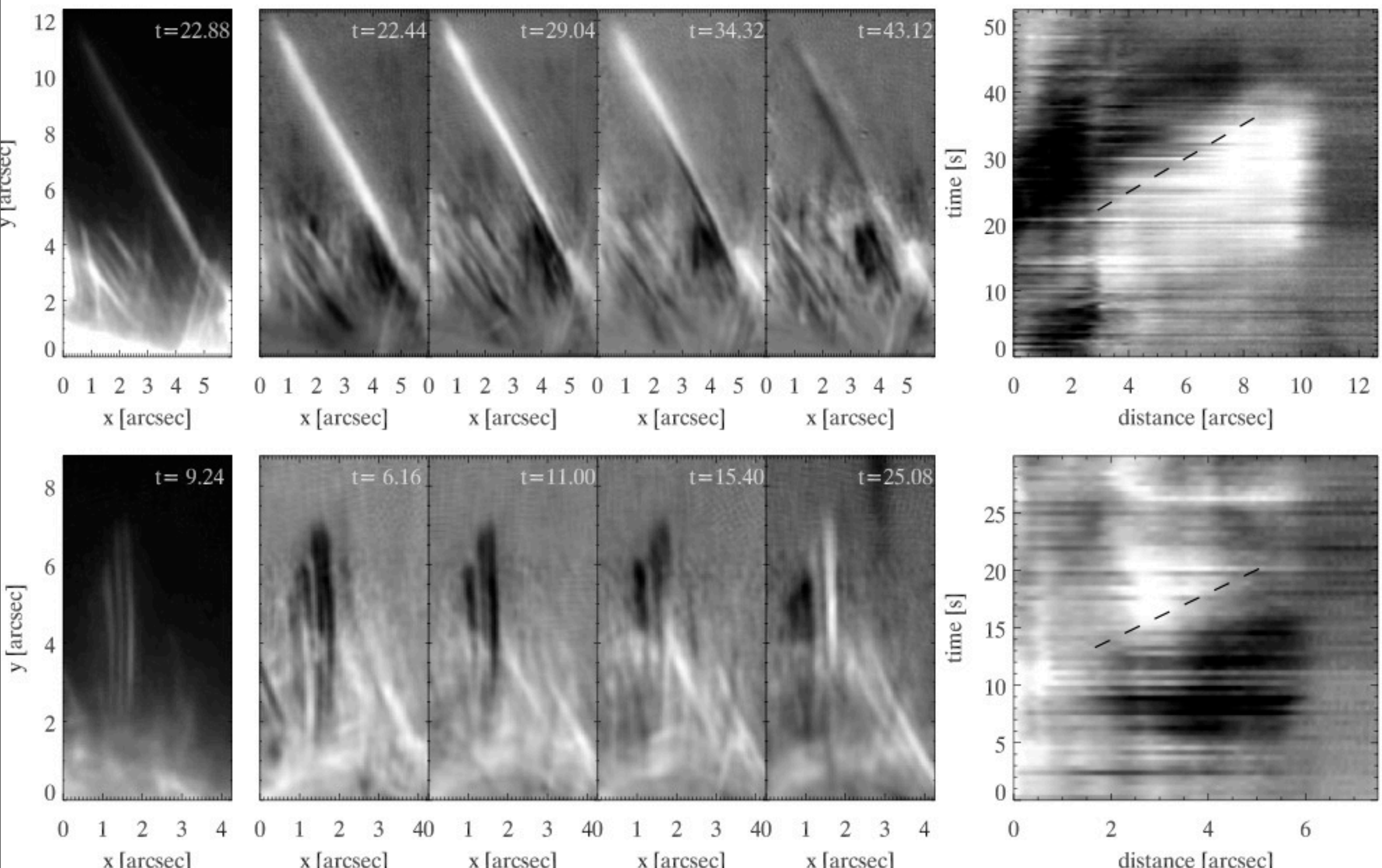
50-100 s swaying periods: too zig-zaggy
50-100 s torsional periods: too zig-zaggy
300-600s swaying periods: not zig-zaggy enough
300-600s torsional periods: not zig-zaggy enough

De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

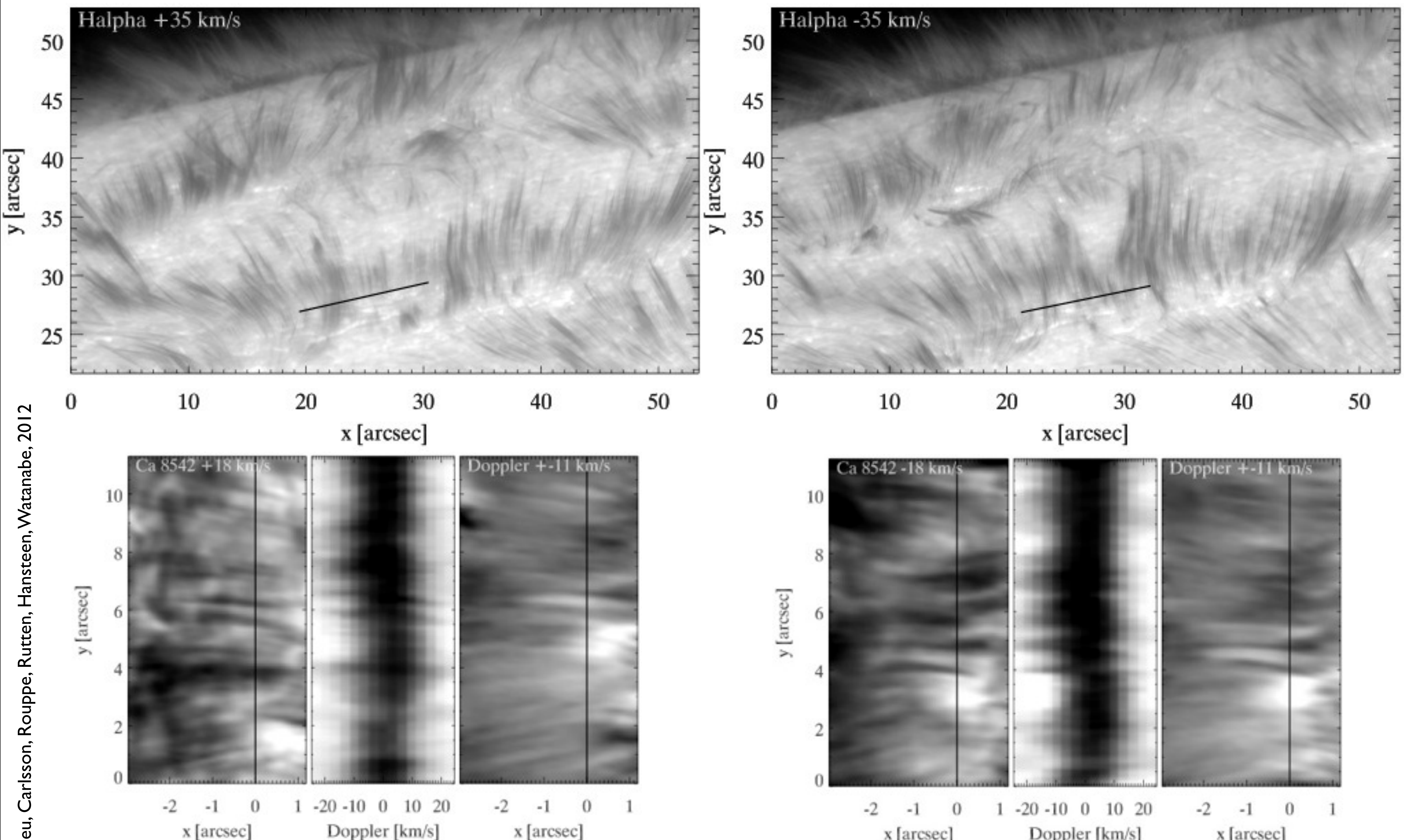
CRISP observations show propagation of torsional waves



De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

Apparent phase speeds of 200-300 km/s ~ Alfven speed

Presence of torsional waves on all spicules can explain morphology of H-alpha wing images on disk



De Pontieu, Carlsson, Rouppe, Rutten, Hansteen, Watanabe, 2012

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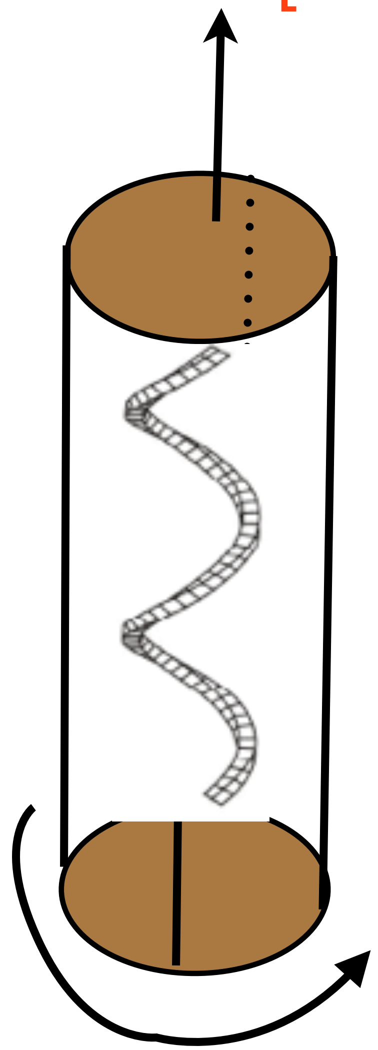
6. Spicules play major role in transport of helicity in solar atmosphere.

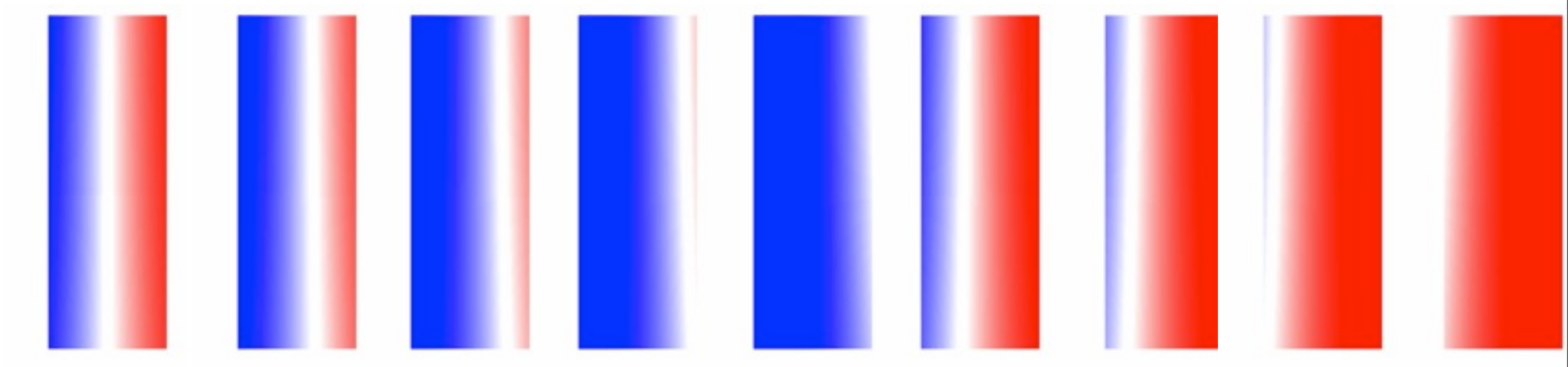
Why don’t we see rows of blue/red flux tubes everywhere?

Appearance of flux tube with field-aligned flow and
strong transverse motion critically dependent on viewing angle (and mix of motions)

LOS
mass flow [km/s]

=0 -10 -20 -30 -40 +10 +20 +30 +40





Observer is looking from above the plane of the screen
at an angle that is not 90 degrees

LOS torsional motion =40 km/s

Note that if there are no mass flows, but transverse swaying motions of the whole flux tube
with the same amplitude, the effects would be the same