solar and stellar prominences

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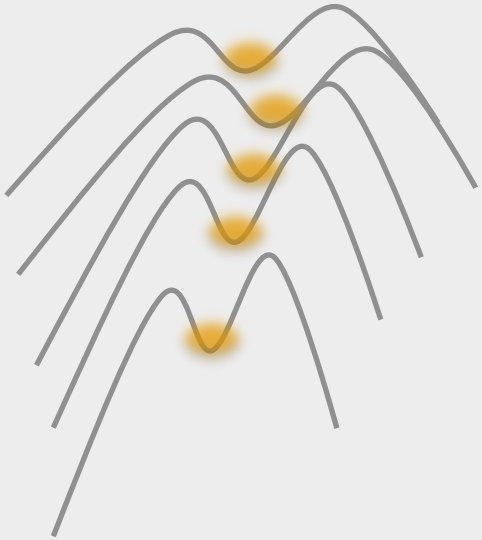
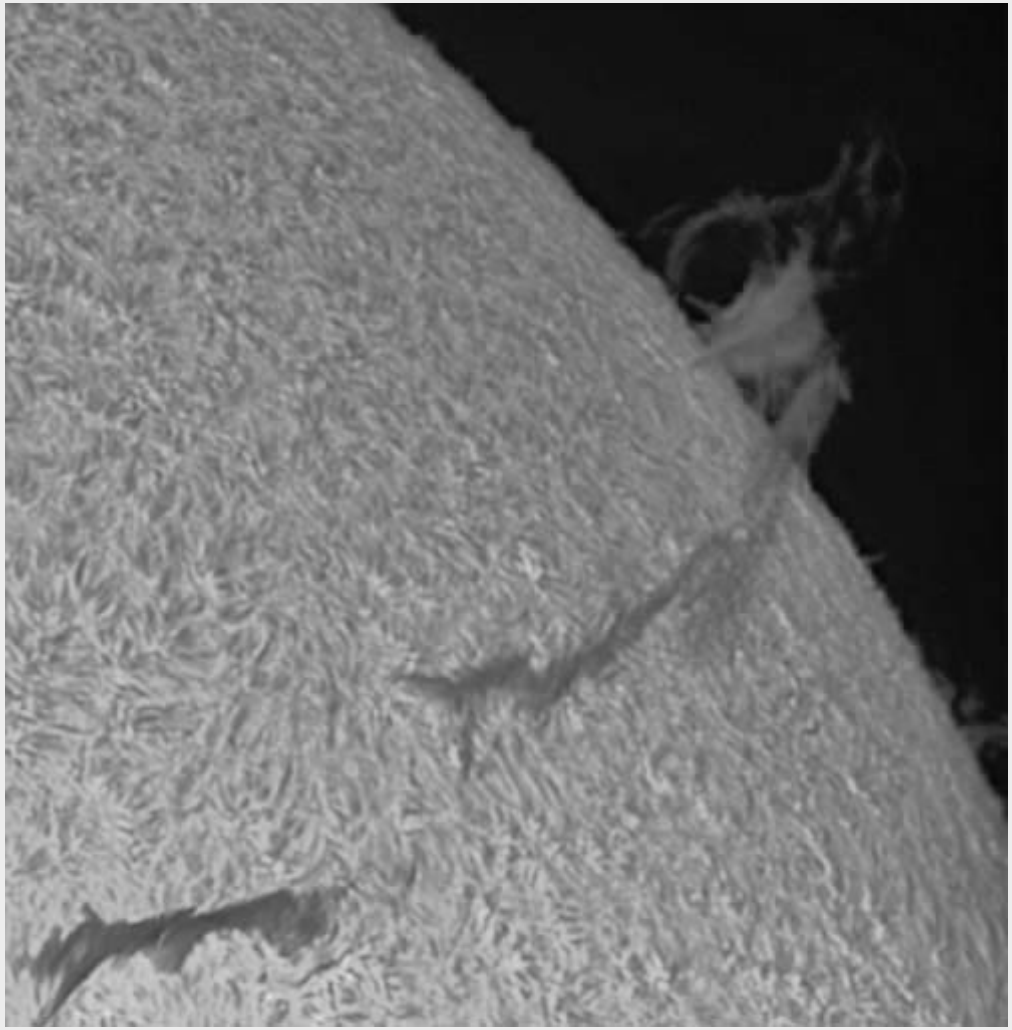
magnetism of solar prominences

solar prominences and filaments, two aspects of the same phenomenon

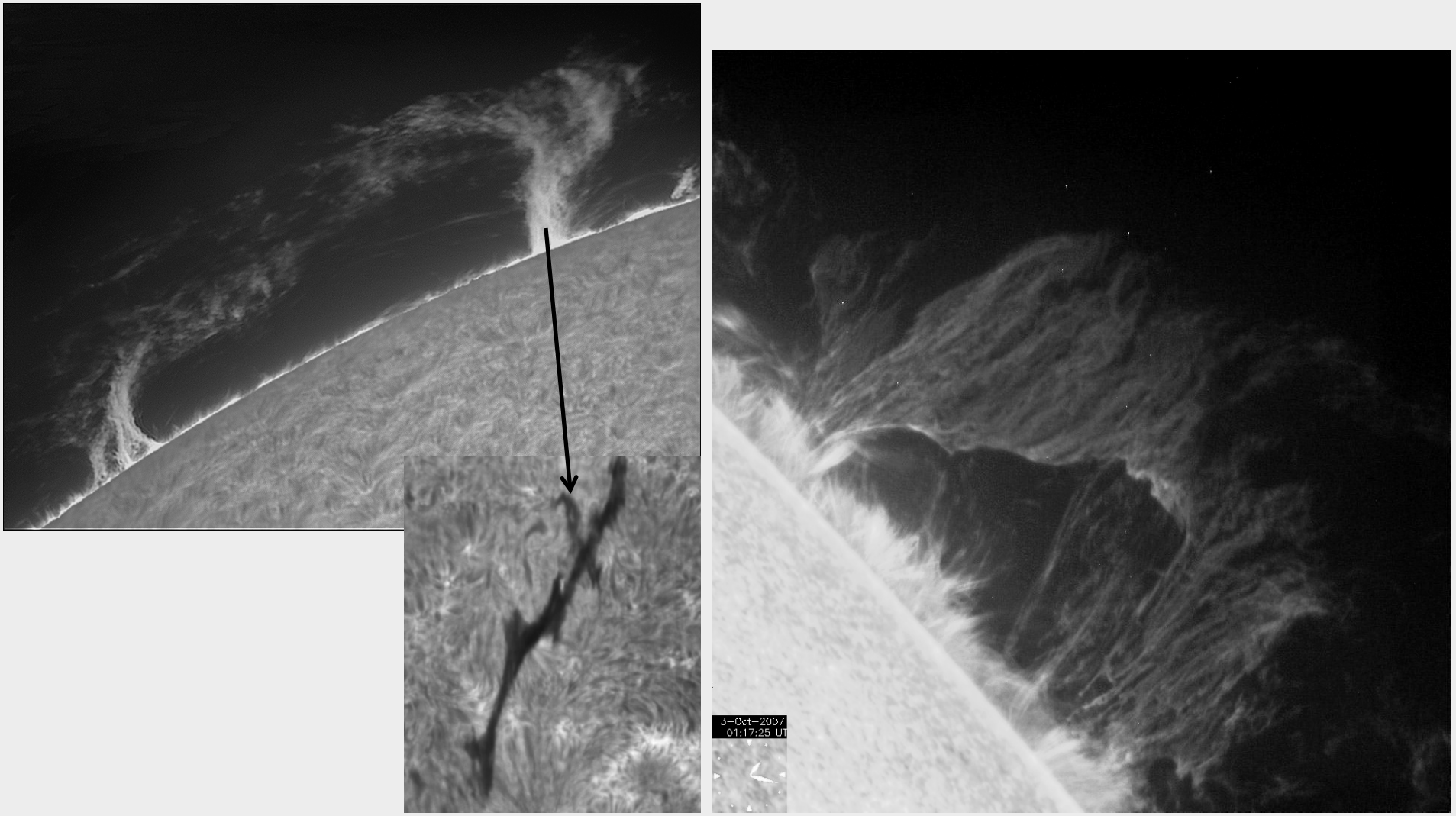
chromospheric plasma [10^4 K]
embedded in the hot corona [10^6 K]

suspended against gravity by
dips in the coronal **magnetic field**



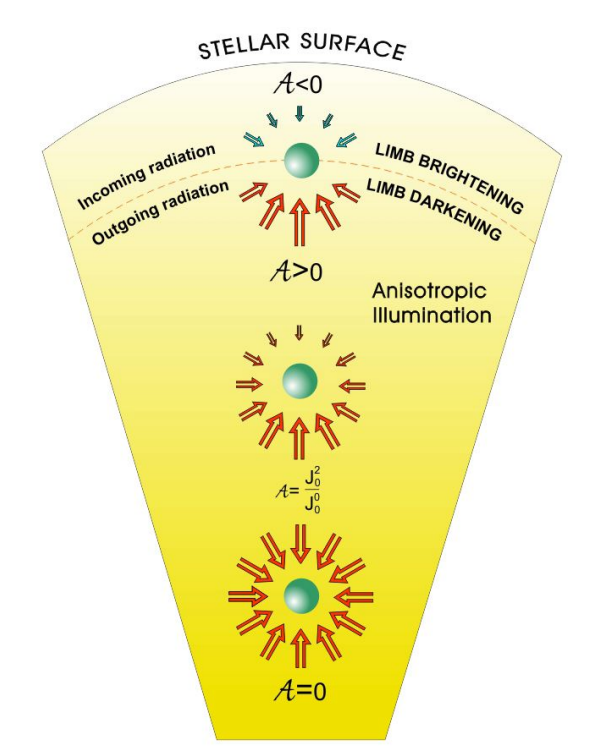


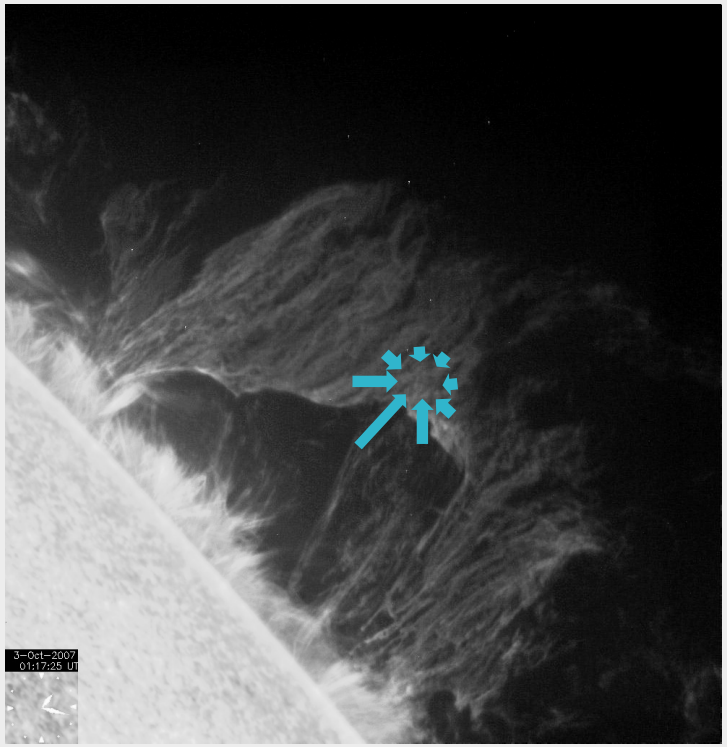
some structures challenge our assumption of horizontal magnetic dips since they appear as being vertically structured



we can quantitatively infer magnetic fields with spectro-polarimetry

polarisation in prominences and filaments is induced by **scattering in spectral lines due to an anisotropic radiation field** and the presence of a magnetic field





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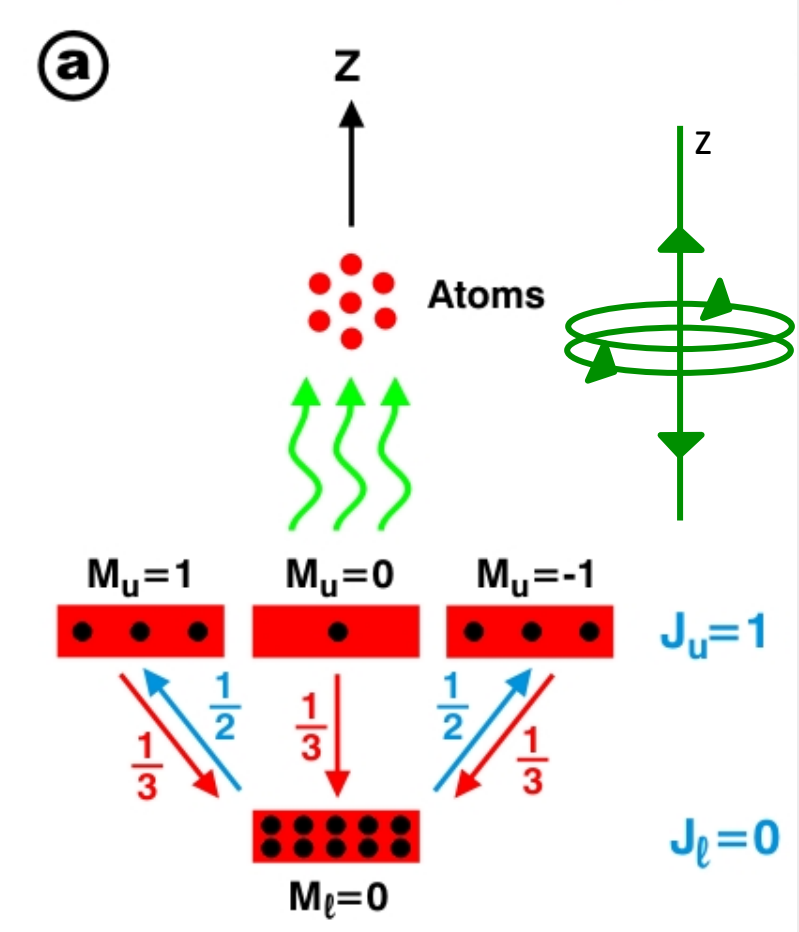

$\Delta M=\pm 1 \rightarrow \sigma_{\pm}$ (circularly polarised)

$\Delta M = 0 \rightarrow \pi$ (linearly polarised)

the vibration along the quantisation axis z is not absorbed because it coincides with the propagation axis of the raditation

+

the relaxation is isotropic

=

the atom is polarised

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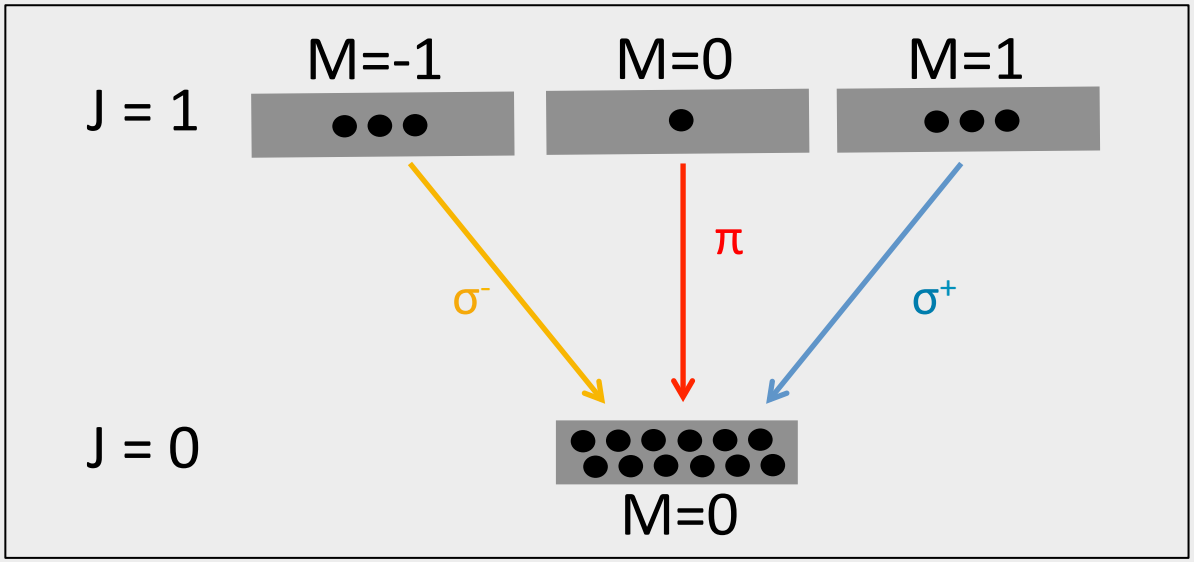

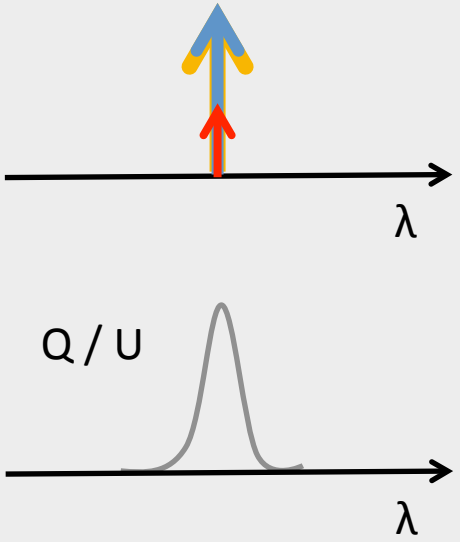

polarised atom

the anisotropy of the radiation field induces alignment in the atom

$$V = \sigma^+ - \sigma^- = 0$$

$$\mathbf{Q \text{ or } U = \sigma^+ + \sigma^- - 2\pi \neq 0}$$

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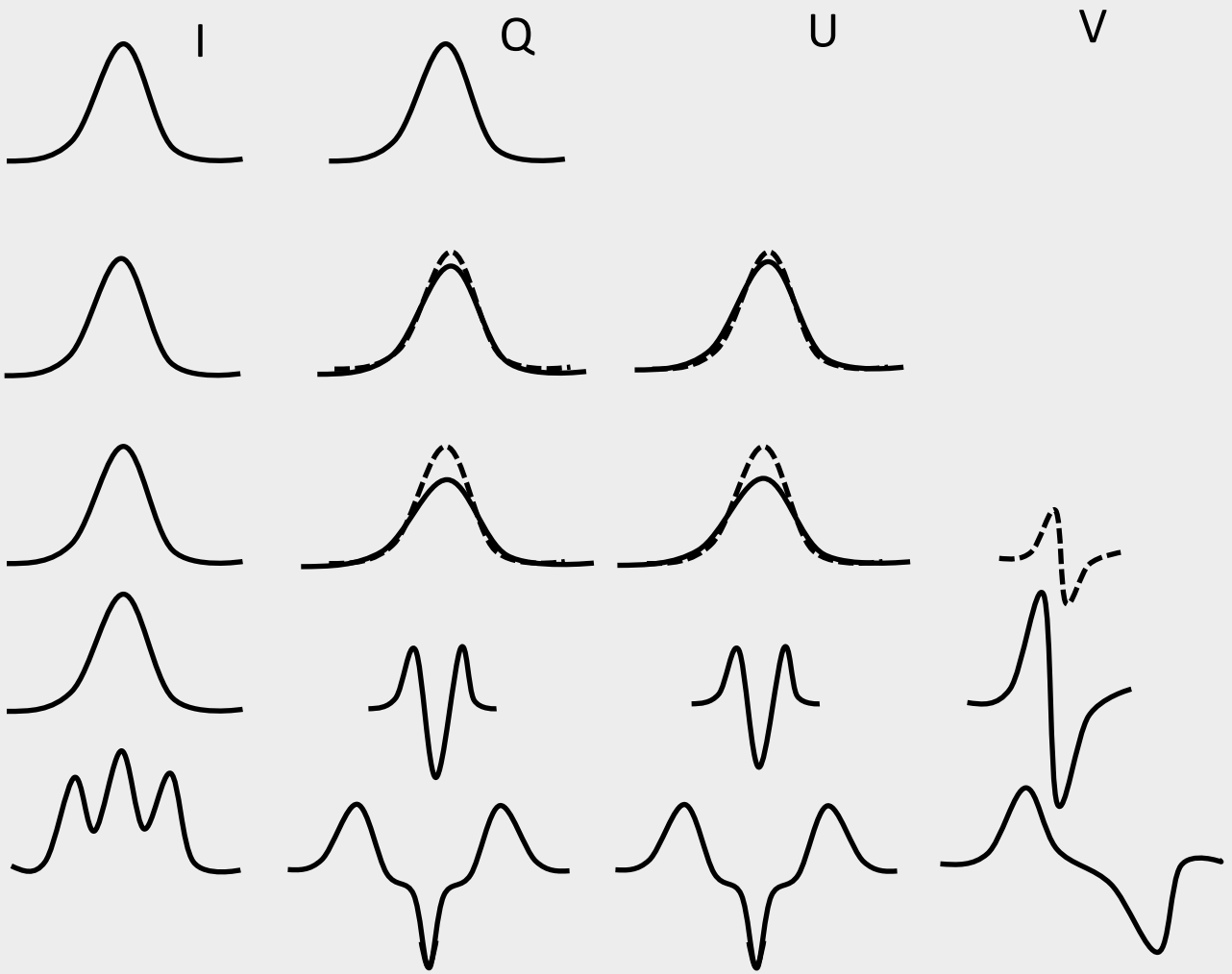

scattering
[no B or extremely small]

Hanle regime
$w_L \approx A_{ul} \rightarrow B_{crit}$

Hanle saturation
$B > 10\ B_{crit}$

Zeeman regime
weak field [$\Delta\lambda_B << \Delta\lambda_D$]

Zeeman regime
strong field [$\Delta\lambda_B >> \Delta\lambda_D$]

we can quantitatively infer magnetic fields with spectro-polarimetry

at present, most of the work is theoretical because

(1) the spectro-polarimetric observations of such structures is challenging

(2) the interpretation of the data in terms of magnetic field vector is not straightforward

the main diagnostic line for the magnetic field vector is the He I multiplet at 10830 Å [$B_{crit} \approx 1$ G]. **The polarisation signatures of this line in prominences are in the Hanle (– Zeeman) regime.**

$$Q \sim \frac{q}{2}\left(3\cos^2\theta_B - 1\right)\sin^2\Theta_B \cos 2\Phi_B$$

$$U \sim \frac{q}{2}\left(3\cos^2\theta_B - 1\right)\sin^2\Theta_B \sin 2\Phi_B$$

$$V \propto \cos\Theta_B$$

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potential ambiguity (Θ_B / 90 + Θ_B) if there is no Stokes V [same as in Zeeman diagnostics]

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± 180 deg ambiguity [same in Zeeman diagnostics]

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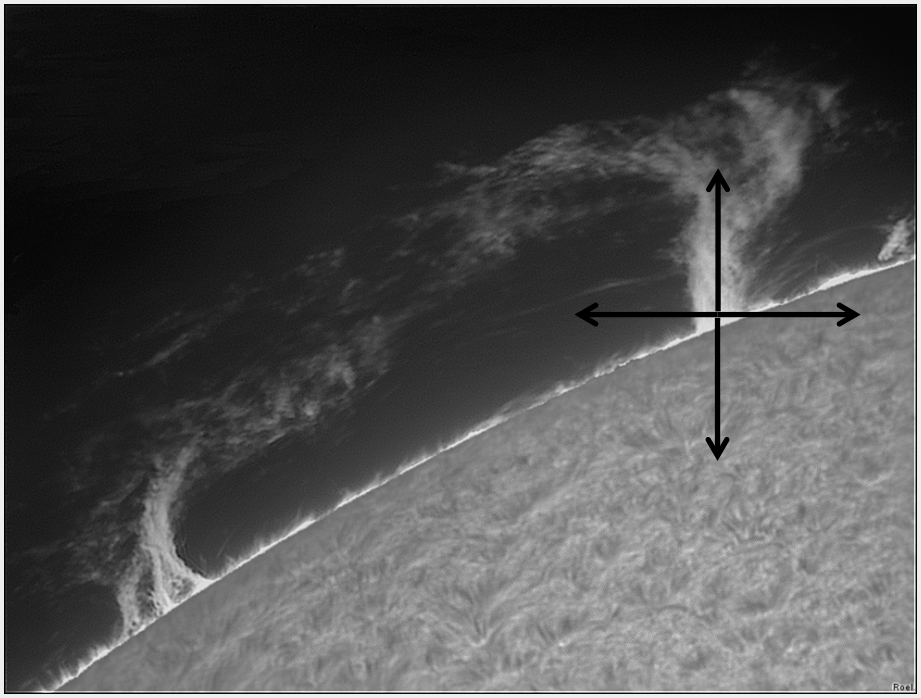
± 90 deg ambiguity if a solution exists for

$(3\cos^2\theta'_B - 1)\sin^2\Theta'_B = -Q$

$(3\cos^2\theta'_B - 1)\sin^2\Theta'_B = -U$

the ± 90 deg ambiguity is particularly annoying for prominence studies

are the fields vertical or horizontal?



how can we solve the ±90 deg ambiguity?

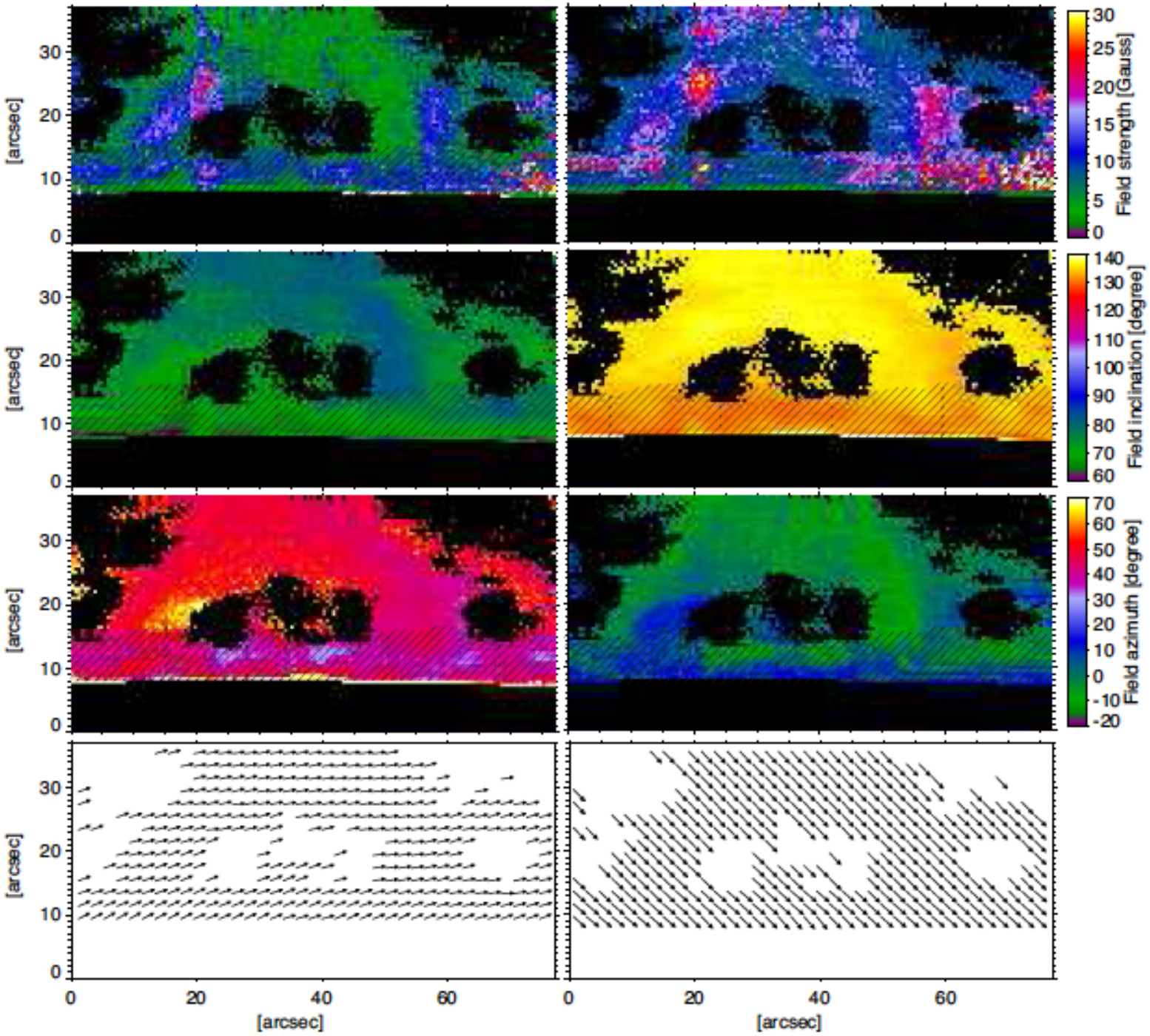
(1)

if the spectral line is in the intermediate Hanle-Zeeman regime
[or using two lines, one Hanle sensitive and another one Zeeman sensitive]

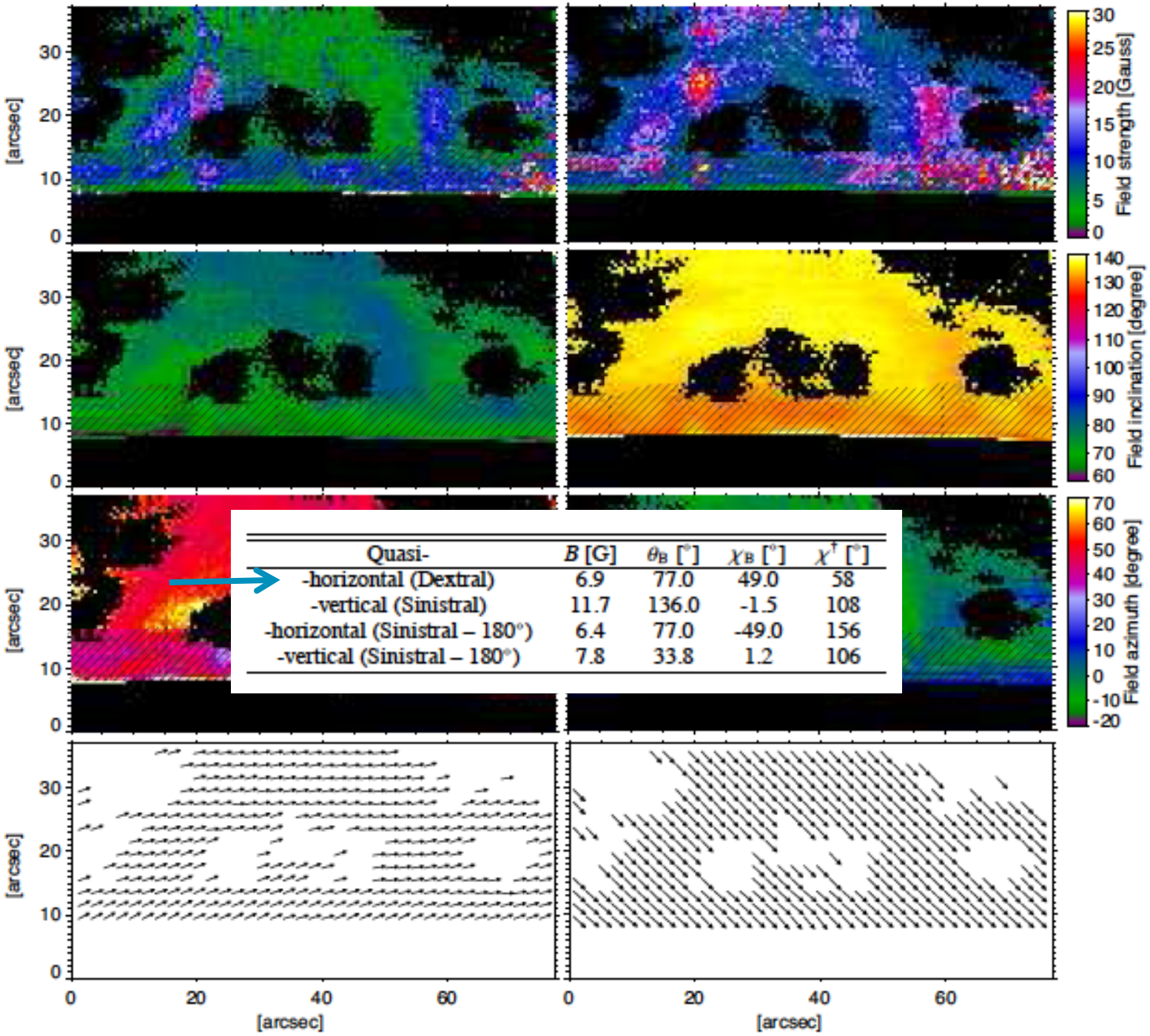
this is not the case in prominences, for He I 10830 Å
[it can be in some active region filaments]

(2)

introduce some extra information



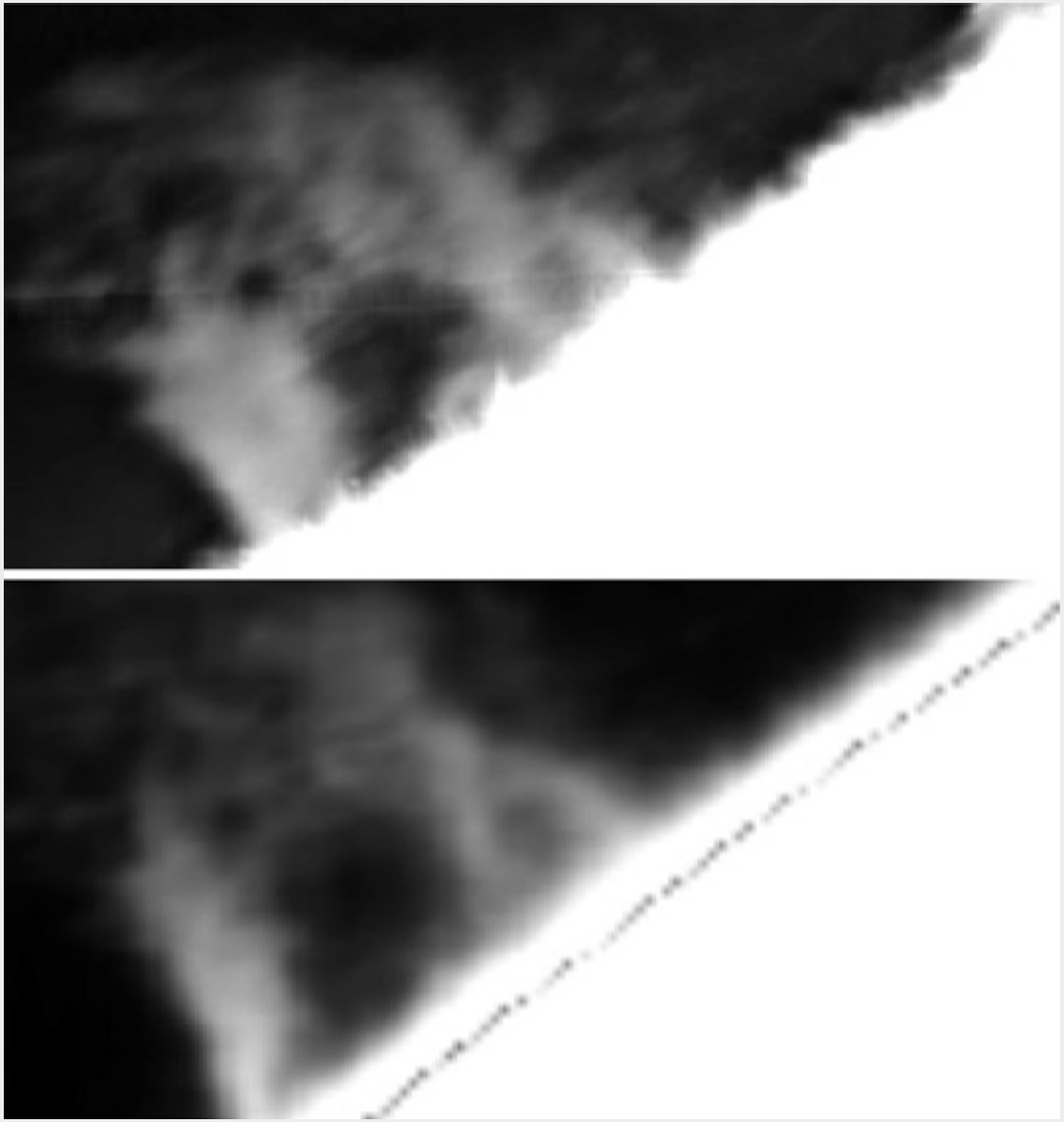
Orozco Suárez et al. 2014, A&A, 566, 46



Quasi-	B [G]	θ_B [°]	χ_B [°]	χ^T [°]
-horizontal (Dextral)	6.9	77.0	49.0	58
-vertical (Sinistral)	11.7	136.0	-1.5	108
-horizontal (Sinistral – 180°)	6.4	77.0	-49.0	156
-vertical (Sinistral – 180°)	7.8	33.8	1.2	106

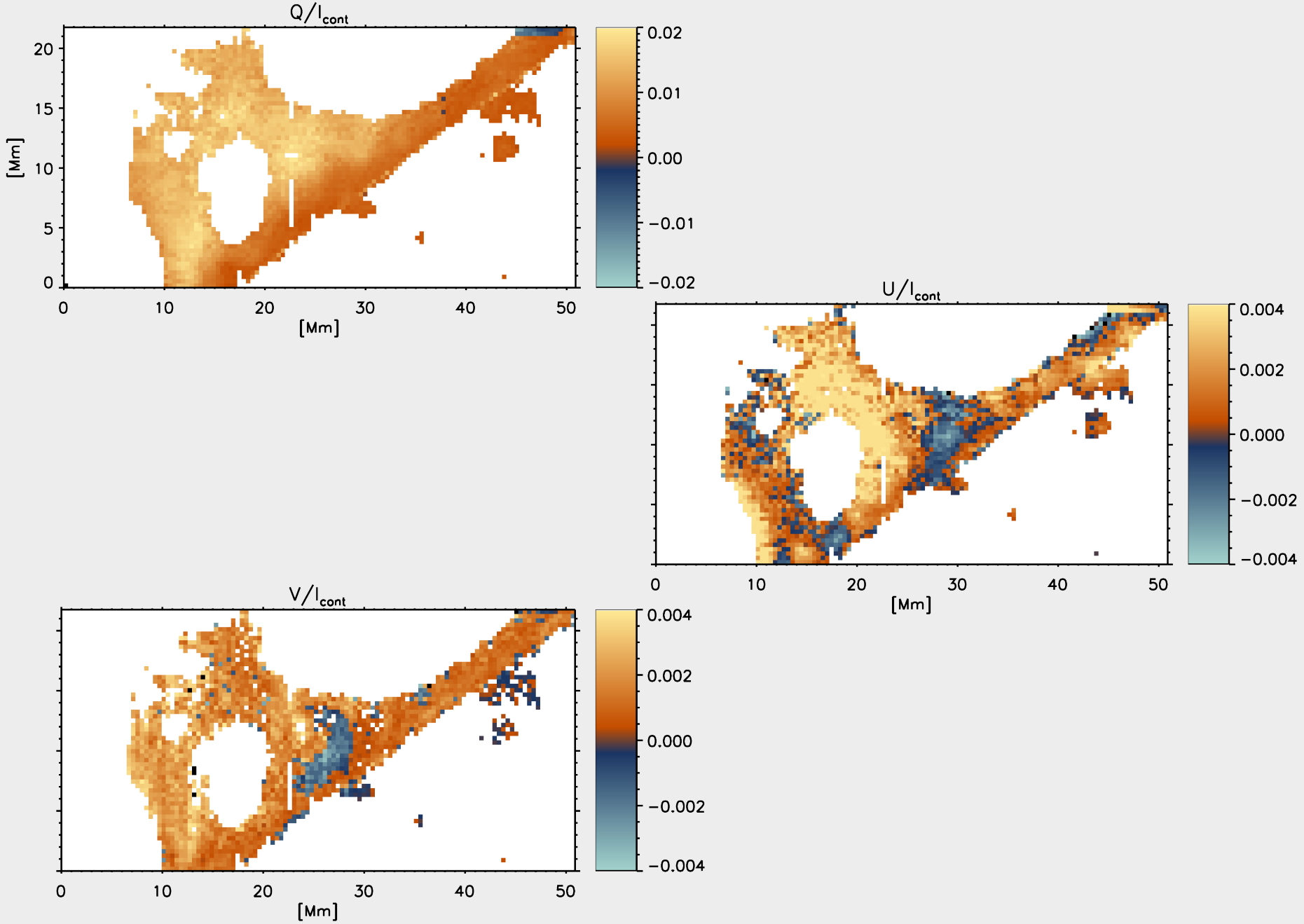
Orozco Suárez et al. 2014, A&A, 566, 46

have the legs of solar prominences horizontal fields?

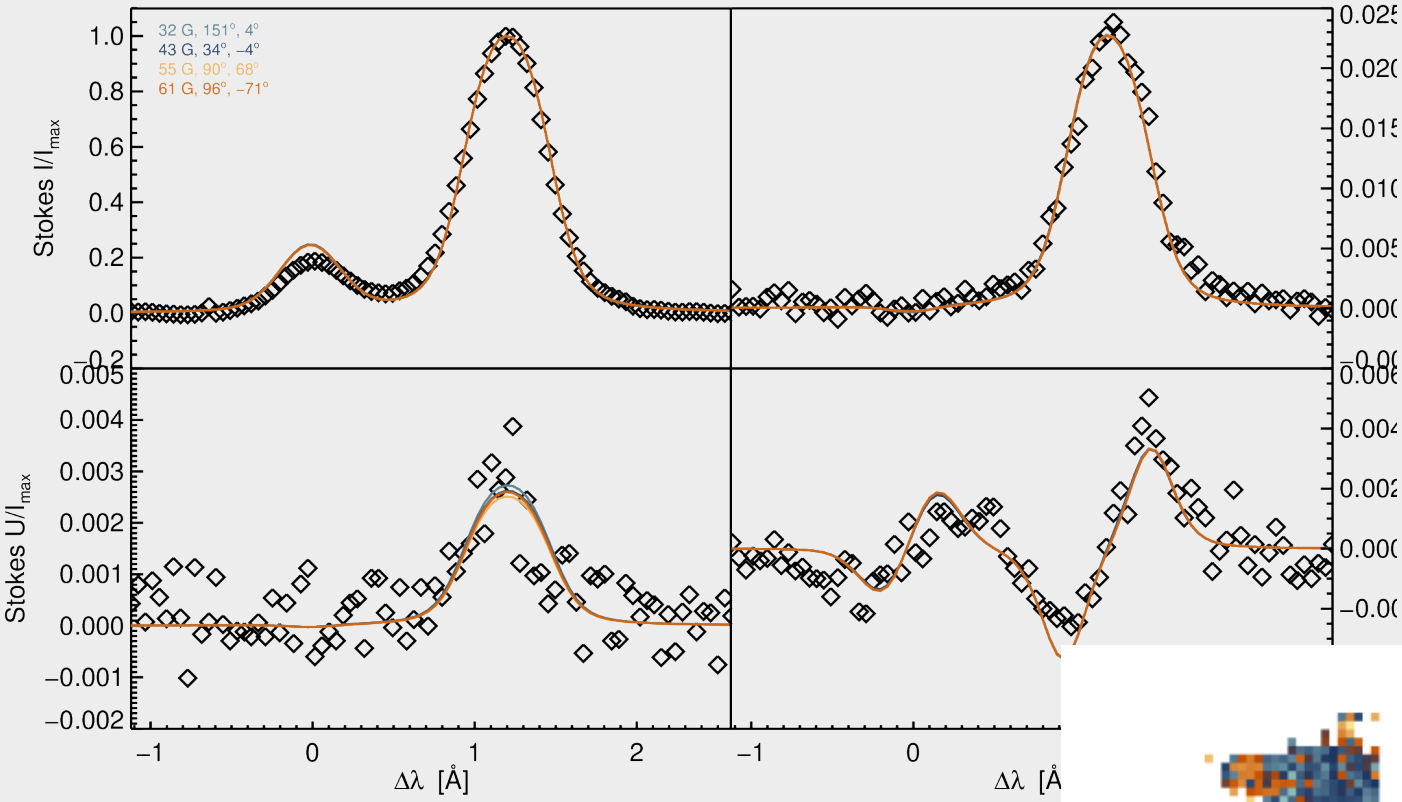


H_α core image in the middle of the He I 10830 Å scan

reconstructed scan at the core of the He I 10830 Å

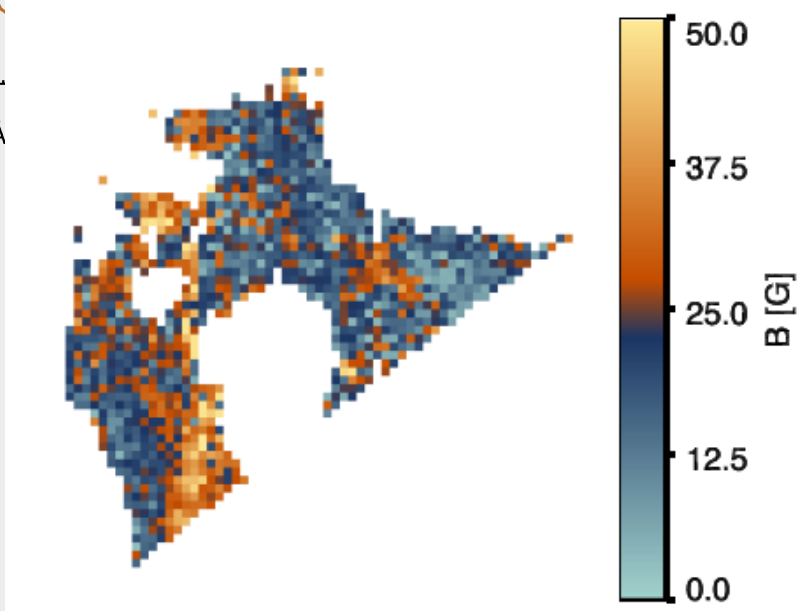

Q/I_cont
U/I_cont
V/I_cont
[Mm]
[Mm]
0
5
10
15
20
0
10
20
30
40
50
0.02
0.01
0.00
−0.01
−0.02
0.004
0.002
0.000
−0.002
−0.004

ambiguous solutions: “vertical” and “horizontal” solutions



https://github.com/aasensio/hazel

but the recovered field strength is robust in the four solutions



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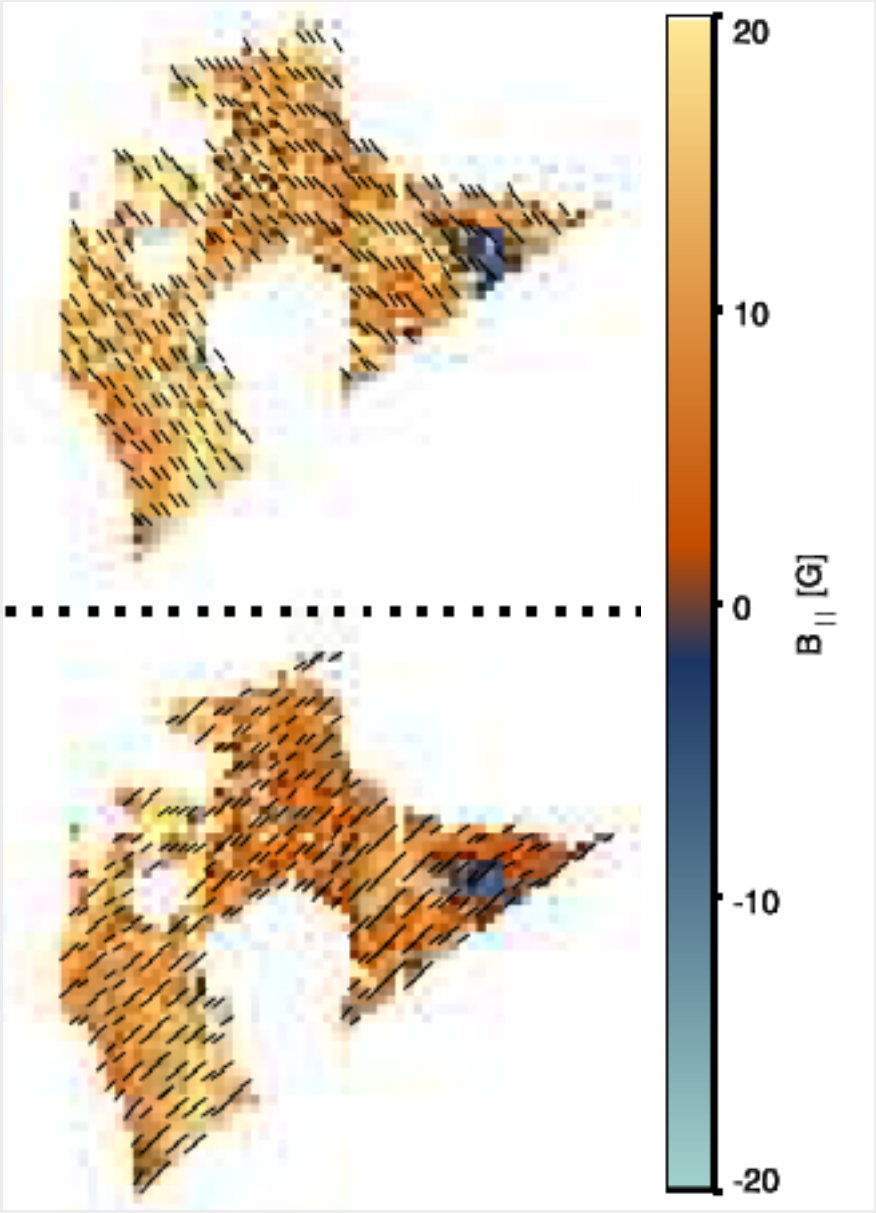
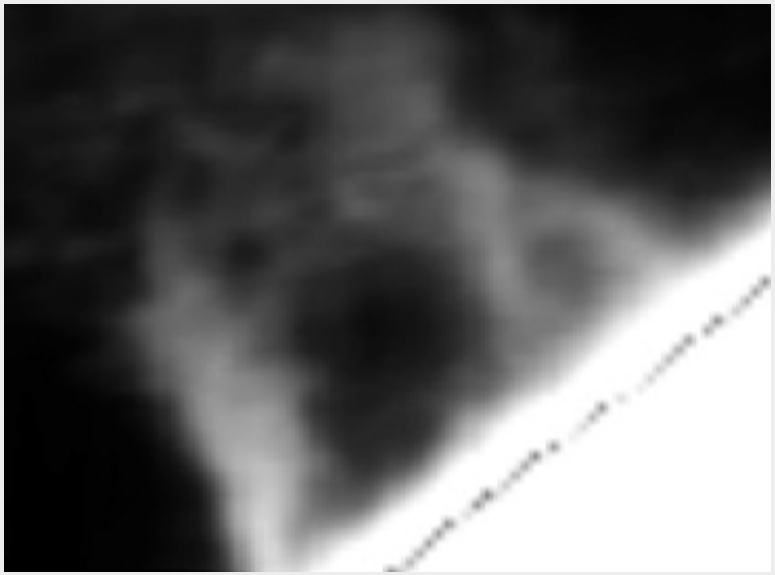
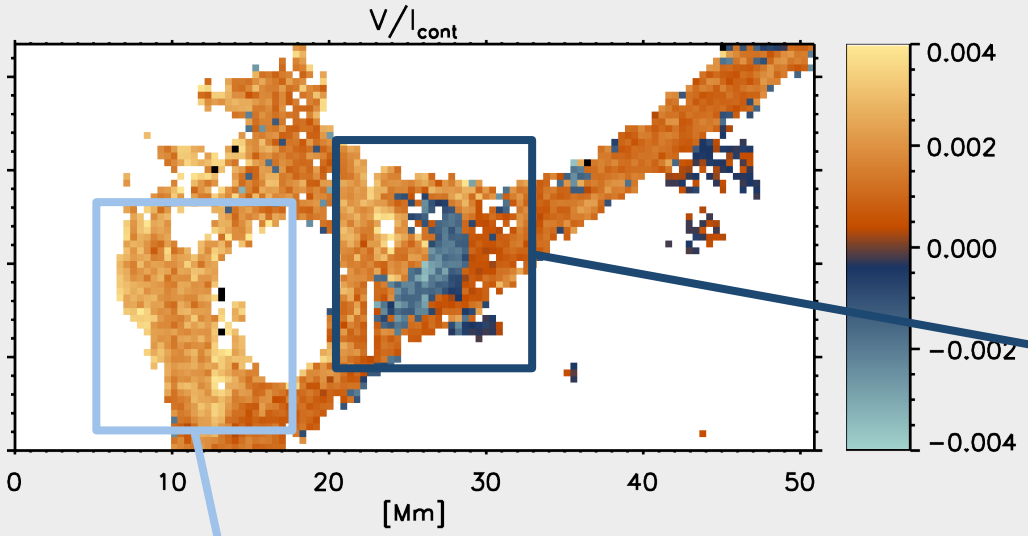
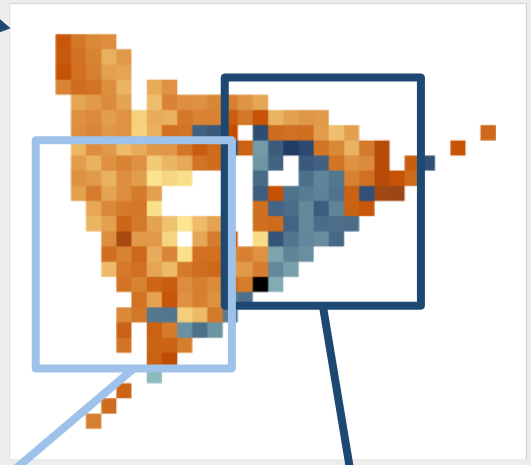


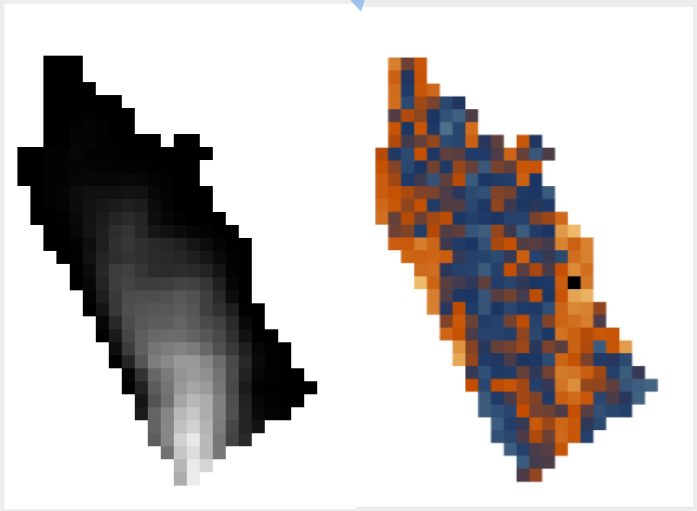
in both cases, the projection of the field onto the plane of the sky is at an angle with the axis of each fibril

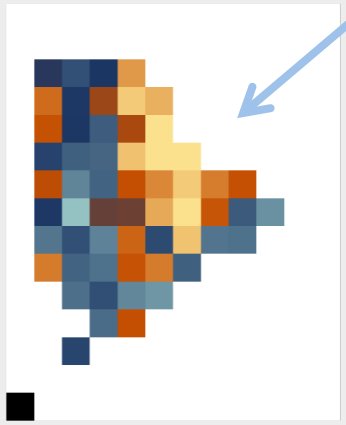


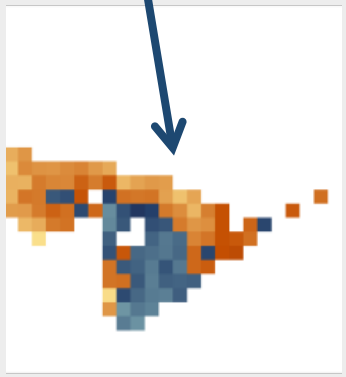
there is a systematic change of polarity in all the fibres











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+

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=

helical fields

“vertical solutions” “horizontal solutions”

stability analysis to disambiguate

according to the Kruskal – Shafranov criterion (Houd & Priest 1979) a kink instability develops when the amount of magnetic twist exceeds a critical value, so that a structure is stable if

$$\frac{2\pi r}{L}\frac{B_z}{B_\theta} \geqslant 1.$$

“vertical solutions”	“horizontal solutions”
1.28	**0.09**

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the magnetic field at the legs of prominence feet connects the main body with the underlying atmosphere

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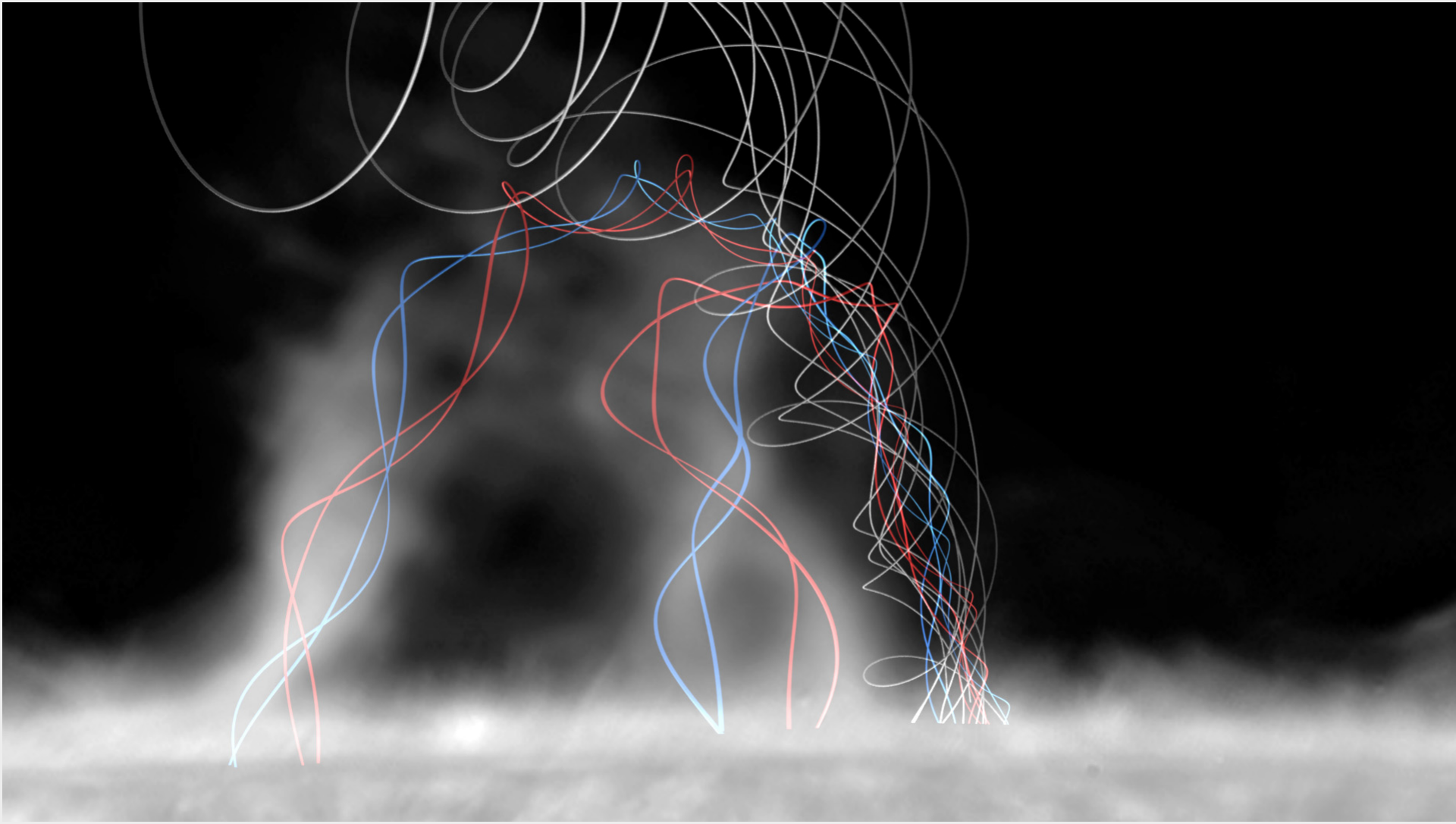
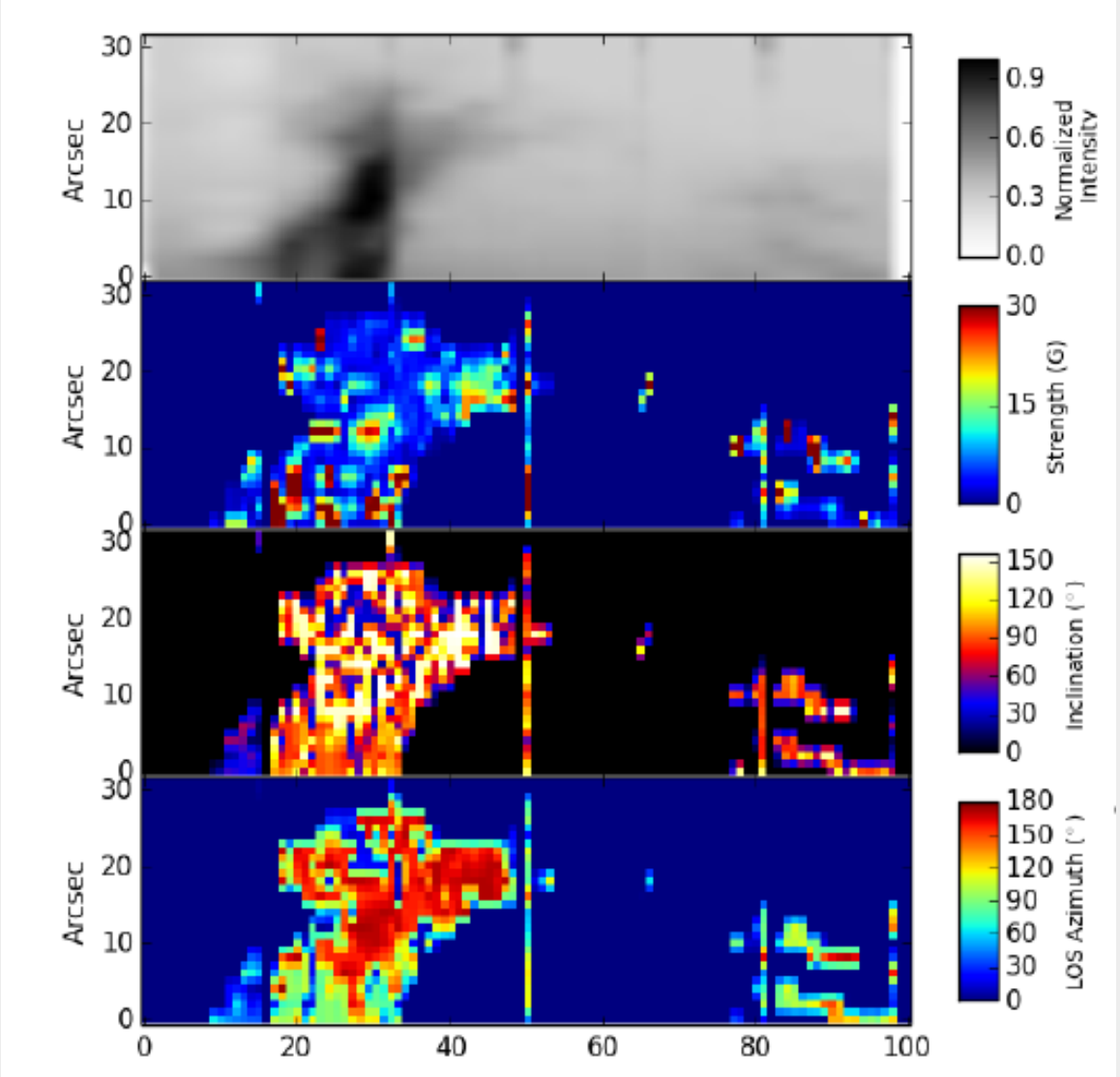


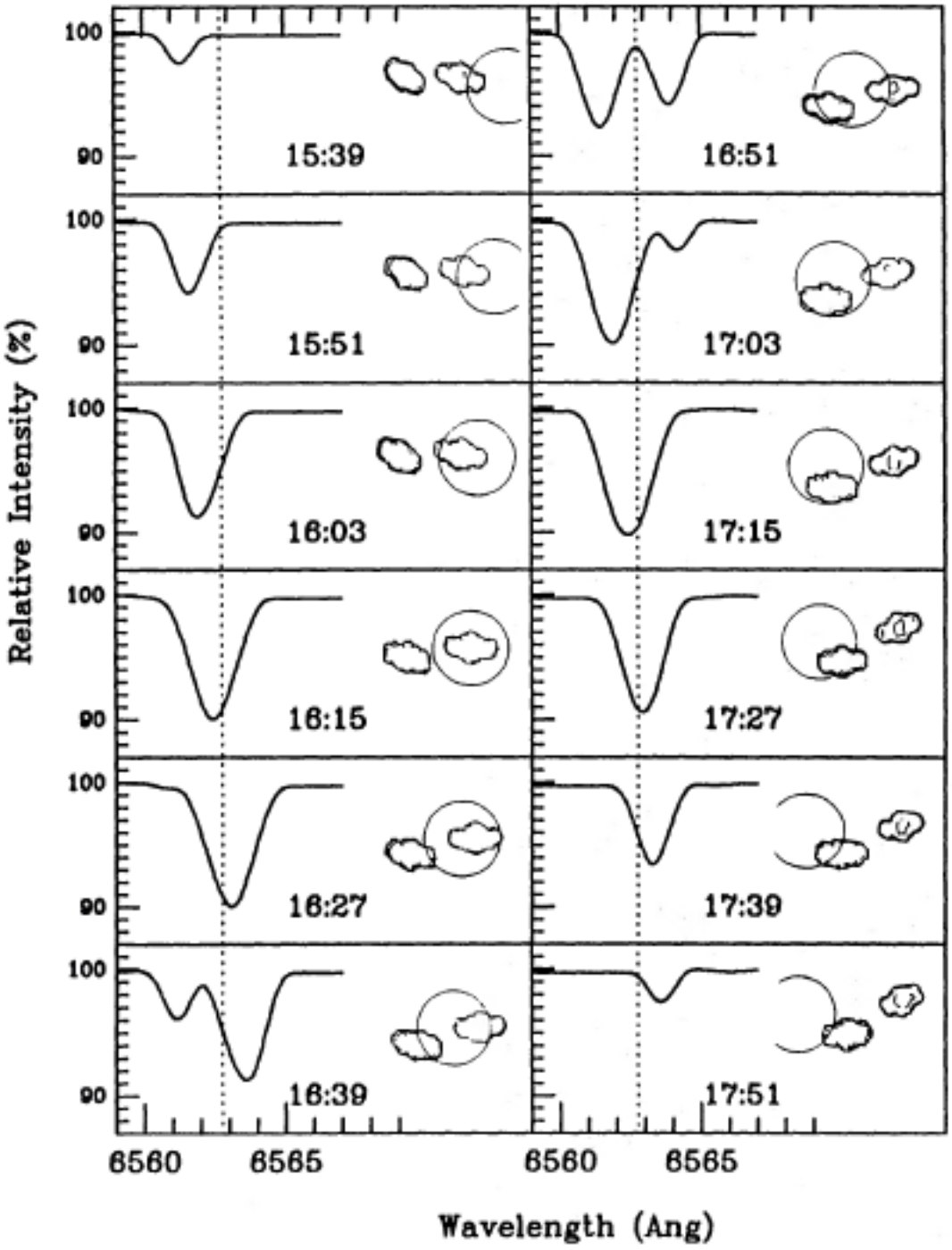
a recent work claims horizontal fields in a similar structure…

… the controversy is served!



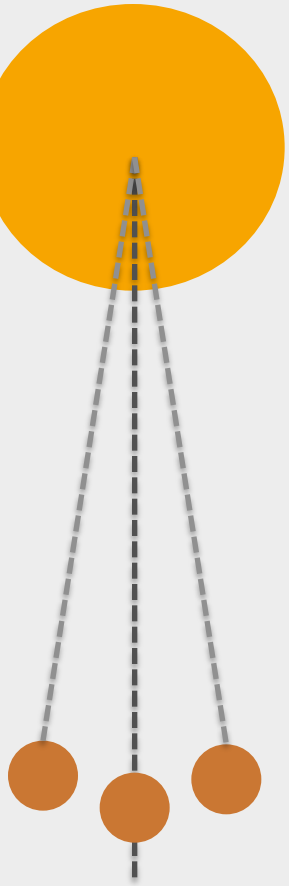
Levens et al. 2016, ApJ, 826, 164

prominences in other stars



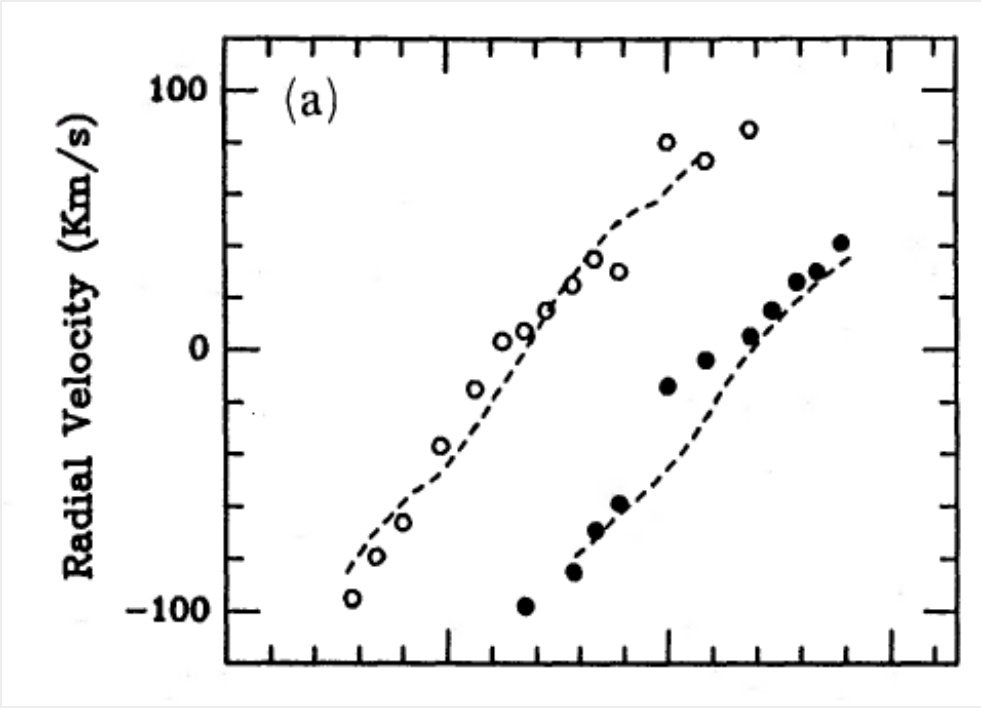
stellar prominences were detected as transient absorption features in H_α that move through the line in the velocity space when the star rotates

Collier Cameron & Robinson 1989, MNRAS, 236, 57



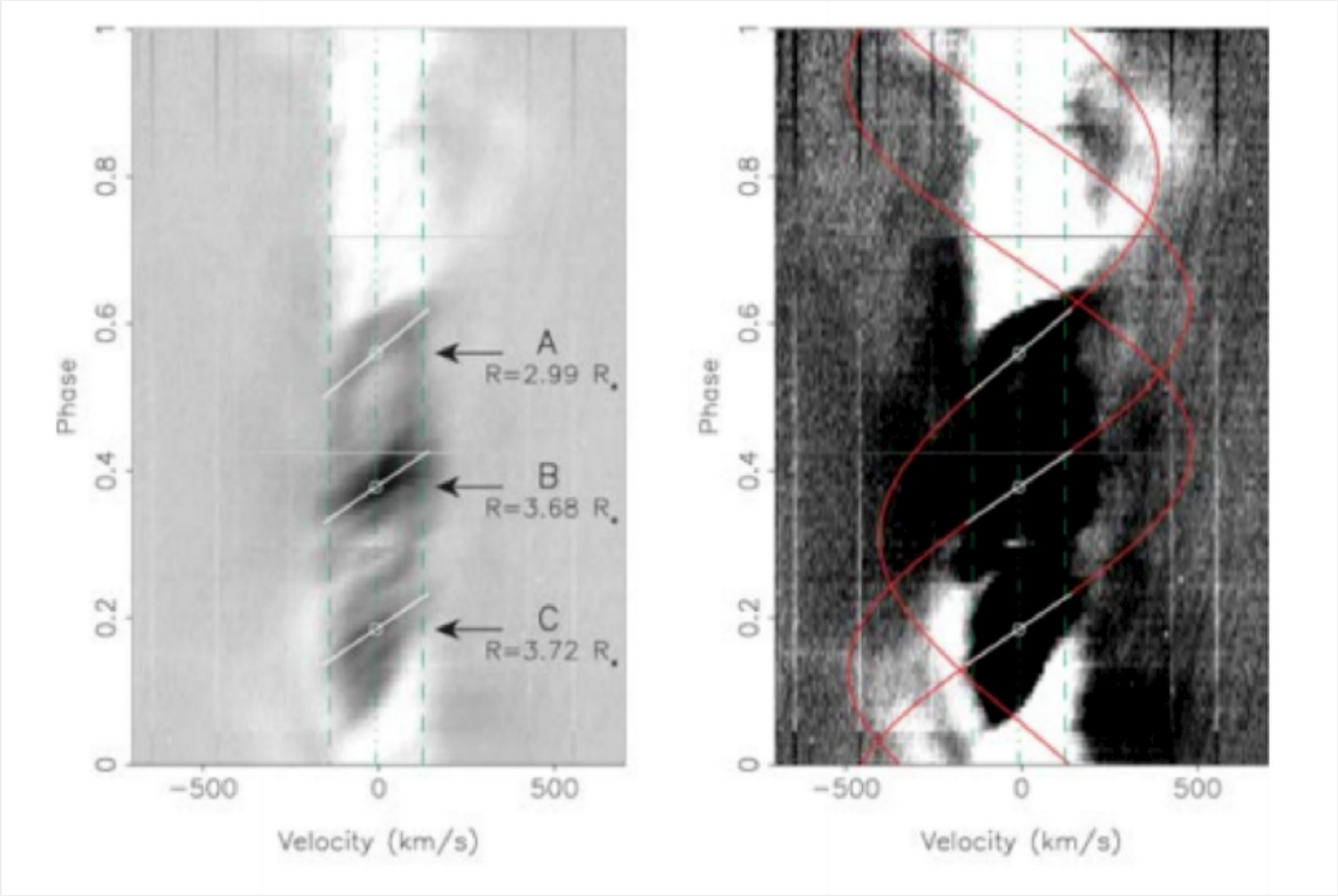
stellar prominences are co-rotating
very high (2-3 stellar radii)

→ the velocity of the transit is linear with time



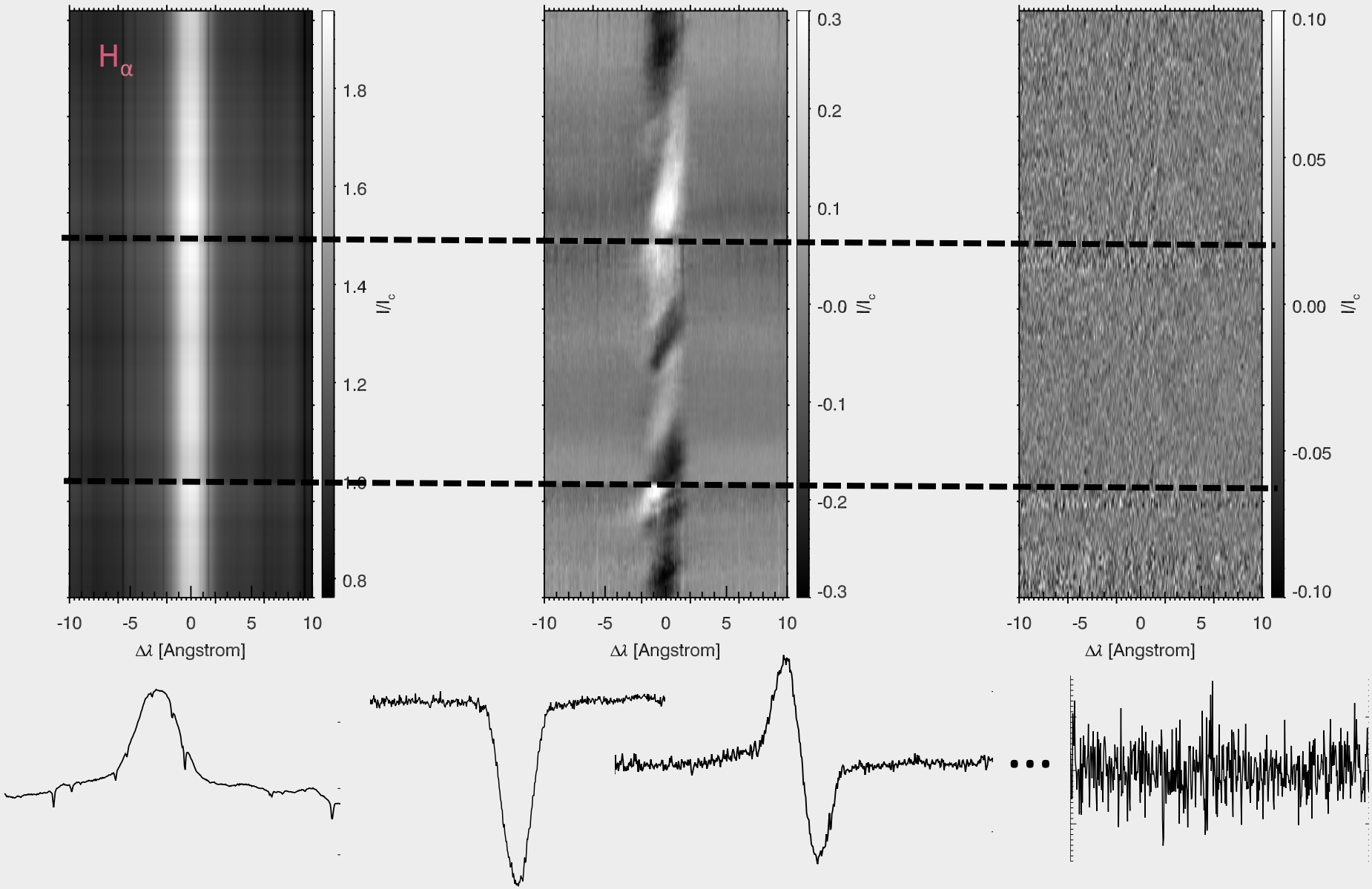
Collier Cameron & Robinson 1989, MNRAS, 236, 57

the transition from a more prominence-like structure to a more filament-like structure has been also detected



Dunstone et al. 2006, MNRAS, 365, 530

last August we obtained HARPS-N observations of the M2 star HK Aqr



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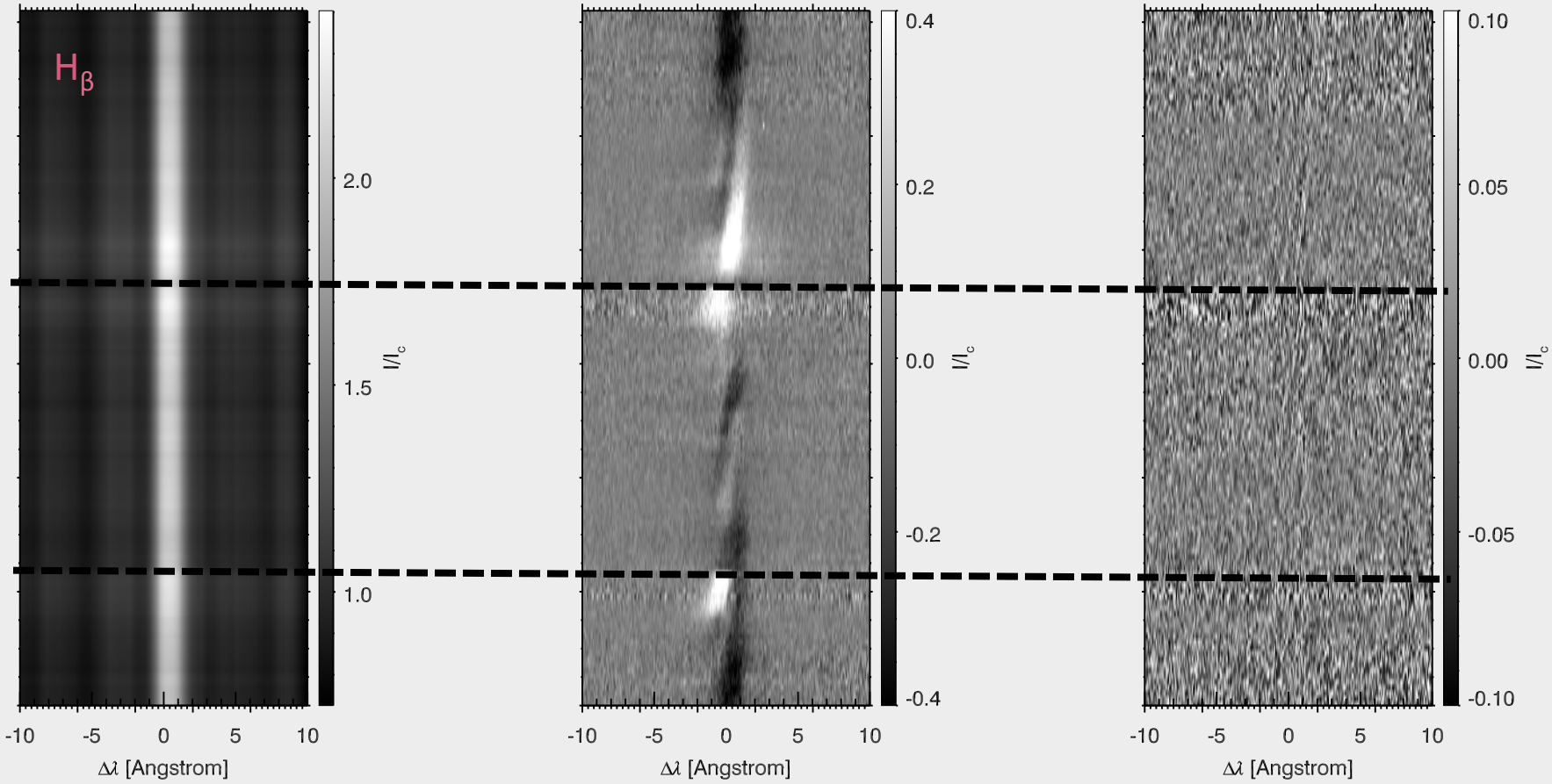

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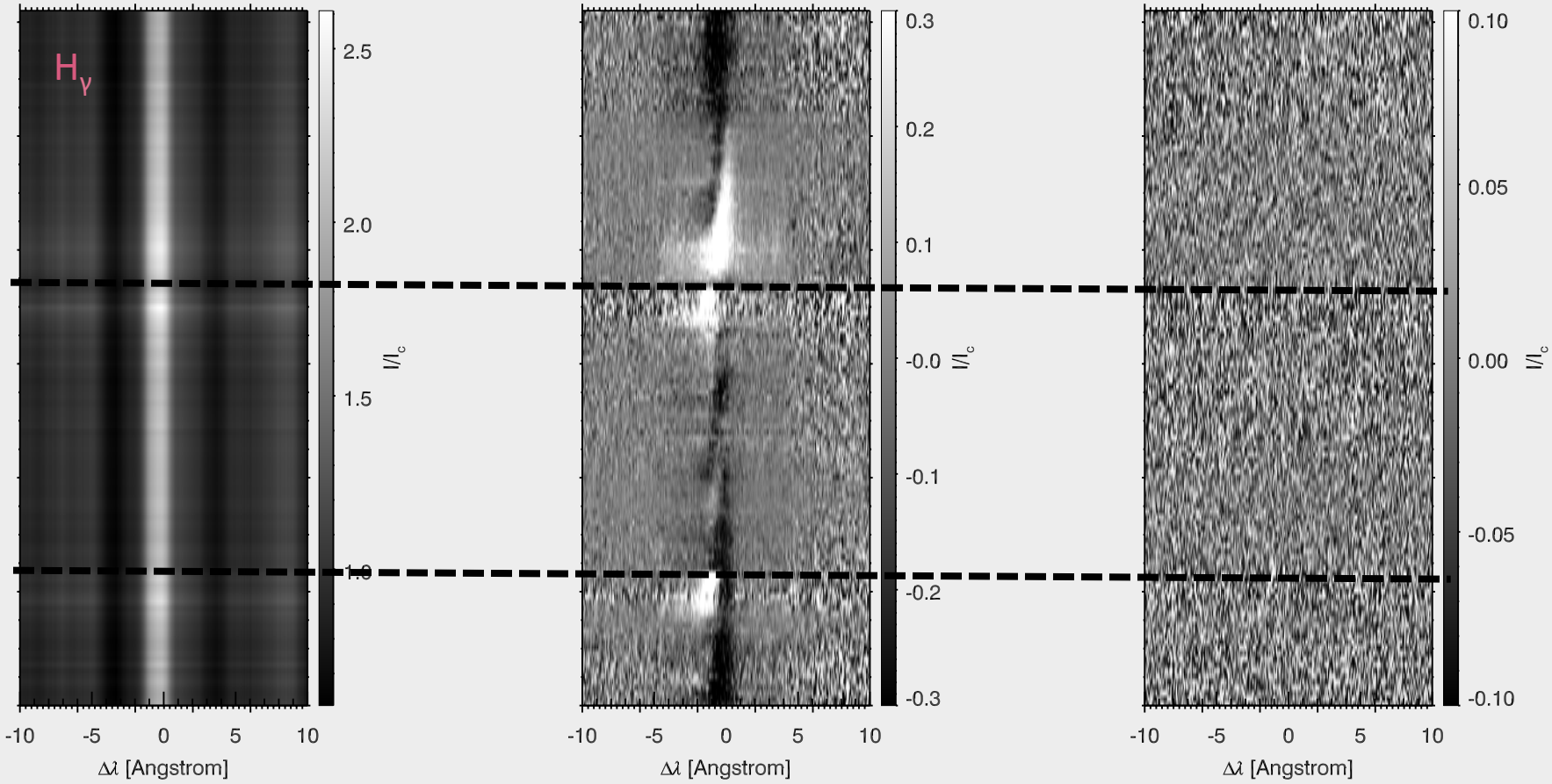

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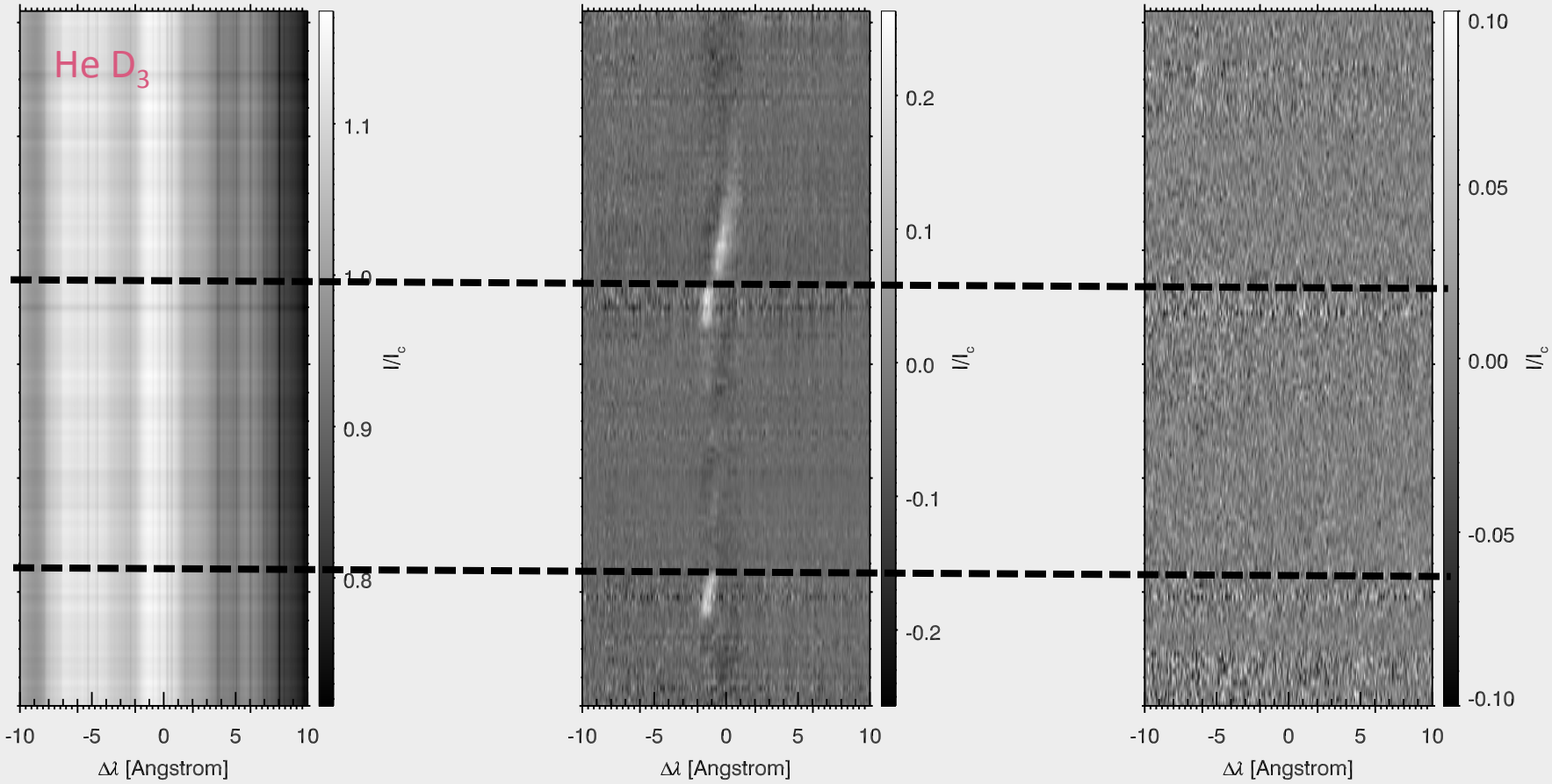

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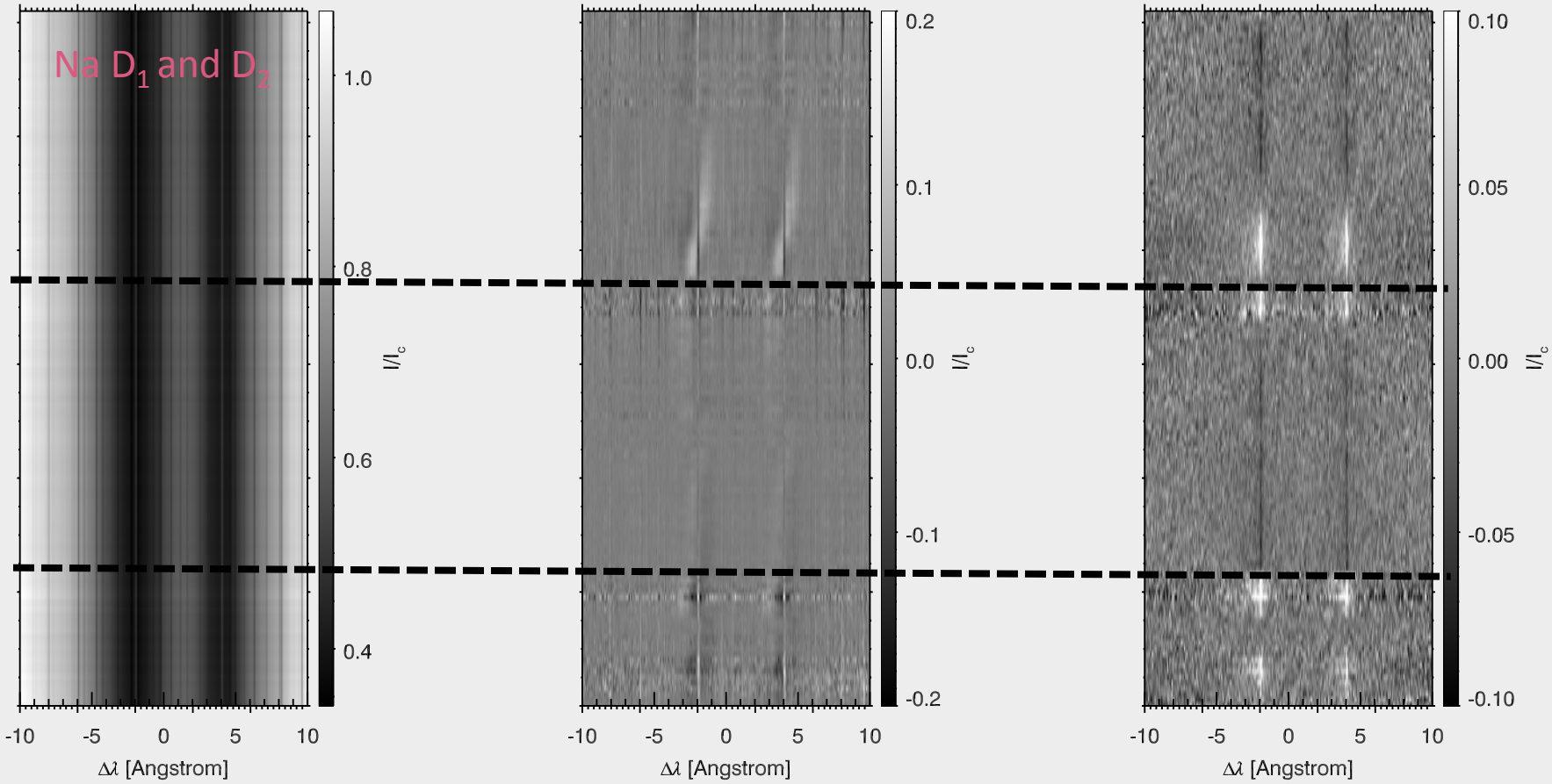
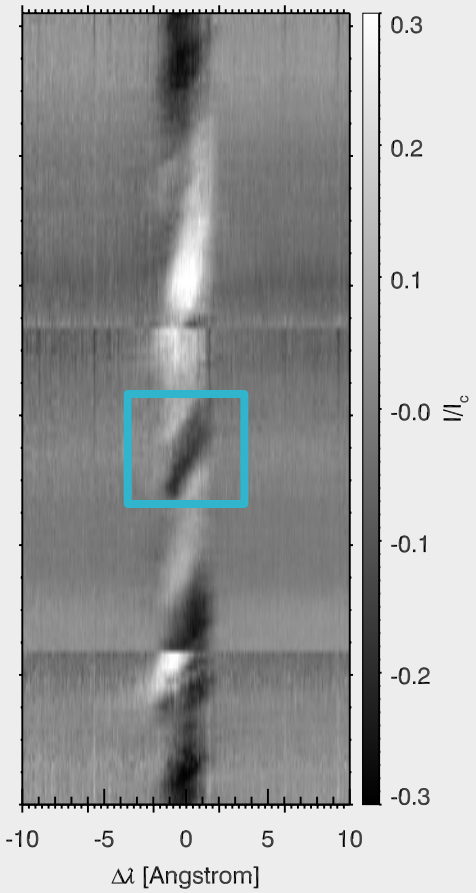
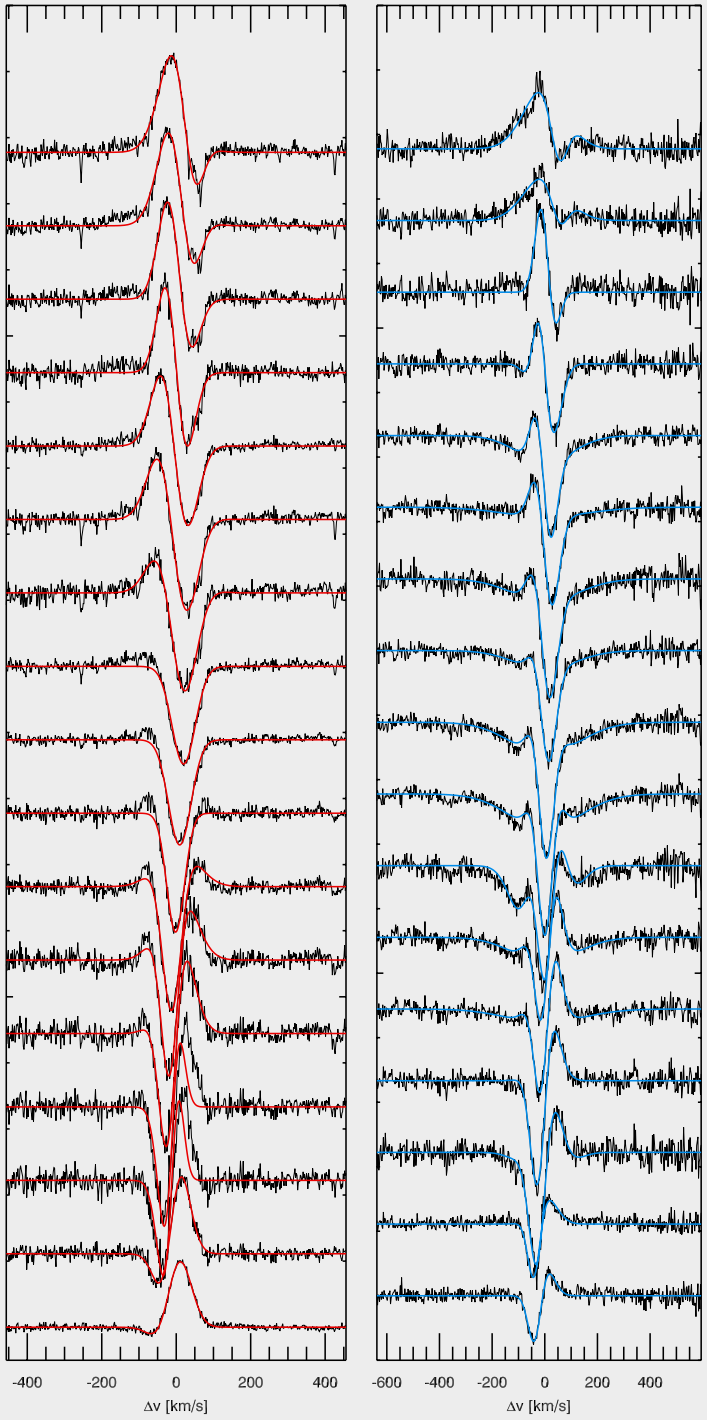
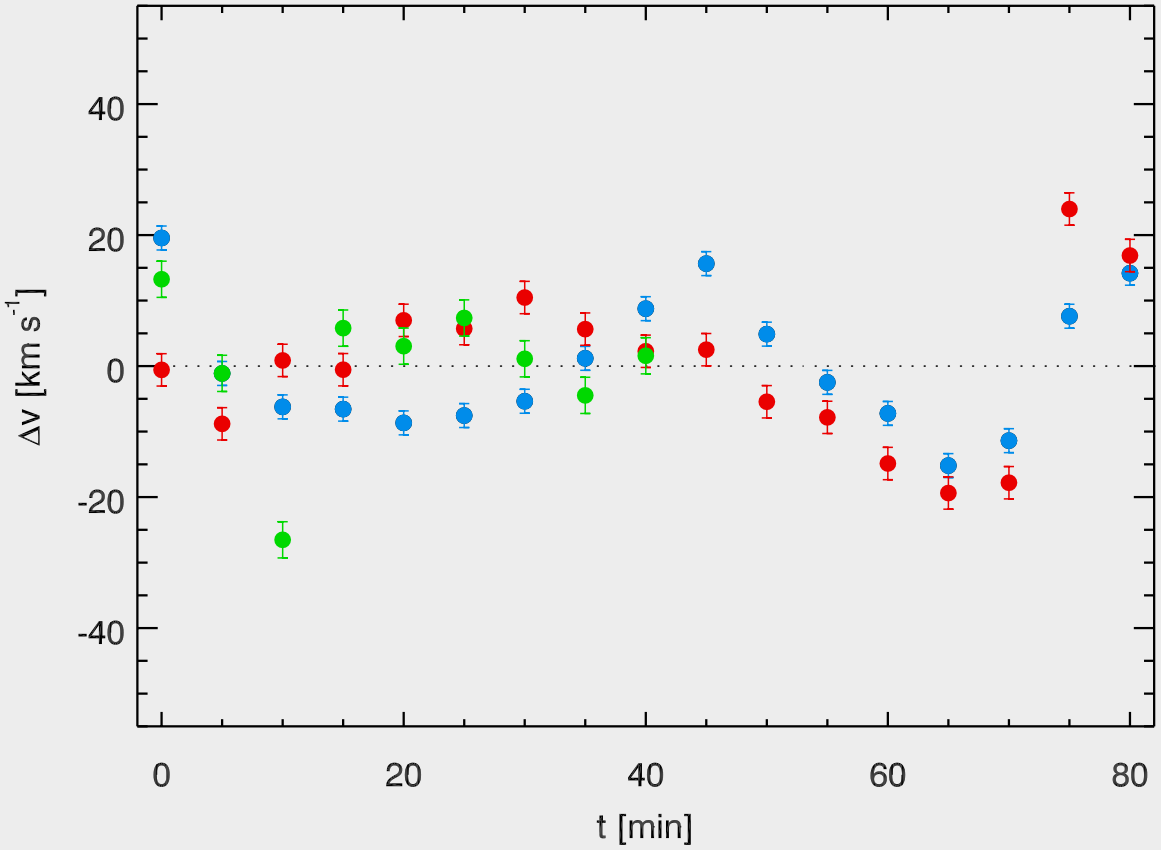



0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
I/I$_c$
-10
-5
0
5
10
Δλ [Angstrom]


-400
-200
0
200
400
Δv [km/s]
-600
-400
-200
0
200
400
Δv [km/s]

the velocity of the absorption feature has an oscillatory character



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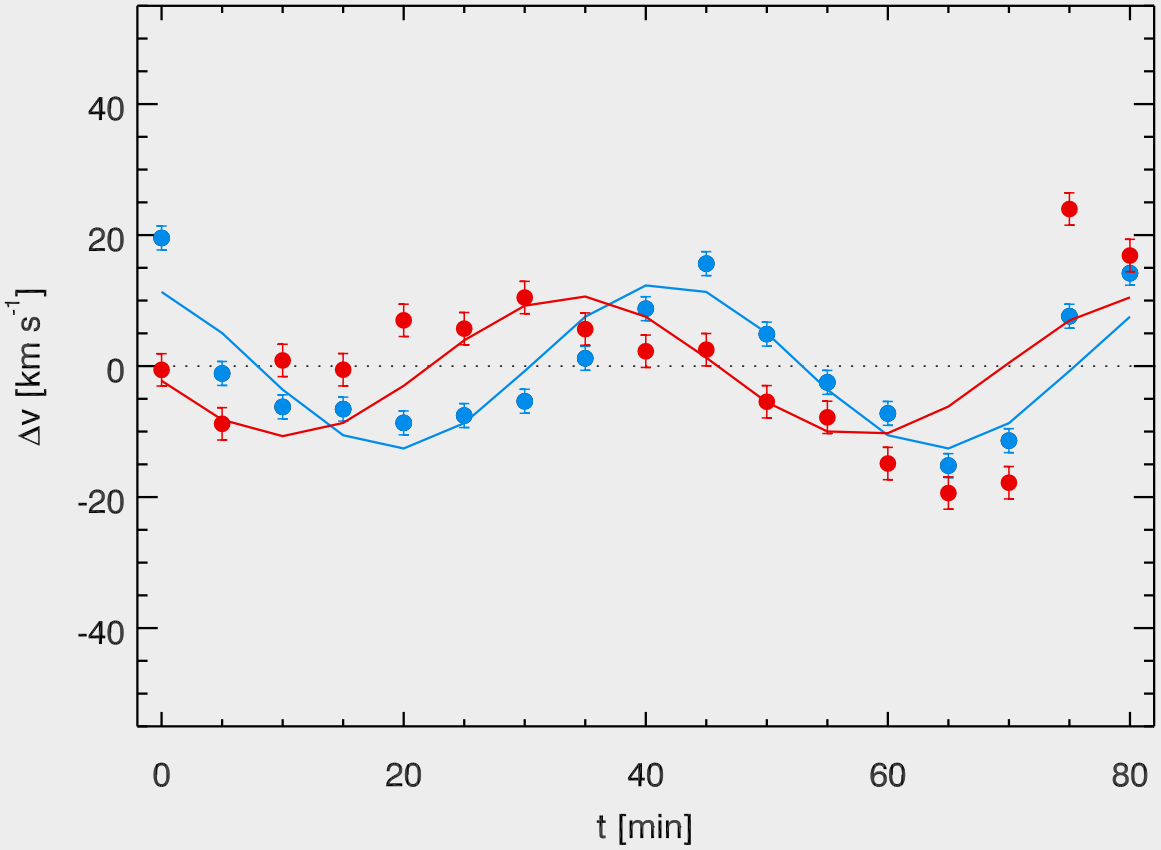

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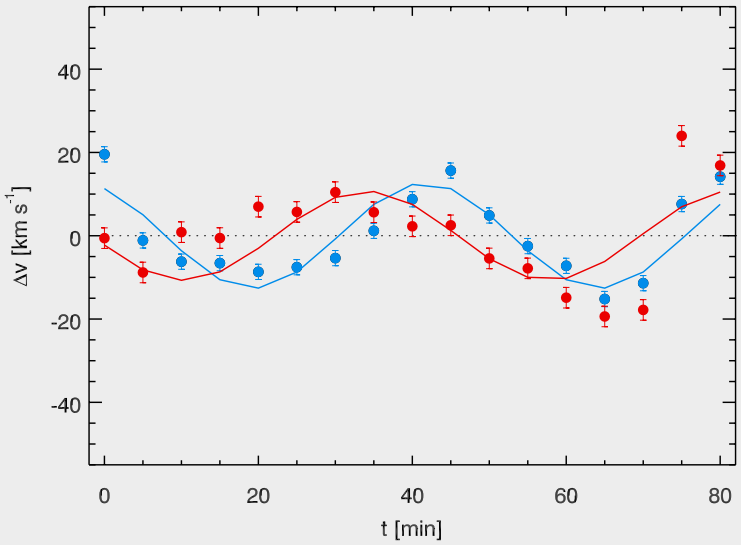
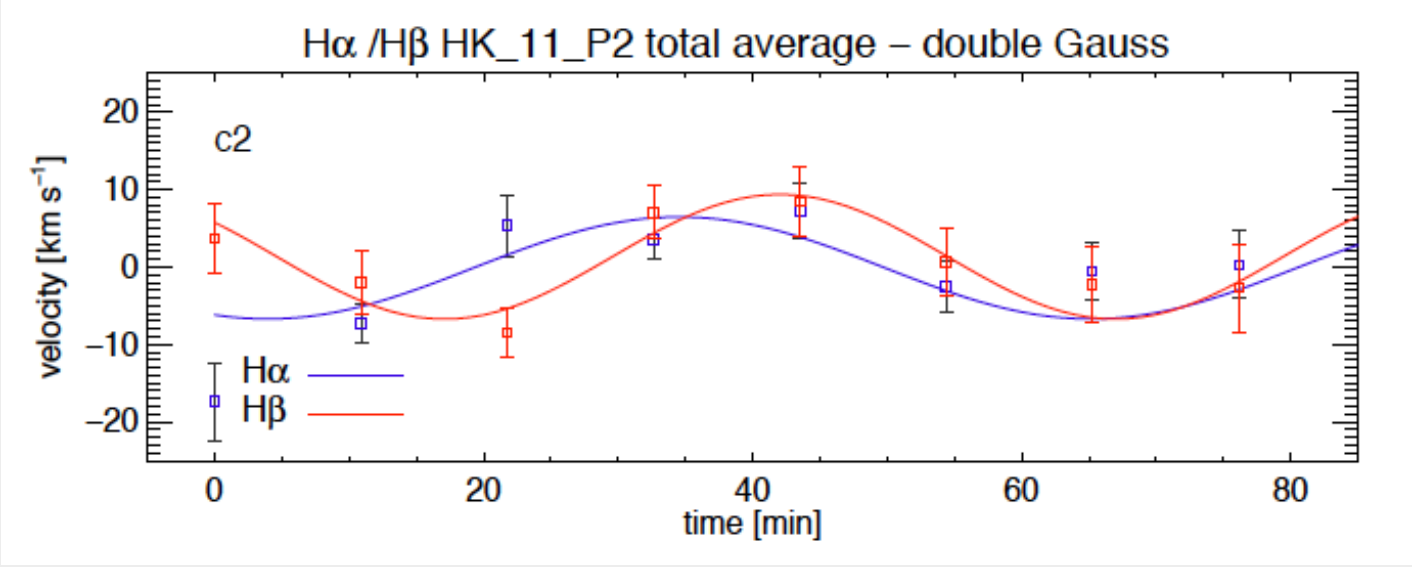


Leitzinger et al. 2016, MNRAS, 463, 935



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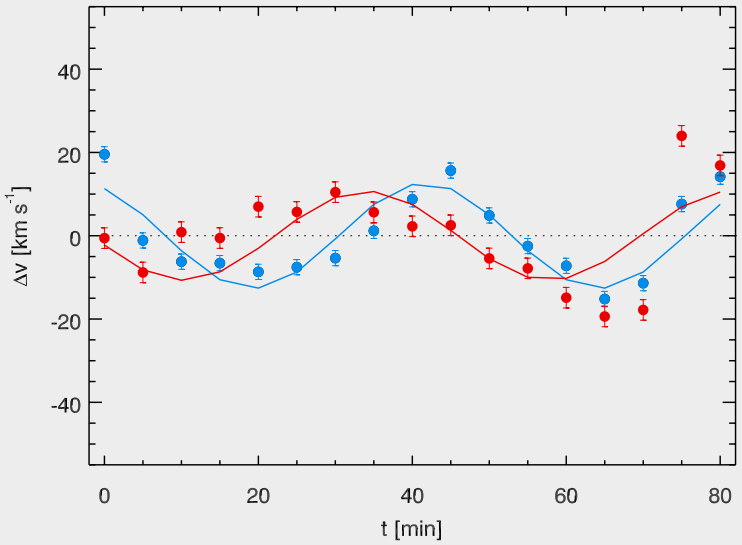

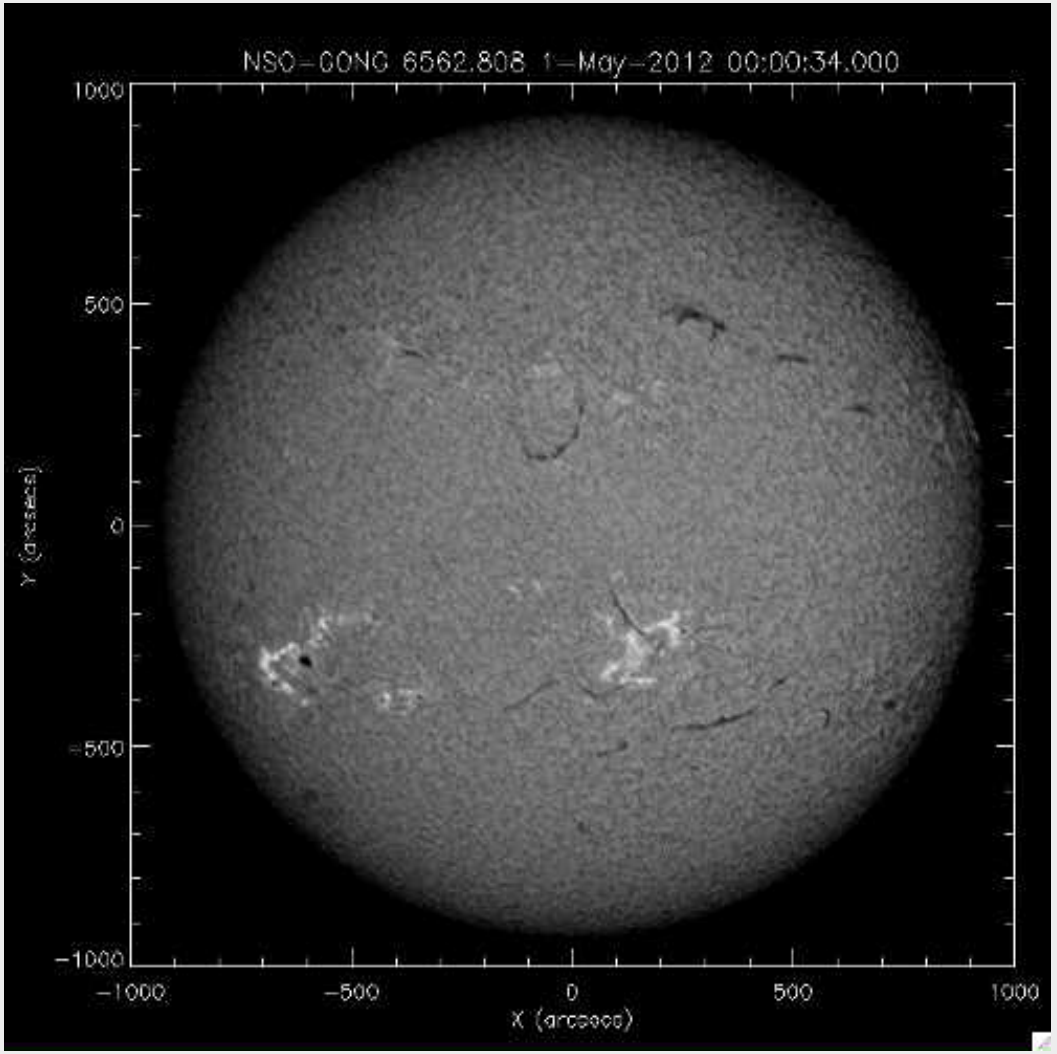

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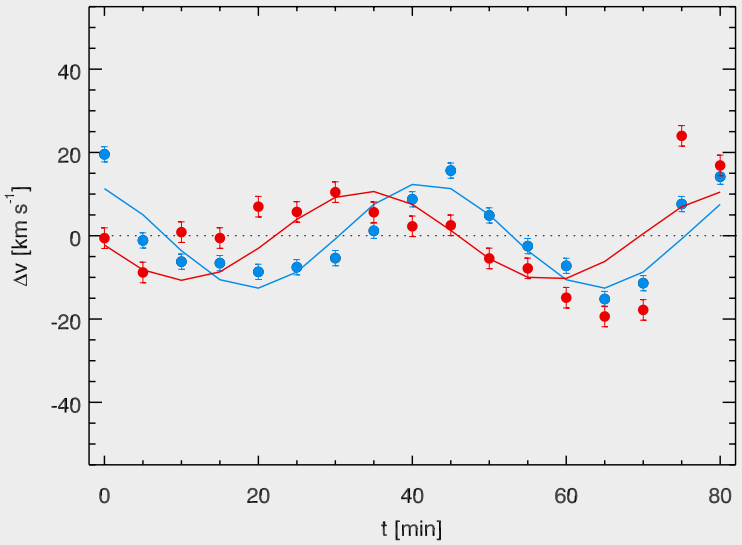
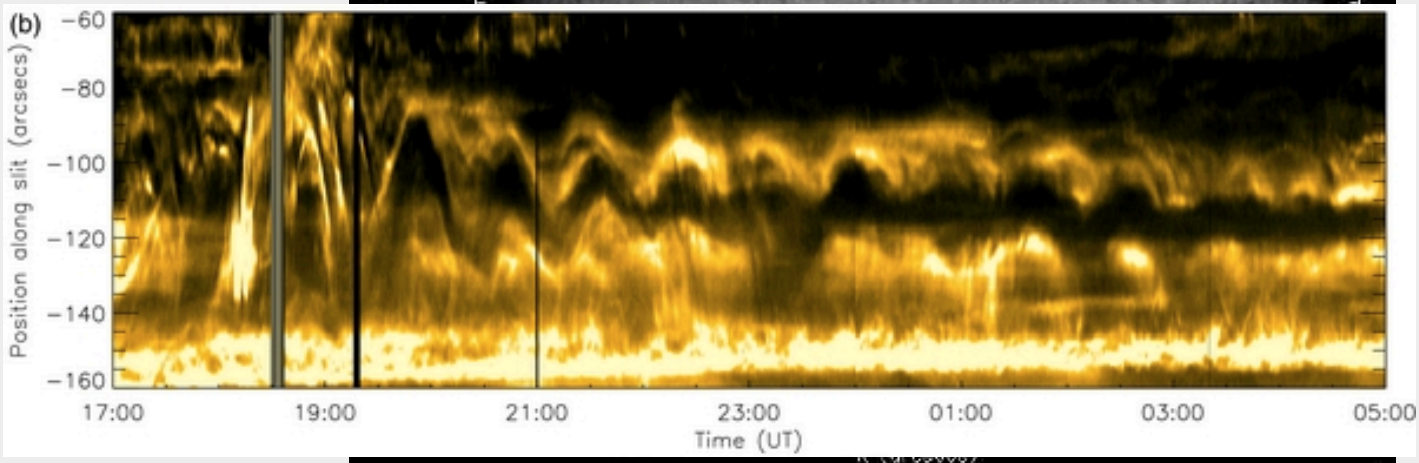
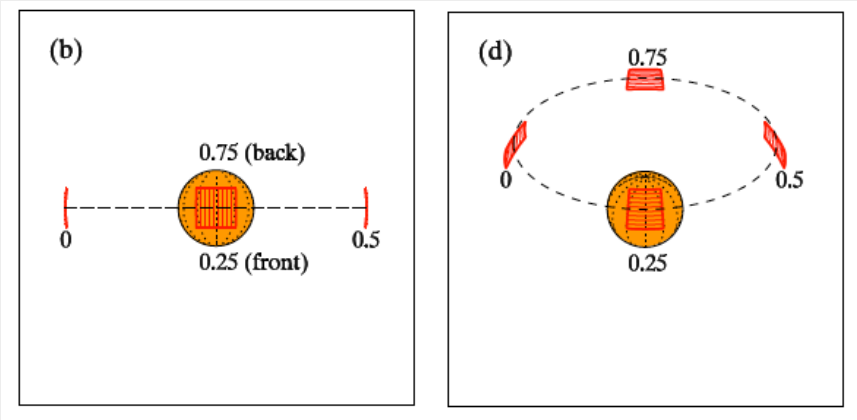


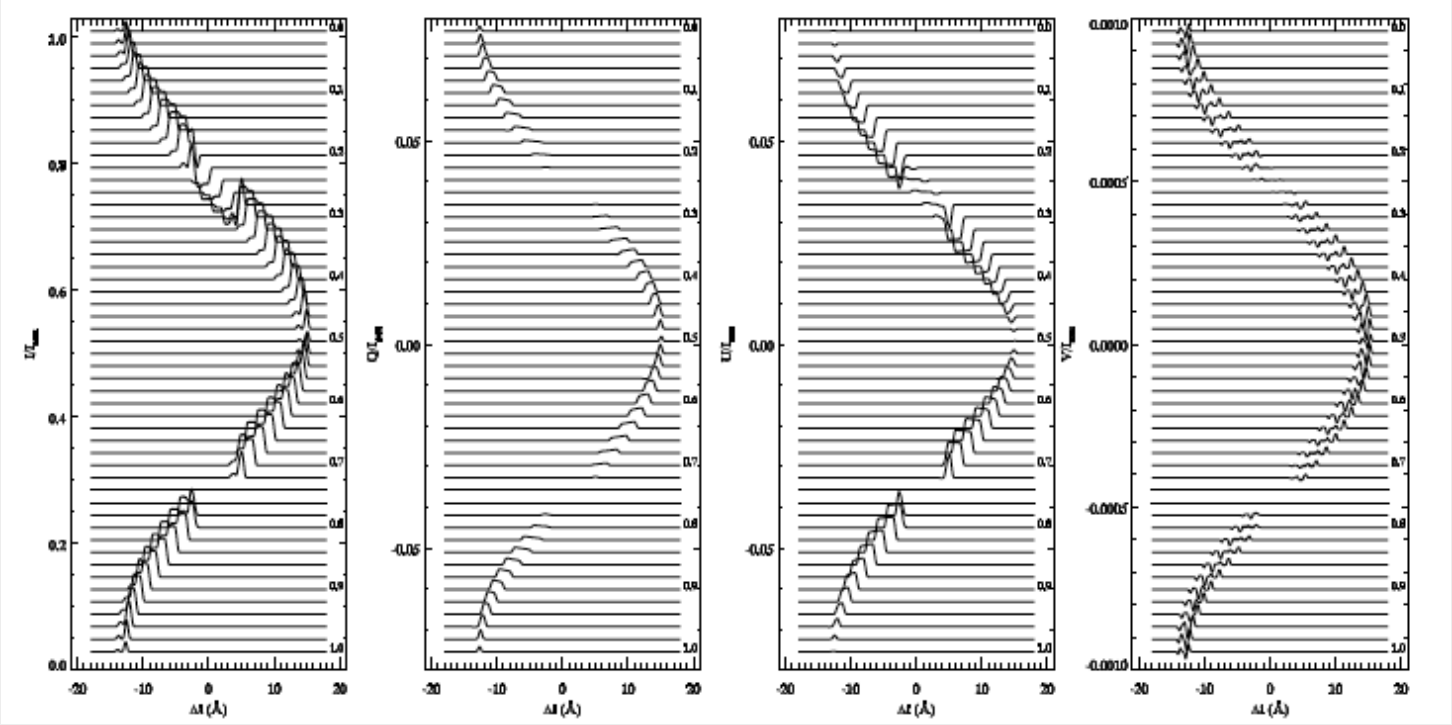
are they the same phenomenon?



can we measure magnetic fields in stellar prominences ?



Felipe et al. 2016, MNRAS, in press



can we measure magnetic fields in stellar prominences ?

in a near future [2019] with MIRADAS@GTC