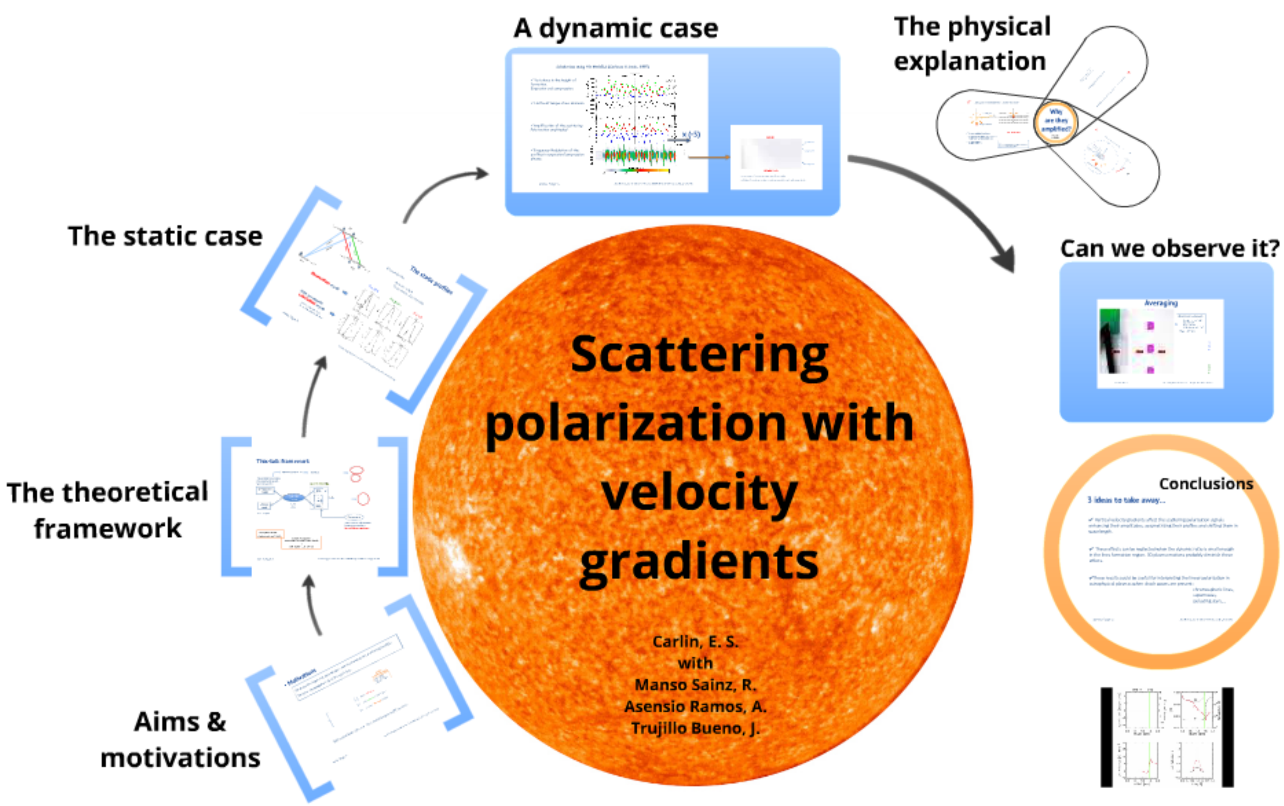

A dynamic case
The physical explanation
The static case
Can we observe it?
Scattering polarization with velocity gradients
Carlin, E. S.
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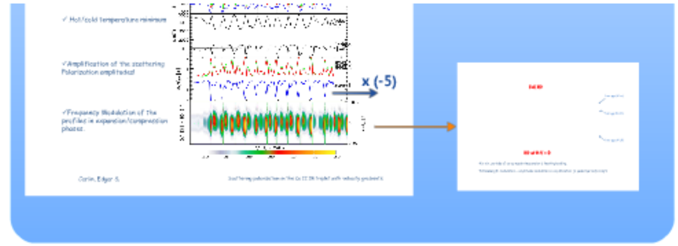
The theoretical framework
Conclusions
Aims & motivations



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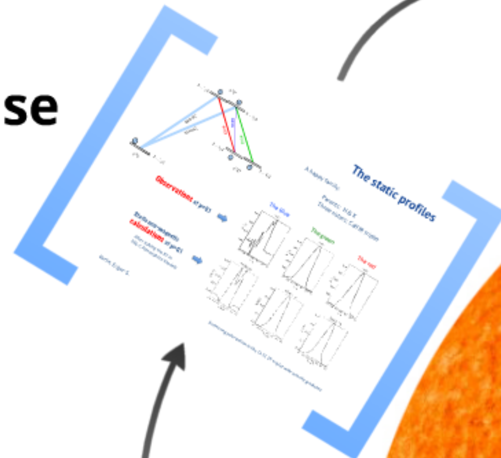

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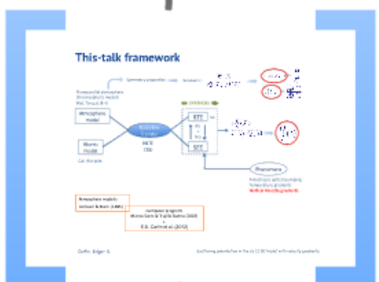
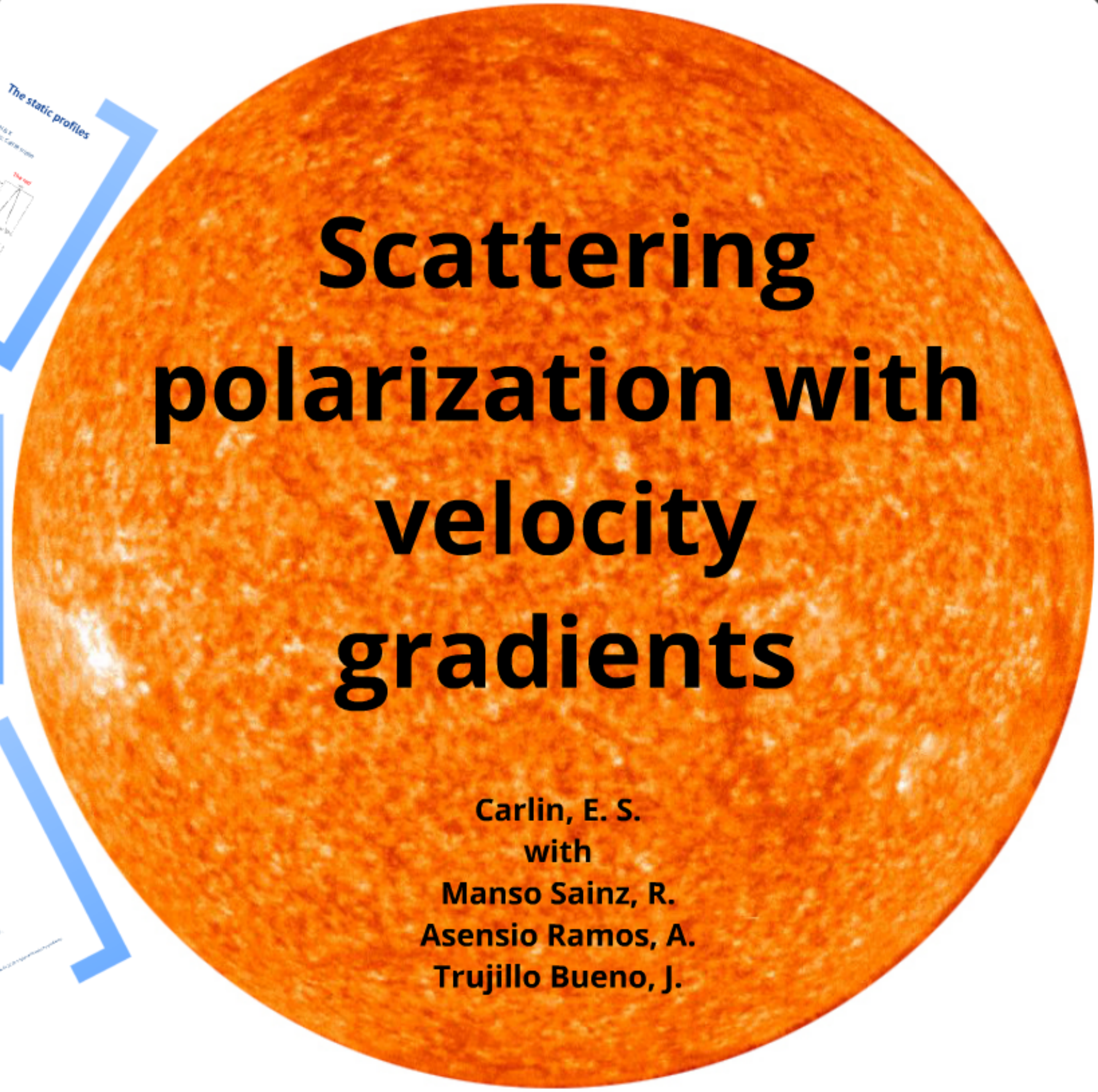


Aims & motivations



Scattering polarization with velocity gradients

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• Motivations

To study the impact of macroscopic velocity fields on the scattering line POL.

To infer chromospheric **B** in the quiet Sun.

QUIET CHROMOSPHERE

fields: WEAK
lines : BROAD
velocities : HIGH

$$\begin{cases} \mathbb{Z} = \dfrac{\Delta\lambda_B}{\Delta\lambda_D} \propto \dfrac{\lambda_0 B}{\sqrt{2kT/m + v_{micro}^2}} \\ \mathbb{H} = \dfrac{\Delta\lambda_B}{\Delta\lambda_{at}} \approx \dfrac{B}{10^{-7}/t_{life}} \\ \mathbb{D} = \dfrac{(\lambda_0/c)v_z}{\Delta\lambda_D} = \dfrac{v_z}{\sqrt{2kT/m + v_{micro}^2}} \end{cases}$$

< 1	Zeeman: insensitive
≈ 1	Hanle : sensitive in CaII IR triplet
> 1	Dynamism : WARNING! → Shocks

Differential Hanle effect → Zero-field polarization (ZFP) needed .

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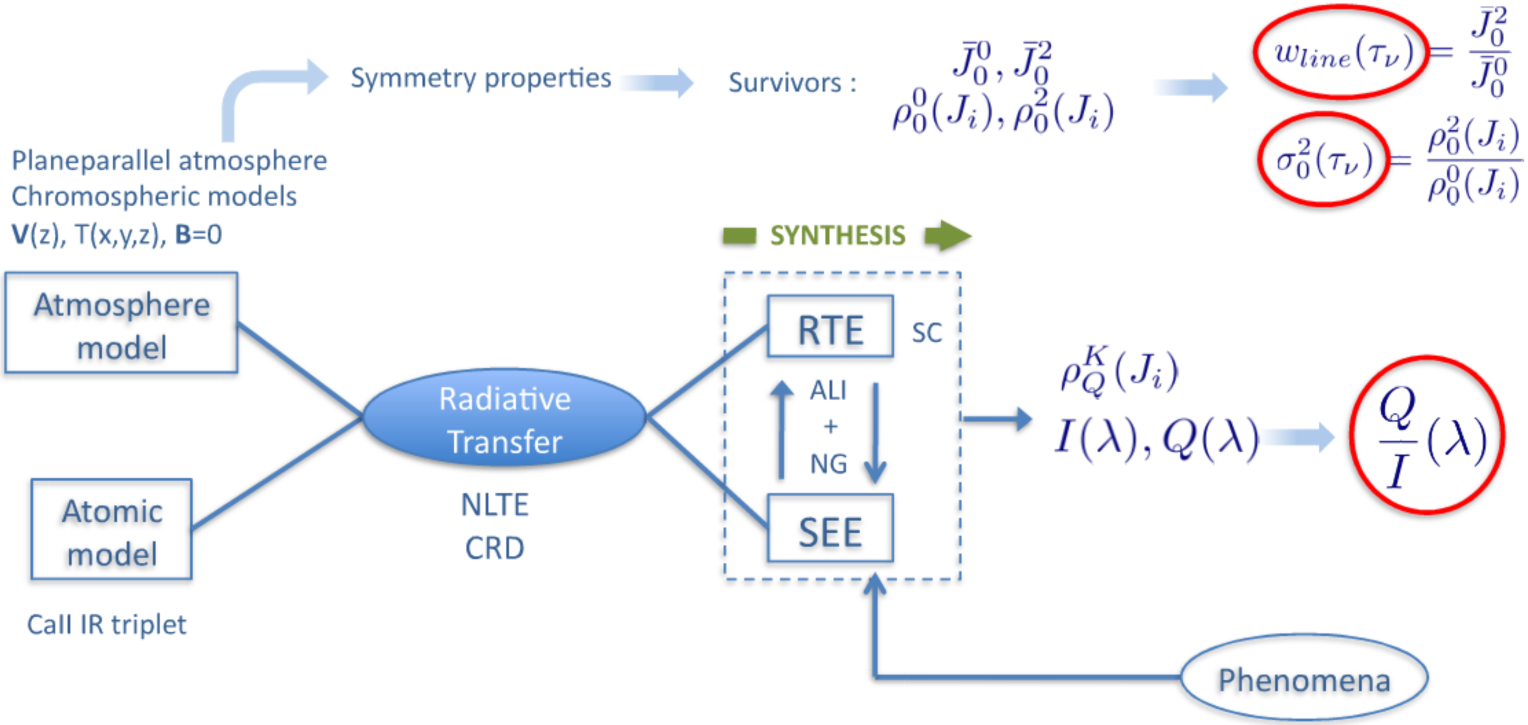
This-talk framework



Anisotropic optical pumping
Temperature gradients
Vertical Velocity gradients

$$\phi = \phi'_{lu}(\nu - \nu_0 - \nu_0 \mu v(z)/c)$$

$$\phi \Rightarrow \bar{\bar{\kappa}}(z,\nu,\mu) \Rightarrow \mathrm{RTE}$$

$$\phi \Rightarrow \bar{J}^K_Q \Rightarrow \mathrm{SEE}$$

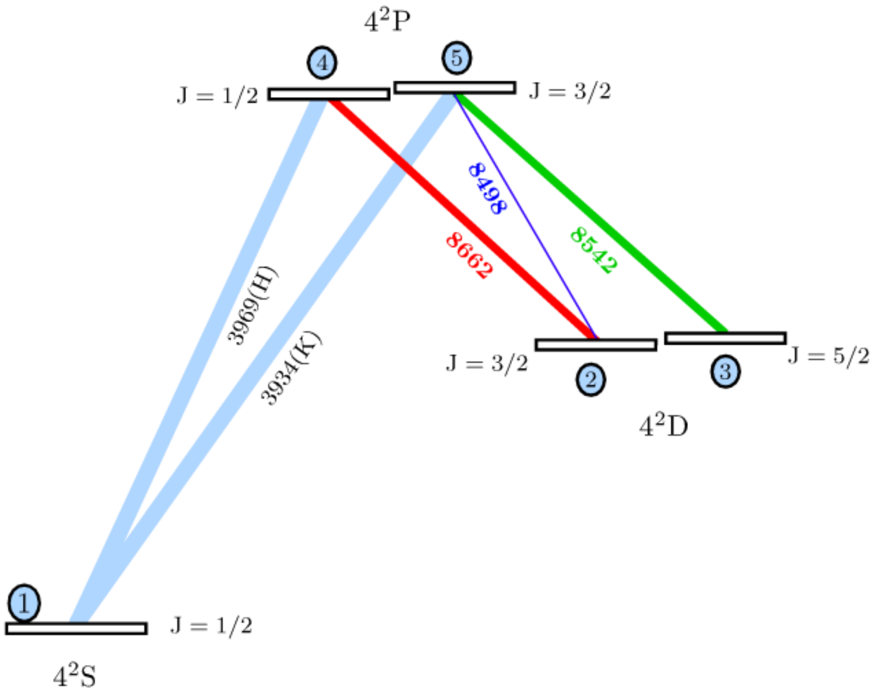
Atmosphere models:
Carlsson & Stein (1995)

Computer program:
Manso Sainz & Trujillo Bueno (2003)
+
E.S. Carlin et al. (2012)

The static profiles

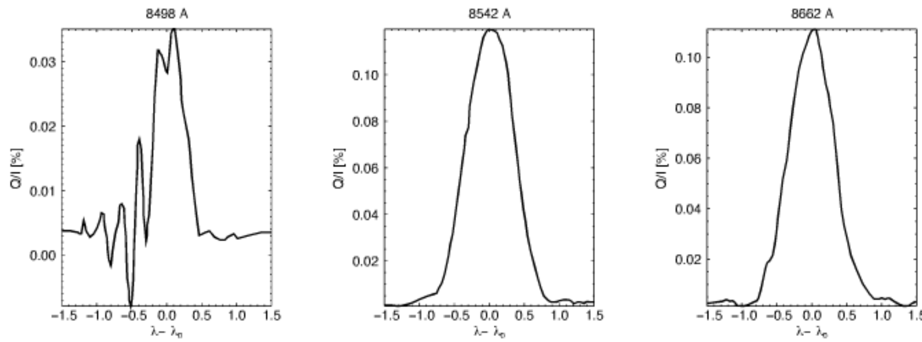
A happy family:

Parents: H & K
Three sisters: CaII IR triplet



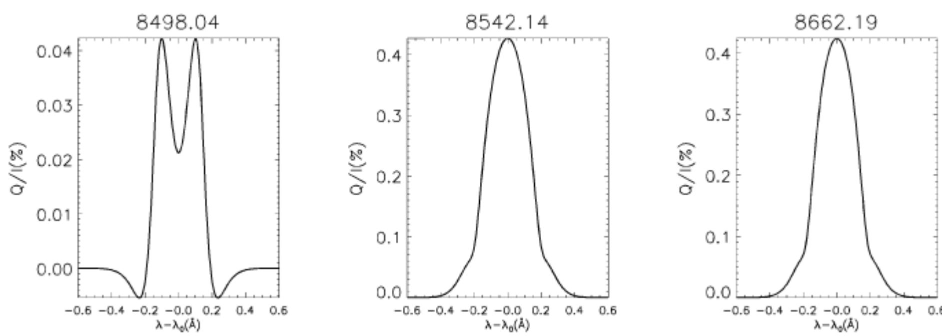
The Blue | The green | The red

Observations at μ=0.1

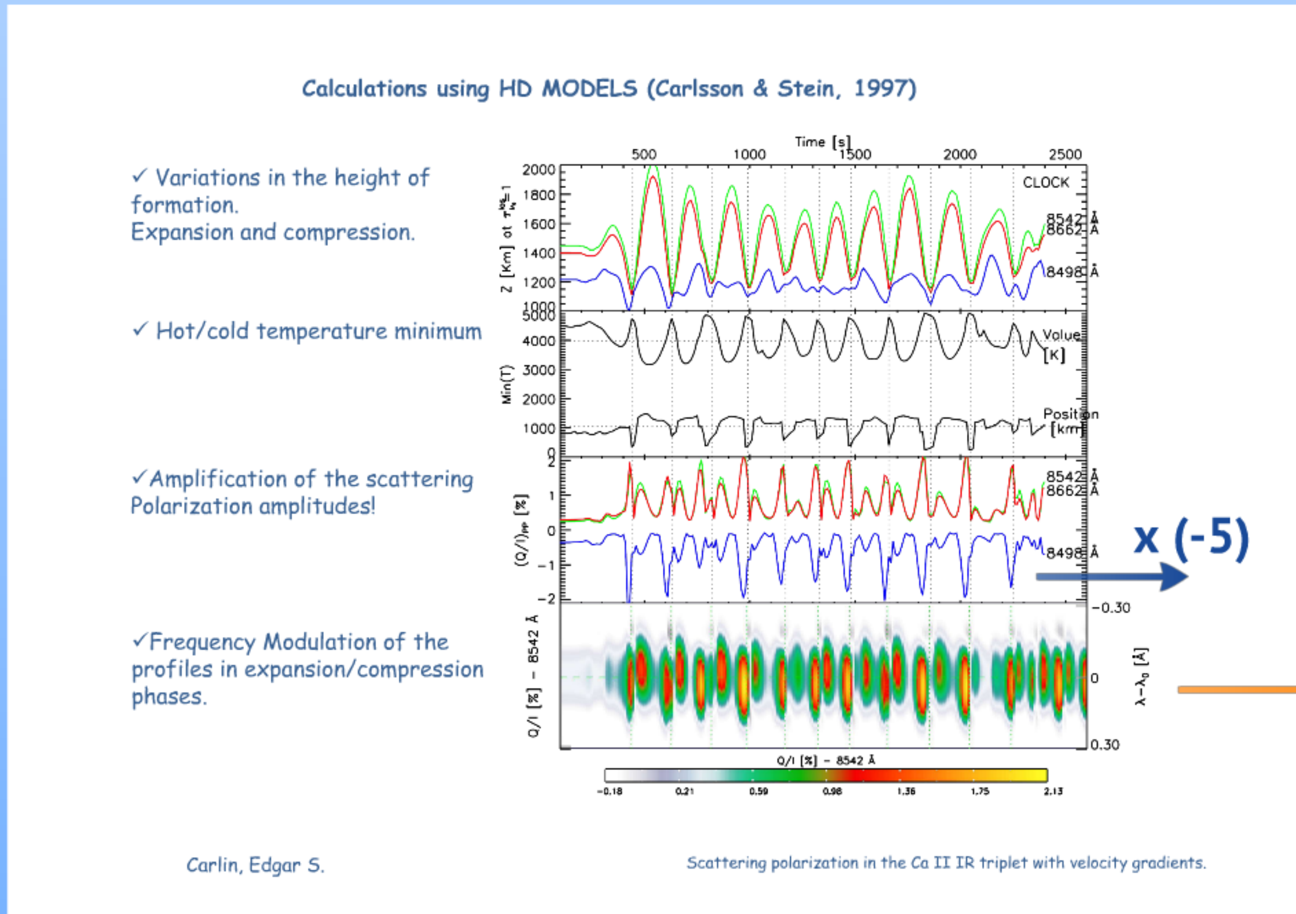


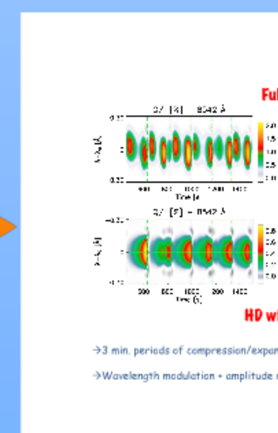
Static non-magnetic calculations at μ=0.1

After solving the RT in
FAL-C Atmosphere Models



A dynamic case





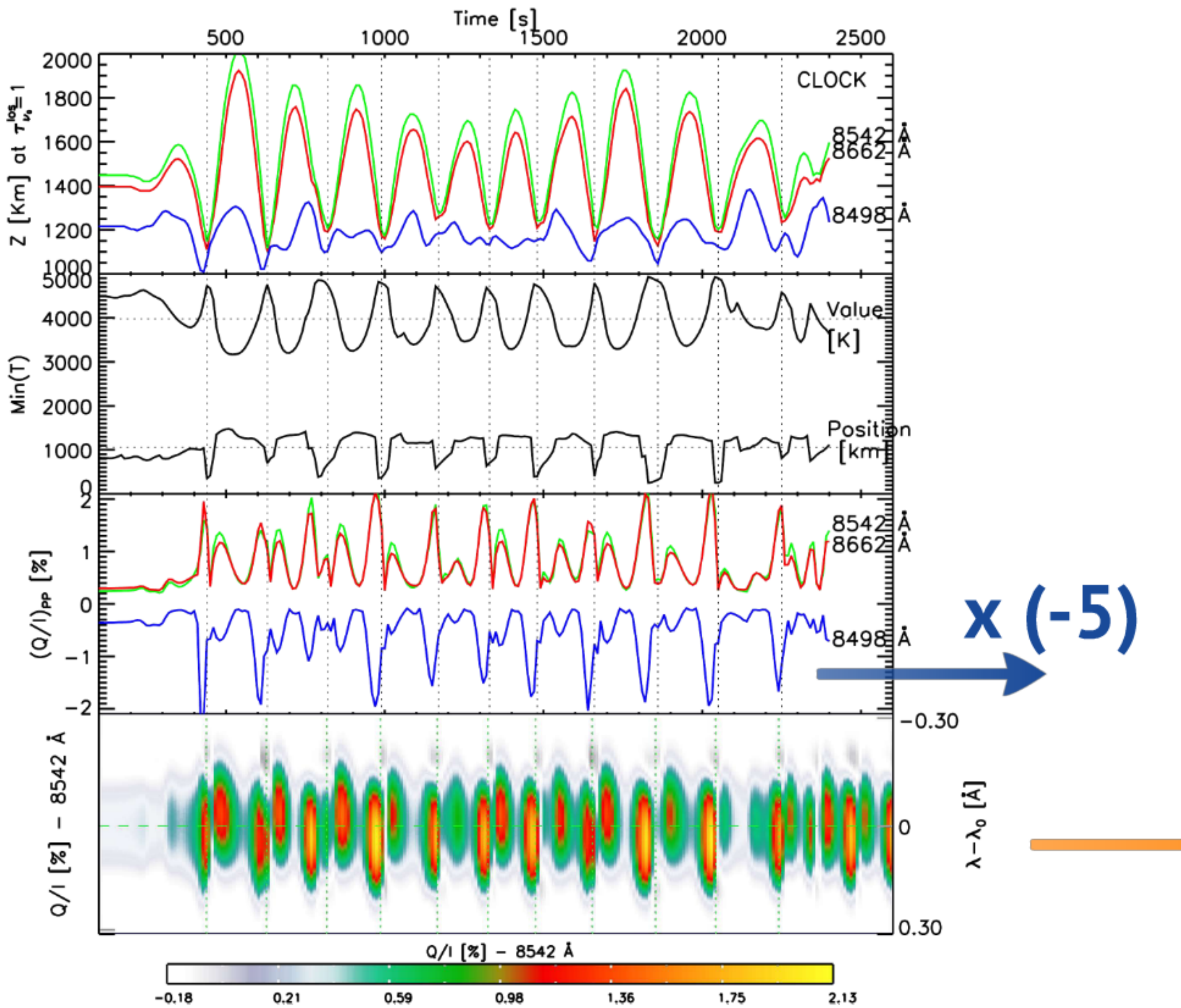
Calculations using HD MODELS (Carlsson & Stein, 1997)

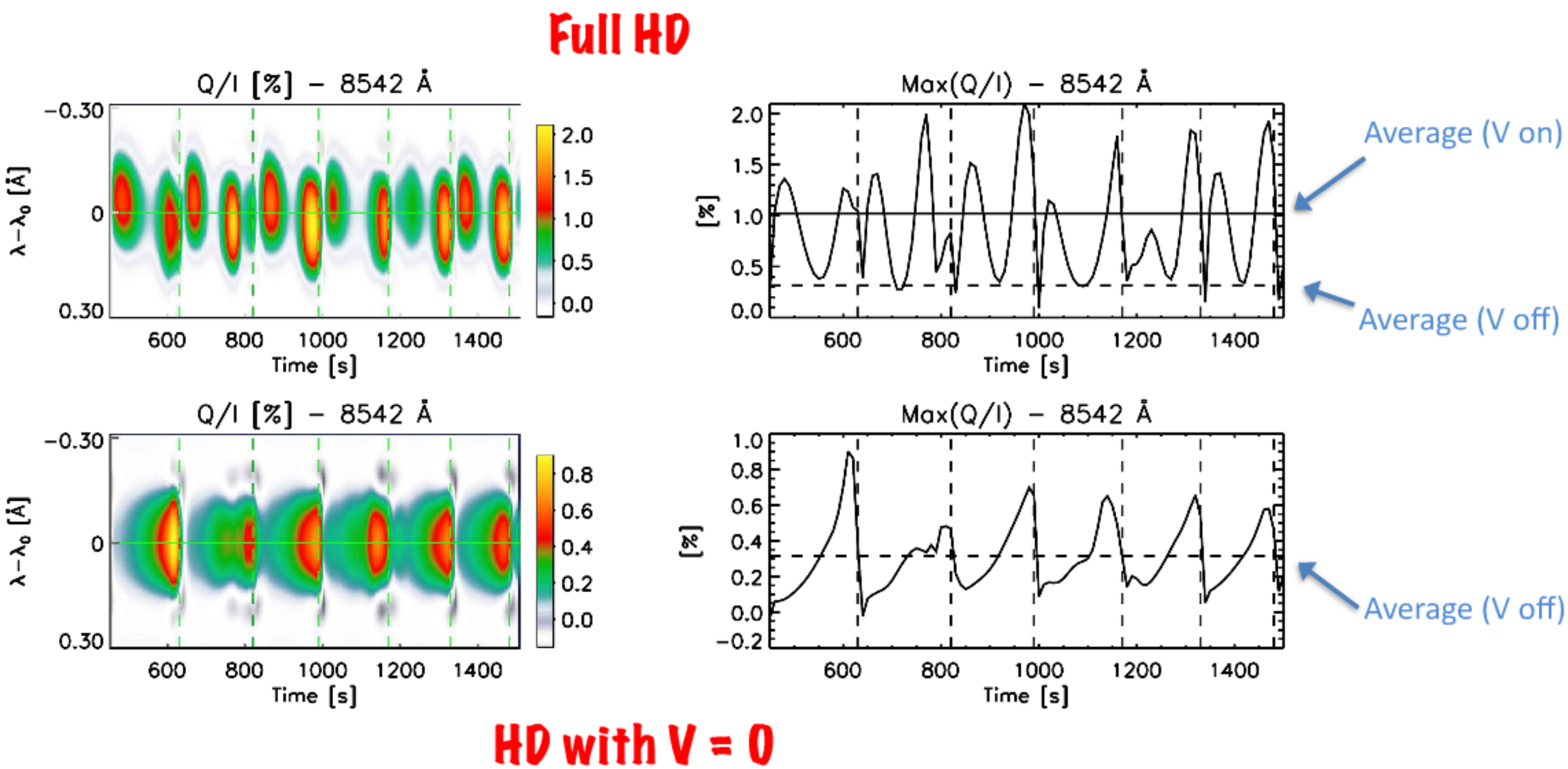
✓ Variations in the height of formation.
Expansion and compression.

✓ Hot/cold temperature minimum

✓Amplification of the scattering Polarization amplitudes!

✓Frequency Modulation of the profiles in expansion/compression phases.

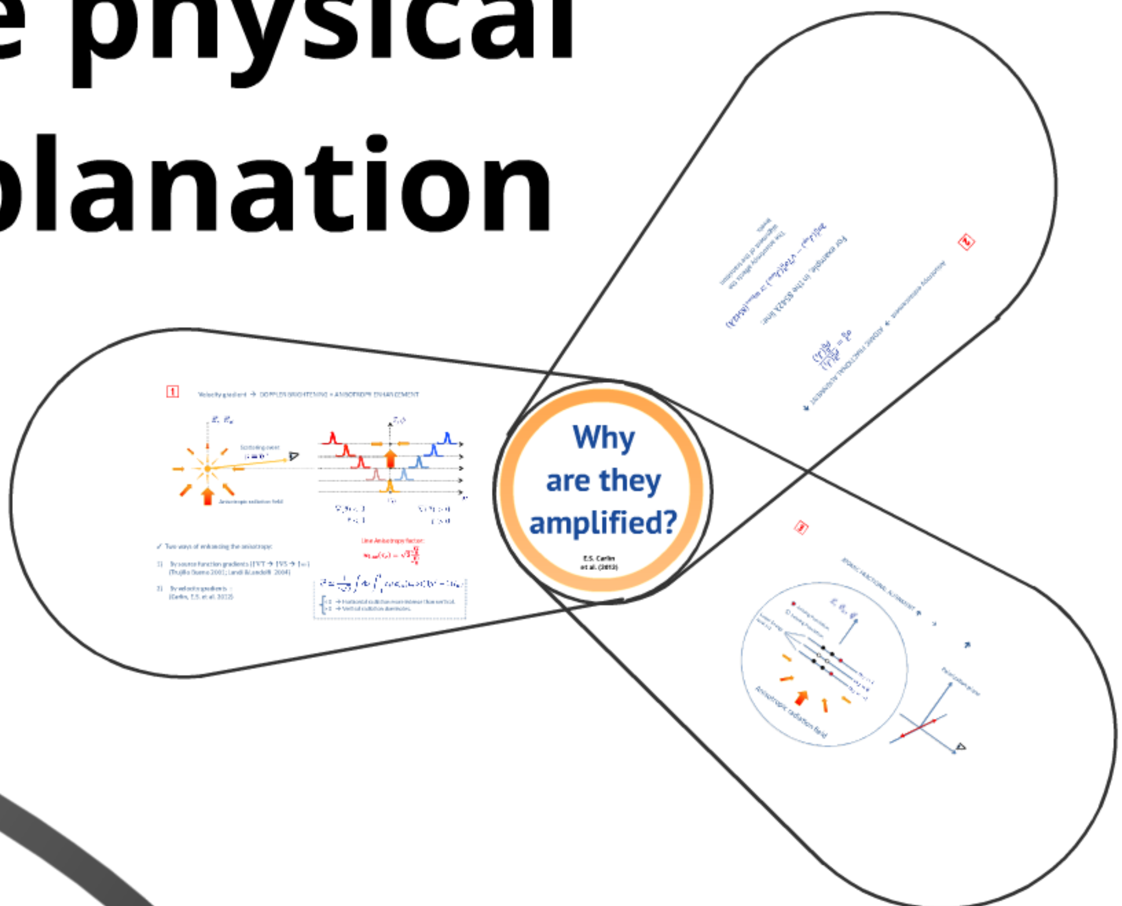




→3 min. periods of compression/expansion & heating/cooling.

→Wavelength modulation + amplitude modulation & amplification (2 peaks/period) in Q/I

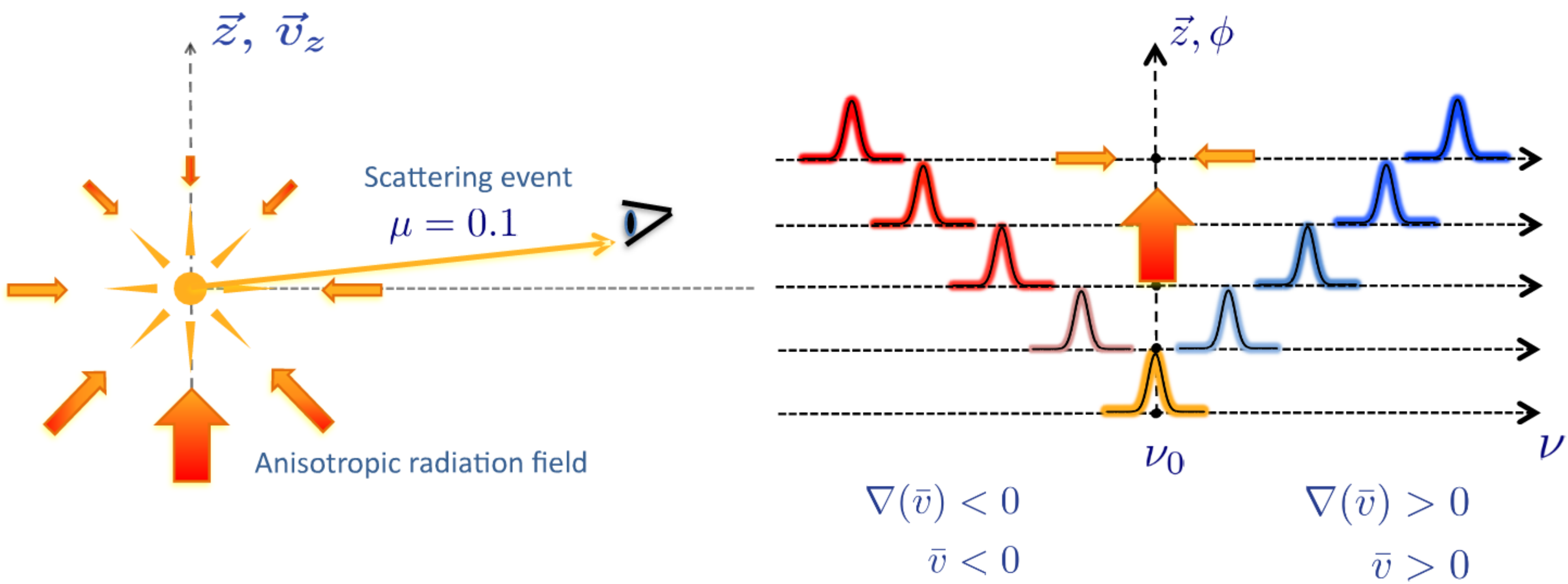
The physical explanation



Can we observe it

1

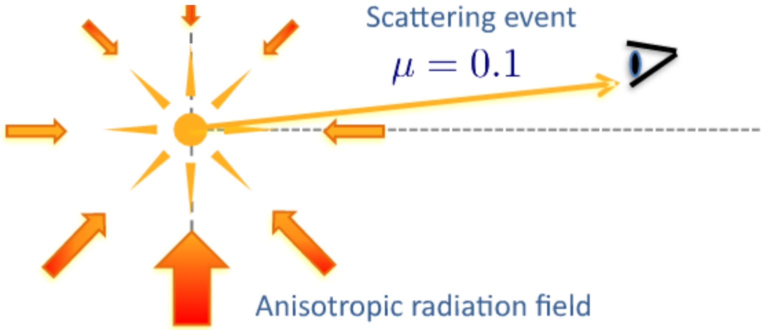
Velocity gradient → DOPPLER BRIGHTENING + ANISOTROPY ENHANCEMENT

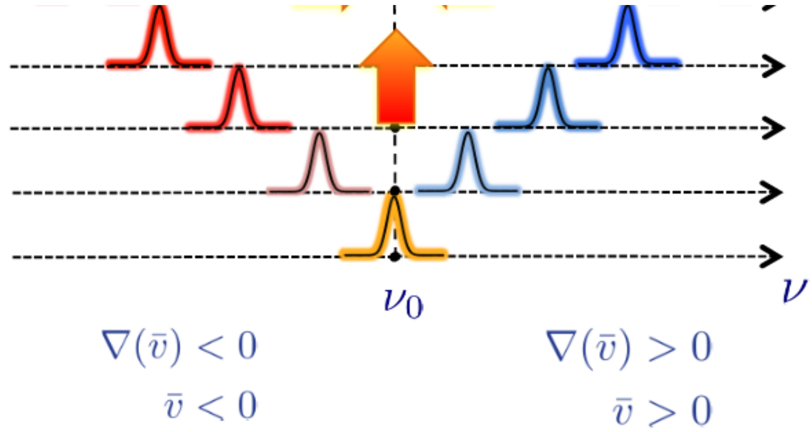


✓ Two ways of enhancing the anisotropy:

Line Anisotropy factor:

$$w_{\rm line}(\tau_\nu) = \sqrt{2}\frac{\bar{J}^2_0}{\bar{J}^0_0}$$





✓ Two ways of enhancing the anisotropy:

1) By source function gradients (↑∇T → ↑∇S → ↑ω)
(Trujillo Bueno 2001; Landi &Landolfi 2004)

2) By velocity gradients :
(Carlin, E.S. et al. 2012)

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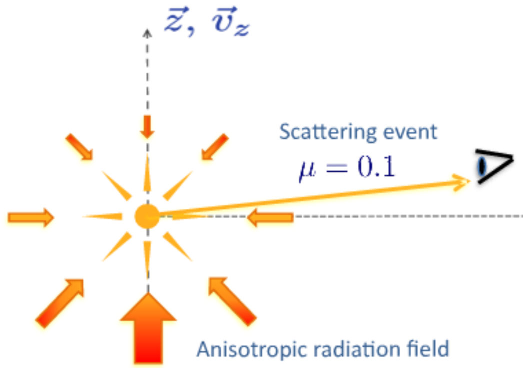
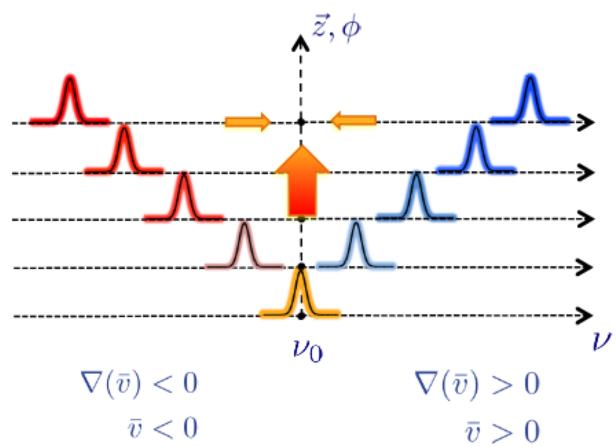
$$w_{\text{line}}(\tau_\nu) = \sqrt{2}\frac{\bar{J}^2_0}{\bar{J}^0_0}$$

$$\bar{J}^2_0 \simeq \frac{1}{4\sqrt{2}} \int \mathrm{d}\nu \int_{-1}^{1} \mathrm{d}\mu \, \phi'_{lu}(\mu,\nu)(3\mu^2 - 1) I_{\mu\nu}$$

- < 0 → Horizontal radiation more intense than vertical.
- > 0 → Vertical radiation dominates.

1 Velocity gradient → DOPPLER BRIGHTENING + ANISOTROPY ENHANCEMENT





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Why are they amplified

E.S. Carlin et al. (2012)

2

Anisotropy enhancement → ATOMIC FRACTIONAL ALIGNMENT ↑

$$\sigma_0^2 = \frac{\rho_0^2(J_i)}{\rho_0^0(J_i)}$$

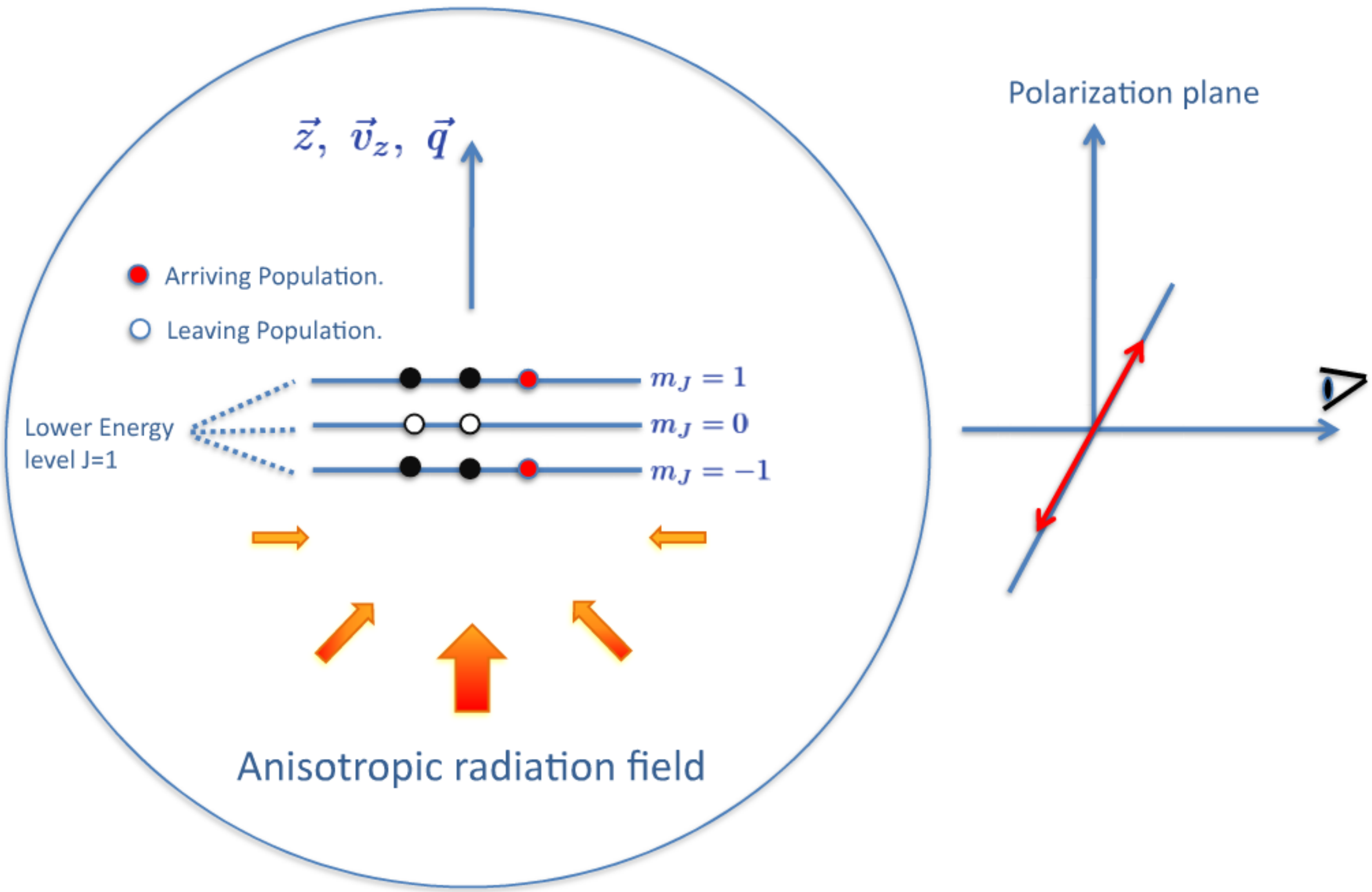
For example, in the 8542λ line:

$$2\sigma_0^2(J_{up}) - \sqrt{7}\sigma_0^2(J_{low}) \simeq w_{line}(8542\mathring{A})$$

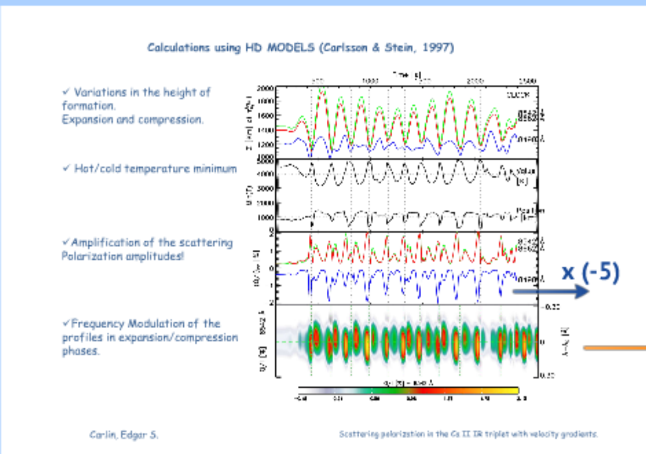
The anisotropy affects the alignment of the transition levels.

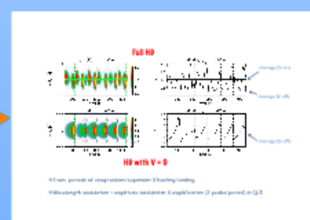
3

ATOMIC FRACTIONAL ALIGNMENT ↑ → Q/I ↑

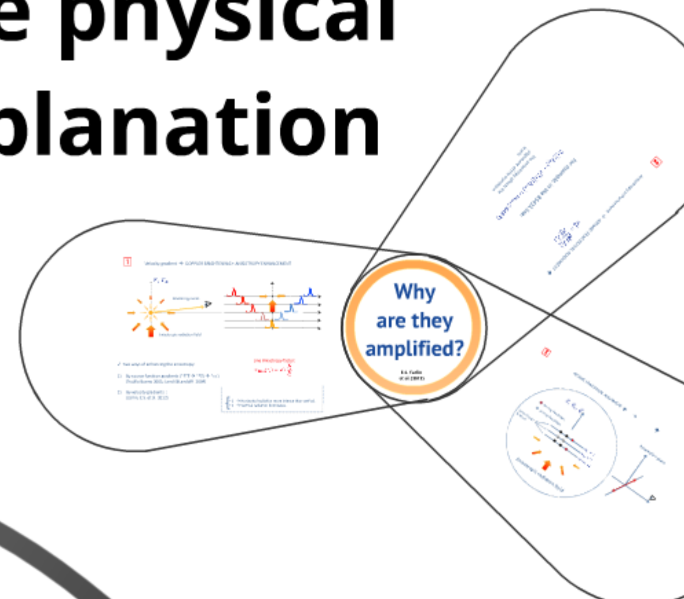


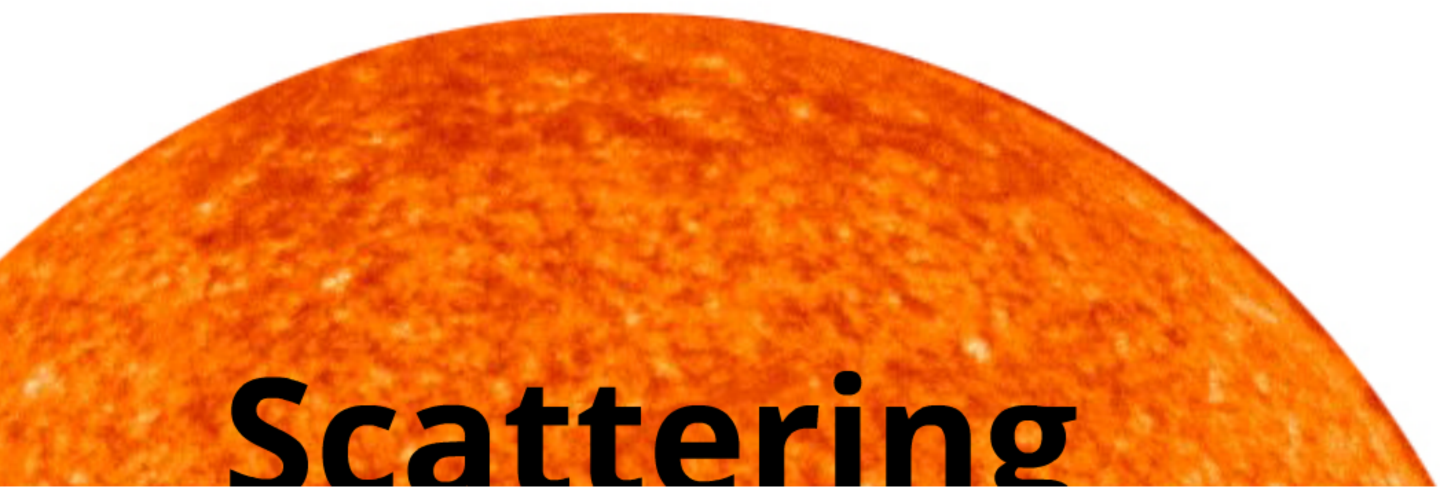
A dynamic case



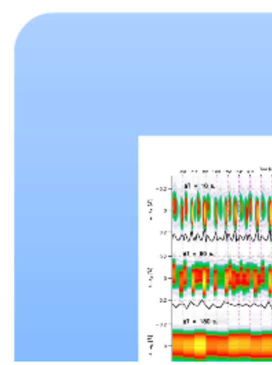


The physical explanation

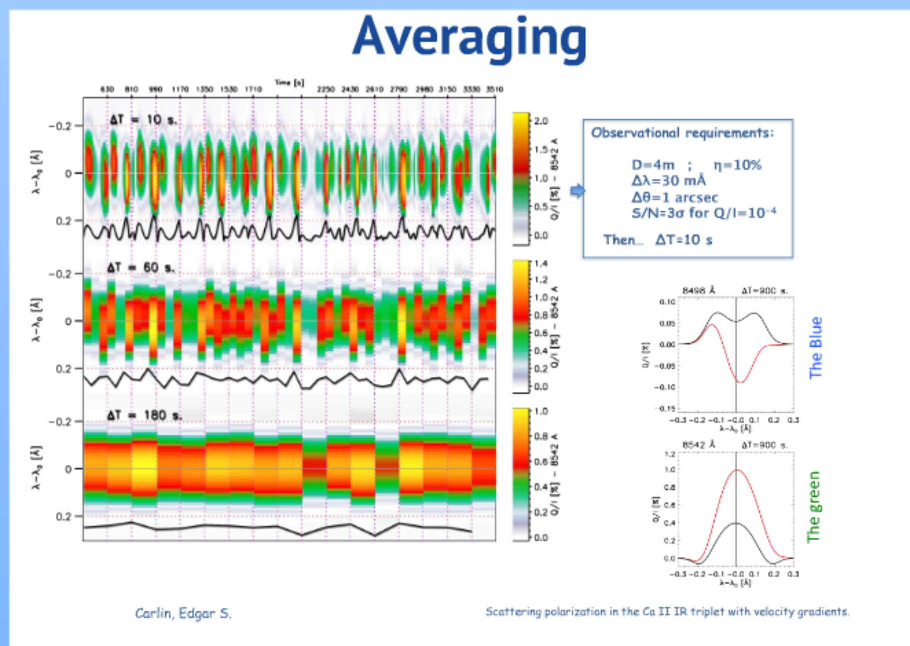




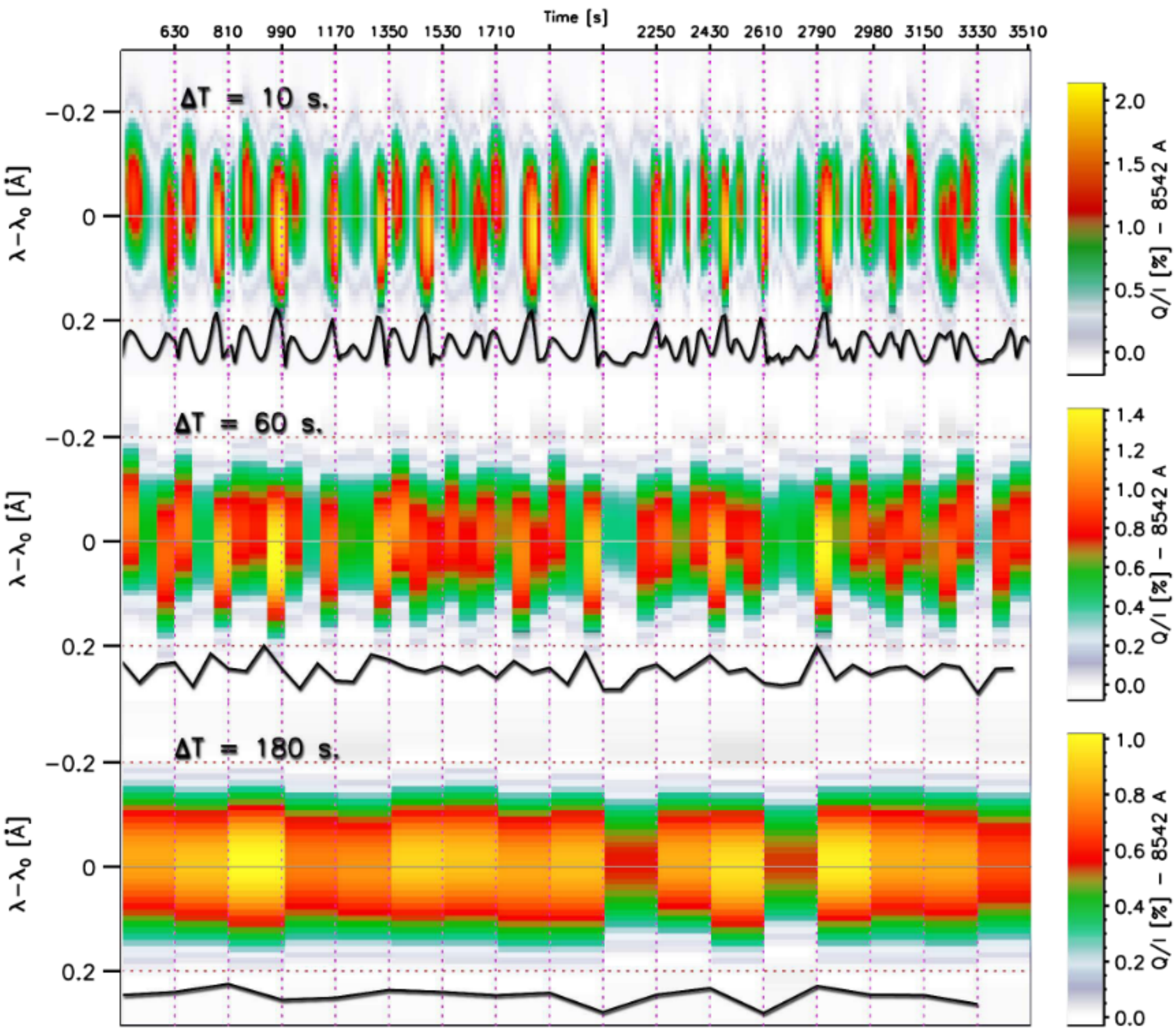
Can we



Can we observe it?



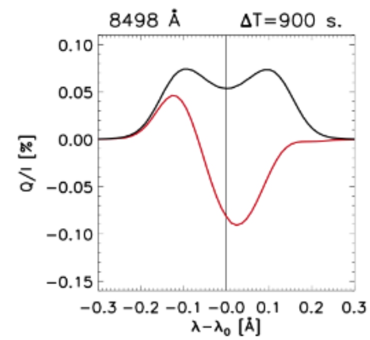
Averaging



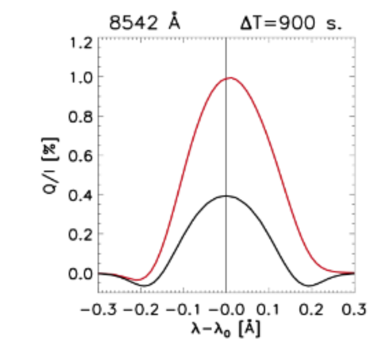
Observational requirements:

D=4m ; η=10%
Δλ=30 mÅ
Δθ=1 arcsec
S/N=3σ for Q/I=10^{-4}

Then... ΔT=10 s



The Blue



The green

Carlin, Edgar S.

Scattering polarization in the Ca II IR triplet with velocity gradients.

Conclusions

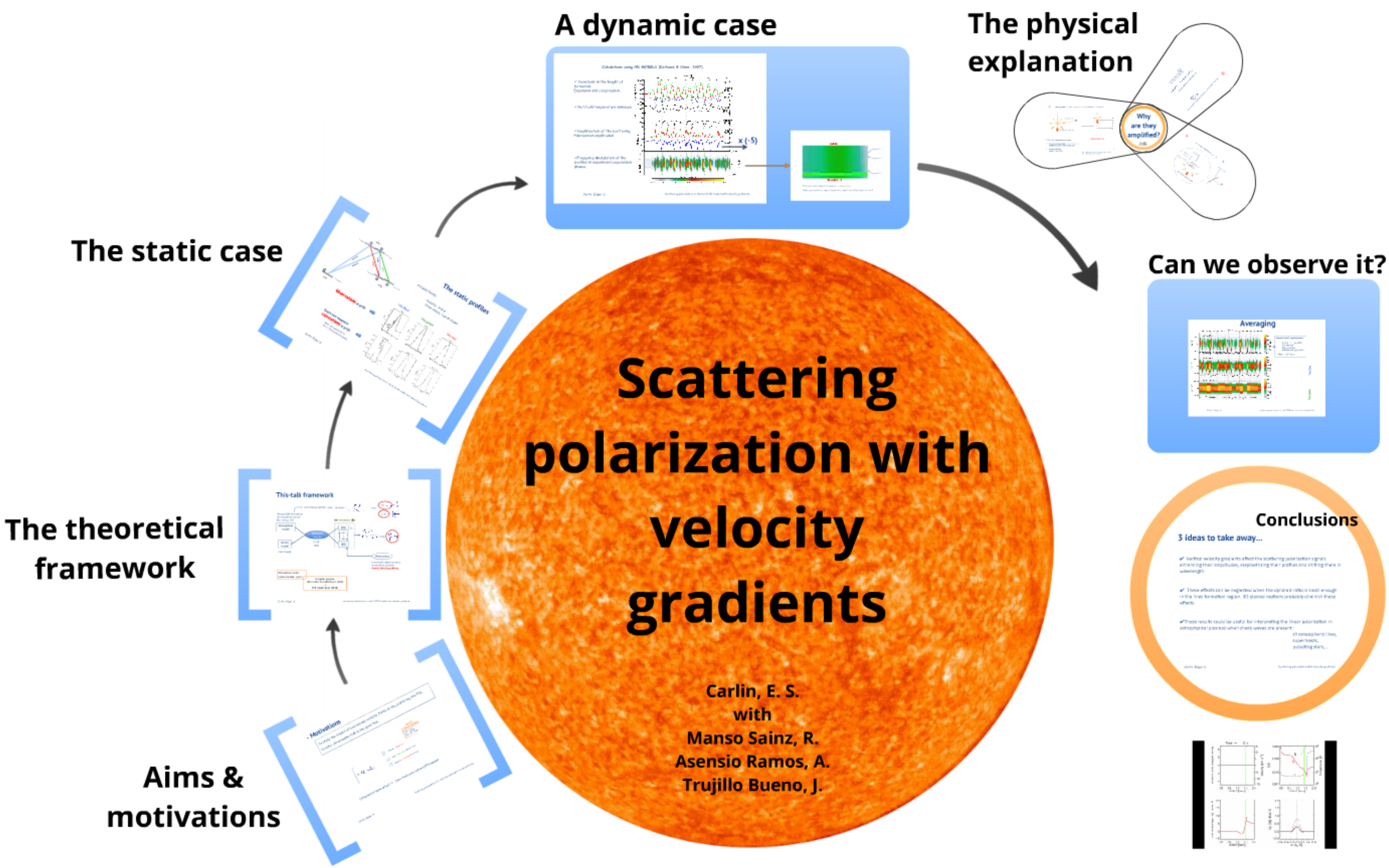
3 ideas to take away...

✔ Vertical velocity gradients affect the scattering polarization signals enhancing their amplitudes, assymetrizing their profiles and shifting them in wavelength.

✔ These effects can be neglected when the dynamic ratio is small enough in the lines formation region. 3D plasma motions probably diminish these effects.

✔These results could be useful for interpreting the linear polarization in astrophysical plasmas when shock waves are present:

chromospheric lines,
supernovas,
pulsating stars,...



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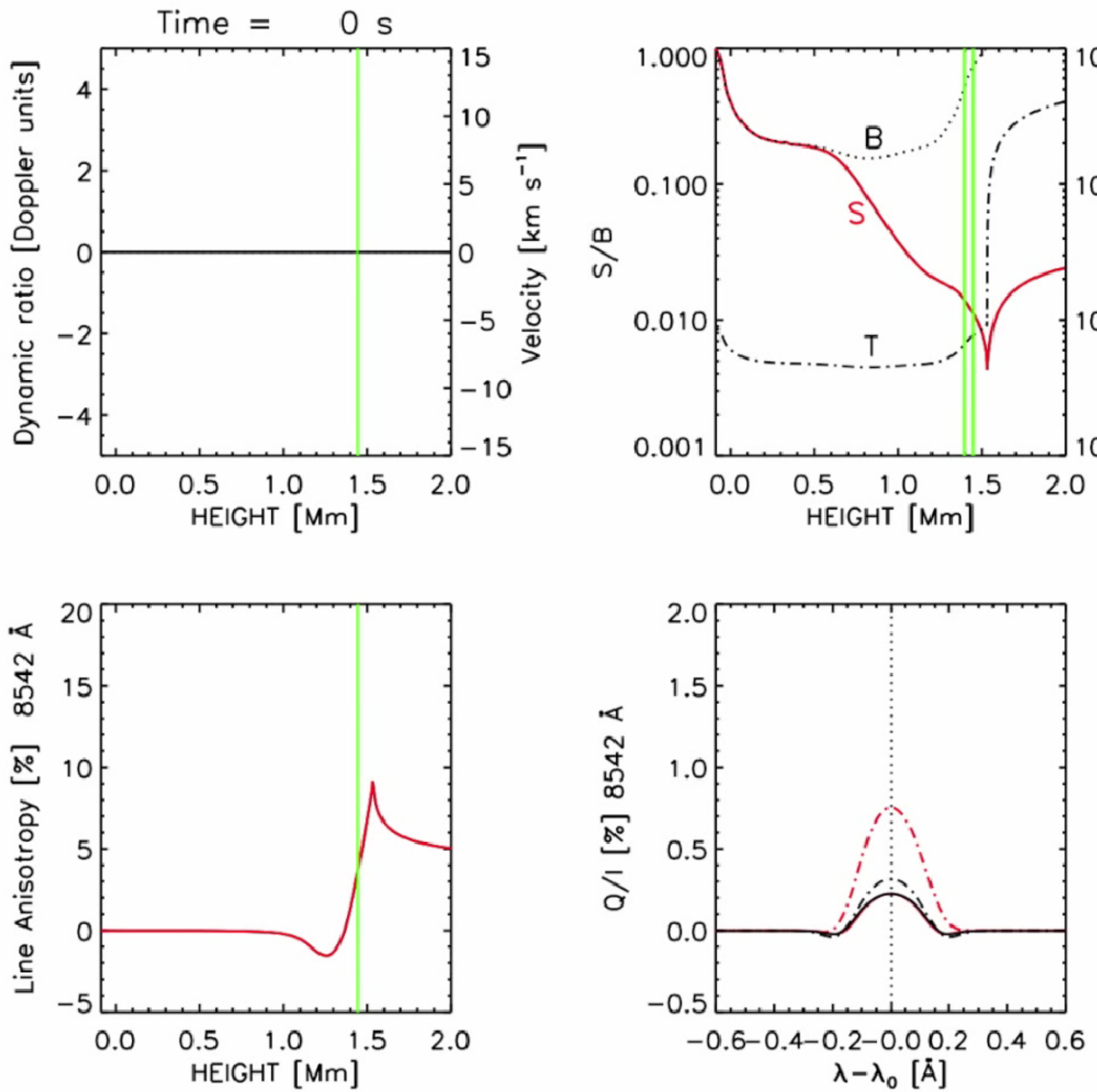

Time = 0 s
Dynamic ratio [Doppler units]
Velocity [km s^-1]
HEIGHT [Mm]
S/B
Temperature [K]
B
S
T
Line Anisotropy [%] 8542 Å
Q/I [%] 8542 Å
λ−λ0 [Å]