Line Formation in Inhomogeneous Magnetic Fields

- Characterizing internetwork magnetic structures -

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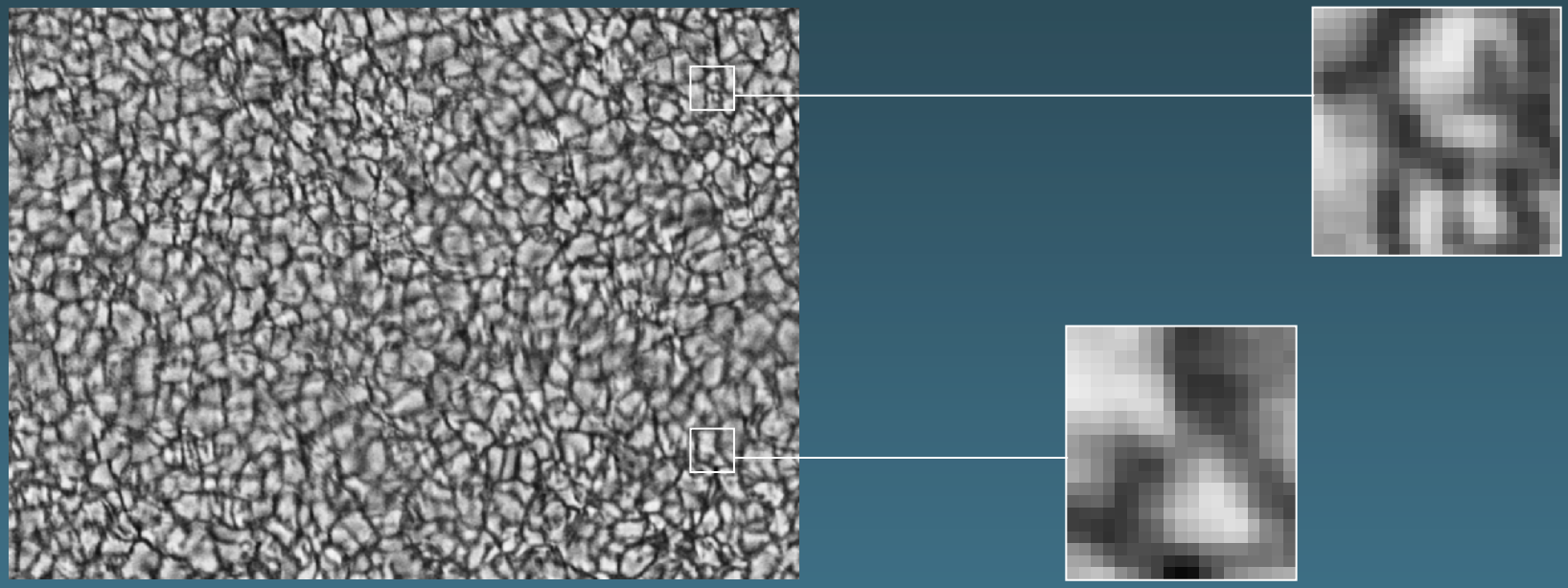
The quiet solar photosphere – a lot of magnetic flux !



How can we describe the line formation in these small scale and unresolved regions ?

$$\frac{d\boldsymbol{I}(s)}{ds} = -\boldsymbol{K}\,\boldsymbol{I} + \boldsymbol{J}$$

The macroscopic perspective

$$\frac{d\langle \boldsymbol{I}(s)\rangle}{ds} = -\langle \boldsymbol{K}\,\boldsymbol{I}\rangle + \langle \boldsymbol{J}\rangle$$

The microscopic perspective

Bridging the gap : The Stochatic Polarized Radiative Transfer

The apriori unknow structuring is described on a statistical basis

The ray path undergoes a stochastic process ⟶ A Master-Like Transport Equation

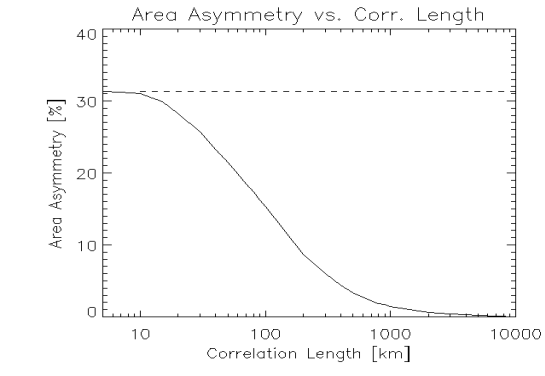
$$\frac{\partial \boldsymbol{Y}_B(s)}{\partial s} = -\boldsymbol{K}_B\boldsymbol{Y}_B + \boldsymbol{J}_B + \int \lambda_{B'}^{-1}\boldsymbol{Y}_{B'}\, p(\boldsymbol{B}')\, d\boldsymbol{B}' - \int \lambda_B^{-1}\boldsymbol{Y}_B\, p(\boldsymbol{B}')\, d\boldsymbol{B}'$$

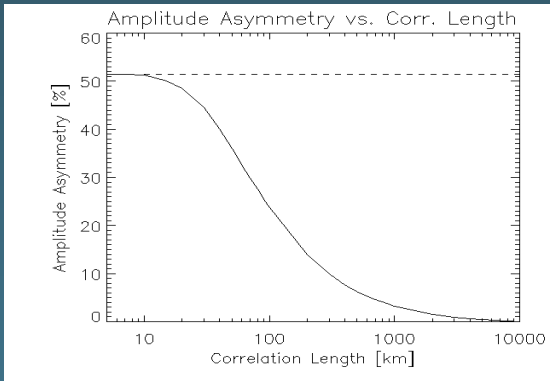
Y_B : the Stokes Vector conditioned on a particular atmospheric component

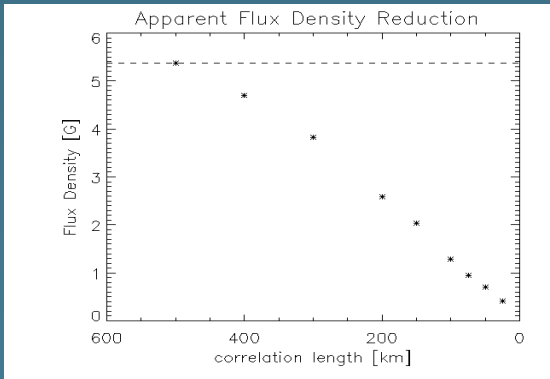
λ : correlation length of the structures

- Statistical scattering : sources and sinks of intensities
- The atmospheric structures are in „contact“ and exchanging intensity
- The amount of exchange is controled by the correlation length λ
- Finite structures can be described

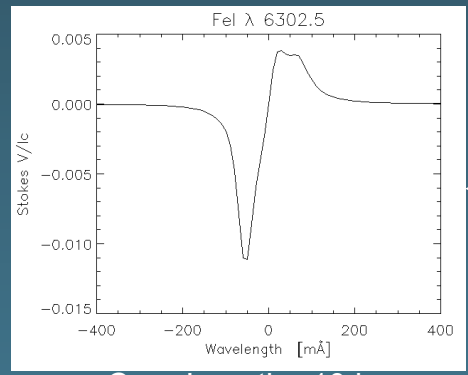
Effects of an atmosphere with finite correlation lengths



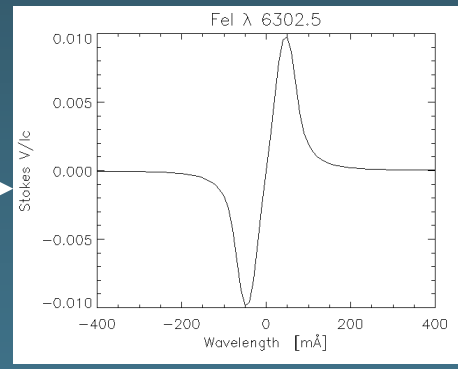




- The area-asymmetry and amplitude-asymmetry is very effectively generated by the statistical scattering integral.
- The asymmetries strongly depends on the correlation length
- The micro- and macrostructured approach are limiting cases of the stochastic (mesostructured) approach
- The micro- and macro approach have a very limited range of applicability



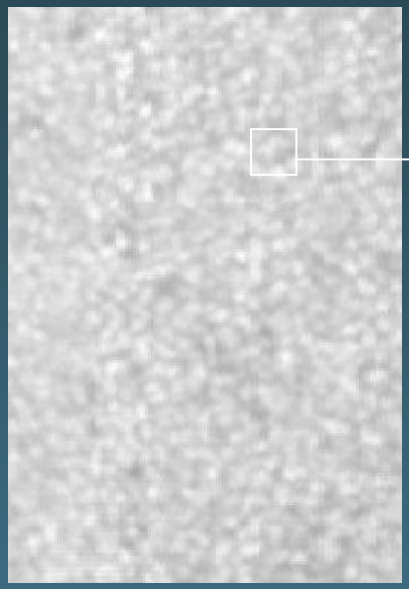
Corr. Length : 10 km



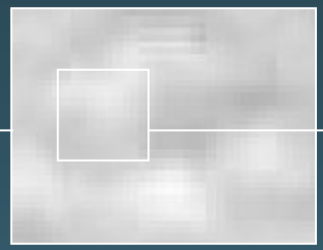
Corr. Length : 5000 km

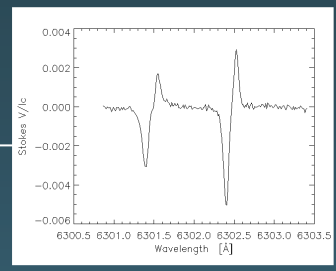
- Any imbalance of the mean length scale between the magnetic and unmagnetic structures leads to an apparent loss of the measured flux density
- The weakening of the measured magnetic flux is not only driven by the filling factor or mixed polarities

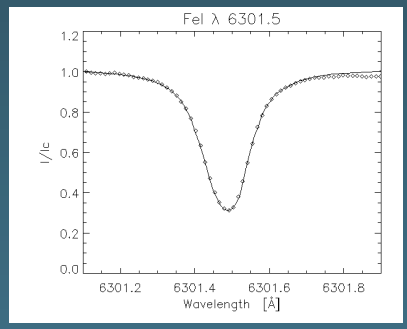
Is there a finite correlation length in the internetwork ?



Courtesy B. Lites & H. Socas-Navarro

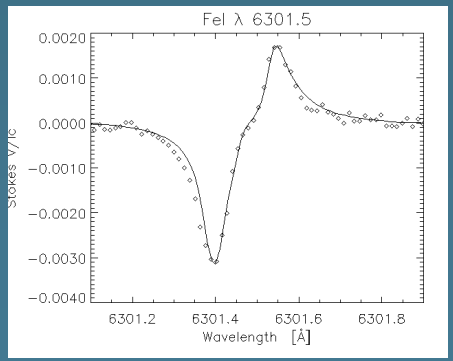


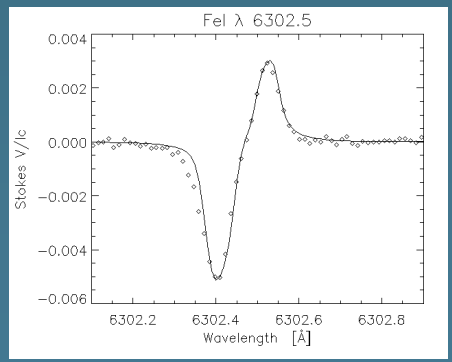




A 3-Component Atmosphere on Mesoscales fits the observed intensity profile
No Need for micro- and/or macroturbulence !
Correlation lengths between 300 and 500 km

A good estimate of the ambient velocity field places tight constraints on the resulting NCP !





2 magnetic structures provide a reasonable fit for both Stokes V Profiles
But these structures have a finite correlation !
Correlation lengths between 50 km and 125 km
Filling factors are 2.7% and 2.1%

Conclusions

- The velocity fields in granules and intergranular lanes have different correlation lengths
- Magnetic structures in the granular regions have a smaller correlation length (50 to 150 km) than structures in the intergranular lanes (170 to 300 km)
- The higher the field strength the larger the correlation length (for typical kG structures > 250 km)
- But for weak flux structures the correlation spectrum is far below the typical canopy spectrum of > 500 km

Summary

- The stochastic (mesostructured) approach allows the interpretation of asymmetric Stokes profiles in terms of the horizontal and vertical structure of the atmosphere
- We may still underestimate the magnetic flux in the quiet solar photosphere