# The linear polarization of the solar continuum radiation from numerical simulations of the solar atmosphere

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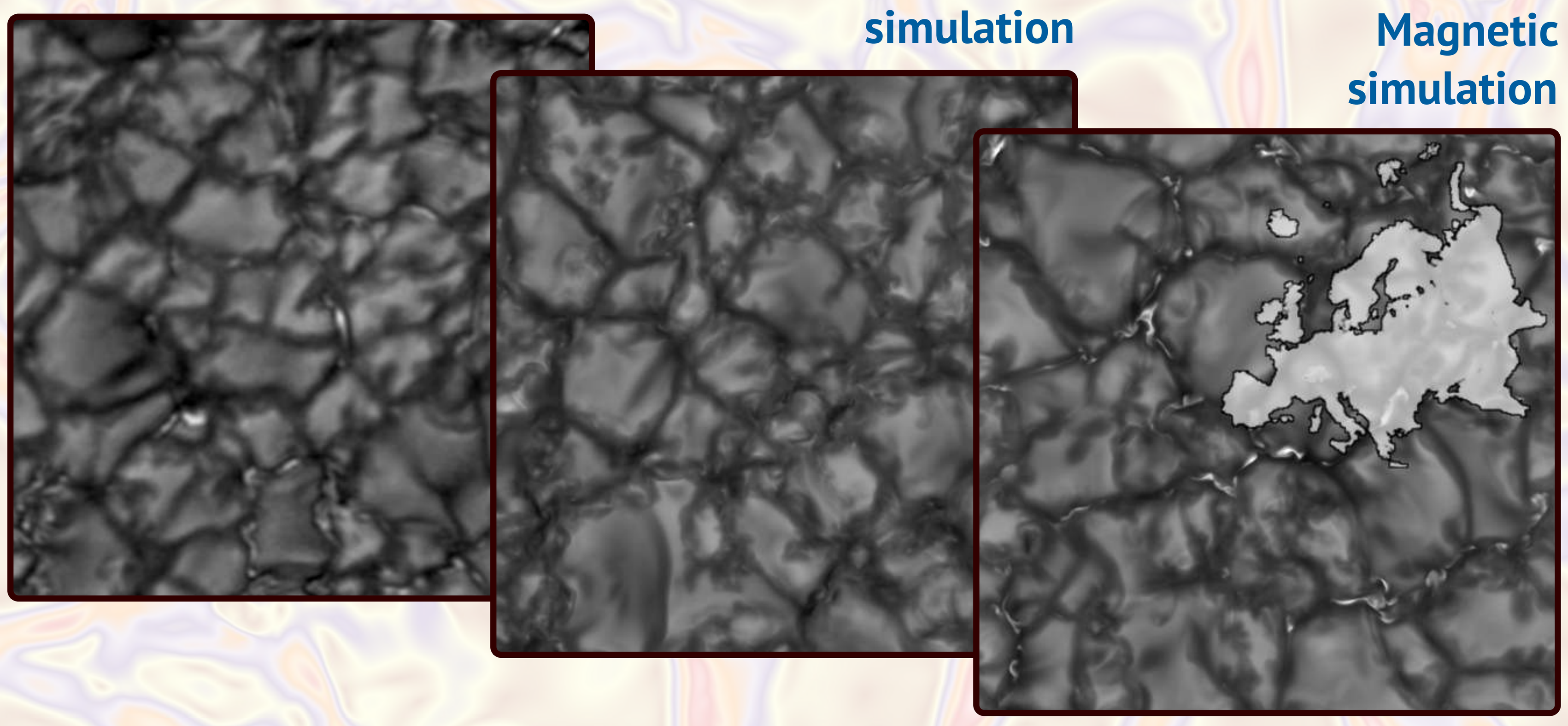
We use numerical radiation magnetohydrodynamics simulations of the near surface layers of the Sun that we have carried out at CSCS to produce synthetic observations (maps), both in intensity and linear polarization of the continuum radiation and at a variety of positions on the solar disk. The synthetic maps are produced by solving the radiative transfer equation for polarized light in three-dimensional space. The polarization at disk centre comes about because of deviations of the three-dimensional structure of the atmosphere from a plane-parallel model atmosphere. Spatial averages as a function of distance between centre and limb of the solar disk display the same behaviour as obtained with one-dimensional models and agree with measurements carried out at IRSOL.

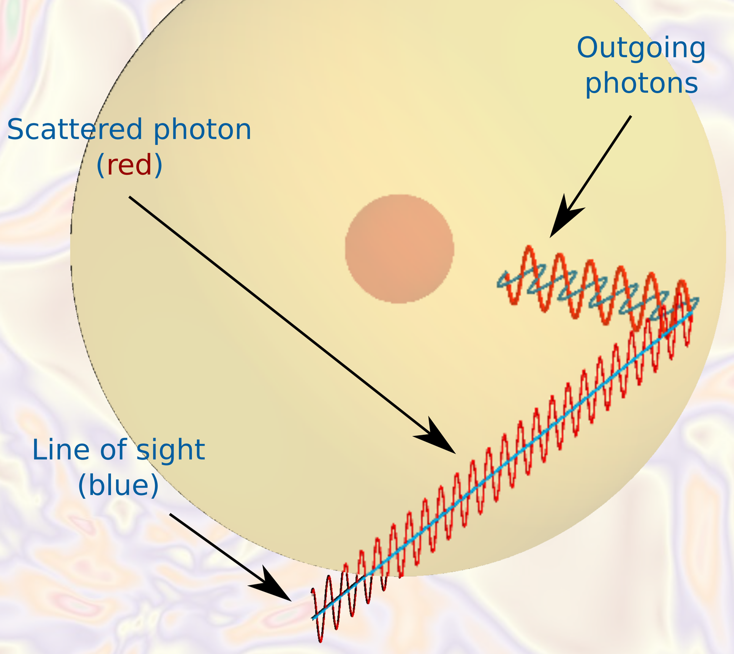
## Radiation Magnetohydrodynamics (MHD)



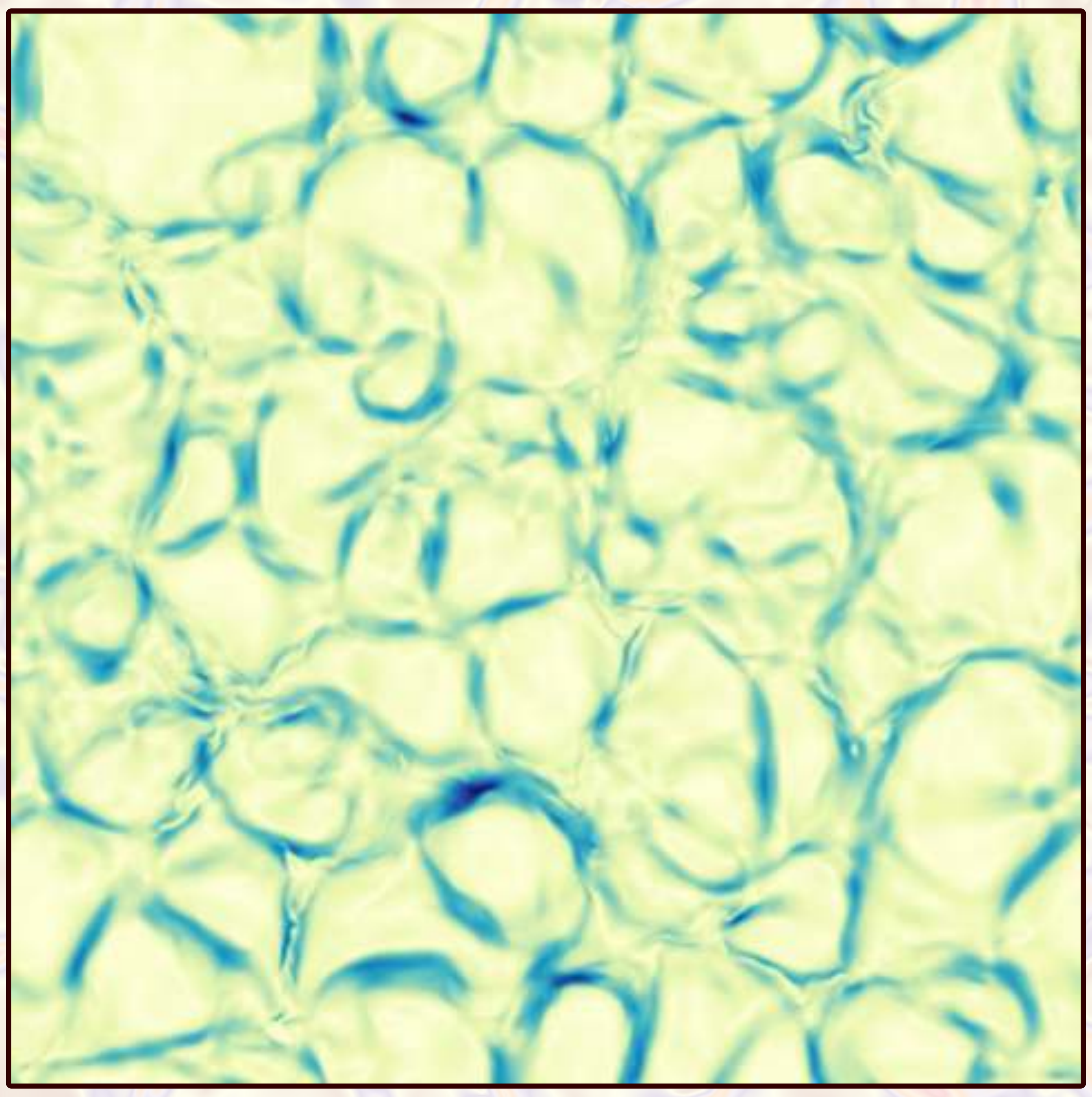

### What comprise those simulations?

(Magneto-)hydrodynamics equations are solved with an explicit method based on Roe and HLL Riemann solvers. The (M)HD step is alternated with a radiative transfer step (operator splitting). We use the $CO^5BOLD$ code of Freytag et al. (2012)[1].

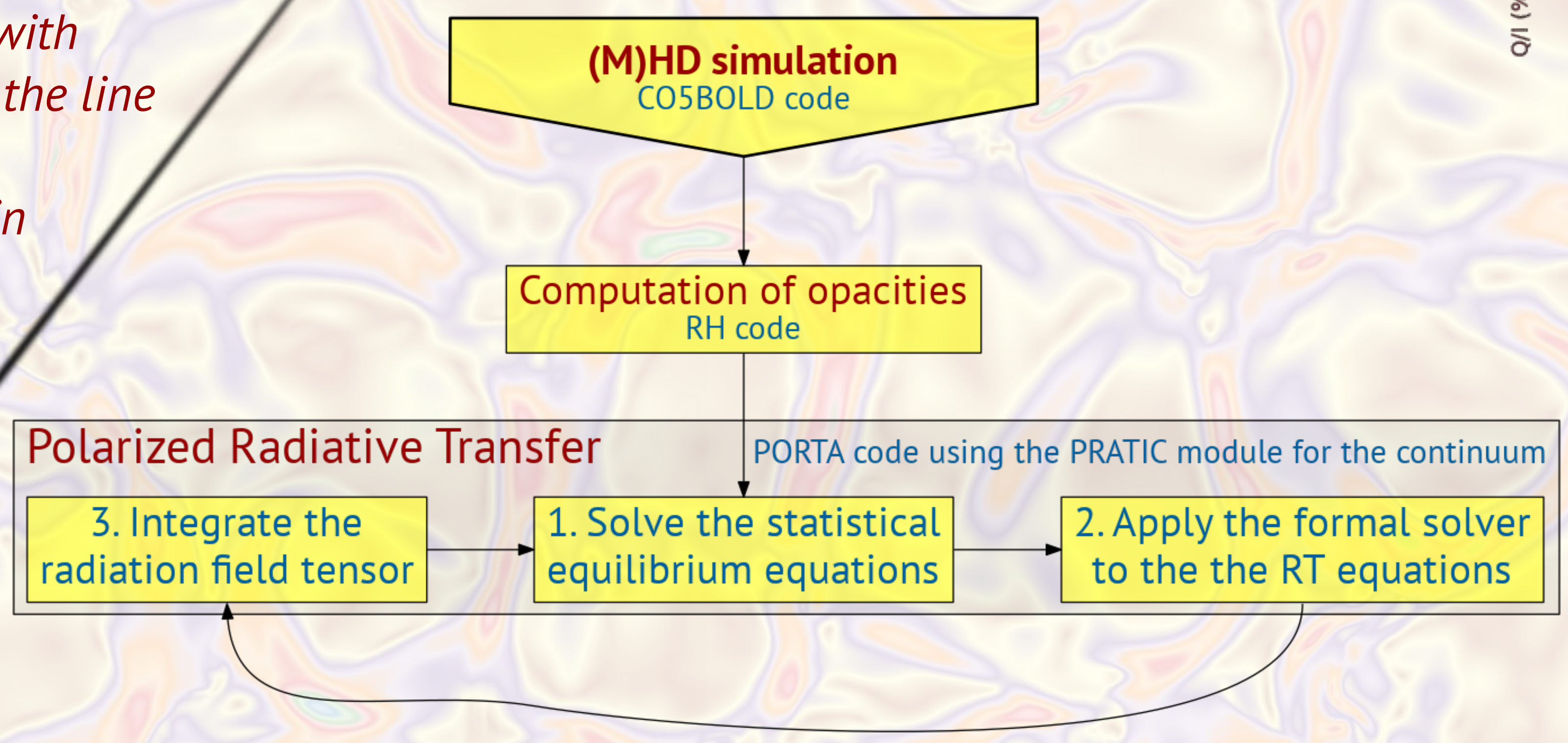
*[1]Freytag et al., 2012, JCP 231, 919*




▲ Top panel: *two photons traveling radially out of the Sun interact with matter. Only the one which is perpendicularly polarized with respect to the line of sight is scattered in that direction.*



▼ Bottom panel: *opacities are computed from the (M)HD simulation boxes, and then an iterative loop has to be performed in order to solve the non-linear equations that describe the generation of light and its propagation through the solar plasma.*




### Scattering polarization

The thermal radiation under the deep layers of the solar atmosphere is unpolarized and is in a very good approximation the radiation of a black body.

When light interacts with the plasma in the photosphere and in the chromosphere, its spectrum is modified and partially polarized.

We study the continuous spectrum of the Sun at (near-)visible wavelengths. Its polarization is ultimately due to the scattering of light by free and bound electrons.

## Radiative Transfer

In this context, radiative transfer (RT) describes how light propagates and interacts with the solar plasma.

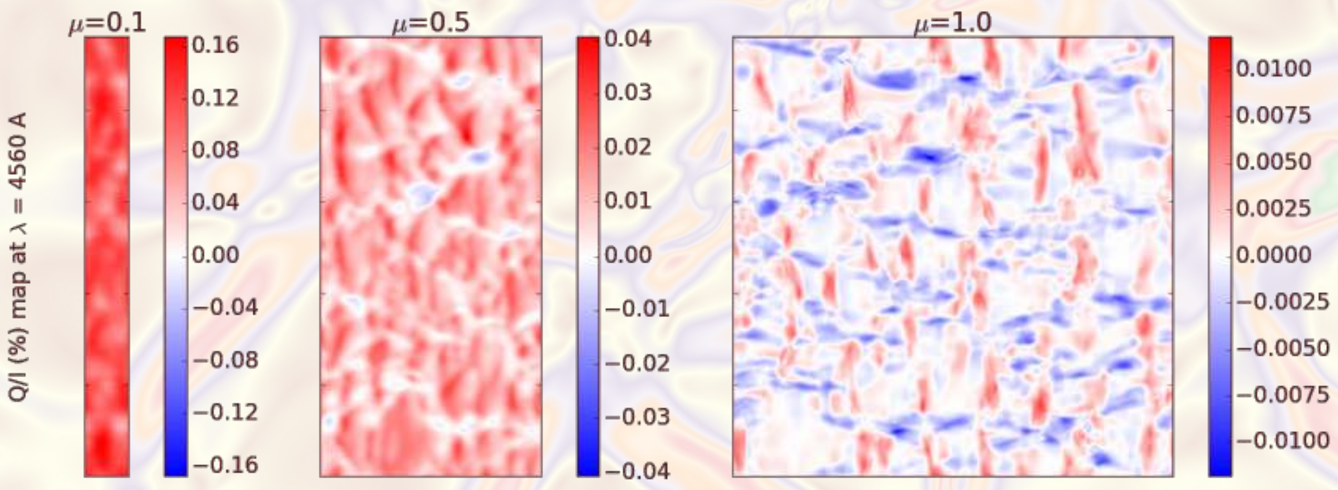
The PORTA MPI-parallel code[2] (POlarized Radiative TrAnsfer) was run at CSCS for producing the polarization maps shown on this poster from our 3-D models of the solar atmosphere. These "virtual observations" are now compared with real observations.

*[2]J. Štěpán & J. Trujillo Bueno, 2013, A&A 557, A143*

◄ Left panel: *linearly polarized light (at 4560 [Å]) emerging from an instant of the 3-D magnetic simulation, at disk centre, resulting from deviations of the 3-D model from a plane-parallel model.*

### Centre-to-limb variation of polarization

The presence of linear polarization indicates an asymmetry around line of sight. At disc centre the polarization signal is mainly due to the granulation pattern and is very faint. In the limb the scattered light provides a more important signal, which is a consequence of the difference of radiation directed radially out and into the Sun.




▲ Top panel: *Stokes Q component of the polarization vector, which is one of the two components of linear polarization. The map on the right is representative of disc centre, and the maps on the left are closer and closer to the solar limb. Red (resp. blue) colour indicates linear polarization parallel (resp. perpendicular) to the limb. For linearly polarized light we observe limb brightening, as opposed to the limb darkening observed for the total intensity (polarized and unpolarized radiation).*