A new Lagrangian stochastic code for stellar convection

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Convection is ubiquitous in stellar interiors. Through large-scale motions that efficiently mix energy, angular momentum and chemical elements, it plays a key role in shaping the structure and evolution of stars. But the proper and realistic inclusion of convection in stellar evolution models constitutes one of the major challenges in stellar physics. In particular, interface layers between convective and radiative regions remain unsatisfactorily described in modern-days stellar evolution codes, which is one of the primary sources of uncertainty in the age determination of massive stars with convective cores. It also has an impact on the asteroseismology of low-mass stars with turbulent, convective surface layers: our inability to model surface convection in these stars leads to a bias in theoretical seismic frequencies (or *surface effects*), which in turn leads to significant errors in the determination of stellar properties from seismic observables. With the upcoming launch of the PLATO mission, overcoming the obstacle that surface effects pose to asteroseismology becomes a crucial and timely challenge, and one that requires our theoretical knowledge of stellar interiors to keep up with the developments of our observational capabilities.

The treatment of convection in stellar evolution models usually involves Mixing Length Theory. While it is useful in describing the bulk of convective regions, it does not allow to properly describe convective/radiative interface layers, and is also notoriously bad at describing the interplay between waves and convection that is at the heart of seismic surface effects. In this presentation, I will propose an alternative theoretical framework to address these issues, and most notably to address the difficulty in deriving physical closure relations. This novel framework makes use of Lagrangian PDF methods for turbulence modelling, whereby the modelled quantities are probability density functions of turbulent properties, rather than mean properties. In practice, these methods are implemented using random realisations of the flow, represented by a large number of notional particles tracked in a purely Lagrangian frame and evolved in time through stochastic differential equations. The Lagrangian nature of these methods proves naturally more suited to the description of stellar convection, which is an advection process by nature.

The presentation will be divided in two parts. First, I will present the basic principles behind this framework, and how it can be adapted to tackle the issue of surface effects, or to assess the efficiency of transport through convective/radiative interface layers. In a second part, I will introduce a new numerical code developed to implement these methods, and I will showcase its capabilities.