THESIS TOPIC – MASTER MATHEMATICAL ENGINEERING

TITLE

Monte Carlo Radiation Transport Simulations for Astrophysical Applications

GUIDANCE

• For more information, please contact:	jon.sundqvist@kuleuven.be
• Promotor:	Prof. Jon Sundqvist
• Co-promotor	Prof. Giovanni Samaey

CONTEXT

Experiments in astrophysics essentially consist of collecting photons (radiation) from remote objects. To interpret such astrophysical observations, one must create models of (i) how radiation is transported through the cosmic object of interest (a star, a galaxy, etc.), (ii) how this radiation interacts with the matter (often a gas) in the system, and (iii) how much of the radiation finally escapes in the direction of the observer.

Stochastic Monte-Carlo simulation is a particularly attractive choice (as compared to, e.g., various alternative ray-tracing techniques) for systems with complex geometries and/or where the distributions of the material interactions are difficult to compute (e.g., for systems dominated by scattering rather than absorption of photons).

GOAL

In this thesis, the student will develop and implement a numerical method for performing Monte-Carlo simulations through an astrophysical medium of given material properties (mass density, velocity, etc.). The numerical behaviour of the method will be analysed.

These simulations can be further used in a potentially wide range of <u>astrophysical applications</u>. Here, building on previous work of prof. Sundqvist, we will focus on the following:

1) <u>creating synthetic images and spectra</u> for direct comparison to astrophysical observations, such as shown in Figure 1.
2) computing photon-forces for <u>systems where the dynamics is dominated by radiation</u> (e.g., for the powerful radiation-driven stellar wind outflows of the most massive stars in the Universe).

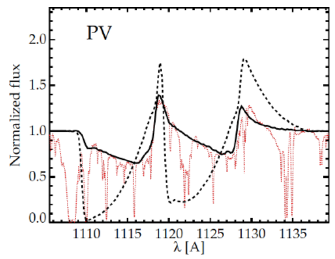

Figure 1. Comparison between observed spectra of a massive star in our Milky Way Galaxy (red line) and synthetic spectra (black solid and dashed lines) computed using the Monte-Carlo radiative transfer code developed by Sundqvist et al. (2010), A&A, 510, 11. Abscissa: wavelength in Angstrom; ordinate: normalized flux. The spectral line displayed in the figure is arising from four times ionized phosphorus. By fitting observations to simulated Monte-Carlo spectra (the solid line fits better than the dashed), we learn how much mass is lost from the surface of the star in a stellar wind outflow.

METHODOLOGY

The key steps will be to:

i) <u>perform a literature study on numerical simulation methods</u> and to get acquainted with the astrophysical background

ii) <u>develop an algorithm</u> tracking photon packets within the (possibly fully 3D) medium

iii) <u>investigate the (numerical) convergence properties</u> of the method

iv) implement the probability distribution functions for computing scattering-angles when photons interact with matter and <u>compute the resulting stochastic radiation quantities</u> and corresponding synthetic spectra/images

PROFILE (e.g. rather theoretical/rather practical implementation, foreknowledge (courses, methods, computer language(s) etc.))

The focus of this thesis is on method design, implementation and evaluation via numerical experiments. The resulting method will be applied in (radiation related) astrophysical applications.

1 student