Monte Carlo code and modelling of polarized radiative transfer in the envelopes of post-AGB objects

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It is widely believed that post-asymptotic giant branch (post-AGB) objects are undergoing a transition phase from a "normal" star burning its nuclear fuel to a planetary nebula [1]. Their progenitors are stars with the main sequence mass in the range from (very approximately) 2 to 8 solar masses. They have extended gas–dust envelopes of various (often very peculiar, and often bipolar) shapes created by an intense mass loss. This is an important stage in star's life; the mass outflow substantially enriches the interstellar medium with heavy elements, driving the chemical evolution of the host galaxy. The asymmetric shape of an outflow from an initially almost spherically symmetric star is not fully explained, but extensive research of this topic is being done worldwide. The binary nature of a star has been proposed as the cause of bipolar outflows, and moreover it has been supposed that some post-AGBs never become planetary nebulae [2].

In recent years, new powerful astronomical instruments have started to provide spatially resolved polarized images of these objects [3,4] as well as high-resolution interferometric data [5]. In order to make conclusions about the morphology and spatial distribution of matter in optically thick circumstellar envelopes as well as about the chemical composition, size, shape and orientation of dust grains, polarized radiative transfer modelling must be performed.

We have created a Monte Carlo computer code for the modelling of polarized continuum radiative transfer in an arbitrarily shaped circumstellar dust cloud. The scattering medium is discretized into rectangular parallelepipeds; the properties of individual dust grains are assumed to be constant inside each parallelepiped, but the concentration of the grains may vary smoothly. The first version of our code assumes a macroscopically isotropic and mirror-symmetric scattering medium [6], but we are working to relax this assumption. The program has been written in the C++ language, and the calculations are done on our computing cluster using one of its nodes with 16 cores.

Our first attempts to interpret really observed post-AGB objects are in progress. Our code can be used for the interpretation of other astronomical objects as well provided that (i) general relativistic effects are not essential, (ii) birefringence is negligible, and (iii) refraction can be neglected, i.e., radiation propagates along straight lines between the successive acts of scattering.

References

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