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Véronique Bommier

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## **Non-Perturbative Theory of Radiative Scattering in the Weak Radiation Field Limit: Resolution of Egidio Landi’s “Paradox”**

V. Bommier

*LESIA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, Univ. Paris Diderot, Sorbonne Paris Cité, 92190 Meudon, France*

Egidio Landi Degl’Innocenti’s “paradox” was submitted to me in 1995, at the first Solar Polarization Workshop in St Petersburg, Russia. It consists in the realization that, when using the standard NLTE formalism for the statistical equilibrium (SE) and radiative transfer (RT) equations for polarization, such as in the formalism of Landi Degl’Innocenti (1983, 1984), physically inconsistent polarization degrees larger than unity can be produced in the scattered radiation, when the spectrum of the incident radiation is strongly modulated. A typical example is the excitation of a single Zeeman component of a spectral multiplet by very narrow band radiation, in the presence of a magnetic field. This inconsistency is due to the presence of line profiles that were heuristically introduced in the SE equations. This is the reason for imposing the so-called *flat-spectrum approximation*, which underlies all the results presented in the monograph by Landi Degl’Innocenti & Landolfi (2004), and limits the validity of those results to the regime of *complete frequency redistribution*.

The solution to this physical inconsistency lies in overcoming the Markov approximation in the derivation of the SE and RT equations from first principles. Then, the proper line profiles naturally enter the formalism, and correct expressions describing the partial frequency redistribution of radiation can be derived, which are not subject to the above mentioned inconsistencies. The principles of this derivation were presented in Bommier (1997a). Polarization and the effects of a magnetic field were taken into account by Bommier (1997b). The generalization of the formalism to a multi-level/multiline atom was the subject of Bommier (2016a), where collisional effects are also described in details, which results in the need to solve the SE equations for each atomic velocity class.

Attempts were made to generalize the standard redistribution function based on the 2-level atom approximation, which allows to avoid a full numerical solution of the SE problem, to the 2-term atom case necessary to model partial redistribution in  $D_1$ - $D_2$  line systems. This 2-term atom can be seen as a particular case of a multilevel system. If there is no coupling between the two upper levels, they can be independently treated within the 2-level approximation. However, the branching ratios that weight the coherent scattering contribution  $R_{II}$  and the incoherent one  $R_{III}$  for this case, which had previously been heuristically derived, still gave rise to similar physical inconsistencies. A formal derivation from first principles of the redistribution function and branching ratios for the 2-term atom that resolve these inconsistencies has been presented by Bommier (2017). However, collisional transitions between the two upper levels, which also have a depolarizing effect, cannot be taken into account within such analytic approach, but require the numerical solution of the SE problem as described in Bommier (2016b).

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