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A study of the redistribution of line radiation scattered in a plasma

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A theoretical investigation was carried out into the effects, arising as a result of the scattering of line radiation within a gaseous atmosphere, on the radiation field emerging from the atmosphere. The consequences of using different atomic models for the individual radiation scattering events in this investigation were examined. One of the models used represented the most realistic physical picture of the individual scattering event that could be constructed. In order to deduce the required solutions from this particular representation of the scattering process, the investigation carried out was based on a Green's function formulation in which the states of interest were selected by suitable projection operators. As well as obtaining a probability distribution law for the radiation scattering event using this approach, it was also possible to deduce the time development of the system as it passed through each of the states during the event. However, in order to obtain a complete theory for the redistribution of radiation during the radiation scattering process, it was also found necessary to examine other mechanisms which produce redistribution; in particular, application of the theories of pressure broadening of spectral lines to the description of the scattering of line radiation by atoms undergoing collisional perturbations was undertaken. This investigation proved particularly fruitful in the quasi-static limit where it was possible to deduce the form of the probability distribution law for the scattering event under conditions appropriate to this limit.

By using the results thus obtained it was possible to evaluate the

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redistribution functions for a small element of a purely scattering atmosphere. In order to obtain a more general form of the redistribution function than is usually used, the condition that the velocity of the particle performing the scattering must remain unchanged for the duration of the scattering event was relaxed. This led to a short investigation of a particle's behaviour, as described by a solution of the Fokker-Planck equation, while the particle undergoes momentum-changing collisions. In this way it was possible to produce a generalized version of redistribution theory from which were deduced two special limiting cases: one of these cases corresponds to the familiar form of redistribution in which the velocity of the scattering centre remains unchanged during the radiation scattering event; the other case produces redistribution functions for scattering events in which the velocity of the atom performing the scattering at absorption was completely uncorrelated with its velocity at emission. The latter case was treated in great detail producing, as well as certain new redistribution functions, physical models for complete redistribution both with a Doppler profile and a Voigt profile.

Finally, these results from redistribution theory were applied to the problem of the transfer of radiation through a uniform semi-infinite atmosphere for which it was expected that the effects of redistribution would be easily observed. Results were obtained and discussed for the cases of pure Doppler broadening and of combined natural and Doppler broadening. It was found that for pure Doppler broadening, the normally emergent intensity from the atmosphere was never very different from the intensity predicted by the corresponding case of complete redistribution. On the other hand, for combined natural and Doppler broadening there existed significant differences in the emergent intensities for the three different cases of redistribution considered.