THE ROLE OF OPACITIES IN ACCRETION DISKS

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An accretion disk is formed when matter with angular momentum is flowing on a gravitating object (as e.g. a white dwarf, a neutron star, a young stellar object, or a black hole). It radiates because the transport of angular momentum (required for the matter to reach the central object) necessarily implies the conversion of potential energy into a form of energy that corresponds to higher entropy. Many aspects of the physics (as e.g. the mechanism for the heat generation) are not yet well understood but they are presently one of the centers of astronomical interest (see e.g. the books by Frank, King, and Raine, 1992, or by Wheeler, 1993).

The importance of opacity for the structure is much higher for accretion disks than for stars for the following reasons:

1.) Accretion disks are configurations of finite optical depth and there is most probably no part in radiative equilibrium. This implies that even for a grey opacity the temperature is no universal function of the optical depth as for usual stellar atmospheres but it reflects directly the temperature and density dependence of the absorption and scattering coefficients (Shaviv and Wehrse, 1991). It can even lead to multiple solutions of the structure equations (Adam et al., 1990).
2.) Accretion disks are intrinsically three dimensional objects and involve large velocity fields so that the mean free path lengths of line photons are highly direction dependent.
3.) In many accretion disks (in particular if the central object is a supermassive black hole) the gas pressures are strongly exceeded by the radiation pressure; in fact, in many cases the density structure and the shape (i.e. run of the height with radius) of the accretion disk is largely determined by the divergence of the radiation flux tensor (Storzer, 1993). Close to the central object the opacity may even be responsible for an increase of the disk height with decreasing radius which can have severe consequences for the optical appearance of the disk and for the illumination of parts further away from the center.

Unfortunately, even for a very simple hydrodynamic model of the disk (as e.g. a stationary, geometrically thin Newtonian disk with a heat generation rate proportional to the gas pressure) it is presently not yet possible to determine the opacity effects quantitatively since methods for the solution of the radiative transfer equation in multi-dimensional media are only emerging now (Adam, 1990; Baschek, Papkalla, Wehrse 1993; for an overview see Wehrse, 1994). Due to the high dimensionality of the problem (2 space, 2 angle, and one frequency variables are coupled so that the solution requires extreme amounts of cpu time and memory) and due to the occurrence of steep gradients the calculations are still restricted to a few frequency points or neglect important couplings (cf. discussion by Wehrse, Baschek,

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Shaviv, 1994). We note that the new opacity data bases are presently only of limited value for the modeling of accretion disks since the tables do not provide data for the low temperatures and densities required. The addition of tables from other sources in the missing range is hardly possible since essentially all solutions for the structure equations require the continuity of high order derivatives. However, it is to be expected that in the near future both the application of solutions for boundary value problems which take switching points explicitly into account (Bock,1994) and the development of adaptive schemes for the solution of the multidimensional radiative transfer equation on parallel computers (Fuhrer, 1994; Kanschat, 1994) will lead to a significant improvement of the situation.

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OPACITIES OLD AND NEW IN WHITE DWARF MODELS

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The new radiative opacity compilations by the Opacity Project (OP) and the Livermore group (OPAL) represent a significant advance in the accuracy of this constitutive quantity. White dwarfs present a useful medium for the analysis of the opacities in regions of the density-temperature-composition phase space that are not sampled by any other stars. The bulk of the interior of white dwarfs is degenerate, and energy transport is therefore through conduction by electrons. This efficient energy transport mechanism results in a nearly isothermal core with temperatures in excess of 10 million K. The cooling of this core