IMPLICATIONS FROM THE SHAPE OF THE VISCOSITY-SURFACE DENSITY RELATION

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ABSTRACT. We present results of new vertical structure computations for cool, convective accretion disks. The influence of the uncertainty in the low temperature opacities on the cool branch of the viscosity-surface density relation is investigated. We discuss how the shape of this relation allows a prediction of temperatures in the accretion disk during the onset of an outburst and we compare this with observations for VW Hydri by Hassall (1984).

1. INTRODUCTION

Two kinds of uncertainty affect the results of vertical structure computations for accretion disks in cataclysmic variables. The first uncertainty is due to our lack of knowledge concerning the source of the viscosity. This is taken into account by different prescriptions for the viscosity parameter α. The change from one constant α to another yields a shift of the viscosity-surface density relation but no essential change of the shape.

The second uncertainty concerns the correct determination of the structure of cool disks, where the low temperature opacities are important. In addition the fact that in the atmospheric layers friction is only roughly taken into account reduces the reliability of surface density values for cool disks with extended atmospheres.

We present here viscosity-surface density relations (f-Σ relations) resulting from the vertical structure. We used the formulae described in Meyer and Meyer-Hofmeister (1983) together with a new set of opacity values from Hübner (1982) with consistent thermodynamic quantities (Hübner, 1986). Figure 1 shows the relations for constant viscosity parameters α. These results are described in detail and compared with corresponding relations based on opacities of Alexander (1975) and Alexander et al. (1982) in Meyer-Hofmeister (1986). The comparison shows that the structure of very cool disks ($\lesssim$ 3800 K) is essentially influenced by the different opacities. The smaller values in Hübner's table lead to higher densities in the atmosphere and therefore higher surface densities for very cool disks.

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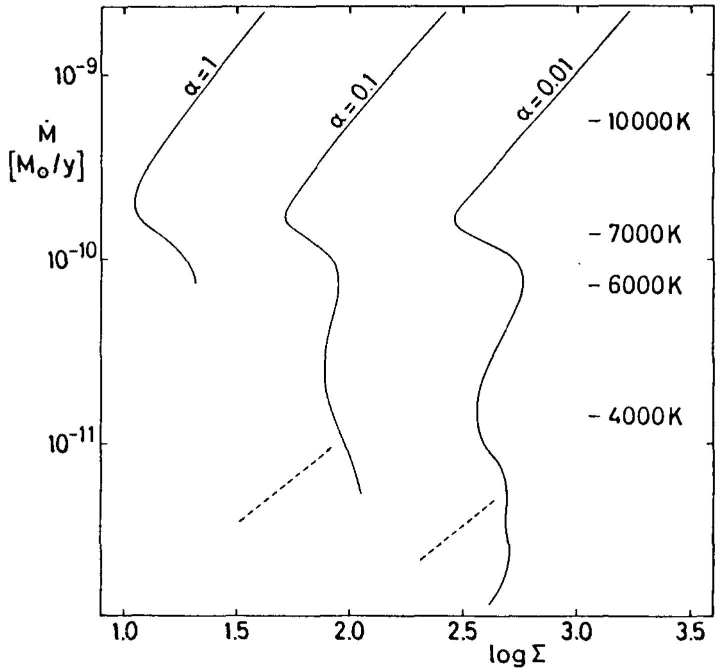

Figure 1. Viscosity (given in units of mass flow M) versus surface density Σ for different viscosity parameters α. Distance from the central star 10^{10} cm. Low temperature opacities from Huebner (1982). Dashed lines indicate the relation for optically thin disks. Relevant effective temperatures are given.

II. IMPLICATIONS ON THE EARLY RISE OF AN OUTBURST

The accretion disks in dwarf novae follow a limit cycle between a cool and a hot state (for a review see Smak 1984). During quiescence the mass accumulates in the cool disk and at each distance r from the central white dwarf the surface density increases according to the f–Σ relation as long as the slope is positive. If the surface density at some distance r increases above the value for which a cool state is still possible the outburst sets in and a transition to the hot state spreads from this region. The structure of the disk then changes locally on a thermal timescale. The values of viscosity and surface density during this transition to the hot state do not follow a straight line in the f–Σ diagram but show an initial increase followed by a decrease of Σ. Due to the fact that the heating front is narrow (Meyer, 1984 and Mineshige, 1986; $\lesssim$ 5% of the extension of the disk) only a small region in the disk can have the temperature of the transition phase. Extended disk regions should show the structure described by the stable parts of the f–Σ relation.

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In Figure 2 we present three different types of f–Σ relations which were found in our recent computations (Meyer-Hofmeister 1986). Type (a) is the result for α taken proportional to H/r or $(H/r)^{3/2}$ (compare also Meyer and Meyer-Hofmeister, 1983 and Duschl, 1985). A relation of type (b) was found for opacities from Alexander (1975) and also for those of Alexander et al. (1982) as used by Cannizzo and Wheeler (1984). Type (c) corresponds to the relation in Figure 1. The marked stable parts yield the temperatures we would expect to observe during the early rise of an outburst. For relations of type (b) and (c) a rise to temperatures around 6000 K can be predicted. From the fact that the f–Σ curves are similar for all distances r in the disk one would expect these temperatures in extended disk regions. An outburst computation is necessary to investigate to detailed changes in the disk with time.

Observations for VW Hydri (Hassall et al., 1983, Hassall, 1984) show that the optical spectrum in the early rise was consistent with a simple temperature spectrum corresponding to 6000–7000 K. This agrees with predictions from the f–Σ relation for small constant α (and not with α proportional to $(H/r)^{3/2}$).

We conclude that the disk instability model predicts for the onset of an outburst either an increase of temperature in the optically thick disk up to about 6000 K or a transition from low to high temperatures above 10000 K depending on the assumed α-prescription for the viscosity. Only if one were to restrict the adopted f–Σ relation to one of type (a) would it be conclusive that the observations discriminate against the disk instability model, as has been suggested by Hassall (1984), Pringle et al. (1986) and Verbunt (1986).

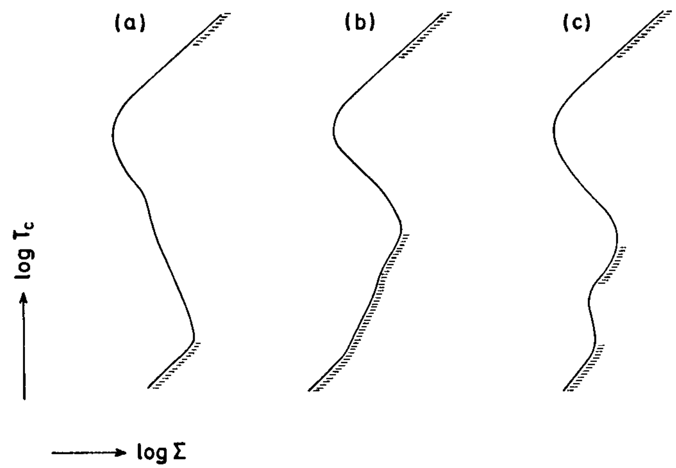

Figure 2. Schematic drawing of f–Σ relations of different shape.

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It would be very interesting to have additional observations for the early rise in different dwarf novae. From such observations one might obtain valuable further insight into the still poorly understood viscosity in cool accretion disks.

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