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TIME-LAPSE AND FLICKERING MAPPING OF ACCRETION DISCS: MEASURING THE DISC VISCOSITY PARAMETER

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I review observational constraints on accretion disc viscosity that are inferred from changes of disc structure with time and from disc flickering distributions.

Accretion discs are cosmic devices where angular momentum and gravitational energy are extracted from matter by an anomalous, still unknown viscosity mechanism, allowing it to be accreted onto a central star. Currently, the most promising explanation for the disc viscosity is related to magnetohydrodynamic (MHD) turbulence in the differentially rotating disc gas (see Balbus & Hawley 1991). From the observational standing point of view, because the properties of steady-state discs are largely independent of viscosity, one must turn to observations of time-dependent disc behavior in order to obtain quantitative information about disc viscosity [2].

Dwarf novae (DN) are excellent sites for studies of disc viscosity. They show recurrent outbursts in which their discs brighten by factors 20-100 as a consequence of mass and angular momentum redistribution on timescales of a few days. DN outbursts are explained in terms of either a thermal-viscous disc-instability (DIM, e.g., Lasota 2001) or a mass-transfer instability (MTIM, e.g., Bath 1975). DIM predicts matter accumulates in a low viscosity disc ($\alpha_{\rm cool} \sim 10^{-2}$) during quiescence, whereas in MTIM the disc viscosity is always high ($\alpha \sim 10^{-1}$). Therefore, measuring α of a quiescent disc is key to infer which model is at work in a given DN.

By measuring the (viscous) timescale $t_{\rm v} = r/v_{\rm r} \simeq r^2/\nu \simeq r^2/(\alpha_{\rm ss}\, c_{\rm s}\, H)$ with which the disc responds to changes in mass input rate, one might infer the average disc viscosity parameter $\alpha_{\rm ss}$,

$$\alpha_{\rm ss} \simeq \frac{r}{c_{\rm s}\, t_{\rm v}} \left[\frac{H}{r}\right]^{-1} \qquad (1)$$

where $v_{\rm r}$ is the viscous radial drift speed. Application of this time-lapse mapping technique to accretion discs of DN in outburst lead to $\alpha_{\rm ss} \simeq 10^{-1}$ (e.g., Baptista & Catalán 2001).

Flickering is the intrinsic brightness fluctuation seen in light curves of T Tau stars, mass-exchanging binaries and active galactic nuclei. In DNs, flickering might arise at the stream-disc impact region (because of unsteady mass inflow or post-shock turbulence, Warner & Nather 1971) and/or in turbulent inner disc regions (Bruch 2000). If the disc-related flickering is caused by MHD turbulence, it is possible to infer $\alpha_{\rm ss}$ from the relative flickering amplitude, $\sigma_{\rm D}/D$ (Geertsema & Achterberg 1992),

$$\alpha_{ss} \simeq 0.23 \left[\frac{r}{50\, H}\right] \left[\frac{\sigma_{\rm D}(r)}{0.05\, \langle D(r) \rangle}\right]^2 . \qquad (2)$$

The analysis of a large ensemble of light curves of a given DN allows one to separately measure the steady-light component, low- and high-frequency flickering amplitudes as a function of binary phase and to derive corresponding maps of surface brightness distributions from their eclipse shapes (Baptista & Bortoletto 2004).

This technique was applied to three DNs and to the nova-like variable UU Aqr to derive, for the first time, the radial run of the viscosity parameter in their accretion discs. The three DN are strong flickers and show high viscosity discs in quiescence ($\alpha_{\rm ss} \simeq 0.1 - 0.5$). This is at odds with DIM, and underscores the suggestion that their outbursts are powered by MTIM. In UU Aqr, flickering arises mainly in tidally-induced spiral shocks in its outer disc. Accordingly, its disc viscosity increases outwards and reach $\alpha_{ss} \sim 0.5$ at the position of the shocks, suggesting that they might be an effective source of angular momentum removal of disc gas.

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[2]here we adopt the prescription of Shakura & Sunyaev (1973) for the accretion disc viscosity, $\nu = \alpha c_{\rm s} H$, where α is the non-dimensional viscosity parameter, $c_{\rm s}$ is the local sound speed and H is the disc scaleheight.

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