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## The study of $\theta\varphi$ component of the viscous stress tensor in the protoplanetary discs

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### Abstract

Observation and numerical documents have shown that the protoplanetary discs (PPDs) around the young stellar objects (YSOs) are gravitationally unstable. The self-gravity can be important in PPDs. The gravitational instability and outflow (mass-loss) are dominant mechanisms for transporting outward angular momentum and inward accretion in the disc cold mid-plane. The structure of the self-gravitating accretion discs depends strongly on the rate at which it cools. In this paper, we have studied the hydrodynamical equations in the presence of  $\theta\varphi$  component of the viscous stress tensor ( $t_{\theta\varphi}$ ) in the spherical coordinates ( $r, \theta, \varphi$ ) by using the semi-analytical self-similar solutions in the steady state and axisymmetric assumptions. This component of the viscous stress tensor is related to the transport outward of angular momentum by outflows. The solutions indicate that the disc is gravitationally unstable. The gravitational instability as a viscous source leads to heat the disc. Our results have shown the toomre parameter ( $Q$ ) decreases by increasing the cooling rate because the heating supplied by gravitational instability is not enough to counteract cooling and so the disk will fragment and produce planets. The results have shown that  $t_{\theta\varphi}$  makes the disc colder, and thinner and outflows form in the regions with lower latitudes. We have shown that the effect of  $t_{\theta\varphi}$  in the mid-plane of the disc is more effective than  $t_{r\varphi}$  (turbulent viscosity).

**Keywords:** accretion, accretion disc, self gravity, protoplanetary disc, planetary systems, formation

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