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The Hardy inequality and large time behaviour of the heat equation on $\mathbb{R}^{N-k} \times (0, \infty)^k$

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Abstract: We study the large time asymptotic behaviour of the heat equation with Hardy inverse-square potential on generalized half-spaces $\mathbb{R}^{N-k} \times (0, \infty)^k$, $k \geq 0$. We first show a new improved Hardy-Poincaré inequality for the quantum harmonic oscillator with Hardy potential. Then we obtain optimal polynomial time decay rates and the first term in the asymptotic expansion of the solutions in $L^2(\mathbb{R}^{N-k} \times (0, \infty)^k)$. Particularly, we extend and improve the results obtained by Vázquez and Zuazua (J. Funct. Anal. 2000) (which correspond to the case $k = 0$) to any $k \geq 0$. We emphasize that the higher the value of k the better time decay rates are. We employ a simplified approach conceding to remove the usage of spherical harmonics decomposition in our analysis. In addition, we also provide polynomial decay rates of the solutions in any L^p -norm with $p \geq 2$.

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