Non-equilibrium string theory and the Schwinger-Keldysh time contour

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Standard arguments using the large-N expansion of quantum systems with matrix degrees of freedom predict a dual description in terms of a genus expansion of a string theory. We extend this picture to the Schwinger-Keldysh formulation of non-equilibrium quantum systems, and identify several universal features of the anticipated dual string theory. We find a rich refinement of the topological genus expansion: The sum over worldsheet topologies is refined into a triple sum; in particular, the future time instant, where the forward and backward branches of the Schwinger-Keldysh time contour meet, is associated with its own worldsheet genus expansion. After the Keldysh rotation, we find that the worldsheets naturally decompose into their "classical" and "quantum" parts. We discuss how these properties anticipated from "non-equilibrium string perturbation theory" can be realized in the worldsheet path integral formulation of the string dynamics.