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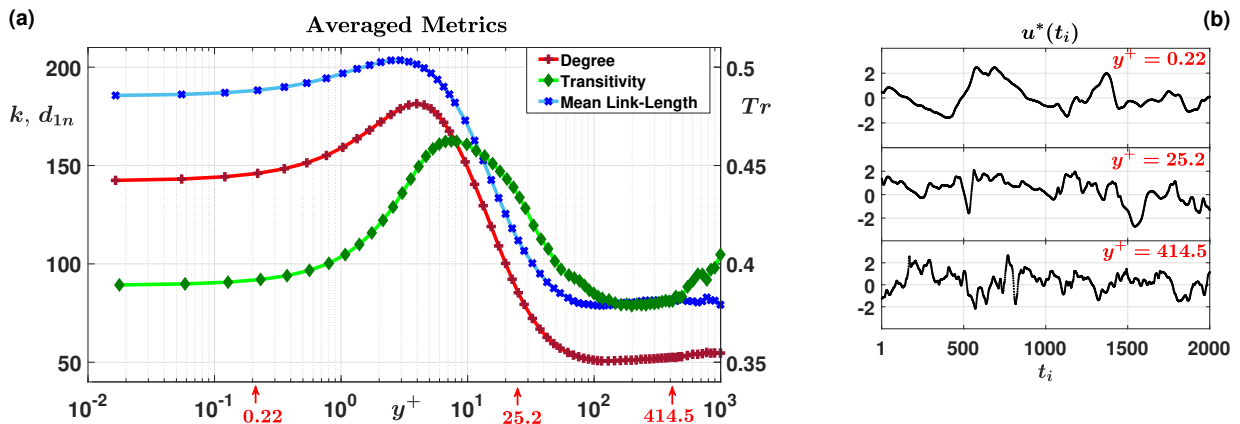
## CHARACTERIZATION OF TURBULENT CHANNEL FLOWS: FROM TIME-SERIES TO COMPLEX NETWORKS

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Experimental and numerical simulations provide nowadays a great amount of detailed spatio-temporal data, which needs to be properly examined to achieve a better description of the turbulence dynamics. New investigative tools are hence continuously required to handle and properly interpret such *big-data*. In this context, complex network theory — by combining graph theory and statistical physics — recently turned out to be a powerful framework to analyze complex systems, such as turbulent flows [4],[5]. In this work, a DNS of a fully-developed turbulent channel flow [1],[3] is investigated through the natural visibility graph (NVG) method [2]. A subset of the simulation grid domain is firstly selected, acquiring all the available temporal data for the velocity field,  $(u, v, w)$ , and for the kinetic energy,  $K$ . The time-series of each selected grid-point is then mapped into a network by means of the NVG method. In particular, two data values constitute a pair of linked nodes of the network if the straight line connecting the two data points lies above the other in-between data. The *degree centrality*,  $k$ , quantifying the visibility of nodes, is the first metric studied. The transitivity,  $Tr$ , and the newly introduced *mean link-length*,  $d_{1n}$ , are then evaluated as indicators of the inter-visibility and mean temporal distance among nodes, respectively. The metrics are averaged along the directions of homogeneity of the flow (i.e.,  $x$  and  $z$ ), thus they only depend on the wall-normal coordinate,  $y^+$  (see Fig. 1a). The visibility-based networks inherit the temporal structure of the corresponding time-series, as we observe the trend of the metrics is closely related to the flow properties along  $y^+$ . In this way, different temporal features of the time-series are mapped in the networks and the metric trends (Fig. 1a) allow one to shed light on how the temporal structure of the series changes moving along  $y^+$  (see Fig. 1b). Although intrinsically simple to be implemented, the visibility graph-based approach then offers a promising support to the classical methods for accurate time-series analyses of inhomogeneous turbulent flows.



**Figure 1.** (a) Averaged metrics ( $k, Tr, d_{1n}$ ) as function of the wall-normal coordinate,  $y^+$ . The metrics are obtained from networks built on time-series extracted from the streamwise velocity component,  $u(t)$ . (b) First 2000 time instants extracted from time-series of the streamwise velocity component at three representative  $y^+$  stations ( $y^+ = \{0.22, 25.2, 414.5\}$ ) and at fixed  $(x, z)$  coordinates. Normalization is taken as  $u^* = (u - \mu)/\sigma$ , where  $\mu$  and  $\sigma$  are the mean and standard deviation values of  $u(t_i)$ , respectively.

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