Brain activity over the entire network is complex. A full understanding of brain activity requires careful study of its multi-scale spatial-temporal organization (from neurons to regions of interest; and from transient events to long-term temporal dynamics). Motivated by these challenges, we will explore some characterizations of dependence between components of a multivariate time series and then apply these to the study of brain functional connectivity. This is potentially interesting for brain scientists because functional brain networks are associated with cognitive function, and mental and neurological diseases. There is no single measure of dependence that can capture all facets of brain connectivity. In this talk, we shall present some new models for exploring potential interactions between oscillations in multivariate time series including non-linear (e.g., phase-amplitude relationships). The proposed approach captures lead-lag relationships and hence can be used as a general framework for spectral causality. This is joint work with Marco Pinto (KAUST and Oslo Metropolitan University).