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Cooperation, Creativity and Closure in Scientific Research Networks:
Modeling the Simpler Dynamics of Invisible Colleges

Scientific research communities or invisible colleges are conceptualized in this paper as social communications structures formed by the overlapping of more compact networks of personal associations among researchers in particular disciplinary fields of inquiry. Within these "colleges" circulate ideas and opinions regarding the "validity" of specific scientific propositions and research methods. Transmission of tacit knowledge (which is complementary to the codified information broadcast in archival publications) takes place through local social network connections, and is regarded to be critical in enabling individual researchers to participate in, and contribute to the collective epistemological tasks. Building on a model proposed by David (1998), this analysis posits a population of rational research agents engaged individually in continuous processes of experimental observation and Bayesian inference, whose interpretations of their current empirical observations are influenced by the prevailing distribution of opinion expressed within their respective local social networks Formulation of this structure in graph theoretic terms, and specification of a random "local opinion polling" process, permits the application of results from Markov random field theory to show how probabilistic micro-level knowledge communication behavior affects the capacity of the invisible college (as the ensemble of inter-linked social networks) to attain a collective cognitive state of "closure." The latter state is represented as a configuration of correlated belief orientations in regard to the validity, or invalidity of particular scientific propositions. This stylized, highly simplified model's key features resemble closely the stochastic process known as the "voter model," a well-studied reversible spin system due to Clifford and Sudbury (1973) and Holley and Liggett (1975). It is shown that the ability of the entire epistemic community to arrive at "closure" regarding a given question depends critically upon the degree to which its members' communication behaviors conform to the norms of cooperation, disclosure and universalism that Merton (1973) identifies with the institutionalized conduct of open science. But the nature of the mechanism posited is such that the resulting "knowledge consensus" will be an emergent and path dependent property of the network ensemble, as has been contended by more recent contributors to the sociology of scientific knowledge.

Further elaboration of this simple structure is focused upon characterizing the endogenous influences upon the communication behaviors of the agents, and deriving the macro-properties of the equivalent deterministic system corresponding to the stochastic "voter model." Here the expected time for achieving closure, as well as the expected rate of "collective creativity" attained through the recombinant generation of ideas, are key macro-level performance features. Along with the size of the global ensemble, they are taken to influence behaviors governing the average rates of transmission of tacit knowledge and opinion through the structure of inter-linked local social networks. With the size of the global network being set exogenously, a wide range of size-related cognitive performance attributes for the invisible college may exist, each representing a (short-run) equilibrium. The larger among these systems generally are associated with greater average "openness" at the micro level, and higher rates of systemic creativity.

In the long run, however, it is supposed that those macro-properties, and the associated expected speed with which closure on new propositions is attained, would influence the network ensemble's ability to grow by drawing in additional qualified researchers from the surrounding environment. Such a process of (lagged) adjustments in network size yields a simple deterministic dynamic model that is found to possess high-level and low-level equilibrium states, both of which are locally stable. An autonomously high average propensity on the part of researchers to disclose knowledge promotes dynamics that lead to the system's high-level attractor. But, seemingly small policy interventions can adversely "shock" a communicative and creative scientific network, causing it to shrink until it can survive only as a much smaller, less open and less creative research community. The concluding section discusses the salient limitations of this heuristic model, and the respects in which its structure may be elaborated, and the resulting systems' properties studied by means of stochastic simulation.