



To Group or Not to Group?

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stars. Given the complex radiative transfer problem posed by Ly α (4), it is difficult to test theoretical predictions of the Ly α flux in star-forming regions based on the observed Balmer-alpha emission. Comparison of the new Ly α measurements of local regions in our galaxy with observed Balmer-alpha and continuum radiation provides the first real test of whether the theory can be applied with confidence to other galaxies.

The first detections of Ly α emission from star-forming regions in our galaxy suggest that future observations of regions with low line-of-sight hydrogen column density, such as the TW Hydrae association, may show a good spatial correlation of Ly α and Balmer-alpha emission. Such data could test whether observed Balmer-alpha emission is a reliable indicator of Ly α flux in star-forming regions. Many stars are formed when strong ultraviolet radiation, including the hydrogen Ly α line flux, from nearby hot stars compresses and ionizes cold gas and dust clouds (5).

It is ironic that the electrical power on the Voyagers is decreasing with time as the Ly α foreground keeps improving. For lack of power, the spectrometer on Voyager 2 has been switched off, and the spectrometer on Voyager 1 can no longer scan the sky. It, too,

could be switched off soon.

Although there are some additional Ly α data from the Voyagers that could be analyzed, any major addition to the galactic Ly α data set will require observations by another spacecraft. NASA's New Horizons Spacecraft on its way to Pluto has an ultraviolet-imaging spectrometer (6) that could observe galactic Ly α emission in a more systematic way.

As of mid-November 2011 (7), the Voyagers are 118.9 and 96.9 AU from the Sun, having passed the TS, and are headed for the heliopause beyond which they will enter the interstellar medium. Voyager 1 may cross the heliopause sometime in the next 10 years. If the instruments are still operating, the telemetry signals can still be heard, and the mission continues, then a whole new set of discoveries await. In situ measurements of the magnetic field and charged-particle densities and energies in the local interstellar medium would provide important information on the environment of the Sun. Knowledge of the location of the heliopause could test theoretical predictions. The primary mission of the Voyagers was to study the outer planets and their environments. Who would have anticipated the new accomplishments of these spacecraft more than 20 years later?

The new results from the Voyagers highlight an unfortunate conundrum in observational astronomy. In their desire to understand phenomena in the distant universe, astronomers often do not study the nearby universe where higher spatial resolution, brighter sources, less absorption, and decreased source confusion provide critical tests of the analysis techniques that are used to study presumably similar phenomena in the more distant universe. Proposals to study phenomena in the distant universe often trump less exciting proposals to test our analysis techniques by observing nearby targets. The results reported by Lallement *et al.* demonstrate that with the new and future Voyager data, we can expect to acquire unique information on interstellar gas and galactic Ly α emission.

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EVOLUTION

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The phenomenon of cooperation between potentially competing individuals raises an interesting question related to evolution: Why should a competitor favor someone else's fitness at the expense of its own (1, 2)? One way to approach this question is through insights on how cooperation and population structure coevolve.

Population structure—the idea that a population is subdivided into transient subgroups rather than being composed of individuals “bathing” in a huge, well-mixed pool—can, in general, provide a possible answer to this question. A cooperative behavior (which benefits other individuals) can evolve if the population structure allows cooperators to benefit from the act, on average, at least as much as noncooperators in the population. In this context, it is useful

to distinguish between “weak” and “strong” altruism. A weak altruist helps others in its group more than it helps itself (i.e., it benefits itself with 5 extra offspring, but others with 10, thus paying a relative fitness cost), whereas a strong altruist pays an absolute cost by helping others even more so (whereby its number of offspring is reduced by, say, 5 offspring), paying an even higher fitness cost. Although weak altruists are cooperative, they are competitive in comparison to strong altruists. The advantage of being a weak altruist is that such individuals can spread through a population without assortment, meaning that groups can form purely at random (2). Although weak altruists within any heterogeneous subgroup are always selected against within that group (because they help the nonaltruists more than themselves), groups with a higher frequency of altruists still contribute more to the overall gene pool of a population than those subgroups with more selfish indi-

The benefits of cooperation can drive the evolution of a population structure that supports cooperative behavior.

viduals. Strong altruists, on the other hand, spread only when they preferentially meet their own kind (positive assortment) (1). This explanation treats population structure (through random or positively assorted groups) as given. What, then, is the origin of a population structure that supports cooperation, provided that individuals can influence how groups are formed?

To address how the evolution of a population structure is affected by selection pressures on cooperative behavior (which is costly), Powers *et al.* examined the evolution of a particular population-structuring trait—the preference of an individual for group size (3). The authors considered individuals with two relevant genes on a chromosome: One gene specifies preference for the size of the group that the individual chooses to join, and the other gene specifies altruistic or selfish behavior of the individual (3). Individuals with a genetic preference to join groups of size n are allowed

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to do so, hence there is positive assortment (nonrandom group formation) based on the group size preference allele, but not directly on social behavior. Within this setting, the “prisoners’ dilemma” and “snow-drift” games (game theory models used to conceptualize cooperation), albeit with N persons per group, show that group size and cooperation do indeed coevolve. The beneficial effects of cooperation are more apparent in groups of smaller size (4). Genetic linkage between alleles for smaller group size at one locus and for alleles for cooperation at the other is favored: Assorted group formation selects for assorted genetic composition. There is also positive feedback: Smaller groups drive cooperation, and cooperators prefer smaller groups. The mechanism works with genetic recombination between the two genes also, although with stricter quantitative conditions.

The coevolution model of Powers *et al.* illustrates how genetic preference for a smaller group size can evolve because it increases the benefits of cooperation that its bearers experience. This view also may help our understanding of an important aspect of the major transitions in evolution (5)—when originally separate individuals come together to form a higher-level evolutionary unit. The success of such a transition hinges on the evolutionary capacity of the groups in which the original individuals come together. As a simple example, the cell membrane that encompasses replicating molecules defines which components interact—a rigorous population structure that strongly favors cooperation because individuals “are sitting in the same boat” (5). The cell membrane can also be regarded as a constructed niche of the genes within (6).

Is such an evolvable population structure always key to the origin of interesting instances of cooperation? The answer is no. In the volunteer’s dilemma game (7, 8), cooperators contribute to the public good, but in a special way: At least M players must contribute to achieve the public goal, but then the benefit is maximal (in economics, $M = 1$ in the volunteer’s dilemma case and $M > 1$ in the teamwork dilemma). Mathematically, such a step function (abruptly jumping from zero to maximal value) is an extreme form of synergy (described by a sigmoid function), and was shown to lead to stable coexistence of cooperators and selfish individuals without any positive assortment (grouping of individuals with the same type of behavior). Cooperators survive without kin selection or repeated interactions (which could allow for punishment). More-



Cooperative hunting. Several individuals hunt down prey more efficiently than alone or in very small groups. The illustration shows *Homo ergaster* attacking a species of saber-toothed cat (Machairorodontinae).

over, the results of the analysis are valid to any sigmoid benefit function, unless the cost of cooperation is prohibitively high. A sigmoid benefit function can be considered as a combination of synergy at low numbers of cooperators and diminishing returns at high numbers, the dynamics of which have been analyzed case by case (9, 10). Nonlinear benefit functions are likely to prevail in several examples hitherto assigned to other games, including many examples of bacterial biofilms in which bacteria of the same or different species on a surface adhere together, embedded in a kind of “glue” synthesized by the bacteria (a public good), thereby making them more efficient in nutrition, for example. Cooperative hunting (in lions and humans, for example; see the figure) is another such case, when several individuals hunt down prey disproportionately more efficiently than alone or, say, in groups of two (11). Teamwork cooperation may have been essential in early scavenging by humans; if so, it likely became linked to early forms of language (12), a spectacular form of cultural niche construction (6).

Ultimately, cooperation must pay off, even if it is immediately costly to cooperators, because otherwise they would go extinct. Grouping may ensure that cooperators preferentially meet cooperators, which

is a must for the case when cooperators pay an absolute fitness cost. Such population structure can (and presumably did) evolve to favor more cooperation. Yet the devil is in the details: Some situations, probably relevant to our human origins, allowed for the coexistence of cooperators and noncooperators without such assortment. Future work should clarify how the group-internal network structure of qualitatively different kinds of cooperative acts might coevolve with the rules of grouping.

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