P125a

Confronting Outflow-Regulated Cluster Formation Model with Observations

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Protostellar outflows have been shown theoretically to be capable of maintaining supersonic turbulence in cluster-forming clumps and keeping the star formation rate per free-fall time as low as a few percent, but this model of outflow-regulated cluster formation has yet to be tested extensively by observations. We aim to test two basic predictions of the model, namely (1) the clump should be close to virial equilibrium and (2) the turbulence dissipation rate should be balanced by the outflow momentum injection rate, using recent outflow surveys toward 8 nearby cluster-forming clumps (B59, L1551, L1641N, Serpens Main Cloud, Serpens South, ρ Oph, IC 348, and NGC 1333). We find, for almost all sources, that the clumps are close to virial equilibrium and the outflow momentum injection rate exceeds the turbulence momentum dissipation rate. In addition, the outflow kinetic energy is significantly smaller than the clump gravitational energy for intermediate and massive clumps with $M_{\rm cl} \gtrsim$ a few $\times 10^2 M_\odot$, suggesting that the outflow feedback is not enough to disperse the clump as a whole. The number of observed protostars also indicates that the star formation rate per free-fall time is as small as a few percent for all clumps. These observationally-based results strengthen the case for outflow-regulated cluster formation.