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The Roles of Protostellar Outflow Feedback in Clustered Star Formation

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Abstract. We discuss the roles of protostellar outflow feedback in cluster formation using observational data of nearby cluster-forming regions like rho Oph, NGC1333, and Serpens. The observations suggest that observed protostellar outflow feedback appears to be sufficient both to maintain supersonic turbulence and to dynamically support the parent cluster-forming clumps. However, it is not enough to destroy the parent clumps by the current outflow activity. This implies that star formation process may not be too short and probably last at least for several local dynamical times.

Keywords. ISM: clouds — ISM: jets and outflows — MHD — stars: formation

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Table 1 summarizes several global properties of the five nearby cluster-forming regions: L1641N, Serpens Main Cloud, Serpens South, ρ Ophiuchus, and NGC1333. Here, the physical quantities are derived by assuming that the outflow gas is optically thin. From the observational data, we address the two important issues of the cluster formation: turbulent generation and clump destruction. Table 1 indicates that for all the clumps, the outflow energy injection rate is comparable to or larger than the turbulence dissipation rate. We conclude that the outflows can maintain supersonic turbulence in the cluster-forming clumps. On the other hand, how the outflow force impacts the global clump dynamics appears to depend on the clump mass. For the clumps with $M \gtrsim 400\ M_\odot$, the clump gravitational force tends to be significantly larger than the outflow force, whereas for the clumps with $M \lesssim 400\ M_\odot$, the outflow force is comparable to the clump gravitational force. It may be difficult to destroy the whole clumps only by the outflow feedback for the clumps with masses larger than 400 $M_\odot$. In contrast, the current observed outflow activity can destroy the small clumps or at least change the clump dynamics significantly. The importance of the outflow feedback in cluster formation may depend on the clump mass. Since the typical YSO ages are around a few Myr, the cluster formation may last for several or more free-fall times. That supports the slow cluster formation scenario or the outflow-regulated cluster formation scenario.

Table 1. Global quantities of nearby parsec-scale cluster-forming clumps

Name	Mass ($M_\odot$)	$\dot{E}_{\rm turb}$ ($L_\odot$)	$\dot{E}_{\rm out}$ ($L_\odot$)	$\dot{E}_{\rm out}/\dot{E}_{\rm turb}$	$F_{\rm grav}$ ($M_\odot$ km/s)	$F_{\rm out}$ ($M_\odot$ km/s)	$F_{\rm out}/F_{\rm grav}$
L1641N	200	0.1	2	20	6	10	1.7
Serpens Main	400	0.2	1	10	2	5	2.5
Serpens South	500	0.2	1	5	40	8	0.2
rho Oph	1000	0.1	0.2	2	13	1	0.08
NGC 1333	2000	0.5	0.7	1.4	20	6	0.3