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Can Massive Stars be formed by Accretion?

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Abstract. Radiative effects strongly hinder the formation of massive stars. A necessary condition for accretion growth of a hydrostatic object up to high masses $M > 20\,\mathrm{M}_\odot$ (rather than coalescence of optically thick objects) is the formation of and accretion through a circumstellar disk. These disks will be photoevaporated on a timescale of $\sim 10^5$ yr, similar to the accretion timescale, and be observed as UCHIIs. Collapse simulations with grey radiation transfer display significantly different results from corresponding frequency-dependent simulations. A single example of a 60 $\mathrm{M}_\odot$ molecular core with resulting stellar masses of $M_{\rm final}^{grey} = 20.7\ \mathrm{M}_\odot$ and $M_{\rm final}^{\nu-dep} = 33.6\ \mathrm{M}_\odot$ is briefly discussed.

Our understanding of the formation of massive stars is still rather limited. Because of their high luminosities we can expect radiative acceleration to significantly influence this process; we cannot simply "scale up" theories of low mass star formation. Furthermore, OB stars form in clusters and associations; their mutual interactions via gravitational torques, powerful winds and ionizing radiation contribute further to the complexity of the problem.

Yorke & Sonnhalter (2000, in prep.) consider the collapse of isolated, rotating, non-magnetic, massive molecular clumps of masses 30 $\mathrm{M}_\odot$ 60 $\mathrm{M}_\odot$, and 120 $\mathrm{M}_\odot$ using an improved frequency-dependent radiation hydrodynamics code (see Fig. 1 and Table 1 for selected results). The "flashlight effect" (Yorke & Bodenheimer 1999: radiation is reflected and reemitted strongly non-isotropically in polar direction) allows material to enter into the central regions through the disk. Because these simulations cannot spatially resolve the innermost regions of the molecular clump, however, they cannot distinguish between the formation of a dense central cluster or a single massive object. They also cannot exclude significant mass loss from the central object(s) which may interact with the inflow into the central grid cell. Thus, with the basic assumption that all material in the innermost grid cell accretes onto a single object, they are only able to provide an upper limit to the mass of stars which could possibly be formed.

Even though no massive disk has yet been directly observed around a main sequence massive star, such disks should be the natural consequence of the star formation process even in the high mass case. The high FUV and EUV fluxes associated with high mass stars will begin to photoevaporate the disks on timescales of $\sim 10^5$ yr (Hollenbach et al. 2000), which will be observable as UCHIIs with comparable lifetimes (Richling & Yorke 1997).

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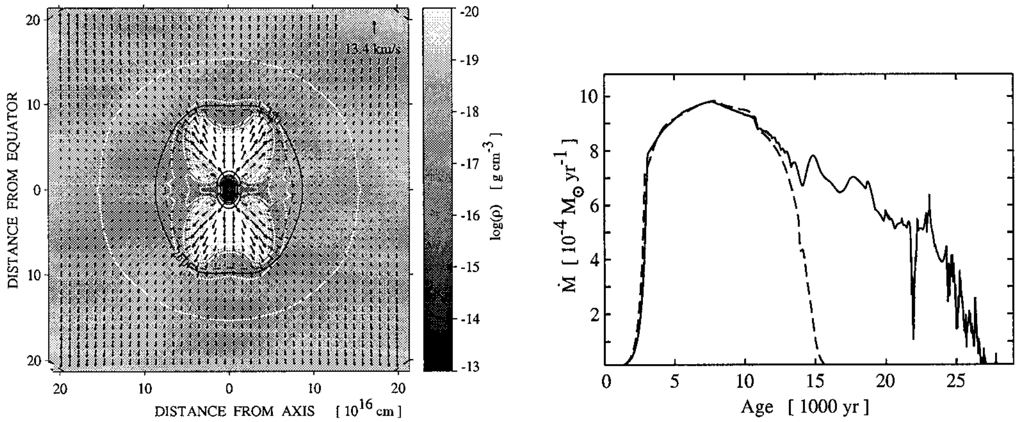

Figure 1. **Left frame:** Distribution of density (*grey-scale* and *white contour lines*), velocity (*arrows*), temperature of amorphous carbon grains (*solid black contour lines*), and temperature of silicate grains (*dotted contour lines*) for $60\,M_\odot$ case at an evolutionary stage $t = 25000$ yr at which time the central zone contains $33\,M_\odot$. **Right frame:** Mass accretion rate of central object for case shown at left (*solid line*) compared to accretion rate for "grey" calculation (*dashed line*).

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References

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Table 1. Initial conditions and final core masses for two simulations of rotating $\rho \propto r^{-2}$ molecular clumps: "grey" assumes grey radiation transfer; "ν-dep" assumes frequency dependent radiation transfer

Mass [1] $[M_\odot]$	$R_{\rm max}$ [pc]	Ω_0 [s^{-1}]	ρ_0 [g cm^{-3}]	$M_{\rm final}^{grey}$ $[M_\odot]$	$M_{\rm final}^{\nu-dep}$ $[M_\odot]$
60	0.1	5×10^{-13}	10^{-20}	20.7	33.6

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[1] Material outside of $R_{\rm max}$ at density ρ_0 was allowed to flow into computational domain