First Hydrodynamics Simulations of Radiation Forces and Photoionization Feedback in Massive Star Formation

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We present the first simulations of the formation of massive stars which account for radiation forces as well as photoionization feedback (along with protostellar outflows) simultaneously. We perform direct hydrodynamics simulations of the gravitational collapse of high-density mass reservoirs toward the formation of massive stars including self-gravity, stellar evolution, protostellar outflows, continuum radiation transport, photoionization, and the potential impact of ram pressure from large-scale gravitational infall. For direct comparison, we execute these simulations with and without the individual feedback components. Furthermore, each simulation series is performed starting from two different accretion scenarios, namely a finite small-scale mass reservoir such as a pre-stellar core vs. a virtually infinite reservoir which accounts for large-scale accretion flows. We determine the relative strength of the feedback components and derive the size of the reservoir from which the forming stars gained their masses. Photoionization and HII regions dominate the feedback ladder only at later times, after the star has already contracted down to the zero-age main sequence, and only on large scales. Specifically, photoionization yields a broadening of the bipolar outflow cavities and a reduction of the gravitational infall momentum by about 50%, but does not limit the stellar mass accretion. On the other hand, we find radiation forces restrain the gravitational infall toward the circumstellar disk, impact the gravito-centrifugal equilibrium at the outer edge of the disk, and eventually shut down stellar accretion completely. The most massive star formed in the simulations accreted 95 Msol before disk destruction; this mass was drawn-in from an accretion reservoir of approximately 240 Msol and 0.24 pc in radius. Concluding, in the regime of very massive stars, the final mass of these stars is controlled by their own radiation force feedback.

Outflows Disk