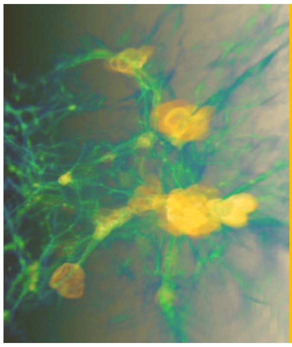

Local and Global Radiative Feedback: The Rise of Early Stellar Populations

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Introduction

In the hierarchical merger paradigm of lambda cold dark matter (ΛCDM) cosmology, the first stars formed in isolation in small dark matter halos, one per halo, at z ~ 20 - 30. However, gravity congregated these halos into small swarms, and radiation from one star influenced the formation of new stars in nearby halos. Furthermore, if a star ended its life in a supernova (SN) explosion, its ejecta also ram-pressure stripped neighboring halos, potentially preventing them from forming stars. At lower redshifts, the appearance of a global Lyman-Werner background from early massive star populations partly sterilized halos of H_2, which suppressed the formation of new stars. How radiative and kinetic feedback regulated the rise of the first stellar populations is a key question in early cosmological structure formation.

Previous work centered on radiative feedback from 120 solar mass stars, which do not die in SN explosions, found that they were less destructive to star formation in nearby halos than commonly believed. However, low mass primordial stars (25 - 80 solar masses) may have been more destructive due to their higher ratios of photodissociative flux to ionizing flux, their longer lives, and their SN flows. Here, we present a survey of both radiative and kinetic feedback by 25-80 solar mass Pop III stars on local star formation rates.

Halo Photoionization Models

We adopt spherically-averaged 2D baryon profiles for a 1.35x10^5 solar mass DM halo computed from cosmological initial conditions in the Enzo AMR code and photoevaporate them in the ZEUS-MP radiation hydrodynamics code. The cylindrical coordinate mesh has 1000 points in Z and 500 in R with box dimensions of 250 pc and 125 pc in Z and R, respectively. We illuminate the halos for the lifetime of the star and then model their behavior out to a total of 10 Myr to follow the evolution of the relic H II region. Each star is placed 150, 250, 500, and 1000 pc from the center of a nearby halo, and each halo is illuminated at four different evolutionary stages marked by the central density to which it has collapsed.

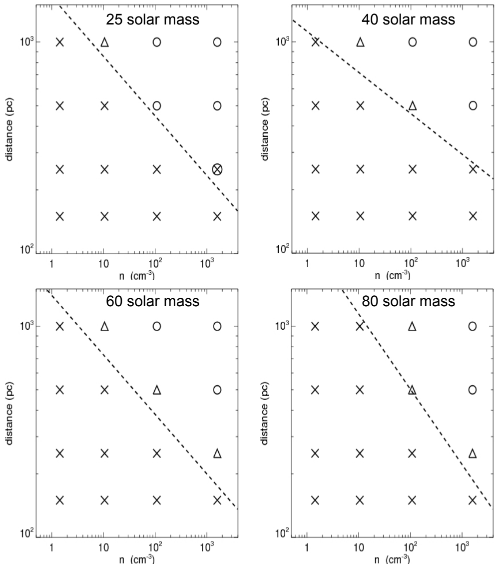

Fig 4: Star formation in the proximity of 25, 40, 60 and 80 solar mass stars. Crosses denote quenched star formation, triangles are delayed star formation, and circles signify uninterrupted star formation. The lines denote the threshold distance for star formation (SF) in the halo to proceed.

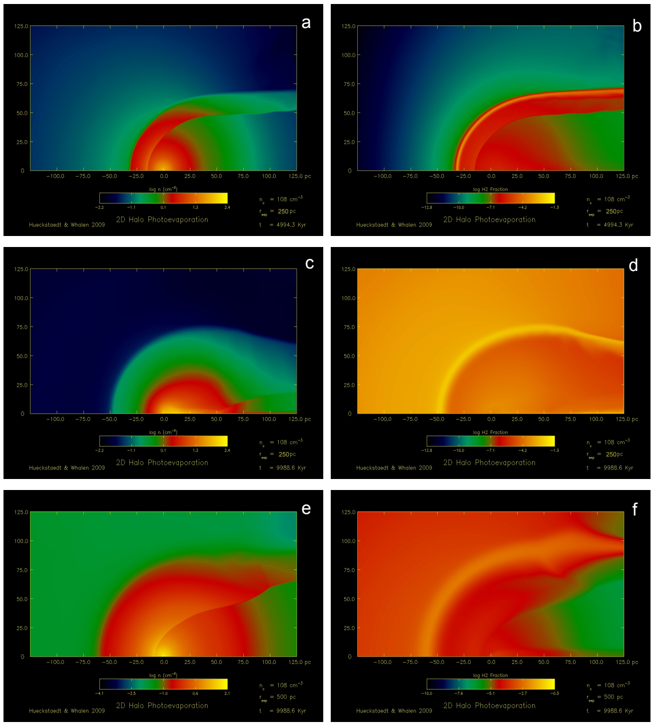

Fig 1: Density (left) and H_2 mass fraction (right) for a core of initial density 108 cm^{-3} irradiated by a 25 solar mass star. (a,b) r_{sep}= 250 pc, t= 5 Myr; (c,d) r_{sep}=250 pc, t= 10 Myr; (e,f) r_{sep}= 500 pc, t= 10 Myr. Star formation is quenched for r_{sep}= 250 pc but not at r_{sep}=500 pc.

Radiative and Kinetic Feedback

We show outcomes for star formation as a function of central baryon density n_c and distance to the star for 25, 40, 60, and 80 solar mass neighbor stars in Fig 4. Results differ only in a relatively narrow belt with stellar mass. This happens because the larger flux of more massive stars is offset by their shorter lifetimes.

Stellar evolution models predict that 25 and 40 solar mass primordial stars end their lives as core-collapse SNe. If we adopt the conservative stance that star formation in a halo is shut down when the SN remnant reaches it, we can account for kinetic feedback by these stars in addition to their radiative effects. We have previously examined the evolution SN remnants from 25 and 40 solar mass stars and computed their radii with time. Kinetic feedback has less effect on SF outcomes than might be expected, primarily because SF time scales in the halo are often shorter than the arrival time of the remnant. When the remnant is capable of halting SF, radiative feedback would have done so anyway.

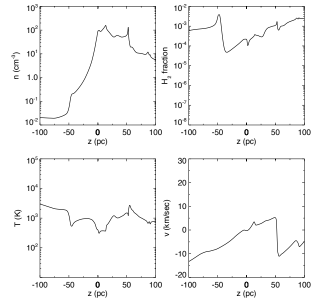

Fig 2: Line-outs along the symmetry axis at t= 10 Myr for the model shown in Fig 1 panels c and d (start formation quenched).

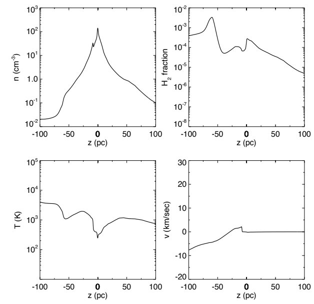

Fig 3: Line-outs along the symmetry axis at t= 10 Myr for the model shown in Fig 1 panels e and f (start formation unquenched).

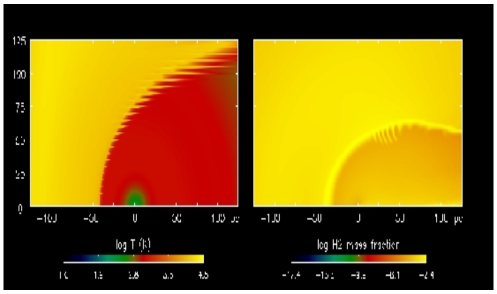

Fig 5: Temperature at 600 kyr (left, note the ionization front instability) and H_2 mass fraction at 10 Myr (right) for a core of initial density 1596 cm^{-3} located 150 pc from a 25 solar mass star.

Expulsion of the Lyman-Werner Background at Lower Redshift?

In Fig 5 we show H_2 mass fractions at 10 Myr in the relic H II region of a partly-evaporated halo. A dense shell of gas with high H_2 fraction cocoons the core, protecting it from the Lyman-Werner background. Regeneration of H_2 within the protected halo may facilitate the formation of a star that would otherwise have been unable to form. Thus, photoevaporation at lower redshifts may enhance star formation rates, a scenario that we are now investigating with new simulations.