The Impacts of Ultraviolet Radiation on Secondary Population III Star Formation

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Abstract

We explore radiation hydrodynamic feedback on the formation of second-generation Pop III stars, by performing Radiative Hydrodynamics (RHD) simulations on the results of recent ultra high-resolution cosmological hydrodynamic simulations by Suwa et al. As a results, we find that the secondary peak, which is at ~70 pc away from the preformed Pop III star, can survive without being ionized. The peak can collapse at ~50Myr after the death of the preformed Pop III star. Comparing the accretion time with Kelvin-Helmholtz time, we find the mass of the second-generation Pop III star is ~30$M_\odot$.

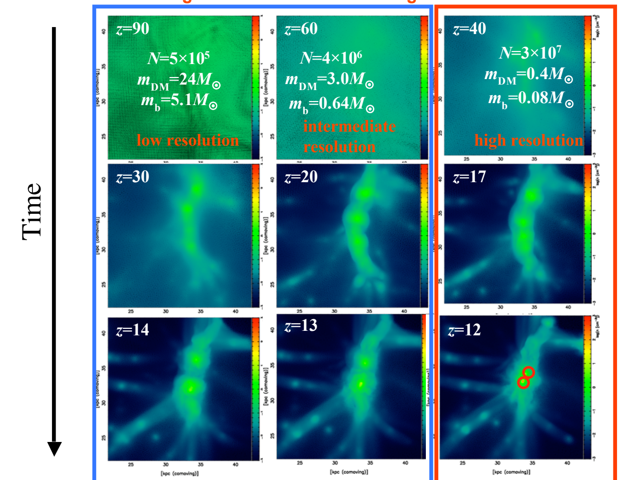
Introduction

P^3M-GRAPE-SPH Simulations

Suwa, Umemura, Susa, 2010, in prep.

z_{in}=1200, 60kpc [comoving]^3

No change of mass resolution throughout the simulation



Collapse after peak merging

Collapse **before** peak merging

What causes the difference?

In the simulation with high spatial resolution, the inner DM cusp region can be resolved well.

⇨ The DM cusp potential drives the collapse !!

The minimum halo mass above which gas clouds can cool is ~ $10^4 M_\odot$.

Q1. Can the second peak collapse to form a star ?

Pop III stars are massive ~10-1000$M_\odot$ ⇨ Strong UV radiation is expected.

(e.g., Bromm, Coppi & Larson 2001; Nakamura & Umemura 2001; Yoshida et al. 2006, O'shea & Norman 2007)

- − Photoheating by ionizing radiation.
- − Destruction of H_2 molecules by Lyman-Werner (LW) band radiation.
- \+ Enhancement of H_2 formation owing to the increase of electron fraction.
- +/− Shock accompanied by I-front. (Positive or Negative ?)

Q2. If yes, what is the mass of the secondary star?

Gas stripping by ionizing radiation and shocks.

⇨ Mass accretion rate is reduced. (Susa, Umemura, KH 2009)

Are H_2 fractions in the second peak changed by radiative hydrodynamic effects?

To answer the questions, we conduct 3DRHD simulations.

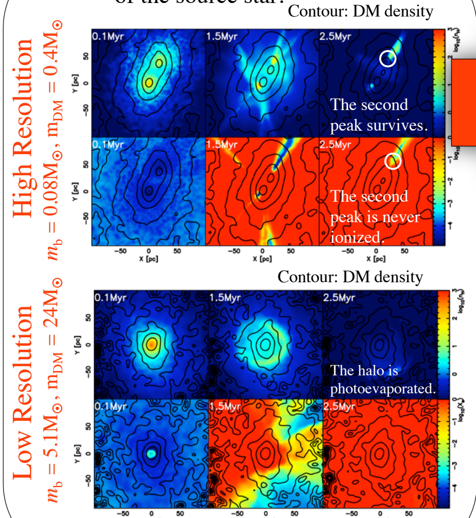
RHD simulations

Simulation Code & Procedure

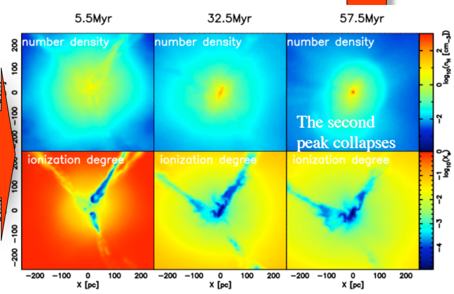
- N-body + Tree-SPH
- UV Radiative Transfer --- (Ionizing + LW radiation)
- Non-equilibrium chemistry (e^-, H^+, H, H^-, H_2, H_2^+)

◆ Initial conditions : the results by Suwa et al.
◆ UV Source: 120$M_\odot$ Pop III star (the lifetime is 2.5Myr) placed at the highest density peak initially.
◆ When the source star dies, it becomes a BH without a SN explosion.

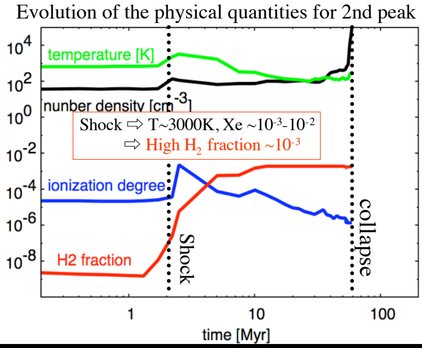
Evolution before the death of the source star.



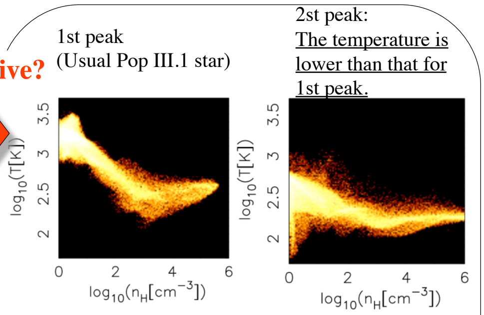
A second generation star formed in the relic HII region after ~200 Myr.



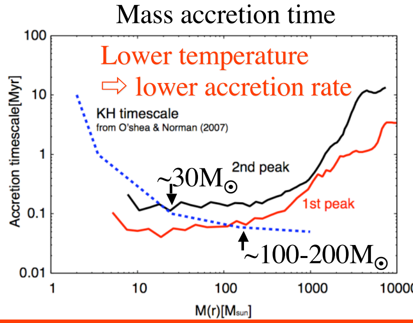
Evolution of the physical quantities for 2nd peak



How massive?



Mass accretion time



Answers

A1. The second peak can collapse.

A2. The secondary star is less massive than the first Pop III star, since H_2 fraction in the second peak is enhanced by radiative hydrodynamic effects.

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