Title: Zero Metallicity with Zero CPU Hours

Speakers: James Gurian

Collection: Dark Matter, First Light

Date: February 27, 2024 - 2:30 PM

URL: https://pirsa.org/24020040

Abstract: I describe an analytic, timescale-based model for the formation of the first stars in the center of collapsing primordial gas clouds. Despite its simplicity, the model reproduces the stellar mass scale and its parameter dependences observed in state-of-the-art cosmological zoom-in simulations, while clarifying the essential underlying physics. The model provides an inexpensive tool for studying the influence of exotic dark matter on early star formation.

Zero Metallicity with Zero CPU Hours

2309.05758

James Gurian

Perimeter Institute

May 12, 2023

No one has (definitely) seen a Pop. III star

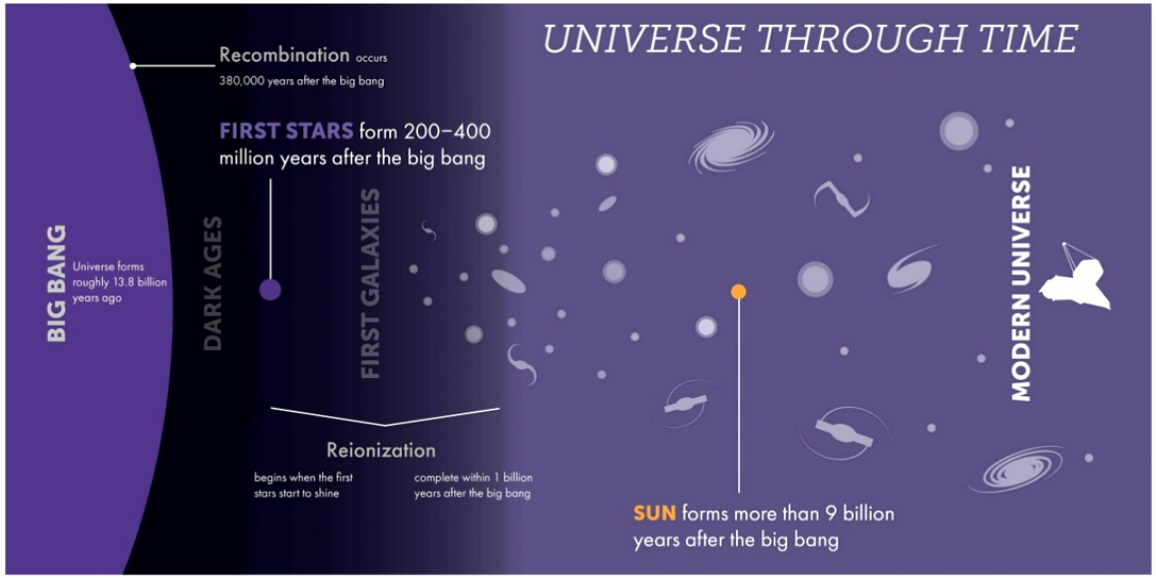
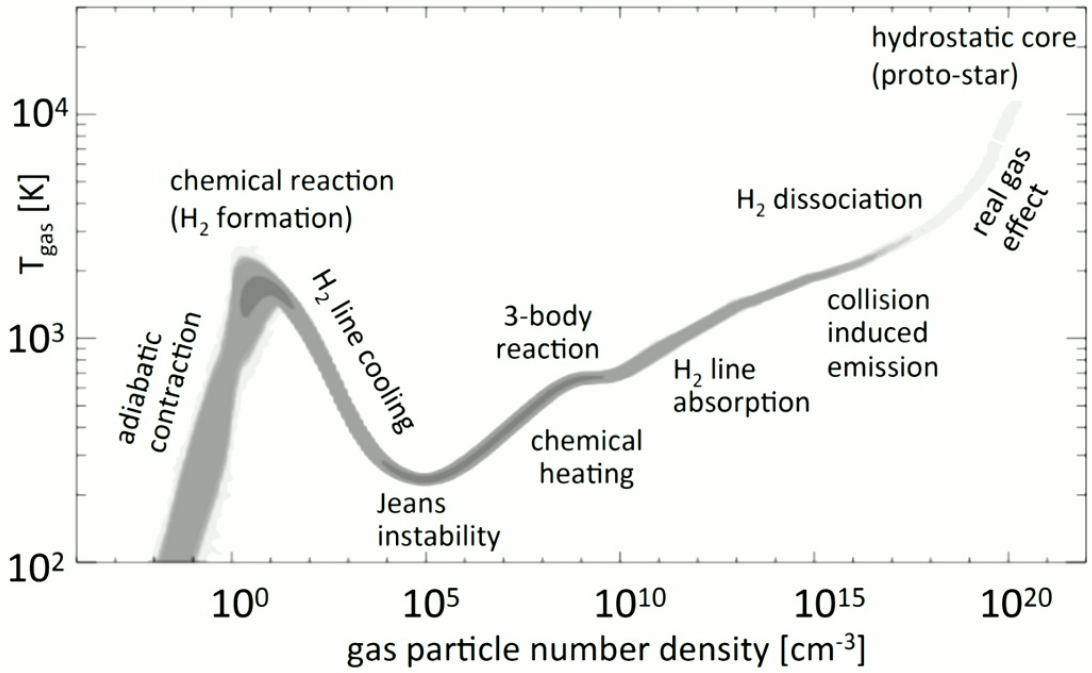


Image: webbtelescope.org

The Plan

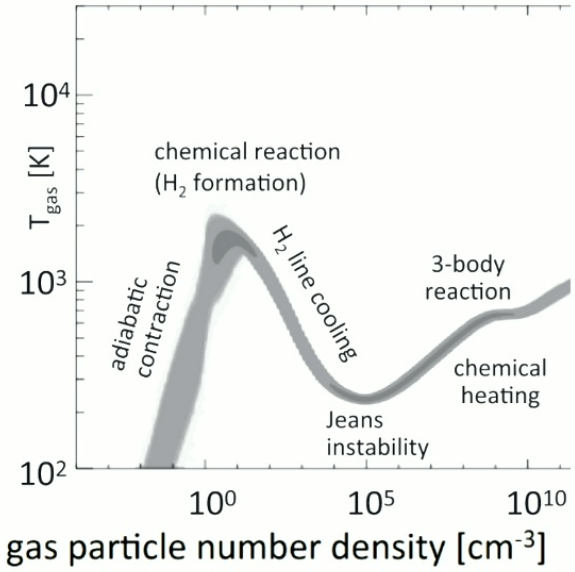
1. Find the mass of the star forming cloud
2. Find the accretion rate on the protostar
3. Model the evolution and ionizing feedback
4. Calculate $M_* = \dot{M} t_B$

The Phase Diagram



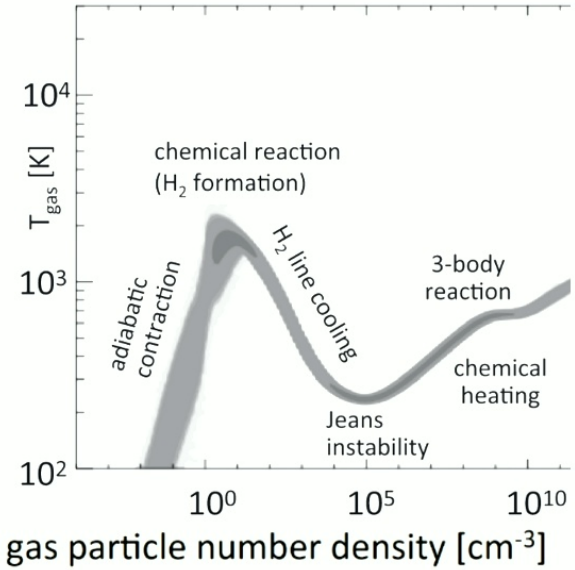
"One Zone" Calculations

State of the art 3D sim (Yoshida 2019)

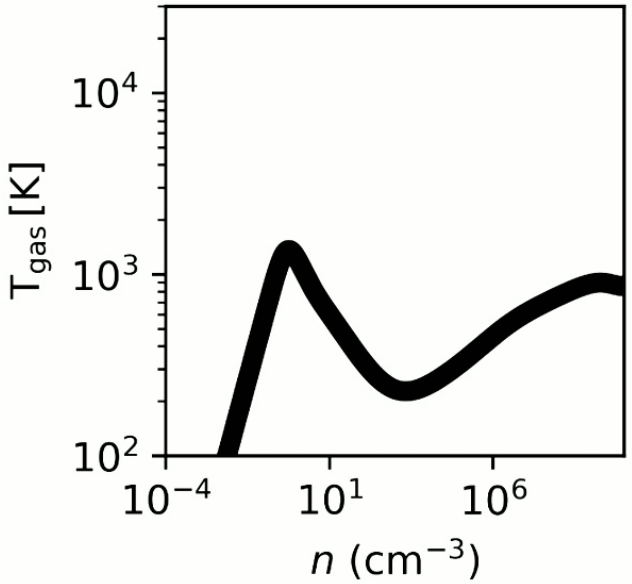


"One Zone" Calculation

State of the art (Yoshida 2019)

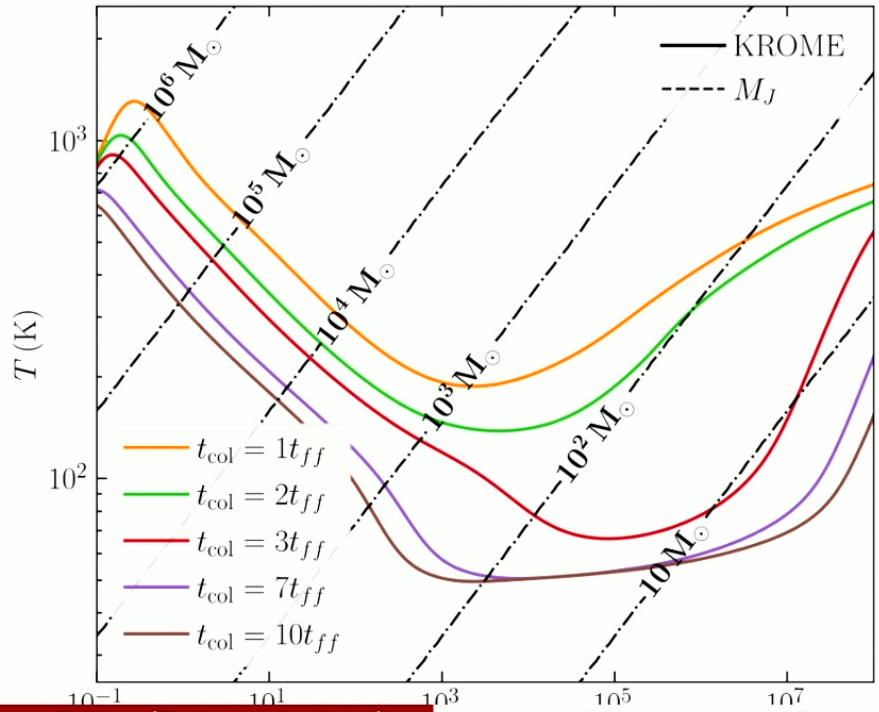


One zone, $\dot{\rho} = \rho / t_{ff}$

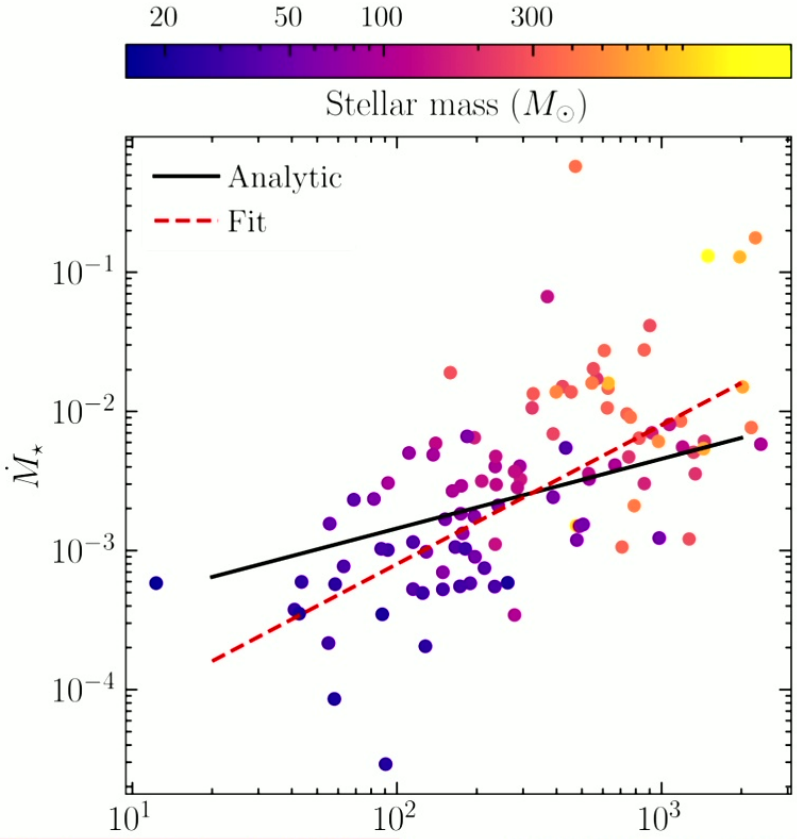


Now let's change the timescale

$t_{col} = t_{\mathrm{H_2,\,form.}}$
Slow collapse allows HD formation, lowering M_J.



Accretion Evolution and Feedback: Accretion

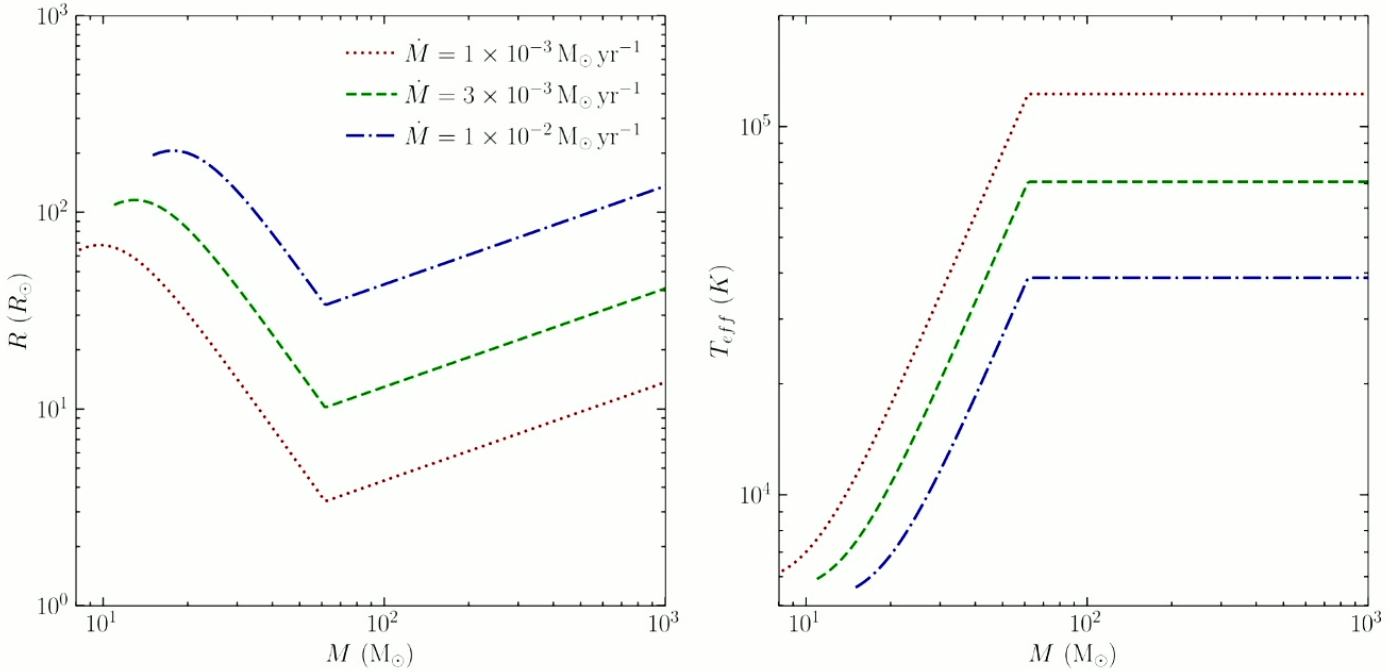


$$\dot{M} = M_J / t_\nu$$

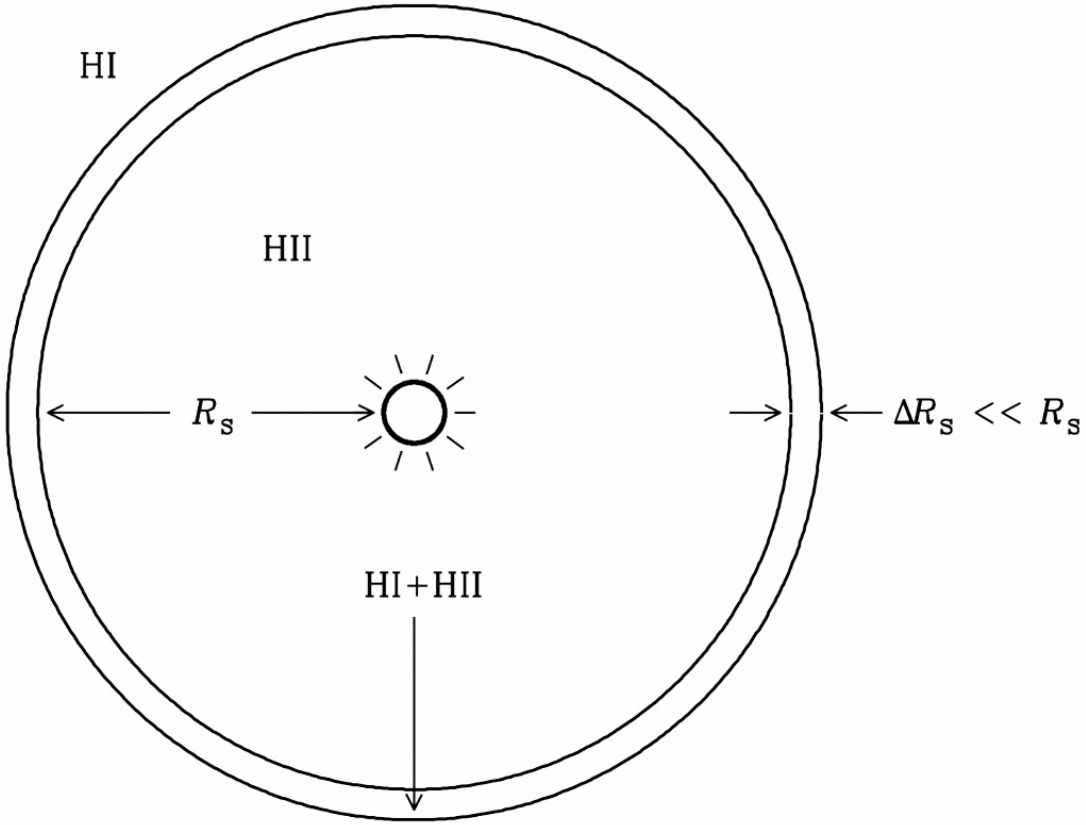
$$t_\nu = \frac{\Omega R^2}{c_s^2 \alpha}$$

Accretion Evolution and Feedback: Evolution

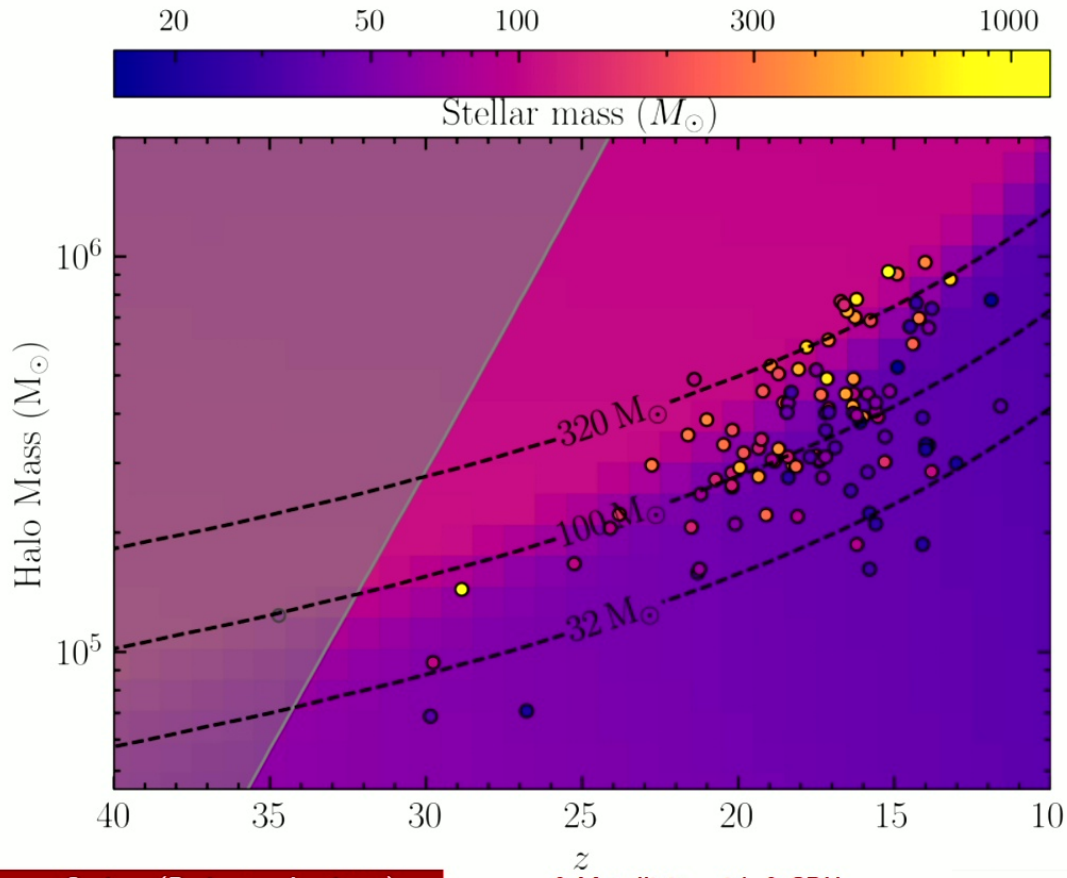
Expand-contract-expand!



Accretion Evolution and Feedback: Feedback



Results


20
50
100
300
1000
Stellar mass ($M_\odot$)
10^6
10^5
Halo Mass ($M_\odot$)
320 $M_\odot$
100 $M_\odot$
32 $M_\odot$
40
35
30
25
20
15
10
z

Summary

- Caveats: only one star, masses tend a bit low
- Can calibrate simulations against each other or (perhaps) observations
- Theorists don't need to be afraid of star formation!