Galaxy Formation With Local Photoionization Feedback

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Outline

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Motivation

Ionizing radiation sources

GASOLINE Implementation

GASOLINE test particle run

Cosmological simulation of MW type galaxy

Conclusion

Gas overcooling Problem

- Gas cools into DM halos and form stars.
- Gas cooling too efficient - gas overcooling problem.
- Solution - dump energy from stars, AGN etc into the gas (a few tweaks included).
  - Thermal Feedback Models (Stinson+2006,2013)
  - Kinetic Feedback Models (Vogelsberger+2013, Puchwein+2012, Davè+2008)
- Are we calculating gas cooling correctly?

Gas cooling in presence of radiation field

- Ionized gas cools more slowly
- Local sources produce ionizing radiation
- This will affect gas cooling in galaxies
  - Cantalupo 2010
  - Gnedin & Hollon 2012

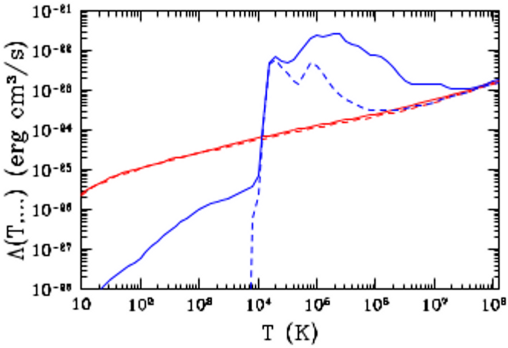

Figure: Cooling curves for neutral (blue) and ionized gas(red) - Gnedin & Hollon 2012

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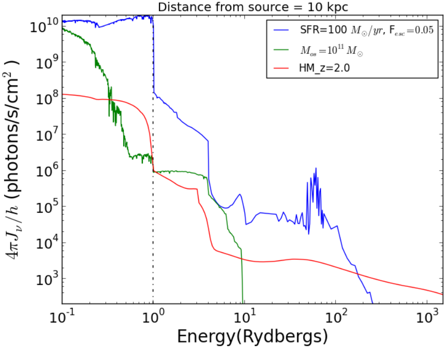
Ionizing radiation sources

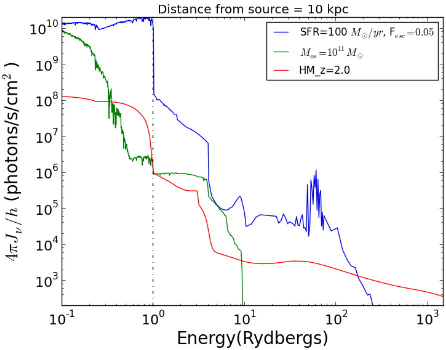
- Photon Flux



- Haardt & Madau 2005 UV background

Ionizing radiation sources

- Radiation from young O&B stars, convolved with the SED of shock heated gas from SNe (Cervino+2002)
- Photon Flux



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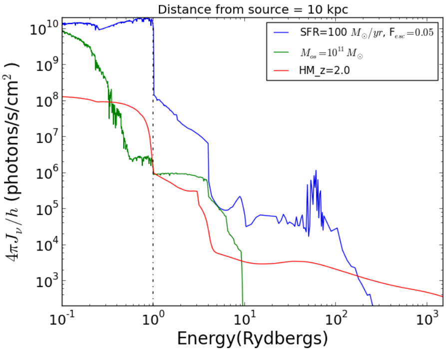
Ionizing radiation sources

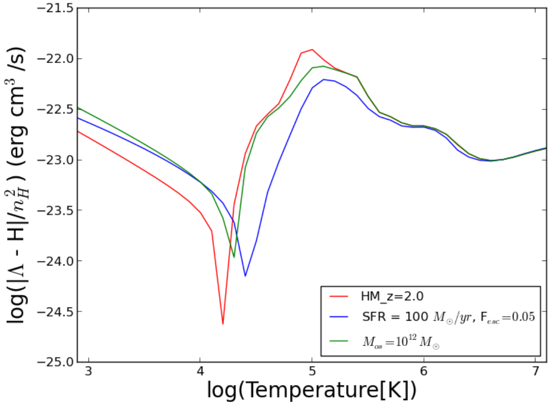
- Radiation from young O&B stars, convolved with the SED of shock heated gas from SNe (Cervino+2002)
- UV photons from Old stellar population due to accumulation of post-AGB stars (Bruzual & Charlot 2003)
- Haardt & Madau 2005 UV background

- Photon Flux



Change in cooling

- $n_H = 0.01cm^{-3}$, $Z = 0.1Z_\odot$, Distance = 10 kpc



Change in cooling

- Reduction in cooling rate / Increase in cooling time of gas

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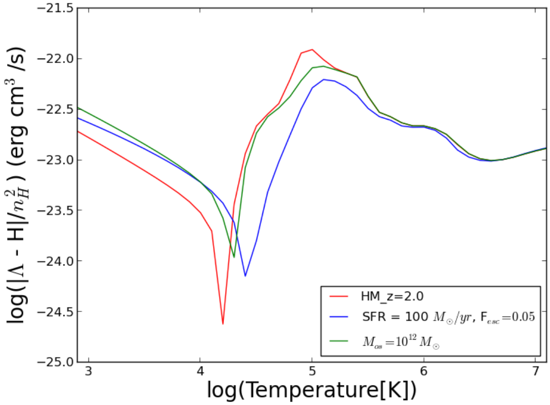

Change in cooling

- Reduction in cooling rate / Increase in cooling time of gas
- Increase in the equilibirum temperature of the gas

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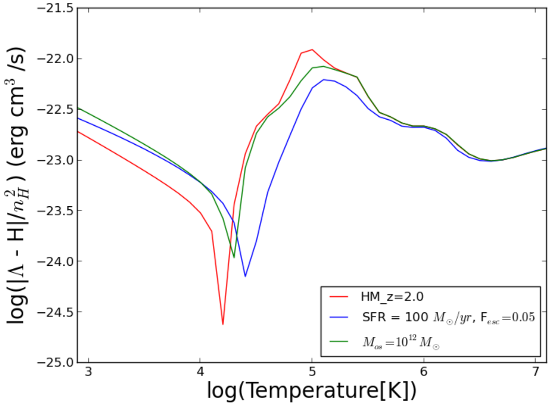

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Basic Assumptions

- The surrounding hot halo gas is optically thin
  - 95 % of flux in Lyman Limit frequencies absorbed by birth coccoon of new stars
  - Old stars are considered field stars and hence the escape fraction is unity
  - $$F_\nu(r) = \frac{F_\nu(r_1) r_1^2}{r^2} \tag{1}$$

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- Non equilibrium H,He + equilibrium metals (from Cloudy v10), ala Shen et al. 2010, Vogelsberger et al. 2013
  - $$\Lambda_{tot} = \Lambda_{H,He} + \frac{Z}{Z_\odot} \Lambda_{Z_\odot} + \Lambda_{Compton} \tag{3}$$

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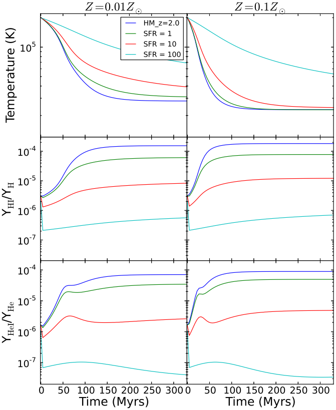
Test Particle Runs

- New Stars



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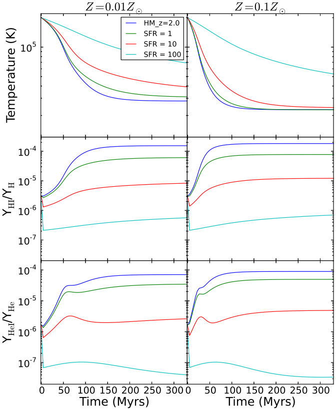

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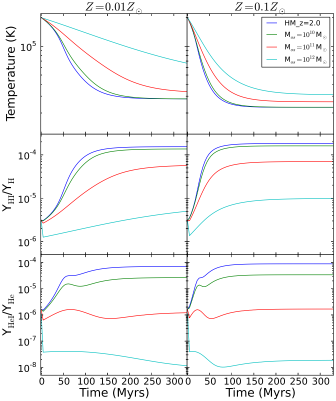

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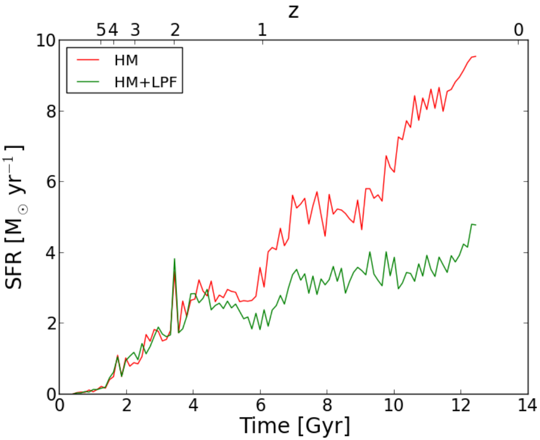
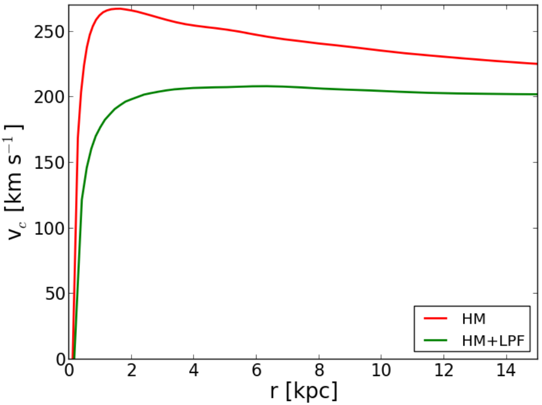
Simulation of MW galaxy

- Halo mass - 7×10^{11} $M_\odot$
- SNe Feedback + Early Stellar feedback - Stinson+2013
- Gas particle mass - 2×10^5 $M_\odot$, Softening - 310 pc
- Metal cooling
    - Only UV background - HM run
    - UV background + local photoionizing radiation sources - HM+LPF run

Star Formation History



Rotation Curves



Phase Space Diagrams

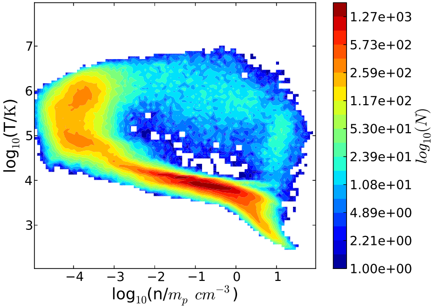


Figure: HM

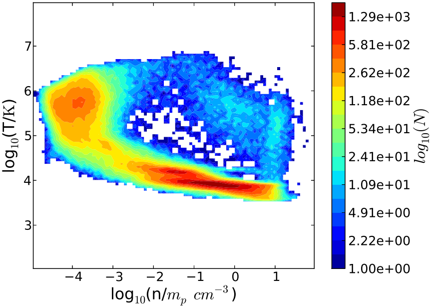
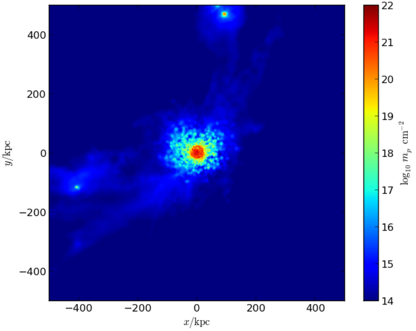


Figure: HM+LPF

HI column density maps



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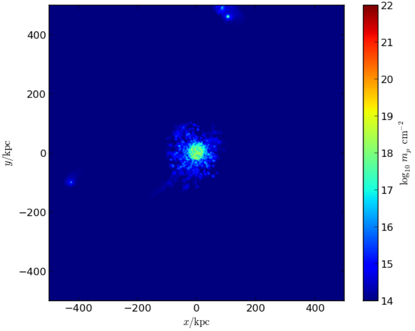
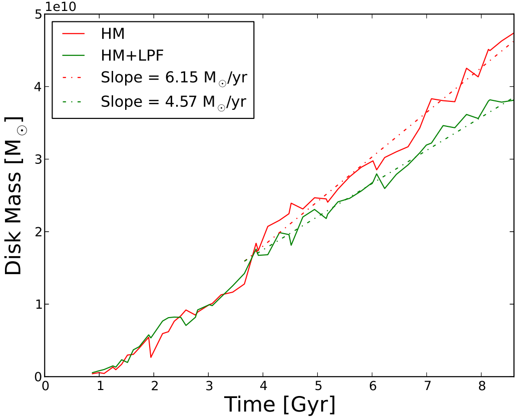


Figure: HM+LPF

Gas Accretion rate



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- Two different effects of LPF as seen in phase diagram
  - Stops gas accretion onto the disk thereby reducing fuel for star formation - Preventive feedback
  - Stops gas in the disk from getting cold - stabilising the disk through pressure support

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- Two different effects of LPF as seen in phase diagram
  - Stops gas accretion onto the disk thereby reducing fuel for star formation - Preventive feedback
  - Stops gas in the disk from getting cold - stabilising the disk through pressure support
- Less gas accretion onto the disk due to
  - Gas highly ionized due to local radiation field
  - Decreases gas cooling rate and increases halo temperature

Take Home Message

Local ionizing radiation is quite important and must be considered in models of galaxy formation