IMPLEMENTING STELLAR FEEDBACK IN A GALAXY EVOLUTION MODEL

PRESENTED BY
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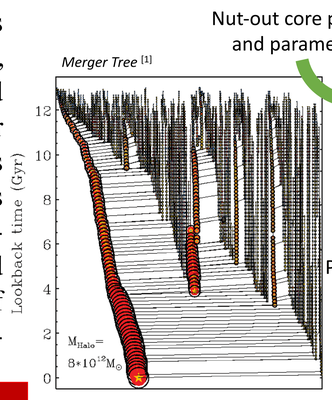
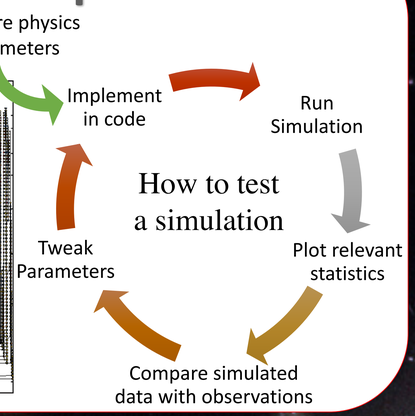
Why Are Simulations Important?

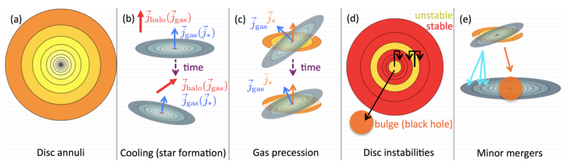
This project explores semi-analytic models, which are constructed by extracting a "merger tree" (right: shows mass accumulation and mass mergers) from an N-body simulation and treating the evolution of baryons as a post-processing step.[1]





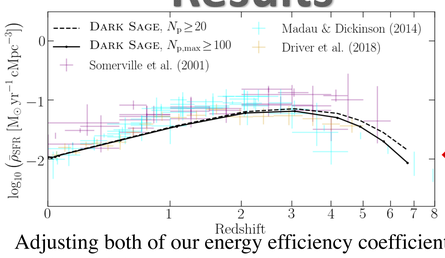
> "Without the ability to construct real universes in a laboratory, we are left to test ideas through conducting supercomputer simulations and comparing their results against what we observe."
>
> – A.R.H Stevens (supervisor) [4]

Introducing DARK SAGE



An updated version of the SAGE model that considers galaxies made up of concentric discs.[2] This means that all processes above are calculated within the annuli.
The original feedback prescription assumes stellar feedback to be a function of local gas density only.[6]

Results



Adjusting both of our energy efficiency coefficients to 0.65 (see right sect.3) we see the above star formation rate prediction. However for this result to be conclusive, we are still in the process of re-calibrating other related factors in the model.

Implementation

In order to answer our previous questions we derive the following.

1) We consider the equations given in the SAGE paper[4]

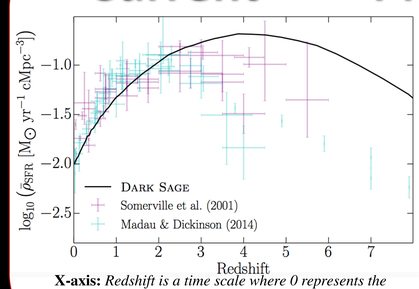
$$E_{SN} = \frac{1}{2}\dot{m}_* V_{SN}^2,\ V_{SN} = 630 \mathrm{kms}^{-1}$$

2) The model is currently designed such that energy emitted from a supernova is transferred to adjacent annuli depending on the ratios of their volumes.

3) Two new free parameters are included that dictate what proportion of SN energy reheats cold gas and another that controls the proportion of excess energy that ejects the hot gas entirely.

4) We compute the total energy (kinetic + gravitational energy) stored in each gas phase (cold, hot and ejected). Then take the difference as the energy required to move gas between phases.

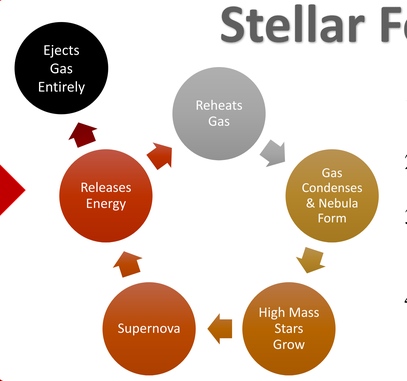
Current Problems



Although DarkSage appears accurate at redshift zero, notice that the star formation rate (SFR) peaks at a higher redshift and predicts a much higher SFR at earlier redshifts than observations suggest.[2]

X-axis: *Redshift is a time scale where 0 represents the present and 7 is roughly 0.77 Gyr after the Big Bang*
Y-axis: *Log of the Universal Average Star Formation Rate Density*

Stellar Feedback

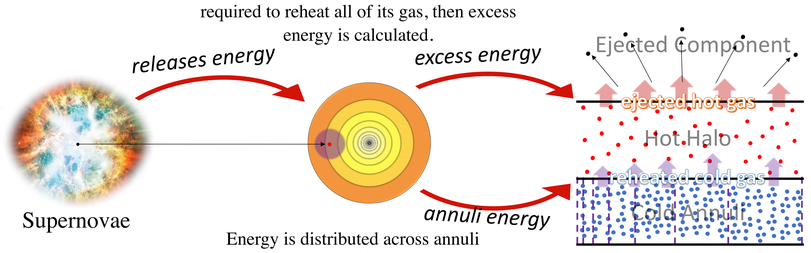


Questions considered:

1) How much energy is released by supernovae?
2) Where is this energy directed and how far does it spread?
3) What proportion of this energy goes into reheating gas/proportion into ejecting gas?
4) What is the energy required to move gas from the cold to the hot phase/hot phase to ejected phase?

The Model

If an annulus receives more energy than is required to reheat all of its gas, then excess energy is calculated.



Energy is distributed across annuli depending on volumetric ratios.

References

1. C. M. Baugh, "*A primer on hierarchical galaxy formation: the semi-analytical approach*", https://arxiv.org/pdf/astro-ph/0610031.pdf, 2006.

2. Adam R. H. Stevens, Darren J. Croton and Simon J. Mutch, "*Building disc structure and galaxy properties through angular momentum: The Dark Sage semi-analytic model*", https://arxiv.org/pdf/1605.00647.pdf, 2016.

3. Adam R. H. Stevens, Claudia del P. Lagos, Danail Obreschkow and Manodeep Sinha, "*Connecting and dissecting galaxies' angular momenta and neutral gas in a hierarchical universe: cue Dark Sage*", https://arxiv.org/pdf/1806.07402.pdf, 2018.

4. Darren J. Croton, Adam R. H. Stevens, Chiara Tonini, Thibault Garel, Maksym Bernyk, Antonio Bibiano, Luke Hodkinson, Simon J. Mutch, Gregory B. Poole and Genevieve M. Shattow, "*Semi-analytic Galaxy Evolution (SAGE): model calibration and basic results*", https://arxiv.org/pdf/1601.04709.pdf, 2016.

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6. Jian Fu, Qi Guo, Guinevere Kauffmann, Mark R. Krumholz, "*The atomic-to-molecular transition and its relation to the scaling properties of galaxy discs in the local Universe*", Monthly Notices of the Royal Astronomical Society, Volume 409, Issue 2, 1 December 2010.