Origin and Evolution of Structure and Nucleosynthesis for Galaxies in the Local Group

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Swine Teaching & Research Center

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Goals of GCE Models

• Explain the distribution of stellar and ISM elemental abundances vs. kinematic properties, location, ages

• Use these to explain the properties of the Galaxy and external galaxies along with how they formed and evolved
Goal in this Work:

Obtain a realistic simulation of the formation of the Milky Way and other members of the Local Group
History of the Milky Way

The traditional theory:

Quasi-spherical gas cloud fragments into smaller pieces, forming the first, metal-poor stars (pop. II, III);

Rotating cloud collapses into a disk-like structure

Later populations of stars (pop. I) are restricted to the disk of the galaxy
Present View:

- The Galaxy did not form in isolation.
- It is the product of the development of much larger structure
- It was formed in concert with the entire Local Group and was affected by star formation and nucleosynthesis processes occurring throughout a large volume.
Virtual Galaxies

Large Scale Structure Simulation

Local Group

no

GADGET SPH Hydro

Gravity N-body

Heating/Cooling

Stellar Wind

yes

Star Formation

Mass ejection

Nucleosynthesis

Heating
Smoothed Particle Hydrodynamics

GADGET:
Springel, Yoshida, White (2000)

Gravity Tree Algorithm
Key Issues

1. What are the conditions for star formation as a function of metallicity, environment (angular momentum, magnetic fields, density, etc.)?

2. How universal is the stellar initial mass function: Function of cloud metallicity and environment, ..?

3. What are the nucleosynthesis yields as a function of progenitor mass, chemical composition, rotation, Mag. Field, …?

4. What are the stellar lifetimes, remnant masses, ejected mass, ejected energy in stellar winds, AGB, SNI, SNII, VMOs, …..?
5. What are the dynamics/timescales and efficiencies for mixing in the interstellar medium?

6. Cooling of the ISM to form cold molecular star forming clouds as a function of environment
Projects JINA Should Undertake

1. Definitive models for star formation and the IMF as a function of metallicity, environment (molecular cloud cooling, angular momentum, magnetic fields, density, etc.)

2. Form a universal updated data base of nucleosynthesis yields, stellar lifetimes, remnant masses, ejected mass, ejected energy in stellar winds, PNe, SNI, SNII, VMOs, based upon various stellar evolution models as a function of progenitor mass, composition, rotation, mag. field, …?
3. Form and maintain a universal easily accessible data base of observed stars, their metallicity, location, proper motion, velocity dispersion, etc.

4. Develop statistical measures of the relevant observables for easy comparison with code results.

5. Develop a state-of-the art data base of cooling functions as a function of metallicity, etc.
The Simulations

http://www.nd.edu/~xzhao/

X. Zhao & GJM (2010)
Begin with LSS

X. Zhao & GJM (2010)
Large Scale Structure Simulations

Box=200000.0 kpc/h  z=0.00

Scan for Poor Clusters

X. Zhao & GJM (2010)
Disk Galaxies
Galaxy Formation

- Galaxies are not isolated objects but are the culmination of halo formation, mergers, star formation and nucleosynthesis in an extended connected environment.

- Significant starformation and nucleosynthesis occurs far from the galaxy in protogalactic structures.

- Protogalactic halos that arrive in a stochastic stream flowing along dark-matter filaments.

- There should be a distribution of kinematic and metallicity distributions in the halo.
Next Step: Reconstruct Abundance vs Metallicity Relations for different stellar populations

Saleh, Beers, Mathews (2006)
Snapshots