Environments effects on fossil groups from cosmological simulations and galaxy formation models

Weiguang Cui*, Volker Springel, Xiaohu Yang, Gabriella De Lucia, Stefano Borgani

University of Trieste

MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

Abstract

The fossil groups are just sampling the tail of the distribution of ordinary groups, or whether they are a physically distinct class of objects, characterized by an unusual and special formation history, is still in a mist. Using the hydrodynamical simulations data of the GIMIC project, and the data from two semi-analytical methods and a conditional luminosity function approach, we investigate this problem. Thanks to the five different density regions (from deep void to proto-cluster) re-simulated in GIMIC simulations, we are able to compare the environment effects on fossil groups. We find that the optical fossil fraction in all of our theoretical models declines with increasing halo mass, and there is no clear environmental dependence. Combining the optical and X-ray selection criteria for fossil groups, the halo mass dependence of the fossil groups seen in optical vanishes. Over the GIMIC halo mass range we resolve best, 9.0×1012 ~ 4.0×1013h−1 M⊙, the central galaxies in the fossil groups show similar properties as those in ordinary groups, in terms of age, metallicity, color, concentration, and mass-to-light ratio. And finally, the satellite galaxy number distribution of fossil groups is consistent with that of non fossil groups. These results support an interpretation of fossil groups as transient phases in the evolution of ordinary galaxy groups rather than forming a physically distinct class of objects.

The Data & method

Method

GIMIC: The GIMIC simulation project re-simulated five different density regions (from -2σ to +2σ, σ is the rms mass fluctuation) of comoving radius ~20 h^-1 Mpc in Millennium Simulation (MS) with hydrodynamics included. The simulations included physics modules for gas cooling and photoionization, quiescent star formation associated with supernovae feed-back, kinetic supernova feedback and chemodynamics, but no AGN feedback. The optical galaxy properties is produced by interpolating a SSP templates, and the X-ray luminosity is obtained by integrating the thermal bremsstrahlung emissivity over the halo's volume.

SAM: The two SAM galaxy catalogues are from the Munich model (De Lucia 07) and the Durham model (Bower 06). Both the SAM galaxy catalogues are based on MS.

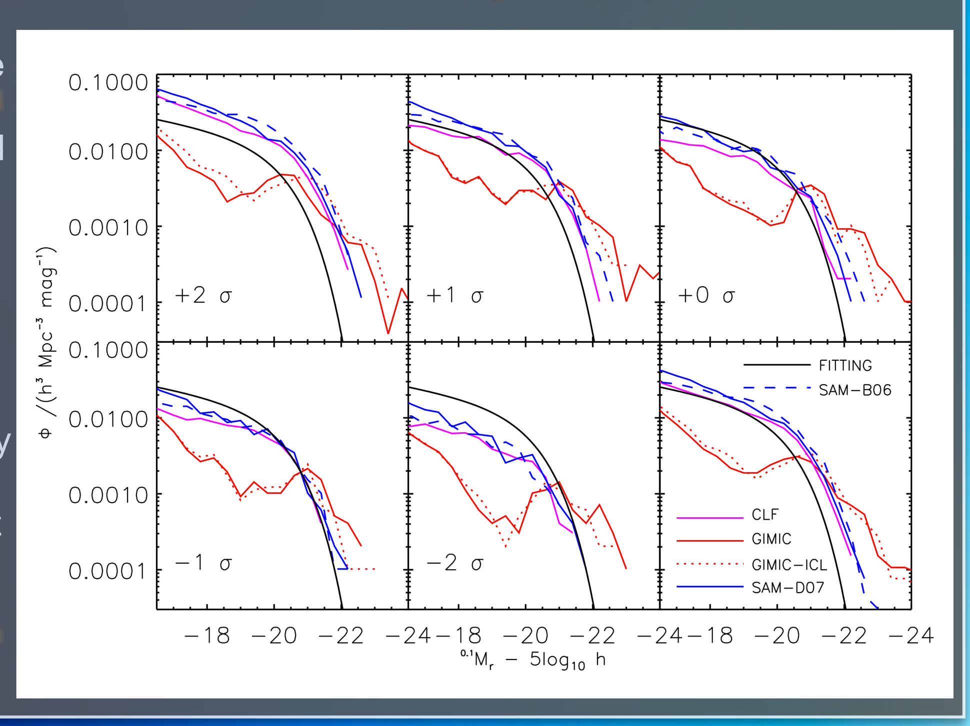
CLF: The Conditional luminosity function catalogues (CLF) is generated by a statistical procedure to populate dark matter halos in MS with galaxies such that the observed galaxy luminosity function (or stellar mass function)can be accurately reproduced.

Since all those galaxy catalogues are based MS, it is simple to cull the semi-analytic models and the CLF catalogues to the same regions as GIMIC. The difference between each model (e.g. absolute magnitude, halo mass) is carefully corrected.

The Results

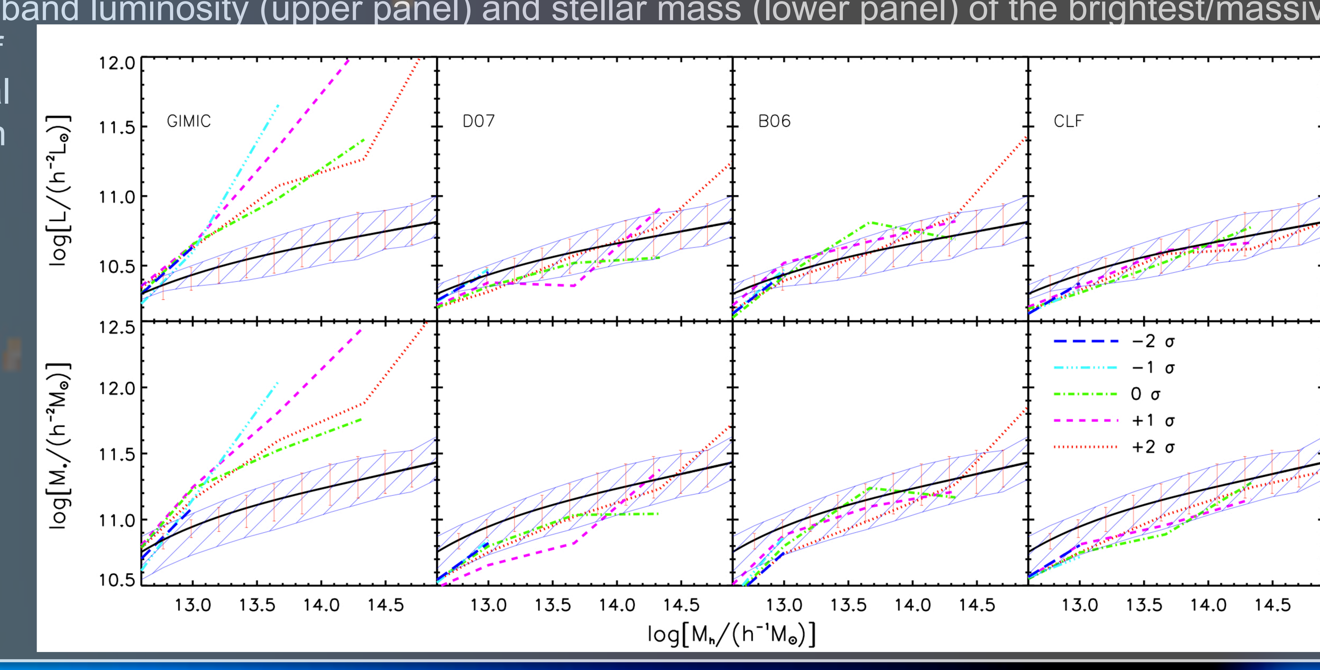
The Luminosity Function

The left figure shows the LF of different models in five different density regions. The black solid line shows the Schechter form luminosity fitting function obtained by Blanton et al. (2001) from the SDSS observational data. The lower-right panel shows the averaged luminosity function of the five regions. The luminosity functions from the CLF and SAM models exhibit a better match than GIMIC to the fitting function. The substantial disagreement between the shape of LF from GIMIC and other theoretical models is caused by the specific feedback model (the efficiency of SN feedback and kinetic SN feedback, over cooling) that was introduced in the hydrodynamic simulations. This indicates that the effect of relevant feedback processes is still poorly understood in direct hydrodynamical simulations.

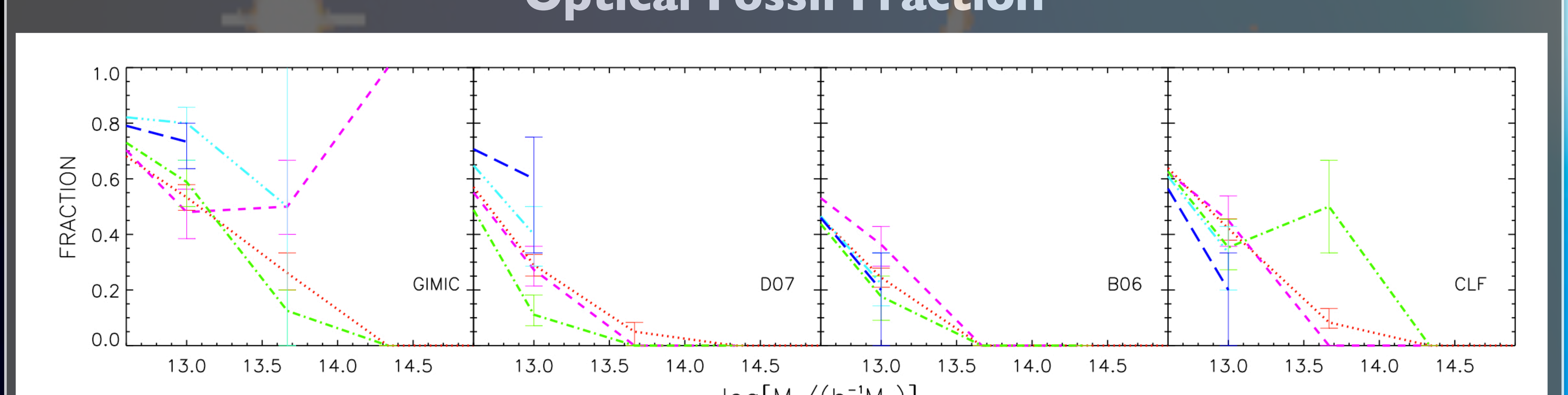


The Properties of Central Galaxies

This figure shows median r-band luminosity (upper panel) and stellar mass (lower panel) of the brightest/massive cluster galaxy as function of halo mass of four theoretical models. Black solid line with shaded area and error bars show the fitting results from SDSS. The other models show better fit than GIMIC again. Without AGN feed back, the central galaxies formed too many star particles at late times in the GIMIC simulations.

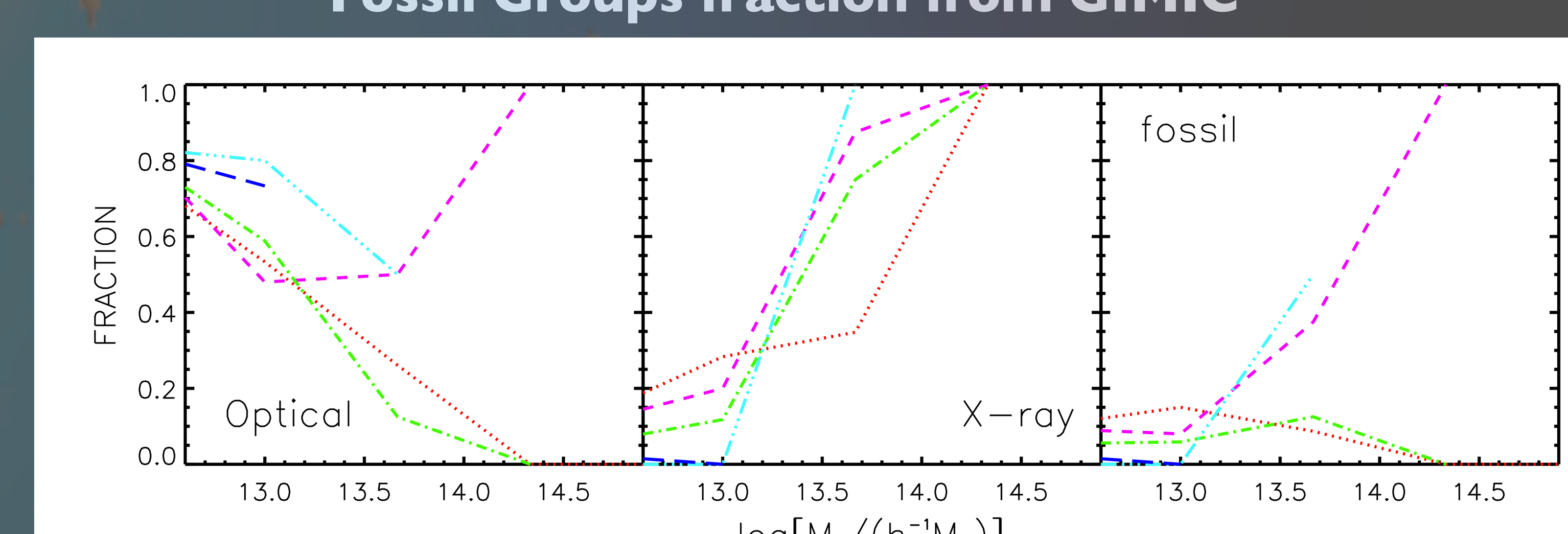


Optical Fossil Fraction



The optical fossil fraction is shown as a function of halo mass for all four theoretical models. The optical fossil fraction in all of our theoretical models declines with increasing halo mass. However, the models do not agree in detail at a specific halo mass. And we did not find clear evidence that the optical fossil fraction has environmental effects in all the theoretical galaxy formation models.

Fossil Groups fraction from GIMIC

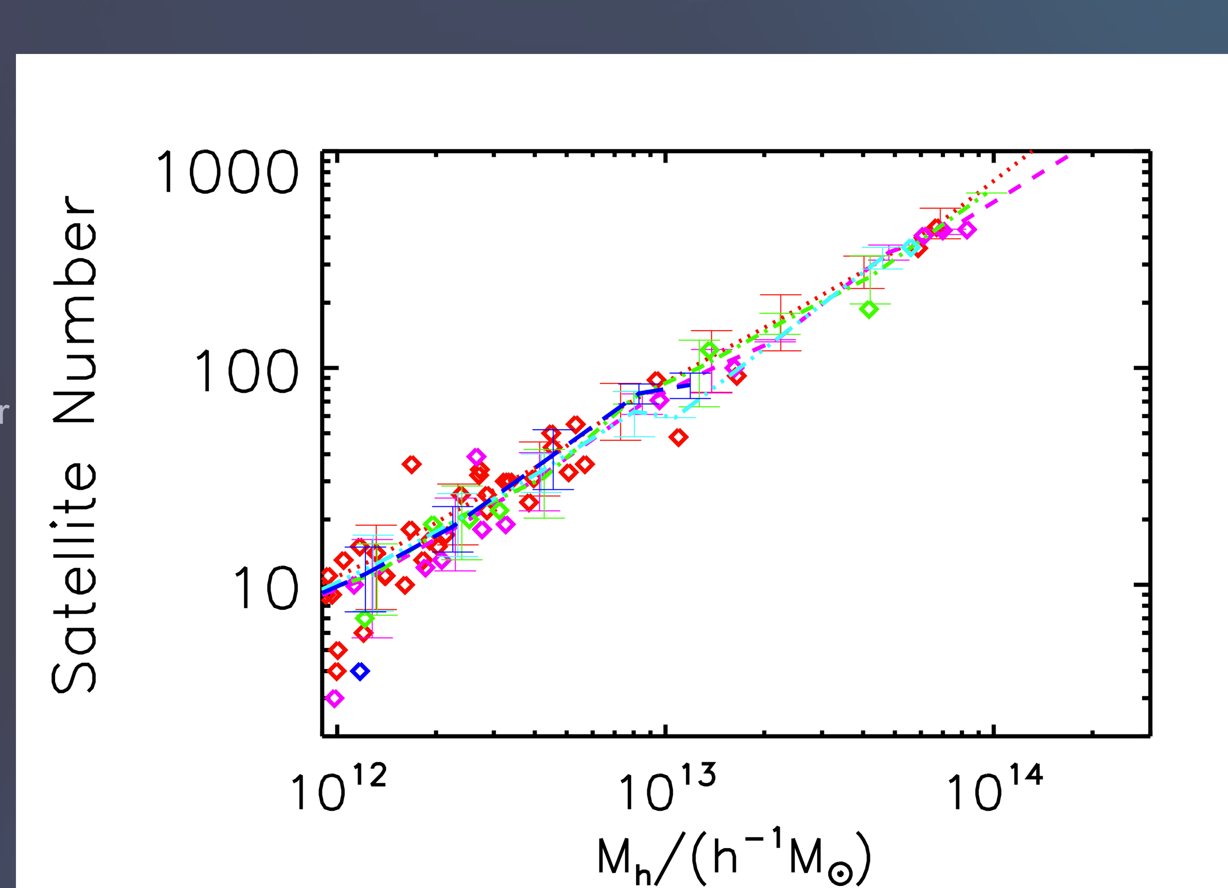


We applied the definition of fossil groups from Jones et al, 2003 on GIMIC simulation, the only one have X-ray informations. With a X-ray luminosity cut, It is not surprising to see that the X-ray fractions show an increasing trend with halo mass in the middle panel. And with a significant X-ray fraction drop at smaller halo mass, the halo mass dependence of fossil groups seen in optical vanishes.

The Satellite galaxies number distribution

There is also a hypothesis that fossil groups are coming from an unusual formation history. Those systems would be rare, but so are the fossil groups. Hence, we investigate the number distribution of all satellite galaxies in the GIMIC simulations. The different lines are the mean satellite number for non fossil groups, and the diamonds shows the results for fossil groups.

The satellite number for fossil groups is not different from that obtained considering non fossil groups, which confirms that the fossil groups do not have unusual formation histories.



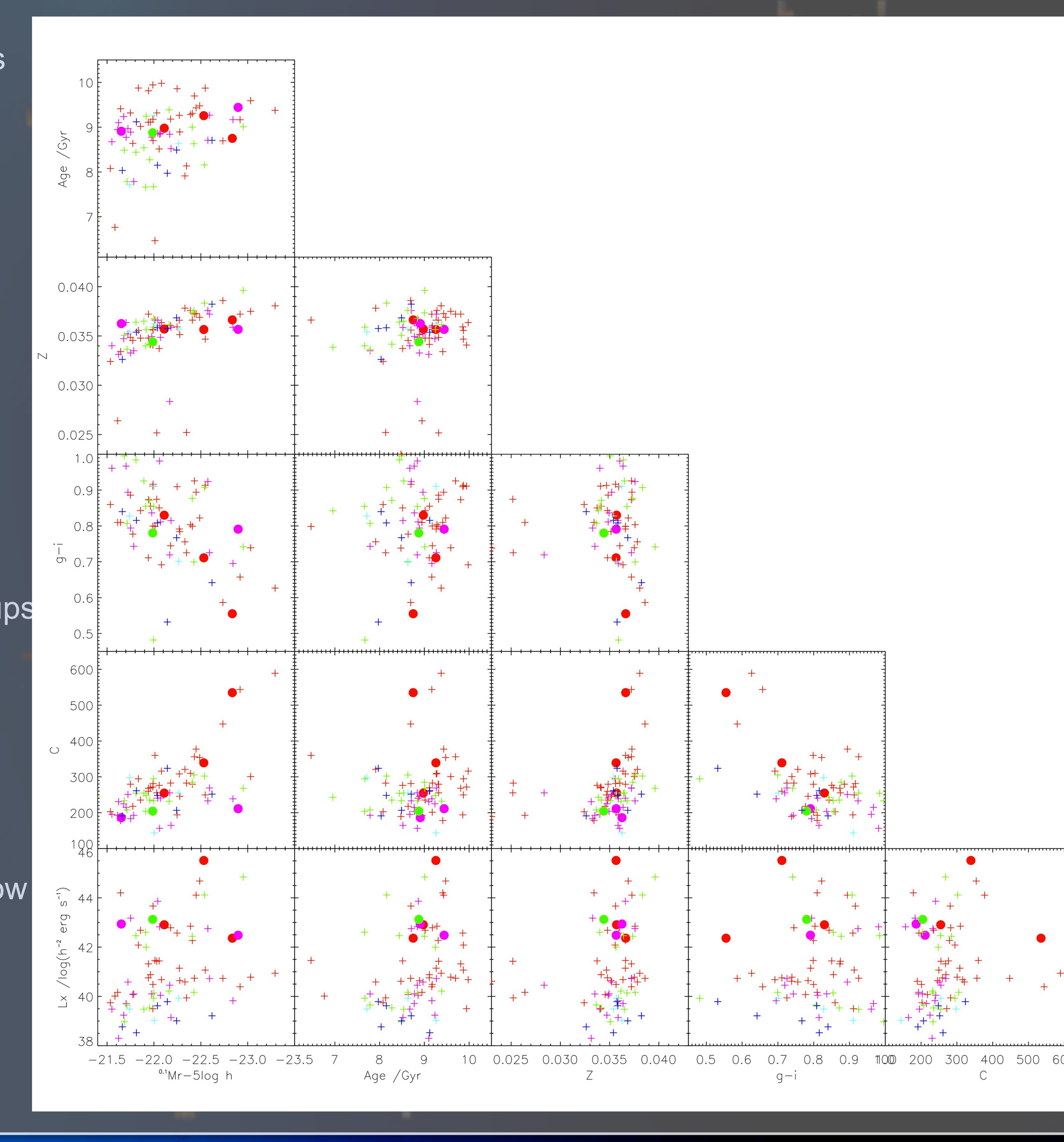
The Properties of Fossil and non-Fossil Groups

We focus on a reliable halo mass range (9*10^12 ~ 4*10^13 M_sun/h) in GIMIC simulation. Some basic properties of the central galaxies of fossil groups and non-fossil groups are summarized in this figure.

* The Mr-Lx relation shown in left-bottom panel do not show systematic increase of the X-ray luminosity for fossil groups at a given optical magnitude.

*The age ~ 9 Gyrs for fossil groups is also not significantly enlarged compared to the age of non-fossil groups.

* The metallicity, color, and concentration from fossil and non-fossil groups also do not show large difference.



* Email : wgcui@oats.inaf.it
Phone: +39-0403199141