THE CONNECTION BETWEEN STAR FORMATION AND DARK MATTER HALOS AS SEEN IN THE INFRARED

Material at http://irfu.cea.fr/Sap/Phocea/Page/index.php?id=537

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CEA Saclay
A STRONG DOWNSIZING OF INFRARED GALAXIES

- Star formation in the local Universe dominated by "normal" galaxies (<10Msun/yr), but dominated by ULIRGs (>100Msun/yr) at z>2 => Strong downsizing
- How can we explain this strong evolution of infrared properties?
  - higher merger rate?
  - intense cold accretion?

Star formation history as seen in the infrared and contribution of various infrared luminosity classes (Béthermin+11)
COSMIC INFRARED BACKGROUND ANISOTROPIES: A PROBE OF THE LINK BETWEEN LOCI OF STAR FORMATION AND LARGE SCALE STRUCTURES

Fluctuations of the cosmic infrared background (Planck collaboration et al.)

Simulation of large scale structures (Pichon, Teyssier)
INTRODUCTION

• Correlations between observed physical quantities (star formation rate, stellar mass, attenuation)

• Connection between infrared properties and dark matter halo (using stellar mass as intermediate proxy)

• Main results: CIB redshift distribution, contribution of various halos to star formation history, star formation history inside halos.
A “MAIN-SEQUENCE” OF STAR-FORMING GALAXIES SEEN BY HERSCHEL

SFR-\(M_\star\) relation at z\(\sim\)2 (Rodighiero+11):
A “MAIN-SEQUENCE” OF STAR-FORMING GALAXIES SEEN BY HERSCHEL

SFR-M_* relation at z~2 (Rodighiero+11):

Cross-section through main sequence at fixed M_*

Distribution of sSFR at fixed M_* at z~2 (Rodighiero+11):
A “MAIN-SEQUENCE” OF STAR-FORMING GALAXIES SEEN BY HERSCHEL

SFR-M* relation at z~2 (Rodighiero+11):

Distribution of sSFR at fixed M* at z~2 (Rodighiero+11):

Cross-section through main sequence at fixed M*:

- Self similar distribution of sSFR

Excess due to starbursts:
- ~15% of the star formation density
- a few % of number density
NEW SED TEMPLATES OF MS AND SB GALAXIES BASED ON HERSCHEL OBSERVATIONS

Evolution of $<U>$ (radiation field in Draine&Li model) with redshift.

Béthermin+12c, Magdis+12b
A NEW MODEL FOR STATISTICAL PROPERTIES OF IR GALAXIES

- Mass function of star-forming galaxies (Ibbert+10, Ibbert+13)
- Evolution of the “main-sequence”: \(<\text{SFR}> = f(M_*, z)\)
- Distribution of sSFR around the “main-sequence”
- New templates of “main-sequence” and starburst galaxies
- Cosmology (for volume and luminosity distance only)
- Distribution of star formation rate split into contribution of “main-sequence” and starburst galaxies
- Infrared luminosity function, split into contribution of “main-sequence” and starburst galaxies
- Number counts of infrared galaxies

Béthermin+12c, Sargent+12
Number counts are globally well reproduced using fiducial parameters based on mean values from literature.

The starburst (dashed line) have a very variable contribution depending on the flux regime and the wavelength.

Comparison between the model and the observations (Béthermin +12c)
CONNECTING STAR FORMATION AND HALO MASS BY ABUNDANCE MATCHING

Halo mass function including sub-structures (Tinker+08, Tinker+09)

Abundance matching

Mass function spitted in star-forming and quenched galaxies (adapted from Ilbert+09)

Star forming

SFR-Mstar model for star forming galaxies (Béthermin+12c)

Quenched

Neglect the IR outputs of quenched galaxies

Main hypotheses:
- same Mstar-Mhalo relation in main and sub-structures
- same Mstar-Mhalo relation for SF and quenched galaxies
- the probability to be quenched depends only on the halo mass
- starburst and main-sequence lies in the same halos
RESULTS

Model A: Fiducial model

Model B: Lowest density, high sSFR

Model C: Lowest density, high, sSFR + no star-formation around passive central galaxies

Check also with SPIRE cross power spectra, ACTxSPIRE, Planck CIBxlensing, angular correlation function of bright PACS sources

CIB power spectrum and galaxy counts
REDSHIFT DISTRIBUTION OF THE CIB

CIB spectral energy distribution spitted by redshift slices

Redshift distribution of CIB fluctuation at l=1000
STAR FORMATION HISTORY AND HOST HALOS

Instantaneous halo mass

Contribution of various halo mass to the star formation history

mass at z=0
Relative contribution of various halo masses as a function of redshift
STAR FORMATION EFFICIENCY

in a main-sequence galaxy

Instantaneous halo mass

Mean ratio between star formation rate and baryonic accretion rate as a function of halo mass and redshift

Mean baryon accretion rate (BAR) = Mean accretion rate (Fakhouri+10) × Ωb / Ωm
STAR FORMATION EFFICIENCY

in a main-sequence galaxy

Instantaneous halo mass

Mass at z=0

Mean ratio between star formation rate and baryonic accretion rate as a function of halo mass and redshift

Supernovae feedback?  
Change of mode of accretion?  
AGN feedback?

Mean baryon accretion rate (BAR) = Mean accretion rate (Fakhouri+10) × Ωb / Ωm
STAR FORMATION EFFICIENCY

Mean star formation efficiency (including passive galaxies)

Mean ratio between star formation rate and baryonic accretion rate as a function of halo mass and redshift

Instantaneous halo mass

mass at z=0

Supernovae feedback?

Change of mode of accretion?

AGN feedback?

Mean ratio between star formation rate and baryonic accretion rate as a function of halo mass and redshift

Mean baryon accretion rate (BAR) = Mean accretion rate (Fakhouri+10) × Ωb / Ωm
CONCLUSION AND PERSPECTIVES

• We propose a new modeling approach to model the evolution of the infrared galaxies and the CIB model based on the observed correlation between stellar mass and star formation rate, called “main-sequence”.

• Infrared galaxy counts, CIB anisotropies and clustering of bright IR sources can be well reproduced with this simple approach.

• This model suggests that galaxies hosted by \( \sim 10^{12} \, M_{\text{sun}} \) halos are the most efficient to form stars and emits the bulk of the CIB. The strong downsizing of infrared galaxies would be caused by an higher baryonic accretion in \( 10^{12} \)-ish halos at high redshift.

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