Properties of Submillimeter Galaxies in a Semi-analytic Model using the "Count Matching" Approach: Application to the ECDF-S

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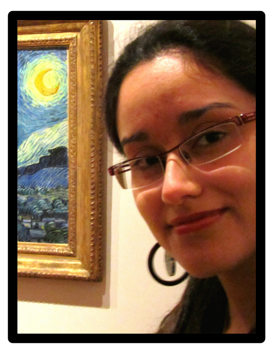


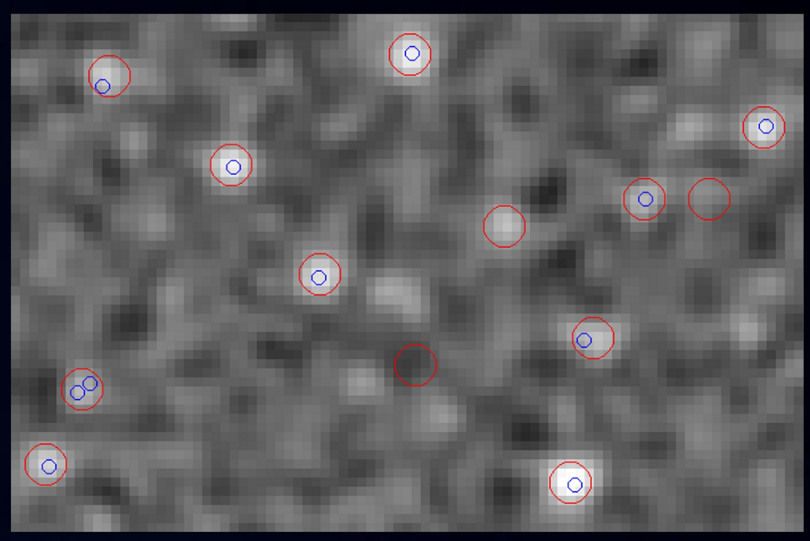
Alejandra M. Muñoz Arancibia[1], Felipe P. Navarrete[2,3], Nelson D. Padilla[1,4], Sofía A. Cora[5,6], Eric Gawiser[7], Peter Kurczynski[7] and Andrés N. Ruiz[6,8,9]

[1]Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Santiago, Chile
[2]Argelander-Institut für Astronomie, Bonn, Germany
[3]Max-Planck-Institut für Radioastronomie, Bonn, Germany
[4]Centro de Astro-Ingeniería, Pontificia Universidad Católica de Chile, Santiago, Chile
[5]Instituto de Astrofísica de La Plata, Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, La Plata, Argentina
[6]Consejo Nacional de Investigaciones Científicas y Técnicas, Buenos Aires, Argentina
[7]Department of Physics and Astronomy, Rutgers University, Piscataway NJ, USA
[8]Instituto de Astronomía Teórica y Experimental, Córdoba, Argentina
[9]Observatorio Astronómico de Córdoba, Universidad Nacional de Córdoba, Córdoba, Argentina

MOTIVATION

Fitting submillimeter galaxies (SMGs) into the current theory of galaxy formation has been a challenge since their discovery. They are the most luminous star-forming sources at the epoch where star formation peaks, being detected by their redshifted far-IR emission from cold dust in the submm wavebands. Recent 870μm continuum ALMA observations of the Extended Chandra Deep Field South (ECDF-S) show that the brightest sources detected using LABOCA@APEX (Weiss et al. 2009) are comprised by emission from multiple fainter sources (Karim et al. 2013).

With the aim of exploring the properties of SMGs in this field, and in analogy to the now-standard abundance matching approach, we perform a "Count Matching" approach through lightcones drawn from the semi-analytic model of galaxy formation and evolution SAG (Cora 2006, Lagos et al. 2008) in a ΛCDM cosmology.



Small section of the simulated map for a given lightcone and proxy. Extracted sources lie in the centers of the red big circles, which have a radius of 13.8''; this is the search radius used for finding the counterparts of these sources in the input catalog down to 1.2mJy (blue small circles). The map resolution is 6''/pix.

THE COUNT MATCHING PHILOSOPHY

*A physical galaxy property from the model is chosen as a proxy for another property whose numerical value is unknown (**the rest-frame 870μm luminosity**), assuming a monotonic relationship.*

*This relationship is used to assign a third property (**the 870μm flux density**) to the lightcone galaxies in such a way that the observational statistics for the latter (**the cumulative number counts at 870μm***) are reproduced.*

Basics

$S_\nu = \dfrac{L_\nu}{4\pi f_k D_L^2}$, where

S_ν: flux density at 870μm (in mJy)

L_ν: rest-frame luminosity at 870μm

$f_k = \dfrac{L_\nu}{(1+z)\,L_{(1+z)\nu}}$: k-correction factor (we assume an Arp220 spectrum)

D_L: luminosity distance

We define

y = <u>Proxy</u>$/(f_k D_L^2)$: galaxy property (or combination of properties) adjusted for cosmological distance

Submm flux density assignment

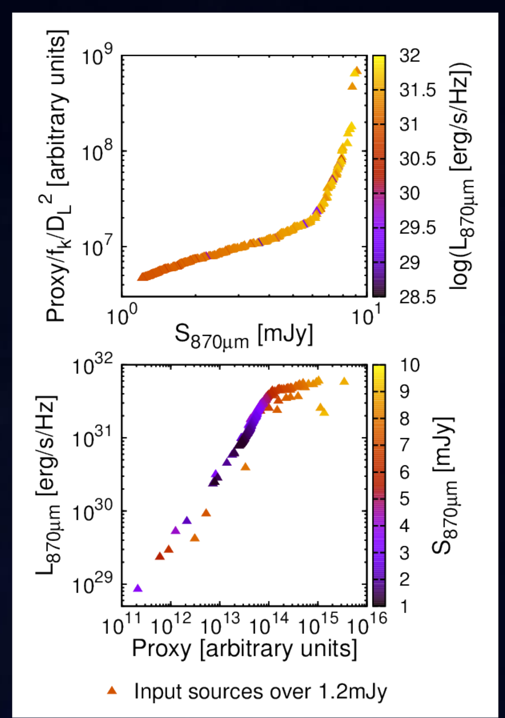
$$\int_{S_\nu'}^{\infty} n(S_\nu)\, dS_\nu = \int_{Y}^{\infty} n(y)\, dy$$

where

$n(S_\nu)$: amount of galaxies having flux densities between S_ν and $S_\nu+dS_\nu$ (and similarly for $n(y)$)

Y and S_ν': particular values of y and S_ν

$Y(S_\nu')$ gives the transformation from flux density to proxy, and can be used to recover the numerical value of L_ν for each galaxy in the simulation, at any redshift.



The Count Matching process. Top: relation between the 870μm flux and the quantity $y = Proxy/f_k/D_L^2$ for the M_{dust} x SFR proxy. Bottom: recovered relation between rest-frame 870μm luminosity and proxy value.

* Submm fluxes are drawn from a Monte Carlo simulation following a combination of LABOCA counts at low fluxes and ALMA counts at fluxes brighter than 8mJy. We want to test whether we are able to recover the LABOCA counts after simulating the observational process, while avoiding biases in the counts arising from targeting only LABOCA sources and not other regions in the ECDF-S having S/N slightly lower than the LABOCA threshold.

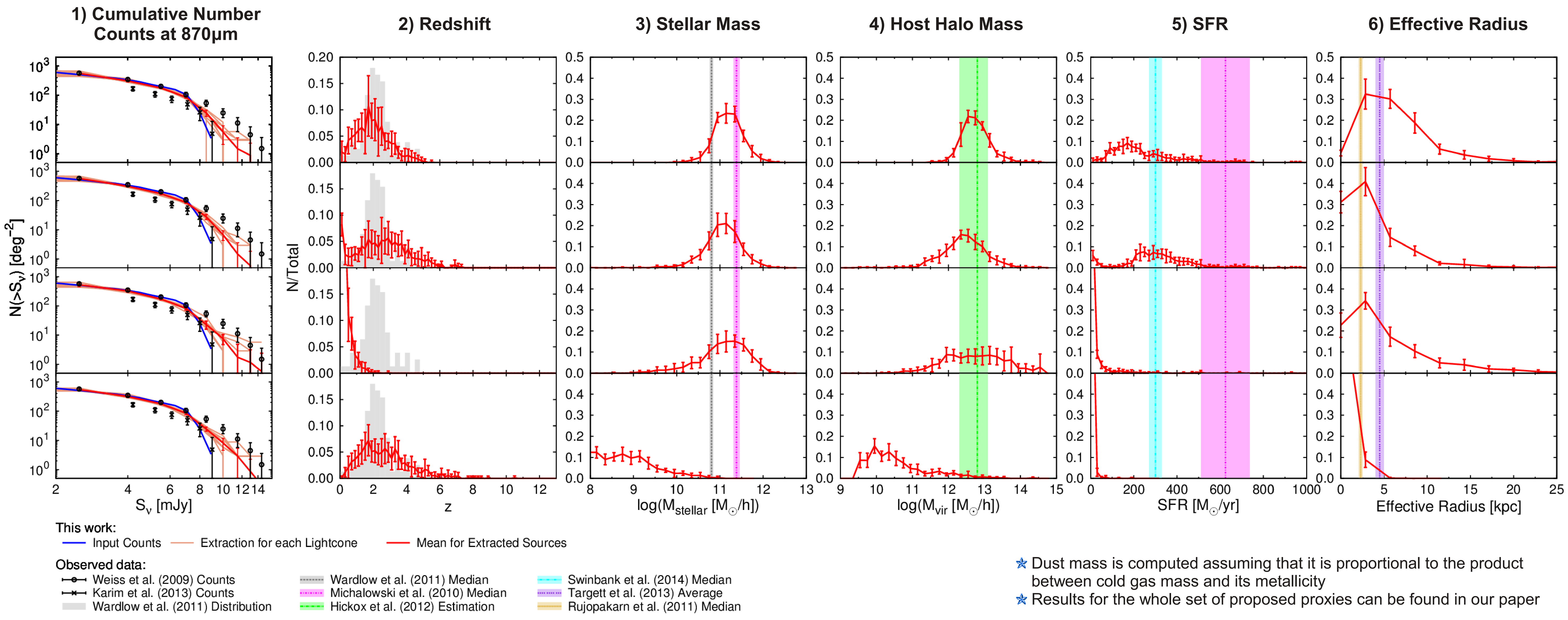
METHODOLOGY

We construct 10 lightcones, each of them covering 30'x30' (as the ECDF-S field) and having a different orientation. After turning the model catalogs given by the proxies into submm maps (LABOCA beamwidth), we perform a source extraction to include the effects of the observational process on the recovered counts and galaxy properties. When finding multiple input sources for a given extraction, we compute the separation in redshift between the components of each blended source.

For determining the best proxy, we explore the redshift, stellar mass and host halo mass distributions of model galaxies selected using the observational flux density cut. Once the best proxy is determined, several properties for SMGs (as well as for their descendants) can be predicted. In general, bright simulated SMGs will have different clustering depending on the assumed proxy, since the sources with the highest value of a given property will be clustered in a particular way.

RECOVERED DISTRIBUTIONS

PROXIES: M_{dust} x SFR; SFR; $M_{stellar}$; Random Coordinates

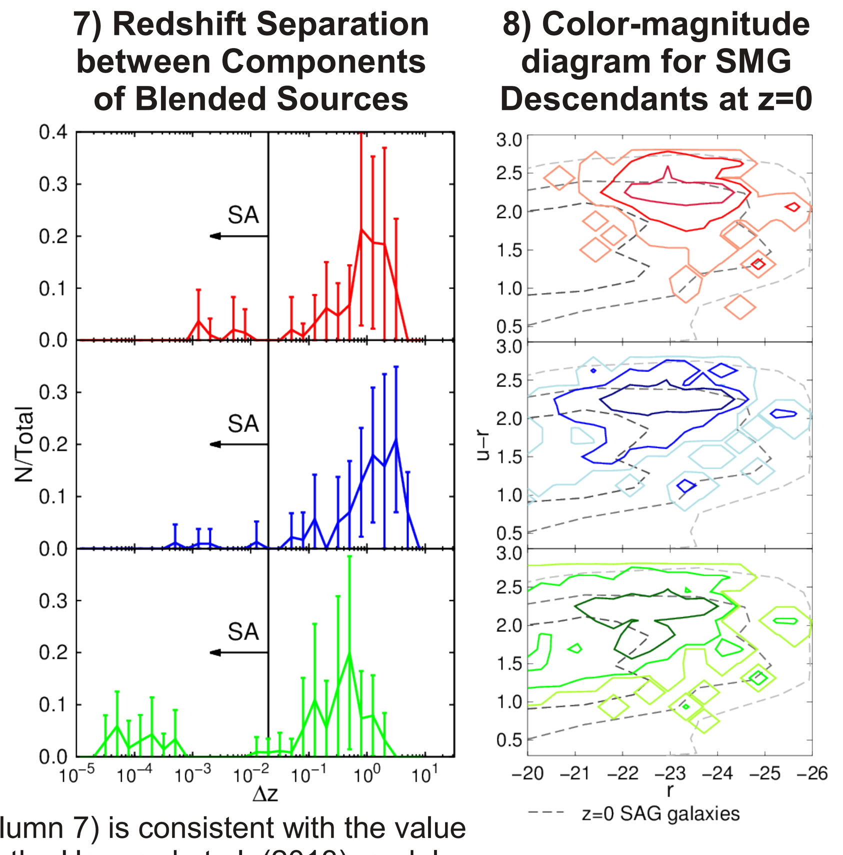


★ Dust mass is computed assuming that it is proportional to the product between cold gas mass and its metallicity

★ Results for the whole set of proposed proxies can be found in our paper

MORE PREDICTIONS

Proxy: M_{dust} x SFR; SFR; $M_{stellar}$



★ Limit in column 7) is consistent with the value derived by the Hayward et al. (2013) model

★ "SA" stands for spatially associated sources

CONCLUSIONS

- ★ For all the proposed proxies, there are lines of sight giving counts consistent with LABOCA data. This is found even for maps having the same distribution of injected fluxes but randomized source coordinates, giving a hint that the clustering has a minor influence in the counts.
- ★ The different proxies retrieve a variety of distributions for a given galaxy property. Comparing the recovered redshift, stellar mass and host halo mass distributions for model SMGs with observational data, we find that the best among the proposed proxies is that in which the submillimeter luminosity increases monotonically with the product between dust mass and SFR. This proxy naturally reproduces a positive trend between SFR and bolometric IR luminosity.
- ★ The majority of components of blended SMGs are spatially unassociated, meaning that most sources lying in a single line of sight are there by chance.

References

Cora, S. A., MNRAS (2006), 368, 1540.
Hayward, C. C., MNRAS (2013), 434, 2572.
Hickox, R. et al, MNRAS (2012), 421, 284.
Karim, A. et al., MNRAS (2013), 432, 2.
Lagos, C. et al., MNRAS (2008), 388, 587.
Michalowski, M. et al., A&A (2010), 514, A67.
Rujopakarn, W. et al., ApJ (2011), 726, 93.
Swinbank, A. M. et al., MNRAS (2014), 438, 1267.
Targett, T. A. et al., MNRAS (2013), 432, 2012.
Wardlow, J. L. et al., MNRAS (2011), 415, 1479.
Weiss, A. et al., ApJ (2009), 707, 1201.

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