MICE-Grand Challenge Galaxy and Halo Light-cone Catalog MICECATv2.0

This file describes the MICE-Grand Challenge (MICE-GC) light-cone halo and galaxy catalog release: MICECAT v2.0. The catalog was generated by the MICE collaboration (www.ice.cat/mice).

There is 1 available Value-Added Data (a detailed description can be found below):

- COSMOS_SEDS_EXTINCTION_LAWS_REF_FILTER.tar.gz (compressed ~496Kb)

To uncompress them, e.g.:

- tar -xzvf COSMOS_SEDS_EXTINCTION_LAWS_REF_FILTER.tar.gz

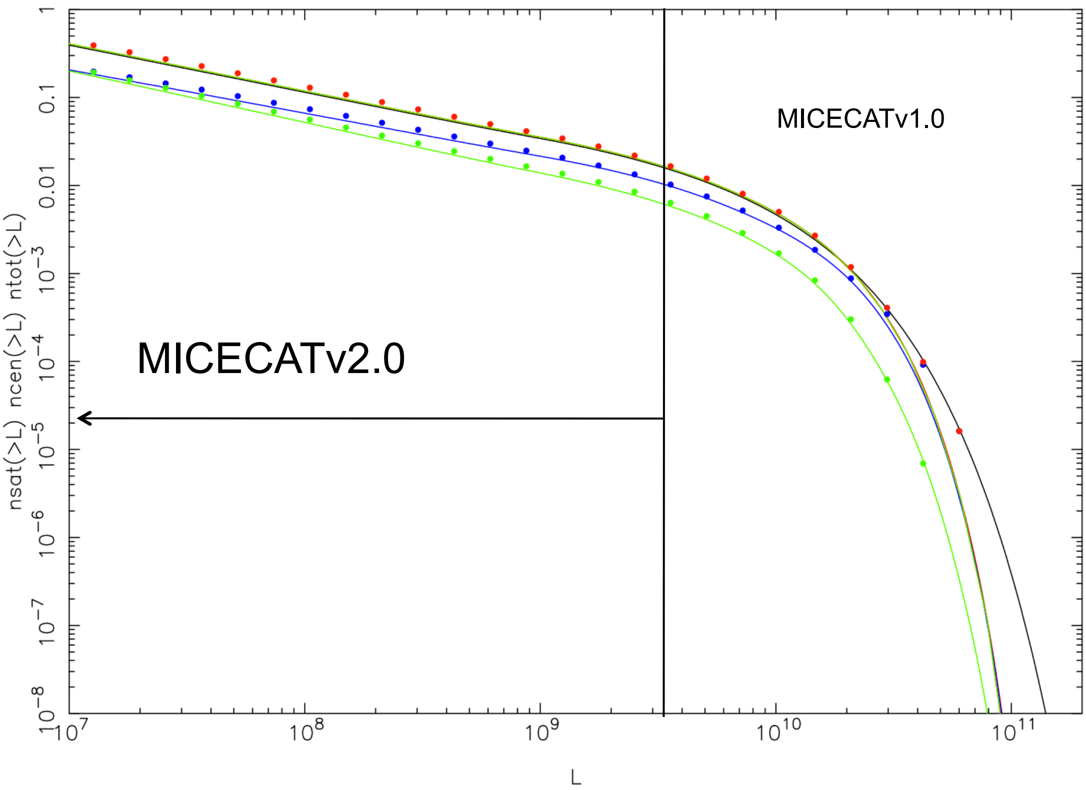
Custom query catalogs of smaller size and/or different formats (comma-separated CSV, space-separated SSV, tab-separated values TSV) can be obtained at http://cosmohub.pic.es/

Overall Description

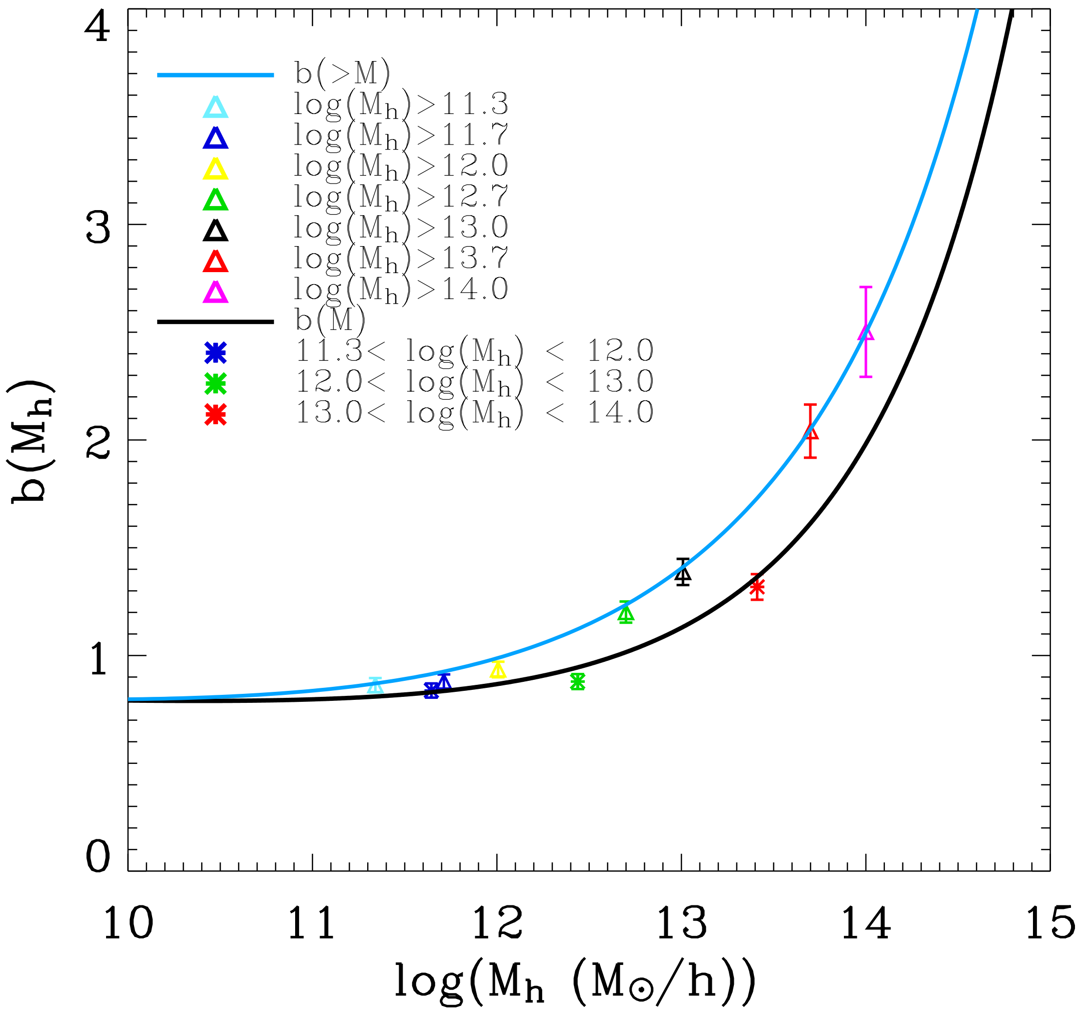
MICECAT v2.0 represents an improvement over the previous **MICECATv1.0** release. There are three important improvements:

1) **Completeness extensively increased**. The range of simulated luminosities has been extensively expanded. Now, the catalog is complete for DES-like surveys (i<24) out to z=1.4. Beware that some regions of the catalog are deeper than others (see below).
We increased the luminosity range by populating halos/groups with fewer number of particles. Now, we reduce the minimum number of particles for a halo/group down to 2 particles whereas before it was 10 particles. This results in the catalog having a minimum absolute magnitude in the r-band of Mr-5log(h) ~ -14.0 ($L_r \sim 10^7$).
The abundance of such small groups (with 2 particles) does not correspond to the abundance of halos at the equivalent halo mass. However, as we build our galaxy catalogues with abundance matching this abundance mismatch is automatically corrected in the galaxy catalog. Besides, the clustering of galaxies is not compromised either given that the clustering of such small groups does not depend strongly on mass (see figure below). In any case, this regime only affects low luminosity galaxies, which can only be seen at the lower redshifts and have more uncertain properties.

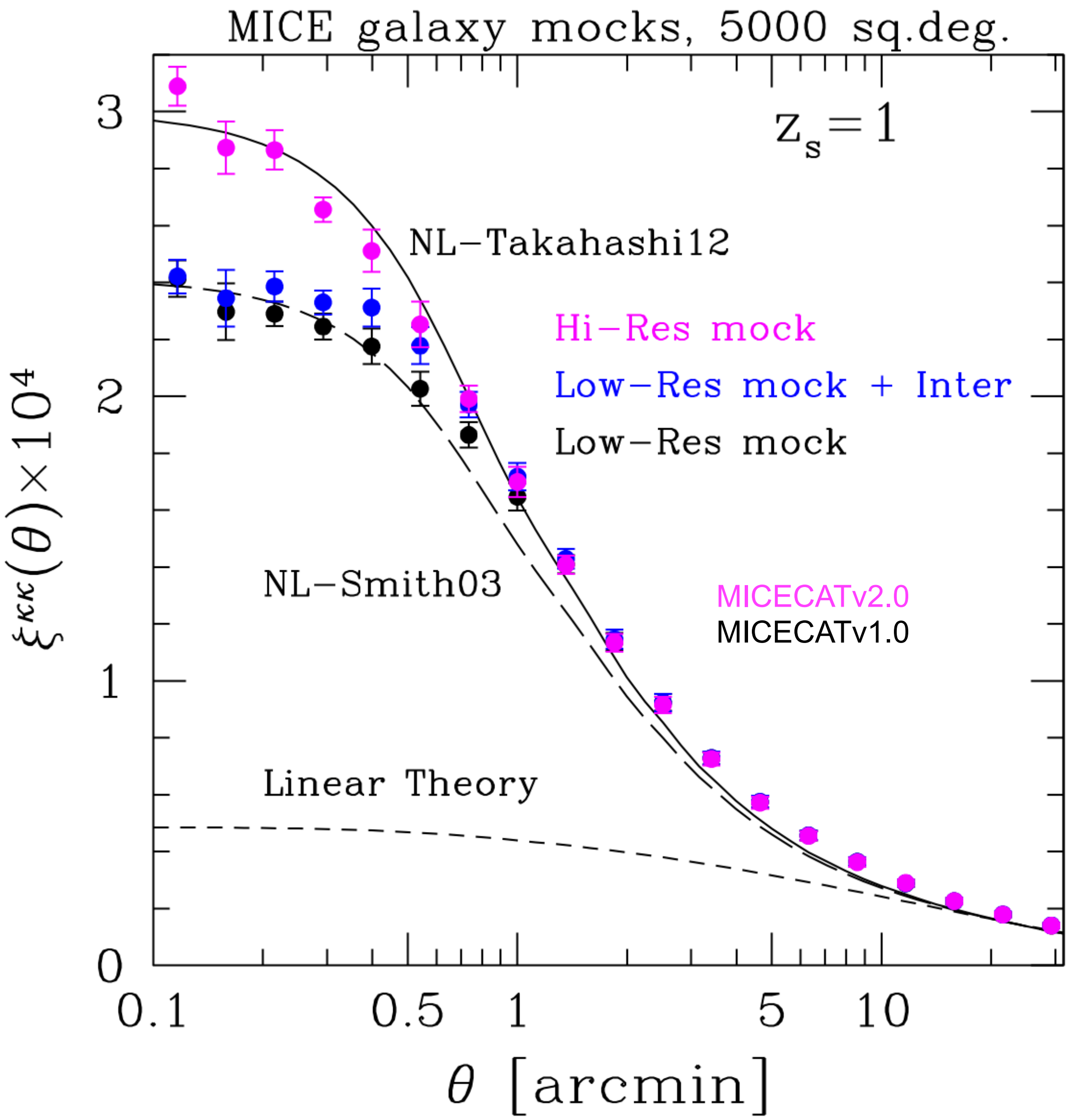
We show the increase in the luminosity range between MICECATv1.0 and v2.0 in the following image:



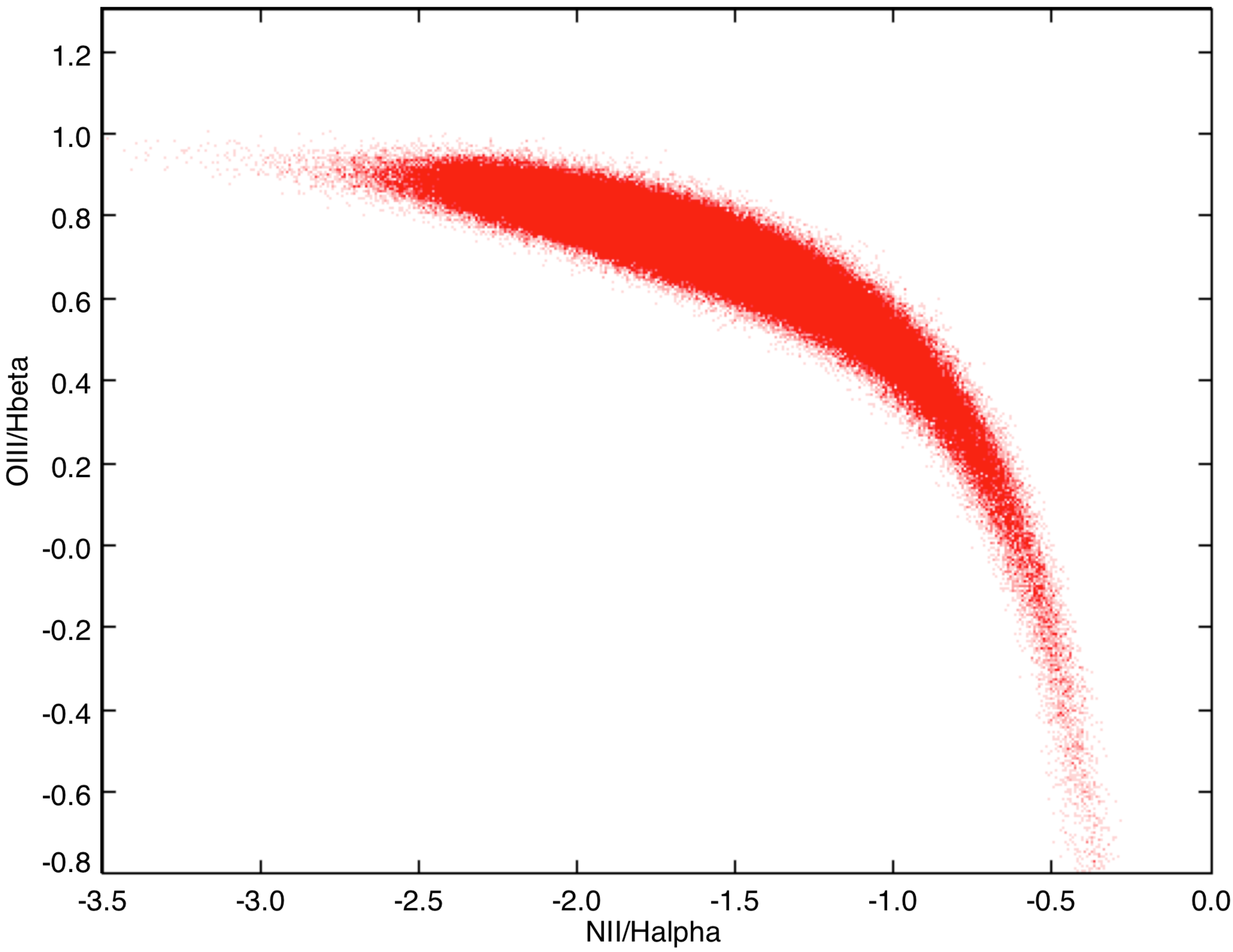
We also show the linear bias at large scales as a function of mass for different halo mass thresholds and bins down to 10 dark matter particles (we use the value of the correlation function at r = 16.9 Mpc/h but the figure is very similar if you use also the adjacent radial bins, scales r = 10.6 or r = 26.8 Mpc/h). We have also found similar results for groups of 2 particles (Castander et al., in prep.). We compare the MICE-GC simulation halo bias to the fits computed by Manera, Sheth & Scoccimarro (2010), who presented a linear bias function for haloes applying the peak background split to a Warren-form halo mass function. The black solid line is the expression of the halo bias given by Manera, Sheth & Scoccimarro (2010) and using the parameters in Crocce et al. (2010) for the MICE simulations (see Appendix A of Carretero et al. 2014 for more details). The blue solid line is the cumulative bias derived by integrating the black solid line. The MICE-GC large scale halo bias and the analytical expression from Manera, Sheth & Scoccimarro (2010) are in reasonable agreement (for a more detailed study of the clustering of the MICE-GC halo population see Crocce et al.(2013)).



1) **Resolution of lensing observables improved**: We have increased the resolution of our lensing maps. In MICECATv1.0 we were using a healpix pixelization of Nside=4096 (i.e, pixel_size = 0.85 arcmin) and now we use Nside=8192 (pixel_size = 0.43 arcmin). Below we show that, for sources at z=1, the convergence 2PCF in MICECATv2.0 is in very good agreement with numerical fits based on high-resolution simulations Takahashi et al. 2012, down to angular scales < 1 arcmin. Similarly, we have checked that other lensing observables are accurately modelled with MICECATv2.0 below 1 arcmin scales.



3) We have computed **new quantities** for the galaxies in the catalog. The properties now include galaxy stellar mass, star formation rate, metallicity, emission lines. These quantities have not been thoroughly tested, so be cautious that they may not fully represent the observed universe.

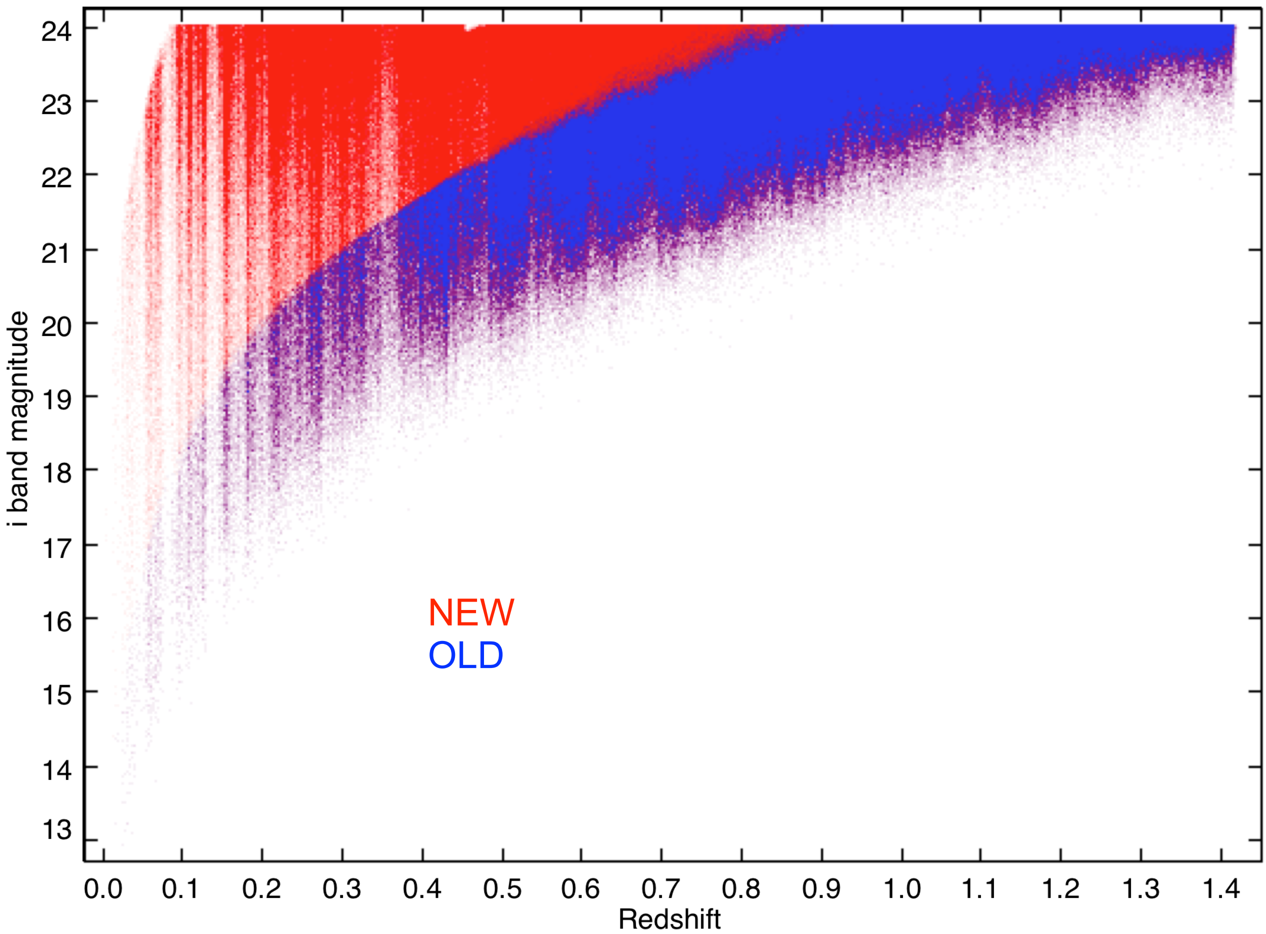


In addition, the catalog also includes quantities that were computed but not released before:

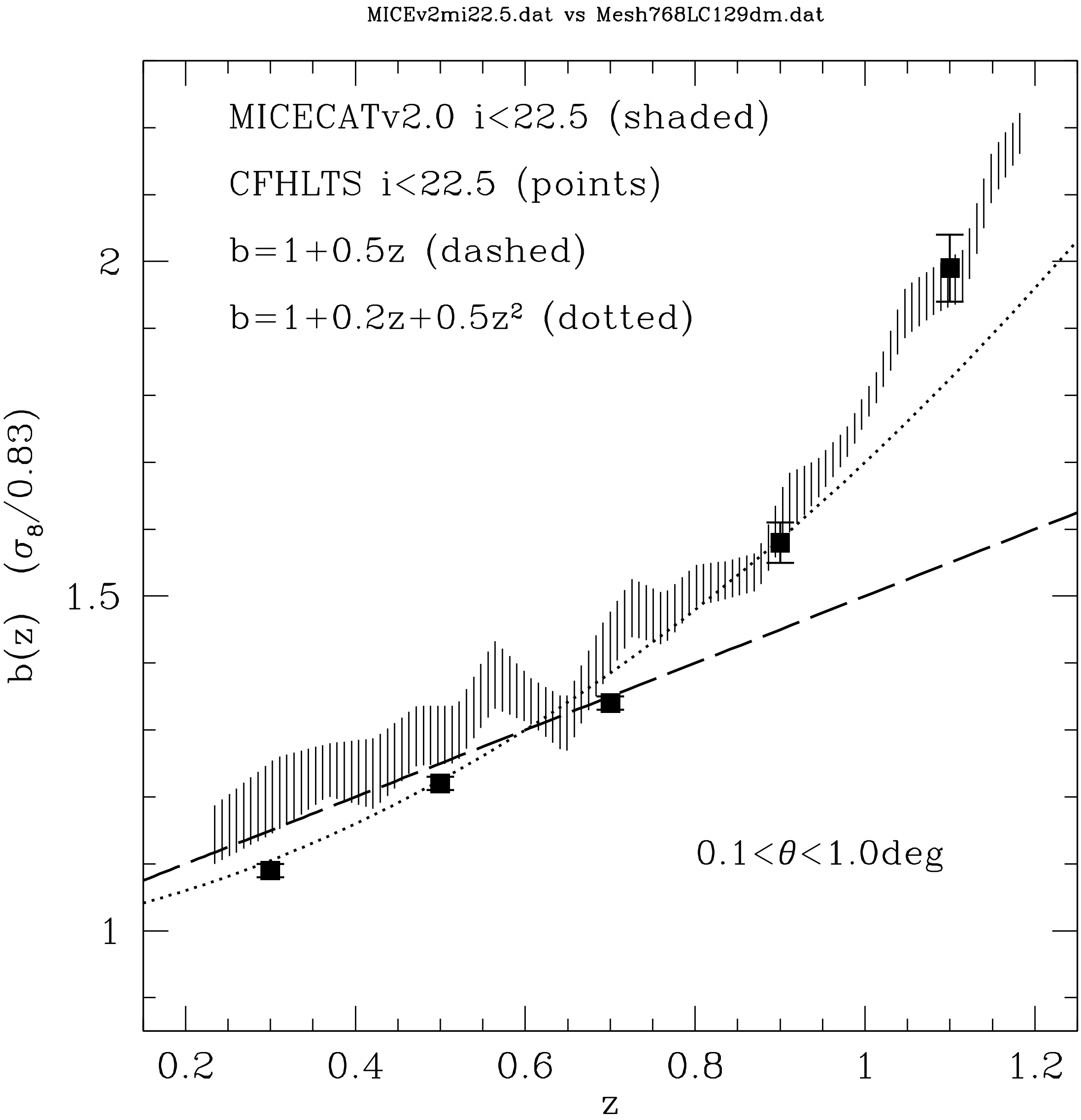
‣ Each galaxy contains the **halo id** of its host halo (**very useful for cluster finder codes**!).

‣ Many **more magnitudes** corresponding to different filters of different projects:

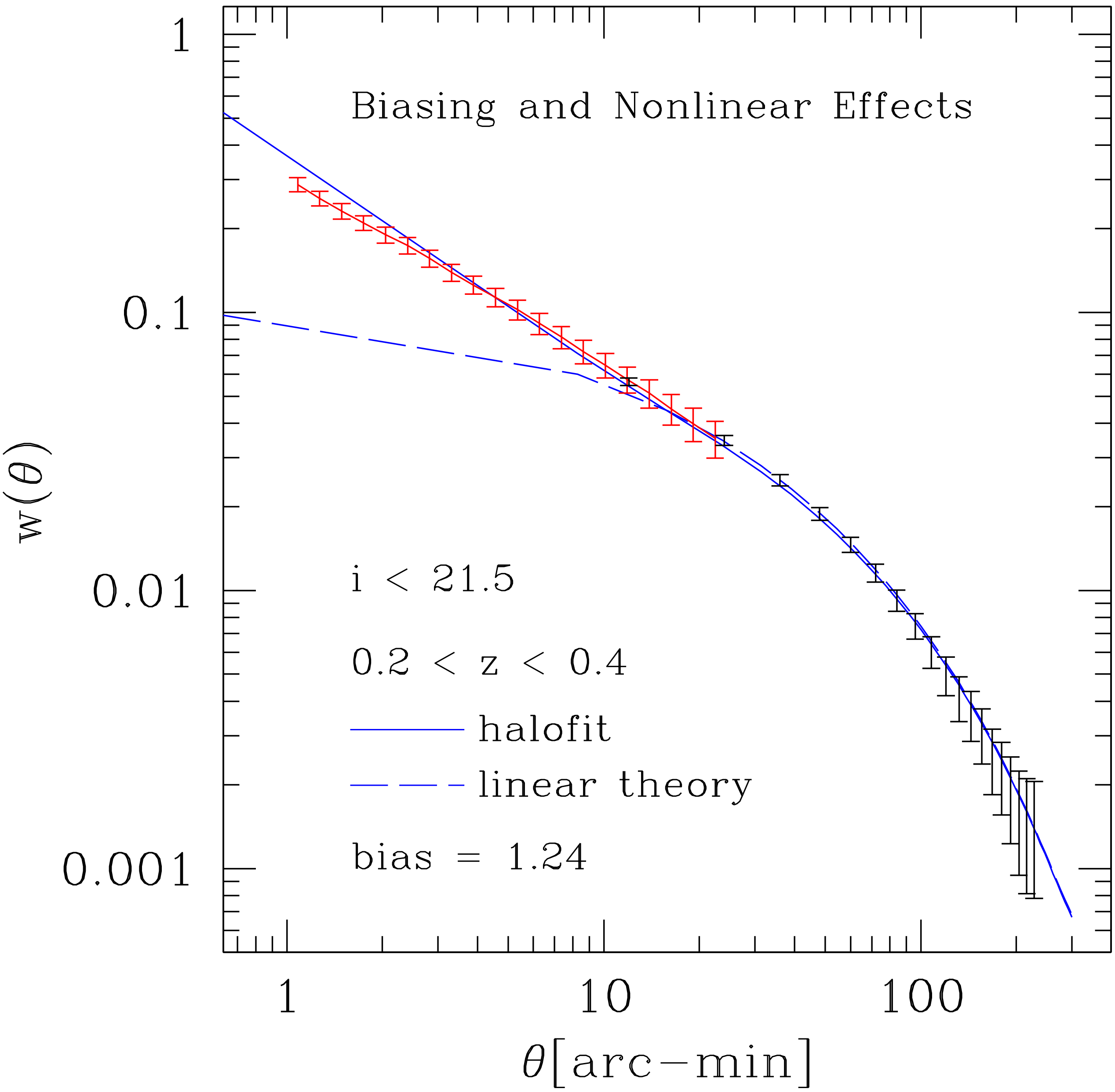
- DES
- Euclid
- COSMOS
- SDSS
- VISTA



In the following figure we show the evolution of the **linear bias** measured in MICECATv2.0 for a catalog selected with $i < 22.5$ (the same criteria as the CFHTLS sample published by Coupon et al 2012). We compare the bias of the catalog to that measured in CFHTLS. In the case of MICECATv2.0 the bias square has been estimated as the ratio of the measured galaxy angular galaxy correlation function to the corresponding measured dark matter correlation in the same (narrow width) redshift bin and averaged over 0.1 and 1.0 degree separation. The bias in MICECATv2.0 agrees with observations (CFHTLS) at all redshifts without any adjustments.



We also compare the angular galaxy correlation in a bright galaxy sample of MICECATv2.0 with the linear and non-linear (halofit) matter predictions scaled by a constant bias. The figure shows clearly how the non-linear gravitational regime starts at larger angular scale ($\theta \sim 10$–20 arcmin) than the non-linear bias regime which goes to scales a factor of ~ 3 smaller. We find similar results in other samples and redshift bins:



The general characteristics of MICECAT v2.0 are the same as those of MICECAT v1.0. We briefly summarize them here:
The catalog was generated using a hybrid Halo Occupation Distribution (HOD) and Halo Abundance Matching (HAM) prescriptions to populate Friends of Friends (FOF) dark matter halos from the MICE-GC simulation.

This catalog used as input the light-cone of the MICE-GC N-body run simulation.
The input cosmological parameters are Ω_m=0.25, σ_8 = 0.8, n_s=0.95, Ω_b=0.044, Ω_Λ=0.75, h=0.7. Further details on the simulation can be found at the MICE web-page (www.ice.cat/mice)

The catalog was built to follow **local observational constraints**:

- The local luminosity function (Blanton et al. (2003) and Blanton et al. (2005) for the faintest galaxies)
- The galaxy clustering as a function of luminosity and colour (Zehavi et al. 2011)

‣ The color-magnitude diagram (NYU dr7 catalog)

It also includes:

‣ galaxy evolution in order to better match the luminosity function and the colour distributions at high redshift
‣ magnified positions due to gravitational lensing effects computed using projected mass density maps (in HEALPIX format) of the MICE-GC light-cone simulation.
‣ shape parameters

Note that unfortunately there was an omission when generating the catalog, and **the evolutionary correction was not applied**. This evolutionary correction is important to get the right number counts at higher redshifts.
Users of the catalog should apply this correction to the galaxy magnitudes if they want to compare to observations. The correction is just the same for all magnitudes and depends on redshift. **Magnitudes should be corrected in the following way**:

magnitude_evolved = magnitude_catalog - 0.8 * (atan(1.5 * z_cgal) - 0.1489)

where magnitude_evolved is the magnitude including the evolutionary correction, magnitude_catalog is the one now in the catalog that does NOT include this correction and z_cgal is the true redshift of the galaxy.

Catalog Completeness

Beware that the magnitude completeness, it is not constant with redshift or position. The way the mock was built results in three different regions with different absolute magnitude cuts. The geometry of these three regions is not "radial", which means that those three different cuts are not the same in redshift in all the area but depend on the ra, dec.

• **DES** completeness: for galaxies, the catalog is complete down to des_asahi_full_i_true_evol < 24.0 at all redshift (0 < z < 1.4) for the following area:
- dec > 30º
- dec < 30º AND 30º < ra < 60º,

where we have applied the evolutionary correction, e.g.,
des_asahi_full_i_true_evol = des_asahi_full_i_true - 0.8 * (atan(1.5 * z_cgal) - 0.1489).
Note that with no evolutonary correction, the catalog is complete down to des_asahi_full_i_true < 25.0 for the same area.

• **Euclid** completeness: in the regions of ra, dec where the catalog is less complete, the resulting completeness in z in the observed H band is:
- up to z ~ 0.45 complete to H ~ 24
- up to z ~ 0.9 complete to H ~ 23.5
- up to z ~ 1.4 complete to H ~ 23.0

In most parts of the area, the completeness is better.

A short summary of the construction (see References for details):

• Galaxy luminosities are assigned using the Halo Abundance Matching technique (HAM) taking into account the HOD.

• g-r galaxy colors are assigned using (HOD) local recipes that depends on whether the galaxy is a central or a satellite and on its absolute magnitude.
• Evolutionary spectral synthesis model libraries of galaxies (PEGASE) are used to apply evolutionary corrections.
• Spectral energy distributions and dust extinctions are resampled from the COSMOS galaxy catalog. See the description of the prebuilt catalog "COSMOS_SEDS_EXTINCTION_LAWS_REF_FILTER.tar.gz" below for more details.
• Morphological parameters are assigned using recipes from Miller et al. 2013 (arXiv: 1210.8201). See the description of the prebuilt catalog MICECAT_v1.0_shapes_order_by_id.ssv.bz2 below (corresponding to the MICECATv1.0) for more details.

Reference papers and useful information:

In the following papers you can find very useful information about the catalogs. If you use MICECAT mock catalogs for scientific publications, we kindly ask you to cite them:

‣ For a description of the calibration algorithm to generate the catalogs (MICECATv1.0, MICECATv2.0) see
Carretero J., Castander F. J., Gaztañaga E., Crocce M., Fosalba P., (2014) arXiv e-print http://arxiv.org/abs/1411.3286

‣ For a detailed study of the dark matter input N-body simulation (MICE-GC run) see Fosalba P., Crocce M., Castander F. J., Gaztañaga E., (2013) arXiv e-print http://arxiv.org/abs/1312.1707

‣ For a description and validation of the catalog and a study of halo and galaxy clustering see Crocce M., Castander F. J., Gaztañaga E., Fosalba P., Carretero J., (2013) arXiv e-print http://arxiv.org/abs/1312.2013

‣ For the lensing implementation and a detailed study of the lensing properties of the catalog see Fosalba P., Gaztañaga E., Castander F. J., Crocce M., (2013) arXiv e-print http://arxiv.org/abs/1312.2947

‣ For higher order clustering see Hoffmann, Kai; Bel, Julien; Gaztanaga, Enrique; Crocce, Martin; Fosalba, Pablo; Castander, Francisco J. http://arxiv.org/abs/1403.1259

‣ For an upgrade of the algorithm to generate the galaxy catalog including evolution see Castander et al. 2014, in prep.

Some numbers

• Number of galaxies: 499609997 (~500M).

• Number of halos: 329344245 (~330M)

• Redshift range of the light-cone: $0 < z < 1.4$.

• Total area of the catalog: one octant of the sky (~ 5000 sq.deg), built with NO repetition of the simulation box.

• Angular coordinates range are:
0º < ra < 90º and 0º < dec < 90º

Description of fields

We adopt the following convention to define (ra,dec) coordinates from cartesian (x,y,z)
ra = 180/pi*atan(x,y) and dec= 90-180/pi*atan(sqrt(x*x+y*y),z) where (ra,dec) are given in degrees, and atan(x,y) = atan(x/y). "atan" denotes the arctangent. Note that this convention is not the one usually assumed in astronomy (i.e, we swap "x" by "y" above, or similarly, ra => 90-ra, with respect to the astronomical convention).

Lensing fields, gamma1 and gamma2, which are dimensionless, are given in the above (ra, dec) coordinate system. In case one prefers to use the standard astronomical convention to go from (x,y,z) to (ra,dec), then the shear (spin-2) components should be rotated accordingly (i.e, apply a 2D rotation matrix to the shear components by an angle 2*(90-2*ra).

Note that some fields (unique_gal_id, unique_halo_id, ra_gal, dec_gal, z_cgal, mr_gal, flag_central and lmhalo) are defined as **indexes in the database**. We recommend that you introduce filters based on those fields for quicker and more efficient use of this database.

Some additional information about some galaxy fields:

‣ Shape parameters:
unique_gal_id bigint, # unique galaxy id
bulge_fraction float, # ratio of the flux in the bulge component to the total flux (often written B/T)
bulge_length float, # bulge length scale (arcsec)
bulge_axis_ratio float, # bulge projected axis ratio (b/a)
bulge_angle float, # position of the bulge rotation axis (CCW with respect to horizontal axis, where CCW means counter clock wise) (degree)
disk_length float, # disk length scale (arcsec)
disk_axis_ratio float, # disk projected axis ratio (b/a)
disk_angle float, # position of the disk rotation axis (CCW with respect to horizontal axis, where CCW means counter clock wise) (degree)

The morphological parameters are estimated following Miller et al. 2013 (arXiv:1210.8201)

The galaxy catalog is split into DISK- or BULGE- dominated galaxies.
We assume that ~15% of the galaxy population are BULGE dominated galaxies. This is a reasonable representation of the
distribution of bulge fraction found at low and high redshift (e.g. Schade et al. 1996, Simard et al. 2002).
We make this cut depending on the galaxy color (gr_restframe). We rank the galaxy catalog by color and we set ~15% reddest galaxies as BULGE- dominated galaxies.

Priors estimated from observations are used to derive the scalelength, the ellipticity and the bulge to flux ratio for every galaxy.

Given the ellipticity, whose distribution depends on the galaxy type, the axis ratio is computed following q = (1-e)/(1+e).
Then q = bulge_axis_ratio = disk_axis_ratio is also assumed.
Uniformly random numbers from -180º to 180º to compute the bulge_angle. Also, bulge_angle = disk_angle.

Finally, these are the assumptions depending on the galaxy type:

BULGE

• bulge_to_flux_ratio = 1.0

• bulge_length = bulge_half_radius = scalelength

• disk_length = 0.0

DISK

• disk_length = scalelength

• bulge_length = bulge_to_flux_ratio*gal_disk_length

Some basic checks can be found in the following link:
> https://dl.dropboxusercontent.com/u/6383382/Galaxy_shapes_DC3.pdf

‣ **COSMOS_SEDS_EXTINCTION_LAWS_REF_FILTER.tar.gz**

Details of these templates can be found in Ilbert O. et al., 2009, ApJ, 690, 1236.

The file contains the spectral energy distribution templates extinction laws used to derive galaxy magnitudes and colurs.
It also contains the r-band SDSS filter shifted to z = 0.1 as a reference filter.

Once the file is unpacked and uncompressed there are:

- 31 different COSMOS spectral energy distribution templates (COSMOS SED files):
  * 7 Ellipticals (Ell):
    - 0 - Ell1_A_0_UV.sed
    - 1 - Ell2_A_0_UV.sed
    - 2 - Ell3_A_0_UV.sed
    - 3 - Ell4_A_0_UV.sed
    - 4 - Ell5_A_0_UV.sed
    - 5 - Ell6_A_0_UV.sed
    - 6 - Ell7_A_0_UV.sed

  * 12 corresponding to 1 lenticular and 11 spiral galaxies (S0-Sp):
    - 7 - S0_A_0_UV.sed
    - 8 - Sa_A_0_UV.sed
    - 9 - Sa_A_1_UV.sed
    - 10 - Sb_A_0_UV.sed
    - 11 - Sb_A_1_UV.sed
    - 12 - Sc_A_0_UV.sed

- 13 - Sc_A_1_UV.sed
- 14 - Sc_A_2_UV.sed
- 15 - Sd_A_0_UV.sed
- 16 - Sd_A_1_UV.sed
- 17 - Sd_A_2_UV.sed
- 18 - Sdm_A_0_UV.sed

* 12 Starburst (SB):
  - 19 - SB0_A_0_UV.sed
  - 20 - SB1_A_0_UV.sed
  - 21 - SB2_A_0_UV.sed
  - 22 - SB3_A_0_UV.sed
  - 23 - SB4_A_0_UV.sed
  - 24 - SB5_A_0_UV.sed
  - 25 - SB6_A_0_UV.sed
  - 26 - SB7_A_0_UV.sed
  - 27 - SB8_A_0_UV.sed
  - 28 - SB9_A_0_UV.sed
  - 29 - SB10_A_0_UV.sed
  - 30 - SB11_A_0_UV.sed

Each file contains 1762 rows and 2 columns, which are lambda (Angstrom) and flux (erg/s/cm^2/Angstrom).

- 5 extinction laws:
  * flatnuspec_noext.sed: no extinction ("extinction_law" = 0)
  * flatnuspec_prevot_ebv02.sed: prevot ("extinction_law" = 1)
  * flatnuspec_calzetti_ebv02.sed: calzetti ("extinction_law" = 2)
  * flatnuspec_calzetti_bump1_ebv02.sed: calzetti-bump1 ("extinction_law" = 3)
  * flatnuspec_calzetti_bump2_ebv02.sed: calzetti-bump2 ("extinction_law" = 4)

  Each file contains 1500 rows and 2 columns, which are also lambda (Angstrom) and flux (erg/s/cm^2/Angstrom)

- 1 reference filter:
  * rp01.pb: r-band SDSS filter shifted to z = 0.1

  The file contains 75 rows (+ the header) and 2 columns, which are lambda (Angstrom) and the filter response.

Each galaxy has a "sed_template", "extinction_law" and "ebv" (color excess) fields.

"sed_template" field varies from -0.5 to 46.5.
"extinction_law" field varies from 0 to 4.
"ebv" field varies from 0. to 0.77

One or more extinction laws can be applied to the COSMOS SED templates:

#field "sed_template"	#COSMOS SED file	#field "extinction_law"
0-6 (7)	0-6	0
7-9 (3)	7-9	0
10-18 (9)	10-18	1
19-22 (4)	19-22	1

23-30 (8)	23-30	2
31-38 (8)	23-30	3
39-46 (8)	23-30	4

The total combination of COSMOS SED file and "extinction_law" is (7+3+9+4+8*3) = 47, which refers to the range of the field "sed_template".

A "sed_template" value refers to an interpolation between 2 templates.
Examples:
- sed_template = -0.5 then SED = 1.5 * Ell1_A_0_UV.sed - 0.5 * Ell2_A_0_UV_sed ("extinction_law" = 0 for both)
- sed_template = 0.0 then SED = Ell1_A_0_UV.sed ("extinction_law" = 0)
- sed_template = 0.3 then SED = 0.7*Ell1_A_0_UV.sed+0.3*Ell1_A_1_UV.sed ("extinction_law" = 0 for both)
- sed_template = 0.5 then SED = 0.5 * Ell1_A_0_UV.sed + 0.5 * Ell2_A_0_UV.sed ("extinction_law" = 0 for both)
- sed_template = 0.7 then SED = 0.3 * Ell1_A_0_UV.sed + 0.7 * Ell2_A_0_UV.sed ("extinction_law" = 0 for both)
- sed_template = 1.0 then SED = Ell2_A_0_UV.sed ("extinction_law" = 0)

and so on.

AB derivation:

AB = integral(lambda * template * filter)/integral(filter/lambda) + constant

The integrals are over lambda.
"template" is the value of the template flux.
"filter" is the value of the filter transmission.
When extinction is included, then the "template" is modified with a factor coming from the extinction laws files:

template_ext = template_no_ext * factor

factor = (ext_curveN/ext_curve0)**(ebv/0.2)

where ext_curve0 means no extinction (flatnuspec_noext.sed) and ext_curveN refers to the rest of the extinction curves (flatnuspec_prevot_ebv02.sed, flatnuspec_calzetti_ebv02.sed, flatnuspec_calzetti_ebv02.sed, flatnuspec_calzetti_bump1_ebv02.sed and flatnuspec_calzetti_bump2_ebv02.sed).