Forecast specifications for the TWG-WP6 code comparison

Document Num.: EC-???-???

Issue: 0

Date: March 13, 2015

Authors: Valeria Pettorino (in charge), Luca Amendola, Rachel Bean, Stefano Camera, Carmelita Carbone, Santiago Casas, Enea Di Dio, Bin Hu, Martin Kunz, Francesco Montanari, ... (people providing feedback will be added to this list)

Authorised by: TWG

Abstract: *Disclaimer: this document contains the forecast specifications to be used for the only purpose of the code comparison, within the TWG. It is not meant to be about the optimal/real forecasts/specifications one should use for Euclid.*

Document Change History

Title: *Forecast specifications for the TWG-WP6 code comparison*			
Issue	**Rev.**	**Date**	**Reason for Change**
Draft 0	0	2015-03-12	Creation

Approved by:

NAME	**Organization**	**Date**	**Signature**

Contents

1 Aim

The aim is to provide a model-independent validated fisher code, available for everyone to use. We will write a paper based on the results of the code comparison. The code comparison will proceed by steps:

1. generating common input
2. compare the fisher matrices for the *minimal* common fisher code (from now on referred to as MCFC)
3. discuss and improve the MCFC
4. make the code public available (terms to be discussed)

2 Fisher comparison v1.0: minimal settings

We start the comparison with a simplified setting. Once we agree on this, we can modify it or add further effects. References: [1, 2, 3].

2.1 Galaxy clustering

We recall the main equations to be used. Observed linear spectrum at all redshifts:

$$P_{r,obs}(k_{ref}, \mu_{ref}; z) = P_s(z) + \frac{D_A(z)^2_{ref} H(z)}{D_A(z)^2 H_{ref}(z)} \frac{P(k,z)}{P(k,z=0)} b^2(z)(1+\beta(z)\mu^2)^2 P(k,z=0)\,, \tag{1}$$

where $b(z)$ is the bias (provided by column 5 of Tab.(1), $\beta(z)$ is the redshift-distortion factor, $P(k)$ is the undistorted linear matter spectrum (provided in the input with the correct normalization), μ is the direction cosine, D_A is the angular diameter distance (provided in the input) and H is the Hubble rate at the shell redshift z (provided in the input). $P_s(z)$ is the z- dependent shot-noise correction. The subscript ref (for 'reference') indicates quantities calculated in the fiducial model. In linear theory we have $\beta_d(z) = f(z)/b(z)$ where $f(z) \equiv d\log G/d\log a$ is the growth rate (f is provided directly in the input for every cosmology, G is the growth factor but you should not need it, the input provides directly the power spectrum).

In this case, the Fisher matrix for every redshift bin shell is integrated in k:

$$F_{ij} = \frac{1}{8\pi^2} \int_{-1}^{+1} \mathrm{d}\mu \int_{k_{min}}^{k_{max}} k^2 \mathrm{d}k \, \frac{\partial \ln P_{obs}(k,\mu)}{\partial \theta_i} \frac{\partial \ln P_{obs}(k,\mu)}{\partial \theta_j} \left[\frac{n(z)P_{obs}(k,\mu)}{n(z)P_{obs}(k,\mu)+1}\right]^2 V_s\,. \tag{2}$$

where $n(z)$ is the galaxy number density at redshift z and V_s is the survey volume of the entire redshift shell. The power spectra are all obtained numerically by solving the background and perturbation equations of the system for each value of the parameters and they are provided as input; you will need to evaluate the derivatives F_{ij} numerically.

The input provides the spectra, $f(z)$, $D_A(z)$, $P(k)$ for each model, with the correct normalization. Therefore we are only going to consider the bias $b(z)$ as a nuisance parameter and we are only marginalising over it (and not over the amplitude or anything else, for now).

In principle, one would need to include a redshift error σ_z and further multiply: $P_{obs} = P_{obs} e^{-k^2\mu^2\sigma_z^2/H(z)^2}$. However here we do not include this error for now.

Specifications for the galaxy clustering:

1. k_{min} : 0.001 h/Mpc
2. $k_{max} = 0.2$ h/Mpc

3. k-binning: use directly the one of the spectra provided in the input
4. $P_{shot} = 0$ (not nuisance parameter, we completely neglect it for now)
5. $\sigma_z = 0$
6. No relativistic corrections.

Specifications for the survey

1. Area : 15,000 sq deg
2. Redshift range : $0.7 < z < 2.0$
3. Bias : Take column 5 (b3) of the following table (derived from Orsi et al. 2009).
4. Binning: use all bins as in the table, starting from 0.65 (the first non-zero).

Galaxy density: take column 4 of Table (1), (dn3) as dn/dz/$d\Omega$ (with Ω in square degrees). There is no need to add in an extra redshift success rate (e.g. epsilon=0.35) as before - this is already included in the numbers, which now account for redshift- and flux-dependent success rate, in addition to using an improved mock catalogues and redshift-measurement technique. There is also no need to include any scaling. These numbers are for the standard integration time (540 sec per dither, standard dither pattern). As an example, to get the total number of galaxies in a bin of width $0.95 < z < 1.05$, one would calculate:

(Number of galaxies $0.95 < z < 1.05$) = $4825.80 * 0.1 * 15000 = 7,239,000$

So in a Euclid survey over $15,000deg^2$ we would get good redshifts for $7,239,000$ galaxies in the redshift range $0.95 < z < 1.05$. Note the 0.1 factor required to turn dn/dz from a derivative to a number in a bin of width $Dz = 0.1$.

This gives you the total number of galaxies. Then the number density that you need in the fisher for GC, n in eq.2 in the formula for the fisher matrix, is the density per volume in each bin, therefore equal to $n = dn3/dV_{dz} * dz$, where the dz is the width of the redshift shell and dV_{dz} is the volume in the redshift shell per degree squared.

2.2 Weak Lensing

Convergence power spectrum with (correlated) sources in redshift bins centered around z_i and z_j:

$$P_{ij}(\ell) = \frac{9}{4}\int_0^\infty \mathrm{d}z \frac{W_i(z)W_j(z)H^3(z)\Omega_m^2(z)}{(1+z)^4} P_m\left(\frac{\ell}{\pi r(z)}\right), \tag{3}$$

where $W_i(z)$ is the window function:

$$W_i(z) = \int_z^\infty \frac{d\tilde{z}}{H(\tilde{z})}\left[1 - \frac{r(z)}{r(\tilde{z})}\right] n_i[r(\tilde{z})] \tag{4}$$

where $r(z)$ is the coming distance. The window function depends on $n_i(z)$, the galaxy distribution in the i-th redshift bin: this is convolved with a Gaussian to account for photometric redshift errors $\Delta_z(1+z)$ (value specified below), i.e.

$$n_i(z) = A_i \int_{i\text{-th bin}} n(\tilde{z}) \exp\left(\frac{-(\tilde{z}-z)^2}{2(\sigma_z(1+\hat{z}_i))^2}\right) \mathrm{d}\tilde{z} \tag{5}$$

where $\hat{z}_i$ is the center of the i-th redshift bin and A_i a normalization factor. In eq. (5), the density is given by:

$$n(z) = z^2 exp(-(z/z_0)^{3/2}) \tag{6}$$

where $z_0 = z_{mean}/1.412$ is the peak of $n(z)$ and z_{mean} is the median redshift (value specified below).

Table 1: Specifications of the redbook, (derived from Orsi et al. 2009).

zmin	zmax	dVol	dn3	b3
0.35	0.45	3.60	0.000	0.992
0.45	0.55	5.10	0.000	1.024
0.55	0.65	6.40	0.000	1.053
0.65	0.75	7.90	2434.280	1.083
0.75	0.85	9.20	4364.812	1.125
0.85	0.95	10.30	4728.559	1.104
0.95	1.05	11.70	4825.798	1.126
1.05	1.15	12.30	4728.797	1.208
1.15	1.25	13.30	4507.625	1.243
1.25	1.35	14.00	4269.851	1.282
1.35	1.45	14.60	3720.657	1.292
1.45	1.55	15.10	3104.309	1.363
1.55	1.65	15.60	2308.975	1.497
1.65	1.75	16.00	1541.831	1.486
1.75	1.85	16.20	1474.707	1.491
1.85	1.95	16.50	893.716	1.573
1.95	2.05	16.70	497.613	1.568

Then the Fisher matrix is summed over all multiples:

$$F_{\alpha\beta} = f_{\rm sky} \sum_{\ell,i,j,k,m} \frac{(2\ell+1)\Delta\ell}{2} \frac{\partial P_{ij}(\ell)}{\partial\theta_\alpha} C^{-1}_{jk} \frac{\partial P_{km}(\ell)}{\partial\theta_\beta} C^{-1}_{mi} \tag{7}$$

with the covariance matrix

$$C_{jk} = P_{jk} + \delta_{jk}\gamma^2_{\rm int} {q_j}^{-1}, \tag{8}$$

where $\gamma_{\rm int}$ is the intrinsic galaxy shear and

$$q_j = 3600 \left(\frac{180}{\pi}\right)^2 n_\theta \int_0^\infty n_j(z)dz\,. \tag{9}$$

Here n_θ is the galaxy density per $\rm arcmin^2$ and $n_j(z)$ is the galaxy density for the j-th redshift bin, as defined in eq.(5).

Since we consider multipoles up to $\ell_{\rm max} = 5000$, we need to apply non-linear corrections to the matter power spectrum, for which we use the halofit (provided in the input spectra).

Specifications for the weak lensing:

1. Area: 15,000 sq deg
2. $f_{sky} = Area/(4\pi(180/\pi)^2)$
3. Median Redshift: $z_{mean} = 0.9$
4. $\gamma_{\rm int} = 0.22$
5. $n_\theta = 30$ galaxies per $\rm arcmin^2$
6. Error on photometric redshift: σ_z = 0.05(1+z)

7. Linear Power Spectrum: CAMB (provided in the input, you shouldn't use it)
8. Method to correct for non-linearities: Halo model (provided in the input, you shouldn't use it)
9. Binning: 10 bins from z = 0 - 2.5
10. k-range: $k_{min} = 0.001$ h/Mpc, $k_{max} = 1.5$ h/Mpc
11. k-binning: use directly the one provided in the input
12. We assume equipopulated bins: the redshift bins chosen such that each contain the same amount of galaxies.
13. ℓ-range: $\ell_{min} = 5$, $\ell_{max} = 5,000$
14. ℓ-binning: 100 bins (with log spaced binning)

References

[1] H.-J. Seo and D. J. Eisenstein, *Probing Dark Energy with Baryonic Acoustic Oscillations from Future Large Galaxy Redshift Surveys*, *ApJ* **598** (Dec., 2003) 720–740, [astro-ph/0307460].

[2] L. Amendola and S. Tsujikawa, *Dark Energy: Theory and Observations*. Cambridge University Press, 2010.

[3] L. Amendola, S. Appleby, D. Bacon, T. Baker, M. Baldi, N. Bartolo, A. Blanchard, C. Bonvin, S. Borgani, E. Branchini, C. Burrage, S. Camera, C. Carbone, L. Casarini, M. Cropper, C. de Rham, C. Di Porto, A. Ealet, P. G. Ferreira, F. Finelli, J. García-Bellido, T. Giannantonio, L. Guzzo, A. Heavens, L. Heisenberg, C. Heymans, H. Hoekstra, L. Hollenstein, R. Holmes, O. Horst, K. Jahnke, T. D. Kitching, T. Koivisto, M. Kunz, G. La Vacca, M. March, E. Majerotto, K. Markovic, D. Marsh, F. Marulli, R. Massey, Y. Mellier, D. F. Mota, N. Nunes, W. Percival, V. Pettorino, C. Porciani, C. Quercellini, J. Read, M. Rinaldi, D. Sapone, R. Scaramella, C. Skordis, F. Simpson, A. Taylor, S. Thomas, R. Trotta, L. Verde, F. Vernizzi, A. Vollmer, Y. Wang, J. Weller, and T. Zlosnik, *Cosmology and Fundamental Physics with the Euclid Satellite*, *Living Reviews in Relativity* **16** (Sept., 2013) 6, [arXiv:1206.1225].