Gravitational lensing and parameter extraction from SNe catalogues

Valerio Marra
The cosmic concordance model

how do large-scale inhomogeneities change this plot?

Kowalski et al. 08

= FLRW + small corrections

or

= FLRW’ + large corrections

“backreaction”

Kolb, Marra, Matarrese
arXiv:0901.4566
How to model the universe?

How is the luminosity distance affected?

The quantity to look at is the lensing PDF.
Weak-lensing basics

\[ \Delta m(z) = 5 \log_{10}(1 - \kappa(z)) \]

\[ \kappa(z) = \int_0^{r_s(z)} dr \ G(r, r_s(z)) \delta_M(r, t(r)) \]

\[ G(r, r_s) = \frac{3H_0^2\Omega_M}{2c^2} \frac{f_k(r)f_k(r_s - r)}{f_k(r_s)} \frac{1}{a(t(r))} \]

\[ \delta_M > 0 \quad \text{magnification} \quad \Delta m < 0 \]

\[ \delta_M < 0 \quad \text{demagnification} \quad \Delta m > 0 \]
\[ \kappa = \int_0^{r_s} dr \ G(r, r_s) \ \delta_M(r, t(r)) \]

- \( r_s \rightarrow N_S \) bins of widths \( \Delta r_i \)
- \( R \rightarrow N_R \) bins of widths \( \Delta b_m \)
- \( \kappa = \sum_{i=1}^{N_S} \sum_{m=1}^{N_R} \kappa_{im} (k_{im} - \Delta N_{im}) \)

halo surface density
convergence due to a halo in the bin \((i, m)\)

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Stochastic method: II

\[
\kappa(\{k_{im}\}) = \sum_{i=1}^{N_S} \sum_{m=1}^{N_R} \kappa_{1im} (k_{im} - \Delta N_{im})
\]

- # of halos in bin (i, m)
- expected # of halos in bin (i, m)

randomly-placed halos

distributed as a Poisson variable of parameter \(\Delta N_{im}\)

to compute lensing PDF, enough to generate the numbers \(k_{im}\): FAST! \(\sim 1\)s
Generalizing...

\[ \kappa(\{ k_{im} \}) = \sum_{i=1}^{N_S} \sum_{m=1}^{N_R} \kappa_{1im} \left( \frac{k_{im}}{N_O} - \Delta N_{im} \right) \]

where \( k_{im} \) is distributed as a Poisson variable of parameter \( N_O P_{im}^{\text{sur}} \Delta N_{im} \)

This extremely simple formula describes both probabilistic and selection biases
...and can be easily generalized

K. Kainulainen and V. Marra
turboGL is a simple and very fast Mathematica code based on the stochastic approach to cumulative weak lensing introduced in Ref. [1]. turboGL can easily compute the convergence PDF relative to arbitrary halo mass distributions, selection biases, number of observations, halo profiles and evolutions. See below for the features included in the current version: we are continuously testing and updating the code in order to include more features. Click the image above for a poster with a fast introduction to the method. If you want to be informed of a new version, please send an email. Do not hesitate to contact us if you have any questions or suggestions.

Kimmo Kainulainen and Valerio Marra

Visits: 155

DOWNLOADS
Available packages are divided in two sections: turboGL (core) code and applications. For the latter follow the respective link in the publications list below.

Publications

turboGL code
turboGL has been written using Mathematica 6.0.3 and it is not directly compatible with earlier versions. Instructions are inside the tarball. It is released under the GPL license.
The actual intrinsic distribution should be a universal function as a function of a variable of parameter \( \mu \) and \( y \).

We define the total likelihood function as the product of the intrinsic source brightness distribution and the lensing distortion distribution.

\[
L_i(\mu) = \int dy P_{wl}(y, z_i) P_{SN}(\Delta m_i - \mu - y, \sigma_i)
\]

\[
L(\Omega_M, \Omega_\Lambda, w) = \int d\mu \prod_i L_i(\mu)
\]

\( M = 5.6 \cdot 10^{14} h^{-1} \Omega_M M_\odot \)

\( R_p^{\Lambda CDM} \simeq 0.7 h^{-1} \text{Mpc (NFW)} \)

Amendola, Kainulainen, Marra and Quartin
arXiv:1002.1232
We used a single-mass halo model. Can we do better?
Work in progress... $f(M, z)$

Slice of $15h^{-1}\text{Mpc}$ (comoving) at $z=0$

MS-parameters

$h^{-1}\text{Mpc}$ vs. $h^{-1}\text{Mpc}$
Work in progress... need to account for voids
Work in progress...

• Better turboGL: $f(M,z)$, survival and selection probabilities, ...

• Better model: effective $f(M,z)$, filaments, voids, ...

• More “channels”: local void, redshift effects, ...
THANKS