`Gevolution`: general simulations and void science

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What gevolution is and isn't

What it is and what it can do:

- particle-mesh N-body C++ code
- weak-field approximation scheme
- small in size (0.5 Mb without outputs) and relatively fast
- front/back end potential
- allows a lot of cosmological background customization
- linked to CLASS (and other IC generators)
- compatible with Gadget-2
- ray-tracing (new feature in 1.2)

Downsides:

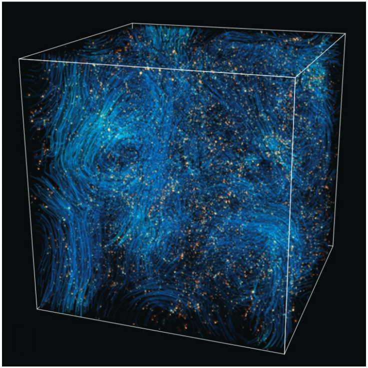
- only choice of background is flat FLRW
- currently not AMR
- lack of documentation (limited manual)
- only collisionless dust (no baryonic physics)
- limited compatibility
- weak-field approximation

Inputs and settings

- IC GENERATOR INPUT
  - power spectrum file (using CMB parameters)
  - transfer function file (CLASS format)
- IC GENERATOR
  - taken from CLASS
  - generated "on the fly"
  - read from disc (resuming a simulation)
  - an IC generator for ultra-relativistic particle species
- PARTICLE TEMPLATE (Gadget-2 format)
- SIMULATION BOX SETTINGS
  - box size
  - tiling factor
  - time step limit
  - time resolution (Courant factor)
  - initial redshift
  - ...

- PRIMORDIAL PERTURBATIONS PARAMETERS
  - spectral amplitude A_s
  - spectral index n_s
  - pivot scale k
- COSMOLOGICAL PARAMETERS
  - Ω's (baryonic, CDM, other particle species)
  - Hubble parameter (h)
- CHOICES OF GRAVITY THEORY
  - Newtonian
  - GR
- OUTPUT SETTINGS
  - power spectrum snapshots
  - particle snapshots
  - lightcone snapshots
  - redshifts of snapshots
- LIGHTCONE SETTINGS

Output



Frame dragging by vortical matter flows (perturbation B_i) on a simulation volume of (512 Mpc/h)^3; orange spots mark dark matter halos [Adamek et.al., Nature Phys. 12 (2016) 346–349]

- outputs (amount, quantities) depend on the simulation settings
- possible formats: HDF5 files, Gadget-2 particle files
- possible output data:
  - metric data ($h_{ij}, B_i, \phi, \chi = \phi - \psi$)
  - particle positions
  - lightcone(s) (`gevolution 1.2`)
  - total T^0_0 and T^i_j
  - total momentum density
  - velocity
  - Newtonian case: ρ and ψ
- output is in Poisson gauge
- for each quantity, a power spectrum can be saved as a snapshot

Theoretical basis

Poisson gauge

$$\mathrm{d}s^2 = a^2(\tau)\left[-(1+2\psi)\mathrm{d}\tau^2 - 2B_i\mathrm{d}x\mathrm{d}\tau + (1-2\phi)\delta_{ij}\mathrm{d}x^i\mathrm{d}x^j + h_{ij}\mathrm{d}x^i\mathrm{d}x^j\right]$$

gauge conditions: $\delta^{ij}B_{i,j} = \delta^{ij}h_{ij} = \delta^{jk}h_{ij,k} = 0$

Line of reasoning:

1. take initial data and calculate initial positions, velocities and other values in the simulation (on-the-fly IC generation)
2. calculate stress-energy tensor
3. calculate metric components
4. output files (if specified at that time step)
5. update particle positions
6. increment the time step
7. repeat steps 2-6 up to the final output redshift

details: Adamek et.al. (2016)

Numerical aspects

LATfield2

- developed for classical field theory [David Daverio et.al.]
- partial differential equations solver
- parallelisation
- handles FFT
- separates and connects fields and particles
- gevolution: keeping numerical aspects “behind the scenes”

Useful links

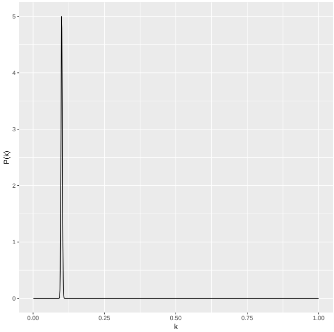
- official website
- main paper
- reference and documentation

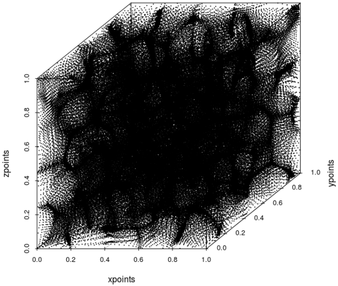
gevolution and void science

What can we learn by studying voids in gevolution?

- going past the linear regime (second order ϕ and ψ)
- Pisani, Massara, Spergel et.al.: large scale N-body simulations of cosmic voids can reduce degeneracies between cosmological models

Modelling voids:





Summary: workshop plans

QMUL contact

- `gevolution` **developers:** gevolution@unige.ch
- **Julian Adamek:** julian.adamek@qmul.ac.uk

Workshop plans

- installation of the code and necessary libraries
- linking CLASS
- running simple simulations
- visualization
- short introduction to C++ syntax
- using LATfield2 classes (for `gevolution` modification)
- implementation of equations in the code