Numerical Galaxy Formation and Cosmology

Lecture/Exercise 6 - 1st Example: A cosmological simulation with Gadget-2

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Performing a cosmological simulation with Gadget-2

- main steps for creating initial conditions:
  - compile initial condition code (e.g. N-GenIC)
  - set parameters for initial condition code
  - create initial condition files
- main steps for running the simulations:
  - compile simulation code (e.g. Gadget-2)
  - set parameters for the simulation code
  - run simulation
- read simulation output and perform analysis (in two *weeks*)

Creating initial conditions

- download N-GenIC (by Volker Springel):
  - ➡ `wget http://www.mpa-garching.mpg.de/gadget/n-genic.tar.gz`
  - ➡ `tar -xvf n-genic.tar.gz`
- compile N-GenIC:
  - requires MPI, FFTW and GSL libraries
  - ➡ `module load openmpi/intel/11.1/1.4.2`
  - ➡ `module load fftw/2.1.5_double`
  - ➡ `module load gsl/1.14`
  - ➡ `module load intel/11.1`

should work on IoA machines,
you can put this in your .profile file

  - edit Makefile: `SYSTYPE="OpenSuse"` and `MPICHLIB = -lmpi`
  - compile with `make`

Creating initial conditions

- parameters for N-GenIC, change e.g.:

```
Nmesh             32        % This is the size of the FFT grid used to
Nsample           32        % sets the maximum k that the code uses,

TileFac           2         % Number of times the glass file is

Box               60.0      % Periodic box size of simulation [Mpc/h]
UnitLength_in_cm   3.085678e24   % defines length unit of output (in cm/h), for Mpc/h

Redshift          99.0      % Starting redshift
OmegaBaryon       0.045     % Baryon density        (at z=0)

Sigma8            0.83      % power spectrum normalization
WhichSpectrum     1         % "1" selects Eisenstein & Hu spectrum,

NumFilesWrittenInParallel 1  % limits the number of files that are
```

controls resolution used for initial displacements and velocities

controls particle number (for 16^3 “glass” file -> 32^2 particles)

set box size and length units

set matter power spectrum

Creating initial conditions

- running N-GenIC:
  - ➡ `mpiexec -np 2 ./N-GenIC ics.param` to run in parallel on two cores, or
  - ➡ `./N-GenIC ics.param` to run as a serial code
- this creates the ICs file(s) in the output directory

Setting up the simulation

- download Gadget-2 (by Volker Springel):
  - ➡ `wget http://www.mpa-garching.mpg.de/gadget/gadget-2.0.7.tar.gz`
  - ➡ `tar -xvf gadget-2.0.7.tar.gz`

Setting up the simulation

- compile Gadget-2:
  - edit Makefile, e.g:

```
< OPT   +=  -DUNEQUALSOFTENINGS
> #OPT   +=  -DUNEQUALSOFTENINGS

< OPT   +=  -DPMGRID=128
> OPT   +=  -DPMGRID=64

< #OPT   +=  -DDOUBLEPRECISION
< #OPT   +=  -DDOUBLEPRECISION_FFTW
> OPT   +=  -DDOUBLEPRECISION
> OPT   +=  -DDOUBLEPRECISION_FFTW

< OPT   +=  -DHAVE_HDF5
> #OPT   +=  -DHAVE_HDF5

< MPICHLIB =  -lmpich
> MPICHLIB =  -lmpi

< SYSTYPE="MPA"
> #SYSTYPE="MPA"
```

  - compile with `make`

described in the Gadget2 user guide

same softening for all particles

size of PM grid (for real applications should not be smaller than 256)

e.g. for computing with 64 bit floats and when linking to double precision FFTW

when not using HDF5 outputs

when using OpenMPI

turn off specific options for MPA machines

Setting up the simulation

- setting the parameters for the simulation:
  - create a parameter file (changes compared to lcdm_gas.param):

```
InitCondFile        ../../N-GenIC/ICs/ics
OutputDir           ../sim/
SnapshotFileBase    snap
OutputListFilename parameterfiles/outputs.txt

SnapFormat              2

TimeBegin           0.01    % z=99, Begin of the simulation
OmegaBaryon         0.045
BoxSize            60.0

CpuTimeBetRestartFile     14400.0   ; here in seconds
MaxSizeTimestep               0.01
UnitLength_in_cm              3.085678e24   ; 1.0 Mpc/h

SofteningGas              0.05
SofteningHalo             0.05
SofteningGasMaxPhys       0.05
SofteningHaloMaxPhys      0.05
```

set input and output file paths

set format of snapshot files

should match values used in N-GenIC

gravitational softening
here: 50 comoving kpc/h (~2.7% of mean inter particle distance)

  - create a file with the desired output scale factors (filename as chosen in parameter file)

Running the simulation

- running Gadget-2:

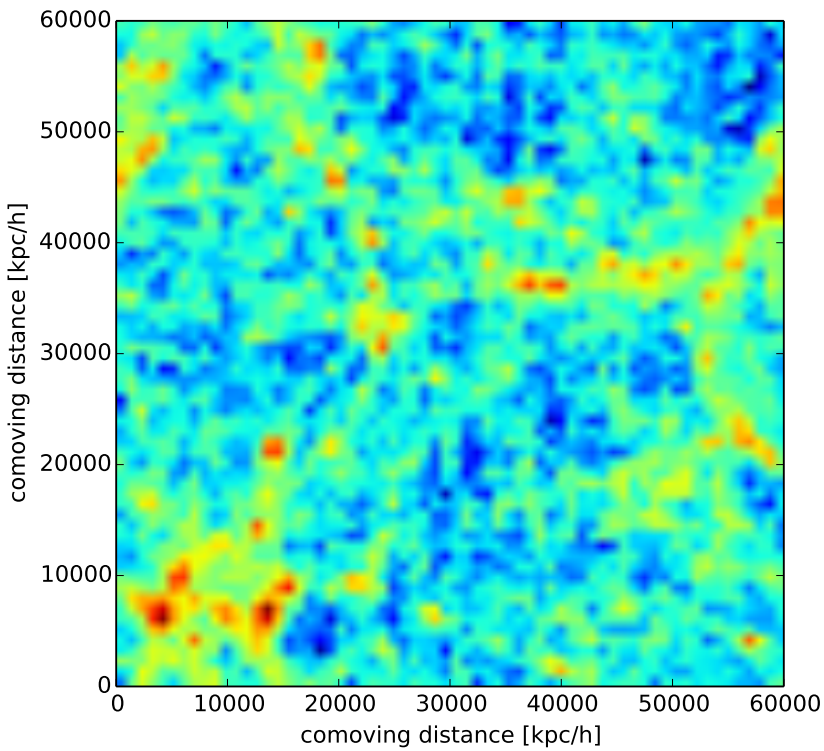
  ➡ `mpiexec -np 2 ./Gadget2  parameterfiles/param.txt` uses 2 cores

- or usually using a job script which is submitted to the scheduler (e.g. for Darwin)

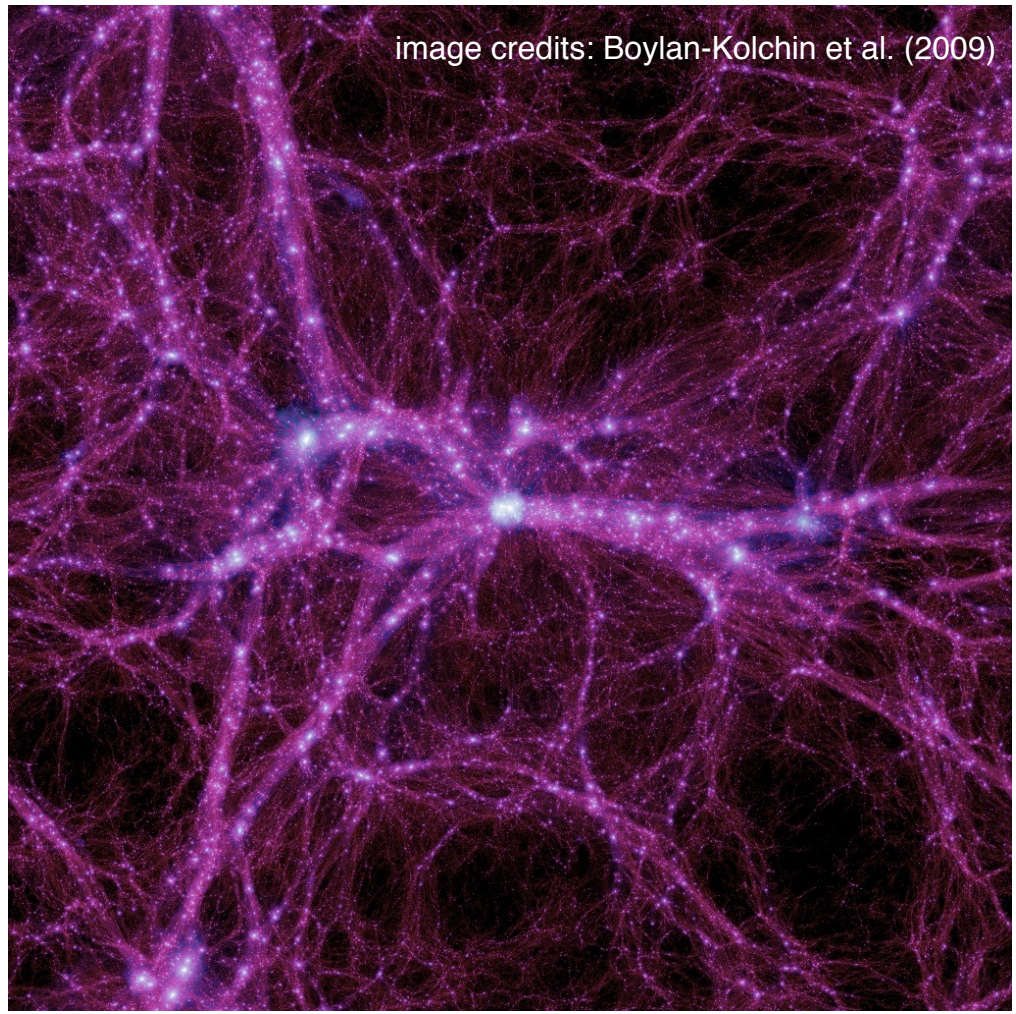
```
#!/bin/bash
#SBATCH -J large
#SBATCH -A DIRAC-DP044
#SBATCH -p sandybridge
#SBATCH --nodes=32
#SBATCH --ntasks=512
#SBATCH --time=36:00:00
#SBATCH --mail-type=ALL
#SBATCH --no-requeue

numnodes=$SLURM_JOB_NUM_NODES
numtasks=$SLURM_NTASKS
mpi_tasks_per_node=$(echo "$SLURM_TASKS_PER_NODE" | sed -e  's/^\([0-9][0-9]*\).*$/\1/')
np=$[${numnodes}*${mpi_tasks_per_node}]
workdir="$SLURM_SUBMIT_DIR"

# … usually some more stuff here

cd $workdir
mpiexec -np $np ./Gadget2 parameterfiles/param.txt
```

submit job with: sbatch job.sh

Results - matter density field



our example: 32^3 particles,
~4 core minutes



100 Mpc / h

Millennium II simulation: 2160^3 particles, 1.4 million core hours

Size of cosmological simulations over time

- computers double speed every 18 months (Moore's law)
- particle number in simulations doubles every 16-17 months
- only possible with algorithms that scale close to ~N (or N log(N))

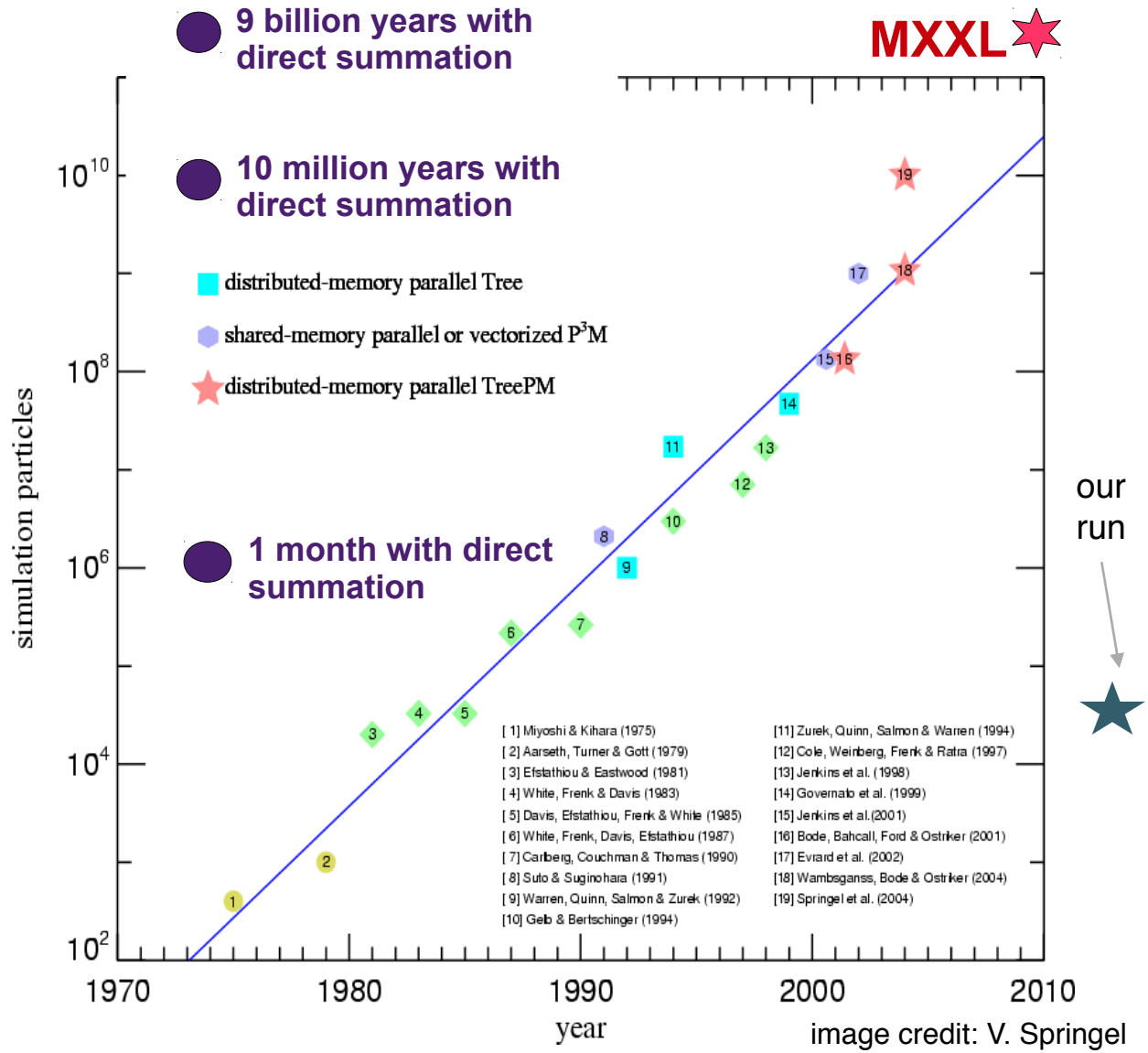


image credit: V. Springel

Literature & Outlook

- "The cosmological simulation code GADGET-2", V. Springel, 2005, MNRAS, 364, 1105, arXiv:astro-ph/0505010
- Gadget-2 user guide in "Documentation" sub-folder
- Next lecture:
  - ***Simulating a galaxy merger***
- In two weeks:
  - ***Analysing the simulation outputs of the cosmological box***
- ***Bonus exercise:***
  - ***Do a higher resolution run, e.g. 64^3 or 128^3***

    (Do not forget to increase Nmesh, Nsample, TileFac when creating ICs, as well as PMGRID when compiling Gadget2. The softening should be reduced accordingly.)