Massively Parallel Simulation of Abelian Higgs Model: LAH & LATfield2d

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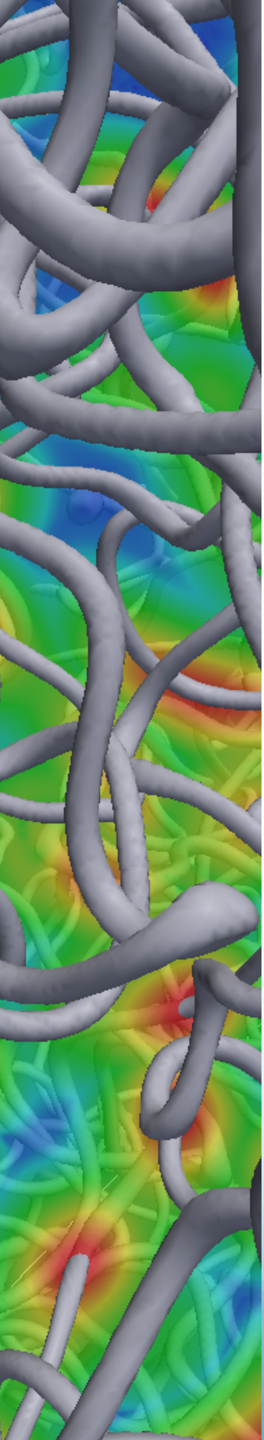


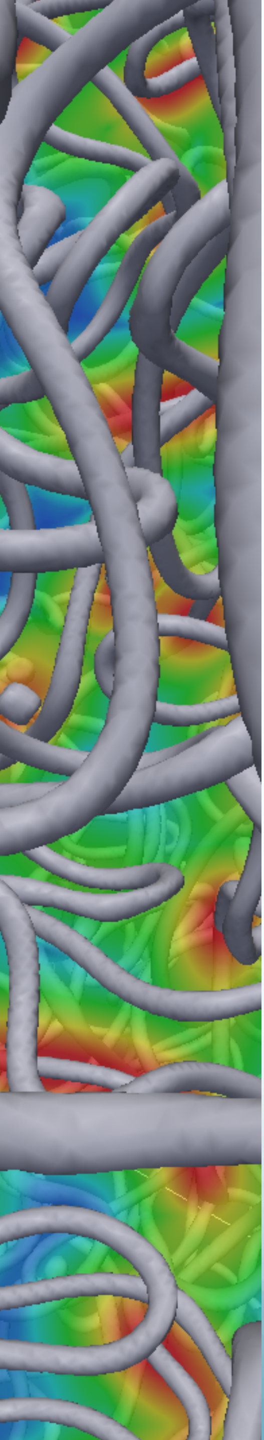
Abelian Higgs Model

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + (D_\mu)^*(D^\mu\phi) - \frac{\lambda}{4}(\phi^*\phi - \sigma^2)^2$$

Modified equation of motion in FRW (Press,Ryden,Spergel (1989)):

$$\ddot{\phi} + 2\frac{\dot{a}}{a}\dot{\phi} - \mathrm{D}_j\mathrm{D}_j\phi \;=\; -a^{2s}\frac{\lambda_0}{2}\left(|\phi|^2 - \sigma^2\right)\phi.$$

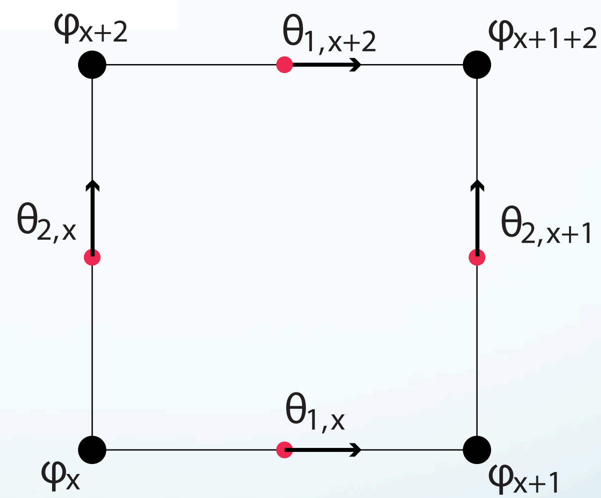
$$\dot{\mathcal{F}}_{0j} + 2(1-s)\frac{\dot{a}}{a}\mathcal{F}_{0j} - \partial_i\mathcal{F}_{ij} \;=\; -2a^{2s}e_0^2\,\mathcal{I}m\left[\phi^*\mathrm{D}_j\phi\right]$$



LAH
(Lattice Abelian Higgs)

$$A_j(x,t) \rightarrow \theta_{j,\mathbf{x}} = \int_{\mathbf{x}+j}^{\mathbf{x}} A_j(y,t)dy \simeq -e\Delta x A(\mathbf{x},t)$$

$$D_j\phi_{\mathbf{x}} = \frac{1}{\Delta x}(e^{-i\theta_{j,\mathbf{x}}}\phi_{\mathbf{x}+j} - \phi_{\mathbf{x}})$$



Time update using leapfrog algorithm
(to ensure energy conservation (discrete version))

LATfield2d

A C++ framework for parallel field simulations.

LATfield2d is a (extensive) rewrite of LATfield (Neil Bevis, Mark Hindmarsh). The parallelization and the I/O has been entirely modified. (www.latfield.org)

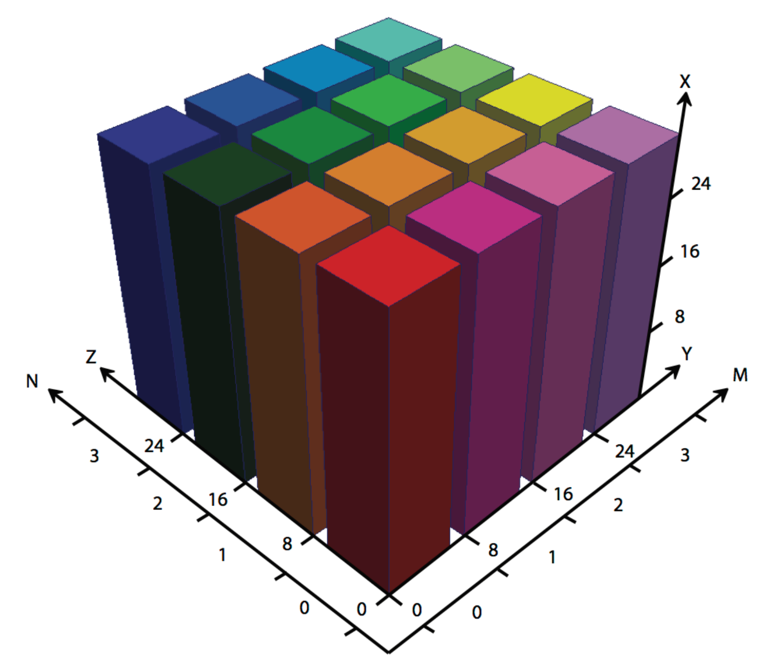
LATfield2d scatters n-dimensional lattices into a 2d grid of MPI processes (rod decomposition).

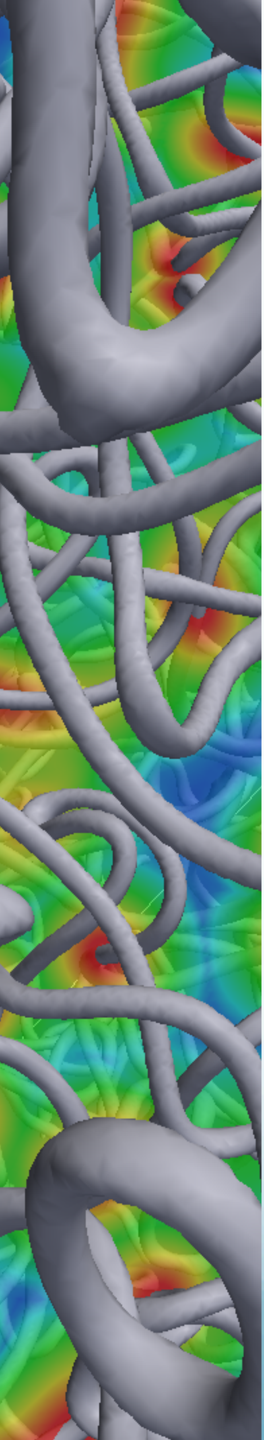
Lattice: “Cartesian static mesh”

Example:

3d lattice with 32 points in each dimension.

Scatter into 16 processes with the geometry 4x4





LATfield2d

A C++ framework for parallel field simulations.

Fast Fourier Transform

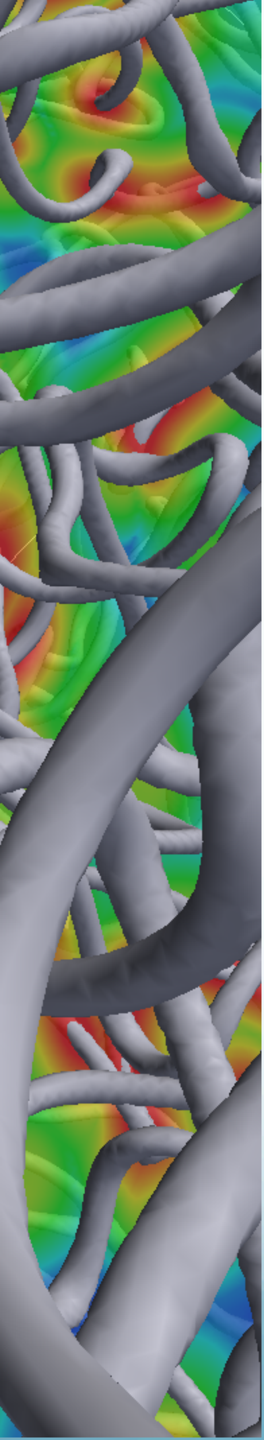
LATfield2d contains a FFT wrapper (based on FFTW) for 3d cubic lattices.
(Tested up to 4096^3 points with 32768 cores)

I/O

LATfield2d supports 3 I/O line (serial, parallel, **I/O server**).
Simple HDF5 wrapper (fields written with 1 command)

Benchmark on Piz Daint (Cray XC30, CSCS, Switzerland)
Maximal bandwidth (32768 compute cores, 2048 I/O cores, 80 stripes):

Parallel I/O (HDF5)	8.7 Gb/s
I/O server:	
Compute to I/O cores	2.6 Tb/s
I/O cores to disk	8.3 Gb/s



Simulation

- 2012-2013 (Monte Rosa) 4.8 Mio CPU hours
- 2013-2014 (Piz Daint & Monte Rosa) 28 Mio CPU hours

- 7 Matter and 7 Radiation runs at 4096^3 (s=0)
- Resolution tests
- 6 Matter and 6 Radiation Run with s=1 (plan 8 runs)
- Radiation-Matter transition runs

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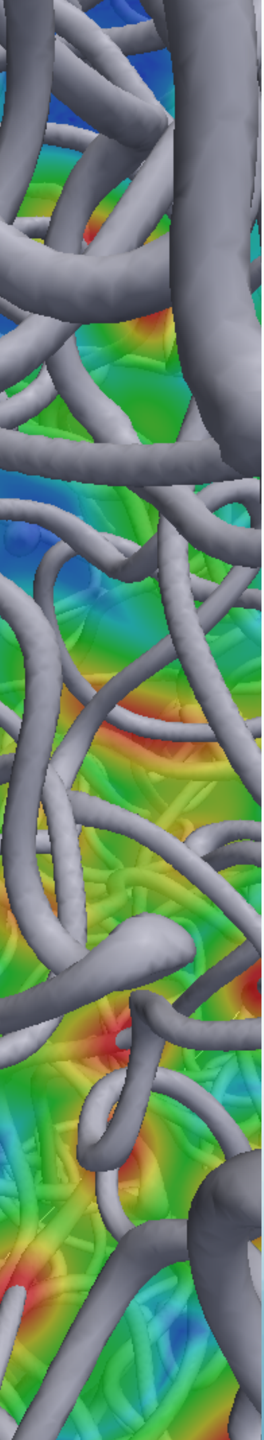
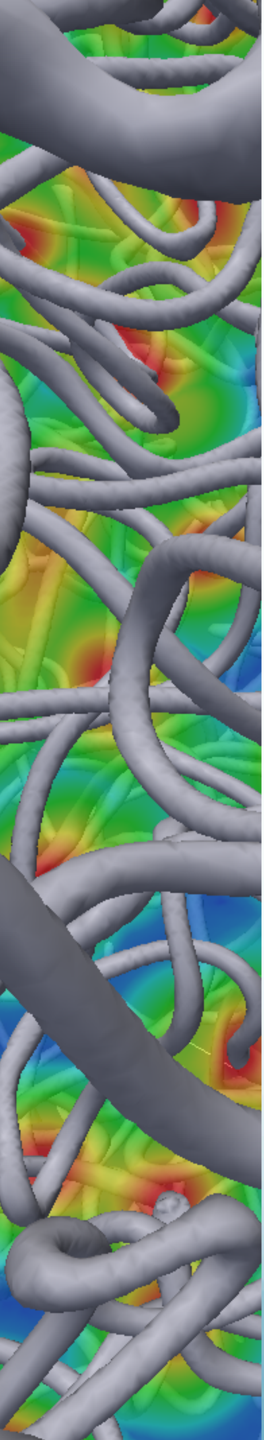


Simulation Numbers

Lattice size	4096^3
Number of float pro sites In memory	40
Memory usage	10 Tb
FFT (size)	2.5 Tb
FFT (number)	150
FFT (total)	0.375 Pb
Compute cores	32768
I/O cores	2048
1 run cost	~380k CPU hours (on XC30)

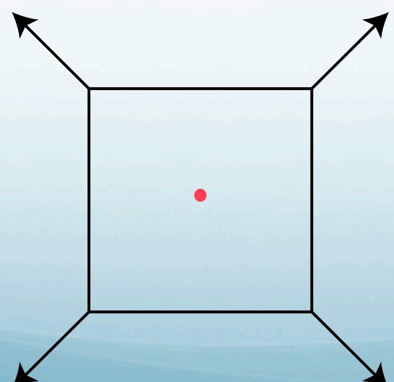


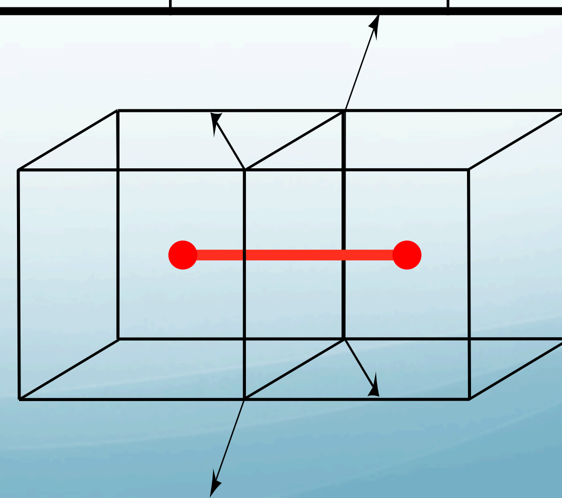
Simulation Outputs

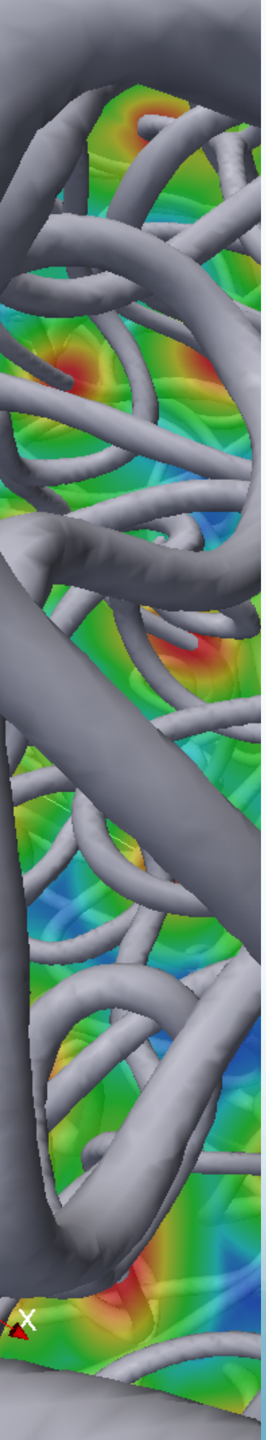
- Unequal time correlators (Jon's talk)
- Winding plaquettes: Decrease the amount of disk usage by a factor 10^5!

$$2\pi n/e = \oint A(x,t)dx$$

	Snapshot size	Total (1 run)
Energy Momentum Tensor (EMT)	2.5Tb	2.2 Pb
Windings with EMT	0.5 Gb (at tref)	25-50 Gb

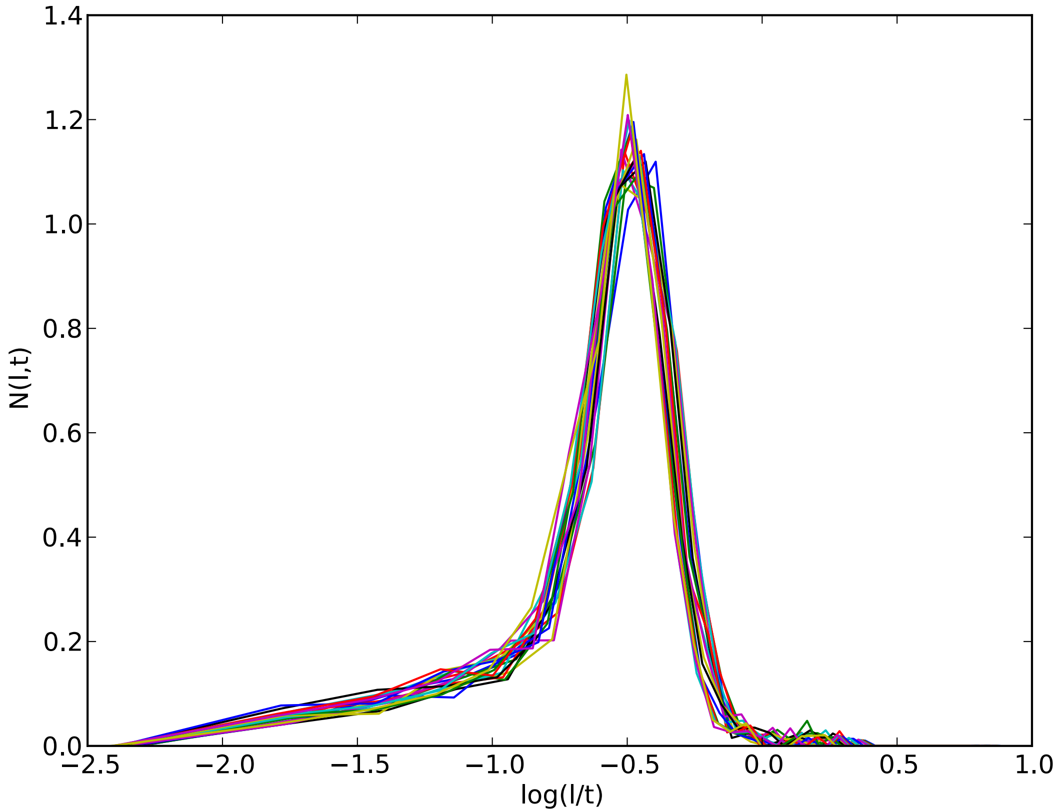






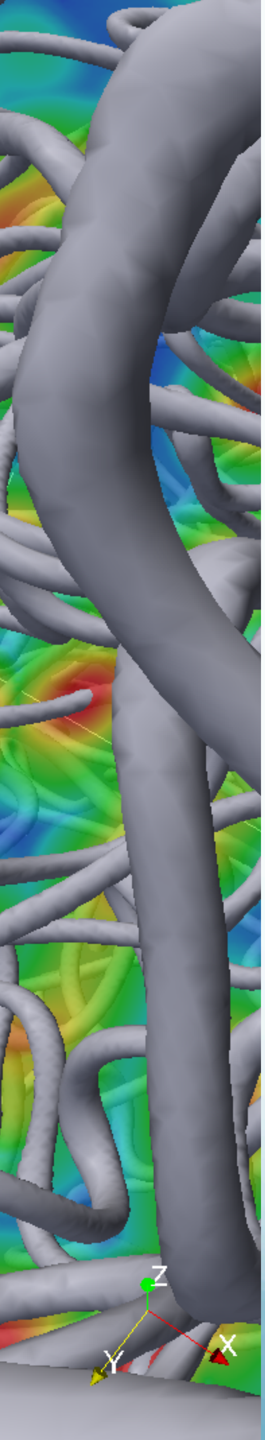
Loop distribution

(Very Preliminary)



$$N(l,t) = \frac{t^3}{l}\int_l^{2l} n(l',t)dl'$$

Commoving length, conformal time



Video