Efficient inference of interactions from non-equilibrium data and application to multi-electrode neural recordings

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Supervisor: Dr. Yasser Roudi[1],[2]

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NETADIS MID-TERM REVIEW
Institut Henri Poincaré, Paris

Kavli Institute for Systems Neuroscience
Centre for Neural Computation

Norwegian Centre of Excellence

THE KAVLI FOUNDATION

NETADIS
Statistical Physics Approaches to Networks Across Disciplines

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My background

July 2012 Master degree in theoretical physics (University of Trieste)

Master's Thesis: *"Criticality of models inferred in Boltzmann learning"*
Supervisor: Dr. Matteo Marsili

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My present

- **September 2012** start as NETADIS ESR at the Kavli Institute for Systems Neuroscience, Trondheim NORWAY
- **October 2012** enrolled as PhD Student in Neuroscience at NTNU, Trondheim NORWAY

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Training experiences

2012

October	Random Matrix Theory by PierPaolo Vivo	Kavli I., Trondheim
11/26-12/07	Winter School on Quantitative Systems Biology	ICTP, Trieste

2013

02/03-02/06	Netadis First Scientific Meeting	Torino
02/13-02/22	Spin glasses by Adriano Barra	NORDITA, Stockholm
03/07-03/15	Stochastic Thermodynamics (Workshop)	NORDITA, Stockholm
04/03-04/05	SMED8005 Communication of Science	Kavli I., Trondheim
05/20-06/14	Spring College on Physics of Complex Systems	ICTP, Trieste
08/09-08/19	Large Deviations by prof.Kamiar Rahnama Rad	Kavli I., Trondheim
09/08-09/22	Netadis Summer School 2013	Hillerod, Denmark
23/10-20/12	Secondment at TUB in prof.Opper group	Berlin

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My work so far

1. Path integral Methods:
   One-loop correction to the Laplace Approximation for systems out of equilibrium

   in collaboration with prof. K. Rahnama Rad (Columbia University, NY)

2. Gaussian Average Method for the kinetic Ising Model

3. Variational Factorizable Approximation for the kinetic Ising Model

   under the supervision of prof. M.Opper & Dr. Y.Roudi

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My work so far

1. Path integral Methods:
   One-loop correction to the Laplace Approximation for systems out of equilibrium
   - TAP: $m_i(t) = \tanh\left[\sum_j J_{ij} m_j(t-1) - m_i(t) \sum_j J_{ij}^2 \left(1 - m_j(t-1)^2\right)\right]$ (Plefka expansion)

   in collaboration with prof. K. Rahnama Rad (Columbia University, NY)

2. Gaussian Average Method for the kinetic Ising Model

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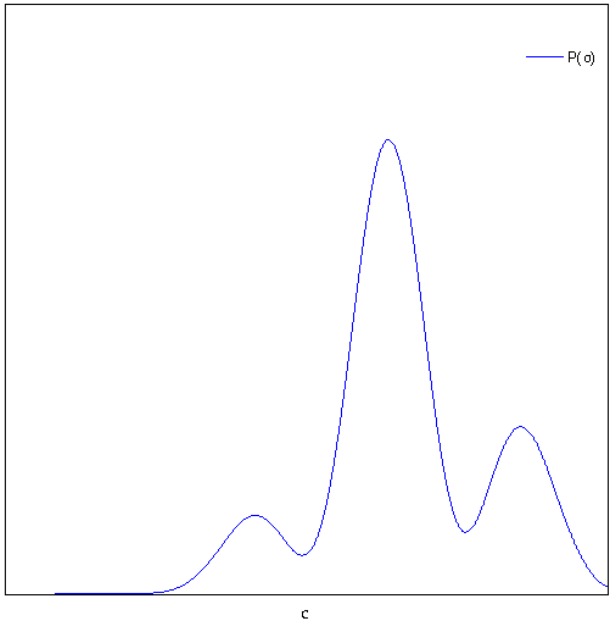
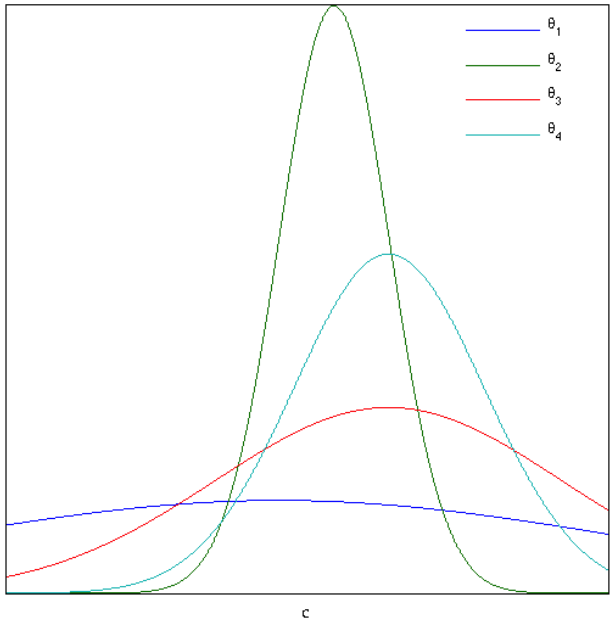
Variational approximation



model distribution $P(\sigma)$



ensamble $Q(\sigma, \theta)$

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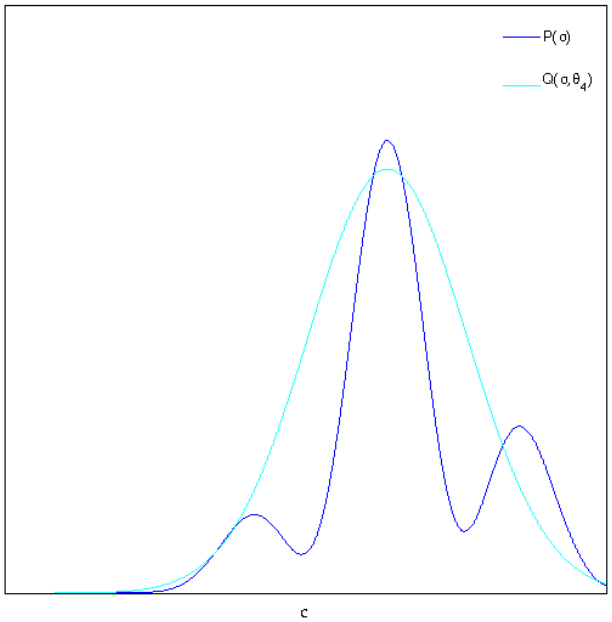
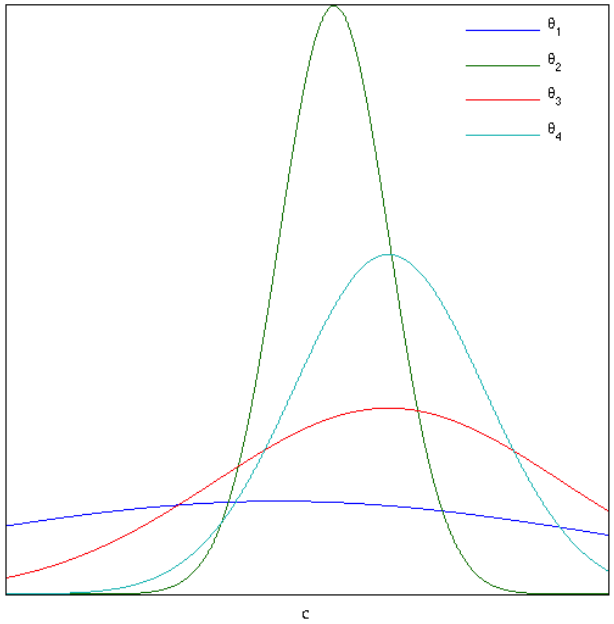
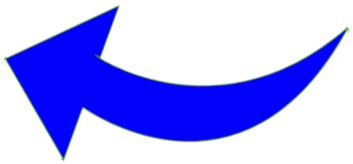
Variational approximation



optimal approximate distribution
$Q(\sigma, \theta^*)$ (TREATABLE!)



ensamble $Q(\sigma, \theta)$



KL-divergence minimization

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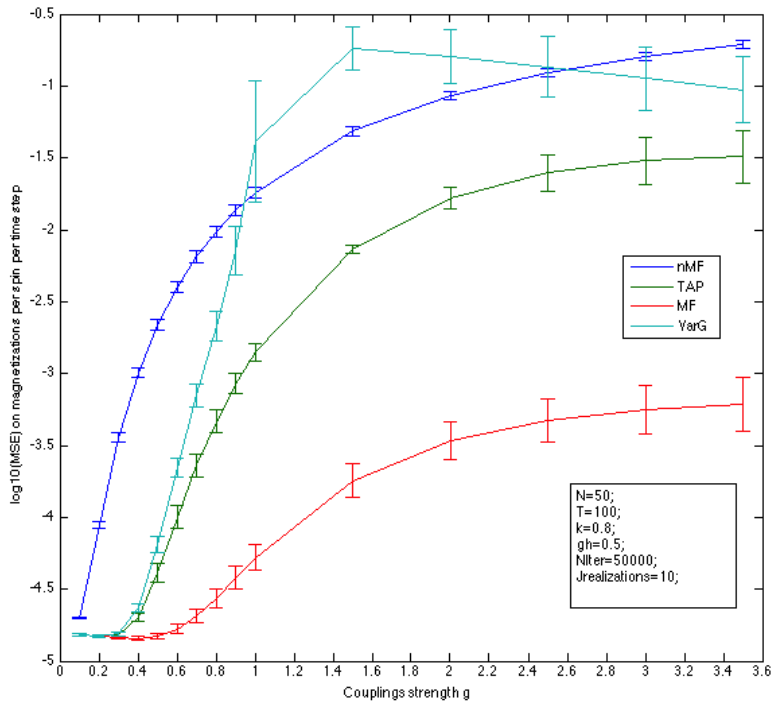
Gaussian Average Method for the kinetic Ising Model

- $m_i(t) = \int \frac{D\mathcal{X}}{(2\pi)^{NT}} \tanh\left[x_i(t-1) + \sum_j J_{ij} m_j(t-1)\right]$

$J_{ij} \perp J_{ji} \;\rightarrow\!\!\!\!\!\!\rightarrow$ Mezard's MF: $m_i(t) = \int Dx \tanh\left[\sum_j J_{ij} m_j(t-1) + x\sqrt{\Delta_i(t-1)}\right]$
where $\Delta_i(t) = \sum_j J_{ij}^2 \left(1 - m_j(t)^2\right)$

$g \ll 1 \;\rightarrow$ TAP: $m_i(t) = \tanh\left[\sum_j J_{ij} m_j(t-1) - m_i(t) \sum_j J_{ij}^2 \left(1 - m_j(t-1)^2\right)\right]$



$k = 0.8$

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Variational Factorizable Approximation for the kinetic Ising Model

Equilibrium Ising model

- Saddle-point Approximation ↘
- Variational Factorizable Approximation ↗

→ Naïve Mean Field Equations

Kinetic Ising model

- Saddle-point Approximation → $m_i(t) = \tanh\left[\sum_j J_{ij} m_j(t-1)\right]$ (nMF)
- Variational Factorizable Approximation →

$$m_i(t) = \tanh\left[\sum_k J_{ik} m_k(t-1) + \sum_k J_{ki} m_k(t+1) - \sum_{j\neq i}\left\langle \tanh^{-1}\left[\tanh\left[\sum_{k\neq i} J_{jk}\sigma_k(t)\right]\tanh\left[J_{ji}\right]\right]\right\rangle_Q\right]$$

where $Q(\sigma)$ is the factorizable distribution

Why poorer predictions? $D_f(\mathbf{m},\mathbf{H}) \geq D_{nMF}(\mathbf{m},\mathbf{H})$

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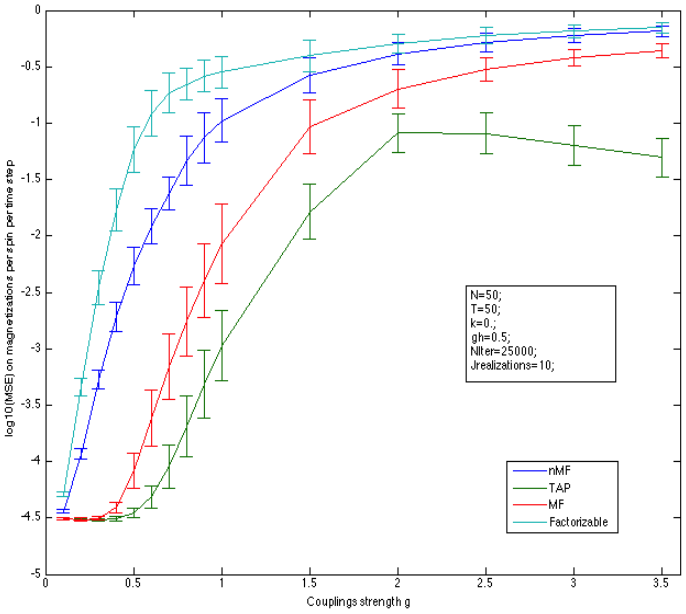
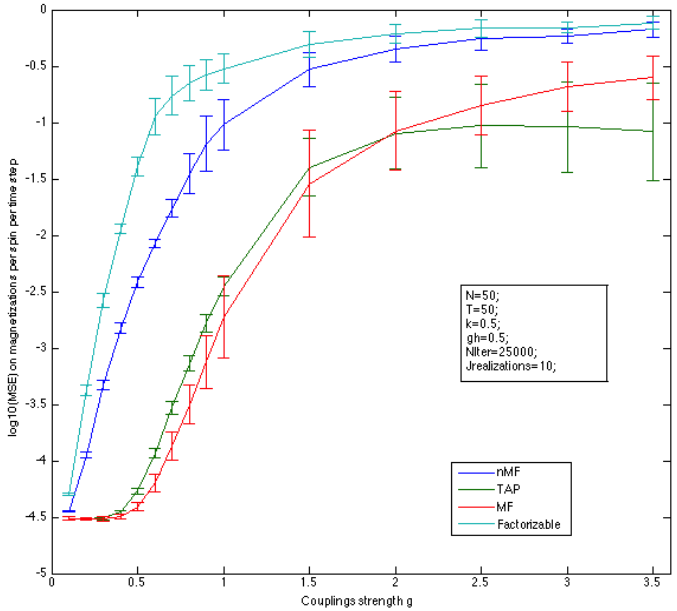
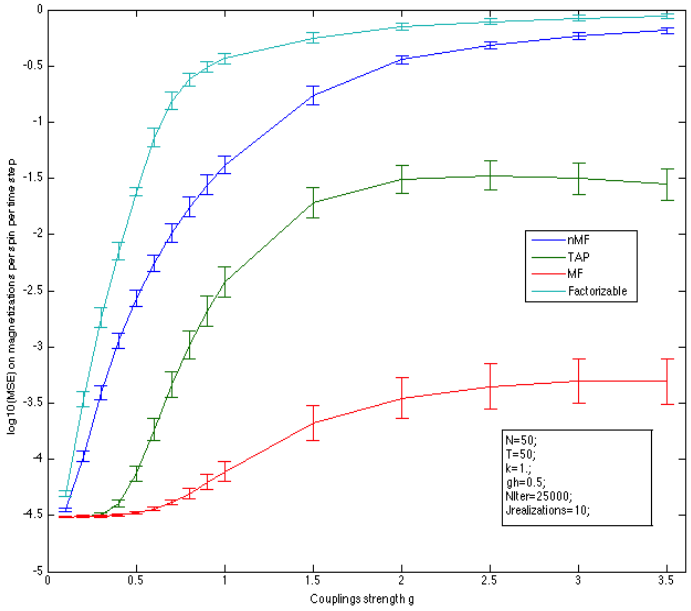
$k = 0$





$k = 0.5$



$k = 1$

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Future developments and expectations

February 2014

Dilute systems:
The Bethe Approximation for the kinetic Ising Model

supervised by prof.John Hertz (NORDITA,Copenhagen) & Dr. Y.Roudi

March 2014

Deep learning in networks with hidden nodes

in collaboration with Benjamin Dunn

Summer 2014

Learning the connectivity of the brain:
performances of the approximations developed so far

using data available at the Kavli Institute for Systems Neuroscience

dates to be decided

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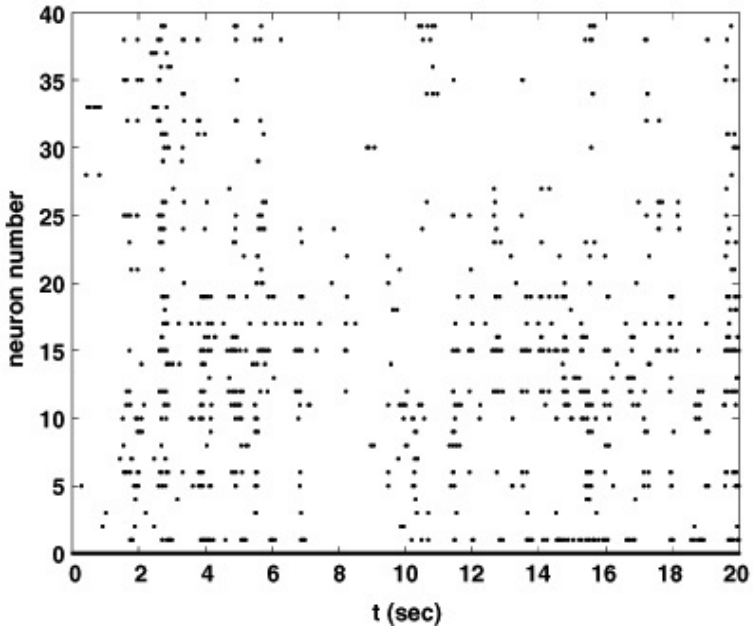

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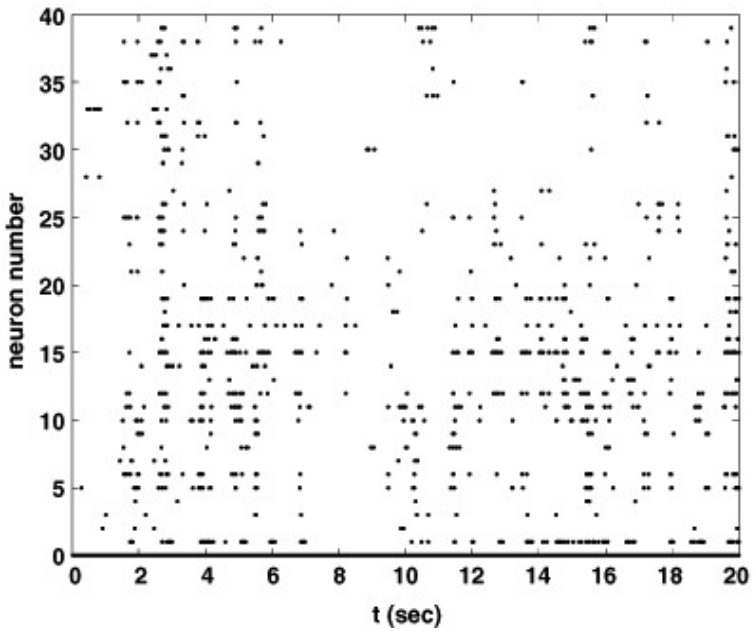

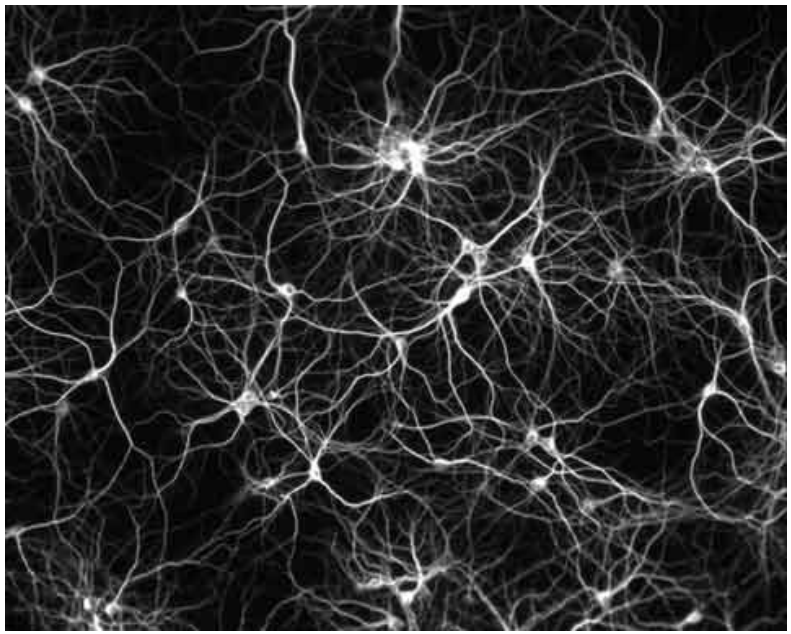

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Thanks!


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to
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