

Computational Studies of Condensed Matter and Complex Systems

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Contents & Acknowledgements

- **Response of HTSC Stripes to External EM Fields**

- Daniel SPRINGER, PhD student, PAP, SPMS, NTU
- Christos PANAGOPOULOS, Nanyang Assoc Prof, PAP, SPMS, NTU

- **Financial Time Series Segmentation**

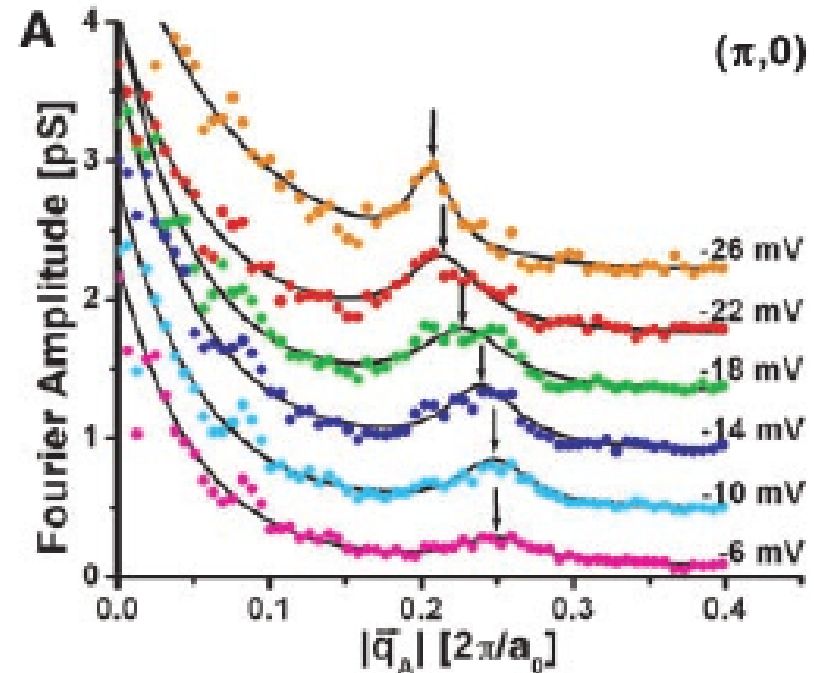
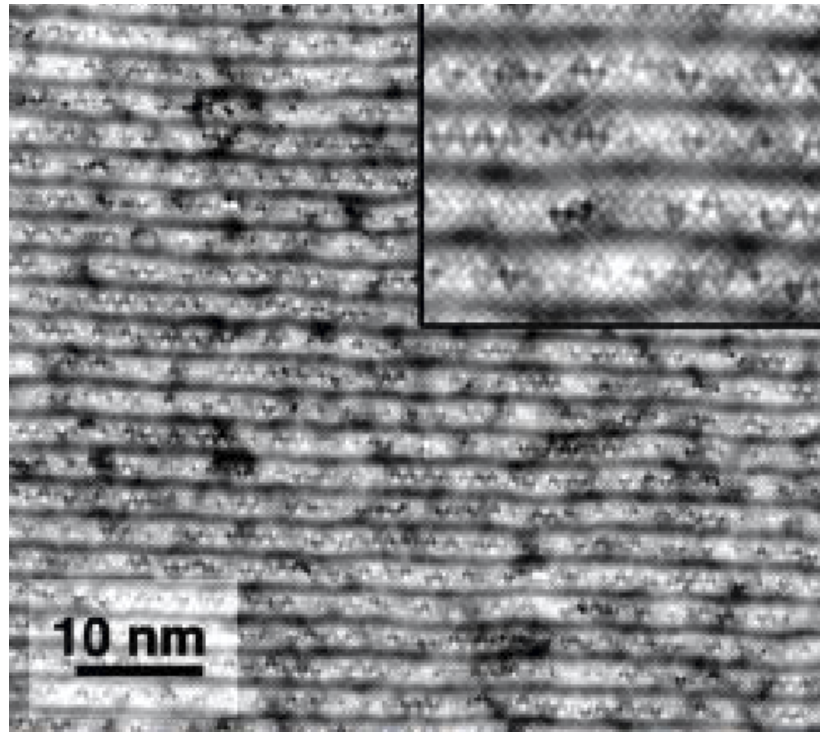
- Jian Cheng WONG, BSc, MAS, SPMS, NTU
- Gladys Hui Ting LEE, undergrad student, MAS, SPMS, NTU
- Yiting ZHANG, undergrad student, MAS, SPMS, NTU
- Heng LIAN, Asst Prof, MAS, SPMS, NTU

- **Financial Time Series Clustering**

- Yik Wen GOO, undergrad student, CN Yang scholar, MAE, NTU
- Tong Wei LIAN, undergrad student, CN Yang scholar, EEE, NTU
- Wei Guang ONG, undergrad student, CN Yang scholar, PAP, SPMS, NTU
- Weihan WANG, undergrad student, MAS, SPMS, NTU

STM Imaging of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$

- [J. E. Hoffman, K. McElroy, D.-H. Lee, K. M. Lang, H. Eisaki, S. Uchida, J. C. Davis, *Science* **297**, 1148–1151 (2002)]



- Dependence of dominant wave vector on STM bias interpreted in terms of quasi-particle interference.
- Incompatible with stripes?

Stripes in the Complex Ginzburg-Landau Equation

- Strong electric fields in vicinity of STM tip.
- “If stripes exist, how would they respond to such electric fields?”
- Microscopic approach via **Hubbard model** or ***t*-*J* model** infeasible.
- Macroscopic approach via the **complex Ginzburg-Landau equation**

$$\left(\partial_t + i\frac{e_s}{\hbar}\Phi\right)\psi = \psi - (1 + i\alpha)|\psi|^2\psi + (1 + i\beta)\left|\left(\nabla - i\frac{e_s}{\hbar}\mathbf{A}\right)\right|^2\psi$$

with **minimal coupling** to EM fields. [See I. S. Aranson and L. Kramer, *Rev. Mod. Phys.* **74**, 99–143 (2002)]

- **complex order parameter ψ**
- scalar potential Φ
- vector potential \mathbf{A}
- **doping-dependent parameters α, β**
- **stable stripe solution** for zero fields

Solving the Complex Ginzburg-Landau Equation

- **Numerical methods**

- Uniform and static **E**

- * pseudo-spectral method with exponential integrators
 - * finite difference method with Adam-Bashforth integrators

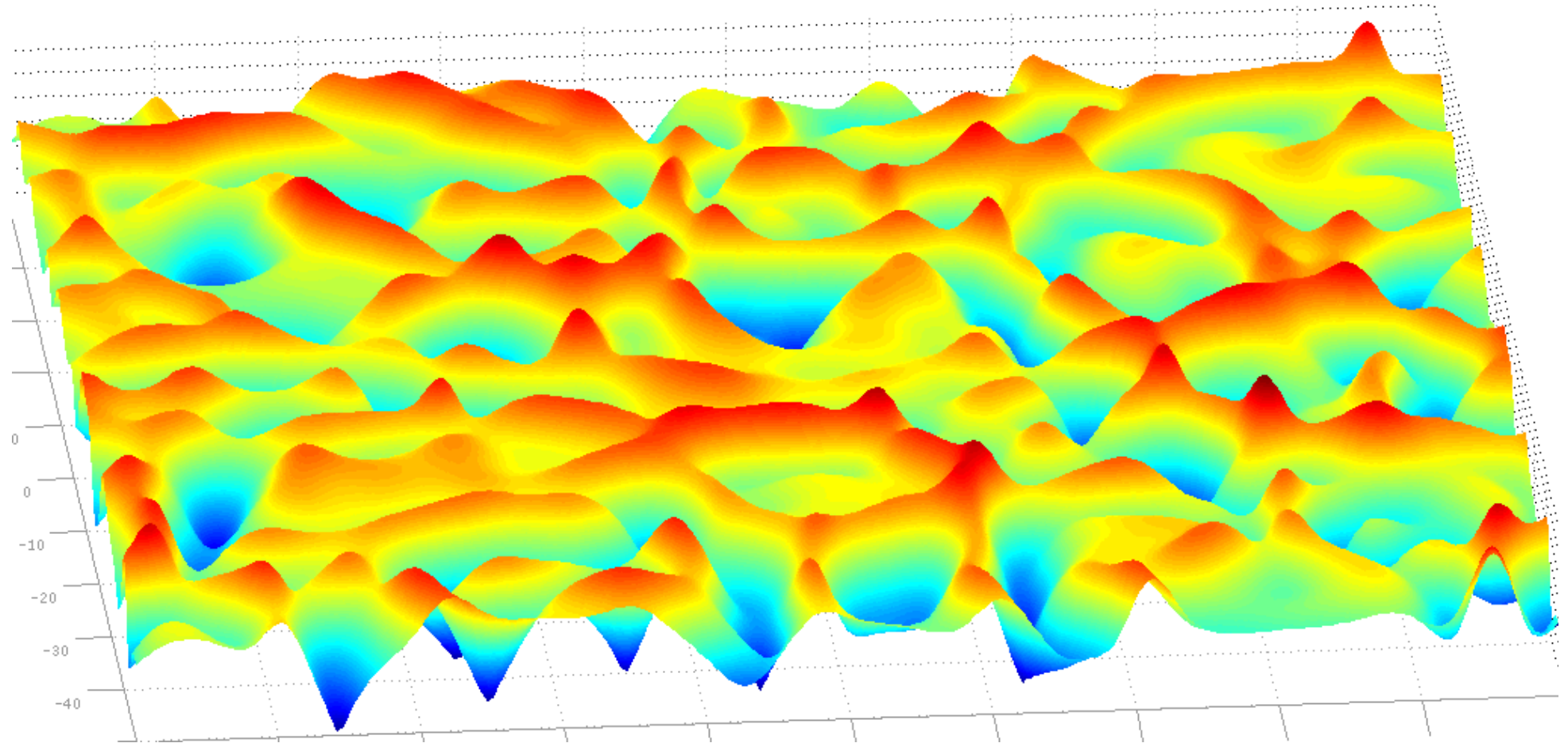
- Uniform and static **B**

- * finite difference method with Adam-Bashforth integrators
 - * work in progress

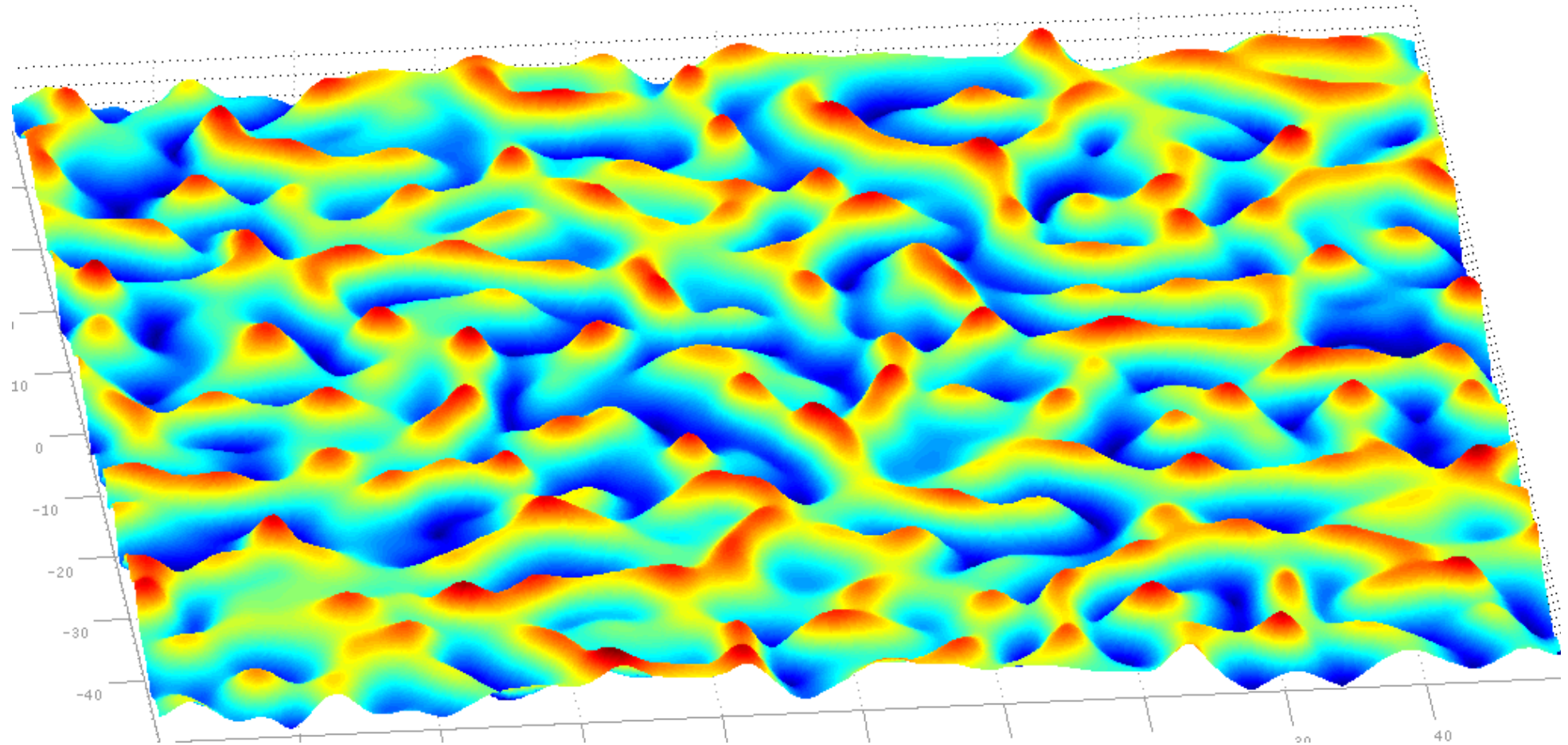
- **Semi-analytical methods**

- Will try **synergetics approach** soon (Daniel too busy!)

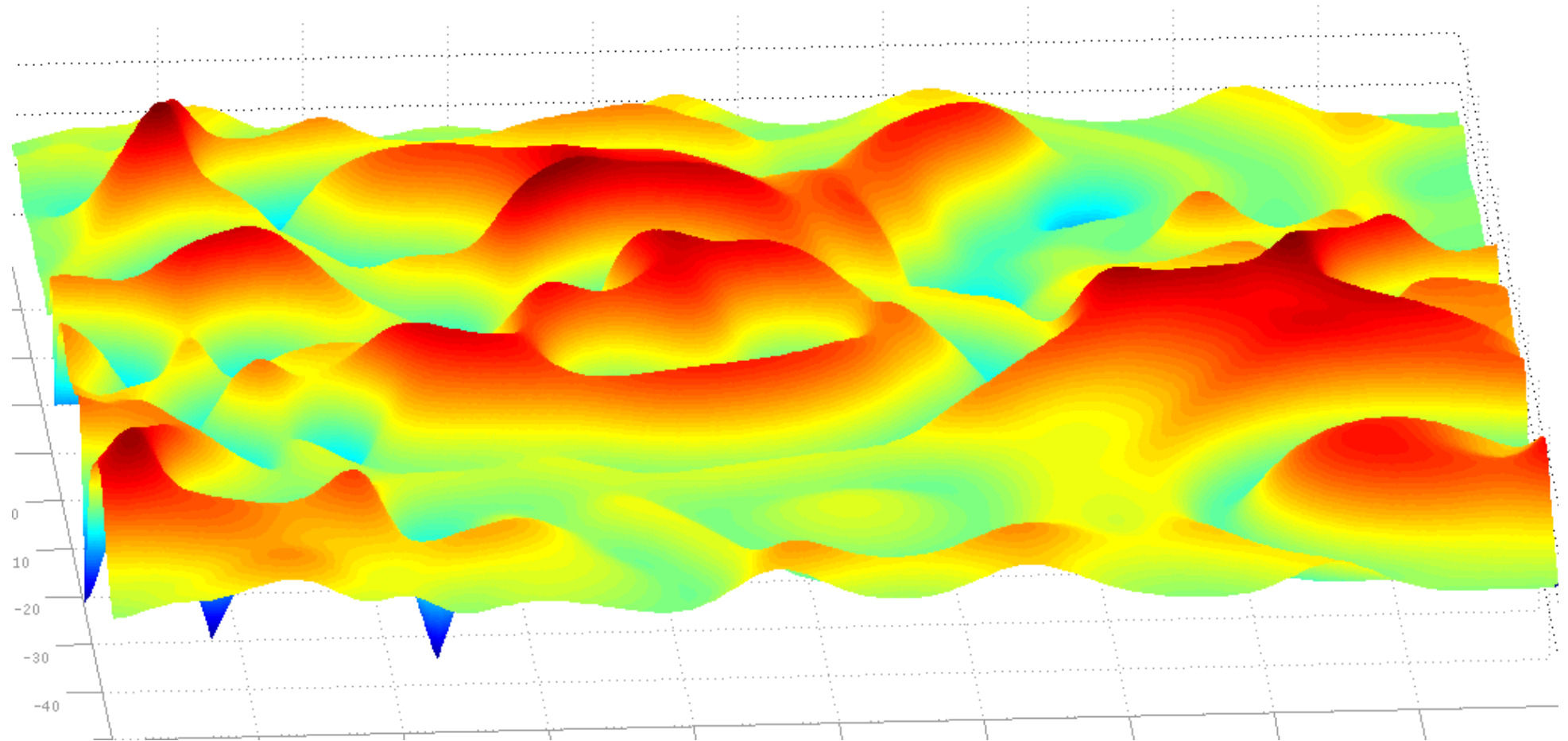
Without Electric Field



Positive Electric Field



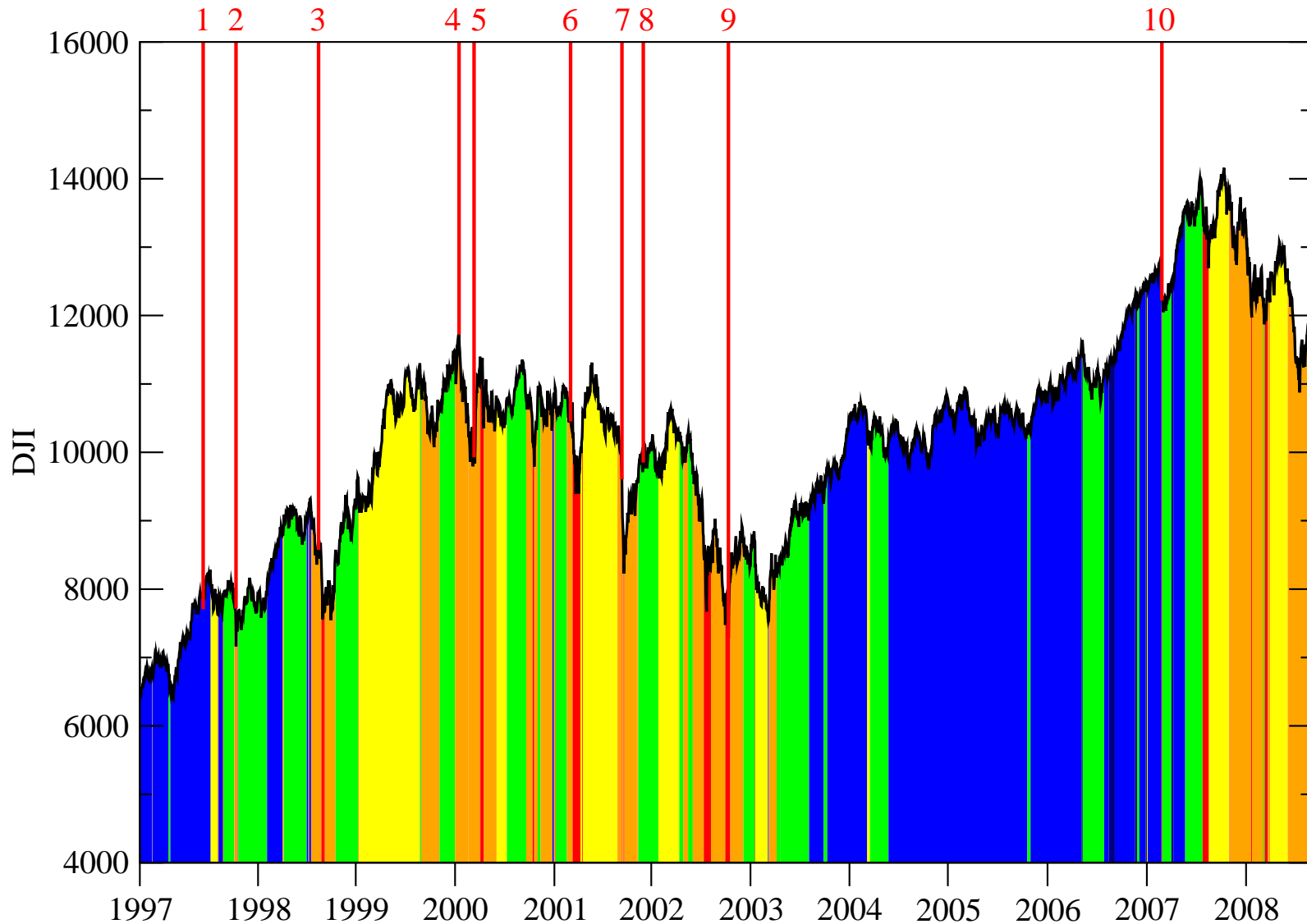
Negative Electric Field



Macroeconomic Phases and Financial Time Series

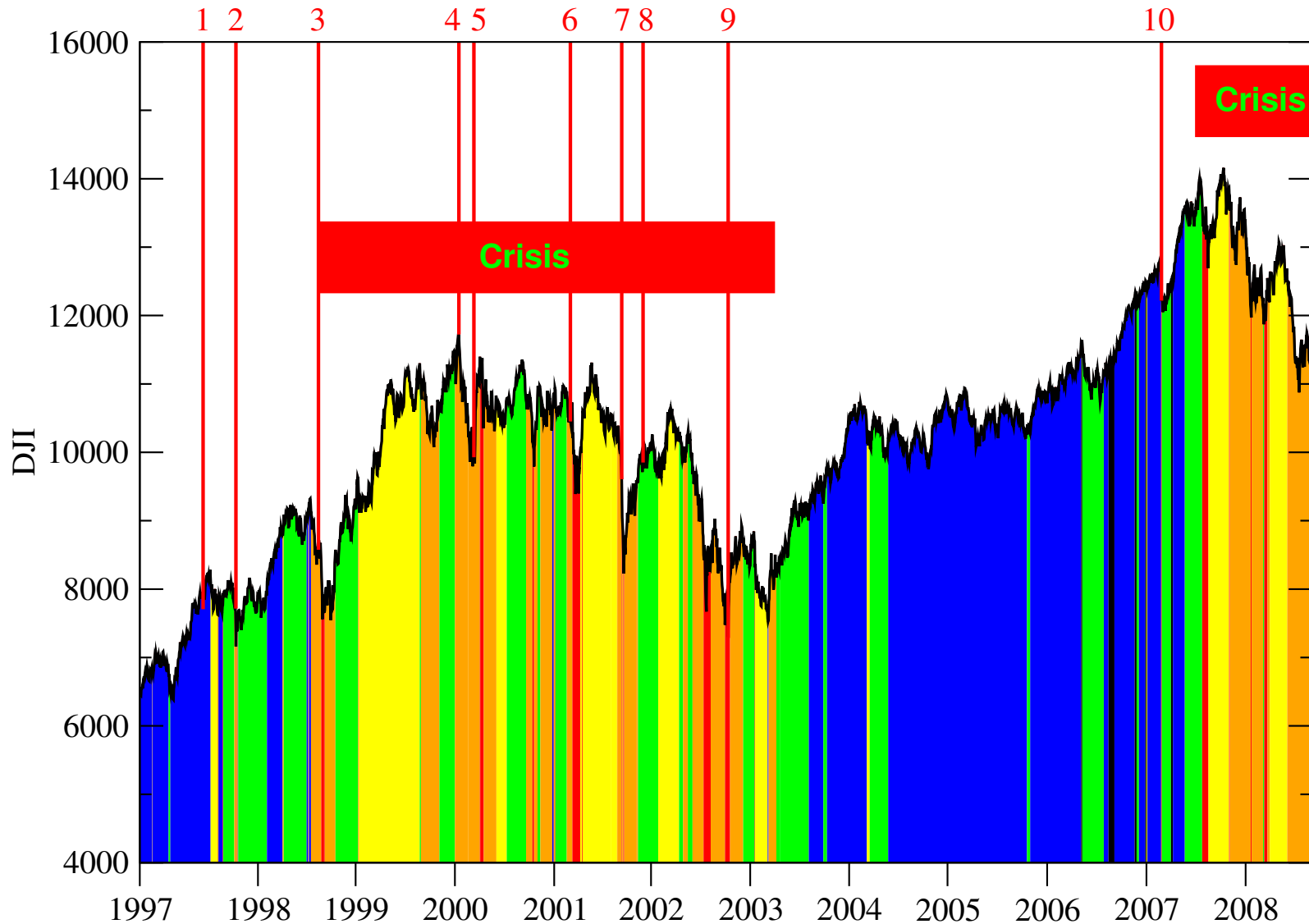
- Economies and financial markets are **complex systems**.
- **Self-organization** into small number of **macroeconomic phases**.
 - Different **statistical signatures** for different macroeconomic phases
 - **Transitions** between phases naturally lead to **segments** in financial time series
- **Recursive entropic segmentation** [Bernaola-Galván *et al*, *Phys. Rev. E* **53**, 5181 (1996); Román-Roldán *et al*, *Phys. Rev. Lett.* **80**, 1344 (1998)]
 - **Jensen-Shannon divergence** [J. Lin, *IEEE Trans. Infor. Theory* **37** 145–151 (1991)]
 - Number of statistically stationary segments
 - Positions of segment boundaries
- **Agglomerative hierarchical clustering**
 - Complete link algorithm
 - Number of macroeconomic phases

Dow Jones Industrial Average (Jan 1997–Aug 2008)



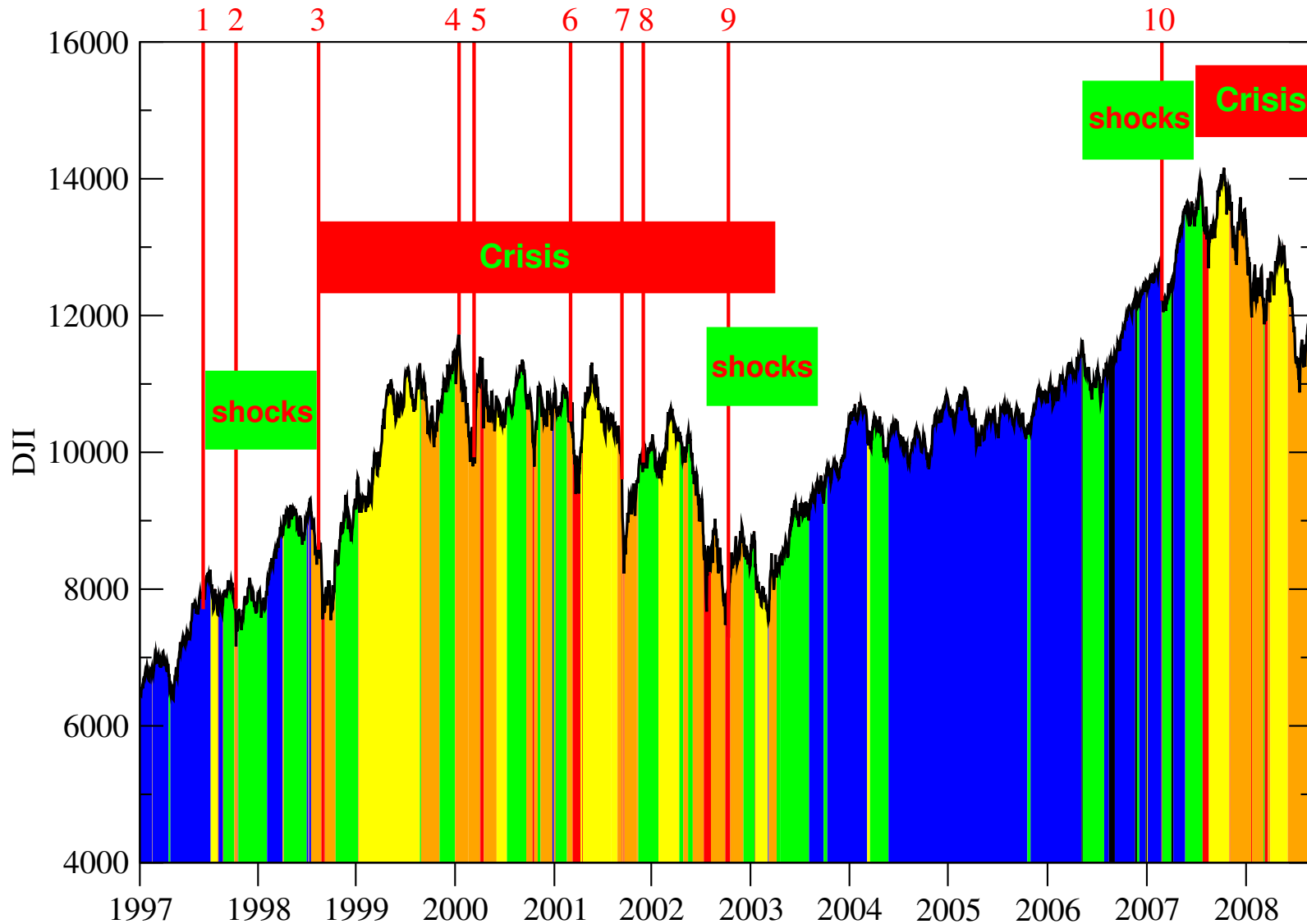
[J. C. Wong, H. Lian, and S. A. Cheong, *Physica A* **388**, 4635-4645 (2009).]

Dow Jones Industrial Average (Jan 1997–Aug 2008)



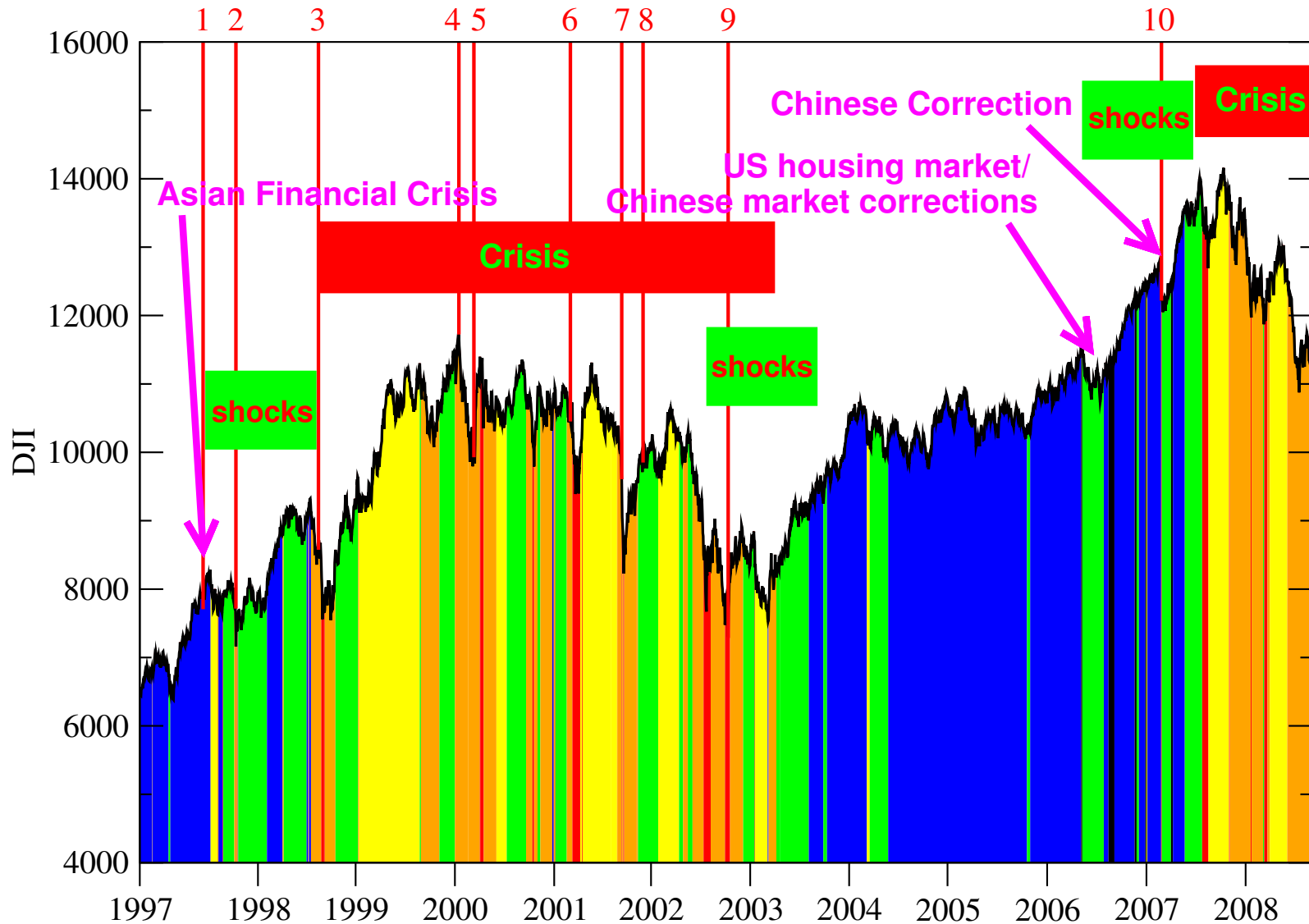
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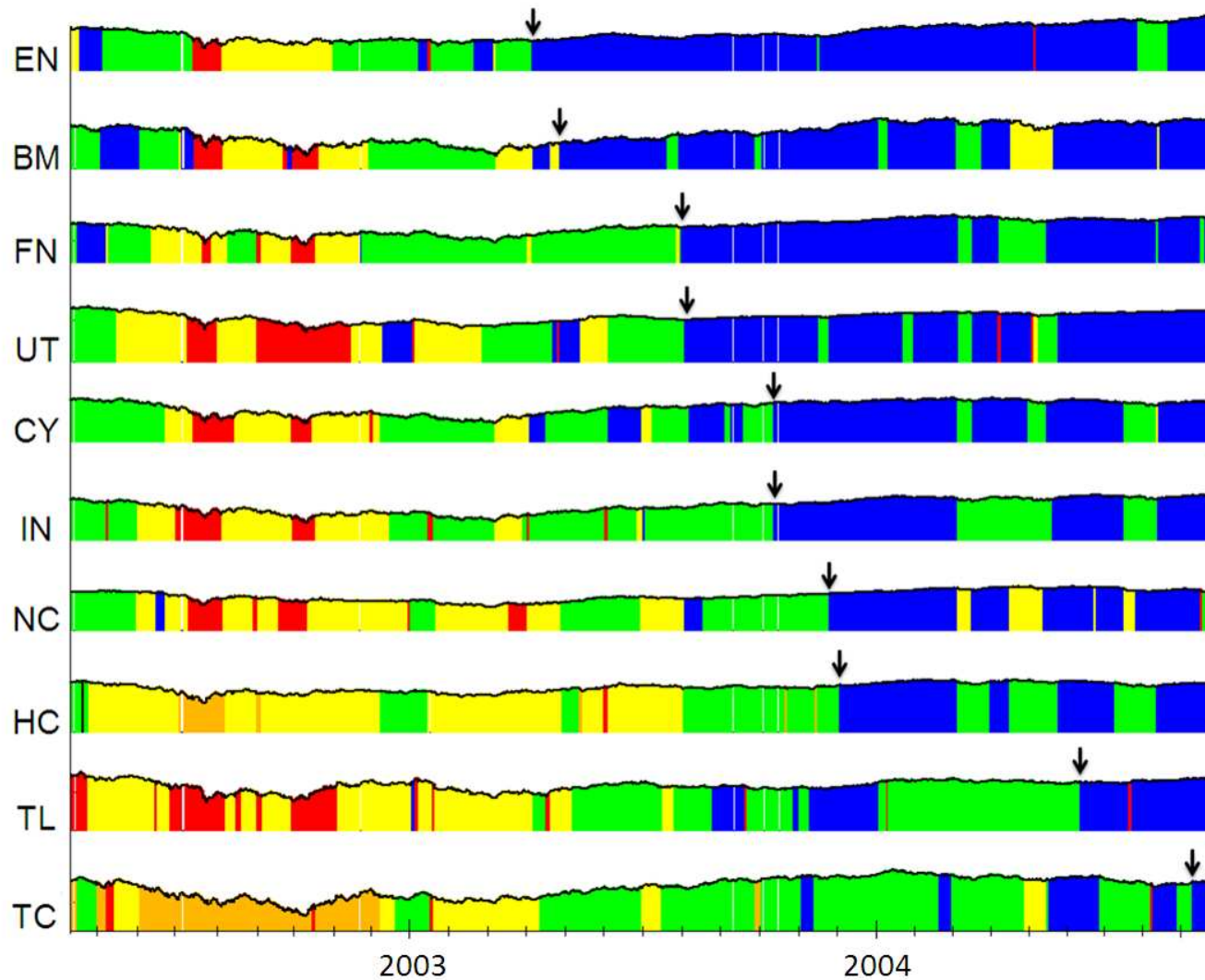
[J. C. Wong, H. Lian, and S. A. Cheong, *Physica A* **388**, 4635-4645 (2009).]

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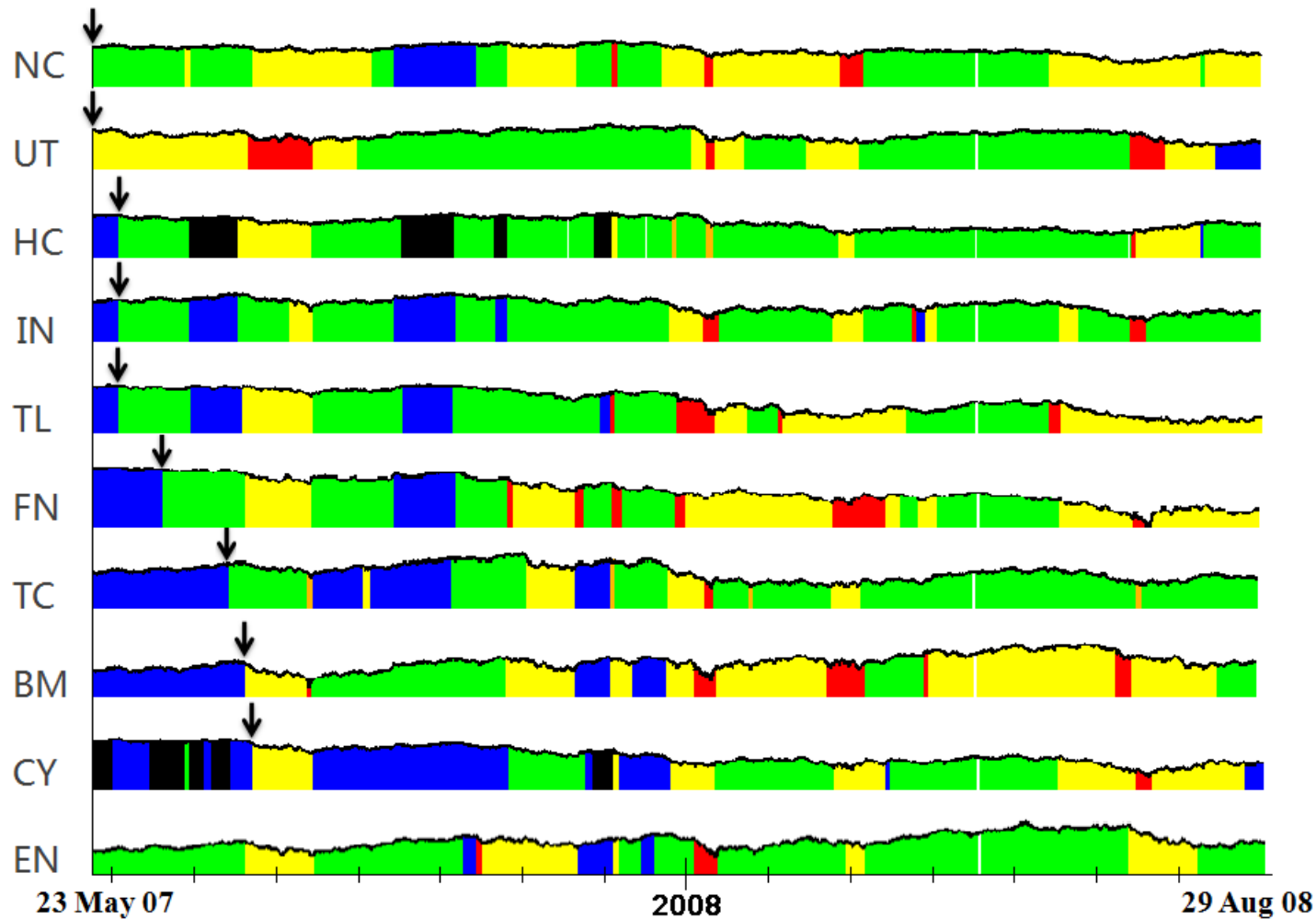
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DJ US Economic Sector Indices (Feb 2000–Aug 2008)



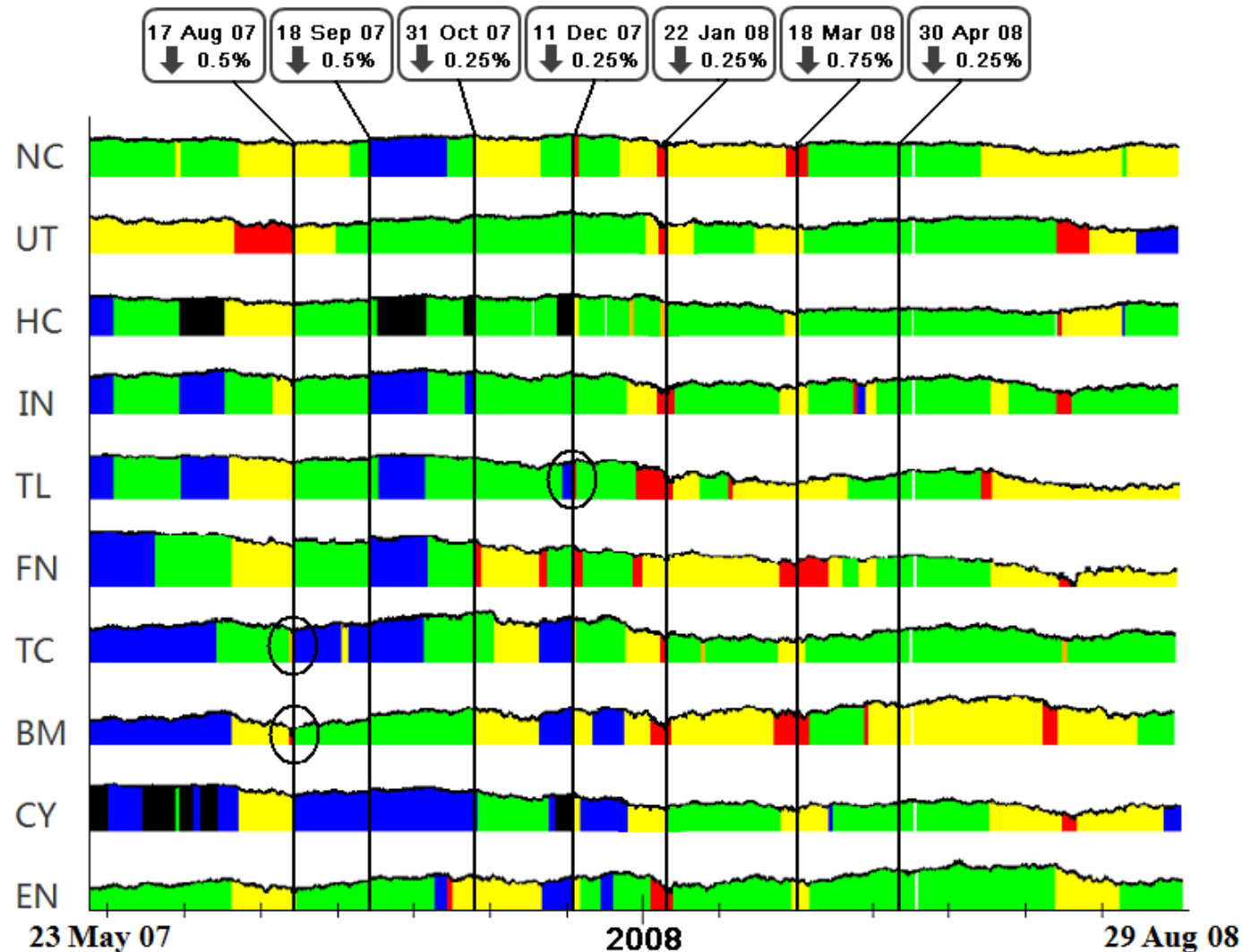
[G. H. T. Lee, Y. Zhang, J. C. Wong, M. Prusty, and S. A. Cheong, q-fin/0911.4763.]

DJ US Economic Sector Indices (Feb 2000–Aug 2008)



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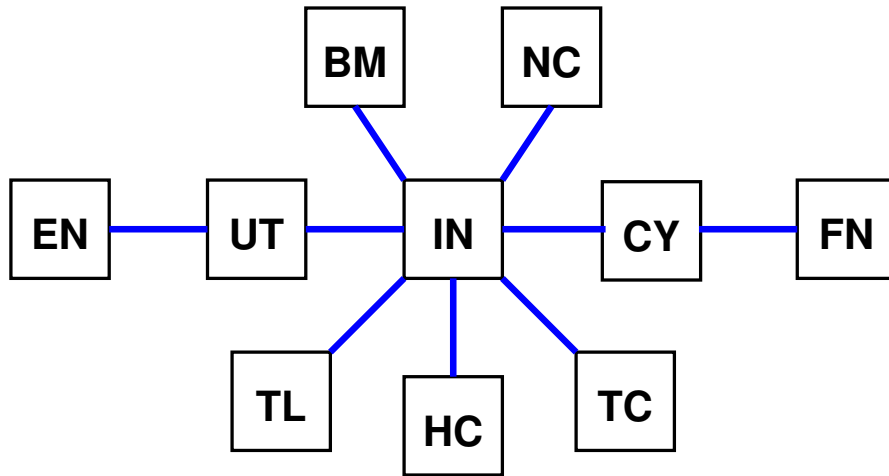
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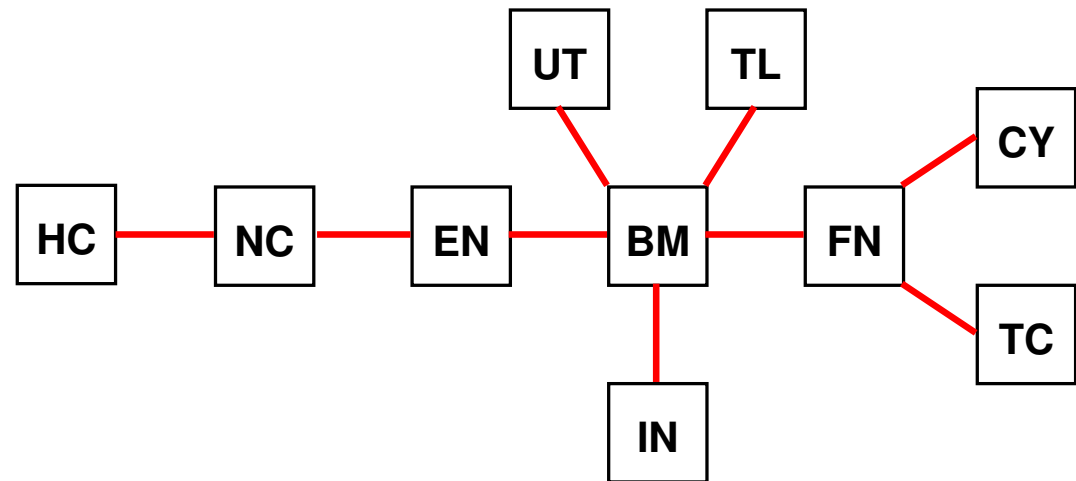
DJ US Economic Sector Indices (Feb 2000–Aug 2008)

Growth



Star-Like MST

Crisis



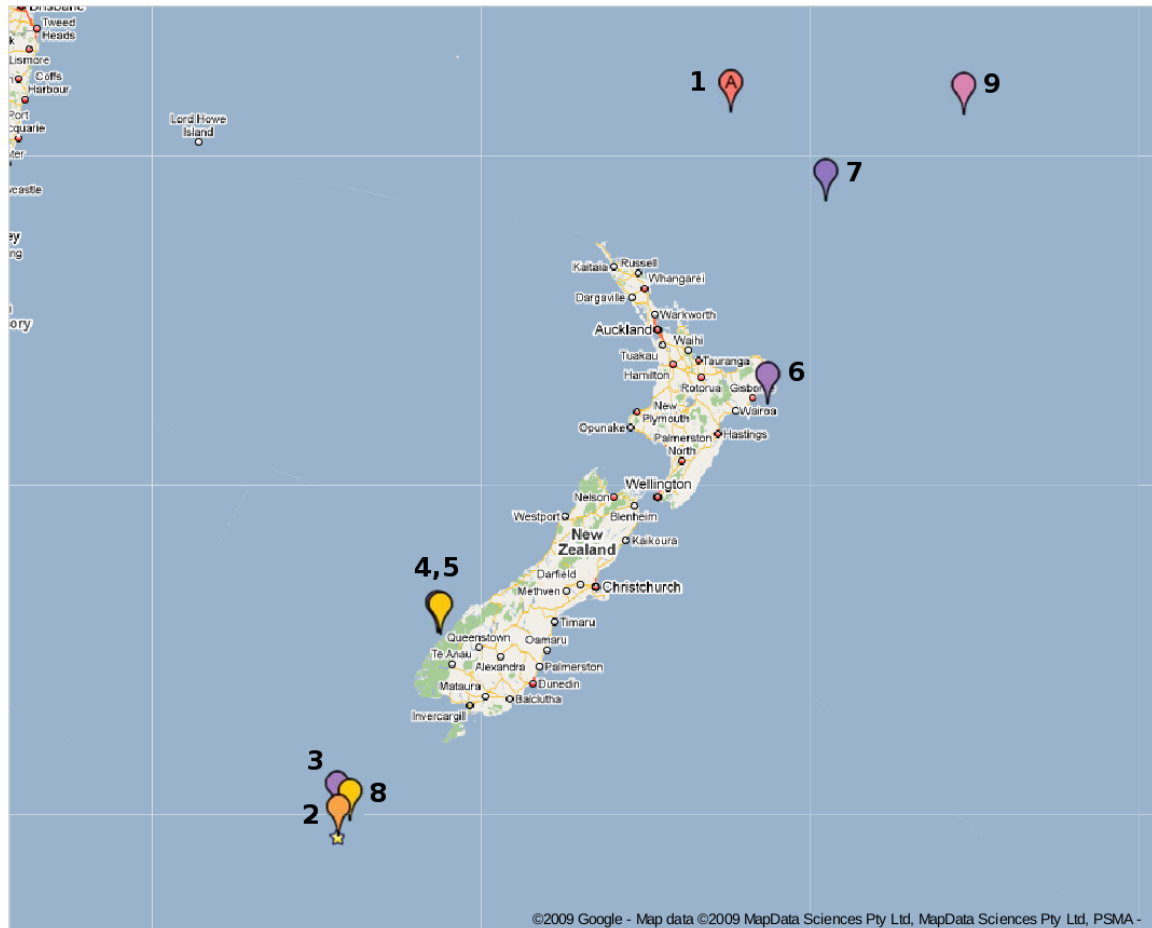
Chain-Like MST

[work in progress]

Precursors for Large Earthquakes

- Complex earth-crust dynamics associated with earthquakes.
- Expect self-organization resulting from competing processes.
 - Statistical signatures for self-organization prior to large earthquakes
- Time series clustering
 - Lower data frequency compared to financial time series
 - Cross-sectional study to enhance statistical significance
 - Insensitive to choice of observables
- Long-time dynamics
 - Long-time correlation matrix
 - Detection of synchronized clusters
 - Internal correlational dynamics of synchronized clusters

$M > 6$ Earthquakes, New Zealand (Oct 2006–Mar 2008)



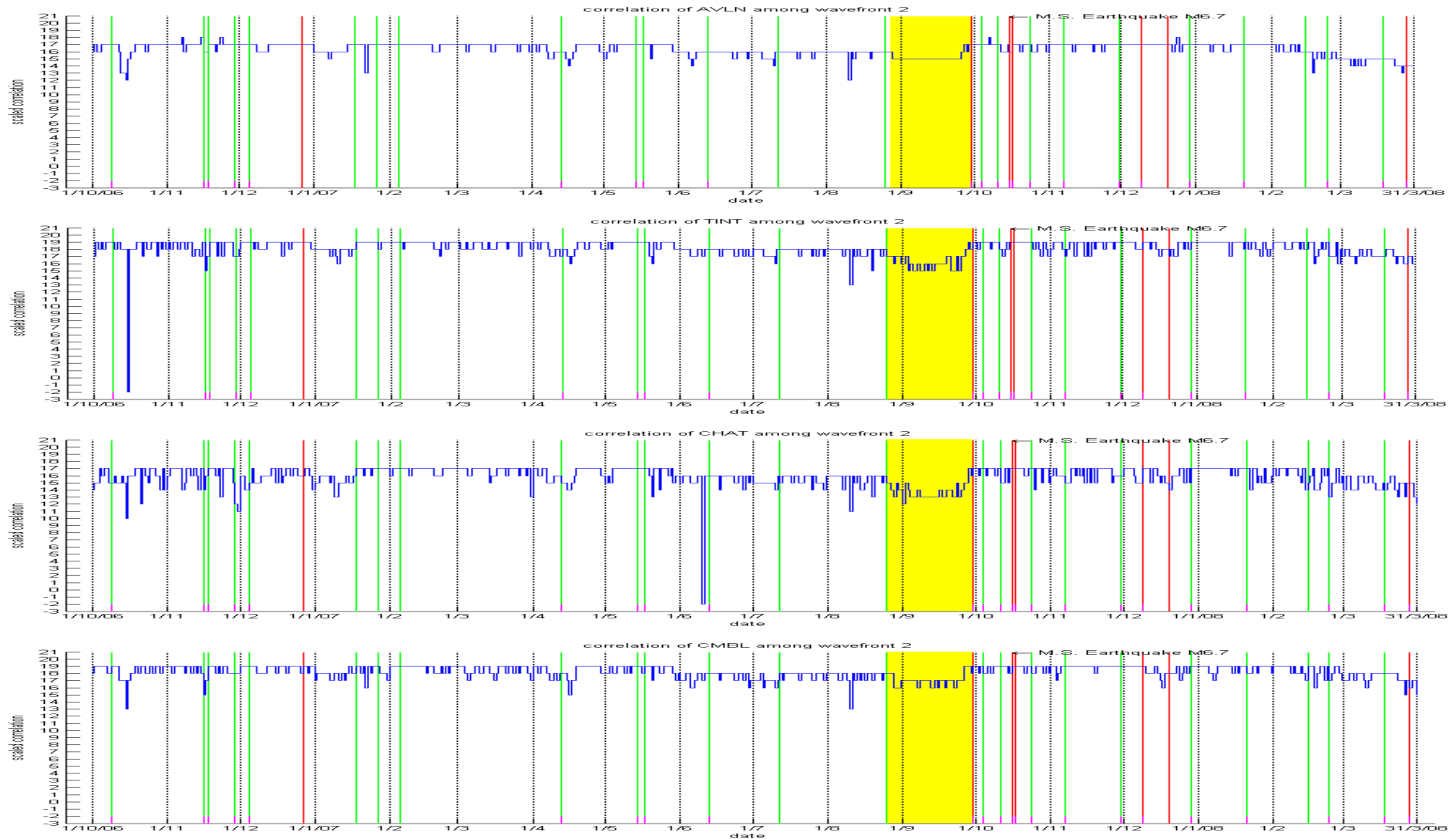
S/No.	Universal date & time
Spatial Cluster 1	
1	26 Dec 2006 at 21:06
6	20 Dec 2007 at 07:55
7	28 Mar 2008 at 06:39
9	29 Sep 2008 at 15:19
Spatial Cluster 2	
2	30 Sep 2007 at 05:23
3	30 Sep 2007 at 09:47
8	26 Apr 2008 at 23:34
Spatial Cluster 3	
4	15 Oct 2007 at 12:29
5	15 Oct 2007 at 21:28

Synchronized Clusters of Monitoring Stations

- 100+ stations in New Zealand monitoring network.
[<http://www.geonet.org.nz>]
- Synchronized clusters in **one-to-one correspondence** with spatial clusters of large earthquakes.

synchronized cluster	stations	geographical location
SC1	HAMT, TRNG, AUUCK, CORM, MAHO, WHNG, NPLY, RIPA, MARW	North Island
SC2	AVLN, KAPT, WGTT, PARW, TINT, KAIK, WAIM, MAST, TRAV, CHAT, LEXA, CLIM, MQZG, BLUF, DUND, MTJQ, OUSD, DUNT, LYTT, CMBL	Southern coast, South Island
SC3	QUAR, WEST, GLDB, WANG, HOKI, VGPK, VGMT, GISB	Northern coast, South Island

Loss-of-Correlation Precursor Feature for SC3



Outlook

- **Condensed Matter & Quantum Information**

- Mechanistic study of AF-to-SC phase transition based on RG analysis
- Quantum games
- No-go theorems for topological quantum states

- **Time Series Segmentation**

- Cross-section study of European economies
- Cross-section study of Asian economies
- Derivative pricing

- **Time Series Clustering**

- Dynamics of synchronized clusters in financial markets
- Effective dynamics in protein folding
- Earthquake precursor studies for Sumatra, Taiwan, and Japan (?)

Thank You!