



Center of Excellence in Scientific Research (2006-2011) of
The Romanian National Commission for Scientific Research in Universities

***Preisach model of hysteresis in magnetic materials and
FORC based identification techniques***

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European School on Magnetism 2009:
Models in magnetism : from basic aspects to practical uses
September 1-10th 2009, Timisoara, Romania

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Outline

- Introduction – about hysteresis
- Scalar Preisach model
- FORC identification technique
- Examples – ferromagnetic systems
- Hysteretic processes in spin-transition materials
- Conclusions

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Which hysteresis model we choose in a given situation ?

- How we choose ?
- Criteria ? To simulate correctly high order magnetization curves ?
- Identification methodologies ...
- In many papers the identification is made using an arbitrary selection of magnetization processes. Is it OK?

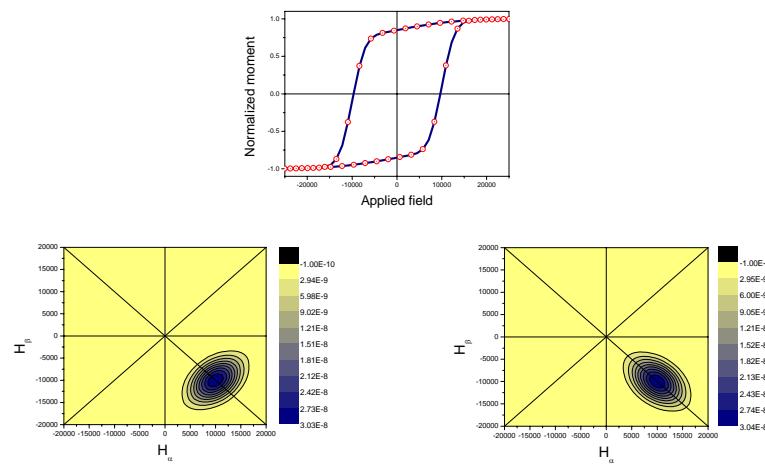
Can we use for identification only the Major Hysteresis Loop ?

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Identical MHL for essentially different systems

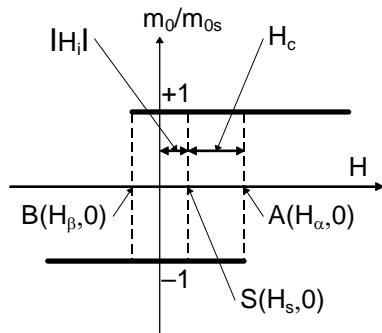


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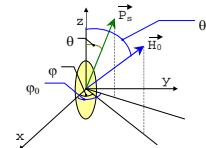
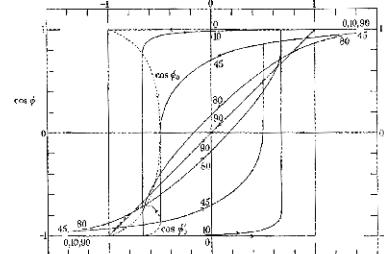
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To understand ... Preisach model



Stoner Wohlfarth model



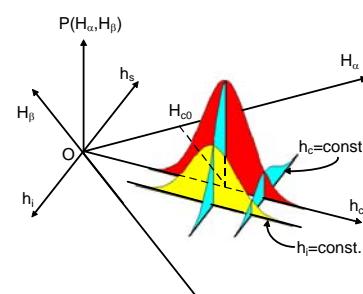
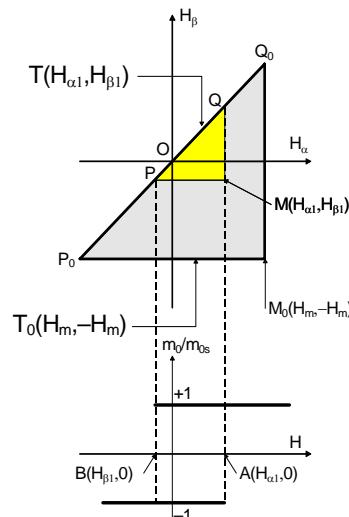
F. Preisach 1935

M.A. Krasnoselskii & A.V. Pokrovskii 1983, 1989
I.D. Mayergoyz 1986**CARPATH**

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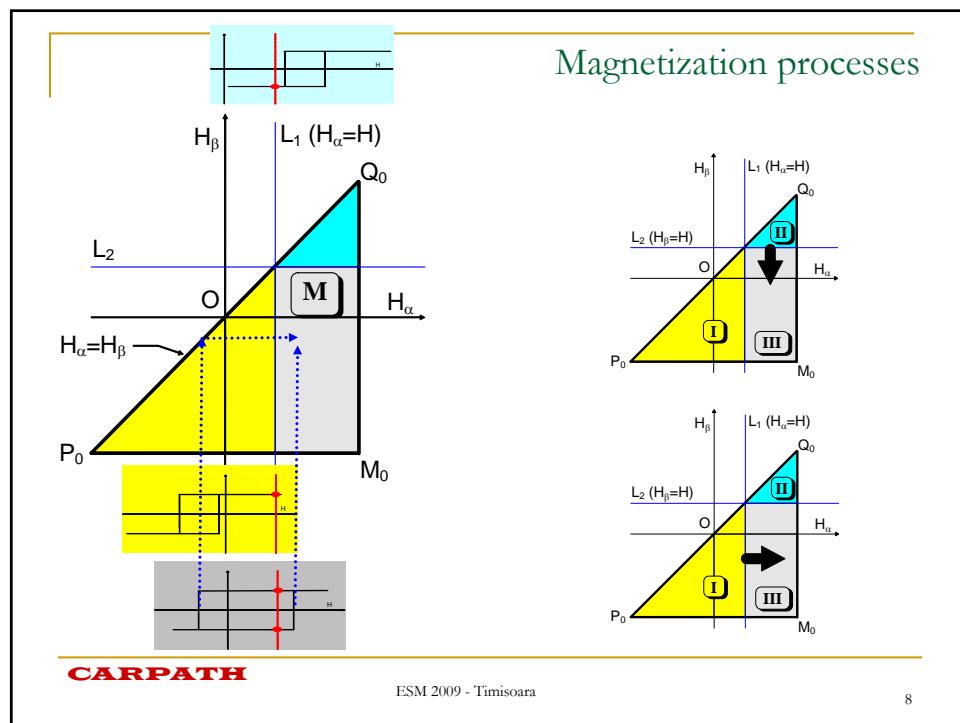
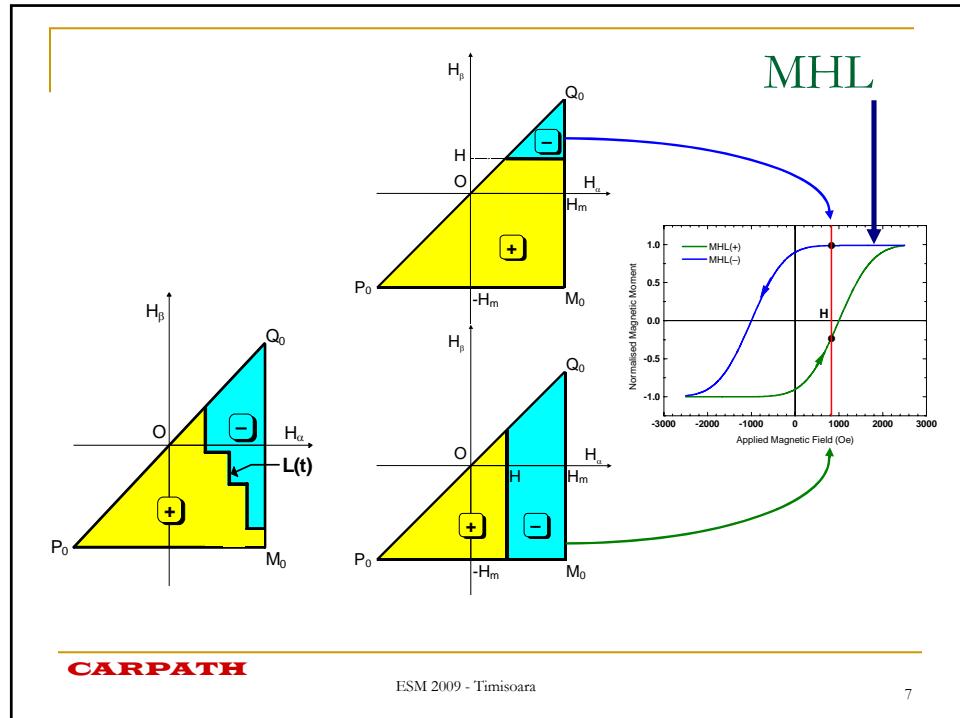
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Preisach plane

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For more examples ... Hystersoft

Univ. of Florida - Iasi University – Technical Univ. Wien

Petru Andrei
Department of Electrical and Computer Engineering
Florida State University and Florida A&M University

<http://www.eng.fsu.edu/~pandrei/HysterSoft/index1.html>

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Generalized use of FORCs

JOURNAL OF APPLIED PHYSICS VOLUME 85, NUMBER 9 1 MAY 1999

Characterizing interactions in fine magnetic particle systems using first order reversal curves

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(Received 1 June 1998; accepted for publication 1 February 1999)

Pike, Roberts, and Verosub 6667

J. Appl. Phys., Vol. 85, No. 9, 1 May 1999

ing particles, as discussed earlier. (These shortcomings are also shared by the more sophisticated versions of the Preisach model.) Because the basic Preisach model is not a rigorously valid physical model, the Preisach distribution used to describe a particular physical system will always be, to some degree, arbitrary. In fact, a number of different algorithms have been proposed in the literature for calculating Preisach distributions. In summary, a Preisach distribution is an ambiguously defined theoretical construction.

A FORC distribution, by contrast, is not based on any assumptions. It is not part of a theoretical model. It is simply a well-defined transform [i.e., Eq. (1)] of the set of first order reversal curves that is useful in making the structure of these data apparent to the human eye.

try can be corrected to some extent by incorporating a moving parameter into the calculations, as is done in the moving Preisach model.¹¹ But even with a moving parameter, some degree of asymmetry will almost always be present in an experimentally acquired FORC distribution. Hence, FORC distributions obtained from experimental data will not, in general, be valid Preisach distributions.

Conclusion: FORC diagram can be calculated for ANY hysteretic system.

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Conclusion ...

FORC distribution and FORC diagram can be obtained from experimental data.

Problems:

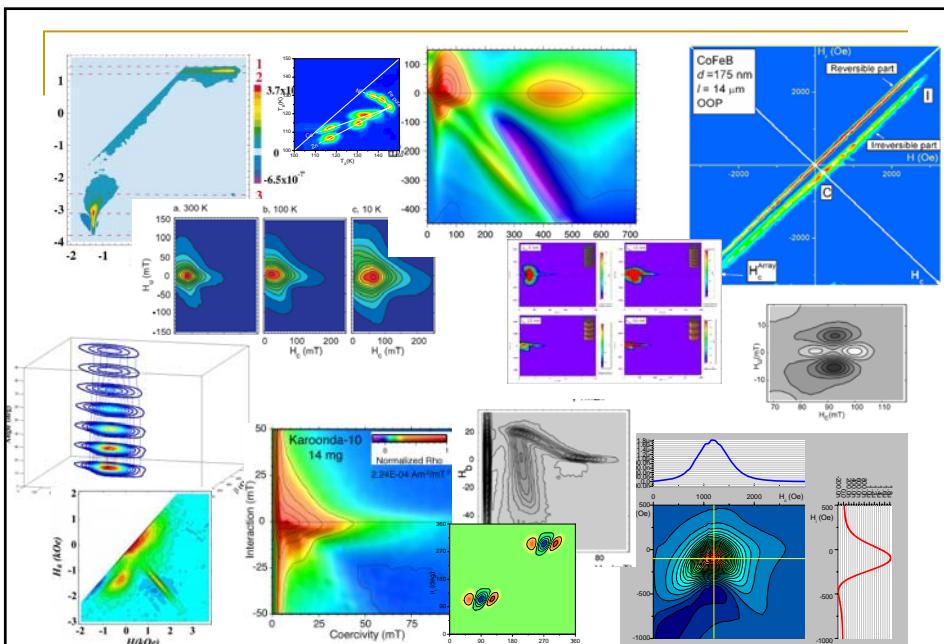
How we “decode” the information contained in an experimental FORC diagram ?

Does it contain sufficient information to identify ANY hysteresis model ?

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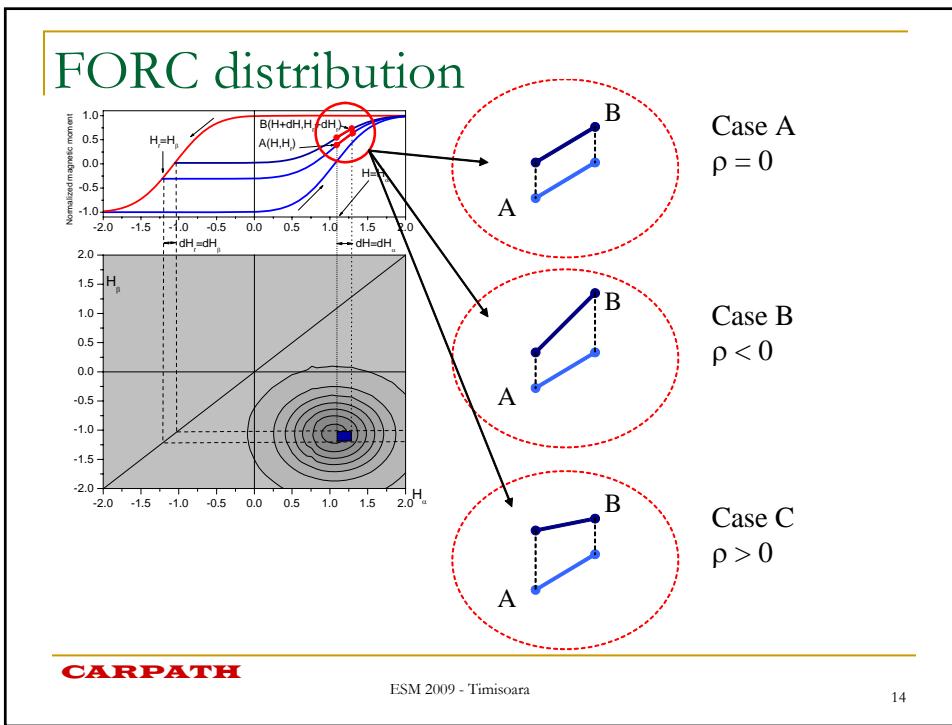
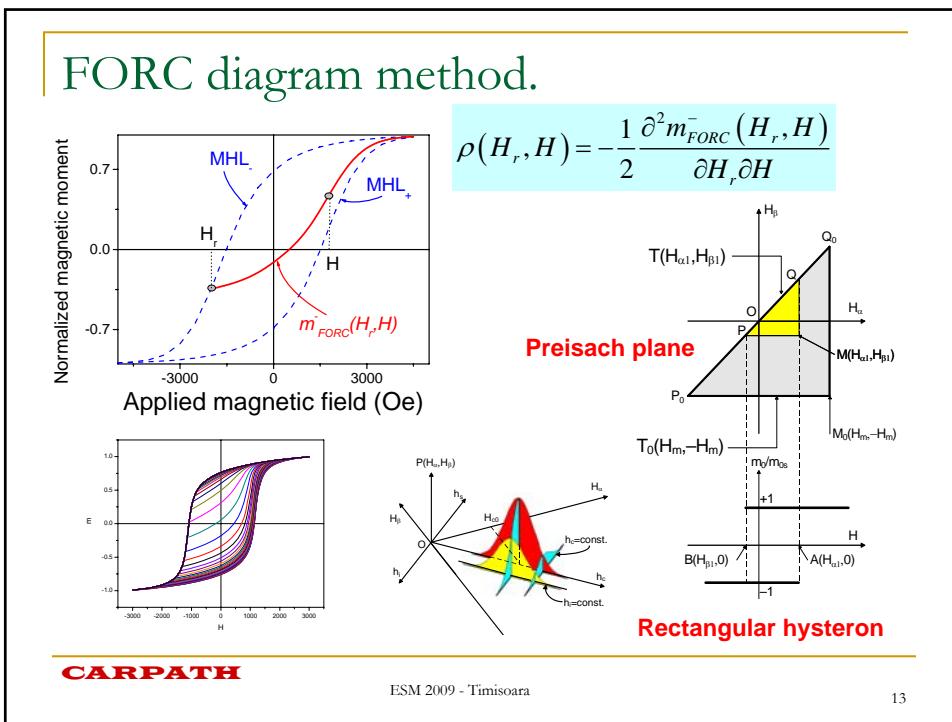
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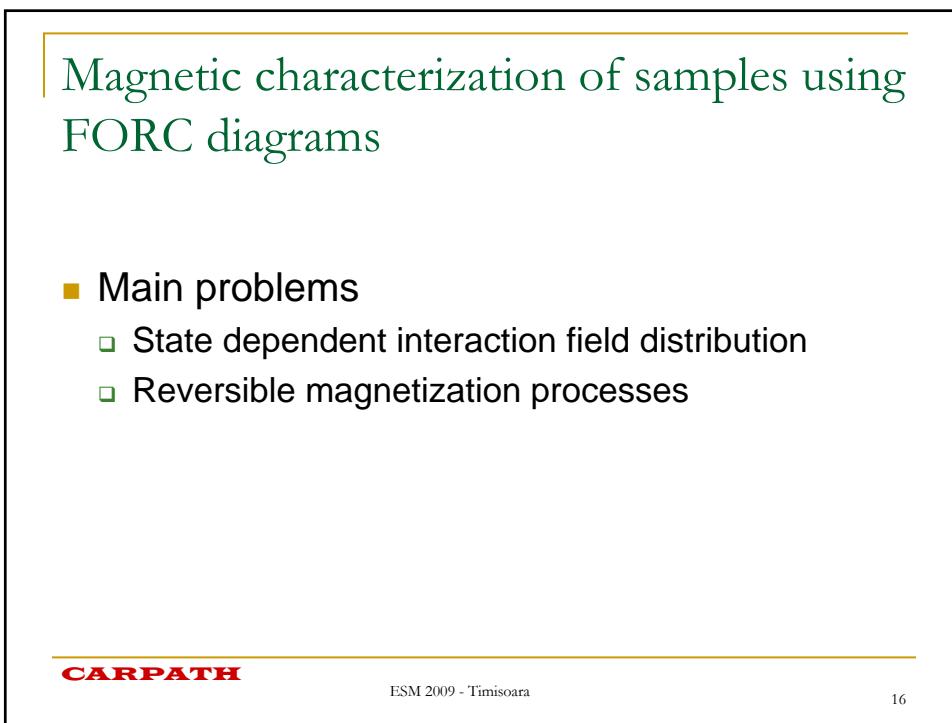
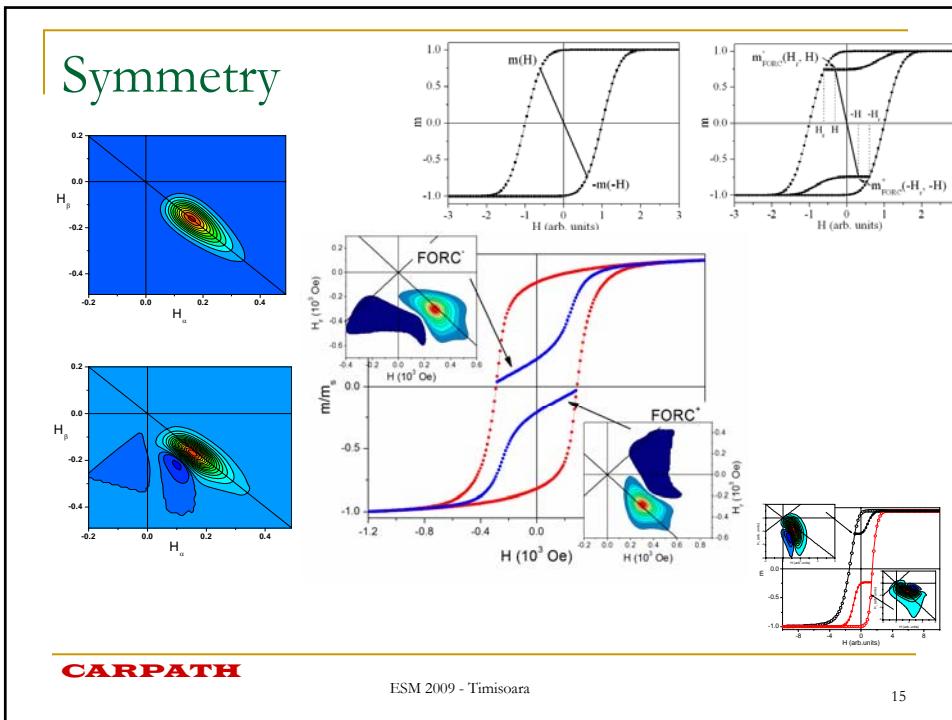


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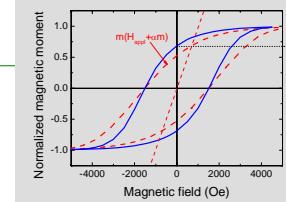
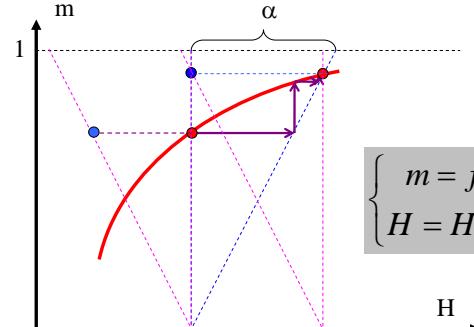
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Mean field interactions



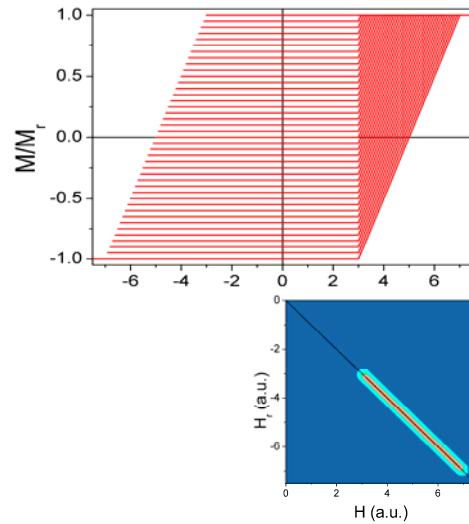
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Preisach – singular distributions

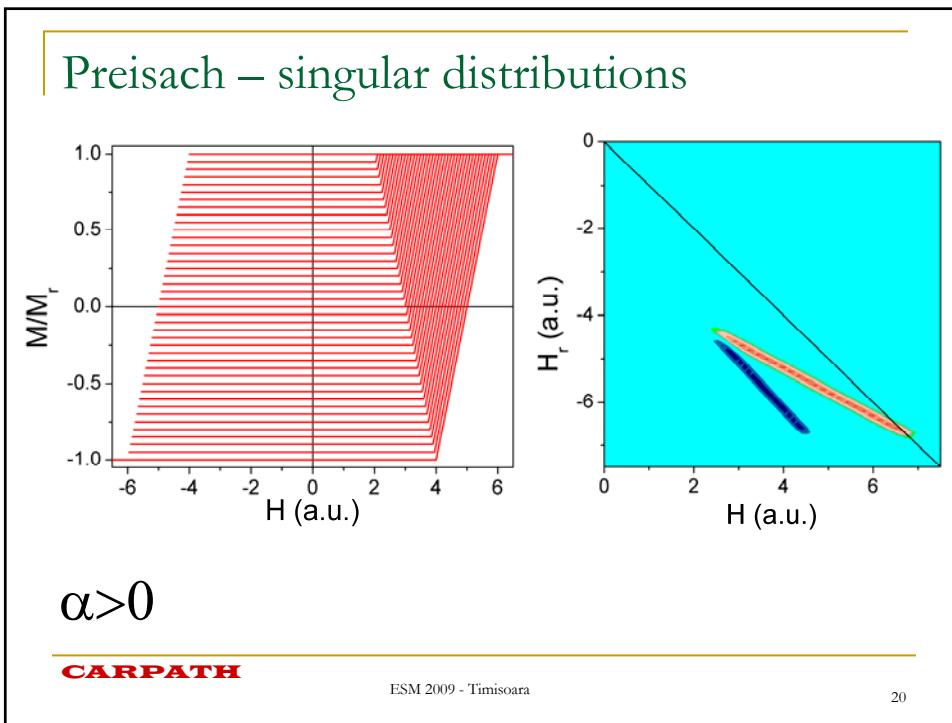
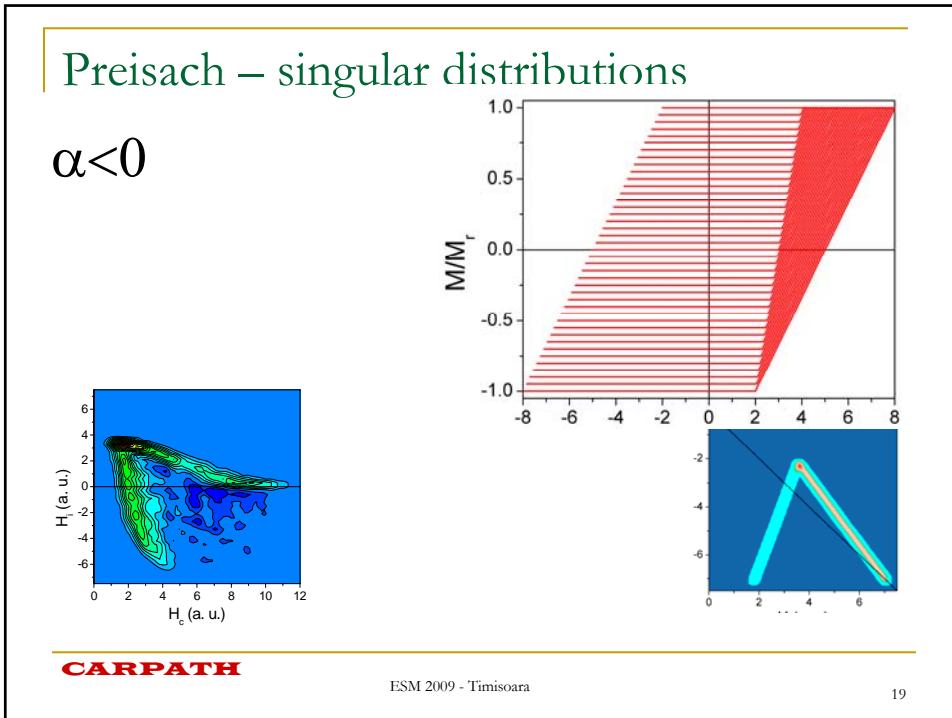
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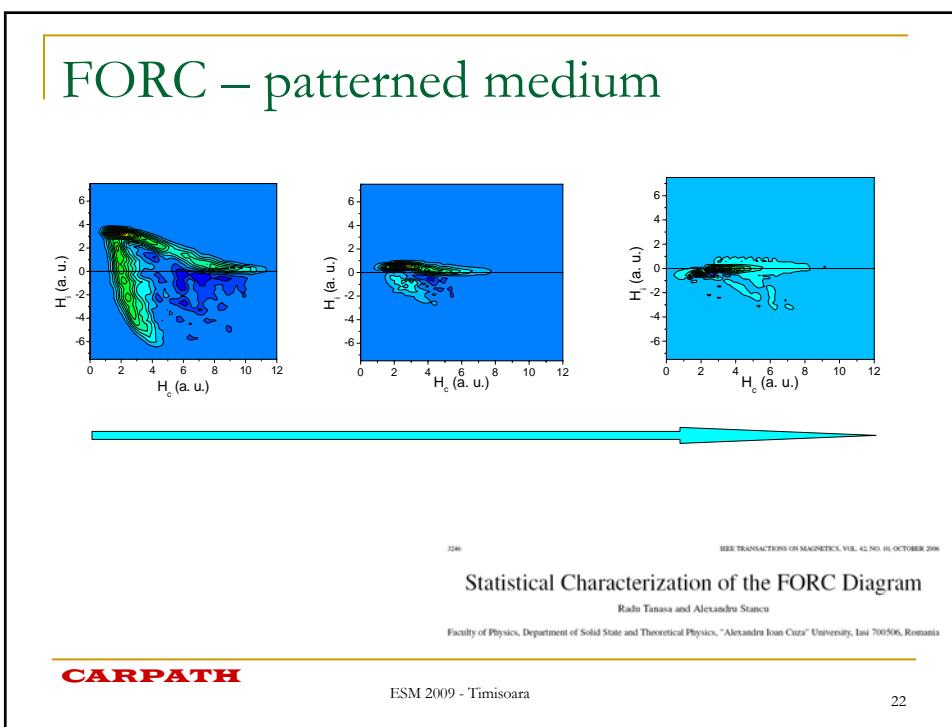
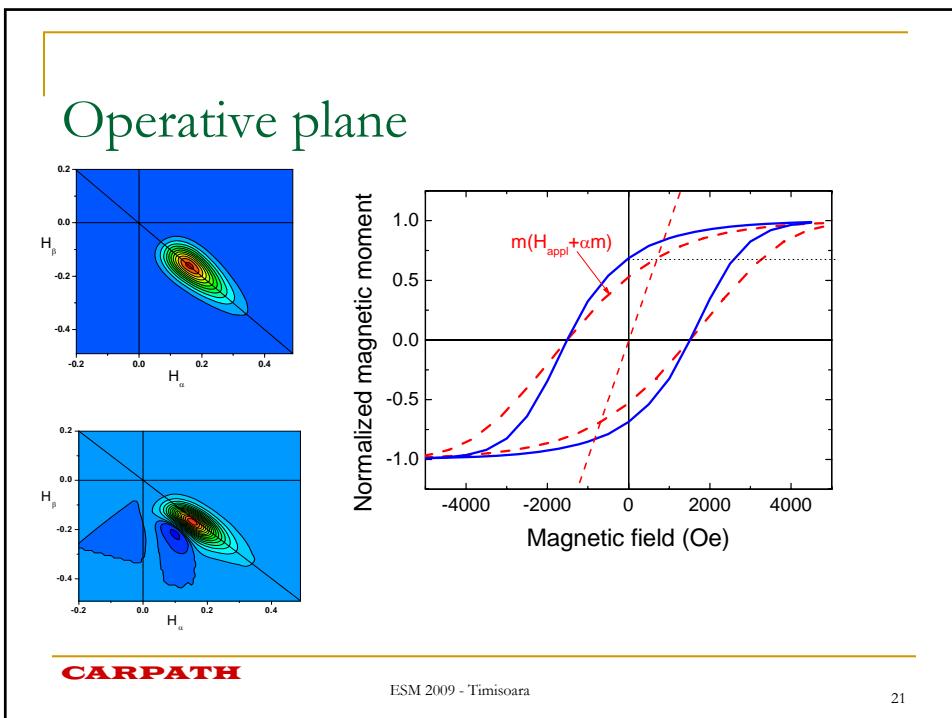


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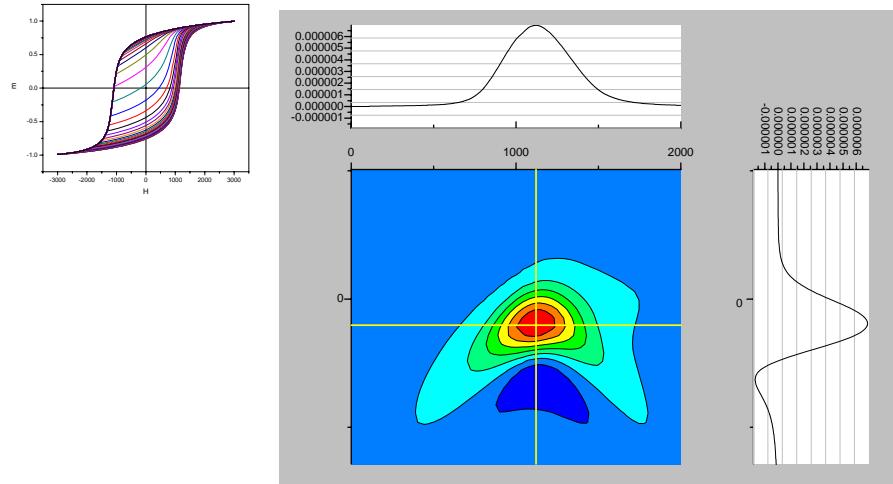
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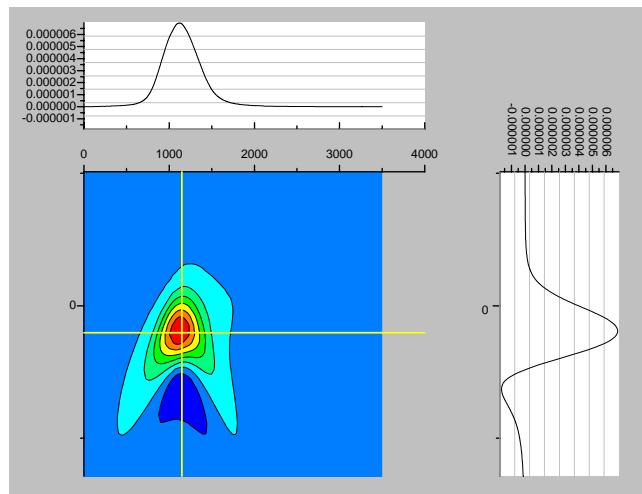
Magnetizing mean field interactions

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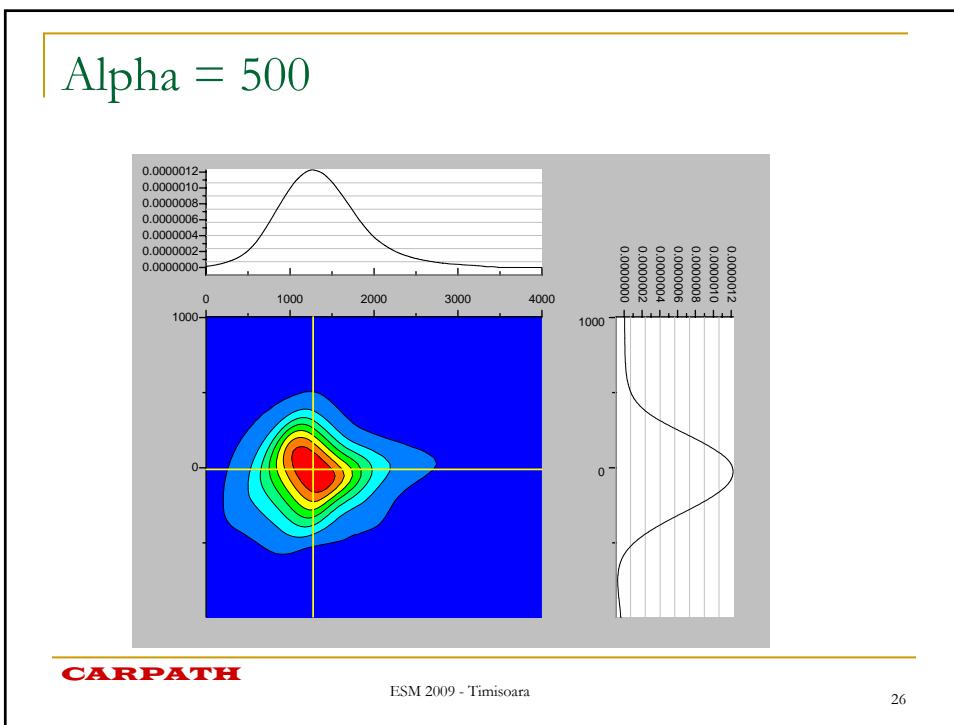
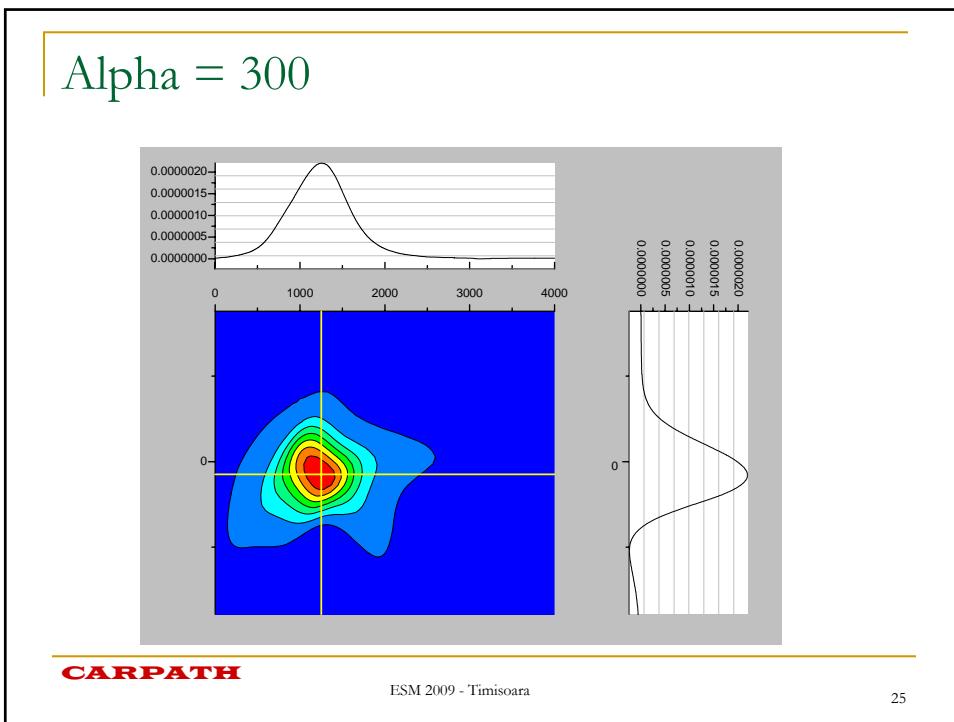
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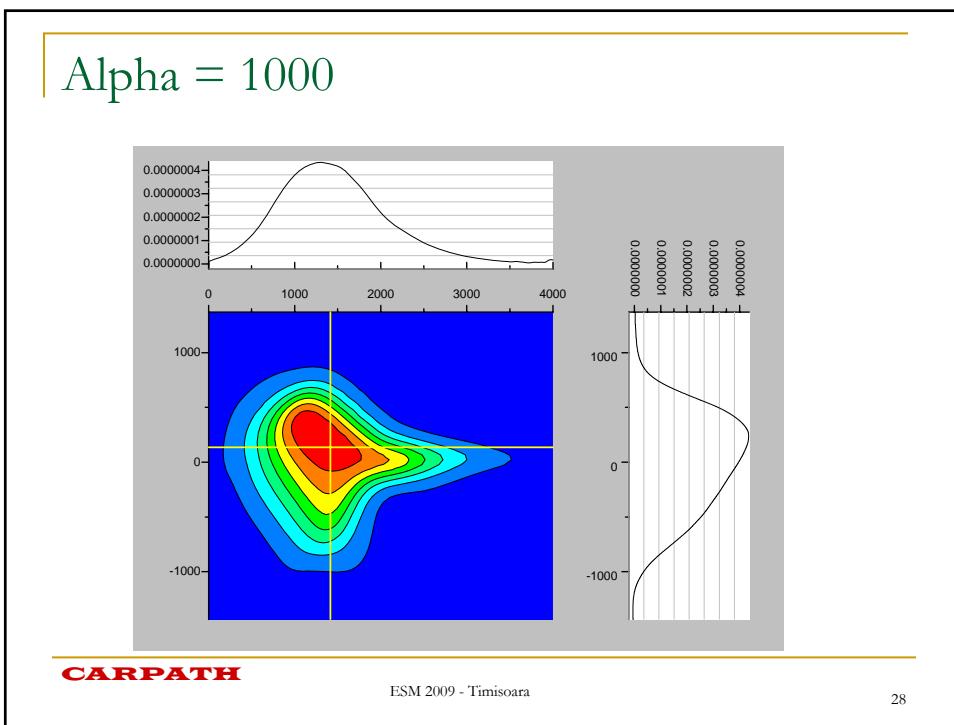
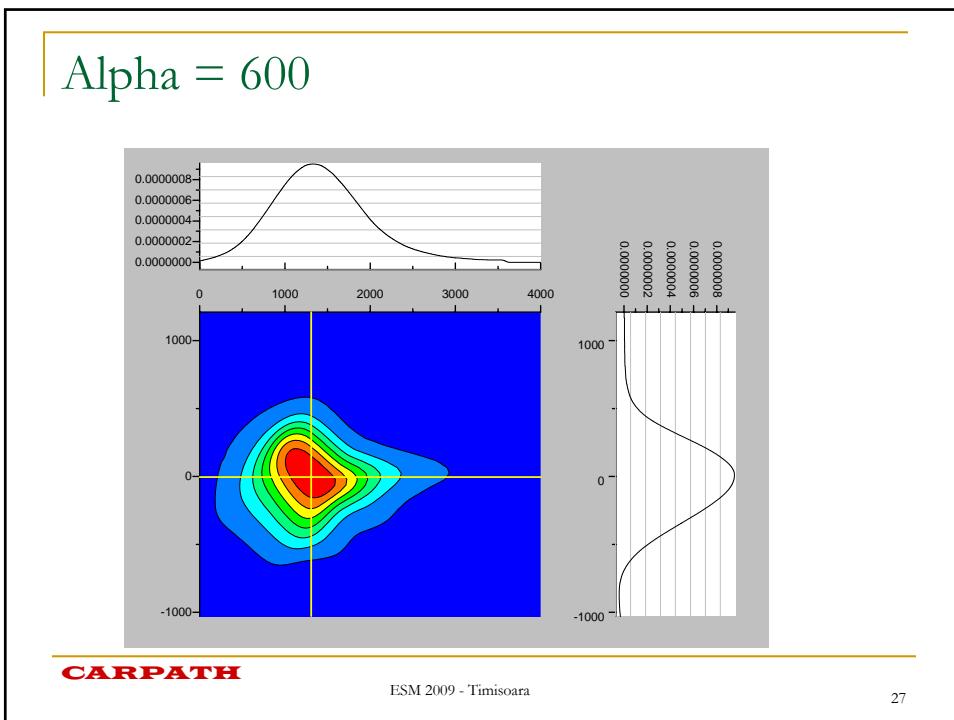
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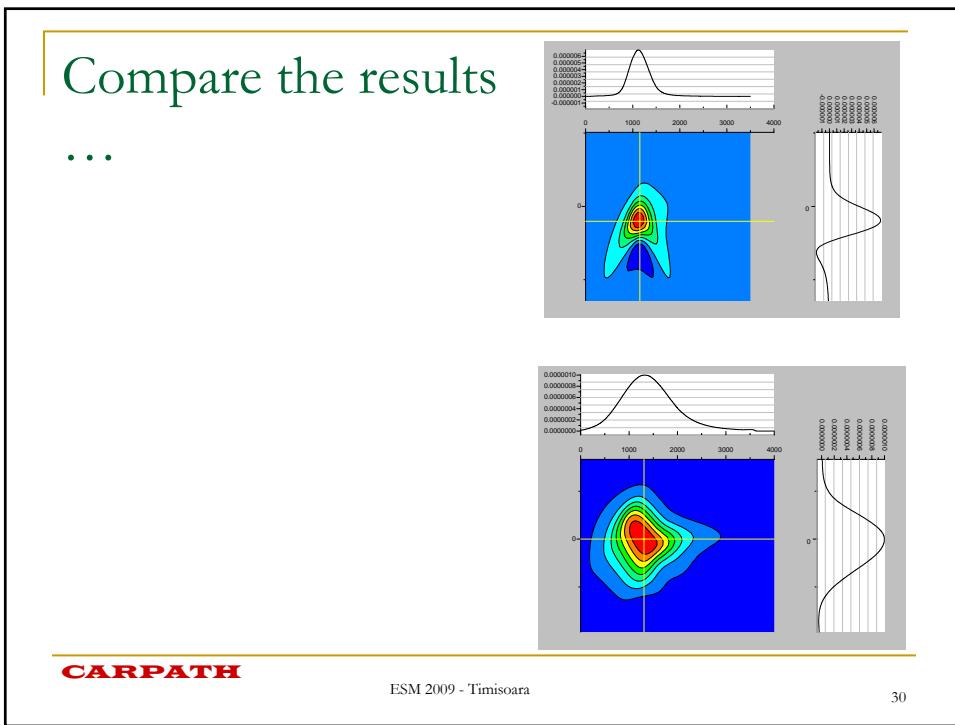
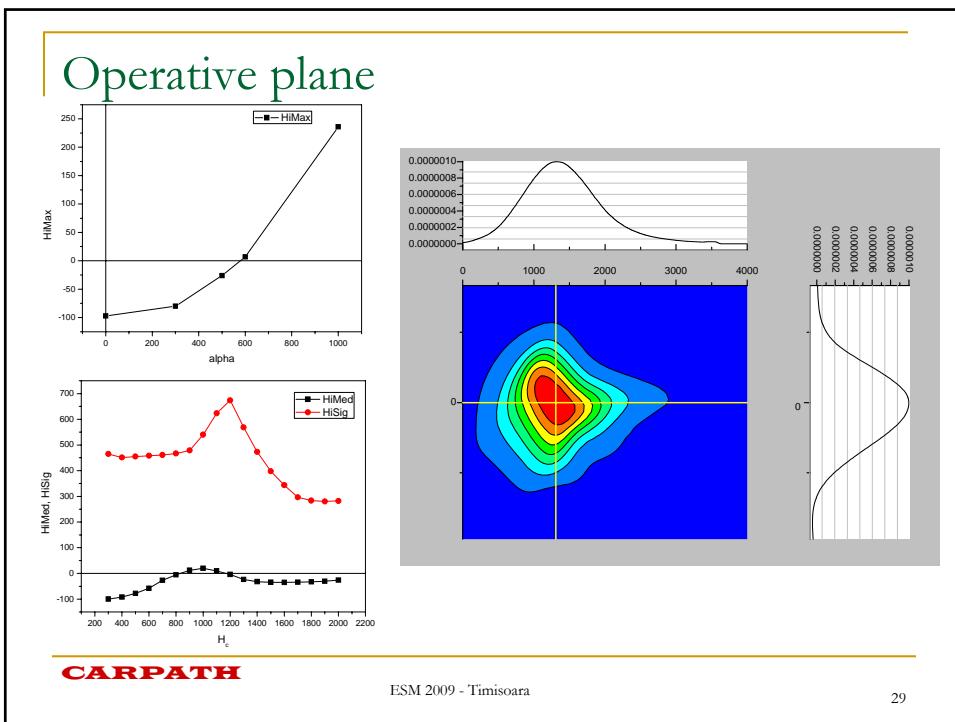
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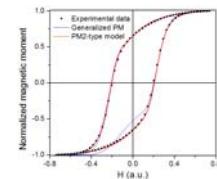
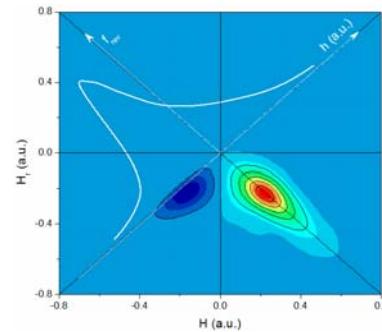
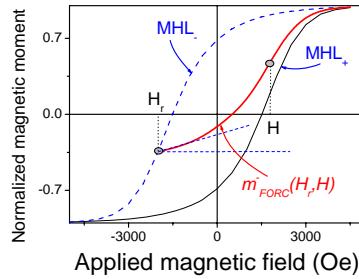
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Reversible vs. irreversible magnetization processes

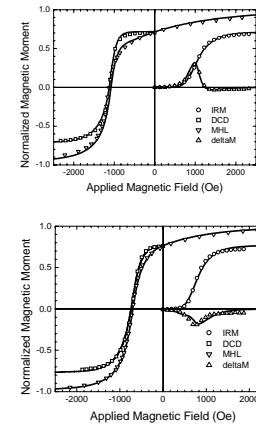
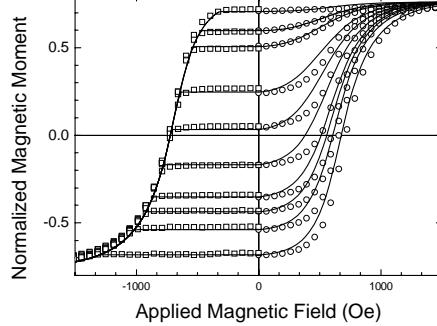


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Relation with deltaM measurement



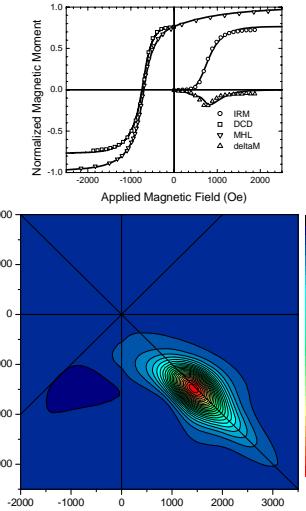
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Stancu A., Bissell PR, Chantrell RW, JAP, 2001
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Problems with deltaM/Henkel plots

- Sensitive to the quality of the demagnetization state in IRM process
- Negative (demagnetizing-like) deltaM is compatible with statistical interactions (no preference to demagnetizing interactions)

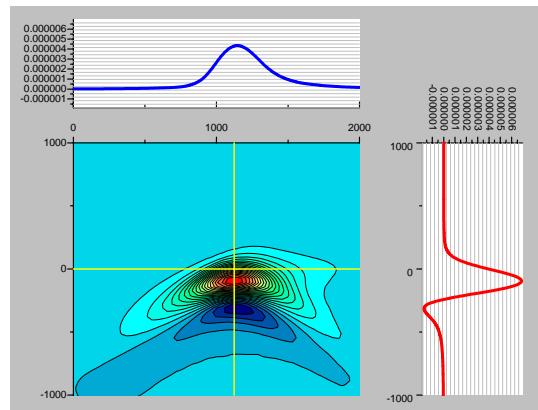
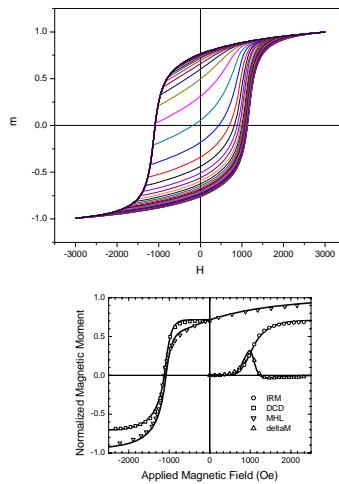


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BaFe (oriented sample)-positive deltaM

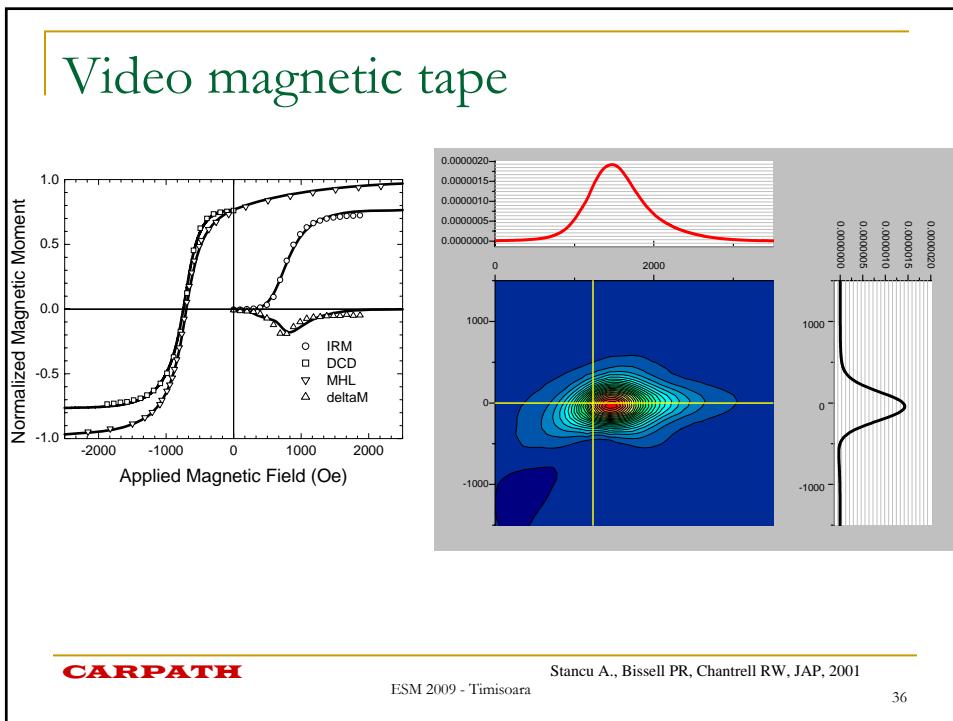
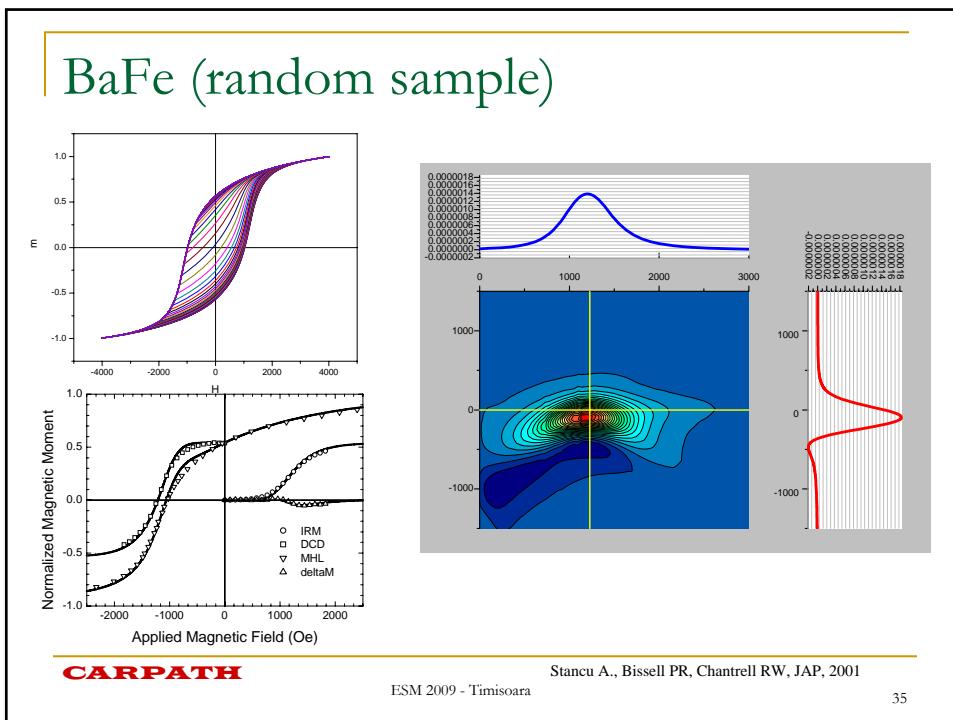


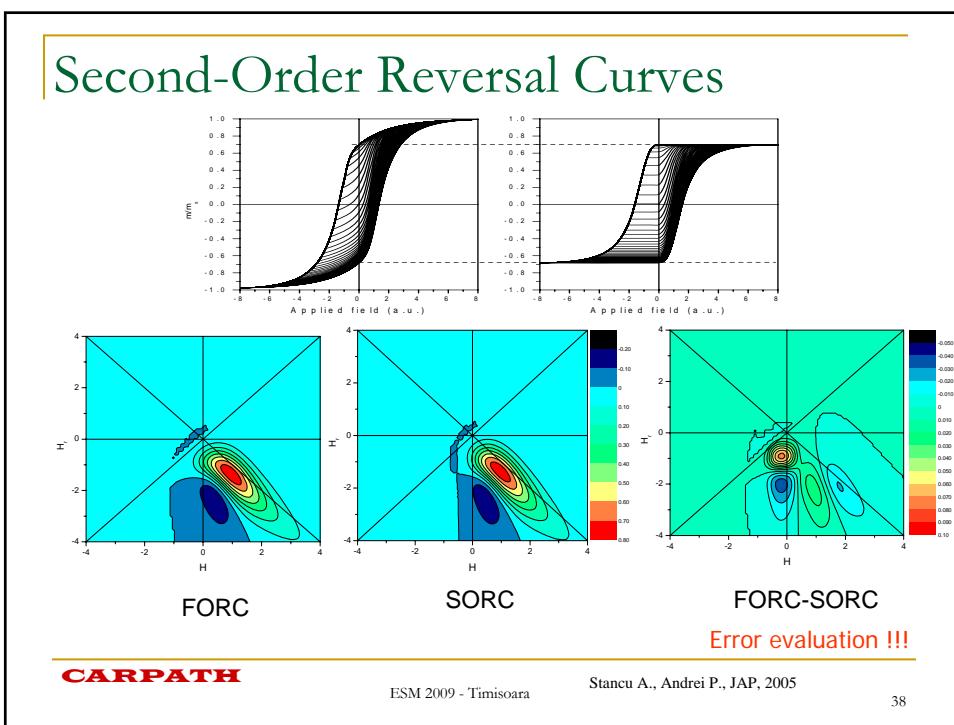
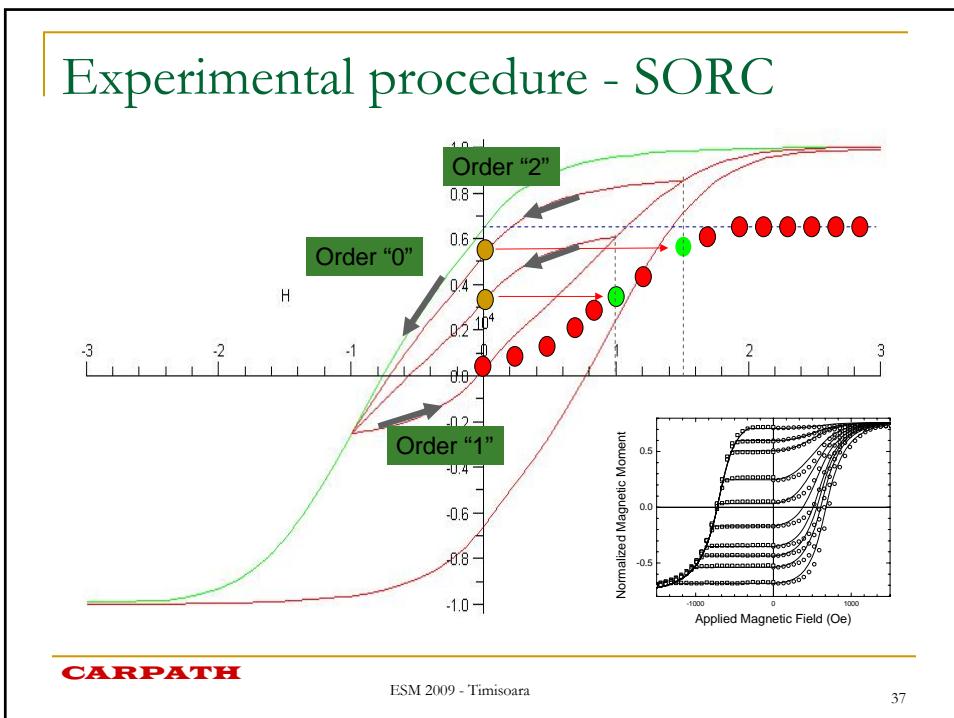
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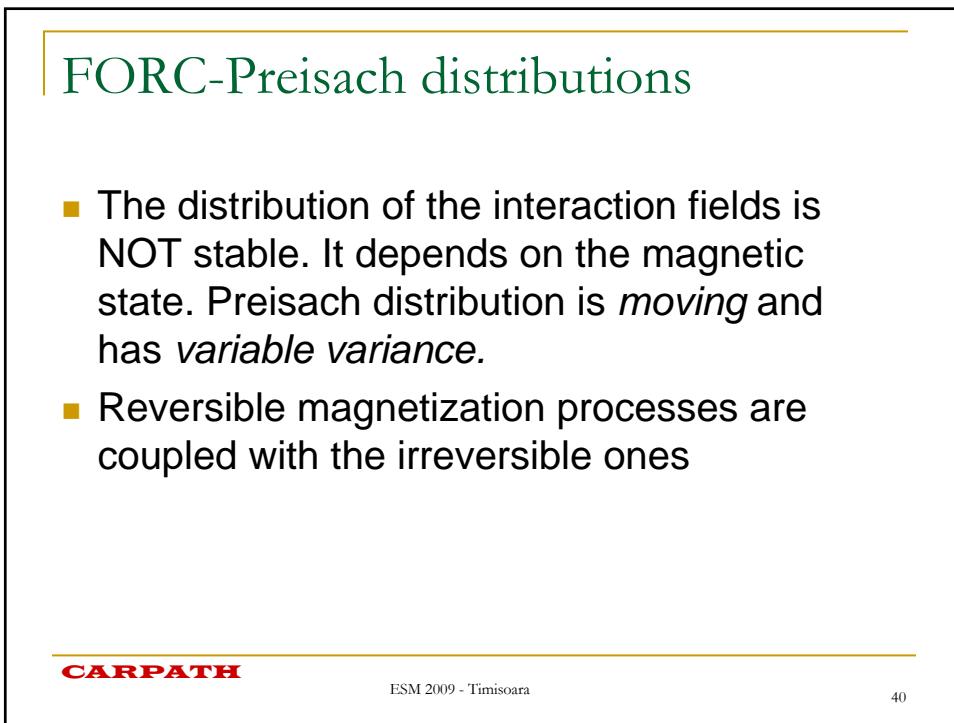
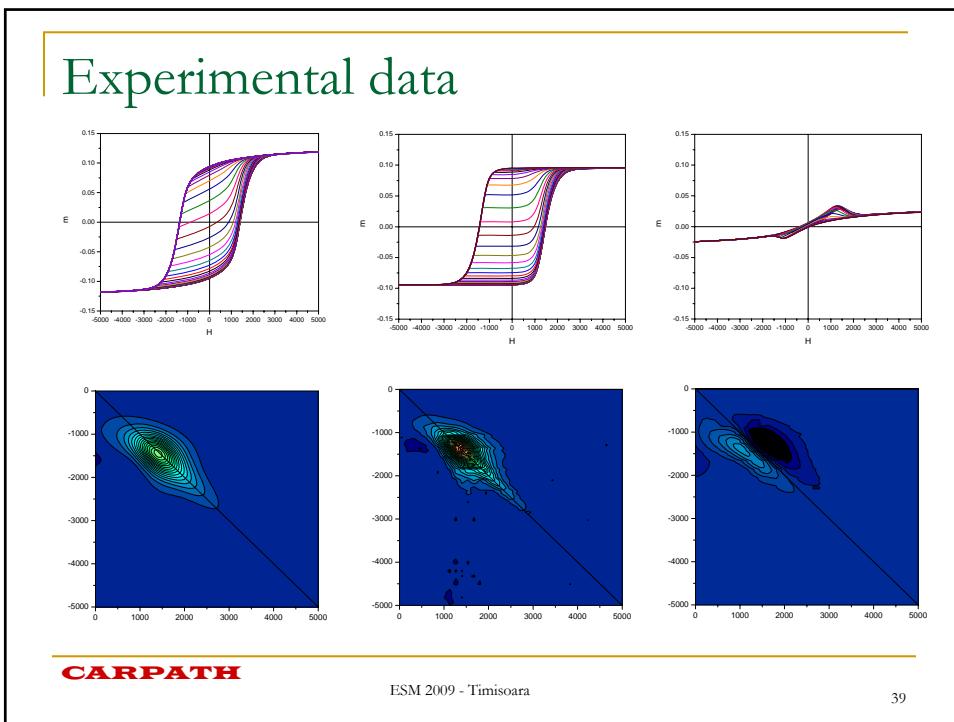
Stancu A., Bissell PR, Chantrell RW, JAP, 2001

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FORC ...

- FORC distribution gives a static, average image of the interactions while the interaction field distribution is changing during the magnetization processes
- Without a proper model the dynamics can't be observed and evaluated

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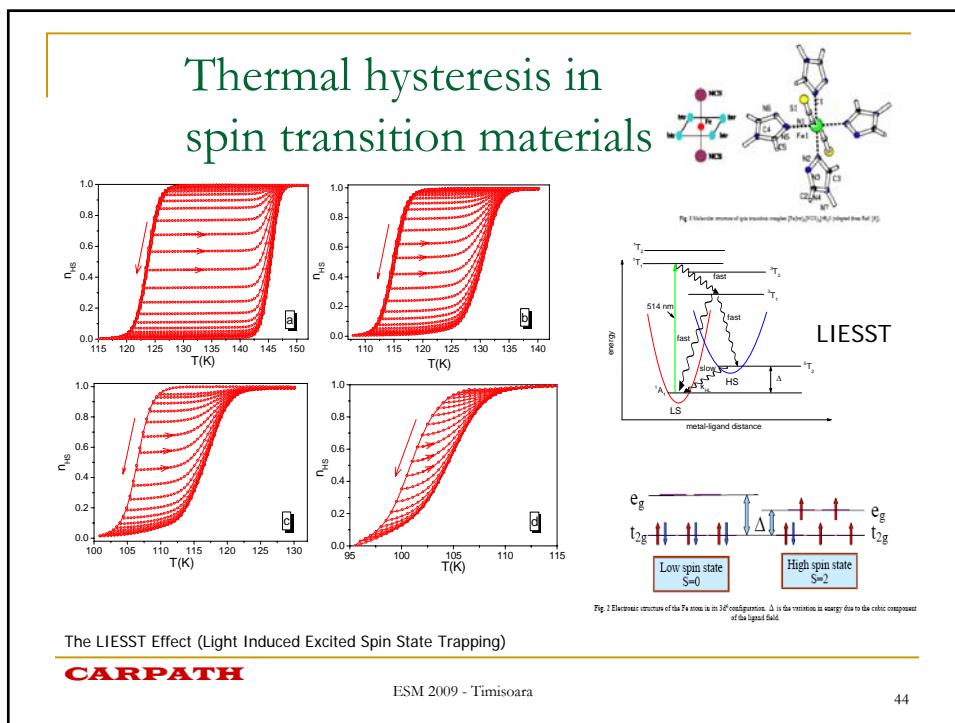
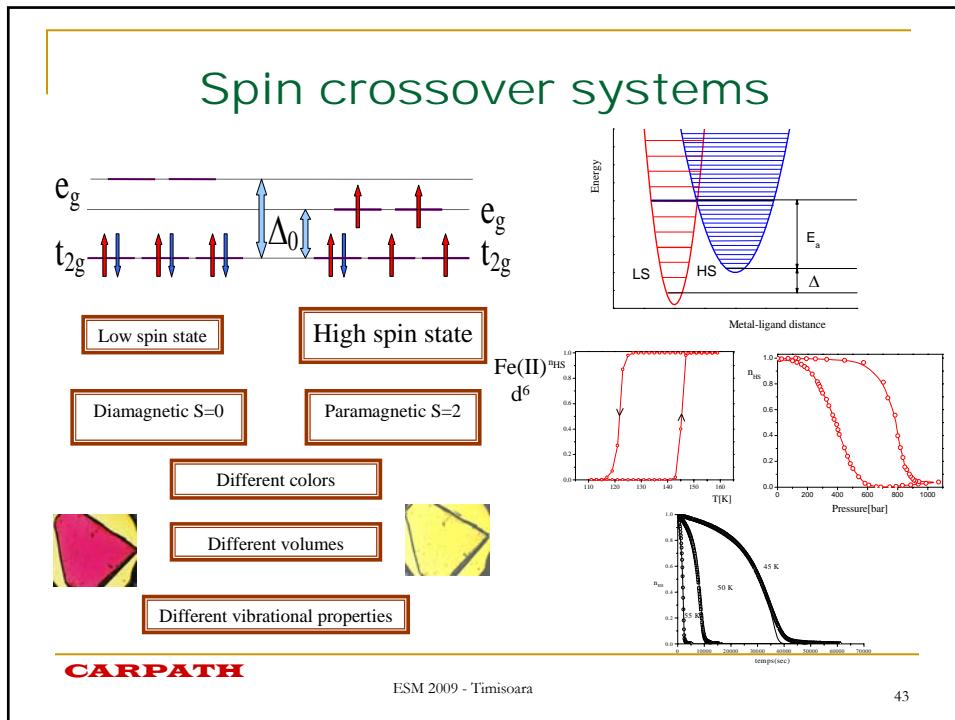
FORC technique applied to other systems

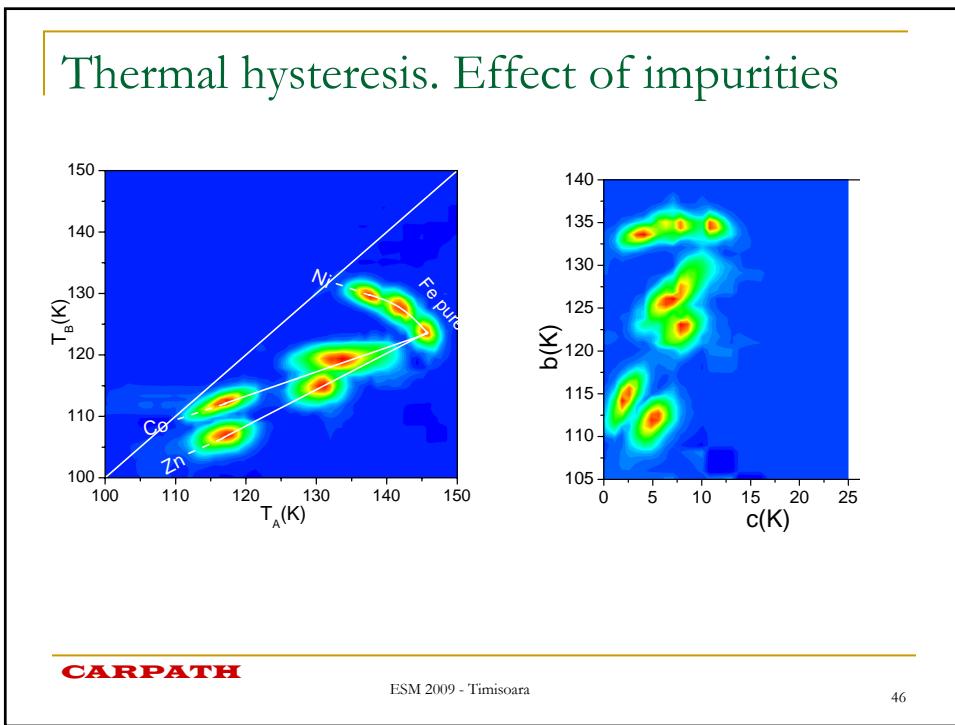
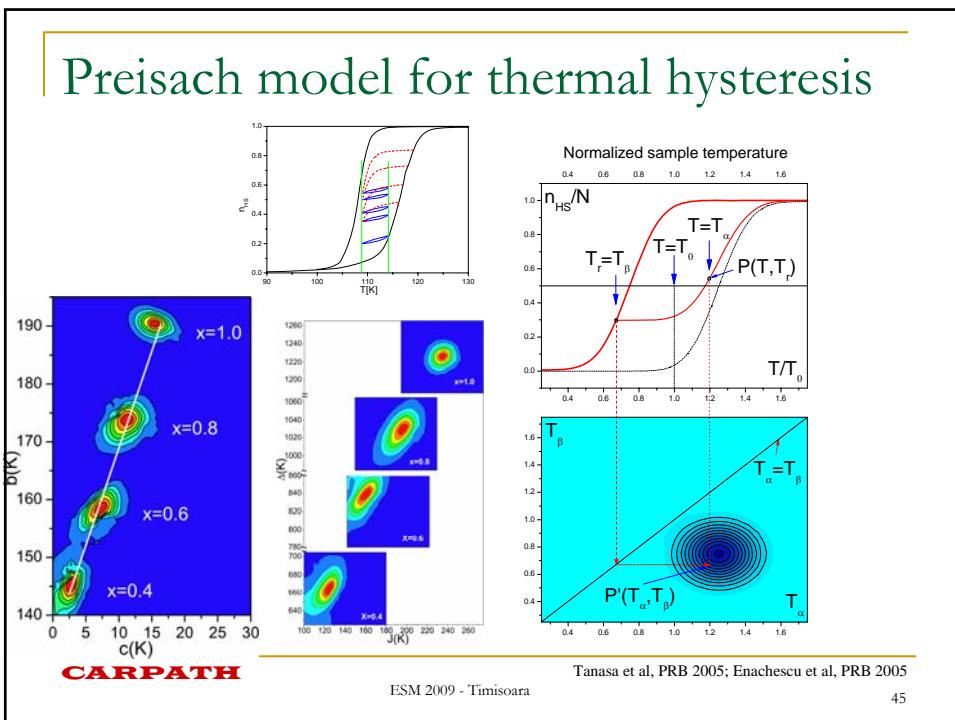
Preisach and FORC identification technique can be applied to ANY hysteretic system ...

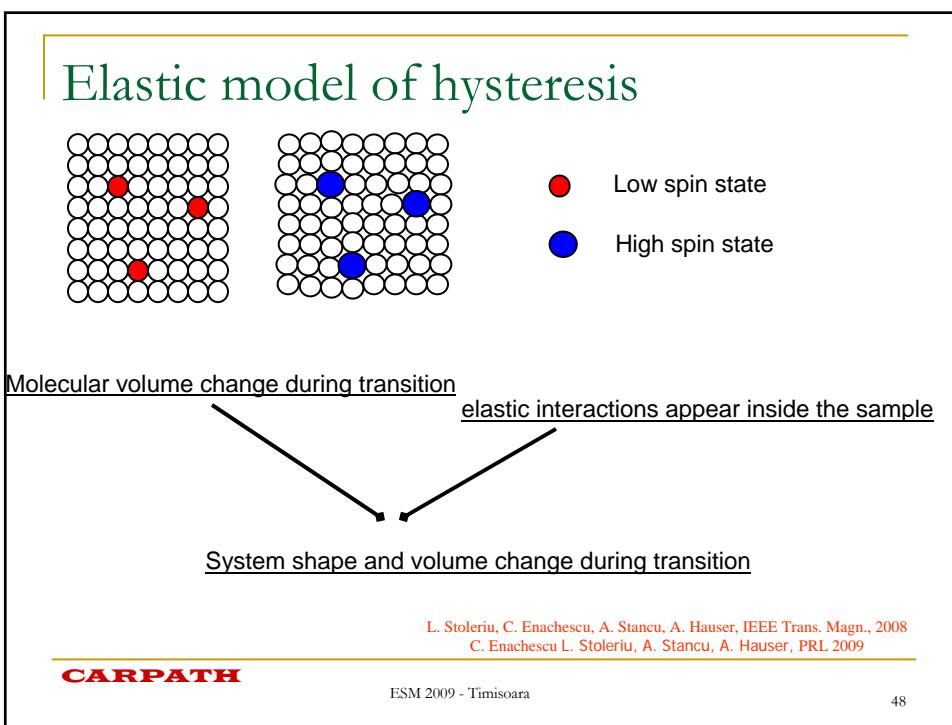
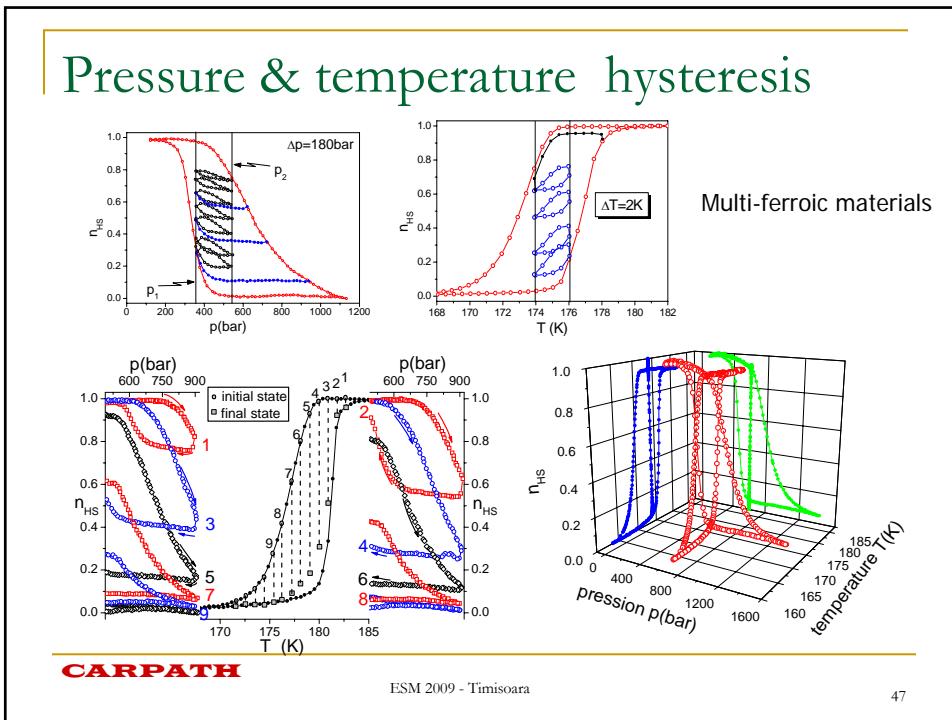
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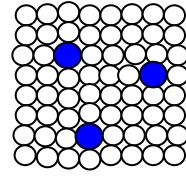
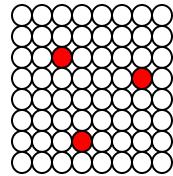
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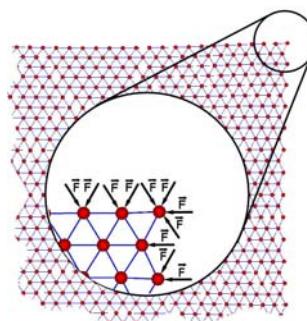


Elastic model of hysteresis and relaxation



● Low spin state

● High spin state



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For every particle the following differential system is solved at every step:

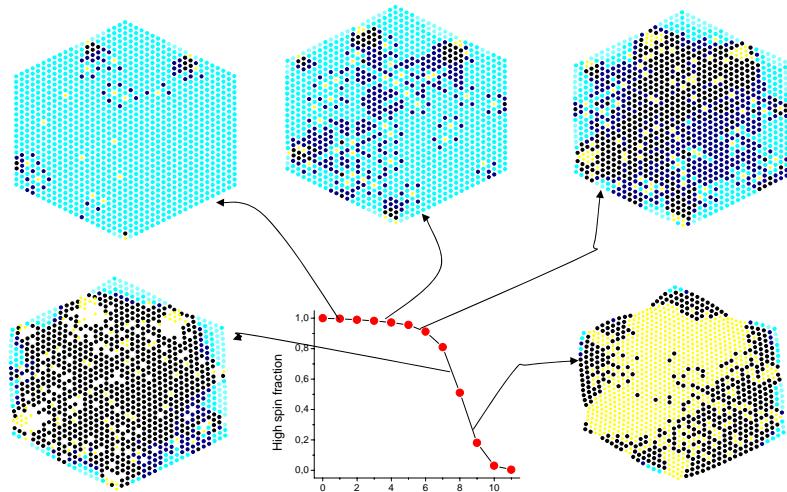
$$\begin{cases} m \frac{d^2 x_i}{dt^2} = F_{xi} - \mu \frac{dx_i}{dt} \\ m \frac{d^2 y_i}{dt^2} = F_{yi} - \mu \frac{dy_i}{dt} \end{cases}$$

F_{xi} are the algebraic sums of forces acting on particule on the two directions
 μ is the damping constant

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Cooperativity effect – relaxation process



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Size effects in nanoparticulate spin transition materials

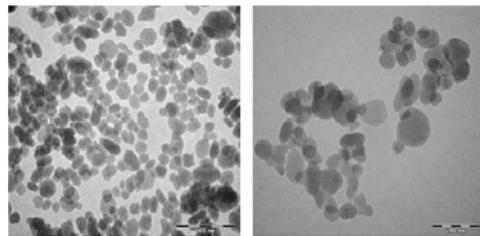


Fig. 6.1 Microographies des nanoparticules de $[\text{Fe}(\text{NH}_3\text{-trz})_3](\text{Br})_2 \cdot 3\text{H}_2\text{O}$.0.03(surfactant) : 90nm (gauche), 70nm (droite)

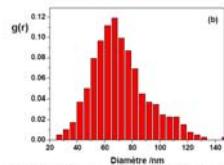


Fig. 6.2 Distributions de taille normalisées obtenues des observations de microscopie électronique au transmission. Représentation en diamètre

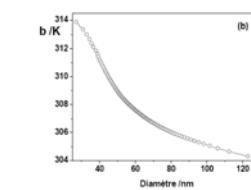
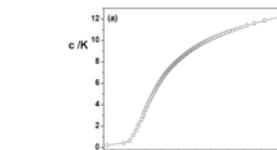
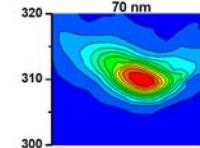


Fig. 6.9 Variation de la coercivité (a), respectivement du bias (b) en fonction de la taille des nanoparticules pour le système caractérisé par une taille moyenne de 70nm

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Conclusions

- The extensive use of the FORC technique induced a new interest in the Preisach model
- Unfortunately, in many cases the analysis is not complete
- We recommend at least a mean field analysis / work in the operative plane
- All FORC analysis should be coupled with a statistical model specific to the physical system analyzed

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