

The image is a composite of two magnetic domain patterns. The top half shows a curved, elongated domain structure with a color gradient from blue to yellow to red, set against a dark blue background. The bottom half shows a complex, interconnected network of purple and white lines, resembling a maze or a highly convoluted domain structure.

Magnetic Domains and Dynamics

Oleg Shpyrko, UC San Diego

“Living On The (Resonant) Edge”*

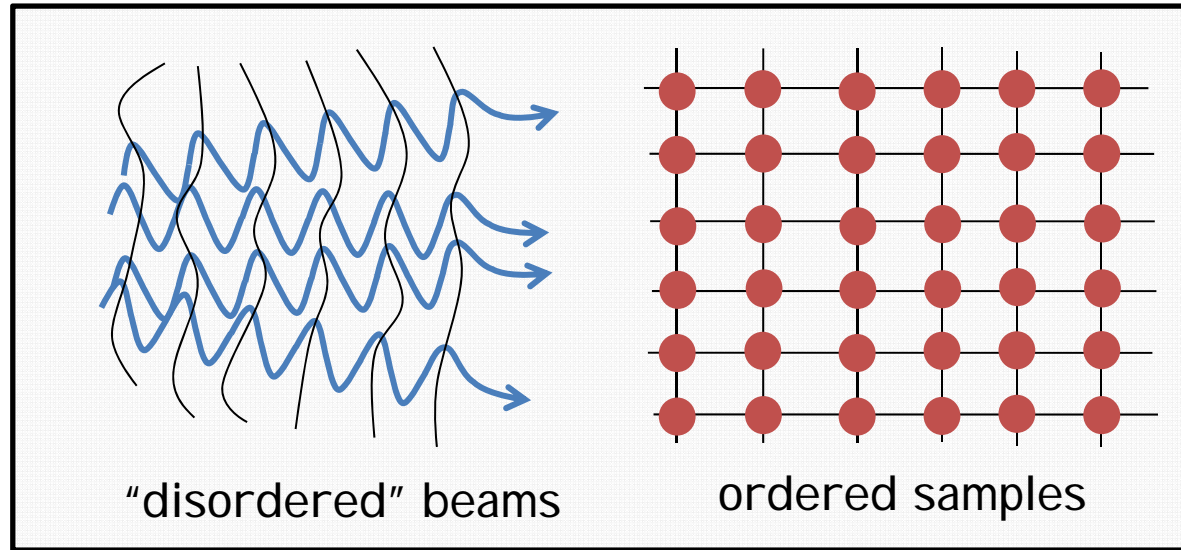
Oleg Shpyrko, UC San Diego

*with apologies to Aerosmith

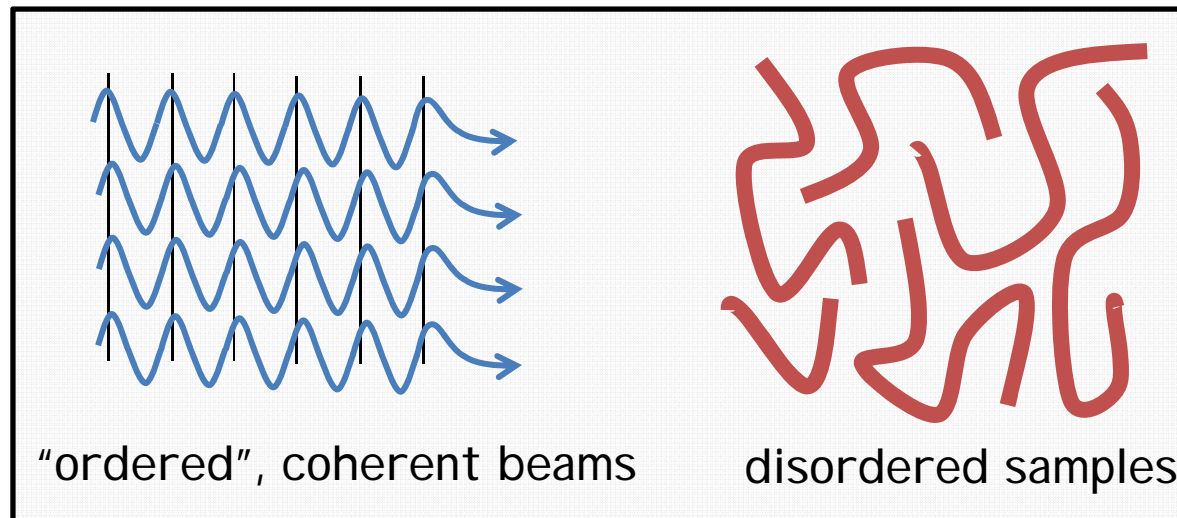


Incoherent vs. coherent X-ray beams

PAST &
PRESENT:

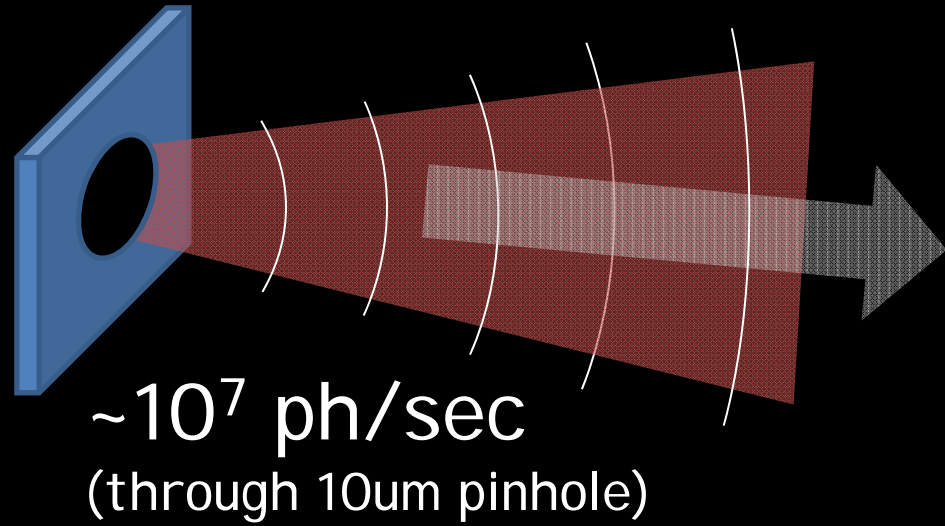


FUTURE:



Coherent beams from "incoherent" sources

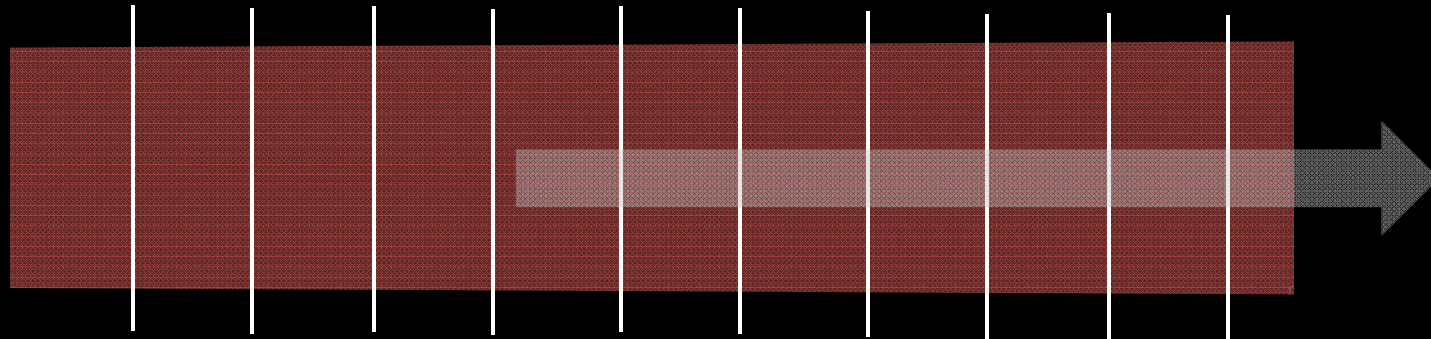
Present:



$\sim 10^7$ ph/sec
(through 10um pinhole)

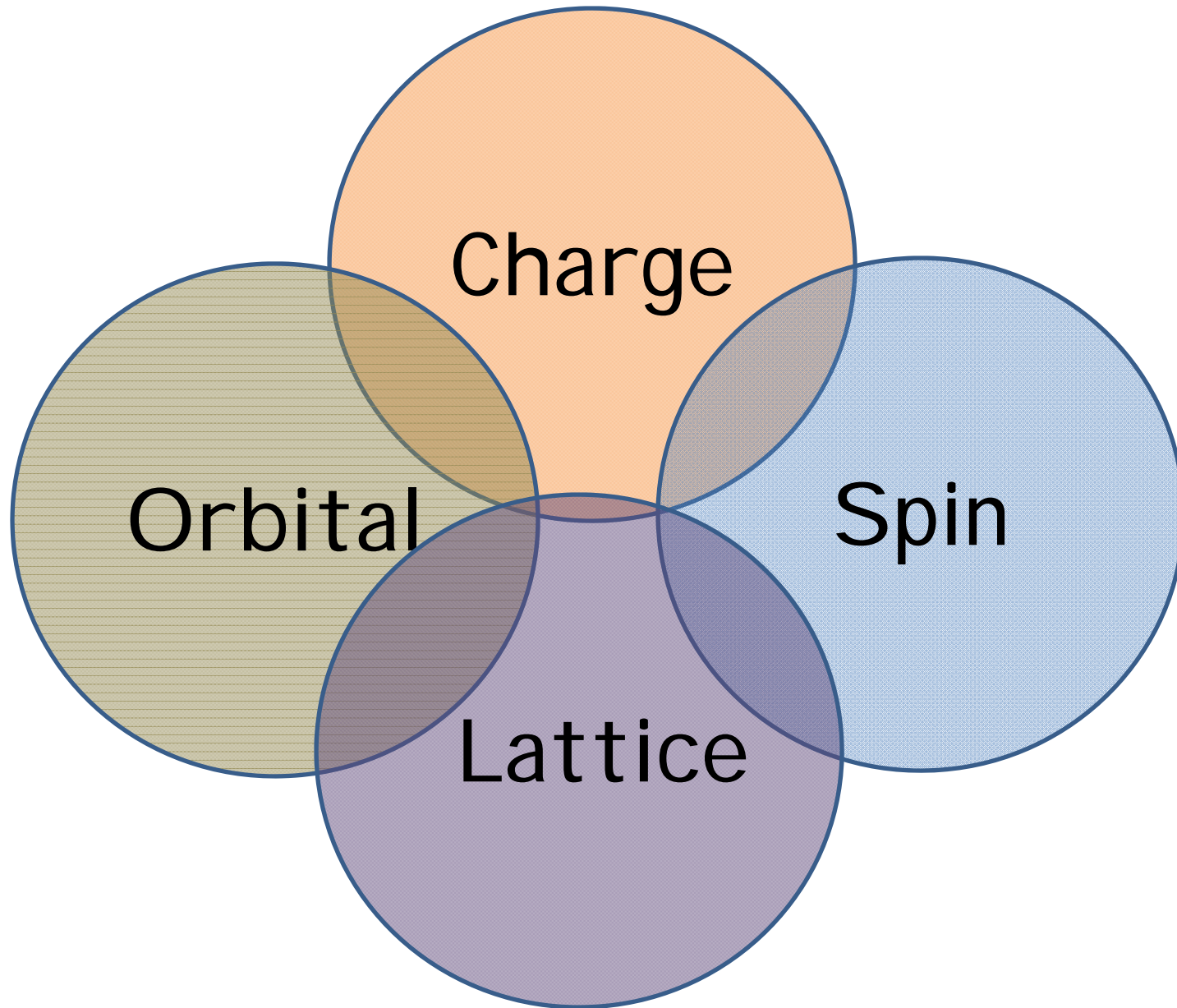
4th generation sources (ERL)

Future:

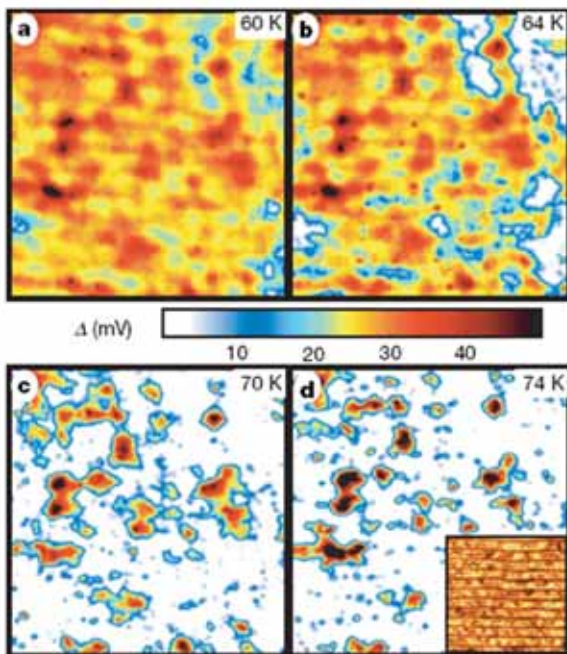


$10^{10}+$ ph/sec

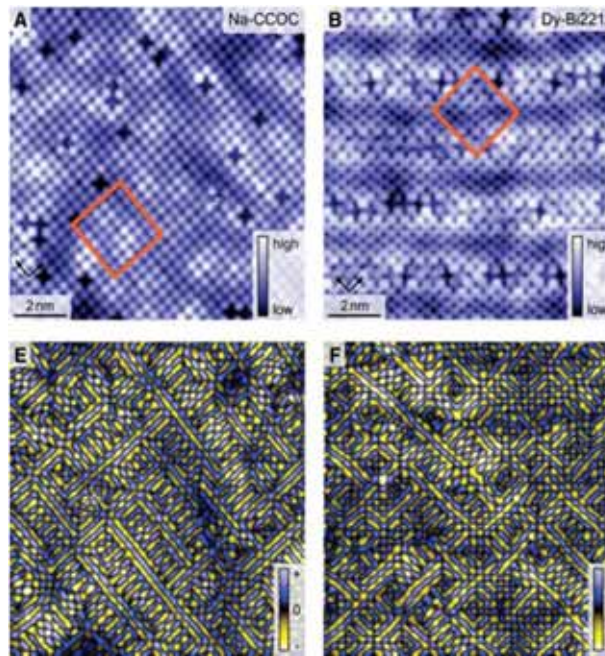
Correlated Electron Systems:



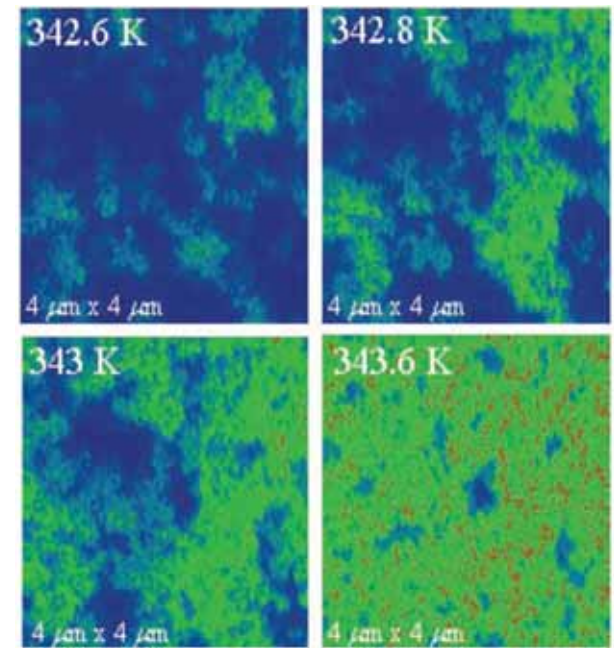
Stripe, "puddles" and domains in strongly correlated materials



Gomes et al.,
Nature 447, 569 (2007)
 SC Gap in BSCCO
 (Yazdani Group, Princeton)



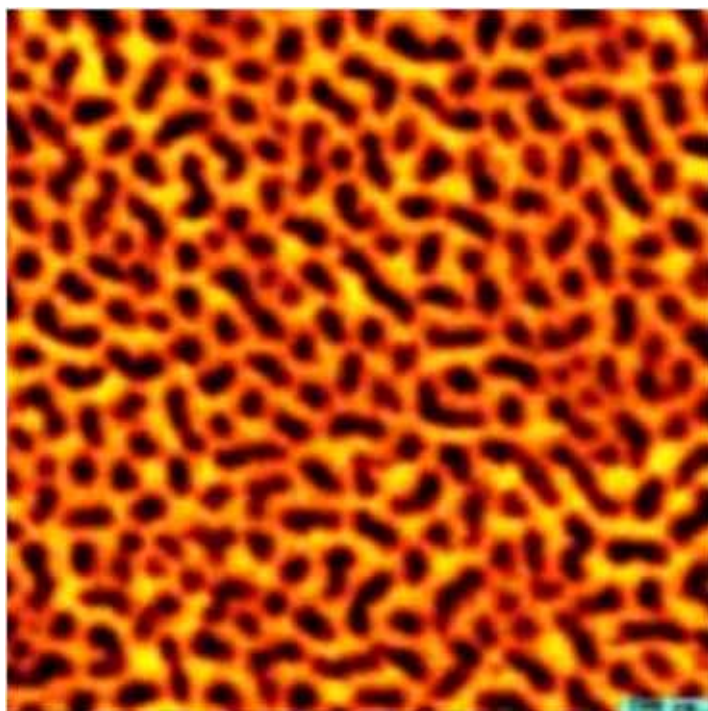
Kohsaka et al.,
Science 315, 1380 (2007)
 SC Gap in Na-CCOC and
 Dy-Bi2212 (Davis Group, Cornell)



Qazilbash et al.,
Science 318, 1750 (2007)
 Metal-Insulator Transition in
 VO₂ (Basov Group, UCSD)

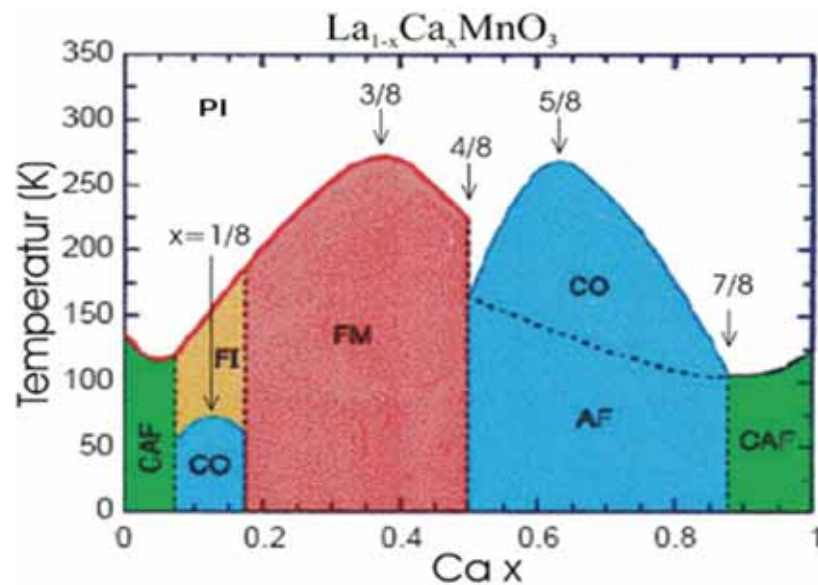
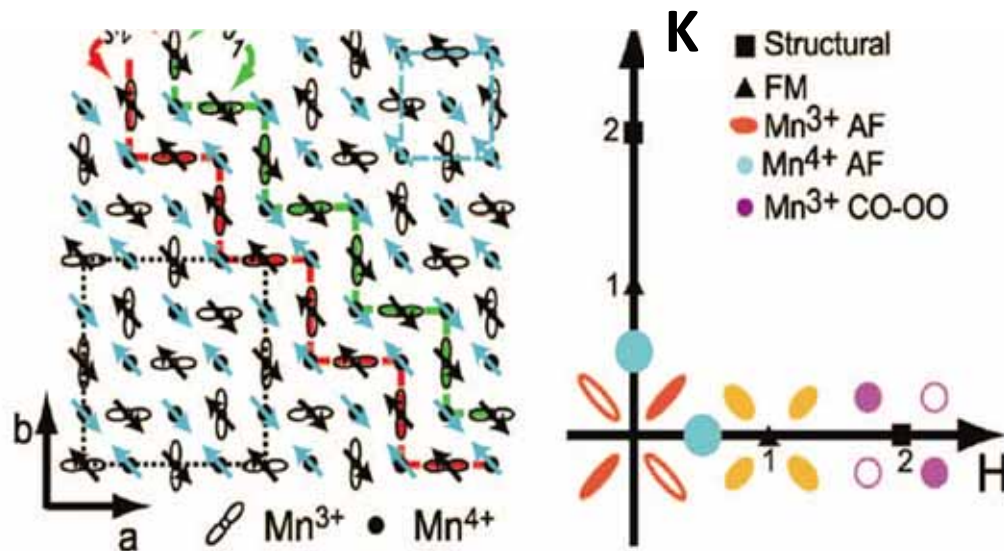
Manganites:

F. Ye et al., Phys Rev. B **72**, 212404 (2005)

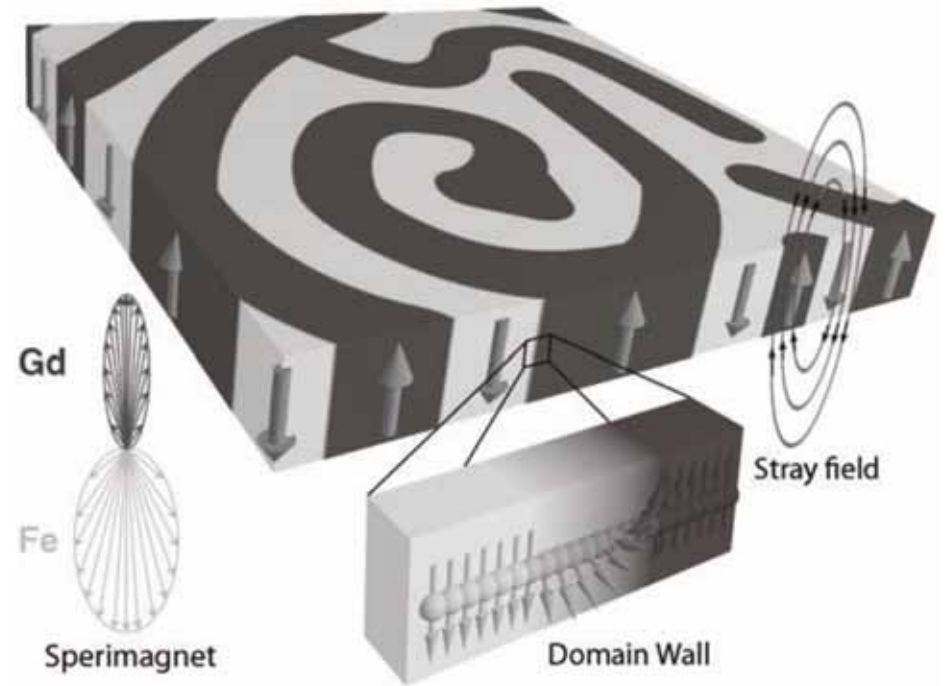
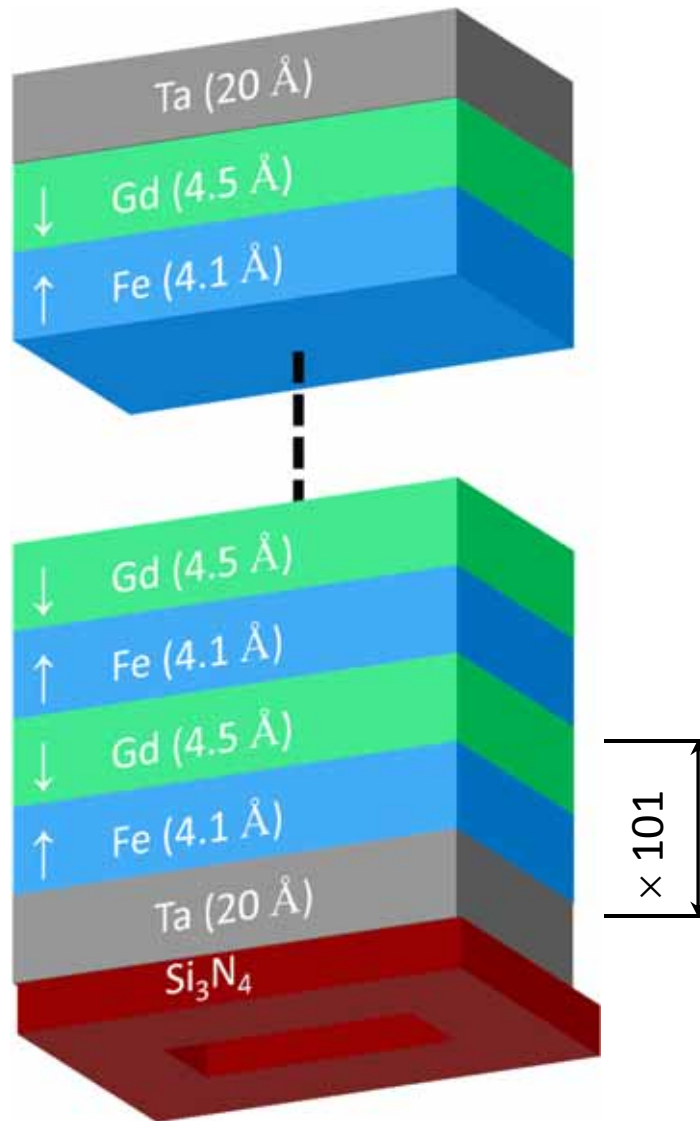


Phase separation
in $\text{La}_{1-x}\text{Ca}_x\text{MnO}_3$

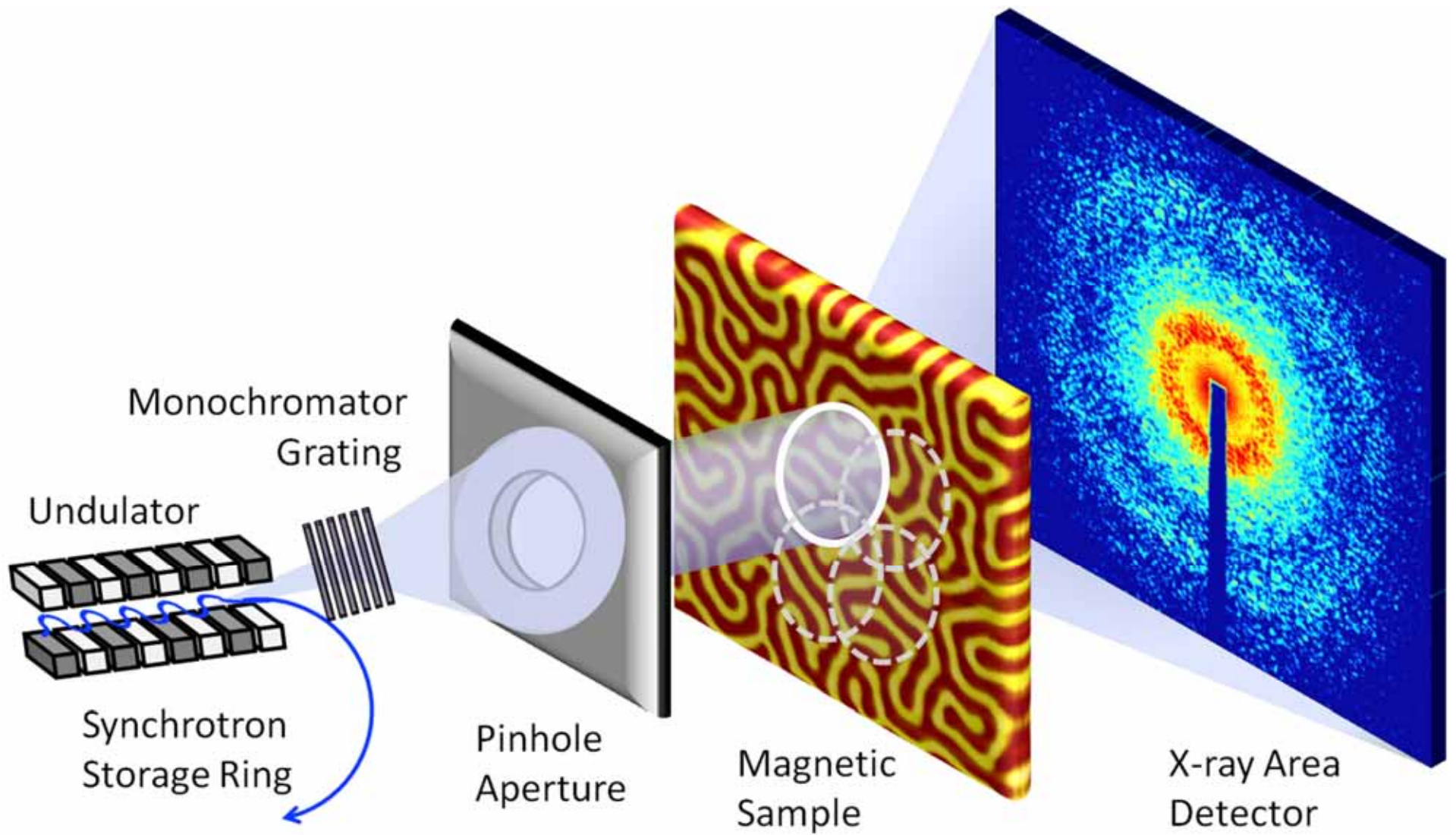
Ian McNulty's Talk
(Coming up NEXT!)

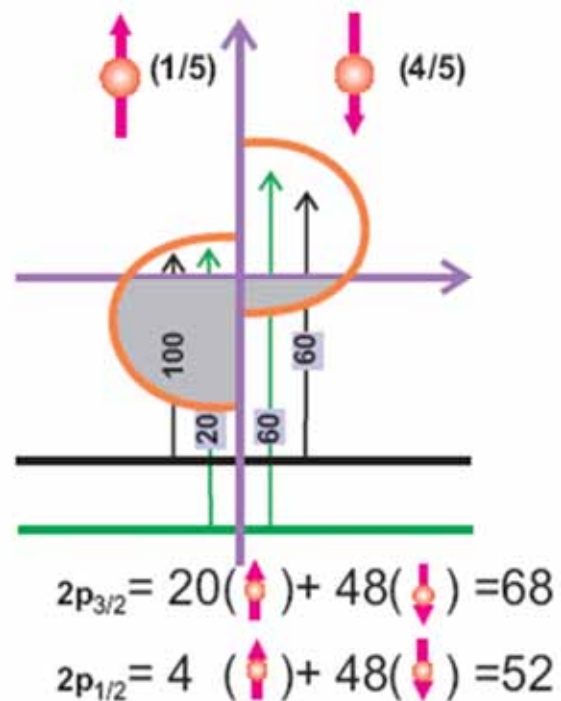
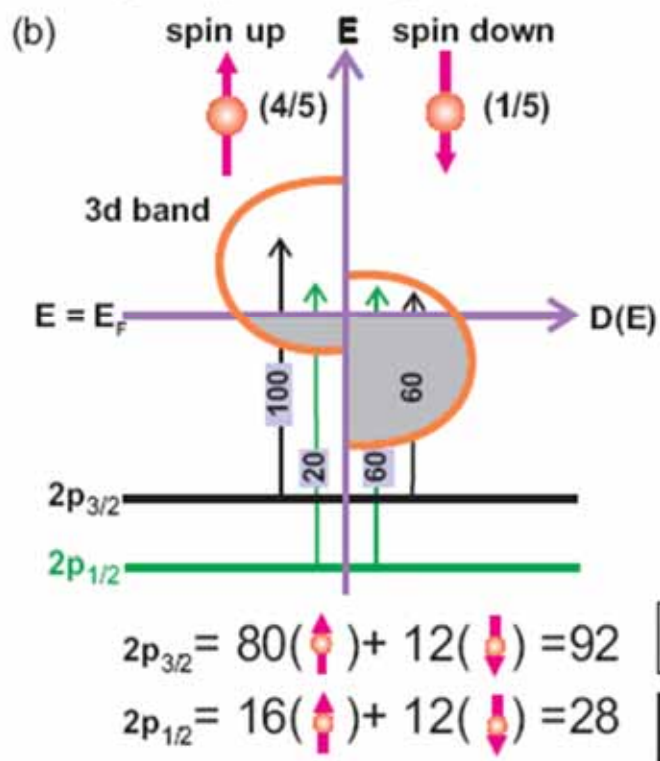
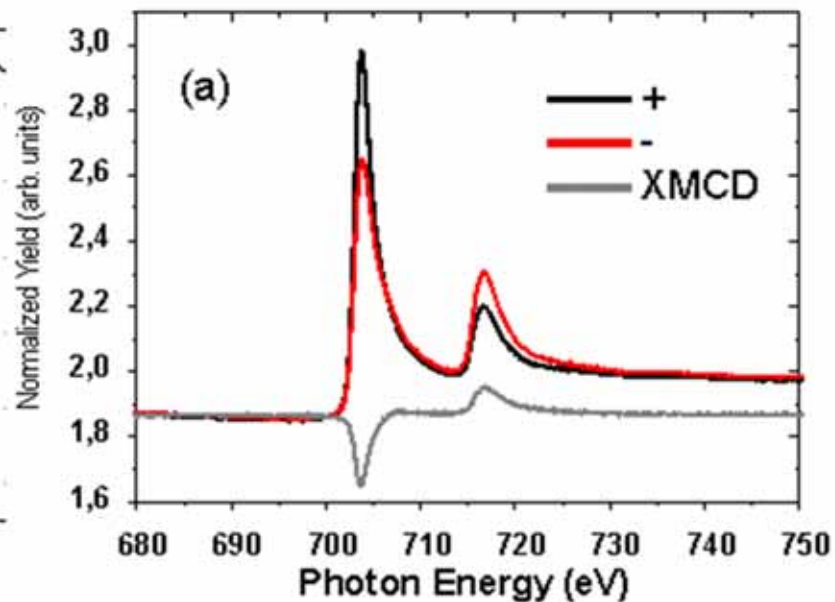
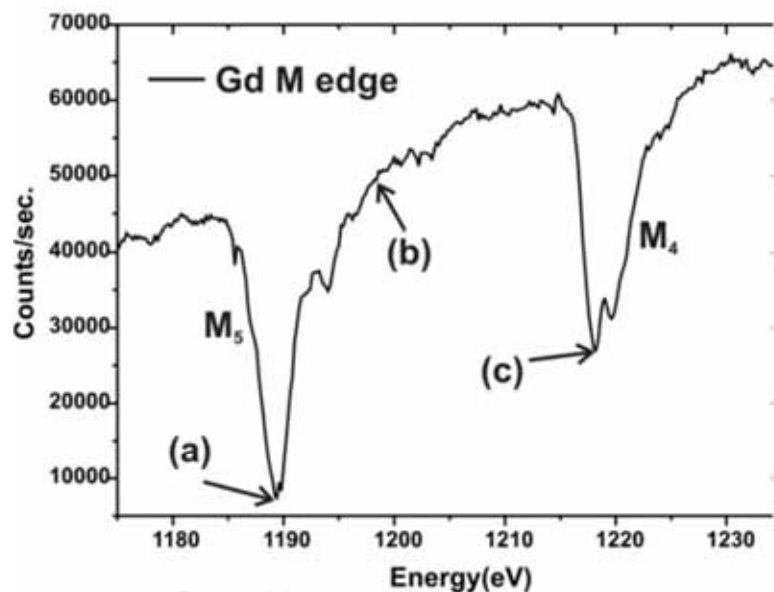


GdFe layered thin PMA films



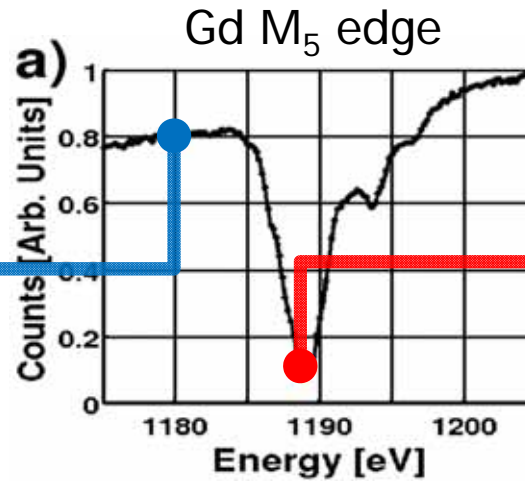
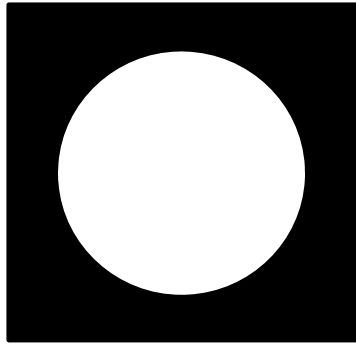
$$E_{tot} = \int \left[\underbrace{e_{ex}(\mathbf{m})}_{exchange} + \underbrace{e_{an}(\mathbf{m})}_{anisotropy} - \underbrace{\mu_0 \mathbf{H}_{ex} \cdot \mathbf{M}}_{ext. field} + \underbrace{\frac{1}{2} \mu_0 \mathbf{H}_d^2}_{stray field} \right] dV$$



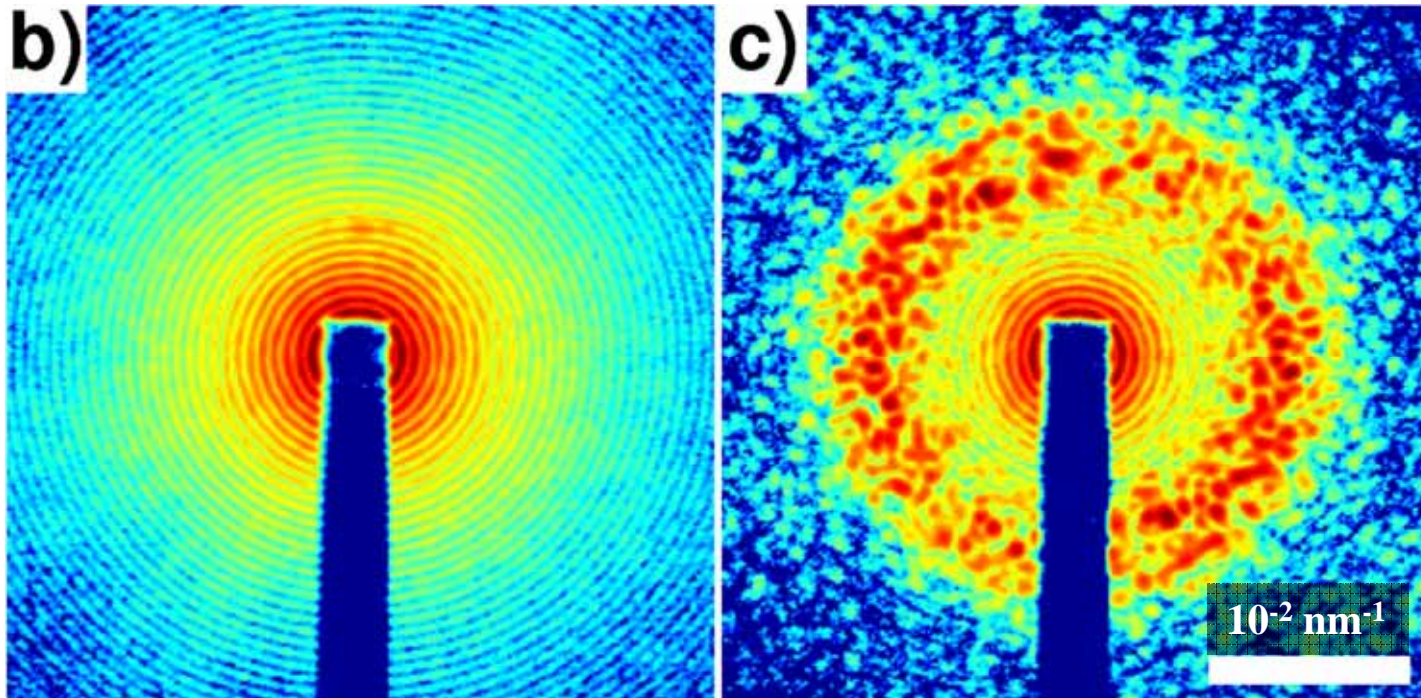
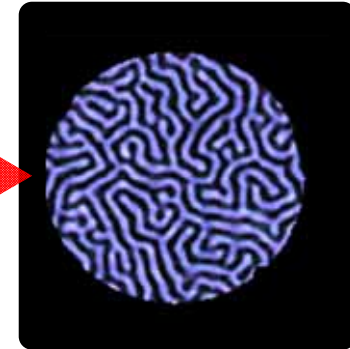


Magnetic Contrast Mechanism

Off-resonance: ●



On-resonance: ●



Circular dichroism with linearly polarized x-rays?

$$\longleftrightarrow = \curvearrowright + \curvearrowleft = (\text{Charge})^2 + (\text{Magnetic})^2$$



:



$$(\text{Charge} + \text{Magnetic})^2 = C^2 + 2C \times M + M^2$$



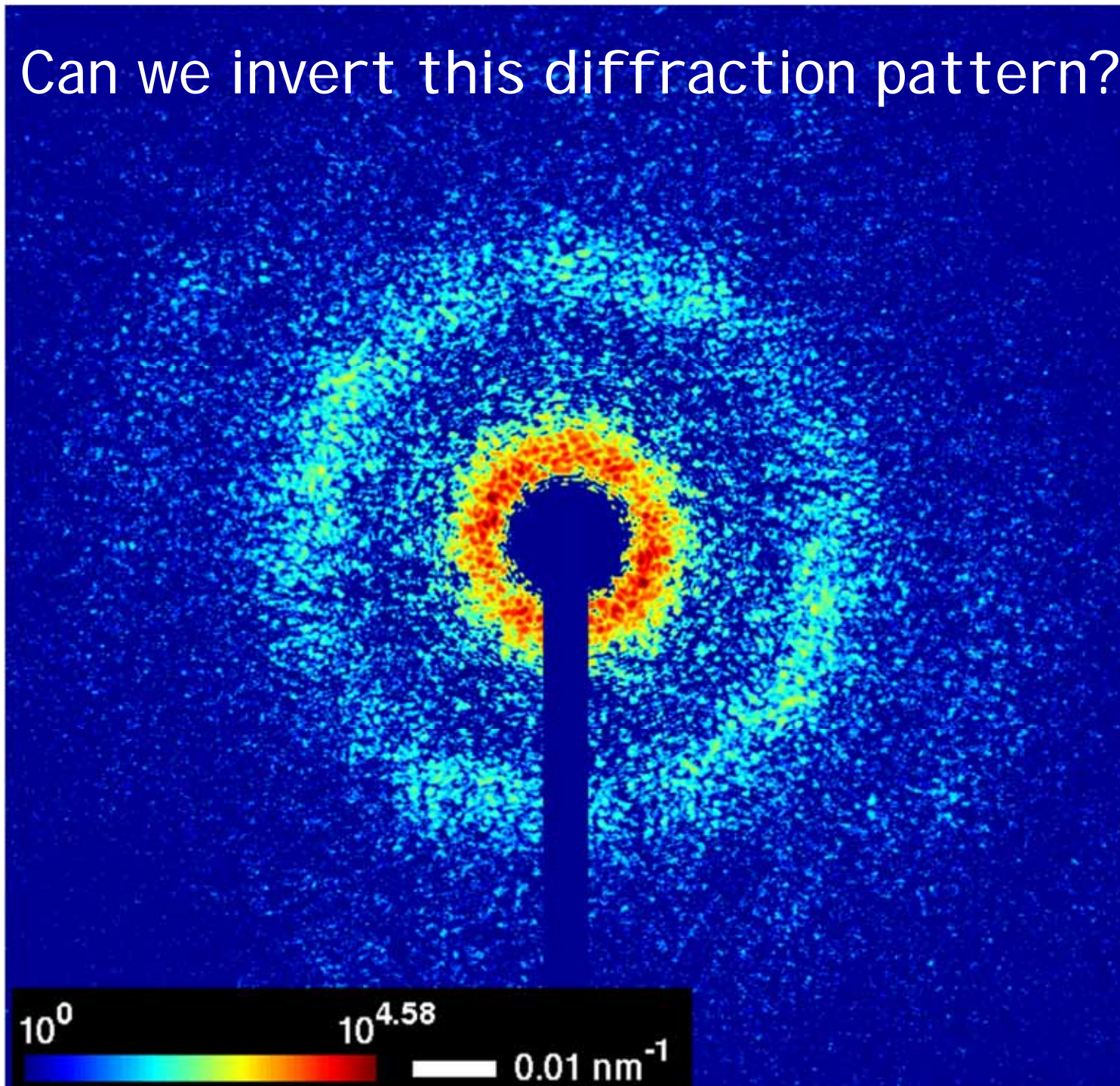
:

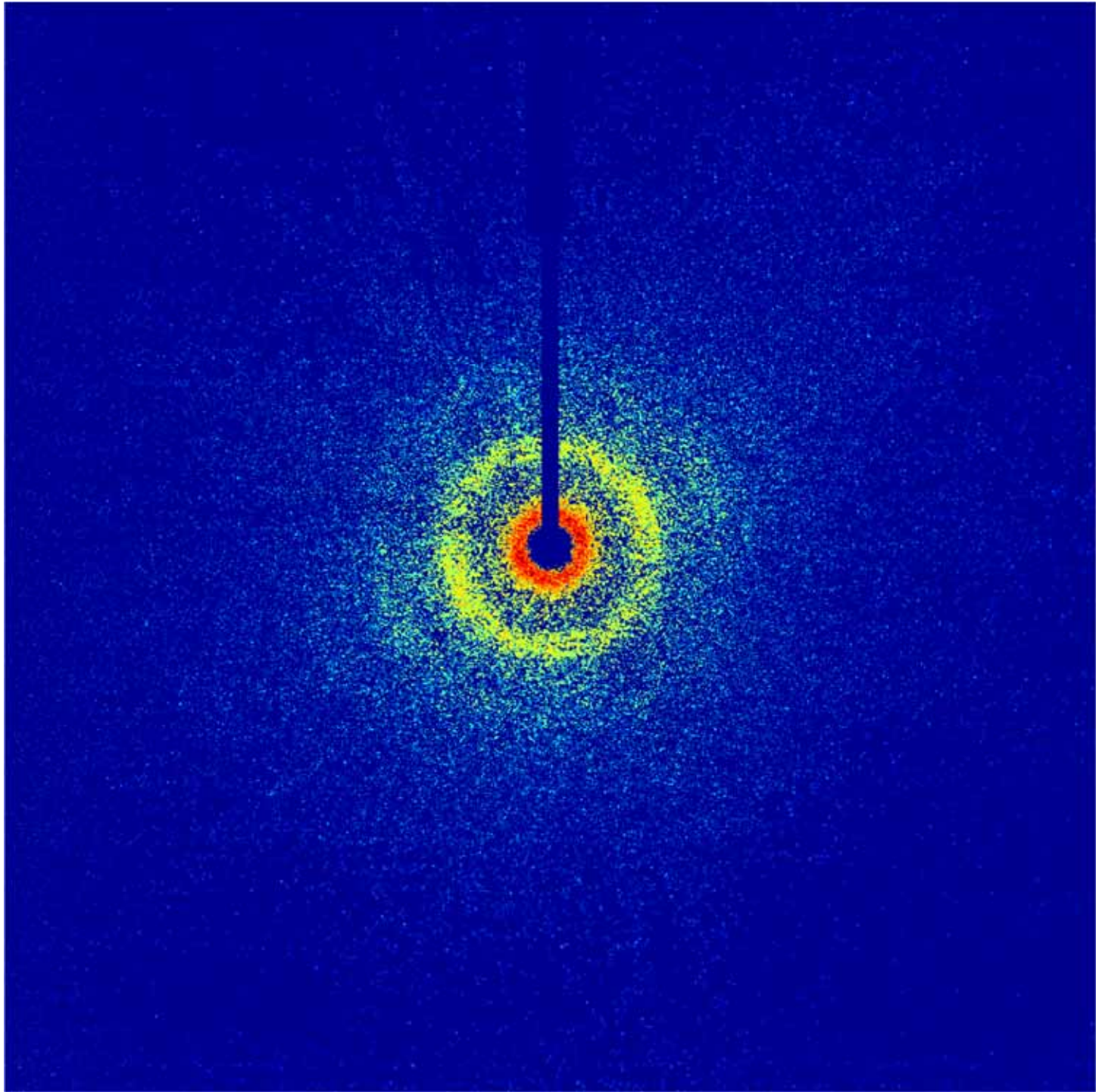


$$(\text{Charge} - \text{Magnetic})^2 = C^2 - 2C \times M + M^2$$

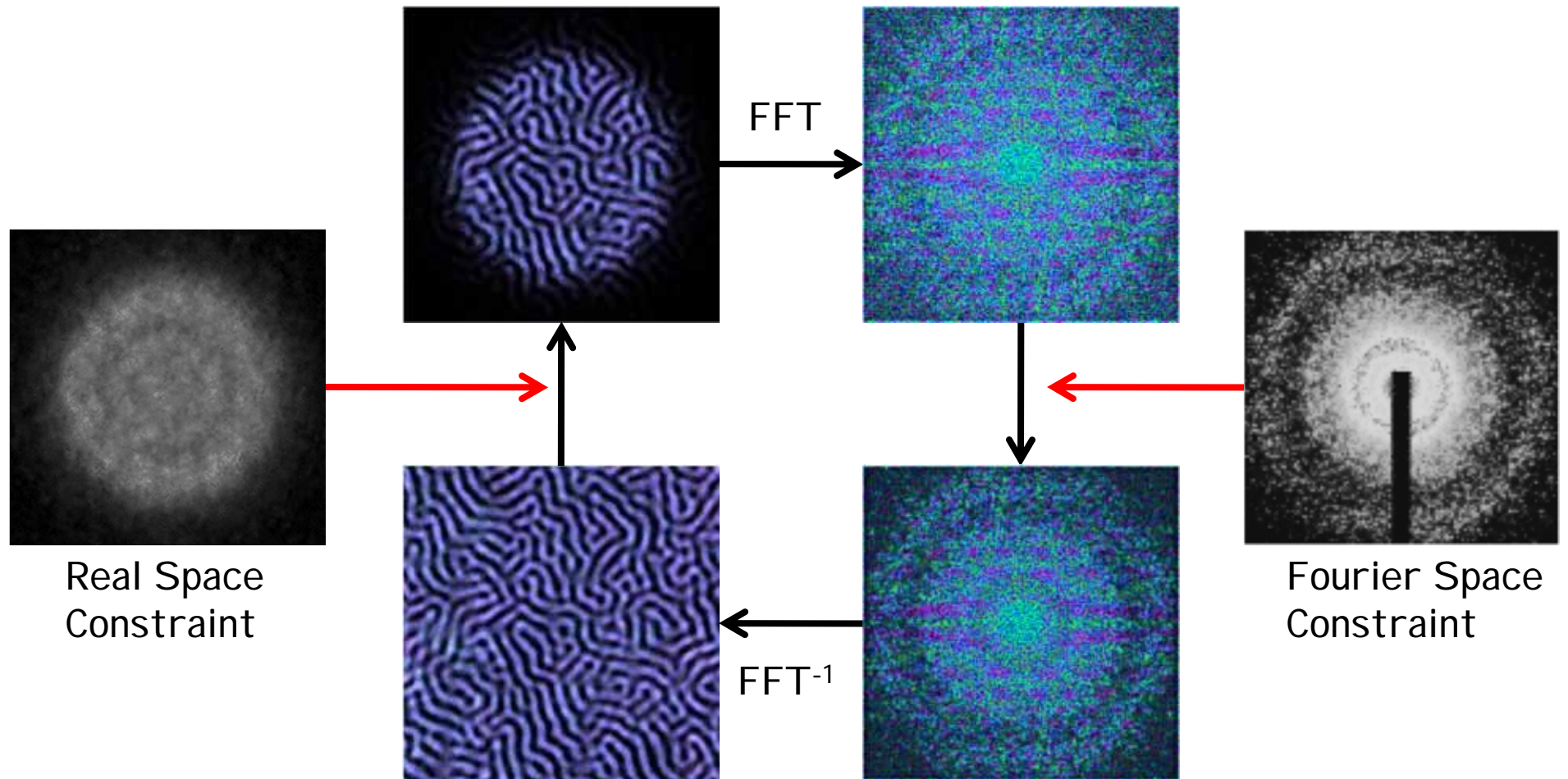


Can we invert this diffraction pattern?

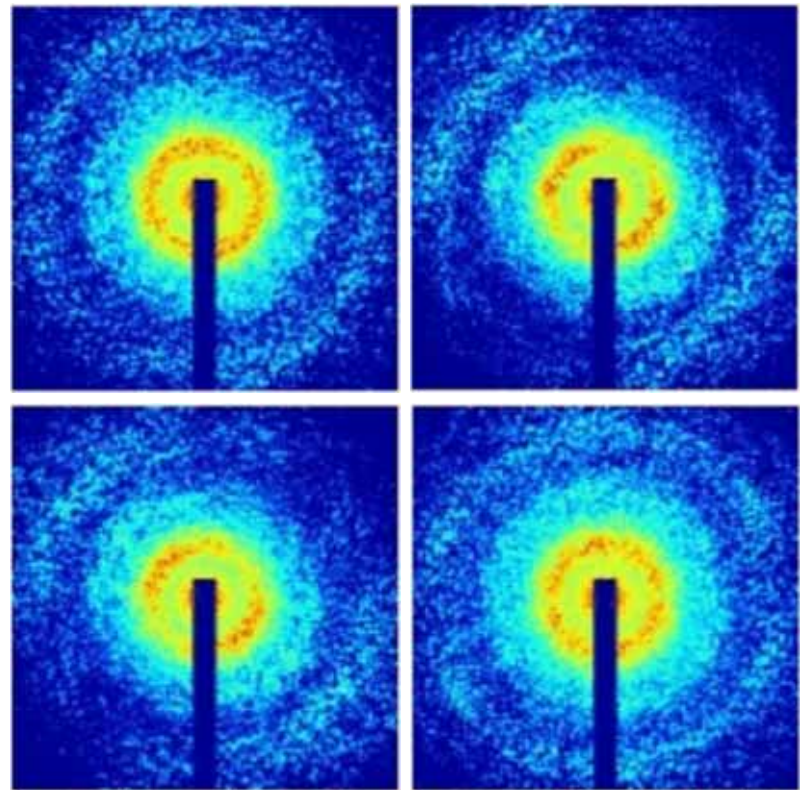
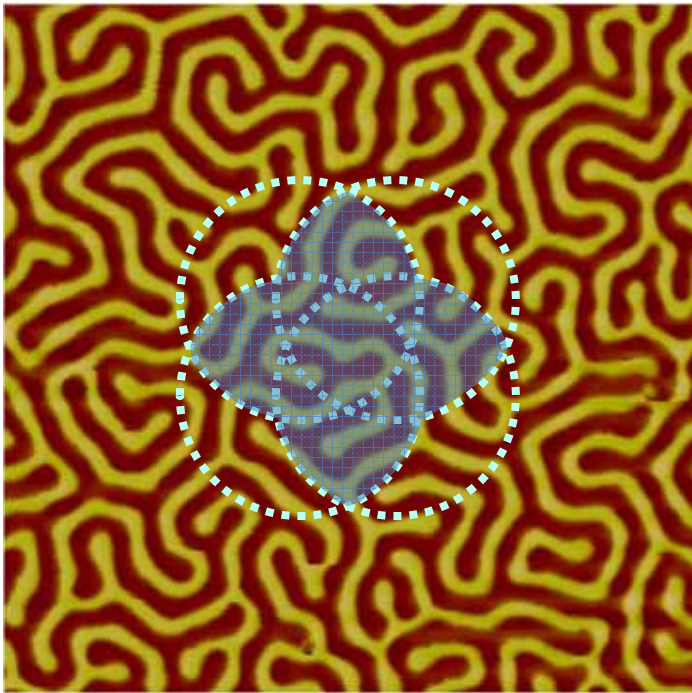




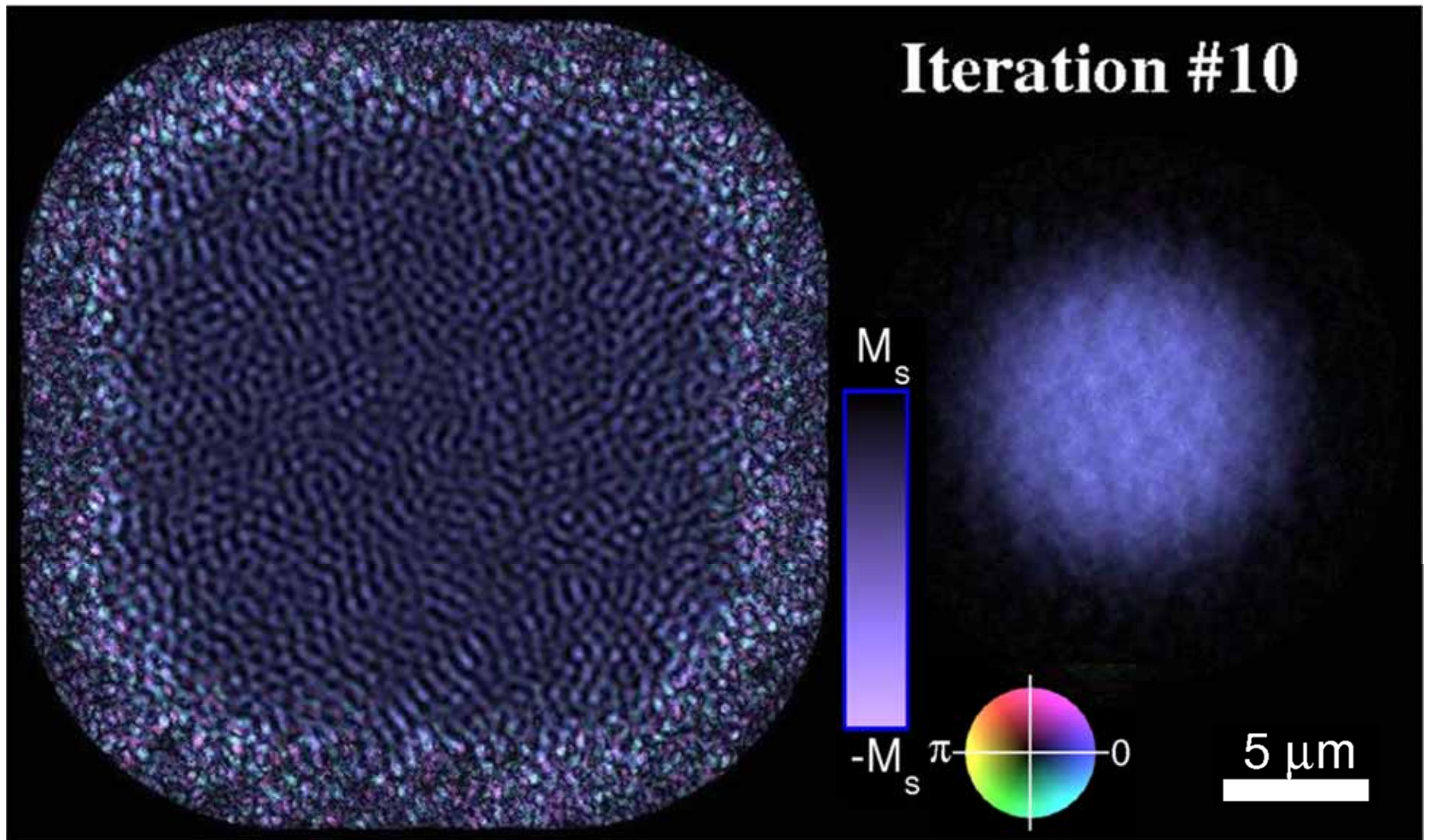
Phase Retrieval Algorithm



Ptychography



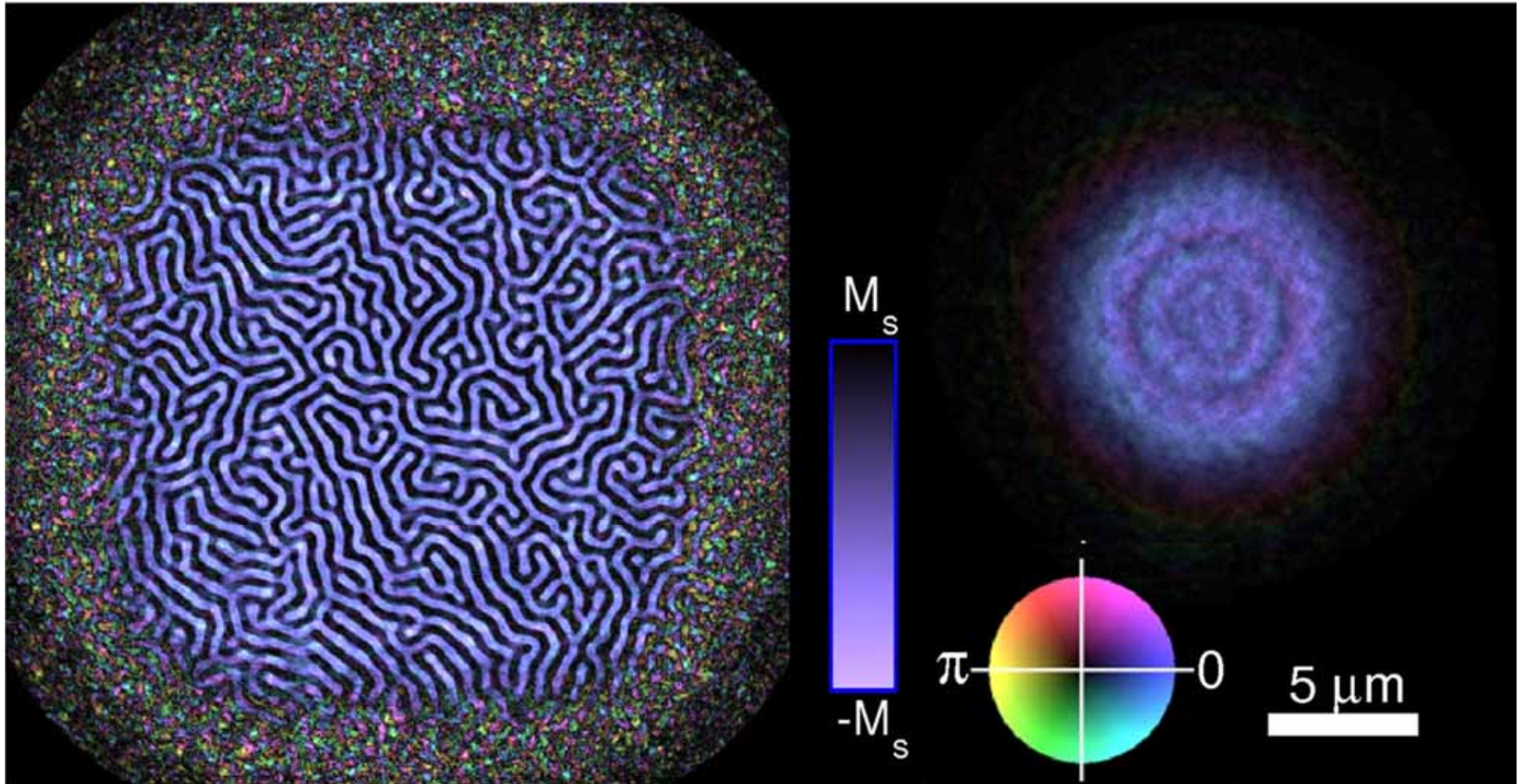
Real Space Reconstruction



Magnetic structure
(exit wave)

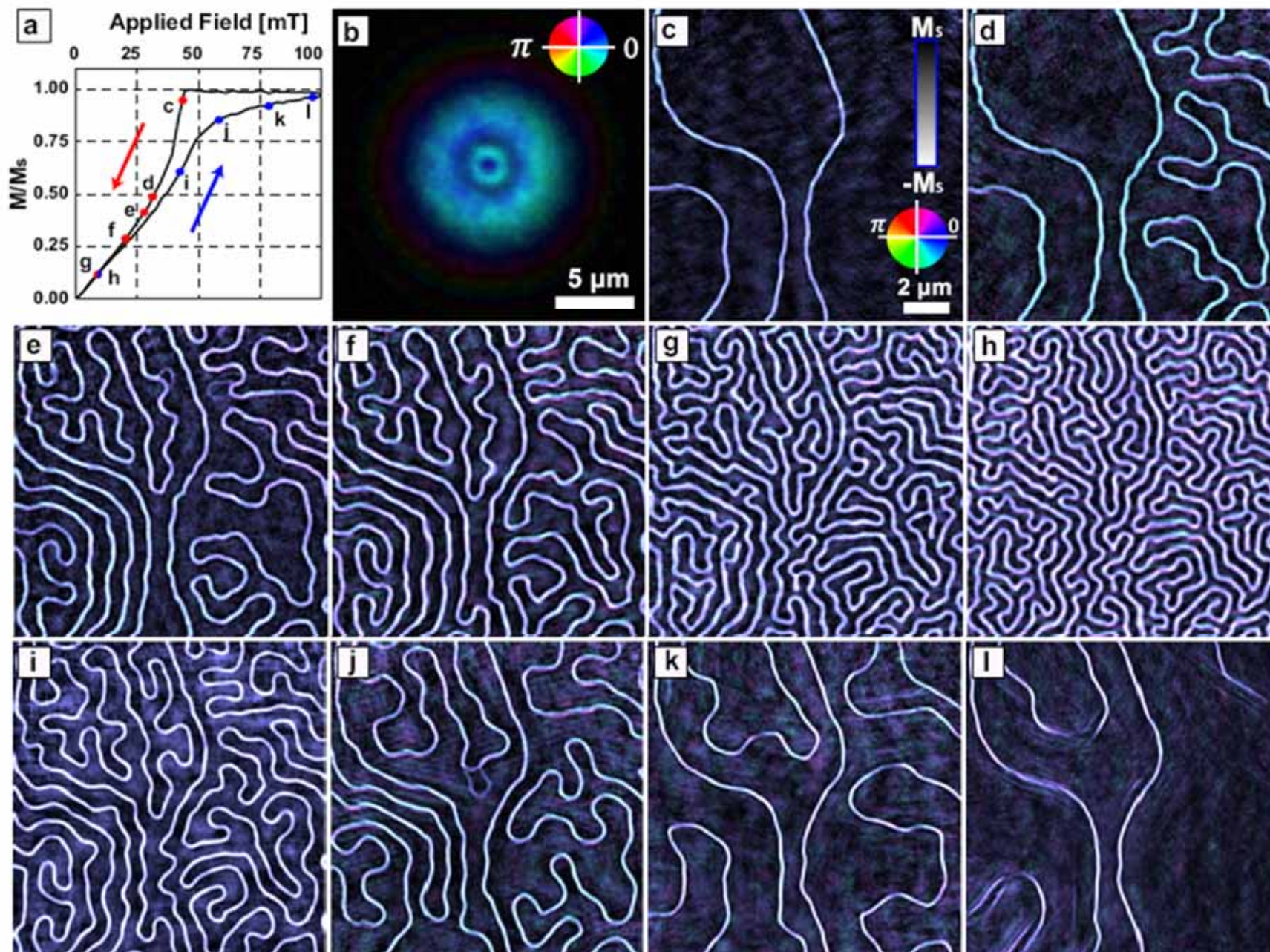
I Illumination Function

Real Space Reconstruction

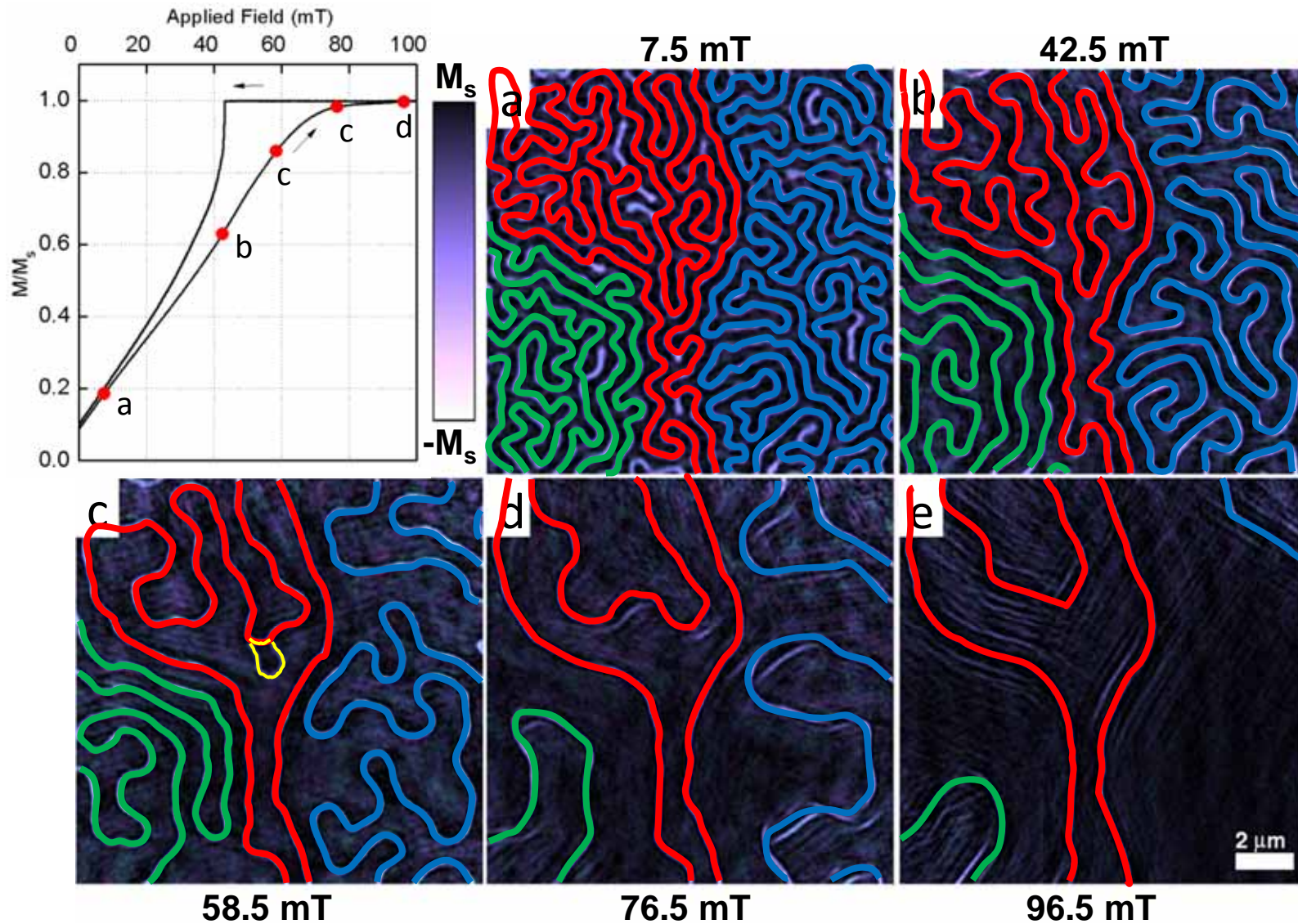


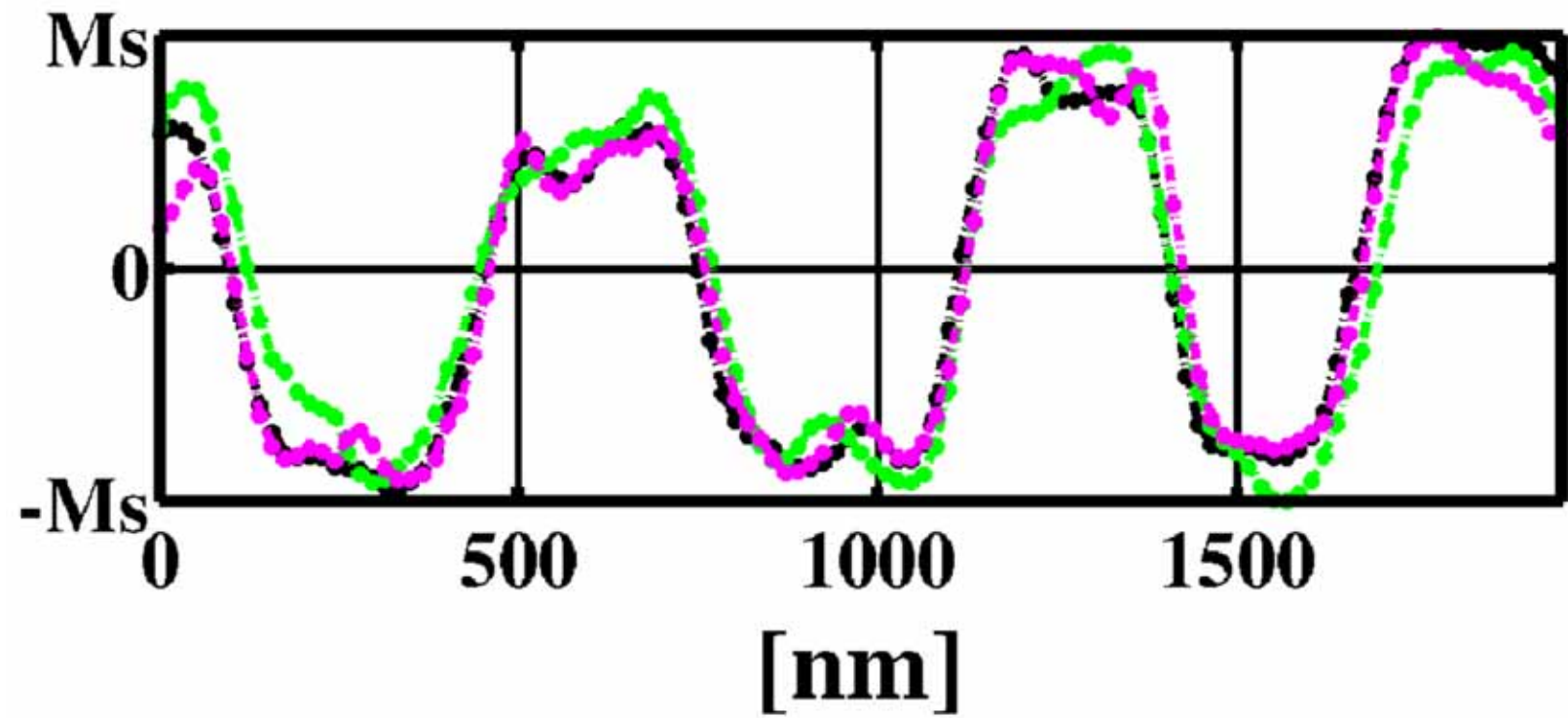
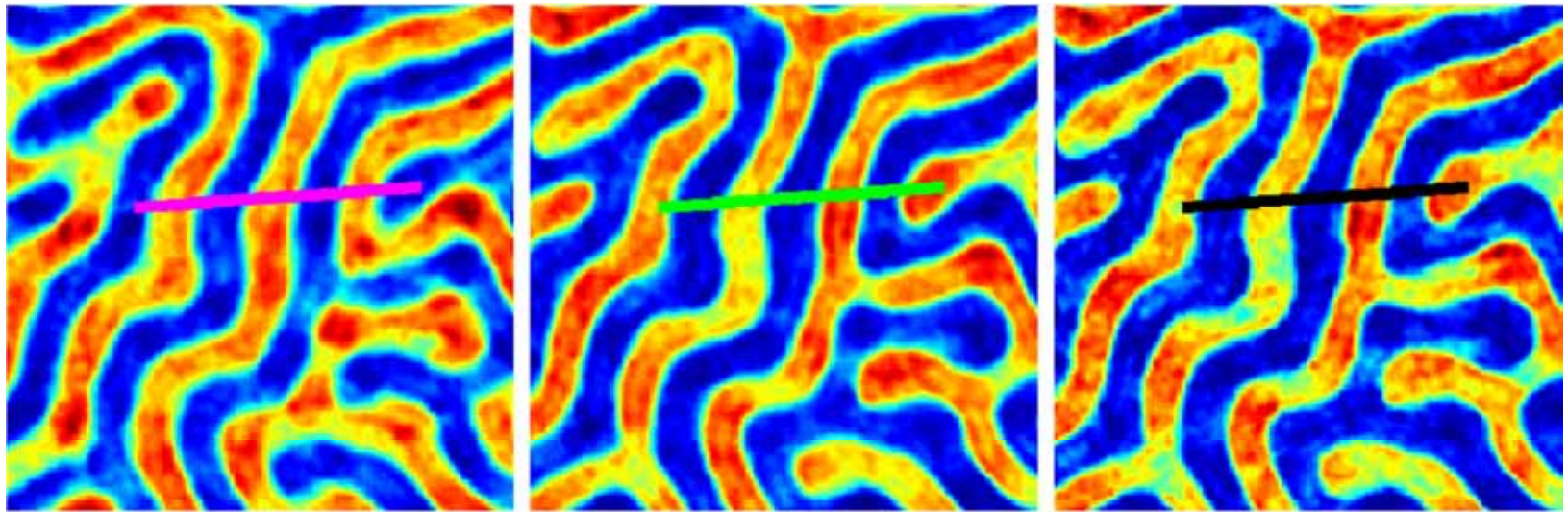
Magnetic structure
(exit wave)

I Illumination Function

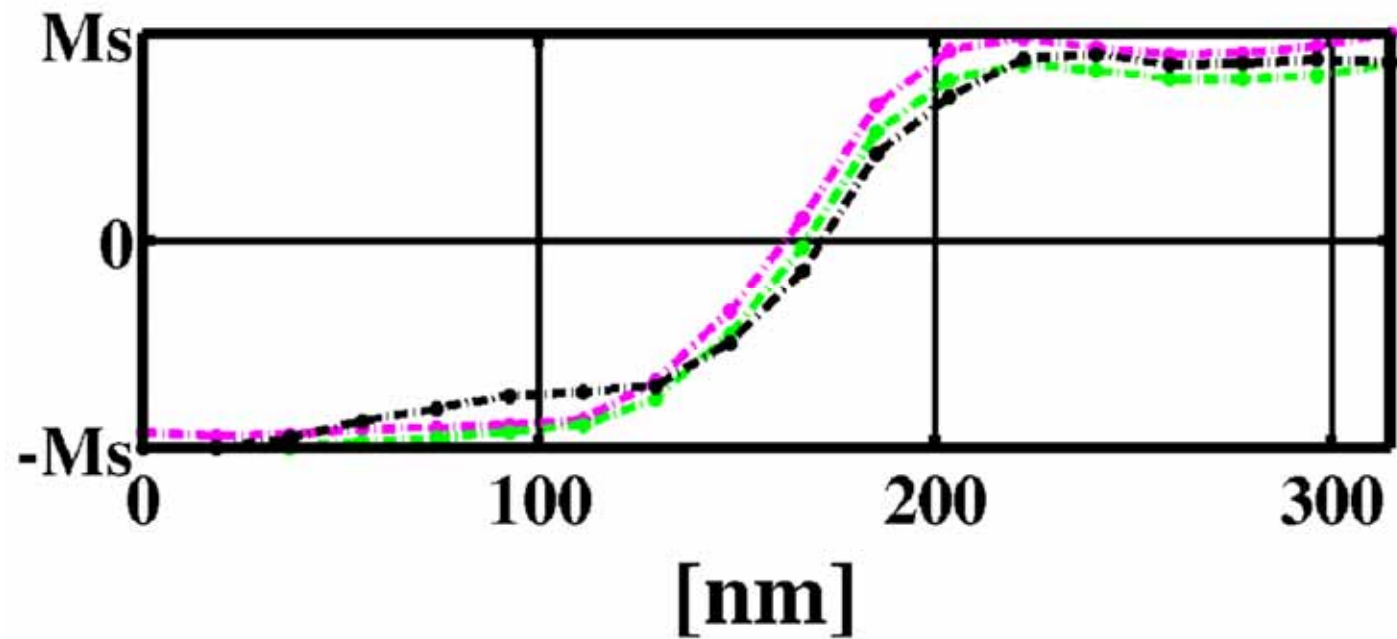
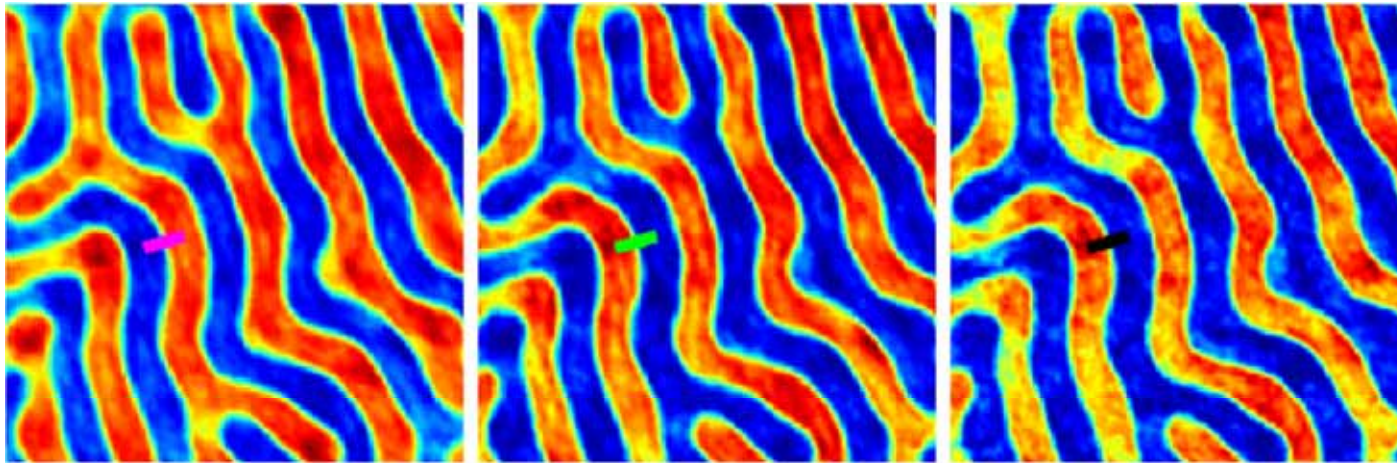


Increasing Field

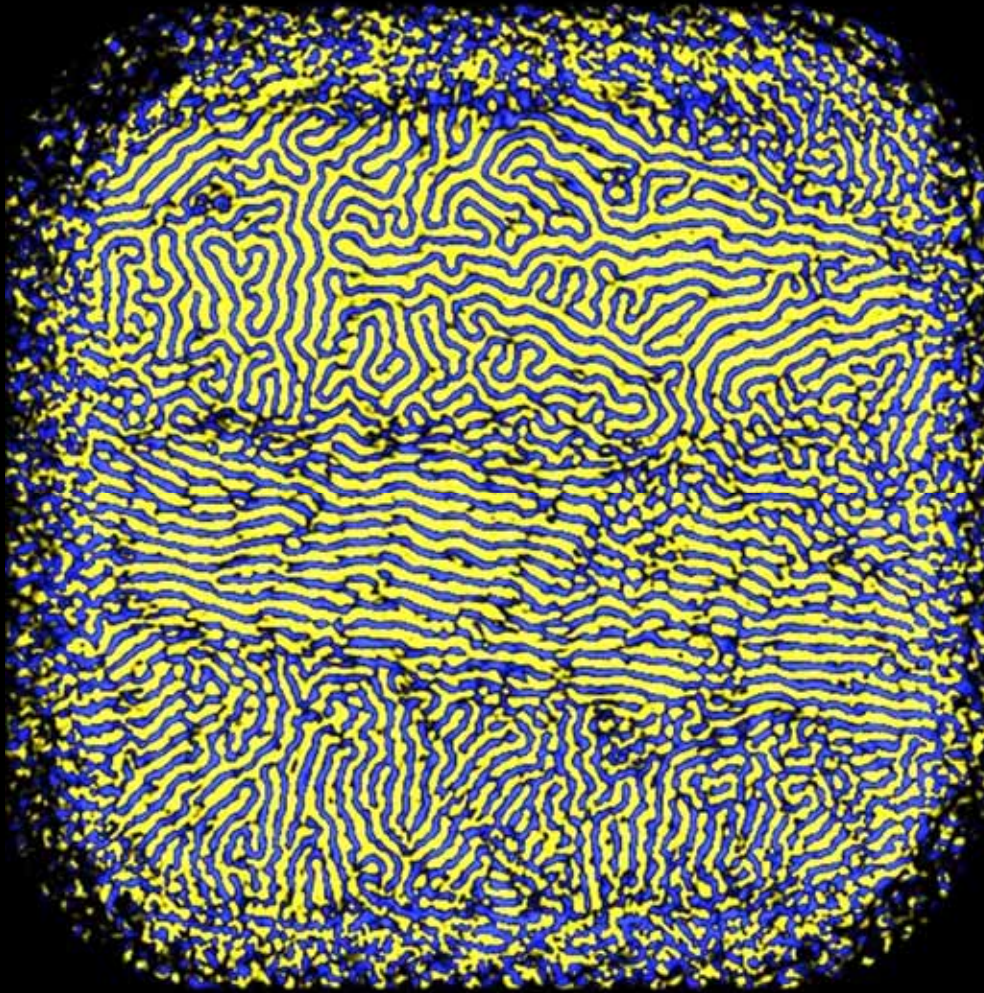




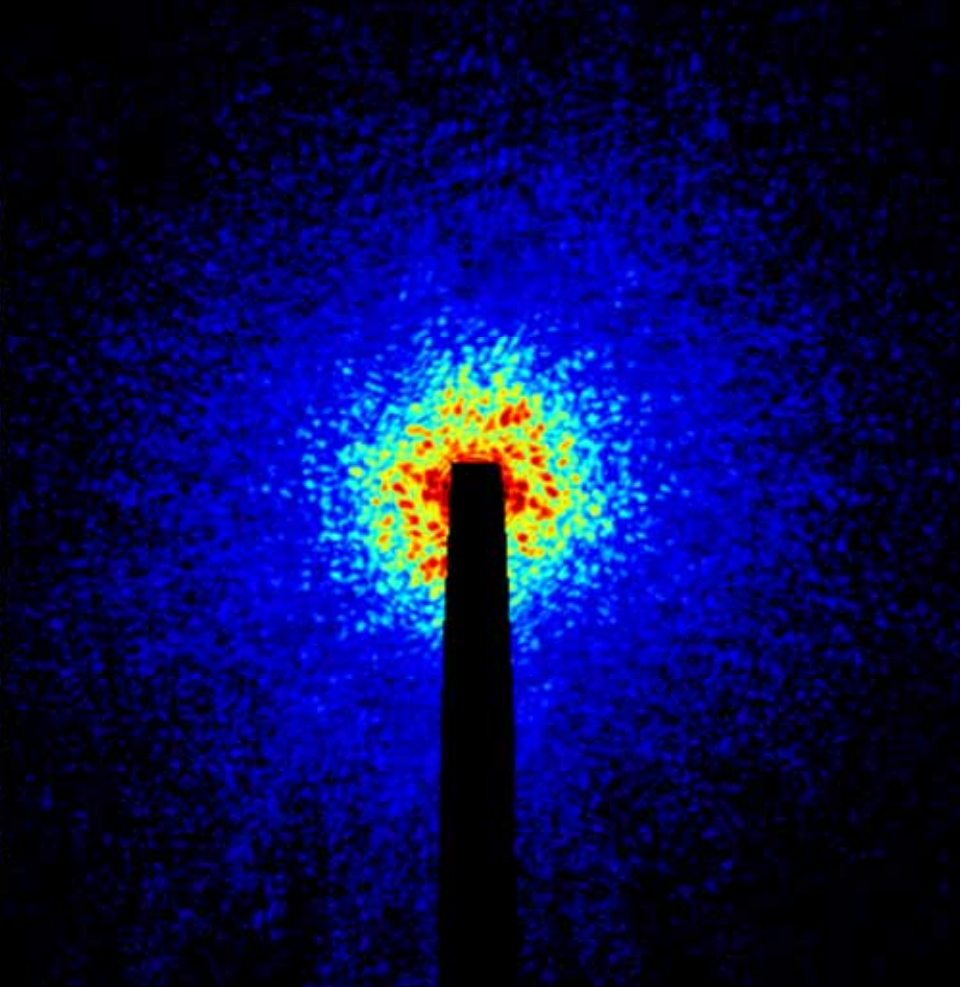
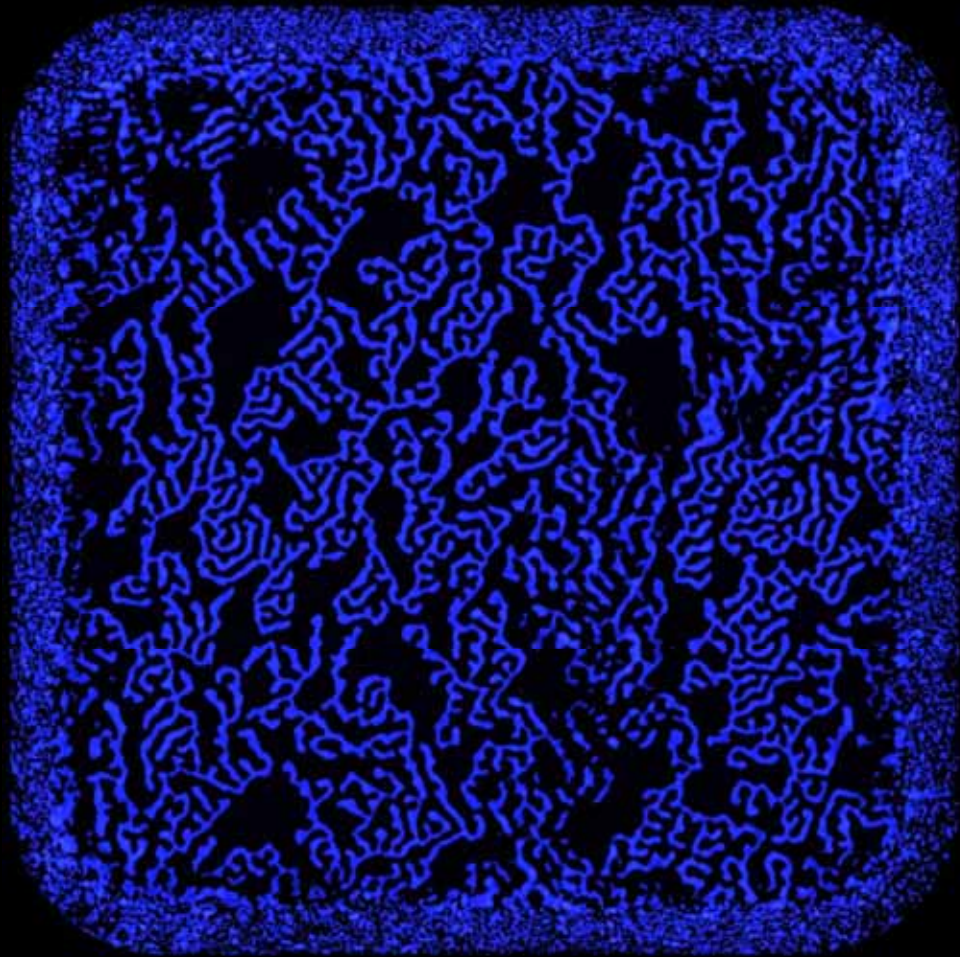
Resolution of reconstruction: 55 nm
(30 nm Block domain wall)

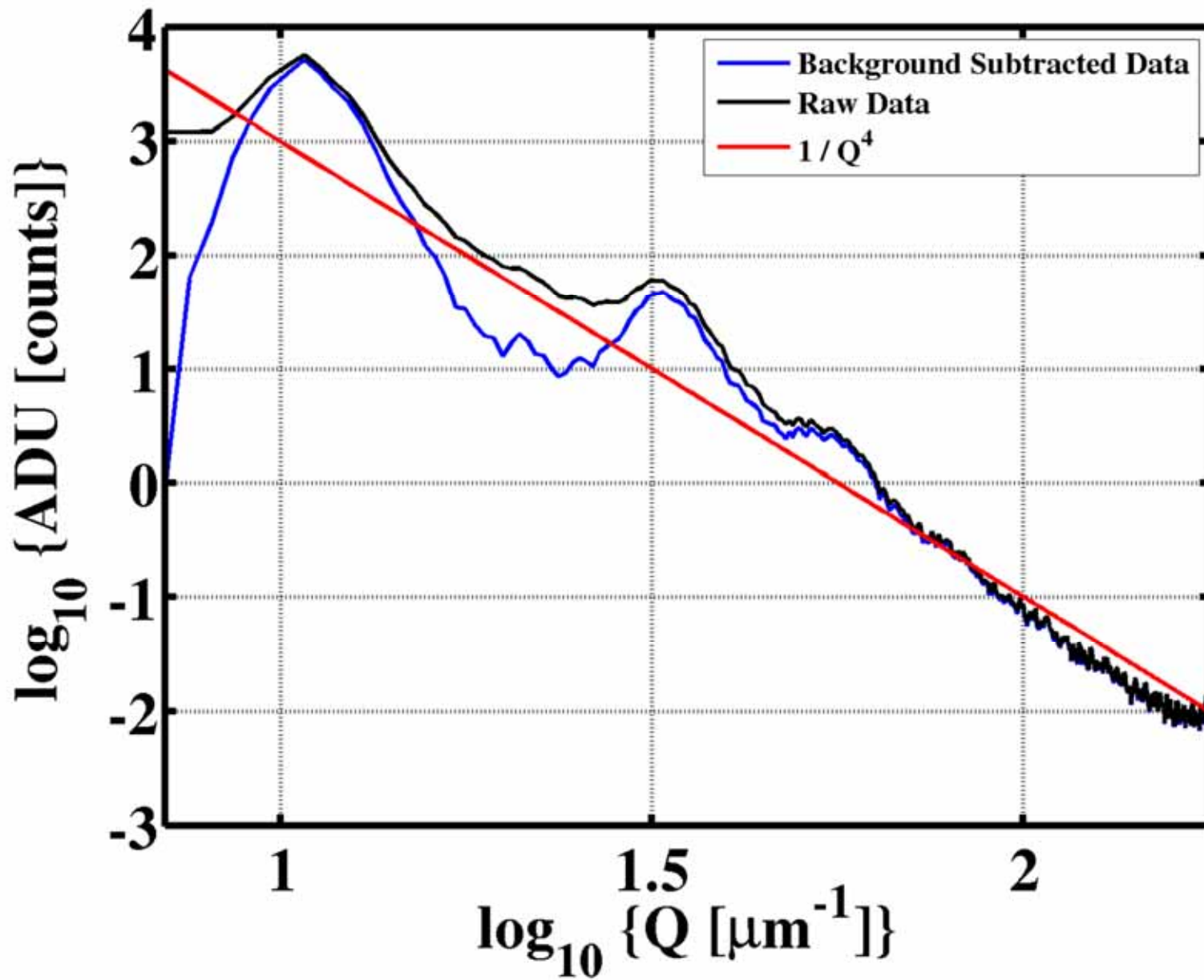


Interactions with Defects:

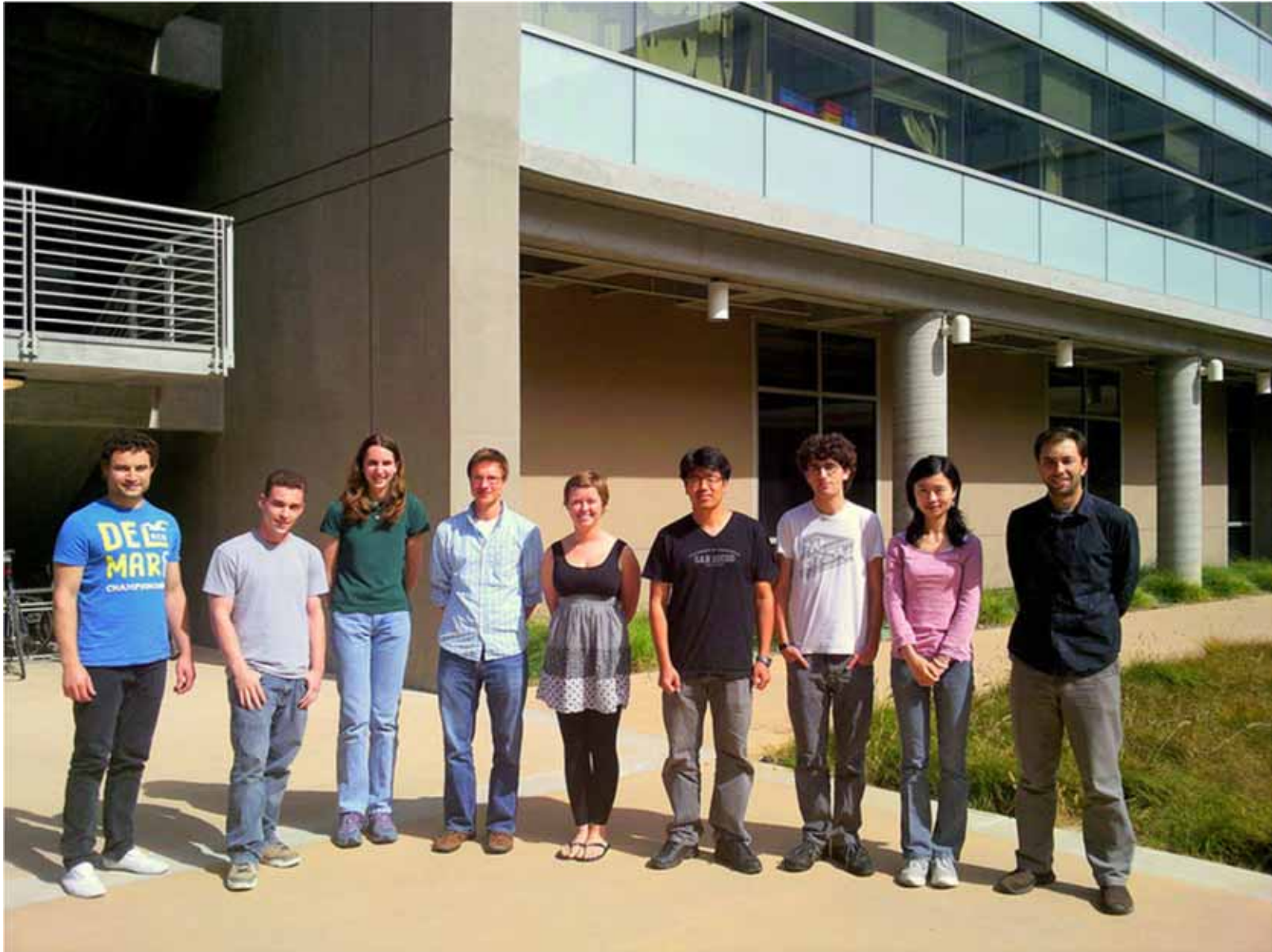


Random disorder





Our Group at UC San Diego



Our Group at UC San Diego

Ash Tripathi

Edwin Fohtung



ERL Experiments

Experiments we want to do...

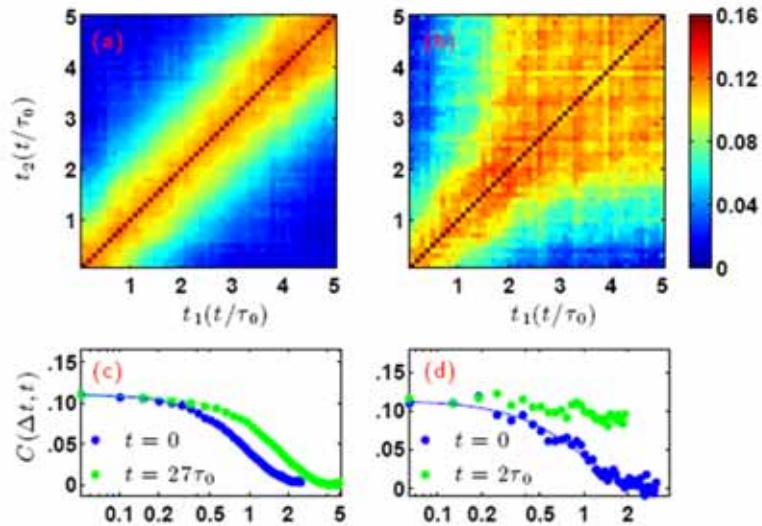
...but haven't done yet

(or not able to do yet)

Charge Density Wave Systems

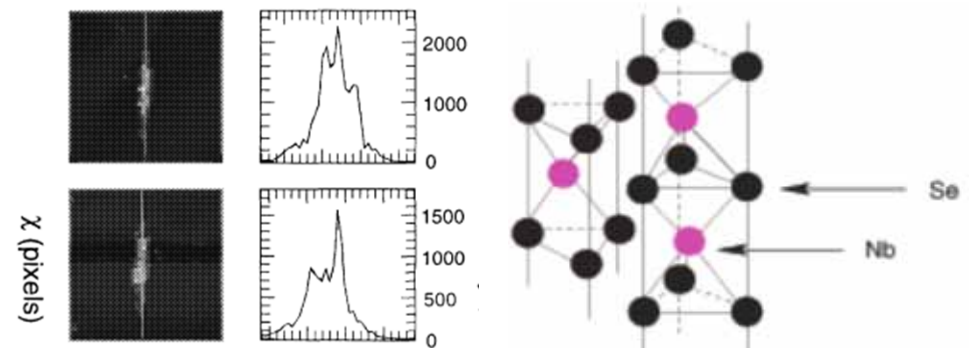
CDW in 1T-TaS₂,

with J.-D. Su, M. Sutton, A. R. Sandy



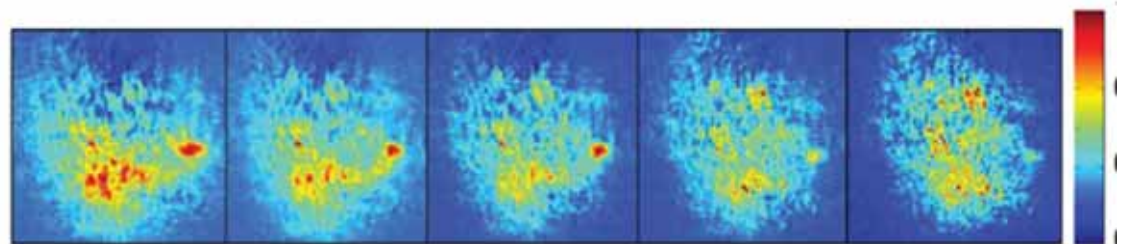
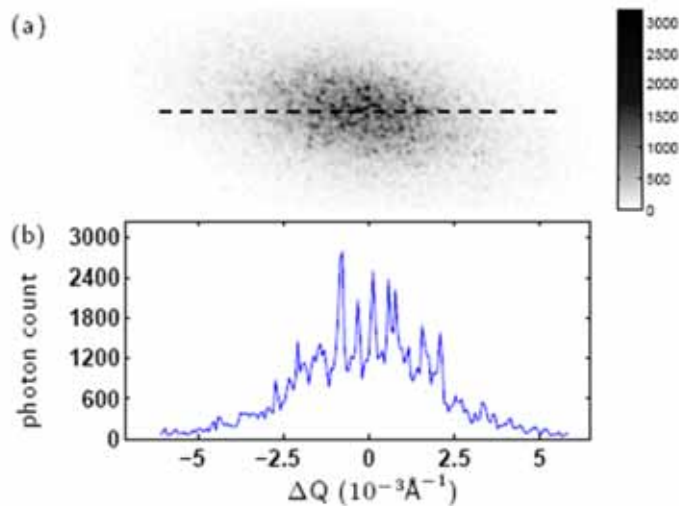
Nb₃Se (classic CDW system)

Sutton, Brock, Thorne et al., J. Phys. 2002, PRB 2001

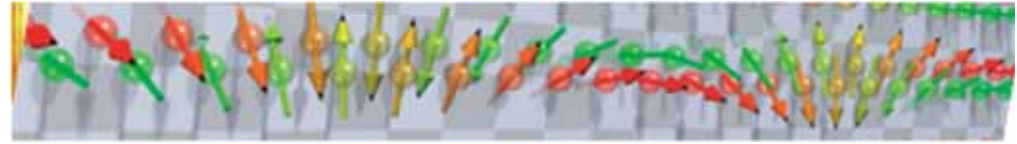
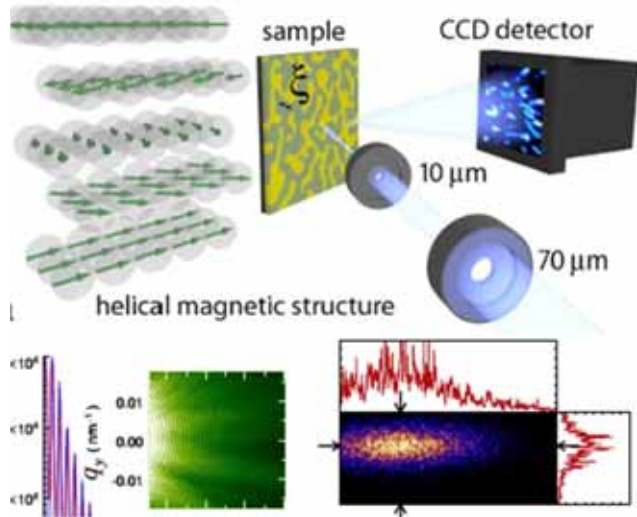


Cr (CDW/SDW Antiferromagnet)

Shpyrko, Isaacs et al., Nature 447, 68 (2007)



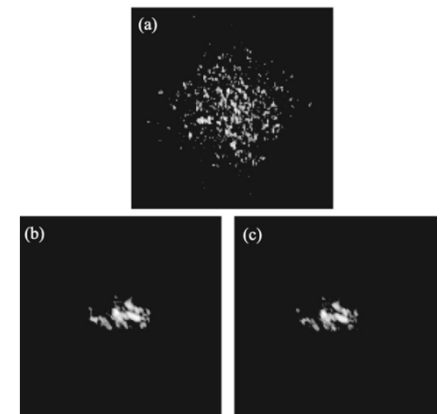
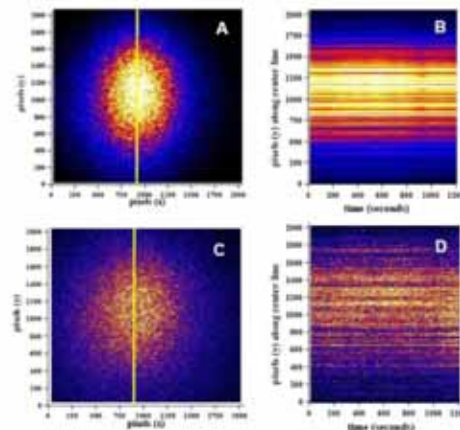
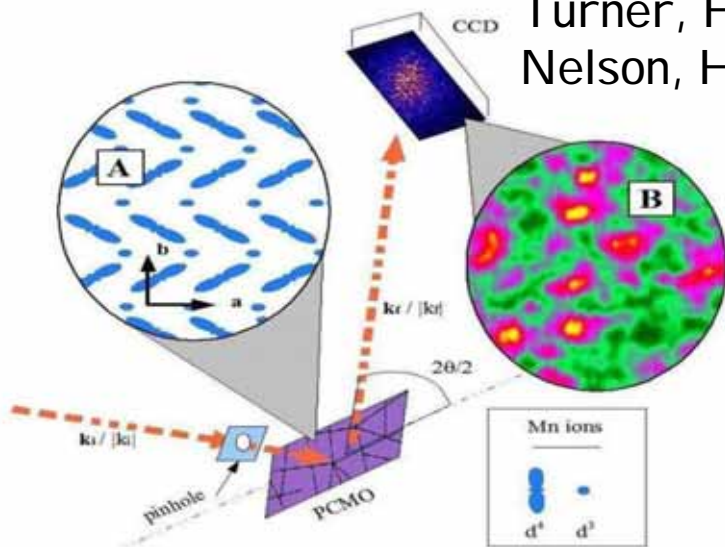
Helical Magnets:



Holmium (helical antiferromagnet)
Koning, Goedkoop, PRL 106, 077402 (2011)

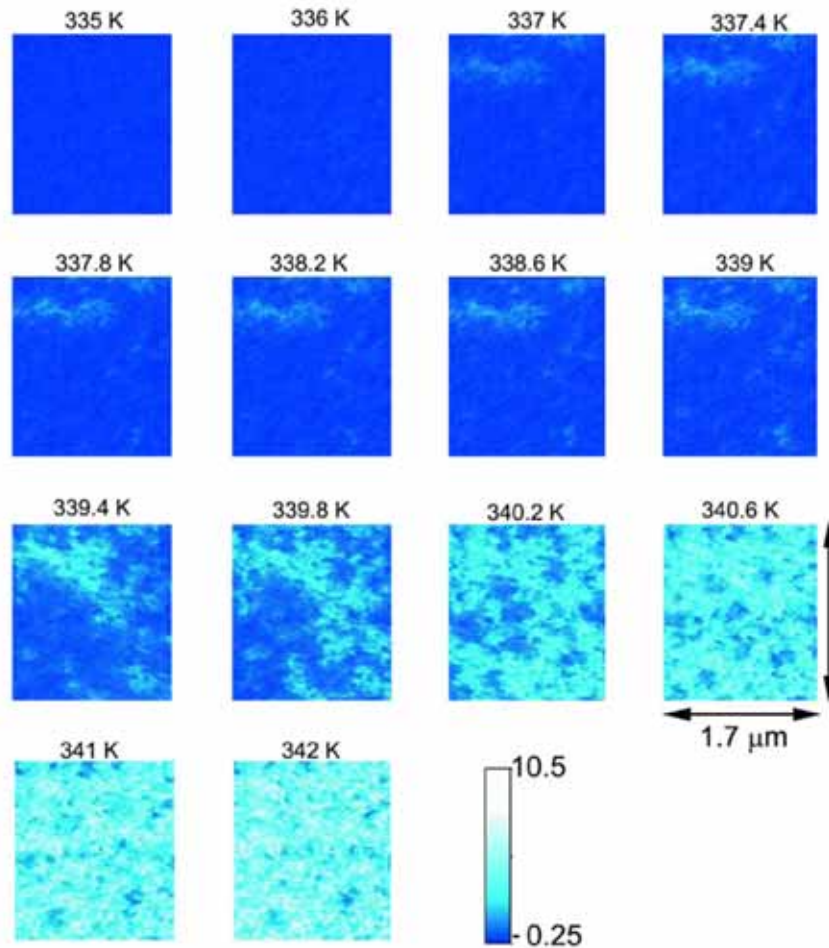
Manganites (Charge- & Orbital-Order):

Turner, Hill, Kevan et al., New J. Phys. 10, 053023 (2008)
Nelson, Hill, Livet et al., PRB 2002
 $\text{Pr}_{0.6}\text{Ca}_{0.4}\text{MnO}_3$, $T = 150$ K



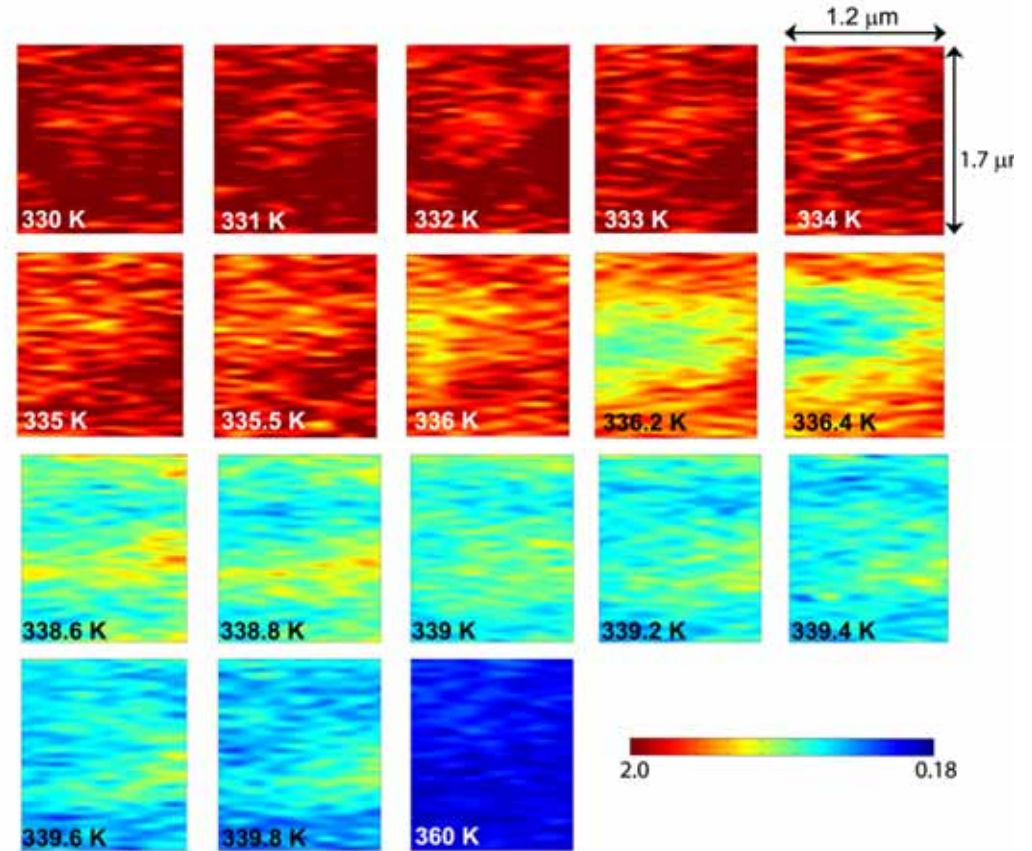
Metal-Insulator Transition in VO₂

Near-Infrared Nanoscopy (Conductivity)
Done at UC San Diego, 30 nm resolution



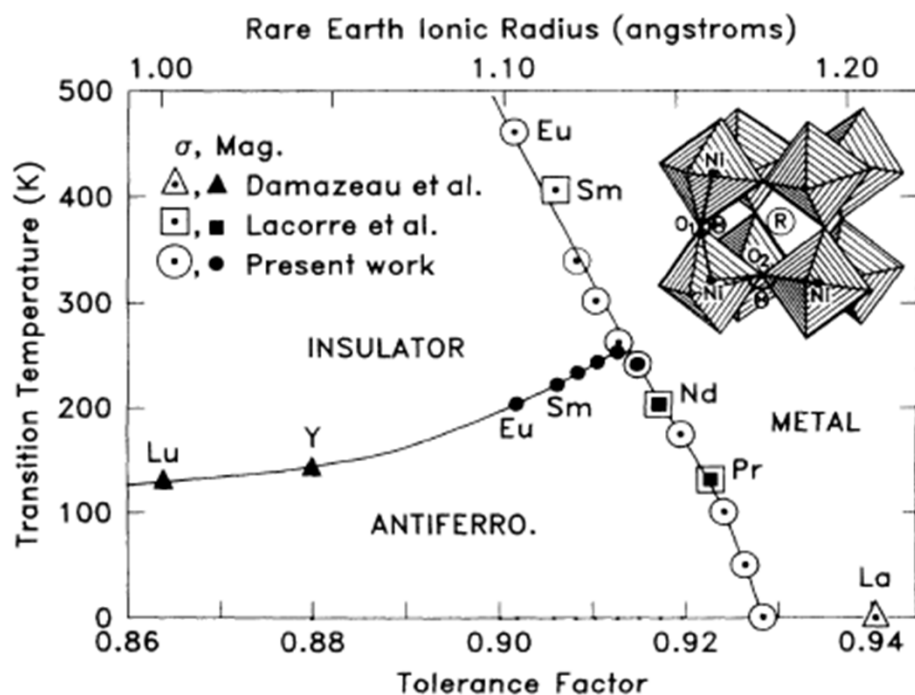
Qazilbash et al., Science 318, 1750 (2007)

X-ray Nanoscopy (Structure)
Done at 34-ID, Nanoprobe APS, Argonne
40 nm resolution

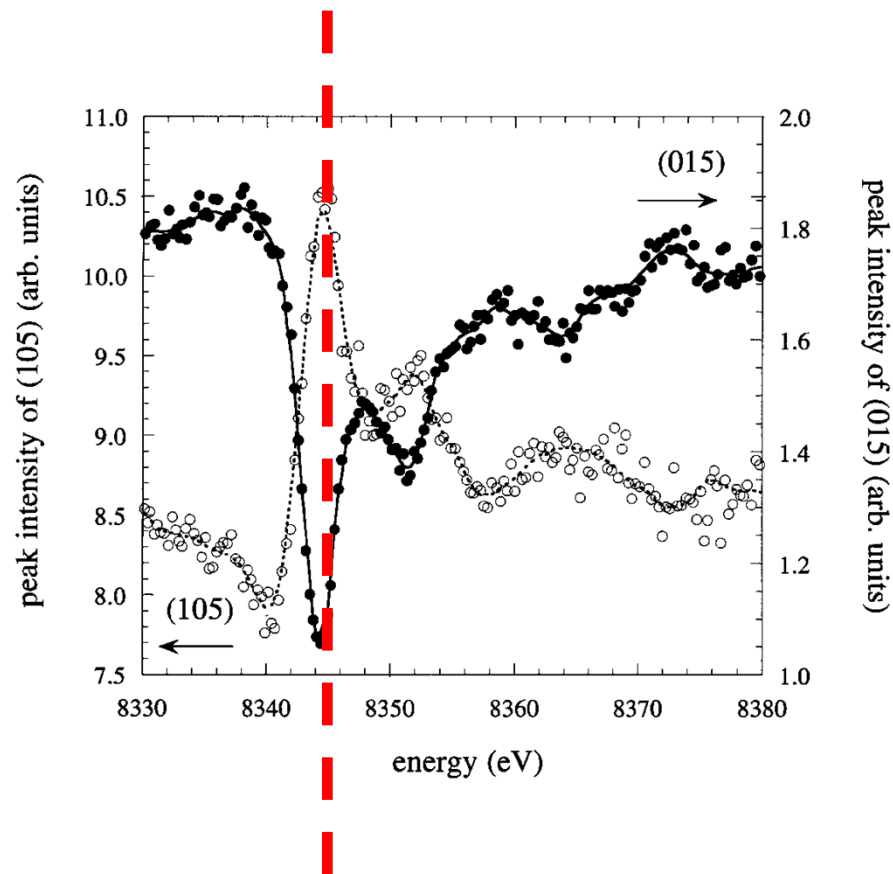


Qazilbash et al., Phys. Rev. B 83, 165108 (2011)

Charge Ordering in NdNiO₃



J.B. Torrance *et al.*, PRB 1992

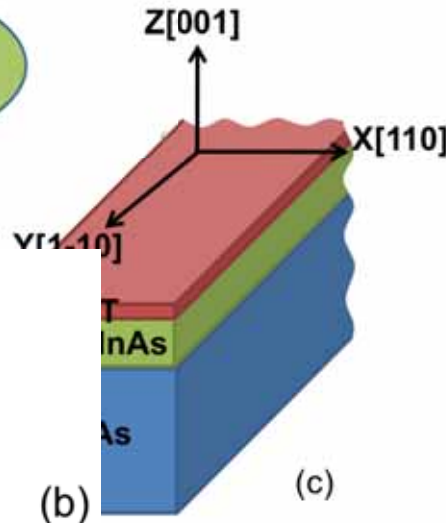
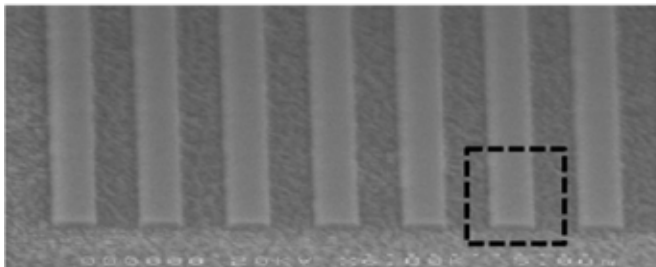
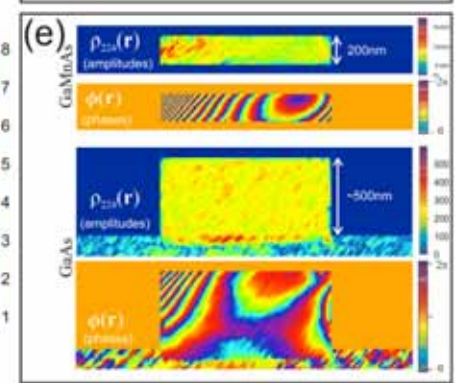
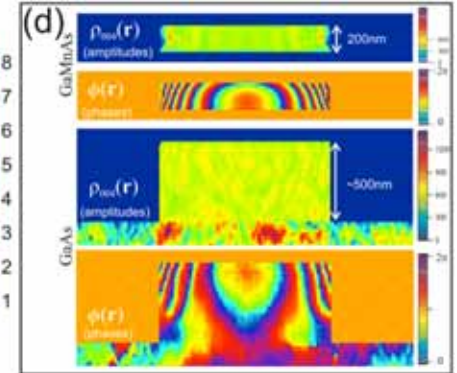
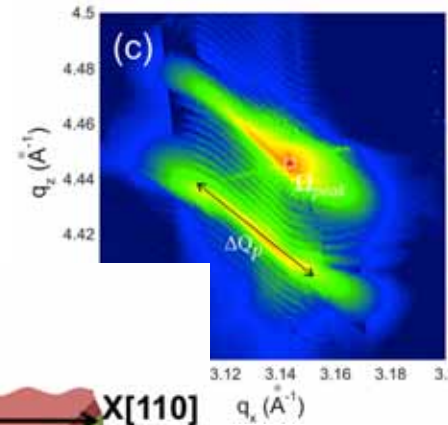
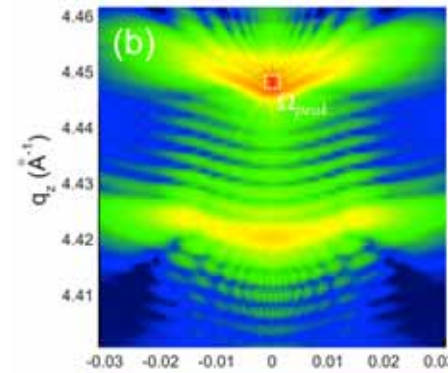
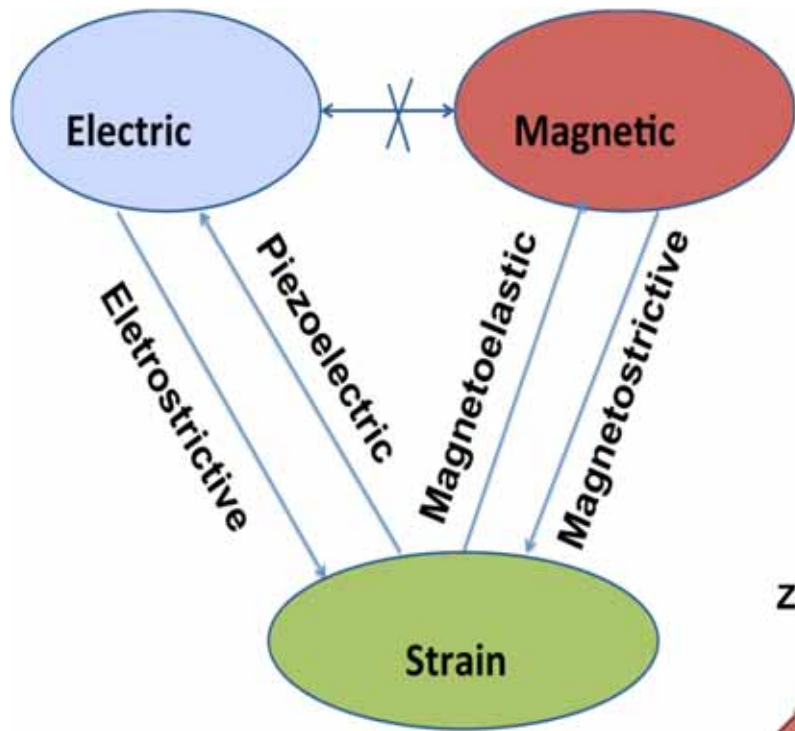


Staub *et al.*, Direct Observation of Charge Order in an Epitaxial NdNiO₃ Film
 Phys. Rev. Lett. 88, 126402 (2002)

Multifunctional Nanostructures

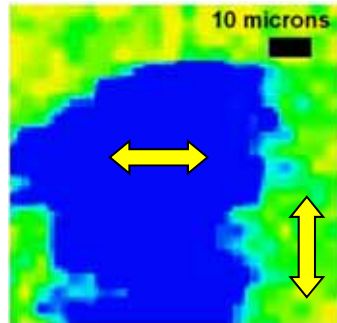
(coupling of Electricity and Magnetism through Strain)

Group project lead by UCSD postdoc Edwin Fohtung



See a poster by Edwin Fohtung!

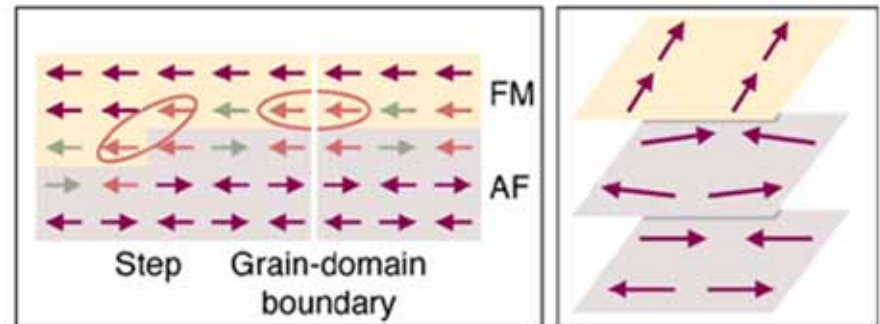
Looking "inside" Antiferromagnetic Domain Walls



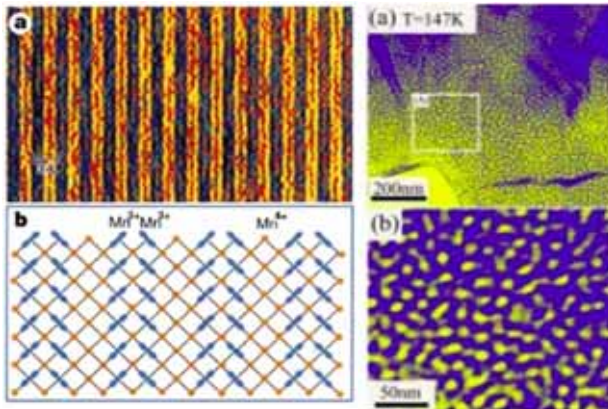
Spin domains in Cr
 P. G. Evans, E. D. Isaacs et al.,
Science 295 1042 (2002)

Exchange Bias:

Where are the uncompensated Spins at buried interfaces?



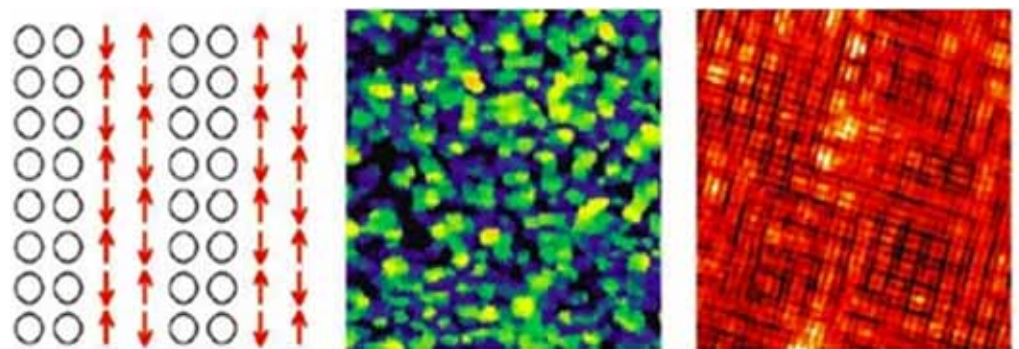
Manganites



S. Mori et al., *Nature* 392, 473 (1998)
 M. Uehara et al., *Nature* 399, 560 (1999)

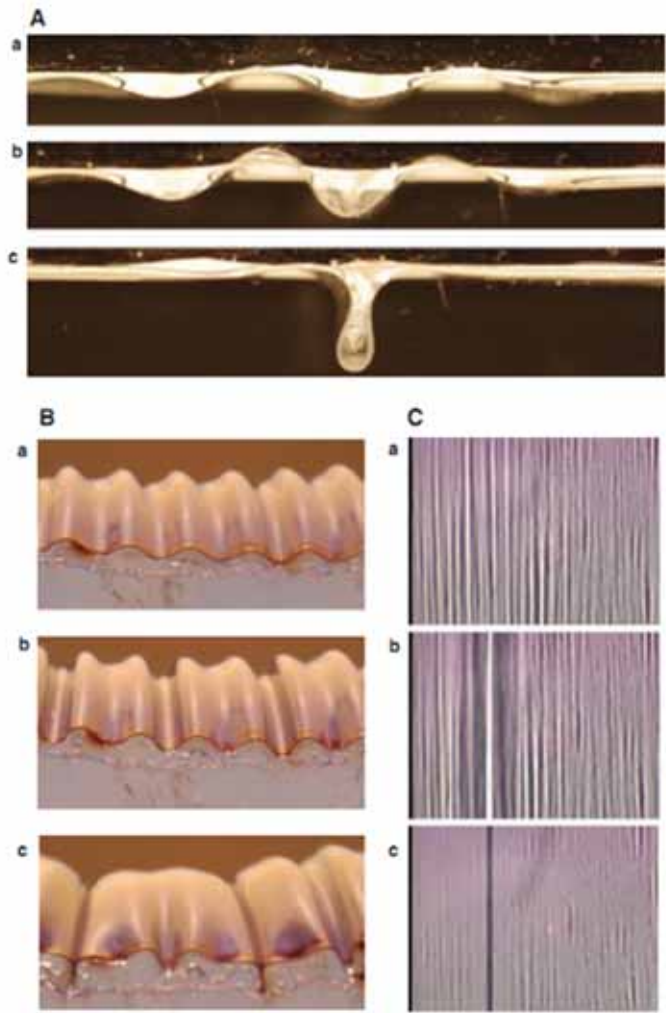
**Ian McNulty's Talk
 (Coming up NEXT!)**

High-Tc Superconductors



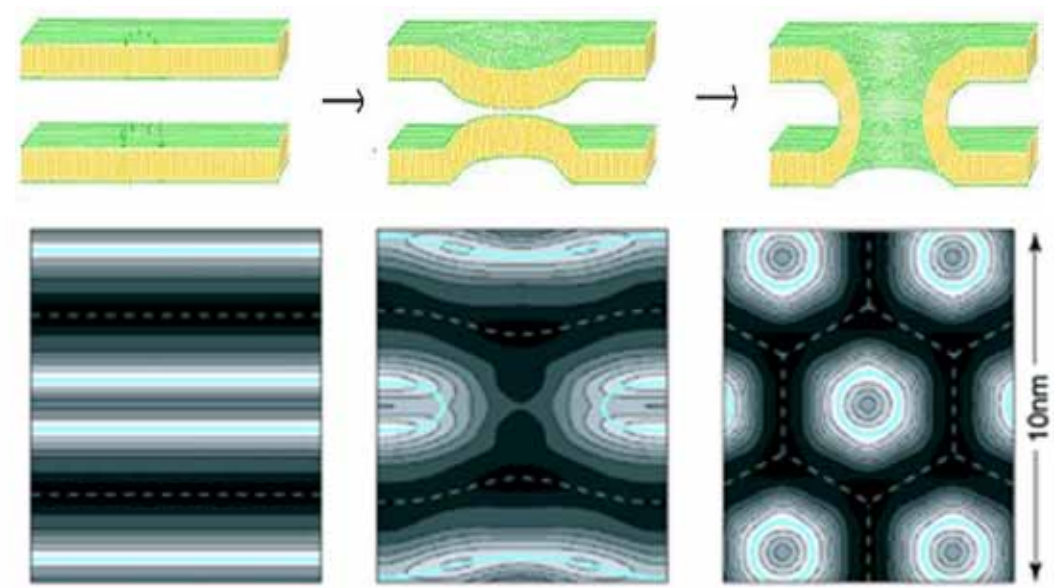
E. Dagotto, T. M. Rice, *Science* 271, 618 (1996).
 T. Hanaguri et al., *Nature* 430, 1001 (2004).

Wrinkling, Buckling instabilities in monolayers and thin films

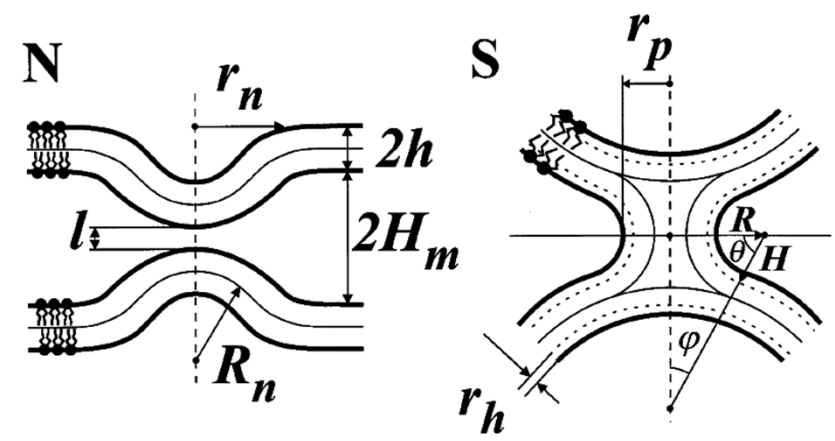


L. Pocivavsek et al.,
Science **320** (5878), 912-916 (2008)

Lipid Membrane Fusion



L. Yang, H.W. Huang, *Science* **297**, 1877 (2002)



P. Kuzmin et al., *PNAS* (2001)

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Jyoti Mohanty

Erik Shipton

Eric Fullerton



APS, Argonne:

Sang-Soo Kim

Ian McNulty



+ Poster by Edwing Fohtung

