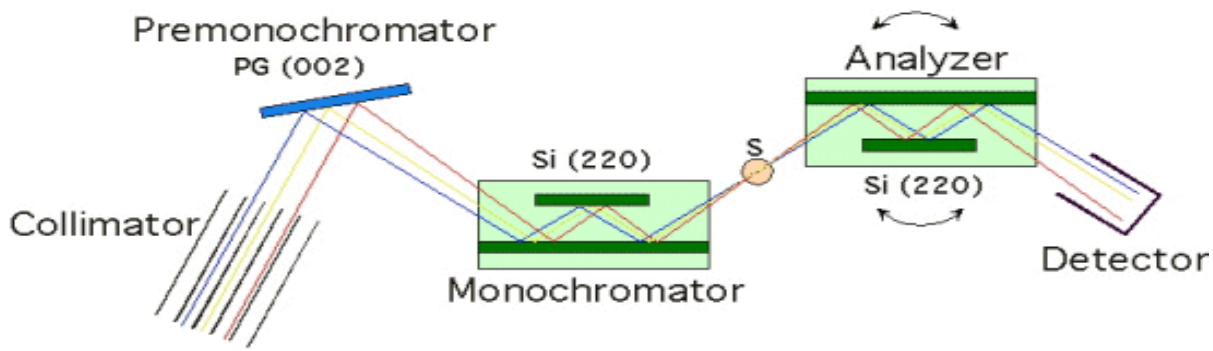
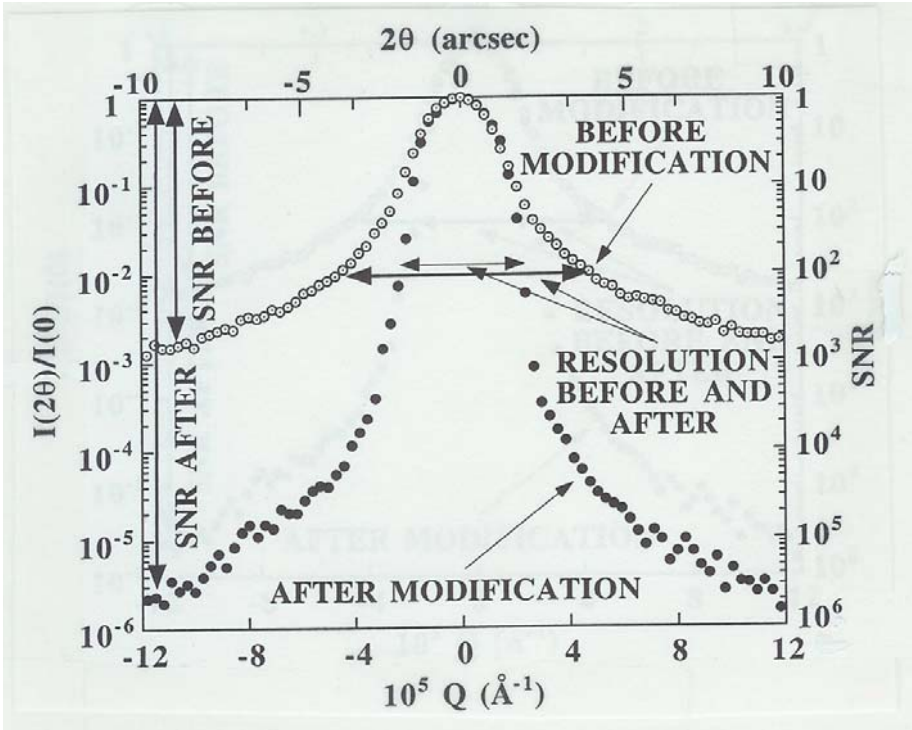
MICHAEL AGAMALIAN
Spallation Neutron Source, ORNL

ULTRA-SMALL-ANGLE NEUTRON SCATTERING:
A NEW TECHNIQUE FOR MATERIALS RESEARCH



M. Agamalian, G. D. Wignall and R. Triolo. *J. Appl. Cryst. (1997), 30, 345.*

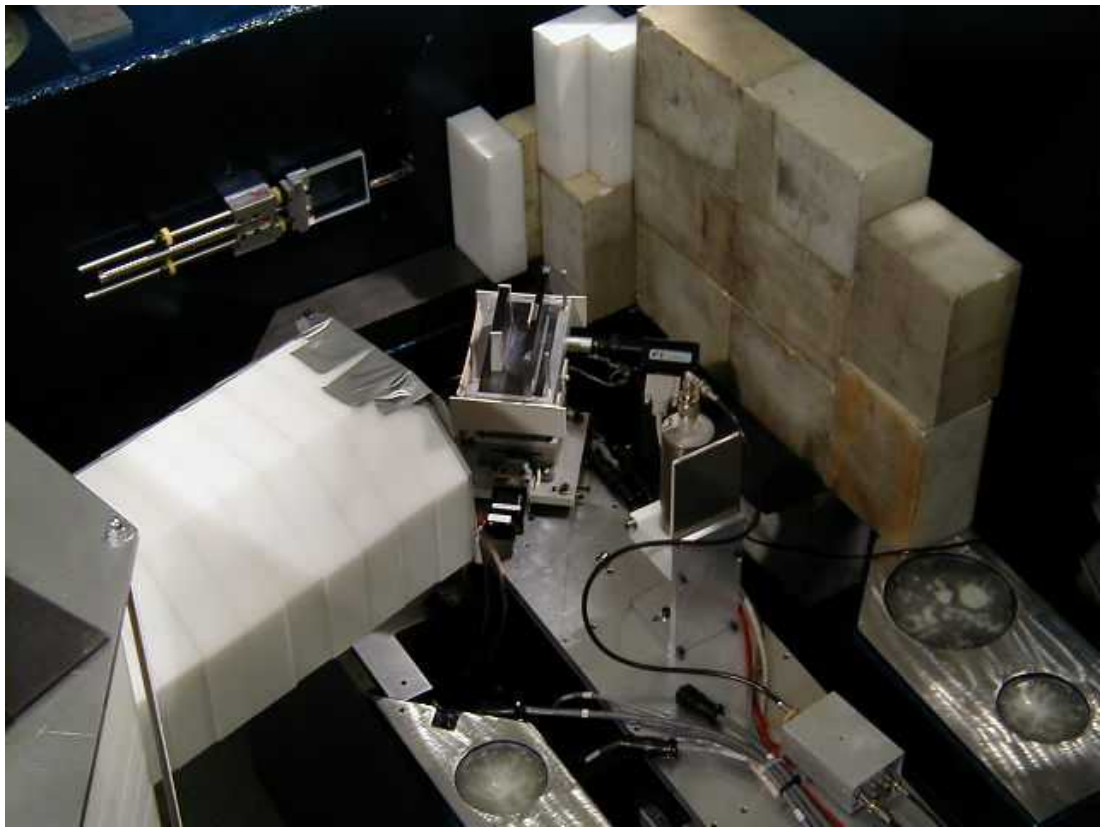
ORNL MEMORIAL USANS INSTRUMENT AT HFIR



ROCKING CURVES OF AN EMPTY INSTRUMENT

NIST BONSE-HART USANS INSTRUMENT AT BT-5 BEAM LINE

FLUX ~ 17000 n/cm^{2}sec
SENSITIVITY ~5x10^{-7}



ATOMIC AND MOLECULAR NEUTRON SCATTERING

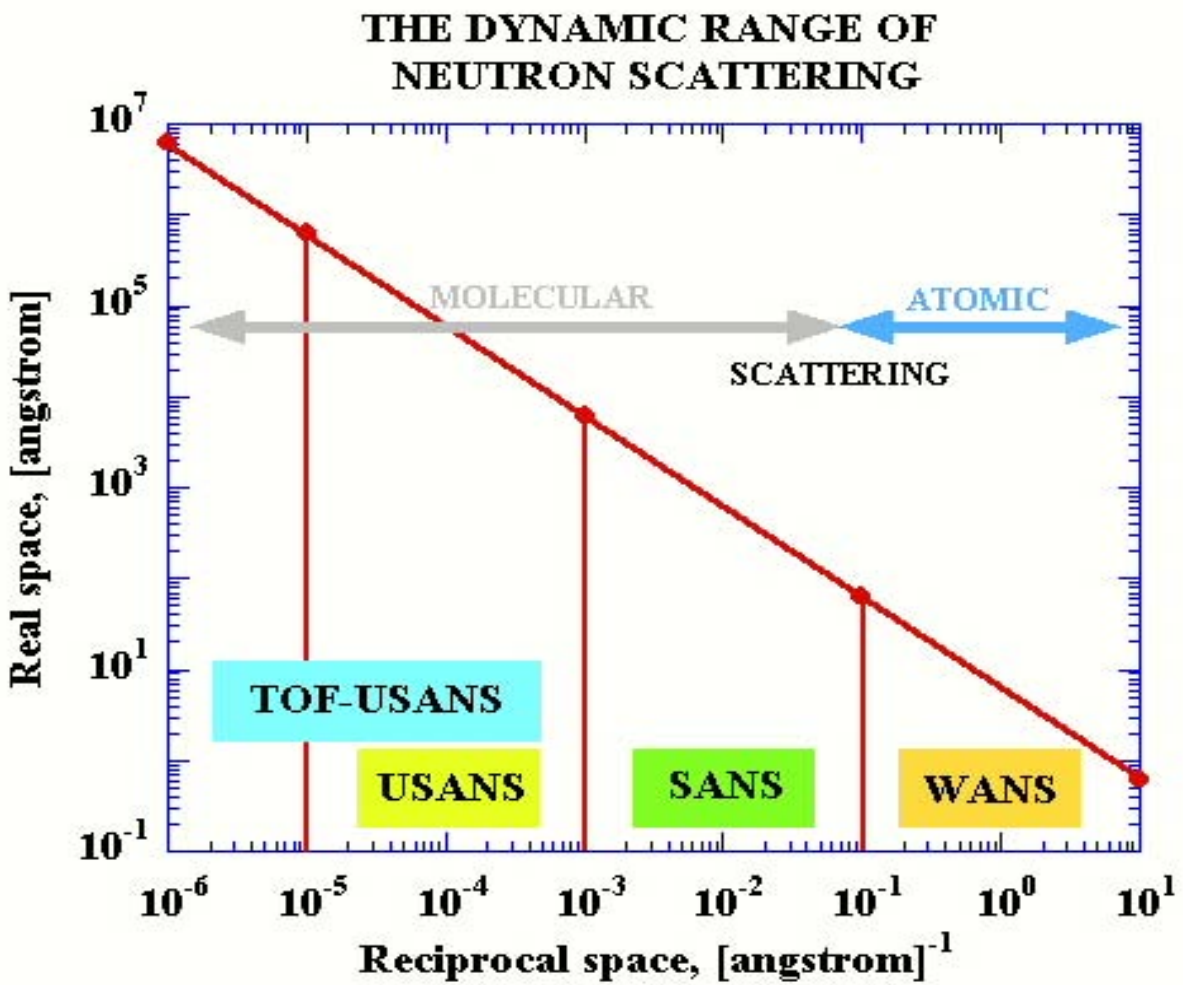
Transition to real space

BRAGG DIFFRACTION

$D \sim 2\pi/Q$

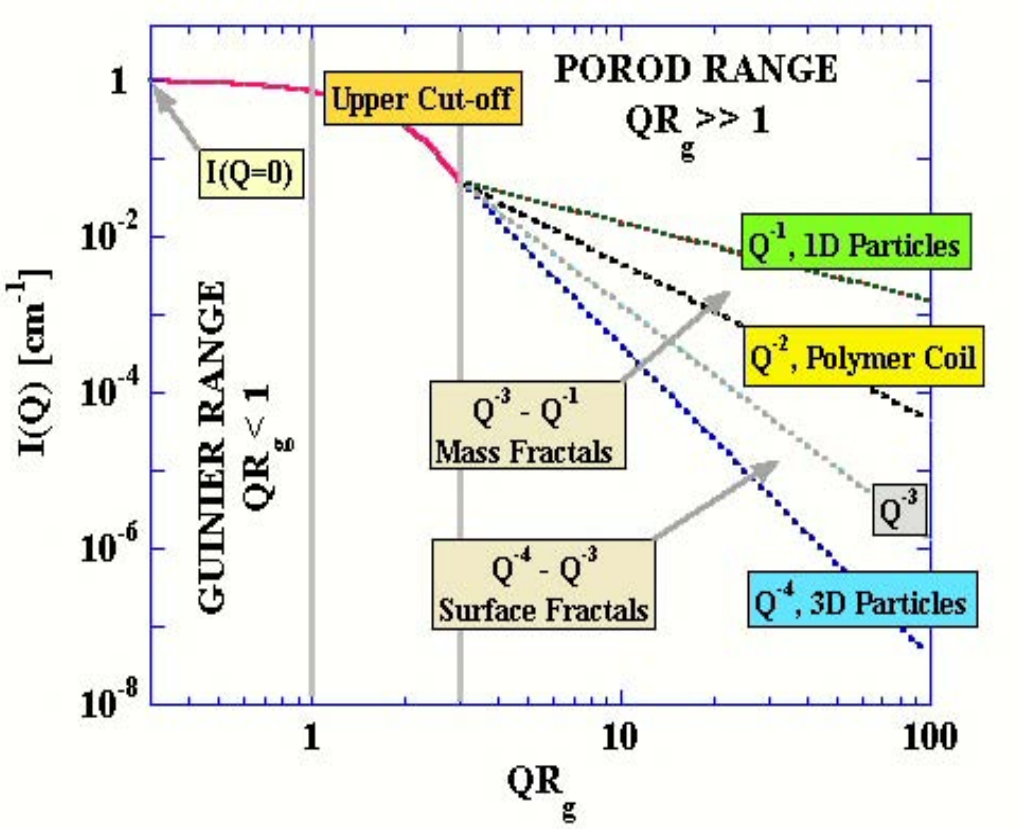
DIFFRACTION FROM PARTICLES

$R_g \sim 1/Q$



POLYDISPERSE DISORDERED HIERARCHICAL STRUCTURES

Molecules → Aggregates → Agglomerates

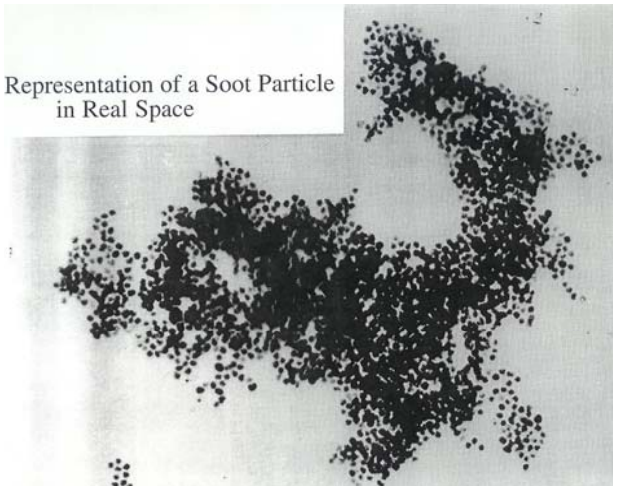


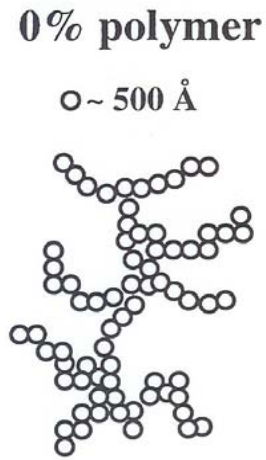
$$I(Q) = I(0) \times \langle F(QR) \rangle \times \{S(QD)=1\}$$
$$I(0) = C \times (\Delta\rho)^2 \times \langle V \rangle^2 \ [cm^{-1}]$$

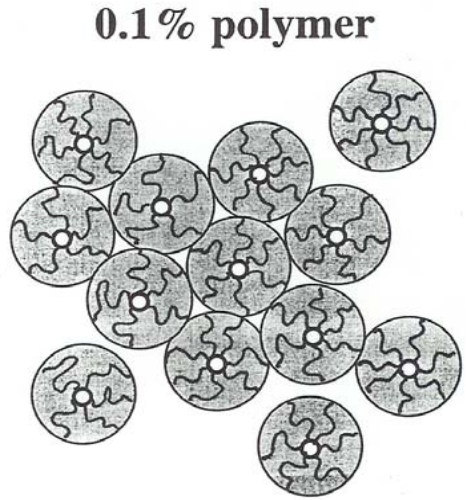
Estimated value of R_g (max)

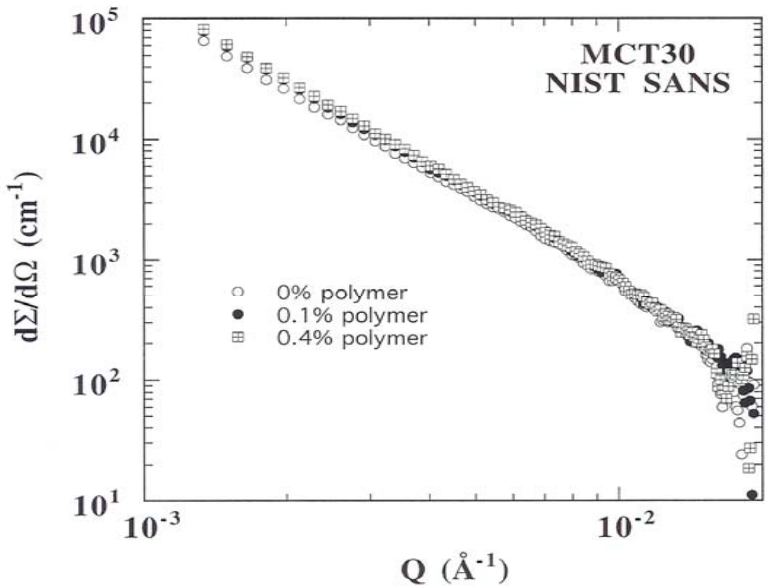
30m pin-hole SANS: ≤ 350 Å
Conventional USANS: ≤ 35000 Å
TOF-USANS (project): ≤ 350000 Å

AGGREGATION OF CARBON PARTICLES IN USED ENGINE OIL







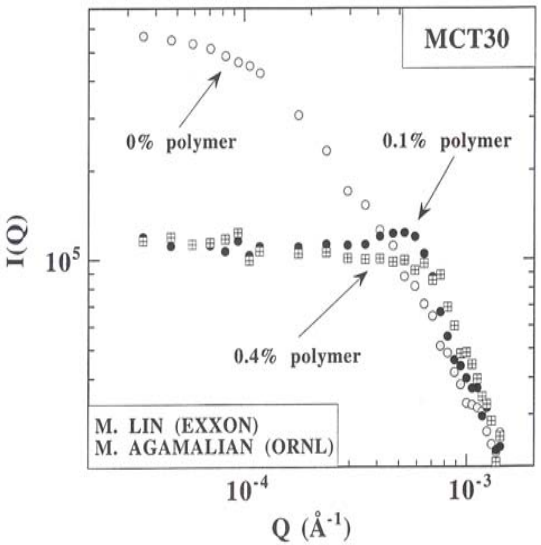


THE SCATTERING CURVES MEASURED AT THE 30m SANS INSTRUMENT

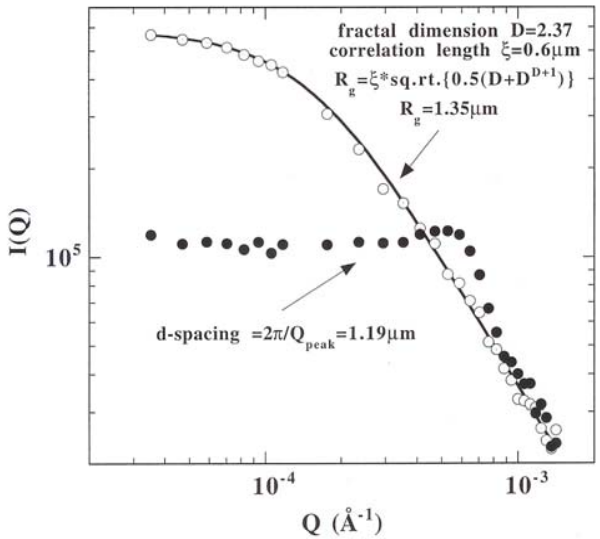
(after Min Lin with co-authors)

AGGREGATION OF CARBON PARTICLES IN USED ENGINE OIL

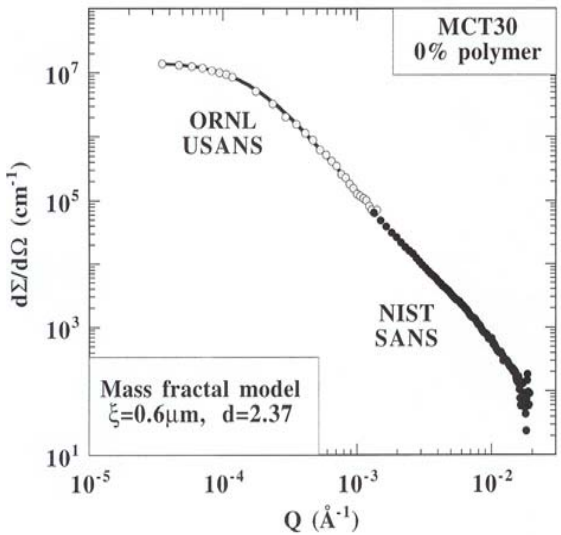
THE RAW USANS DATA OBTAINED AT ORNL



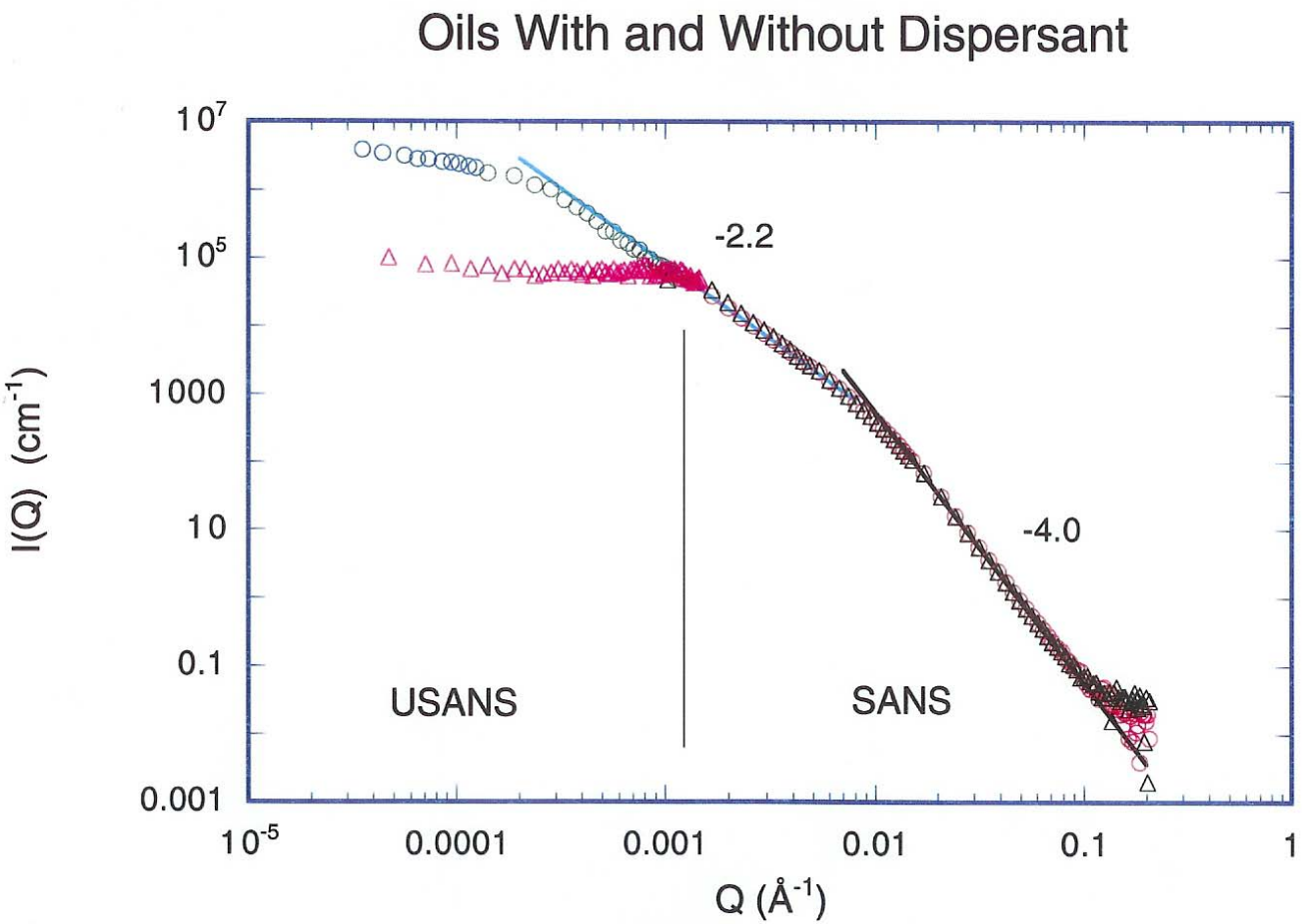
FIT TO THE SINHA MODEL OF UPPER CUT-OFF FOR MASS FRACTAL SYSTEMS



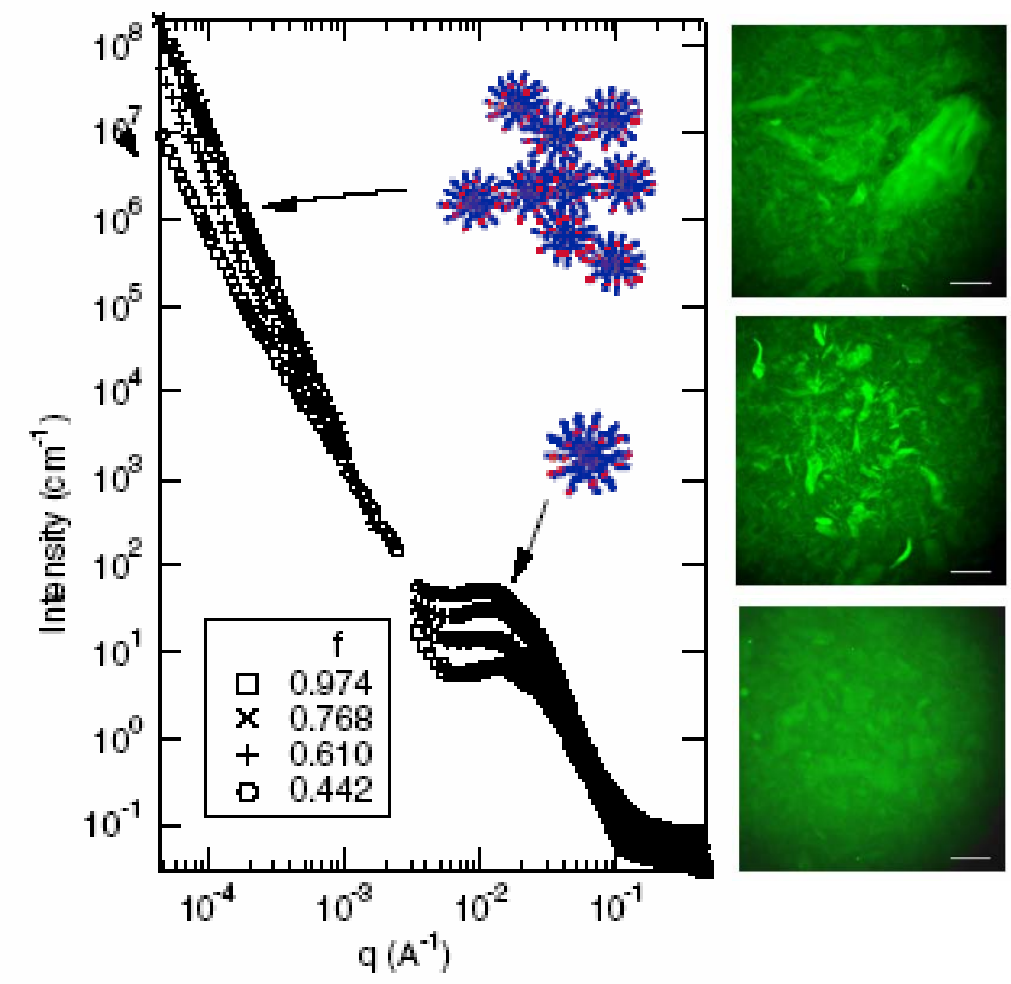
THE COMBINED USANS/SANS DATA



AGGREGATS OF CARBON PARTICLES IN USED ENGINE OIL SHOW A HIERARCHICAL STRUCTURE



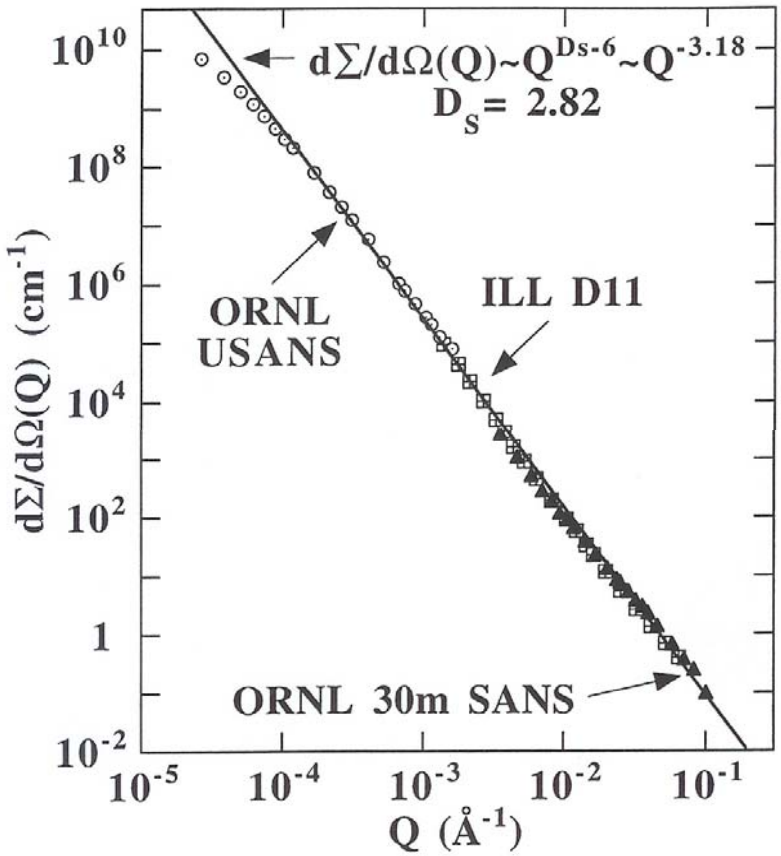
ATTRACTIVE COLLOIDAL GLASSES OF PS-PAA/EA MICELLES

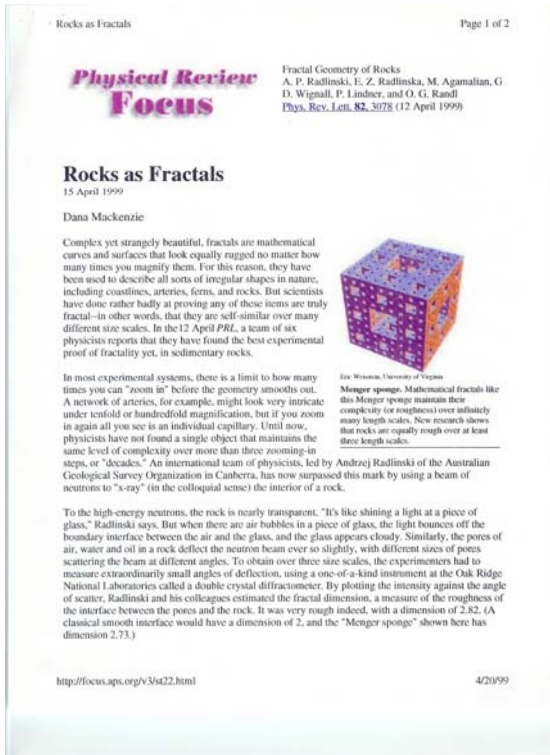


(after M. A. Crichton and S. R. Bhatia)

SUPFACE FRACTALS IN SEDIMENTARY ROCKS EXTENDED OVER THREE ORDERS OF MAGNITUDE IN THE LENGTH SCALE

(after A. Radlinski with co-authors)





Rocks as Fractals Page 1 of 2

Physical Review Focus

Fractal Geometry of Rocks
A. P. Radlinski, E. Z. Radlinska, M. Agamalian, G. D. Wignall, P. Lindner, and O. G. Randl
Phys. Rev. Lett. 82, 3078 (12 April 1999)

Rocks as Fractals

15 April 1999

Dana Mackenzie

Complex yet strangely beautiful, fractals are mathematical curves and surfaces that look equally rugged no matter how many times you magnify them. For this reason, they have been used to describe all sorts of irregular shapes in nature, including coastlines, arteries, ferns, and rocks. But scientists have done rather badly at proving any of these items are truly fractal—in other words, that they are self-similar over many different size scales. In the 12 April *PRL*, a team of six physicists reports that they have found the best experimental proof of fractality yet, in sedimentary rocks.

Eric Weisstein, University of Virginia

Menger sponge. Mathematical fractals like this Menger sponge maintain their complexity (or roughness) over infinitely many length scales. New research shows that rocks are equally rough over at least three length scales.

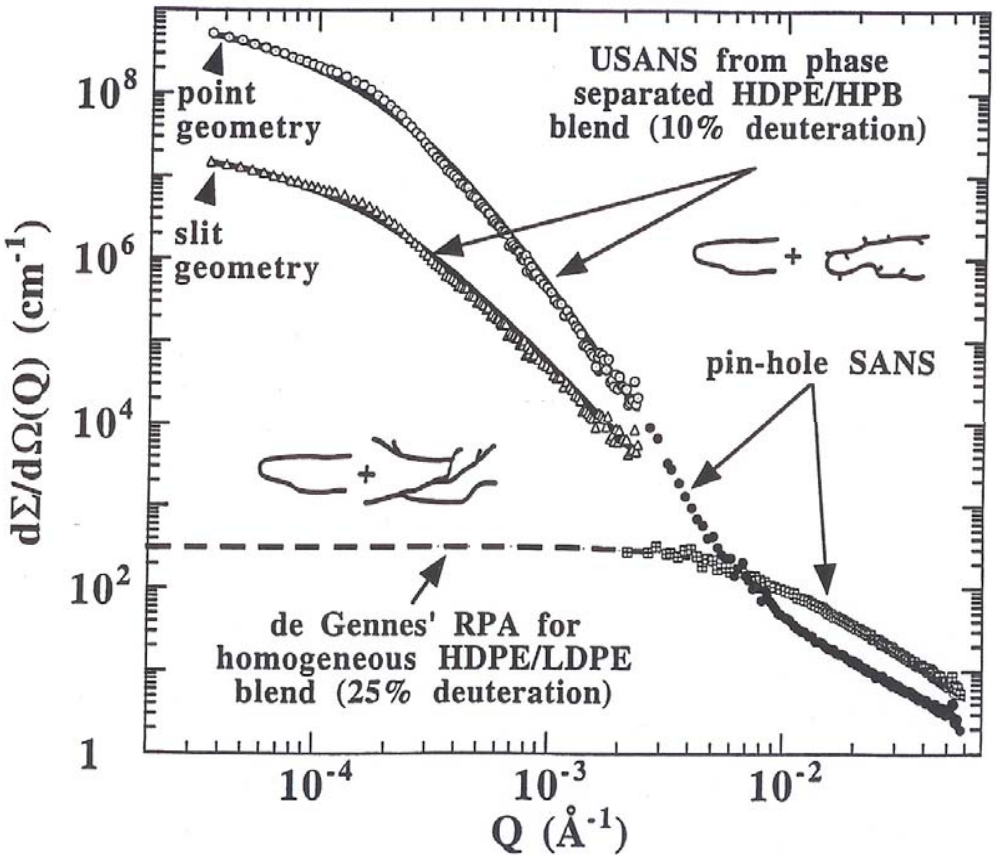
In most experimental systems, there is a limit to how many times you can "zoom in" before the geometry smooths out. A network of arteries, for example, might look very intricate under tenfold or hundredfold magnification, but if you zoom in again all you see is an individual capillary. Until now, physicists have not found a single object that maintains the same level of complexity over more than three zooming-in steps, or "decades." An international team of physicists, led by Andrzej Radlinski of the Australian Geological Survey Organization in Canberra, has now surpassed this mark by using a beam of neutrons to "x-ray" (in the colloquial sense) the interior of a rock.

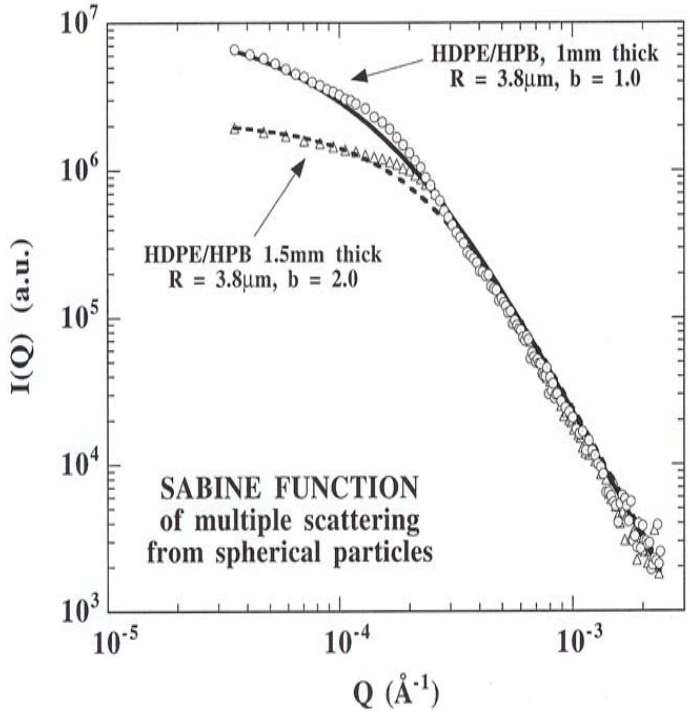
To the high-energy neutrons, the rock is nearly transparent. "It's like shining a light at a piece of glass," Radlinski says. But when there are air bubbles in a piece of glass, the light bounces off the boundary interface between the air and the glass, and the glass appears cloudy. Similarly, the pores of air, water and oil in a rock deflect the neutron beam ever so slightly, with different sizes of pores scattering the beam at different angles. To obtain over three size scales, the experimenters had to measure extraordinarily small angles of deflection, using a one-of-a-kind instrument at the Oak Ridge National Laboratories called a double crystal diffractometer. By plotting the intensity against the angle of scatter, Radlinski and his colleagues estimated the fractal dimension, a measure of the roughness of the interface between the pores and the rock. It was very rough indeed, with a dimension of 2.82. (A classical smooth interface would have a dimension of 2, and the "Menger sponge" shown here has dimension 2.73.)

http://focus.aps.org/v3/st22.html 4/20/99

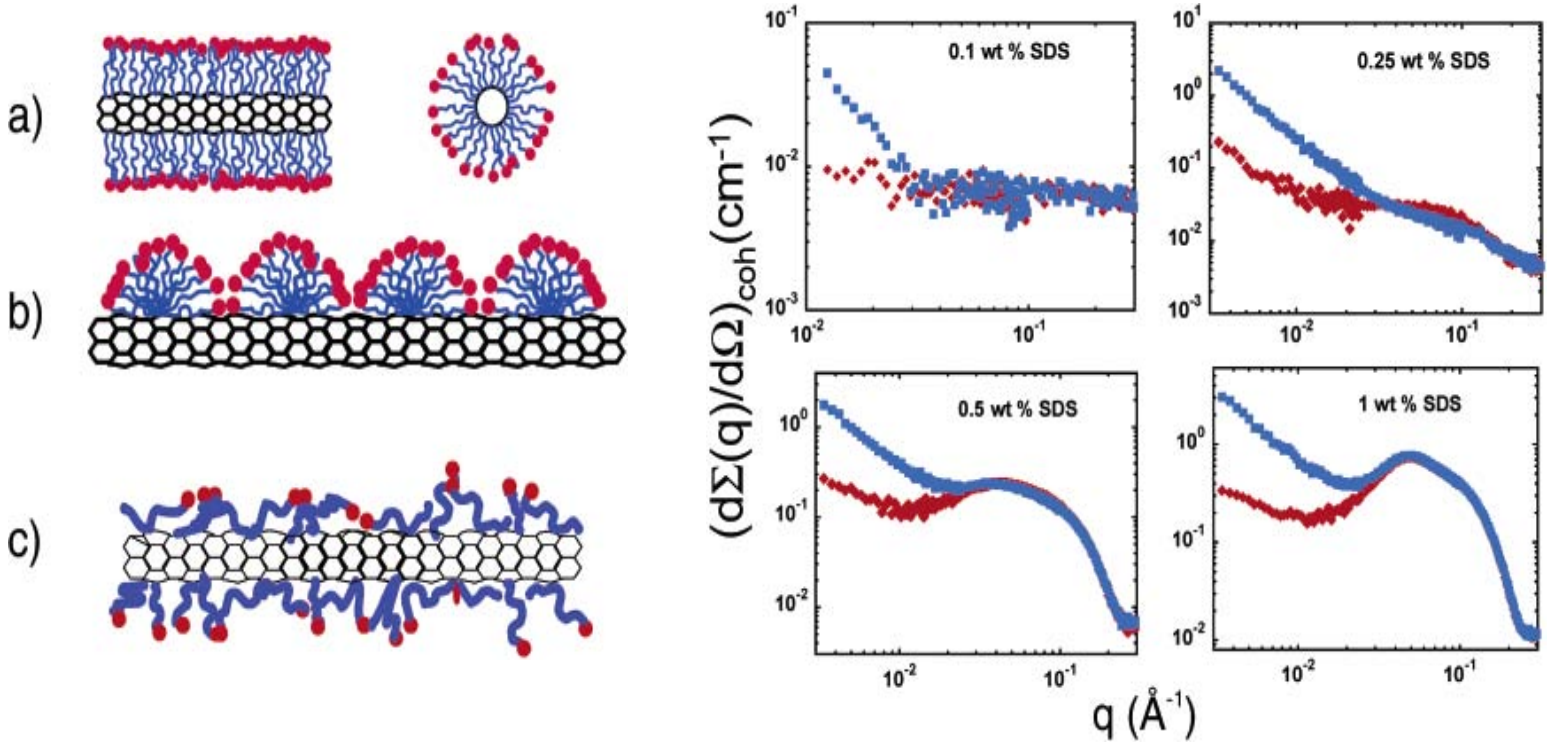
PHASE SEPARATION OF LINEAR AND BRANCHED PE MACROMOLECULES IN THE MELT

(after M. Agamalian with co-authors)





SANS ON NANOTUBES (WITHOUT USANS DATA)



Small-Angle Neutron Scattering from Surfactant-Assisted Aqueous Dispersions of Carbon Nanotubes

K. Yurekli, C. A. Mitchell & R. Krishnamoorti, J. Am. Chem. Soc. 126, 2004

- **ORNL WILL OFFER TWO BONSE-HART USANS INSTRUMENTS (at SNS and at HFIR) AND TWO HIGH-RESOLUTION CONVENTIONAL SANS INSTRUMENTS (at HFIR)**
- **THE CURRENT WORLD'S BEST BONSE-HART USANS INSTRUMENT OPERATES AT NIST (BT-5)**
- **NIST CENTER FOR NEUTRON RESEARCH IS CURRENTLY THE BEST FACILITY FOR COMBINED SANS/USANS EXPERIMENTS**
- **ACCORDING TO OUR ESTIMATES THE MAJORITY OF SANS STUDIES ON MATERIALS CANNOT BE COMPLETED WITHOUT USANS MEASUREMENTS**