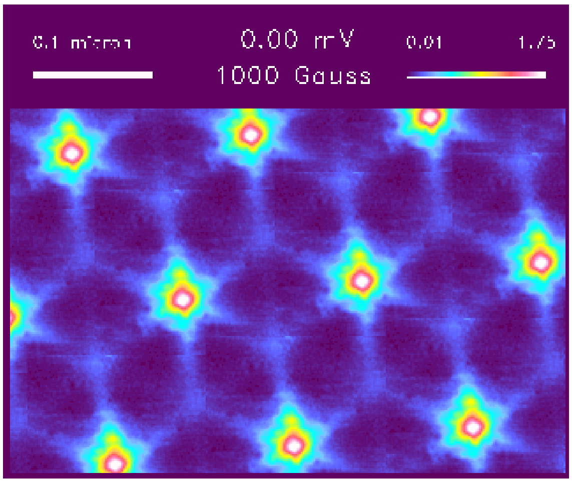
Vortex Core States of a Superconductor Imaged by Scanning Tunneling Microscopy



A vortex is formed when a magnetic field line goes through a superconductor, where circulating electrical current keeps one magnetic flux quantum confined to a microscopic region. When large numbers of vortices are present they pack into a hexagonal lattice called the Abrikosov Flux Lattice. Electronic states are bound to each vortex core much like electrons are bound to the nucleus while they orbit or form a cloud about it in an atom. The images show the size and shape of these clouds in vortices for different energies.

More scanning probe microscope pictures are in the Scanned Probe Microscopy Gallery.

More images of magnetic flux vortices are in the Superconducting Flux Lattice Gallery.

This picture is part of work done by Harald Hess and R.B. Robinson, and J.V. Waszczak.

See *Physica* B 169 pg 422 (1991) for more information.

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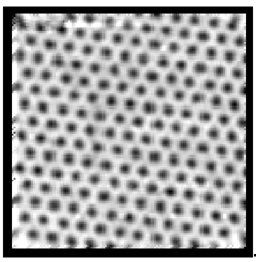
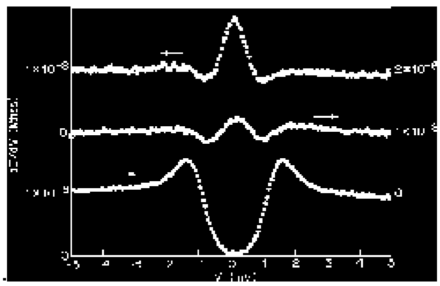
A Brief History and some Abstracts of Related Papers

This first paper describes the initial observation of vortices and something called a zero-bias peak in their energy spectrum.



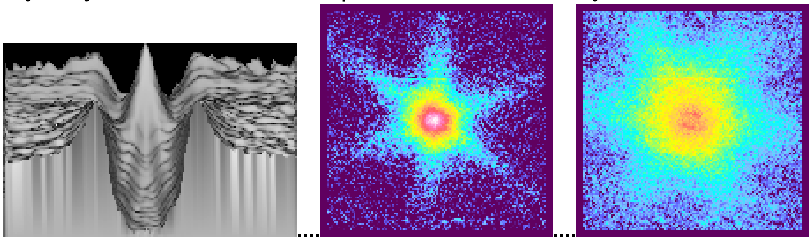


Abrikosov Flux Lattice .... Zero Bias Peak

Several theorists were intrigued by the energy spectrum of the vortex core with its mysterious zero bias peak and offered various explainations including some predictions. A.W. Overhauser and L.L. Daemen [Phys. Rev. Lett. 62 1691 (1989)] explained it in terms of a simple macroscopic model. J. D. Shore, M.Huang, A.T. Doresy and J.P. Sethna [Phys. Rev. Lett. 62 3089 (1989)] offered the first microscopic model based on solutions to the Bogoliubov equations that confirmed this peak and also made an important prediction: **the peak should split if spectra are taken at some distance from the core**. F. Gygi and M. Schluter [Phys. Rev. B 41 822 (1990)] came to the same conclusions with a more stringent self consistent calculation and as well as U. Klein [Phys. Rev. B 41 4819 (1990)] based on quasiclassical equations.

Splitting Confirmed!, but Why Stars?

The next paper confirmed the microscopic theoretical models of a splitting of the zero bias peak but posed a new mystery: the vortices are shaped like stars and they twinkel when viewing its different energy states.



Splitting of the Zero Bias Peak .... Stars!....That twinkle

Soon after this observation, a theory based on a six fold perturbation explained that the two states can be interpreted as bonding or antibonding states.

More detailed experimental and theoretical summaries are given at this stage here in these references.

Further measurements indicated that the twinkling process is very intricate and more subtle than the initial theory would indicate. (see the lattice photos at the top of the page). Also the spectral evolution across the vortex does not just split in two but four subpeaks. Even more intriging is that these peaks vary with the angle that the spectral evolution was taken. This mystery still does not have a satisfactory quantitative explaination.

Next we turned our attention to the behavior of tilted flux lattices. There were theoretical predictions that the whole lattice should stretch and have a well defined orientation in layered superconductors like NbSe2.

We confirmed the stretching and showed also how that is reduced in low magnetic. More surprising was that the orientation of the lattice was wrong, at least for this superconductor.

Pointers to related Homepages

Jim Sethna at Cornell
hess@physics.att.com

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