Mathematician Michael H. Freedman presents new topology theorem at UCSD

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Contact: Yvonne Baskin, (619) 534-3120 or AAAS Newsroom For Release THURSDAY PMS

UCSD MATH VIRTUOSO PRESENTS NEW THEOREM THAT APPLIES TOPOLOGY TO STUDY OF FLUIDS

SAN FRANCISCO--A surprising new theorem that describes how topology can bound energy was presented here Thursday by University of California, San Diego mathematician and MacArthur Fellow Michael H. Freedman.

"What this theorem says is that just knowing something about the topology of the field lines in a flow--say the magnetic field lines in a neutron star--allows you to deduce the minimal energy levels of the system," says Freedman.

The techniques he used to derive the theorem might be extended to more complicated problems such as magnetic confinement of hot plasmas (ionized gases) in experimental nuclear fusion reactors.

Freedman has captured many of the highest honors in mathematics and science since 1982 when he solved the four-dimensional Poincare conjecture, a problem that had eluded solution since 1904.

In his most recent work, he has found it surprising that topology--a branch of mathematics that deals with the qualitative nature of shapes rather than their quantitative aspects--should apply to something as quantitative as energy levels in fluids and produce specific numbers.

"The joke about topologists is that we can't tell a donut from a coffee cup because they have the same qualitative nature."

Freedman and Z. X. He, a doctoral student from the People's Republic of China, developed the theorem during the past six months after reading the recent work of Russian mathematical physicist V. I. Arnold.

Arnold discovered the principle that topology can bound energy in incompressible flows such as magnetic fields, but his work applied only to a special case. Specifically, Arnold found that when magnetic field lines are appropriately knotted or tangled, they keep energy from dissipating below a certain minimum level.

"Arnold put his theorem in algebraic terms and related it to situations that involve linking numbers," Freedman says. "We took a different approach, putting the theorem on a more geometric footing and extending it to situations in abstract topology in which there are no non-zero linking numbers. (For example, configurations such as Borromean Rings, the symbol used on Ballantine beer cans, which stay together without any two circles being linked.)

"This suggests wider applicability of the topological lower bound principle than was visible from Arnold's work."

To extend this work to magnetic confinement fusion problems, complicating factors such as the presence of charged particles and the compressibility of the plasma would have to be considered, Freedman notes.

Nuclear fusion--the reaction that fuels the stars--has not yet been harnessed for energy production on Earth, in part because of the difficulty of confining hot plasmas.

"The way plasma escapes from so-called 'magnetic bottles' is that it pushes up against the magnetic field lines and spreads them apart like a child poking at a screen door. Arnold's work and ours suggests that tangling up these lines might keep energy from dissipating below a certain level.

"This suggests that a good strategy would be to create a configuration of magnetic field lines that would bunch up or tangle instead of separating when pressed."

Freedman, 37, was awarded the Fields Medal, the mathematics equivalent of the Nobel Prize, in 1986. The following year, President Reagan presented him with the National Medal of Science. Two years before, he had been elected to the National Academy of Sciences, awarded a five-year "genius grant" from the John D. and Catherine T. MacArthur Foundation and named California Scientist of the Year.

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