Bundling of Flux Tubes in Neutron Stars

Jeremy S. Heyl

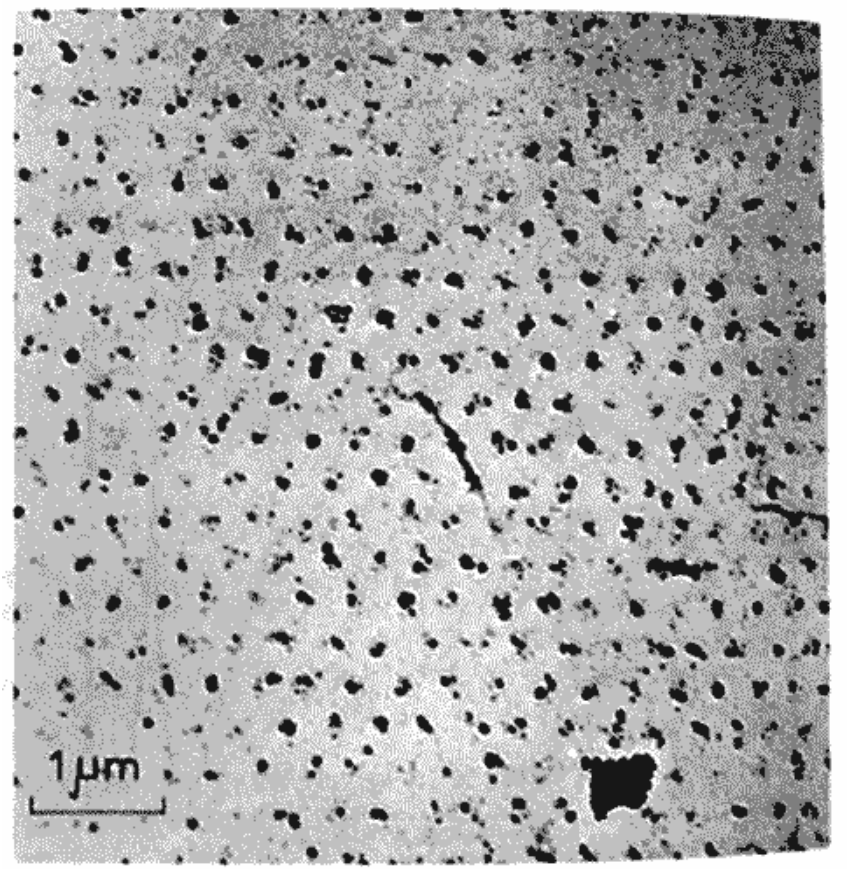
Dan Mazur (1209.4409)

21 January 2013

a place of mind

THE UNIVERSITY OF BRITISH COLUMBIA

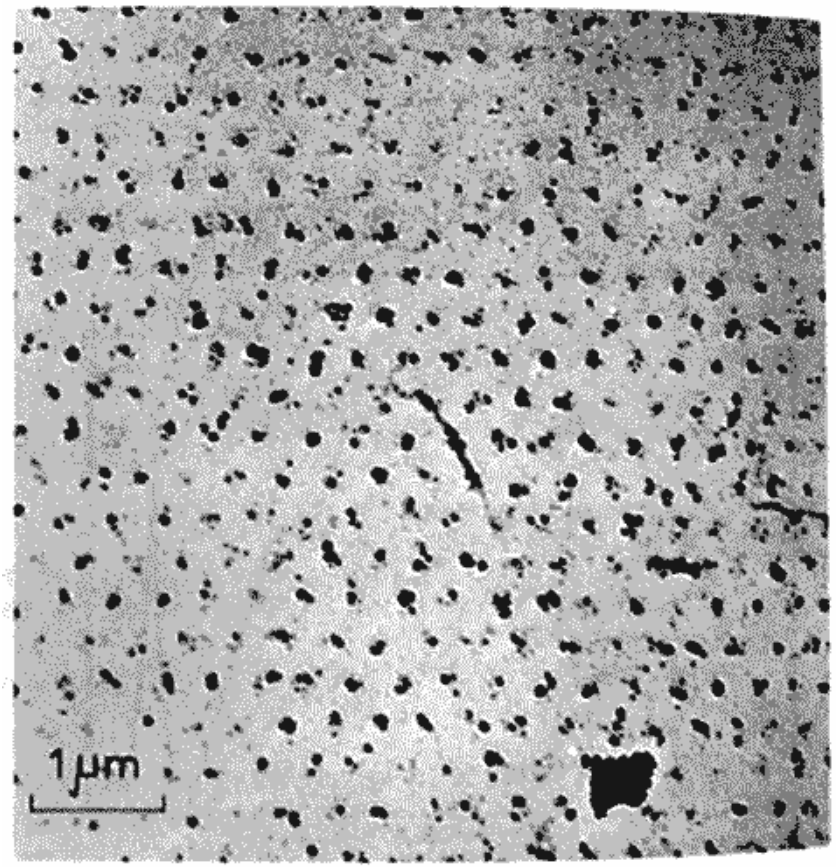
Superconductivity



Essmann & Träuble 1967

In a lab superconductor the distance between vortices is $\sim 1\mu$m, and their size is $\sim$ 100nm.

Superconductivity



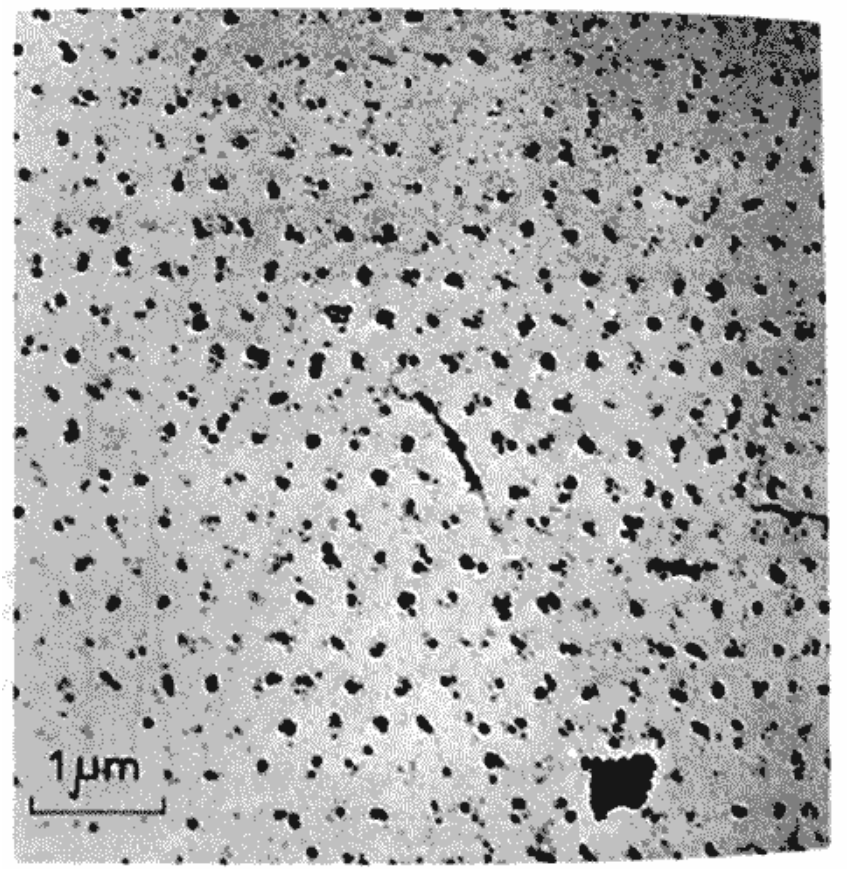
Essmann & Träuble 1967

In a lab superconductor the distance between vortices is $\sim 1\mu$m, and their size is ~ 100nm.

In a neutron star we have

$$a \sim \sqrt{\frac{4h}{\pi eB}} = 7B_{12}\mathrm{pm} = 19\lambda\!\!\!^{-}_e$$

Superconductivity



Essmann & Träuble 1967

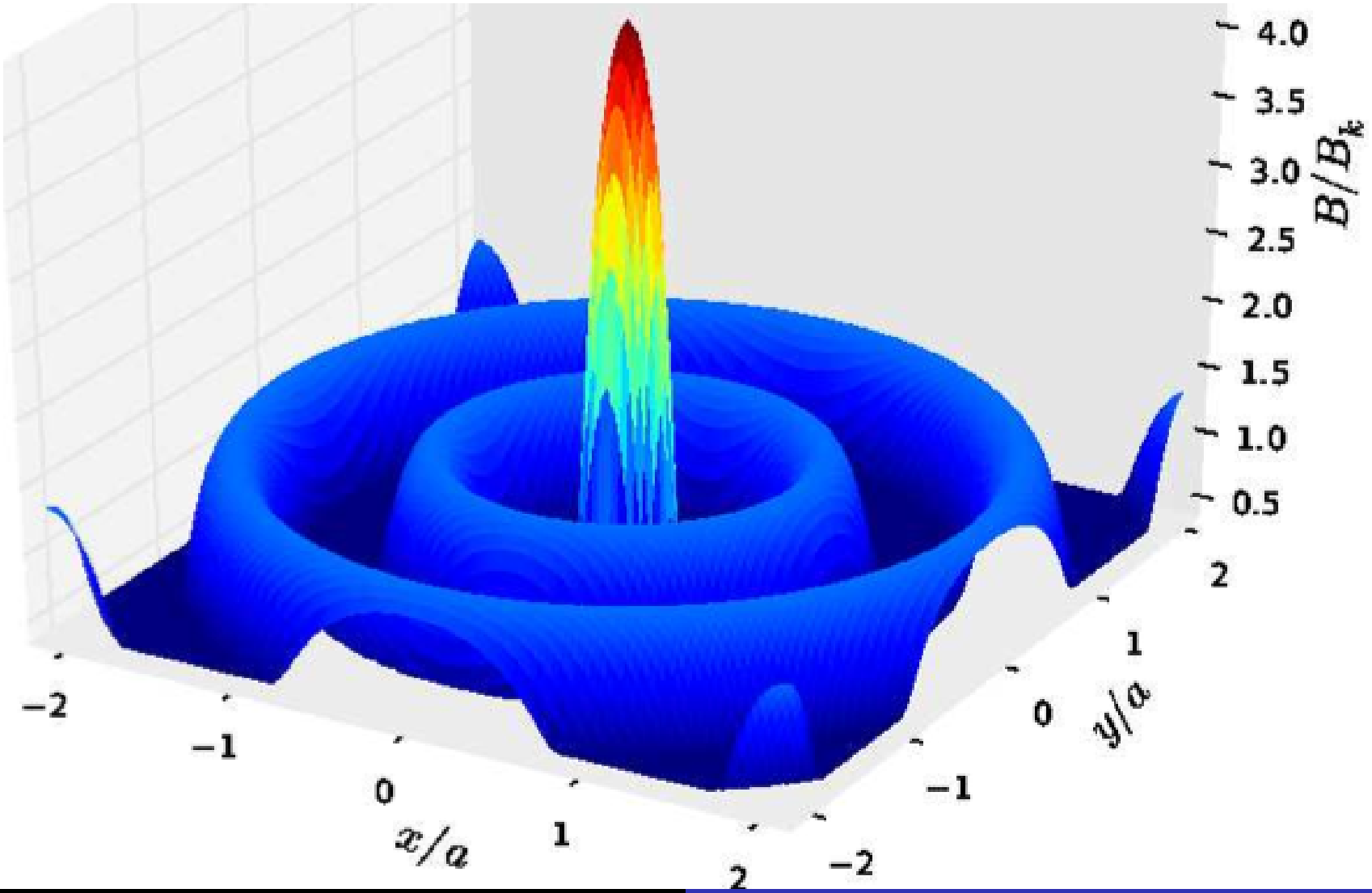
In a lab superconductor the distance between vortices is $\sim 1\mu$m, and their size is ~ 100nm.
In a neutron star we have

$$a \sim \sqrt{\frac{4h}{\pi eB}} = 7B_{12}\mathrm{pm} = 19\lambda\!\!\!^{-}_e$$

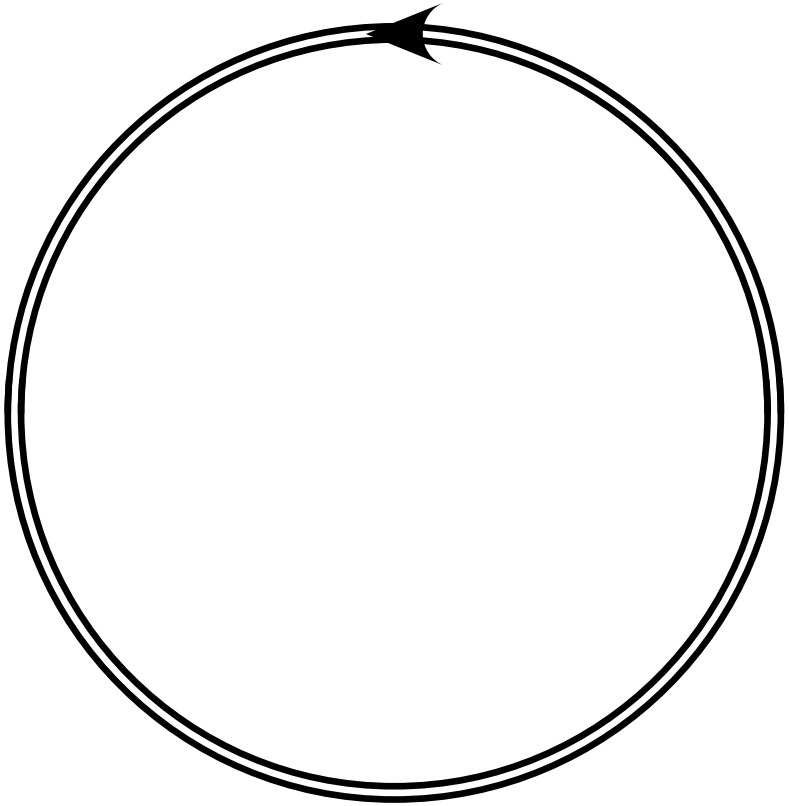
and

$$\lambda_L = \sqrt{\frac{mc^2}{8\pi q^2 n_0}} = 7\rho_{15}\mathrm{fm}$$

Cylindrical Geometry



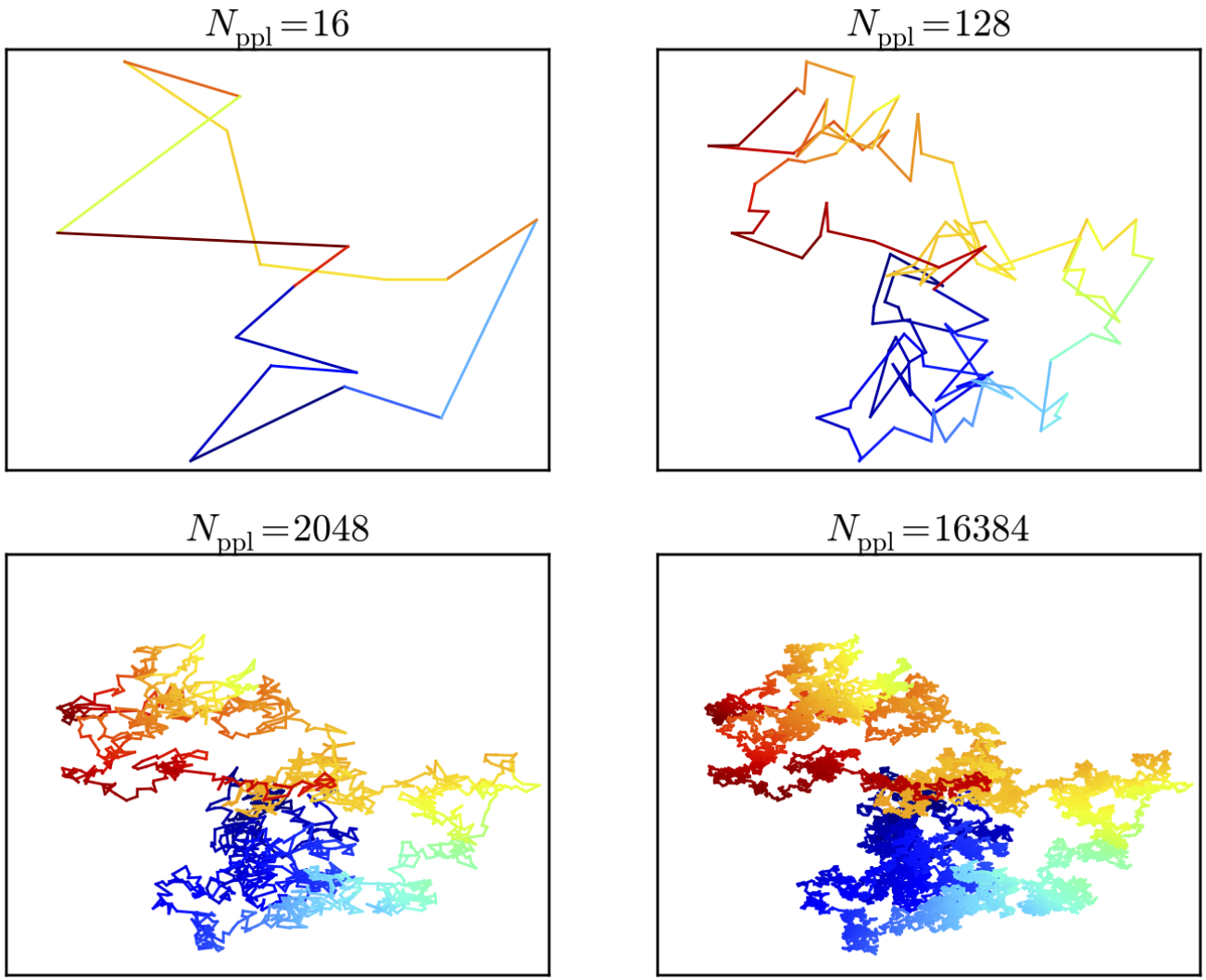
Effective Action



For a magnetic field the effective action is the free energy of the system (actually minus the free energy).

$$\Gamma[A^0_\mu] = \int \mathrm{d}x^4 \left(-\frac{1}{4} F^0_{\mu\nu} F^{0,\mu\nu}\right) - i\hbar \mathrm{Tr} \ln\left[\frac{\not{\nabla} - m}{\not{p} - m}\right]$$

Worldline Numerics



Gies, Roessler, Klingmuller
hep-th/ 0511092
1107.0286

Our Developments

Implementation of world-line numerics on GPUs

- a factor of 10^3 speed-up relative to CPUs,

Our Developments

Implementation of world-line numerics on GPUs

- a factor of 10^3 speed-up relative to CPUs,
- new robust estimates of statistical errors,

Our Developments

Implementation of world-line numerics on GPUs

- a factor of 10^3 speed-up relative to CPUs,
- new robust estimates of statistical errors,
- simplify with cylindrical symmetry,

Our Developments

Implementation of world-line numerics on GPUs

- a factor of 10^3 speed-up relative to CPUs,
- new robust estimates of statistical errors,
- simplify with cylindrical symmetry,
- used scalars instead of spinors (the spinor result is qualitatively similar)

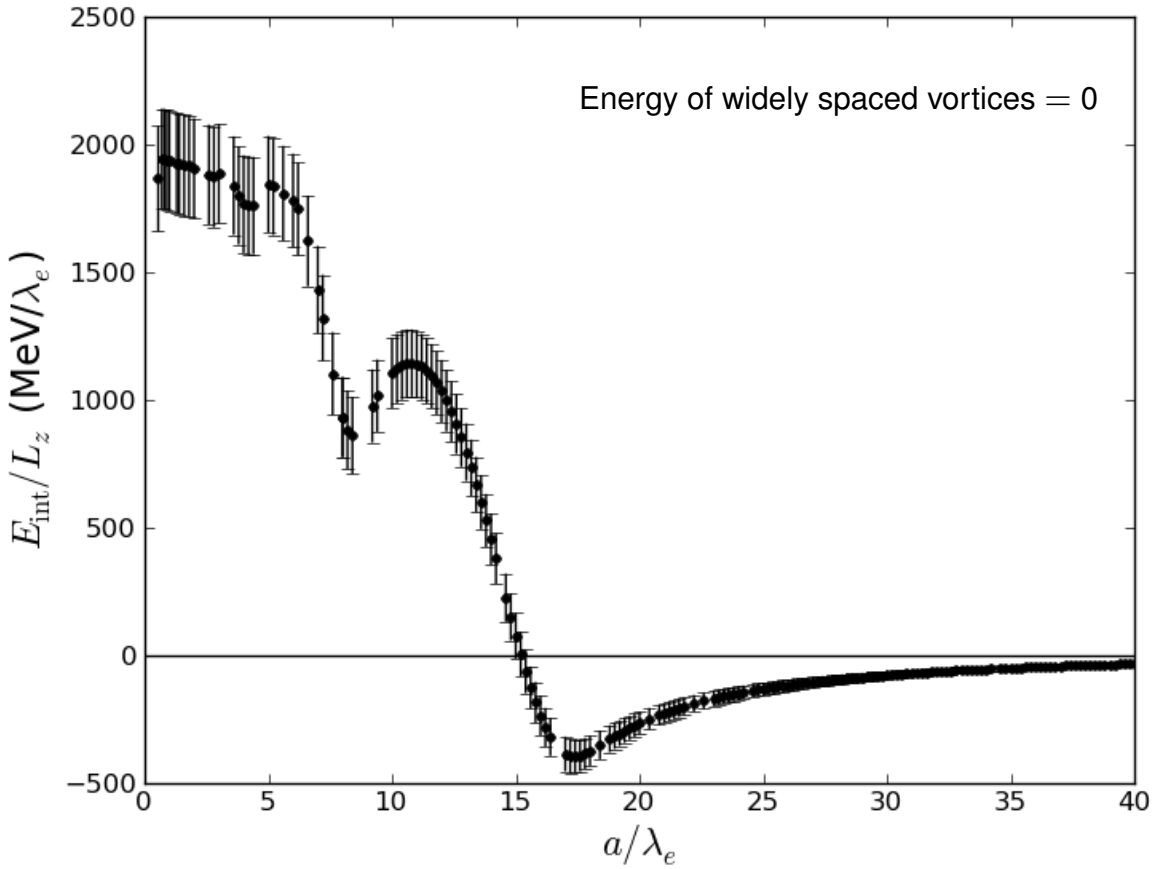
Our Developments

Implementation of world-line numerics on GPUs

- a factor of 10^3 speed-up relative to CPUs,
- new robust estimates of statistical errors,
- simplify with cylindrical symmetry,
- used scalars instead of spinors (the spinor result is qualitatively similar)
- vortex line and vortex cylinders,

Casimir Force

Discovery of an attractive Casimir interaction



Consequences

- For fields less than 10^{12} G the flux tubes will be about seventeen Compton wavelengths apart with large regions free of flux tubes.

Consequences

- For fields less than 10^{12} G the flux tubes will be about seventeen Compton wavelengths apart with large regions free of flux tubes.
- For fields between 10^{12} G and 2×10^{12} G, the tubes will be evenly and closely packed (like the conventional model).

Consequences

- For fields less than 10^{12} G the flux tubes will be about seventeen Compton wavelengths apart with large regions free of flux tubes.
- For fields between 10^{12} G and 2×10^{12} G, the tubes will be evenly and closely packed (like the conventional model).
- For fields between 2×10^{12} G and 5×10^{12} G the flux tubes will be either about eight or seventeen Compton wavelengths apart forming a (possibly irregular) lattice filling the entire region.

Consequences

- For fields less than 10^{12} G the flux tubes will be about seventeen Compton wavelengths apart with large regions free of flux tubes.
- For fields between 10^{12} G and 2×10^{12} G, the tubes will be evenly and closely packed (like the conventional model).
- For fields between 2×10^{12} G and 5×10^{12} G the flux tubes will be either about eight or seventeen Compton wavelengths apart forming a (possibly irregular) lattice filling the entire region.
- For stronger fields, the tubes will be evenly and closely packed (like the conventional model).

Consequences

- For fields less than 10^{12} G the flux tubes will be about seventeen Compton wavelengths apart with large regions free of flux tubes.
- For fields between 10^{12} G and 2×10^{12} G, the tubes will be evenly and closely packed (like the conventional model).
- For fields between 2×10^{12} G and 5×10^{12} G the flux tubes will be either about eight or seventeen Compton wavelengths apart forming a (possibly irregular) lattice filling the entire region.
- For stronger fields, the tubes will be evenly and closely packed (like the conventional model).
- These bounds are qualitative as we need to model the superconductor more accurately.

Future directions

- Consequences (glitches – how to weak field stars glitch),
- Eliminate cylindrical symmetry,
- Two-vortex calculation,
- Fermions in two-vortex configuration,
- Scalars in multiple vortex configuration,
- Include electron coherence length,
- Include chemical potential,
- Fermions in multiple vortex configuration.

Up-Goer Five Abstract

I study what is left over when a star dies. When a really big star runs out of what gives its power, the insides fall in because of the force that pulls us toward the ground. I learn about the force that is made by moving things that make shocks when you rub. The force is made from the changes on a hidden round closed line that you can make without changing what you see.
Inside the left over, the lines of force come together in sticks because the changes on the hidden round closed line are broken. I told you about the forces between these sticks which bring them together in groups with no lines of force in between. This may change how the left overs suddenly turn faster. Left overs with not strong lines of force will turn faster in a different way than those with strong lines of force. How those that turn really fast will change the most.

Alford & Good 2008