Abstract
We present equilibria solutions for neutron stars crusts containing toroidal and poloidal magnetic field. They correspond to Hall equilibria and are confined in the crust of the neutron star. Some simple cases are solved analytically while more complicated configurations are found numerically through a Gauss-Seidel elliptic partial differential equation solver.

1. Neutron Star Crusts
The crust is the upper layer of a neutron star (~2km) and consists of a highly conducting crystal lattice. Lorentz forces exerted by the magnetic field are balanced by the elastic crust and the field evolves through Hall effect[1].

2. Hall Evolution
In the electric current which is carried by electrons. Ohmic diffusion for neutron star crust applications is much slower and is treated as a secondary effect.

\[ \frac{\partial B}{\partial t} = -\frac{e}{4\pi} \nabla \times \left( \frac{\nabla \times B}{n_e} \times B \right) - \frac{c^2}{4\pi} \nabla \times \left( \frac{1}{\sigma} \nabla \times B \right) \]

Hall term

Ohmic term

In a system dominated by Hall drift, equilibrium occurs when the Hall term is equal to zero and is the state it may settle after several Hall timescales. We solve for Hall equilibrium inside the neutron star crust while requiring that the field connects to an external vacuum dipole field.

3. Analytical Solutions
We find Hall equilibria solving the Grad-Shafranov[2] equation. The fields have an overall dipole structure and correspond to uniform rotation of the electron fluid. Analytical solutions are possible for purely poloidal field or for mixed poloidal-toroidal fields fully confined in the crust and bear similarities with previously known MHD solutions[3,4].

4. Numerical Solutions
To avoid the essential simplifications of analytical solutions we numerically solve the Grad-Shafranov equation. The azimuthal field is constrained in closed tori as the external vacuum cannot support currents. The numerical scheme reproduces the analytical results and is in accordance with Hall simulations[5,6].

5. Neutron Star Magnetic Evolution
The solutions presented, subject to their stability, may represent long term states in the magnetic evolution of neutron stars. Despite their similarities, they do not coincide with MHD equilibria, thus a phase transition during the formation of a neutron star from a fluid to a lattice state will be accompanied by magnetic activity. For long enough timescales Ohmic diffusion may become important and the neutron star shall deviate from Hall equilibrium.

References
2. Shafranov V D, 1966, Reviews of Plasma Physics, 2, 103