

DOE grant DE-FG02-07ER41458: Dense Quark Matter in Magnetic Fields
FINAL REPORT
PI: Vivian Incera

This grant was originally a three-year project. However, this final report summarizes the results of the first two years, as at the end of the second year of the grant the PIs moved to a new university and the grant was not transferred. The work done under the first two years of the DOE grant led to several papers and presentations. It also served to train one undergraduate and three graduate students. Below, we summarize the main results of this work.

Papers:

- 1) E.J. Ferrer and V. de la Incera, Super-Dense Matter at Super- Strong Magnetic Fields, arXiv:0810.3886 [hep-ph]
- 2) E.J. Ferrer and V. de la Incera Dynamically Induced Zeeman Effect in Massless QED, arXiv:0807.4744 [hep-ph]. Submitted to PRL.
- 3) E. J. Ferrer and V. de la Incera, Magnetic Phases in Three-Flavor Color Superconductivity. Phys.Rev.D76:045011, 2007.
- 4) V. de la Incera, Magnetic Phases in Dense Quark Matter. AIP Conf.Proc.947:395-400, 2007.
- 5) E. J. Ferrer, Gluon Vortices and Induced Magnetic Field in Compact Stars. AIP Conf.Proc.947:401-406,2007.
- 6) E. J. Ferrer and V. de la Incera, Chromomagnetic Instability and Induced Magnetic Field in Neutral Two-Flavor Color Superconductivity. Phys.Rev.D76:114012, 2007.
- 7) E. J. Ferrer and V. de la Incera, Paramagnetism in color superconductivity and compact stars. J.Phys.A40:6913-6918, 2007.
- 8) E. J. Ferrer and V. de la Incera, Magnetic fields boosted by gluon vortices in color superconductivity. Phys.Rev.Lett.97:122301, 2006.

Results Dissemination

- 1) V. de la Incera, On Color Superconductivity, Magnetic Fields & Instabilities. Mid-West Nuclear Theory Get-Together, Argonne National Lab, October 17- 18, 2008.
- 2) Efrain J. Ferrer, Induced Anomalous Magnetic Moment in Massless QED & CS. Mid-West Nuclear Theory Get-Together, Argonne National Lab, October 17- 18, 2008
- 3) Efrain J. Ferrer, Physics in the large and in the small. University of Texas at El Paso, July 21, 2008.
- 4) Vivian de la Incera, Nature at its Extreme: Dense Quark Matter and Strong Magnetic Fields. University of Texas at El Paso, July 14, 2008.
- 5) Vivian de la Incera, Dense Matter at Strong Magnetic Fields. University of Barcelona, Spain, June 20, 2008.
- 6) Vivian de la Incera, Super-Dense Matter at Super- Strong Magnetic Fields. 4th International Workshop on the Dark Side of the Universe, The British University in Egypt (BUE), Cairo, Egypt, 1st - 5th June, 2008.
- 7) Vivian de la Incera, Magnetism in Superdense Matter, Western Illinois University, October 19, 2007.
- 8) Efrain J. Ferrer, Magnetism in Color Superconductivity. Brookhaven National Lab, NY, Nov 20, 2007.
- 9) Tom Topel, 2SC Color Superconductivity in a Magnetic Field. Western Illinois University, May 6, 2008.

- 10) V. de la Incera, Magnetic phases in Color Superconductivity. Washington University Mini-Workshop in Color Superconductivity, Washington University, San Luis, Missouri. March 2007.
- 11) E. J. Ferrer, Paramagnetism in Color Superconductivity. Washington University Mini-Workshop in Color Superconductivity, Washington University, San Luis, Missouri. March 2007.
- 12) E. J. Ferrer, Gluon Vortex and Induced Magnetic Fields in Color Superconductivity. Exotic States of Hot and Dense Matter and their Dual Description. Perimeter Institute, Canada, May 2007.
- 13) V. de la Incera, Magnetic Phases in Dense Quark Matter. VII Latin American Symposium on Nuclear Physics and Applications. San Antonio Abad del Cusco National University, Cusco, Peru. June 2007.
- 14) E. J. Ferrer, Gluon Vortices and Induced Magnetic Field in Compact Stars. VII Latin American Symposium on Nuclear Physics and Applications. San Antonio Abad del Cusco National University, Cusco, Peru. June 2007.
- 15) E. J. Ferrer, Gluon Vortices and Induced Magnetic Fields in Color Superconductivity. Niels Bohr Institute, University of Copenhagen. Copenhagen, Denmark. June 2007.
- 16) E. J. Ferrer, Gluon Vortices and Induced Magnetic Fields in Color Superconductivity. Frankfurt Institute for Advanced Studies, J.W. Goethe-University. Frankfurt, Germany. July 2007.
- 17) V. de la Incera, Magnetism in Color Superconductivity. Granada University. Granada, Spain. July 2007.

Students Trained

1. Tom Topel (graduate)
2. Ryan Sotelo (graduate)
3. Mani Pokharel (graduate)
4. Jacob Brown (undergraduate)

Sotelo and Pokharel were still doing their MS when we left WIU. Brown was finishing his honor thesis.

MS Thesis Defended

Tom Topel. Thesis: "2SC Color Superconductivity in a Magnetic Field." Defended at WIU on May 2008. This thesis was nominated by Western Illinois University for the 2009 Midwestern Association of Graduate Schools Distinguished Thesis Award.

Impact

The results obtained during the first two years of work in this project have had a significant impact in the understanding of the magnetic field effects in color superconductivity and in the relevance of this topic within the physics community. When we started our investigations on the effects of a magnetic field in a color superconductor, some people in the physics community were skeptic about the possibility to find any relevant effect connected to the magnetic field. These critics expected that the magnetic fields required for any effect would be physically unattainable. Since then, we have proven them wrong. Not only there is a whole richness of magnetic phases and physical effects that have been found, but also, most of them can be triggered at realistic stellar magnetic fields. Moreover, because of the connection between our results with the physics of magnetars, they might open a new window to find the so much sought-out signature of color superconductivity in astrophysical objects. The phases we have found can boost a seed magnetic field in the star or even create one through spontaneous symmetry breaking.

These characteristics can be used to design clever ways to distinguish between a compact star made entirely of neutrons and one with a quark matter core. Certainly these results have opened a lot of new questions and have served to motivate other authors to work in the topic of Color Superconductivity in Magnetic Fields (see for example: D.T.Son and M.A. Stephanov, Phys.Rev.D77:014021,2008; J.L. Noronha and I.A. Shovkovy, Phys.Rev.D76:105030,2007; K. Fukushima and H. J. Warringa, Phys.Rev.Lett. 100, 032007 (2008)).