

**Final Technical Report**  
**DE-FC02-04ER54800**  
**"Center for Extended Magnetohydrodynamic Modeling"**  
**Scott E. Parker, PI**  
**University of Colorado**

This document is the Final Technical Report for DOE cooperative agreement DE-FC02-08ER54971, titled "Center for Extended Magnetohydrodynamic Modeling" (CEMM). Scott E. Parker was the University of Colorado Principal Investigator (PI) on this cooperative agreement. The PI of CEMM is Steve Jardin, Princeton Plasma Physics Laboratory. This report covers the period between 8/15/2004 - 8/14/2007. The grant supports a Physics Department Ph.D. student. We are developing kinetic ion models for the simulation of extended MHD phenomena. The model we have developed uses full Lorentz force ions, and either drift-kinetic or gyro-kinetic electrons. Quasi-neutrality is assumed and the displacement current is neglected. We are also studying alpha particle driven Toroidal Alfvén Eigenmodes (TAE) in the GEM gyrokinetic code [Chen 07].

The basic kinetic ion MHD model was recently reported in an invited talk given by Dan Barnes at the 2007 American Physical Society - Division of Plasma Physics (APS-DPP) and it has been published [Jones 04, Barnes 08]. The model uses an Ohm's law that includes the Hall term, pressure term and the electron inertia [Jones 04]. These results focused on the ion physics and assumed an isothermal electron closure. It is found in conventional gyrokinetic turbulence simulations that the timestep cannot be made much greater than the ion cyclotron period. However, the kinetic ion MHD model has the compressional mode, which further limits the timestep. We have developed an implicit scheme to avoid this timestep constraint. We have also added drift kinetic electrons. This model has been benchmarked linearly. Waves investigated were shear and compressional Alfvén, whistler, ion acoustic, and drift waves, including the kinetic damping rates. This work is ongoing and was first reported at the 2008 Sherwood Fusion Theory Conference [Chen 08] and we are working on a publication. We have also formulated an integrated gyrokinetic electron model, which is of interest for studying electron gradient instabilities and weak guide-field magnetic reconnection.

Additionally, we have been investigating alpha particle driven TAEs with the GEM code as part of "Center for the Study of Energetic Particle Physics," with G. Fu, Princeton Plasma Physics Laboratory as the PI. This work is a continuation of our contributions to energetic particle physics as part of CEMM where we implemented energetic particles in NIMROD. We have successfully observed TAEs in GEM. We observe the correct linear growth rates of the TAEs and have been investigating the effect of core ion kinetic damping. This work is part of Ph.D. Physics Student Jianying Lang's Ph.D. thesis and will be reported in a future

publication. She also reported this work as part of an oral talk at the Sherwood Fusion Theory Conference [Lang 08].

### References

- [Chen 07] Y. Chen and S. Parker, J. Comput. Phys. **220** 839 (2007)
- [Jones 04] S. Jones, S. Parker J. Comput. Phys. **191** 332 (2004)
- [Barnes 08] D. Barnes, S. Parker, J. Cheng Phys. Plasmas **15** 055702 (2008)
- [Chen 08] Sherwood Fusion Theory Conference Poster (2008)
- [Lang 08] Sherwood Fusion Theory Conference Oral Talk (2008)

PATENT CERTIFICATION

University of Colorado  
Awardee

Interim Certification

Subcontract to DE-FG02-04ER54800  
DOE Prime and/or Subcontract Nos.

Final Certification

Awardee hereby certifies unless indicated to the contrary, that:

- All procedures for identifying and disclosing subject inventions as required by the patent clause of the contract have been followed throughout the reporting period.  
Yes
- There were no subcontracts or purchase orders involving research, development, and demonstration except as follows: (a separate certification must be provided to DOE for each subcontract or purchase order awarded.)  
None
- No inventions or discoveries were made or conceived in the course of or under this contract other than the following (Certification includes , does not include  all subcontracts):  
None

<u>TITLE</u>	<u>INVENTOR</u>	<u>DATE REPORTED</u>	<u>DOE "S" NO.*</u>
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4. The completion date of this contract is as follows: August 14, 2007

5. The following period is covered by this certification:

August 15, 2004 to August 14, 2007  
 Month Day Year                      Month Day Year

University of Colorado  
 Contractor                       Signature Kathleen Reneau Lorenzi

Office of Contract/Grants,                      Associate Director, Office of Contracts and Grants  
 Title

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Boulder, CO 80309

Address

8/1/2007

Date of Certification

\* Also include Subcontract No. if available.

NOTE: A positive certification for this Item 3 does not negate the requirement for furnishing to DOE a fully executed Patent Certification from each subawardee identified in Item 2.