Happy New Year 2006 from SSX-FRC!

Here's a quick review of 2005 (and the first half of my sabbatical) as well as plans for 2006 (and the second half of my sabbatical). We had several visits from senior collaborators Mike Schaffer of GA (back in July and most recently a week in Nov 2005) and Bill Matthaeus of Bartol. We had a nice visit from Nick Murphy, a CMSO supported grad student at Wisconsin in July.

Chris Cothran and I made several trips the past year to present SSX results. There was MR2005, the Magnetic Reconnection 2005 meeting at Awaji-shima Island, Japan in March 2005: http://www.kwasan.kyoto-u.ac.jp/mr2005/. Then IPELS 2005, the International Plasma Experiments in Labs and Space (IPELS) meeting in Tromso, Norway in July 2005: http:// www.phys.uit.no/IPELS05/. Chris and I both gave talks at the US-Japan CT workshop in Himeji, Japan in October 2005. I had an invited talk at the APS-DPP meeting in Denver in October 2005. I gave a bunch of talks for APS-DPP at various non-plasma places (St Olafs, Kansas, Ohio Northern, Reed, Bucknell, Loyola, Lawrence...http://apsdpp.org/lecturers.html). We are also continuing our participation in the NSF Center on Magnetic Self Organization in Laboratory and Astrophysical Plasmas (CMSO for short, http://www.cmso.info/). We're gearing up for the ICC meeting in Austin in February 2006 http:// icc2006.ph.utexas.edu/ and the APS April meeting in Dallas.

Our main result in 2005 was a nice measurement by Chris of bi-directional flow (simultaneous blue and red-shift from the IDS) during a reconnection event. We presented this at APS and it will appear in our May 2006 PoP paper (and elsewhere).

Summary of 2005 and plans for 2006:

Ion Doppler Spectroscopy (IDS): Our McPherson model 209 Czerny-Turner 1.33 meter focal length ($f/9.4$ aperture) spectrometer is now a routine diagnostic on SSX. The big result of the summer 2005 was an observation of bi-directional jets (simultaneous measurement of ± 40 km/s flows) with two well separated gaussians (each with $15-20$ eV thermal width). We have also recently accessed a new low-density, high-temperature regime in SSX-FRC by using helium glow discharge conditioning in which $T_i \cong 80$ eV (see below).

This instrument has been used to record the time dependence of the 229.687 nm C_{III} impurity emission line during spheromak merging experi-

ments. The IDS diagnostic analyzes the C_{III} line at 25th order with a dispersion of 0.008 nm/mm at the detector. Velocity resolution (obtained by fitting the lineshape) depends on both signal strength and thermal Doppler width, but can be as good as a few km/s (a few percent of the Alfvén speed); the width (FWHM) of the instrument function corresponds to 5 km/s (3.4 eV for C ions). Chris is finalizing an RSI paper on the IDS instrument with detailed discussion of calibration and zeroing. Jerome's thesis will also be focusing on the IDS instrument. Jerome has been working on Abel-like inversions of IDS scans along different chords so we can get some sense of the radial dependence of T_i and flow in SSX.

Glow discharge conditioning (GDC): With Mike Schaffer's help, we designed and installed a helium GDC system on SSX. The system features a new turbo pump with gate valve and scroll pump (cryo pump won't do helium) and a helium bleed valve. We can run with the gun electrodes either positive or negative potential (anode or cathode). The idea is that the inner walls of SSX have a surface area of about 1 m^2 or 10^{20} $\mathring{A}^2$ so the walls can accommodate 10^{20} hydrogen or water or oxygen molecules. Since we only puff in about 10^{19} hydrogen molecules from the gas valves, this can be a problem... the hot SSX plasma can liberate lots of cool gas off the walls. By scrubbing the walls with helium ions (0.1 $A, 300$ V at 50 microns or so for a few hours) we can get down to bare copper metal. Turns out that to scrub the electrodes (making them negative or cathodes so they're bombarded with helium ions) we run at 0.05 $A, 800$ V at 700 microns. After a GDC session and by making the gas valve delay as short as possible, we can get densities (measured by the HeNe interferometer) down to a few 10^{14} cm^{-3} and $T_i \cong 80$ eV!

Simulations: Elena Belova of PPPL has done several more runs of her HYM code for us. The goal is to compare her simulation to our experimental data for the counter-helicity spheromak merging runs as well as co-helicity and single spheromak runs. Her HYM code does 3D single- and two-fluid modeling of spheromak merging in a cylinder. Nick Murphy is beginning to do simulations using the NIMROD code (2D single fluid for now).

Other diagnostics: We re-installed our 0.2 m vacuum ultra-violet (VUV) spectrometer on SSX. It has it's own pumping port, bellows, and valve system so we can isolate it from the main experimental volume and even remove it completely if necessary. We've recently been able to monitor the time signatures for L_α 122 nm, C_{IV} 155 nm, C_{III} 97.7 nm, and of course our favorite line C_{III} at 229.7 nm. We're also working on increasing our resolution of magnetic structure to a few mm (best to date is 10 mm). During summer

2005, students Jason and Brie made some prototype arrays using #40 and #44 wire (tiny!). Our prototypes have spacings of 3 mm and 5 mm and will be inserted in tiny quartz tubes. Victoria and David have been re-visiting the soft x-ray diagnostic for measuring T_e. They have a nice analysis package using PrismSpec software and fitting routines (including both bremsstrahlung and line emission). Victoria has been analyzing new combinations of SXR filters. We just ordered a new set of 0.1 micron thick metal filters from Lebow including tin, titanium (0.05 micron), zirconium, and aluminum.

For the new magnetic probes, the SXR array, and even IDS, we've been working on designing some fast amplifiers. These will be special purpose, low-noise amps with a typical gain of 10 and a bandwidth of 50 MHz. We're looking at some surface mount designs as well as some quick and dirty "dead-bug" designs (where the chips are splayed out looking like dead bugs).

Papers and manuscripts (2005): We had several manuscripts either appear in print in 2005 or will appear shortly. We're also working on several more that should be submitted early in 2006 (see below).

1. C. D. Cothran, J. Fung, M. R. Brown, and M. J. Schaffer, "Fast, High Resolution Echelle Spectroscopy of a Laboratory Plasma". *Review of Scientific Instruments* (to be submitted soon)

2. M. R. Brown, C. D. Cothran, and J. Fung, "Two Fluid Effects on 3D Reconnection in the SSX Experiment with Comparisons to Space Data". *Physics of Plasmas* (to appear, May 2006)

3. W. H. Matthaeus, C. D. Cothran, M. Landreman, and M. R. Brown, "Fluid and Kinetic Structure of Magnetic Merging in the Swarthmore Spheromak Experiment". *Geophysical Research Letters* (to appear)

4. C. D. Cothran, M. Landreman, M. R. Brown, and W. H. Matthaeus, "Generalized Ohm's Law in a 3D Reconnection Experiment", *Geophysical Research Letters* **32**, L03105 (2005).

5. E. V. Belova, R. C. Davidson, H. Ji, M. Yamada, C. D. Cothran, M. R. Brown, and M. J. Schaffer, "Numerical Study of the Formation, Ion Spin-up, and Nonlinear Stability Properties of Field Reversed Configurations", *Nuclear Fusion* (to appear)

Manuscripts in progress (2006): We have been working on at least four possible manuscripts that should be ready for submission soon.

1. **Properties of the Doublet Compact Torus Configuration:** Here's where we report the observation and characterization of a novel doublet compact toroidal (CT) configuration formed in SSX. It is studied in the prolate (tilt unstable) 0.4 m diameter, $L = 0.6$ m length, 3 mm wall copper flux conserver in SSX formed by counter helicity merging of spheromaks. The doublet CT is characterized by fully reconnected poloidal flux but persistance of oppositely directed toroidal fields. Three dimensional MHD simulations of this configuration are also discussed.

2. **Dynamics of a Tilted $m = 1$ Spheromak in a Prolate Flux Conserver:** Here's where we discuss a fully tilted, $m = 1$ spheromak, formed by co-helicity merging of two spheromaks (either right-right or left-left handed) and studied in the prolate (tilt unstable) 0.4 m diameter, $L = 0.6$ m length, 3 mm wall copper flux conserver in SSX.

3. **Dipole Trapped Spheromak in a Prolate Flux Conserver:** Here's where we report the observation and characterization of a single $m = 0$ spheromak formed in SSX and trapped in externally applied dipole magnetic field. Remarkably, this plasma does not tilt, despite the prolate flux conserver.

4. **Simultaneous Bi-directional Plasma Jets from a Laboratory Magnetic Reconnection Volume (PRL?):** We report the first direct laboratory measurement of simultaneous bi-directional outflows from a reconnection event. The ratio of inflow speed to outflow speed is the normalized reconnection rate. A rapid reconnection rate is corroborated with a separate measurement of reconnecting magnetic flux.

Students: Jerome Fung is wrapping up his thesis Spring 2006 and will be heading off somewhere nice for grad school. Victoria Swisher (working with David Cohen) and Marc Chang will be graduating this spring also. Jason Horwitz and Brie Coellner (Wellesley) did some excellent work for us last summer. I was gratified to see several SSX alums at the APS-DPP meeting in October (Cameron, Tim, Dave, Amy, Slava...).

cheers and happy new year, mb