1. Purpose of Experiments
Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

To exploit C-Mod’s unique capability to study and understand the structure of blobs/filaments in regions away from the outboard midplane. To examine the parallel correlation length of the filaments with improved measurement capability and at field-line lengths that are ~2x those of the only previous study [1]. To examine whether or not filaments extend to the divertor targets in C-Mod, and, if they do, under what conditions they do so (e.g. what range of \( \rho \) (the field-line distance outside the separatrix mapped to the outer midplane) and collisionality).

2. Background
Discuss Physics Basis of the proposed research. Prior results at Alcator or elsewhere, and any related work being carried out separately.

Research on C-Mod has played a leading role in elucidating the structure and dynamics of the blobs/filaments that exist in the outboard far SOL. This phenomenon is the dominant mechanism for perpendicular particle transport there. Previous turbulence imaging near the outboard midplane has shown that the cross-field cross-section of the blobs is approximately circular (at least with a spatial resolution of a few mm) and that they are actually filaments that are approximately aligned with the magnetic field. During the 2009 run campaign, a new diagnostic was installed on C-Mod that allows continuous fast 2D turbulence imaging at the outboard midplane. In addition, the divertor probes in the lower divertor are now being sampled at 500 kHz routinely. Thus at the present time on C-Mod we have the capability to do 2D-turbulence-imaging in three poloidal locations (outboard midplane, just outboard of the lower X-pt, and inboard midplane), as well as to make fast fluctuation measurements with one of the outboard scanning probes and arrays.
of flush probes in the lower and upper divertor targets. The poloidal locations of the key diagnostics for this study are shown in Fig. 1. These diagnostics are at different toroidal locations, and this allows the possibility of studying correlations and dynamics along field lines if the diagnostic regions can be connected magnetically.

A study connecting the GPI views at the outboard midplane and the “F port” vertical scanning probe was done previously [1]. A maximum ~30% correlation between probe $I_{sat}$ fluctuations and GPI emission fluctuations with a time delay of tens of microseconds was observed and the associated potential fluctuations revealed an interchange dominated, dipolar structure. The experiment was complicated by the limited viewing area of the GPI and the fact that essentially only mapping to a single diode view (~3.7 mm diam.) was possible. A key question raised by these experiments is the causal connection between the midplane and near X-pt turbulence. Observations of spatiotemporal fluctuation structure characteristics at the lower X-pt view revealed a good agreement with the hypothesis of a passive magnetic mapping of the structures at the outer midplane along the magnetic field. However, the observed time delay in the cross-correlation function is not in agreement with any of the expected timescales for parallel fluctuation dynamics (sound wave, Alfvén wave, electron thermal speed). However, the reliability of the previously measured time delay is questionable and could easily be influenced by the dynamics of blobs. The new 2D imaging diagnostic at the outer midplane provides a unique possibility to investigate the timescale of the turbulence dynamics along the magnetic field with poloidal and radial resolution.

The proposed experiment will be done with the GPI array of views having been expanded to a 9x10 array of fibers spanning the $R_{major}$ region from 87 cm to 92 cm at $Z$ from -5cm to the midplane. Thus the FSP probe plunge can be tracked along the views of the new GPI views during almost all of its entire trajectory. The trajectory of the probe plunge to the separatrix mapped to the 2D GPI-viewed region is shown in Fig. 2 for $I_p=0.64$ MA.

Figure 1 – Poloidal locations of the key diagnostics. Also noted are their toroidal port locations.
and for a magnetic field variation in the range $B_t=5.4-5.9$ T (based on the reference shot #1031204009). It shows that we can achieve a mapping for various positions of the probe in the SOL, which yields the parameter dependence of the correlation, allows for a 2D reconstruction of the cross-correlation, and allows for a reliable measurement of the time delay for comparison with turbulence models.

In order to see whether or not the filaments extend beyond the high-shear region around the X-point, all the way to the divertor targets, we also wish to map magnetically from the outboard midplane GPI views to the outer divertor probe array at F port. This connection/disconnection has been discussed theoretically [2], and to our knowledge has been observed only on NSTX [3], where connection is observed only beyond a certain $\rho$.

One possible mapping on C-Mod is accomplished by running a $B_t$ of 5.4 T and plasma currents ranging from ~0.73 to ~1.10 MA with the strike point held fixed at $R_{\text{major}}=62.0-62.5$ cm, $Z=-59.6$ cm (i.e. in the slot). As the current is raised from ~0.72 MA to 1.10 MA, divertor probe 8 maps to the midplane GPI view array (at ~0.72 MA), then probe 7 (at ~1.01 MA), and finally probe 6 (at ~ 1.10 MA) The “trajectories” of the mappings of the three fixed probes as mapped to the array as the plasma current is ramped in shot 1090930303 is shown in Figure 3. The different time points are the times of the EFIT mappings. In this instance the current ramp is faster than what we would want for the correlation experiment. In order to see how a 1 cm blob at the midplane might map onto or “splash” onto the outer divertor target, we have plotted the “splash” region of a 1 cm flux tube at the midplane at the toroidal location of the outboard GPI as it maps to the divertor. This is shown in Fig. 4, where it is evident that the toroidal extent of the “splash” is ~1/4 of the toroidal circumference, if it passively maps to the target.

We also wish to map magnetically from the outboard midplane GPI array to the “X-pt” GPI view, which is registered using a 250,000 fr/sec camera with 64x64 pixel resolution. We will examine the spatial and temporal correlations of the fluctuations observed at each location to see if the magnetic mapping of blob cross-sections is observed for the same blobs. The field-line length in such a mapping is longer (~ 5.4 m) than the field-line length mapped to the vertical scanning probe, and the mapping occurs only at very high $q$, i.e. with $I_p=0.30$ MA and $B_t=5.39$ T. The mapping is shown in Figs 5 (side view) and 6 (top view).
Figure 3 – Magnetic mapping from probes 6 (blue), 7 (pink), and 8 (red) in the outer divertor array to the outboard midplane GPI view as the current is ramped from 0.72 at $t=0.23$ s to 1.10 MA at 0.50 s. The mapping is for shot 1090903030 for which $B_t=5.4$ T.

Figure 4. Mapped “splash” region on outer divertor for a 1 cm diam. blob at outboard midplane, if it maps passively to the target without disconnecting.
Figure 5 – Poloidal X-section of the “X-pt” GPI view, shown with the mappings of the right, left, top, and bottom corners of the array of the fast 2D midplane GPI. Thus the purple region in the detail shows the mapped “coverage” of the APD views.

Figure 6 – Toroidal projection of the field-line-mapping from the 2D outer midplane array of views to the “X-pt” GPI view. Bt=5.39 T, Ip=0.300 MA

3. Approach
Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

We propose to make simultaneous measurements of edge turbulence at 3 pairs of magnetically connected regions. The common region for each pair is the array of views covered by the GPI APD system at the outboard midplane. We will connect it with 1) the
F port scanning probe, 2) the outer divertor probe array at F port (lower divertor), and 3) the “X-point” GPI view. The magnetic mapping between each pair obviously requires different plasma currents. We propose to do this in Ohmic L-mode plasmas.

The mapping to the “X-point” GPI is the only one that may be difficult to achieve. For this mapping a high q is required while maintaining the LSN diverted shape. For $B_t=5.4$ T a current of $\sim 0.30$ MA is required. Such conditions have been produced in C-Mod only in some current rampdown phases and early (at about 0.4 s) in the discharges produced for the 1070412 run. Thus we propose to run a discharge similar to 1070412018, but with a somewhat larger outer gap.

We will see if the time histories of the outboard midplane APD signals are time-delayed correlated with the signals from the other diagnostic measurements. Previously it was shown – by correlating the old “crossed” array diode signals with the F-port scanning probe $I_{sat}$ and $V_{float}$ – that the parallel correlation length of the filaments was at least $\sim 2.7$ m [1]. We will be able to measure or at least set an upper limit on the time delay, which should help to elucidate how the turbulence communicates along the field-lines. Furthermore we will be able to see how the filaments in the outboard midplane view locations in fact map into the “X-pt” view locations and see whether or not this has the “finger-like” elongation predicted by the field-line mapping with $k||=0$. In these experiments (excepting the correlations with the FSP signals) we will be correlating the signals for a few tenths of a second (max 0.5 s), rather than for the few ms in the previous experiment. In the FSP experiment, the time period will be over the entire plunge, rather than only those points in the plunge that mapped to the old “crossed” array of views. These experiments will also allow for study of correlations of turbulence on closed field lines.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 5.4 T
Plasma Current: ~5% variation around 0.64 MA, slow current ramp from 0.72 MA to 1.10 MA with strike point fixed, ~5% variation around 0.30 MA
Working Gas Species: D$_2$
Density: NL$_{04}$= $\sim 0.5 \times 10^{20}$ m$^{-3}$ with variation for higher Ips, NL$_{04}$= $\sim 0.3 \times 10^{20}$ m$^{-3}$ for $I_p=0.3$ MA
Boronization Requested (if yes, specify whether overnight or between-shot, how recently needed, and any special conditions.): not necessary
Equilibrium configuration (if possible, refer to database equilibria): LSN
Similar to shot 1031207009 – for mapping to FSP
Similar to shot 1090903030 but with a slower $I_p$ ramp – for mapping to outer div. probe array
Similar to shot 1070412018 at 0.42 s, but with an outer gap of 2.3 cm – for mapping to “X-pt” GPI view

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing:
LHCD Power, pulse length, phasing:
Pellet Injection (species):
Impurity blow-off injection:
Diagnostic Neutral Beam:
Special gas puffing: NINJA (D₂) for GPI
Cryopump:
Non-axisymmetric Coils (Connections, Current);
Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

All standard, but especially GPI outboard midplane APD array, GPI outboard midplane fast camera, GPI “X-pt” fast-camera, FSP (scanning), and ASP (scanning or dwell).

5. Experimental Plan

Both sections must be filled in.

5.1 Run sequence Plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period – 10 hours maximum – etc.

0.5 to 1 run day

5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

Load or reproduce shot 1031204009 for mapping between FSP and midplane GPI.
Scan FSP 3 times during the ~0.5 s gas puff period at outboard midplane. Measure correlations between GPI signals and probe I_sat and V_float. Start with NL04~0.4x10²⁰ m⁻². If correlation mapping is achieved, then vary the NL04 by ~0.4 and -0.2x10²⁰ m⁻².
4 good shots

Repeat with Ip scanned slowly and dynamically between ~0.72 and ~1.10 MA (Bₜ=5.4 T) with fixed strike points for which the APD array view maps to the lower divertor probes. Start with NL04~0.5x10²⁰ m⁻². If correlation mapping is achieved, then vary the NL04 by ~0.4 and -0.2x10²⁰ m⁻².
4 good shots with APD array views magnetically connected to the lower divertor probes.

Start with shot 1070412018; extend time for which the plasma current is 0.30 MA from 0.4 s to 0.6 s. During this time the X-point GPI view should be connected to the outboard midplane GPI view(s). (We could also consider doing this during rampdown, although...
there are no shots to date that could be used as models for this scenario. In this scenario, we would want a ~0.5 s plateau with Ip=0.3 MA in the rampdown.)

\[ NL04 = 0.3 \times 10^{20} \text{ m}^{-2}. \]

Repeat for 4 good shots with “X-pt” view, APD array views, “outer midplane” camera view.

We will be running the correlation program between shots in order to check the correlation as we go.

6. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, an ITER request, or an external database.

Elucidation of structure and dynamics of blobs/filaments. Data for a possible invited talk by J.Terry at High Temperature Plasma Diagnostics conference (May 2010). (He has been nominated.)

7. References

Include references both to external and internal literature or communications which bear on this proposal. See Section 2.