1 Coil healing

- S.R.Hudson and the PIES and COIL groups
- Free-boundary healing.
- Dynamical healing.

II Representation of Modular Coils

- The coils lie on a winding surface :

$$R = \sum_i r_i \cos(m_i\theta + n_i N\phi), \tag{1}$$

$$Z = \sum_i z_i \sin(m_i\theta + n_i N\phi). \tag{2}$$

- Each coil has toroidal variation :

$$\phi_i = \phi_{i0} + \sum_k \left[\phi_{i,k,c}\cos(k\theta') + \phi_{i,k,s}\sin(k\theta')\right], \tag{3}$$

$$\theta' = \theta + \sum_j \theta'_j \sin(j\theta). \tag{4}$$

- A subset of the $\phi_{i,k,c}$, $\phi_{i,k,s}$ modes is chosen to be the independent parameters.
- These parameters will be varied to produce healed configurations.

III Elimination of resonances

- The resonant harmonics of the magnetic field normal to the rational surfaces are computed using PIES.
- Changes in these resonant harmonics are related to changes in the independent variables via a coupling matrix $\mathbf{C}$:

$$\mathbf{B}(\mathbf{r}_0 + \delta\mathbf{r}) = \mathbf{B}(\mathbf{r}_0) + \mathbf{C} \cdot \delta\mathbf{r} + \ldots \qquad . \tag{5}$$

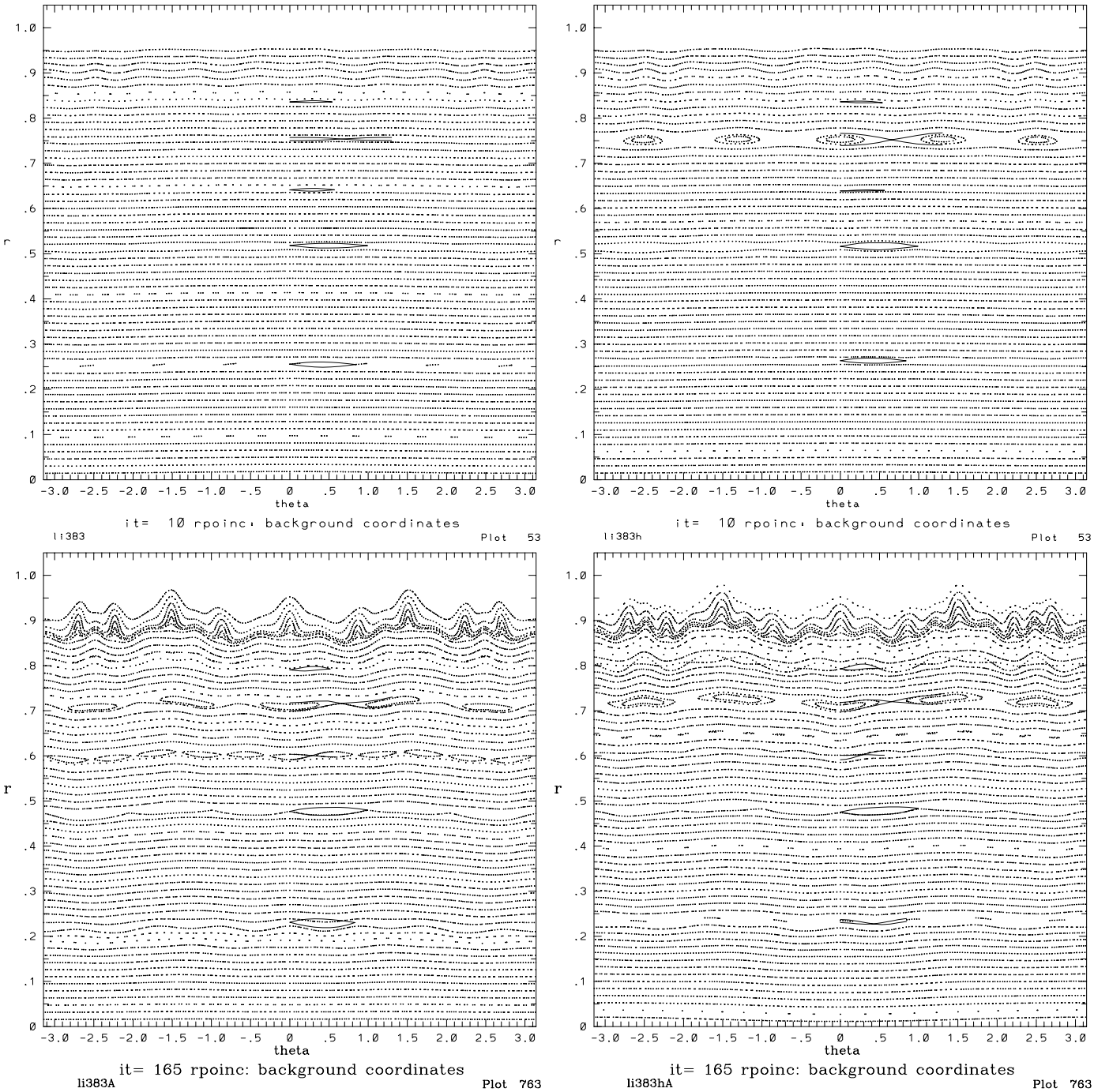
- Inversion of the coupling matrix using $\mathbf{C} = \mathbf{U}\mathbf{w}\mathbf{V}^T$ allows an iterative Newton procedure which will find the parameter set eliminating resonances :

$$\delta\mathbf{r}_{i+1} = -\mathbf{V}\mathbf{w}^{-1}\mathbf{U}^T\mathbf{B}_i. \tag{6}$$

- Two methods :
  - Static healing,
  - Dynamic healing.

IV Free-boundary PIES

- Initialized with (fixed-boundary) VMEC equilibrium.
- Converged equilibrium defined by coils.
- Different initializations temporarily appear different, but converge to similar equilibrium.
- Shown are PIES runs, initialized with li383 and li383h, with 0907h coil set at 10 and 165 iterations.



v Static healing

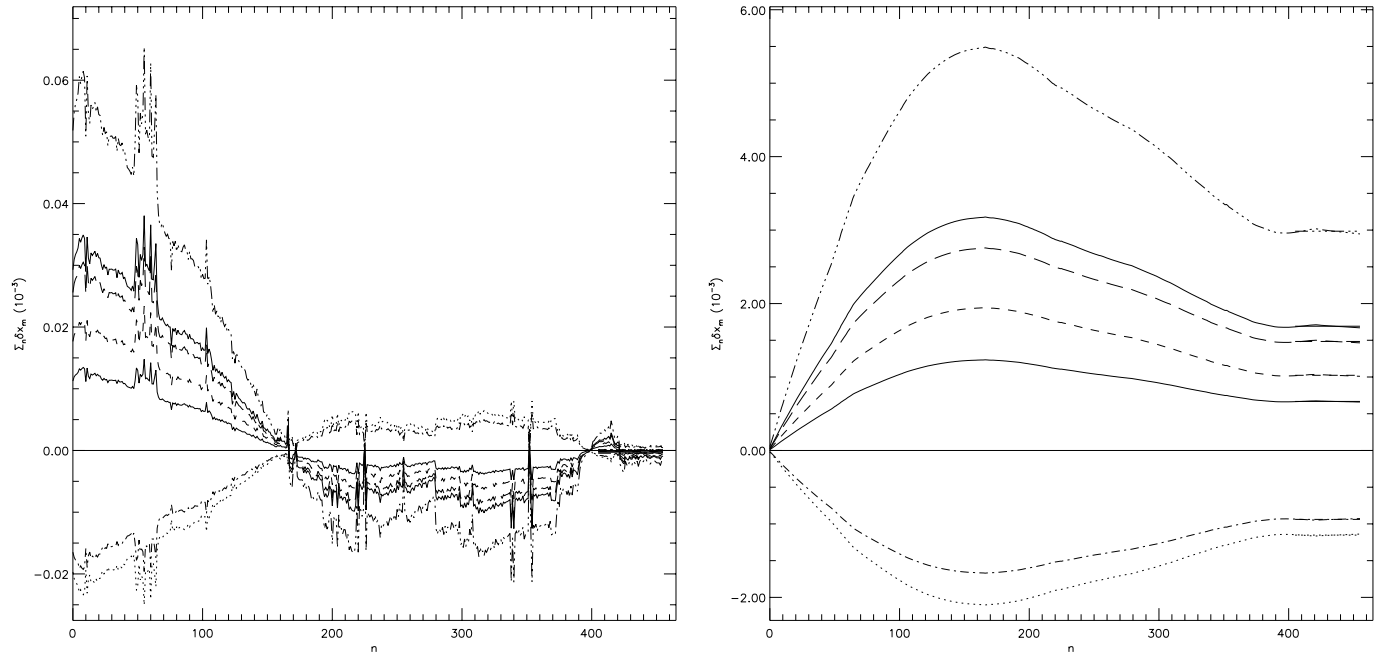
- A vector function of coil geometry is defined as the resonant fields calculated by PIES after a fixed number N of iterations.
- No changes are made to the coils during the PIES iterations (hence term static).
- Finding the zero of this function determines the coil set that will 'heal' the configuration at N PIES iterations.
- Presently being applied to 0227a1 coils – with Ron Hatcher.
- Problem :
  - Configurations healed at N iterations may or may not remain healed as the iterations continue.

VI Dynamical healing

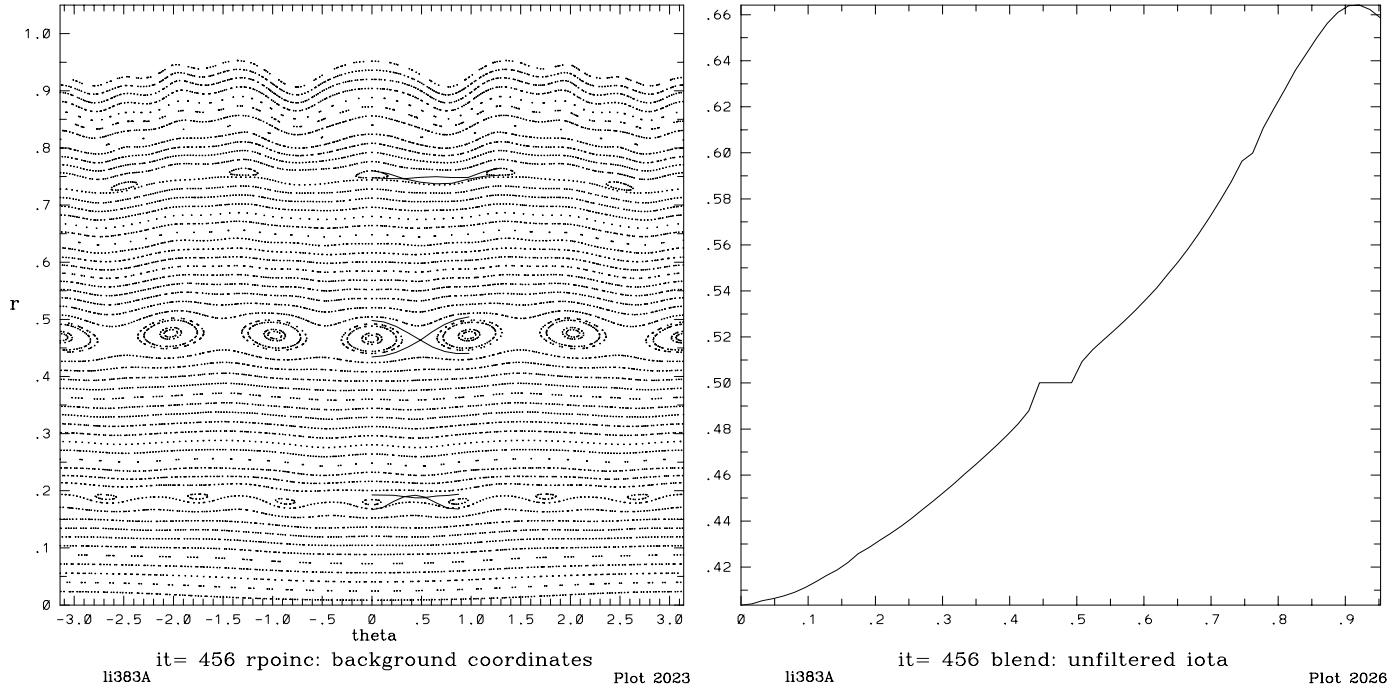
- At every iteration of PIES, a vector function of coil geometry is defined as the resonant harmonics of the coil field at the rational surfaces.
- At every iteration of PIES, the coil geometry is varied (dynamic wrt. PIES iteration; not time) so the resonant coil field cancels the resonant plasma field.
- By construction, the configuration never has islands.
- Question
  - Do the coil corrections converge to zero ?
  - If so, will the coil set constructed yield healed PIES configurations without the dynamical healing ?
- The following details results targeting the (1,5) island and varying the $\phi_{i,5,c}$, $\phi_{i,5,s}$ modes (7 independent variables).

VII Dynamical healing results

- Coil Change vs PIES iteration



- Poincaré plot and Rotational Transform



VIII Comments / Questions

- Dynamical healing appears to have past the first test – that the coil changes converge. The configuration is very similar to the original initialization (li383).
- Convergence test (from VMEC initialization with healed coils) presently in progress.
- Questions :
  - Why do the changes appear to 'overshoot' ?
  - What will happen if the dynamically healed case is continued with the dynamically healing off ?
  - Will a PIES run, with VMEC initialization, with the healed coils converge to the dynamically healed configuration ?
  - How will a different VMEC initialization affect the convergence of the coil changes ?