A self-force primer

- The *Self-Force* on a "charge" arises from the interaction of the "charge" with its own "retarded field." This includes the dissipative effects of radiation reaction and may also have some conservative effects as well.

- The acceleration from the self-force is proportional to q^2/m. For gravity this acceleration is proportional to m.

- Example: The orbital frequency of a circular Newtonian binary is

$$\Omega^2 = \frac{M}{R^3(1+m/M)^2} \approx \frac{M}{R^3}(1-2m/M)$$

where R is the radius of the orbit of m, *not* the separation between the masses. The $-2m/M$ term is a consequence of the Newtonian gravitational self-force.

- For gravity, analysis of the self-force uses perturbation theory, $g_{ab} = g^{\circ}_{ab} + h_{ab}$.

Some Details

• A *gauge choice in perturbation theory* is not just a choice of coordinates, but rather is a choice of how to associate an event on the background manifold with an event on the perturbed manifold. The change in h_{ab} from a gauge transformation (an infinitesimal change in coordinates) ξ^a, is $\Delta h_{ab} - \nabla_a \xi_b - \nabla_b \xi_a$.

• Freedom in the choice of gauge adds confusion to a self-force calculation. There is no gauge-invariant definition of a self-force.

• The field from a charge is singular at the location of the charge — which is precisely where we need to know the field to calculate the self-force.

• *Regularizing* the field is the act of removing the *singular part* from the *actual* field leaving behind the *regular part* of the field, which is then used to calculate the self-force.

• Common ways of distinguishing between the singular and regular parts are

$$\left.\begin{array}{l} h_{ab}^{\mathrm{act}} \\ h_{ab}^{\mathrm{ret}} \\ h_{ab}^{\mathrm{full}} \end{array}\right\} = \left\{\begin{array}{lcl} h_{ab}^{\mathrm{S}} & + & h_{ab}^{\mathrm{R}} \\ h_{ab}^{\mathrm{direct}} & + & h_{ab}^{\mathrm{tail}} \\ h_{ab}^{\tilde{S}} & + & h_{ab}^{\tilde{R}} \end{array}\right.$$

Capra Issues

- Evolution of the Carter constant.
- Metric perturbations of the Kerr geometry.
- Gauge invariant descriptions of self-force effects.
- Formal analysis of second order metric perturbations with a point (small, black hole) source.
- A "practical" scheme for implementing the second order perturbation theory for a point source.

Capra Goals

- Better waveforms for LISA and LIGO.
- Comparison between perturbation analysis and the post-Newtonian approximation.
- Better understanding of the relativistic two body problem.