Dominant diabatic long-range electron-atom interaction

The interaction $V$ between an electron ($e^-$) and an atom or ion at a large separation $r$ is a sum of terms. Using the Feshbach projection operator formalism, we showed [53] that $V$, at large $r$, included a term $-3a_0\beta_1/r^6$. ($\beta_1$ is defined in terms of matrix elements. We provided rough estimates of $\beta_1$ for a number of atoms.) The interaction had been obtained previously, by Mittleman and Watson, and by Dalgarno and co-workers. (I have been told that the first derivation was given in the 1930’s, in a German journal, but I do not know the reference.) We later gave a very much simpler proof, based on third-order perturbation theory – see App. A of [101].

Retardation effects for the interaction of an atom or ion and an $e^-$ are considered elsewhere in this collection, but I will mention that $V_{pol} = -\left(\frac{1}{2}\alpha(0) \frac{e^2}{r^4}\right)$, the polarization potential, where $\alpha(0)$ is the static electric-dipole polarizability of the atom or ion, is a static one; the atom or ion has an unlimited amount of time to adjust to the presence of the fixed $e^-$, and $V_{pol}$ is valid even for $r \sim \infty$. The $1/r^6$ interaction, on the other hand, is a dynamic one; the atom or ion must adjust to the effect of the moving outer $e^-$ [106]. If $r$ is sufficiently large, one must take into account the fact that due to the finite speed of light, the electrons in the atom or ion know where the outer electron was, not is. The atom or ion cannot sufficiently rapidly respond to the motion of the outer $e^-$, and the $1/r^6$ term turns into a $1/r^7$ term. This is very similar to the change of the van der Waals $1/r^6$ atom-atom to the Casimir-Polder $1/r^7$ interaction.

It would be nice to imagine an experiment, which could measure $\beta_1$ directly. I published a paper that purported to do just that, but the argument in that paper was all wrong.