**To continue this study** we need accurate laboratory measurements of atomic transition frequencies. These are compared with frequencies in quasar absorption spectra to search for variations in $\alpha$.

The required wavelengths are for E1 transitions to the ground state in a variety of atoms and ions. The wavelengths range from around 900 - 6000 Å, and require an accuracy of better than $10^{-4}$ Å.

### CALCULATIONS

The difference between the transition frequencies in quasar absorption spectra ($\nu_{q}$) and in the laboratory ($\nu_{l}$) is related to the difference in $\alpha$ by $\Delta \nu = \nu_{q} - \nu_{l} = (\nu_{q} / \nu_{l})^{2} - 1$. The relative energy shifts, $\Delta \nu / \nu$, are calculated using atomic physics codes.

- Atomic energy levels are calculated in a first approximation using relativistic Hartree-Fock, usually in the $V(N-1)$ approximation.
- Higher order effects are taken into account using many-body perturbation theory for single-valence-electron systems, or configuration interaction for many-valence-electron systems. Both methods assume a frozen Hartree-Fock core.
- We first obtain “dressed” relativistic Hartree-Fock orbitals that include the rescaled isotope shift operator.

The energy is then calculated using many-body perturbation theory for single-valence-electron systems, or configuration interaction for many-valence-electron systems. The field shift comes from the changed charge distribution in the nucleus. We modify the nuclear potential directly to include it, with a scaling parameter $\xi$.

### References