Electron, photon and atom scattering, recombination and photoionization via dense spectrum of chaotic compound resonances

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Synopsis We developed a statistical theory for finite Fermi systems (atoms, molecules, nuclei) based on properties of chaotic eigenstates which are formed when several particles are excited [1, 2, 3, 5].

Level density of many-body states exponentially increases with the number of excited particles. When residual interaction exceeds the interval between these levels, the eigenstates (compound states) become chaotic superpositions of of thousands, or even millions of Slater determinant basis states. "Exact" calculations of such eigenstates (compound states) are impossible in principle since all minor perturbations (e.g., higher-order correlations or relativistic effects) are enhanced due to exponentially small energy denominators, and strongly affect the eigenstates. This situation takes place in highly excited nuclei, rare-earth and actinide atoms [3, 4] and open f-shell ions excited by the electron recombination [6]. Chaotic compound resonances have been recently found in ultracold collisions of erbium atoms [7].

We applied the statistical theory to calculate orbital occupation numbers, matrix elements, enhancement of weak interactions and electromagnetic amplitudes between chaotic compound states. Statistical theory predicts observables averaged over a small energy interval containing many compound states. Our predictions of the 10^5 enhancement of the parity violation effects in neutron-nucleus reactions near chaotic p-wave compound resonances [8, 1] have been confirmed by numerous experiments [2]. Our calculations of the electromagnetic transition probabilities between chaotic excited states in Ce atom agree with the experimental data.

We derived formulas for the resonant multi-electron recombination via di-electron doorway states leading to the many-electron compound resonances [6, 5] and performed numerical calculations for the electron recombination with gold (Au+25) [6] and tungsten ions (W+17 - 24) [9, 10, 11]. The electron recombination of tungsten ions exceeds the direct recombination by three order of magnitude.

Another manifestation of chaos is enhancement of the Raman photon scattering and suppression of the photoionization via chaotic compound resonances [10, 5].

In Ref. [5] it is shown that the interference between the chaotic compound resonances (neglected in independent resonance approximation) leads to a coherent contribution, which determines the energy-averaged total cross sections of electron- and photon-induced reactions.

The statistical theory can be applied to intramolecular vibrational energy redistribution in polyatomic molecules, which is key to most chemical reactions.

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References

[1] V. V. Flambaum and O. K. Vorov, Phys. Rev. Lett. **70**, 4051 (1993).

[2] V. V. Flambaum and G. F. Gribakin, Progress in Particle and Nuclear Physics **35**, 423 (1995).

[3] V. V. Flambaum, A.A. Gribakina, G.F. Gribakin, M.G. Kozlov, Phys. Rev. A **50**, 267 (1994).

[4] A. V. Viatkina, M. G. Kozlov, V. V. Flambaum, arxiv: 1611.01028, accepted to Phys. Rev. A.

[5] V.V. Flambaum, M.G. Kozlov, G.F. Gribakin, arxiv: 1404.4151

[6] V. V. Flambaum, A.A. Gribakina, G.F. Gribakin, C. Harabati, Phys. Rev. A **66**, 012713 (2002).

[7] A. Frisch, M. Mark, K. Aikawa, F. Ferlaino, J. L. Bohn, C. Makrides, A. Petrov, and S. Kotochigova. Nature **507**, 475 (2014).

[8] O.P. Sushkov, V.V. Flambaum. JETP Lett. **32**, 352 (1980); Sov. Phys. Usp. **25**, 1 (1982).

[9] V.A. Dzuba, V.V. Flambaum, G.F. Gribakin, C. Harabati, Phys. Rev. A **86**, 022714 (2012).

[10] V.A. Dzuba, V.V. Flambaum, G.F. Gribakin, C. Harabati, M.G. Kozlov, Phys. Rev. A **88**, 062713 (2013).

[11] C. Harabati, J. C. Berengut, V. V. Flambaum, and V. A. Dzuba, arxiv: 1608.07932