Low-energy limit of the radiative dipole strength in nuclei

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We explain the upbend phenomenon, which was first reported in Ref. [1], later observed systematically in the γ-ray strength functions below neutron threshold of various light and medium-mass nuclei and probed by different experimental techniques [2]. Studies of Ref. [3] have revealed that this phenomenon, occuring in various astrophysical sites, can have a significant impact on their elemental abundances.

Phenomenological approaches approximate the γ-strength in this energy region by the tail of the giant dipole resonance with a temperature-dependent width. This is, however, absolutely not justified, because the low-lying γ-strength originates from underlying physics which is completely different from the giant vibrational motion. In addition, such approaches fail to reproduce the low-energy anomaly which is observed in medium-mass nuclei.

We propose a microscopic approach for the radiative strength function which is based on the statistical description of an excited compound nucleus. In is shown [4] that the thermal mean field model provides a very reasonable approach to the compound nucleus. At the same time, it is simple enough to allow a straightforward generalization of very complicated microscopic approaches to nuclear response for the case of a compound nucleus, in terms of finite temperature corresponding to the nuclear excitation energy. To describe transitions from a thermally excited state, in the first approximation we employ the finite-temperature continuum QRPA developed in [5]. Variation $\delta\mathcal{R}$ of the density matrix $\mathcal{R}$ in the external field P obeys the following integral equation:

$$\delta\mathcal{R}(x;\omega,T) = \int dx' \mathcal{A}(x,x';\omega,T) \times \Big(P(x') + \int dx'' F(x',x'')\delta\mathcal{R}(x'';\omega,T)\Big), \qquad (1)$$

where $x = \{\mathbf{r}, s, \tau\}$, and $F(x,x')$ is the effective nucleon-nucleon interaction. The two-quasiparticle propagator $\mathcal{A}(x,x';\omega,T)$ is calculated in terms of the Matsubara temperature Green functions in the coordinate space [5]. Its continuum part is responsible for transitions from the thermally unblocked discrete spectrum states to the continuum (see Fig. 1). The radiative dipole strength function is determined as:

$$f_{E1}(E_\gamma,T) = -\frac{16e^2}{27(\hbar c)^3} Im \int dx \delta\mathcal{R}_{E1}(x;\omega,T)P_{E1}(x), \qquad (2)$$

$\omega = E_\gamma + i\Delta$. Fig. 2 displays f_{E1} in ^{94}Mo at the excitation energy around its neutron separation energy S_n, that represents the case of radiative thermal neutron capture, compared to f_{E1} in the ground state. The upbend of the strength due to the transitions illustrated schematically in Fig. 1 appears as a typical feature of γ-strength in medium mass nuclei while in heavy nuclei f_{E1} comes out rather flat at $E_\gamma \to 0$.

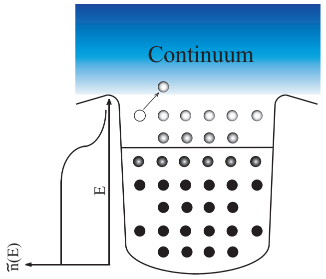

Figure 1: Schematic picture of the lowest-energy single-quasiparticle transitions from the thermally unblocked states with effective occupation probabilties $\tilde{n}(E)$ to the continuum.

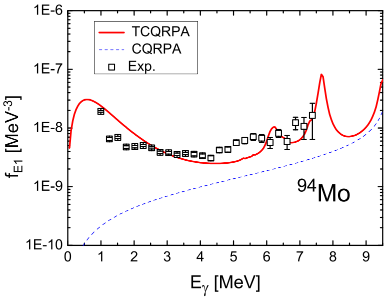

Figure 2: The E1 γ-strength for the thermally excited state of ^{94}Mo near S_n (solid), compared to the strength for the ground state (dashed) and to Oslo data.

In conclusion, we explain the systematic low-energy enhancement of the γ-strength on the microscopic level and show that the approaches to r-process nucleosynthesis, involving Brink hypothesis, may need to be revised.

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References

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