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Research Article

Application of Correlated wave Packets for Stimulation of LENR in Remote Targets

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Abstract

The paper discusses the features of the formation, evolution and propagation of coherent wave packets and their energy characteristics. Such packages can be created with a certain effect on a slow moving particles. A feature of such packets is a self-controlled remote collapse, in the zone of which there is a very strong self-compression of the packet and a giant increase in the fluctuation of its kinetic energy. Such correlated states can be used to carry out LENR reactions in remote targets.

Keywords: Coherent correlated states, Collapse of wave function, Correlated wave packet, LENR in remote targets

1. Introduction

The traditional method for generating LENR involves fulfilling the appropriate conditions (optimal screening, local micro-acceleration, local compression, "proton-electron to neutron" conversion etc.) for fixed interacting particles in a specific material medium. The situation remains approximately the same in the case of particles with low energy of motion (e.g. injection or diffusion of low energy protons into the material medium). In any of these methods, the properties of particles (except for a change in their energy) remain almost unchanged as they approach the target.

The typical example of such a system is the interaction of moving particle with target nuclei. We can describe the state of this particle in the form of a normalized Gaussian wave packet with the wave function

$$\Psi(x,t) = \left\{ \left(u + \frac{it\hbar}{mu} \right) \sqrt{\pi} \right\}^{-1/2} \exp\left\{ -\left[\frac{(x-v_0 t)^2}{2(u^2 + t^2\hbar^2/m^2u^2)} \right] + ip_o x/\hbar \right\} \tag{1}$$

and initial structure

$$|\Psi(x,0)|^2 = (\pi u^2)^{-1/2} \mathrm{e}^{-x^2/u^2}. \tag{2}$$

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Here $\Delta x(0) = u$ is the initial (at $t = 0$) "size" of wave packet, $v_0 = p_0/m$ is the average speed of the packet, m is the mass of the particle.

Such a packet is synthesized from a continuous continuum of spectral components $c(p)$, the specific form of which

$$c(p) = \int_{-\infty}^{\infty} \Psi(x,0)\Psi_p^*(x)\,\mathrm{d}x = \sqrt{u/\sqrt{\pi}\hbar}\exp\left\{-\frac{(p_0-p)^2u^2}{2\hbar^2}\right\} \tag{3}$$

can be determined from the standard expansion of the total nonstationary wave function

$$\Psi(x,t) = \int c(p)\Psi_p(x)\exp\{-iE_pt/\hbar\}\,\mathrm{d}p, \quad E_p = p^2/2m \tag{4}$$

in plane waves

$$\Psi_p(x) = (2\pi\hbar)^{-1/2}\mathrm{e}^{ipx/\hbar} \tag{5}$$

in free space. It is traditionally believed that the description of a realistic particle using a Gaussian wave packet is more adequate than using a plane wave, which is typical for quantum mechanics. Such Gaussian wave packets correspond to uncorrelated states of a moving particle with a minimal initial dispersion of the coordinate

$$\sigma_x(0) = \langle (x - \langle x\rangle)^2\rangle = u^2/2 \tag{6a}$$

and momentum

$$\sigma_p(0) = \langle (p - \langle p\rangle)^2\rangle = \hbar^2/2u^2 \tag{6b}$$

of the particle, which corresponds to the minimum of Heisenberg uncertainty relation

$$\sigma_x(0)\sigma_p(0) = \hbar^2/4. \tag{7}$$

These features of the spatial evolution of the Gaussian wave packet are connected with phase relations between different spectral (Fourier) components. These components correspond to the wave function of the same packet in momentum space.

The presence of spatially localization of a moving wave packet allows us to describe the dynamics of its interaction with a specific target in more detail. The possibility of such localization of the particle wave function favorably distinguishes this description from the traditionally used particle wave function in the form of a fully delocalized plane wave.

On the other hand, such a package is characterized by a very strong dispersion and spatial "spreading", which corresponds to the variance of the coordinate

$$\begin{aligned}\sigma_x = \langle x^2\rangle - (\langle x\rangle)^2 &= \int_{-\infty}^{\infty} \Psi^*(x,t)x^2\Psi(x,t)\,\mathrm{d}x - \left\{\int_{-\infty}^{\infty} \Psi^*(x,t)x\Psi(x,t)\,\mathrm{d}x\right\}^2 \\ &= u^2\{1 + (t\hbar/mu^2)^2\}/2, \quad \langle x\rangle = v_0t. \end{aligned} \tag{8}$$

The similar results follow from a direct analysis of the wave function (4). In particular, it can be seen from the structure of the packet

$$|\Psi(x,t)|^2 = \left\{\pi\left[u^2 + \left(\frac{t\hbar}{mu}\right)^2\right]\right\}^{-1/2} \exp\left\{-\left[\frac{(x-v_0t)^2}{(u^2+t^2\hbar^2/m^2u^2)}\right]\right\}, \tag{9}$$

that its width

$$\Delta x \approx \sqrt{u^2 + (t\hbar/mu)^2} \tag{10}$$

and the area of space localization during spatial propagation continuously increases, while the packet amplitude

$$|\Psi(x,t)|^2_{\max} = 1/\sqrt{u^2 + (t\hbar/mu)^2} \tag{11}$$

continuously decreases.

These well known features of the packet structure are presented in Fig. 1.
These features do not allow the effective (localized) distant action of such packages (e.g., stimulation of nuclear reactions in the remote targets).

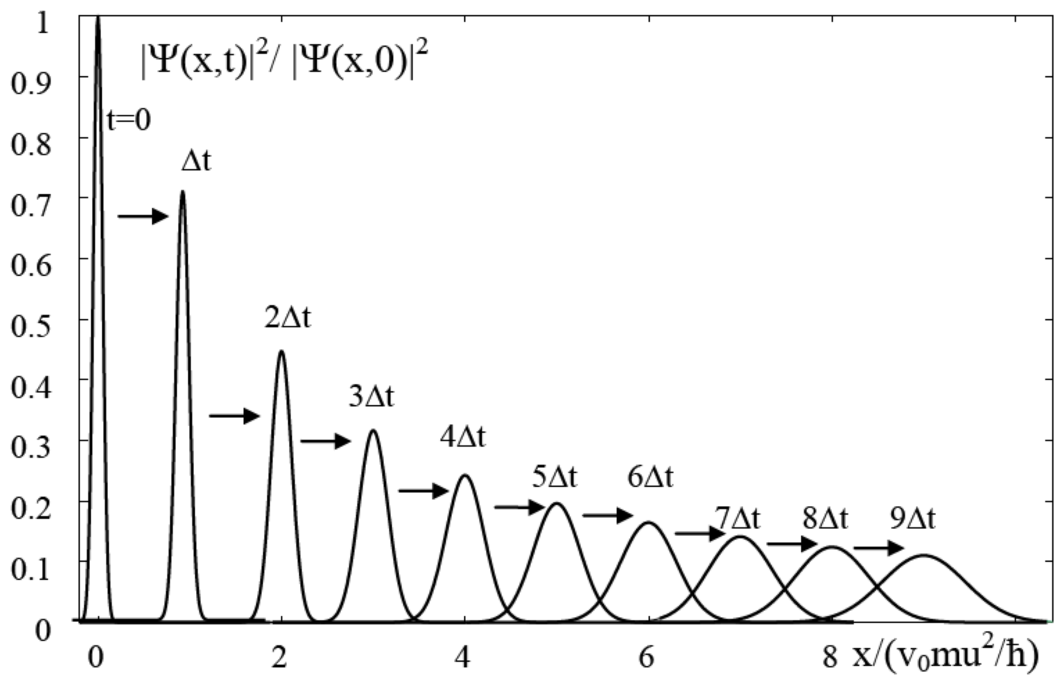

Figure 1. Spatial evolution of Gaussian uncorrelated wave packet. Here $\Delta t = mu^2/\hbar$.

2. Features of Space Structure, Energy Fluctuations and Space Evolution of the Correlated Wave Packet

As noted above, fundamental drawbacks (spatial spreading and amplitude reduction immediately after the creation) of a standard Gaussian wave packet can be completely eliminated and even inverted using a correlated wave packet.

In the initial state (at $t = 0$), the wave function of the correlated wave packet, which describes the motion of the same particle with velocity $v_0 = p_0/m$, has the form [1]

$$\Psi(x,0) = \frac{1}{\sqrt[4]{\pi u^2}} \exp\left\{-\frac{x^2 g}{2u^2} + ip_0 x/\hbar\right\}. \tag{12}$$

At the initial moment of time, the structure of the correlated wave packet

$$|\Psi(x,0)|^2 = (\pi u^2)^{-1/2} \mathrm{e}^{-x^2/u^2} \tag{13}$$

completely coincides with the initial structure of the "ordinary" Gaussian uncorrelated packet.

Here $g = 1 + i\rho$ and $\rho = r/\sqrt{1-r^2}$ is a parameter that can change in the interval $-\infty < \rho < \infty$. The parameter r is the coefficient of correlation. For a pair of dynamic variables A and B this coefficient r is introduced by the expressions

$$r = \frac{\sigma_{AB}}{\sqrt{\sigma_A \sigma_B}}, \quad \sigma_{AB} = \frac{(\langle \widehat{A}\widehat{B} + \widehat{B}\widehat{A} \rangle)}{2} - \langle A \rangle \langle B \rangle, \quad \sigma_C = \langle (\widehat{C} - \langle C \rangle)^2 > \rangle, \quad |r| \le 1. \tag{14}$$

For correlated states, the product of the variances of the variables A and is limited by the Schrödinger–Robertson uncertainty relation [2–16]

$$\sigma_A \sigma_B \ \ge \ \frac{|\langle [\widehat{A}\widehat{B}] \rangle|^2}{4(1-r^2)} \equiv G^2 \frac{|\langle [\widehat{A}\widehat{B}] \rangle|^2}{4}, \quad G = 1/\sqrt{1-r^2}, \tag{15}$$

which is the generalization of the Heisenberg uncertainty relation and coincides with it under the condition $r = 0$. In the case under consideration $A = x,\ B = p$ this relation (15) takes the following form

$$\sigma_p\, \sigma_x \ge \frac{\hbar^2}{4(1-r^2)} \equiv \frac{(\hbar^*)^2}{4}, \quad \delta p\, \delta x \ge \frac{\hbar}{2\sqrt{1-r^2}} \equiv \frac{\hbar^*}{2}, \quad \hbar^* = G\hbar. \tag{16}$$

Here $G \equiv \hbar^*/\hbar = 1/\sqrt{1-r^2}$ is the correlation efficiency coefficient, which can vary in the unlimited interval $1 \le G < \infty$.

The wave function of the correlated packet can be found on the basis on the general presentation of packet wave function in the form of a spectral expansion (4) in plane waves (5) and formula (3) for determining the coefficients $c(p)$

$$\begin{aligned} c(p) &= \int\limits_{-\infty}^{-\infty} \Psi(x,0)\Psi_p^*(x)\,\mathrm{d}x \\ &= \frac{1}{\sqrt[4]{4\pi^3\hbar^2 u^2}} \int\limits_{-\infty}^{+\infty} \exp\left\{-\frac{x^2 g}{2u^2} + i(p_0 - p)x/\hbar\right\}\,\mathrm{d}x = \sqrt{\frac{u}{g\hbar\sqrt{\pi}}} \exp\left\{-\frac{(p_0-p)^2 u^2}{2\hbar^2 g}\right\}. \end{aligned} \tag{17}$$

This is the standard method of calculating the weighting factors (weighting coefficients) in any superposition state in the equations of quantum mechanics.

The combination (complete set) of these coefficients, supplemented by the time evolution operator

$$\widehat{K} = \exp\{-i(p^2/2m)t/\hbar\}$$

is the full wave function of the same particle in p-representation.

After substituting this coefficient into Eq. (4), we can obtain the wave function of the correlated wave packet

$$\begin{aligned}\Psi(x,t) &= \int\limits_{-\infty}^{\infty} c(p)\Psi_p(x)\exp\{-iE_p t/\hbar\}\,\mathrm{d}p \\ &= \left(1/\sqrt{[(1-\rho t\hbar/mu^2)+it\hbar/mu^2]u\sqrt{\pi}}\right)\exp\left\{-\frac{x^2(1+i\rho)-2iu^2k_0x+it\hbar k_0^2u^2/m}{2u^2[(1-\rho t\hbar/mu^2)+it\hbar/mu^2]}\right\} \qquad (18)\end{aligned}$$

and the expression for the probability density of localization of a moving correlated packet

$$|\Psi(x,t)|^2 = \left\{u\sqrt{\pi}\sqrt{\left\{1-\rho\frac{t\hbar}{mu^2}\right\}^2+\left\{\frac{t\hbar}{mu^2}\right\}^2}\right\}^{-1}\exp\left\{-\frac{[x-v_0t]^2}{u^2[(1-\rho\hbar t/mu^2)^2+(\hbar t/mu^2)^2]}\right\}. \qquad (19)$$

The spatial evolution of Gaussian uncorrelated wave packet for different consecutive moments of time is presented in Fig. 2.

Using this wave function, one can calculate the variances of the coordinate of a moving particle corresponding to the correlated wave packet

$$\sigma_x = \frac{u^2}{2}\left\{\left(1-\rho\frac{t\hbar}{mu^2}\right)^2+\left(\frac{t\hbar}{mu^2}\right)^2\right\}. \qquad (20)$$

From the analysis of formulas (18)–(20) it follows that the spatial width of the correlated packet

$$u(t) = u(0)\sqrt{\left\{1-\rho\frac{t\hbar}{mu^2}\right\}^2+\left\{\frac{t\hbar}{mu^2}\right\}^2} \qquad (21)$$

over the time

$$t_{\text{collapse}} = \frac{\rho mu^2}{(1+\rho^2)\hbar} \qquad (22)$$

decreases from the initial value $u(0)$ to the minimum value (state of collapse of the wave packet)

$$u_{\min} = u(0)/\sqrt{1+\rho^2} = u(0)/G \qquad (23)$$

and then monotonically increases. It is very important to note that the spatial spreading rate of the correlated packet immediately after its collapse

$$u(t>t_{\text{collapse}}) \approx u(0)\hbar tG/mu^2 \qquad (24)$$

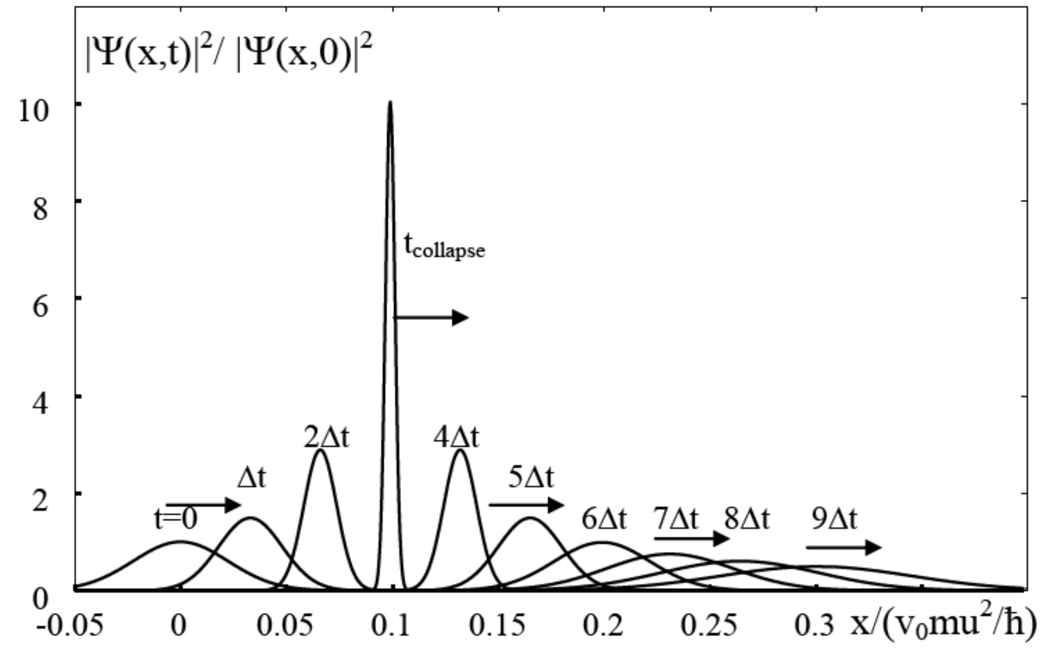

Figure 2. Spatial evolution and controlled remote collapse of a correlated wave packet at G=10. Here $\Delta t = mu^2/30\hbar$.

at $G \gg 1$ significantly exceeds the rate of similar spreading of the uncorrelated packet

$$u(t) \approx u(0)\hbar t/mu^2 \tag{25}$$

for the same time interval.

The coordinate of the spatial collapse of the correlated packet corresponds to the distance

$$x_{\text{collapse}} = v_0 t_{\text{collapse}} = \frac{v_0 \rho m u^2}{(1+\rho^2)\hbar} \approx v_0 m u^2/G\hbar. \tag{26}$$

Synchronously with the compression of the packet to the state of collapse, its amplitude increases sharply by $\sqrt{1+\rho^2} \approx G$ times from the initial value $|\Psi(x,0)|^2_{\max} \approx 1/u\sqrt{\pi}$ to the maximum value

$$|\Psi(x_{\text{collapse}}, t_{\text{collapse}})|^2_{\max} = \sqrt{1+\rho^2}/u\sqrt{\pi} \approx G/u\sqrt{\pi}. \tag{27}$$

It is important to note that after moving through the collapse region, the amplitude of the packet very quickly decreases (much faster than in the case of uncorrelated packet). It can be described by the asymptotic law determined by the formula

$$|\Psi(x > x_{\text{collapse}}, t > t_{\text{collapse}})|^2_{\max} \approx \frac{mu}{t\hbar\sqrt{\pi(1+\rho^2)}} \approx \frac{mu}{Gt\hbar\sqrt{\pi}}. \tag{28}$$

These features of the evolution of the package are presented in Fig. 2.

The most important transformations correspond to the energy characteristics of a moving packet. The dispersion of a particle momentum in a correlated state can be determined using the explicit form (18) of the wave function $\Psi(x,t)$

$$\sigma_p = \langle p^2\rangle - (\langle p\rangle)^2 = \int\limits_{-\infty}^{\infty} |\widehat{p}\Psi(x,t)|^2 \,\mathrm{d}x - \left\{ \int\limits_{-\infty}^{\infty} \Psi^*(x,t)\widehat{p}\Psi(x,t)\,\mathrm{d}x \right\}^2$$

$$= \frac{\hbar^2(1+\rho^2)}{2u^2} \left\{ \left(1-\rho\frac{t\hbar}{mu^2}\right)^2 + \left(\frac{t\hbar}{mu^2}\right)^2 \right\}^{-1}. \quad (29)$$

This dispersion corresponds to a very large (under conditions $|\rho| \gg 1, G \gg 1$) fluctuations of the kinetic energy of the particle

$$\delta T = \frac{\sigma_p}{2m} = \frac{\hbar^2(1+\rho^2)}{4mu^2} \left\{ \left(1-\rho\frac{t\hbar}{mu^2}\right)^2 + \left(\frac{t\hbar}{mu^2}\right)^2 \right\}^{-1}$$

$$\approx \frac{\hbar^2(1+G^2)}{4mu^2} \left\{ \left(1-G\frac{t\hbar}{mu^2}\right)^2 + \left(\frac{t\hbar}{mu^2}\right)^2 \right\}^{-1}. \quad (30)$$

The dependences of the variances of coordinate, momentum and kinetic energy of such correlated packet for different values of the correlation efficiency coefficient G are shown in Fig. 3. The maximum fluctuation of the kinetic energy of a particle

$$\delta T_{\max} = \delta T(x_{\text{collapse}}, t_{\text{collapse}}) \approx \frac{\hbar^2(1+G^2)^2}{4mu^2} \quad (31)$$

is generated in the region of the collapse $x_{\text{collapse}} = v_0 t_{\text{collapse}}$ (23) of wave function of correlated wave packet (18).

3. Possible Applications of the Correlated Wave Packet in LENR Experiments

Basing on such coherent correlated states, it is possible to generate targeted nuclear reactions using particles of relatively low energy. The analysis above has shown that the correlated wave packet can be used to implement LENR experiments in remote targets. It is easy to verify that in the region of the collapse, the fluctuation of the kinetic energy of a particle can significantly exceed its average kinetic energy.

For example, if a moving proton is represented in the form of a "usual" uncorrelated Gaussian wave packet with a longitudinal size $u = 0.2$ nm, then in the uncorrelated state the energy fluctuation of such a packet is limited to a small value

$$\delta T_{\text{uncorr}} = \frac{\sigma_p}{2m} = \frac{\hbar^2}{4mu^2} \approx 2\times 10^{-4}\,\text{eV}. \quad (32)$$

A completely different situation corresponds to a correlated state. With a real (and very far from record values $G \approx 10^3$–10^4 [8–16]) correlation efficiency coefficient G =100–200, this fluctuation increases to a value that can

$$\delta T_{\text{corr}} \approx \hbar^2 G^4/4mu^2 \approx 25 \text{ to } 100 \text{ keV} \quad (33)$$

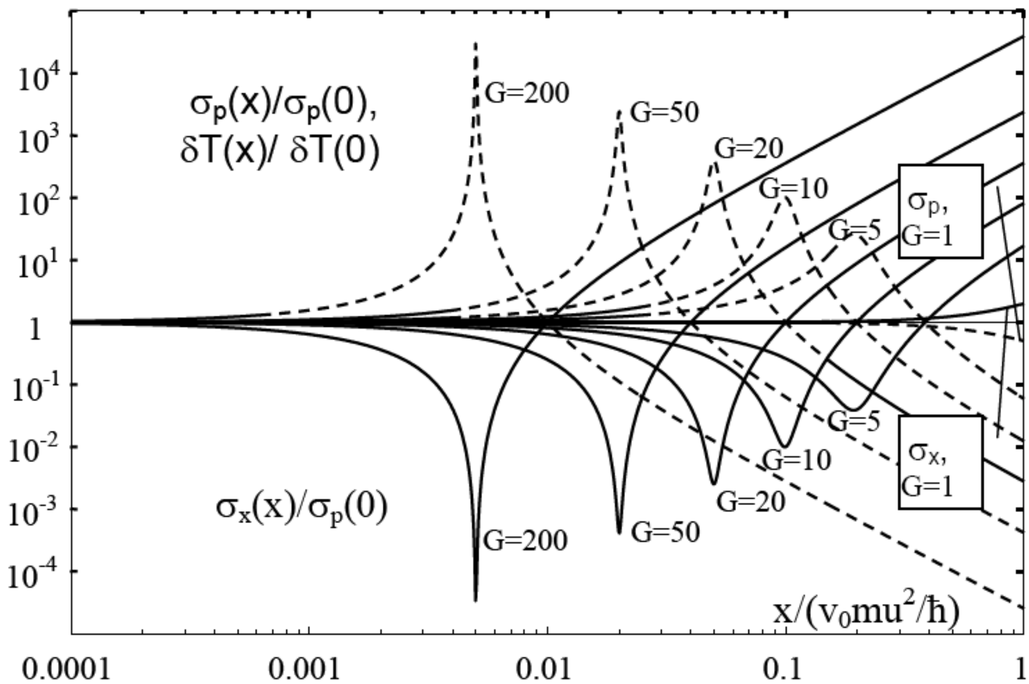

Figure 3. Variances of coordinate, momentum and kinetic energy of a particle in the form of correlated packet for different values of the coefficient $G$of correlation efficiency.

significantly exceed the average energy of the longitudinal motion, which can be equal, for example, $\langle T\rangle \approx p_0^2/2m$ ≈100-200 eV.

For such a system, the distance from the formation region of such a packet to the zone of its collapse is equal to

$$x_{\text{collapse}} \approx v_0 mu^2/G\hbar \approx 250\,/G \text{ cm} \approx \text{ 1 to 2 cm}, \tag{34}$$

which makes it possible to implement such experiments in the conditions of the simplest laboratory.

In works [6–17] various methods for the formation of such a correlated state are considered. Such correlated states can be formed, for example, when particles pass through a local region of existence of a periodic or monotonically changing electric or magnetic field, at crossing of laser beams, at passing through a crystal etc. Apparently, one of the simplest methods is to pass a beam of weakly accelerated protons through a thin magnetic crystal or above the surface of a periodic magnetic domain structure.

It is interesting to note that although some features of the evolution of the "standard" Gaussian packet in free space were investigated almost a hundred years ago [18], only recently there have been proposed new interesting methods for optimizing the use of such a package (including methods directly related to the LENR systems and models).

These problems will be discussed in another article.

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