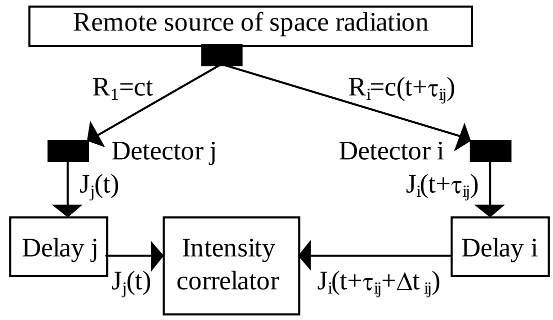
# THE THEORY AND METHOD OF SPATIAL 3-D DETECTING OF SOLITARY AND REMOTE SPACE SOURCES OF NUCLEAR AND PARTICLE RADIATION BY CORRELATION OF RADIATION INTENSITY

Vladimir I.Vysotskii
Kiev Shevchenko University, Radiophysical Faculty, Kiev, Ukraine

The intensity correlation method of spatial and angular (three-dimensional) location of solitary or remote space sources of X-radiation, gamma-radiation or neutrons is suggested and studied. The main idea of the method is based on the phenomenon of pair correlation of intensities $J_j(t) = \varepsilon_j |\xi_j(t)|^2$ and $J_i(t+\tau_{ij}) = \varepsilon_i |\xi_i(t+\tau_{ij})|^2$ of nuclear radiation measured by two separated detectors i and j [1]. Here $\xi_k(t) = \Sigma_n \Psi_k(\mathbf{R}_k, t-t_{kn})$ are sums of pulse spherical waves $\Psi_k(\mathbf{R}_k, t-t_{kn}) \equiv F(t-t_{kn})\exp(i\mathbf{k}\mathbf{R}_k)/R_k$ of quanta (or wave functions of neutrons) coming from a remote source, location $\mathbf{r}_o$ of which is to be found. The pair correlation function $K_{ij}(\tau_{ij})$ of intensities $J_j(t)$ and $J_i(t+\tau_{ij})$ for two spatially separated independent detectors, situated at $\mathbf{r}_i = \mathbf{R}_i+\mathbf{r}_o$, $\mathbf{r}_j = \mathbf{R}_j+\mathbf{r}_o$ and having the effectiveness $\varepsilon_i$ and $\varepsilon_j$ of the quantum detecting, equals




$$K_{ij}(\tau_{ij}) = \langle J_i(t)\, J_j(t+\tau_{ij})\rangle - \langle J_i(t)\rangle \langle J_j(t+\tau_{ij})\rangle.$$

Here $\tau_{ij} = (R_i-R_j)/c$ is the time-delay of measured intensities $J_j(t)$ and $J_i(t+\tau_{ij})$ in different detectors i and j from the same remote detected source.

For the case of quasi-stationary source of radiation and for the usual case of the random Gaussian process of quanta detecting $\xi_k(t)$ the correlation function of intensity has the form

$$K_{ij}(\tau_{ij}) = \varepsilon_i\varepsilon_j \{\langle\xi_i(t)\, \xi_i^*(t)\rangle \langle\xi_j(t+\tau_{ij})\, \xi_j^*(t+\tau_{ij})\rangle + \langle\xi_i(t)\, \xi_j(t+\tau_{ij})\rangle \langle\xi_i^*(t)\, \xi_j^*(t+\tau_{ij})\rangle + \langle\xi_i(t)\, \xi_j^*(t+\tau_{ij})\rangle \langle\xi_i^*(t)\, \xi_j(t+\tau_{ij})\rangle\} - \langle J_i(t)\rangle \langle J_j(t+\tau_{ij})\rangle = \varepsilon_i\varepsilon_j |\langle\xi_i(t)\, \xi_j^*(t+\tau_{ij})\rangle|^2 = \langle n_i\rangle \langle n_j\rangle \left|\int_{-\Delta\omega/2}^{\Delta\omega/2} |F(\omega)|^2 \exp(-i\omega\tau_{ij})\, d\omega\right|^2.$$

Here $F(\omega) = \int_{-\infty}^{\infty} F(t)\exp(-i\omega t)\, dt$; $|F(\omega)|^2$ is the spectral intensity (having the spectral half-width $\delta\omega$) of the single detected quantum (or neutron) after detector (on the exit of detector);
$\Delta\omega$ is the spectral band of the intensity correlator (signal acquisition and processing system);
$\langle n_i\rangle$ and $\langle n_j\rangle$ are the averaged quantity of detected quanta (neutrons) in the detectors i and j.

For the usual case $\Delta\omega<\delta\omega$ we have the correlation function

$$K_{ij}(\tau_{ij}) \approx 4\langle n_i\rangle \langle n_j\rangle |F(0)|^4 |\sin(\Delta\omega\tau_{ij})/\tau_{ij}|^2.$$

The maximum value of this correlation function is equal $K_{ij}(0)= 4\langle n_i\rangle \langle n_j\rangle |F(0)|^4 |\Delta\omega|^2$ and corresponds to the additional delay $\Delta t_{ij} = -\tau_{ij}$ of the registered intensity signal $J_i(t+\tau_{ij})$ from one of the detectors (i) or both detectors (i and j) introduced in the correlator.

The maximal distance to an investigated source of radiation equals $L_{(max)} = \Delta\omega a^2/4c\sqrt{\delta}$.

Here $a$ is the distance between two detectors, $\delta = | K_{ij}(0) - K_{ij}(\tau_{ij(min)}| / K_{ij}(0) \approx 10^{-5} - 10^{-6}$ is measurement accuracy of correlation function near its maximum value $K_{ij}(0)$,
$\tau_{ij(min)} = a^2/2L_{(max)}c$. At usual values $\Delta\omega = 10^9\ s^{-1}$, $a = 10^4$ km we have $L_{(max)} \approx 10^{14}$ km.

For three-dimensional location of the remote source of radiation it is necessary to use three or more spatially separated independent detectors, situated at $\mathbf{r}_1$, $\mathbf{r}_2$, $\mathbf{r}_3$,..., and three or more independent intensity correlators. For this case the position of the detected remote source
$\mathbf{r_0}=\{x_0, y_0, z_0\}$ of radiation may be calculated using the system of equations

$$[(x_i- x_0)^2+(y_i- y_0)^2+(z_i-z_0)^2]^{1/2} +c\Delta t_{ij} = [(x_j- x_0)^2+(y_j - y_0)^2+(z_j-z_0)^2]^{1/2};$$

for maximum values of correlation functions $K_{ij}(0)$ for different pairs ij ($i\neq j=1,2,3...$) of detectors of investigated radiation.

1. Rusov V.D., Vysotskii V.I. and Zelentsova T.N. Journal of Nuclear and Radiation Safety. v.1, 66 (1998) (In Russian).