

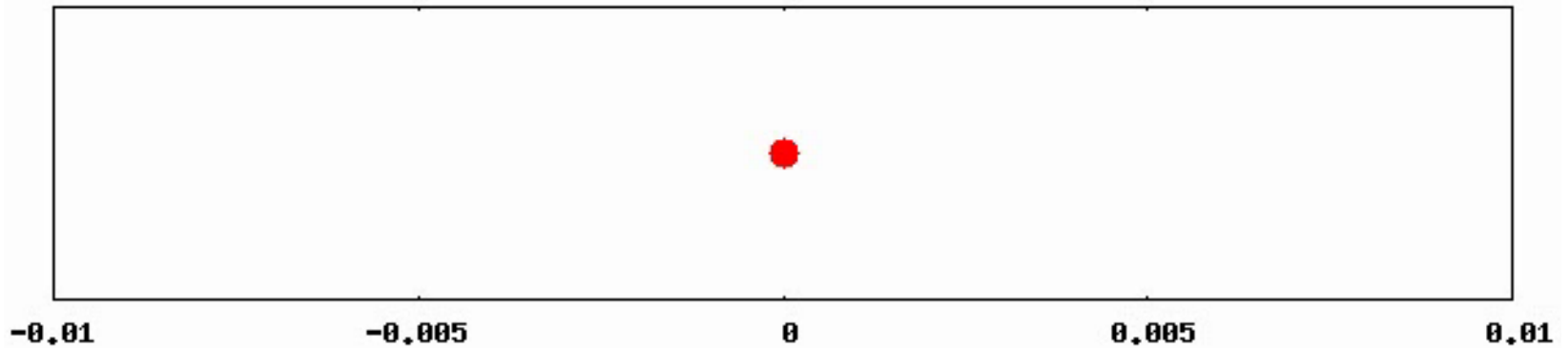
# Langevin方程式

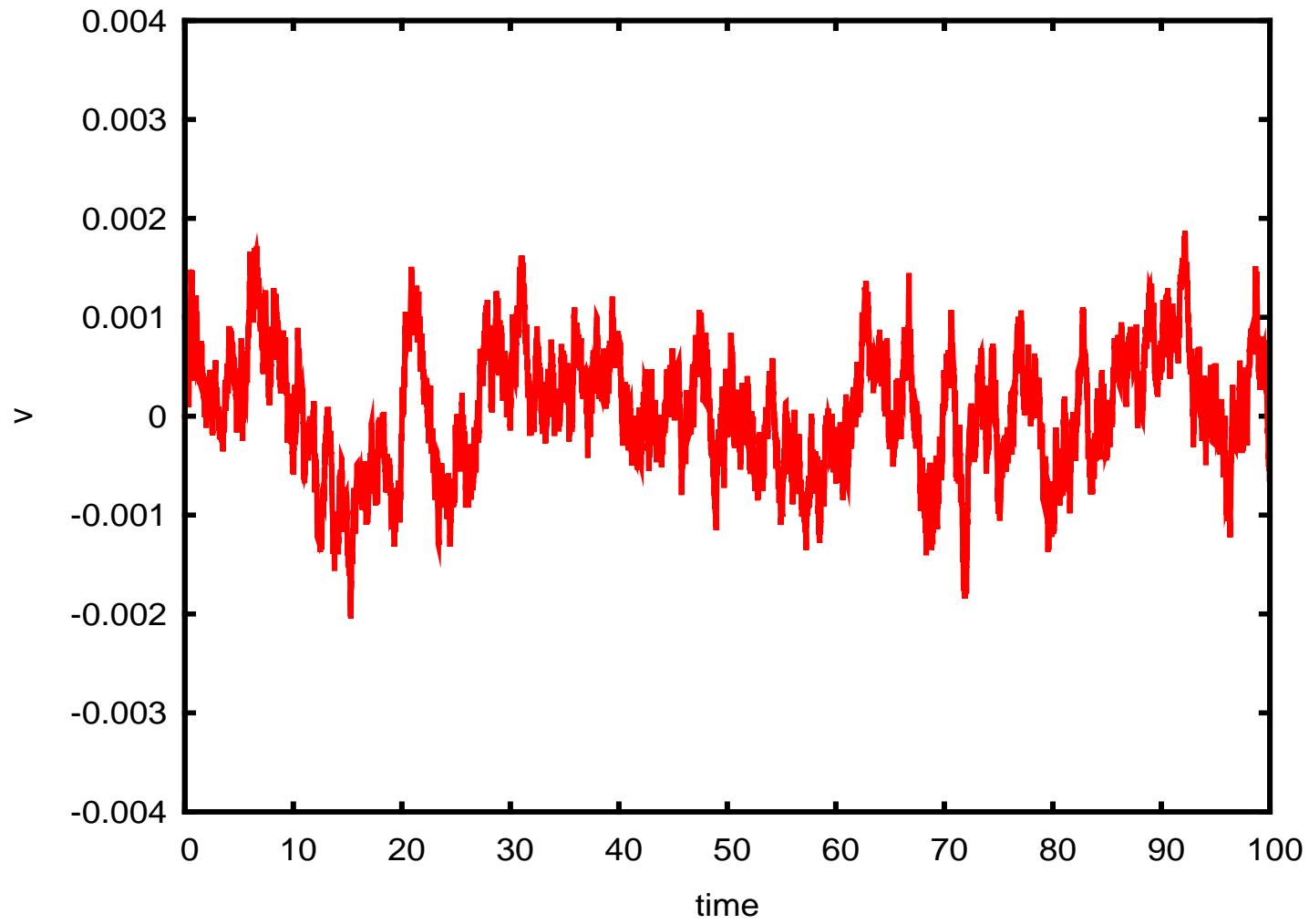
$$m \frac{d^2 \mathbf{r}}{dt^2} = -k \frac{d\mathbf{r}}{dt} + \boldsymbol{\xi}(t)$$

$$\langle \boldsymbol{\xi}(t) \rangle = 0$$

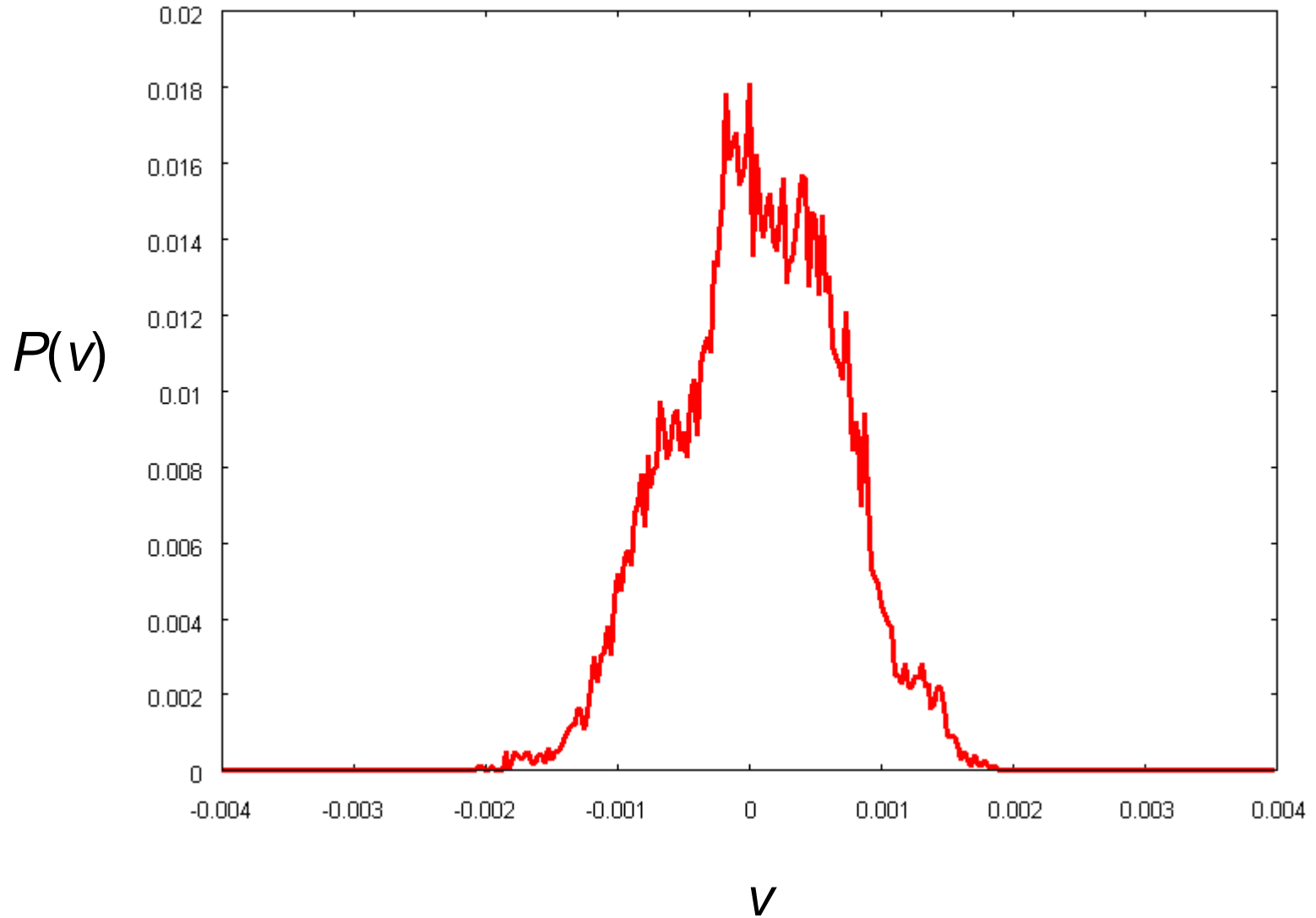
$$\langle \boldsymbol{\xi}(t) \cdot \boldsymbol{\xi}(s) \rangle = M \delta(t - s)$$

# 1次元系でのLangevin方程式による挙動





# 速度の分布



# 外力があるときのLangevin方程式

$$m \frac{d^2 \mathbf{r}}{dt^2} = -k \frac{d\mathbf{r}}{dt} + \mathbf{F}(\mathbf{r}) + \boldsymbol{\xi}(t)$$

$$\langle \boldsymbol{\xi}(t) \rangle = 0$$

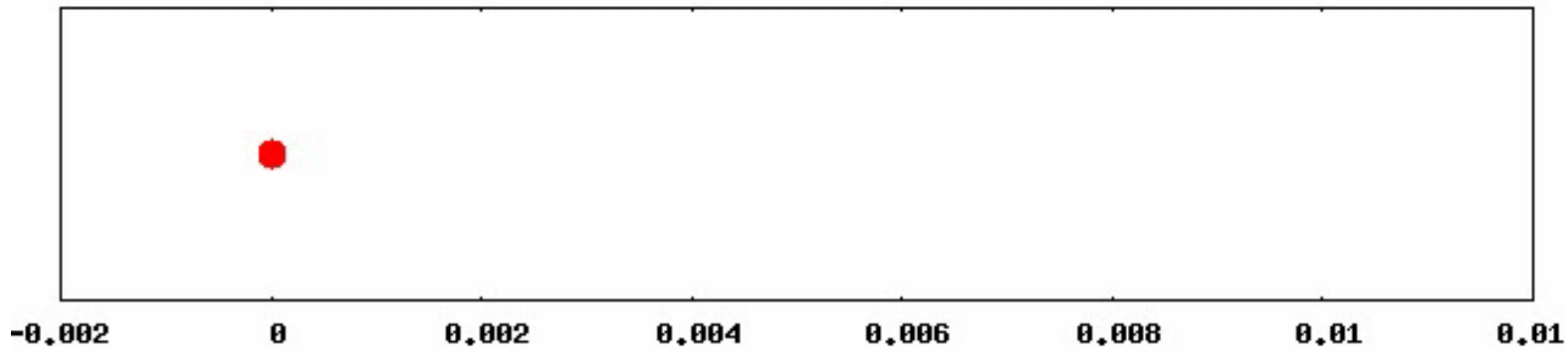
$$\langle \boldsymbol{\xi}(t) \cdot \boldsymbol{\xi}(s) \rangle = M \delta(t - s)$$

# 1次元で一定の外力の場合

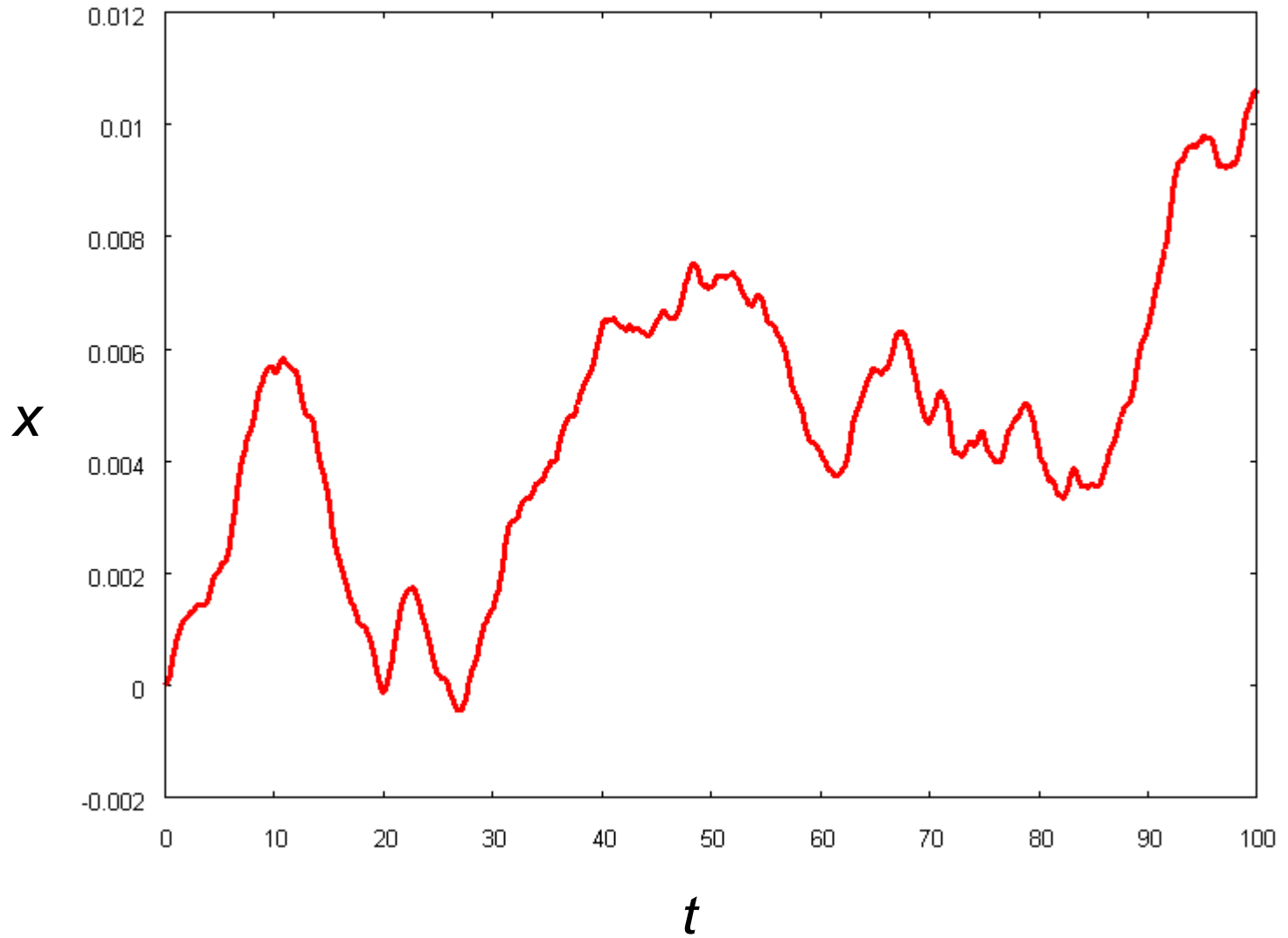
$$m \frac{d^2 x}{dt^2} = -k \frac{dx}{dt} + F + \xi(t)$$

$$\langle \xi(t) \rangle = 0$$

$$\langle \xi(t) \cdot \xi(s) \rangle = M \delta(t - s)$$

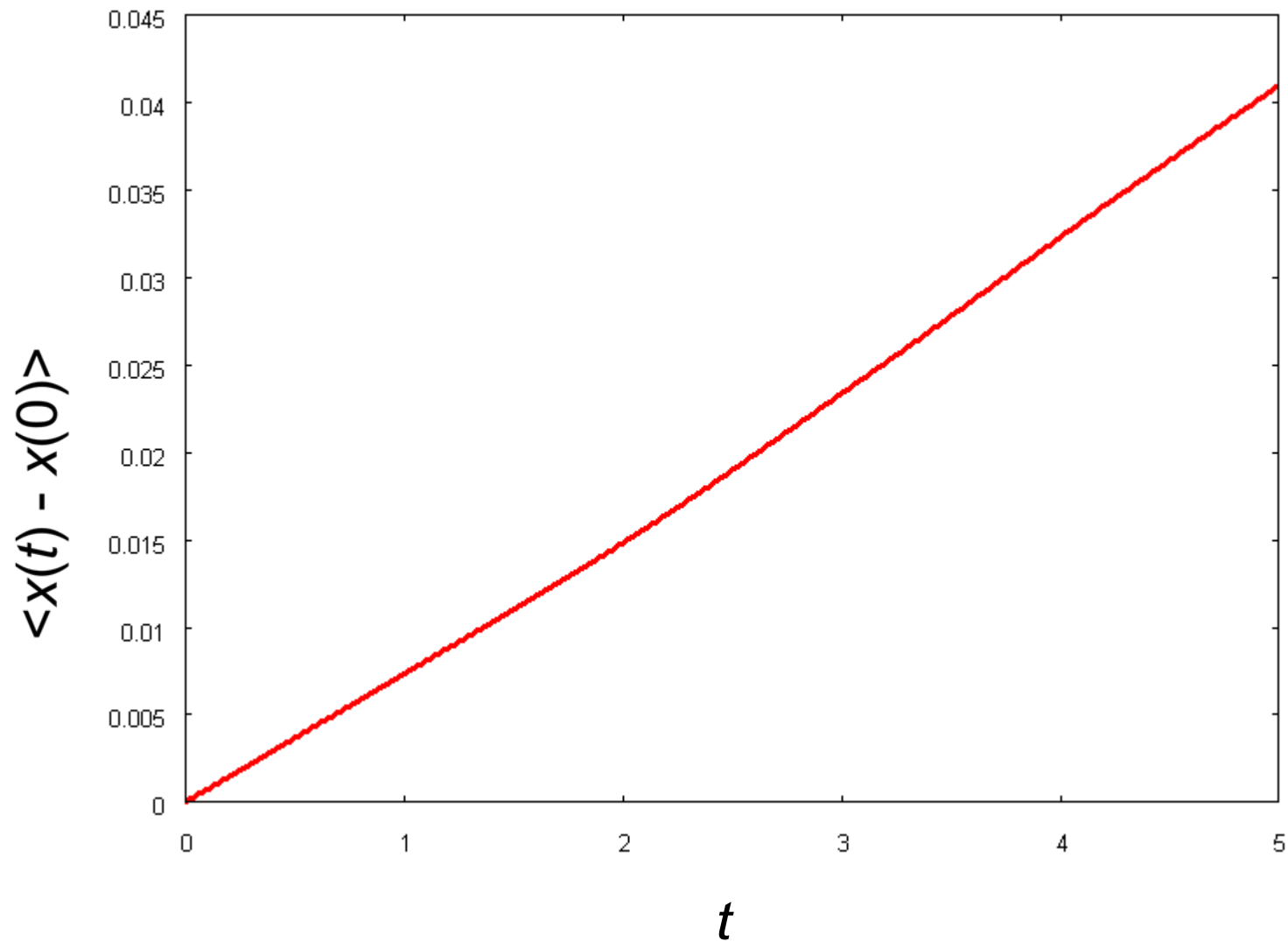


# $x(t)$ vs. $t$



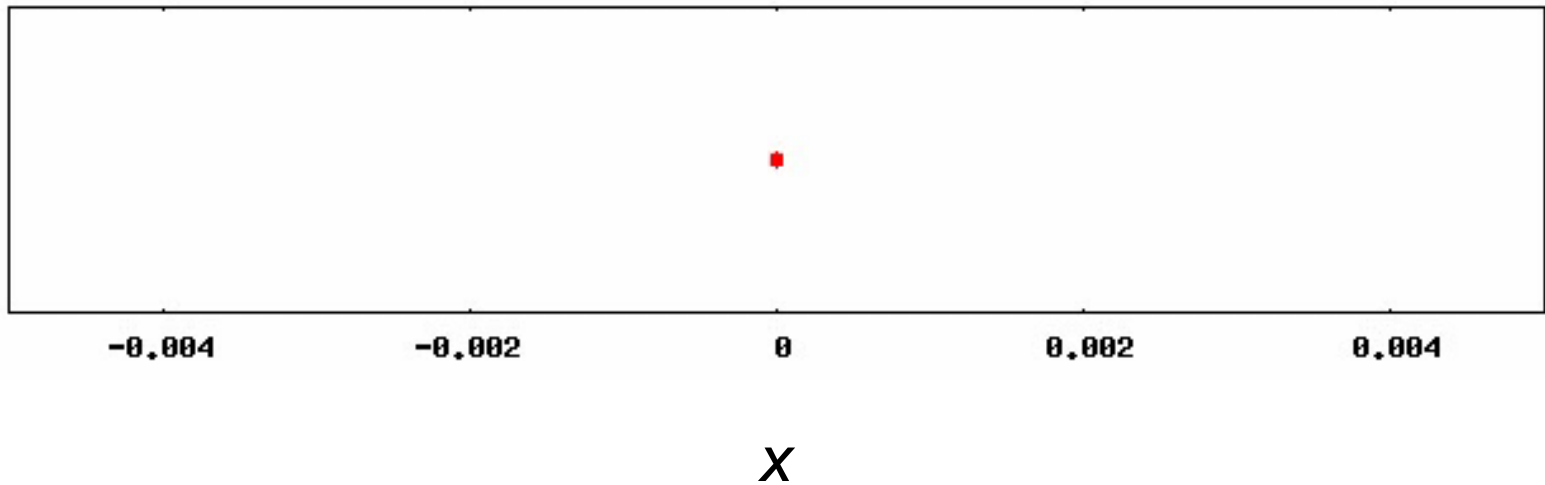


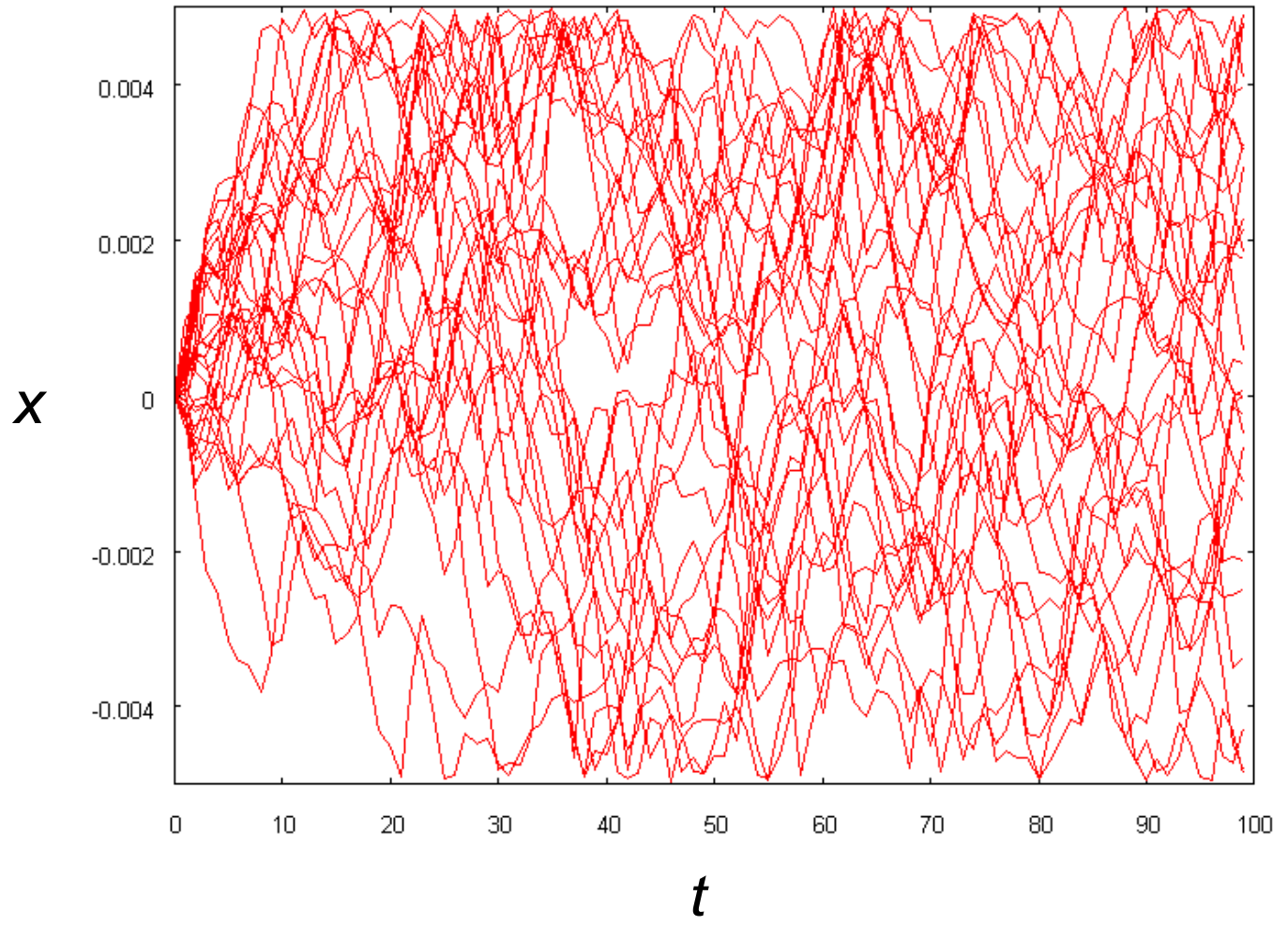
$\langle x(t) - x(0) \rangle$  vs.  $t$



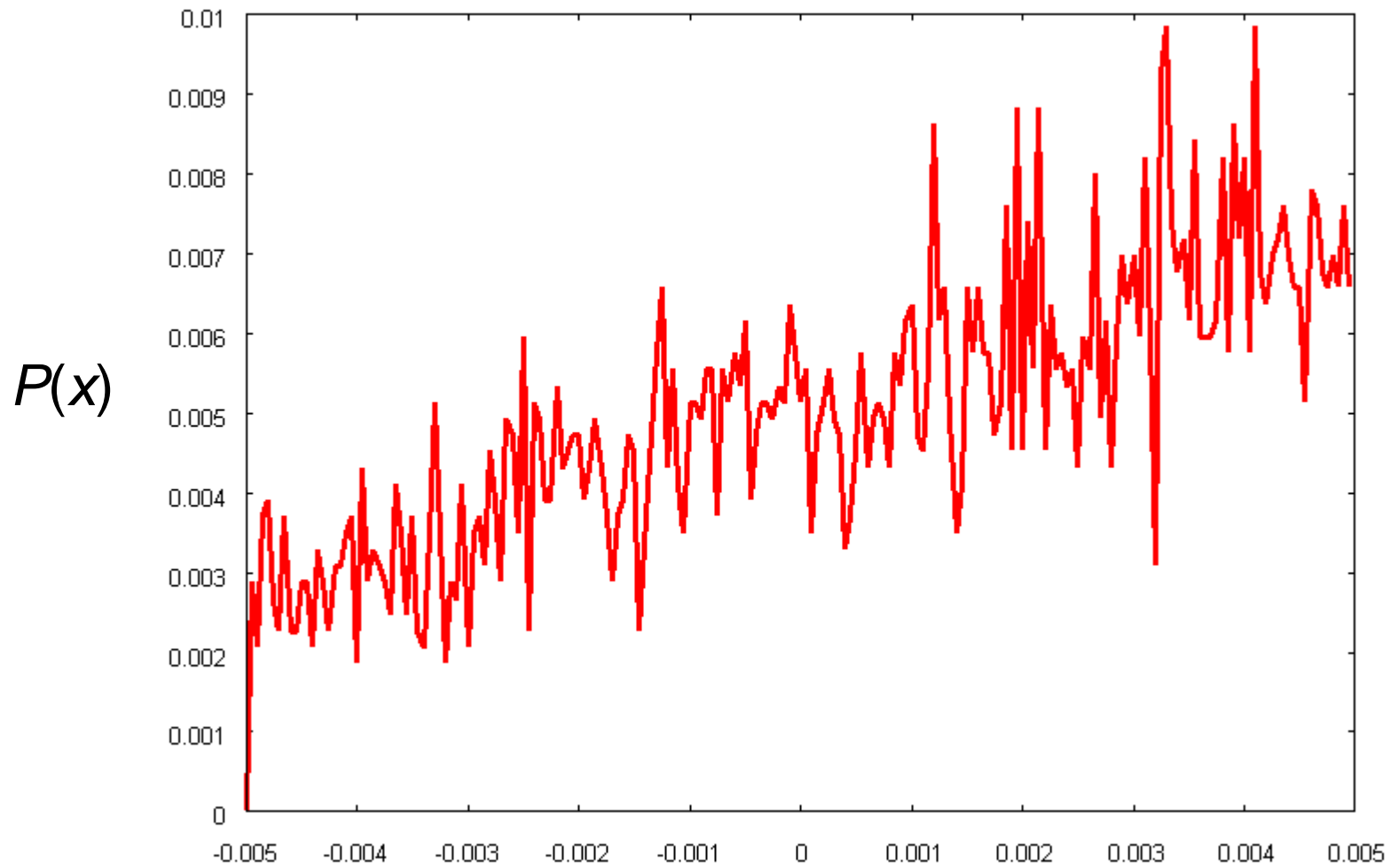
$$\langle v(t) \rangle = F / \gamma$$

# 1次元で一定の外力の場合 (多くの粒子を入れて、領域を区切ると...)





# 分布



$x$

$$U(x) = -ax$$

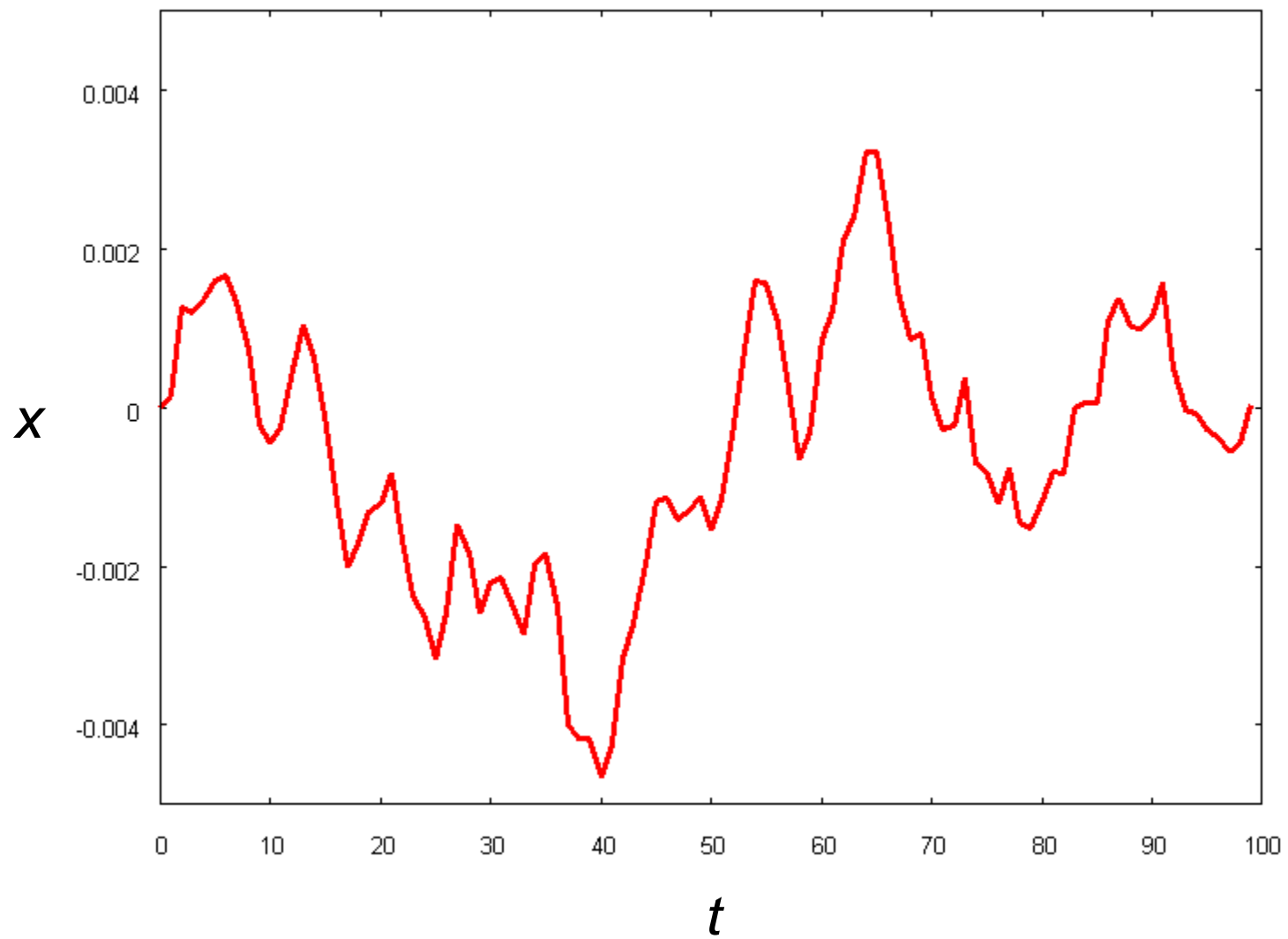
# 1次元で調和ポテンシャル中の場合

$$m \frac{d^2 x}{dt^2} = -k \frac{dx}{dt} - ax + \xi(t)$$

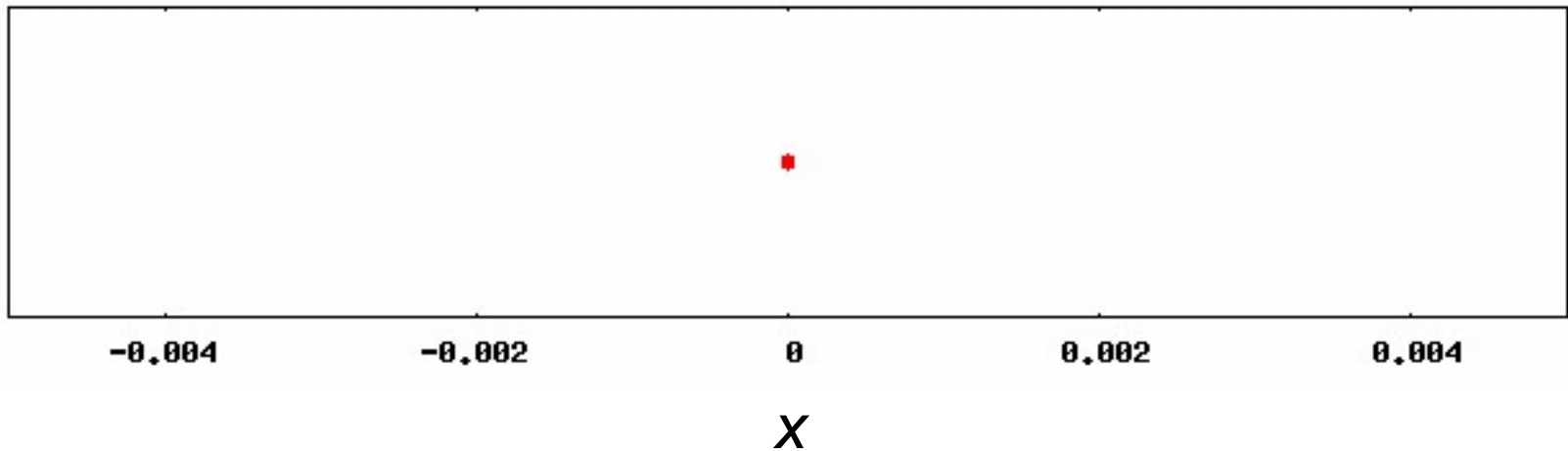
$$\Phi(x) = \frac{a}{2} x^2$$

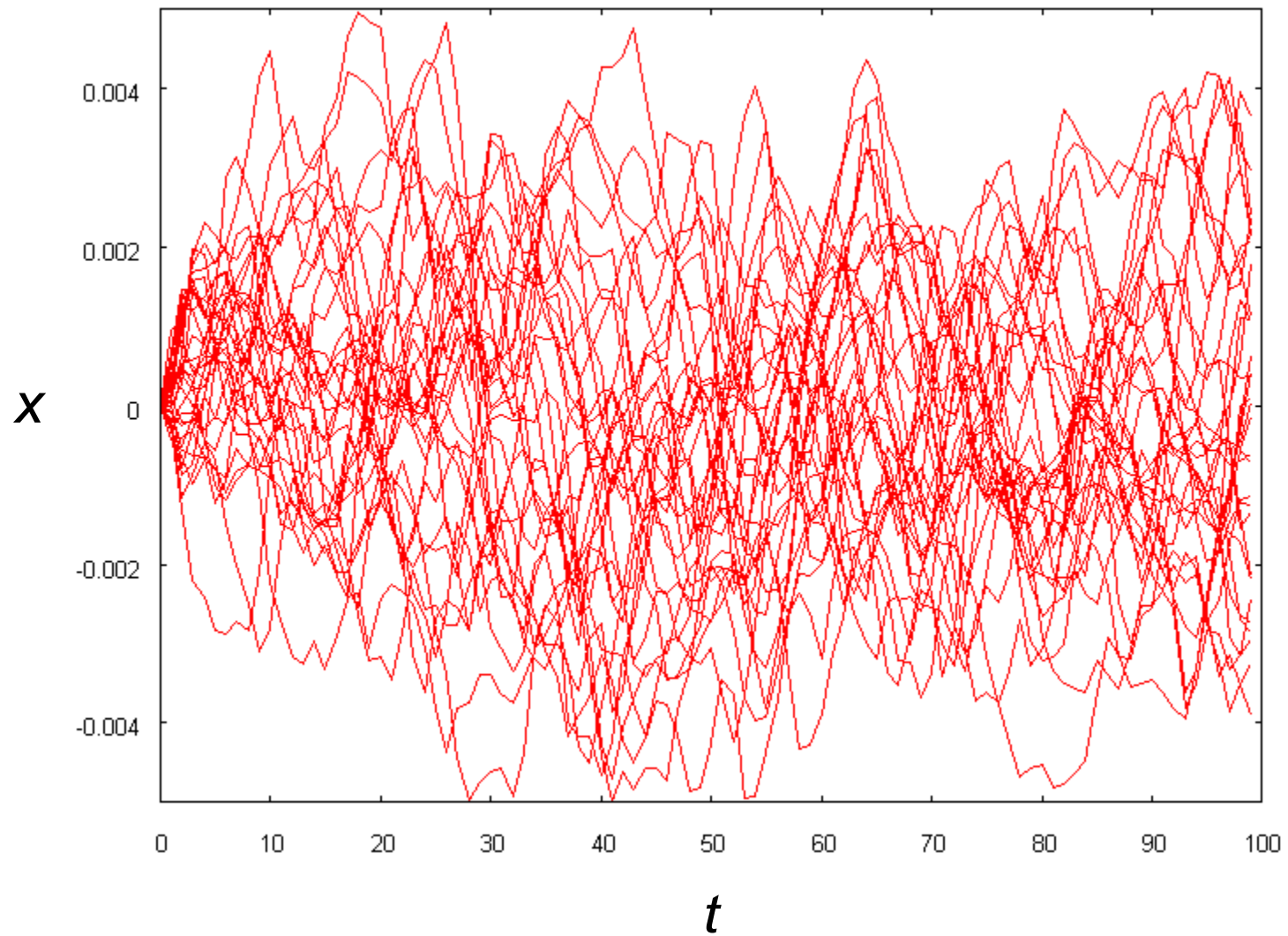
$$\langle \xi(t) \rangle = 0$$

$$\langle \xi(t) \cdot \xi(s) \rangle = M \delta(t - s)$$



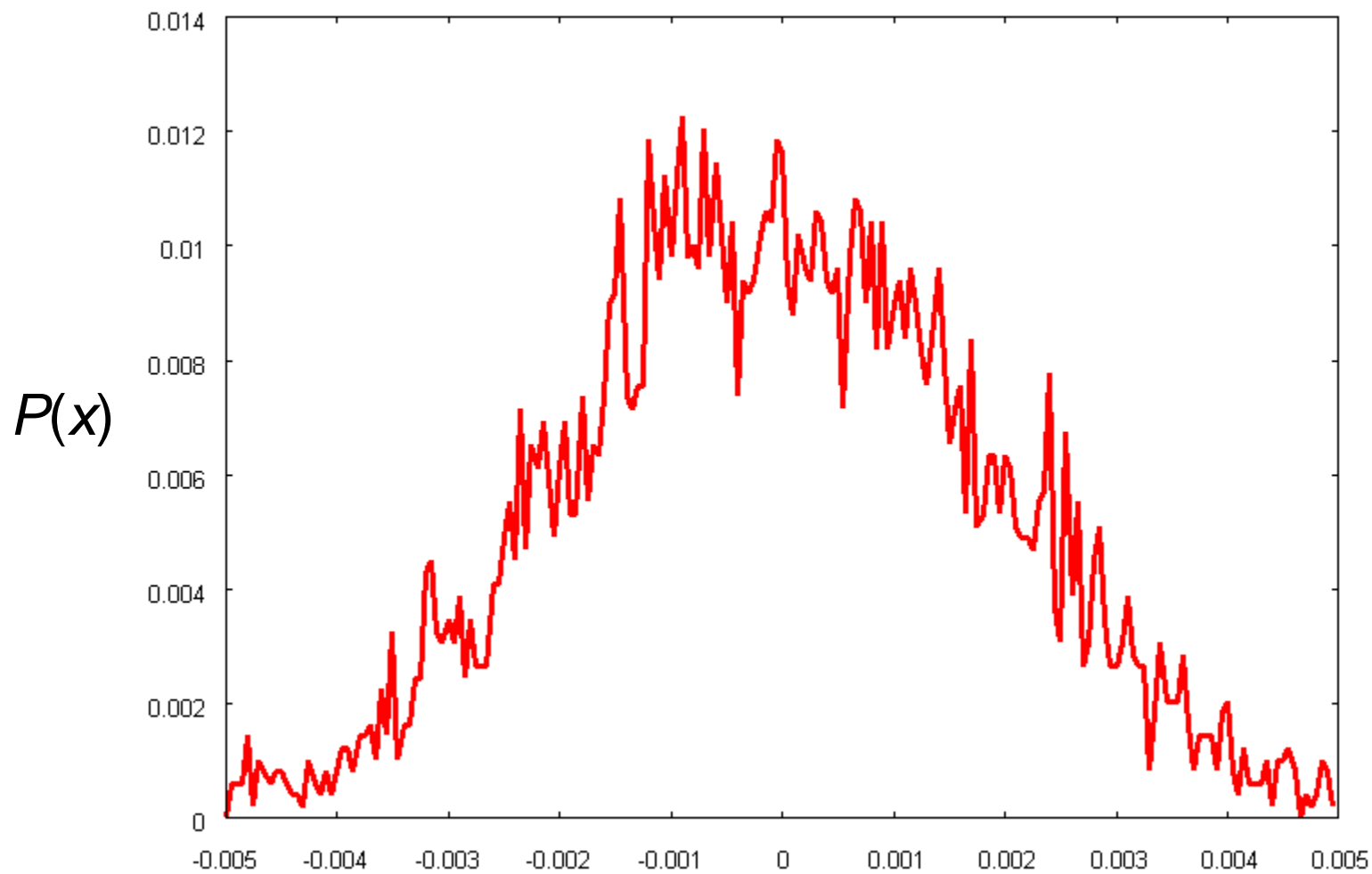
# 1次元で調和ポテンシャル中の場合 (多くの粒子を入れると...)







# 分布



$x$

$$U(x) = ax^2/2$$