Second class particles just walk sometimes

Joint with
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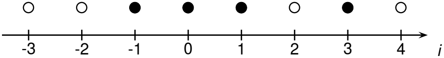
Márton Balázs

University of Bristol

UCD Probability Seminars
16th September, 2026.

Asymmetric simple exclusion



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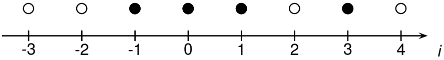

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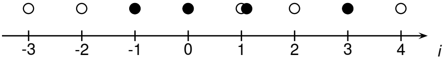

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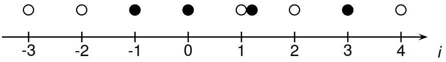

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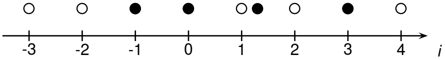

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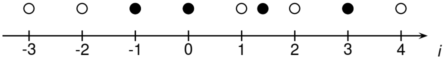

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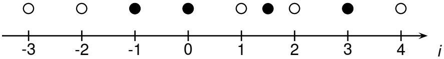

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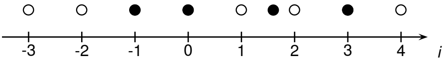

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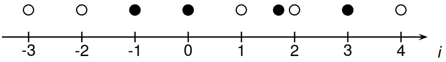

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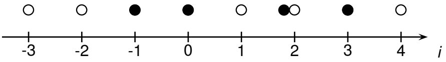

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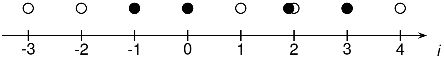

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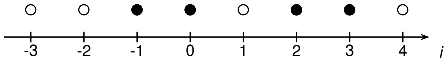

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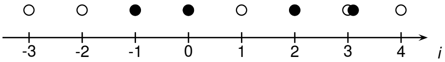

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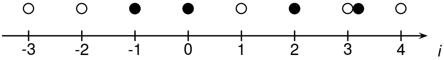

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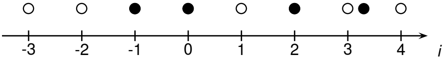

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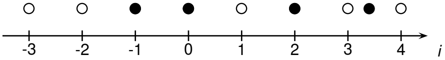

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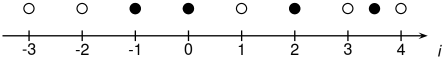

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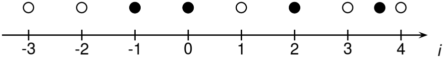

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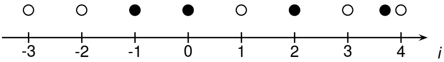

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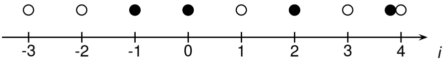

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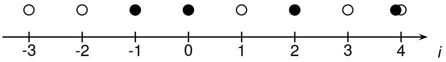

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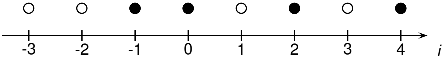

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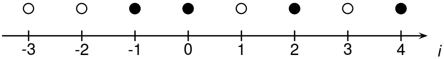

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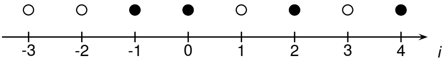

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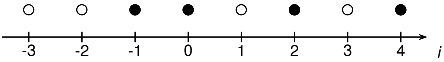

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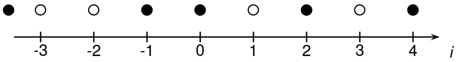

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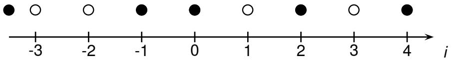

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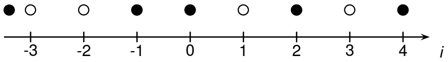

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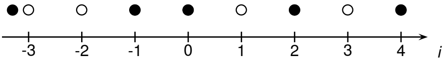

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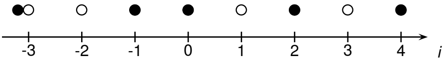

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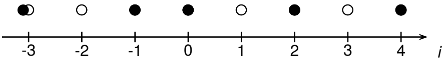

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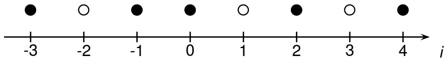

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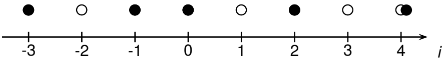

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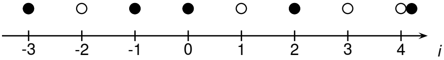

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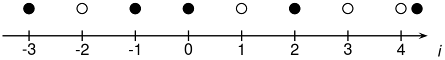

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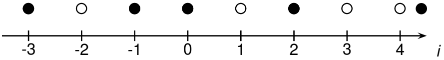

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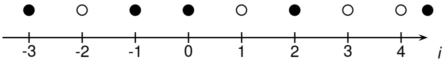

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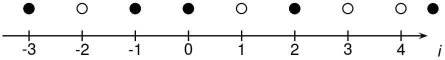

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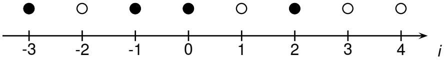

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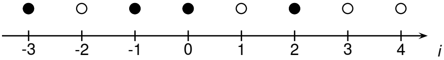

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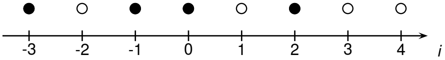

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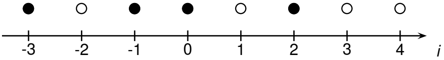

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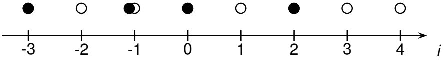

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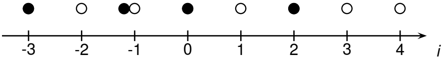

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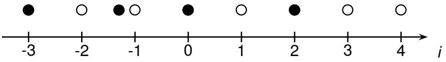

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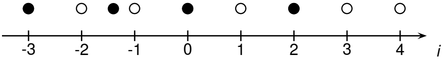

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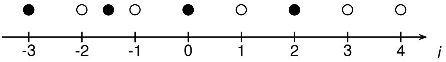

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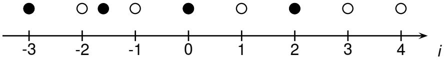

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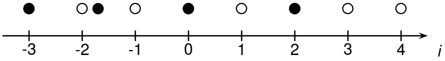

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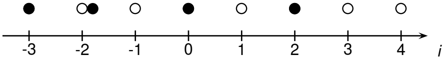

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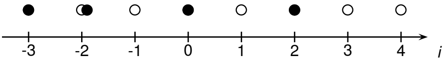

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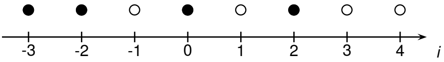
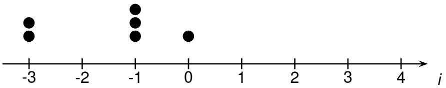


Particles try to jump

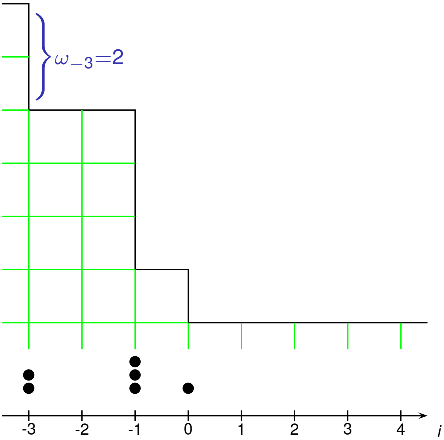
to the right with rate p,
to the left with rate $q = 1 - p < p$.

The jump is suppressed if the destination site is occupied by another particle.

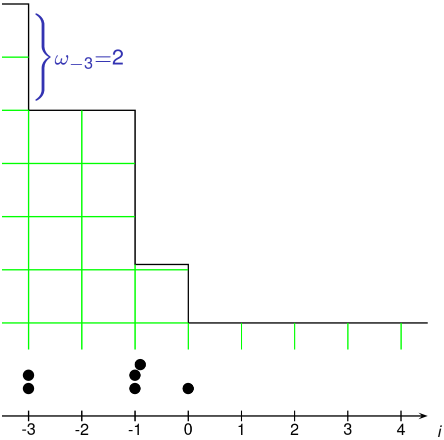
The totally asymmetric zero range process



The totally asymmetric zero range process



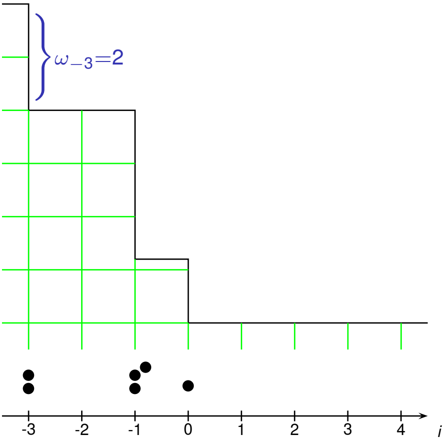
The totally asymmetric zero range process



Particles jump to the right from site i with rate $r(\omega_i)$

(r non-decreasing).

The totally asymmetric zero range process



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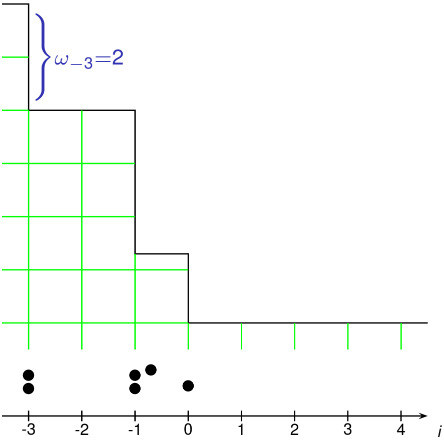
The totally asymmetric zero range process



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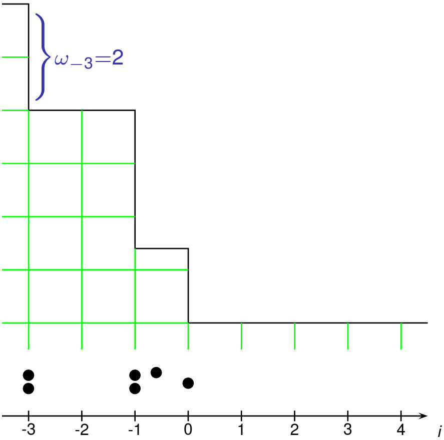
The totally asymmetric zero range process



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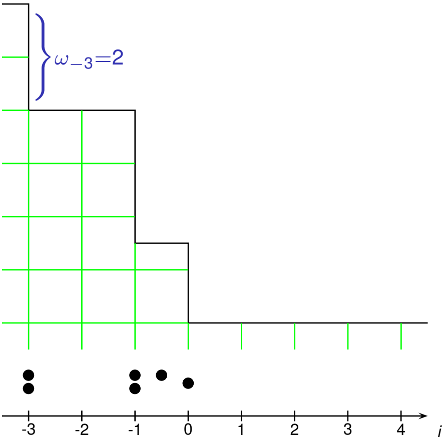
The totally asymmetric zero range process



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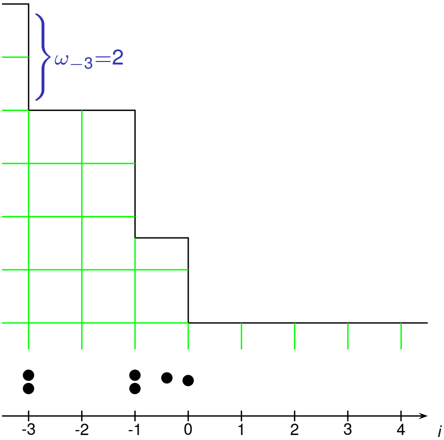
The totally asymmetric zero range process



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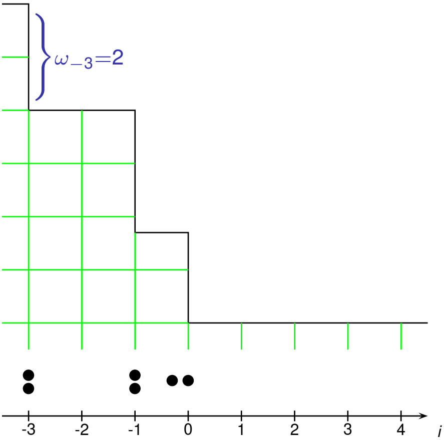

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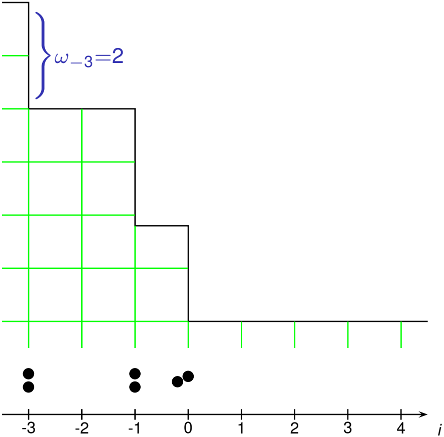

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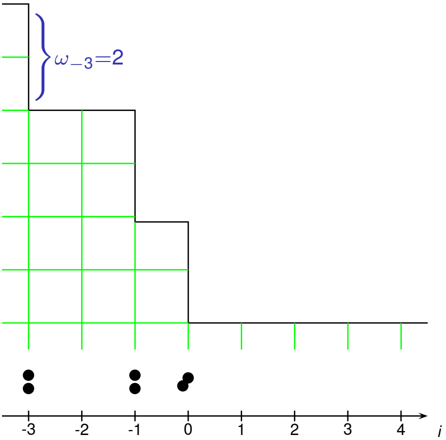
The totally asymmetric zero range process



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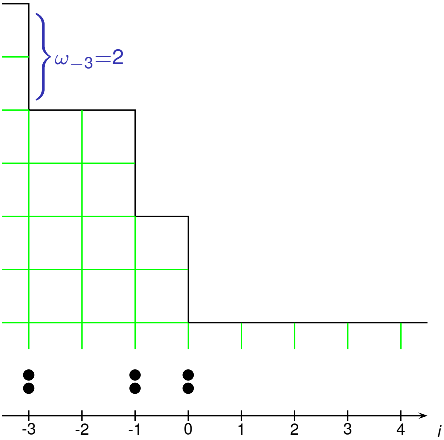
The totally asymmetric zero range process



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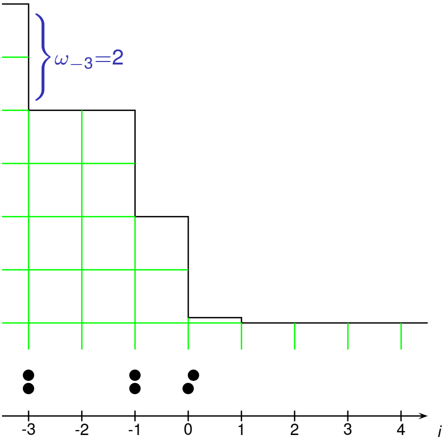
The totally asymmetric zero range process



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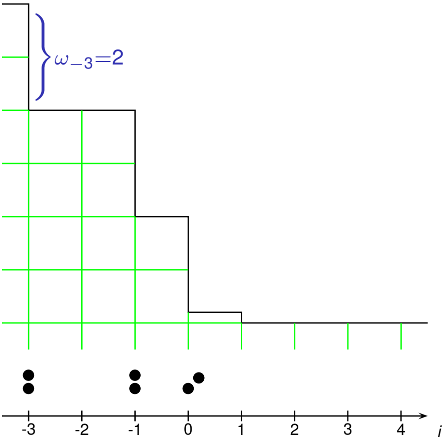

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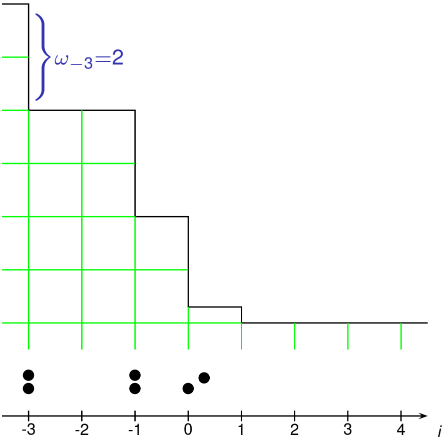

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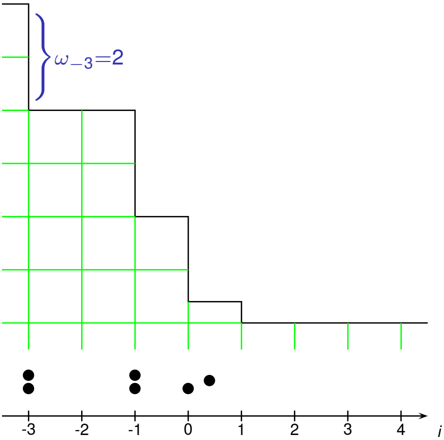

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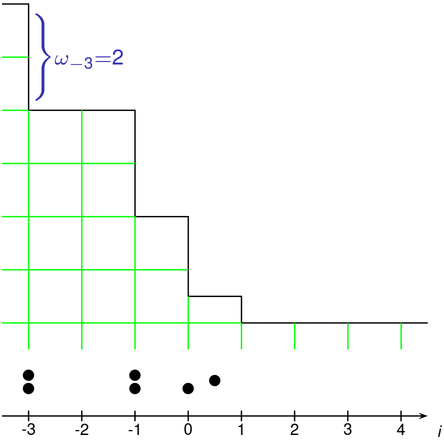

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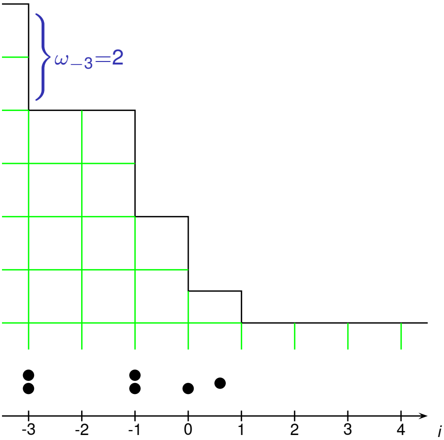
The totally asymmetric zero range process



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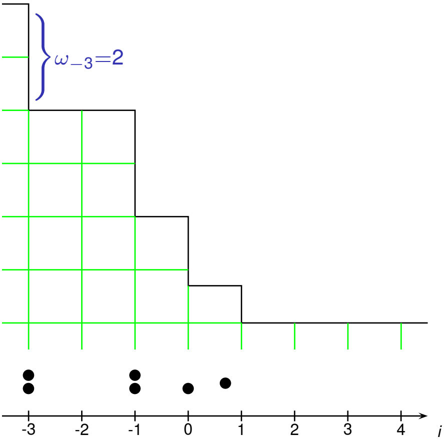
The totally asymmetric zero range process



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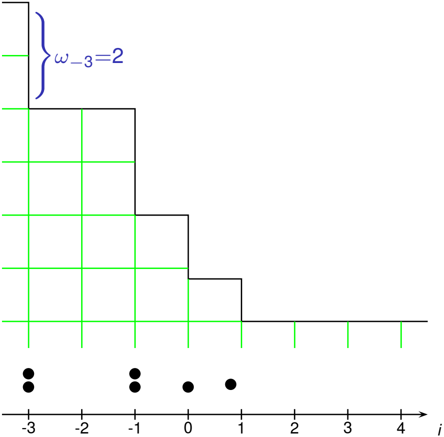
The totally asymmetric zero range process



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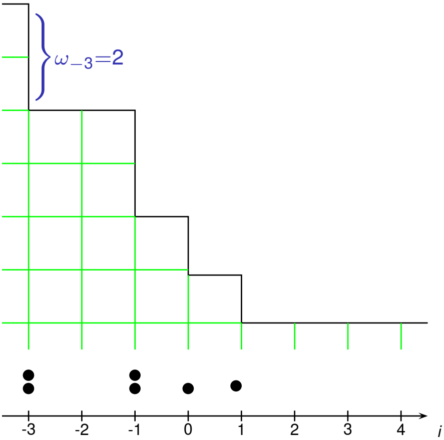

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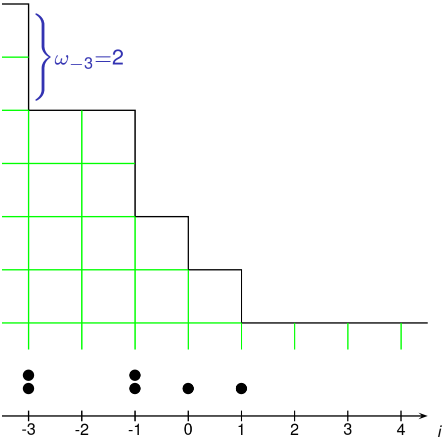
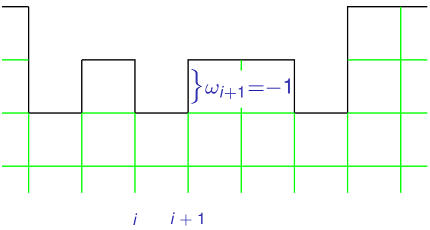
The totally asymmetric zero range process



Particles jump to the right from site i with rate $r(\omega_i)$

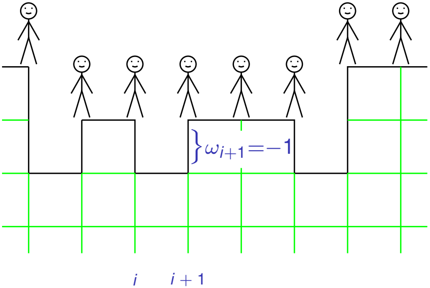
(r non-decreasing).

A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$



$$\begin{pmatrix}\omega_i\\ \omega_{i+1}\end{pmatrix} = \begin{pmatrix}1\\ -1\end{pmatrix}$$

A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$

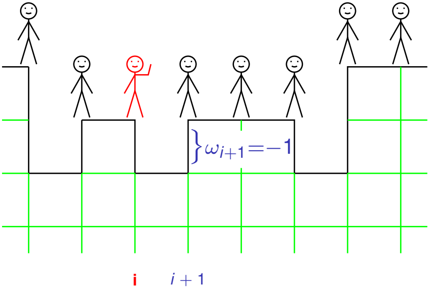


$$\begin{pmatrix}\omega_i\\ \omega_{i+1}\end{pmatrix} = \begin{pmatrix}1\\ -1\end{pmatrix}$$

a brick is added with rate $r(\omega_i)$.

(r non-decreasing).

A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$

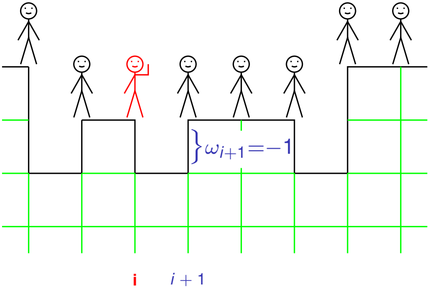


$$\begin{pmatrix} \omega_i \\ \omega_{i+1} \end{pmatrix} = \begin{pmatrix} 1 \\ -1 \end{pmatrix}$$

a brick is added with rate $\mathbf{r}(\omega_\mathbf{i})$.

(r non-decreasing).

A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$



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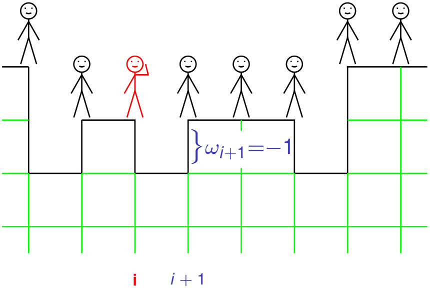

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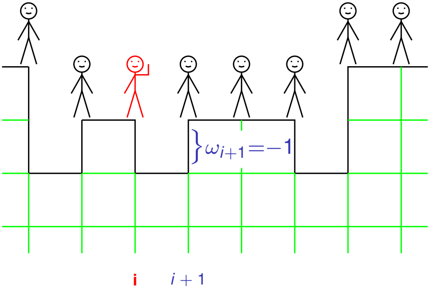

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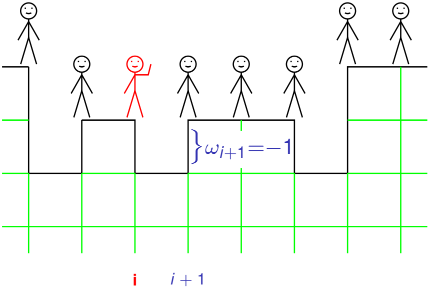

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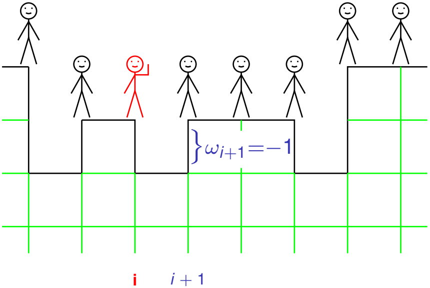

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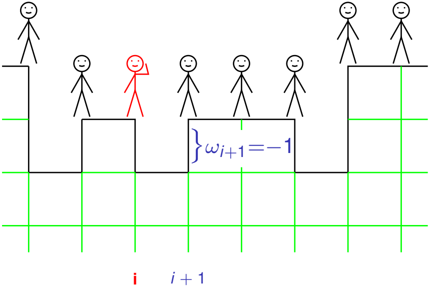

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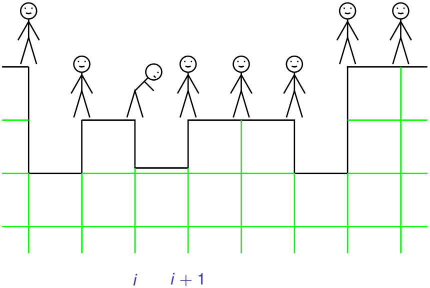
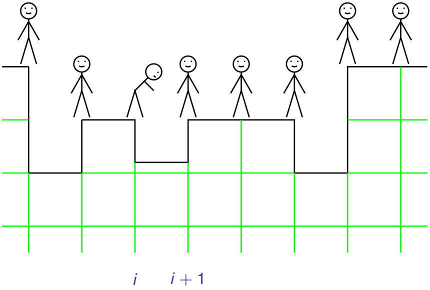


$$\begin{pmatrix} \omega_i \\ \omega_{i+1} \end{pmatrix} \to \begin{pmatrix} \omega_i - 1 \\ \omega_{i+1} + 1 \end{pmatrix}$$
$$\| \qquad\qquad \|$$
$$\begin{pmatrix} 1 \\ -1 \end{pmatrix} \to \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

a brick is added with rate $r(\omega_i)$.

(r non-decreasing).

A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$



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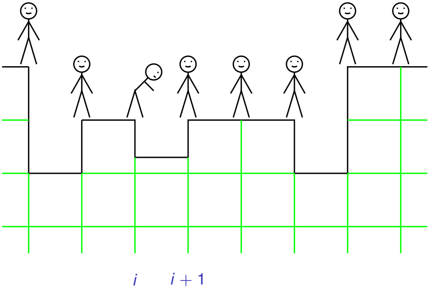

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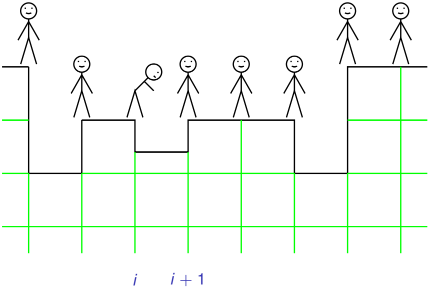

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a brick is added with rate $r(\omega_i)$.

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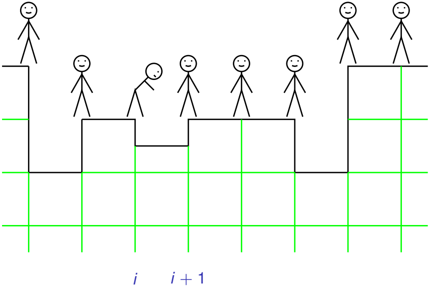
A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$



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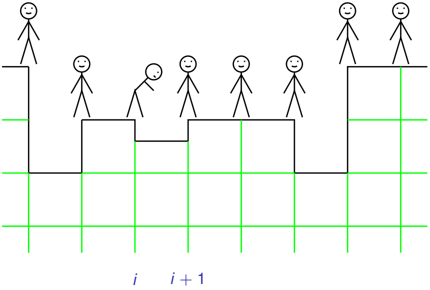

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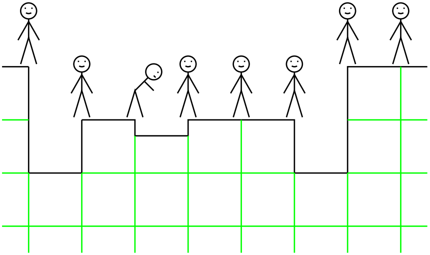

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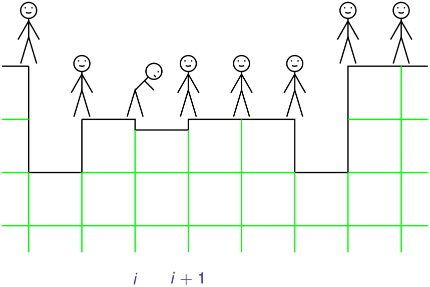

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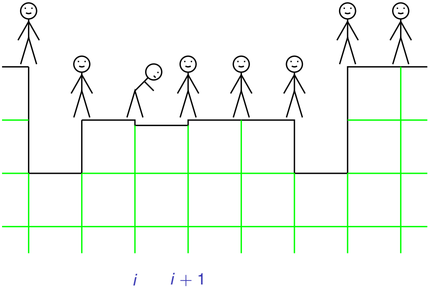

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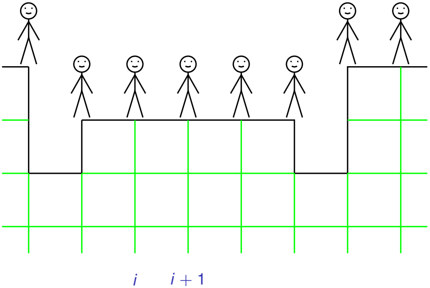

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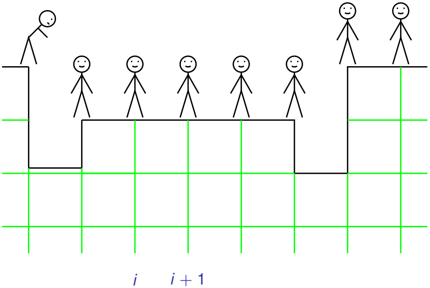

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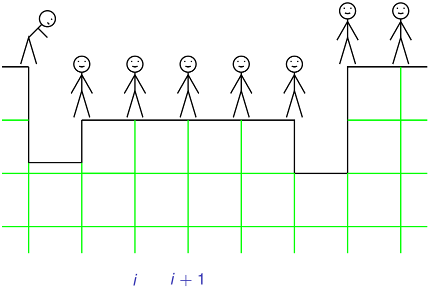

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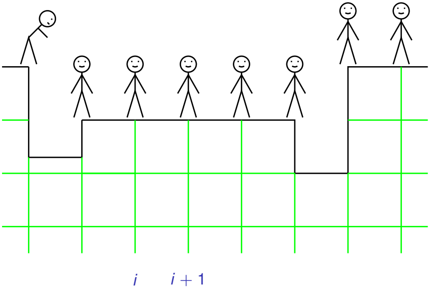

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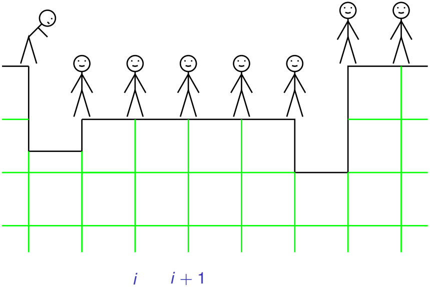

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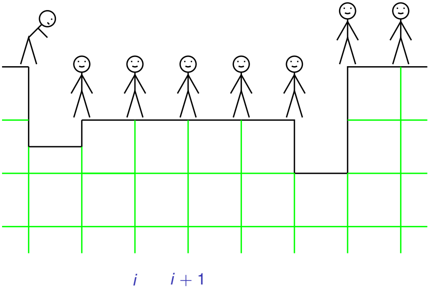
a brick is added with rate $r(\omega_i)$.

(r non-decreasing).

A generalized totally asymmetric zero range process: $\omega_i \in \mathbb{Z}$



$$\begin{pmatrix}\omega_i\\ \omega_{i+1}\end{pmatrix} \rightarrow \begin{pmatrix}\omega_i - 1\\ \omega_{i+1}+1\end{pmatrix}$$
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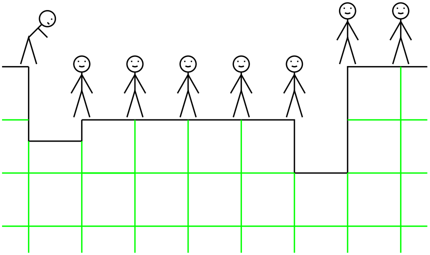

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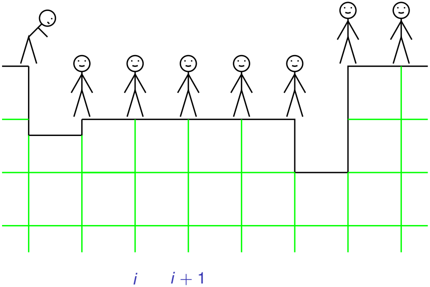

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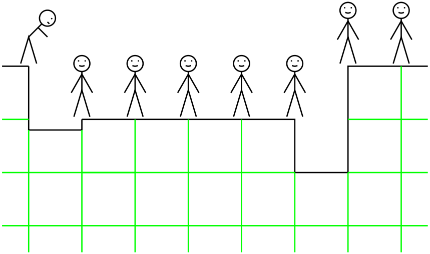

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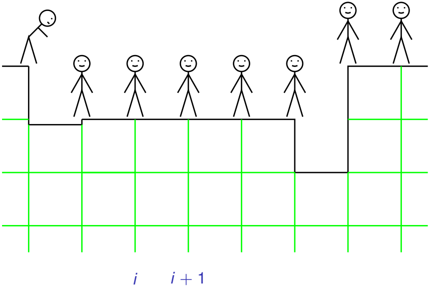

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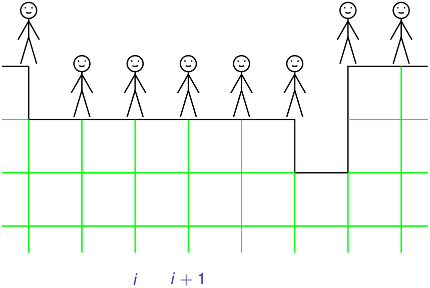

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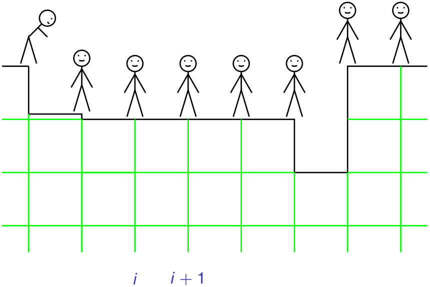

$$\begin{array}{ccc}
\begin{pmatrix}\omega_i\\ \omega_{i+1}\end{pmatrix} & \to & \begin{pmatrix}\omega_i-1\\ \omega_{i+1}+1\end{pmatrix}\\
\| & & \|\\
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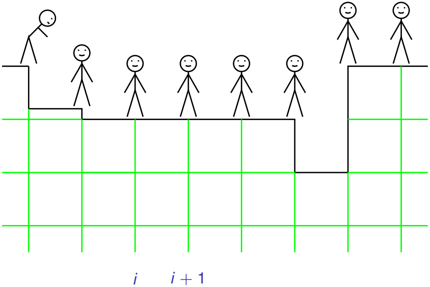

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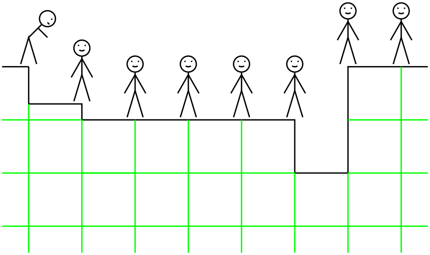

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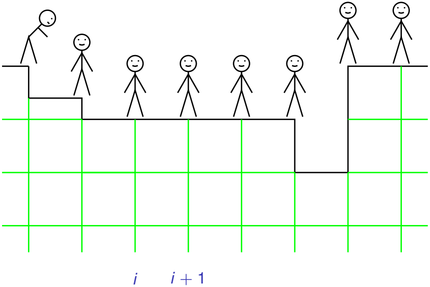

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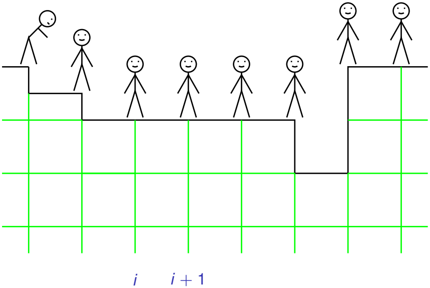

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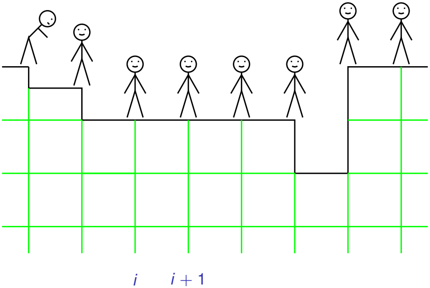

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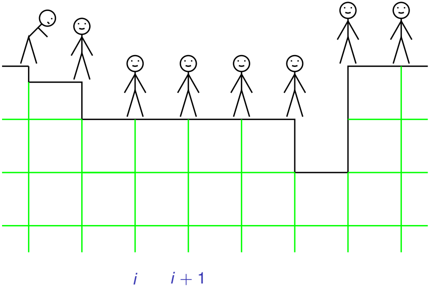

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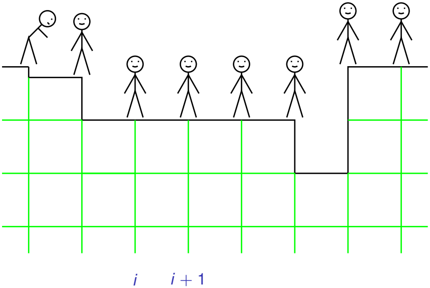

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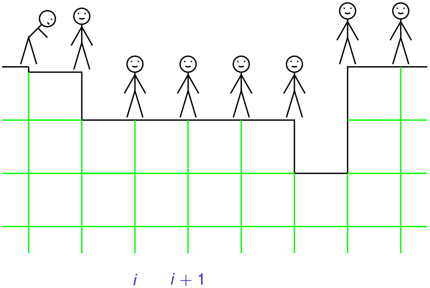

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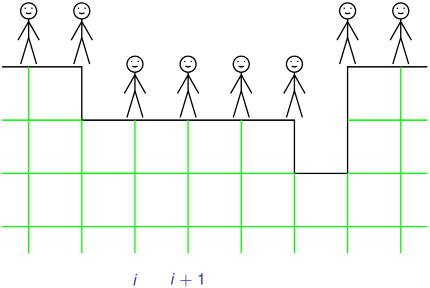

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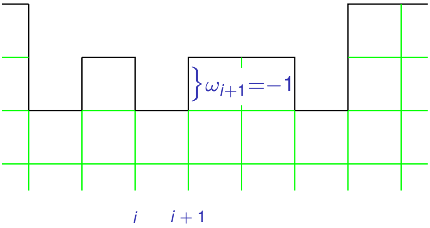
The totally asymmetric bricklayers process



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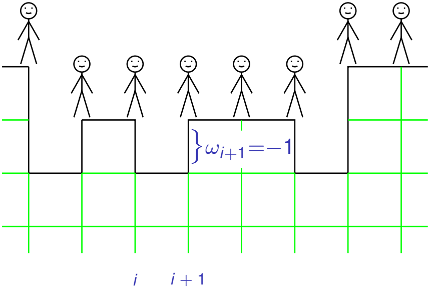

$$\begin{pmatrix}\omega_i\\ \omega_{i+1}\end{pmatrix} = \begin{pmatrix}1\\ -1\end{pmatrix}$$

a brick is added with rate $r(\omega_i) + r(-\omega_{i+1})$.

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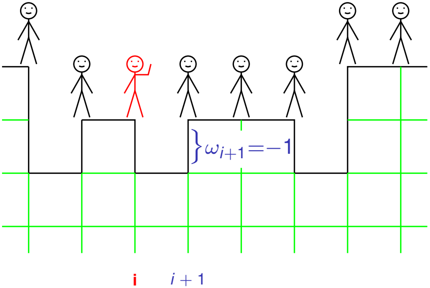

$$\begin{pmatrix}\omega_i\\ \omega_{i+1}\end{pmatrix} = \begin{pmatrix}1\\ -1\end{pmatrix}$$

a brick is added with rate $\mathbf{r}(\omega_{\mathbf{i}}) + r(-\omega_{i+1})$.

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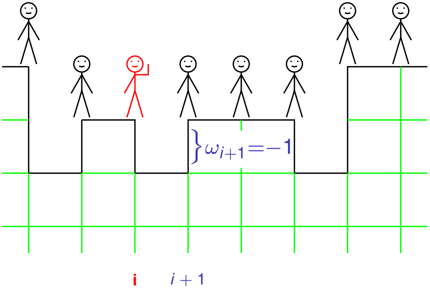

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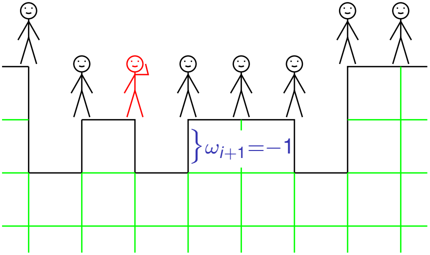

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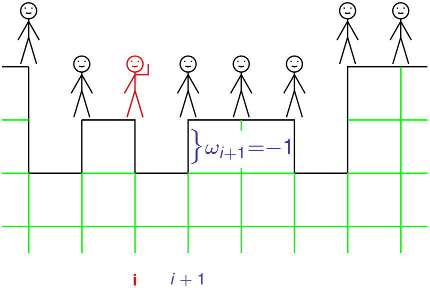

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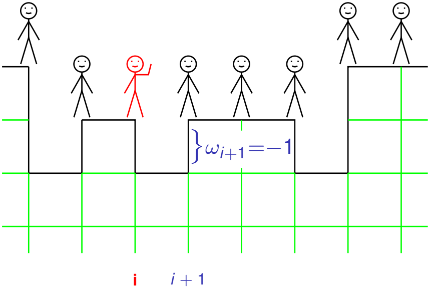

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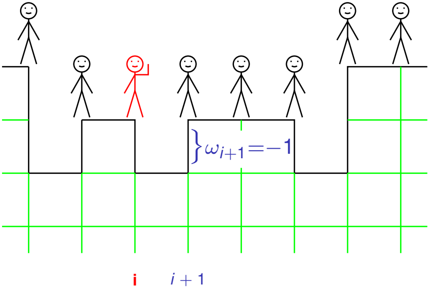

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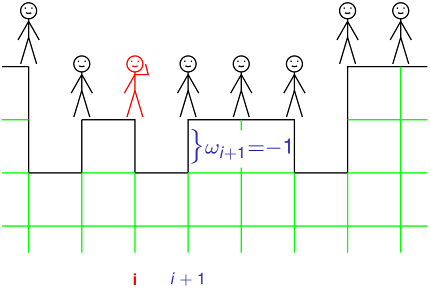

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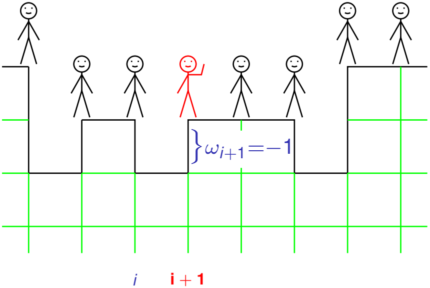

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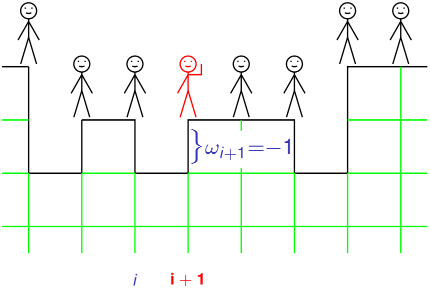

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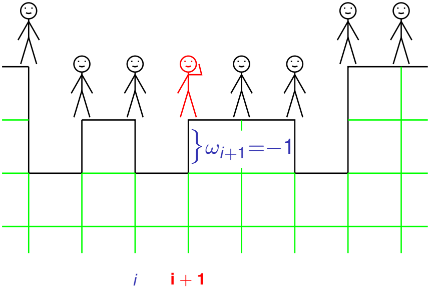

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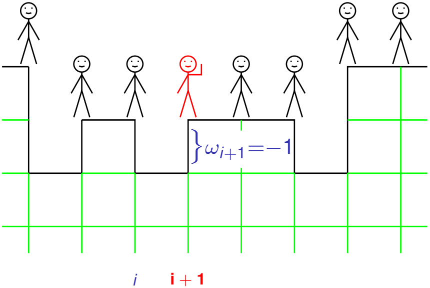

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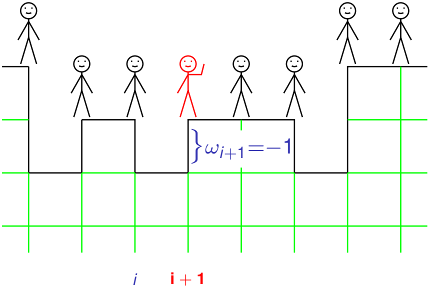

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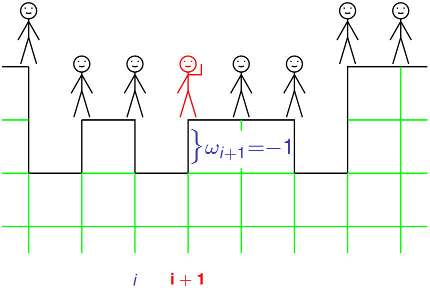

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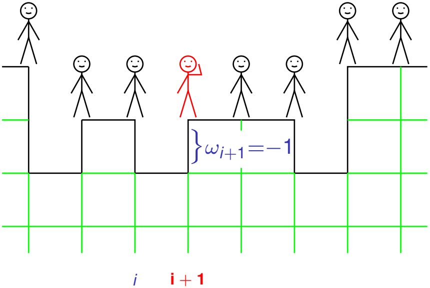

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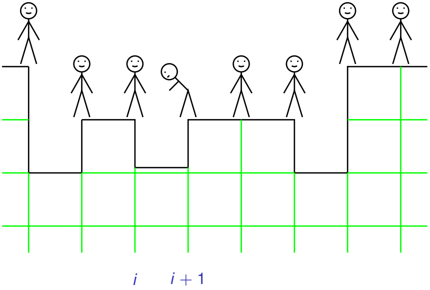

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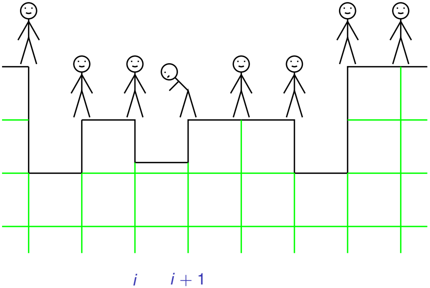

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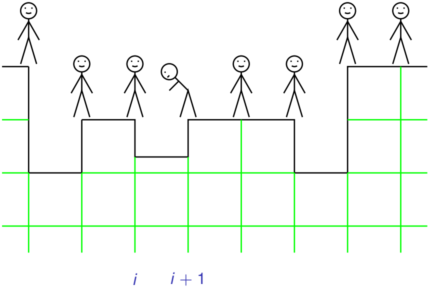

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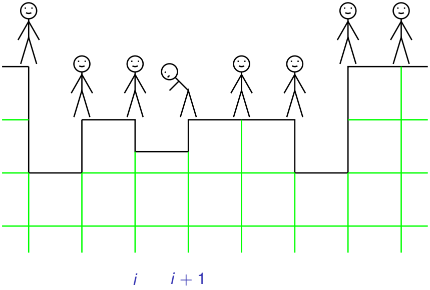

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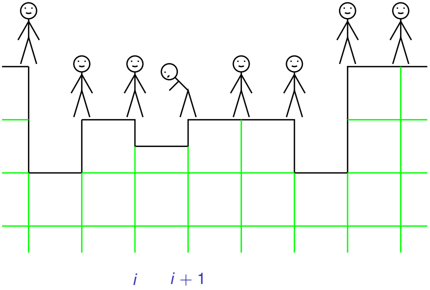

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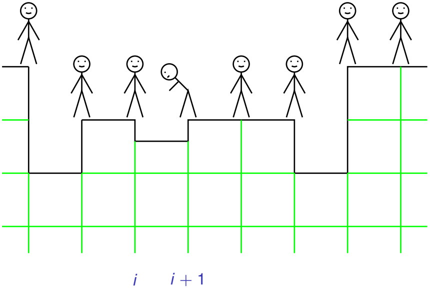

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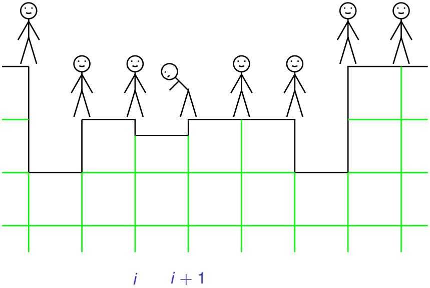

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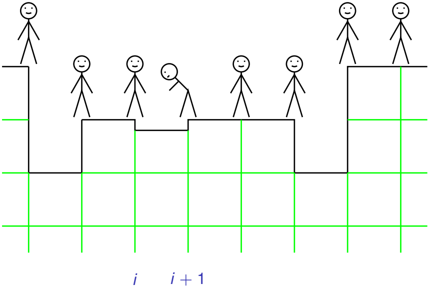

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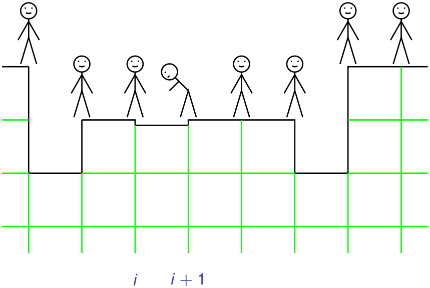

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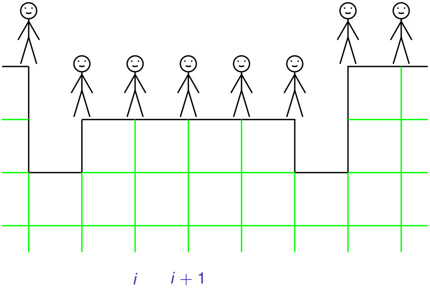

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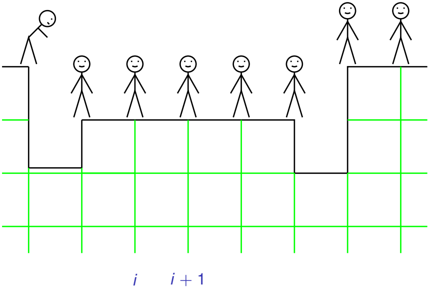

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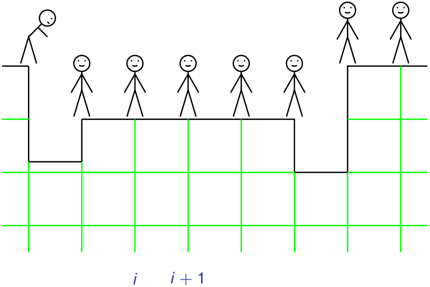

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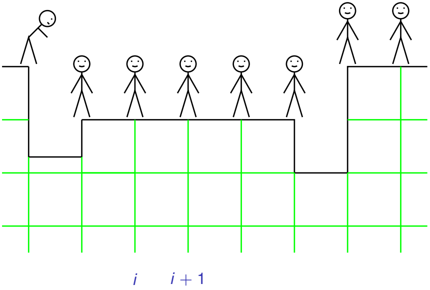

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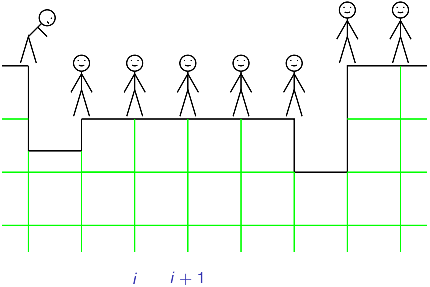

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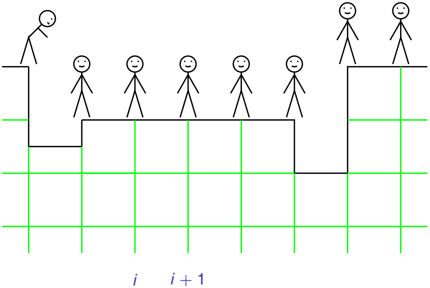

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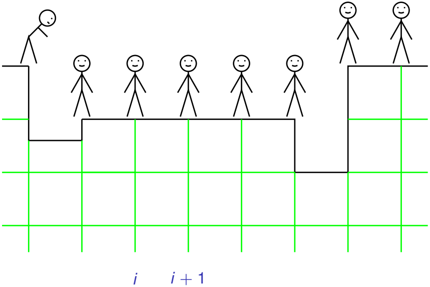

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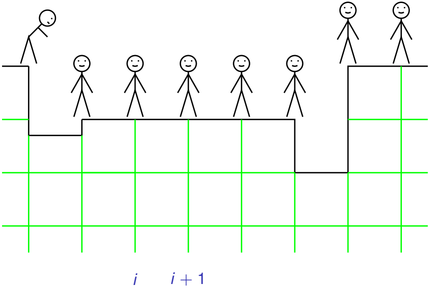

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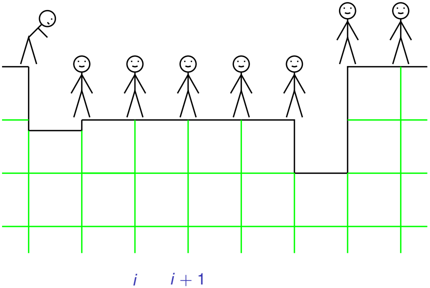

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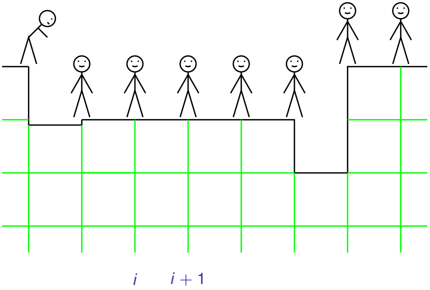

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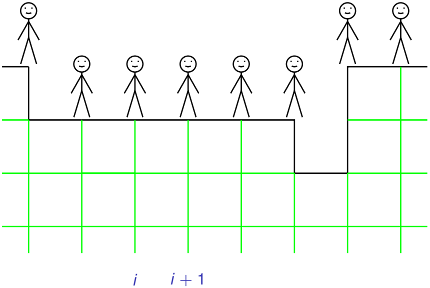

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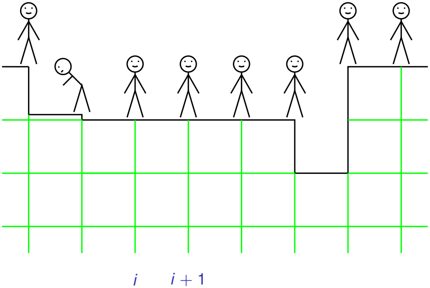

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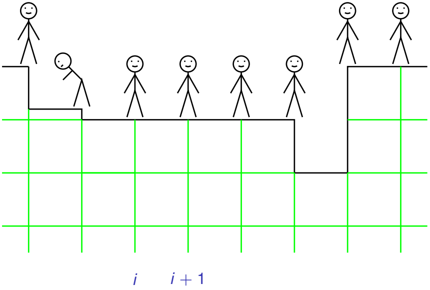

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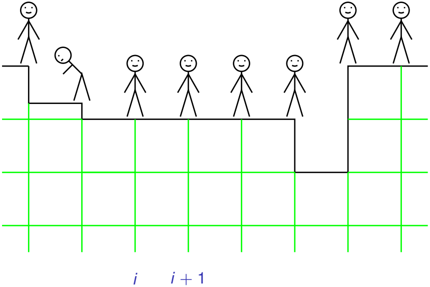

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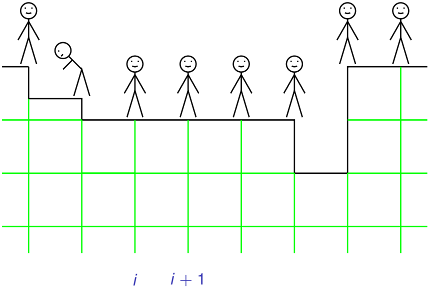

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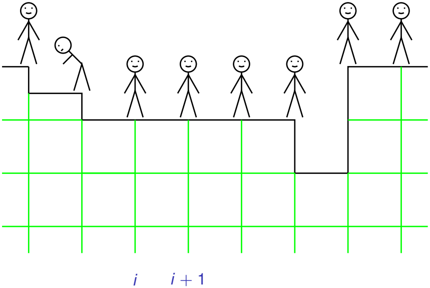

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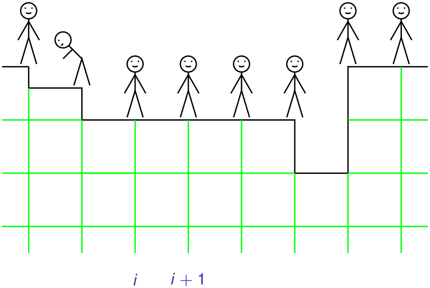

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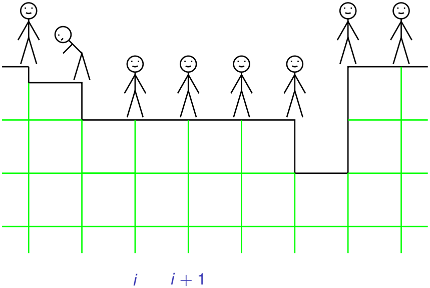

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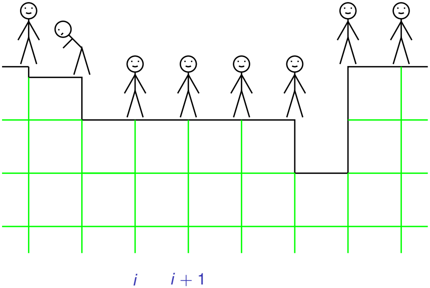

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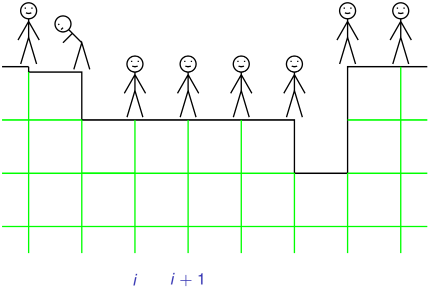

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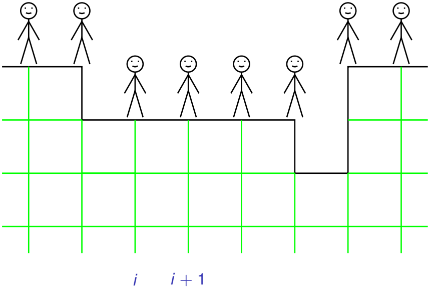

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A mirror-symmetrized version of the extended zero range. Left and right jumps of the dynamics cooperate, if
$(r(\omega) \cdot r(1 - \omega) = 1; \quad r$ non-decreasing$)$.

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Here $r!(0) := 1$, and $r!(z+1) = r!(z) \cdot r(z+1)$ for all $z \in \mathbb{Z}$.

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The *density* $\varrho = \varrho(\theta) := \mathbf{E}^\theta(\omega)$ and the *hydrodynamic flux* $H = H^\theta := \mathbf{E}^\theta$[growth rate] both depend on a parameter ϱ or θ of the stationary distribution.

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For the ASEP, $H(\varrho) = (p - q) \cdot \varrho(1 - \varrho)$, concave.

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$\rightsquigarrow$ Either convex or concave, discontinuous shock solutions exist.

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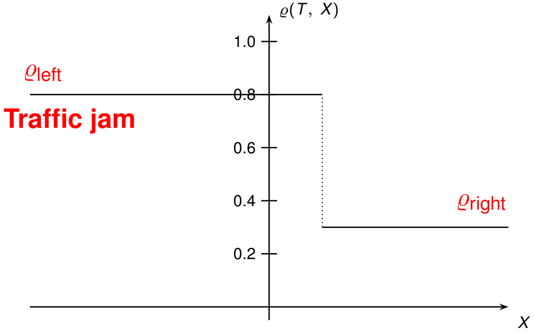
Rarefaction wave



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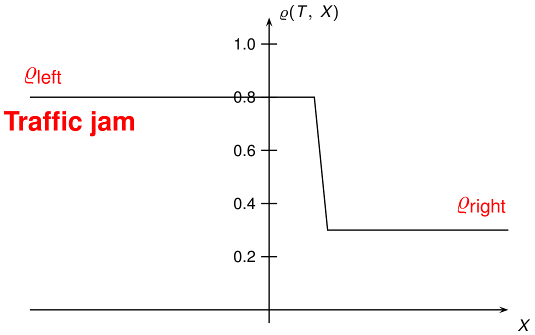

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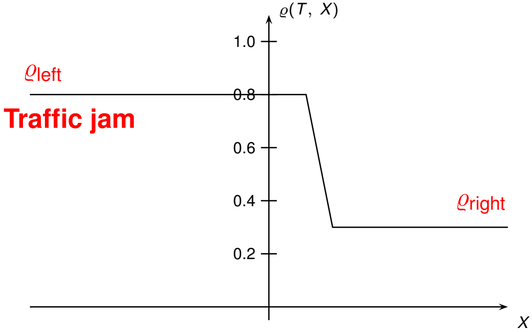

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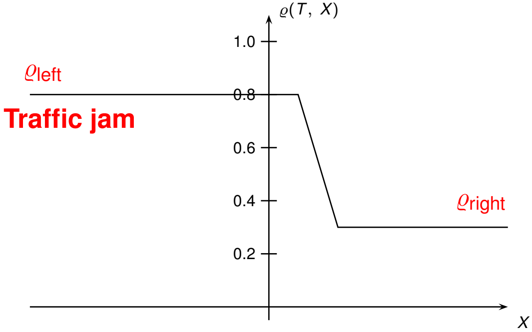

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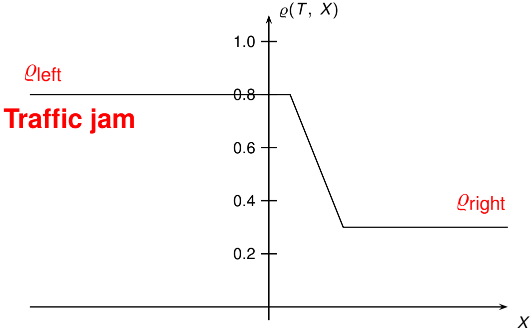

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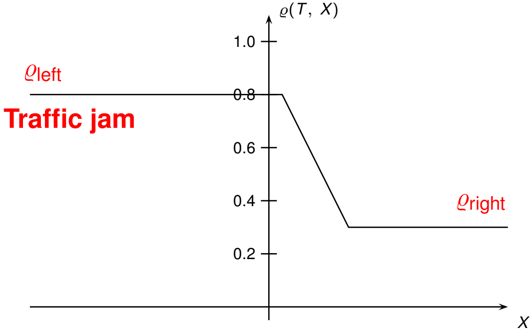

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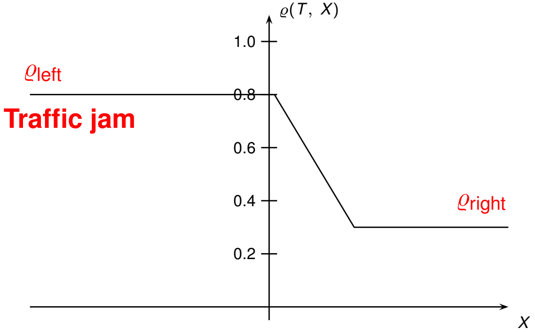

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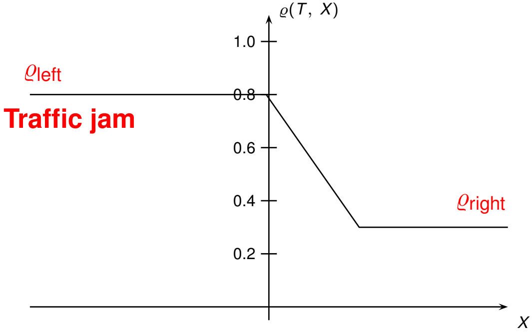
Rarefaction wave



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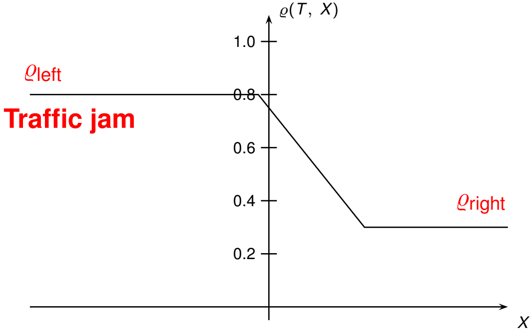
Rarefaction wave



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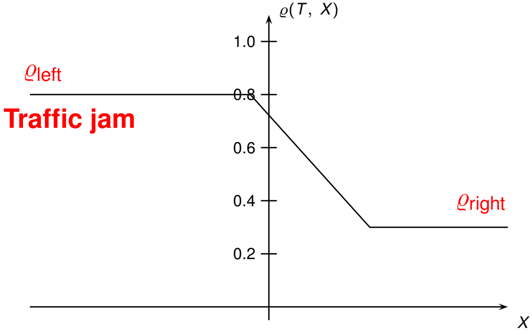
Rarefaction wave



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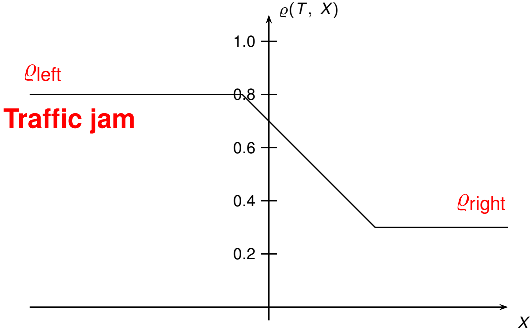
Rarefaction wave



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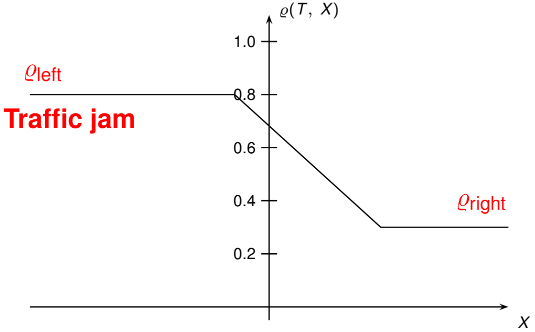
Rarefaction wave



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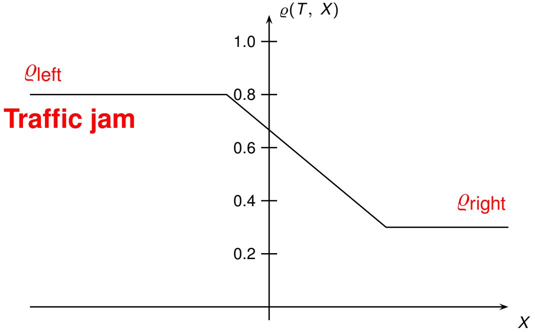
Rarefaction wave



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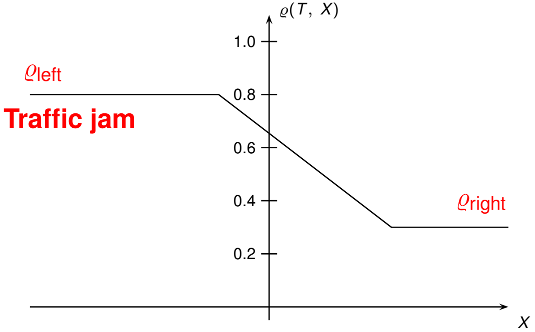
Rarefaction wave



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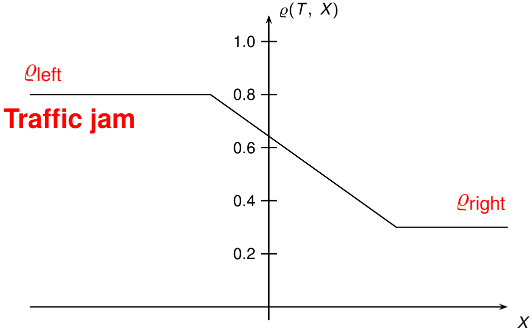
Rarefaction wave



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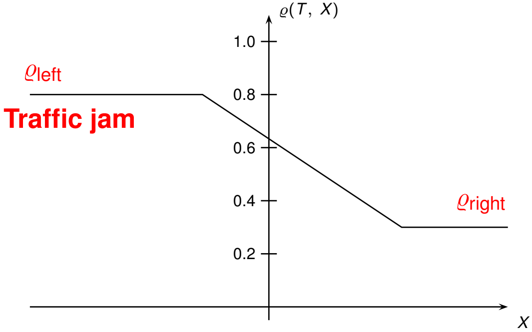
Rarefaction wave



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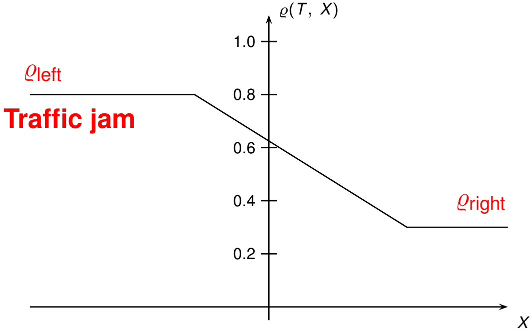
Rarefaction wave



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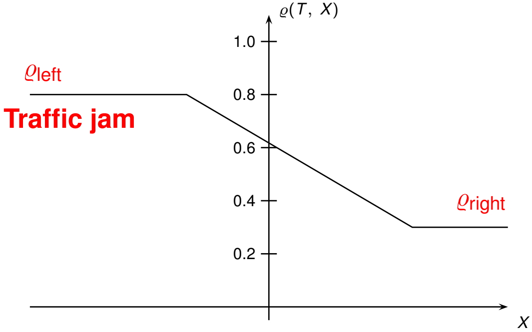
Rarefaction wave



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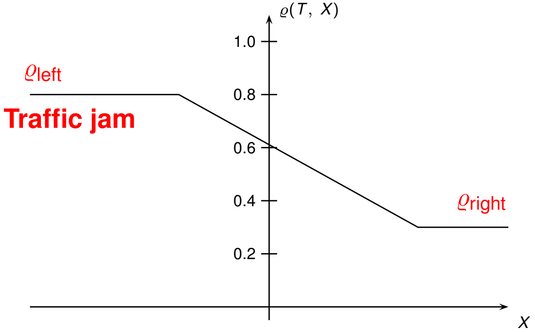
Rarefaction wave



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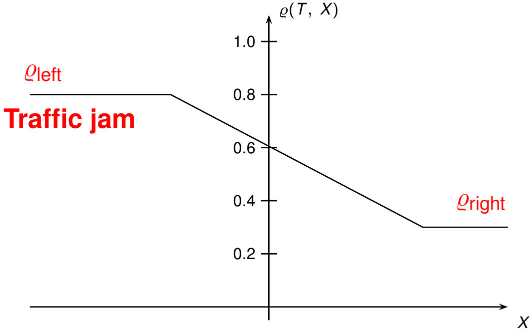
Rarefaction wave



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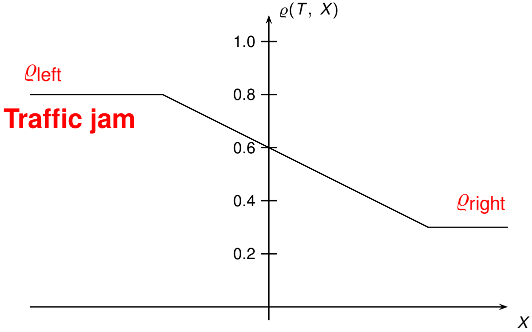
Rarefaction wave



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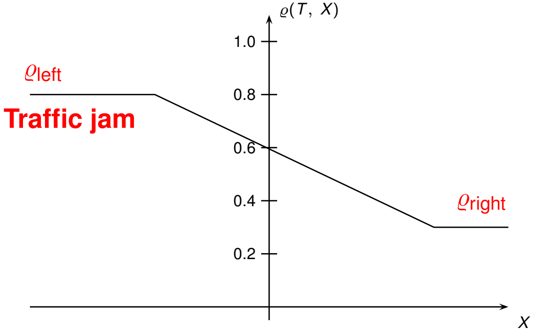
Rarefaction wave



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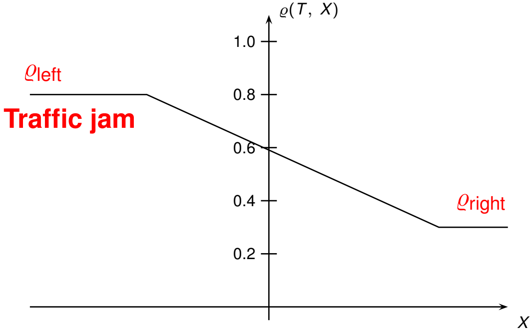
Rarefaction wave



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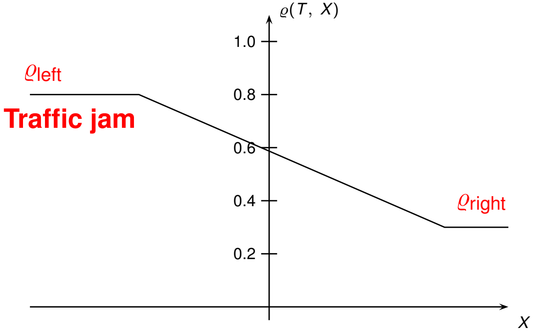
Rarefaction wave



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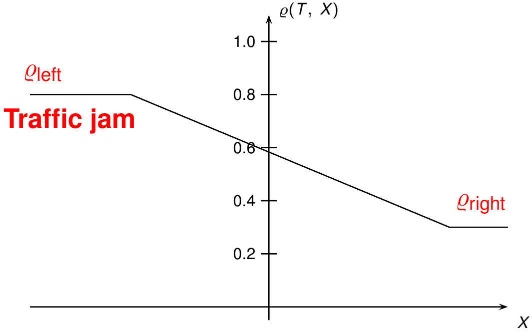
Rarefaction wave



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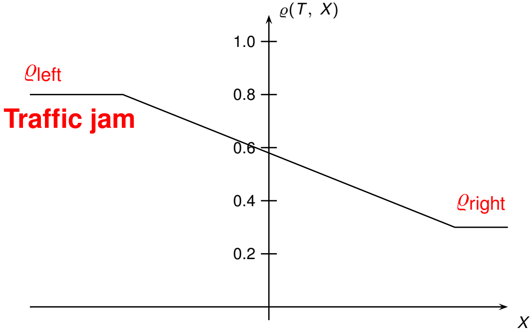
Rarefaction wave



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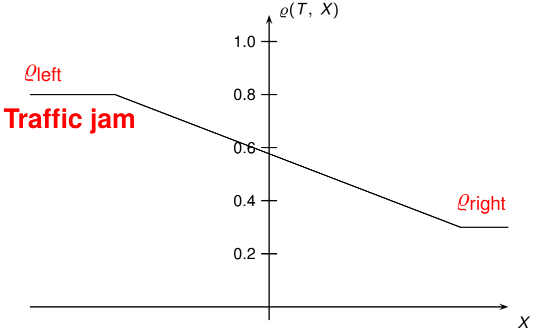
Rarefaction wave



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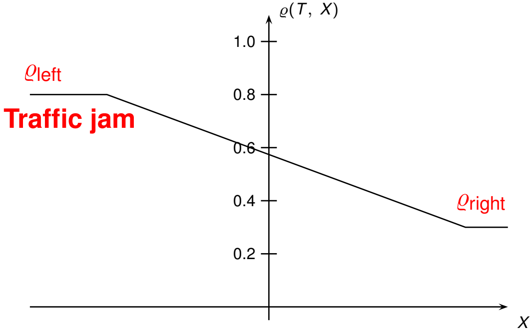
Rarefaction wave



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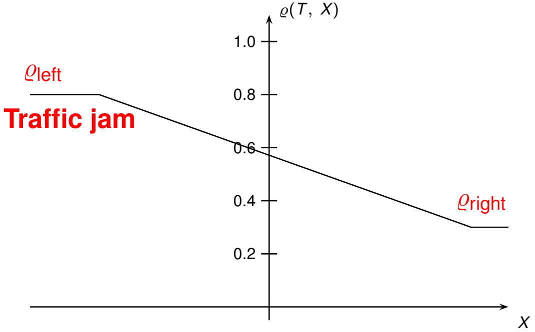
Rarefaction wave



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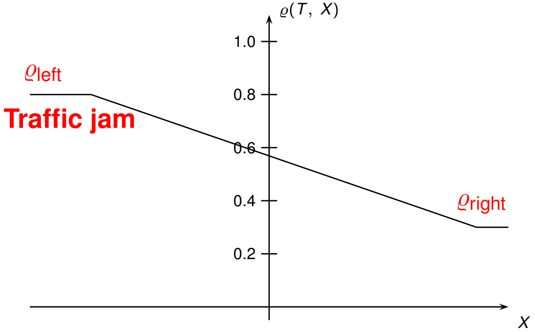
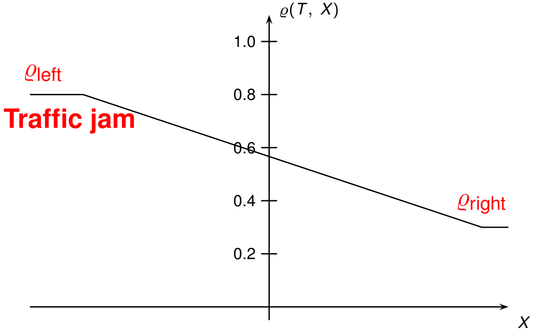
Rarefaction wave



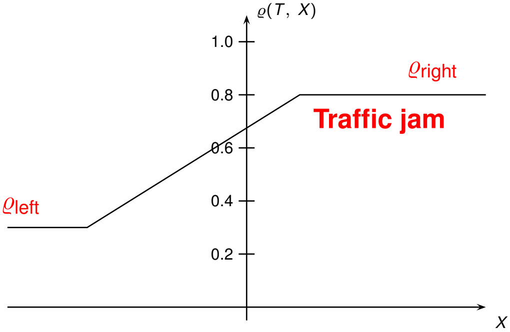
$$\partial_T \varrho + \partial_X H(\varrho) = 0 \qquad \varrho = \mathbf{E}(\omega), \quad H(\varrho) = \mathbf{E}^{\theta(\varrho)}[\text{growth rate}]$$

Rarefaction wave



$\partial_T \varrho + \partial_X H(\varrho) = 0$ $\qquad$ $\varrho = \mathbf{E}(\omega), \quad H(\varrho) = \mathbf{E}^{\theta(\varrho)}[\text{growth rate}]$

Shock wave



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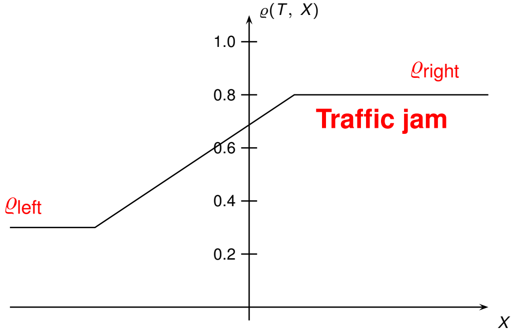
Shock wave



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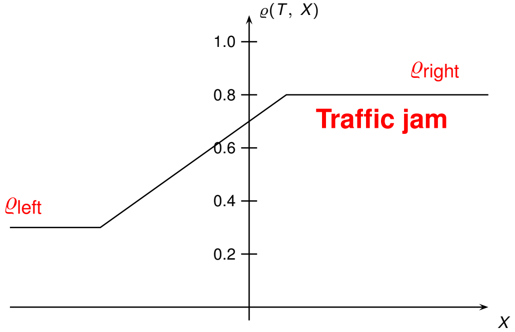
Shock wave



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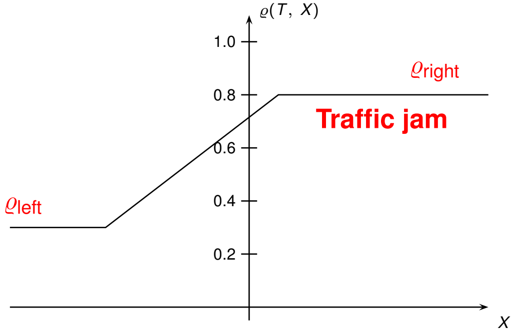
Shock wave



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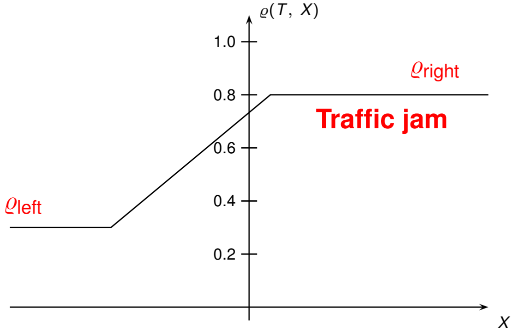
Shock wave



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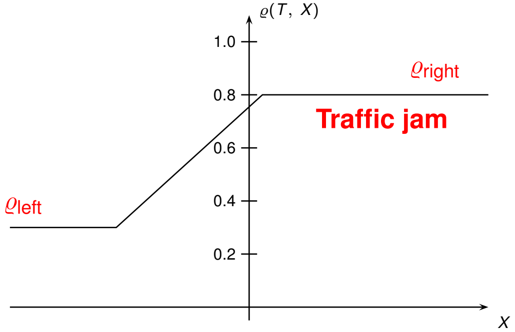
Shock wave



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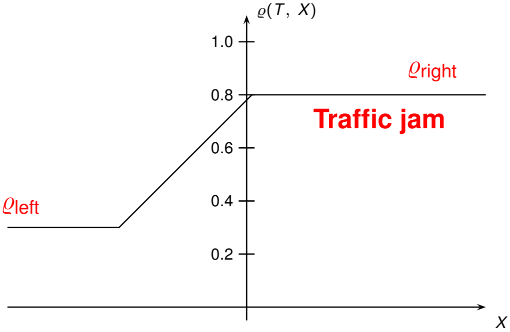
Shock wave



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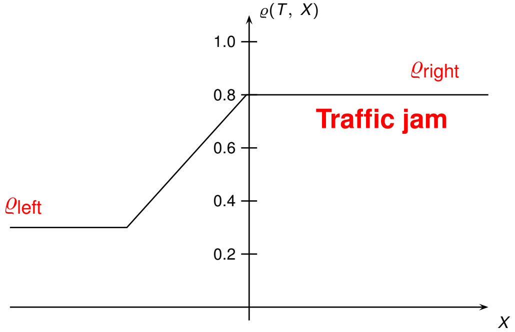
Shock wave



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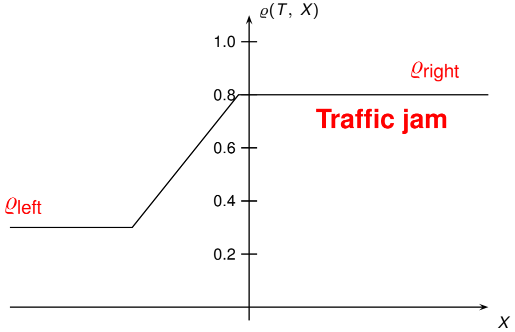
Shock wave



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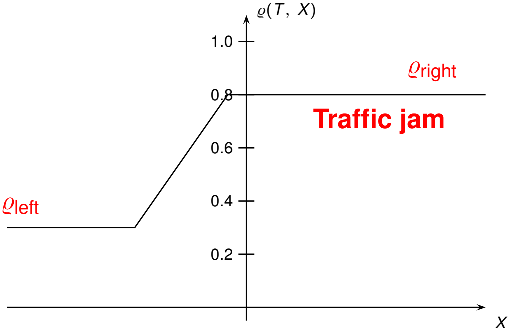
Shock wave



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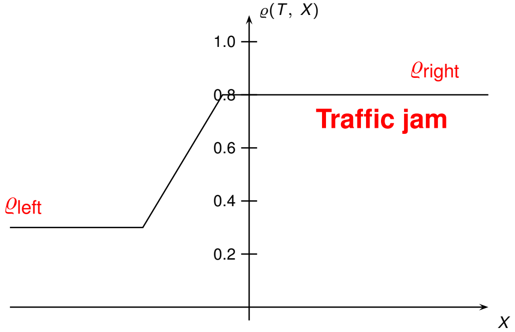
Shock wave



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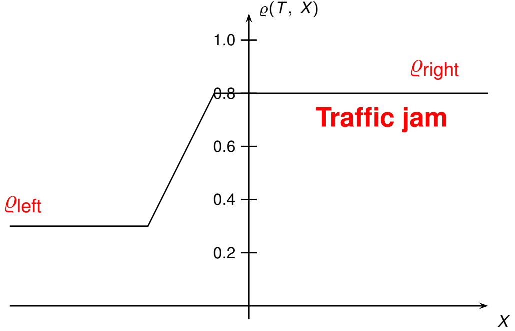
Shock wave



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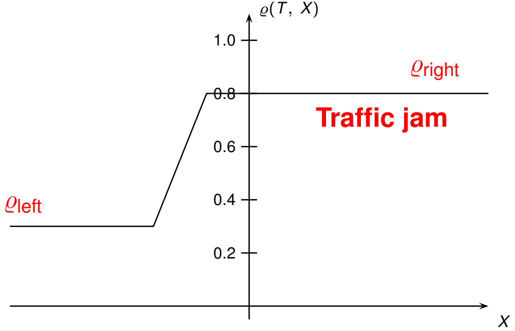
Shock wave



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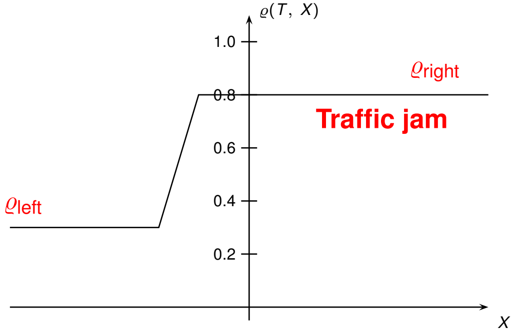
Shock wave



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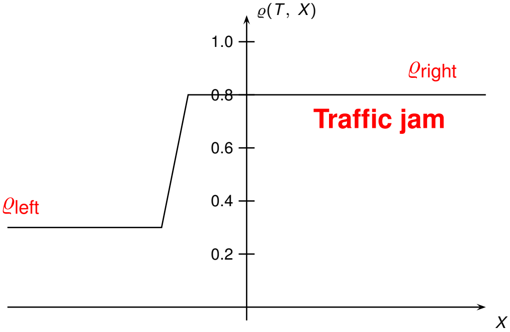
Shock wave



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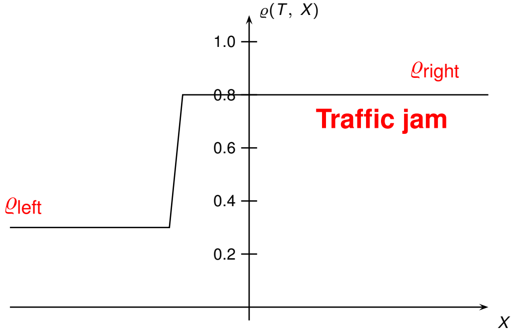
Shock wave



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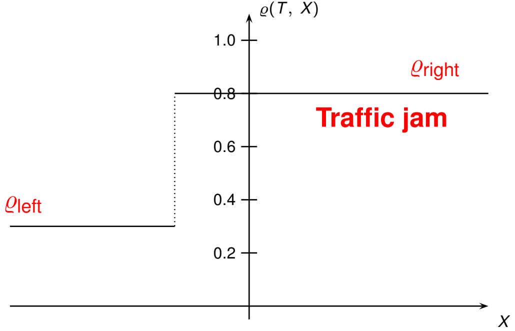
Shock wave



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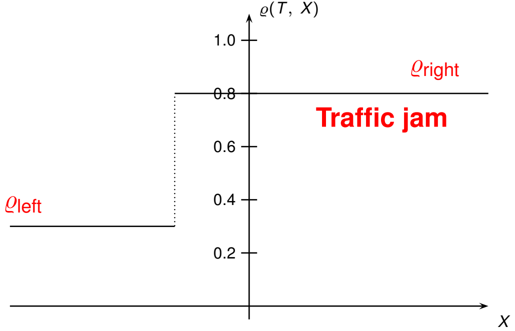
Shock wave



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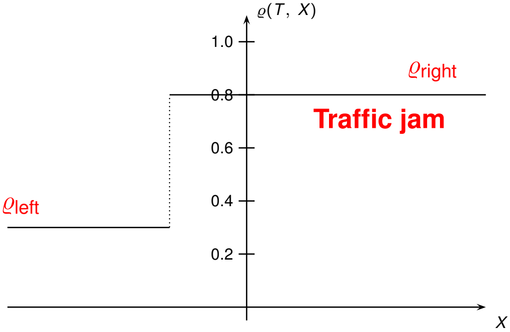
Shock wave



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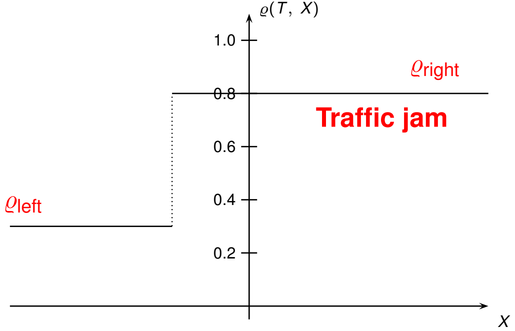
Shock wave



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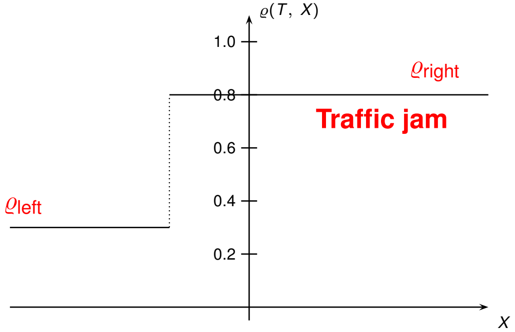
Shock wave



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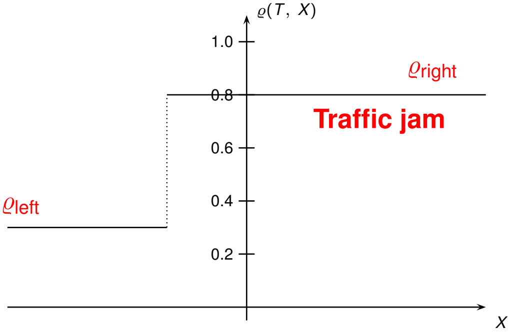
Shock wave



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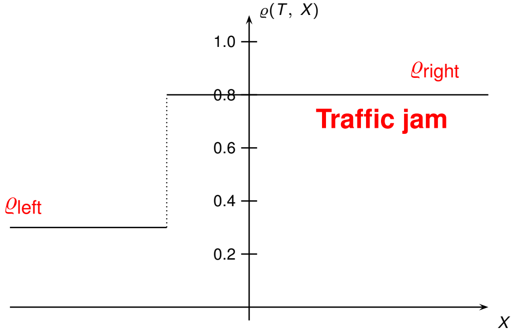
Shock wave



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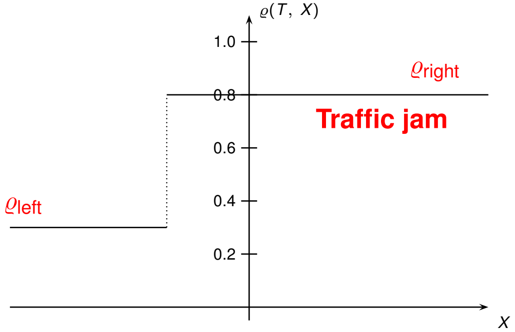
Shock wave



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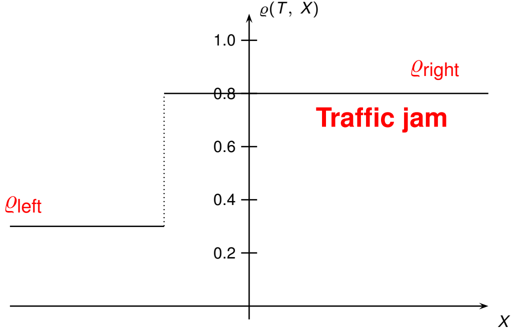
Shock wave



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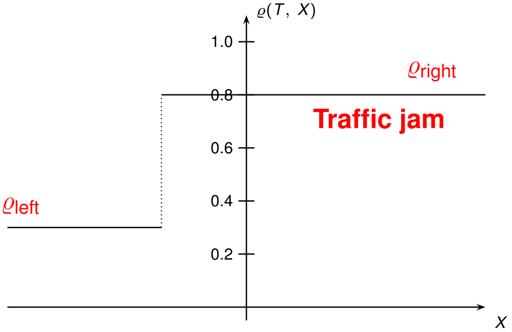
Shock wave



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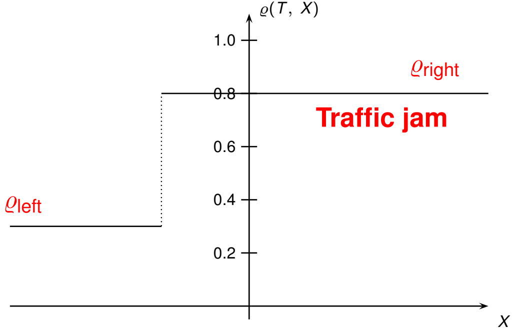

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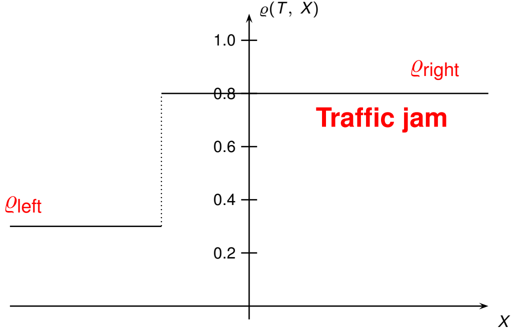

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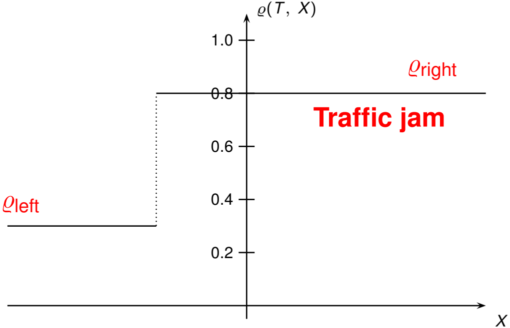

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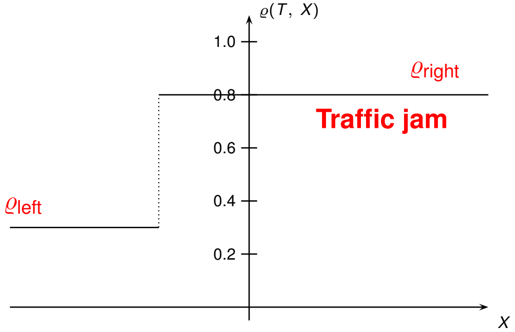

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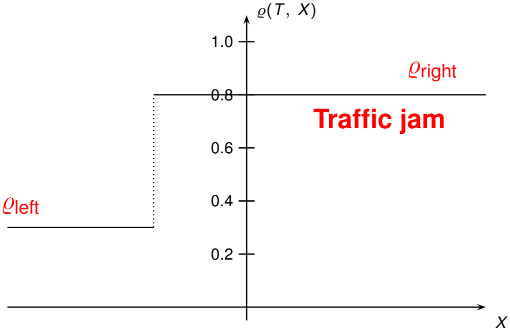

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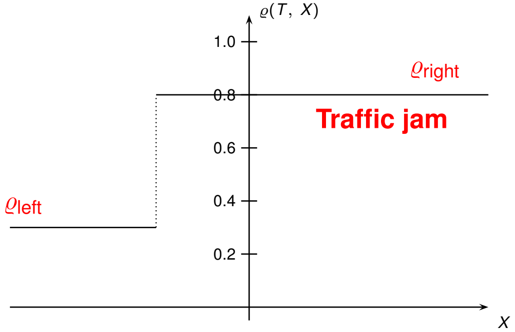

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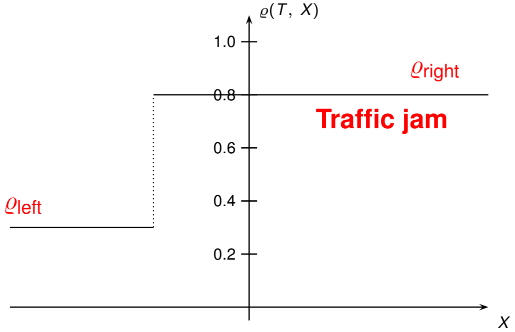

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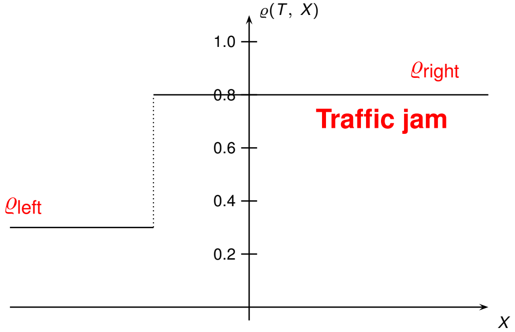

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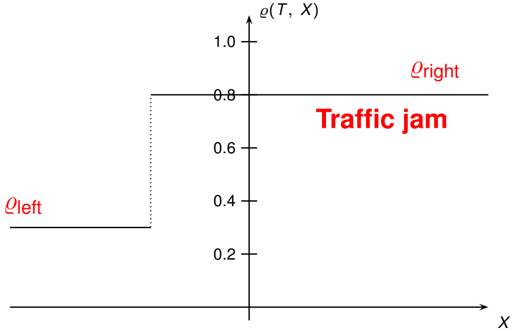

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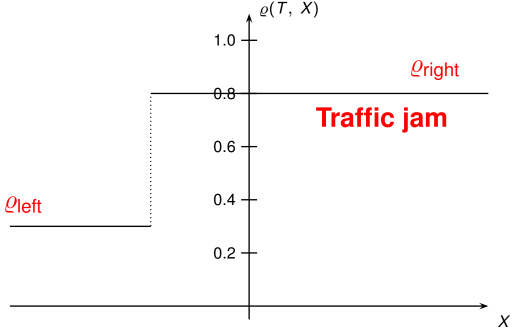

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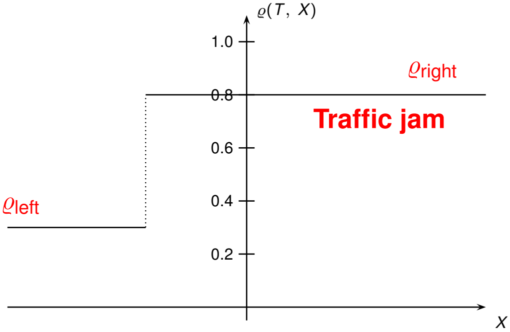

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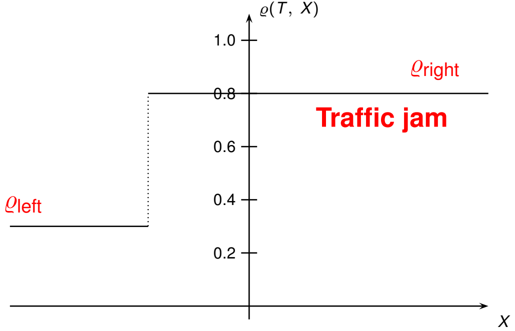

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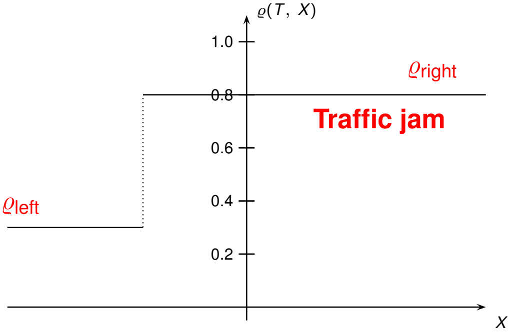

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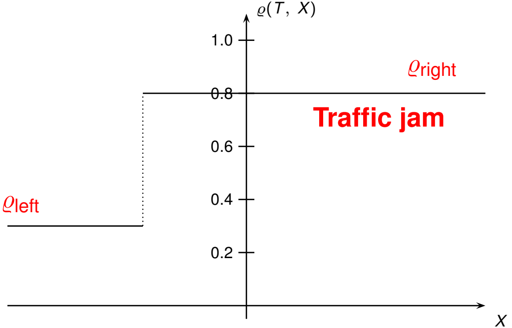

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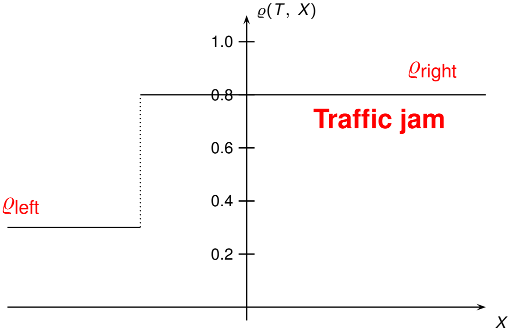

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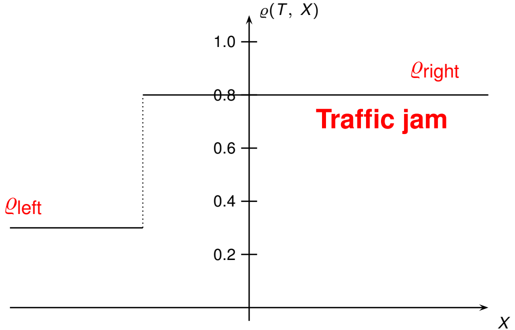

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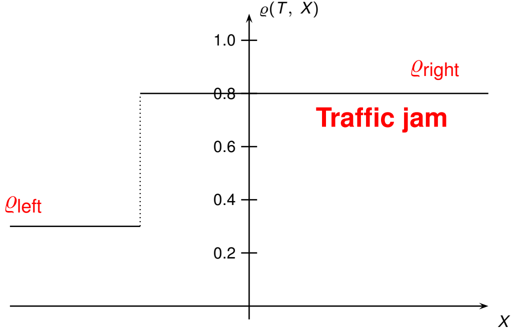

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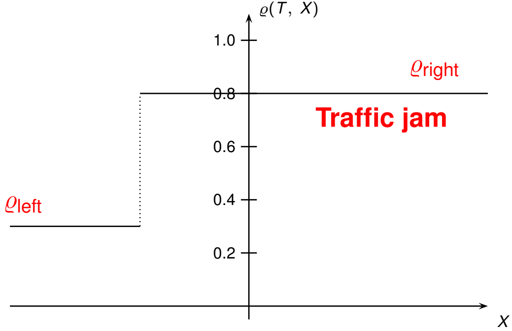

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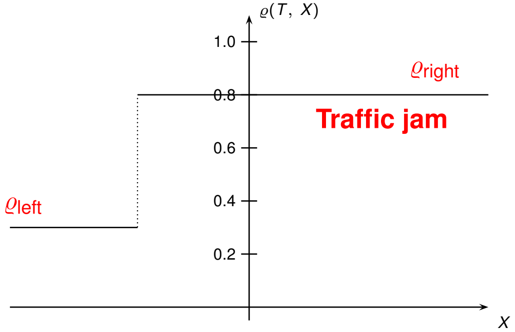

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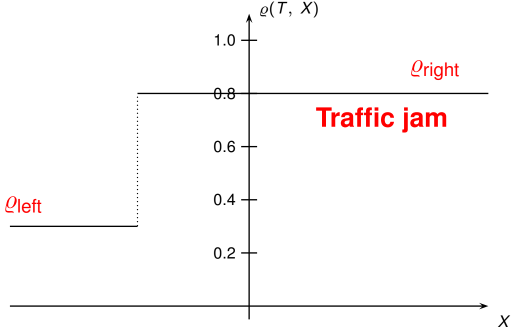

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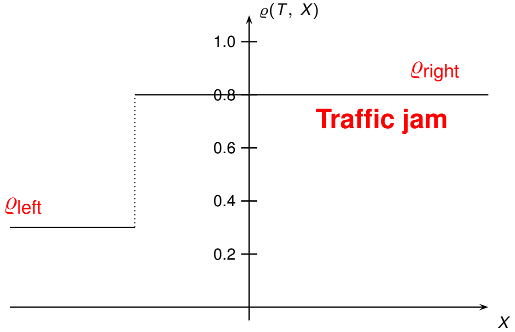

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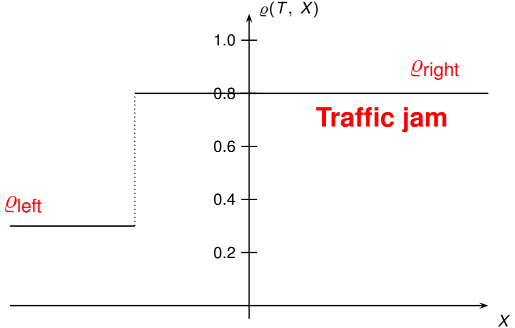

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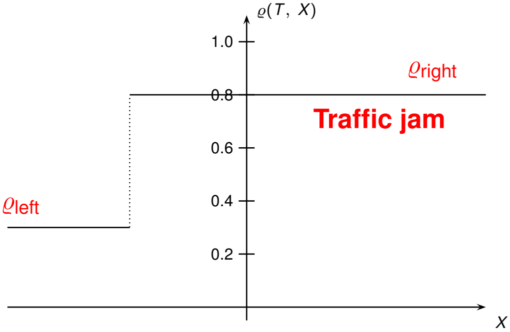

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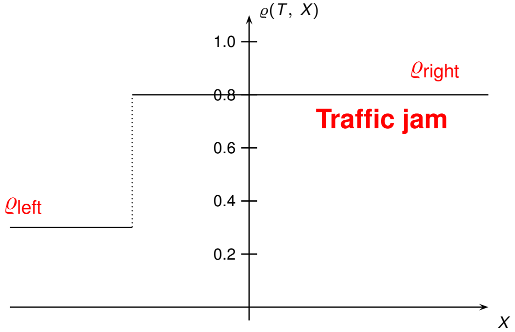

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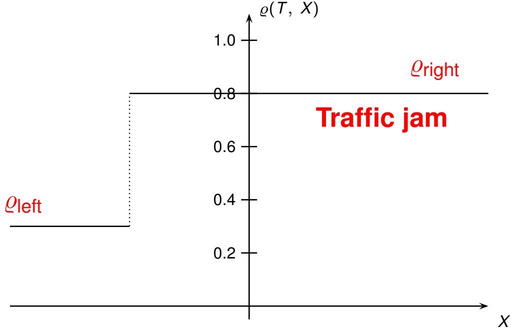

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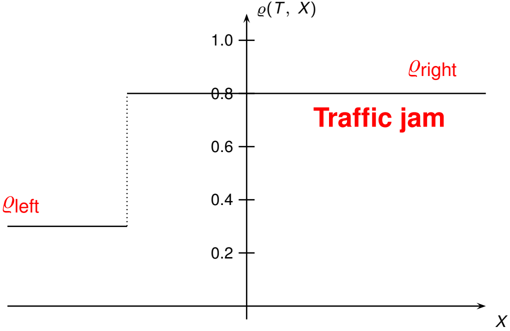

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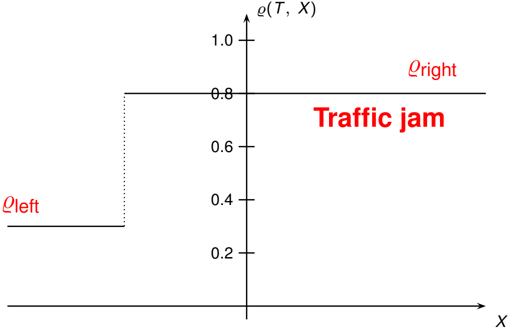

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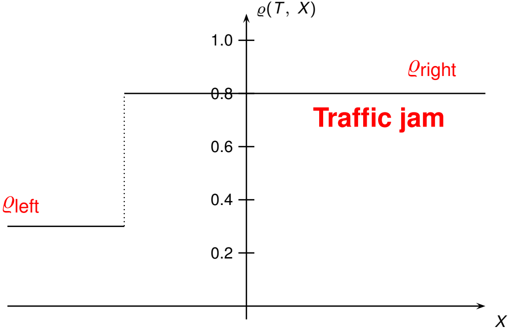

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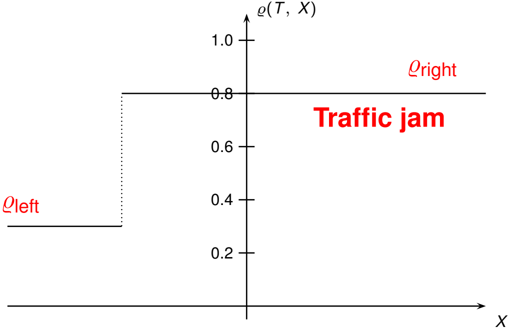

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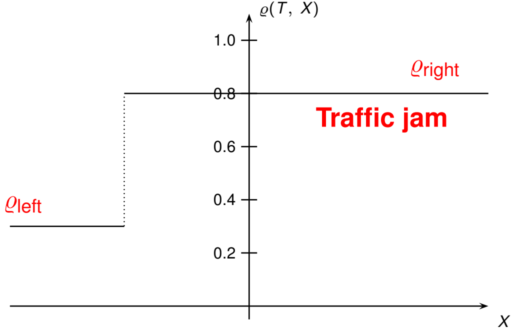

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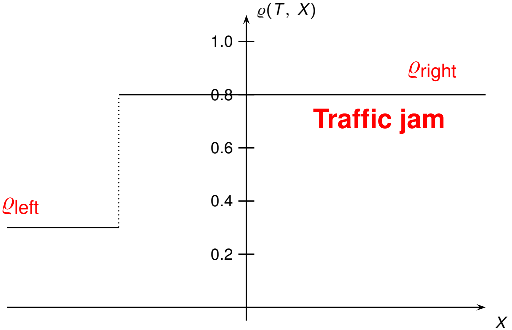

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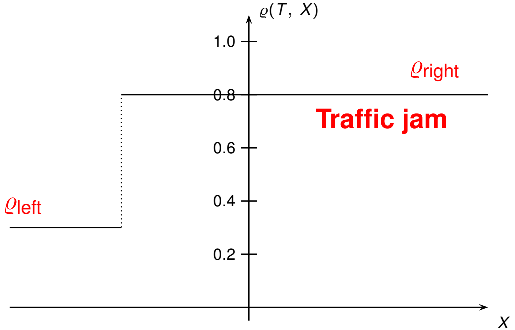

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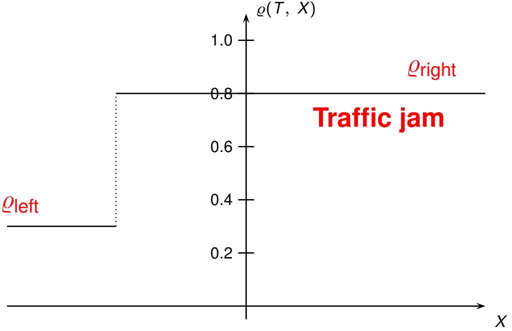

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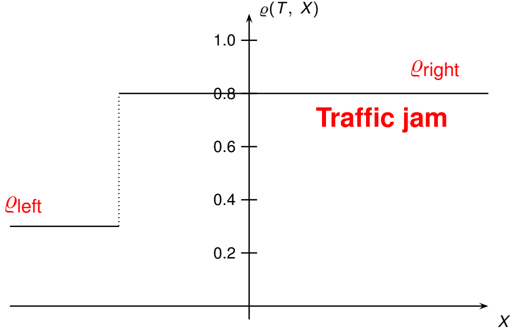

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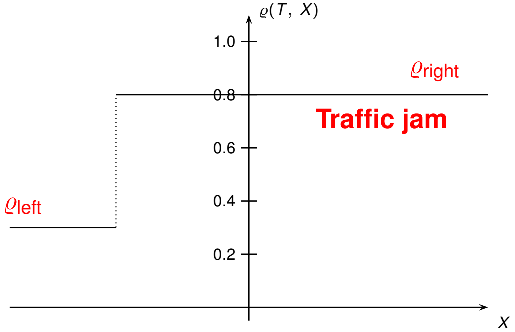

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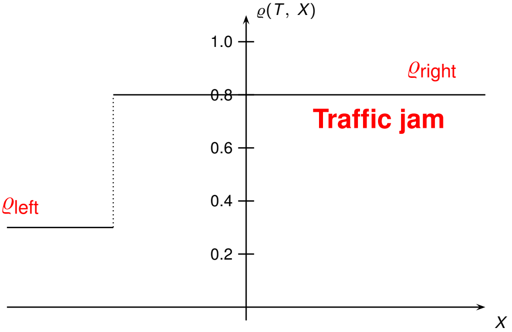

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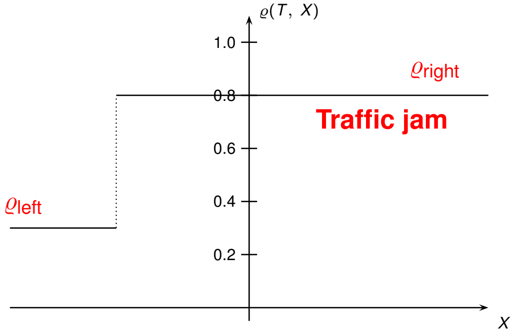
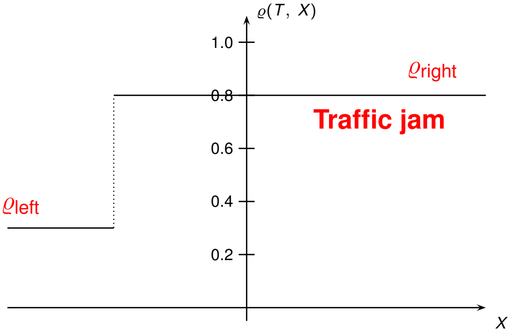


Discontinuous shock appears. Its velocity is given by *the Rankine-Hugoniot speed for densities* ϱ_{left} *and* ϱ_{right}

$$R = \frac{H(\varrho_{\text{left}}) - H(\varrho_{\text{right}})}{\varrho_{\text{left}} - \varrho_{\text{right}}}.$$

Shock wave



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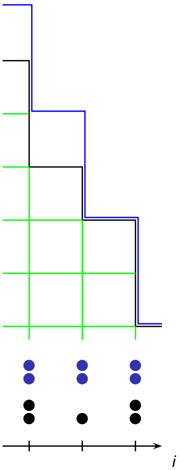
Let's look for the corresponding microscopic structure.

The second class particle

States ω and ω only differ at one site.



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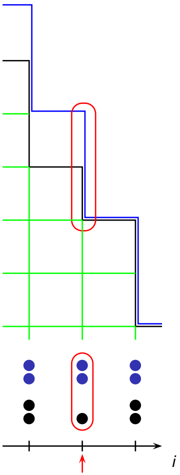

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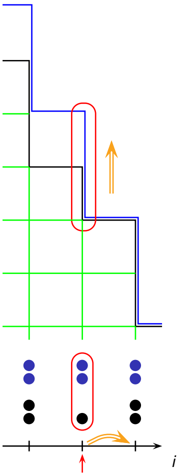

Growth on the right:
rate$\leq$rate

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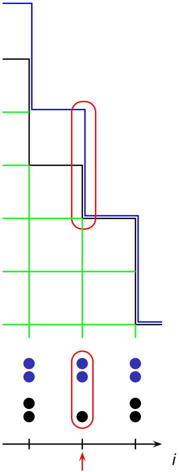

Growth on the right:
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with rate:

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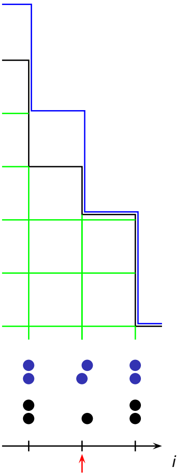

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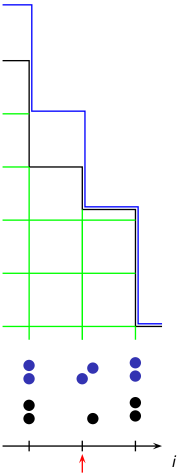

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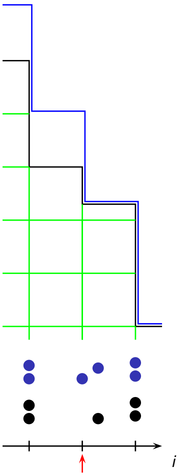

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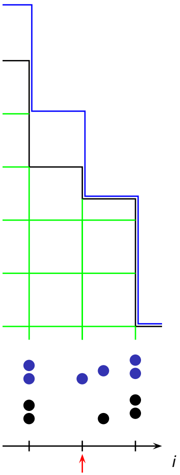

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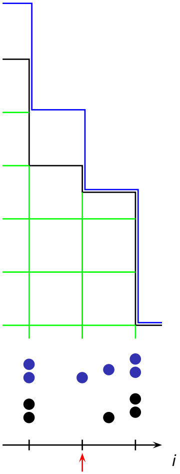

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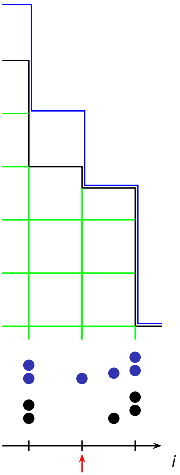

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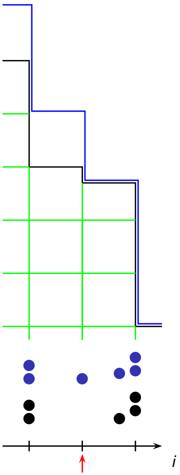

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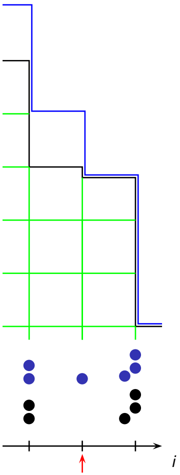

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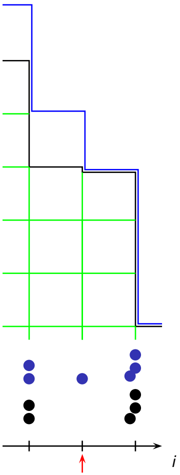

Growth on the right:

rate≤rate

with rate:

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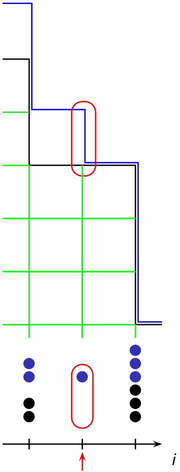

Growth on the right:

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with rate:

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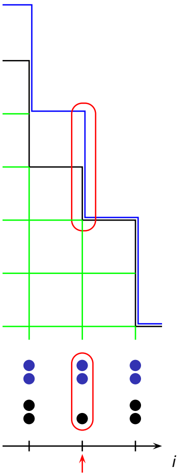

Growth on the right:
rate≤rate
with rate-rate:

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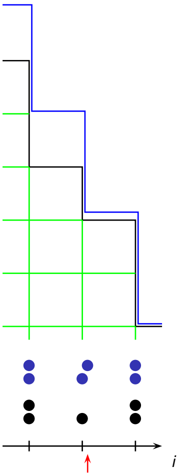

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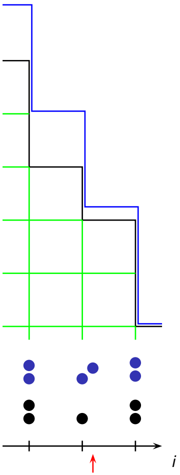

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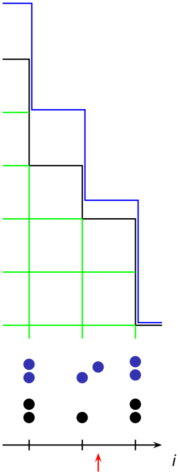

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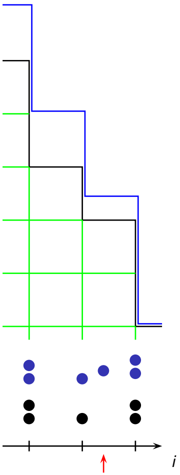

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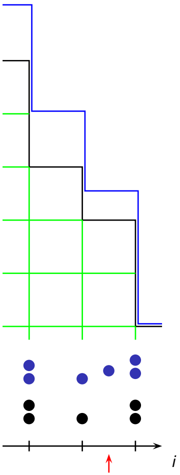

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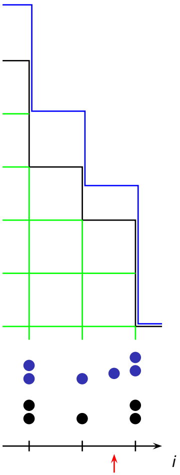

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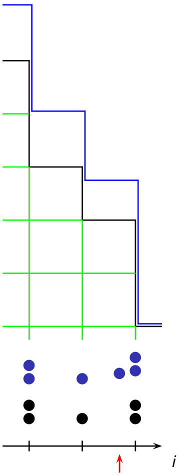

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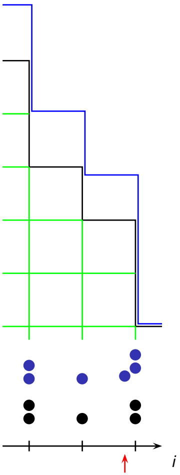

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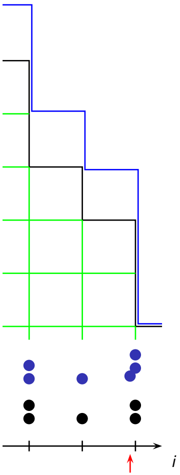

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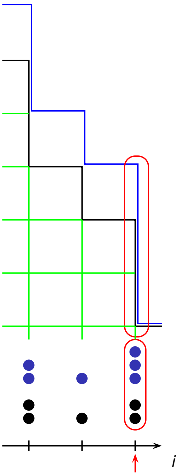

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The second class particle

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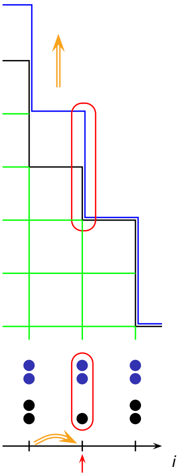

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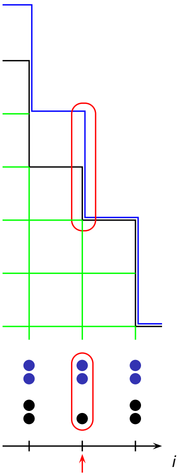
with rate:



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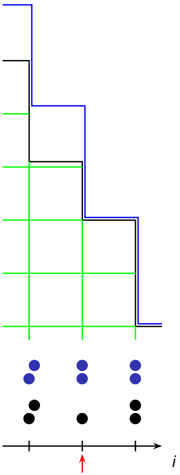

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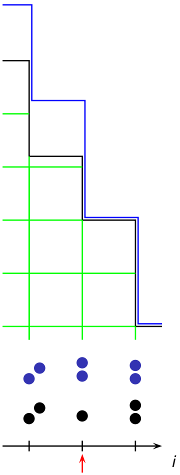

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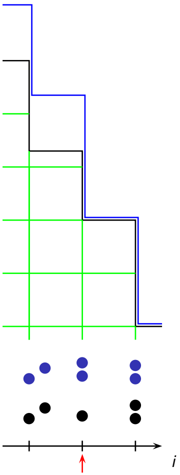

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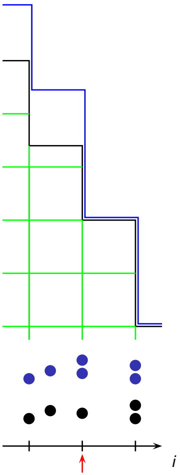

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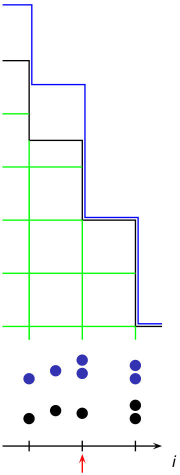

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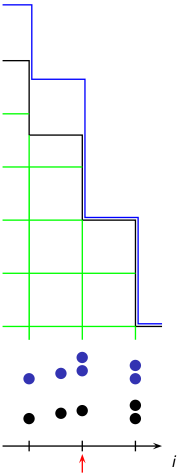

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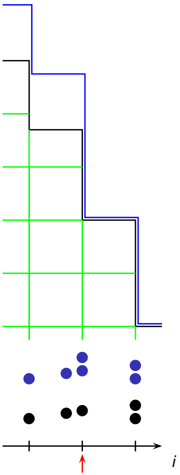

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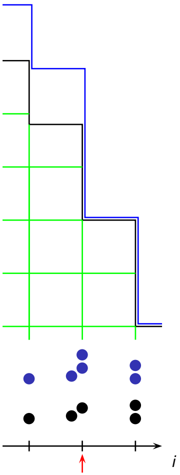

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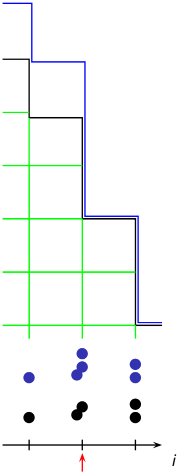

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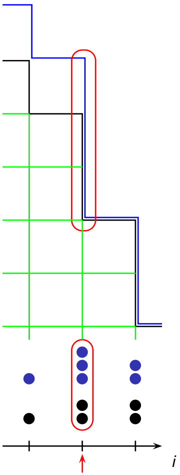

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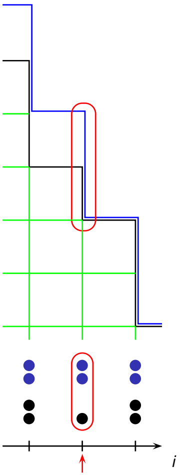

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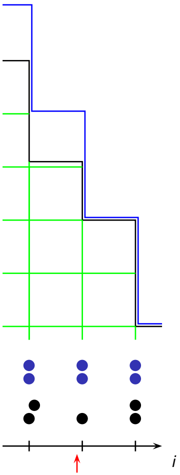

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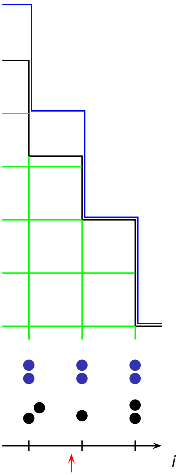

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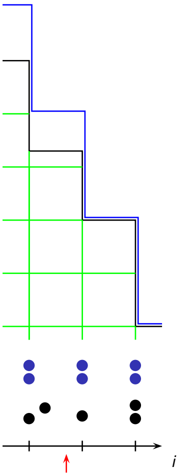

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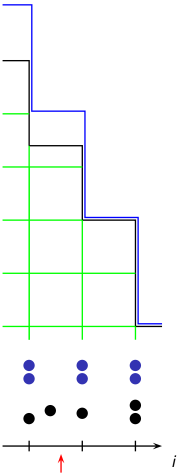

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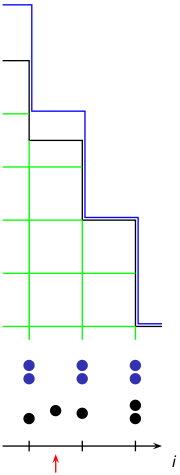

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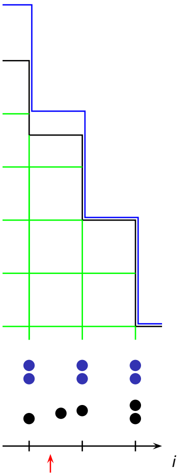

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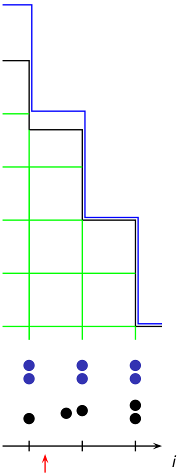

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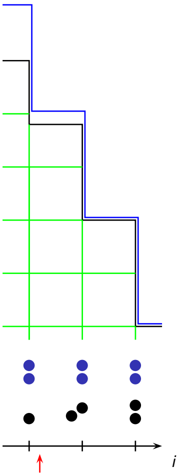

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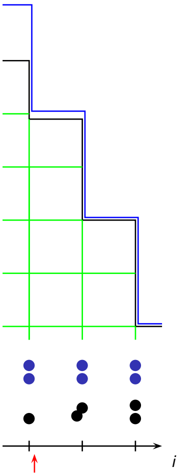

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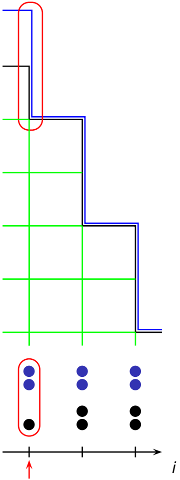

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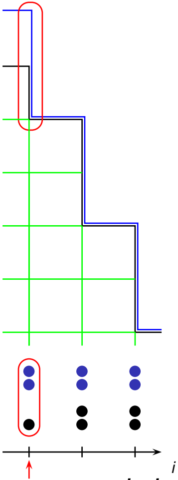

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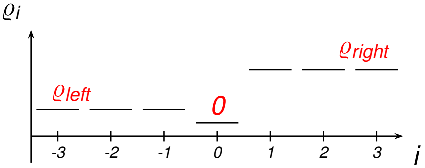
A single discrepancy ↑, the *second class particle*, is conserved.

Earlier results: as seen by the second class particle

Theorem (Derrida, Lebowitz, Speer '97)

For the ASEP, the Bernoulli product distribution with densities



is stationary for the process, as seen from the second class particle, if

$$\frac{\varrho_{right}\cdot(1-\varrho_{left})}{\varrho_{left}\cdot(1-\varrho_{right})}=\frac{p}{q}.$$

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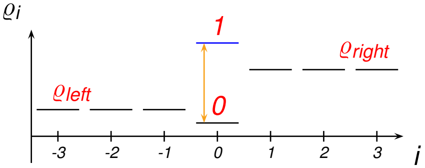


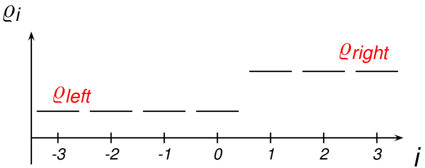
is stationary for the process, as seen from the second class particle, if

$$\frac{\varrho_{right} \cdot (1 - \varrho_{left})}{\varrho_{left} \cdot (1 - \varrho_{right})} = \frac{p}{q}.$$

Earlier results: random walking shocks

Theorem (Belitsky and Schütz '02)

For the ASEP with the very same parameters, the Bernoulli product distribution μ_0 *with densities*



evolves according to

$$\frac{\mathrm{d}}{\mathrm{d}t}\mu_0 = p \cdot \frac{\varrho_{left}}{\varrho_{right}} \cdot [\mu_{-1} - \mu_0] + q \cdot \frac{\varrho_{right}}{\varrho_{left}} \cdot [\mu_1 - \mu_0].$$

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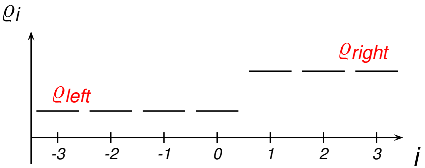

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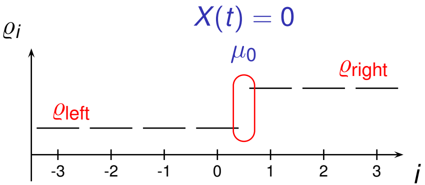
Multiple shocks and their interactions are also handled.

Earlier results: random walking shocks

Interpretation: random walking shock $\mu(t) = \mu_{X(t)}$:

with rate $p \cdot \frac{\varrho_{\text{left}}}{\varrho_{\text{right}}}$:



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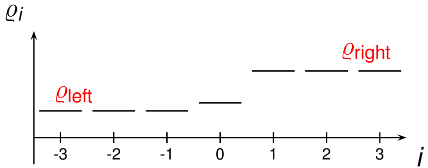

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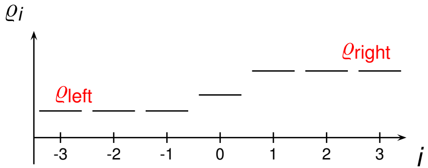

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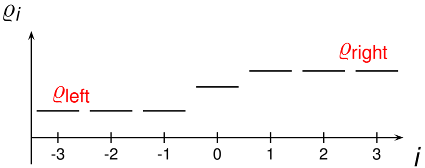

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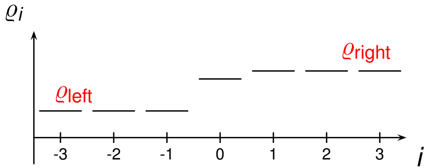

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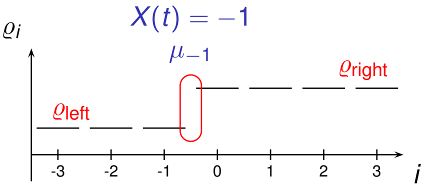

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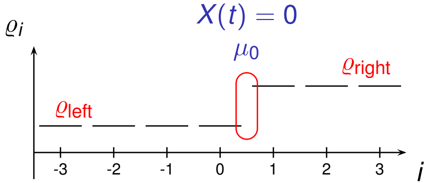

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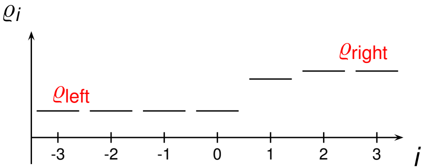

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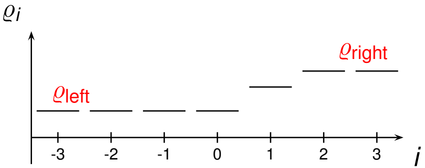

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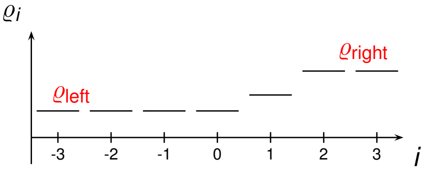

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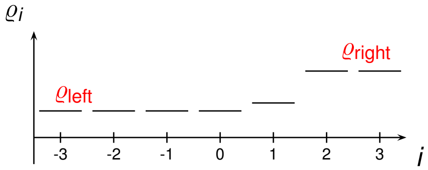

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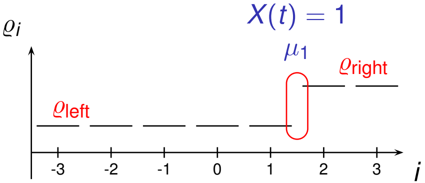

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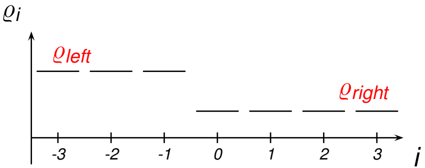
Theorem (B. '01)

For the TAEBLP, the product distribution of marginals μ^{ϱ_i} *with densities*



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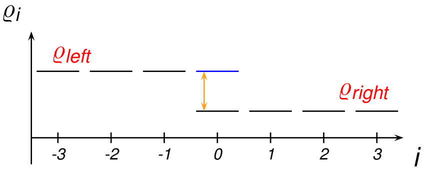

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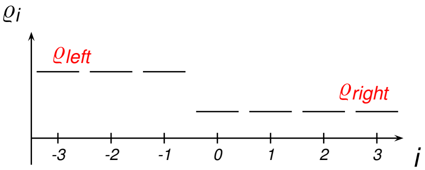

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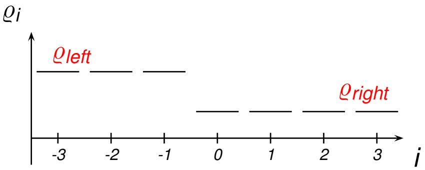

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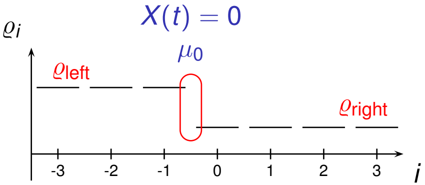

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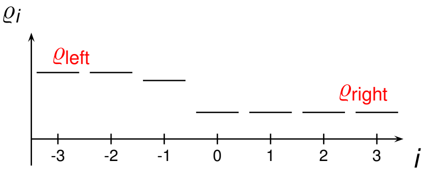

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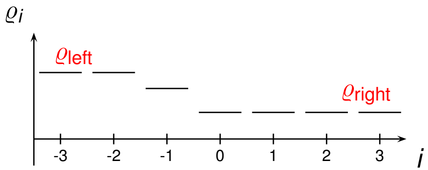

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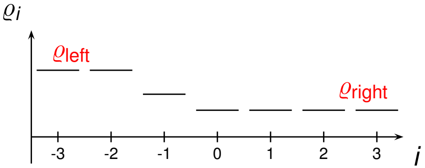

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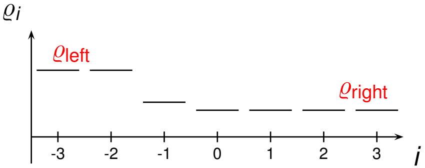

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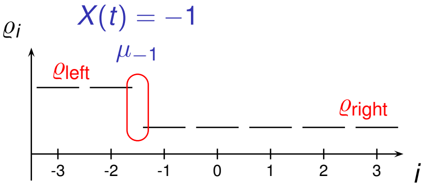

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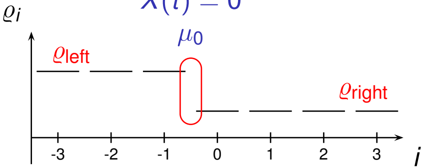

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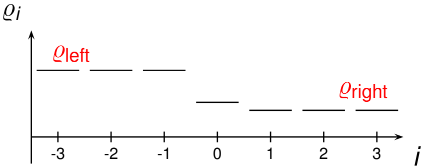

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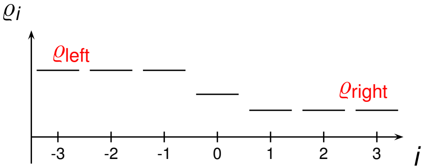

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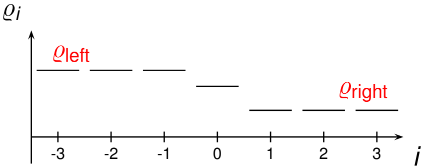

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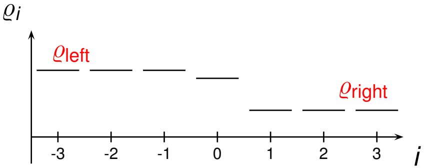

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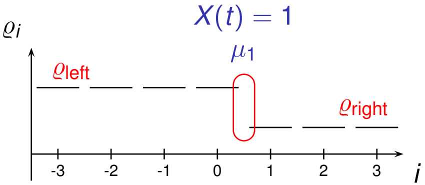

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Is it the second class particle that performs the simple random walk in the middle of a shock?

In what sense? Annealed w.r.t. the initial shock distribution... But what does this mean?

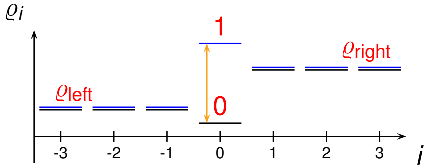
Here is the question:

For the ASEP, let ν_0 be the Bernoulli product distribution

$$\nu_0 = \Big(\bigotimes_{i<0} \mu^{\varrho_{\text{left}}}\Big) \otimes \big(\delta\big) \otimes \Big(\bigotimes_{i>0} \mu^{\varrho_{\text{right}}}\Big),$$

where

$$\mu^{\varrho}(\omega = \omega) = \begin{cases} \varrho, & \text{if } \omega = 1, \\ 1 - \varrho, & \text{if } \omega = 0; \end{cases} \qquad \delta(0,\, 1) = 1.$$



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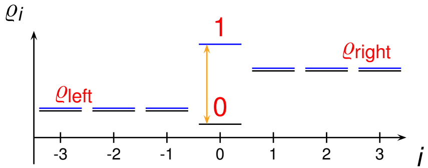

Does it satisfy

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when

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$$\mu^{\varrho}(\omega = \omega) = \frac{e^{\theta(\varrho)\cdot\omega}}{r!(\omega)} \cdot \frac{1}{Z(\theta(\varrho))};$$

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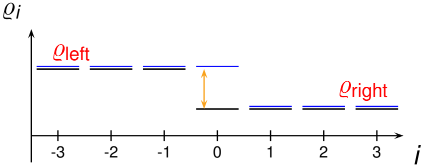

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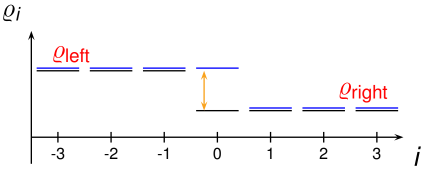

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Theorem (Gy. Farkas, P. Kovács, A. Rákos, B. '10)

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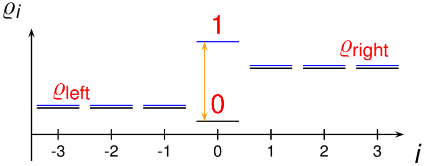
The presence of a second class particle in the measure significantly simplifies the computations. $\rightsquigarrow$ This is how we discovered the TAGEZRP.

Why do we like...

- ASEP: Fundamental example, nice combinatorics, unique second class particle.



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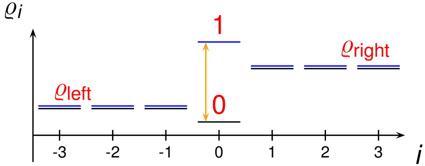
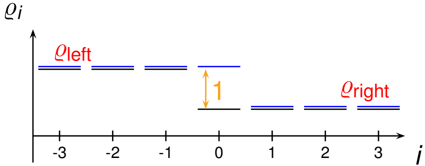


- EBLP, TAGEZRP: Nice convex rates; $\omega \sim \mu^{\varrho} \Rightarrow \omega + 1 \sim \mu^{\varrho+1}$.



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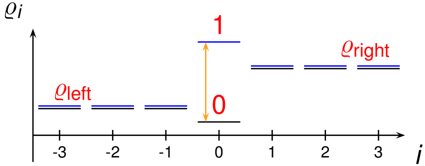

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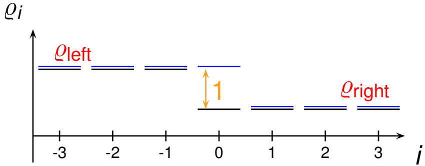

- TA$\mathfrak{q}$-ZRP: Nice concave rates; *Bethe Ansatz, exact solvability. . . ?*

The story of a search

The ZRP family is simple enough that we can feed it into the

Big RandomWalkingShocksMachine.

Here's what comes out (L. Duffy, D. Pantelli, B. '18).

- AZRP with linear rates, $r(\omega) = \omega$, no shock ($\varrho_{\text{left}} = \varrho_{\text{right}}$).
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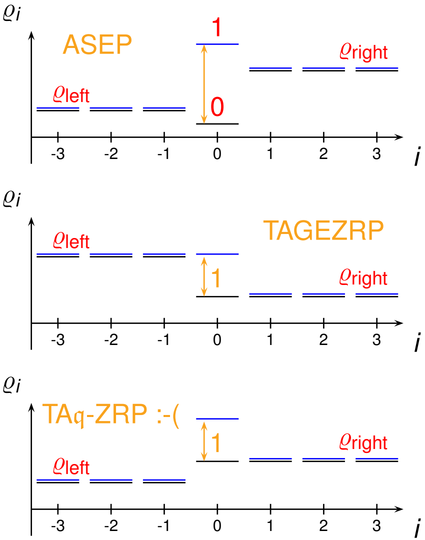
- In fact, $r(\omega) = \mathrm{e}^{\beta\omega} + \text{const}$. When const $= -1$, TAEZRP.
- Surprise: TA$\mathfrak{q}$-ZRP; $r(\omega) = 1 - \mathfrak{q}^{\omega}$.

TAq-ZRP



Impossible to find this without the second class particle.

Interactions:

We also see that shocks+second class particles

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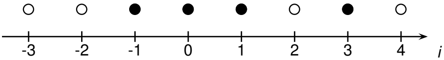
- It's a mess for TA$\mathfrak{q}$-ZRP. Shocks+second class particles locally interact *and* their jump rates depend on ranks,
- we could only verify Rankine-Hugoniot for two shocks.

Boundaries for the finite-volume case

Liggett's condition (Liggett '75):

ASEP: $\overset{p}{\curvearrowright}$ $\overset{q}{\curvearrowleft}$ i.i.d. Bernoulli(ϱ)



Boundaries for the finite-volume case

Liggett's condition (Liggett '75):

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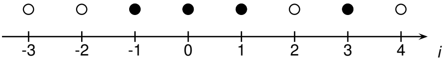

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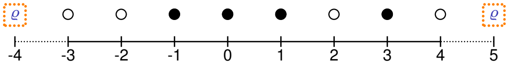

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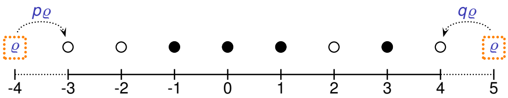

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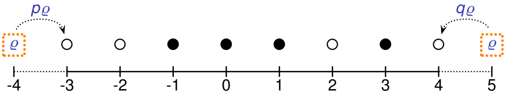

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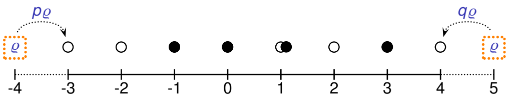

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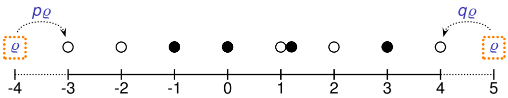

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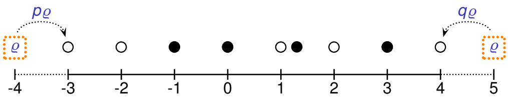

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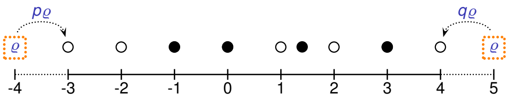

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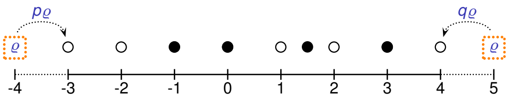

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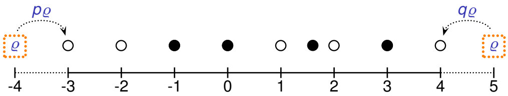

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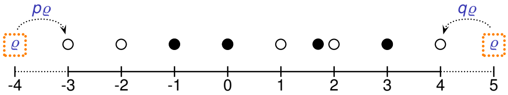

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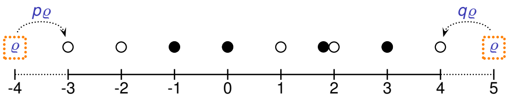

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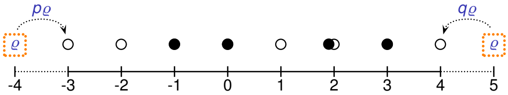

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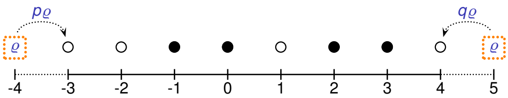

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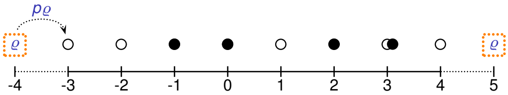

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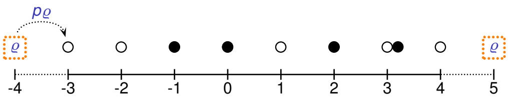

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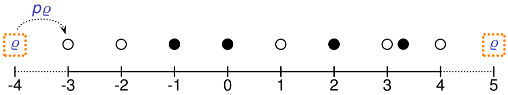

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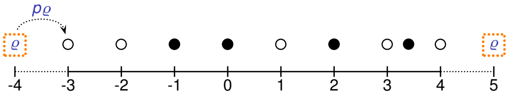

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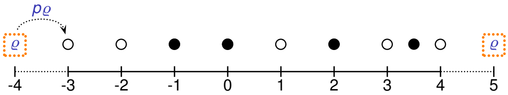

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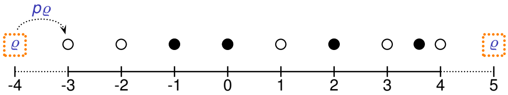

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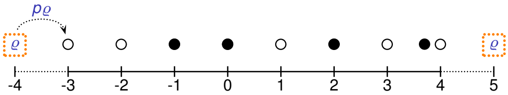

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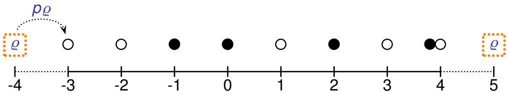

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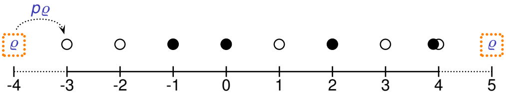

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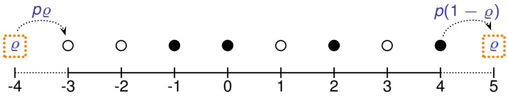

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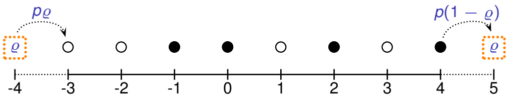

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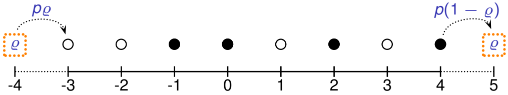

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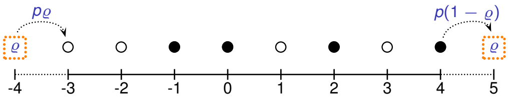

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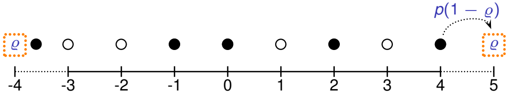

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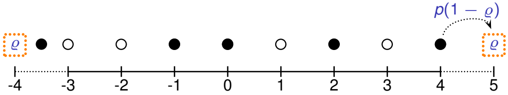

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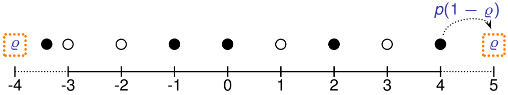

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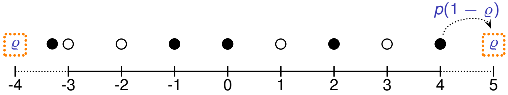

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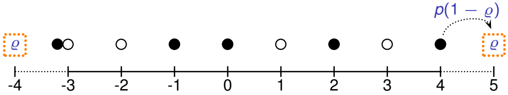

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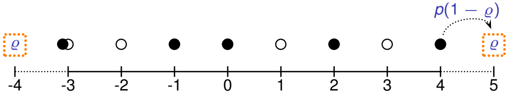

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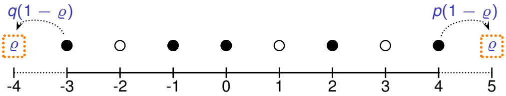

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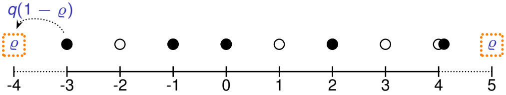

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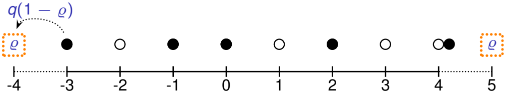

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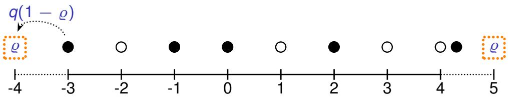

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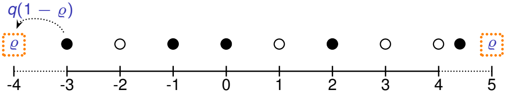

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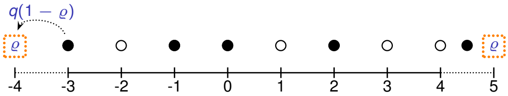

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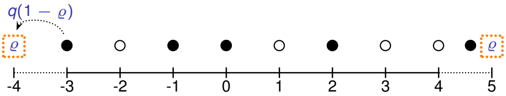

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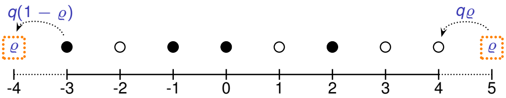

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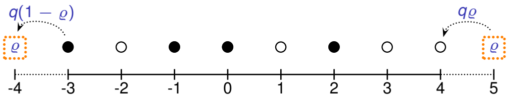

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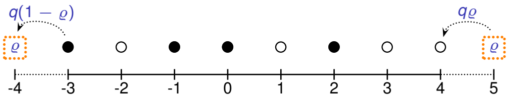

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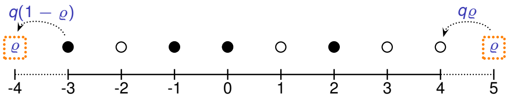

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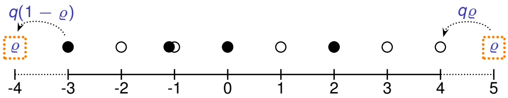

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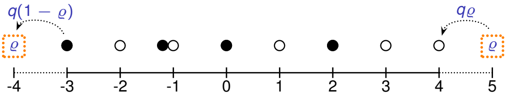

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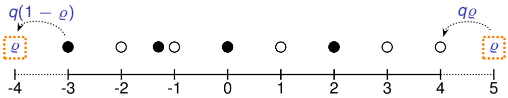

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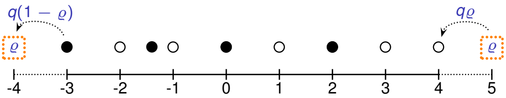

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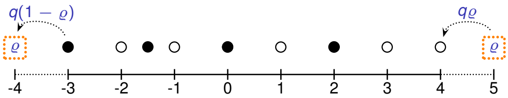

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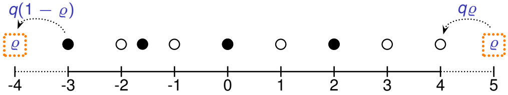

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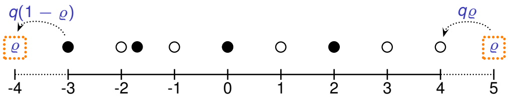

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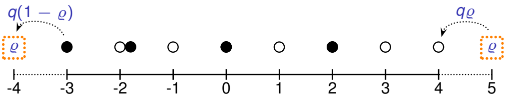

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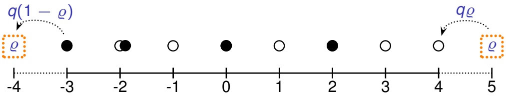

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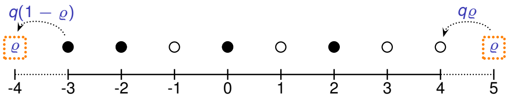

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Thank you.

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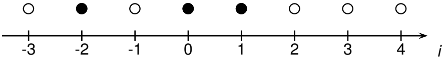

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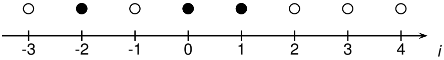

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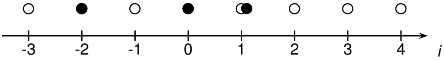

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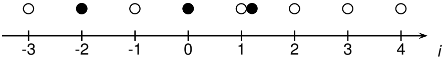

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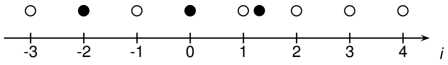

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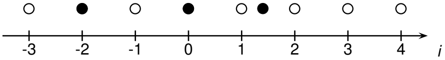

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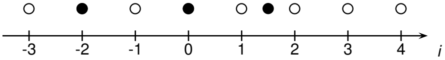

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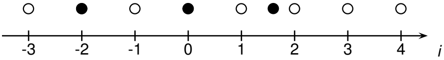

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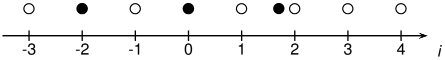

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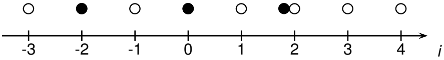

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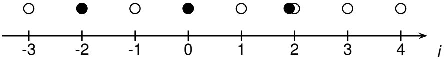

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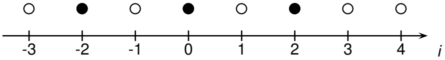

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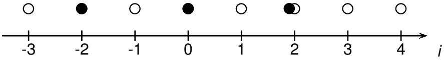

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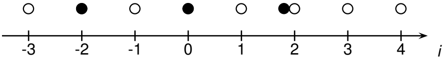

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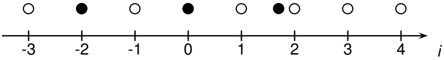

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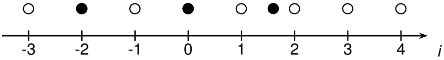

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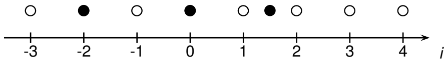

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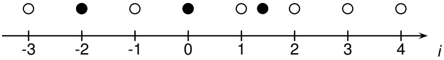

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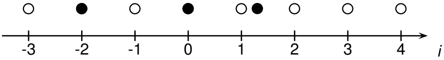

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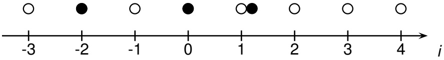

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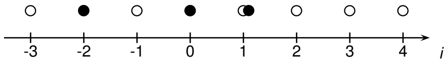

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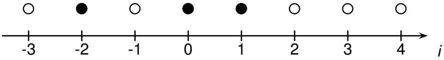

With rate c_r: coalescence to the right

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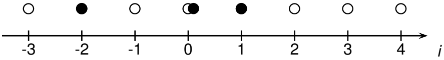

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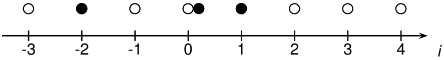

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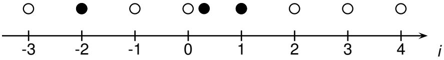

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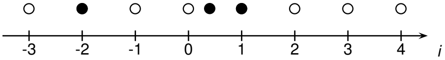

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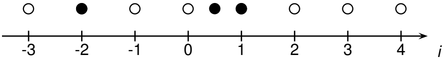

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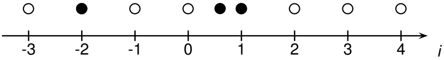

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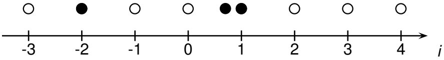

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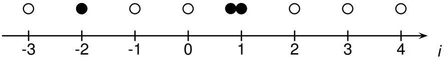

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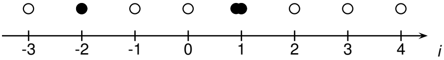

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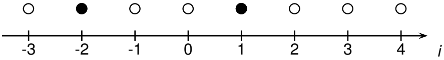
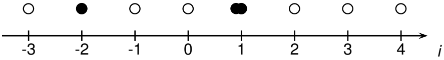


With rate b_l: branching to the left

A similar result: branching coalescing random walk



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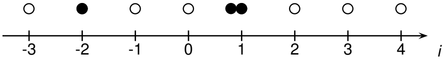
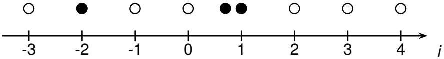


With rate b_l: branching to the left

A similar result: branching coalescing random walk



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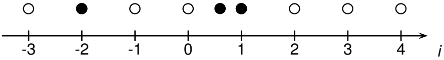
A similar result: branching coalescing random walk



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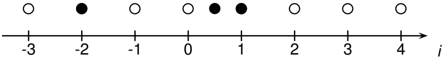

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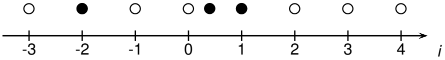

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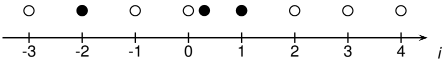

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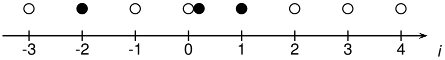

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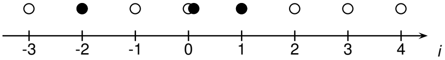

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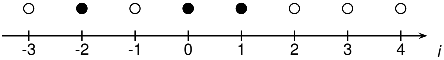

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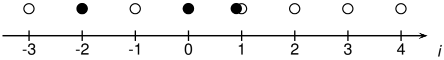

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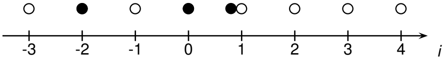

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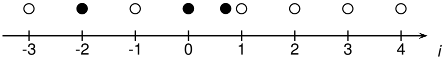

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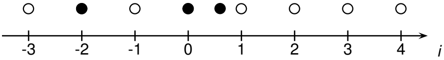

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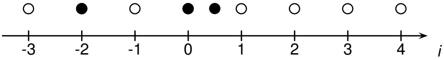

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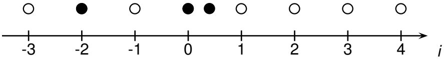

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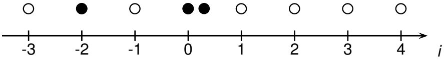

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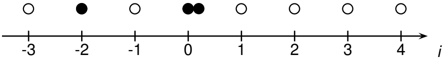

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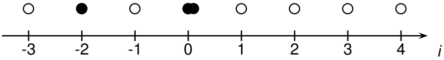

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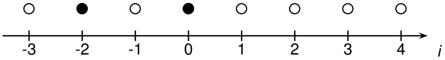
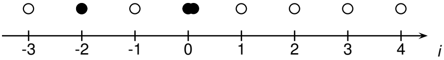


With rate b_r: branching to the right

A similar result: branching coalescing random walk



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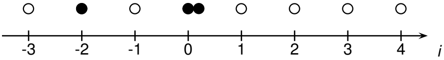
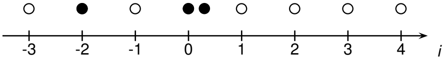
A similar result: branching coalescing random walk



With rate b_r: branching to the right

A similar result: branching coalescing random walk



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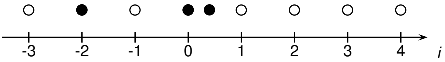

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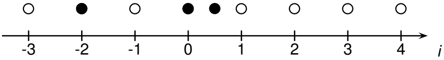

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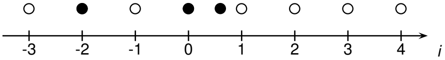

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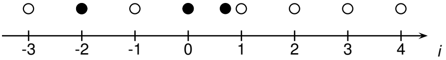

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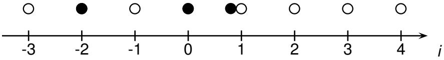

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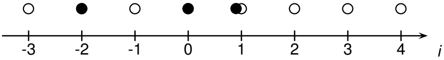

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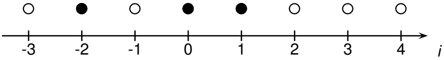

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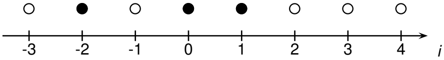


With rate b_r: branching to the right

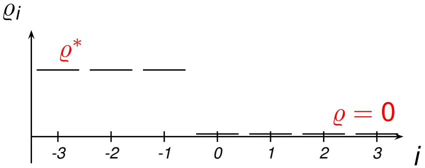
The Bernoulli(ϱ^*) distribution is stationary for

$$\varrho^* = \frac{b_l + b_r}{b_l + b_r + c_l + c_r}.$$

Earlier results: as seen by the rightmost particle

Theorem

For the BCRW, the Bernoulli product distribution with densities

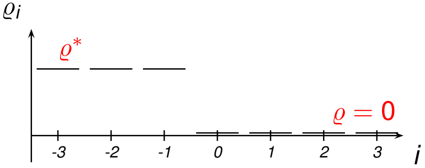


is stationary for the process, as seen from the *rightmost particle*.

Earlier results: random walking shocks

Theorem (Krebs, Jafarpour and Schütz '03)

For the BCRW with the very same parameters, the Bernoulli product distribution μ_0 *with densities*



evolves according to

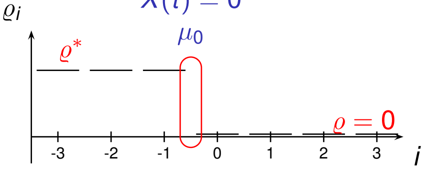
$$\frac{\mathrm{d}}{\mathrm{d}t}\mu_0 = \frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r} \cdot [\mu_{-1} - \mu_0]$$
$$+ p \cdot \frac{b_l + b_r + c_l + c_r}{c_l + c_r} \cdot [\mu_1 - \mu_0].$$

Earlier results: random walking shocks

Interpretation: random walking shock $\mu(t) = \mu_{X(t)}$:

with rate $\frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r}$:

$X(t) = 0$



$$\frac{\mathrm{d}}{\mathrm{d}t}\mu_0 = \frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r} \cdot [\mu_{-1} - \mu_0] + p \cdot \frac{b_l + b_r + c_l + c_r}{c_l + c_r} \cdot [\mu_1 - \mu_0].$$

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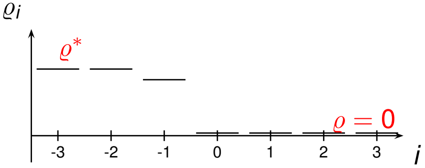

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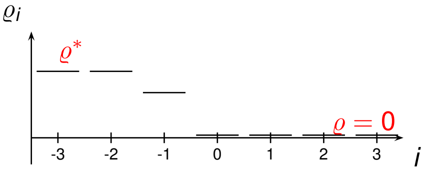

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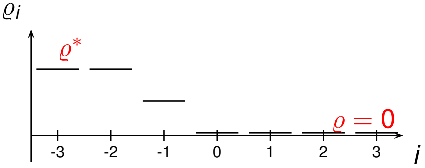

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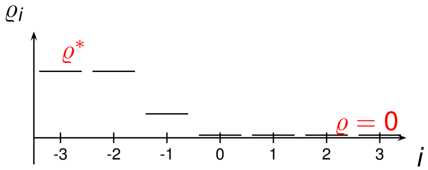

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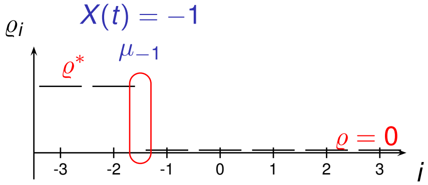

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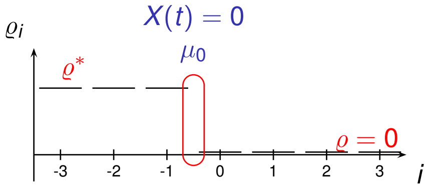

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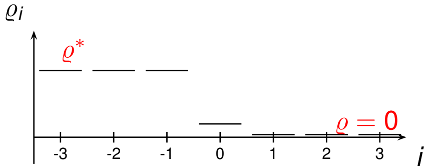

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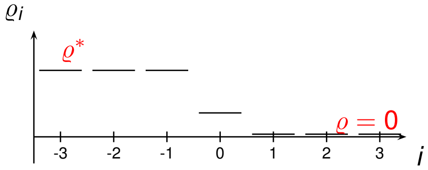

$$\frac{\mathrm{d}}{\mathrm{d}t}\mu_0 = \frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r} \cdot [\mu_{-1} - \mu_0]$$

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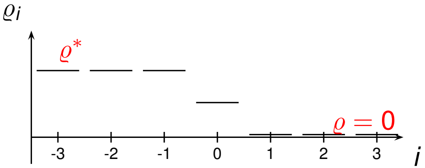

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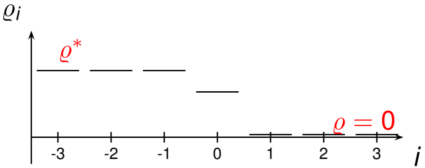


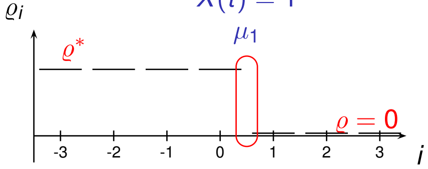
$$\frac{\mathrm{d}}{\mathrm{d}t}\mu_0 = \frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r} \cdot [\mu_{-1} - \mu_0] + p \cdot \frac{b_l + b_r + c_l + c_r}{c_l + c_r} \cdot [\mu_1 - \mu_0].$$

Earlier results: random walking shocks

Interpretation: random walking shock $\mu(t) = \mu_{X(t)}$:

with rate $p \cdot \frac{b_l+b_r+c_l+c_r}{c_l+c_r}$:

$X(t) = 1$



$$\frac{\mathrm{d}}{\mathrm{d}t}\mu_0 = \frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r} \cdot [\mu_{-1} - \mu_0] + p \cdot \frac{b_l + b_r + c_l + c_r}{c_l + c_r} \cdot [\mu_1 - \mu_0].$$

The question:

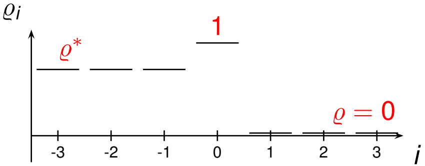
Is it the rightmost particle that performs the random walk?

Here is the question:

For the BCRW, let ν_0 be the Bernoulli product distribution

$$\nu_0 = \Big(\bigotimes_{i<0} \mu^{\varrho^*}\Big) \otimes \big(\delta\big) \otimes \Big(\bigotimes_{i>0} \mu^{0}\Big),$$

where $\delta(0) = 1$.



Does it satisfy

$$\frac{\mathrm{d}}{\mathrm{d}t}\nu_0 = \frac{c_l \cdot (b_l + b_r) + q \cdot (c_l + c_r)}{b_l + b_r + c_l + c_r} \cdot [\nu_{-1} - \nu_0] + p \cdot \frac{b_l + b_r + c_l + c_r}{c_l + c_r} \cdot [\nu_1 - \nu_0]?$$

The answer

- ... is, of course, yes again. [Gy. Farkas, P. Kovács, A. Rákos, B. '10]

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- Fronts of the other direction: $0 - 1 - \varrho^*$ can also be handled.

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Thank you.