



The Abdus Salam  
International Centre for Theoretical Physics



2265-15

**Advanced School on Understanding and Prediction of Earthquakes and  
other Extreme Events in Complex Systems**

*26 September - 8 October, 2011*

**Early Warning Signals  
and Binary Classifications  
of Historical Paths**

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Austria*

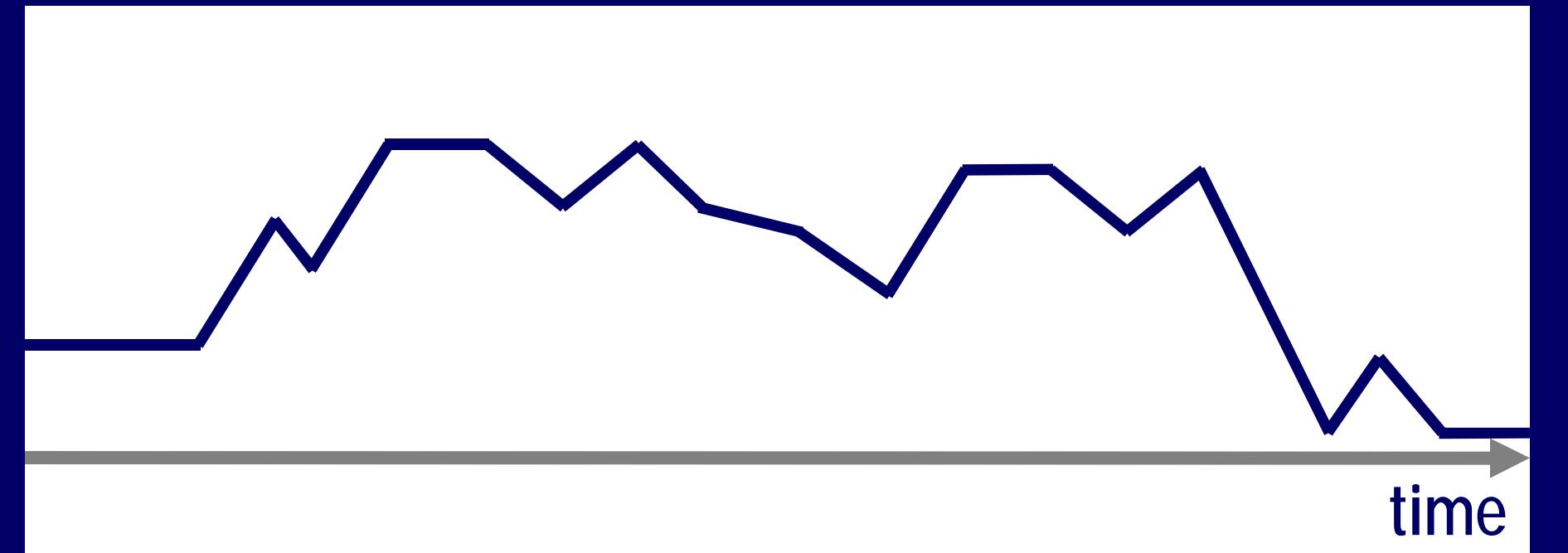
Arkady Kryazhimskiy

# Early Warning Signals and Binary Classifications of Historical Paths

Trieste, October 4, 2011

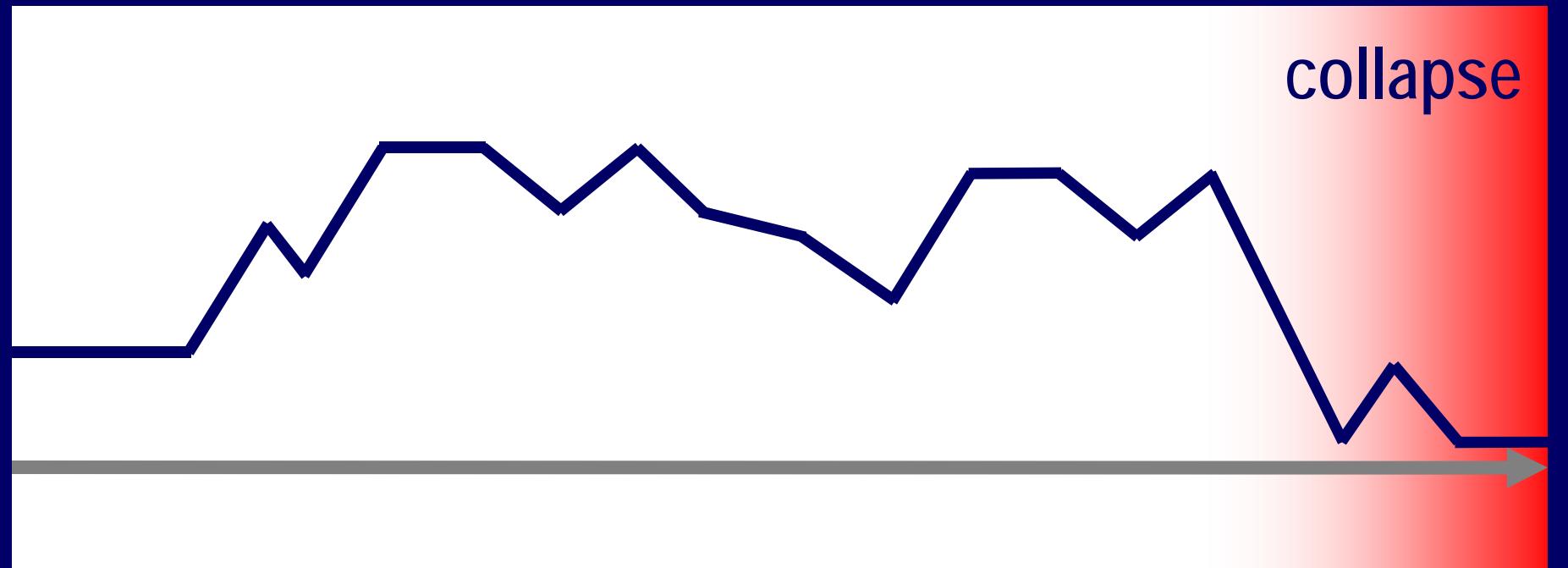
# Recognition

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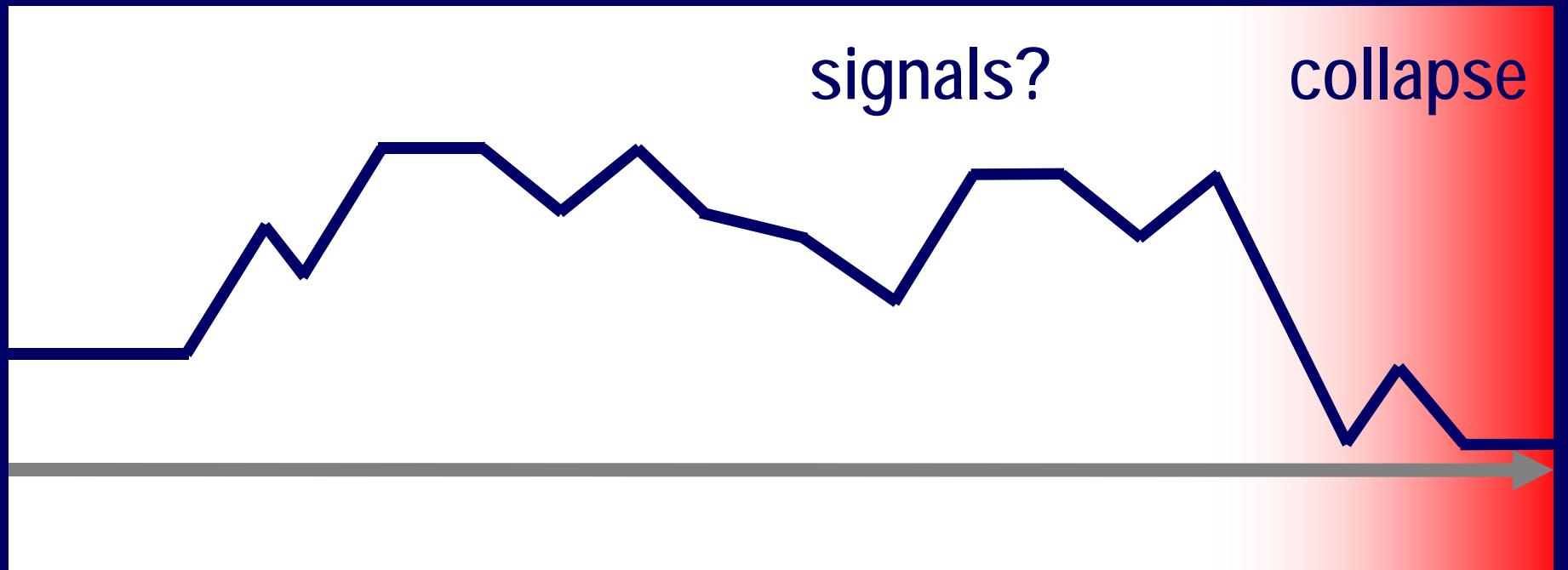
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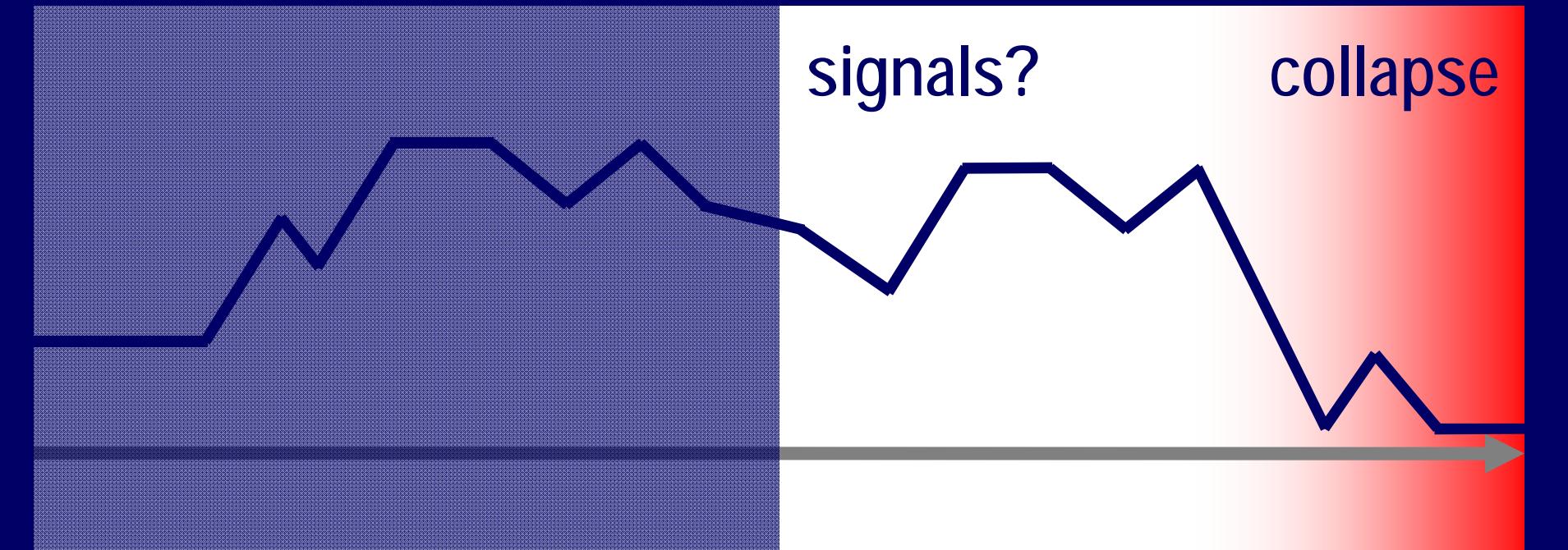
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signals?

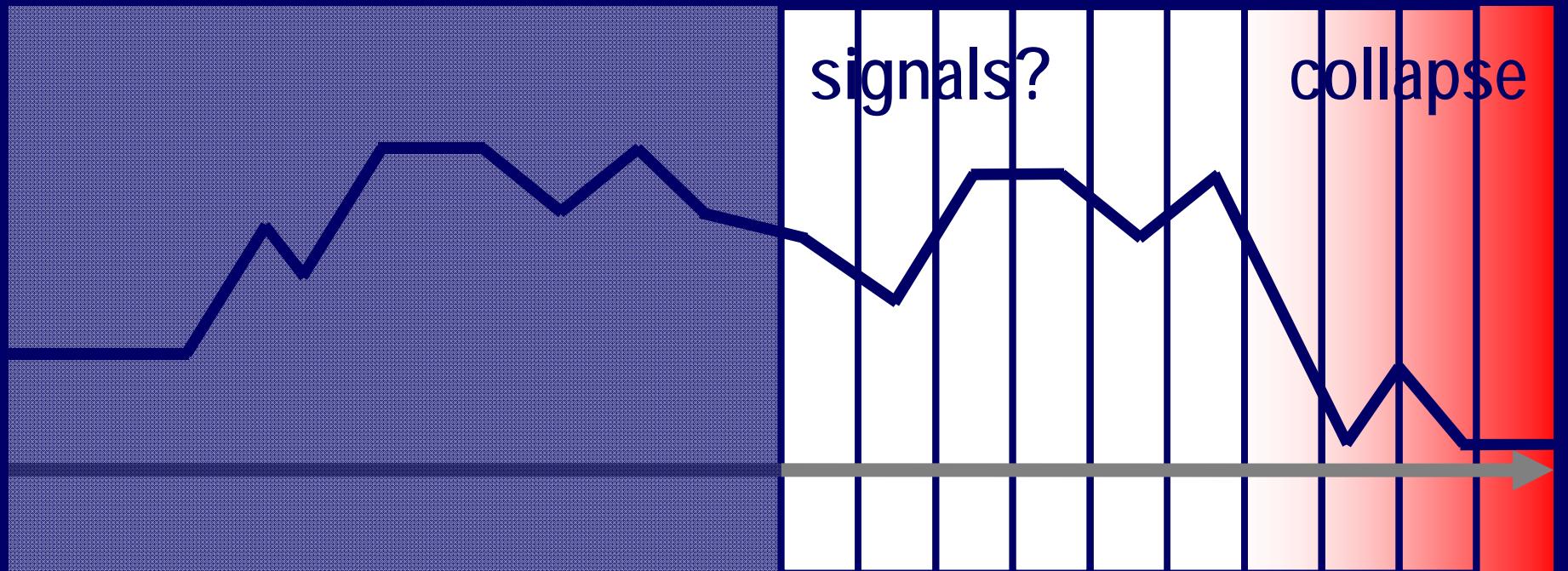
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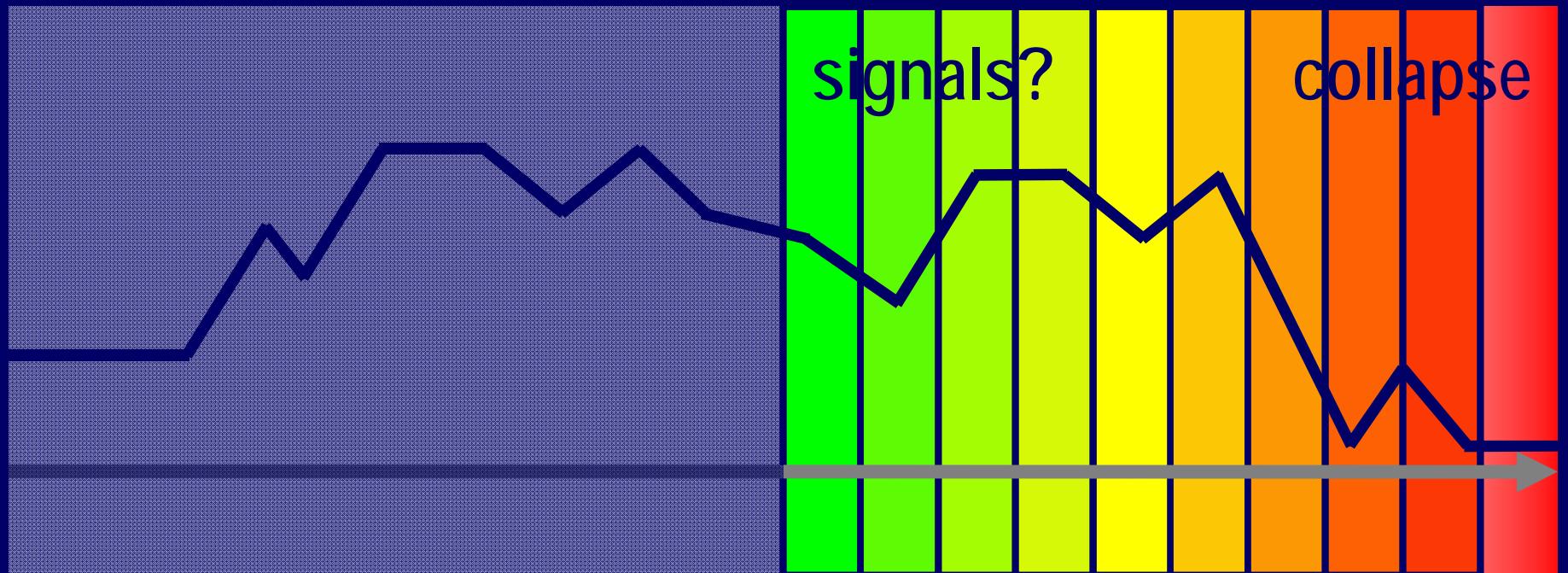
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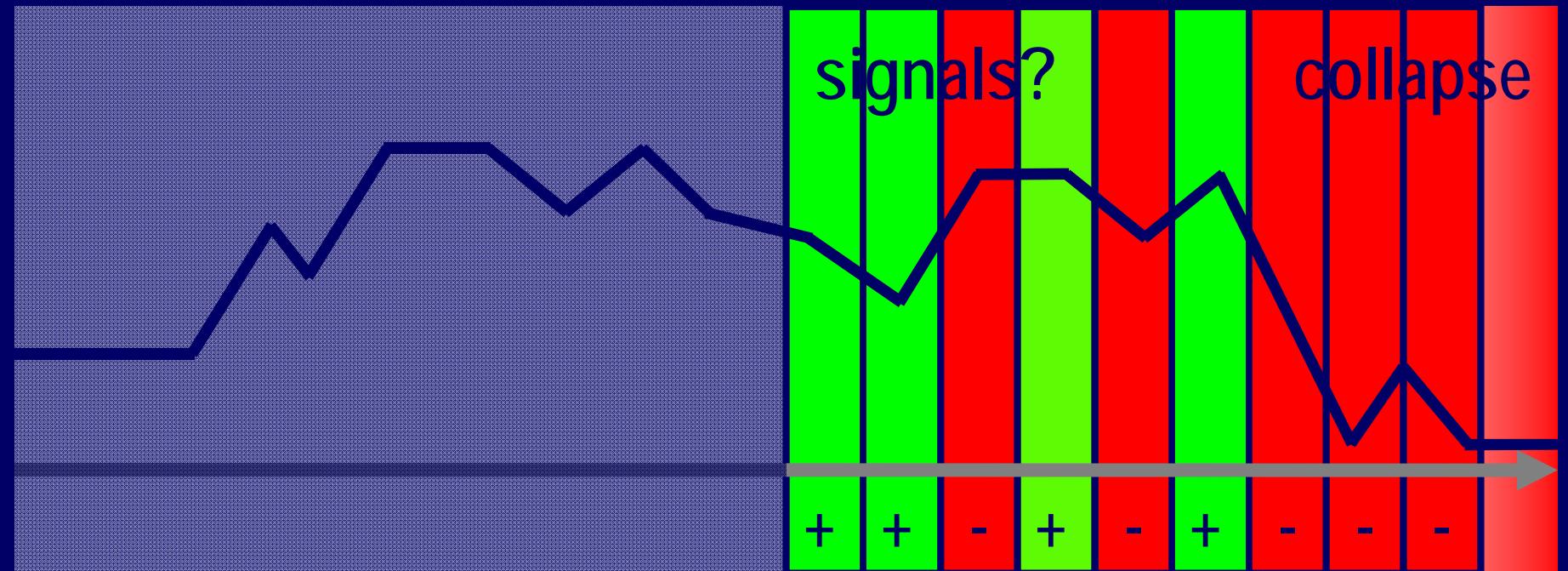
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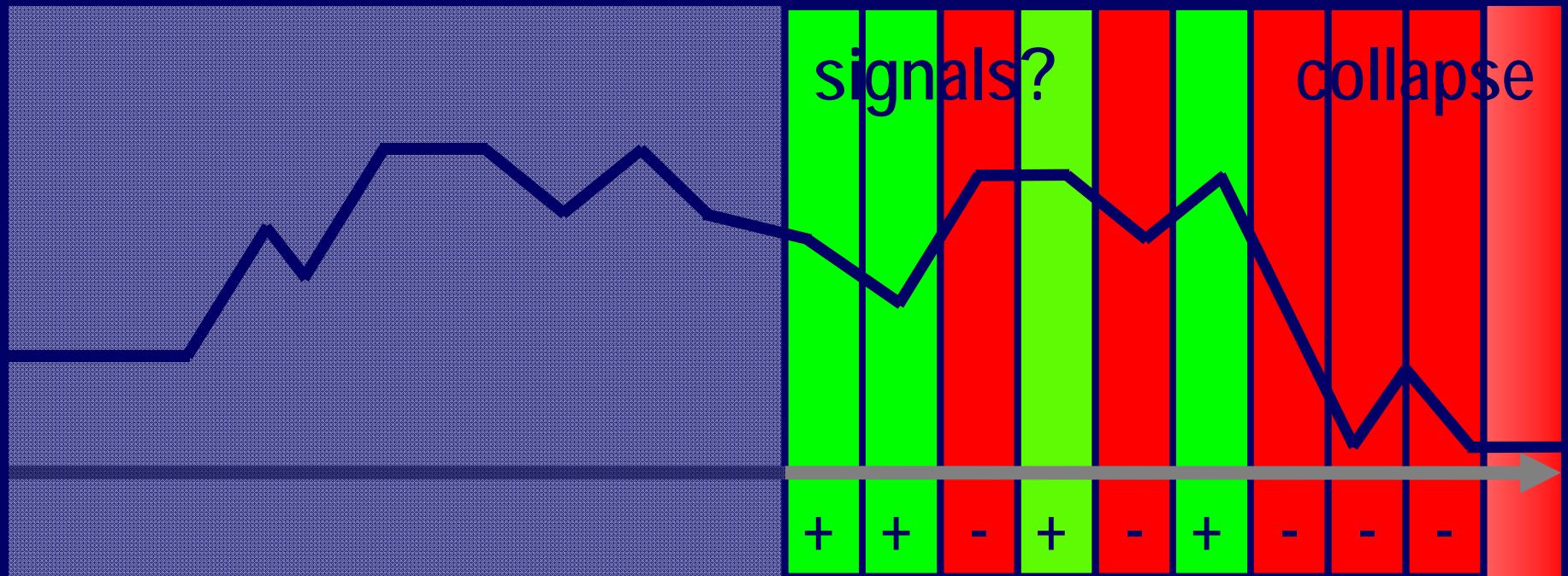
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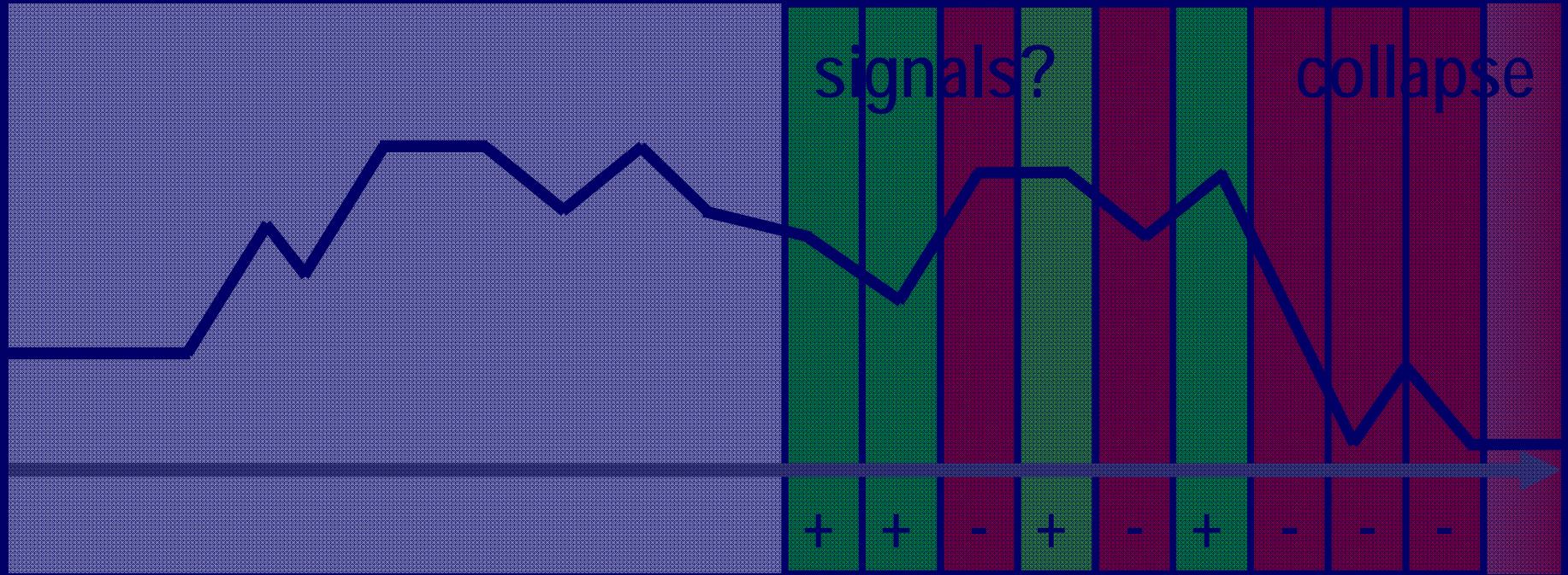


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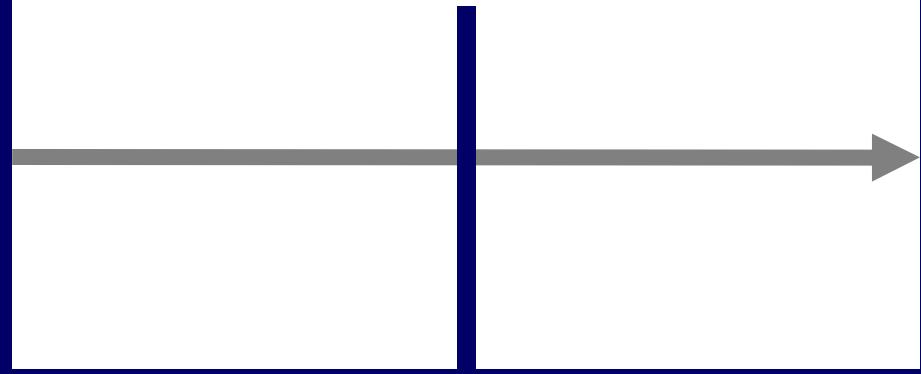


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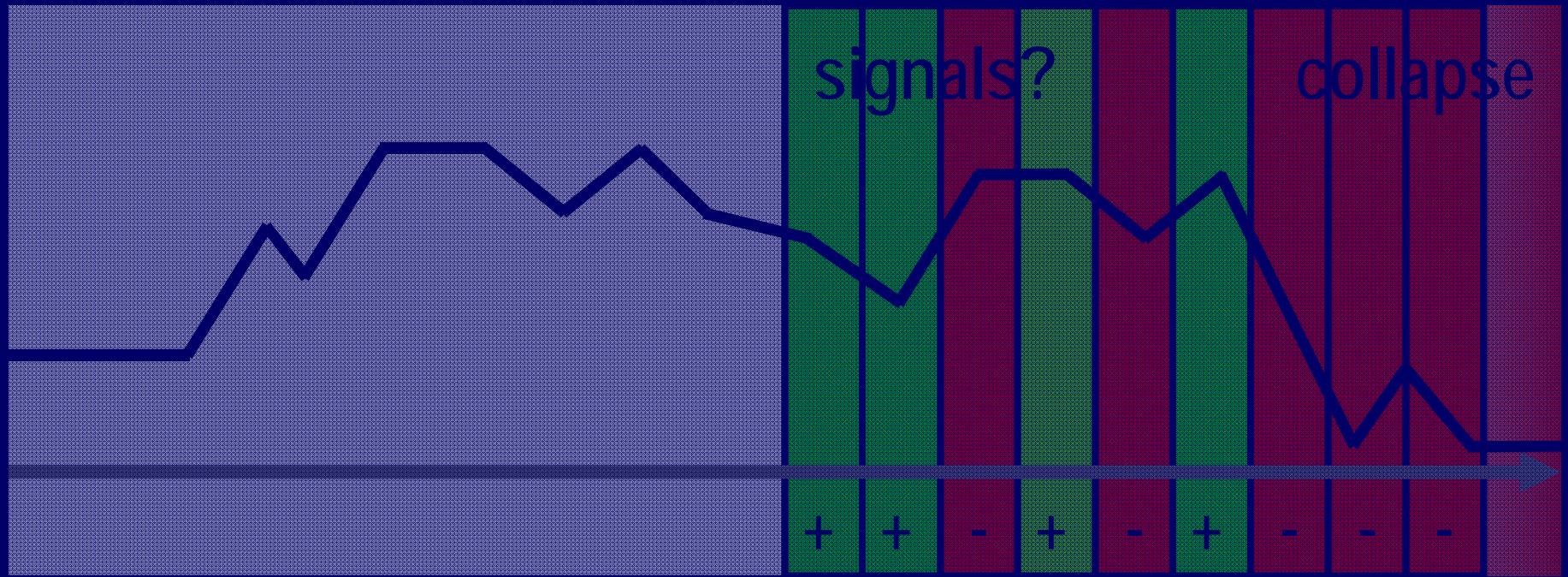
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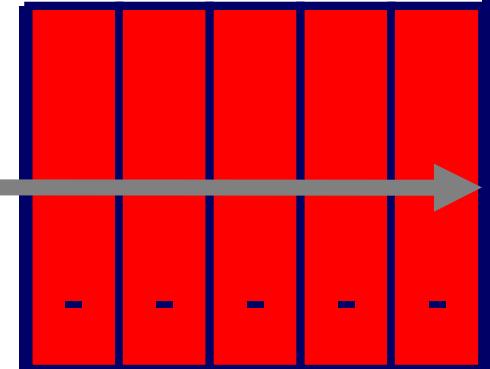
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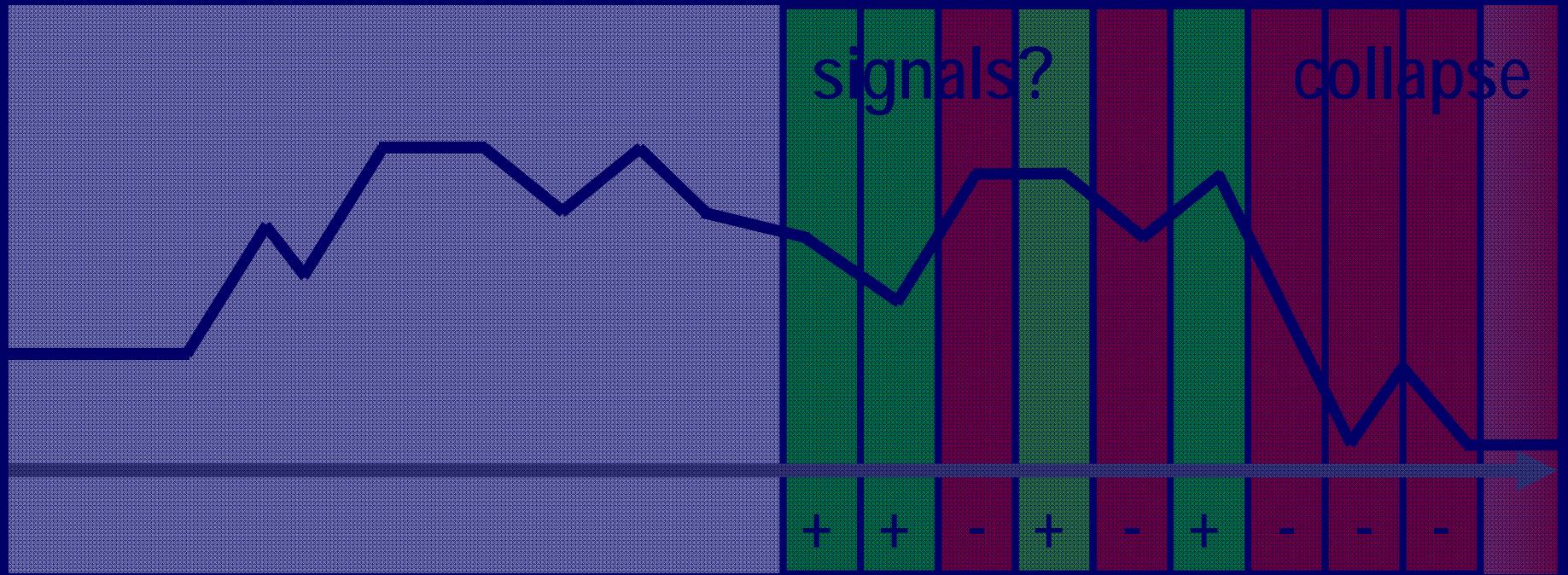
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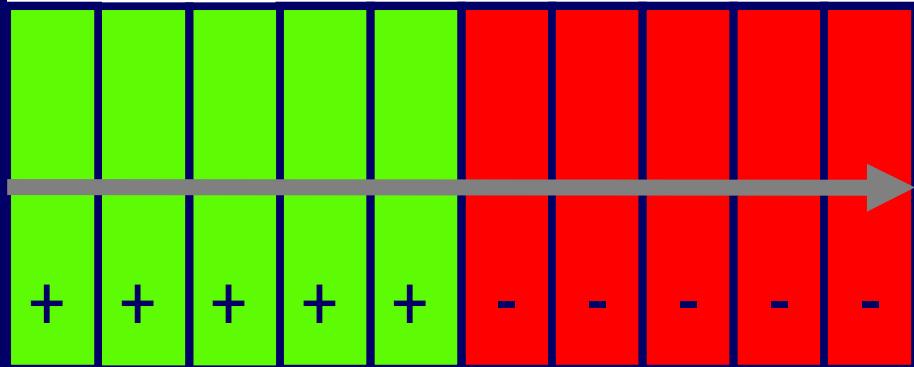
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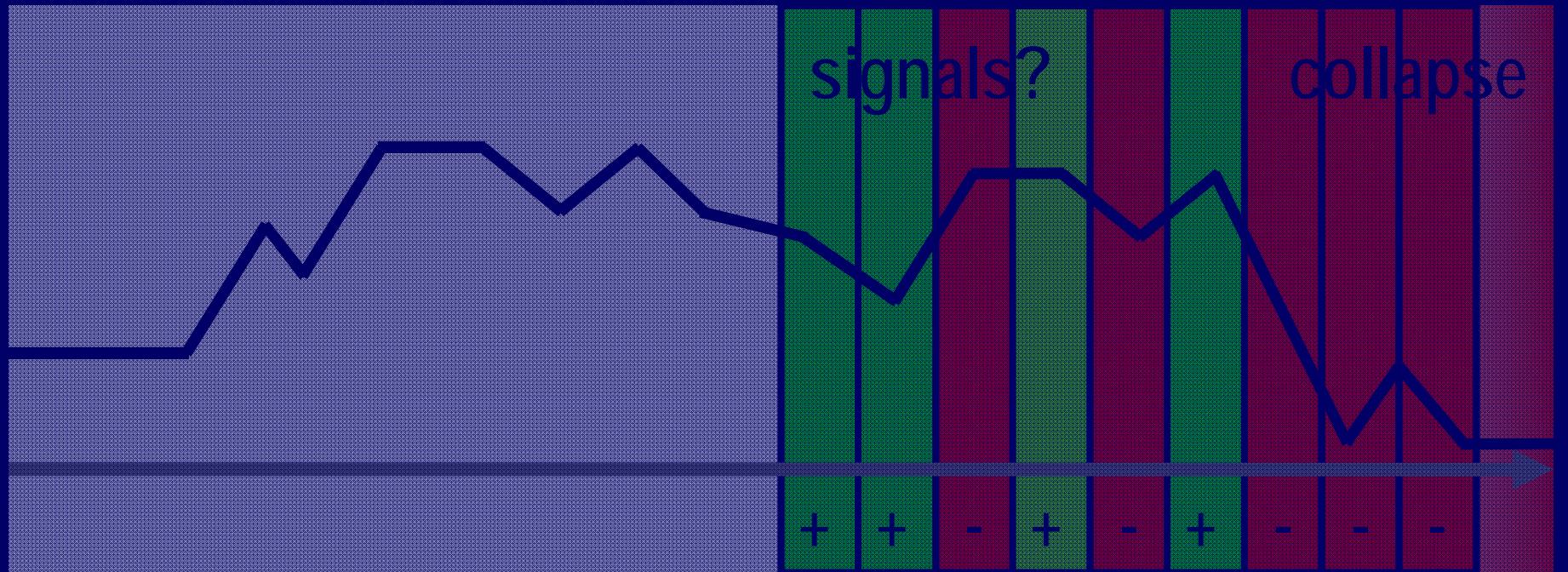
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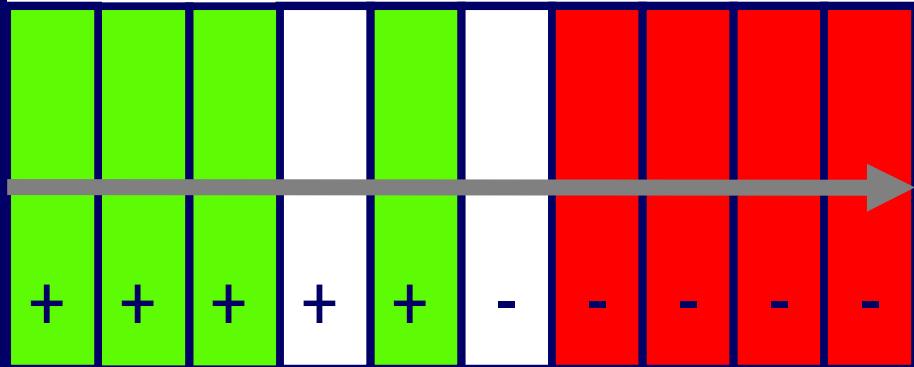
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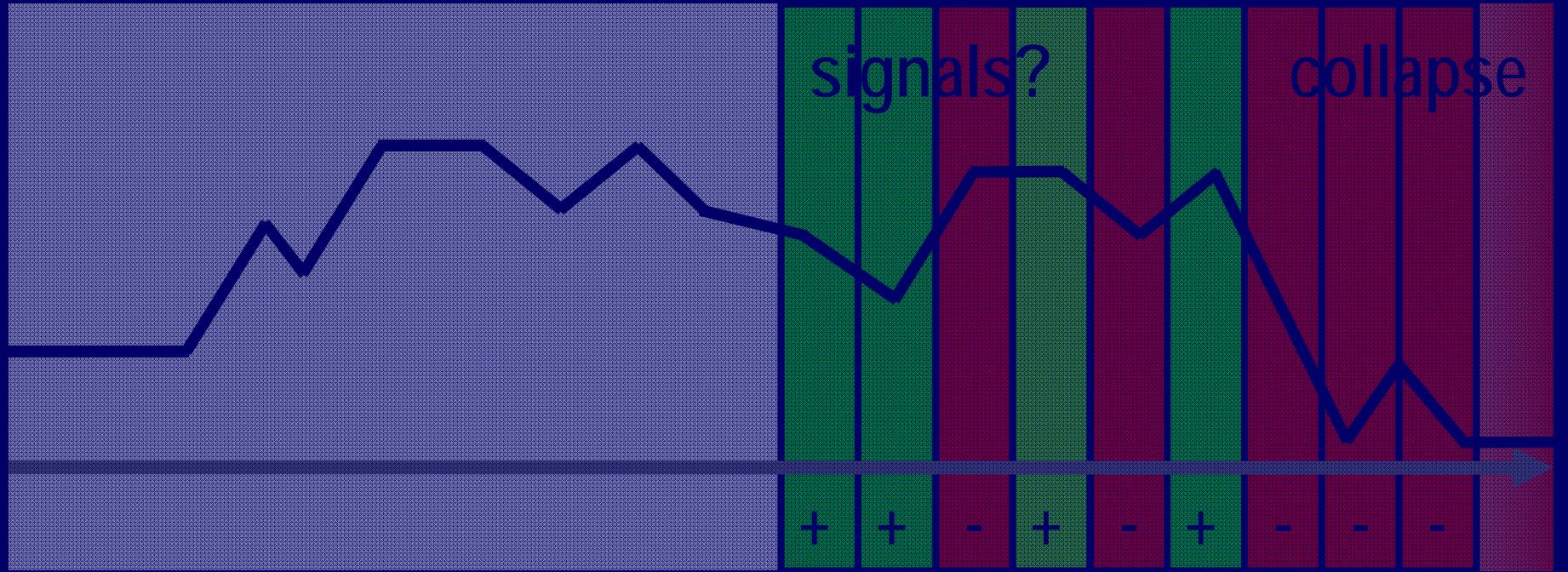
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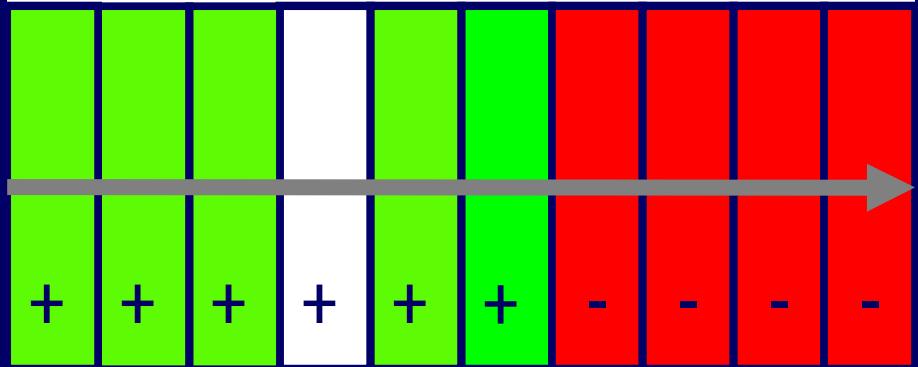
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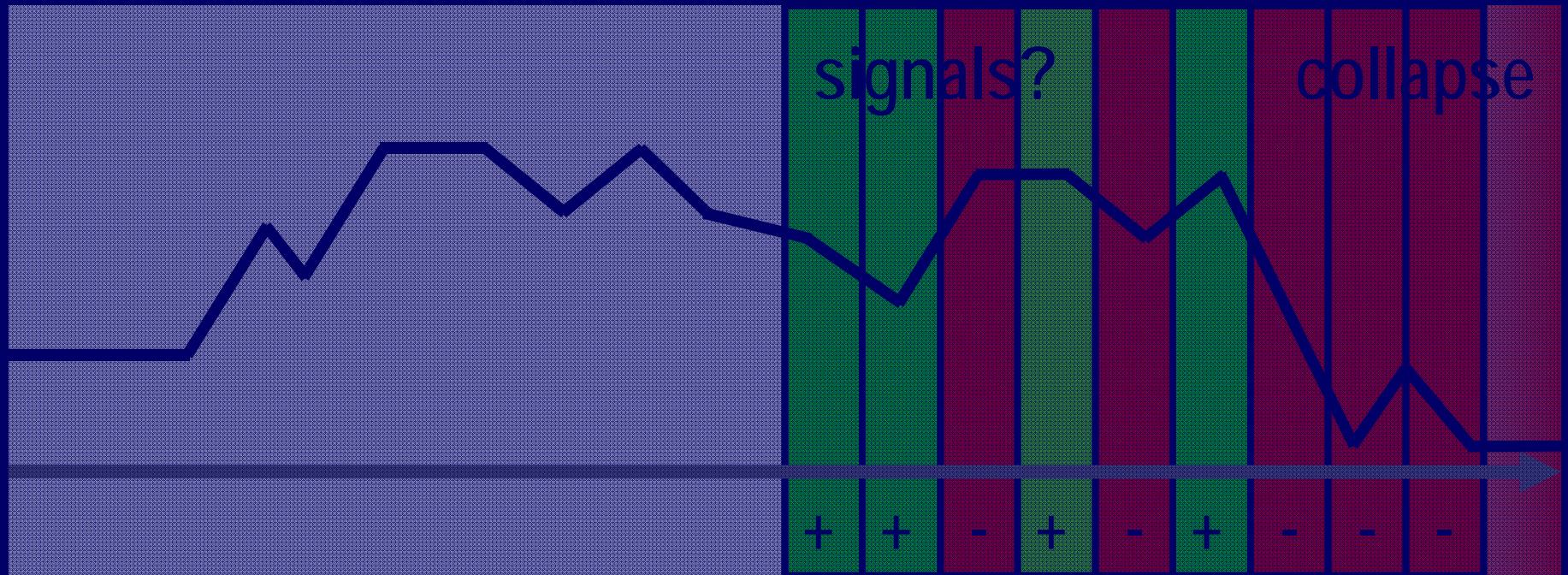
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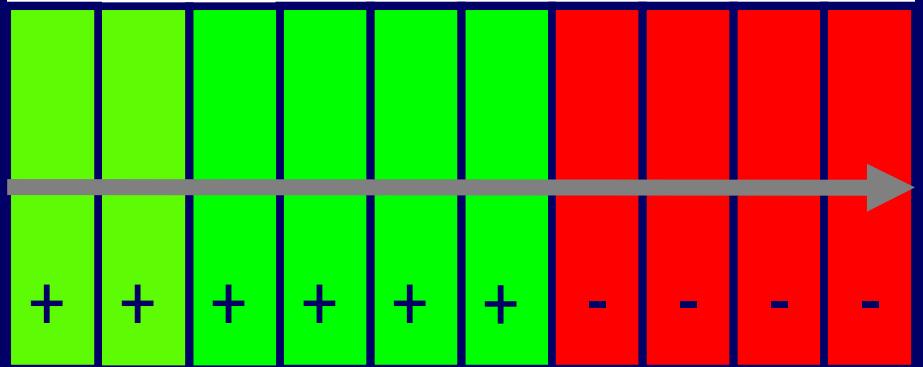
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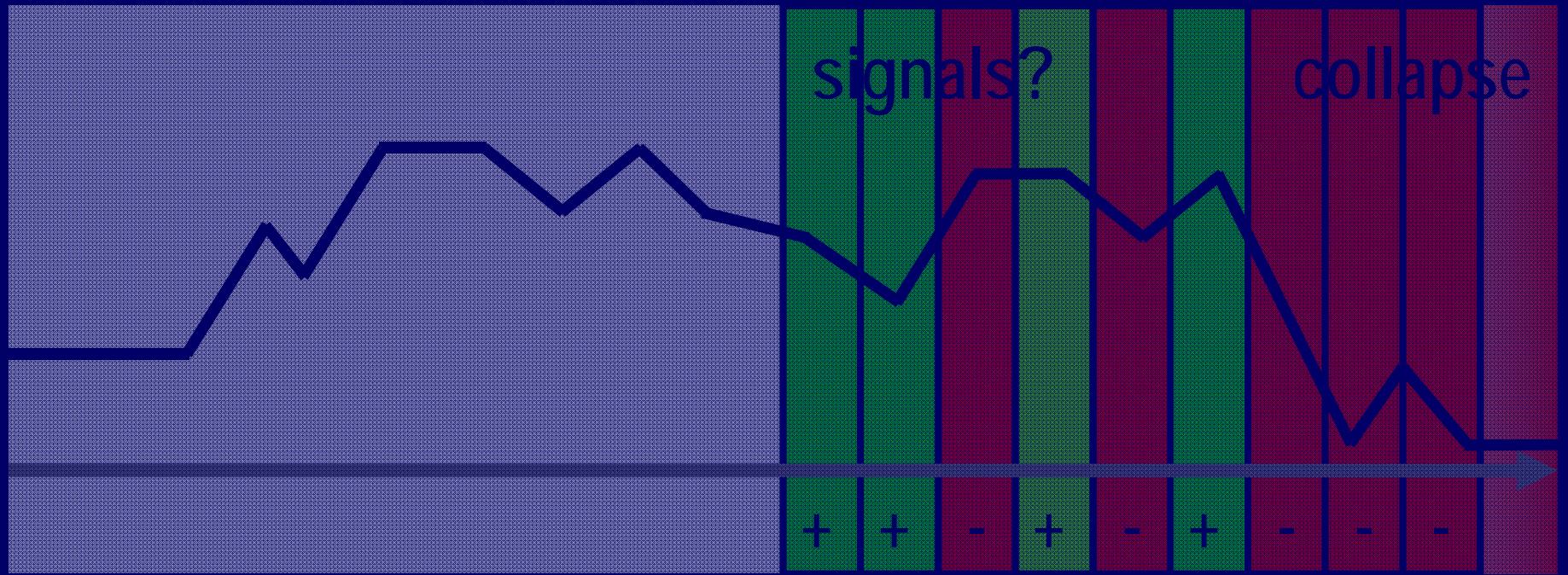
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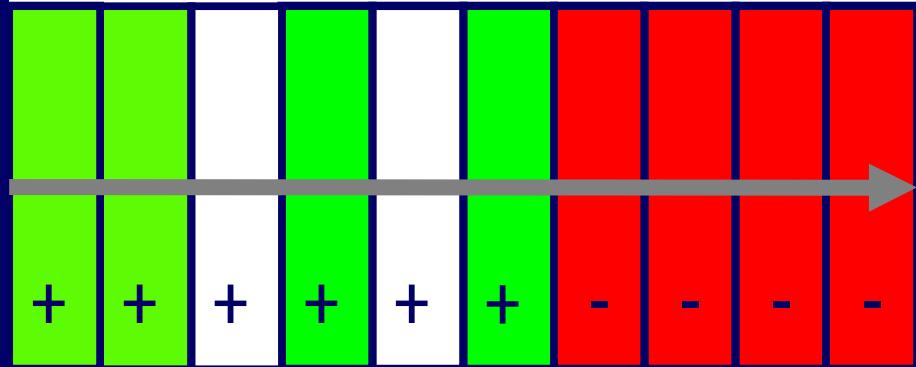
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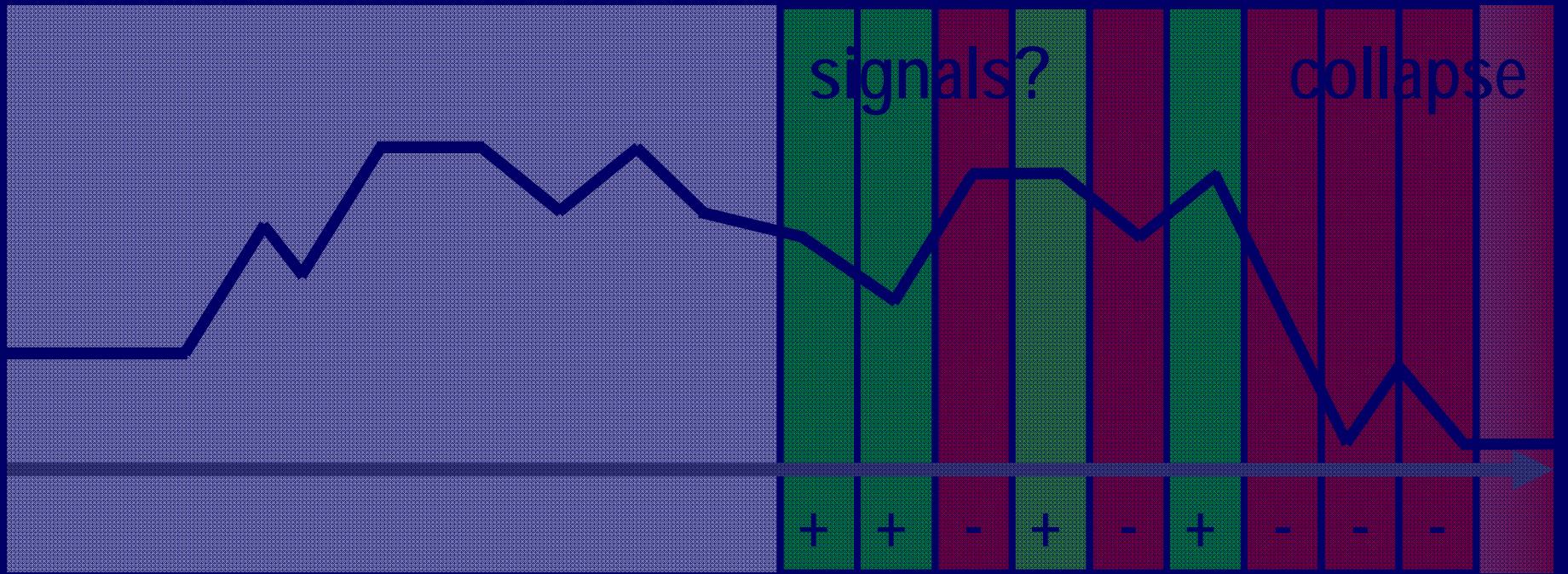
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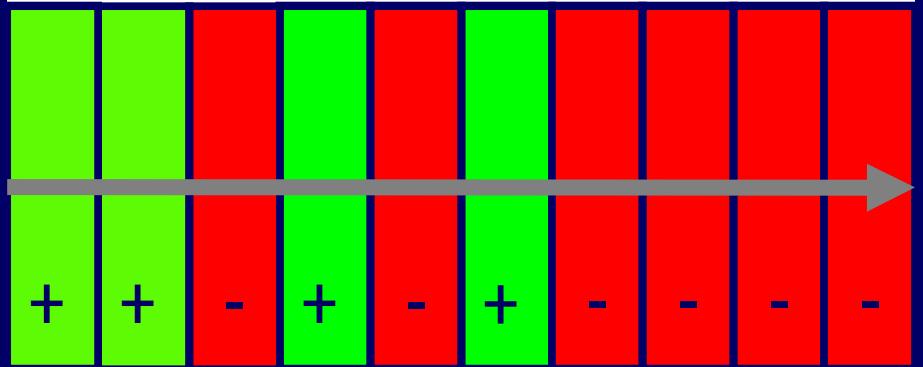
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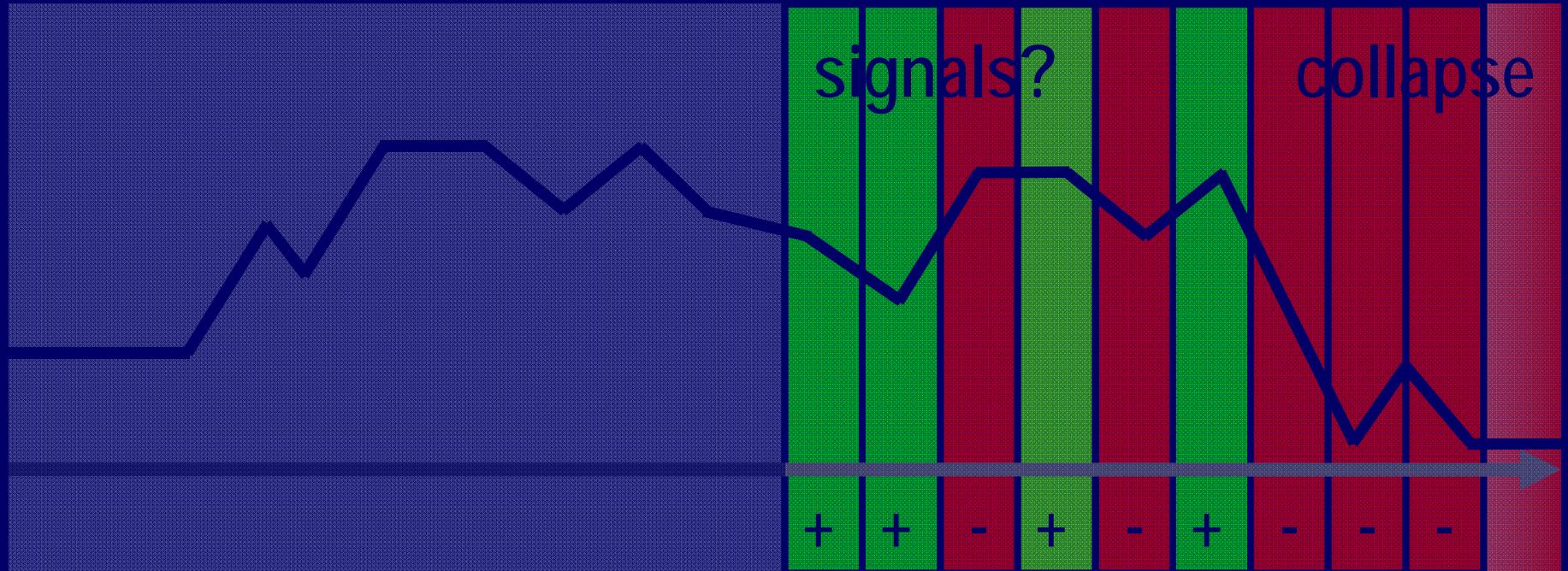
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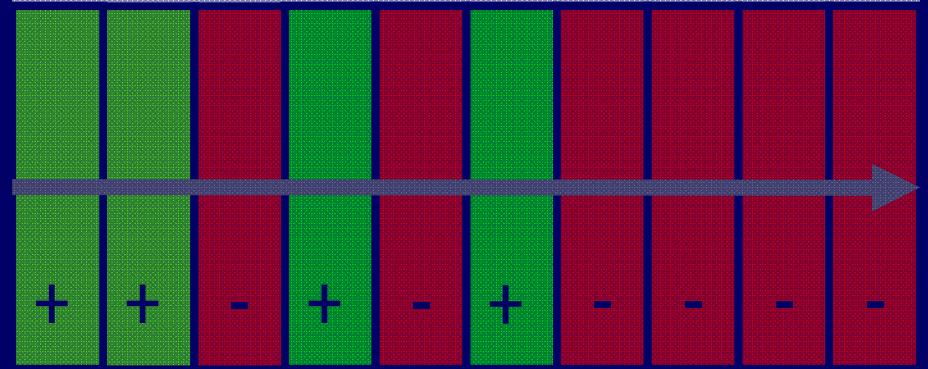
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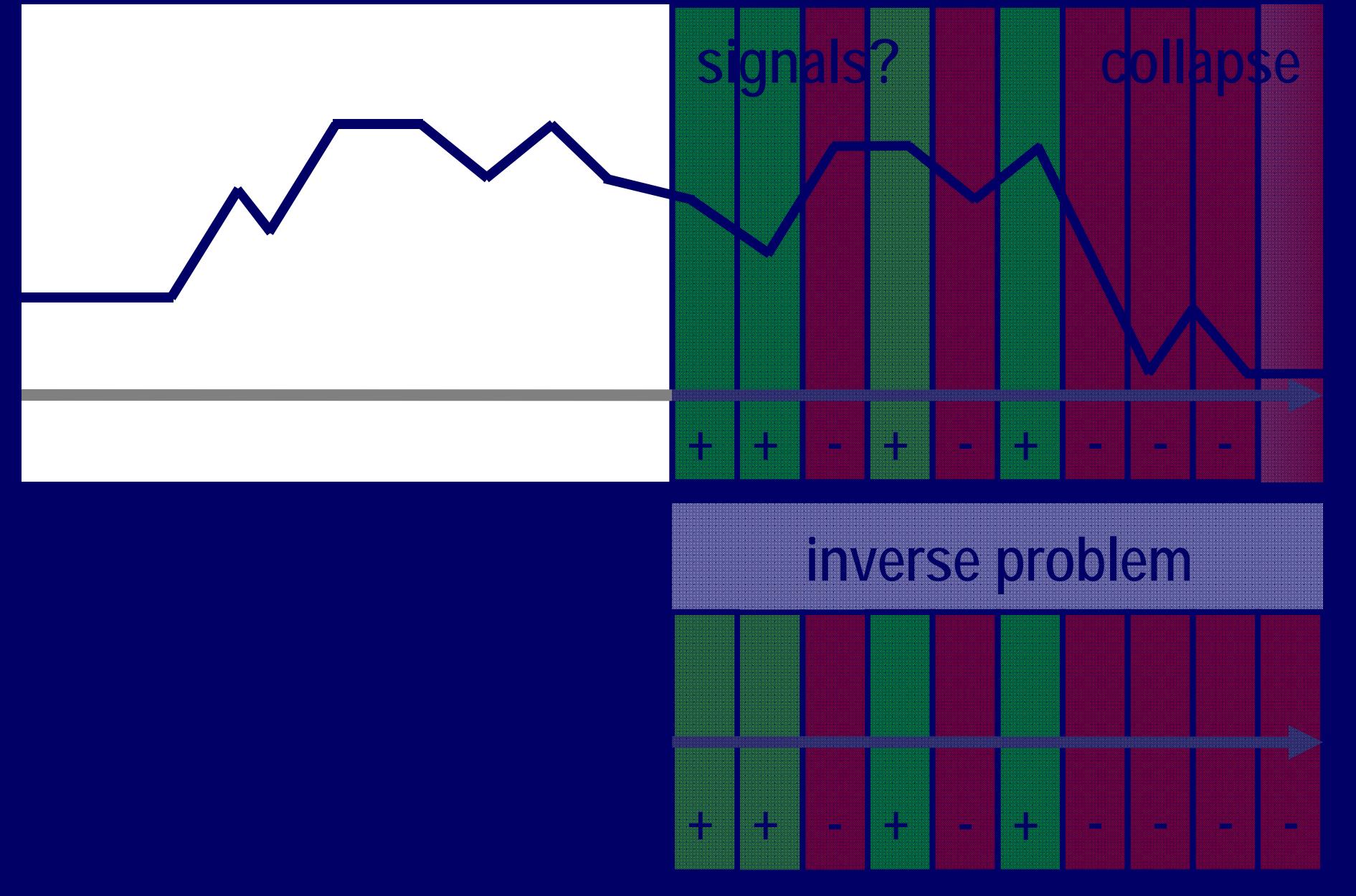
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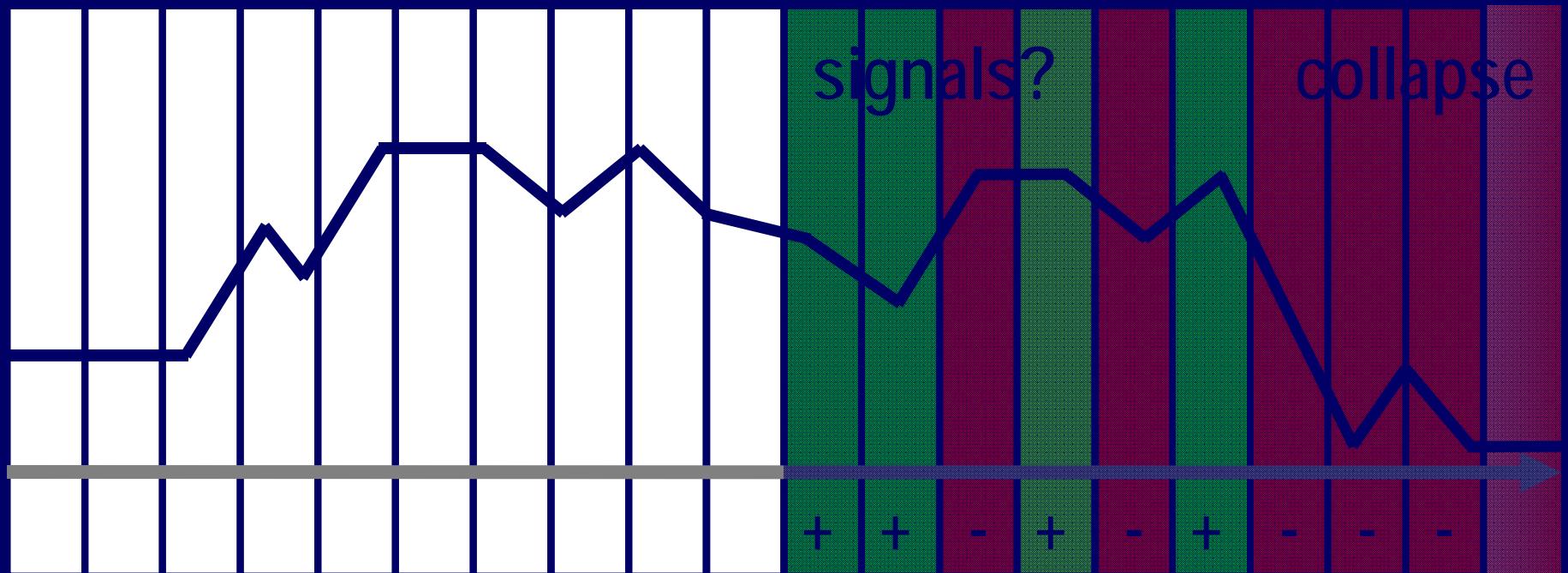
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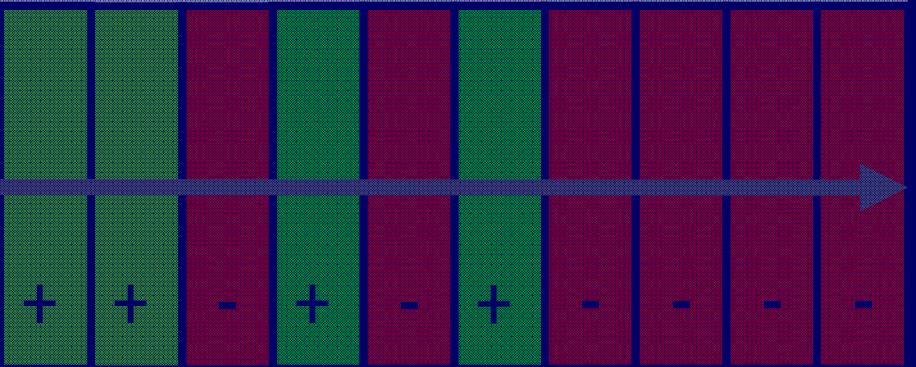
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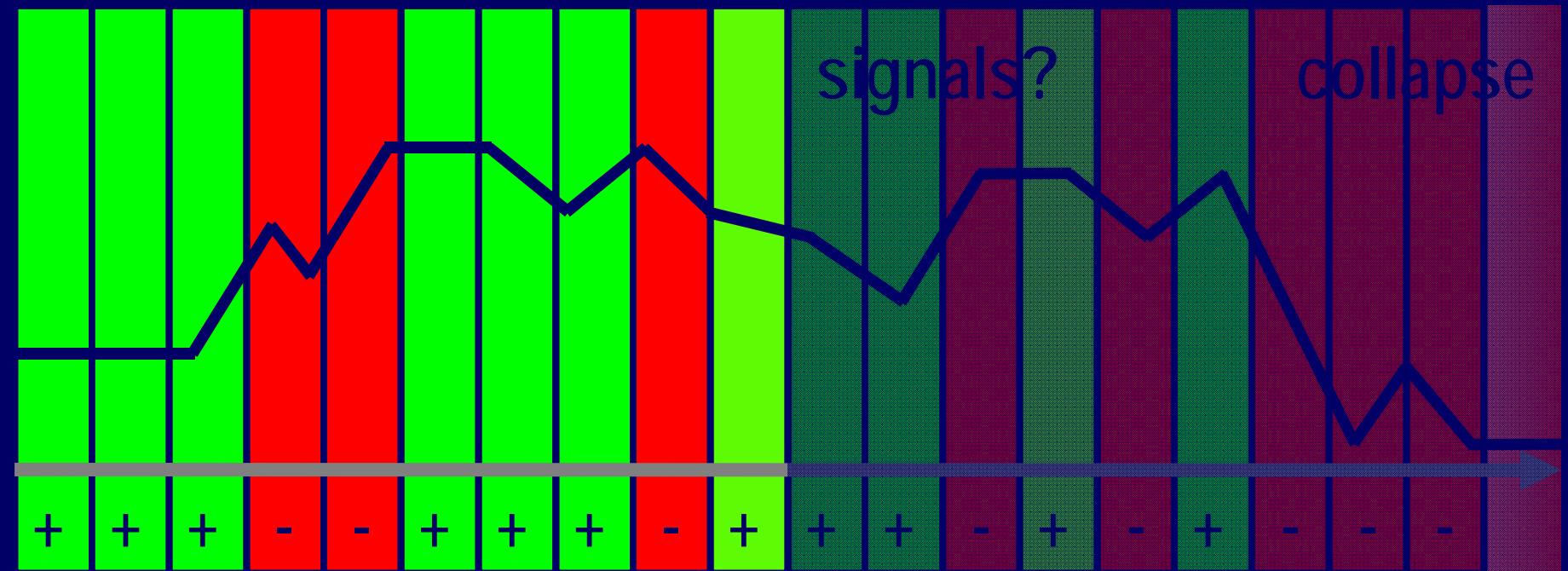
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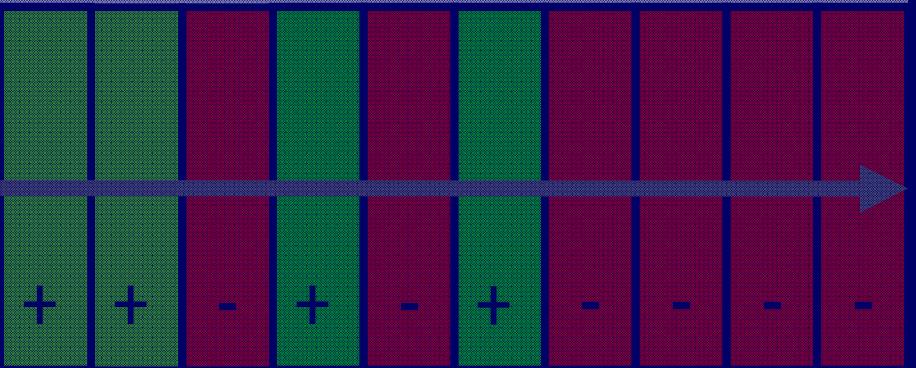
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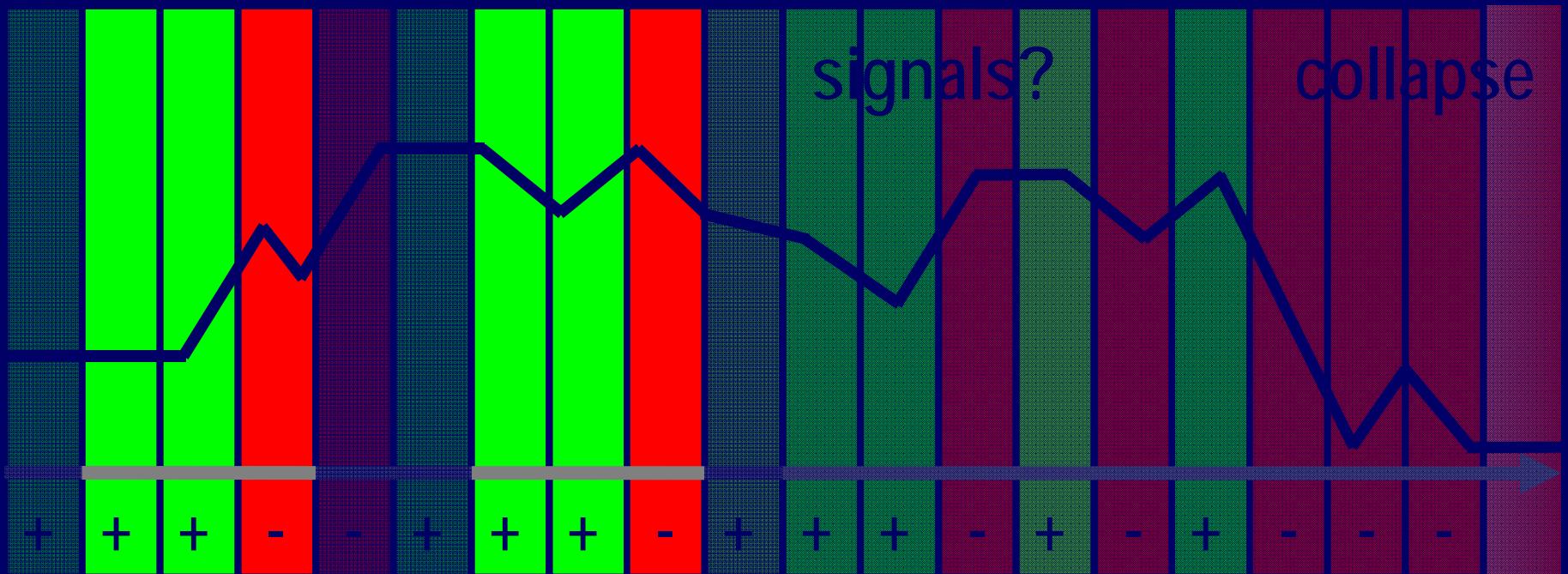
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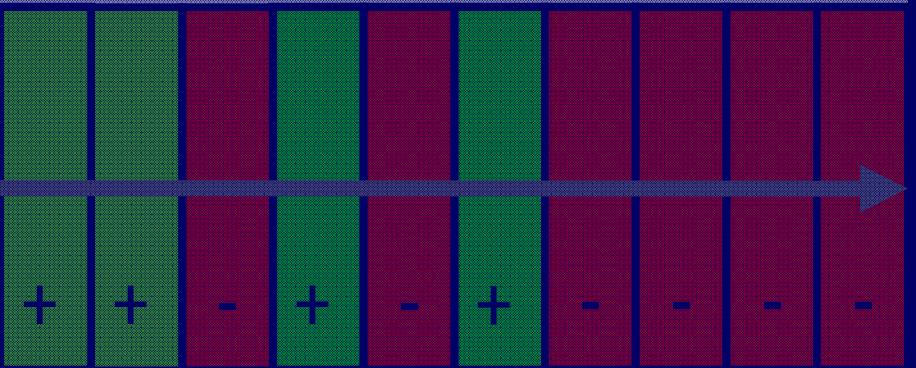
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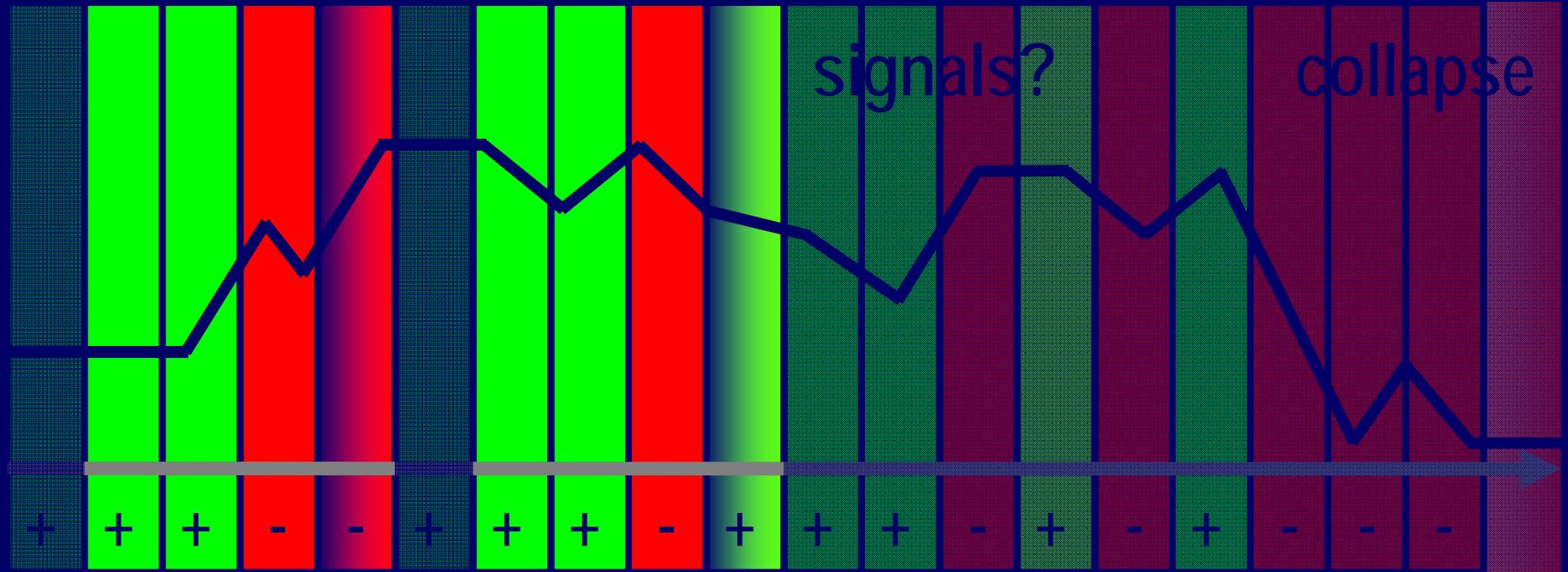
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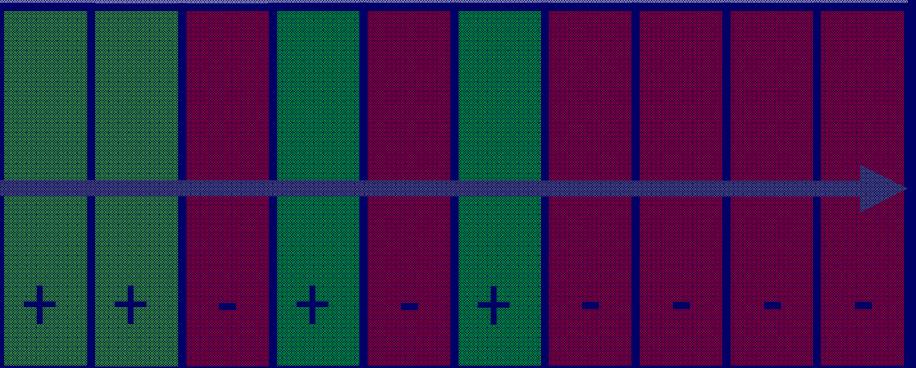
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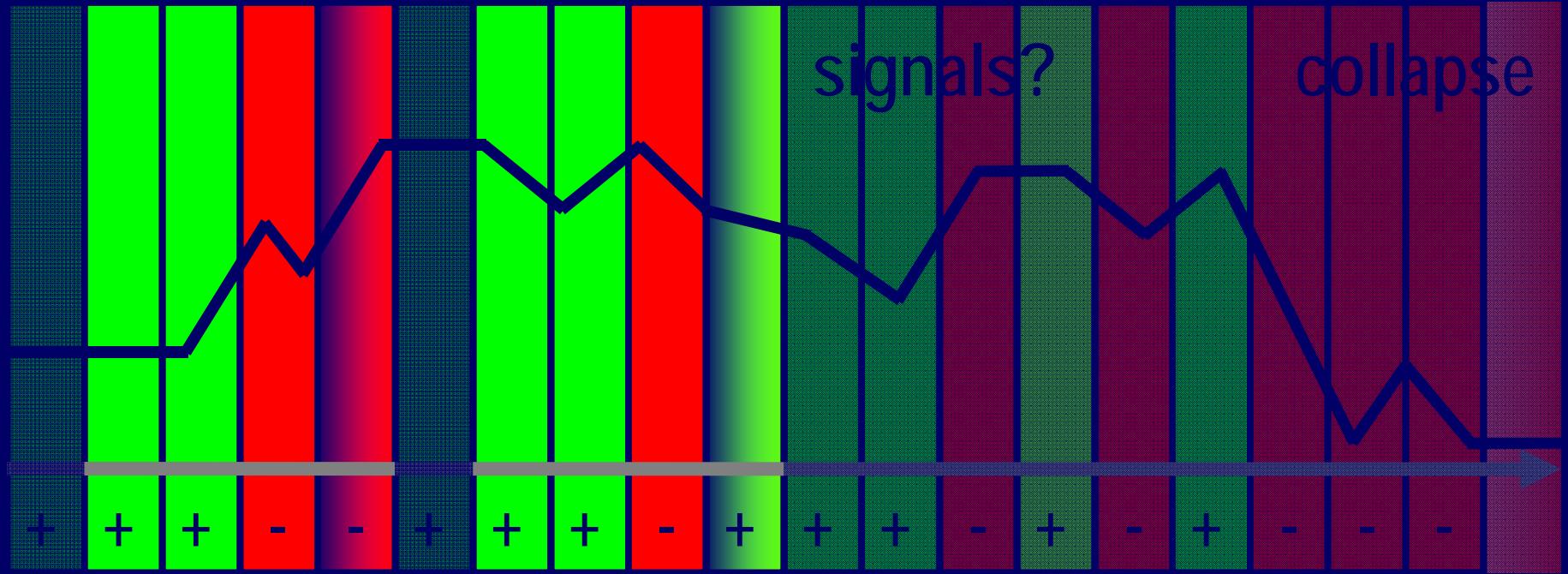
# Statistical analysis



inverse problem



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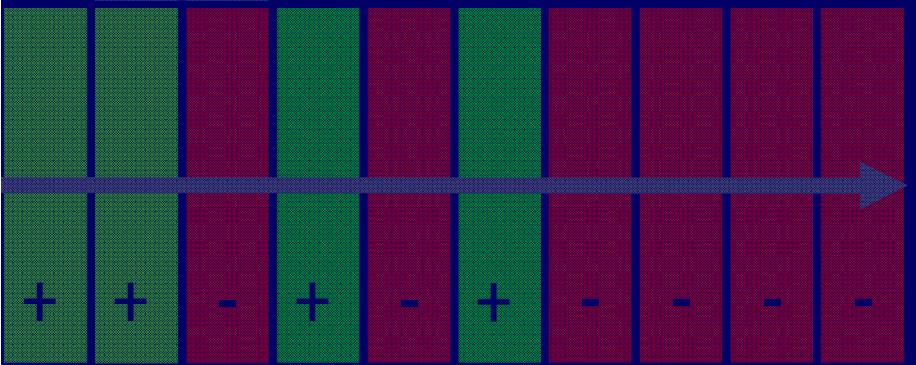
random process

$\omega$

$p(\omega)$

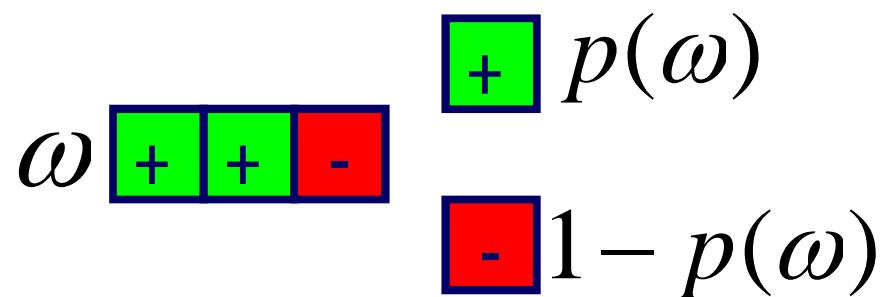
$1 - p(\omega)$

inverse problem



# Forecasting

random process

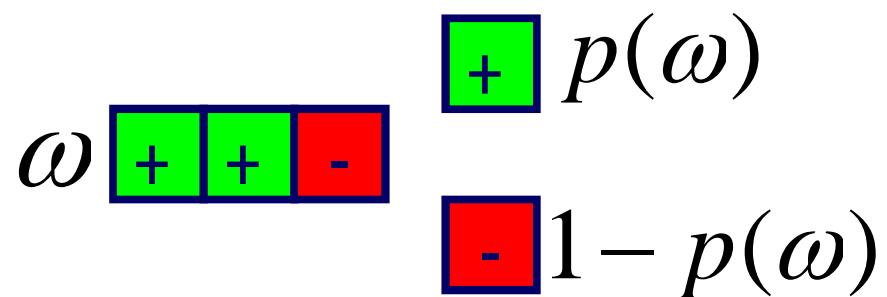


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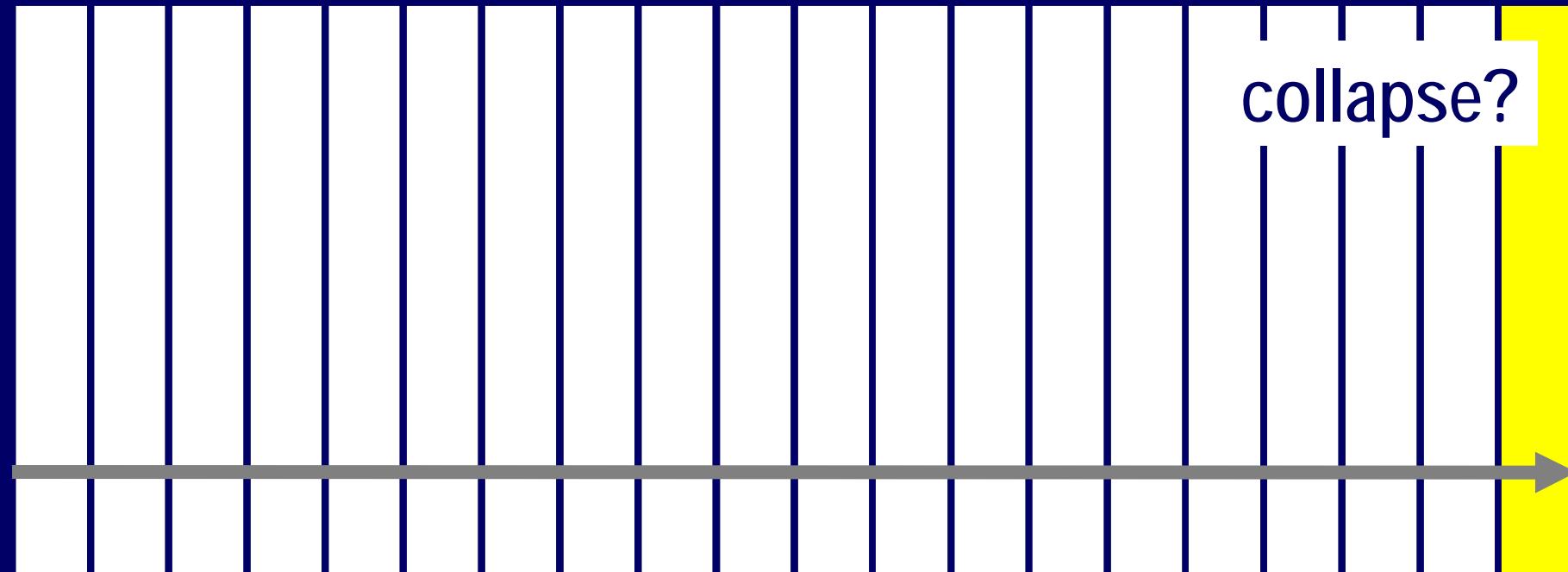
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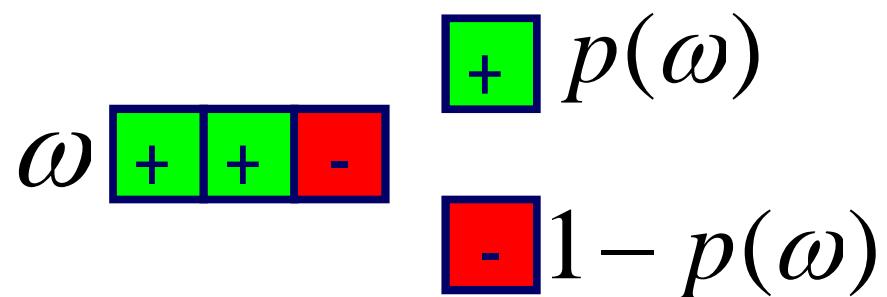
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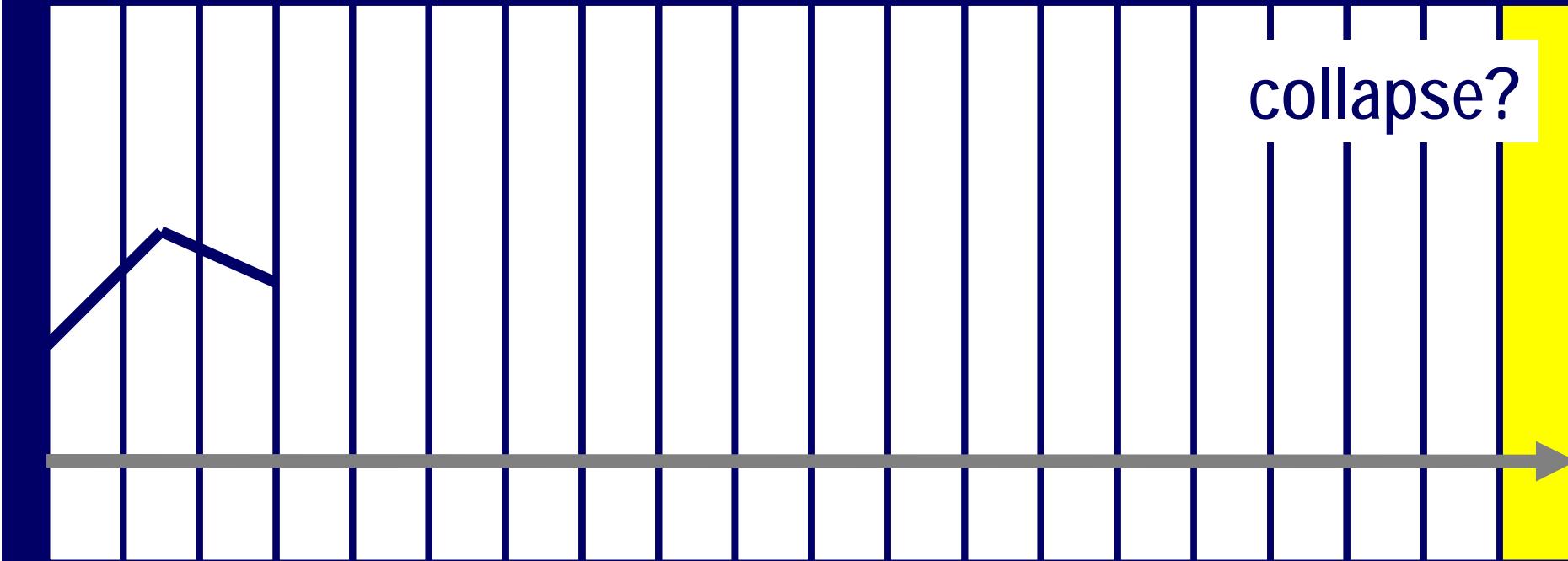
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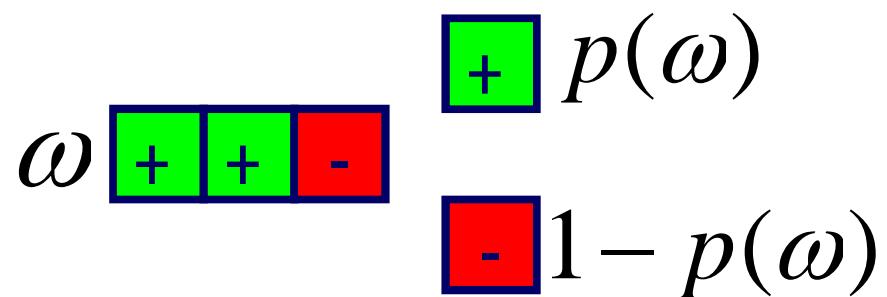
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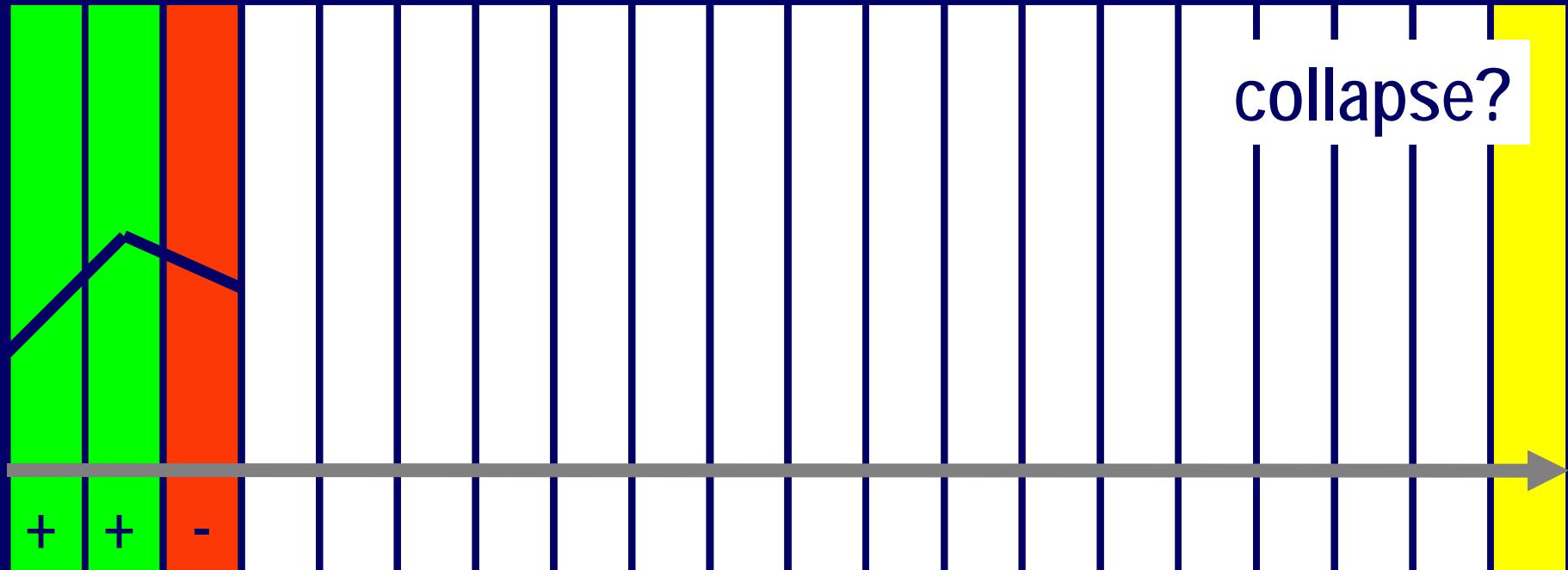
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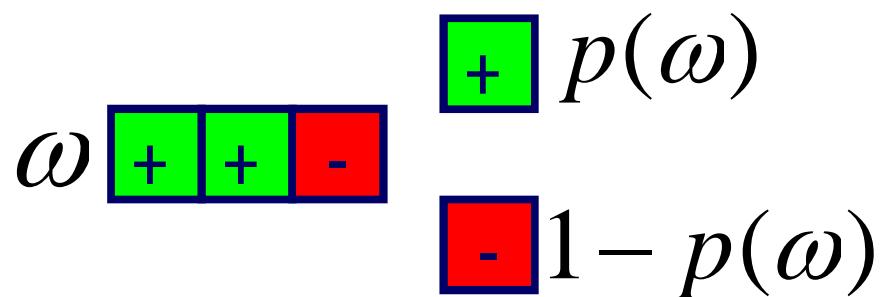
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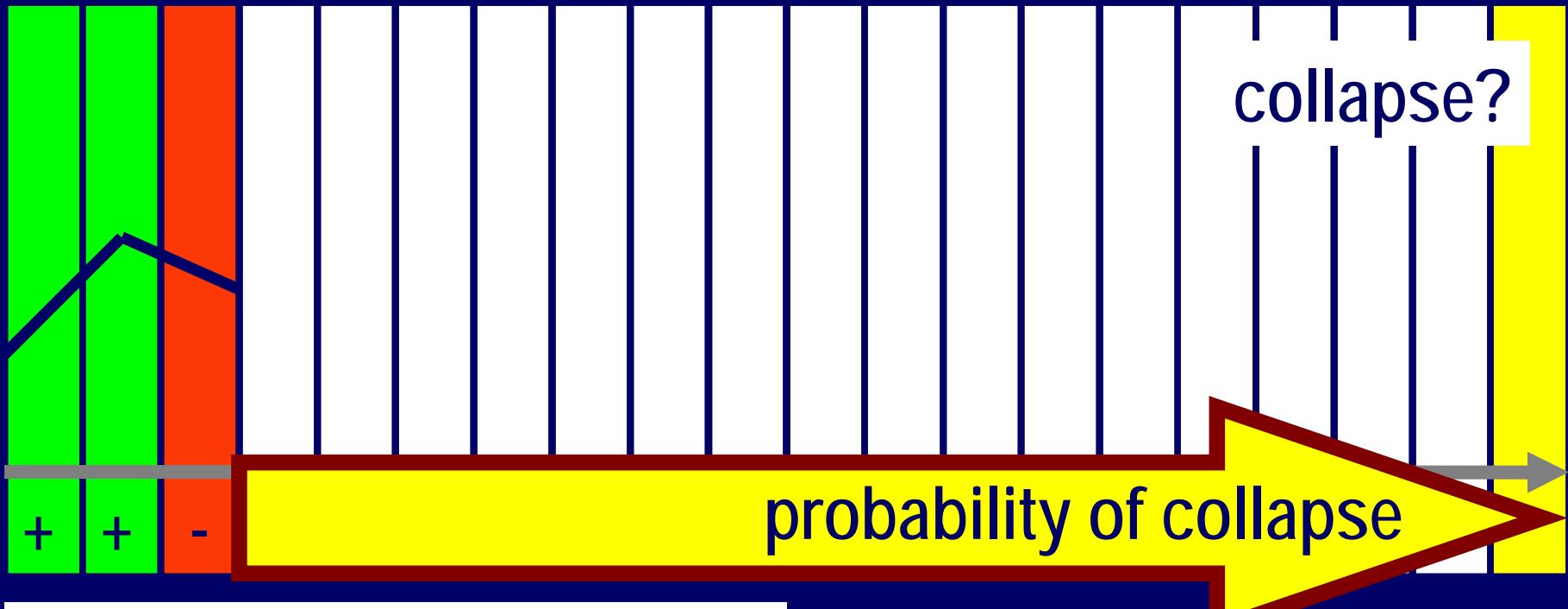
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random process



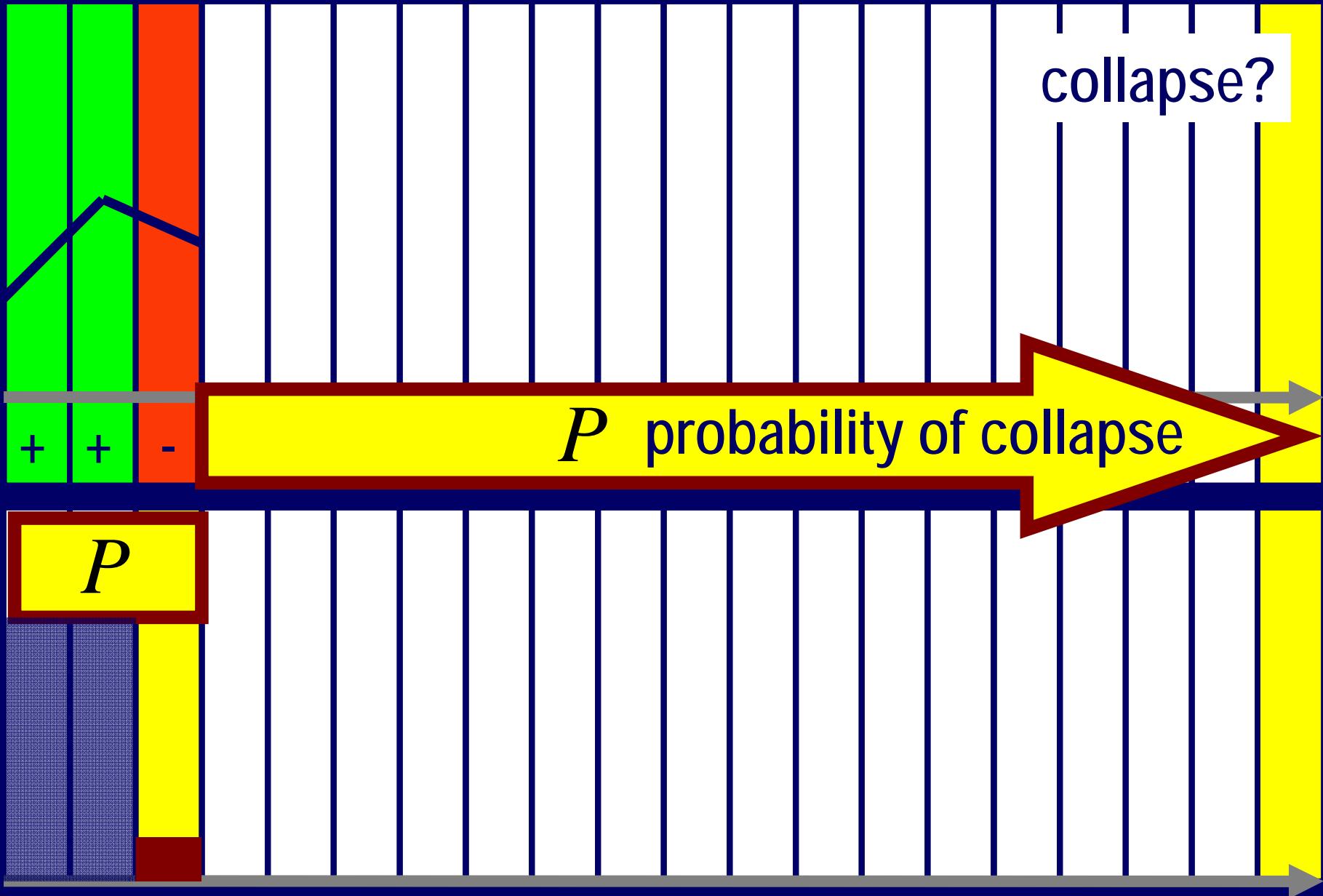
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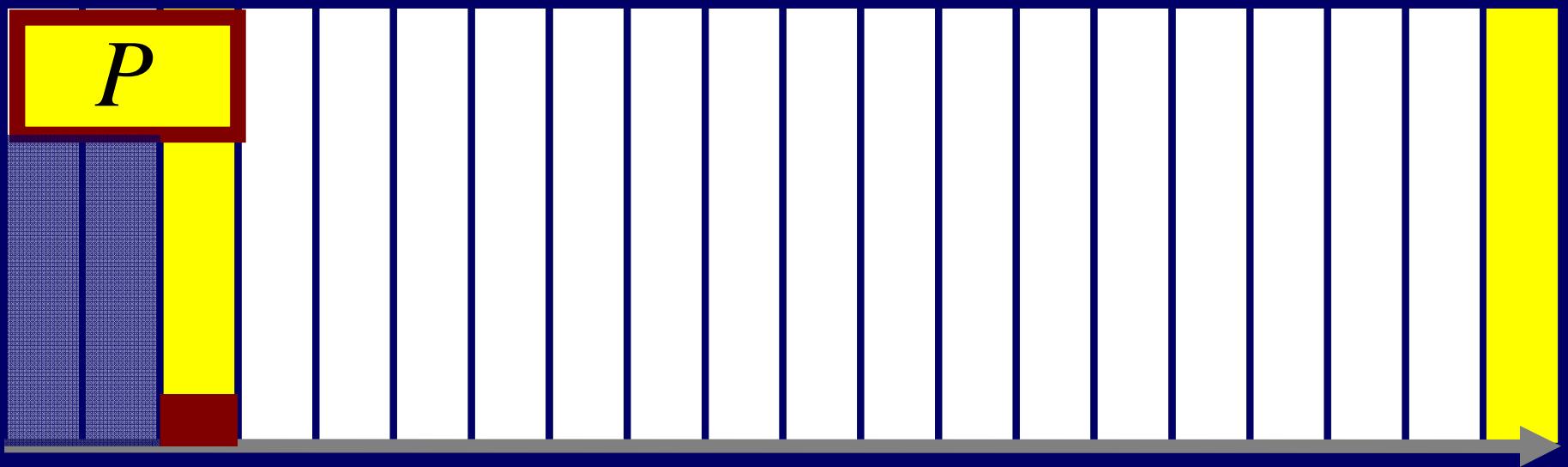
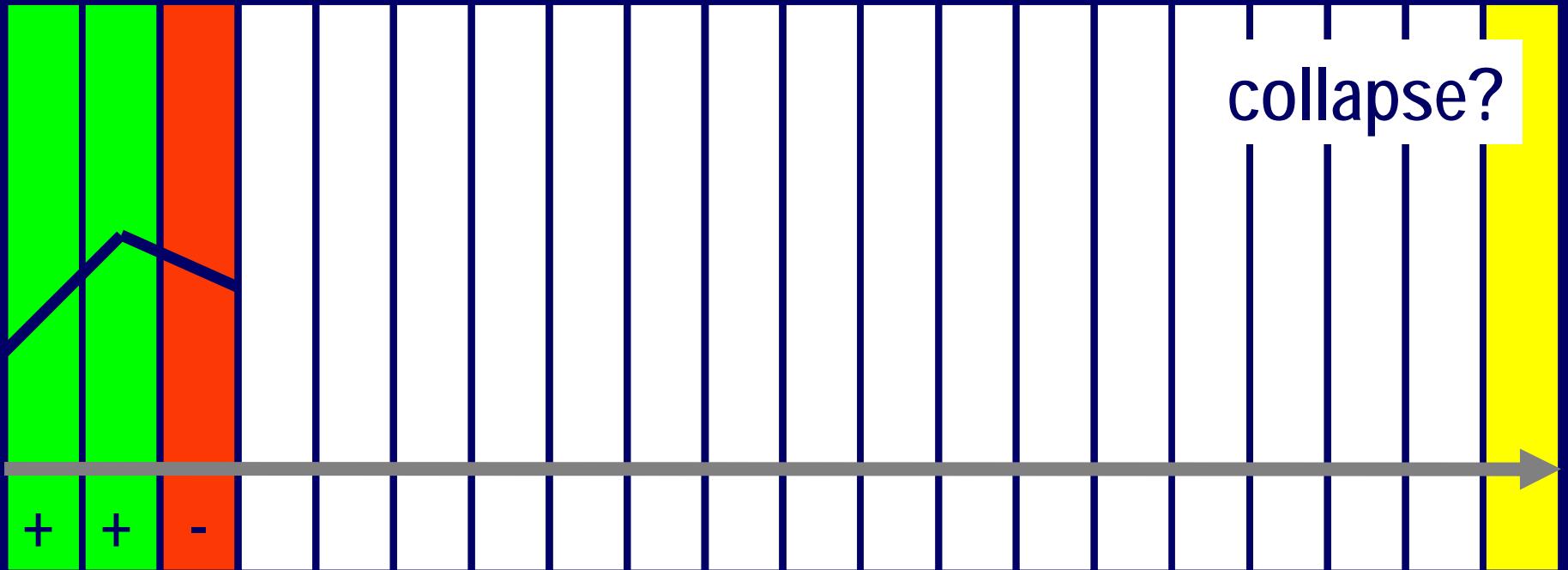
random process

$\omega$   $p(\omega)$   
  $1 - p(\omega)$

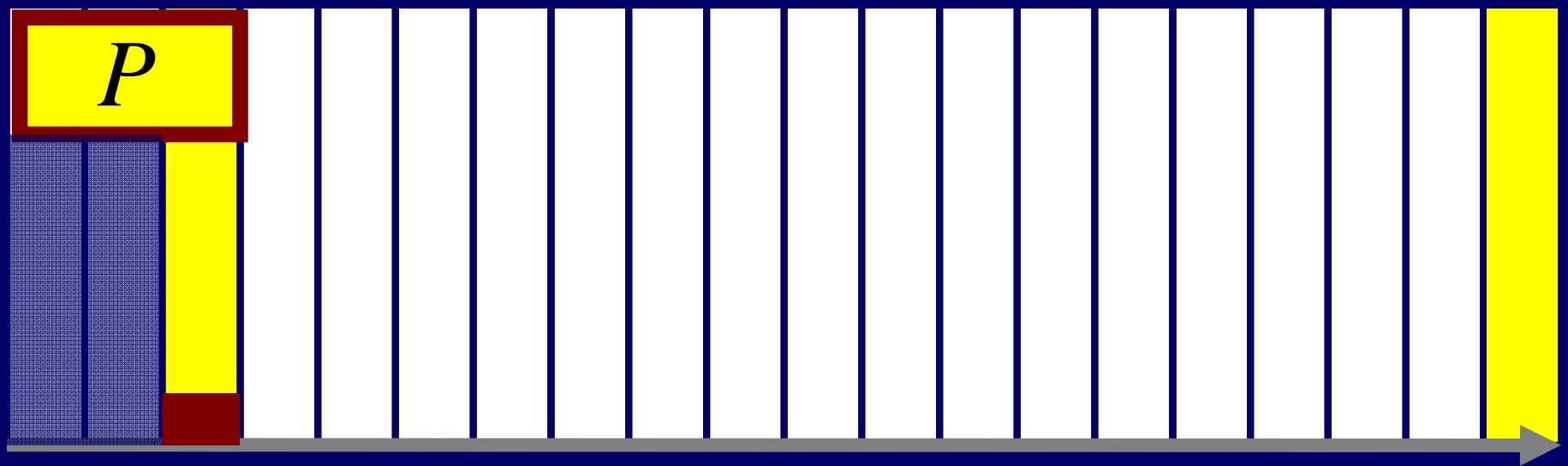
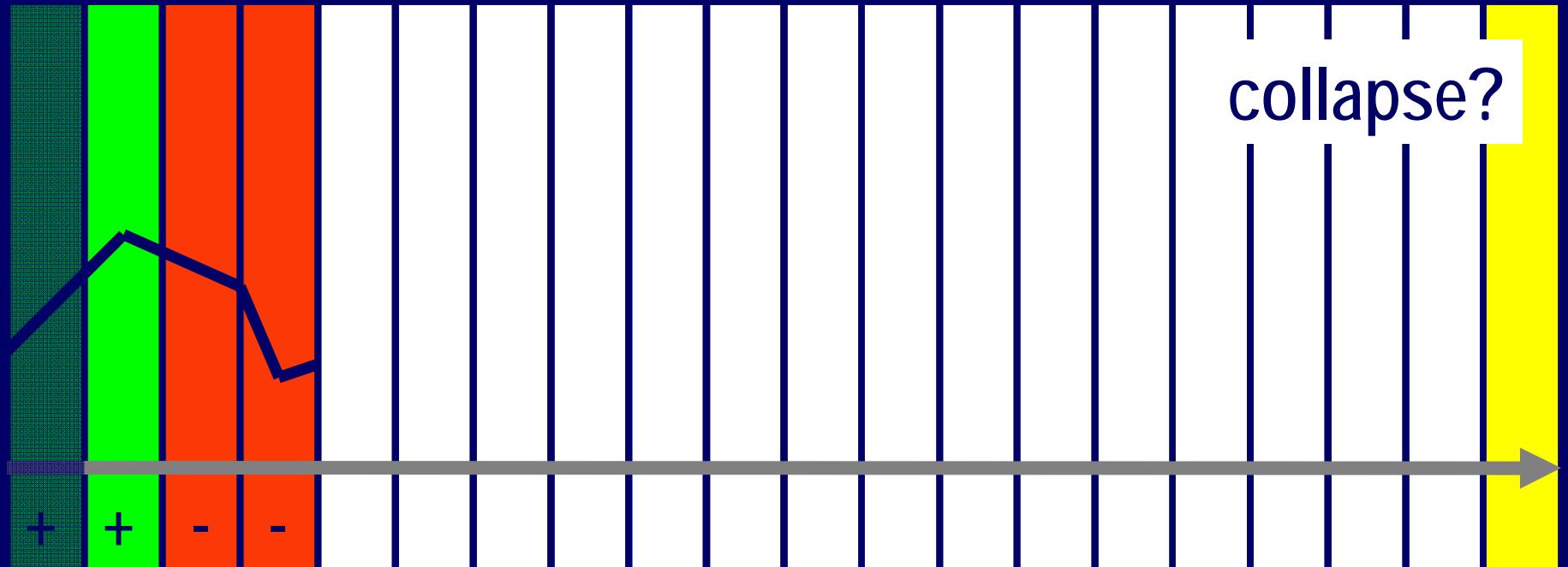
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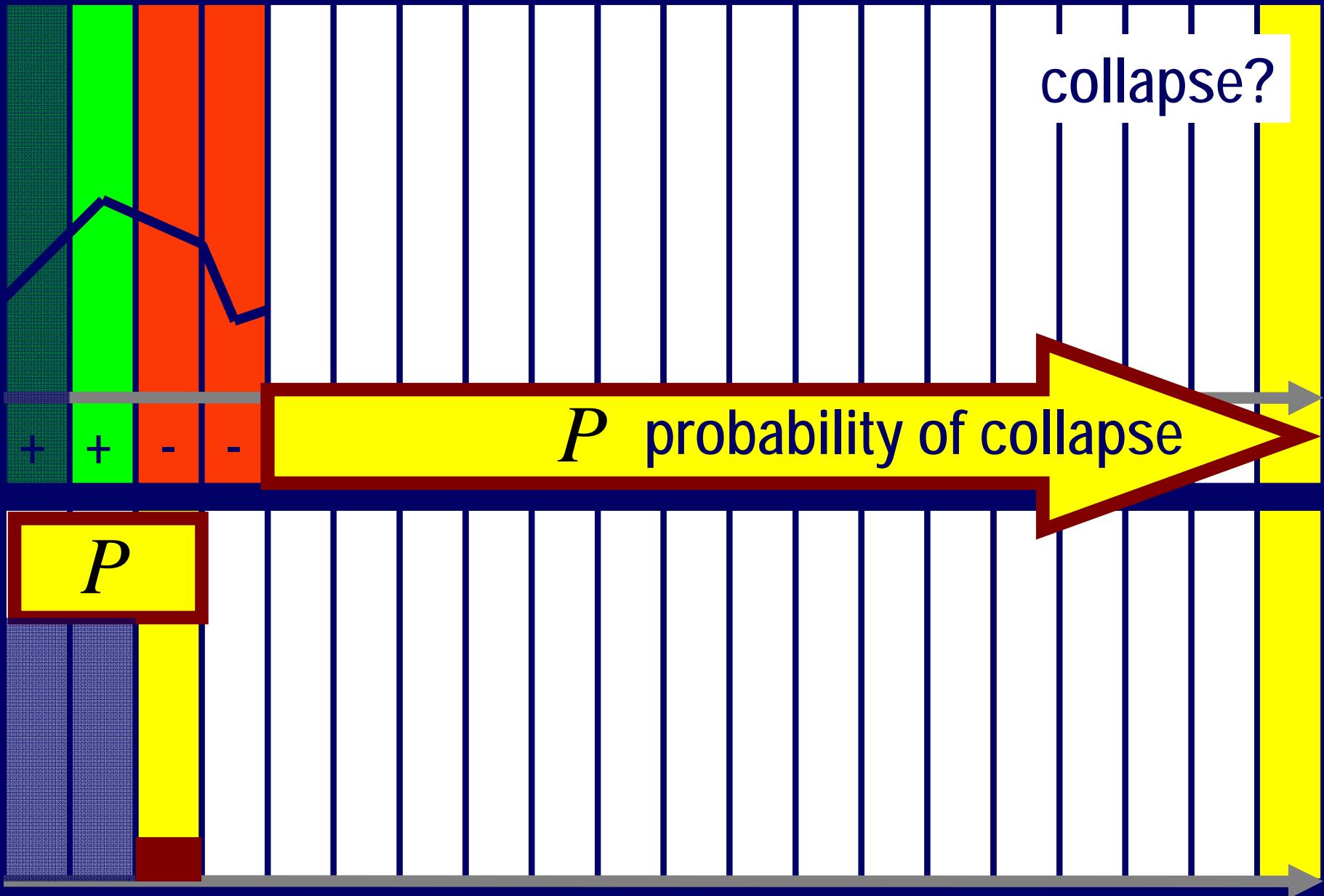
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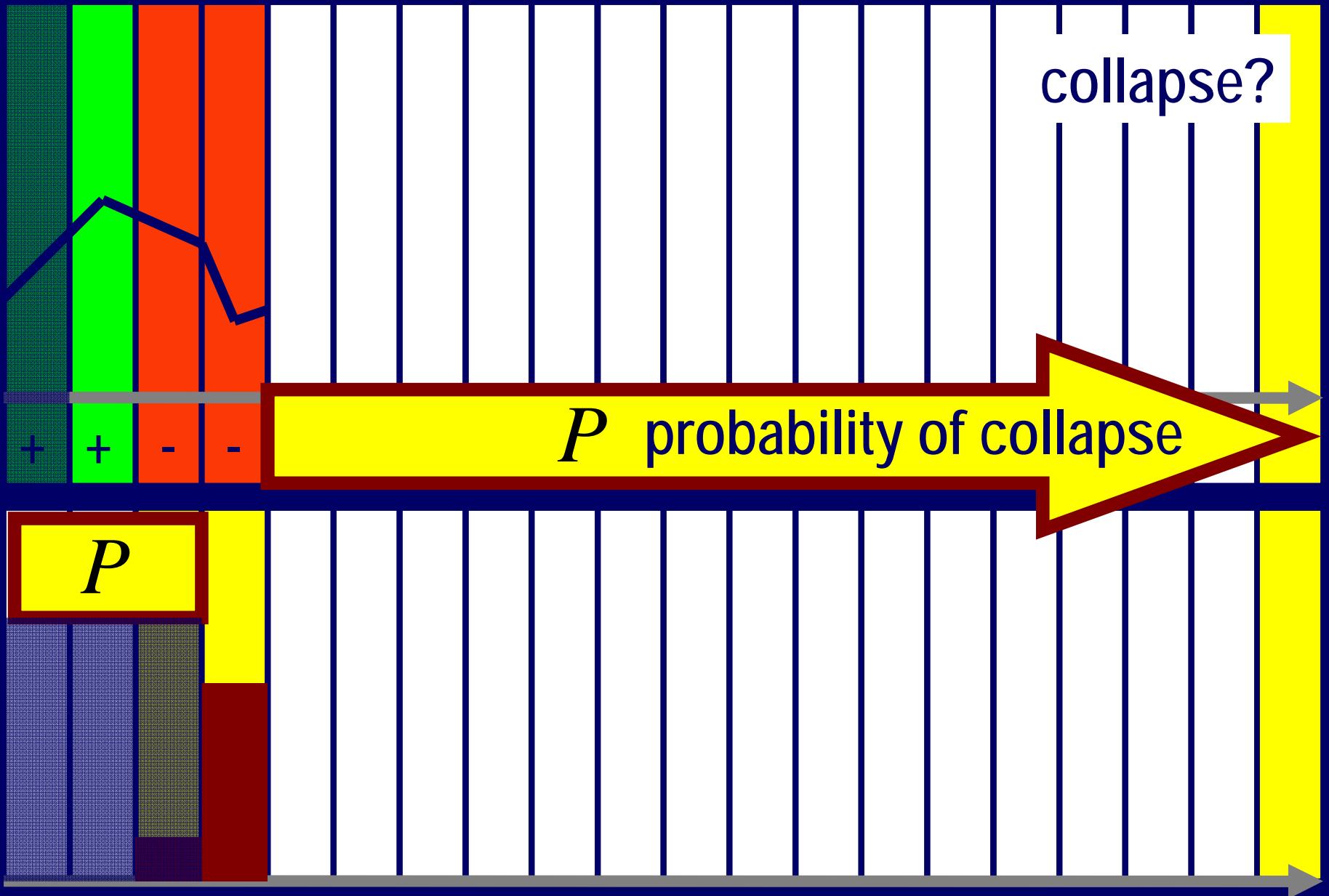
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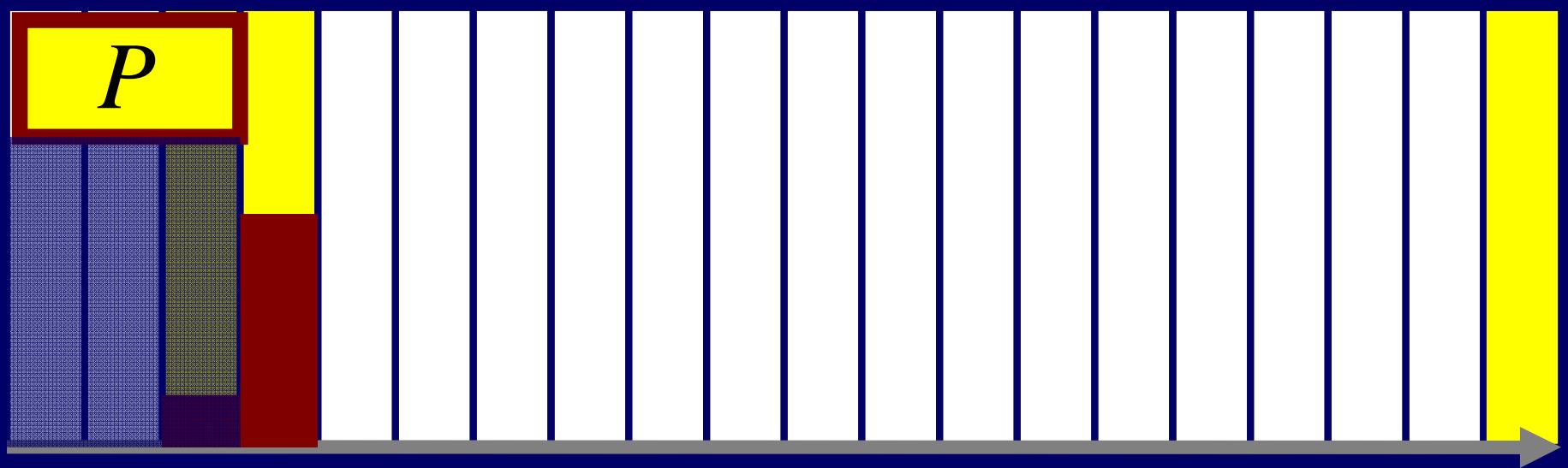
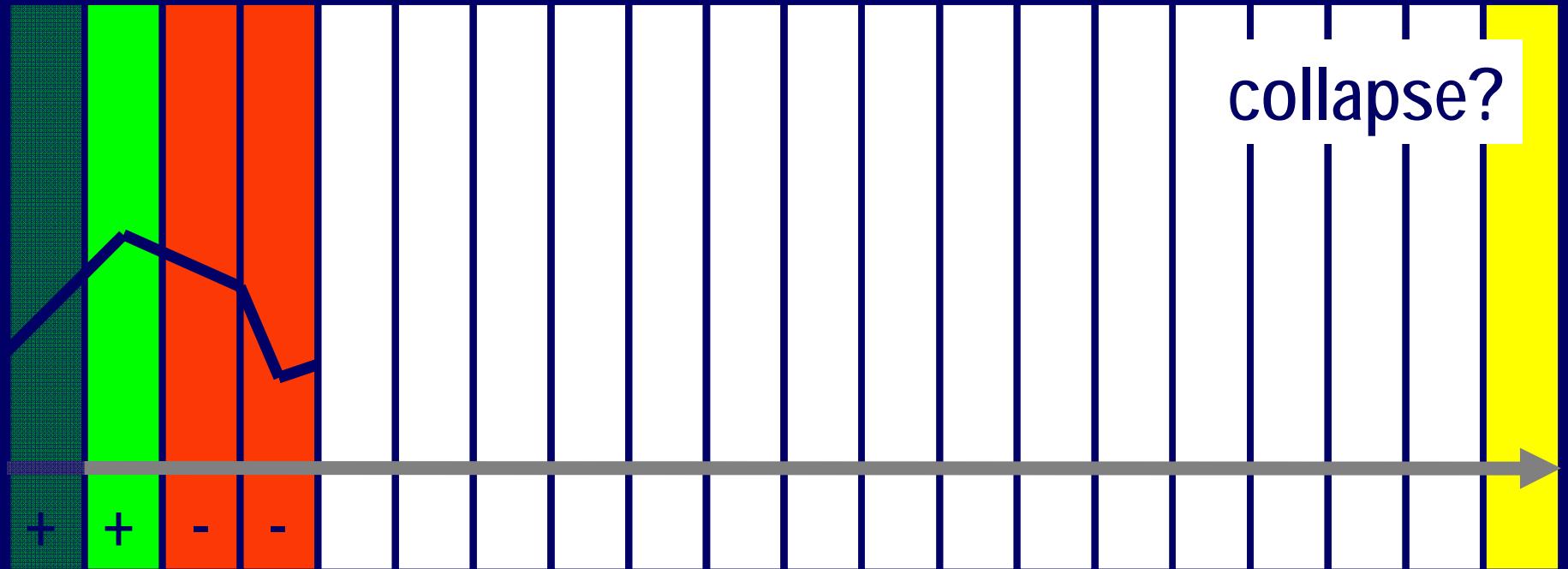
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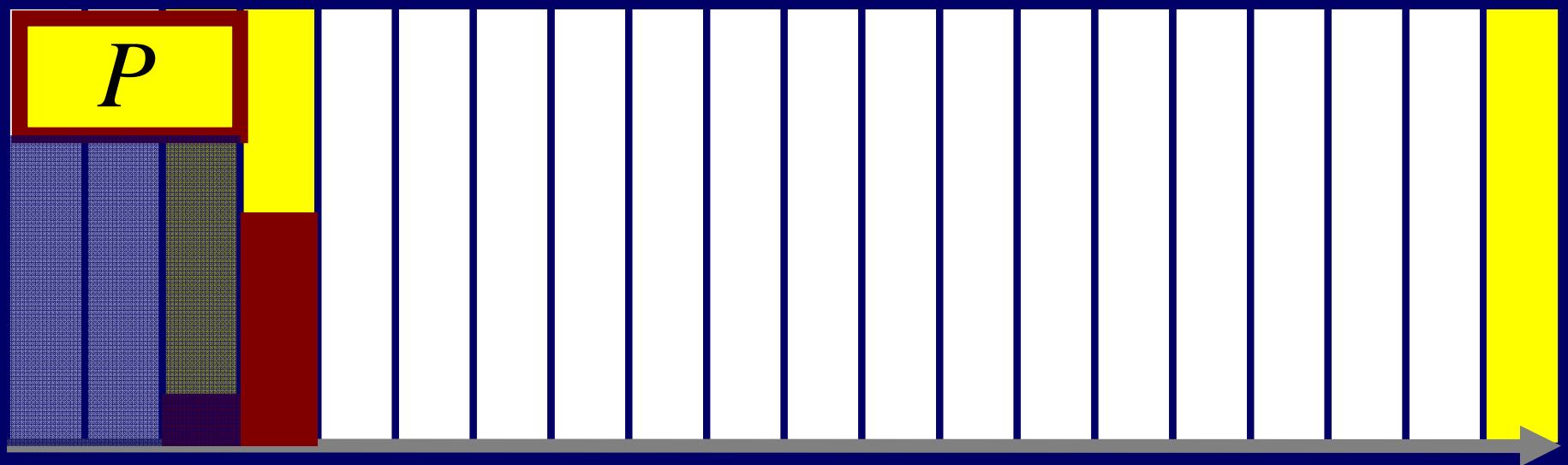
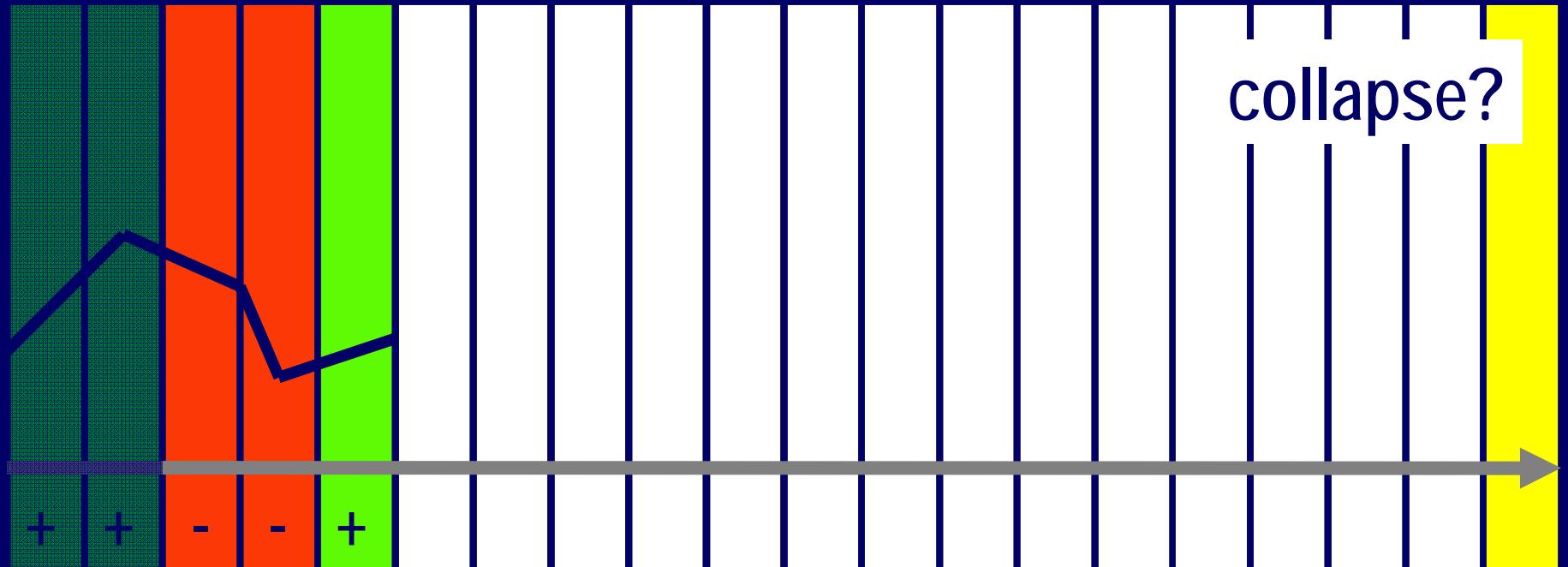
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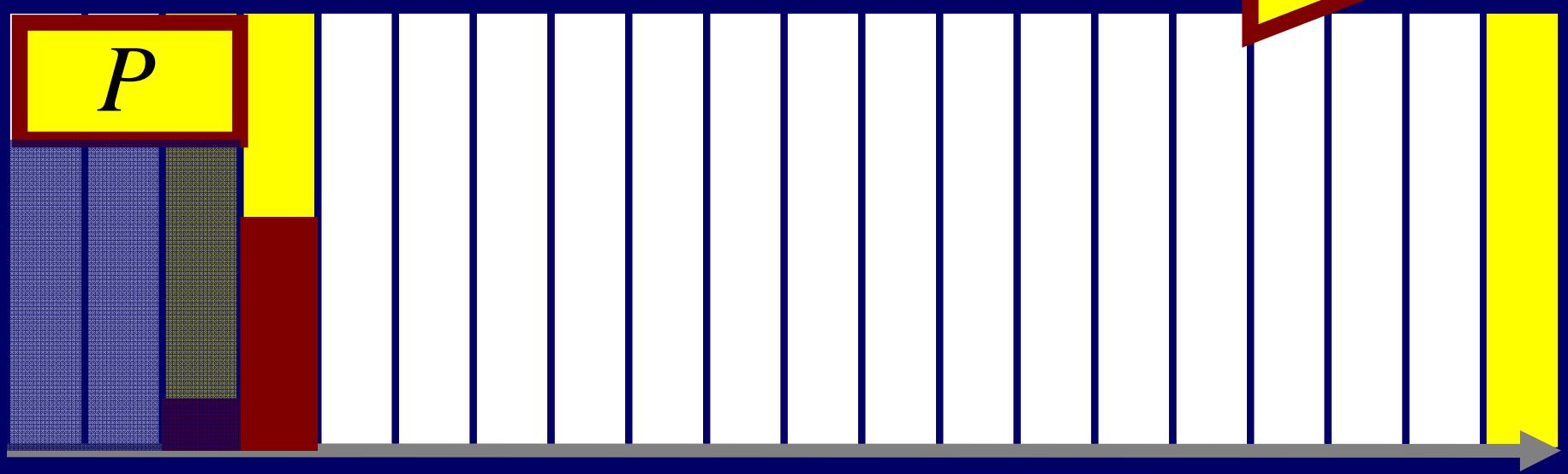
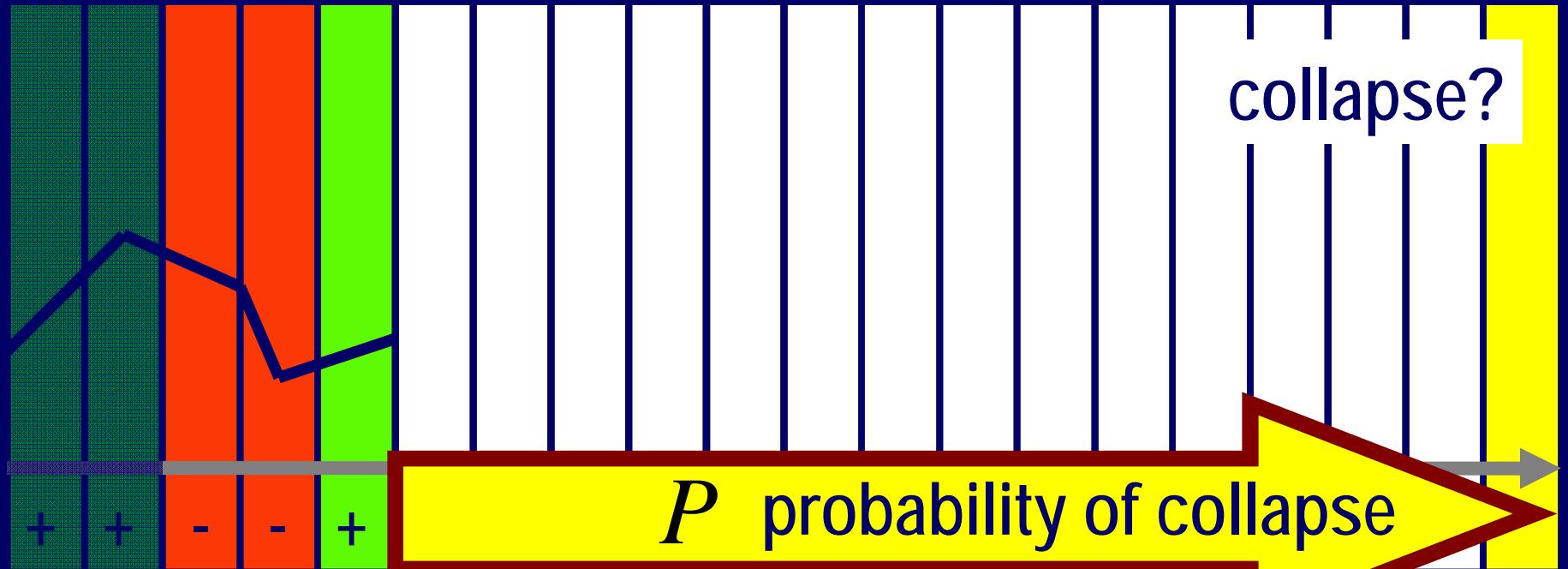
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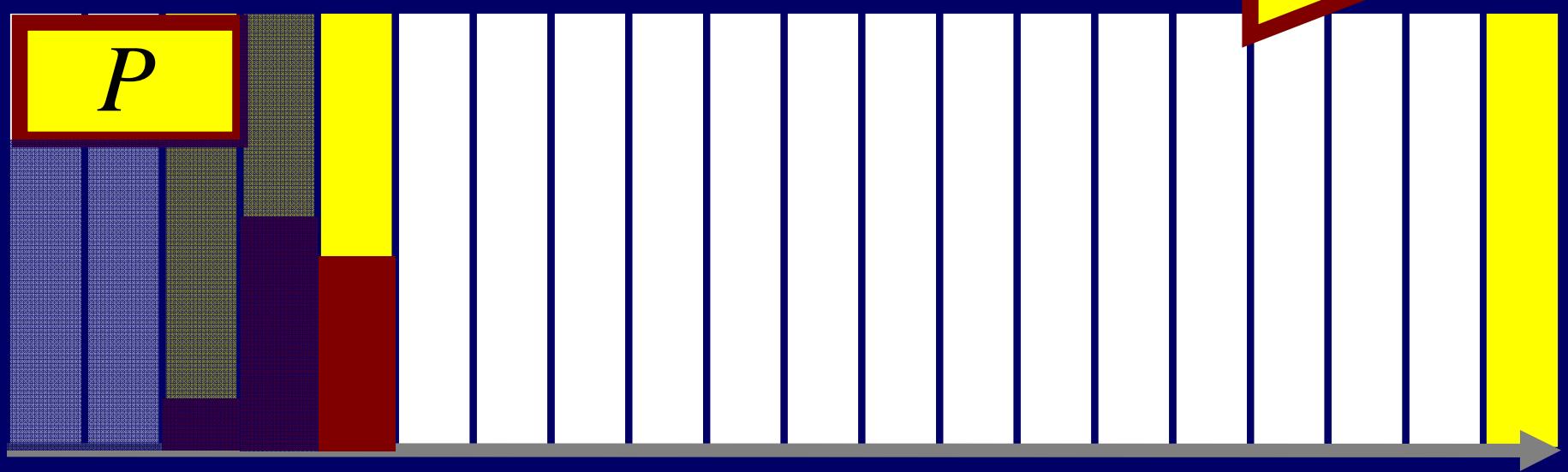
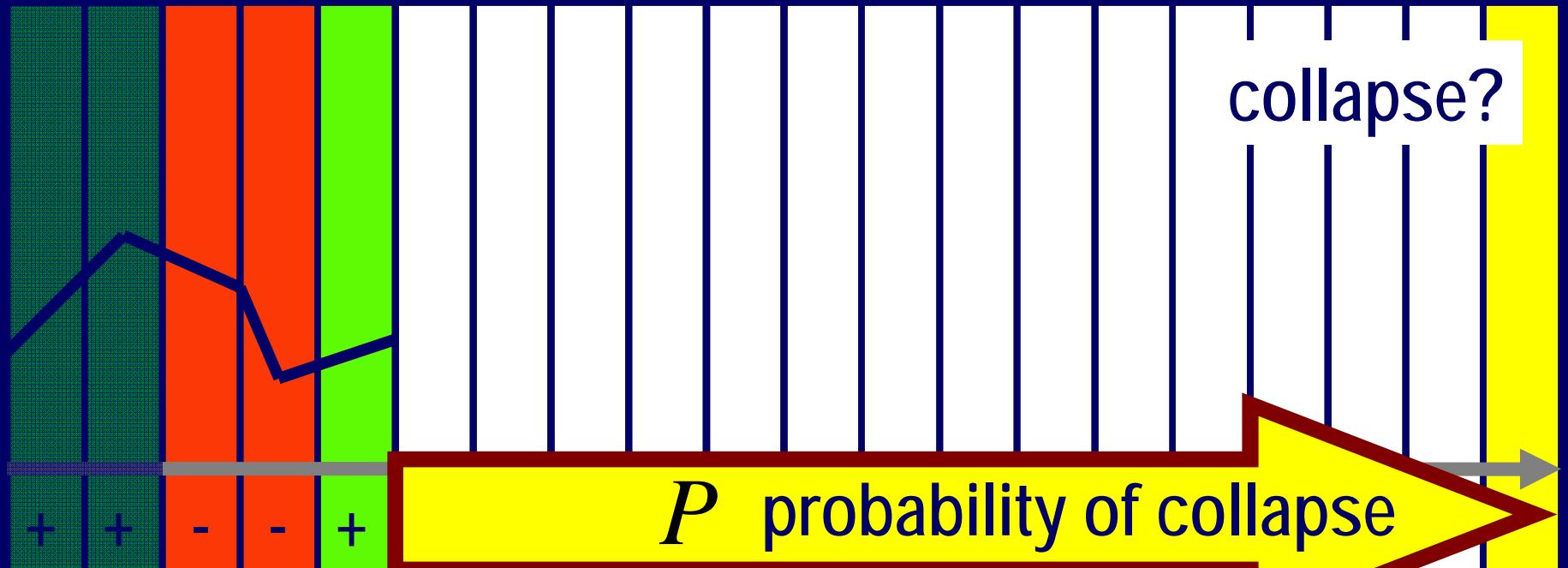
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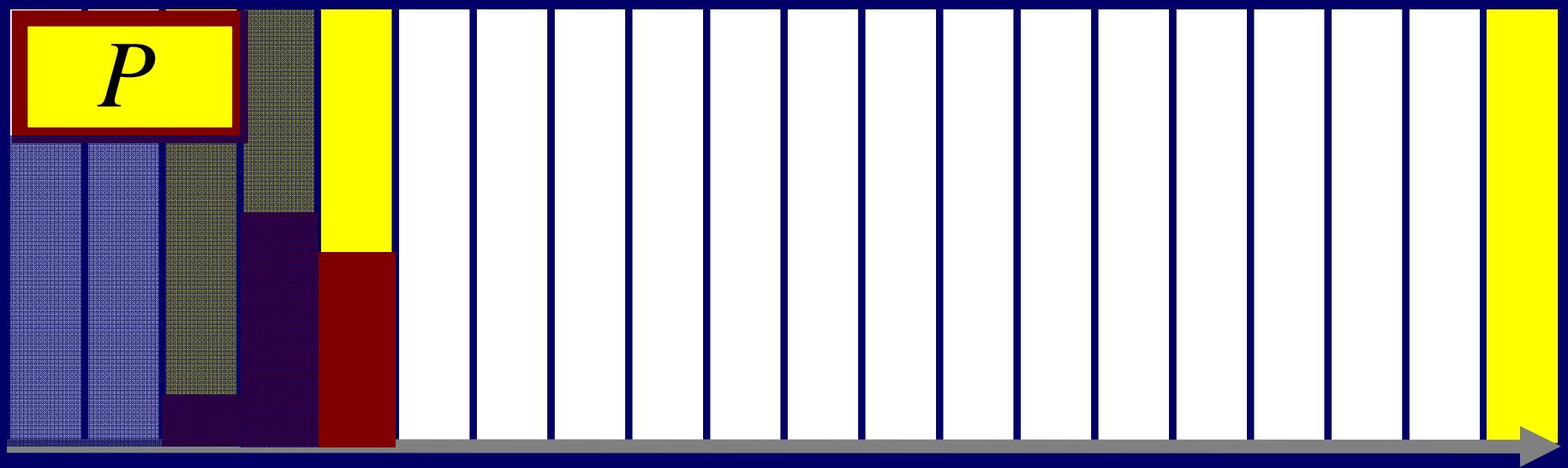
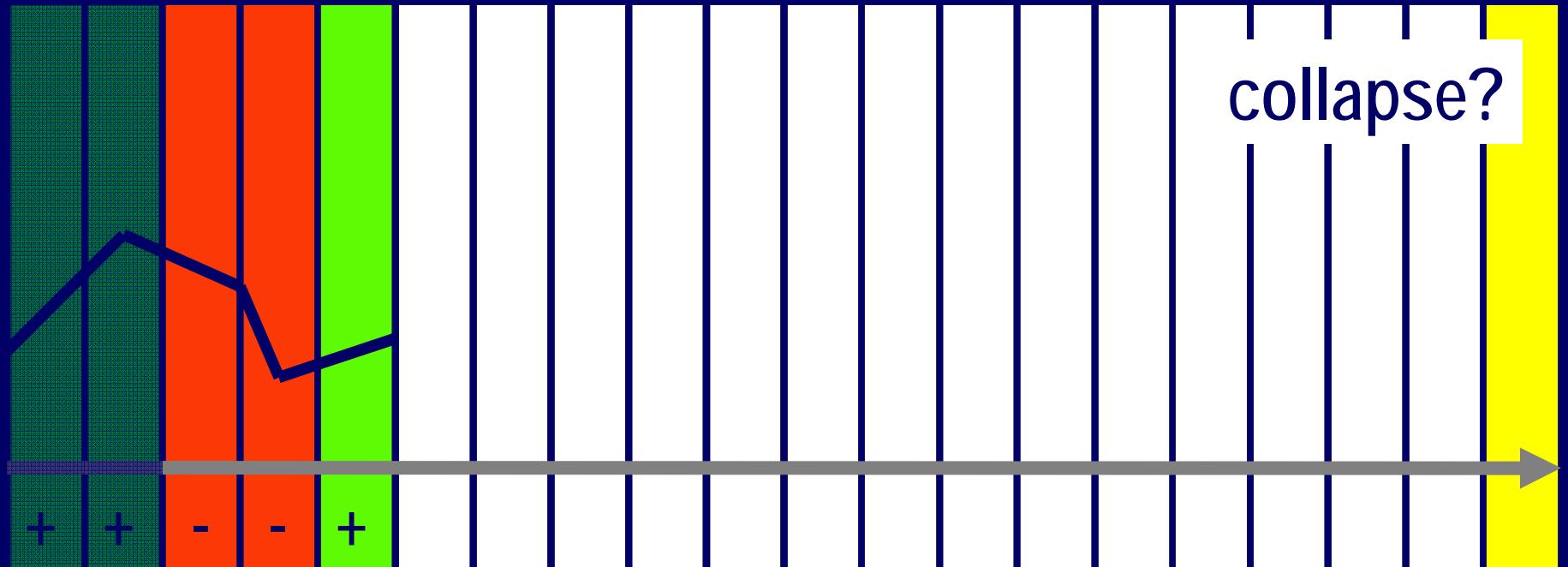
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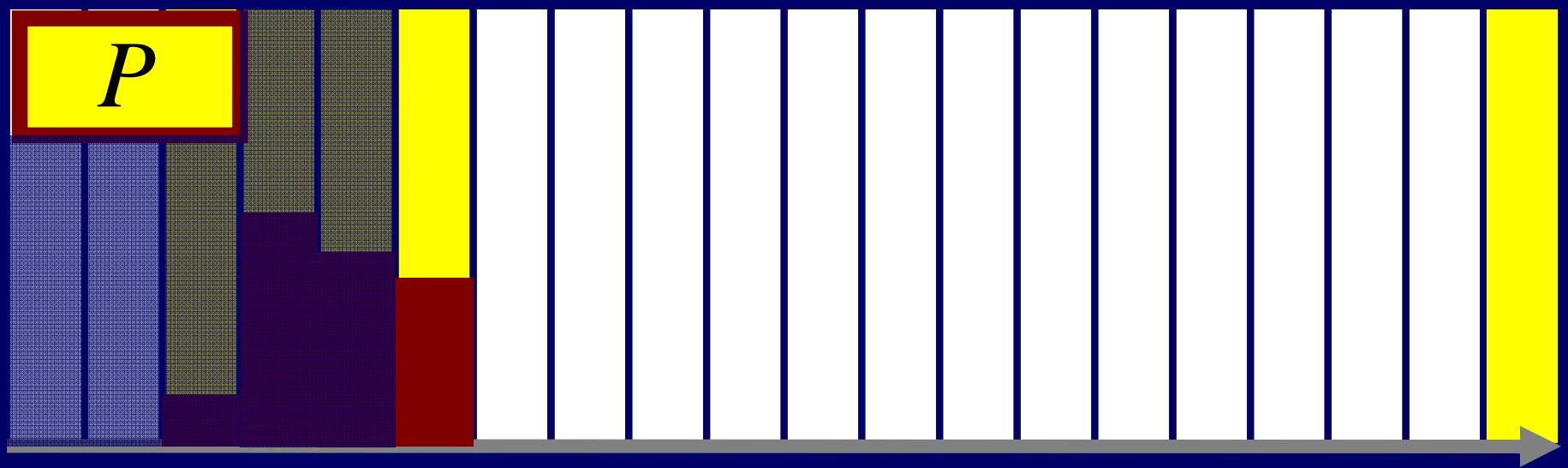
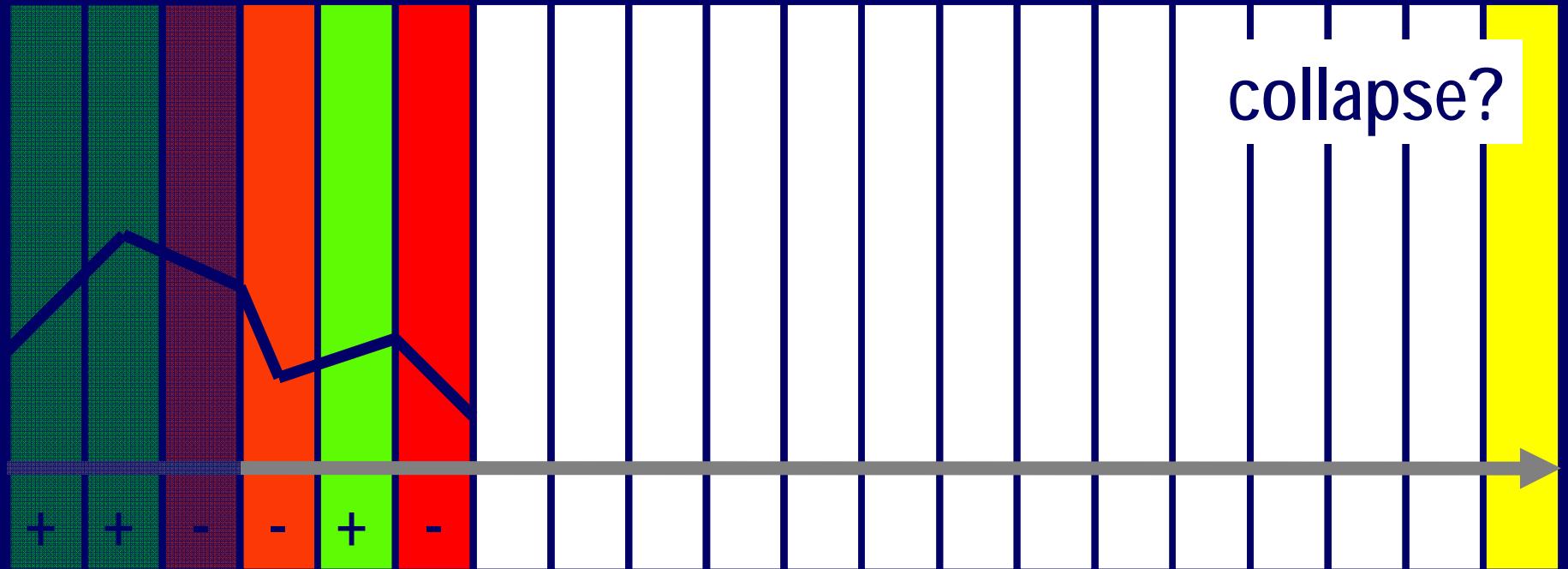
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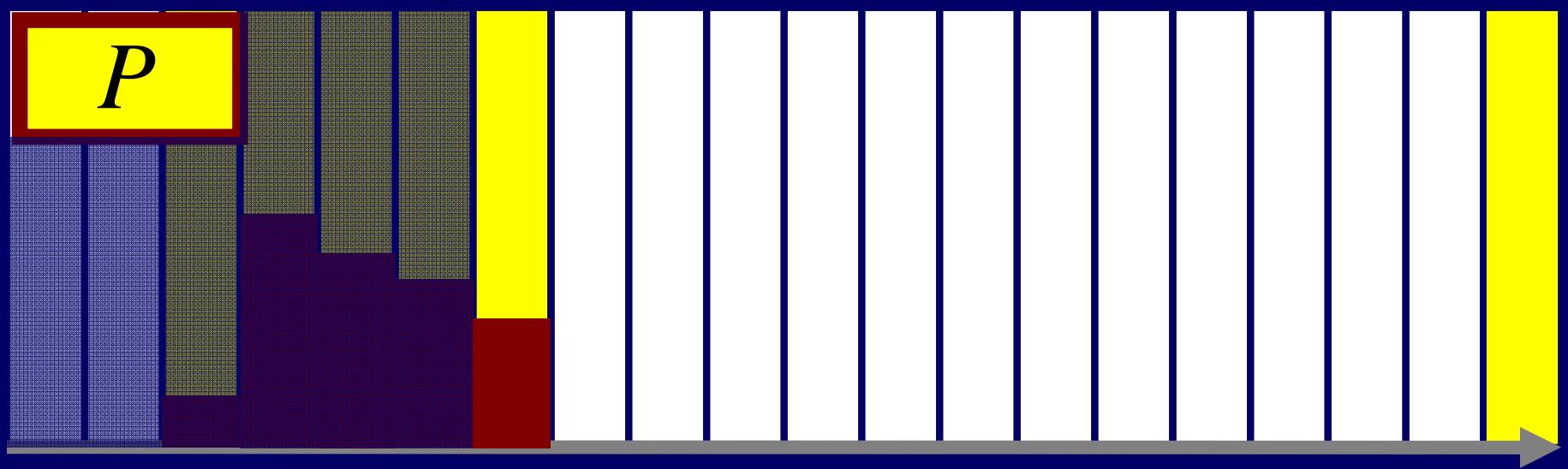
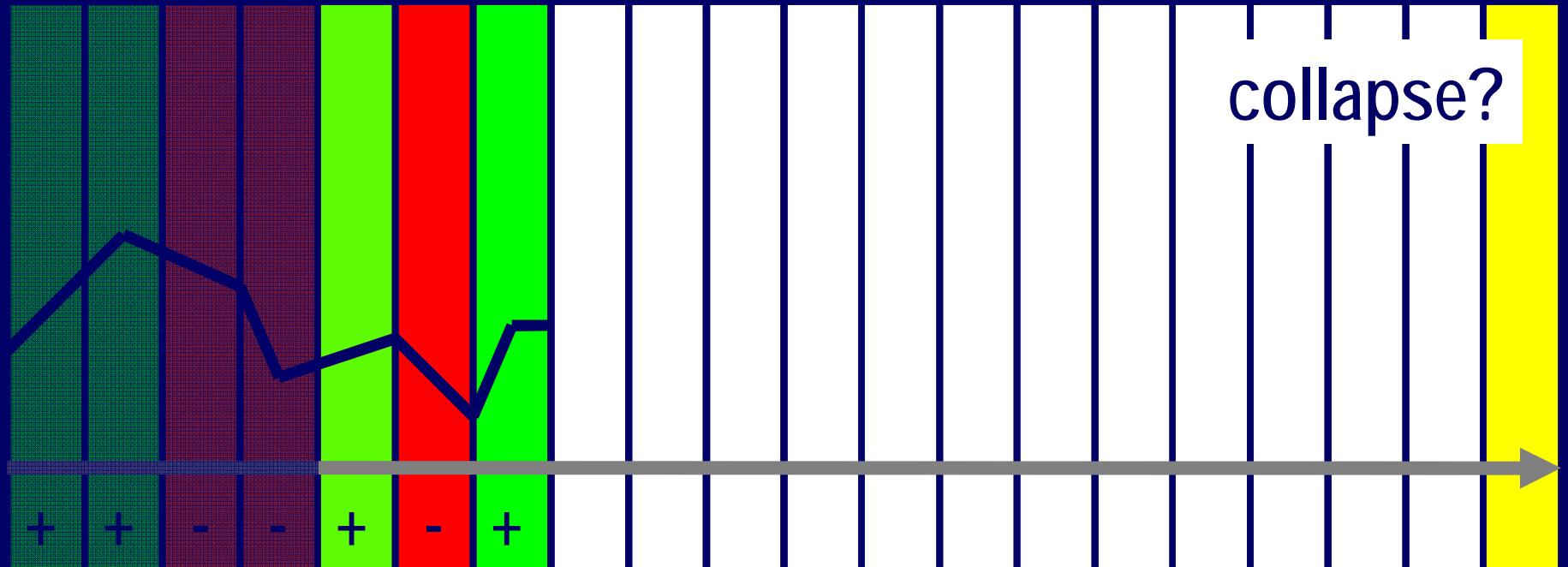
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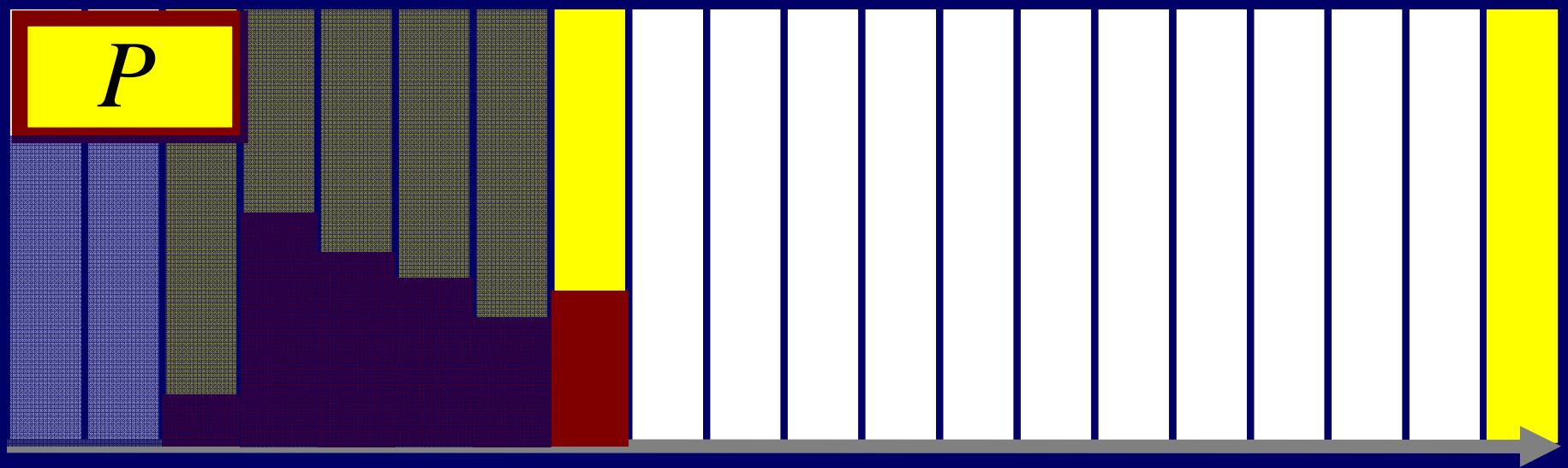
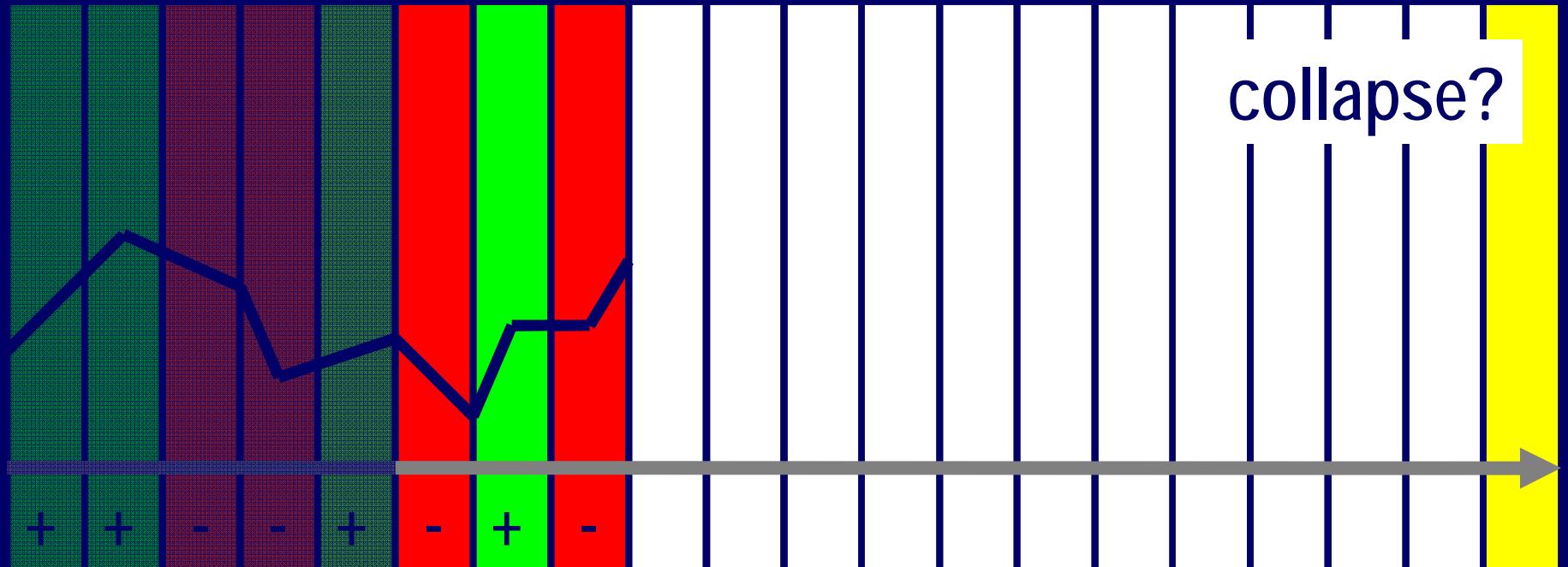
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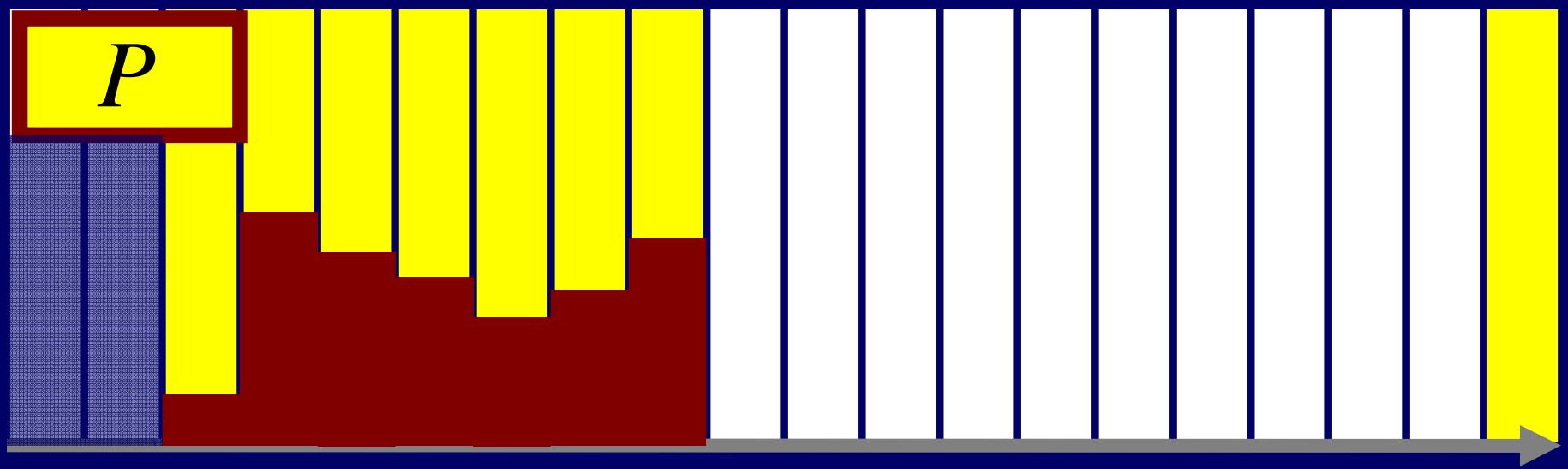
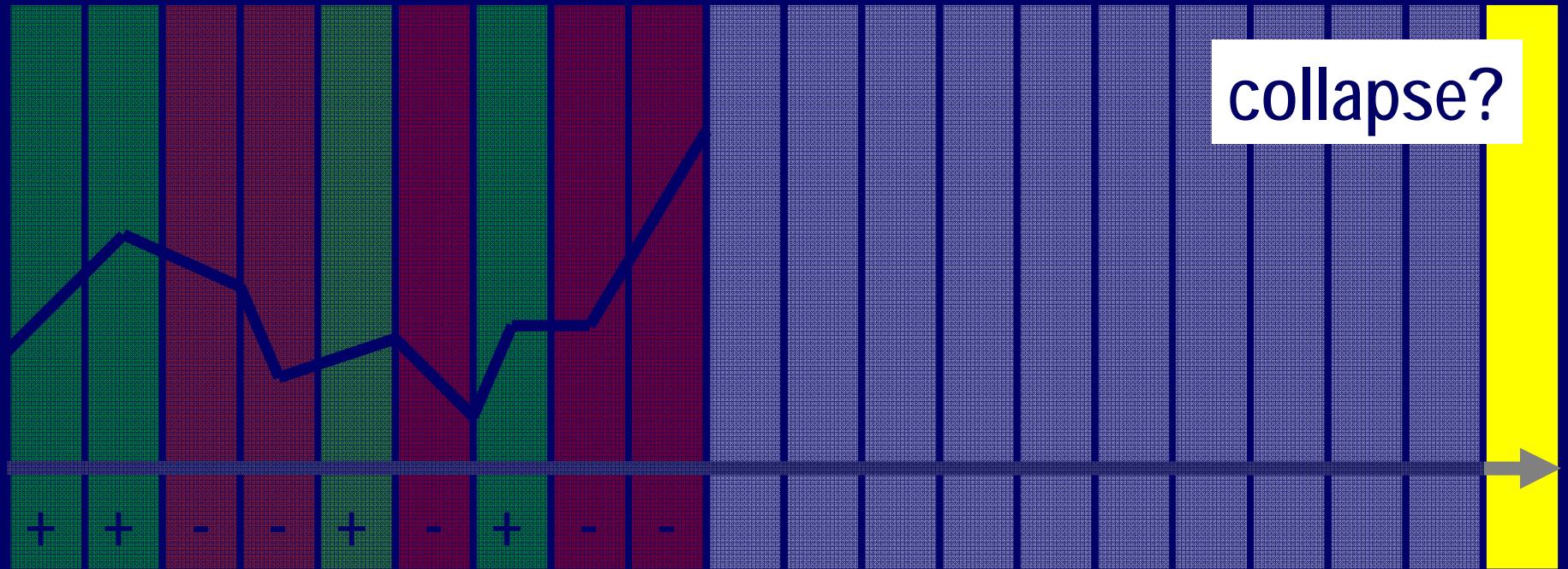
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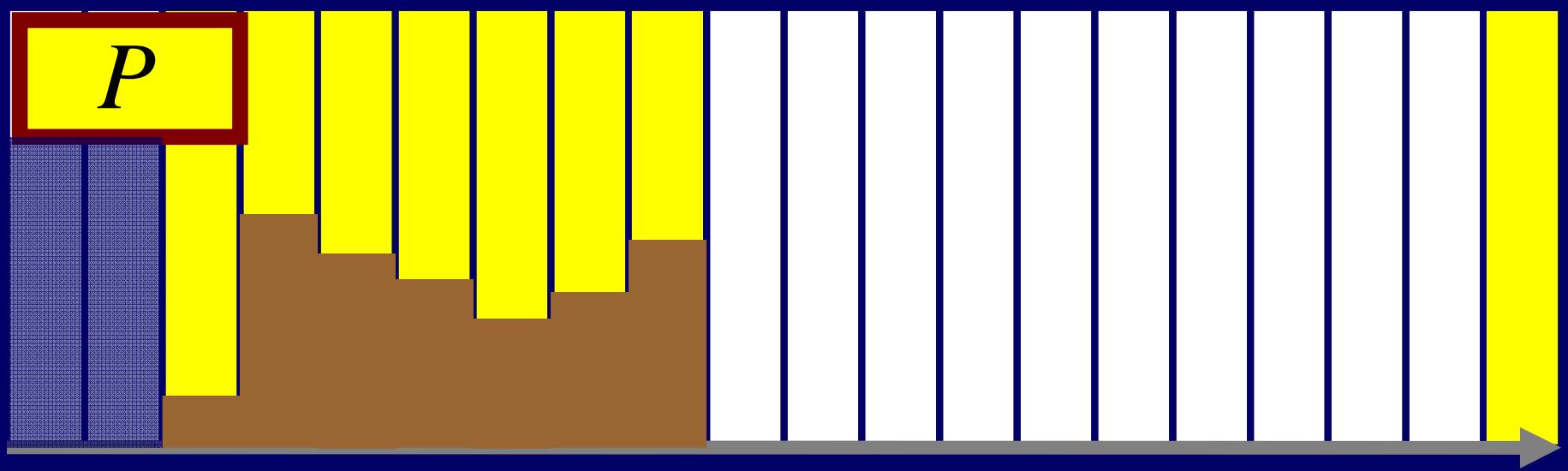
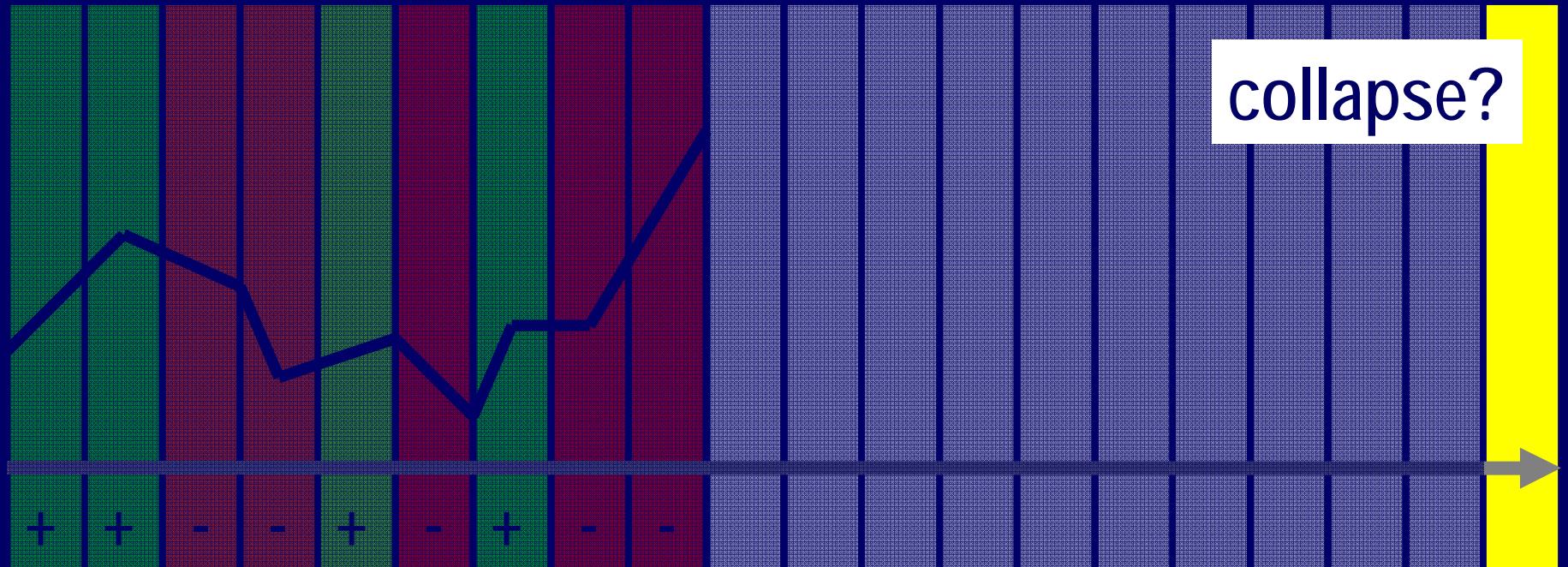
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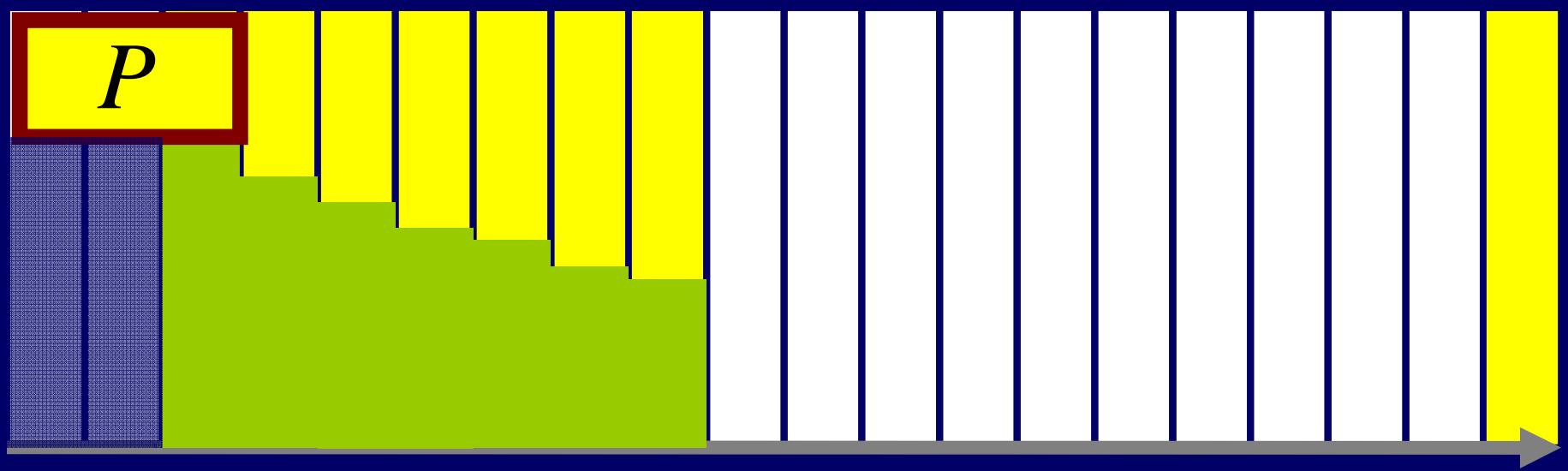
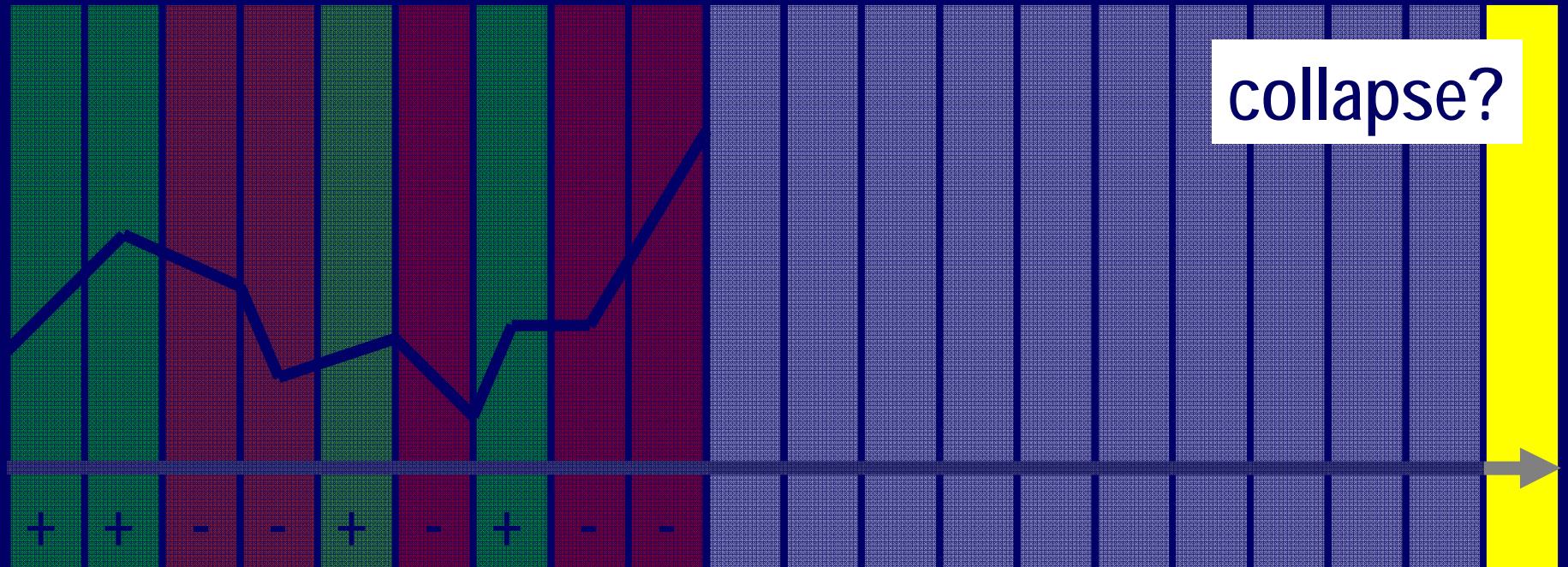
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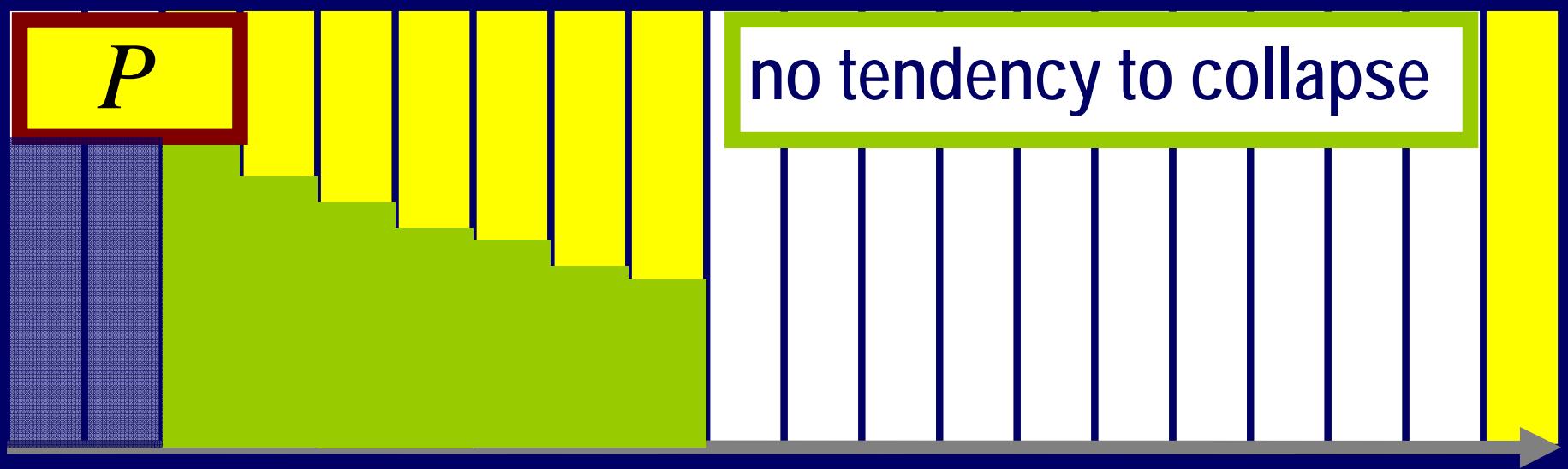
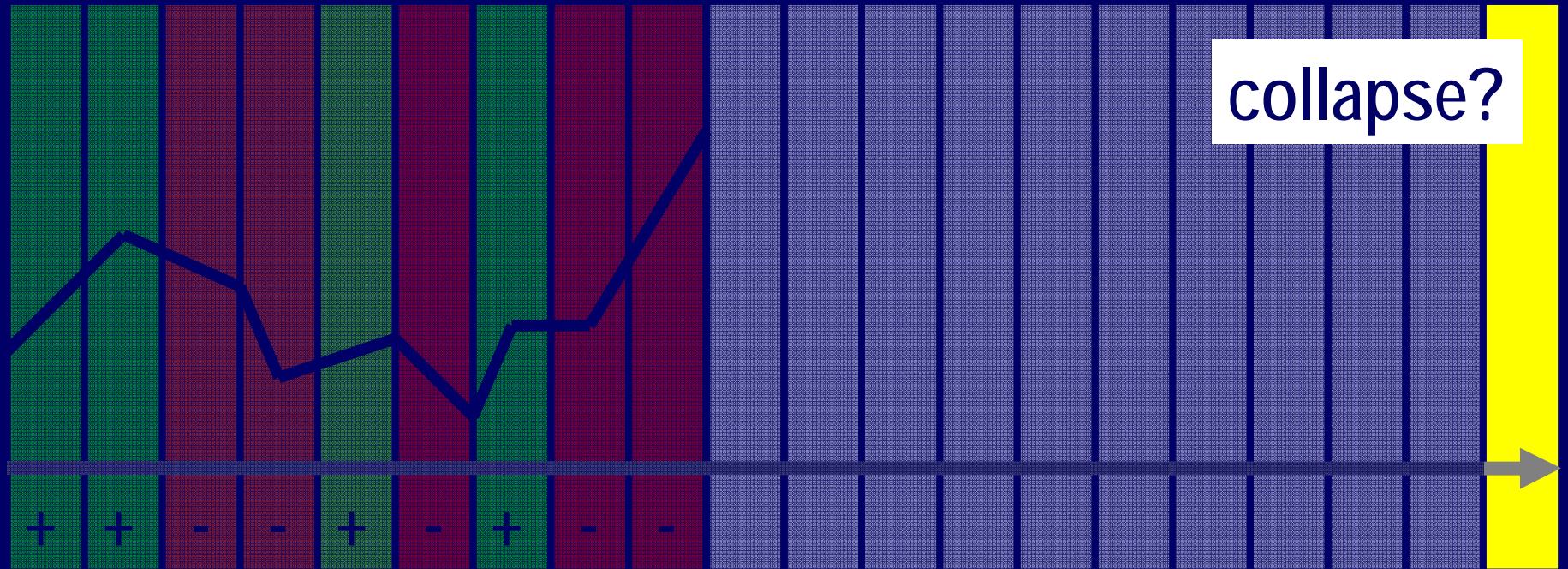
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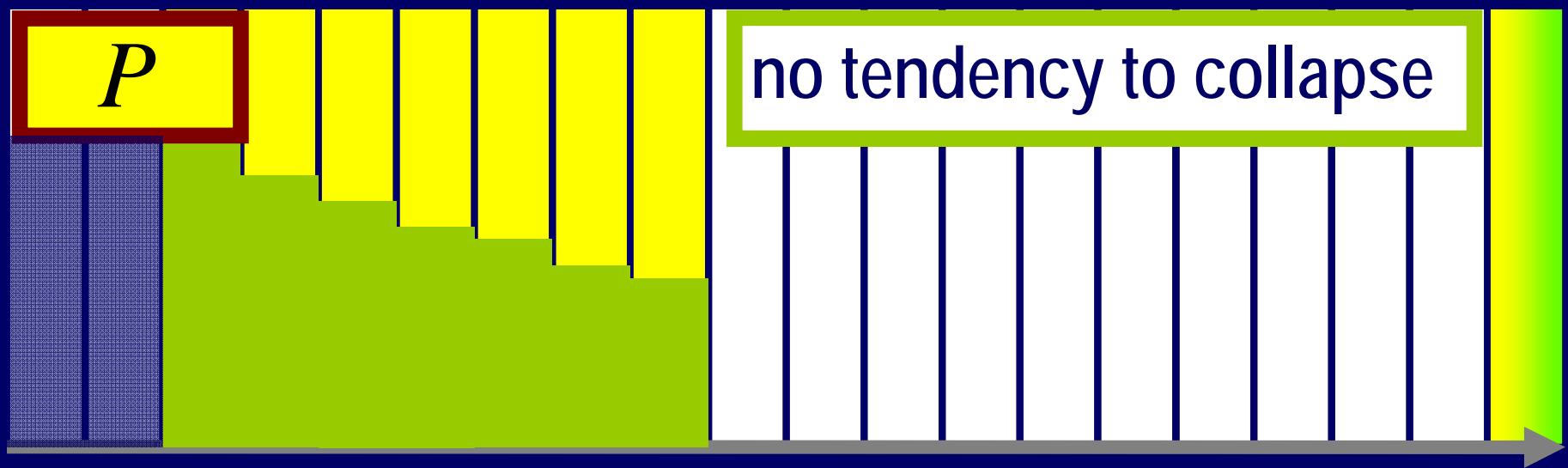
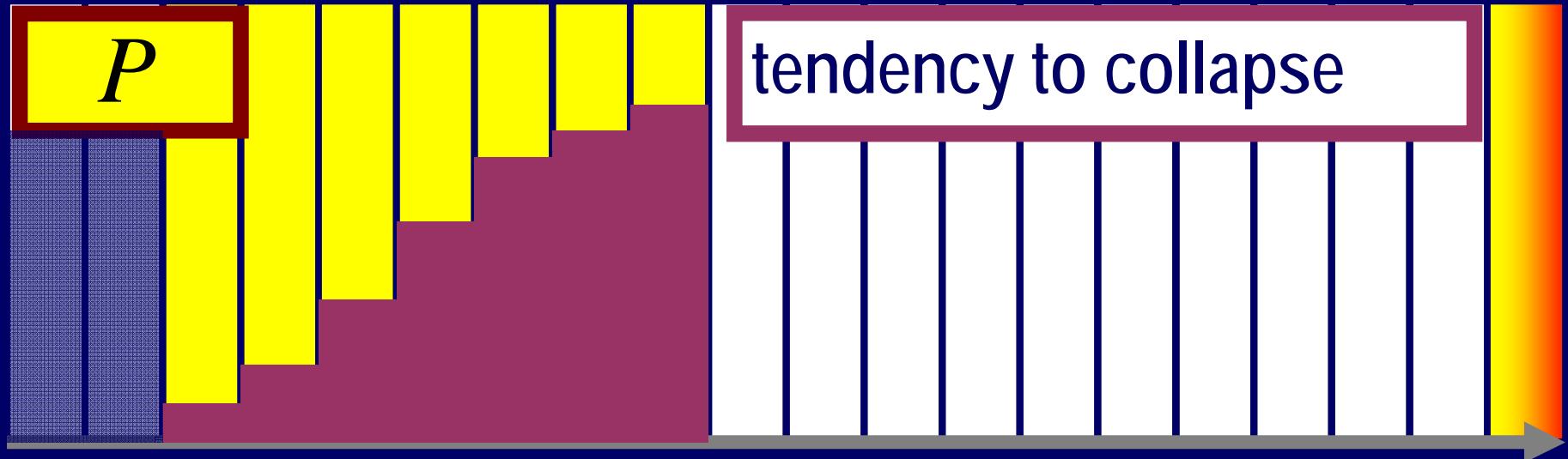
# Forecasting



# Forecasting



# Forecasting



# Example: financial crises

Financial crises are periods of significant economic instability and decline.

They can lead to widespread job losses, bankruptcies, and declines in asset values.

Common causes include overvalued asset markets, excessive debt, and regulatory failures.

Notable examples include the Great Depression, the 1929 stock market crash, and the 2008 global financial crisis.

These events often have long-term impacts on economies and societies.

Preparedness and early intervention are key to mitigating their effects.

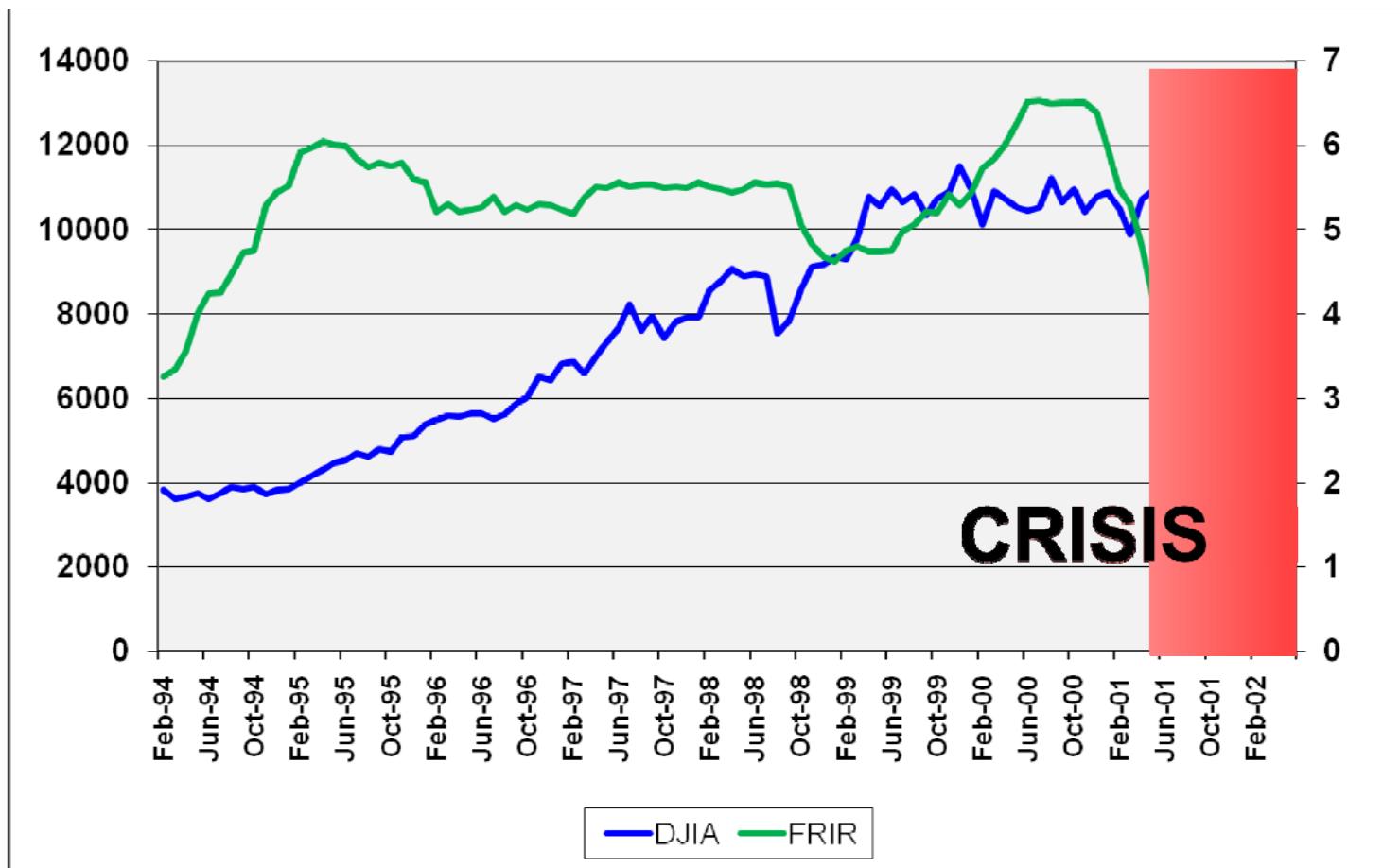
Understanding the underlying causes is crucial for preventing future crises.

Strategic planning and diversified portfolios can help manage financial risks.

International cooperation is essential for addressing global financial challenges.

# Example: financial crises

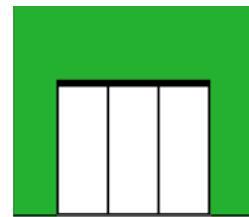
Inverse problem: Dot Com crisis, 2000-2001



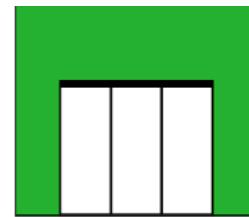
# Example: financial crises

Inverse problem: Dot Com crisis, 2000-2001

FRIR

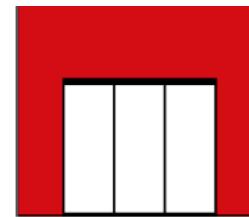


DJIA

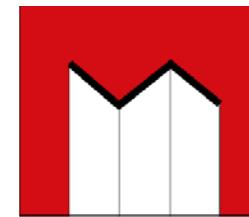


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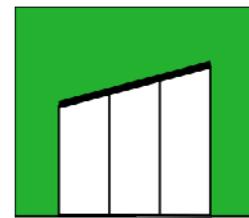
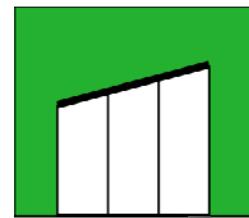
FRIR



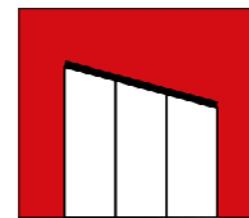
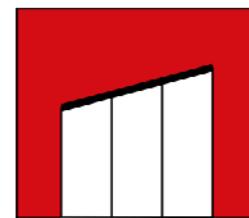
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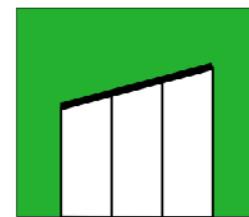
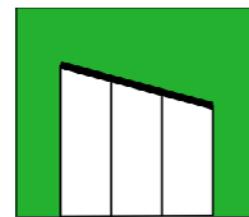
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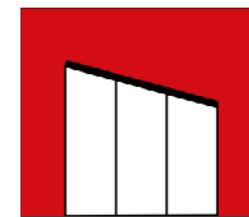
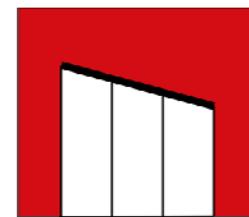
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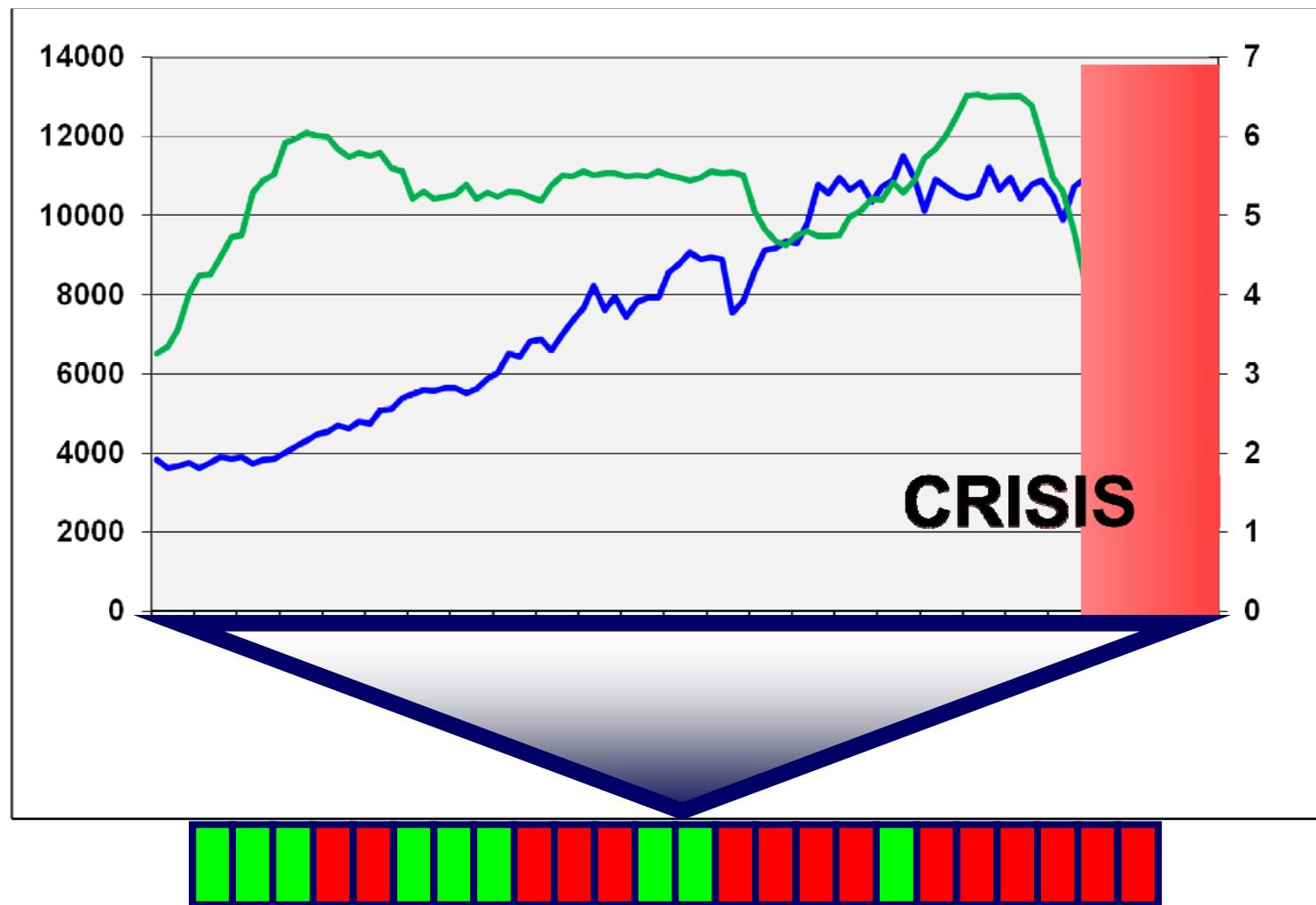
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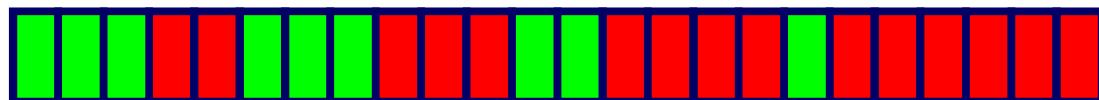
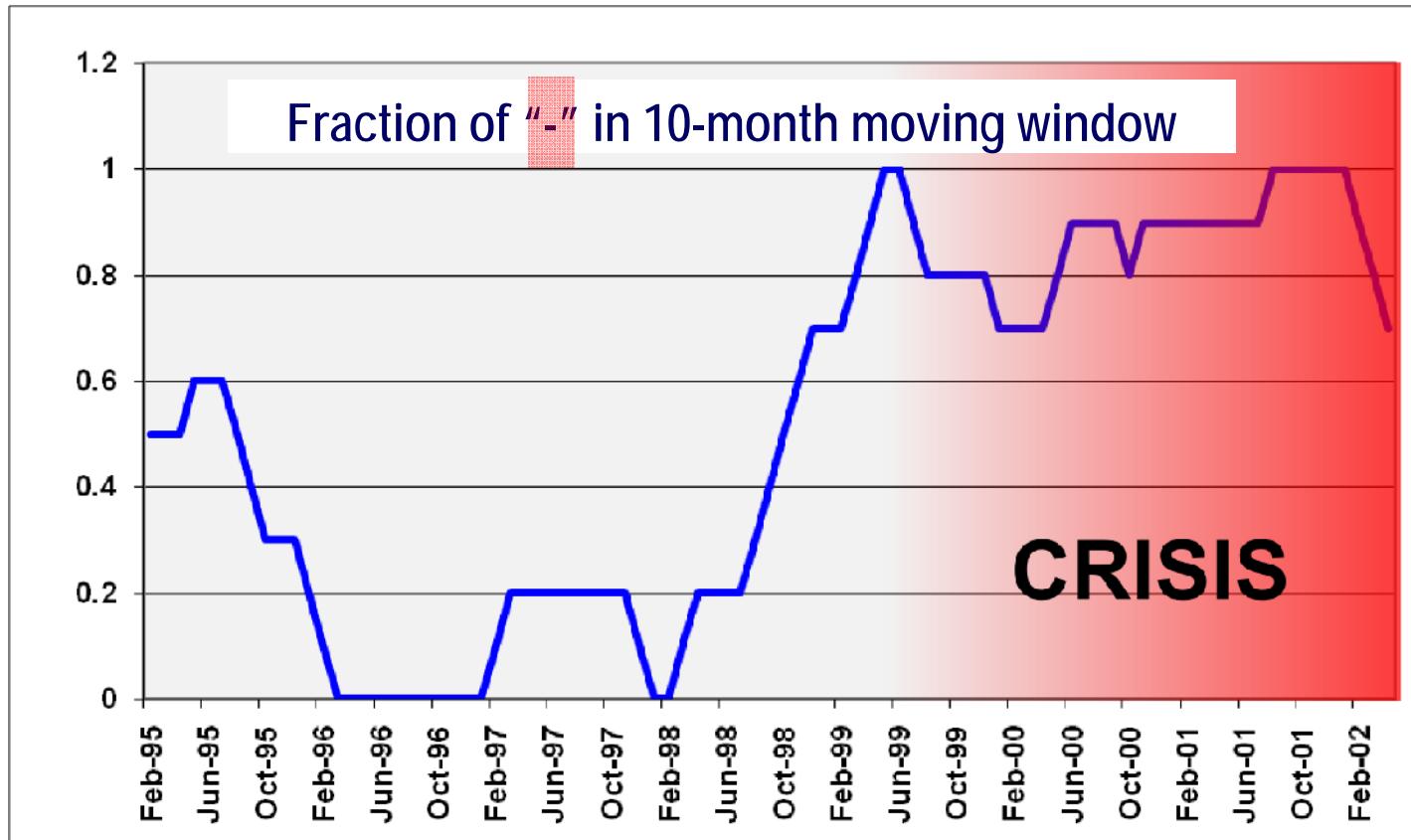
# Example: financial crises

Inverse problem: Dot Com crisis, 2000-2001



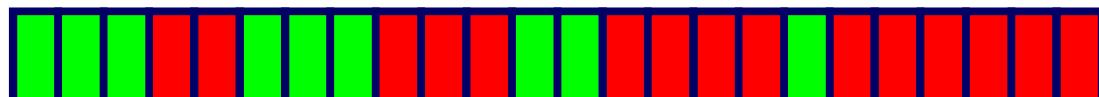
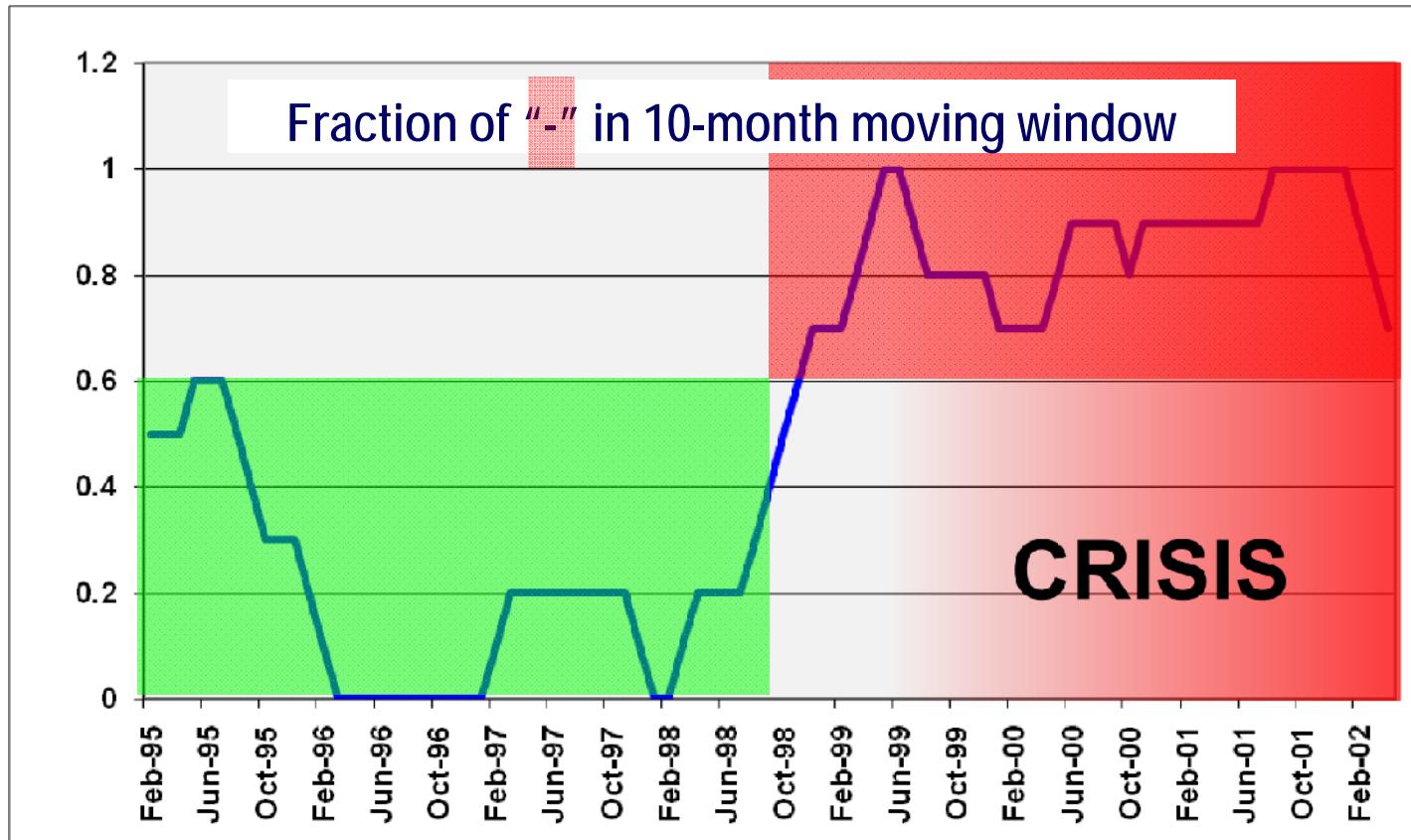
# Example: financial crises

Inverse problem: Dot Com crisis, 2000-2001



# Example: financial crises

Inverse problem: Dot Com crisis, 2000-2001



# Example: financial crises

Statistical analysis of 1954-2001 data

+ + +	+ + -	+ - +	+ - -	- + +	- + -	- - +	- - -	
453/479	0	0	0	26/29	0	0	0	+ + +
26/479	0	0	0	3/29	0	0	0	+ + -
0	0	0	0	0	0	0	0	+ - +
0	1	0	0	0	1	0	0	+ - -
0	0	1/2	0	0	0	29/33	0	- + +
0	0	1/2	0	0	0	4/33	0	- + -
0	0	0	9/33	0	0	0	24/45	- - +
0	0	0	24/33	0	0	0	21/45	- - -

# Example: financial crises

Statistical analysis of 1954-2001 data

+ + +	+ + -	+ - +	+ - -	- + +	- + -	- - +	- - -	+ + +
453/479								+ + -
26/479	0	0	0	3/29	0	0		+ - +
0	1	0	0	0	1	0	0	+ - -
0	0	1/2	0	0	0	29/33	0	- + +
0	0	1/2	0	0	0	4/33	0	- + -
0	0	0	9/33	0	0	0	24/45	- - +
0	0	0	24/33	0	0	0	21/45	- - -

# Example: financial crises

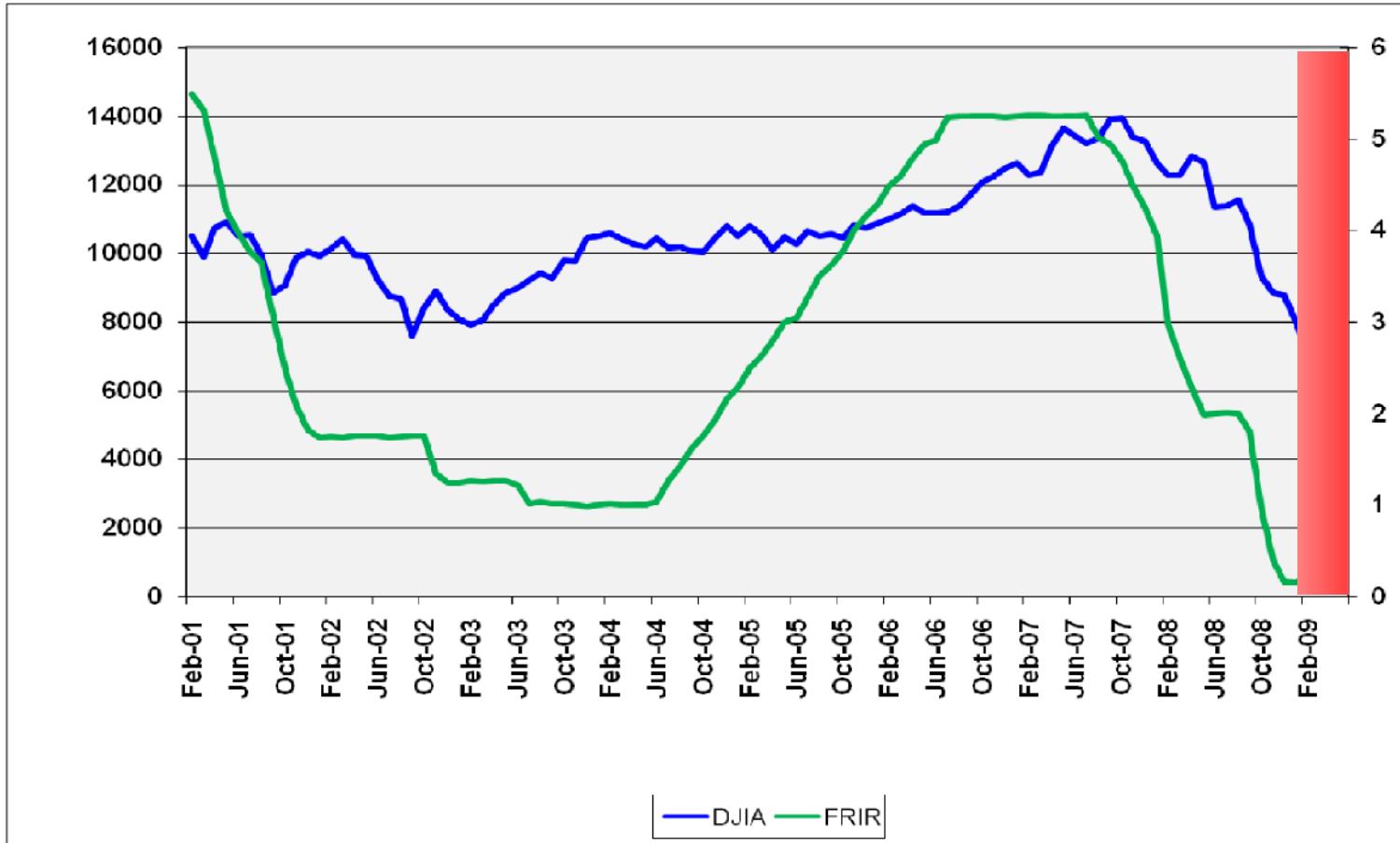
Statistical analysis of 1954-2001 data

Random process

+ + +	+ + -	+ - +	+ - -	- + +	- + -	- - +	- - -	
453/479	0	0	0	26/29	0	0	0	+ + +
26/479	0	0	0	3/29	0	0	0	+ + -
0	0	0	0	0	0	0	0	+ - +
0	1	0	0	0	1	0	0	+ - -
0	0	1/2	0	0	0	29/33	0	- + +
0	0	1/2	0	0	0	4/33	0	- + -
0	0	0	9/33	0	0	0	24/45	- - +
0	0	0	24/33	0	0	0	21/45	- - -

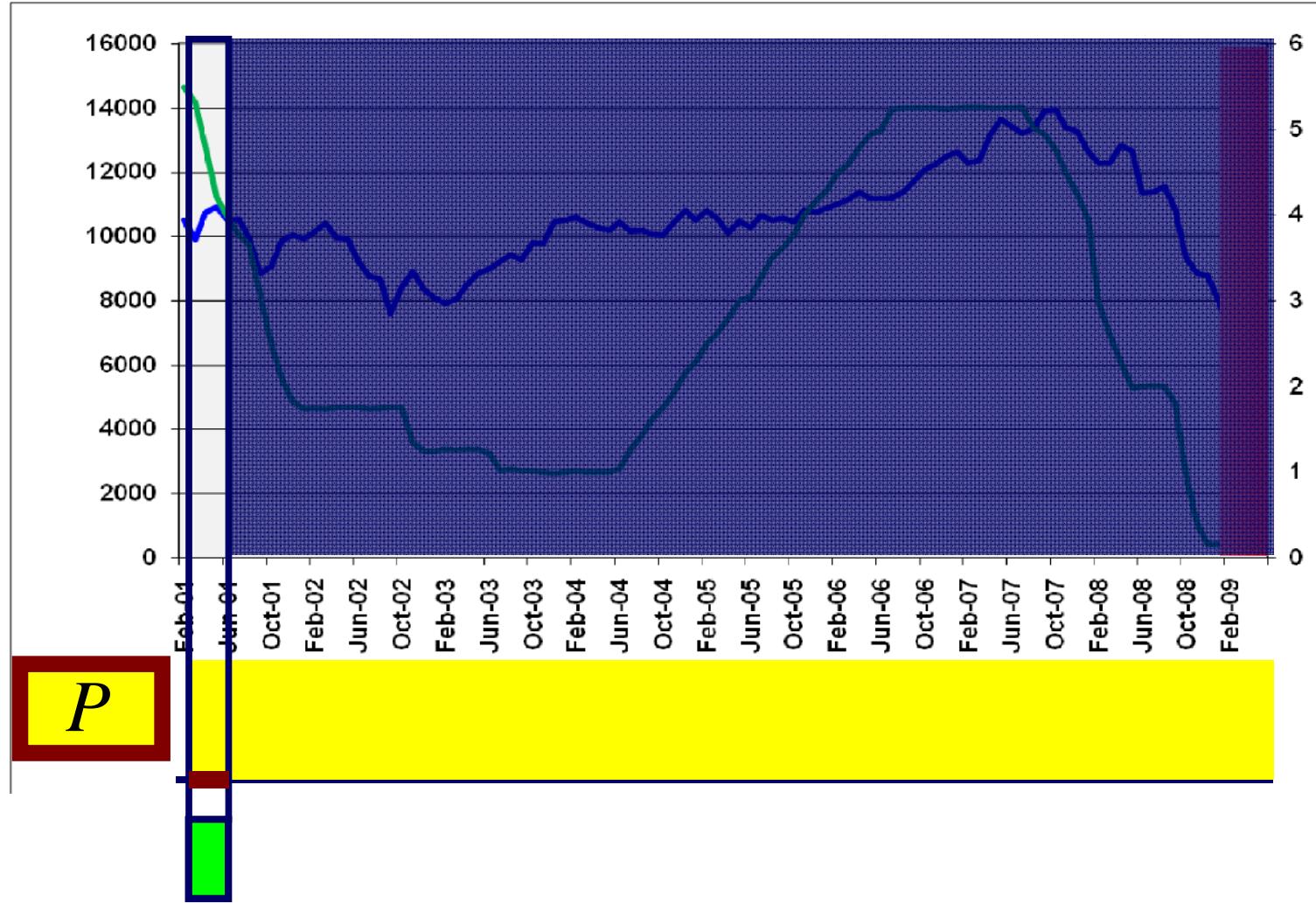
# Example: financial crises

Forecasting: crisis of 2008-2009



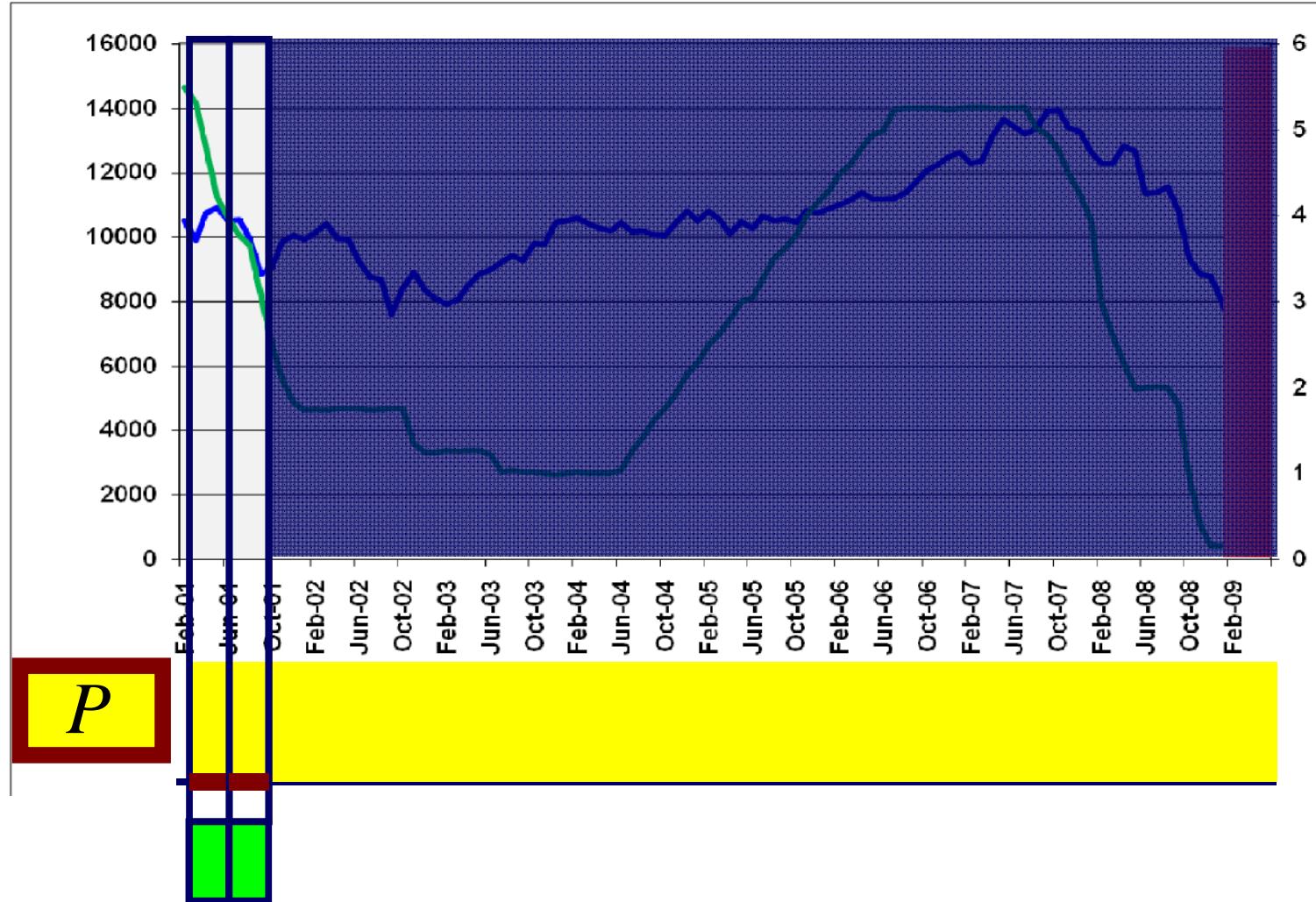
# Example: financial crises

## Forecasting: crisis of 2008-2009



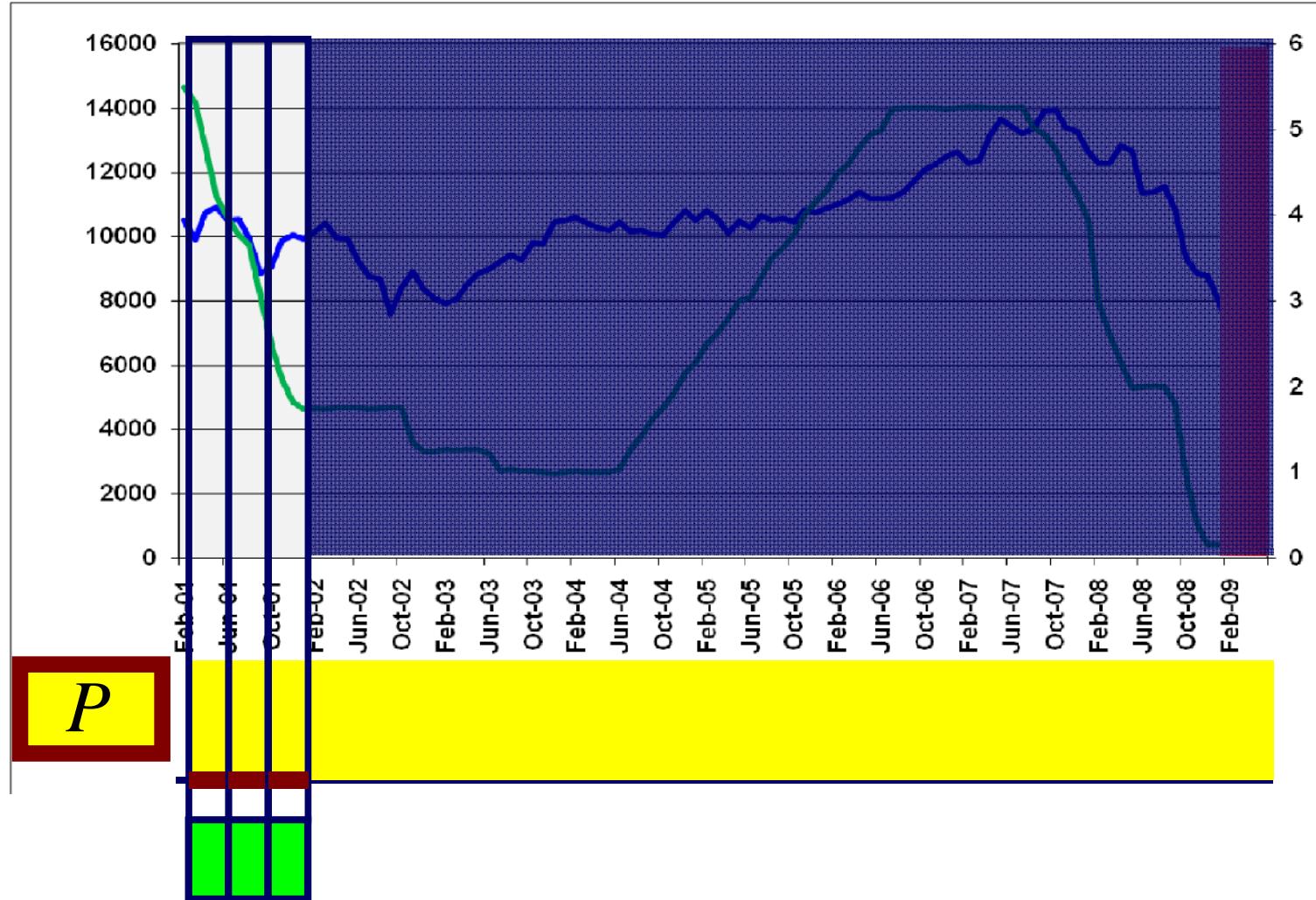
# Example: financial crises

Forecasting: crisis of 2008-2009



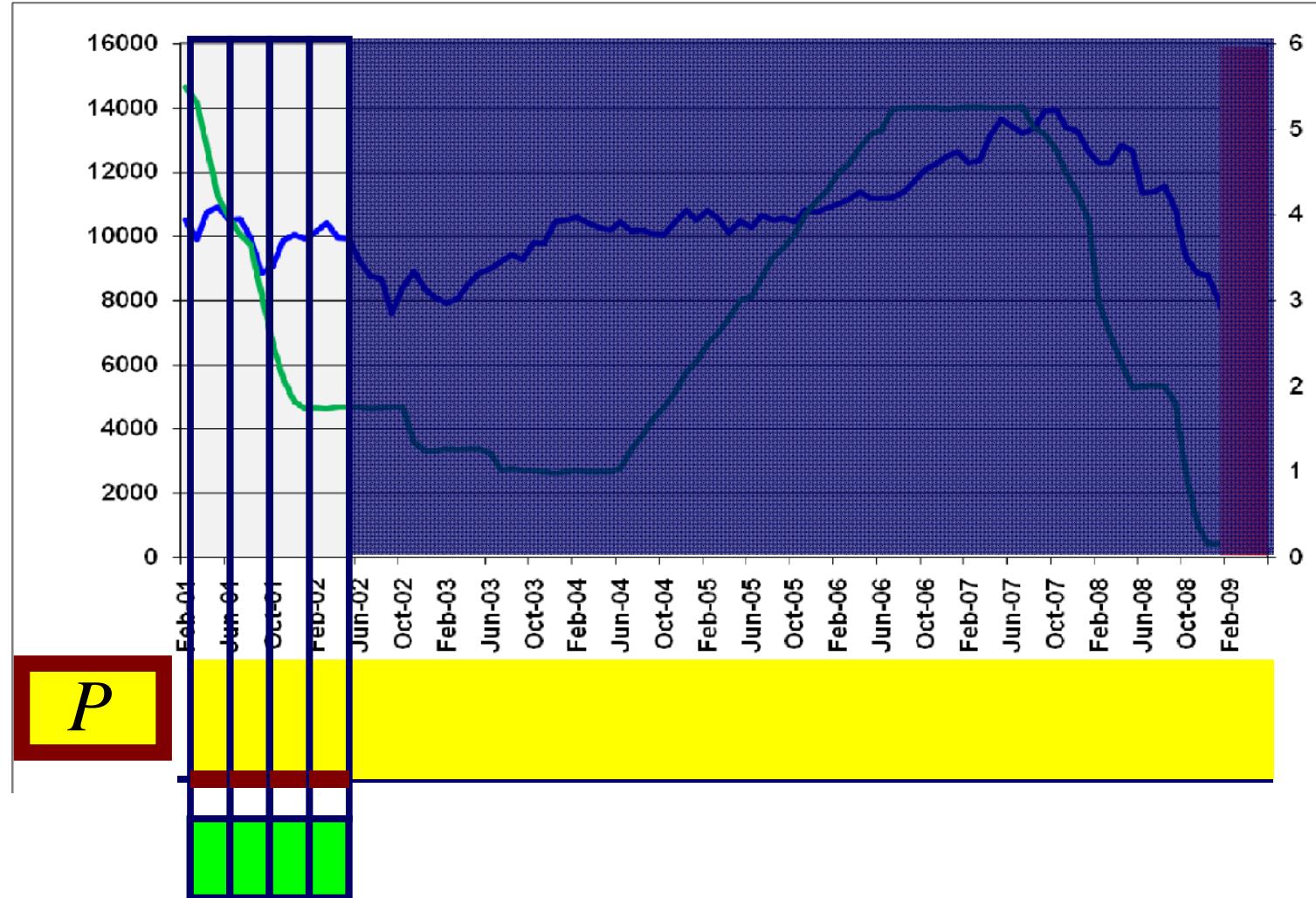
# Example: financial crises

Forecasting: crisis of 2008-2009



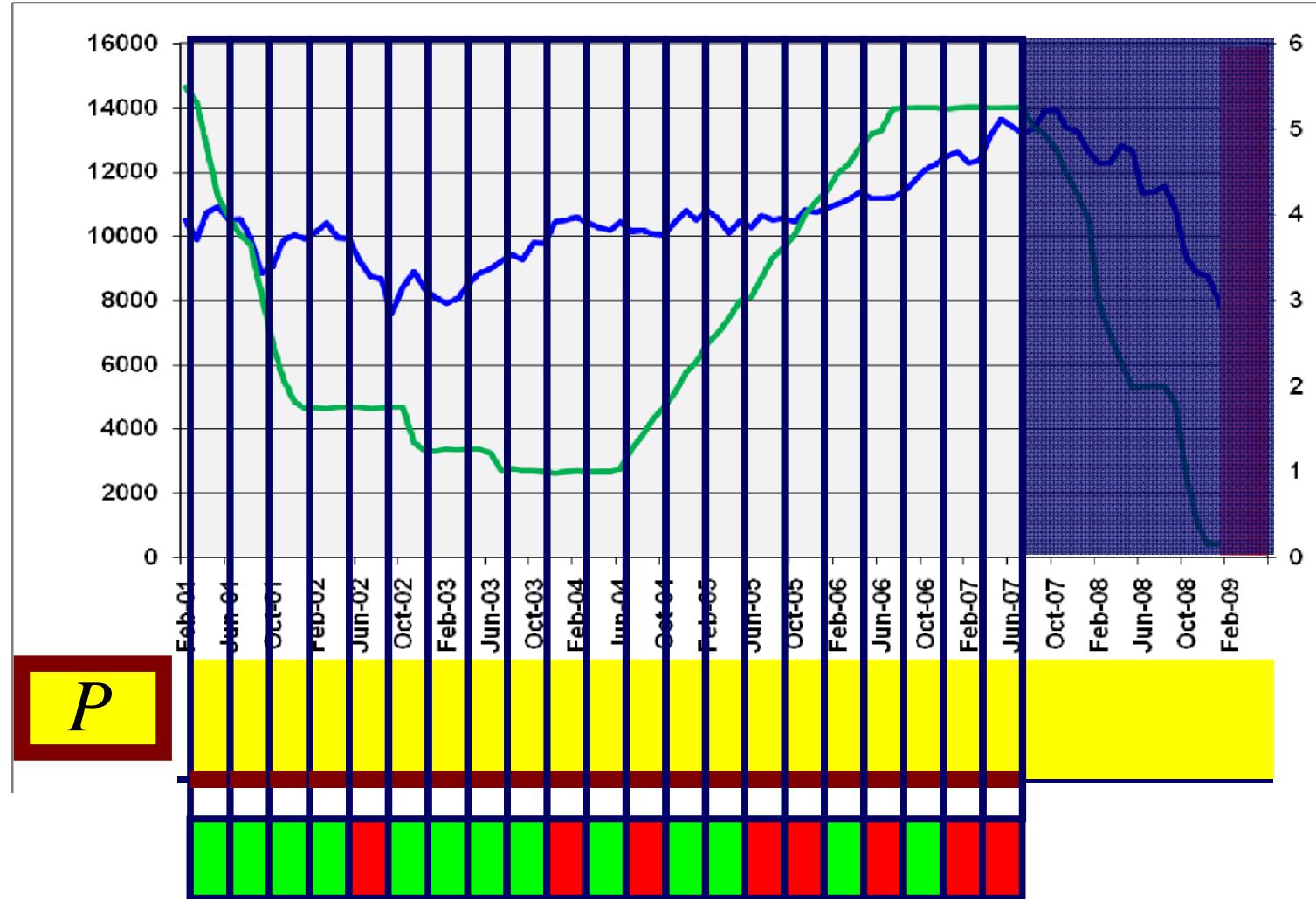
# Example: financial crises

Forecasting: crisis of 2008-2009



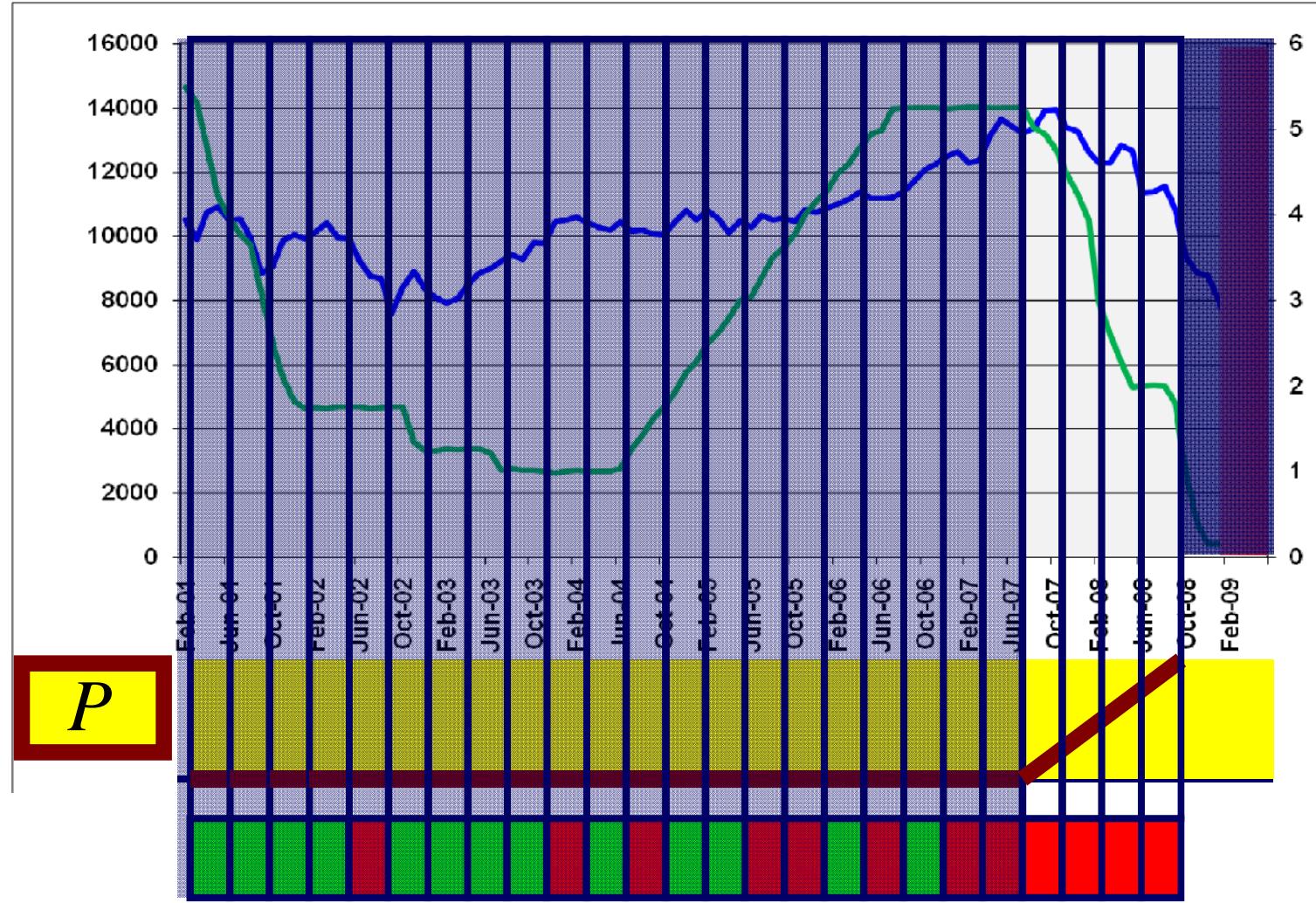
# Example: financial crises

Forecasting: crisis of 2008-2009



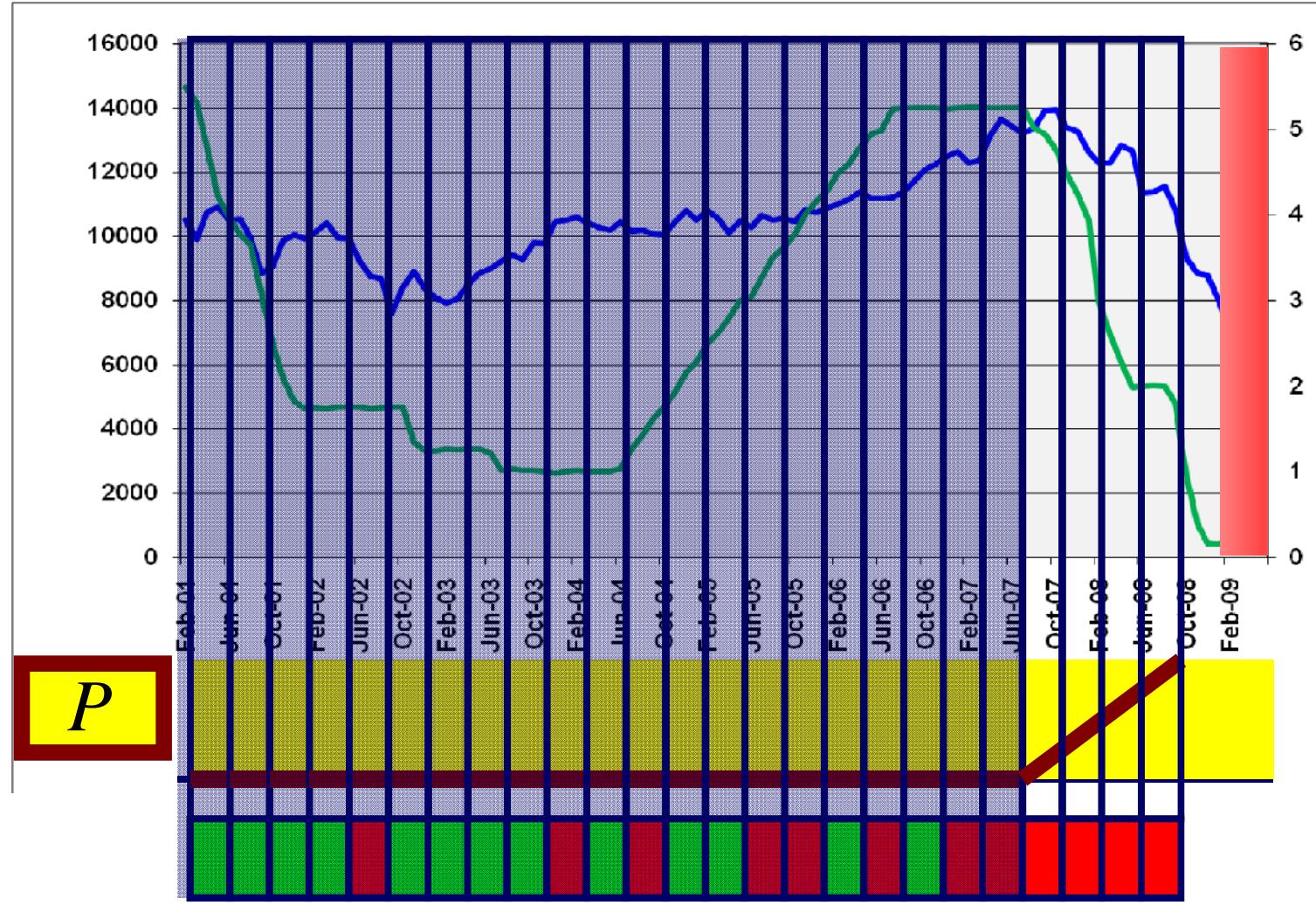
# Example: financial crises

## Forecasting: crisis of 2008-2009



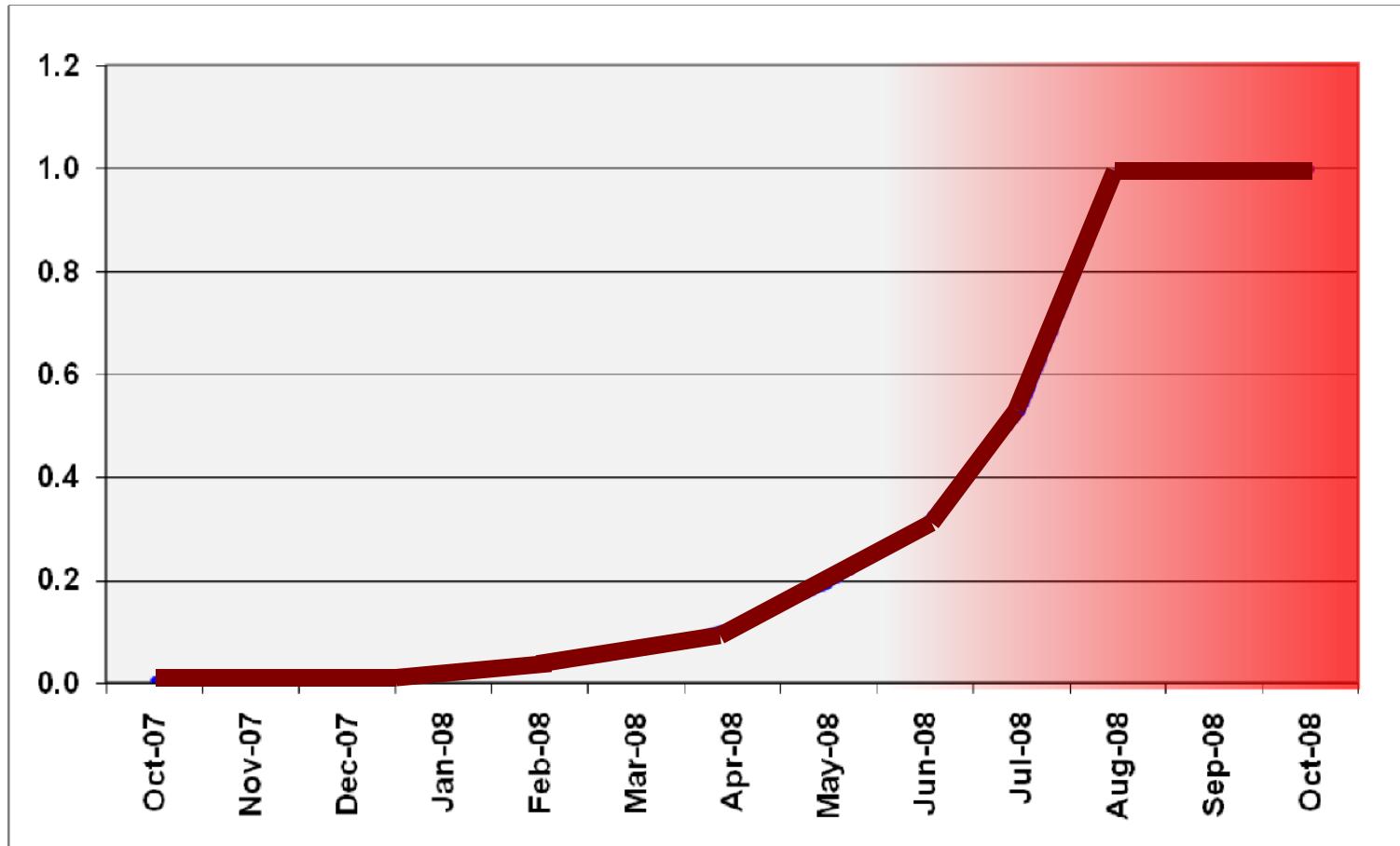
# Example: financial crises

## Forecasting: crisis of 2008-2009



# Example: financial crises

## Forecasting: crisis of 2008-2009



Thank you