SIMC

Probably the best tuning rule in the world

simple

$$K_{\mathrm{PI}}(s) = k_c \frac{(\tau_i s + 1)}{\tau_i s} \qquad G(s) = \frac{k e^{-\theta s}}{(\tau s + 1)}$$

SIMC rule (first order)

$$k_c = \frac{1}{k} \frac{\tau}{\tau_c + \theta}$$

$$\tau_i = \min\{\tau, 4(\tau_c + \theta)\}$$

speed up for slow poles (load disturbance)

tuning constant

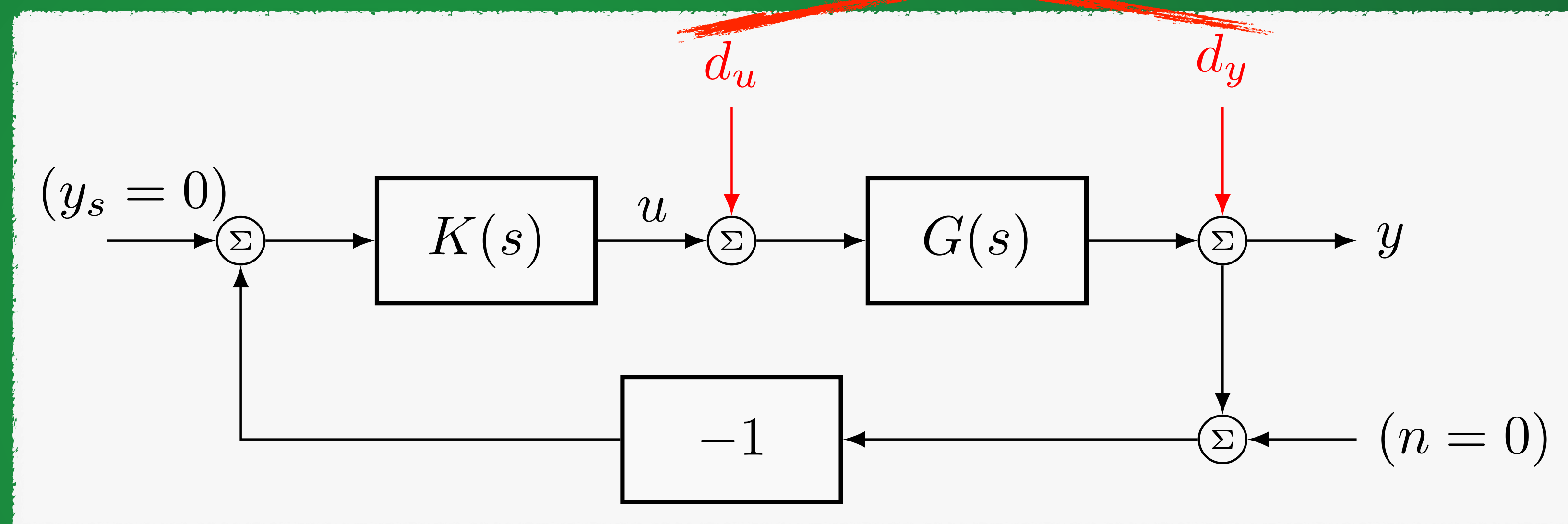
recommended $\tau_c = \theta$

Defining the optimum

Trade-off between performance and robustness

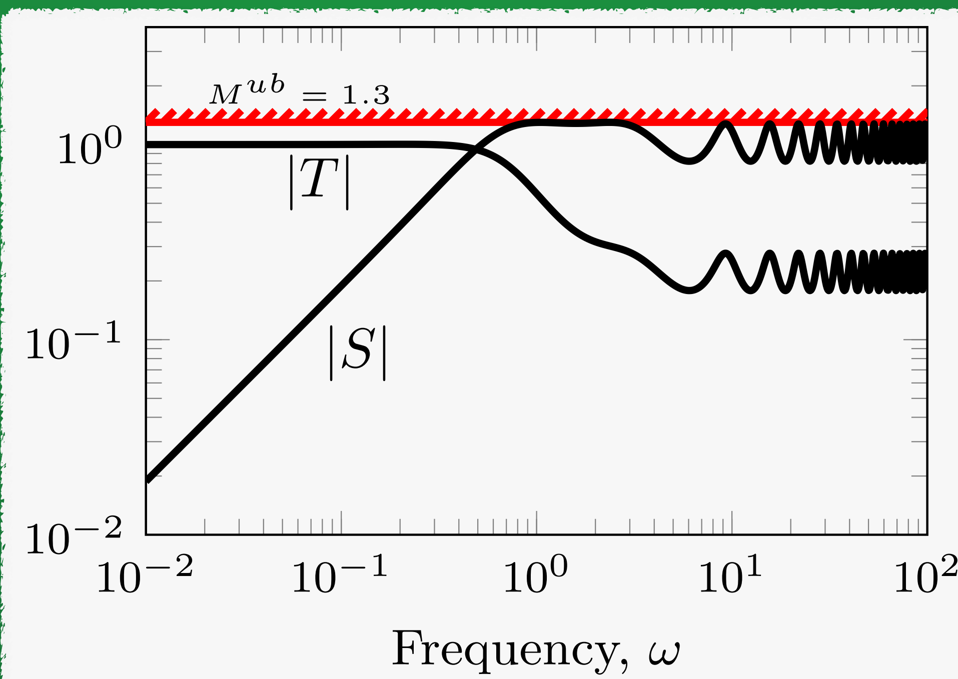
both input and output disturbance

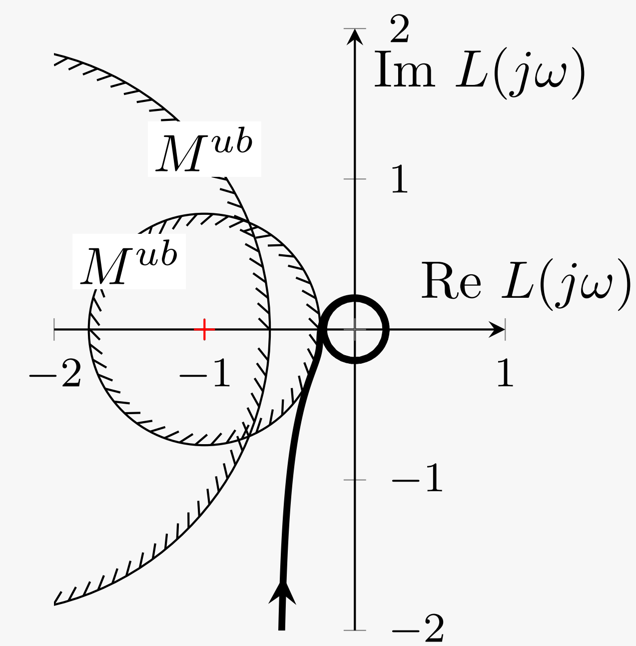
Performance:
weighted IAE



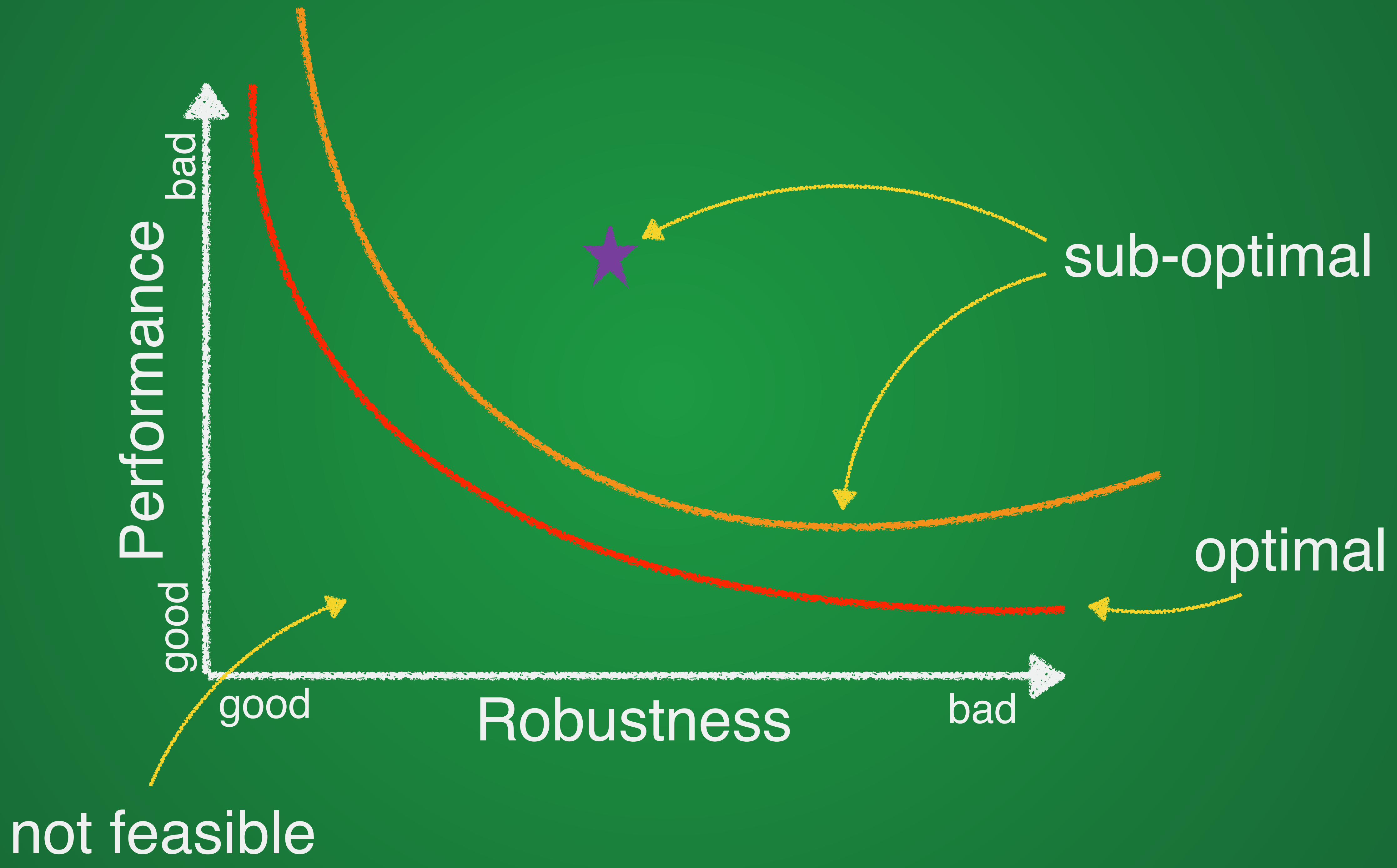
$$0.5\left(\frac{\mathrm{IAE}_{dy}(p)}{\mathrm{IAE}^{\circ}_{dy}} + \frac{\mathrm{IAE}_{du}(p)}{\mathrm{IAE}^{\circ}_{du}}\right)$$

Robustness:
Ms and Mt





The trade-off



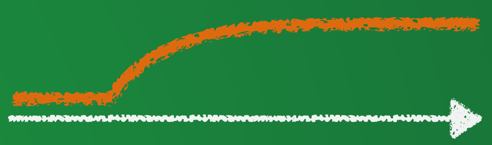
The Models

$$G(s) = e^{-s}$$

Delay dominated

$$G(s) = \frac{e^{-s}}{s+1}$$

Balanced

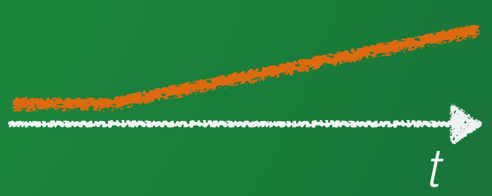


$$G(s) = \frac{e^{-s}}{8s+1}$$

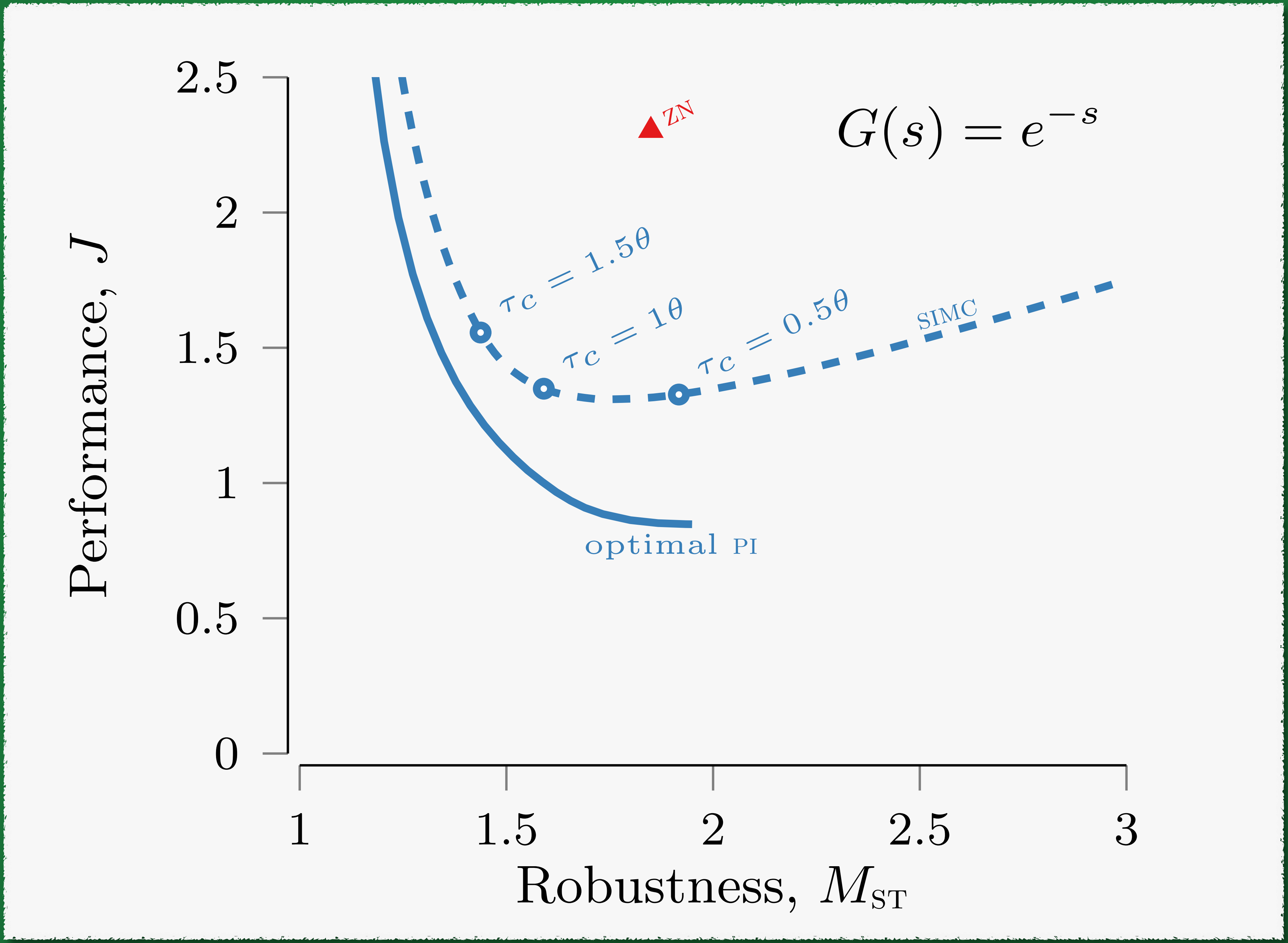
SIMC Special

$$G(s) = \frac{e^{-s}}{s}$$

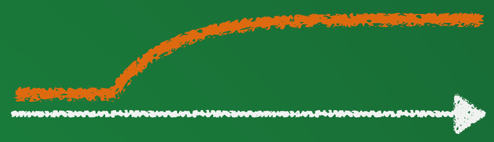
Lag dominated

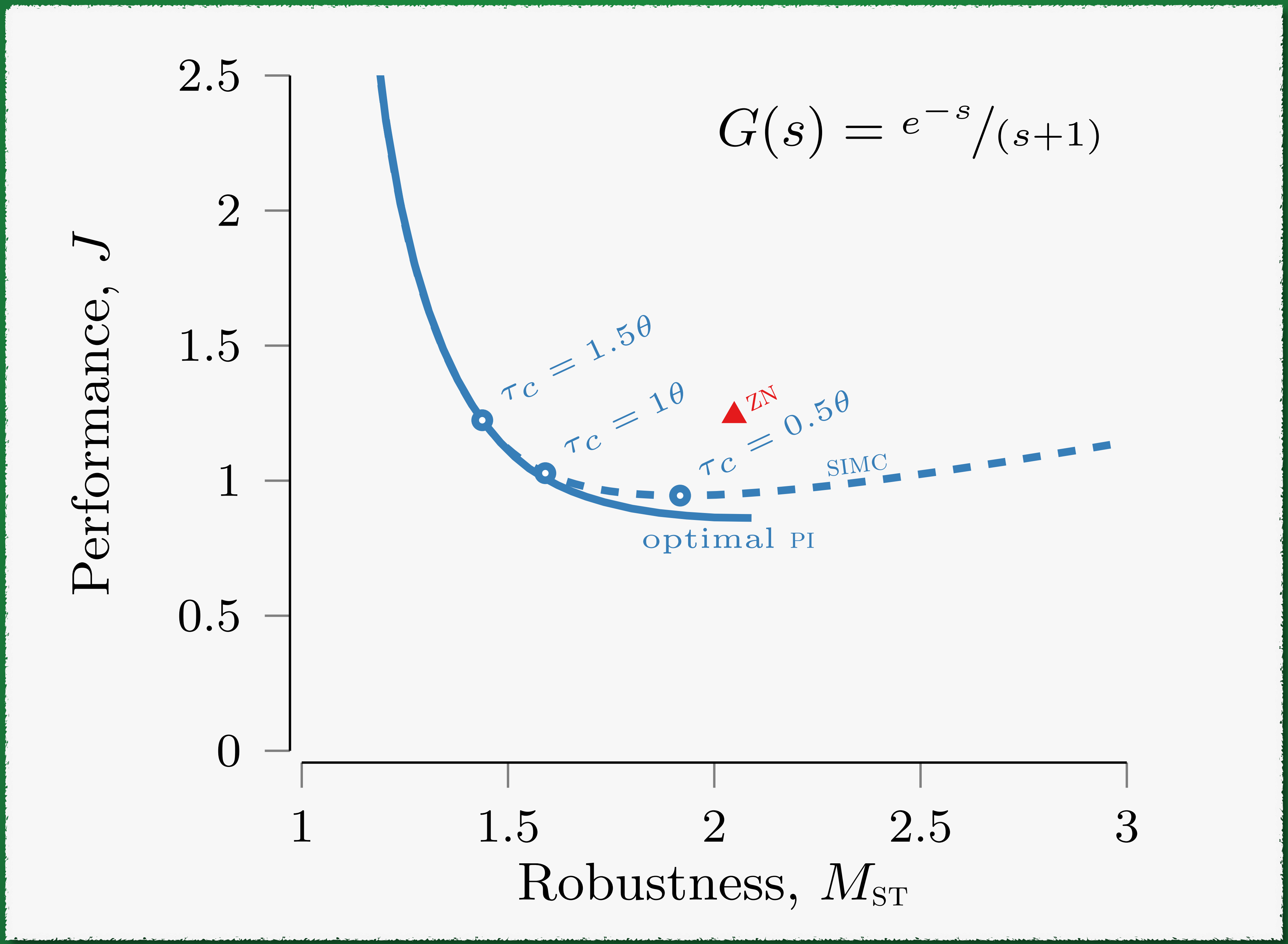


$G(s) = e^{-s}$ Delay dominated

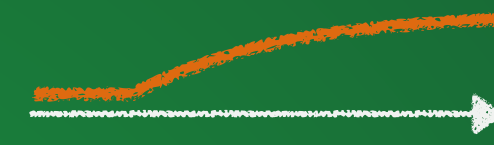


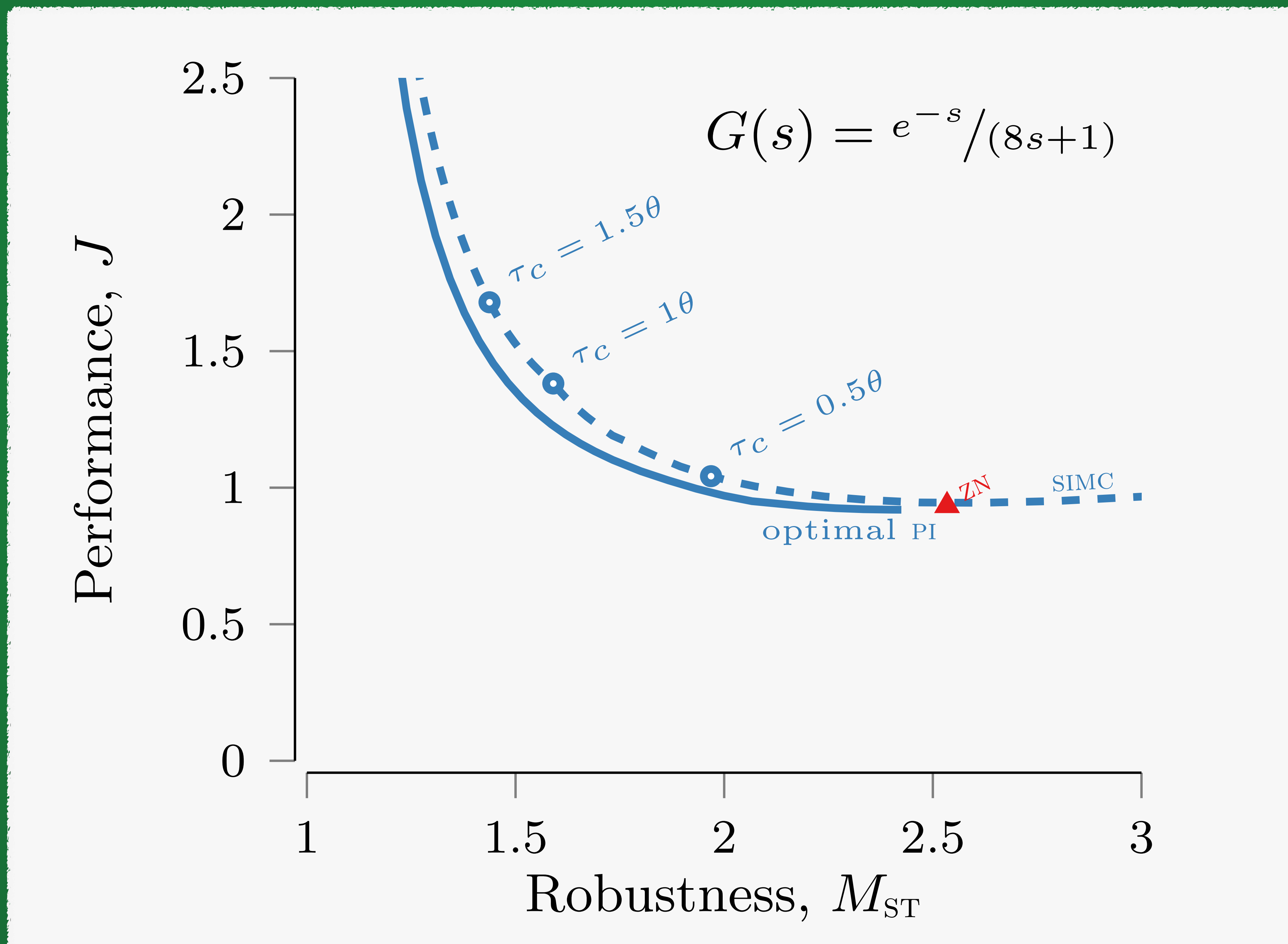
$$G(s) = \frac{e^{-s}}{s+1}$$ Balanced





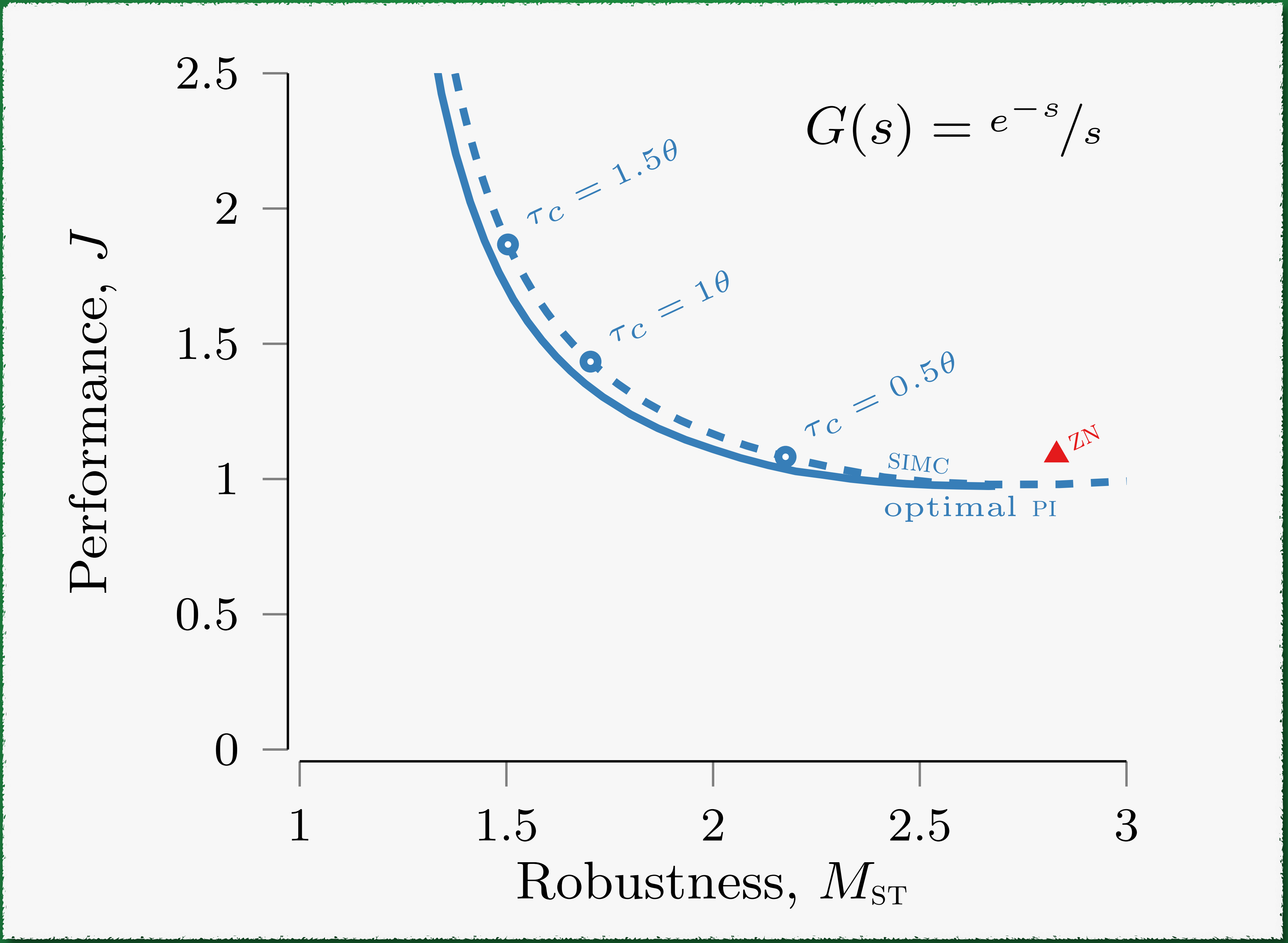
$$G(s) = \frac{e^{-s}}{8s+1}$$ SIMC Special

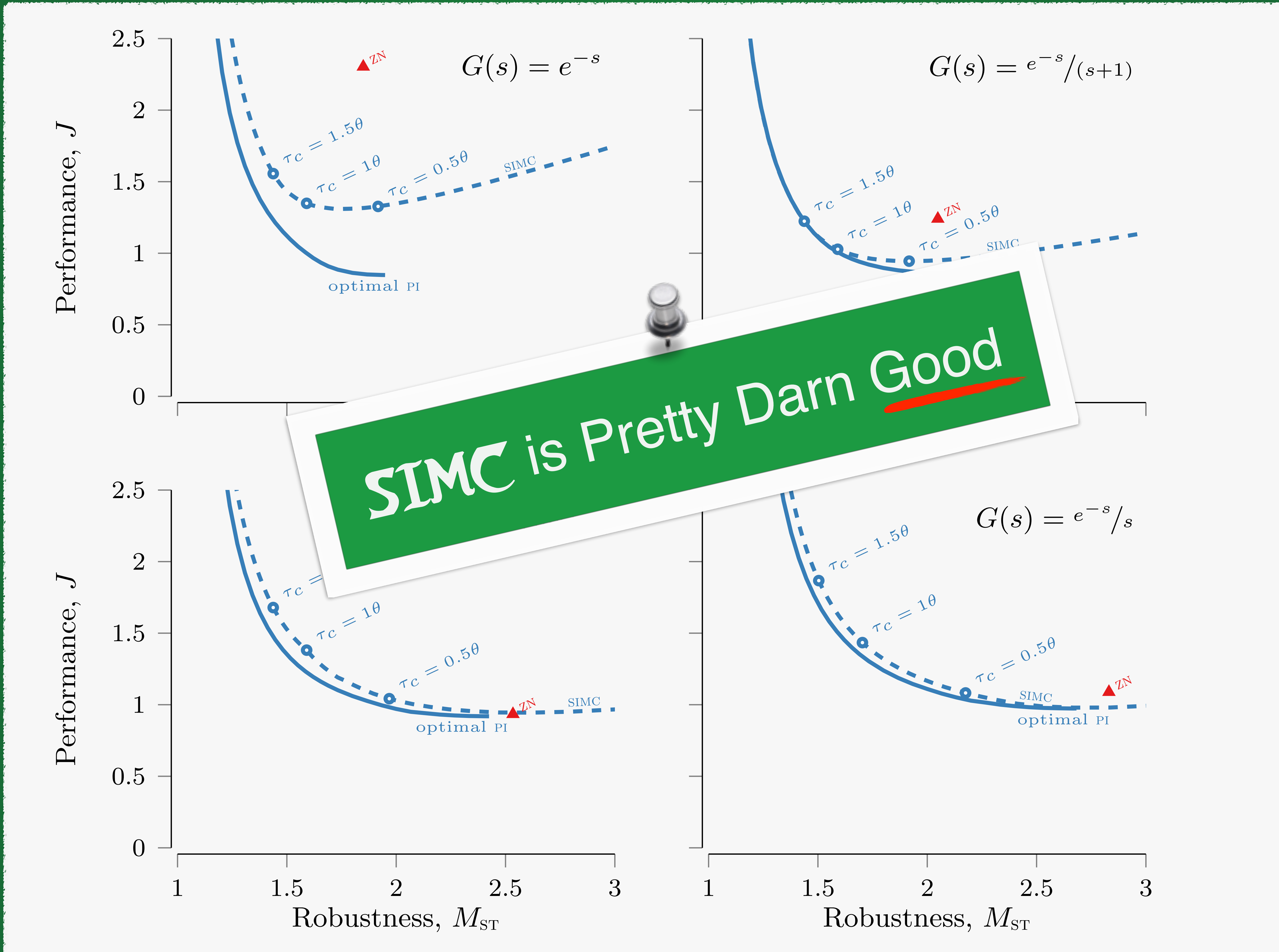




$$G(s) = \frac{e^{-s}}{s}$$

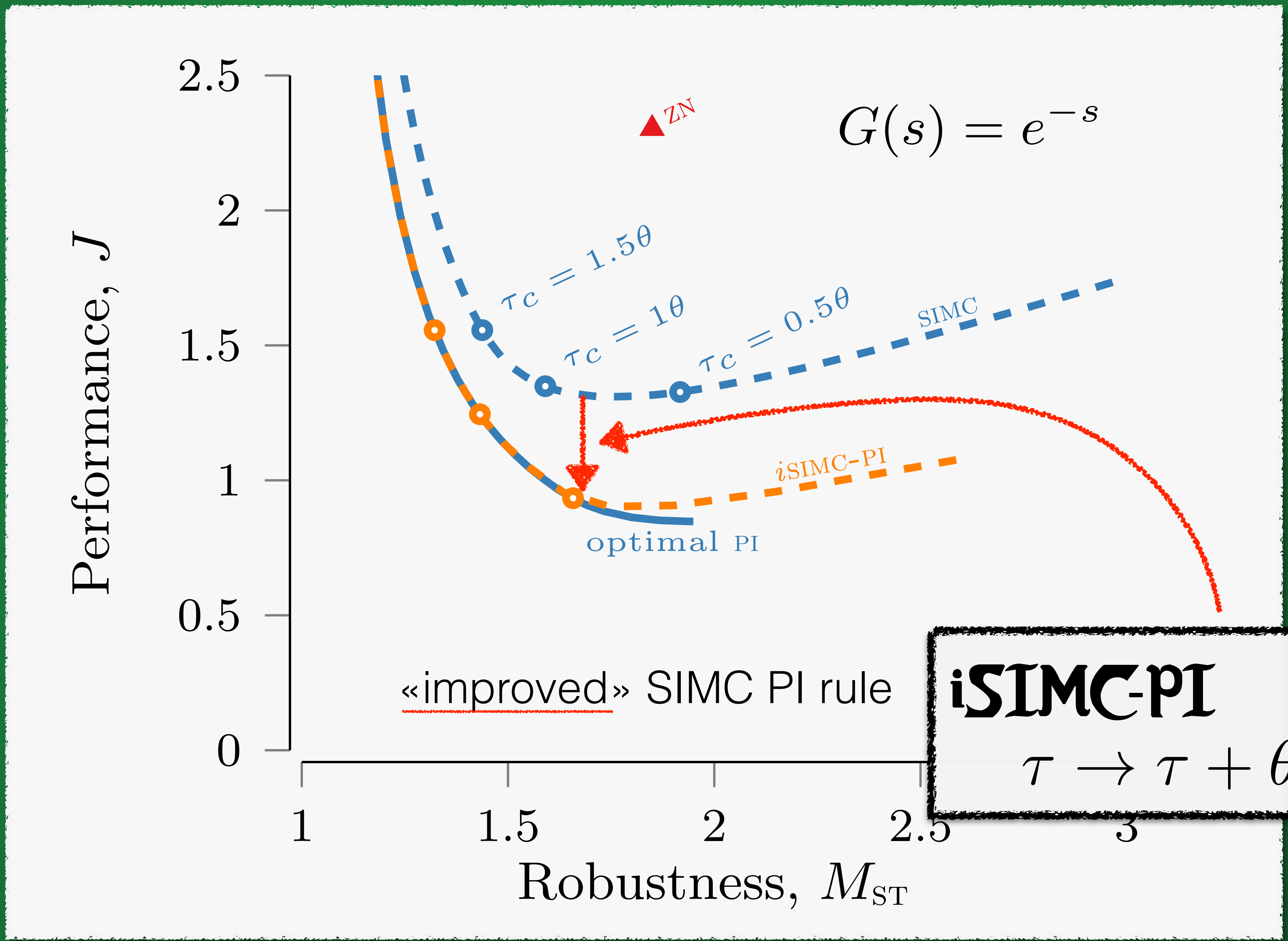
Lag dominated





SIMC is Pretty Darn Good
$G(s) = e^{-s}$
$G(s) = e^{-s}/(s+1)$
$G(s) = e^{-s}/s$
Performance, J
Robustness, M_{ST}
$\tau_c = 1.5\theta$
$\tau_c = 1\theta$
$\tau_c = 0.5\theta$
SIMC
ZN
optimal PI

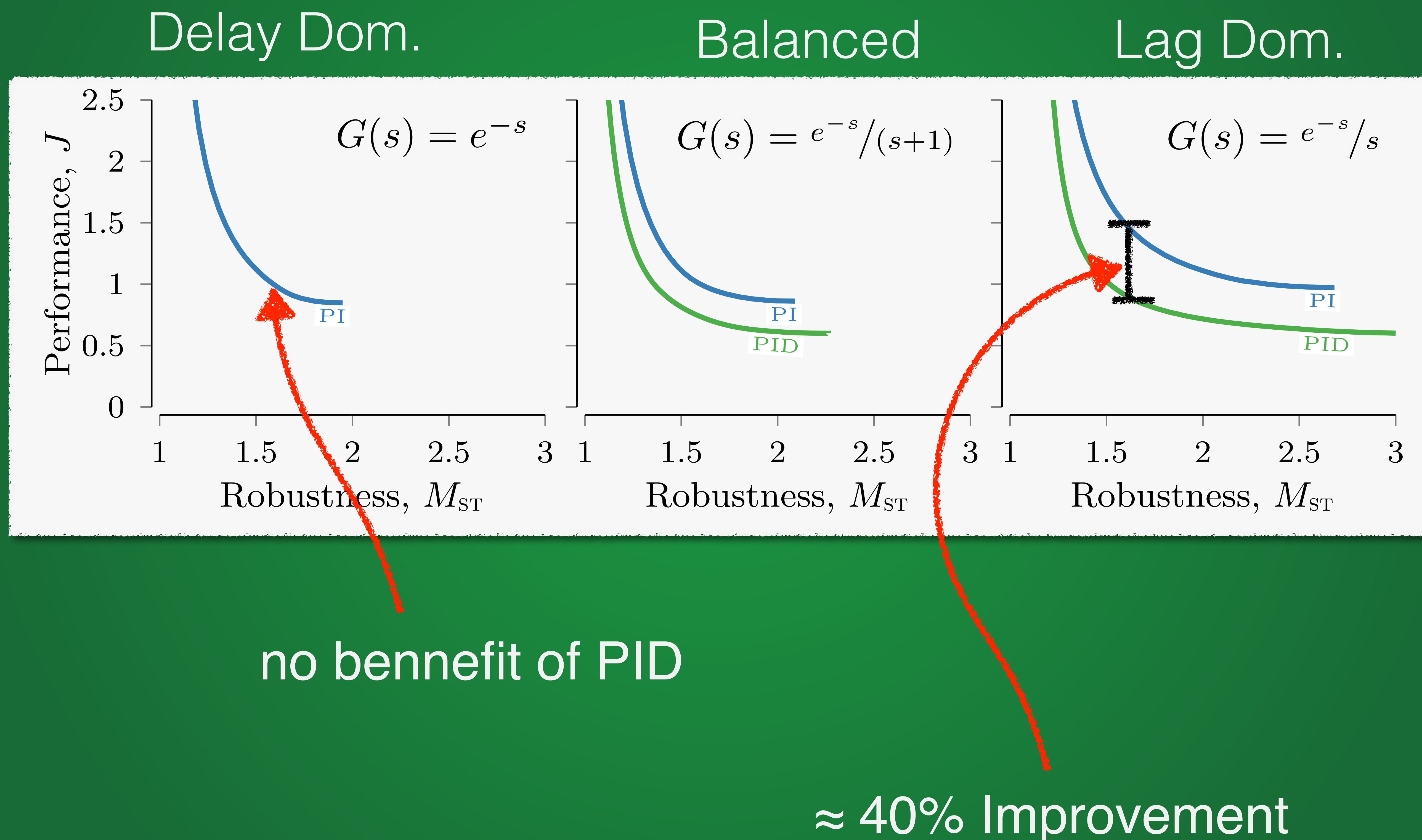
$G(s) = e^{-s}$ Delay dominated



iSIMC-PI

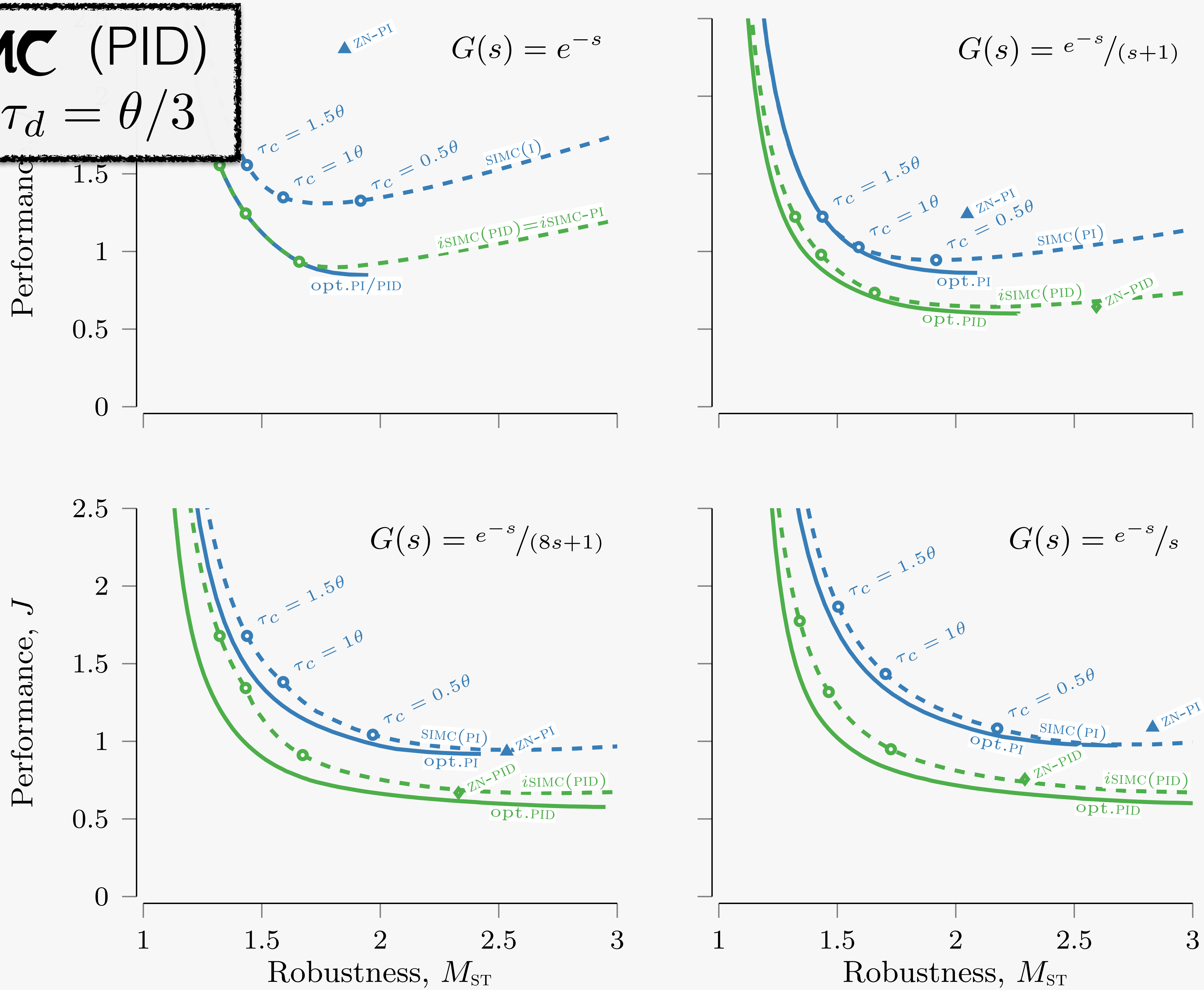
$\tau \rightarrow \tau + \theta/3$

What about PID?



iSIMC (PID)

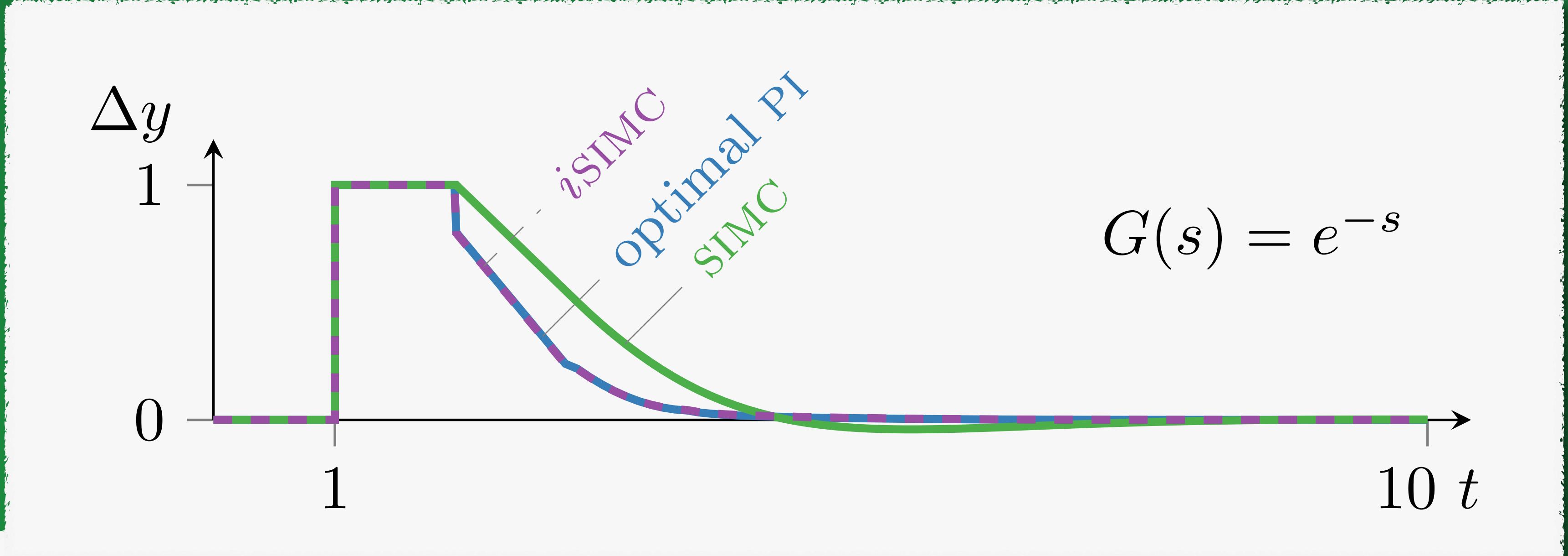
$\tau_d = \theta/3$

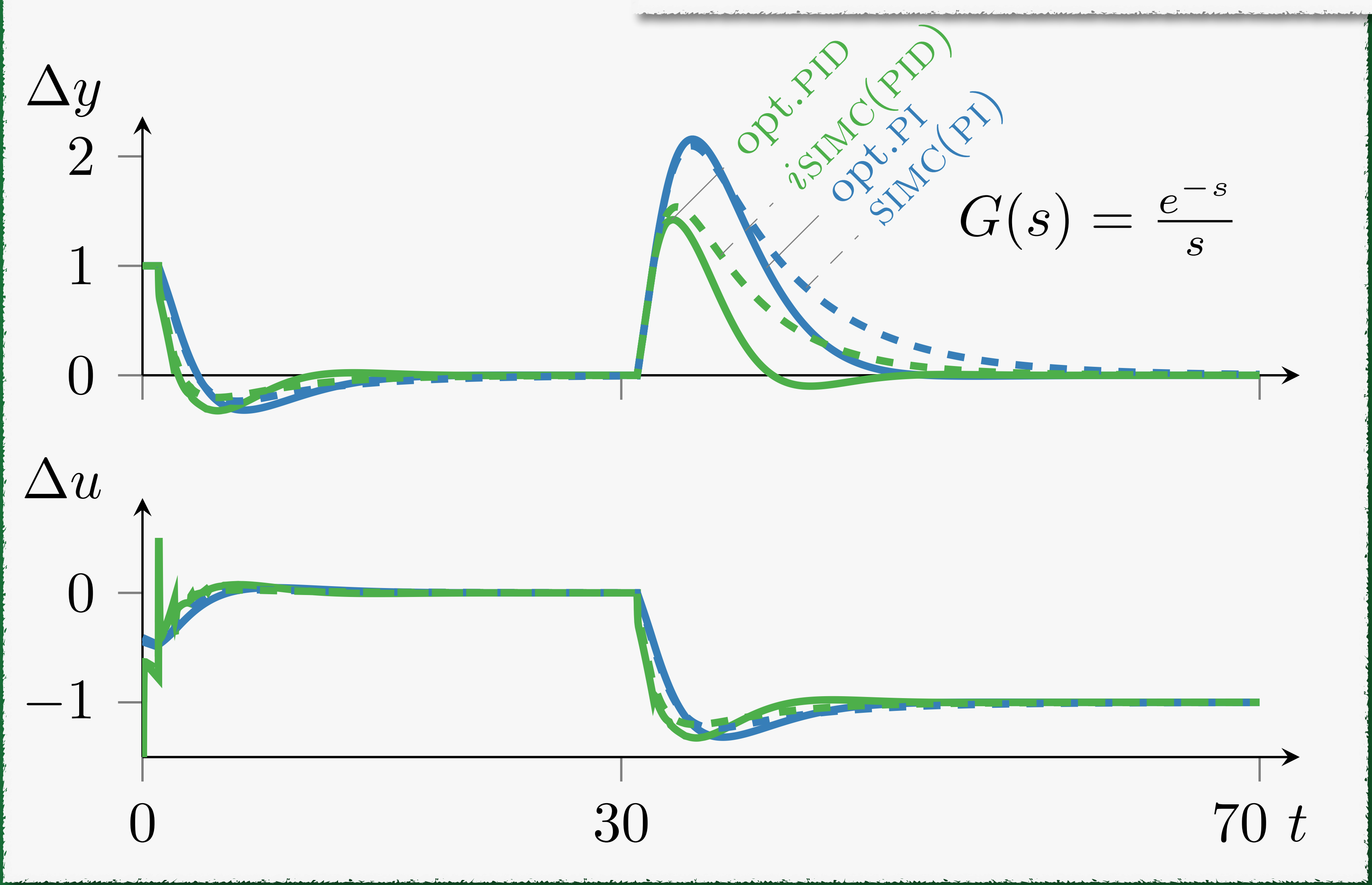


iSIMC (PID)

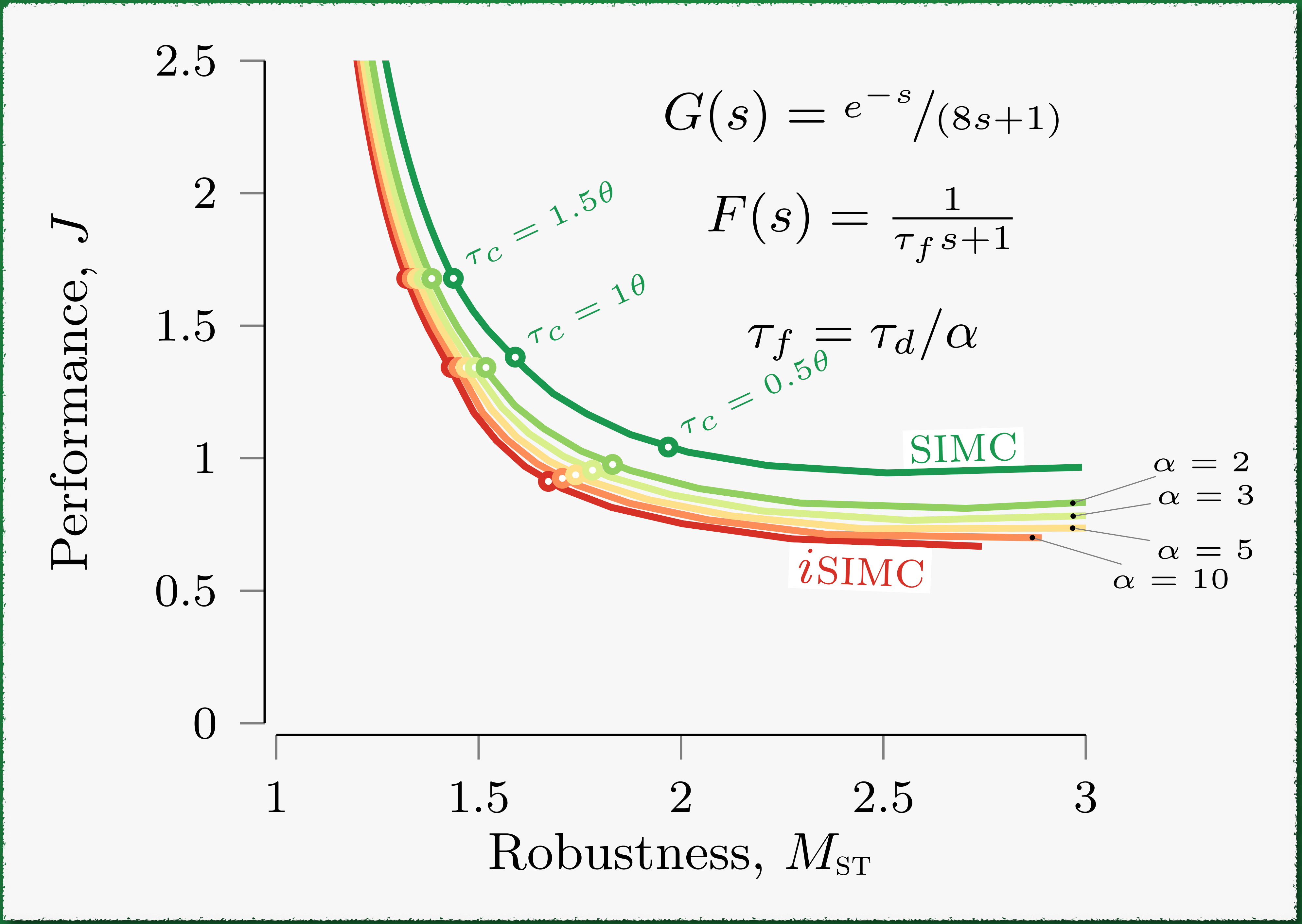
$\tau_d = \theta/3$

The step responses





Measurement filtering



Smith predictor vs. PID

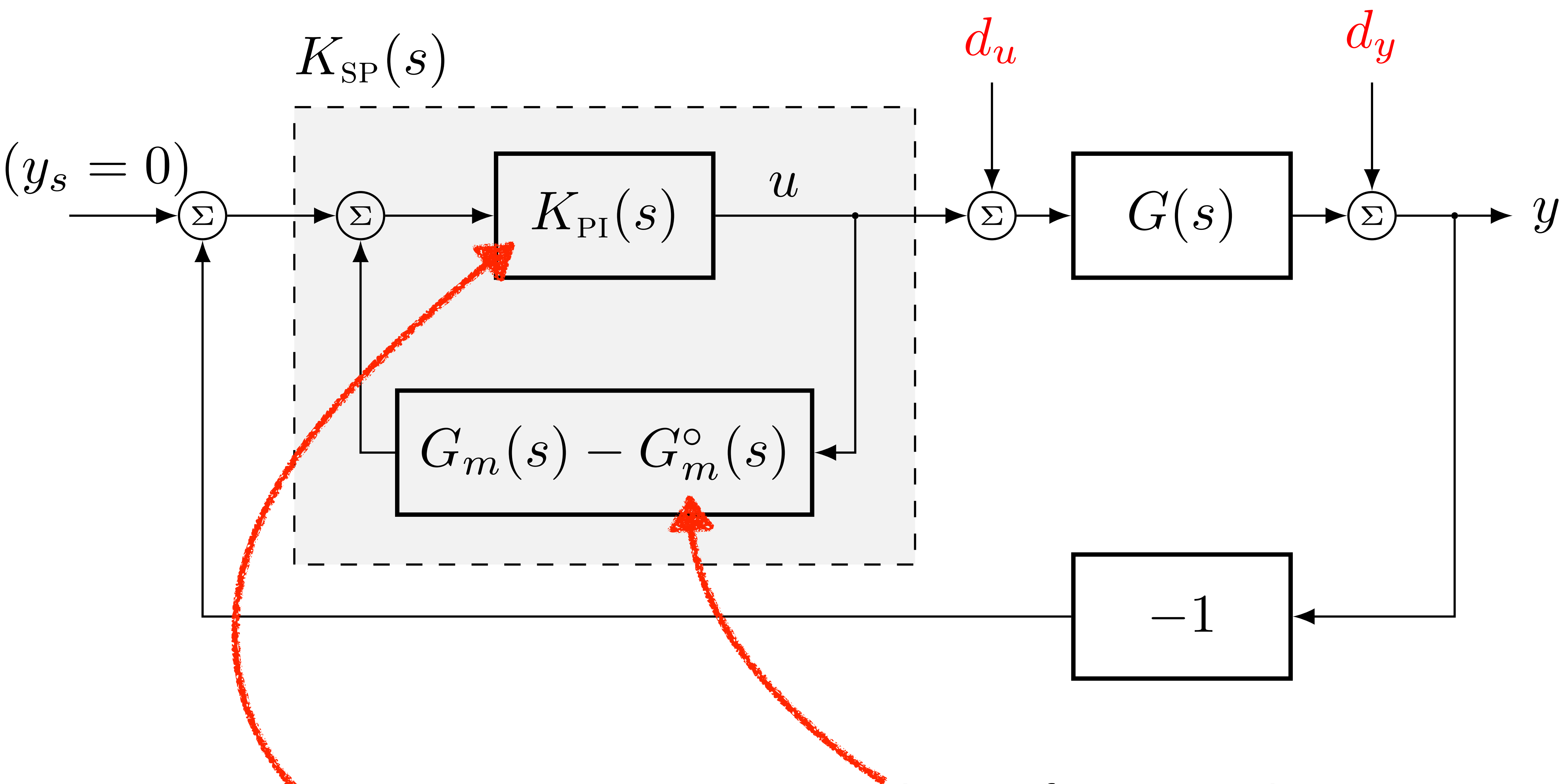
SMITH PREDICTOR

BORN TO PERFORM

PID-CTRL

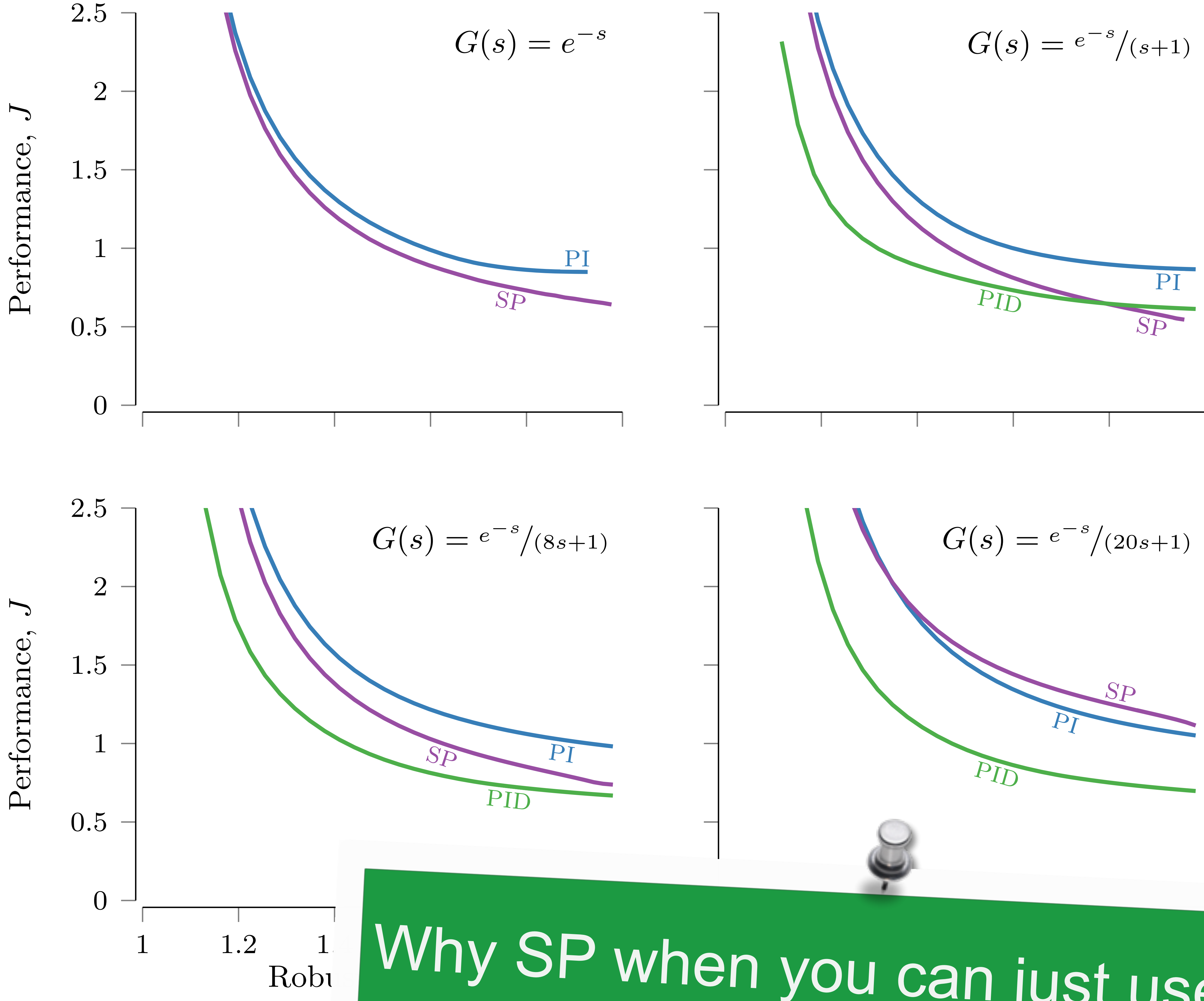
there is no substitute

SMITH PREDICTOR



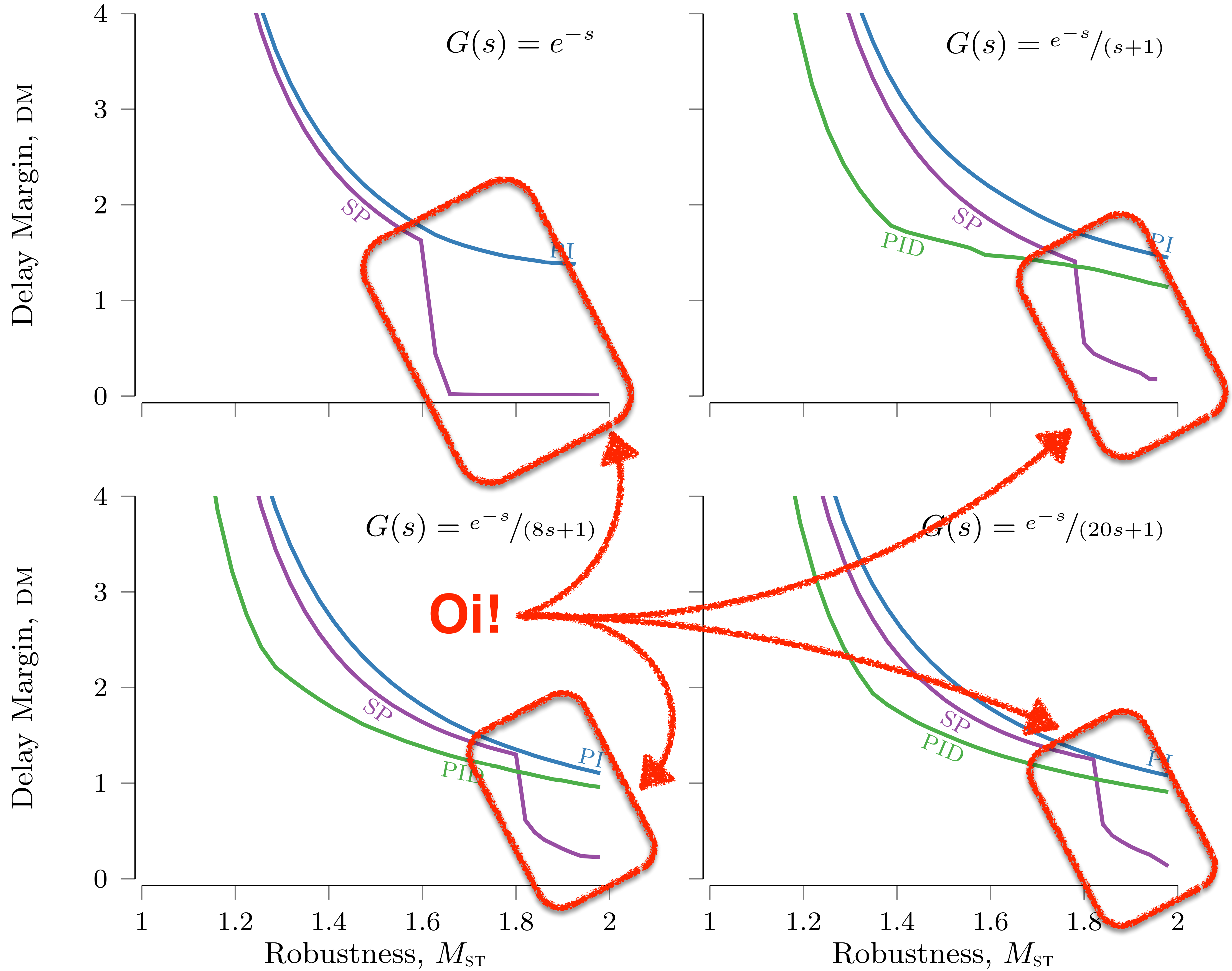
PI as internal controller

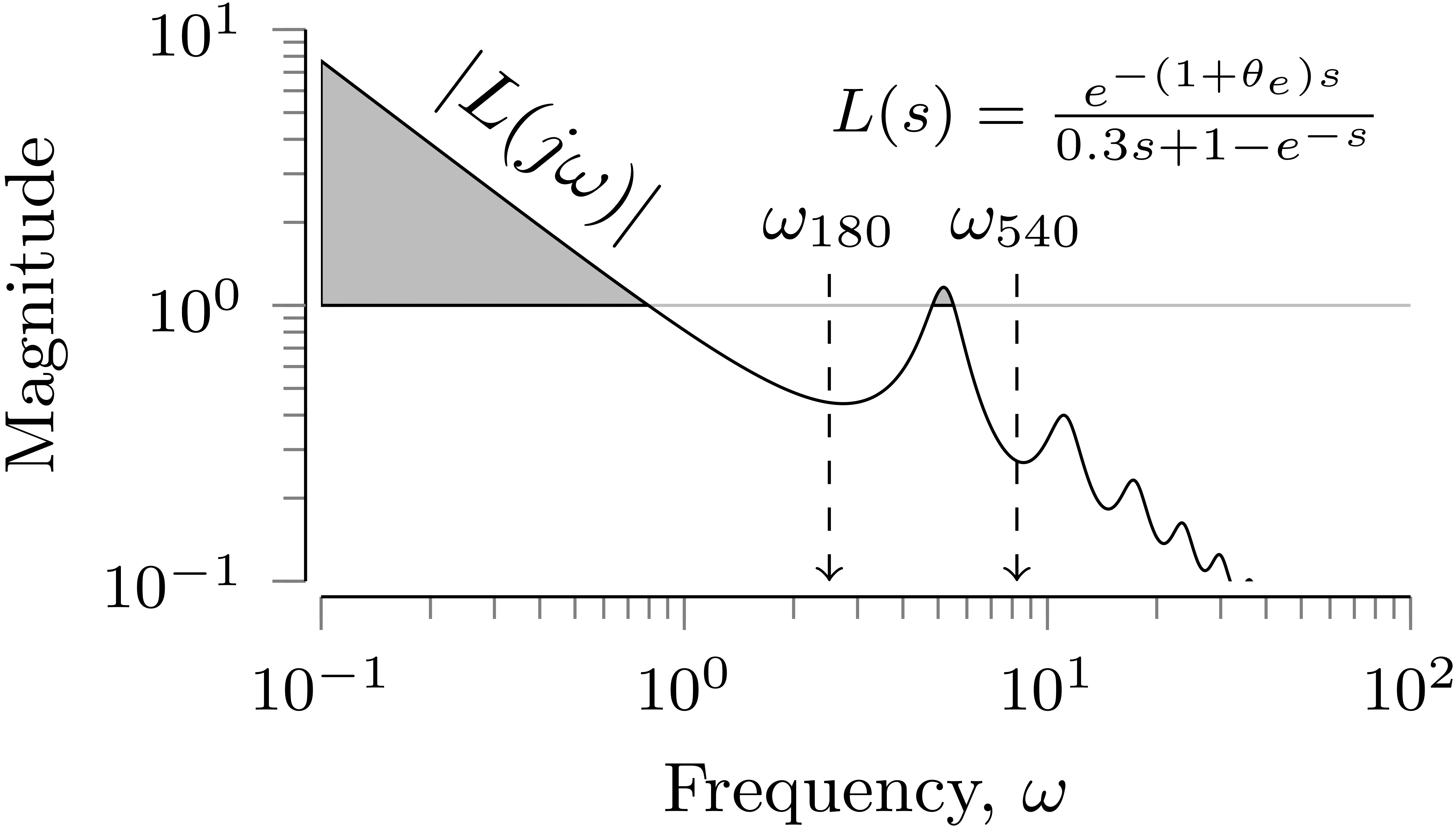
delay free model



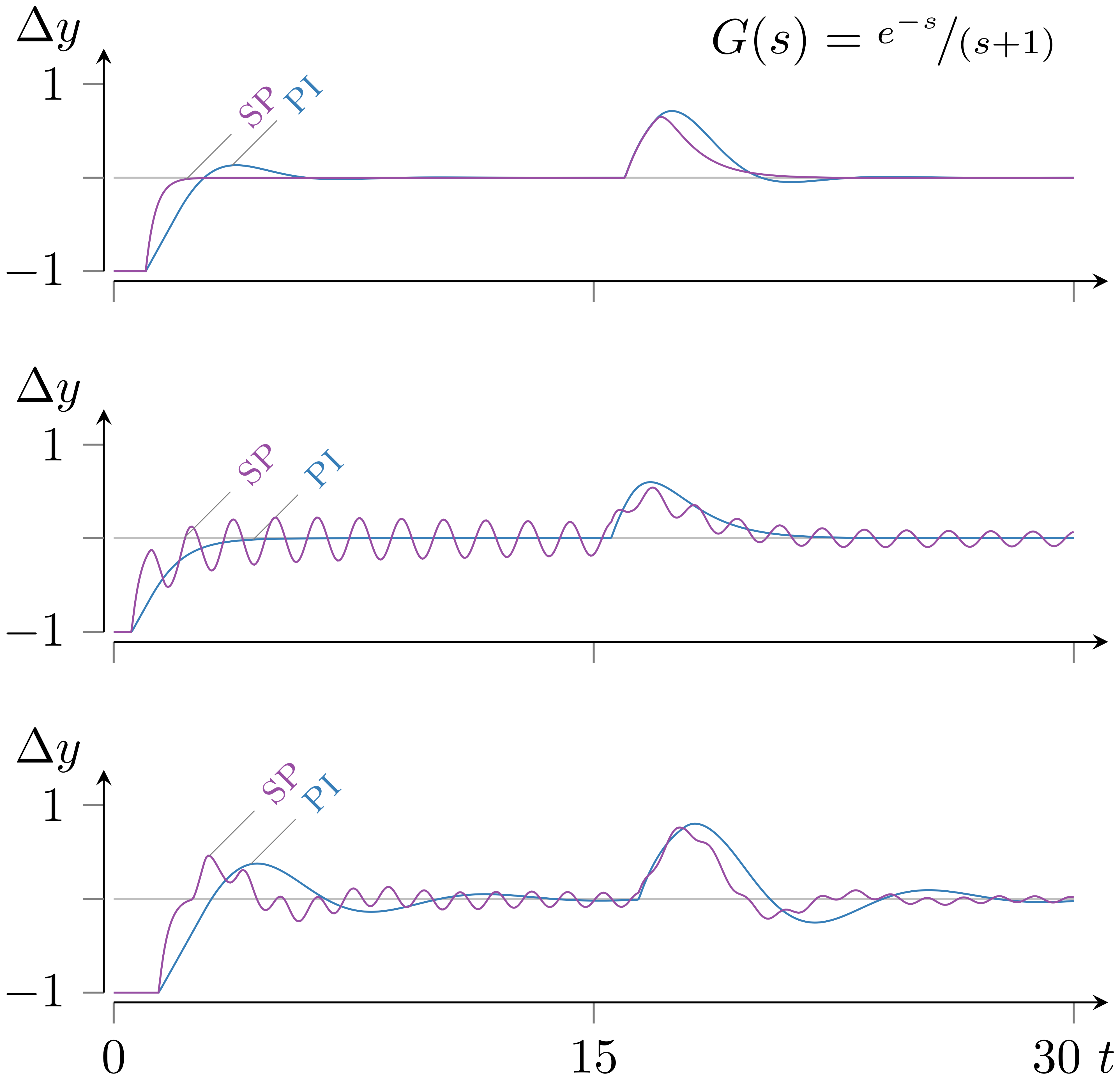
Why SP when you can just use PID?

Delay Margin





$|L(j\omega)|$
$L(s) = \frac{e^{-(1+\theta_e)s}}{0.3s+1-e^{-s}}$
ω_{180}
ω_{540}
Magnitude
10^{1}
10^{0}
10^{-1}
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency, ω



$G(s) = e^{-s}/(s+1)$
Δy
1
−1
SP
PI
0
15
30
t

JUST DO IT.

GRADIENTS

SIMPLIFIED PROBLEM

$$\begin{aligned} \underset{p}{\text{minimize}} \quad & \text{IAE}(p) \\ \text{subject to} \quad & |S(j\omega;\, p)| \le M^{ub} \quad \text{for all } \omega \\ & |T(j\omega;\, p)| \le M^{ub} \quad \text{for all } \omega \end{aligned}$$

Gradients
of the constraints

$$|S(j\omega;\, p)| \leq M^{ub} \quad \text{for all } \omega$$
$$|T(j\omega;\, p)| \leq M^{ub} \quad \text{for all } \omega$$

$$\nabla|S(j\omega)| = \frac{1}{|S(j\omega)|}\Re\{S^*(j\omega)\nabla S(j\omega)\} \qquad \text{for all } \omega$$
$$\nabla|T(j\omega)| = \frac{1}{|T(j\omega)|}\Re\{T^*(j\omega)\nabla T(j\omega)\} \qquad \text{for all } \omega$$

$$\nabla S(j\omega) = -GS(j\omega)\, S(j\omega)\, \nabla K(j\omega)$$
$$\nabla T(j\omega) = \nabla\left(1 - S(j\omega)\right) = -\nabla S(j\omega)$$

$$S = \frac{1}{1+GK}$$

Gradient
of the cost function

$$\mathrm{IAE} = \int |y - y_s| \mathrm{d}t$$

$$\nabla \mathrm{IAE}_{du}(p) = \int_0^{t_f} \mathrm{sign}\{e_{du}(t)\} \nabla e_{du}(t) \mathrm{d}t.$$

impulse response

$$\nabla e_{du} = -G(s)^2 S(s)^2 \nabla K(s)\, d_u$$

input disturbance