Critical mass effect in evolutionary games on networks triggered by zealots

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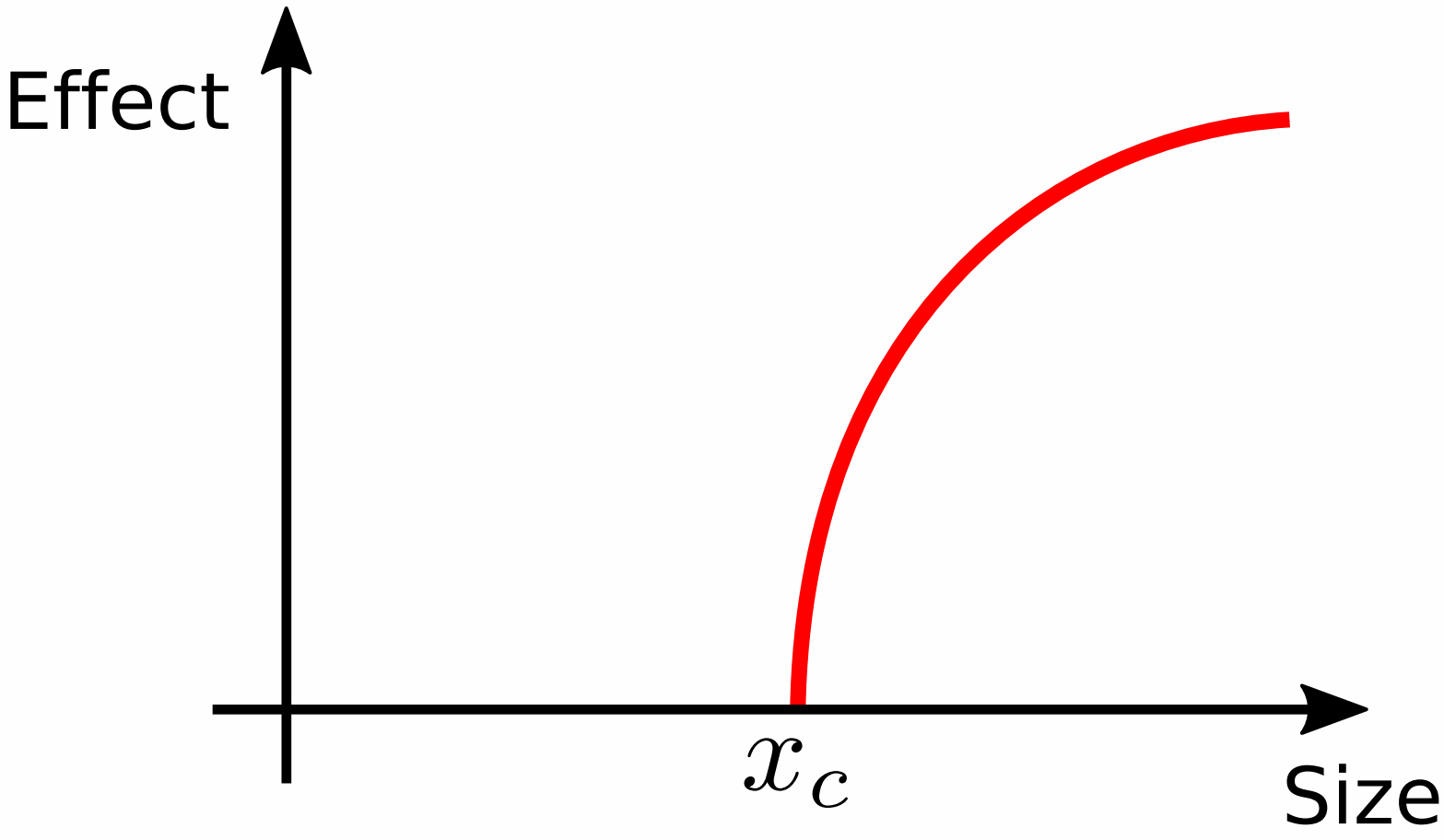
UNIVERSITAT ROVIRA i VIRGILI


Why do
1 in 100
children
have
AUTISM



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- D. Centola *et al.* , Science, **360**, 1116 (2018).

Main questions:

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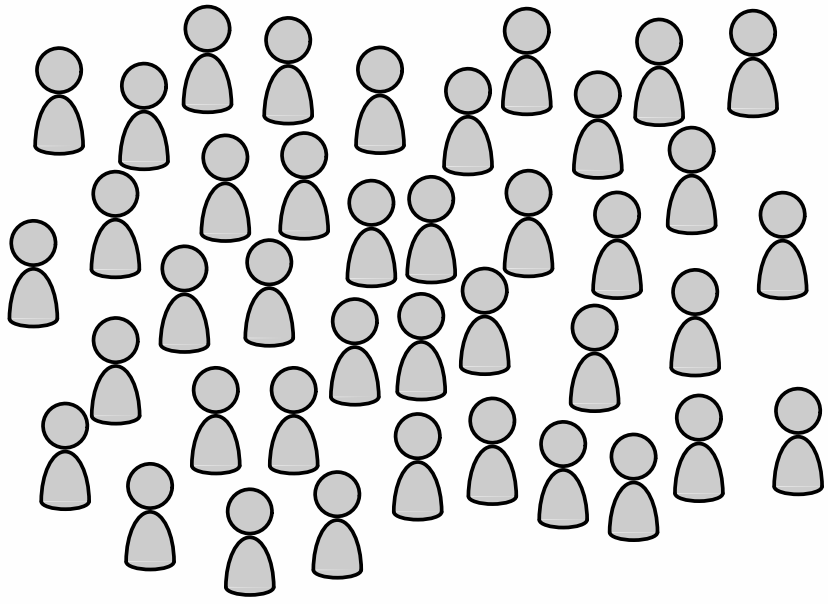
1. Is there a **critical mass effect** in evolutionary games?
2. Which **factors affect** the presence of such effect?
3. What about **networked interactions**?

The model

- Population of N agents



- Gintis, H. (2009). Game theory evolving (2nd ed.). Princeton Univ. Press.
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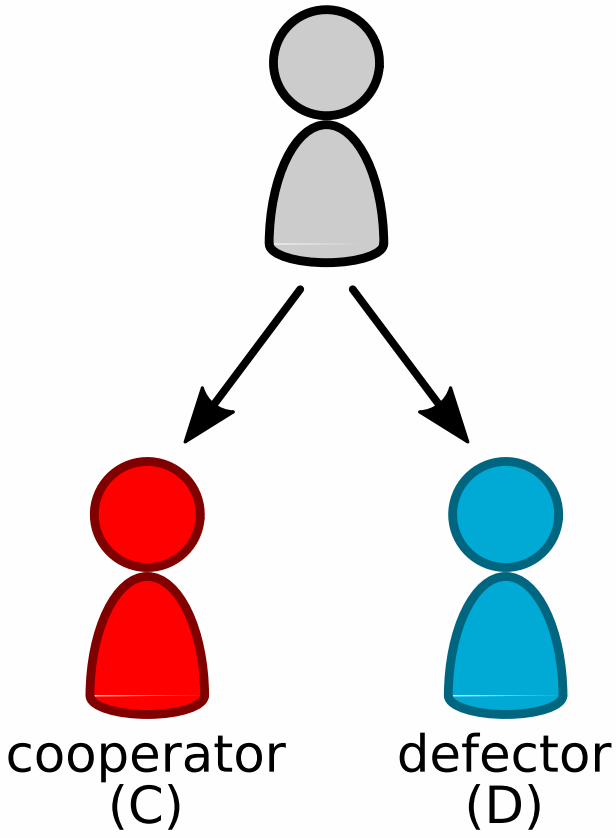
The model

- Population of N agents
- Two strategies: **cooperation** (C) and **defection** (D)



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The model

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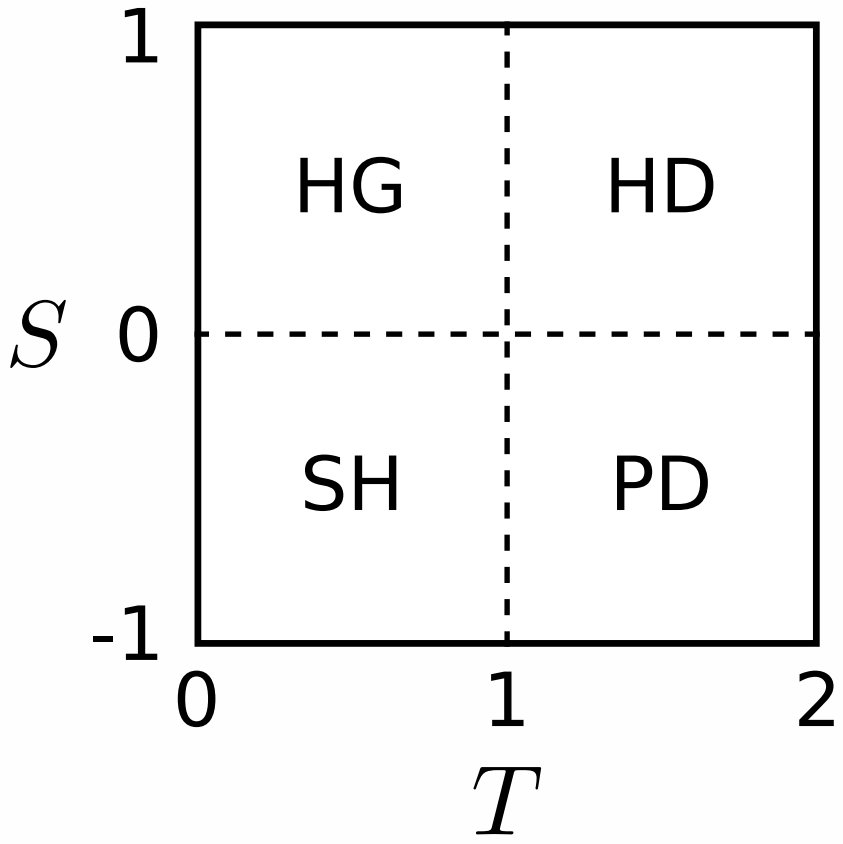
- Pairwise game with **payoff matrix**

$$\begin{array}{c} \\ \mathrm{C} \\ \mathrm{D} \end{array} \begin{array}{c} \begin{array}{cc} \mathrm{C} & \mathrm{D} \end{array} \\ \begin{pmatrix} 1 & S \\ T & 0 \end{pmatrix} \end{array} \quad \text{with} \quad \begin{cases} T \in [0, 2] \\ S \in [-1, 1] \end{cases}$$



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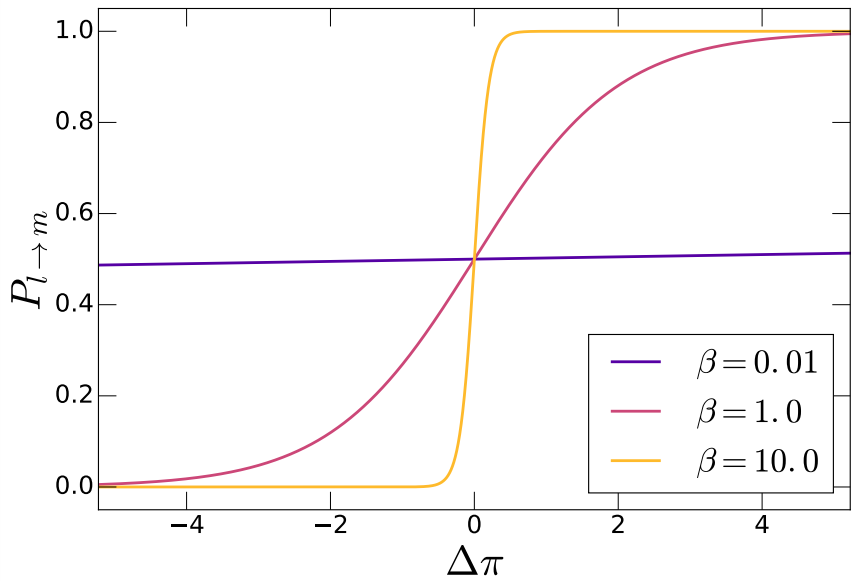
- Strategies evolve according to the **Fermi rule**

$$P_{\mathrm{X} \leftarrow \mathrm{Y}} = \frac{1}{1 + e^{-\beta(\pi_{\mathrm{Y}} - \pi_{\mathrm{X}})}} \quad \beta \in [0, \infty[$$



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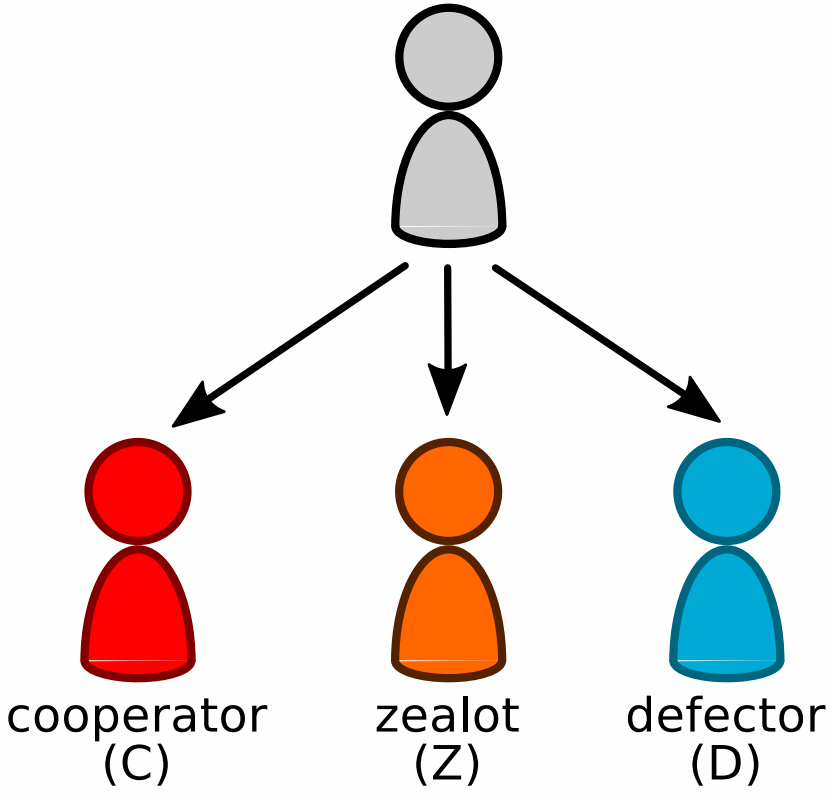
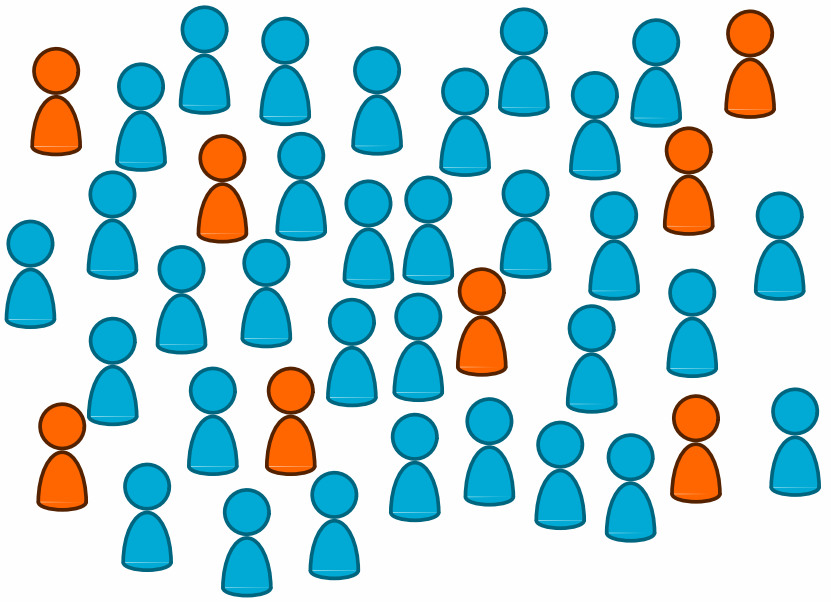
The model

- New type of player: (cooperative) **zealot**.



The model

- New type of player: (cooperative) **zealot**.
- Population fully made of defectors & replace a fraction $f_Z \in \left[0, \frac{1}{2}\right]$ of agents with zealots.



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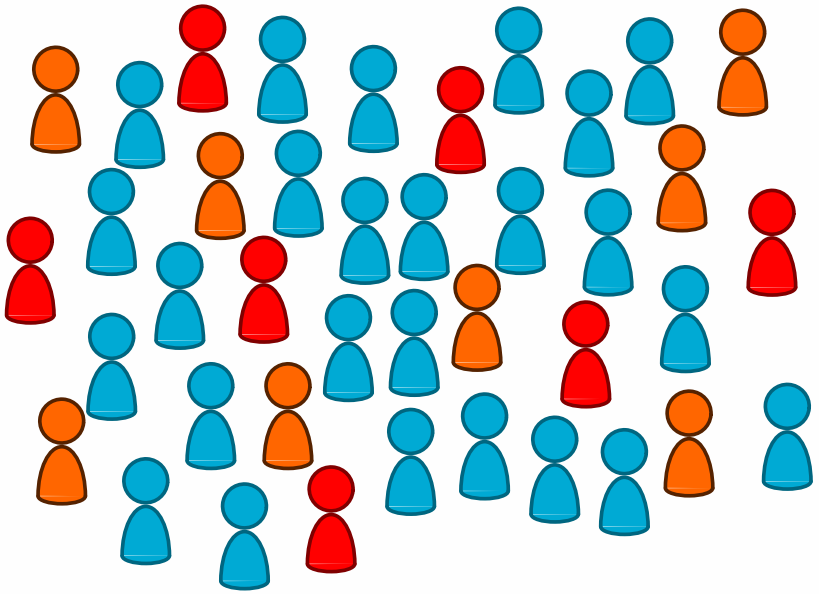

The model

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- Defectors can copy the strategy of zealots and become cooperators.
- Compute fraction of cooperators **among normal agents**, f_C

$$f_C = \frac{N_C}{(1 - f_Z)\, N} \qquad f_C \in [0, 1]$$

Results in mean field populations

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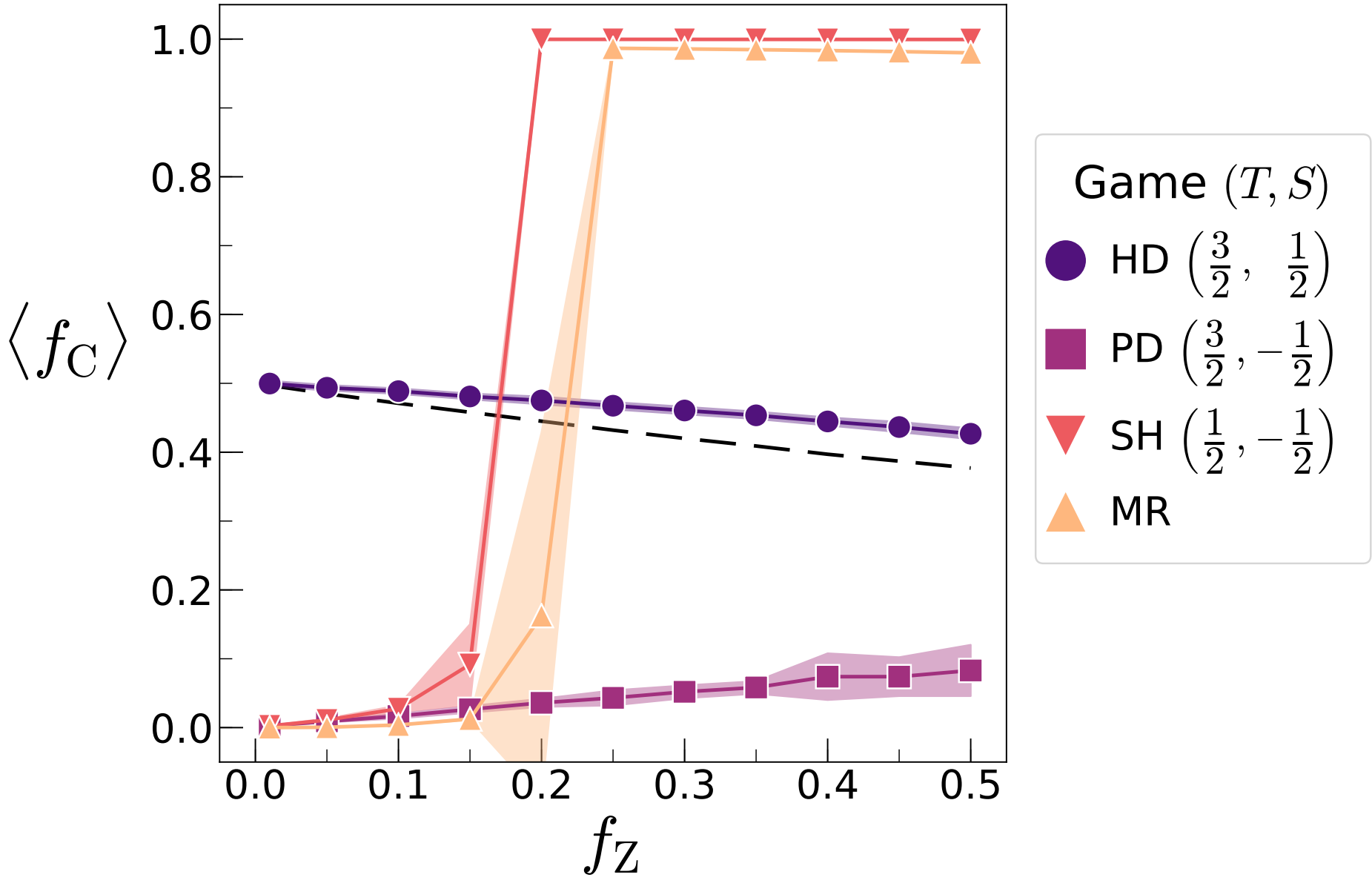

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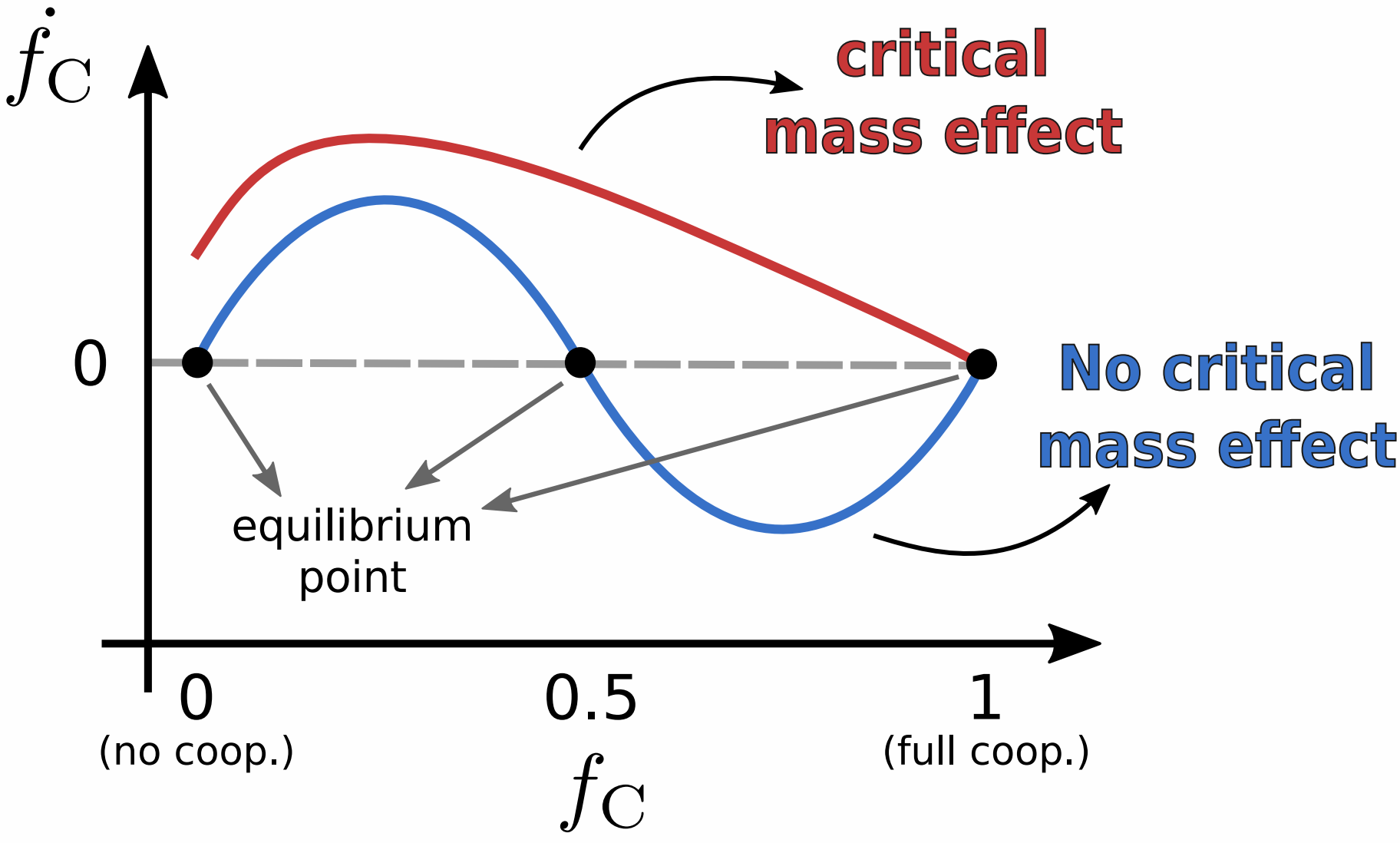

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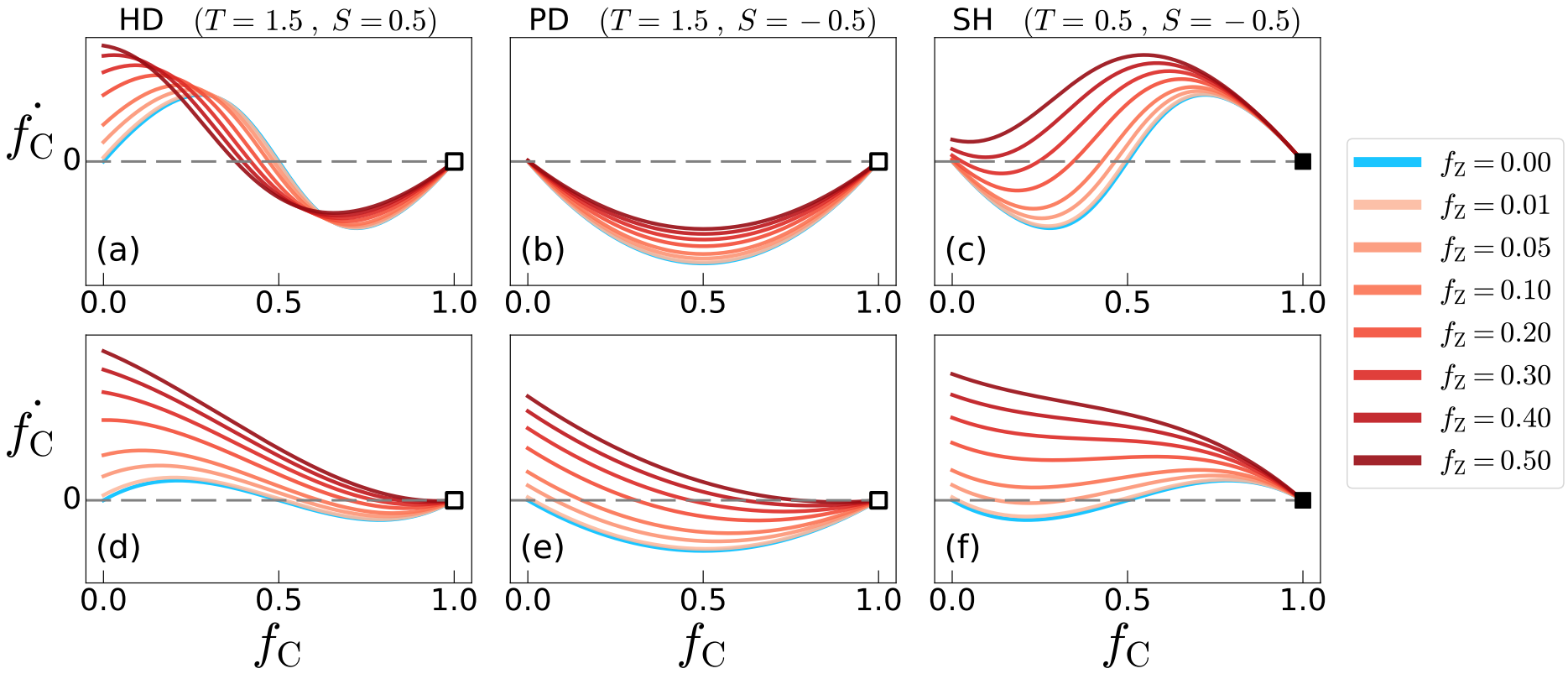

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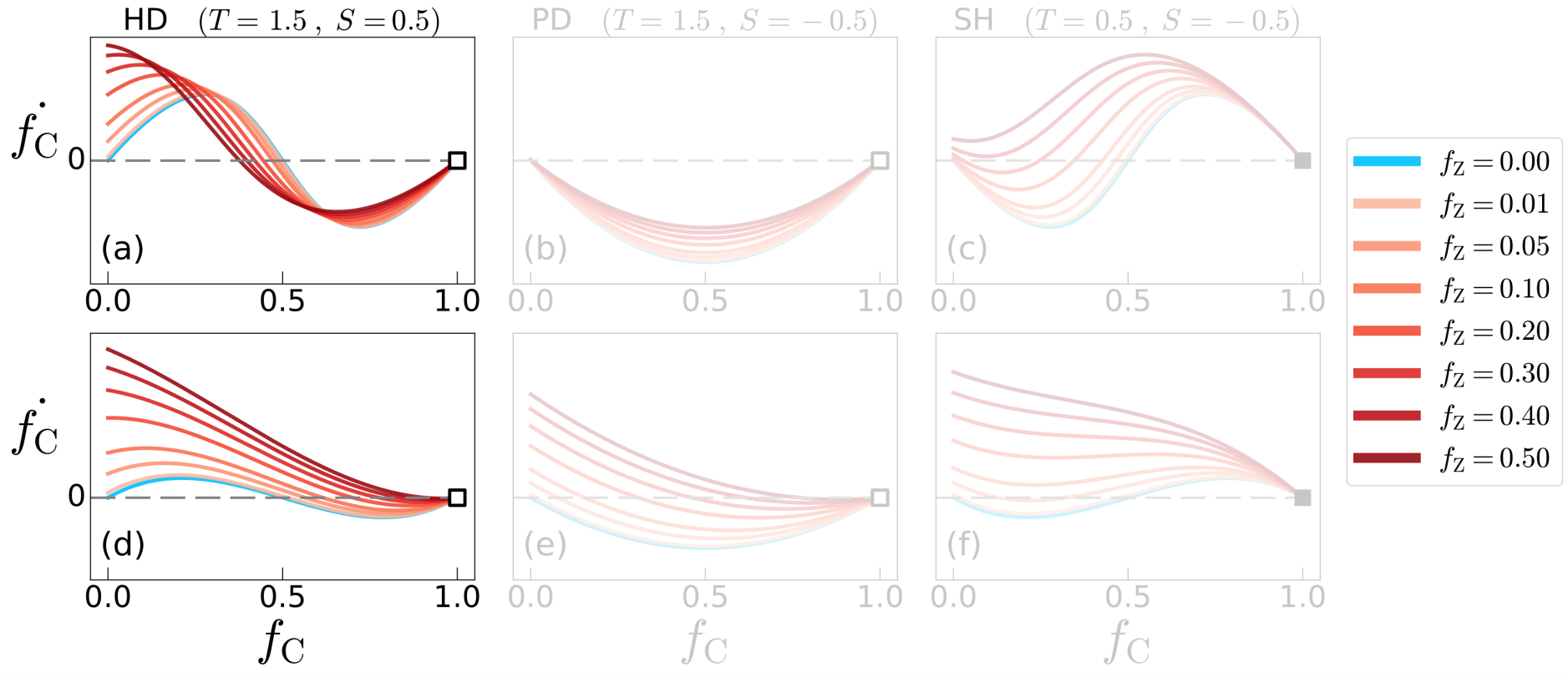

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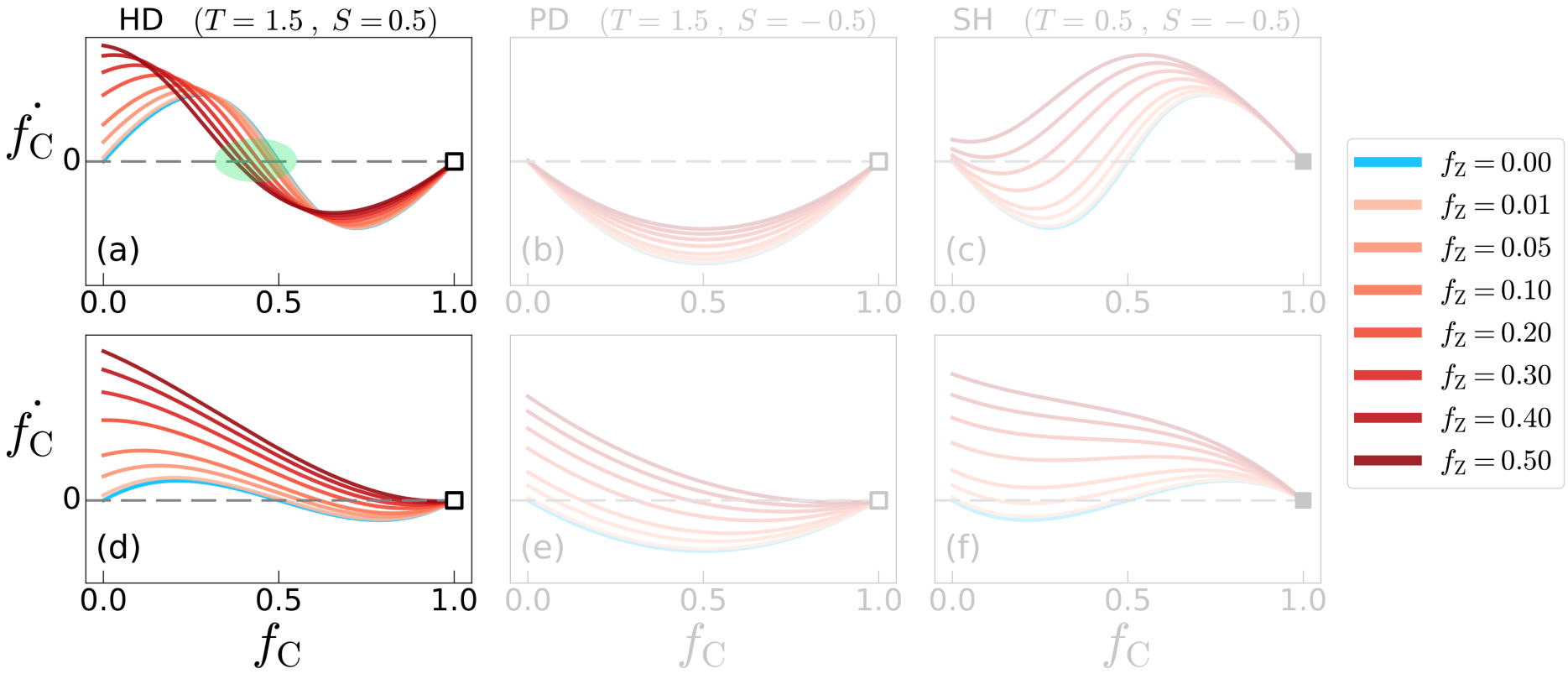

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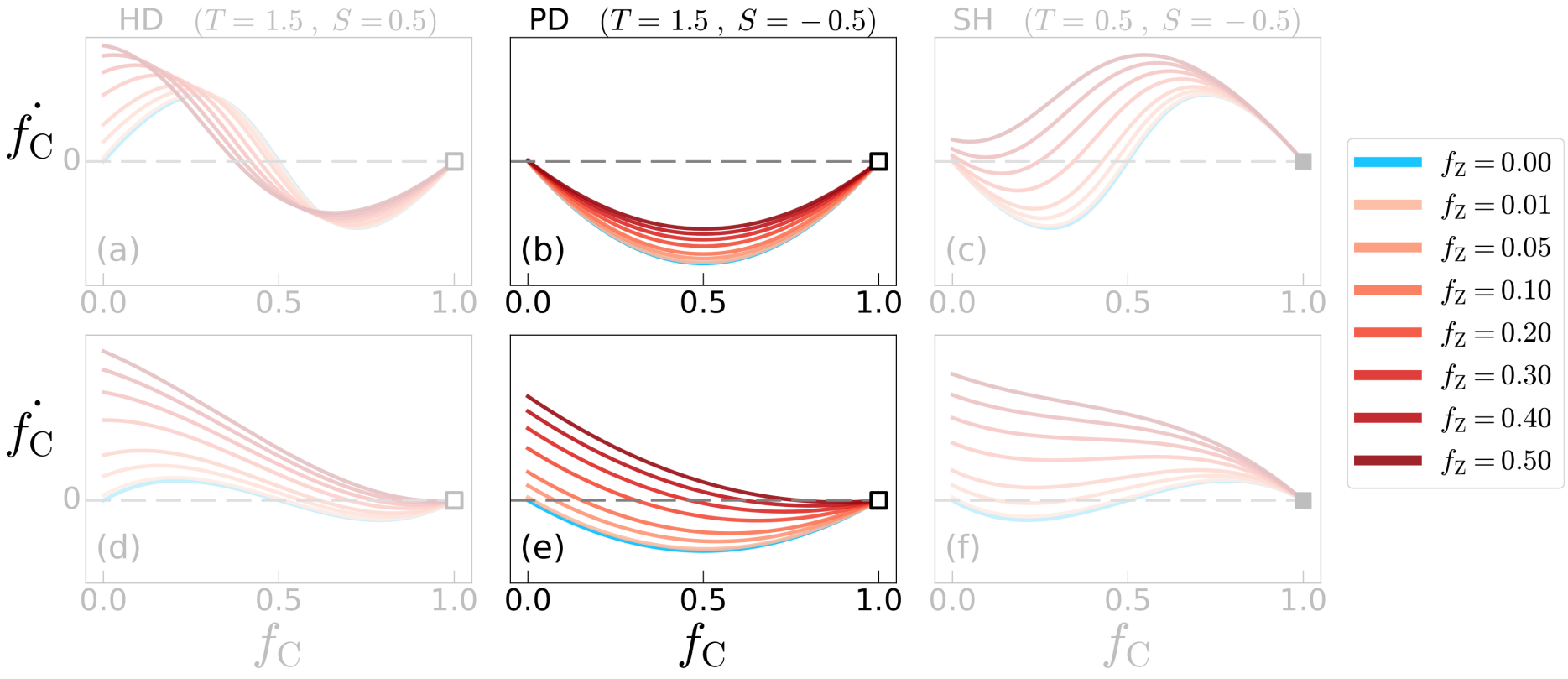

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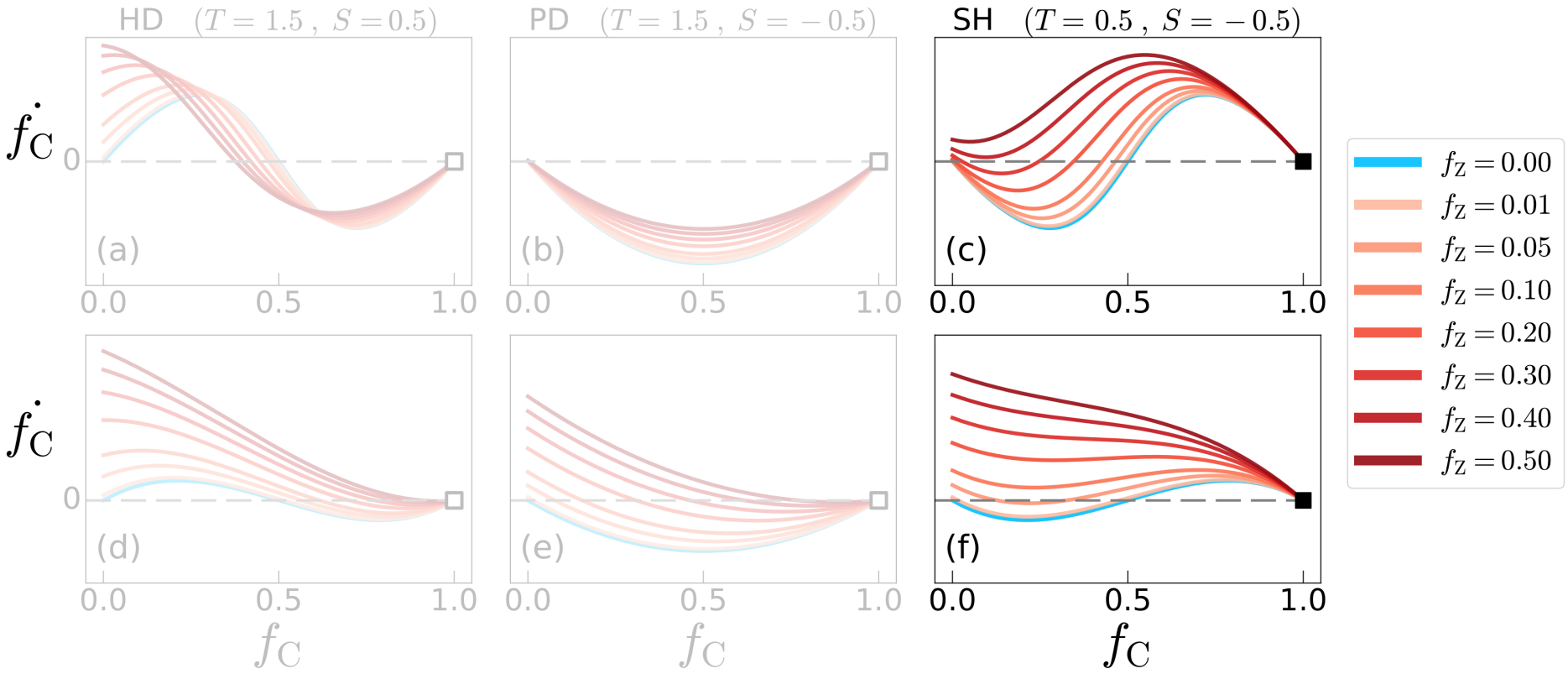

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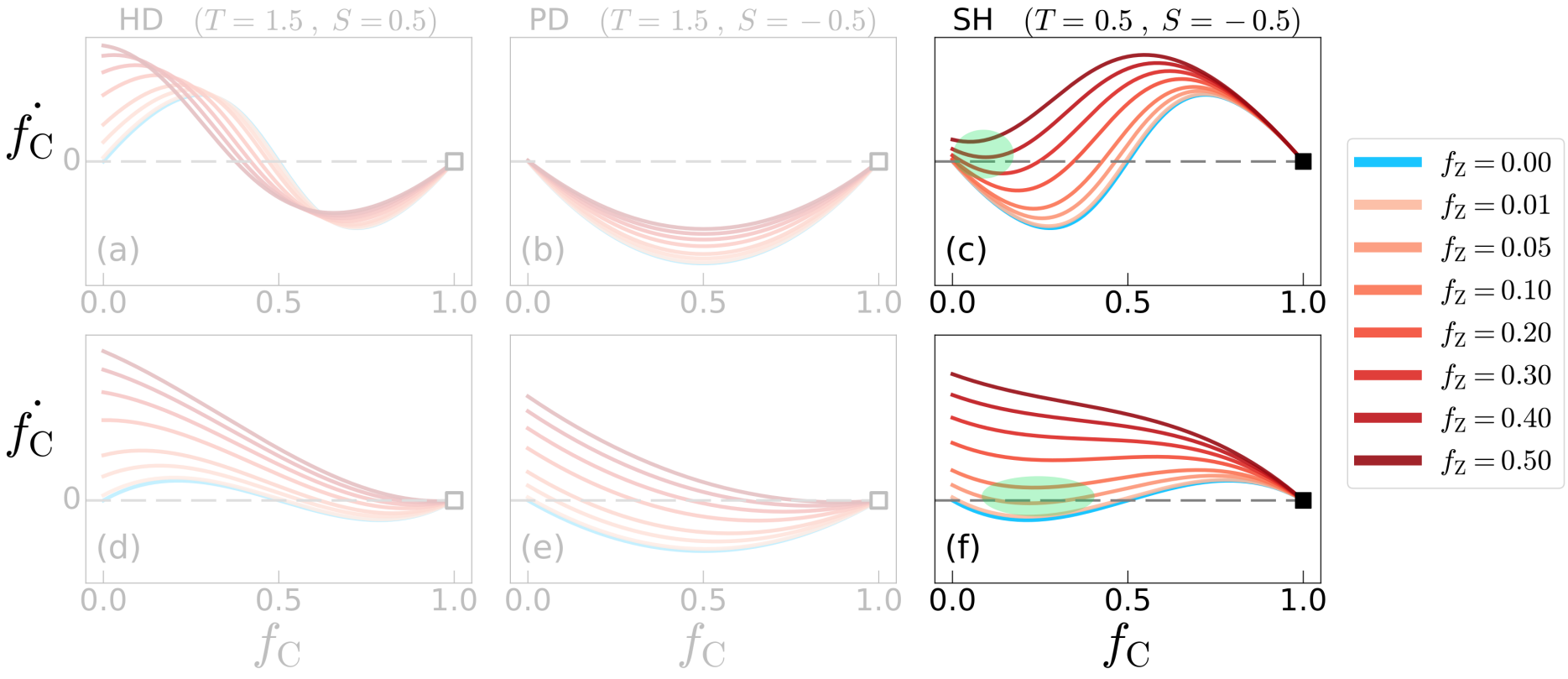

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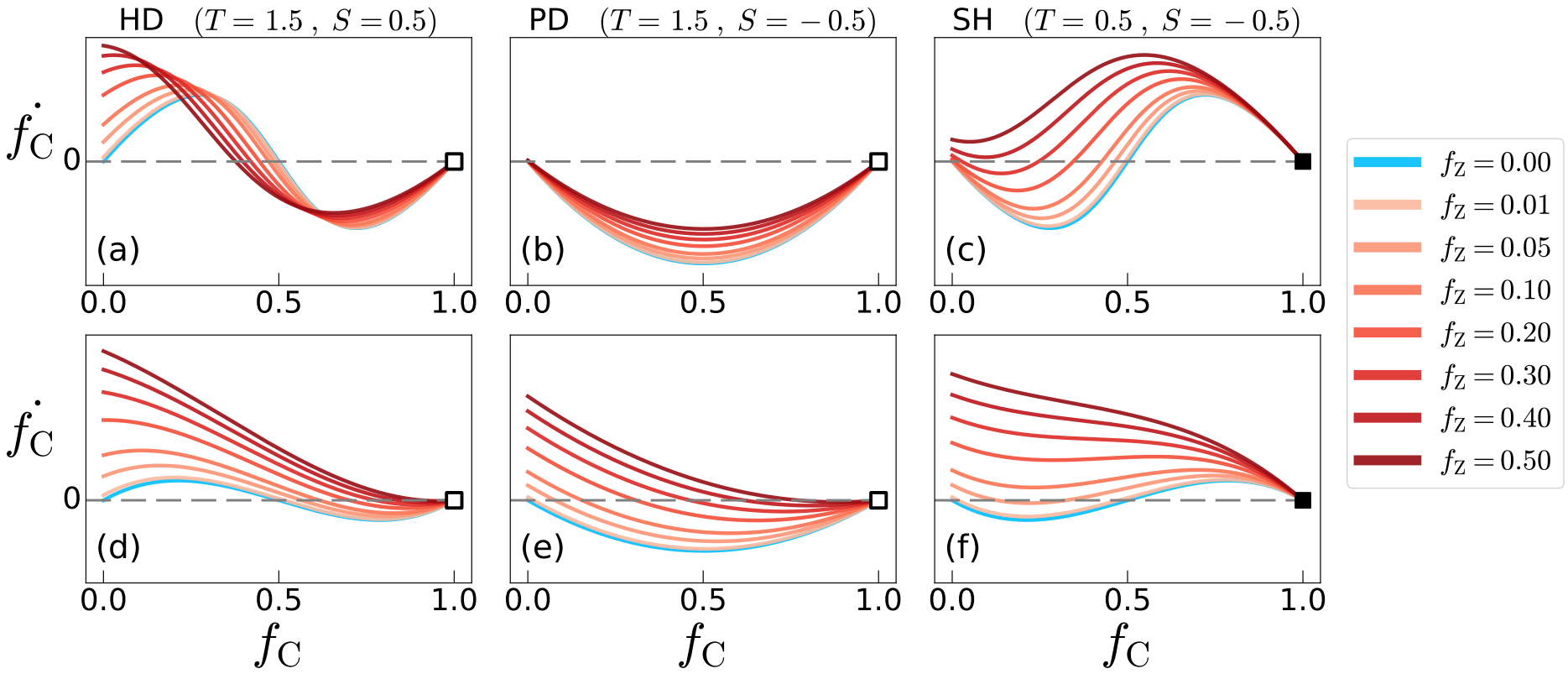
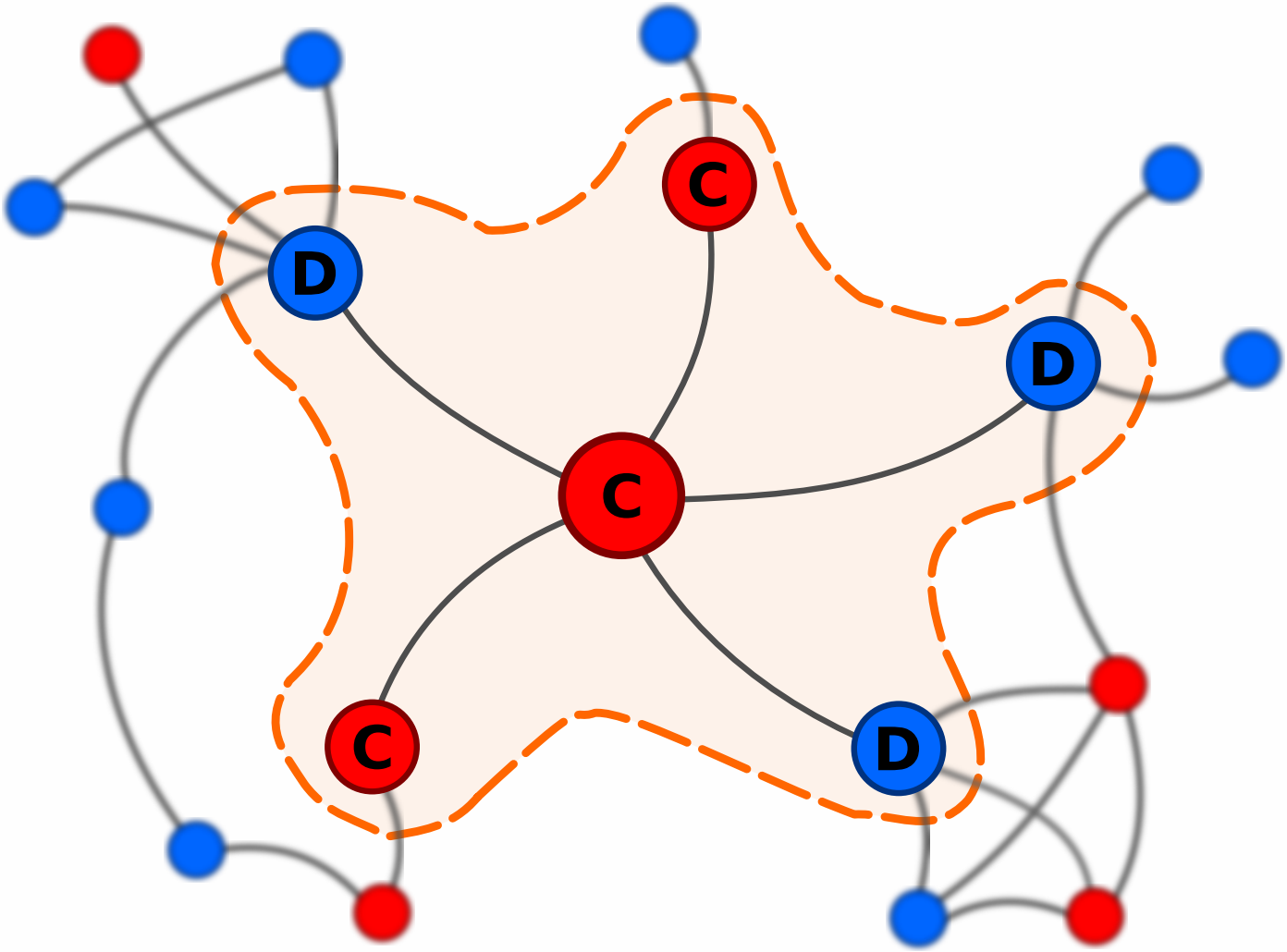


Results in networked populations



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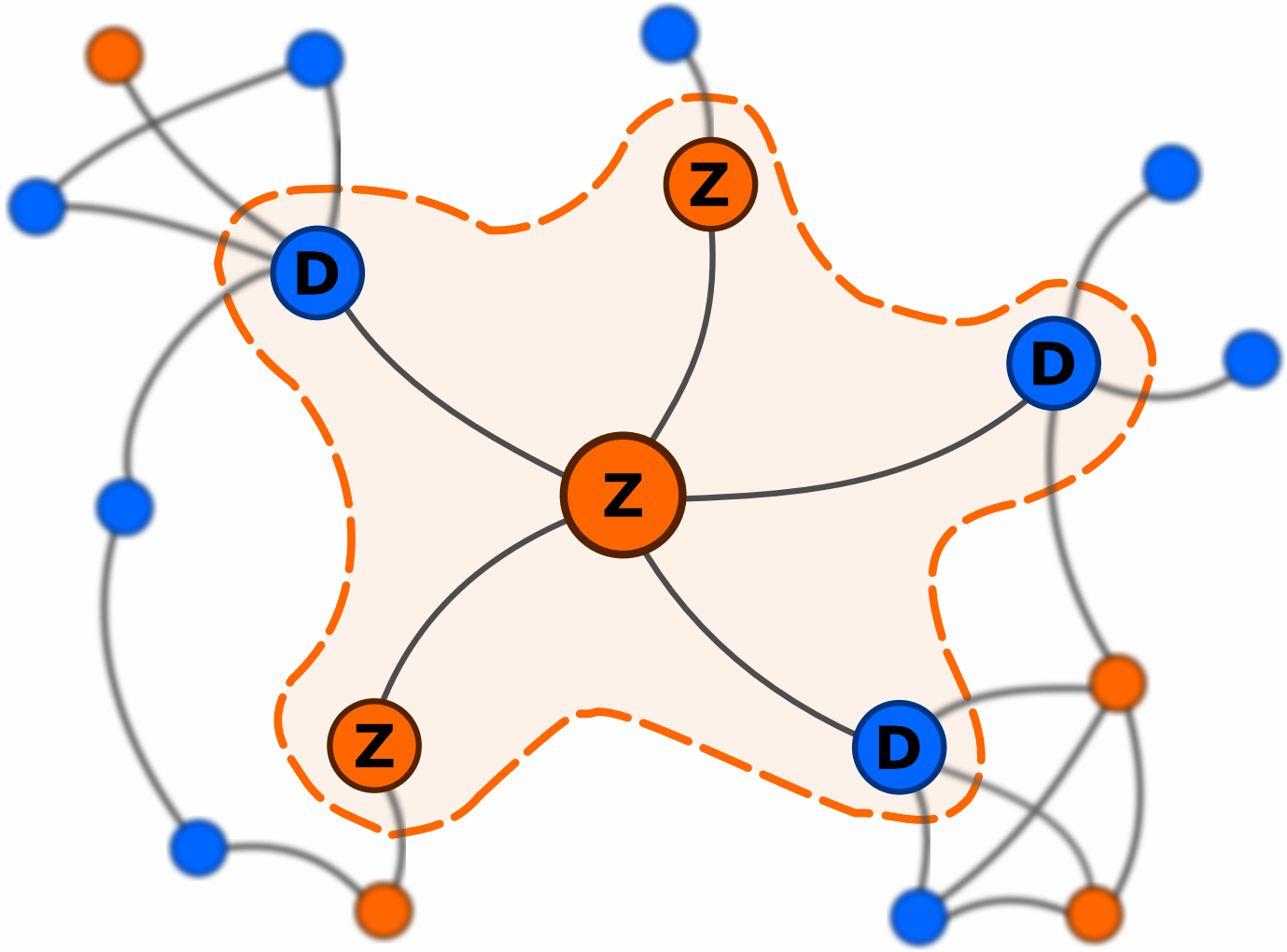

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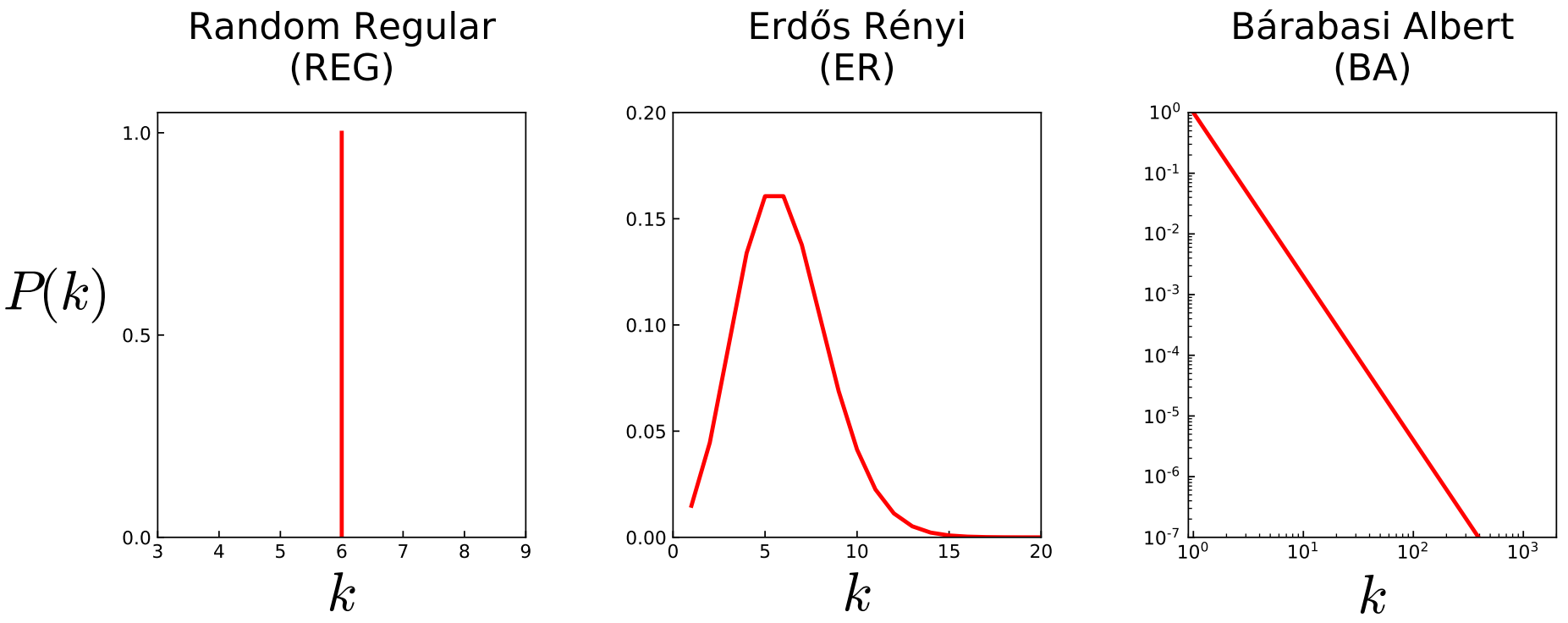
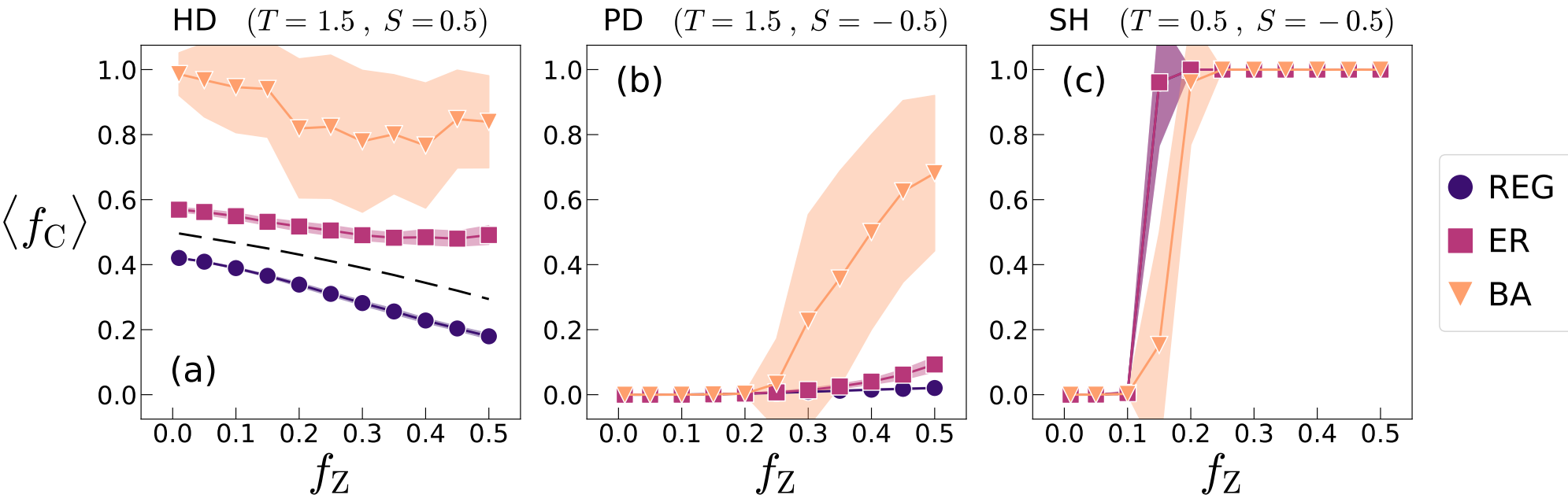


Note:

All nets have $N = 1000$ and $\langle k \rangle = 6$

Results in networked populations



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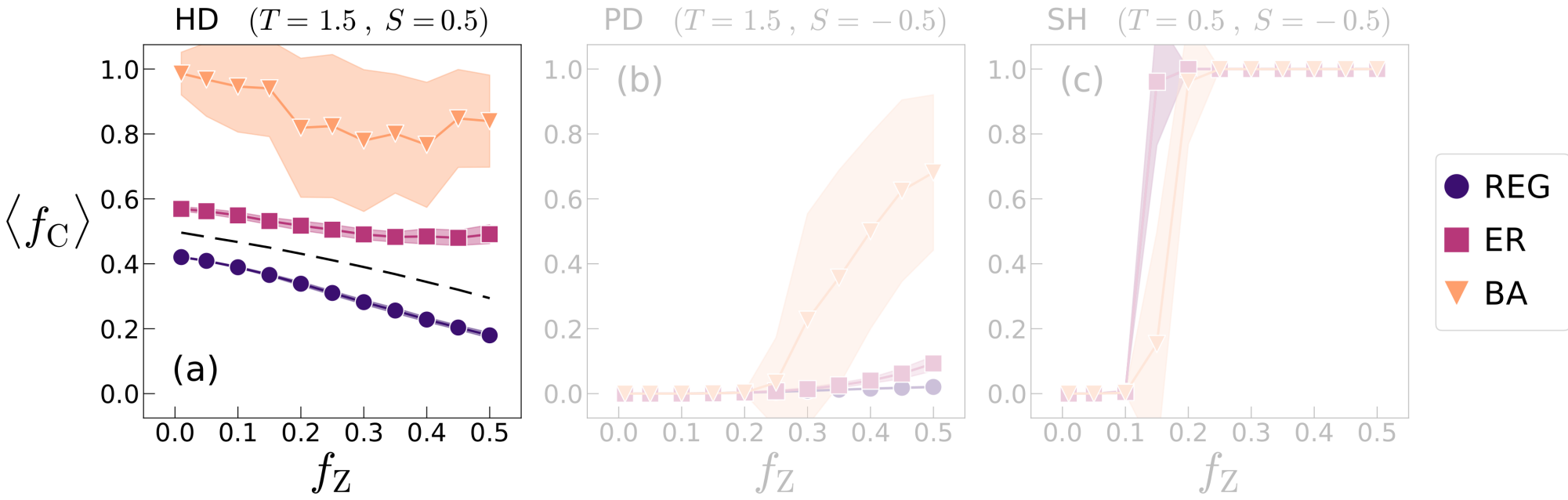

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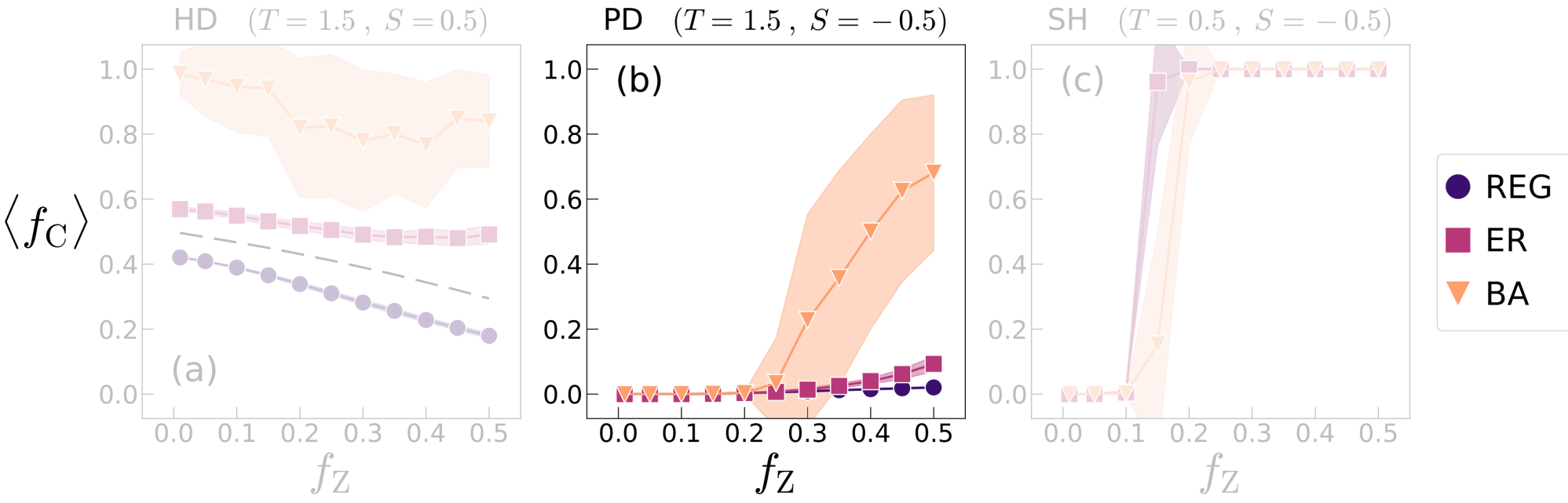

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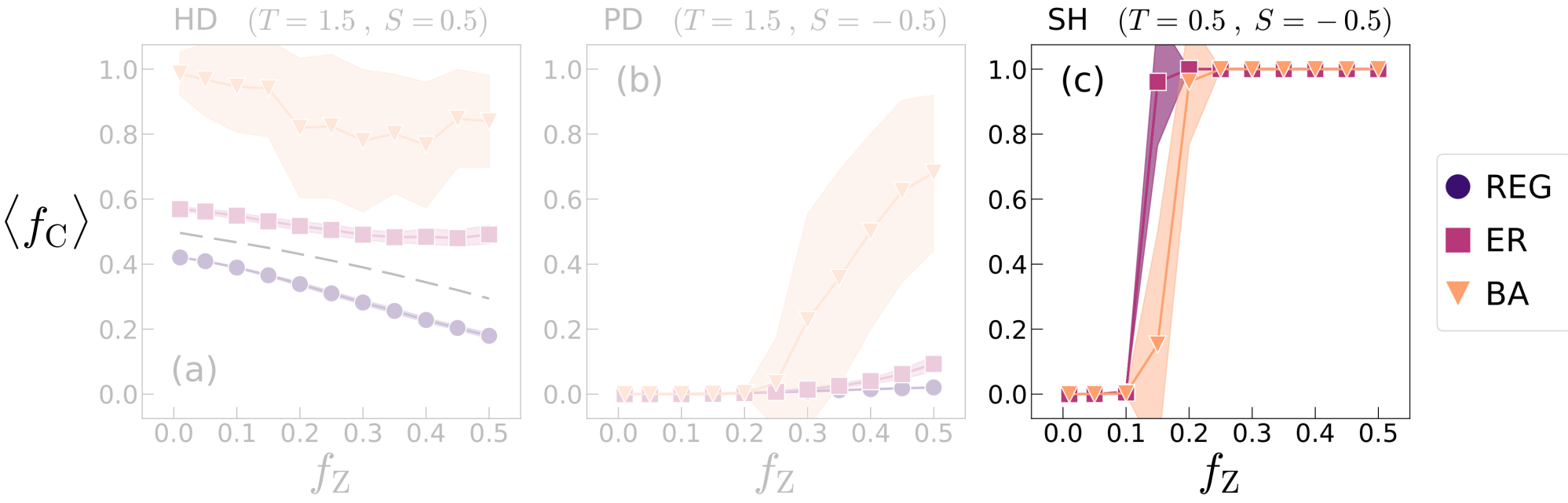

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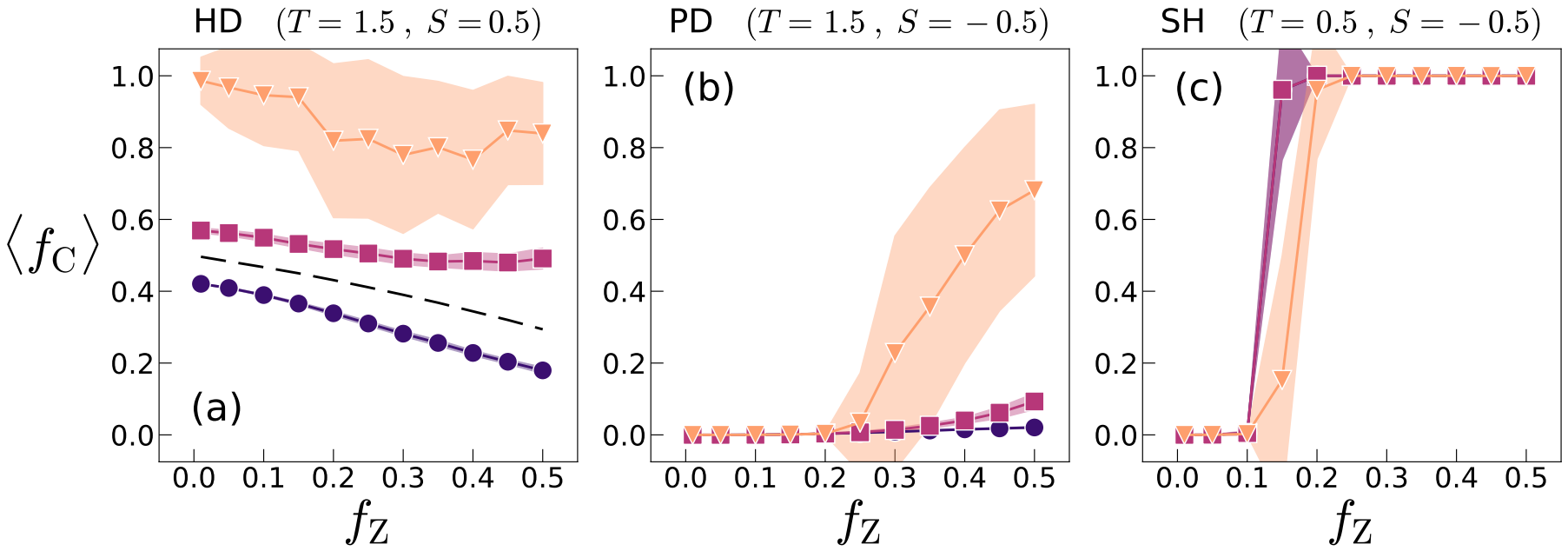
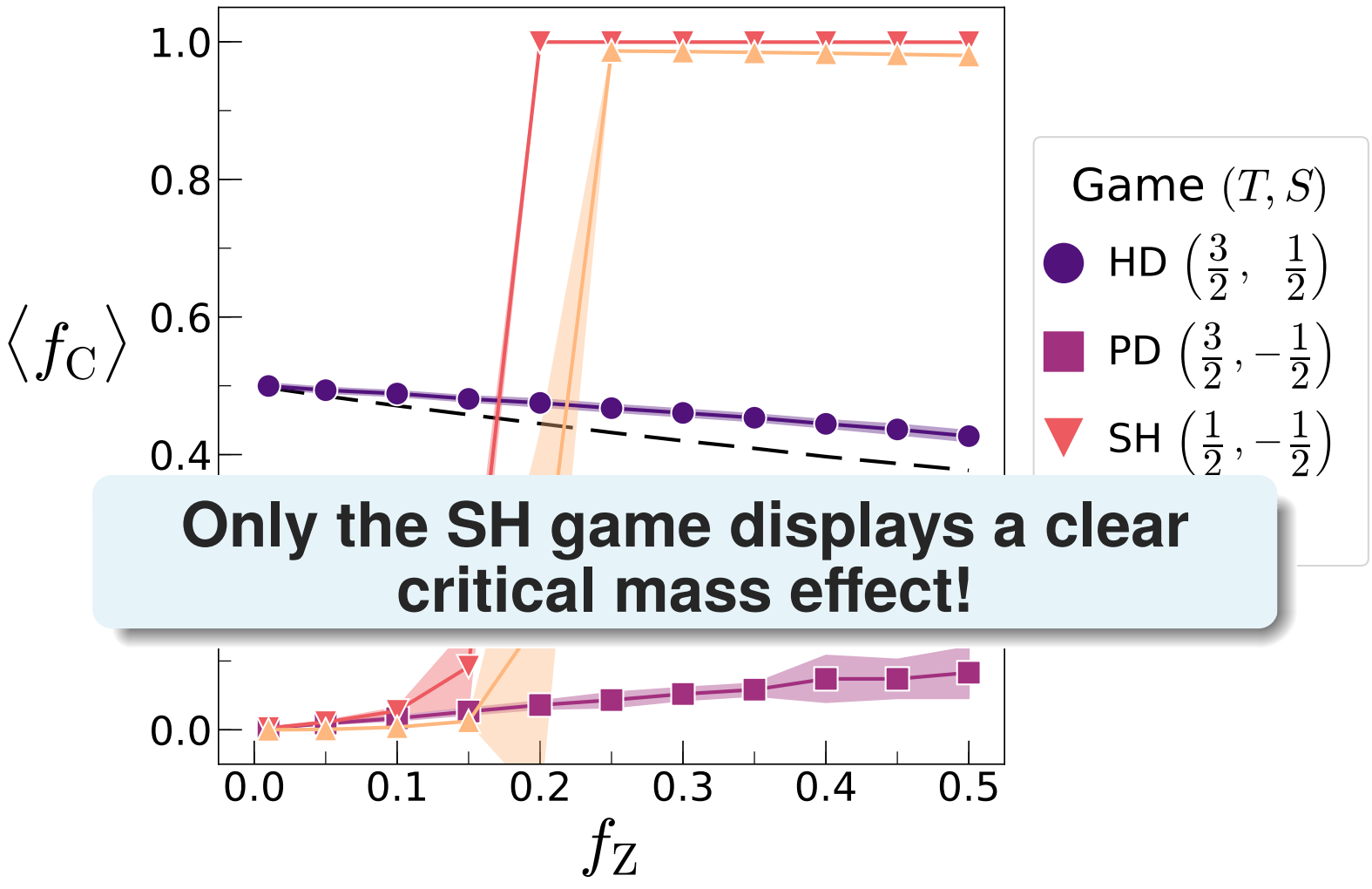


Remark:

Zealots nodes are placed **at random**!

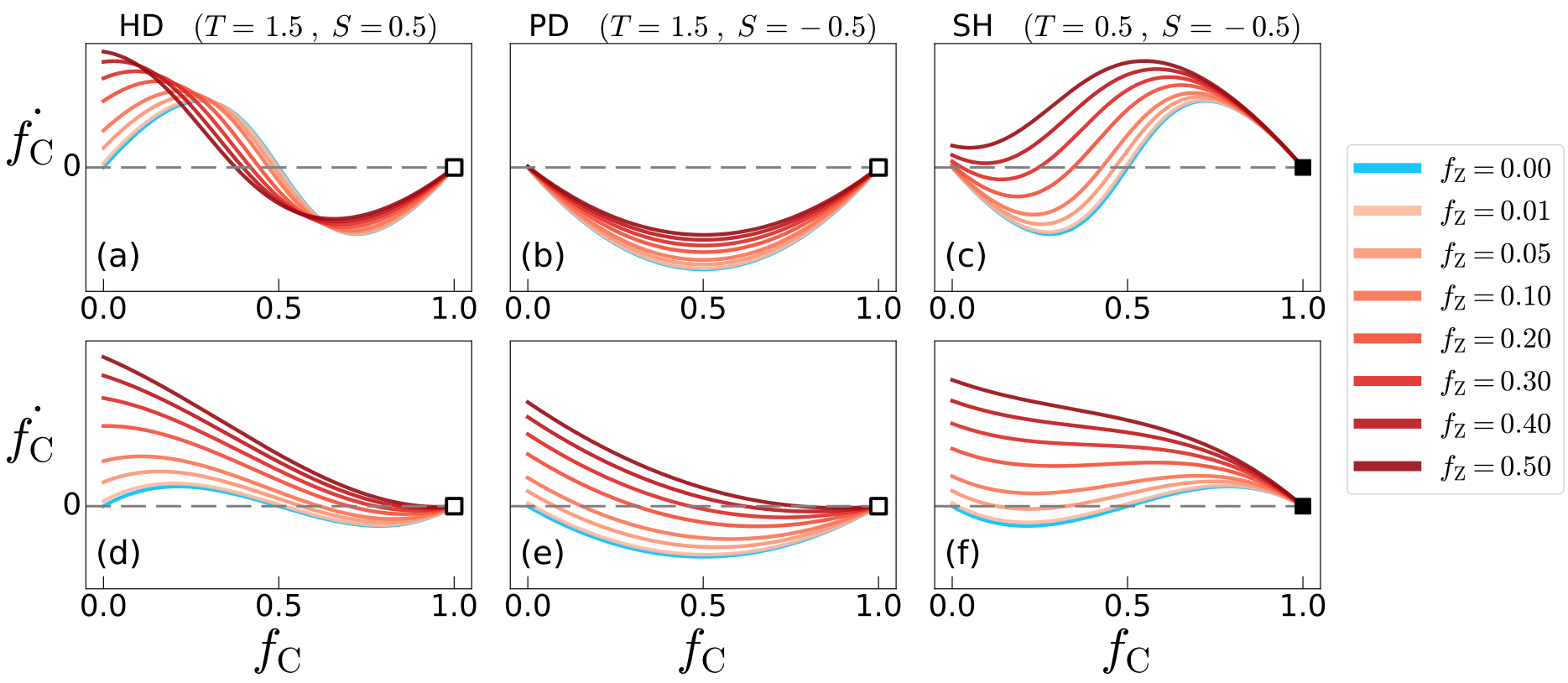
Summing up ...

Take home messages



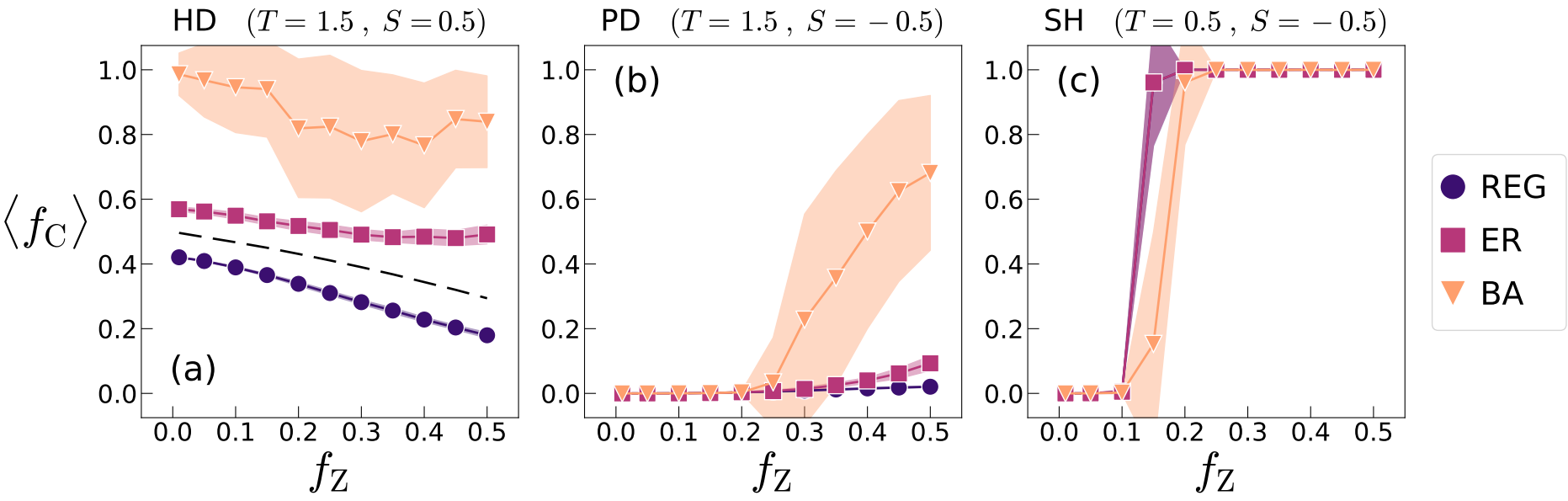
Only the SH game displays a clear critical mass effect!

Take home messages



Reducing the selection presure (or changing the update rule) can trigger the appearance of a critical mass effect

Take home messages



The topology of the interactions plays a crucial role!

Acknowledgements

Naoki Masuda

(SUNY Buffalo / Univ. of Bristol)

Acknowledgements

arXiv.org > physics > arXiv:1912.00400

Physics > Physics and Society

Critical mass effect in evolutionary games triggered by zealots

Alessio Cardillo, Naoki Masuda

(Submitted on 1 Dec 2019)

Tiny perturbations may trigger large responses in systems near criticality, shifting them across equilibria. Committed minorities are sugge systems. Using evolutionary game theory, we address the question whether a finite fraction of zealots can drive the system to large-scale depends on the selection pressure, update rule, and network structure in other types of games. Our study paves the way to understand s behavior or cooperative transports in animal groups.

Comments: Main + Supplementary. Submitted for publication. Comments are welcome
Subjects: **Physics and Society (physics.soc-ph)**; Computer Science and Game Theory (cs.GT)
Cite as: arXiv:1912.00400 [physics.soc-ph]
(or arXiv:1912.00400v1 [physics.soc-ph] for this version)

https://arxiv.org/abs/1912.00400

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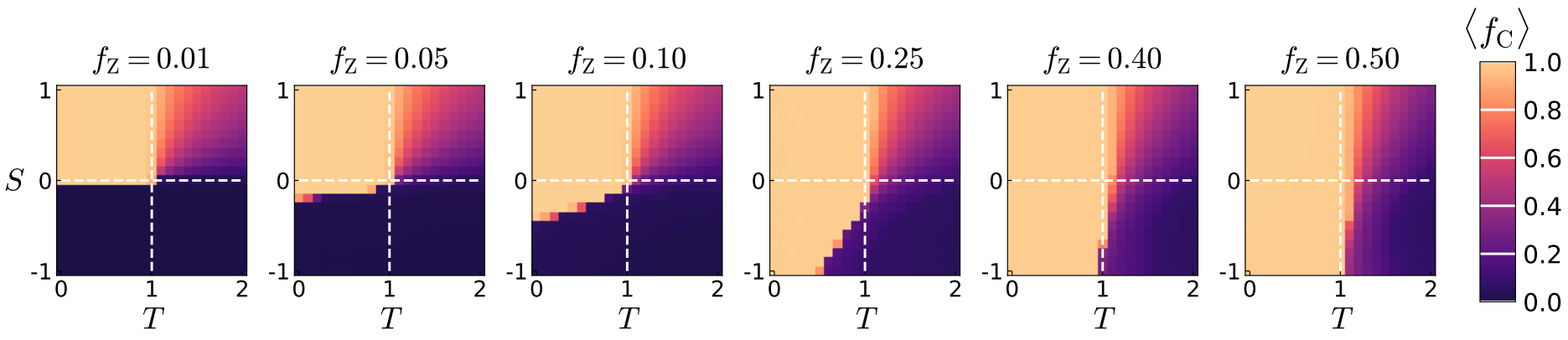
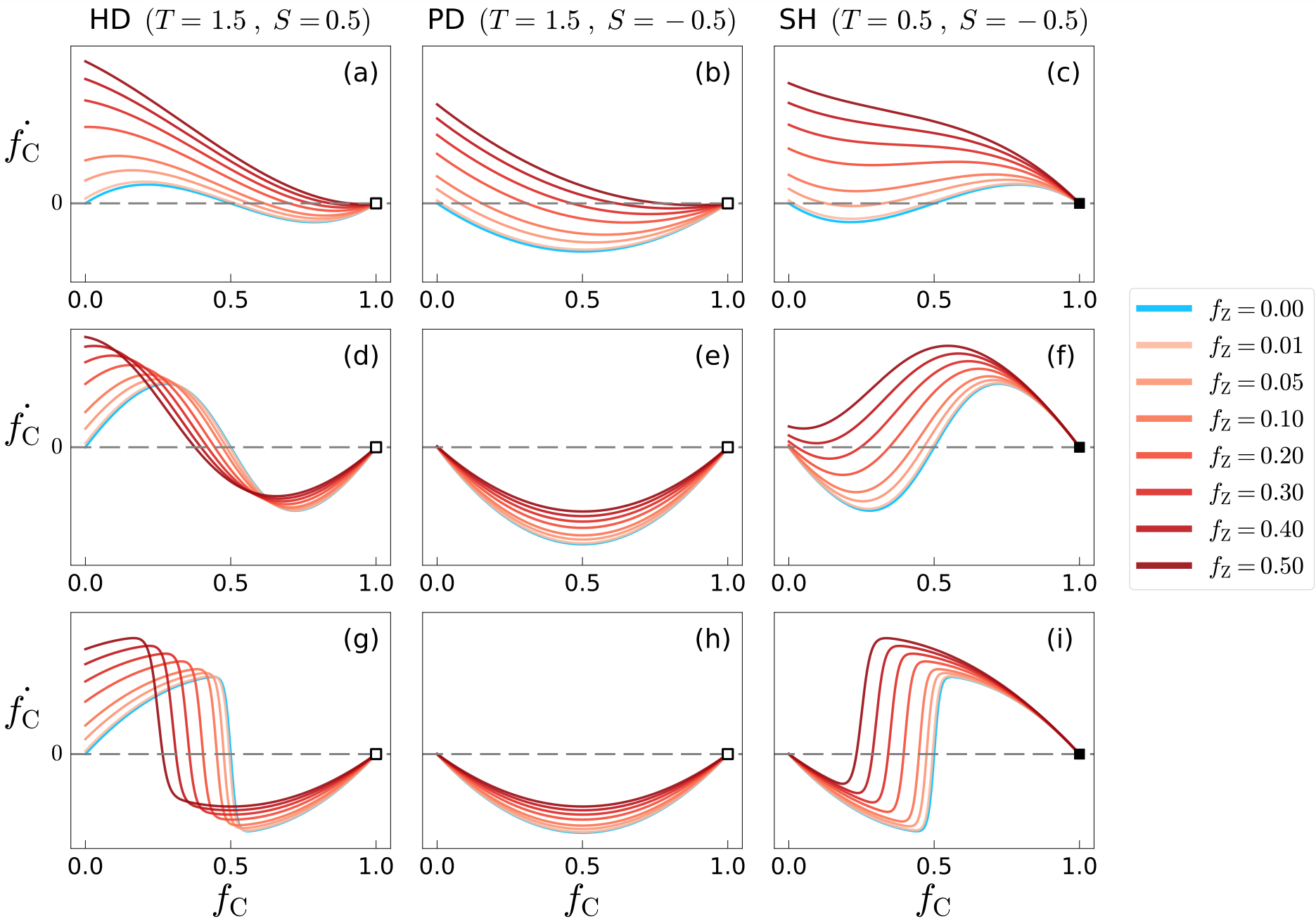

$f_{\mathrm{Z}} = 0.01$
$f_{\mathrm{Z}} = 0.05$
$f_{\mathrm{Z}} = 0.10$
$f_{\mathrm{Z}} = 0.25$
$f_{\mathrm{Z}} = 0.40$
$f_{\mathrm{Z}} = 0.50$
S
T
1
0
-1
0
1
2
$\langle f_{\mathrm{C}} \rangle$
1.0
0.8
0.6
0.4
0.2
0.0


HD $(T = 1.5\,,\ S = 0.5)$
PD $(T = 1.5\,,\ S = -0.5)$
SH $(T = 0.5\,,\ S = -0.5)$
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
$\dot{f}_{\mathrm{C}}$
0
0.0
0.5
1.0
f_{C}
$f_{\mathrm{Z}} = 0.00$
$f_{\mathrm{Z}} = 0.01$
$f_{\mathrm{Z}} = 0.05$
$f_{\mathrm{Z}} = 0.10$
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$f_{\mathrm{Z}} = 0.40$
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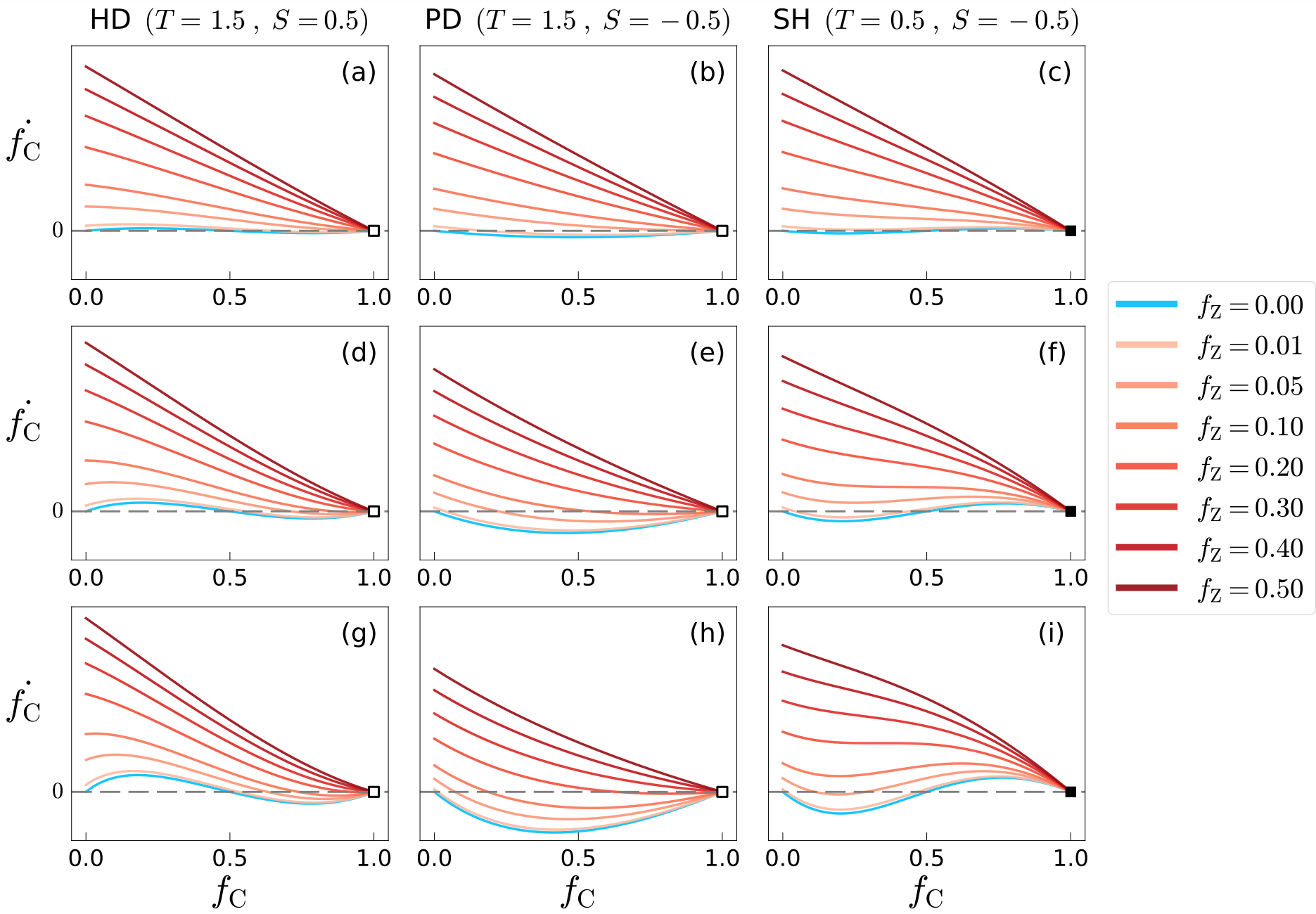
HD $(T = 1.5\ ,\ S = 0.5)$
PD $(T = 1.5\ ,\ S = -0.5)$
SH $(T = 0.5\ ,\ S = -0.5)$
(a)
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$\dot{f}_{\mathrm{C}}$
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f_{C}
$f_{\mathrm{Z}} = 0.00$
$f_{\mathrm{Z}} = 0.01$
$f_{\mathrm{Z}} = 0.05$
$f_{\mathrm{Z}} = 0.10$
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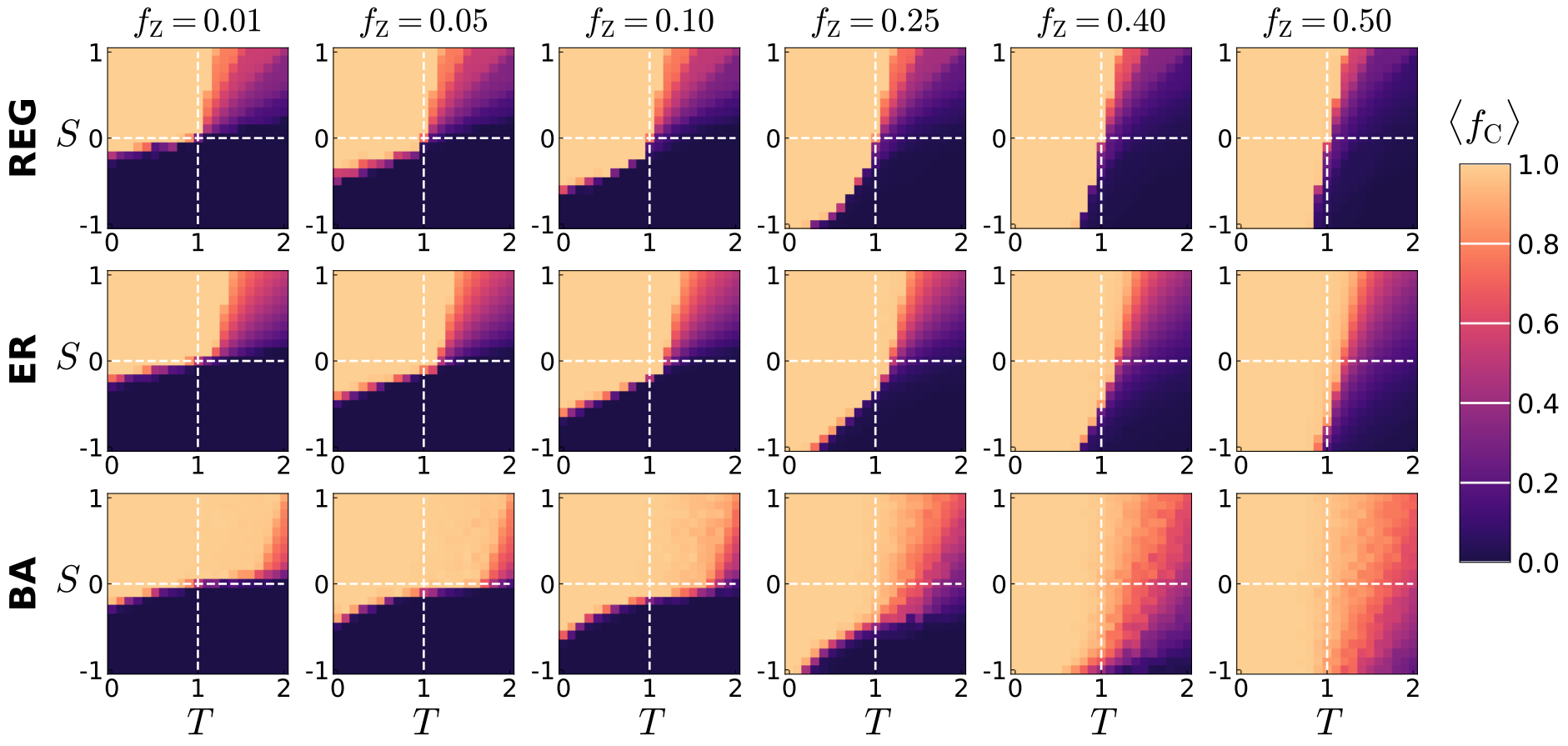
$f_{\mathrm{Z}} = 0.50$


$f_Z = 0.01$
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$f_Z = 0.25$
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$f_Z = 0.50$
REG
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0.8
0.6
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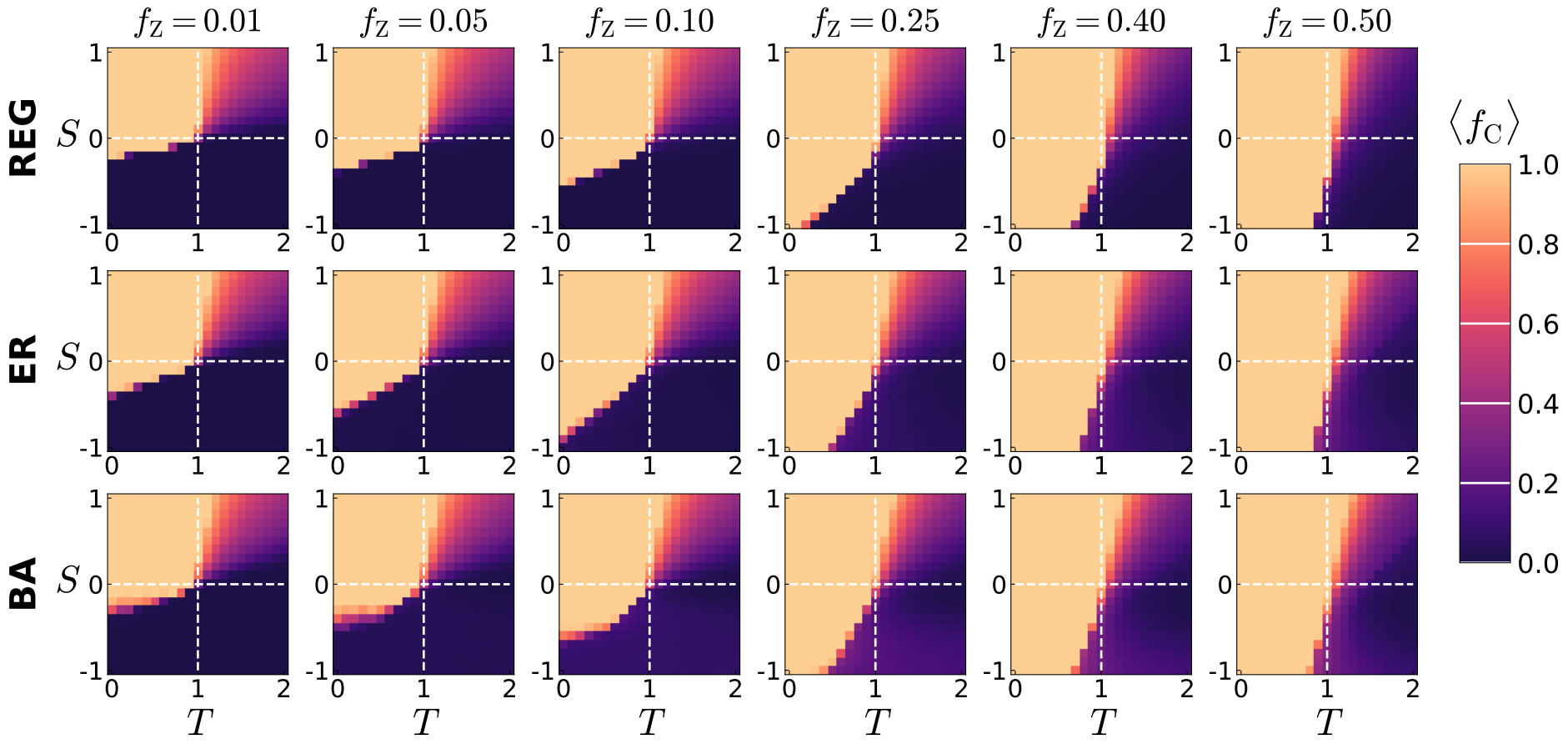
0.2
0.0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