“False Distribution”

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(Kirstin Peters)

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OPCT Bertinoro

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$$[\![P \mid Q]\!] = C[\, [\![P]\!] \mid [\![Q]\!] \,]$$

The first unsolved problem I want to talk about is the problem of developing a fundamental theory of concurrency. By a fundamental theory, I mean one that's not based upon arbitrary formal models or specific languages, but one that's really fundamental.

1983 Invited Address

Solved Problems, Unsolved Problems and Non-Problems in Concurrency

Leslie Lamport[1]

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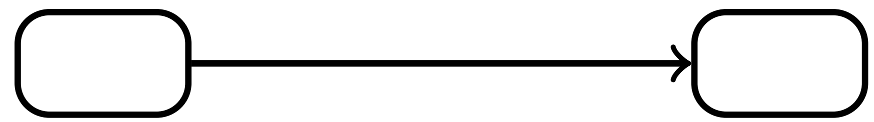
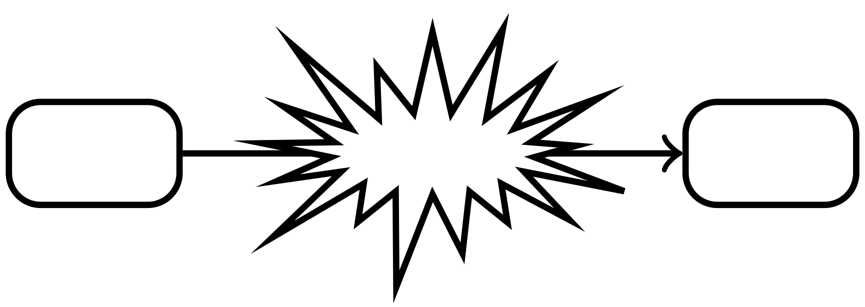
Asynchrony
&
Distributability

(A)Synchronous Interaction

(* joint project with TU Braunschweig [Goltz, Schicke, Glabbeek] *)

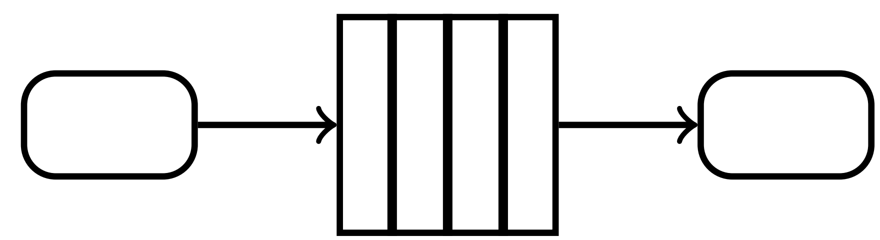


Synchronous Communication:



- instantaneous
- *abstract* specification

Asynchronous Communication:



- takes time
- *concrete* implementation

Distributability

Two activities can be implemented at different nodes, if they do not share anything they need to proceed.

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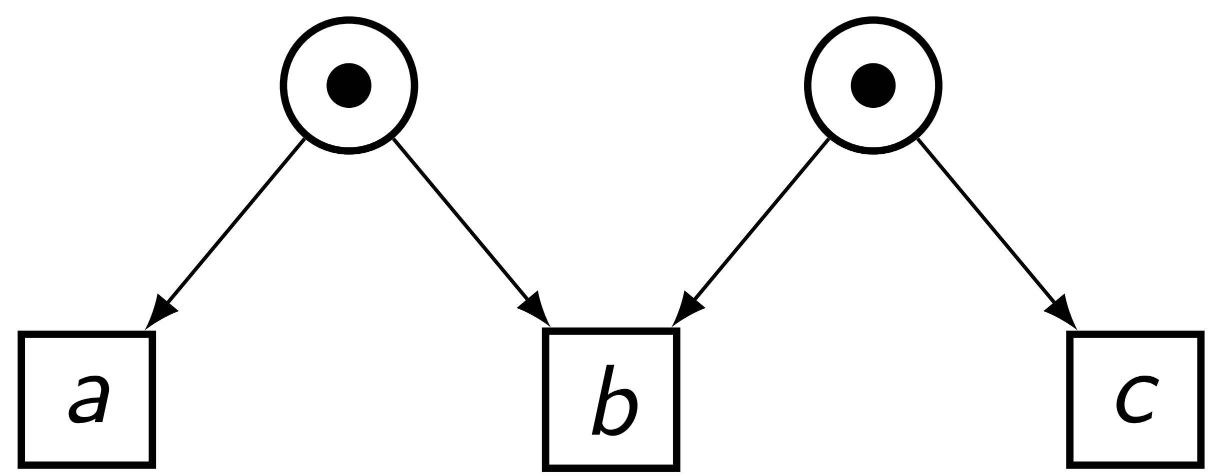
A fully reachable pure M in Petri nets [vGGS08, vGGS12]:

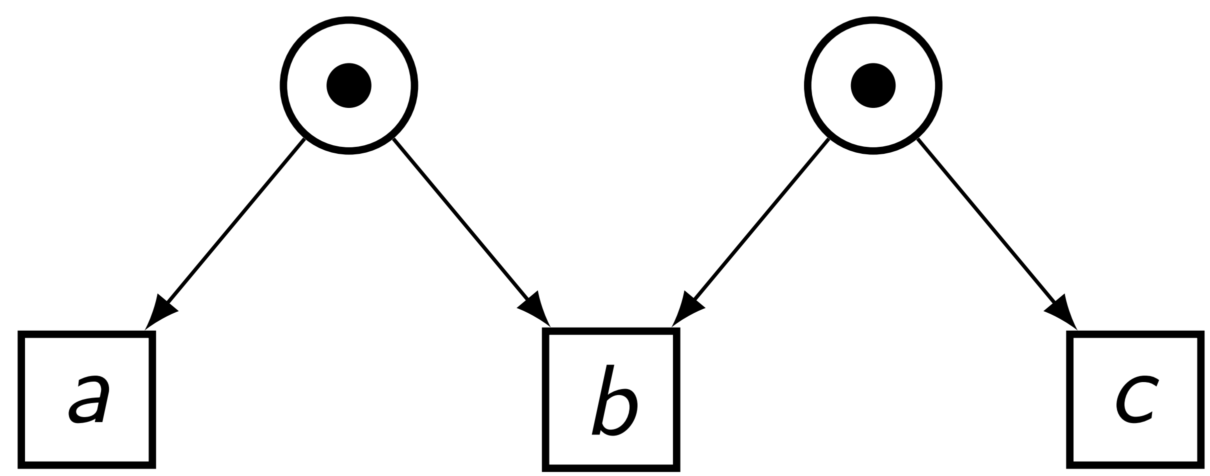


Distributability

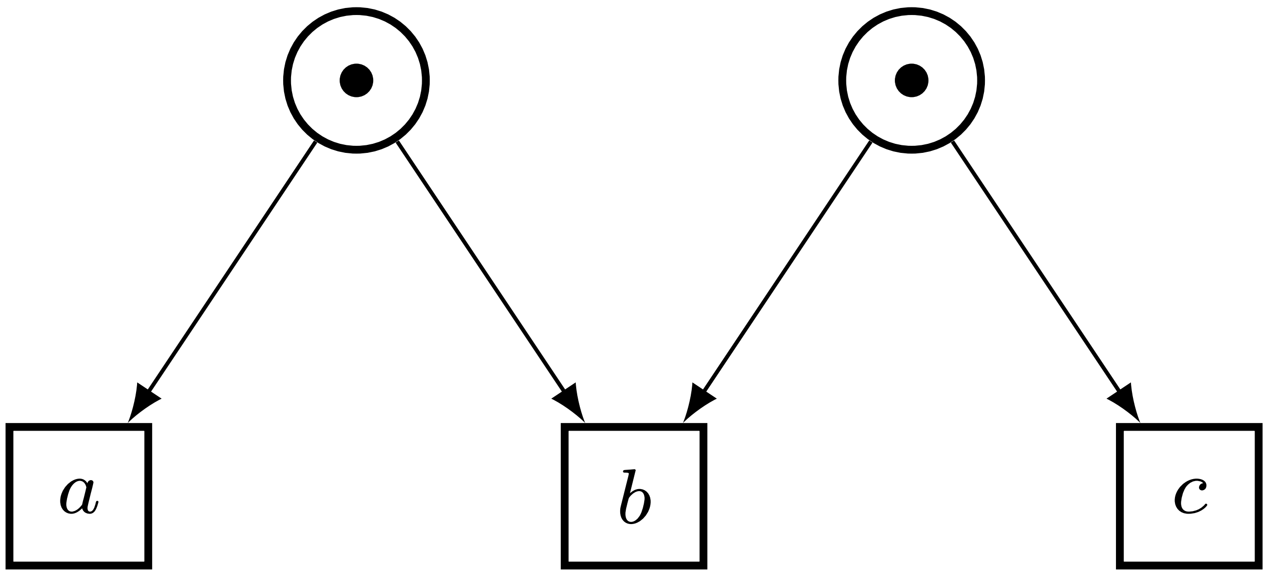
Two activities can be implemented at different nodes, if they do not share anything they need to proceed.

Theorem

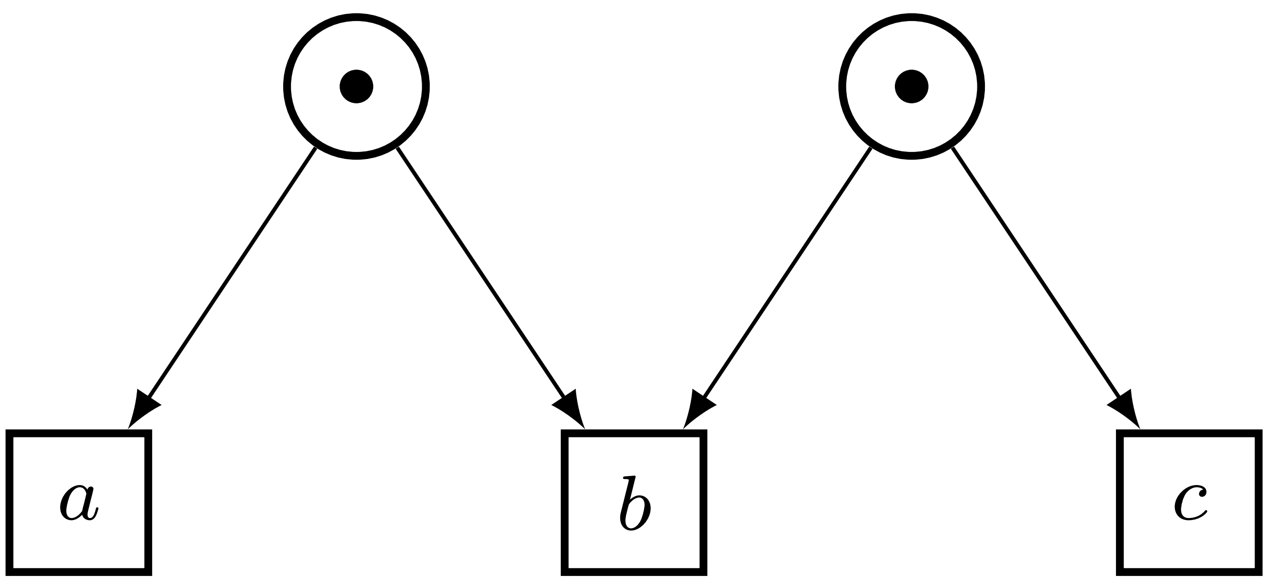
A Petri net is distributable if it does not contain a fully reachable pure M.

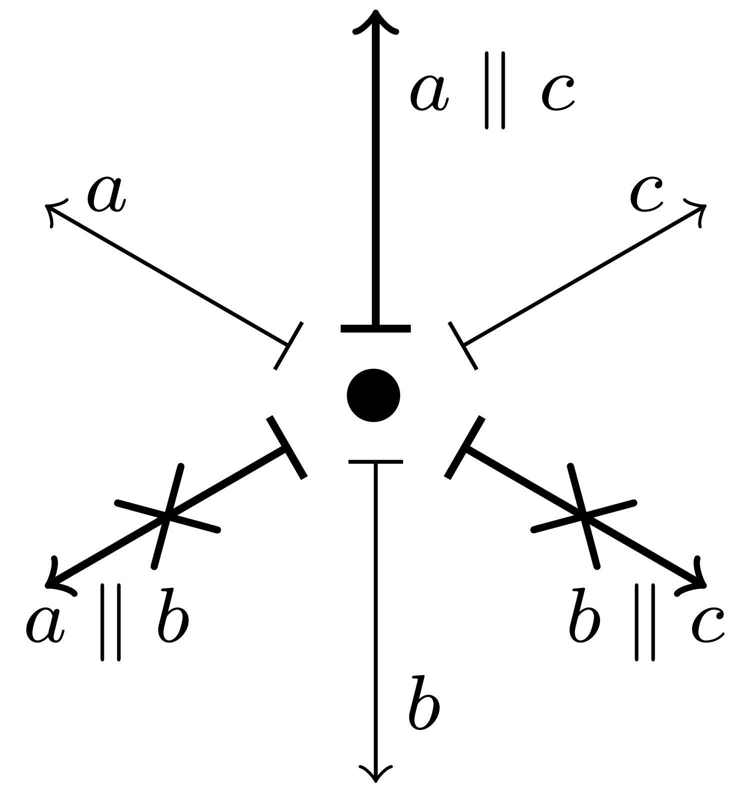


Distributability : Steps

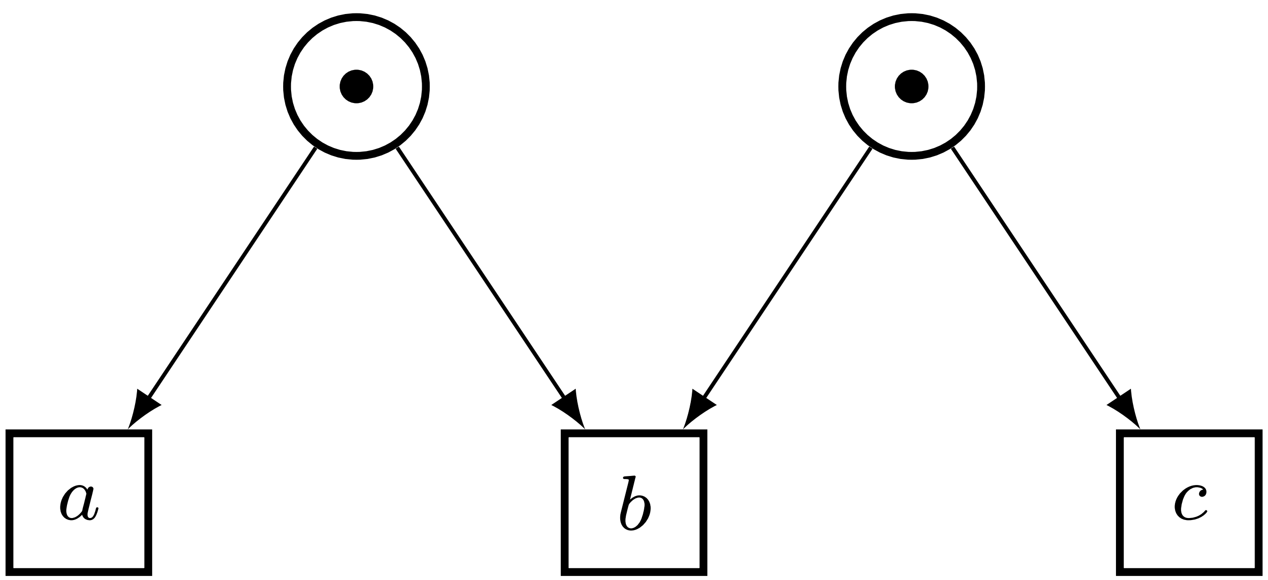


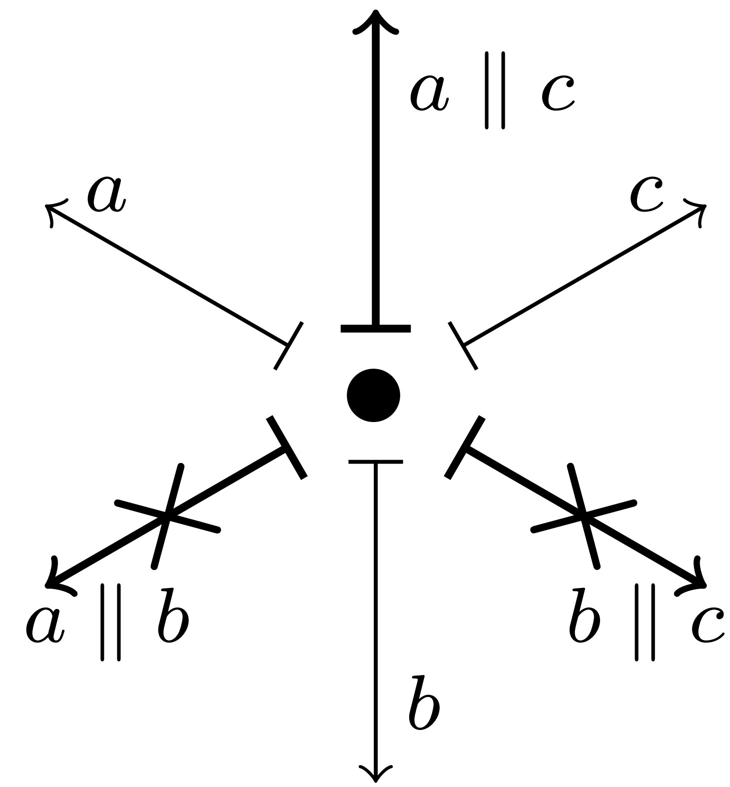
Distributability : Steps





Distributability : Steps





also compare : *(non-)overlapping redexes* in TRSs …

Distributability : Components

<u>for Petri Nets:</u>
groups of transitions that do not share places with other groups of transitions

<u>for process calculi, in essence:</u>
all parallel components at syntactic top-level

Gorla-Criteria

- **(weak) compositionality**
  $[\![P \mid Q]\!] = C[\, [\![P]\!] \mid [\![Q]\!] \,]$ is allowed !

- **name invariance**

- **operational correspondence**
  (*soundness/completeness of transition sequences, up to some target equivalence*)

- **divergence-reflection**

- **success-sensitiveness**

Distributability-Preservation

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distributability-preserving encodings preserve M !

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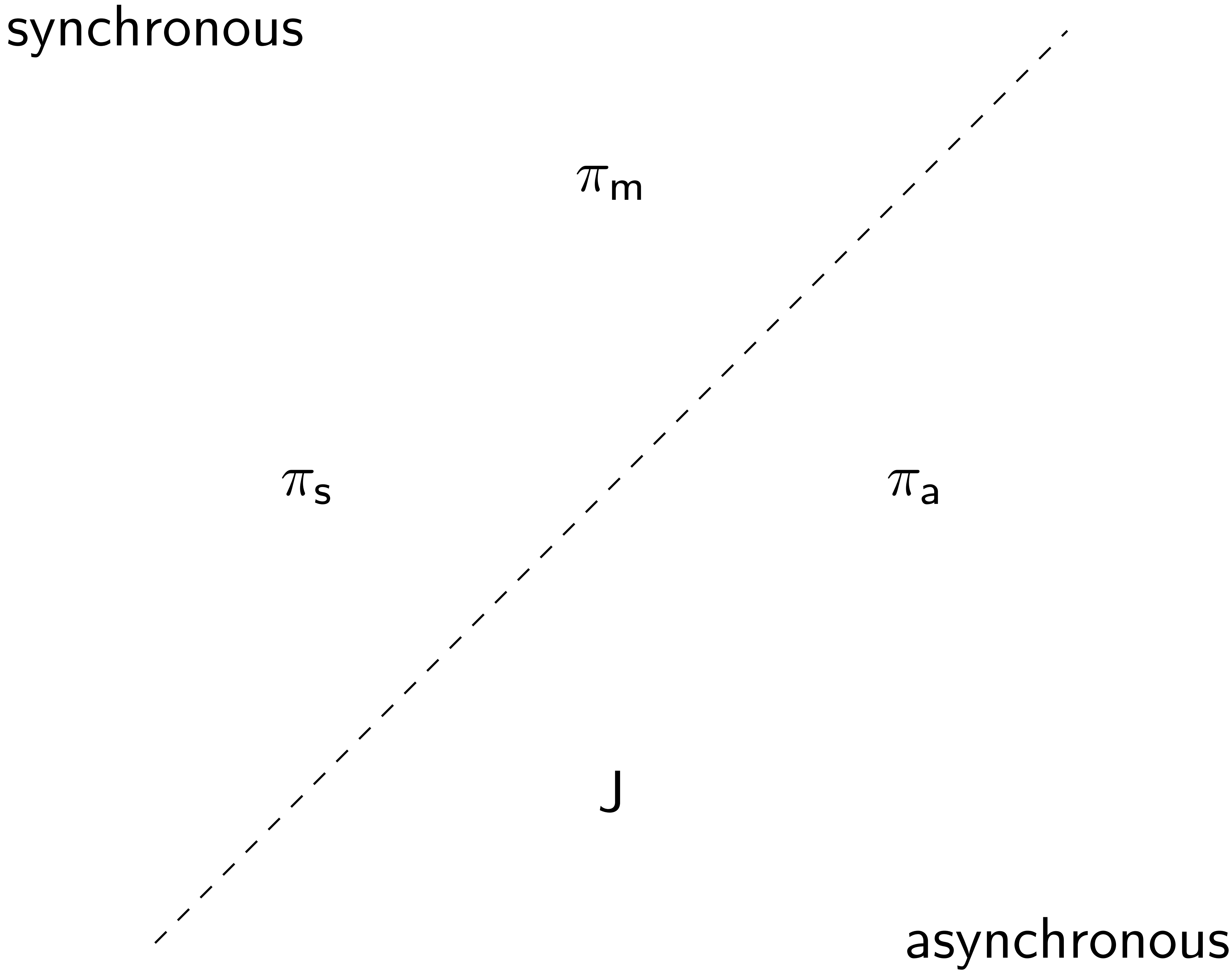
distributability-preserving encodings
preserve M !

good for separation results !

Some Calculi


synchronous
π_m
π_s
π_a
J
asynchronous

synchronous

interaction

π_m

π_s

π_a

J

asynchronous

$$\mathcal{L} = \langle\ \mathcal{P}, \longmapsto\ \rangle$$

Process Terms:

$$\mathcal{P}_{\mathsf{a}} ::= 0 \quad | \quad P_1 \mid P_2 \quad | \quad (\nu x)\, P \quad | \quad \overline{y}\langle z\rangle\,.0 \quad | \quad y(x)\,.P \quad | \quad y^{\star}(x)\,.P$$

$$\mathcal{P}_{\mathsf{s}} ::= \ldots \quad | \quad \overline{y}\langle z\rangle\,.P \quad | \quad \ldots \quad | \quad \sum_{i\in I} \overline{y_i}\langle z_i\rangle\,.P_i \quad | \quad \sum_{i\in I} y_i(x_i)\,.P_i$$

$$\mathcal{P}_{\mathsf{m}} ::= \ldots \quad | \quad \sum_{i\in I} \pi_i.P_i \qquad\qquad \text{where } \pi ::= \overline{y}\langle z\rangle \quad | \quad y(x)$$

synchronous

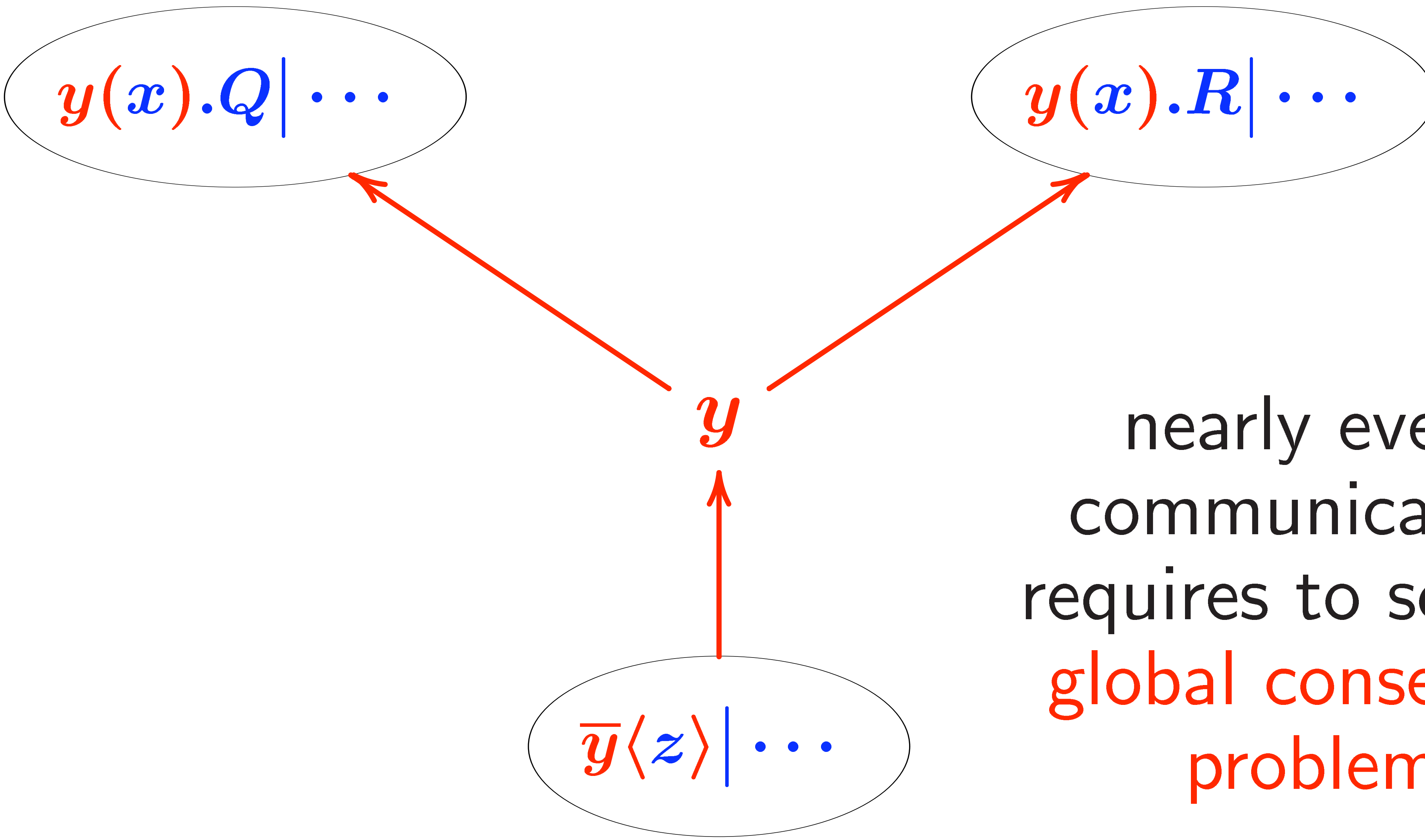
π_m

π_s π_a

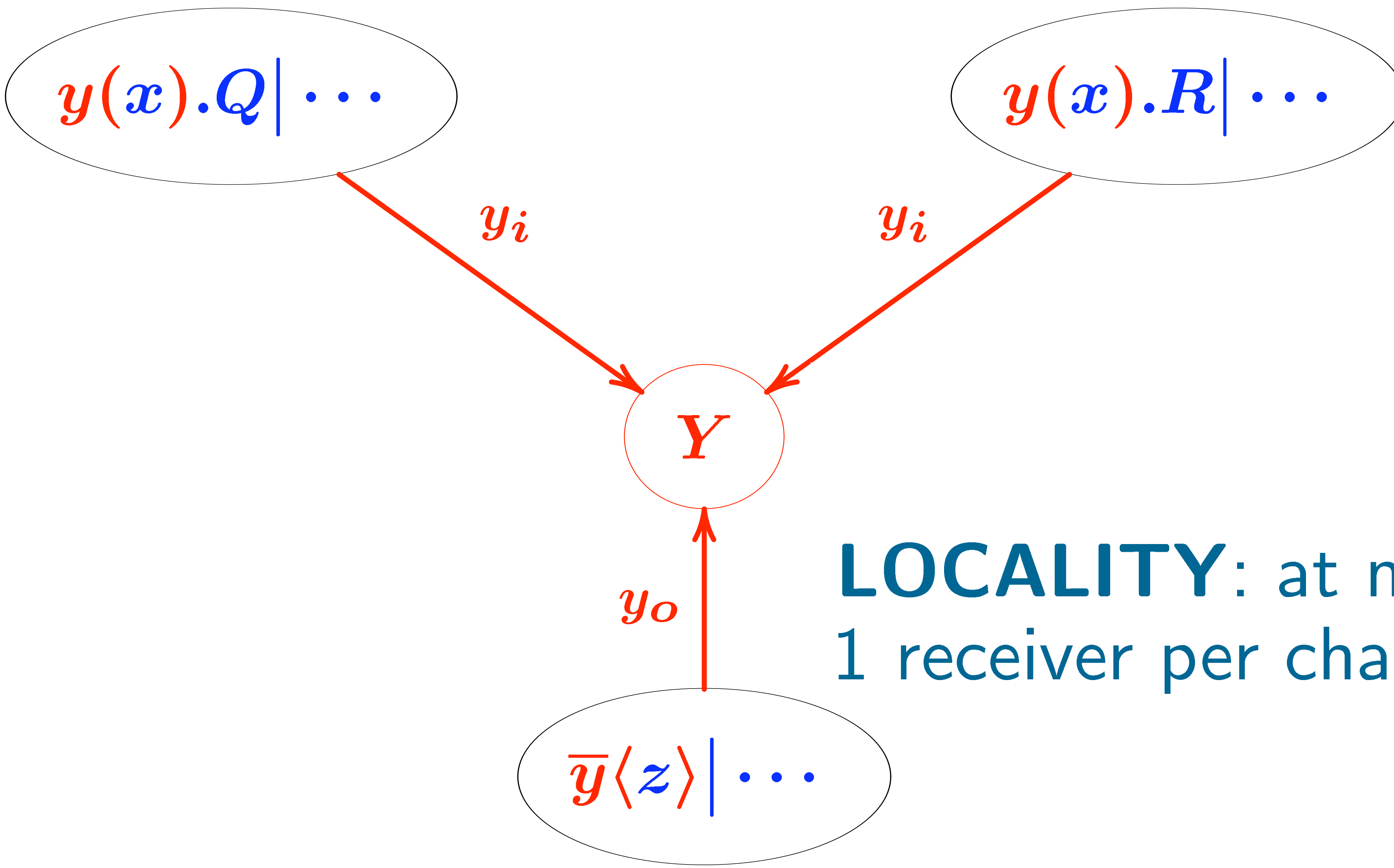
J

asynchronous

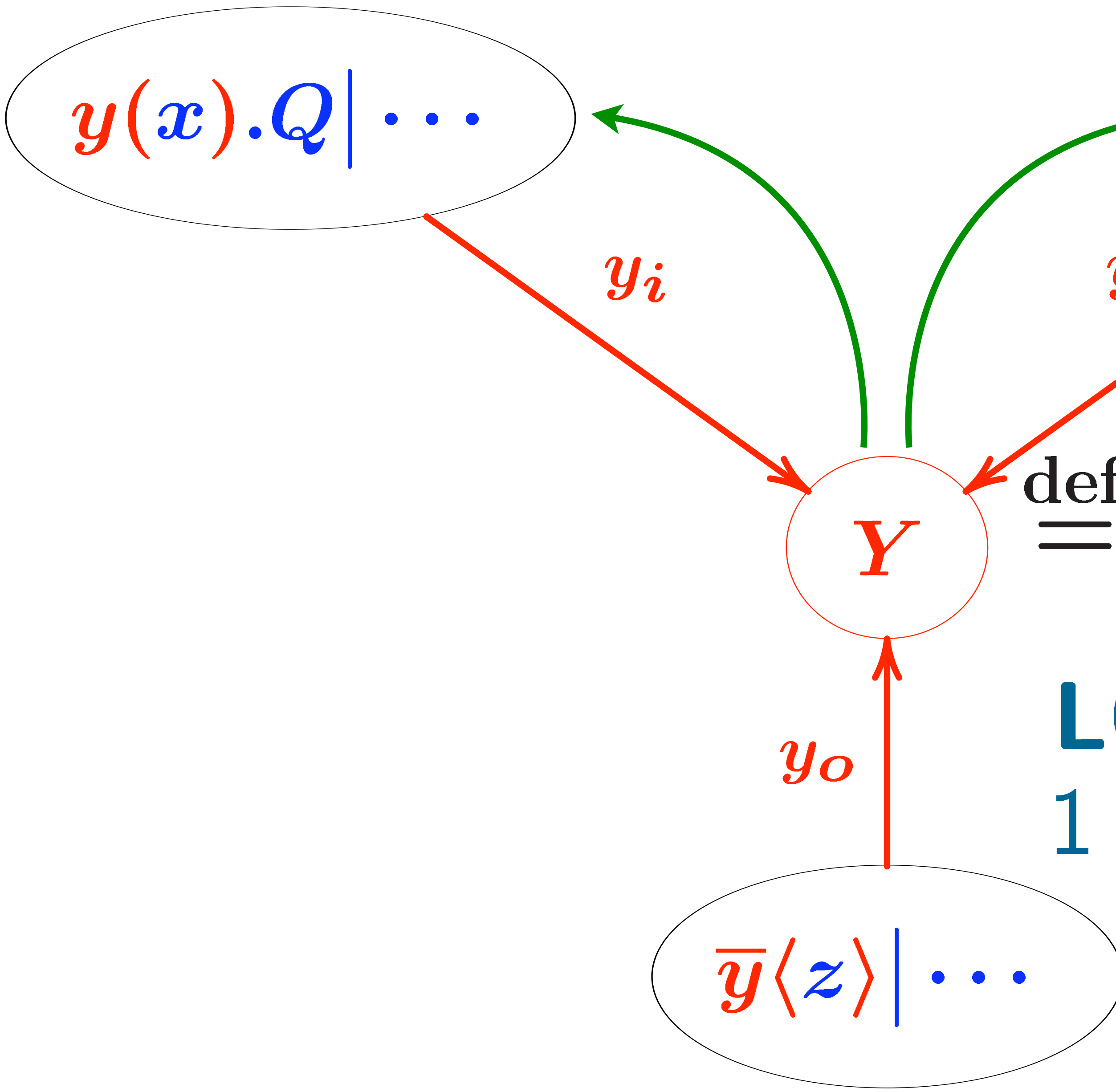
Join Calculus



nearly every communication requires to solve a global consensus problem



LOCALITY: at most 1 receiver per channel



$$Y \stackrel{\text{def}}{=} *\, y_i(a).y_o(z).\overline{a}\ z$$

LOCALITY: at most 1 receiver per channel

residence site = creation site
avoids unnecessary global communications

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$$\boxed{\begin{array}{r} (\nu y)\ P \\ y(x).P \\ *P \end{array}}$$

$$(\nu y)\ (\ *\ y(x).P\ \mid\ Q\ )$$

residence site = creation site

avoids unnecessary global communications

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$$\textbf{def}\ \ y(x) = P\ \ \textbf{in}\ \ Q$$

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$$(\nu y)\ (\ *\, y(x).P \mid Q\ )$$

$$\textbf{def}\ \ y(x) = P\ \ \textbf{in}\ \ Q$$

channel managers are like function definitions

Core Join

[Fournet, Gonthier, Lévy, ... 1995-2000]

$$D \quad ::= \quad \overbrace{y(x)|u(w)}^{J} = P$$

$$P, Q \quad ::= \quad \textbf{def } D \textbf{ in } Q \quad | \quad y(x) \quad | \quad P|Q$$

simultaneous multi-channel reception

Expressiveness !

$$\llbracket\, (\nu y)\, P \,\rrbracket \overset{\text{def}}{=} \textbf{def}\; y_o(x_o, x_i) \,|\, y_i(\kappa) = \kappa(x_o, x_i)\; \textbf{in}\; \llbracket\, P \,\rrbracket$$

$$\llbracket\, \overline{y}\langle z \rangle \,\rrbracket \overset{\text{def}}{=} y_o(z_o, z_i)$$

$$\llbracket\, y(x).P \,\rrbracket \overset{\text{def}}{=} \textbf{def}\; \kappa(x_o, x_i) = \llbracket\, P \,\rrbracket\; \textbf{in}\; y_i(\kappa)$$

Expressiveness !

$$[\![(\nu y)\, P]\!] \stackrel{\text{def}}{=} \textbf{def}\; y_o(x_o, x_i) | y_i(\kappa) = \kappa(x_o, x_i) \;\textbf{in}\; [\![P]\!]$$

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$$[\![\textbf{def}\; y(x) | u(w) = P \;\textbf{in}\; Q]\!] \stackrel{\text{def}}{=} (\nu x, u)\, \big(y(x).u(w).[\![P]\!] \mid [\![Q]\!] \big)$$

$$[\![x(u)]\!] \stackrel{\text{def}}{=} \overline{x}\langle u \rangle$$

$$[\![P \mid Q]\!] \stackrel{\text{def}}{=} [\![P]\!] \mid [\![Q]\!]$$

Expressiveness !

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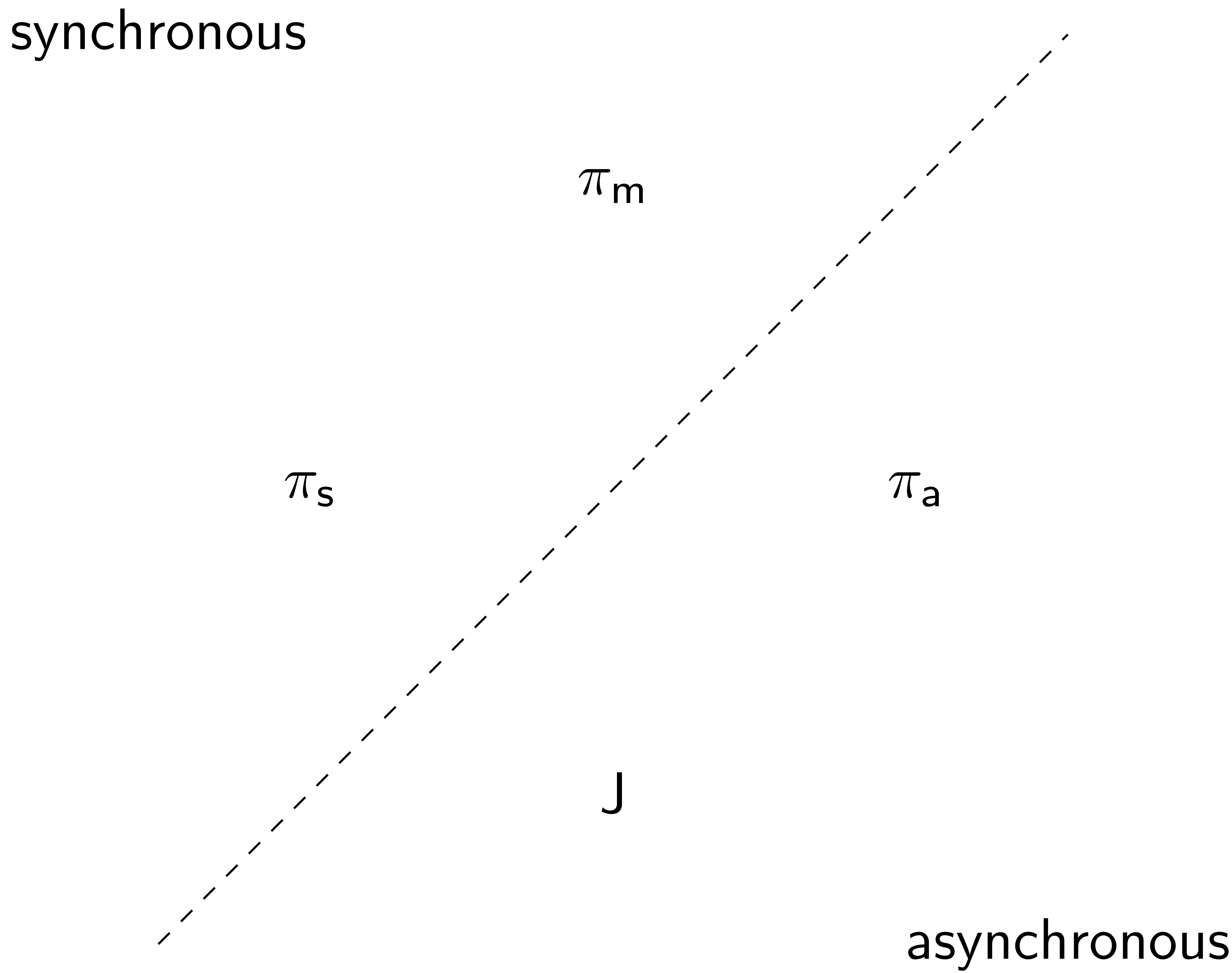
$$[\![P \mid Q]\!] \stackrel{\text{def}}{=} [\![P]\!] \mid [\![Q]\!]$$

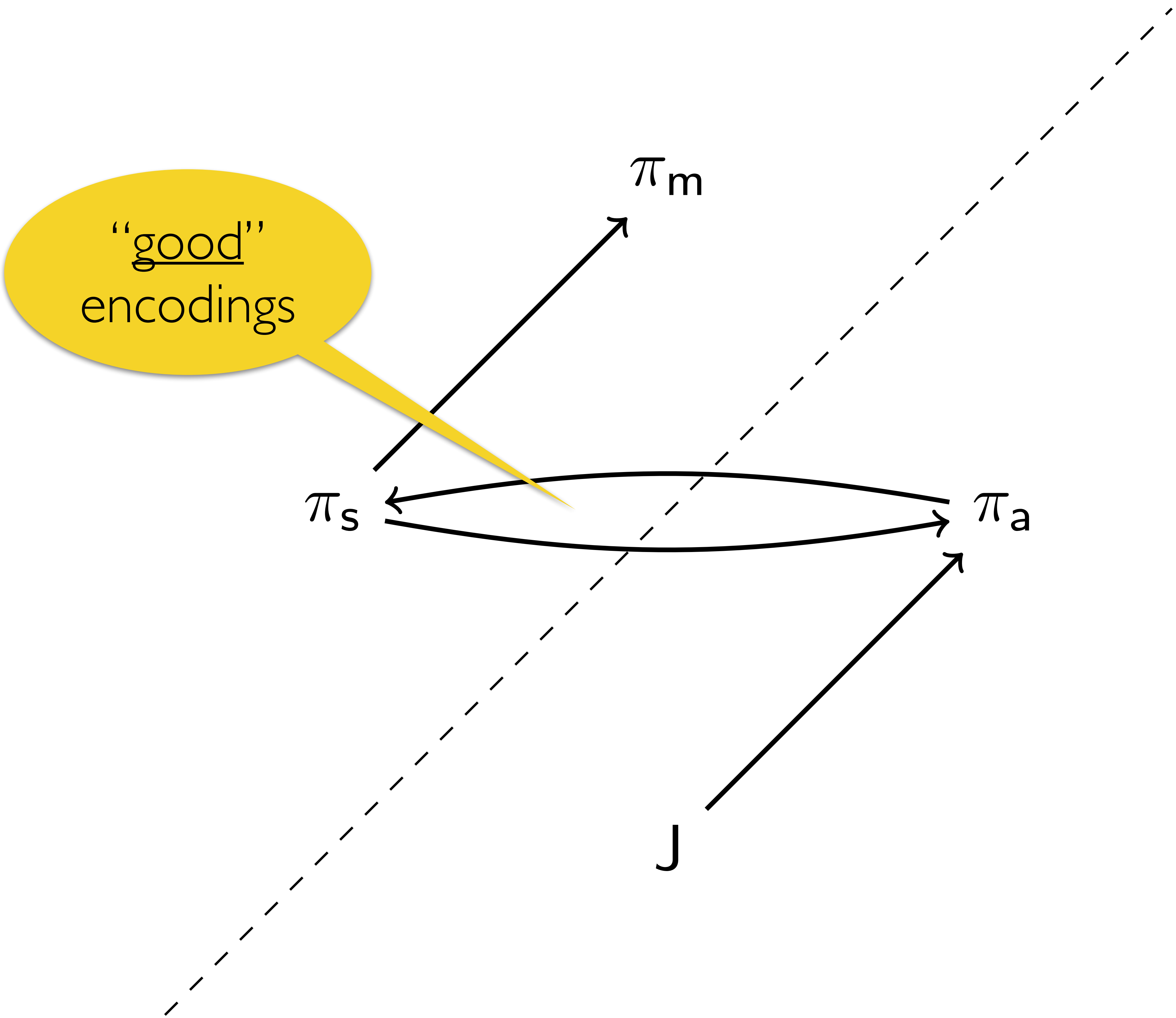
(and they are even fully abstract ! *)*


synchronous
π_{m}
π_{s}
π_{a}
J
asynchronous

$$\begin{tikzcd}
\pi_m \arrow[r, bend right=15, color=blue] \arrow[rr, bend right=40, color=blue] & \pi_s \arrow[l, bend right=15, "\mathrm{id}"'] \arrow[r, bend right=15, "{[\mathrm{Nes00}]}"'] & \pi_a \arrow[l, bend right=15, "\mathrm{id}"'] \arrow[r, bend right=15, "{[\mathrm{FG96,\ Fou98}]}"'] & J \arrow[l, bend right=15, "{[\mathrm{FG96,\ Fou98}]}"']
\end{tikzcd}$$

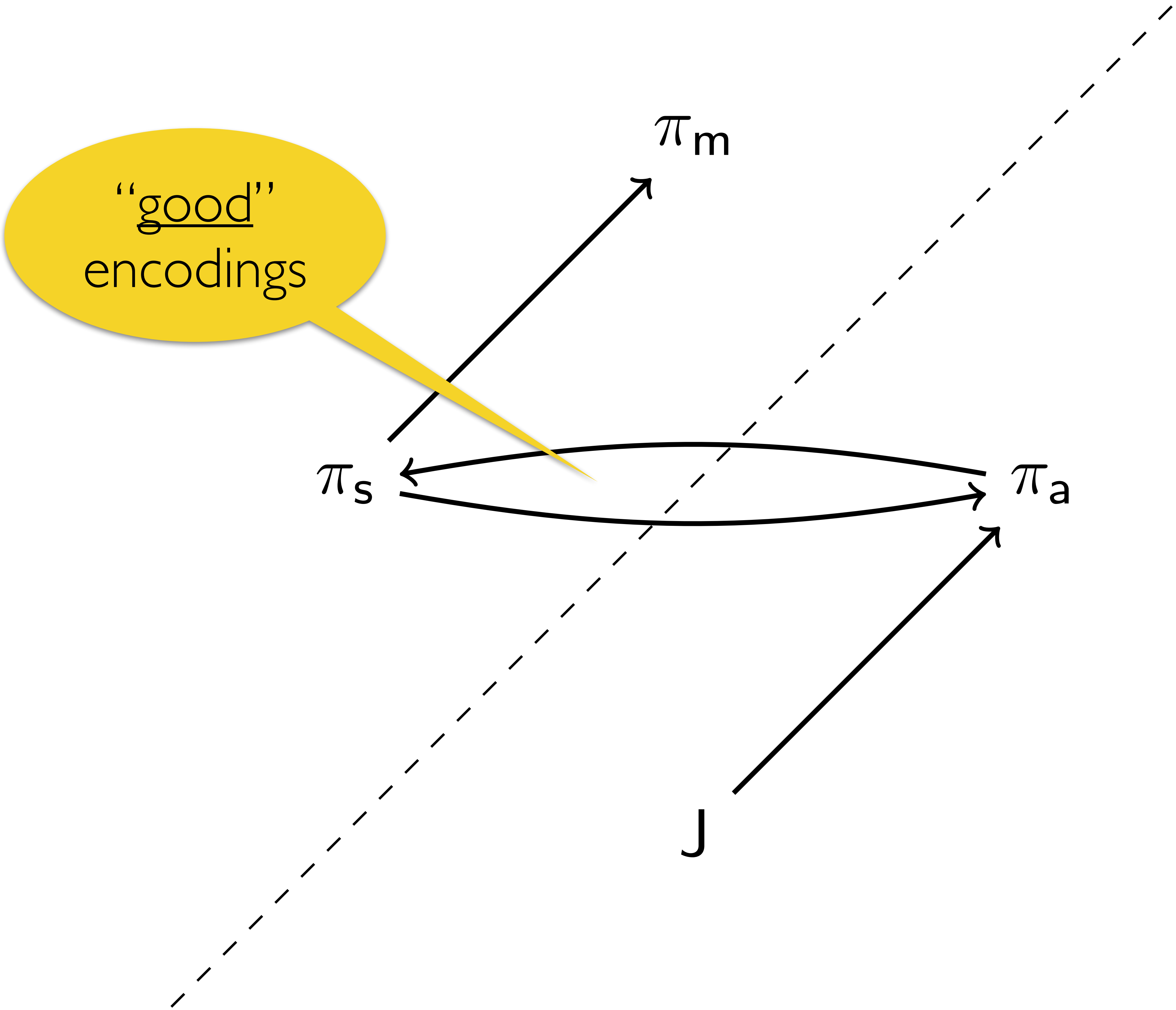
[PN12], with weak compositionality

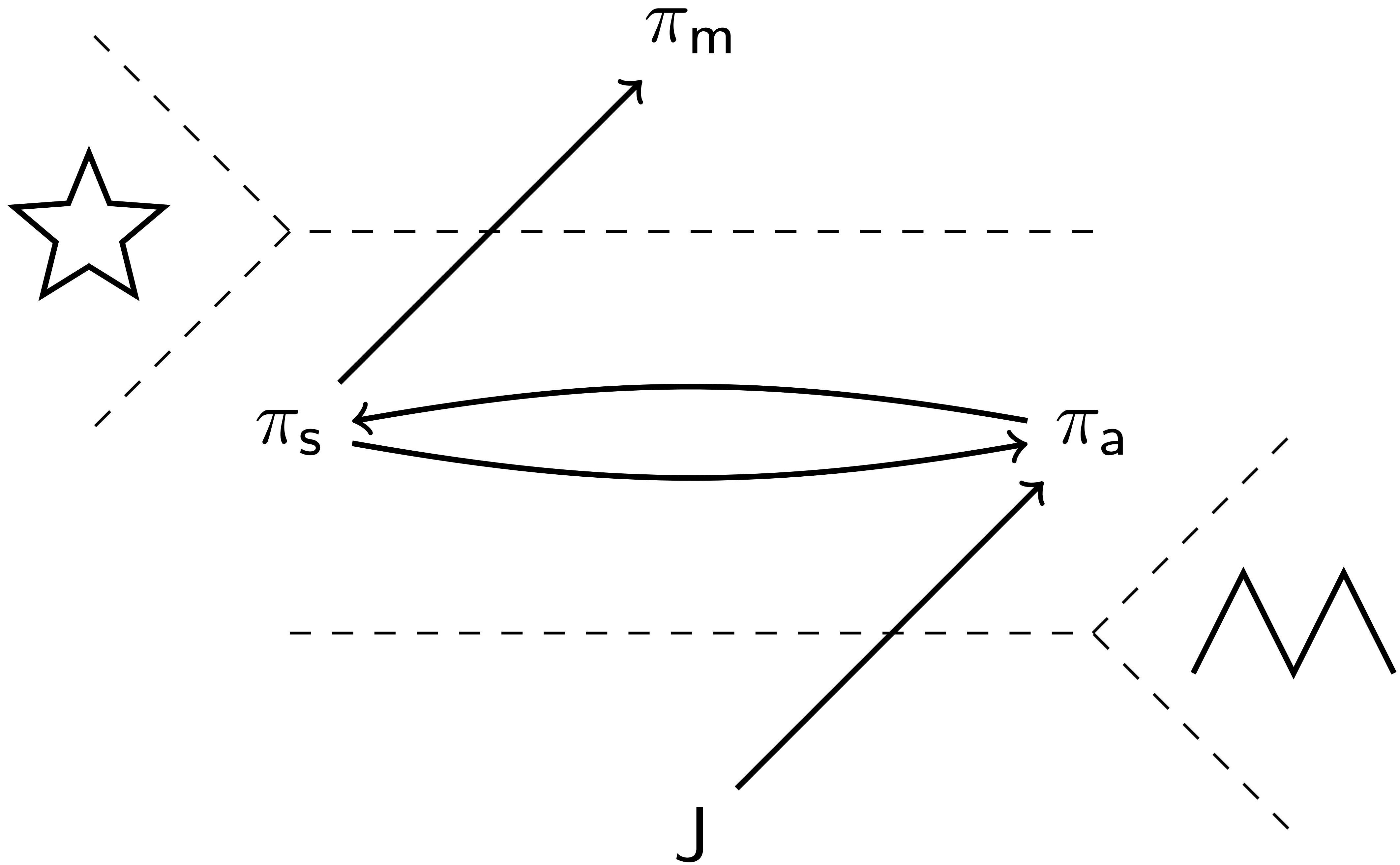
$$
\begin{tikzcd}
 & \pi_m & \\
\pi_s \arrow[ur] \arrow[rr, bend right] & & \pi_a \arrow[ll, bend right] \\
 & J \arrow[ur] &
\end{tikzcd}
$$



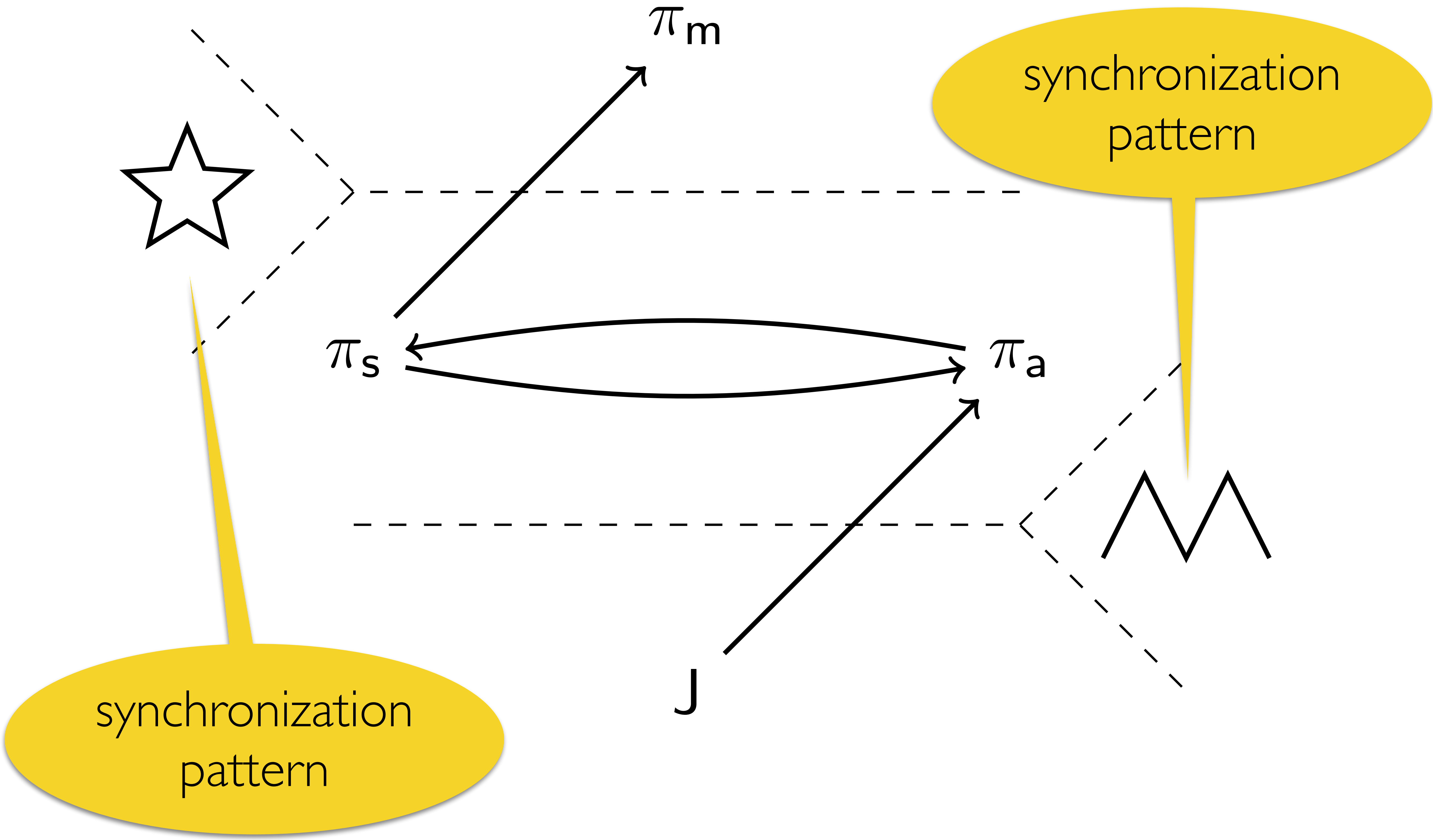
"good" encodings
π_m
π_s
π_a
J

“good” = [Gorla] + “distributability-preserving”

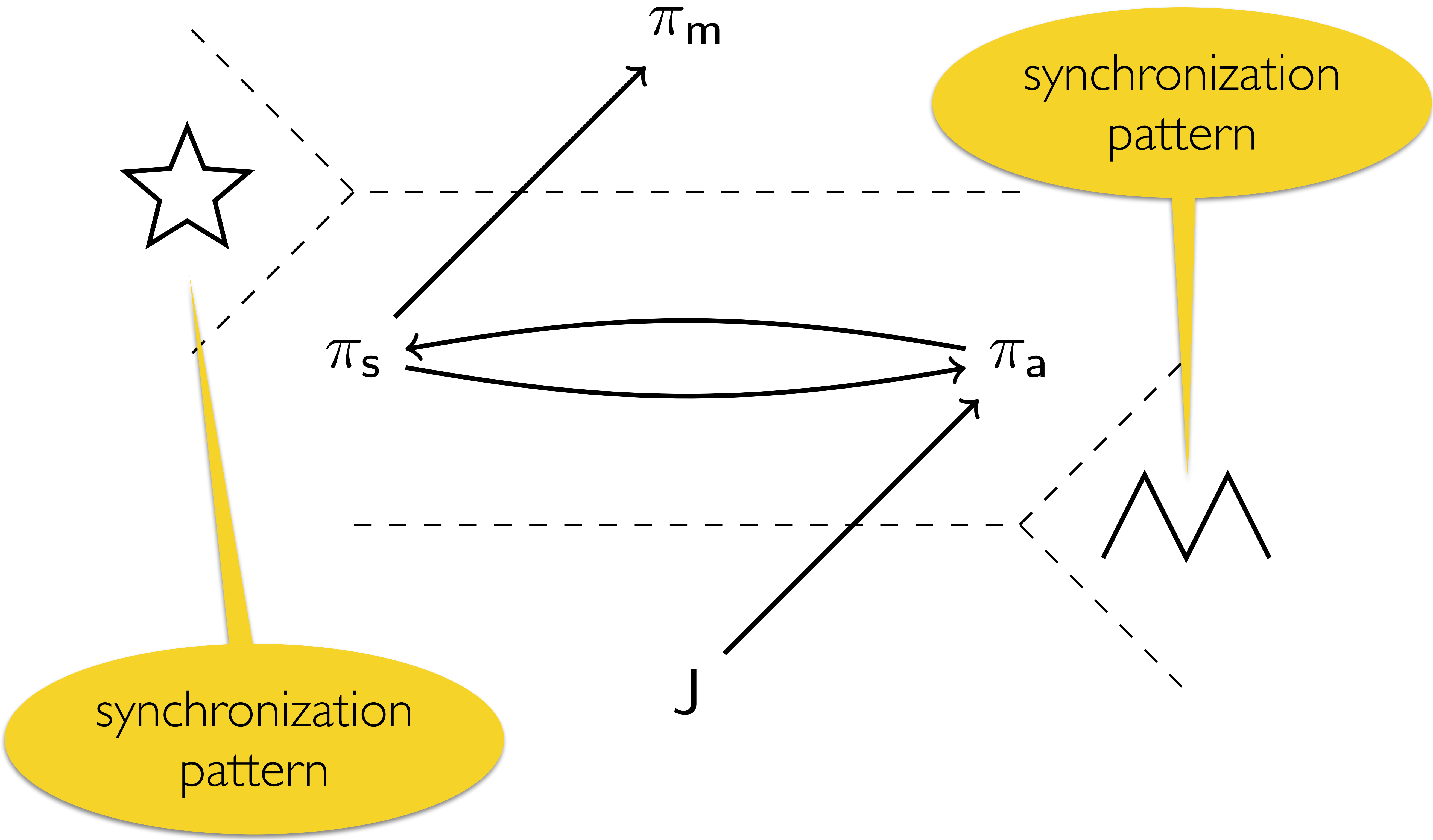


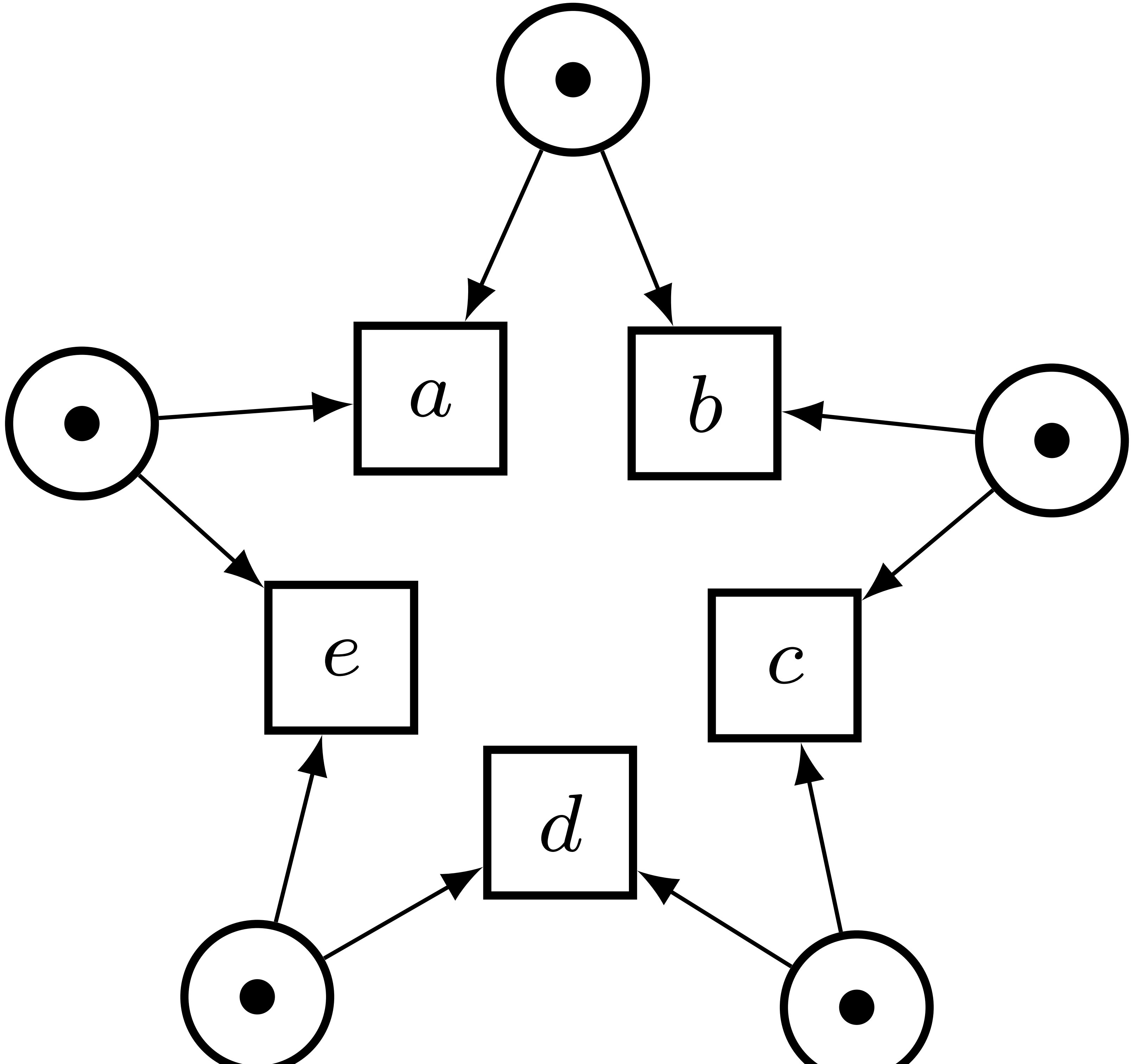


π_m
π_s
π_a
J


π_m
synchronization pattern
π_s
π_a
J
synchronization pattern

“distributability-preserving” preserves patterns




a
b
c
d
e

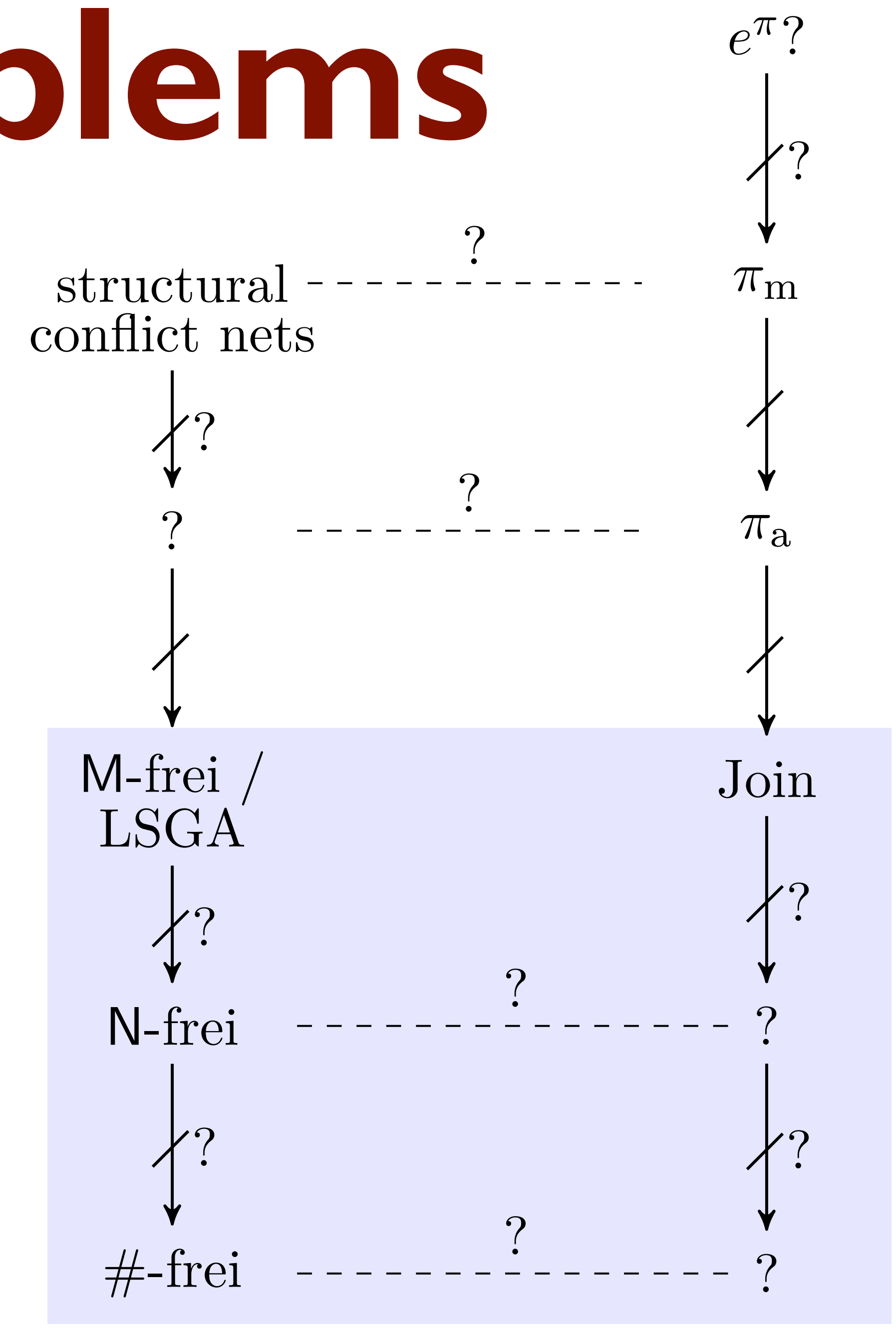
[Peters, Nestmann, Goltz : ESOP 2013]

Open Problems

$$
\begin{tikzcd}
 & e^{\pi}? \arrow[d, "/" marking, "?"] \\
\text{structural conflict nets} \arrow[r, dash, dashed, "?"] \arrow[d, "/" marking, "?"] & \pi_{\mathrm{m}} \arrow[d, "/" marking] \\
? \arrow[r, dash, dashed, "?"] \arrow[d, "/" marking] & \pi_{\mathrm{a}} \arrow[d, "/" marking] \\
\text{M-frei / LSGA} \arrow[d, "/" marking, "?"] & \text{Join} \arrow[d, "/" marking, "?"] \\
\text{N-frei} \arrow[r, dash, dashed, "?"] \arrow[d, "/" marking, "?"] & ? \arrow[d, "/" marking, "?"] \\
\#\text{-frei} \arrow[r, dash, dashed, "?"] & ?
\end{tikzcd}
$$

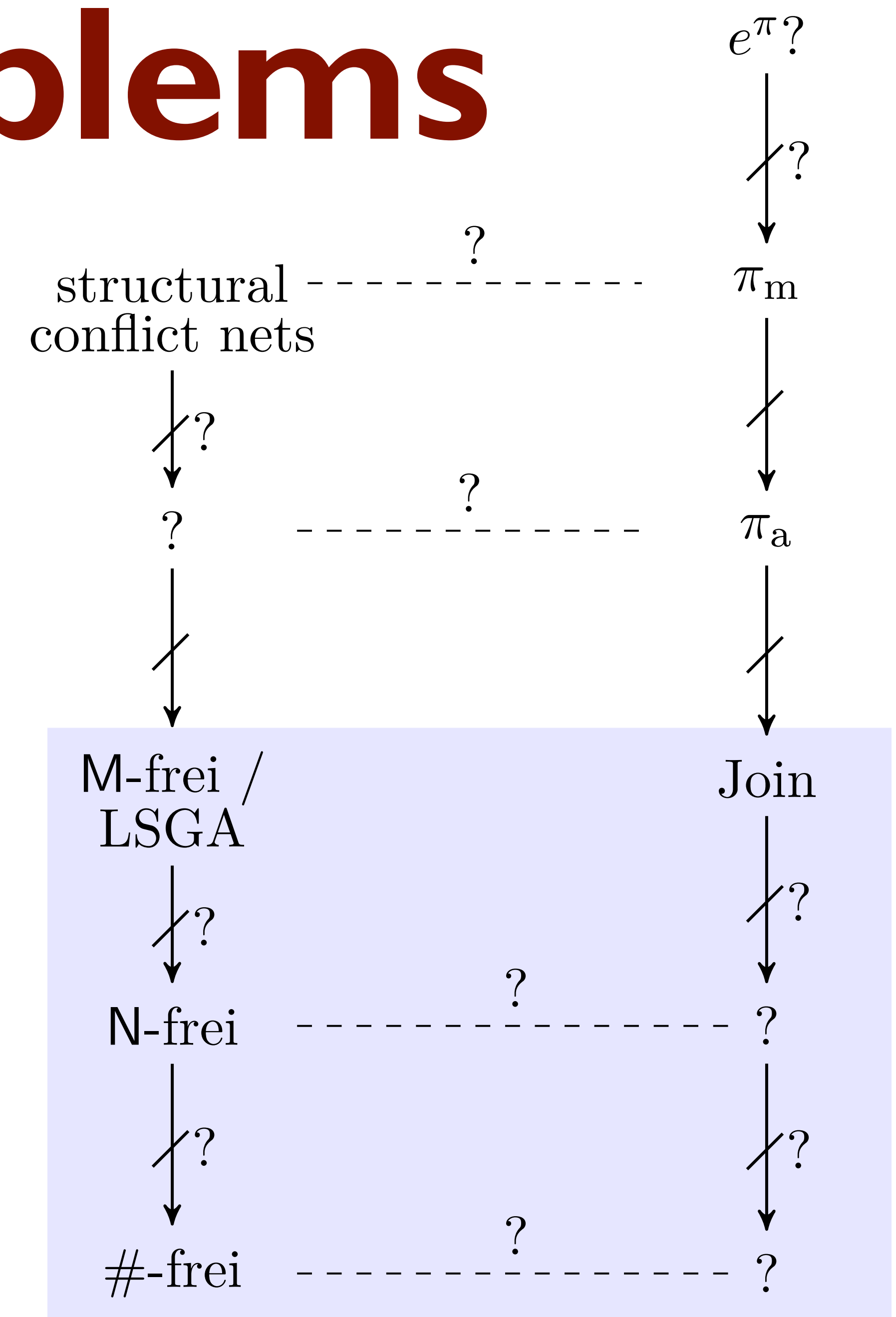
Open Problems

- exact borderlines?



Open Problems

- exact borderlines?
- distributability of other calculi (ambients, Dpi, e^{pi}, …)



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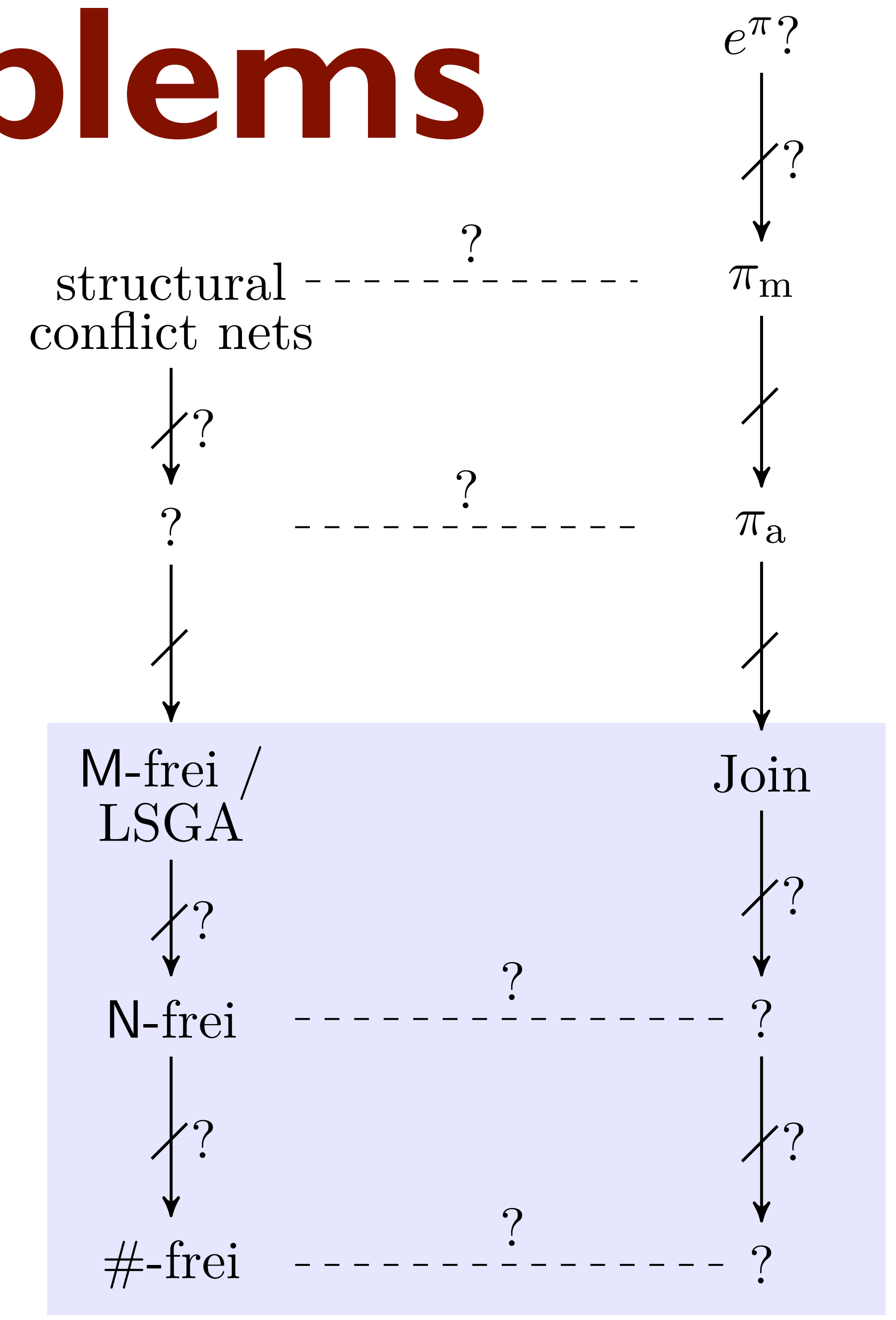
- IT vs NL/AU (with DE)



Open Problems

- exact borderlines?
- distributability of other calculi (ambients, Dpi, e$^{\text{pi}}$, …)
- IT vs NL/AU (with DE)
- fundamental theory of concurrency …