The Hierarchy of Hyperlogics*:
A Knowledge Reasoning Perspective

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*[LICS 2019]

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Expressiveness Study

Temporal logics for hyperproperties vs
First-order/second-order logics for hyperproperties
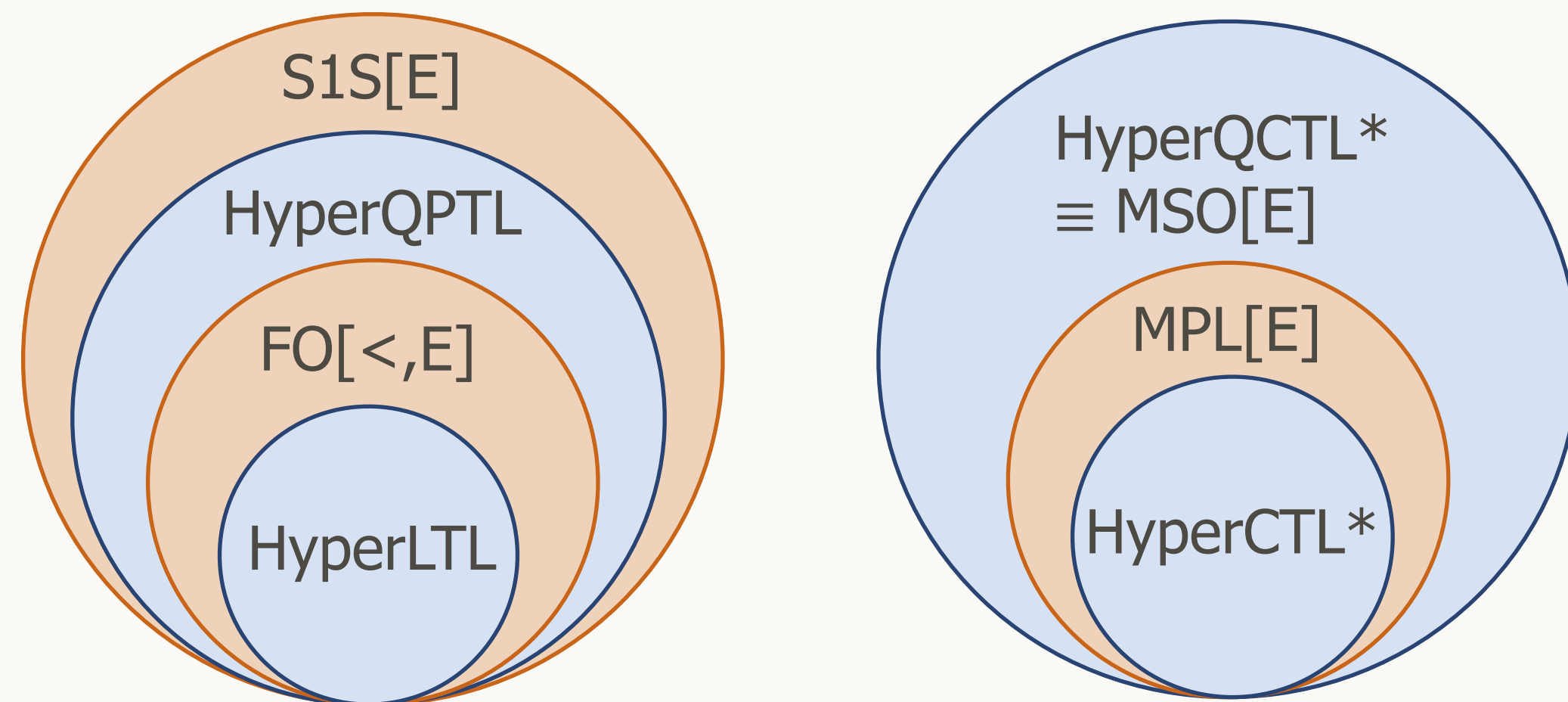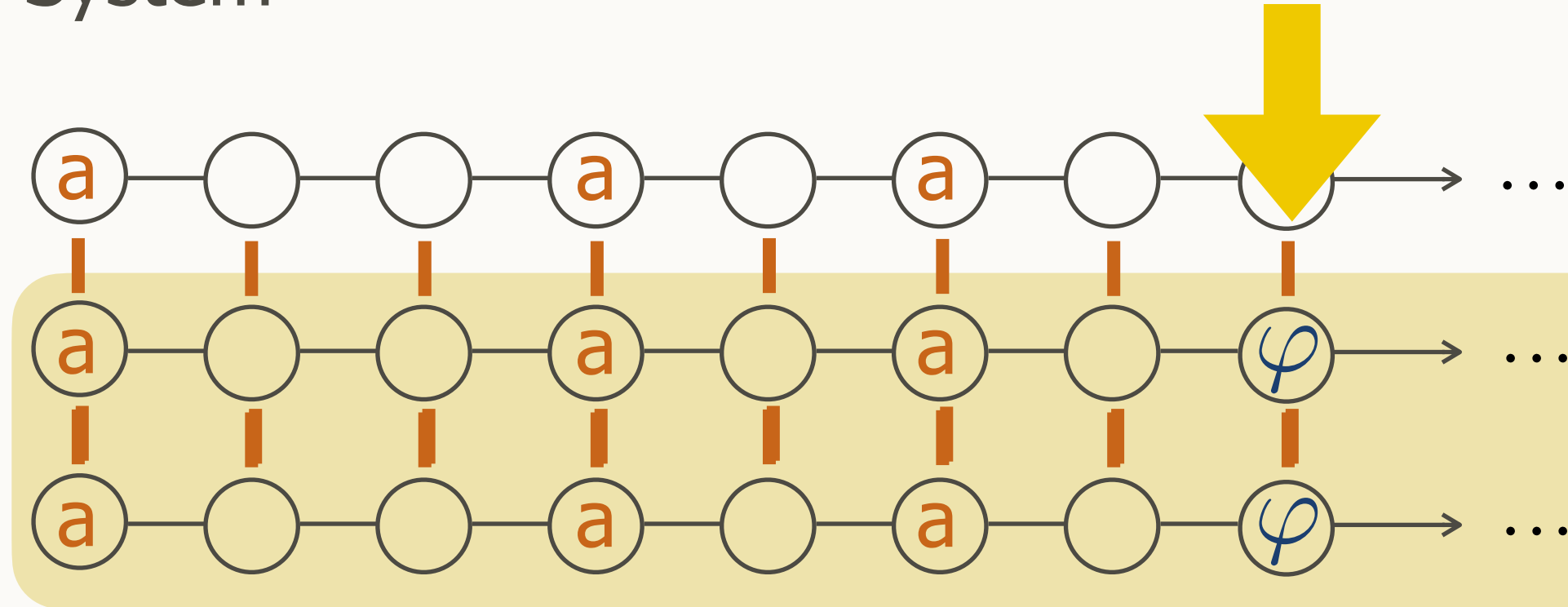

inspired by Kamp's theorem: LTL = FO[<]
and QPTL = S1S, CTL* = MPL, QCTL* = MSO

FO/SO hyperlogics are in general more
expressive than their temporal counterpart

Hyperproperties

Hyperproperties relate multiple execution traces.

System

Agent

I know φ

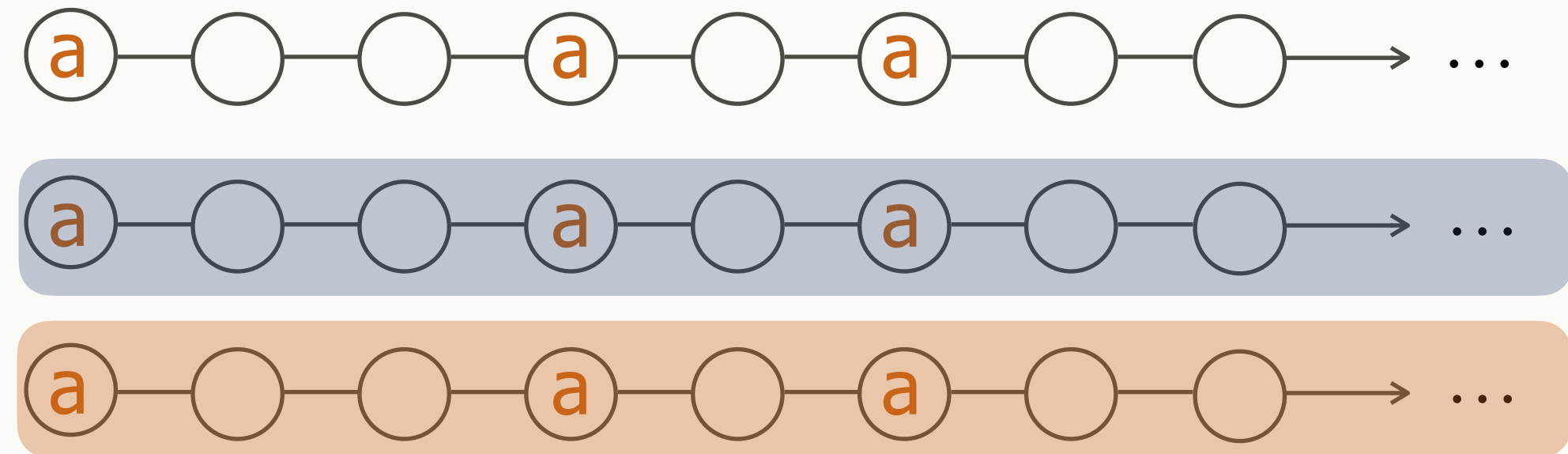"All traces globally agree on a"

- Noninterference

- Robustness

- Distributivity

- Fault tolerance

- Epistemic properties!

Temporal Logics for Hyperproperties

Temporal hyperlogic = temporal logic + trace/path quantification

HyperLTL = LTL + trace quantification [Clarkson et al, 2014]

System

"All traces globally agree on a":

$$\forall \pi. \forall \pi'. \underbrace{G(a_\pi \leftrightarrow a_{\pi'})}$$
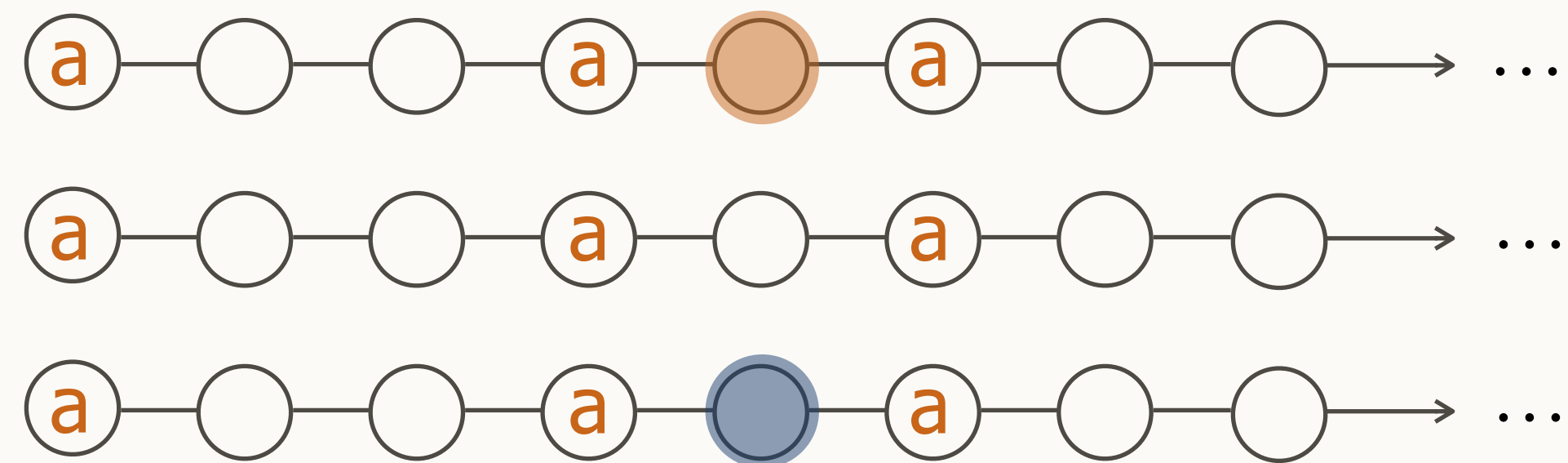
LTL with indexed atomic propositions

First-Order/Second-Order Hyperlogics

FO/SO hyperlogic = monadic FO/SO logic + < predicate + E predicate

FO[<,E] = FO[<] + equal-level predicate [Finkbeiner et al, 2017]
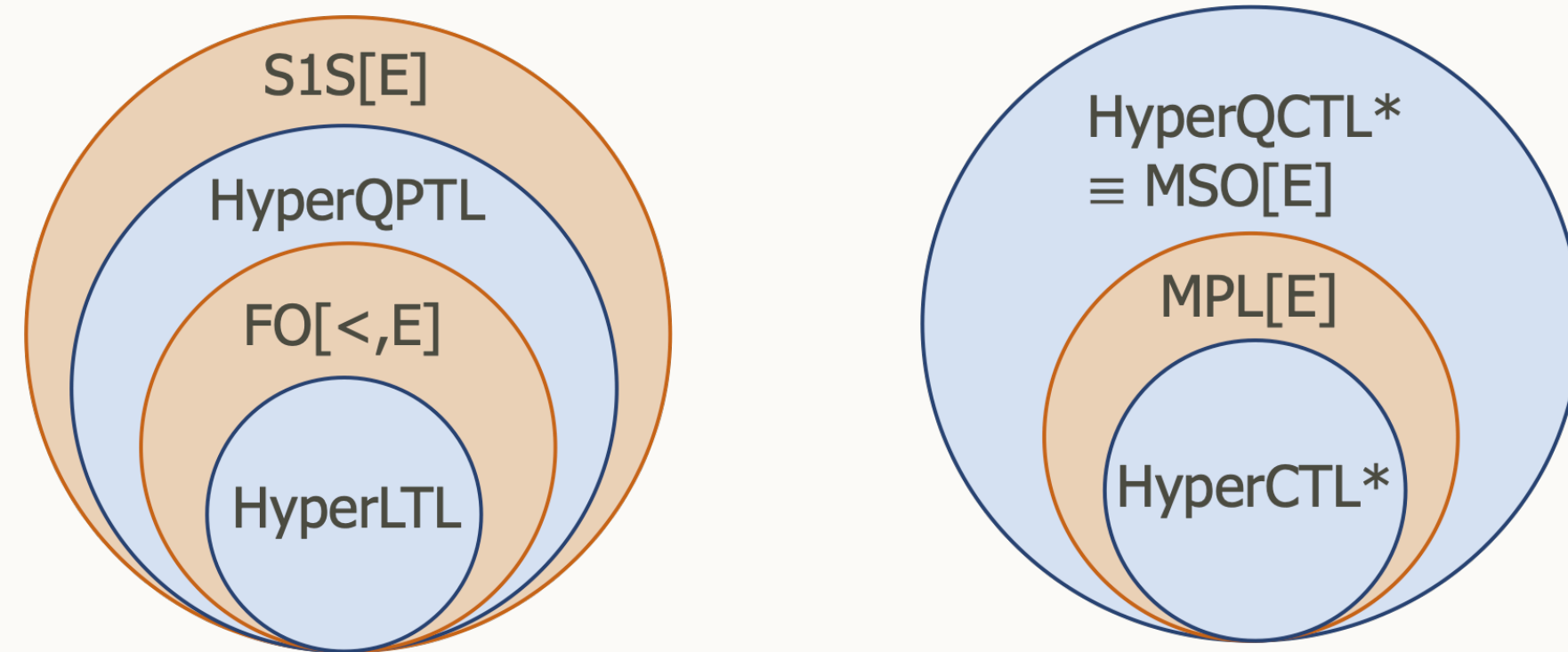
System

"All traces globally agree on a":

$$\forall x. \forall y.\ E(x, y) \rightarrow (P_a(x) \leftrightarrow P_a(y))$$

Hyperlogics and Knowledge Reasoning

S1S[E]
HyperQPTL
FO[<,E]
HyperLTL

HyperQCTL*
≡ MSO[E]
MPL[E]
HyperCTL*

Temporal Hyperlogics vs FO/SO Hyperlogics:

FO/SO logics are in general more expressive than their temporal counterpart

HyperQPTL can express knowledge operator from LTL$\mathcal{K}$

⟹ epistemic reasoning + ω-regular expressions

⟹ epistemic reasoning over distributed architectures

For more see:

Coenen, Finkbeiner, Hahn, Hofmann
The Hierarchy of Hyperlogics, LICS 2019

Classic reasoning methods (tableau, chase, etc) directly applicable to hyperlogics like FO[<,E] / S1S[E] / ...

⟹ new decidability results?