Title: The structure of meaning in natural language: a big money quantum foundations spin-off.

Date: Feb 12, 2013 03:30 PM

URL: http://pirsa.org/13020131

Abstract:

from quantum picturalism to language meaning

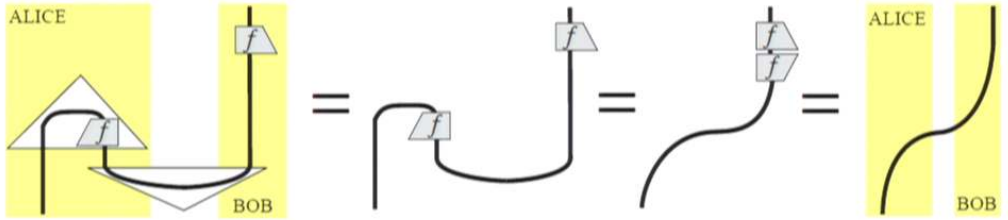
Bob Coecke

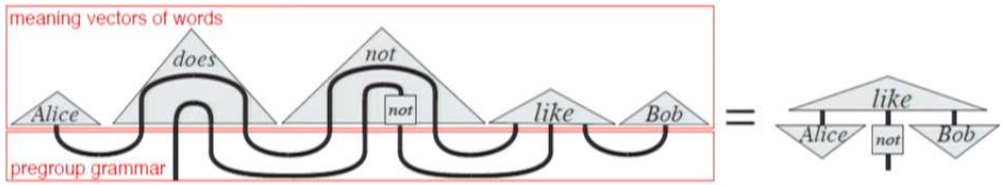
Oxford University, Department of Computer Science, Quantum Group

"Kindergarten quantum mechanics" (2005) arXiv:quant-ph/0510032

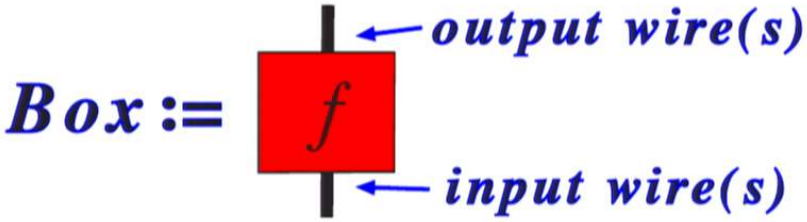
"Quantum Picturalism" (2010) *Contemporary Physics* **51**. arXiv:0908.1787

"The logic of quantum mechanics - take II" (2012) arXiv:1204.3458





— *wire and box language* —

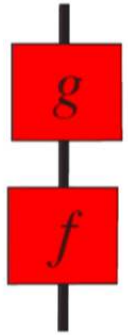


Interpretation: wire := **system** ; box := **process**

— *wire and box games* —

sequential or *causal* or *connected* composition:

$g \circ f \equiv$



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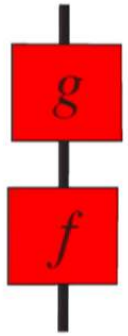
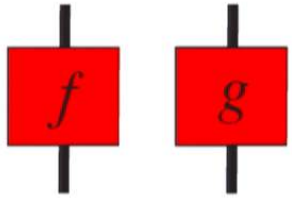


parallel or *acausal* or *disconnected* composition:

$f \otimes g \equiv$



— *merely a new notation?* —

$$(g \circ f) \otimes (k \circ h) = (g \otimes k) \circ (f \otimes h)$$

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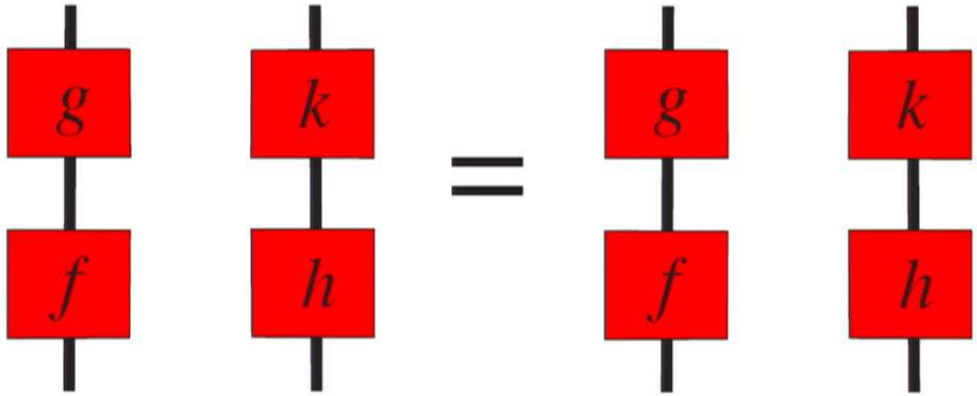

— *Why does a tiger have stripes and a lion doesn't?* —

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prey $\otimes$ predator $\otimes$ environment

hunt

dead prey $\otimes$ eating predator

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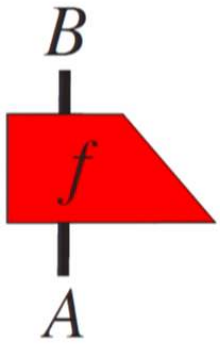
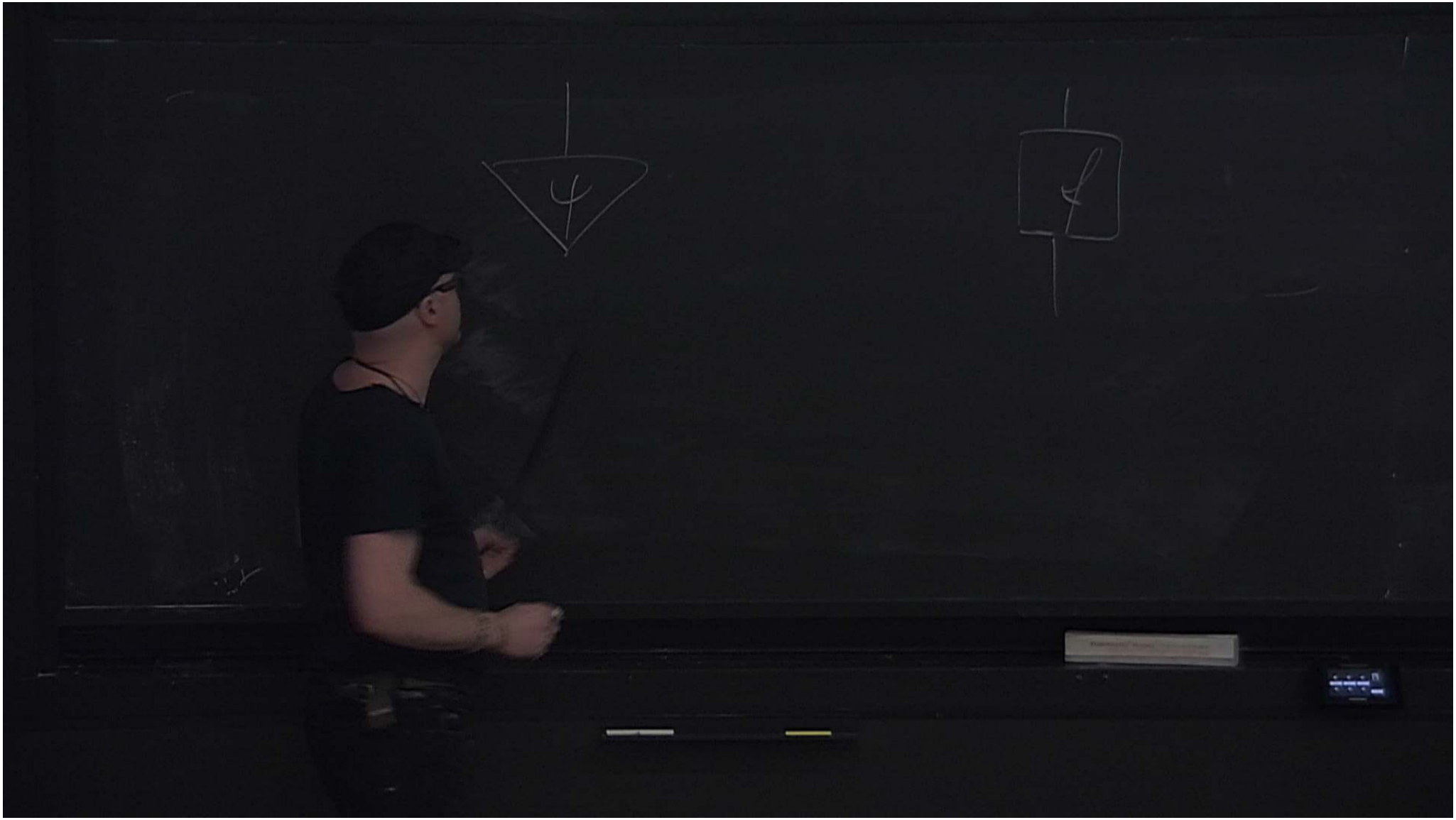
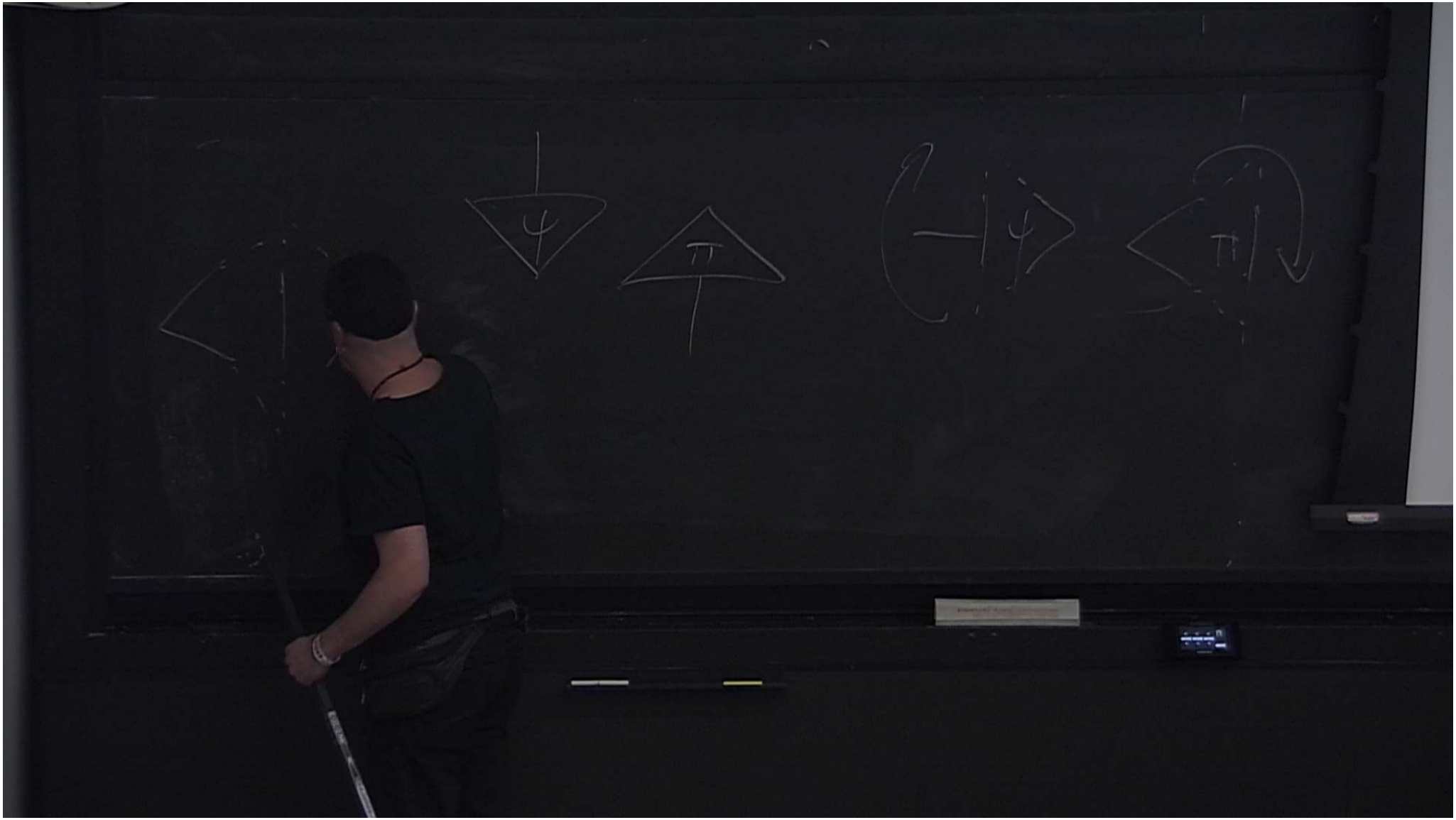
— *quantitative metric* —

$$f : A \to B$$



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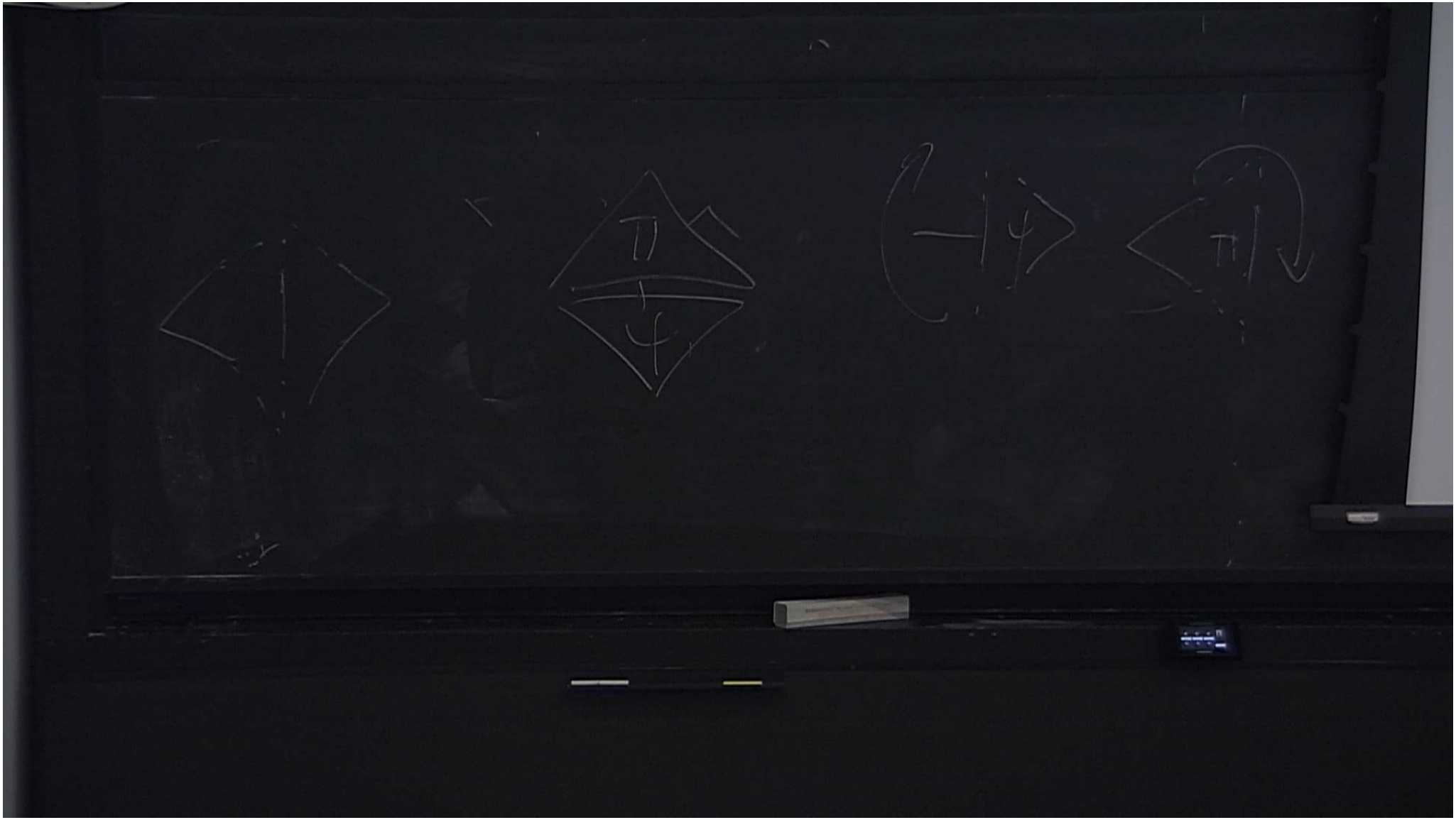
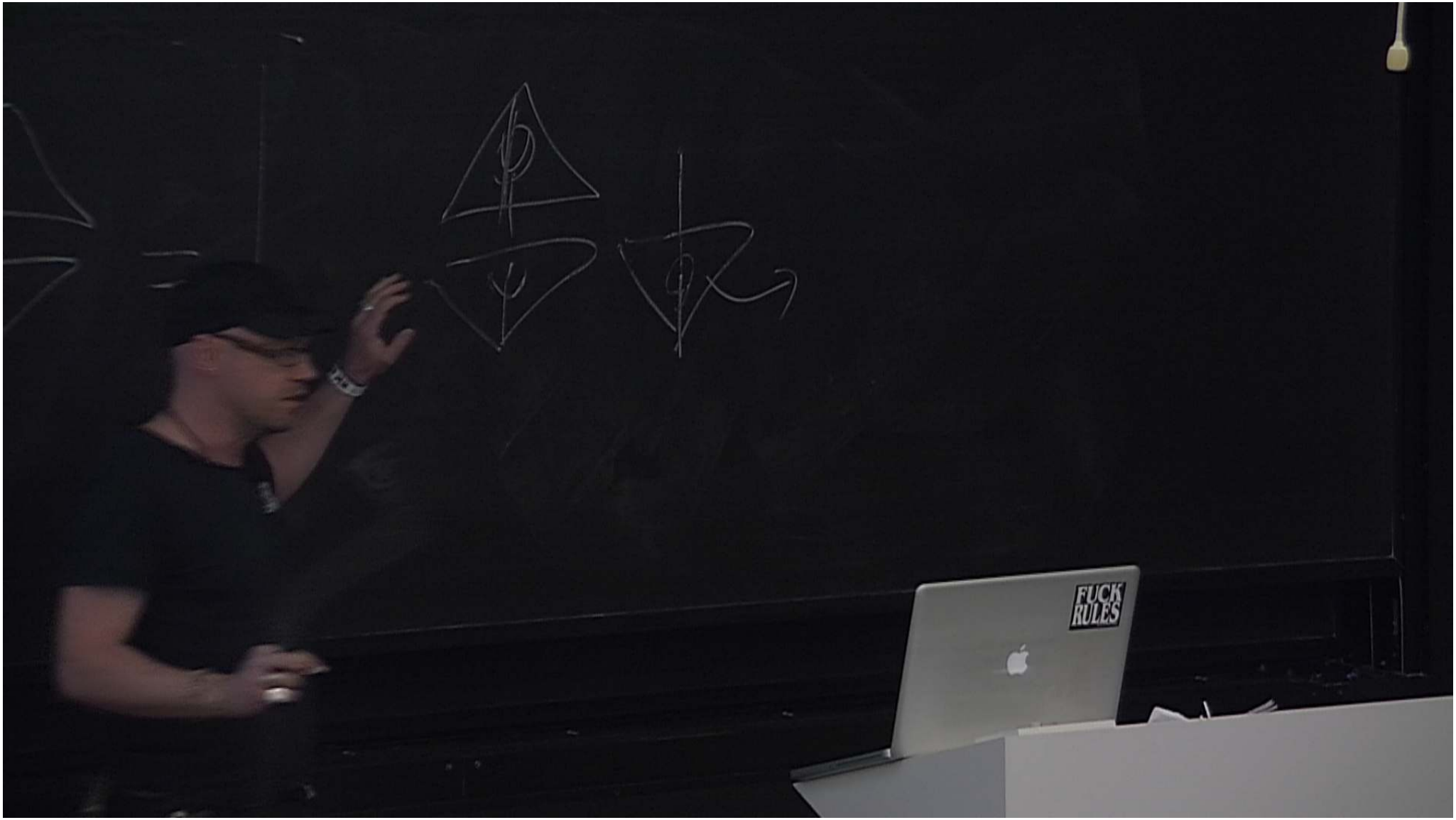



FUCK
RULES

— *asserting (pure) entanglement* —

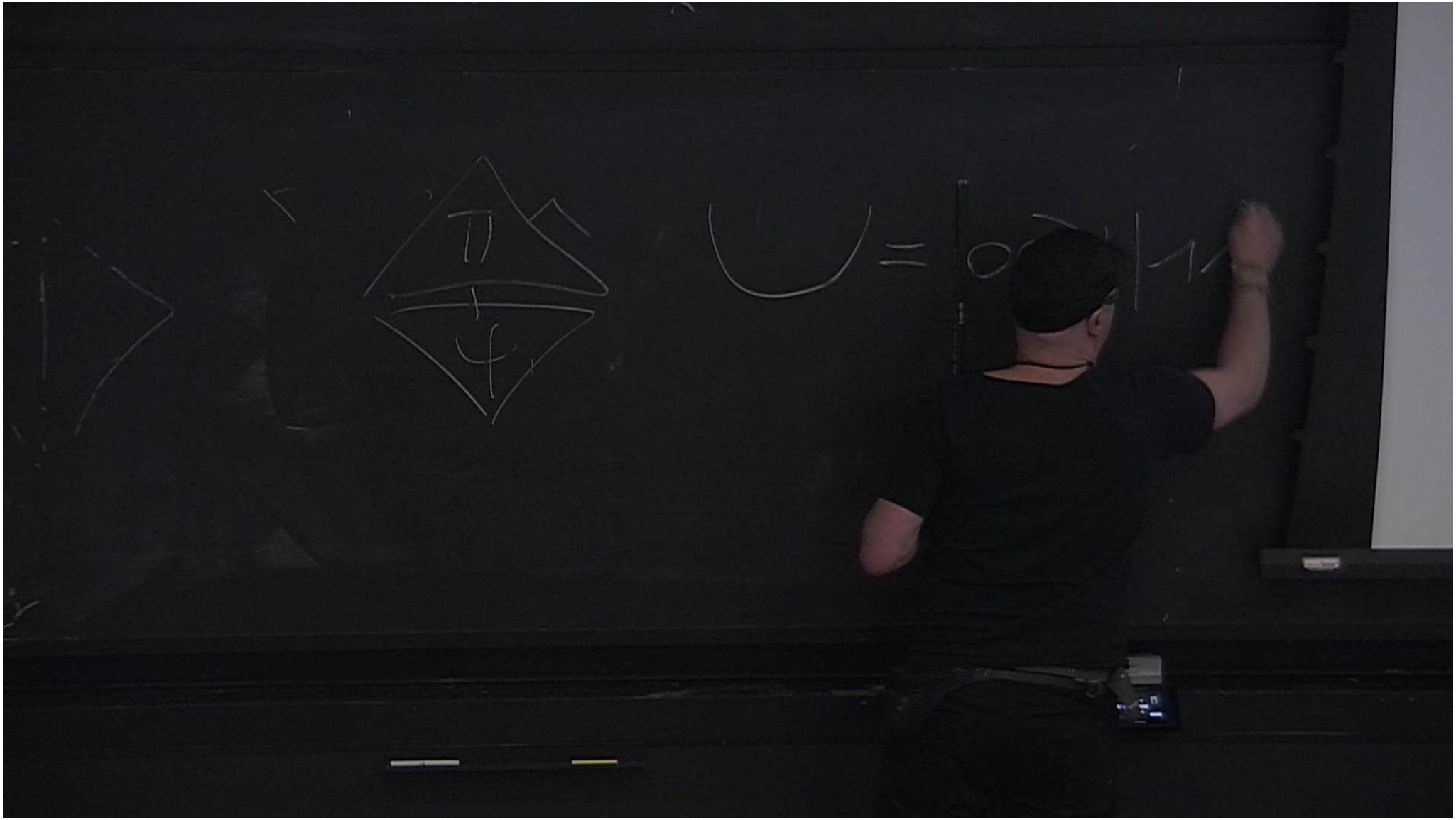
$$\frac{quantum}{classical} = \frac{\blacktriangledown\blacktriangledown \neq \blacktriangledown\ \blacktriangledown}{\blacktriangledown\blacktriangledown = \blacktriangledown\ \blacktriangledown}$$

— *quantum-like* —

E.g.

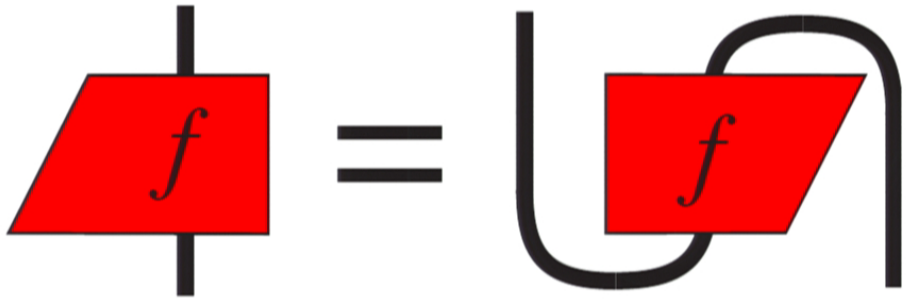
— *quantum-like* —

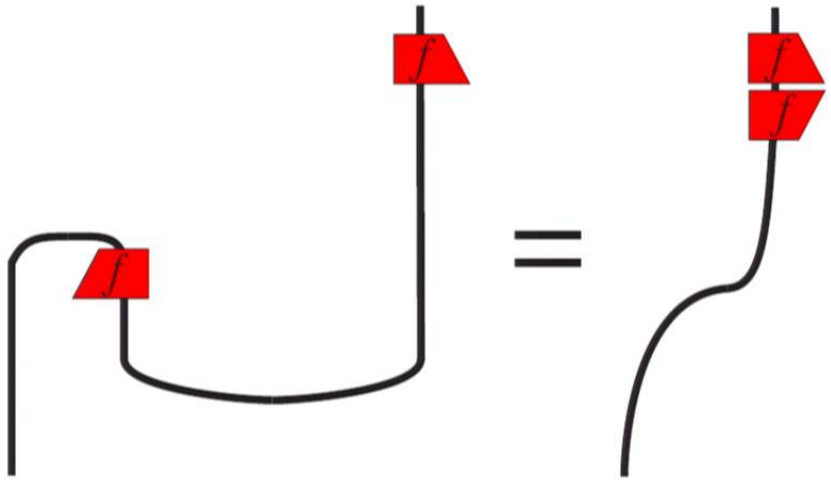
E.g.



Transpose:

Conjugate:

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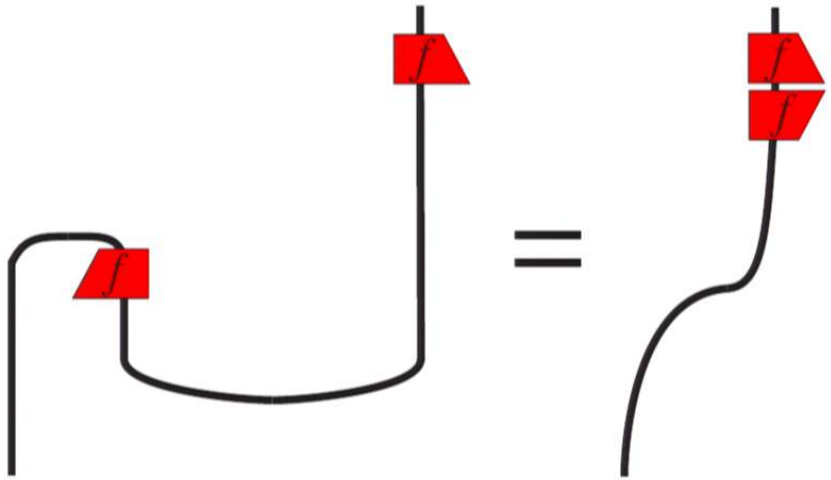
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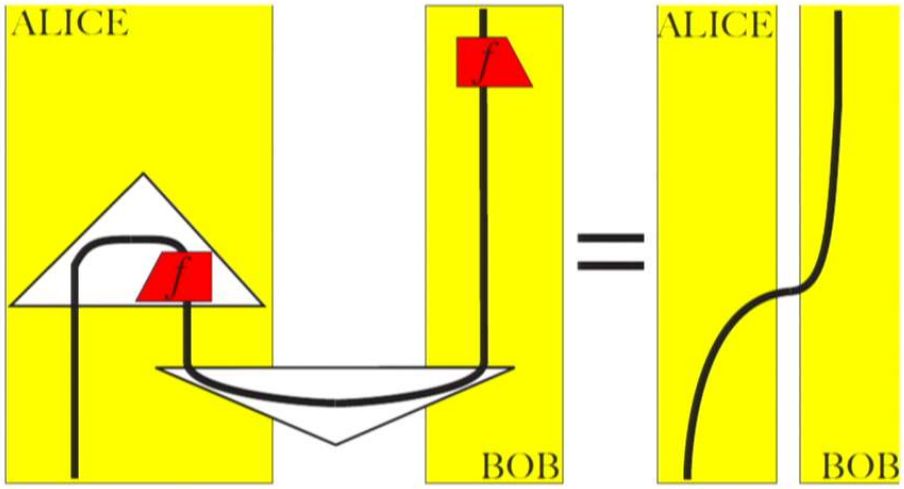
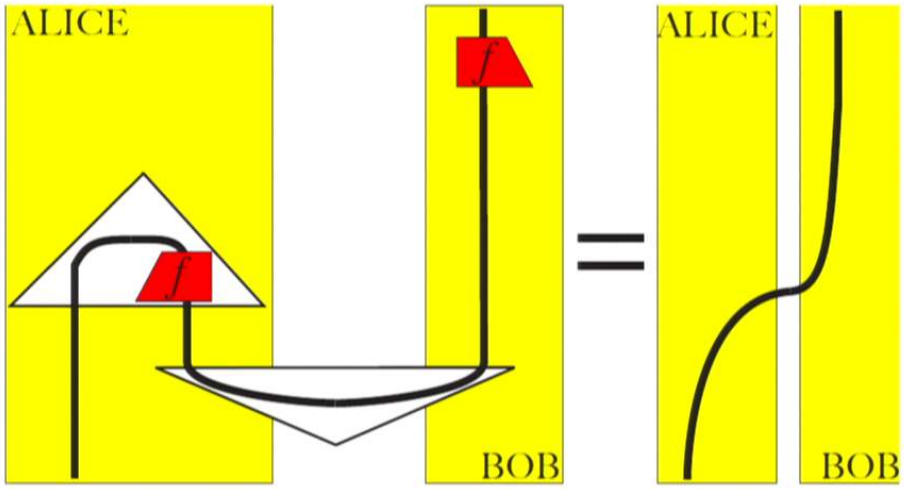


$\Rightarrow$ **quantum teleportation**



$\Rightarrow$ **quantum teleportation**

— *symbolically: dagger compact categories* —

Theorem (Selinger 2008). *Any equation involving:*

- *states, operations, effects*
- *unitarity, adjoints (e.g. self-adjoint), projections*
- *Bell-states/effects, transpose, conjugation*
- *inner-product, trace, Hilbert-Schmidt norm*
- *positivity, completely positive maps, ...*

holds in quantum theory if and only if it can be derived in the graphical language via homotopy.

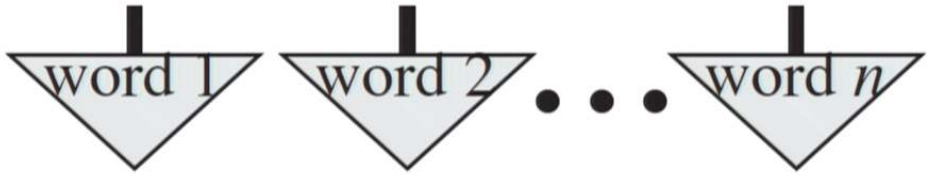
A SLIGHTLY DIFFERENT LANGUAGE FOR NATURAL LANGUAGE MEANING

BC, Mehrnoosh Sadrzadeh & Stephen Clark (2010) *Mathematical foundations for a compositional distributional model of meaning*. arXiv:1003.4394

BC (2012) *The logic of quantum mechanics – Take II*. arXiv:1204.3458

— *the from-words-to-a-sentence process* —

Consider meanings of **words**, e.g. as vectors (cf. Google):



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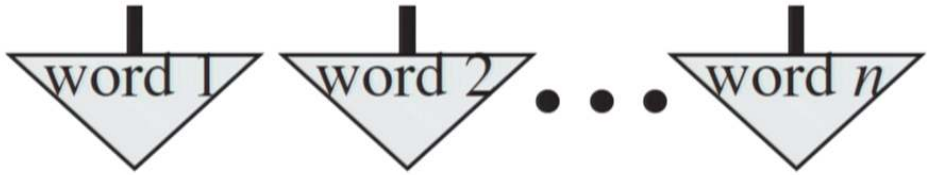

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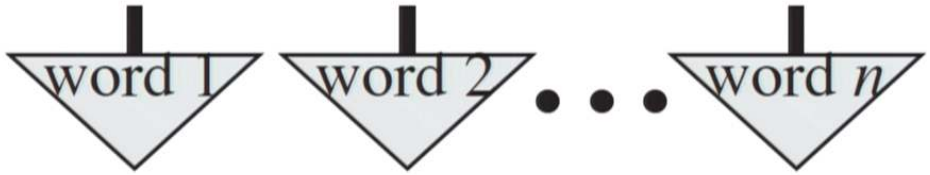

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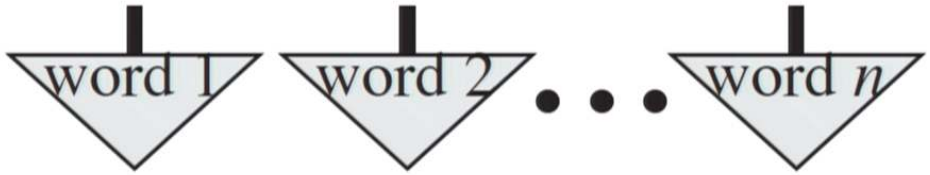

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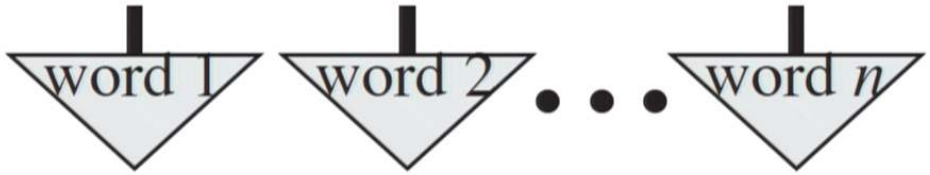

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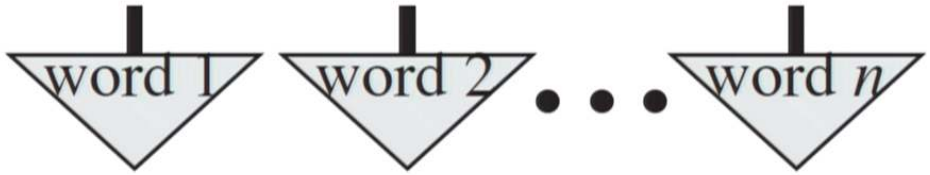

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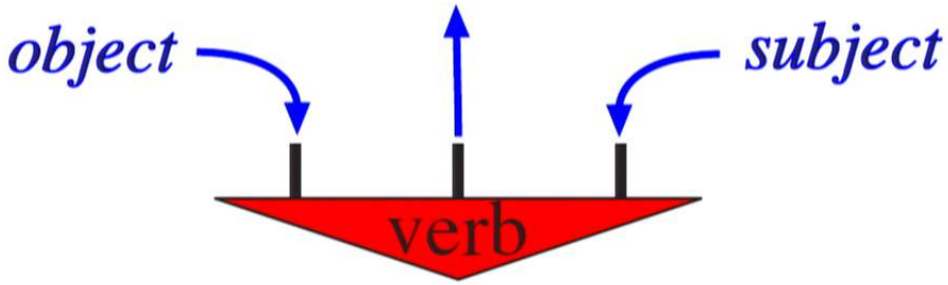
Information flow within a verb:



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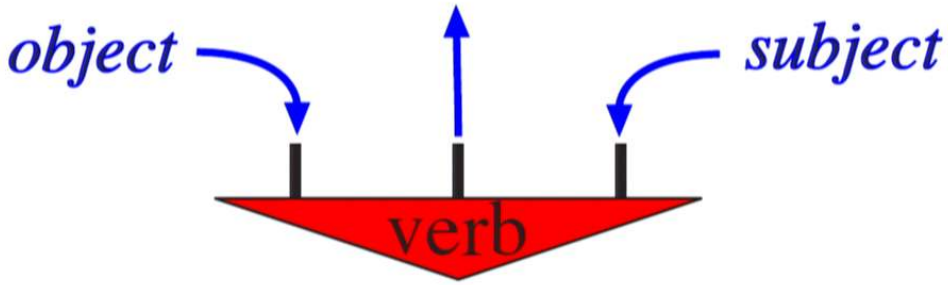

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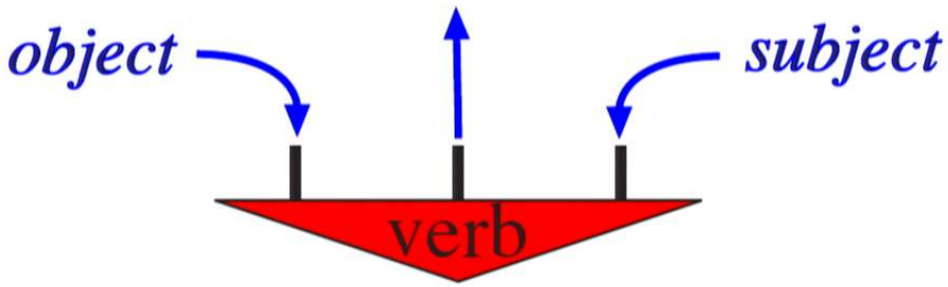
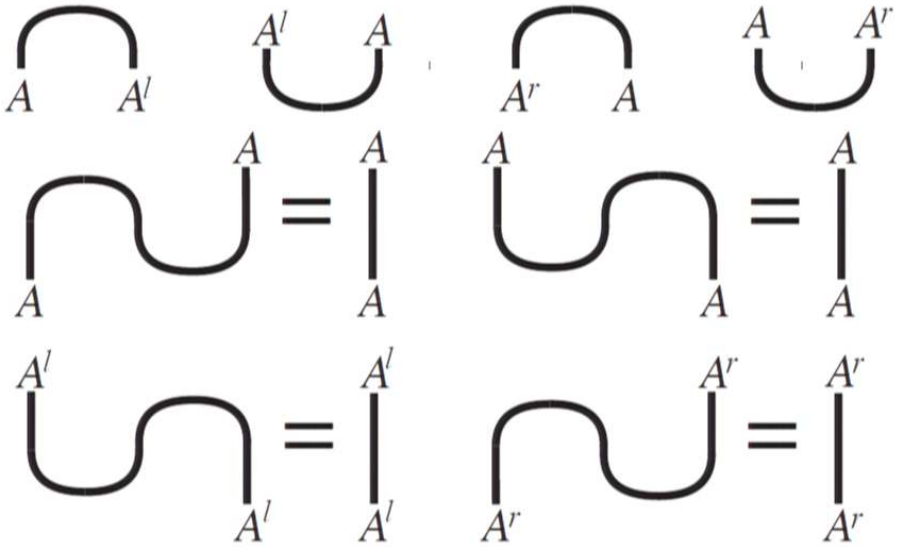


Again we have:

— *grammar as pregroups – Lambek '99* —



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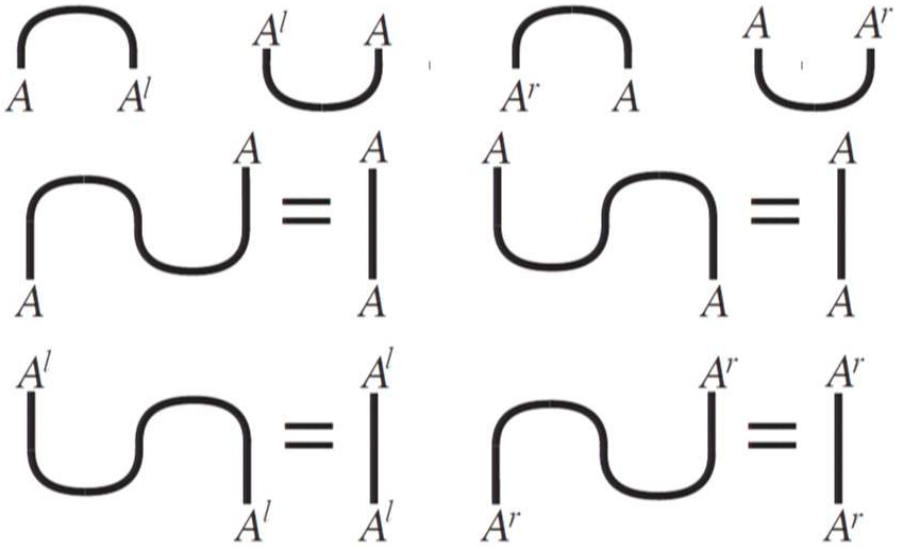

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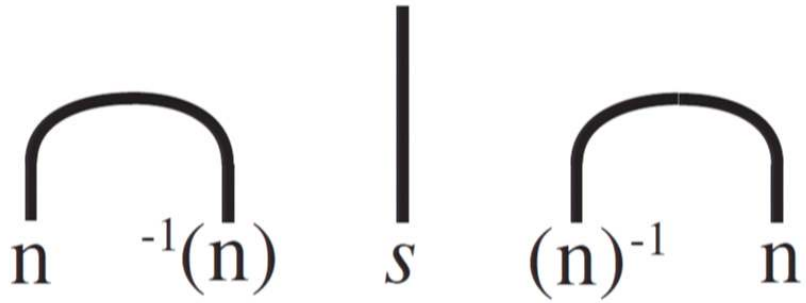
Diagrammatic typing:



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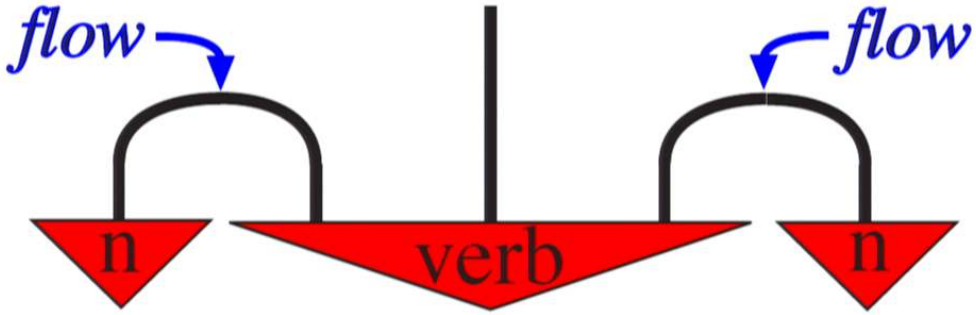
Diagrammatic meaning:



— *experiment: word disambiguation* —

E.g. what is "saw"' in: "Alice saw Bob with a saw".

Model	High	Low	ρ
Baseline	0.47	0.44	0.16
Add	0.90	0.90	0.05
Multiply	0.67	0.59	0.17
Categorical (1)	**0.73**	**0.72**	**0.21**
Categorical (2)	**0.34**	**0.26**	**0.28**
UpperBound	4.80	2.49	0.62

Edward Grefenstette & Mehrnoosh Sadrzadeh (2011) *Experimental support for a categorical compositional distributional model of meaning*. In: Empirical Methods in Natural Language Processing (EMNLP'11).

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— *analogy: "non-local" info-flows* —

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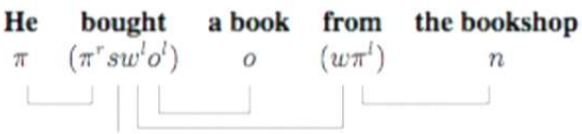
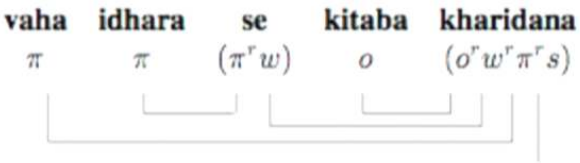
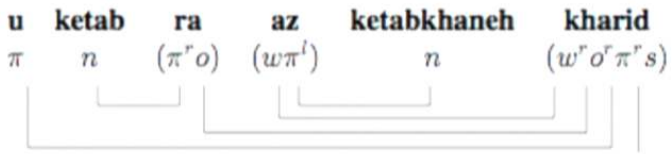


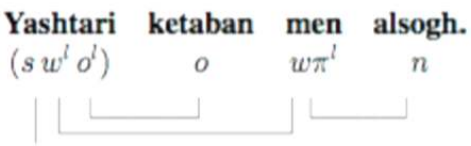
Hindi:



Persian:



Arabic (and Hebrew):



Mehrnoosh Sadrzadeh (2008) *Pregroup analysis of Persian sentences.*

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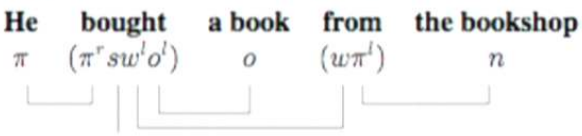

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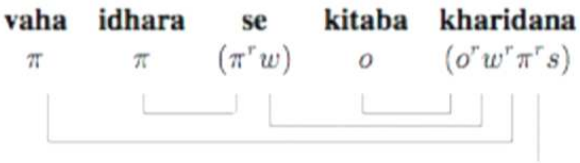

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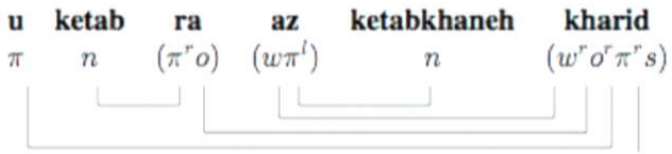

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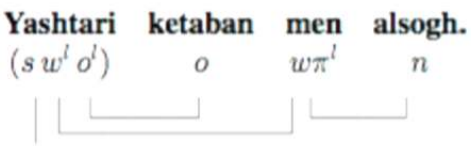

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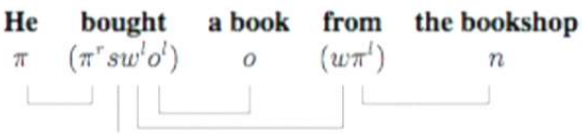
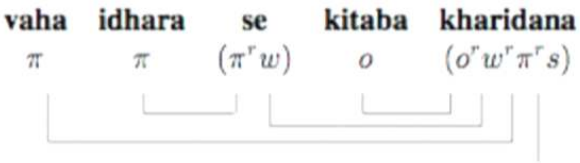
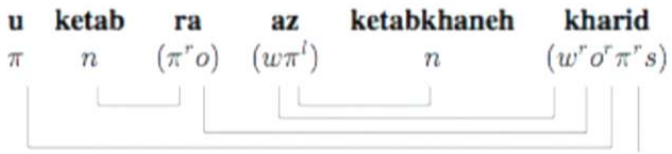


Hindi:



Persian:



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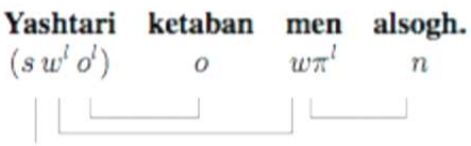
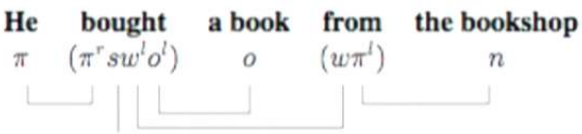


Mehrnoosh Sadrzadeh (2008) *Pregroup analysis of Persian sentences.*

— *analogy: "non-local" info-flows* —

English (& French):



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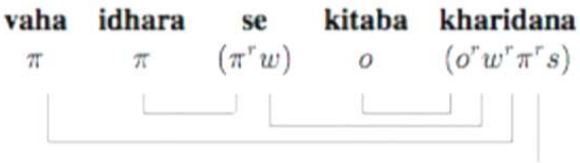

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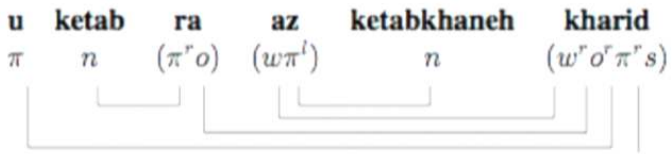
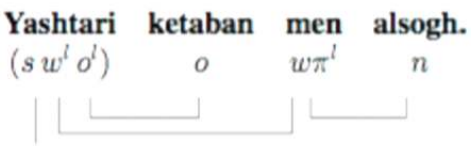


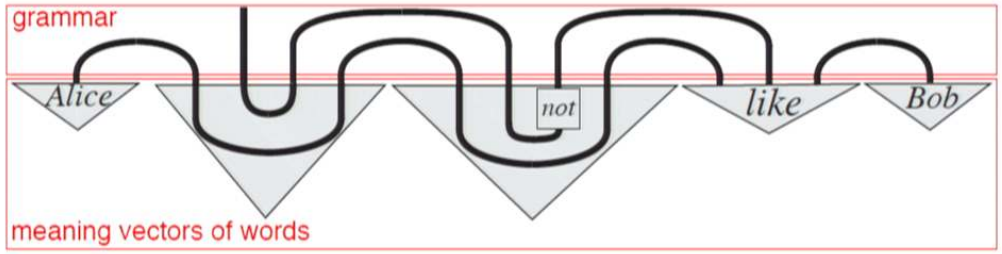
Arabic (and Hebrew):



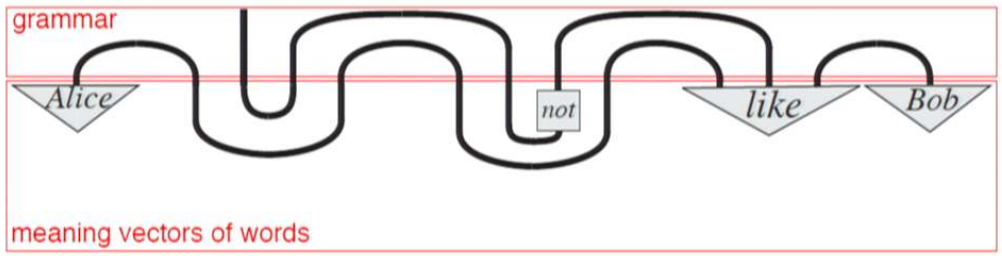
Mehrnoosh Sadrzadeh (2008) *Pregroup analysis of Persian sentences.*

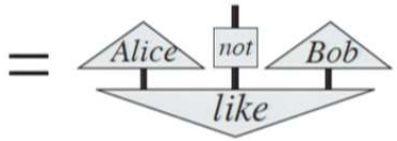
“LOGICAL” WORDS

$$— \overrightarrow{Alice} \otimes \overrightarrow{does} \otimes \overrightarrow{not} \otimes \overrightarrow{like} \otimes \overrightarrow{Bob} —$$



$$— \overrightarrow{Alice} \otimes \overrightarrow{does} \otimes \overrightarrow{not} \otimes \overrightarrow{like} \otimes \overrightarrow{Bob} —$$





UNIVERSAL QUANTUM PICTURALISM

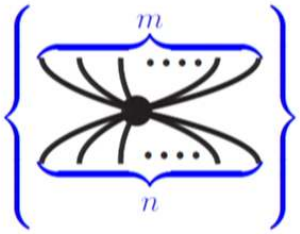
BC & Ross Duncan (2008) *Interacting quantum observables.* ICALP'08 & New Journal of Physics **13**, 043016. arXiv:0906.4725

ONBs AS SPIDERS

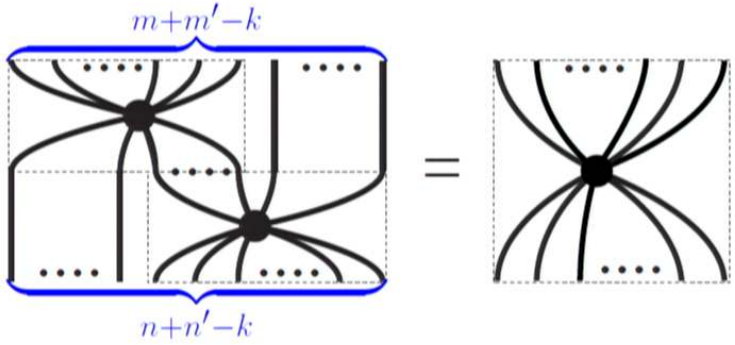
B.C. and D. Pavlovic – arXiv:quant-ph/0608035

B.C., D. Pavlovic and J. Vicary – arXiv:0810.0812

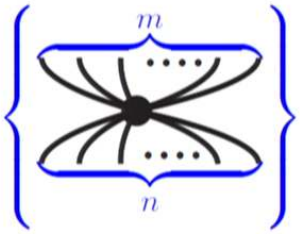
— *spiders* —

'spiders' = 

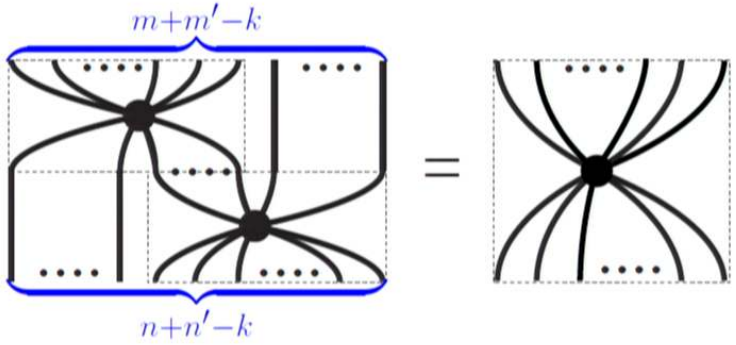
such that, for $k > 0$:



— *spiders* —

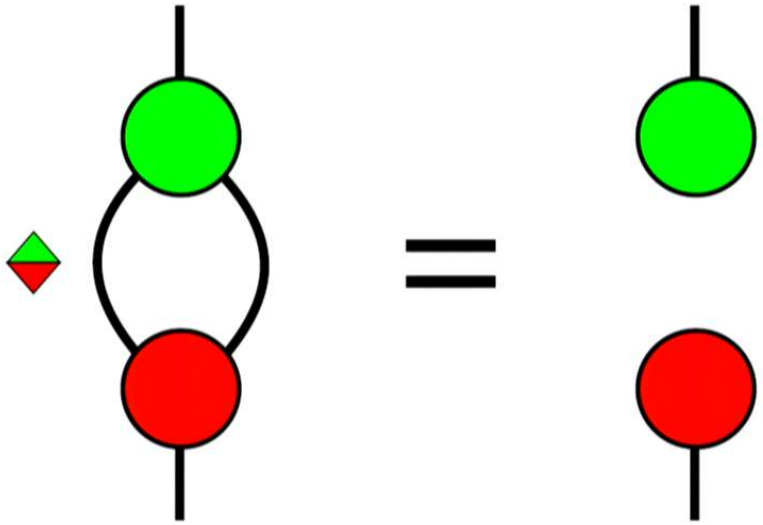
'spiders' = 

such that, for $k > 0$:



— *complementary spiders* —

Thm.



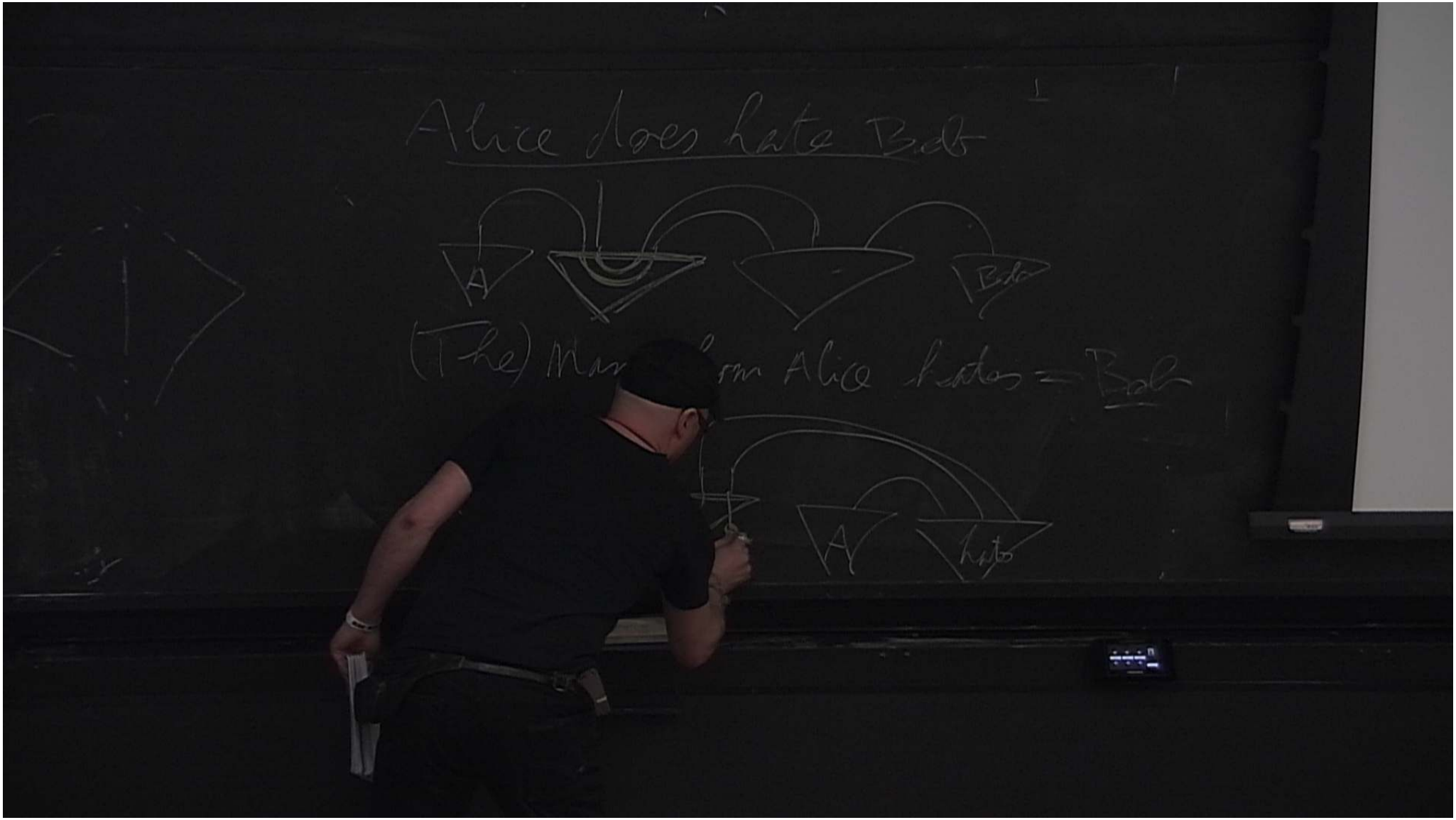
BC & Ross Duncan (2008) *Interacting quantum observables.* ICALP'08 & New Journal of Physics **13**, 043016. arXiv:0906.4725

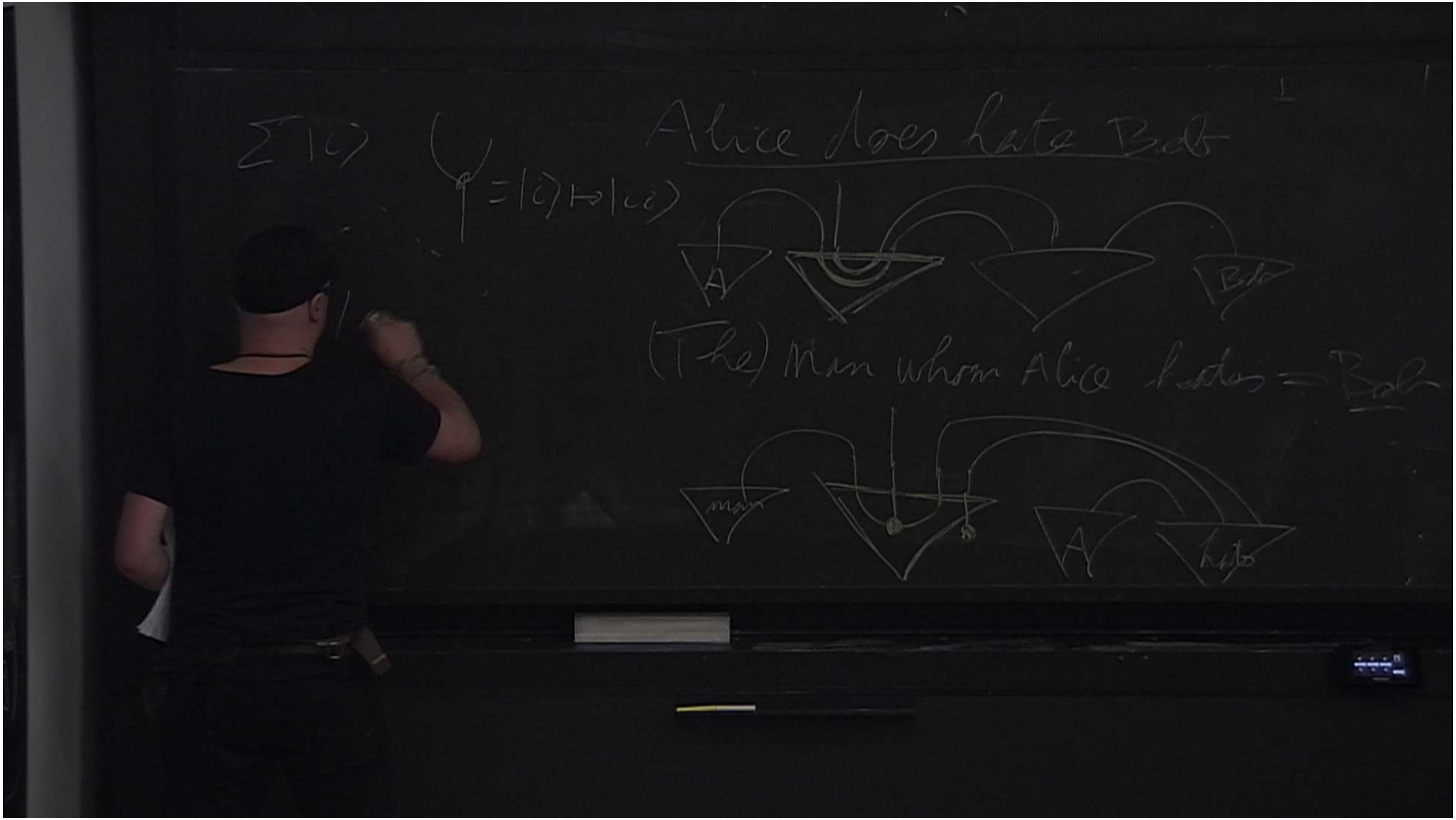
SPIDERS IN LANGUAGE MEANING

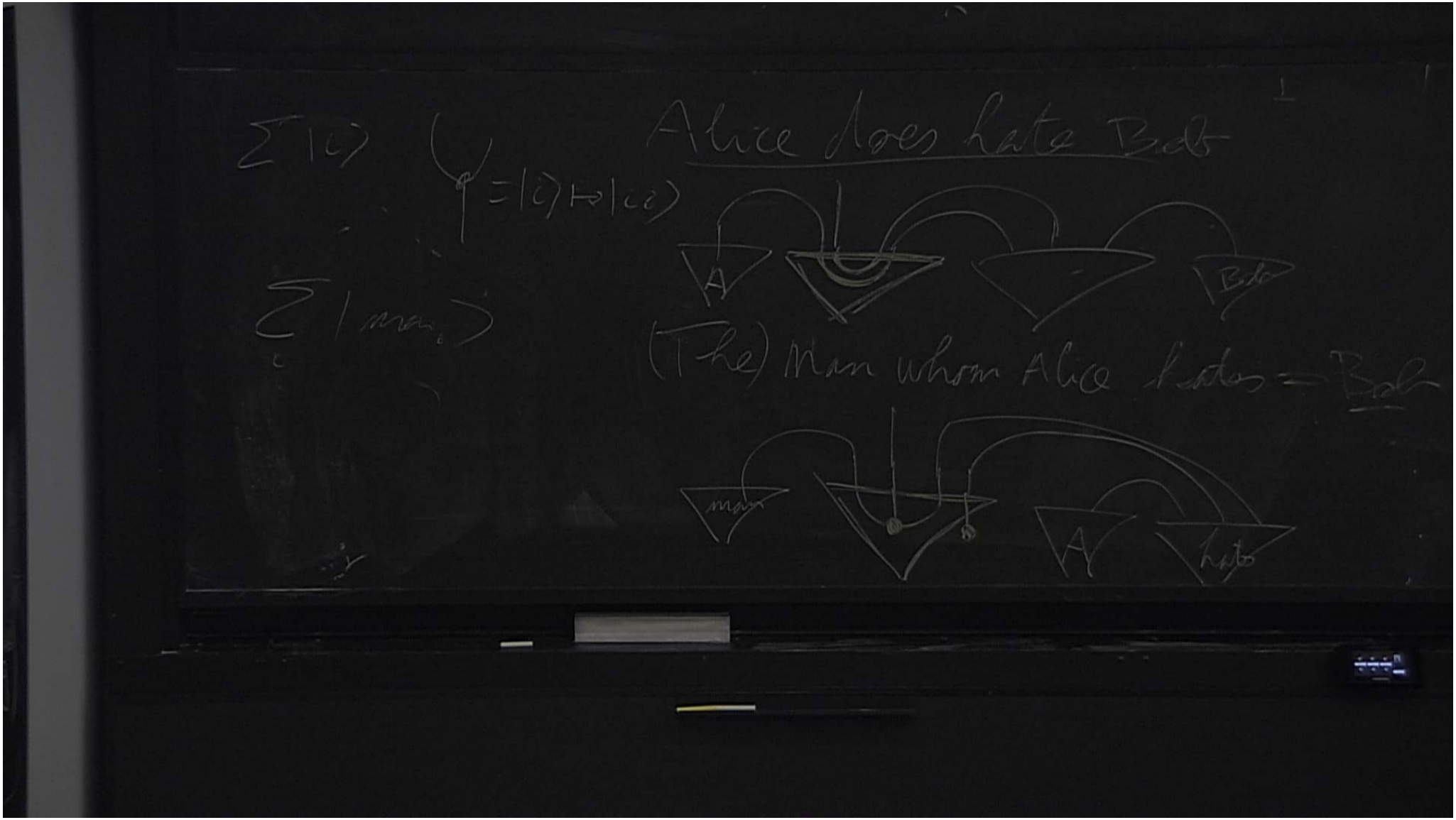
Sadrzadeh, Clark, Coecke (work in progress)

Example 1.

$$\overrightarrow{Alice} \otimes \overrightarrow{does} \otimes \overrightarrow{hate} \otimes \overrightarrow{Bob}$$


Alice does hate Bob
A
Bob
(The) Man from Alice hates = Bob
A
hate


Alice does hate Bob
(The) Man whom Alice hates = Bob


Alice does hate Bob
(The) Man whom Alice hates = Bob