

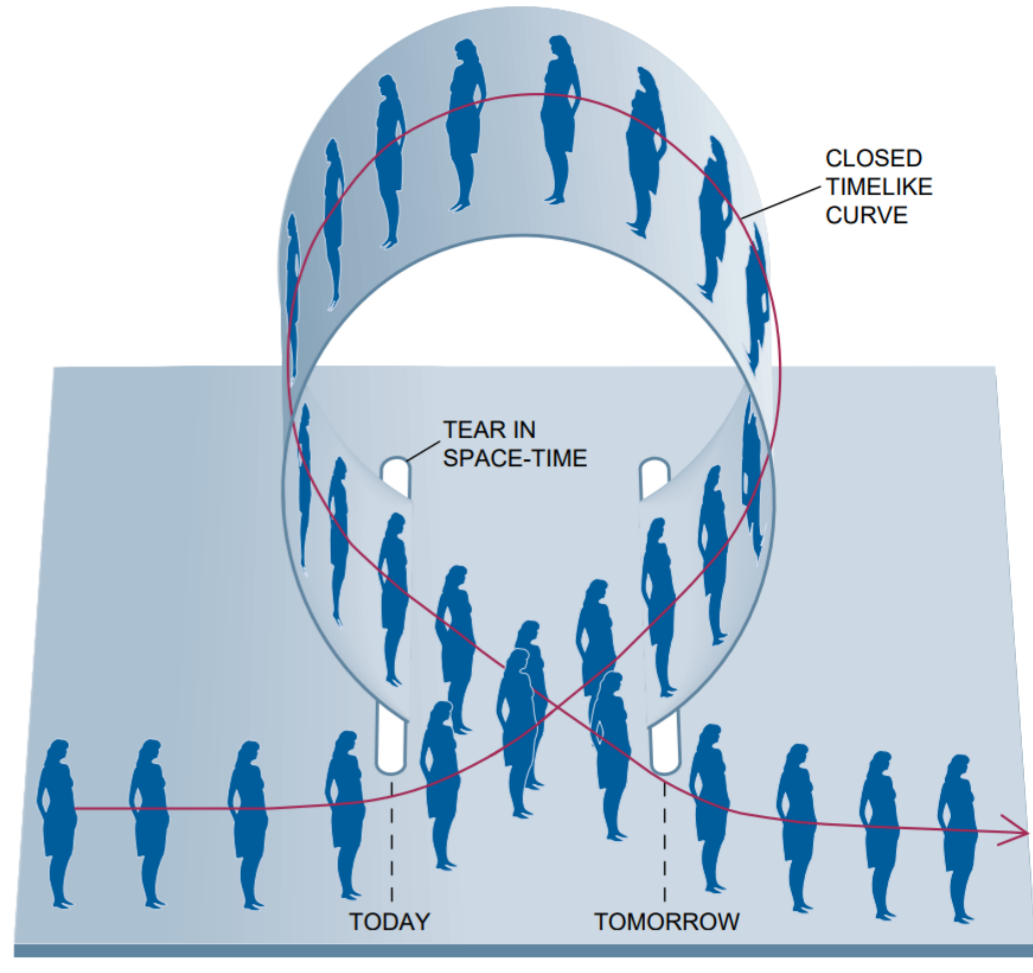
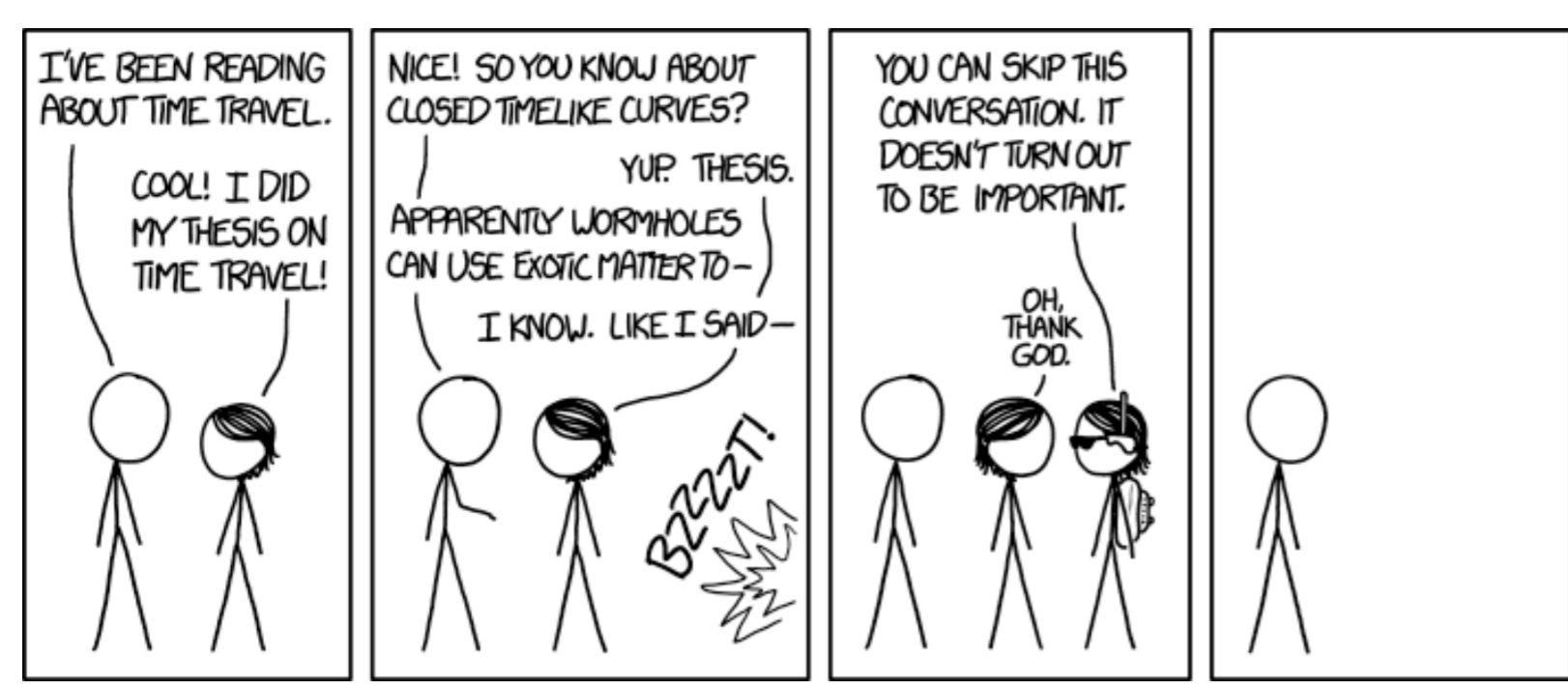
Administrivia.

- Final should be out by today



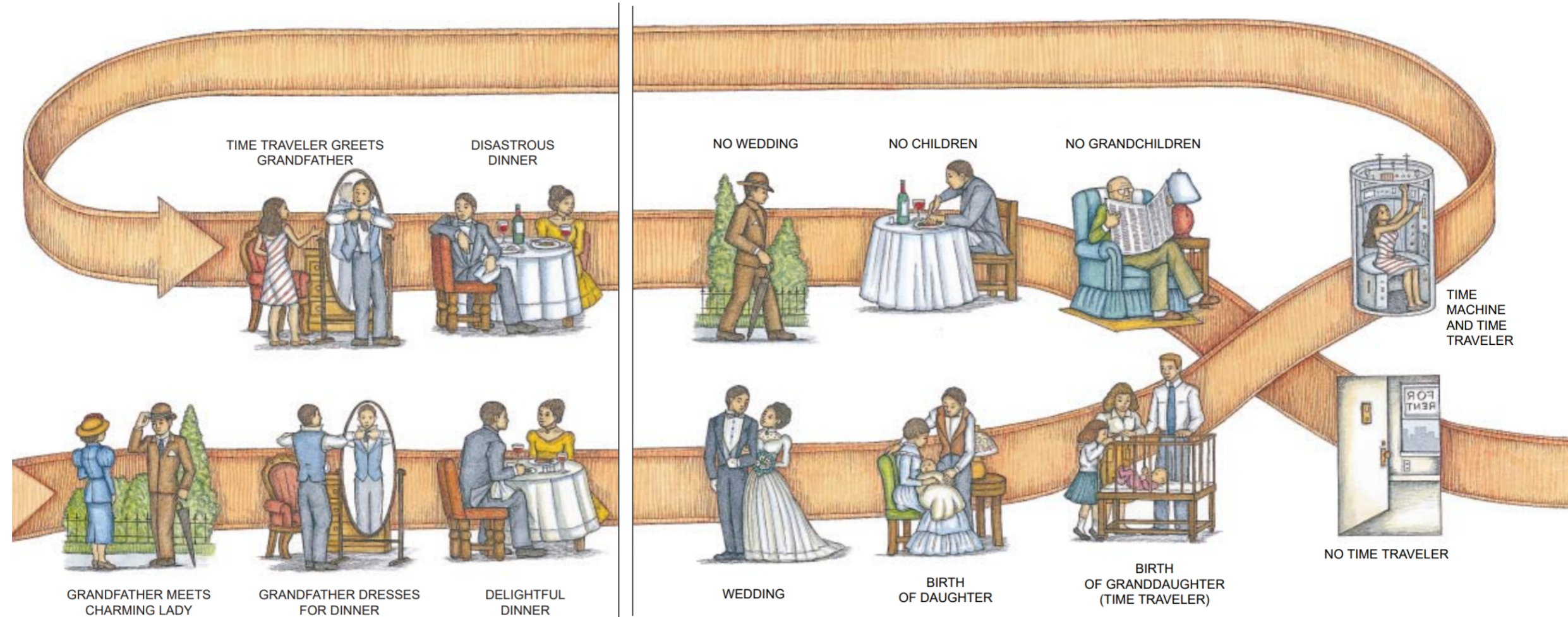
How do we use new phenomena as resource?
Start w/ a basic one:

Closed Timelike Curves. (CTCs)



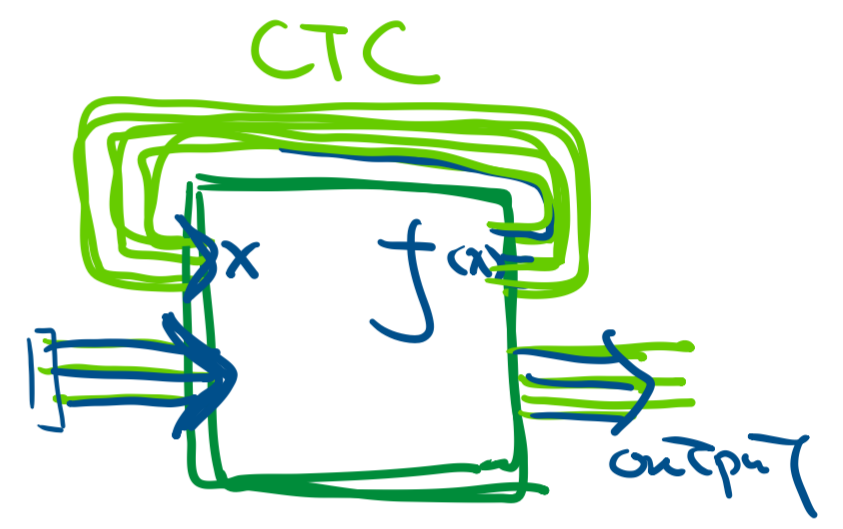
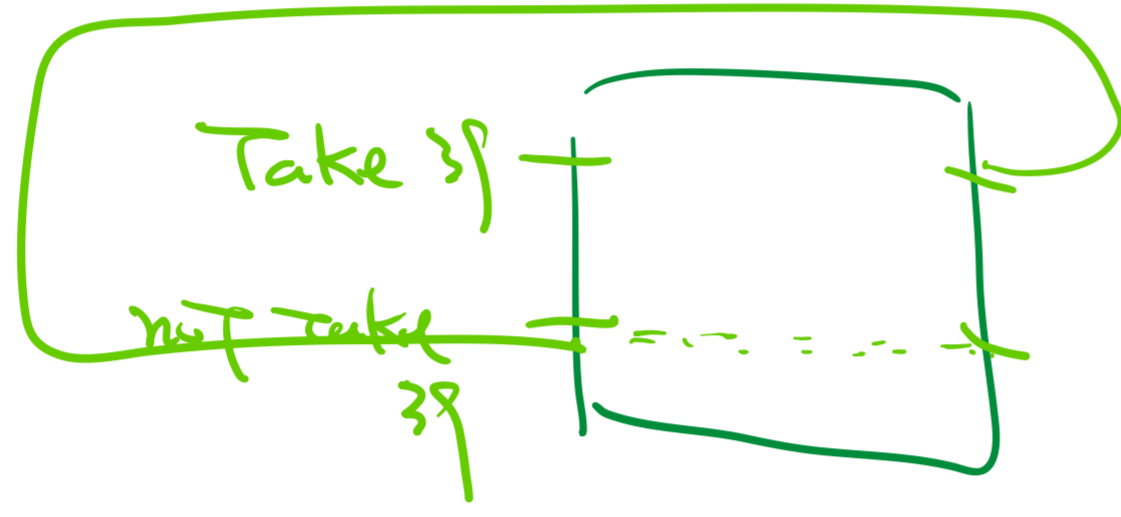
Obvious Problems:

- Grandfather paradox



Deutsch Model [Deutsch '91], [Brun '03], [Bacon '04], [Aaronson-Watrous '08]

- key idea: causal consistency.



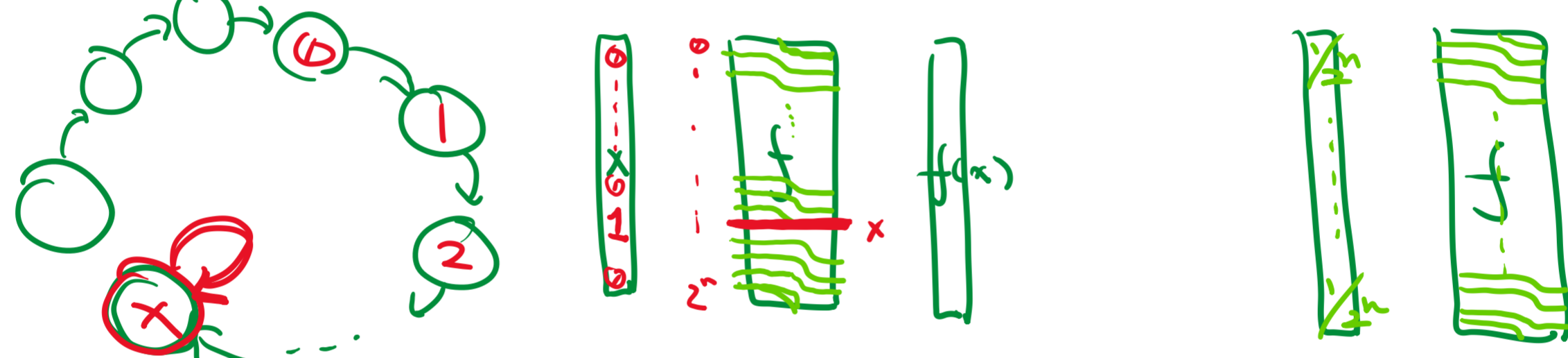
$$f \begin{bmatrix} \vdots \\ x \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots \\ f(x) \\ \vdots \end{bmatrix} \quad \begin{bmatrix} \vdots \\ x \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots \\ f(x) \\ \vdots \end{bmatrix}$$

Example. SAT ϕ

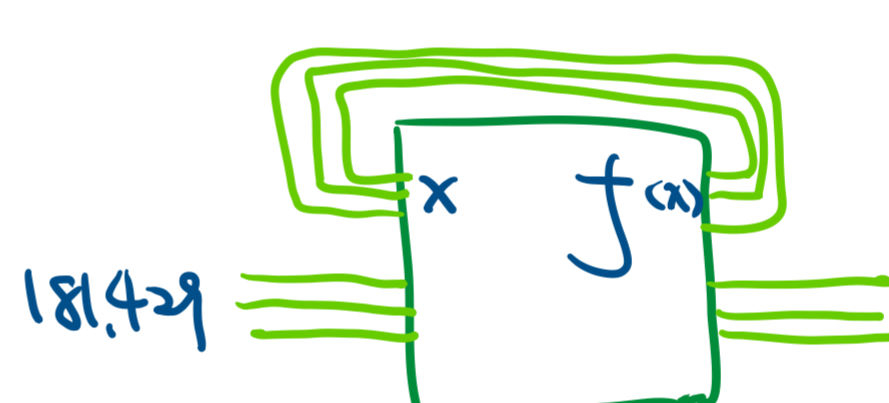
$$\text{Build } f(x) = \begin{cases} x & \text{if } \phi(x) \text{ sat.} \\ (x+1) \bmod 2 & \text{if } x \text{ not sat.} \end{cases}$$

yes-list (ϕ sat).

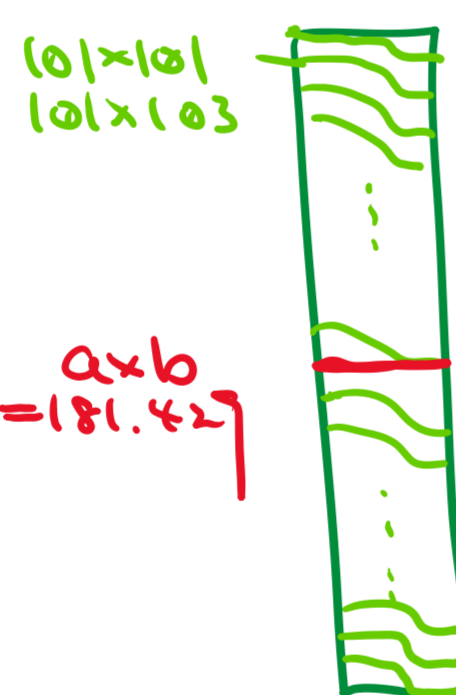
no-list (ϕ no-sat).



Example. [HPMR, Ch17].



$$f(x) = \begin{cases} 101 \times 101 \\ a \times b \\ a \times (b+1) \\ (a+1) \times 101 \end{cases} \quad \begin{aligned} x &= 119 \times 119 \\ x &= a \times b \\ &= 181,429 \\ x &= a \times b \\ &\neq 181,429 \end{aligned}$$



"DO NOT MESS W/ TIME"

They $NP \subseteq P_{CTC} = PSPACE$.

"pf": Using time like space under general relativity!

- Grandfather paradox is not the obstacle, $NP = P$ is.



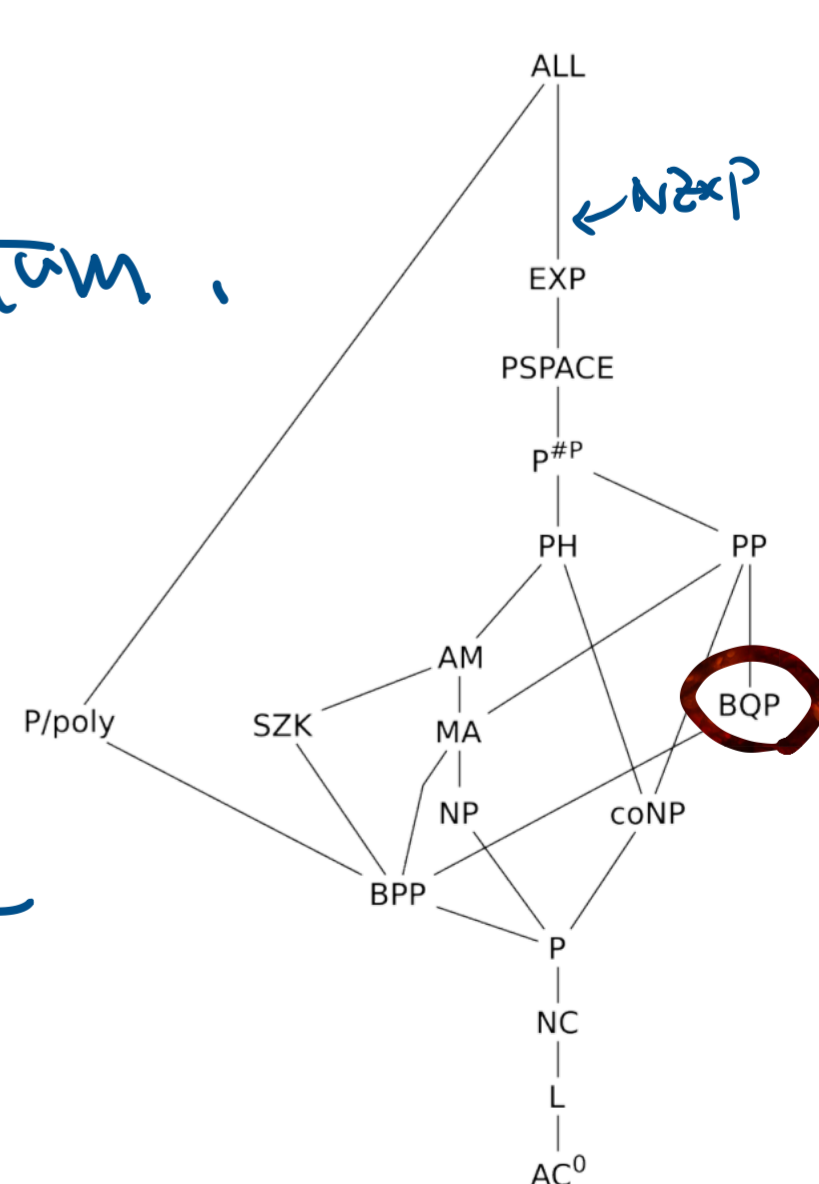
I wish I could talk about quantum.

$$\begin{bmatrix} \vdots \\ \vdots \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots \\ M \\ \vdots \end{bmatrix} \begin{bmatrix} \vdots \\ x \\ \vdots \end{bmatrix}$$

BQP QMA $BQP_{CTC} = P_{CTC}$

$MIP = NEXP$

$MIP^* = RE$



Conclusion.

- Universal Computation is (one of) the greatest innovation.
- Challenges how to view the world.
- Can be modeled & studied.
- Sharpens thinking skills.

Where to go from here? (Onward!)

Thank you for learning ToC w/ me.

Fin