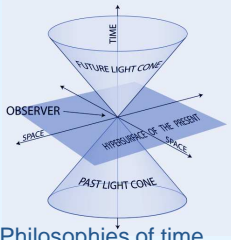


Time of Philosophers, Time of Physicists, Time of Mathematicians

Fabien Besnard
EPF

7 July 2010



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- The Andromeda Paradox
- Consequences of the Andromeda Paradox
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- Presentism and possibilism in General Relativity
- Closed time-like curves
- Quantum heads-or-tails
- The positivistic and realist postulates
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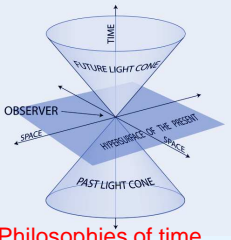
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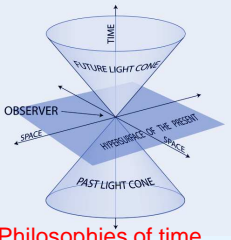


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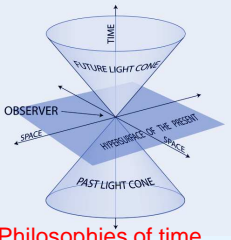
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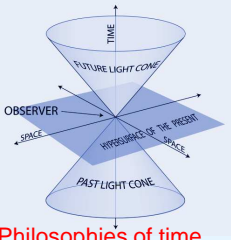
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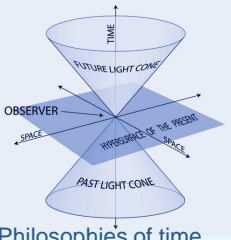
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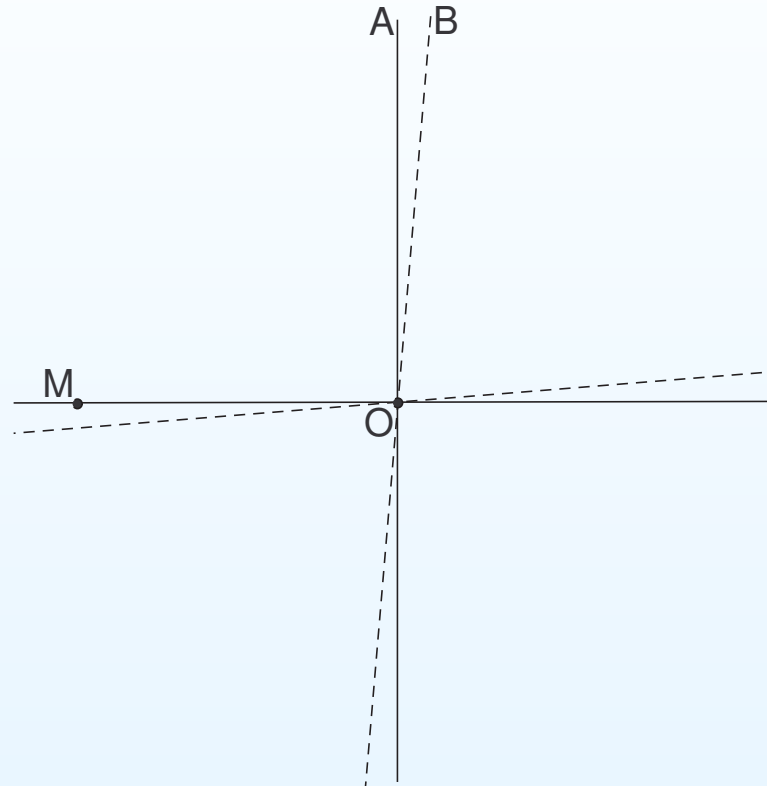
2. Possibilism (growing universe): the present and the past exist
 - (a) Reality grows,
 - (b) The future is open.

3. Eternalism (block-universe): the past, the present, and the future exist



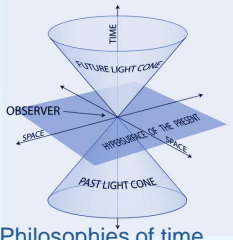
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The Andromeda Paradox



On Earth, A and B meet at O , relative speed = 4 km/h.

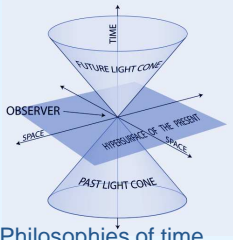
Event M : Andromedians launch a float of spaceships to invade Earth.



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Presentism implies that reality depends on simultaneity.
SR implies that simultaneity depends on the observer.



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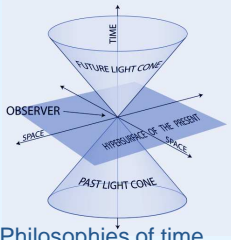
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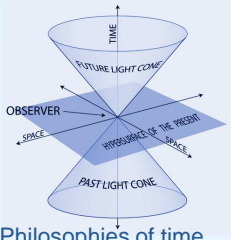
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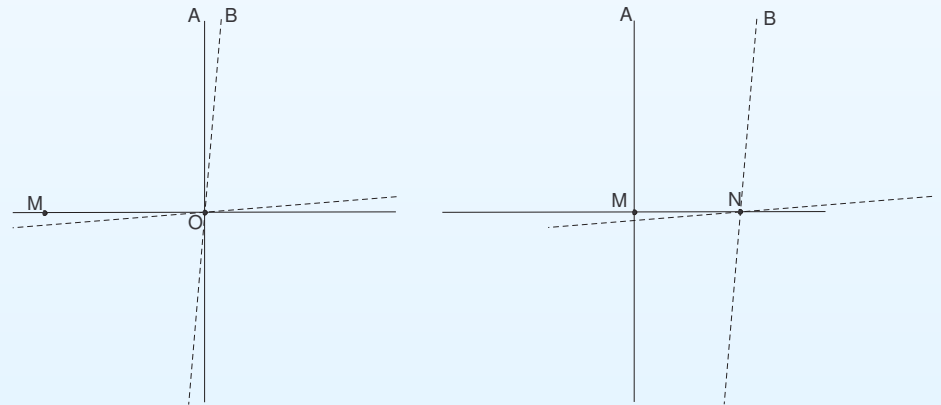
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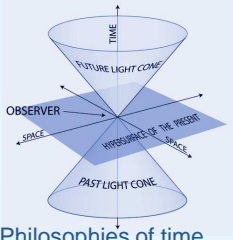
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$$1. NR_{\mathcal{A}}M \not\equiv MR_{\mathcal{B}}N$$

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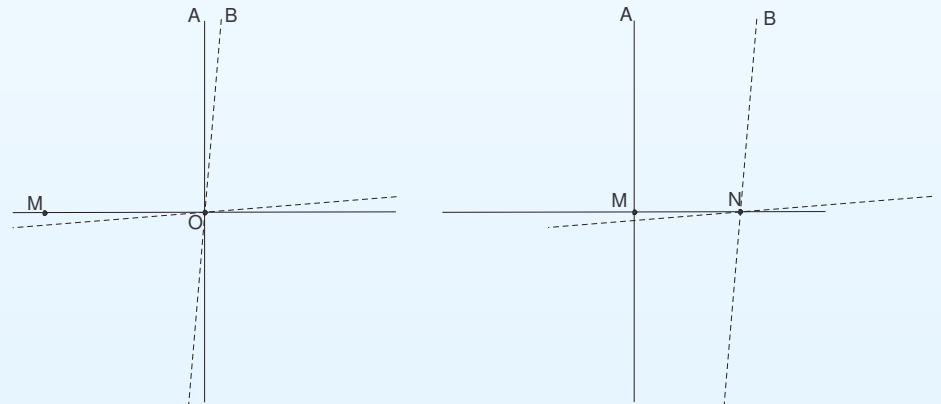
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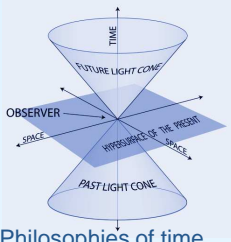
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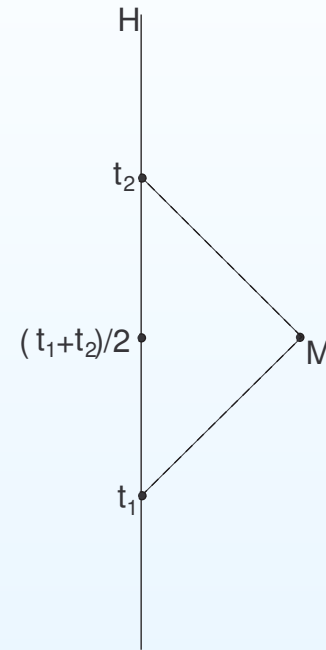
- Presentism turns away from common sense.
- The reality of \mathcal{O} depends on \mathcal{O} 's movement: weird !

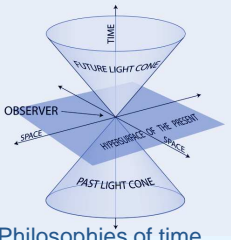


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Other simultaneity relations ? (1)

Poincaré-Einstein convention (PE):

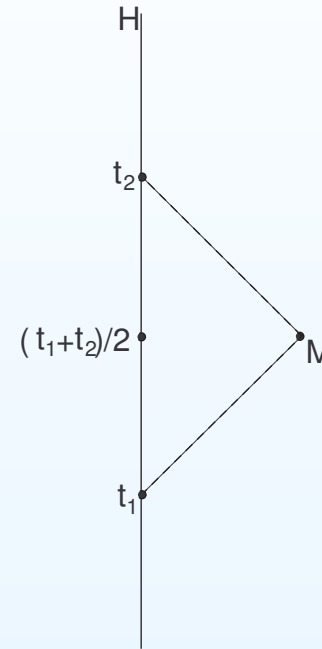




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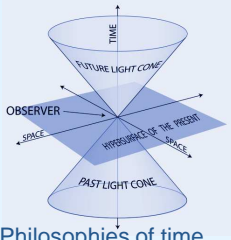
Other simultaneity relations ? (1)

Poincaré-Einstein convention (PE):



Theorem [Malament, 1977] *Let \mathcal{H} = be (the world-line of) an inertial observer. PE relation wrt \mathcal{H} is the only one which is:*

1. *a non-trivial equivalence relation,*
2. *invariant under causal automorphisms which stabilize \mathcal{H} .*



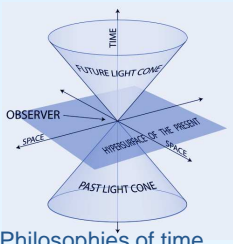
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Other simultaneity relations ? (2)

Invariance under causal automorphisms is too strong → allow only those which preserve a spatial and a temporal orientation.

Theorem [Sarkar & Stachel, 1999]

1. *PE is the only relation which satisfies the above requirements and only depends on the direction of \mathcal{H} .*
2. *The relations defined by the past (resp. future) light cones are the only ones which satisfy the above requirements and only depend on the position of \mathcal{H} .*



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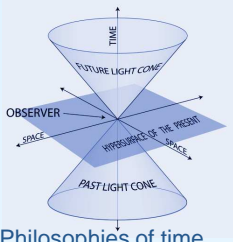
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→ 2 possible definitions of the present: PE and OS (observed simultaneity).

→ 2 possible versions of (relativized) presentism/possibilism.

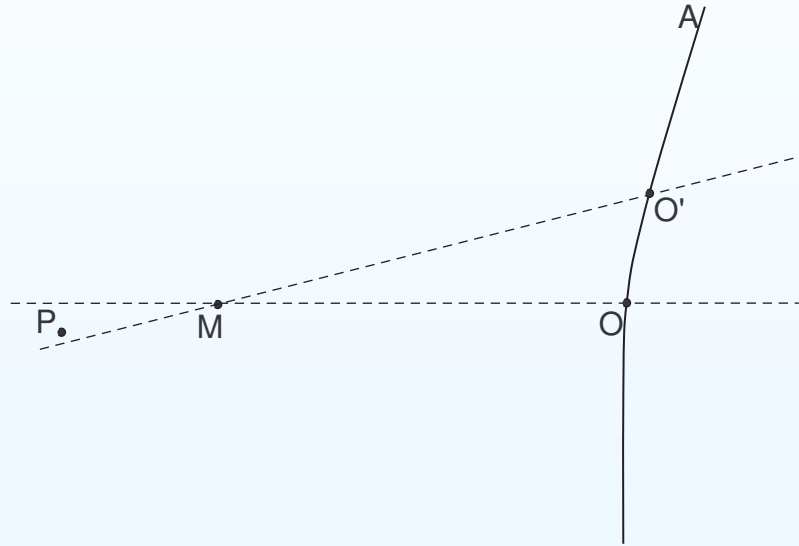
A clear-cut definition of reality for OS presentism: “what is real is what I see”.

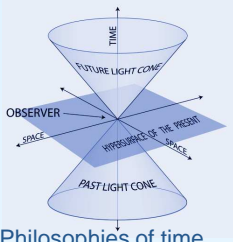


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Accelerated observers and PE

An observer which is inertial, then accelerated, then inertial.

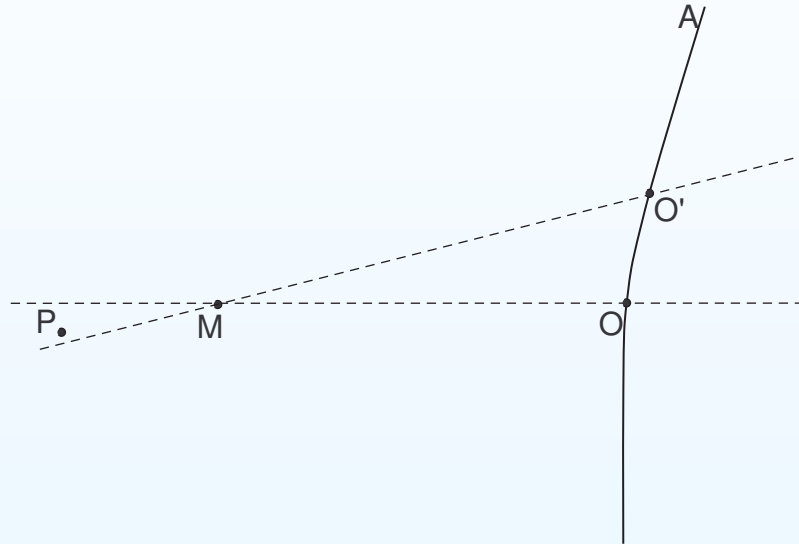




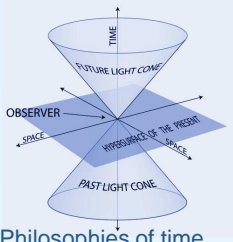
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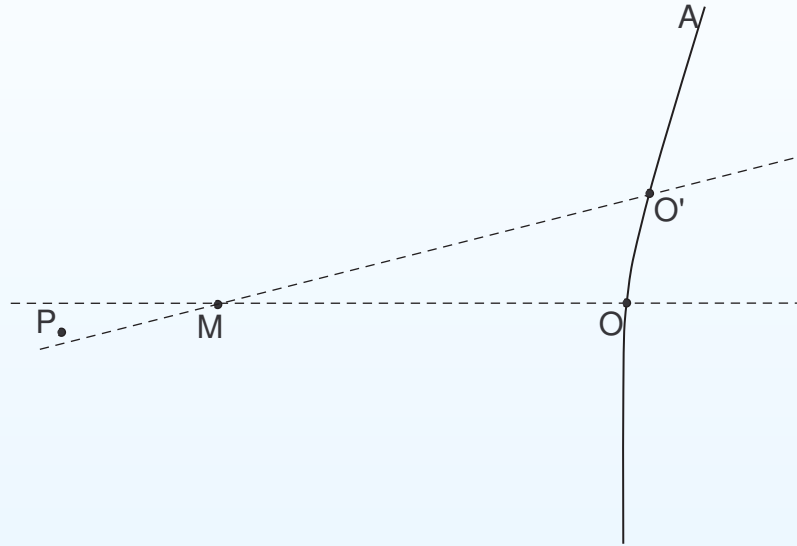
M is present for \mathcal{A} both at O and at O' .



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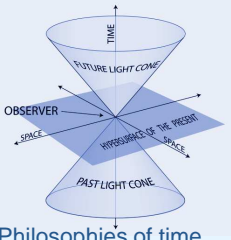
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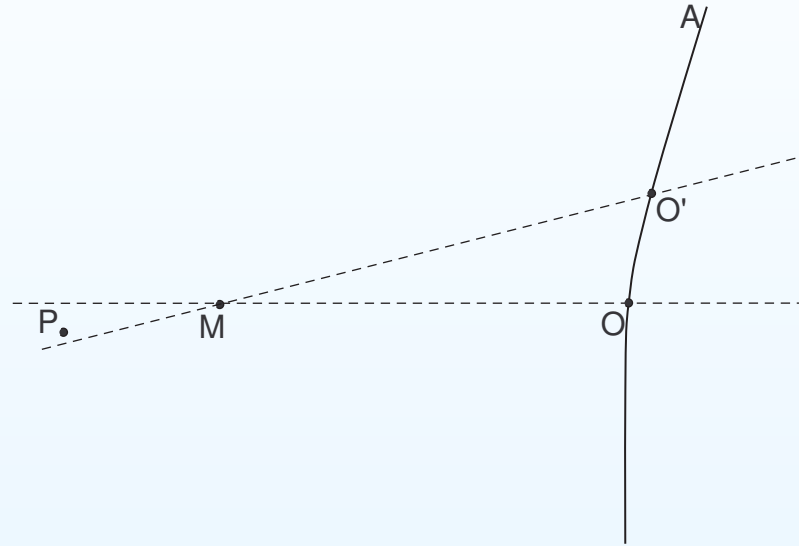
P is in the past for \mathcal{A} at some moment, but later it's in the future !



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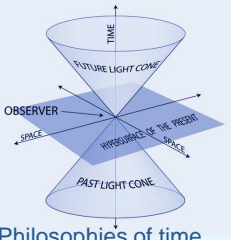
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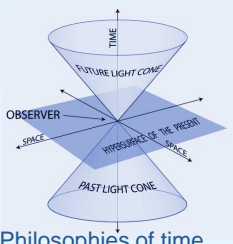
→ PE version of the present is only local.



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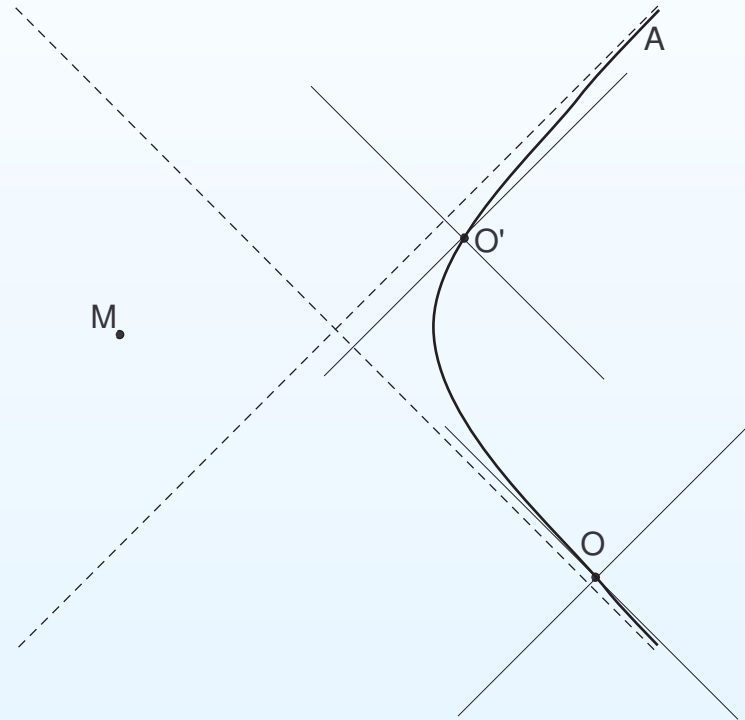
In SR, past cones do not intersect.



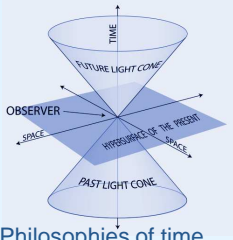
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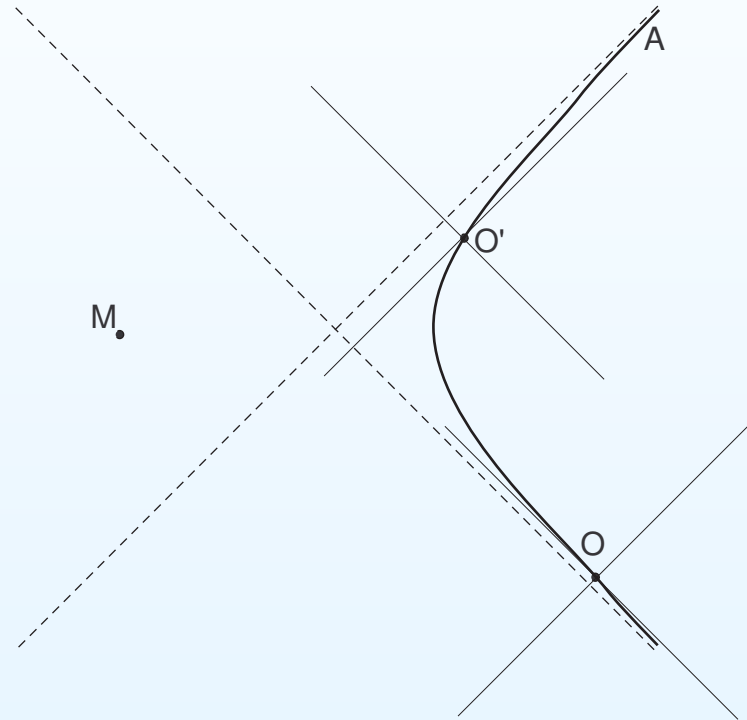
Some events are never in the present of \mathcal{A} !



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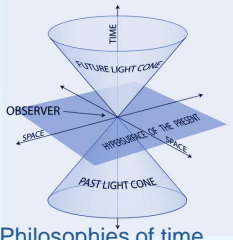
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Some events are never in the present of \mathcal{A} !

→ OS version of the present is also local (but in a more natural way).

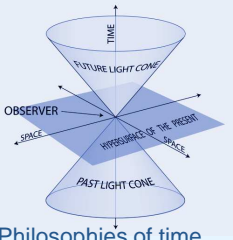


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Presentism and possibilism in General Relativity

Two new features:

- the metric is not a background structure anymore + it has non-vanishing curvature
- the global topology might be non-trivial.



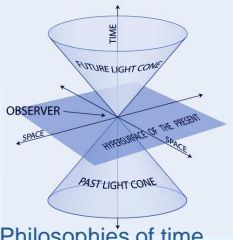
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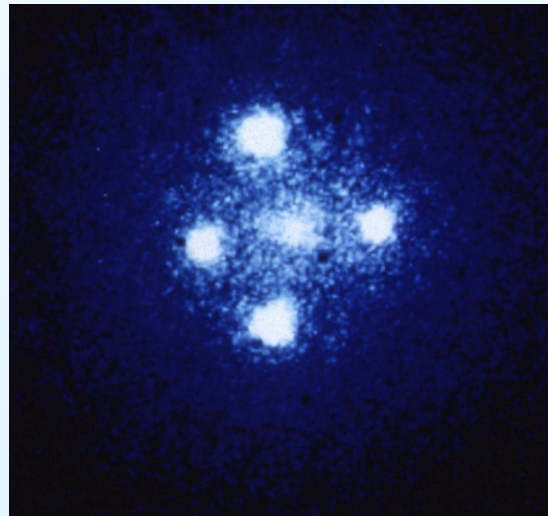
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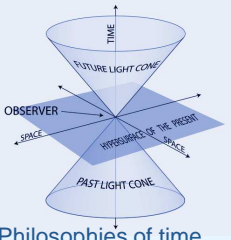
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PE becomes purely conventional.

OS still has a physical meaning, but:



the past light cones generally intersect.

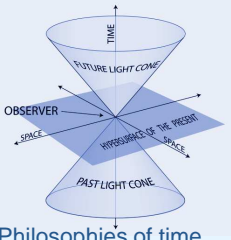


Closed time-like curves

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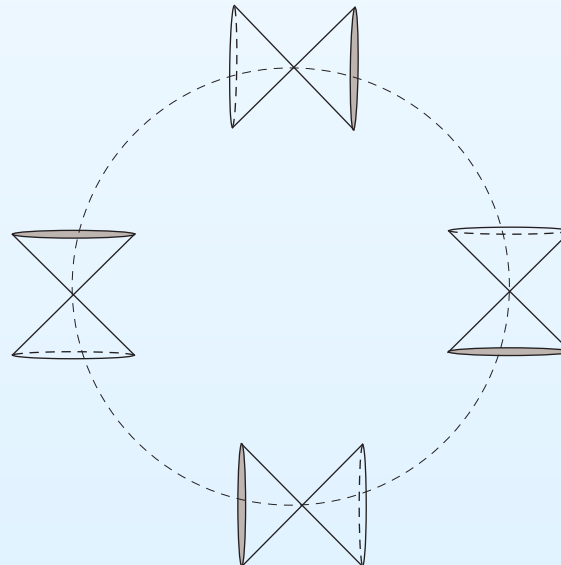
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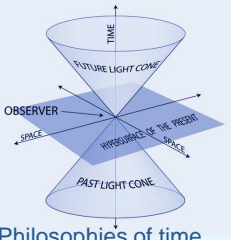
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But if CTC's exist, even OS possibilism becomes inconsistent !





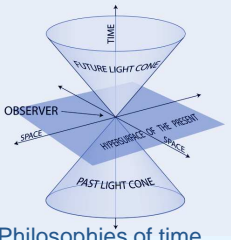
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Quantum heads-or-tails

$S = \text{spin-1/2}$ particle prepared in pure state $|+, z\rangle$

Sequence of measures along (Oz) , (Ox) , (Oz) etc... at time interval

$\Delta\tau > 0$.



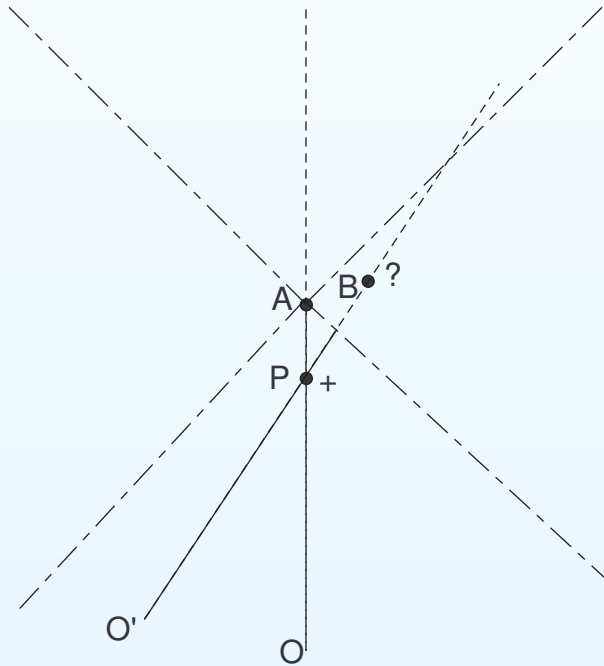
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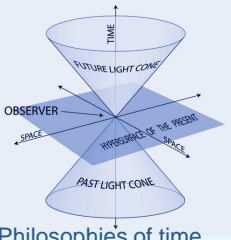
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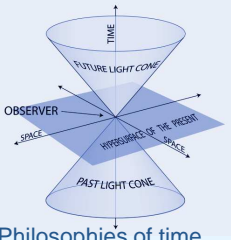
- A fixed, P varies in the past of A on \mathcal{O} .
- B can be anywhere in the elsewhere of future of A .



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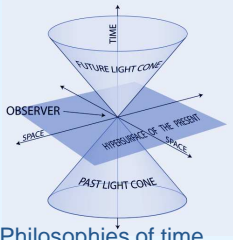


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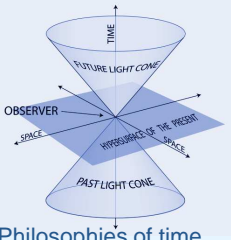


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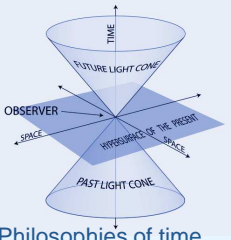


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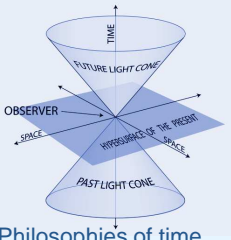
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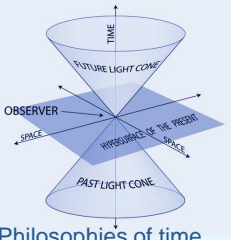
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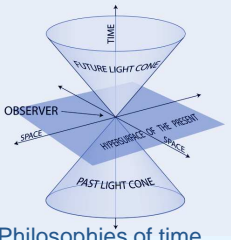
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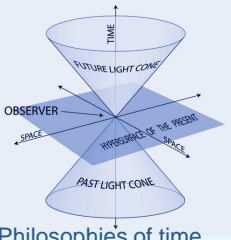
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Works as long as there is a mathematical structure encompassing all partial observations (Minkowski spacetime, GR spacetime, Everett multiverse)

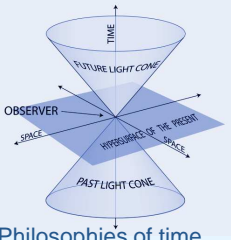


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On the one hand: open future (pure randomness, free will ?), passage of time, ...

- Only my past cone exists,
- Only some portion of spacetime *ever* exists,
- Only my branch of the multiverse exists.



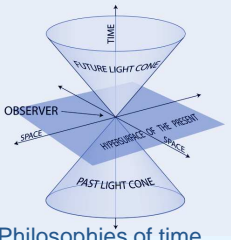
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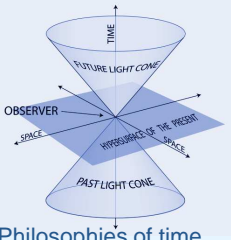
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These are timeless mathematical objects.

Eternalism + physics \implies mathematical ontology. Reality becomes bigger.