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INSTITUT SUPÉRIEUR DE PHILOSOPHIE

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Physics and Metaphysics: a Sellarsian project ... sort of

FRANCQUI CHAIR 2018-2019

KU LEUVEN

2 – Dynamical laws, or the source of modality

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Physical necessity

1 – What is change?

2 – What is the metaphysical source (and possibly the explanantion) of change?

I will come back to the first question in the second part of this lecture. Let us start with the second one.

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Concepts of physical necessity

Governism: entities are subjected to change. Change is enacted upon them.

It is possible to have a world with the same fundamental properties but different laws.

Dispositionalism: even if the initial condition of change could be external, the modal source of change is in a certain sense internal.

It is physically impossible to have a world with the same fundamental properties but different laws.

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Concepts of physical necessity

Primitivism: change is the result of a local primitive modal source.

Regularism: change is a fact that has no modal source.

Nevertheless, change could maybe be explained using non-modal information.

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Implementation: governism

Armstrong, Tooley, Dretske…

A law, for example N(F,G), is a nomic/necessitation relation among universals.

A law governs its instances.

Implementation: dispositionalism

Ellis, Bird, Mumford…

If properties have a dispositional essence then certain relations will hold of necessity between the relevant universals; these relations we may identify with the laws of nature. Bird 2007

$D_{(I,O)}x$, x will manifest O if input I happens.

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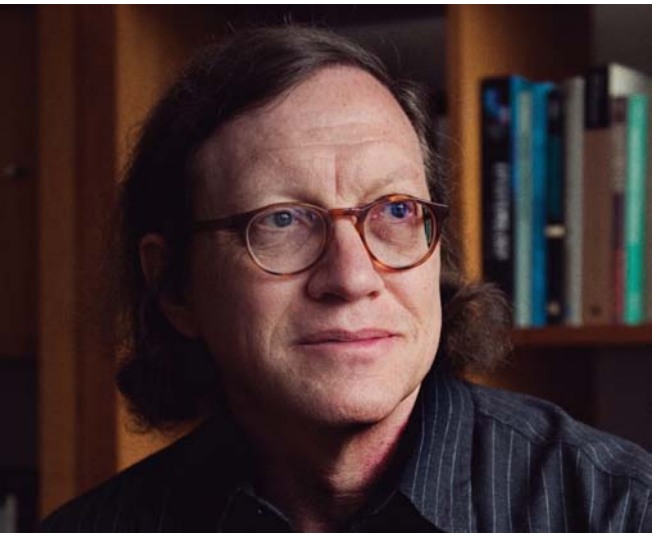
Implementation: primitivism



To the ontological question of what makes a regularity into a law of nature I answer that lawhood is a primitive status. […] If a law governs a particular space-time region then the physical states there will so evolve. Maudlin 2007

The genuine laws are local dynamical principles.

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Implementation: regularism

Lewis, Ramsey, Earman, Beebee…

Laws supervene on facts.

Laws are regularities that are singled out by science. They do not have a special ontological status.

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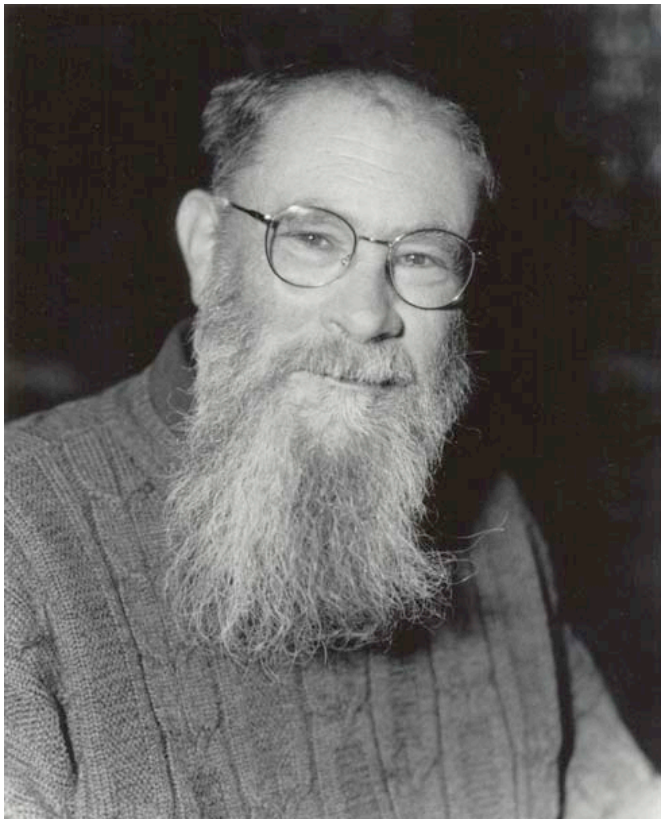
Implementation: regularism

A proposed definition:

A contingent generalization is a law of nature if and only if it appears as a theorem (or axiom) in each of the true deductive systems that achieves a best combination of simplicity and strength.

Lewis 1973



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First Challenge

How to explain the modal role of principles of invariance?

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What are principles of invariance

PIs are nomological claims about laws.

The invariance principles apply only to the second category of our knowledge of nature; to the so-called laws of nature. […] The laws of nature describe the further fate of a system, once the initial conditions are given.
Houtappel, Van Dam & Wigner 1965

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What are principles of invariance

PIs are symmetries of laws.

The symmetries physicists are concerned with–e.g. Poincaré invariance, time reversal invariance, etc.–typically are symmetries of lawlike connections among events and not symmetries of particular histories (sequences of states) satisfying the laws or of particular states belonging to these histories. Earman 2002

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What are principles of invariance

Earman's formalisation:

Let us imagine a theoretical structure and its associated set *M* of physical models. The laws L of physics pick out a distinguished sub-class of models M_L:=mod(L) in *M*, the models satisfying the laws L.

A symmetry operation is a map S: *M*->*M*. S is a symmetry of the laws L just in case it preserves M_L, i.e. for any m in M_L, S(m) in M_L.

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What are principles of invariance

An example

Physical laws (the dynamics) are invariant under a CPT transformation.

C: charge conjugation

P: parity reversal

T: time reversal

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Some uncontroversial features of PIs

PIs seem to be constraints on laws.

[Principles of invariance are] the structure of the laws of nature, and of the set of possible observations, even though we do not know the laws of nature themselves, nor the set of possible observations. Houtappel, Van Dam & Wigner 1965

Some of the heuristic uses of PIs are justified based on this claim.

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Some uncontroversial features of PIs

PIs come in different kinds:

Geometrical/Dynamical

Internal/External

Global/Local

Discrete/Continuous…

An unified account is not, at this point, very plausible.

Some uncontroversial features of PIs

Noether's first theorem:

For a large collection of systems, symmetry represented by a Lie group described by a finite number of parameters

conservation law

Temporal translation invariance
<-> conservation of energy, etc.

Some uncontroversial features of PIs

Noether's second theorem:

For a large collection of systems, symmetry represented by a Lie group described by a finite number of smooth functions

Δ

generalized Bianchi identities

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Three metaphysical answers

Principles of invariance could be

Meta-laws

Byproducts of laws

Attributes of spacetime

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Three metaphysical answers: Governism

PIs as meta-laws

1) $N_{NI}(N_U(F,G),I)$ -> More than one kind of N

No justification for this plurality of N, especially if N is a causal.

2) N(L,S) -> More than one kind of lawhood (depending on the domain of application of the symmetry)

No independent justification for this plurality of L. Difficult to understand L as a natural property (universal).

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Three metaphysical answers: Governism

PIs as byproducts of laws (not a law constraint)

1) They are a certain feature of specific universals such as "to be a law of type x".

   Same problems as before.

2) They are a certain feature of specific laws.

   What aspect makes two distinct laws share the same symmetry? For example, why electromagnetic and nuclear interactions Poincaré invariant? Something about the universals involved? About N?

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Three metaphysical answers: Governism

Since universals are not indexed to spacetime, this approach does not have much to say about spacetime.

I'll skip a discussion about Noether's theorems.

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Three metaphysical answers: Dispositionalism

PIs as meta-dispositions

$D_{(D(O,I),S)}x$, x will manifest the symmetry S if the disposition $D_{(O,I)}$ is present.

These meta-dispositions would always be actualised.

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Three metaphysical answers: Dispositionalism

The disposition to O is part of the nature of I.

In consequence, the disposition to manifest the symmetry S is part of the disposition $D_{(O,I)}$.

PIs are at best byproducts.

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Three metaphysical answers: Dispositionalism

<u>Pis as byproducts</u>

Laws are necessary but PIs and conservation principles are pseudo-laws.

What about the appearance of constraint, the diversity of PIs, Noether's theorems?

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Three metaphysical answers: Dispositionalism

Worlds like ours are ones which display certain global symmetries. The symmetry principles derive from this. […] We speculate […] that when the fundamental nature of the world is better understood, it will be predictable what kinds of fundamental particles and fields there are, and what their essences must be. The particles or fields which exist in the world change and interact with each other in all of the ways permitted by the conservation laws. […] This is the kind of way we think the various laws of nature are to be understood as arising out of essences. They all derive ultimately from the nature of the world we inhabit.

Bigelow, Ellis, Lierse 1992

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Three metaphysical answers: Dispositionalism

If PIs and principles of conservation are, in a certain sense brute facts, an arbitrary result of the dispositions, than why not be Humean?

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Three metaphysical answers: Primitivism

Since the dynamics is primitive, we could believe that Maudlin's approach is necessarily committed to defend that metaphysically:

Conservation principles -> associated PIs.

But this primacy of CPs as closer to the dynamics is not obvious.

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Three metaphysical answers: Primitivism

[…] les principes ou théorèmes connus sous les noms de conservation des forces vives, de conservation du mouvement du centre de gravité, de conservation des moments de rotation ou Principe des aires, et de Principe de la moindre quantité d'action. Ces principes doivent être regardés plutôt comme des résultats généraux des lois de la Dynamique que comme des principes primitifs de cette science […]
Lagrange 1811

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Three metaphysical answers: Primitivism

Lagrange argued that PIs, contrary to the conservation principles, characterize types of dynamics.

Principles of conservation are byproducts.

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Three metaphysical answers: Primitivism

Since Maudlin is substantivalist about space-time, he could sustain a natural position about the relation between laws and PIs:

Space-time symmetries (Wigner's geometrical PIs) are constraints on all dynamics and, in consequence, on laws.

Dynamical PIs are excluded from this interpretation.

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Three metaphysical answers: Regularism

PIs are descriptions of structural aspects of the set of laws.

They can be used as constraints on laws (heuristic strategy), because they usually denote very general properties of the dynamics of facts.

Noether's theorems are understood as important results about the inter-relation between dynamics and symmetries.

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Three metaphysical answers: Regularism

On a certain interpretation of what is a physical theory, they could be seen as general theoretical axioms.

But all this relies on a clarification of what is a fact, in particular what is a non-local fact.

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Second challenge

The problem of time.

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From movement to classical change

The static approach

Motion consists broadly in the correlation of different terms of t [a continuous one-dimensional series] with different terms of s [a continuous three-dimensional series]. […] Motion consists merely in the occupation of different places at different times, […] There is no transition from place to place, no consecutive moment or consecutive position, no such thing as velocity except in the sense of a real number which is the limit of a certain set of quotients. Russell 1903

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From movement to classical change

The dynamical approach

In claiming [in Phys. 8.8] that a continuously moving body is at such a [intermediate] position only potentially, [Aristotle] is simply saying that there is a legitimate sense of the modal 'could' for which it is true to say that the body *could* have stopped there but, in fact, did not. White 1992

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Hamiltonian approach

Space of initial data: space of instantaneous dynamical states of a system

History of a system: a trajectory through the space of initial data

Change: define a function on the space of initial data corresponding to the quantity of interest, and examine its behaviour as the state evolves

Time: time translation invariance of laws implies the existence of a map between a point in the initial data space and the state it will evolve to *t* units of time

Based on Belot 2007

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Physical necessity in Hamiltonian formalism

Governism: the state evolution is guided by the laws

Dispositionalism: the evolution is produced by the dispositions that defined the states

Primitivism: the states are defined as fields on slices of spacetime. The laws govern the evolution from the initial state to the final state

Regularism: the laws describe the possible histories

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Lagrangian approach

Kinematical possibilities: the set of possible histories or situations

Dynamical possibilities: genuine physically possible histories or situations according to the laws

Change: the absence of changelessness

Changelessness: invariance of the histories under a time translation group of the underlying spacetime

When the system is well-behaved the space of initial data is isomorphic to the space of dynamical possibilities

The problem of time

In the context of general relativity, the space of initial data and the space of histories are not isomorphic.

On neither the space of solutions nor the reduced space of solutions do we find an action of the real numbers implementing time translation. Nor do we find a non-trivial action implementing time evolution on the reduced space of initial data, since the Hamiltonian trajectories are all trivial there. Belot 2007

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The problem of time

Change is either non-existent or has to be redefined in such a way as it is not parametrized by a single real number (time).

Consequences of the problem of time

Governism: the necessitation relations must be understood in an a-temporal way. They are not causal. Not Armstrong.

Dispositionalism: dispositions should not be defined in a temporal/conditional way. Vetter?

Primitivism: ?

Regularism: the system is still describable in terms of regularist laws.

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What about change it self?

The *static approach* of change could be adapted. However, change will not be indexed by time but by more than one parameter.

What about change itself?

- Hamilton function (HF): defined as the value of the action on a physical trajectory (namely a solution of the equations of motion).

- *The dynamical approach* could be "recovered" without time by using the HF as an order function when possible.

  This order function would ground the relevant modal talk about shorter processes.

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What about quantum change?

Hamilton function –> transition amplitude (TA)

Contrary to the HF, all kinematical possibilities could potentially contribute to the genuine quantum change.

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Conclusion

Most metaphysical approaches to laws do not meet the challenge imposed by Pis and the problem of time.

In their current form, they are at best incomplete, at worst irrelevant.

It is deeply troubling and worrisome about the current state of philosophy that the metaphysics of laws has been developed for so long without paying sufficient attention to physics.

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Collaborators

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