

Excerpts from

Øyvind Grøn and Kjell Vøyenli, *On the Foundation of the Principle of Relativity*, *Found. Phys.* 29(11) 1695-1733 (1999)

15.1. Mach's Principle

The general principle of relativity is valid only if one also assumes that inertial fields can be interpreted as true gravitational fields caused by the distant matter of the universe. This view may be considered a variant of Mach's principle, adding to the list of 10 versions of this principle recently presented by H. Bondi and J. Samuel:⁽²⁹⁾

The so-called "inertial effects," occurring in a non-inertial frame, are gravitational effects caused by the distribution and motion of the distant matter in the universe, relative to the frame.

We call this **Mach 11**. In his presentation of the general principle of relativity Møller⁽¹³⁾ expresses similar views:

Einstein advocated a new interpretation of the fictitious forces in accelerated systems of reference: instead of regarding them as an expression of a difference in principle between the fundamental equations in uniformly moving and accelerated systems he considered both kinds of systems of reference to be completely equivalent as regards the form of the fundamental equations; and the "fictitious" forces were treated as real forces on the same footing as any other force of nature. The reason for the occurrence in accelerated systems of reference of such peculiar forces should according to this new idea, be sought in the circumstance that the distant masses of the fixed stars are accelerated relative to these systems of reference. The "fictitious forces" are thus treated as a kind of gravitational force, the acceleration of the distant masses causing a "field of gravitation" in the system of reference considered. Previously the effect of the celestial masses had been considered to be negligible; now, however, we must include the distant masses in the physical system considered. Only when we work in special systems of reference, *viz.* systems of inertia, is it not necessary to include the distant masses in our considerations, and this is the only point which distinguishes the systems of inertia from other systems of reference.

Whether **Mach 11** really is contained in, or at least compatible with the general theory, is, however, an open question. This question is the subject of the remaining sections.

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There exist other situations where the question of instantaneous propagation of gravitational effects seems more intrusive. E. L. Schucking⁽⁴⁰⁾ has illustrated the causal problem connected with the "instantaneous" propagation of Machian effects, in an amusing way.

Mach's principles -- whatever they may be -- will always find their defenders and believers. When one of its promoters, Dennis Sciama, slammed on the brakes of his car, propelling his girlfriend, seated next to him, toward the windshield, she was said to be heard moaning, "All those distant galaxies!"

The present case corresponds to a situation where a cosmic mass suddenly gets an acceleration. If this acceleration had the effect that all observers inside the shell simultaneously experienced the onset of a gravitational "dragging force," this would clearly constitute an "instantaneous action at a distance." Sciama's girlfriend, however, might have seen the acceleration of the galaxies at the same moment that she experienced the inertial force, and she appears to have interpreted this force as an instantaneous action from "all those distant galaxies."

However, gravity is propagated with the velocity of light according to general relativity.
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15.6. Is Mach's Principle Satisfied in Relativistic Universe Models?

We do not, however, live in a universe with Minkowski metric. In order to investigate whether the theory of relativity as applied to realistic universe models, fulfills Einstein's general principle of relativity, the inertial properties of "rotating Robertson-Walker universe models" should be considered. Such investigations have been performed.⁽⁴⁶⁻⁵³⁾

The results are summarized by Ciufolini and Wheeler (Ref. 15, p. 249) as follows:

In agreement with some strong general relativistic interpretation of the Mach principle, if one also includes the energy flux of cosmological gravitational waves, the local compass of inertia, that is, the local gyroscopes, should then be at rest relative to an "average, global flux of matter and energy" in the universe.

Comments: We take for granted that "gravity is propagated with the velocity of light", yet Sciama's girlfriend could feel *quasi-instantaneous* inertial "force", much like the back-reaction experienced by a fish from 'the school of fish':

<http://www.god-does-not-play-dice.net/#shoal>

Regarding the puzzle of "rotating" Robertson-Walker universe models (cf. Ciufolini and Wheeler above), recall the so-called cosmic equator (correlation of octopole and quadrupole components of the Cosmic Microwave Background) and the "handedness" of the universe:

<http://www.god-does-not-play-dice.net/#Longo>

The "rotation" of the universe can only be **global** -- with respect to the "ether" or the reference fluid in GR, if you prefer -- in order to be concealed as 'directly unobservable'.

Namely, we observe a 3-D cross-section -- one-at-a-time along the Arrow of Space -- of the "rotating" space, but the "spin axis" itself is never projected in 3-D space. This is the starting point for discussing the CMB anisotropy, particularly the so-called cosmic equator: check out Michael J. Longo [arXiv:astro-ph/0703325v3](http://arxiv.org/abs/astro-ph/0703325v3) and Craig J. Copi *et al.* [arXiv:1004.5602v2](http://arxiv.org/abs/1004.5602v2) [astro-ph.CO].

NB: Notice that the 'rotating bucket' comes back in a modern incarnation: the topology of the alleged "expansion" of space is non-trivial, as it follows both a line and a circle.

As to the question of an "average, global flux of matter and energy" in the universe, the energy flux of cosmological gravitational waves could spring from the "ether", provided the latter is again totally "hidden", hence the incoming energy flux would look "dark":

<http://www.god-does-not-play-dice.net/#Yau>

Notice that the *absolute reference frame* ("ether") of "the distant stars" in Machian quantum gravity is the putative 'global mode of spacetime' -- a **pre-quantum** state of the whole universe, resembling Platonic ideas -- check out the note (30.11.2010) at the end of

<http://www.god-does-not-play-dice.net/#Leydesdorff>

Details at

<http://www.god-does-not-play-dice.net/Margenau.html>

<http://www.god-does-not-play-dice.net/#Lawrie>

<http://www.god-does-not-play-dice.net/#continuum>

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