Does the Moon Pull à la Newton or à la Einstein or in a Third Way?

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Z. Naturforsch. **55a**, 981–982 (2000); received November 20, 2000

A new experiment, "Gravity Point", is proposed: The momentary direction of the pull of gravity on the surface of the earth can be probed. The time-dependent changes of the gravitational potential are either instantaneous in accord with Newton, or follow the change of the moon's position belatedly in accord with Einstein. A pendulum-based design is proposed.

Newton discovered the dependency of gravity on the position of the moon, thereby explaining the tides. He conjectured an instantaneous "action at a distance" to be at work. Following the discovery of special relativity, Einstein proposed a non-instantaneous action in a "gravitodynamics" analogous to electrodynamics. In his general relativity, gravitational waves form a special case, as is well known.

In which direction precisely does gravity pull at every moment? Finding the answer to this question may be much easier than detecting gravitational waves themselves. The time-dependent changes of the gravitational potential on the surface of the earth, in dependence on the moon's position, do represent a time-dependent change in the local spacetime curvature, according to general relativity. However, they strictly speaking do not form a special case of a gravitational wave. They only represent a "gravitational ripple" so to speak, for they do not propagate unchanged like gravitational waves.

Unfortunately, while gravitational wave-solutions are well known in explicit form, the exact momentary angular direction of pull on earth predicted by general relativity has, apparently, yet to be calculated explicitly for a point on earth facing the moon (in the absence of the rotation of the earth for simplicity). Nevertheless, the resulting direction can be guessed: It will be roughly coincident (except for a well-defined minor deviation) with the visible direction of the moon's center. It therefore suffices to check whether the moon's "visible position" (after subtraction of the earth's rotation) is responsible for the tidal pull, or whether the more advanced "actual position" is responsible. The former alternative will be called the "Einstein conjecture" in the following, the second the "Newton conjecture". Of course, the experiment like any successful experiment may turn out to favor a third, presently unfathomable, alternative.

Can the two conjectures be distinguished empirically? The answer is "in principle yes". All it takes is to determine the momentary local direction of gravity at a sufficient temporal and spatial resolution. The requisite temporal resolution is less than one second, the requisite spatial resolution less than 10^{-4} degrees. The reason for these constraints is that the distance of the moon is about one light second, and the change of position of the moon per second is about 360 degrees divided by 3 000 000 (the number of seconds per month).

An accelerometer which is that fast and accurate does not exist at present. Nevertheless a prototype can apparently be designed using currently available technology. A straight proposal is a long pendulum in a mine shaft.

The main problem to be overcome in the design of the experiment is noise. The three major sources of perturbation are temperature, wind, and seismic noise. Both temperature regulation and wind shielding can be achieved by using an evacuated cylinder with a thermostated low temperature to house the pendulum. The pendulum itself could be a fine metal chain. The weight at its tip would carry a point-shaped light source. The latter could be observed by means of a strongly magnifying, ultrahigh-resolution TV camera (or set of cameras). The camera should be firmly attached to the neighborhood of the suspension point of the pendulum, at the center of the cylinder's lid.

The seismic noise needs to be damped out as much as possible, in the lid's central part just mentioned (housing the suspension point and the camera). This vibration-insulated piece probably forms the most critical element in the design of the experiment. Similar techniques as are currently used to shield the mirrors in groundbased gravitational-wave detectors may turn out to be needed. Any remaining seismic effects on the magnifying camera can be corrected with the aid of two auxiliary stationary light sources.

The net "live signal", obtained after the subtraction, then has to be compared to a mathematical model of the quasiperiodically forced pendulum. Hereby, current techniques of chaos theory can be applied. The experiment contains two "free parameters", the pendulum's

0932-0784 / 2000 / 1100-0981 $ 06.00 © Verlag der Zeitschrift für Naturforschung, Tübingen · www.znaturforsch.com

length and its damping. They can be optimized both theoretically and empirically. Hereby, methods developed over the years by Peter Richter can be expected to be helpful (work in preparation).

In a final third step, the phases of the two periods that are present in the both observed and calculated "rosette" of the quasiperiodically forced pendulum (rotation phase of earth, rotation phase of moon) are to be matched to the momentarily visible (and computationally confirmed) apparent position of the moon. Hereby the fact that the earth's rotation causes a spurious one-second delay in the astronomical data needs to be taken into account.

This finishes the description of the proposed experiment. The suggested design appears to impose no insoluble problems. It is simpler than currently planned experiments to detect gravitational waves at ultrahigh sensitivities, after lesser sensitivities failed to yield a positive answer. A drawback of the present experiment could be seen to lie in its lack of sophistication. Note that a first version could already have been built (using mirrors) during the life time of Newton. Still, since a time-dependent change in gravitational potential or spacetime curvature, measured on a slow time scale, "mimics" an ultralow-frequency gravitational wave, the present experiment can at the same time be used as a gravitational-wave detector – especially in conjunction with a second one. Only "in addition" can it be used to resolve the Einstein conjecture described above.

To conclude, a simple terrestrial gravitational experiment has been proposed. It measures the momentary pull of gravity to an unprecedented accuracy which, nevertheless, is not intimidating. By simply extending the duration of the experiment, the signal-to-noise ratio can be almost arbitrarily improved. The experiment forms a "telescope" for the net force of gravity experienced at one point in the universe. Its philosophy is both Einsteinian and Newtonian. Even though there can be little doubt about its outcome, the experiment will make the voice of nature audible in a new way.

We thank John Wheeler for inspiration. For J.O.R.