Paper ID: 15853
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MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Gravity and Fundamental Physics (1)

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CLOCKS ON GOUND AND IN SPACE FOR GEODESY

Abstract

At the moment the experimental capabilities regarding clock precision are dramatically increasing:

- Today, clocks are capable of measuring a height difference of 30 cm through its gravitational redshift and relative velocities of nm/s. In the next years clocks will further improve so that they are sensitive to gravity at the 1 cm level and to relative velocities of, e.g., the order of the continental drift.
- Microwave and optical fiber links between clocks on long distances (approx. 1000 km) and with a precision of up to 10^{-19} establish first steps towards a clock network on Earth. Correspondingly improved links between clocks on Earth and in space are in development.
- For clocks and networks of clocks on Earth as well as in space one has to take into account all special and general relativistic effects like redshift, Doppler effect, time delay, Sagnac effect, and even the Lense–Thirring effect for clocks. In fact, these effects give all the information about the clocks' motion and their gravitational environment.

In realistic situations clocks on ground and in space (and also the orbit of satellites) are sensitive to the relativistic gravitational field of the gravitating mass with multipole moments. The problem to be solved here within a fully relativistic context is the clock comparison within a network of clocks on Earth or in space (or combinations of both) including all special and general relativistic effects (redshift, time delays, gravitomagnetic clocks effects, etc) with the aim to extract a maximum of information about the local gravitational field of the Earth as well as the local states of motion on the surface of the Earth. Furthermore, high precision optical clocks may stabilize geodetic height systems on regional and global scales. As an add-on we also would like to analyze whether these high precision clocks in the gravitational field of the Earth can also be used for new high precision tests of Special and General Relativity.

We investigate the applications of networks of the new generation optical clocks on ground as well as in space with the described capabilities for a variety of applications such as Earth gravity determination, timing, navigation and positioning, and fundamental physics tests. Since clocks directly measure the gravitational potential this opens up a fundamentally new way to do geodesy.