

基于最小二乘拟合的扭秤热噪声限制

摘要

万有引力常数 G 是物理学界的重要参数，在实验室中常用扭秤周期法去测量万有引力常数 G 。这个实验方法是通过比较扭秤运动在远程配置和近程配置下周期的变化来获得 G 值，所以 G 值的精确主要取决于扭秤运动周期 T 的高精度提取。然而在扭秤实验中，扭秤运动会收到各种噪声的干扰和影响，其中扭转周期 T 的灵敏度和精度主要受到热噪声的影响，因此热噪声对扭秤周期的影响是非常值得研究的。

高精度确定扭秤运动的周期是扭秤周期法测 G 的一项关键工作，直接影响 G 的测量精度。因扭秤有限振幅会引起非线性效应，进而对扭秤周期精确测量带来影响，所以采用非线性目标函数逼近拟合是一种较为理想的方法，能够获得高精度的待测参数结果。

本文通过研究扭秤周期法中热噪声对周期 T

的影响,运用非线性最小二乘拟合法去进行数据处理,对这一计算过程进行复现,在白噪声模型下给出方差最小的无偏周期估计,得到周期测量热噪声极限的严格公式和周期的不确定度,将扭秤运动的周期 T 的精度提取到最高,从而进一步提高万有引力常数 G 的精度。

关键词: 热噪声, 非线性最小二乘拟合法, 不确定度

Abstract

The gravitational constant G is an important parameter in physics. The periodic method of torsional scales is often used to measure the gravitational constant G in laboratories. This experimental method obtains G value by comparing the period change of the torsion balance movement under the remote configuration and zero configuration, and the accuracy of G value depends on the high precision extraction of the torsion balance motion period T . But in the experiment of torsion scale, the motion of torsion scale will be disturbed and influenced by various noises, among which the sensitivity and accuracy of torsion period T are mainly affected by thermal noise, so the influence of thermal noise on the period of torsion scale is worth studying.

It is a key work to determine the period of the torsion balance motion accurately, which directly affects the measurement accuracy of G . Because the limited amplitude

of the torsion balance will cause the non-linear effect, which will affect the accurate measurement of the torsion balance period, it is an ideal method to use the non-linear objective function approximation fitting, which can obtain the high-precision results of the parameters to be measured.

In this paper, the influence of thermal noise on the period T in the period method of torsion balance is studied, and the data processing is carried out by using the non-linear least squares fitting method. The calculation process is reproduced. The unbiased periodic estimation with minimum variance is given under the white noise model, and the strict formula of the limit of thermal noise for periodic measurement is obtained. The accuracy of the period T of torsion balance motion is extracted to the highest level, thus further improving. Accuracy of the gravitational constant G .

Key words: thermal noise; nonlinear least squares fitting method; the period with an uncertainty

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