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Postprint of Testing the Titius-Bode Law for Earthquake Prediction

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Abstract

The core of the Titius-Bode law is commensurability. According to the principle of commensurability, for earthquakes, the extrapolated commensurable points on their temporal axis correspond to the potential occurrence times of future earthquakes, which constitutes the scientific basis for earthquake prediction using commensurability. This paper presents a retrospective validation of our earthquake prediction efforts conducted over the past several years based on this principle. The validation results demonstrate that commensurability can indeed serve as an effective method for pre-earthquake prediction and warrants further in-depth investigation.

Full Text

ChinaXiv Collaborative Journal: Testing Earthquake Prediction Using the Titius-Bode Law

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Abstract

The core of the Titius-Bode Law is commensurability. According to this principle, for earthquakes, the commensurable points extrapolated on their temporal axis represent potential occurrence times for future seismic events. This provides the scientific basis for using commensurability to predict earthquakes. This paper summarizes and tests our earthquake prediction work conducted over recent

years based on this principle. The test results demonstrate that commensurability can indeed serve as a method for pre-earthquake prediction and warrants further in-depth investigation.

Keywords: Titius-Bode law; commensurability; earthquake prediction; test

A sudden major earthquake often causes significant casualties and property damage, which is why earthquake monitoring, prediction, and forecasting have been prioritized throughout history. Against this background, as early as the Western Han Dynasty in 132 AD, Chinese scientist Zhang Heng developed the seismoscope, representing a major ancient Chinese invention in earthquake observation research. Through centuries of effort, monitoring capabilities have expanded from surface-based to subsurface and space-based systems. In addition to gravity monitoring, observations now include ground tilt, crustal stress, crustal deformation, groundwater, geomagnetism, geoelectricity, and subsurface fluids (water level, temperature, geochemistry, radon gas, etc.). Space-based observations include thermal infrared, GPS, and ionospheric monitoring. Both China and Japan have established space monitoring networks using the Global Positioning System. Despite this comprehensive "heaven-and-earth" monitoring network, successfully predicted earthquakes remain limited.

Recognizing the difficulty of conventional prediction approaches, Weng Wenbo pioneered an alternative path, studying the Titius-Bode Law from an information theory perspective. In 1981, he first proposed that commensurability represents a natural order and that earthquake occurrence times are commensurable, thereby extending commensurability research from spatial domains to temporal domains within specific regions. Subsequent Chinese scholars have conducted extensive applied research on commensurability. For predictive analysis of historical events, most researchers employ pentad or triad commensurability formulas, as seen in the work of Weng Wenbo and Long Xiaoxia, while others use ordered network structures for analysis and prediction. These widespread research efforts have promoted the application of commensurability. However, due to limited data, the information contained in finite historical datasets is naturally restricted, resulting in predictions with annual-level precision at best.

We have developed a Fortran software package to perform commensurability analysis on data, with results output directly by computer. Using this tool, we analyzed earthquakes of M$ $7.0 occurring since 2000 in various regions, publishing our findings in the *Journal of Asian Earth Sciences*. The results demonstrated that major global earthquakes essentially occur at commensurable points on their temporal axes. The paper also presented predictions that future earthquakes in each study region would likely occur at extrapolated commensurable points on their temporal axes. Following publication, Chinese scholars including Professor Yang Xuexiang of Jilin University and Professor Zhang Shijie of Yunnan University suggested we prepare a similar article in Chinese to facilitate broader attention and application among Chinese researchers. Several years have passed, and this paper specifically summarizes both the predictions from that article and our more recent forecasting results to encourage colleagues to participate in the practice of earthquake prediction using commensurability. The test results confirm that commensurability can indeed serve as a method for pre-earthquake prediction, warranting further in-depth research.

1. Titius-Bode Law and Its Extension

The Titius-Bode Law was discovered in 1766 when German astronomer Titius found that the average distances of planets from the Sun are commensurable. Subsequent research by Johann Bode, director of the Berlin Observatory, led to the formulation of the famous Titius-Bode Law. Shortly thereafter, French astronomer and mathematician Pierre-Simon Laplace discovered that Jupiter' s three satellites (Io, Europa, and Ganymede) also obey this law. Later discoveries of Uranus and Ceres confirmed orbital predictions nearly identical to those of the law. The Titius-Bode Law can be expressed as:

$$a_n = 0.4 + 0.3 \times 2^{n-2}$$

where a_n is the distance of planet n from the Sun in astronomical units, and n is the planetary sequence number outward from the Sun. For Mercury, n is not 1 but $-\infty$, and β represents the commensurability value for solar system planets.

Following the 1966 Xingtai earthquake in Hebei Province, China, renowned geophysicist Weng Wenbo, entrusted by Premier Zhou Enlai to study earthquake prediction, took an innovative approach. From information theory, he investigated the Titius-Bode Law and in 1981 first proposed that commensurability is a natural order and that earthquake occurrence times are commensurable, thereby extending commensurability applications from spatial domains to temporal domains within specific regions. The commensurability relationship can be expressed as:

$$X_{i+1} = X_i + \beta K$$

where K is an integer. If this relationship holds, the dataset $\{X_i\}$ is commensurable, and β is the commensurability value of the dataset. Regarding the theoretical mechanism of the Titius-Bode Law, little explanation exists, because commensurability reflects the inherent developmental patterns of phenomena—an objective fact that constitutes an information system.

2. Verification of Earthquake Predictions

2.1 Japanese Earthquakes

On December 7, 2012, April 15, 2016, and November 22, 2016, earthquakes of magnitude 7.4, 7.3, and 7.4 occurred successively off the east coast of Japan, off Kyushu, and in the Fukushima region. According to Table 4 in reference [9], the commensurability value for earthquakes in this region is 0.55 years. Their preceding earthquakes occurred on March 11, 2011 (2011.18), December 7, 2012 (2012.93), and April 15, 2016 (2016.29), respectively. Consequently, these three earthquakes occurred exactly at the 3rd, 6th, and 1st extrapolated commensurable points on their temporal axes following the previous earthquakes:

$$2012.93 = 2011.18 + 0.55 \times 3 = \text{December 9, 2012}$$

$$2016.29 = 2012.93 + 0.55 \times 6 = \text{April 22, 2016}$$

$$2016.92 = 2016.29 + 0.55 \times 1 = \text{November 17, 2016}$$

On February 13, 2021, a magnitude 7.3 earthquake occurred in the Fukushima region. According to NHK reports, this was an aftershock of the March 11, 2011 earthquake. Using that event as the starting point on the temporal axis, this earthquake occurred exactly at the 18th extrapolated commensurable point:

$$2021.13 = 2011.18 + 0.55 \times 18 = \text{February 28, 2021}$$

The absolute prediction errors for these four earthquakes were 39 days, 7 days, 19 days, and 15 days, respectively, with relative errors of 0.11, 0.03, 0.07, and 0.07.

2.2 Indonesian Earthquakes

On March 2, 2016 and September 28, 2018, earthquakes of magnitude 7.8 and 7.4 occurred in the Sumatra region of Indonesia. According to Table 3 in reference [9], the commensurability value for this region is 0.53 years. Their preceding earthquakes occurred on December 26, 2004 (2004.99) and March 2, 2016 (2016.17), respectively. Therefore, these two earthquakes occurred at the 21st and 5th extrapolated commensurable points on their temporal axes:

$$2016.17 = 2004.99 + 0.53 \times 21 = \text{February 13, 2016} + 18 \text{ days}$$

$$2018.73 = 2016.17 + 0.53 \times 5 = \text{October 26, 2018} - 28 \text{ days}$$

The absolute prediction errors were 18 days and 28 days, with relative errors of 0.09 and 0.14.

2.3 Qinghai Earthquakes

Following the magnitude 7.1 earthquake in Yushu, Qinghai Province on April 14, 2010, we analyzed both the astronomical background and the commensurability of M$ $7.0 earthquakes in central and eastern Qinghai since 1900, obtaining a commensurability value of 1.24 years. After this earthquake, a magnitude 7.0 earthquake and a magnitude 7.4 earthquake occurred on August 8, 2017 in Jiuzhaigou, Sichuan and on May 22, 2021 in Maduo, Guoluo, Qinghai, respectively. Although the Jiuzhaigou earthquake administratively belongs to Sichuan Province, geologically it may belong to the Qinghai Plateau, as it is very close to Qinghai (and our study region for central and eastern Qinghai included this area). According to Table 1, their preceding earthquakes occurred on April 14, 2010 and August 8, 2017, respectively, yielding:

$$2017.60 = 2010.28 + 1.24 \times 6 = \text{September 19, 2017} - 42 \text{ days}$$

$$2021.39 = 2017.60 + 1.24 \times 3 = \text{April 27, 2021} + 23 \text{ days}$$

The absolute prediction errors were 42 days and 23 days, with relative errors of 0.09 and 0.05.

Table 1 Commensurability of M$ $7.0 earthquake events in central and eastern Qinghai since 1900

Additionally, we accurately predicted the September 21, 1999 M7.6 earthquake in Taiwan, the April 20, 2013 M7.0 Lushan earthquake in China, and the April 1, 2014 M8.2 Iquique earthquake in Chile, with absolute prediction errors of 1 day, 22 days, and 11 days, respectively.

3. Conclusions and Discussion

1. The core of the Titius-Bode Law is commensurability, which exists universally across various natural phenomena. This principle warrants further investigation.

2. Many events appear to occur randomly, but this is not the case. Necessity resides within contingency. Therefore, commensurability can provide a scientific basis for predicting future events in a region, revealing that many occurrences are inevitable.

3. Predicted points extrapolated on the temporal axis using commensurability values represent only a necessary condition, making some false predictions inevitable. To achieve precise predictions and avoid false alarms, this method must be combined with triad or pentad commensurability formulas and other approaches.

4. Different regions have different commensurability values, likely related to their geological structures—just as the commensurability values for solar system planets differ from those for satellites of Jupiter, Saturn, and Uranus. The key challenge lies in defining study regions, which is crucial for improving prediction accuracy. Our study regions are often rectangular areas bounded by longitude and latitude lines, which contributes to larger prediction errors.
5. We selected earthquakes with M$ 7.0since1900.0basedonEngdahl′sresearchindicatingthattheearthquake events since 1900.0 is complete and reliable.

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