Strong Earthquakes, Novae and Cosmic Ray Environment

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Abstract

This paper suggests some new observations about the relationship between seismic activity and astronomical phenomena. First, after investigating the seismic data (magnitude 7.0 and over) with the method of superposed epochs we find that the world seismicity evidently increased after the occurring of novae with maximum apparent magnitude brighter than 2.2. Second, a great many earthquakes of magnitude 7.0 and over concentrated to occur in the 13th month after the occurring of two largest Ground Level Solar Cosmic Ray Events (GLEs). From these, we put forward explanations of the causes about three high level phenomena of global seismic activity in 1918-1965 and suggest that according to the information of large GLE or bright nova we shall be able to predict the occurring time of global intense seismic activity.

Is seismic activity affected by astronomical phenomena? This paper tries to offer some noticeable results.

A. Seismic data used in this paper

Gutenberg and Richter (1954)[1] edited the catalog of worldwide large earthquakes in 1904-1952. But the number of earthquakes is incomplete for magnitude below 7.9 in 1904-1917. Duda (1965)[2] and Rothe (1969)[3] continued Gutenberg-Richter's classical work. They extended the catalog to 1965. Therefore, this paper discusses world seismicity of magnitude 7.0 and over in 1918-1965.

B. The effect of bright novae on world seismicity of magnitude 7.0 and over

During this period of 1918-1965 there appeared six novae with maximum apparent magnitude brighter than 2.2.[4] For investigating the effect of novae on seismic activity, the method of superposed epochs requires to define the "zero day". This date ought to be the date when nova started explosion. But this date was often uncertain. Because brightness rose very fast for most novae, from starting explosion to maximum brightness the duration was only a few days, we unify to use the date of maximum brightness as the "zero day". It is available to those six except Nova RR Pic.The character for Nova RR Pic was that its risen period sustained for a long time (Payne-Gaposchkin,1957)[4]. Its maximum apparent magnitude was 1.2 on June 8,1925 and before two months, however, it had already reached apparent magnitude 3.0. It probably took a long time from starting explosion (apparent magnitude 12.7),to apparent magnitude 3.0. So for the present we move the date up 3 months from its maximum brightness date, namely March 8,1925, as the "zero day".

From the next day of the "zero day" on,we take every two months as one time-interval and investigate the numbers of worldwide earthquakes in every time-interval.For six novae we obtain the mean value of earthquake number in each time-interval.They are shown in figure 1.

From fig. 1 we note that after the occurrence of bright novae the curve of seismic activity was evidently higher than horizontal line. The increased effect showed successive two waves. In the forty months after the occurrence of bright novae the number of worldwide earthquakes of magnitude 7.0 and over increased eleven or so on average than the mean level before the occurrence of novae. Because there is no third party which can affect the nova and the seismic activity simultaneously, the obvious relationship of them has to be understood as the causation. Therefore, statistical analysis shows that there is an effect that bright novae caused enhanced seismic activity of magnitude 7.0 and over.

Although it is still unclear now about the variation of cosmic-ray environment around Earth after the occurrence of bright novae, yet we can presume that the enhanced seismic activity was caused by nova's x-, r-rays incident upon the earth.

C. The effect of large GLE on world seismicity of magnitude 7.0 and over

Since the start of systematic and continuous observation of cosmic rays,the number of GLE was rare in past forty years or more (Duggal,1979)[5]. Among them large GLE happened only five times and they are shown in table 1 (Dorman,1957)[6]. In table 1 in the years of the occurrence of front three GLEs there also occurred bright novae, their seismic effects were overlapped. The single seismic effect of large GLE cannot be shown. So we discuss the last two events, i.e.two largest GLEs.

From the next day of those two GLE's dates on, we investigate the numbers of worldwide earthquakes of magnitude 7.0 and over in every month and obtain fig.2. From fig.2 we note that in the

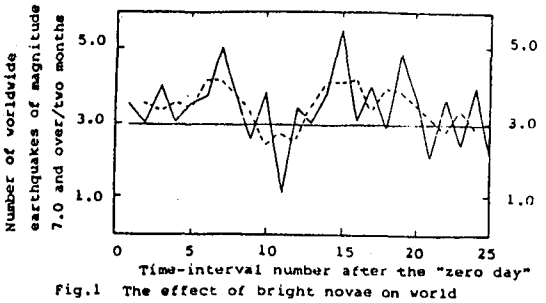

Fig.1 The effect of bright novae on world seismicity of magnitude 7.0 and over six bright novae:V603Aql,V476Cyg,RRPic,DQHer,CPLac,CPPup.
solid line: curve of the average of earthquake numbers
dashed line:curve of three time-intervals running average
The horizontal line of 2.97 is two-monthly average of the number of worldvide earthquakes of magnitude 7.0 and over in six two-years before the "zero days" of six bright novae (before the "zero day" of each bright nova all take two years). It *represents the mean level of seismic* activity when the seismic effect of bright novae did not occur yet.

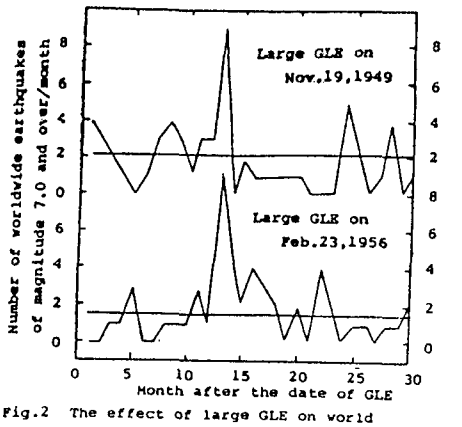

Fig.2 The effect of large GLE on world seismicity of magnitude 7.0 and over
The horizontal lines of 2.17 for upper part and 1.46 for under part represent respectively the monthly mean level of global seismic activity before the occurrence of two GLEs. They are the averages of the numbers of worldvide earthquakes of magnitude 7.0 and over in two years prior to the GLE date.

Table 1 The large GLE data

No.	Date	$\frac{I_{max}}{I}$ *, %	Remarks
1	Feb.28,1942	15.5	average on 15 minutes
2	Mar. 7,1942	15	"
3	Jul.25,1946	22	"
4	Nov.19,1949	57	"
5	Feb.23,1956	200	

* The sea-level enhanced magnitude of cosmic ray hard component at high latitudes (Dorman,1957).

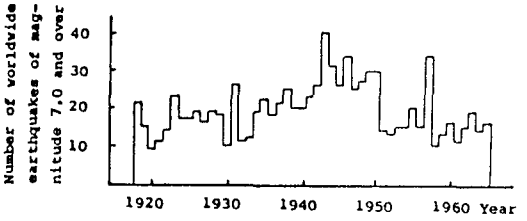

Fig.3 The annual number of worldvide earthquakes of magnitude 7.0 and over in 1918-1965

13th month after the occurrence of the GLE there occurred unusual groups of worldvide large earthquakes. Earthquake number increased extremely obviously. Both of two events were just the same. The risen amplitudes are so high and the peak times are so uniform, thereby fig.2 clearly shows the effect of large GLE on seismic activity of magnitude 7.0 and over. About large GLE in 1949, in increased period (7th-13th month afte the GLE's date) the number of worldvide earthquakes of magnitude 7.0 and over increased eleven than that of mean level prior to the occurring of the GLE. About large GLE in 1956, in increased period (11th-18th month after the GLE's date) the number of worldvide earthquakes of magnitude 7.0 and over increased seventeen than that of mean level prior to the occurring of the GLE.

It can be questioned that whether the enhanced seismic activity would be able to cause by other emission component of those two solar flares on Nov.19,1949 and on Feb.23,1956.Among solar flare emissions, besides solar cosmic rays (SCR) there were also plasma cloud, vissible light,UV, X-rays and radio emission. At the time of the occurring of other large solar flares, except for the large GLE the sudden big increase of these components had been observed many times. But after them the enhanced seismic activity has not been observed. The enhanced seismic activity was only after the large GLE. Therefore we could judge that the enhanced seismic activity was just caused by enhanced high-energy SCR.

D. About causes of three high level phenomena of global seismic activity of magnitude 7.0 and over

1. About the decade of the most earthquake number

From fig.3 we note that the forties were the decade of the most earthquake number. Why was this? It turned out to be that the Earth's cosmic ray environment occurred quite a few enhanced events. In the forties there occurred four times out of five large GLEs described above.At the same time, in 1942 there occurred the Nova CP Pup which is the brightest nova in the last sixty years. Besides, in 1946 there also occurred the recurrent Nova T CrB (Payne-Gaposchkin,1957)[4]. These astronomical phenomena all gave rise to enhanced effects of seismic activity. So the forties became the decade of the most earthquake number.

2. About the year of the most earthquake number and about the years in which earthquake number strikingly increased

From fig.3 we note that in 1943 there occurred the most earthquake number and it unexpectedly was forty. Why was this? It turned out to be that in 1942 there simultaneously occurred two large GLEs and the bright Nova CP Pup. The enhanced periods of seismic activity caused by them were in 1943. So the number of large earthquakes was so high in that year. From fig.3 we note that in some years the earthquake number suddenly increased over ten than their last year. These years were1931, 1943 and 1957. Why was this? The reason for 1943 has explained above. For 1957 it was due to the occurrence of large GLE on Feb.23,1956 which was the largest GLE since the start of systematic and continuous observation of cosmic rays. The enhanced period of seismic activity caused by it was in 1957, so the number of large earthquakes unusually increased than 1956. As regards 1931,because at that time it had not the data of cosmic ray observation, we cannot explain it now.

3. About unusually concentrated periods of earthquakes of magnitude 7.0 and over

The yearly average of the number of worldwide earthquakes of magnitude 7.0 and over was 19.5 in 1918-1965. It corresponded to 3.25 per two months. Nevertheless, in the some periods the seismic activity was unusually high. The number of earthquakes reached over ten in two months and was three times or more of the average. Why was this? In table 2 we listed all of these data in 1918-1965 and put forward explanations of their causes.

The concentrated phenomenon of large earthquakes was more projecting for one month. The monthly average of the number of worldwide earthquakes of magnitude 7.0 and over was 1.6 in 1918-1965. Nevertheless, in the some periods the earthquake number reached unexpectedly 8 or 9 in a month and was five times of the average. In table 3 we listed all of these data in 1918-1965 and put forward explanations of their causes.

Above explanations could already illustrate that the occurring of high level phenomena of global seismic activity of magnitude 7.0 and over was neither accidental nor at random.

Table 2 The explanation of causes on all of the data which the earthquake number of magnitude 7.0 and over reached over ten in two months(61 days) in 1918-1965

No.	Date	Earthquake number M≥7.0	Explanation on causes
1	Jan.27,1931-Mar.28,1931	11	?
2	Oct.10,1938-Dec. 6,1938	11	The Nova CP Lac in 1936; Possible large GLE in Oct.1937?
3	Feb.16,1943-Apr. 9,1943	11	Large GLEs on Feb.28,1942 and on Mar.7,1942; Also existing the effect of the Nova CP Pup in 1942
4	Oct.21,1943-Dec. 1,1943	12	The Nova CP Pup in 1942; Also existing the effect of two large GLEs on Feb.28,1942 and on Mar.7,1942
5	Aug. 2,1946-Sept.30,1946	11	The Nova T CrB in 1946; Large GLE on July 25,1946
6	Jan. 4,1948-Mar. 3,1948	11	The Nova T CrB in 1946; Large GLE on July 25,1946
7	Oct.23,1950-Dec.14,1950	12	Large GLE on Nov.19,1949
8	Mar. 9,1957-Apr.25,1957	15	Large GLE on Feb.23,1956

Table 3 The explanation of causes on all of the data which the earthquake number of magnitude 7.0 and over reached eight in 31 days in 1918-1965

No.	Date	Earthquake number M≥7.0	Explanation on causes	Interval*
1	Nov. 5,1938-Nov.30,1938	8	Possible large GLE in Oct.1937?	
2	Mar. 9,1943-Apr. 9,1943**	8	Large GLEs on Feb.28,1942 and on Mar. 7,1942; Also existing the effect of the Nova CP Pup in 1942	12 months or more
3	Nov. 2,1943-Dec. 1,1943	9	The Nova CP Pup in Nov.1942; Also existing the effect of two large GLEs in 1942	12 months or so
4	Dec. 1,1950-Dec.14,1950	9	Large GLE on Nov.19,1949	12 months or more
5	Mar. 9,1957-Mar.23,1957	9	Large GLE on Feb.23,1956	12 months or more

* The interval between the beginning date of seismic activity increased period and the occurring date of its major cause.

** The interval was 30 days 23 hours between the large earthquakes on Mar.9 and on Apr.9.

E. Discussion

1. We discuss some tentative ideas on mechanisms that cosmic rays affect seismic activity. The cosmic ray particles incident in lithosphere were rare. It was still limited when occurring large GLE. So the effect of the direct action probably is very small for the mechanisms.

Cosmic rays gave rise to atmospheric ionization when they passed though the atmosphere. The ionicity had difference at different atmospheric altitude and at different geomagnetic latitude. From the atmospheric ionization there forms an atmospheric electric-field,we call it *cosmic ray* atmospheric electric-field. Its maximum intensity was at the top of troposphere or at the bottom of stratosphere. When occurring the large GLE the cosmic-ray atmospheric electric-field would intensify. The sudden intensifying of atmospheric electric-field probably was just the factor which led to the occurrence of enhanced seismic activity. Through affecting the telluric electric-field and atmospheric circulation which affected the rate variation of the Earth's rotation it finally led to the occurrence of large earthquakes. The possible *mechanisms are as follows*:

solar cosmic rays or nova's x-,r-rays ⟶ cosmic ray atmospheric electric-field ⇄
⟶ atmospheric circulation ⟶ Earth's rotation ↘
↘ telluric electric-field ⟶ earthquakes

2. About the groups of largeearthquakes in Mar.1943,Dec.1950 and Mar.1957(see table 3),we think they were caused by the corresponding large GLE one year ago.It seems to show that at least for some earthquakes of magnitude 7.0 and over their brewing time was not long,only one year or so.

3. Fig.1 shows the seismic effect of bright novae had successive two waves. We think that it probably was caused by two batches of nova's radiation which reached Earth in different time.The first batch reached Earth in the time which was soon after or simultaneous with the visible light. From fig.1 we estimate that the main current of the second batch reached Earth in the 17th month or so on average after nova started explosion. Aikin et al.(1980)[7] suggested that among supernova radiation caused Earth effects the first batch was prior to the second batch to reach Earth for several months. Maybe nova is similar to supernova.

4. The explosion scale of supernova is more violent than that of nova. If occurring the bright supernova visible to the naked eyes, we could infer that the global seismic activity will soon increase obviously.

5. Since aforesaid change of cosmic ray environment could lead to the increase of world seismicity, we could infer that the background and other variations of cosmic rays should also be able to affect the world seismicity.

6. The occurring of the groups of large earthquakes is not a mystery to us now.Moreover,as a means it could help us to research the changes of cosmic ray environment. That is,it is an "indicator", according to this indicator we can know the enhanced event of cosmic ray environment had already occurred before it. For example, about the groups of worldwide large earthquakes($M \geq 7.0$) in 1931 and in Nov.1938[1] we could infer that in 1930 there probably had occurred the enhanced event of cosmic ray environment and in Oct.1937 there probably had occurred a large GLE.

7. When occurring the large GLE or bright nova in future, according to fig.1,fig.2, and table 3 we shall be able to predict the occurring time of global intense seismic activity.

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