Rise of activity, i.e. inverse cascading, at the approach of an extreme event

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Outline

- Universality of multiple fracturing and cascading activity
  Example: The longest sequence of “starquakes” on Soft Gamma Repeater, SGR1806-20

- Cascading of earthquakes by far more diverse than a power-law family yet it implies…

- … Earthquake Prediction

- What stands behind?
A 5000-km segment of the area where the standard versions of M8 and MSc algorithms were setup for real-time monitoring.
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The M8-MSc prediction pinpoints the epicenter and aftershocks of the 4 June 2000, Ms8.0 Southern Sumatera earthquake.
SGR1806-20 sequence

Soft-Gamma-Repeater 1806-20 is the source in Sagittarius, from which more than a hundred X-ray pulsations have been detected. Its location on the sky (1806-20 refer to celestial coordinates: 18 hours 06 minutes right ascension, -20 degrees declination) is near the Galactic center, which is 25,000 light years away.

The energy of one burst varies from $1.4 \cdot 10^{40}$ erg to $5.3 \cdot 10^{41}$ erg (the largest earthquakes release about $10^{26}$ erg).
Common general features

A fundamental property of multiple fracturing is the power-law distribution of energy:

\[ \log_{10} N(E) = a + b \cdot \log_{10} E \]

(Gutenberg-Richter relation)
Symptoms of transition to the main rupture

- Escalation of fracturing lasting nearly 1000 days and culminated with the largest starquake on November 16
- The power-law increase of activity, e.g. Benioff strain release $\varepsilon(t)$, with a possible trace of the four log-periodic oscillations.
Seismic premonitory patterns

- **Pattern** $\Sigma \sim E^{2/3}$
  
  *Keilis-Borok & Malinovskaya, 1964*

- **Pattern B**
  
  *Keilis-Borok, Knopoff & Rotwain, 1980*

- **M8 algorithm**
  
  *Keilis-Borok & Kossobokov, 1990*
Similarity of starquakes and earthquakes

Qualitative so far
- Gutenberg-Richter relation
- Premonitory changes
- Decay of “aftershocks”
  - Omori power-law

Starquakes evidence drastic expansion of the Realm of Multiple Fracturing previously observed from the lithosphere of the Earth to laboratory samples

Kossobokov, Keilis-Borok & Cheng, 2000
How to explain such similarity?

The simplest answer is –

- Multiple fracturing reflects scenarios of critical transition, common for a broader class of non-linear systems


Cascading of earthquakes

Apparently more complicated than so far suggested power-laws...
It is still unclear if “the best fit” is random…?

Free parameters: dT, Mc, aftershocks
Does “the best fit” fit data points?
Does "the best fit" fit data points?

Romashkova & Kossobokov, 2001

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Cascading of earthquakes

... detectable by reproducible earthquake prediction methods

- Case histories of the recent earthquakes of magnitude 8 or above prove it and evidence consecutive stages of inverse cascading of seismic activity to the main shock.
Worldwide performance of earthquake prediction algorithms M8 and M8-MSc: Magnitude 8.0 or more.

<table>
<thead>
<tr>
<th>Test period</th>
<th>Large earthquakes Total</th>
<th>Percentage of alarms</th>
<th>Significance, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted by M8</td>
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<tr>
<td></td>
<td>Predicted by M8-MSc</td>
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</tr>
<tr>
<td>1985-2001</td>
<td>9</td>
<td>34.9</td>
<td>99.86</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>18.0</td>
<td>99.98</td>
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<tr>
<td>1992-2001</td>
<td>7</td>
<td>30.2</td>
<td>99.61</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>15.3</td>
<td>99.87</td>
</tr>
</tbody>
</table>

The significance level estimates use the most conservative measure of the alarm volume accounting for empirical distribution of epicenters.
“Predicting earthquakes is as easy as one-two-three.

Step 1: Deploy your precursor detection instruments at the site of the coming earthquake.

Step 2: Detect and recognize the precursors.

Step 3: Get all your colleagues to agree and then publicly predict the earthquake through approved channels.”

What stands behind?

... Of course, the correct answer *is very uncertain*

- Geophysics is lacking continuous data over extended areas and times.

Hopefully, their collection has started.
One example from ENE off Tibet

- An ULF electromagnetic signal around 21 July 1995, M5.7, Yong Deng (China) earthquake
Two independent, 110 and 250 m long, lines
Frequency-Time diagrams for the NS 250 m line
Signal evolution

Both

- Intensity and
- Period

GROW
The signal start and collapse

The Yong Deng earthquake has occurred in a near vicinity of electromagnetic observations at the time when the characteristic ULF and/or its exponential show decrease, on the component pointing at epicenter.

The start of the ULF decrease was accompanied with a seismic activation of associate segment of Haiyuan fault system.

The collapse of the characteristic ULF happened before the Yong Deng aftershocks vanished exponentially.
... an obvious one -

- More seismological and other data should be analyzed systematically to establish reliable correlations between the occurrence of extreme earthquakes and observable geophysical phenomena.
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