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From stars' magnitude trough Richter's earthquake magnitude back to the stellarquakes' magnitude

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Summary
The incredible development of the magnitude scale invented by Ch. Richter to calculate seismic energy release by measurement of an earthquake seismogram was inspired by the stars' magnitude scale (widely performed by his colleagues in Caltech), just transformed for seismic events application. During the last years the space remote sensing of measurements permitted the sunquakes registration and the transformation of the energy of such phenomena to the equivalent of the earthquake magnitude. Using this transformation formula, the assessment of the possible stellarquakes magnitude is done. For now this assessment might look like a fantastic approach, but the increased resolution of the recent telescopes (like Webb, Hubble, etc.) put the remote sensing methods close to the possibility to register stellaruakes, especially on the fluid stars similar to the Sun. So, an amazing cycle was recognized – from stars' magnitude going through the earthquake magnitude and back to the stellaquakes magnitude, the full cycle was fulfilled giving the science almost universal method of energy calculation and classification.

Introduction

The problem of earthquake unified scale for energy release assessment was solved by Richter in 1935 when proposed definition of magnitude scale was published for the first time. Using the recorded seismogram of a standard calibrated seismograph, Richter propose a magnitude 1 to be considered as an amplitude of 1 mm on a seismogram of registered earthquake at a distance of 100 km. The development of the scale was improved, by introduction of logarithm amplitude over pulse and correction coefficients for distance correction and equipment constant. Thus, the classical formula has a simple expression:

$$M = \log (A/T) - f(\Delta,h) + k\,, \tag{1}$$

where A is maximum amplitude, T – respective period of the wave, $f(\Delta,h)$ – function depending on distance and depth of the earthquake source, k – empirical calibration constant (Gutenberg and Richter 1936).
The important development of the magnitude scale was the introduction of the relationship magnitude – energy. The relationship of kinetic energy ($E \sim A^2$) is proportional to the amplitude (A^2), then the transformation formulas are:

$$\log E_S = 4.4 + 1.5\, Me \tag{2}$$

or

$$Me = (\log E_S - 4.4)/1.5. \tag{3}$$

where E_S is the earthquake energy in Joules, Me – is called energy magnitude. This means that this magnitude is calculated using empirical relationship E_S between Me – (2) and (3), (Gutenberg and Richter 1956).

Stars' magnitude

The idea for earthquake magnitude scale of Richter was inspired by the stars' magnitude, where the values of the magnitude expressed "lower to larger". This means that the brighter star has lower magnitude than the weaker one (Fig. 1). On this scale the Sun has a magnitude of -26, full moon -12, unarmed eye can see the sky object of magnitude 6 and Hubble telescope has resolution of magnitude 28 (Fig. 2) (http://What is stellar magnitude 2025).

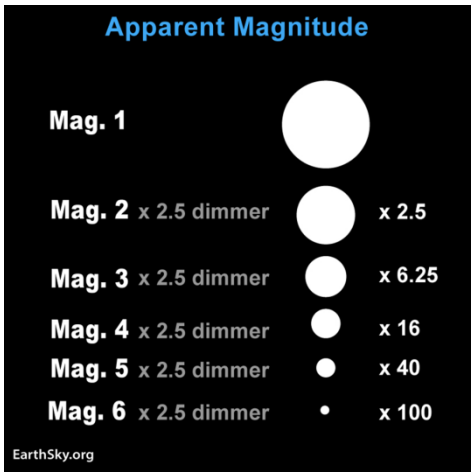


Figure 1. The stars' magnitude versus the brightness of stars (note: larger magnitude means less bright star)

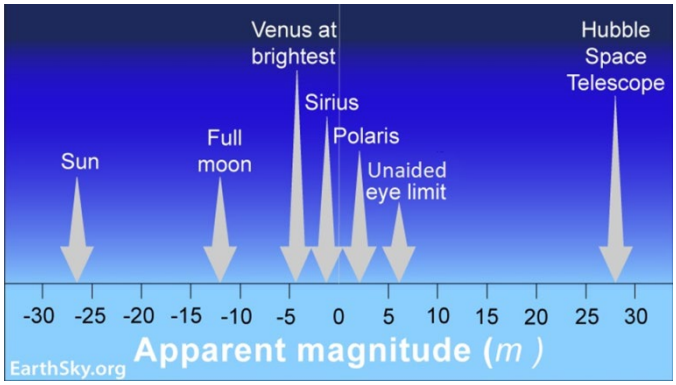


Figure 2. Illustration of the brightness versus star magnitude for some night sky objects

The earthquake magnitude

The importance of these ideas is that the dynamic range of magnitude can be expressed by a logarithmic scale. The graphical calculation of earthquake magnitude using the seismogram is easy to perform following the graphical algorithm (Fig. 3) (Gutenberg and Richter 1936).

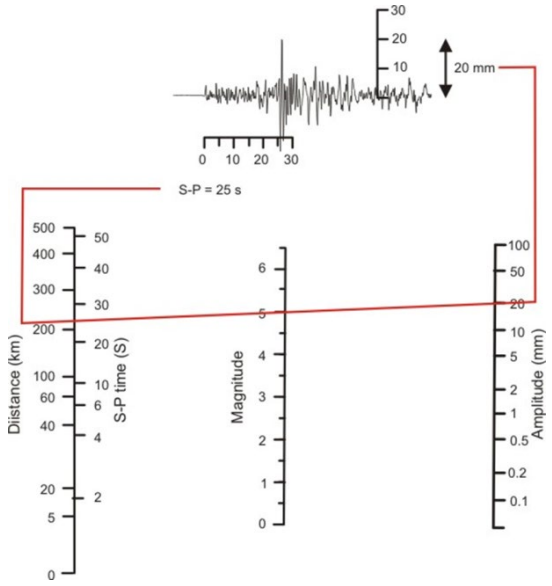


Figure 3. Graphical algorithm for Richter's earthquake magnitude determination from a seismogram

First Sunquake

One of the best examples of Sunquake was registered on July 9th 1996 by SOHO mission (Fig. 4). The sunquake magnitude based on the observed surface waves was calculated as 11.4 and the seismic energy released as $6x10^{20}$ Joules. Then the numerous calculations show the energy diapason of observed sunquakes between $0.5x10^{19}$ to $60x10^{19}$ Joules. These numbers give the possibility to use the sunquakes as calibration function for stellarquakes assessment.

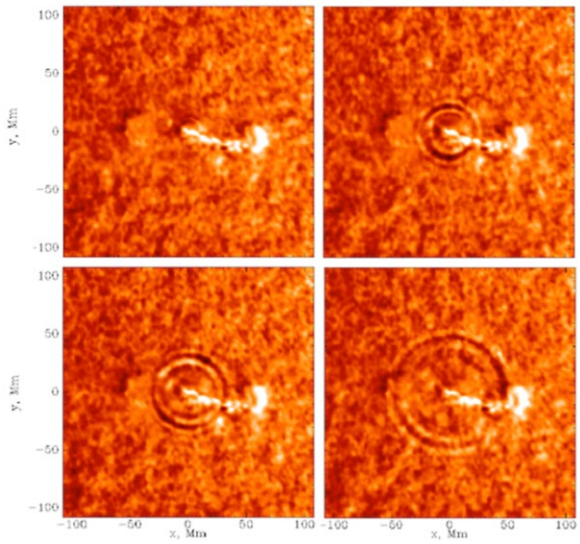


Figure 4. Surface waves on the sun surface generated by the protuberance of July 9th 1996 (Kosovichev 2014)

Stellarquakes magnitude assessment

Using the obtained energy of sunquakes as calibration function, the attempt to assess the dispassion of the possible stellarquakes magnitude, the so-called H-R (Hertzsprung-Russell 2019) diagram was used (Fig. 5).

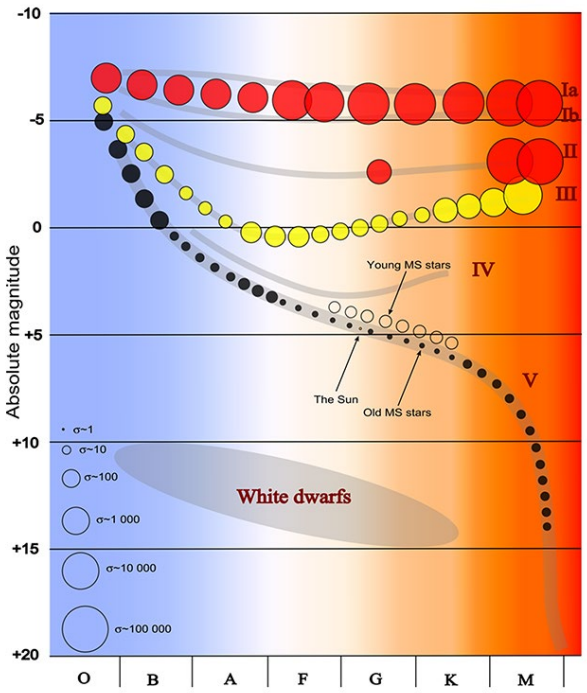


Figure 5. A typical example of the H-R diagram used in astronomy showing the dependence of absolute stars' magnitude and the brightness classes (O-M)

The created magnitude assessment scale for stellarquakes on fluid like stars is presented on Figure 6 (Ranguelov 2025).

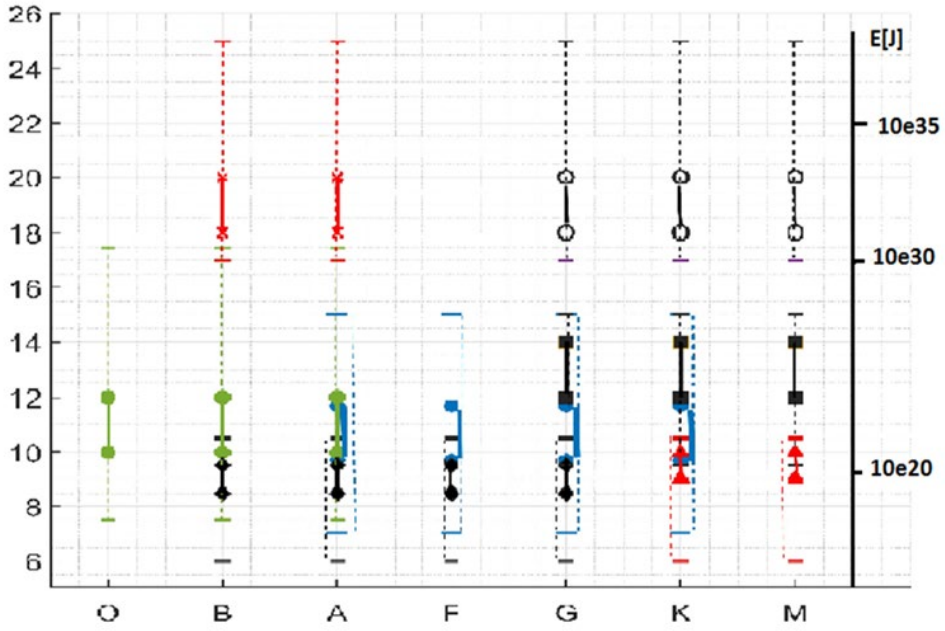


Figure 6. The graphic for magnitude assessment of stellarquakes. Seismic energy, magnitude diapason (solid lines) and uncertainties (dashed lines and horizontal bars) are presented vs spectral classes (O-M) for: Main sequence – green and blue dots and red triangles. White dwarfs – black diamonds. Giants – black quadrats. Blue super giants – red crosses. Red super giants – black circles.

Conclusion

A short description of magnitude assessment of stars, earthquakes (Richter scale) and stellarquakes on fluid stars (like Sun) is presented showing the universality of the magnitude scales for energy classifications using logarithmic dependences. This gives possibilities to use these scales for the large dynamic range of energy release.

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