Flare Energy Release and Helioseismic Response

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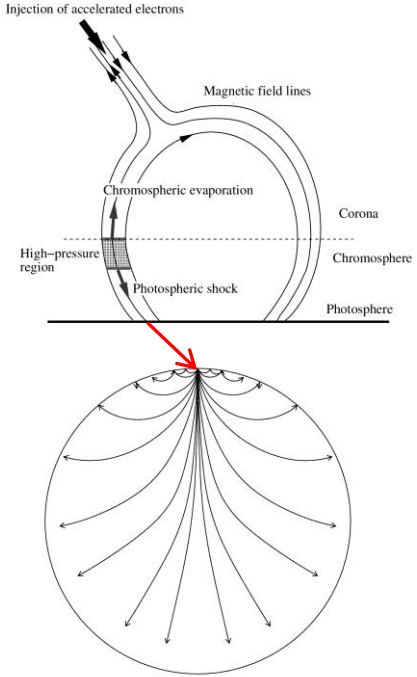
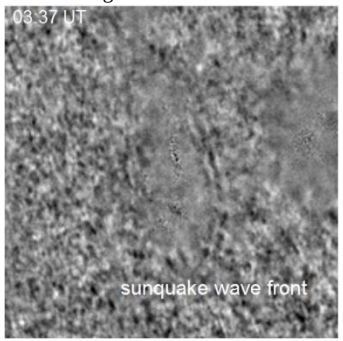
Helioseismic response to solar flares ("sunquakes") occurs due to localized force or/and momentum impacts observed during the flare impulsive phase in the lower atmosphere.
Such impacts may be caused by precipitation of high-energy particles, downward shocks, or magnetic Lorentz force.
Understanding the mechanism of sunquakes is a key problem of the flare energy release and transport.

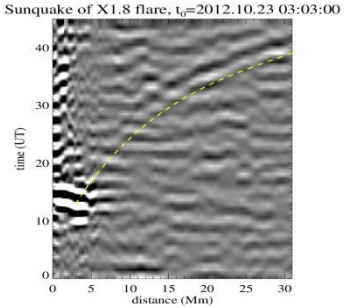


Sunquake are observed in Dopplergrams as ripples travelling on the solar surface

Most powerful sunquake of Cycle 24 was observed during X1.8 flare on 23 October 2012



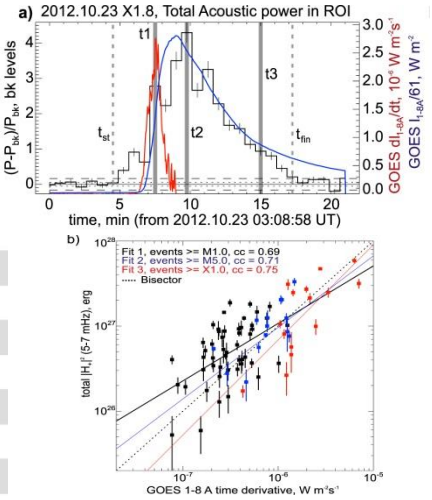
Sunquakes are detected as characteristic ridges on time-distance diagrams.
The sunquake energy is determined by the acoustic holography technique.



Catalog of Sunquakes of Solar Cycle 24 is obtained from analysis of all flares of the X-ray class greater than M1.0
The catalog is available at **http://sun.njit.edu**

Start time (UT)	GOES class	AR NOAA	Location (arcsec)	Movie method	Holography method	TD method	$\|H_1\|^2$, 10^{26} ergs	S_{max}, 10^{17} cm^2	df/dt(1-8A 10^{-7} Watt m^{-2} s^{-1}
13.02.2011 17:28	M6.6	11158	211	-	?	-	3.0	4.4	5.8
14.02.2011 17:20	M2.2	11158	278	-	?	-	3.4	2.9	3.8
15.02.2011 01:44	X2.2	11158	319	+	+	+	10.6	9.6	10.5
18.02.2011 09:55	M6.6	11158	809	+	+	+	12.4	9.0	12.2
18.02.2011 12:59	M1.4	11158	808	-	+	+	4.2	3.7	2.1
14.03.2011 19:30	M4.2	11169	733	-	+	-	12.4	11.1	7.6
15.03.2011 00:18	M1.0	11169	761	-	?	-	6.3	4.9	3.0
30.07.2011 02:04	M9.3	11261	493	+	+	+	33.2	15.0	14.8

Statistical analysis showed that the sunquake power correlates with the maximum value of the soft X-ray flux time derivative better than with the X-ray class, indicating that the sunquake mechanism is associated with high-energy particles.



Conclusions

1. We have found that 94 flares among 507 flares of the X-ray class greater than M1.0 were seismically active. Our analysis has shown that there are many solar flares of moderate class with strong sunquakes, while in some powerful X-class flares, helioseismic waves were not observed or were weak.
2. During Solar Cycle 24, there were several active regions characterized by the most efficient generation of sunquakes.
3. The sunquake total energy correlates with the maximum value of the soft X-ray time derivative better than with the X-ray class (contrary to what one could expect from the "big-flare syndrome" idea). The impulsiveness of the energy release plays an important role.
4. The flares producing sunquakes are more impulsive (shorter flare times and higher heating rate) compared to the flares without sunquakes. The most evident difference between distributions of the seismic and nonseismic flares appears in terms of the maximum values of the flare-energy release rate.

Reference: Sharykin I.N. and Kosovichev A.G., 2020, Astrophysical J., 895, 76