Flare Accelerated Particles and It Photospheric Response

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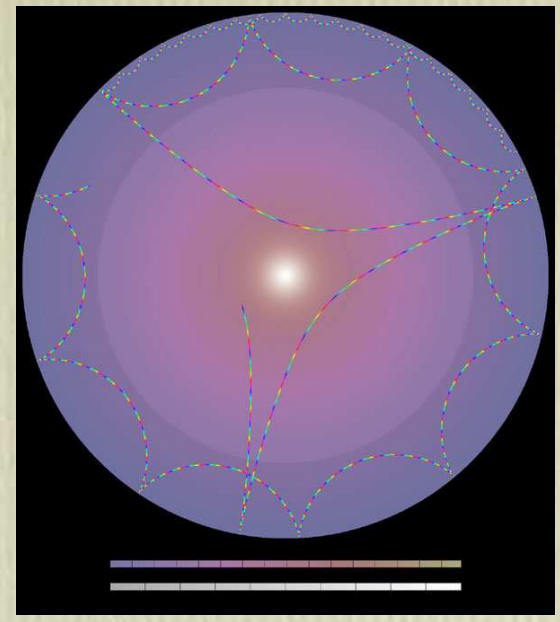
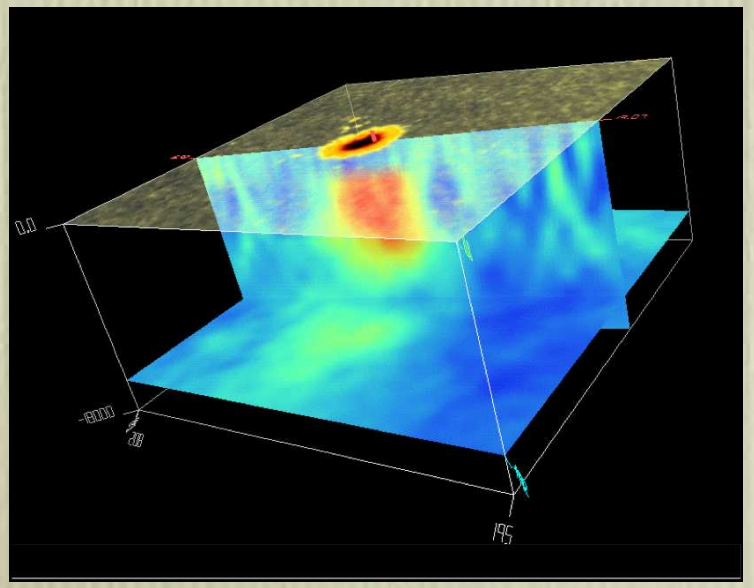
Helioseismology

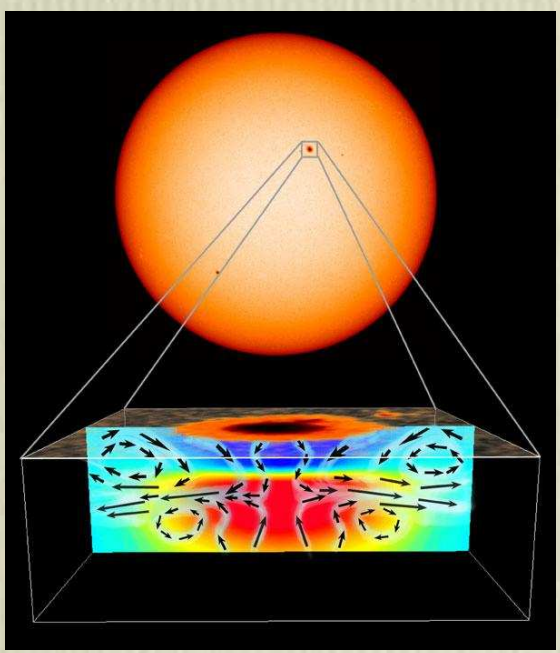
Helioseismology is the study of the interior of the Sun from observations of the vibrations of its surface.

Some applications:

- The internal structure of the Sun.
- Magnetic fields structures
- Internal flows
- Predictions





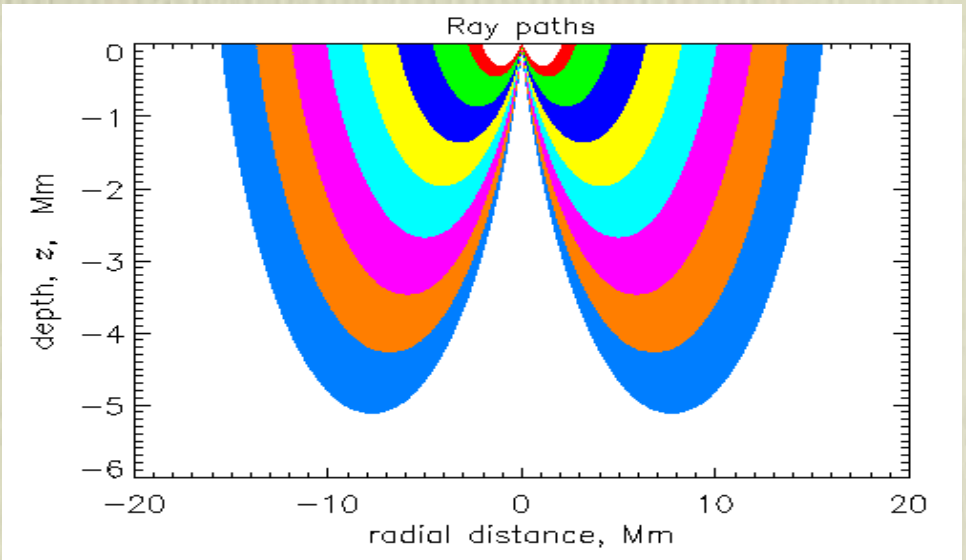


figures by A. Kosovichev, Stanford U. (SOI-MDI)

Local helioseismology is based on the measurement of local wave propagation properties.

One of the methods used in local helioseismology is the computational helioseismic holography.

QuickTime™ and a
BMP decompressor
are needed to see this picture.



movie courtesy A.-C. Donea

figure by A. Kosovichev, Stanford U. (SOI-MDI)

So, what all these has to do with flares?

It is believed that flares are one source of solar seismicity, leading to the generation of Sunquakes.

Mechanisms of generation:

- Shock waves
- Direct proton collisions
- Back-warming by electron bombardment.
- Magnetic field variations.

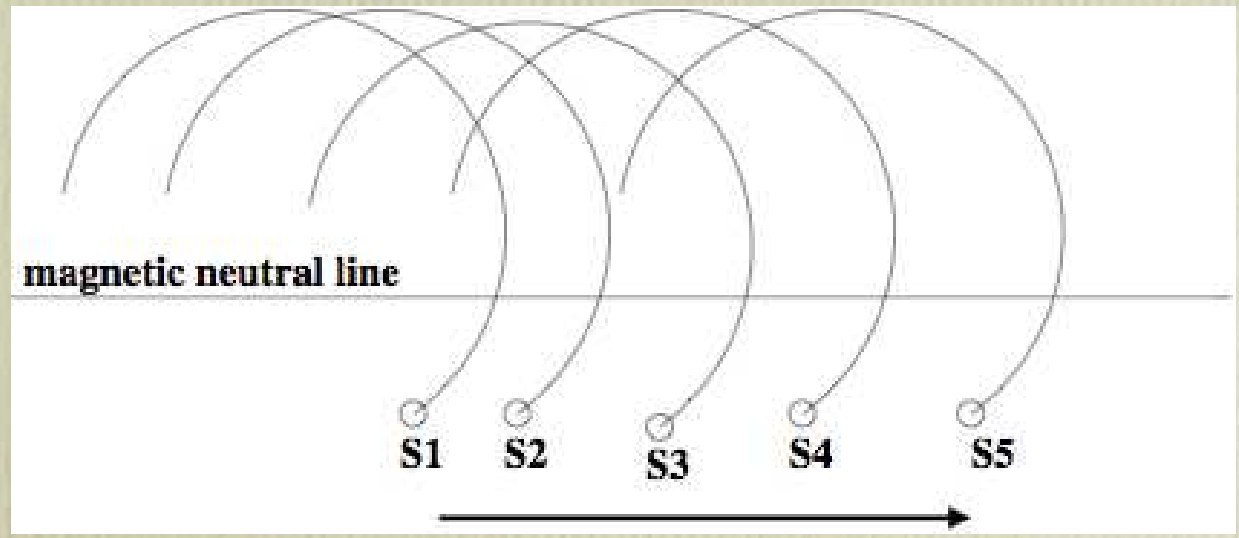
QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Movie by A. Kosovichev, Stanford U. (SOI-MDI)

Shapes and Structures

Using helioseismic holography seismic sources are reconstructed, revealing a variety of shapes.

Simulations show that may exist a relation between the motion of the initial perturbation and the structure of the seismic signatures.

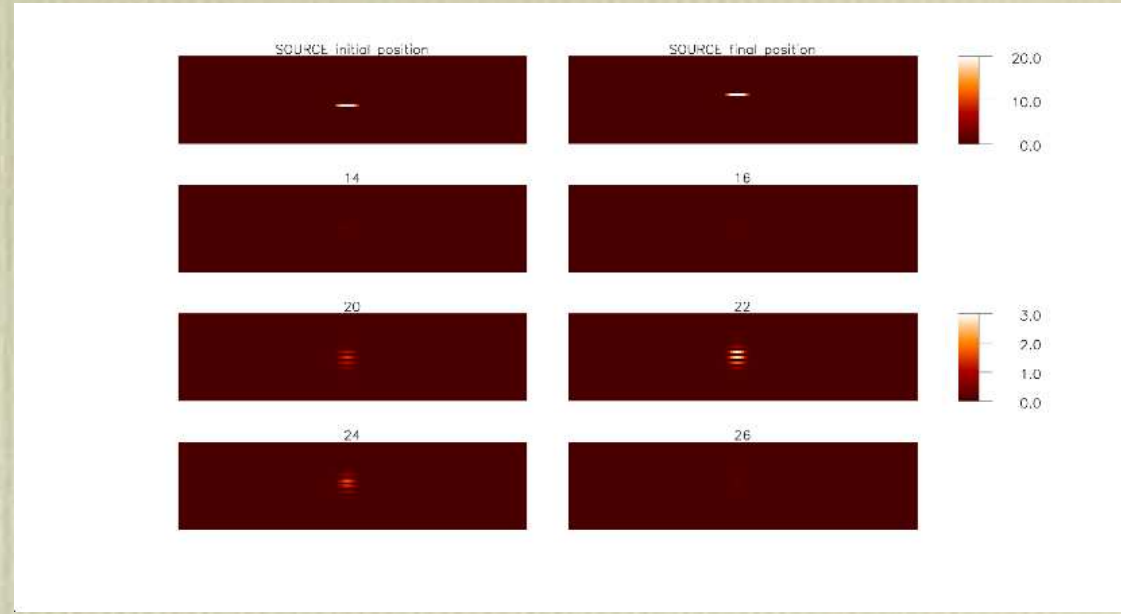


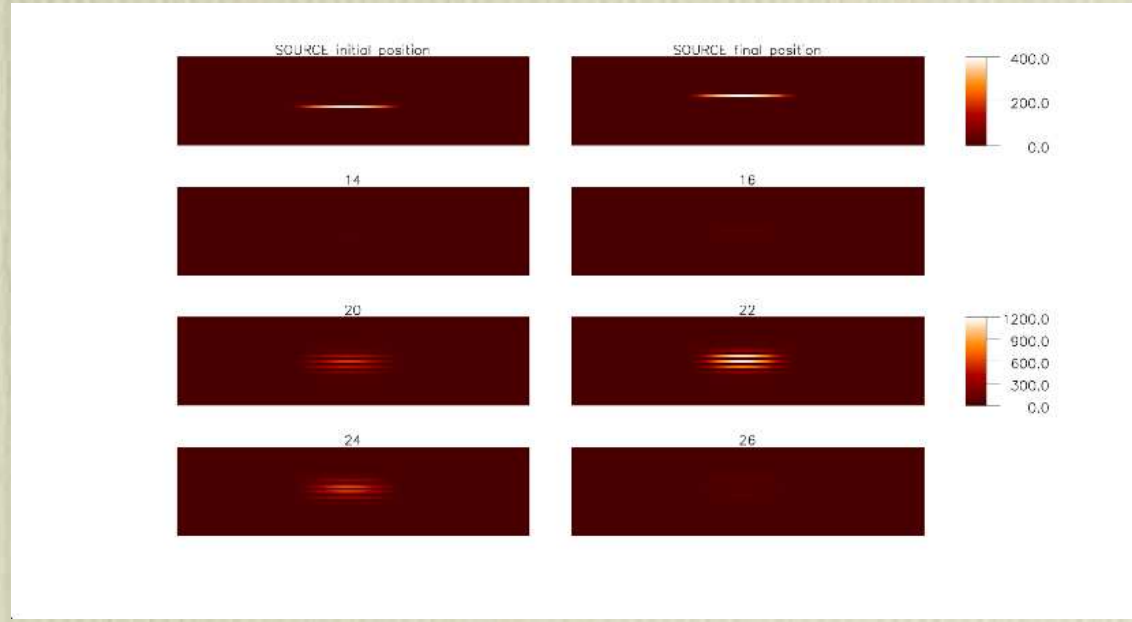
Martinez-Oliveros & A.-C. Donea, 2009 in preparation

We apply helioseismic holography to simulations of acoustic disturbances from dipole sources.

We solve the wave equation in the standard solar model of Christensen-Dalsgaard et al. (1993) for the acoustic field emanating from a single dipole emitter.

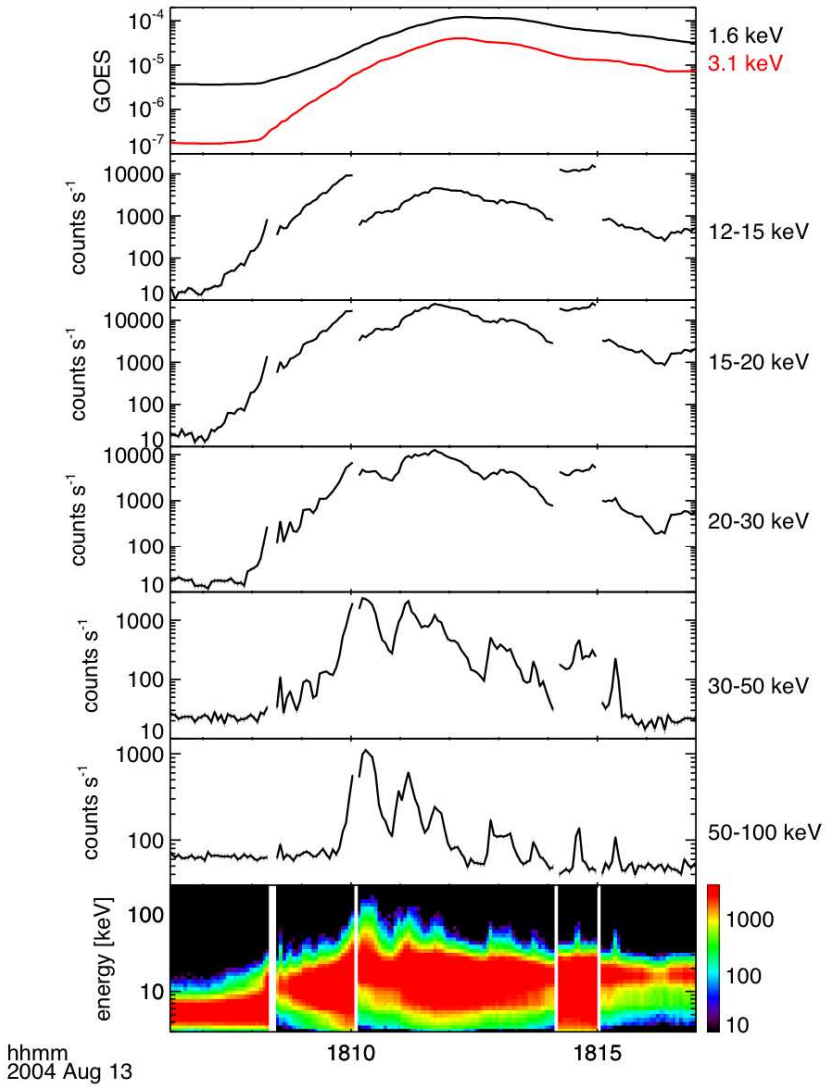
In these studies the focal plane is at the surface, and the pupil is an annulus of radial range 15 – 60 Mm centred on the focus.





Martinez-Oliveros & A.-C. Donea, 2009 in preparation

On 13 August 2004 at 18:10 UT GOES reported a X1.0 solar flare produced in AR10656. The flare started at 18:07 UT, reached maximum at 18:12 UT and finally ended at 18:15 UT. We synthesized the RHESSI raw data using the CLEAN algorithm to obtain images of the 28-100 keV X-ray footpoints at the time of each peak in the light-curve.



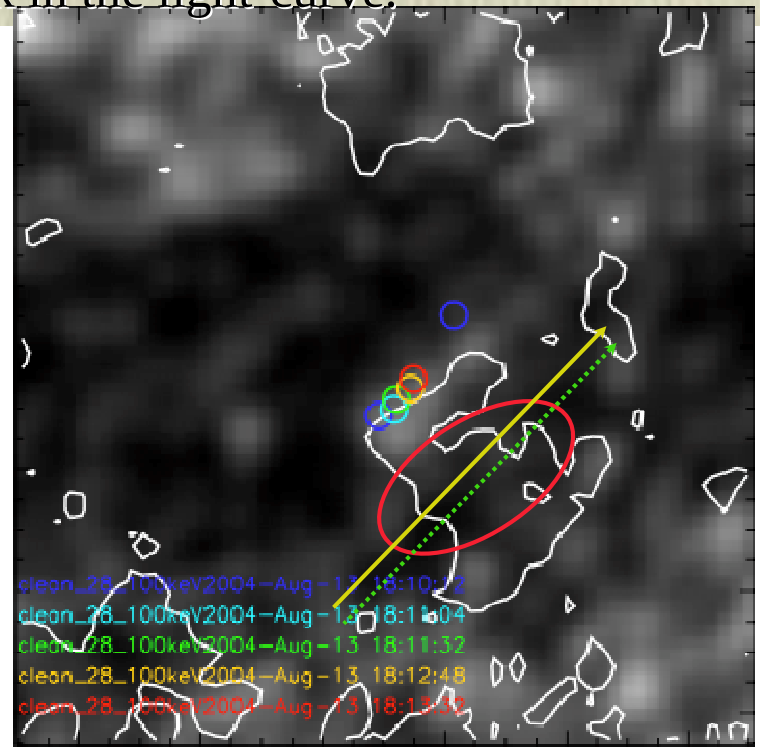
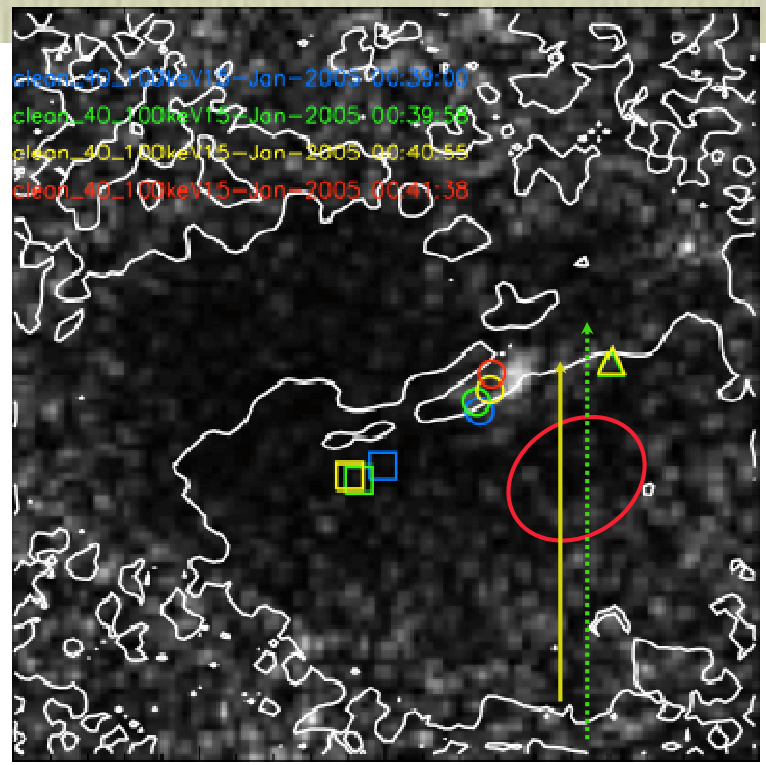


Figure by A.-C. Donea

The seismically active flare of 15 January 2005 hosted by the AR 10720, started at 00:22 UT, reaching maximum at 00:43 UT and finally ending at 01:02 UT. This flare produced the most conspicuous and powerful sunquake detected so far.



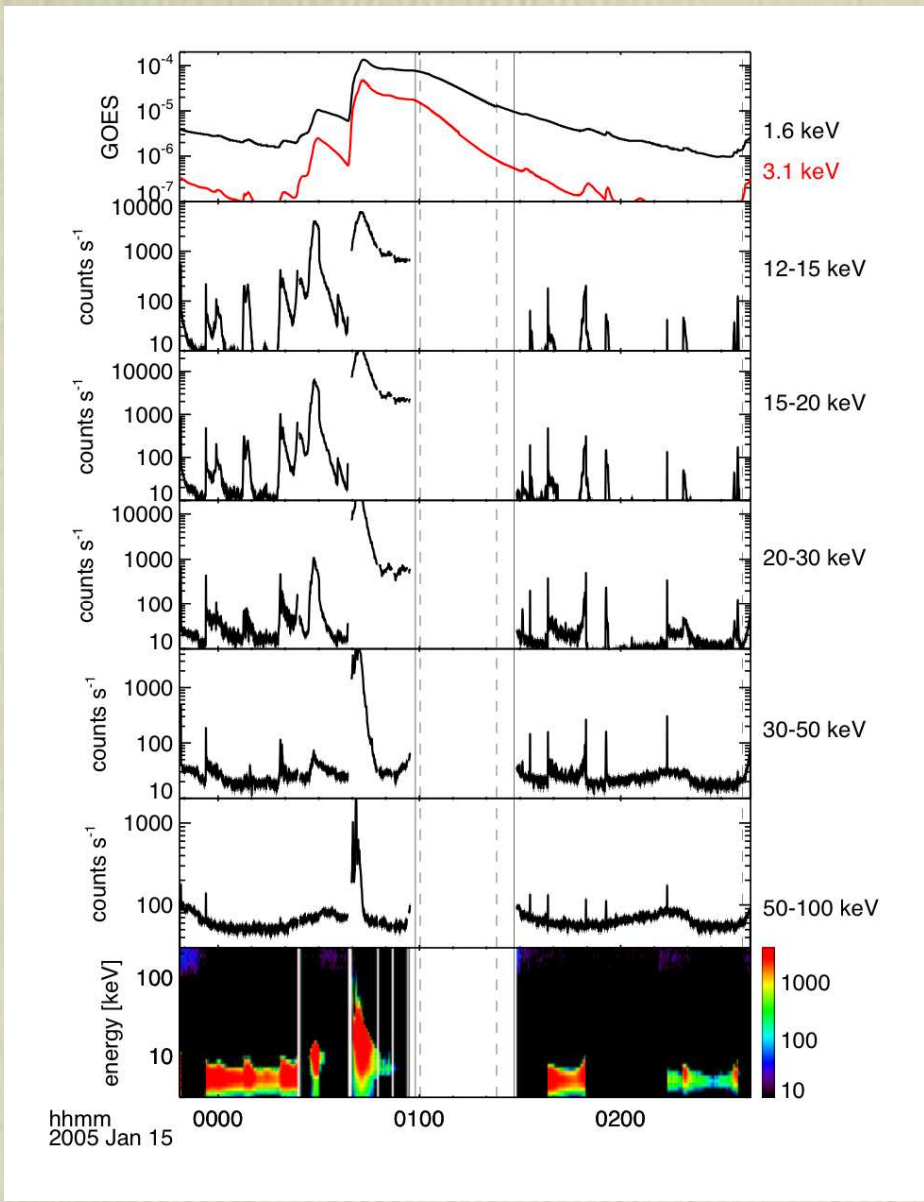
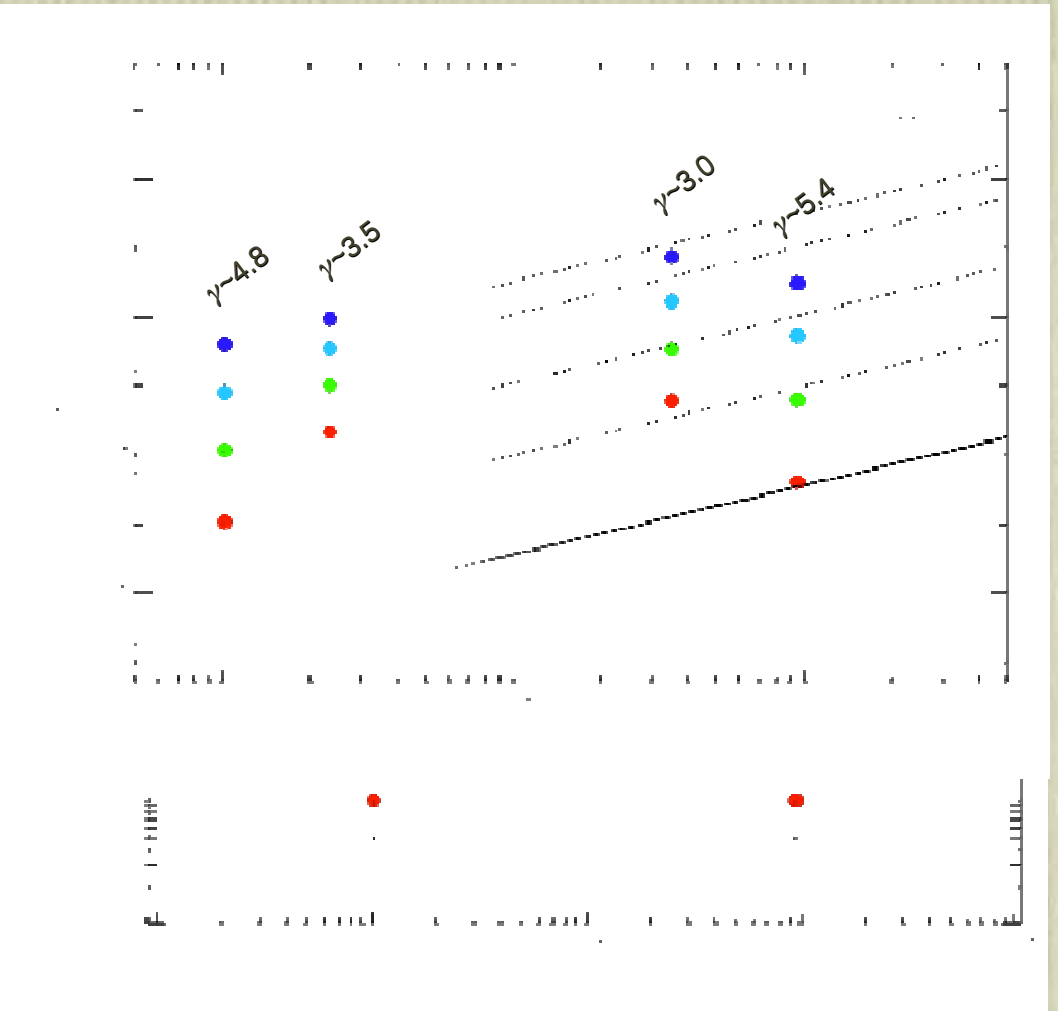


Figure by H. Moradi

Protons and Electrons?



- We studied the spectral behavior of four seismically active solar flares.
- We compute the electron energy deposit and compared with the seismic energy of each sunquake.
- A rough correlation between the seismic energy and the energy deposit by electron was found at low energies.
- For γ-rays the situation is similar to the high energy electrons. No clear correlation was found.

Summary

It appears to be a relation between the direction of motion of the HXR footpoints and the spatial alignment and structure of the seismic sources.

Simulations show that the observed egression power kernels of acoustic source, can be the result of consecutive energy deposition by the flare, seen as HXR footpoint motions.

Open questions

- What is the most dominant mechanism of generation?
- How is the energy and momentum transported to the photosphere?
- Why is not a correlation at high energies, if exist a correlation with white light emission?
- Why not all strong flares generate sunquakes? Is the magnetic field geometry, the acceleration process or transport in the chromosphere responsible?

Thank you