Determining the q-index of heliospheric particle populations during three Solar cycles, and their periodicities

'Pythagoras doctrine is that numbers have maximal power to describe and understand nature and he is always referred to numbers, as for example the periods of celestial bodies, Plutarch'

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The Sun is the only star that affects our lives not only with the light and heat it provides to our planet, the electromagnetic radiation, but also with the flows of particles that are generated from our nearest star, in the form of a continuous supersonic plasma flow that is called solar wind and more energetic particles of much higher energy, from a few MeV/p up to relativistic energies, that are a form of cosmic rays mainly produced from the Sun, especially during energetic events like flares and the coronal mass ejections (CMEs), or produced locally in the interplanetary medium where they are accelerated in shock waves travelling from the Sun outwards inside the solar wind, in which these shock are generated.

Energetic particles are mainly protons with a small percentage of alphas and energetic electrons too. Heliospheric energetic particle populations of energies measured at 1 AU with various spacecraft that monitor the solar wind. These experiments measure energetic particles with kinetic energies higher than 1 MeV. A time period that covers a substantial time span of three solar cycles that average 11 years, i.e. a 33 year long data record that come from the OMNI dataset compiled and kept by the NASA Goddard Space Flight Center.

The periodicities of energetic particles have been studied, shown to agree with the sunspot number periodicities, as expected for this energetic particle population that have the Sun as their main source and expected to vary with solar activity. This solar cycle dependence is expected not only for the particles that originate from the Sun, but also the energetic particles that are generated in the interplanetary medium shock waves that too depend on solar activity and even of some galactic cosmic rays of low energy which are modulated by the extend and structure of the heliosphere, a huge variable bubble around the sun created as the solar wind interacts with the interstellar medium of the Galaxy. The distributions of energetic particles in energy have been studied also during the same 33 year period. The q-index analogue to the kappa-index is computed for every hour in the 33 year data set and used to investigate deviations of the gas is from the classical thermal equilibrium, characterized by $q = 1$.

As derived from the analyses of suprathermal tails of the probability distribution, we assume that the gas kinetics is described by kappa distributions. It is concluded that the gas is in continuously variable states away from thermal equilibrium with q¿1. During the first 15 years period the q-indices follow a pattern which can be considered homogeneous. However, just before 1990, q-indices begin to fluctuate more violently, as they continuously increase, to pick during the solar minimum 19961997. After 1998, the q-indices return to similar pattern as before the solar minimum. We can explain this behavior either as a change the Sun's behavior or perhaps related to the recording system of spacecraft.

A higher number of even small solar bursts could easily affect the gas but further research of solar flare and CME time series from the same period is required to draw a more robust conclusion of what may have caused the observed anomaly.

Why did the q-index peak in 1996-1997 occur? Possible answers: 1) Weird behavior of the sun, such as an unusually high number of solar flares? But we have no indication that this should have been the case. 2) Instrumental OMNI data is based on measurements from many different spacecraft. Perhaps the fleet was renewed around 1990? It doesnt explain the return to normal after 1997 though. 3) The proton flux was so low during the 1996-1997 minimum that the detectors were basically measuring noise (similar amounts of counts in each energy channel)? But why didnt that happen during the previous minima? What happened during the next deep minimum 2008 and during the current one?