

Objective 3: How do solar eruptions produce energetic particle radiation that fills the heliosphere?

Introductory remarks

Astrophysical sites throughout the solar system and galaxy have the universal ability to accelerate ions and electrons to high speeds, forming energetic particle radiation. Detected remotely from radio and light emission around supernovae remnants, the Sun, and planets, or directly from particles that reach our detectors, this radiation arises from the explosive release of stored energy that can cause magnetic fields to rearrange, or can launch shock waves which accelerate particles by repeatedly imparting many small boosts to their speed. The nearly universal occurrence of energetic particle radiation, along with the effects it can have on planetary environments, evolution of life forms, and space systems has fostered a broad interest in this phenomenon that has long made it a high priority area of investigation in space science. Since remote sites in the galaxy cannot be studied directly, solar system sources of energetic particles give the best opportunity for studying all aspects of this complex problem.

The Sun is the most powerful particle accelerator in the solar system, routinely producing energetic particle radiation at speeds close to the speed of light, sufficiently energetic to be detected at ground level on Earth even under the protection of our magnetic field and atmosphere. SEP events can severely affect space hardware, disrupt radio communications, and cause re-routing of commercial air traffic away from polar regions. In addition to large events, which occur roughly monthly during periods of high sunspot count, more numerous, smaller solar events can occur by thousands each year, providing multiple opportunities to understand the physical processes involved. In the following sections, we have divided in more detail three interrelated questions that flow down from this top-level question: How and where are energetic particles accelerated at the Sun? How are energetic particles released from their sources and distributed in space and time? What are the seed populations for energetic particles?

- 3.1 How and where are energetic particles accelerated at the Sun?
 - 3.1.0 Explore in depth the SEP properties
 - 3.1.1 CME and shock associated SEP sources
 - 3.1.1.1 Where and when are shocks most efficient in accelerating particles?
 - 3.1.1.2 Why are gradual SEP events so variable?
 - 3.1.1.2.1 Intensity variability
 - 3.1.1.2.2 Composition variations
 - 3.1.1.2.3 Warped shock fronts
 - 3.1.1.2.4 Turbulence and inhomogeneities
 - 3.1.1.3 How are superhalo particles accelerated continuously in the corona and solar wind?
 - 3.1.1.4 How can SEPs be accelerated to high energies so rapidly?
 - 3.1.1.5 Do proton-amplified Alfvén waves play a role in accelerating particles at shocks?
 - 3.1.1.6 What causes SEPs' spectral breaks?
 - 3.1.1.7 Are there favourable environments for particle acceleration?
 - 3.1.2 SEPs associated with flares, coronal loops and reconnection regions
 - 3.1.2.0 Impulsive SEP event sources
 - 3.1.2.0.1 Measure the enhancements of trans-iron elements in impulsive SEPs (to be deleted - trans-iron SEPs cannot be detected by EPD)
 - 3.1.2.1 Understand energy release and particle acceleration process
 - 3.1.2.2 Evaluate how significantly large flares contribute directly to gradual SEP events
 - 3.1.2.3 Flare seed particles
 - 3.1.2.4 Explore the fact that only some of the hard X-ray peaks are related to escaping electrons, while others are not
 - 3.1.2.5 X-ray prompt events
 - 3.1.2.6 Delayed events (between X-ray peak and electron release time)
 - 3.1.2.7 How are so many electrons accelerated on such short time scales to explain the observed hard X-ray fluxes?
 - 3.1.2.8 Explore the type III radio bursts delays
 - 3.1.3 Relativistic electron acceleration
 - 3.1.3.1 How shocks can accelerate electrons to relativistic energies (never observed for shocks near 1 AU)?
 - 3.1.3.2 Double-power law spectra
 - 3.1.4 Other high sensitivity X-ray studies
 - 3.1.4.1 Hard X-ray emission of escaping electron beams (thin-target emission)
 - 3.1.4.2 X-ray emission from electrons accelerated at CME shocks
- 3.2 How are energetic particles released from their sources and distribute in space and time?
 - 3.2.0 What controls the escape of the particles to the heliosphere?
 - 3.2.1 How do energetic particles scatter and move along the interplanetary magnetic field?
 - 3.2.1.1 Map the power spectrum of the turbulent magnetic field as a function of heliocentric distance in order to provide ground-truth for transport models
 - 3.2.1.2 Measurements of SEP events time profiles and anisotropy in order to probe solar wind turbulence
 - 3.2.1.3 Identify dropouts and measure scattering of SEPs by turbulence.
 - 3.2.2 Latitudinal and longitudinal transport of SEPs
 - 3.2.3 Properties and distribution of near-Sun shocks, their fluctuations and particle acceleration
 - 3.2.4 How do large and small-scale structures modulate particle fluxes?
 - 3.2.5 Shock-surfing acceleration mechanism
 - 3.2.6 Effects of energetic particles propagating downward in the chromosphere
- 3.3 What are the seed populations for energetic particles?
 - 3.3.1 What are the properties and distribution of suprathermal seed populations?
 - 3.3.1.1 Characterization of the suprathermal population
 - 3.3.1.2 Characterize the suprathermal elemental and charge-state composition as a function of energy, time and location.
 - 3.3.1.3 Role of shocks in generating SEPs

SAP meeting on Objective 3 (22 September 2016) presentations:

Àngels Aran: [SEP events characteristics and particle transport](#)

Angelos Vourlidas: [CME-associated SEP sources](#)

Sam Krucker: [Flare-associated SEP sources](#)

George Ho: [Suprathermal ions in the inner heliosphere](#)