Solar energetic electrons as predictors of geo-effective CME-driven shocks and solar energetic particle events

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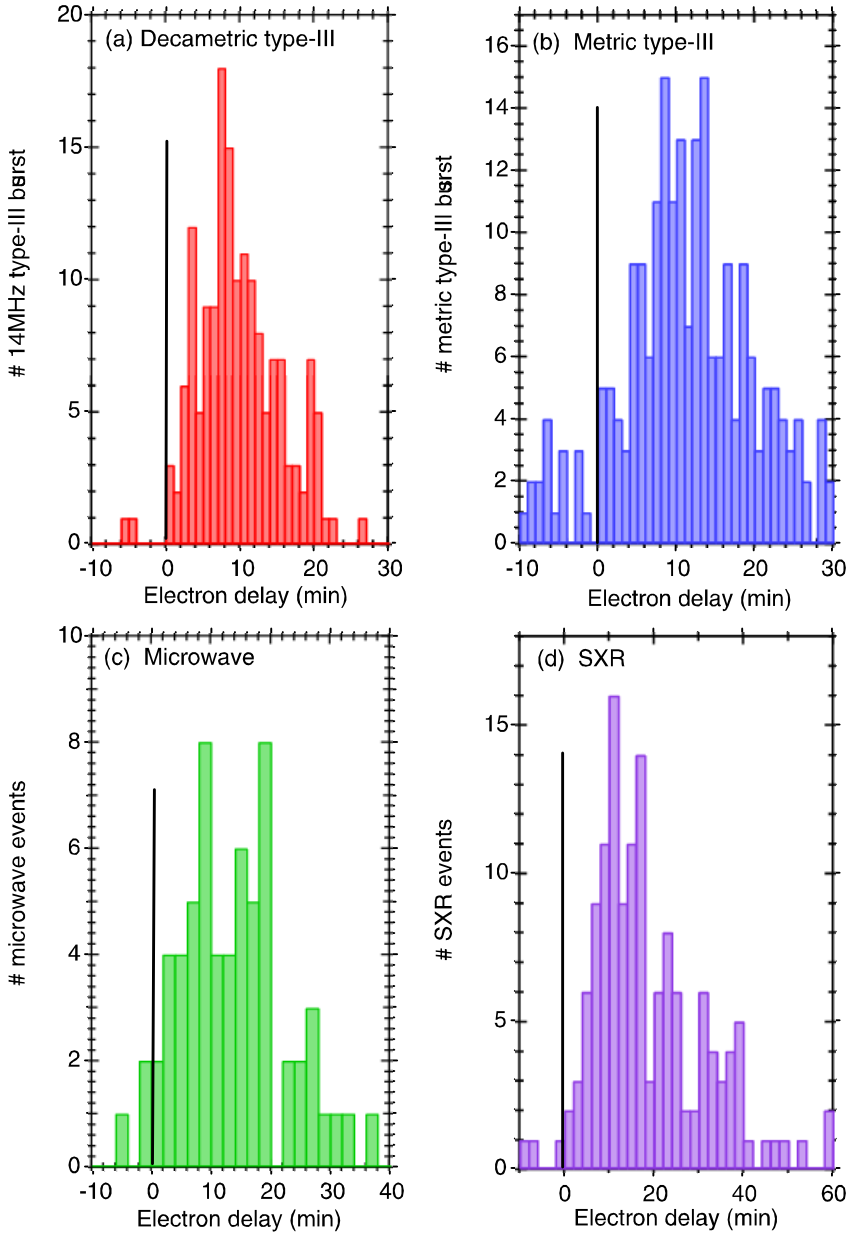
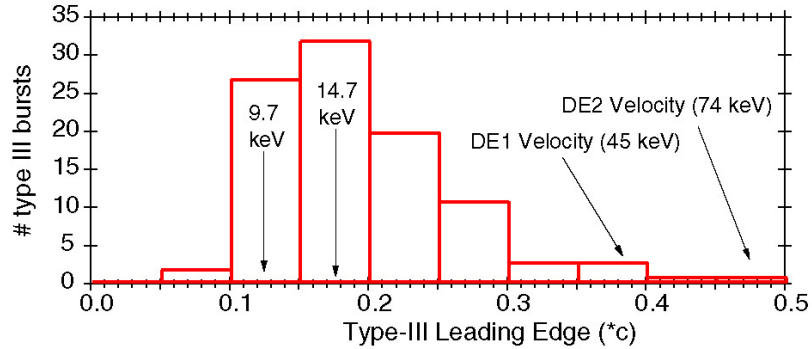
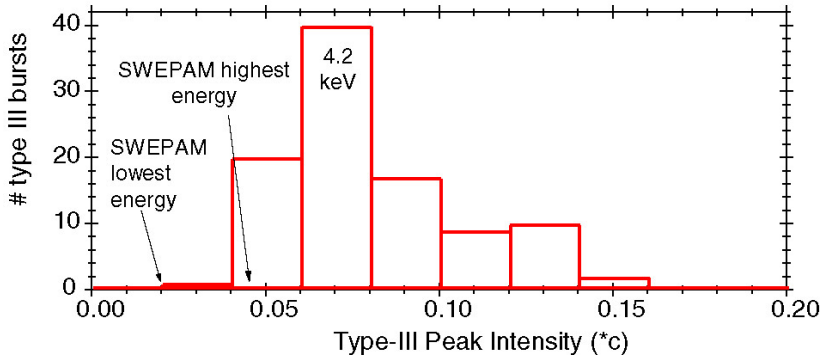
Under this grant we have made significant strides in understanding the acceleration of near-relativistic electrons and how they relate to electromagnetic emissions from the low solar corona, coronal mass ejections (CMEs), and the subsequent acceleration and injection of energetic ions that comprise solar energetic particle (SEP) events. An understanding of the temporal relationships between the acceleration and injection of these energetic electrons and the other associated observations is critical in using timing signatures of these electrons to predict the approach of a CME-driven shock. The first stage in this understanding has come from a thorough study of the well connected events where interplanetary influences such as transport through the heliosphere can be minimized. Toward that goal and as part of our proposed grant we have focused on the relationships between the electrons, CMEs, and SEPs.

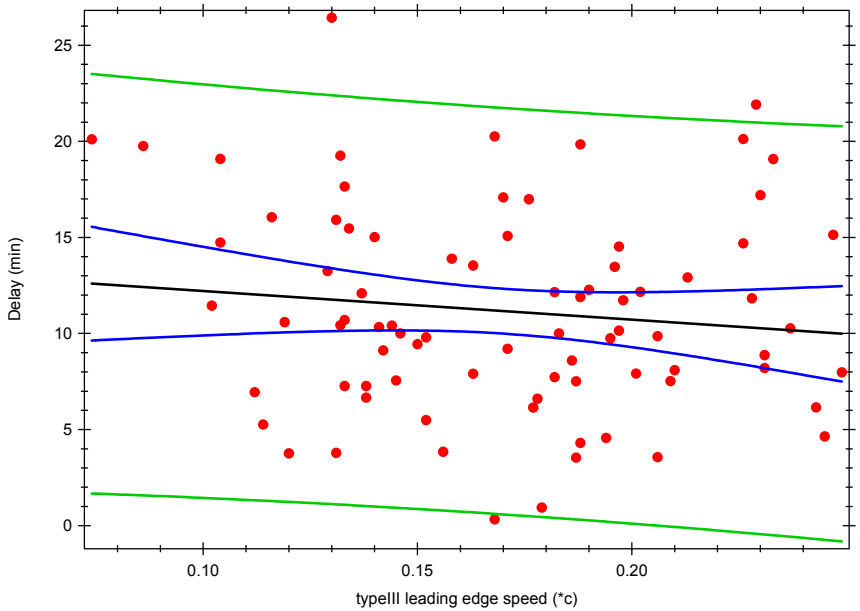
Since the launch of the Advanced Composition Explorer (ACE) spacecraft the energetic proton and alpha monitor (EPAM) instrument has observed over 560 near-relativistic electron events. By carefully selecting those events that are magnetically well connected to the solar active regions we have compiled a list of over 171 events where a good electron release time can be identified. We have published a number of papers on the methods used to select the electron events, the comparison between the events and solar electromagnetic emissions, and the comparison with CMEs.



We have shown that the near-relativistic electrons observed near 1 AU are released from the Sun some ~10 minutes after all of the following electromagnetic emissions: microwave burst, soft Xray event onset, optical flare, metric and decametric type-III bursts. This delay implies that there are three different populations of electrons typically associated with a major energy release at the Sun. First there are the prompt relativistic electrons that produce the hard Xray and microwave observations, second there is another prompt population of lower energy electrons that produce the type-III emissions, and finally, delayed by some 10 minutes, there is the near-relativistic population. This delayed population is well correlated with CMEs. Of 171 electron events through January 2004 for which there were concurrent SOHO/LASCO images, 89% have an associated CME.



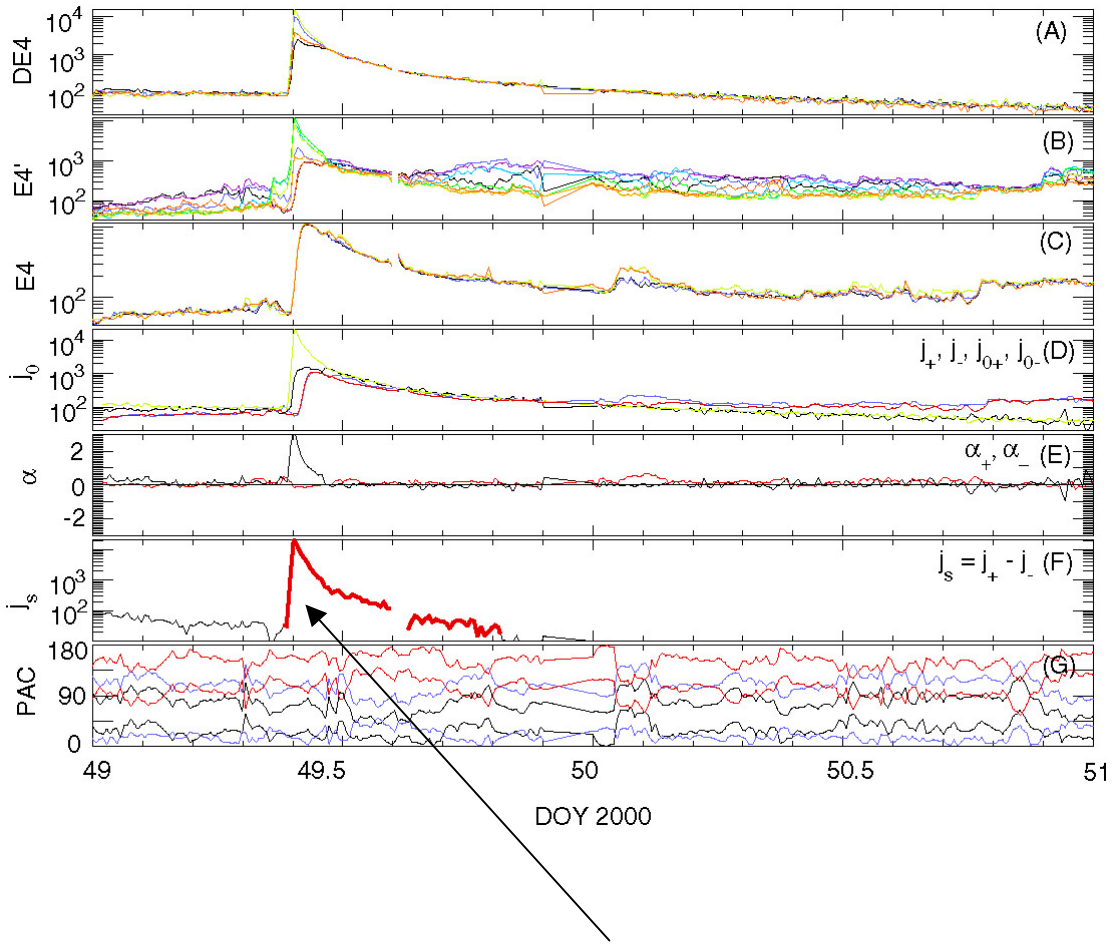




We have been actively working on the relationships between the near-relativistic electron events and those electrons responsible for the interplanetary type-III bursts. We have shown that the exciter front producing the type-III bursts travels at ~0.2c out to at least 0.5 AU and that this speed is unrelated to the delays observed between the type-III burst in the corona and the injection of the near-relativistic electrons. An improved understanding of the different populations of solar electrons is essential in any physics based prediction system

In the coming year we are prepared to make significant contributions to our scientific understanding of these important events and how they relate to other major events of consequence. Our first goal this next year is to continue the important work of cataloging observed events, obtaining the onset time at the Sun for the observed events, and sharing these electron lists with the community. Currently a listing of 171 events is publicly available through web sites at the ACE Science Center, and our web site at http://sd-www.jhuapl.edu/ACE/EPAM/. Sharing these lists with the community has proven to be a very effective method to generate interest in our work and to motivate other groups with relevant observations to contribute to this effort. Our second goal of this year is to continue to foster important collaborations that will produce strong scientific results on this topic: the ACE/SIS group who have observations and great experience in high energy ion acceleration and transport; the ACE/SWEPAM group who have extensive experience with lower energy electron observations; the SOHO/LASCO group that continues to be active in this effort; the WIND/3DP group that has similar electron observations and does key work on this topic; the WIND/WAVES group continues to make excellent observations of interplanetary type-III bursts that is essential to this effort; and the RHESSI group that can supply observations of the major energy release in the low corona.

Solar electron event on Feb 18, 2000



Injection history at the Sun

A third goal with great scientific possibilities is to produce an actual electron injection profile. To date the electron injection history has been produced only theoretically and through modeling efforts. Our advances in this area have given us confidence that we can extract directly from the observaitons the injection history ***at the Sun***. Very promising initial results continue to emerge and will be shared with the community at up-coming scientific conferences and workshops.

Publications and presentations partially funded through this grant to date:

Haggerty, D. K., E. C. Roelof, A Quantitative Measure of Strong Pitch-angle Anisotropies, COSPAR, Paris, E2.3-0088-04, July 19-23, 2004

Haggerty, D. K., E. C. Roelof, Effective drift velocity and initiation times of interplanetary type-III bursts, COSPAR, Paris, E2.3-0091-04, July 19-23, 2004

Haggerty, D.K., and E.C. Roelof, Effective Drift Velocity and Initiation Times of Interplanetary Type-III Radio Bursts, SHINE, Big Sky MT., June 28-July 2, 2004

Haggerty, D.K., E.C. Roelof, Effective drift velocity and initiation times of interplanetary type-III radio bursts, Spring AGU, Montreal, May 17-21, 2004

Haggerty, D.K., E.C.Roelof, and G.M.Simnett, Escaping Near-relativistic Electron Beams from the Solar Corona, Adv. Space Res., Vol. 32, No. 12, 2673-2678, 2003

Haggerty, D.K., E.C.Roelof, Electron Monte Carlo Simulations in Solid State Detectors: GEANT4 simulation, Adv. Space Res., Vol. 32, No. 3, 423-428, 2003

Haggerty, D.K., Three Distinct Populations of Solar Energetic Electrons: Flare, Beam, and Type-III, SHINE, Maui, HI, July 6-13, 2003

Haggerty, D.K., Near-relativistic Beam-like Electron Events, Space and Cosmic Ray Physics Seminar, University of Maryland, March 10, 2003

Haggerty, D.K., Associations between Near-relativistic electron events and coronal mass ejections, SHINE 2003, Maui, July 6-13 2003.

Haggerty, D. K., EPAM-SIS SEP event onset comparison, SHINE 2002, Banff, Canada, Aug 18-22, 2002