LWS TR&T SEP Team Meeting, January 10 and 11, 2008, Pasadena

Present: Hilary, Igor, Dick, Christina, Ian, Marty, Ilia, Gang, and Kobus

General Comments:

Thanks to everyone for an enjoyable productive meeting. Special thanks go to Christina and Dick for local organization. In this communication I shall try to capture some of our discussion at the meeting, in part by extending the descriptions of the previous 8 collaborative projects and adding the two new ones suggested at the meeting. I shall also list the events for the remainder of this year that relate to our Team. I think our emphasis on general issues in SEP transport and acceleration, including both theoretical and observational studies, and focusing primarily on statistical studies of many events, complements the work of the other group and is appropriate for this team. Of course, members of our team are involved in the work of the Desai Team and that connection is valuable for both teams.

Events in 2008:

- IGPP Conference on Particle Acceleration and Transport, Kauai, March 7 – 13: I presume several of us will attend since the theme is central to our team effort. Although we shall not have a formal team meeting, the conference provides an opportunity for subgroups to get together.
- Spring AGU, Ft. Lauderdale, May 27 – 30: We have proposed a special session on particle acceleration in the inner heliosphere. If it is accepted we expect that many of us will attend and submit abstracts for the session. In that case it is probably useful for those in attendance to meet on either 5/26 or 5/31. When the fate of the special session is clear and abstracts have been submitted, I'll request the preferences of those attending for which day.
- SHINE, Midway, UT, June 23 – 27: Here too we expect that several of us will attend this workshop. It is probably a good idea for those present to meet before or after the meeting perhaps for a half day. This could occur on 6/22 or on 6/27 in the afternoon.
- COSPAR, Montreal, July 13 – 20: Some of us may attend the COSPAR Assembly, but I do not expect that we shall plan any formal meeting of our Team.
- Team Meeting, Pasadena (?), September (?): As we discussed, this period is an optimal opportunity for a formal 2-day (?) meeting to present results and prepare for the final year of our funding to insure that we accomplish a majority of our collaborative efforts. It would be nice if Mona or Lika could attend all or part of the meeting; I shall invite them to do so and I shall explore possible dates.

Possible Joint Projects Within the Team:

1. Exponential Rollovers (DICK, Christina, Marty, Gang, Glenn, Dennis, Hilary, Ian)

An important objective in SEP studies is measuring and understanding the form of the energy rollover in the particle intensity (Is it an exponential as a function of energy E or a more general power of velocity v?) and establishing its dependence on Q/A and cosθbn. It is important to establish these characteristics for as large a sample of events as possible, which exhibit clear rollovers. The rollovers are sensitive to upstream scattering and ion escape and provide information on the proton-excited wave intensity and perhaps magnetic mirroring. Also is it possible to interpret the rollover as a result of the limited lifetime of the shock? Spectra exhibiting double power laws are interesting, but may be more difficult to interpret; they may be due to a superposition of exponential rollovers for a range of shock obliquities (as suggested by Tylka and Lee, 2006).

2. ESP Events (Dick, CHRISTINA, Ian, Marty)

ESP events provide the simplest configuration for the study of shock acceleration (presumably they are planar and stationary, or at least as close as can be expected), and yet they do not often agree with the simple theory. It is important to measure the characteristics of as large a sample of ESP events as possible, together with the associated shocks and possibly ICMEs, in order to compare these with theory. The characteristics include for all key ion species the energy spectral power-law index at low energy, the form of the energy rollover, the upstream spatial gradient, and anisotropies (using Wind and IMP 8). These should be established as functions of Q/A, E and θbn. The power-law index should be compared with the shock plasma compression ratio, and the wave-frame compression ratio based on the magnetic-field-aligned Alfven speed upstream and the frame downstream in which the ions are approximately isotropic. Extrapolation of the low-energy power law to a particle speed of approximately the solar wind speed should provide a measure of the injection rate if ions are injected out of the solar wind. A more complicated behavior may indicate that the seed population includes a substantial component of energetic remnant particles. Chuck Smith and Marty have been awarded a Heliospheric GI grant to compare the measured magnetic fluctuation power spectra upstream of the shock for a sample of ESP events. This study should have relevance to the ESP project.

3. Streaming Limit (Hilary, Christina, MARTY, Dick)

An important feature of SEP events is the "streaming limit", which characterizes the ions which stream away from the shock, escaping with high anisotropies. These ions tend to have a harder energy spectrum, an enhancement in heavy ions, and a rather robust intensity maximum (the "streaming limit"). This feature of SEP events provides information on the properties of the scattering turbulence and perhaps the ion escape by mirroring, and should be closely related to the form of the energy rollover. An observational survey of the streaming limit for different events is of interest, in particular the extent to which the ion intensity is indeed limited prior to the onset of the ESP phase. It will be interesting to determine the energy *E*, radial *r*, and *Q/A* dependence of these escaping particles from theory and compare them with the observed dependencies. For example, Reames & Ng (1998) find a radial dependence in the range $r^{-2} - r^{-3}$ and an energy dependence $\approx E^{-2}$. These particles can affect the composition of the fluence in well-connected events since they favor higher *A/Q*.

4. The remnant suprathermal/energetic ion distribution in the heliosphere (DICK, Christina, Marty, Hilary, Glenn)

The remnant ion distribution is crucial to our understanding of the origin and composition of SEP events. Measurements of the ion energy spectrum and its composition at quiet times, and also at more elevated levels of solar activity, are of interest since a shock may plow through regions with different levels of remnant energetic particles and accelerate them more efficiently than solar wind ions. It will be particularly interesting to see how the composition and energy spectra depend on the level of solar activity. An important issue to address theoretically is the expected spatial and temporal distribution of these particles in the heliosphere, which are impulsively released near the Sun by either flares or shocks or are produced in the inner heliosphere by solar wind turbulence or interplanetary shocks. It is important to establish whether remnant particles are likely to be present close to the Sun, in spite of outward convection, when a new shock is launched by a CME and is able to accelerate these ions to high energies while it is in the lower corona. The same theoretical considerations should also apply to the long-time evolution of SEP/ESP events in the so-called "invariant spectra" phase when particles fill the inner heliosphere (Reames et al., 1997).

5. Shock Formation Close to the Sun (Angelos, Hilary, Igor, Dick, ILIA)

A key question in determining the flare or shock origin of the highest energy SEP particles close to the Sun is whether a fast CME drives a shock and whether the shock forms rapidly enough and is strong enough to be effective in accelerating ions early in the event when the highest energy particles are produced. This question is best answered by identifying shocks in the white-light coronagraph images, trying to interpret their white-light spatial profile as a function of time in terms of CME shape and speed, and correlating the identified shocks with observed particle events and their timing. Using pre-CME-launch magnetograms and potential field models could establish shock Mach number and magnetic obliquity. These observations can be compared with MHD models based on the same pre-CME-launch coronal parameters. This project is clearly challenging since the magnetic complexity of active regions makes the calculation of the Alfven speed and the extrapolation of magnetic field lines to the observing spacecraft difficult.

6. Hilary's 338-SEP-Event Survey (Dick, HILARY, Ian, Christina)

Hilary's comprehensive survey of 338 SEP events from the ACE era (including 8 prior to the ACE launch) and her inferred separation of the acceleration process into first, second and third phases needs to be digested and scrutinized. What inferences do we draw from the study? Could other observations be included in the study, which would be informative? It was suggested that Helium-3 could be included as a signature of remnant impulsive event material or as a signature of a direct flare contribution either in the first or second phase. There was also some disagreement on the Fe/O ratio of the particles clearly associated with the shock (the ESP enhancement). Hilary said that Fe/O ~ 0.1 in this component, whereas Dick said that Fe/O ~ 0.3 is more characteristic. What is going on here? Marty wondered whether the variation of the Fe/O ratio in an event, measured at the same energy/nucleon, could be reduced by measuring Fe and O at the same value of the diffusion coefficient, presumably at the same speed times a power of rigidity, as suggested by the work of Mason et al. (2006). See transport effects below. Clearly this survey is a tremendous resource, to which we can add and perhaps from which we can extract new information. I'm not sure I have captured the important issues here according to our discussion and I welcome input from the experts!

7. Transport Effects in SEP Events (Dick, HILARY, Marty, Gang, Glenn)

A crucial aspect in interpreting SEP events, particularly their composition, is the role of ion transport. How large are transport effects? Clearly the mode of ion transport (either scatter-free or diffusive) and the ion spatial diffusion coefficients affect transport. Also the connection geometry of a given event affects the transport of particles to the observing spacecraft. We need to be able to assess these effects theoretically and see how they are born out in observed events. Mason et al. (2006) have suggested that transport affects the variation of composition through an event. An interesting point is that a larger diffusion coefficient decreases the contribution of an ion species to the fluence when particles are impulsively released into the solar wind, but may increase the contribution in a shock event for energies that are not too high by virtue of a larger upstream scalelength. As mentioned in Project 3, the dominance of escaping particles early in a well-connected event can modify the composition substantially. Clearly both observational and theoretical studies are required to solve this fundamental problem.

8. Comparison of CME and SEP Total Energies (DICK, Angelos, Christina)

The efficiency of particle acceleration is an important quantity in assessing the potential hazard of a given event. Also, in determining the origin of SEP events (flares versus shocks), the correlation of CME and SEP total energy content is crucial. Presumably adiabatic deceleration is a small correction to the SEP energy content. We need to assess the influence of ion injection rates out of the solar wind, and remnant energetic ion distribution functions on the energy conversion from the shock-associated flows to the accelerated energetic ions.

9. Studies of Ion injection (KOBUS, Christina, Ian, Gang)

The rate of injection of ions out of the solar wind and its suprathermal tail at a shock has important consequences for the composition and intensity of the shock accelerated ion population. The injected fraction of the advected ions depends on ion speed, Q/A, shock compression ratio X, and magnetic obliquity, and is not deriveable from the theory of diffusive shock acceleration. In Project 2, we mentioned the possibility of extrapolating the low-energy distribution function at the shock to approximately the upstream flow speed to infer the injection rate in a given ESP event. With Kobus's code to solve the focused transport equation, which includes both the solar wind and the accelerated energetic particles, we have an ideal tool to investigate the injection process theoretically. We must first assess, however, whether the features of the shock transition and the solar wind that are anticipated to be important in the injection process are present in formalism: For example, is the assumption that the solar wind has a κ- distribution limiting? Does the magnetic field at the shock include a kink, and is there an associated shock potential? Is the assumption that the ion distribution be nearly gyrotropic sufficient to describe the first scattering and drift of freshly injected ions at the shock?

10. Calculation of the Upstream Wave intensity (GANG, Marty, Kobus, Igor, Ilia)

As mentioned explicitly in Project 2, and implied in Projects 1, 3 and 7, the wave enhancement excited by the accelerating protons plays a crucial role in determining the transport of the ions, the form of the exponential rollover, the ion upstream spatial gradients, and the ion anisotropies. A major goal for us is determining the wave intensity as a function of wavenumber, distance upstream of the shock, and shock parameters. Marty has proposed to extend the previous calculations of Lee (1983), Gordon et al. (1999), and Lee (2005) to include an advected energetic ion population and magnetic focusing. The calculations will include an analytical approximation and an iterative numerical calculation. The analytical approximation should be useful for inclusion into Gang's global code, which determines the distribution functions of the SEP/ESP particles. The results will also be compared with the wave intensities obtained in Kobus's and Igor's/Ilia's calculations. As part of Marty's Heliospheric GI grant, these predictions of the upstream wave intensity will be compared with the magnetic fluctuation power spectra upstream of a sample of ESP events (presumably the same sample studied in Project 2).

Other Issues:

- Why did the recent Lario et al. and Ho et al. studies seem to show less correlation of the ion distributions with shock parameters than the van Nes et al. (1984) study?
- Do we understand "shock spike" events?
- The Tylka & Lee (2006) superposition model needs to be extended to consider a more general weighting on magnetic obliquity, more realistic charge states for the remnant energetic particles, and a more accurate form for the exponential rollover.
- How important are turbulent processes in the foreshock: nonlinear mode-mode coupling, the Jokipii/Giacalone flow interactions induced by shock ripples?

Please respond to the distribution list as you see fit. If you would like to add your name to other projects or add content to any project, please do so using Track Changes. I am adding Glenn's name to the distribution.

Cheers, Marty