2004 SHINE Meeting

Relativistic Solar Electrons _ An Overview

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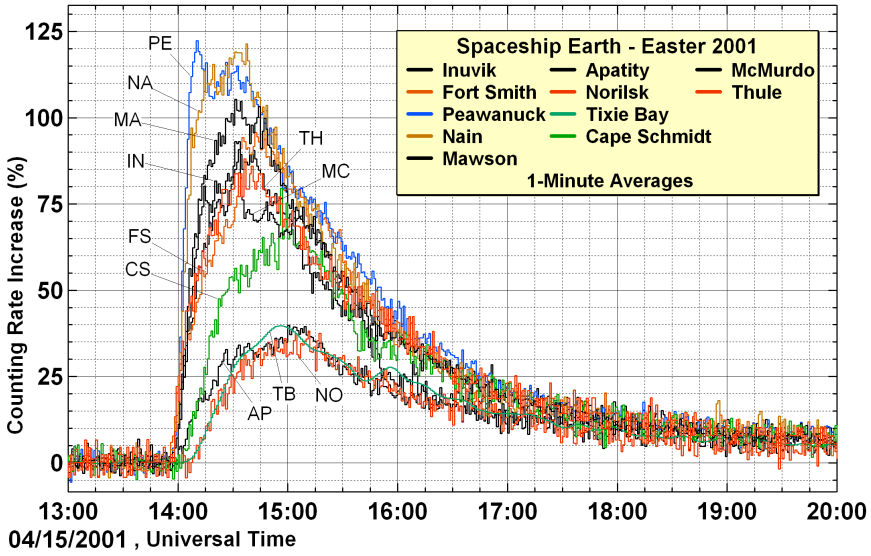
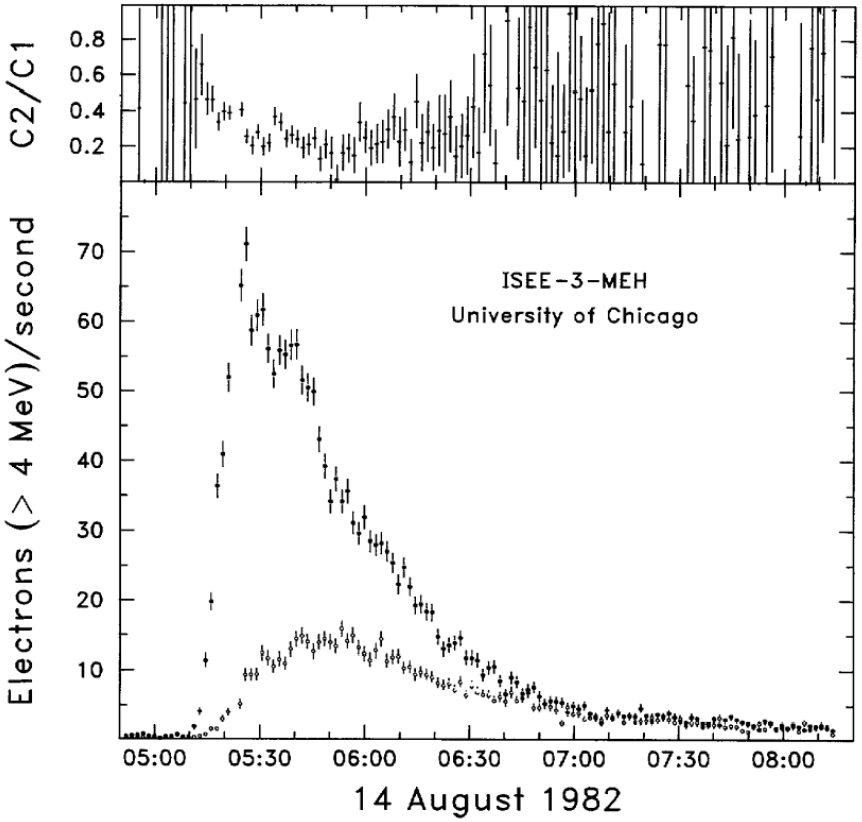
Relativistic Solar Electrons -- Puzzling Observations

- Time profile is similar to that of GeV protons, yet they show a spectral continuity with much lower energy electrons
- Spectral shape is quite variable from event to event, but a characteristic hardening of the spectrum at a few MeV is well correlated with short duration x-ray emission from a flare
- Spectral features are independent of connection longitude
- Some electrons are released coincident with gamma ray emission in the impulsive phase of the flare, yet overall apparent "injection" times of an hour or more are observed in the same events

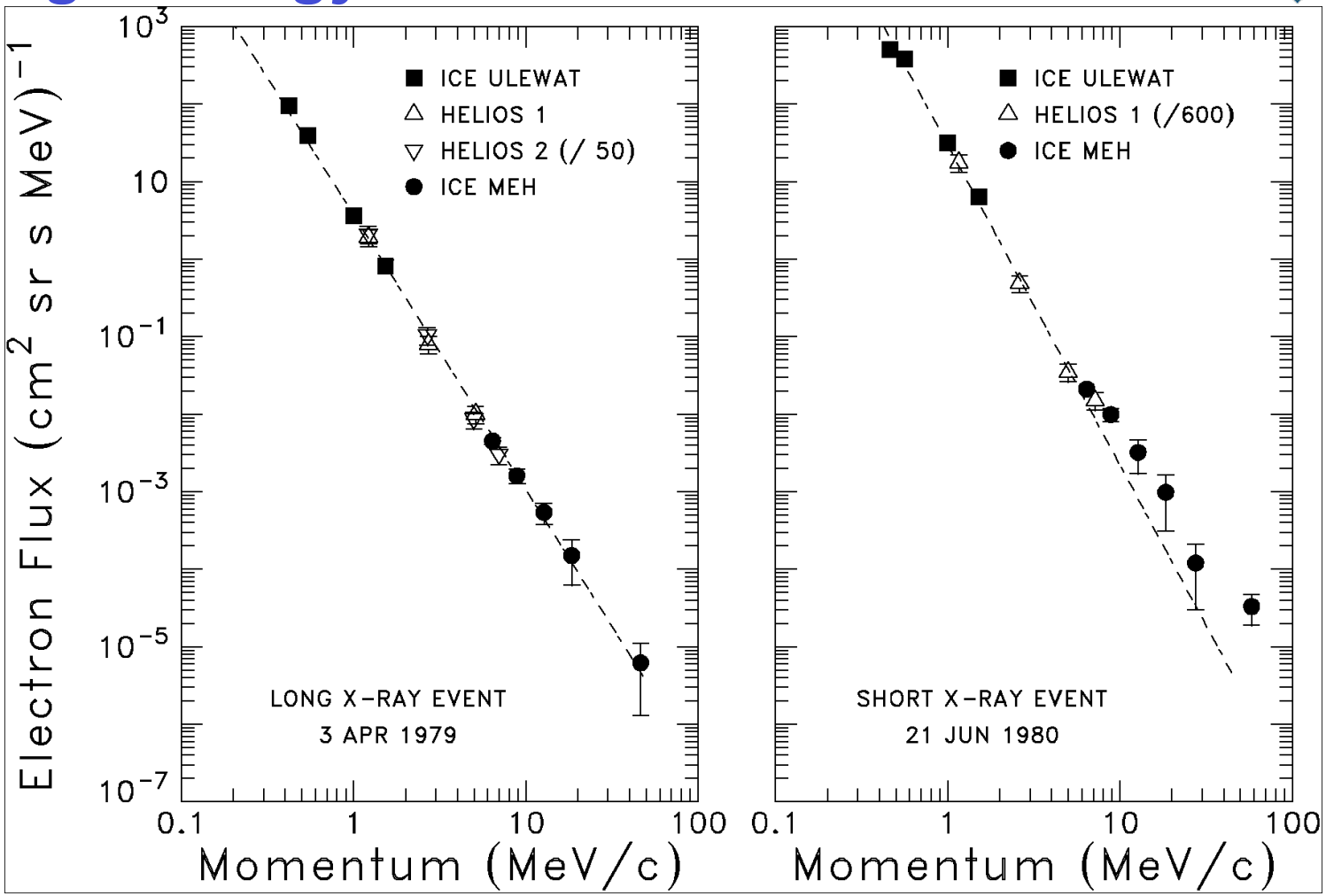
- Time profile is similar to that of GeV protons, yet electrons show a spectral continuity with much lower energy electrons

Time Profiles – Neutron Monitor and Relativistic Electrons

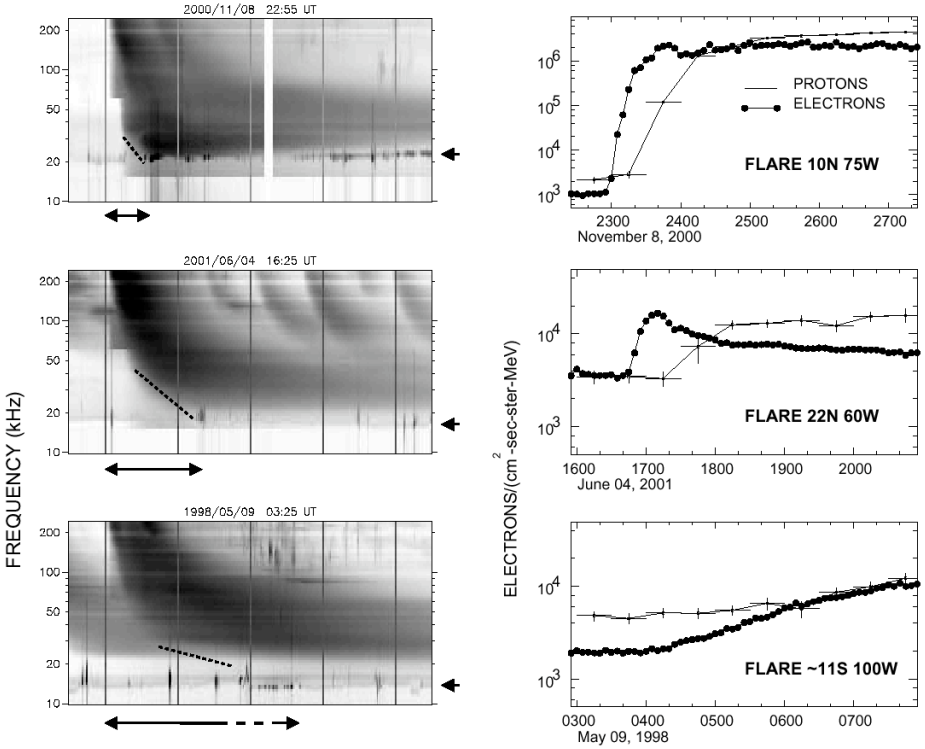




Solar Electron Spectrum – Continuity Between Low and High Energy Electrons

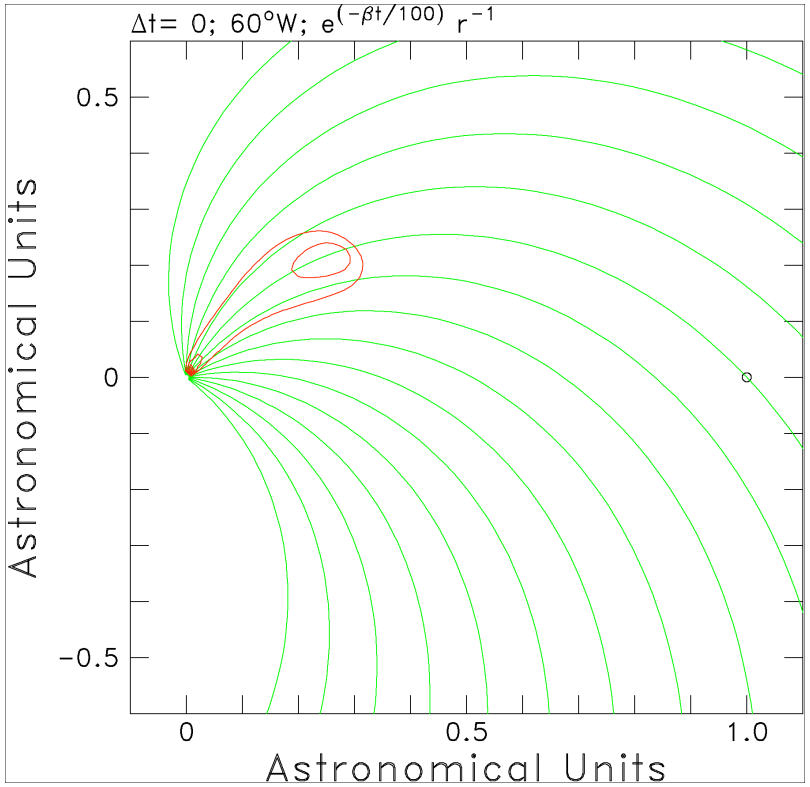


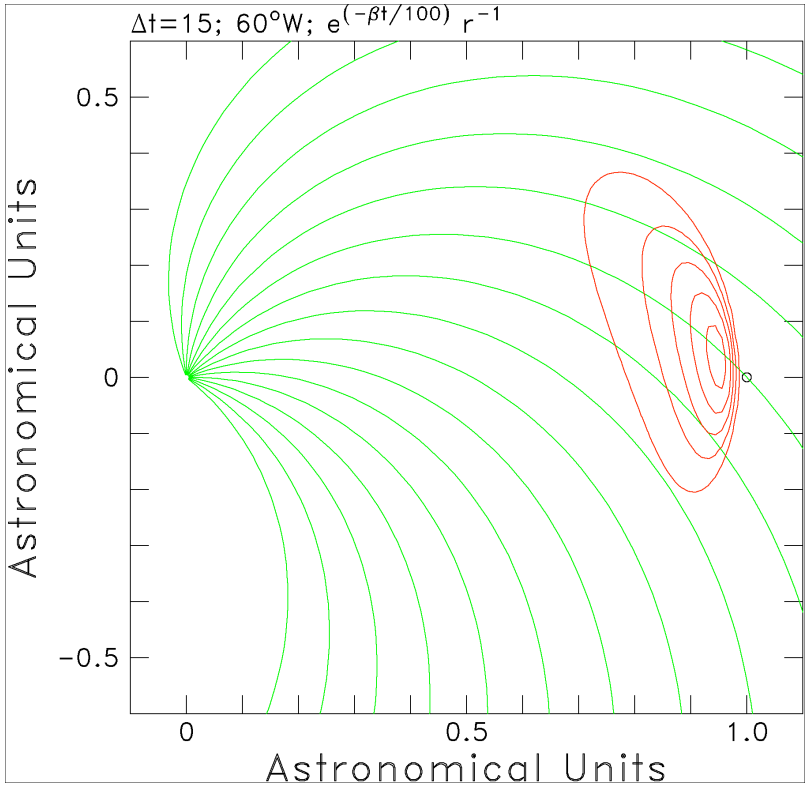
Aside on Low Energy Electron Propagation:



- Closely Related to the Propagation of Nuclei (Cane and Erickson 2003)
- Tracked by Type III Emission (Reiner and Stone (1988,1989)
- Can be treated by Particle Propagation Models
- Timing of Particle Arrival Can "Close the Loop" and Reduce Model Dependence

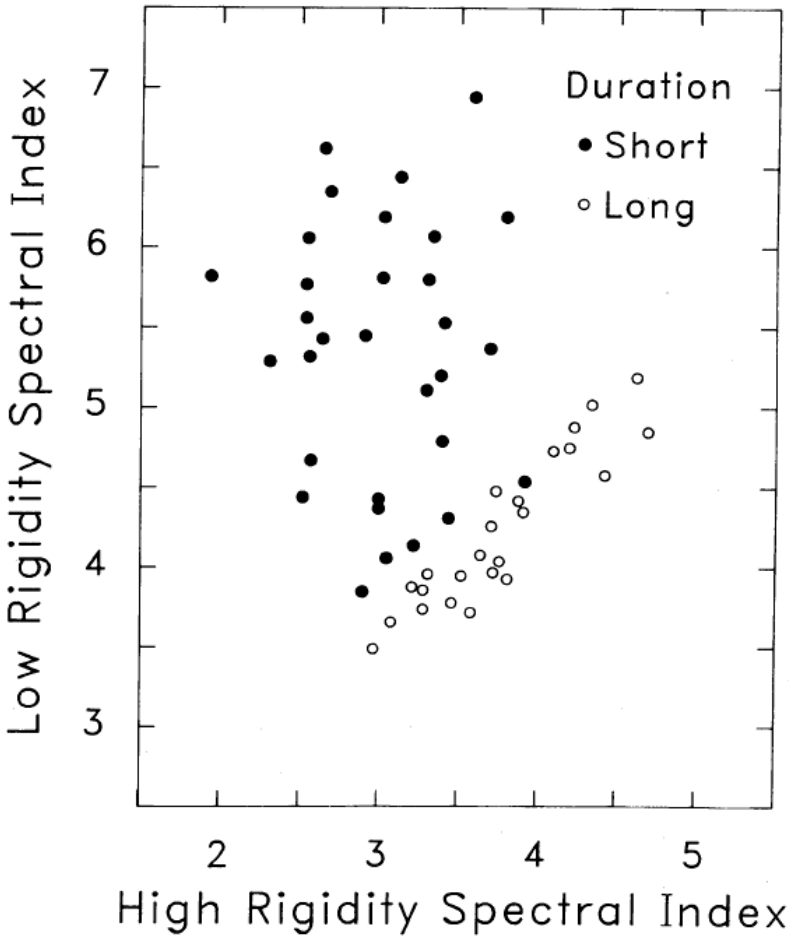
Example: Electron Density in a Simple Model Developed for GLE's





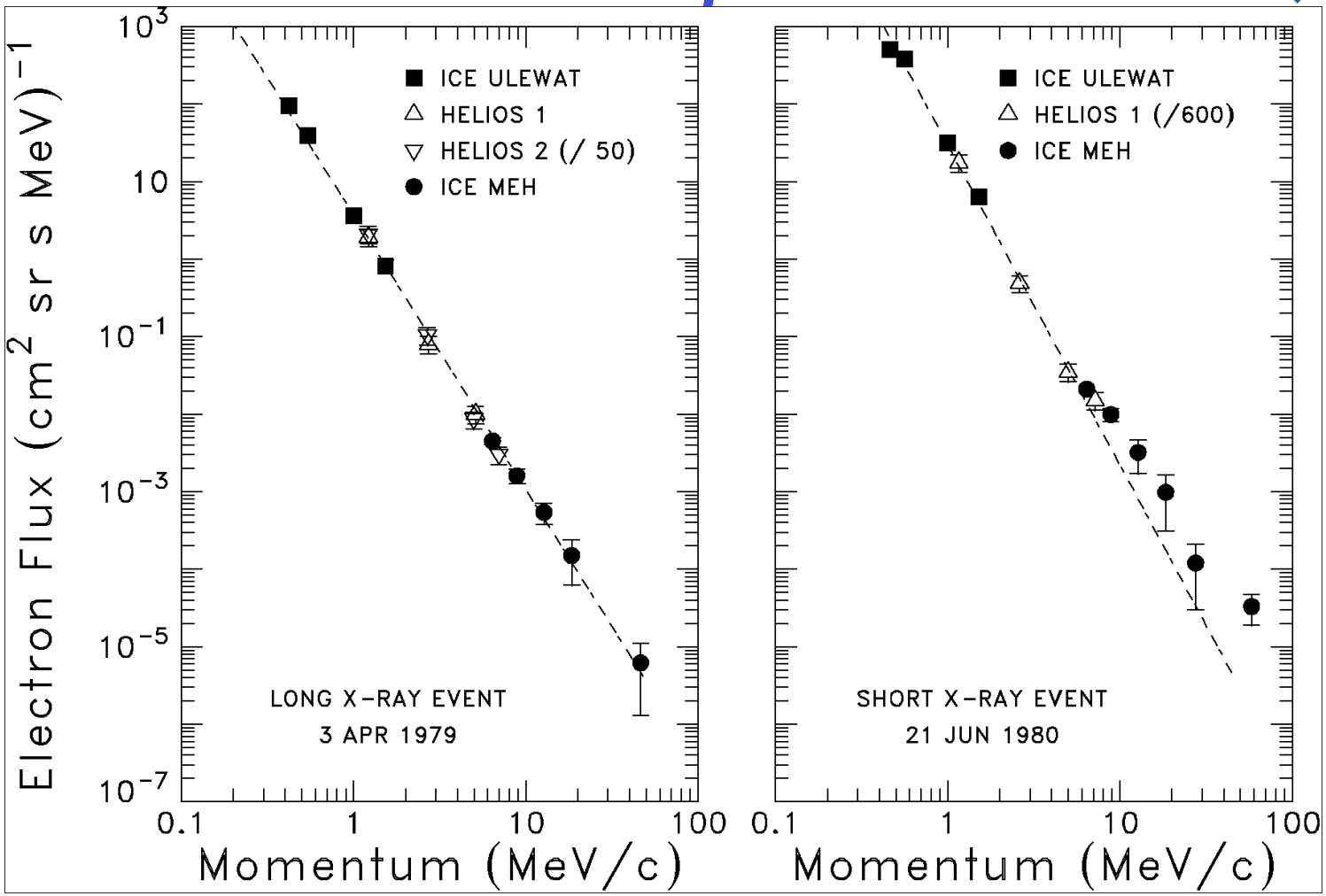
- Spectral shape is quite variable, but a characteristic hardening of the spectrum at a few MeV is well correlated with short duration x-ray emission from a flare (and thus the location of the flare in the solar atmosphere)

Electron Spectral Shape is Related to X-Ray Signature (aka Flare Depth in the Solar Atmosphere)



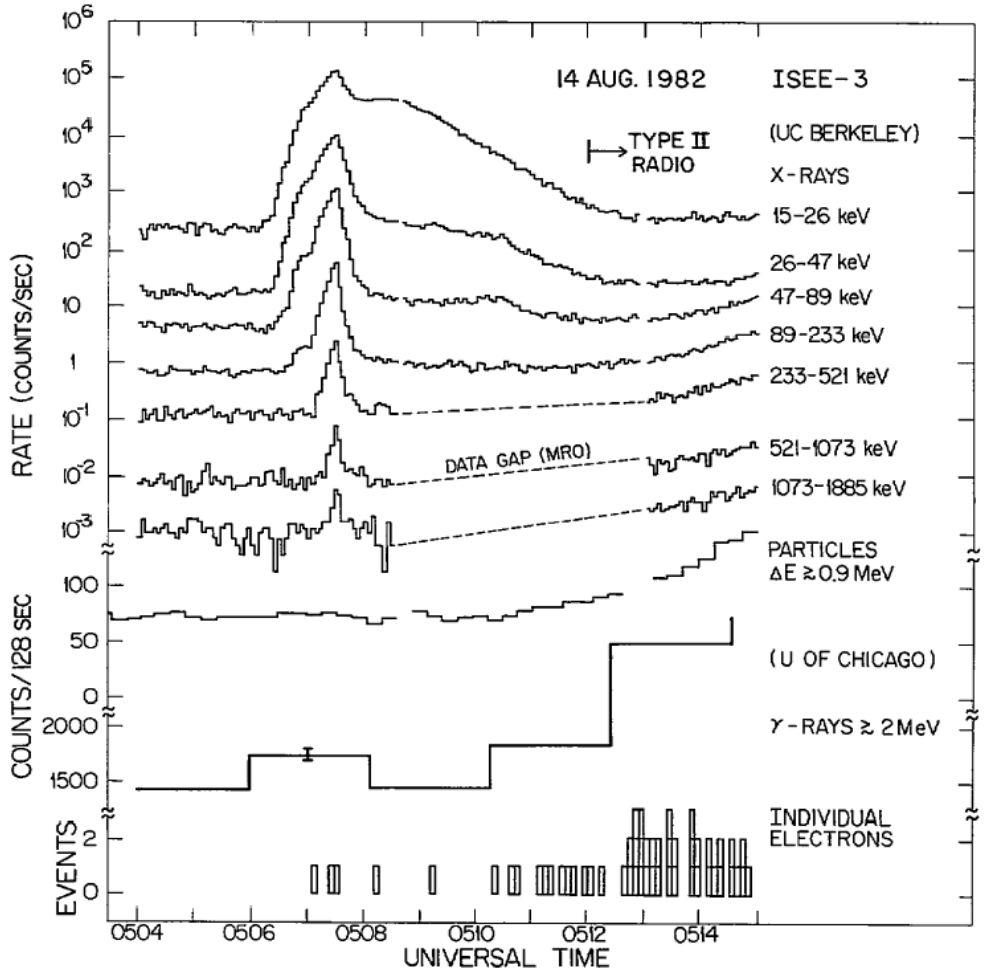
- Spectral features are independent of connection longitude

Solar Electron Spectrum at Different Locations in the Heliosphere

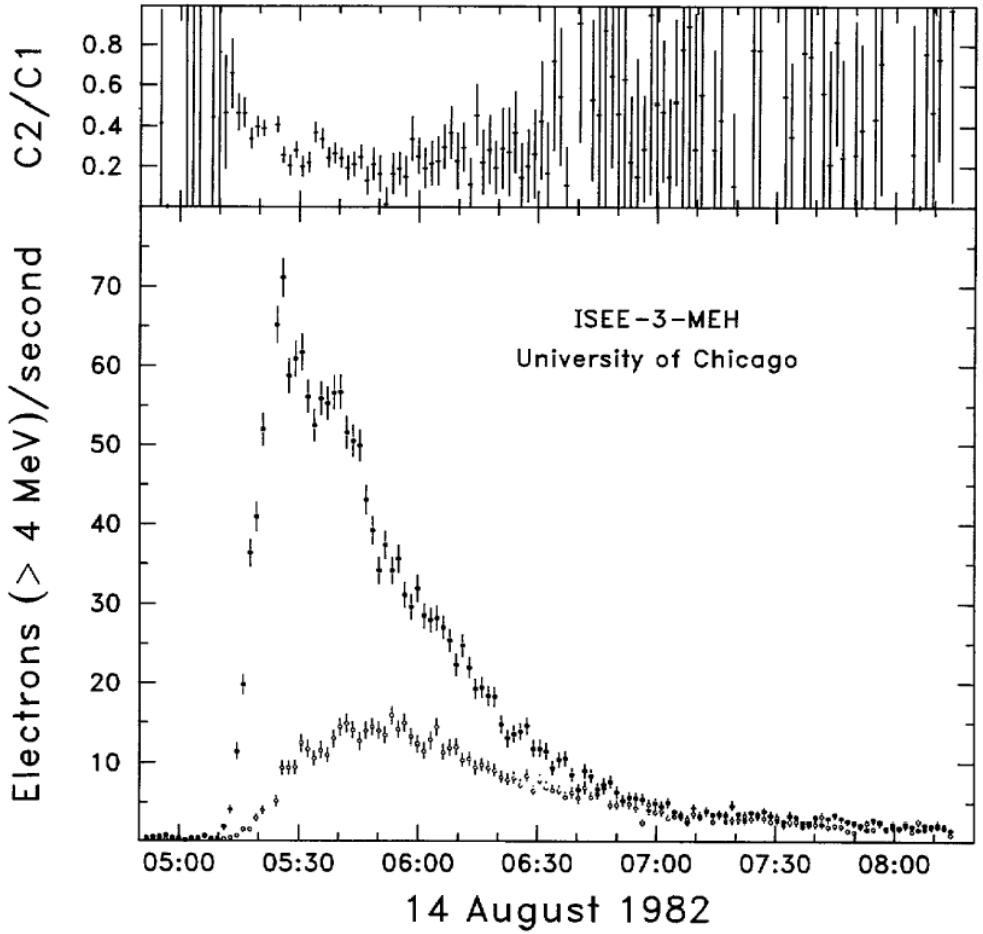


- Some electrons are released coincident with gamma ray emission in the impulsive phase of the flare, yet overall injection times of an hour or more are observed in the same events

Some Interplanetary Electrons are Released "Instantly"



Yet There is Often an Apparent Long Term Electron "Injection"



Conclusion

- Relativistic electrons exhibit many if not all the propagation characteristics of "GLE" particles in spite of their low rigidity.
- There is clear spectral and temporal continuity between relativistic and non-relativistic electrons.
- To me, this continues to suggest that there is a mechanism for very local (in space and time) energization of particles in solar flares, and that most of what we see as "injection" time structure originates in the propagation of the particles.

The Basic Puzzle Leading to This Conclusion:

- If the hours long extended production of electrons is due to a propagating shock (for example) how does this retain the memory of the depth of the flare in the solar atmosphere so as to produce a spectrum essentially invariant in time and in helio longitude?