# Case studies on the effect of pre-event background in solar particle event timing

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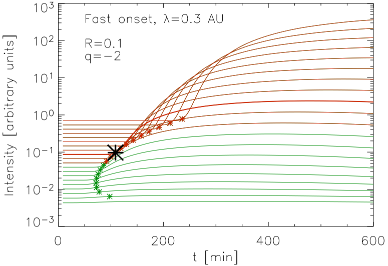
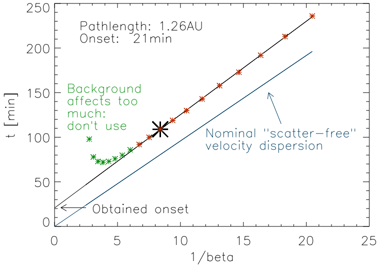
# Velocity Dispersion Analysis (VDA)




A simulated SEP event (1-100 MeV protons) overlaid on a pre-event background




VDA fit on a simulated event, compared to "nominal" fit

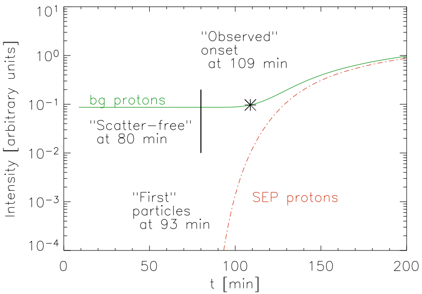
- Measure the **arrival time** of the first particles and **fit** $t_{arrival} = t_{injection} + s/v$
- Leave out "**bad channels**" ( with $\max\{I_{event}\} < 10 \cdot I_{bg}$ )

# What's wrong with the velocity dispersion?

- The **event onset** is **masked** by the pre-event background, to a varying degree

-> The obtained "**solar onset time**" is **wrong**

- ... but **how much wrong**?



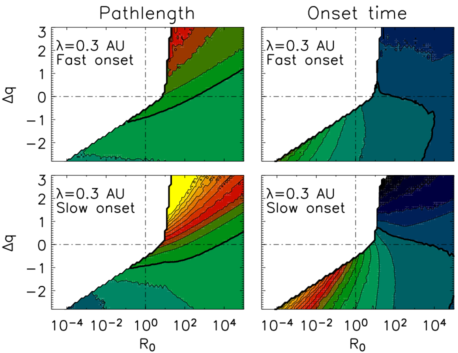

Simulated solar event overlaid on a pre-event background for 5 MeV proton

# Study strategy

- Simulate particle events with **varying injections and transport conditions**
  - Use 1-100 MeV protons
  - Overlay on **varying levels** of energy-dependent pre-event **backgrounds**
  - See how well the velocity dispersion analysis works
- Simulations based on **Monte Carlo** method
  - parallel transport along Parker spiral, guiding centre approximation
  - SQLT **isotropic scattering** off parallel Alfvén waves (method from Kocharov et al 1997)
  - **adiabatic focusing** and **deceleration** taken into account

# Parametric study

- $R = I_{event}/I_{bg}$ at 88 MeV, $\Delta q < 0$ for soft event
- **Left panel:** the fitted **pathlength** (nominal 1.12 AU). **The thick curve 1.4 AU**, 0.2 AU contours, increasing to upper right.
- **Right panel:** the fitted **onset time**. **The thick curve the nominal**, 10 min contours, the green and red contour fills show delayed fit result




- Velocity dispersion in **high-intensity events** seems to be **usable**
- **Large**, tens of minutes **error** for "**non-optimal**" **events**

# Correction to the onset times?

- **Fit rise rate**, $D = d\ln(I)/dt$, to analytic estimates?
- **Diffusion equation?**

$$I \propto \frac{1}{(4\lambda vt/3)^{3/2}} e^{-3r^2/(4\lambda v t)}$$

gives for the rise rate $D \approx 3r^2/(4\lambda v t^2)$ at the onset

  - First particles arrive to 1 AU at $t = \varepsilon$: **not usable at the onset**
  - **Lacks physics** relevant for the onset

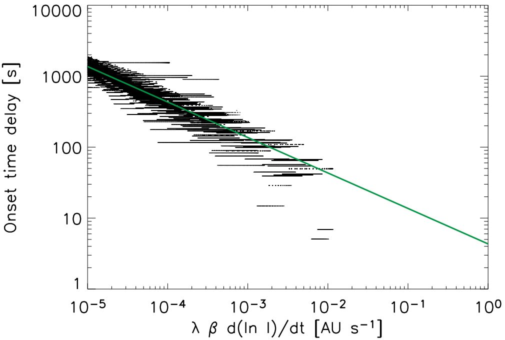
- **Telegraph equation?**
  - "**Signal speed**" $v_s$: First particles arrive at $t = r/v_s$
  - **Tricky**, Bessel functions, **no** solutions with **adiabatic changes**

# Simple estimate

- Use **onset error time** $t' = t - r/v_{particle}$ in **diffusion equation**
- Focusing, deceleration and scattering model modify the arrival time: **Fit the modification from the simulated events**

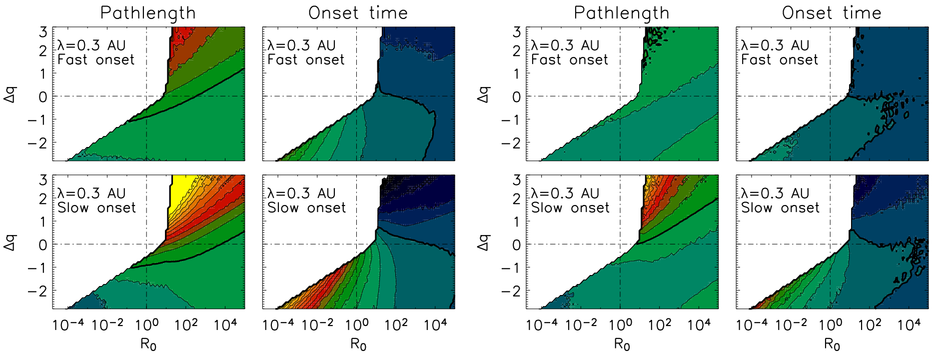
-> Rise rate

$$D \equiv \frac{\partial \ln I}{\partial t'} = A\frac{3}{4}\frac{r^2}{\lambda v t'^2}$$




-> obtain correction $t' = \sqrt{A\frac{3}{4}\frac{r^2}{\lambda v t D}}$ for all energy channels

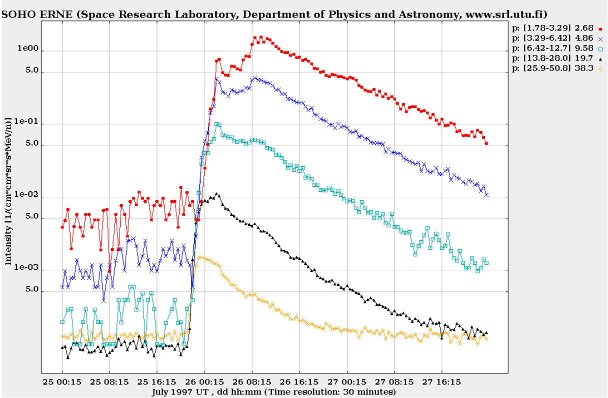
# Simple estimate




- Right-hand panel: VDA with corrected onset times, using $\lambda$ =0.3 AU for all energies

# July 25, 1997

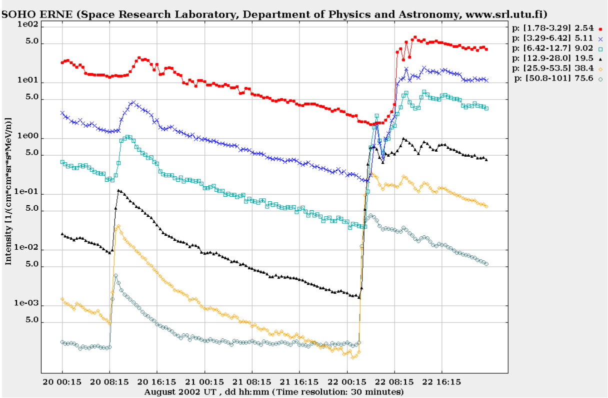
- Fairly steep rise, background and maximum spectra similar
- Uncorrected onset 20:11, corrected to 20:01
- Uncorrected pathlength 2.35, corrected to 2.18




CME at 19:54, 611 km/s, western, wide

# Aug 20 2002

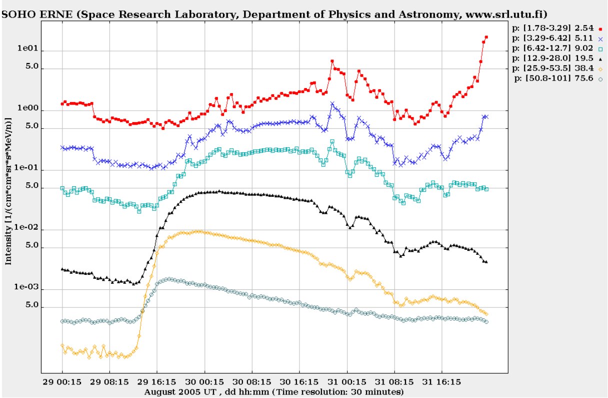
- Significantly masked at low energies
- Uncorrected onset 08:30, corrected to 08:26
- Uncorrected pathlength 1.07, corrected to 1.05




8:22-8:26-8:30 M3.4 S10W38 Southern partial-halo CME 8:10, 1099 km/s, at 4.9 rs at 8:54

# Aug 25 2005

- Gradual rise, masked at low energies
- Uncorrected onset 12:22, unchanged
- Uncorrected pathlength 2.01, corrected to 1.7




4:30-4:40-4:45 M6.4 N09E80, CME at 4:16, 1327 km/s (eastern partial halo)

# Conclusions

- Velocity dispersion analysis **suffers from pre-event background**: large errors possible
- **Large events ok**, partially **masked events** may have **large errors**
- **Corrections** based on rise rate **can be devised**
- **Won't correct "everything"**
  - More physics needed in analysis
  - All assumptions not satisfied (e.g. Parker field, simultaneous injection)