Microburst duration distributions using FIREBIRD-II

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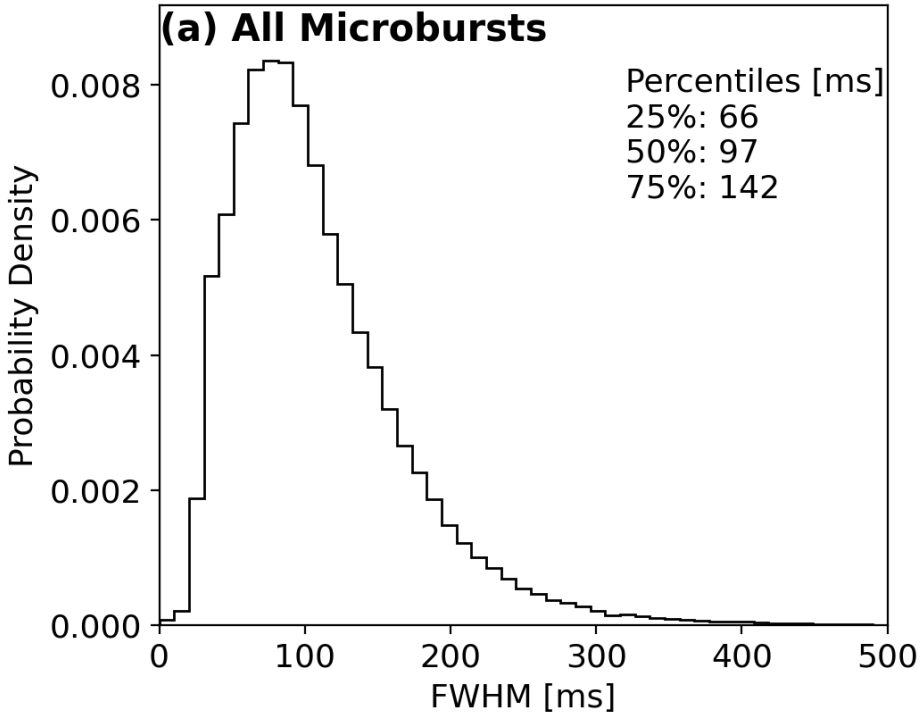
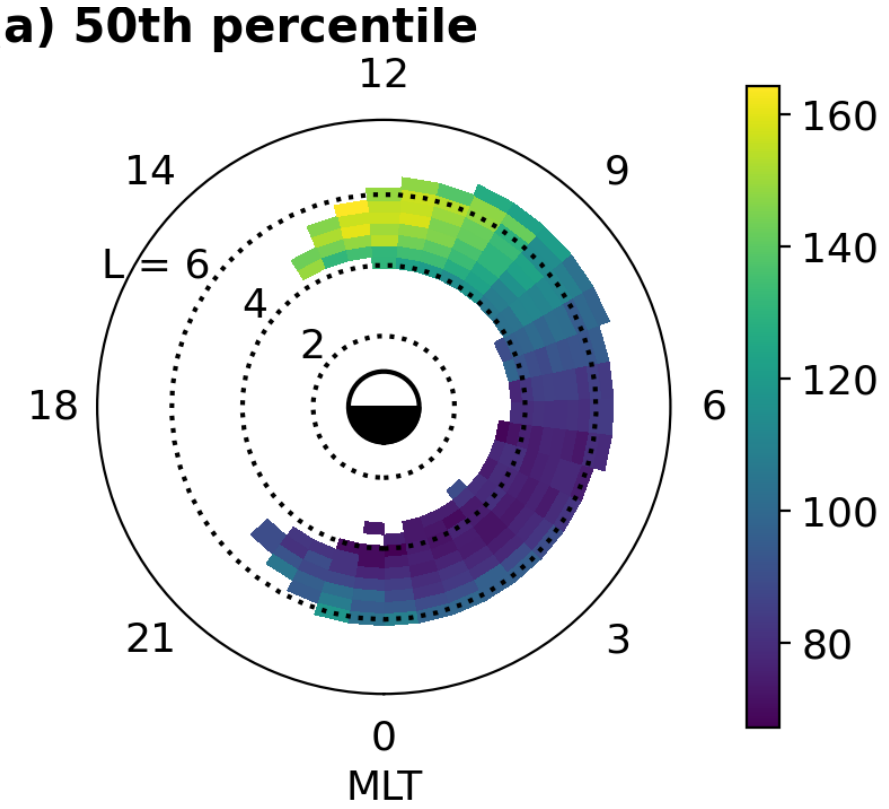
Background: a follow-on study from the Shumko et al., (2021) SAMPEX study

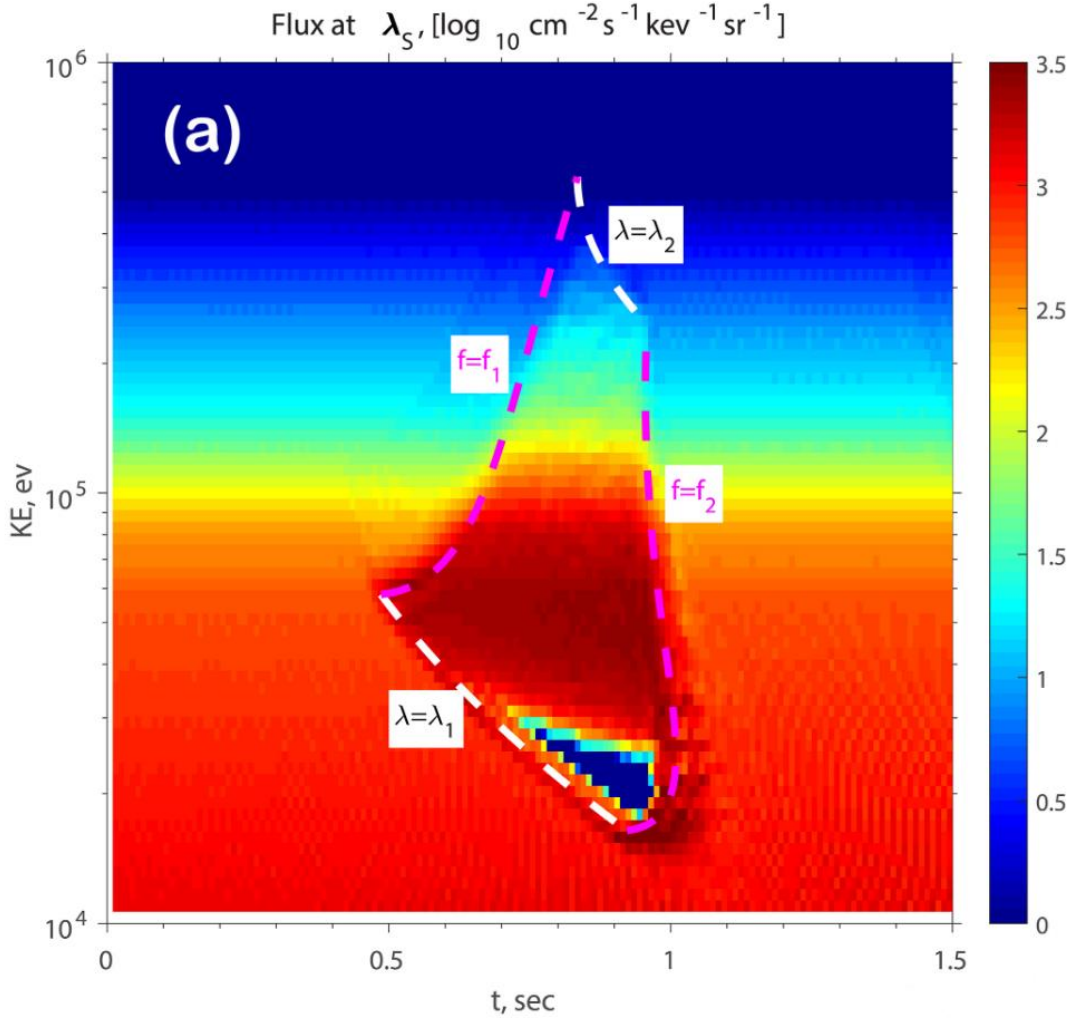
- > 1 MeV microbursts have a ~ 100 ms duration.
- Doubles in MLT.





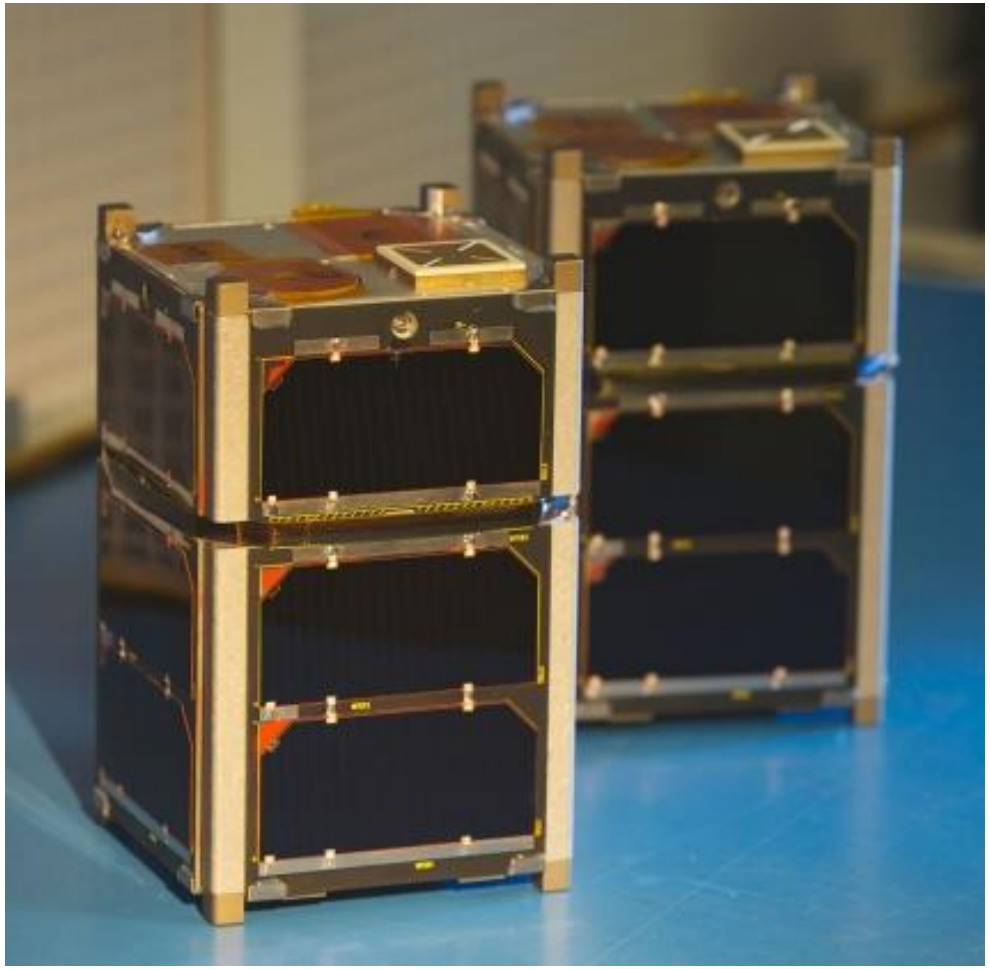
Background: a follow-on study from the Shumko et al., (2021) SAMPEX study

- What about as a function of energy?
- Chen et al., (2020) shows that the duration of the increased microburst flux has an energy dependence.
- Our hypothesis: microburst duration decreases for > 100 keV microbursts
- Will we see this in the FIREBIRD-II data?



Present study: microbursts observed by FIREBIRD-II.

- Pair of 1.5-U CubeSats launched in 2015.
- Collimated detector sensitive to 200 keV - > 1 MeV electrons in 6 energy channels
- Geometric factor ~ 5 cm^2 sr
- Programmable cadence from 12.5 to 50 ms.
- See Johnson et al., (2020) paper for more information



Fitting microbursts

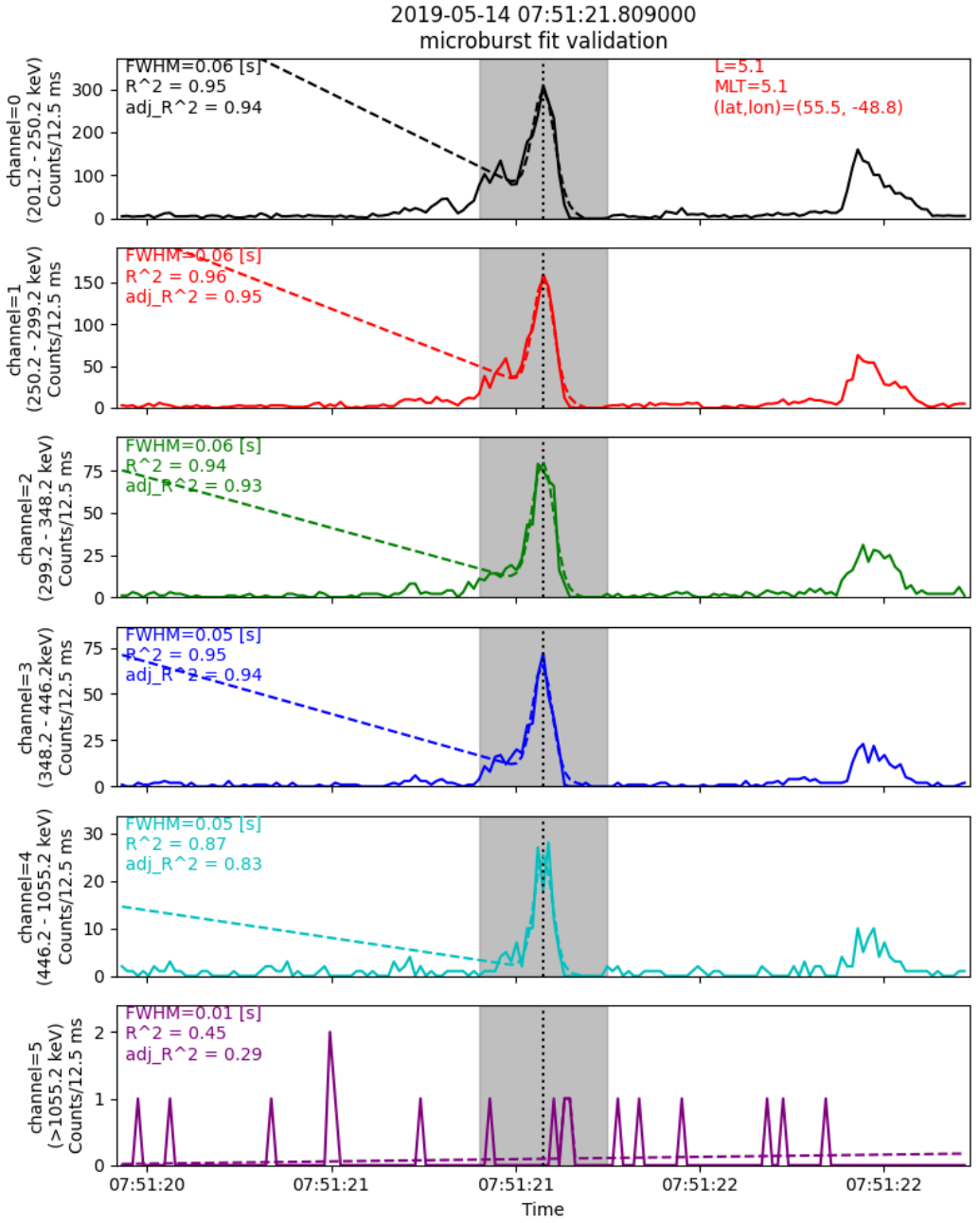
- Use only microbursts taken at a < 50 ms cadence
  - Including 18.75 & 12.50 ms cadence
  - Refer to Johnson et al., (2020) for cadence and campaign details (table 4)
- Identified via the burst parameter with > 10 threshold
- Resulting 1710 microbursts were fit with a Gaussian + linear trend

$$c(t|A,t_0,\sigma,c_0,c_1) = Ae^{\frac{(t-t_0)^2}{2\sigma^2}} + c_0 + c_1 t$$

- Duration quantified by FWHM of the Gaussian
- Version 0 of the fit parameters:
  - Fit 0.3-seconds of data
  - Initial FWHM guess = 0.1-seconds
- Goodness of fit quantified by the R^2 and adjusted R^2 metrics.
- 650 microbursts with max(r^2) > 0.9 across the 6 energy channels.

Good Examples

- Collimated counts vs time for all energy channels
- Solid lines show the data, dashed lines show the fit
- Fit duration shown by the grey bar
- Peak time in the 200 keV channel show by the dotted black line
- Fit parameters for each channel shown on the left of each panel
- FIREBIRD location shown in the upper-right corner



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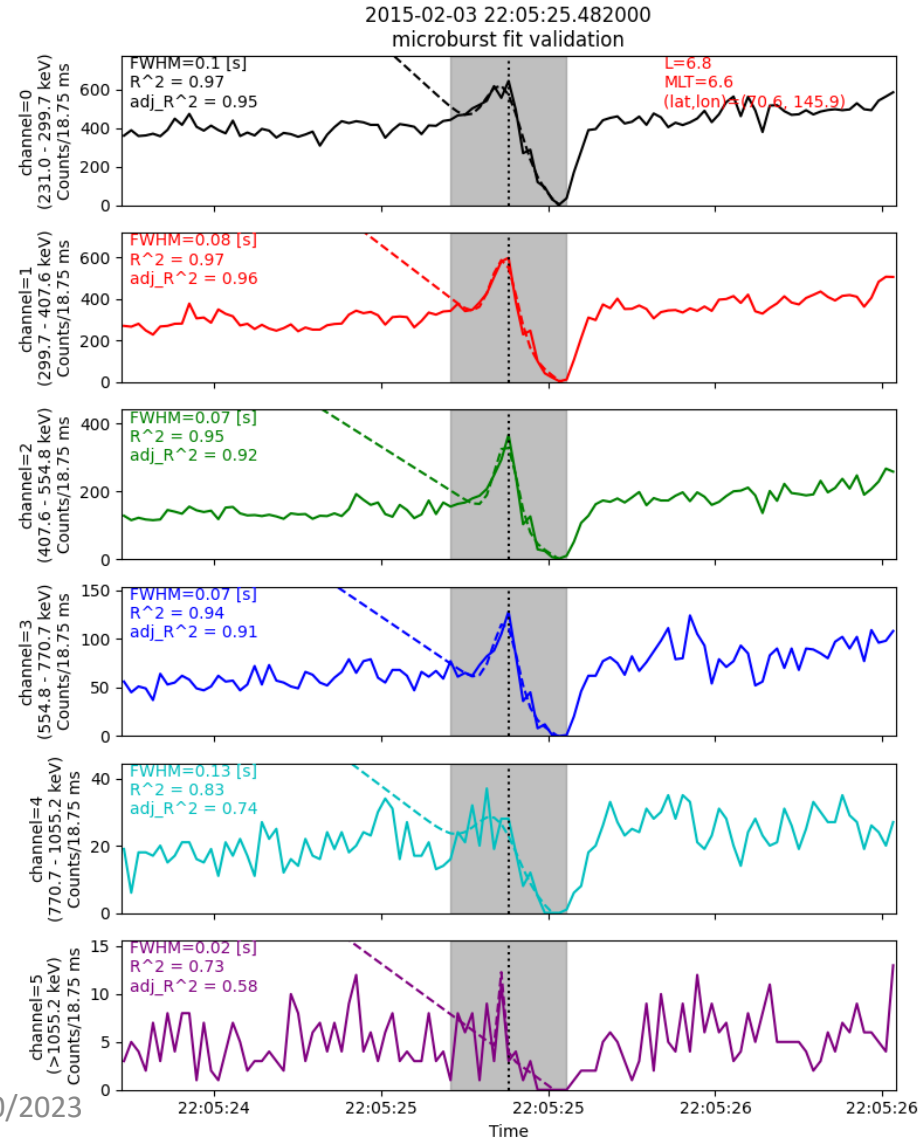
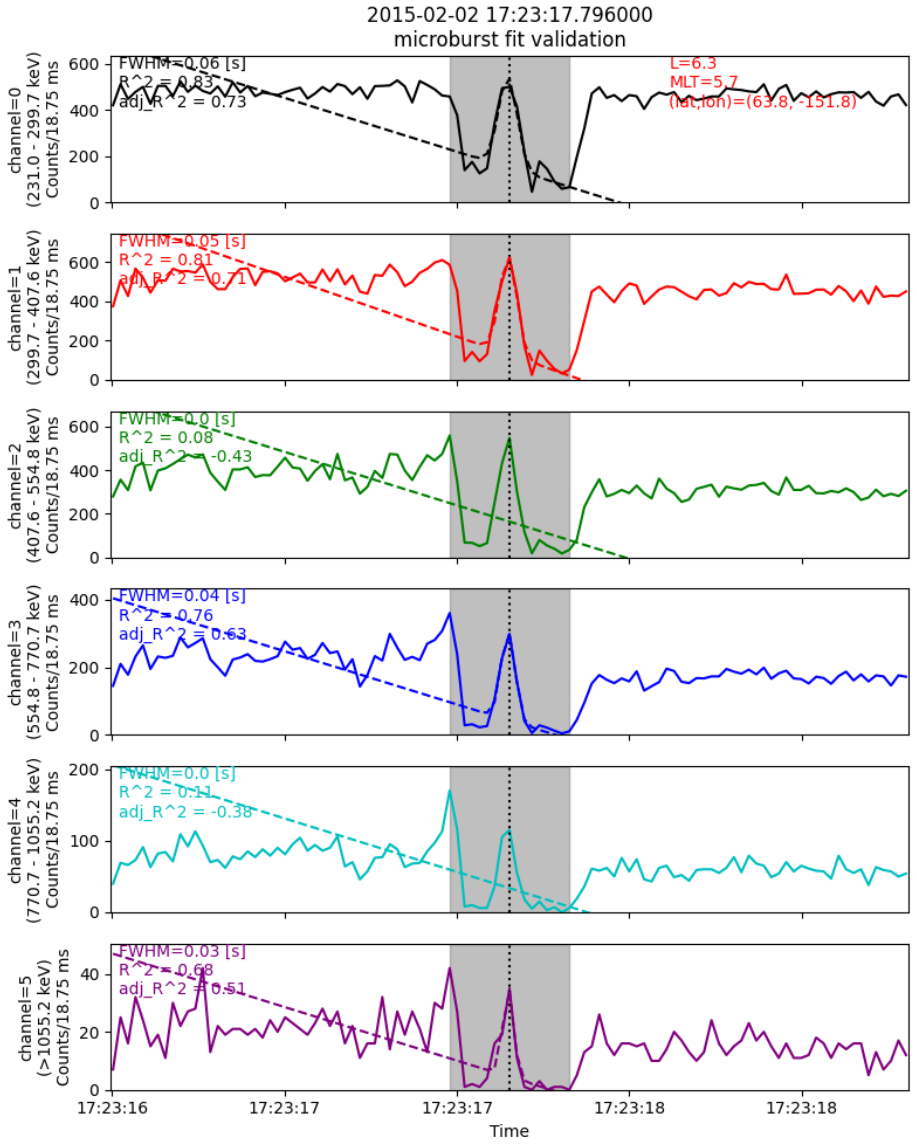
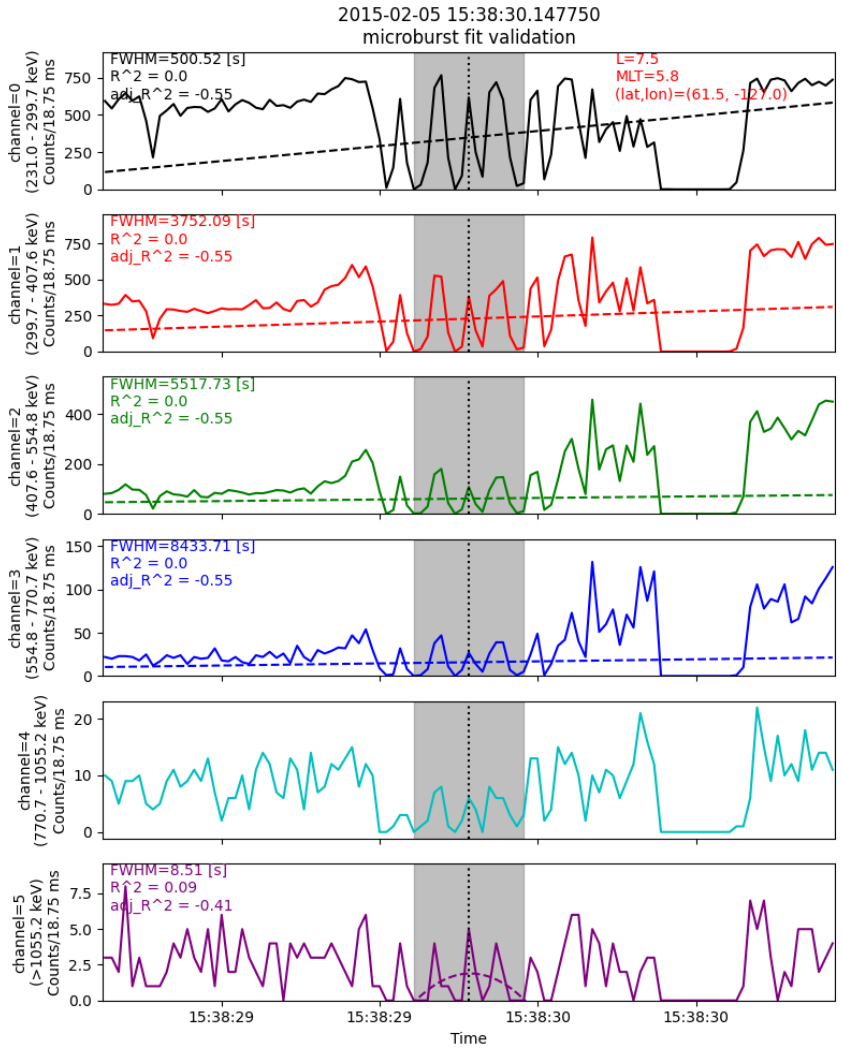
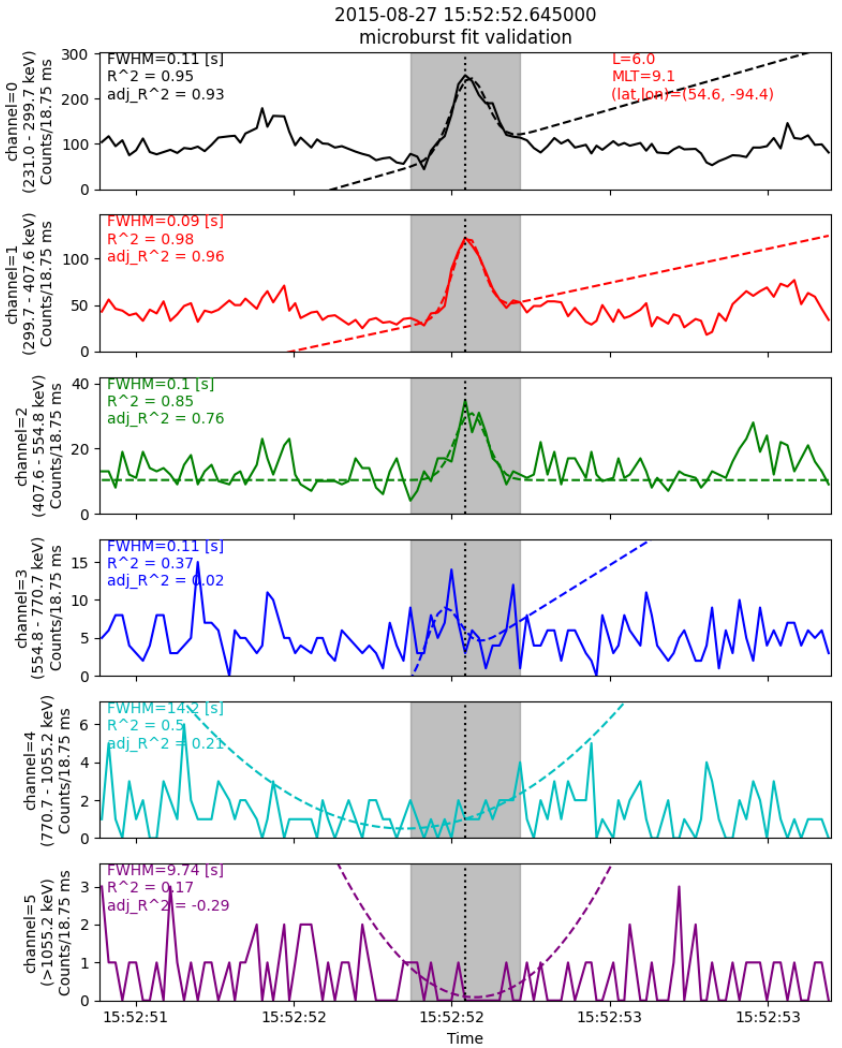




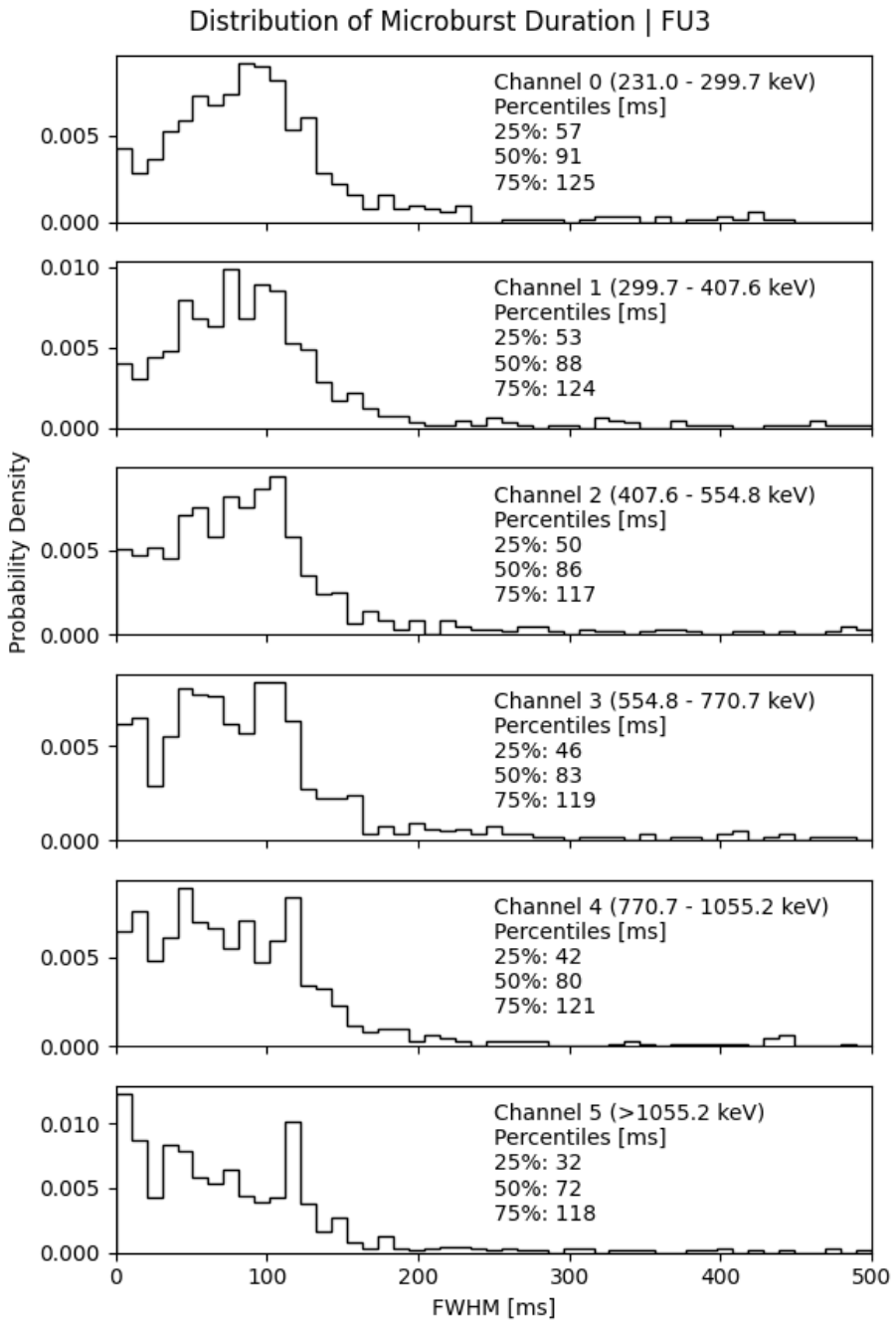
Bad fits


2015-02-05 15:38:30.147750
microburst fit validation
FWHM=500.52 [s]
R^2 = 0.0
adj_R^2 = -0.55
L=7.5
MLT=5.8
(lat,lon)=(61.5, -127.0)
channel=0 (231.0 - 299.7 keV) Counts/18.75 ms
FWHM=3752.09 [s]
R^2 = 0.0
adj_R^2 = -0.55
channel=1 (299.7 - 407.6 keV) Counts/18.75 ms
FWHM=5517.73 [s]
R^2 = 0.0
adj_R^2 = -0.55
channel=2 (407.6 - 554.8 keV) Counts/18.75 ms
FWHM=8433.71 [s]
R^2 = 0.0
adj_R^2 = -0.55
channel=3 (554.8 - 770.7 keV) Counts/18.75 ms
channel=4 (770.7 - 1055.2 keV) Counts/18.75 ms
FWHM=8.51 [s]
R^2 = 0.09
adj_R^2 = -0.41
channel=5 (>1055.2 keV) Counts/18.75 ms
15:38:29
15:38:29
15:38:30
15:38:30
Time


2015-08-27 15:52:52.645000
microburst fit validation
FWHM=0.11 [s]
R^2 = 0.95
adj_R^2 = 0.93
L=6.0
MLT=9.1
(lat,lon)=(54.6, -94.4)
channel=0 (231.0 - 299.7 keV) Counts/18.75 ms
FWHM=0.09 [s]
R^2 = 0.98
adj_R^2 = 0.96
channel=1 (299.7 - 407.6 keV) Counts/18.75 ms
FWHM=0.1 [s]
R^2 = 0.85
adj_R^2 = 0.76
channel=2 (407.6 - 554.8 keV) Counts/18.75 ms
FWHM=0.11 [s]
R^2 = 0.37
adj_R^2 = 0.02
channel=3 (554.8 - 770.7 keV) Counts/18.75 ms
channel=4 (770.7 - 1055.2 keV) Counts/18.75 ms
FWHM=9.74 [s]
R^2 = 0.17
adj_R^2 = -0.29
channel=5 (>1055.2 keV) Counts/18.75 ms
15:52:51
15:52:52
15:52:52
15:52:53
15:52:53
Time

Duration Distributions

- Microburst fits were filtered
  - Each microburst max(R^2) > 0.9 in all energy channels
- Distributions in channels 0-2 look believable
  - Durations slightly decrease in energy and are already narrower than SAMPEX.
  - Perhaps this can be attributed to the drastically different geometric factors of FIREBIRD-II and SAMPEX?
- Channels 3-5 don't look as nice.
- A suspicious peak around 120 ms. Most evident in 4th and 5th energy channel.
- Possible fit filtering modifications
  - Ensure that the 6 channel FWHMs are within X% of the mean FWHM
  - Check that the amplitudes are all positive
  - Use a 0s filter to remove dead time saturation



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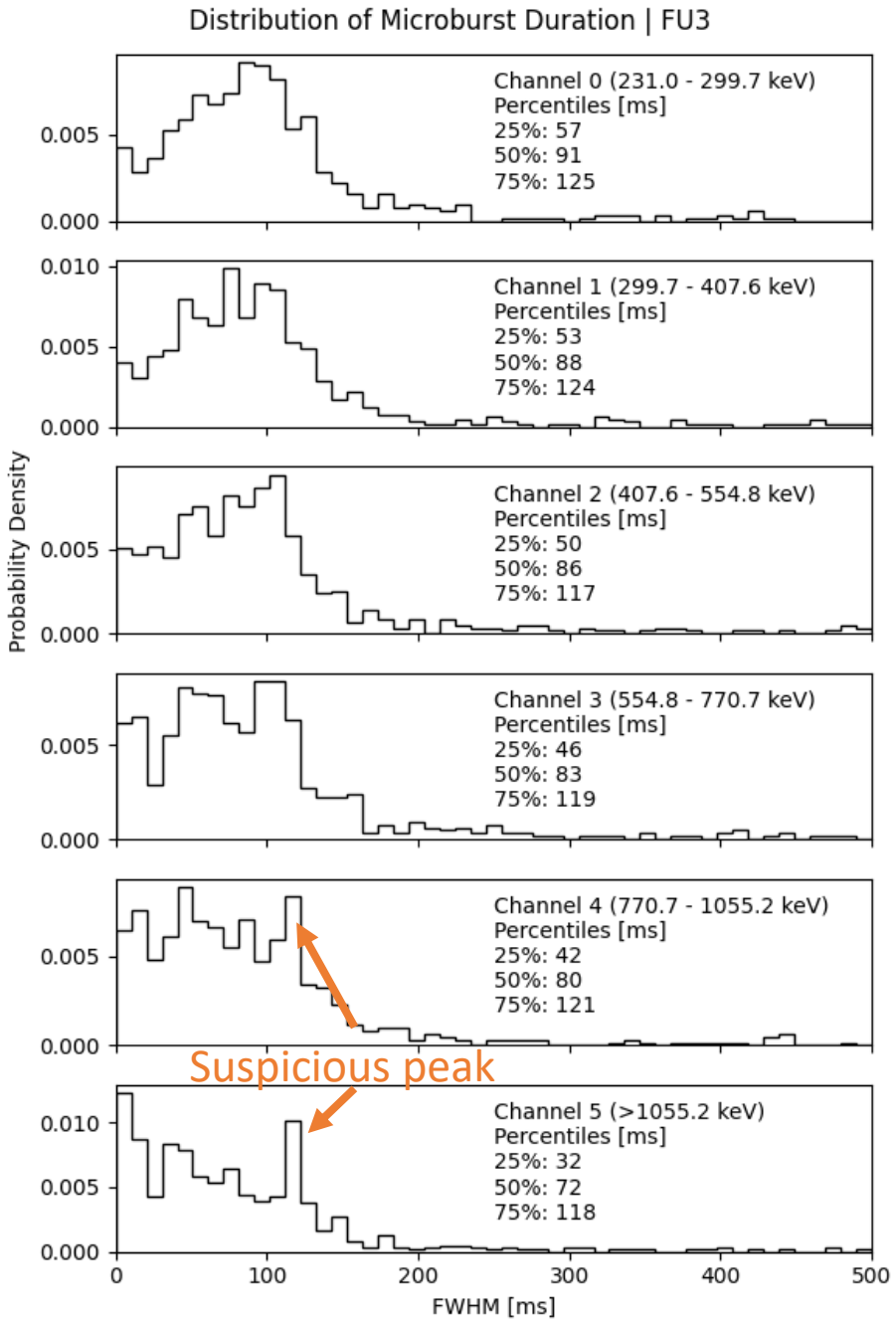
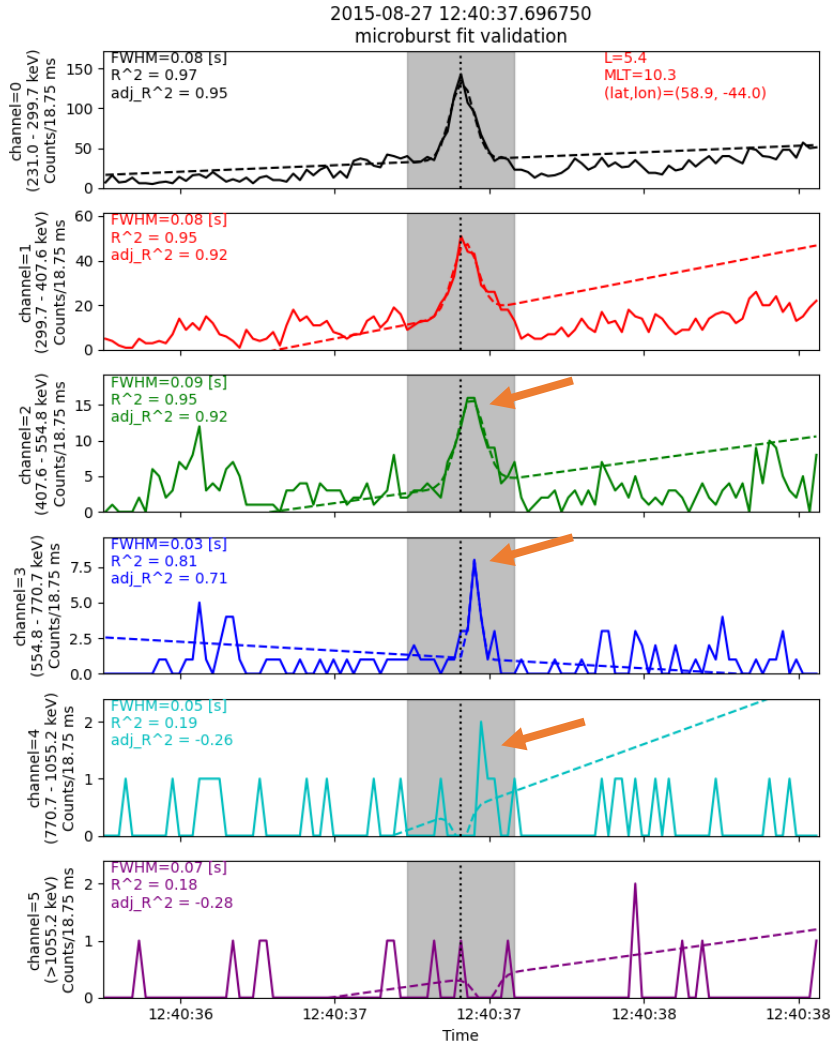
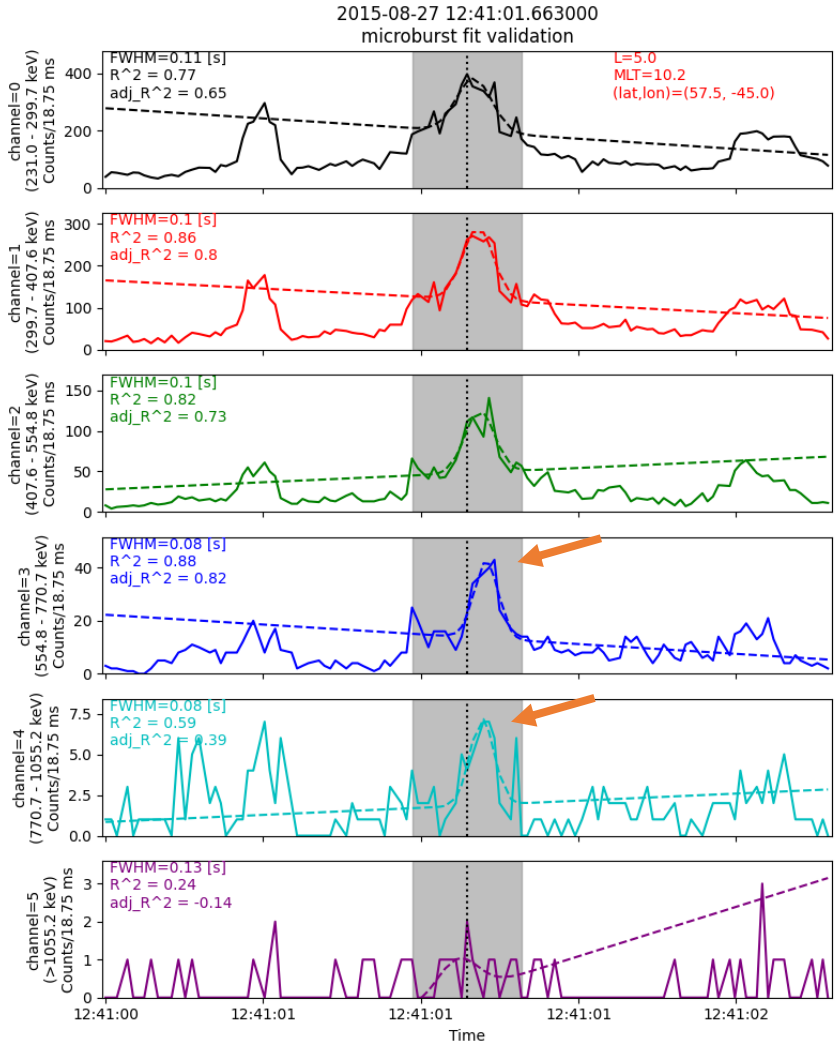


Inverse Dispersion?

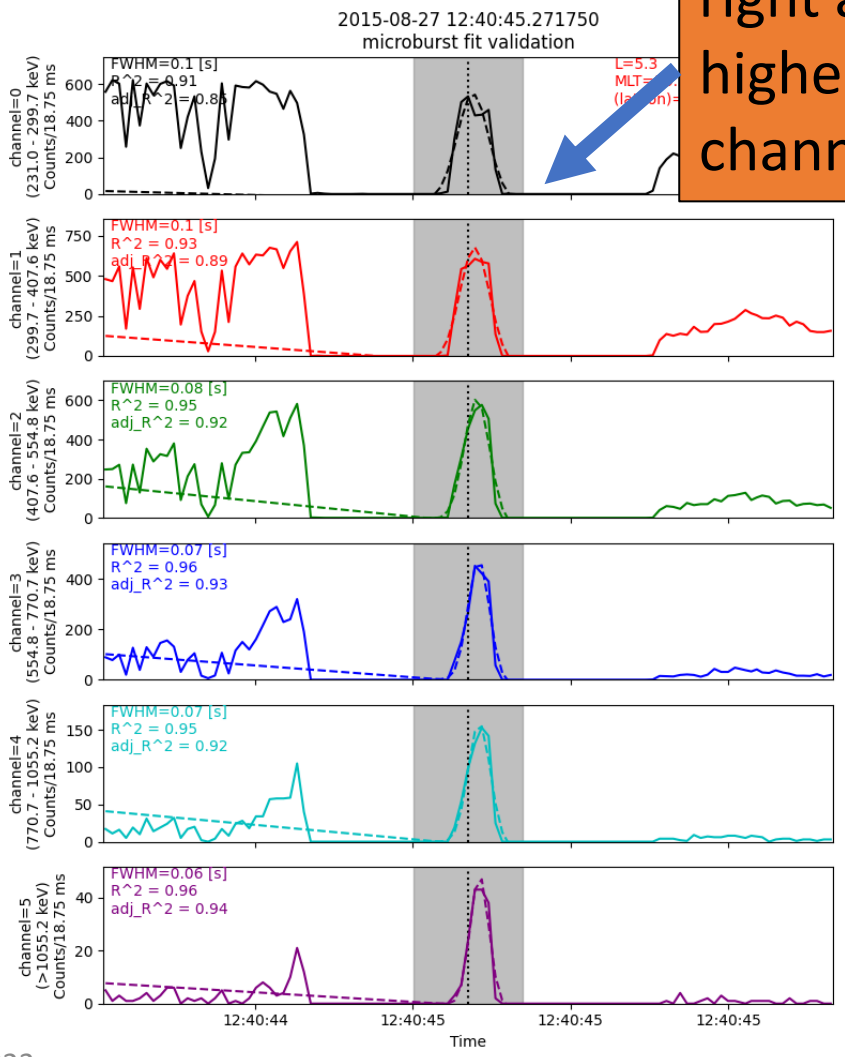
I don’t see saturation and I’m surprised that I didn’t catch them earlier.



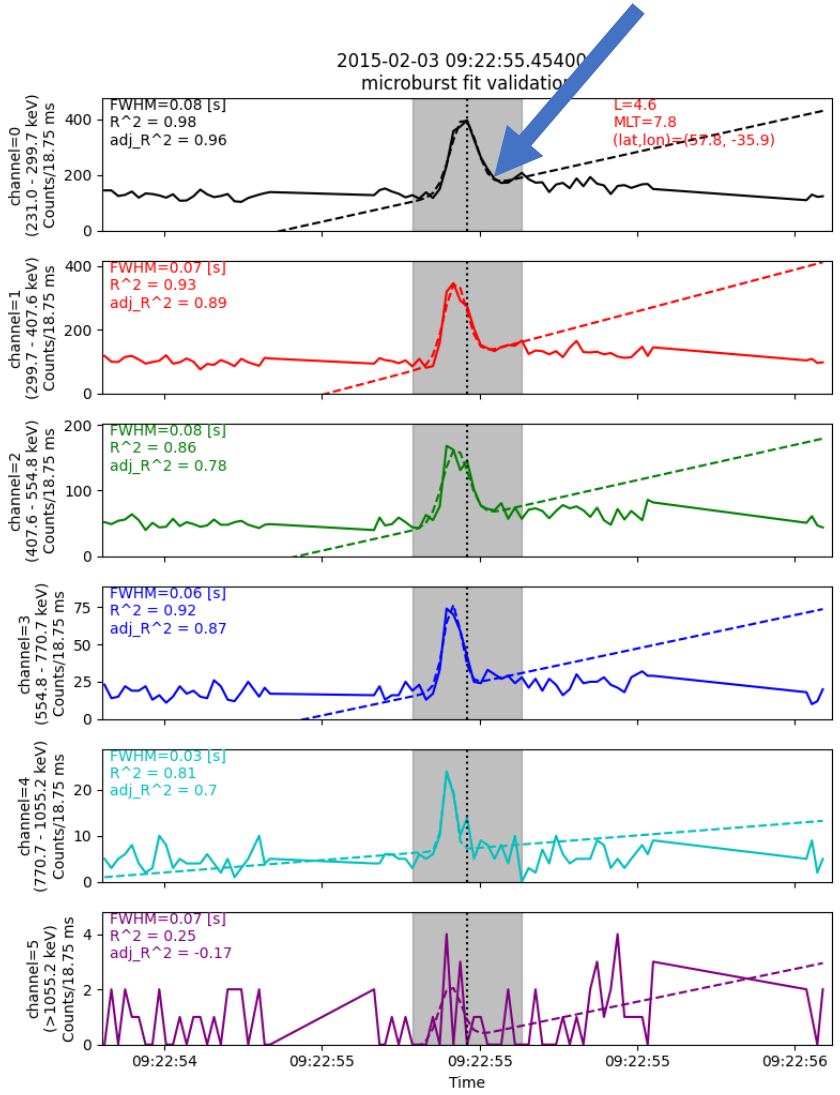


Dispersion?

Saturation? Lower energy channels dip right as the higher energy channel peaks.



Regular dispersion



Impressions & Improvements

- Impressions
  - The 200-500 keV durations look nice and surprisingly don't change much in energy.
  - The > 1 MeV microburst durations should have been close to 100 ms, but the distribution looks wrong
- Improvements
  - Use my "number of 0's" based saturation filter to remove bad events.
  - Closely inspect the fits
  - Try out different fit initial guesses such as initial fwhm
  - Maybe could try this using the BARREL data?
- This presentation and code is on github: https://github.com/mshumko/fbrbsp/tree/main/fbrbsp/microburst_duration & https://github.com/mshumko/fbrbsp/tree/main/presentations