UNIVERSITY OF TURKU

CONNECTING SOLAR FLARE HARD X-RAY SPECTRA TO IN-SITU ELECTRON SPECTRA USING RHESSI AND STEREO/SEPT OBSERVATIONS

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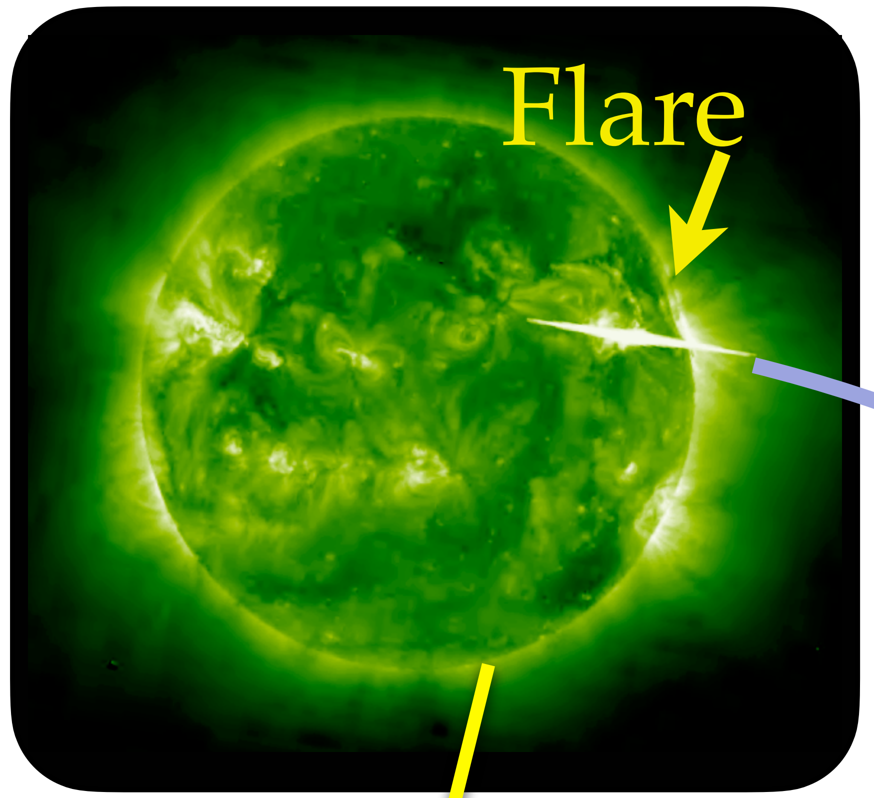
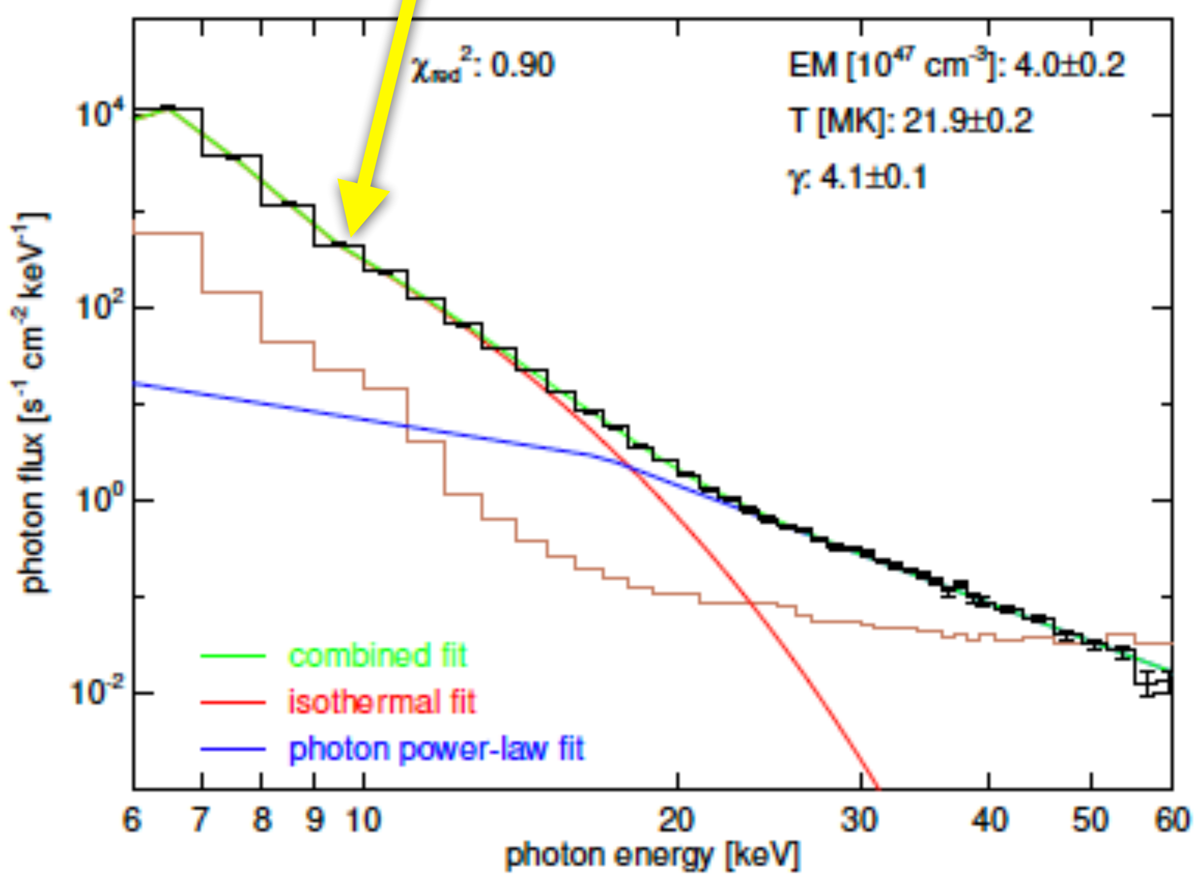
MOTIVATION AND DATA SELECTION

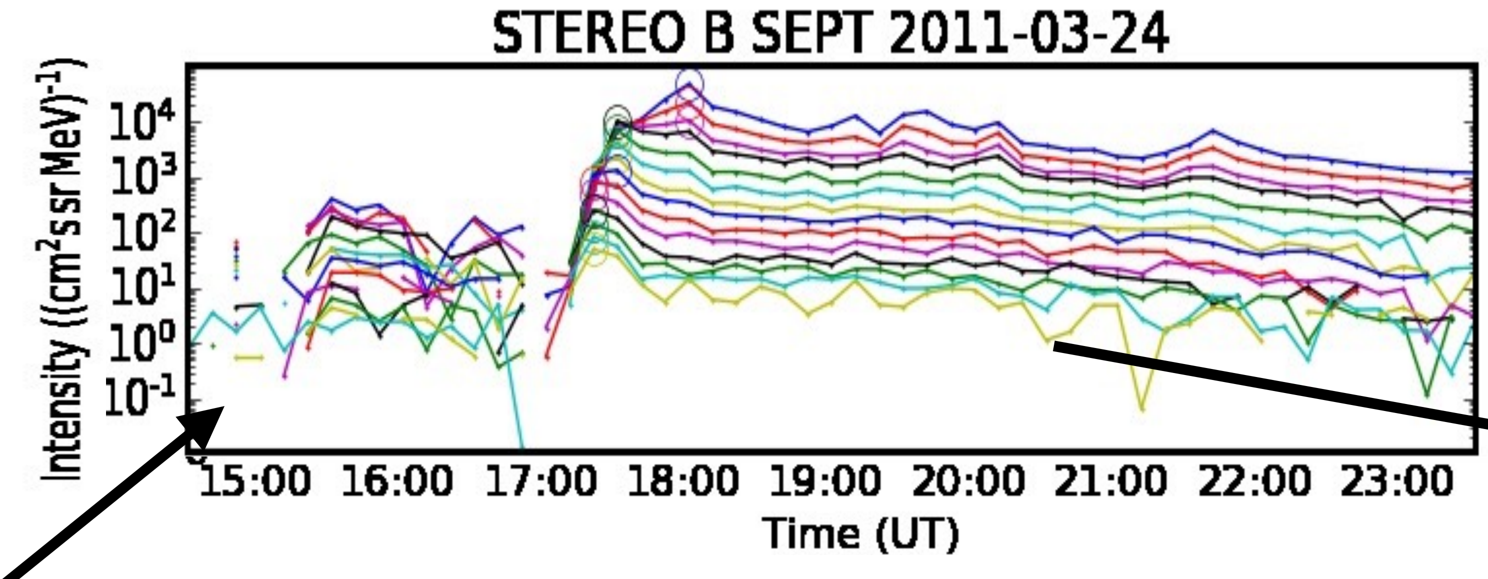
We compare the flare HXR spectra with in-situ near-relativistic electron spectra which are assumed to represent the same accelerated electron population

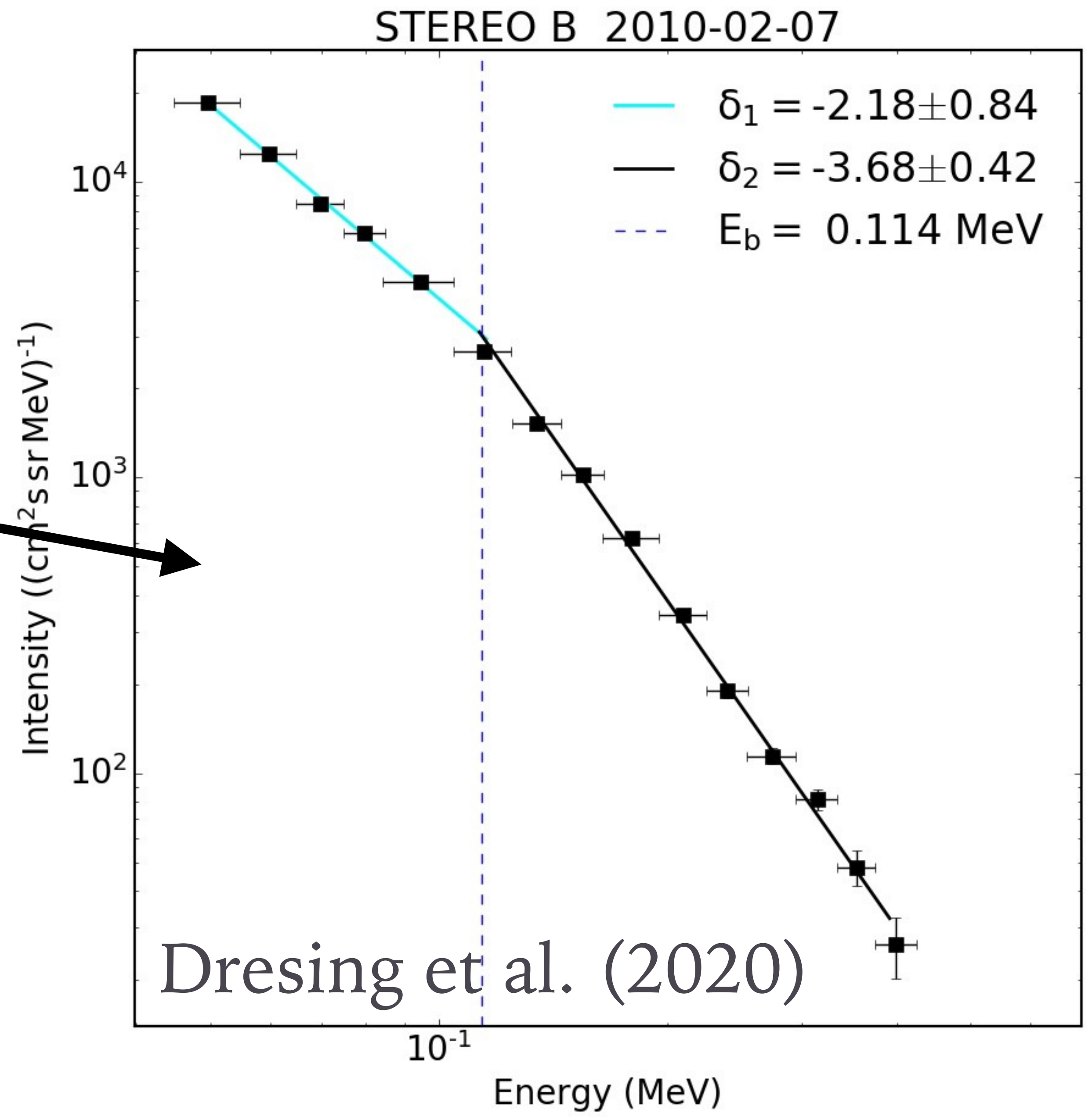


Energetic electrons

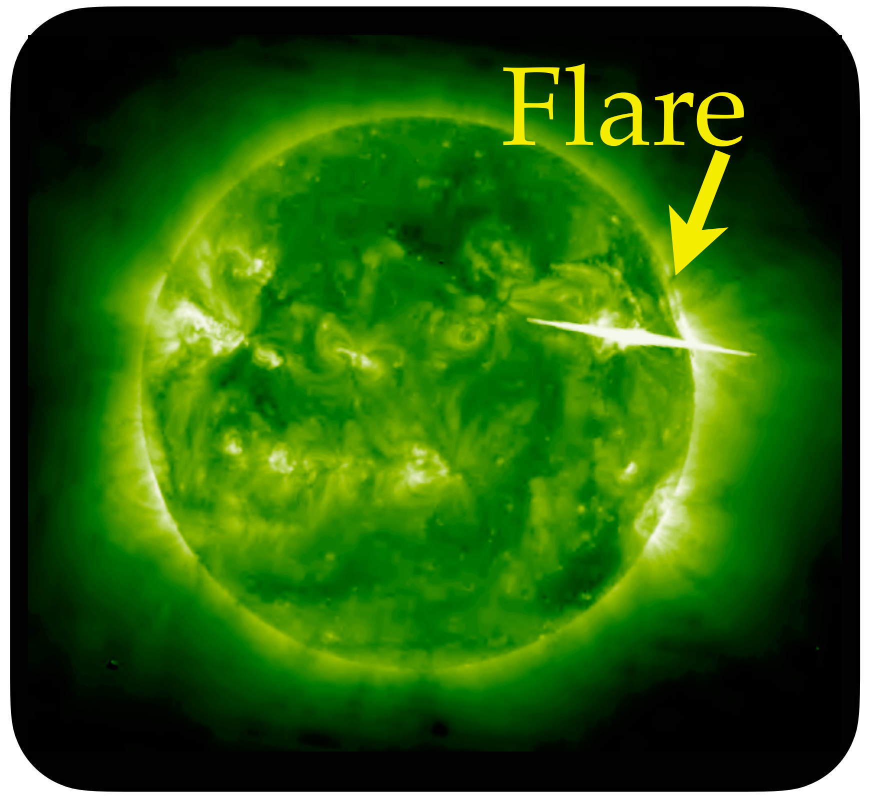
Hard X-Ray (HXR) spectrum observed by RHESSI







THE CHOICE OF THE CORRECT SPECTRAL PART OF THE IN-SITU SPECTRUM



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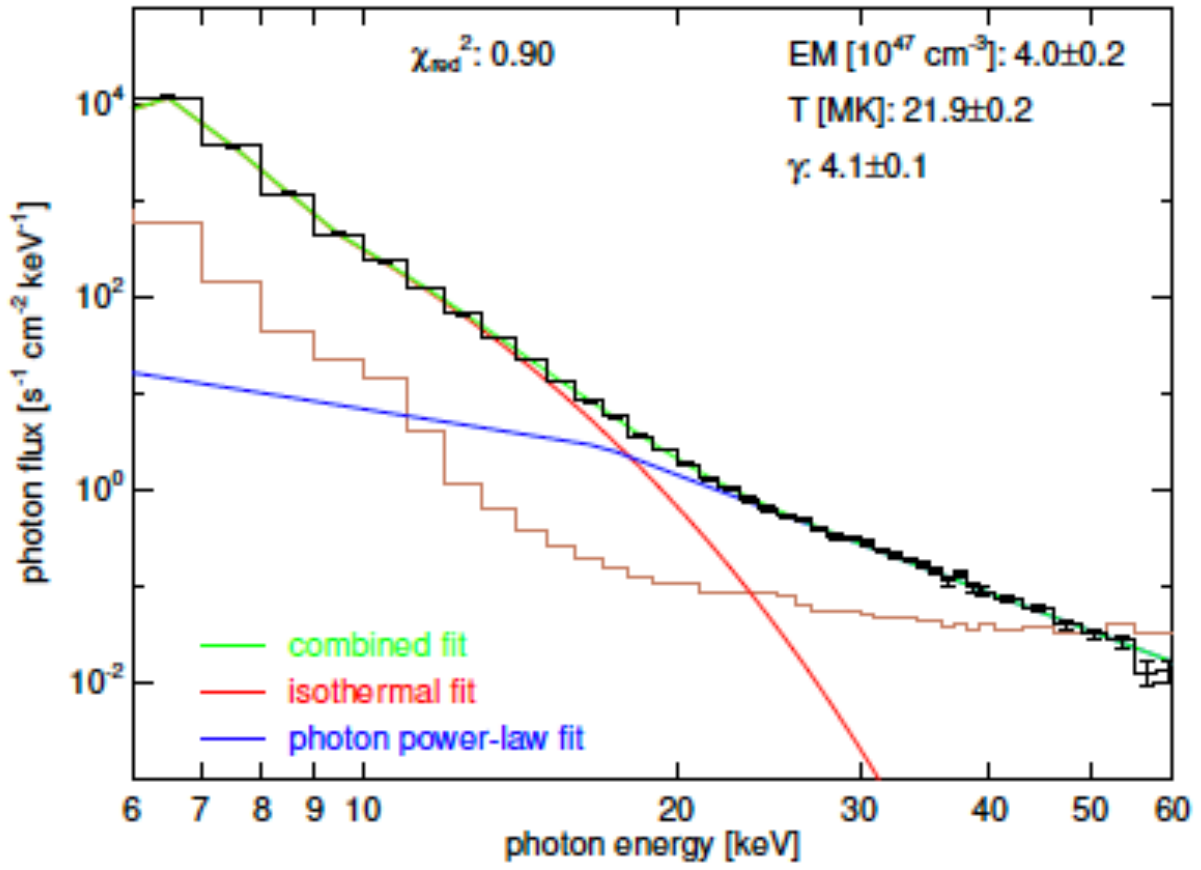

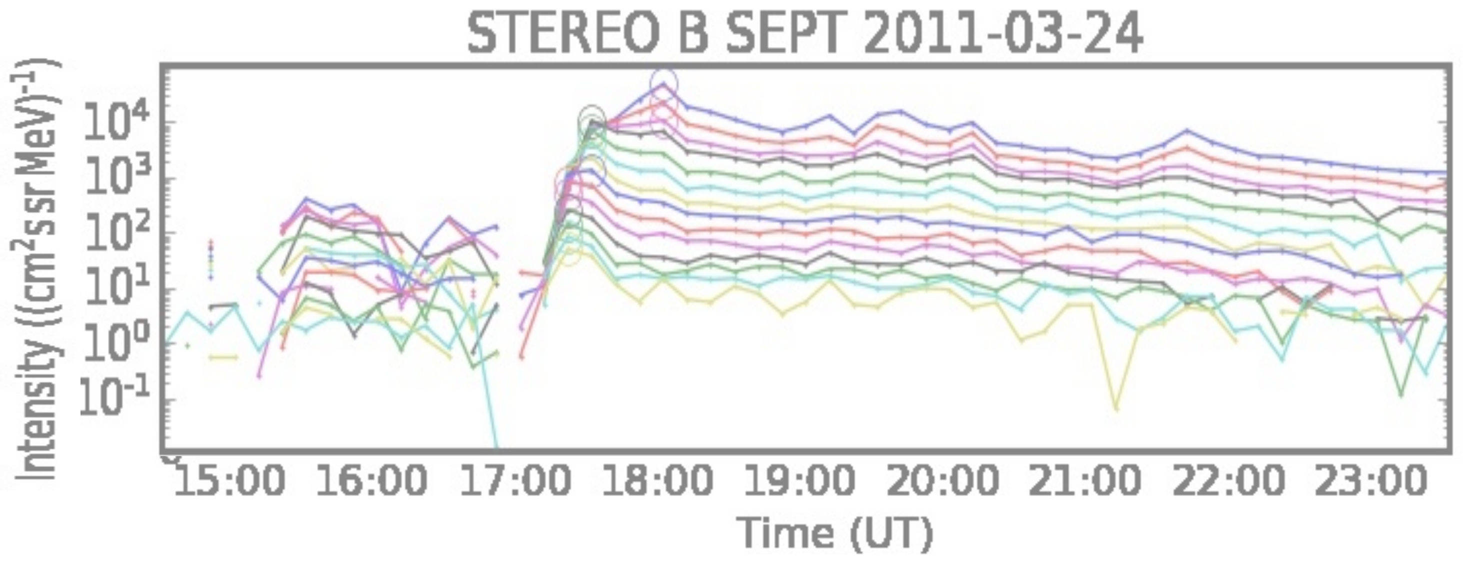

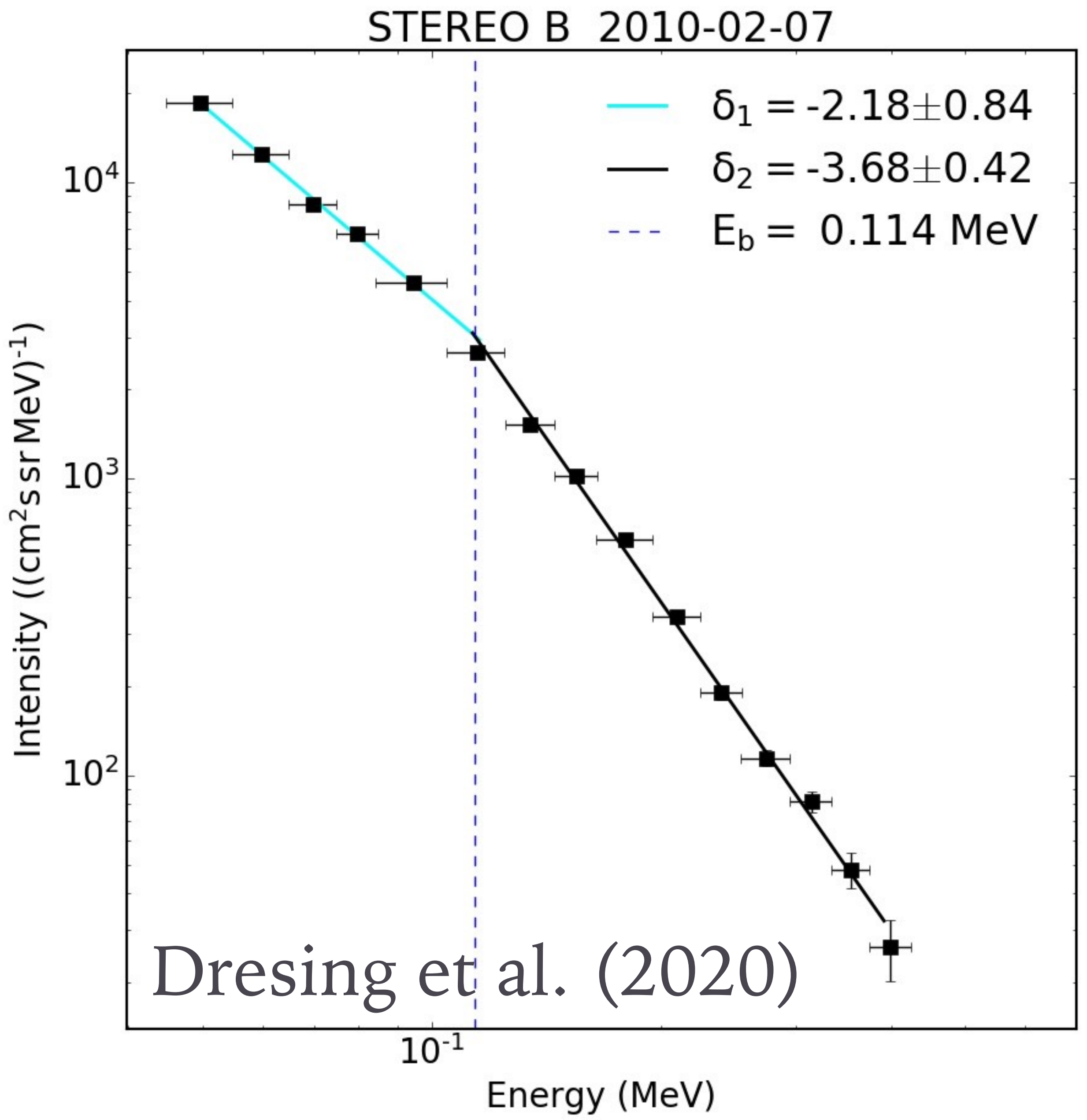

Is the footprint of the flare acceleration still observed at 1AU?

Does the spectrum change from the Sun to 1AU?

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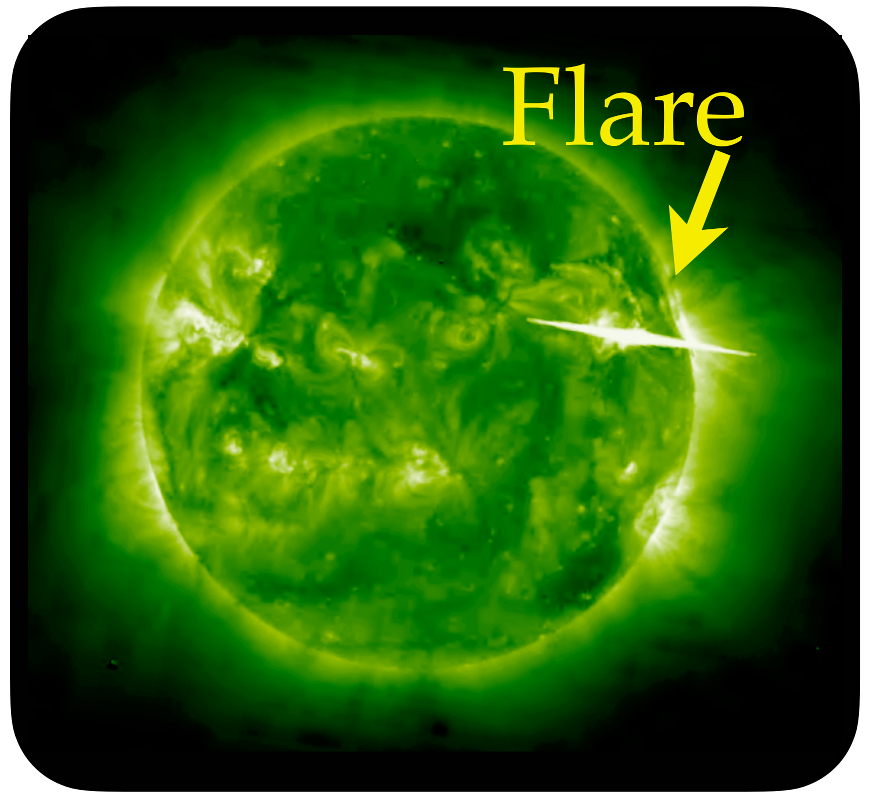
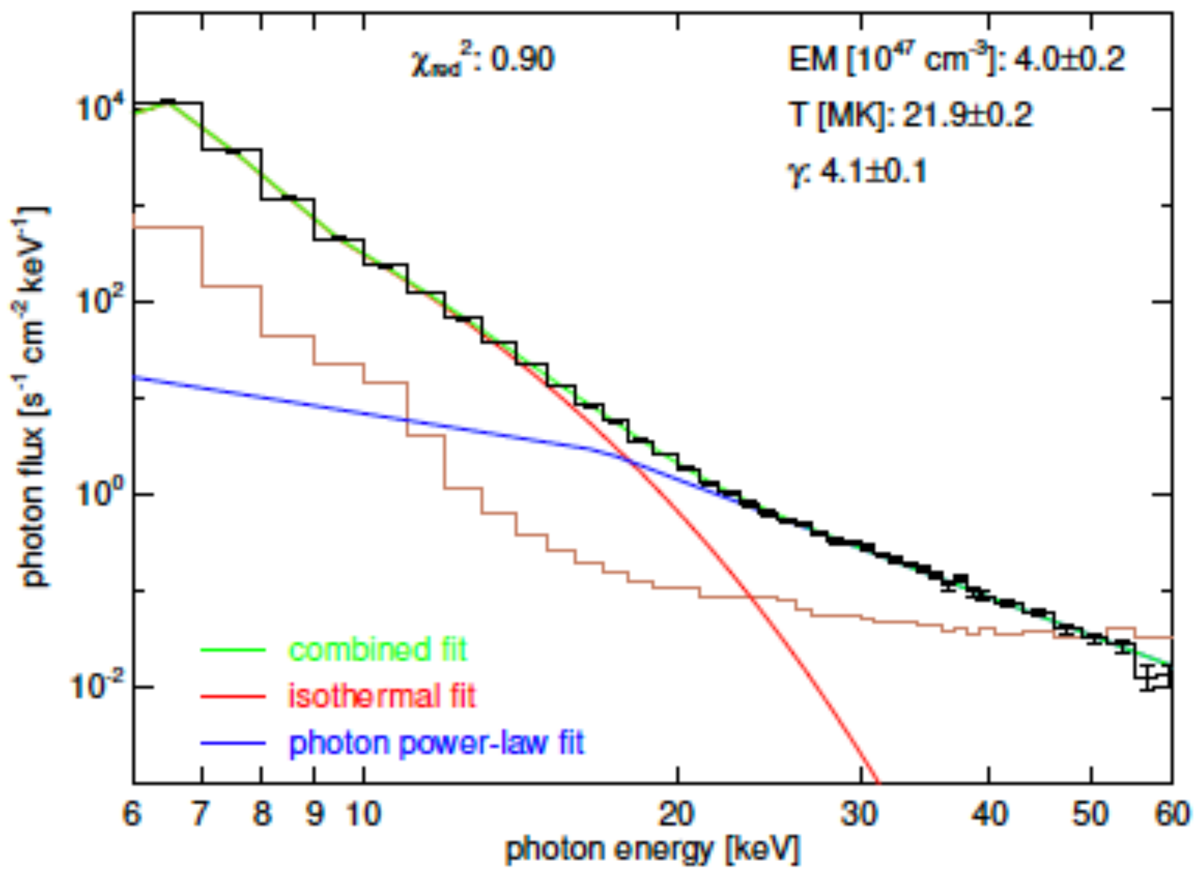
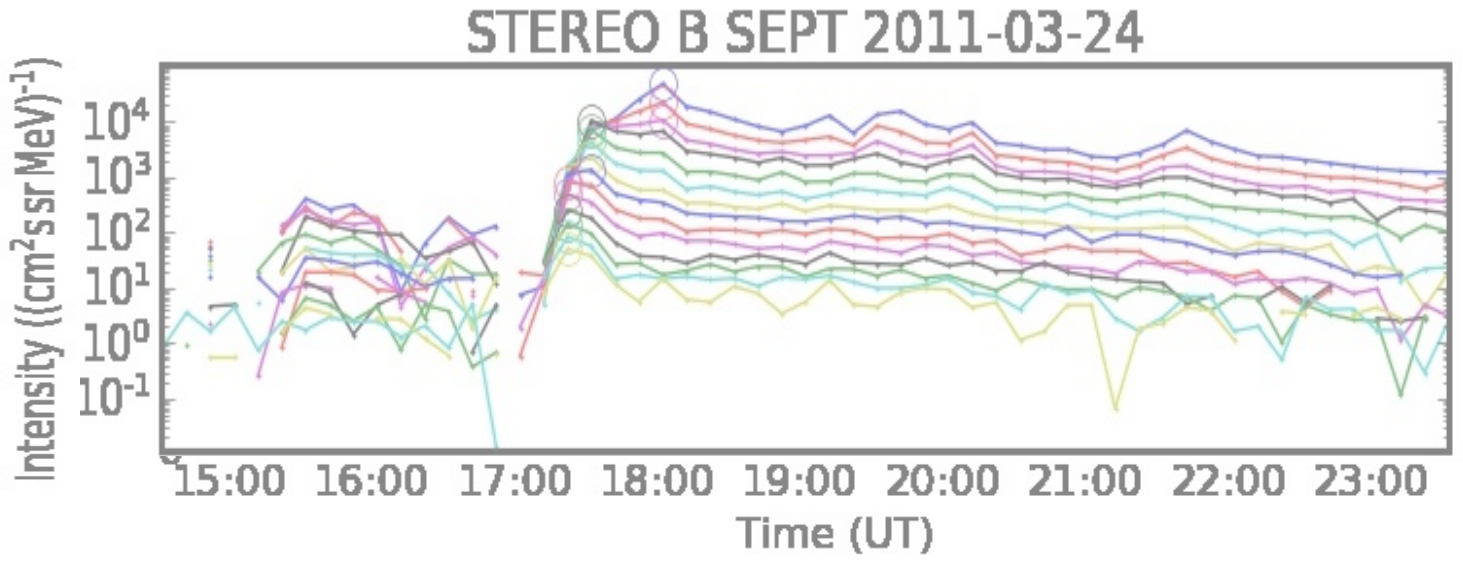


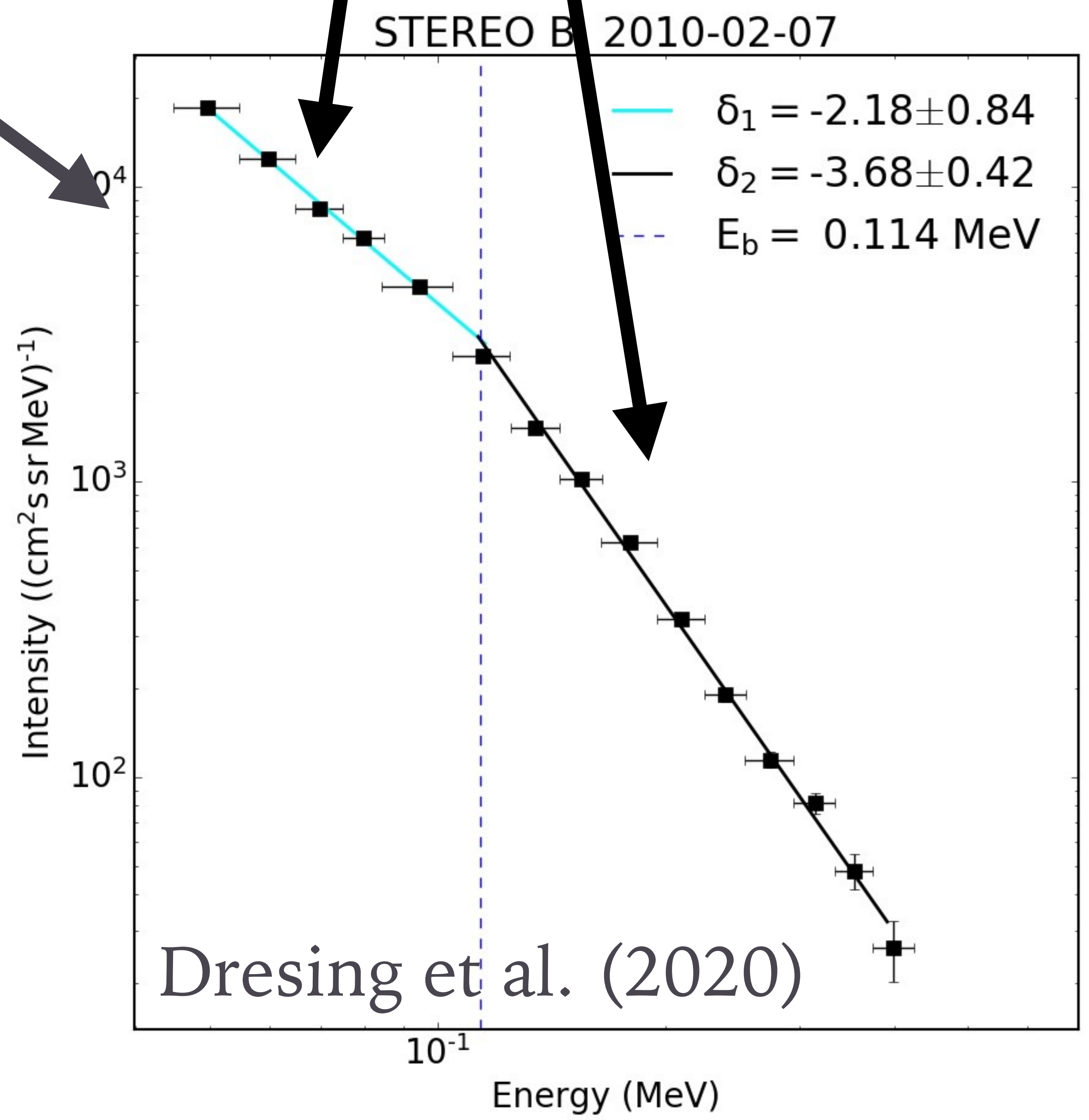
Which part of the in-situ spectrum should be used for correlation?

However, near-relativistic electron spectra reveal often a double power law shape

Hard X-Ray (HXR) spectrum observed by RHESSI







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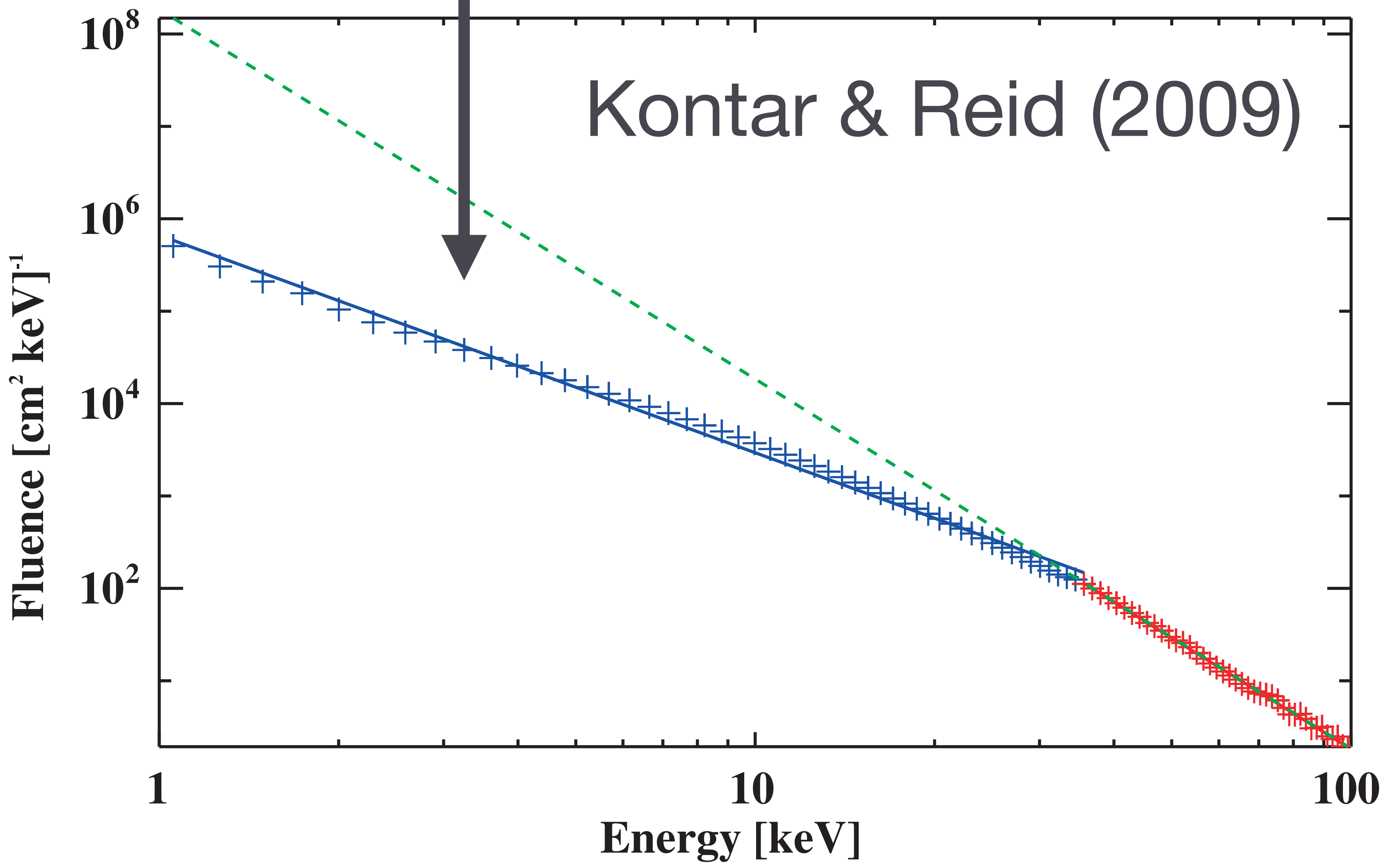
MODIFICATIONS OF THE ORIGINAL SPECTRUM

There are at least two potential transport-related processes that can cause spectral transitions:

1) The generation of Langmuir turbulence by a few keV electrons (which results into type III radio bursts). This causes a depression of the low energy part of the spectrum.



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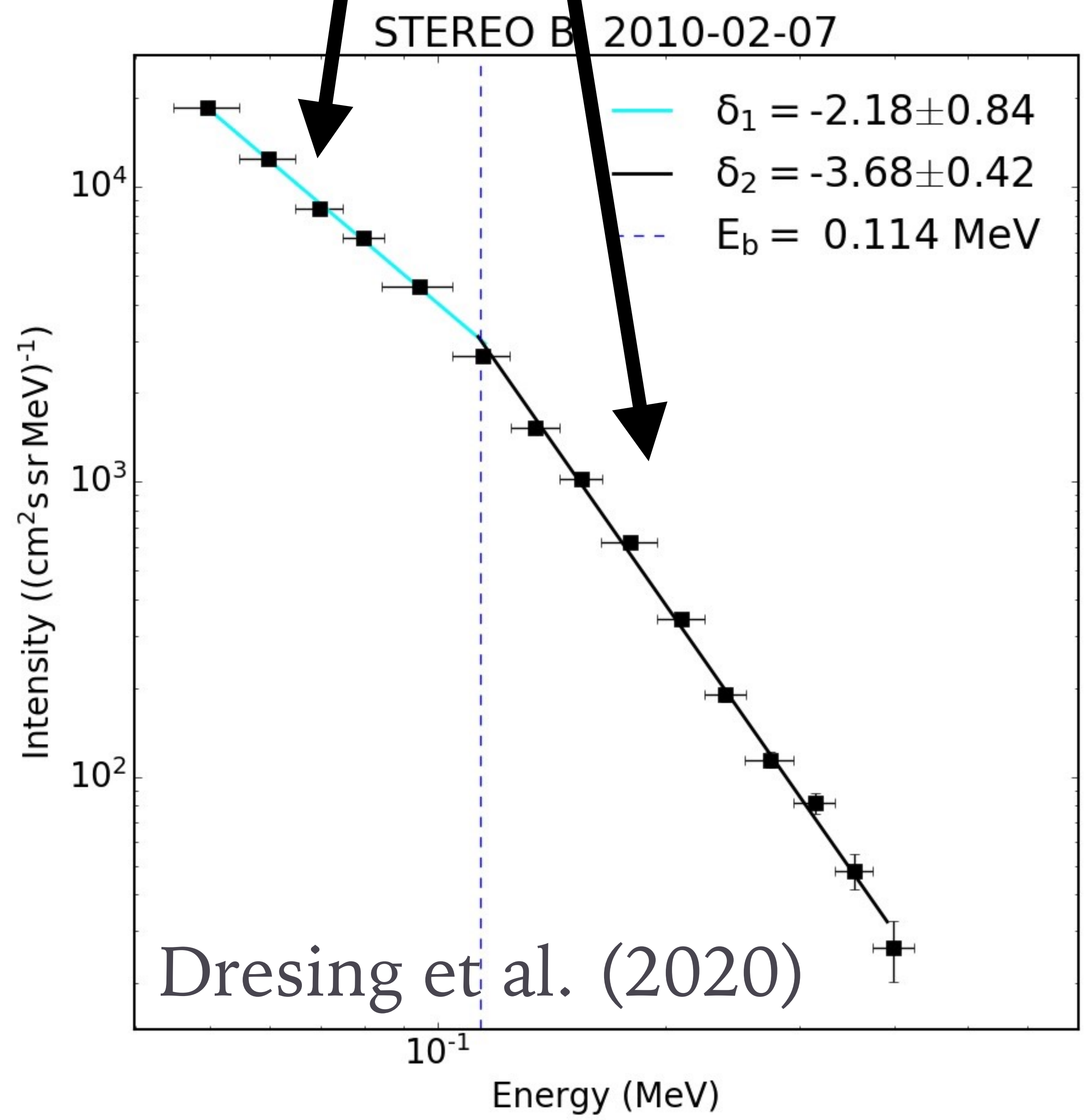

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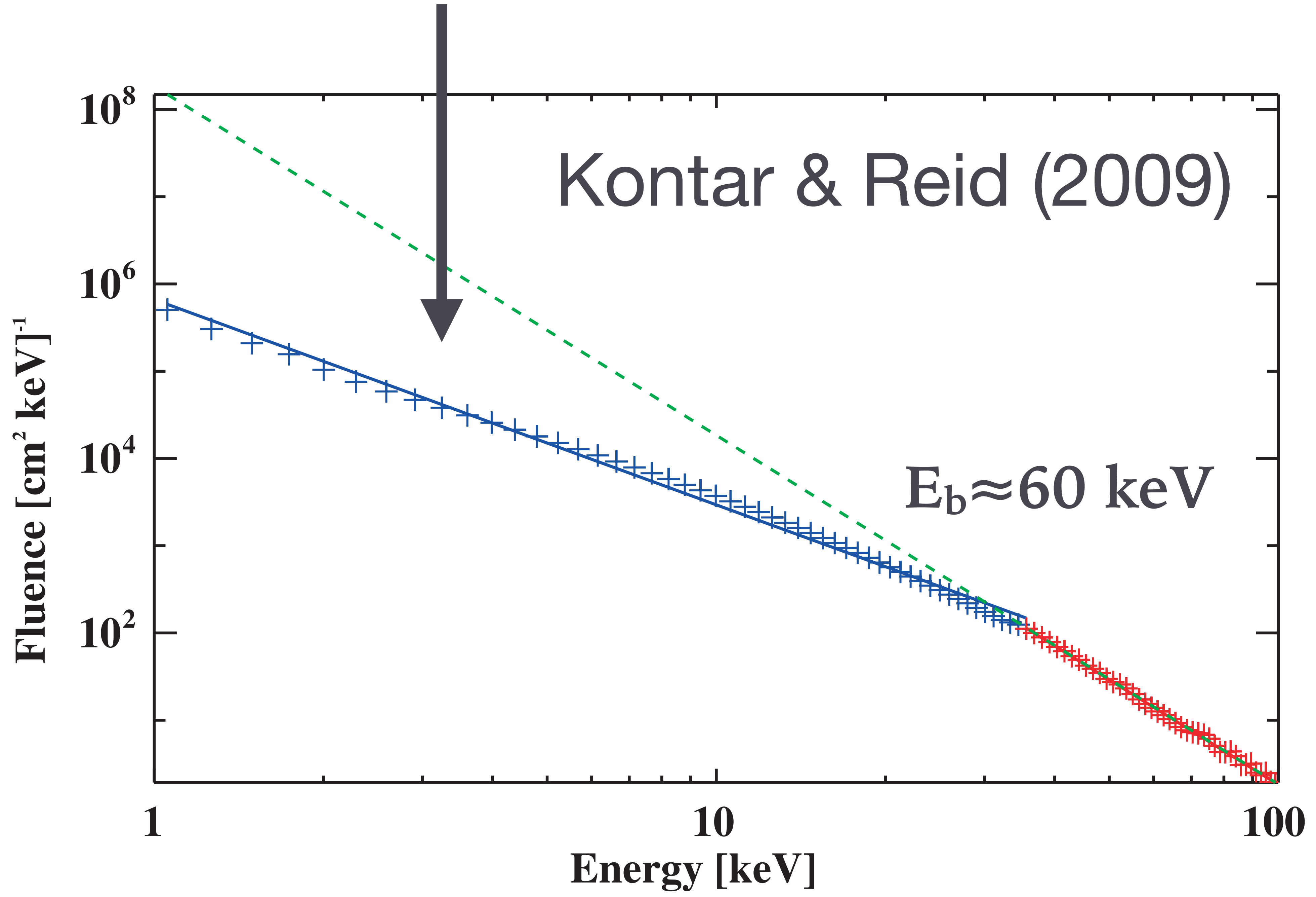

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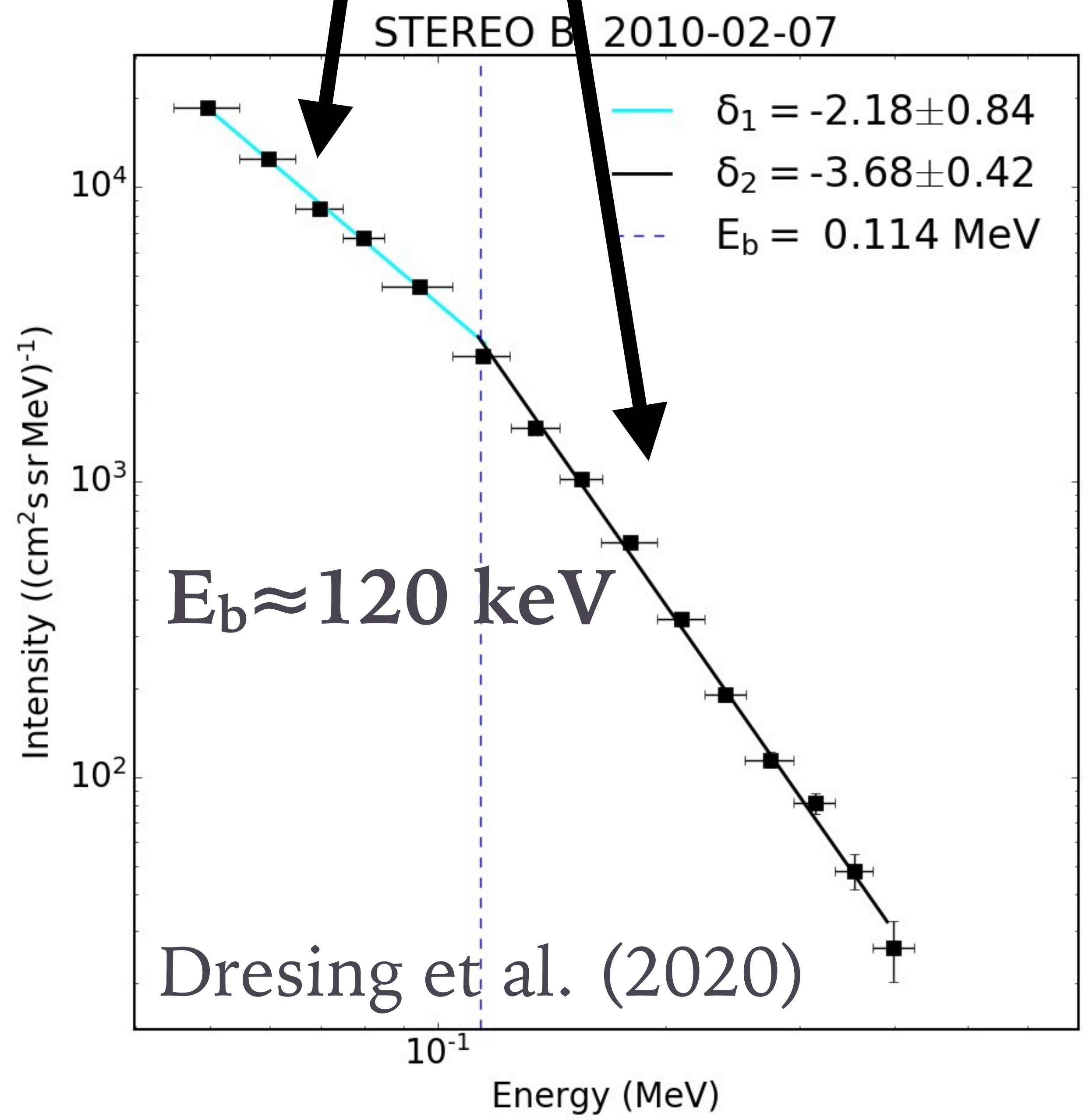

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There are at least two potential transport-related processes that can cause spectral transitions:

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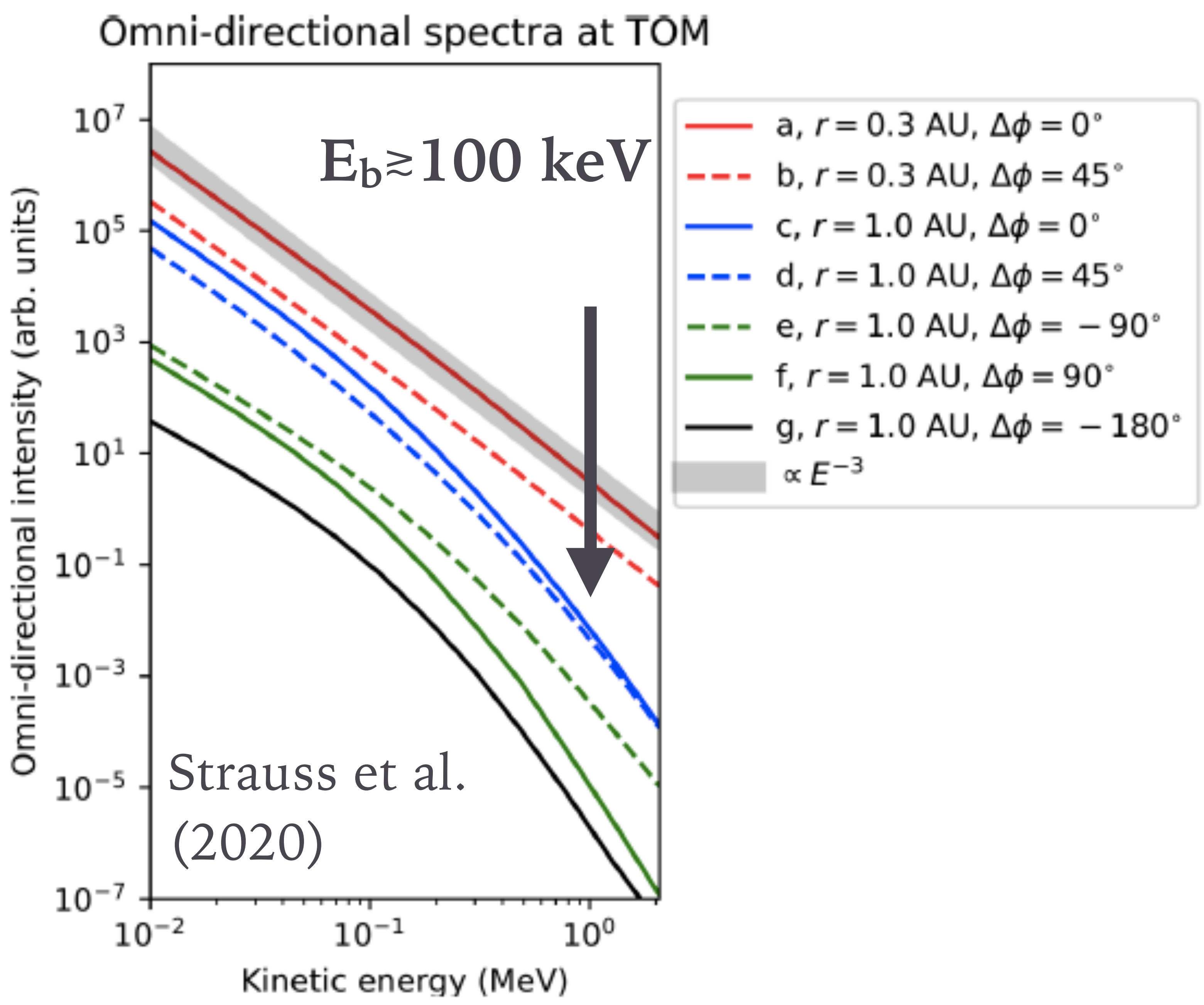

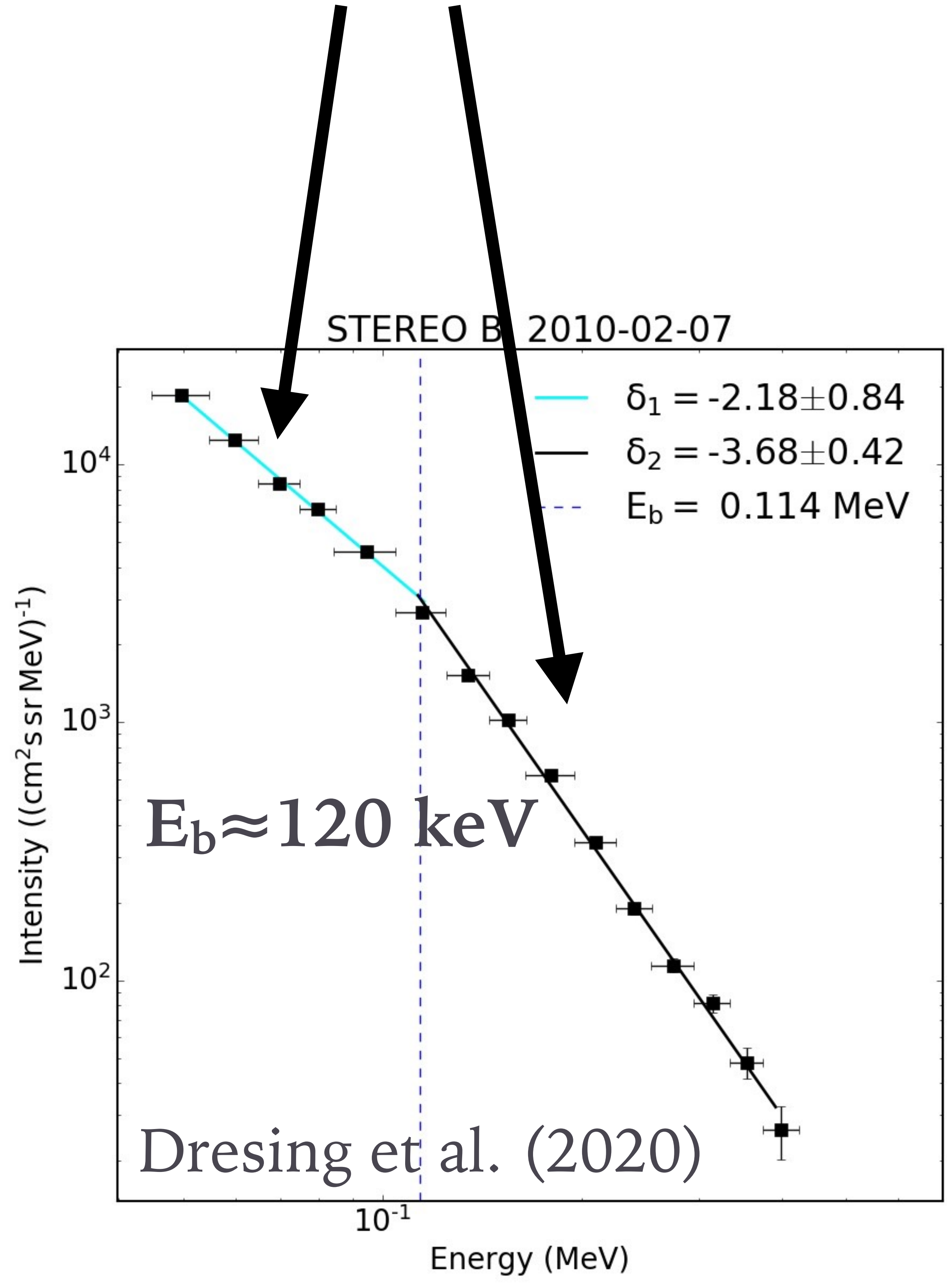

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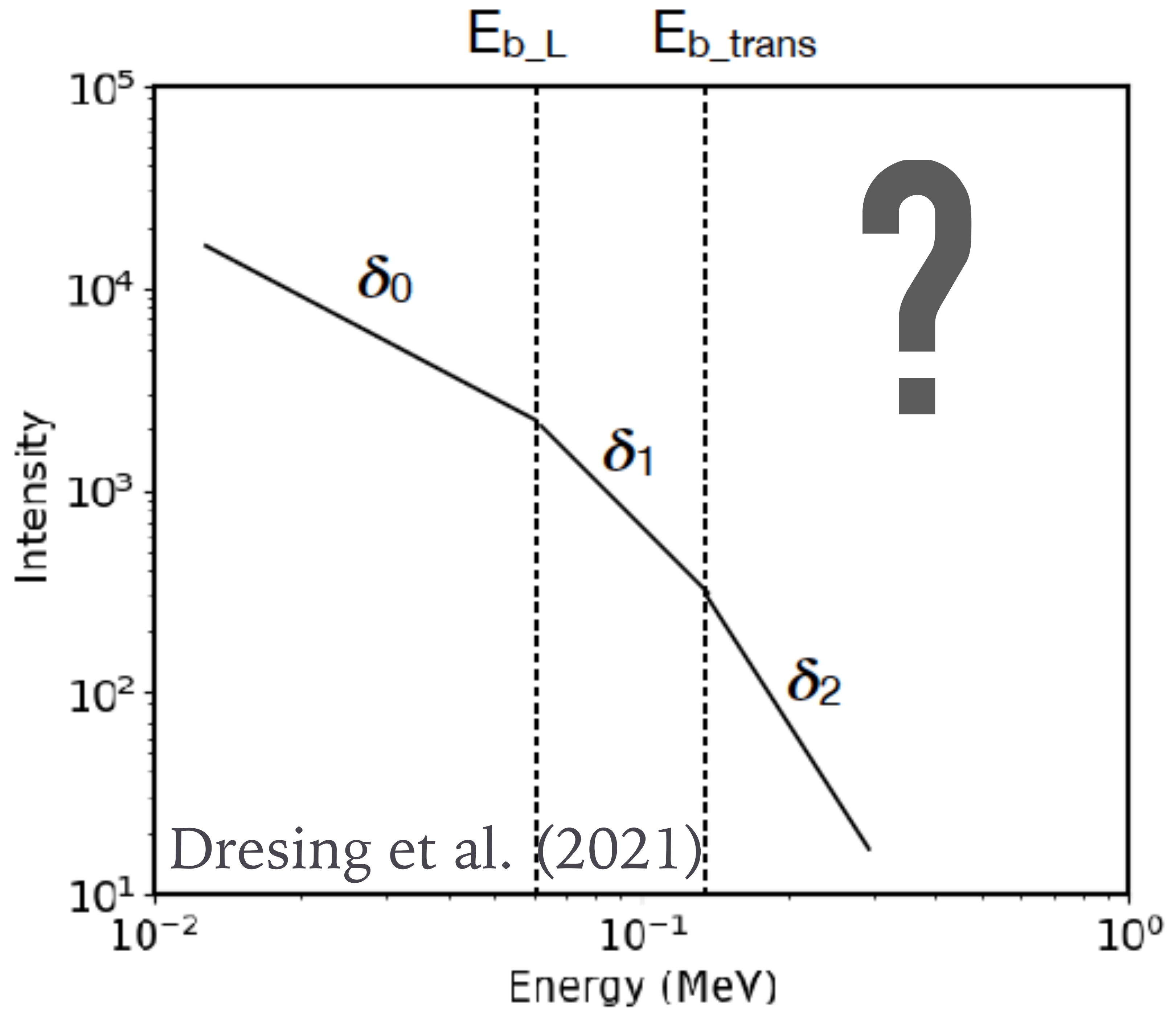
It is therefore possible that two different kinds of spectral breaks exist. These were not yet clearly resolved in a single spacecraft measurement and could also overlap.



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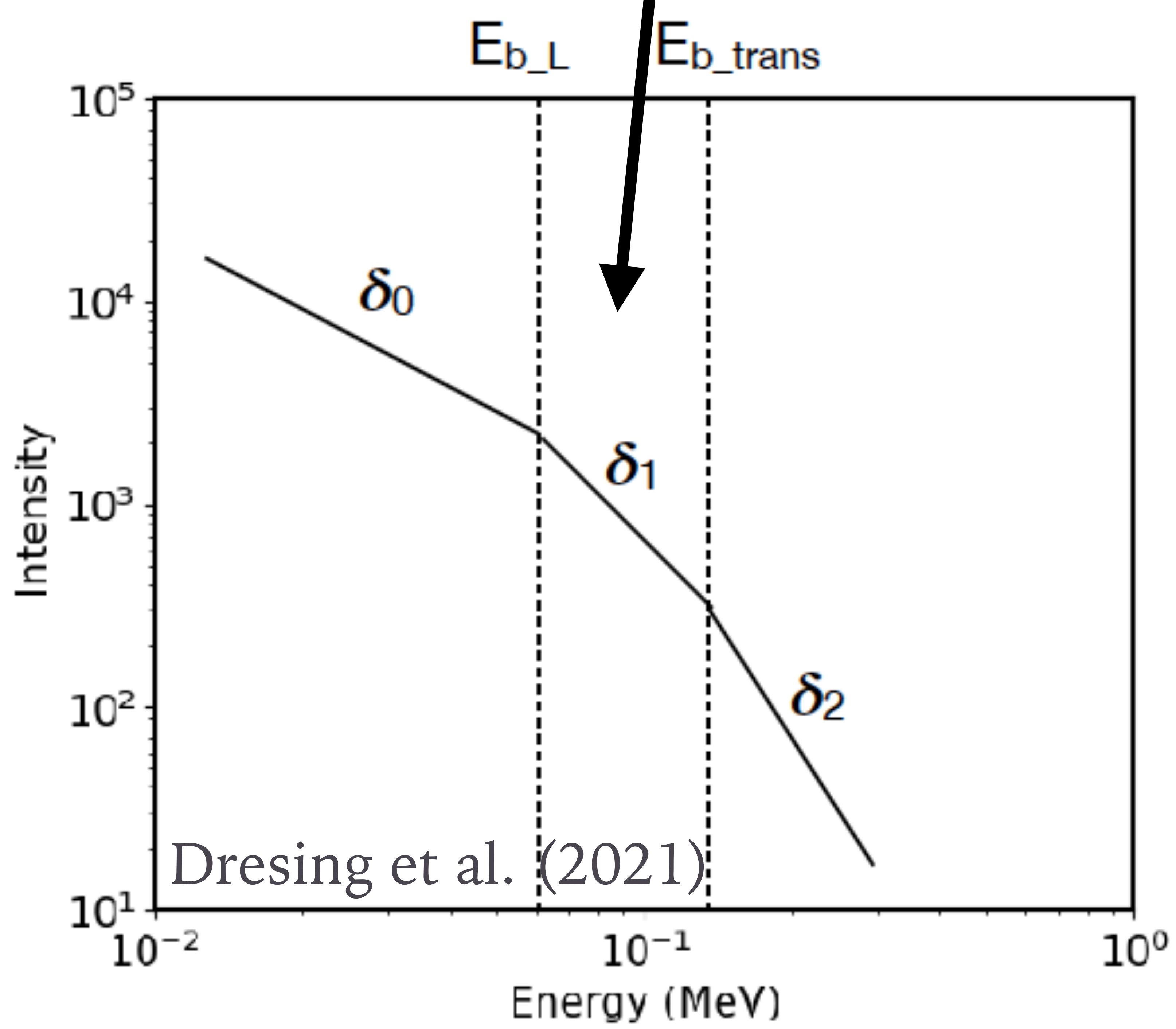

Dresing et al. (2021)

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STEREO ELECTRON EVENTS WITH ASSOCIATED RHESSI HXR FLARE OBSERVATIONS

Using RHESSI HXR flare observations and STEREO/SEPT near-relativistic electron observations between 2007 and 2018 we find 17 common events which allow for a spectral comparison

HXR peak time	GOES class	flare location	γ	δ_1	δ_2	E_b [keV]	s/c
2007/01/24 00:31:24	B5.1	S05W61	3.2 ± 0.09	3.0 ± 1.0	3.8 ± 0.6	79	A
2007/01/24 00:31:24	B5.1	S05W61	3.2 ± 0.09	2.7 ± 1.0	3.6 ± 0.9	107	B
2007/01/24 05:16:09	B6.8	S05W64	4.1 ± 0.26	3.6 ± 0.3	–	–	B
2007/01/24 05:16:09	B6.8	S05W64	4.1 ± 0.26	3.2 ± 0.6	3.9 ± 1.3	98	A
2009/12/22 04:56:10	C7.2	S28W47	2.7 ± 0.04	2.0 ± 0.1	3.0 ± 0.2	122	B
2010/02/08 03:12:24	C6.2	N22E00	3.4 ± 0.10	2.4 ± 0.2	–	–	B
2010/11/12 03:53:41	C1.0	S21E02	3.7 ± 0.06	3.6 ± 0.3	–	–	B
2010/11/12 08:01:54	C1.5	S23W01	3.9 ± 0.08	2.9 ± 0.3	4.5 ± 0.5	118	B
2010/11/17 04:36:44	B7.8	S34E21	4.3 ± 0.11	1.6 ± 1.7	3.4 ± 1.0	69	B
2011/03/24 17:04:34	C9.1	S15E41	4.1 ± 0.05	2.9 ± 0.6	5.1 ± 2.3	195	B
2012/01/12 00:51:58	C1.5	N21E20	4.9 ± 0.53	4.4 ± 0.4	6.4 ± 2.0	87	B
2012/03/25 00:27:54	C3.0	N20E26	3.4 ± 0.03	2.7 ± 0.4	4.0 ± 0.9	110	B
2012/04/16 00:26:14	C1.8	N13E89	4.9 ± 0.10	4.8 ± 0.5	–	–	B
2012/05/07 03:21:58	C2.7	N13E67	4.4 ± 0.03	2.9 ± 0.2	4.9 ± 0.6	106	B
2012/06/27 12:36:00	C3.4	N15E64	3.7 ± 0.03	2.4 ± 0.3	4.9 ± 0.6	90	B
2012/06/28 02:12:24	C2.6	N17E56	4.3 ± 0.09	2.8 ± 0.6	3.7 ± 0.4	90	B
2012/07/01 07:14:44	C5.4	N16E11	4.3 ± 0.14	3.6 ± 0.3	5.5 ± 0.7	104	B
2014/03/19 16:26:14	C3.3	S12E81	5.9 ± 0.20	3.1 ± 0.7	4.0 ± 0.7	101	B
2014/06/09 17:05:04	C8.8	S19E90	3.5 ± 0.05	2.6 ± 0.5	4.0 ± 1.4	90	B

Dresing et al. (2021)

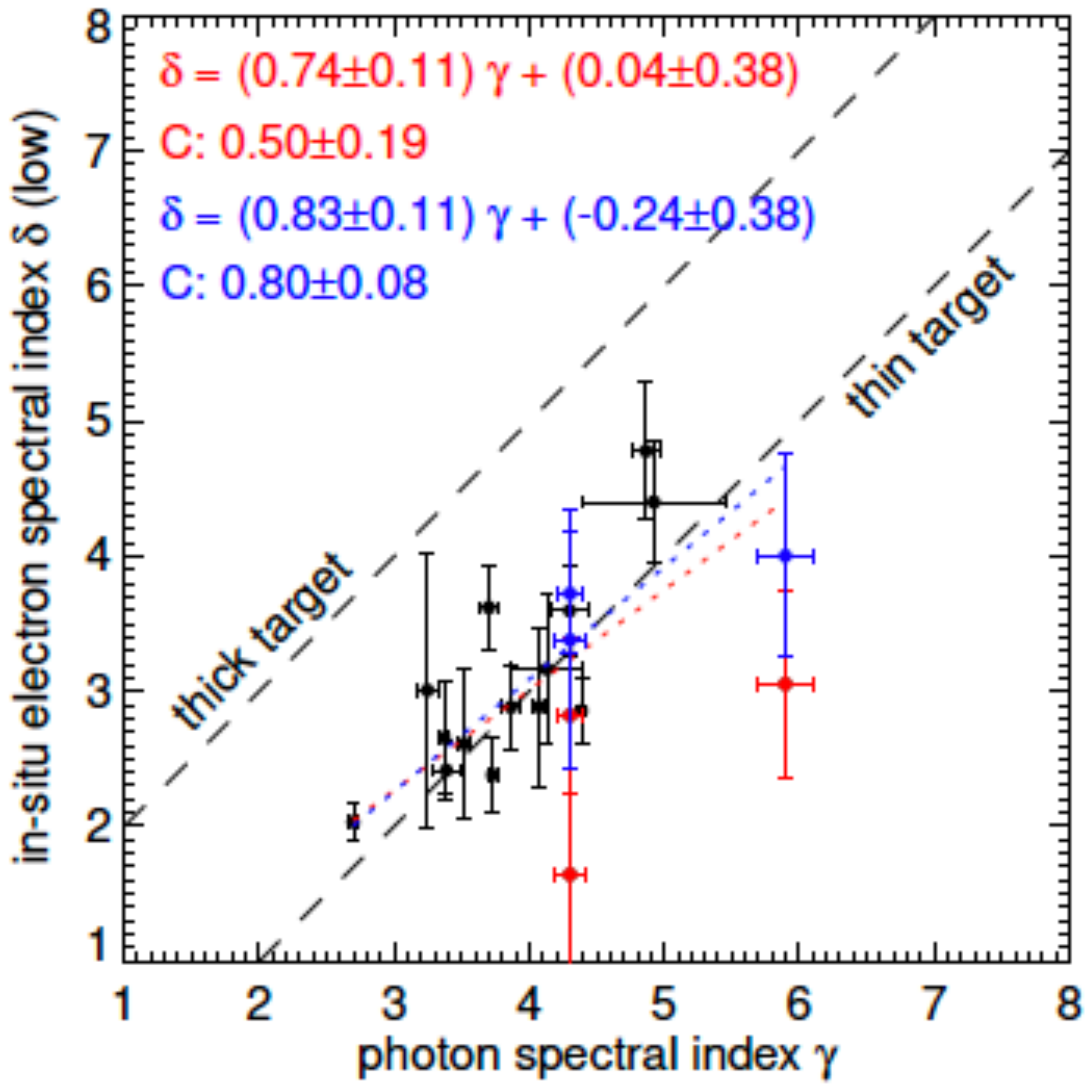
Strauss et al. (2020) therefore suggest to use the spectral range between ~50-100 keV as it might be least modified by transport effects

Unfortunately, many spectral breaks of are lying in the suggested range making a choice between the two spectral indices difficult.

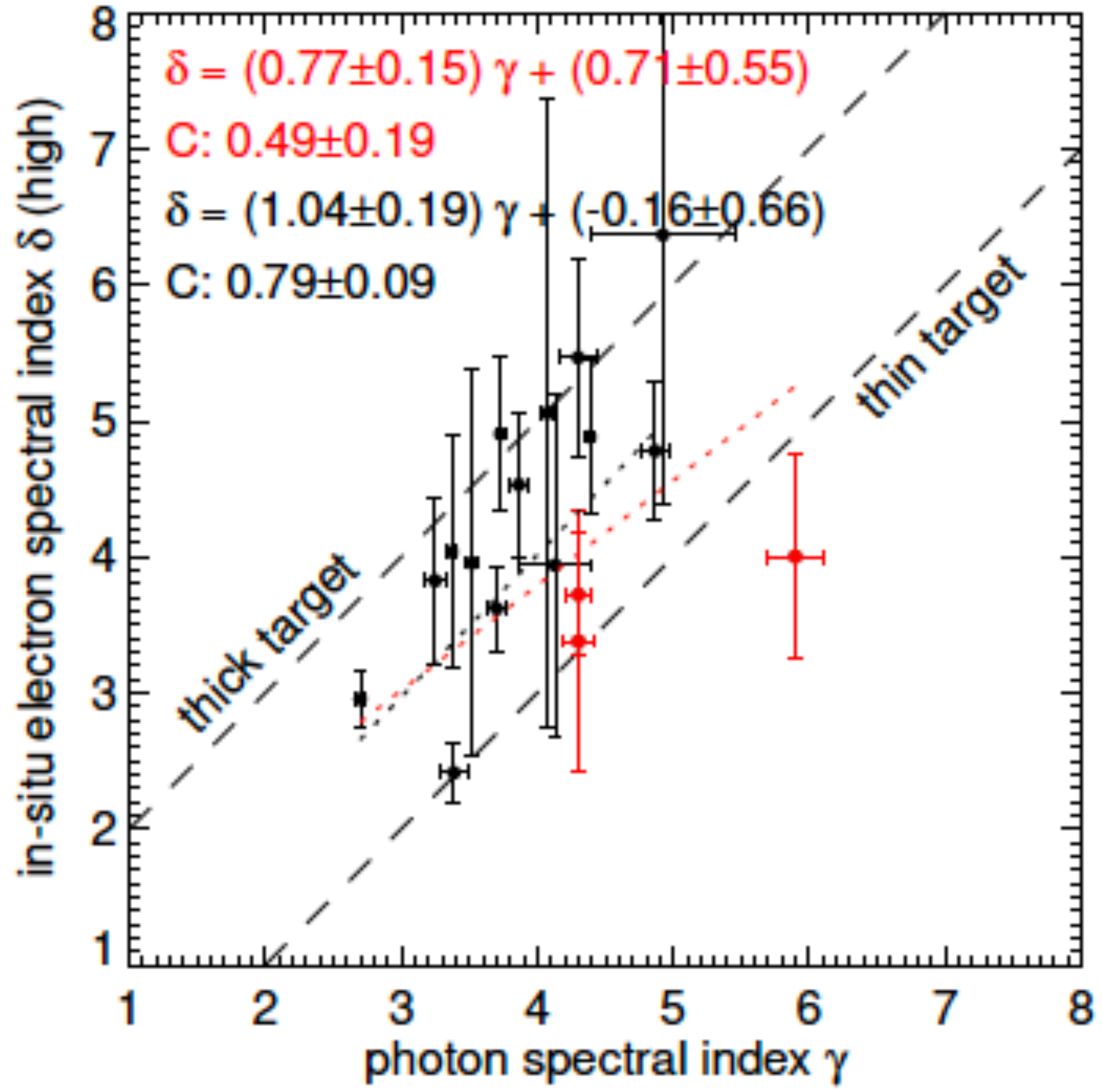
CORRELATING HXR AND IN-SITU ELECTRON SPECTRAL INDICES

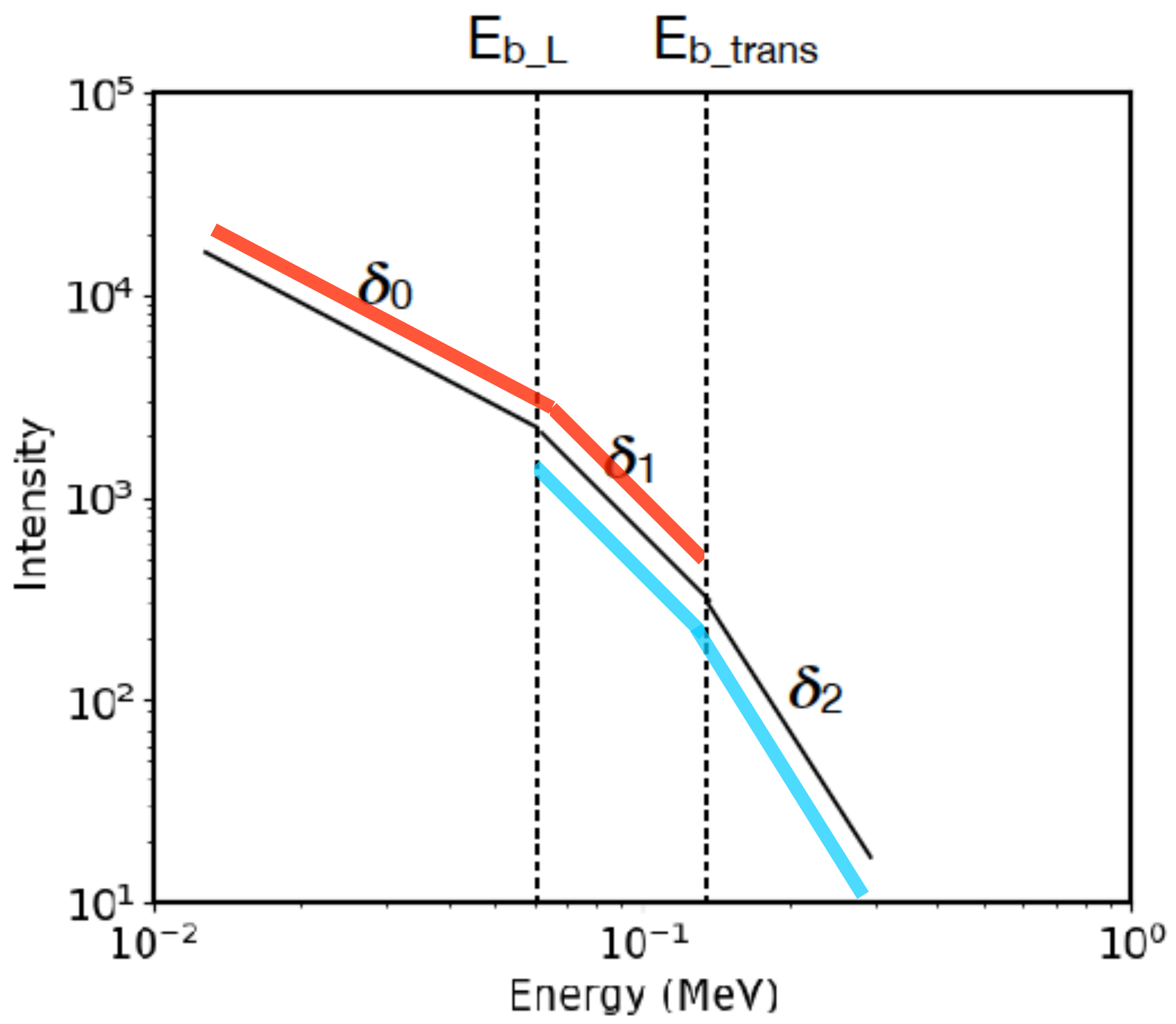
- Correlated HXR spectral index γ separately with the in-situ spectral index δ_{low} and δ_{high}
- Good correlation of ~0.8 for both sets of value pairs
- Alignment along the thin-target solution (shift toward harder in situ electron spectra) when using δ_{low}
- Shift toward the thick-target solution when using δ_{high}.

δ_{low}



δ_{high}



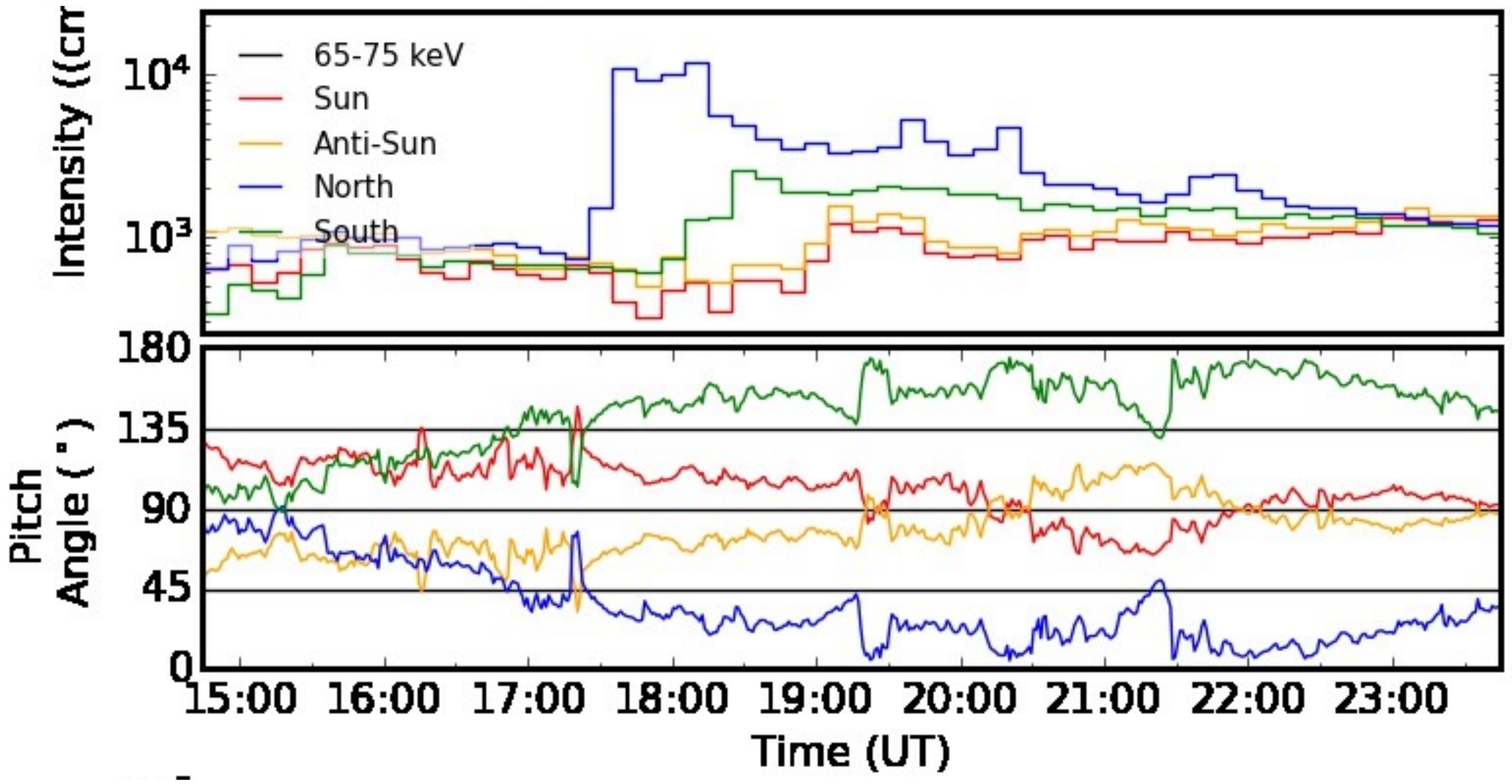


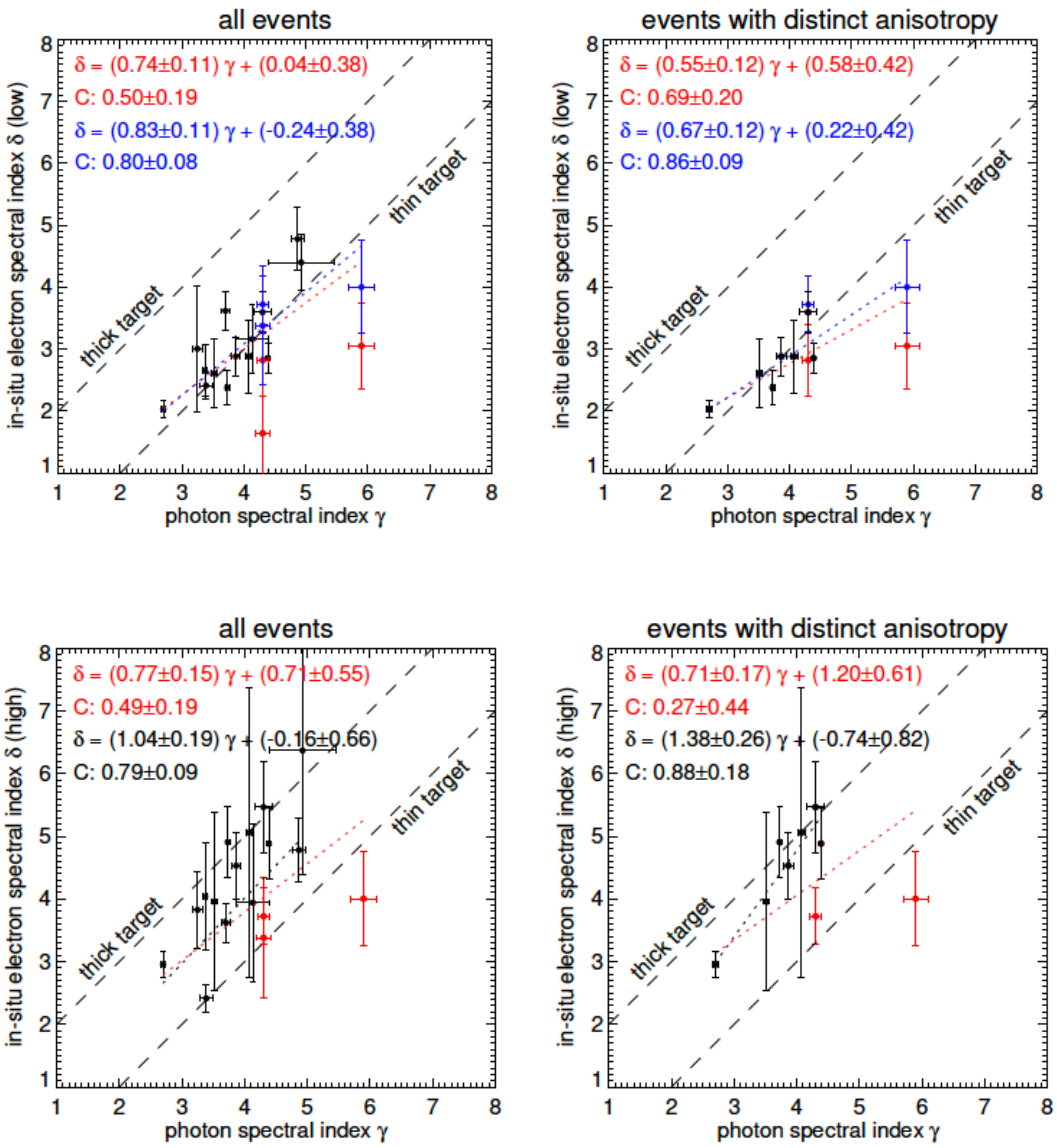
THE ROLE OF THE ANISOTROPY

When only using those events with medium to high anisotropies we find that the correlations improve

➡ Transport effects can diminish the imprint of the flare

STEREO/SEPT sectored intensities showing large anisotropy:





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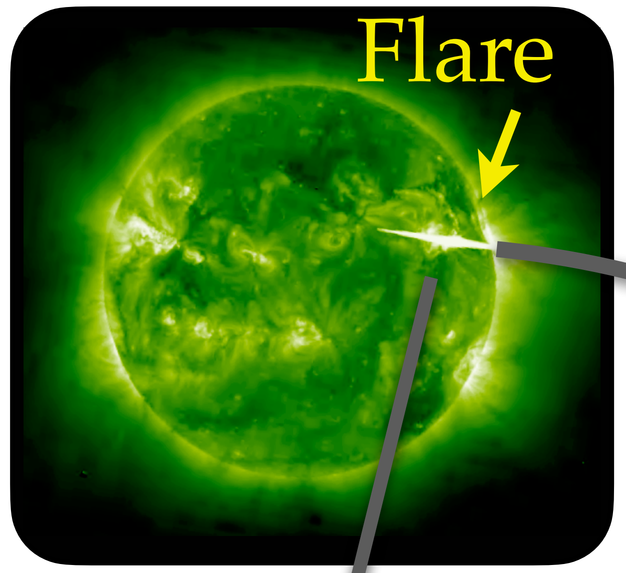
SUMMARY

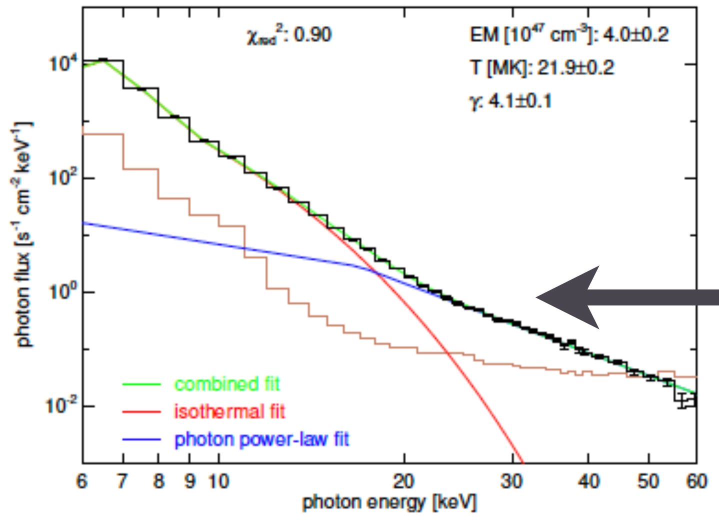
- We find clear correlations of c≈0.8 between HXR and in-situ electron spectra (despite the frequent presence of CMEs and the observed electron onsets delays)
- The choice of the in-situ spectral index for comparison with the HXR spectrum is not straightforward and can strongly influence the results (thin-target vs. thick-target solution)
- Transport effects can diminish the imprint of injected spectrum



Energetic electrons

Hard X-Rays

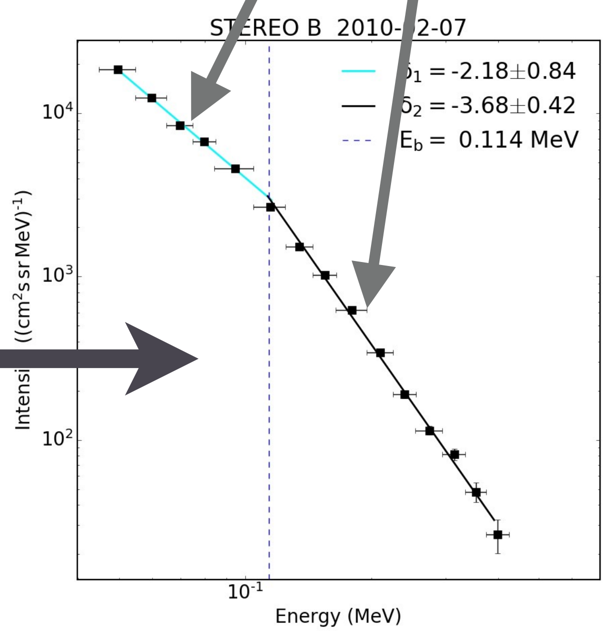
RHESSI spacecraft



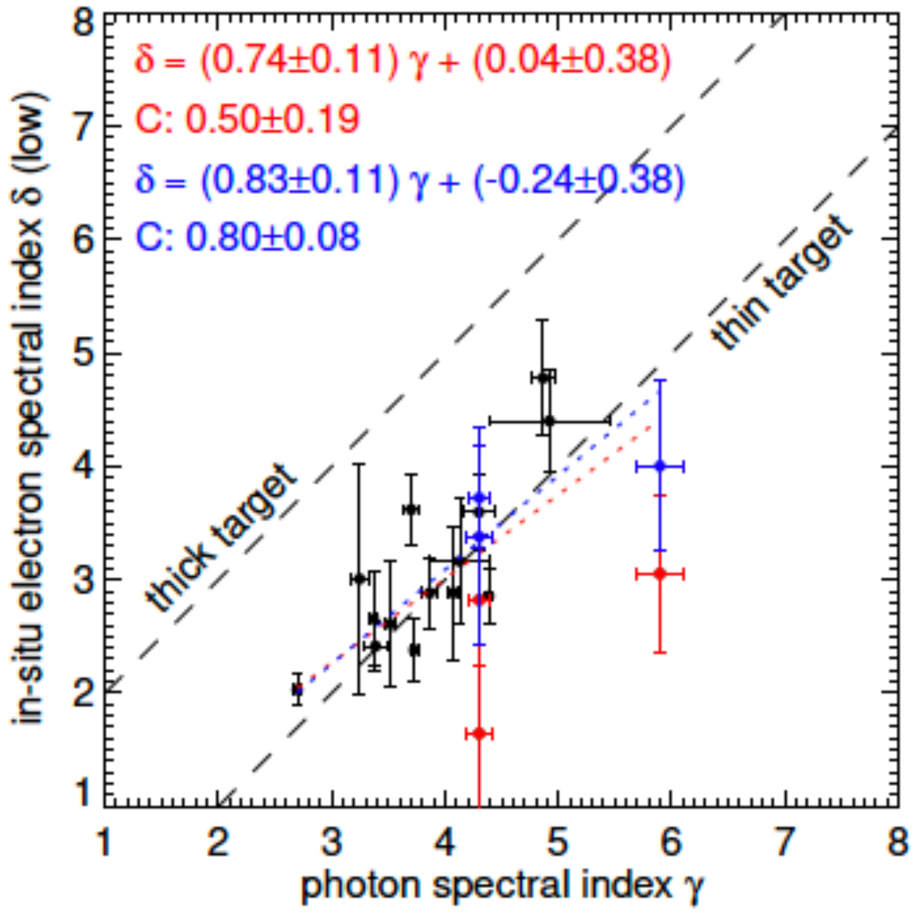
STEREO spacecraft

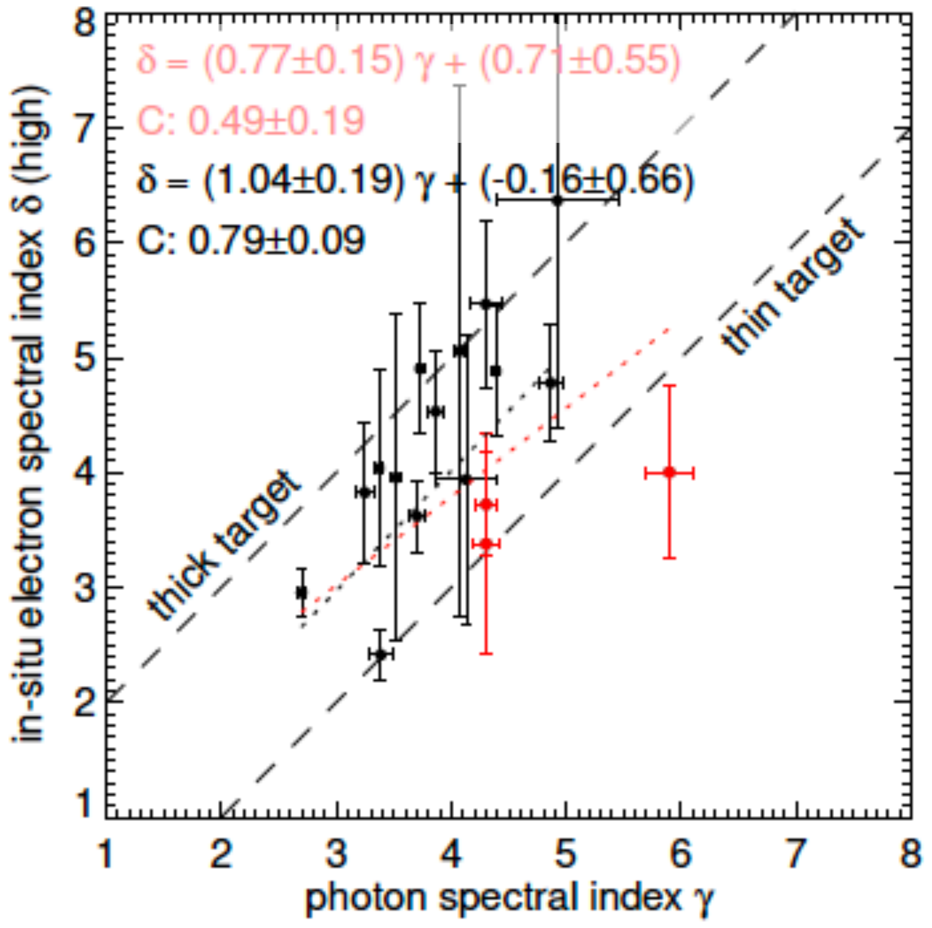
We analyze 17 common events for spectral correlations

Which part of the in-situ spectrum should be used for correlation?



This study is accepted for publication in A&A: Dresing et al. (2021)





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