Study on the features of the SEP solar origin based on microwave observations

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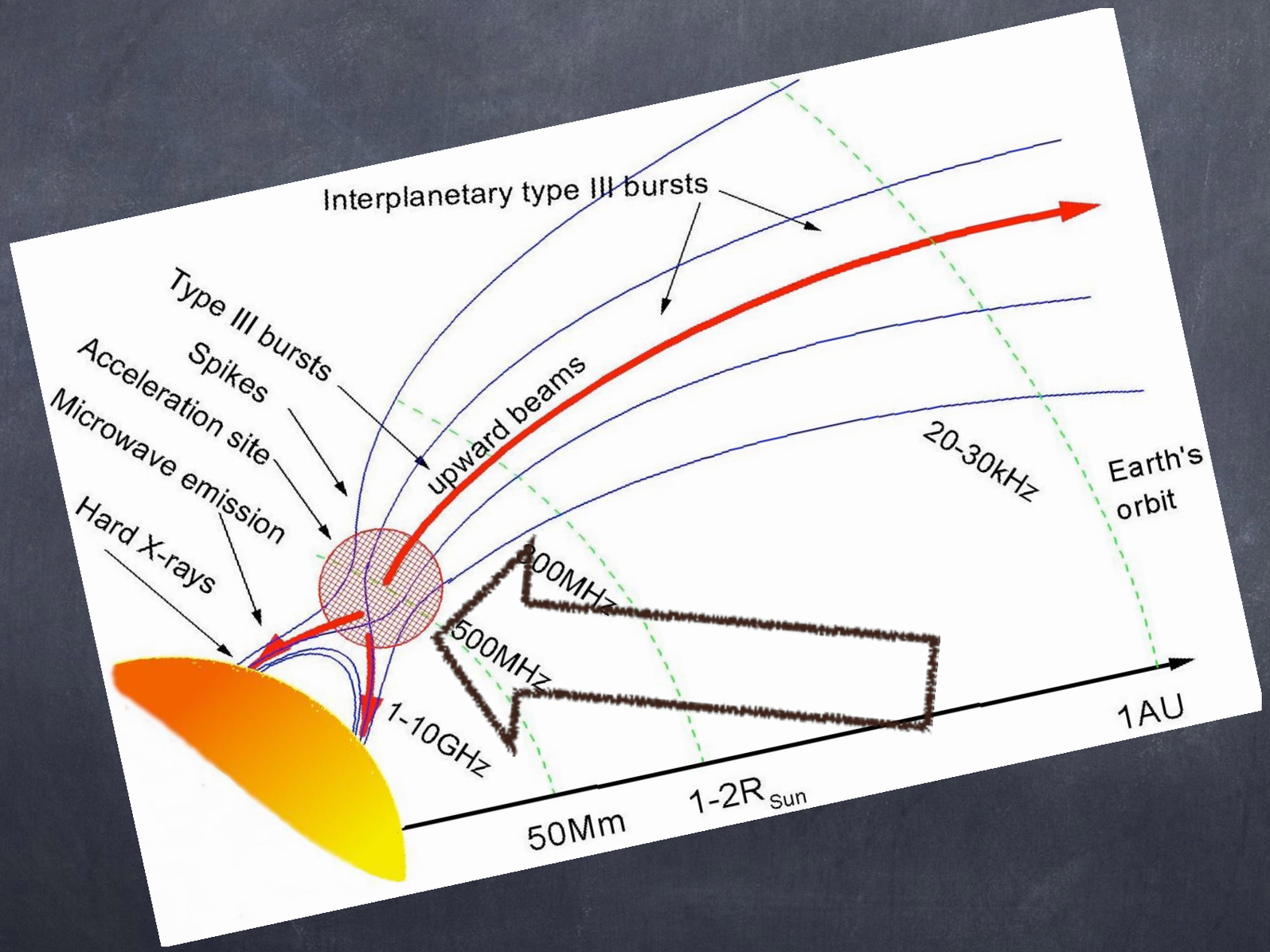
SEP particle are accelerating during solar flares

SEP particles are accelerating on the CMEs shock waves

Signatures in MW and HXR

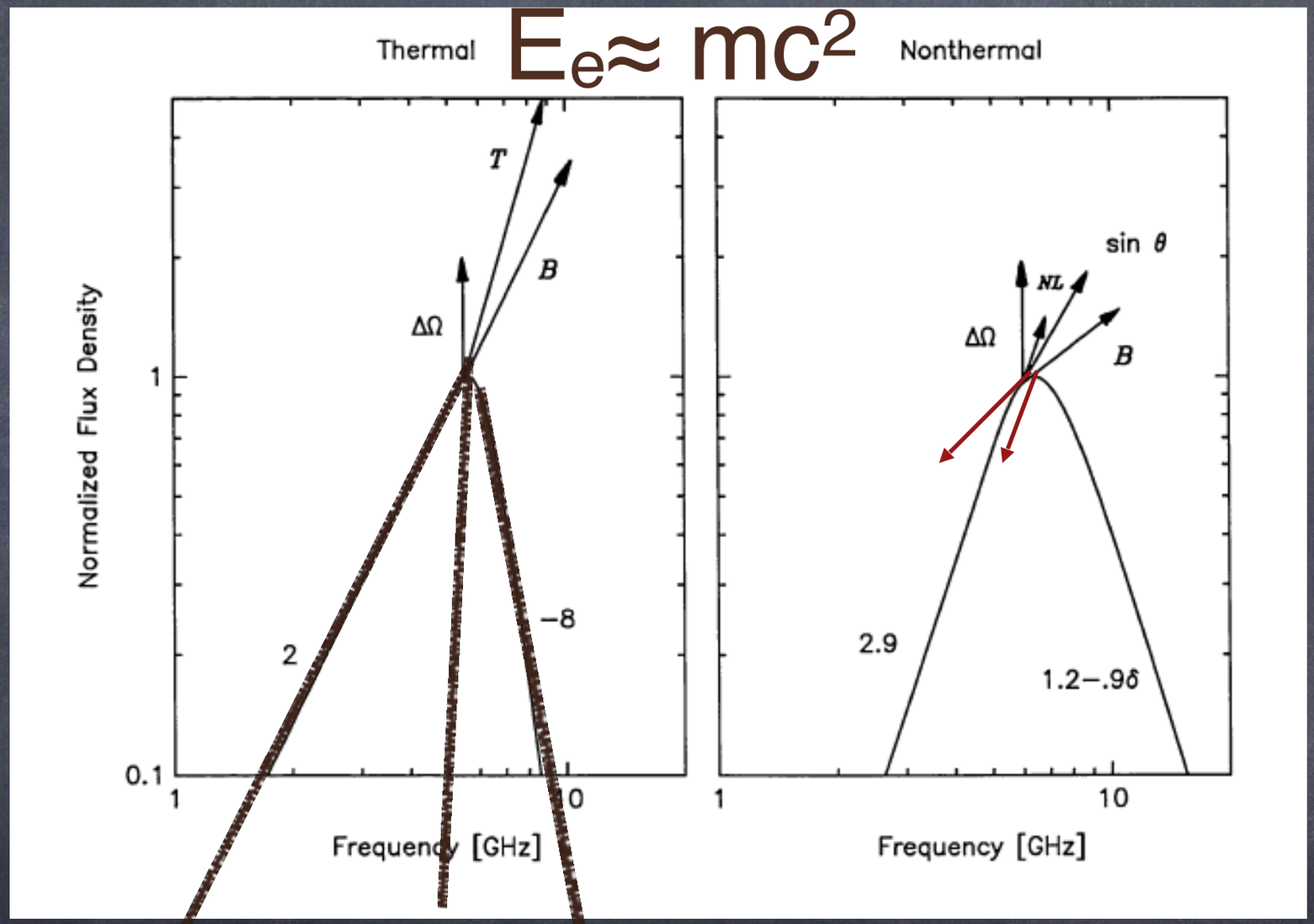
CMEs parameters

Accelerated particles in solar flares: HXR & radio observations



Gyrosynchrotron spectrum

$E_e \approx mc^2$



Low fr. spectral index

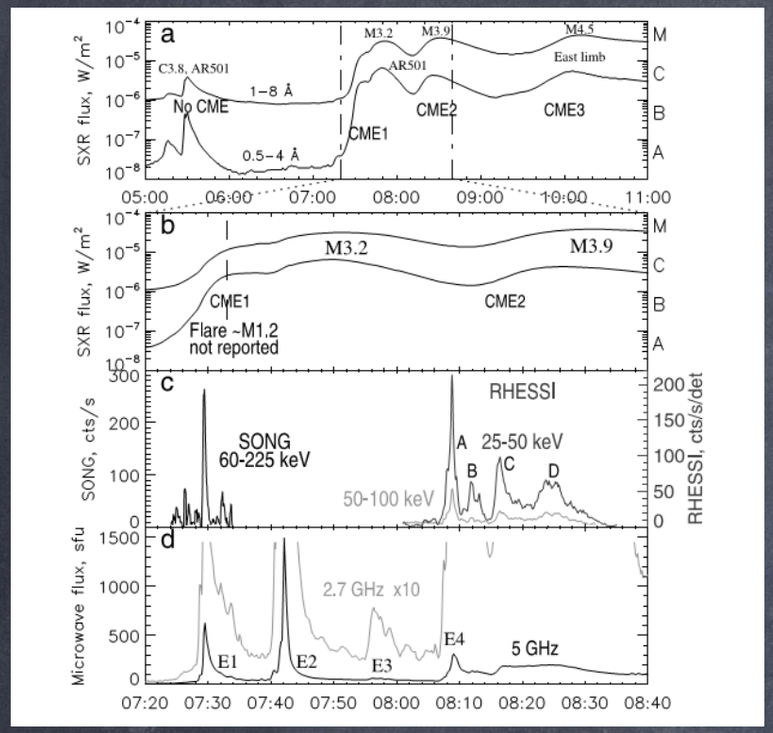
Peak fr.

High fr. spectral index
$\alpha \rightarrow \delta = 1.1\,1\alpha + 1.36$
(Dulk&Marsh, 1982)

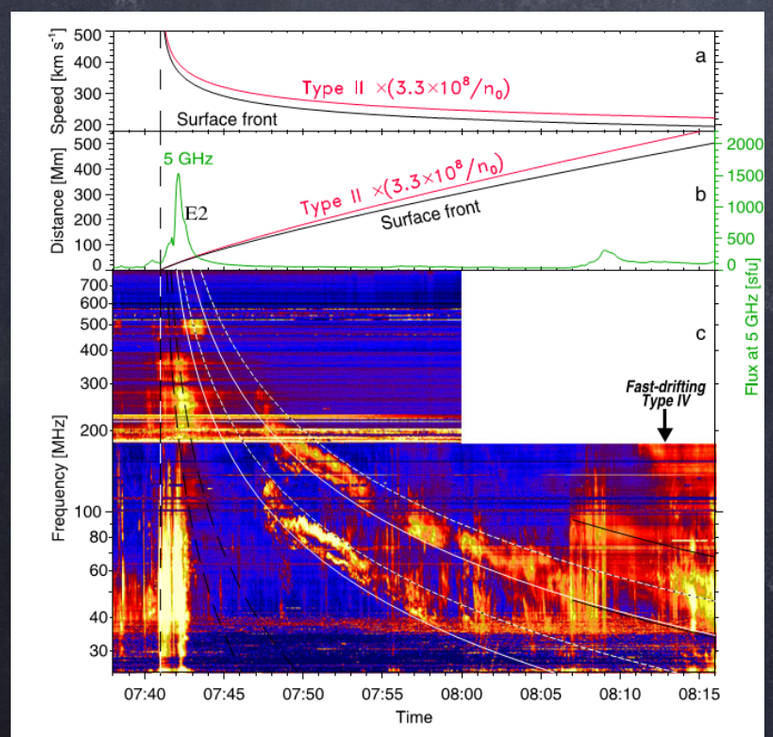
We have excellent results in case study

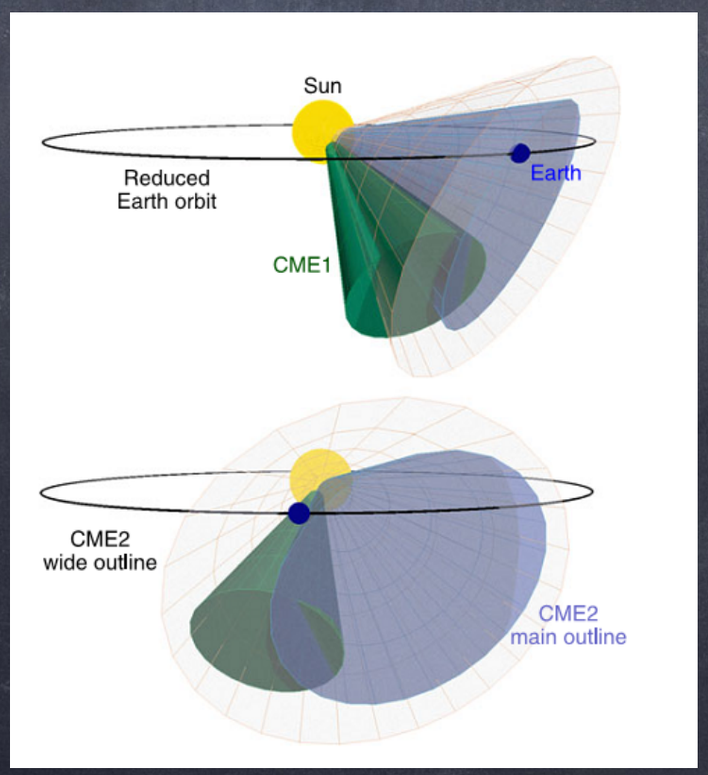
but

Contradictory statistical results



V.V. Grechnev et al "A Challenging Solar Eruptive Event of 18 November 2003 and the Causes of the 20 November Geomagnetic Superstorm. Parts I +II





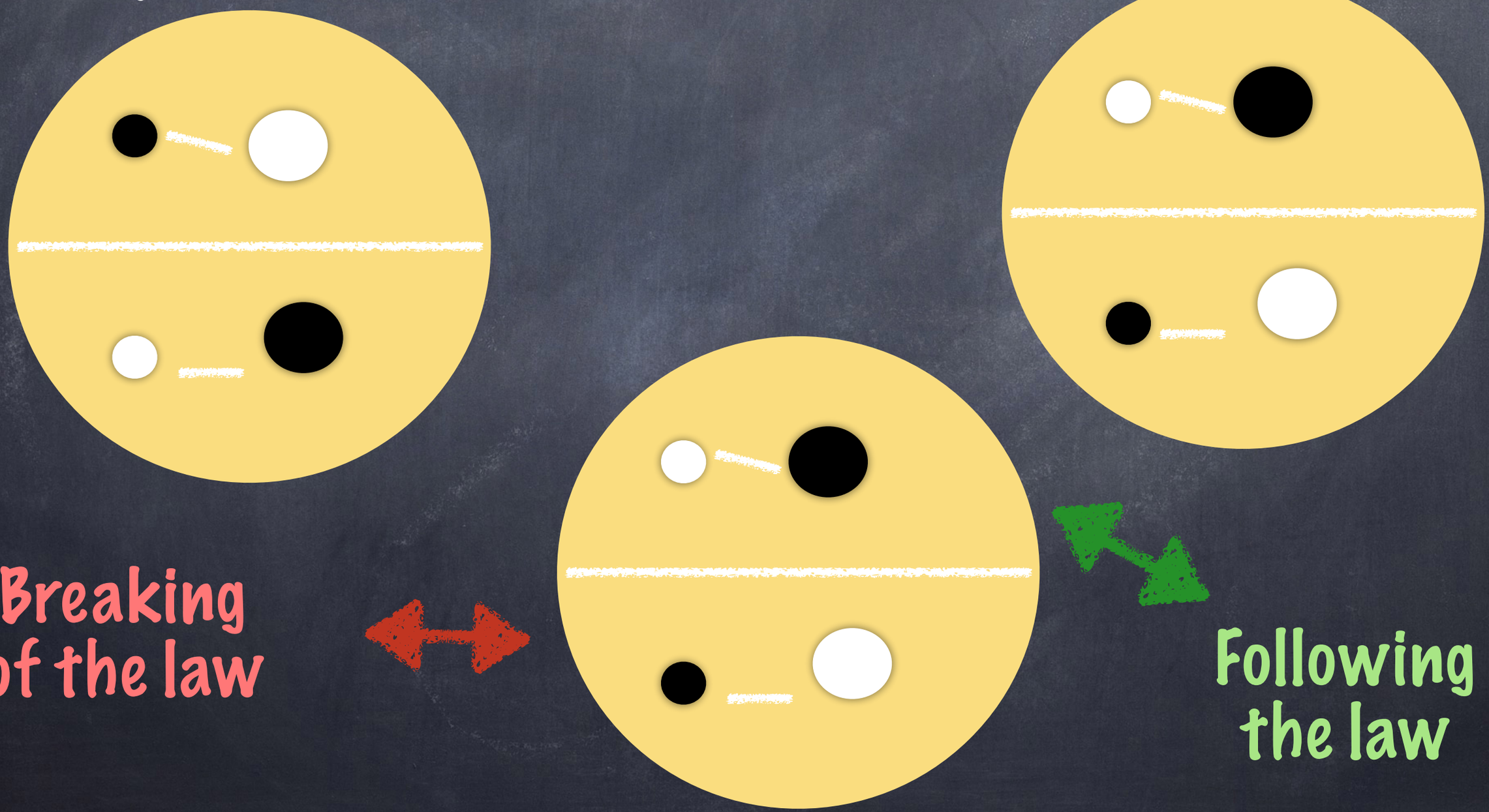
Is it magnetic topology effect?

The task is to do statistical study based on results of results obtained by Abramenko et al (2018)

Active regions (ARs) the breaking of Hale's polarity law (Abramenko et al., 2018)

23rd cycle

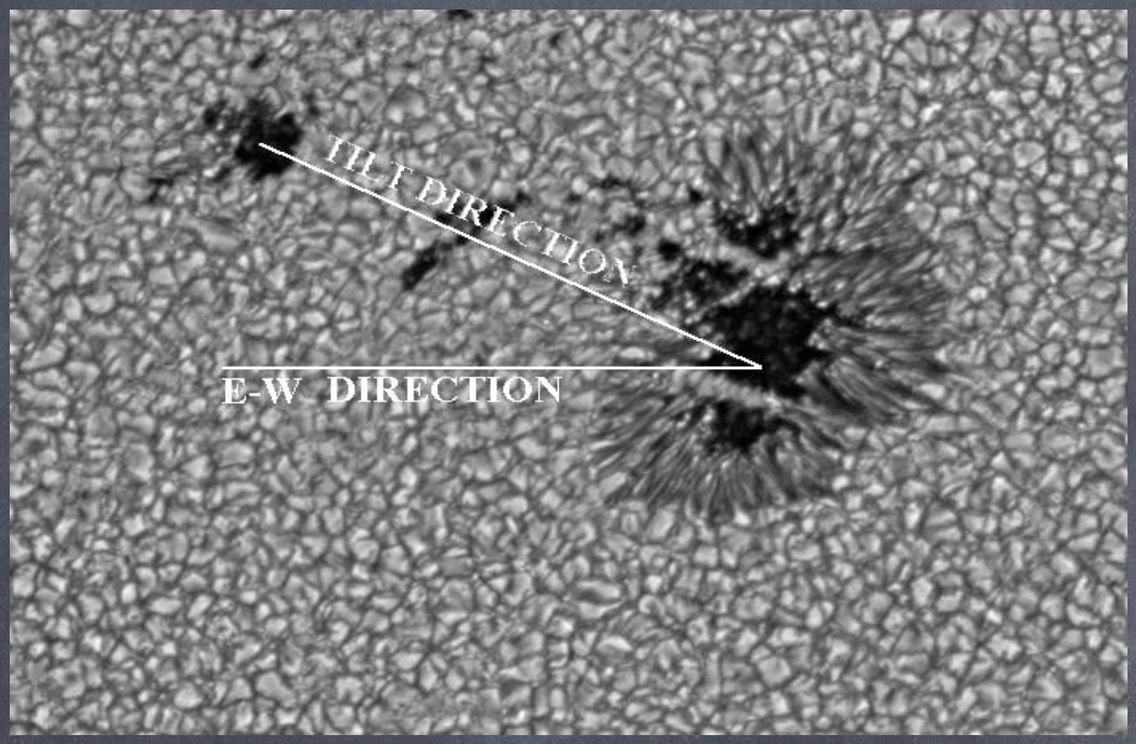
24rd cycle

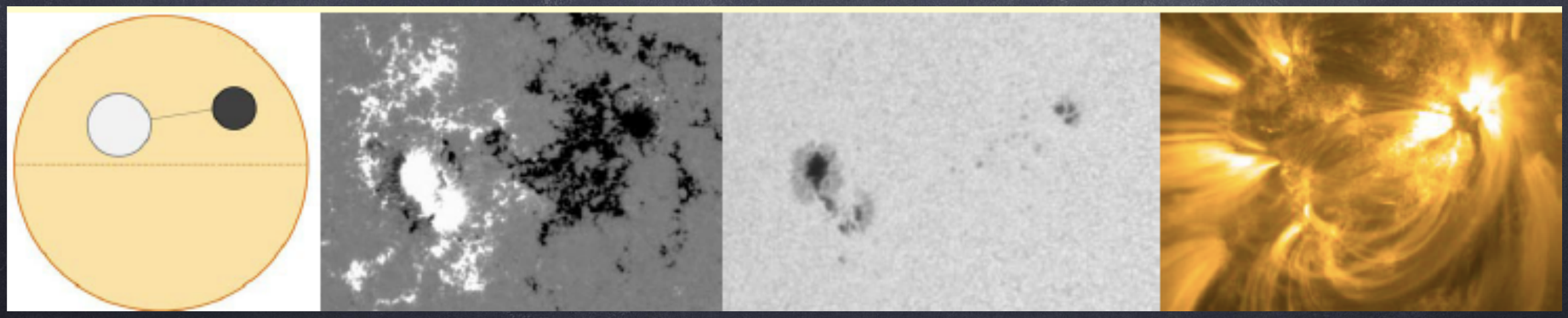


Breaking of the law

Following the law

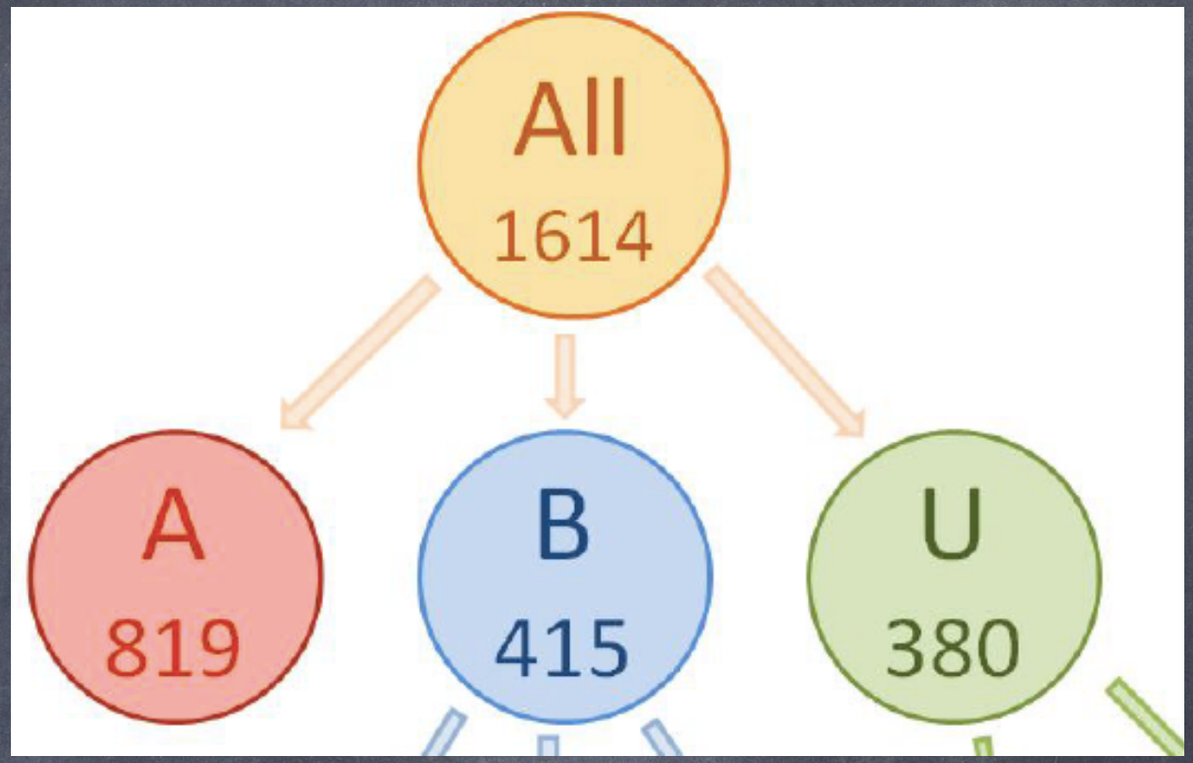
ARs breaking Joy 's law

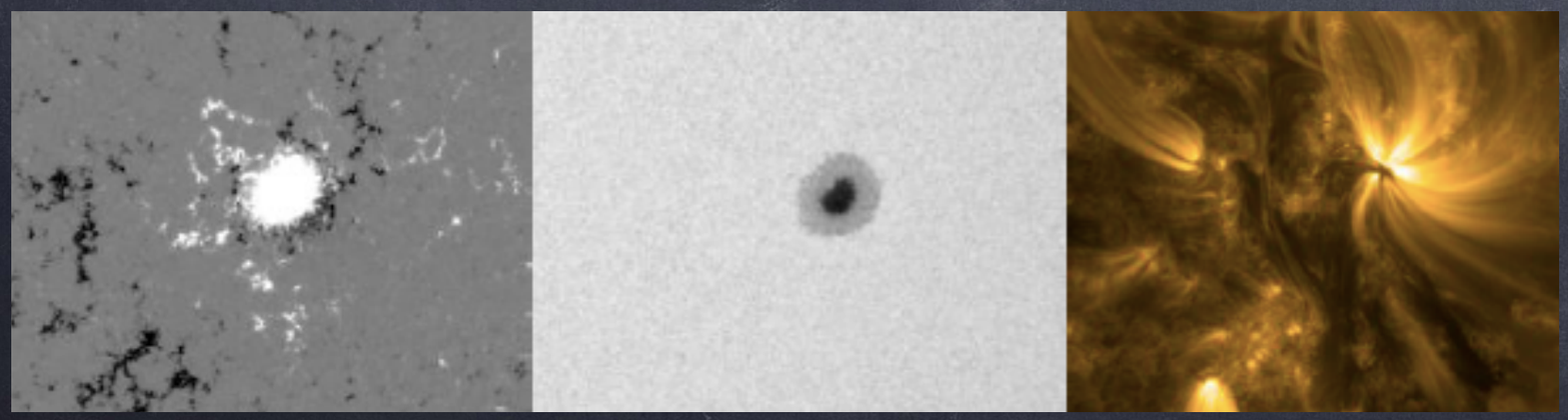




Results for the 24th cycle based on SDO/HMI data

- A -bipolar regular («right») ARs
- B -bipolar ARs breaking one of the laws
- U - unipolar ARs





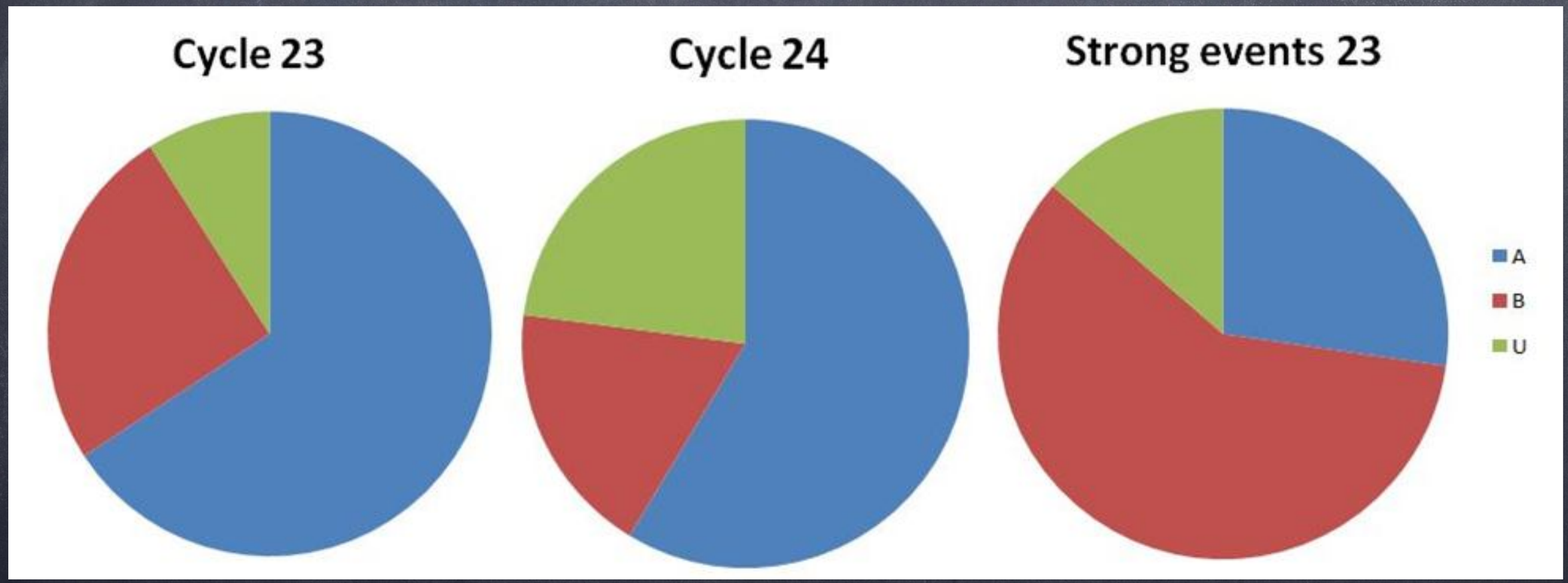
Observational data (23th solar cycle)

Solar Energetic Particles (SEPs) - ratio of proton fluxes by GOES (E>10MeV/E>30 MeV) and (E>10 MeV /E >60 MeV) - Papaioannou et al (2016)

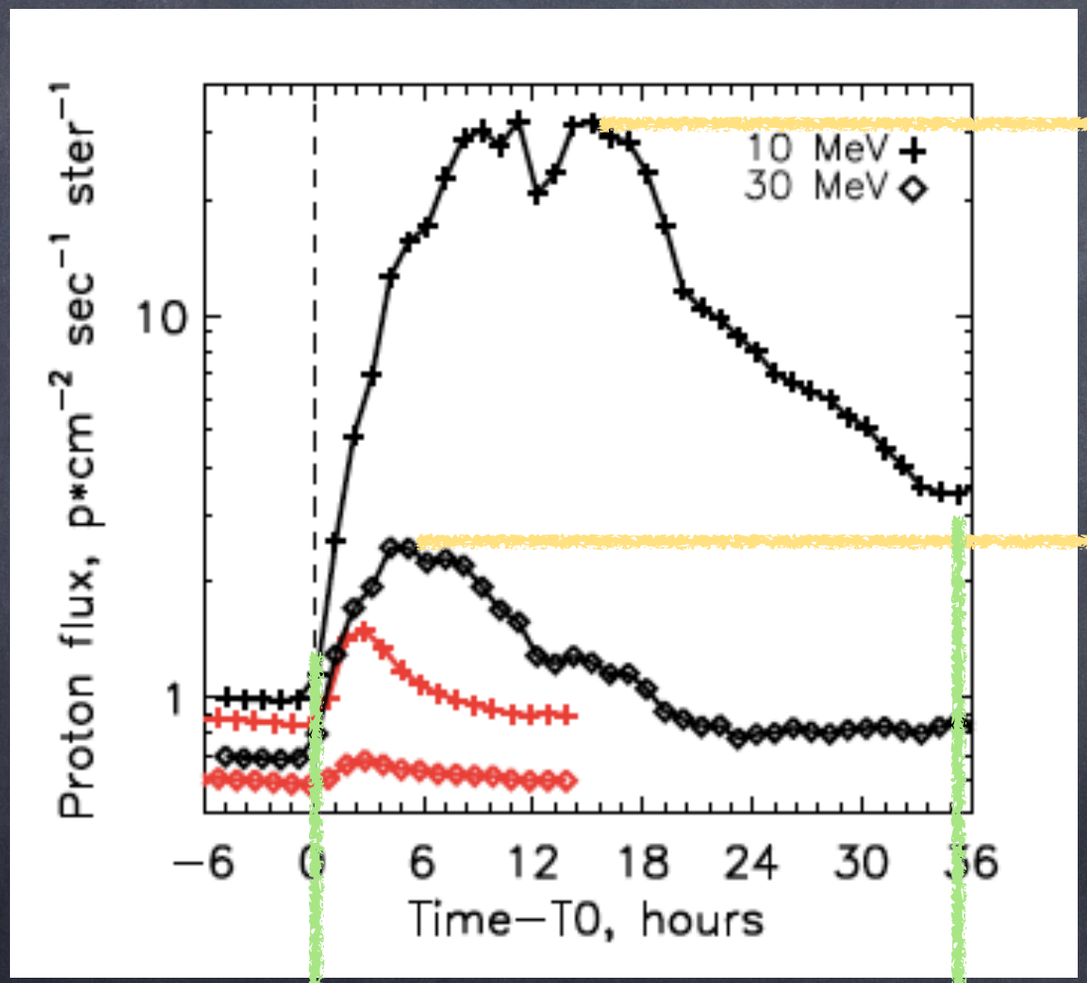
Microwave spectra - Radio Solar Telescope Net (RSTN) + Nobeyama radiopolarimeter + hard X-ray response (CORONAS-F/SONG + RHESSI, 2001-2005)

SOHO/MDI data for testing of the law breaking

Ratio between the different groups of ARs



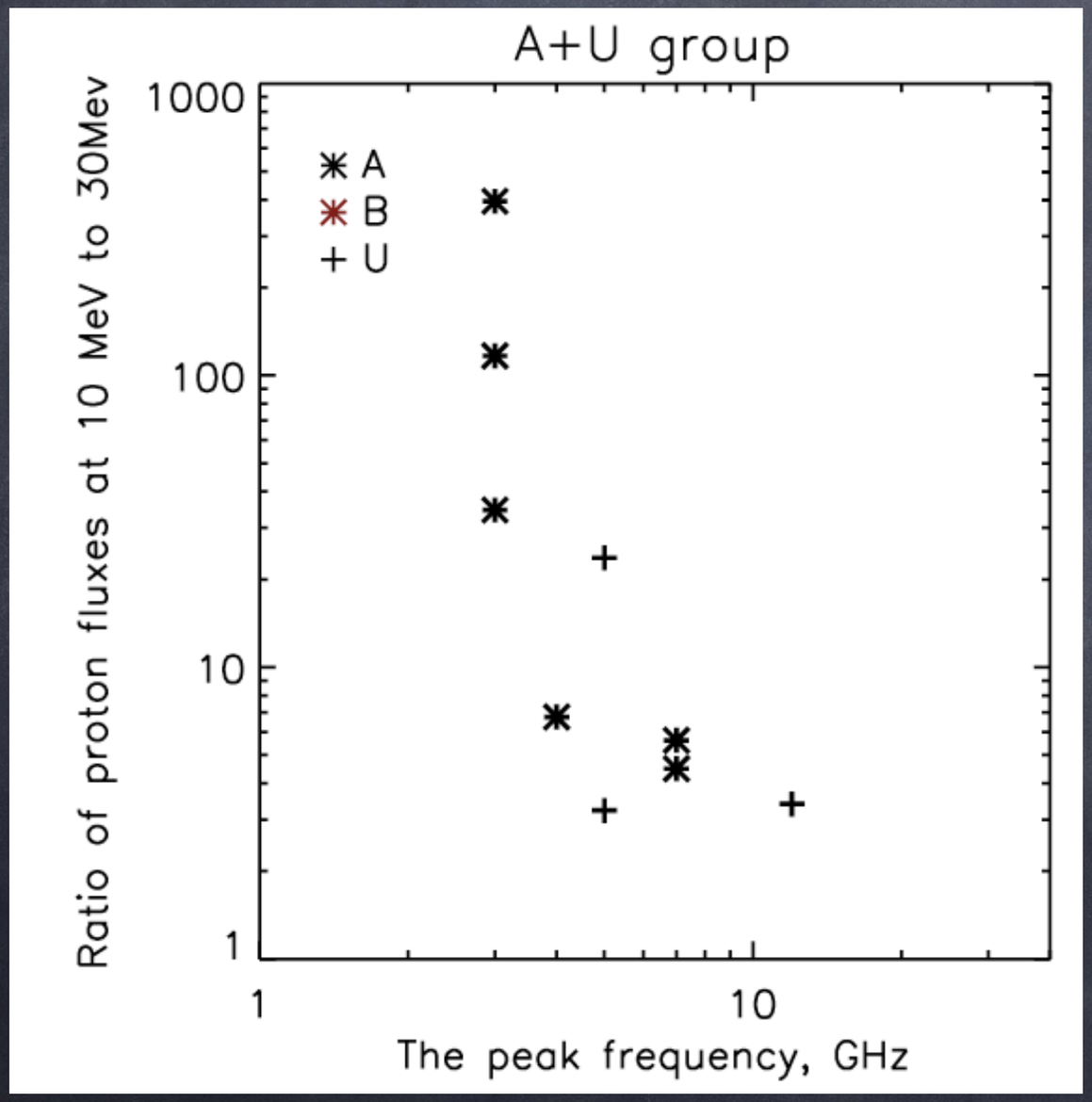
Flux at the peak vs fluence

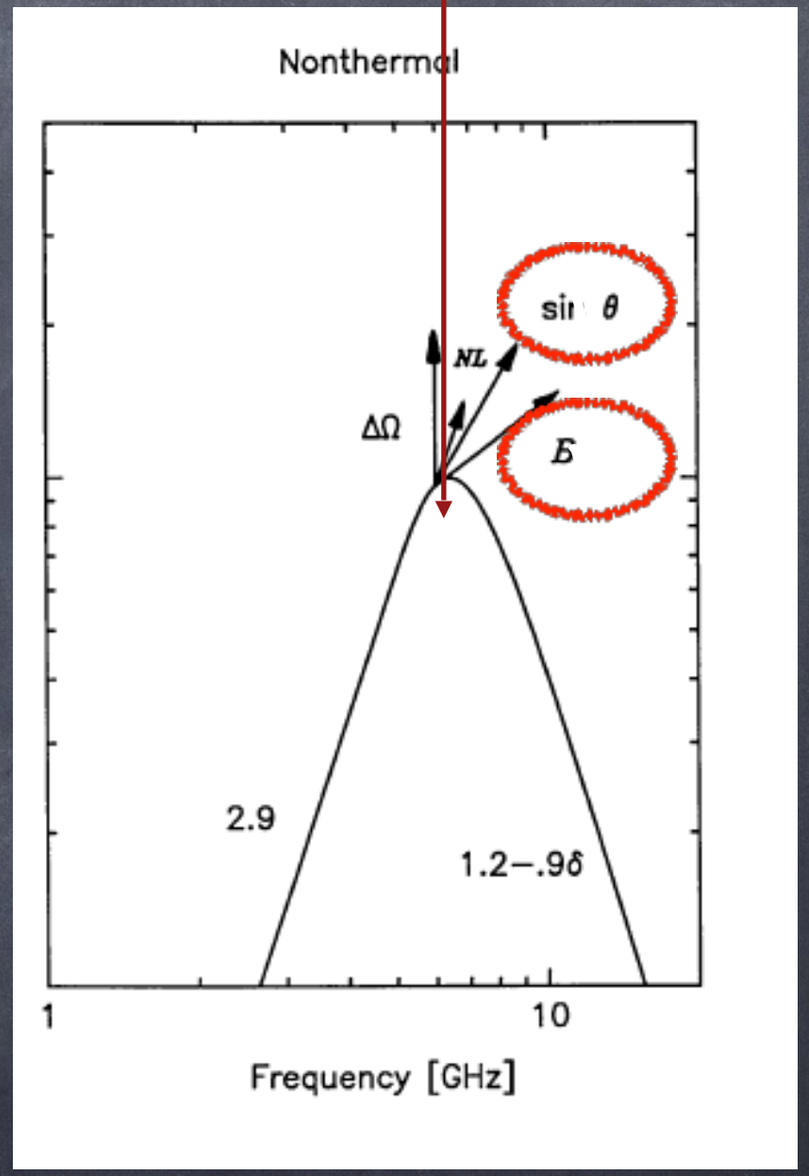


Flux at peak

Fluence

The proton flux ration vs the peak frequency





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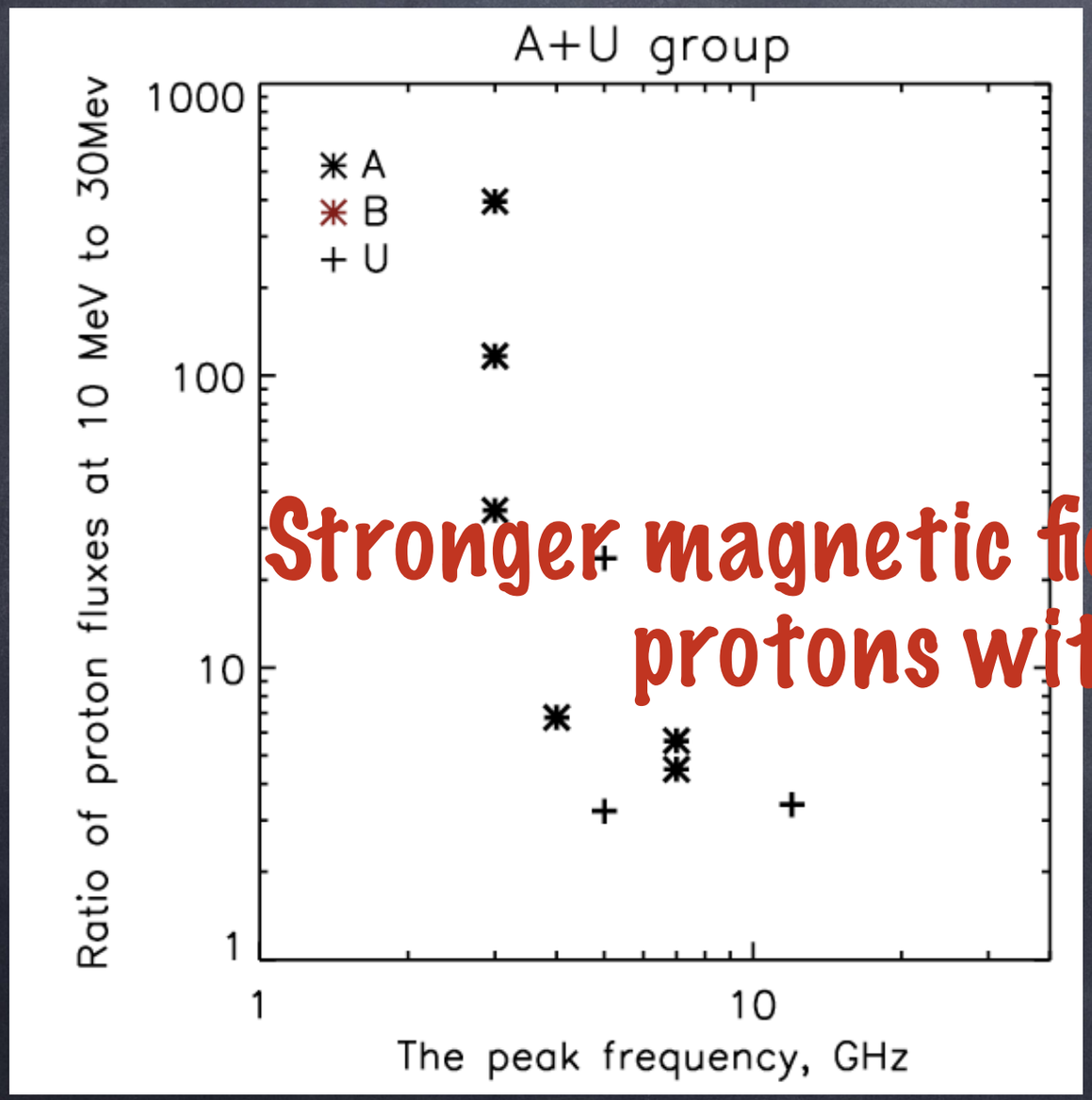
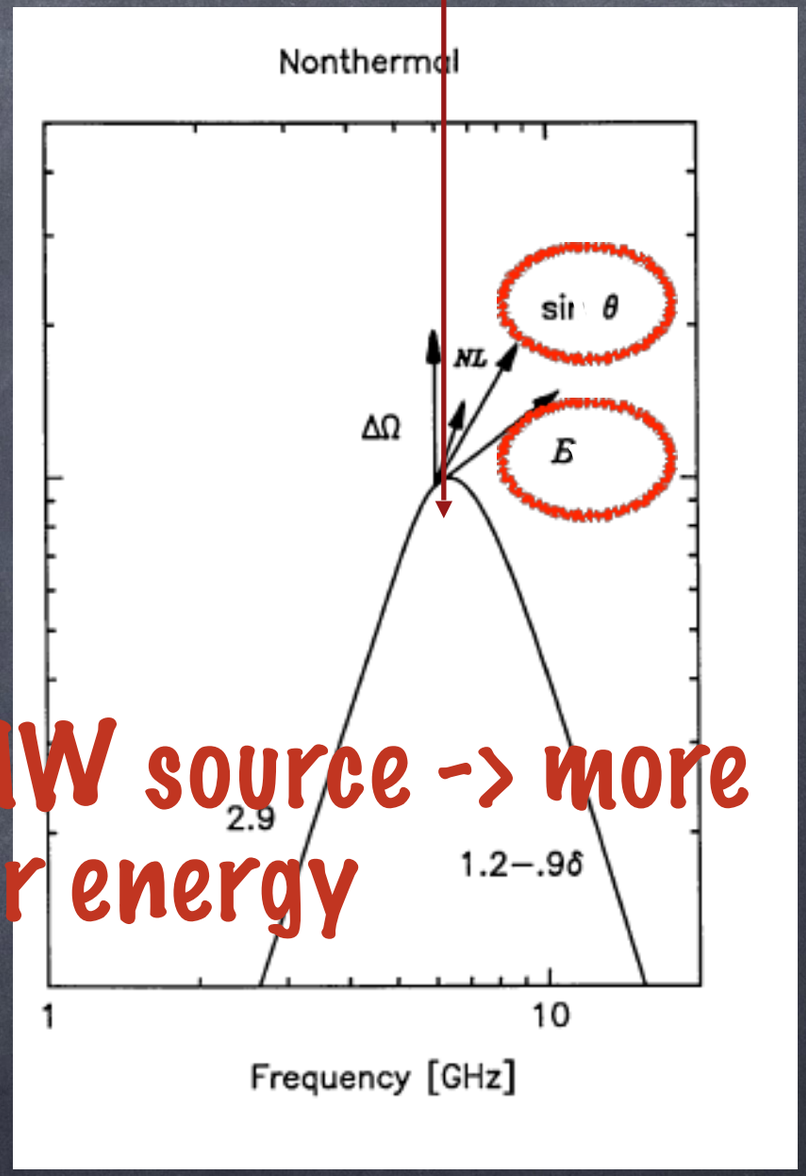
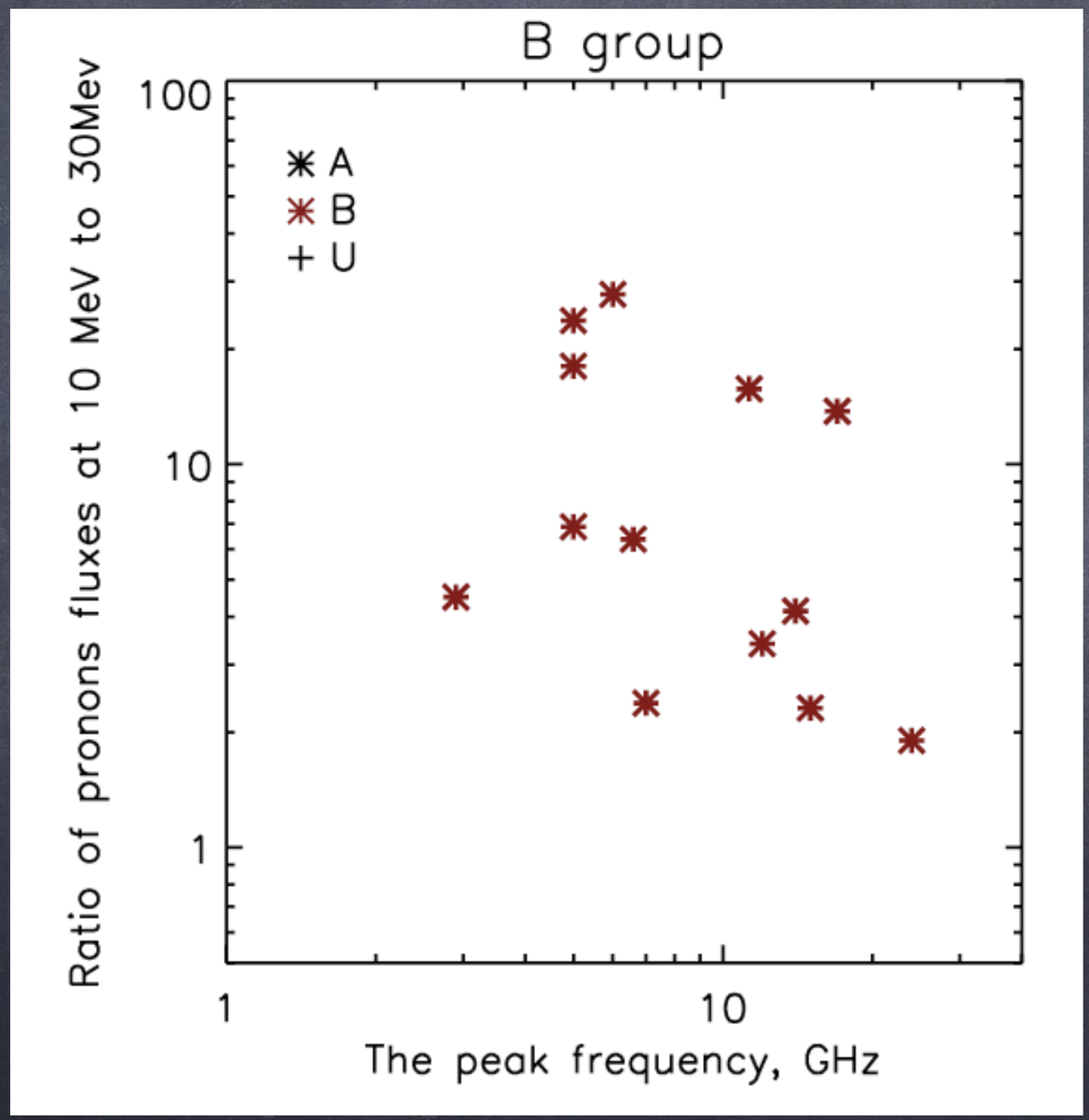


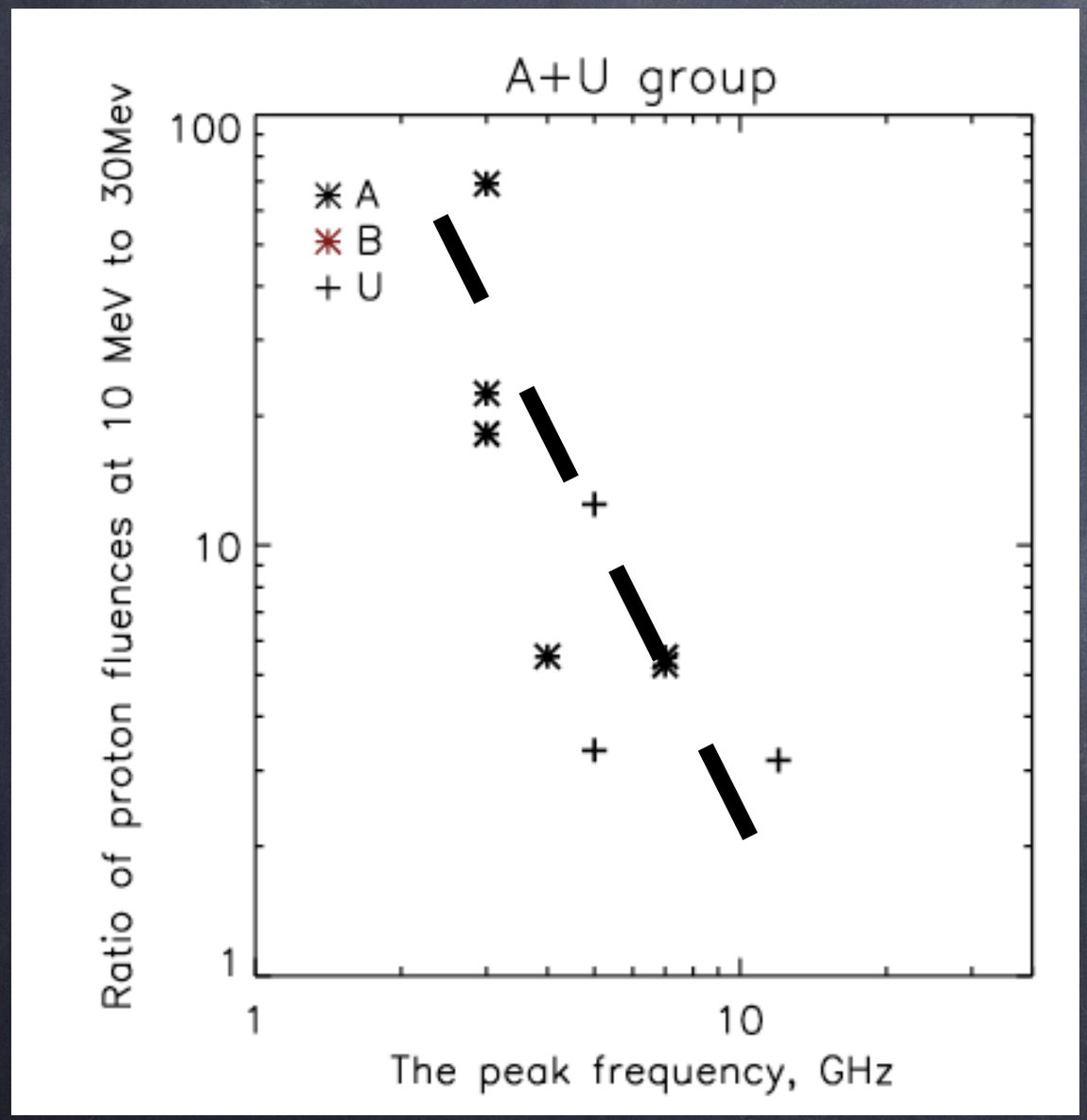


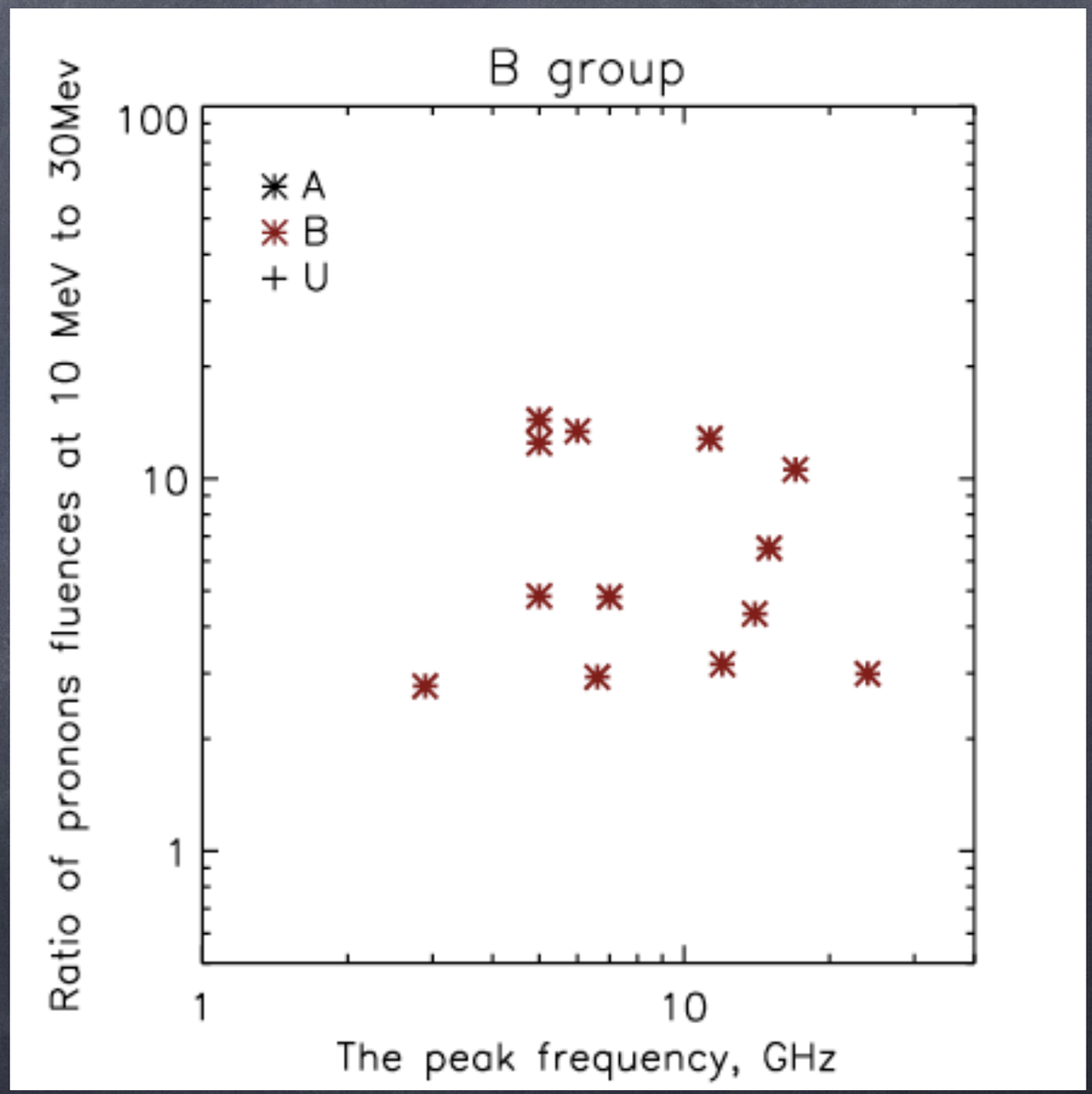
Stronger magnetic field in MW source -> more protons with higher energy

The proton flux ration vs the peak frequency

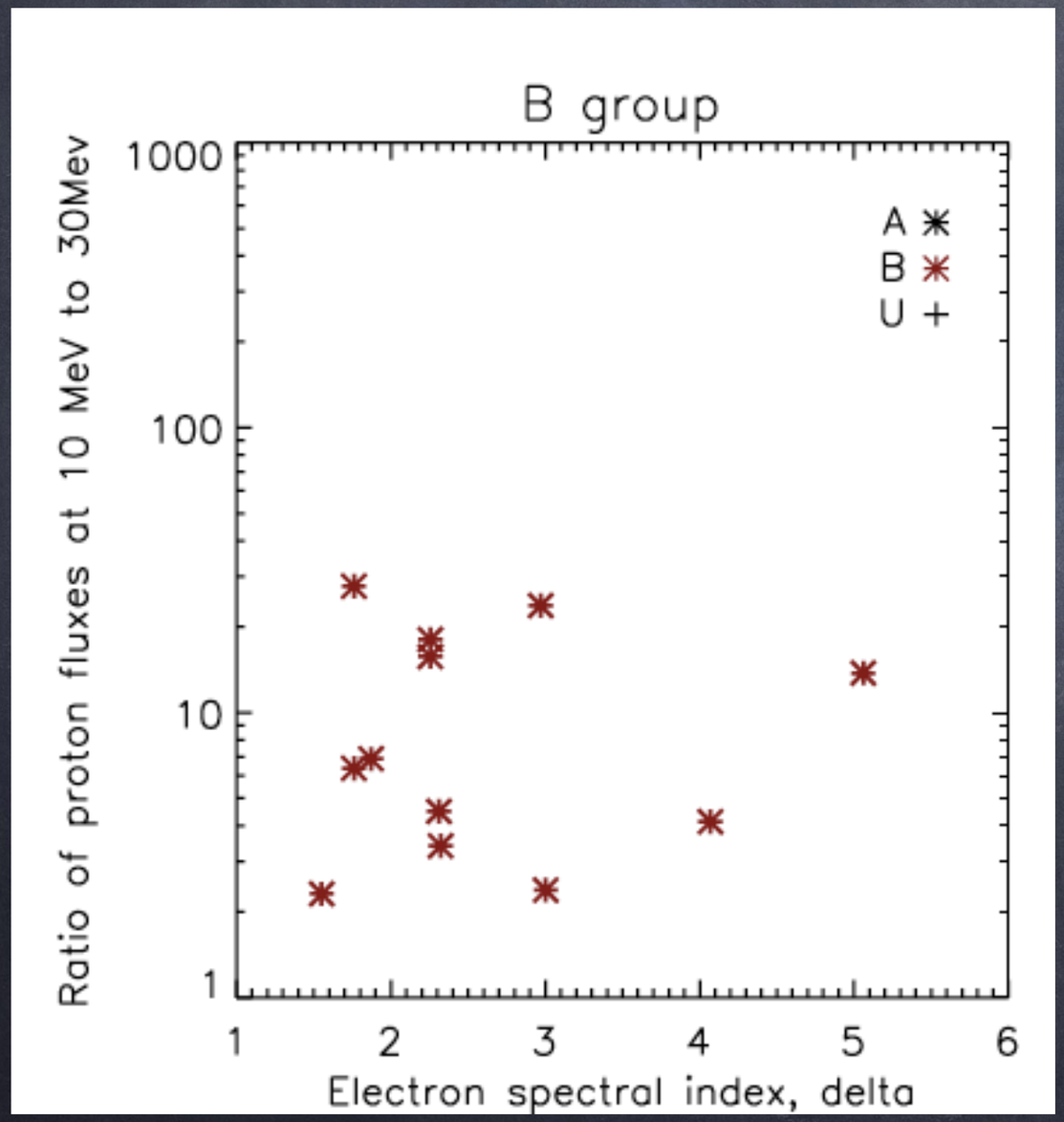


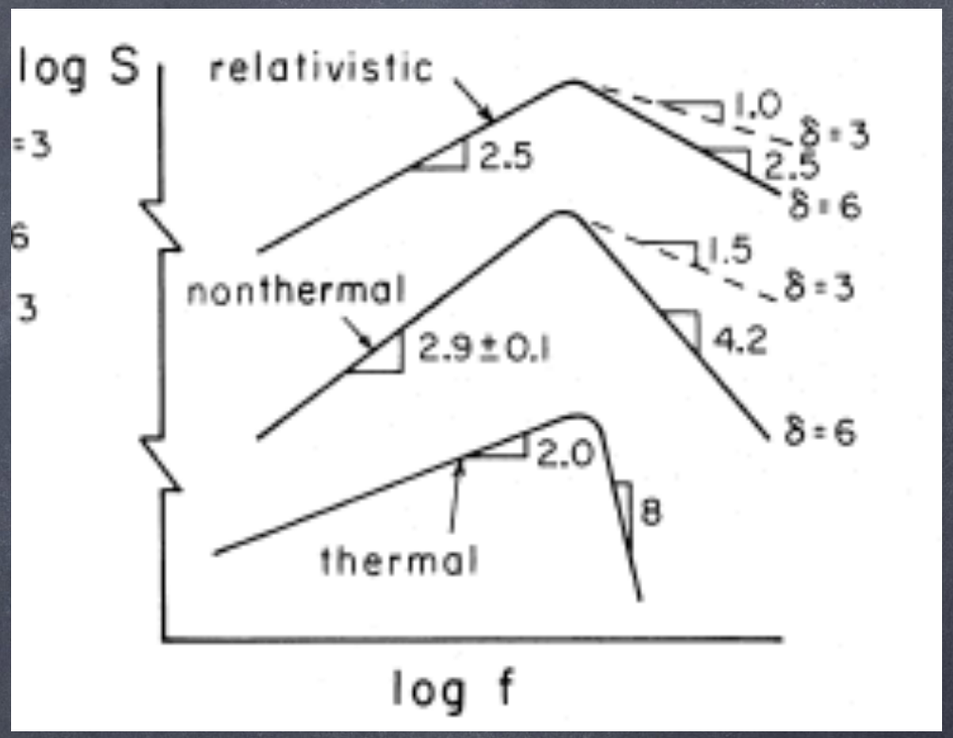
The peak frequency vs proton fluence ratios





The proton flux ration vs the electron spectral index





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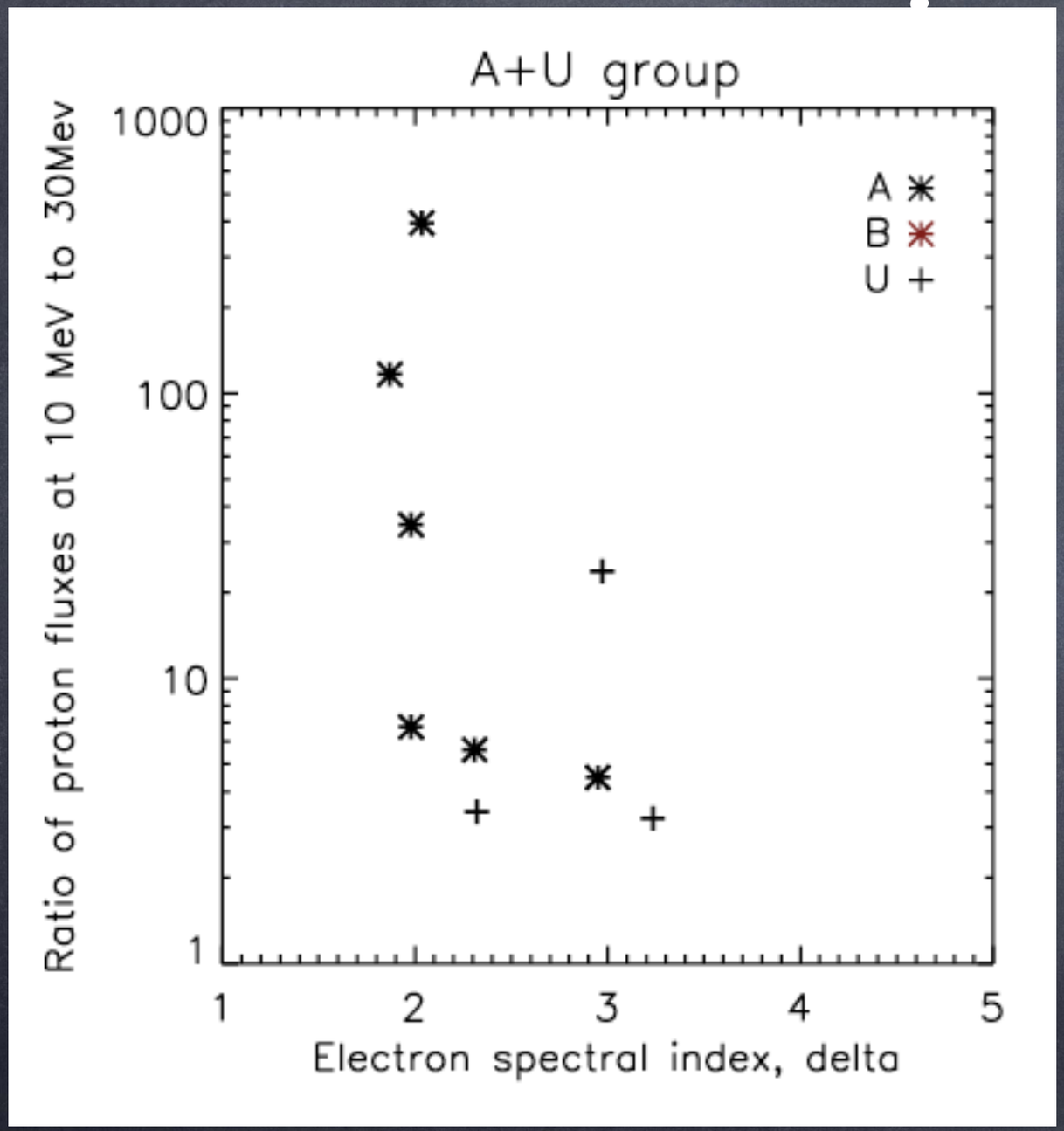
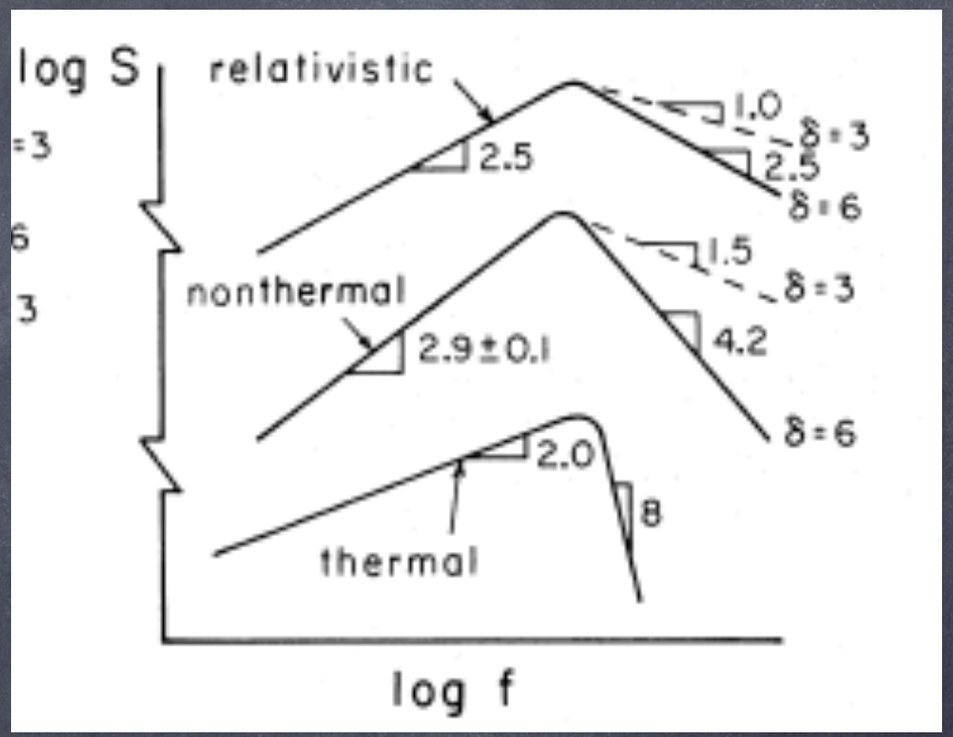
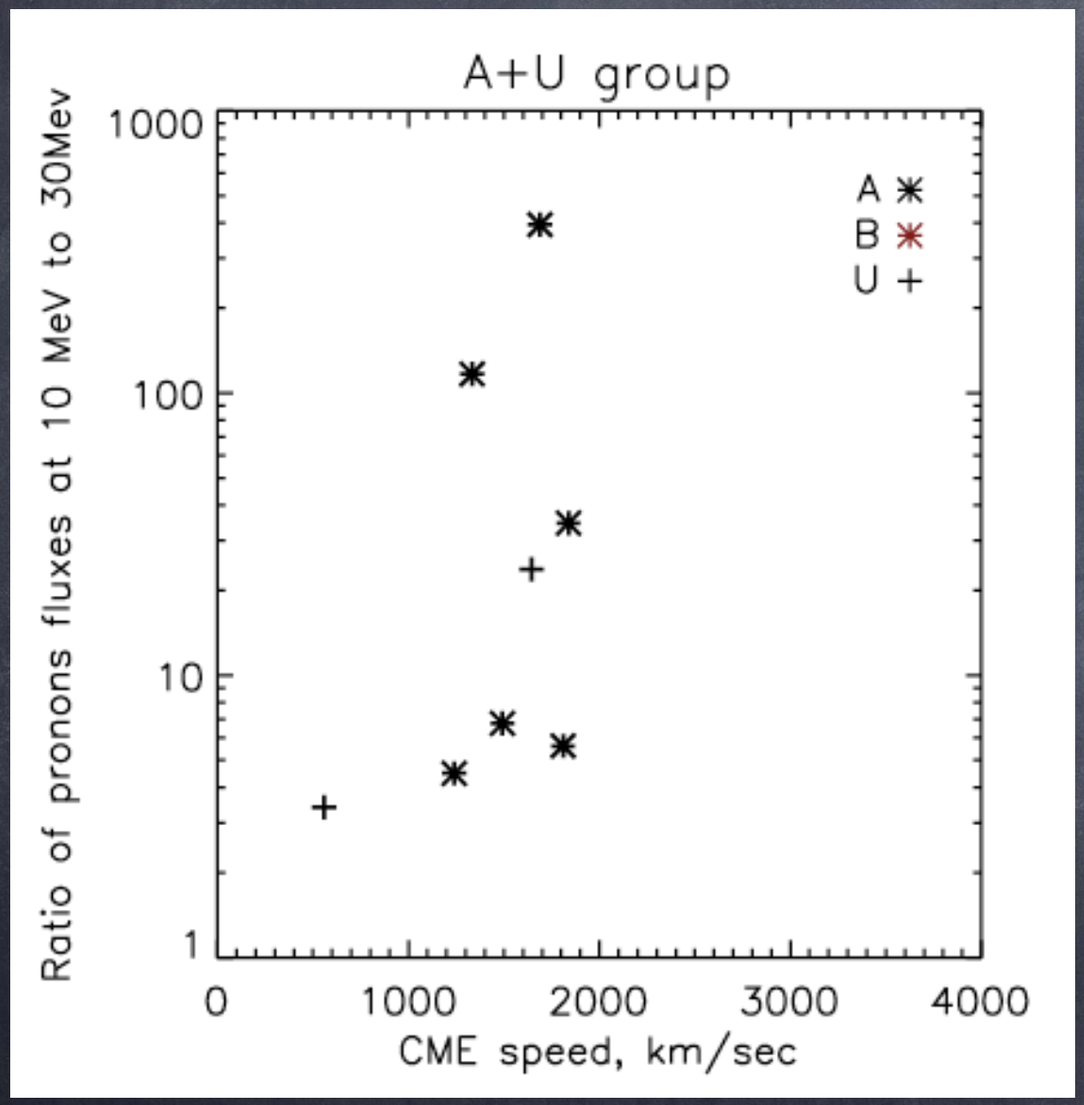
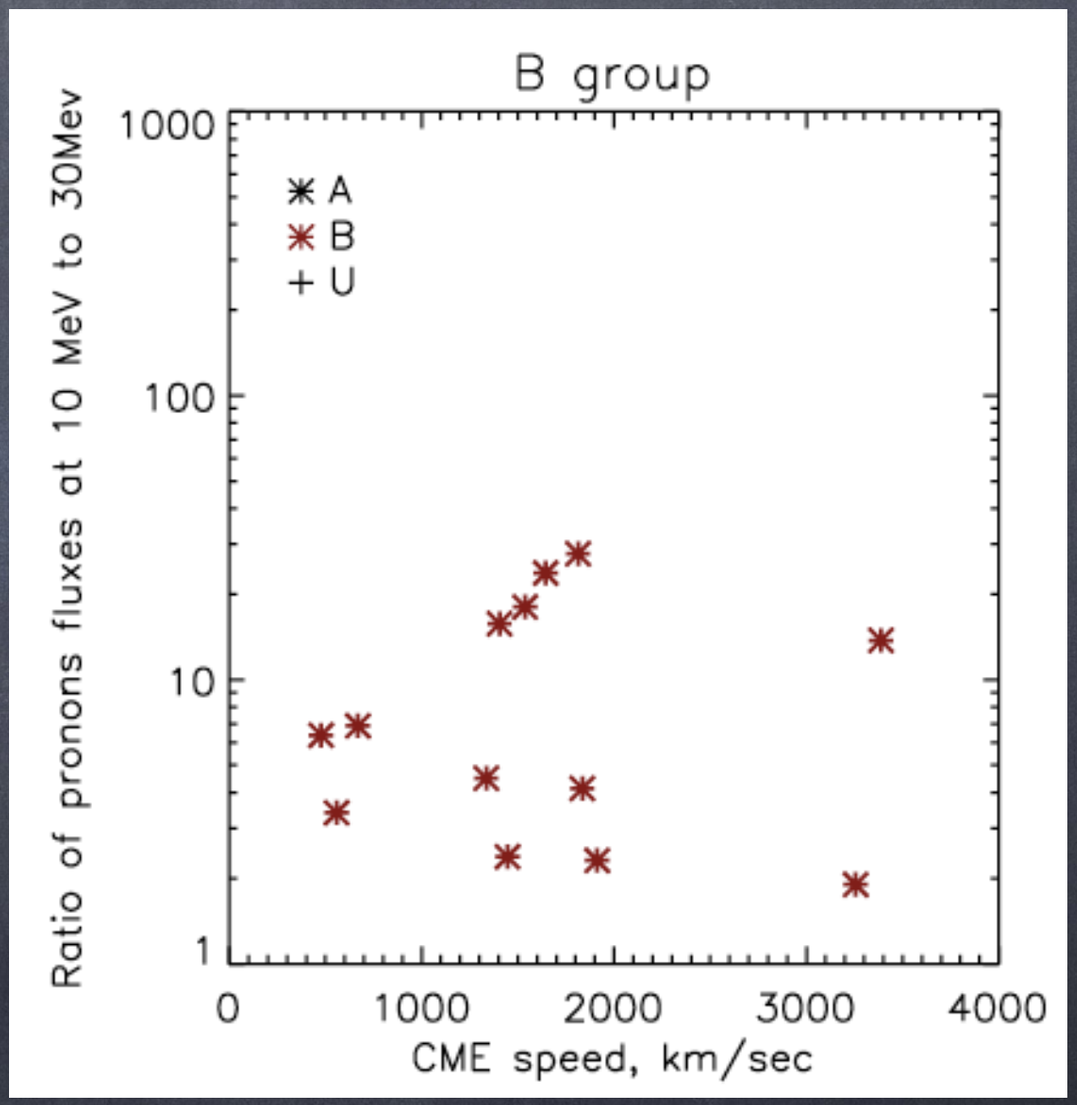




Agree with results
by Daibog et al (1989, 1993)

CME's speed vs the ratio





Conclusions. Good news

- The ratio of the breaking of the law (group B) is anomaly high for selected events than for all group of the cycle in the whole
- The «right» ARs show good correlation of SEP's parameters with indicators of acceleration taken from microwaves (spectral index, peak frequency)

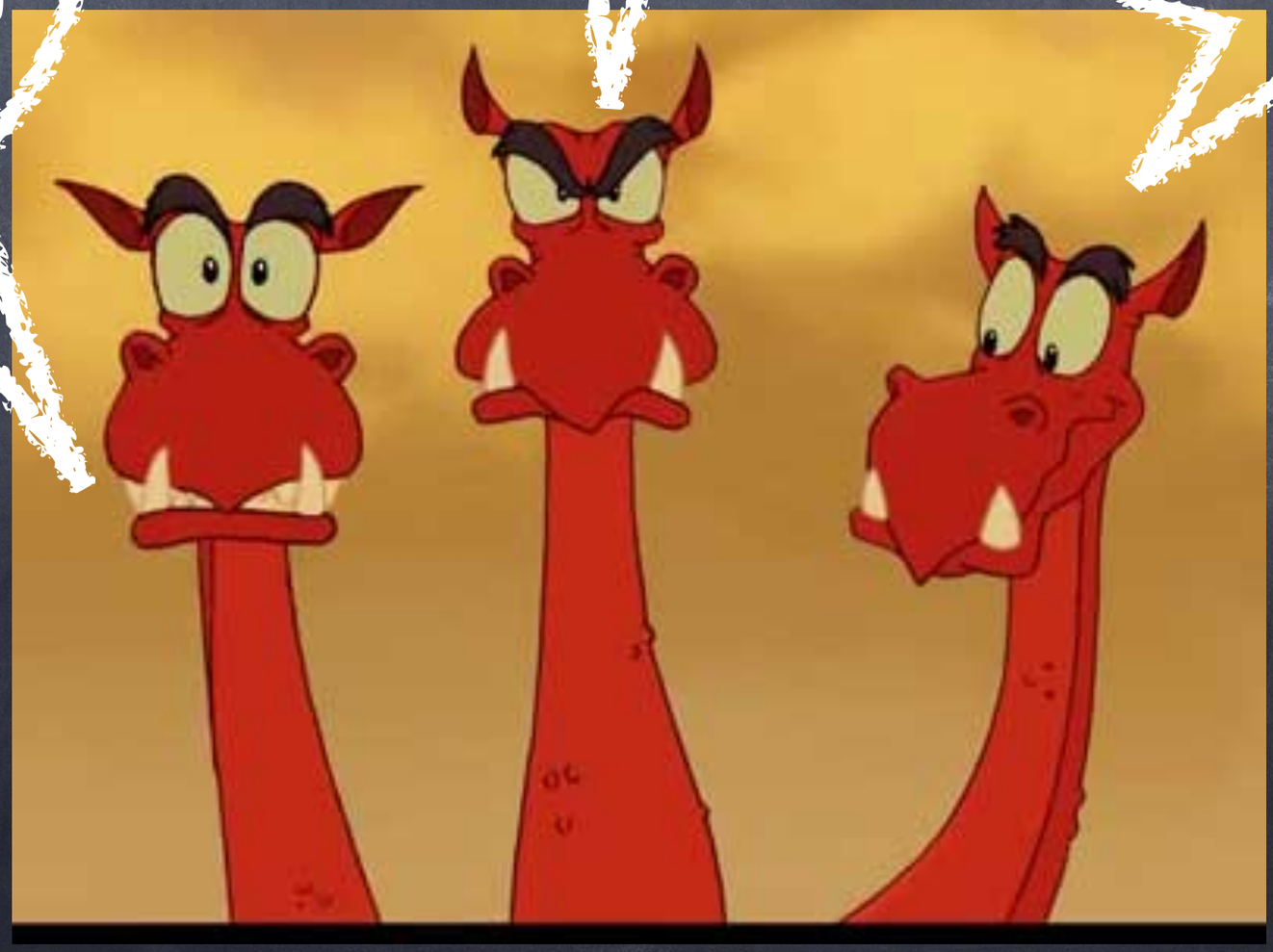
Conclusions. Bad news

- There are no pronounced correlation both the indicator of acceleration in flares and CME velocity for group B
- The most of ARs produced proton events are ARs breaking the law

We have to look for new approaches ARs breaking the rules

We have the group that could be used for statistics based on «classical model»

We need more statistics



Thank you for attention!!