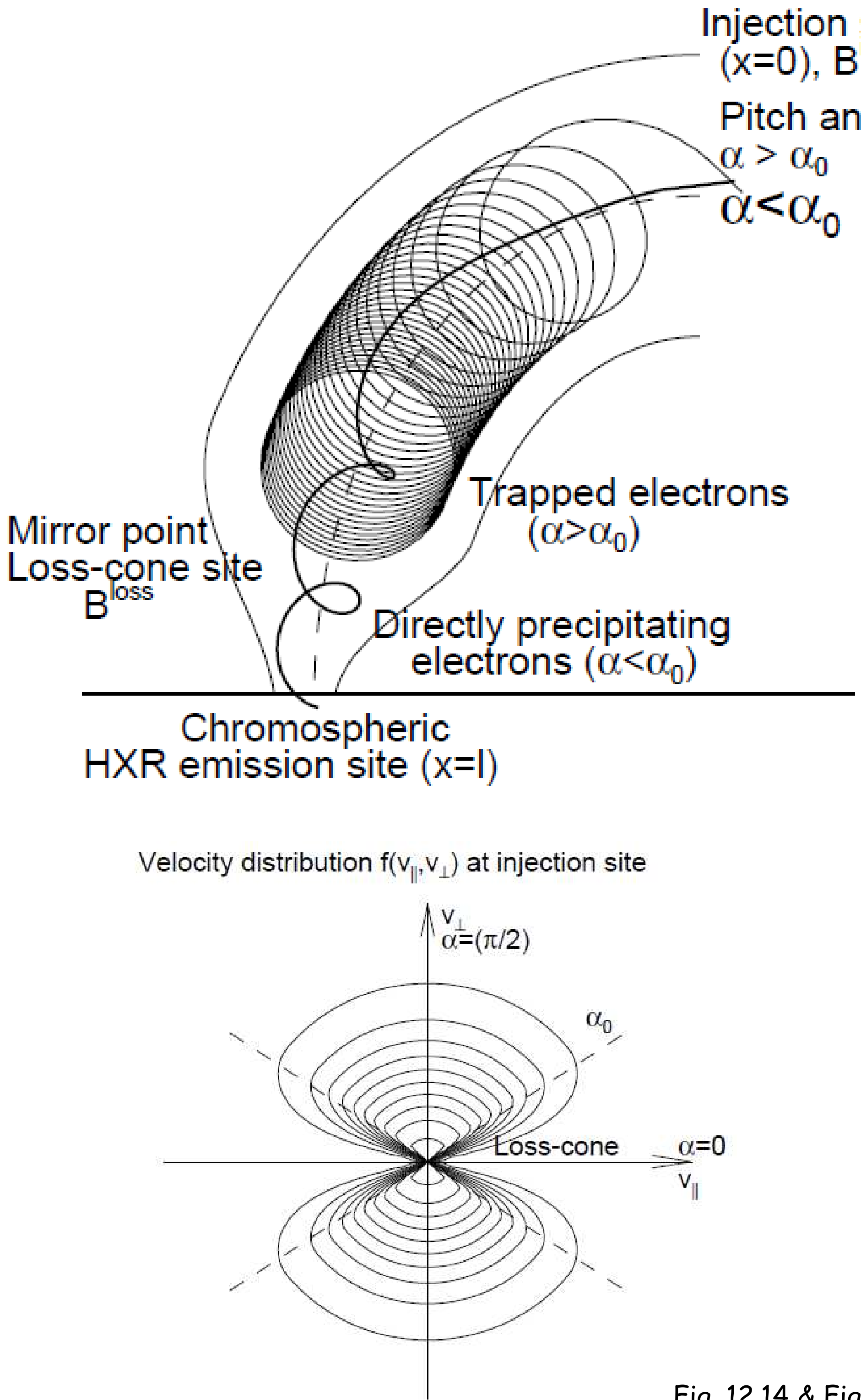


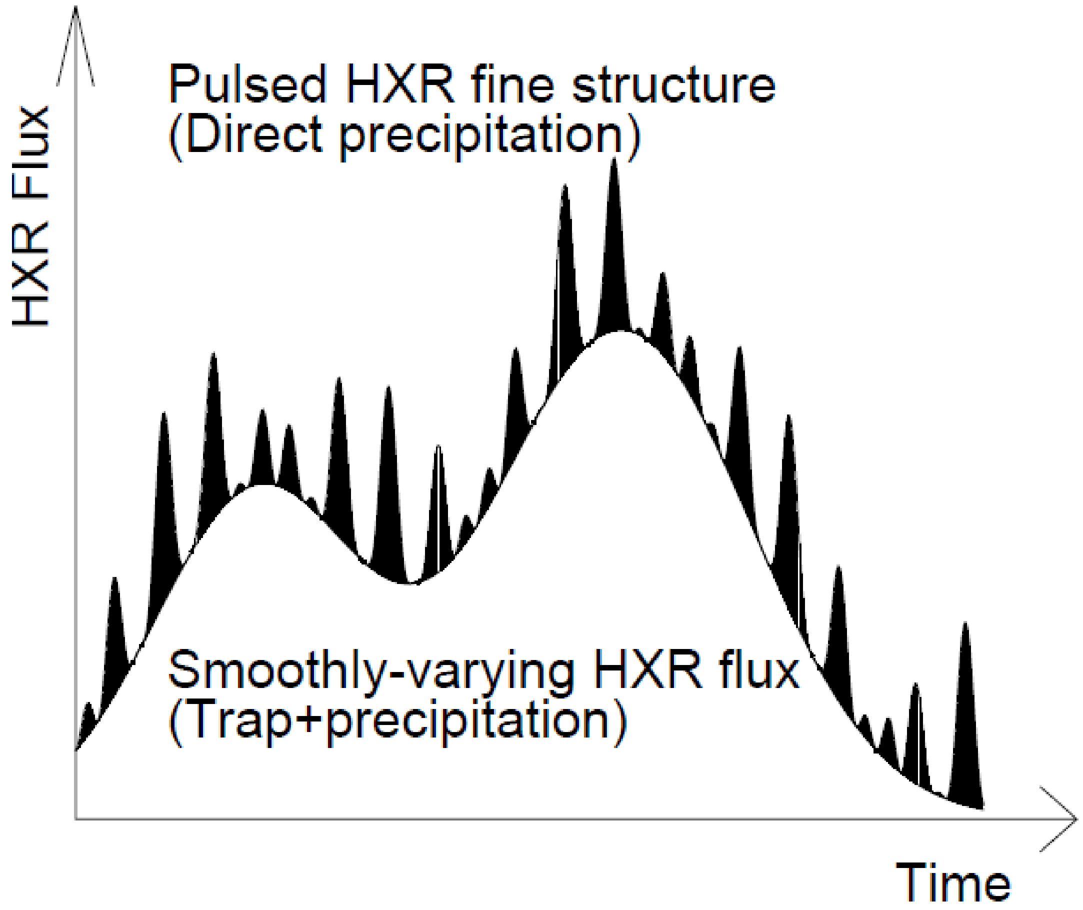
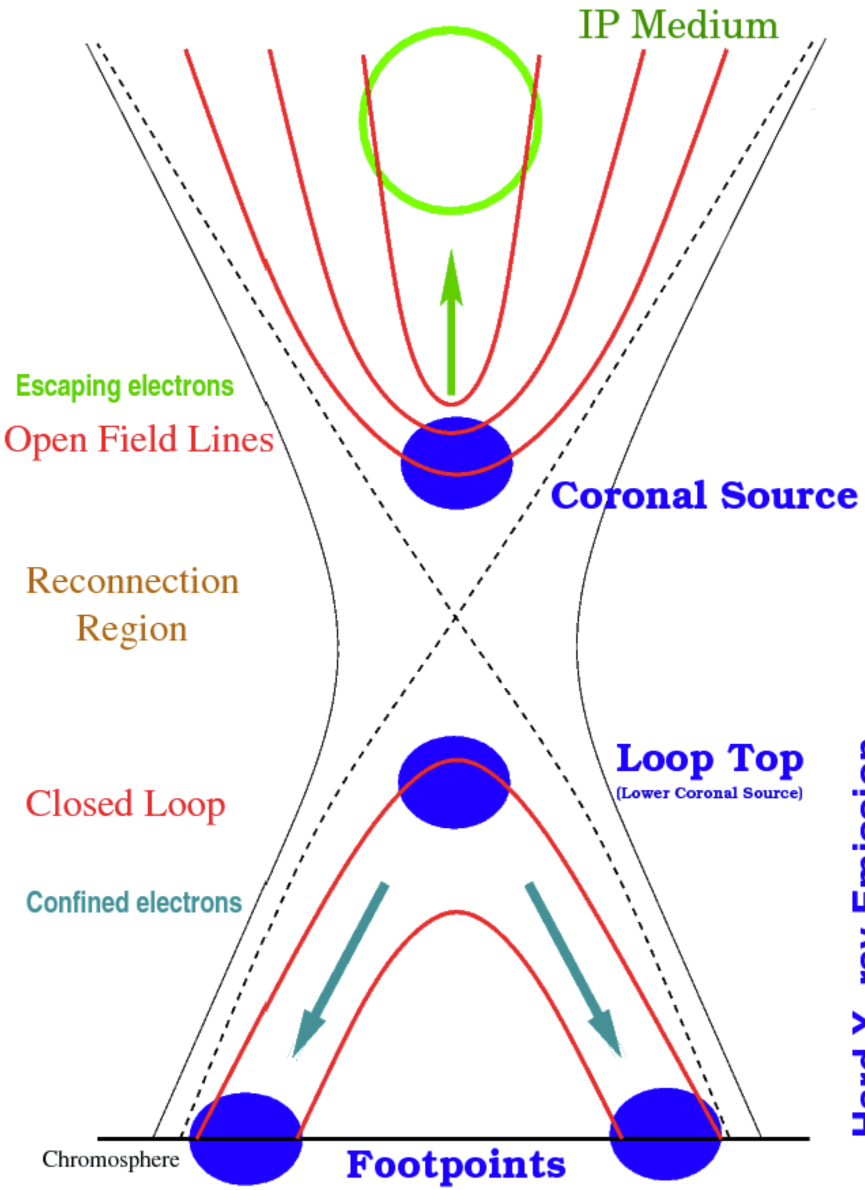
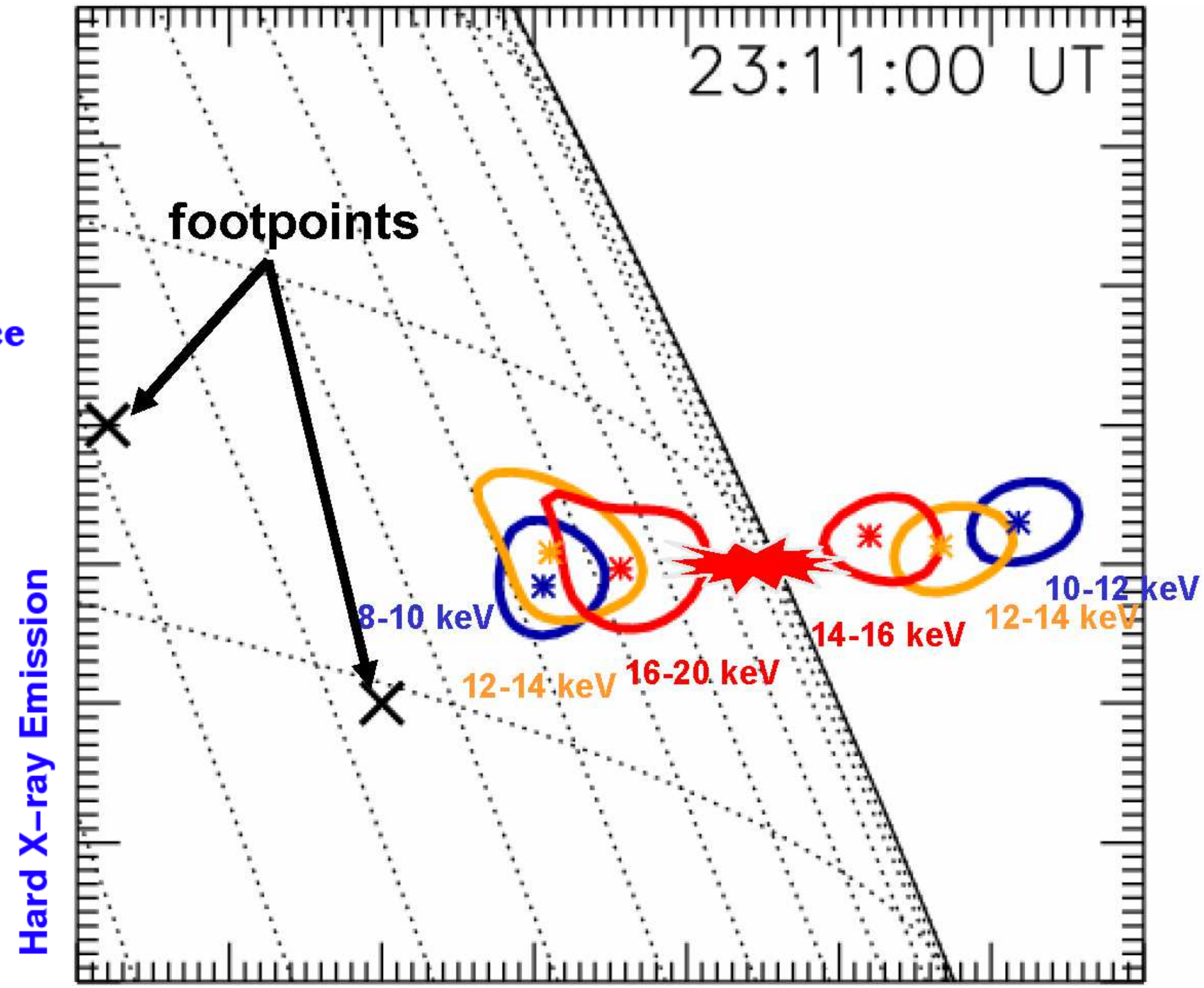


Fig. 12.14 & Fig. 12.15 in Markus J. Aschwanden (2005)

Double Coronal Sources

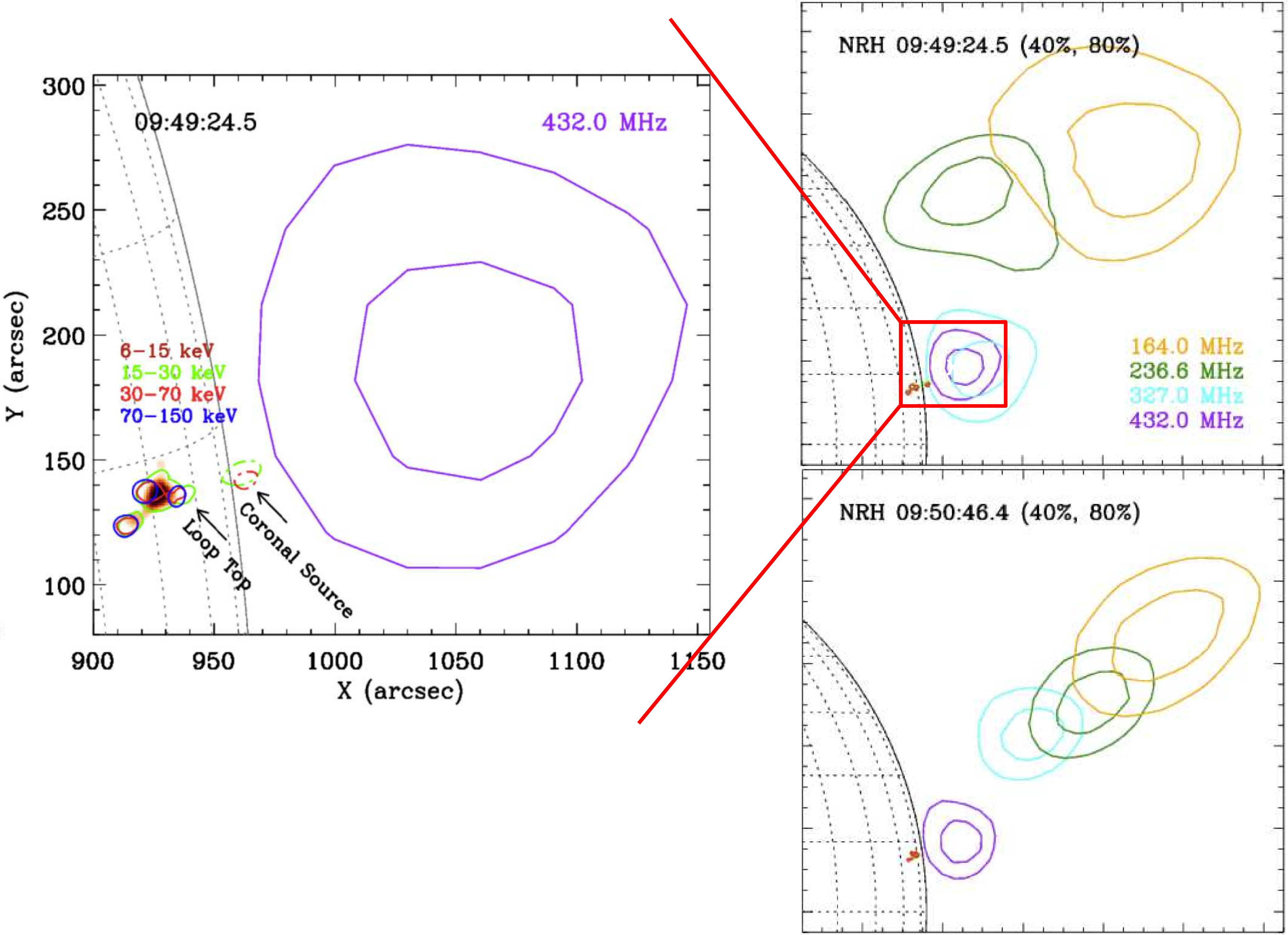


HXR coronal sources: close to acceleration site



Qingrong Chen in 2010 RHESSI Workshop

Sam Krucker in RHESSI 2008 Workshop



Qingrong Chen in 2010 RHESSI Workshop

Electric DC-Field Acceleration

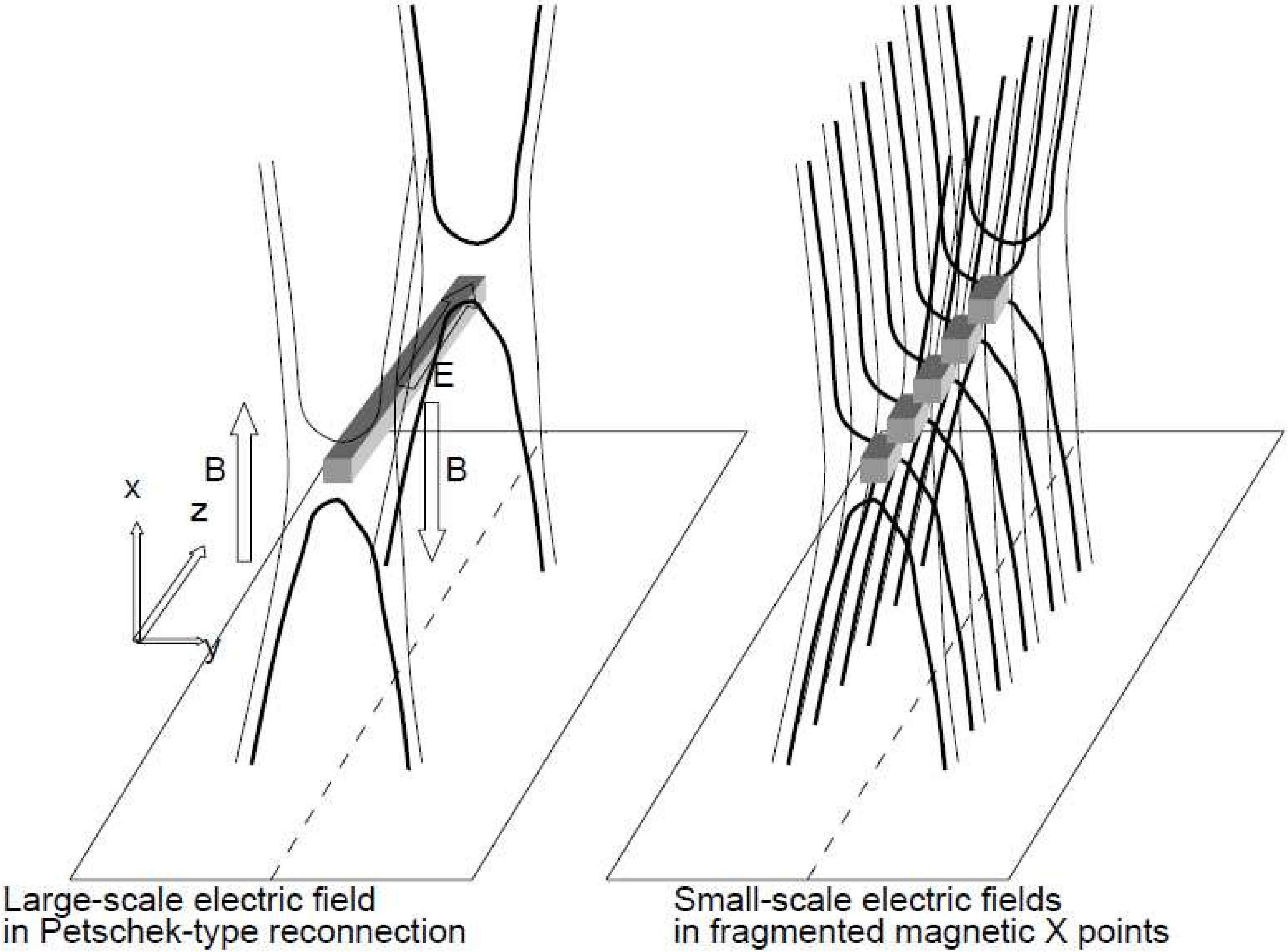
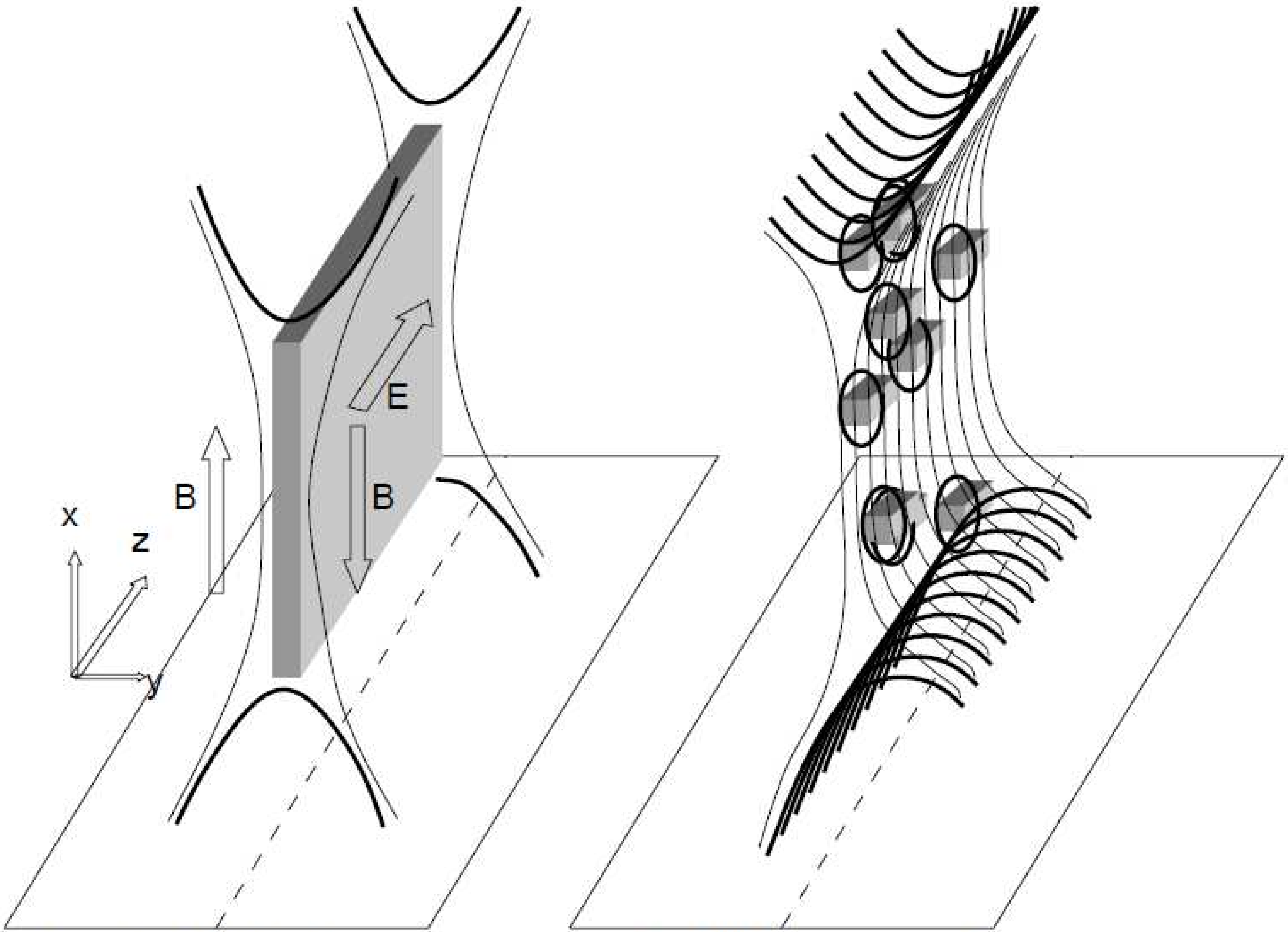


Fig. 48 in Markus J. Aschwanden (2002)

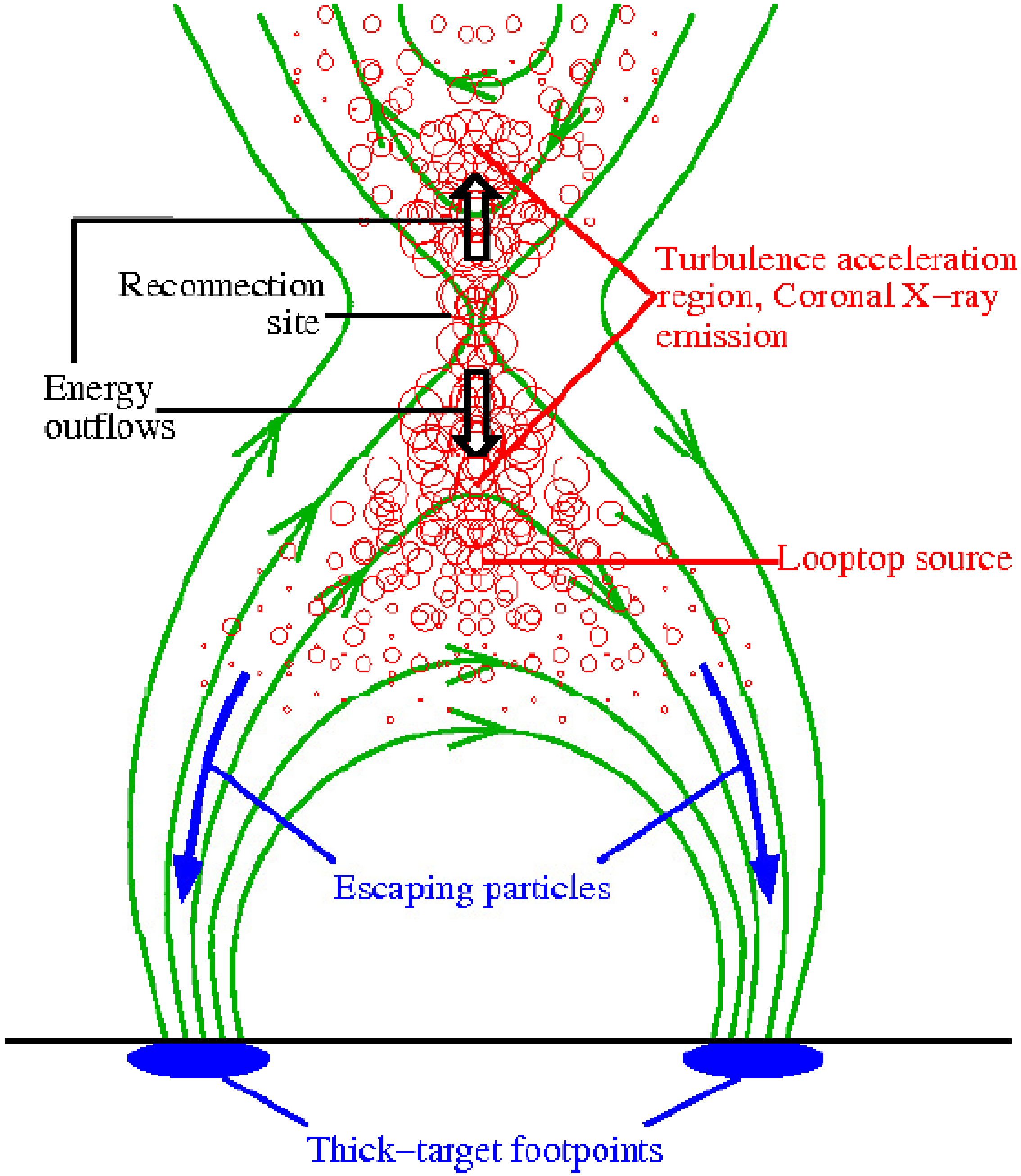


Large-scale electric field
in Sweet-Parker current sheet

Small-scale electric fields
in magnetic X and O points

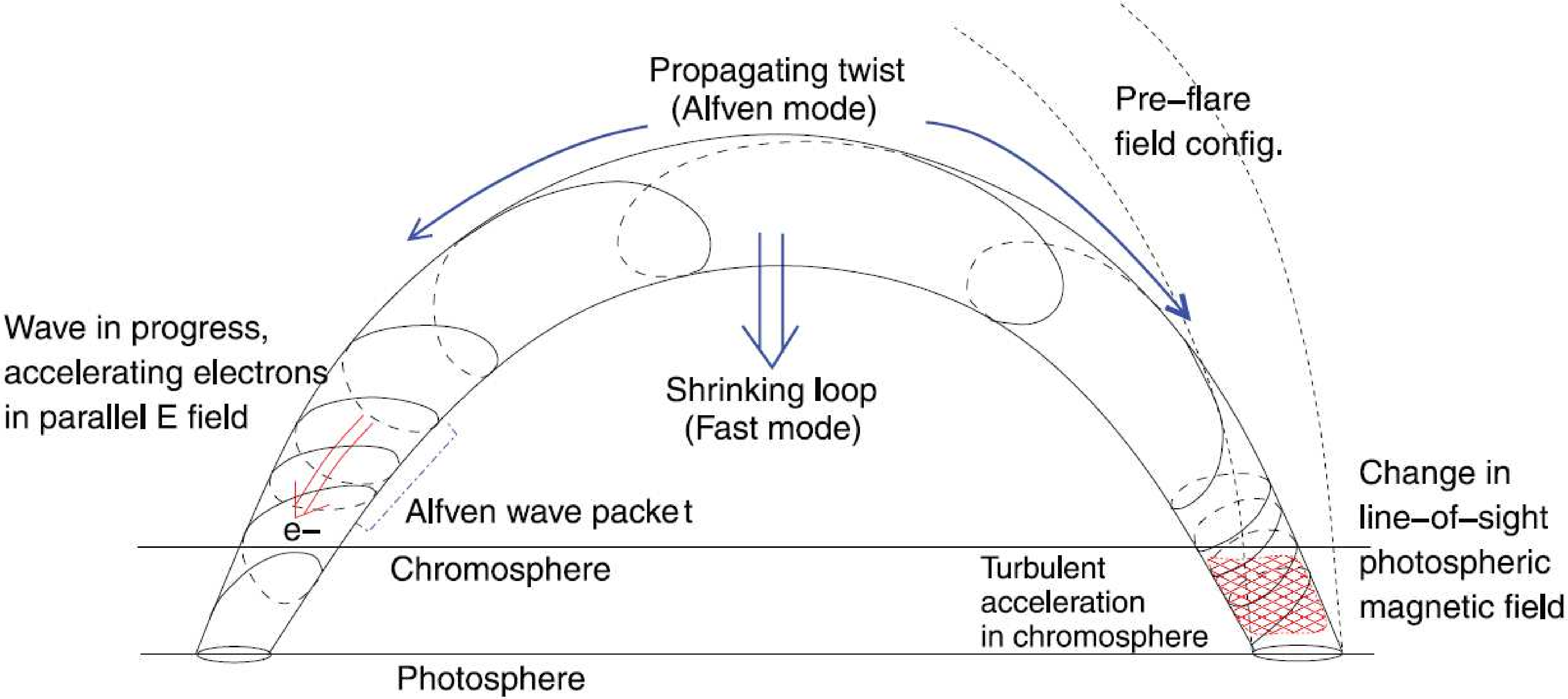
Fig. 11.2 in Markus J. Aschwanden (2005)

Stochastic Acceleration



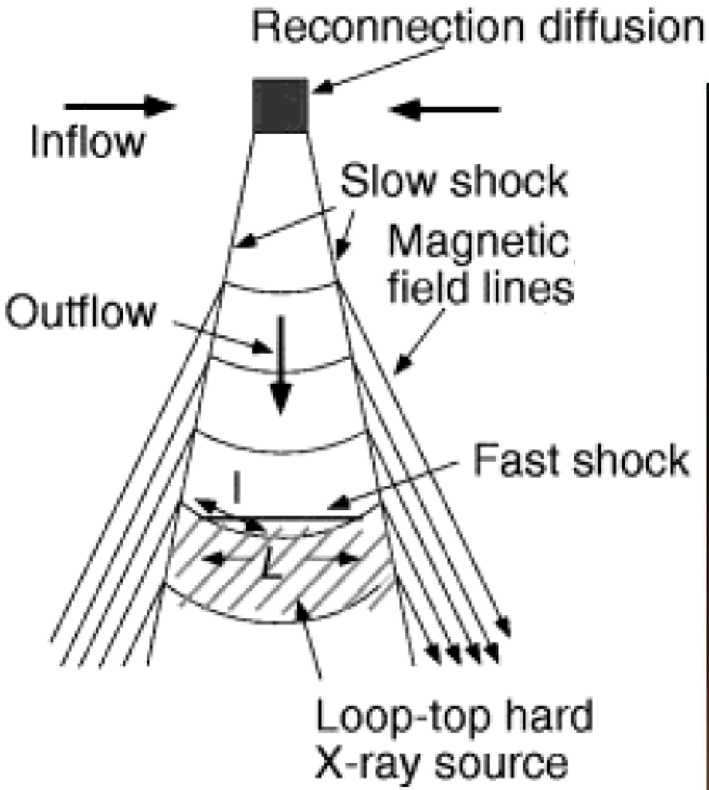
Petrosian (2012)

Wave-Particle Interaction



Fletcher & Hudson (2008)

Shock Acceleration



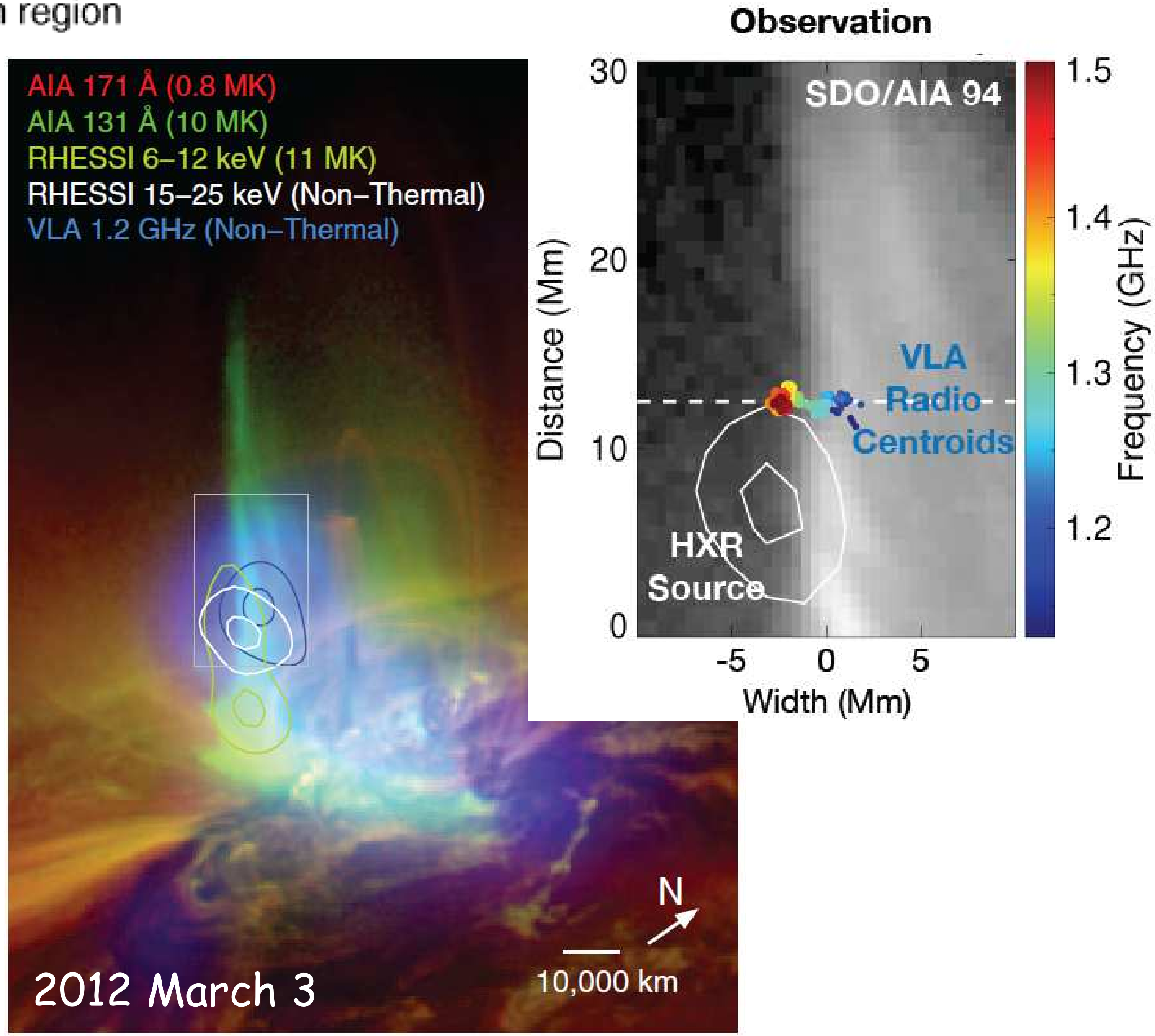
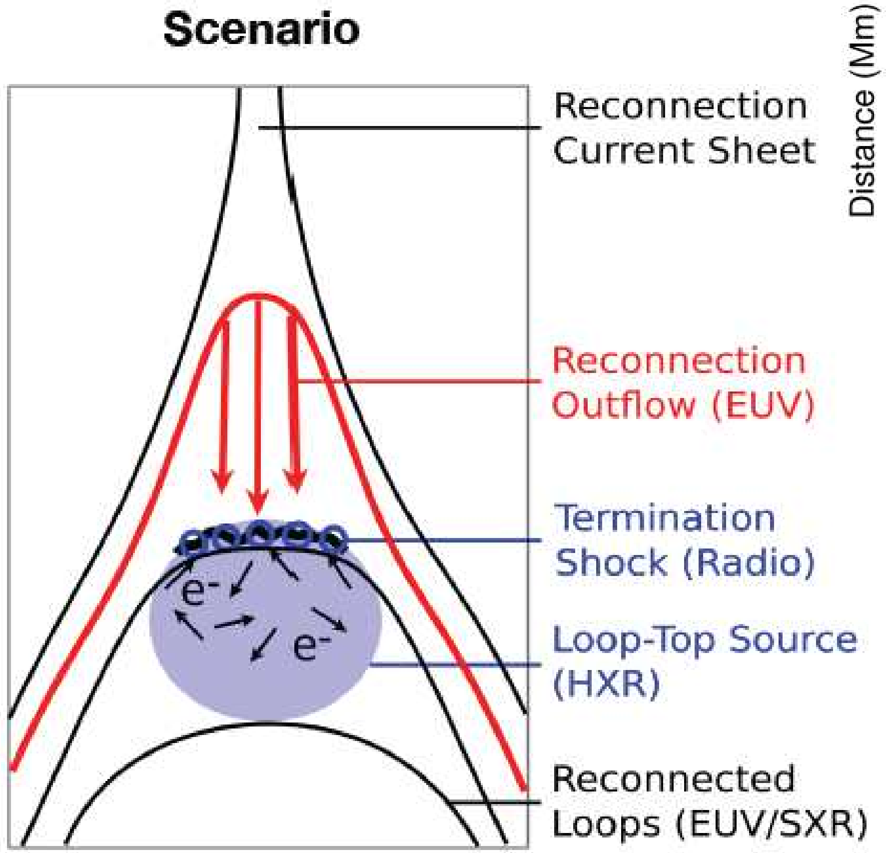
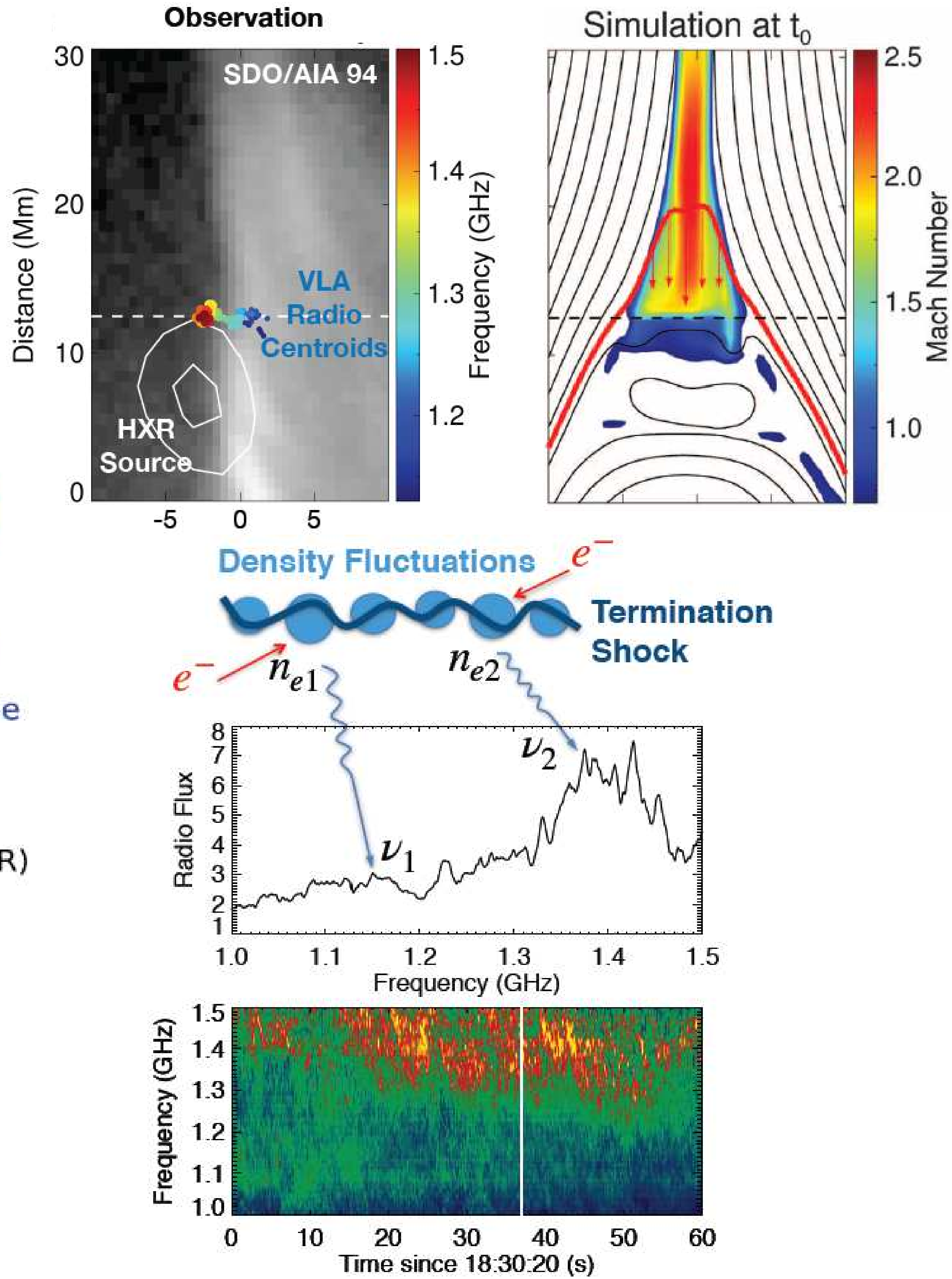


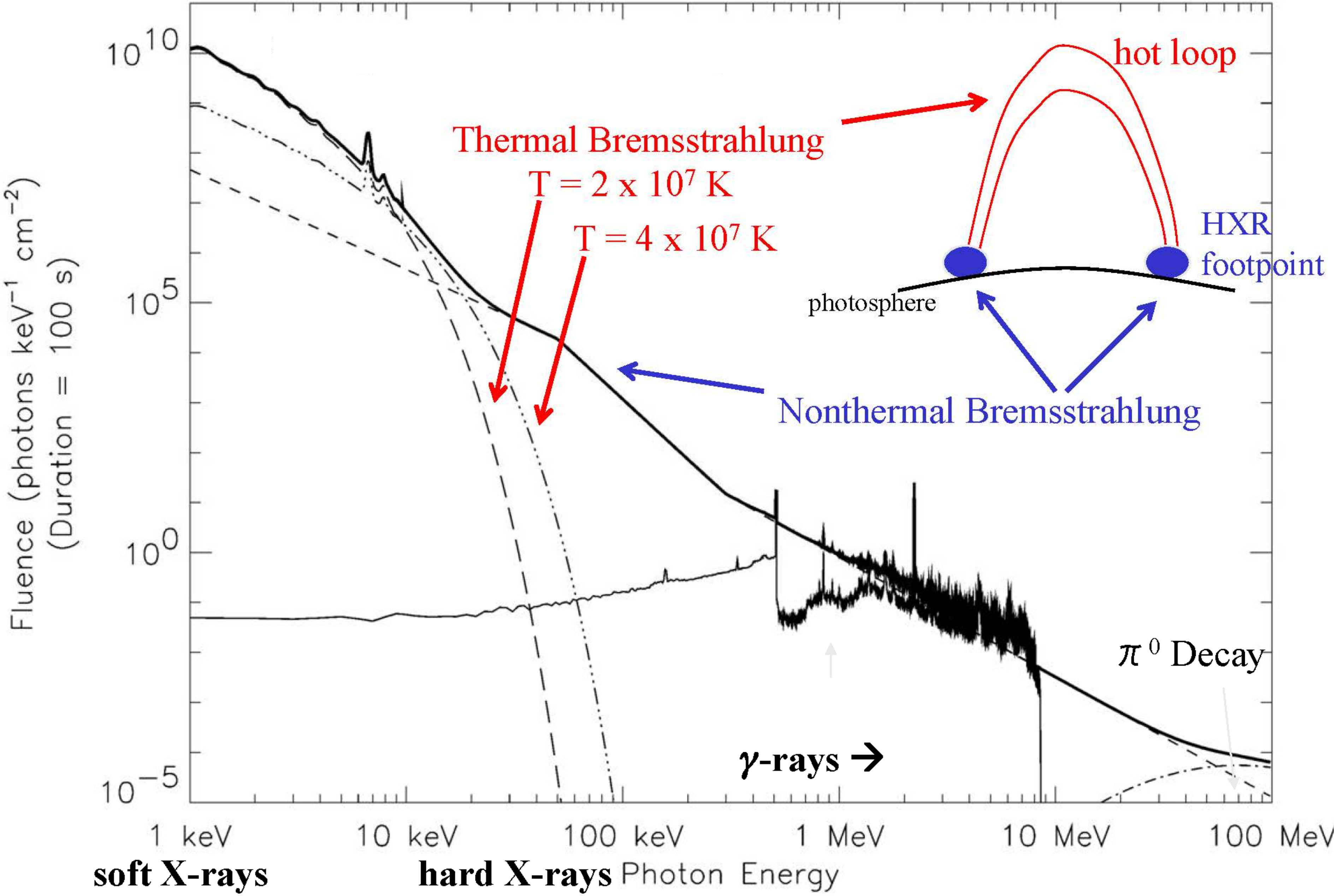
Fig. 11.19 in Markus J. Aschwanden (2005)   https://web.njit.edu/~binchen/phys780/   Chen et al. (2015) & Chen et al. (2019)





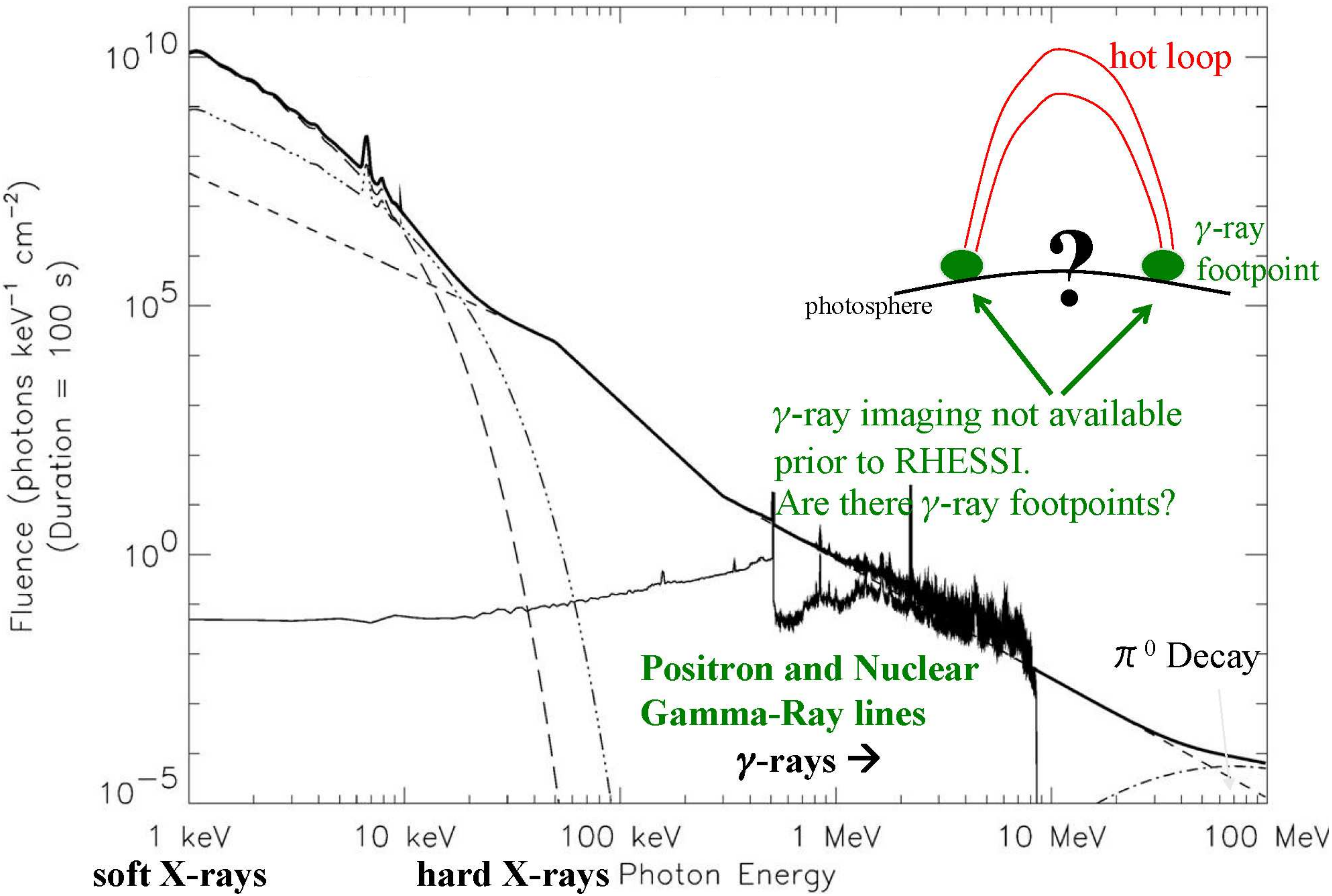
Chen et al. (2015) & Chen et al. (2019)

Composite Solar Flare Spectrum



Sam Krucker in Nobeyama 2005 Workshop

Composite Solar Flare Spectrum



Sam Krucker in Nobeyama 2005 Workshop

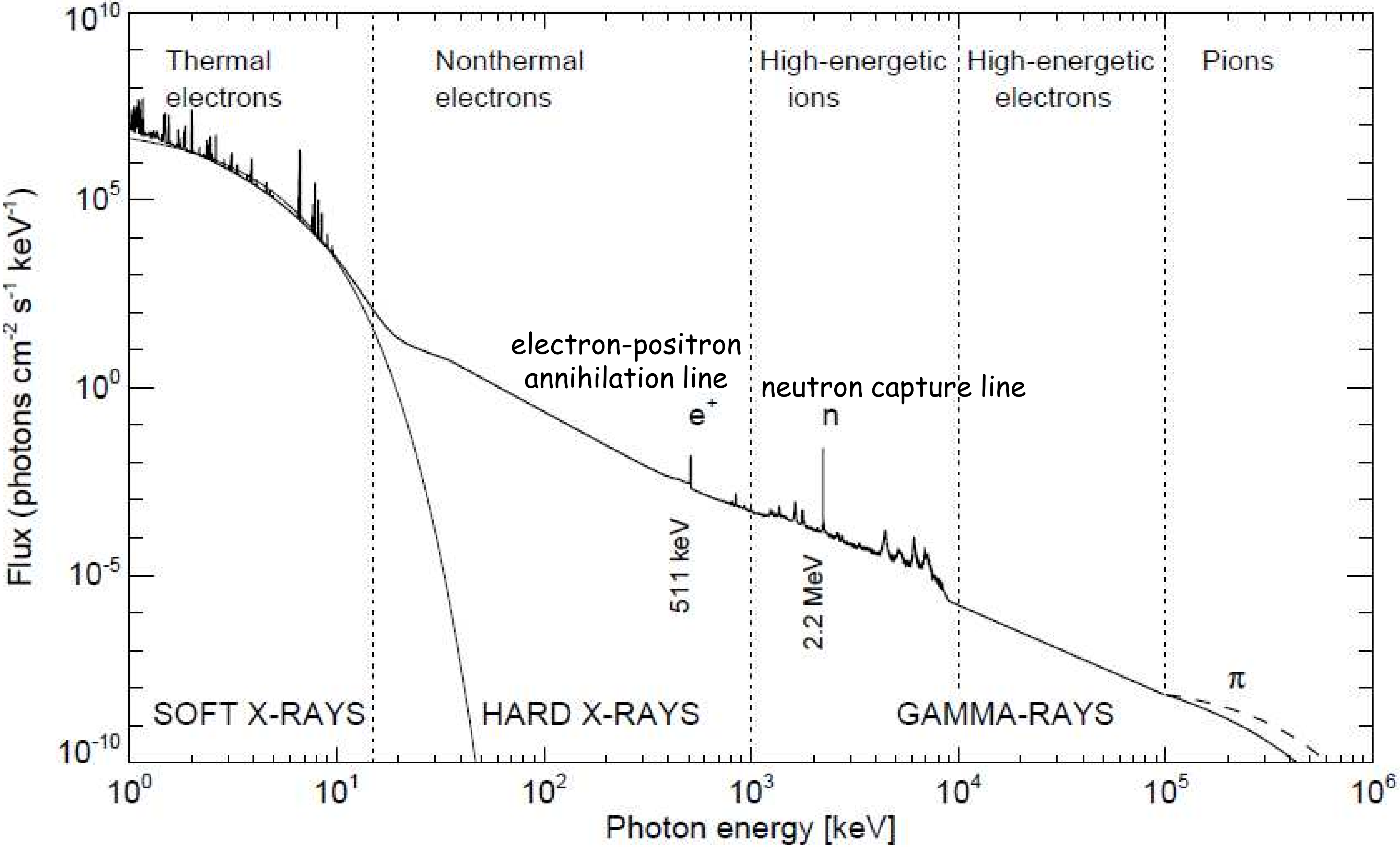


Fig. 14.1 & Fig. 14.7 in Markus J. Aschwanden (2005)

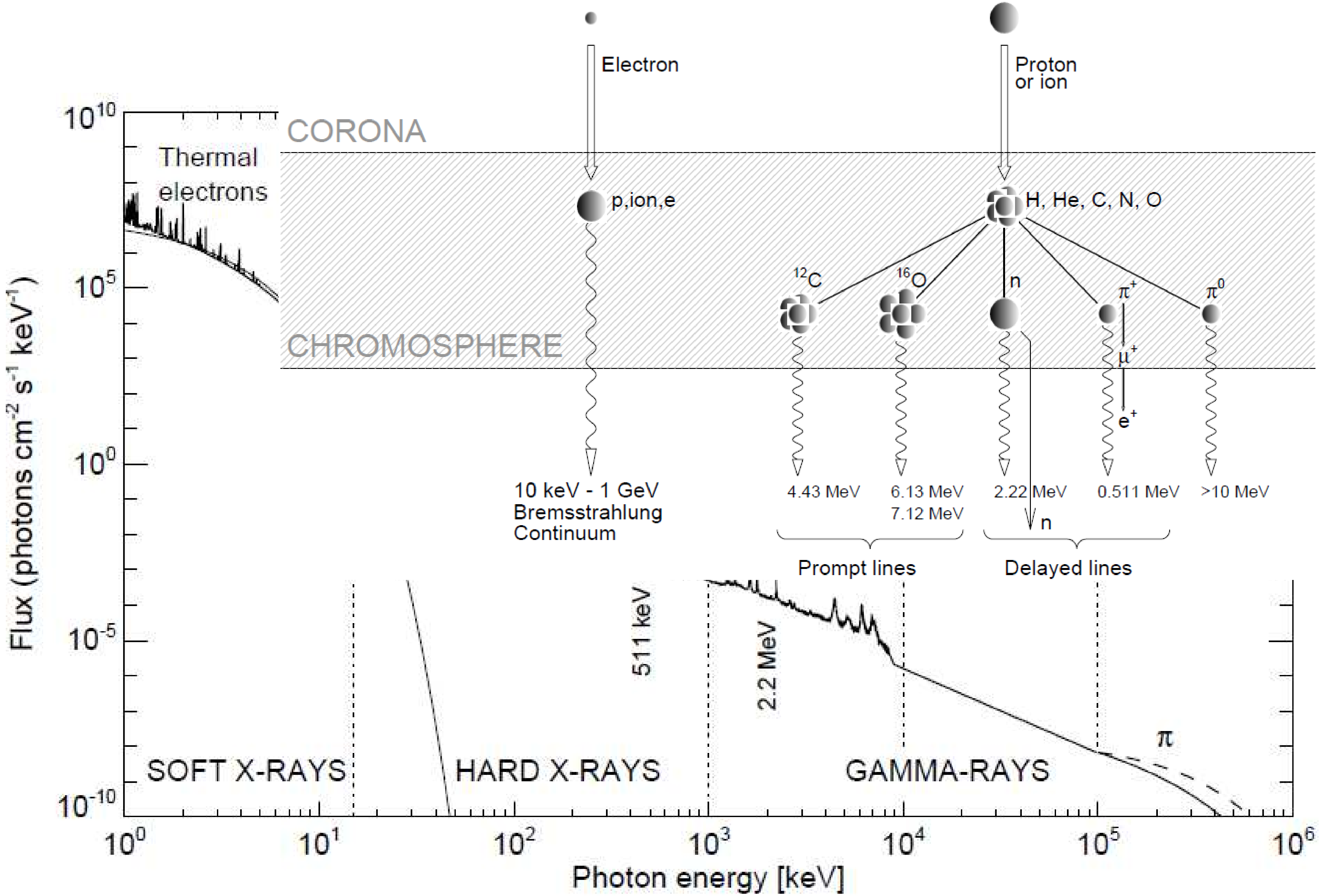
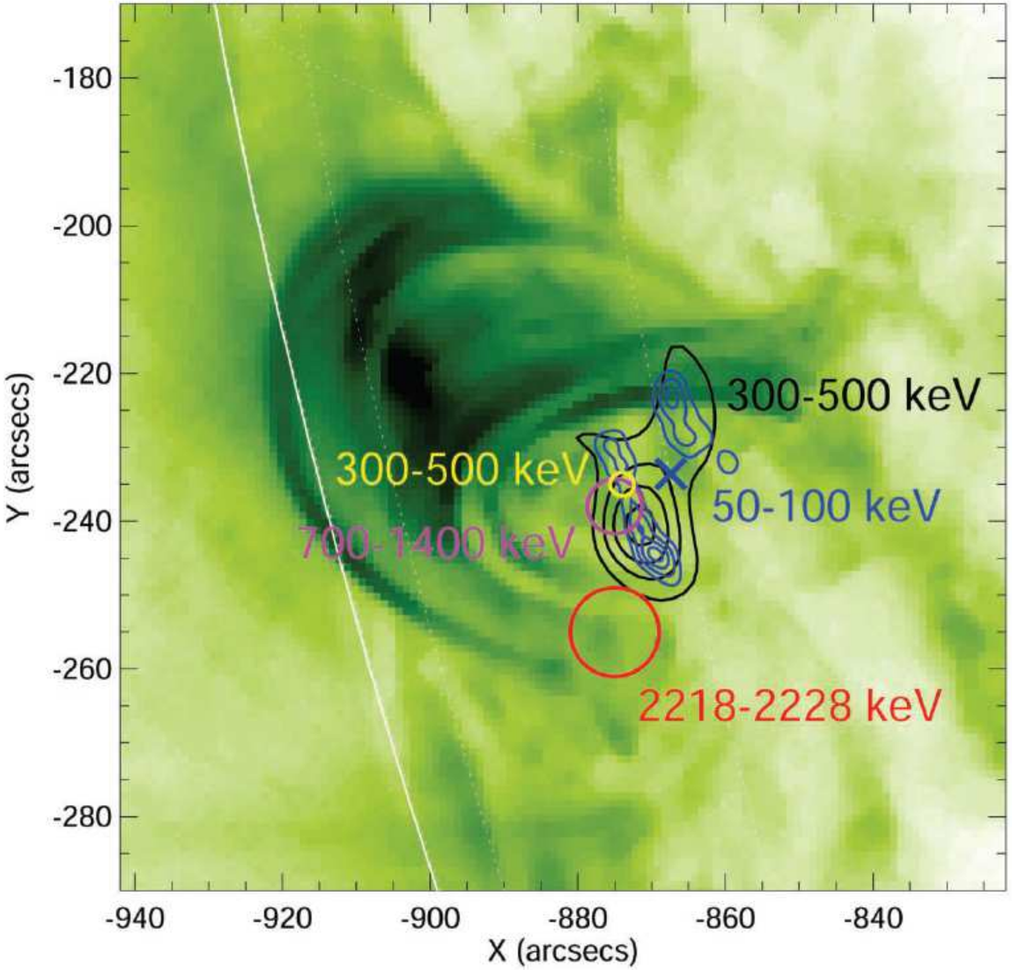
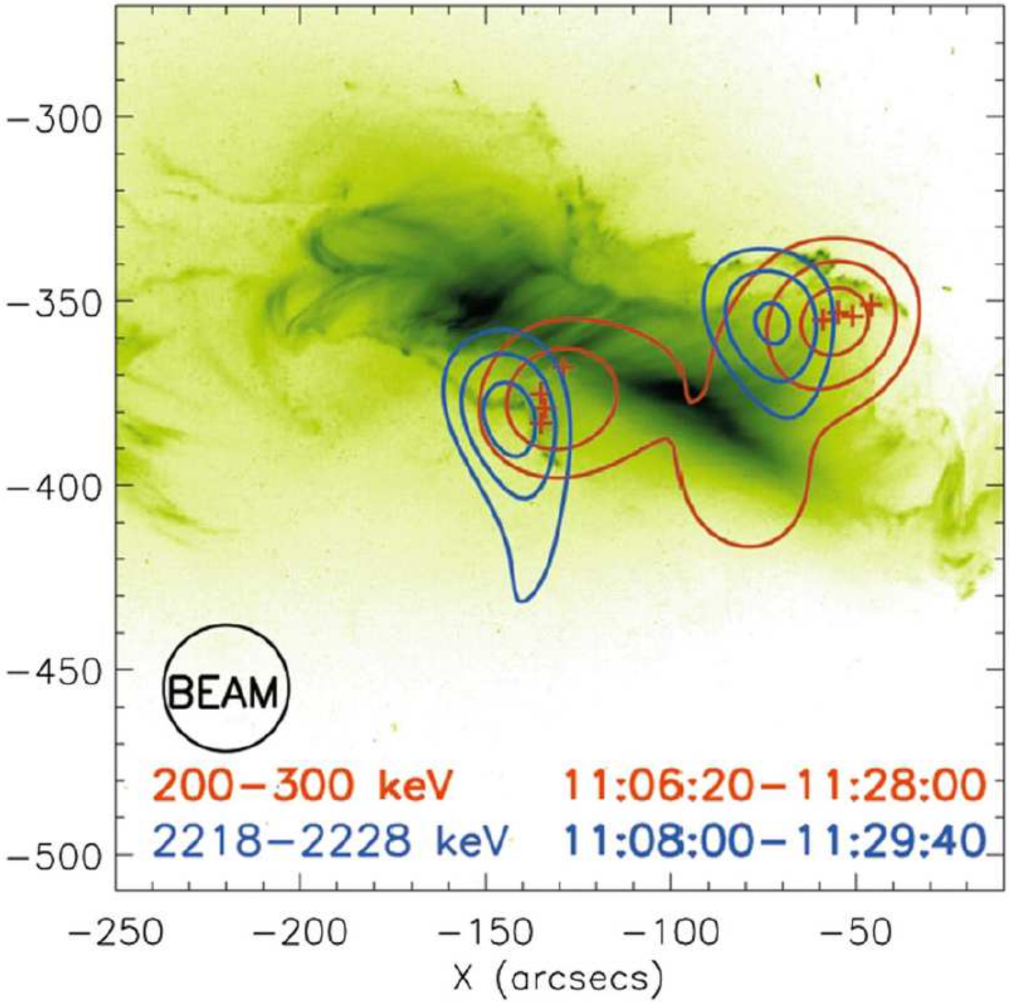


Fig. 14.1 & Fig. 14.7 in Markus J. Aschwanden (2005)

2002 July 23 X4.8



2003 October 28 X17



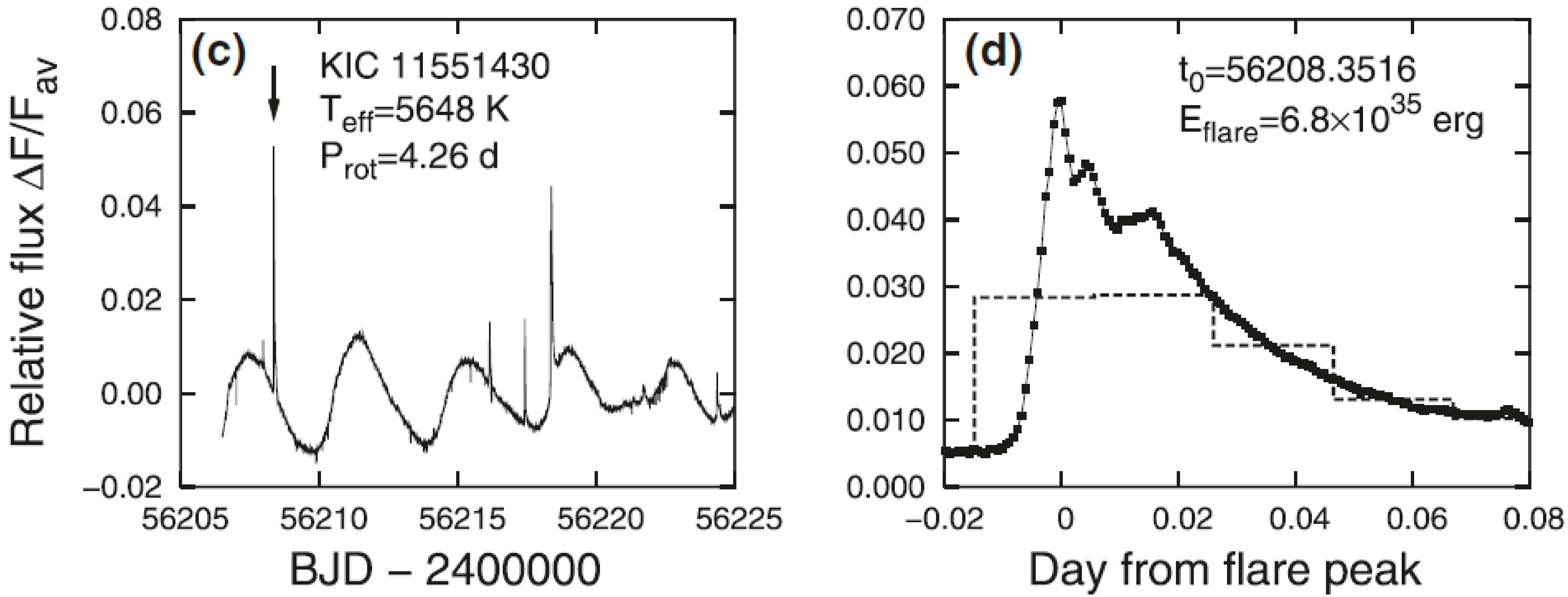
RHESSI found that the footpoints of the 2.223 MeV line— indicating ion precipitation—and the footpoints of the non-thermal continuum emission—produced by precipitating electrons—do not always coincide. This implies spatial differences in acceleration and/or propagation between the flare-accelerated ions and electrons.

Lin et al. (2003)

Hurford et al. (2006)

Superflare

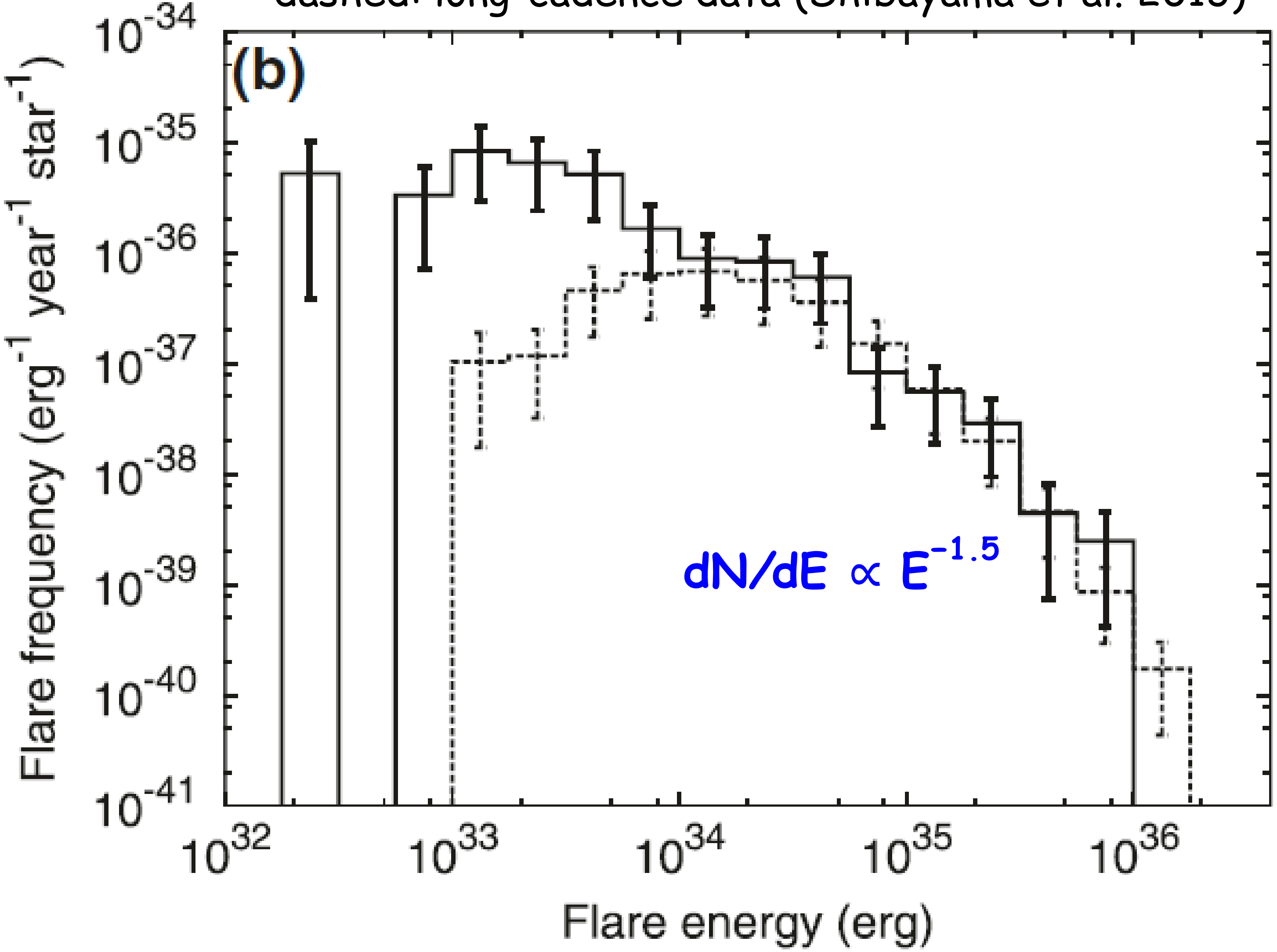
187 superflares on 23 solar-type stars with the energy ranges from the order of 10^{32} to 10^{36} erg using 1-min sampling of Kepler data



(Barycentric Julian Date)

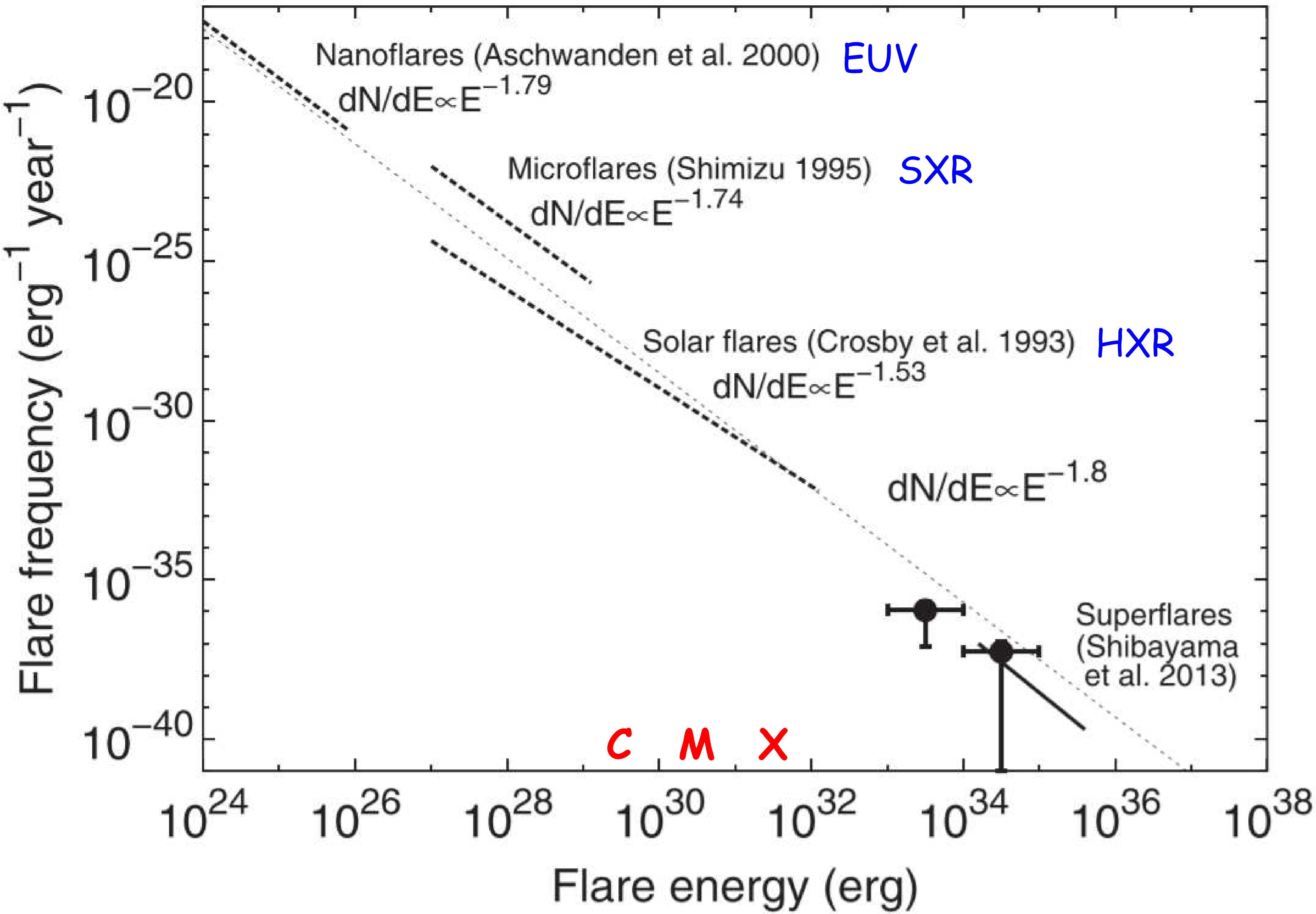
Maehara et al. (2015)

solid: short-cadence data (this work)
dashed: long-cadence data (Shibayama et al. 2013)



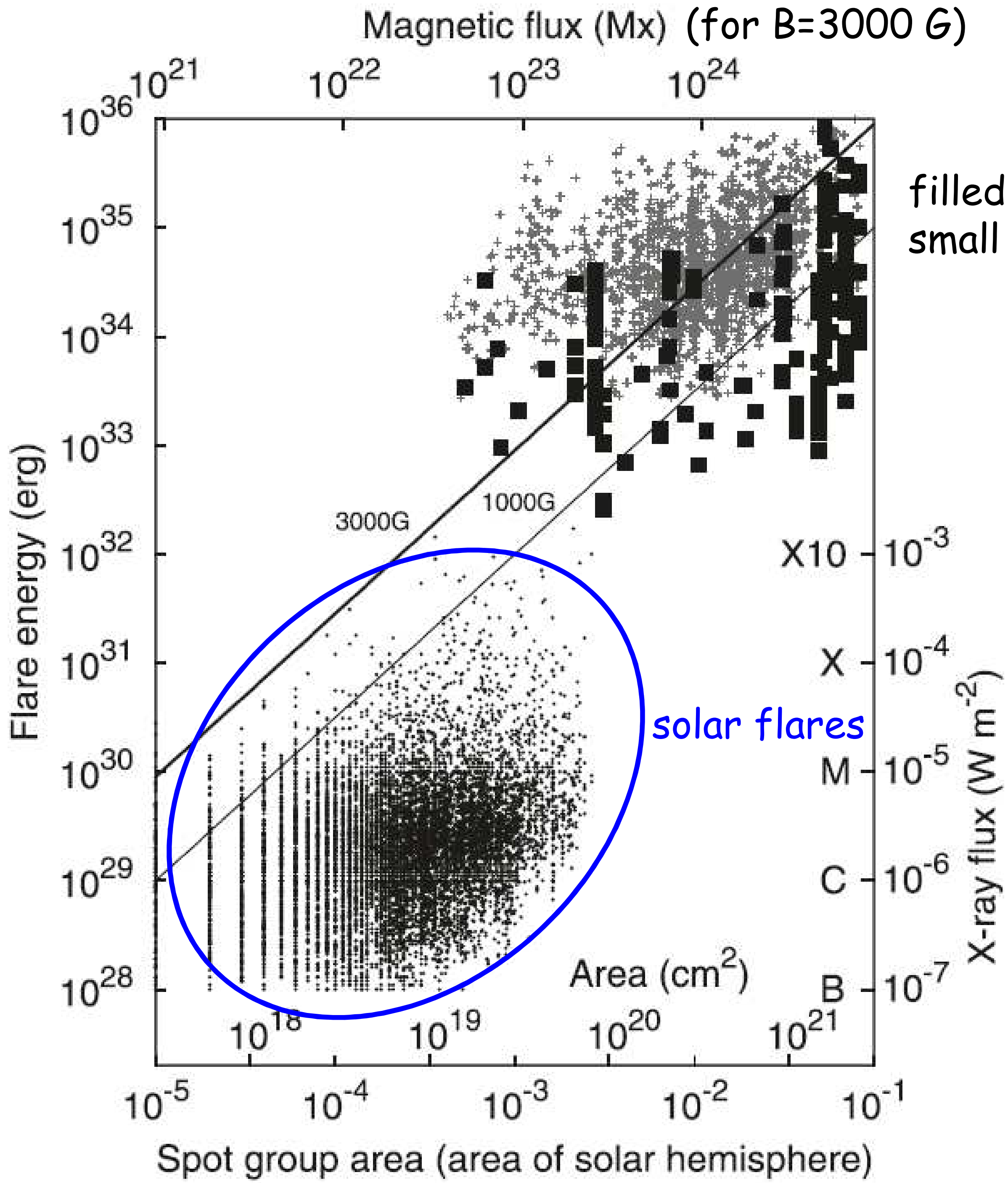
Using the combined data set from both short- and long-cadence data, the power-law index is -1.5 ± 0.1 for the flare energy of 4×10^{33} to 1×10^{36} erg.

Maehara et al. (2015)



Occurrence frequency distributions of superflares on Sun-like stars and solar flares are roughly on the same power-law line with an index of −1.8 (thin solid line) for the wide energy range between 10^{24} and 10^{35} erg.

Maehara et al. (2015)

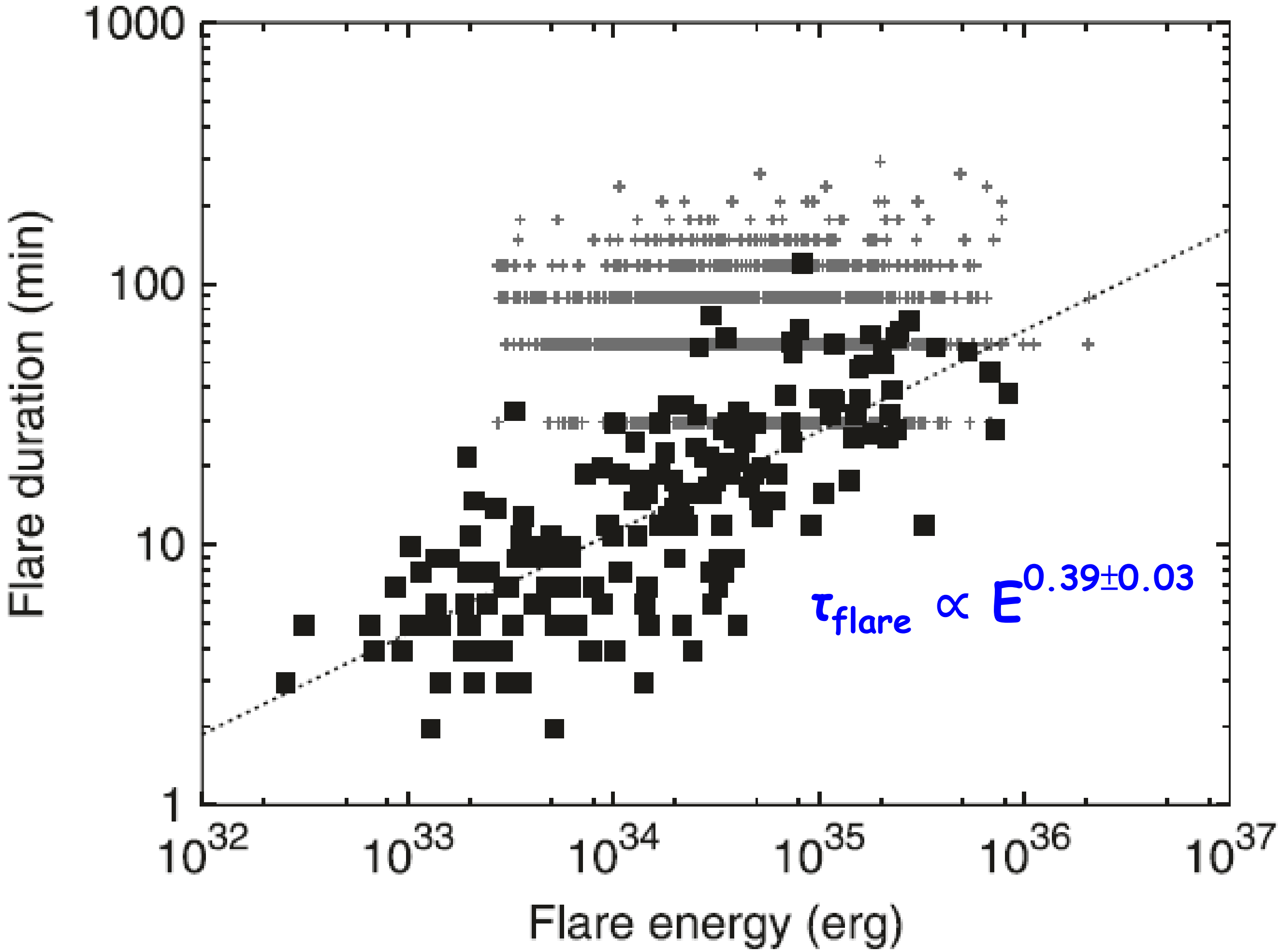


filled squares: short-cadence data
small crosses: long-cadence data

$$E_{\text{flare}} \sim fE_{\text{mag}} \sim \frac{fB^2 A_{\text{spot}}^{3/2}}{8\pi}$$

f is the fraction of magnetic energy released by the flare. The typical value of *f* is in the order of 0.1.

Maehara et al. (2015)



Theoretically,

$$E_{\rm flare} \sim fE_{\rm mag} \propto fB^2L^3$$

$$\tau_{\rm flare} \sim \tau_{\rm rec} \sim \tau_{\rm A}/M_{\rm A}$$
$$\sim L/v_{\rm A}/M_{\rm A}$$

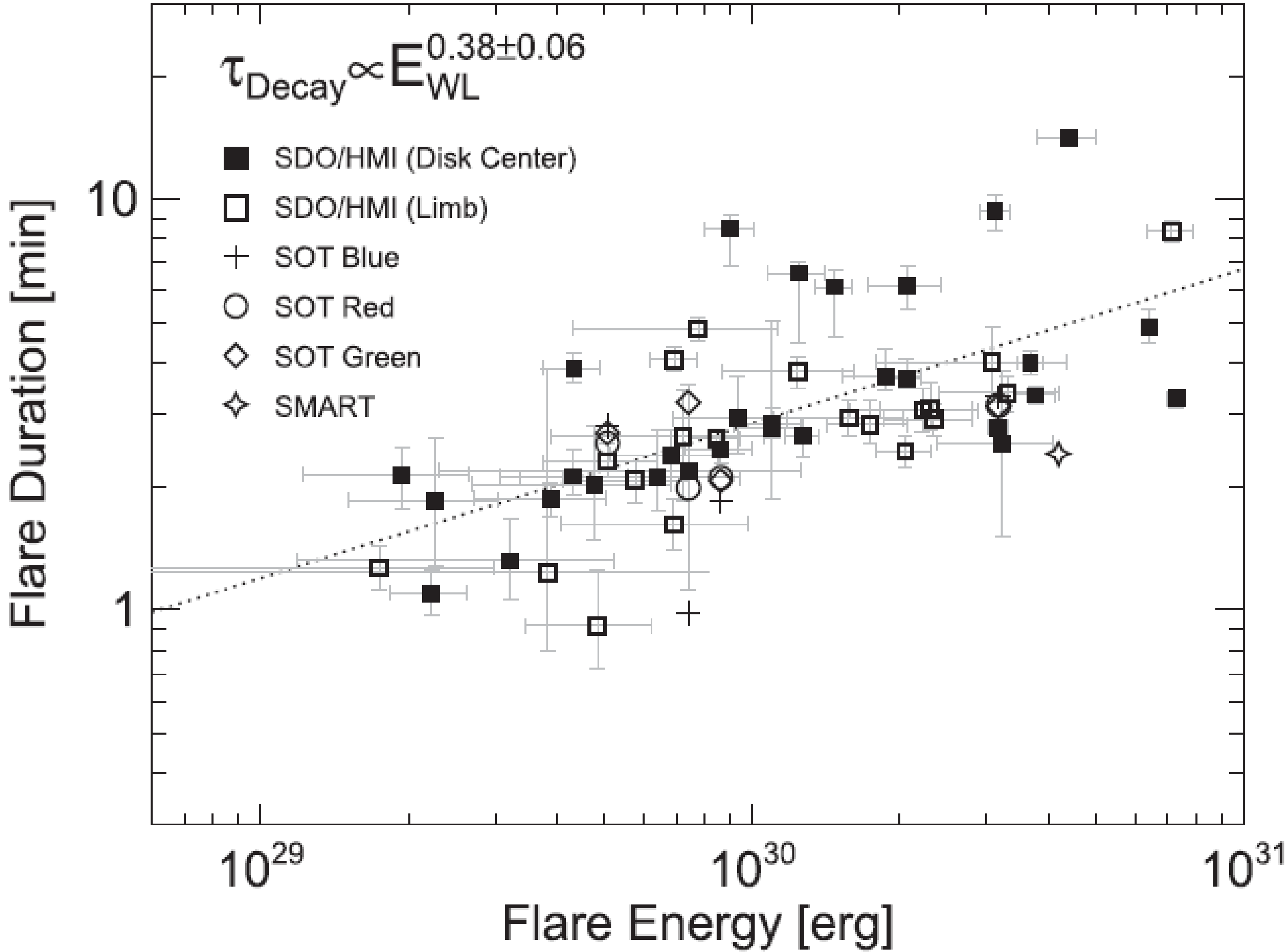
τ_A is the Alfvén time
v_A is the Alfvén velocity
M_A is the non-dimensional reconnection rate (0.01-0.1)

Since all G-type main sequence stars have similar stellar properties, *B* and v_A might not be so different among them. Therefore,

$$\tau_{\rm flare} \propto E_{\rm flare}^{1/3}$$

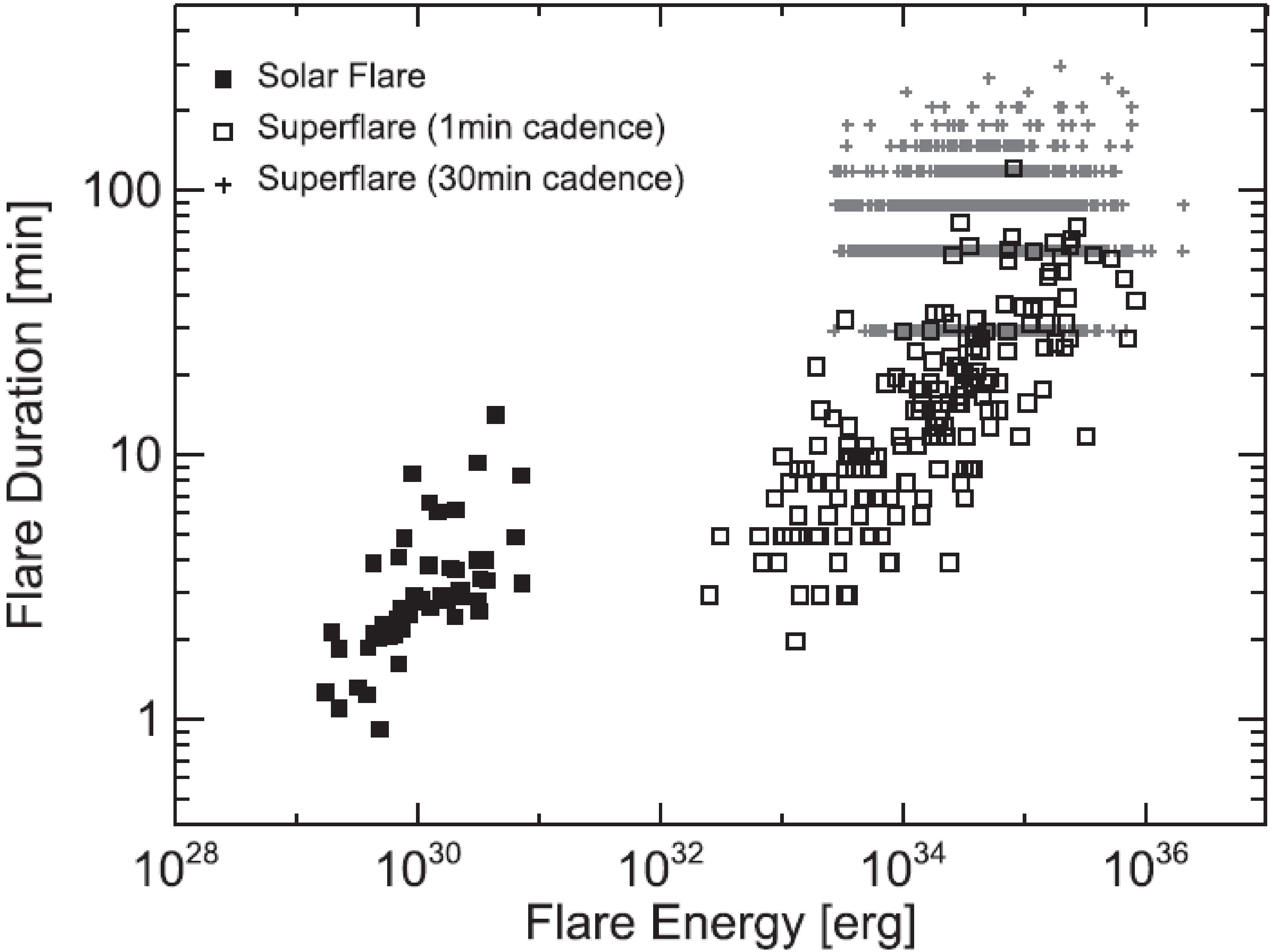
The observations show that the flare duration increases with the flare energy as $\tau_{flare} \propto E^{0.39\pm0.03}$.

Maehara et al. (2015)



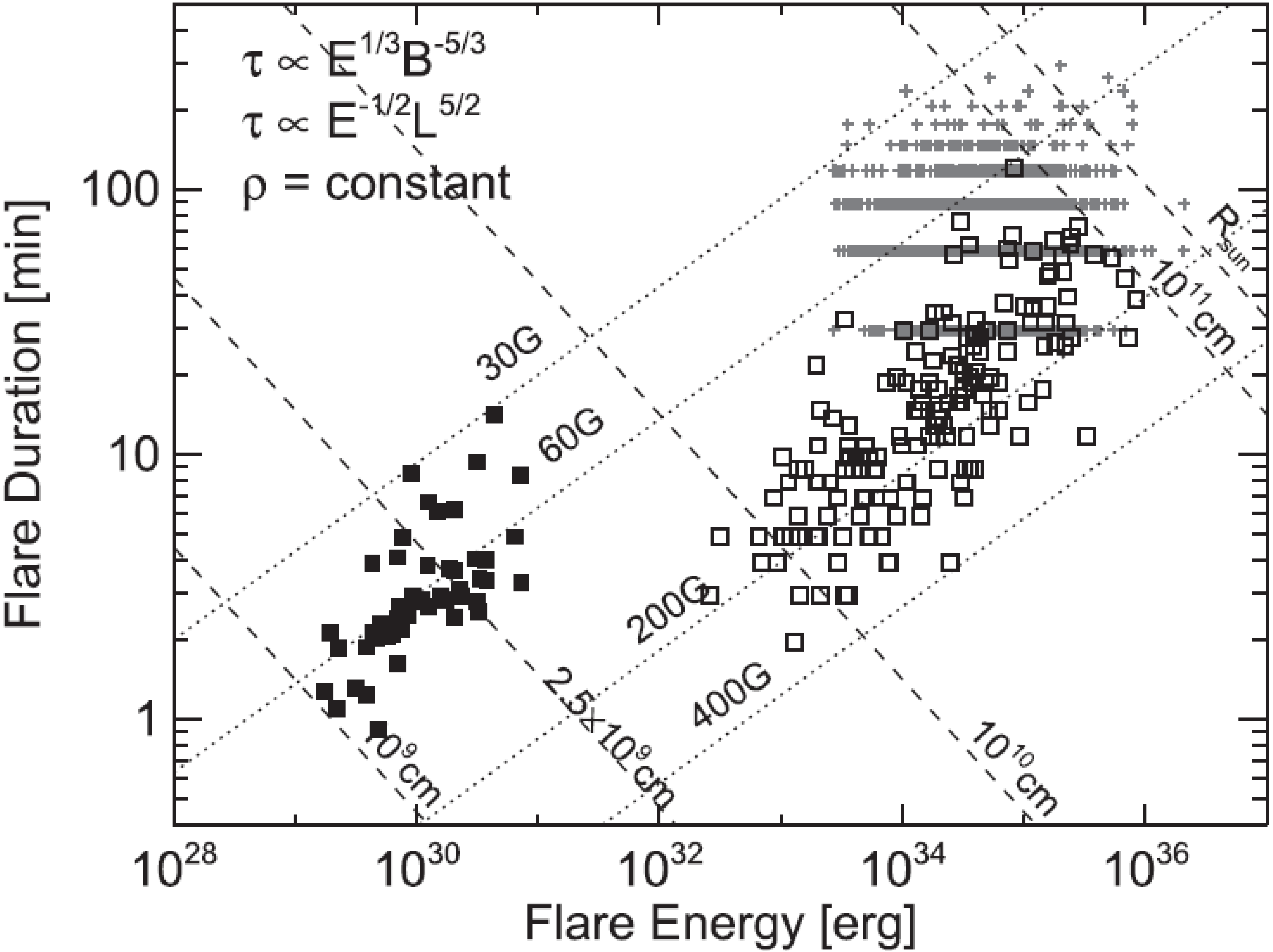
The E–τ relation on solar white-light flares (WLFs, $\tau \propto E^{0.38}$) is quite similar to that on stellar superflares ($\tau \propto E^{0.39}$).

Namekata et al. (2017)



However, the durations of stellar superflares are one order of magnitude shorter than those extrapolated from the power-law relation of solar WLFs.

Namekata et al. (2017)



$$E \sim fE_{\mathrm{mag}} \sim fB^2L^3$$

$$\tau \sim \tau_{\mathrm{rec}} \sim \tau_A/M_A \propto L/v_A/M_A$$

assuming that the pre-flare coronal density is a constant

$$\tau \propto E^{1/3}B^{-5/3}$$

$$\tau \propto E^{-1/2}L^{5/2}.$$

The distribution can be understood by applying a scaling law ($\tau \propto E^{1/3}B^{-5/3}$) derived from the magnetic reconnection theory. The observed superflares are expected to have 2–4 times stronger magnetic field strength than solar flares.

Namekata et al. (2017)