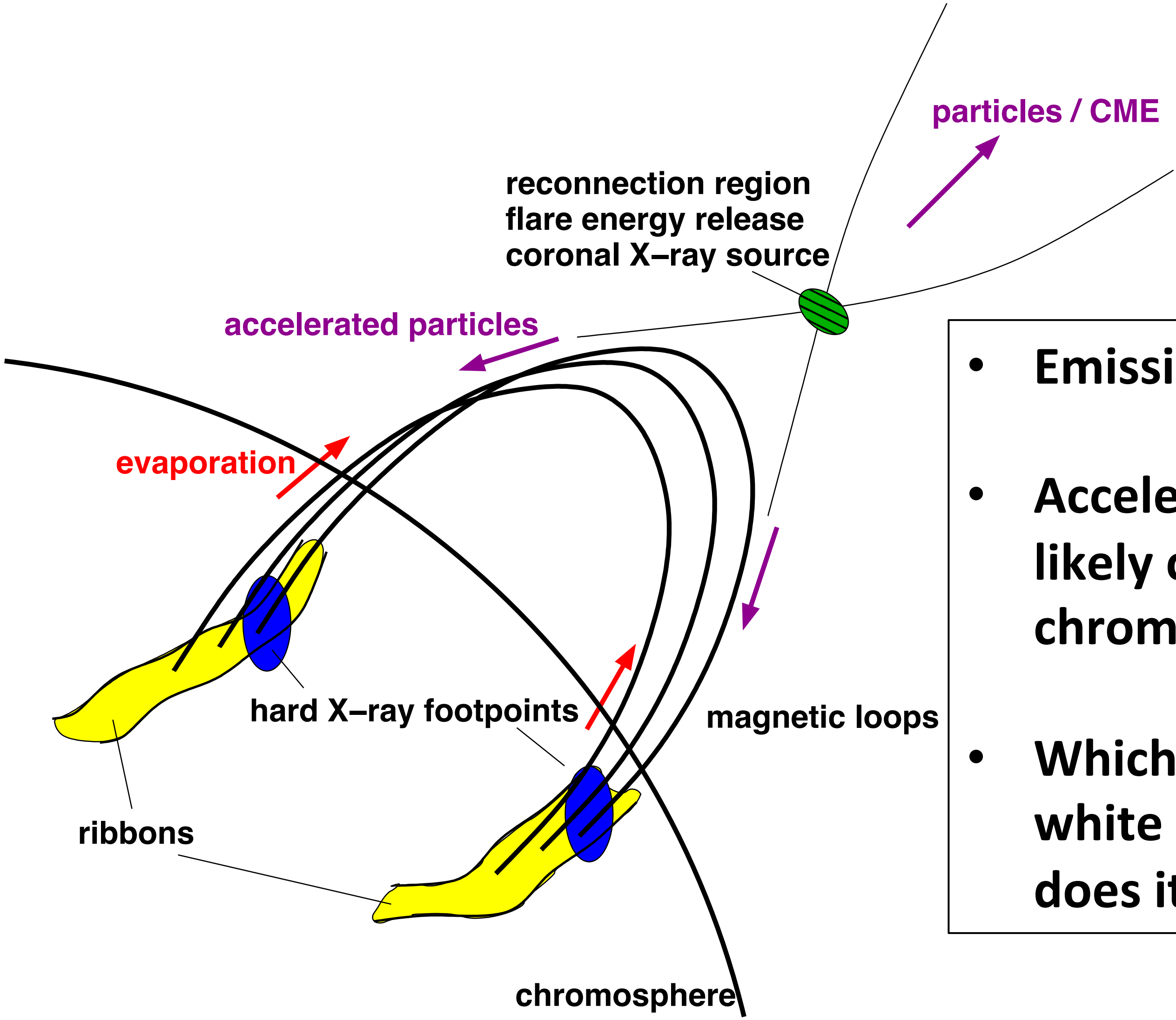
Combined IRIS and RHESSI observations to investigate continuum ("white light") emission

Lucia Kleint

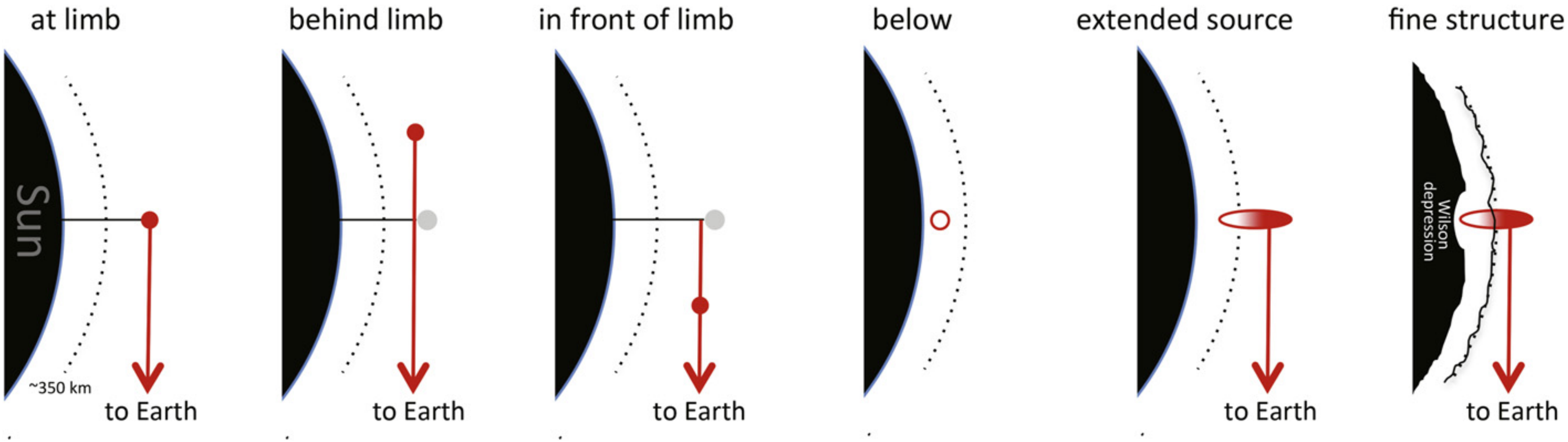
University of Applied Sciences and Arts Northwestern Switzerland

Flares: Principles



- **Emission observed in continua**
- **Accelerated electrons most likely cannot reach below chromosphere**
- **Which mechanism excites the white light emission? Where does it originate?**

Previous studies on WL height

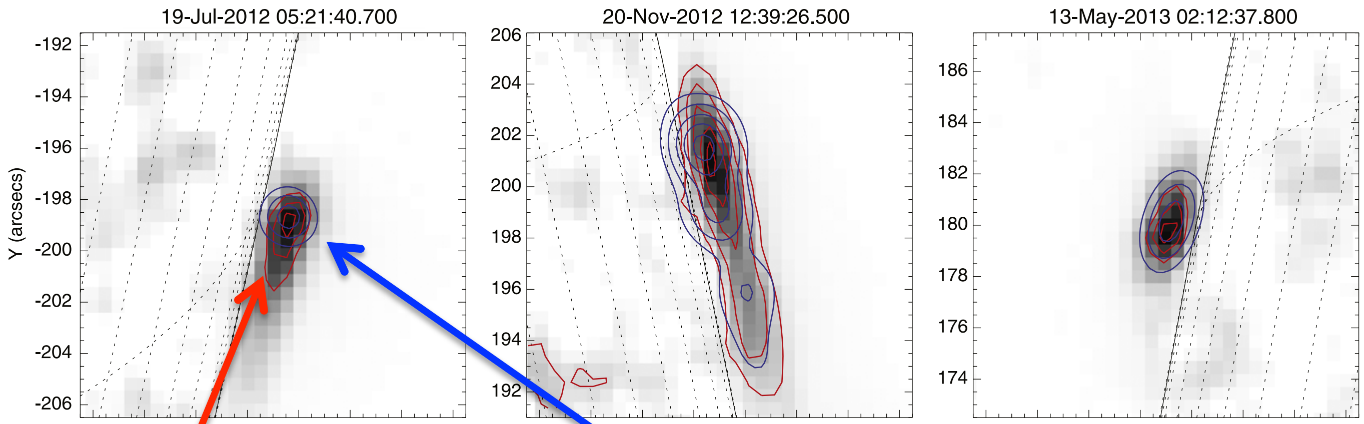


Even if we see a source at the limb, its height is not trivial.
Need STEREO to determine its position.

Krucker et al. 2015

Previous studies on WL height

RHESSI HXR and HMI white light emission for 3 different flares



background+ red contours.: HMI difference images

blue: HXR, 30-80 keV

nearly co-spatial!

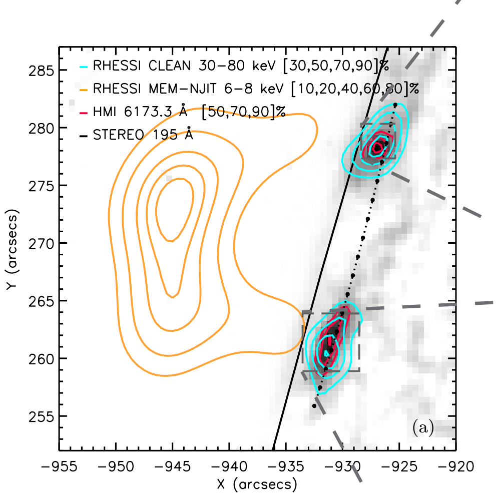
Parameters of the WL (617.3 nm) and HXR (30–100 keV) Footpoints (Values of the Stronger Footpoint (see Figure 5) are Shown in Bold)

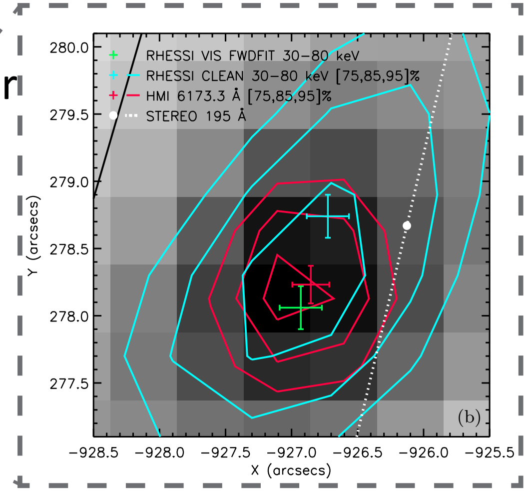
Parameters	2012 Jul 19	2012 Nov 20	2013 May 13
HMI time	05:21:40.7	12:39:26.5	02:12:37.8
GOES flare class	M7.7	M1.7	X1.7
WL altitude	**824 ± 70 km**	**799 ± 70 km**	**810 ± 70 km**
WL radial extent (FWHM)	**~862 km**	**~652 km**	**~839 km**
HXR altitude	**946 ± 103 km**	**746 ± 51 km**	**722 ± 140 km**

Krucker et al. 2015

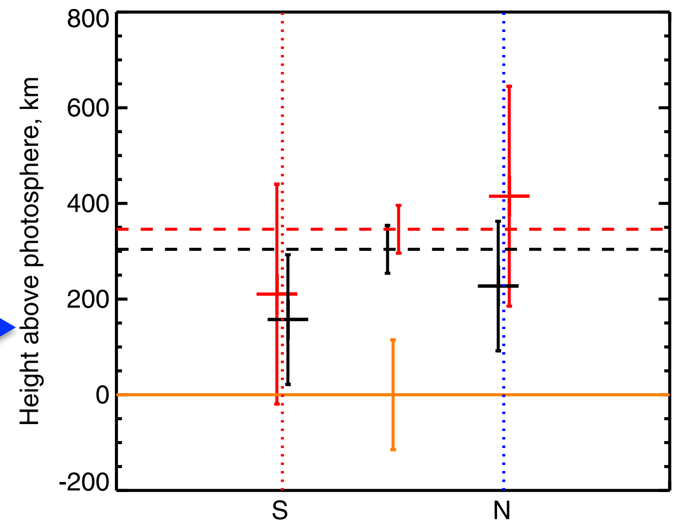
Previous studies on WL height

determined height together with STEREO data





Martinez Oliveros et al. 2015

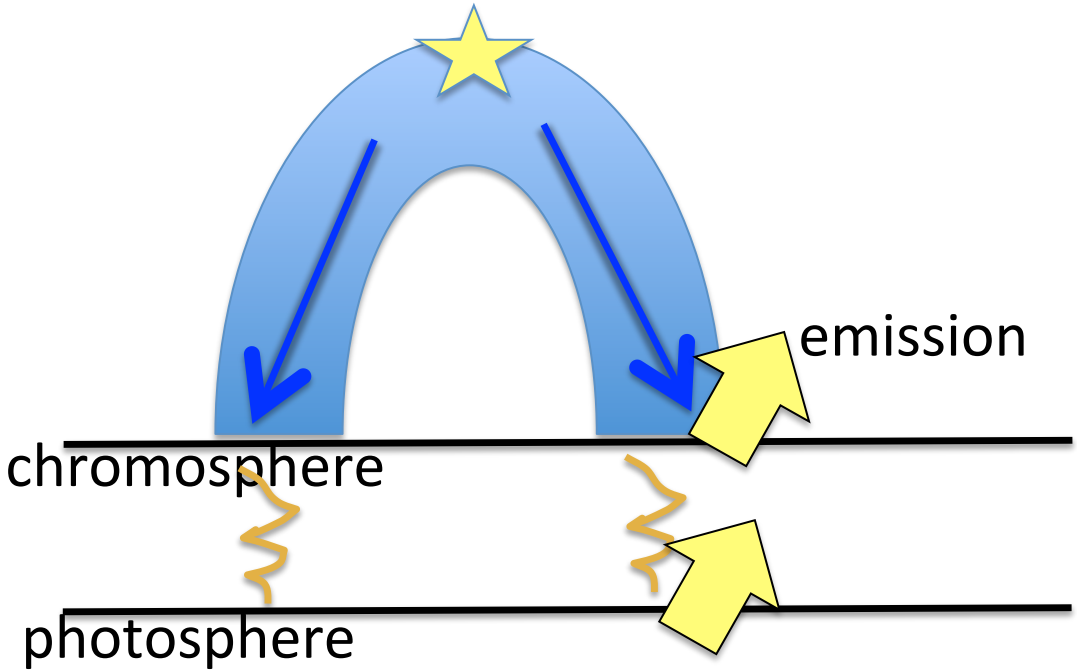


Emission heights (red: HXR, black: WL)

Heights in different studies disagree significantly (~800 km vs. 300 km)
Spectra contain more information about WL mechanisms.

Continuum Emission

Some theory:



- electrons probably stopped in chromosphere
- hydrogen recombination (=jumps in spectra)

- backwarming may heat photosphere
- H^- and hydrogen continua

Flare Energetics

Open questions for flares:

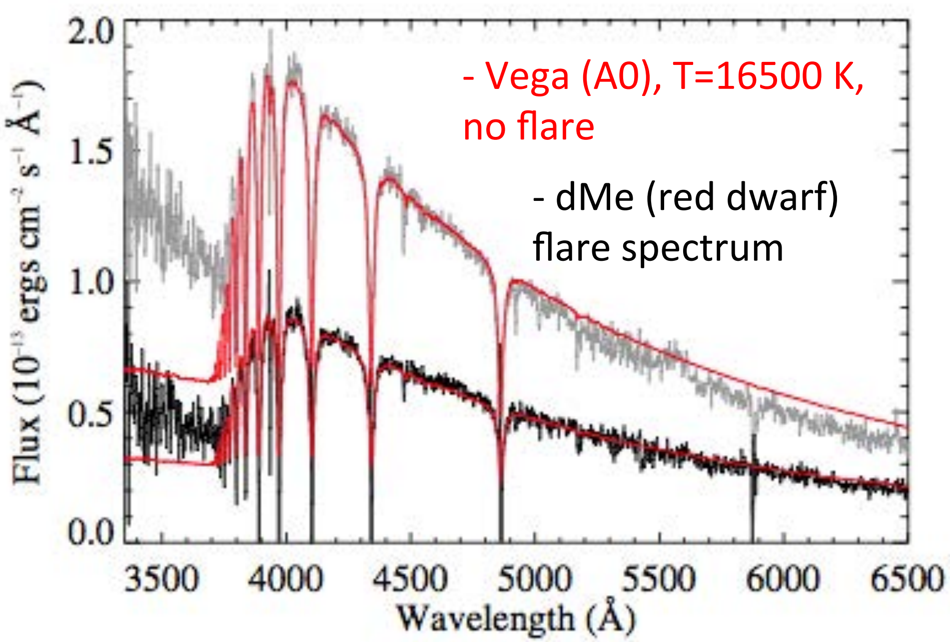
- Where does the continuum radiation form?
- How is flare energy dissipated?
- What fraction of flare energy goes into radiation?

=> check emission in the continuum (and lines)

Flare Energetics

Stellar spectra have advantages:
1) wider spectral coverage, 2) larger field of view (whole star)

Red dwarf flare spectrum (Kowalski et al. 2011)



Solar flare spectra (Hudson et al. 2010)

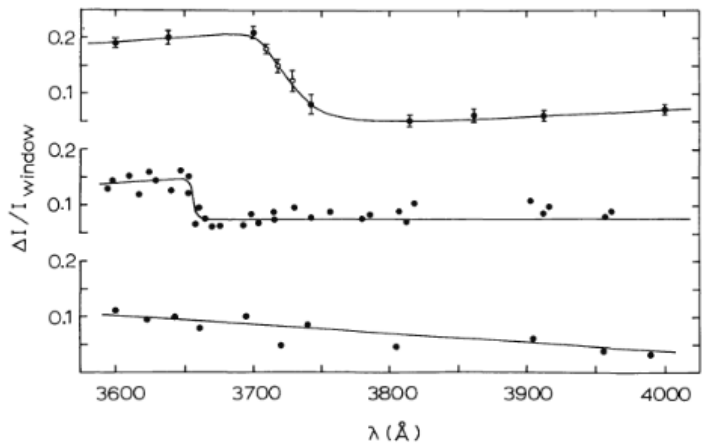


Fig. 1. Comparison of UV spectra of three white-light flares, from Neidig (1983): (*upper*), Hiei (1982, *middle*), and Machado & Rust (1974, *lower*).

=> Combine multiple instruments for solar flare spectra

Flare Energetics

Wide solar flare spectrum:
Combine IRIS (UV), HMI (vis), FIRS (IR) and RHESSI (X-rays)

March 29, 2014 X1 flare

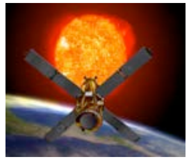
Dunn Solar Telescope
(observing campaign)

coordination

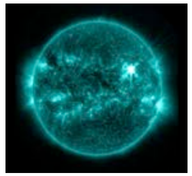
coordination

IRIS

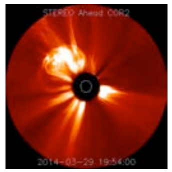
Hinode



RHESSI:
- Caught full flare



SDO:
- AIA and HMI



STEREO:
- Recorded CME

2014-03-29, X1 flare: IRIS & RHESSI

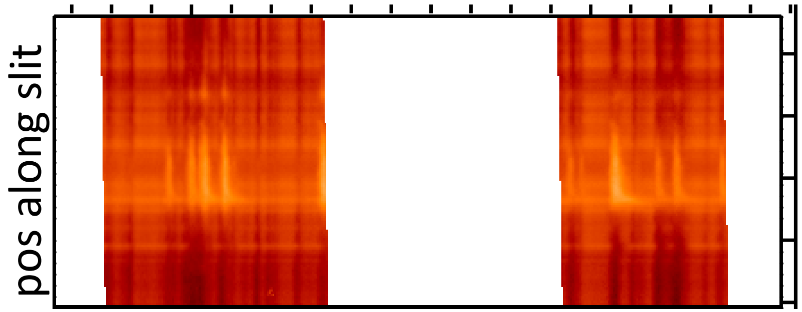
IRIS slit crossed HXR footpoint during X1 20140329.

HXR 30-70 keV: blue
IRIS 1400 SJI: background image

IRIS: 2014-03-29 (X1.0), WL emission

Detection of the Balmer continuum.

The whole spectrum is enhanced at some locations.

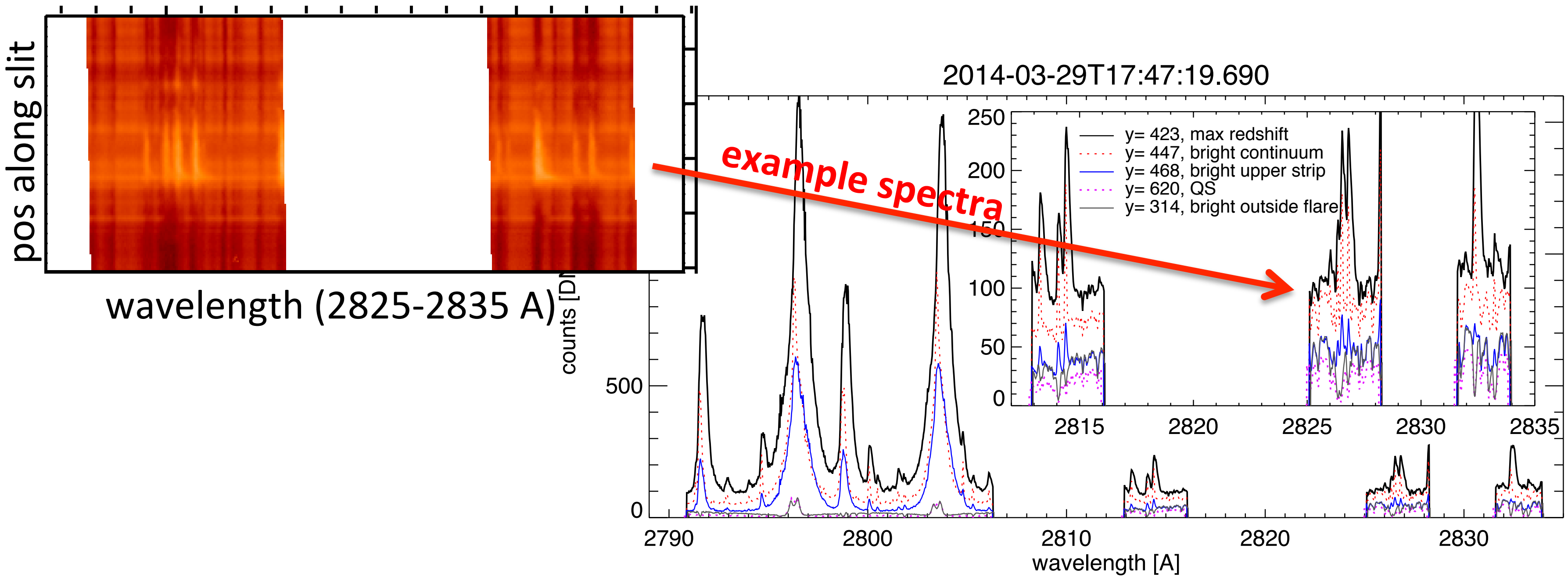


Heinzel & Kleint, ApJL 794, 23, 2015

IRIS: 2014-03-29 (X1.0), WL emission

Detection of the Balmer continuum.

The whole spectrum is enhanced at some locations.

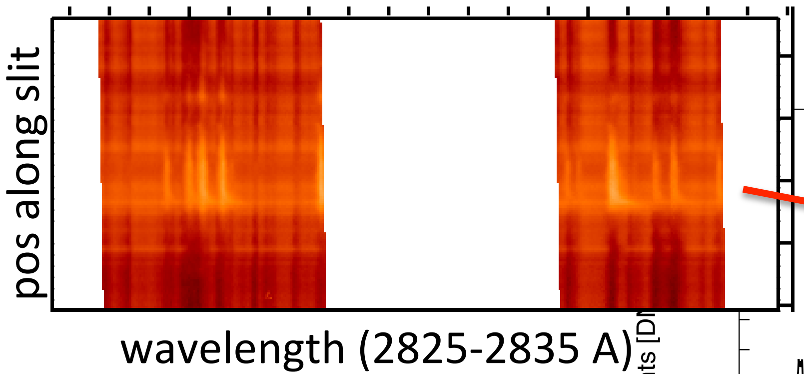


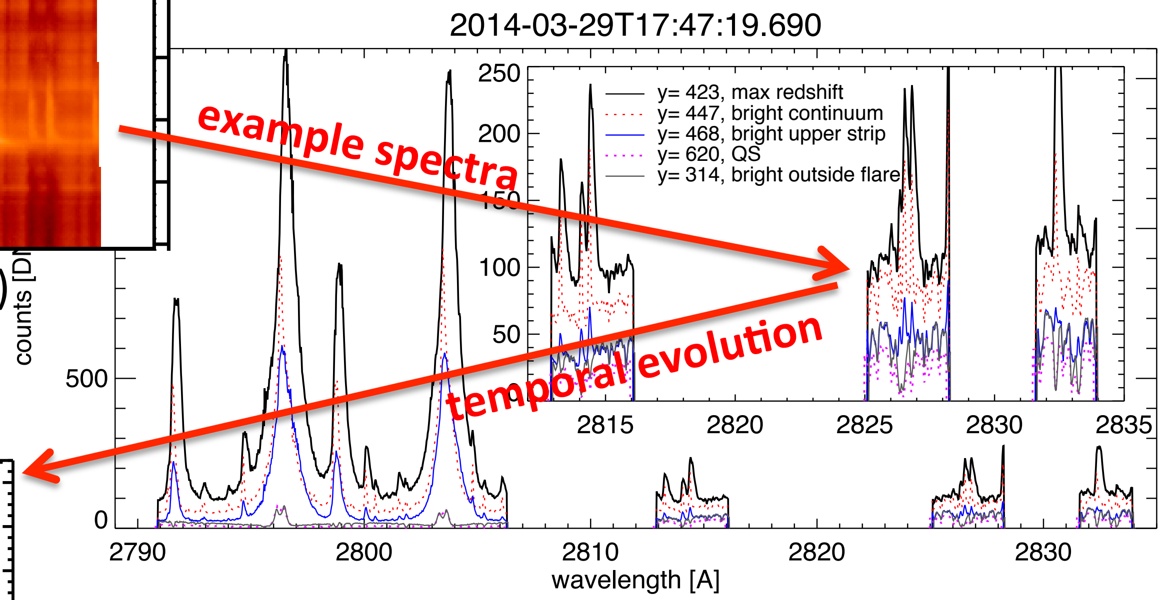
Heinzel & Kleint, ApJL 794, 23, 2015

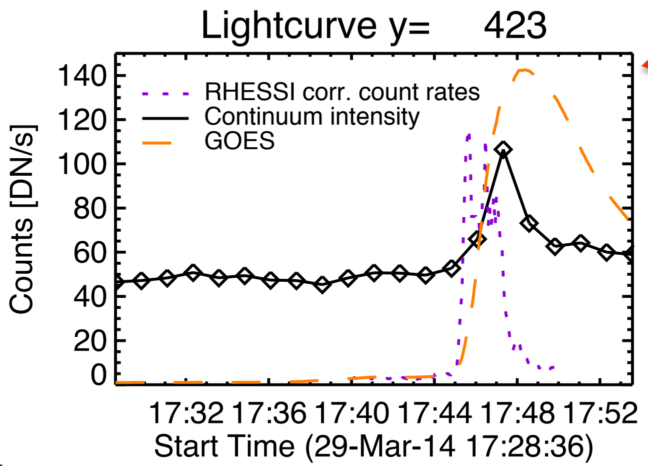
IRIS: 2014-03-29 (X1.0), WL emission

Detection of the Balmer continuum.

The whole spectrum is enhanced at some locations.

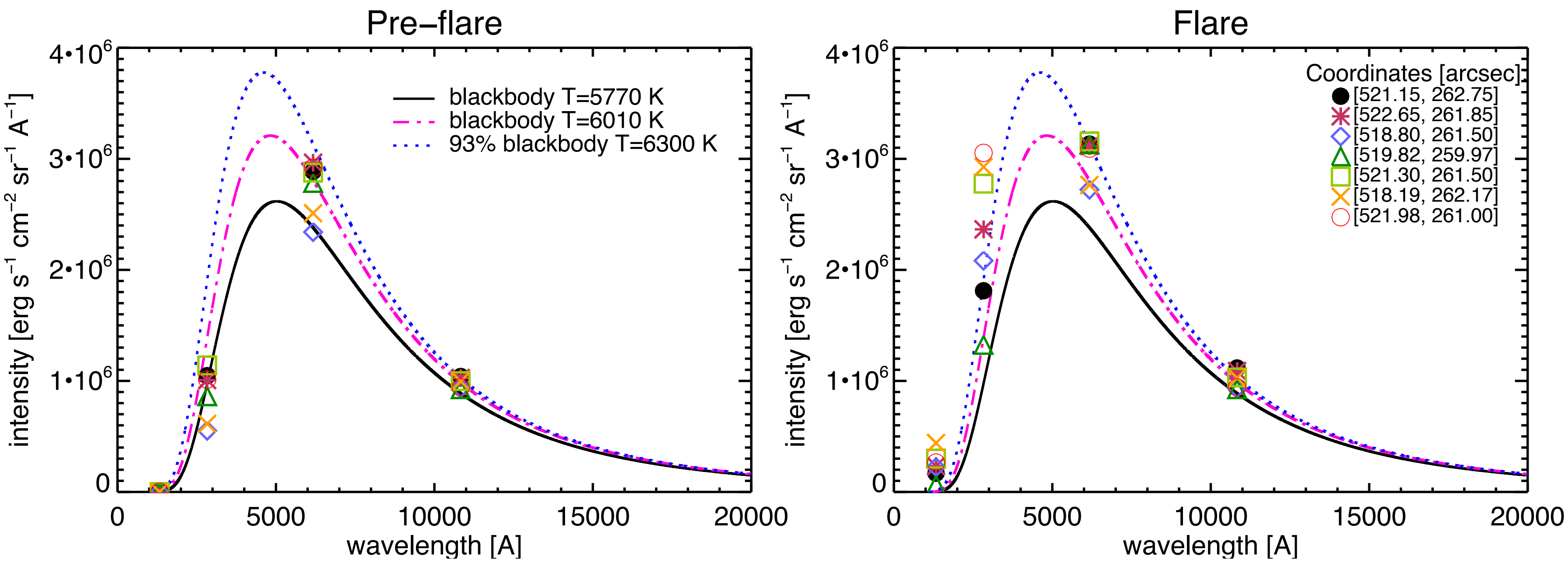






Heinzel & Kleint, ApJL 794, 23, 2015

Continuum Emission: X1 Flare



NUV increases more than VIS+IR. Therefore Balmer continuum, not H^- in UV.
=> Continuum has contribution from H^- (VIS+IR)=photosphere and hydrogen recombination (UV)=chromosphere.

Kleint, Heinzel, Judge & Krucker, ApJ, 816, 88, 2016

Continuum Emission

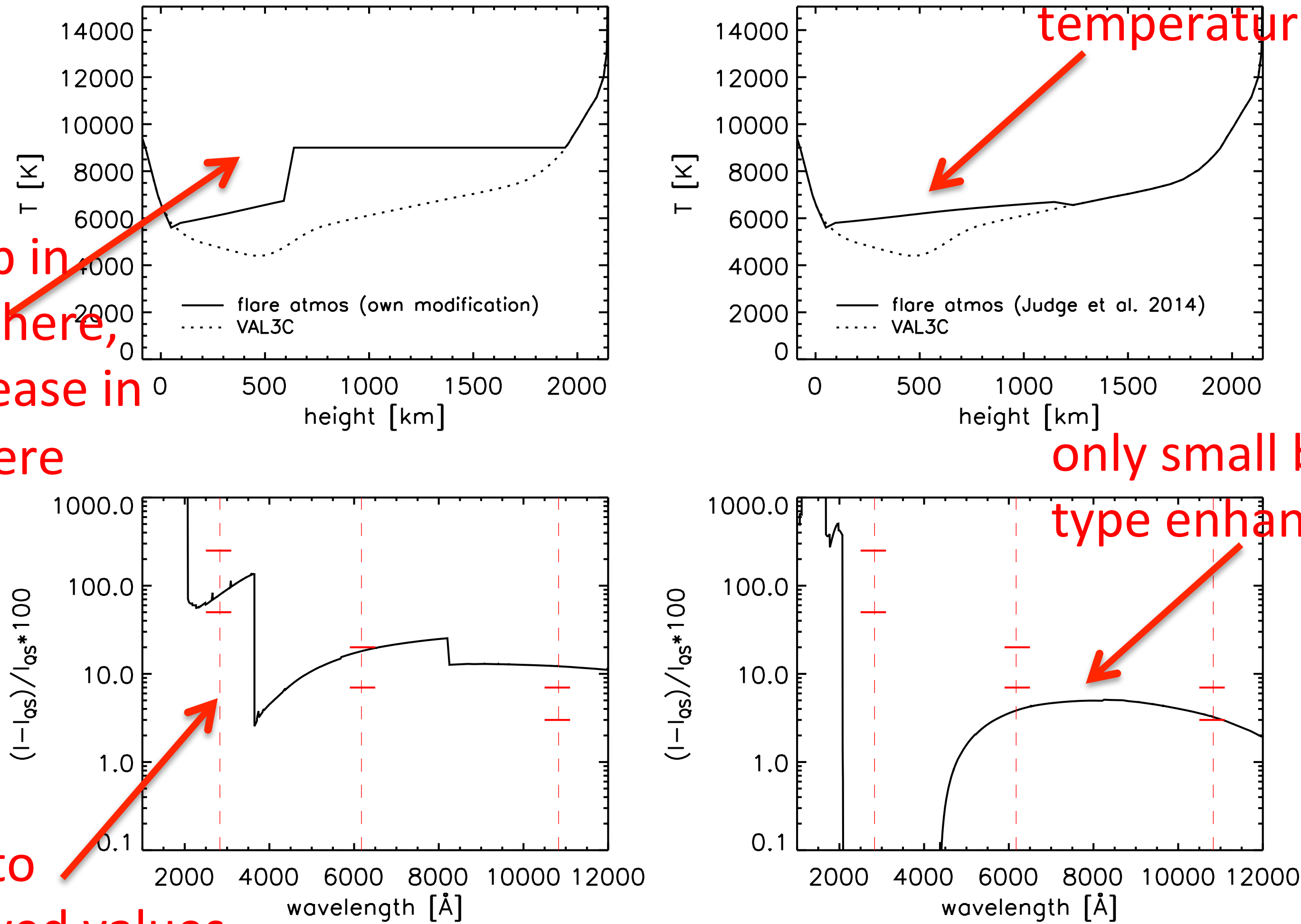
A simple blackbody is not a good fit to the continuum!

Because continuum forms at different heights (temperatures). NUV => chromospheric Balmer cont.

Use radiative transfer modeling.

Continuum Emission

Modeling with RH code (Uitenbroek 2001)



only small photospheric temperature increase

large jump in chromosphere, large increase in photosphere

only small blackbody-type enhancement

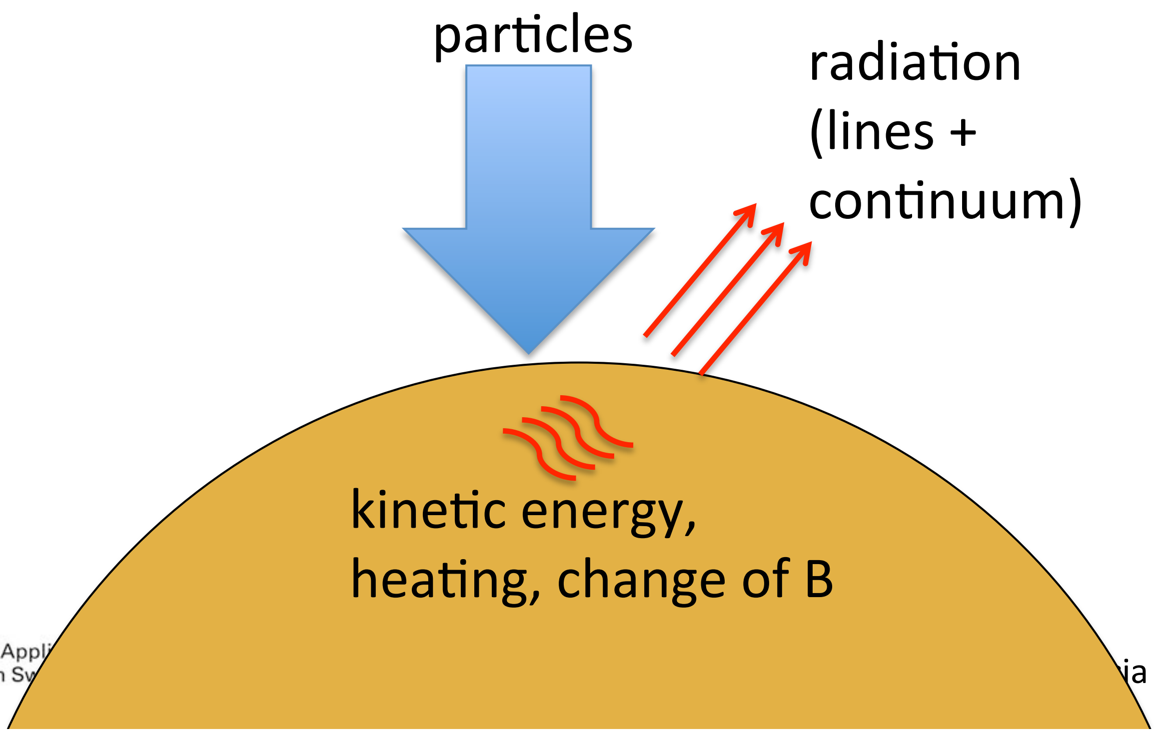
close to observed values

=> talk by Petr Heinzel for more details about modeling

Flare Energetics

How is flare energy dissipated?

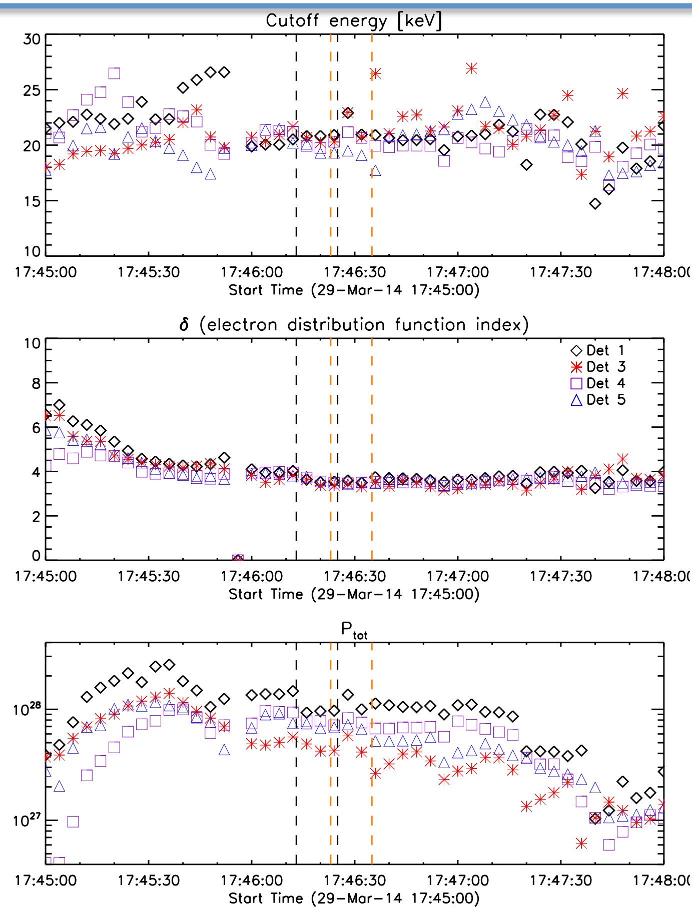
Compare energy input derived from RHESSI (accelerated electrons) to
energy output in continuum and line radiation.



Energy input: RHESSI

Input energy calculated from RHESSI (cutoff 20 keV):
3.5×10^{11} erg s^{-1} cm^{-2}

valid for a time when RHESSI HXR and IRIS slit coincided.



↓

footpoint area

↓

energy deposition rate [erg/s/cm^2]

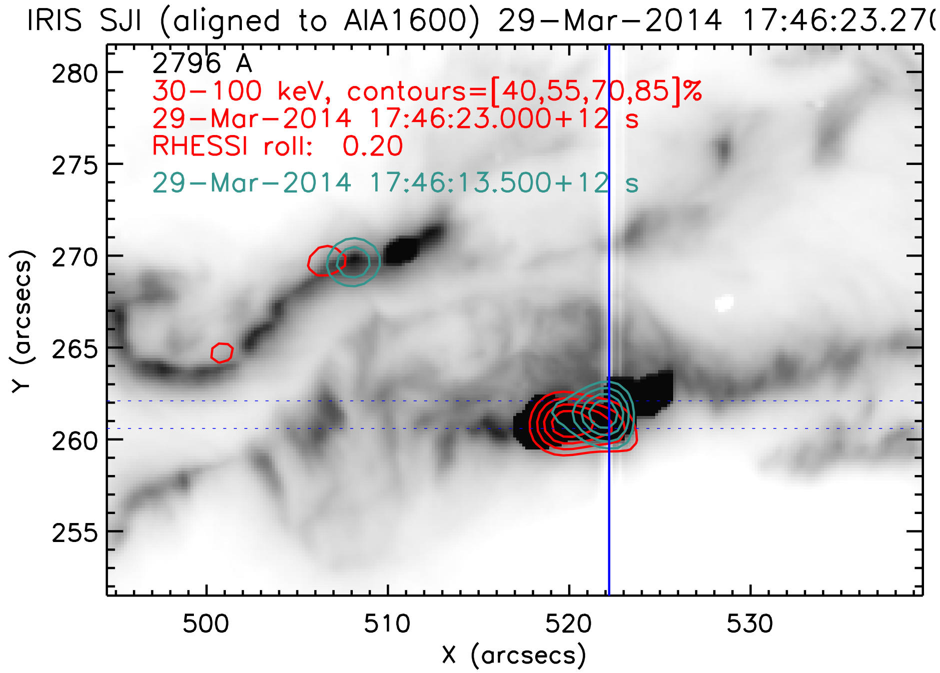
Continuum Emission: X1 Flare

RHESSI (red) and IRIS slit (blue) coincided => input vs. output

Input energy calculated from RHESSI (cutoff 20 keV):
3.5×10^{11} erg s^{-1} cm^{-2}

Energy losses in the continuum:
8×10^{10} erg s^{-1} cm^{-2}

=> ~20% of input energy emitted by continuum (method not exact!)



Future step: estimate radiation by spectral lines, heating

Summary

- **Height of continuum: Contribution from photosphere and chromosphere. Energetics agree with backwarming model.**

- **Flare Energetics: can investigate Balmer continuum and white-light flares by combining instruments. ~20% of input energy [for cutoff 20 keV] goes into continuum radiation.**