# Improved DEM calculation and its applications to flare studies

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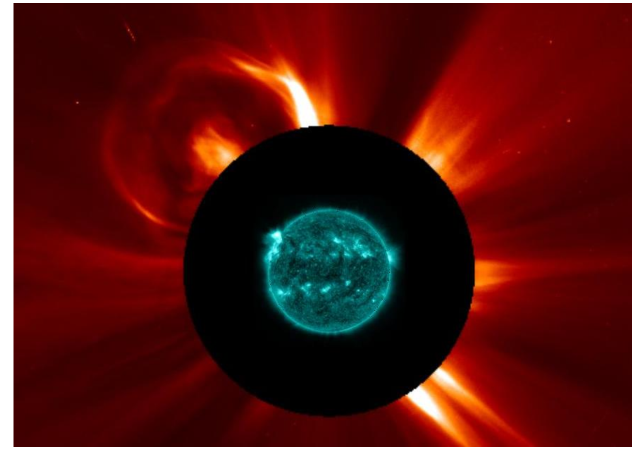
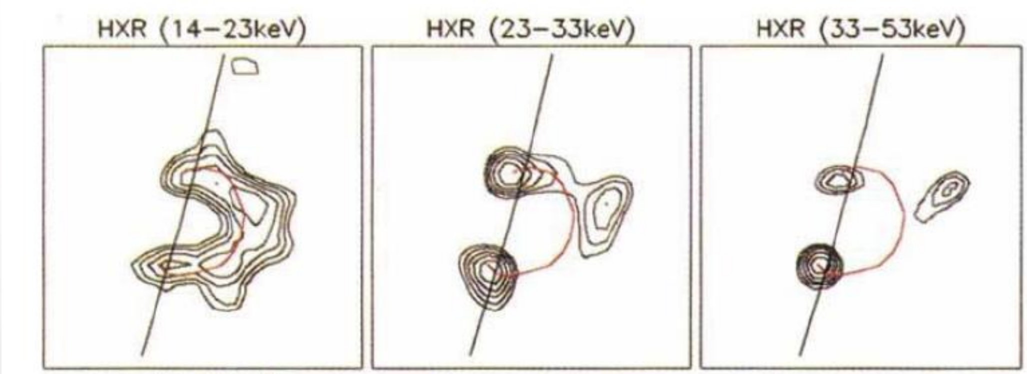
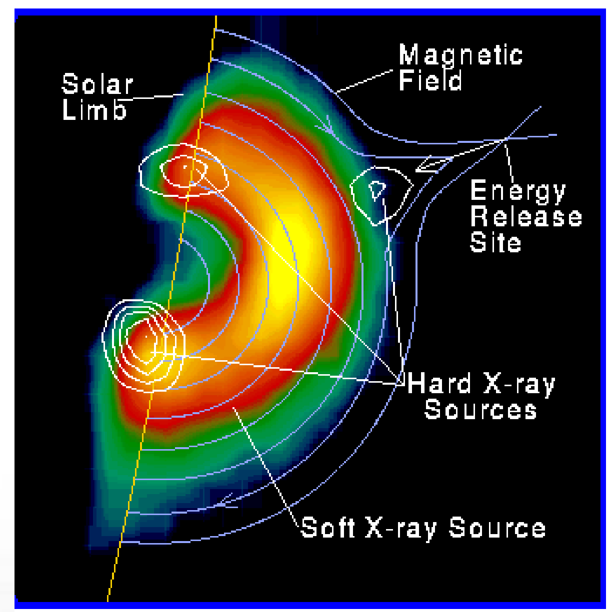
# Overview:

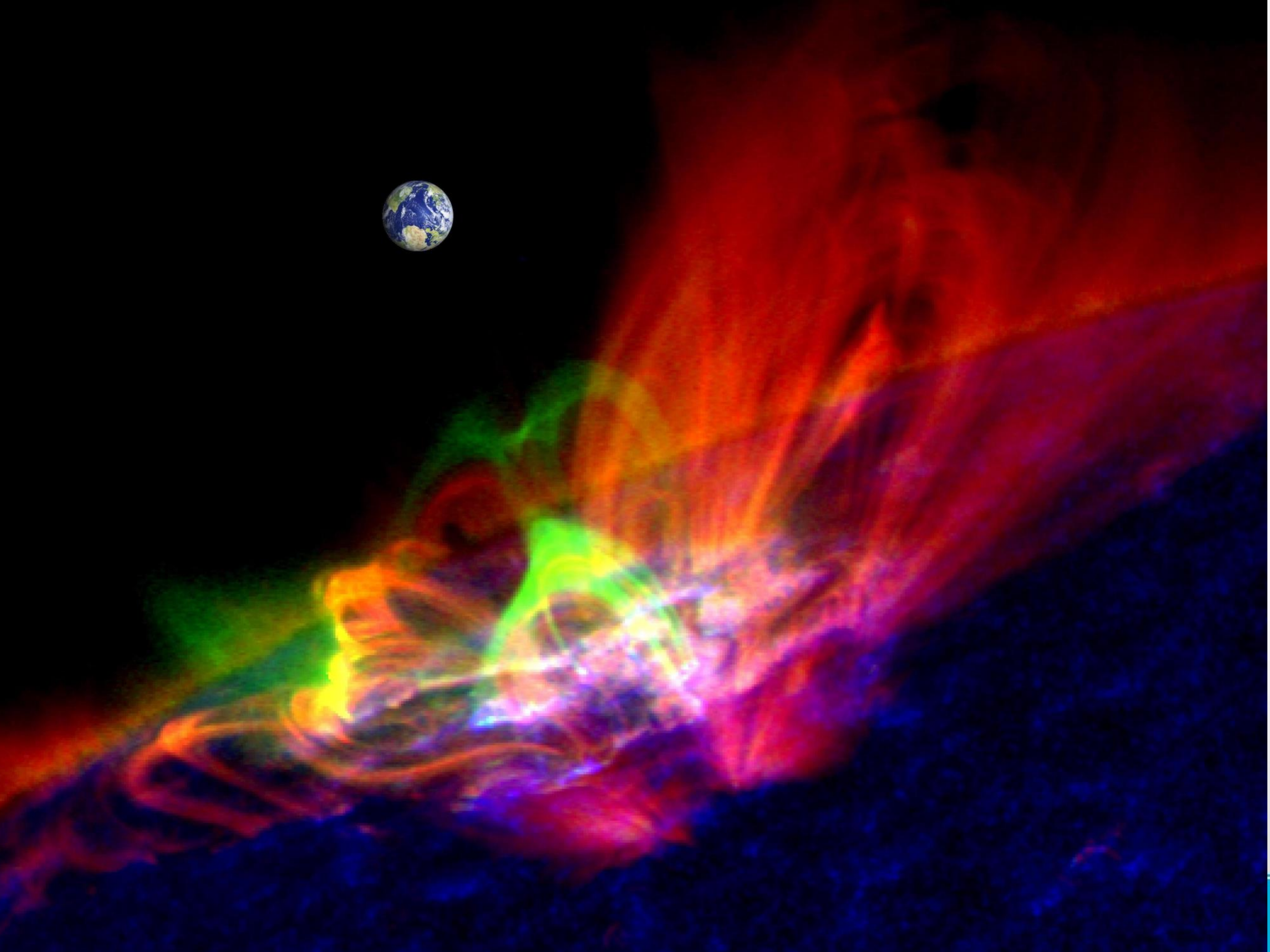
- **Solar eruptive events** (flares and CMEs)
- are main factors of space weather
- are driven by magnetic reconnection （Su et al. 2013 Nature Physics）
- the details of plasma heating and particle acceleration are not clear.






- X-ray sources （Masuda et al. 1994, Nature）



# Motivation:

- DEM: differential emission measure
- Boerner et al. 2011:

$$\mathrm{DEM}(T) = n_e^2 \frac{\mathrm{d}z}{\mathrm{d}T},$$

- For AIA observations:

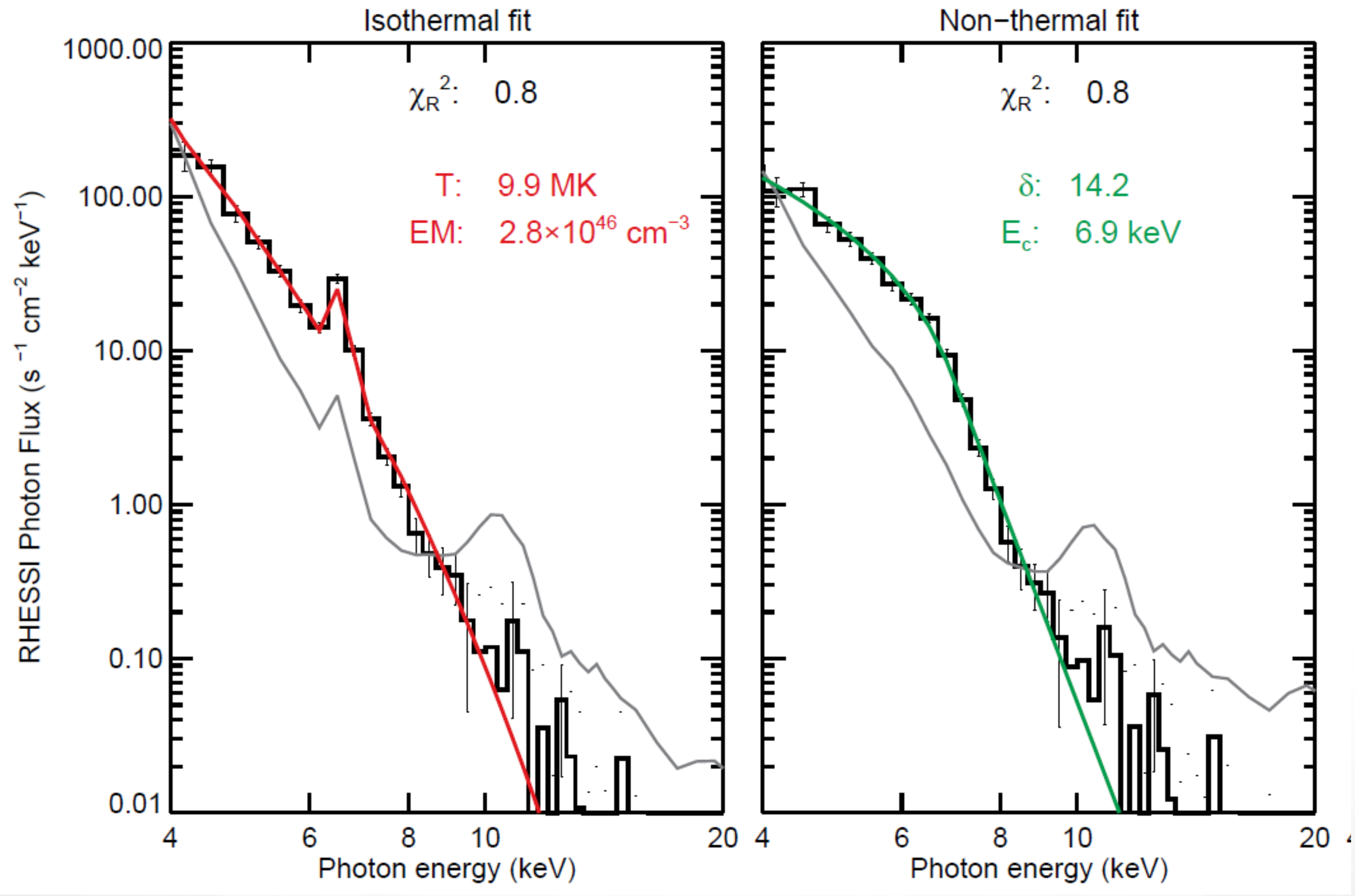
$$\sum \mathrm{DEM} * \Delta T * \mathrm{TResp} = \mathrm{DN/s}$$

# Motivation:

- what can DEM tell us:
  - the temperature of coronal structures
  - estimation of density and energy
  - X-rays from hot plasma
  - indentify thermal / non-thermal emissions
  - low energy cutoff
  - ...

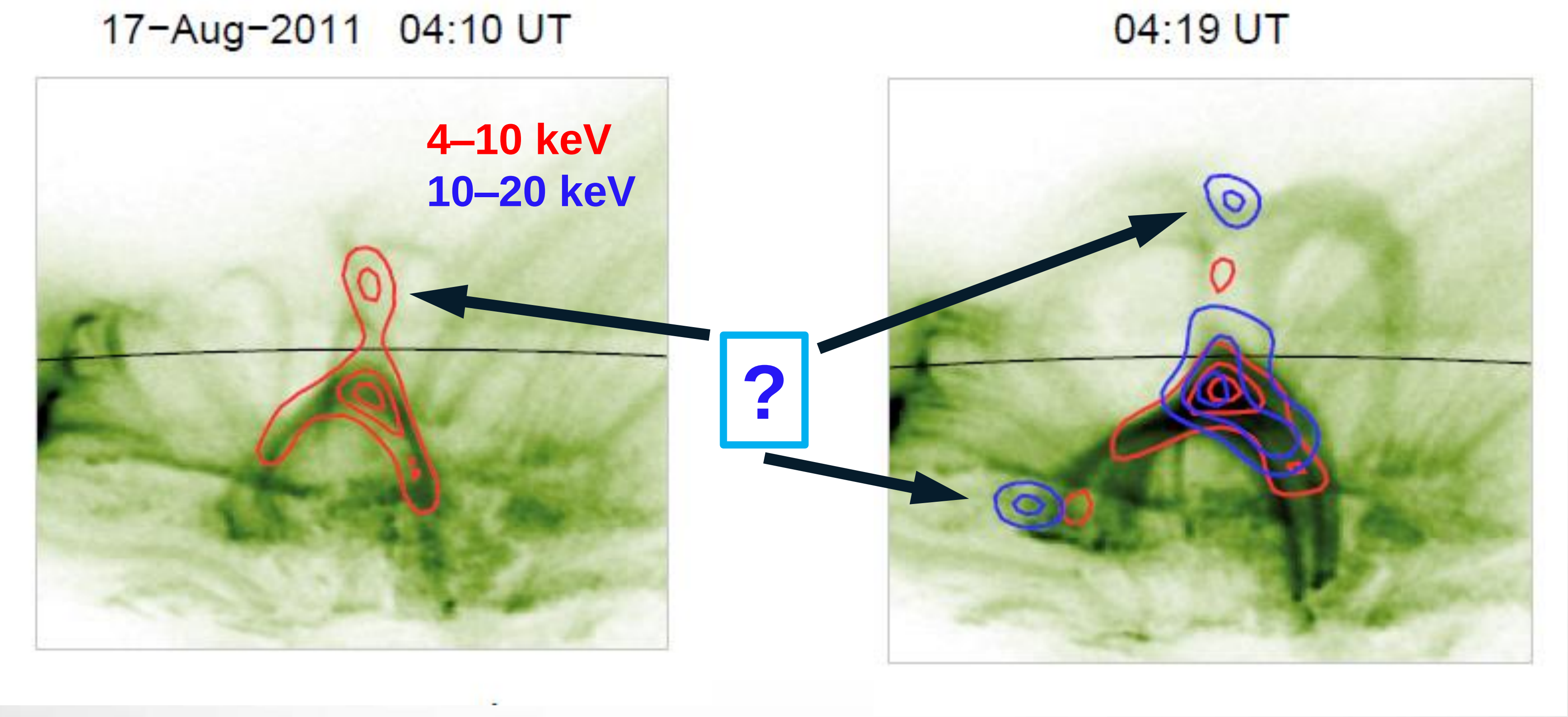
# Motivation:

- Why do we need DEM?



# Motivation:

- Why do we need DEM?
- are these sources thermal? (Su et al. 2013)



# The problem:

- AIA Characteristic temperature
  http://aia.lmsal.com/public/instrument.htm

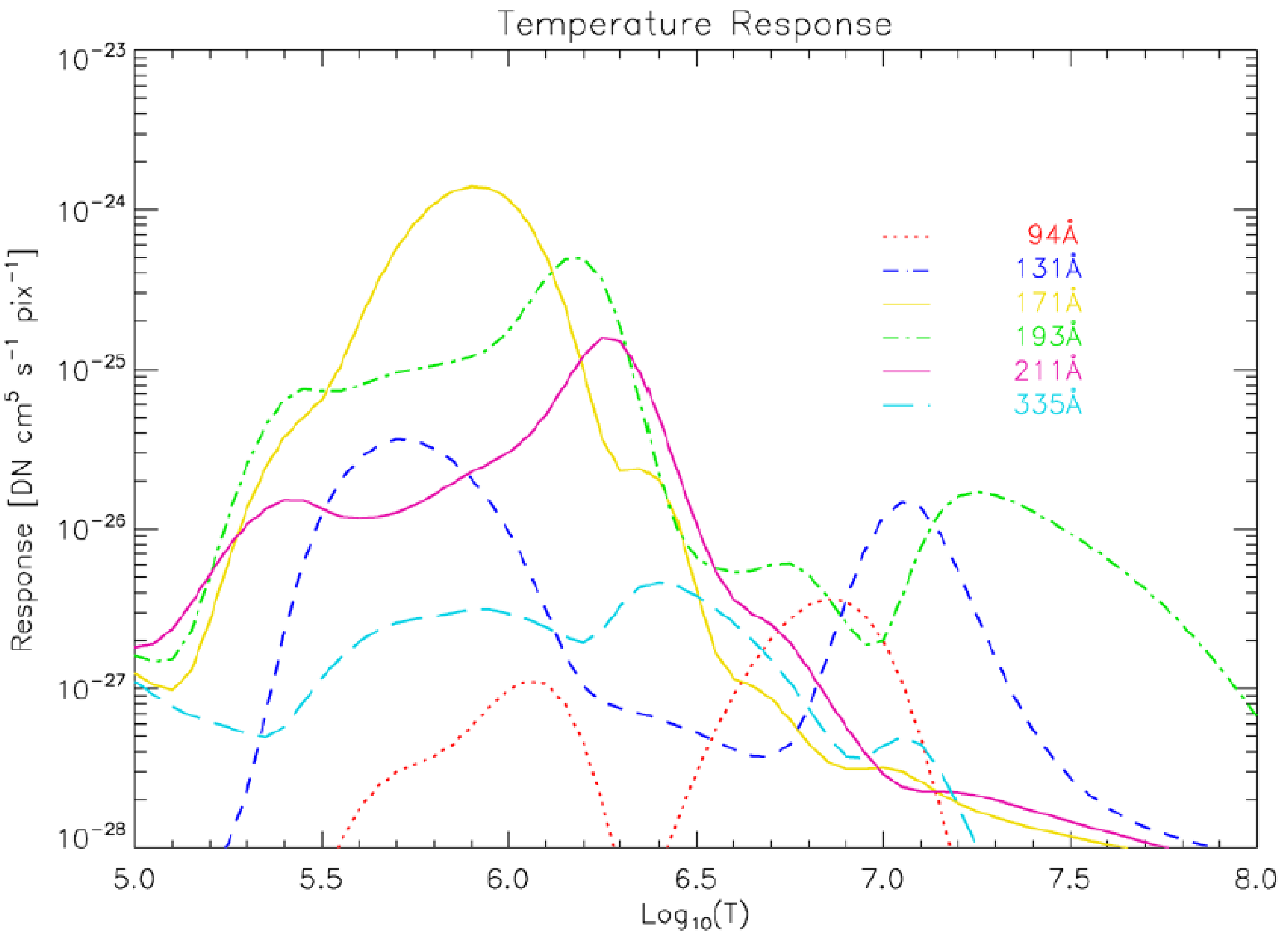
Table A1: AIA wavelength bands.

| Channel name | Primary ion(s) | Region of atmosphere* | Char. log(T) |
|---|---|---|---|
| white light | continuum | photosphere | 3.7 |
| 1700Å | continuum | temperature minimum, photosphere | 3.7 |
| 304Å** | He II | chromosphere, transition region | 4.7 |
| 1600Å** | C IV+cont. | transition region + upper photosphere | 5.0 |
| 171Å** | Fe IX | quiet corona, upper transition region | 5.8 |
| 193Å** | Fe XII, XXIV | corona and hot flare plasma | 6.1, 7.3 |
| 211Å** | Fe XIV | active-region corona | 6.3 |
| 335Å** | Fe XVI | active-region corona | 6.4 |
| 94Å** | Fe XVIII | flaring regions (partial readout possible) | 6.8 |
| 131Å** | Fe VIII, XX, XXIII | flaring regions (partial readout possible) | 5.6, 7.0, 7.2 |

* Absorption allows imaging of chromospheric material within the corona; ** in baseline program

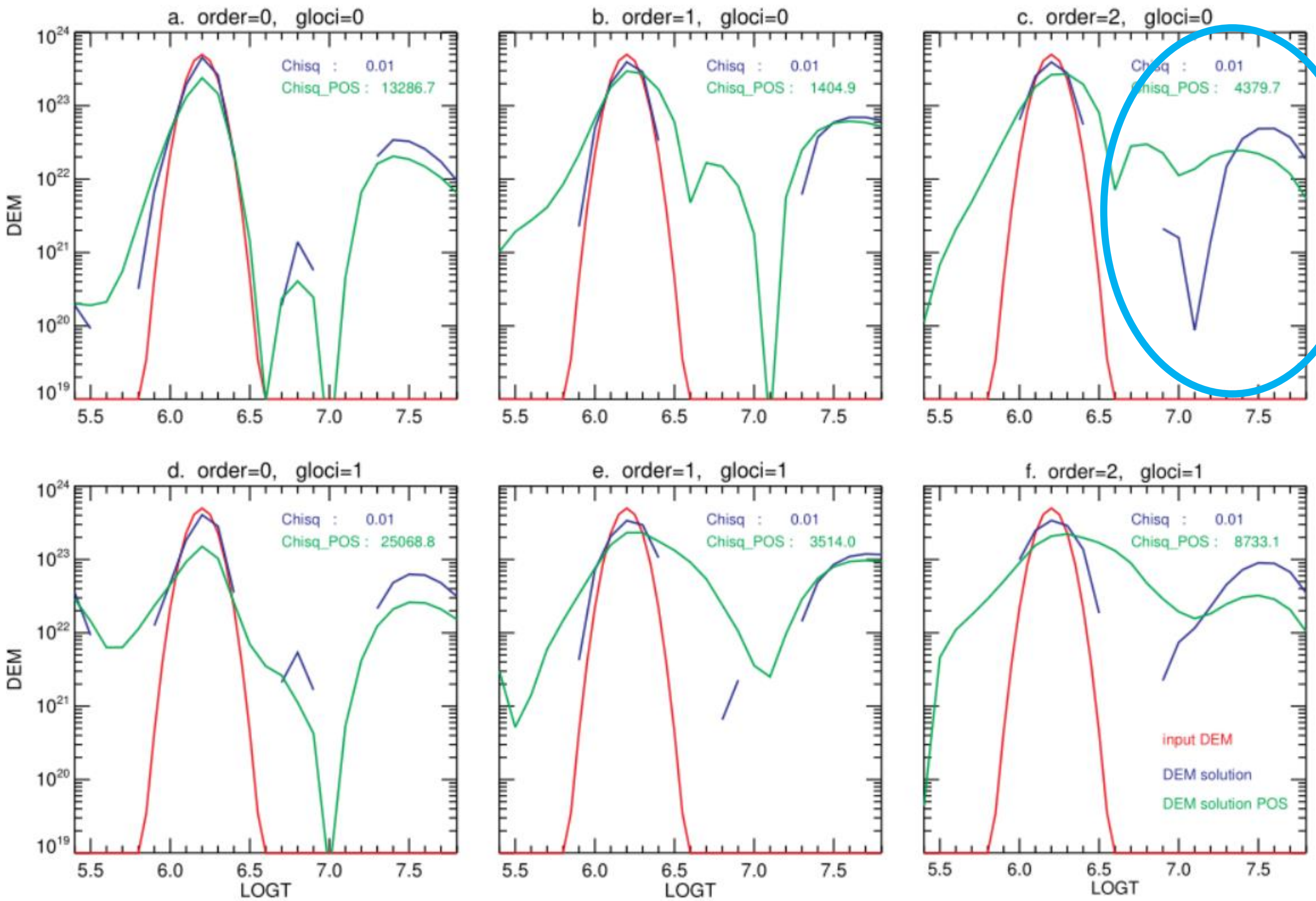
# The problem:

- AIA temperature response  ∑DEM* ΔT*TResp

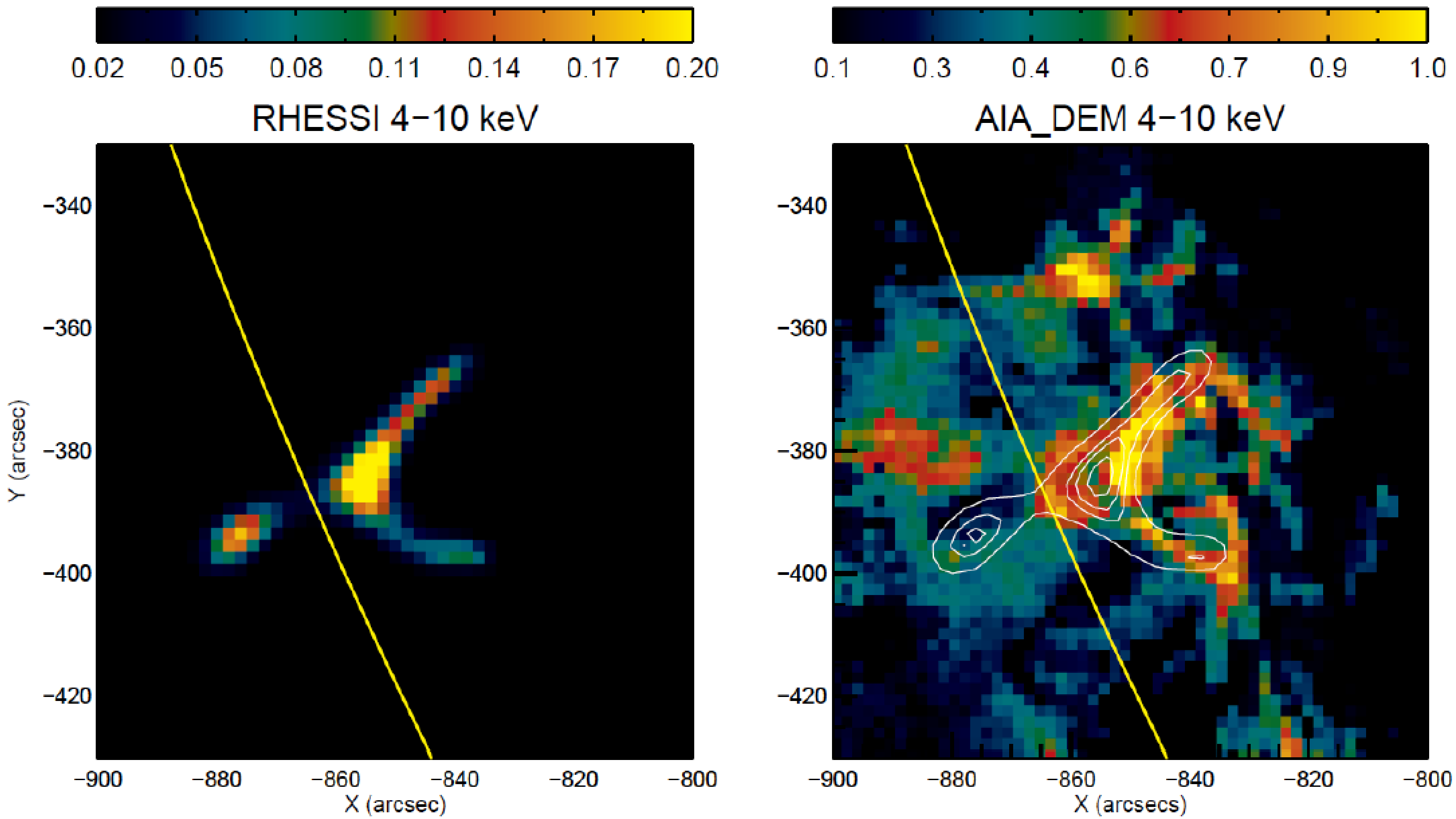


# The problem:

- input DEM -> DN/s -> Inversion -> DEM solution



# Results: spectrum



# The problem:

- The problem :
  - limited number of channels
  - Inaccurate temperature response
  - Inaccurate estimation of errors on data
  - Incomplete knowledge of spectral lines ( CHIANTI , Dere et al., 1997, 2009 )
- Introduced flaws : the methods
- SDO/EVE , Hinode/EIS , Hinode/XRT, RHESSI

  ---> no (bad) spatial resolution

- the regularization inversion method (Hannah and Kontar 2012)
- Benchmark test: Aschwanden et al. 2015

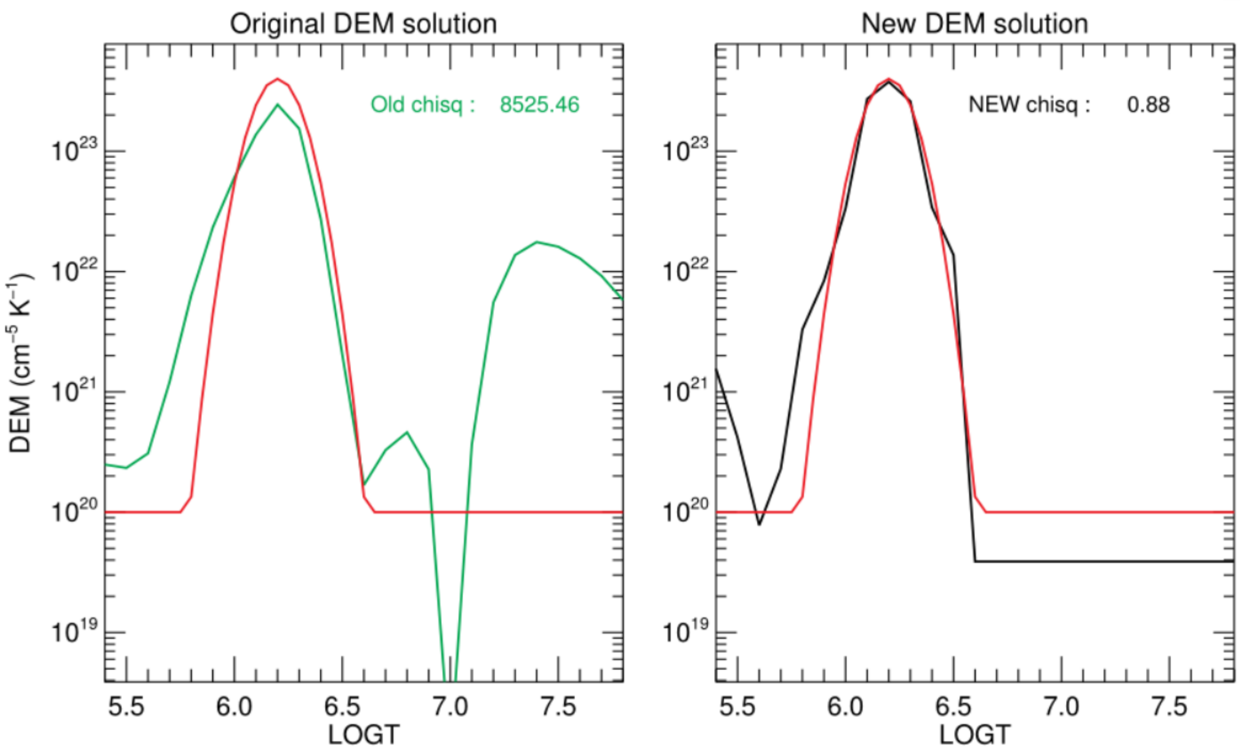
# The problem:

- Two solutions:
  - DEM solution: perfect in math, but may have negative values -- introduce false peaks at high temperatures.
  - DEM pos solution: trys to find positive solution within certain iterations --- increasing desired chisq

- What we need: positive solution with small chisq
- 1st way: indentify DEM peaks and modify their peak value, peak temperature, peak width.
- 2nd way: change the way the code calculate DEMs, and add some other changes $\sum [\, DEM* [\, \Delta T \,] *TR \,] = DN/s$
- 3rd: combine 1 and 2.

# The problem:

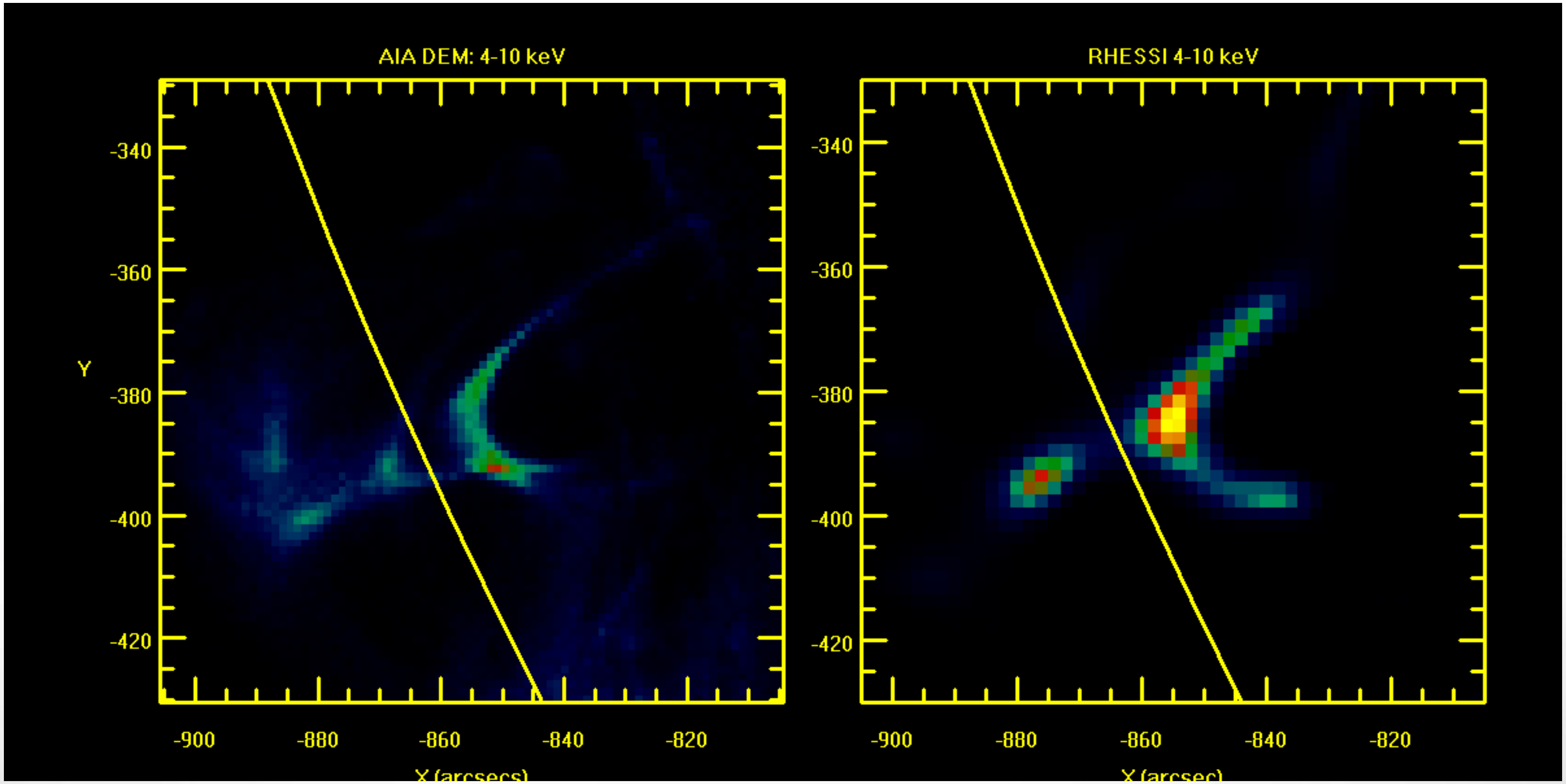
- 1st way: indentify DEM peaks and modify their peak value, peak temperature, peak width.
- slow
- random




| | A94 | A131 | A171 | A193 | A211 | A335 |
|---|---|---|---|---|---|---|
| Input: | 260.7 | 996.4 | 61038.2 | 118028.5 | 33686.4 | 332.1 |
| POS : | 181.9 | 1163.4 | 46881.6 | 77893.7 | 21030.9 | 215.8 |
| NEW : | 261.7 | 996.2 | 60644.7 | 117834.1 | 33690.8 | 330.8 |

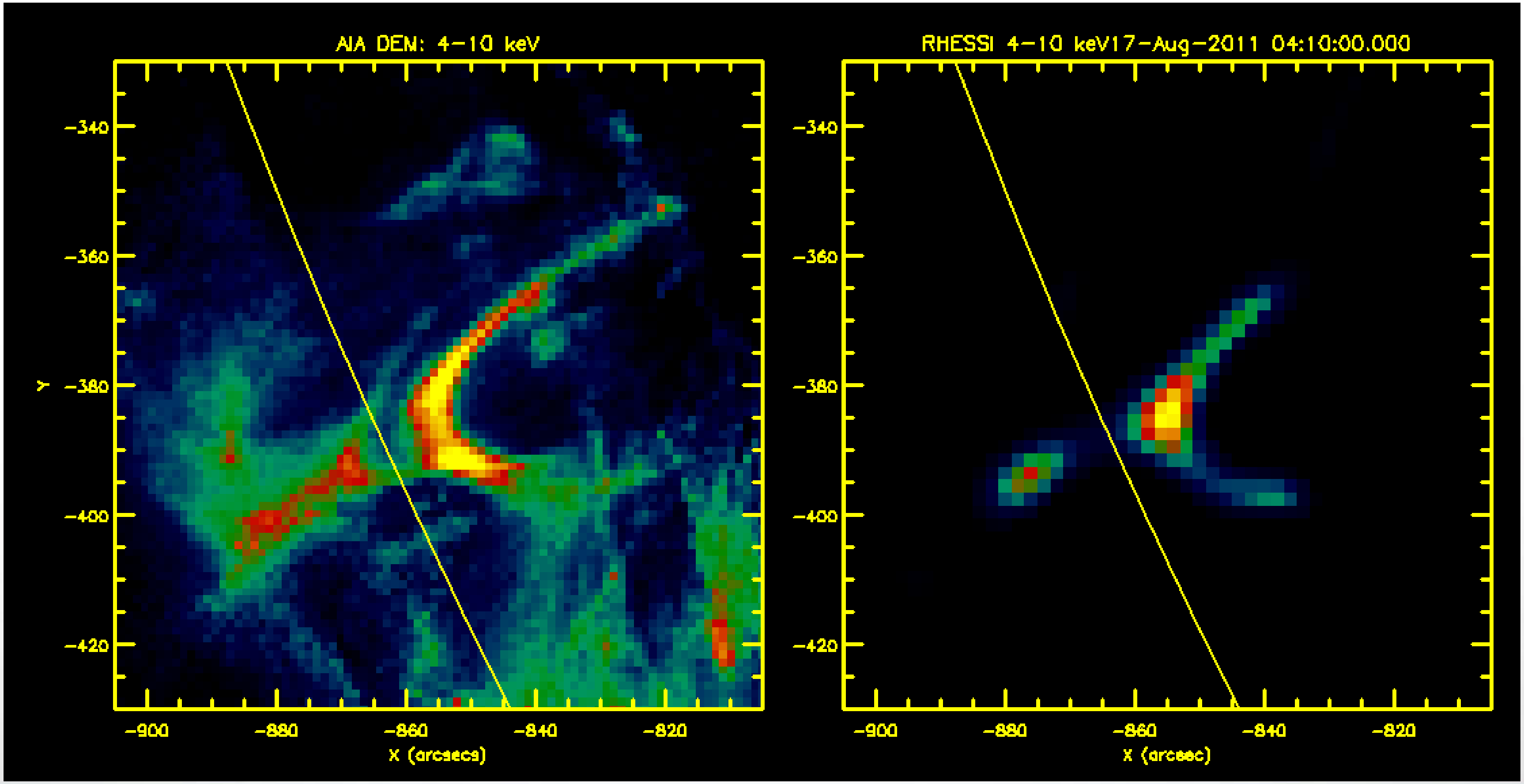
# Results: case 1: X-ray images

- 2nd method:
- 2011-Aug-17,    DEM in logT: 5.4 to 7.8
- 4-10 keV



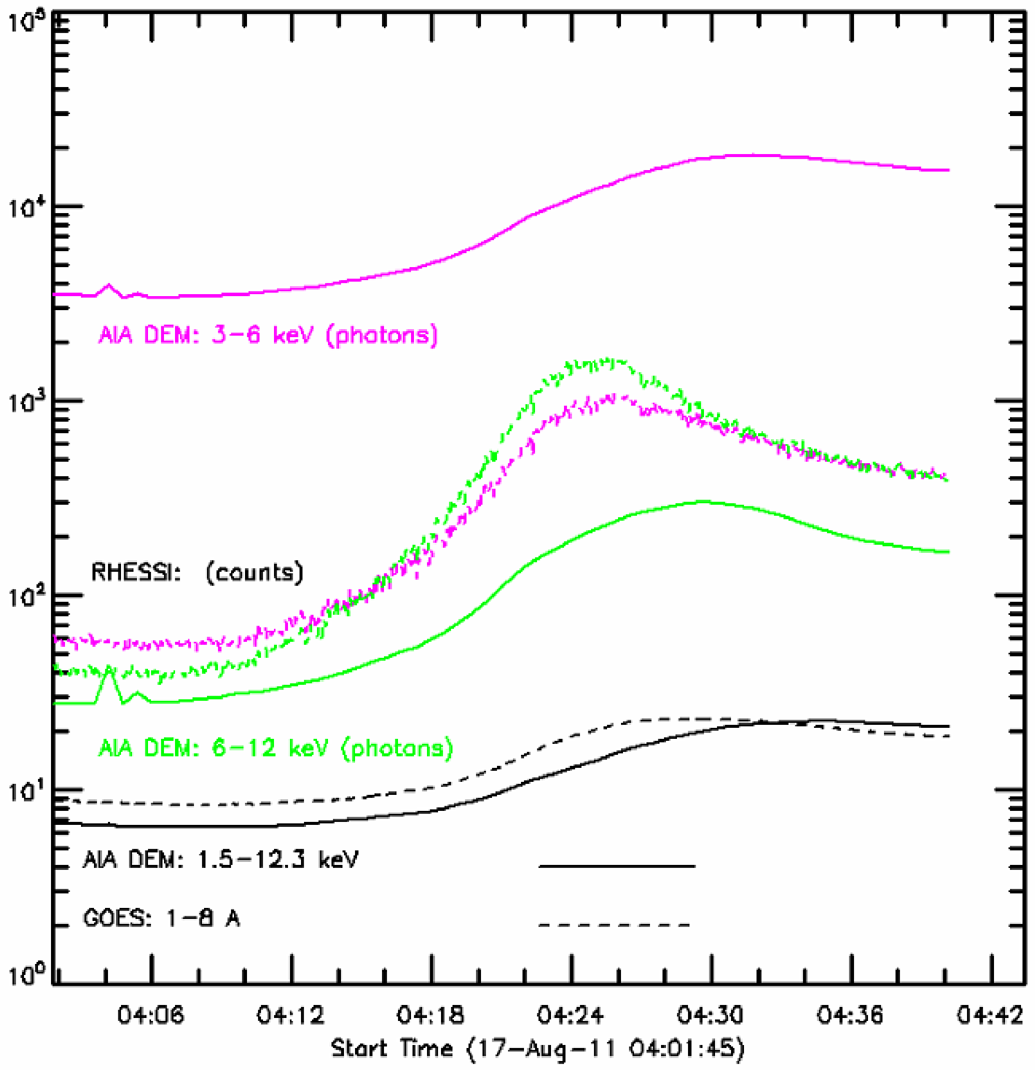
# Results: case 1: X-ray images

- DEM in logT: 5.4 to 7.8
- 4-10 keV , different  TR (with evenorm and chiantifix )

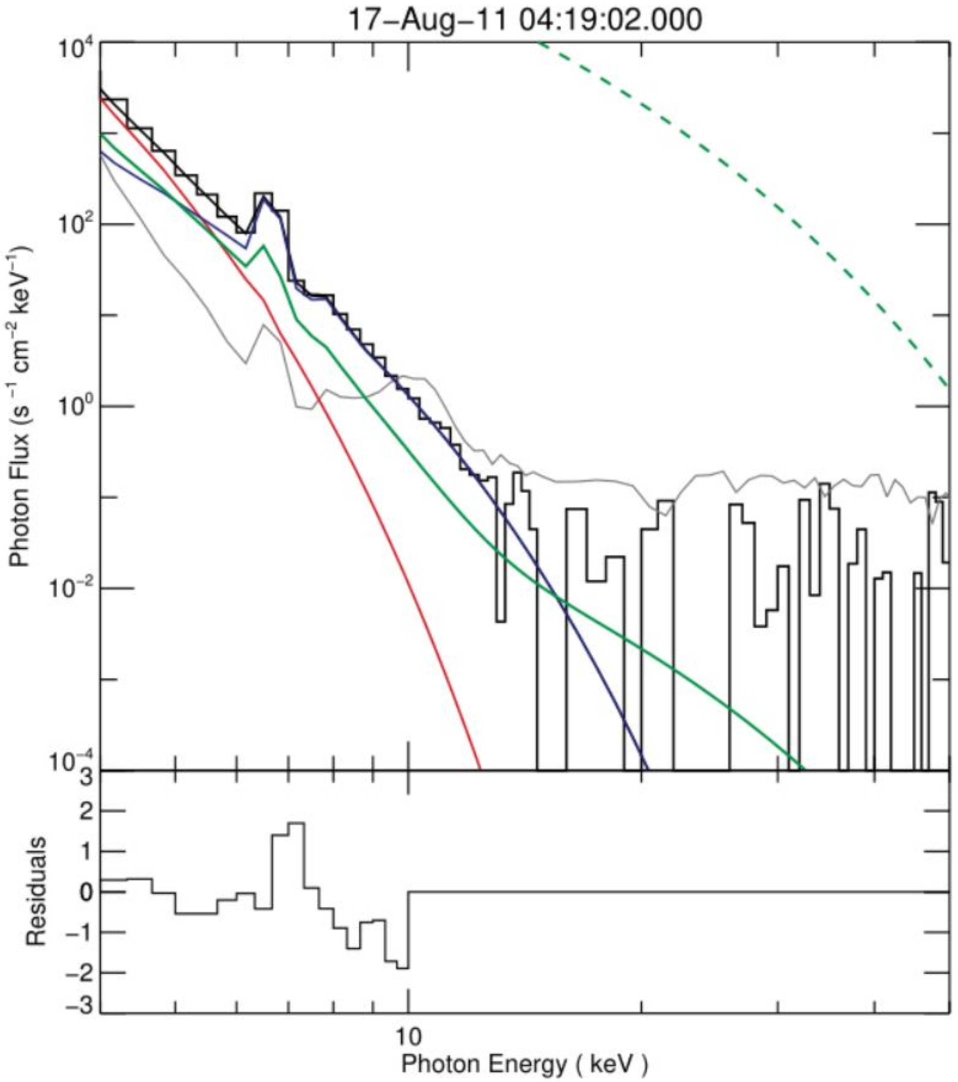


# Results: case 1: X-ray light curves

- X-ray Light Curves from AIA DEM
- 2011-Aug-17
- LogT: 6.3-7.8



# Results: case 1: spectrum



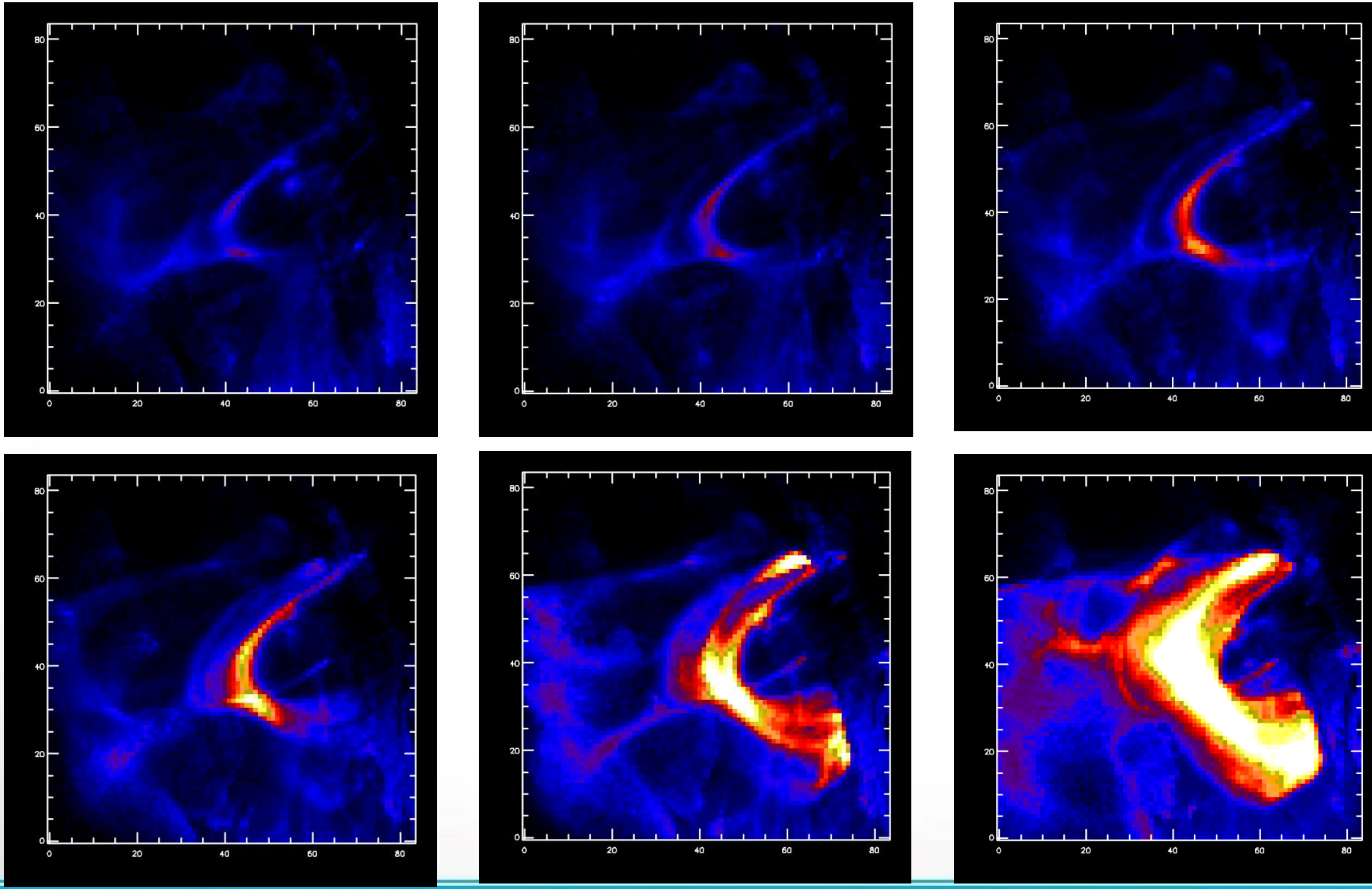

RHESSI X-ray spectrum

thermal 1

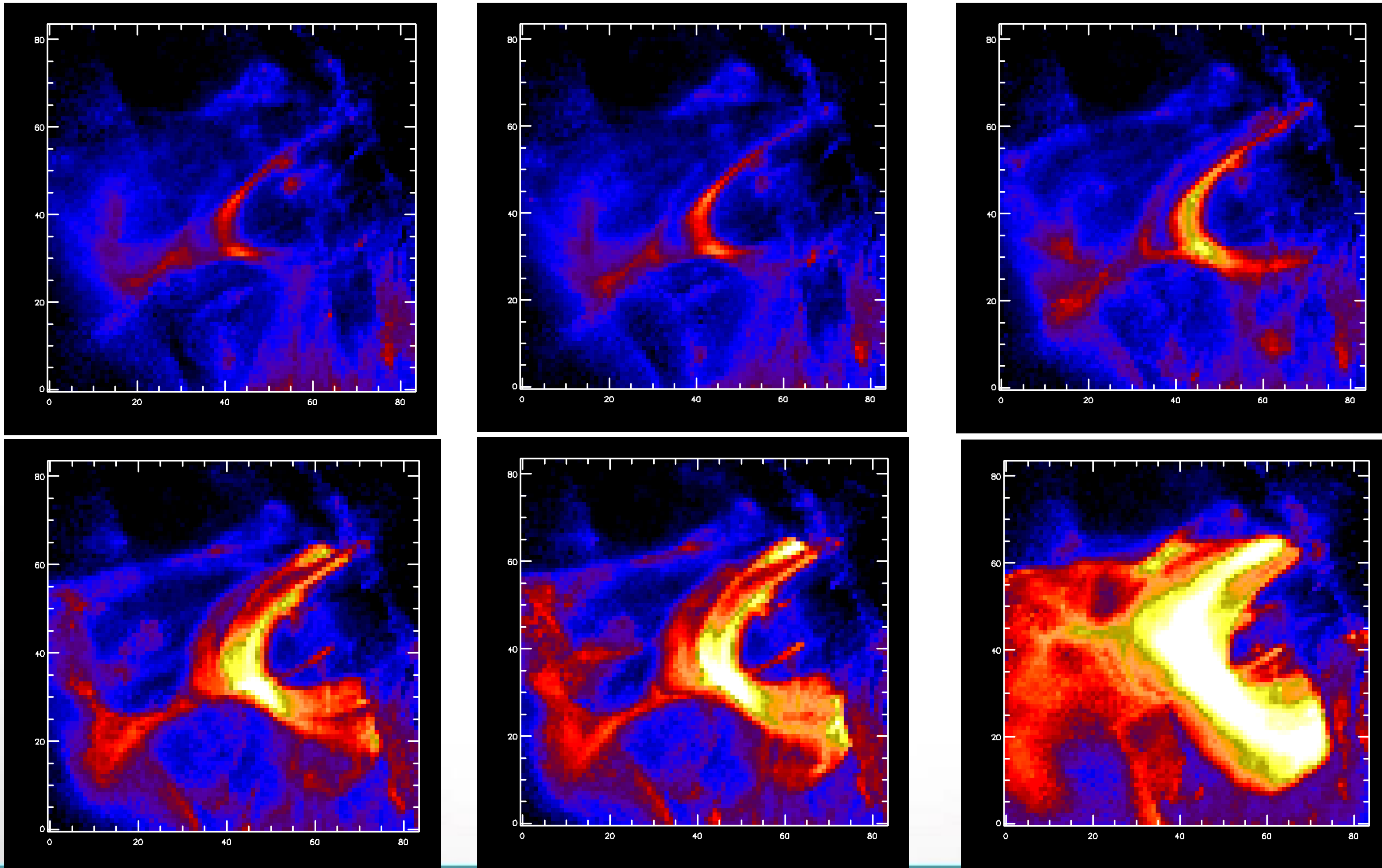
thermal 2

AIA DEM

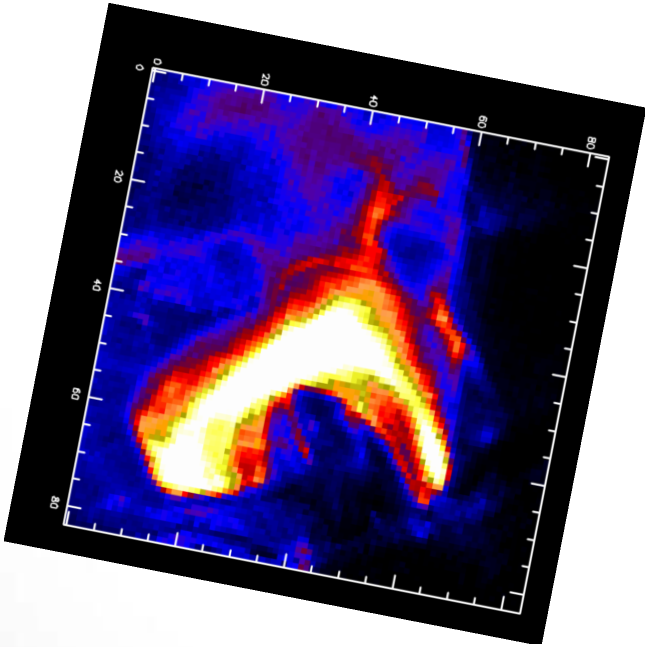
# Results: case 1: time evolution

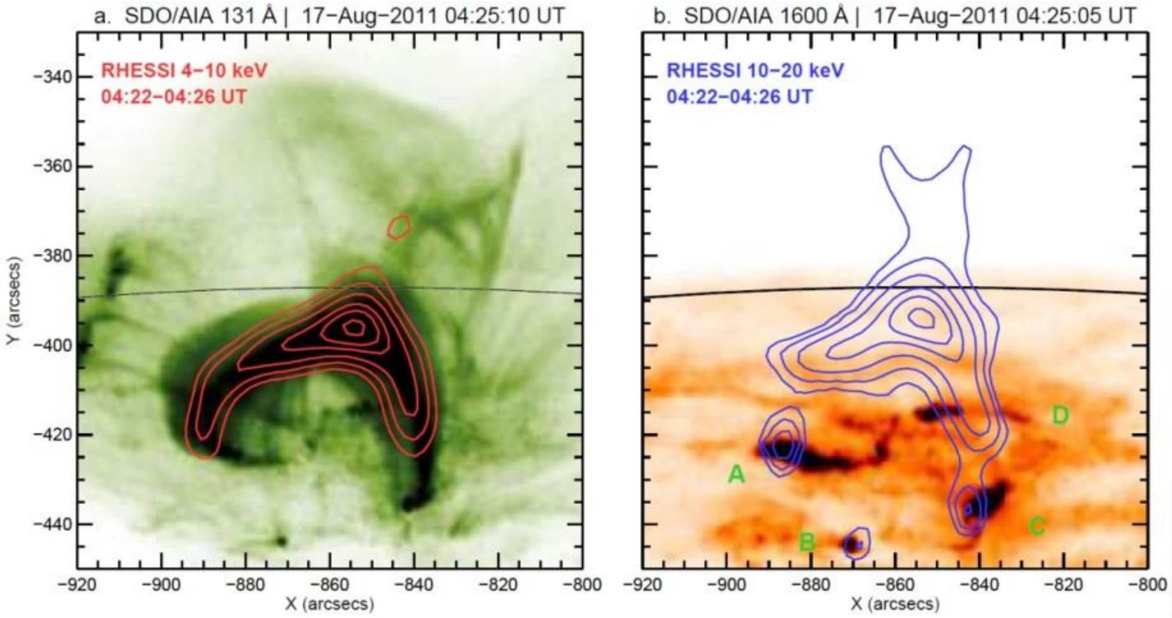


# Results: case 1: time evolution



# Results:




a. SDO/AIA 131 Å | 17−Aug−2011 04:25:10 UT
RHESSI 4−10 keV
04:22−04:26 UT
b. SDO/AIA 1600 Å | 17−Aug−2011 04:25:05 UT
RHESSI 10−20 keV
04:22−04:26 UT
A
B
C
D
Y (arcsecs)
X (arcsecs)
X (arcsecs)
−340
−360
−380
−400
−420
−440
−920
−900
−880
−860
−840
−820
−800

# Results: case2: X-ray images

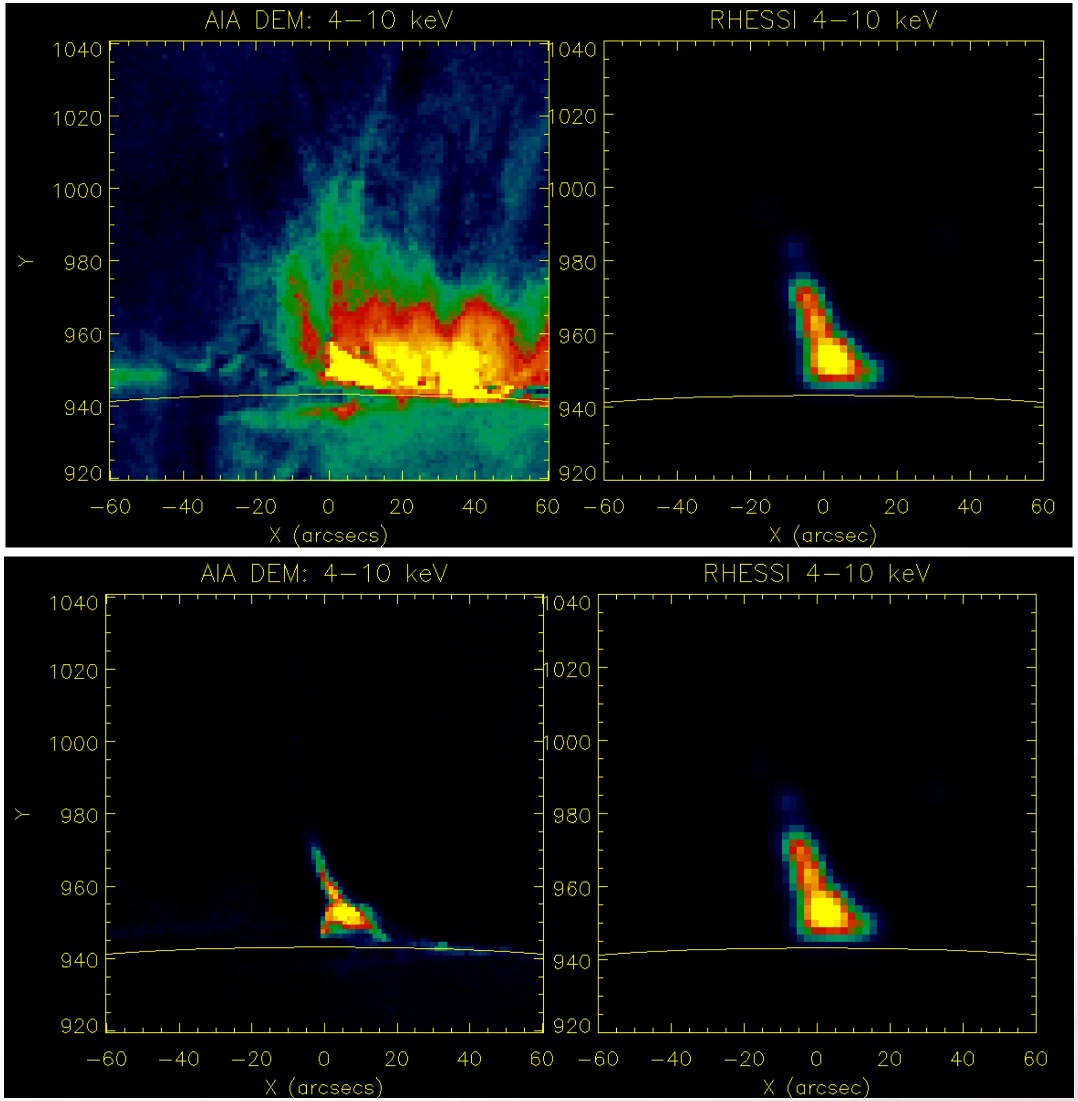
old result

much larger intensity
different structure

LOGT : 6.3-7.8
4-10 keV

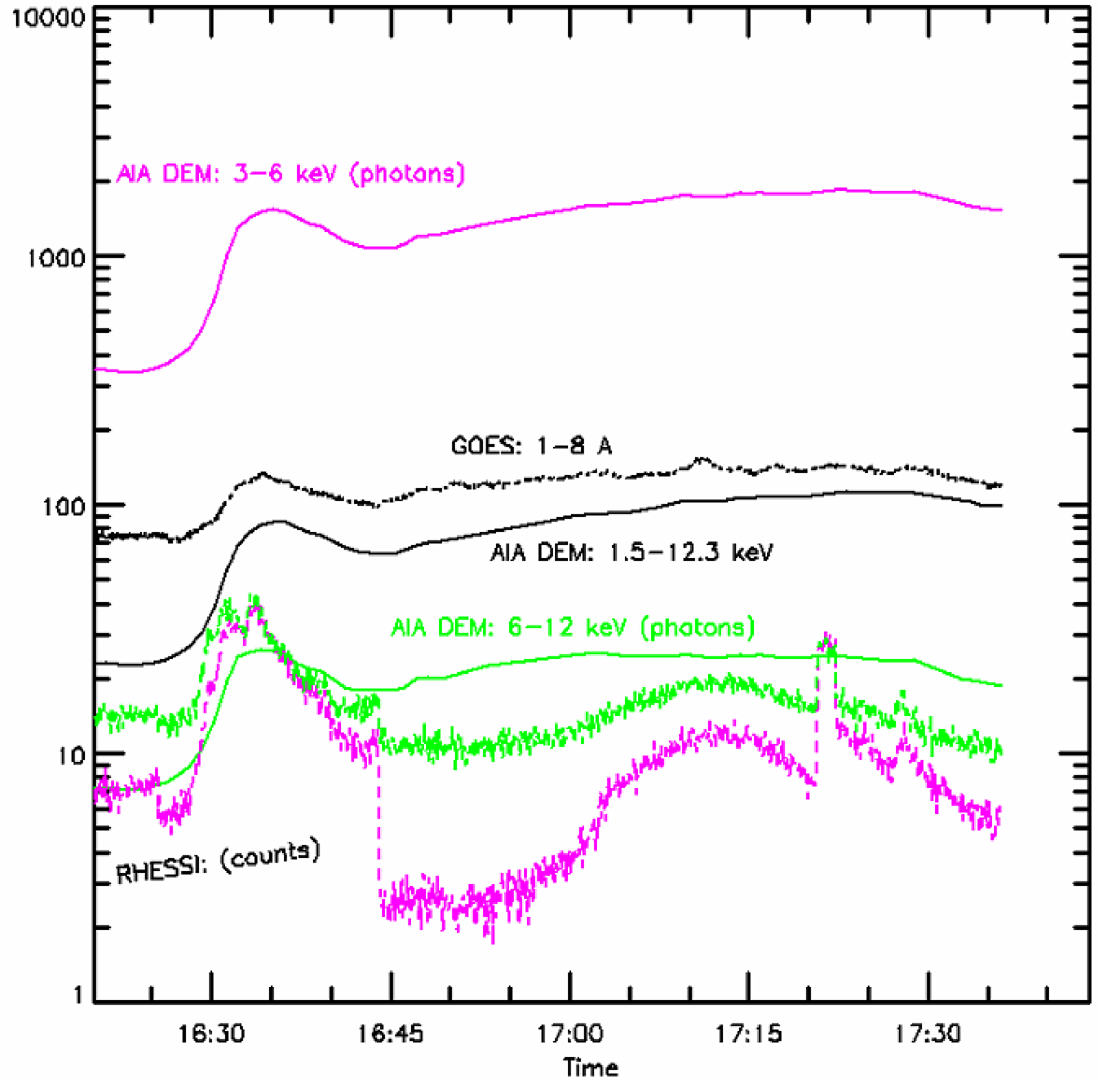
new result

same intensity
same structure

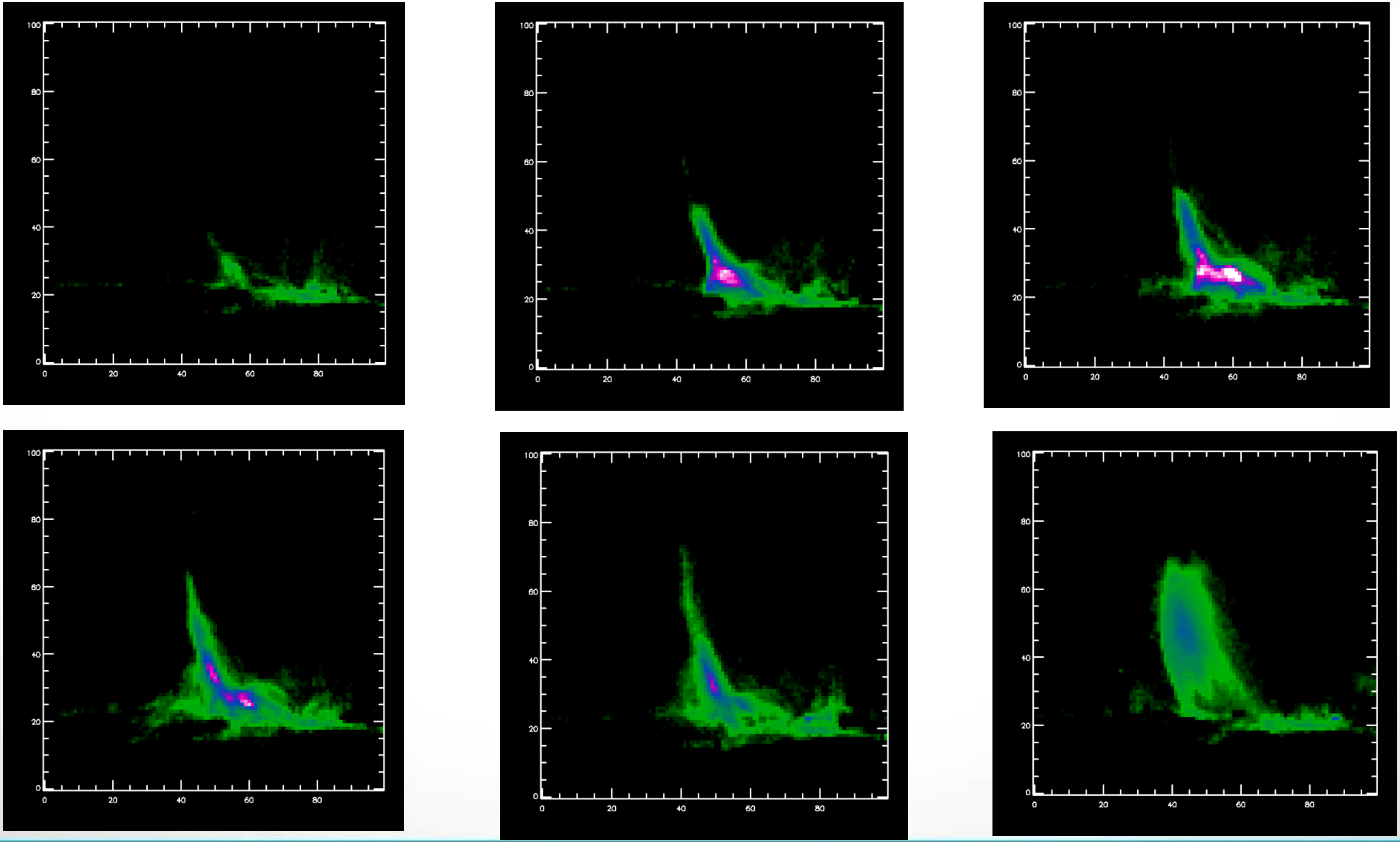


# Results: case 2: X-ray light curves

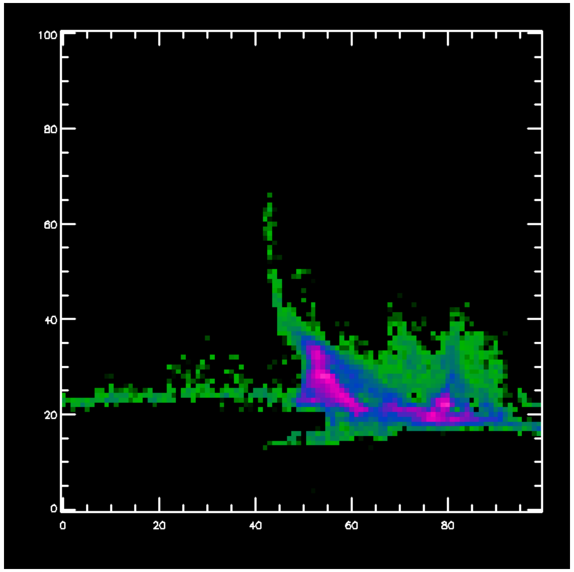
- X-ray Light Curves from AIA DEM
- LogT: 6.3-7.8

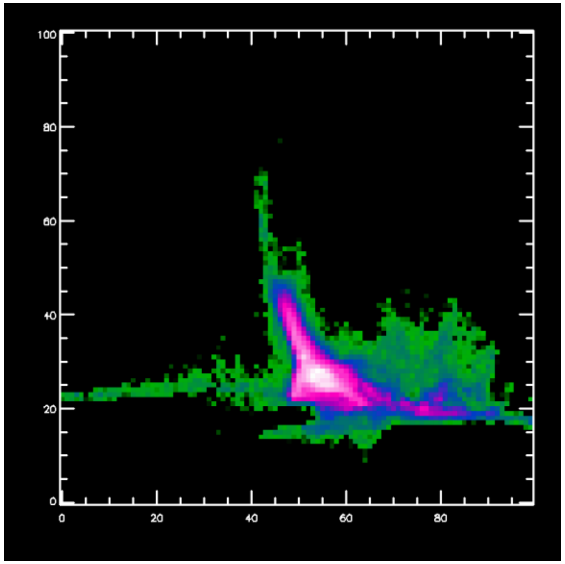


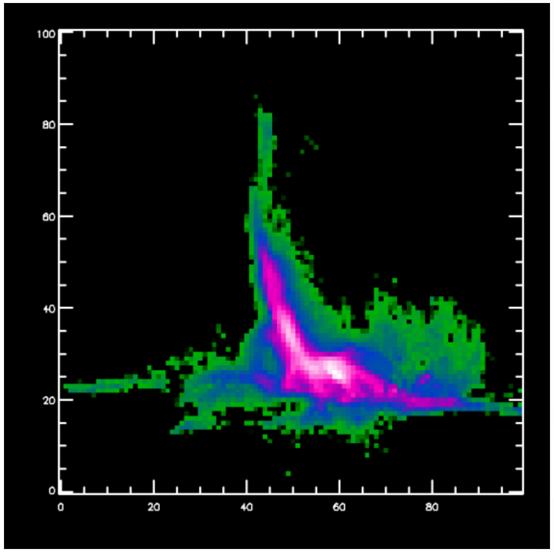
# Results: case 2: images

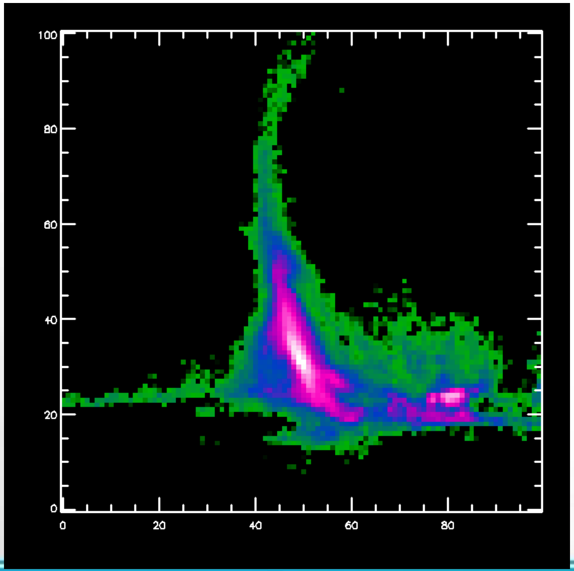


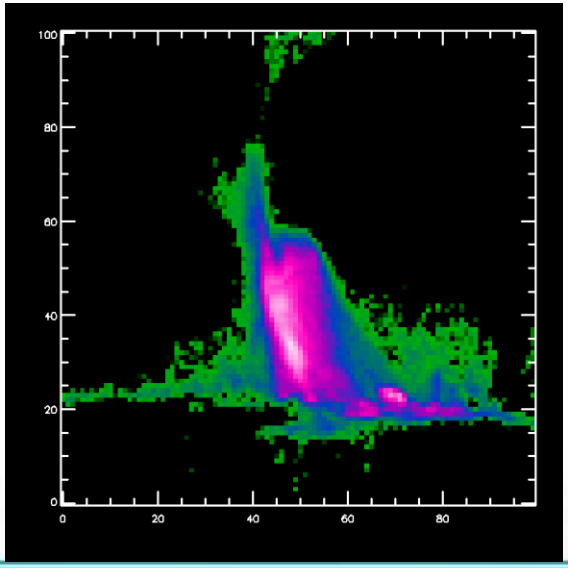
# Results: case 2: images

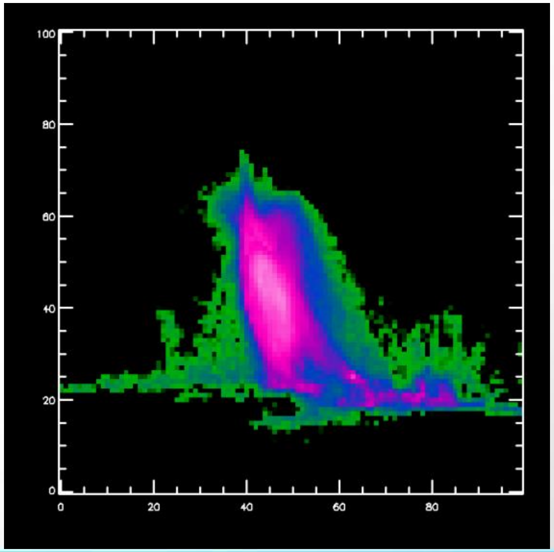


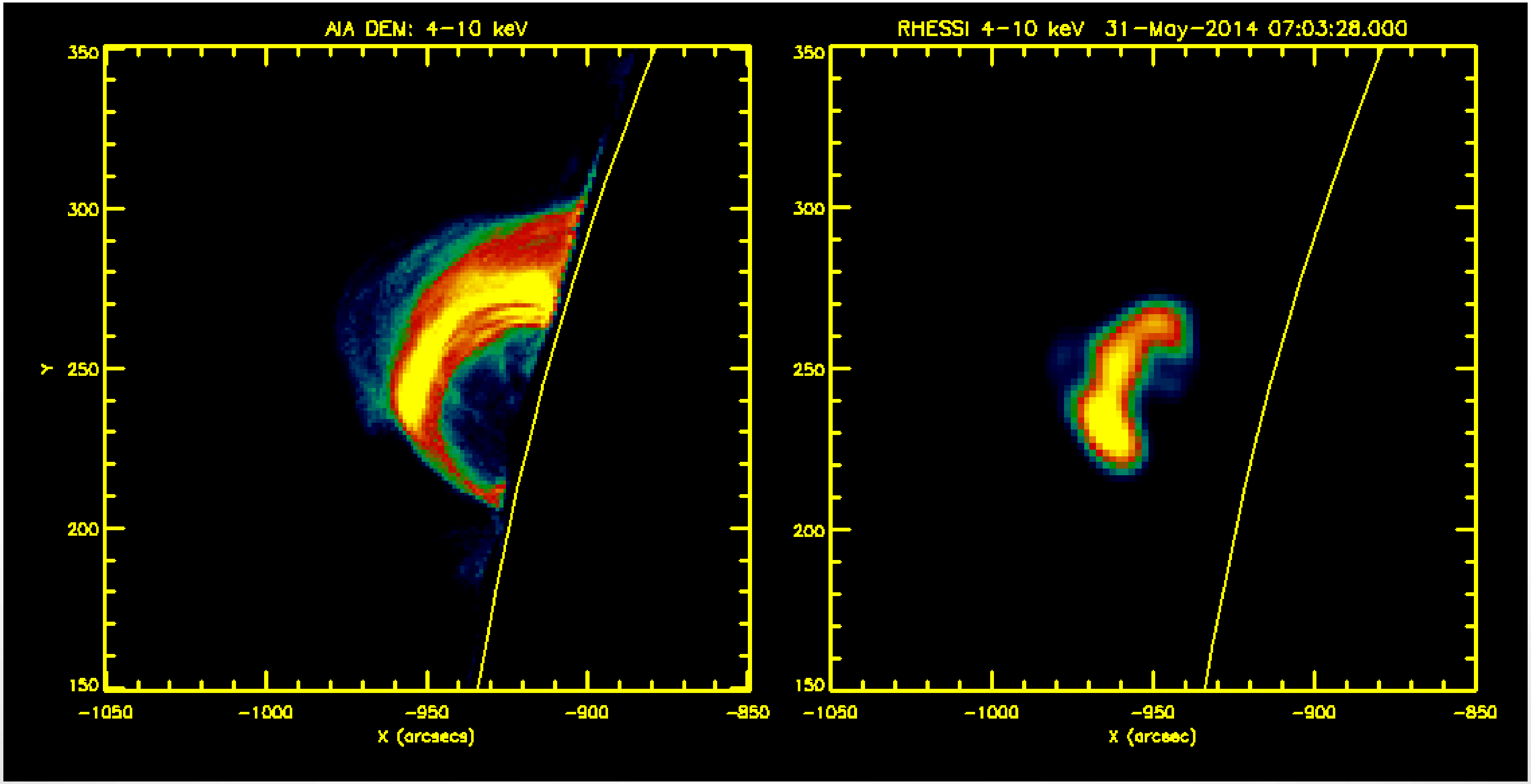



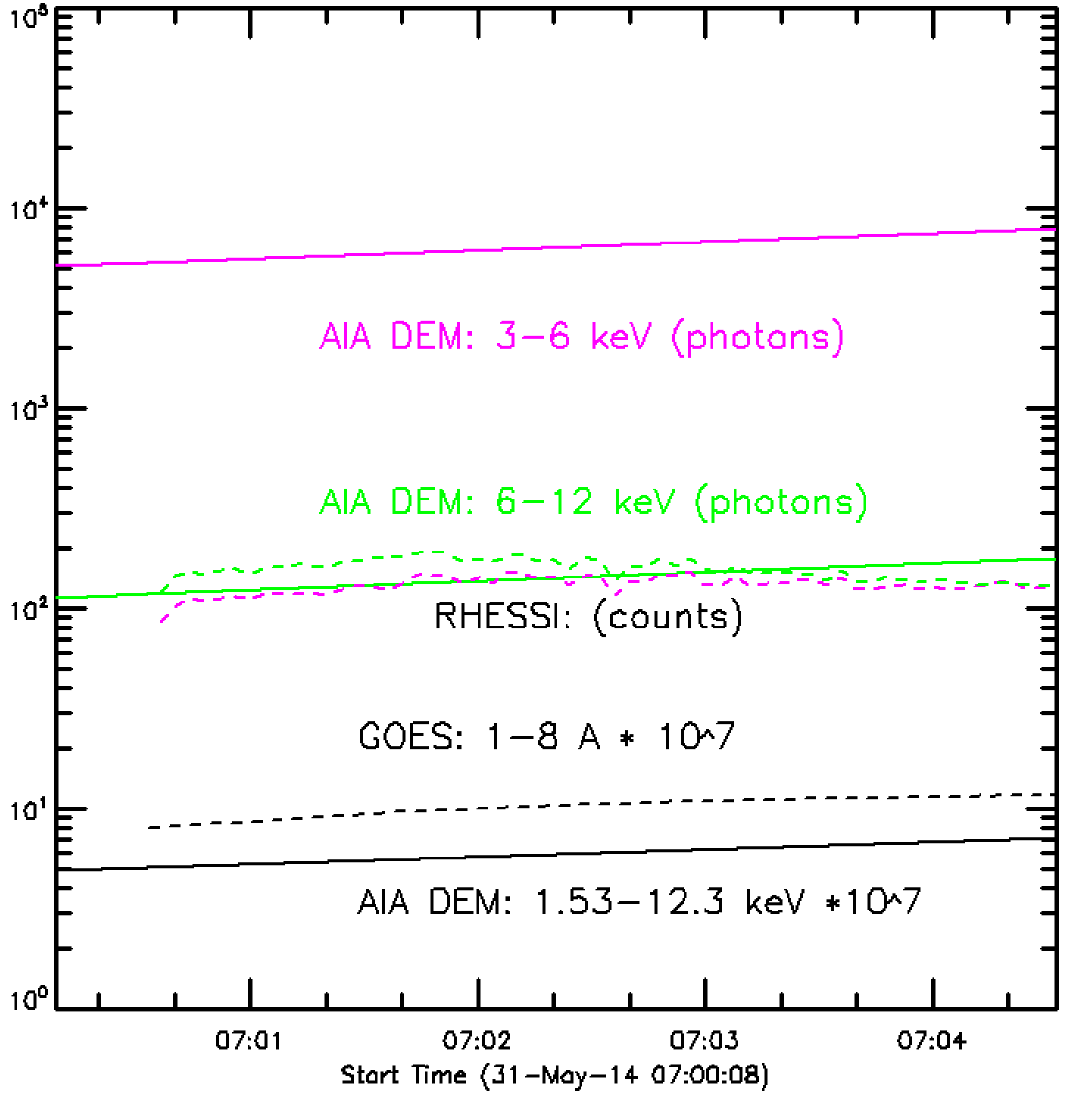



# Results: case3: X-ray images

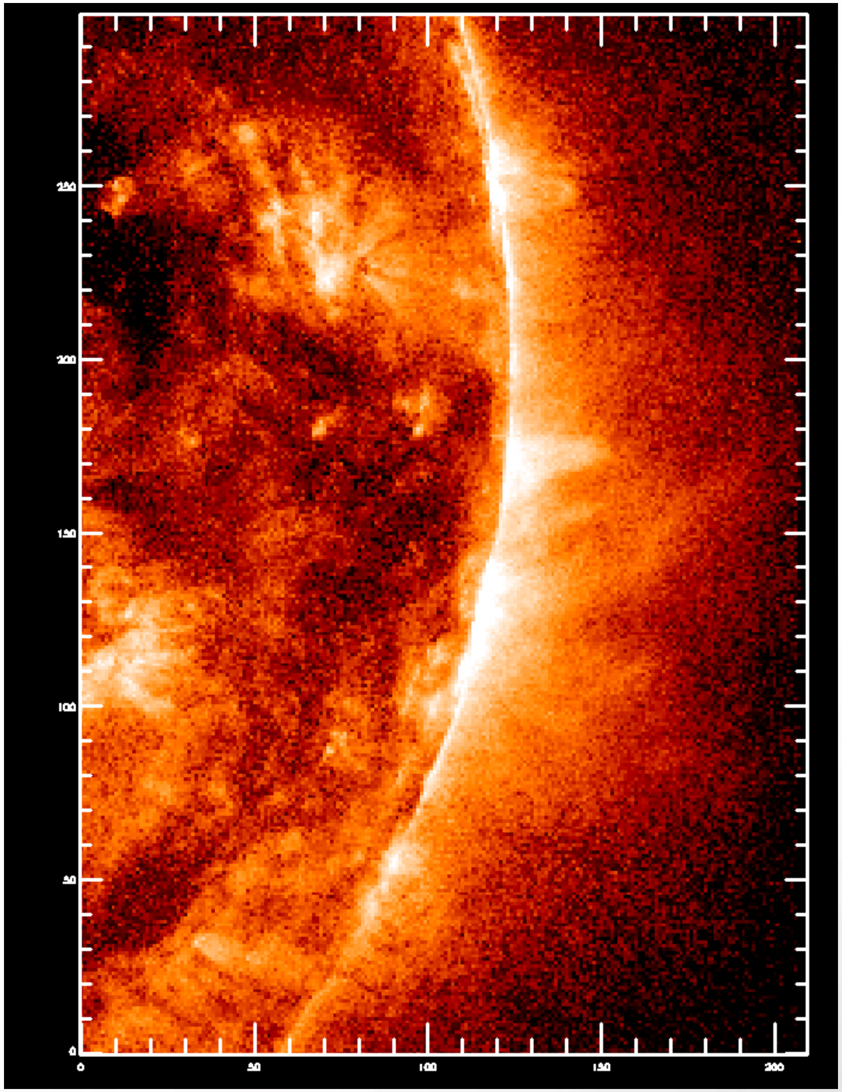


# Results: case3: light curves



# Results: case4: active region

- AIA DEM:  2-4 keV
- 2014-Nov-01



# Results: case4: footpoints

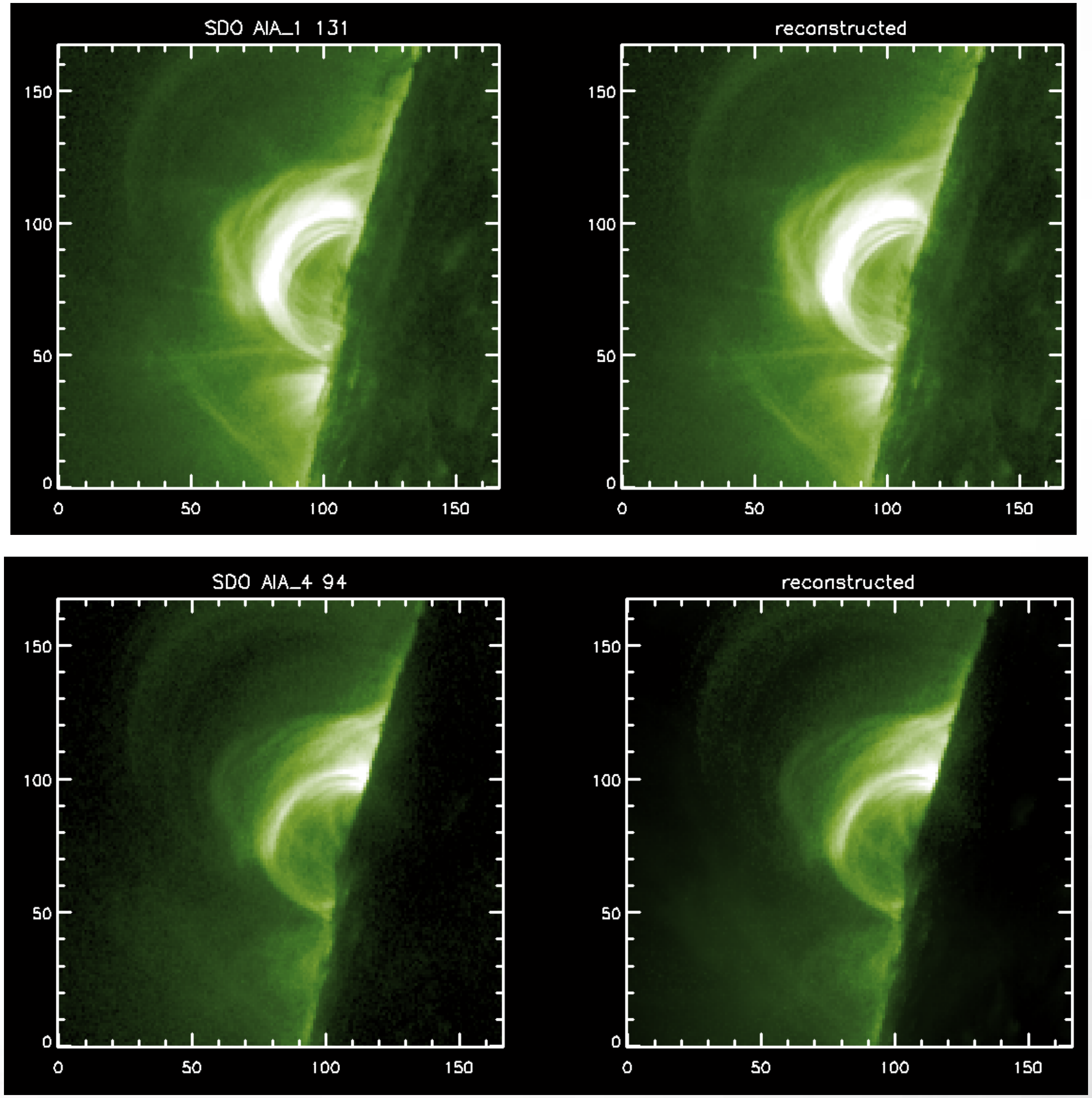
AIA  saturation

end of story

# Results: new problems

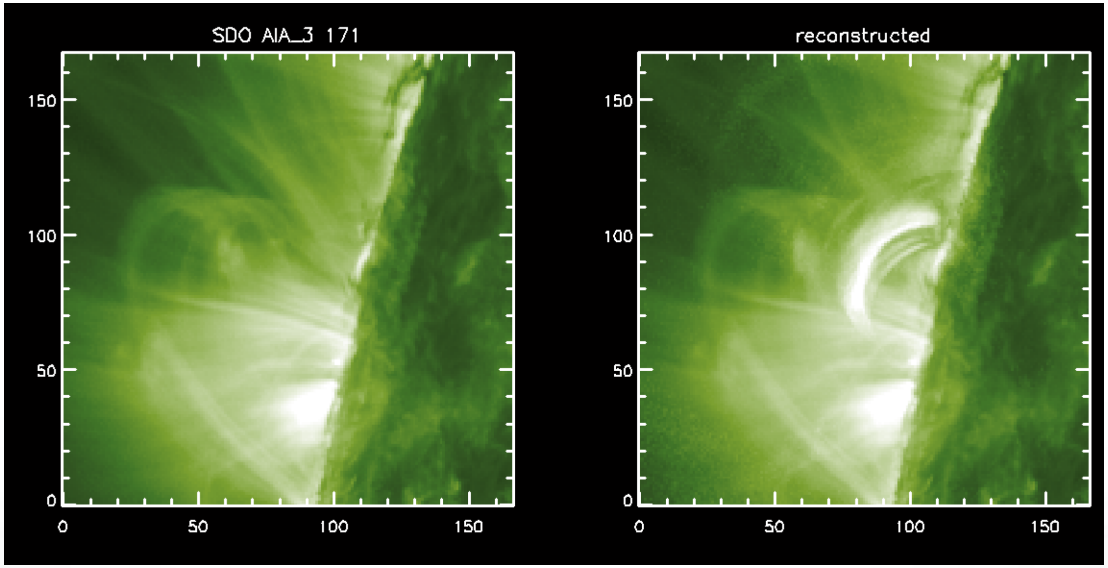
- AIA hot channels: 94,131, 335 are well reconstructed
- It seems that the new code 'solved' the problems at high T.

WOW ?



# Results: case4: footpoints

- AIA 171, 193 are not well reconstructed.
- But it may simply moved the problem to low T.



# Results: new problems

Factors:

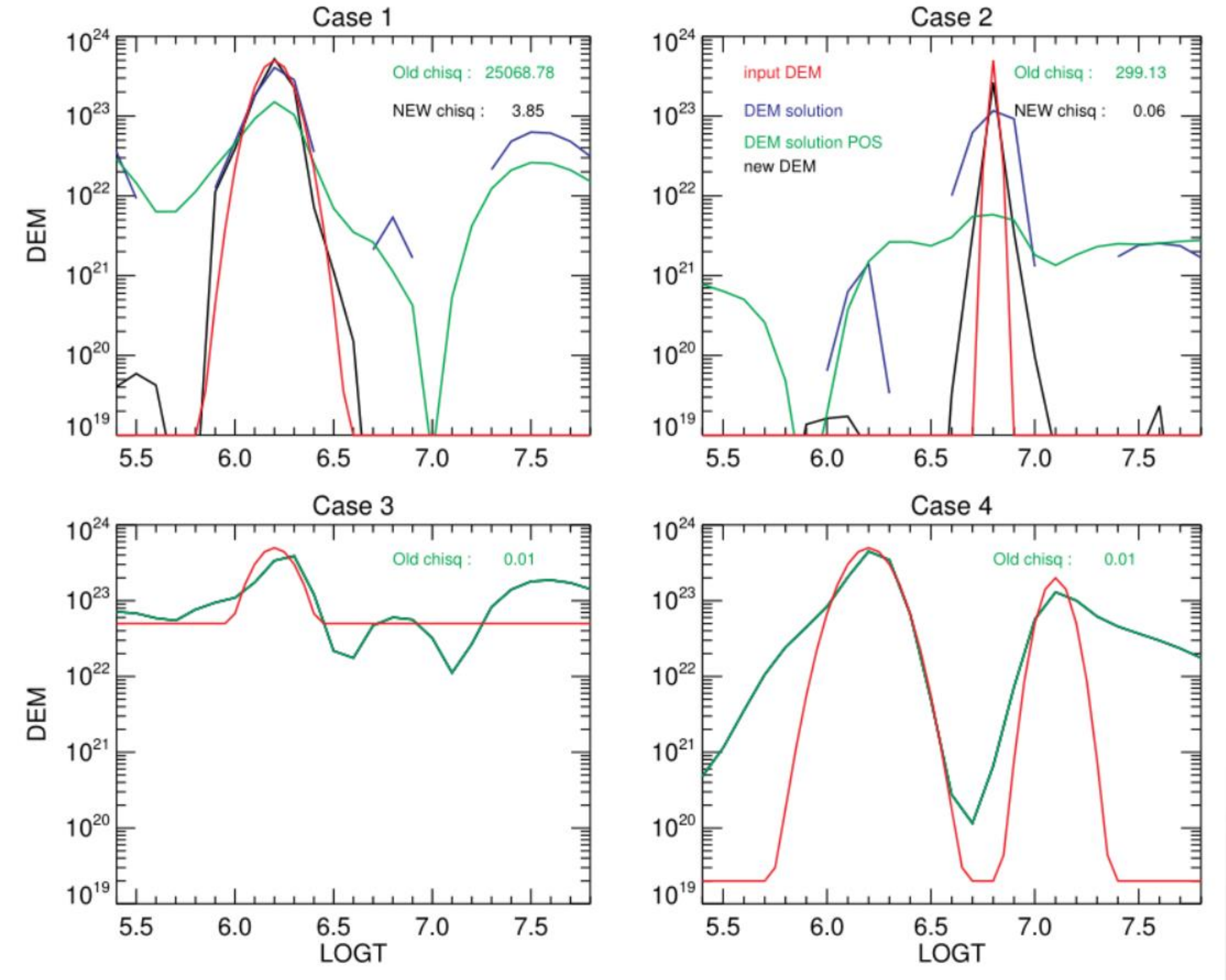
- T response
- CHIANTI line database
- errors on data
- the way of calculating in the code

$$\sum (DEM/factors)^* \Delta T^*(TR^*factors)=DN/s$$

- T-range
- other parameters

- case by case!
- sometimes the original solutions are good enough!

# Results: new problems



# To do list:

study on the uncertainties!

DEM of shocks

DEM of footpoints

DEM of dark downflows

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