# Study of the White-light Emission During the X9.3 Flare on September 06, 2017

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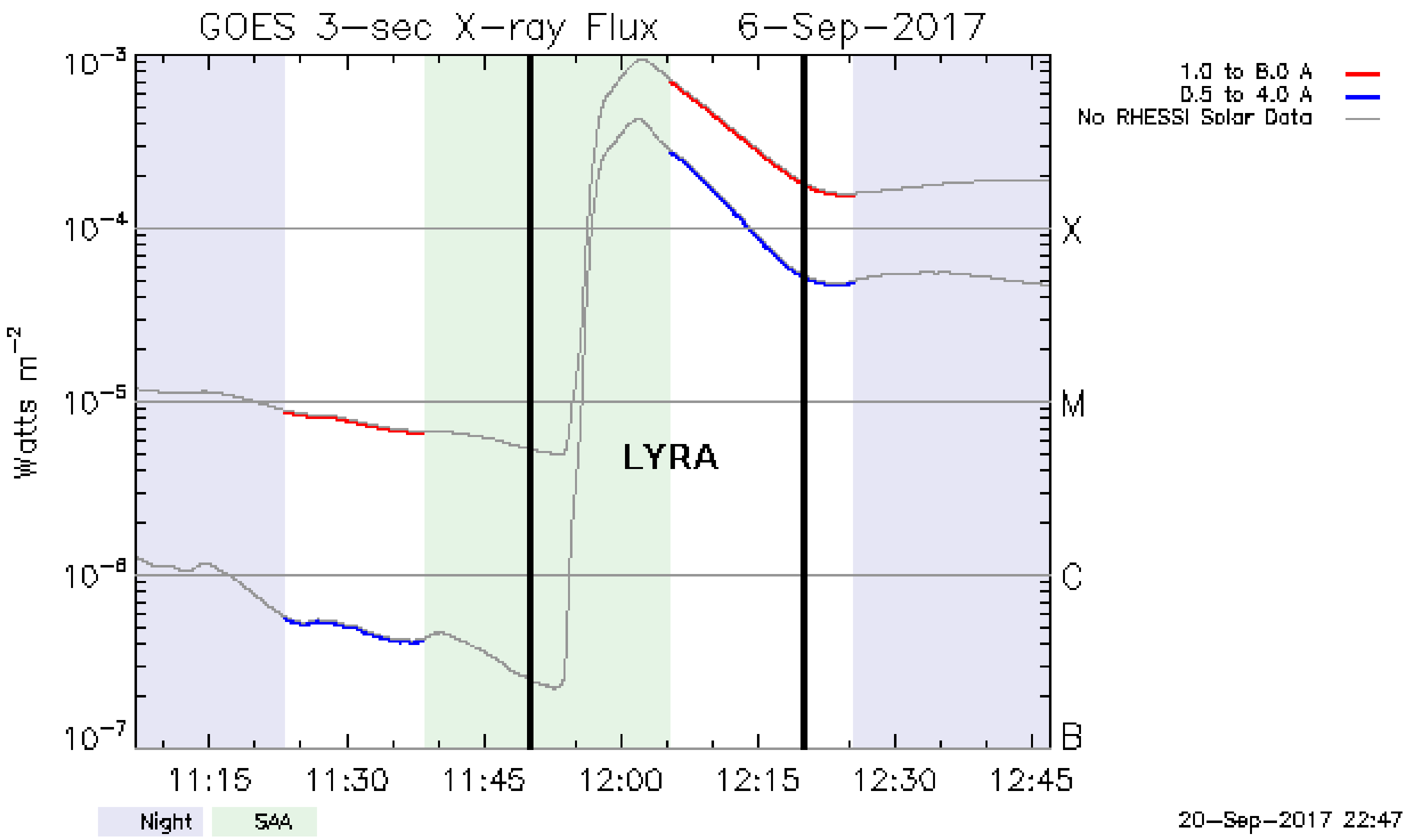
**Abstract.** Using data from SDO/HMI, Hinode/SOT, and LYRA instruments we study the white-light continuum emission during the X9.3 solar flare (SOL2017-09-06T11:53). Assuming that the emission is due to hydrogen Balmer and Paschen continua, we estimate the temperature evolution during that solar flare.

# September 6, 2017 X9.3 flare

- the largest flare of $24^{th}$ solar cycle
- started at $\sim 11:53$ UT
- detected by several instruments, e.g.:
  - RHESSI, Fermi: gradual phase only
  - Hinode: SOT/SP
  - *SDO*/HMI: white-light pseudo-continuum
  - LYRA: solar irradiance in UV range

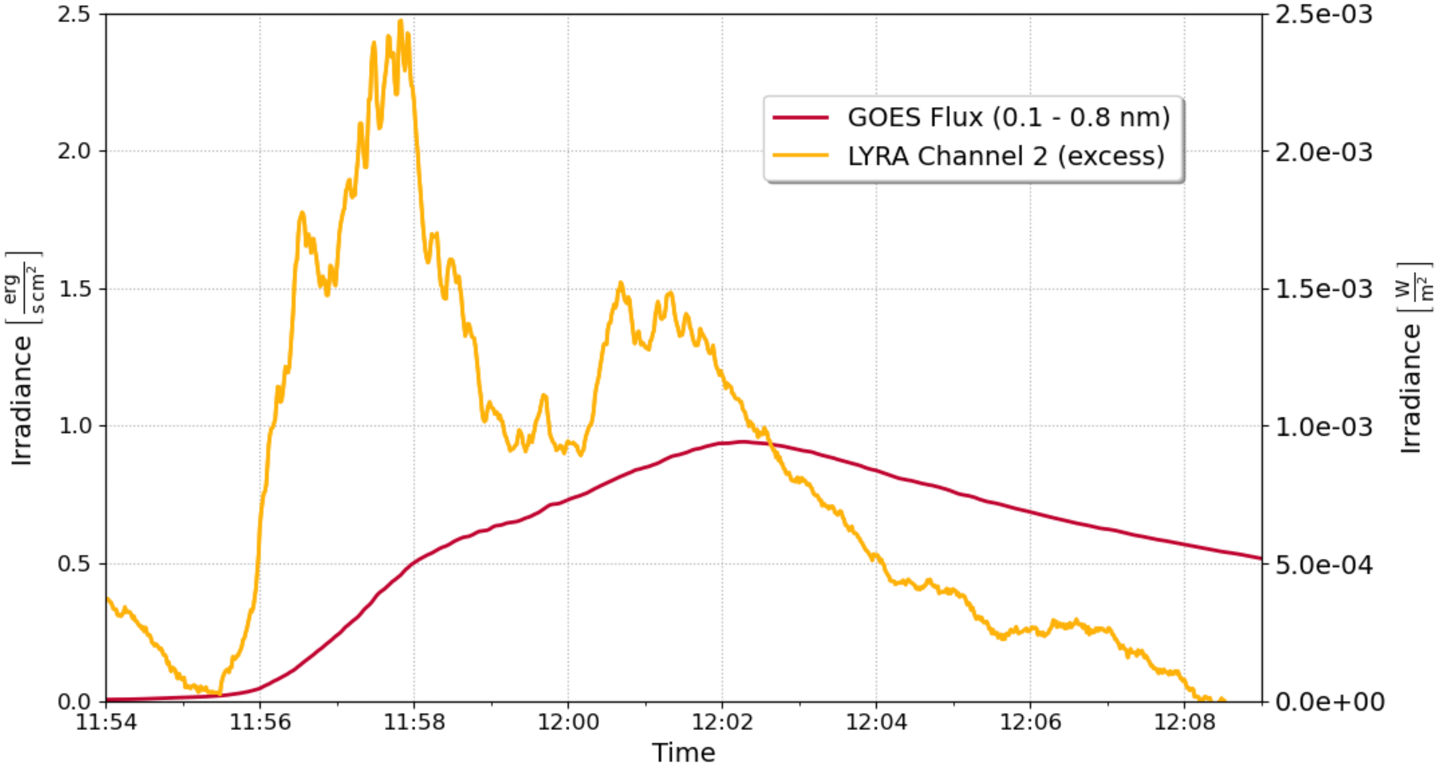


# Proba 2/LYRA Channel 2 data

- Large Yield RAdiometer (LYRA) on board Proba 2 (Hochedez et al., 2006)
  - solar irradiance at 4 channels
  - Channel 2: Herzberg channel, 1990 - 2200 Å, temporal cadence 20 Hz

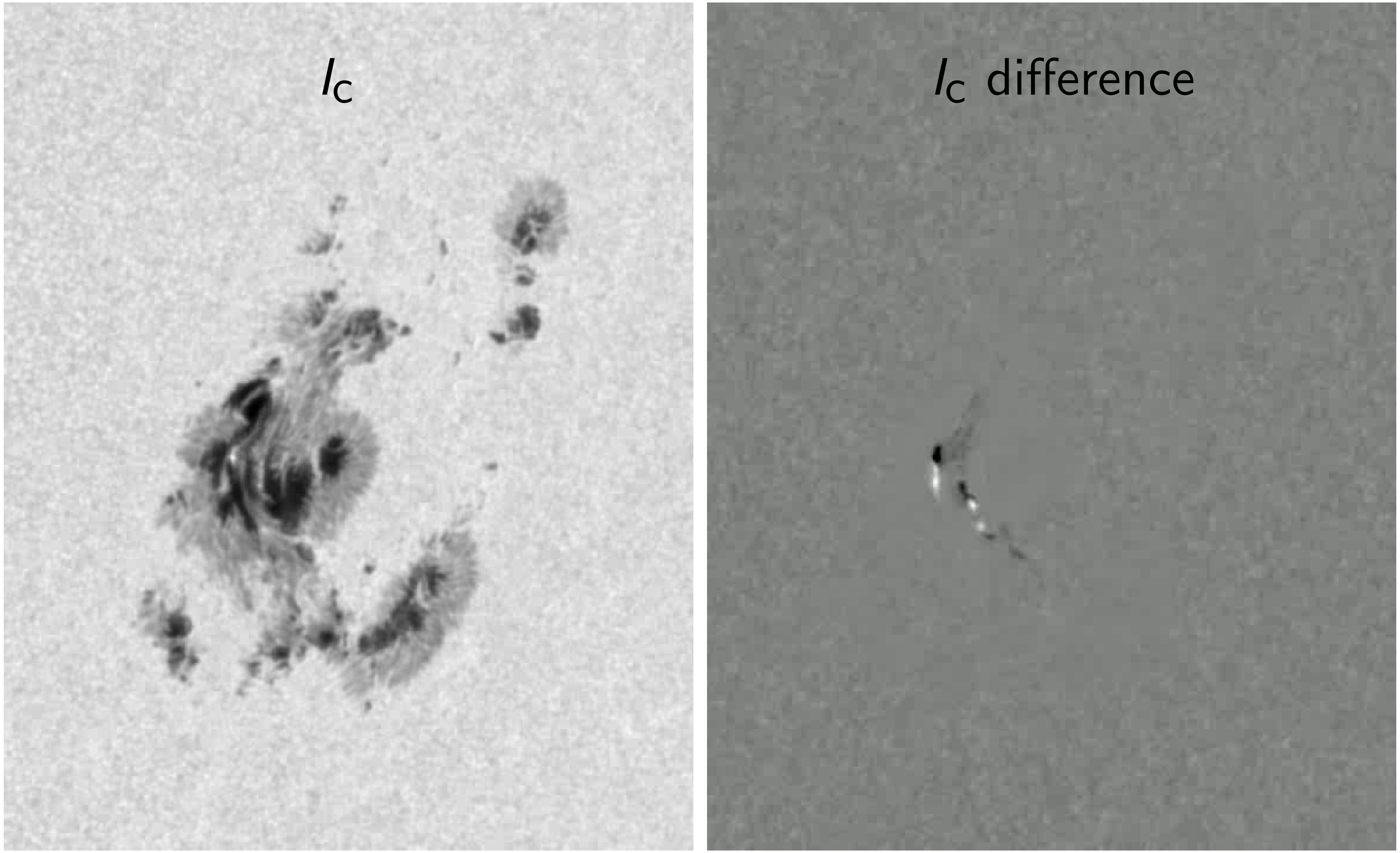
Sep 6, 2017 flare - Dominique et al. (2018)

- the first flare detected in Channel 2
- emission consistent with hydrogen Balmer continuum



# HMI pseudo-continuum $I_C$

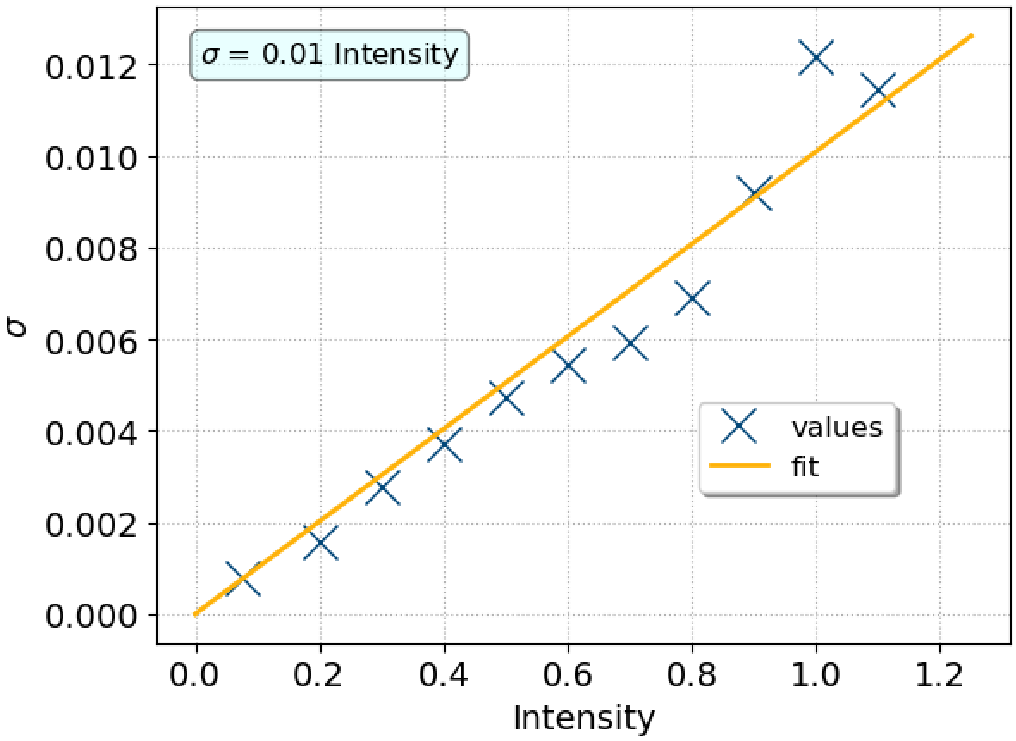
- HMI data product from Fe I 617.3 nm scans
- 45 s time cadence, 0.5″ spatial sampling



# HMI flare emission

- space-temporal analysis
- based on $I_C$ difference above a threshold

  $I_C^{\text{diff}}(x,y) > 5\,k\,I_C^{\text{PF}}(x,y)\,,$
  $k = 0.01,$
  $I_C^{\text{PF}} = \overline{I_C(11{:}30 - 11{:}40)}$
- a flare pixel must
  - have at least 2 neighbours at start
  - occur on 3 subsequent frames at least
- end of a flare pixel light curve defined as time when $\overline{I_C}(x,y)$ reached $I_C^{PF}(x,y)$ within 5%
  - a box car over 5 frames

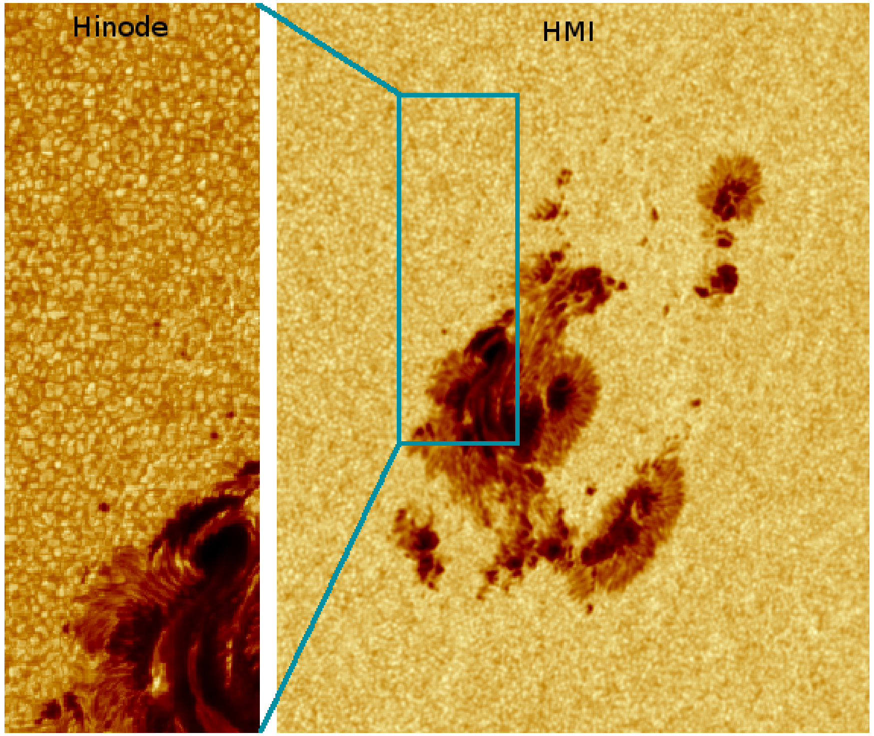


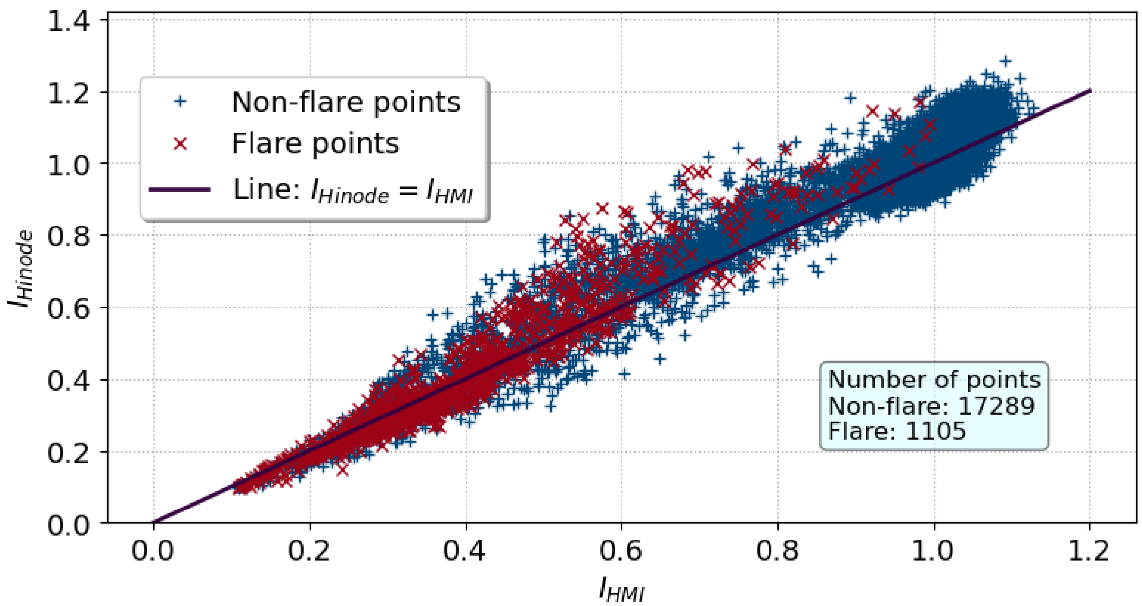

$I_C$ at 10:00 and 11:30 UT
$\sigma(I_C) = kI_C$

$\Rightarrow$ Flare pixel light curves

# HMI versus Hinode data check

- Švanda et al. (2018) showed HMI product $I_C$ can be off from continuum intensity close to Fe I 630 nm lines observed by Hinode




- no systematic offset of $I_C$
- no correction applied

# Hydrogen continuum emission

## Assumptions

- optically thin emission from a layer of thickness $L$
- intensity of recombination continua

(Heinzel et al. 2017; Dominique et al., 2018)

$i$=2,3,4.. Balmer, Paschen, Brackett,..

$$I_\nu = n_e^2 F_i(\nu, T) L$$

$$F_i(\nu, T) \sim B_\nu(T) T^{-3/2} e^{h\nu_i/kT}(1 - e^{h\nu/kT})/(i\nu)^3$$

continuum heads: $\lambda_2 = 364.6\,\text{nm}$ $\lambda_3 = 820.4\,\text{nm}$ $\lambda_4 = 1458\,\text{nm}$

emission data: $\lambda_{\text{LYRA}} = 200\,\text{nm}$ $\lambda_{\text{HMI}} = 617.3\,\text{nm}$

# Predicted LYRA emission from HMI data

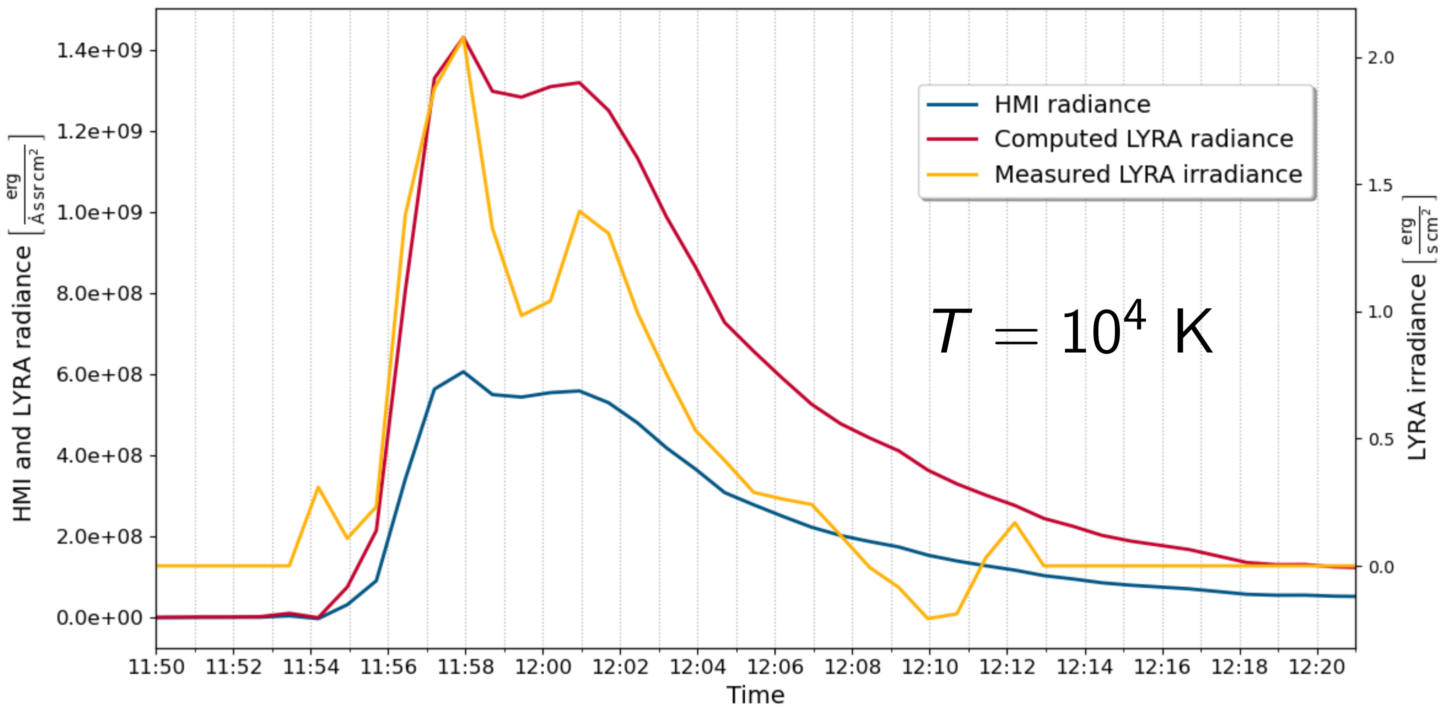
- for a given $T$, HMI gives emission measure $[n_e^2 L](t)$

$$[n_e^2 L](t) = \sum_{\text{flare pixels}} I_{\text{HMI}}(t) / \left[F_3(\nu_{\text{HMI}}, T) + F_4(\nu_{\text{HMI}}, T)\right]$$

$$I_{\text{LYRA}}(t) = [n_e^2 L](t) \left[F_2(\nu_{\text{LYRA}}, T) + F_3(\nu_{\text{LYRA}}, T) + F_4(\nu_{\text{LYRA}}, T)\right]$$

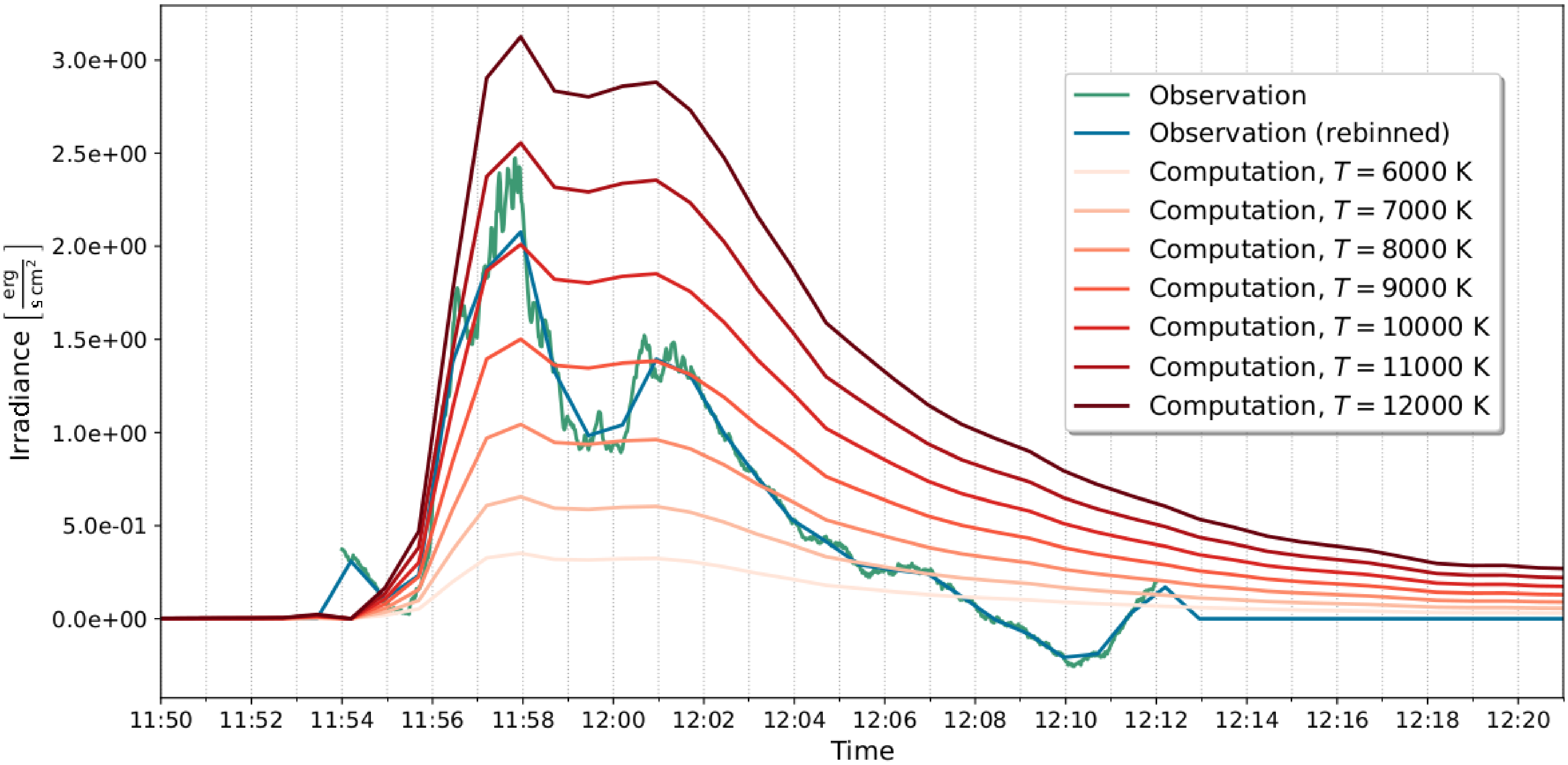
- predicted LYRA irradiance $E_2(t)$ using Dominique et al. (2018)

$$E_2(t) \sim \int_\lambda S_2(\lambda) I_{\text{LYRA}}(t)\, \mathrm{d}\lambda \qquad S_2(\lambda) \ldots \text{ eff. area}$$



# Predicted LYRA emission for several $T$

- predicted LYRA irradiance $E_2(t)$ for a set of $T$



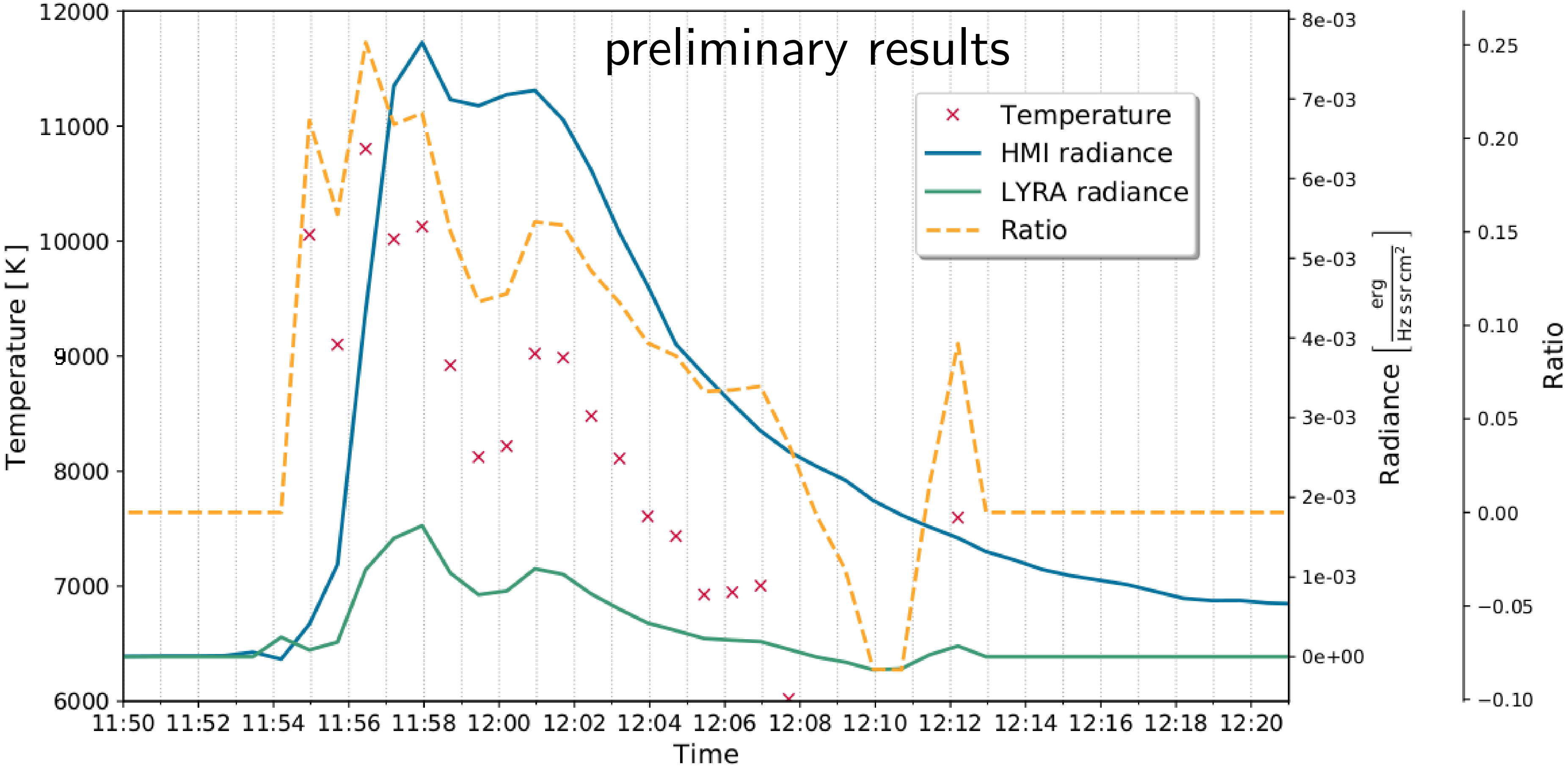

- $E_2(t)$ sensitive to $T$

# Temperature evolution

## Assumptions

- $I_\mathrm{c}$ and $E_2$ given by hydrogen recombination continua
- continua formed within the same optically thin layer

$$\Rightarrow \text{ratio } I_\mathrm{c}/E_2 \equiv f(T) \Rightarrow \text{mean } T(t)$$



# Conclusions

- HMI and LYRA data were used to study flare continuum emission
- assuming the emission is due to hydrogen recombination, mean temperature in the flaring area can be determined

- preliminary results show $T(t) \sim 7\,000 - 11\,000$ K during the impulsive phase of an X9.3 flare

**References**


Dominique et al, 2018, ApJL, 867, L24

Heinzel et al, 2017, ApJ, id. 48

Hochedez et al, 2006, AdSpR, 37, 303

Švanda et al, 2018, ApJ, 860, id. 144