



# EIS, IRIS and AIA observations of coronal rain

**Ignacio Ugarte-Urra**

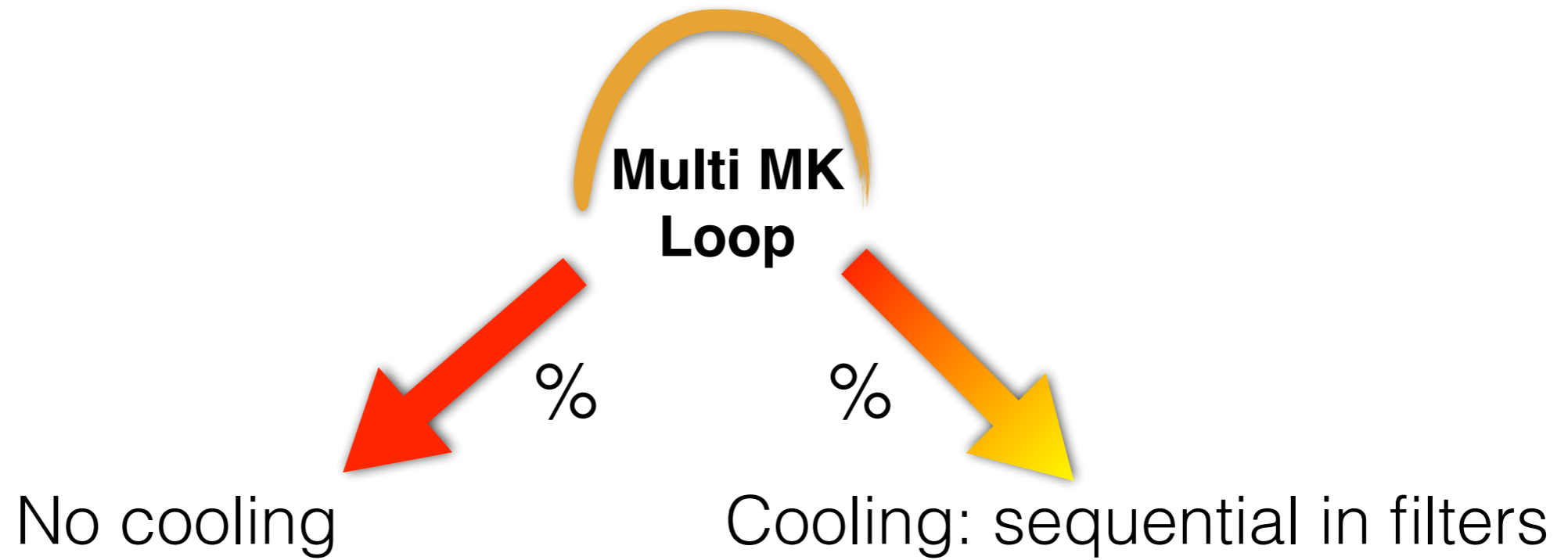
**Coronal Loops Workshop, Palermo, Italy, June 2017**

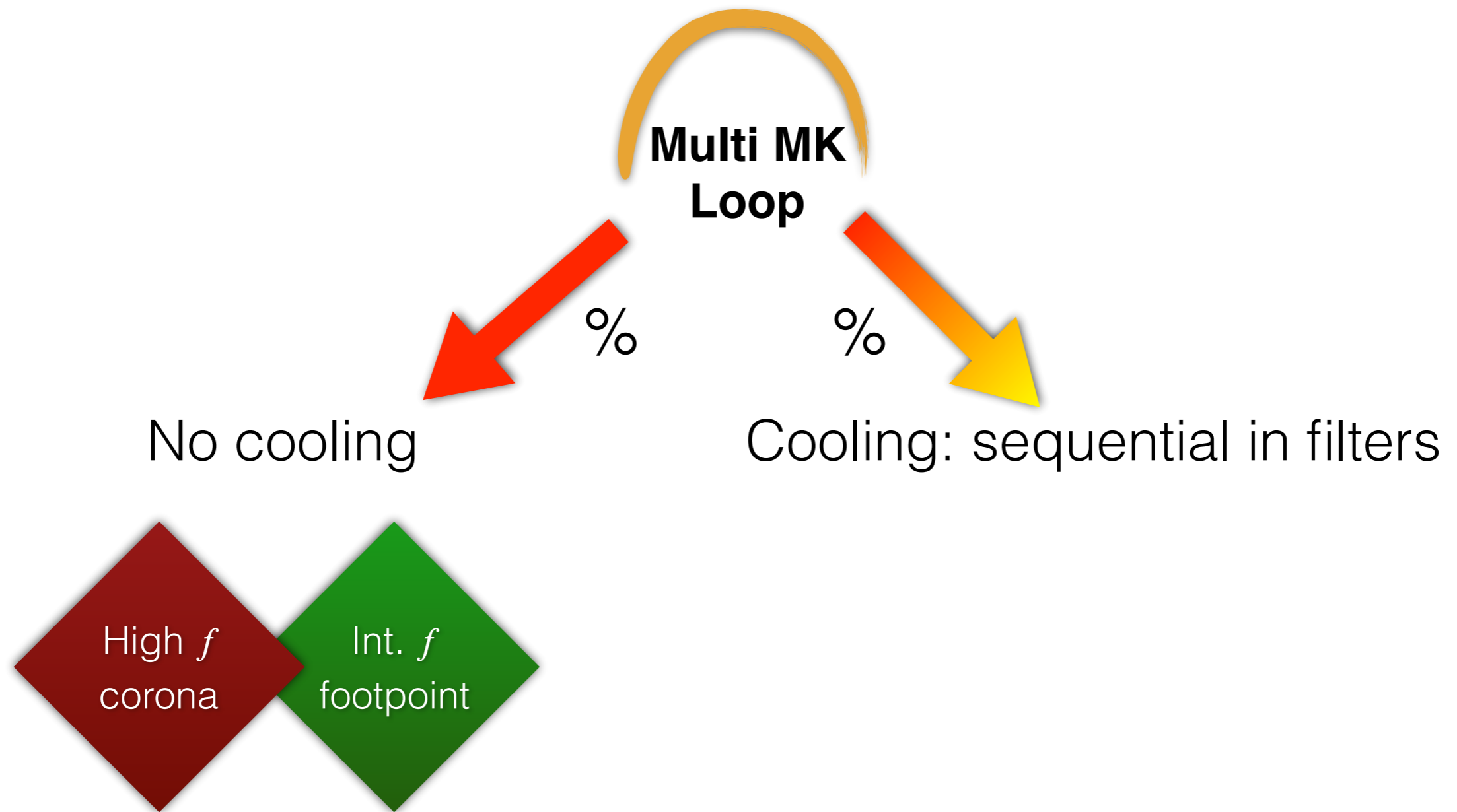
## **EIS and IRIS observations of coronal rain**

I. Ugarte-Urra, J. Reep, H.P. Warren, D.H. Brooks

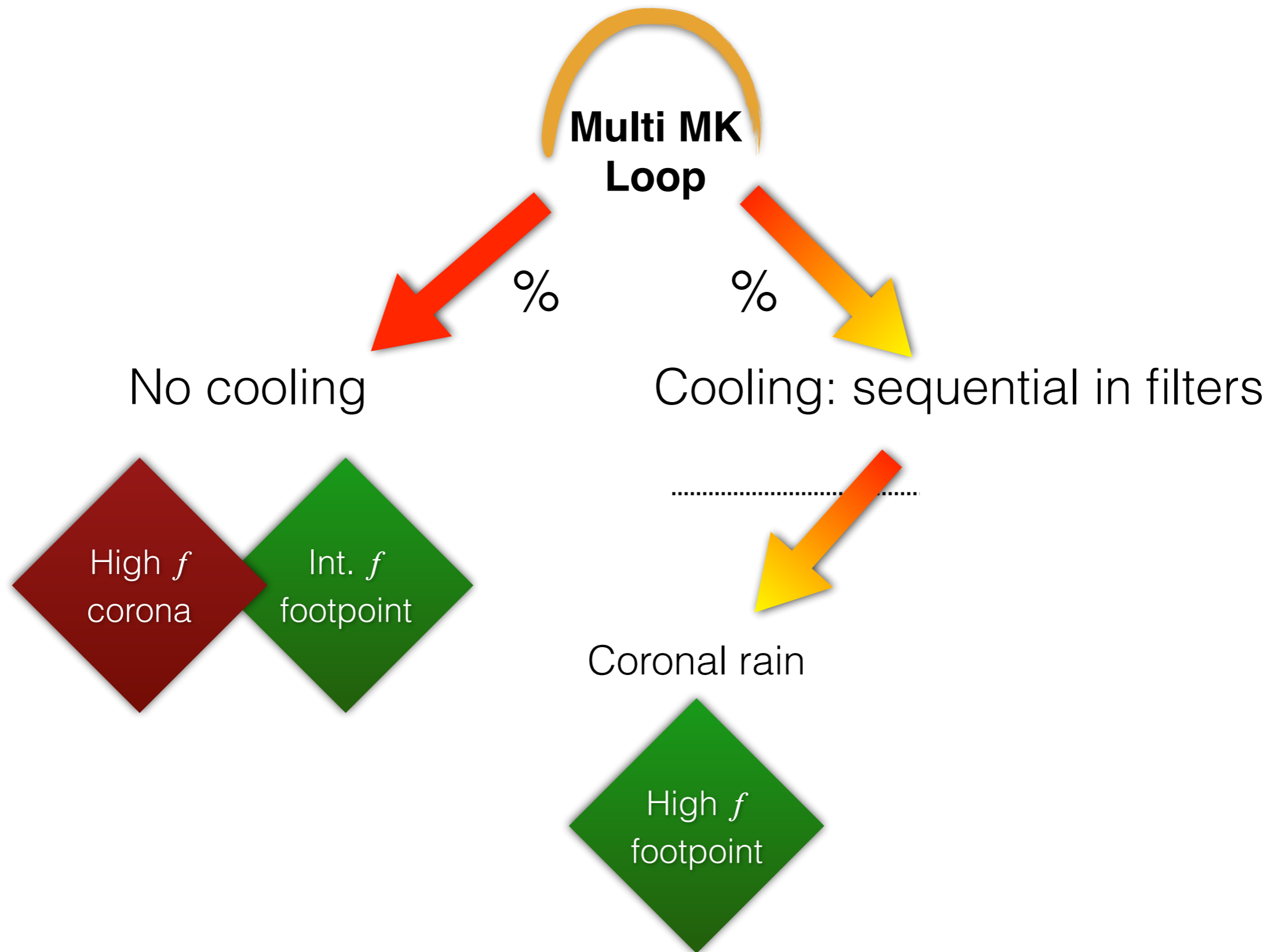
### Abstract

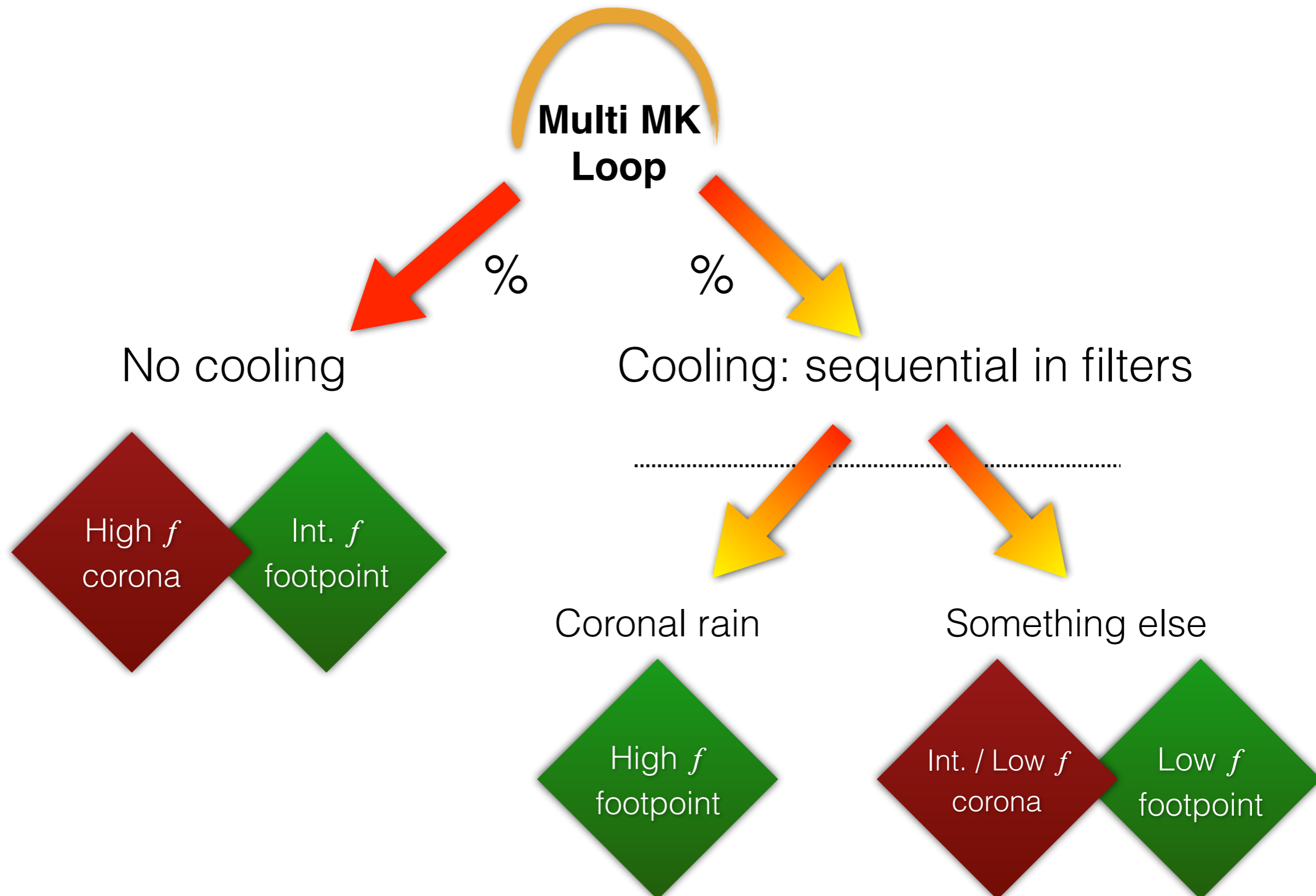
We present novel observations of coronal rain from the Extreme-ultraviolet Imaging Spectrometer on board Hinode taken in coordination with IRIS. The observations show that active region loops seen off-limb in transition region lines such as Si VII, exhibit coronal rain signatures when they cool down to the temperature of formation of lines such as Si IV observed by IRIS. As the Si VII loops are known to result from the cooling of multi-million degree loops, these results indicate that coronal rain is likely to be a fundamental part of the standard cooling of loops in active regions. We present numerical 1D simulations with HYDRAD addressing the formation of rain condensations in multistranded loops.



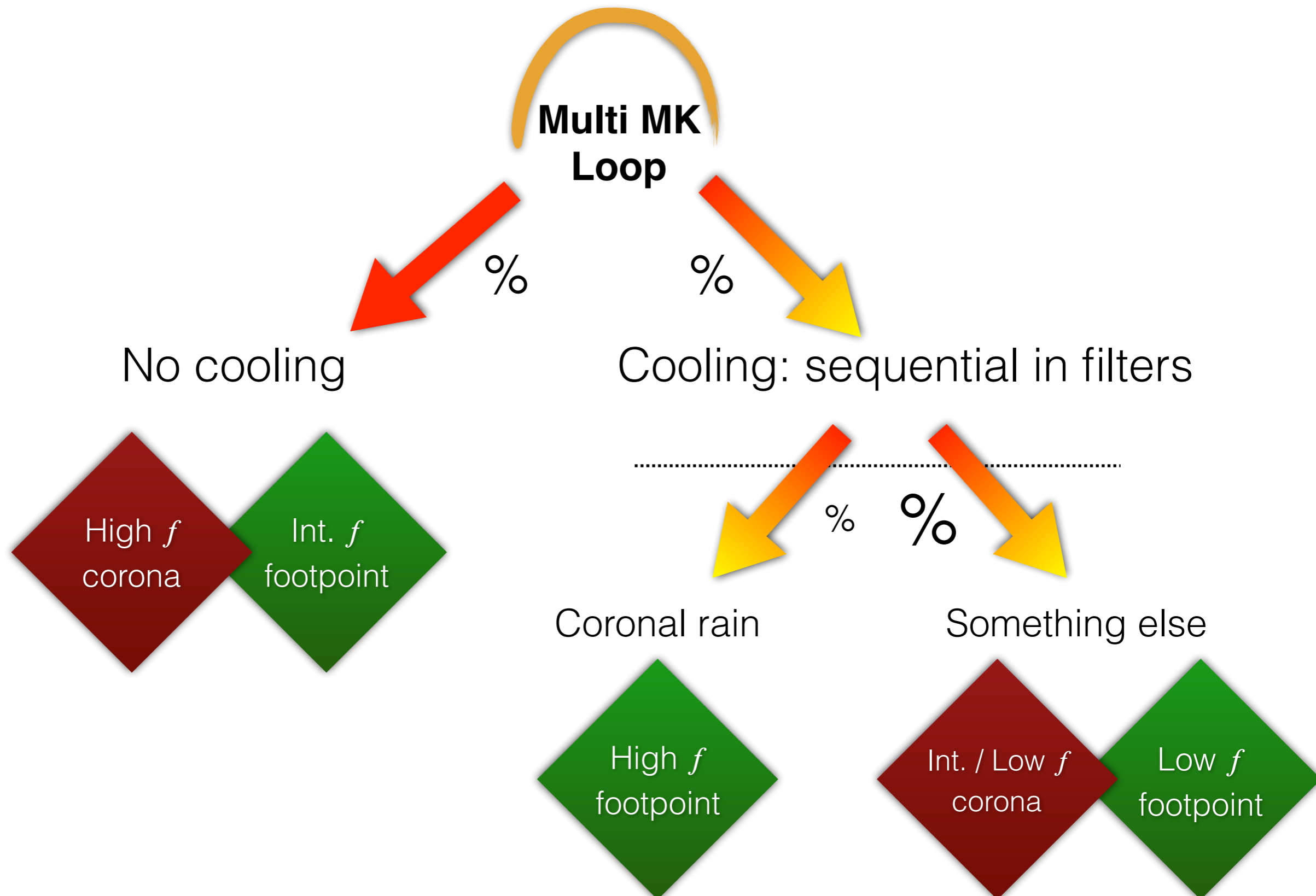






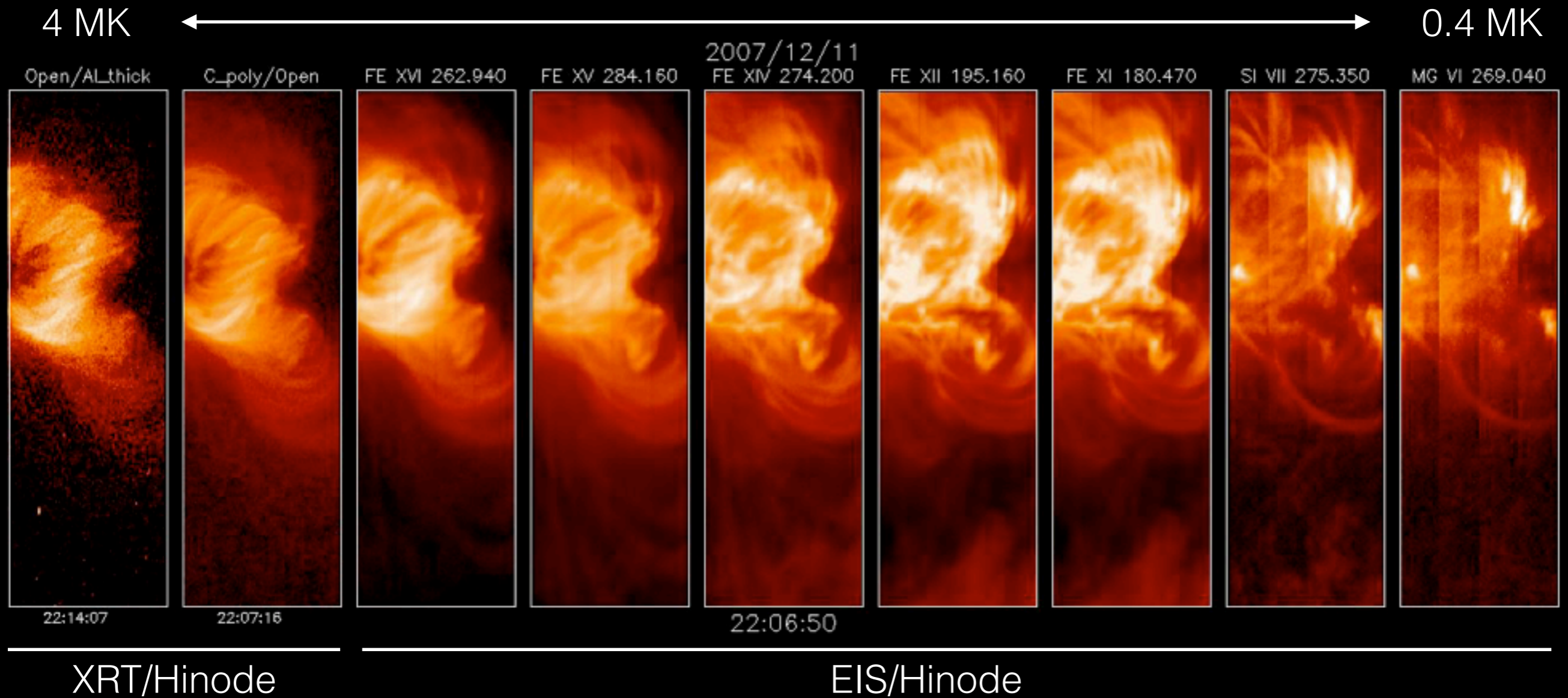


# Framework



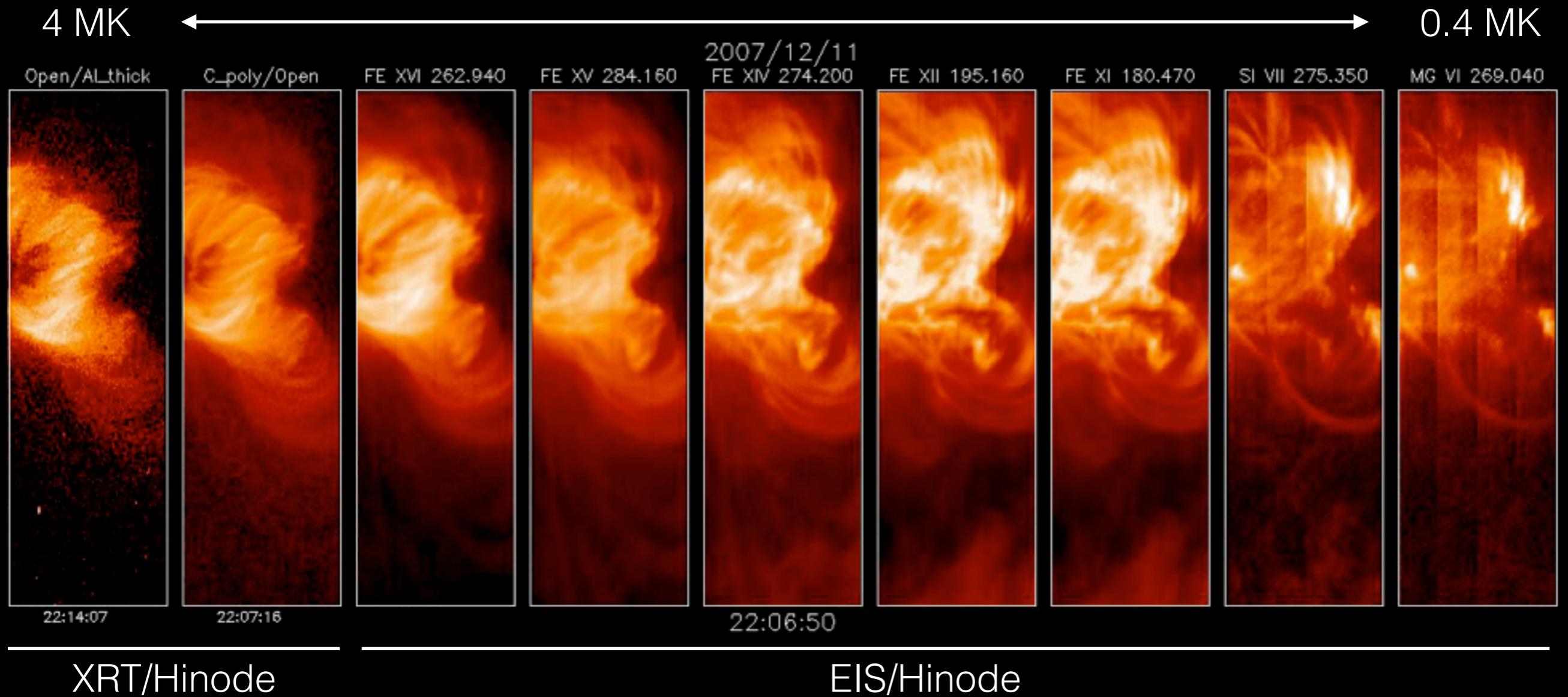
1. Is coronal rain an unusual result of cooling?
2. Is the spatial scale of coronal rain a signature of the spatial scale of the heating?

# Active region cooling



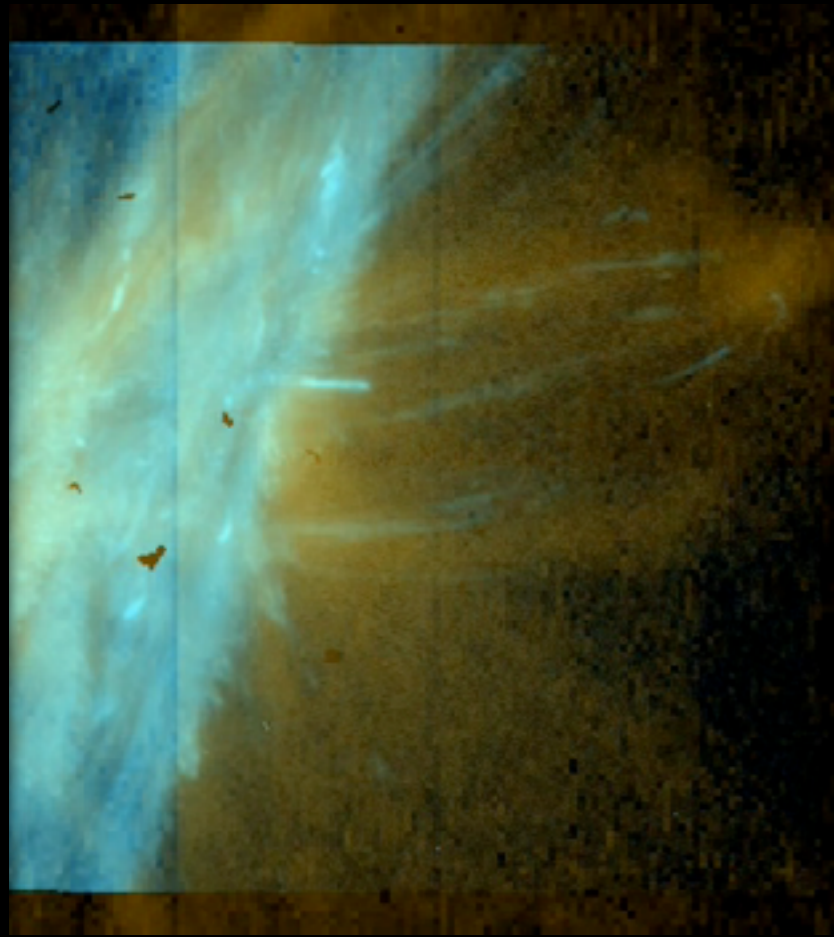


# Active region cooling

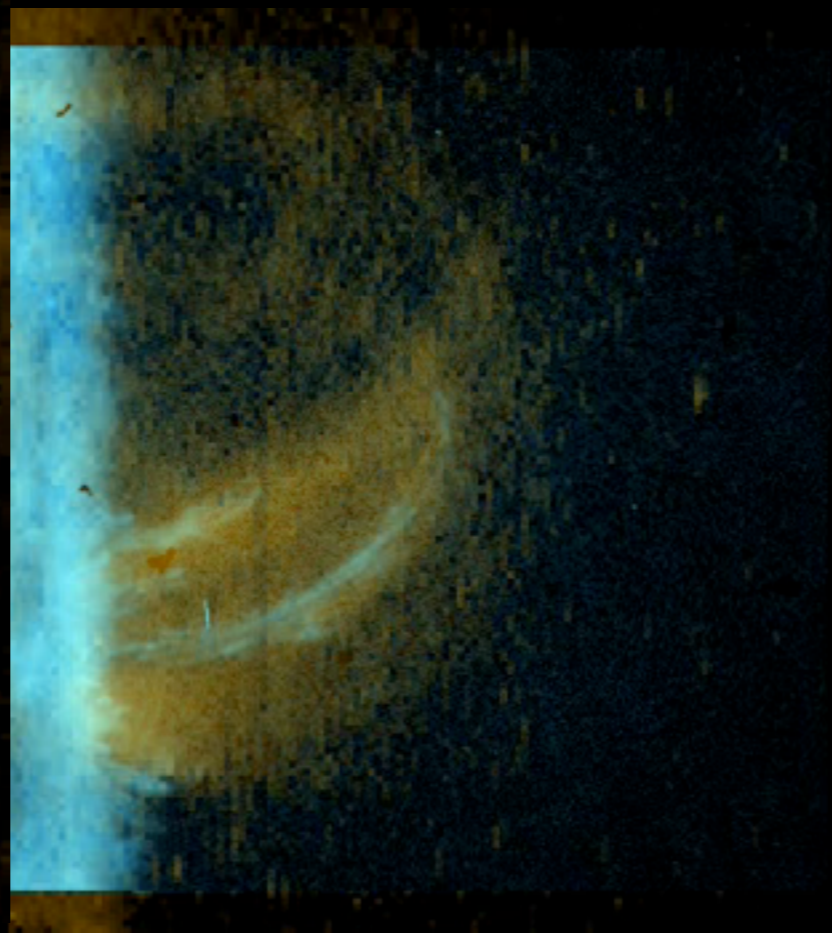


# Coronal loops and rain

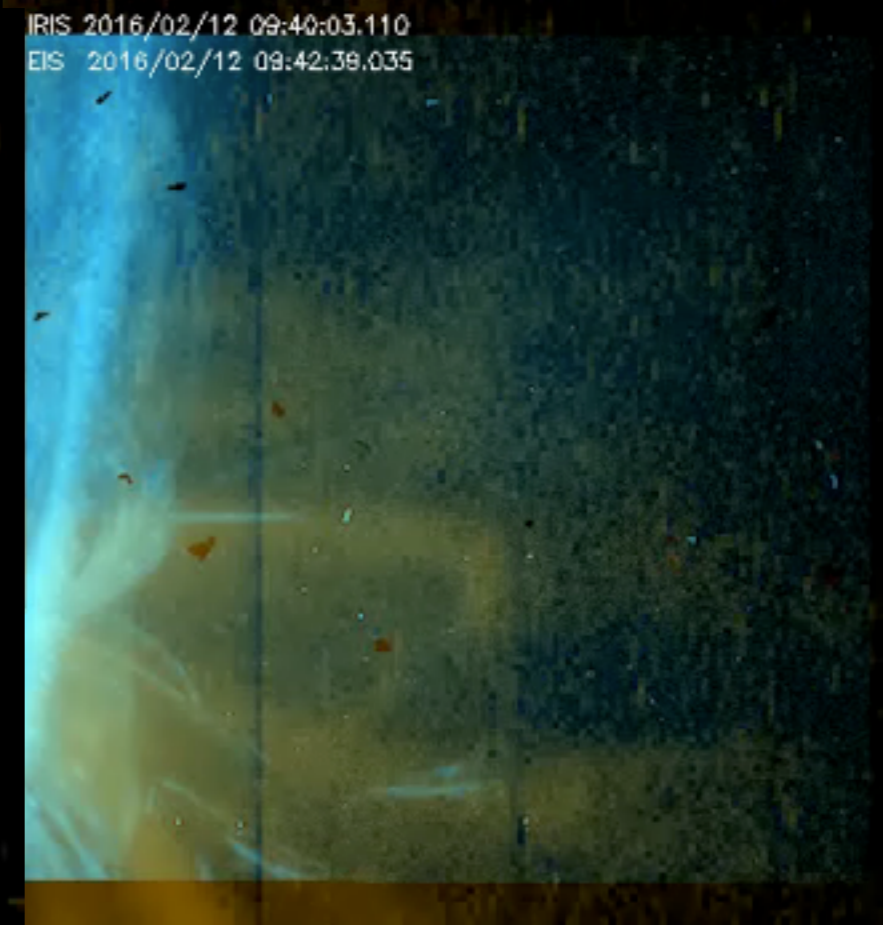
IRIS Si IV 1400Å (0.08MK) vs EIS/Hinode Si VII 275.35Å (0.6MK)



2015/08/13 23:58 - 2015/08/14 02:37



2015/09/07 22:24 - 2015/09/08 04:07



2016/02/12 09:40 - 2016/02/12 13:40

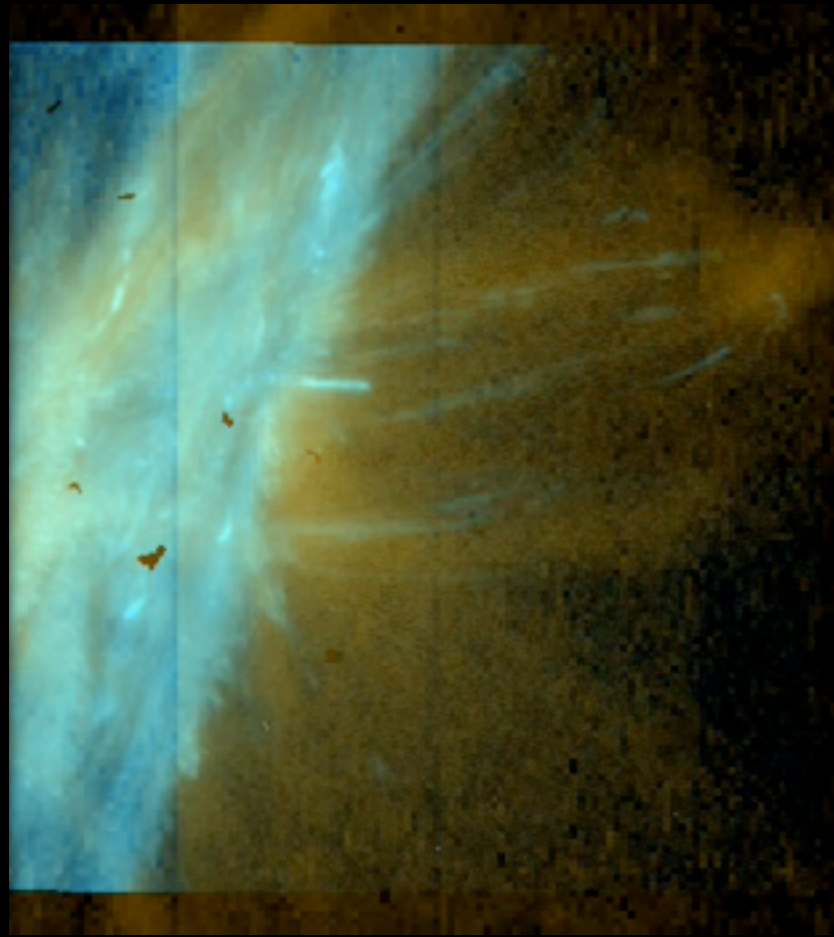
dt<sub>IRIS</sub> = 20s

dt<sub>EIS</sub> = 70s

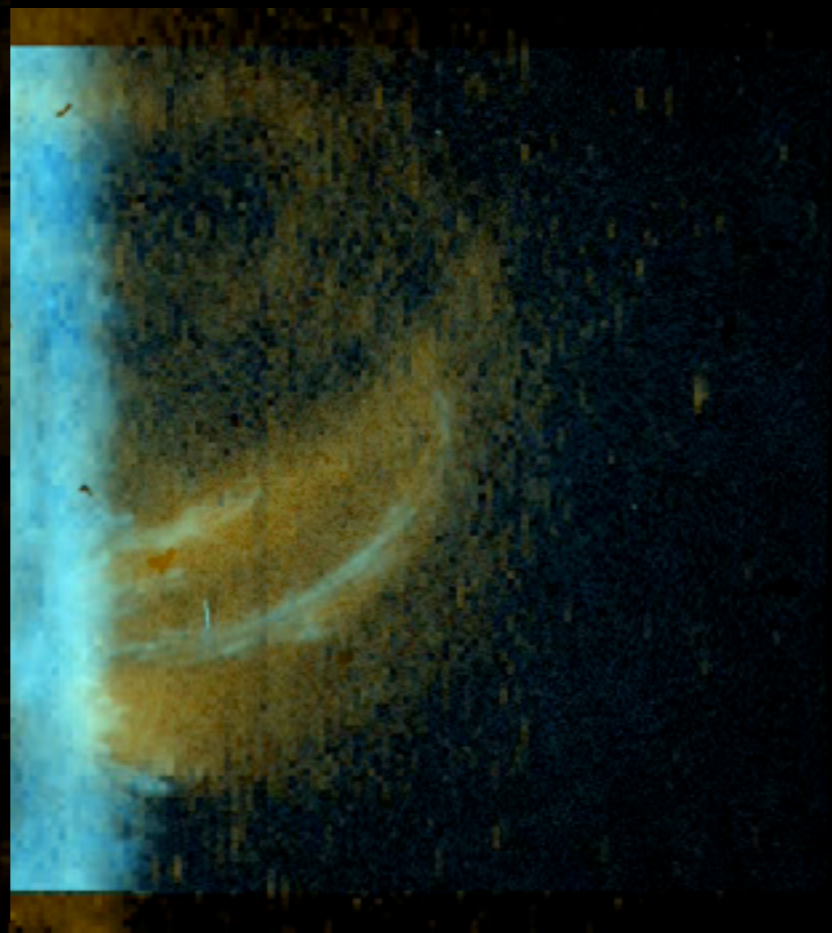


# Coronal loops and rain

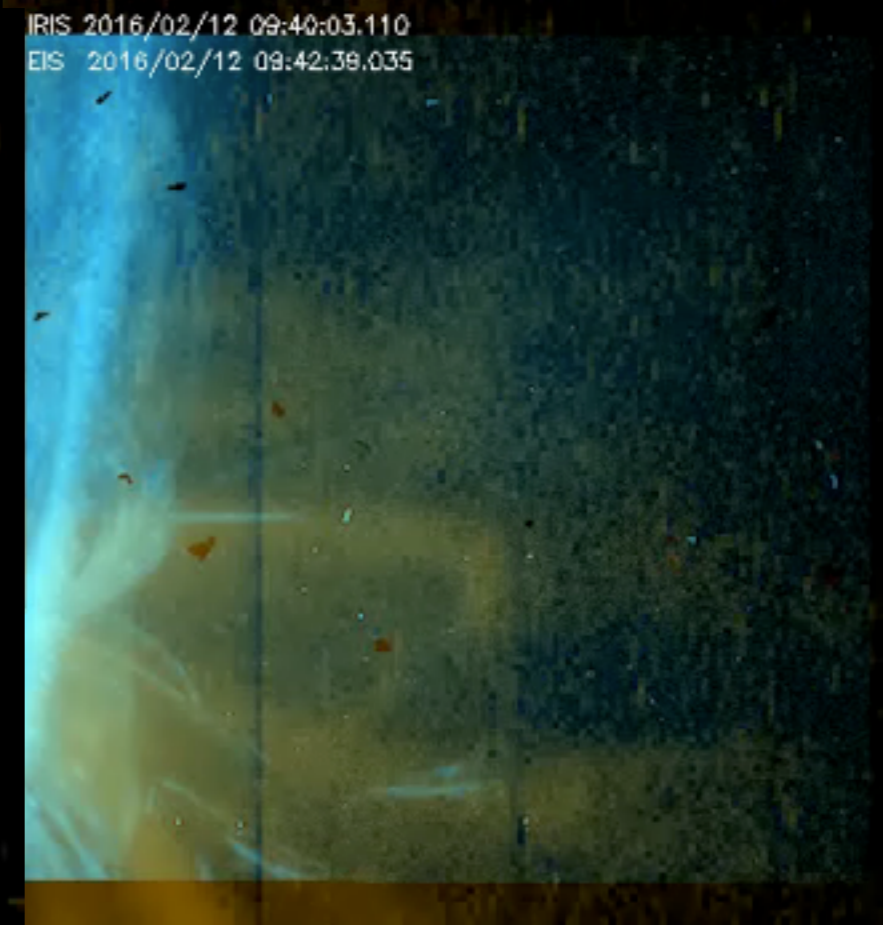
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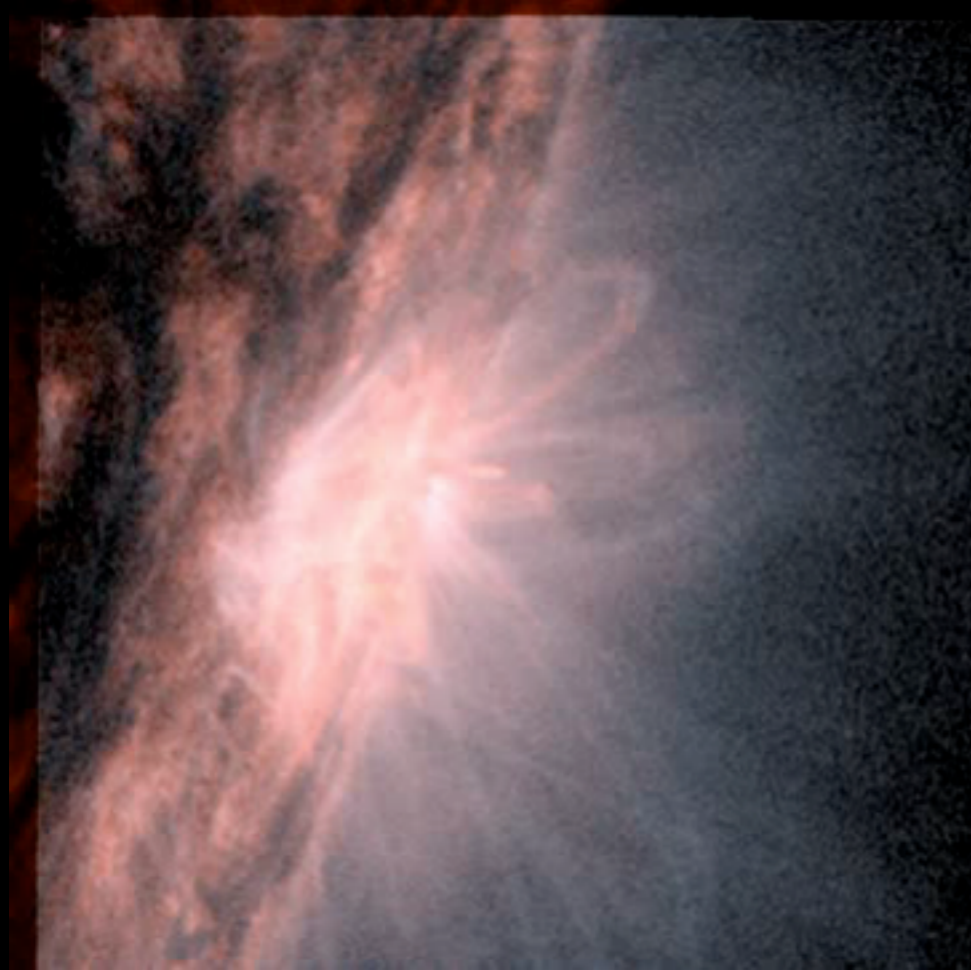
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dt<sub>EIS</sub> = 70s

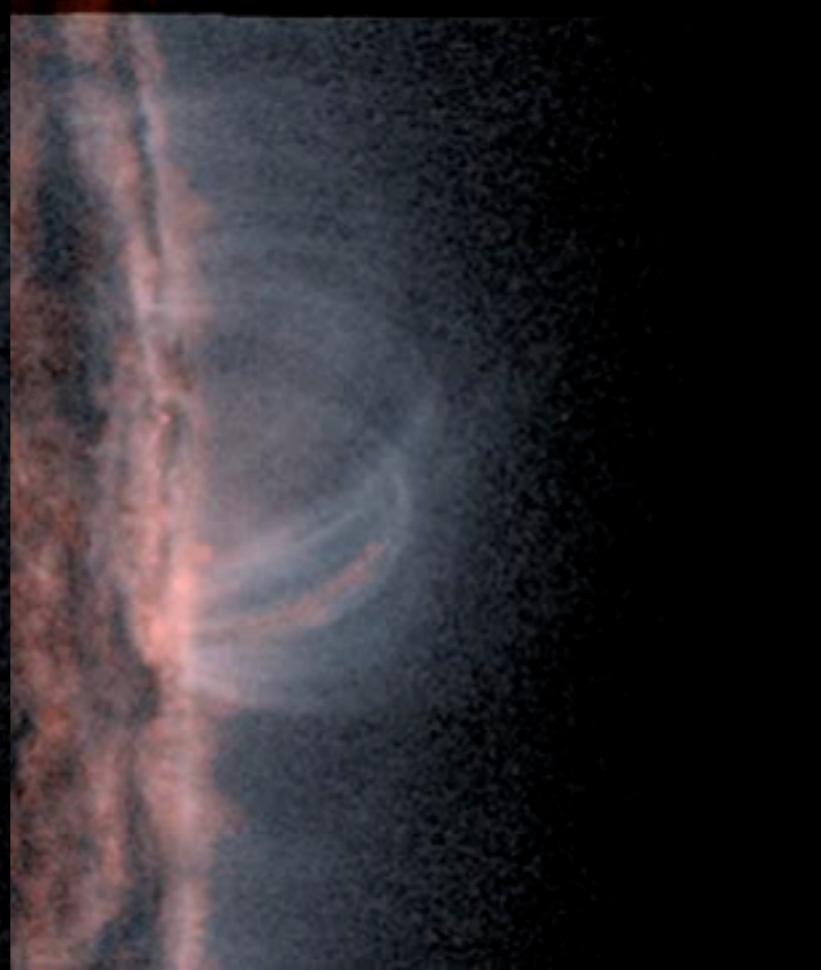


# Coronal loops and rain

AIA/SDO He II 304Å (0.02MK) vs AIA/SDO Fe VIII 131Å (0.45MK)



2015/08/13 22:59 - 2015/08/14 03:32



2015/09/07 22:24 - 2015/09/08 04:06



2016/02/12 09:30 - 2016/02/12 15:29

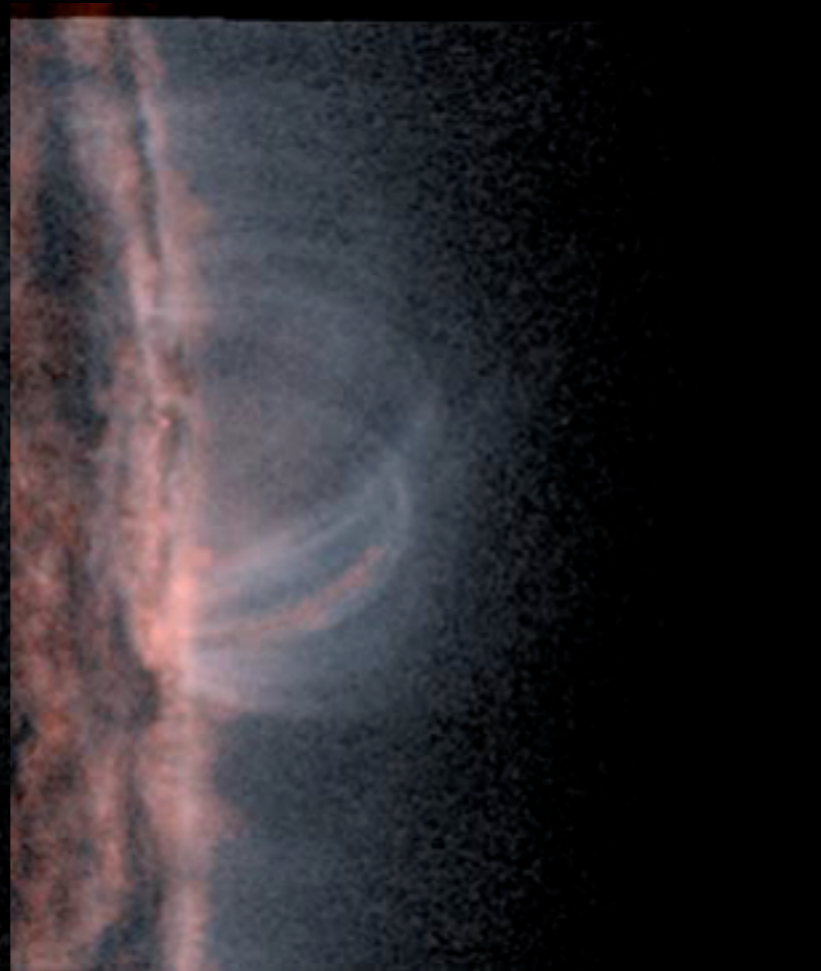


# Coronal loops and rain

AIA/SDO He II 304Å (0.02MK) vs AIA/SDO Fe VIII 131Å (0.45MK)



2015/08/13 22:59 - 2015/08/14 03:32



2015/09/07 22:24 - 2015/09/08 04:06

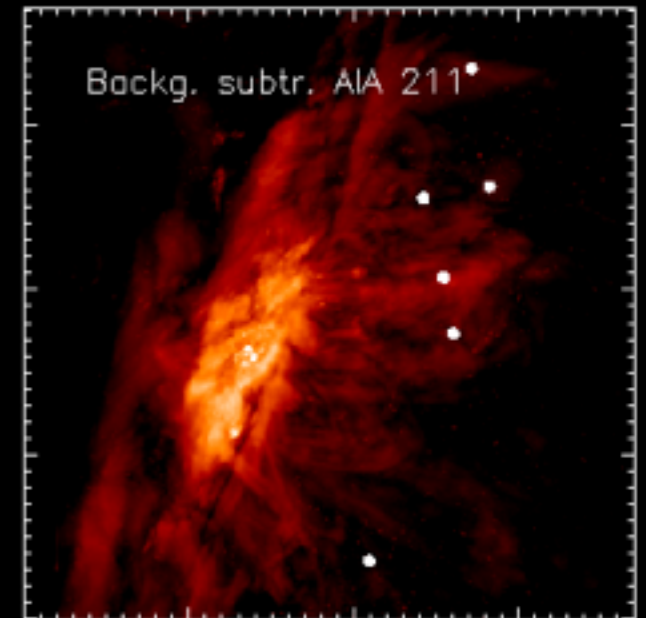
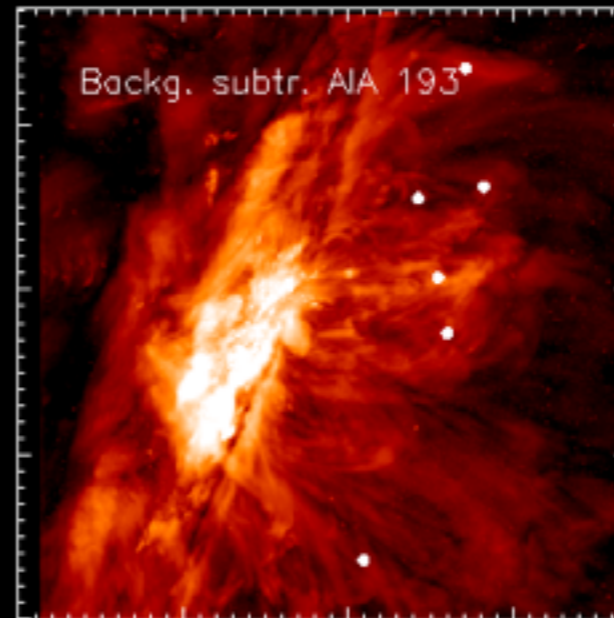
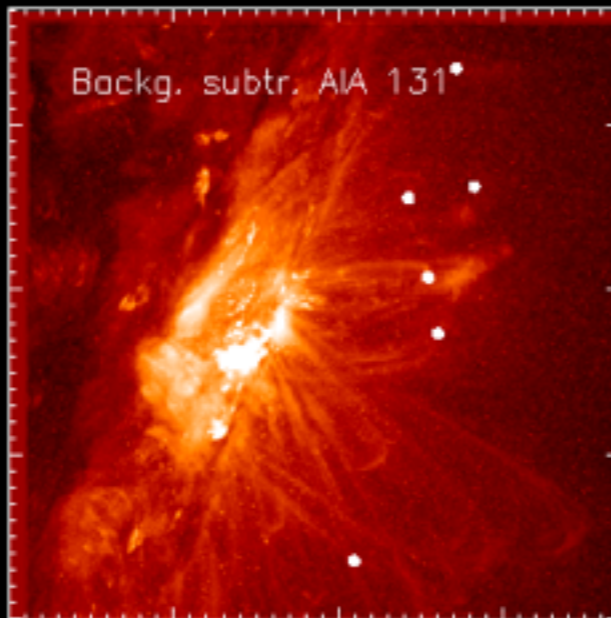
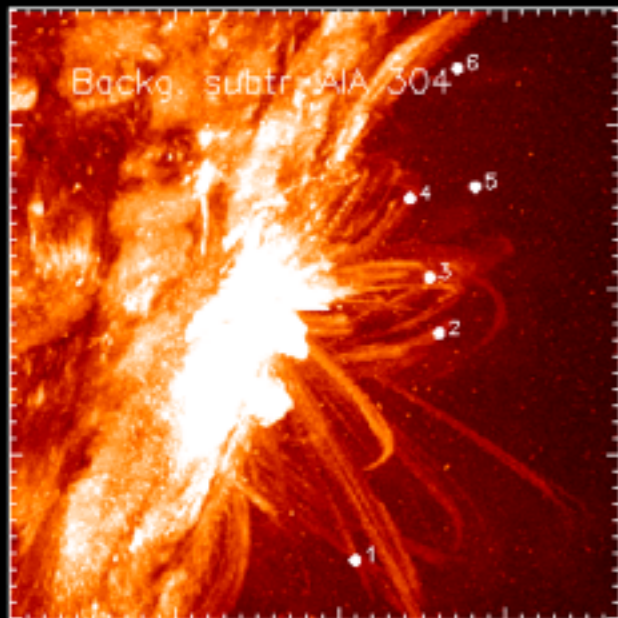
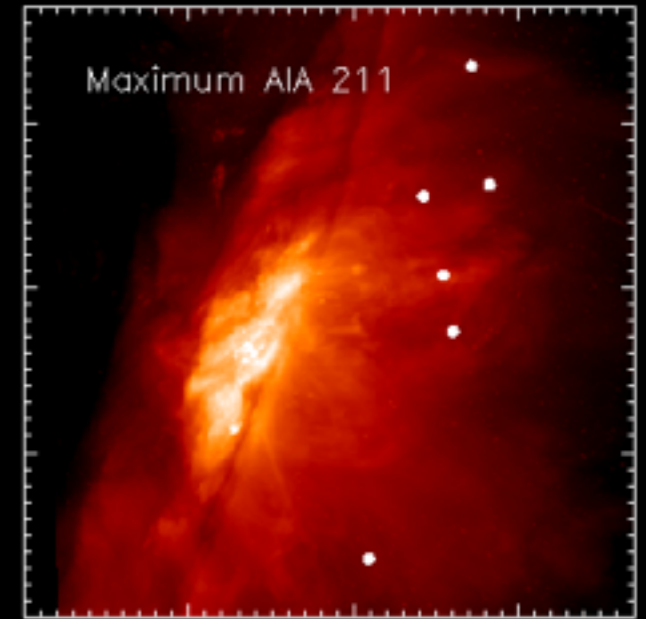
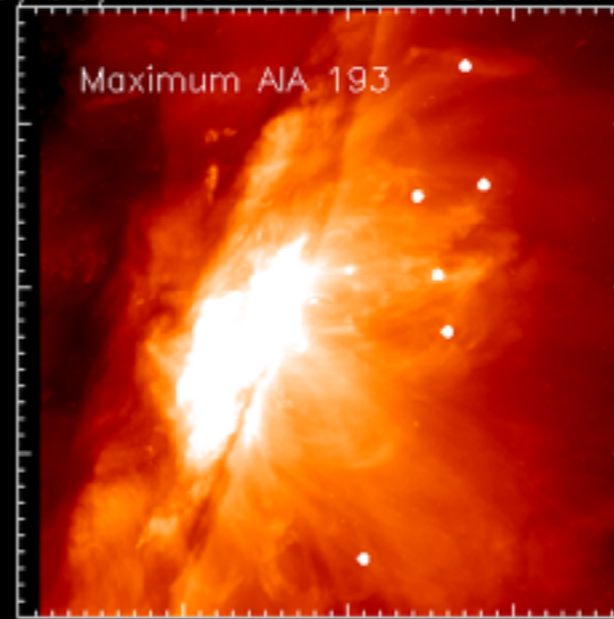
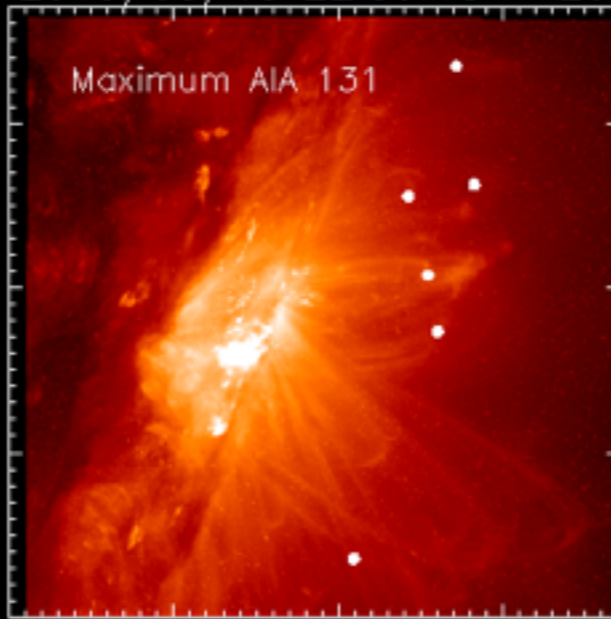
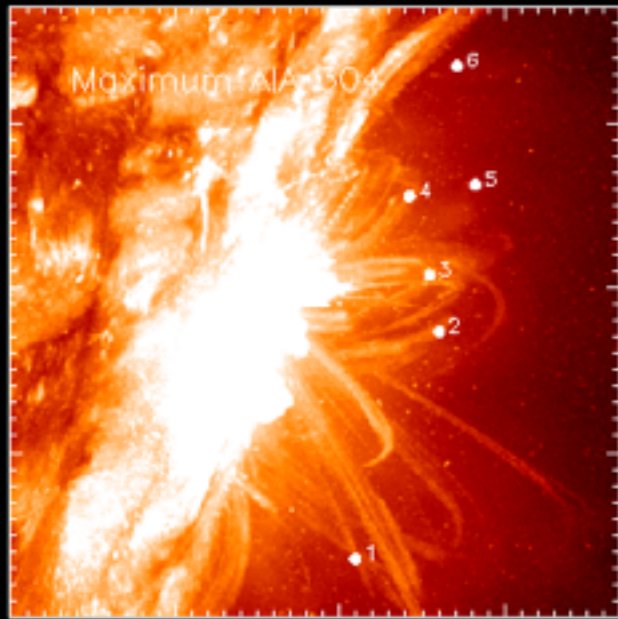


2016/02/12 09:30 - 2016/02/12 15:29



# Coronal loops and rain

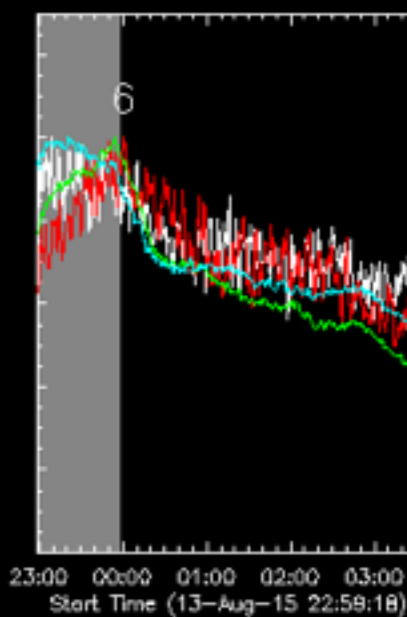
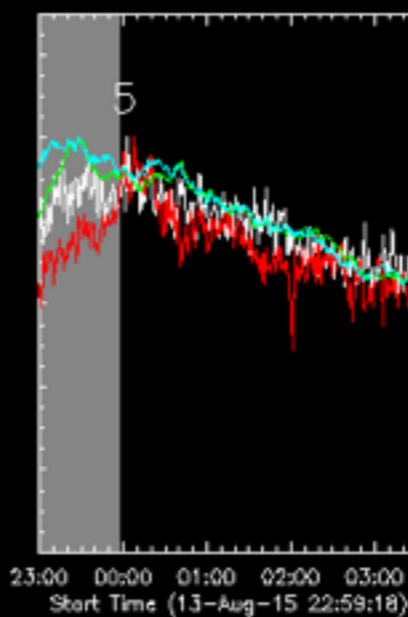
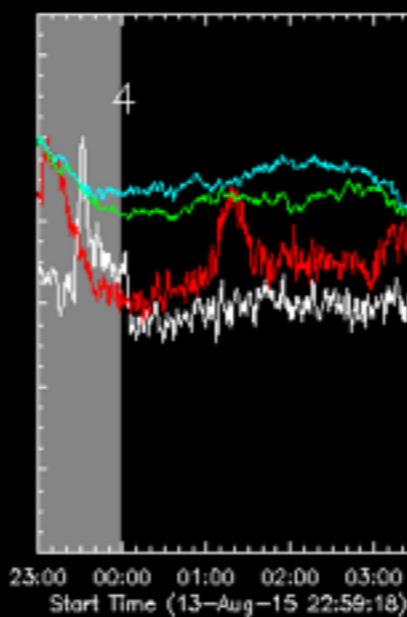
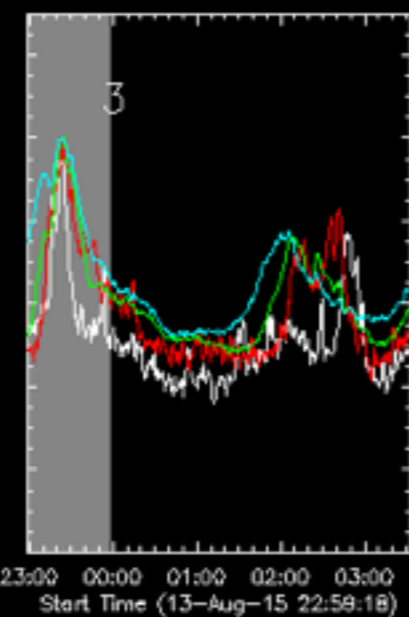
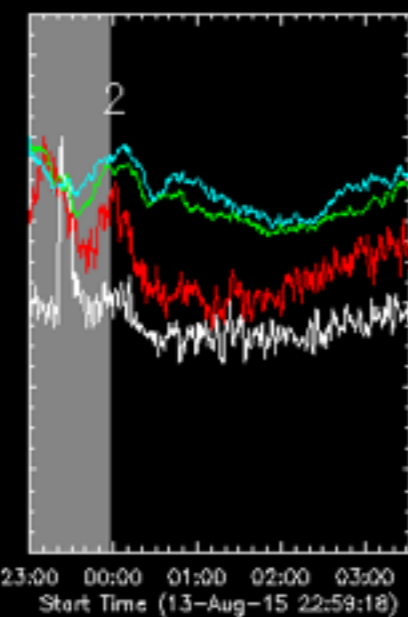
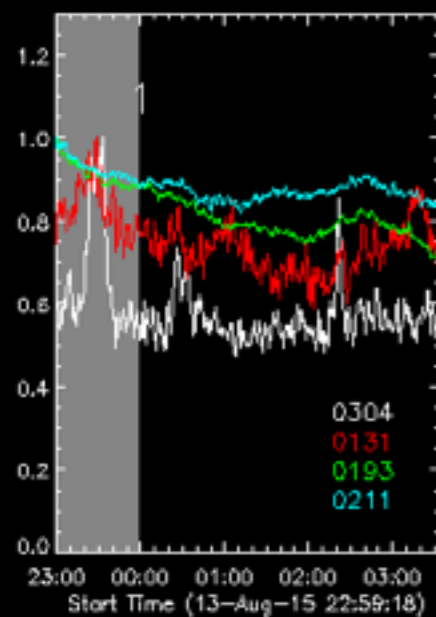
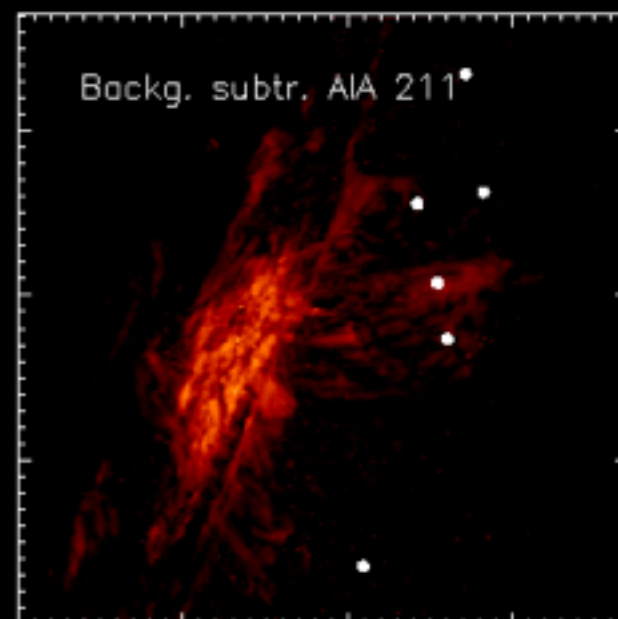
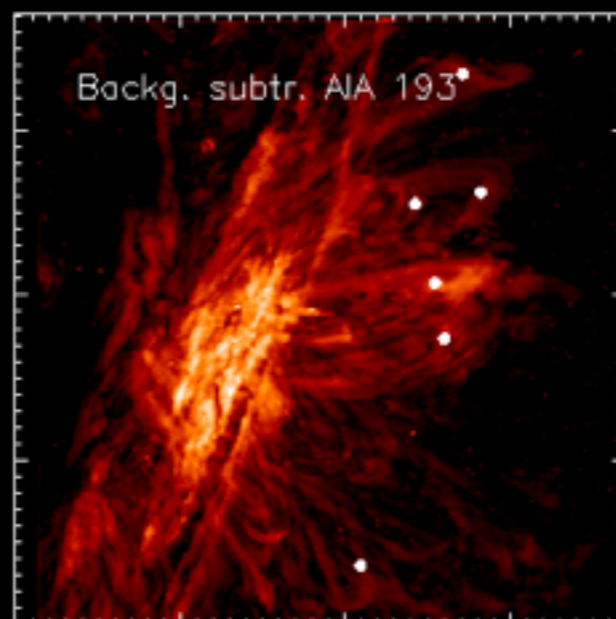
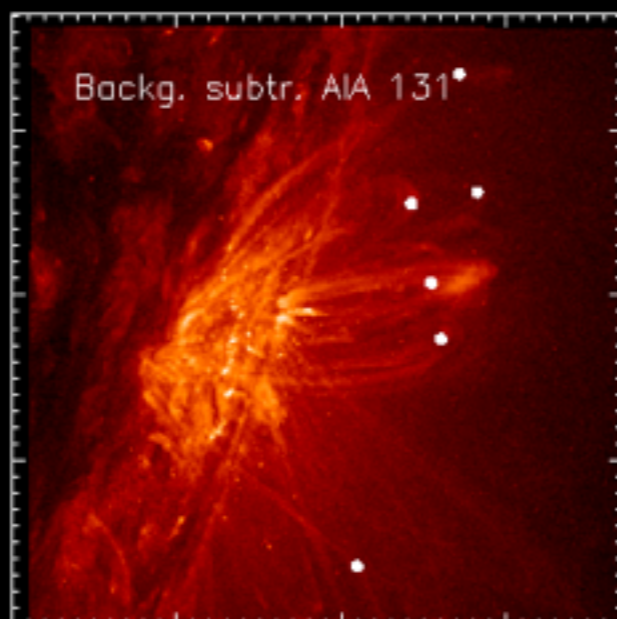
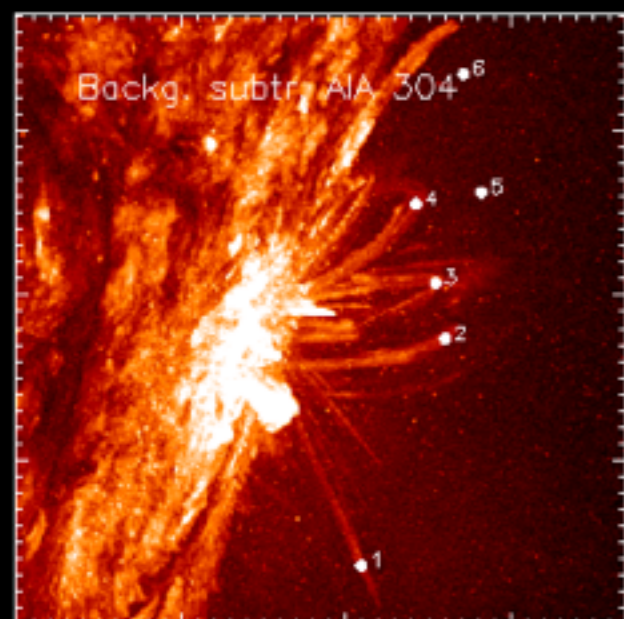
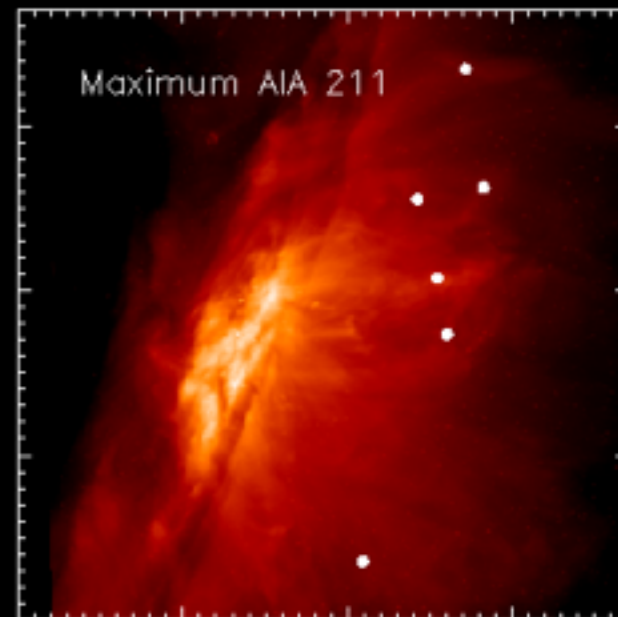
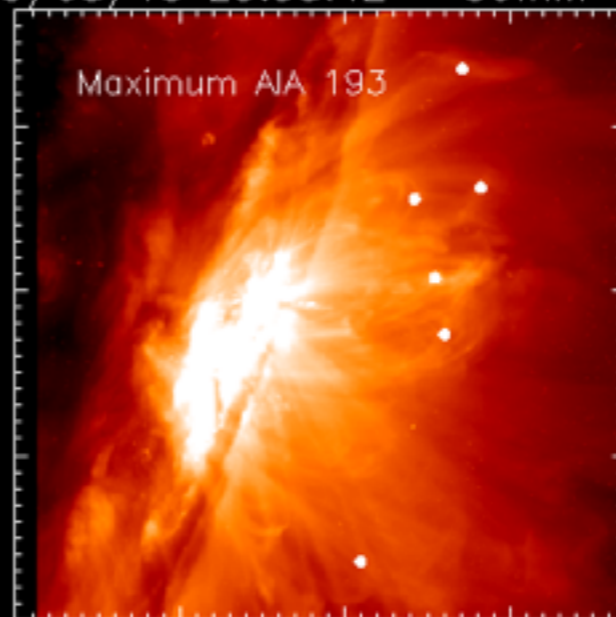
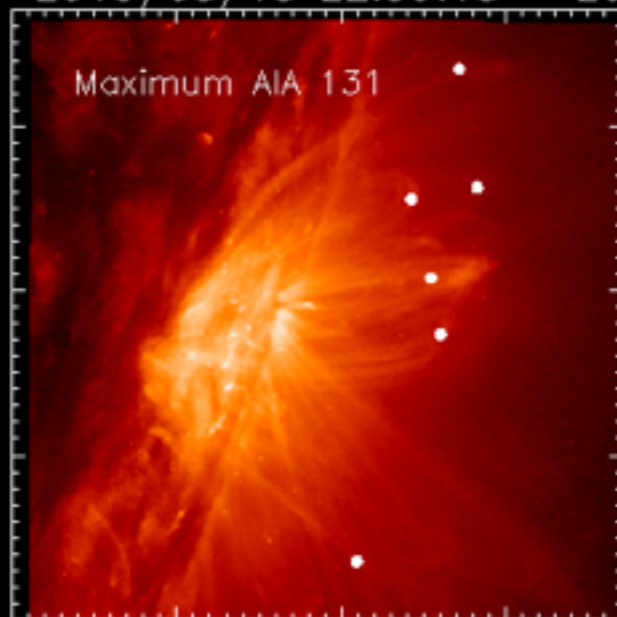
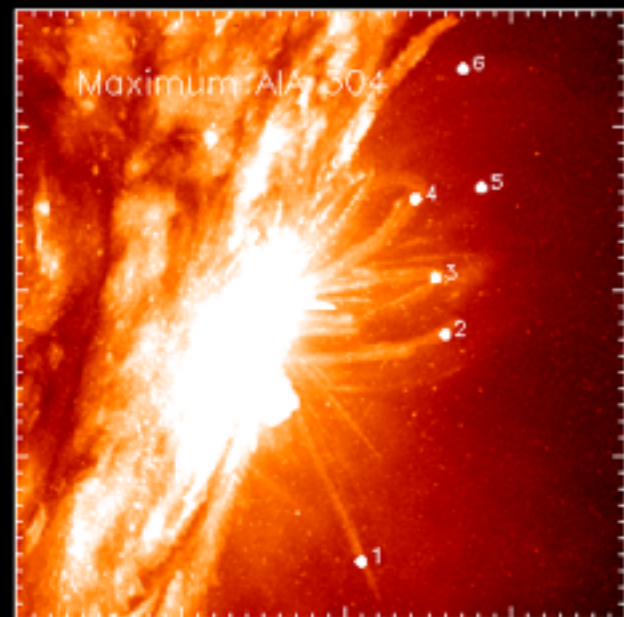
2015/08/13 22:59:18 – 2015/08/14 03:28:42 – 269min



Where do the loops form at different wavelengths?  
Maximum intensity in 4.5h

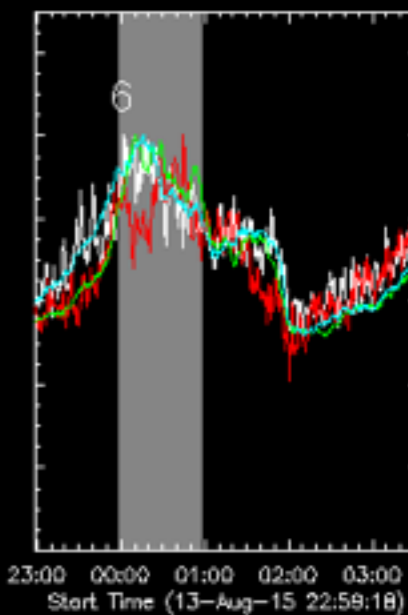
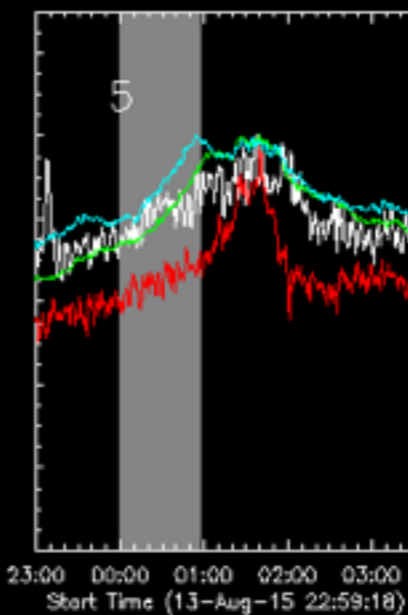
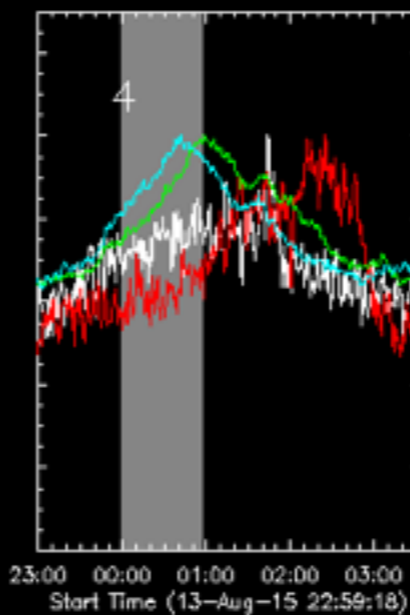
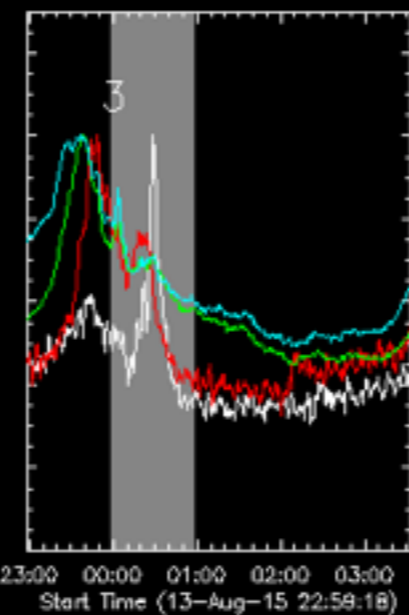
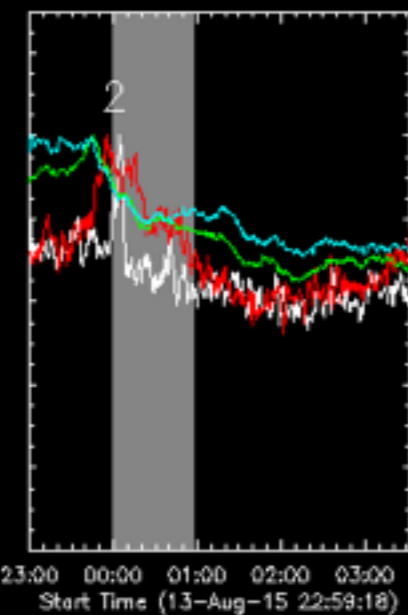
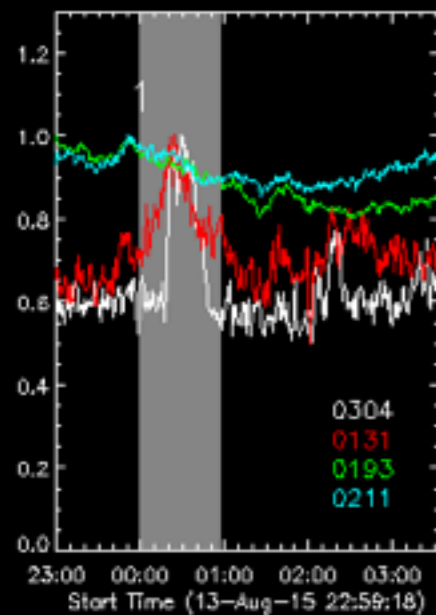
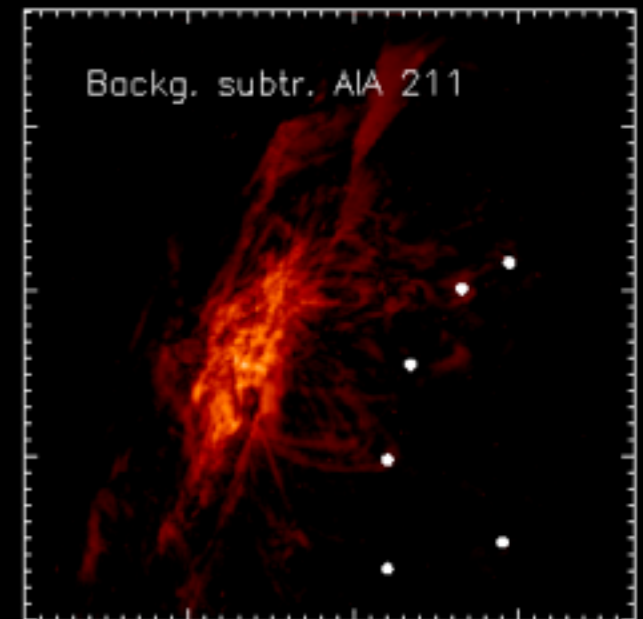
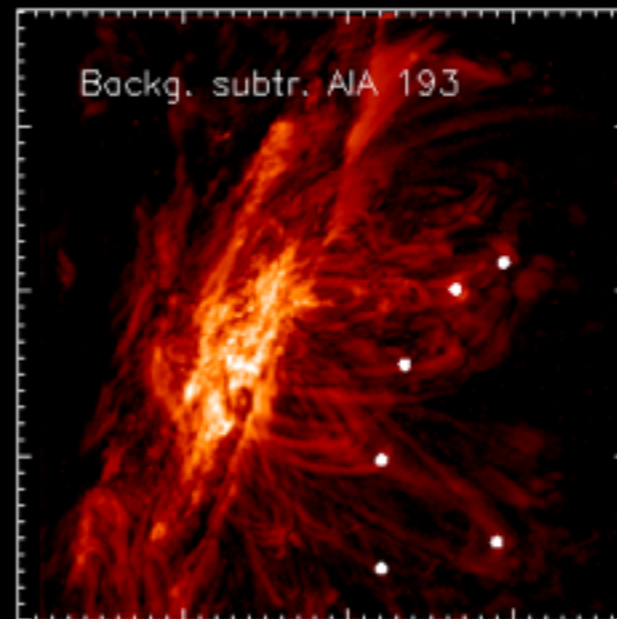
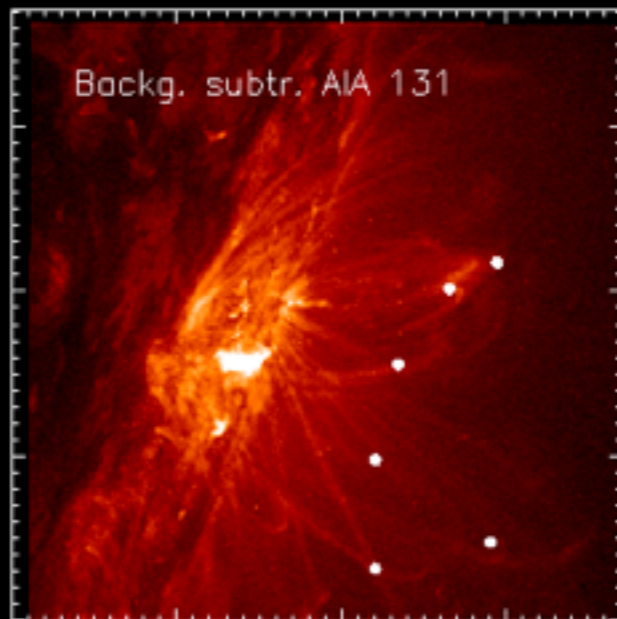
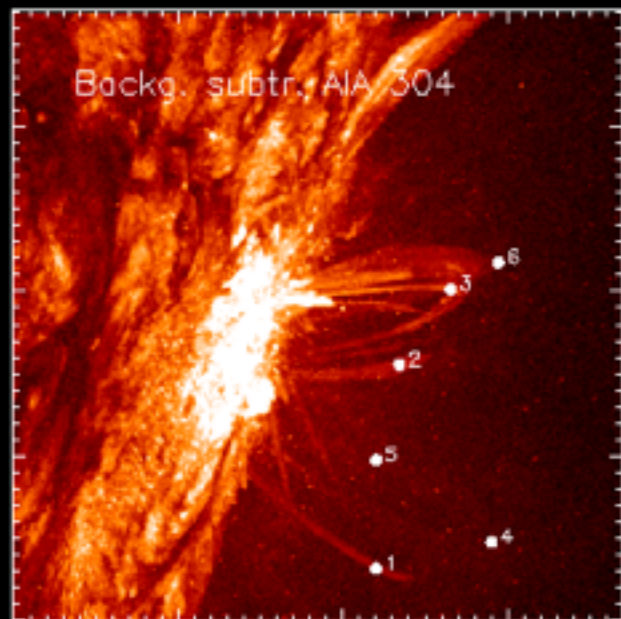
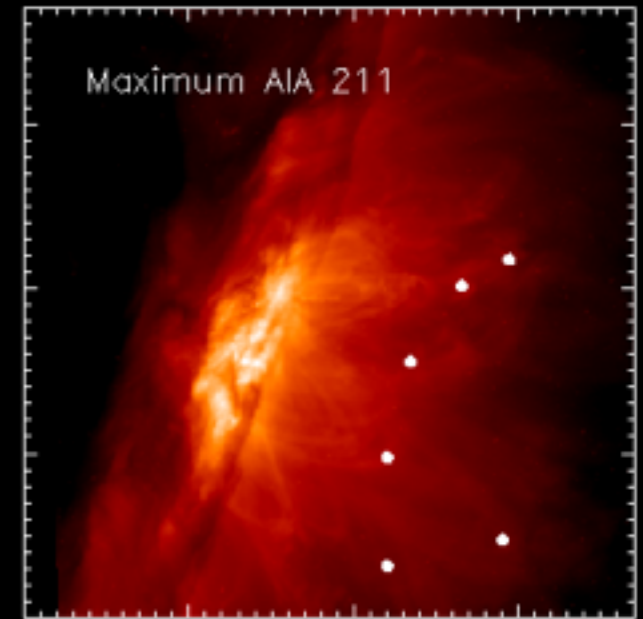
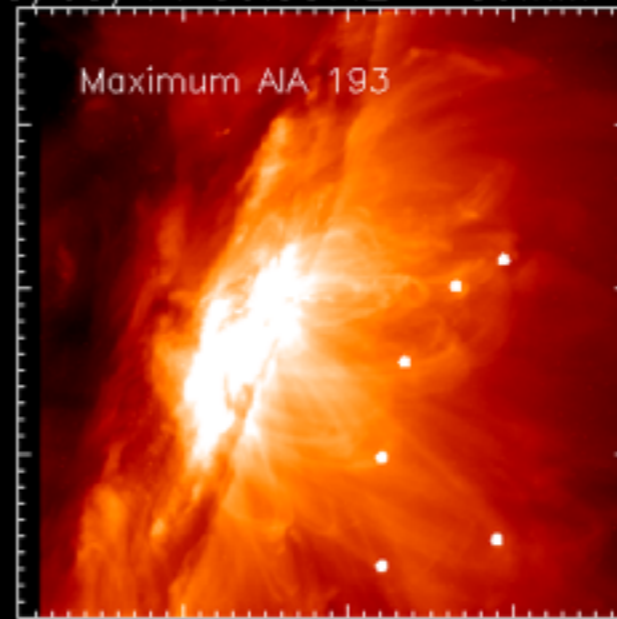
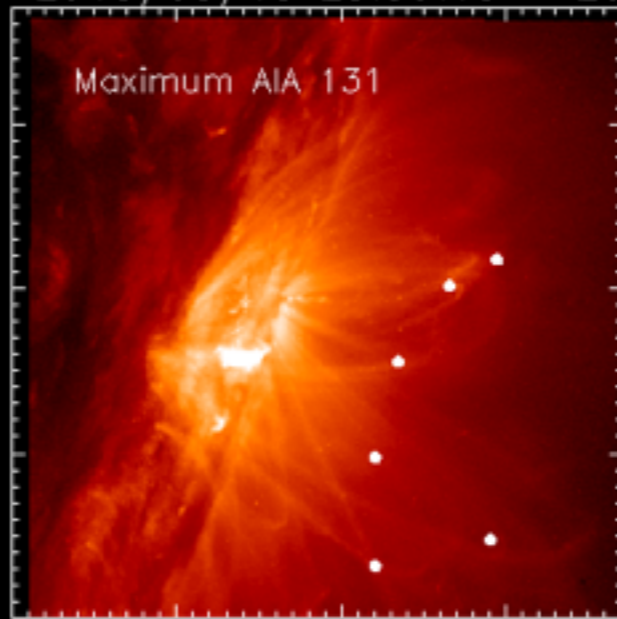
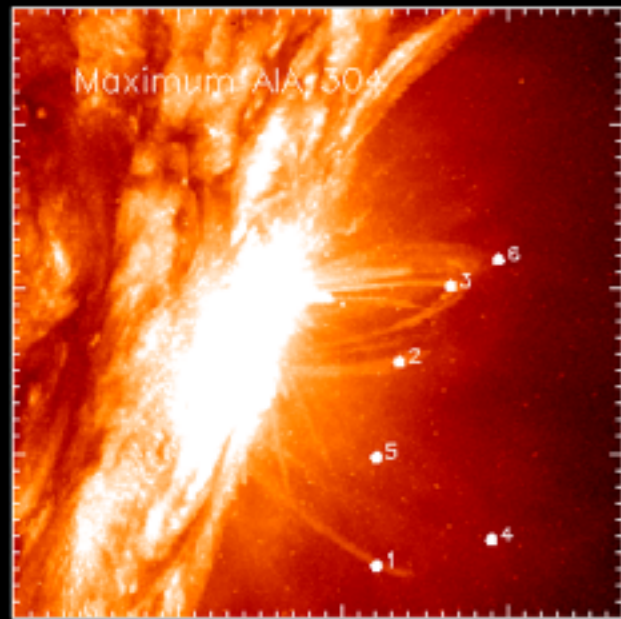


2015/08/13 22:59:18 – 2015/08/13 23:58:42 – 59min



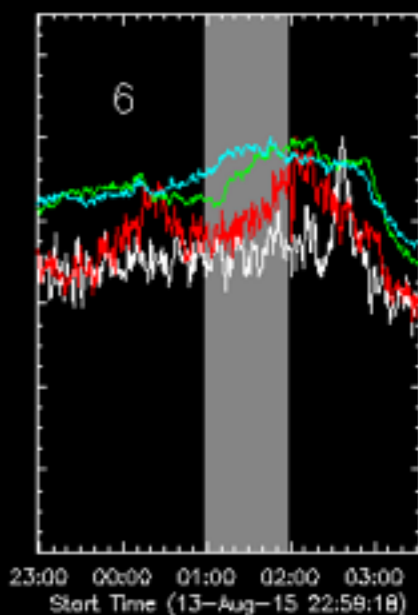
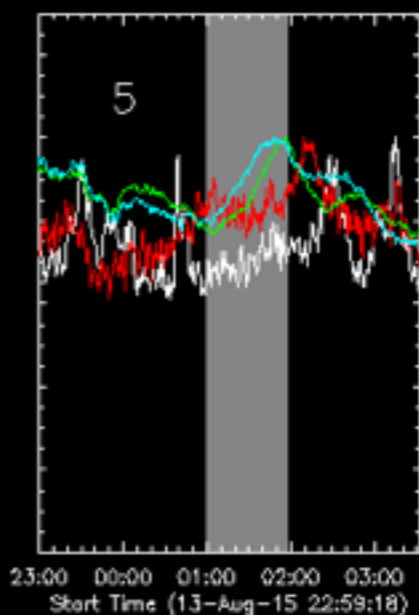
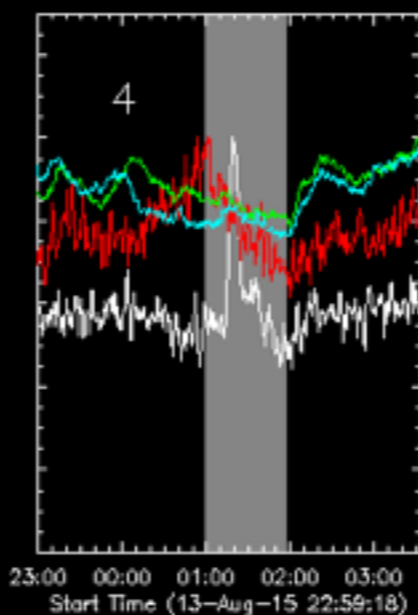
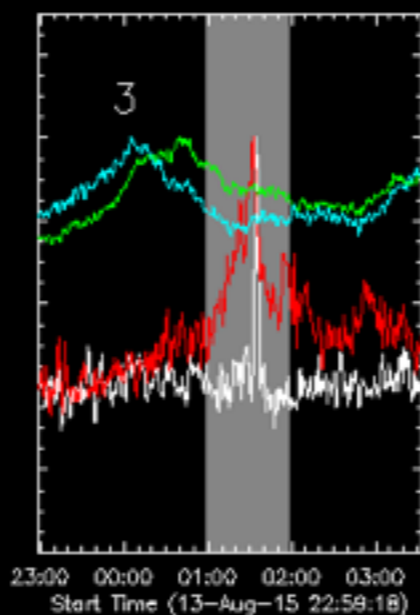
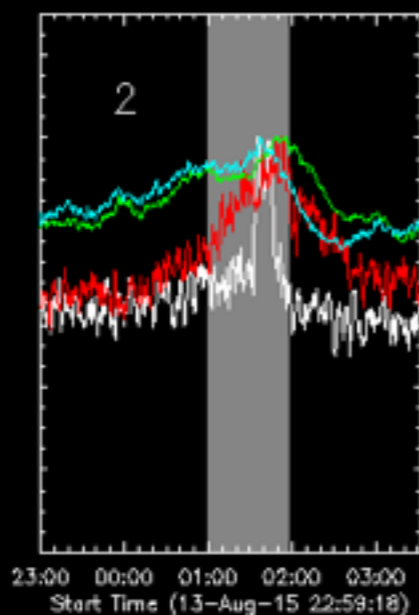
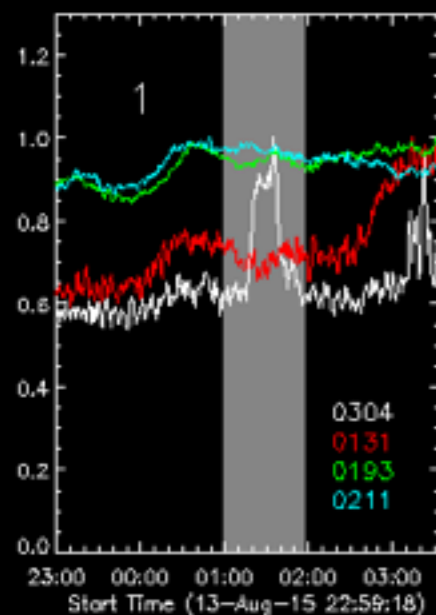
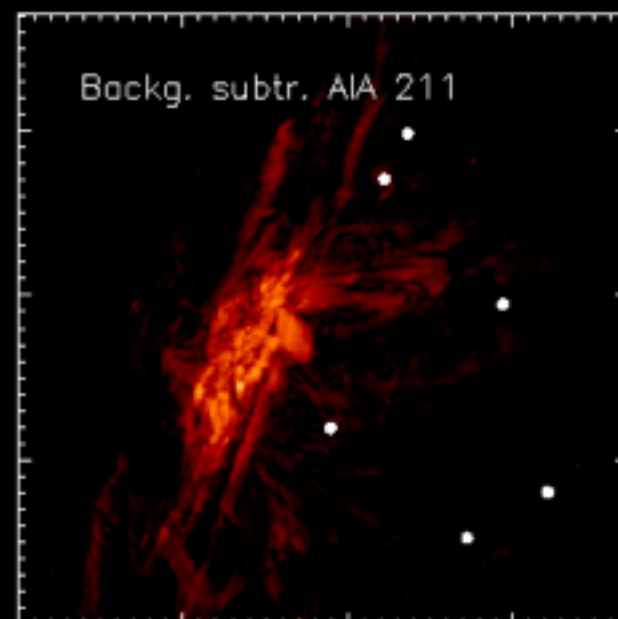
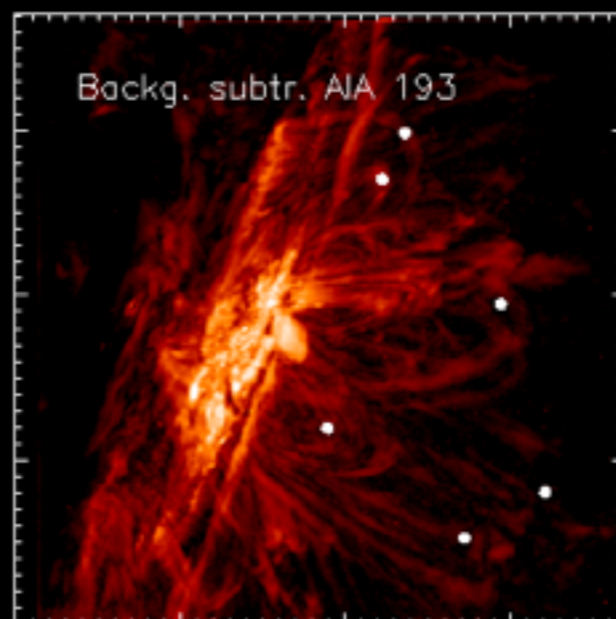
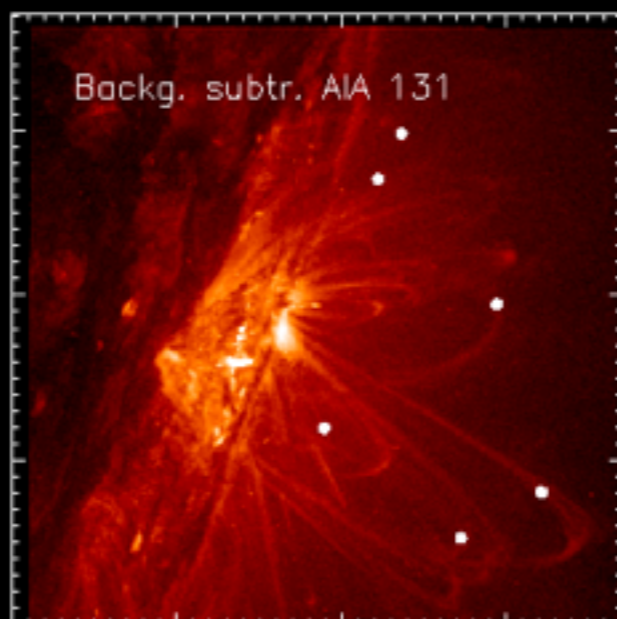
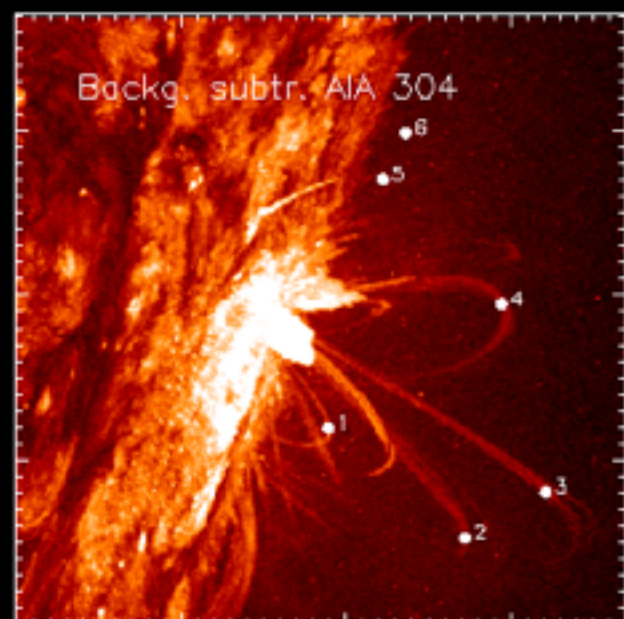
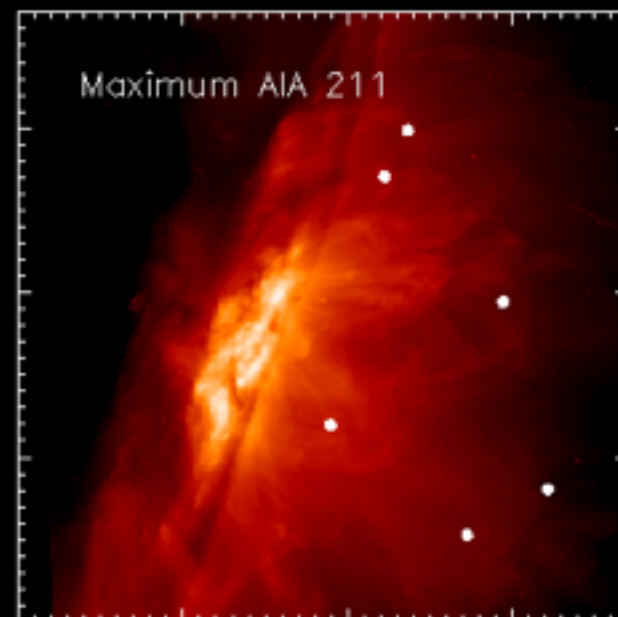
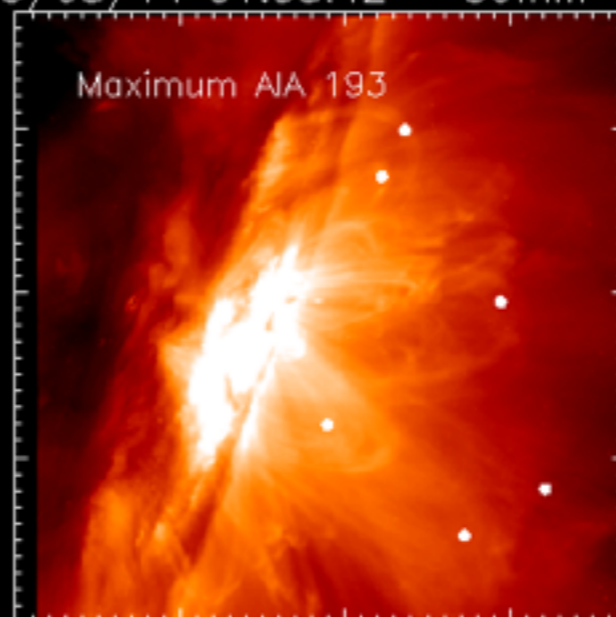
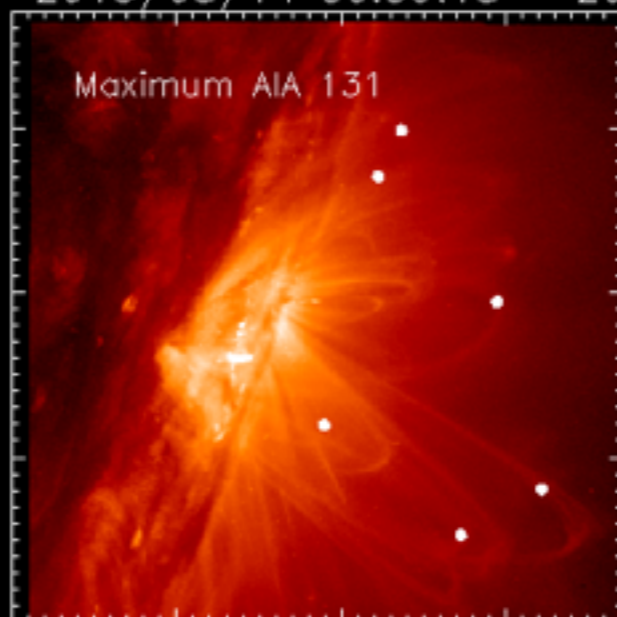
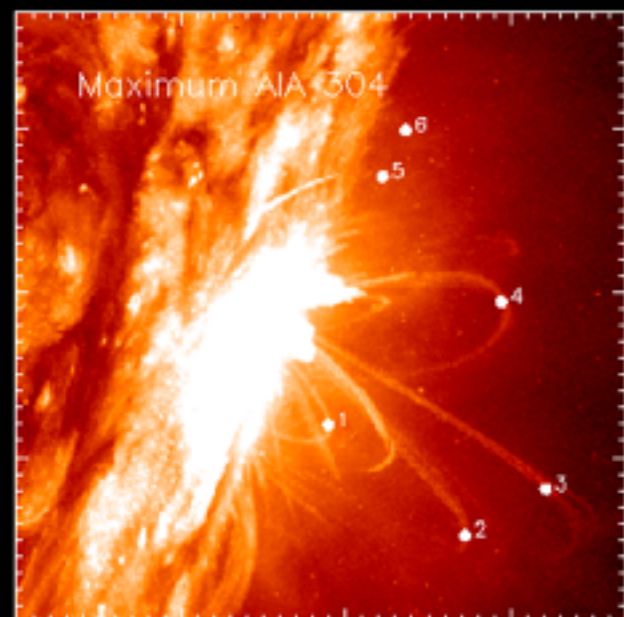


2015/08/13 23:59:18 - 2015/08/14 00:58:42 - 59min



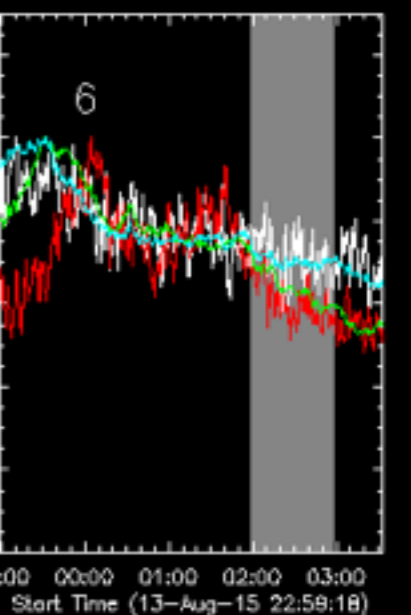
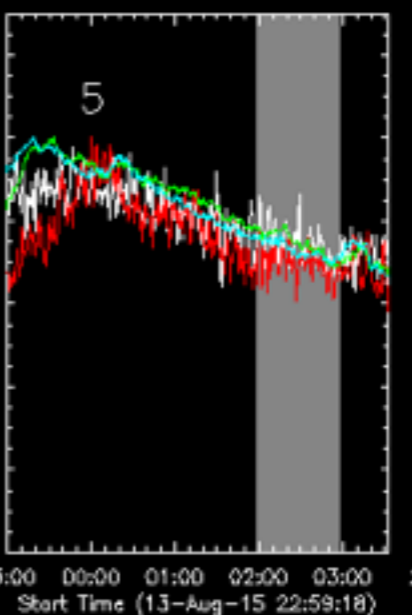
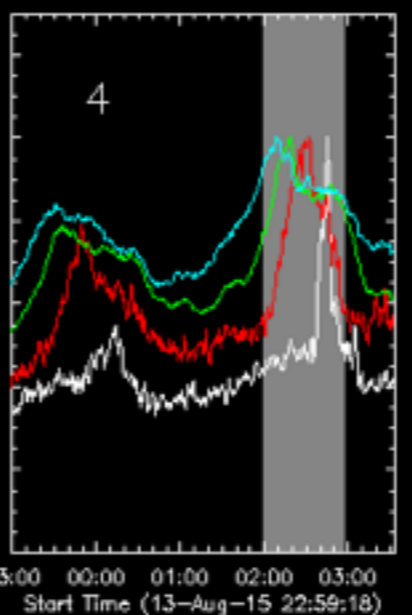
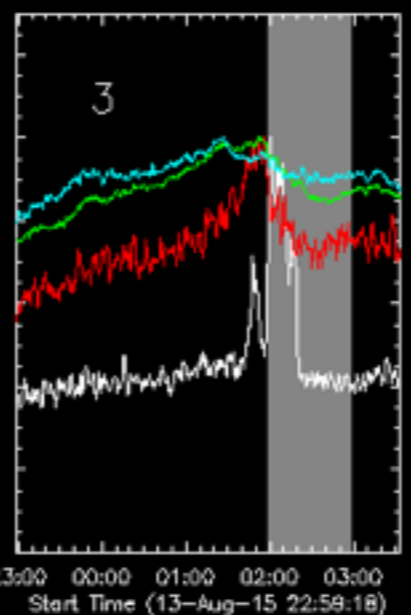
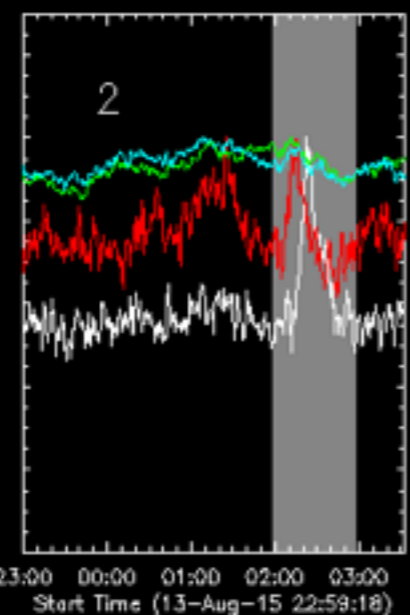
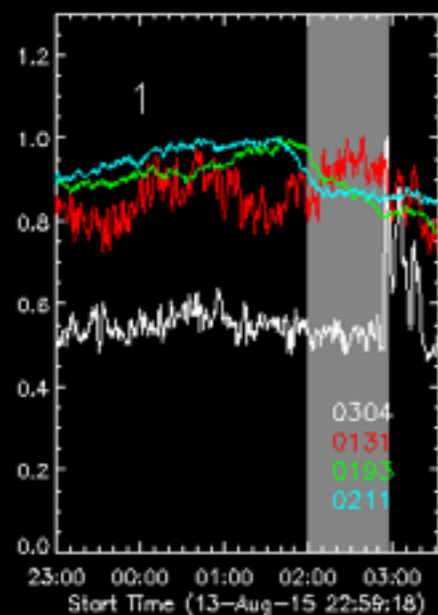
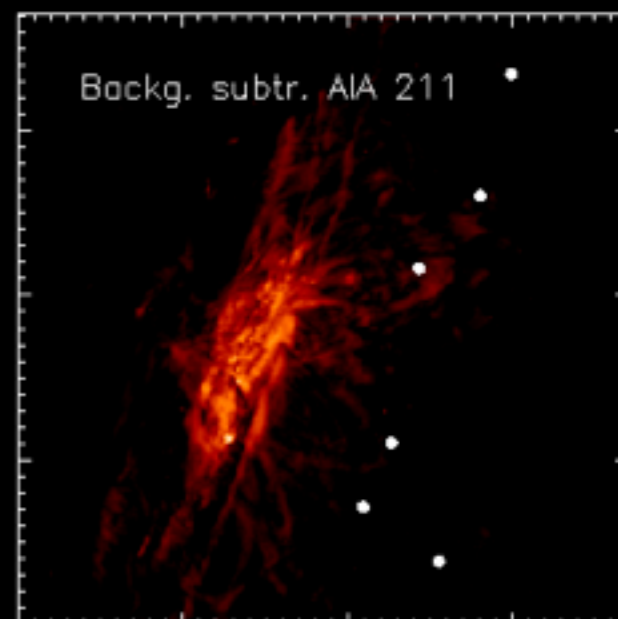
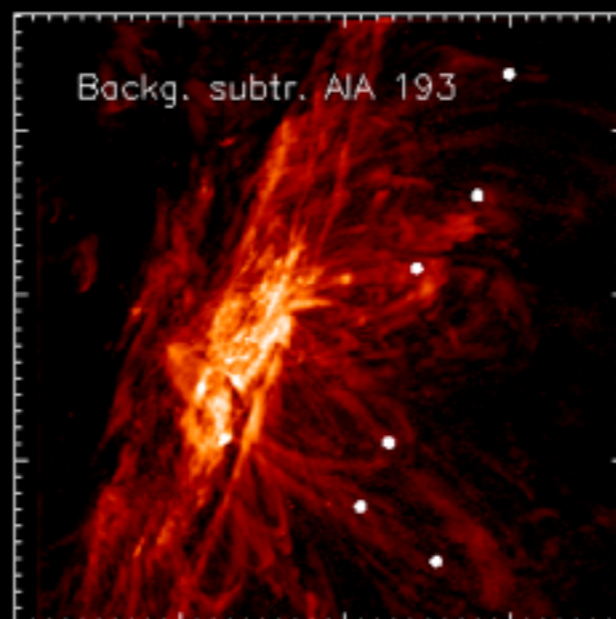
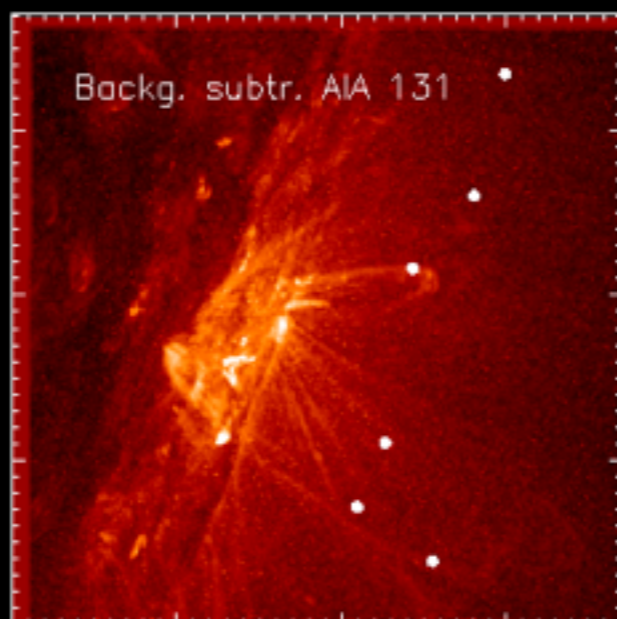
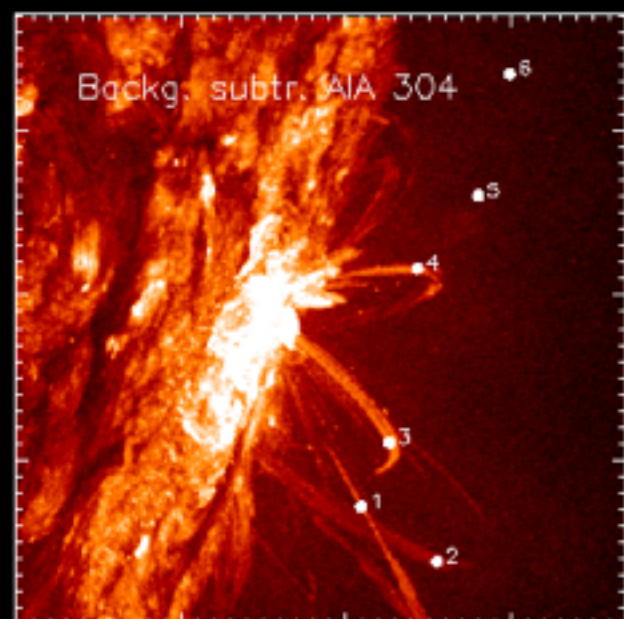
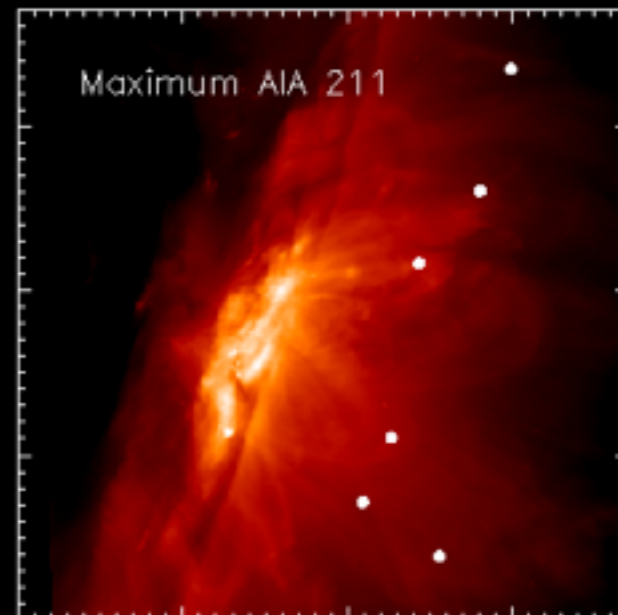
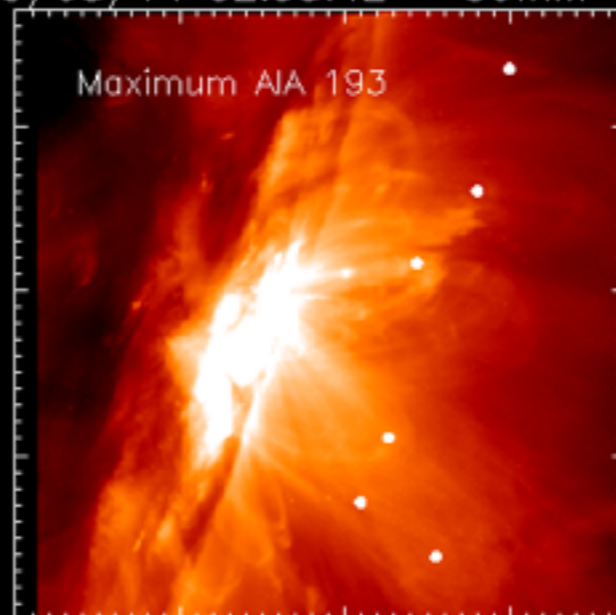
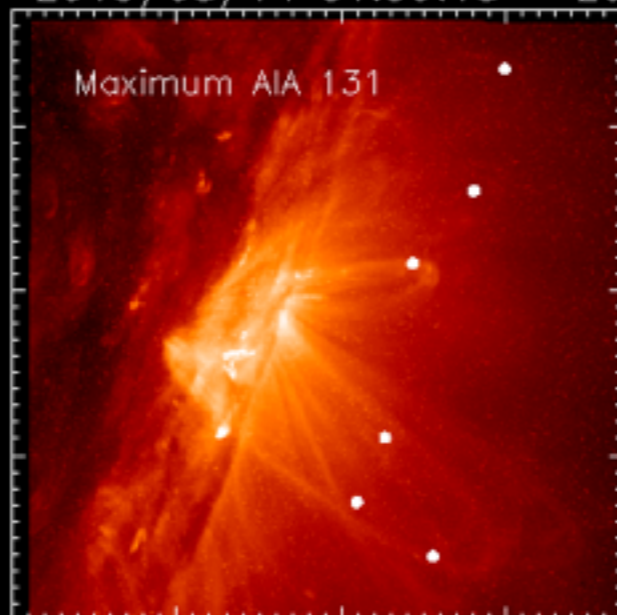
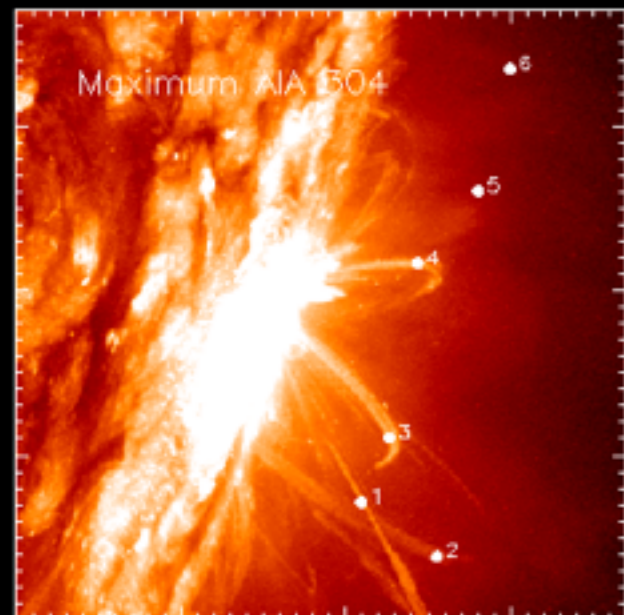


2015/08/14 00:59:18 – 2015/08/14 01:58:42 – 59min

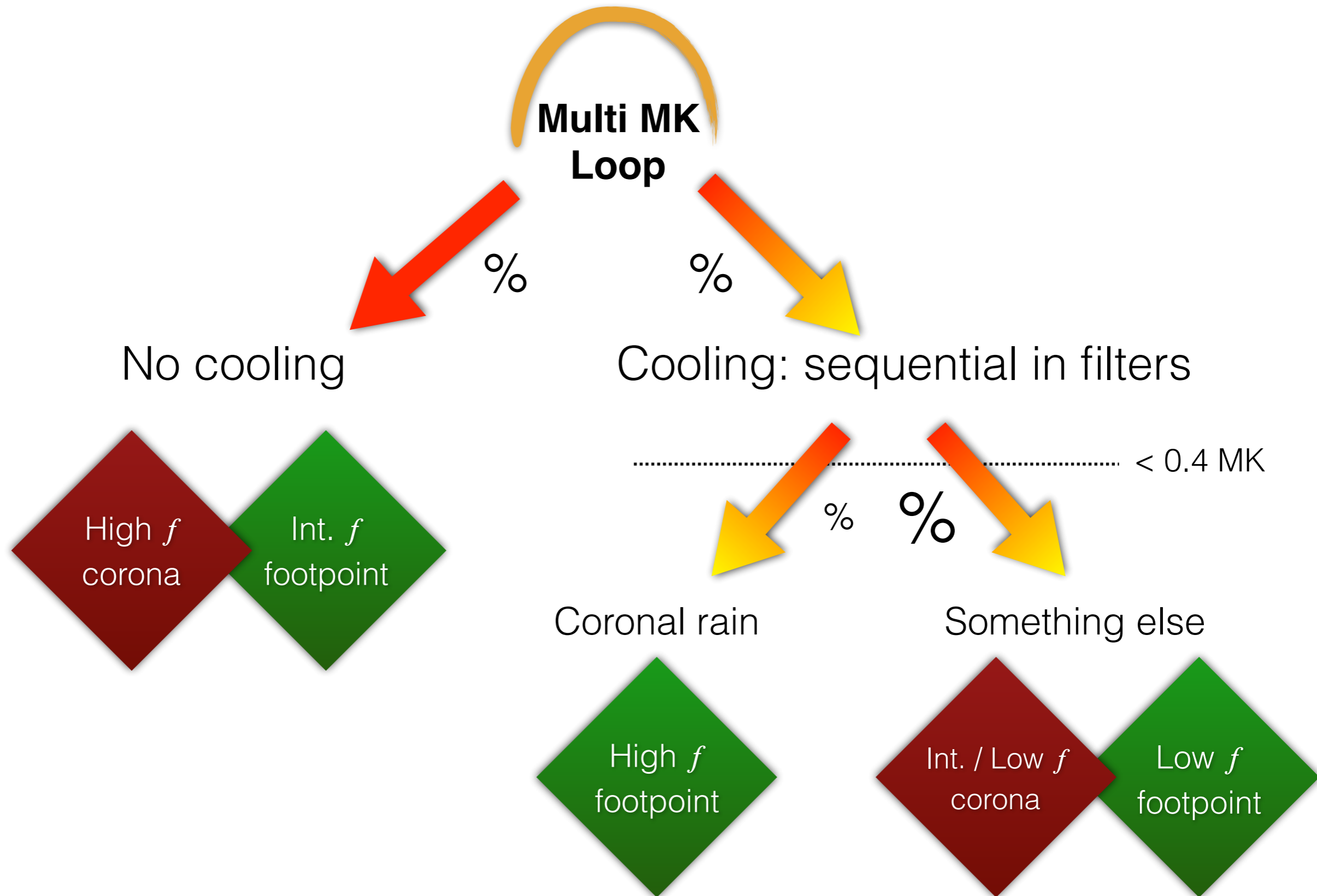




2015/08/14 01:59:18 – 2015/08/14 02:58:42 – 59min

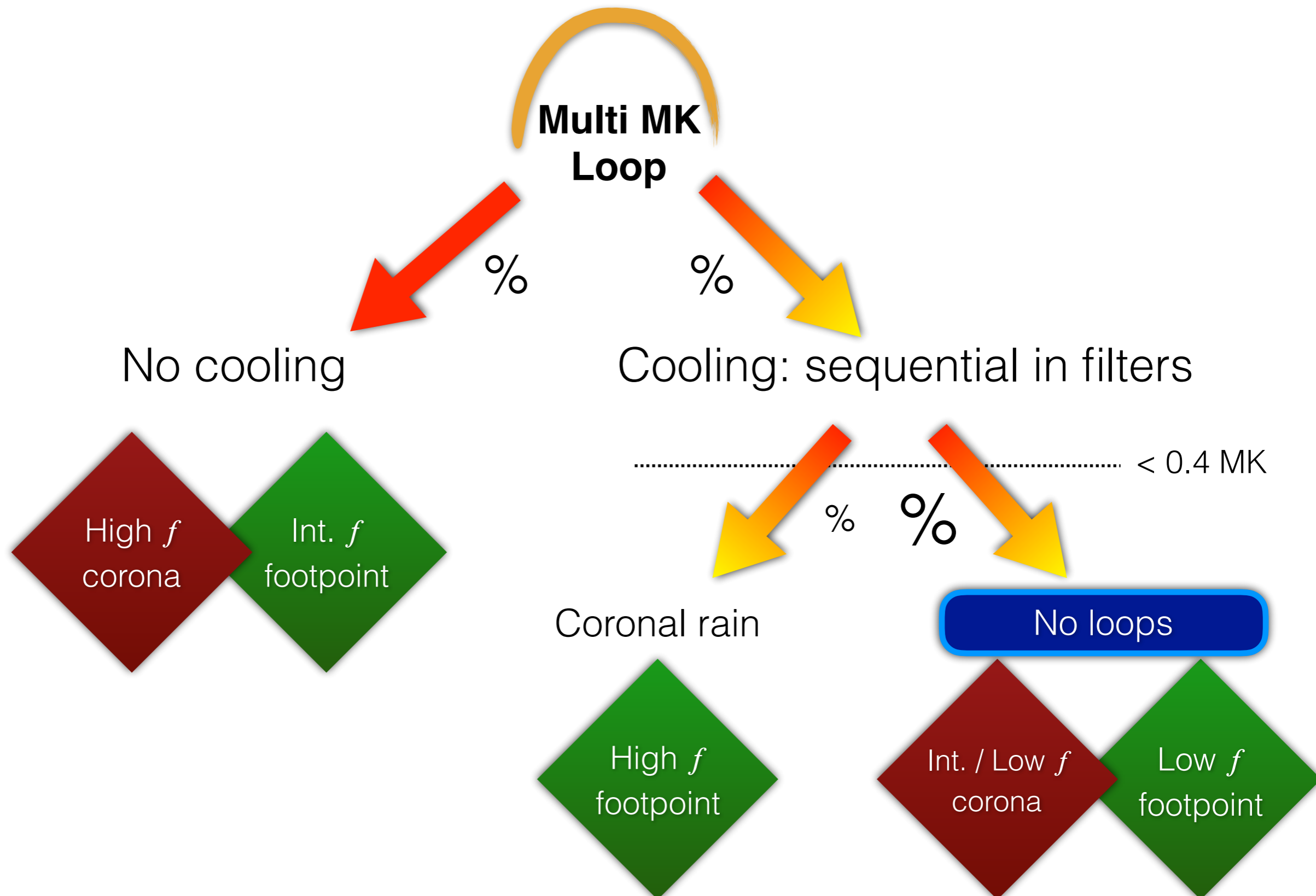


# Framework

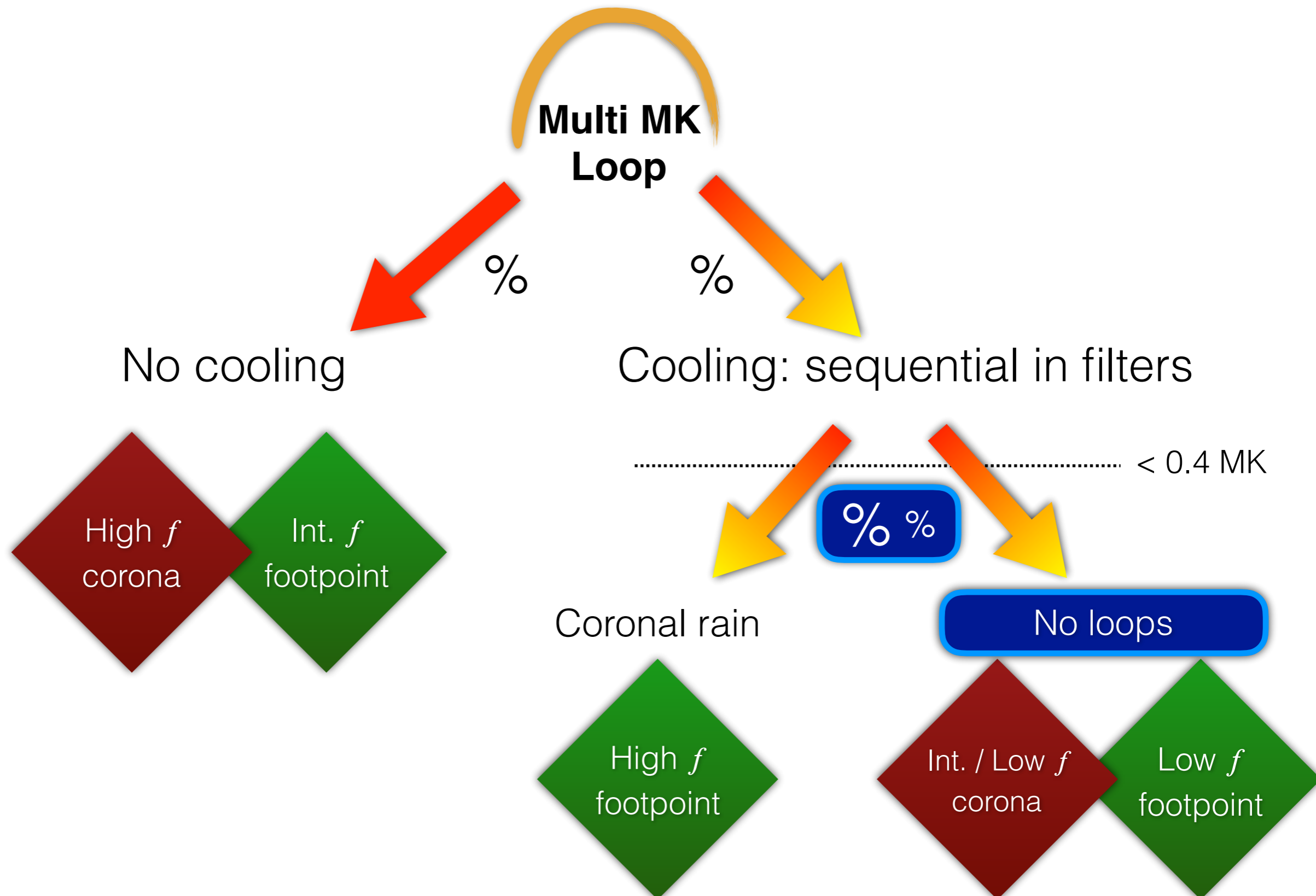




# Framework



# Framework



1. Is coronal rain an unusual result of cooling?

Not if plasma cools down to form  $T < 0.6\text{MK}$  loops...

2. Is the spatial scale of coronal rain a signature of the spatial scale of the heating?

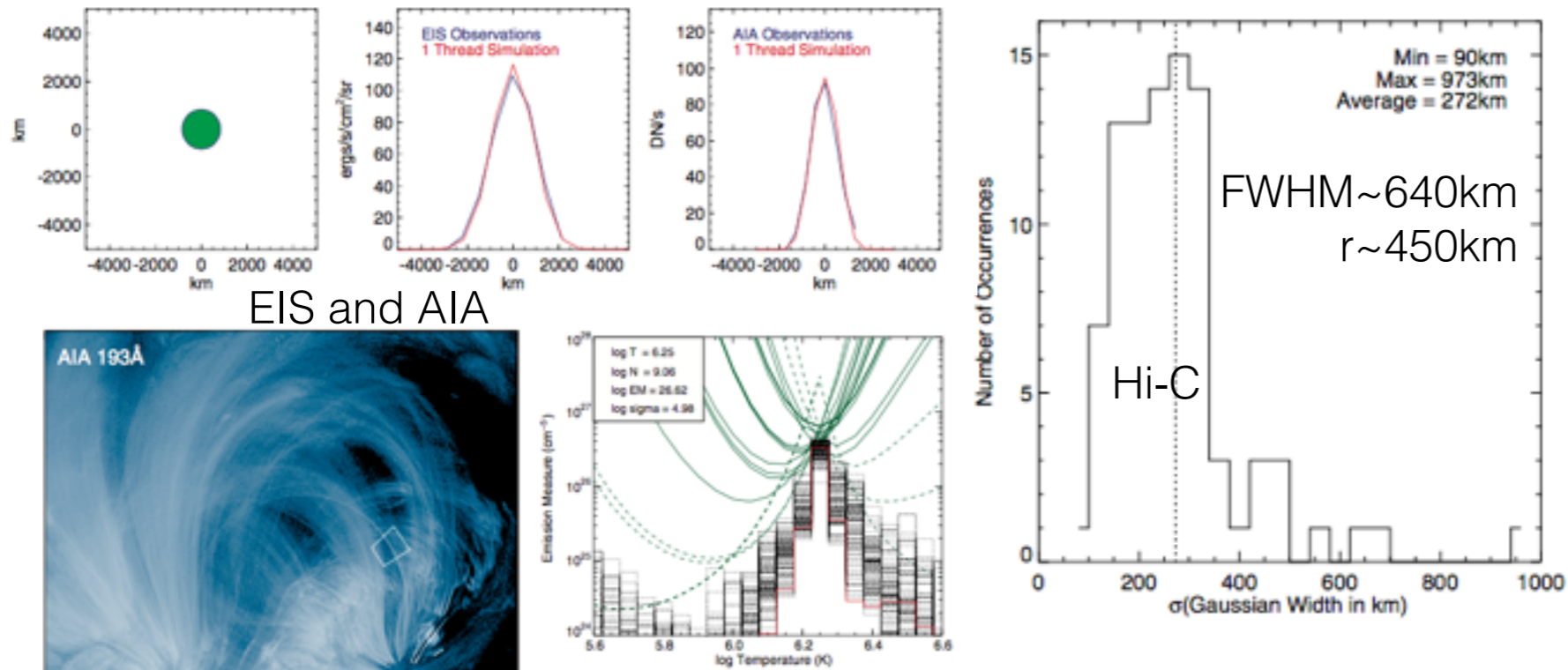
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Not if plasma cools down to form  $T < 0.6\text{MK}$  loops...

2. Is the spatial scale of coronal rain a signature of the spatial scale of the heating?

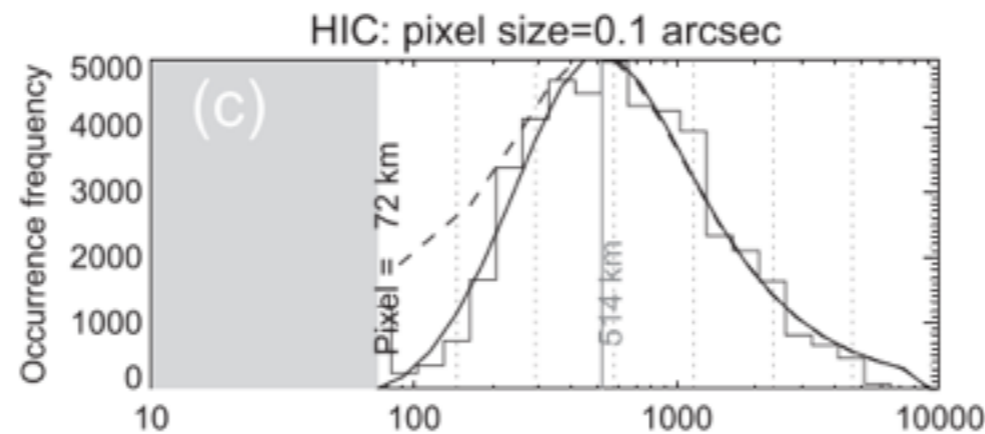
# Spatial scales

## Coronal loops resolved at hundreds of km cross-section



EIS and AIA

Brooks et al. (2012, 2013)



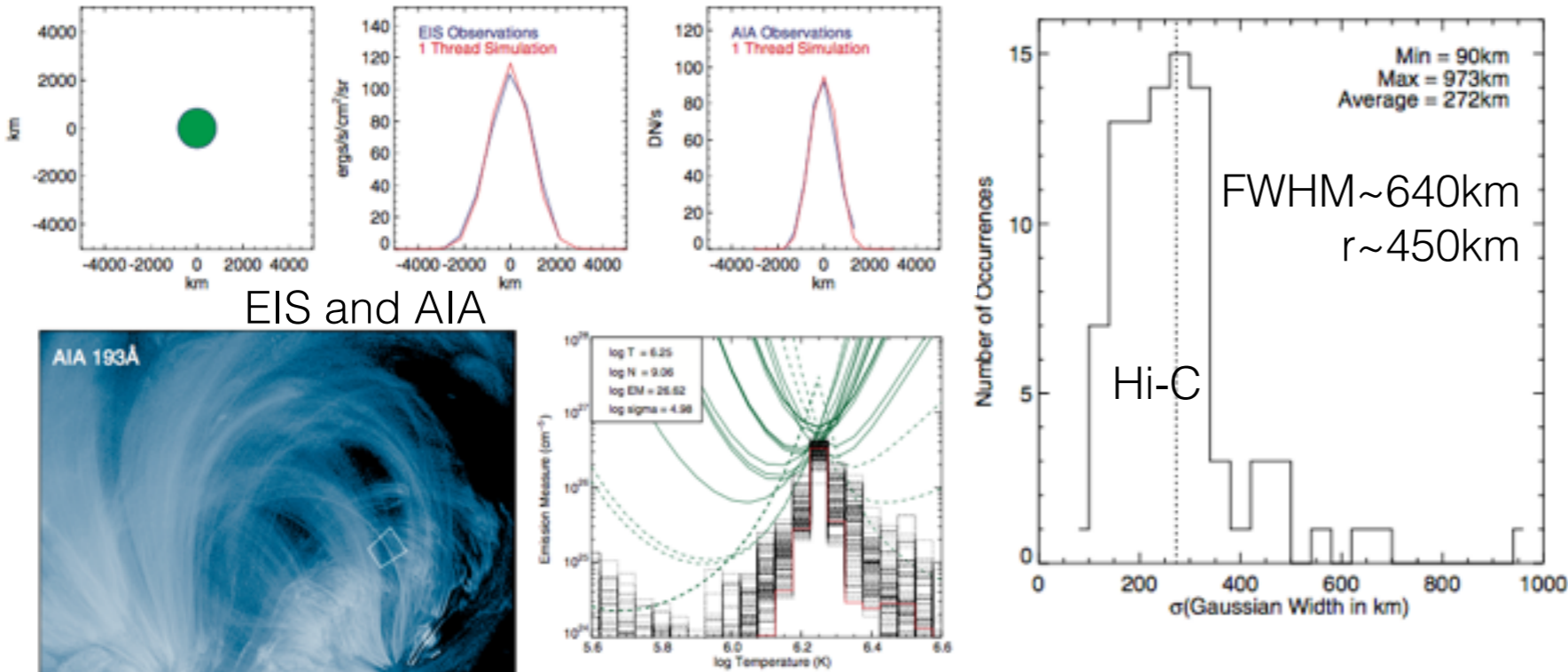
Aschwanden & Peter (2017)



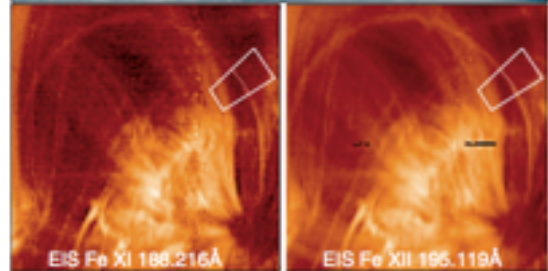
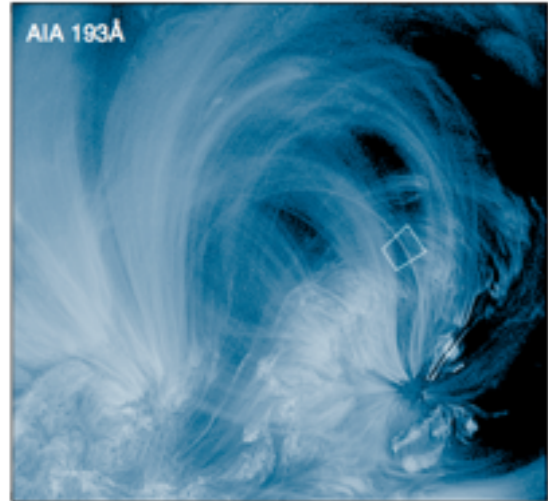
# Spatial scales

## Coronal loops resolved at hundreds of km cross-section

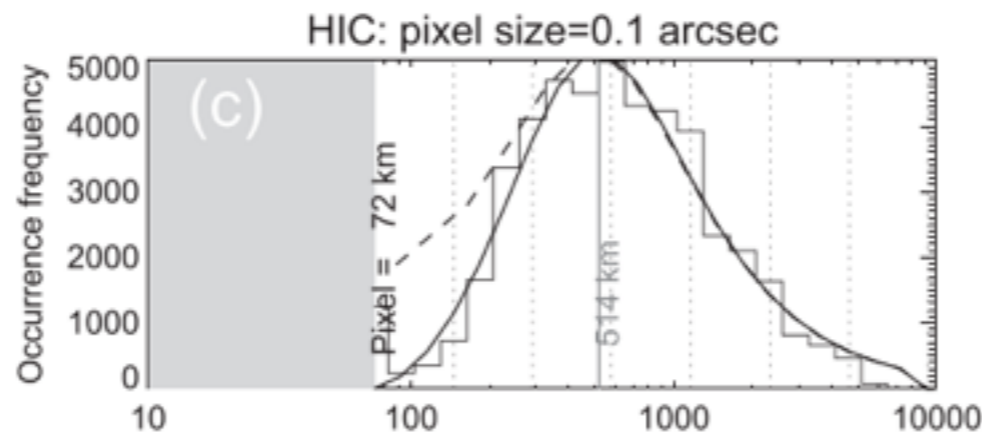
## Coronal rain: smaller



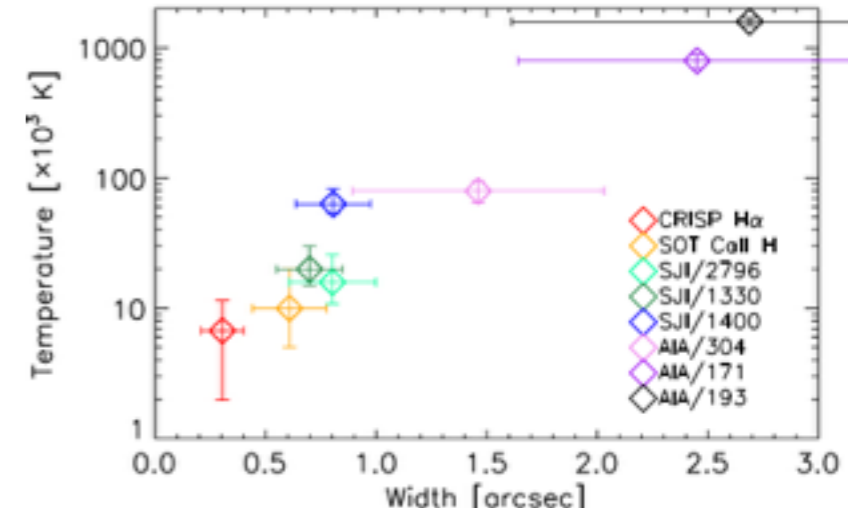
EIS and AIA



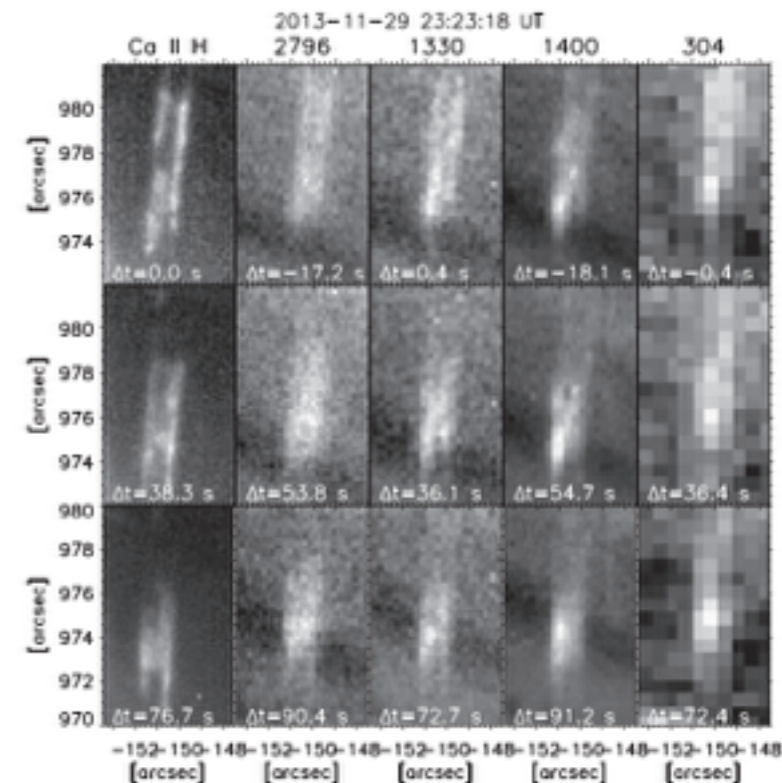
Brooks et al. (2012, 2013)



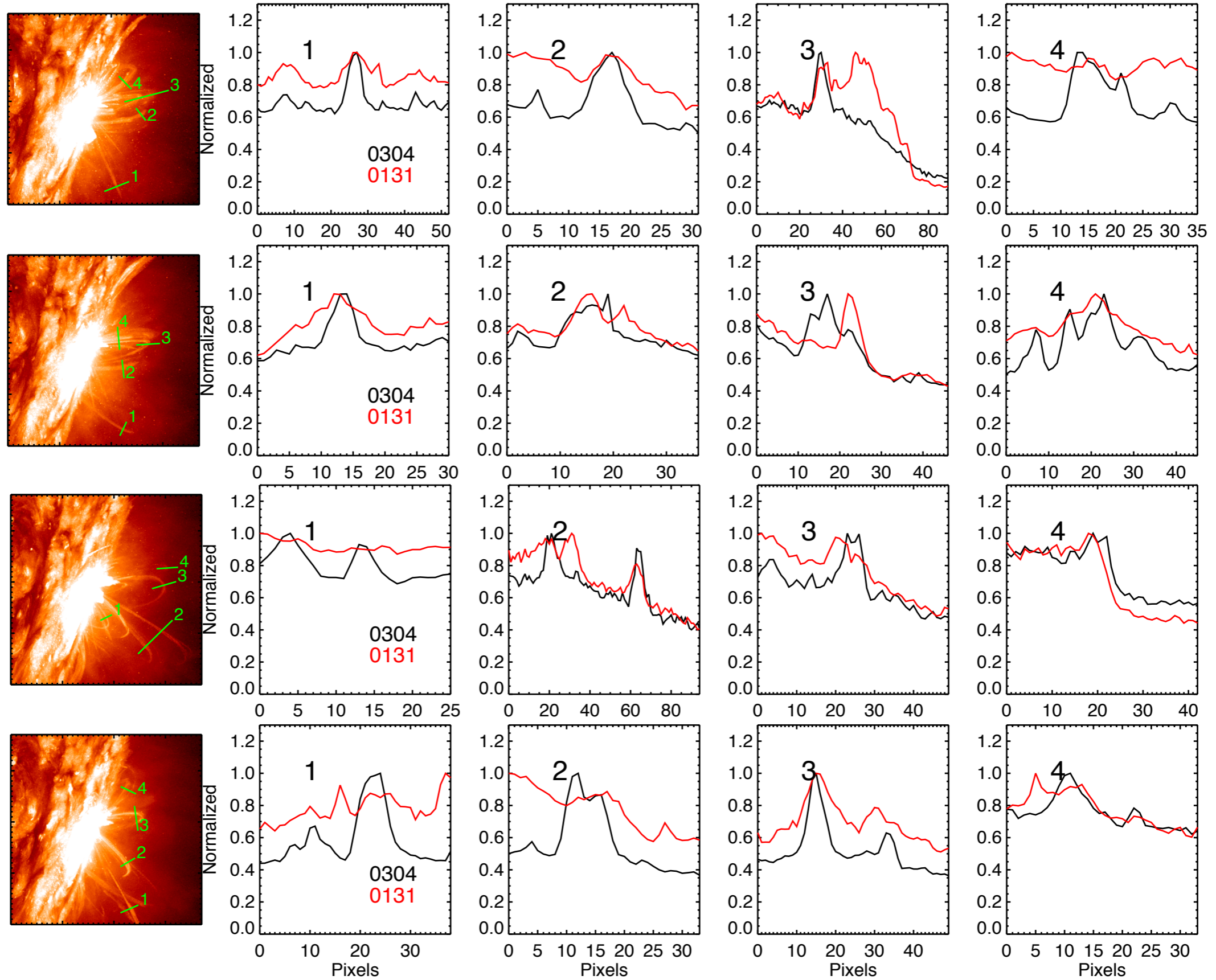
Aschwanden & Peter (2017)



Antolin et al. (2015)

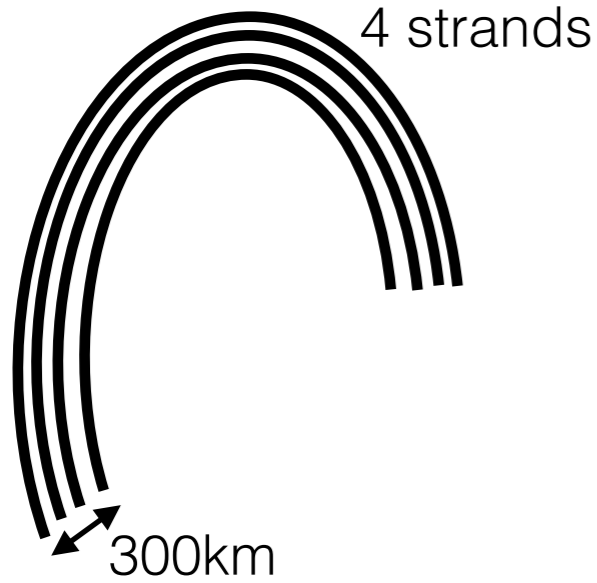


# Loop cross-sections



# 1D-Models

HYDRAD

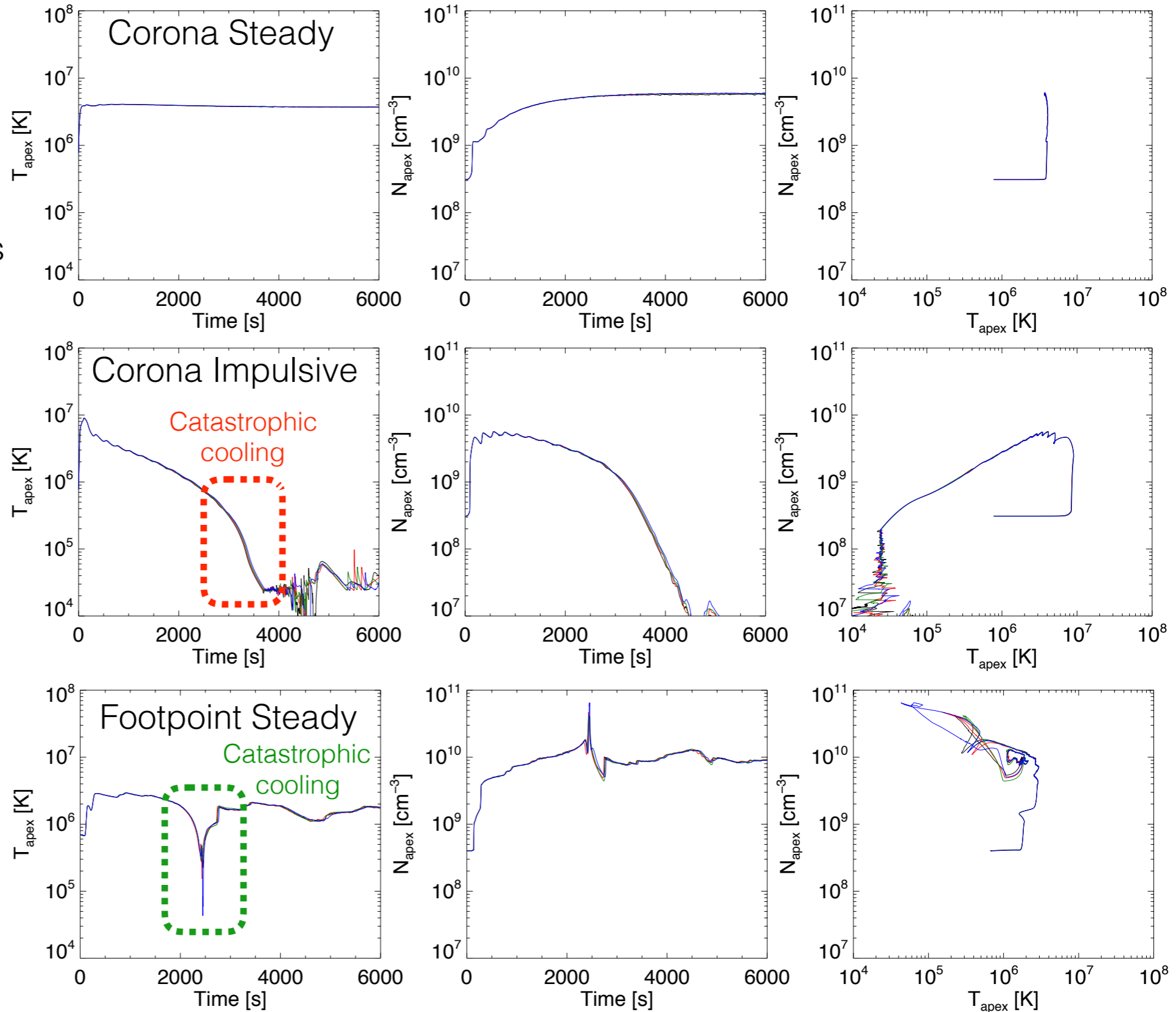


$$L = (r + dr) \pi$$

$$L(dr=0) = 59\text{Mm}$$

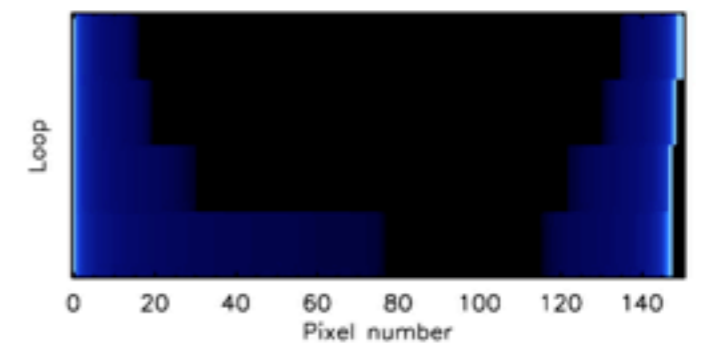
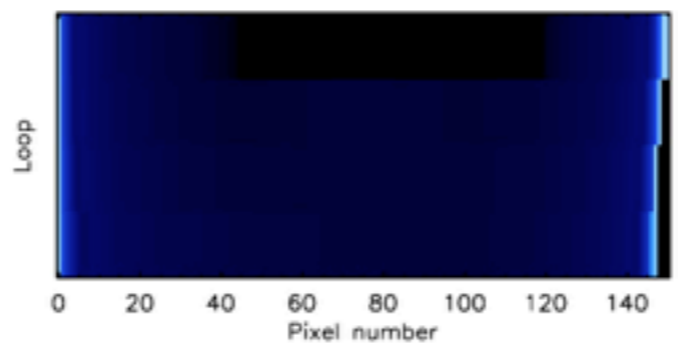
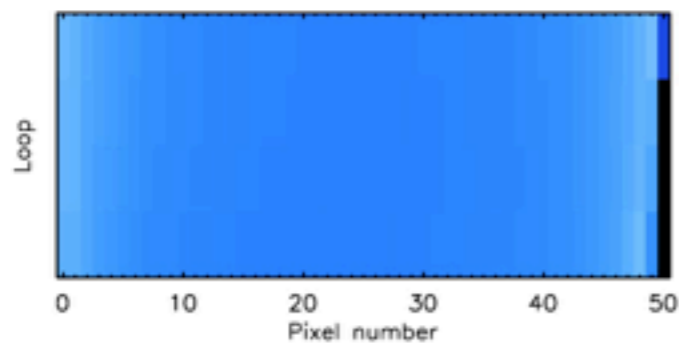
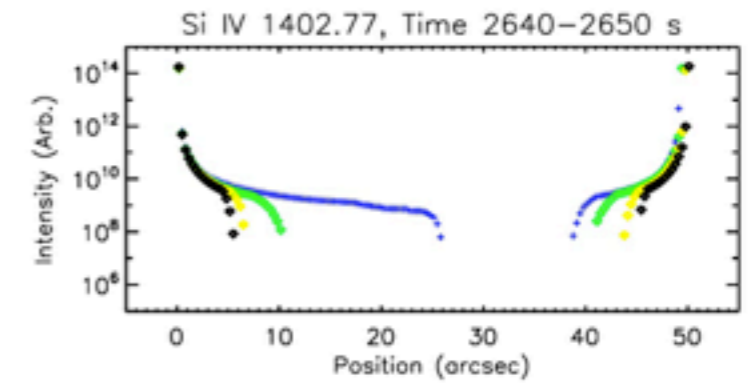
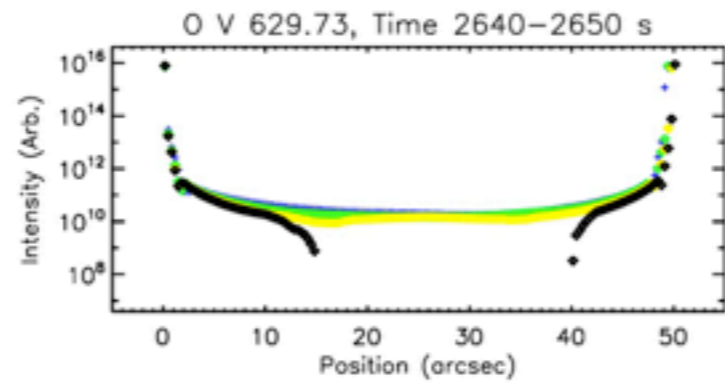
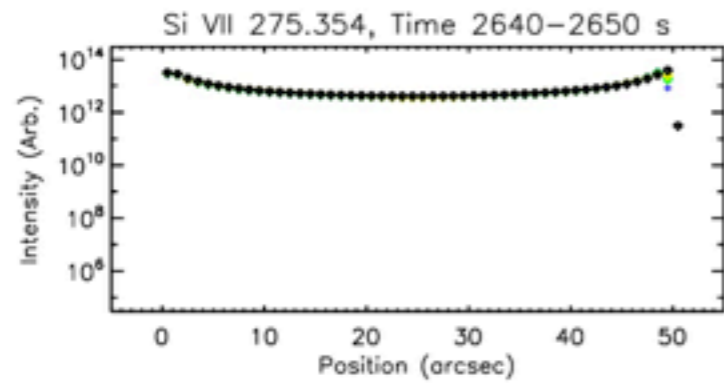
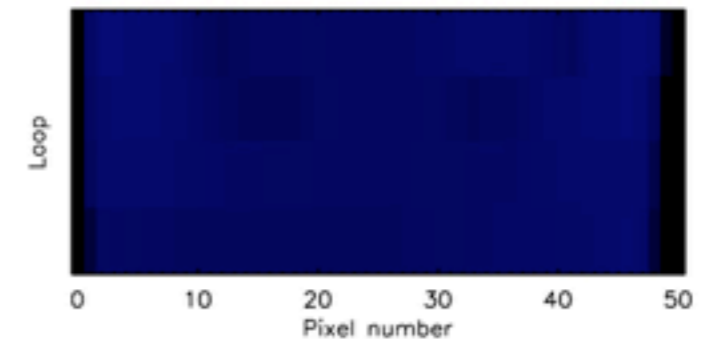
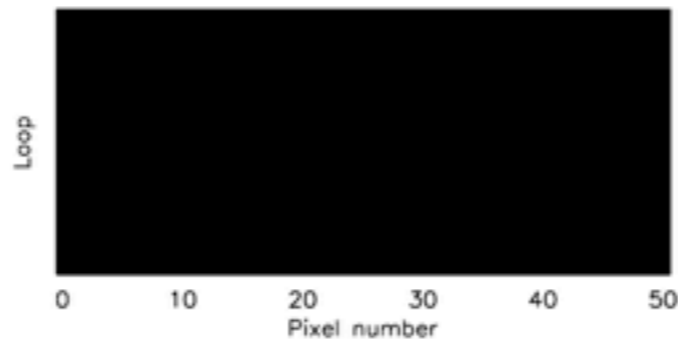
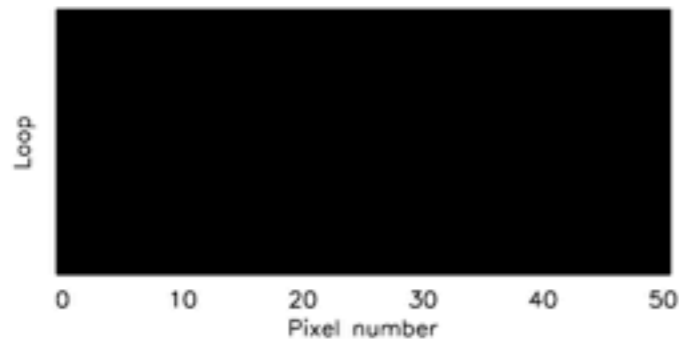
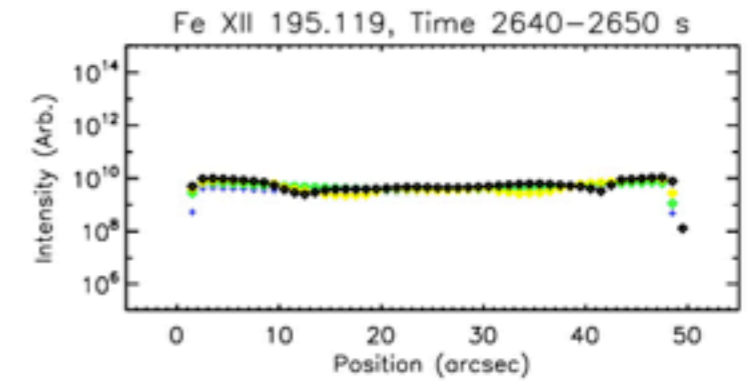
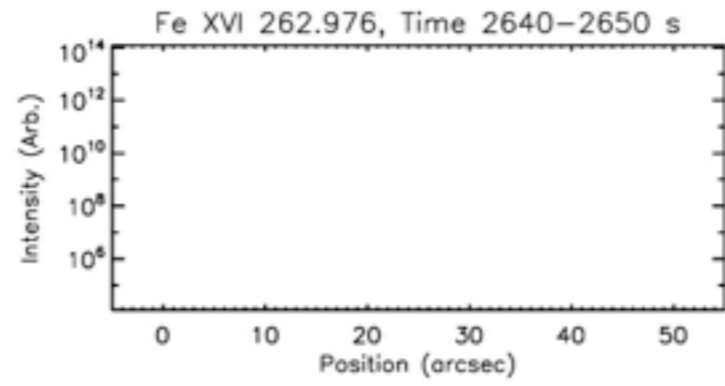
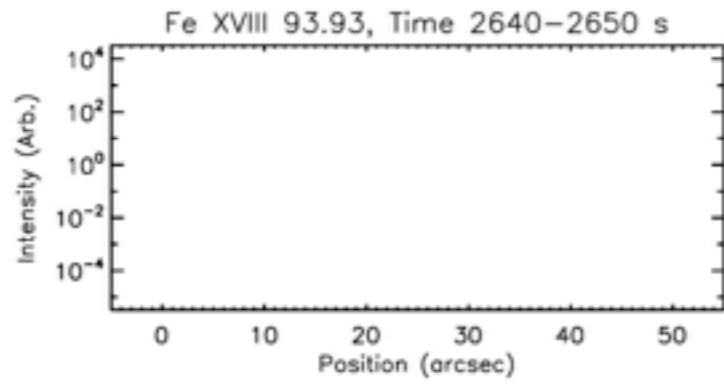
$$dr = 100\text{km}$$

$$E_T = 12 \text{ ergs cm}^{-3}$$

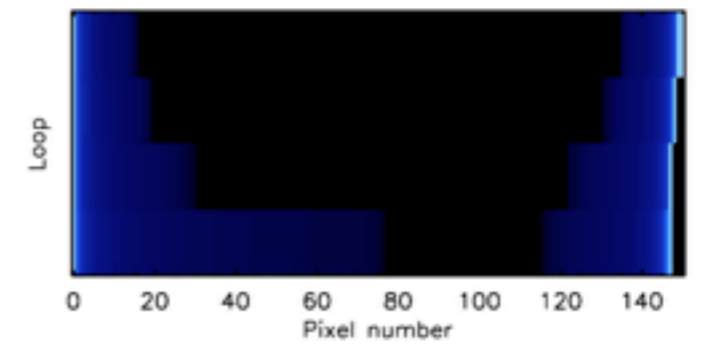
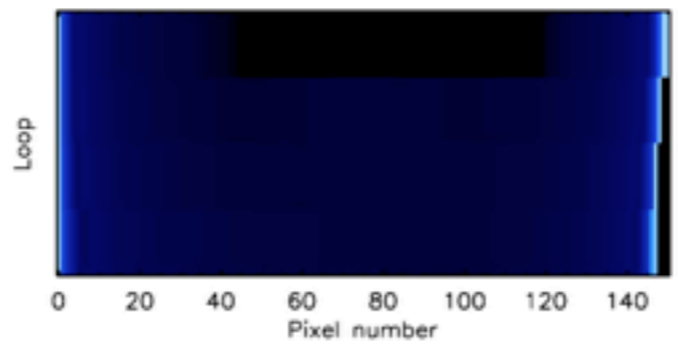
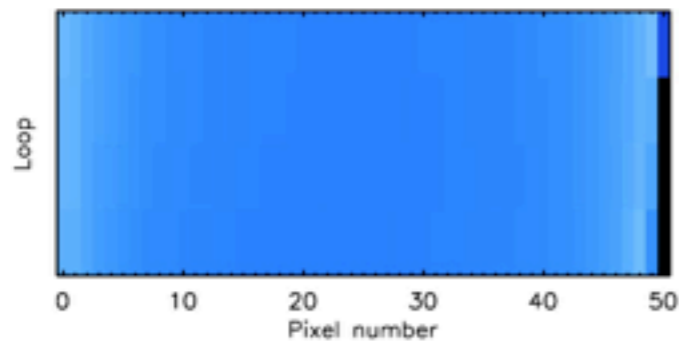
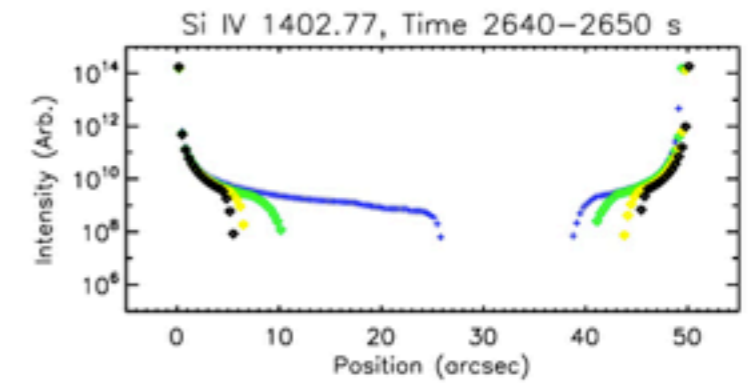
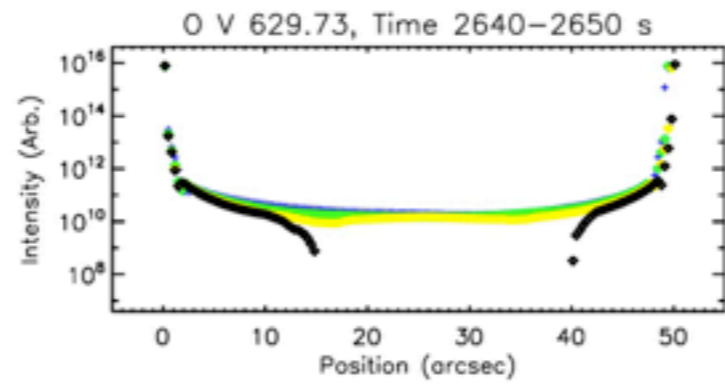
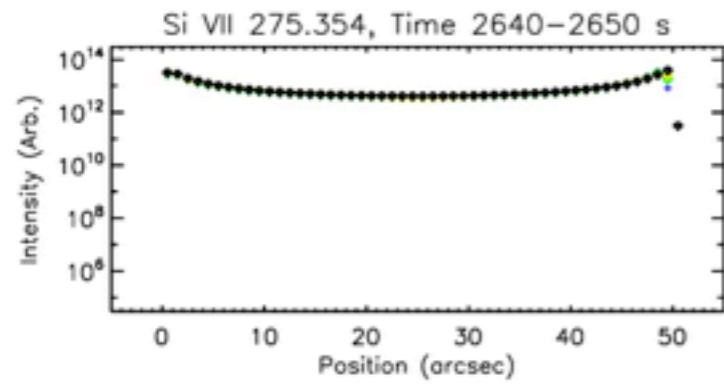
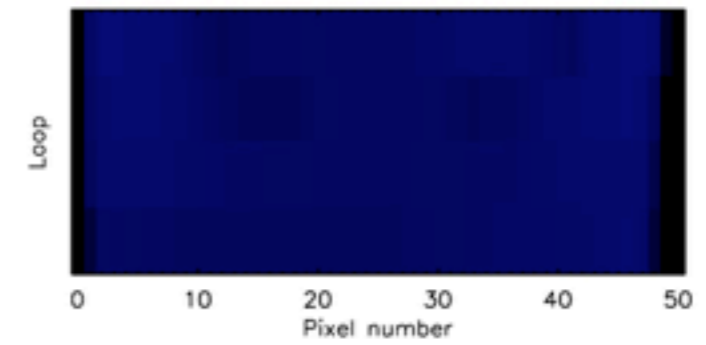
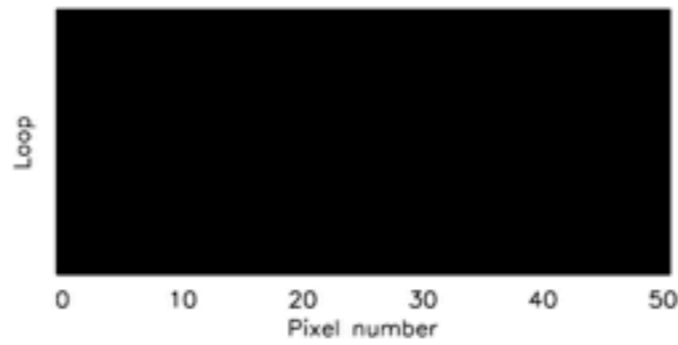
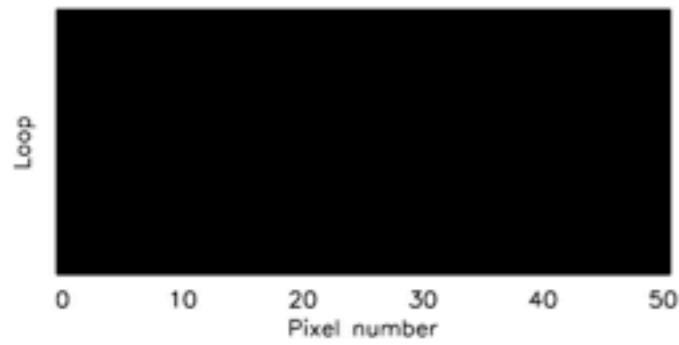
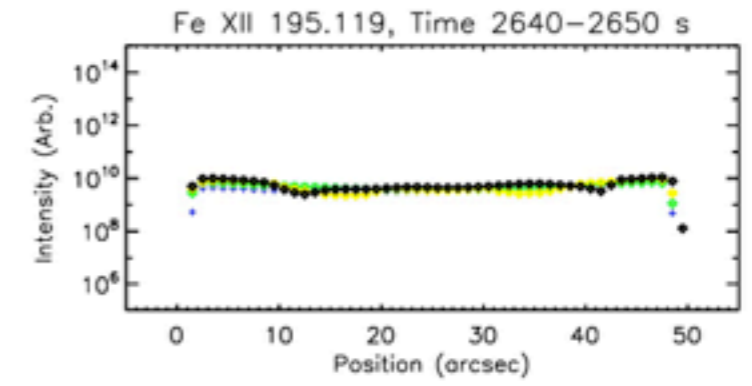
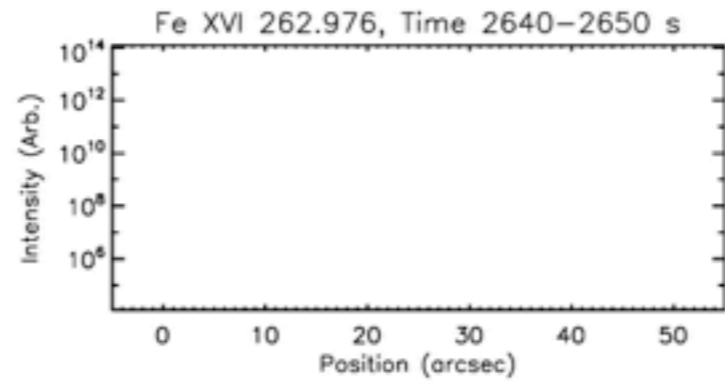
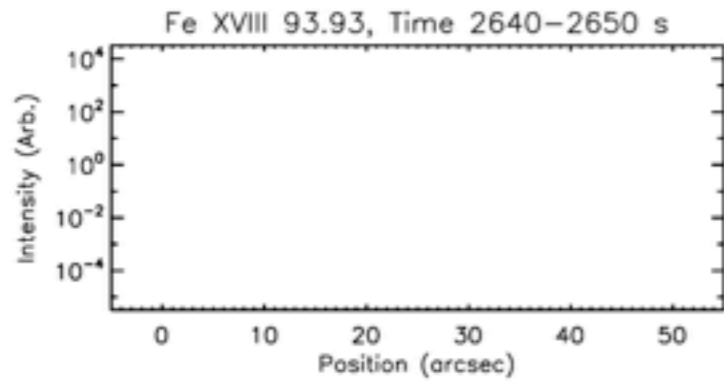




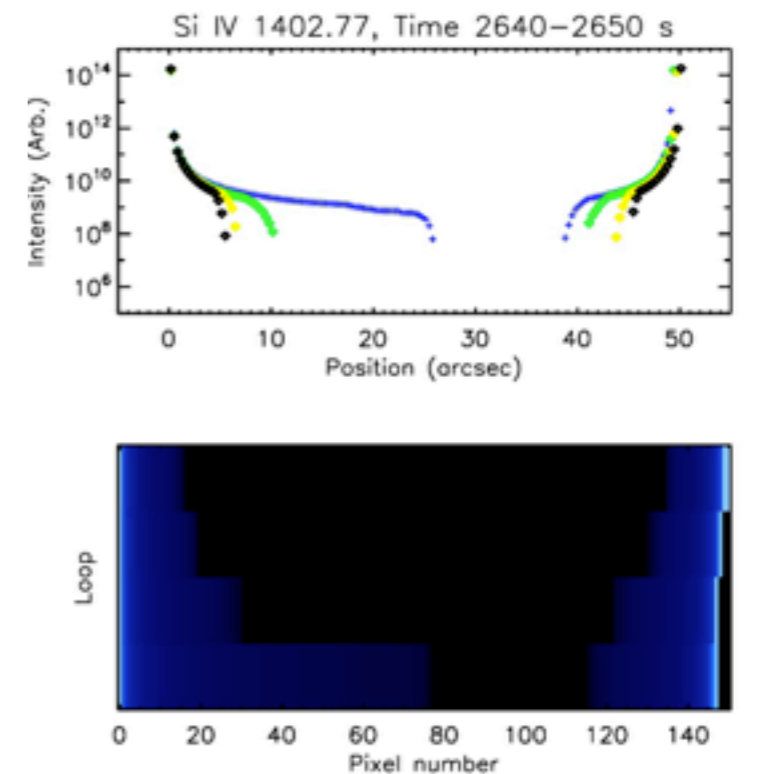
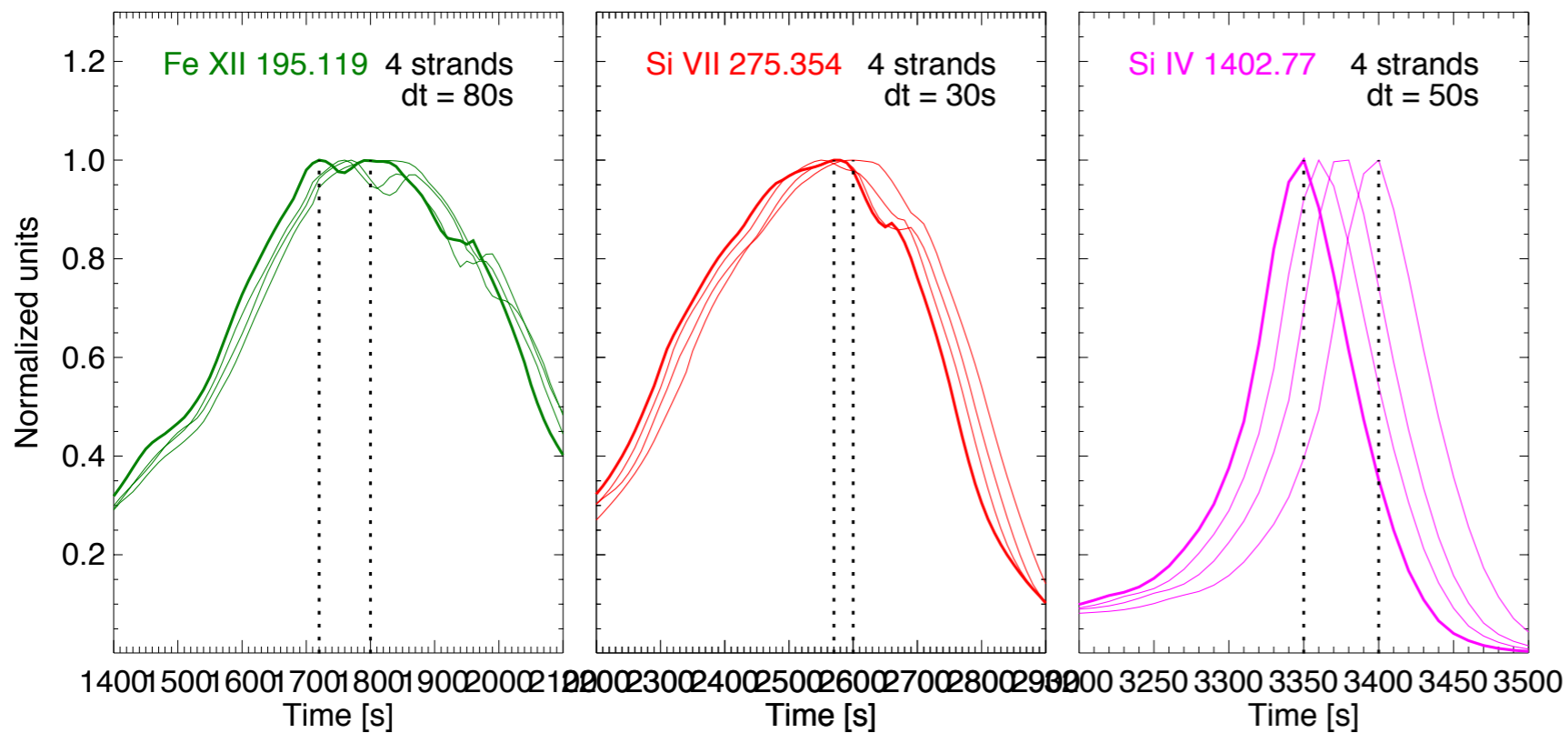
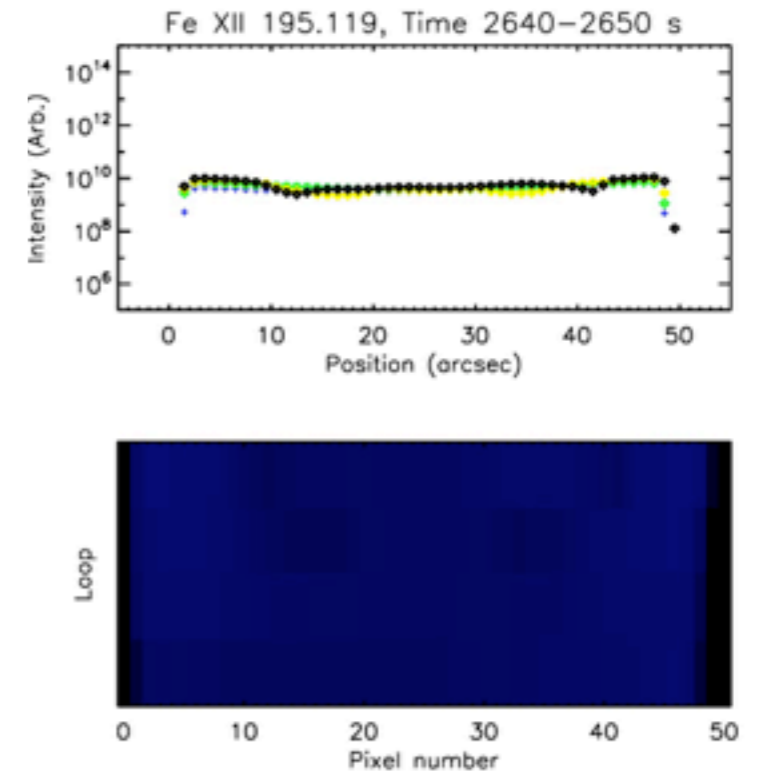
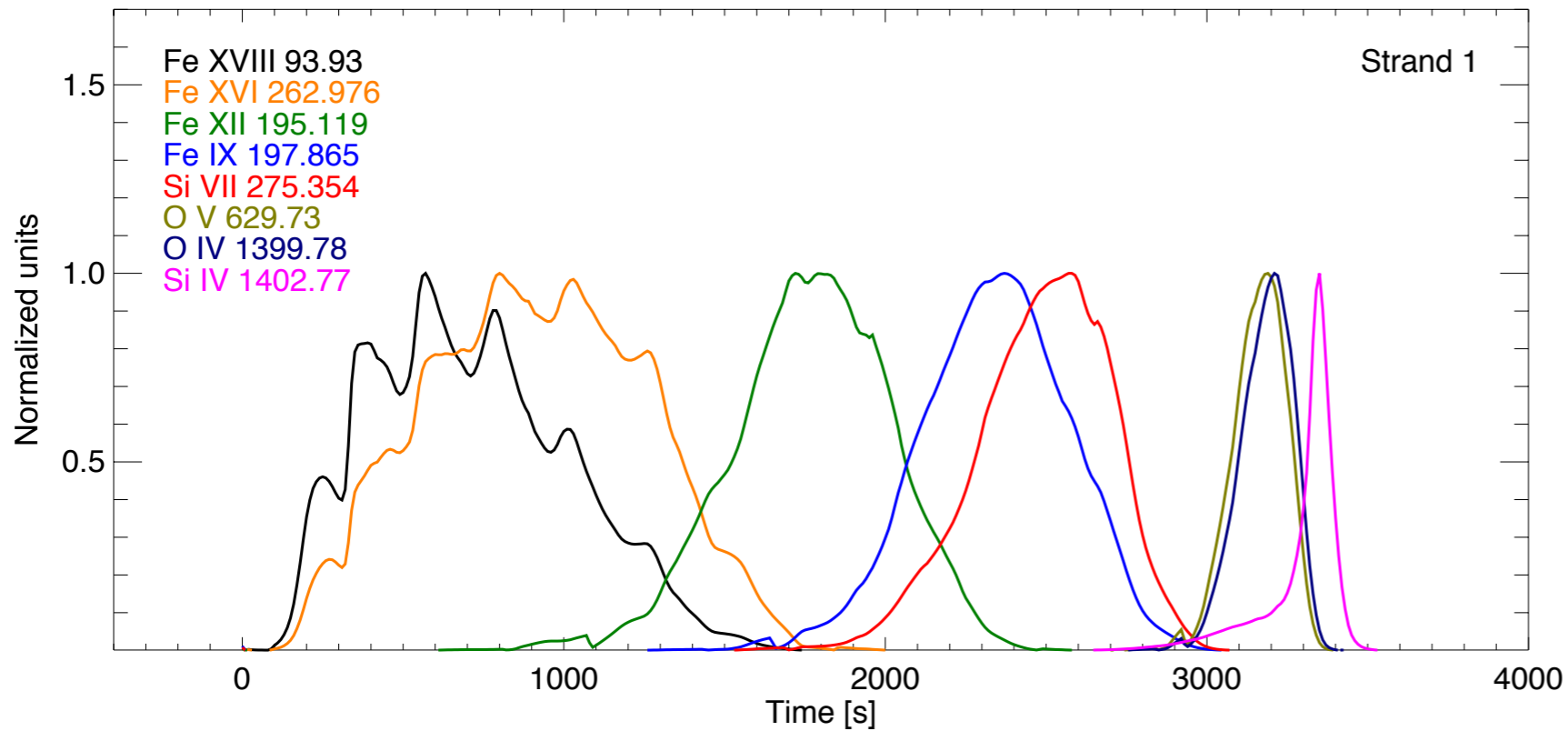
# Corona - Impulsive



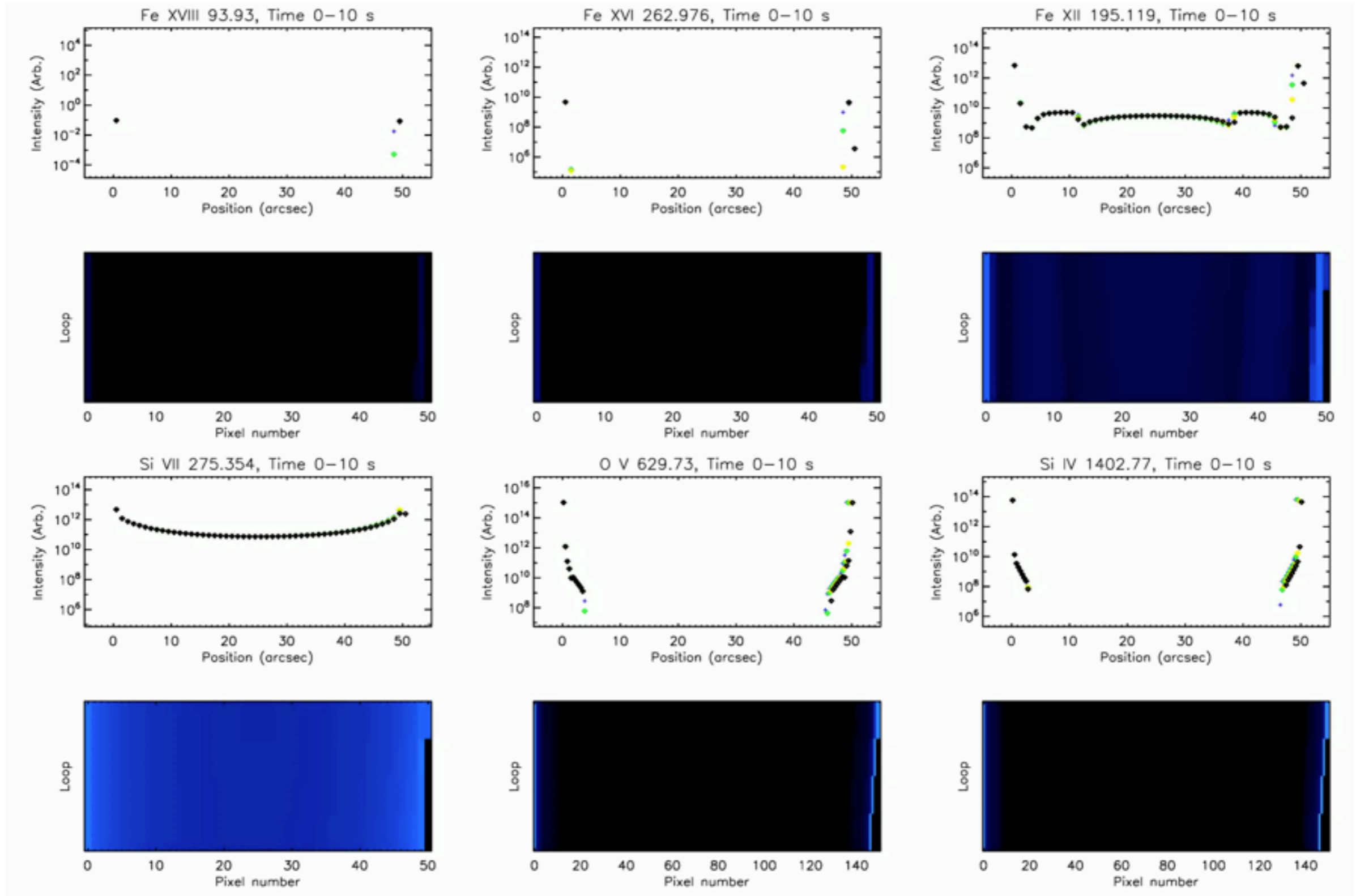
# Corona - Impulsive



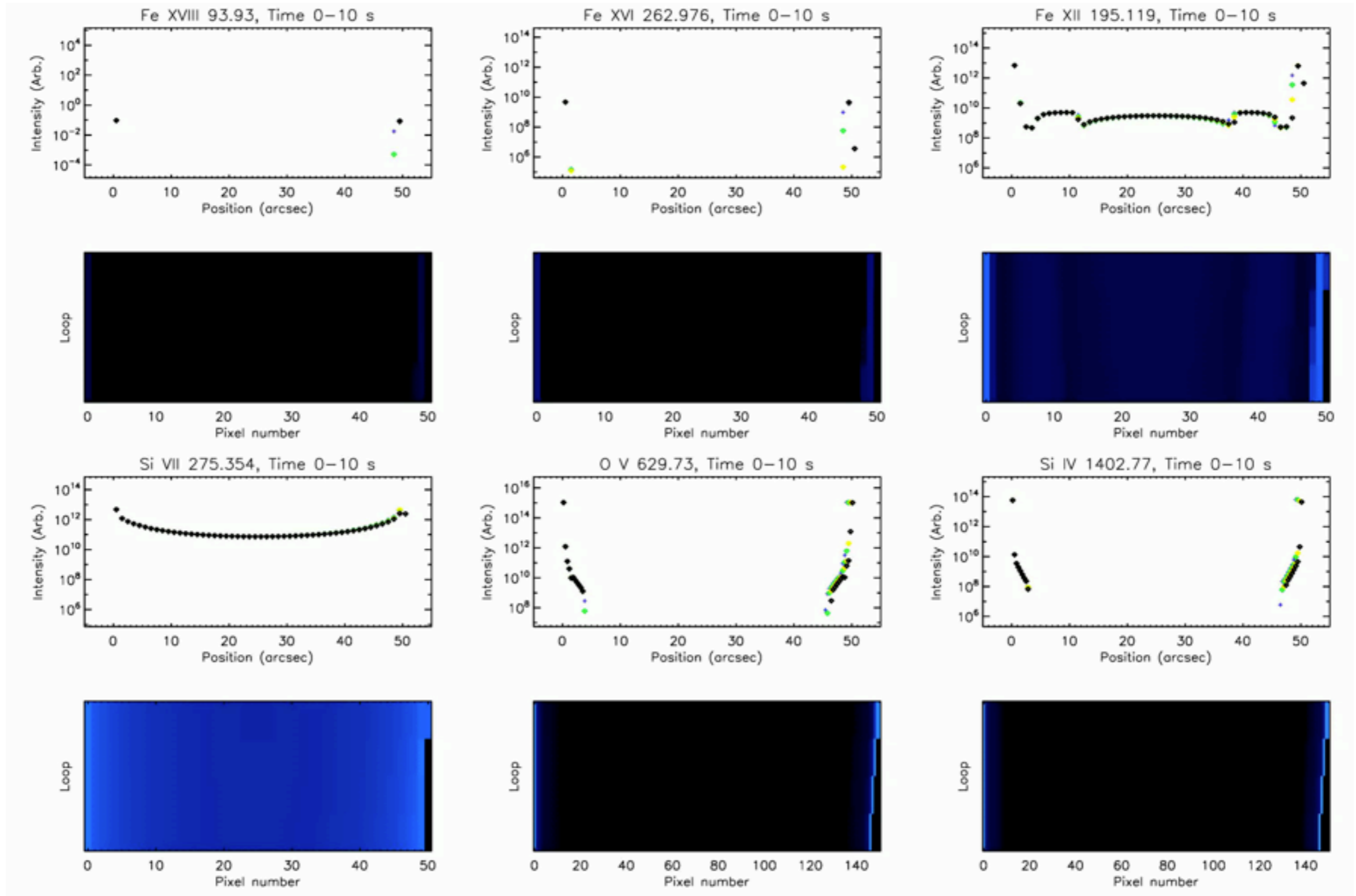
# Corona - Impulsive



# Footpoint - Impulsive

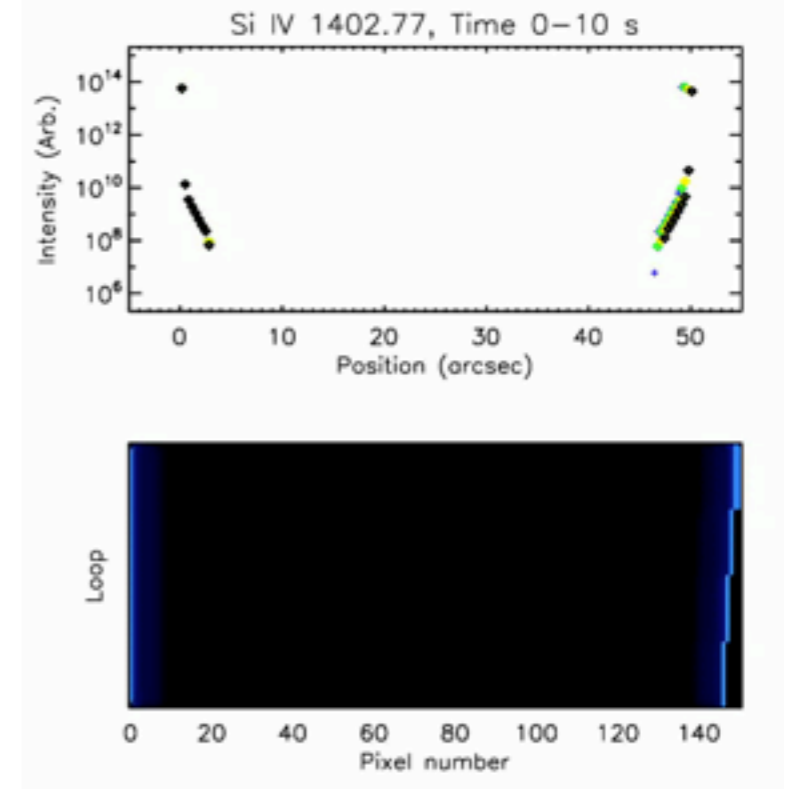
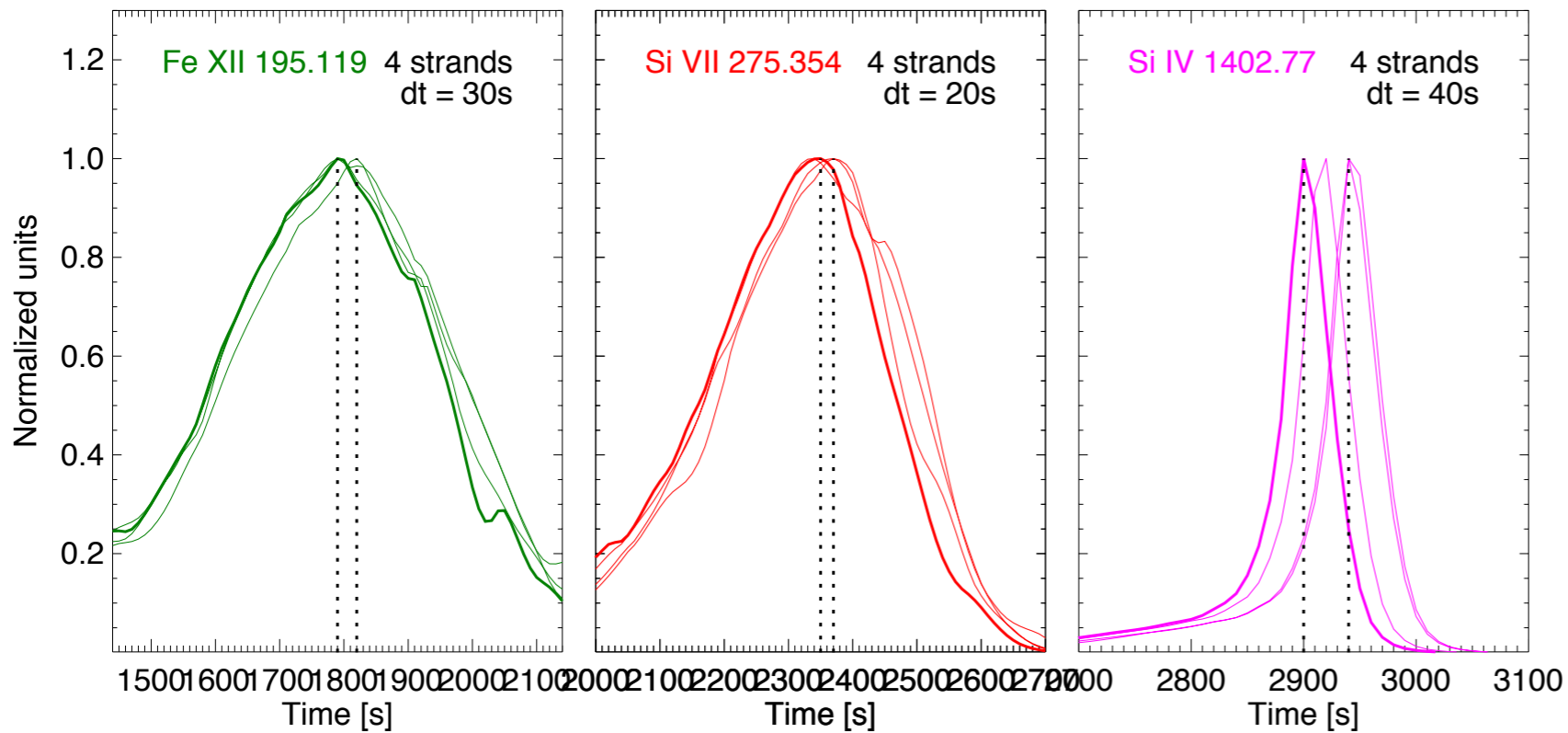
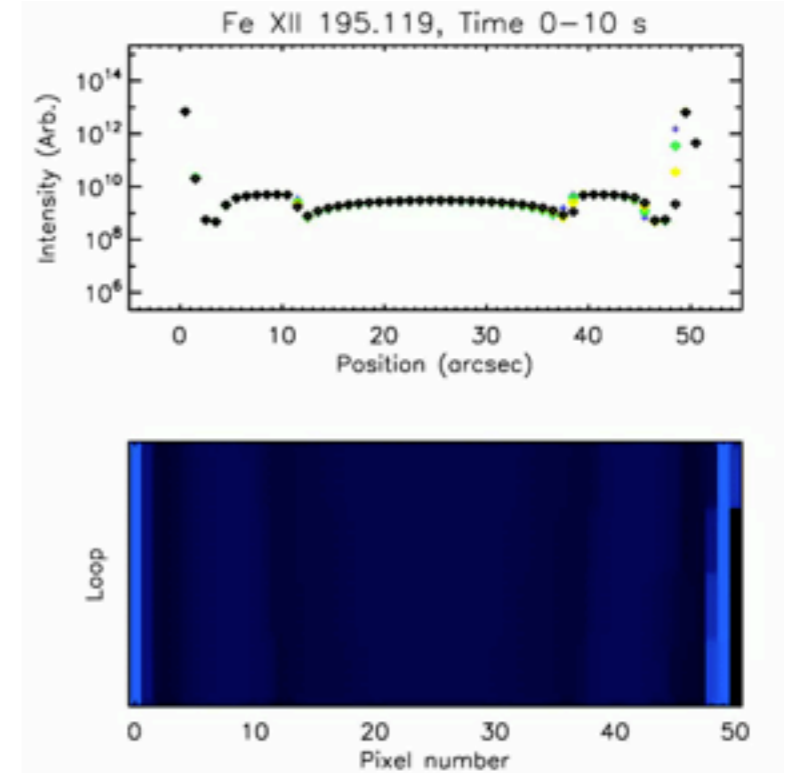
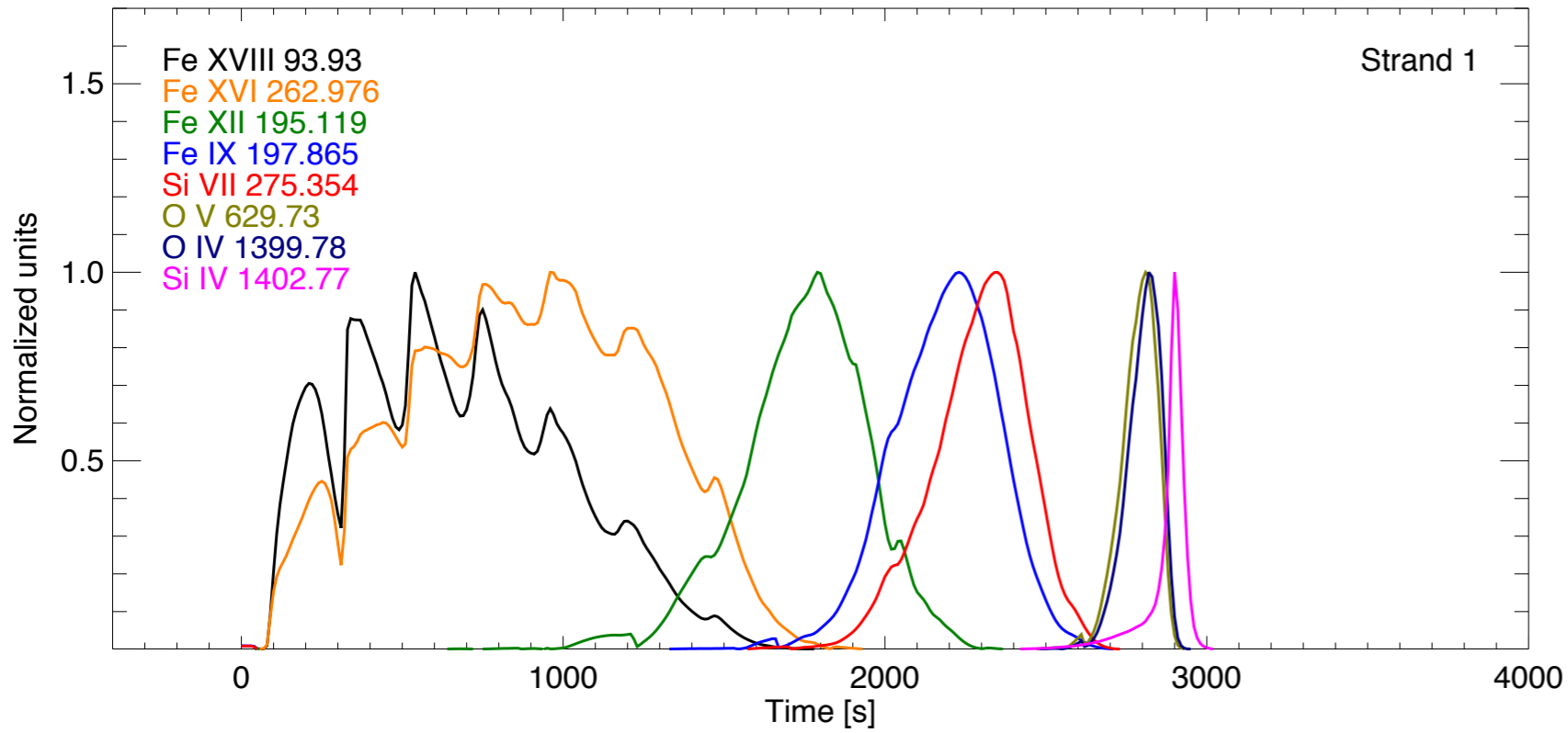


# Footpoint - Impulsive

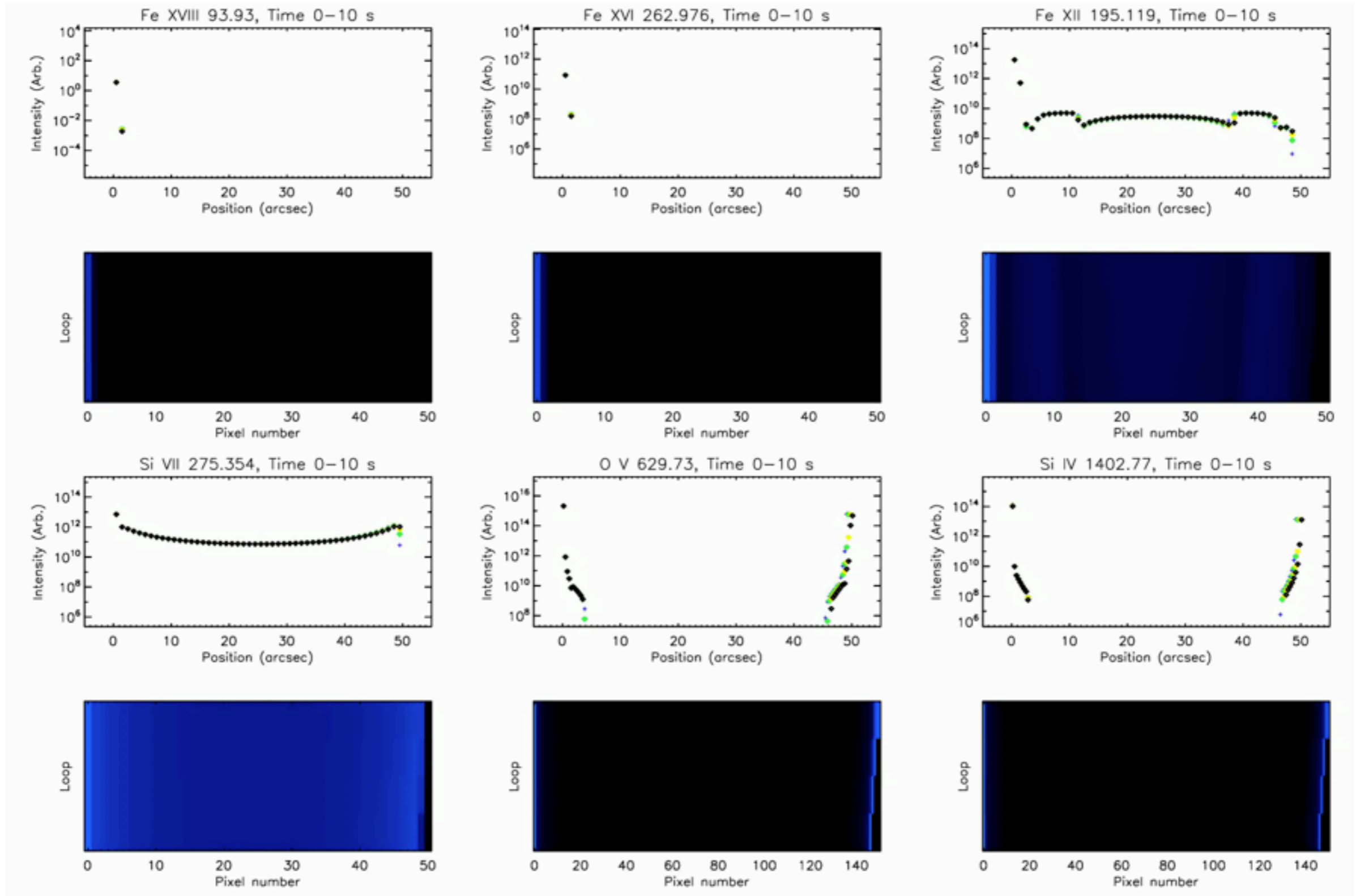




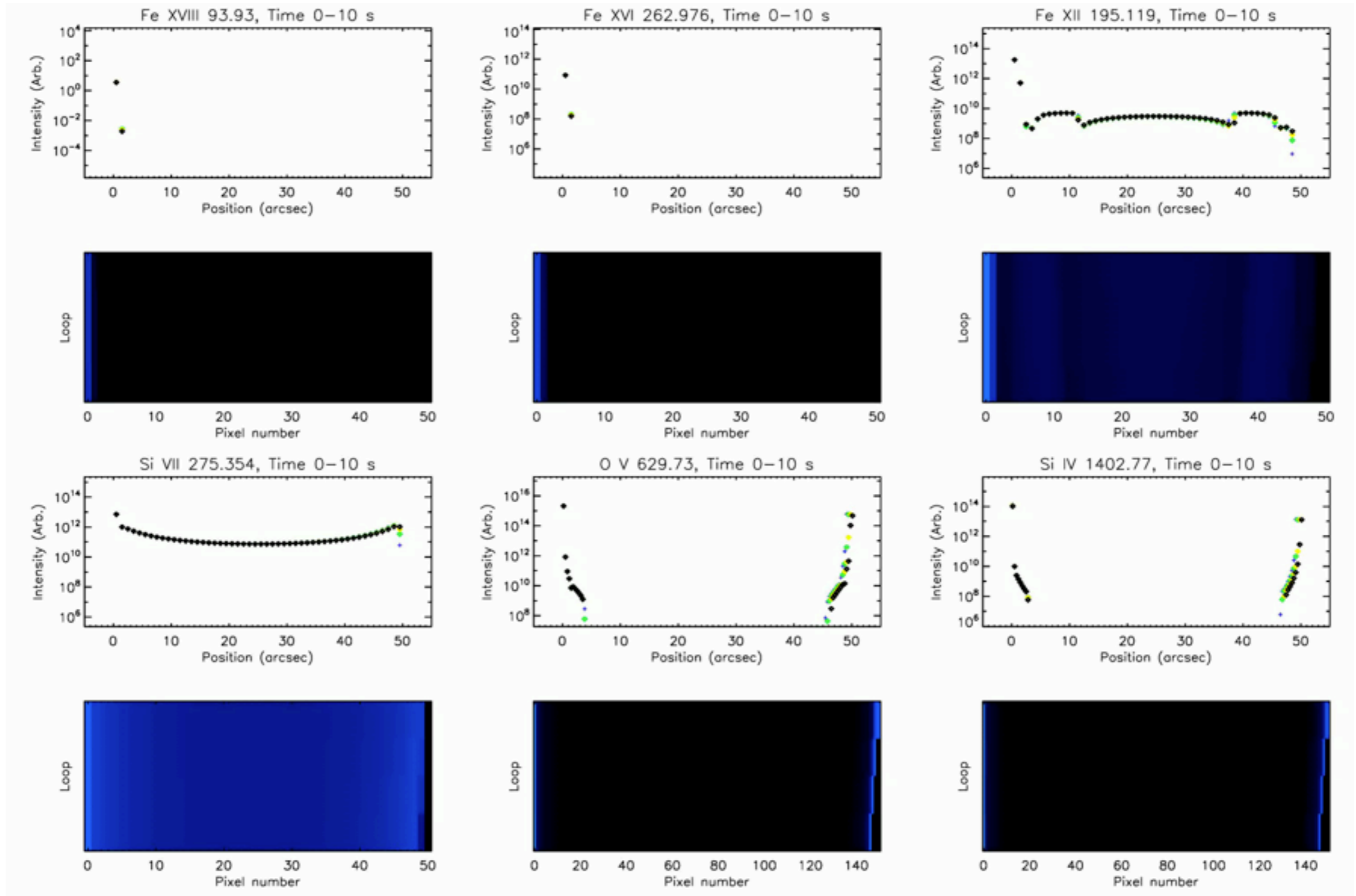
# Footpoint - Impulsive



# Footpoint - Steady

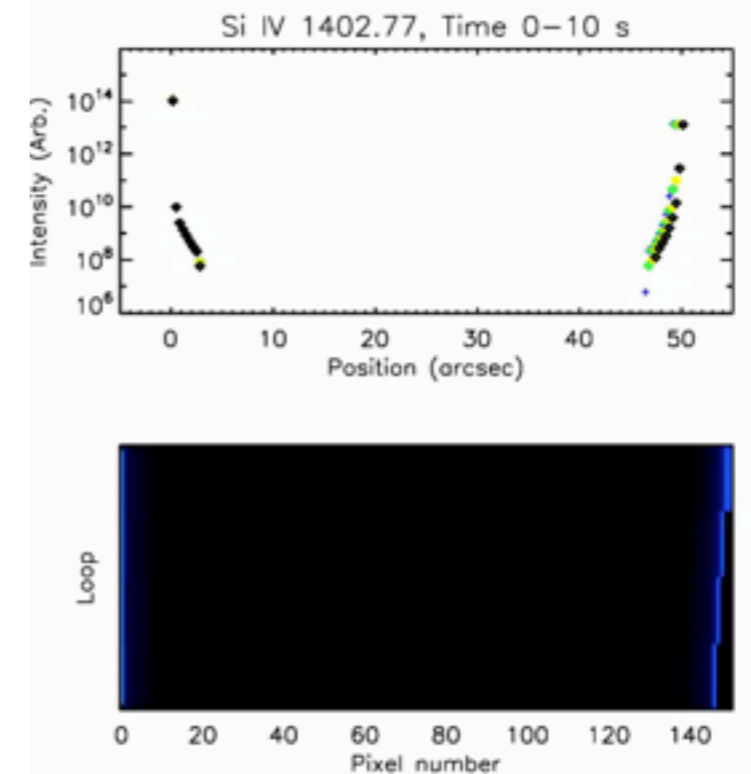
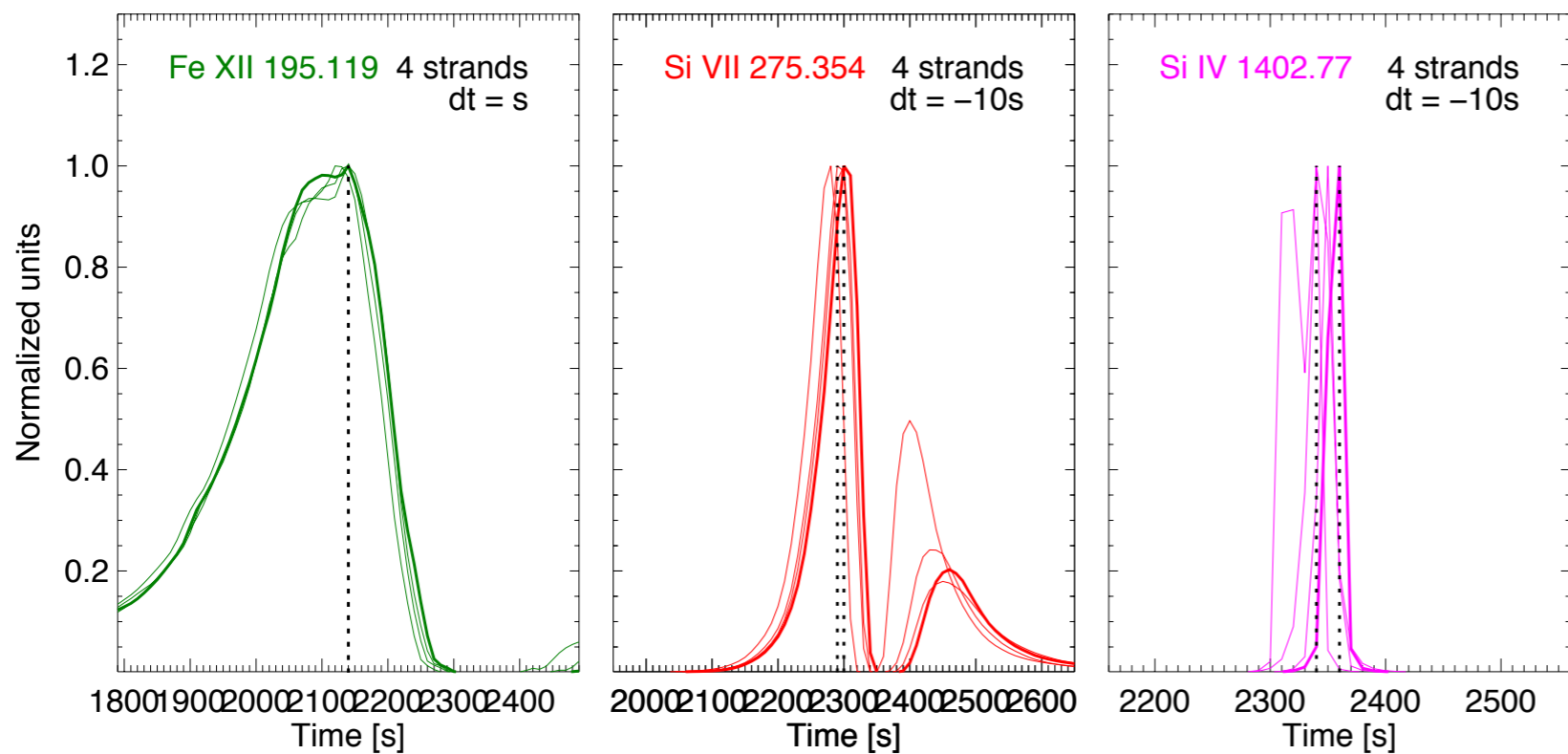
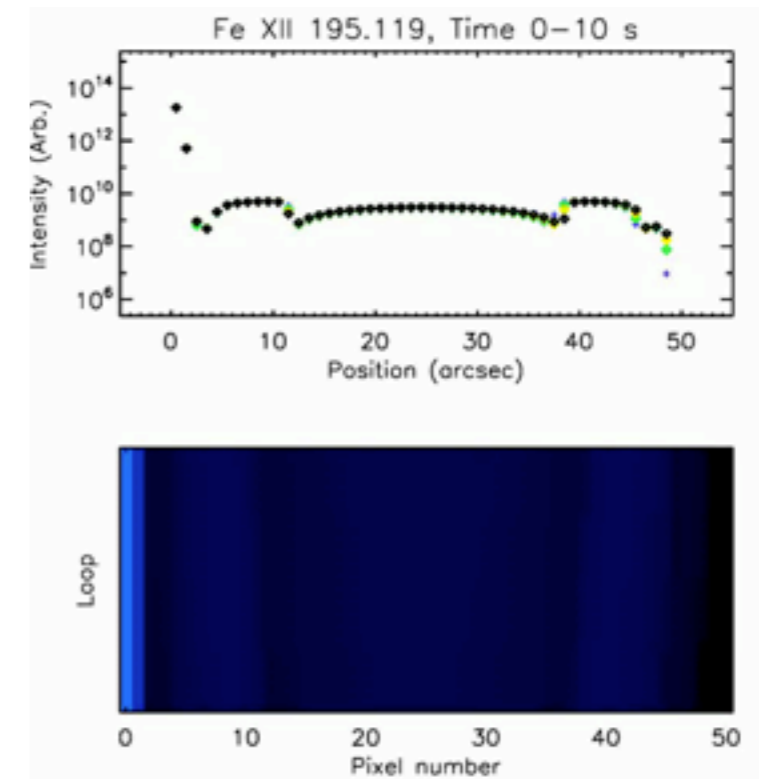
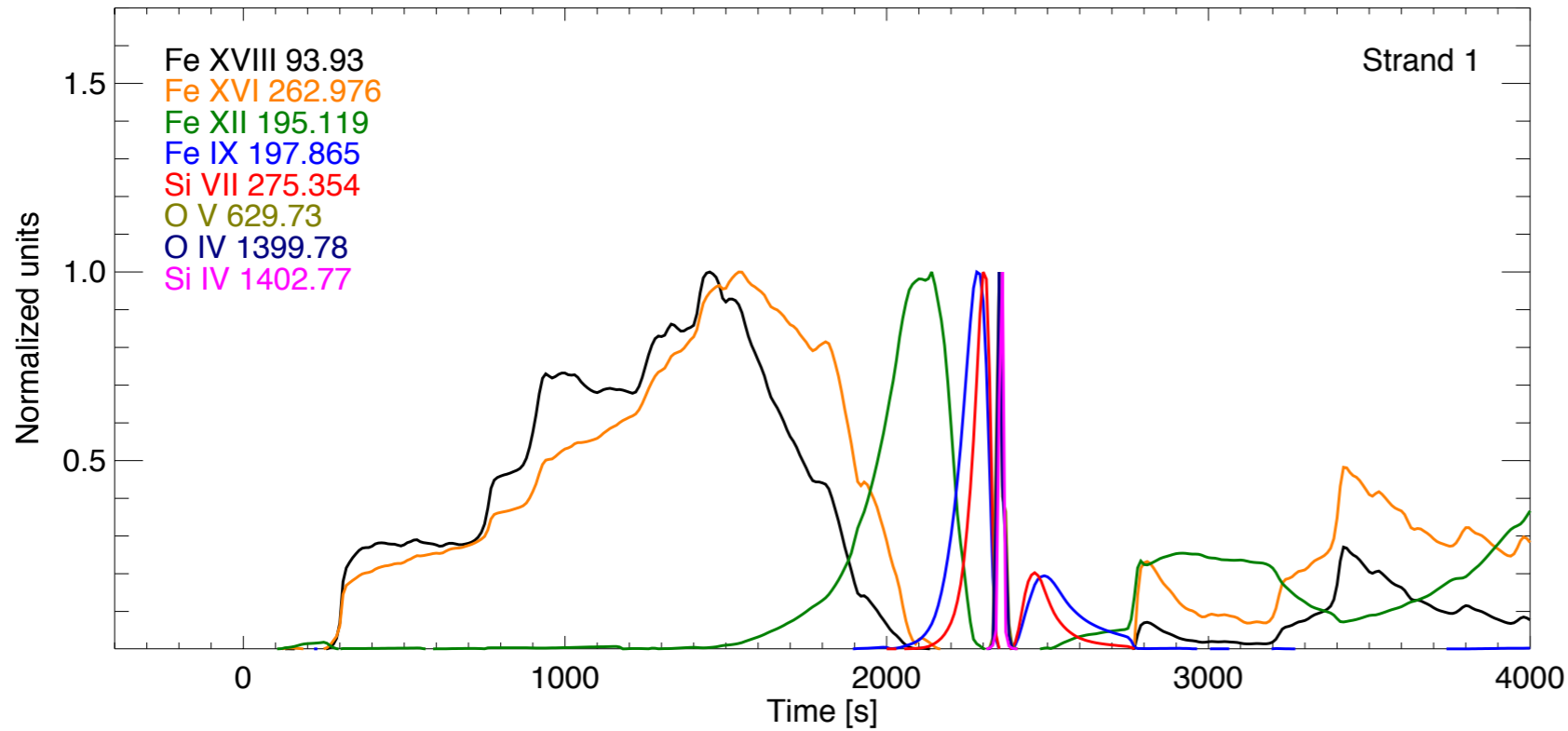


# Footpoint - Steady





# Footpoint - Steady



# Take-away

1. Is coronal rain an unusual result of cooling?

Not if plasma cools down to form  $T < 0.6\text{MK}$  loops...

2. Is the spatial scale of coronal rain a signature of the spatial scale of the heating?

Not necessarily the strand size.  
Envelope of strands is important.

