IMAGING AND SPECTROSCOPIC OBSERVATIONS OF EUV BRIGHTENINGS USING EUI AND SPICE ON BOARD SOLAR ORBITER

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■■ ■■■■ ABSTRACT ■■ ■■■

■ The smallest EUV brightening events (hereafter EUI brightenings) that were detected so far have recently been uncovered by the High Resolution EUV telescope (HRI$_{EUV}$), which is part of the Extreme Ultraviolet Imager (EUI) on board Solar Orbiter.

■ We study the thermal properties of EUI brightening events by simultaneously observing their responses at different wavelengths using spectral data from the Spectral Imaging of the Coronal Environment (SPICE) and imaging data from EUI.

■ Our results indicate that at least some EUI brightenings barely reach coronal temperatures.

OBSERVATIONS ■ ■ ■ ■

We select 3 EUI brightening events that can be identified in HRI$_{EUV}$ data and are also covered by the slit of SPICE from two different parts of the spacecraft orbit.

(see Table 1 and Figure 1)

Table 1. Overview of the observations

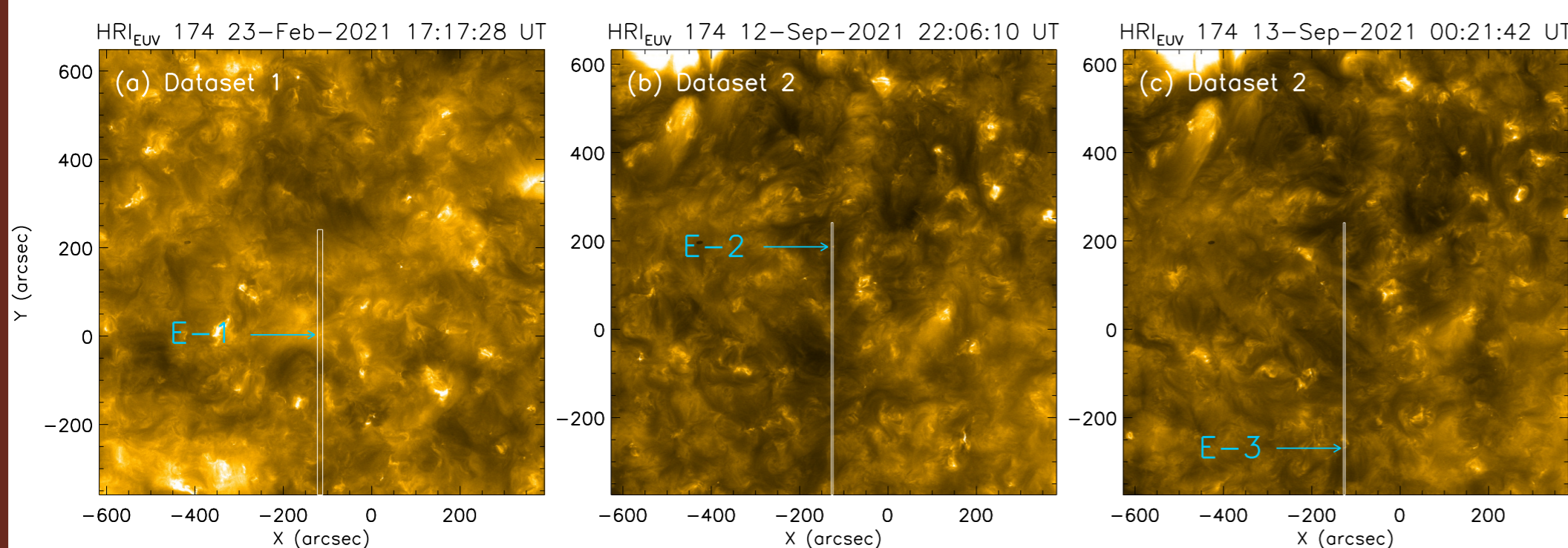| Date	HRI$_{EUV}$			SPICE				
	Time	Cadence	Exposure	Time	Cadence	Exposure	Type	Version
23-Feb-2021	17:13:25-17:20:59	2 s	1.65 s	15:44:00	N/A	20 s	Context rasters	V10
				17:33:43				
				16:50:31-17:23:31	20 s	4.7 s	Small rasters	V10
12/13-Sep-2021	22:00:59-22:14:59	2 s	1.65 s	22:04:19-23:12:09	10.2 s	10 s	Sit and stare	V08
	23:05:00-23:19:00	1 m		23:12:20-00:20:10				V12
	00:11:51-00:24:59	2 s		00:20:20-01:28:10				V05

Figure 1. HRI$_{EUV}$ field of view covered in the analyzed data sets

White boxes : SPICE slit

(3-step raster mode in data set 1; sit and stare mode in data set 2)

Blue arrows : positions of EUI brightenings

2-step data alignment (HRI$_{EUV}$ data & SPICE data):

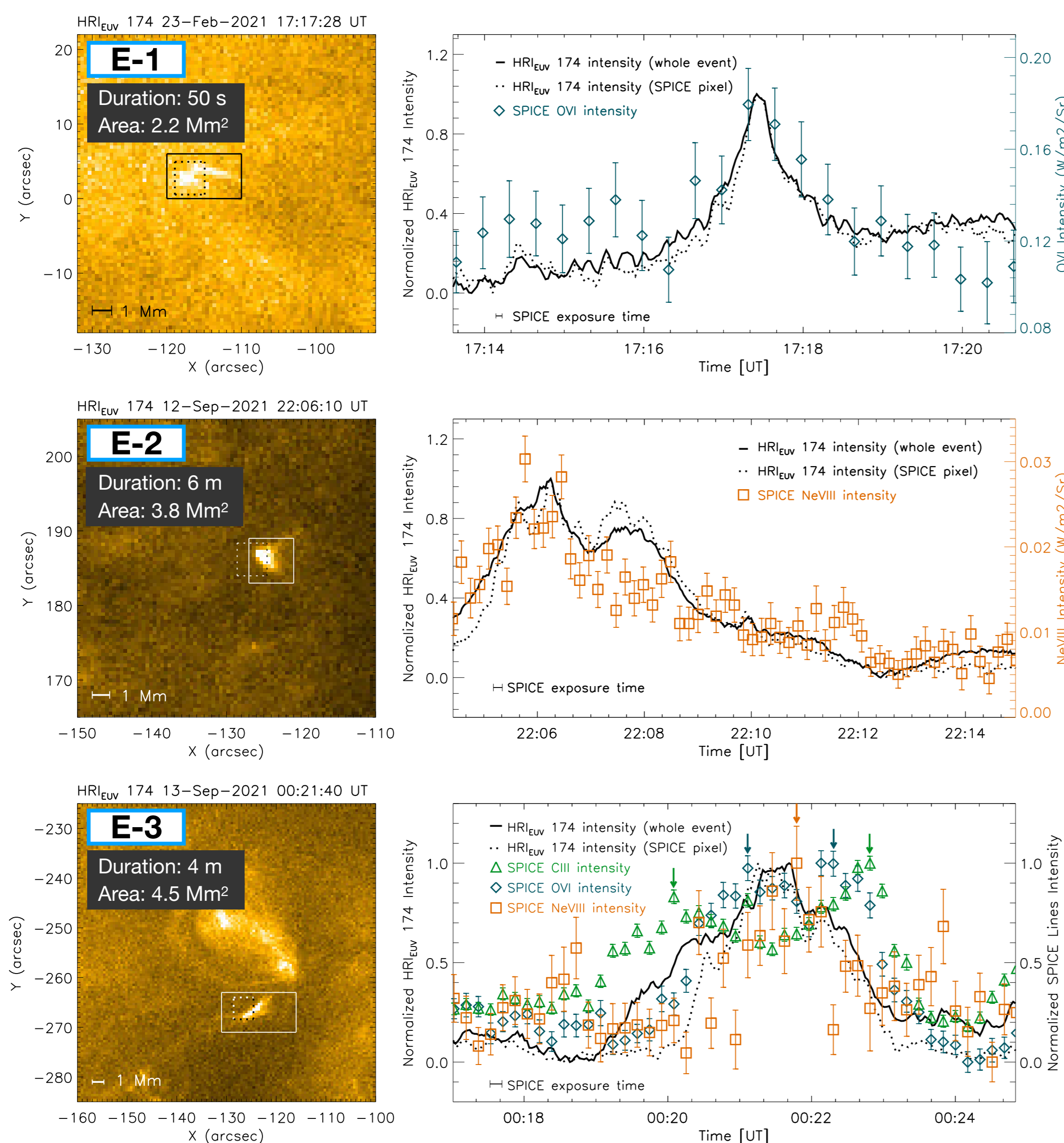(I) Manual coarse coalignment (II) Correlation of time-slice plots

RESULTS ■ ■ ■ ■

Figure 2. HRI$_{EUV}$ images and light curves

(HRI$_{EUV}$ intensities and integrated line radiances)

Dashed box : one SPICE-binned pixel

Solid box : whole event

Blue diamonds : O VI

Orange squares : Ne VIII

Green triangles : C III

E-1 — Duration: 50 s, Area: 2.2 Mm²

E-2 — Duration: 6 m, Area: 3.8 Mm²

E-3 — Duration: 4 m, Area: 4.5 Mm²

■ The detection of these EUI brightenings is at the limit of the SPICE capabilities.

■ E-1 is only detectable in O VI (0.3 MK).

■ E-2 and E-3 (with longer lifetimes) are observed up to Ne VIII temperatures (0.6 MK). They are also detected in O VI (0.3 MK) and other TR lines.

■ In E-3, the EUI brightening emission in some TR lines shows two peaks around the peak time of the HRI$_{EUV}$ data and of Ne VIII, which may indicate its thermal evolution.

ERROR ANALYSIS ■ ■ ■ ■

The uncertainties of SPICE data (Level-2):

$$\Sigma_{cal}(\lambda) = \frac{1}{\alpha(\lambda)} \sqrt{\frac{F^2\alpha(\lambda)I_{cal}G}{n_u} + \frac{n_p}{n_u}\sigma_{read}^2 + \frac{n_p}{n_u}I_{dark}t}$$

$\alpha[DN/(W/m^2/sr/nm)]$ calibration factor

Photon noise   Readout noise   Dark noise   *n_p, n_u are binning numbers

Table 2. Error estimate parameters

	F	G(DN/phot)	σ_{read}(DN)	I_{dark}(DN/s)
SW	1	3.58	6.9	0.89
LW	1.6	0.57	6.9	0.54

F : intensifier noise factor

G : camera conversion gain

σ_{read} : readout noise

I_{dark} : dark current

Figure 3. Noise estimation test with unbinned SW/LW data

*full detector observation using the wide 30″ slot

2D histogram :

standard deviation over 3x3 boxes

orange :

median of the standard deviation

black : calculated uncertainty

blue : data number density

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