

Determining coronal bright point size via cross-correlation using multi-wavelength images from AIA/*SDO*

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ABSTRACT

Subject headings: Sun: corona-Sun: bright points-

1. Introduction

It is currently thought that after magnetic flux tubes rise from the tachocline of the sun (between the convection and radiative zones) to the photosphere, they are moved across the photosphere by the process of advection to the junctions between supergranules (source?) and are observed as bright points (BPs). Though they only cover about 1.6 % of the photosphere (Srivastava & Dwivedi (2010)), BPs (together with sunspots) contribute over 90% of the total magnetic flux (Howard & Stenflo (1972)). Over the course of the solar cycle, they can contribute significantly to the global intensity variation of the sun, particularly in the ultraviolet regime (Riethmüller et al. (2014)).

These BPs can be seen in the upper layers of the solar atmosphere in the form of coronal BPs. The cross-sectional area of these BPs is known to increase with height above the photosphere as the density decreases and temperature increases (source?).

Several techniques for determining the size of coronal BPs have been investigated in the literature. Alipour & Safari (2015) developed an algorithm to locate BPs in the corona, using size determined by intensity as part of the criteria for distinguishing BPs from other features, such as top-down views of coronal loops or nanoflares.

The goal for the project discussed in this Letter was to determine size in another way, using the cross-correlation between the pixels in and around

the visible area occupied by the BP. The data is described in § 2, the analysis is discussed in § 3, and conclusions are in § 5.

2. Data

This analysis was carried out using multi-wavelength data from AIA/*SDO* spanning one hour on June 1, 2012 from 13:00:00 to 13:59:59, at a cadence of 12 seconds. Each EUV passband corresponds to emission from different transitions of ion species in the corona, each of which takes place at different temperatures, and hence different heights, above the photosphere. The relevant values for each passband are given in table 1.

Wavel. [Å]	log(T) [K]	Ion
94	6.8	Fe XVIII
131	5.6, 7.0	Fe VIII, XXI
171	5.8	Fe IX
193	6.2, 7.3	Fe XII, XXIV
211	6.3	Fe XIV
304	4.7	He II
335	6.4	Fe XVI

Table 1: Characteristic temperatures corresponding to the wavelengths observed in emission in the solar corona (from Lemen et al. (2012)).

A grayscale image of the full disk at the beginning of the time series for each bandpass is shown in figure 1. A single BP from a coronal hole located in the full disk was selected for analysis. Grayscale images showing this BP in each

passband are shown in figure 2.

3. Analysis

The intensity of each BP as a function of radius gives a visual estimate of the size of the BP. For comparison, the intensity of the first image in each passband is plotted as a function of radial distance from the center pixel in figures 10 and 11.

For this project, the size was estimated by running a cross-correlation between a pixel roughly in the center of the BP and the remaining pixels over the 100×100 pixel² area through the full time series. The central pixel was arbitrarily determined by locating the brightest pixel in the center of the BP from the first image in the time series. The cross-correlation analysis helped to determine what parts of the feature were moving together as a single physical structure.

4. Results

Images illustrating the highest cross-correlation value of each pixel and the timelag corresponding to that correlation value are shown in figures 4 and 5. The correlation was cut off at 0.5 and rescaled to obtain a better illustration of the structure of the BP. These images are shown in figures 6 and 7.

As Alipour & Safari (2015) noted, the BP structure is most evident for the 131Å, 193Å, and 211Å images.

4.1. Variation in BP size with temperature

Even though the temperature of the corona increases with height from the transition region to wherever the corona actually ends (need source here), there is not necessarily a direct correlation between temperature and absolute height above the photosphere due to the variety of structures and overall inhomogeneity that exists in the solar atmosphere ([source](#)). However, the *relative* height between each bandpass for a given structure is possible to determine, and is relevant to this study.

4.2. Extra emission in 211Å

The 211Å data is particularly notable as it shows strong correlation values at two points to the right of where the BP appears visually in figure

1. This could be the result of a jet of light emitted from the main structure, or a possible indicator of the main structure splitting into several tubes at the height where the 211 Å emission is strongest. A movie showing all images from this wavelength (?) revealed a flash of emission around the 45th image, which matches the timelag at which the high correlation values occurred as shown in figure 9.

4.3. Crossing time

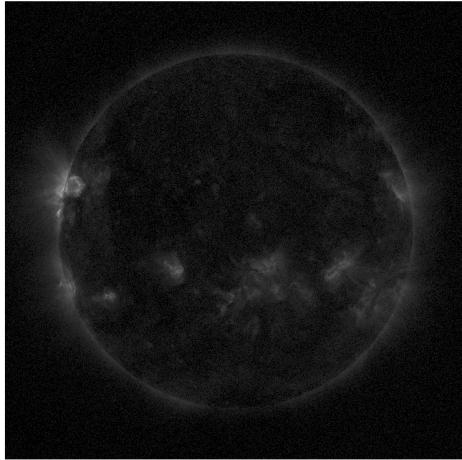
A test on this method can be done by using the derived size and the timelag across the BP to calculate a velocity. In the corona, this should be close to the Alfvén velocity, around 1000 km s^{-1} . (With a cadence of 12 seconds, do we have enough sampling to do this?)

5. Conclusion

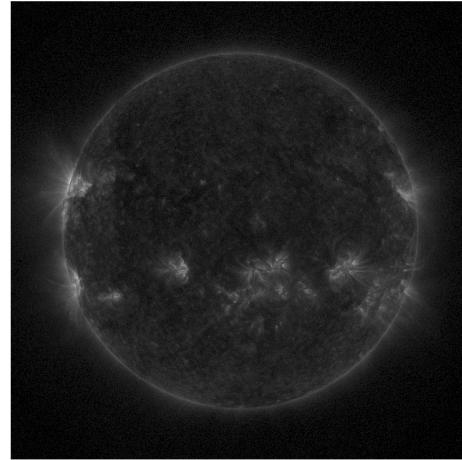
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Howard, R., & Stenflo, J. O. 1972, Sol. Phys., 22, 402
Lemen, J. R., Title, A. M., Akin, D. J., et al. 2012, Sol. Phys., 275, 17
Riethmüller, T. L., Solanki, S. K., Berdyugina, S. V., et al. 2014, A&A, 568, A13
Srivastava, A. K., & Dwivedi, B. N. 2010, MNRAS, 405, 2317

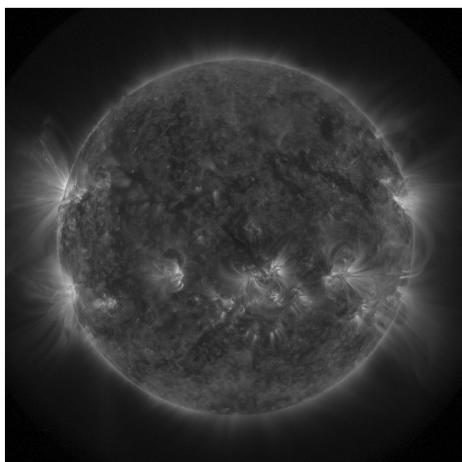
$\lambda = 94 \text{ \AA}, \log(T) = 6.8 \text{ K}$



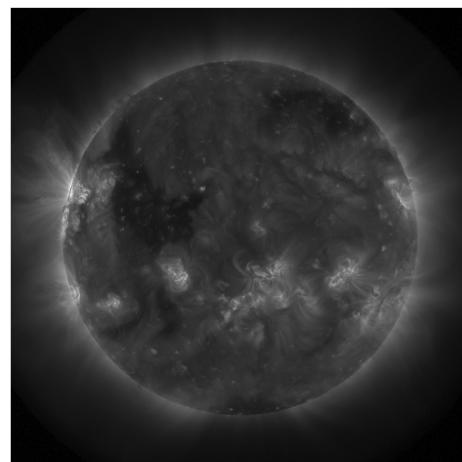
$\lambda = 131 \text{ \AA}, \log(T) = 5.6, 7.0 \text{ K}$



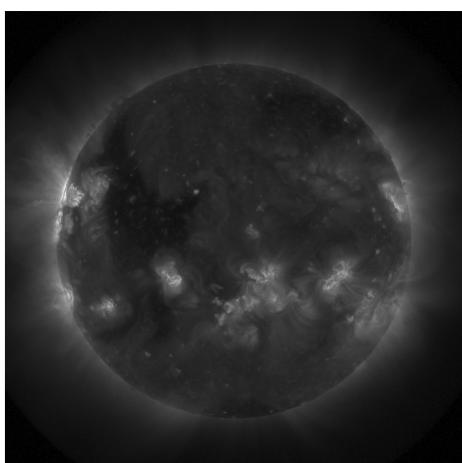
$\lambda = 171 \text{ \AA}, \log(T) = 5.8 \text{ K}$



$\lambda = 193 \text{ \AA}, \log(T) = 6.2, 7.3 \text{ K}$



$\lambda = 211 \text{ \AA}, \log(T) = 6.3 \text{ K}$



$\lambda = 304 \text{ \AA}, \log(T) = 4.7 \text{ K}$

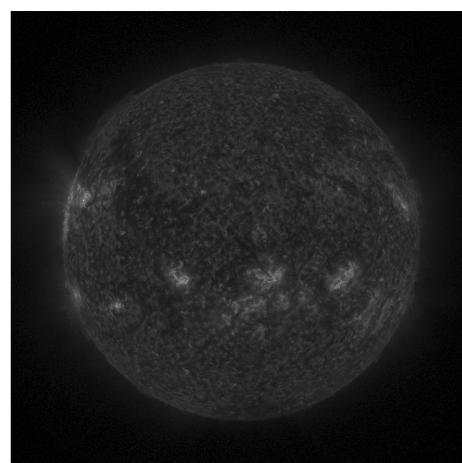


Fig. 1.— Full disk showing the relative intensity at the start of the time series for each AIA bandpass used in this study.

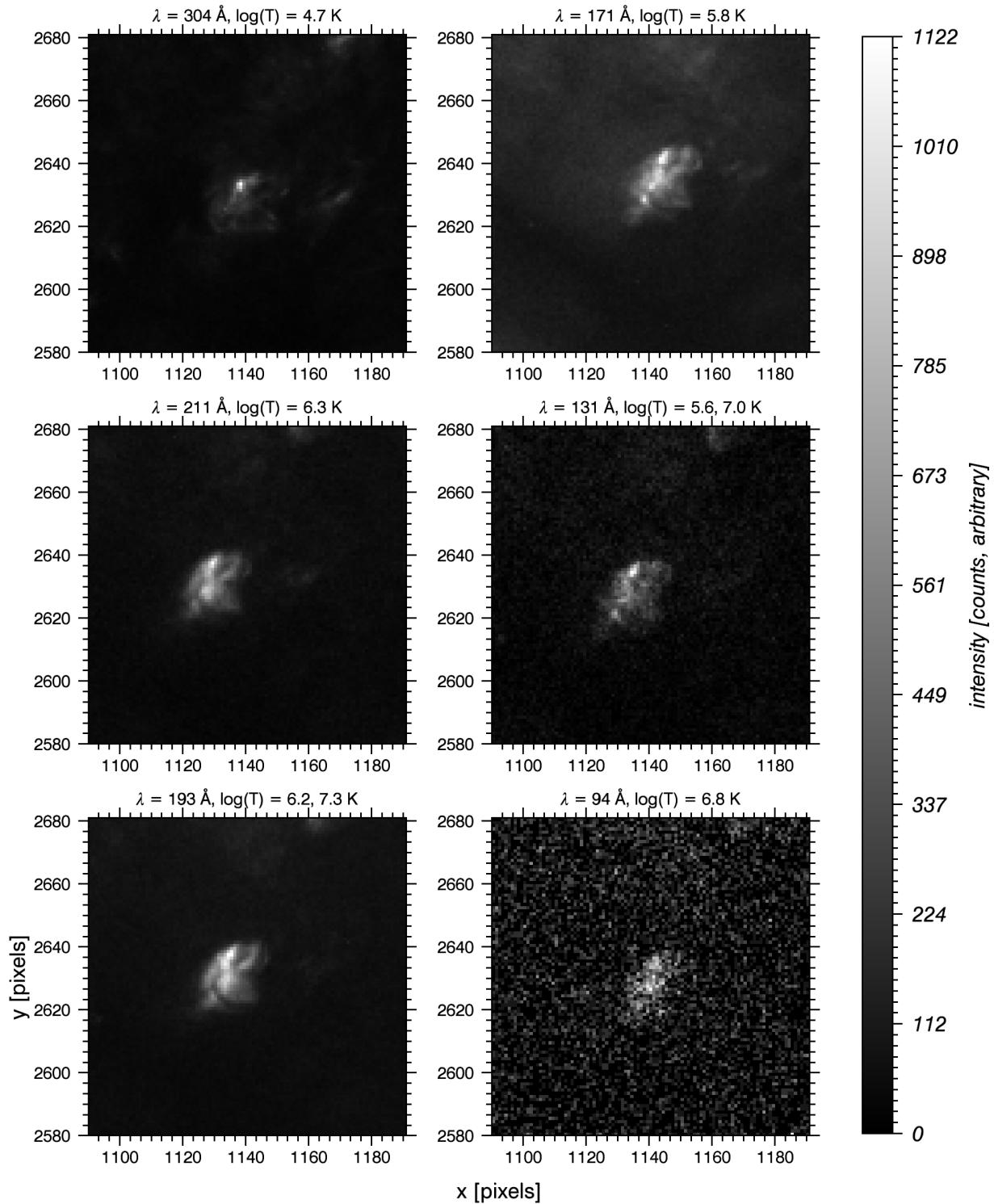


Fig. 2.— Images of the BP in six different AIA wavelengths. The pixel coordinates are given relative to the full disk shown in figure 1. The location of the BP appears to shift from one bandpass to next, which may indicate a structure that is not completely straight, or a possible shift in the data itself.

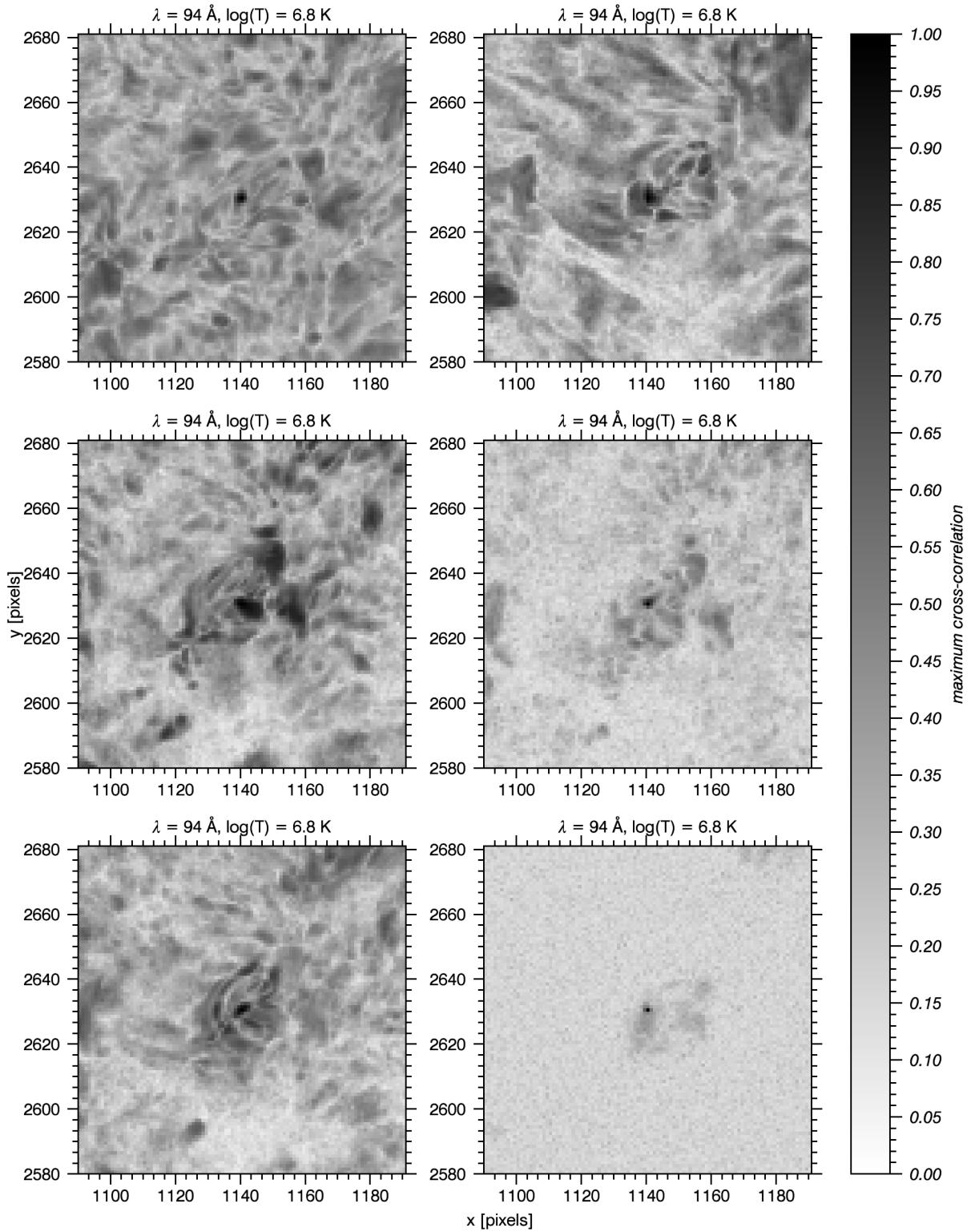


Fig. 3.— Images showing the highest cross-correlation value for each pixel.

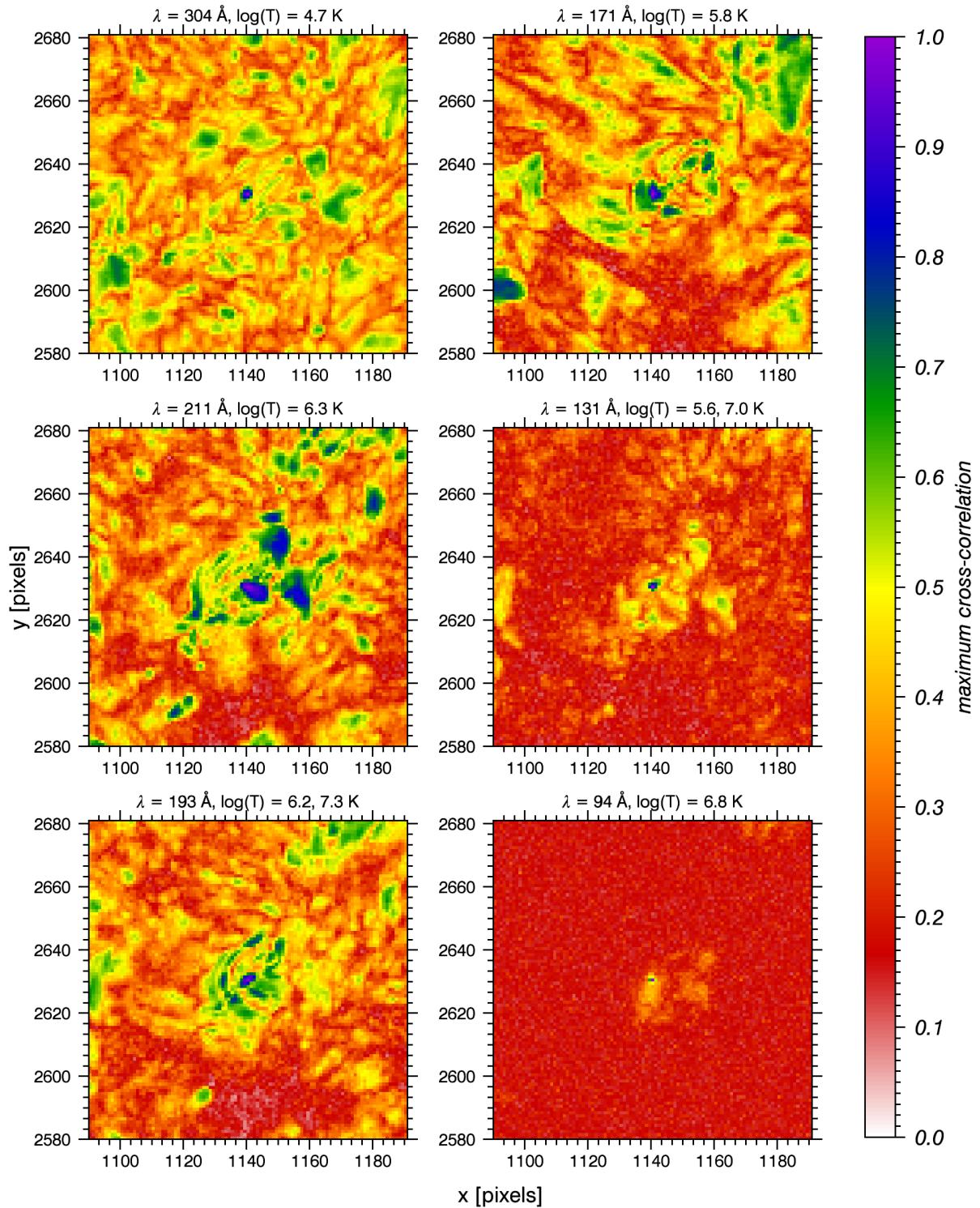


Fig. 4.— Color images showing the highest cross-correlation value for each pixel.

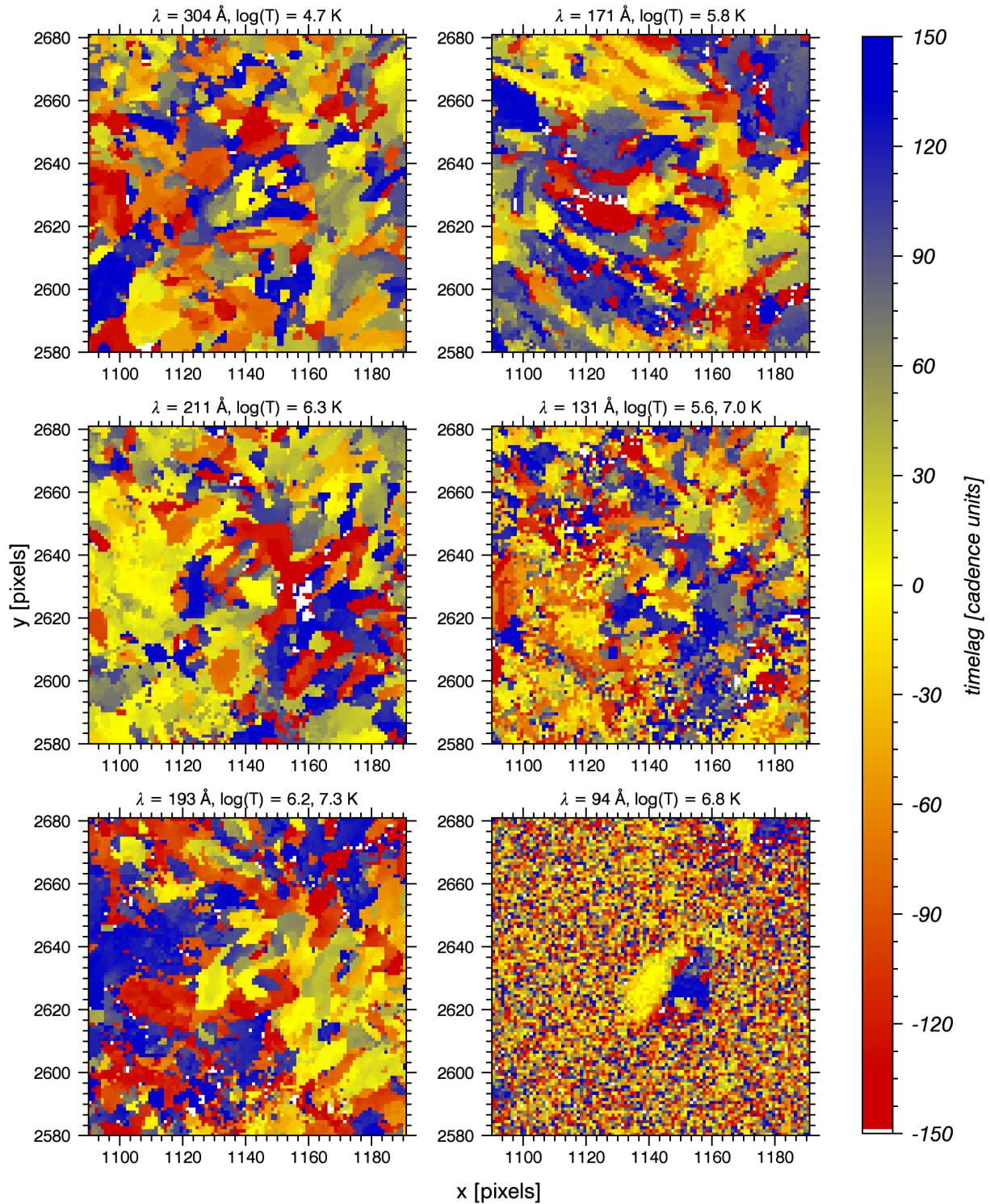


Fig. 5.— Images showing the timelag corresponding to the correlation values illustrated in figure 4.

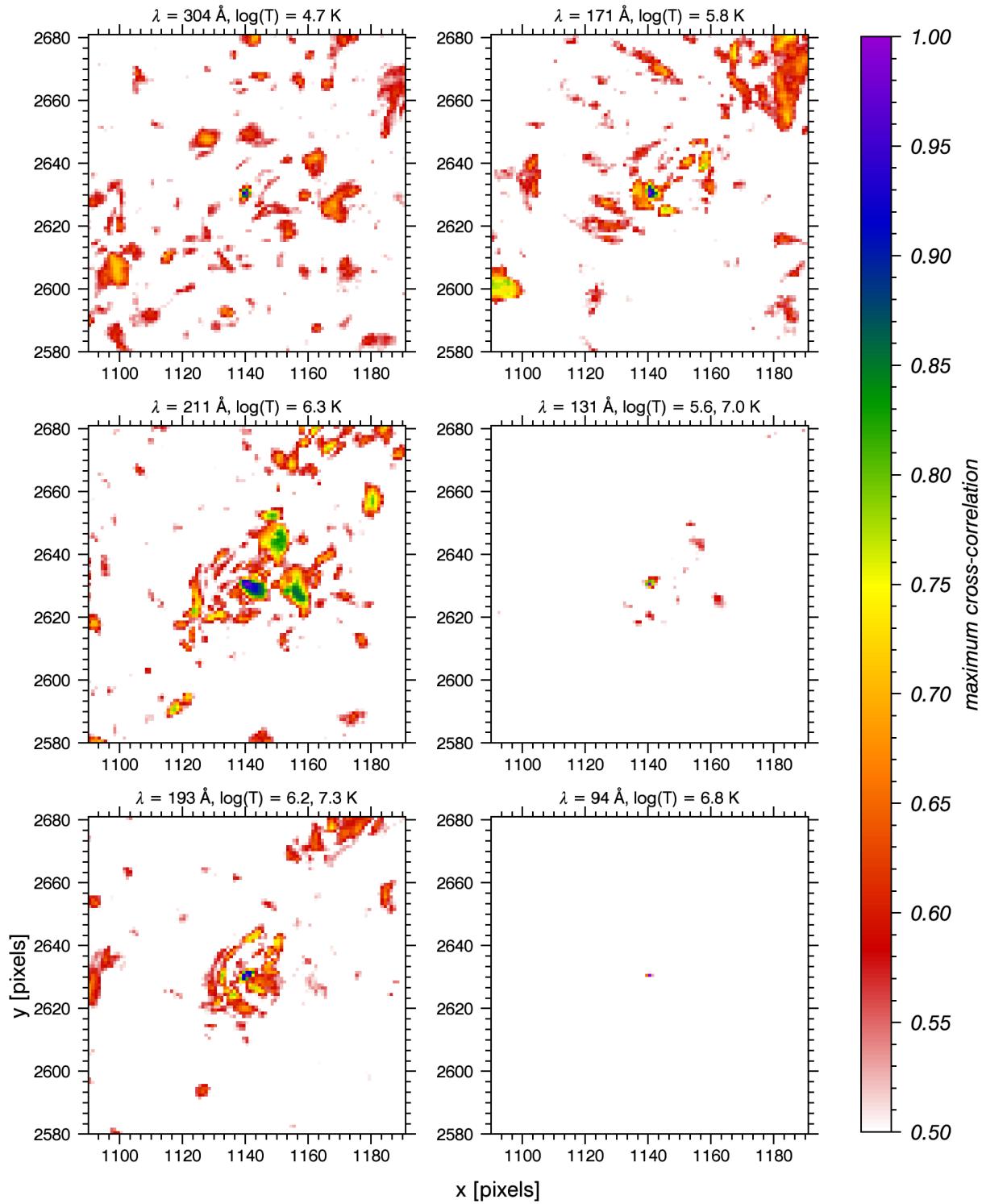


Fig. 6.— Cross-correlation images scaled to show only values higher than 0.5.

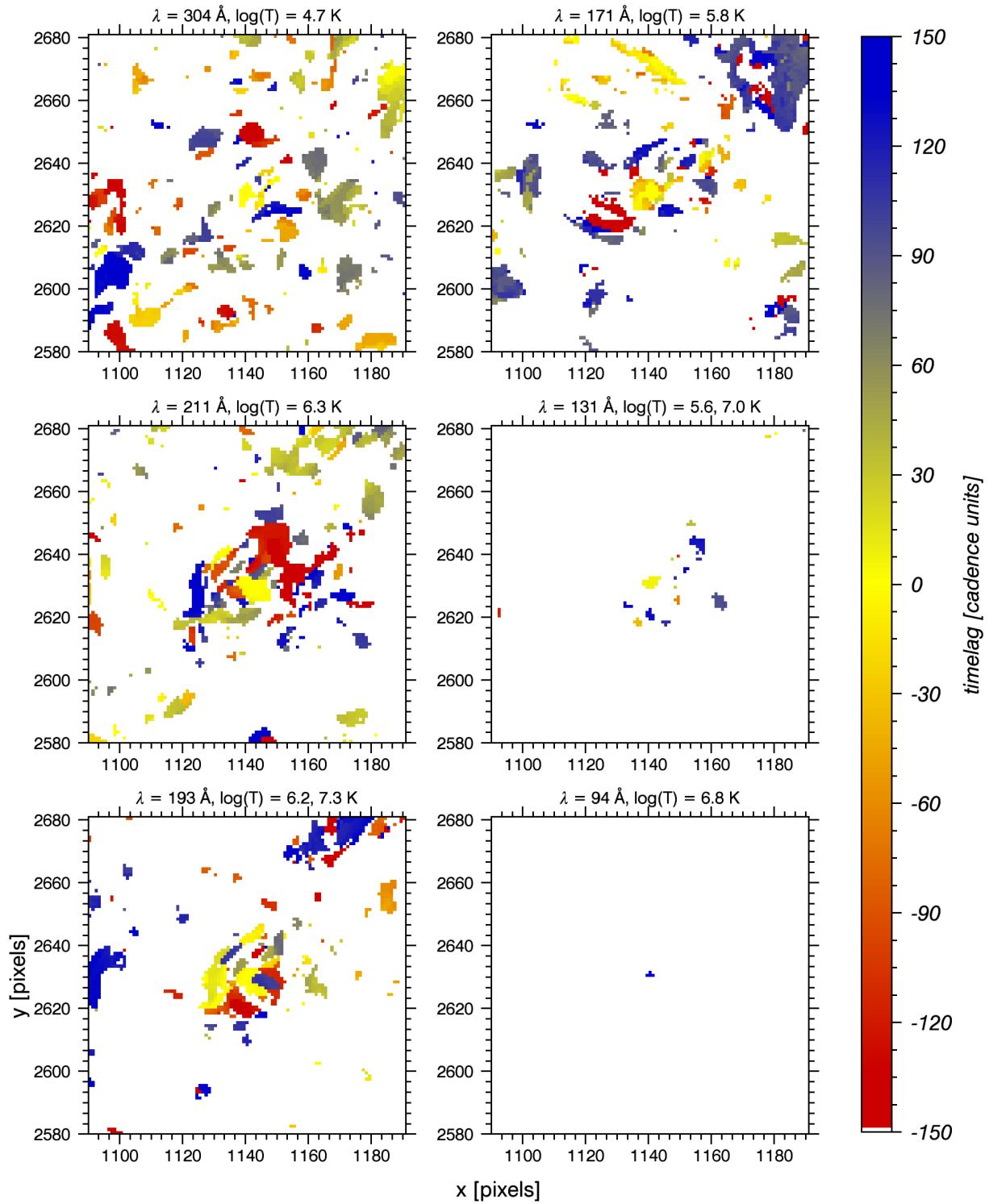


Fig. 7.— Timelag corresponding to the cross-correlation values higher than 0.5.

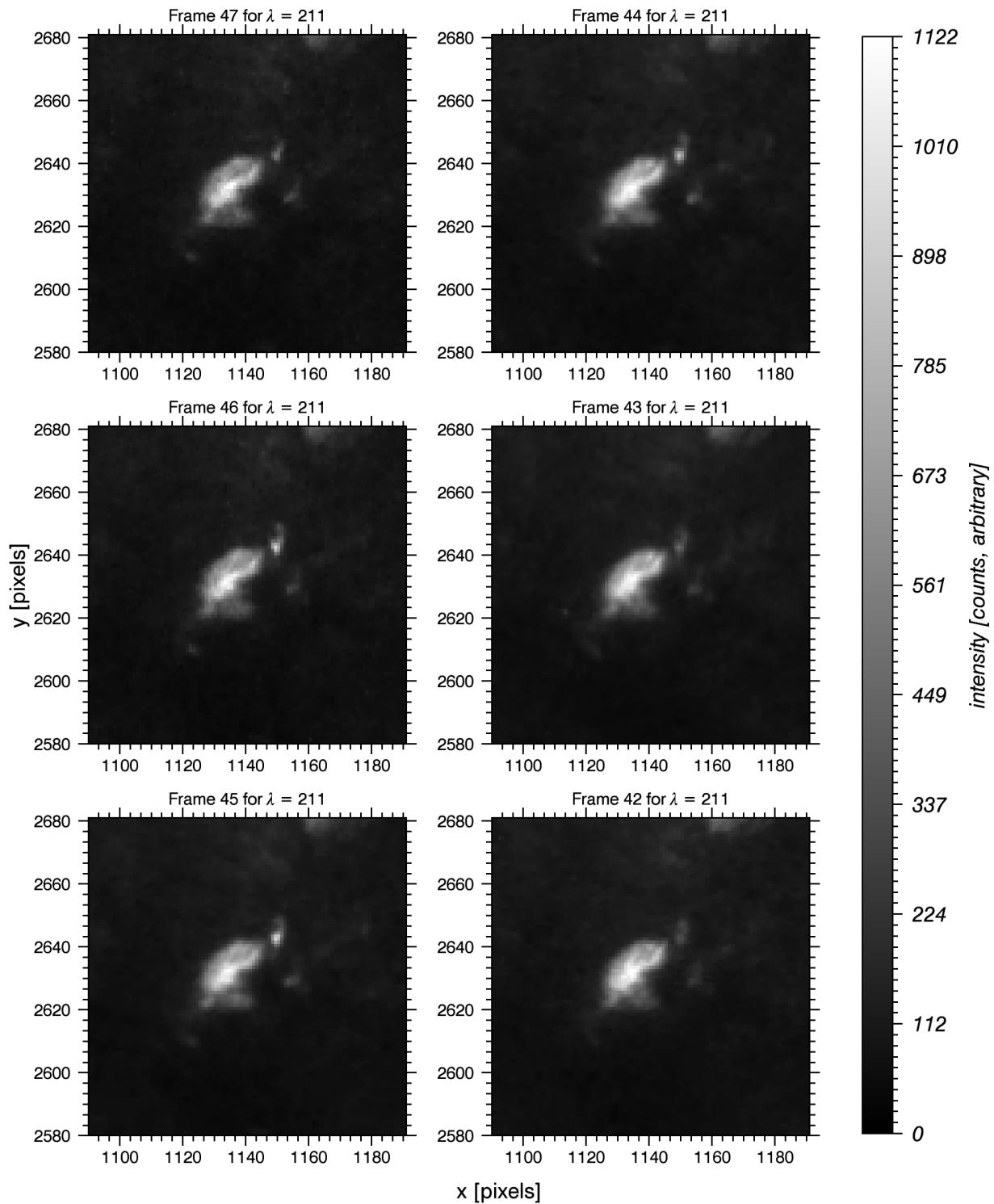


Fig. 8.— Images from the 211 Å bandpass only, around the times when the two jets of light appeared in the upper right region of the main body of the BP.

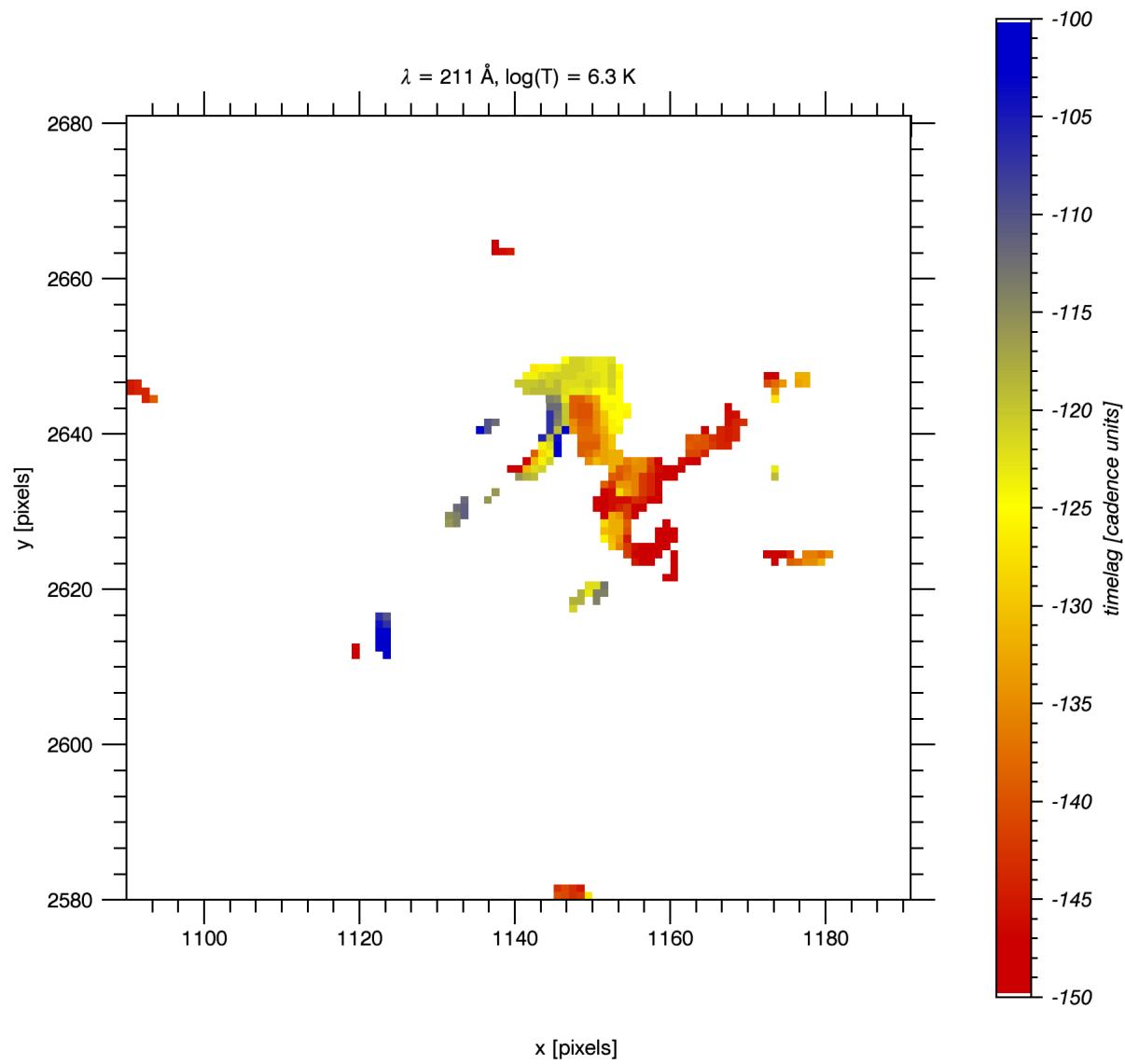


Fig. 9.— Timelag at 211 Å “zoomed in” around the two jets of light.

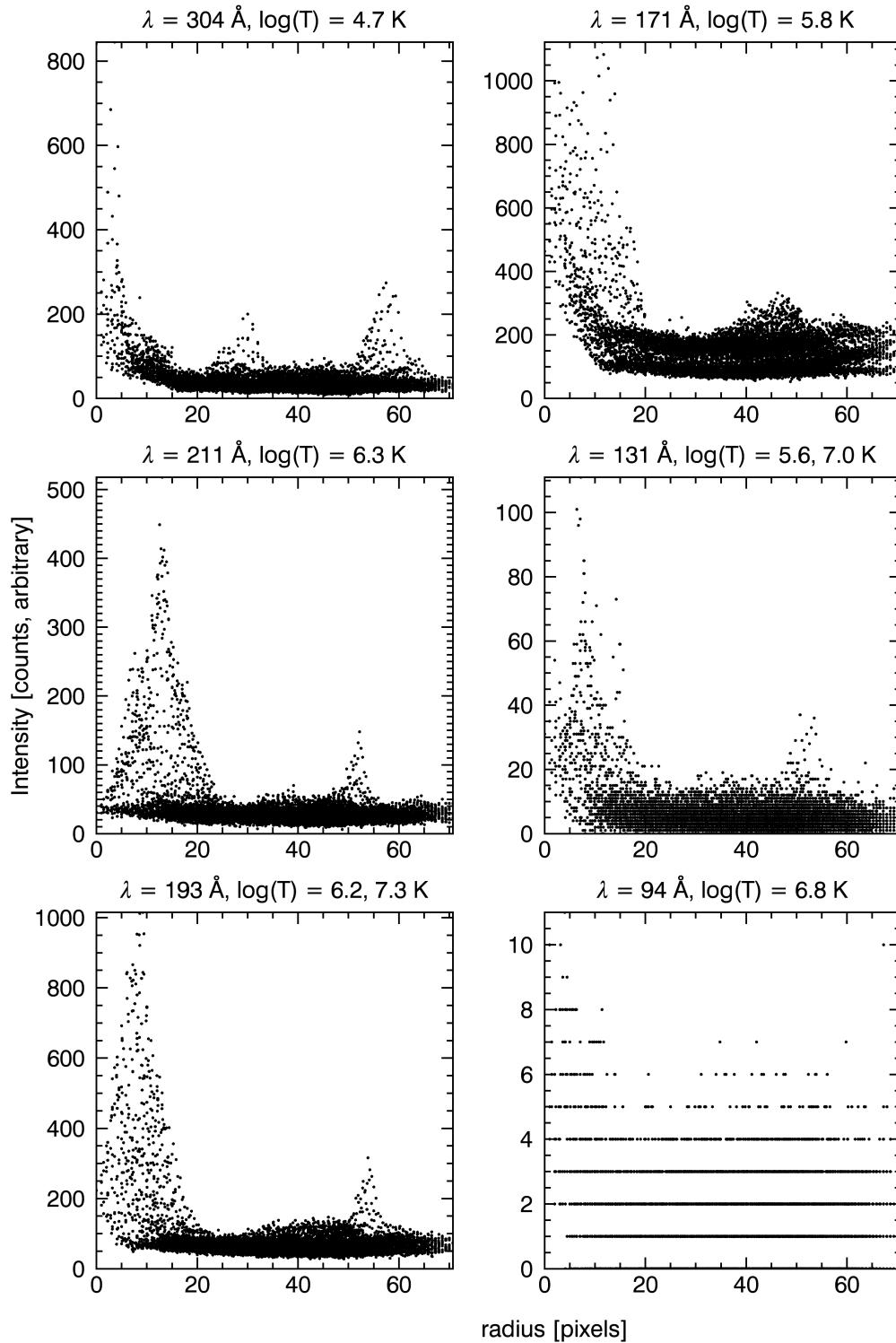


Fig. 10.— Intensity of each pixel is plotted as a function of radius for each passband. I have no idea what's going on with the 94 \AA data.

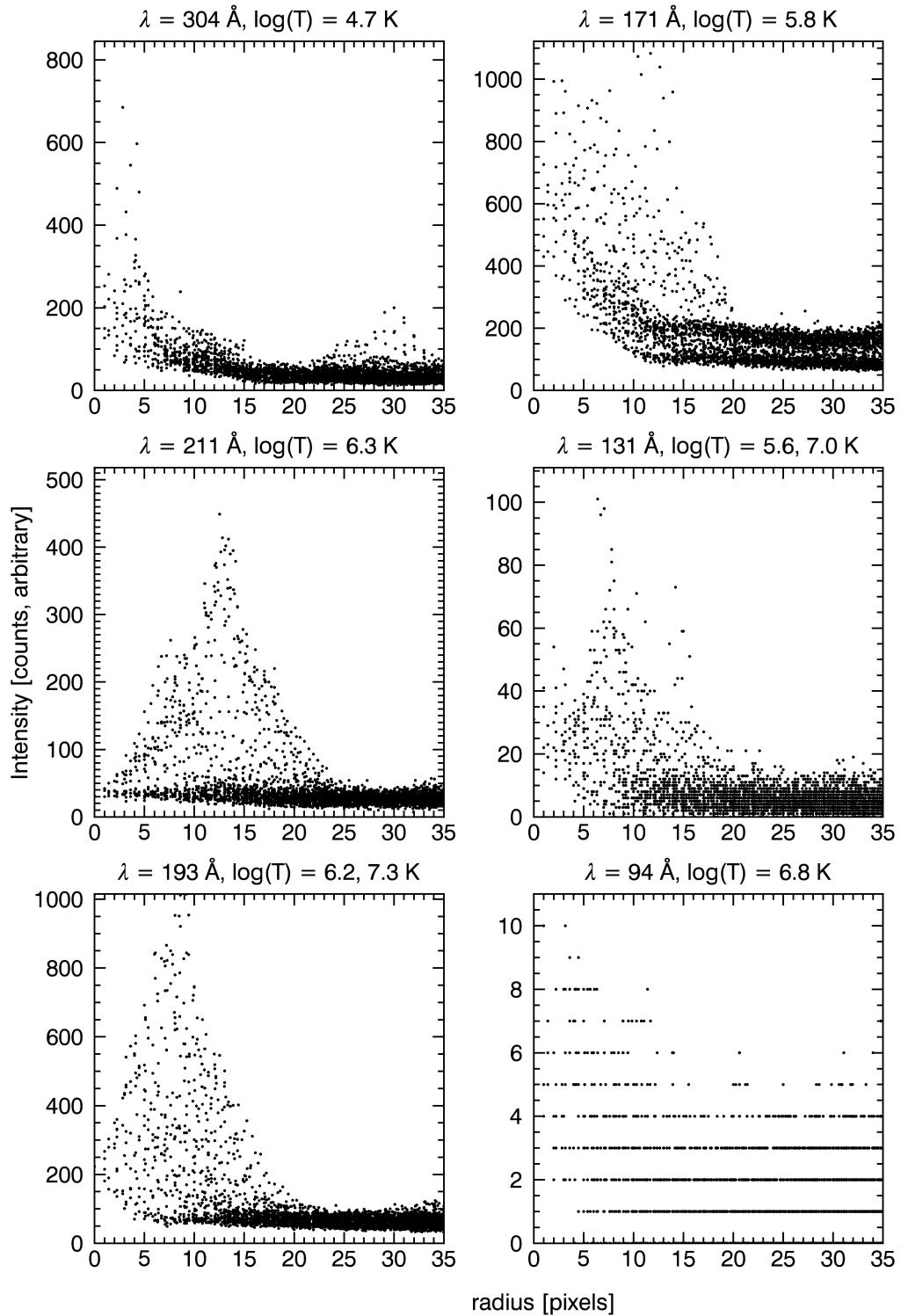


Fig. 11.— Same as figure 10, but with half the radius range cut off to better view the values around the main BP.

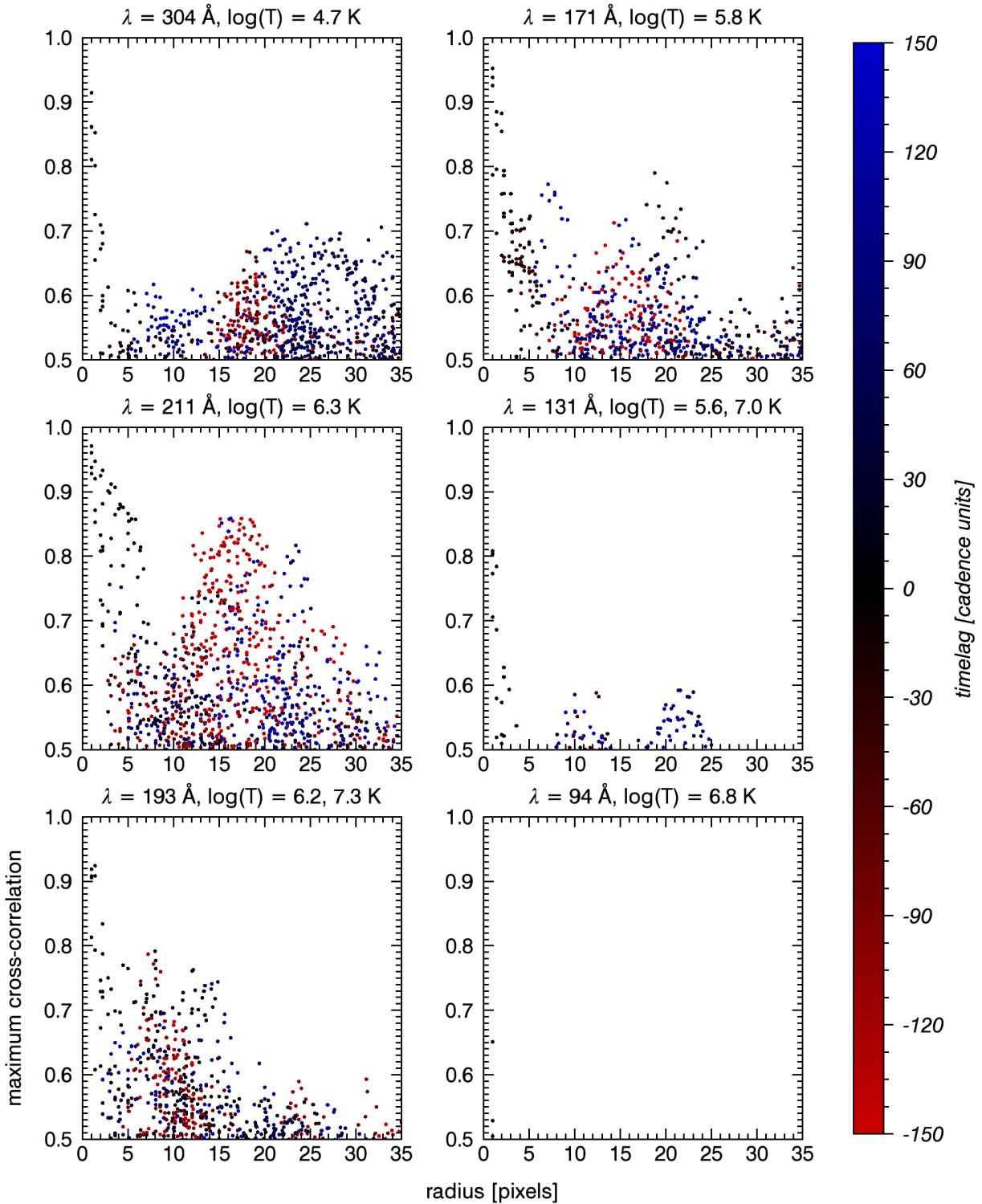


Fig. 12.— The highest cross-correlation value of each pixel is plotted as a function of its distance from the center pixel. The color indicates the timelag corresponding to the maximum cross-correlation for that pixel.

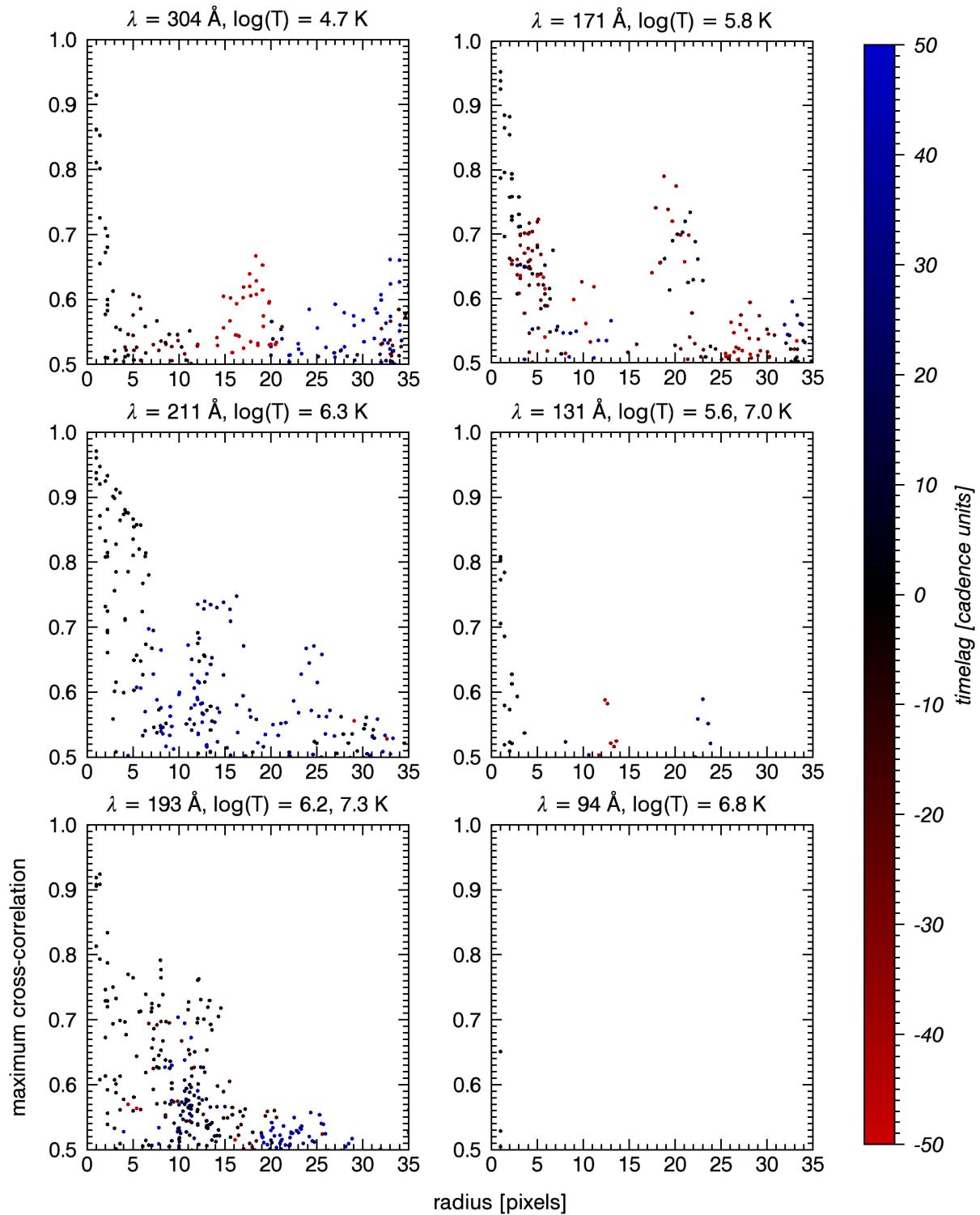


Fig. 13.— Same as figure 12, but with two thirds of the timelag cut out at both ends.