

# Description of Keck HIRES data reduction steps

William J. Henney

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## ABSTRACT

Material that may get included in a paper. Describes the data reduction steps carried out for the Keck HIRES spectra of the Orion proplyds. Basic reduction steps: order extraction, wavelength calibration, detilting, de-overlapping, flat-fielding. Decomposition into continuum plus line. Deconvolution of fine-structure multiplets. Decomposition of line into sky plus nebula plus proplyd. Sample results for slit p84 from the giant proplyd 244-440.

## 1 BASIC REDUCTION

With `mhchem` package:  $\text{O}^{2+} 2s^2 2p^2 \text{D}_2 \longrightarrow 2s^2 2p^2 \text{P}_{0,1,2}$   
 With normal math commands:  
 $\text{O}^{2+} 2s^2 2p^2 \text{D}_2 \rightarrow 2s^2 2p^2 \text{P}_{0,1,2}$

## 2 DECOMPOSITION

### 2.1 Continuum subtraction

We fit the continuum and subtract it.

### 2.2 Deconvolution of multiplets

For the O I lines

### 2.3 Nebular subtraction

## 3 SAMPLE RESULTS: 244-440 SLIT 84

### 3.1 High-ionization lines

#### 3.1.1 [O III] forbidden lines

The only [O III] lines that fall in the wavelength range of our observations are the three components of the  $^1\text{D}-^3\text{P}$  5007, 4959, and 4931 multiplet is the only one that is detected, with theoretical relative intensities 1:0.34:0.00013. Only the 5007 component is shown in Figure 2. The 4959 component shows identical structure, while the very weak 4931 component is barely detected.

The line is very strong from the nebula (X times H b) but significantly weaker from the proplyd (Y times Hb). As a result the proplyd contrast against the underlying nebula line is only 10–20%. Nonetheless, the very high S/N allows a reliable separation of the proplyd and nebula contributions, as shown in the right column of Figure 2. The proplyd emission separates into blue and red components peaking at  $V_{\text{prop}} = -19$  and  $+15$  km/s in the proplyd reference frame. The red component is about 3 times weaker and more compact and shows a larger mean spatial shift of 2 arcsec from the proplyd center, as opposed to 1 arcsec for the blue component.

It is 200 times weaker than [O III] 5007 and is a similar intensity to the adjacent continuum. However, the proplyd shows a contrast of about 100% with respect to the nebula, which again allows for a reliable separation. The proplyd emission is extremely similar to that of [O III].

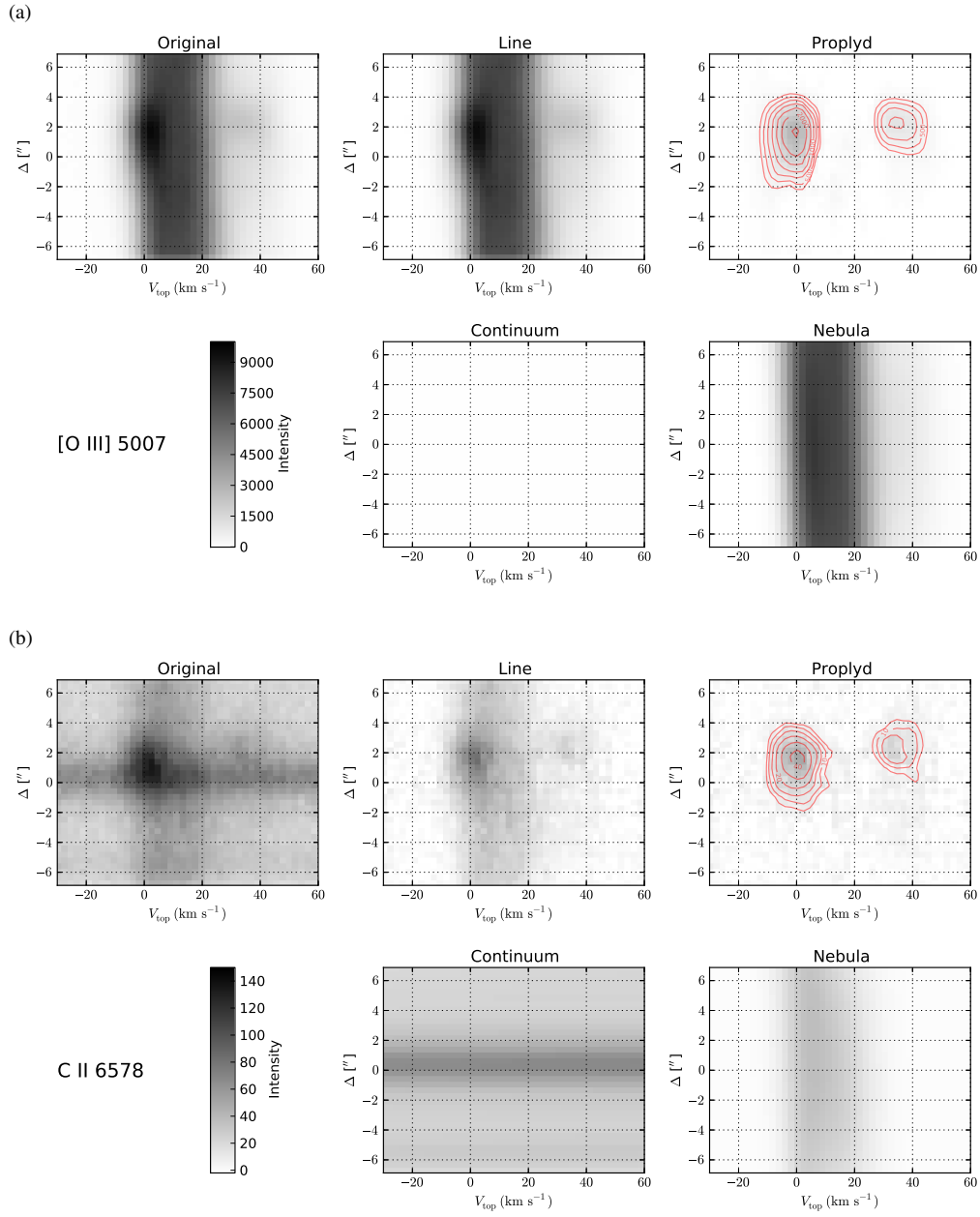
It is an important question whether the apparent complete lack of emission around the proplyd systemic velocity is real or whether it is an artifact induced by extinction of background nebular emission by the proplyd. Henney & O’Dell (1999) discuss this issue in detail and show that an effective proplyd extinction as low as  $A_V = 0.2$  would be enough to fill-in this missing emission. However, there are two reasons to believe that this does not occur in 244-440. First, the two-dimensional line profile would appear very unnatural, since the extra emission would appear at spatial positions in the core of the proplyd, rather than displaced along the slit, where the peak of the high ionization emission occurs. Secondly, the same amount of proplyd extinction would have a much smaller effect on C II than it would on [O III].

The conclusion is that in 244-440 is not affected by internal extinction of the nebular emission. This implies that either the extended neutral core of the proplyd is optically thin at visual wavelengths or that the majority of the nebular emission arises from gas that is foreground to the proplyd. This is consistent with the kinematic profile of this proplyd, which suggests that it is seen head-on and therefore lies behind its ionizing source.

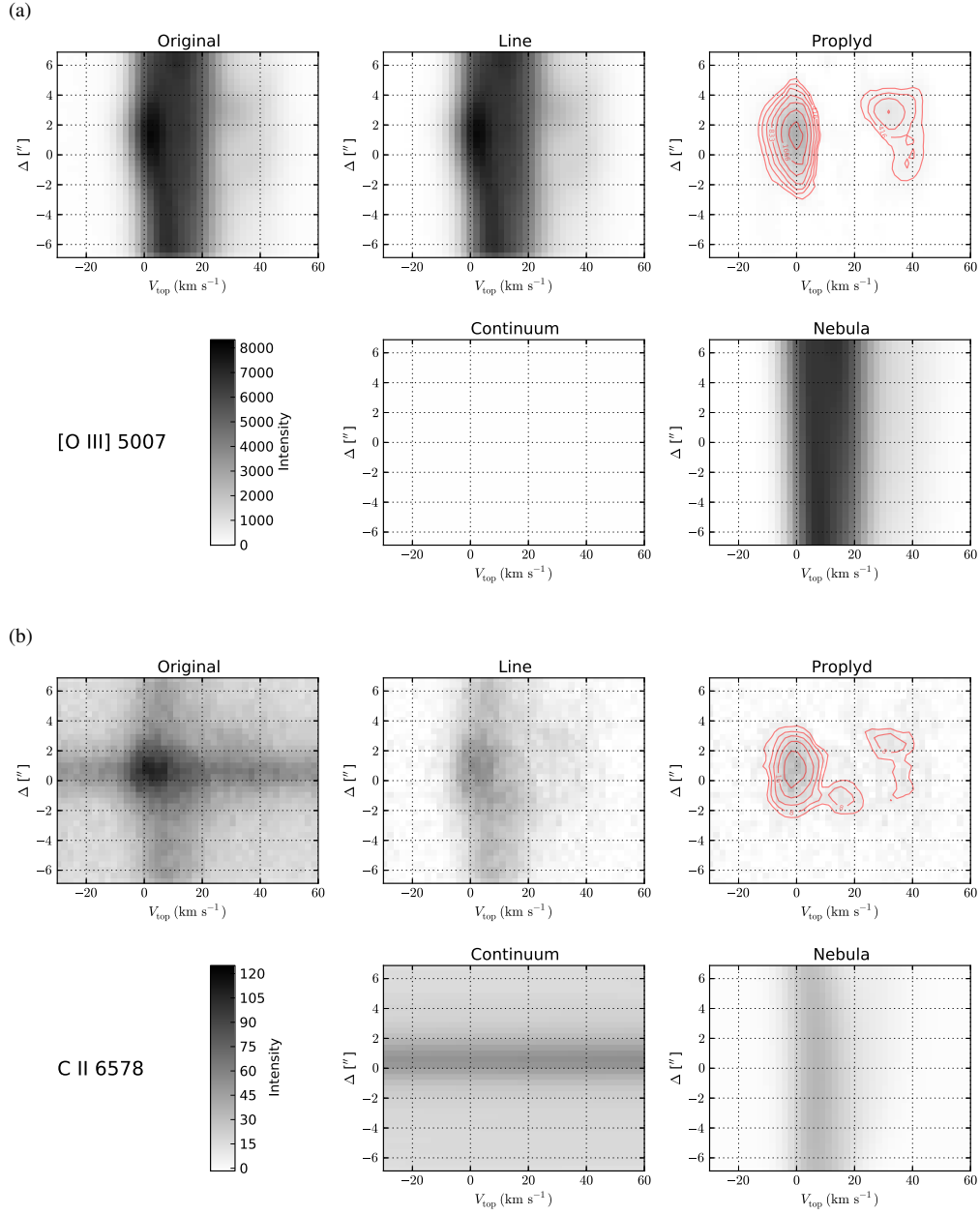
### 3.2 Moderate-ionization lines

#### 3.1.2 C II permitted line

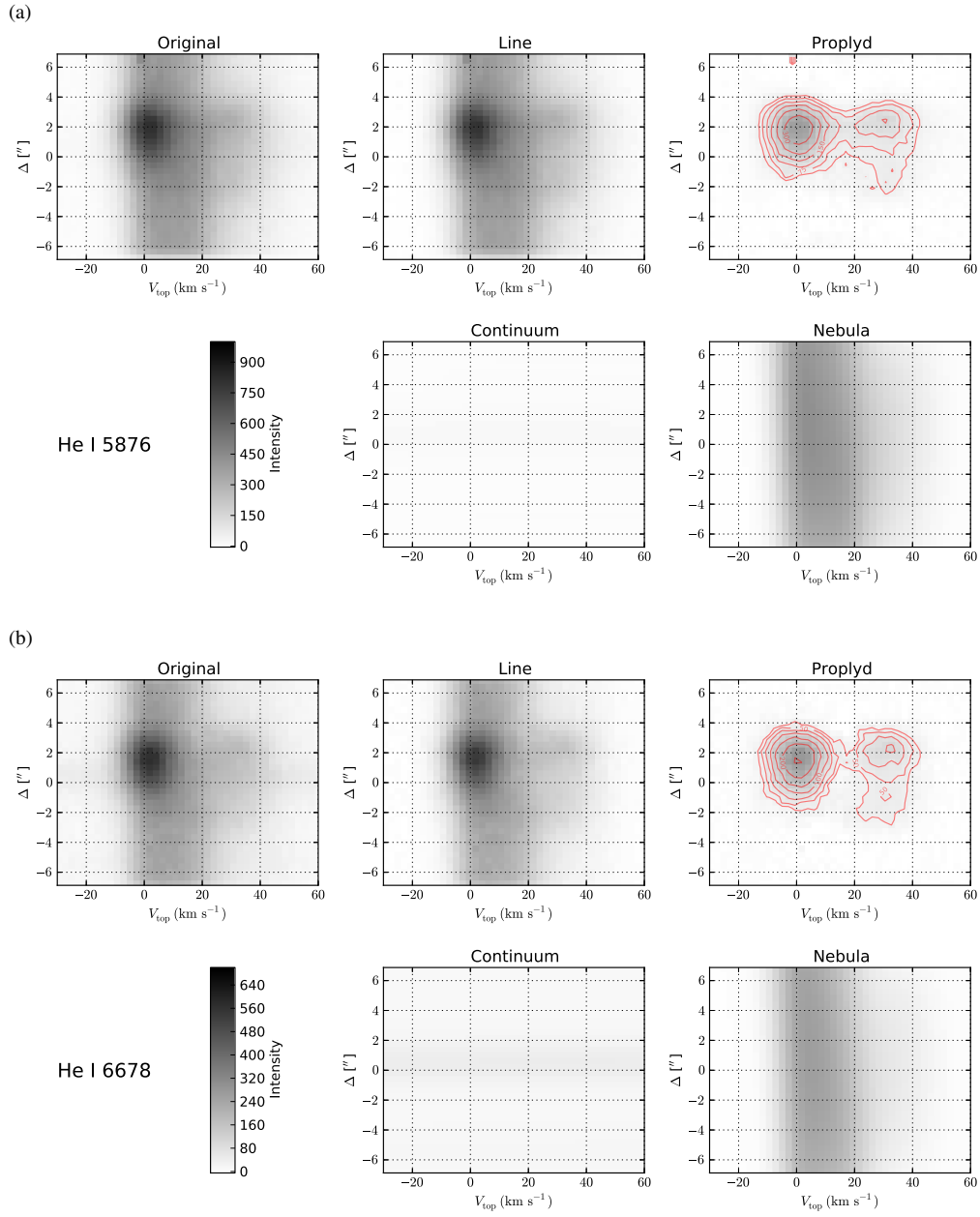
This line is produced from the recombination of  $\text{C}^{2+}$ .



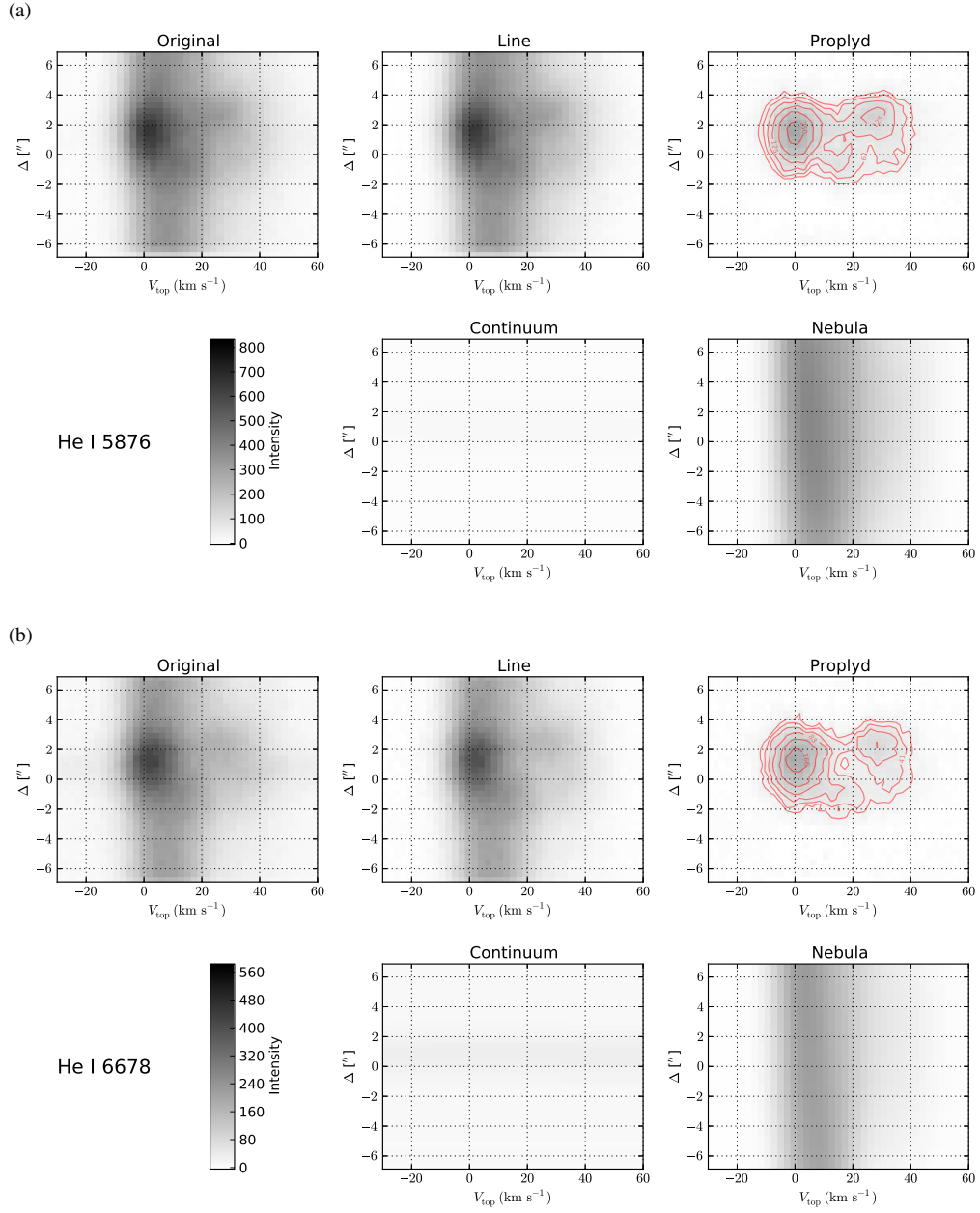
**Figure 1.** (a) Collisionally excited forbidden line of doubly ionized oxygen: [O III]  $\lambda$ 5007. (b) Recombination line of singly ionized carbon: C II  $\lambda$ 6578



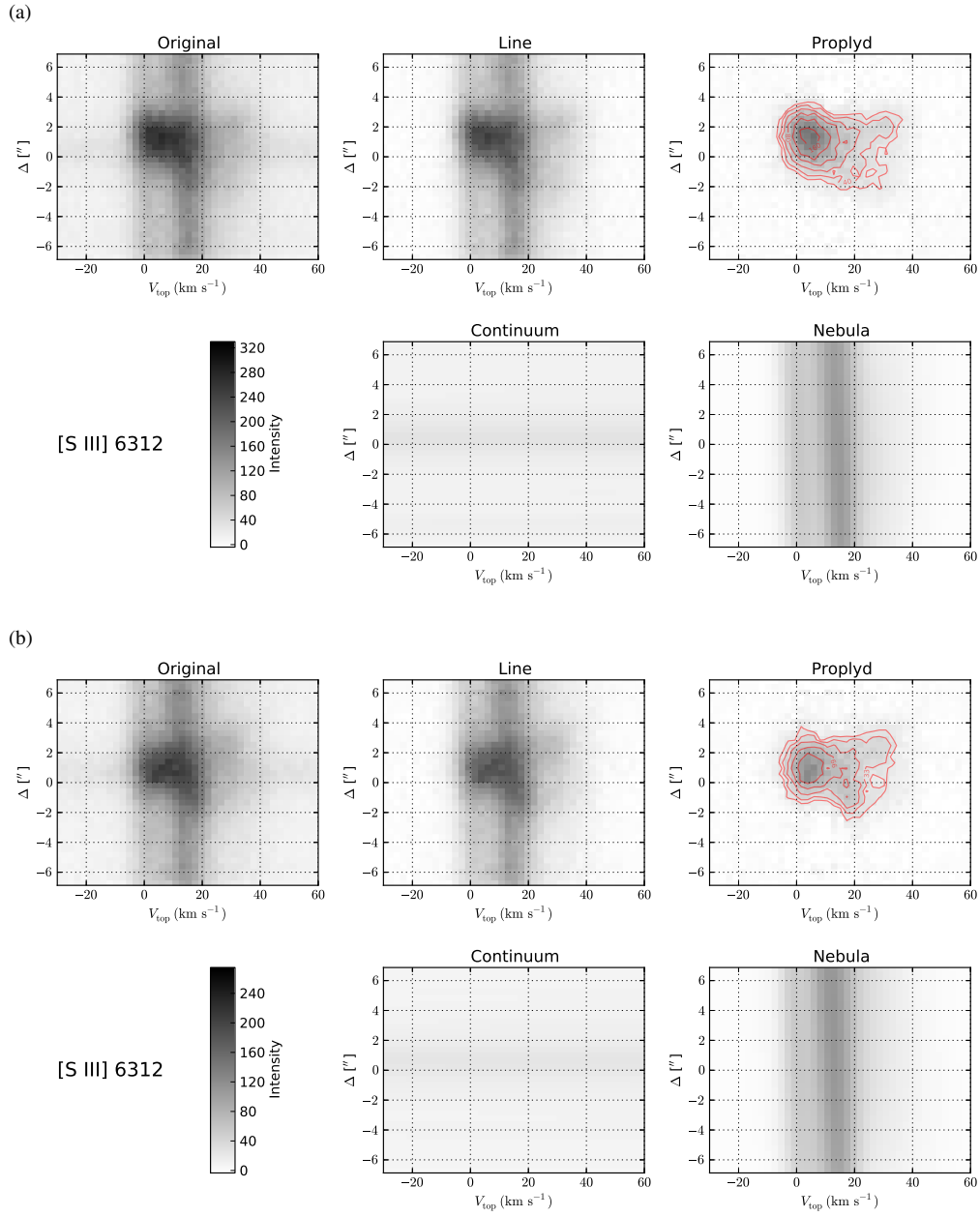
**Figure 2.** (a) Collisionally excited forbidden line of doubly ionized oxygen: [O III]  $\lambda$ 5007. (b) Recombination line of singly ionized carbon: C II  $\lambda$ 6578



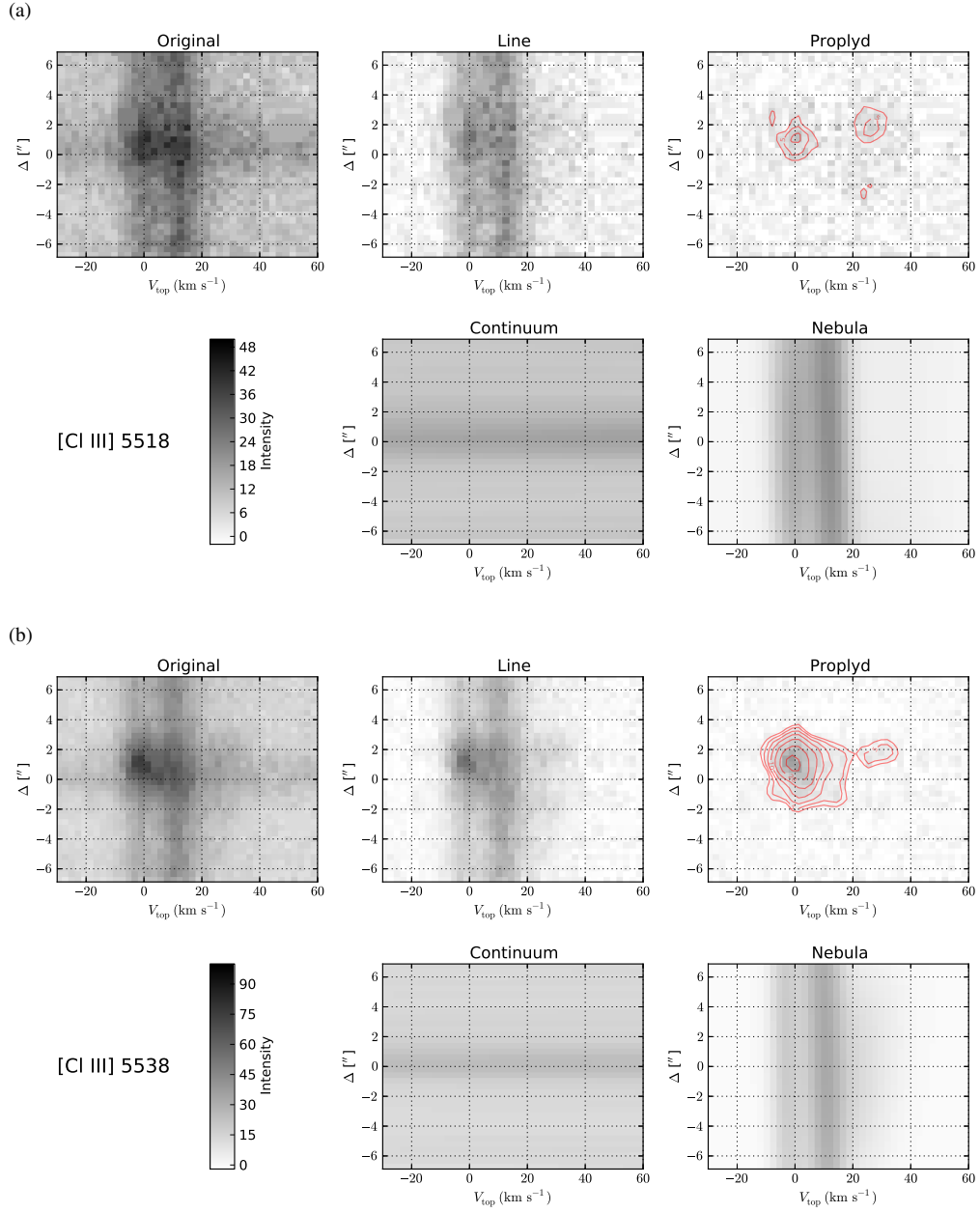
**Figure 3.** Recombination lines of neutral helium: (a) He I  $\lambda$ 5876 triplet; (b) He I  $\lambda$ 6678 singlet.



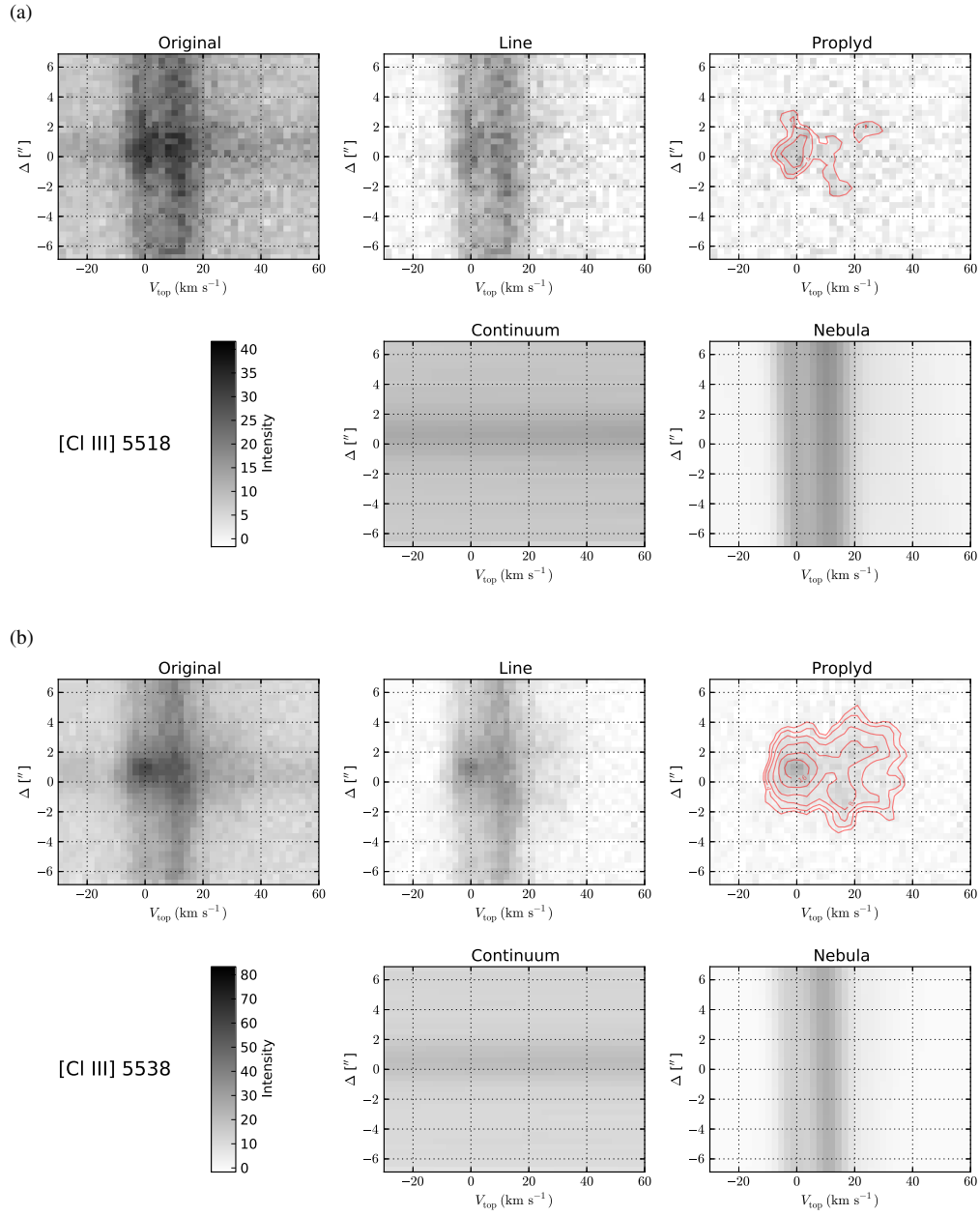
**Figure 4.** Recombination lines of neutral helium: (a) He I  $\lambda 5876$  triplet; (b) He I  $\lambda 6678$  singlet.



**Figure 5.** Collisionally excited line of doubly ionized sulfur: [S III]  $\lambda 6312$ .



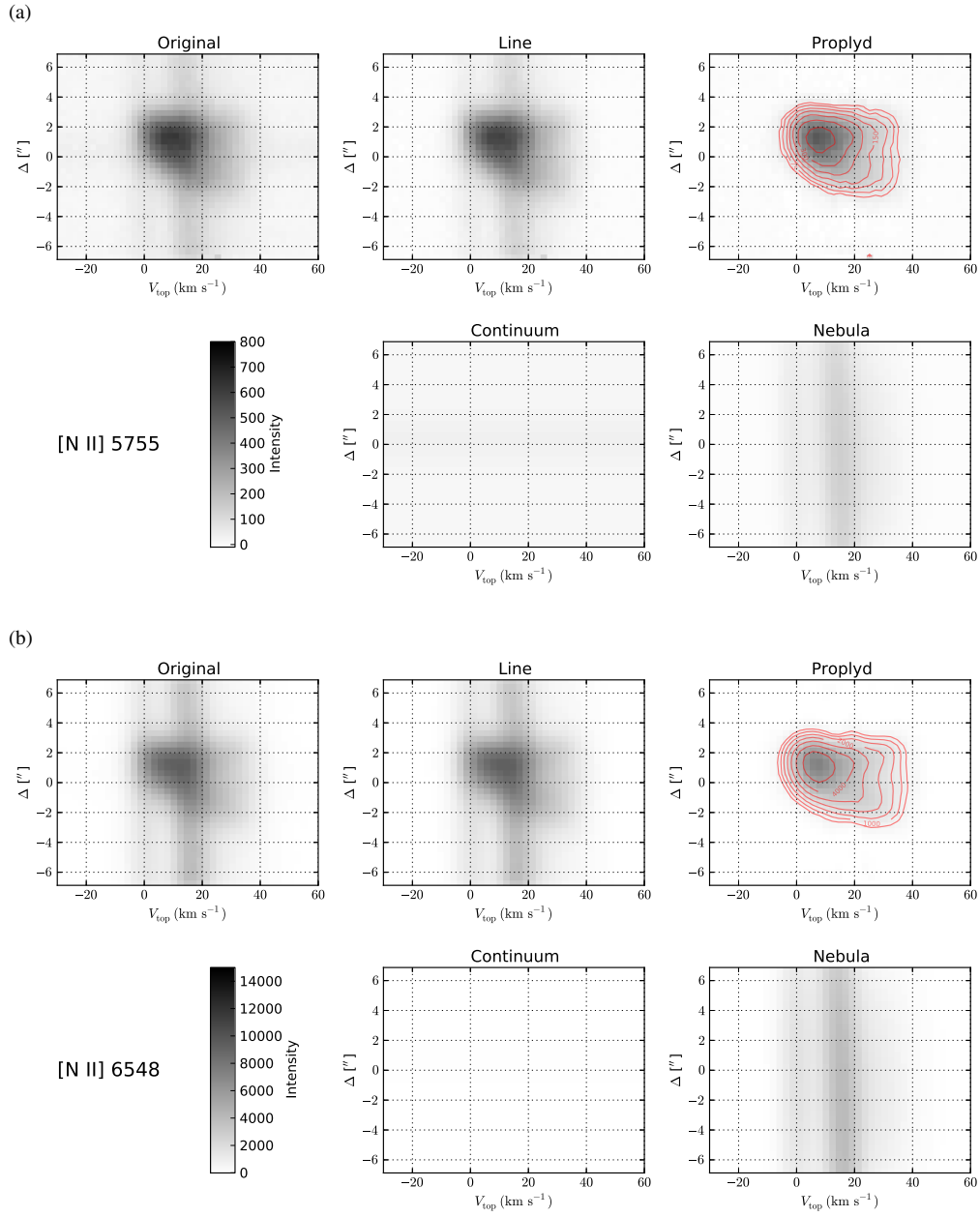
**Figure 6.** Collisionally excited lines of doubly ionized chlorine: (a) [Cl III]  $\lambda 5518$ ; (b) [Cl III]  $\lambda 5538$ .



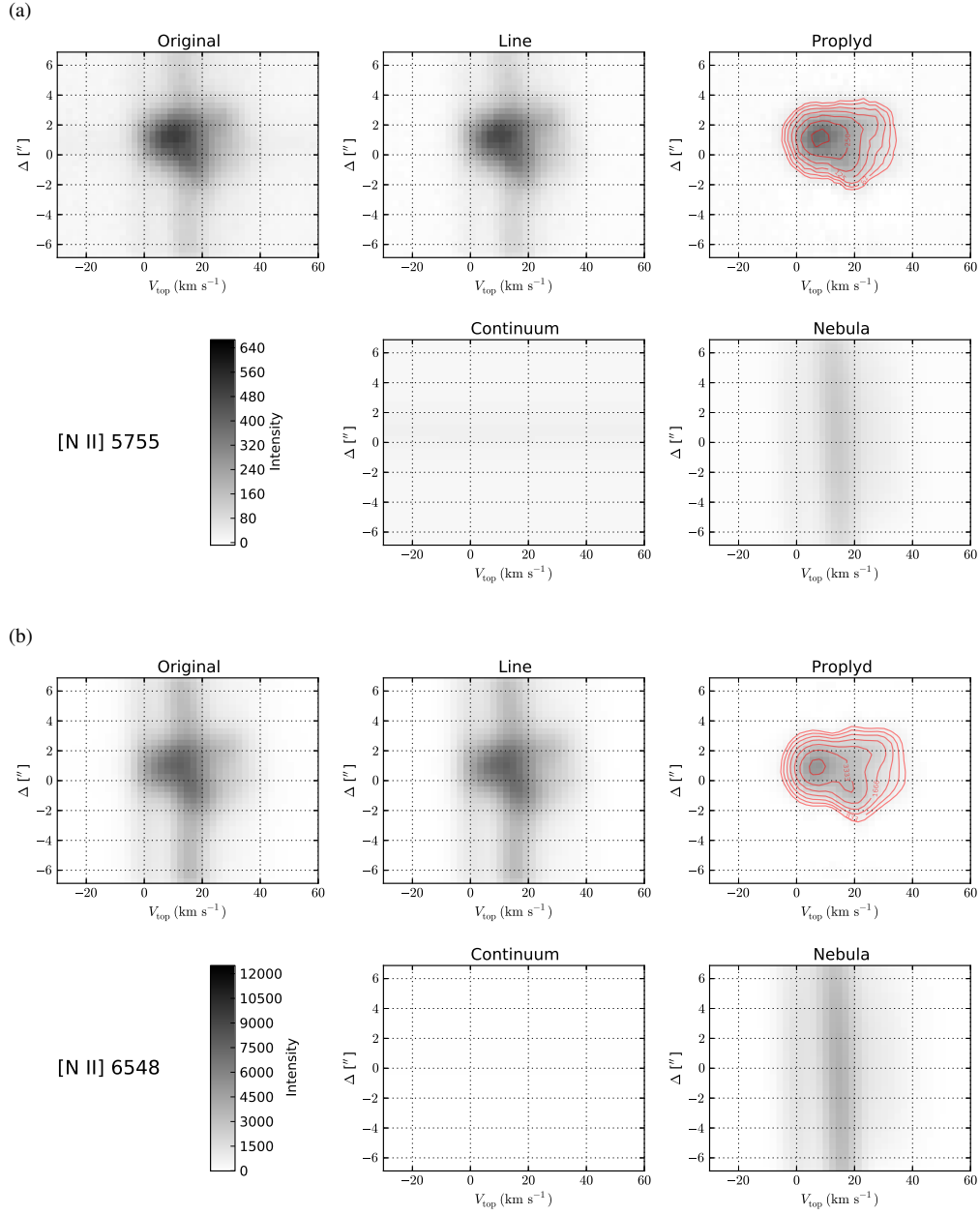
**Figure 7.** Collisionally excited lines of doubly ionized chlorine: (a) [Cl III]  $\lambda 5518$ ; (b) [Cl III]  $\lambda 5538$ .



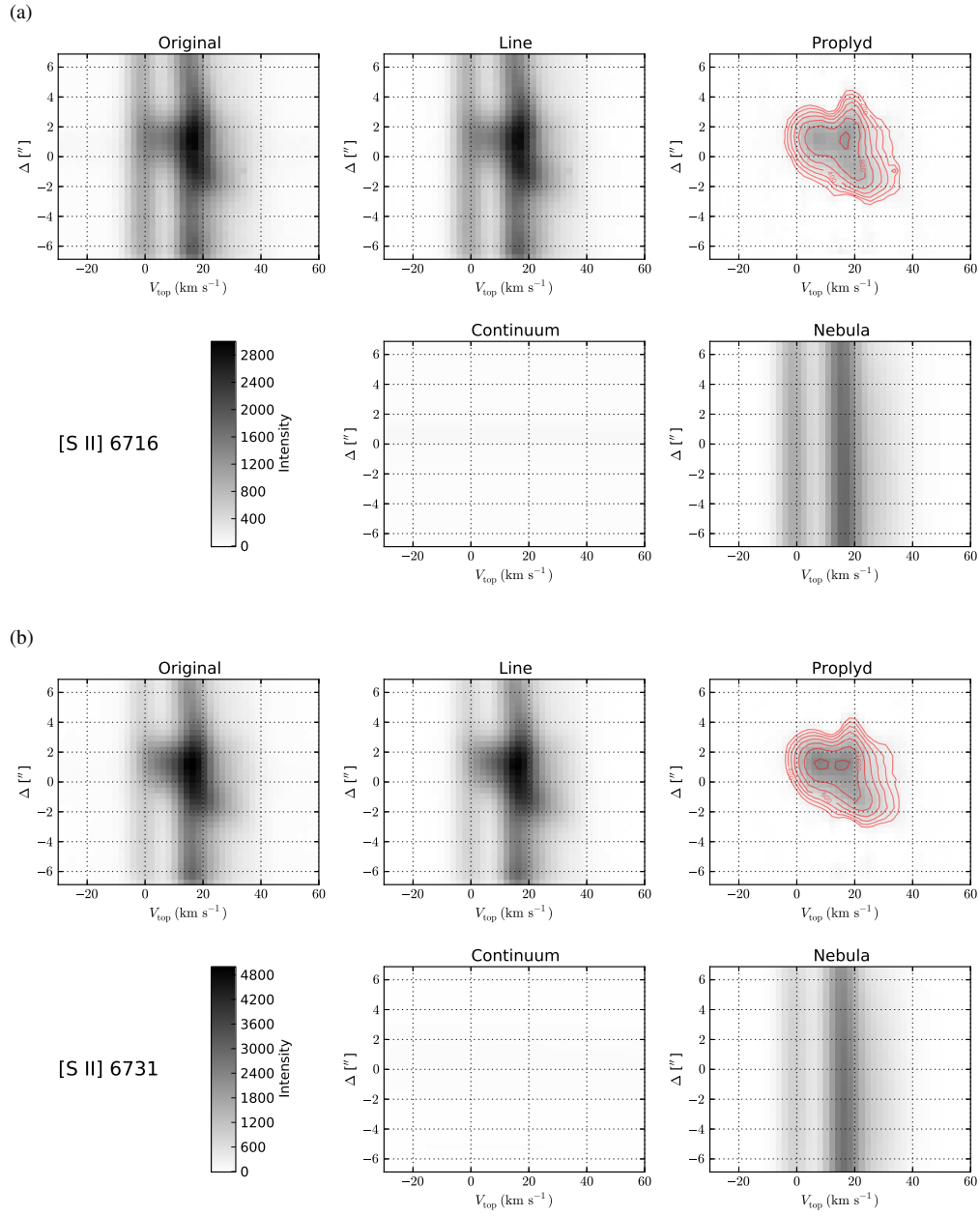
### **3.3 Low-ionization lines**



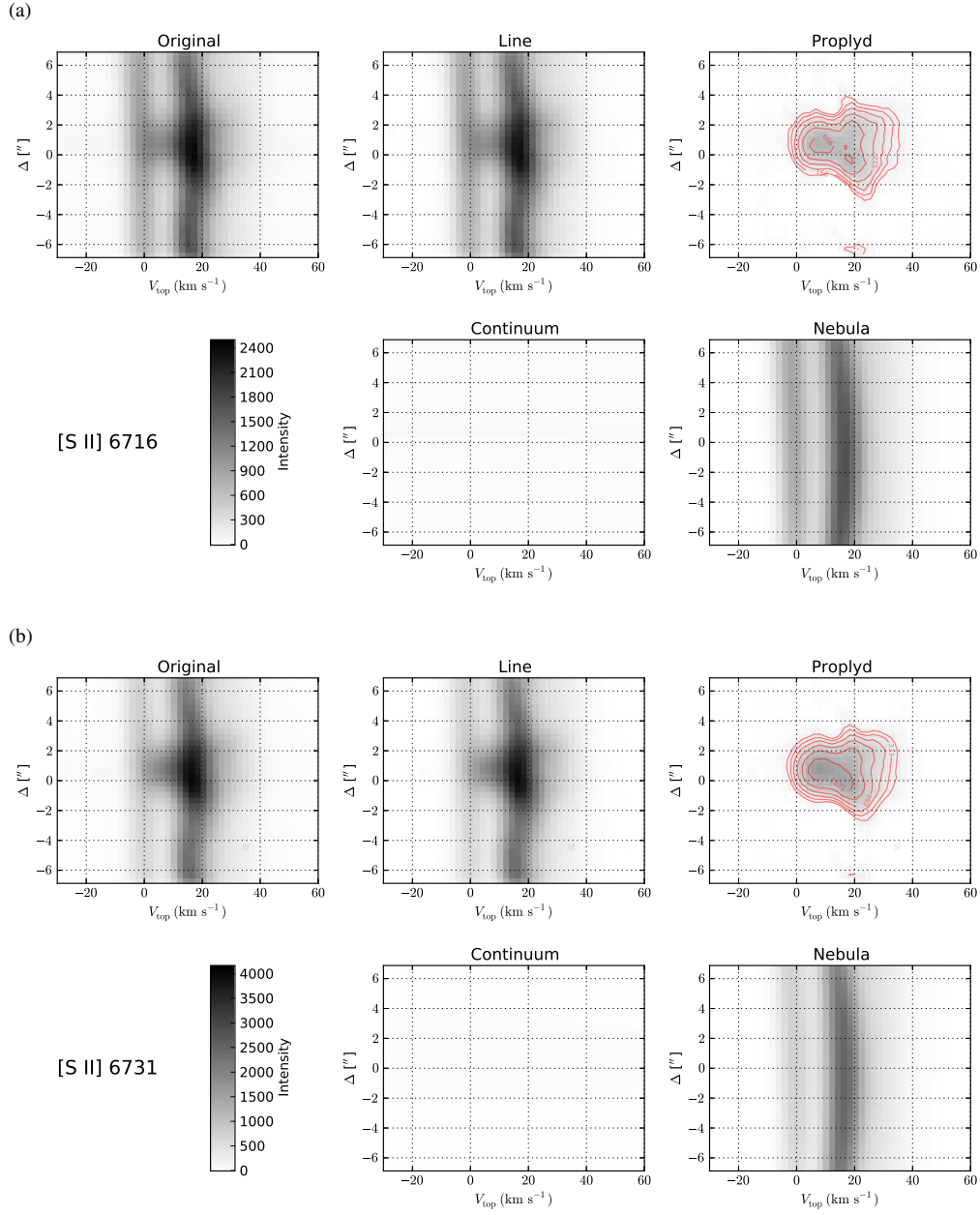
**Figure 8.** Collisionally excited lines of singly ionized nitrogen: (a) [N II]  $\lambda 5755$  auroral line; (b) [N II]  $\lambda 6548$  nebular line.



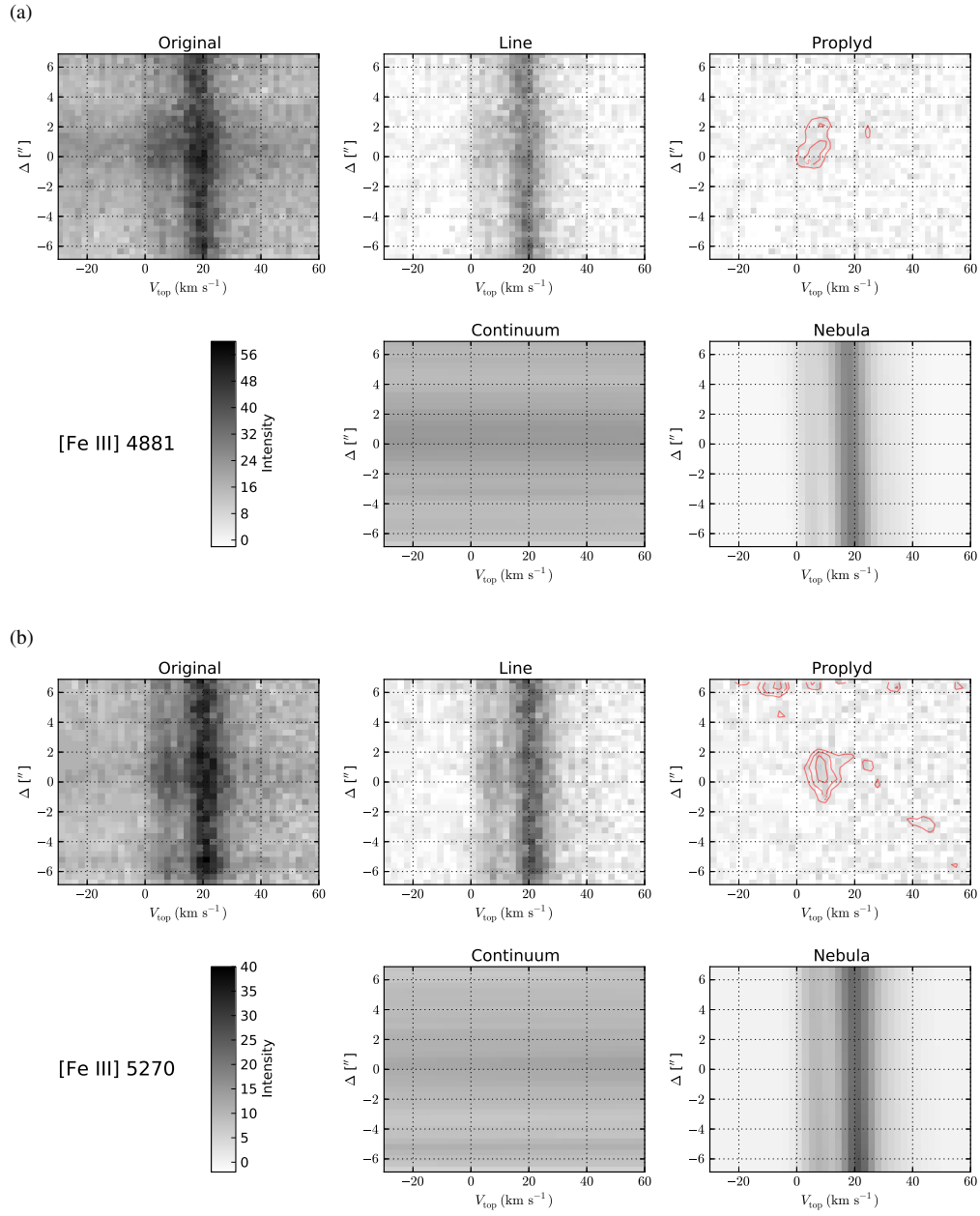
**Figure 9.** Collisionally excited lines of singly ionized nitrogen: (a) [N II]  $\lambda 5755$  auroral line; (b) [N II]  $\lambda 6548$  nebular line.



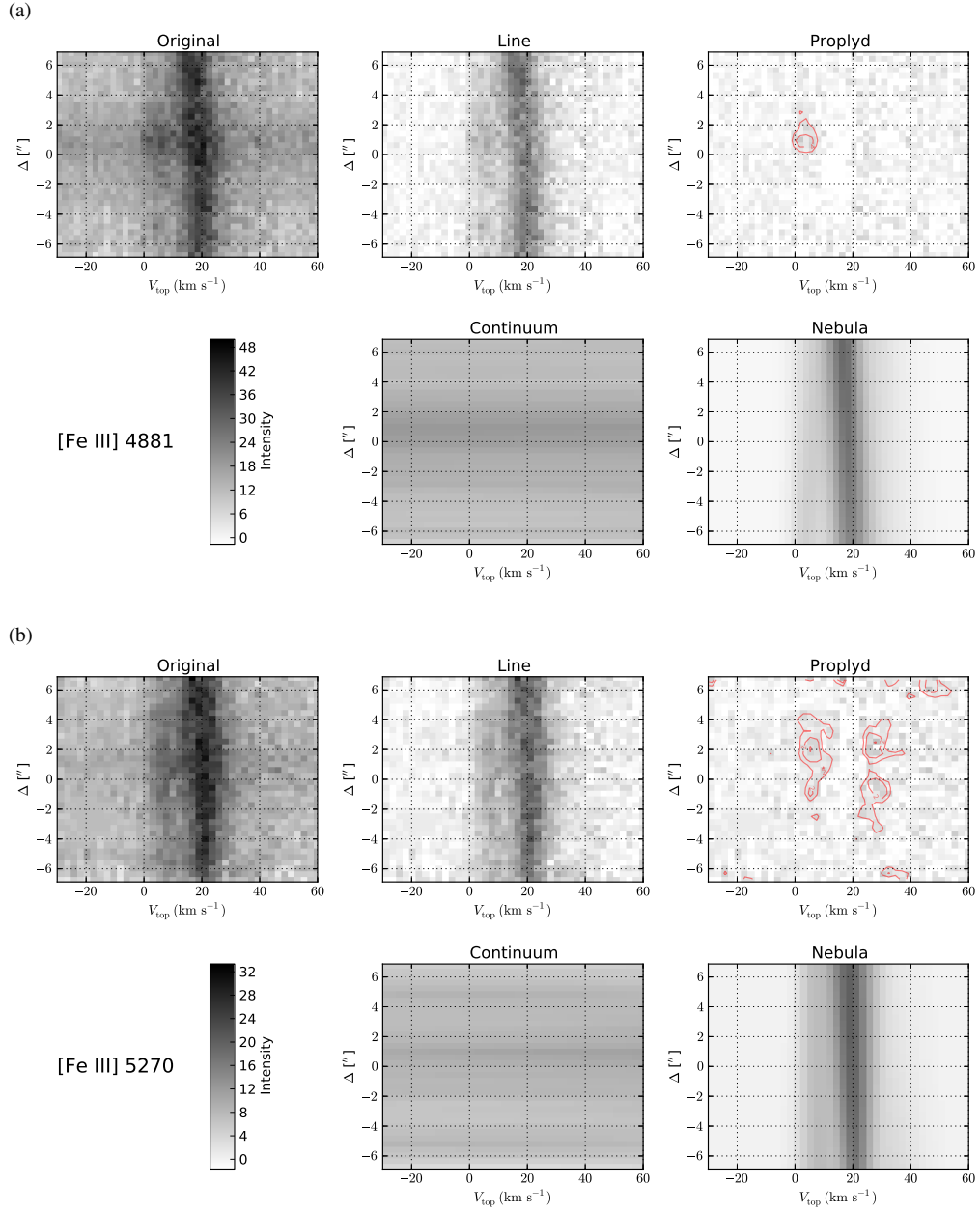
**Figure 10.** Collisionally excited lines of singly ionized sulfur: (a) [S II]  $\lambda 6731$ ; (b) [S II]  $\lambda 6716$ .



**Figure 11.** Collisionally excited lines of singly ionized sulfur: (a) [S II]  $\lambda 6731$ ; (b) [S II]  $\lambda 6716$ .



**Figure 12.** Collisionally excited lines of doubly ionized iron: (a) [Fe III]  $\lambda 4881$ ; (b) [Fe III]  $\lambda 5270$ .

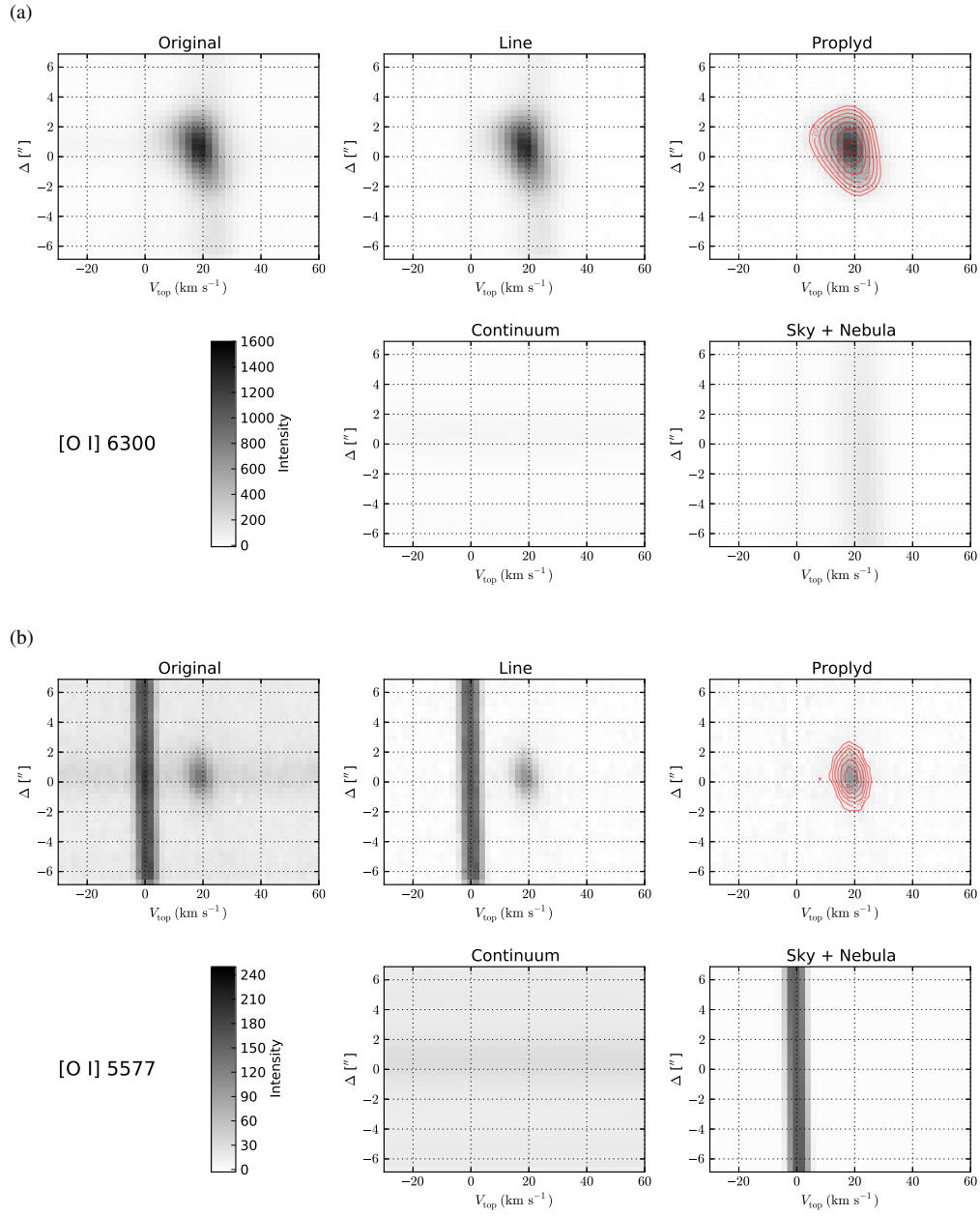


**Figure 13.** Collisionally excited lines of doubly ionized iron: (a) [Fe III]  $\lambda 4881$ ; (b) [Fe III]  $\lambda 5270$ .

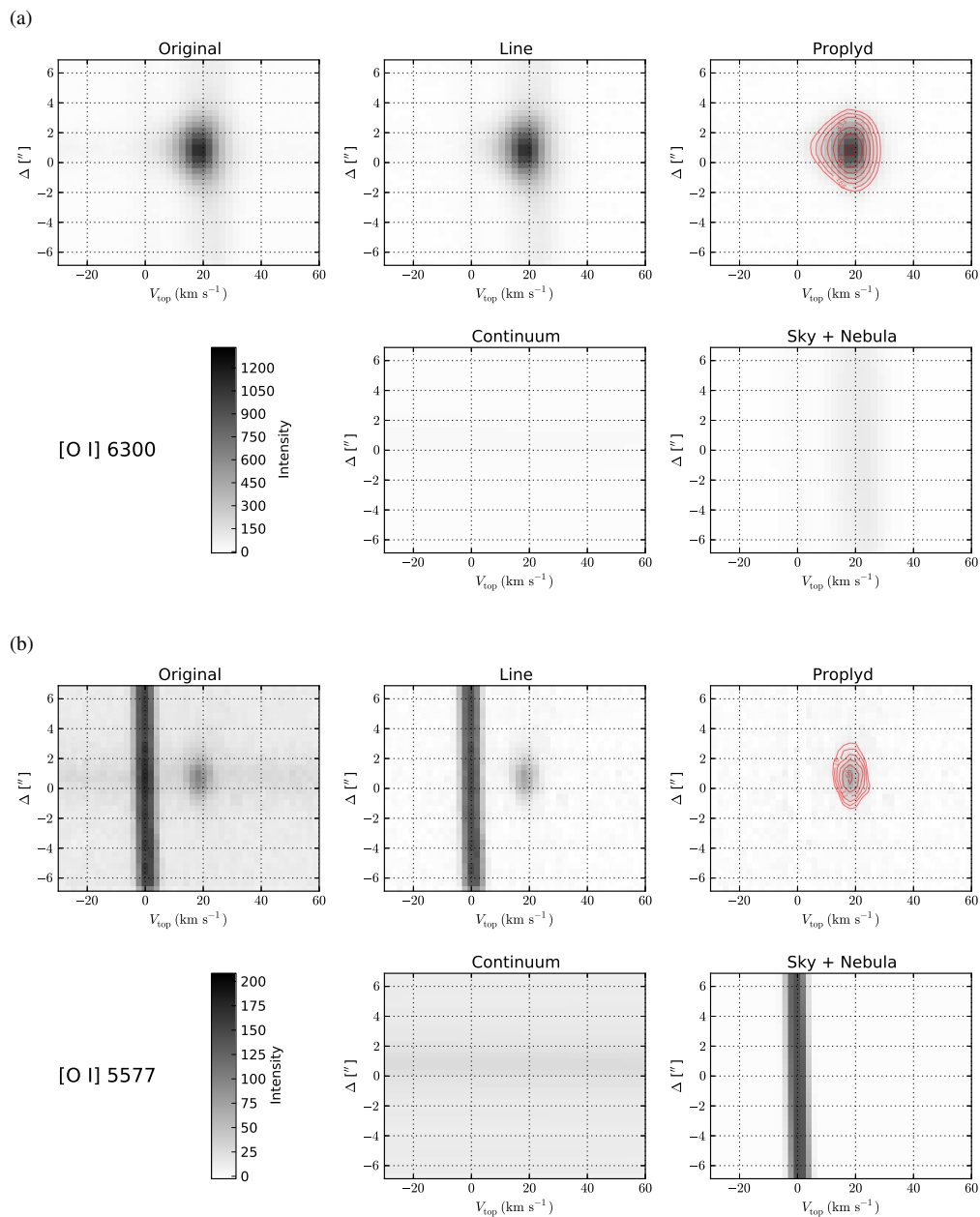
**3.4 Neutral collisional lines**



### 3.5 [O I] lines



**Figure 14.** Collisionally excited forbidden lines of neutral oxygen: [O I]  $\lambda 6300$  and  $\lambda 5577$



**Figure 15.** Collisionally excited forbidden lines of neutral oxygen: [O I]  $\lambda 6300$  and  $\lambda 5577$

### **3.6 Fluorescent lines**

3.6.1 *[N I] lines*

3.6.2 *O I lines*

3.6.3 *Fe II lines*

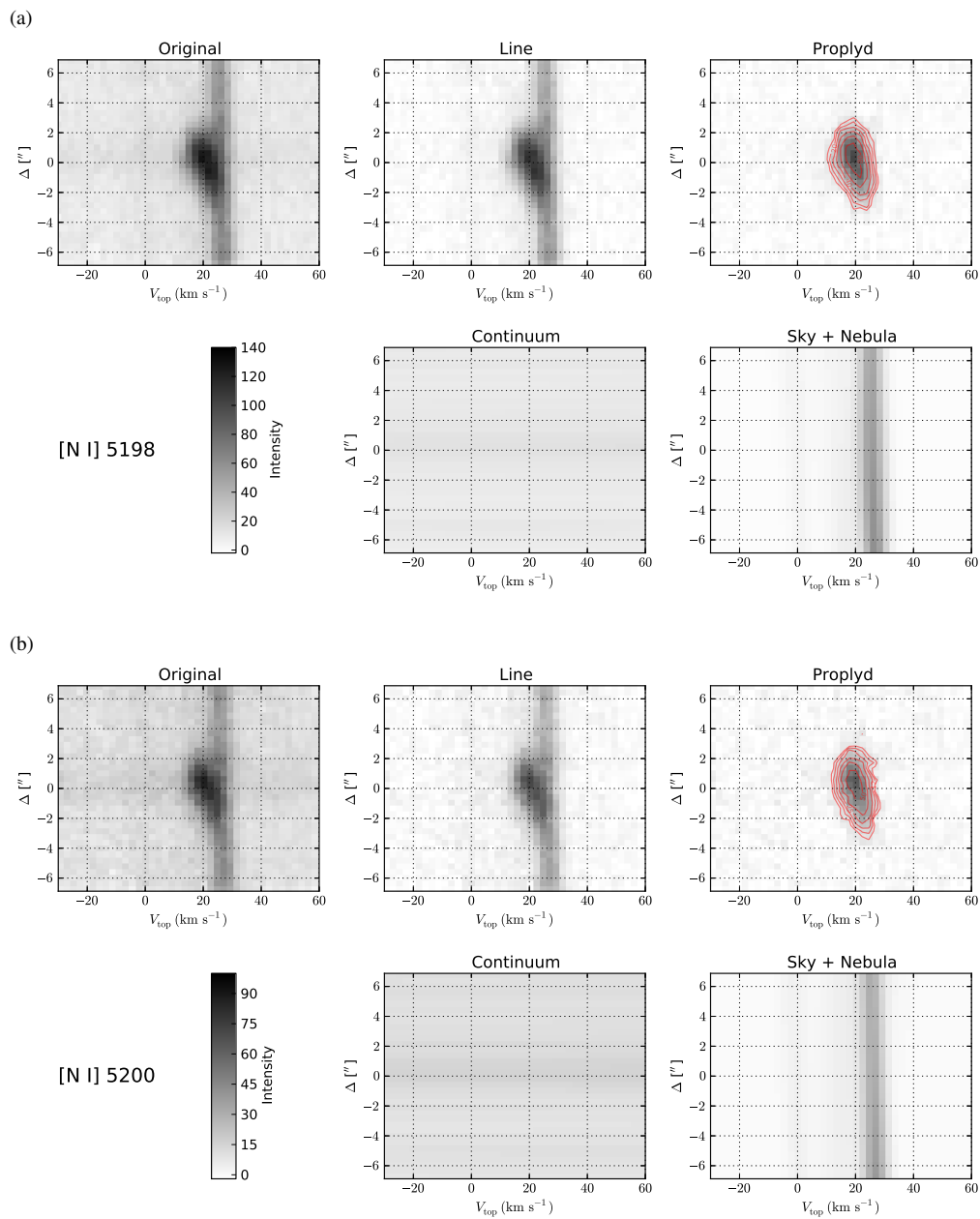
3.6.4 *Si II lines*

### **ACKNOWLEDGEMENTS**

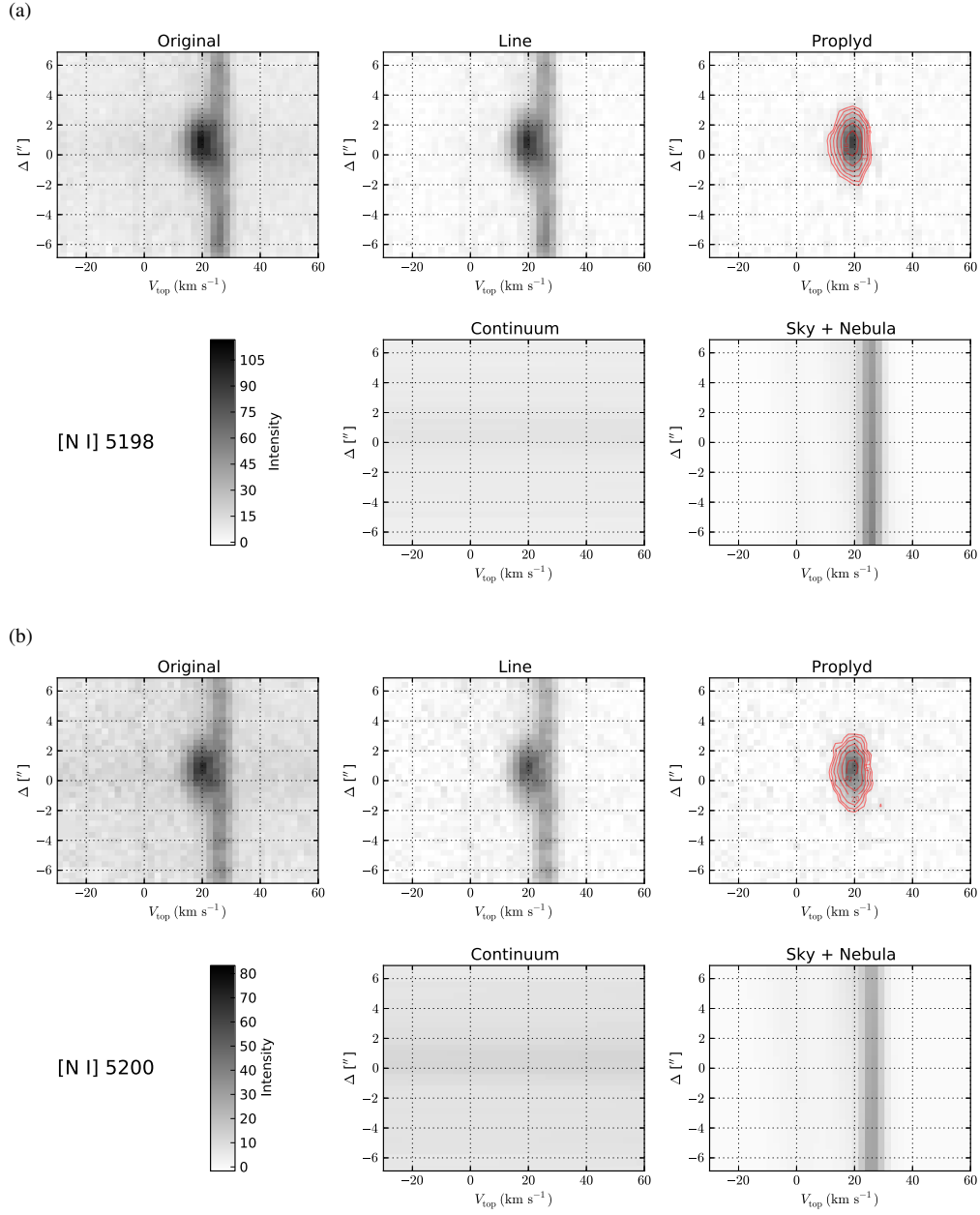
WJH and NFF acknowledge financial support from DGAPA-UNAM through project PAPIIT IN102012 and from a postdoctoral fellowship to NFF.

### **References**

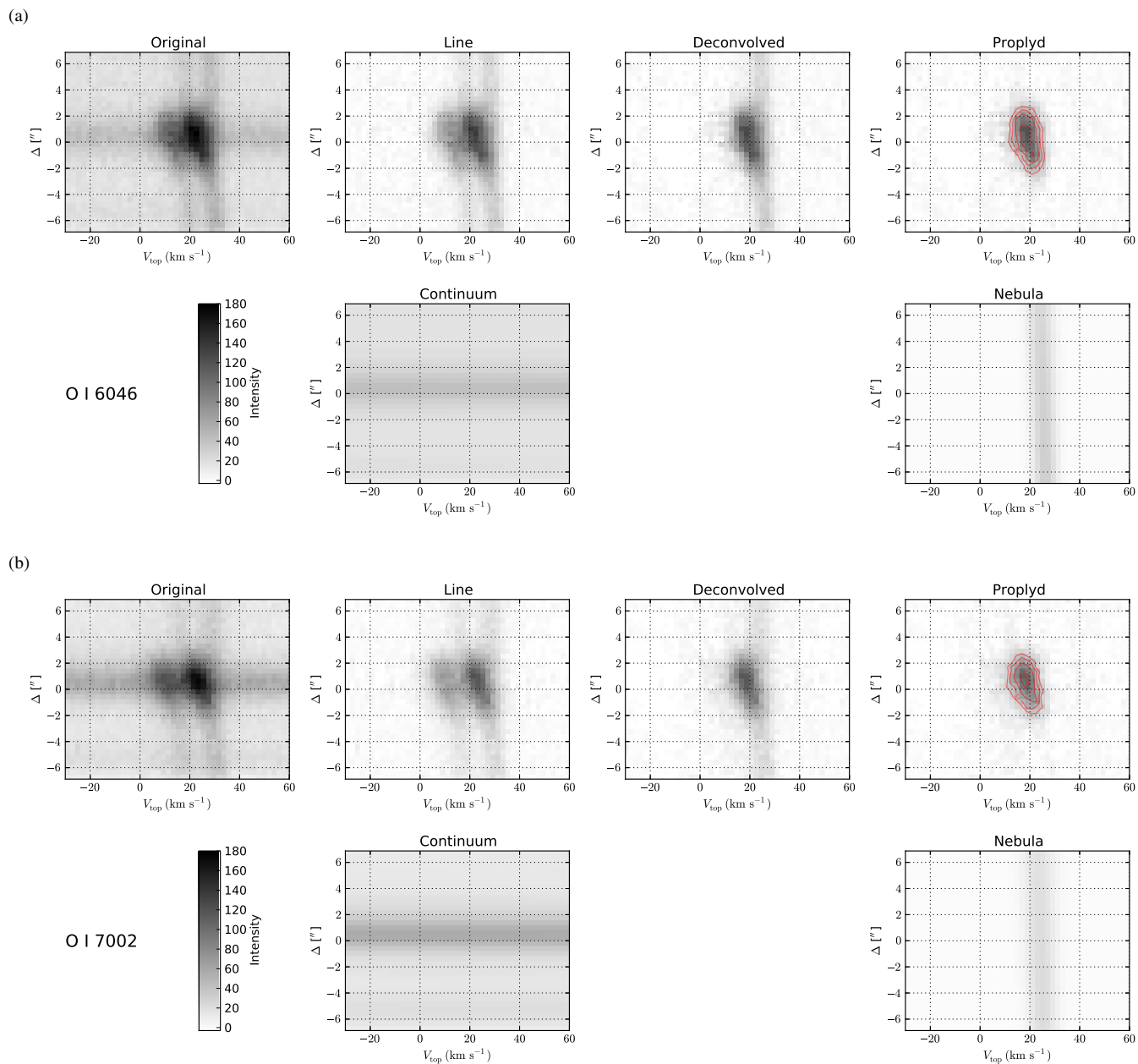
Henney W. J., O'Dell C. R., 1999, AJ, 118, 2350



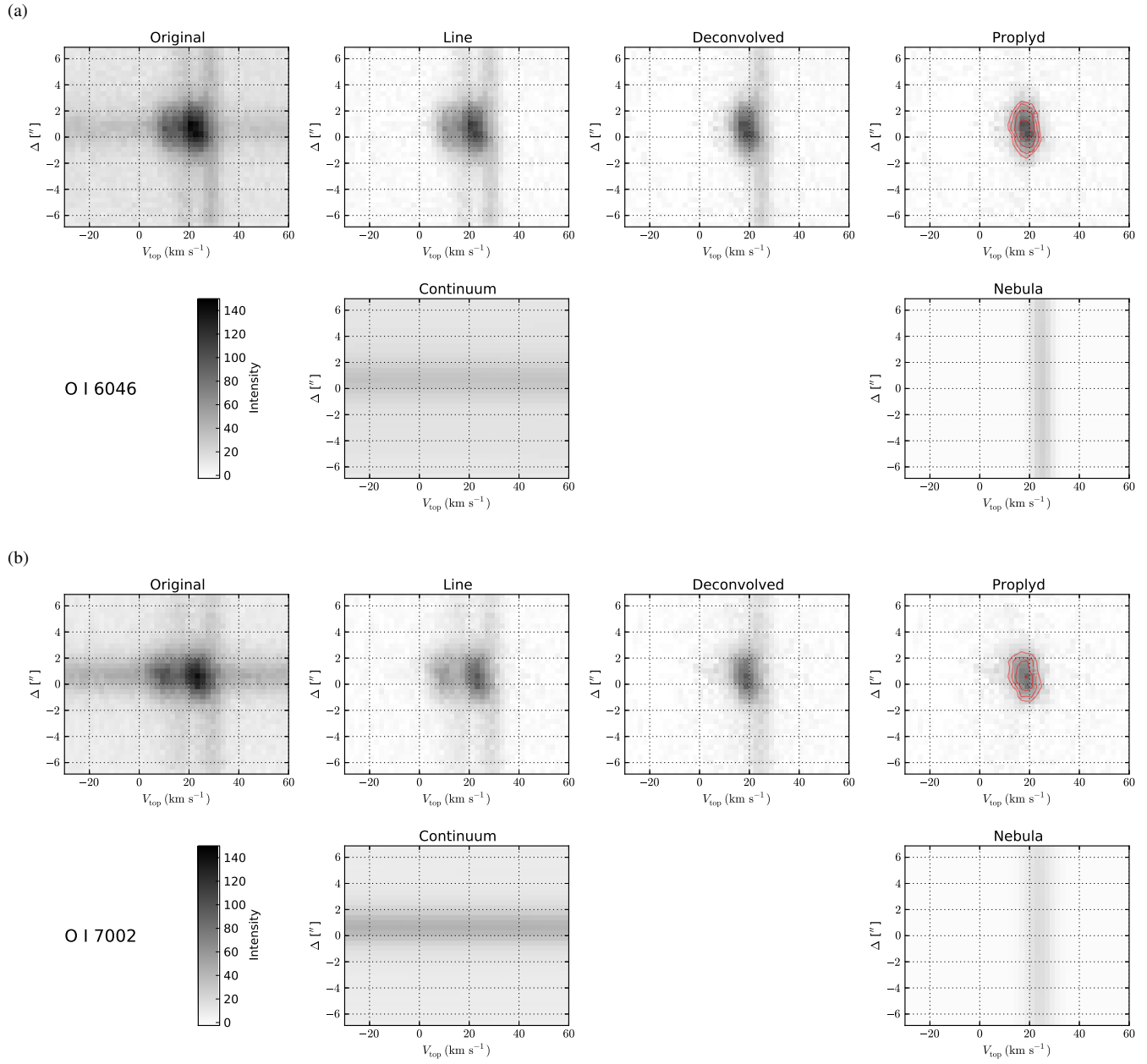
**Figure 16.** Continuum fluorescence-excited forbidden lines of neutral nitrogen: [N I]  $\lambda$ 5198, 5200



**Figure 17.** Continuum fluorescence-excited forbidden lines of neutral nitrogen: [N I]  $\lambda$ 5198, 5200

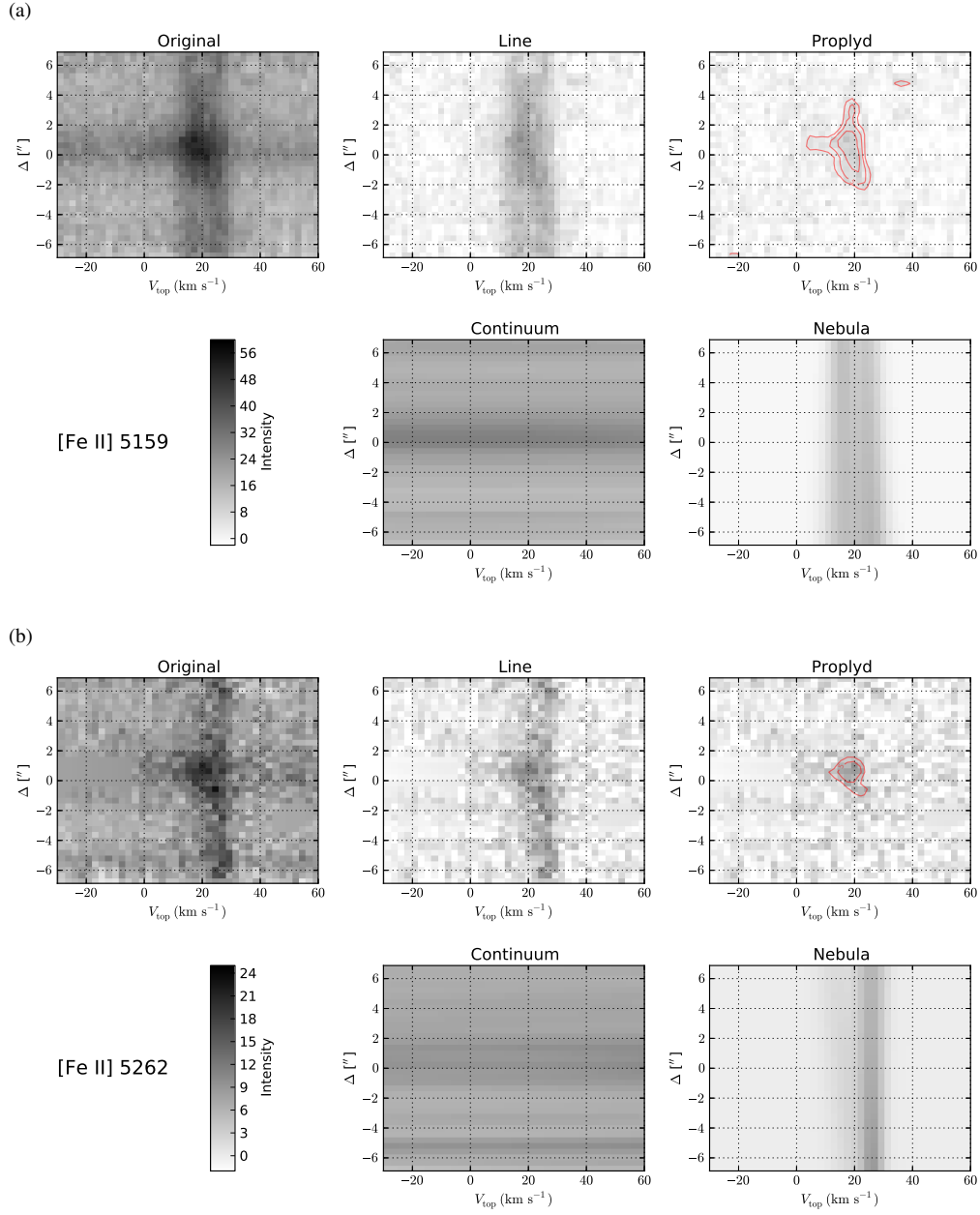


**Figure 18.** Continuum fluorescence-excited forbidden lines of neutral oxygen: [O I]  $\lambda 6046$  and  $\lambda 7002$ .

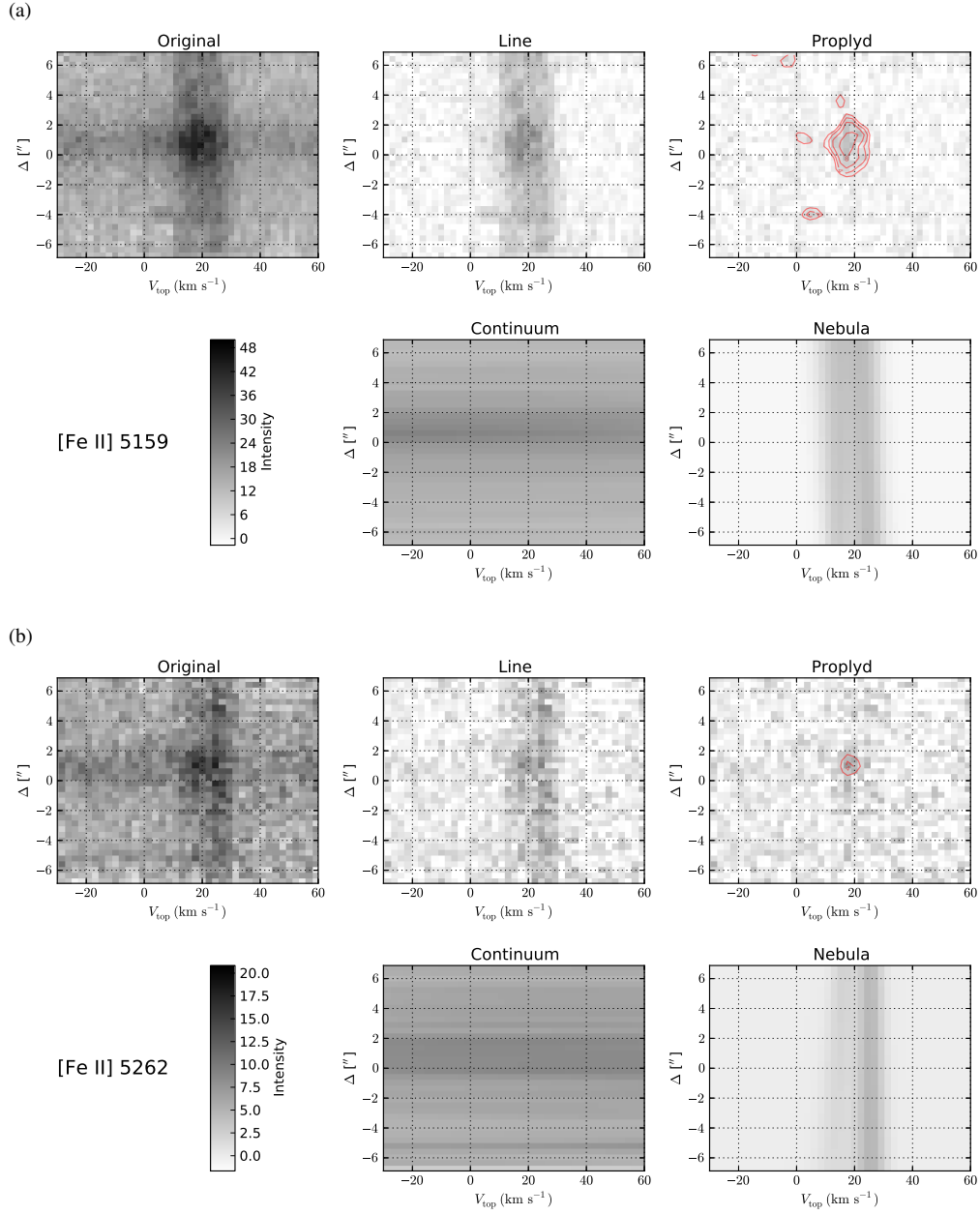


**Figure 19.** Continuum fluorescence-excited forbidden lines of neutral oxygen: [O I]  $\lambda 6046$  and  $\lambda 7002$ .

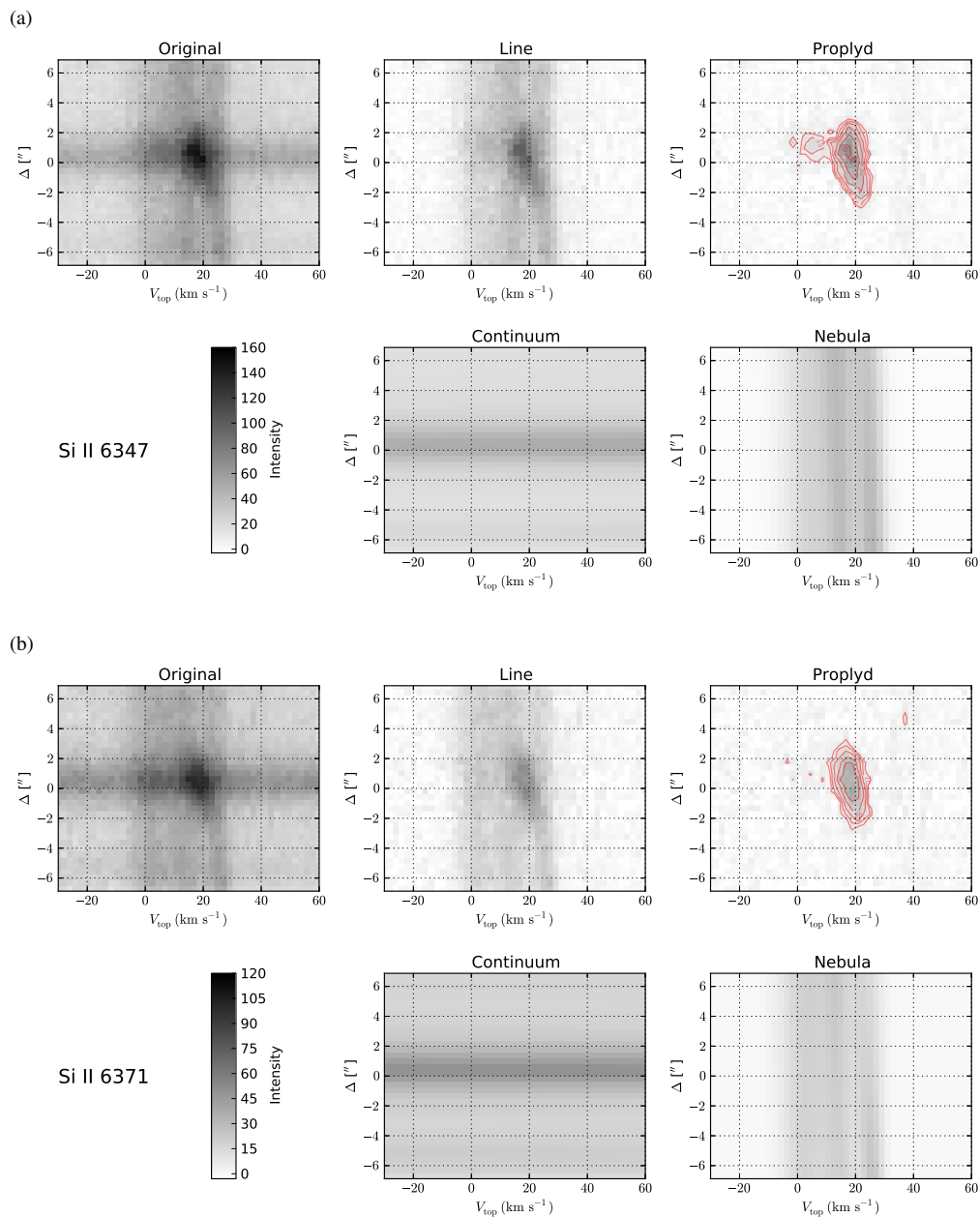




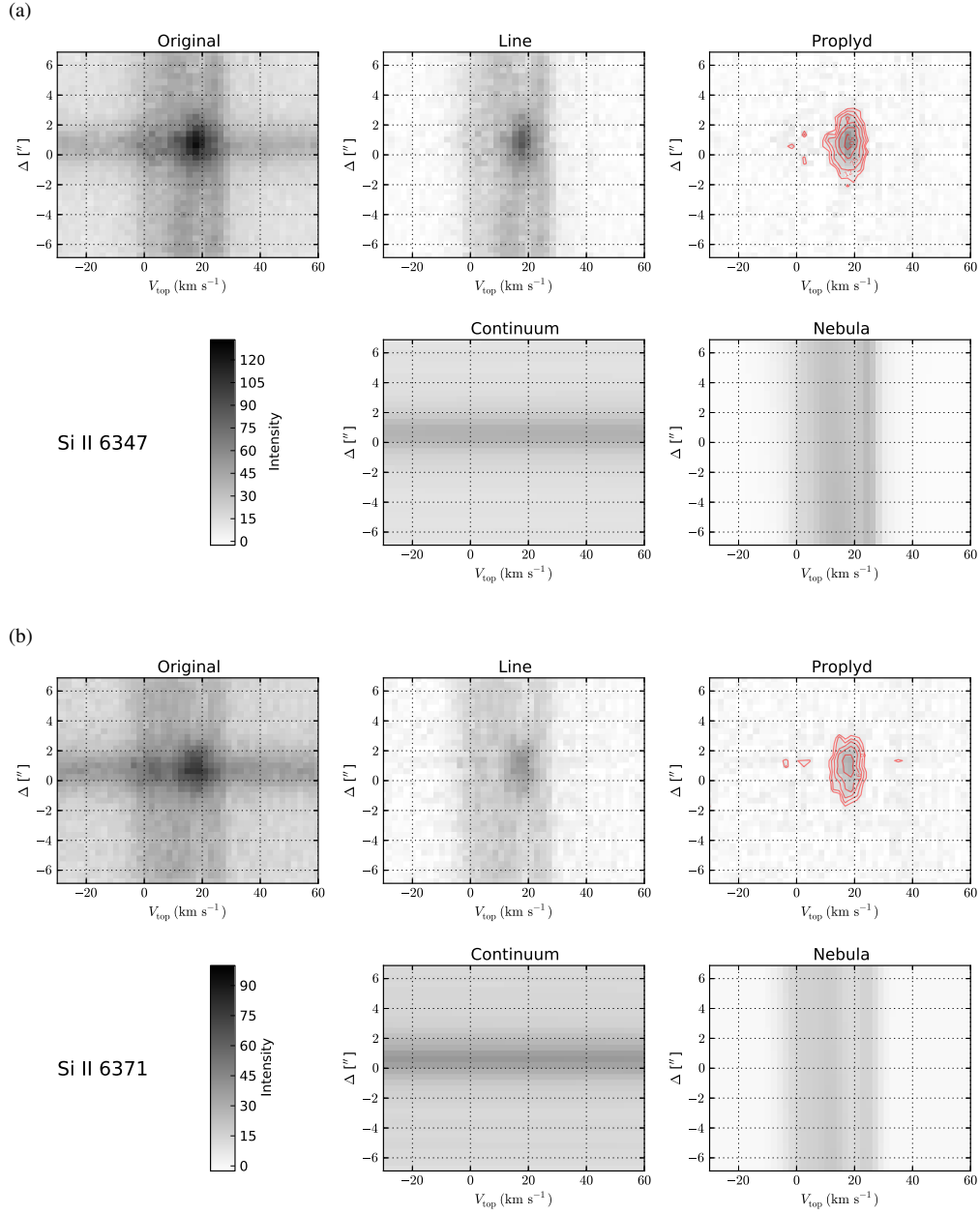
**Figure 20.** Continuum fluorescence-excited forbidden lines of singly-ionized iron: [Fe II]  $\lambda 5159$  and  $\lambda 5262$ .



**Figure 21.** Continuum fluorescence-excited forbidden lines of singly-ionized iron: [Fe II]  $\lambda$ 5159 and  $\lambda$ 5262.



**Figure 22.** Continuum fluorescence/recombination-excited permitted lines of singly-ionized silicon: Si II  $\lambda 6347$  and  $\lambda 6371$ .



**Figure 23.** Continuum fluorescence/recombination-excited permitted lines of singly-ionized silicon: Si II  $\lambda 6347$  and  $\lambda 6371$ .