

# Delayed Stellar Mass Assembly in the Low Surface Brightness Dwarf Galaxy KDG 215

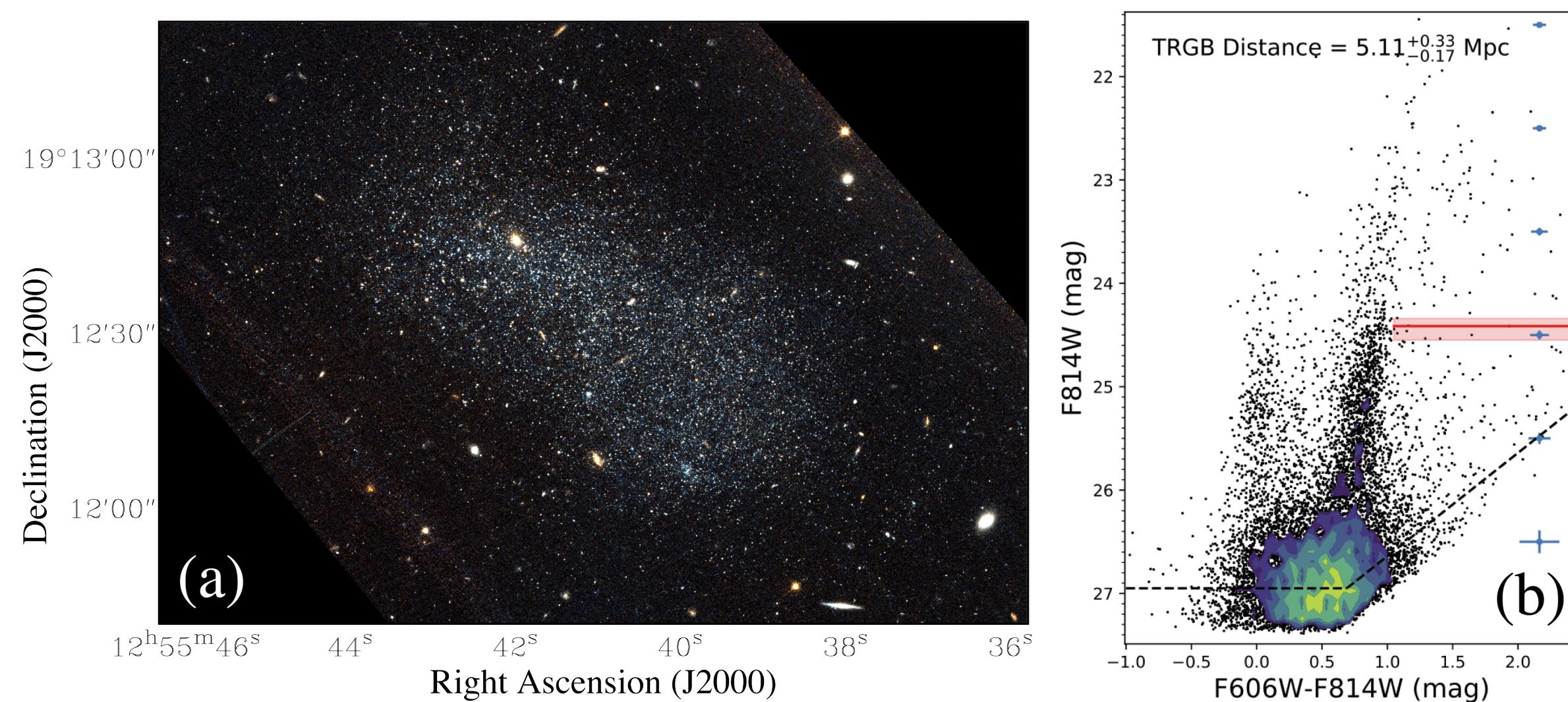


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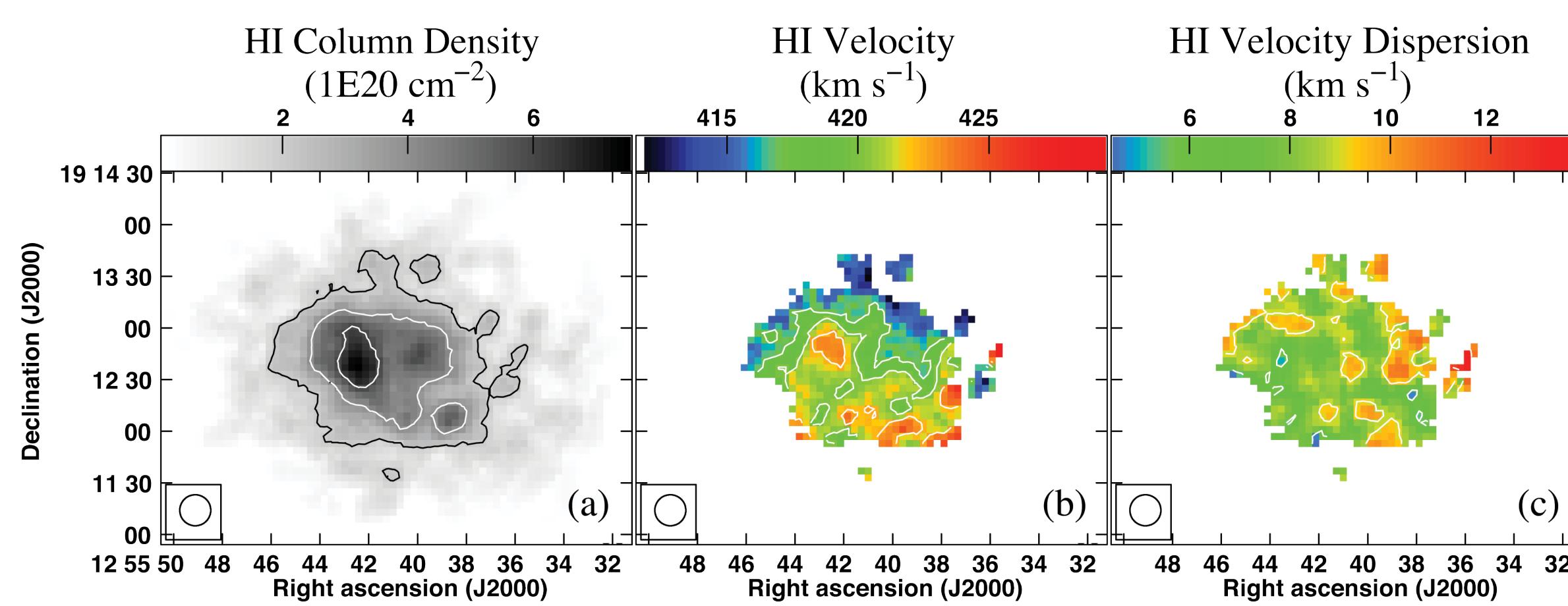
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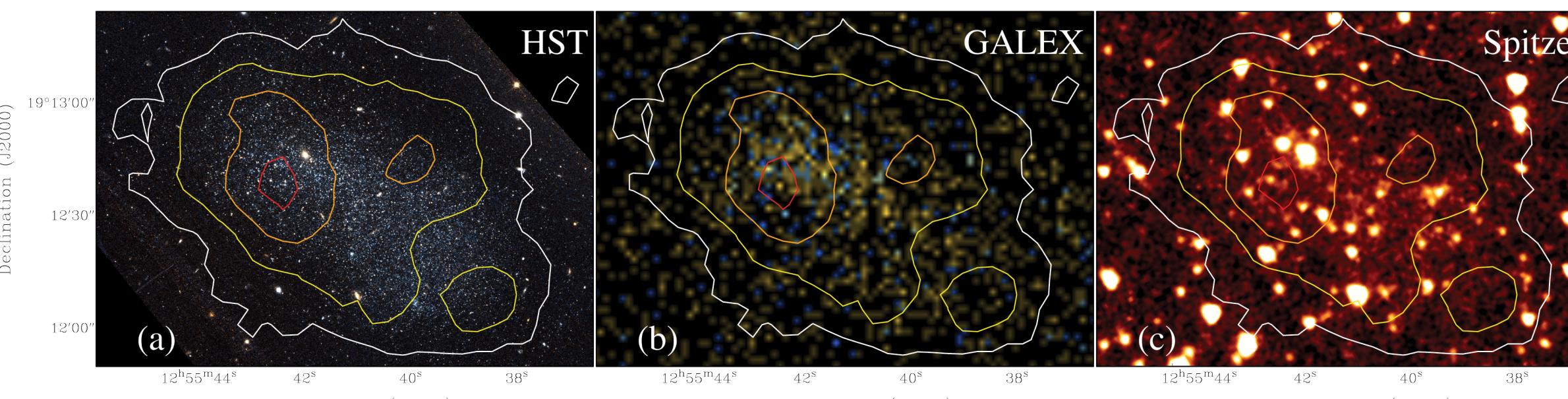
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**Figure 1.** HST color image (a) and color-magnitude diagram (CMD) (b) of KDG 215. The CMD reveals a strong red giant branch, a significant population of red supergiants, a weak blue plume, and red clump stars. The more densely populated fainter magnitudes are shown as number density contours for clarity. The TRGB is marked by a red line and shaded red area resulting in a distance  $D = 5.11^{+0.33}_{-0.17}$  Mpc.



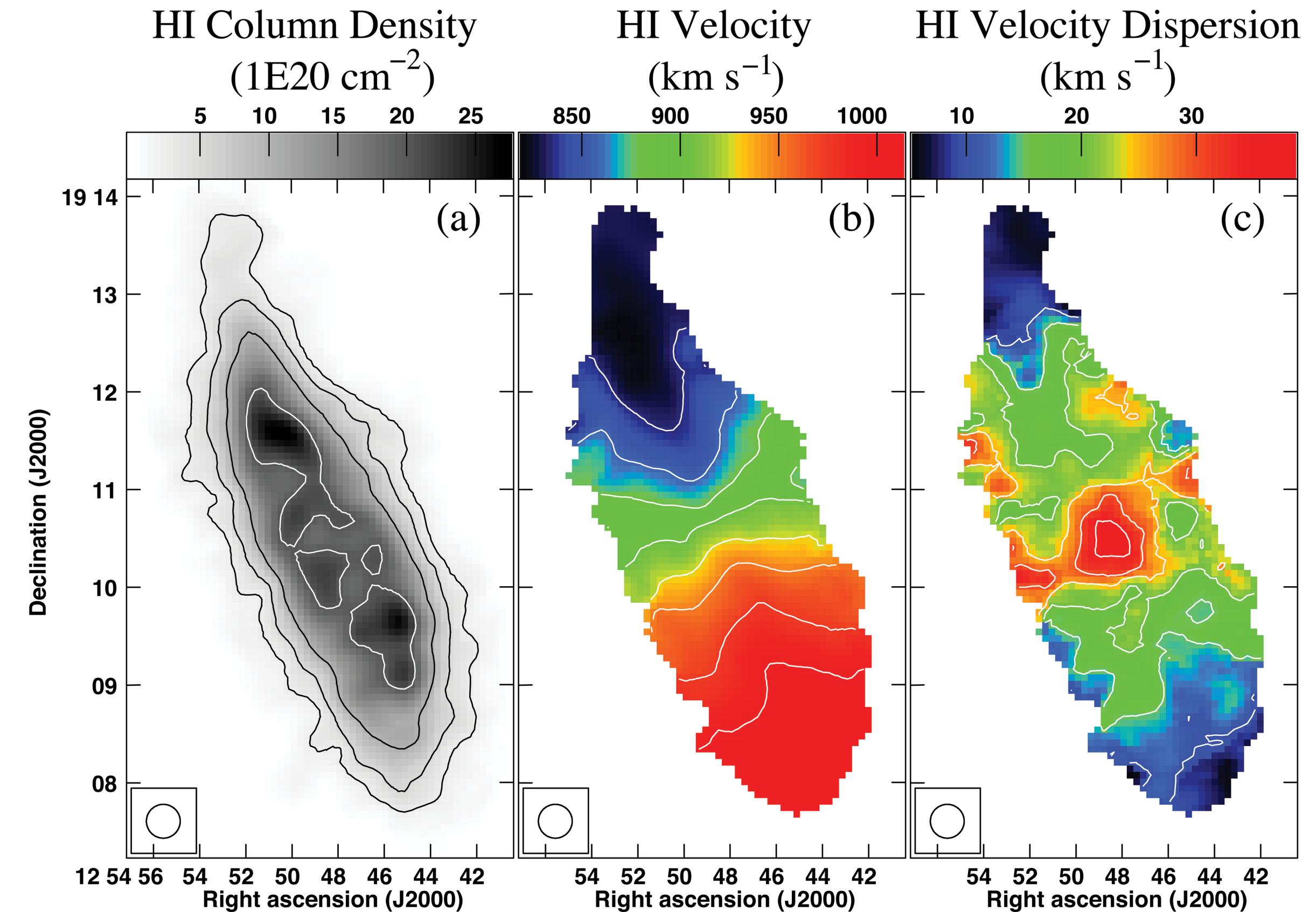
**Figure 2.** HI images of KDG 215. Panel (a) shows the HI column density distribution in units of  $10^{20}$  cm $^{-2}$ ; contours are at levels of  $(2, 4, 6) \times 10^{20}$  cm $^{-2}$ . Panel (b) shows the intensity weighted velocity field in units of km s $^{-1}$ ; contours are at levels of 417.5, 420, and 422.5 km s $^{-1}$ . Panel (c) shows the intensity-weighted velocity dispersion; contours are at levels of 6, 9, and 12 km s $^{-1}$ . Panels (b) and (c) are threshold blanked using the column density image shown in panel (a) with a threshold of  $2 \times 10^{20}$  cm $^{-2}$  (i.e., the outermost contour shown in panel a). The circular beam size of 18" (shown in the bottom left of each panel) corresponds to a physical resolution of 446 pc at the adopted distance of 5.11 Mpc. The total HI mass is  $M_{\text{HI}} = (3.40 \pm 0.34) \times 10^7 M_{\odot}$ .



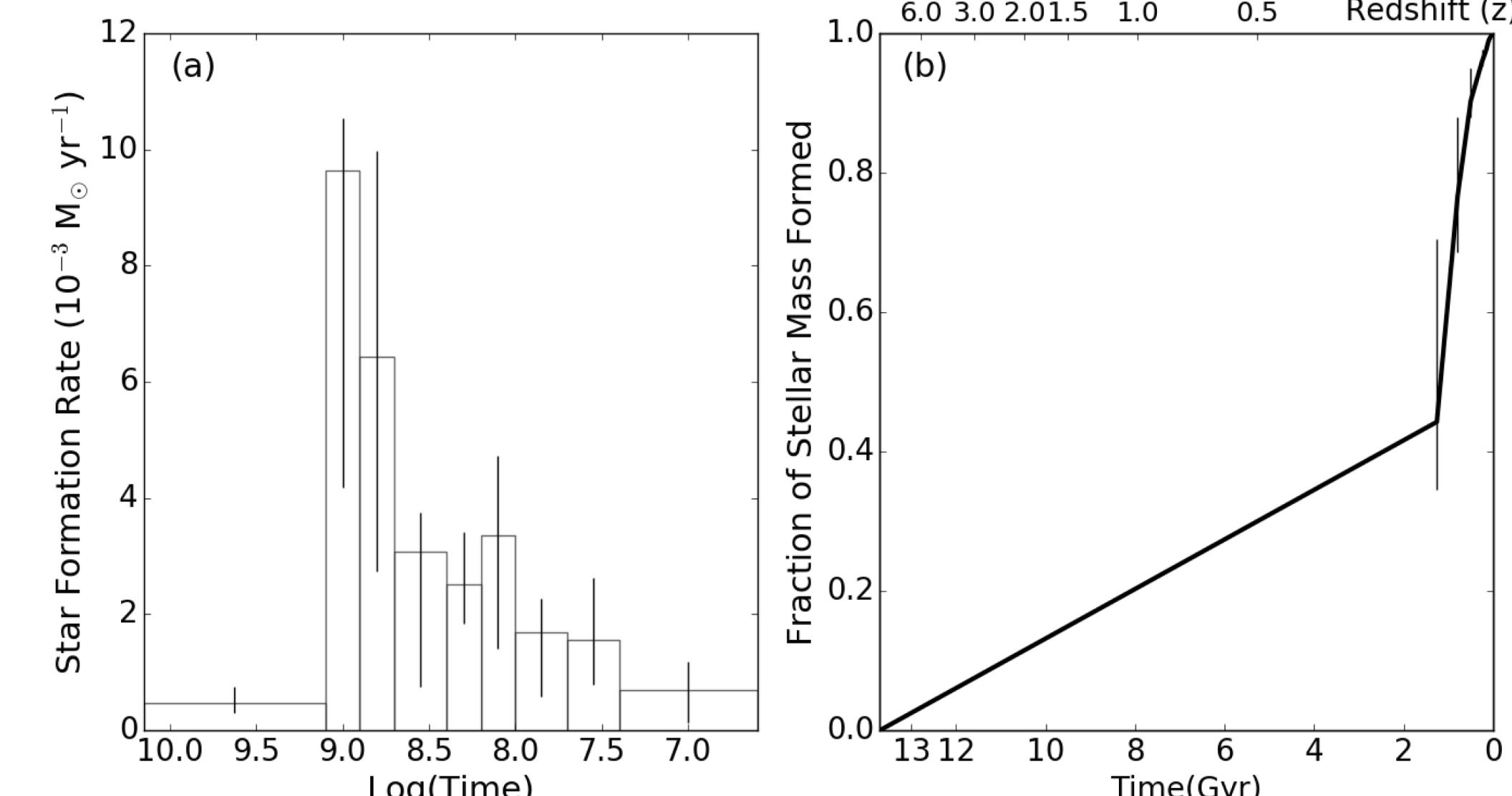
**Figure 3.** Comparison of HI surface density and the stellar populations of KDG 215. Panel (a) shows a color HST image (F606W in blue, F814W in red, and a linear average of the two as green); panel (b) shows a color GALEX image (far-UV in blue, near-UV in red, and a linear average of the two as green); panel (c) shows a Spitzer 3.6  $\mu$ m image. Contours of HI column density (18" beam; same image as shown in Figure 2) are overlaid at levels of  $2.5 \times 10^{20}$  cm $^{-2}$  (white),  $4 \times 10^{20}$  cm $^{-2}$  (yellow),  $5.5 \times 10^{20}$  cm $^{-2}$  (orange), and  $7 \times 10^{20}$  cm $^{-2}$  (red). The total stellar mass is  $M_* = (8.0^{+1.2}_{-3.2}) \times 10^6 M_{\odot}$ , derived from the HST star formation history of KDG 215.

## Abstract

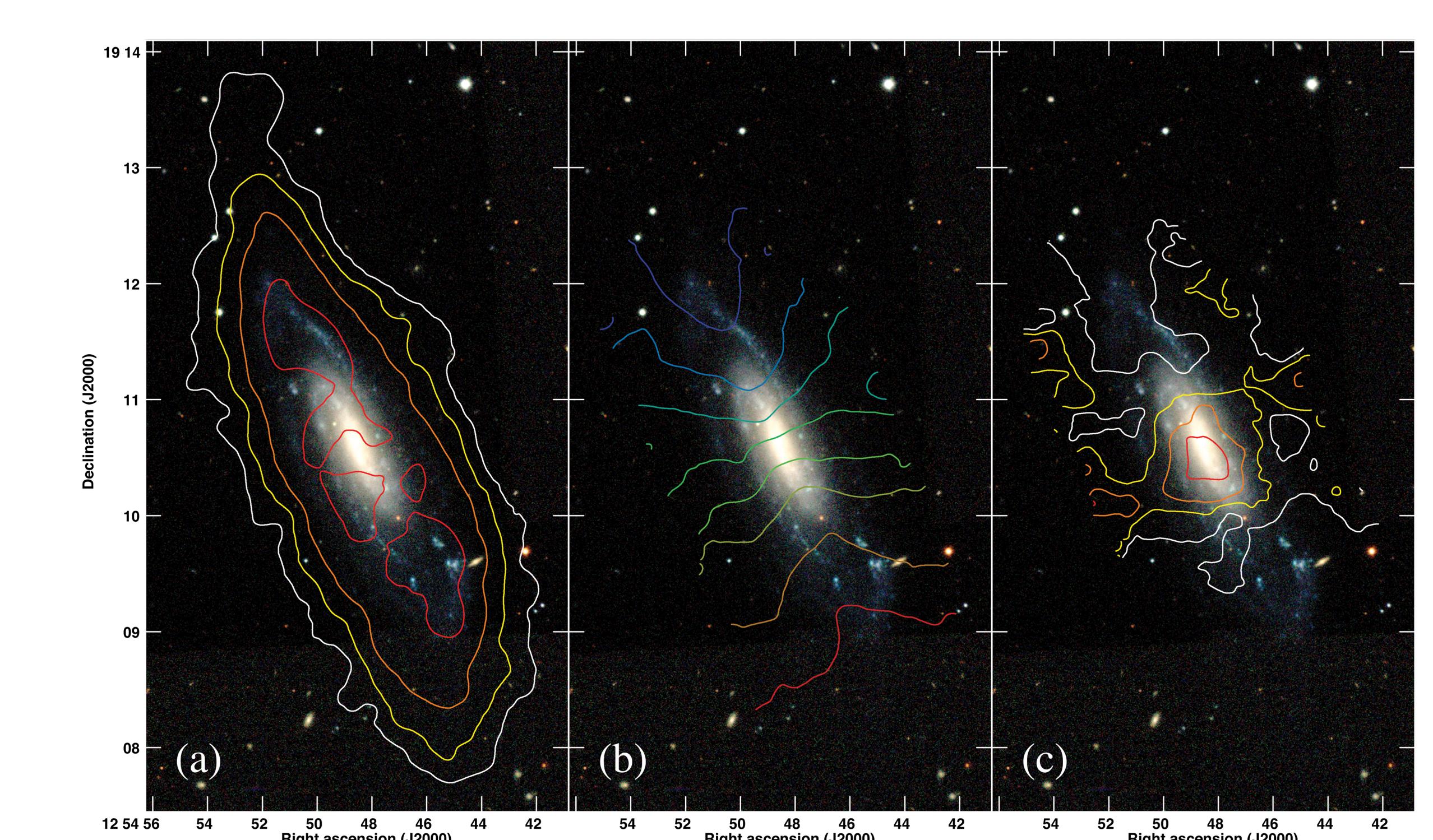
We present neutral hydrogen spectral line and optical broadband images of the nearby low surface brightness dwarf galaxy KDG 215. The HI images, acquired with the Karl G. Jansky Very Large Array, reveal a dispersion-dominated interstellar medium with only weak signatures of coherent rotation. The HI gas reaches a peak mass surface density of  $6 M_{\odot}$  pc $^{-2}$  at the location of the peak surface brightness in the optical and the ultraviolet. Although KDG 215 is gas-rich, the H $\alpha$  non-detection implies a very low current massive star formation rate. In order to investigate the recent evolution of this system, we have derived the recent and lifetime star formation histories from archival Hubble Space Telescope images. The recent star formation history shows a peak star formation rate  $\sim 1$  Gyr ago, followed by a decreasing star formation rate to the present day quiescent state. The cumulative star formation history indicates that a significant fraction of the stellar mass assembly in KDG 215 has occurred within the last 1.25 Gyr. KDG 215 is one of only a few known galaxies that demonstrates such a delayed star formation history. While the ancient stellar population (predominantly red giants) is prominent, the look-back time by which 50% of the mass of all stars ever formed had been created is among the youngest of any known galaxy. We also present HI images of the field spiral galaxy IC 3877, observed in the same data cube.



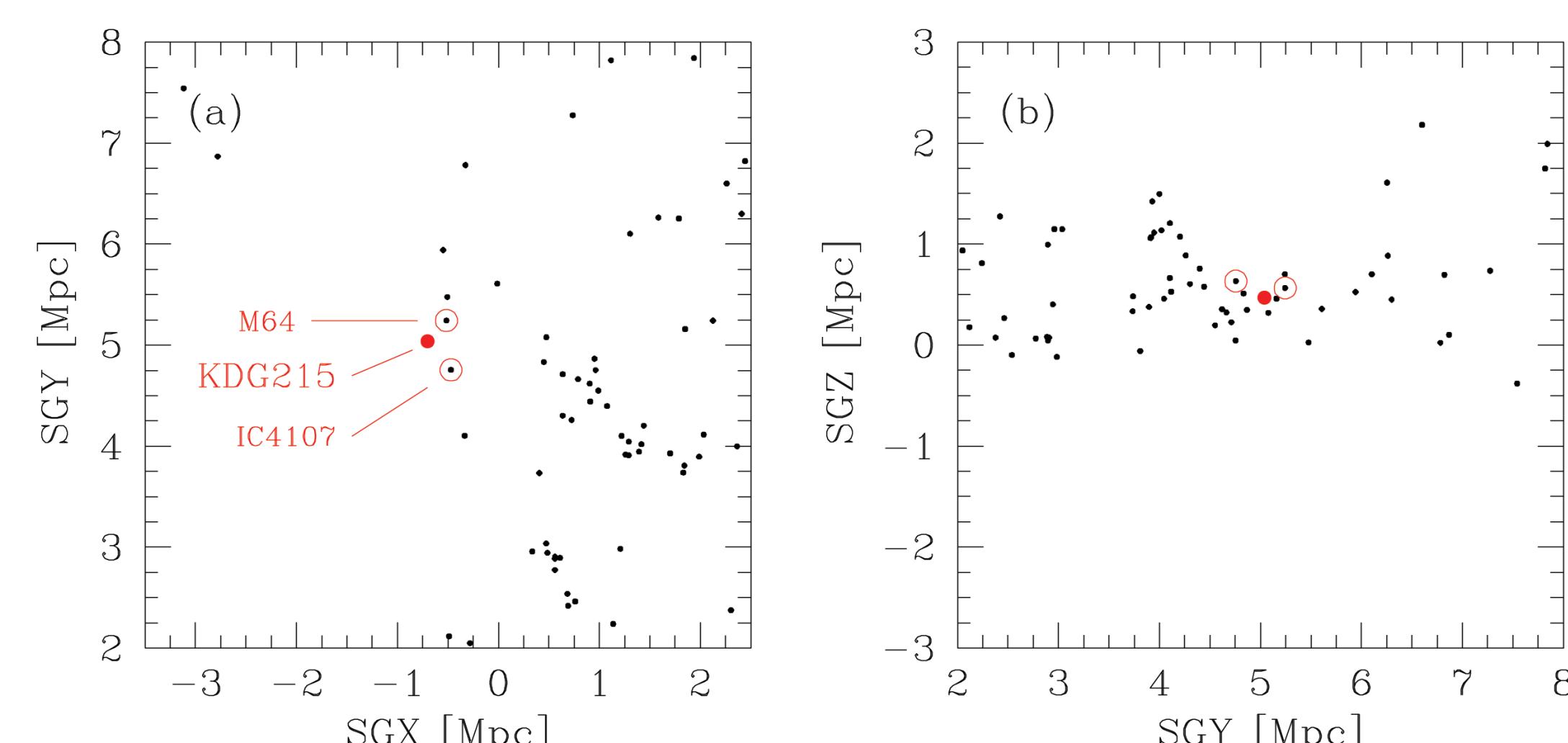
**Figure 6.** HI images of the field spiral galaxy IC 3877. Panel (a) shows the HI column density distribution in units of  $10^{20}$  cm $^{-2}$ ; contours are shown at levels of  $(2.5, 5, 10, 20) \times 10^{20}$  cm $^{-2}$ . Panel (b) shows the intensity weighted velocity field in units of km s $^{-1}$ ; contours span the range from 835 km s $^{-1}$  to 996 km s $^{-1}$ , and are separated by 23 km s $^{-1}$  per contour. Panel (c) shows the intensity weighted velocity dispersion; contours span the range from 10 km s $^{-1}$  to 35 km s $^{-1}$ , and are separated by 5 km s $^{-1}$  per contour. The circular beam size of 20.76" is shown in the bottom left of each panel.



**Figure 4.** Star formation history of KDG 215. Panel (a) shows the SFR as a function of time in the galaxy, while panel (b) shows the cumulative SF as a function of time. The SF event that peaked in intensity  $\sim 1$  Gyr ago formed more than 50% of the total stellar mass in KDG 215. The median look-back time by which 50% of the mass of all stars ever formed had been created in KDG 215 is on the order of a Gyr.



**Figure 7.** SDSS color image of the field spiral galaxy IC 3877. Panel (a) shows the HI column density distribution as contours; white, yellow, orange, and red show levels of  $(2.5, 5, 10, 20) \times 10^{20}$  cm $^{-2}$ , respectively. Panel (b) shows the intensity weighted velocity field as contours in units of km s $^{-1}$ ; contours span the range from 835 km s $^{-1}$  (blue) to 996 km s $^{-1}$  (red), and are separated by 23 km s $^{-1}$  per contour. Panel (c) shows the intensity weighted velocity distribution as contours; for ease of interpretation, contours are shown at levels of 20 km s $^{-1}$  (white), 25 km s $^{-1}$  (yellow), 30 km s $^{-1}$  (orange), and 35 km s $^{-1}$  (red).



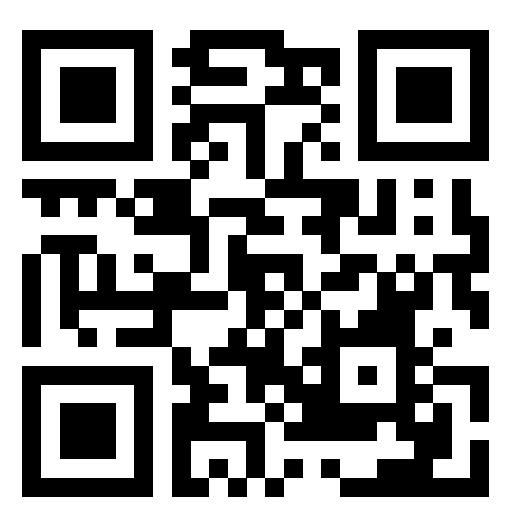
**Figure 5.** Nearby environment of KDG 215. All of the galaxies from the Tully et al. (2016) database that are located within a cubical volume 6 Mpc on a side and roughly centered on KDG 215 are plotted. The nearest neighbor of KDG 215 is the spiral galaxy M64, with a physical separation of 295 kpc. Also labeled is IC 4107 (physical separation  $\sim 400$  kpc; Karachentsev et al. 2018).

## Acknowledgments

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## References

- Karachentsev, I.D., et al. 2018, ApJ, 858, 62  
Tully, R. B., et al. 2016, AJ, 152, 50



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