

Ionised gas in the Scutum-Centaurus Arm

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Introduction

The warm ionised medium (WIM) is a major component of the ISM of star-forming galaxies. Extending more than 1 kpc from the midplane, it contains $\sim 90\%$ of the ionised gas (by mass) in the Milky Way. It traces feedback from massive stars: supernovae drive turbulence which establish low-density pathways through the multi-phase ISM, allowing ionising photons from O stars to photoionise the WIM.

Here, we present observations of optical emission from the WIM in the Scutum-Centaurus Arm. We use these data to diagnose the scale height, temperature, and physical conditions of the WIM in this environment in the inner Galaxy.

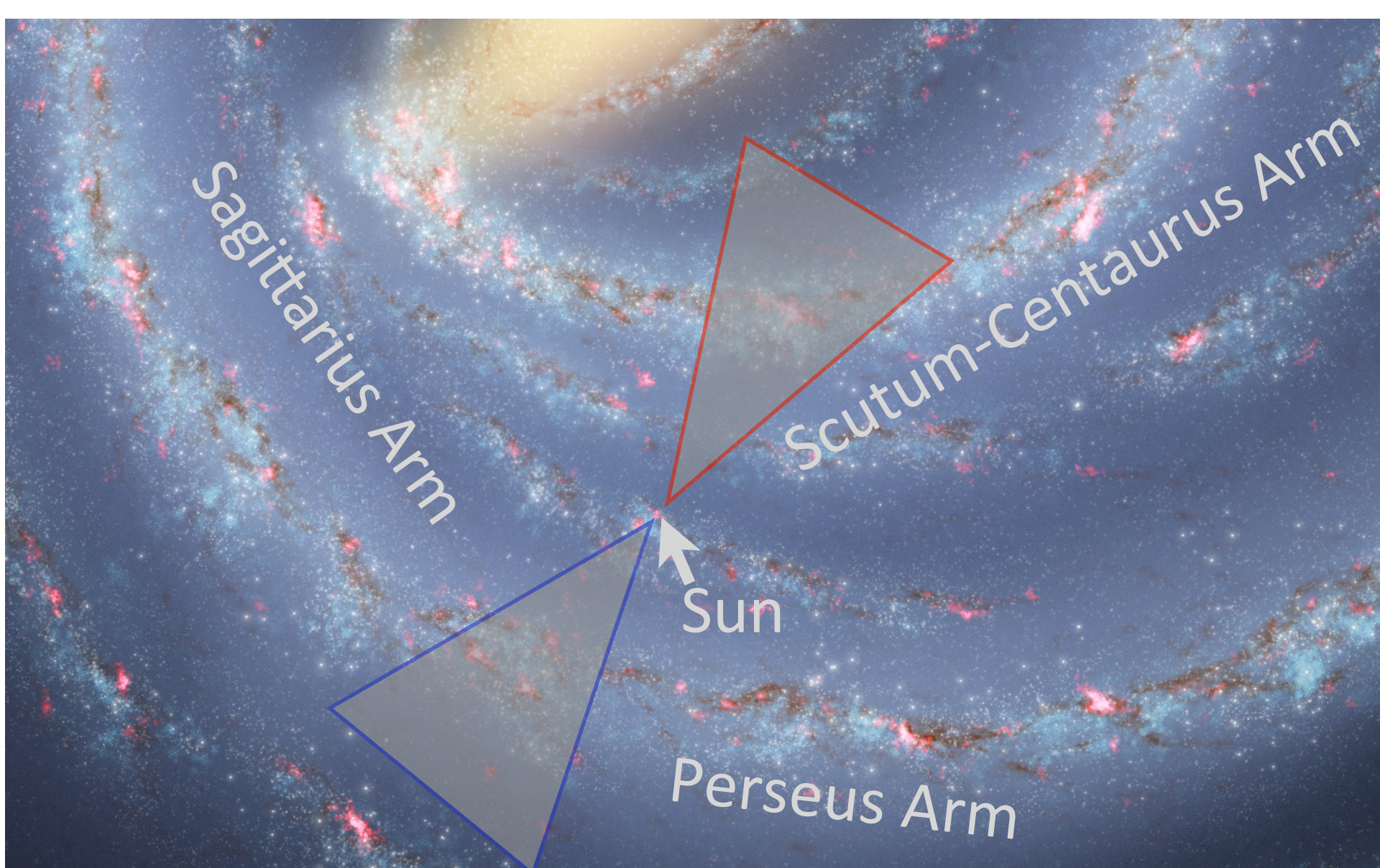


Fig. 1: Region of the Scutum-Centaurus Arm covered by the present work (red) and the Perseus Arm covered previously (blue), superimposed on an artist's conception of the Milky Way (R Hurt).

Observations

We used the Wisconsin H-Alpha Mapper (WHAM) to obtain spectroscopic maps of the red region in Fig. 1 in H α and [S II] $\lambda 6713$.

- 12.5 km/s spectral resolution over $-120 \text{ km/s} < v_{\text{LSR}} < +80 \text{ km/s}$
- Sensitivity of $\approx 0.15 \text{ R}$
- 1° angular resolution

Results

- **Maps** (Fig. 2): Emission from Scutum-Centaurus Arm clearly detected in both tracers.

- **Scale height** (Fig. 3): We measure an H α scale height of $H_{n^2} = 0.30 \pm 0.02 \text{ kpc}$, intermediate between that in the Perseus Arm (Haffner et al 1999) and inner Galaxy (Madsen & Reynolds 2005). Assuming that the filling factor does not change with height, the electron scale height in the arm is $H_n = 0.59 \pm 0.04 \text{ kpc}$. It is likely that the filling fraction of the WIM increases with height, suggesting a larger H_n (Gaensler et al 2008).

- **Line ratios** (Fig. 4): The [S II]/H α line ratio is highest at low H α intensities (Fig. 4a) and large heights (Fig. 4b), as is well known (eg Otte et al 2002, Madsen et al 2006). This indicates that the WIM is physically distinct from classical H II regions with a higher temperature and lower sulfur ionisation state.

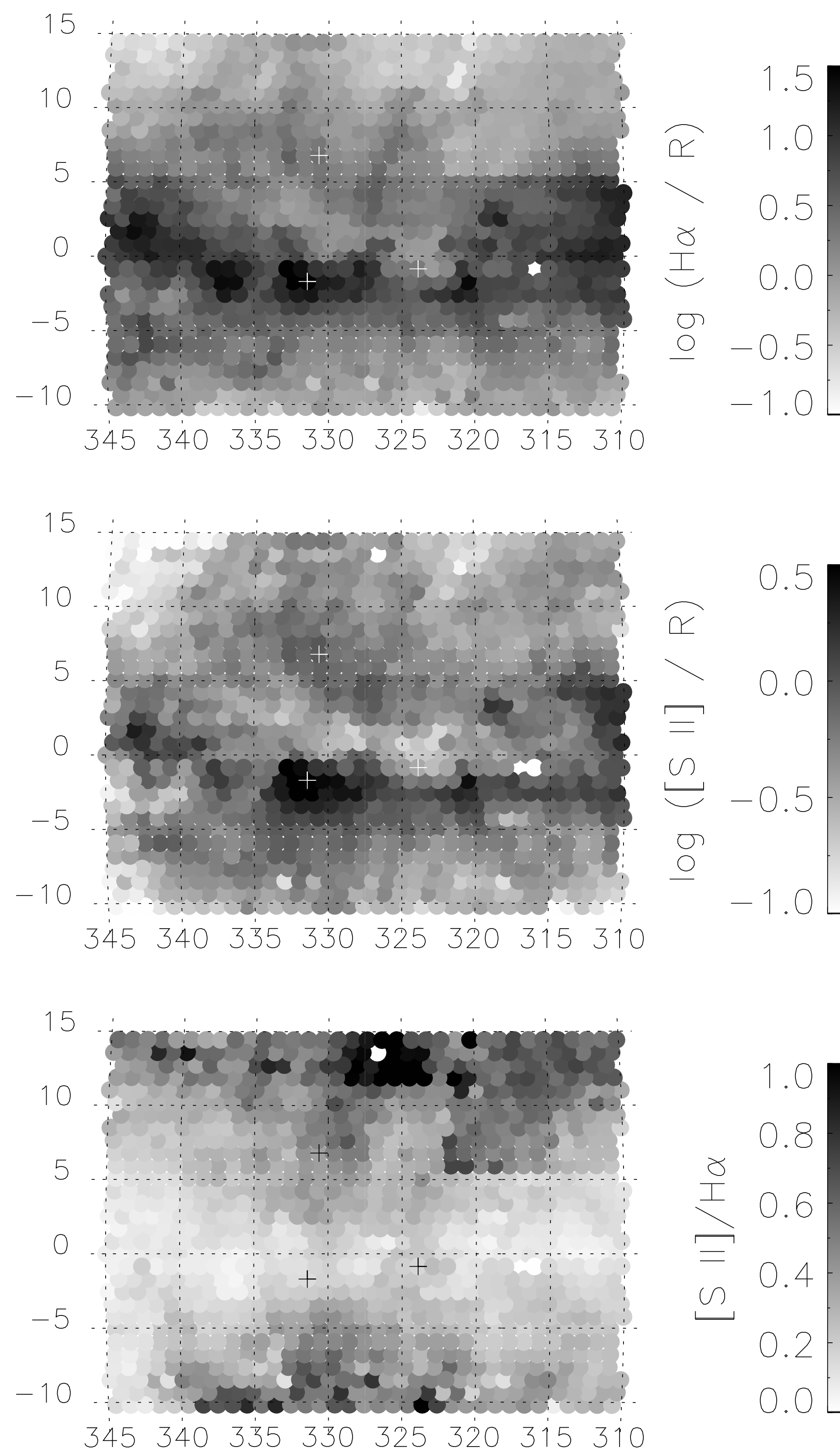


Fig. 2: Maps of H α intensity (top), [S II] intensity (middle), and the line ratio H α /[S II] (bottom) integrated over $-80 \text{ km/s} < v_{\text{LSR}} < -40 \text{ km/s}$.

We divide out the height dependence of this relationship (Fig. 4c) and the intensity dependence (Fig. 4d). We find that a statistically significant trend remains with the height dependence removed, but no trend remains with the intensity dependence removed. We thus conclude that [S II]/H α depends primarily on the intensity of the emitting region. This suggests that the local density determines the temperature and ionisation state of the gas, with height (and presumably the ionising and heating radiation field) a secondary effect only.

Conclusions

- H α emission: higher midplane density and lower scale height in the Scutum-Centaurus Arm than near the Sun or in the Perseus Arm. This suggests that the volume filling fraction increases with height.
- The [S II]/H α line ratio follows an inverse power law relationship with H α intensity. The line ratio is primarily correlated with intensity; there is no significant correlation with height independent of intensity.

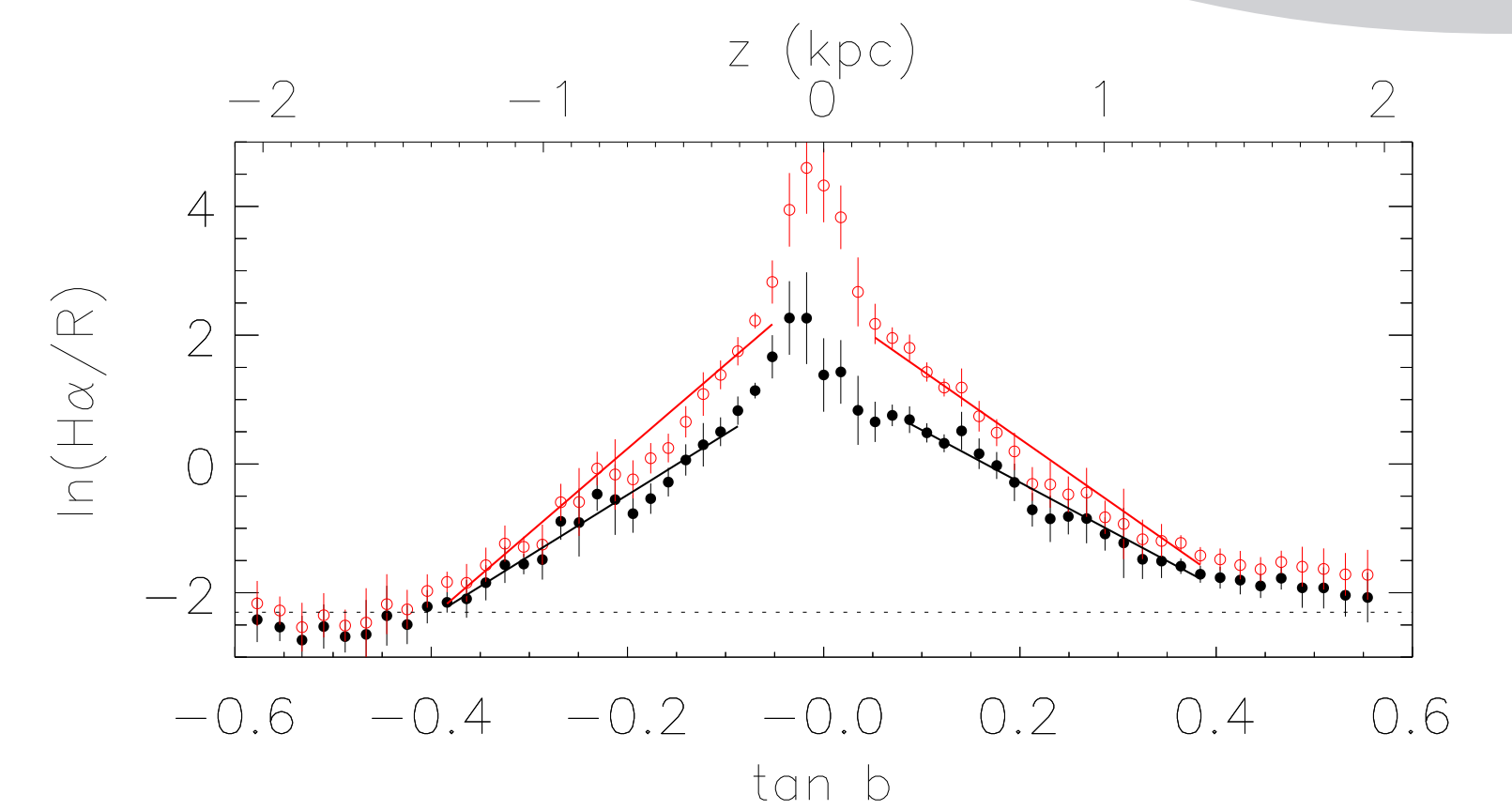


Fig. 3: H α intensity (with, red, and without, black, an extinction correction derived from H I spectra) as a function of height z above the midplane.

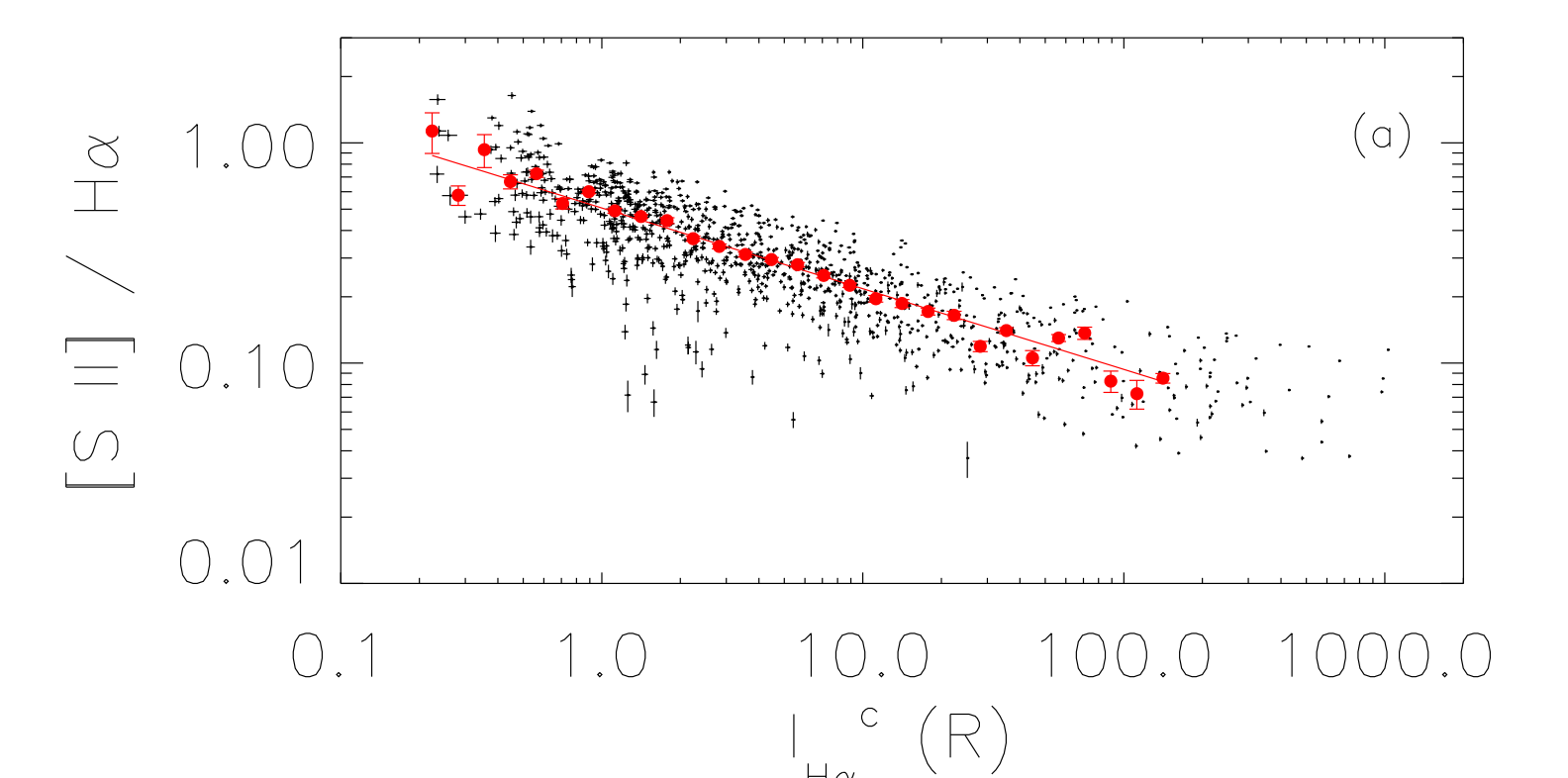


Fig. 4a: The line ratio [S II]/H α from the Scutum-Centaurus Arm as a function of H α intensity. There is a power law relationship, with the line ratio highest in low-intensity regions. At high intensities ($I_{\text{H}\alpha} > 100 \text{ R}$), the line ratio is H II region-like ([S II]/H $\alpha < 0.1$).

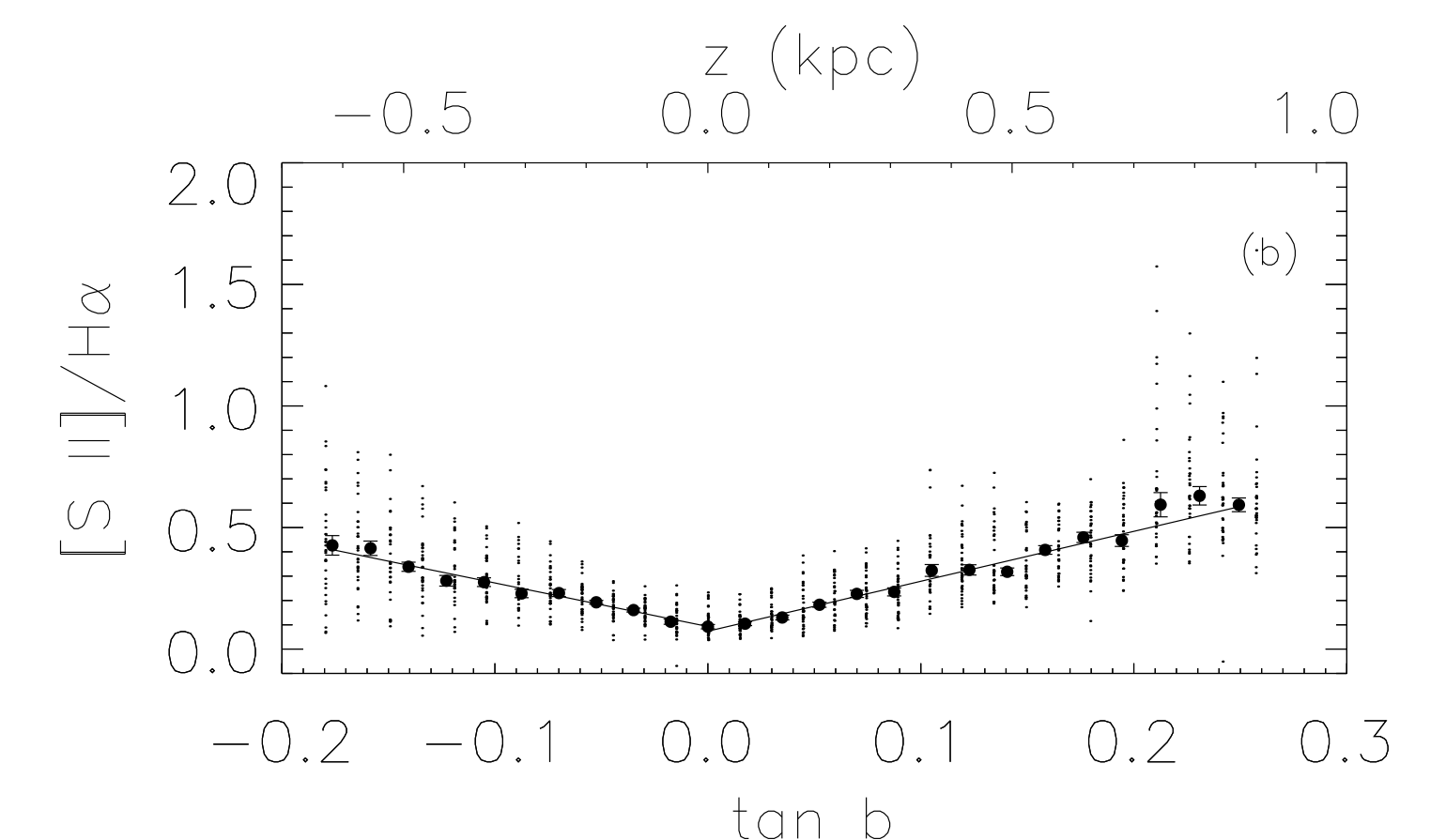


Fig. 4b: The line ratio [S II]/H α from the Scutum-Centaurus Arm as a function of height z . The line ratio decreases with height.

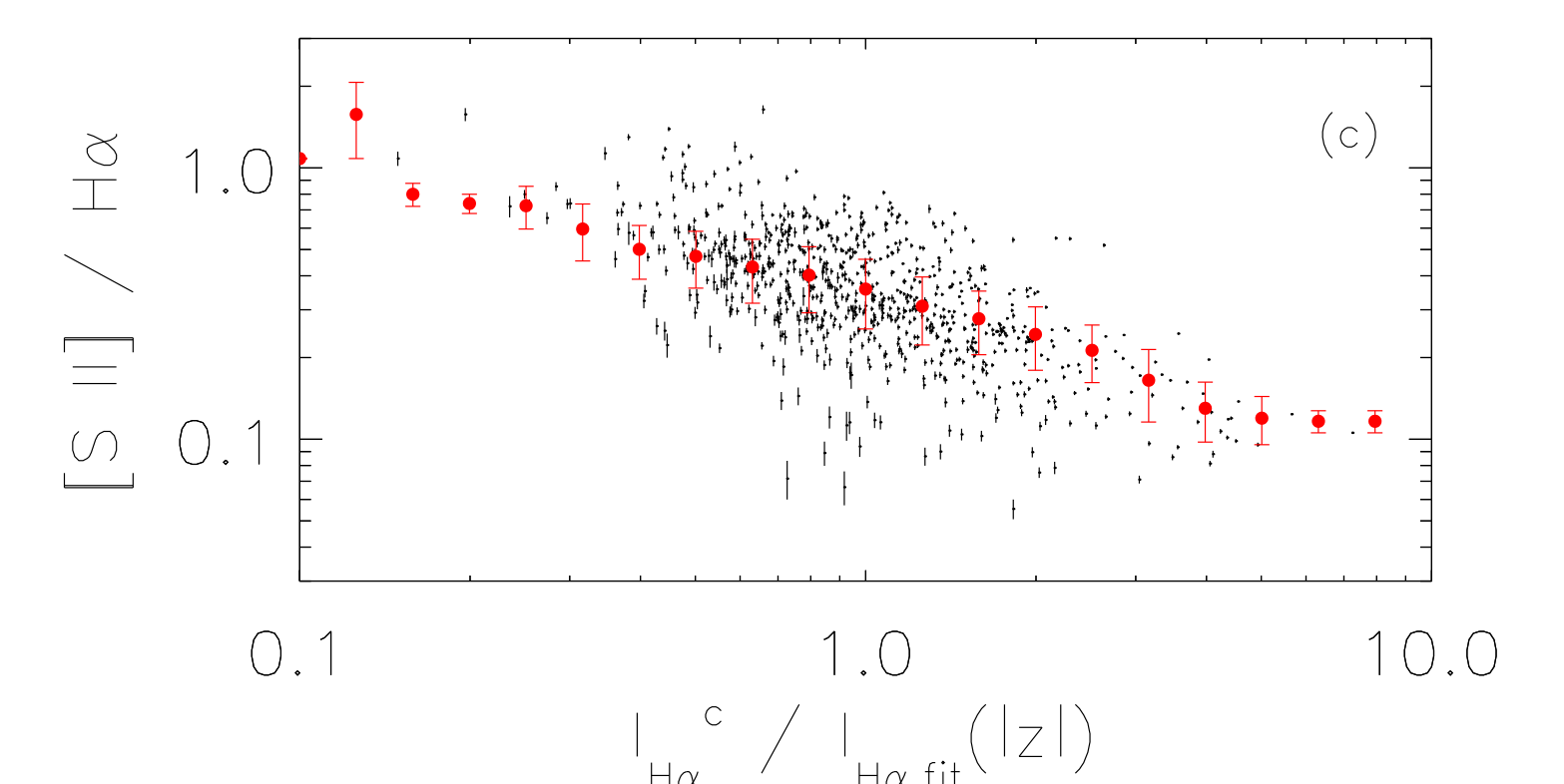


Fig. 4c: As Fig. 4a but with the H α intensity for each point divided by a fit to $I_{\text{H}\alpha}$ as a function of $|z|$. A significant residual trend remains.

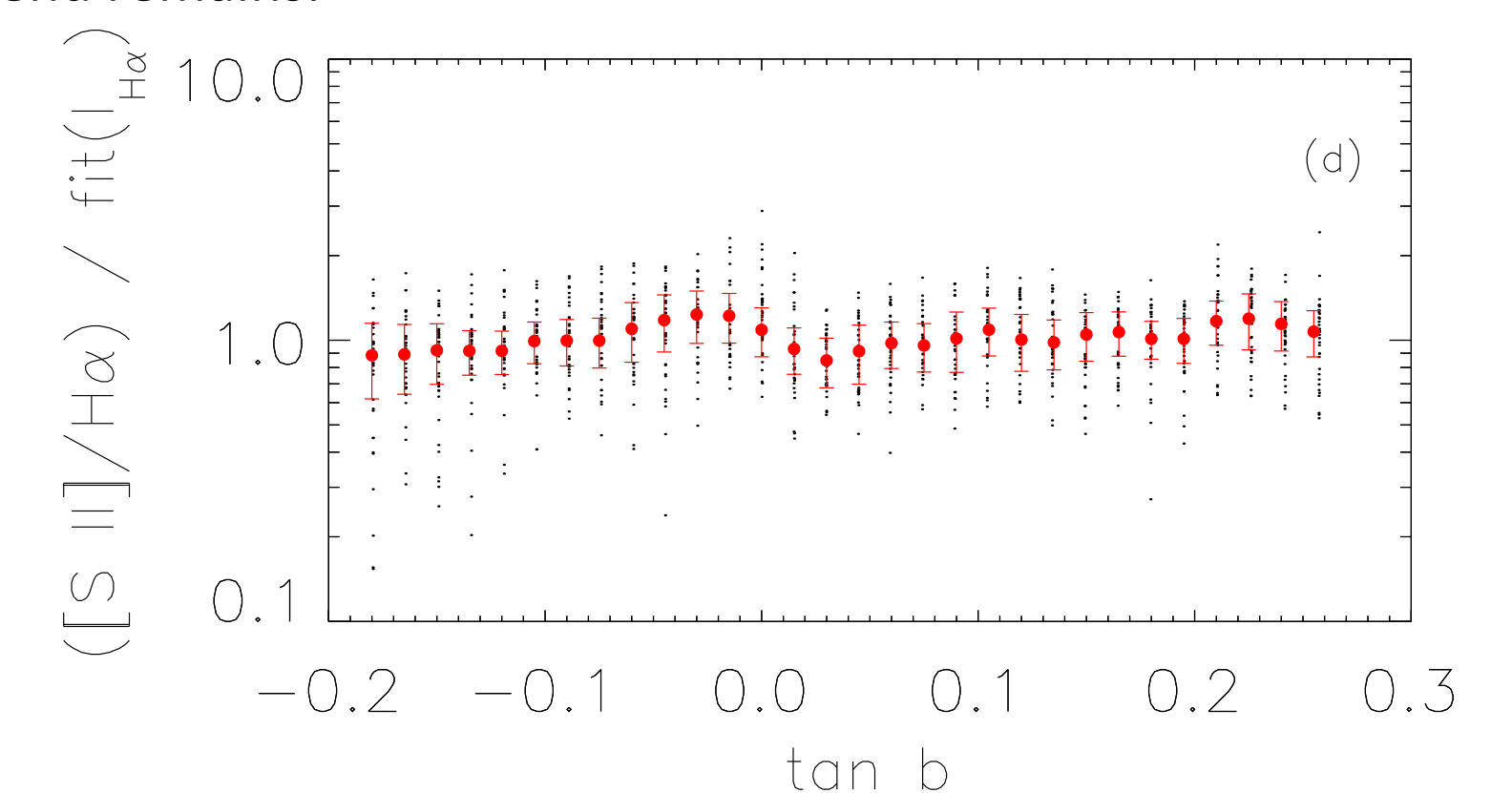


Fig. 4d: As Fig. 4b but with [S II]/H α for each point divided by a fit to [S II]/H α as a function of $I_{\text{H}\alpha}$. No significant residual trend remains.

FOR FURTHER INFORMATION

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