

Spitzer finds cosmic neon's and sulfur's sweet spot: part III, NGC 6822

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Abstract. We observed several H II regions in the dwarf irregular galaxy NGC 6822 using the infrared spectrograph on the *Spitzer Space Telescope*. Our aim is twofold: first, to examine the neon to sulfur abundance ratio in order to determine how much it may vary and whether or not, it is fairly 'universal'; second, to discriminate and test the predicted ionizing spectral energy distribution between various stellar atmosphere models by comparing with our derivation of the ratio of fractional ionizations involving neon and sulfur. This work extends our previous similar studies of H II regions in M83 and M33 to lower metallicities.

Keywords. ISM: abundances, H II regions, stars: atmospheres, galaxies: individual (NGC 6822)

1. Synopsis

We have observed emission lines of [S IV] 10.51, [Ne II] 12.81, [Ne III] 15.56, and [S III] 18.71 μm in a number of extragalactic H II regions with the *Spitzer Space Telescope*. Previous papers (Rubin *et al.* 2007 and 2008) presented our data and analysis for the substantially face-on spiral galaxies M83 and M33. We undertook a similar program for H II regions in the dwarf irregular galaxy NGC 6822. The observations were made with the Infrared Spectrograph with the short wavelength, high resolution module. The above set of four lines is observed cospatially, thus permitting a reliable comparison of the fluxes. From the measured fluxes, we determine the ionic abundance ratios including $\text{Ne}^{++}/\text{Ne}^+$, $\text{S}^{3+}/\text{S}^{++}$, and $\text{S}^{++}/\text{Ne}^+$. By sampling the dominant ionization states of Ne (Ne^+ , Ne^{++}) and S (S^{++} , S^{3+}) for H II regions, we can estimate the Ne/S ratios. From our own Cycle 4 data, we had clear detections of all 4 program lines in only 5 sources after subtracting a background 'off'. We also measured these 4 ionic lines in four large H II regions (Hu I, III, V, X) in NGC 6822 previously observed by the SINGS team. The results from the analysis of these new data have been added to those we published previously. There is no variation in the Ne/S ratio with R_G . Because of the low metallicity and high ionization of H II regions in NGC 6822, the Ne/S ratios we derive are likely a robust estimate of the true value. The median Ne/S ratio derived for the 9 H II regions in NGC 6822 is 10.8. We compare this with previous values. Figure 1 presents these new data along with the previous data sets. We continue to conclude that the Ne/S ratio is significantly higher than the controversial solar value.

Our observations may also be used to test the predicted ionizing spectral energy distribution of various stellar atmosphere models. We compare the ratio of fractional

ionizations $\langle \text{Ne}^{++} \rangle / \langle \text{S}^{++} \rangle$, $\langle \text{Ne}^{++} \rangle / \langle \text{S}^{3+} \rangle$, and $\langle \text{Ne}^{++} \rangle / \langle \text{Ne}^+ \rangle$ vs. $\langle \text{S}^{3+} \rangle / \langle \text{S}^{++} \rangle$ with predictions made from our photoionization models using several of the state-of-the-art stellar atmosphere model grids. The trends of the ionic ratios established from the prior M83 and M33 studies continue to higher ionizations with the present NGC 6822 objects, and are remarkably similar.

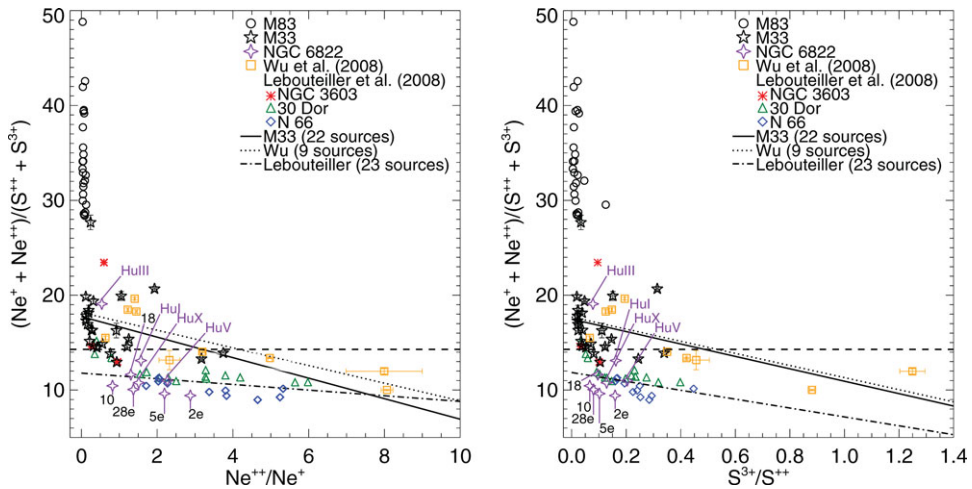


Figure 1. *Colour version in on-line edition only.* Plot of Ne/S vs. $\text{Ne}^{++}/\text{Ne}^+$ [left panel] and $\text{S}^{3+}/\text{S}^{++}$ [right panel]. Our prior M33 results are shown as black stars for the 22 sources where we detected all four lines. There are various linear least-squares fits to the data, all described in Rubin *et al.* (2008). Space precludes a repeat here. The results from our prior M83 study are shown as circles. These data demonstrate a huge variation in the inferred Ne/S ratio at low ionization. The orange squares show the Wu *et al.* (2008) data for blue compact dwarf galaxies, as reanalyzed with our program. We show only 9 points, those objects where they actually detected *all four* lines: [S IV], [Ne II], [Ne III], and [S III]. The median Ne/S for the 9 galaxies is 14.0 very close to the Orion value of 14.3 (Simpson *et al.* 2004) shown as the dashed line. The Leboutteiller *et al.* (2008) data were also reanalyzed and are presented as follows: NGC 3603 (red asterisks), 30 Dor (green triangles), and N 66 (blue diamonds). The median Ne/S ratios for each are 14.6, 11.4, and 10.1, respectively, possibly indicating a decreasing trend with lower metallicity. The 4-sided violet stars show our new *Spitzer* preliminary results for NGC 6822. Only five H II regions labeled in black with their KD number (Killen & Dufour 1982), have all four lines measured. Our remeasure of the four SINGS giant H II regions are labeled in violet.

Acknowledgements

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