FROM AN IMAGE TO A MODEL: THE OWL NEBULA



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Introduction

The Owl Nebula is an old and faint planetary nebula. It is known for its structure, with two cavities that resemble the face of an owl. This research focusses on simulating a model in Python, for the intensity profile **(IP)** of the Owl Nebula. From this we derived a density profile **(DP)** for ionized hydrogen and doubly ionized oxygen. This model was used to further inspect the structure of the nebula and examine which physical processes are responsible for this specific structure. Due to the corona-crisis, third year bachelor students have gathered our data.

Method

We created the intensity model by trying different functions for emission. Through integration of the emission functions along the line of sight, the IP was calculated. Ignoring the faint outer halo, the nebula can be divided into an inner layer with two cavities and an outer layer [1][2]. We used spheres to resemble the shapes of the listed regions, with relative radii 3.1, 7 and 10 to each other for the eyes, inner- and outer layer, respectively [2]. The square root of the IP gives an approximation of the DP [3].

Results

We used the χ²-test, as a measure of how well the model matches with our narrow band data (Table 1).

	$\chi^2_{H\alpha}$	χ^2_{OIII}
Perpendicular	1.20	2.89
Through the eyes	0.09	0.55

Table 1. χ²-values for the model and data IPs along two different axes.

The stellar wind model relationship described the outer layer well [4]. We also found other functions that matched the data, but these were not based on physical principles.

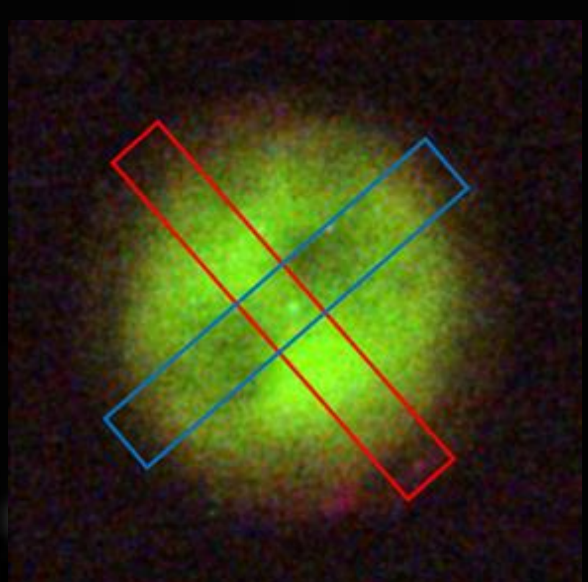

Figure 1. Stacked and coloured image of the Owl Nebula in Hα, OIII and SII. The two boxes indicate the lines along which the emission functions were fitted.

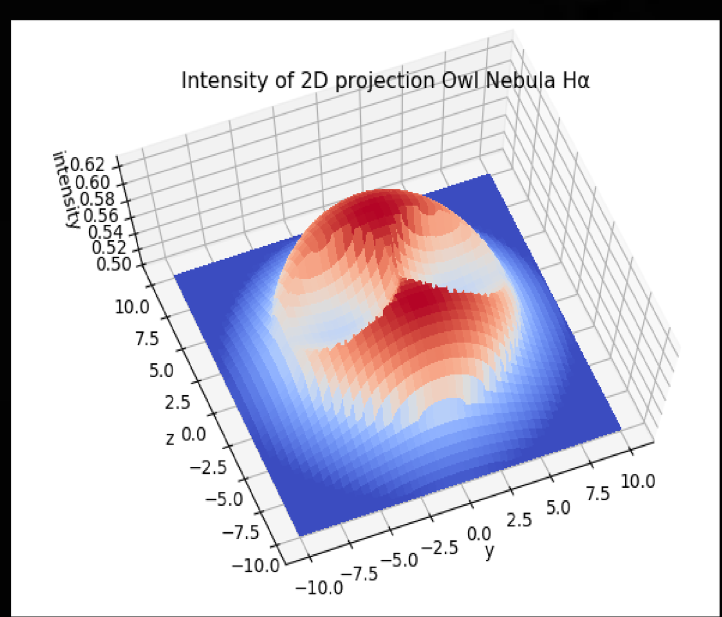

Figure 2. Area plot for model Owl Nebula in Hα.

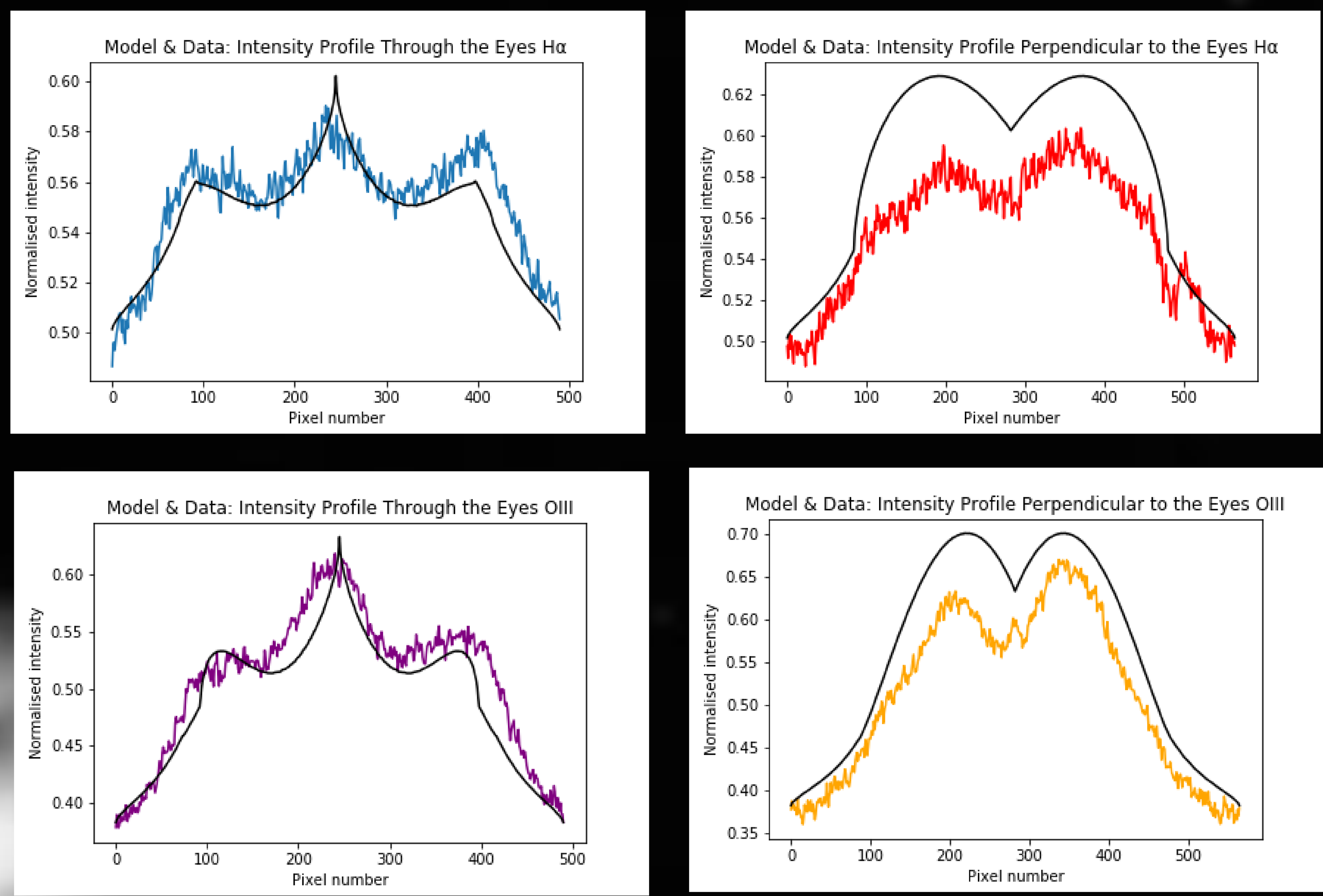

Figure 3. The graphs indicate how the model compares with our data. The data resulted from averaging the values along the smaller sides of the rectangles from figure 1. The coloured lines correspond with the data and the black with to the model.

Conclusion

With the exclusion of dust, a lower density coinciding with the eyes, is the only explanation for this specific IP.
The two peaks in the perpendicular IP are the result of both temperature and density variations. Our model was able to verify that a stellar wind is responsible for the outer layer, but it could not identify physical causes for the eyes and the inner layer. This is due to our inability to separate density from temperature.

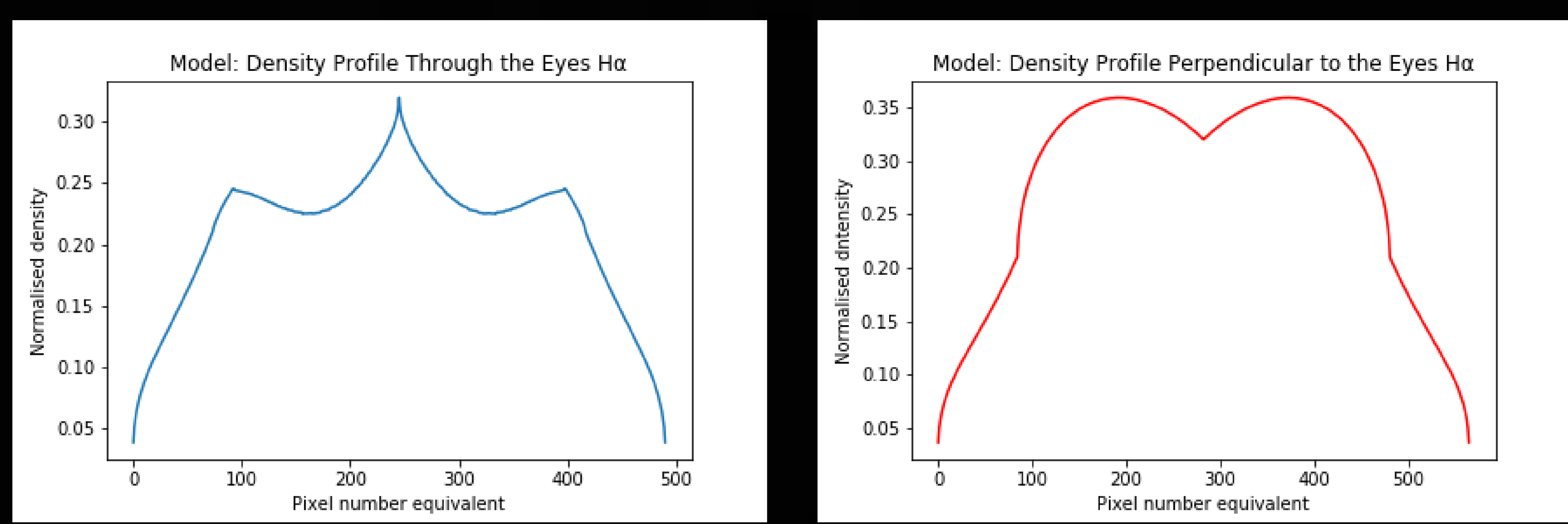

Figure 4. These are the DPs for Hα. The square root of the IP is a rough approximation of the DP.

Discussion

Our perpendicular χ² values were a tad higher, than the ones for the data through the eyes, so they all indicate a good correspondence of the model with the data. Because the outer layer is described by the stellar wind model, a stellar wind is most likely responsible for this layer. An IP is determined by the types of the particles involved, temperature and density. For the Owl Nebula dust plays no role [2]. We only observed elements with one specific ionization, transits in ionization state cause us to lose sight of these elements. The degree of ionization is temperature dependent [5]. Emission depends on the density, of the ions responsible for it, squared [3]. Modifications of the emission functions and the shapes of the regions might lead to even better fits. With more time, more functions and shapes could have been tried.

References

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