Planetary Nebulae in our Galaxy and Beyond
Proceedings IAU Symposium No. 234, 2006
M. J. Barlow & R. H. Méndez, eds.

doi:10.1017/S1743921306004169

3D Photoionisation Modelling of NGC 6302

N. Wright, B. Ercolano, and M. J. Barlow

Department of Physics and Astronomy, University College London

Abstract. We present the first results from our 3D photoionisation modelling of NGC 6302, an extreme high-excitation bipolar planetary nebula with a dense dusty circumstellar disc. We are attempting to fully match the observed spectrum, including the high-ionization infrared coronal lines as well as the observed *ISO* spectrum. We use a bipolar model nebula with a dense circumstellar torus. Our initial results show that, considering the very high stellar temperature required to match the high ionization coronal lines, an extremely high density contrast between the bipolar lobes and the circumstellar disc is required to match the nebular line ratios.

Keywords. planetary nebulae: individual (NGC 6302)

1. Introduction

NGC 6302 is a high-excitation bipolar planetary nebula with a complex emission-line spectrum and a major dust component that shows both O-rich and C-rich chemistry. Its Type I status and the wide range of observed ion stages, particularly [Si IX] (Casassus *et al.* 2000), point towards a very hot central star with a potentially massive progenitor. The central star itself has never been observed, surrounded as it is by a massive (0.5-3 $M_{\odot}$) circumstellar torus of material including a large dust component (0.3 $M_{\odot}$; Matsuura *et al.* 2005). The *ISO* spectrum of NGC 6302 shows the presence of multiple dust features attributed to crystalline silicates (Molster *et al.* 2001).

2. Modelling

The modelling of an object with such a complicated structure provides an excellent testing ground for the 3D photo-ionisation code Mocassin (Ercolano *et al.* 2003, 2005), which is not only capable of treating all dust-related processes but can also model complicated three-dimensional structures using multiple spatial grids. The extreme bipolar structure of NGC 6302 requires a fully three-dimensional treatment. The model used for NGC 6302 is that of an hourglass-shaped axisymmetric nebula with a very dense circumstellar torus (Figure 1). An initial goal, prior to including dust species, has been matching the high-ionization coronal lines and the temperature- and density-sensitive nebular line ratios.

3. Results

We find that a blackbody of approximately 230,000 K is sufficient to get an order-of-magnitude match to the high-ionization coronal lines of magnesium and silicon, as seen in Table 1. However, using a model stellar atmosphere necessitates a higher effective temperature. At such high temperatures it is very difficult to match the temperature- and density- sensitive line ratios. To match both the high-ionization lines and the temperature sensitive line ratios we have been forced to adopt a high density contrast between areas of the model nebula. The circumstellar disc reaches an inner density in excess of 2×10^5 cm^{-3}, while the density in the large bipolar lobes drops to 10^3 cm^{-3}. This

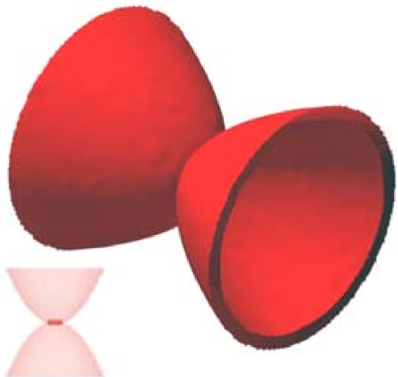

Figure 1. The 3D bipolar density distribution used for the modelling of NGC 6302 with (inset) a side-on view showing the circumstellar disc at the centre.

Table 1. Major diagnostic line ratios and coronal line strengths for models of NGC 6302 using 190,000 K and 230,000 K blackbody central stars (line strengths in 10^{36} erg/s). Observations from Tsamis *et al.* (2003) and Casassus *et al.* (2000).

ID λ	Observed	190,000 K	230,000 K
Hβ	0.0895	0.106	0.0899
He II 4686 / He I 5876	4.30	10.65	14.19
[N II] (6584 + 6546) / 5754	34.66	21.20	25.36
[S II] 6731 / 6717	1.96	2.13	2.12
[Si VI] 1.96μm	3.04 x 10^{-3}	0.260	36.5 x 10^{-3}
[Si VII] 2.47μm	2.66 x 10^{-3}	14.0 x 10^{-3}	5.91 x 10^{-3}
[Si IX] 3.93μm	3.89 x 10^{-6}	1.17 x 10^{-6}	1.94 x 10^{-6}

combination allows us to closely match both the high-ionization coronal lines and the diagnostic line ratios.

4. Conclusions

We can obtain a reasonable match to the IR coronal lines and temperature- and density-sensitive line ratios using a three-dimensional model for the extreme planetary nebula NGC 6302 and find that a large density contrast between the bipolar lobes and the circumstellar disc is necessary to match the diagnostic line ratios and the high-ionization species. With the imminent inclusion of multiple dust species in the models, we aim to more fully elucidate the 3D structure, as well as the central star, nebular and dust properties of this extreme object.

References

Casassus S., Roche P.F., & Barlow M.J. 2000, *MNRAS* 314, 657

Ercolano B., Barlow M.J., Storey P.J., & Liu X.-W. 2005, *MNRAS* 340, 1136

Ercolano B., Barlow M.J., & Storey P.J. 2005, *MNRAS* 362, 1038

Matsuura M., Zijlstra A.A., Molster F.J., Waters L.B.F.M., Nomura H., Sahai R., & Hoare M.G. 2005, *MNRAS* 359, 383

Molster F.J., Lim T.L., Sylvester R.J., Waters L.B.F.M., Barlow M.J., Beintema D.A., Cohen M., Cox P., & Schmitt B. 2001, *A&A* 372, 165

Tsamis Y.G., Barlow M.J., Liu X.-W., Danziger I.J., & Storey P.J. 2003, *MNRAS* 345, 186

https://doi.org/10.1017/S1743921306004169 Published online by Cambridge University Press