



UNIVERSITY OF LEEDS

This is a repository copy of *The Interplay Between Molecular and Ionised Gas Surrounding the Massive Embedded Star AFGL 4176*.

White Rose Research Online URL for this paper:  
<http://eprints.whiterose.ac.uk/138438/>

Version: Accepted Version

---

**Proceedings Paper:**

Johnston, KG [orcid.org/0000-0003-4509-1180](http://orcid.org/0000-0003-4509-1180), Beuther, H, Linz, H et al. (5 more authors) (2014) *The Interplay Between Molecular and Ionised Gas Surrounding the Massive Embedded Star AFGL 4176*. In: Stamatellos, D, Goodwin, S and Ward-Thompson, D, (eds.) *Astrophysics and Space Science Proceedings. The Labyrinth of Star Formation*, 18-22 Jun 2012, Crete, Greece. Springer , pp. 413-414. ISBN 978-3-319-03040-1

[https://doi.org/10.1007/978-3-319-03041-8\\_80](https://doi.org/10.1007/978-3-319-03041-8_80)

---

© 2014, Springer International Publishing Switzerland. This is a post-peer-review, pre-copyedit version of an article published in *Astrophysics and Space Science Proceedings*. The final authenticated version is available online at: [https://doi.org/10.1007/978-3-319-03041-8\\_80](https://doi.org/10.1007/978-3-319-03041-8_80). Uploaded in accordance with the publisher's self-archiving policy.

**Reuse**

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

**Takedown**

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing [eprints@whiterose.ac.uk](mailto:eprints@whiterose.ac.uk) including the URL of the record and the reason for the withdrawal request.



[eprints@whiterose.ac.uk](mailto:eprints@whiterose.ac.uk)  
<https://eprints.whiterose.ac.uk/>

# The interplay between molecular and ionised gas surrounding the massive embedded star AFGL 4176

K.G. Johnston, H. Beuther, H. Linz, P. Boley, T.P. Robitaille, E. Keto, K. Wood, and R. van Boekel

**Abstract** In order to investigate whether the feedback produced by photo-ionisation has an important effect on the geometry of the circumstellar dust and gas around forming massive stars, we have observed the luminous southern embedded star AFGL 4176 in transitions of  $\text{NH}_3$  and the hydrogen recombination line  $\text{H}68\alpha$ . We present our preliminary results, which show a compact HII region embedded in a parsec-scale (radius  $\sim 0.7$  pc) rotating envelope/torus. In addition, the HII region is found to be offset from the centre of the envelope, and the velocity gradient in the ionised gas is not aligned with the rotation axis of the envelope, suggesting complex dynamics and multiplicity.

## 1 Introduction, Observations and Results

As massive protostars greater than  $\sim 10 M_\odot$  can be on the main sequence while still accreting [?], they must do so while producing vast amounts of ionising radiation. Characterising both the ionised and molecular gas around massive stars can therefore determine how they manage to accrete while an HII region forms around them.

To do so, we observed AFGL 4176, a highly luminous ( $1.7 \times 10^5 L_\odot$  at 5 kpc) embedded massive star with a compact HII region [?], whose cm flux corresponds to that of a B0-type star. Here we present our first results from ATCA observations of  $\text{NH}_3(1,1)$  and  $(2,2)$  as well as the radio recombination line  $\text{H}68\alpha$ , to trace both the molecular and ionised gas respectively.

---

K.G. Johnston, H. Beuther, H. Linz, P. Boley, T.P. Robitaille, and R. van Boekel  
Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany  
e-mail: johnston@mpia.de

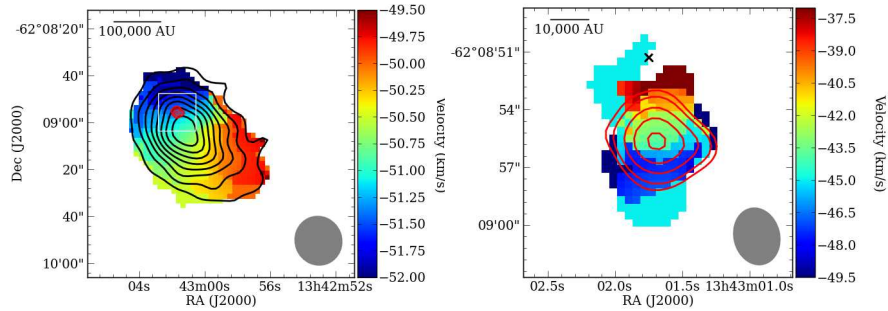
E. Keto  
Center for Astrophysics, 60 Garden Street Cambridge, MA 02138, United States

K. Wood  
School of Physics & Astronomy, University of St Andrews, St Andrews, KY16 9SS, UK

The left panel of Fig. 1 presents the first moment map of the main hyperfine component of  $\text{NH}_3(1,1)$ , overlaid with contours of integrated  $\text{NH}_3(1,1)$  and  $\text{H68}\alpha$  emission. There is a clear southwest-northeast velocity gradient across the  $\text{NH}_3$  emission, which we interpret as rotation of the outer envelope of AFGL 4176 (with radius  $\sim 30''$  or 0.7 pc). By fitting the  $\text{NH}_3(1,1)$  and (2,2) line profiles, we have also uncovered a temperature gradient which increases towards the north of the molecular envelope, likely due to the presence of the HII region heating the surrounding gas. The right panel of Fig. 1 shows the first moment map of the  $\text{H68}\alpha$  emission, covering the area shown by the white box in the left panel of Fig. 1. Here there is instead a roughly north-south gradient in the velocity of the ionised gas. As the velocity gradient is in the opposite sense to that of the  $\text{NH}_3$ , we conclude that the main component of this velocity gradient cannot be due to inheritance of the envelope rotation by the ionised gas, and instead may be explained by an ionised outflow. The HII region traced by  $\text{H68}\alpha$  also does not lie towards the centre of the  $\text{NH}_3$  emission, but is offset by  $8.4''$  (0.2 pc at 5 kpc). Given this offset, the high luminosity of AFGL 4176, and the offset between the HII region and the infrared source ( $4.5''$  or 0.1 pc, see Fig. 1), it is likely that there are in fact multiple young stars forming in the vicinity of AFGL 4176.

## References

1. Hosokawa, T., Omukai, K.: Evolution of Massive Protostars with High Accretion Rates. *ApJ* **691**, 823–846 (2009)
2. Caswell, J. L., Kesteven, M. J., Stewart, R. T., Milne, D. K., et al.: G308.8-0.1 - an unusual supernova remnant containing a short-period pulsar, PSR J1341-6220. *ApJL* **399**, L151–L153 (1992)



**Fig. 1** *Left panel*: First moment map of the  $\text{NH}_3(1,1)$  emission, imaged with a  $20''$  FWHM beam to recover extended emission. Black contours: integrated  $\text{NH}_3(1,1)$  emission, peak:  $0.45 \text{ Jy beam}^{-1} \text{ kms}^{-1}$ . Red contours: integrated  $\text{H68}\alpha$  emission, peak:  $0.62 \text{ Jy beam}^{-1} \text{ kms}^{-1}$ . The white box shows the area covered by the right panel. *Right panel*: First moment map of the  $\text{H68}\alpha$  emission. Beam:  $3.0 \times 2.4''$ , P.A.= $13.7^\circ$ . Red contours show integrated  $\text{H68}\alpha$  emission. The cross marks the 2MASS position of the associated IR source, which dominates the near- and mid-IR.