

Tracing major structures of the inner Galaxy with 6.7-GHz methanol masers

J.A. Green^{1,a}, J.L. Caswell¹, N.M. McClure-Griffiths¹, A. Avison², S.L. Breen¹, M.G. Burton³, S.P. Ellingsen⁴, G.A. Fuller², M.D. Gray², M. Pestalozzi⁵, M.A. Thompson⁶ and M.A. Voronkov¹

¹ CSIRO Astronomy and Space Science, Australia Telescope National Facility, Australia

² Jodrell Bank Centre for Astrophysics, University of Manchester, UK

³ School of Physics, University of New South Wales, Australia

⁴ School of Mathematics and Physics, University of Tasmania, Australia

⁵ INAF/IIFS, Roma, Italy

⁶ Centre for Astrophysics Research, Science and Technology Research Institute, University of Hertfordshire, UK

Abstract. Through analysis of correlations within the longitude-velocity distribution of 6.7-GHz methanol masers, we identify density enhancements indicative of large-scale regions of enhanced star formation. In the context of the inner structure of our Galaxy these are interpreted as the starting points of the spiral arms and the interaction of the long Galactic bar with the 3-kpc arms. Signatures of a continuous 3-kpc arm structure are seen including a prominent tangent at -22° Galactic longitude.

1. INTRODUCTION

6.7-GHz methanol masers have an exclusive association with high-mass star formation [1–3]. As such they are excellent tracers of the spiral arm structure of our Galaxy and provide a new observational basis to constrain dynamical models. The Methanol Multibeam (MMB) survey, using the Parkes and Australia Telescope Compact Array Radio Telescopes, has produced the largest and most complete catalogue of Galactic 6.7-GHz methanol masers, detecting over 900 sources throughout the Galaxy [4]. The longitude-velocity distribution of the inner Galaxy (Figure 1) identifies regions of enhanced star formation believed to be indicative of the starting points of the spiral arms and the interaction of the Galactic bar with the 3-kpc arms.

2. TRACING THE GALACTIC BAR AND THE SPIRAL ARM ORIGINS

We have examined the distribution and density of 6.7-GHz methanol masers in the longitude-velocity domain. Both the longitude-velocity distribution and its structure function demonstrate the presence of structures on small ($<0.03^\circ$) and large ($>3^\circ$) scales. Through smoothing the density distribution on the small scales and binning on the large scales we identify statistically significant dense regions of masers indicative of enhanced high-mass star formation within Galactic scale structures. The maser distribution supports the presence of a long thin bar [5–7] inclined at angle of $\sim 45^\circ$ to the Sun-Galactic centre line

^a e-mail: james.green@csiro.au

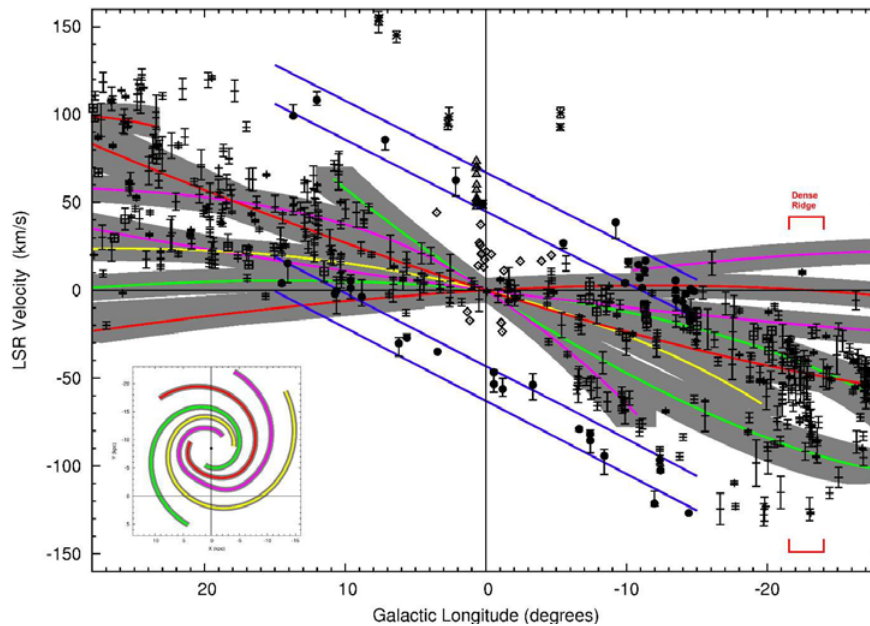


Figure 1. The distribution of 6.7-GHz methanol masers in Longitude and (LSR) velocity within longitudes $\pm 28^\circ$ overlaid with example spiral arm loci (coloured loci) [8]. The grey shading represents an arm thickness of 1 kpc and a velocity tolerance of 7 km s^{-1} . Yellow loci represent the Perseus spiral arm; Purple: Carina-Sagittarius; Orange: Crux-Scutum; Green: Norma. The blue lines delineate the region identified in CO emission as the 3-kpc arms [9]. Crosses show 6.7-GHz methanol masers of the MMB survey. Circles are masers associated with the 3-kpc arms [10]. Diamonds are masers which are interior to the 3-kpc arms, primarily candidates for belonging to the Galactic Centre Zone [11]. Triangles are masers associated with the Sagittarius B2 complex. Stars are masers associated with the Galactic bar. Crosses enclosed in squares are masers with high latitudes (and therefore likely to be closer to us than 4.5 kpc). The starting points of the spiral arms have been adjusted to match the results of this study. The red brackets highlight the longitude range of the dense ridge of sources associated with the 3-kpc arm tangent.

of sight. We identify in the distribution a prominent tangent of the 3-kpc arms near longitude -22° and find the maser distribution of the 3-kpc arms is readily associated with a continuous ring structure in the longitude-velocity domain. High densities of masers identify the approximate starting points of the spiral arms: the major arms, Crux-Scutum at longitude $+26^\circ$ and Perseus at longitude -22° , slightly offset from the bar ends; the minor arms, Norma at longitude 12° and Carina-Sagittarius at longitude -8° , possibly branching from the major arms. The 3-kpc arm ring and spiral arm origins, combined with the spiral arms themselves, account for essentially all the 6.7 GHz methanol masers and their density enhancements within longitudes $\pm 28^\circ$ [12].

References

- [1] Pestalozzi M. R., Minier V., Booth R. S., *A&A* **432**, (737)
- [2] Minier V., et al., *A&A* **403**, (2003) 1095
- [3] Xu Y., et al., *A&A* **485**, (2008) 729
- [4] Green J. A., et al., *MNRAS* **392**, (2009) 783
- [5] Hammersley P. L., et al., *MNRAS* **317**, (2000) L45
- [6] Benjamin R. A., et al., *ApJ* **630**, (2005) L149

Assembling the Puzzle of the Milky Way

- [7] Cabrera-Lavers A., et al., *A&A* **491**, (2008) 781
- [8] Taylor J. H., Cordes J. M., *ApJ* **411**, (1993) 674
- [9] Dame T. M., Thaddeus P., *ApJ* **683**, (2008) L143
- [10] Green J. A., et al., *ApJ* **696**, (2009) L156
- [11] Caswell J. L., et al., *MNRAS* **404**, (2010) 1029
- [12] Green J. A., et al., *ApJ* **733**, (2011) 27