Cosmic Masers - from OH to H_0
Proceedings IAU Symposium No. 287, 2012
R.S. Booth, E.M.L. Humphreys & W.H.T. Vlemmings, eds.

doi:10.1017/S1743921312006692

Observational tests of SiO maser polarisation models

L. L. Richter[1], A. J. Kemball[1,2] and J. L. Jonas[1]

[1]Physics and Electronics Department, Rhodes University, Grahamstown, 6140, South Africa

[2]Department of Astronomy, University of Illinois at Urbana-Champaign, 1002 W. Green Street, Urbana, IL 61801, USA

Abstract. SiO masers are often observed in the near-circumstellar envelope of late-type evolved stars. The polarisation of the masers can be used as a probe of the magnetic field in this region, subject to maser polarisation radiative transfer model. Two main maser polarisation models have been developed for the weak Zeeman splitting case applicable to circumstellar SiO masers. Observational tests aimed at discriminating between these models were performed at maser component level, using VLBA observations of v=1 J=1-0, v=2 J=1-0 and v=1 J=2-1 SiO masers towards the high-luminosity source VY CMa.

Keywords. stars: late-type, polarization, masers

The magnetic fields in the near-circumstellar envelopes of late-type, evolved stars can potentially be derived from observations of polarised Silicon Monoxide masers. This requires a theory of maser polarisation transport for the weak-splitting Zeeman regime appropriate to circumstellar SiO masers.

Two main weak-splitting maser polarisation theories have been developed, by Elitzur (2002) (and references therein) and Watson (2009) (and references therein). The theories conflict in several key respects, and can provide orders of magnitude different magnetic field estimates from the same observed levels of SiO maser circular polarisation. This work describes observational tests aimed at discriminating between the two theories.

The observations were performed with the VLBA (Very Large Baseline Array) in March 2007, towards the supergiant star VY CMa, chosen for it's high SiO luminosity. The SiO transitions v=1 J=1-0, v=2 J=1-0 and v=1 J=2-1 were observed. The data were reduced and imaged in AIPS, using methods described in Kemball & Richter (2011).

The total intensity images of each line are plotted in Figure 1. The images were aligned through spatial cross-correlation of the zero moment maps, to an estimated accuracy of less than 0.05 mas. Three observational tests of weak-splitting maser polarisation theory are described below. Two of the tests were performed using the six maser features shown in the figure, which overlap in multiple transitions.

Comparison of m_l at J=1-0 and J=2-1

The Elitzur model predicts similar levels of m_l in v=1 J=1-0 and v=1 J=2-1. The Watson model predicts larger m_l in the J=1-0 transition, when the level of saturation of the two transitions is similar.

The percentage m_l was compared in the overlapping maser features shown in Figure 1. There is no consistent ordinal relationship between the measured m_l in J=1-0 and J=2-1. However, the results are more consistent with the Elitzur model prediction of similar m_l in the two lines.

Comparison of m_c at J=1-0 and J=2-1

Under the Elitzur model, circular polarisation is caused by standard Zeeman splitting, so the v=1 J=1-0 m_c will be double that of v=1 J=2-1. Under the Watson model, circular

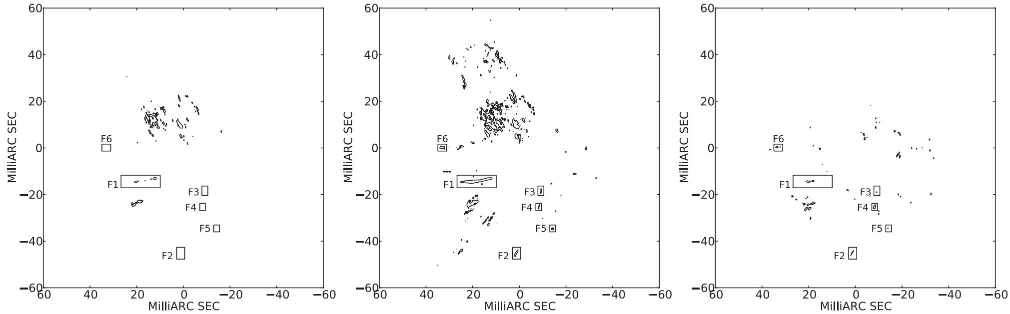

Figure 1. Contour plots of v=2 J=1-0 (left), v=1 J=1-0 (middle) and v=1 J=2-1 (right) SiO maser emission towards VY CMa. The contours are plotted at a level of 5%, 2% and 2% of the image maxima of 12.15 Jy/beam, 22.15 Jy/beam and 46.96 Jy/beam respectively.

polarisation caused by standard Zeeman splitting may be increased by a factor of up to a few due to saturation, and non-Zeeman circular polarisation can arise which is not significantly dependent on the J level of the transition.

The m_c comparison could only be performed for feature F1, at a single channel. There the m_c values were: $4.61 \pm 0.30\%$ for v=1 J=1-0, and $4.31 \pm 2.06\%$ for v=1 J=2-1. Due to the large uncertainties, standard Zeeman circular polarisation cannot be ruled out by this result.

Comparison of m_c and m_l

The non-Zeeman circular polarisation of the Watson model is created by rotation of linear polarisation, and may consequently be correlated with the linear polarisation (Watson 2009). If many maser features show m_c much greater than the average value of $m_l^2/4$, then the circular polarisation is unlikely to be caused by non-Zeeman effects (Wiebe & Watson 1998).

In the current observations, 14 maser features show statistically significant m_c and m_l. There is no correlation between m_c and m_l for these features. For all 14 features, m_c is greater than $m_l^2/4$. This is strong evidence against the non-Zeeman circular polarisation mechanism of the Watson model (Wiebe & Watson 1998).

These component-level observational tests of the SiO maser polarisation theory are an important improvement on previous single-dish implementations of the tests, which are affected by spatial blending of the many maser components.

Overall, the tests are not supportive of Watson model non-Zeeman circular polarisation. The most definitive test of Zeeman circular polarisation is the v=1 J=1-0 and J=2-1 circular polarisation comparison, which provided inconclusive results in these observations. Further observations are suggested to provide additional data for these tests.

References

Elitzur, M. 2002, in: V. Migenes & M. J. Reid (eds.), *IAU Symposium 206* (Astronomical Society of the Pacific), p. 452

Kemball, A. J. & Richter, L. L. 2011, *A&A*, 533, A26

Watson, W. D. 2009, in: A. Esquivel, J. Franco, G. Garcia-Segura, E. de Gouveia Dal Pino, A. Lazarian, S. Lizano & A. Raga (eds.), *Revista Mexicana de Astronomia y Astrofisica Conference Series Vol. 36* (Instituto de Astronomia), p. 113

Wiebe, D. S. & Watson, W. D. 1998, *ApJ* (Letters), 503, L71