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Periodic methanol masers and colliding wind binaries

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Abstract. Since the discovery of periodic variability of Class II methanol masers associated with high-mass star formation, several possible driving mechanisms have been proposed to explain this phenomenon. Here the colliding wind binary (CWB) hypothesis is proposed to describe the periodic variability. It is shown that the recombination of a partially ionized gas describes the flare profiles remarkably well. In addition, the quiescent state flux density is also described remarkably well by the time-dependent change of the electron density. This suggests that the periodicity is caused by the time-dependent change in the radio free-free emission from the background HII regions against which the maser is projected.

Keywords. masers, ISM: HII regions, radio continuum: ISM, stars: mass loss, X-rays: Binaries

1. Introduction

Since the discovery of the widespread class II methanol masers at 12.2 GHz Batrla *et al.* (1987) and 6.7 GHz Menten (1991), a number of these methanol masers have been discovered Goedhart *et al.* (2003) to show periodic/regular variability. Several possible hypotheses have since been proposed to describe the periodic/regular variability. For the masers with flare profiles similar to G9.62+0.20E, we invoke the CWB model proposed by van der Walt *et al.* (2009) and van der Walt (2011), because the decay of the flare profile resemble that of a recombining partially ionized gas. The CWB model describes the flare profile as the time-dependent change in free-free emission from some small volume of partially ionized gas at the ionization front of the background HII region. This is described by the time-dependent change of the electron density from that volume in the optically thin limit (i.e. $I_\nu \propto n_e^2$). The time-dependent electron density at the ionization front is solved for using:

$$\frac{dn_e}{dt} = -\beta n_e^2 + \Gamma n_{H^0} \tag{1.1}$$

where β is the recombination coefficient, Γ is the ionization rate which is obtained from the equation of ionization balance, and n_e and n_{H^0} have their normal meaning.

2. Results

The top left panel of Figure 1 show the $n^2_{e,min}$'s and $n^2_{e,max}$'s obtained from recombination fits applied to each flare. It also shows a linear regression to both $n^2_{e,min}$(t) and $n^2_{e,max}$(t). The top right panel show both the linear regression of $n^2_{e,min}$ to the quiescent state flux density as well as a linear regression to the quiescent state flux density. The

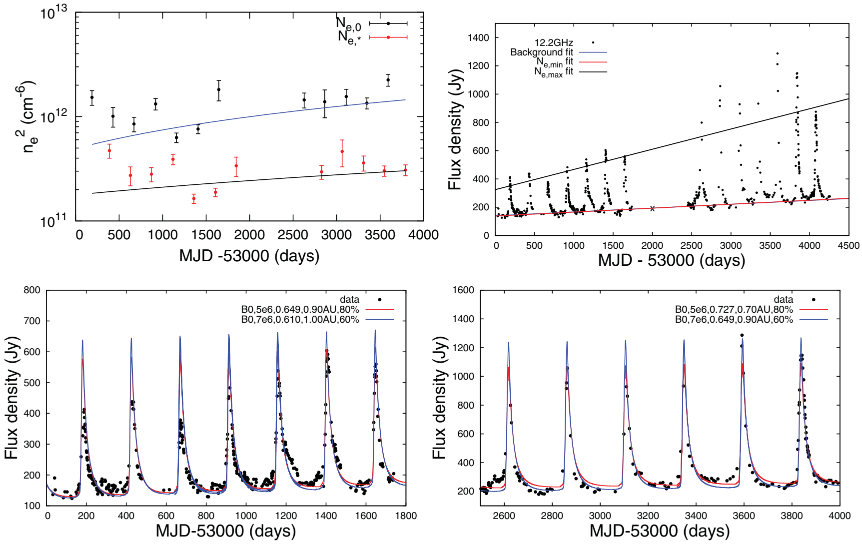

Figure 1. Top left: $n^2_{e,min}$'s and $n^2_{e,max}$'s from recombination fits and linear regression fits. Top right: linear regression fit of $n^2_{n,min}$ fitted to the quiescent state flux density, as well as the linear regression fit of $n^2_{e,max}$ to the observed data at "x". Bottom panels: two CWB models compared with two observed datasets. The legends show several parameters used to obtain the best fit.

gradients are almost identical with values of 0.027 ± 0.010 Jy day^{-1} and 0.026 ± 0.001 Jy day^{-1}, respectively. It shows a remarkable similarity, suggesting that the flare profiles are described by the time-dependent change in the electron density from the background HII region. Additionally, the linear regression of $n^2_{e,max}$ was also applied to the observed flux density at MJD 55000 (indicated by "x") assuming a relative amplitude of $\simeq 2.2$, defined by Goedhart *et al.* (2003). This also describes the increase in the peak flux density remarkably well.

From these results, the best fit peak and quiescent electron densities associated with the flares were used to choose the best fit CWB model. The bottom panels of Figure 1 show the comparisons of two CWB models with the observed flux density. It shows that the time-dependent electron density describes the observed flux density remarkably well. The CWB model also describe the flare profiles of three other sources.

3. Conclusion

This remarkable comparison suggests that the observed flare profiles can be described by the CWB model. The high electron densities (10^{5-6} cm^{-3}) derived suggests a early stage of stellar evolution.

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