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/S174392131200676X

On the Methanol masers in G9.62+0.20E: Preliminary colliding-wind binary (CWB) calculations

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Abstract. A comparison between the observed periodic flaring of methanol maser sources in the star forming region G9.62+0.20E and the continuum emission from parts of a background HII region is made. Using a colliding wind binary (CWB) model preliminary calculations show that the CWB model results fit the maser light curves very well.

Keywords. masers, hydrodynamics

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1. Introduction

Class II methanol masers are exclusively associated with massive star forming regions. At present about seven class II methanol masers show periodic or highly regular flaring behavior. Recently van der Walt *et al.* (2009) and van der Walt (2011) proposed that periodic methanol masers might be due to changes in the background free-free emission associated with a CWB system. Although the toy model of van der Walt (2011) is able to reproduce the observed maser light curves quite well, some untested assumptions have to be checked. The two most important assumptions are:

- The shocked gas cools adiabatically and the shock luminosity L_{shock} scales as $1/r$ where r is the distance between the stars.
- The flux of ionizing radiation emerging from the shocked gas is sufficient to produce the ionization required to explain the observed variation in the masers.

As a start, before some more elaborate numerical calculations we first investigated the validity of the above mentioned assumptions and present some very early results here. For the ionizing source, a B0 type star was assumed with $L_\star = 38.5 ergs^{-1}$ cm^{-2}, M = 20 $M_\odot$ and $\dot{M} = 10^{-6} M_\odot yr^{-1}$ (see Sternberg *et al.* 2003). For possible post-shock temperatures we assumed $T_{shock} = 10^6$ K and 5×10^6 K, and calculated the corresponding emission spectra with `Cloudy`. The luminosity of the shocked gas was taken as $\log(L_{shock}) =$ 35, 35.5, 36, and 36.5. Figure 1(left) shows the combined spectra of the central star and the hot shocked gas for the two temperatures and $\log(L_{shock}) = 35.5$. Figure 1(right) compares the resulting electron density distributions at the ionization front (based on G9.62+0.20E) for $T_{shock} = 10^6$ K and for different shock luminosities as indicated in the figure.

Inspection of Figure 1(right) shows that for $\log L_{shock} < 35$ there is practically no effect, while for $\log \mathrm{L_{shock}} = 35.5$ and $\log \mathrm{L_{shock}} = 36$ there is a marked increase in the electron density. In fact the required change in electron density to explain the observed changes in 12.2 GHz masers in G9.62+0.20E can be obtained with $\mathrm{L_{shock}} = 10^{35.5}$.

A 2D numerical hydrodynamic code (see e.g. Pittard & Stevens 1997)) was used to investigate whether $\mathrm{L_{shock}} \simeq 10^{35.5}\mathrm{erg\,s^{-1}}$ can be produced and what r dependence

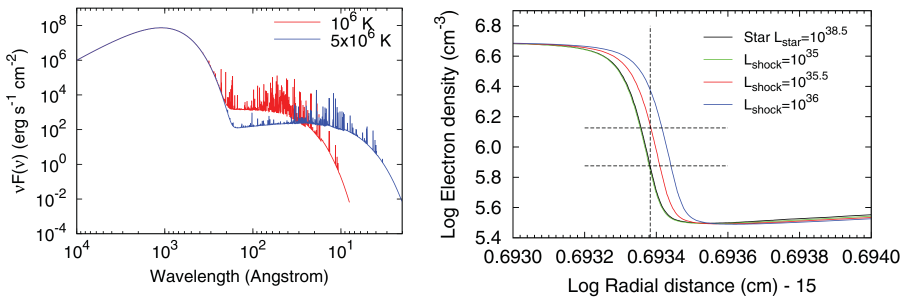

Figure 1. (left) Combined stellar and hot shocked gas spectra for temperatures as indicated in the graph. (right) Electron density distribution in the ionization front for various shock luminosities. Horizontal lines show required change in electron density.

follows from reasonable assumptions about mass loss rate and terminal wind speed. These calculations showed that most probably the shocks cool radiatively resulting in an $L_{shock} \propto r^{-2}$ dependence. It was also found that the requirement that $\log L_{shock} \simeq 35.5$ can be met with reasonable assumptions on the mass loss rates and wind speeds.

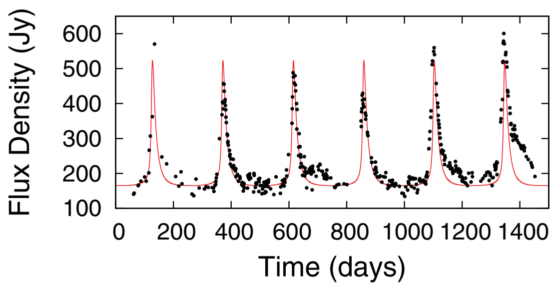

Figure 2. Comparison between the simulated results and the observed 12.2 GHz maser light curves.

An $L_{shock} \propto r^{-2}$ dependence was used in the toy model of van der Walt (2011). Figure 2 compares the observed time series for the 12.2 GHz maser in G9.62 + 0.20E with the model results. The $L_{shock} \propto r^{-2}$ dependence requires the eccentricity of the orbit to be 0.81 compared to 0.9 for $L_{shock} \propto r^{-1}$. Otherwise the model seems to reproduce the observed time series very well.

From an energetics point of view it seems that the shock is sufficient to reproduce the required energy. From the results the 12.2 GHz masers in G9.62+0.20E can be explained by a radiative shock ($L_{shock} \propto r^{-2}$) rather than adiabatic ($L_{shock} \propto r^{-1}$).

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https://doi.org/10.1017/S174392131200676X Published online by Cambridge University Press