METHANOL MASERS IN W3(OH)

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ABSTRACT. The formation conditions of the methanol masers in W3(OH) are studied separately. The lower limits of the densities of the A- and E-type maser regions are 10^5 and 10^6 cm^{-3}. The A-type maser requires a stronger excitation from HII region than the E-type maser. The relative abundance of methanol to molecular hydrogen is more than 5×10^{-5}. The calculation indicates that there are maser series $(J_0-(J+1)_{-1})E$, $(J_1-(J+1)_0)E$ J=1,2 and $(J_2-(J+1)_1)A^+$ J=7,8,9 in W3(OH).

W3(OH) is a compact HII region $9_2-10_1 A^+$(Wilson et al.1984), 2_1-3_0E (Wilson et al.1985) and 2_0-3_{-1} E (Batrla et al.1987) masers were detected by single dishes and subsquently by VLA and VLBI(Menten et al.1988a,b)

The goals of this paper are studying the formation conditions of the masers separately and focusing our attention on the correlation between these masers and the radiation field.

The statistical calculations covers the lowest 203 energy levels of A-type methanol (Zeng and Lou 1990, hereinafter Paper I) below 250 cm^{-1} and 68 energy levels of E type methanol (Zeng et al.1987, hereinafter Paper II) below 231 cm^{-1} (Fig.1). Adopting a large velocity gradient model and escape probability method (Golgreich and Kwan 1974, Paper I,II) the statistical equilibrium and radiative transfer equations are solved. The compact HII region excited by stars (or stellars clusters) is charaterized as a blackbody with a radiation temperature Trd and a filling factor f. The bulk of the dust, which emits primarily in the far-infred, lies in a dense shell immediately outside the ionized zone with an average optical depth of $\tau_d=0.5$ and dust temperature Td=45K (Thronson and Harper 1979). The observed dust spectrum is fitted by $\eta_{ij}B_{ij}(Td)$, Where B_{ij} is the Planck function,
$\eta_{ij}=(\nu_{ij}/\nu_0)$ if $\nu_{ij}<\nu_0$
$=1$ if $\nu_{ij}\geqslant\nu_0$. $\nu_0=8.565\times10^{12}$ Hz (Paper I).
The kinetic temperature is taken as 100K similar to the value obtained from NH_3 .We refer to Lees et al.(1973), Lovas et al.(1982) and Moruzzi et al.(1990) for the energy data and to Lees (1973),Lovas et al. (1982)

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and Pei, Zeng and Gou (1988) for the Einstein A-values. A tentative estimation for the collision rates is made based on Paper II.

Fig.2 (a) and (b) show the maser brightness temperatures Tb's of (2_0 -3_{-1})E and (2_1-3_0)E as the functions of density. The other parameters are F/Vgr=10^{-6} km^{-1} s pc , where F is the relative abundance between methanol and molecular hydrogen .The values of Trd*f equals 300 K and 30 K for curve a and b separately . It is found that Tb's of (2_0- 3_{-1})E and (2_1-3_0)E sensitively depend on the density. The density of more than 2x10^5 cm^{-3} is required to get a Tb of more than 10^6 K even there is an external field of Trd*f=300 k.

Tb(9_2-10_1 A$^+$) is the sensitive functions of density and external field (Fig.3-4). Shown in Fig.3 , Tb(9_2-10_1 A$^+$) could be higher than 10^5 K if Trd*f larger than 900K. While if Trd*f less than 250K there would be no (9_2-10_1)A$^+$maser to display even the density is 10^5 cm^{-3} . Fig.4 shows Tb(9_2-10_1 A$^+$) could be higher than 10^5K if the density larger than 10^5 cm^{-3} and Trd*f=900K.

According the observation results (Menten et al.1988 (a),(b)) ,assume the ratios of the Tb's as

Tb(2_0-3_{-1} E)/Tb(2_1-3_0E)=10 , Tb(2_0-3_{-1} E)/Tb(9_2-10_1A$^+$)=100.

Suppose that (2_0-3_{-1} E) and (2_1-3_0E) masers emerge in the same region which is called E region. This status can be found in Fig.4,where the density of E and A-type maser regions are around 10^6 and 10^5 cm^{-3} ,the Trd*f=300K and 900K (or Trd=3000K,the filling factors of both maser regions is 0.1 and 0.3.).Since either (9_2-10_1)A$^+$or (2_0-3_{-1}),(2_1 -3_0)E masers require the pumping from HII ,and ,the masers coexist with the absoption line 10_1-9_2A$^-$,the maser regions should be infront of the HII region. The schematic diagram of E,A maser and HII regions is shown in Fig.5. Where L_A and L_E are the distances between HII region and A and E-type maser regions. $L_A/L_E = \sqrt{1/3}$.The lower limits of the densities of A and E region are 10^5 and 10^6 cm^{-3}. F/Vgr=10^{-6}km^{-1}s pc is necessary for fitting the high brightness temperature of the masers. According the results of VLA observation assume a lower limit of Vgr of 50 km s^{-1} pc^{-1} . Therefore the relative abundance of CH_3OH/H_2 should be larger than 5x10^{-5} . The overabundance of methanol may be caused by rich C^+ in the partly ionized region ,the interface of HII region and molecular cloud, because carbon gas phase chemistry is initiated by the radiative association of C^+ and H_2 . It also may be caused by the shock and the dust reactions.

The calculation results indicate there are maser series :(J_0 -(J+1)$_{-1}$)E ,(J_1-(J+1)$_0$)E J=1,2 and (J_2-(J+1)$_1$)A$^+$ J=7,8,9 in W3(OH). Some masers in the series have not been detected, because they are relatively weak or/and hard to be detected by based ground instruments. Only (7_2-8_1)A$^+$ at 111.289GHz could be the candidate to be detected and to prove the existence of the maser series of (J_2-(J+1)$_1$)A$^+$.

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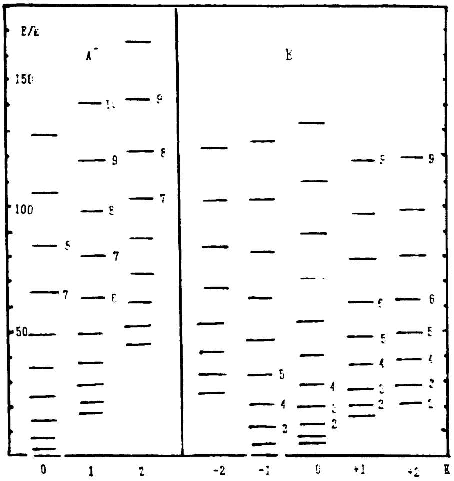

Fig.1 The energy diagram of methanol

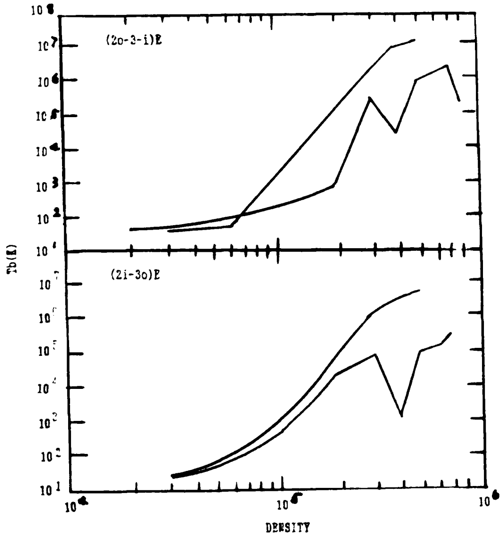

Fig.2 (a) (b) The brightness temperatures Tb of $(2_0-3_{-1})E$ and $(2_1-3_0)E$ are shown as the functions of density. Other parameters are indicated in the text.

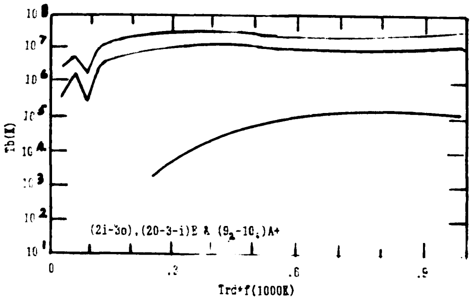

Fig.3 The Tb of $(2_0-3_{-1})E$ (curve a), $(2_1-3_0)E$ (curve b) and $(9_2-10_1)A^+$ (curve c) are shown as the funtions of Trd*f. Where densities are 7×10^5 cm^{-3} for curves a and b and 10^5cm^{-3} for curve c.

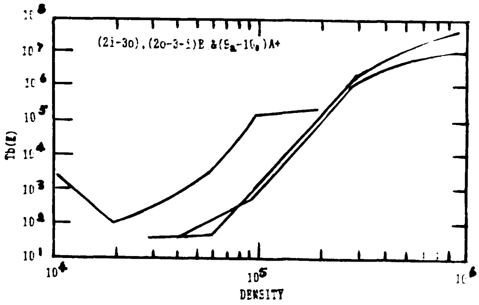

Fig.4 The Tb of $(2_0-3_{-1})E$ (curve a), $(2_1-3_0)E$ (curve b) and $(9_2-10_1)A^+$ (curve c) are shown as the functions of density. Where the value of Trd*f are taken as 300K for the curves a and b and 900K for the curve c.

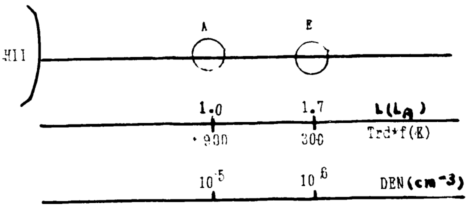

Fig.5 The schematic diagram of the regions of HII and E,A-type masers.

References

Batrla,W.,Matthews,H.E.,Menten,K.M.,Walmsley,C.M.(1987) 'Detection of strong methanol masers towards galatic HII regions',Nature 326(5),49-51

Goldreich,P.,Kwan,J.(1974) 'Molecular clouds',Astrophys.J.189,441-453

Lees,R.M.(1973)'On the E_2-E_1 labeling of energy levels and the anomalous excitation of interstellar methanol',Astrophys.J.184, 763-771

Lees,R.M.,Lovas,F.G.,Kirchhoff,W.H.,Johnson,D.R.(1973) 'Microwave spectra of molecules of astrophysical interest III.Methanol',J. Phys.Chem.Ref.Data,2,205-214

Lovas,F.J.,Suenram,R.D.,Snyder,L.e.,Hollis,J.M.,Lees,r.M.(1982) 'Detection of the torsionally excited state of methanol in Orion A',Astrophys.J.253,149-153

Menten,K.M,Johnston,K.J.,Wadiak,E.J.,Walmsley,C.M.,Wilson,T.L. (1988a) 'High resolution VLA observations of the W3(OH) methanol masers',Astrophys.J.,331,L41-L45

Menten,K.M.,Reid,M.J.,Moran,J.M.,Wilson,T.L.,Johnston,K.J.Batrla, W.(1988b) 'VLBI observations of 12 GHz methanol masers', Astrophys.J.333,L83-L86

Moruzzi,G.,Riminucci,P.,Strumia,F.,Carli,B.,Carlotti,M.,Lees,R.M., Mukhopadhyay,I.,Johns,J.W.C.,Winnewisser,B.P.,Winnewisser,M. (1990) 'The spectrum of CH_3OH between 100 and 200 cm torsional and forbidden transitions',J.Mole.Spectro.144,139-200

Pei,C.C.,Zeng,Q.,Gou,Q.Q.(1988) 'Einstein A-values of A-type methanol',Astron.Astrophys.Suppl.Ser.76,35-52

Thronson,H.A.Jr.,Harper,D.A.(1979) 'Compact HII regions in the far -infrared',Astrophys.J.230,133-148

Wilson,T.L.,Walmsley,C.M.,Snyder,L.E.,Jewell,P.R.(1984) 'Detection of a new type of methanol maser',Astron. Astrophys. 134,L7-L10

Wilson,T.L.,Walmsley,C.M.,Menten,K.M.,Hersen,W.(1985) 'The discovery of a new masering transition of interstellar methanol' ,Astron.Astrophys.147,L19-L22

Zeng,Q.,Lou,G.F.(1990) 'Interstellar A-type methanol masers', Astron.Astrophys.228,480-482(Paper I)

Zeng,Q.,Lou,G.F.,Li,S.Z.(1987) 'The masers of E-type methanol in Orion KL and Sgr B2',Astrophys. Space Sci.132,263-268(Paper II)