Results of identifying the g-factor of 6.7 GHz methanol maser via polarization observations (E22C002)

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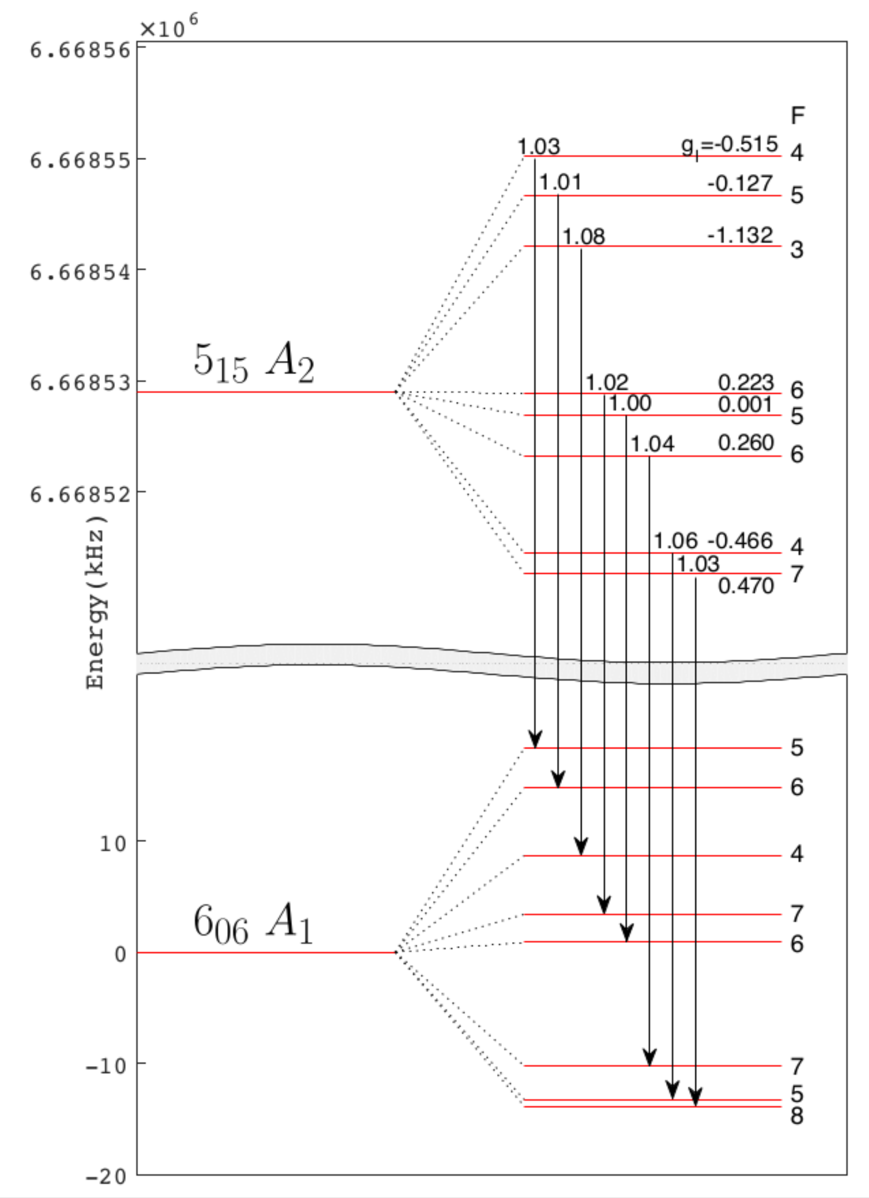
E22C002

- The goal of the project is to compare the magnetic field strength measured with the ex-OH with the Zeeman splitting of the 6.7 GHz methanol masers.
- Two sources W75N (G81.871+0.781) and ON1 (G69.540-0.976)
- That allows to determine which is the favoured hyperfine transition among the eight ones that may contribute to the 6.7 methanol maser emission.
- Each transition has its own Landé g-factor
- g-factor → dimensionless quantity that characterizes the magnetic moment and angular momentum of an atom, a particle or the nucleus
- $g_l \rightarrow \alpha_Z \rightarrow B_{||} = \Delta V_Z / \alpha_Z$

6.7 GHz ($5_{15}\ A_2 \rightarrow 6_{06}\ A_1$)

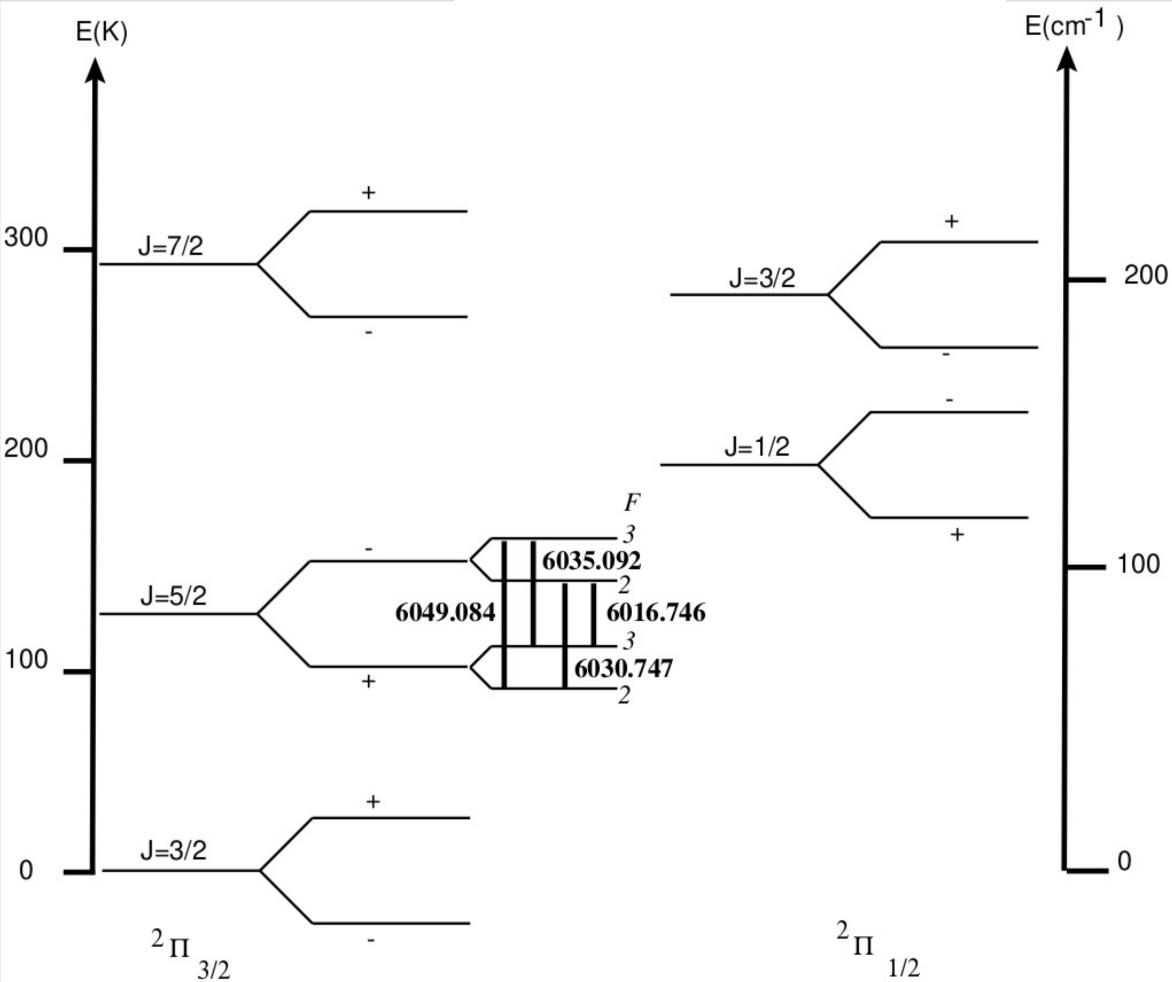


Supplementary Table 3: 6.7 GHz ($5_{15}\ A_2 \rightarrow 6_{06}\ A_1$)

$F_{\rm up}$	$F_{\rm down}$	ΔE (kHz)	g_l	α_Z(Hz mG^{-1})	α_Z(m s^{-1}G^{-1})	A (10^{-8} s^{-1})
7	8	2.500	0.619	0.472	21.176	0.103
6	7	−4.397	0.342	0.261	11.716	0.104
6	7	3.541	0.294	0.224	10.067	0.102
5	6	−2.889	−0.167	−0.127	−5.712	0.101
5	6	3.015	0.002	0.002	0.070	0.100
4	5	1.240	−0.612	−0.467	−20.963	0.106
4	5	−2.835	−0.677	−0.516	−23.187	0.103
3	4	−4.417	−1.489	−1.135	−50.955	0.108

Credits: Lankhaar et al. 2018

6.035 GHz $^2\Pi_{3/2}, J = 5/2$

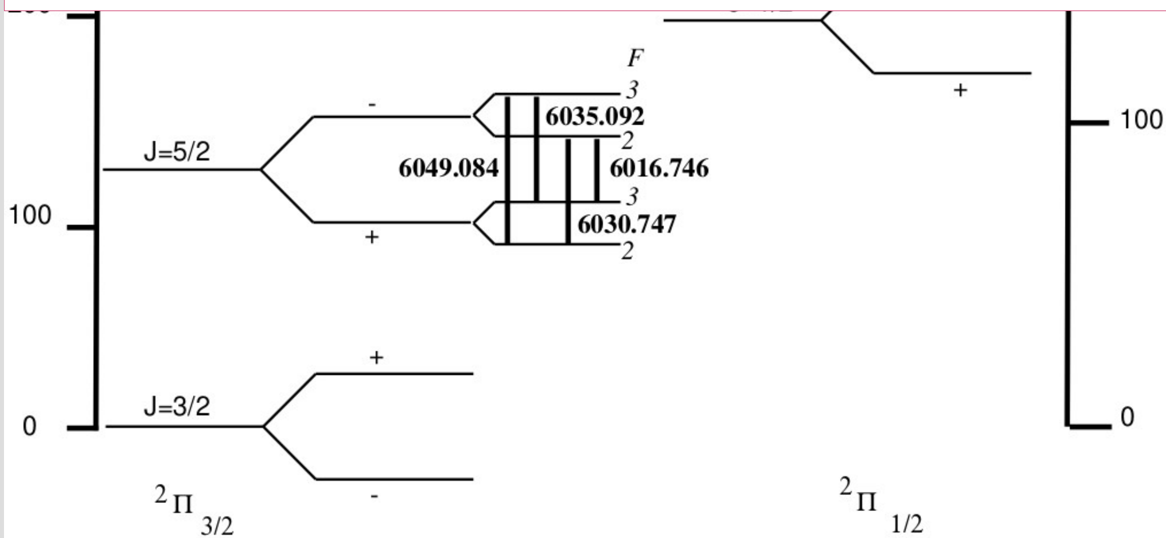


Credits: Baudry et al. 1997

6.035 GHz $^2\Pi_{3/2}, J = 5/2$

				(km s^{-1} G^{-1})
$J=5/2$	$F=2\to3$	6016.7	0.678	33.8
g_l = 0.485	$2\to2$	6030.7	1.582	79.0
	$3\to3$	6035.0	1.132	56.4
	$3\to2$	6049.0	0.678	33.8

Credits: Davies 1974



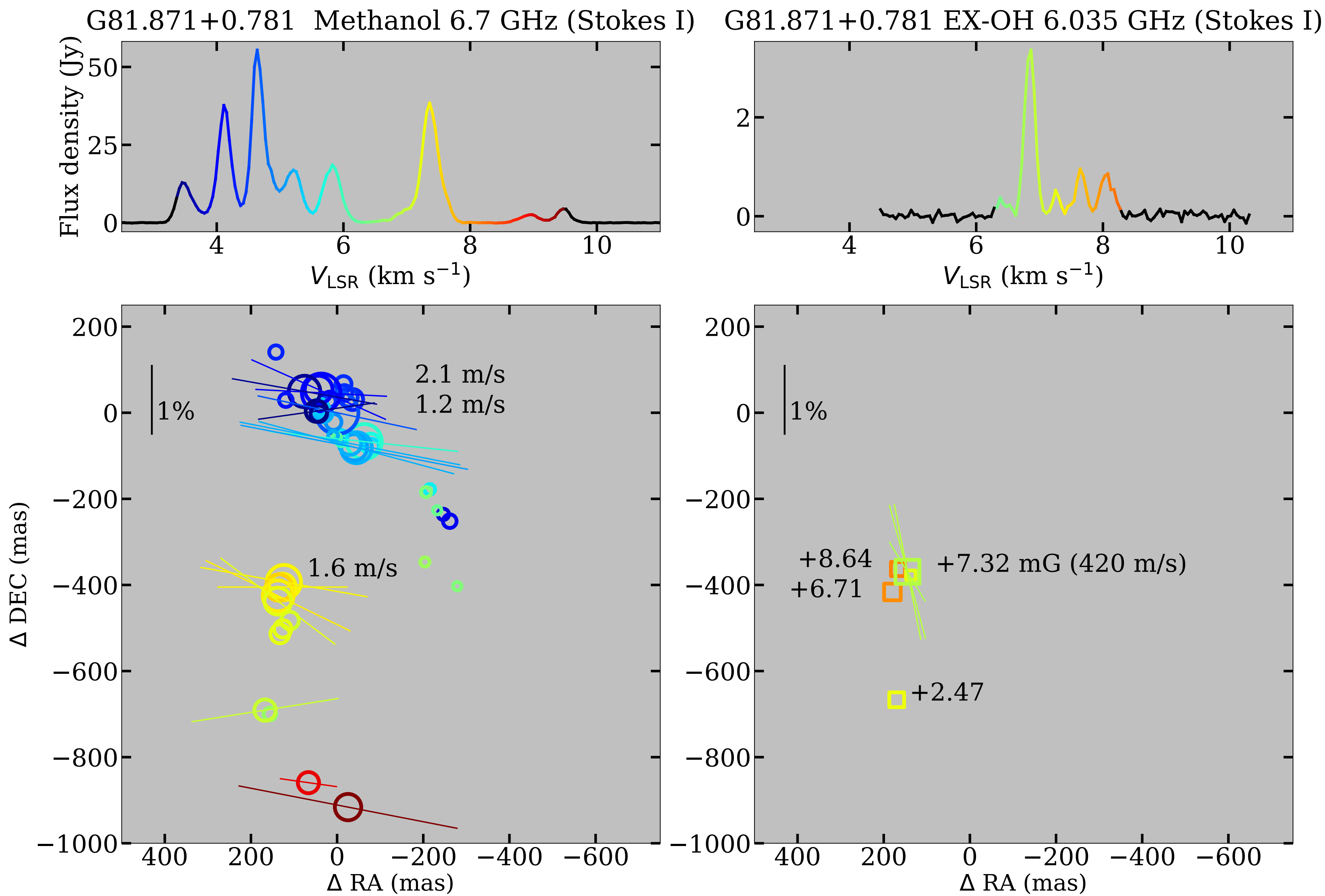
$$B_{||} = \Delta V_Z / \alpha_Z$$

$$B_{||}\ (G) = (RHC - LHC) / 56.4$$

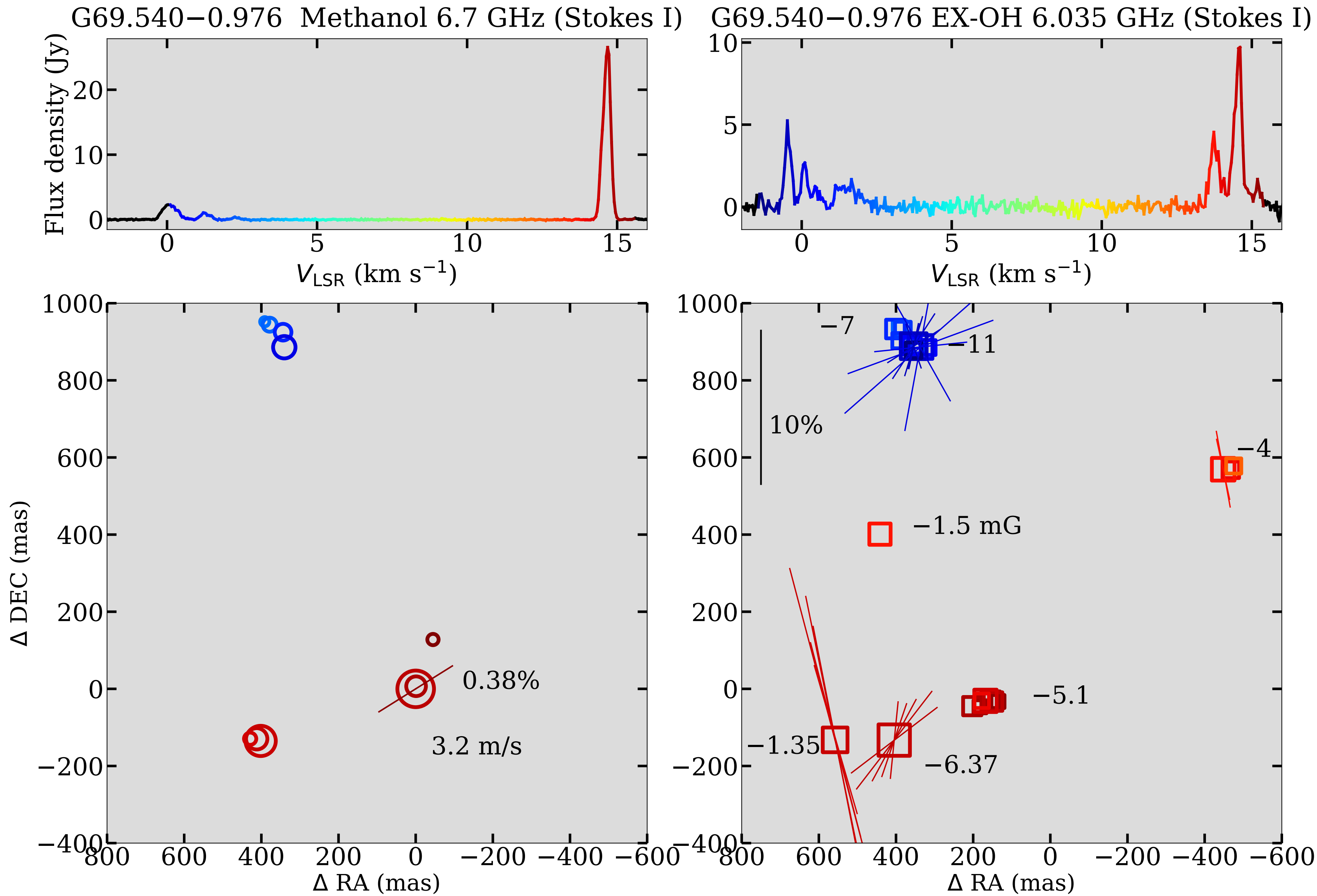
Credits: Baudry et al. 1997

The assumptions for analysis:

- CH_3OH and ex-OH maser features coincide in the space
- Circulary polarized spectrum for 6.7 GHz maser (V-stokes spectrum):
  - V_{peak} > 3 rms
  - V_{peak} > 3 $\sigma_{s.-n.}$ (self-noise produced by the total intensity of the maser feature in its channels)



G81.871+0.781 Methanol 6.7 GHz (Stokes I)
G81.871+0.781 EX-OH 6.035 GHz (Stokes I)
Flux density (Jy)
V_{LSR} (km s^{-1})
Δ DEC (mas)
Δ RA (mas)
1%
2.1 m/s
1.2 m/s
1.6 m/s
+8.64
+6.71
+7.32 mG (420 m/s)
+2.47


G69.540−0.976 Methanol 6.7 GHz (Stokes I)
G69.540−0.976 EX-OH 6.035 GHz (Stokes I)
Flux density (Jy)
V_{LSR} (km s^{-1})
Δ DEC (mas)
Δ RA (mas)
0.38%
3.2 m/s
−7
−11
10%
−4
−1.5 mG
−5.1
−1.35
−6.37

W75N :

$$\alpha_Z^{meth} = \frac{\Delta V_Z}{B_{||}^{exOH}} = \frac{1.6\ m/s}{7.32\ mG} = 0.21858\ ms^{-1}mG^{-1} = 218.58\ ms^{-1}G^{-1}$$

$$\alpha_Z^{meth} = \frac{\Delta V_Z}{B_{||}^{exOH}} = \frac{1.2\ m/s}{7.32\ mG} = 0.16393\ ms^{-1}mG^{-1} = 163.39\ ms^{-1}G^{-1}$$

ON1:

$$\alpha_Z^{meth} = \frac{\Delta V_Z}{B_{||}^{exOH}} = \frac{3.2\ m/s}{-5.1\ mG} = -0.62745\ ms^{-1}mG^{-1} = -627.45\ ms^{-1}G^{-1}$$

$$\alpha_Z^{meth} = 218.58\, ms^{-1}G^{-1}$$

$$\alpha_Z^{meth} = 163.39\, ms^{-1}G^{-1}$$

$$\alpha_Z^{meth} = -627.45\, ms^{-1}G^{-1}$$

Supplementary Table 3: 6.7 GHz ($5_{15}\ A_2 \rightarrow 6_{06}\ A_1$)

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Credits: Lankhaar et al. 2018

Any of the calculated values do not agree with the reported values if only one hyperfine transition dominates over the others → density of the gas might be different?

If we assume the methanol maser does not arise in the same volume of gas as ex-OH maser, let's calculate magnetic field using factor from the table.

We assume the preferred hyperfine transition is:
F = 3 → 4:

For ON1 (G69.54):

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F_{up}	F_{down}	ΔE (kHz)	g_l	α_Z(Hz mG^{-1})	α_Z(m s^{-1}G^{-1})	A (10^{-8} s^{-1})
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Credits: Lankhaar et al. 2018

$$B_{\|}^{meth} = \frac{\Delta V_Z}{\alpha_Z}^{meth} = \frac{3.2\ m/s}{-50.955\ m/s/G} = -62.8\ mG$$

$$B_{\|}^{exOH} = -5.1\ mG$$

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Credits: Lankhaar et al. 2018

$$B_{\parallel}^{meth} = \frac{\Delta V_Z}{\alpha_Z}^{meth} = \frac{1.6\ m/s}{-50.955\ m/s/G} = -31.4\ mG$$

$$B_{\parallel}^{meth} = \frac{\Delta V_Z}{\alpha_Z}^{meth} = \frac{1.2\ m/s}{-50.955\ m/s/G} = -23.5\ mG$$

$$B_{\parallel}^{exOH} = 7.32\ mG$$

Now we can check if density is proper for those values of magnetic field using relation: $|B| \propto (n_{H_2})^{0.65}$ (Crutcher et al. 2010):

For ON1 (G69.54):

$$n_{H_2}^{exOH} = \left(\frac{B_{||}^{exOH}}{B_{||}^{meth}}\right)^{0.65^{-1}} n_{H_2}^{meth}$$

$$n_{H_2}^{exOH} = \left(\frac{-5.1}{-62.8}\right)^{0.65^{-1}} n_{H_2}^{meth}$$

$$n_{H_2}^{exOH} = 0.02\, n_{H_2}^{meth}$$

Now we can check if density is proper for those values of magnetic field using relation: $|B| \propto (n_{H_2})^{0.65}$ (Crutcher et al. 2010):

For ON1 (G69.54):

$$n_{H_2}^{exOH} = \left(\frac{B_{||}^{exOH}}{B_{||}^{meth}} \right)^{0.65^{-1}} n_{H_2}^{meth}$$

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$$n_{H_2}^{exOH} = 0.02\, n_{H_2}^{meth}$$

Considering the lowest possible density 10^7 cm^{-1} for the 6.7 methanol maser (Cragg et al. 2005) we get:

$$n_{H_2}^{exOH} = 2 \cdot 10^5\ cm^{-1}$$

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$$n_{H_2}^{exOH} = 0.02\, n_{H_2}^{meth}$$

For W75N:

$$n_{H_2}^{exOH} = 0.04\, n_{H_2}^{meth}$$

$$n_{H_2}^{exOH} = 0.05\, n_{H_2}^{meth}$$

Conclusion:

- Due to the fact if we consider F=3 $\rightarrow$ 4 as a favored hyperfine transition then we have a discordance with the sign of magnetic field (W75N) and different relation between gas densities in both sources it can means there is no not always a favored hyperifine transition.
- Transition F=6 $\rightarrow$ 7 and F=7 $\rightarrow$ 8 can be favoured in the case of W75N. This transition give the same sign of B and similar gas density relation.
- More sources are needed, becase these caluclation rely on on two cases.