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Research Note

The H_2O/OH maser 342.01+0.25: a case of supernova-induced star formation?

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Summary. We have detected time variable H_2O emission toward the 1612/1667 MHz OH maser OH 342.01+0.25. The maser is seen in the direction of a windswept dark nebula interacting with the supernova remnant Kes 45. The maser has no optical counterpart, although it is a rather bright object in the IR (L=2.83). The rapid temporal variations of the H_2O maser suggest that the maser is associated with a young object and not a late type star. Possibly the H_2O/1667 MHz OH maser originates in an object not associated with the 1612 MHz OH/IR source. If the H_2O maser is young, the close association with Kes 45 may represent an example of supernova-induced star formation.

Key words: maser – OH sources – IR sources – supernova remnants – radio frequency lines: molecular lines – star formation – late type stars

Table 1. Summary of temporal variations in the H_2O 342.01+0.25 spectrum

H_2O peak intensity (Jy)	One sigma-rms (Jy)	Radial velocity v_{lsr} (km s^{-1})	Line width (km s^{-1})	Date
{32 11	1.5	{−44 −24	{6 4	1980.10.04
{15 11	2.5	{−44 −31	{2 3.5	1981.06.11-14
{15 10	2.0	{−41 −30	{3 2	1981.07.15
–	4.0	–	–	1981.07.27
70	15	−45	5	1981.09.10
50	10	−42	1.5	1981.09.18
21	5	−41	4	1981.10.25

1. Introduction

The maser OH 342.01+0.25 was detected by Caswell et al. (1981) in a 1612 MHz survey of the galactic plane. The 1612 MHz OH maser has a ~10 km s^{-1} broad emission line at $v_{lsr}=-48$ km s^{-1}, which appears to vary in intensity. Caswell et al. also detected weak 1667 MHz OH maser emission, but at a different velocity, $v_{lsr}=-31$ km s^{-1}. They found no emission at 1665 or 1720 MHz. Accordingly, the maser is not readily classified as type II or type I, especially since the 1612 MHz appearance is quite atypical.

Braz and Scalise (1982) included this maser in their search for H_2O masers associated with type I OH masers and H II continuum peaks. They detected two weak, broad components at −44 and −24 km s^{-1}, respectively. Recently Epchtein and Nguyen-Q-Rieu (1982) also found a bright, although not very red ($K-L$=1.83) IR object at the 1612 MHz position. To obtain additional information on the nature of this object, we have studied the time variation of the H_2O maser on every occasion, when we have had access to an H_2O receiver.

2. Observations and results

The observations discussed here, were carried out from October 1980 to May 1982 using the 13.7 m radome covered radio telescope at the Itapetinga Radio Observatory[1], in Brazil. At a frequency of 22.2 GHz the antenna halfpower beamwidth is 4.′5, and by accounting for aperture efficiency and radome transmission, the flux conversion factor is 38 Jy/K. The observing procedures and the receiver system are the same as described in Scalise et al. (1981), except for a few observing runs, when we used a room temperature mixer instead of the cooled maser fronted. In these cases the SSB noise temperature was ~1400 K compared to 200–400 K for the cooled maser receiver system.

H_2O spectra taken between Oct. 1980 and Nov. 1981 are given in Fig. 1 and the spectral features >5σ are summarized in Table 1. The Maser has been below our detection limit (10–20 Jy, 5σ-limit) since Nov. 1981. During the first observing run, on Oct. 4th 1980, we also searched for high velocity lines, extending the velocity coverage from −115 km s^{-1} to +50 km s^{-1}, but detected none to a limit of 15 Jy (5σ). Since the maser is quite weak, most of the spectra suffer from low S/N. Furthermore, because our velocity resolution is very moderate, 1.35 km s^{-1}/channel, most of the lines listed in Table 1 are unresolved and probably consist of several blended velocity components. The radial velocities in Table 1 should therefore be considered as velocity centroids rather than as specific

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1 Operated by the Instituto de Pesquisas Espaciais from the Conselho Nacional de Desenvolvimento Cientifico e Tecnológico, CNPq

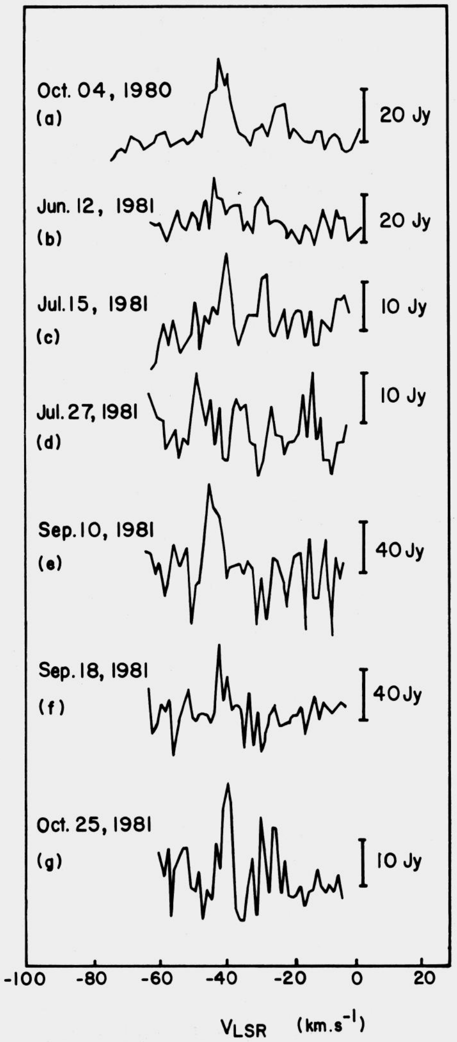

Fig. 1. H_2O spectra of H_2O 342.01 + 0.25 at different epochs. Note that the intensity scale varies. The velocity resolution is 1.35 km s^{-1}

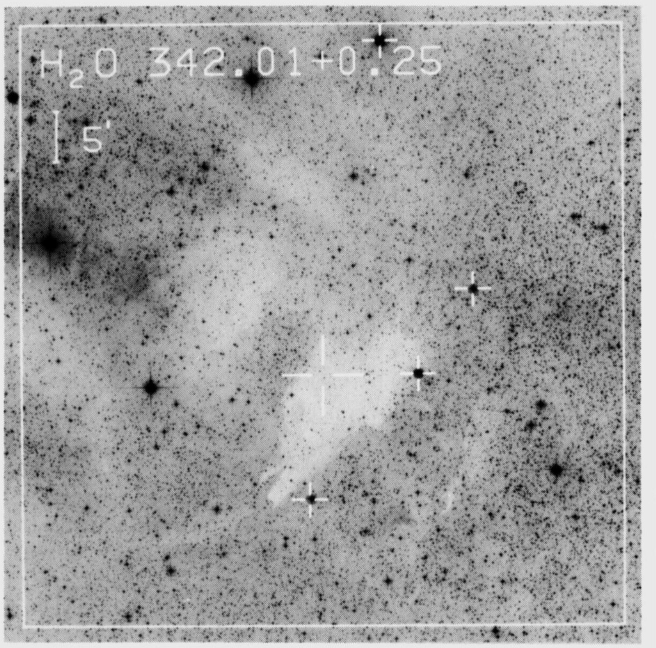

Fig. 2. A reproduction of a ESO/SRC Southern Sky Atlas blue plate indicating the position of the maser (large cross); $\alpha_{1950.0} = 16^h49^m31^s.1$, $\delta_{1950.0} = -43°27'40''$. The four small crosses mark positions of known SAO stars in the field

velocity components. The intensity variations of individual velocity components within a "line" in Table 1 may therefore appear as a velocity shift or a linewidth change, although such an effect is not real, and would not be seen if the lines were resolved.

The weakness of the maser has also resulted in that we have not been able to establish a reliable position for the H_2O maser. All the fluxes quoted here assume the H_2O position to coincide with that of the 1612 MHz OH maser and the IR object, i.e.: $\alpha_{1950.0} = 16^h49^m31^s.1$, $\delta_{1950.0} = -43°27'40''$, although the H_2O emission could originate from a spatially separate object.

3. Discussion

In Fig. 2 we have indicated the position of the H_2O maser on a reproduction of the blue ESO/SRC Southern Sky Atlas. The maser is seen toward the outskirt of an elephant trunk like dark nebula. Zealey et al. (1979) find that the field close to the nebula is filled with filamentary nebulosity (cf. their Fig. 7), apparently outlining a supernova shell identified with the supernova remnant Kes 45 (G 342.1 + 0.1). Somewhat to the north lies the Sco OB1 association (NGC 6231, $\alpha_{1950.0} = 16^h58^m.5$, $\delta_{1950.0} = -41°43'$) and Zealey et al. argue tha the H II complex interacts with the SNR, which would place the SNR at the same distance as NGC 6231, i.e. about 2 kpc (Schild et al., 1969). Caswell et al. (1975) could not see the SNR in their 408 MHz and 5 GHz radiomaps, perhaps because the SNR is quite evolved and of low surface brightness. This setting of an H_2O/OH maser seen projected upon a supernova shell raises the possibility, that the maser, if it is at the same distance, may represent a case of a supernova triggered star formation. In the following we therefore examine the observational data, which may help us to deduce the age of the maser star.

The very bright IR source ($L = 2.83$, $K - L = 1.83$) that Epchtein and Nguyen-Q-Rieu (1982) found at the position of the OH maser lacks an optical counterpart. The UKSTU deep IIIaF and IVN plates (Zealey, personal comm.) does not yield more than what is already seen in Fig. 1, and therefore the IR source is hidden by large extinction. On the basis of the IR colours it is not yet possible to deduce whether the IR object is a young object or a late type star (Epchtein and Nguyen-Q-Rieu, 1982; see also Glass, 1978), although recent IR observations (Epchtein, personal comm.) support the late type star hypothesis.

The presence of type IIb maser emission, i.e. 1612 MHz strongest, is usually a strong indication of a late type object: Mira, semiregular, supergiant or unidentified OH/IR. Main line emission is sometimes seen, although it is not very common. However, the radial velocity of the main line emission is always within the same velocity range as the 1612 MHz emission (cf. Olnon et al., 1980).

For this maser the H_2O emission and the 1667 MHz OH emission is outside the velocity range of the 1612 MHz OH emission. Caswell (personal comm.) reports that the 1667 MHz emission is much weaker, 0.5–1 Jy, than the 1612 MHz emission. It is also circularly polarized and time variable. These characteristics suggest that the 1667 MHz emission is a maser. The position of the 1667 MHz maser agrees within uncertainties ($\pm 30''$) with the 1612 MHz maser.

Observations of 6 cm H_2CO toward the dark nebula (Zealey, unpublished data) reveal three different velocity components: -8, -20.8, and -40.5 km s^{-1}. The -8 km s^{-1} velocity component is probably associated with the H II region G 341.96+0.20 (Haynes et al., 1978), since its recombination line velocity (Caswell, unpublished data) is the same. Since the H II region is not seen optically, it probably lies at the far kinematic distance of ~ 19 kpc. The -20.8 km s^{-1} component is seen in all H_2CO spectra and is probably due to the elephant trunk nebula (Fig. 1) associated with Kes 45. The relatively narrow linewidth $\Delta v \lesssim 2$ km s^{-1}, also supports this interpretation. The near kinematic distance, ~ 2 kpc, is in good agreement with the photometrically determined distance for NGC 6231 (Schild et al., 1969), which we assume to lie at the same distance as Kes 45. Blair et al. (1975) made CO observations of another elephant trunk nebula about 2°.5 to the north, which Sherwood and Dachs (1976) associate with the NGC 6231 complex, both from its morphology and from its agreement in distance. The radial velocity of this complex, $v_{\rm lsr} = -25.3$ km s^{-1}, is in rough agreement with our -20.8 km s^{-1} dark cloud. Therefore they presumably are at the same distance. The -40.5 km s^{-1} component is the strongest one in H_2CO, but only visible close ($\lesssim 4'$) to the maser/IR object. This coincidence in both velocity and position with the maser points toward a physical association. The velocity corresponds to a near kinematic distance of ~ 4 kpc, but it is also possible that the velocity difference to the -20.8 km s^{-1} component is caused by the supernova shock wave. In such a case the -40.5 km s^{-1} component would represent the postshock component, which is in agreement with its broader linewidth ($\Delta v \sim 3$ km s^{-1}).

The detection of the H_2O maser emission makes the interpretation of a late type star maser more unlikely, since the late type stars associated with H_2O masers are quite nearby, <0.3–0.5 kpc for Mira variables (Lépine and Paes de Barros, 1977; Olnon et al., 1980) although supergiants can be seen up to about 3 kpc (cf. Bowers, 1981). The H_2O maser does have some resemblance to a supergiant H_2O maser, although some of the velocity components fall outside the 1612 MHz OH velocity range. There is a possibility that the 1612 MHz OH maser could be a double ("OH/IR-type") with the other velocity component below the detection limit, although this is not very probable, since the 1612 MHz line does not look like an OH/IR wing. Instead we may have two spatially separate masers, one associated with the H_2O and 1667 MHz OH maser and one with the 1612 MHz OH maser and IR source. This would remove the discrepancy in velocity between the 1612 MHz OH maser and the H_2O/1667 MHz OH maser.

The time variation of the H_2O emission bears no resemblance to that of a late type star. Such masers vary slowly with time, with no sudden appearance or disappearance of velocity components (Cox and Parker, 1979). Even in supergiants, which have the richest emission spectrum of all H_2O masers associated with late type objects, the monthly variations are quite small, although one can see significant changes in the spectra on a time scale of years (cf. Cox and Parker, 1978, 1979; Rosen et al., 1978).

Instead, the variations seen in H_2O 342.01+0.25 appear very similar to the time variations one finds in H_2O masers associated with young stars, i.e. rapid and irregular (see e.g. Rodriguez et al., 1980). In Table 1 we note for example that the component at -24 km s^{-1} seen in October 1980, completely disappeared before June 1981, while a new component appeared at -31 km s^{-1}. Also in the blended -44 km s^{-1} component some velocity components disappeared at the same time, since the line was much narrower in June 1981. In fact, the H_2O spectrum has been different on every observing session, showing clear changes on a time scale less than a month (Fig. 1, Table 1).

On the basis of the H_2O appearance, in particular the rapid and irregular time variations, it is most likely that the OH/H_2O maser is associated with a young object. However, no 1612 MHz OH maser has previously been known to be associated with a young star, which would make this maser a rather unique case. As argued above, we cannot exclude the possibility of two separate masers, one associated with the 1612 MHz OH maser and one with the H_2O and 1667 MHz OH maser. If the latter one is young, which is strongly suggested on the basis of our present observations, it may be an interesting object, since its close connection to a supernova remnant suggests that the star formation could be induced by the supernova shock wave.

If the 1612 MHz OH maser is a late type object it could also be an SiO maser, and therefore a search for SiO maser emission is clearly warranted. It would also be valuable to extend the IR observations by Epchtein and Nguyen-Q-Rieu (1982) to longer wavelengths and to obtain narrowband IR spectroscopy to search for H_2O/silicate absorption bands. One should also try to improve the H_2O and 1667 MHz OH maser positions and search for a possible IR counterpart to these masers, in case they are separate objects.

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Note added in proof: Dr. Caswell points out, that in their study of OH masers (*Australian J. Phys.* (1980) **33**, 639) they find that 6 out of 40 main line masers do have accompanying prominent 1612 MHz maser emission. Therefore our remark, that no 1612 MHz maser has previously been known to be associated with a young star, may not be strictly true.