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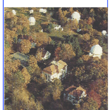
Hamburger Sternwarte



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Variations of masers in circumstellar shells on the timescale of decades

Dieter Engels, Hamburger Sternwarte, Hamburg, Germany
Anders Winnberg, Onsala Rymdobservatorium, Onsala, Sweden
Jan Brand, INAF - Istituto di Radioastronomia, Bologna, Italy
Francisco Jimenez-Esteban, Obs. Astronomico Nacional, Alcala de Henares, Spain

Based on a 15-20 year long monitoring program of H_2O masers and new observations of OH masers discovered 35 years ago we studied maser variation in AGB stars over the timescales of decades. The H_2O maser features in the semiregular variable stars RX Boo and SV Peg, and in the Miras U Her and R Cas showed strong fluctuations superposed in case of the Miras on regular variations due to the pulsation of the stars. In contrast the spatial distribution of the emission regions in RX Boo and U Her showing deviations from spherical symmetry, which remained unchanged over >7 years. We conclude that the observed spatial asymmetry is determined by the underlying asymmetry of the mass loss process. There is no evidence that mass loss rates or the wind geometry in these stars have varied over the last 20 years. 113 OH/IR stars discovered before 1978 were redetected at 1612 MHz in 2005, implying a lifetime of >3200 years (1σ).

Introduction

Maser emission from OH, H_2O and SiO molecules are frequently observed on the Asymptotic Giant Branch (AGB). Interestingly a large fraction of any sample of IRAS sources, with colors qualifying them as AGB stars, do not exhibit detectable masers or show only some of them. The reasons for the absence of masers among apparently similar stars (e.g. equal distances, luminosities, mass loss rates) is not known. Recently the idea that the (non-)detection of masers is a temporary effect has gained support by the disappearance of five 1612 MHz OH masers in a sample of 112, when revisited 12 years after their detection (Lewis 2002). Lewis concluded that the mean lifetime of 1612 OH emssion is merely 100-400 years.

Lewis finding implies that maser in general might be short-lived phenomena. Long-term monitoring programs and revisits of known masers should then uncover more stars having lost their masers. This question can be adressed with our systematic study of the variability of H_2O maser properties of several AGB stars. We also made a simple test to determine the lower limit of the lifetime of 1612 OH masers in OH/IR stars.

RX Boo

The 22 GHz H_2O maser line was observed with the Effelberg and Medicina radiotelescopes between 1987 and 2007. Typical sensitivities were 0.1 - 2 Jy (rms). Maps with a resolution of 80 mas and sensitivities 10-30 mJy were obtained with the VLA on five occasions between 1990 and 1995. The maser was strongly variable with peak flux densities varying between a few Jy and >1000 Jy. The development of the maser is shown in Fig. 1. During the last twenty years the masers appeared over an almost constant velocity interval [-5,+5] km/s, although it has been broader in the past (Engels et al. 1993). The red-shifted maser features were always stronger than the blue-shifted. In each of the VLA maps we identified 10 - 15 unresolved maser spots. Some of them were found in consecutive maps so that an alignment to a common origin was possible (Fig.2).

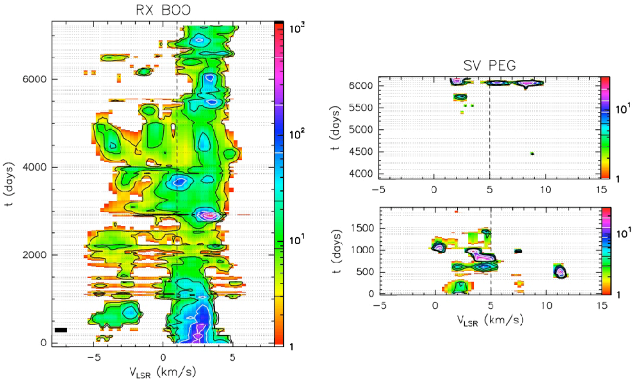

Figure 1: Flux density variations of the H_2O masers of RX Boo and SV Peg as function of velocity and time. The time axis for RX Boo covers the years 1987 - 2007 starting on 1987 March 30. For SV Peg the time axis starts on 1990 Feb. 17. The maser was not observed 1995-1999. The dashed horizontal lines mark the actual observations. Flux densities in between the observations were interpolated. The dashed vertical lines mark the stellar systemic velocities as measured by CO (Loup et al. 1993).

The maps show that most of the emission comes from an incomplete ring of radius 91 mas (15 AU). A velocity gradient is found in north-east direction. We tentatively placed the star into the center of the ring. The maser region can then be modelled as a shell with thickness 14--35 AU (~4 - 12 $R_\star$), which is filled only in part. The wind crossing time is 18 years. Combining our maps with one obtained in 1985 (Bowers et al. 1993) we find that the ring-like structure and the velocity gradient remained stable over at least 11 years, while the maser line profiles from the single-dish telescopes varied strongly. This implies that the spatial distribution observed at a given observing epoch is not accidental due to the random process of maser cloud formation, but that the mass loss process in RX Boo itself is not spherically symmetric. The strong variability of the spectral maser features is mainly due to incoherent intensity fluctuations from maser emission spots, which have lifetimes of the order of 1 year.

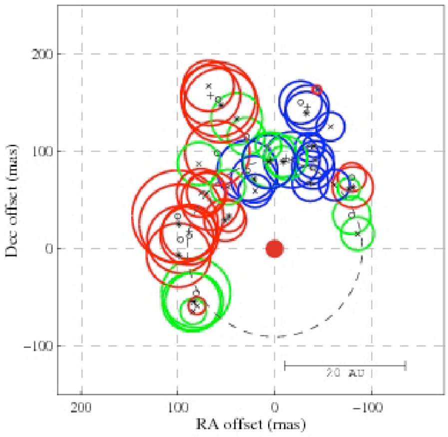

Figure 2: All maser components of RX Boo identified between 1990 and 1992 in the VLA maps plotted on the sky. Each component is represented by a symbol and a circle whose diameter is logarithmically proportional to the flux density of the component. The circles around the components are colour coded according to the velocity of the component. Components with line-of-sight velocities smaller than -1.4 km/s are blue, those with velocities between -1.4 and +2.3 km/s are green and those v > +2.3 km/s are red. A circle (dashed) of radius 91 mas has been fitted to the inner components and the origin has been moved to the centre of this circle The filled dark red circle at the origin symbolizes the central star with a diameter of 19 mas.

SV Peg, U Her and R Cas

The H_2O maser of SV Peg was monitored 1990-1995 and 2000-2007. Except for the first three years and for the last few months the maser was rather weak (<5 Jy) or even not detectable (Figure 1). The shell supports less maser sites than RX Boo. Unlike RX Boo SV Peg has no preferred velocity range, where the masers predominantly appear. The long periods of the order of years with weak or absent (<1 Jy) maser emission indicates that the non-detection of masers in SRVs is often a temporary effect.

As representatives of the Mira variable population we monitored U Her and R Cas. Multiepoch VLA maps were obtained for U Her. The main emission region in this star is in the southern part of the shell and this distribution can be followed at least over 8 years, while the intensities vary. Similar to the results for RX Boo the lifetimes of the individual maser features are at least several month (Engels et al. 1999). Contrary to the semi-regular variables the overall luminosity of the H_2O maser of both Mira variables vary with the optical variations, although secular changes, like the gradual decrease of the H_2O maser luminosity 1987-1999 shown by R Cas are superposed (Brand et al. 2002).

A lower limit for OH maser lifetime

To access the stability of the 1612 OH maser emission in OH/IR stars we reobserved in 2005 with the Effelsberg radio telescope a sample of OH masers discovered before 1978 (Baud et al. 1981). The sample contained N=116 sources, for which we identified infrared counterparts for 113. The remaining sources are probably of interstellar origin. We rediscovered 114 masers including all OH/IR stars. Probabilities that all masers are redetected for lifetimes T are: 1% for T=700 years, 10% for T=1400 years, and 30% for T=3200 years. The probable lifetimes T>3200 years are a factor of ten higher then reported by Lewis. However, the stability of the OH masers depends probably on the gas density, and hence on the mass loss rates. Lewis found the ‘dead OH/IR stars’ only among the blue objects of his sample, which have a much lower mass loss rate as the typical star of our sample. The two results may therefore not be contradictory.

References

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