COMPARISON OF WATER MASER EMISSION AND THE VISUAL LIGHT CURVE

PRISCILLA J. BENSON
IRENE R. LITTLE-MARENIN
Astronomy Department
Whitin Observatory
Wellesley College
Wellesley, MA 02181

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Abstract

We have been monitoring the water maser emission from the circumstellar shells of 11 variable stars and comparing the variation in maser emission to the visible light curves. Two of these stars (V778 Cyg and EU And) in which we have detected maser emission are carbon stars which are not expected to have water in their circumstellar material. We encourage AAVSO observers to observe these unusual carbon stars.

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In 1987 we instituted a program at Haystack Observatory[1] to monitor water maser emission associated with variable stars. MASER's (Microwave Amplification by Stimulated Emission of Radiation) are commonly found in the circumstellar shells of red giants. Water masers are located at a distance of about 10 stellar radii (about 50 AU) from the center of the evolved cool star. When the water is "pumped," i.e., excited into a higher energy level by an external source of energy, a passing photon possessing the correct energy and phase can interact with the excited water molecules causing the electrons to transit into a lower energy level accompanied by the stimulated release of a photon of the same characteristics as the original. This produces a cascading effect releasing many photons with the same characteristics and we have a maser.

Molecules can either be a) radiatively pumped, i.e., photons from the star can directly interact with the water molecules exiting them or b) collisionally pumped, i.e., collisions between hydrogen and the water molecules can excite the latter. It has been shown theoretically that a water maser is collisionally pumped. The regular monitoring of the water maser emission will allow us to check the theoretical predictions by observing different types of variable stars during different parts of their light cycle. The observations should allow us to distinguish between the two pumping mechanisms. The radiation from the star passes through the masing region of about 10 stellar radii in less than a light day. Hence, if the masers are radiatively pumped, we expect to see variations of the water maser emission that are in phase with the light variations. On the other hand, if the masers are collisionally pumped, we expect to see a phase lag between the time when the star is visually at maximum and when the maser emission is at maximum. It takes time to translate the increase in radiation at maximum into an increase in the temperature of the gas which causes the molecules to move faster and produce more collisions to pump the water molecules.

Observations of the exact correlation between the visual energy

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input and the water maser emission allow us to study the temporal development of the maser. In order to study more clearly the correlation between the maser emission and the optical variability of the central star we have selected 11 stars of different variability, type, and period. These stars are listed in Table I. Some of the results on three of the stars we are monitoring (R Cet, V CVn, and T UMa) are presented in other papers in this journal.

The two stars EU And [R.A.(1950) = 23^h 17^m 41^s; Dec. = 46^o 58′ 00"] and V778 Cyg [R.A.(1950) = 20^h 35^m 07^s; Dec. = 59^o 54′ 48"] are particularly interesting, because they are both carbon stars with C4,4 and C5,5 spectra respectively. The detection of an oxygen-bearing molecule in the circumstellar shell of a carbon star was very unexpected since carbon is more abundant than oxygen in the carbon stars. The very stable CO molecule forms until all the oxygen is used up. The remaining carbon will then form carbon-bearing molecules such as C_2, CN, HCN, etc... No oxygen-bearing molecules are expected in the photosphere or the circumstellar shell of carbon stars. These two stars are the only carbon stars visible from the northern hemisphere known to have water masers in their circumstellar material. Two theories have been proposed to explain this phenomenon. One is that the star is in the process of converting from an ordinary Mira with M spectral type to a carbon star with C spectral type. The other is that EU And and V778 Cyg are both members of a binary system in which one star is a carbon star and is brighter in the visual range where the carbon star classification was made, and the other is an M Mira in whose shell we find the water maser emission. One problem with trying to determine which theory is correct is that the stars are not well studied. Very little is known about their optical variability. We have found that the water maser flux for both stars has varied considerably. The emission from V778 Cyg has ranged from <1 Janskys (Jy) to over 17 Jy with short term fluctuations on the order of 8 hours (Figure 1). The maser flux from EU And was 8 Jy at discovery, December 1986, and has been declining since then. Figure 2 shows the variation in maser emission from V778 Cyg plotted versus Julian Day.

The major purpose of this article is to request that AAVSO observers monitor these stars. V778 Cyg is listed as an AAVSO program star, but in the time since our original water maser detection (March 23, 1987), there has not been a single observation of this star. Consequently, we wish to point out that V778 Cyg is a very unusual star, and it would be very useful to know how the light curve varies as we continue our observations of the maser activity. We also thank AAVSO observers for the many observations of the other stars on our monitoring list. We have found them very useful.

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TABLE I

Stars Studied for Maser Emission/Optical Variability Correlation

Star	Type	Period
EU And	SR	---
RX Boo	SRb	340 days
R Cet	M	166
V CVn	SR	192
AC Cyg	SRb	142
V778 Cyg	Lb	---
SV Peg	SRb	145
S Per	SRc	822
RZ Sco	M	160
T UMa	M	257
T Vir	M	339

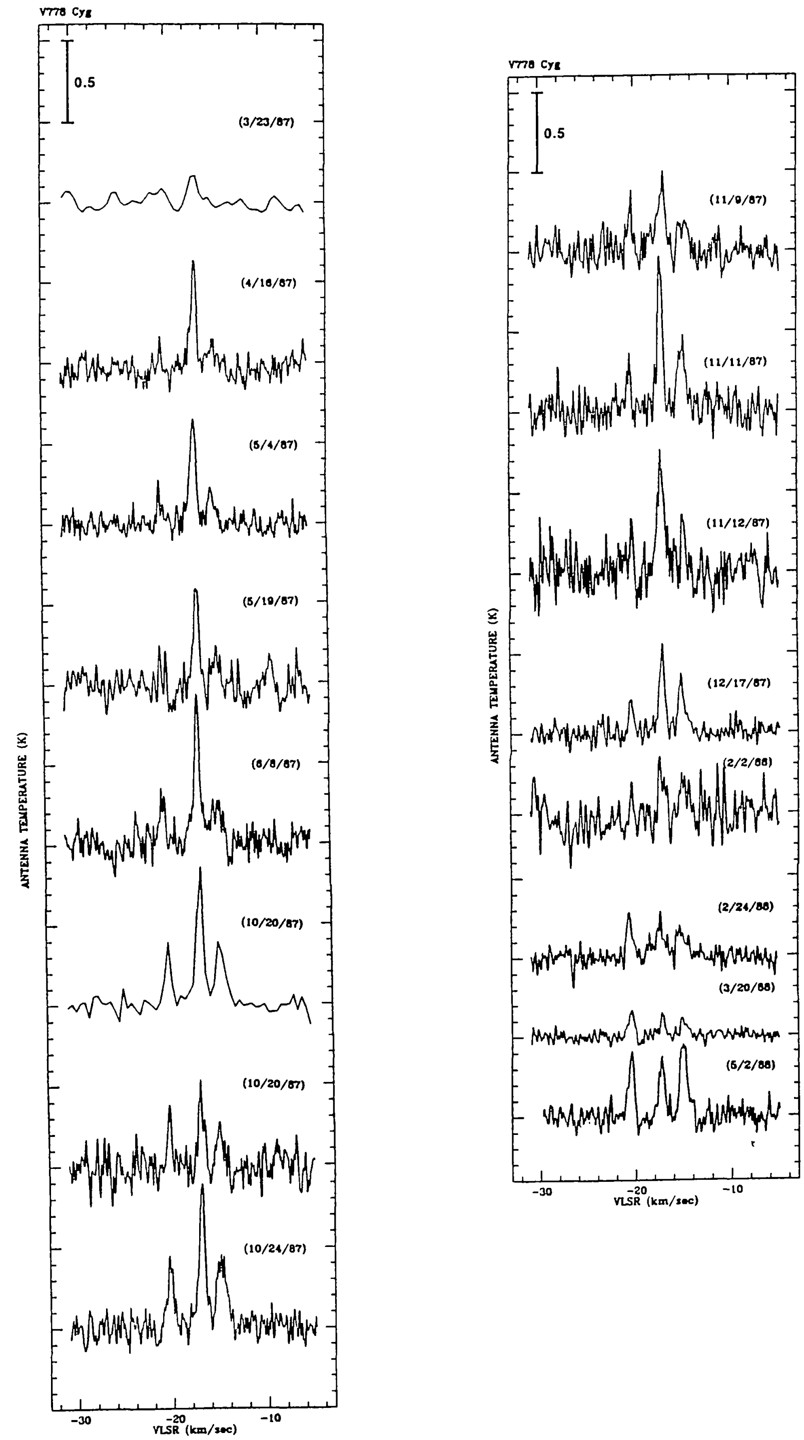

Figure 1. Several spectra of the water maser emission from V778 Cyg. The antenna temperature corrected for atmospheric effects and the variation in gain of the telescope is along the y-axis. The x-axis shows the radial velocity of the emission relative to the local standard of rest.

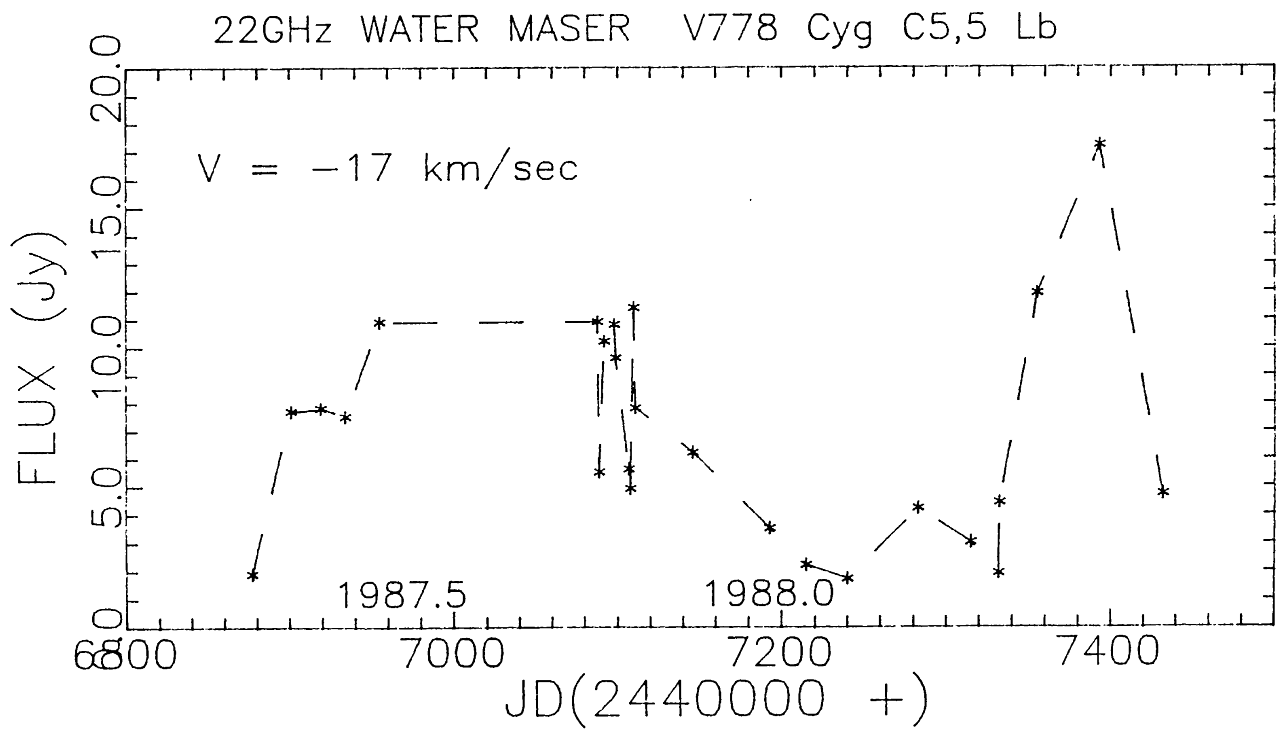

Figure 2: The variation in maser flux measured in Jy versus the Julian Day number of the observation.