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SHOCK INDUCED POLARIZED HYDROGEN EMISSION LINES IN OMICRON CETI

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Abstract. We have performed a spectropolarimetric survey of the variable Mira star omicron Ceti along three pulsation cycles. We present those new data collected with the Narval instrument mounted on the Télescope Bernard Lyot in Pic du Midi, France. We have detected time variable polarimetric signatures (on QUV Stokes spectra) associated with Balmer hydrogen emission lines supposed to be formed behind the front of a shock wave propagating throughout the stellar atmosphere. We associate the linear polarization of Balmer emission lines in Mira stars to the presence and the structure of the radiative shock wave.

Keywords: shocks, Mira, AGB, spectropolarimetry, line: formation

1 Introduction

Mira stars are cool, evolved (AGB) and late-type variable stars. They are radially pulsating stars with a long period of brightness variation (from 150 to 1000 days), time during which the luminosity might change up to 2.5 visual magnitudes on average. A cool and very extended stellar atmosphere is present, surrounded with a circumstellar envelope. Their low surface temperature ($< 3000K$) allows the existence of molecules inducing a strong absorption on the stellar spectrum.
Another interesting feature is the presence of strong emissions on the Balmer hydrogen lines. These lines are observed during about 80% of the luminosity period. Radiative hypersonic shock waves propagating periodically throughout the atmosphere are believed to be at the origin of those emissions. The structure of those shocks ar complex (Fadeyev & Gillet 2004). The front of the shock is a region where strong gradients of temperature, pressure and velocity are formed due to the strength of the shock. Just behind the front, there is a region of strong ionization and, further behind, the gas gets cooler and recombines. The radiation thus produced propagates and may interact with the region before the front, called the precursor.
Omicron Ceti (also known as Mira) is the prototype of the Mira stars. It is an oxygen-rich (M type) star with a period of 332 days and a visual magnitude varying from 3 to 10. It is also a binary star.

2 Observations with Narval

With the Narval spectropolarimeter mounted on the TBL at the Pic du Midi, we did a survey of omicron Ceti during three pulsation cycles (from 2007 to 2010, see Fig.1). The wavelength coverage runs from 369 to 1048 nm in a single exposure, with a resolving power of about 65000. The outputs are the four Stokes parameters (intensity I, linear polarization Q and U, circular polarization V). We have detected a strong polarization in hydrogen Balmer lines at maximum light. Hereafter, we present two spectropolarimetric observations, one around minimum light ($\phi = 1.67$) and one around maximum light ($\phi = 3.05$) in Hδ (Fig.2).

Around the minimum light, the shock wave is high in the stellar atmosphere and weakening. It is therefore not strong enough to produce the emission lines as illustrated in our observation at $\phi = 1.67$. There is no signature in any of the Stokes parameter. Around the maximum light, the shock wave is just emerging from the photosphere and accelerating. The hydrogen Balmer emission is very intense as we can see in our observation at phase $\phi = 3.05$ and this emission seems to be polarized because of the signatures detected on the other Stokes parameters (especially U). On the Q-U graph, the linear polarization is all along the U-axis.

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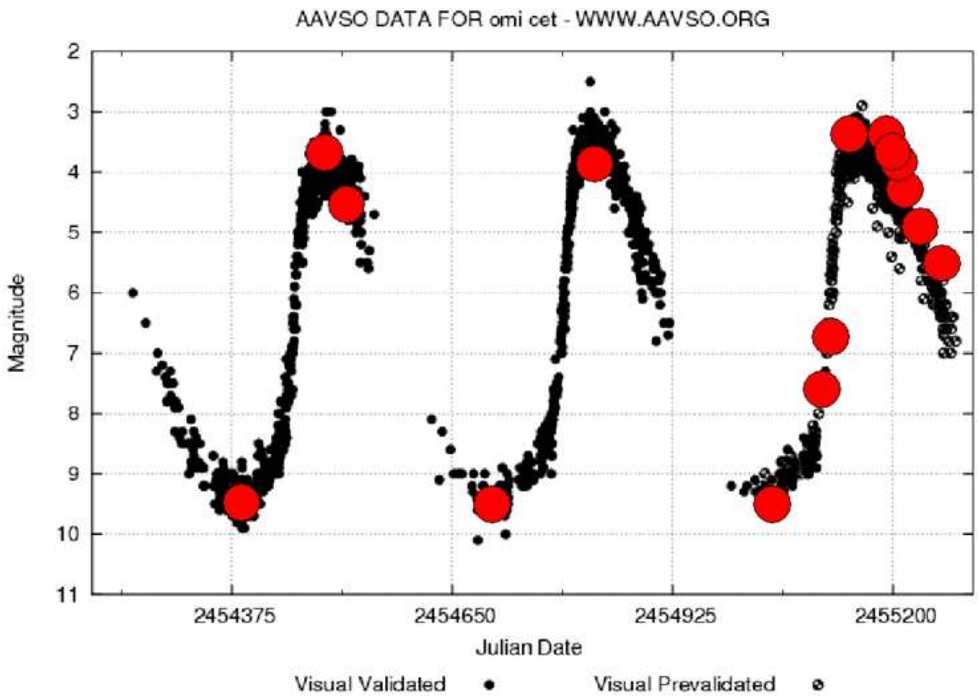

Fig. 1. Light curve of omicron Ceti (from AAVSO) on the three cycles of the survey. Each red circle is one spectropolarimetric observation. The three maxima are set at phases $\phi = 1.00$, $\phi = 2.00$ and $\phi = 3.00$ consecutively

3 Main results

We confirm, in the Hδ line, the high linear polarization already reported by McLean & Coyne (1978) in Hβ for o Cet at its 1977 maximum of luminosity. Besides, our work on the aforementioned survey allowed us to see that the linear polarization in the Balmer lines appears to be time variable and null at the minimum light. We think that this emission, supposedly formed in the recombination part of the shock wave, is also locally polarized in this shock. Behind its front, hydrogen atoms are ionized. Turbulence generated by the shock into these charged particles might create a magnetic field and therefore polarization.

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References

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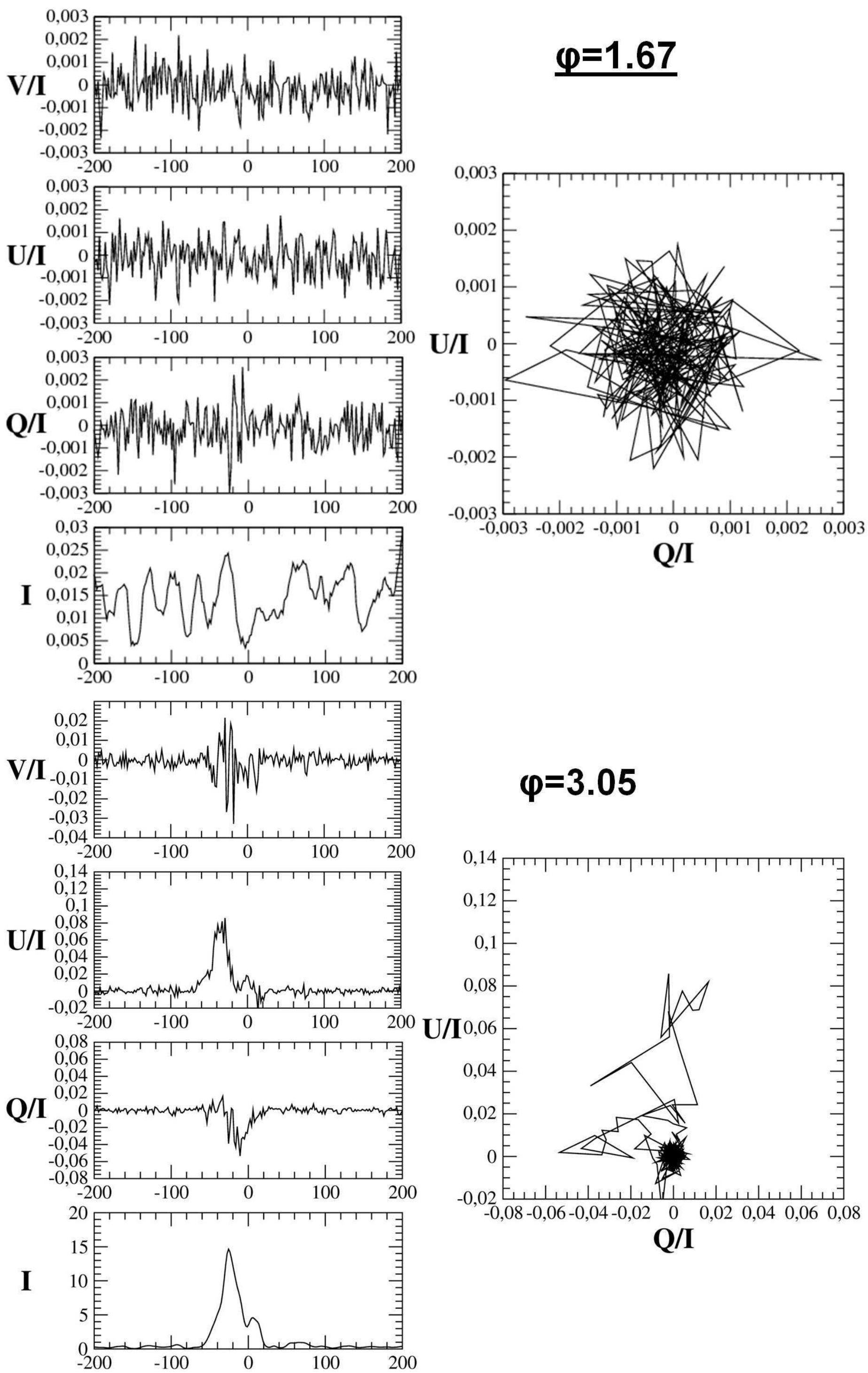

Fig. 2. Two spectropolarimetric observations of *o* Ceti around minimum light ($\phi = 1.67$) and maximum light ($\phi = 3.05$). For each phase, we have a series of spectra for the 4 Stokes parameters (abscissa is stellar rest frame velocity in km s^{-1}) and also a graph showing U against Q in order to visualise the direction of linear polarization.