PULSATION OF WOLF–RAYET STARS: WR40*

H. SCHNEIDER[1)], M. KIRIAKIDIS[1)], W.W. WEISS[2)],
W. GLATZEL[1)] and K.J. FRICKE[1)]
[1)] *Universitäts–Sternwarte, Geismarlandstr. 11, D-37083 Göttingen, FRG*
[2)] *Institut für Astronomie, Türkenschanzstr. 17, A-1180 Wien, Austria*

1. Observations

In the past several Wolf–Rayet stars have been investigated photometrically by different authors to search for fast pulsations. So far all results were negative. However, in 1992 Blecha, Schaller & Maeder published a 627sec period with a semi–amplitude of about 2.5mmag for the Southern Wolf–Rayet star WR40 (HD96548).

In order to check the significance of this result, WR40 was observed during three nights in May/April 1993 at La Silla/Chile using the ESO 1m telescope equipped with a standard photometer. The observations were carried out using a Johnson B filter and an integration time of 20sec.

The typical observing sequence for detecting rapid oscillations is to continuously monitor the program star, interrupted only approximately every 20 minutes for checking the centering of the star in the photometer aperture. This technique relies on a stable atmosphere, but even under moderate conditions a clear detection of pulsations with amplitudes as small as about 1mmag is possible.

The data were corrected for extinction and in addition small changes in the sky transparency ($>$ 30 minutes) were removed. The atmospheric quality of the nights was good, only the first night was moderate. Nevertheless, small erratic fluctuations in the sky transparency could not be removed completely. As a consequence of this (and the observation mode) we can not make statements about pulsations with $f < 4\text{h}^{-1}$.

From the amplitude spectra of the individual nights it is evident that no pulsations with $f > 4\text{h}^{-1}$ above the noise level ($\approx$ 0.1mmag, $\approx$ 0.25mmag in the first night, respectively) are detectable. In the amplitude spectrum of the merged data some peaks exceed the level of 0.1mmag (noise level $\approx$ 0.08mmag), but they are unequivocally not significant. In order to reduce the influence of time gaps we applied the CLEAN algorithm to the amplitude spectra. Again, no significant peaks could be found.

A detailed analysis of these observations is in preparation (Schneider & Weiss, 1993) and will be published elsewhere.

* based on observations made at ESO, La Silla, Chile

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2. Theory

As models for Wolf–Rayet stars we have used generalized inhomogeneous helium burning main sequence stars where the chemical composition $(X, Y, Z) = (0.2, 0.78, 0.02)$ has been adopted for the stellar envelope to account for the hydrogen observed in WR40. The hydrogen profile was chosen such that shell burning did not occur. The stability analysis is based on complete stellar models which are constructed using the Göttingen stellar evolution code. Opacities are taken from the latest version of the OPAL library.

In a first step, stability is tested with respect to infinitesimal radial perturbations, where convection is treated in the frozen–in approximation and the linear nonadiabatic stability analysis is performed using the Riccati method. All ordinary acoustic modes are damped and the ε–instability of the ordinary fundamental mode is not present. In addition to the ordinary modes we find a set of strange modes, whose frequencies decrease with mass. These strange modes are associated with extremely strong instabilities above $4.6 M_\odot$ having growth rates in the dynamical range.

As a result of the linear stability analysis we predict fast, in most cases multiperiodic, variability of Wolf–Rayet stars with periods below 30 minutes. The strong dependence on mass of the periods of the unstable strange modes could provide a powerful tool to determine masses of WR stars from observed pulsation periods. Their extremely high growth rates indicate that strange modes play an important role in driving WR winds.

In selected cases we have followed the evolution of the strange mode instabilities discovered into the nonlinear regime using the dynamical version of the Göttingen stellar evolution code. For moderate growth rates of the instability its final result is a nonlinear finite amplitude pulsation.

3. Conclusions

From our 11.4 hours of observations no pulsations of WR40 can be established unambiguously above the noise level of about 0.1 mmag. On the other hand, stellar models appropriate to match the parameters of WR40 show a large variety of simultaneously unstable modes. At present we are not able to provide a satisfactory explanation for this discrepancy. However, we speculate that a large number of simultaneously excited modes could result in a distribution of power over a frequency interval, which simulates an increased noise level in the amplitude spectrum.

References

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