Radial and Nonradial Pulsations as Probes of Stellar Physics
ASP Conference Series, Vol. 259, 2002
C. Aerts, T.R. Bedding, & J. Christensen-Dalsgaard, eds.

From Planetary Nebulae to White Dwarfs: Constraints from the Asteroseismology of the Pulsating Planetary Nebula Central Star RXJ 2117+3412

P. Moskalik

Copernicus Astronomical Center, ul. Bartycka 18, 00-716 Warsaw, Poland

G. Vauclair

Observatoire Midi-Pyrénées, 14 av. E. Belin, 31400 Toulouse, France

Abstract. We summarize the results of an asteroseismological study of the pulsating planetary nebula central star RXJ 2117+3412.

1. Introducing RXJ 2117+3412

RXJ 2117+3412 is an X-ray source identified as a PG 1159 star (Motch et al., 1993). With $T_{\rm eff}$= 170,000 K (Werner et al., 1996), it is the hottest member of this class. A planetary nebula surrounds it (Appleton et al., 1993). The UV and FUV spectra show evidence of ongoing mass loss from the central star (Koesterke & Werner, 1998). It is the best example of the evolutionary link between the planetary nebulae phase and the white dwarf cooling sequence. It is a pulsating PG 1159 star (Vauclair et al., 1993) and it presently defines the blue edge of the PG 1159 instability strip.

Multi-site, high-speed photometry data have been obtained in 1992, 1993 and 1994. We summarize here the main results. Full details will be published in a forthcoming paper (Vauclair et al., 2002).

2. Main asteroseismological results

Because many modes are observed only during one season, we combine the list of frequencies derived from each of the three datasets. A total of 48 independent modes are found: among them, two complete triplets and eight doublets.

Using the period spacing and the rotational splitting, we identify most of the modes. All the modes are identified to have ℓ=1. The linear least-squares fit to the period distribution of the 20 m=0 modes leads to an average period spacing ΔP= 21.639 $\pm$0.021 s. The residuals of this fit to the period distribution show a quasiperiodic variation which is the signature of mode trapping. Repeating the fitting procedure, but with a sine wave added to the fit, leads to the trapping cycle parameters: refined period spacing: ΔP= 21.618 $\pm$0.008 s, semiamplitude of the trapping cycle: A = 0.823 $\pm$0.078 s, length of the trapping cycle: T_k= 3.880 $\pm$0.026 modes (which translates into a period of the trapping cycle of P_{tc}=83.88 $\pm$0.57 s).

https://doi.org/10.1017/S0252921100017243 Published online by Cambridge University Press

From the average frequency separation within the multiplets (4.998 μHz), we derive a mean rotational period of 1.16 d $\pm$0.05 day. The rotational splitting decreases with increasing period, which is not compatible with a solid body rotation. The absence of any asymmetry in the splitting of the triplet components puts an upper limit of about 500 G on the magnetic field of the star.

From the observed mode trapping, one can in principle derive the mass of the He-rich envelope. However, because there is presently no suitable evolutionary model to fit RXJ 2117+3412, we have to extrapolate the calculation performed for PG 1159–035 (Kawaler & Bradley, 1994). We find the mass of the He-rich envelope to be in the range of 0.013–0.078 M_*. The total mass of RXJ 2117+3412 is $0.56^{+0.02}_{-0.04}$ $M_\odot$. The quoted errors can be substantially reduced in the future, when evolutionary models appropriate for RXJ 2117+3412 become available.

Knowing the mass of RXJ 2117 and its surface gravity (from spectroscopy), one derives the radius, which, combined with $T_{\rm eff}$, leads to a luminosity of $\log(L/L_\odot) = 4.05^{+0.23}_{-0.32}$. The distance, taking into account the interstellar absorption, is $D = 760 \pm 235$ pc. At such a distance, the linear extension of the PN is: $L_{PN} = 2.9 \pm 0.9$ pc.

Knowing the approximate mass of the outer layers, and the rate of mass loss of RXJ 2117+3412, we derive an order-of-magnitude estimate of the evolutionary time scale it would take RXJ 2117+3412 to become similar to PG 1159–035. We find this time to be between 1.3×10^5 yr and 1.1×10^6 yr. This translates into a rate of period change ($\dot{P}$) between 2.4 $\times10^{-10}$s s^{-1} and 2.9 $\times10^{-11}$s s^{-1} for periods around 1000 s. Such a $\dot{P}$ could be detected as soon as a mode with a reasonably stable amplitude could be found in its power spectrum.

The modes observed in RXJ 2117+3412 are excited by the κ-mechanism via the partial ionization of carbon (Starrfield et al., 1983). This mechanism operates at a depth of $T \approx 10^6$ K, i.e., in the outer 10^{-8} mass of the star. At the observed rate of mass loss, the mass confined in the driving zone is renewed every $\approx$50 days. This implies that any time variation in the mass-loss rate must affect the chemical composition in the driving zone. We suggest that the amplitude variations observed for most of the modes could be a consequence of the mass-loss rate variability affecting the efficiency of the driving mechanism.

References

Appleton, P.N., Kawaler, S.D. & Eitter, J.J. 1993, AJ, 106, 1973

Kawaler, S.D. & Bradley, P.A. 1994, ApJ, 427, 415

Koesterke, L. & Werner, K. 1998, ApJ, 500, L55

Motch, C., Werner, K., & Pakull, M.W. 1993, A&A, 268, 561

Starrfield, S.G., et al. 1983, ApJ, 268, L27

Vauclair, G., et al. 1993, A&A, 267, L35

Vauclair, G., et al. 2002, A&A, in press

Werner, K., et al. 1996, A&A, 307, 860