V605 Aquilae: a born-again star, a nova or both?

Herbert H. B. Lau,1,2* Orsola De Marco3 and X.-W. Liu2,4

1Centre for Stellar and Planetary Astrophysics, School of Mathematical Sciences, Building 28, Monash University, Clayton VIC 3800, Australia
2Kavli Institute for Astronomy & Astrophysics, Peking University, Beijing 100871, China
3Department of Physics & Astronomy, Macquarie University Sydney, NSW 2109, Australia
4Department of Astronomy, Peking University, Beijing 100871, China

Accepted 2010 August 19. Received 2010 June 28

ABSTRACT

V605 Aquilae is today widely assumed to have been the result of a final helium shell flash occurring on a single-post-asymptotic giant branch star. The fact that the outbursting star is in the middle of an old planetary nebula and that the ejecta associated with the outburst is hydrogen deficient supports this diagnosis. However, the material ejected during that outburst is also extremely neon rich, suggesting that it derives from an oxygen–neon–magnesium star, as is the case in the so-called neon novae. We have therefore attempted to construct a scenario that explains all the observations of the nebula and its central star, including the ejecta abundances. We find two scenarios that have the potential to explain the observations, although neither is a perfect match. The first scenario invokes the merger of a main-sequence star and a massive oxygen–neon–magnesium white dwarf. The second invokes an oxygen–neon–magnesium classical nova that takes place shortly after a final helium shell flash. The main drawback of the first scenario is the inability to determine whether the ejecta would have the observed composition and whether a merger could result in the observed hydrogen-deficient stellar abundances observed in the star today. The second scenario is based on better-understood physics, but, through a population synthesis technique, we determine that its frequency of occurrence should be very low and possibly lower than what is implied by the number of observed systems. While we could not envisage a scenario that naturally explains this object, this is the second final flash star which, upon closer scrutiny, is found to have hydrogen-deficient ejecta with abnormally high neon abundances. These findings are in stark contrast with the predictions of the final helium shell flash and beg for an alternative explanation.

Key words: stars: AGB and post-AGB – binaries: general – stars: evolution – novae, cataclysmic variables – planetary nebulae: individual: Abell 58.

1 INTRODUCTION

In 1919 a star was noticed to have brightened in the constellation of Aquila (Wolf 1920). A spectrum of the central source revealed it to be a hydrogen-deficient giant (Lundmark 1921). Shortly after the nova-like outburst, V605 Aql brightened over a period of 2 years to a peak of $m_{pg} = 10.2$ in 1919. The surface temperature of the star was $\sim$5000 K, and its spectrum in 1921 was very similar to that of R Coronae Borealis (RCB) stars, hydrogen-deficient, helium-rich supergiants (Clayton 1996; Clayton & De Marco 1997). V605 Aql was later noticed to be in the middle of an old and faint planetary nebula (PN; Bidelman 1971), Abell 58 (A58), with a dynamical age of 20 000 yr (Pollacco et al. 1992). A bright hydrogen-deficient knot was noticed growing at its geometric centre by Seitter (1987). Clayton et al. (2006) estimated today’s surface temperature of the central star to be 95 000 K. The stellar spectrum and chemical abundances place this central star of PN in the Wolf–Rayet spectral class (also called [WR] by van der Hucht et al. 1981, to distinguish these stars from their massive counterparts).

Today, the explanation for the observations of A58 and its central star is that the central star, after the formation of its surrounding PN, underwent a very late helium shell flash, also called a final flash, which ejected freshly processed stellar material into the centre of the nebula (Iben et al. 1983; Herwig 2001). V605 Aql is considered an older twin of Sakurai’s object that underwent a similar outburst in 1995 (Nakano et al. 1996). Other PNe consisting of (or containing) hydrogen-deficient ejecta have been found (e.g. A30 and A78; Jacoby & Ford 1983) and they too are considered final flash objects. The extent of the hydrogen deficiency of their stellar
atmospheres or ejecta is explained by the timing of the final flash (Herwig 2001).

The central star of A58 has a Wolf–Rayet spectral type, a class that comprises about 15 per cent of all central stars. Atmospheric abundances of these stars show carbon and helium with a small percentage of oxygen. The atmospheric mass fractions of V605 Aql are C = 0.40, He = 0.54 and O = 0.05 (Clayton et al. 2006) and they are typical of the intershell region and in line with predictions of a post-final flash star (Werner & Herwig 2006).

Observations of V605 Aql and its surrounding PN therefore seem to agree with final flash models. There is however one observational measurement that is so glaringly in disagreement with final flash models that it demands a reconsideration of the final flash model as applied not only to V605 Aql but also the other objects in this class. Wesson et al. (2008a) determined accurate abundances of the inner hydrogen-deficient nebula in A58 and found C/O = 0.06 and a neon mass fraction of 0.34. They argued that these abundance patterns have more in common with oxygen–neon–magnesium (ONeMg) nova ejecta than the predictions of the final flash. The very low C/O ratio observed in the hydrogen-deficient ejecta inside the A58 PN is hard to reproduce in stellar models, for example, Karakas et al. (2009) showed that the C/O ratio in a PN can be lower than unity, but not lower than 0.38 by number (∼0.29 by mass). Even more importantly, the extremely high neon abundances cannot be reproduced in any final flash model. The only way to obtain such high neon abundance is to dredge neon up from a neon core.

In addition two of the hydrogen-deficient knots in the centre of the old PN A30, also thought to be a final flash star, were measured by Wesson, Liu & Barlow (2003) to have C/O = 0.19 and 0.21, respectively, and neon mass fractions of 0.08 and 0.20, respectively. It therefore appears that two of the handful of known final flash stars do not fit the final flash scenario.

For these reasons we investigate possible scenarios that invoke an ONeMg white dwarf (WD) as the cause of the hydrogen-deficient ejecta in A58, while at the same time explaining the other observed characteristics.

In Section 2 we construct plausible scenarios and outline their drawbacks. In Section 3 we explain the population synthesis code that was used to determine the likelihood of one of the proposed scenarios, and describe the population synthesis results. We conclude in Section 4.

2 POSSIBLE SCENARIOS

The premise under which we operate is that the presence of neon- and oxygen-rich ejecta came about because of an explosion that involved a massive, ONeMg WD. ONeMg WDs derive from superasymptotic giant branch (SAGB) stars, stars hot enough to ignite carbon in the early AGB phase resulting in an ONeMg core. An extensive set of SAGB models can be found, e.g. in Doherty et al. (2010). Additional requirements derived from observations are that the outburst took place shortly after departure from the SAGB and the ejection of a regular PN. In addition, after the outburst the star became a hydrogen deficient supergiant in only a few years (1917–21), after which it heated up and developed a WC spectral type (taking no longer than ∼65 yr; Clayton et al. 2006). Moreover, we need to explain the event that led to the 1917 outburst itself. An obvious scenario is that of a nova that went off in 1917–19 and that was misinterpreted as a final flash. The immediate problem with this scenario is that a nova is unlikely to produce a hydrogen-deficient star, although one neon nova with abnormally low abundances of hydrogen in its ejecta is actually known (V1370 Aql; Snijders et al. 1987; Table 1). According to Austin et al. (1996), the observed high neon abundances of this nova can only be explained by the ejection of core material from an ONeMg WD and the estimated mass of the WD is 1.3 M⊙. A second problem with a nova scenario to explain the 1917–19 outburst of V605 Aql is that the light curve behaviour of this object is not that of a neon nova: V605 Aql remained a giant after the outburst for at least ∼50 yr. Its dust production as well as its current spectral type also do not match the behaviour of post-nova stars. These are the reason why we have searched for alternative scenarios. The best two scenarios are described below and summarized in Table 2, along with the observations they attempt to explain.

2.1 The common-envelope-merger scenario

As we have described, after the outburst V605 Aql became a hydrogen-deficient giant. Its spectrum and variability behaviour

Table 1. Abundance comparison.

| Name/type          | H | He | C  | N  | O  | Ne |
|--------------------|---|----|----|----|----|----|
| A58 knot           | 2 | 25 | 2  | 4  | 32 | 35 |
| A30-32 knot        | 1 | 52 | 7  | 5  | 27 | 8  |
| A30-32 knot        | 1 | 49 | 6  | 4  | 21 | 20 |
| Nova prediction    | 27–33 | 16–22 | 0.6–4 | 2–9 | 7–12 | 17–25 |
| V693 CrA Ne nova   | 41 | 21 | 0.4 | 7  | 7  | 24 |
| V4160 Sgr Ne nova  | 47 | 34 | 0.6 | 6  | 6  | 7  |
| V1370 Aql Ne nova  | 5  | 9  | 3  | 14 | 5  | 52 |
| QU Vul Ne nova     | 33 | 26 | 1  | 7  | 17 | 9  |
| Final flash prediction | ~30 | ~45 | <=3 | ~20 | ~2 |
| V605 Aql star      | –  | 54 | 40 | –  | 5  | –  |
| PG1159 star        | ≤2 | 33 | 48 | 0.1| 17 | 2  |

*a*We assumed this number from the prediction of 1 to a few per cent of Werner & Herwig (2006).

*b*We assumed these average numbers from different predictions cited in Werner & Herwig (2006).

*c*This is by summing 12C and 13C.

*d*This is by summing 14N and 15N.

*e*This is by summing 16O and 17O.
was that of an RCB star (Clayton & De Marco 1997) and very similar to that of Sakurai’s object (e.g. Tyne et al. 2002). We do not know what the exact abundance of V605 Aql at that time was, as that spectrum could not be reliably modelled, but we do know that RCB stars are primarily made of helium. Since we know that RCB stars are likely to result from a merger (Clayton et al. 2007), we have constructed a merger scenario for V605 Aql even if abundances of the post-merger RCB stars are dominated by helium rather than carbon and helium as is the case for V605 Aql today (Clayton et al. 2007). This said, since mergers remain quite complex phenomena, we will relax this constraint and assume that there is a way to make a WC star with a merger (see also De Marco & Soker 2002).

In this scenario a massive AGB star ($M_1 \lesssim 6-8 M_\odot$) suffers a common envelope (Paczynski 1976) with a lower mass main-sequence star, when the primary evolves to the SAGB. This common envelope results in a merger which strips the primary of hydrogen (by ejection and ingestion) revealing the intershell region. If the primary is massive enough to have an ONeMg core, then the ejecta would be rich in neon and have a C/O ratio lower than unity, as observed.

One way in which a single-common-envelope event would result in a regular, oxygen-rich PN and in hydrogen-deficient ejecta inside the main PN is if the common-envelope interaction takes place over a much longer time than the few years envisaged by hydrodynamic simulations (Sandquist et al. 1998; De Marco et al. 2003). Bear & Soker (2010) envisaged such a slow common envelope where the companion lingers on the outskirts of the primary inducing mass ejection. Only later does it plummet toward the core in a faster phase of inspiral. In such a scenario the first PN would derive from early ejection of regular envelope material (the pre-common-envelope mass-loss), while the hydrogen-deficient ejecta would derive from the final inspiral and merger.

A main criticism of this scenario is that a PN becomes visible because post-AGB stellar wind ploughs up the material ejected during the AGB phase. In this scenario by the time the star is in the post-AGB phase and able to plough up material, both the hydrogen-rich and hydrogen-deficient ejecta have been expelled. This is contrary to what is implied by the two nebulae, where the first, larger one must have been plowed up by the post-AGB wind before the ejection of the second, hydrogen-deficient one. To fix this inconsistency we envisage a variation of this scenario where the first common envelope resulted in a regular, hydrogen-rich PN approximately 20000 yr ago. The envelope of the primary was slowly stripped off through this slow common-envelope process. The post-common-envelope object was a short-period binary where the primary is an ONeMg WD and the secondary a low-mass main-sequence star. Eventually the WD suffers a final flash. The resulting expansion forms a new common envelope with the nearby secondary. This second common envelope results in a merger. The ejected second common envelope is hydrogen deficient and neon rich.

A SAGB star might be expected to eject a Type I PN, or a PN heavily enriched in nitrogen by the hot-bottom-burning process ($N/O = 0.8$, by number; Kingsburgh & Barlow 1994). AS8 has $N/O = 0.78$ (Guerrero & Manchado 1996), very close to the Type I limit. Finally, the shape of the old PN is not what one might expect of a post-common-envelope PN, which tend to be bipolar (although they are not exclusively bipolar; Miszalski et al. 2009). A possible drawback of this scenario is that the mass of today’s [WR] central star would be expected to be relatively large ($\sim 0.95 M_\odot$; Weidemann 2000), while the mass of V605 Aql today appears to be lower ($\sim 0.61 M_\odot$; Lechner & Kimeswenger 2004).

In this scenario the witnessed 1917–19 outburst would be the common-envelope event (the time-scale for the existence of the giant would not be dissimilar from those of a common-envelope event – one to a few decades (Sandquist et al. 1998; De Marco et al. 2003), if we adopt the single-common-envelope scenario. In the double-common-envelope scenario the outburst would be the final flash. We note that in this scenario the neon ejecta do not derive from a nova type outburst, but rather from a merger with a massive ONeMg WD.

### Table 2. Initial conditions and comparison with observations for two binary scenarios.

|                     | Merger scenario | Nova scenario |
|---------------------|-----------------|--------------|
| $M_1$               | Massive AGB     | ONeMg WD     |
| $M_2$               | Main-sequence star | AGB         |
| Separation          | < few au        | A few hundred au |
| Observations        |                 |              |
| Old PN (borderline Type I) | Accounted | Type I or non-Type I, depending on secondary mass |
| Old PN elliptical   | Accounted?      | Accounted    |
| Final flash: 1917   | Is the merger event | Final flash from secondary |
| H-deficient giant 1921 | Produced by the merger | From final flash |
| O- and Ne-rich ejecta | From the ONeMg primary | From nova right after final flash |
| WC 1987–today       | Evolution of post-merger object | Regular evolution of the post-final flash star |

© 2010 The Authors. Journal compilation © 2010 RAS, MNRAS 410, 1870–1876
The observed hydrogen-deficient ejecta are, in this scenario, a mix of the final flash and nova ejecta. As we can see from Table 1, it is not impossible to conceive of a scenario that mixing of these two types of ejecta would result in the observed abundances, as long as the ejected masses are approximately similar. This is likely to be the case: the hydrogen-deficient ejecta mass of A58 was measured to be $5.25 \times 10^{-5} \, M_\odot$ (Wesson et al. 2008a), while nova ejecta masses could be in the range of $10^{-7}$ to $10^{-6}$ (Starrfield et al. 1998). If today’s [WR] central star is the secondary, final flashes can explain the surface temperature change from 5000 K in 1919 to 95 000 K now. This scenario would also explain the difference in the ejecta and the stellar abundances: the massive WD primary is responsible for the observed abundances of the hydrogen-deficient knot, while the secondary is responsible for the observed central star abundances.

The nova explosion would, in this scenario, closely follow the final flash. We therefore wonder whether the nova outburst should have been detected, as was the case for the outburst due to the final flash. As it turns out, monitoring of this star since 1917 has been relatively sparse and ONeMg novae tend to be relatively dim and return to light minimum in relatively short time-scales. The lowest apparent peak $V$ magnitude of novae observed in the Large Magellanic Cloud (LMC) is $\sim 12.5$ (Shida & Liller 2004). Scaling this magnitude to the distance of V605 Aql ($\sim 3.5$ kpc; Clayton & De Marco 1997), the apparent (dereddened) $V$ magnitude of our nova might have been $\sim 6.8$.

If we take into account an interstellar reddening $A_V = 1.7$ (for a full discussion of the reddening see Clayton & De Marco 1997), the apparent magnitude could have been as low as 8.5 mag. The light curve reported by Harrison (1996) between 1917 and 1924 shows that V605 Aql reached a peak of $m_{pl} \sim 10$ but later remained between 12 and 14 mag. A nova with an apparent magnitude of 9 might have been easily detected were it not for the fact that the light curve of V605 Aql was sparsely sampled and a nova could have gone off and returned to minimum light between observations.

If the accretion rate at the time of the final flash was high enough and the WD was massive, the neon nova decline time could be as short as 12 days and its luminosity would be a meagre $\sim 4.8 \times 10^7 \, L_\odot$ (Prialnik & Kovetz 1995). It is therefore not excluded that a nova did indeed take place but remained undetected. We also note that if we require a dim nova with a fast return to light minimum, other nova explosions must have occurred in the past of this system. Hence, it is possible that other knots with similar abundances could be found within the PN, though they will be further away from the central star. It would also follow that other outbursts may yet be detected.

# 3 POPULATION SYNTHESIS TEST

Of the two scenarios, the nova one described in Section 2.2 is the only one where each phase is reasonably well understood and we can therefore apply a stellar population synthesis model to determine its frequency of occurrence. To determine the frequency of such systems, we use a rapid binary-evolution algorithm (BSE; Hurley, Tout & Pols 2002). Using this code, we can generate a binary population and determine which systems can lead to the formation of A58-like systems. The code uses the detailed single-star evolution formulae of Hurley, Pols & Tout (2000) to calculate the stellar luminosity, radius, core mass, core radius and spin frequency for each of the component stars as they evolve. A prescription for common-envelope evolution is also included. The $\delta_{CE}$ parameter, the efficiency of the orbital energy transfer to the envelope during the common-envelope evolution, is set to be equal to unity. This parameter is very uncertain.

Details of the binary-evolution algorithm are described by Hurley et al. (2002). Here, we want to highlight the treatment of wind accretion. This is a key process for the scenario described in Section 2.2 because for a moderately wide binary that avoids common-envelope phase and Roche lobe overflow, mass is transferred through wind accretion instead. When a star loses mass in a stellar wind, its companion can accrete some of the material as it orbits through it. Moreover, the mass-loss may be tidally enhanced by the presence of the companion if the secondary is moderately close. A descriptive formula given by Tout & Eggleton (1988) is used in the code to calculate the enhanced mass-loss rate. Typically, the mass accretion rate on to the secondary will be significantly tidally enhanced when the radius of the primary reaches 10 per cent of the Roche lobe radius. The accretion rate is typically of the order of $10^{-6}$ to $10^{-8} \, M_\odot \, yr^{-1}$ in the systems that we are investigating.

In our scenario, the primary is already an ONeMg WD and mass is deposited on to it by wind accretion from an AGB secondary. However, the accretion stops when the secondary evolves into a WD and its mass-loss decreases. When the final flash causes the secondary to expand again as it evolves back to the post-AGB track, wind accretion restarts. Renewed mass transfer can take place for only a brief time since the star will soon shrink again, so the amount of mass accreted during this post-final flash phase cannot be large.

The code is unable to predict exactly when a nova occurs, but it can trace the amount of mass deposited on to the WD. A few test models are used to simulate the mass accretion after the final flash, with a subroutine forcing the secondary WD to be reborn from the WD cooling track back on to the AGB. Based on the test models and nova evolution models by Prialnik & Kovetz (1995), systems with mass accretion rates reaching $10^{-7} \, M_\odot \, yr^{-1}$ at the end of AGB evolution will result in a nova shortly after the final flash. The recurrent periods of such novae are 0.771–19.6 yr. The actual required accretion rates could be slightly lower because mass may be deposited on the WD primary before the final flash, but it will not significantly alter our estimated frequency. Our binary system needs to be close enough so that the accretion rate on to the primary WD is high enough to trigger a nova explosion.

As an example of a system that may satisfy our observational constraints, we present here the case of a primary star with main-sequence mass of 6.8 $M_\odot$ and a companion with a main-sequence mass of 2 $M_\odot$; their initial separation is 2930 $R_\odot$ (see cartoon in Fig. 1). The primary star evolves into a SAGB star at the age of 58.7 million years and the two stars enter a common-envelope phase at an age of 59.5 million years. After the common-envelope phase, the primary has lost all of its envelope and has become an ONeMg WD of mass 1.2 $M_\odot$ and the secondary is now accreting some of the envelope and has therefore increased in mass to 2.1 $M_\odot$.

The system’s separation has been reduced to 1880 $R_\odot$. Eventually, the secondary evolves to the early AGB phase at a system age of 1.2 billion years. Mass is at this point accreted on to the ONeMg WD at a slow rate of $10^{-11} \, M_\odot \, yr^{-1}$. Eventually the accretion rate increases as the AGB secondary grows in size, reaching a rate of $10^{-7} \, M_\odot \, yr^{-1}$. Since the exact accretion rate during this phase is fundamental to time the nova outburst right after the final flash, the initial separation is crucial.

The lower limit for the separation is set by the requirement that a second common envelope between the AGB secondary and the now WD primary be avoided. This is because the accretion rate before or during a common-envelope interaction is extremely uncertain. During the common envelope the accretion rate on to the secondary may be very low, or non-existent due to the supersonic nature of
For a 0–1870–1876 We have not taken into account the fact that the secondary’s main-sequence mass is increased by accretion during the SAGB phase of the primary and that this will accelerate the secondary evolution. Uncertainties over the exact amount of accretion make it difficult to assess exactly the actual lower limit of the secondary mass. The lower this limit, the larger the number of systems that can evolve via our scenario.

1 We have not taken into account the fact that the secondary’s main-sequence mass is increased by accretion during the SAGB phase of the primary and that this will accelerate the secondary evolution. Uncertainties over the exact amount of accretion make it difficult to assess exactly the actual lower limit of the secondary mass. The lower this limit, the larger the number of systems that can evolve via our scenario.
modelling. We only remark here on the fact that the actual number of binary channels that can lead to the observed characteristics and time-scales of V605 Aql is not very large.

5 DISCUSSION

Beside V605 Aql, there are six other systems with hydrogen-deficient ejecta, all of which have been explained with some variation of the final flash scenario. An eighth system, CK Vul, may or may not be related to final flash (Hajduk et al. 2007). Sakurai’s object appears to be a modern twin of V605 Aql (but the abundances of carbon and neon in its hydrogen-deficient nebula have not been determined); its hydrogen-deficient material is distributed in a disc (Chesneau et al. 2009), as is the case for V605 Aql (Hinkle et al. 2008). FG Sge (Gonzalez et al. 1998) was observed to undergo an outburst in the late 1800s. Two other systems, A 30 and A 78, have hydrogen-deficient ejecta inside old, round or elliptical PNe (Harrington 1996). A 30 is the only other system where the C/O ratio was determined to be subunity and the neon mass fraction was very large (Wesson et al. 2003). A 30 and A 78 are broadly regarded to be almost identical systems, both having central stars with the abundances predicted for a final flash (e.g. Herald, Bianchi & Hillier 2005). Two additional hydrogen-deficient PNe are known: IRAS15154−5258 (Zijlstra 2002) and IRAS18333−2357. IRAS18333−2357 is the only hydrogen-deficient PN which does not reside inside a hydrogen-rich one. Gillett et al. (1989) also found this hydrogen-deficient PN to be extremely neon rich. This object is associated with the globular cluster M 22 and is one of the four PN known in the globular cluster system of the Galaxy (Jacoby & Fullton 1994; Jacoby et al. 1997). IRAS18333−2357’s hydrogen-deficient PN is very irregularly shaped. Its central star is a reasonably hydrogen-rich O star (Gillett et al. 1989; Rauch, Dreizler & Wolff 1998), implying the presence of a second undetected star that ejected the hydrogen-deficient material and that is therefore expected to be hydrogen deficient.

Finally, there is another system we should keep in mind when considering the plausibility of nova scenarios in the context of PN. Wesson et al. (2008b) discovered a PN surrounding Nova Vul 2007. Rodríguez-Gil et al. (2010) measured the period of the central binary to be 0.069 d, the shortest period binary known in a PN. They suggested V458 Vulpeculae to be a post-double-common-envelope system, composing a relatively massive WD accreting matter from a post-AGB star which produced the PN observed. The fast nova, with its rapid 21-day 3-magnitude brightness decrease from light maximum, suggested the WD mass to be at least 1 M⊙. Despite the clear indication that this system is indeed what it appears, i.e. a nova in a PN, it is difficult to determine a likely scenario for the accretion of mass on to the massive WD at the hand of the secondary: the AGB secondary may have transferred mass on to the WD primary, before the system entered a common envelope. The mass accretion on to the primary during the common-envelope phase is likely to have been low, and after the common envelope, when the secondary mass donor detached from its Roche lobe and was shrinking to post-AGB size, one may suppose that accretion stopped altogether. However accretion must have been happening to detonate the nova. It is possible that finding a scenario for this object may illuminate the past of the V605 Aql star.

Despite the successes of the final flash scenario in explaining the varied yet relatively homogeneous characteristics of the seven objects with hydrogen-deficient nebular material, the C/O ratio and neon abundances of the hydrogen-deficient ejecta of two of these seven objects are in glaring disagreement with the final flash sce-
Lundmark K., 1921, PASP, 33, 314
Miszalski B., Acker A., Parker Q. A., Moffat A. F. J., 2009, A&A, 505, 249
Nakano S., Sakurai Y., Hazen M., McNaught R. H., Benetti S., Duerbeck H. W., Cappellaro E., Leibundgut B., 1996, IAU Circ., 6322, 1
Paczynski B., 1976, in Eggleton P., Mitton S., Whelan J., eds, Proc. IAU Symp. 73, Structure and Evolution of Close Binary Systems. Reidel, Dordrecht, p. 75
Phillips J. P., 1989, in Torres-Peimbert S., ed., Proc. IAU Symp. 131, Planetary Nebulae. Kluwer, Dordrecht, p. 425
Poelarends A. J. T., Herwig F., Langer N., Heger A., 2008, ApJ, 675, 614
Pollacco D. L., Lawson W. A., Clegg R. E. S., Hill P. W., 1992, MNRAS, 257, 33P
Priahlnik D., Kovetz A., 1995, ApJ, 445, 789
Rauch T., Dreizler S., Wolff B., 1998, A&A, 338, 651
Rodríguez-Gil P. et al., 2010, MNRAS, 407, 21
Sandquist E. L., Taam R. E., Chen X., Bodenheimer P., Burkert A., 1998, ApJ, 500, 909
Schwarz G. J., Shore S. N., Starrfield S., Vanlandingham K. M., 2007, ApJ, 657, 453
Seitter W. C., 1987, Messenger, 50, 14
Shida R. Y., Liller W., 2004, in Kurtz D. W., Pollard K. R., eds, Proc. IAU Colloq. 193, ASP Conf. Ser. Vol. 310, Variable Stars in the Local Group. Astron. Soc. Pac., San Francisco, p. 184
Snijders M. A. J., Batt T. J., Roche P. F., Seaton M. J., Morton D. C., Spoelstra T. A. T., Blades J. C., 1987, MNRAS, 228, 329
Starrfield S., Truran J. W., Wiescher M. C., Sparks W. M., 1998, MNRAS, 296, 502
Tout C. A., Eggleton P. P., 1988, MNRAS, 231, 823
Tyne V. H., Evans A., Smalley B., Geballe T. R., Eyres S. P. S., 2002, Ap&SS, 279, 139
van der Hucht K. A., Conti P. S., Lundstrom I., Stenholm B., 1981, Space Sci. Rev., 28, 227
Vanlandingham K. M., Starrfield S., Shore S. N., 1997, MNRAS, 290, 87
Weidemann V., 2000, A&A, 363, 647
Werner K., Herwig F., 2006, PASP, 118, 183
Wesson R., Liu X.-W., Barlow M. J., 2003, MNRAS, 340, 253
Wesson R., Barlow M. J., Liu X., Storey P. J., Ercolano B., de Marco O., 2008a, MNRAS, 383, 1639
Wesson R. et al., 2008b, ApJ, 688, L21
Wolf M., 1920, Astron. Nachr., 211, 119
Zijlstra A. A., 2002, Ap&SS, 279, 171

This paper has been typeset from a TEX/LTEX file prepared by the author.