Cosmic abundances: The impact of stellar duplicity

A. Jorissen, S. Van Eck

Institut d’Astronomie et d’Astrophysique, Université Libre de Bruxelles, CP 226, Boulevard du Triomphe, B-1050 Bruxelles, Belgium

Abstract. The mass-transfer scenario links chemical peculiarities with stellar duplicity for an increasing number of stellar classes (classical and dwarf barium stars, subgiant and giant CH stars, S stars without technetium, yellow symbiotic stars, WIRRING stars, Abell-35-like nuclei of planetary nebulae...). Despite these successes, the mass-transfer scenario still faces several problems: What is the mass-transfer mode? Why orbital elements of dwarf barium stars do not fully match those of the classical barium stars? What is the origin of the few non-binary stars among dwarf barium stars?

1. The mass-transfer scenario: The origins

The impact of the binary nature of a star on its chemical composition seems to have been recognized first in the context of Am and Ap stars in the years 1960–1968 (Bonsack 1961; Fowler et al. 1965; Conti 1965; Van den Heuvel 1967a,b, 1968a,b,c). Van den Heuvel (1968a) writes: [many properties of] Ap and Am stars (...) can all be explained if these stars were originally the less massive members in spectroscopic binaries in which the primary during its post-main-sequence evolution filled its Roche lobe, transferred a large fraction of its mass towards the secondary and finally evolved into a white dwarf. Current views about the role of duplicity among Am and Ap stars will be shortly reviewed in Sects. 2. and 4.3.

Two decades later, the mass-transfer scenario popped up again, this time in relation with barium stars and following the discovery by McClure et al. (1980) of a large frequency of spectroscopic binaries among the family of barium stars. According to McClure, it is not unreasonable to conclude that BaII stars are all binaries with low-mass secondaries consisting of degenerate objects. It is possible that these systems are such that mass has been lost from a more massive evolving star and deposited onto the present primary, the secondary having now evolved to the white dwarf stage. The carbon and s-process elements in this case could be dumped onto the present primary-star atmosphere. (...) The CH stars, which are probably the Population II equivalent of BaII stars, may also, by implication, be binaries.

1At the time, E. Van den Heuvel was still affiliated with the Astronomical Institute of Brussels Free University!

2For a review about the s-process of nucleosynthesis and its major astrophysical site, the asymptotic giant branch (AGB) stars, the reader is referred to Lattanzio & Wood 2003
These are the first definitions of the mass-transfer scenario that appeared in the literature. From the very beginning, this scenario was thus supposed to pollute not only giant companions but also dwarf ones.

2. The early problems with the mass-transfer scenario: David Lambert’s question Where are the barium dwarfs?

Although willing to support the mass-transfer scenario, David Lambert nevertheless raised the question Where are the main-sequence progenitors of the classical Ba stars? in his review talk (Lambert 1988) at the IAU Symposium 132 in Paris where one of the authors (AJ) first met him. This question naturally arose from the realization that the mass-transfer scenario does not pollute more efficiently giant companions than dwarf companions. Since the accretion flow is governed by gravity and by pressure forces, the actual accretion cross section is much larger than the star geometrical cross section (Bondi & Hoyle 1944; Boffin & Jorissen 1988; Theuns et al. 1996). Therefore, dwarf stars polluted by mass transfer should be at least as common among main sequence stars as barium stars are among G-K giants (a few percents; McClure 1984). Yet, apart from the carbon dwarf G77-61 (Dahn et al. 1977), the only polluted dwarf stars identified at the time were the CH subgiants (Bond 1974), and those had discrepant Li abundances as compared to the barium giants (as well as discrepant neutron exposures; Lambert 1988, and Busso et al. 2001 for an update on this question). Since barium dwarfs should be found all along the main sequence, it was thus puzzling that subgiant CH stars were restricted to a very narrow temperature range around G0 (Bond 1974; Lambert 1988).

These objections were lifted several years later, when Lambert et al. (1993) realized that the resonant Li I line in the barium giants was blended, so that earlier Li abundances were overestimated. Classical barium stars and subgiant CH stars now had abundances consistent with their suspected evolutionary link (see also Smith et al. 1993).

As for the second objection, Tomkin et al. (1989) quite appropriately remarked that among the stars of spectral types A to F, discovery of the barium stars may have been hampered by the presence of large numbers of chemically peculiar stars. Indeed, the diffusive separation that leads to abundance anomalies in the atmospheres of the normal stars may operate too in the young barium stars so obscuring their true nature. The bright F5V star HR 107 was the first example (Tomkin et al. 1989) of a candidate barium dwarf warmer than the subgiant CH stars (later studies did not confirm the binary nature of this star, though; see Sect. 4.1). A few years later, North & Duquennoy (1991) identified many more dwarf barium stars among the stars flagged by Bidelman as F str A4077 in the Michigan spectral survey. Nowadays, several cool C dwarf stars (collected in Table 9.5 of Jorissen 2003b), blue metal-poor stars (Preston & Sneden 2001, 2001) and ‘Wind-Induced Rapidly Rotating’ K dwarfs (known as WIRRING stars after Jeffries & Smalley 1996; Jeffries & Stevens 1996) have joined the family of barium dwarfs. The possible incidence of the mass-transfer scenario among Am stars is not quite clear yet (Sect. 4.3). Furthermore, a definite proof of the filiation between these various classes requires as well a careful comparison of
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their respective chemical composition. Such a comparison is beyond the scope of the present review, which is restricted to a discussion of the orbital elements. The reader interested in a comparison of the chemical compositions is referred to Lambert (1985); North et al. (1994); Busso et al. (2001).

3. Successes of the mass transfer scenario

The mass-transfer scenario now encompasses many more stellar families than in the early days, as displayed in Fig. 11. This growth is in itself an illustration of the success achieved by this scenario; more specifically (see Jorissen 2003), for a more detailed review):

- The filiation barium stars – S stars without technetium ['S(no-Tc)'] is fully endorsed by the similarity of their orbital elements;
- Yellow symbiotic stars have been shown to be the low-metallicity, high-luminosity counterparts of barium stars (the CH giants mentioned in Sect. 1 have lower luminosities than yellow symbiotics; see Fig. 3 of Jorissen 2003a);
- WIRRING stars and Abell-35-like binary nuclei of planetary nebulae all show, on top of their s-process overabundances, signatures of rapid rotation, most probably caused by spin accretion accompanying mass accretion, as predicted by hydrodynamical simulations of mass transfer.

4. Recent problems with the mass-transfer scenario

Despite the successes sketched in Sect. 3, the mass-transfer scenario is currently not without problems. First, several barium dwarfs do not seem to be binaries (Sect. 4.1). Second, the exact nature of the mass transfer process is not fully elucidated yet (Sect. 4.2). Third, the expected filiation between post-AGB stars, barium dwarfs and barium giants is not fully supported by their eccentricity – period diagrams (Sect. 4.3), since there is an excess of short-period, large-eccentricity systems among post-AGB and dwarf barium stars.

4.1. What is the nature of the non-binary barium dwarfs?

The family of dwarf stars enriched in carbon and s-process elements appears to be a very heterogeneous one, as can be seen on Table 11. For instance, among sub-giant CH stars, ‘disk’ stars behave differently from low-metallicity stars as far as their binary frequency is concerned (Preston & Sneden 2001). Similarly, among the 6 ‘mild’ Ba dwarfs \(0.23 \leq \frac{[\text{Ba}/\text{Fe}]}{0.68}\) found from a high-accuracy abundance survey of 200 F dwarfs in the solar neighbourhood (Edvardsson et al. 1993), only HR 4395 seems to be a binary. On the contrary, the frequency of

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3 Both Lambert (1982) and North et al. (1994) remark for example that the abundance pattern of Am and Fm stars differ markedly from those of barium and F str \(\lambda 4077\) stars, but remember the quotation from Tomkin et al. (1980) earlier in this section
|   |   |
|---|---|
| 1. | Main sequence |
| 2. | K III, M III \( \text{TiO} \) |
| 3. | S(Tc) \( \text{ZrO} \) |
| 4. | SC(Tc) \( \text{ZrO, C}_2 \) |
| 5. | C(Tc) \( \text{C}_2 \) \( \text{RLOF or wind accretion} \) |
| 6. | post-AGB |
| 7. | PN Abell 35-like |
| 8. | hot WD \( \text{KVBa} \) |
| 9. | WD \( \text{Ba (F strong Sr4077)} \) |
| 10. | subgiant CH |
| 11. | giant Ba \( \text{(Pop.I)} \) |
| 12. | CH \( \text{(Pop.II)} \) |
| 13. | S or C (no Tc) \( \text{yellow symbiotic (Pop.II)} \) |
| 14. | C (Tc) (+ WD) |
| 15. | post-AGB (+ WD) |
|   | wide WD pair |

Figure 1. The evolution of a system consisting initially of two low- or intermediate-mass main-sequence stars. The left column corresponds to the normal evolutionary sequence of single stars, while the right column represents the various classes of stars with chemical peculiarities specifically produced by mass transfer across the binary system. Hatched circles denote stars with atmospheres enriched in carbon or heavy elements (see Jorissen 2003b, for a detailed description of the various stellar families involved).
Table 1. The various families of dwarf Ba and C stars, along with the observed fraction of binaries among them. The column labelled Refs. provides the references where the binary statistics and the orbital elements may be found.

| Family                        | Fraction of binaries | Refs. |
|-------------------------------|----------------------|-------|
| dwarf Ba                      |                      |       |
| “FV str λ4077” and disk CH subgiants | 28/30                | [1]   |
| blue metal-poor with Ba overabundances | 100%?               | [2]   |
| Ba dwarfs among FV from [3]   | 1/6                  | [4]   |
| low-metallicity CH subgiants  | 0/3                  | [5]   |
| dwarf C                       | ≥4/31                | [6]   |

References:

[1] McClure (1997); North & Duquennoy (1992); North et al. (2000); Preston & Sneden (2001)
[2] Preston & Sneden (2000); Sneden et al. (2003); Masseron et al. (2004)
[3] Edvardsson et al. (1993). The Ba dwarfs are HR 107, HR 2906, HR 4285, HR 4395 (binary), HR 5338, HD 6434. Their Ba overabundances (in the range $0.23 \leq \text{[Ba/Fe]} \leq 0.68$) cannot be ascribed to the normal galactic chemical evolution.
[4] Jorissen & Boffin (1992); North & Duquennoy (1992); North et al. (2000)
[5] Preston & Sneden (2001)
[6] see Table 9.5 of Jorissen (2003b)

binaries is close to 100% among ‘strong’ Ba dwarfs (with $[\text{s/Fe}] \geq 0.5$), consisting mainly of the “FV str λ4077” stars and the disk CH subgiants. It is also suspected to be 100% among the blue metal-poor stars with Ba overabundances.

Table 1 thus reveals that, among Ba dwarfs, the binary frequency is either consistent with 100% or close to 0%. The existence of non-binary, low-luminosity stars with Ba overabundances immediately raises the question of the origin of their chemical anomalies. Three broad classes of scenarios have been proposed so far: (i) ‘non-standard’ stellar evolution; (ii) disguised mass-transfer scenarios; (iii) coalescence of the two components of a binary system, or even possibly planet-engulfing.

The original suggestion by Bond (1974) of a mixing that returns a post-He flash star to the subgiant region belongs to the first category. Smith & Demarque (1980) concluded, however, that this hypothesis could work only if some new physics were acting. As far as low-mass, extremely metal-poor stars are concerned, Fujimoto et al. (2000) found that they can evolve into carbon stars at the end of their red giant branch evolution. As for the second class of scenarios, Beveridge & Sneden (1994) (see also Lambert 2001) suggest that Ba dwarfs (especially low-metallicity ones) may form after their atmosphere has been polluted by pockets of ISM material enriched in carbon and s-process elements by mass loss from a nearby AGB star. The third class of scenarios (coalescence or planet-engulfing) involves a modification of the internal angular-momentum distribution, which may possibly lead to some non-standard mixing and nucleosynthesis, or to flare-related nucleosynthesis if the star has been spun up
substantially. No studies specific to the problem under consideration have been performed yet, however (see McClure 1997; Siess & Livio 1999, for a more general discussion).

4.2. The mass transfer mode: Importance of periastron mass transfer?

Pols et al. (2003) have convincingly shown that the current prescriptions for binary evolution (both wind accretion and Roche lobe overflow – RLOF) fail to reproduce the orbital elements observed in barium stars. The orbital periods of the barium systems predicted by the synthetic binary evolution codes are either too short (when they result from RLOF) or too long (when they result from wind accretion in a system which must remain detached). Almost no systems are predicted in the observed period range for barium systems ($100 \leq P(d) \leq 10^4$; see Fig. 2). It is likely that something is wrong with our understanding of RLOF when it involves a giant star with a deep convective envelope (Iben 2000; Jorissen 2003b), as it is the case for the former AGB companion which polluted the barium star. It is generally believed that RLOF is dynamically unstable when the mass-losing star has a deep convective envelope and is the more massive component of the system. This situation leads to a common envelope stage and subsequently to dramatic orbital shrinkage as orbital energy is used to expell the common envelope (Jorissen 2003b).

As binary stars evolve along the sequence displayed in Fig. 1, their orbital elements are expected to vary, be it due to tidal effects, to interaction with a circumbinary disk, or to mass transfer. Therefore, the comparison of orbital elements for binary stars located at different stages in the sequence is expected to shed light on this puzzle about the mass transfer mode.

Extensive sets of orbital elements are now available for binary stars with a KIII primary (Mermilliod 1996), MIII primary (Jorissen 2004; Mikolajewska et al. 2003, for M giants in classical symbiotic systems, excluding symbiotic and recurrent novae), and barium or S(no-Tc) primary (Jorissen et al. 1998).

Figure 2 reveals a smooth evolution along the sequence KIII–MIII–Ba/S(no-Tc), in the sense that the upper boundary of the populated region in the eccentricity–period diagram moves towards larger periods. This is clearly a consequence of the larger radii reached by stars evolving along this sequence. Equating the stellar radius to the Roche radius results in a threshold period (for given component masses) below which the primary star undergoes RLOF. Adopting the usual expression for the Roche radius $R_{R,1}$ around star 1

$$R_{R,1}/A = 0.38 + 0.2 \log q \quad (0.5 \leq q = M_1/M_2 \leq 20),$$

where $A$ is the orbital separation, yields from Kepler’s third law, $P = 70$ d for a star of radius $40 \, R_\odot$ filling its Roche lobe (adopting $M_1 = 1.3$ and $M_2 = 0.6 \, M_\odot$). Although the Roche lobe concept is in principle only applicable to circular orbits, one may formally compute the orbital periods for which the primary star fills its Roche lobe at periastron, by replacing $A$ by $A(1-e)$ in the above expression (with $e$ being the orbital eccentricity). It is quite remarkable that the relationship between $P$ and $e$ so obtained (assuming $R_R = 40 \, R_\odot$) exactly matches the boundary of the region occupied by KIII giants in the $(e, \log P)$ diagram. This excellent match thus clearly suggests that tidal effects and/or mass transfer...
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at periastron play a crucial role in shaping the eccentricity – period diagram, through the processes described by Duquennoy et al. (1992); Soker (2000).

The value of $40 R_\odot$ falls in the upper range of radii measured by van Belle et al. (1999) for KIII stars. As far as MIII binaries are concerned, a periastron Roche radius of $85 R_\odot$ encompasses all the binaries with MIII primaries, though the match here is not as good as for KIII binaries. This may probably be explained by the smaller sample size, and by the larger detection biases (eccentric systems are not so easily detected among M giants, because they have less conspicuous velocity variations, which are often confused by their intrinsic pulsational jitter; see Jorissen 2004). Again, the value of $85 R_\odot$ derived from the $(e, \log P)$ diagram is somewhat larger than the radii measured by van Belle et al. (1999) for early MIII stars. This suggests that the upper left envelope observed in the $(e, \log P)$ diagram is mainly shaped by tidal effects, which operate already before the star fills its Roche lobe (e.g., Duquennoy et al. 1992).

Another striking difference between the K and M giants on Fig. 2 is the lack, among binaries involving M giants, of the many circular systems at the short-period end as observed among the K giants. This difference is surprising, since both stellar families involve stars with deep convective envelopes which should react similarly to tidal effects and mass transfer. M giants suffer, however, from a much more severe wind mass loss than K giants, and this offers a clue to explain the differences observed in their eccentricity – period diagram.

Finally, it must be remarked that barium systems almost exclusively fall in a gap observed at $P > 400$ d, $e < 0.1$ in the $(e, \log P)$ diagram of pre-mass-transfer binaries. This gap is especially apparent in the $(e, \log P)$ diagram of G and K dwarfs of the solar neighbourhood (Duquennoy & Mayor 1991). Figure 1 of North et al. (2000) clearly shows that barium dwarfs fall almost exclusively within this gap. The few KIII and MIII binaries located in this gap could in fact be post-mass-transfer binaries, a possibility that would be worth testing by looking for Ba-like abundance anomalies in those stars.

4.3. The filiation post-AGB – dwarf Ba – Ba/S(no Tc) stars

With many orbital elements now available for post-AGB stars and dwarf barium stars, it is interesting to check whether orbital elements support the filiation post-AGB – dwarf Ba – Ba/S(no-Tc) stars.

Post-AGB stars and dwarf Ba stars share the same region of the eccentricity – period diagram (Fig. 3). The discrepancies between two other properties of these families might, however, lead one to believe that binary post-AGB stars are unlikely to become Ba stars. These (apparently) discrepant properties are the fact that (i) the mass functions of post-AGB systems (0.14–0.97 M$_\odot$; Maas 2003) are much larger than those of barium dwarfs (0.080 M$_\odot$; Jorissen 2003b), and (ii) the fact that the binary post-AGB stars do not exhibit s-process overabundances (van Winckel 2003).

These discrepancies appear instead quite natural when one realizes that it is the companion of the post-AGB star, rather than the post-AGB star itself, which should become the Ba star (for post-AGB stars with main sequence companions)! First, the chemical composition of this companion (the future Ba star) cannot unfortunately be derived from spectral analysis, given its faintness, but it might well turn out to be rather different from that of the current post-AGB star.
Figure 2. The period – eccentricity diagram for binary systems involving a KIII primary (open squares), MIII primary (black dots; black squares for M giants in symbiotic systems) and Ba or S(no-Tc) primary (starred symbols). The dashed lines correspond to the loci of constant periastron distance (100 and 190 $R_\odot$), translating into Roche radii of 45 and 85 $R_\odot$, respectively (assuming masses of 1.3 and 0.6 $M_\odot$ for the two components).
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The composition of the companion is determined by the mass accreted in a former state of the binary system, when the post-AGB star was still on the AGB. In the current state of the binary system, the post-AGB star is known to undergo very specific chemical fractionation processes (like gas-grain segregation, and re-accretion of gas depleted in refractory elements; van Winckel 2003), but these processes were not necessarily operating at the time when the bulk of the mass was accreted by the Ba star in the making. Second, if dwarf barium stars are indeed the progeny of post-AGB stars, their mass functions $f_{\text{pAGB}}, f_{\text{Ba}}$ must be related by the simple relation $f_{\text{Ba}} = f_{\text{pAGB}} (M_{\text{pAGB}}/M_{\text{Ba}})^3$, resulting from the fact that the (observed) primary components are reversed between those two classes. To be more specific, if $M_{\text{pAGB}} = 0.67 M_\odot, M_{\text{Ba}} = 1.25 M_\odot$ (Jorissen 2003), and $f_{\text{pAGB}} = 0.5 M_\odot$, then $f_{\text{Ba}} = 0.08 M_\odot$, in perfect agreement with the average value for Ba dwarfs (Jorissen 2003).

Comparing now barium dwarfs to the giant barium and S(no-Tc) stars, there is a significant excess of eccentric systems in the 300 – 600 d range among barium dwarfs and post-AGB stars. These rather short-period, eccentric systems seem to form a distinct group from the bulk of the sample. Two giant Ba stars (HD 58368 and HD 199939) and one S(no-Tc) star (HD 191589) belong as well to this group of short-period, eccentric systems. Interestingly enough, the S star HD 191589 has an unusually large mass function of 0.394 $M_\odot$, pointing to a main-sequence rather than white-dwarf companion. The F0-F2 main-sequence companion of HD 191589 has indeed been detected by the International Ultraviolet Explorer (Ake & Johnson 1992). Could it be that the small group of short-period, eccentric systems are in fact pre-mass-transfer systems? But how to explain then the origin of their chemical peculiarities? These systems would then join the group of non-binary barium dwarfs (Sect. 4.1.), in the sense that they call as well for an alternative to the mass-transfer scenario in order to explain their chemical peculiarities.

To conclude this section on eccentricity – period diagrams, it must be remarked that the available orbital elements for Am stars (derived from modern spectrovelocimeter data like CORAVEL or ELODIE; Baranne et al. 1979, 1996) do not convincingly point towards a strong incidence of the mass-transfer scenario among this family. As can be seen on Fig. 1, the large number of short-period ($P \lesssim 100$ d) Am binaries contrasts with the situation prevailing for barium stars (see Fig. 2). Tidal effects in these close binaries play a key role in synchronizing the stellar spin with the orbital motion. Small rotational velocities are needed for the gravitational settling to operate and to lead to the observed chemical peculiarities (Michaud et al. 2002). A few binaries with periods in excess of 100 d (HD 36360: Carquillat et al. 2004; KW 538, vB 130: Debernardi et al. 2000) are present among Am stars, but they lie at the short-period edge of the region occupied by the barium dwarfs. The conclusion that very few – if any – Am binaries fall among the region occupied by Ba giants in the ($e, \log P$) diagram must however await confirmation from the forthcoming release of complete samples of orbital elements by Carquillat, Debernardi and North. In the meantime, the reader is referred to North & Duquennoy (1991); North et al. (1998); Debernardi (2000); Bidemari (2002); Carquillat et al. (2003).

4excluding the wide pairs in triple systems
Figure 3. The period–eccentricity diagram for binary systems involving post-AGB stars (open circles, from Maas 2003), dwarf barium stars (open squares, McClure 1997; Sneden et al. 2003; North et al. 2000, and priv. comm.) and Ba/S(no-Tc) stars (starred symbols, from Jorissen et al. 1998). Note that the triple system BD+38°118 (Ba star) has not been represented.
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Figure 4. The period – eccentricity diagram for binary systems involving Am stars (open circles) with orbital elements collected from the literature, but restricted to modern data obtained from the Swiss or Cambridge correlation spectrovelocimeters (The long-period pairs of triple systems have not been displayed). For comparison, Ba dwarfs and CH subgiants (open squares), and Ba/S(no-Tc) (starred symbols) are displayed as well.
for the most recent discussions on the role of duplicity among Am and Ap stars.

5. Conclusion

The impact of stellar duplicity on cosmic abundances has been investigated for more than 35 years now. The mass-transfer scenario, producing polluted stars with abundance patterns otherwise incompatible with their evolutionary stage, is widely accepted as the cause of the chemical peculiarities exhibited by classical barium giants, S(ng-Tc) stars, CH stars, yellow symbiotics, WIRRING stars, Abell-35-like binary nuclei of planetary nebulae... Yet this is not the end of the story, as the mass-transfer scenario still faces some difficulties:

- Precisely how the mass transfer occurs is not at all understood. Physical insight and constraints come essentially from the comparison of orbital elements of pre- and post-mass-transfer stellar families. Such a comparison reveals in particular that (i) dynamical effects occurring at periastron are probably decisive for the circularization and/or spiral-in of the binary system; (ii) the total lack of short-period, circular systems among pre-mass-transfer M giants (whereas such systems are numerous among K giants) may hint at the key role of wind mass loss from the mass donor.

- Orbital elements do not contradict the filiation post-AGB – dwarf barium stars. The very specific abundance pattern of post-AGB stars seems to result from chemical fractionation processes occurring after the bulk of the AGB envelope has been transferred to the companion star (the barium star in the making). Abundance analyses of post-AGB companions are needed to confirm that their abundances are consistent with those of barium stars.

- The barium dwarf – barium giant filiation is generally well supported by the comparison of their orbital elements, with the exception, however, of a small excess of short-period, eccentric orbits among dwarf barium (and post-AGB) stars. These systems might disappear through spiral-in when they reach the red giant branch. Alternatively, these barium dwarfs could have a main sequence companion (rather than the expected white dwarf), as is the case, incidentally, for the Tc-poor S star HD 191589 which falls in the same region of the period – eccentricity diagram. But their chemical peculiarities cannot be attributed then to the mass-transfer scenario. These systems would thus join the small set of Tc-poor S stars with a main-sequence companion (like HD 191589) and of non-binary dwarf barium stars and subgiant CH stars, which require as well an alternative to the mass-transfer scenario.

Acknowledgments. AJ first wants to thank D. Lambert for the opportunity he offered him to spend nine months in Texas, back in 1990. These months were a source of inspiration for many years thereafter. We thank P. North for communicating us orbital elements of barium dwarfs in advance of publication. Discussions with A. Frankowski and J.M. Carquillat also helped to clarify some of the topics discussed here. AJ is Senior Research Associate from the Fonds
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National de la Recherche Scientifique, SVE is Research Associate from the Fonds National de la Recherche Scientifique.

References

Ake T. B., Johnson H. R. 1992, in Seventh Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, ASP Conf. Ser. 26, San Francisco, p. 579
Baranne A., Mayor M., Poncet J. L. 1979, Vistas in Astronomy, 23, 279
Baranne A., Queloz D., Mayor M., Adrianzyk G., Knisel G., Kohler D., Lacroix D., Meunier J.-P., Rimbaud G., Vin A. 1996, A&AS, 119, 373
Beveridge R. C., Sneden C. 1994, AJ, 108, 285
Bidelman W. P. 2002, The Observatory, 122, 343
Boffin H. M. J., Jorissen A. 1988, A&A, 205, 155
Bond H. E. 1974, ApJ, 194, 95
Bondi H., Hoyle F. 1944, MNRAS, 104, 273
Bonsack W. K. 1961, ApJ, 133, 551
Busso M., Gallino R., Lambert D. L., Travaglio C., Smith V. V. 2001, ApJ, 557, 802
Carquillat J.-M., Ginestet N., Prieur J.-L., Debernardi Y. 2003, MNRAS, 346, 555
Carquillat J.-M., Prieur J.-L., Ginestet N., Oblak E., Kurpinas-Winiarska M. 2004, MNRAS, 352, 708
Conti P. S. 1965, ApJ, 142, 594
Dahn C. C., Liebert J., Kron R. G., Spinrad H., Hintzen P. M. 1977, ApJ, 216, 757
Debernardi Y. 2000, in B. Reipurth, H. Zinnecker (eds.), Birth and Evolution of Binary Stars (IAU Symposium 200), ASP, San Francisco, 161P
Debernardi Y., Mermilliod J.-C., Carquillat J.-M., Ginestet N. 2000, A&A, 354, 881
Duquennoy A., Mayor M. 1991, A&A, 248, 485
Duquennoy A., Mayor M., Mermilliod J. 1992, in A. Duquennoy, M. Mayor (eds.), Binaries as Tracers of Stellar Formation, Cambridge University Press, Cambridge, 52
Edvardsson B., Andersen J., Gustafsson B., Lambert D. L., Nissen P. E., Tomkin J. 1993, A&A, 275, 101
Fowler W. A., Burbidge E. M., Burbidge G. R., Hoyle F. 1965, ApJ, 142, 423
Fujimoto M. Y., Ikeda Y., Iben I. J. 2000, ApJ, 529, L25
Iben I. J. 2000, in J. Kastner, N. Soker, S. Rappaport (eds.), Asymmetrical Planetary Nebulæ II: From Origins to Microstructures (ASP Conf. Ser. 199), Astron. Soc. Pacific, San Francisco, 107
Jeffries R. D., Smalley B. 1996, A&A, 315, L19
Jeffries R. D., Stevens I. R. 1996, MNRAS, 279, 180
Jorissen A. 2003a, in R. L. M. Corradi, J. Mikolajewska, T. J. Mahoney (eds.), Symbiotic stars probing stellar evolution, Astron. Soc. Pacific Conf. Ser. Vol. 303, San Francisco, 25
Jorissen A. 2003b, in H. Habing, H. Olofsson (eds.), Asymptotic Giant Branch Stars, Springer Verlag, New York, p. 461
Jorissen A. 2004, Rev. Mex. Astron. Astrof., in press
Jorissen A., Boffin H. M. J. 1992, in A. Duquennoy, M. Mayor (eds.), Binaries as Tracers of Stellar Formation, Cambridge University Press, Cambridge, 110
Jorissen A., Van Eck S., Mayor M., Udry S. 1998, A&A, 332, 877
Lambert D. L. 1985, in Cool Stars with Excesses of Heavy Elements, Reidel, Dordrecht, p. 191
Lambert D. L. 1988, in G. Cayrel de Strobel, M. Spite (eds.), The Impact of Very High S/N Spectroscopy on Stellar Physics (IAU Symp. 132), Kluwer, Dordrecht, 563
Lambert D. L. 2001, in 11th Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, Astron. Soc. Pacific Conf. Ser. 223, p. 163
Lambert D. L., Smith V. V., Heath J. 1993, PASP, 105, 568
W. P. Bidelman: I have recently decided that the most interesting binaries are those that have coalesced and become single stars, though we may not know it. I have thought the Ap stars might be such objects.