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Barium-rich G stars in the nuclei of the planetary nebulae Abell 35 and LoTr5*

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Abstract. A spectroscopic analysis of the G-star located at the centre of Abell 35 leads to a surface gravity $\log g = 3.7 \pm 0.5$ and an effective temperature $T_{\rm eff} = 5300 \pm 200$ K, which are typical of a G8IV spectral type. We estimate a projected rotational velocity of $55 \pm 10\,{\rm km\,s^{-1}}$ and deduce a radius $1.5 \leq R_{\rm G} \leq 3.5 R_{\odot}$ in agreement with the subgiant luminosity class: the star is rapidly rotating, near the break-up as for LoTr5 (Jasniewicz et al. 1996a). For both late-type central stars of Abell 35 and LoTr5, we show a photospheric enhancement of the barium element which can be understood as caused by the transfer of s-process-overabundant material from the former AGB star which is now the hot star of the binary. These G-stars could be pre-barium stars in detached binary systems.

Key words: planetary nebulae: individual: Abell 35, LoTr5 – stars: binaries – stars: abundances – stars: chemically peculiar

1. Introduction

Abell 35 and LoTr5 (respectively PN G 303.6+40.0 and PN G339.9+88.4 in the Strasbourg-ESO catalogue of galactic planetary nebulae, Acker et al. 1992) are low-surface brightness and large-angular diameter objects classified as planetary nebulae. Both objects have a cold visible G-star at the centre of the nebula (PN): BD$-22°$3467 for Abell 35 and HD 112313 for LoTr 5. They share the following common properties (see Jasniewicz & Acker 1988, Jasniewicz et al. 1987, 1992, 1994a, 1994b, 1996a):
– The nucleus is a binary star. The hot star which ionizes the nebula has been detected in IUE spectra (Grewing & Bianchi 1989, Feibelman & Kaler 1983). However, no clear indication of photometric and/or spectroscopic variations due to reflection effects in a very close binary have been given by authors.
– The G-star is a high rotator. The projected rotational velocity of HD 112313 is $60 \pm 5\,{\rm km\,s^{-1}}$.
– The G-star is an active star and there is a modulation of the light curve by dark spots. The rotational period is 0.766 ± 0.008d for Abell 35 and 5.9 ± 0.3d for LoTr 5.
– The orbital period is unknown because of poor radial velocity measurements of wide absorption lines enlarged by rotational velocity.
Jasniewicz et al. (1987) have emphasized the similarity between the late-type central stars of the Abell 35-type planetary nebulae and the so-called FK Comae stars. In order to show possible contamination by companions in these high rotators, Jasniewicz et al. (1994c, 1996b) have announced and started in 1994 a program of chemical analysis by means of low and high resolution spectra. We report here new spectroscopic observations of Abell 35 and LoTr5 in various spectral ranges which show that the late-type central stars of Abell 35 and LoTr5 are barium-rich due to a contamination of their photosphere by barium and other s-elements by the envelope of the asymptotic giant branch (AGB) progenitor of the white dwarf in the binary system.

1.1. Inside Abell 35

The G-star at the centre of Abell 35 was observed by Jacoby (1981) who deduced from the DDO colors a spectral type G8 III-IV and a metallicity index [Fe/H]≈ -0.22 dex. Using an absolute magnitude of +1.9 which corresponds to a luminosity class between giant and subgiant G-stars, Jacoby (1981) estimated a distance of 360 ± 80 pc. Jacoby also raised some doubt on the validity of the classification of Abell 35 as a planetary nebula, because of its unusual morphology with a small expansion velocity and its large size with a moderate height above the galactic plane. Hollis et al. (1996) have given observational evidence of a dynamical interaction between the nebular material of Abell 35 and the interstellar medium.

A complete physical understanding of the peculiar nucleus of Abell 35 has not yet been found. The present knowledge about Abell 35 and BD$-22°$3467 is the following (see the review on this object by Jasniewicz et al. 1994a): the red component is an

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* Based on measurements collected at the European Southern Observatory (La Silla, Chile) and at the Observatoire de Haute Provence (France).

active star which experiences a RS–CVn like variability. Thus the photometric period $P = 0.766$ d is interpreted as the rotational period of the star. The star displays H&K, CaII, Mg II and H_α emission lines which vary with time, the variations being correlated with the rotational period. The hot component is a subdwarf star. By using NLTE model atmospheres from Napiwotzki, Jasniewicz et al. (1994a) have estimated its temperature $T_{\rm eff}$ = 150 000 ± 30 000 K. Hollis et al. (1996) have derived a mass-loss rate of $\leq 3.0\,10^{-10}\,M_\odot {\rm yr}^{-1}$ and a systemic wind velocity of $\geq$ 530km s^{-1}. However, Abell 35 has not been found to emit detectable X-rays with the EXOSAT satellite (Apparao and Tarafdar 1989) and during the ROSAT All Sky Survey (Kreysing et al. 1992). Abell 35 was also observed during the Extreme Ultraviolet Explorer (EUVE) all-sky survey by Fruscione et al. (1995), but no significant source was detected in the two shortest EUV bandpasses (Lex/B and Al/C) from 67 to 364Å.

1.2. Inside LoTr 5

For this object, see the review by Jasniewicz et al. (1996a). For the visible central star HD 112313, we derived a gravity log g= 2.7±0.5 and an effective temperature $T_{\rm eff}$ = 5250 ± 200 K, in full agreement with a spectral type G5III. The iron abundance is found to be nearly solar: $[{\rm Fe/H}]^*_\odot = -0.25 \pm$ 0.25 dex. As mentioned above, this late-type star is rapidly rotating, near break-up, with a projected rotational velocity of 60 ± 5 km s^{-1}. The true period of the orbital motion $P_{\rm orb}$ and the size of the Roche lobe are presently uncertain. An orbital period of a few years is not excluded.

The companion of HD 112313 is one of the hottest stars known. By fitting respectively blackbody and high gravity-hydrogen models computed by Hummer and Mihalas (1970), Kaler and Feibelman (1985) estimated effective temperatures ($T_{\rm eff}$) of 185 000 K and 122 000 K, respectively. LoTr5 was also detected as an X-ray emitter by Apparao et al. (1992) with EXOSAT and by Kreysing et al. (1992) using the ROSAT All Sky Survey. It is not known in this case whether the X-rays are coming from a point source or an extended region, and thus the origin of the emission – from a very hot black body temperature or from thermal bremsstrahlung – is uncertain.

2. Spectroscopic observations

Spectra used in this paper have various resolutions:
– High-resolution spectra (≈ 0.17Å) centered on the H_α line were obtained with the spectrograph *Aurélie* (Gillet et al. 1994) installed on the 1.52m telescope at Observatoire de Haute Provence. This spectrograph uses a cooled 2048-photodiode detector forming a 13μm pixel linear array. The entrance spherical diaphragm was 3". A grating with 1800 grooves mm^{-1} was used, giving a mean dispersion of 4.7Å mm^{-1}. The spectral coverage was about 120Å. A part of the spectrum of BD−22°3467 is displayed in Fig. 1.
– Medium-resolution spectra (≈ 0.65 Å) in the blue (respectively red) spectral range centered on λ 4555Å (respectively λ 6650Å) were also obtained with *Aurélie* in using a grating of 600 grooves mm^{-1}. The spectral coverage was about 440Å. A part of the spectrum of HD 112313 in the blue spectral range is displayed in Fig. 2.
– Low-resolution spectra (≈ 2.3Å) centered on the lines H_α and H_β, obtained at La Silla (Chile) with the 1.52m telescope and the Boller & Chivens spectrograph were taken and used to help us in the determination of the physical parameter of the stellar photophere of BD−22°3467.
– Low-resolution spectra (≈ 14Å) taken with the reflective aspherized grating spectrograph *Carelec* (Lemaitre et al. 1990) at the OHP with the 193 cm telescope were analysed. A grating with 150 grooves mm^{-1} blazed at 5000Å was used; the mean dispersion was 259Å mm^{-1}, giving 7Å per pixel. The spectral range was about 3700Å.

Spectrophotometric flux standards recommended by Massey et al. (1988), Breger (1976) and Taylor (1984) were observed several times each night. Calibration lamps were observed before and after each stellar observation for wavelength calibration. At the beginning and at the end of each night, flat-fields were obtained using an external lamp. Flat-field corrections and wavelength calibrations were performed at Strasbourg using the MIDAS package. Each stellar spectrum was corrected for both sky and nebular emissions.

3. Analysis and discussion of data

3.1. Spectrophotometric analysis of BD−22°3467 (Abell 35)

The spectrophotometric analysis of the photosphere of BD−22°3467 has been carried out in a similar way as for HD 112313 (LoTr5) (Jasniewicz et al. 1996a).

3.1.1. First step

First, we compare low-resolution spectra covering the wavelength range $\lambda\lambda \approx$ 4000-5400Å to a grid of synthetic spectra (in the same resolution and for the same wavelength range) reproducing the spectra of all kinds of late-type stars. The computation of the spectra with photospheric models from the grid of Bell et al. (1976) and the comparison is performed using a method developed and described in Thévenin & Jasniewicz (1992, TF92). This method has been also developed by others in a more complicated way and is described in Cayrel et al. (1991). We recall here only the results of the performance of such a technique used to derive the three fundamental parameters of a stellar photosphere of a late-type star. For more details and applications of the method, see TF92 or Jasniewicz & Thévenin (1994). *It has been proved that this technique gives an accuracy equivalent to the spectroscopic detailed analysis*. One of the advantages of this technique is to be independent of the position of the average continuum.

In the case of BD −22°3467, the effective temperature $T_{\rm eff}$= 5300K is obtained with an accuracy of 150K, the logarithm of the surface gravity log g=3.7 is given with an uncertainty of 0.5 and the metal abundance $[{\rm M/H}]^*_\odot$=-0.2 dex is as accurate as 0.2 dex. These parameters are in agreement with a spectral type G8IV and exclude the luminosity class III mentioned by Jacoby (1981). The spectroscopic parallax thus gives a distance of 200 ± 100pc for Abell 35. Because of the low resolution, only these three fundamental parameters of the stellar photosphere are derived. The high rotational velocity detected for the star prevents us to the use of the classical detailed analysis based on the curve-of-growth technique of equivalent widths measured on high-resolved spectra to derive the chemical abundances of peculiar elements. The resolution given by the rotational velocity is ≈2.4Å at λ = 6550Å for the G-star of Abell 35.

3.1.2. Second step

We use high-resolution spectra having the resolution of the rotational velocity. After determining a pseudo-continuum on the spectra centered on the H_α line where short continuum windows exist, we have confirmed by fitting a synthetic spectrum computed as described in Thévenin et al. (1992) using the previously determined photospheric parameters that they reproduced perfectly the profile of the observed spectrum. So we conclude definitively that $T_{\rm eff}$ = 5300 ± 100 K, log g= 3.7±0.5 and $[\rm Fe/H]^{\star}_{\odot} = -0.2 \pm 0.3$ dex. This result improves the accuracy of the position of the red-continuum drawn, which is consequently accurate enough to allow us to derive the chemical abundances of peculiar elements such as the s-process ones.

A blend of saturated lines of iron (around λ 6594Å) has been used to estimate the photospheric microturbulent velocity : $\zeta_{\rm turb} = 1.1 \pm 0.4\,{\rm km\,s^{-1}}$ which is compatible with the mean adopted values for this parameter in dwarf or subgiant stars. The best fit of the observed spectrum by a computed one is given in Fig. 1. The rotational velocity $V_{\rm rot}$ sin $i_{\rm rot}$ is clearly very high, about $55 \pm 5\,{\rm km\,s^{-1}}$.

We were now able to determine the chemical abundances of Ca, Si, V, Ni and Ba for BD-22°3467 by using several unresolved blended lines, strong enough (≈ 100 mÅ) to be detectable and measurable with a good accuracy by means of a synthetic spectrum. We estimated an uncertainty ±0.3 dex on the abundances by varying the abundance values and taking account of the uncertainties on the temperature and the surface gravity. The identification of the lines comes from the Rowland's table of solar spectrum wavelengths (Moore et al. 1966) and are : Ba II (6496.9 Å), Si I (6526.4, 6527.2 Å), Ca I (6499.6, 6493.8 Å), V I (6504.1 Å), Ni I (6586.3, 6592.9 Å). Atomic parameters as gf values used for these blended lines are from Thévenin (1989, 1990). Because most of the lines used are not strong lines enlarged by damping, we can neglect the NLTE effect in the discussion. We tried also to derive an abundance of the carbon C using the CH molecular lines within the wavelength region $\lambda\lambda$ 4300–4390 Å and found it to be normal compared to the Fe abundance in the star. Results are given in Table 1.

Except for Ba, the chemical abundances of the star BD −22°3467 are nearly solar. The overabundance of Ba is significant (+0.5 dex) with respect to the accuracy (±0.3 dex) of the method used here.

Table 1. Iron abundance and [Element/Fe] ratios of BD −22°3467 (Abell 35). Solar abundances are from Holweger (1979). $[\rm M/H]^*_\odot = \log(M/H)^* - \log(M/H)_\odot$.

$[\rm Fe/H]^*_\odot$	=	–0.20	±0.30
$[\rm C/Fe]^*_\odot$	=	+0.00	±0.40
$[\rm Si/Fe]^*_\odot$	=	+0.20	±0.30
$[\rm Ca/Fe]^*_\odot$	=	+0.15	±0.30
$[\rm Ba/Fe]^*_\odot$	=	+0.50	±0.30
$[\rm V/Fe]^*_\odot$	=	+0.20	±0.30
$[\rm Ni/Fe]^*_\odot$	=	+0.00	±0.30

Table 2. Iron abundance and [Element/Fe] ratios of HD 112313 (LotTr5) with respect to the sun. Solar abundances are from Holweger (1979). $[\rm M/H]^*_\odot = \log(M/H)^* - \log(M/H)_\odot$.

$[\rm Fe/H]^*_\odot$	=	–0.25	±0.25
$[\rm C/Fe]^*_\odot$	=	0.00	±0.40
$[\rm Mg/Fe]^*_\odot$	=	+0.10	±0.25
$[\rm Ca/Fe]^*_\odot$	=	+0.10	±0.25
$[\rm Si/Fe]^*_\odot$	=	+0.35	±0.25
$[\rm Ni/Fe]^*_\odot$	=	+0.05	±0.30
$[\rm Ba/Fe]^*_\odot$	=	+0.50	±0.30
$[\rm Y/Fe]^*_\odot$	=	+0.40	±0.30
$[\rm Sr/Fe]^*_\odot$	=	+0.80	±0.30

3.2. Spectroscopic analysis of HD 112313 (LoTr5)

We recall that we have found in a previous paper the following photospheric parameters for HD 112313 : $T_{\rm eff}$ = 5250 ± 200 K, log g= 2.7±0.5 and $[\rm Fe/H]^{\star}_{\odot} = -0.25 \pm 0.2$ dex. In the previous paper (Jasniewicz et al. 1996a) we were able to estimate the chemical abundances of Si, Ca and Ni with the same lines as for the analysis of BD −22°3467. Thanks to new spectroscopic observations we have been able to analyse the elements : Ba, Mg, Y and Sr. We have used the following blended lines for this analysis : Mg I (4351.9, 4571.1 Å), Ba II (4554.0 Å), Y II (4374.9, 4398.0 Å), Sr I (4607.3 Å). Results are given in Table 2. The

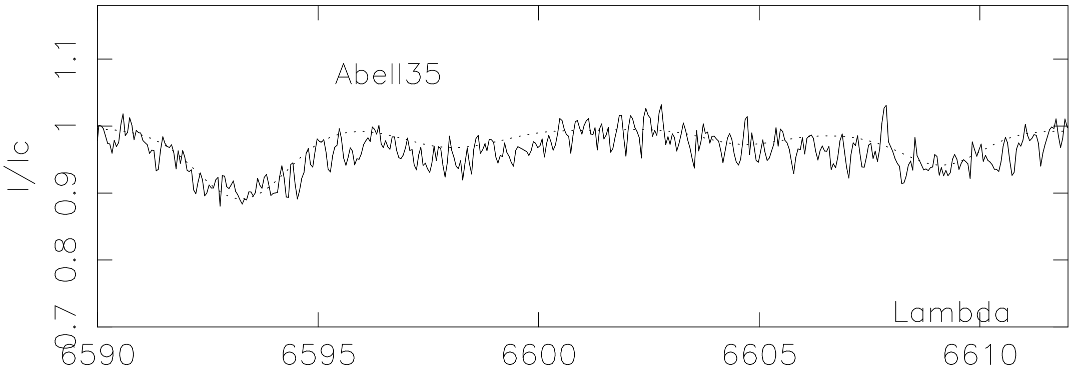

Fig. 1. High-resolution spectrum of BD-22°3467 (Abell 35) taken on JD 2 448 285.65. The full line is the observed spectrum of the star. Dotted line is the stellar spectrum computed with parameters described in Sect. 3.1 ($T_{\rm eff}$ = 5300 K, log g= 3.7 and $[{\rm Fe/H}]^{\star}_{\odot} = -0.2$ dex). Fluxes have been divided by the continuum. Wavelengths are given in Å.

overabundances of barium, strontium, yttrium in HD 112313 are significant with respect to the accuracy (±0.3 dex) of the method used in this paper. The abundance of the carbon C was derived as in Sect. 3.1.2. by using the CH molecular lines around 4300 Å: it is normal compared to the Fe abundance in the star. Because of the poor resolution of the spectra due to the high rotational velocity of BD −22°3467 and HD 112313, it was not possible to reduce the error bar of the carbon abundance values proposed in Tables 1 and 2. We show on Fig. 2 the comparison of part of the observed spectrum of HD 112313 with the computed one near the wavelength range of the Ba II (4554.0 Å) line.

3.3. Discussion

The overabundance of barium and related s-process elements in BD-22°3467 and HD 112313 (see Tables 1 and 2) can be explained as being due to a transfer of matter enhanced by s-processed elements present in the atmosphere of the secondary star. The s-elements are produced by nucleosynthesis associated with ^{4}He burning in thermally pulsating asymptotic giant branch stars. Binarity and transfer of matter from the AGB star to the companion are invoked by many authors since the pioneering work of McClure et al. (1980) in order to explain why non-AGB stars such as Ba stars are enriched in barium. Han et al. (1995) consider four evolutionary channels for the formation of Ba stars and related objects via binary interactions: wind accretion, wind exposure, stable Roche lobe overflow and common-envelope ejection. In the case of BD-22°3467 (resp. HD 112313), the AGB star has evolved as the current hot subdwarf star whilst the accretor has become the visible subgiant (resp. giant). The high equatorial rotational velocity of BD-22°3467 and HD 112313 can be explained by two scenarios: spin-up during a common envelope interaction (Bond 1993) or during a wind-accretion phase (Jeffries & Stevens 1996). Both scenarios could explain the observed contamination of the companion by the s-process-overabundant envelope of the former AGB star. But in the first case, the actual binary should be a *close* binary whilst in the second case the binary could be a wide one (Jeffries & Stevens 1996). This point is discussed in the next section.

4. Close or wide binaries?

In this section, we discuss the data from previous papers by Acker & Jasniewicz (1990) and Jasniewicz et al. (1996a), concerning Abell 35 and LoTr 5, in order to examine if they are consistent with wide binaries in these planetaries. Indeed, the small observed radial-velocity variations can play in favour of a close binary with a very low orbital inclination or of a wide binary. This discussion is crucial in order to answer the question whether the binaries of Abell 35 type have been formed through a common-envelope or wind-accretion phase (see Sect.3). The fundamental parameters (effective temperature, surface gravity, projected rotational velocity) given in Sect.3.3 for BD-22°3467 will be helpful for the discussion.

4.1. The nucleus of LoTr 5

We recall here some of the results of Jasniewicz et al. (1996a): the nucleus is not a very short-period binary; if the orbital period is a few days, the orbital inclination is very low (say $\leq 5°$) and there is no coplanarity of the orbital and equatorial planes; an orbital period of a few years is not excluded. Thus our data are consistent with a detached configuration for the binary nucleus in LoTr 5.

4.2. The nucleus of Abell 35

The emission-line profile of H_α is double peaked with a separation $\Delta\lambda$ = 6.3Å (see Fig.2 in Acker & Jasniewicz 1990). Firstly we note that the red and blue peaks are very sharp, and secondly that the central absorption sometimes dips below the continuum level.

The double peak appearance is naturally explained by a central absorption superposed upon a broad emission profile. According to Acker & Jasniewicz (1990) the H_α emission centroid exhibits a radial velocity variation with a period equal to $P_{\rm rot}$ at a amplitude $K_{\rm E}$ = 50 ± 20km s^{-1}. We emphasize here that such variations are difficult to prove due to the extrapolation technique used by the authors which consists to fit a gaussian

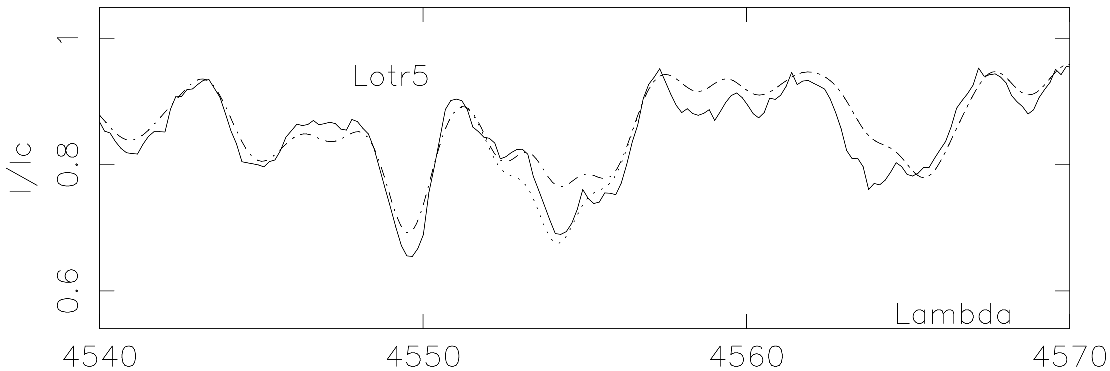

Fig. 2. Medium-resolution spectrum of HD 112313 (LoTr5) taken on JD 2 450 220.36. The full line is the observed spectrum of the star. Dotted (resp. dotted-dashed) line is the stellar spectrum computed with parameters described in Sect. 3.2 ($T_{\rm eff}$ = 5250 K, log g = 2.7 and $[{\rm Fe/H}]^{\star}_{\odot}$ = −0.25 dex) and $[{\rm Ba/Fe}]^{\star}_{\odot}$ = +0.50 dex (resp. $[{\rm Ba/Fe}]^{\star}_{\odot}$ = 0.00 dex). Fluxes have been divided by the continuum of energy. Wavelengths are given in Å.

from the wings of the emission profile. New observations with a better resolution are planned in order to confirm the variations of the emission centroid. Again according to Acker & Jasniewicz (1990) the H_α absorption line and metallic lines exhibit a small radial velocity variation, poorly correlated to $P_{\rm rot}$, at a amplitude $K_{\rm A}$ = 20 ± 20km s^{-1}. Since these variations are quite questionable, we discuss now two assumptions: the measured amplitude $K_{\rm A}$ = 20 km s^{-1} reflects/does not reflect an orbital motion synchronized with rotation.

i) We address now the first assumption, already investigated by Acker & Jasniewicz (1990). In this case $M_{\rm G}/M_{\rm SD}$ = 2.5. The binary system is a very short-period star, and the orbit is consequently circularized. In assuming a mean total mass of $2M_\odot$ for the binary system, we deduce a semi-major axis of $4 \pm 2R_\odot$ so that the G-star is actually filling its Roche lobe of radius $R_{\rm Roche} \sim 2R_\odot$. Thus the orbital motion is coplanar with the rotational plane. Under these conditions, Acker & Jasniewicz (1990) deduced an inclination $i = 15 \pm 5°$ for the binary system and a mass $M_{\rm G} = 1.5 \pm 0.5 M_\odot$. This mass seems to be too high for a star classified as G8IV in this work ; according to Schmidt-Kaler (1982), $0.8 \leq M_{G8IV} \leq 1.1$. Moreover, the inclination for the rotational plane implies a rotational velocity $v \sin i = 2\pi P_{\rm rot}^{-1} R \sin i \simeq 15R \leq 30\,{\rm km\,s^{-1}}$, where $R \leq R_{\rm Roche}$ is the radius of the star, which is in contradiction with the observed value of $v \sin i$ (see Sect. 3.3).

(ii) Let us now assume that the measured radial velocity variations in the absorption spectrum during a period $P_{\rm rot}$ are of poor quality and that the amplitude due to the orbital motion of the G-star is $K_G \leq 10\,{\rm km\,s^{-1}}$: this last assumption is in agreement with the mean radial velocity measurements of BD-22° 3467 obtained by Acker & Jasniewicz (1990) (+10 ± 10 km s^{-1}) and Vilhu et al. (1991) (−13 ± 10 km s^{-1}) within one year. Now we hypothesize that the amplitude $K_{\rm E}$ = 50 ± 20 km s^{-1} is due to radial velocity variations induced by the rotation of the G-star. This circular velocity agrees well with our estimate of $v \sin i$ = 55 km s^{-1} (Sect. 3.3). As for FK Comae (Walter and Basri 1982), we deduce that the bulk of the H_α emission arises on, or close to, the surface of the G-star. The origin and stability of this "hot spot" are open to question. In this scenario the H_α emission comes from a region close to the boundary between photo-ionization and collisions dominated by electrons. From the fractional chromospheric H_α emission luminosity $L_{H_\alpha}/L_{\rm bol}$, Vilhu et al. (1991) have shown that BD-22° 3467 is close to the saturated level of activity. In this star the chromospheric H_α-transition is probably optically thick so that the photosphere is obscured by the chromosphere. A wind-component can explain erratic variations of the H_α profile. H_α flares could be expected.

Table 3. Rotational velocity and break-up velocities ($V_{\rm rot}$, $V_{\rm b}$) (km s^{-1}) according to various values of the stellar mass M and radius R expressed in solar units

$R\backslash M$	0.8	0.9	1.0	1.1
2	133, 276	133, 292	133, 308	133, 323
3	200, 225	200, 239	200, 252	200, 264
4	266, 194	266, 207	266, 218	266, 229

The breakup angular velocity $V_{\rm b}$ of a star can be expressed in terms of the mass M and radius R_0 of the corresponding non-rotating star; it specifies the upper limit of the equatorial rotational velocity

$$V_{\rm b} = 436\sqrt{M/R_0} \qquad (1)$$

where M and R_0 are in solar units. Because $V_{\rm rot} = 51\,R\,P_{\rm rot}^{-1} = 66R$, we deduce $R/R_\odot \leq 3.5 M/M_\odot$. Table 3 displays the rotational velocity $V_{\rm rot}$ and the upper value of the equatorial rotational velocity $V_{\rm b}$ for various values of R and M.

It follows that the star has a typical radius $R \sim 2.5 \pm 1 R_\odot$ in agreement with measured radii of subgiant stars by Popper (1980), and with the gravity determined in Sect.2.3 (log g = 3.7 implies $R \simeq 2.3 R_\odot$ for a solar mass star); for $R \sim 3R_\odot$ the star is near break-up.

Combining the 0.77d rotation period with the 55 $\mathrm{km\,s^{-1}}$ projected rotational velocity, we obtain

$$i_{\rm rot} = \arcsin(0.83 R_\odot\, R^{-1}) \quad (2)$$

say $i_{\rm rot} = 33°$ (resp. 14°) for a radius $R_{\rm G} = 1.5 R_\odot$ (resp. $3.5 R_\odot$).

From the definition of the mass function and in assuming a standard mass of $0.6 M_\odot$ for the hot star, it is easy to evaluate the amplitude $K_{\rm G}$ as a function of the orbital inclination $i_{\rm orb}$ and the orbital period $P_{\rm orb}$:

$$K_{\rm G} \sim 100\, \sin i_{\rm orb}\, P_{\rm orb}^{-1/3} \quad (3)$$

Under conditions $K_G \leq 10 \mathrm{km\,s^{-1}}$ and $P_{\rm orb} \leq 1$yr, then $i_{\rm orb} \leq 45°$ and $\alpha \leq 1.14\,\pi$ where π is the trigonometric parallax and α the angular distance (expressed in arc seconds) corresponding to the semi-major axis a. New CORAVEL observations of BD-22° 3467 are planned in 1996-1997 in order to give better constraints on K_G and $P_{\rm orb}$. A period $P_{\rm orb} \geq 1$yr could be envisaged provided that the amplitude K_E is induced by the rotation of the G-star as discussed before.

5. Conclusions

We have performed spectral analysis of new optical spectra in the blue and red ranges of the visible G-stars in Abell 35 and LoTr 5.

i) We have assigned a spectral type G8IV to BD$-22°$3467, the visible central star of Abell 35. The subgiant luminosity is in agreement with the upper radius value determined by the break-up velocity. We have estimated a high projected rotational velocity $v \sin i$ (55 $\mathrm{km\,s^{-1}}$) for the G-star which is compatible with the rotational velocity $P_{\rm rot}$ provided that $i_{\rm rot} = 33°$ (resp. 14°) for a radius $R_{\rm G} = 1.5 R_\odot$ (resp. $3.5 R_\odot$). The spot activity in BD$-22°$3467 could be more important than in classical G stars because of its rapid rotation. This conclusion is similar to that formulated by Jasniewicz et al. (1996a) for LoTr 5.

ii) We have re-discussed the observations of Abell 35 by Acker & Jasniewicz (1990) and given a new interpretation: instead of coming from an accretion disk around the hot subdwarf, the H_α emission centroid could emerge from a hot spot corotating with the stellar photosphere of the cold G-star and the observed radial-velocity variations of the H_α emission centroid could be due to the rotation of this spot. High-resolution observations at H_α and simultaneous photometric observations are needed in order to confirm this interpretation. If true, the small radial-velocity variations of absorption lines of BD$-22°$3467 could be explained by a wide binary. Jasniewicz et al. (1996a) have also envisaged the possibility of a wide binary in LoTr 5.

iii) For the first time, we have detected a strong enhancement of the barium abundance in nuclei of planetary nebulae: the subgiant BD$-22°$3467 in Abell 35 and the giant HD 112313 in LoTr 5 have a nearly solar iron abundance, but the ratio [Ba/Fe] is near of 0.5 for both stars. High resolution spectra of HD 112313 also indicate an enhancement of other s-process elements such as Sr and Y. Our results suggest a similarity of the binary nuclei in the Abell 35-type planetary nebulae with Ba stars for which binarity is also invoked: the atmosphere of the actual G-star would have been polluted by s-process elements of the former AGB star which has become the hot subdwarf detected by IUE.

Independently, Jeffries and Stevens (1996) have also conjectured a possible evolutionary link between the rapidly rotating, late-type central stars in Abell 35-type planetaries and barium giants. These authors do not believe that a common envelope interaction is involved in the Abell 35 systems, but they suspect from their modelling that they can be produced by AGB wind accretion in a detached configuration. Our results (see *ii)* above) are consistent with this assumption.

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