1. Appendix

This appendix fully explains our evaluation of the parameters listed in Table 3.

1.1. Distances, mass-loss rates and fractional ionization

1.1.1. Massive supergiants

The mass loss rate of α Ori for d=200 pc is presently rather well determined at 2.0 10^{-6} $M_\odot\,yr^{-1}$ by recent CI radio emission (Huggins et al. 1994), in agreement with the value based on HI 21 cm by Bowers and Knapp (1987). A number of observations suggest that CO and dust are underabundant in the shell which is mainly atomic (see discussion in Haas and Glassgold 1993), so we choose x_e=3 10^{-4}.

The M supergiant μ Cep is at $\sim$830 pc and is a member of Cep OB2 (Humphreys 1978; see also Le Borgne and Mauron (1989) for a discussion of its distance, luminosity and discrete absorption lines). Bujarrabal (private communication) has kindly provided us with CO J=1-0 and J=2-1 IRAM-30m profiles which supersedes the J=2-1 profile of Le Borgne and Mauron (1989). These profiles (Figure 2) suggest an expansion velocity of $\sim$20 km s^{-1}, which is in agreement with one of the CO infrared circumstellar lines detected by Bernat (1981). The 30-m antenna temperatures, T_{MB}(1-0)$\sim$0.035 K and T_{MB}(2-1)$\sim$0.1 K, allow us to infer a mass loss rate by adopting the method of Loup et al. (1993): with v=20 km s^{-1}, d=830 pc and f=CO/H_2=5 10^{-4}, we obtain $\dot{M}$=1.1 10^{-6} $M_\odot\,yr^{-1}$. Considering mass loss rates deduced from dust, Jura and Kleinmann (1990) derive from the IRAS 60 μm flux a rate of 0.9 10^{-6} $M_\odot\,yr^{-1}$ with v=10 km s^{-1}. Skinner and Whitmore (1988) found from LRS and PSC2 data a value of $\dot{M}$=2.1 10^{-6} $M_\odot\,yr^{-1}$, with a modelisation which takes into account free-free chromospheric emission, adopts the values d=600 pc and v=15 km $s^{-1}$and assumes a gas to dust mass ratio of 500, about two times larger than the standard $\sim$ 200. Le Borgne and Mauron (1989), who investigated the dust scattered halo around the star, showed the existence of 2 shells, inside and outside $\sim$17 arcsec, a geometry which is supported by KAO scans at 50 and 100 μm reported by Hawkins et al. (1993). For the inner shell which is relevant here, Le Borgne and Mauron (1989) have inferred a mass loss rate of 1.6 10^{-7} $M_\odot\,yr^{-1}$ if the dust condensation is complete, that is if their f, which is the fraction of Si atoms locked in dust, is set to 1 (although they argue with considerable uncertainty for f$\sim$0.2). In view of these various determinations, a first choice is $\dot{M}$=10^{-6} $M_\odot\,yr^{-1}$, together with a normal dust/gas ratio leading to take x_e=2 10^{-5}.

According to Sanner (1976), the star CE Tau (119 Tau) is at 400 pc, with a wind velocity of 8 km s^{-1}, and $\dot{M}$=2.4 10^{-7} $M_\odot\,yr^{-1}$. Heske (1990) reports a non-detection of the CO J=1-0 line with T_{rms}=0.18 K at the IRAM 30-m antenna. With Loup's formulae, T_{MB}<0.18 K and f=5 10^{-4} , one obtains $\dot{M}_{CO}$<3.3 10^{-7} $M_\odot\,yr^{-1}$. In terms of dust, the PSC2 fluxes are 145 Jy, 46 Jy and 7 Jy at 12, 25 and 60μm respectively. The ratio F_{12}/F_{60}=20.6 is identical to that (21.6) of M stars without infrared excess (Stencel and Backmann 1991). Also, considering the K-band flux as free from dust emission, the ratio F_{60}/F_K can be compared to similar dust-poor stars in the list of Jura and Kleinmann (1990), revealing no infrared excess. Its LRS spectrum is flat. An interesting feature of CE Tau however is the presence of an extended emission seen at 60μm (Stencel et al. 1988), but it is not clear to us whether this shell is really due to past mass loss or rather illuminated interstellar dust. CE Tau was not examined by Young et al. (1993a,b) in their survey of IRAS resolved shells. In summary, we think that compared to α Ori and with an almost identical spectral classification, CE Tau displays even less CO and dust in its envelope, which is probably mainly atomic, so that we infer x_e=3 10^{-4}, with an uncertain $\dot{M}$=2 10^{-7} $M_\odot\,yr^{-1}$.

For α Sco, we have adopted d=180 pc, v=17 km s^{-1} and $\dot{M}$=1.0 10^{-6} $M_\odot\,yr^{-1}$ from the studies of Kudritzki & Reimers (1978), and Hagen et al. (1987), which are based on optical and ultraviolet lines in the spectra of the M-giant and its B2V companion. Depending on $\dot{M}$ and the uncertain amount of Lyman continuum photons emitted by the hot star, the HII region may or may not be extended around it. Our observations were done $\sim$4" West of the M-giant, that is on the side of the B companion located at ρ=2.9" with a position angle from North to East PA=274^o (Proust et al. 1981). Although the cool wind might be significantly ionized in the B-star surroundings, we shall assume for homogeneity with other objects an $x_e\geq$3 10^{-4} corresponding to complete (single) ionization of C.

Sanner (1976) attributes to BU Gem a mass loss rate of 2 10^{-6} $M_\odot\,yr^{-1}$, with v=10 km $s^{-1}$and a distance of 1300 pc based on its membership to Gem OB1. Heske's (1990) non-detection of CO J=1-0 with T_{rms}=0.11 K at the 30-m leads, with f=5 10^{-4}, T_{MB}<0.11 and the above distance and velocity, to $\dot{M}_{CO}$<1.2 10^{-6} $M_\odot\,yr^{-1}$ (Loup's formulae). Infrared data clearly show dust emission, and Skinner and Whitmore (1988) give 2.7 10^{-6} $M_\odot\,yr^{-1}$ for d=1700 pc. In their study of nearby massive red supergiants, Jura and Kleinmann (1990) rejected BU Gem because of insufficient luminosity (L<10^5 $L_\odot$). If we apply their formula (2) with F_{60}=10.5 Jy, λ_{10}=0.2 and taking L<10^5 from M_{bol}=-7.9 of Sanner (1978), we obtain $\dot{M}$>2.8 10^{-7} $M_\odot\,yr^{-1}$. We have adopted $\dot{M}$=1 10^{-6} $M_\odot\,yr^{-1}$, and since dust appears abundant, x_e=2 10^{-5}.

1.1.2. Irregular Giants

The characteristics of α Her, detailed in MC92, are in essential agreement with the results of Thiering and Reimers (1993): we take d=70 pc, $\dot{M}$=1 10^{-7} $M_\odot\,yr^{-1}$, v=8 km $s^{-1}$and x_e=3 10^{-4}.

Those of β Peg are $d\sim$60 pc from its parallax of 0.015$\pm$0.05 arcsec, v=5 km s^{-1}; the only available $\dot{M}$ is from Sanner (1978) at 1 10^{-9} $M_\odot\,yr^{-1}$; no evidence for circumstellar dust exists, and this star is even considered as a standard case of photospheric 2-60μm continua by Engelke (1992), again supporting no dust, so that we shall adopt x_e=3 10^{-4} as a first approximation.

For ρ Per, one has d$\sim$95 pc, v=7 km s^{-1} from Sanner (1978) who obtains $\dot{M}$=1.2 10^{-8} $M_\odot\,yr^{-1}$, and his estimations of circumstellar column densities are about 3 times those of β Peg. The IRAS or LRS data do not indicate any dust infrared emission. From the absence of 10 μm silicate bump, we can derive with the method of MC92 (appendix B) an upper limit to the dust loss rate: by taking $\tau_{10\mu}$<0.01, T_{eff}=3450 K and ϕ_*=0.0155 arcsec from di Benedetto (1993), R∼160 R$_\odot$, we find an inner shell radius r_i=26R$_*$ and $\dot{M}_{dust}$<1 10^{-10} M$_\odot$ yr^{-1} , which implies that, if we keep the assumption of normal gas/dust mass ratio (∼200), we find $\dot{M}$<2 10^{-8} M$_\odot$ yr^{-1} in compatibility with Sanner's rate. The only attempt to detect CO radio emission on ρ Per is that of Wannier and Sahai (1986) who did not find any J=2-1 signal at T_{rms}=0.26 K with the 12-m NRAO antenna. With Loup's formulae and taking T_{MB}(2-1)/T_{MB}(1-0)∼3, one obtains an upper limit of $\dot{M}_{CO}$<1 10^{-7} M$_\odot$ yr^{-1} . We therefore consider $\dot{M}$=1. 10^{-8} M$_\odot$ yr^{-1} and x_e=3 10^{-4} as plausible values.

The star g Her is included in the recent study of semi-regulars by Kahane & Jura (1994), based on very good IRAM-30m CO 1-0 and 2-1 observations and careful modelisation. From that work, we adopt d=130 pc, v=8 km s^{-1}and $\dot{M}$=1.1 10^{-7} M$_\odot$ yr^{-1} . Exactly the same rate would be found from Loup's formula with the observed T_{MB}(1-0)=0.20 K and above parameters. The mass-loss rate that Kahane and Jura derive from the 60μm flux is about 3 times smaller, but a number of uncertainties are recognized, including the unknown CO and dust to H_2 ratios, the rather poor fit of the CO profiles and the important asymmetry of the shell shown by Plez and Lambert (1994). We shall adopt the above $\dot{M}$ based on CO, with x_e=2 10^{-5} since dust and CO are certainly present in the envelope.

1.1.3. Oxygen-rich miras

The case of o Cet has already been discussed in MC92, who adopted d=77 pc (parallax 0.013 ±0.005"), v=4 km s^{-1}, $\dot{M}$=1 10^{-7} M$_\odot$ yr^{-1} from HI, CO and dust data. Concerning the distance, we might also follow Jura and Kleinmann (1992) and apply their M_K-log$P$ relation to obtain d=100 pc. More recent observations or analysis include: i/the one of Young (1995) from detections of CO J=3-2 and J=4-3 submillimeter lines which lead to $\dot{M}$=2-3.6 10^{-7} M$_\odot$ yr^{-1} for d=100 pc; ii/ the CO J=3-2 maps of Stanek et al. (1995) giving $\dot{M}$=2-3.6 10^{-7} M$_\odot$ yr^{-1} for 80 pc; iii/ the one of Ivezic & Elitzur (1995) based on a new physical model of infrared data, who derive a value of 4 10^{-7} M$_\odot$ yr^{-1} for a distance of 110 pc. We shall adopt $\dot{M}$=2 10^{-7} M$_\odot$ yr^{-1} and x_e=2 10^{-5} since dust and molecules appear abundant compared to HI.

The star W Hya is classified SRa in the General Catalog of Variable Stars but is considered as Mira-type by Jura and Kleinmann (1992) whom we follow. It is unusual because of its huge envelope (Hawkins 1990). Its period is P=361 days, putting it at 80 pc with the M_K-log$P$ relation. The wind velocity is 8 km s^{-1} from CO observations. Bujarrabal et al. (1986) reports T_{MB}(1-0)=0.17 K with the IRAM 30m, which gives with Loup's formula 0.6 10^{-7} M$_\odot$ yr^{-1} . A 3-times larger rate would be derived from the T_{MB}(2-1)=0.63 K seen by Wannier & Sahai (1986) with the NRAO 12m. With the CO J=3-2 and 4-3 lines, Young (1995) finds 1.8 & 2.1 10^{-7} M$_\odot$ yr^{-1} for 80 pc. With CO 3-2 maps, Stanek et al. give 0.8 10^{-7} M$_\odot$ yr^{-1} for 90 pc. From data concerning dust, Jura and Kleinmann (1992) estimate that $\dot{M}$= 1.0 10^{-7} M$_\odot$ yr^{-1} whereas Ivezic & Elitzur find 3 10^{-7} M$_\odot$ yr^{-1} for 120 pc. Appropriate scaling on d and f leads us to finally adopt $\dot{M}$= 1.0 10^{-7} M$_\odot$ yr^{-1} . It is interesting to note that the ratio SiO/CO is especially large for W Hya according to Bujarrabal et al. (1994), suggesting at first glance either incomplete CO formation or incomplete inclusion of Si in dust. The HCN molecule has also been detected on this object, by Lindqvist et al. (1992). We have adopted x_e=2 10^{-5} because the abundances of dust and molecules seem quite significant.

The object R Hya is an ordinary Mira-type variable with a period of 388 days, and a distance of 110 pc through the M_K-log$P$ relation. Like many other objects, its dust shell has been angularly resolved by IRAS at 60 μm, with an external radius of ∼6' (Young et al. 1993a,b). From CO J=2-1 data, Loup et al. (1993) give $\dot{M}$= 1.4 10^{-7} M$_\odot$ yr^{-1} for 130 pc and v=8 km s^{-1}, while Young (1995) derive 4±0.2 10^{-7} M$_\odot$ yr^{-1} at 110 pc from CO J=3-2 and 4-3 lines. Ivezic and Elitzur (1995) give $\dot{M}$= 2 10^{-7} M$_\odot$ yr^{-1} for 130 pc. We adopt d=110 pc, v=8 km s^{-1}, $\dot{M}$= 2.5 10^{-7} M$_\odot$ yr^{-1} and x_e=2 10^{-5}.

1.1.4. Carbon stars

For the carbon stars TX Psc, Y CVn and U Hya, our distances are taken from Olofsson et al. (1993), and are based on an assumed absolute magnitude M_K=-8.1 which is the mean M_K of LMC optical carbon stars. Mass loss rates of these stars have been determined among others, by Claussen et al. (1987), Groenewegen et al. (1992), Olofsson et al. (1993a) from which we consider their $\dot{M}_{g,CO}$ and their $\dot{M}_{\Delta IRe}$, Loup et al. (1993) and Kastner (1990). The last two authors put the stars at somewhat larger distances, giving larger values of $\dot{M}$. Our compilation yields the following values, in units of 10^{-7} M$_\odot$ yr^{-1} : TX Psc 0.7, 1.0, 0.91, 0.29, 5.6, 4.7; Y CVn 1.1, 0.36, 0.49, 1.2, 4.2, 1.2; U Hya 1.2, 2.7, 1.2, 1.4, 5.0, 2.8. We finally adopted as reasonable estimates 1.5 10^{-7}, 1.5 10^{-7} and 2 10^{-7} M$_\odot$ yr^{-1} for TX Psc, Y CVn and U Hya respectively. Dust and molecules (CO, HCN, CN, CS) being usually well observed (see Olofsson et al. 1993b), we take x_e=2 10^{-5}.

1.2. Chromospheric ultraviolet and KI photoionizing rates

The goal of this section is to estimate $G_\oplus$ which is the KI stellar photoionization rate in Equ. (1) , i.e. convolution of the KI ionization cross-section with the ultraviolet stellar flux. This flux is taken as observed at Earth, but should be corrected up in case of significant interstellar extinction. The uncertainty on $G_\oplus$ is mainly dependent on the knowledge of UV fluxes of red giants below the KI ionization threshold (λ<2856 Å). This knowledge is usually rather poor and best estimates of $G_\oplus$ for α Ori, α Her, β Peg, o Cet and TX Psc were obtained by MC92 from IUE or other UV data. When the recent data from Hubble Space Telescope are considered for α Ori (Carpenter et al. 1994), one finds $G_\oplus$ =3.7 10^{-18} s^{-1}, or almost half the rate given by MC92, but we keep the MC92 rate to account for a plausible interstellar extinction (A$_v$∼0.5mag). As for α Her, adopting an A9 type (Thiering and Reimers 1993) for its companion, instead of the average on F2-F8 types as in MC92, increases $G_\oplus$ by a factor of ∼3, giving $G_\oplus$ =19 10^{-18} s^{-1}.

The determination of $G_\oplus$ for the other objects was essentially based on the assumption that similar spectral types (see Table 3) should correspond to identical UV fluxes normalized to luminosity. The results are given in Table 3, and details are given below.

For μ Cep for which IUE spectrophotometry indicates a strong interstellar absorption $A_v \sim 2.0$ mag., making IUE data useless for $\lambda < 2600$ Å (Rodgers et al. 1983), we scaled the α Ori rate with the mean difference on I, K and L magnitudes of these similar objects, giving $\Delta m = 2.54 \pm 0.2$ mag. or a factor of $\sim$10 on the $G_\oplus$'s. These passbands are chosen because they contain the bulk of luminosity and are not strongly sensitive to both possible dust infrared excess and interstellar absorption. Scaling on commonly adopted distances would have given a factor 17. For CE Tau, similar scaling on α Ori and I, K and L yields $\Delta m = 3.3 \pm 0.2$ mag. (factor 20); alternatively scaling on β Peg gives the same $G_\oplus$. The BU Gem ultraviolet flux was also obtained by scaling on α Ori with IJKL bands, yielding $\Delta m = 5.2 \pm 0.2$ mag.

The UV radiation of α Sco is dominated by its B2.5V V=5.17 companion and suffers an interstellar $A_v = 0.6$ (Kudritzki and Reimers 1978). Because the B-star IUE spectrum is not given by these authors nor by Hagen et al. 1987, we considered the IUE spectrophotometry of HD 61831 (B2.5V) in the atlas of Wu et al. (1983) with appropriate correction for extinction, and we obtained a very strong $G_\oplus = 25000\ 10^{-18}\ s^{-1}$. As in the case of α Her, this value must be considered as only indicative because of the off-center position of the UV source relative to the M giant wind, but it provides an order of magnitude which is good enough for discussion.

For ρ Per, we adopted the IUE spectrophotometry from Wu et al (1983) which is useful down to 2400 Å. Below this limit, extrapolation was achieved with the slope observed between 3000 Å and 2500 Å, that is $d(\log F_\lambda)/d(\log\lambda) = 7$. About 80 percent of the resulting $G_\oplus$ value unfortunately comes from this extrapolated region.

For g Her which is a semi-regular clearly cooler than ρ Per, IUE only provided a few emission line fluxes as listed by Eaton and Johnson (1988, Table 3). The ratios of these line fluxes in the sense $F_{\rho\ Per}/F_{g\ Her}$ have an average of 4 ± 2, so that we adopted $G_\oplus$ (g Her)$\sim$0.25 $G_\oplus$ (ρ Per) with a large uncertainty. A scaling between these two stars based on JKL photometry would have attributed about the same UV flux as for g Her than for ρ Per, but this procedure does not take into account the cooler spectral type of the former and is a priori worse.

Whereas the UV radiation which is present in the circumstellar shell of o Cet is mainly due to its hot companion (see MC92), and at least is observable and measurable with however some uncertainty, the case of R Hya and W Hya, which are not known as binaries, is quite different. The chromospheres and transition regions of such stars are poorly known. Radio emission detected at 250GHz by Altenhoff et al. (1994) is a source of information in the general case of giants and supergiants, but in the case of cool Mira stars, it is satisfactorily explained by warm dust, without need to invoke a chromosphere. The MgII lines nearly constitute the only observable diagnostic.

IUE spectra of W Hya were reported by Kafatos et al. (1980) who did not find any MgII doublet emission, nor any continuum which could be convincingly attributed to a chromosphere, one observational problem being scattered light contamination. However, these lines are variable, and a non-detection does not mean a constant absence of emission. Indeed, the lines of MgII have been detected on two Mira stars: S Car and R Car (Bookbinder et al. 1989). The case of S Car (P=149 days, d=460 pc from Jura 1994) is interesting because its strong velocity shift ($v_{helio} = +284$ km s^{-1}) prevents mutilation by interstellar MgII atoms. Its MgII lines are variable both in intensity and profile and are attributed to a post-shock cooling region. Because S Car (M2.5IIIe) is notably warmer than W Hya and R Hya, it seems plausible that for these two objects, any ultraviolet emitted by shocks will suffer a substantially larger circumstellar absorption than for S Car. The S Car apparent total MgII flux being in the range 0.2 to 2 10^{-12} ergs $cm^{-2}\ s^{-1}$ for a distance of 460 pc, we may first estimate that MgII fluxes for W Hya and R Hya (at $\sim$ 100 pc) should be at most $(460/100)^2 \sim 20$ times that level, i.e. $<$ 4 to 40 10^{-12} ergs $cm^{-2}\ s^{-1}$.

The other star R Car (M6.5IIIe, P=308 days) is more similar to W Hya (M8IIIe, P=361 days) and R Hya (M7IIIe, P=389 days). It has K=-0.99 (Fouque et al. 1992) yielding a distance of 185 pc with the M_K–Log P relation. Considering Table 2 of Bookbinder et al. (1989), the MgII fluxes of R Car are of the order of 2 to 7 10^{-12} ergs $cm^{-2}\ s^{-1}$, but probably suffer interstellar extinction. Taking into account the distances, a second estimation of the total MgII fluxes for W Hya and R Hya might be around $\sim$ 7 to 25 10^{-12} ergs $cm^2\ s^{-1}$. Consequently, we have adopted as a plausible estimate for W Hya and R Hya a MgII flux $F_{MgII} = 10\ 10^{-12}$ ergs $cm^2\ s^{-1}$.

In order to assess the KI photoionization rate due to this stellar MgII flux at $r = \theta d$, noted $G_{MgII,\theta}$, with $\theta \sim 5$" in the shell, we compare it to the interstellar rate G_{IS}: we have $G_{MgII,\theta} = \sigma_{2800}.(F_{MgII}/h\nu)./\theta^2$ where the KI cross-section at 2800 A is $\sigma_{2800} \sim 0.004\ 10^{-18}\ cm^2$. One obtains $G_{MgII,5"} \sim 0.095\ 10^{-10}\ s^{-1}$ which is 6 times lower than $G_{IS} = 0.6\ 10^{-10}\ s^{-1}$ (for the stars studied here, the interstellar field and G_{IS} are not expected to be significantly reduced by circumstellar extinction for the outer layers of interest, i.e. at $r = \theta d$). The importance of other possible emission lines and a continuum has also to be adressed, but proves relatively uncertain since no observation is available. For example, let us consider CII] λ2325. According to Judge (1989), and Judge and Stencel (1991), if this line and the MgII ones are emitted by a chromosphere, the flux ratio F(MgII λ2800)/F(CII] λ2325) is about 16 and 11 for M and C giants, respectively. Adopting a value of 16 and since $\sigma_{2325} \sim 0.052\ 10^{-18}\ cm^2$, one obtains $G_{CII,5"} \sim 0.064\ 10^{-10}\ s^{-1}$, which is comparable to the MgII rate. Again, we do not really know whether this chromospheric MgII/CII] line ratio is really applicable in the present case. The continuum, especially between $\sim$2400 Å and the KI threshold at 2856 Å, may on its side contribute significantly to $G_\oplus$. For example, consideration of the IUE spectrum of Mira A at maximum but excluding the Mira B emission lines (Fig.1 bottom, in Reimers and Cassatella 1985) allowed us to find that the MgII contribution is rougly 1/5 of that from the 2300-2860 Å region.

Applying this ratio for R Hya and W Hya gives $G_{5''} \sim G_{IS}$, equivalent to $G_{\oplus}$ =0.035 10^{-18} s^{-1}, which we take as our best estimate. There is of course a large uncertainty on this value $G_{\oplus}$. The factor I_r in equation (1) is correspondingly set at 0.4 .

For the carbon stars U Hya and Y CVn, we have adopted the same estimation as for TX Psc: $G_{\oplus}$ =0.02 10^{-18} s^{-1}. IUE observations of U Hya (Johnson and Luttermoser 1987) show no significant flux difference compared to TX Psc, and the fact that we ignore the region λ<2300 Å is the main source of uncertainty. Because again the stellar photoionization is comparable with interstellar rate, I_r is set to 0.4 .

This article was processed by the author using Springer-Verlag LaTeX A&A style file 1990.