THE ASTROPHYSICAL JOURNAL, 312:812, 1987 January 15

SOME COMMENTS ON EMPIRICAL FITS TO STELLAR MASS LOSS RATES

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Received 1986 February 3; accepted 1986 July 15

ABSTRACT

Two empirical fits to stellar mass loss rates have been examined and found lacking in physical content.

Subject heading: stars: mass loss

The data on stellar rates of mass loss, derived from spectral analysis, have been fitted to empirical or semi-empirical expressions by a large number of authors (cf. Vardya 1984). The purpose of this note is to examine a few of these empirical expressions and their implications.

A large number of empirical and semi-empirical expressions for the rates of mass loss $\dot{M}$ have been expressed in terms of mass M, radius R, and luminosity L of the star in the form

$$\dot{M} = AM^{\eta}R^{\nu}L^{\mu} .$$

Here A is the scaling factor or proportionality constant, which along with the exponents η, ν, and μ are determined by least-squares. A comparison of some of these expressions by the author (Vardya 1984) showed that the exponents of M and R are equal but opposite in sign, i.e., $\eta = -\nu$, in all the expressions except the one given by Lamers (1981). In Lamers' relation, η and ν have opposite signs but their absolute values are *not* equal. Recently, Garmany and Conti (1984) have fitted rates of mass loss as a function of M, R, and L in which $\eta = -\nu$ is not satisfied; in fact, in their relation, η and ν have the *same* sign, and $|\eta| \neq |\nu|$. In fact, Garmany and Conti's (1984) relation is the only one in which $\dot{M}$ is directly proportional to M, rather than inversely as in all other cases. What are the physical implications of such expressions?

Except when $\eta = -\nu = \frac{2}{3}$, $\mu = \frac{1}{3}$, A will not be dimensionless. Therefore, in general, A will be composed of, besides the scaling factor and factors of π, universal constants. With mass loss depending on M, R, and L, the appropriate universal constants are G, the gravitational constant, and c, the velocity of light. Besides these two, no other universal constants are relevant to the situation. Table 1 gives the values of η, ν, and μ and the dimensions of A for expressions given by Lamers (1981) and by Garmany and Conti (1984).

TABLE 1

DIMENSION OF A

				DIMENSION OF A		
EXPRESSION	η	ν	μ	m	l	t
Lamers	−0.99	0.61	1.42	+0.57	−3.45	3.26
Garmany and Conti	+0.6	0.8	1.0	−0.6	−2.8	2

If the dimension of A is composed of G and c, we can write

$$A = A'G^{\alpha}c^{\beta} ,$$

where A' is a dimensionless constant and α and β are exponents of G and c respectively, such that A has the correct dimension. However, we find that there are no values of α and β which will yield the correct dimension of A for either Lamers' (1981) or Garmany and Conti's (1984) expression for mass loss. This implies that the least-squares fits of the type attempted by Lamers (1981) and by Garmany and Conti (1984) are merely four-parameter fits with no physical meaning. This, then, is rather unfortunate, especially when they are trying to imply by such fits that the rate of mass loss is a global property of the star and therefore depends on M, R, and L. Hence, such least-squares fits, with no physical meaning, are four-parameter (A, η, ν, and μ) fits, and nothing more.

Lamers (1981) and, following him, Garmany and Conti (1984), assuming that the mass loss is a surface phenomenon, have fitted mass flux, $F_m = \dot{M}/4\pi R^2$, to power-law expressions of the kind

$$F_m = BT_{\rm eff}^{\gamma} g_{\rm eff}^{\delta} ,$$

where the three parameters B, γ, and δ are determined from the least-squares. Here $T_{\rm eff} = (L/4\pi\sigma R^2)^{1/4}$, $g_{\rm eff} = (GM/R^2)(1 - \Gamma)$, $\Gamma = L/L_{\rm Eddington}$, and σ is the Stefan-Boltzmann constant. (Note the misprint in defining $g_{\rm eff}$ by Garmany and Conti: m should read GM.) As F_m also depends on L, M, and R, though with some restriction on the exponents, it is basically a similar fit to the above four-parameter fit, except that the choice is restricted to three parameters. It has no physical implication that the mass loss is a surface phenomenon, as the former (four-parameter) does not imply global property. And if the various variables are known accurately enough, one can reduce the four-parameter expression to the three-parameter one, though not vice versa, as the former has more information content than the latter.

It is a pleasure to thank my colleagues here and E. P. J. van den Heuvel for useful discussions.

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