LA-UR -87-3357

CONF-8710002--20

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

LA-UR--87-3357

DE88 001842

TITLE: MAIN SEQUENCE MASS LOSS

AUTHOR(S): W. M. Brunish, ESS-5
J. A. Guzik, ISU
L. A. Willson, ISU
G. Bowen, ISU

SUBMITTED TO: American Chemical Society

DISCLAIMER

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

MASTER

Main Sequence Mass Loss

by

Wendee M. Brunish
Los Alamos National Laboratory
P.O. Box 1663, MS F665
Los Alamos NM 87545

Joyce A. Guzik, Lee Anne Willson and George Bowen
Department of Physics
Iowa State University
Ames Iowa 50011

It has been hypothesized that variable stars may experience mass loss, driven, at least in part, by oscillations [1]. The class of stars we are discussing here are the δ Scuti variables. These are variable stars with masses between about 1.2 and 2.25 M_θ, lying on or very near the main sequence. According to this theory, high rotation rates enhance the rate of mass loss, so main sequence stars born in this mass range would have a range of mass loss rates, depending on their initial rotation velocity and the amplitude of the oscillations. The stars would evolve rapidly down the main sequence until (at about 1.25 M_θ) a surface convection zone began to form. The presence of this convective region would slow the rotation, perhaps allowing magnetic braking to occur, and thus sharply reduce the mass loss rate.

We have constructed models and evolved them to reproduce the sun's mass radius and luminosity, at approximately the same time as the standard age [2]. Our best fit was derived with models with an initial mass of 2.0 M_θ, and an initial helium abundance of $Y = 0.20$ to 0.22. Initial mass loss rates were on the order of 10^{-8} M_θ/yr, decreasing exponentially with an e-folding time of about 2×10^{8} years.

The basic structure of our models was similar to the standard model. However, in our models the core is somewhat hotter and denser and therefore more of the hydrogen has been exhausted. This results in a total lifetime for our models of about 10 percent less than for the standard model. Because of the core conditions, the neutrino flux is also slightly higher than in the standard model. The depth of the convection zones in our models in somewhat deeper than in the standard models (approximately 0.25 R_θ compared to 0.20 R_θ). This structure should result in improved agreement over the standard model of the solar oscillation spectrum with observations. A detailed study of solar oscillations and calculations of the p-mode spectrum for our models are planned [3].

Another consequence of the deeper convection zone is that the temperature at the base of the zone is hot enough so that all of the ^{7}Li in the surface layers will be destroyed. Therefore the observed lithium in the solar atmosphere cannot be primordial and must have been created by some other mechanism. We believe that it is energetically feasible for solar flare and coronal spallation to account for the observed abundances of ^{7}Li and ^{9}Be in the sun and main sequence A-F stars, and work is now underway on the details of the process and the resulting abundances. [4].

The luminosity history of these models is obviously quite different from the standard models. Instead of gradually increasing over billions of years, the luminosity starts out much higher and drops rapidly to about the current solar luminosity. This will obviously have considerable effects on the early solar system [5]. The "faint early sun paradox", where many solar system bodies including the earth, suggest a more luminous sun in the past, is solved. These models also provide an explanation for the gravitational locking of Venus, since the gravitational tidal forces would have been much larger in the early epochs of the solar system. The large core found in the planet Mercury can also be explained by the presence of the much higher solar flux in the past, boiling off a large percentage of the planet's mantle. This provides a good constraint on the 2 $M_\odot$ initial mass, because if the sun were initially much more massive, the entire planet would have been boiled away, and a significantly less luminous early sun would not have stripped off as much of Mercury's mantle.

This work has many interesting implications not only for the solar system but for the galaxy as well. Recent determinations of the IMF have suggested that their may be a "bump" at about 1 $M_\odot$ [6]. Observations of clusters and binary stars reveal a paucity of stars between 1.2 and 2.3 $M_\odot$, coinciding with the δ Scuti instability region, and a definite gap at 2.0 to 2.3 $M_\odot$ (see [7] and references therein). These observations are nicely explained if some stars formed with masses of 2 to 2.5 $M_\odot$ evolve down the main sequence until formation of a convective surface layer effectively halts the mass loss.

Another consequence of this behavior is that the ages of the oldest clusters in the galaxy cannot be accurately determined from the cluster turnoff mass. An intrinsic uncertainty is introduced if stars evolve down the main sequence since stars with the same mass do not necessarily have the same age. The universe may well be younger than the age determinations based on the oldest clusters lead us to believe.

This work was supported by the United States Department of Energy.

References

Willson, L.A., Bowen, G., and Struck-Marcell, C. 1987, **Comm. Ap.** 12, 17.

Guzik, J.A., Willson, L.A. and Brunish, W.M. 1987, **Ap. J.** 319, 957.

Guzik, J.A. 1987, private communication.

Willson, L.A. 1987, private communication.

Bowen, G. 1987, preprint.

Scalo, J.M. 1986, **Fund. Cosmic Phys.** 11, 3.

Willson, L.A. 1987, Proceedings Trieste Workshop on Pulsation and Mass Loss, eds. Stalio and Willson, Reidel Publishing.