MASS LOSS UPPER LIMITS FOR A AND F DWARFS

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Abstract  It has been suggested by Wilson, Bowen and Struck-Marcell
that A- and F-type main sequence stars might undergo significant mass
loss due to pulsationally-driven winds. We have tested this claim by
obtaining stringent upper limits on the ionized mass loss from A and
F dwarfs using the VLA. These limits show that any mass loss that
might be occurring is not evolutionarily significant. We have shown that
any wind flowing from such stars is likely to be significantly ionized and
hence detectable by our observations, both by means of radiative equi-
librium atmospheric models and by noting the occurrence of significant
non-radiative heating among late-A and F dwarfs. Therefore, we con-
clude that A and F dwarfs are not losing enough mass to result in the
evolution of A dwarfs into G dwarfs as has been proposed.

WHY LOOK FOR MASS LOSS FROM A AND F DWARFS?

Wilson et al. (1987) proposed that main sequence stars lying in the δ Scuti
instability strip might lose mass at rates between $10^{-9}$ and $10^{-8} \, \text{M}_\odot \, \text{yr}^{-1}$. As
proposed, such mass loss would have severe evolutionary implications and its net
effect would be for A and F dwarfs to evolve down the main sequence to become
mid-F or G dwarfs. If it were true that A and F dwarfs evolved into G dwarfs
due to mass loss, this would have severe implications for the study of stellar
evolution, the initial mass function of low mass stars, light element abundances
in solar-like stars, and the early history of the solar system.

The proposed mass loss mechanism is the deposition of pulsational energy
into a stellar outer atmosphere whose effective surface gravity is already some-
what reduced by rapid rotation. It is not clear if rapid rotation is a necessary
condition for this mass loss to occur. The rotational velocities of A dwarfs, while
large, are still far from the breakup velocity, and the wind-driving mechanism
will still need to impart considerable energy and momentum as it lifts material
out of the stellar gravitational potential well.
VLA RADIO CONTINUUM OBSERVATIONS

A sample of ten nearby (distances from 3.4 to 28 pc) A and F stars was observed with the NRAO Very Large Array (VLA) on 1988 May 27. We have also used results from Bookbinder and Walter (1987) for seven additional F dwarfs. Most of these stars have large rotational velocities and are known or suspected pulsating stars. Some of the stars are members of the relatively young Ursa Major cluster with ages of about $3 \times 10^8$ yrs. By choosing stars showing pulsations and high rotational velocities we should meet the fundamental conditions of the proposed mass loss mechanism and by observing relatively young stars we can be confident that the mass loss has not died away, if it follows the exponential decay law proposed by Willson and colleagues.

OBSERVATIONAL RESULTS

Our observations were made with the C/D VLA array configuration at 6 cm using two adjacent 50 MHz bandwidths centered at 4835 and 4885 MHz. Local phase calibrators were observed at least every 30 minutes. 3C48 was the primary flux calibrator and its 6 cm flux was taken to be 5.59 Jy.

None of the sources were detected at the 3σ level. The observed upper limits ranged from 0.08 to 0.15 mJy, depending on the on-source observing time which ranged from 30 minutes to one hour. The upper limits were measured from areas close to the expected positions of the stars, which were taken from the SAO Catalog and corrected for proper motion. In Figure 1 the mass loss rate upper limits are plotted against B-V color, which is a good proxy for effective temperature and mass along the main sequence for the stars being studied. Also shown are four mass loss loci discussed by Willson et al. (1987) and Guzik, Willson and Brunish (1988). Our upper limits are clearly at least an order of magnitude lower than these curves. Early A dwarfs at age $3 \times 10^8$ yrs (e.g δ Leo and α Oph) have ionized mass loss rates no larger than $4.5 \times 10^{-10} \, M_\odot \, yr^{-1}$ and by ages of a few $10^9$ yrs (α PsA,α Aql) the ionized mass loss rate for A dwarfs is less than $10^{-10} \, M_\odot \, yr^{-1}$.

IONIZATION STATE OF THE WIND

Our VLA observations provide upper limits to the ionized mass loss rates from A and F dwarfs but can only be understood when we know what fraction of the mass loss is in the form of ionized material. We calculated LTE and NLTE atmospheric models appropriate for an early A (A2-3) dwarf, so as to investigate the fractional ionization of a wind around such a star. In our analysis we have assumed that individual shocks in the wind are quickly subsumed into a smoothly-varying average wind. We find that non-LTE effects are small. After considering a wide range of wind velocities and mass loss rates, we conclude that the wind from an early A dwarf must contain at least partially ionized and very likely fully ionized hydrogen. Late A and early F dwarfs show considerable non-radiative heating resulting in chromospheric emission; these stars will also have large fractional ionizations.
CONCLUSIONS

None of the A and F stars that we observed with the VLA was detected as a radio source. The upper limits derived for the ionized mass loss rate provide stringent limits on the amount of mass that these stars can lose while on the main sequence. Given that the winds are likely to contain primarily ionized hydrogen, our upper limits provide an accurate limit on the total mass loss rates from A and F dwarfs. Even if the total mass loss rates are only $10^{-10} \, M_\odot \, \text{yr}^{-1}$, the cumulative mass loss may not be entirely negligible when integrated over the main sequence lifetimes of A and F dwarfs. However we can conclude that A and F dwarfs are not losing enough mass for A dwarfs to be converted into G dwarfs, as suggested by Willson et al.

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REFERENCES


Figure 1: Ionized mass loss rate upper limits as a function of B-V.