Evolution of the Sun & Solar Wind

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With the nuclear fusion reaction in the central region, the temperature and the density in the core region gradually increase, which leads to the increase of the bolometric luminosity. In contrast, the mass loss rate of the solar wind is supposed to decrease with time, as reported by Wood et al.(2002; 2005) based on observations of solar-like stars. To investigate the mass-loss history, we perform forward-type magnetohydrodynamical numerical experiments for Alfvén wave-driven stellar winds with a wide range of the input Poynting flux from the photosphere. Increasing the magnetic field strength and the turbulent velocity at the stellar photosphere from the current solar level, the mass loss rate rapidly increases at first owing to the suppression of the reflection of the Alfvén waves. The surface materials are lifted up by the magnetic pressure associated with the Alfvén waves, and the cool dense chromosphere is transiently extended to 10 – 20 % of the stellar radius. The dense atmospheres enhance the radiative losses and eventually most of the input Poynting energy from the stellar surface escapes by the radiation. As a result, there is no more sufficient energy remained for the kinetic energy of the wind; the stellar wind saturates in very active stars, as observed in Wood et al. (2005). The saturation level is positively correlated with $B_{r,0}f_0$, where $B_{r,0}$ and f_0 are the magnetic field strength and the filling factor of open flux tubes at the photosphere. If $B_{r,0}f_0$ is relatively large $\gtrsim$ 5 G, the mass loss rate could be as high as 1000 times. If such a strong mass loss lasts for ~ 1 billion years, the stellar mass itself is affected, which could be a solution to the faint young sun paradox.