Mem. S.A.It. Vol. 77, 460

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Measuring plasmon neutrino rates using DBVs

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Abstract.
Pulsating white dwarfs can be used as laboratories to study plasmon neutrinos. In the degenerate interiors of hotter white dwarfs, plasmon decay is the dominant neutrino producing process. We can measure the neutrino luminosity using asteroseismology and constrain plasmon neutrino rates. After a brief description of plasmon neutrino production, we explore the effect of uncertainties in the measured mass and effective temperature on the neutrino rates. The latter are most sensitive to the effective temperature. With our current uncertainties, we can hope to tell whether plasmon neutrinos are indeed produced in white dwarfs, and what the rates are to within a factor of about two.

1. Introduction

Above a temperature of about 26 000 K, more than half of the luminosity of an average mass white dwarf comes from neutrino emission (Fig. 1). In that temperature range, the neutrinos are mainly produced by the decay of plasmons (photons coupled to electrons in a plasma). Neutrinos produced through plasmon decay (plasmon neutrinos) cannot be observed in the lab or in the Sun and remain to this day in the realm of theory. Following the discovery of DBVs (pulsating helium atmosphere white dwarf stars) as hot as 28 000 K, Winget et al. (2004) demonstrated that one could use hot DBVs to measure neutrino rates. One can use the change in the pulsation periods over time ($\dot{P}$) to measure the neutrino luminosity. As a white dwarf cools, the period of a given mode increases. The faster the cooling, the faster the period increases. Mestel theory (Mestel 1952) predicts $\dot{P}$ if the white dwarf is leaking energy exclusively through photons. A higher $\dot{P}$ than expected means that the star is cooling faster than expected, and indicates an extra source of energy loss. $\dot{P}$ provides therefore a measure of the neutrino luminosity.

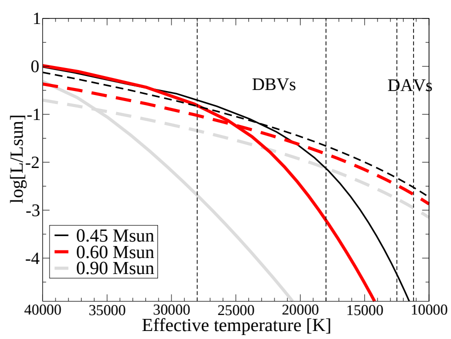

Fig. 1. Time evolution of the neutrino luminosity (solid lines) for different mass white dwarf models. The vertical dashed lines mark the DBV and DAV instability strips. The corresponding photon luminosities are also shown (dashed curves). For the lower mass models, the neutrino luminosity dominates well into the DBV temperature range.

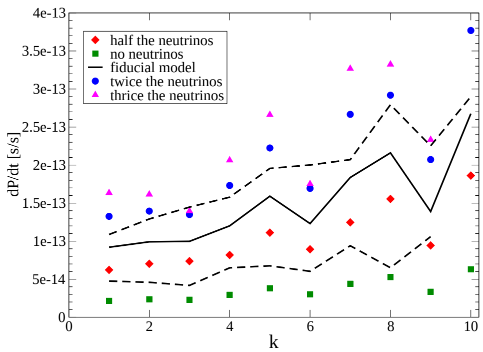

Fig. 2. The effect of differing neutrino rates on the $\dot{P}$'s for a star like EC20058, and how they compare with the uncertainties in $\dot{P}$ that result from 10 % uncertain mass and effective temperature. This model has a mass of 0.54 $M_{\odot}$ and a temperature of 28 400K. Within the region delimited by the dashed lines, variations in $\dot{P}$ may be completely explained by the uncertainties in mass and effective temperature.

2. About plasmon neutrinos

A plasmon is made up of a photon and of an organized oscillation of the electrons present in the plasma in response to its passage. The electrons allow energy and momentum to be conserved as the plasmon decays into a neutrino-antineutrino pair. This is how plasmon neutrinos are produced.

3. Uncertainties

The neutrino luminosity derived from the observations is model dependent. Effective temperature, in particular, has a large effect on the plasmon neutrino rates. Looking at error bars given in the literature and typical disagreements among authors, we decided to consider uncertainties both in mass and effective temperature of 2, 5, and 10 %.

For those uncertainties in mass and effective temperature, neutrino luminosities can be known to better than a factor of two. Decreasing the uncertainties in effective temperature in particular greatly improve the result.

4. Effect of neutrinos on $\dot{P}$ for a star like EC20058, a hot DBV

In this section we present a result (Fig.2) that is more readily applicable to a measurement of $\dot{P}$. We picked one fiducial model (chosen to be as close to EC20058 as a rudimentary analysis allowed), calculated $\dot{P}$'s for its pulsation spectrum, and looked at the effect of the uncertainties mentioned above.

With the uncertainties in mass and temperatures that we have today, we would be able to tell if neutrinos are not produced in EC20058 or if the actual rates are as much as twice as large (arguably), but not for instance, if they are really half what the theory predicts.

5. Conclusions

Hot DBVs offer a unique way to measure plasmon neutrino rates. The neutrino luminosity may be deduced from a measurement of $\dot{P}$. Such a measurement has been made before for a different kind of pulsating white dwarf (Kepler et al. 2000), and is in progress for hot DBV EC20058 (Sullivan & Sullivan, 2000). The difficulties lie in the modeling. In particular, a precise determination of the effective temperature is important if one wants to place a tight constraint on the neutrino rates. In the near future, effective temperature determinations are likely to improve, leading to drastically tighter constraints on plasmon neutrino rates. We discuss one strategy to obtain better effective temperatures for white dwarfs in this volume (Kim et al. 2006).

References

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