H_3^+ Line Opacity in Cool Population III Stars.

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Abstract. The first generation of stars (population III) comprised almost entirely of hydrogen and helium with trace quantities of Lithium. However no population III stars have yet been observed, but the detection of the most iron poor star known HE0107-5240 ([Fe/H]=-5.3) has sparked a new wave of interest in these stars. If population III stars formed with a mass of less than 0.8 $M_\odot$, they will still be on the main sequence and may be observable within the galaxy. As H_2 has no dipole moment, it may seem that such stars would be devoid of molecular absorption lines. However Harris et al. ApJ, **600**, 1025, (2004), have shown that H_3^+ line opacity can be a significant source of opacity in a hydrogen-helium gas.

We are in the process of constructing new model atmospheres and synthetic spectra for population III stars. Here, we present some of our preliminary results which indicate that H_3^+ rotation-vibration lines may be present in the spectra of dwarf population III stars.

1 Introduction.

The WMAP estimate of the age of the universe is 13.4 ± 0.3 Gyr [1], implying that population III stars of mass less than 0.8 $M_\odot$, should still exist. As yet no population III stars have yet been observed, however recent searches for extremely metal poor halo stars have yielded the identification of the most iron poor star known, HE0107-5240, [Fe/H]=-5.3 [2].

It is known [3] that in the absence of metals the molecular ion H_3^+ acts as an electron donor and as such can significantly affect the opacity of a hydrogen helium gas. We [4] have shown that this increase in opacity can significantly effect the structure and evolution of population III stars of mass less than 0.4 $M_\odot$. It might be assumed that the spectra of population III stars would be devoid of absorption lines, however we have shown that H_3^+ line absorption can have a significant effect upon the opacity of a hydrogen helium gas.

In this poster paper we discuss the effects of H_3^+ on the continuum opacity as well as H_3^+ line absorption in a hydrogen helium gas. We then present preliminary synthetic stellar spectra for a low mass population III star.

2 H_3^+, Electron Donor and Line Absorber

In our earlier work [4] we calculated the number densities of various hydrogen and helium species (H_2, H, H^+, H^-, H_2^+, H_2^-, H_3^+, He, He^+, HeH^+ and e^-) at

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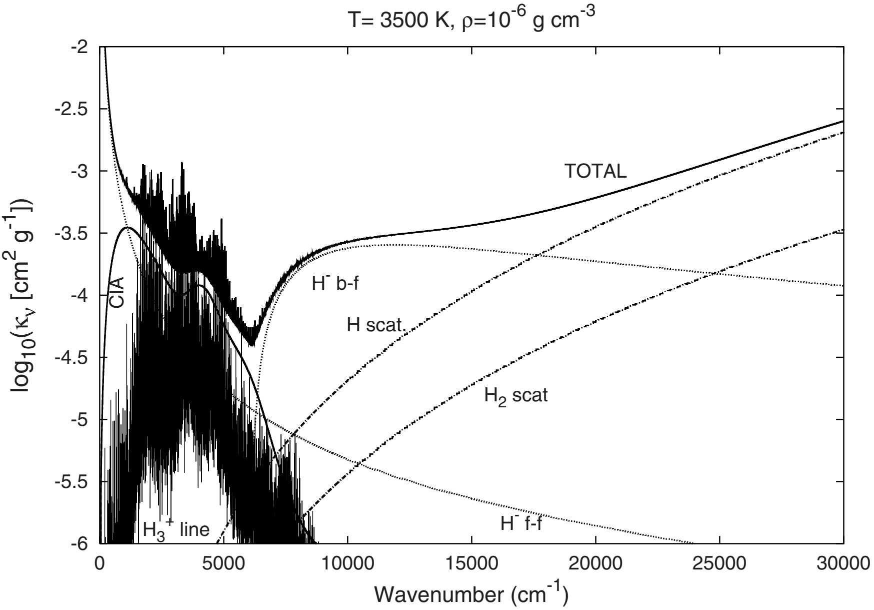

Fig. 1. H_3^+ line opacity and various sources of continuous opacity as a function of wavenumber.

equilibrium in a hydrogen-helium gas. The endothermic nature of the dissociation reaction $H_3^+ \rightarrow H_2 + H^+$ and the H_3^+ rotation-vibration partition function, combine to make H_3^+ the dominant positive ion at densities around 10^{-6} g cm^{-3} and below about 3500 K. Under these physical conditions H_3^+ is responsible for all free electrons and thus the abundance of the important source of opacity, H^-.

As reported in our earlier work [4] we have incorporated the Neale, Miller & Tennyson H_3^+ linelist [5] into our opacity calculations, this linelist has previously been used in brown dwarf model atmospheres [6]. Figure 1 shows the total, and various important sources of, monochromatic opacity of a hydrogen helium gas at a temperature of 3500 K and density of 10^{-6} g cm^{-3}. These opacity calculations make use of the most recent collision induced absorption data for H-He, H_2-H_2, H_2-He [7],[8],[9]. Full details of the other data sources can be found in our earlier work [4]. Clearly H_3^+ lines contribute significantly to the opacity and, as we see below, may well result in absorption lines within the spectra of population III stars.

3 Preliminary Synthetic Spectra.

Non-gray model atmospheres are needed for accurate stellar evolution calculations on very low mass stars. To this end we are in the process of writing a fast non-gray model atmosphere code. At present this code does not account for convection!

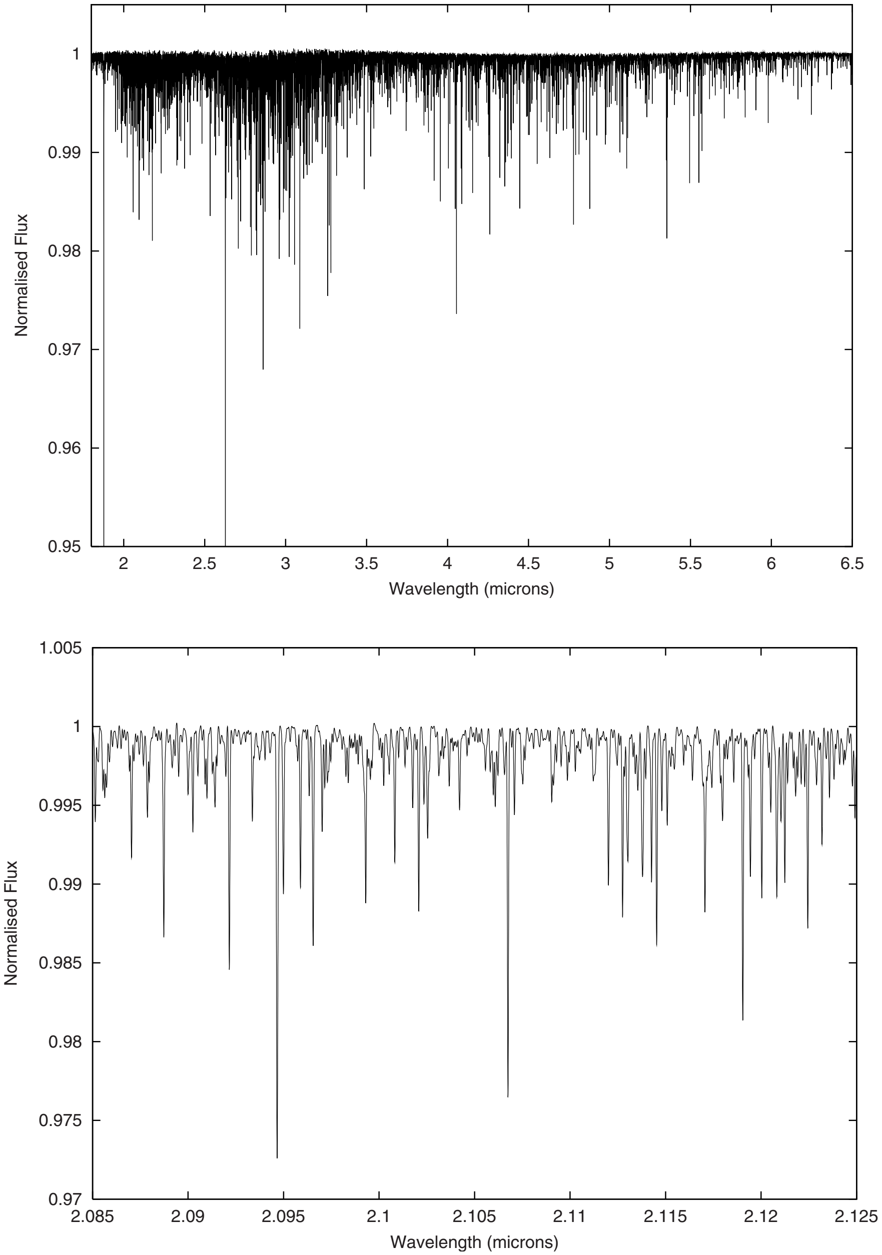

Fig. 2. This figure shows the normalised synthetic spectra of a hydrogen-helium atmosphere with $\log g = 4.86$ and $T_{\mathrm{eff}} = 4800$ K, between 1.8–6.5 μm (**top**) and 2.085–2.125 μm (**bottom**).

Convection is of great importance in the optically thick regions of cool stellar atmospheres, so it is currently being built into our models. However using these purely radiative plane parallel model atmospheres we have generated some preliminary synthetic spectra. We used the same opacity data and equation of state for the model atmospheres and synthetic spectra as discussed in our earlier work [4].

Despite the lack of convection, as the H_3^+ absorption lines are generated predominantly in the upper layers of the star, these synthetic spectra are sufficient to illustrate that H_3^+ line opacity is important in low mass dwarf population III stars. Figure 2 shows these synthetic spectra, which are normalised using synthetic spectra calculated without H_3^+ line opacity. This has the effect of eliminating all absorption features that are not a result of H_3^+ line opacity, including the only other source of line opacity HI . The spectra shown in figure 2 are calculated with a $T_{\rm eff}$ of 4800 K and a log g of 4.86 which corresponds to a 0.5 $M_\odot$ Main Sequence population III star. There is a wealth of H_3^+ lines in both these spectra which may well be observable.

4 Conclusion.

We have discussed the effects of H_3^+ as an electron donor upon the number density of electrons and H^- in a hydrogen-helium gas and the resulting increase in opacity of the gas. We have calculated new radiative synthetic spectra that illustrate that H_3^+ absorption lines may well be detectable in very low mass population III stars.

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