Spectral analysis of ultra-cool white dwarfs polluted by planetary debris

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We have identified two ultra-cool ($T_{\rm eff} < 4000\,{\rm K}$) metal-polluted (DZ) white dwarfs WD J2147−4035 and WD J1922+0233 as the coolest and second coolest DZ stars known to date with $T_{\rm eff} \approx 3050\,{\rm K}$ and $T_{\rm eff} \approx 3340\,{\rm K}$, respectively. Strong atmospheric collision-induced absorption (CIA) causes the suppression of red optical and infra-red flux in WD J1922+0233, resulting in an unusually blue colour given its low temperature. WD J2147−4035 has moderate infra-red CIA yet has the reddest optical colours known for a DZ white dwarf. Microphysics improvements to the non-ideal effects and CIA opacities in our model atmosphere code yields reasonable solutions to observations of these ultra-cool stars. WD J2147−4035 has a cooling age of over 10 Gyr which is the largest known for a DZ white dwarf, whereas WD J1922+0233 is slightly younger with a cooling age of 9 Gyr. Using intermediate-resolution spectroscopy, we have detected sodium and potassium in both white dwarfs, calcium in WD J1922+0233 and lithium in WD J2147−4035. We have identified the magnetic nature of WD J2147−4035 from Zeeman splitting in the lithium line and have also made a tentative detection of carbon, so we have classified this star as DZQH. WD J1922+0233 likely accreted planetary crust debris, while the debris composition that polluted WD J2147−4035 remains unconstrained.