Limits on the dependence of the fine-structure constant on gravitational potential from white-dwarf spectra

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We propose a new probe of the dependence of the fine-structure constant on a strong gravitational field using sensitive transitions in the absorption spectra of white-dwarf stars [1]. The sensitivity of an atomic transition to variations in the fine structure constant, $\alpha = e^2/\hbar c$, increases with the ionisation degree. In our study, we used around 100 far-UV transitions in Fe V and Ni V observed in the white-dwarf star G191-B2B by the Hubble Space Telescope Imaging Spectrograph.

These iron and nickel ions reside in the atmosphere of the white dwarf and the observed features are formed in its outer layers, near the surface of white dwarf. Consequently, the ions experience the strong downward surface gravity of the star, but are supported against this by the transfer of momentum from high-energy photons, a process termed "radiative levitation". The dimensionless gravitational potential for these ions (relative to the laboratory) is $\Delta\phi \approx 5 \times 10^{-5}$.

We obtained the limit on the change in α due to this gravitational field as $\Delta\alpha/\alpha = (4.2 \pm 1.6) \times 10^{-5}$ and $(-6.1 \pm 5.8) \times 10^{-5}$ for Fe V and Ni V spectra, respectively. This constrains theories where light scalar fields change parameters of the Standard Model (such as α).

Finally, we also calculated isotope shifts for these transitions, which can be used to constrain models of chemical evolution of our galaxy [2].

References

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