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Precision isotope-shift spectroscopy for new physics searches and nuclear insights

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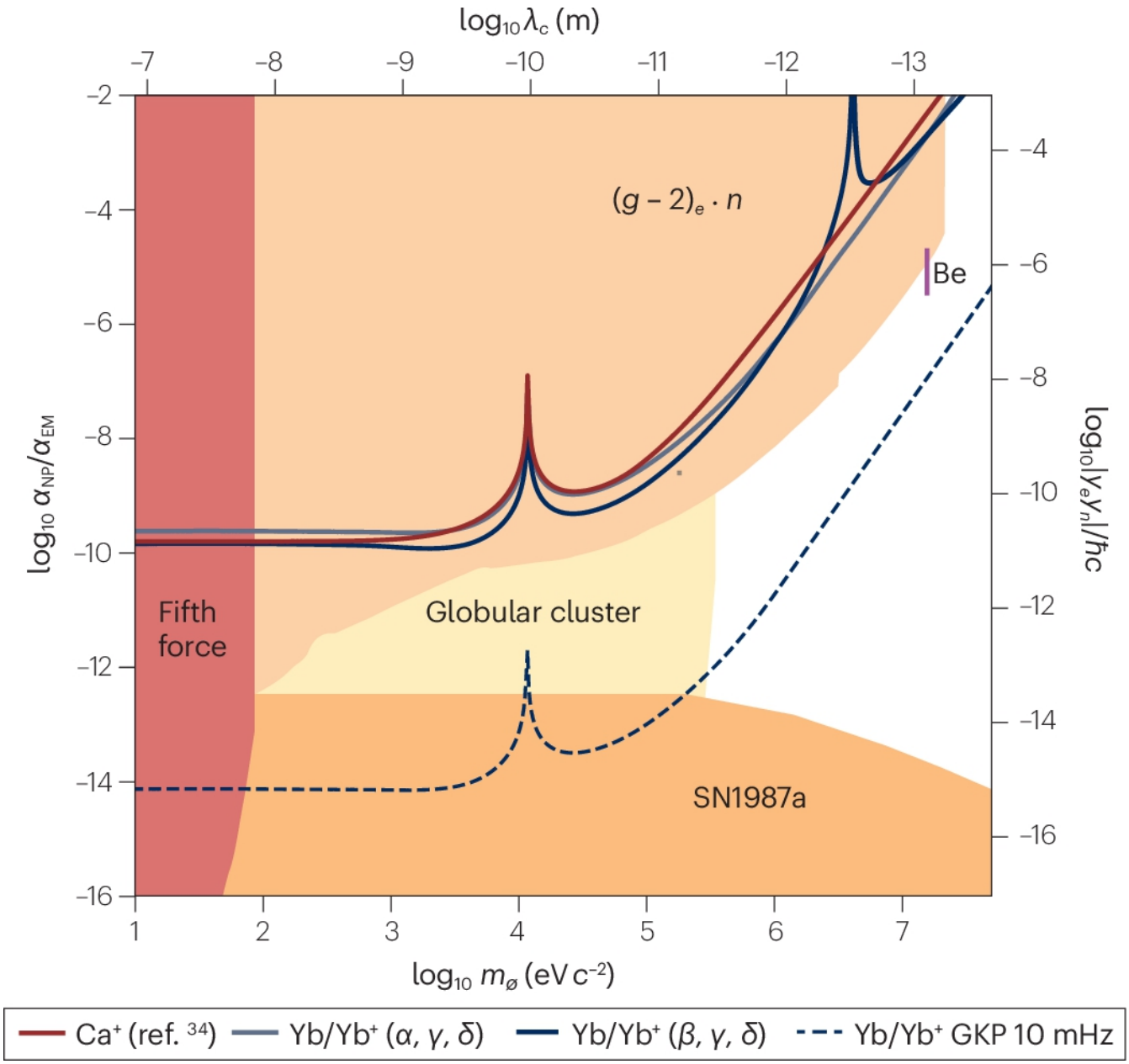
Searching for New Physics Through Precise Measurement of Isotopic Shifts in Spectral Lines.

Recent advances in optical spectroscopy of trapped atoms and ions have achieved unprecedented measurement precision, with relative uncertainties reaching the part-per-billion-billion level. Such precision opens new avenues for exploring physics beyond the Standard Model, complementing research conducted through high-energy particle colliders as well as astronomical and cosmological studies.

Shifts in the frequency of atomic spectral lines between different isotopes reveal subtle changes in nuclear properties. For a long time, optical spectroscopy has been used to extract variations in the nuclear charge radius between isotopes. However, with the advent of ultra-high-precision spectroscopy, it is now possible to probe finer aspects of nuclear structure.

Isotopic shifts also serve as a unique probe for exploring physics beyond the Standard Model, particularly in testing the existence of a fifth force. They are especially sensitive to tiny couplings between neutrons and electrons—effects so weak that they elude detection in conventional particle physics experiments.

This article presents the progress made in this field, the challenges encountered, and the promising prospects for the future


log10 λc (m)
−7
−8
−9
−10
−11
−12
−13
−2
−4
−6
−8
−10
−12
−14
−16
log10 αNP/αEM
log10|yeyn|/ħc
(g − 2)e · n
Be
Fifth force
Globular cluster
SN1987a
1
2
3
4
5
6
7
log10 mø (eV c−2)
Ca+ (ref. 34)
Yb/Yb+ (α, γ, δ)
Yb/Yb+ (β, γ, δ)
Yb/Yb+ GKP 10 mHz