DIFFERENT LAWS OF NATURE IN STRONG GRAVITATIONAL FIELDS?

Dependence of the fine-structure constant on gravitational potential using white-dwarf spectra

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Motivation

- appearance of scalar field would result in variation in fundamental constants
- coupling of scalar field with other fields (i.e. gravitational field) would have different strength near massive bodies

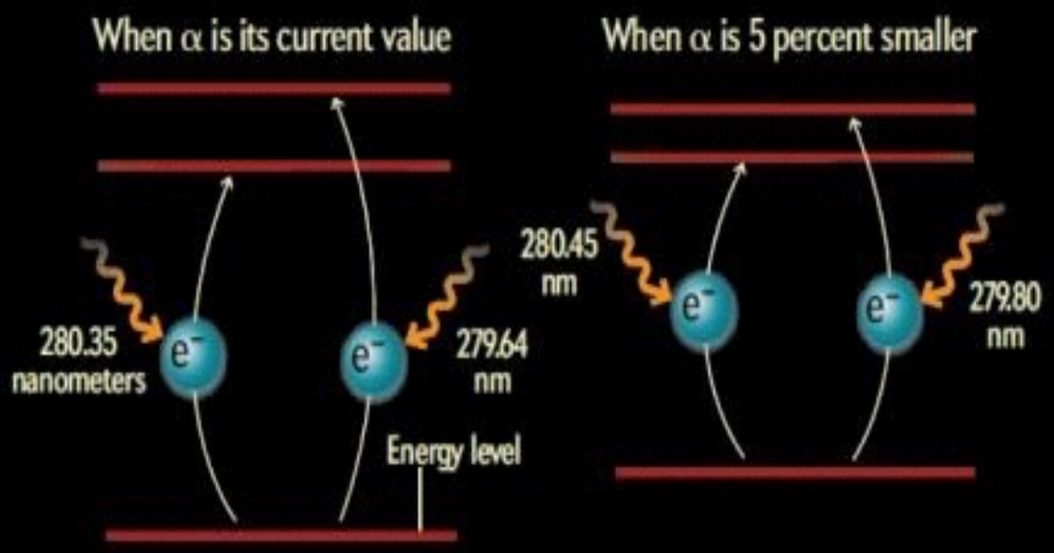
$$\Delta\alpha/\alpha = k_\alpha \Delta\phi$$

Magueijo et al. (2002)
Bekenstein (1982).
Sandvik et al. (2002).

Many-multiplet Method

Sensitivity to variation in α ?

If a changes…



(Credit: Alison Kendall)

The transition energy will change, thus
the transition line will be shifted.

q-coefficient

Characterize sensitivity of transition frequency ω to the change in α [4]:

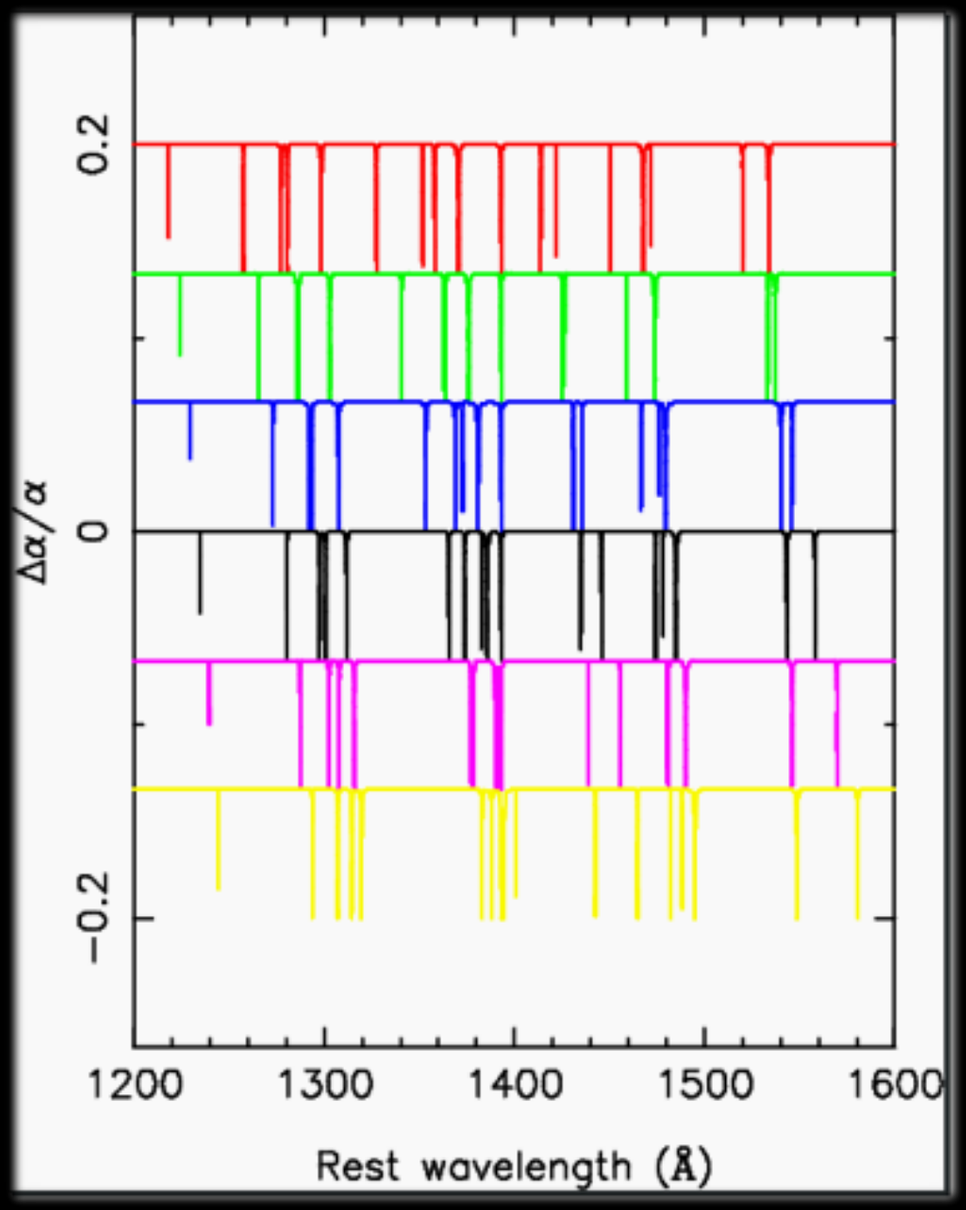
$$q = \frac{d\omega}{dx}\Big|_{x=0},$$

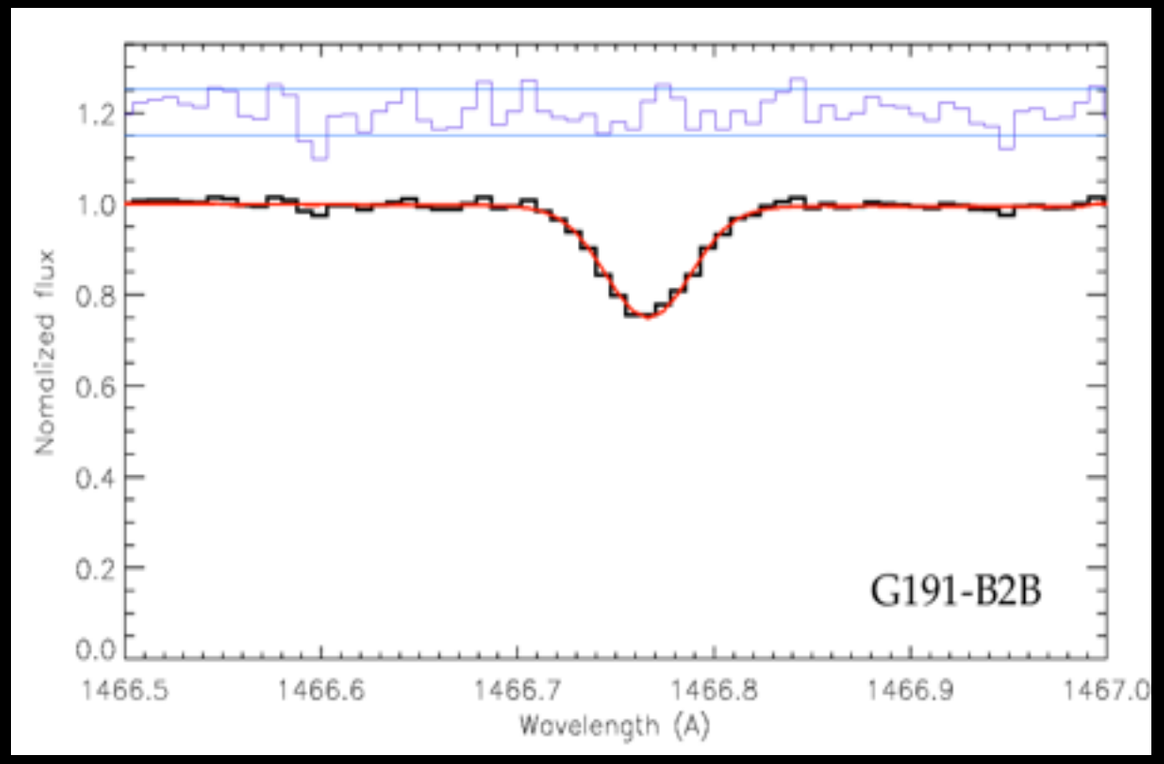
where $x = (\alpha/\alpha 0)^2 - 1 \approx 2\Delta\alpha/\alpha$

- *q is different for different transitions*
- *Atoms* with higher Z and higher ionization state generally have larger $|q|$

Many-multiplet Method

Sensitivity of Fe V lines to Δα/α





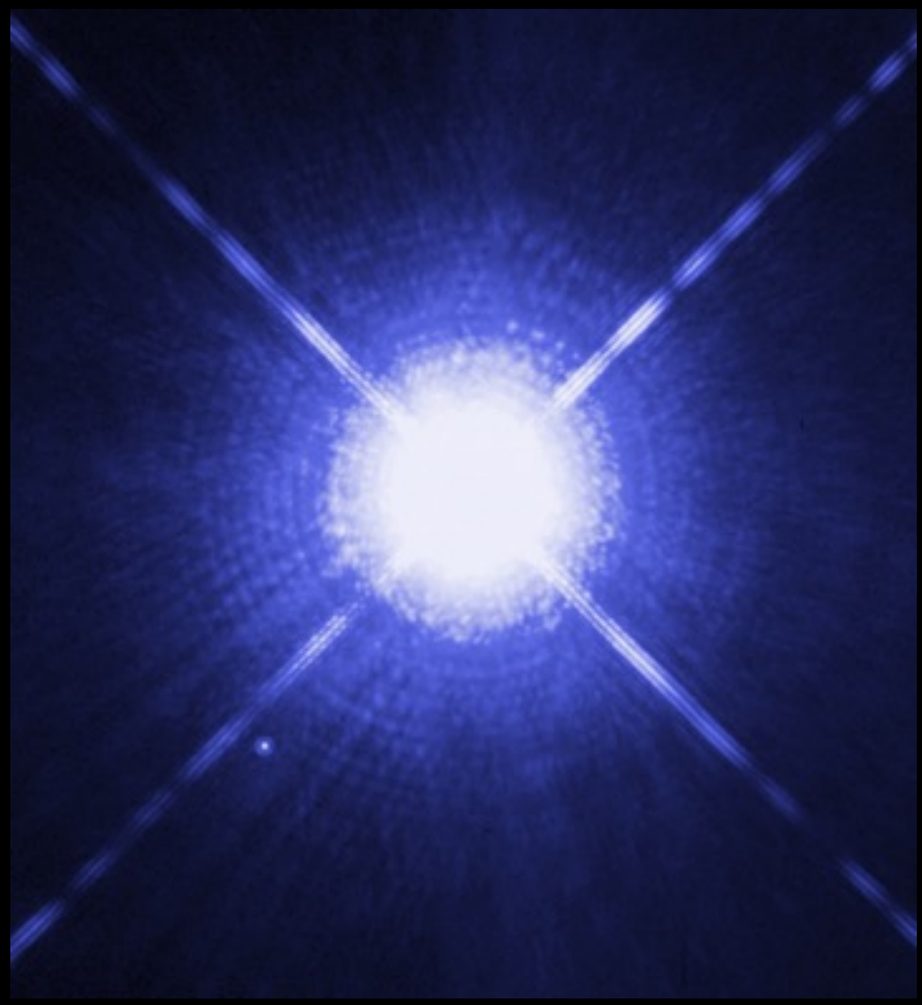
absorption line profile

fit {log N, z, b, Δα/α}
simultaneously for all the sample lines

What to observe?

Why white dwarfs?

- Compact, high surface gravity
  - ($\phi_{WD} \sim 10^5\ \phi_{Earth}$)
- For DA white dwarf $T_{eff} > 50{,}000\ K$
  - (UV bright)
- numerous highly ionized metal lines in photosphere
  - ★ *Radiative Levitation process*
  - ★ *Metal pollution*

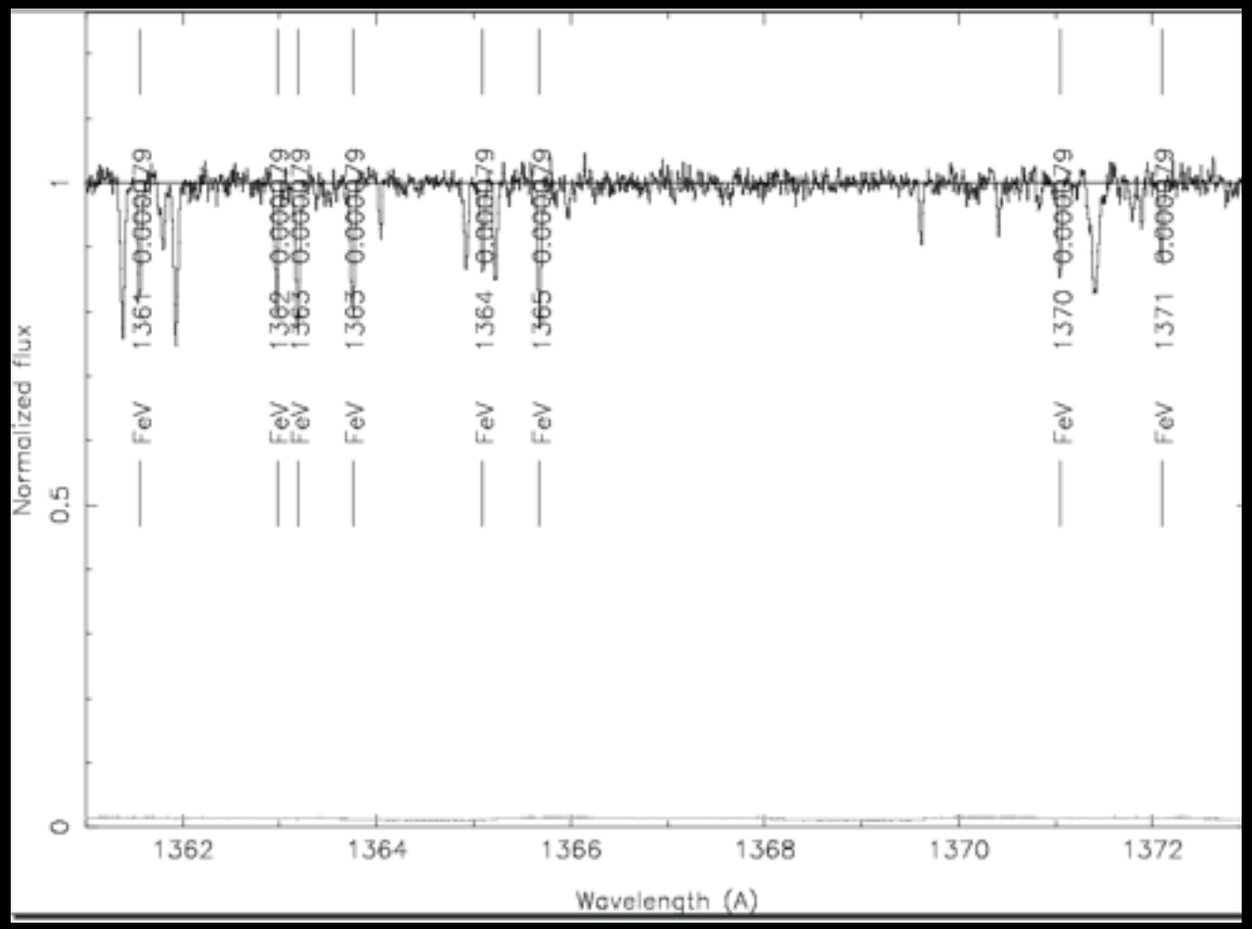


What to observe?

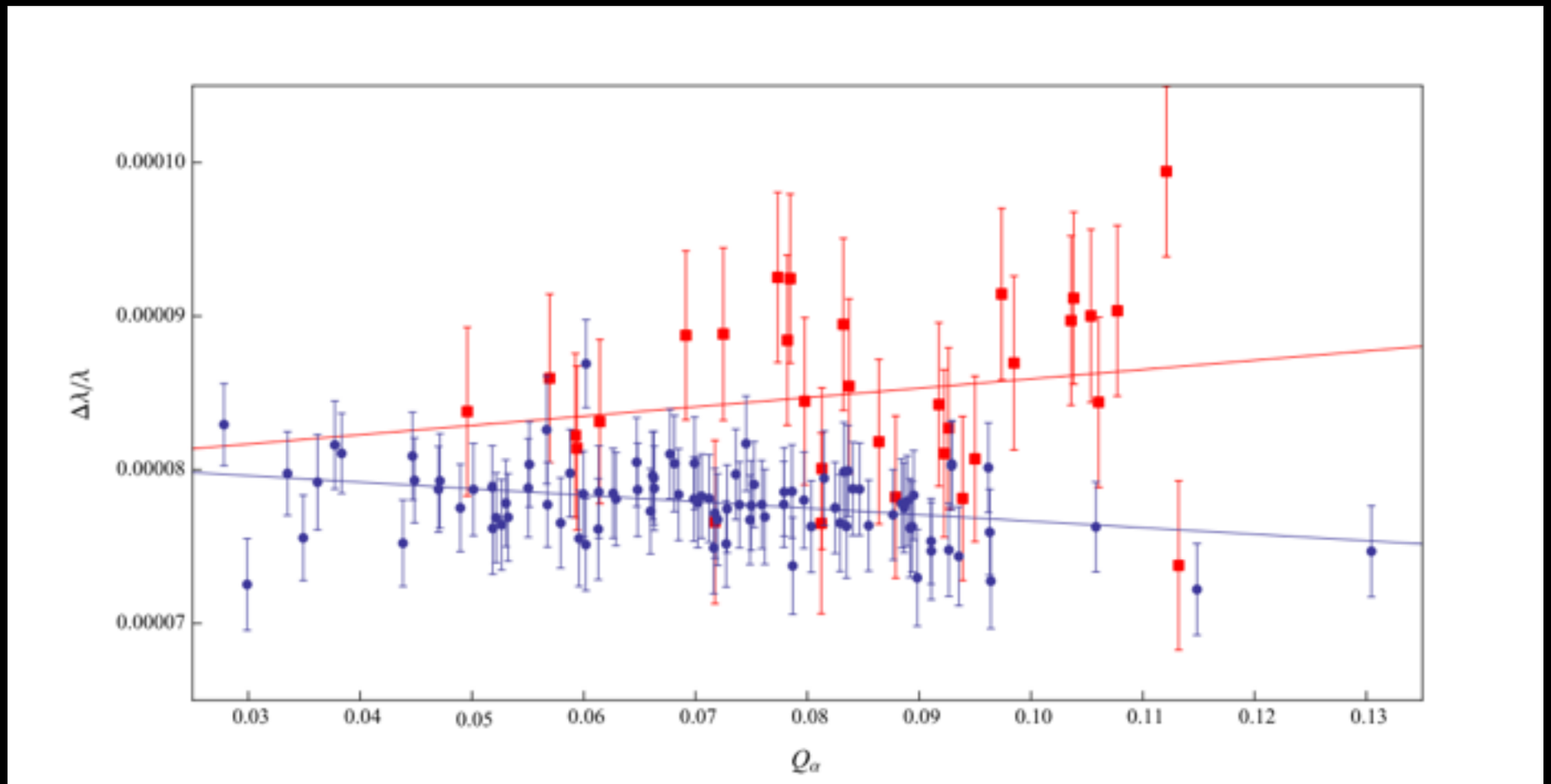
Fortunately, we also have good data available!

- Instrumentation: HST/STIS (R ~ 114,000), ƛ ~ [1140, 3150] Å
- First target: G191-B2B

Properties	FUV ~ 11.97, NUV ~11.66, ~50 pc rich in Fe V, Ni V, Fe IV
Observations	standard calibration source, 39 observations (62579s), S/N ~ 100
Data Processing	STIS handbook Ver. 6 (2011) new protocol ASTRAL (2015)



Primal result



Berengut et al. (*2013*)

Using Fe V: $\Delta\alpha/\alpha = (4.2 \pm 1.6) \times 10^{-5}$
Using Ni V: $\Delta\alpha/\alpha = (-6.1 \pm 5.8) \times 10^{-5}$

Something not quite right …

WD spectrum

↓

line identification

↓

laboratory wavelength → NLS fitting (VPFIT) → Δα/α

↑

q-coefficient

WD spectrum

- Other physical processes
- Instrumentation: long-range distortion?

↓

- mis-identification
- blends
- bias

line identification

↓

laboratory wavelength → MC fitting (VPFIT) → Δα/α

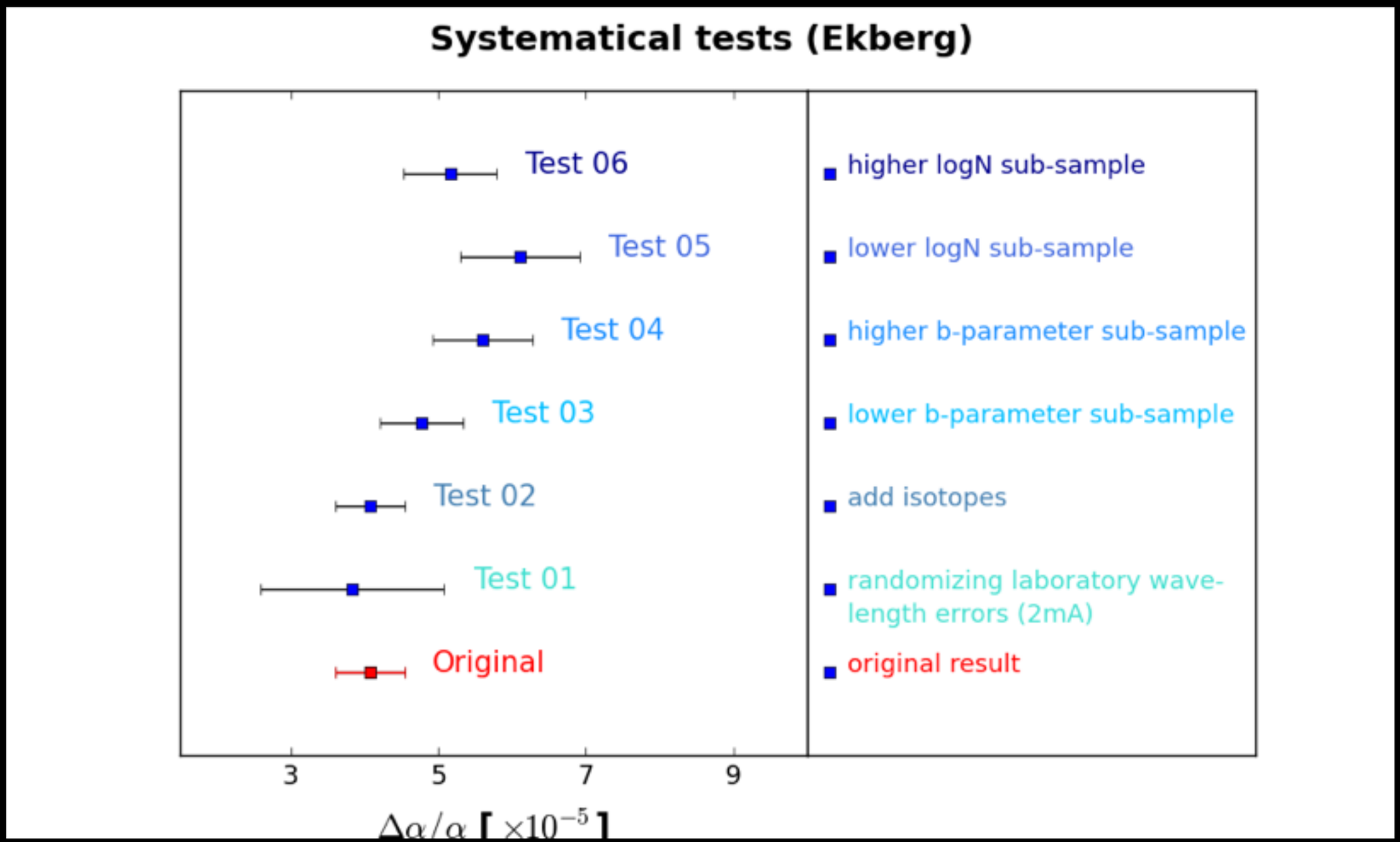
measurement uncertainties

q-coefficient ↑

+/- δ(Δα/α) …

Systematics Analysis

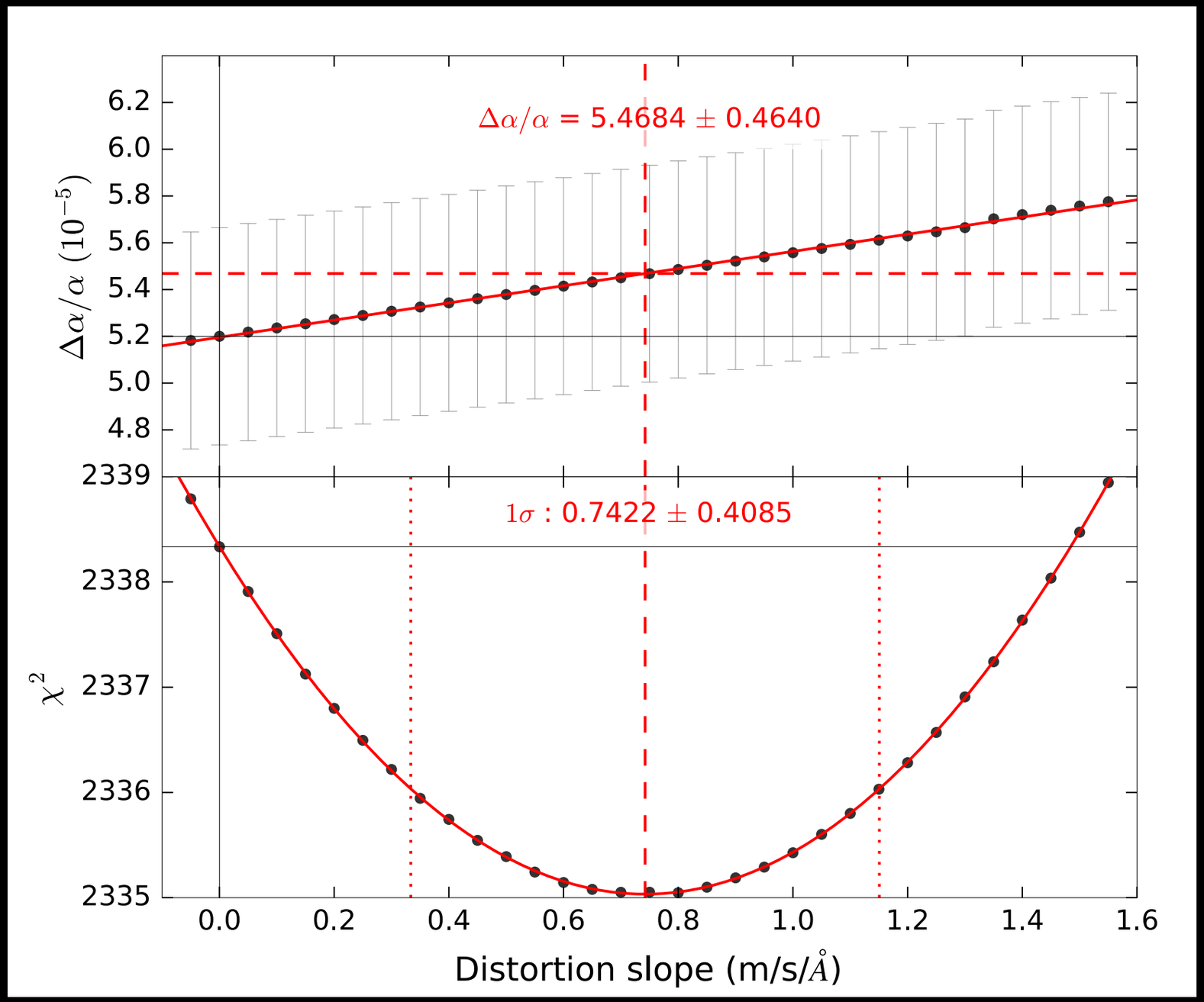
Using Fe V: $\Delta\alpha/\alpha = (4.1 +/- 0.47) \times 10^{-5}$



Systematics Analysis

Systematics Test	Constrain	Estimation
Zeeman quadratic shift	B < 4 T	~ 3×10^{-6}
Stark shift	E = 7 esu	~ 3×10^{-12}
Long-range distortion	linear distortion model	small effect

Systematics Analysis

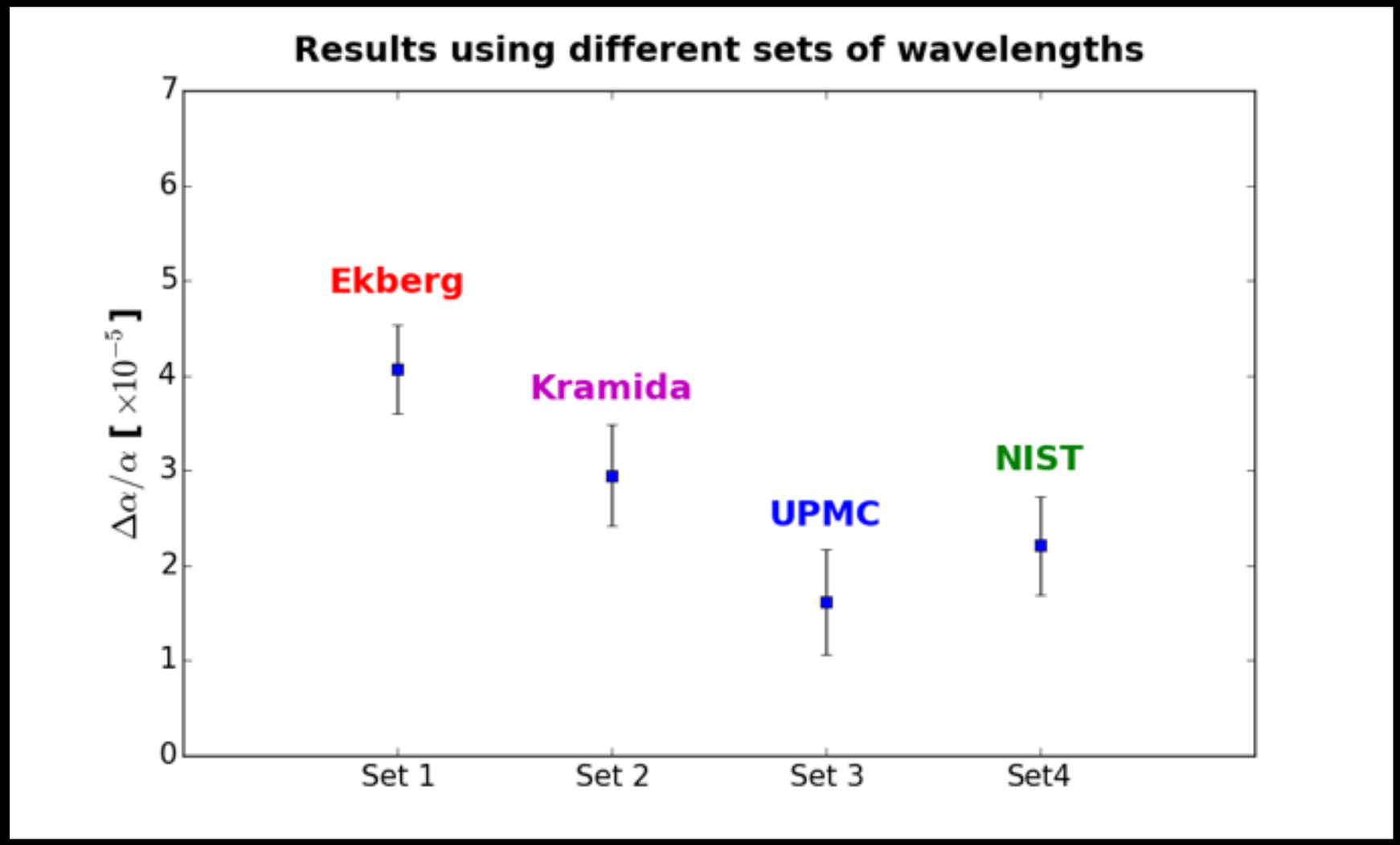


V. Dumont (2016)

New results

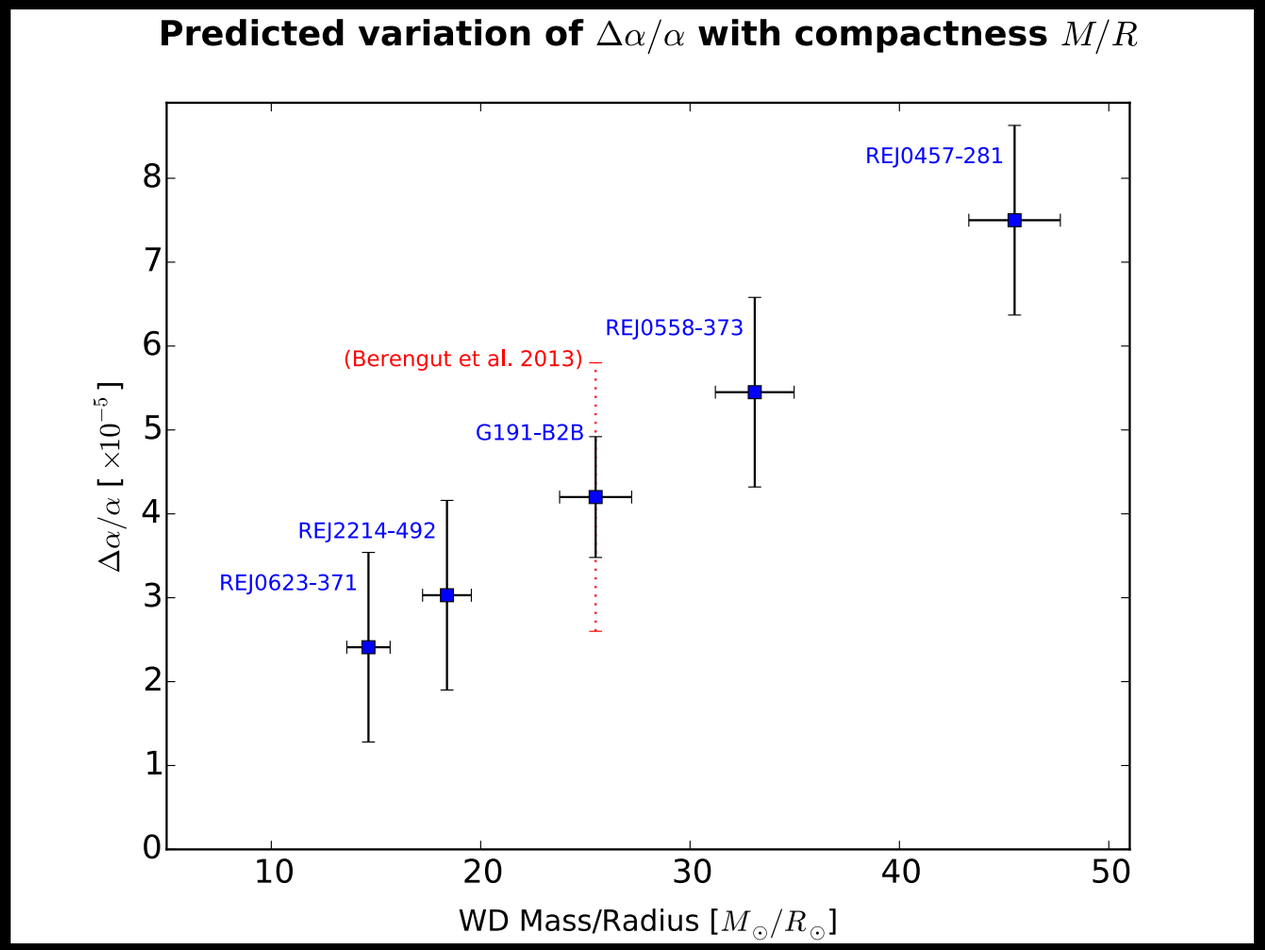
New laboratory wavelength measurements

Measurement	Uncertainties
Ekberg	4mA
UPMC	1 - 5 mA
NIST	3 - 5 mA



What we can do next?

- more measurements of plates in lab
- measurements of other ions: Ni V, Fe IV, etc.
- investigate other WDs (archive & new observations)



Thank you!