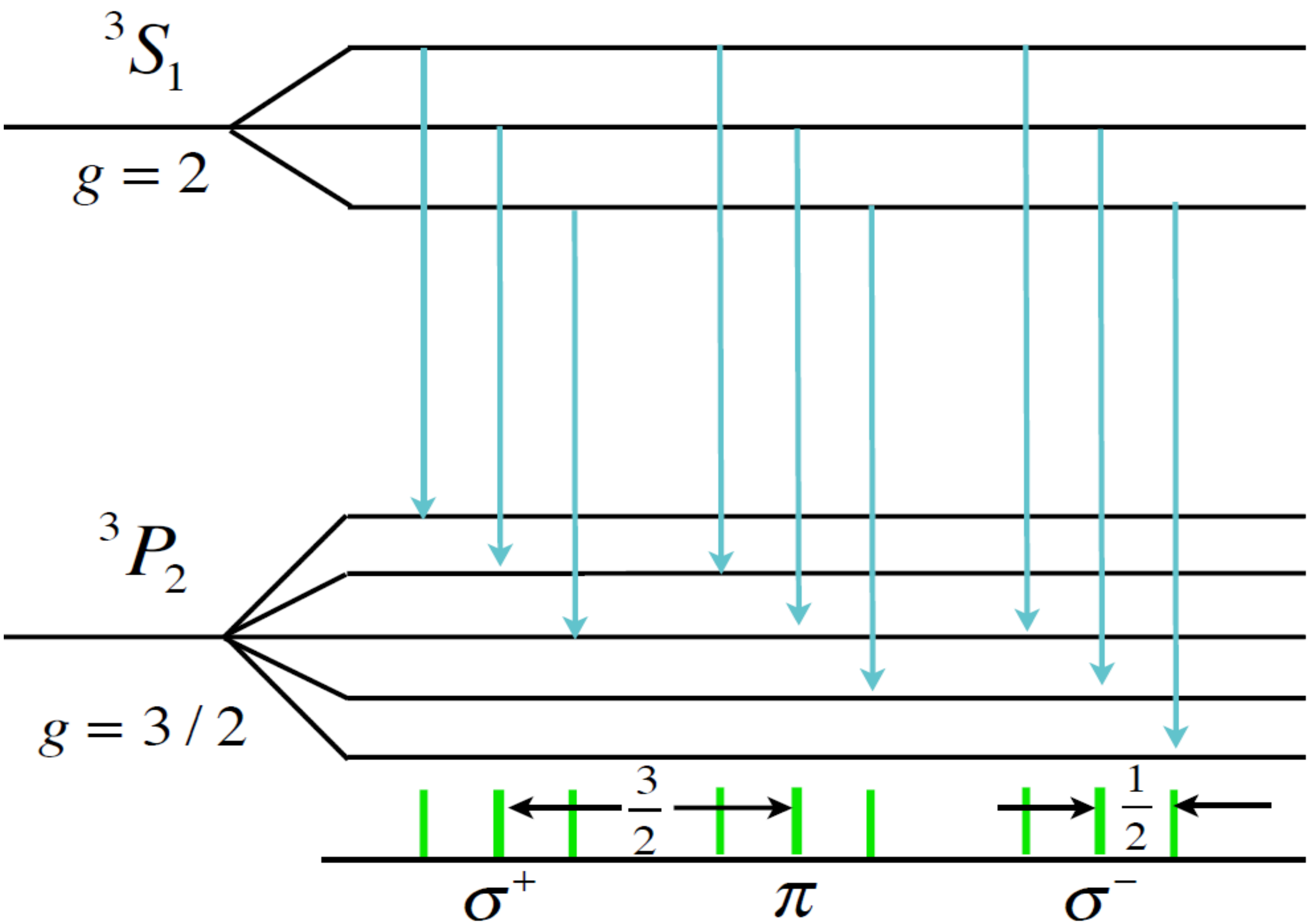
The Zeemen Effect:

Mercury Fine Structure and Determination of e/m

Edwin Ng | 14 March 2012

Theory of the Zeeman Effect



Relating FP Spectrum to Energy

- Governing equation for Fabry-Perot

$$\delta\lambda = \frac{\lambda^2}{2L}\frac{\delta\theta}{\Delta\theta}$$

- Relate this to the energy of a splitting

$$\delta E = \frac{hc}{\lambda^2}\delta\lambda = \frac{hc}{2L}\frac{\delta\theta}{\Delta\theta}$$

Governing Equation for e/m

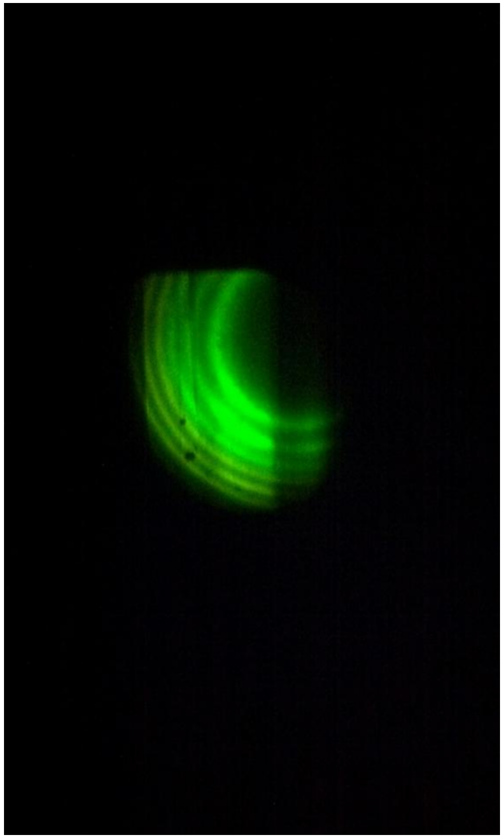
- From theory of the Zeeman effect,

$$\mu_0 B \delta g = \delta E = \frac{hc}{2L}\frac{\delta\theta}{\Delta\theta}$$

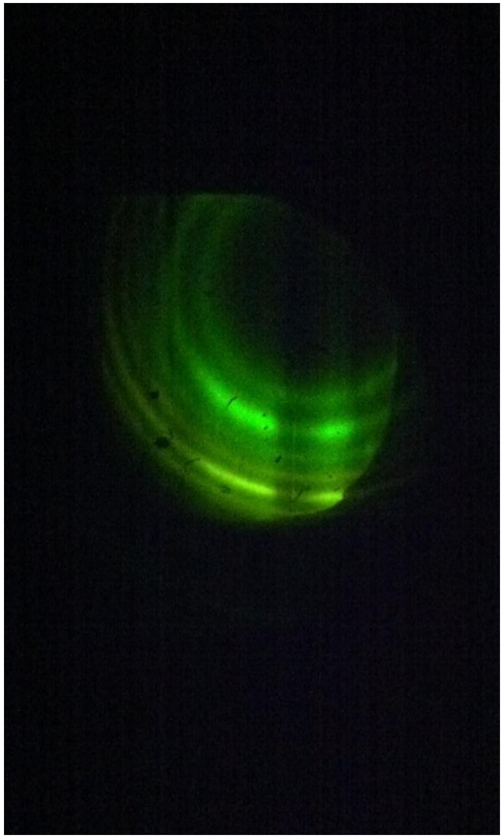
- Solve for *e*/*m* in the Bohr magneton

$$\frac{e}{m} = \frac{2\pi c}{BL\delta g}\frac{\delta\theta}{\Delta\theta}$$

Zeeman Splitting: Pictures



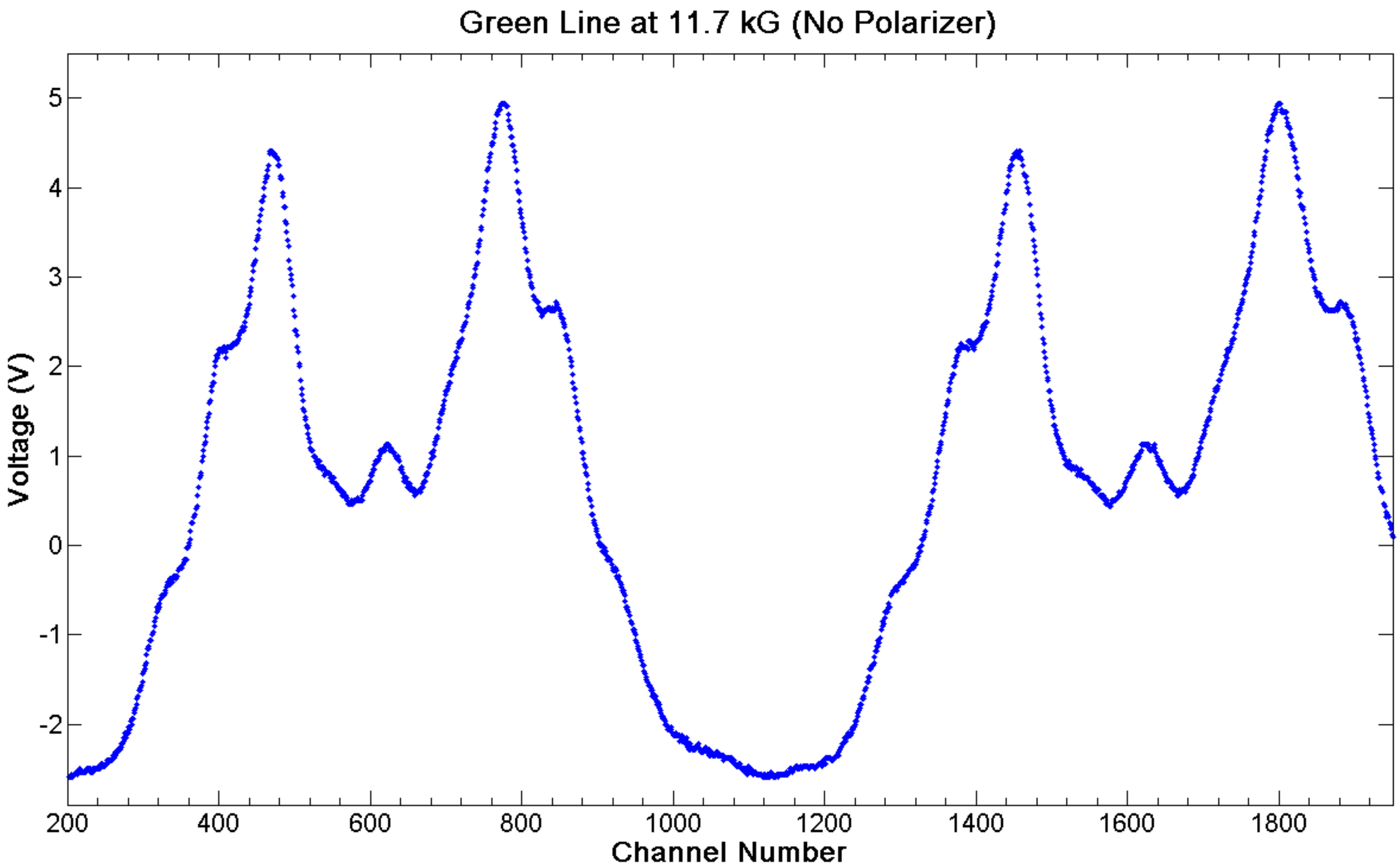
Unpolarized



σ Polarized

π Polarized

Zeeman Splitting: Interferograms



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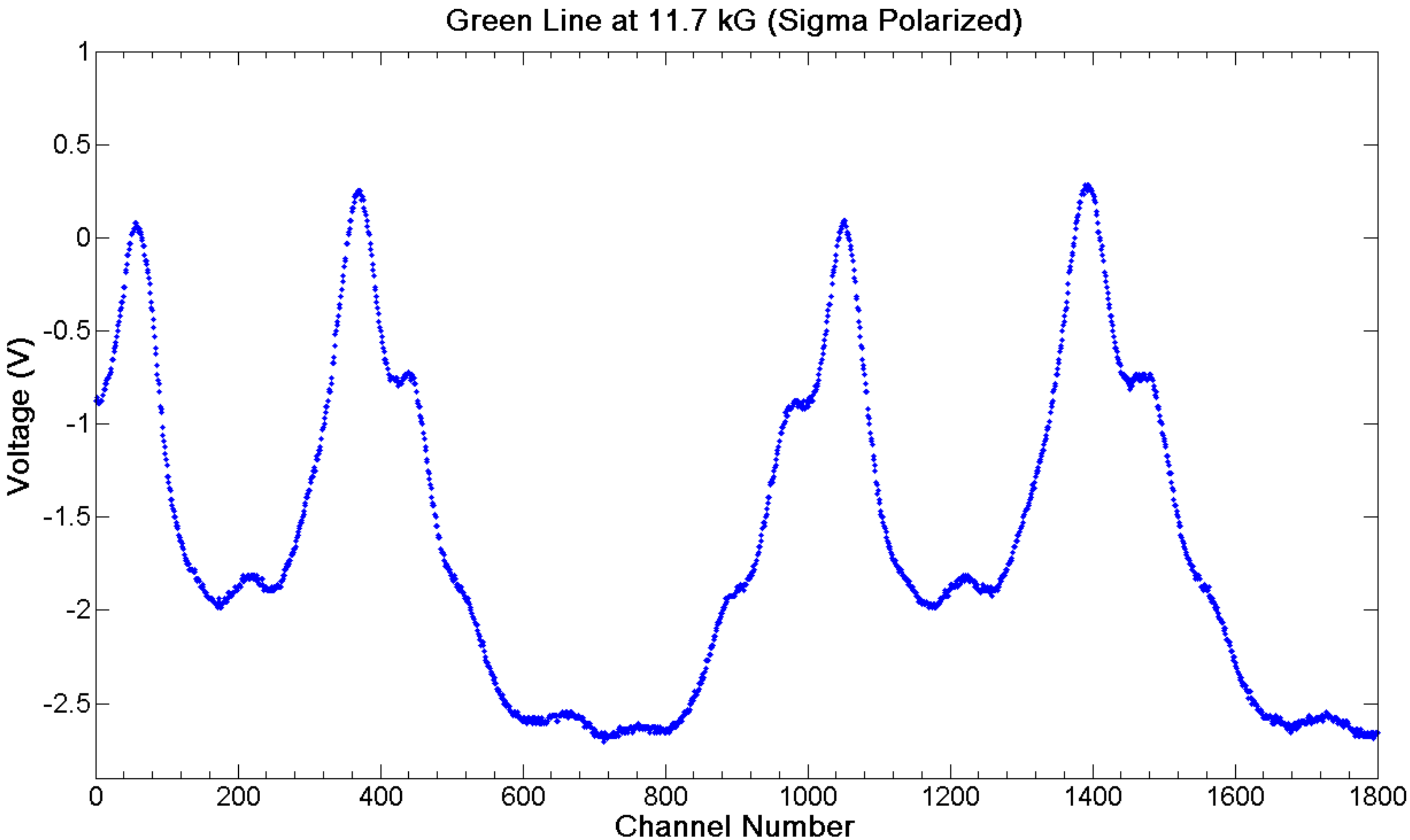

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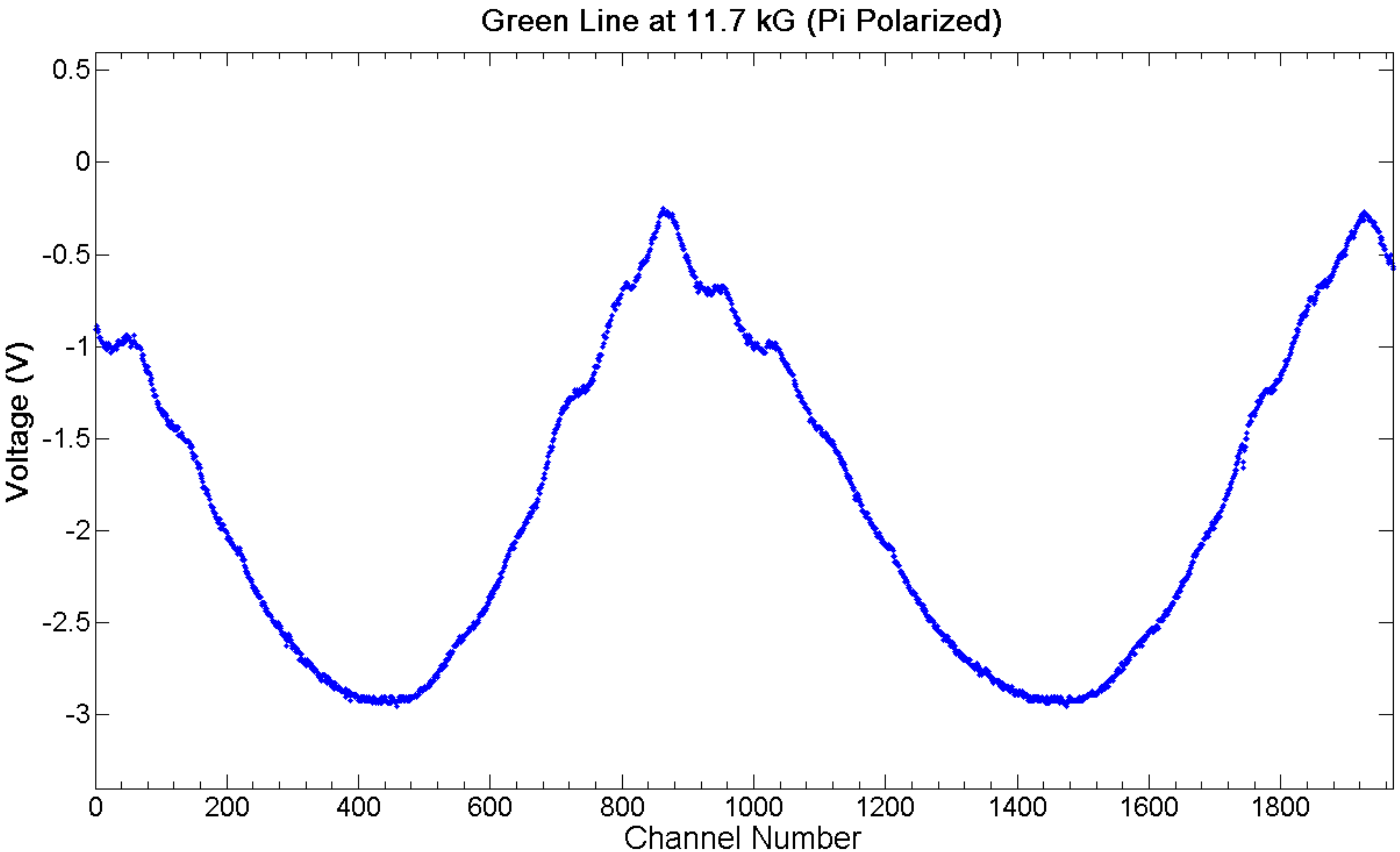

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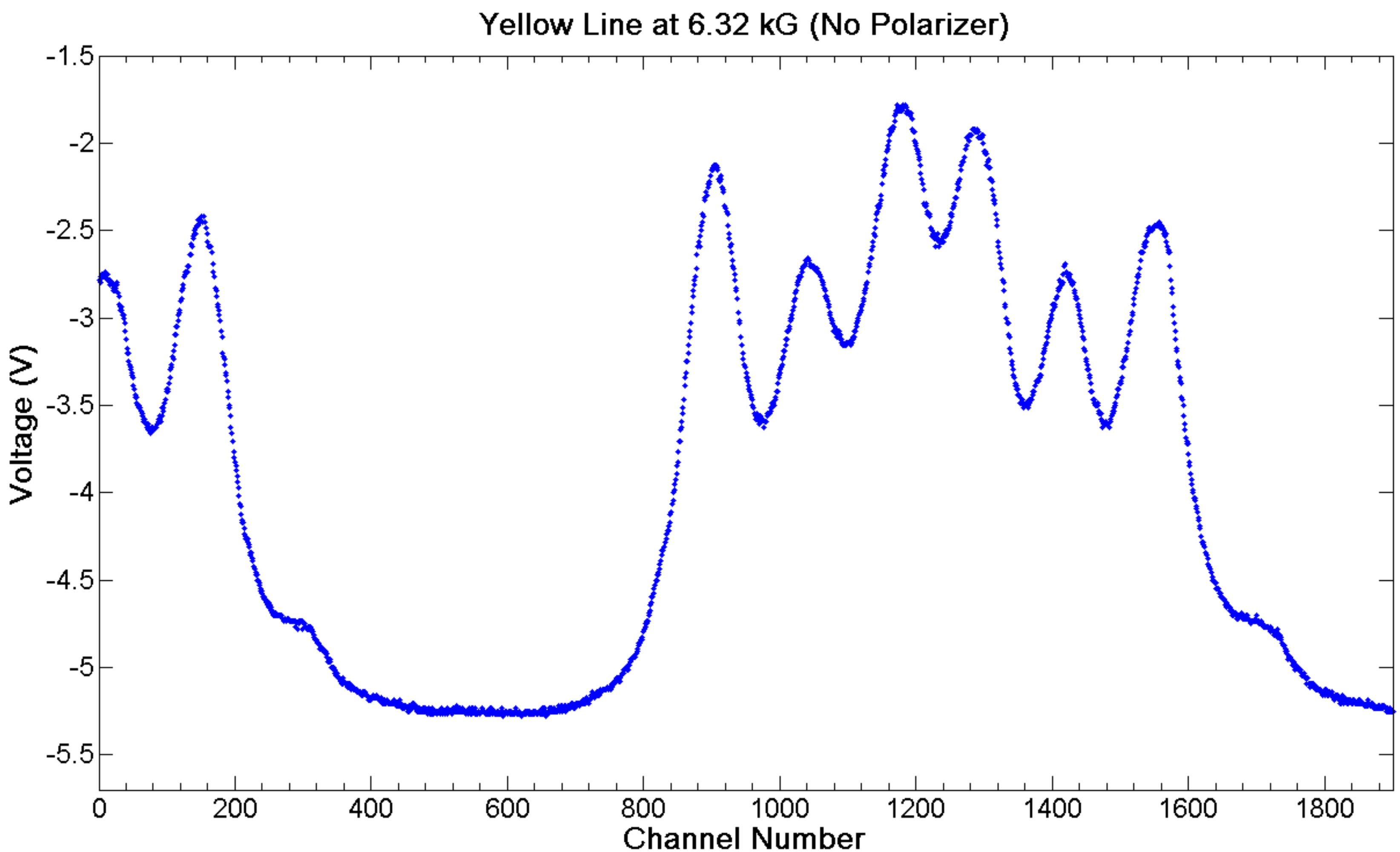

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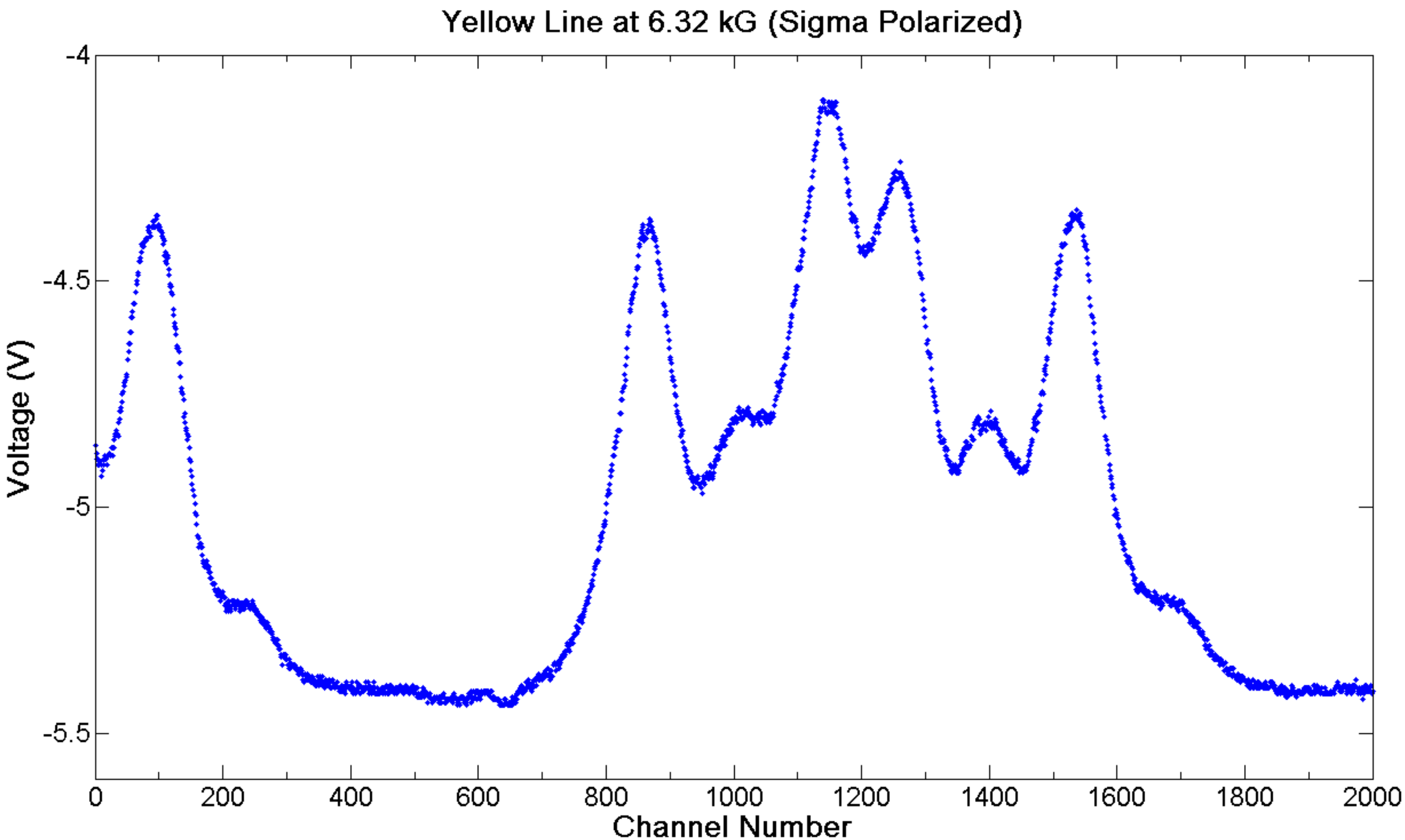
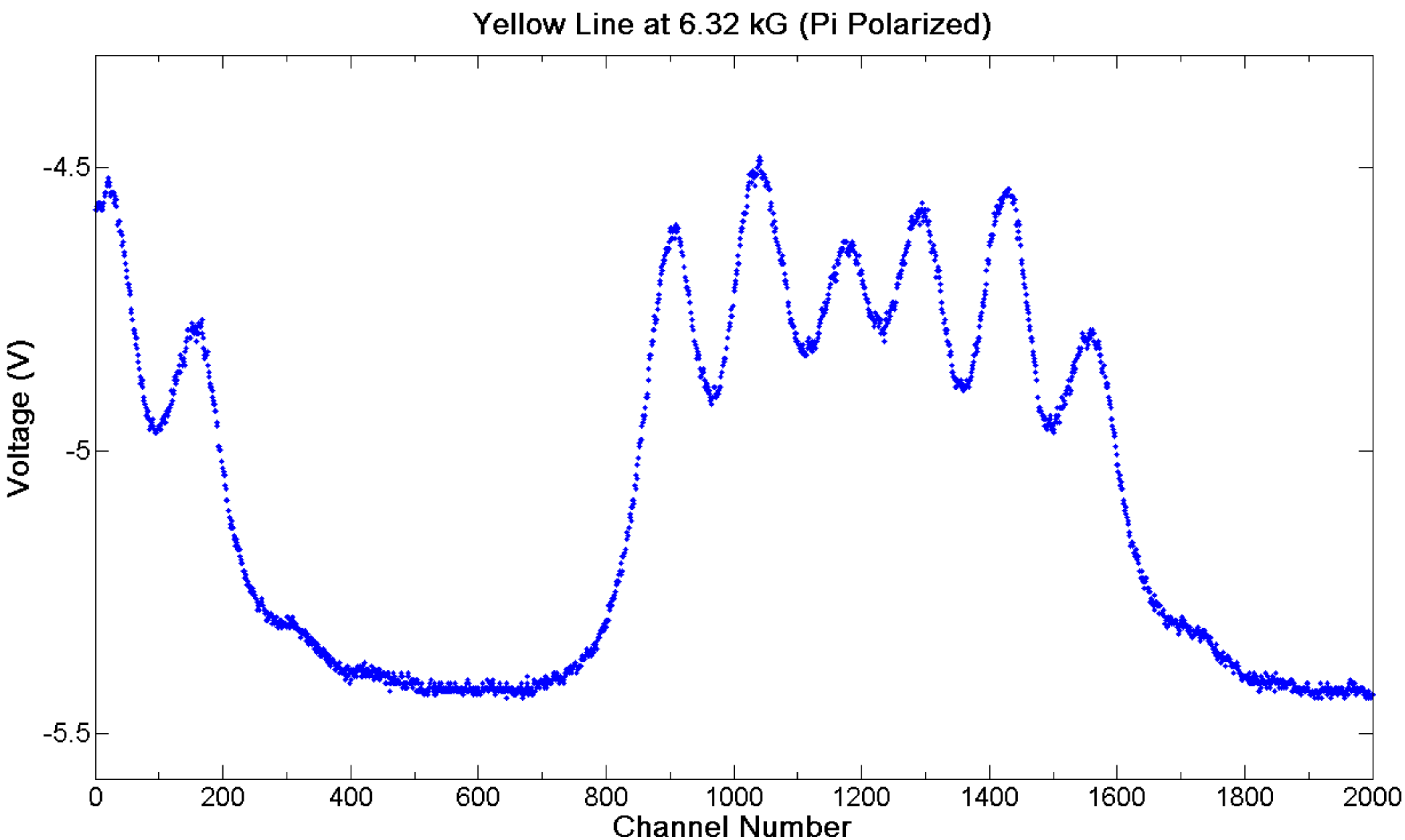


Zeeman Splitting: Interferograms



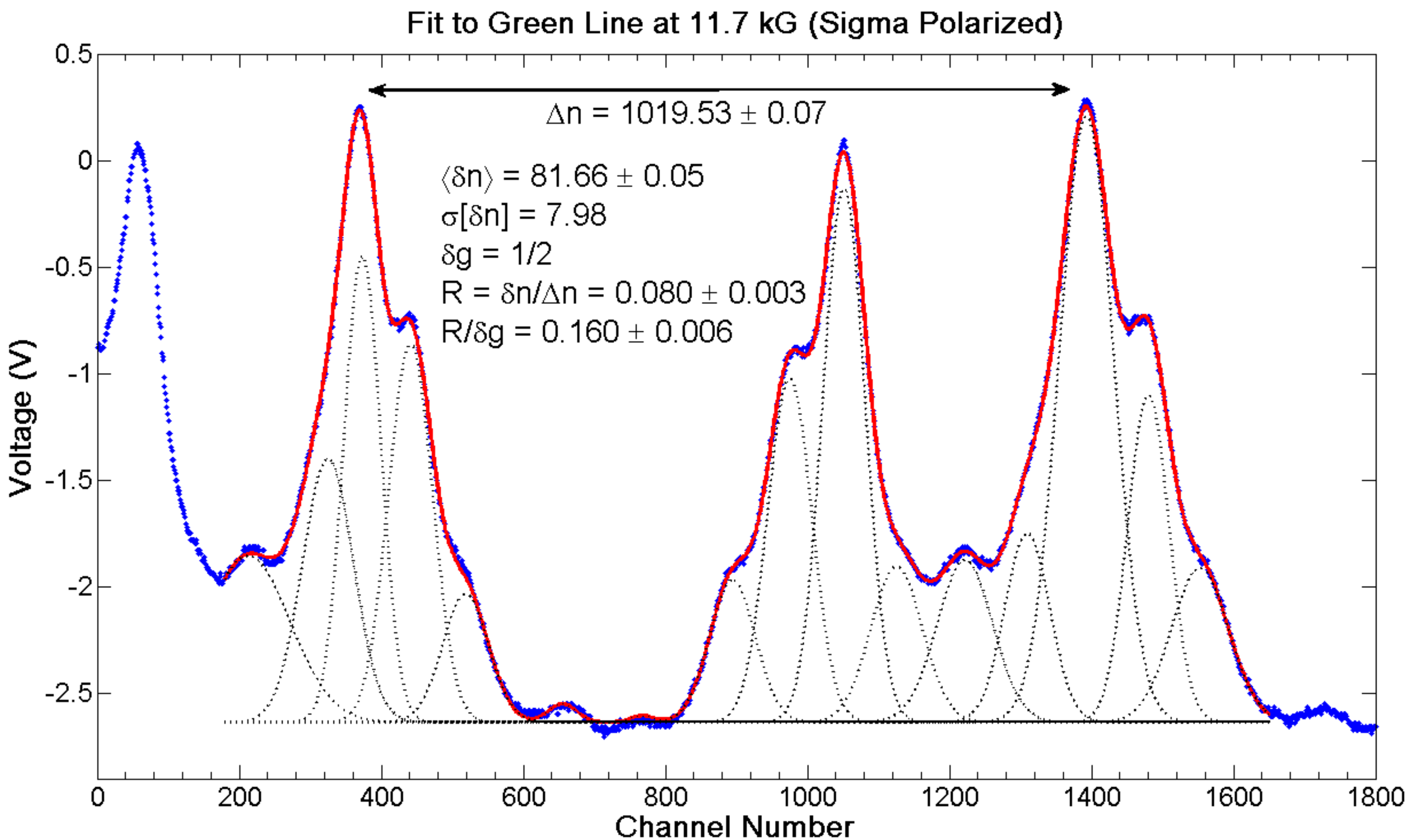
Fitting Procedure: Overview

- Fit selected regions of interferogram with a sum of Gaussians on top of a background

$$y = b + \sum_j A_j \exp\left[-\frac{(x-n_j)^2}{2\sigma_j^2}\right]$$

- Interested in n_j which give peak positions

Fitting Procedure: Method I

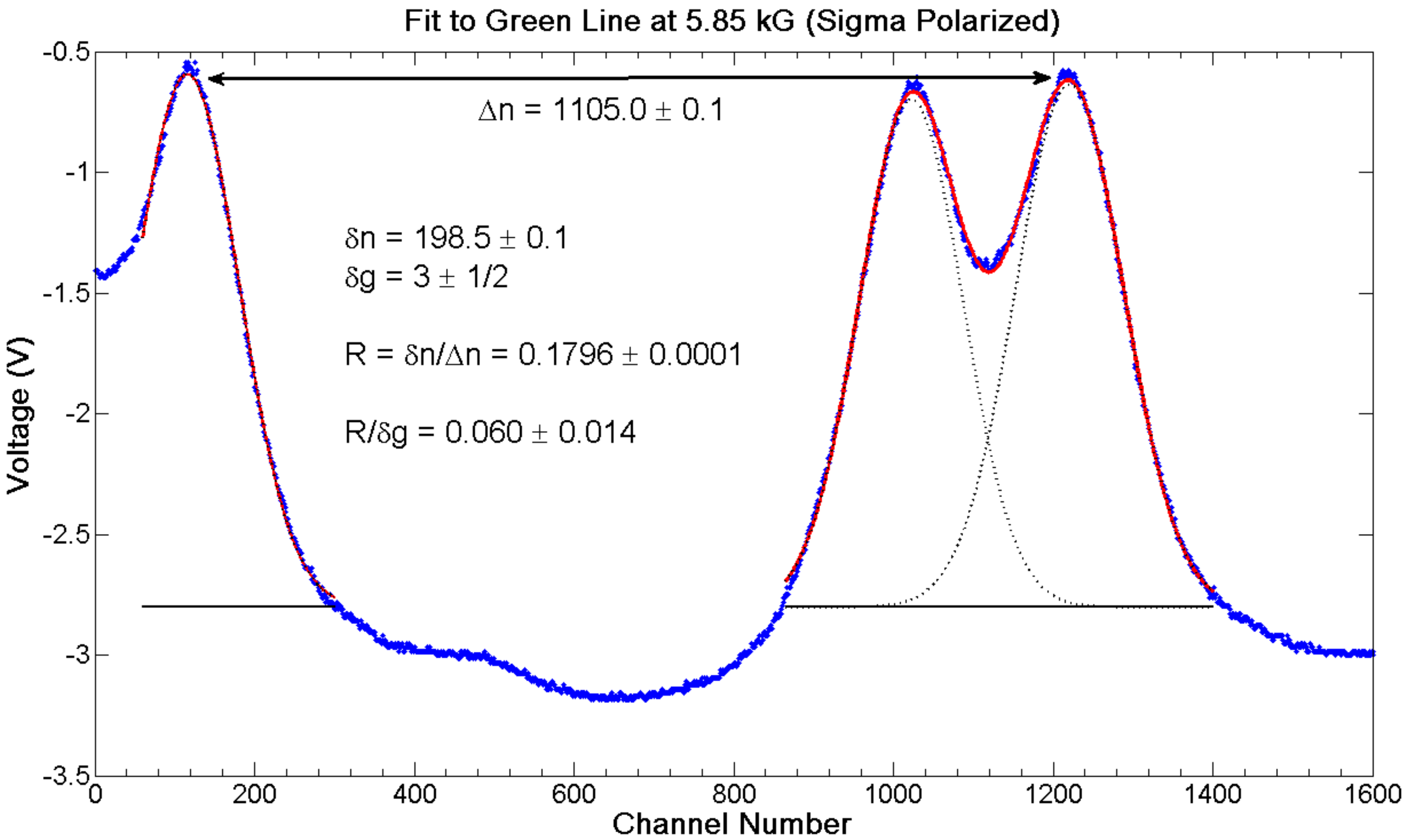


Fitting Procedure: Method I Summary

- δn is the *average* of consecutive peaks
- Uncertainties on δn:
  - Statistical uncertainty: Uncertainty of splitting $n_j - n_{j-1}$
  - Systematic uncertainty: S.D. of all such splittings divided by square root of (peaks-1)
- Δn is the FSR (diff. between two reference peaks)

- The ratio $R = \delta n / \Delta n$ propagates all uncertainties
- Finally, extract $R/\delta g$ (δg = ½ for green)

Fitting Procedure: Method II

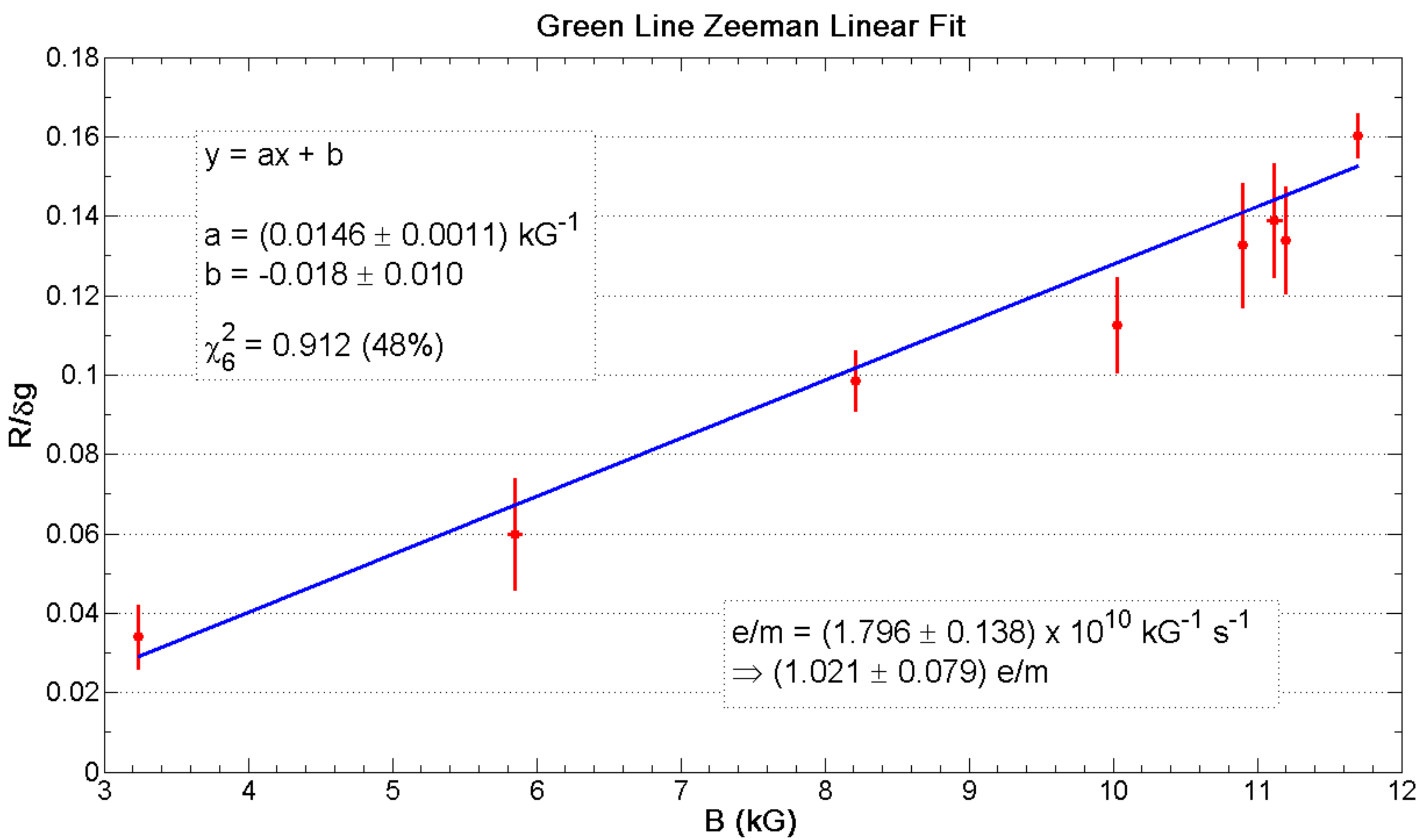


Fitting Procedure: Method II Summary

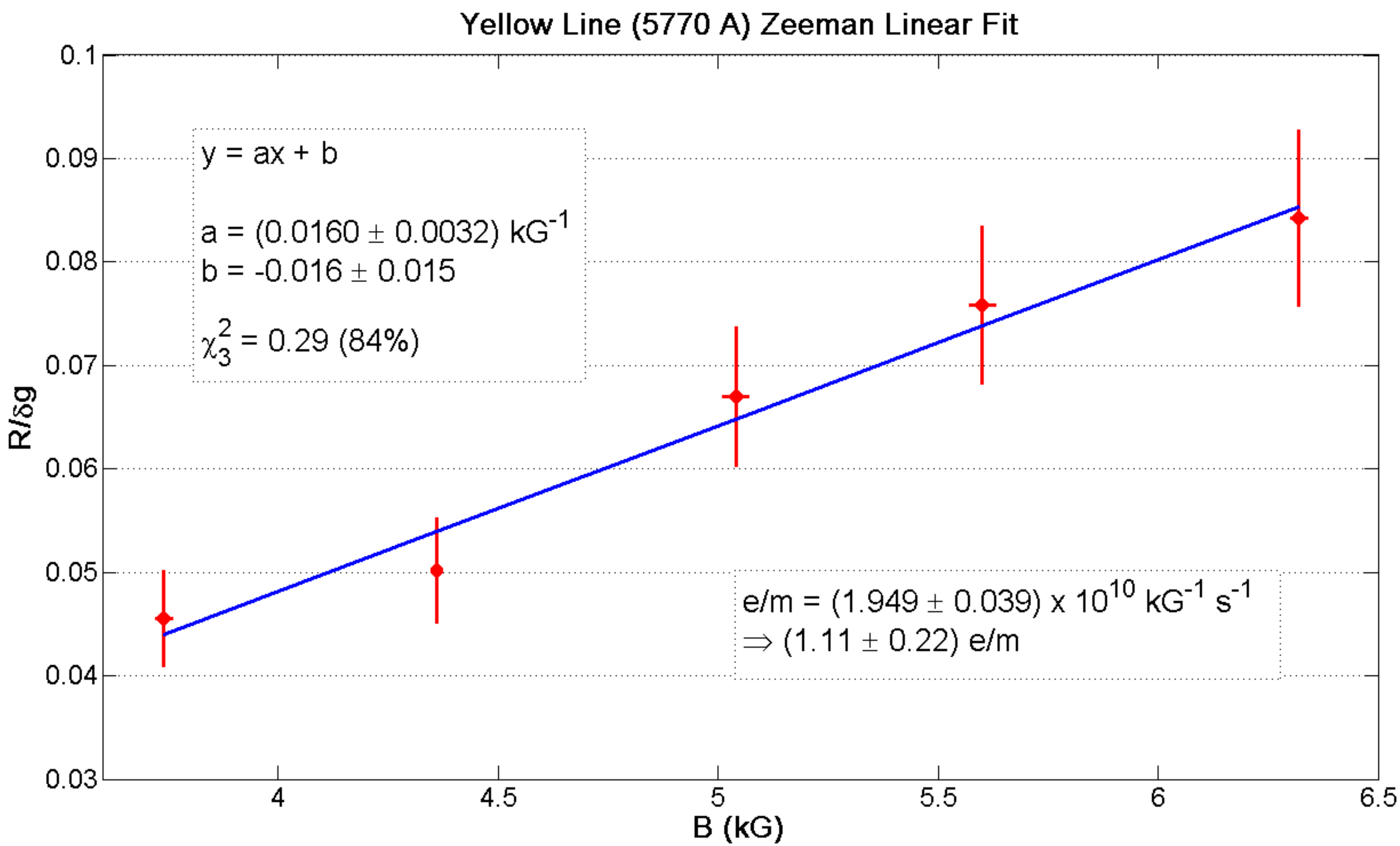
- δn is splitting of two *representative* lines
- Uncertainty on δn is just uncertainty of $n_j - n_{j-1}$
- Δn is the FSR (diff. between two reference peaks)
- Calculate the ratio R = $\delta n / \Delta n$ (small uncertainty)

- δg is now between the two *representative* lines
  - $\delta g = 3$ for σ-σ green; $\delta g = {}^{14}/_{6}$ for σ-σ 5770 yellow
- Uncertainty on δg: neighboring (unresolved) lines
  - ±½ for green line and $\pm{}^{1}/_{6}$ for 5770 yellow

e/m From Green Line



e/m From Yellow Line (5770 Å)



Conclusions

- Observed splitting of energy degeneracy by Zeeman effect
- Observed polarization of emitted photons
- Final determination of *e*/*m*
  - $(1.813 \pm 0.130_{rand.} \pm 0.076_{syst.}) \times 10^{10}\ kG^{-1}s^{-1}$
  - Correct value: $1.759 \times 10^{10}\ kG^{-1}s^{-1}$
  - Result: $(1.031 \pm 0.074_{rand.} \pm 0.043_{syst.})\ e/m$

Question and Answer