Paschen-Back effect in the CrH molecule

New diagnostic tool for measuring magnetic fields in ultra-cool dwarfs

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Today's program

Why we study CrH

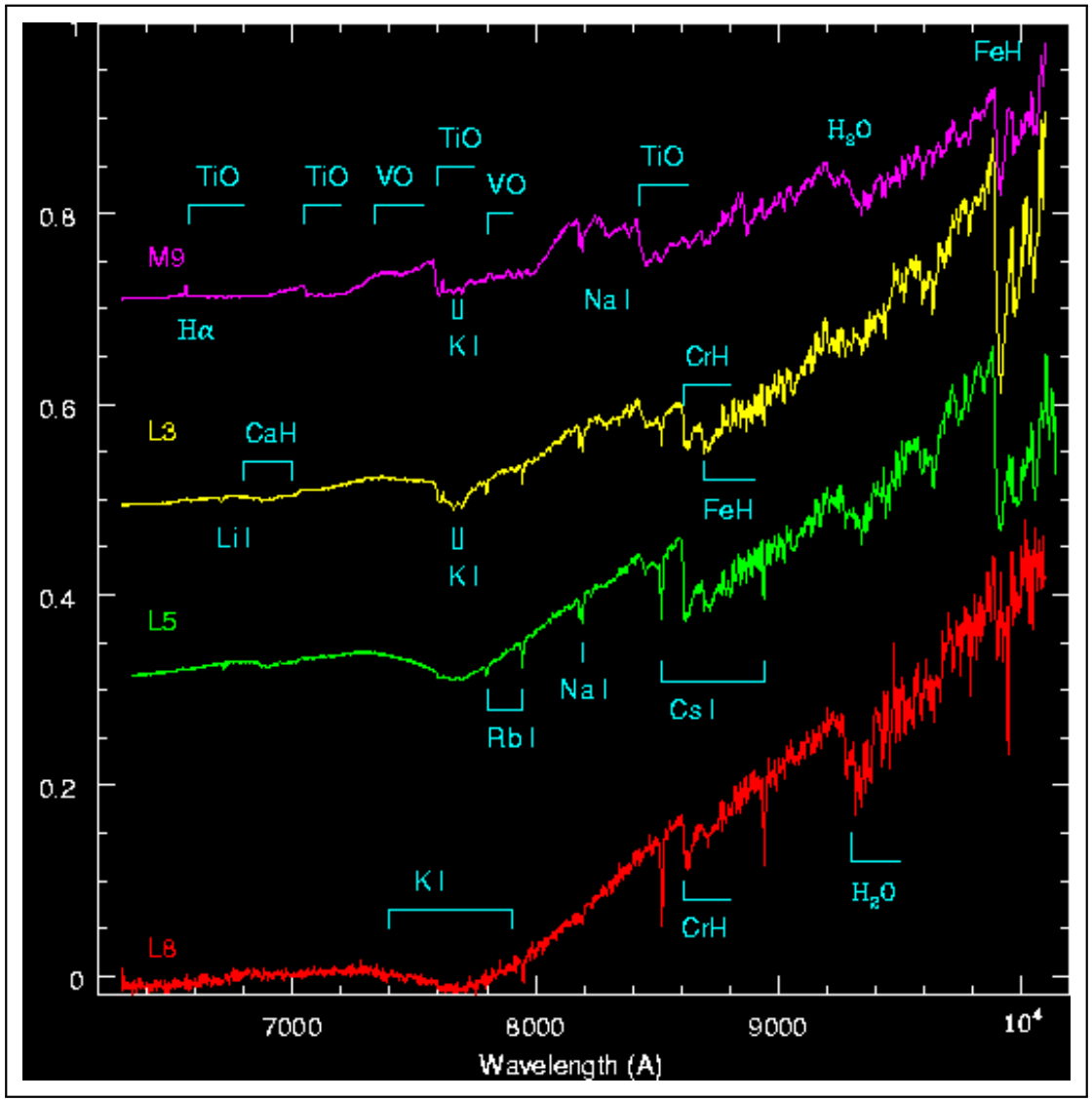
How we study CrH

Simulations with STOPRO

- Individual lines
- $0 - 0$ band

Outlook

Why CrH? Fig. from http://www.stsci.edu/∼inr/ldwarf1.html



Objectives

- linelist for CrH,
- line strengths (in the absence/presence of a mag. field),
- simulation of a CrH spectra (Stokes I, Q and V),
- observations.

Hamiltonian for $^6\Sigma$ el. state

$$\hat{\mathcal{H}} = \underbrace{\hat{\mathcal{H}}_{\text{int}} + \hat{\mathcal{H}}_{\text{rot}} + \hat{\mathcal{H}}_{\text{so}} + \hat{\mathcal{H}}_{\text{sr}} + \ldots}_{\text{Ram et al. 1993}} + \underbrace{\hat{\mathcal{H}}_H}_{\text{Berdyugina et al. 2005}}$$

- eigenvalues,
- eigenvectors.

Intensity

$$I_{n''}^{n'} \propto A_{n''}^{n'} \propto \sum \left| R_{n''}^{n'} \right|^2 ,$$

where

$$\sum_{M'M''} \left| R_{n''}^{n'} \right|^2 = f_e \times q_{v'v''} \times \underbrace{\sum_{M'M''} q^2_{\Omega'\Omega'' J' J'' M' M''}}_{\text{line strength}}$$

Amplitudes

$$q_{\Omega'\Omega'' J' J'' M' M''}{}^{1} = q_{\Omega'\Omega'' J' J''} \times q_{J' J'' M' M''}$$

$$q^{(b)}_{\Omega'_i\Omega''_j J'_k J''_l} = \sum_{\Omega'_i} \sum_{\Omega''_j} C^{*}_{\Omega'_i J'_k} \; q^{(a)}_{\Omega'_i\Omega''_j J'_k J''_l} \; C_{\Omega''_j J''_l}$$

$$q^{pb}_{\Omega'_k\Omega''_l J'_k J''_l M'_{km} M''_{ln}} = \sum_{M'_k} \sum_{M''_l} C^{*}_{J'_k M'_{km}} \; q^{(b)}_{\Omega'_k\Omega''_l J'_k J''_l} \; q_{J'_k J''_l M'_{km} M''_{ln}} \; C_{J''_l M''_{ln}}$$

Indices:

$i, j = -5/2, -3/2, \ldots, 5/2$	case (a)
$k, l = -5/2, -3/2, \ldots, 5/2$	case (b)
$m, n = -J, -J+1, \ldots, J$	both cases

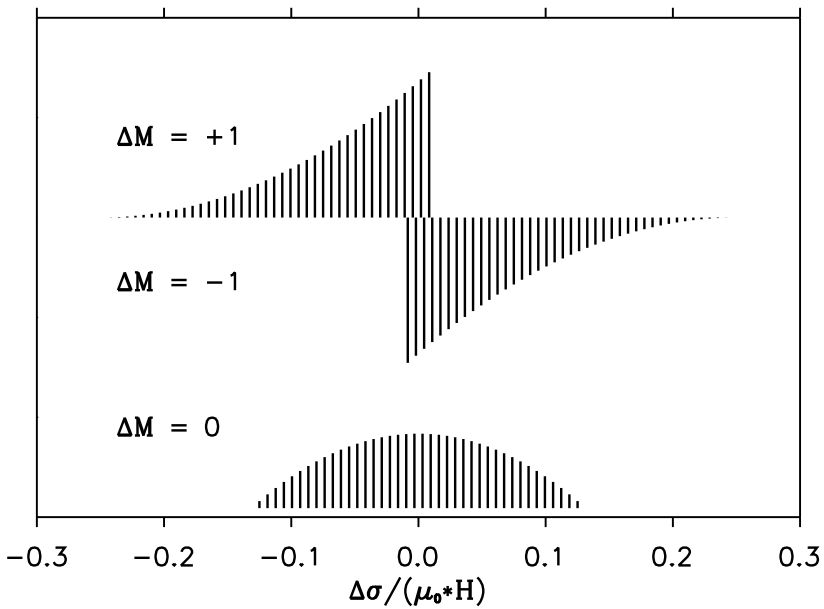
[1] Schadee 1978

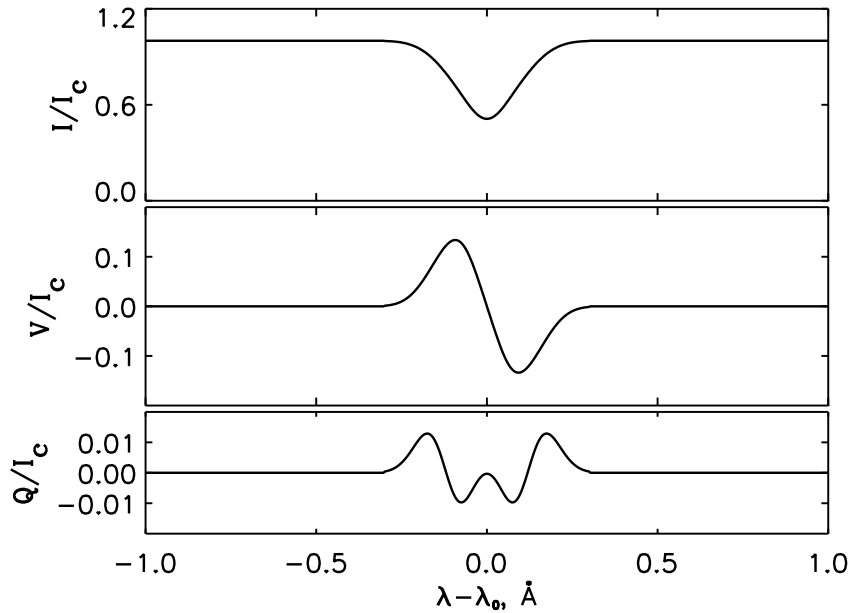
Recipe for simulations with STOPRO[2]

- linelist
  - energies of transitions
  - strengths of transitions
- spectroscopic data:
  damping constants, FC factor, ...
- atmospheric model ($T = 2500$ K, $\log g = 4.5$)
- strength of the mag. field
- orientation of the mag. field ($\chi = 0°$, $\gamma = 45°$)

[2] Solanki 1987 and Solanki et al. 1992

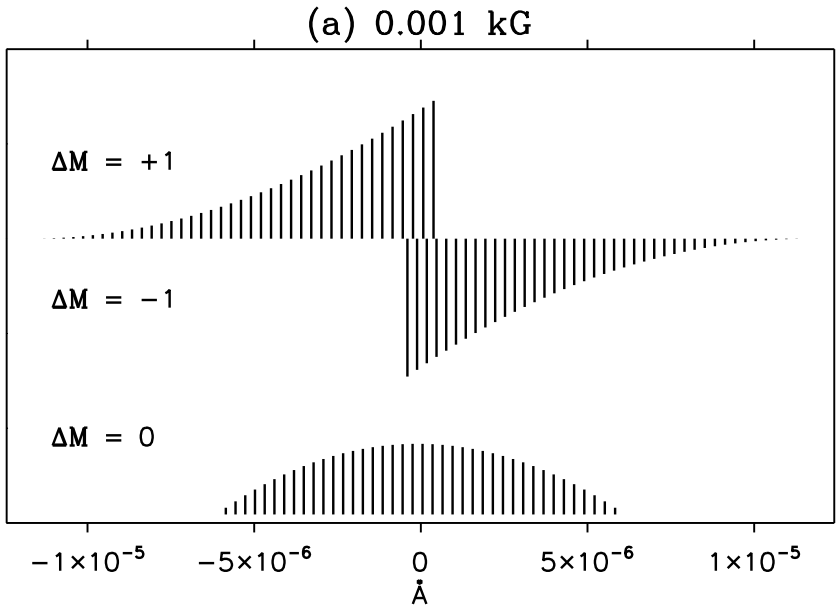
Zeeman regime

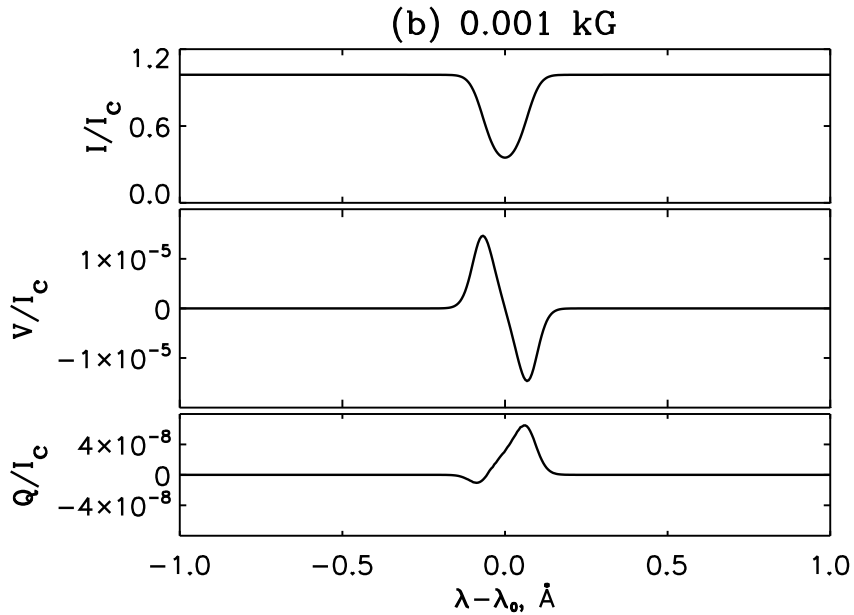




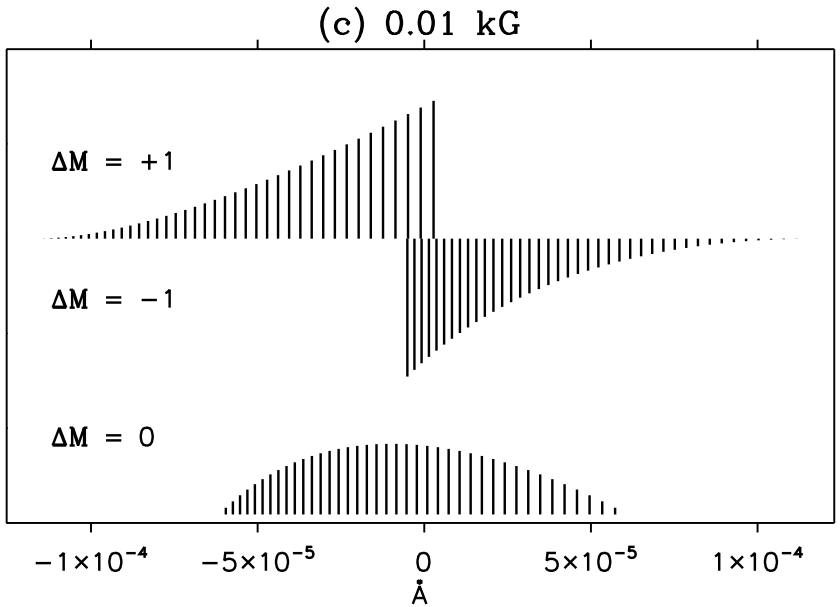
$$\Delta E = g\mu_0 MH$$

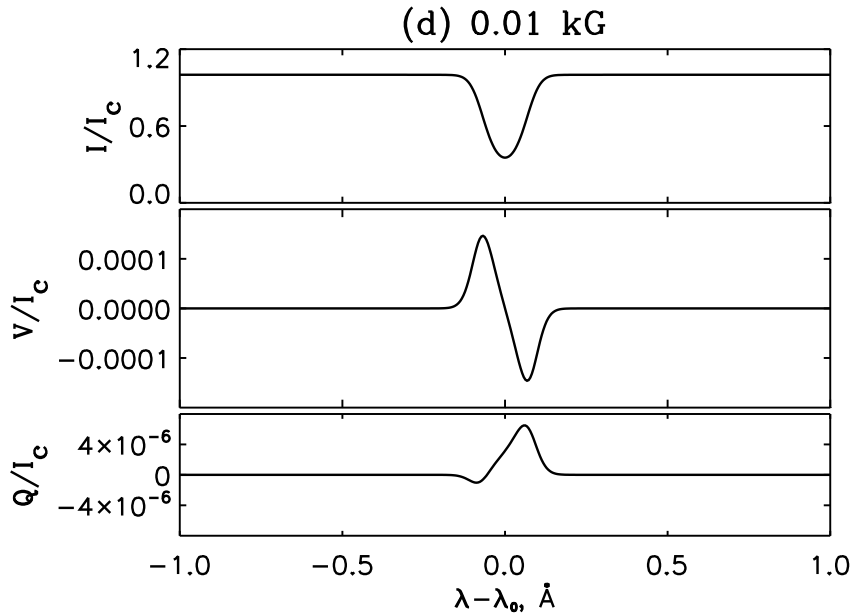
Paschen-Back regime



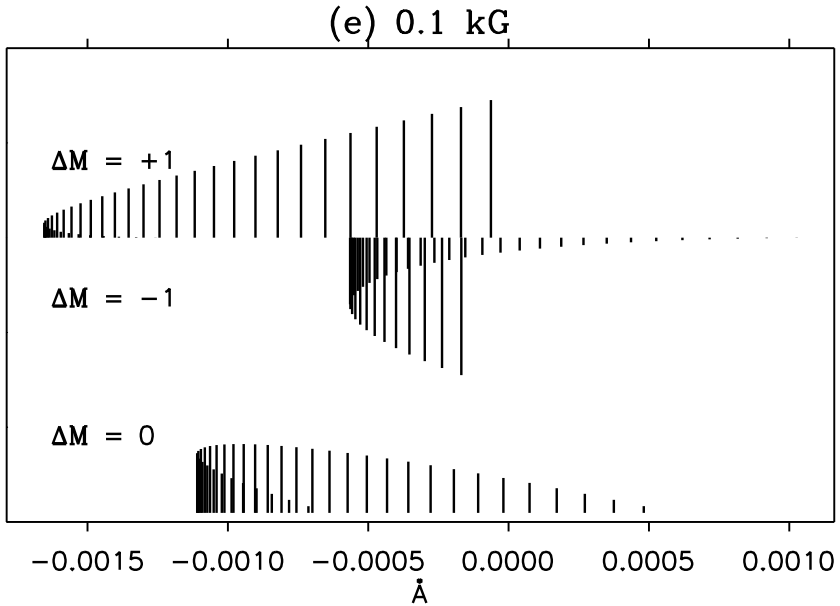


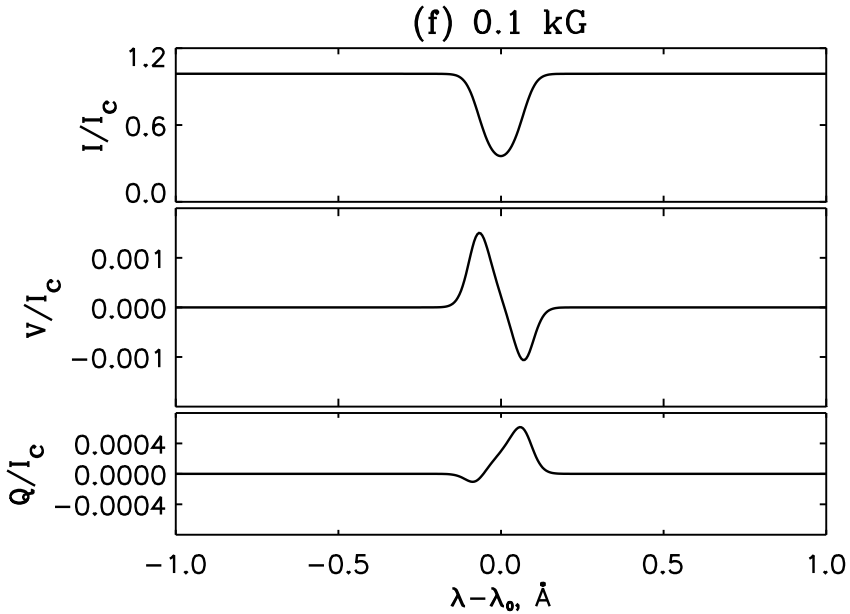
Paschen-Back regime



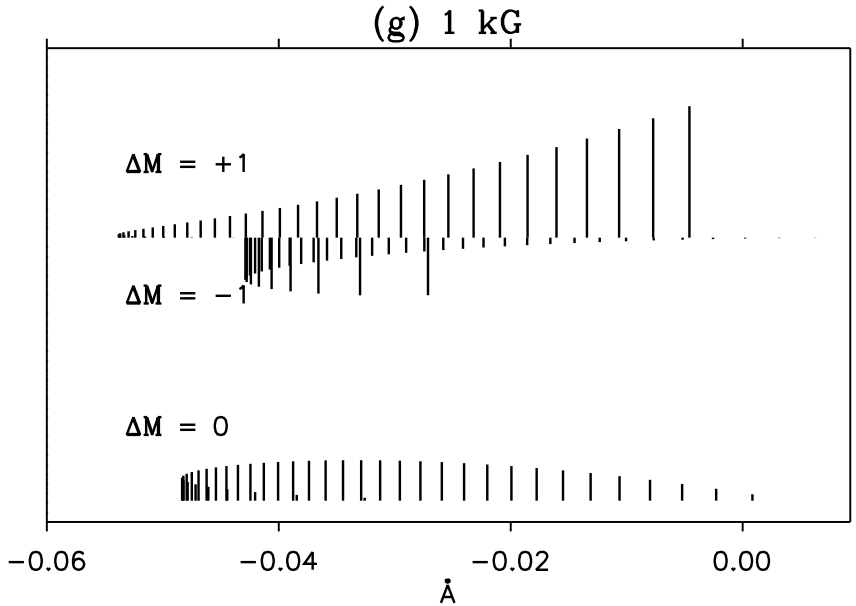


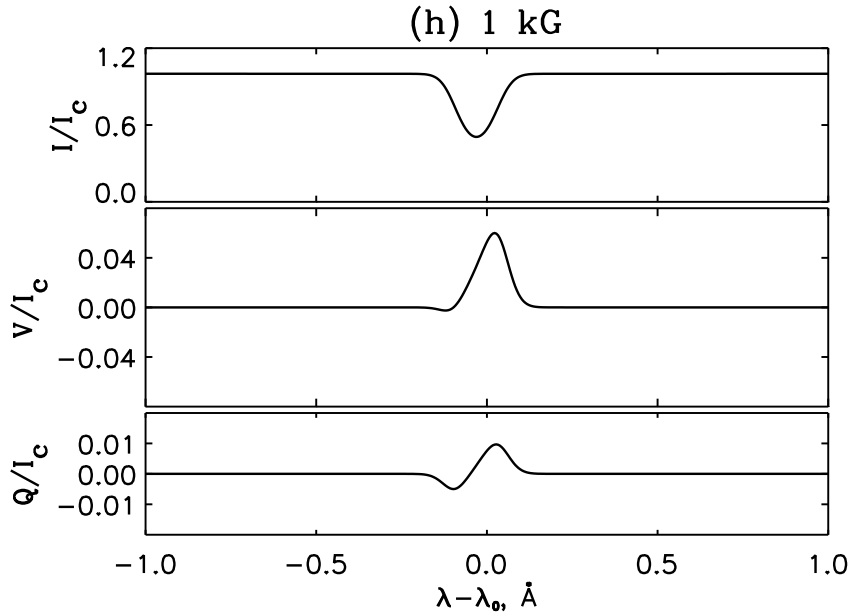
Paschen-Back regime



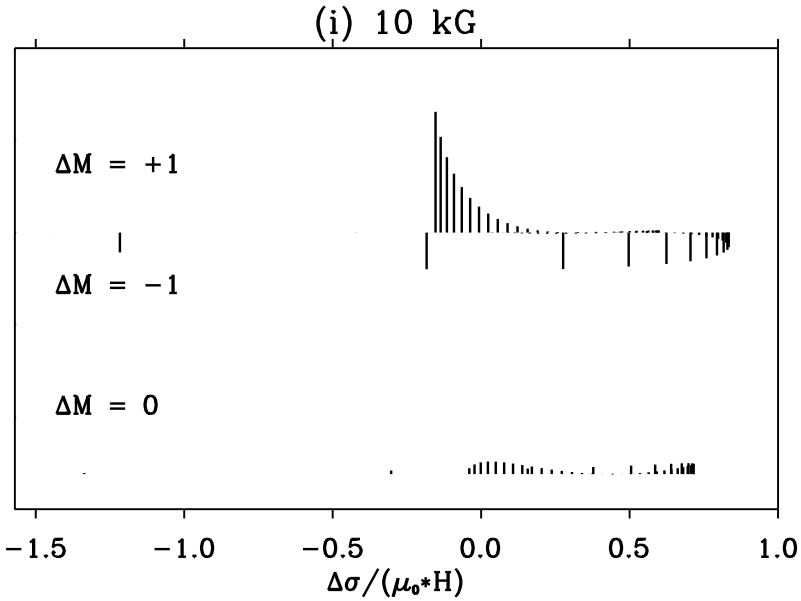


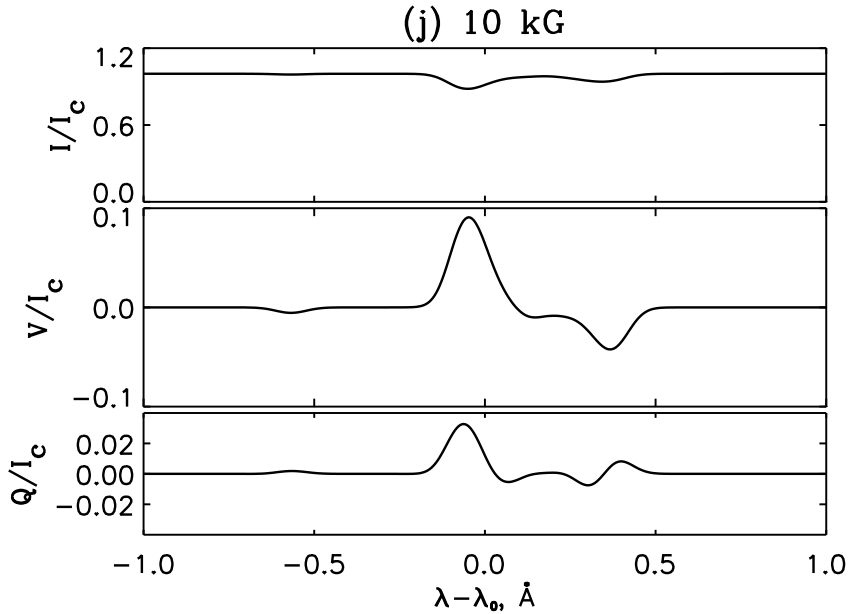
Paschen-Back regime

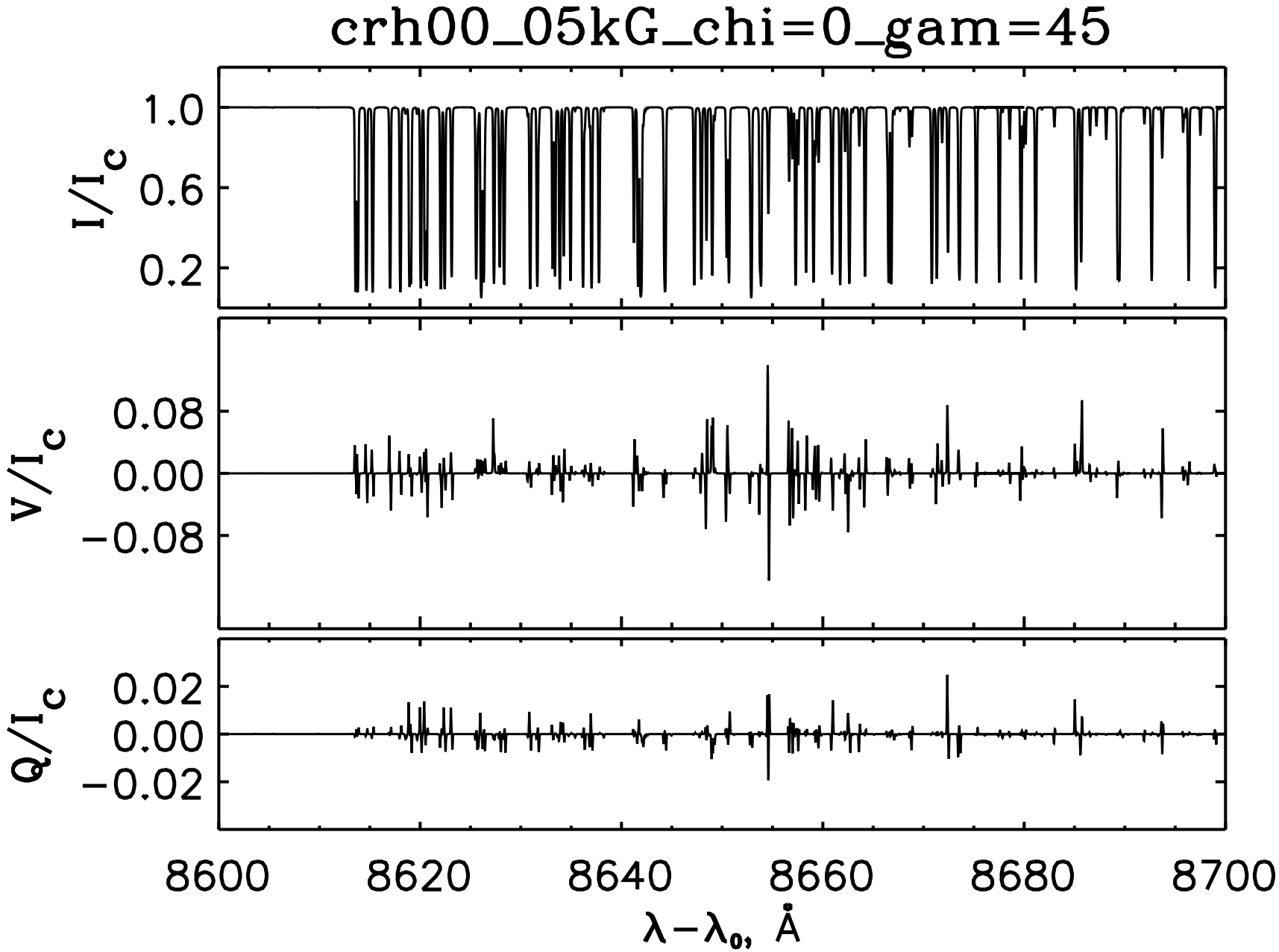




Paschen-Back regime



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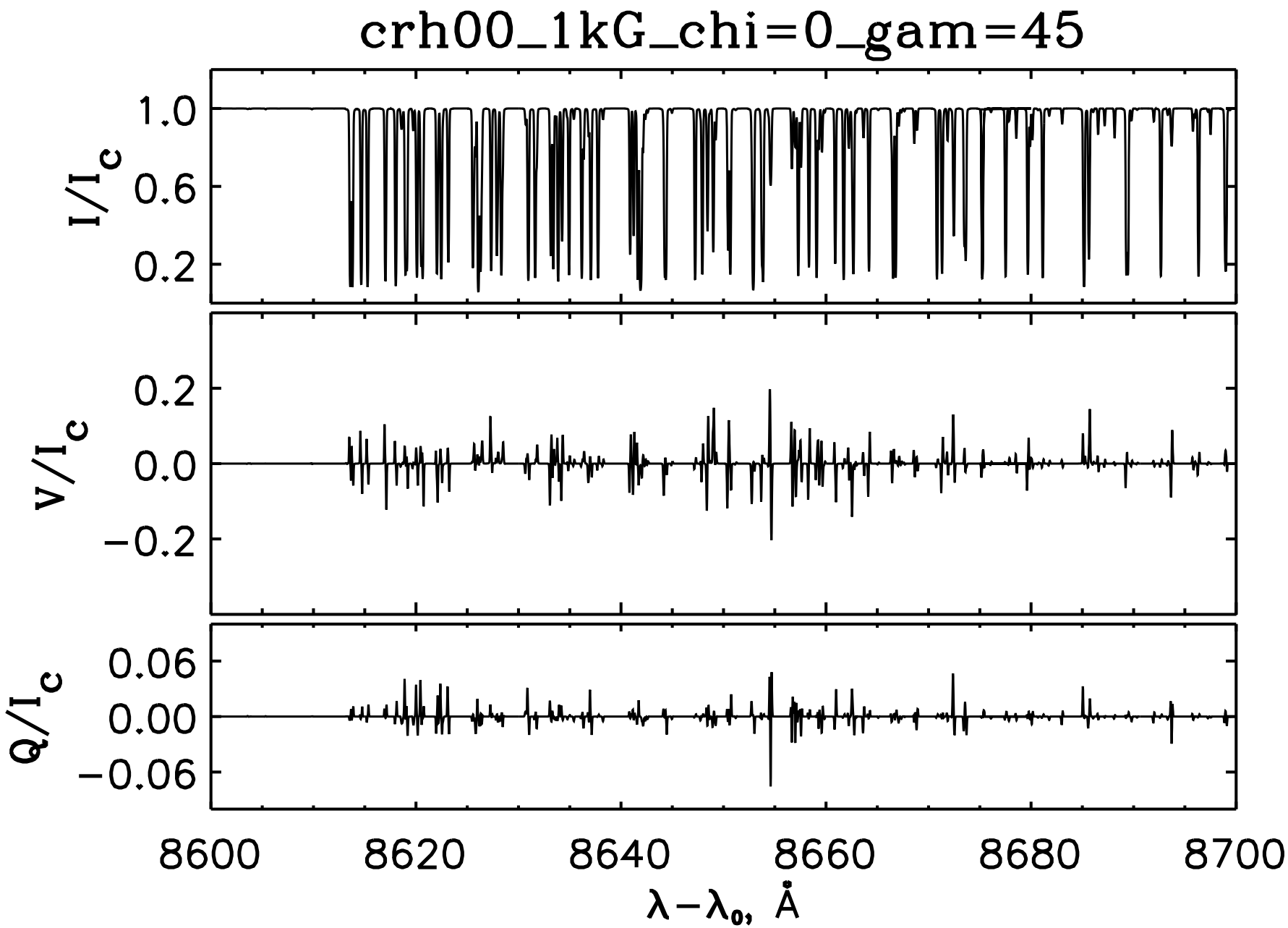
0.2
V/I_c
0.08
0.00
−0.08
Q/I_c
0.02
0.00
−0.02
8600
8620
8640
8660
8680
8700
λ−λ_0, Å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V/I_c
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Q/I_c
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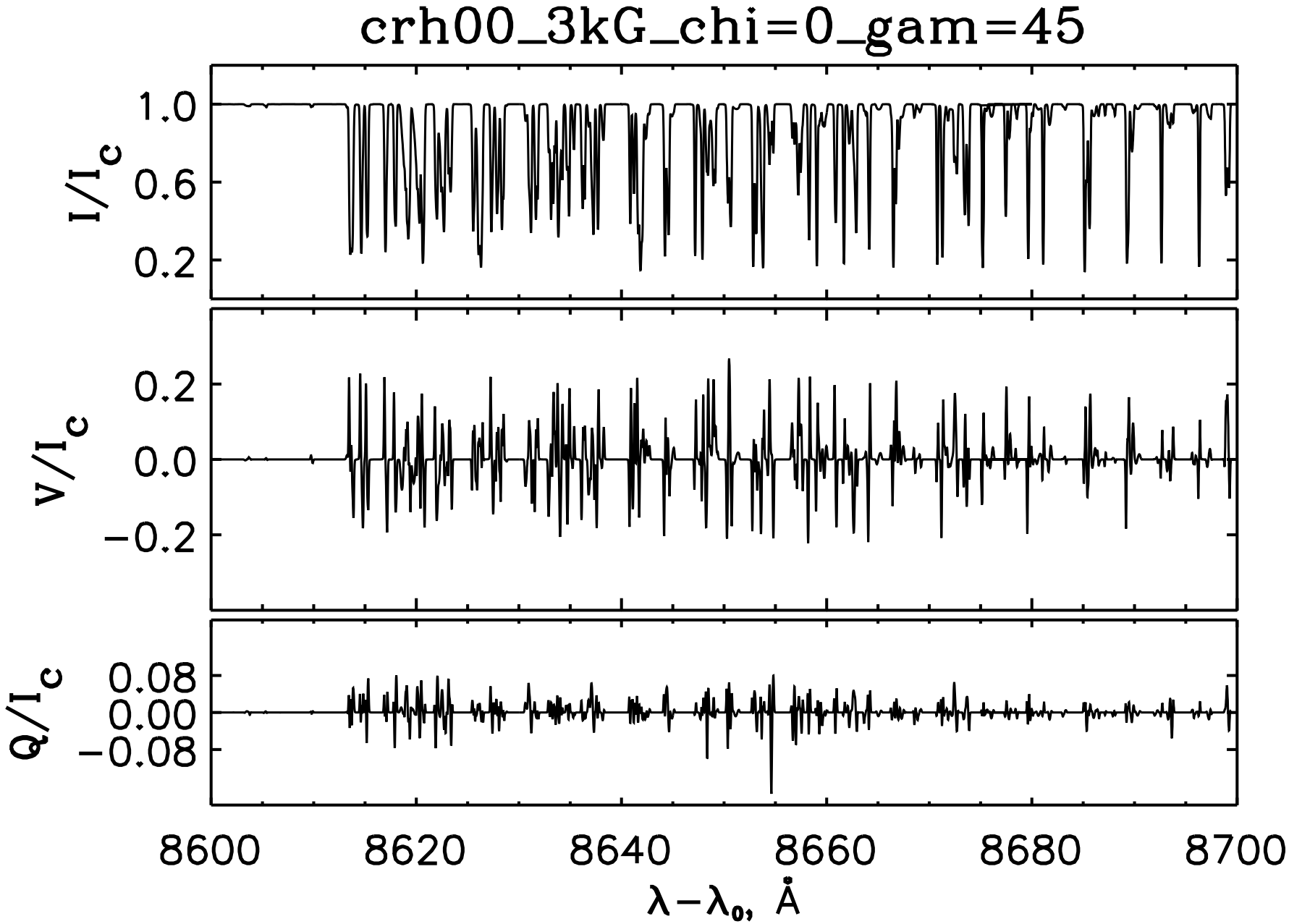
0.00
−0.06
8600
8620
8640
8660
8680
8700
λ−λ_0, Å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V/I_c
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Q/I_c
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0.00
−0.08
8600
8620
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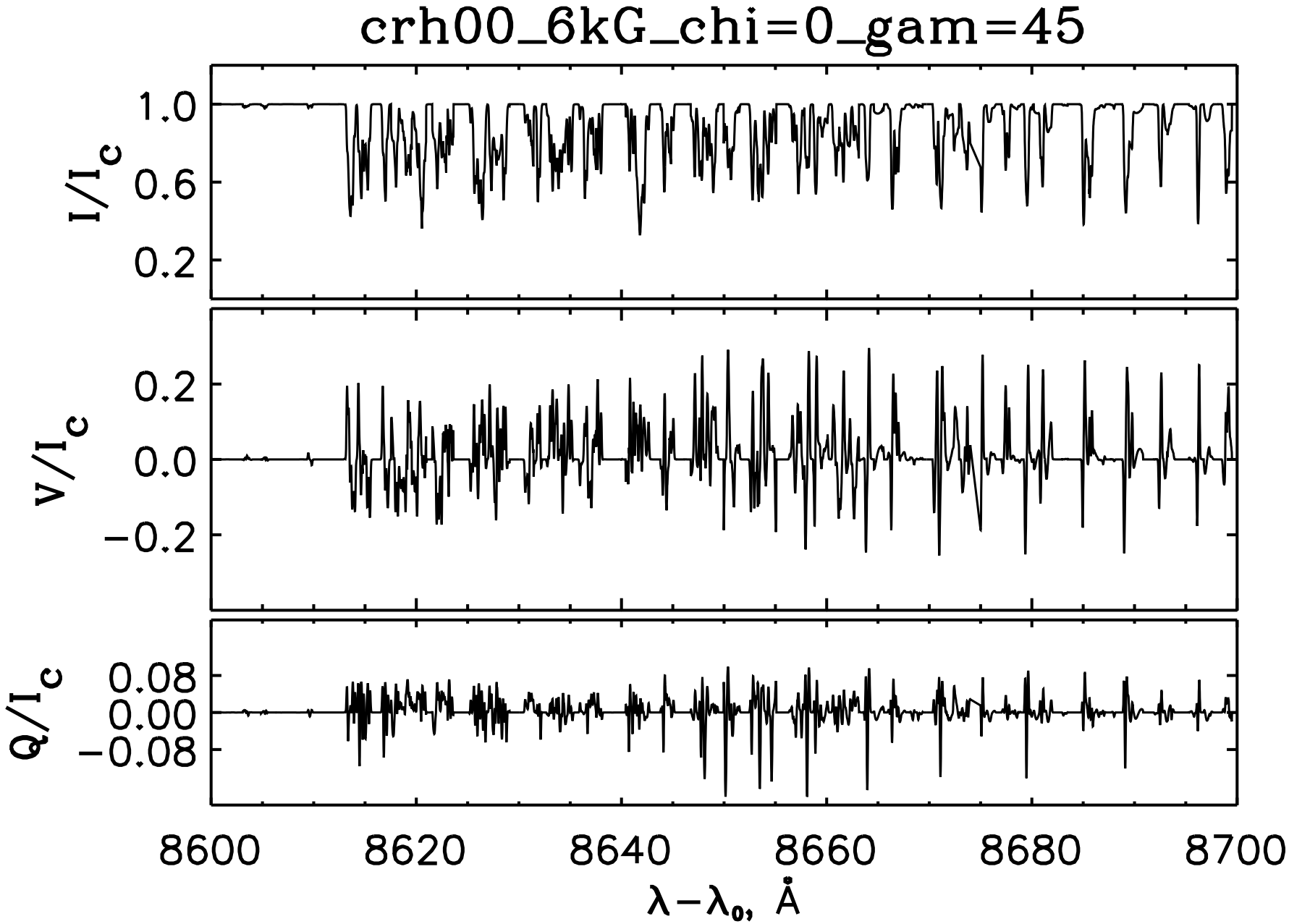
λ−λ_0, Å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V/I_c
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0.0
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Q/I_c
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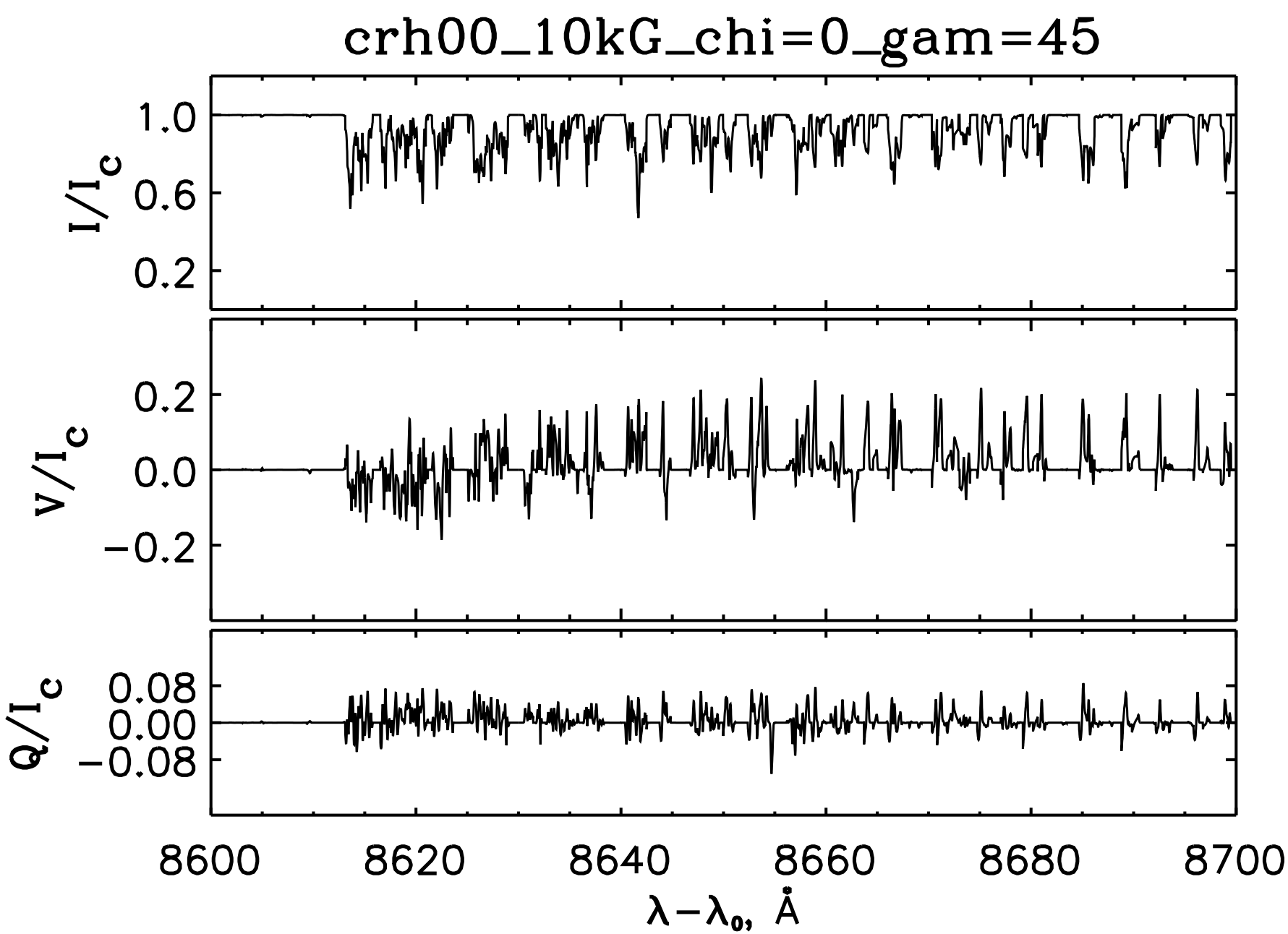
λ−λ_0, Å


crh00_10kG_chi=0_gam=45
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0.6
0.2
V/I_c
0.2
0.0
−0.2
Q/I_c
0.08
0.00
−0.08
8600
8620
8640
8660
8680
8700
λ−λ_0, Å

Summary & Outlook

- promising potential of the CrH,
- observing campaign is pursued,
- if success $\Rightarrow$ first mag. field maps for L-dwarfs.