Determination of the Magnetic Field Vector via the Hanle and Zeeman effects in the He I 10830 A Multiplet: Evidence for nearly vertical magnetic fields in a polar crown prominence

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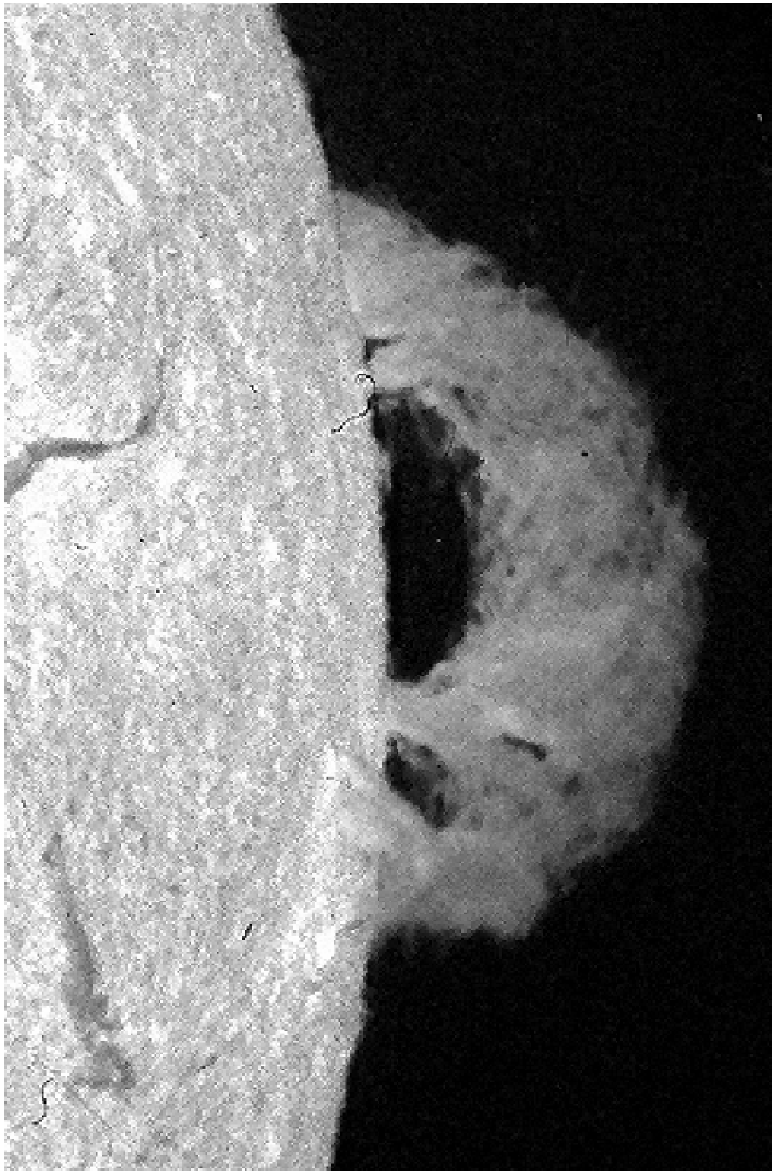


Our reaserch focuses on magnetic field measurements in solar prominences

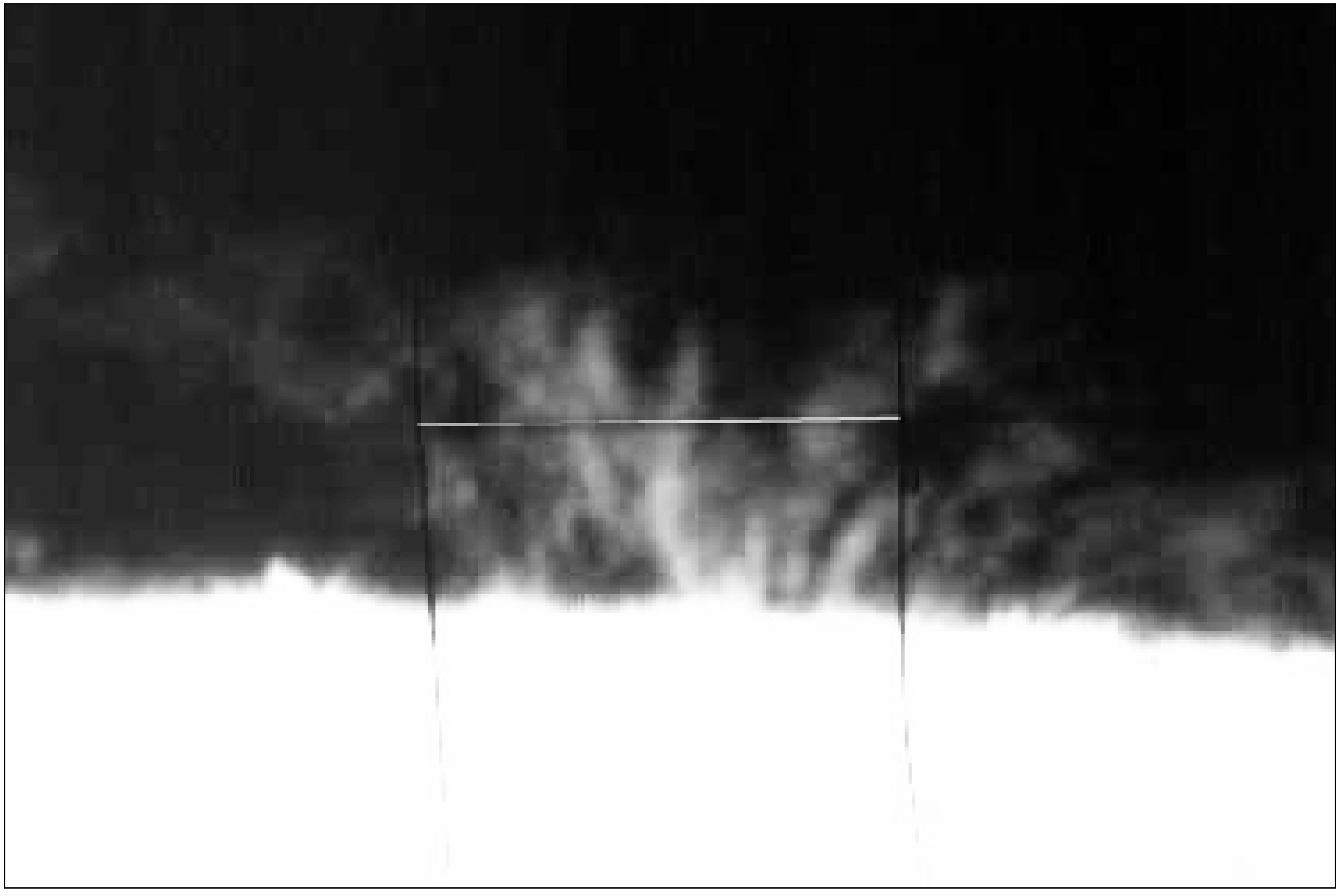
The magnetic field vector is inferred via the theoretical modelling of spectropolarimetric observations in the He I 10830 A multiplet.

The observed polarization is sensitive to magnetic fields via the Hanle and Zeeman effects.

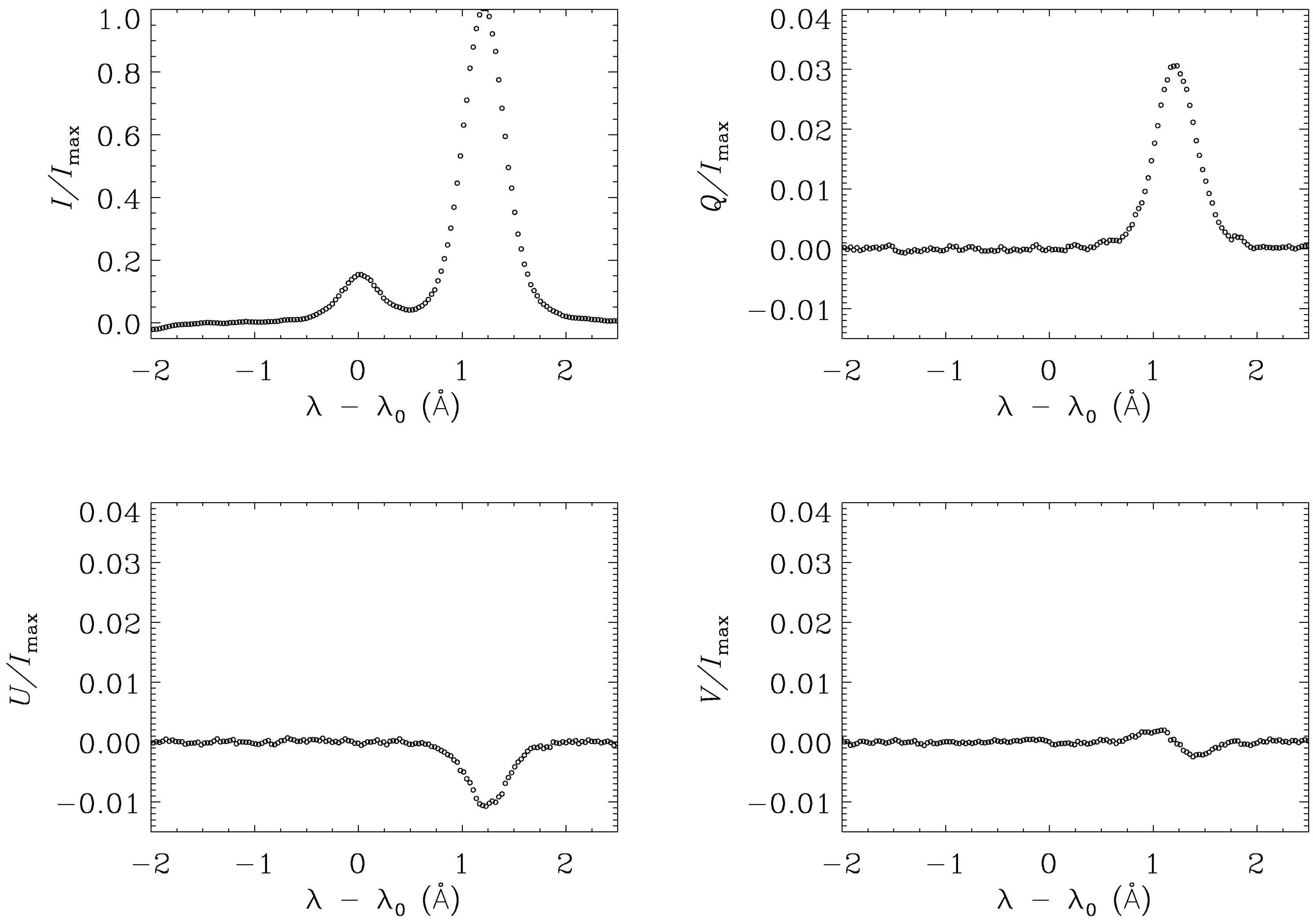
Observations obtained during May 2001
at the Teide Observatory, Canary Islands,

using the
Tenerife Infrared Polarimeter (TIP)
attached to the Vacuum Tower Telescope

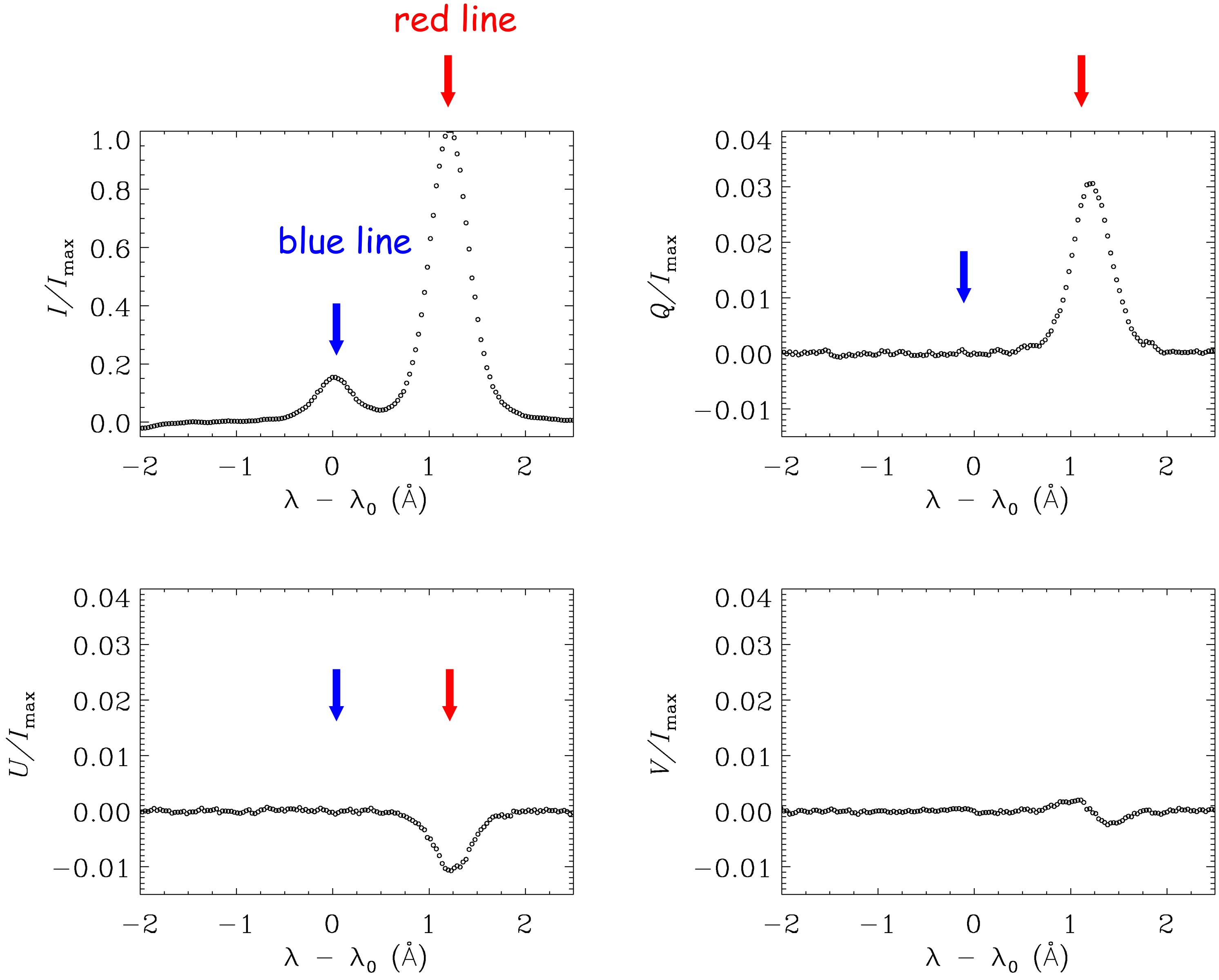
Observation of a polar prominence



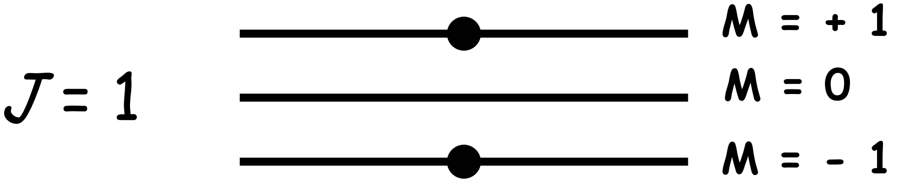
Example of an observation (He I 10830 Å multiplet)

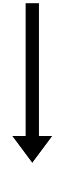


Example of an observation (He I 10830 Å multiplet)



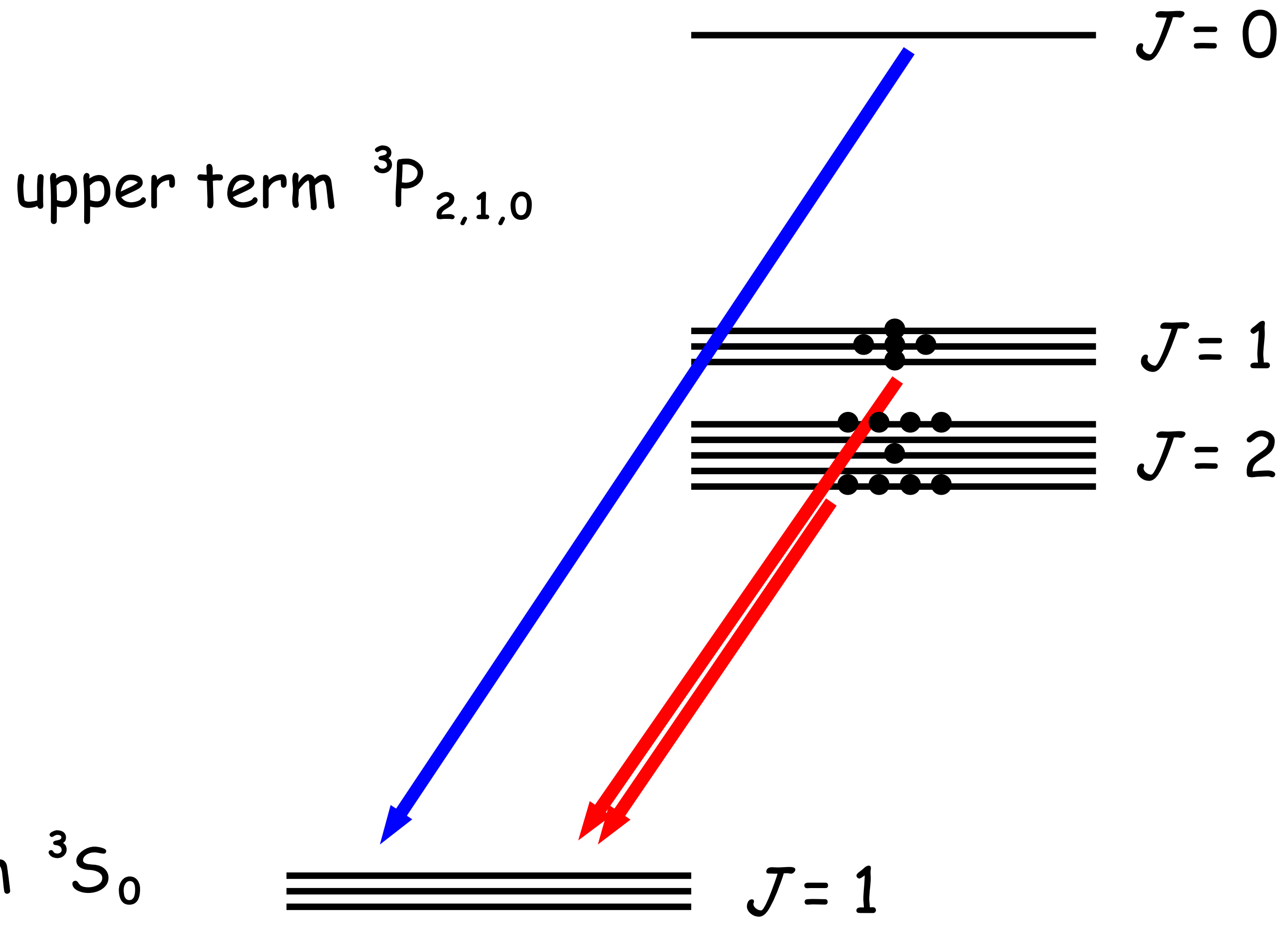
polarized atom





emission of polarized light

The 10830 Å multiplet



In the case of solar prominences the unpolarized and anisotropic photospheric illumination produces atomic level polarization.

The magnetic field reduces and modifies the atomic polarization (Hanle effect).

It is convenient to introduce appropriate combinations of the elements of the atomic density matrix called irreducible spherical tensor

$$ {}^{\beta LS}\rho^K_Q(J,J') = \sum_{jMj'M'} C^j_J(\beta LS,M)C^{j'}_{J'}(\beta LS,M') \times (-1)^{J-M}\sqrt{2K+1}\begin{pmatrix} J & J' & K \\ M & -M' & -Q \end{pmatrix}\rho_{\beta LS}(jM,j'M'). $$

where $K = 0, \ldots, 2J$ (if $J<J'$) and $-K \le Q \le K$

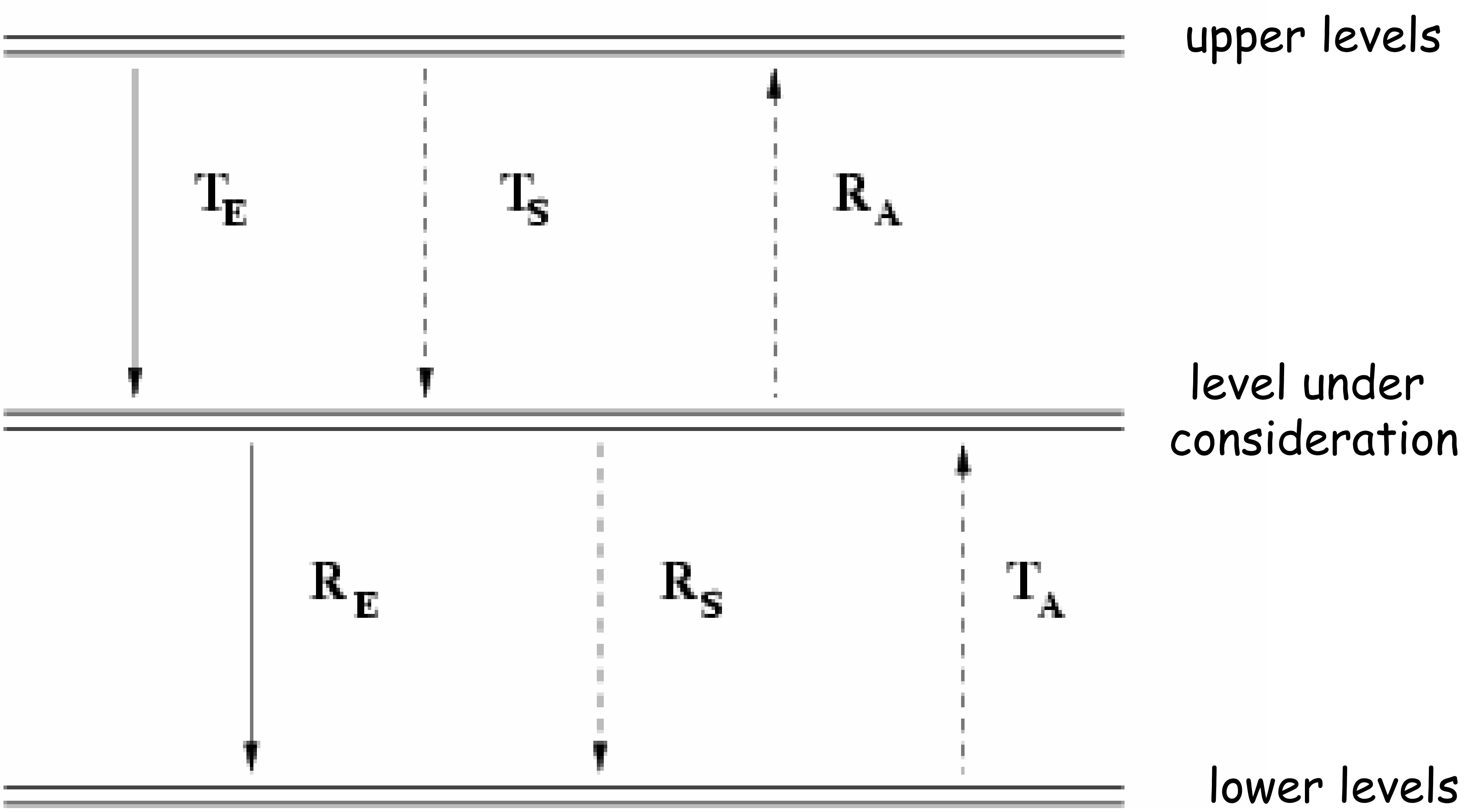
ρ^0_0 : populations

ρ^K_Q : population imbalances and coherences

Statistical equilibrium equations

$$
\begin{aligned}
\frac{\mathrm{d}}{\mathrm{d}t}\,{}^{\beta LS}\rho^K_Q(J,J') = -2\pi\mathrm{i} \sum_{K'Q'J''J'''} & \mathbf{N}(\beta LS;KQJJ';K'Q'J''J''')\ {}^{\beta LS}\rho^{K'}_{Q'}(J'',J''') \\
+ \sum_{\beta_l L_l K_l Q_l J_l J'_l} & \mathbf{T}_\mathrm{A}(\beta LSKQJJ';\beta_l L_l S K_l Q_l J_l J'_l)\ {}^{\beta_l L_l S}\rho^{K_l}_{Q_l}(J_l,J'_l) \\
+ \sum_{\beta_u L_u K_u Q_u J_u J'_u} & \mathbf{T}_\mathrm{E}(\beta LSKQJJ';\beta_u L_u S K_u Q_u J_u J'_u)\ {}^{\beta_u L_u S}\rho^{K_u}_{Q_u}(J_u,J'_u) \\
+ \sum_{\beta_u L_u K_u Q_u J_u J'_u} & \mathbf{T}_\mathrm{S}(\beta LSKQJJ';\beta_u L_u S K_u Q_u J_u J'_u)\ {}^{\beta_u L_u S}\rho^{K_u}_{Q_u}(J_u,J'_u) \\
- \sum_{K'Q'J''J'''} & \mathbf{R}_\mathrm{A}(\beta LS;KQJJ';K'Q'J''J''')\ {}^{\beta LS}\rho^{K'}_{Q'}(J'',J''') \\
- \sum_{K'Q'J''J'''} & \mathbf{R}_\mathrm{E}(\beta LS;KQJJ';K'Q'J''J''')\ {}^{\beta LS}\rho^{K'}_{Q'}(J'',J''') \\
- \sum_{K'Q'J''J'''} & \mathbf{R}_\mathrm{S}(\beta LS;KQJJ';K'Q'J''J''')\ {}^{\beta LS}\rho^{K'}_{Q'}(J'',J''')
\end{aligned}
$$

Radiative rates



Emission coefficients of the polarized radiation:

$$\epsilon_i(\nu,\vec{\Omega}) = \frac{h^2\nu^4}{2\pi c^2}\mathcal{N} \sum_{\beta_u L_u S \beta_l L_l} (2L_u+1)\, B(\beta_u L_u S \rightarrow \beta_l L_l S)$$

$$\times \sum_{KQ} J_u J_u' (-1)^{1-L_l+S+J_u+K} \sqrt{3(2J_u+1)(2J_u'+1)}$$

$$\times \left\{ \begin{matrix} L_u & L_u & K \\ J_u & J_u' & S \end{matrix} \right\} \left\{ \begin{matrix} 1 & 1 & K \\ L_u & L_u & L_l \end{matrix} \right\}$$

where *i* = I, Q, U, V

$$\times \mathcal{T}_Q^K(i,\vec{\Omega}) \; {}^{\beta_u L_u S}\rho_Q^K(J_u', J_u) \; \phi(\nu_{\beta_u L_u S, \beta_l L_l S} - \nu)$$

geometrical tensor

populations and coherences

line profile

The magnetic field component along the line of sight ($B_{||}$) can be estimate by using the formula:

$$V(\lambda) = c\, B_{||} \frac{dI(\lambda)}{d\lambda} \qquad \text{(weak field)}$$

for all the observed points along the slit, $B_{||}$ is always > 10 gauss

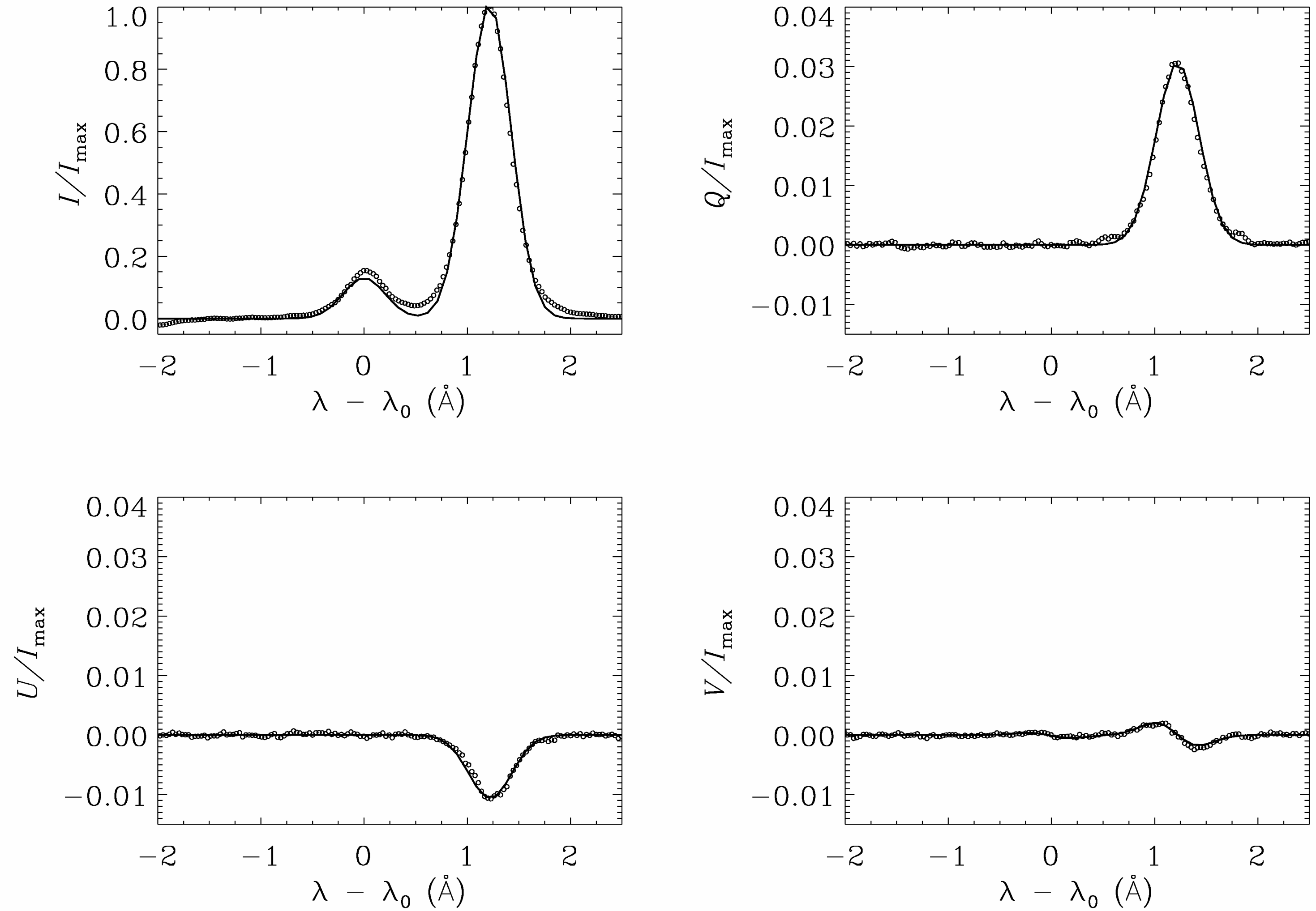
For magnetic fields stronger than 10 gauss
the 10830 A line enters into the saturation regime.

Saturation regime means that
the linear polarization
is no more a function of the magnetic field strength,
but only a function
of the **direction** of the magnetic field vector

The observed Stokes *Q* and *U* parameters are contrasted with the theoretical ones of the computed database.

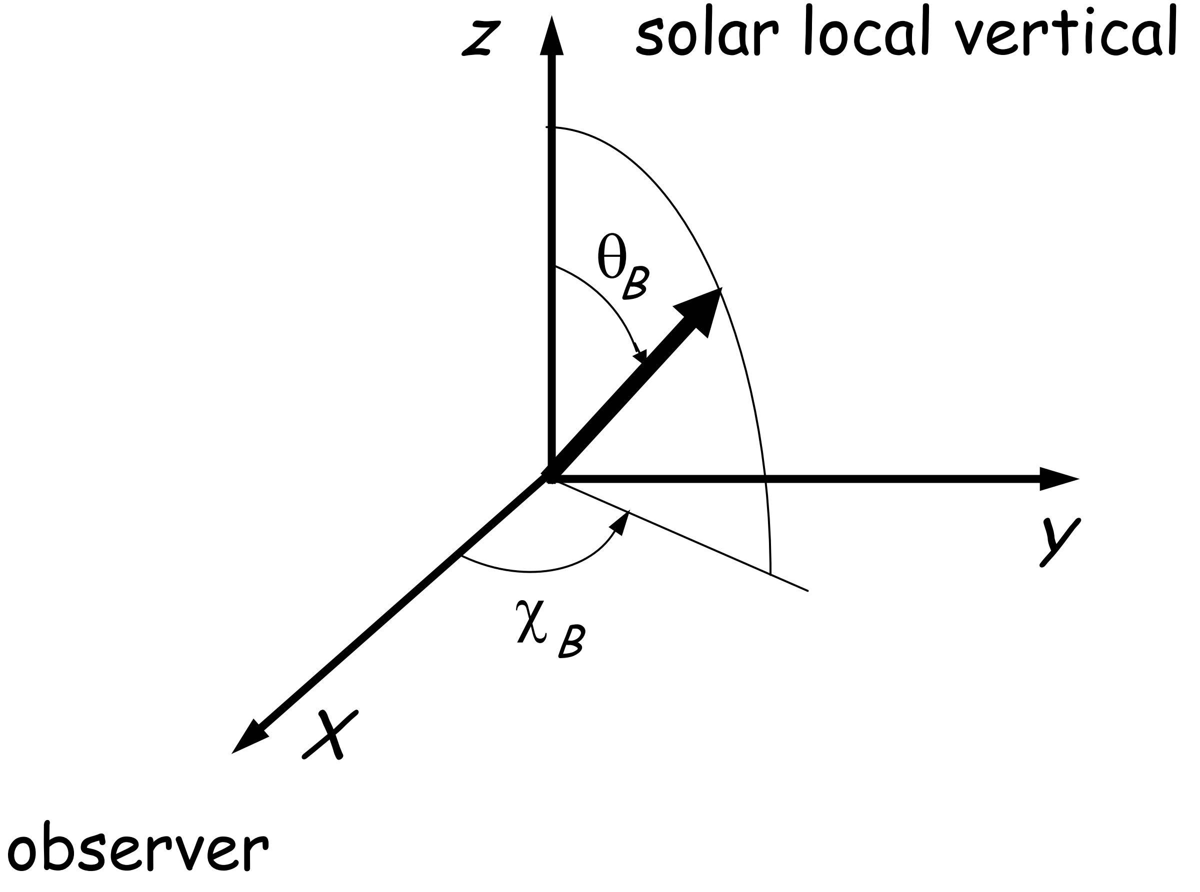
We infer the magnetic field intensity by using the circular polarization information

Example of a theoretical fit:

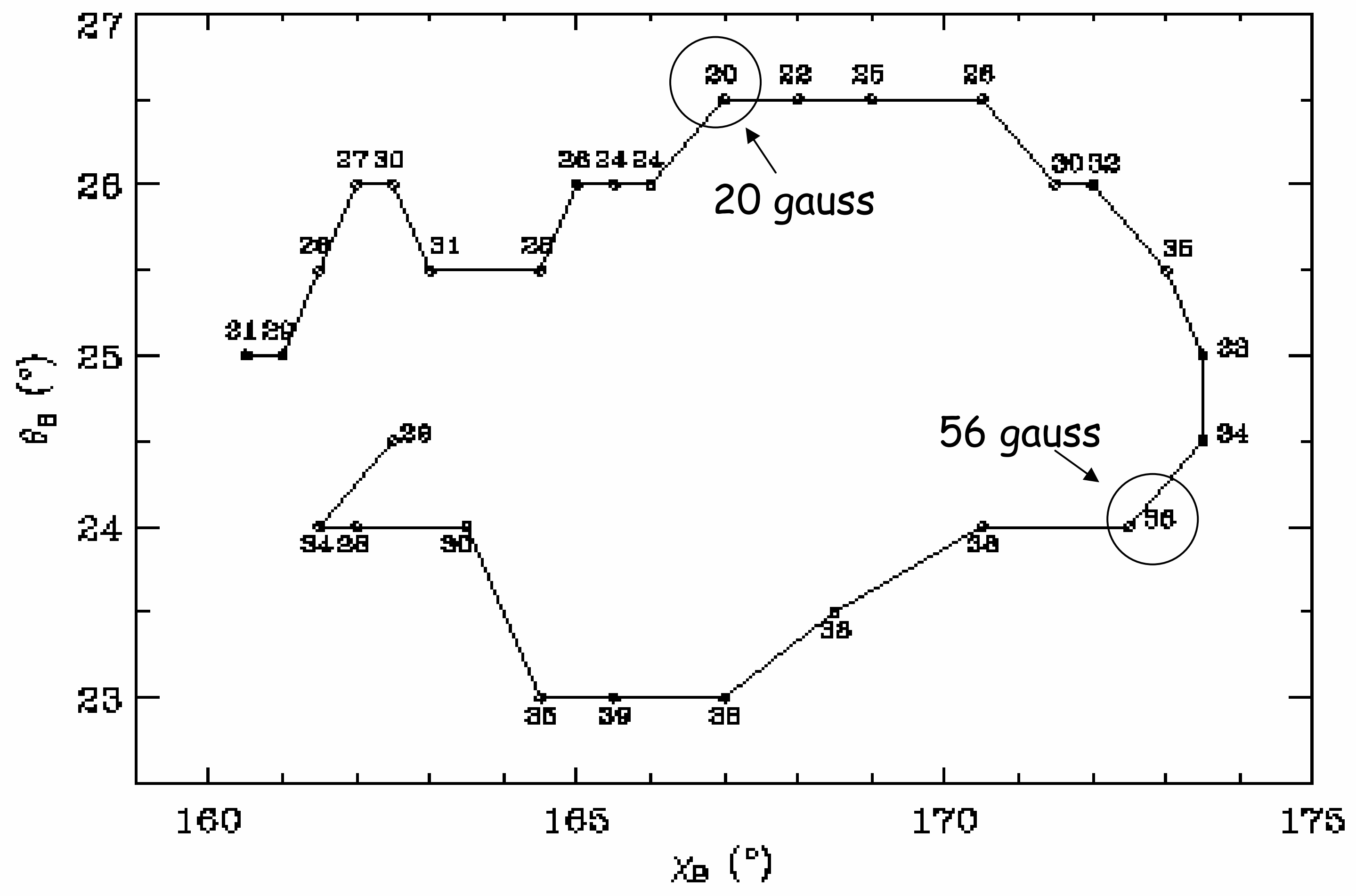


B = 26 Gauss inclination $\theta_{\mathbf{B}}$ = 25° *azimuth* $\chi_{\mathbf{B}}$ = 160°

reference frame



We find that the vector $\vec{B}$ rotates around a mean direction (θ_B =25° and χ_B =167°) as we move along the spatial direction of the slit



Conclusions for the observed polar prominence:

- magnetic field is mostly vertical: $\theta_{\mathbf{B}} = 25^{o}$
- the mean intensity is 30 gauss
- with a smooth spatial variation

Thank you for your attention

Our observed Stokes *Q* and *U* parameters are here contrasted with the theoretical ones of our computed database.