Direct spectroscopic measurements of active region magnetic fields of the solar corona

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Coronal Magnetic fields

- The magnetic field of the solar corona is one of the most critical parameters in solar physics; plays an important part in the origin of solar flares and the variations of space weather.
- Measurements of the coronal magnetic field are very difficult because of the weakness of its signatures.
- Current measurement status:
  - No direct space-based methods are currently available;
  - Ground-based side: radio observations, and spectropolarimetry of visible and near infrared radiation.

Magnetic-field induced transitions, MITs

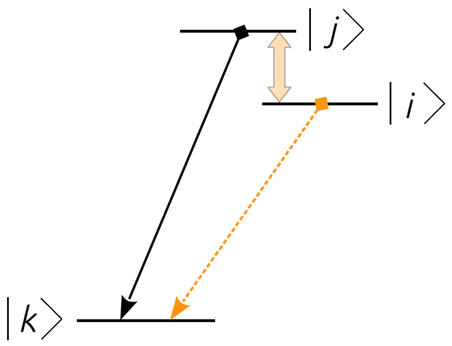

Figure: A simple three-level system

- State j has a “fast” decay channel to the ground state k; strong spectral feature
- State i is metastable; small transition probability $A(i \to k)$
- External magnetic fields mix i and j; a new line i $\to$ k – magnetic-field induced transition (MIT) [1]

$$A_{MIT}(i \to k) \propto A(j \to k)\frac{\mathbf{B}^2}{\lambda^3(\Delta E_{ij})^2}$$

$\Rightarrow$ MITs can therefore be used for magnetic field strength diagnostics.

MIT in Fe X

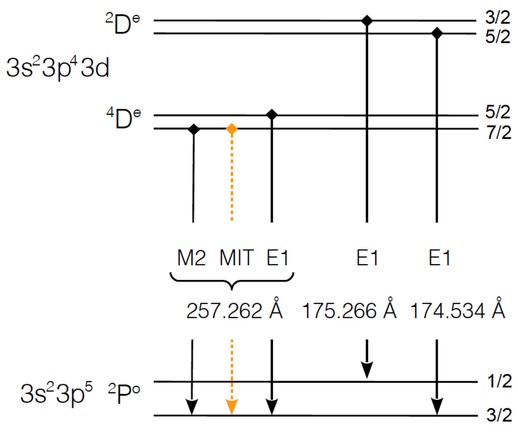

Figure: Schematic energy level diagram of Fe X

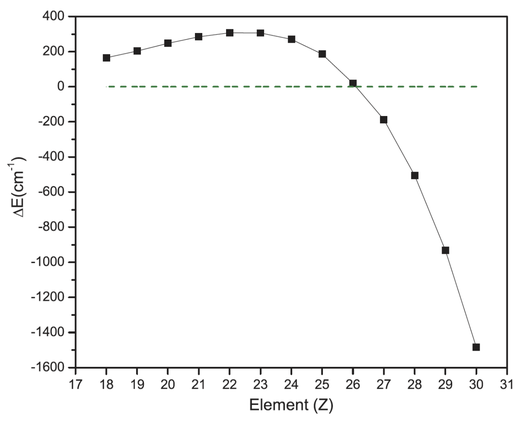

Figure: Pseudo-degeneracy of $^4D_{5/2,7/2}$ in Fe X

- $|\text{“}7/2\text{”}\rangle = c_1|7/2\rangle + c_2|5/2\rangle \Rightarrow A_{MIT}(7/2 \to 3/2) = |c_2|^2 A_{E1}(5/2 \to 3/2)$
- Pseudo-degeneracy of $^4D_{5/2,7/2}$ $\Rightarrow$ sensitive to the relatively weak magnetic fields [2].

Methodology

- 257.26 Å lines: E1 + M2 + MIT
- reference Fe X line: 175.266 Å or 174.534 Å line or other suitable line
- line ratio of reference line/256.26 is also density sensitive, therefore simultaneous determination of density is necessary, density diagnostic line pair: 175.266/174.534 or other suitable line pair
- Spectral modelling: CHIANTI database [3] + new published radiative transition data [4]
- This diagnostic technique can be applied to the existing EIS archive spanning from 2006 to 2020.

Measurements of an active region magnetic fields of the solar corona

- An active region observed on Nov. 4 2006 on the solar disk from Hinode/EIS [5]

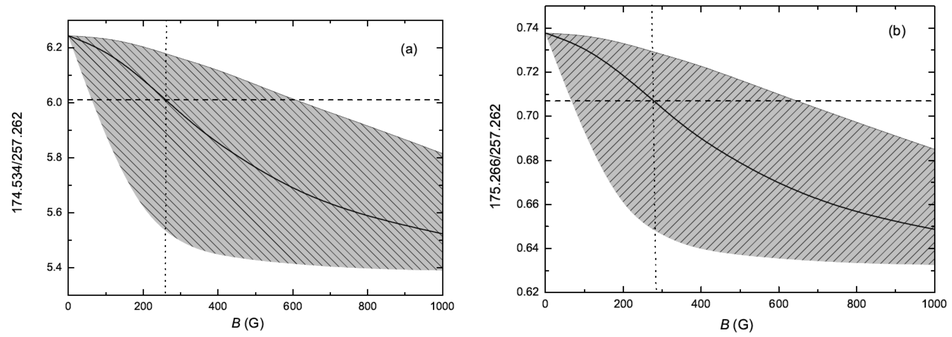

Figure: Simulated intensity ratio (black line) of (a) 174.534/257.262 and (b) 175.266/257.262 as a function of B. The grey shaded area shows the uncertainty caused by the uncertainty in the ΔE-parameter($\approx$ 80% uncertainty). The horizontal dashed line is the line ratio measured from HINODE. The vertical dotted line shows our estimated magnetic strength.

$\Rightarrow$ An average field of B_e = 270 G from 265 G and 275 G, more details can be found in [6].

- New effort has been made for the ΔE determination [7] and application of the diagnostic technique [8].

References and acknowledgement

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