New insights from Hinode-VTT He10830 observation

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Purpose: Finding chromospheric counterparts of THMFs (transient horizontal fields) seen in the photosphere

Cutoff due to the threshold and/or the sensitivity issue of Zeeman effect

Green: Vertical field, 13G
Yellow: THMF, 140G

THMFs reach the chromosphere?

\[
\frac{B^2}{8\pi} \approx P
\]

Pph: Gas pressure @ photosphere
Bph: field strength of THMFs @ photosphere, average: 400 G

Chromosphere: \(10^6\) m = 1000 km = 10 Hp
\(P_{ch} \sim e^{-10}P_{ph} \Rightarrow B_{ch} \sim e^{-5}B_{ph} = 2.7\) G

The magnetic field would be detected only by Hanle effect.

VTT-TIP He 1083 nm
+A few G to kG magnetic field can be detected with Hanle and Zeeman effect
+Inversion of Stokes profiles is available (understood)
+Simultaneous observation with photosphere of Si (easy to perform alignment with Hinode/SOT)

1083 nm: 2s3S-2p3p^0 absorption
Observation
SOT-NFI Na D magnetogram

SP FOV: 15\" x 82\", TIP FOV: 20\" x 78\"
Cadence: 7.5 min
Stokes signals are dominated by Zeeman effect.
Completely different from photosphere!!!

Stokes signals are dominated by Zeeman and Hanle.

Integration time: 7 sec
S/N: \(7 \times 10^{-4}\)
Spatial resolution: 0.64" (scan direction), 0.72" (slit direction)

FOV: 20" x 78"
Completely different from photosphere!!!

Stokes signals are dominated by Zeeman and Hanle.

Intensity Stokes-I

Linear pol.
$\sqrt{Q^2 + U^2}$

Circular pol.
Stokes-V

Chromospheric magnetic signals

FOV: 20" x 78"

VTT-TIP HeI 1083 nm

Example of Stokes profile

Stokes-I Si He

1082.6 1082.8 1083.0

Stokes-Q

1082.6 1082.8 1083.0

Stokes-U Hanle!

1082.6 1082.8 1083.0

Stokes-V

1082.6 1082.8 1083.0

Integration time: 7 sec S/N: 7x10^-4 Spatial resolution: 0.64" (scan direction), 0.72" (slit direction)
Chromospheric mag. signals 7.5 min later

Stokes signals have changed in 7.5 min!!!

Change of LP

Change of magnetic field vector in Hanle regime (field strength, azimuth, inclination)

FOV: 20"x78"

VTT-TIP HeI 1083 nm

Intensity Stokes-I

Linear pol. sqrt(Q^2+U^2)

Circular pol. Stokes-V
Possible case of emerging flux in the chromosphere

Chromosphere (HeI 1083nm)

Stokes-I Linear Pol. Circular Pol.

Photosphere (FeI 630nm)

LP between negative and positive patches in the photosphere
Possible case of emerging flux in the chromosphere

Chromosphere (HeI 1083nm)

Stokes-I  Linear Pol.  Circular Pol.

Photosphere (FeI 630nm)

7.5 min later

separating
Disappearance of chromospheric fields with photospheric magnetic cancellation

Chromosphere (HeI 1083nm)

8"

Linear Pol.

Circular Pol.

Stokes-I

Photosphere (FeI 630nm)
Disappearance of chromospheric fields with photospheric magnetic cancellation

Chromosphere (HeI 1083nm) 8" 7.5min later

Stokes-I  Linear Pol.  Circular Pol.

Photosphere (FeI 630nm)
Sudden appearances of chromospheric magnetic fields without photospheric signature

Chromosphere (HeI 1083nm)

Photosphere (FeI 630nm)
Sudden appearances of chromospheric magnetic fields without photospheric signature

Chromosphere
(HeI 1083nm)

Stokes-I
Linear Pol.
Circular Pol.

Photosphere
(FeI 630nm)

7.5min later

Significant difference in photospheric magnetic fields are not seen.
New insights from He 1083nm

- Chromospheric magnetic fields appear to be completely different from photosphere: for example.
  - Chromospheric small loops with the size of a few granules are detected.
  - Magnetic signals without photospheric counterparts are also found.

*Nice feature of He 1083*
- Purely chromospheric
- Enable us to detect 1G to a few kG with Hanle & Zeeman effects
- Easy to interpret (inversion code is already available)

*Lessons learned from Hinode observation*
- Long integration can be done, and we will be able to detect much weaker magnetic signals.
- Spectro-polarimetry is compatible with high spatial resolution.

*Disadvantage*
- He 1083 nm needs coronal illumination, and it may be difficult to observe the pure quiet region. Further verification should be needed.
- Spatial resolution (0.5" @50cm telescope) is not as good as that in visible light.

- Seeing free He 1083 observation potentially brings us to the new world of chromospheric magnetic fields.
**S/N comparison between VTT and Solar-C**

- **Size of telescope**
  - Solar-C: 50cm
  - VTT: 70cm

- **Telescope and spectrograph throughput**
  - Solar-C: 13.4% (assume SOT-SP at 630.2nm)
  - VTT: 1% (assume 70% atmosphere transmission)

- **Quantum efficiency of detector**
  - Solar-C: 60% (NICMOS)
  - VTT: 60% (NICMOS)

- **VTT-TIP He 1083nm**
  - Integration time: 24sec
  - S/N: $4 \times 10^{-4}$
  - Pixel size: 0.5”

- **Factor of** $(5/7)^2$ gain
- **Factor of 13.4 gain**
- **Factor of 1 gain**
S/N comparison between VTT and Solar-C

**Quantum efficiency of detector**
- Solar-C: 60% (NICMOS)
- VTT: 60% (NICMOS)

**Factor of 1 gain**

**Total gain of Solar-C relative to VTT:** Factor of 7 gain

**VTT-TIP He 1083nm**
- Integration time: 24sec
- S/N: $4 \times 10^{-4}$
- Pixel size: 0.5"

**Gain**
- Factor of $(5/7)^2$ gain

**Telescope and spectrograph throughput**
- Solar-C: 13.4%
- VTT: 1%

**(assume SOT-SP at 630.2nm)**

**S/N comparison between VTT and Solar-C**

**Solar-C exposure time:** 24 sec/7 < 4sec
S/N comparison between VTT and Solar-C

**Total gain of Solar-C relative to VTT:**
Factor of 7 gain

**Solar-C exposure time:**
24 sec / 7 < 4 sec

50cm Solar-C telescope is factor of 7 more sensitive than VTT

- Achieve better S/N by increasing integration time
- Scan with higher cadence keeping the good S/N
- Achieve better spatial resolution keeping good S/N