

Observations of absolute convective blue-shifts with LARS at the VTT

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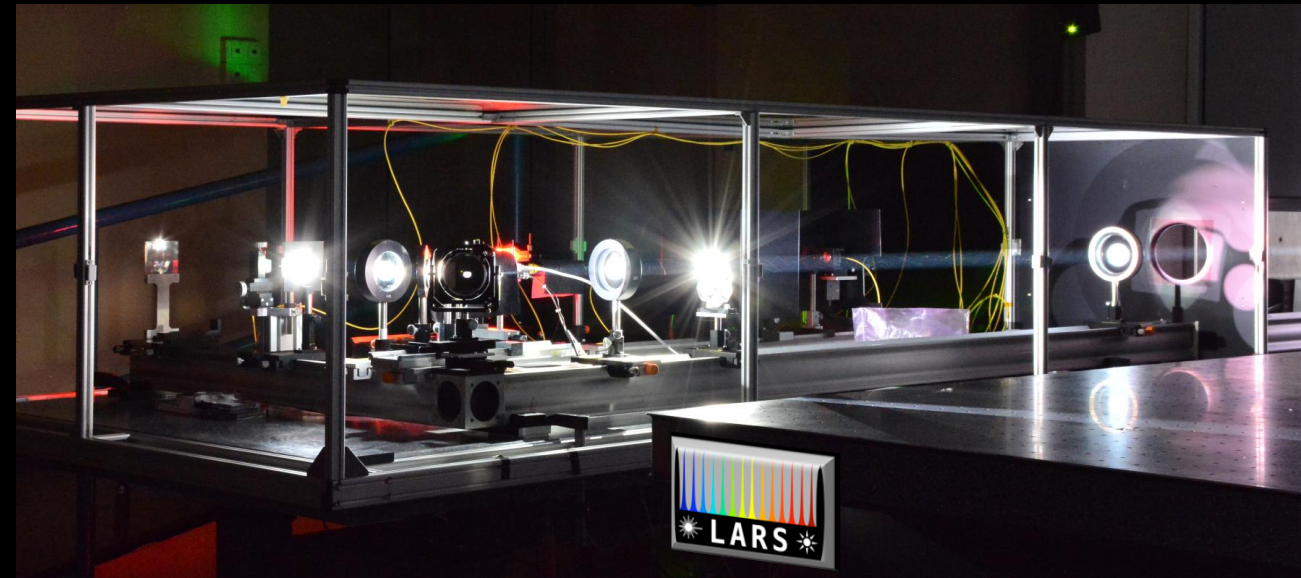
**Kiepenheuer-Institut für Sonnenphysik, Freiburg*

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SOLARNET IV MEETING, Lanzarote, 16-20 January 2017

LARS

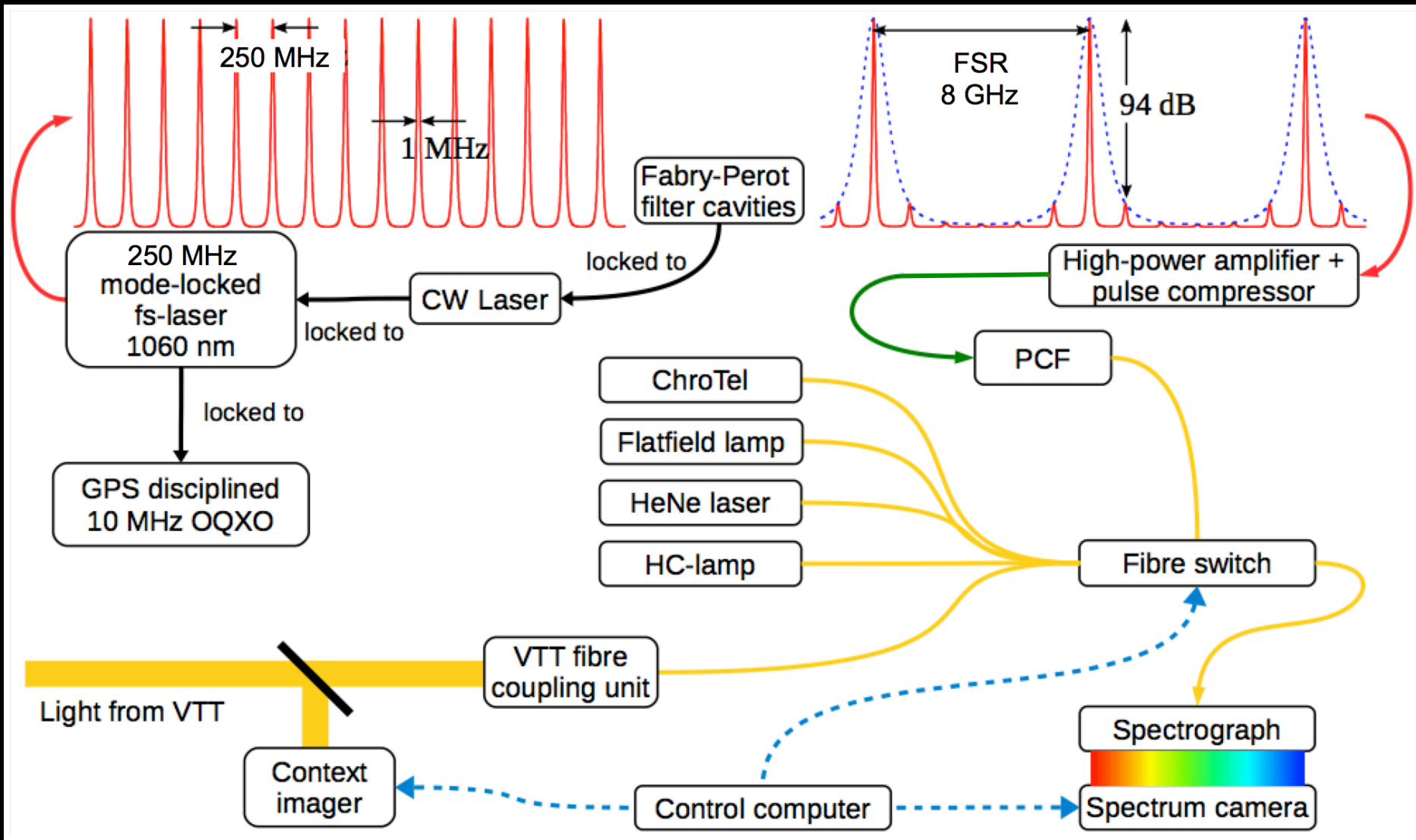
The **L**aser **A**bsolute **R**eference **S**pectrograph at the VTT



Basic setup:

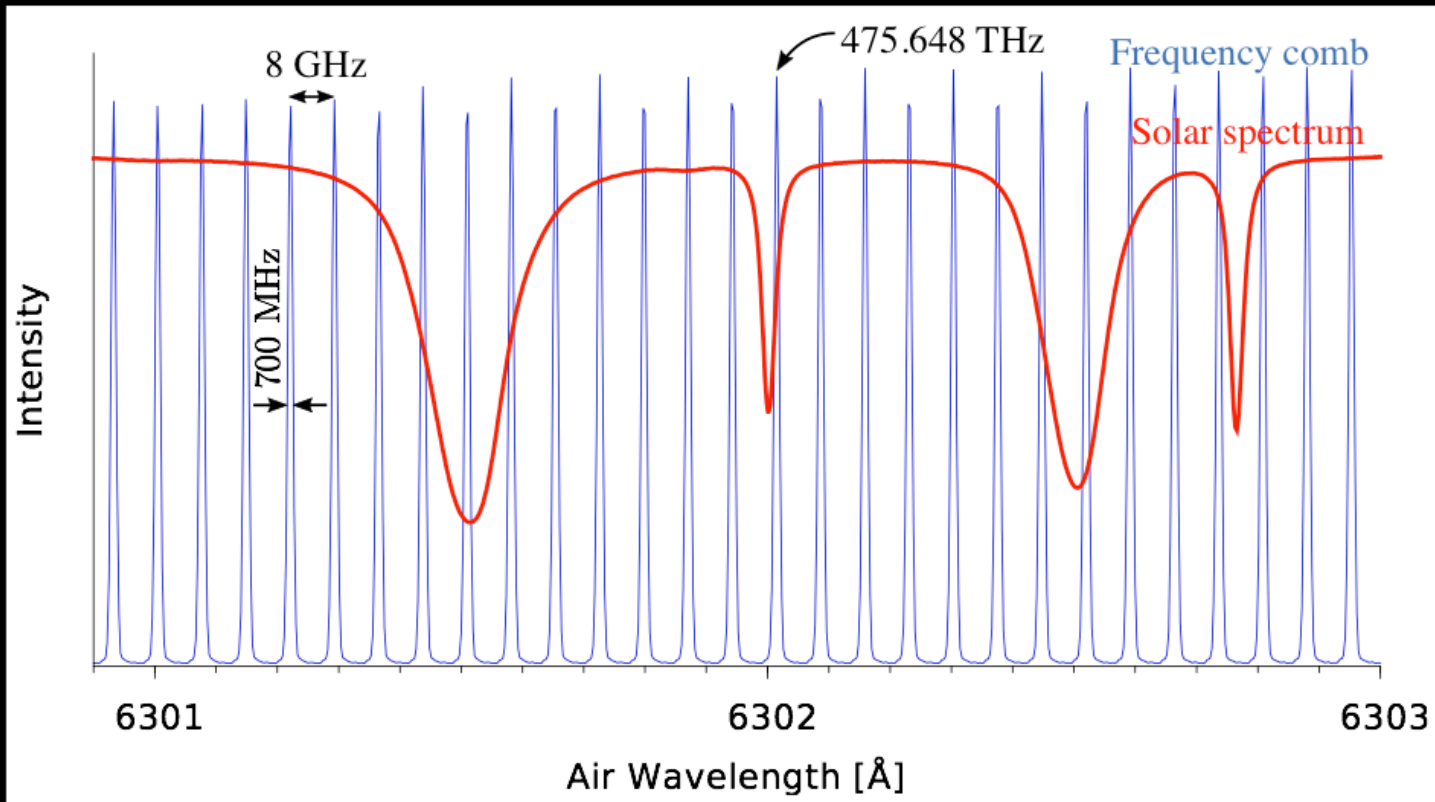
Fiber-integrated solar observations supported by a Laser Frequency Comb coupled to the Echelle Spectrograph of the Vacuum Tower Telescope (VTT) at the Observatorio del Teide

LARS - Instrument setup



adapted from Doerr, H.-P. 2015, PhD thesis

LARS - Data



Doerr, H.-P. 2015, PhD thesis

- Sequential measurement of the solar spectrum and comb
- Absolute wavelength calibration for the solar spectrum
- Spectral resolution $> 700,000$
- Accuracy of the spectral calibration down to 1 m s^{-1}
- Wavelength range **480 – 700 nm**
- Temporal cadence down to **0.5s**

LARS - Science: Convective blue-shift

Observational setup:

Center-to-limb variation of the convective blue-shift:

Positions: DC,N,S,E,W

Heliocentric μ : 1.0 – 0.3

Field-of-view: 10''

Oscillation: on

Sequence: comb/vtt

Exposure time: 0.5s

Cycle time: 1.5s

Cycles: n=800

Time series: 20min

Measurements: 98

Spectral bands ($\pm 3\text{\AA}$):

6302 \AA

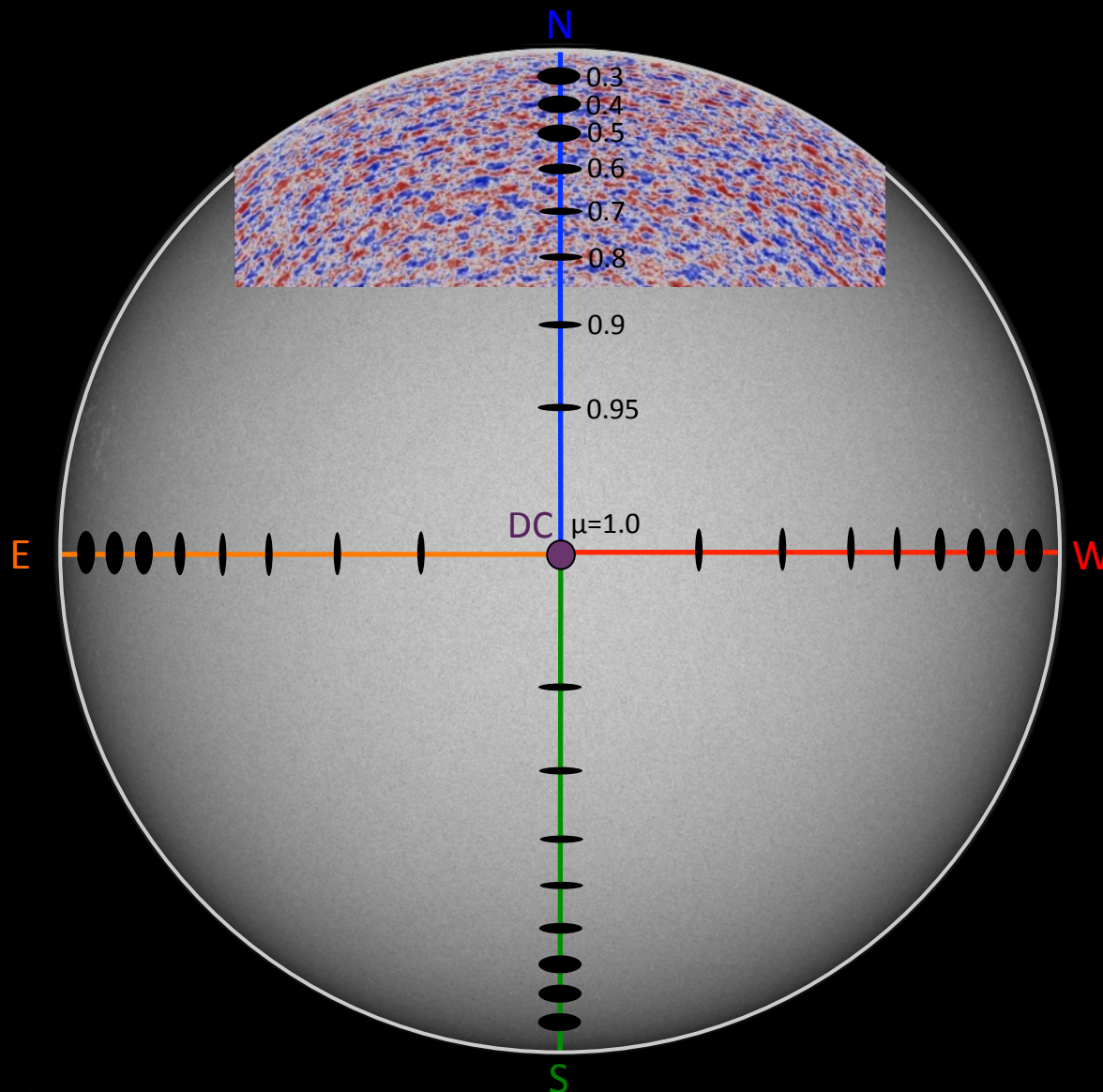
6173 \AA

5896 \AA

5434 \AA

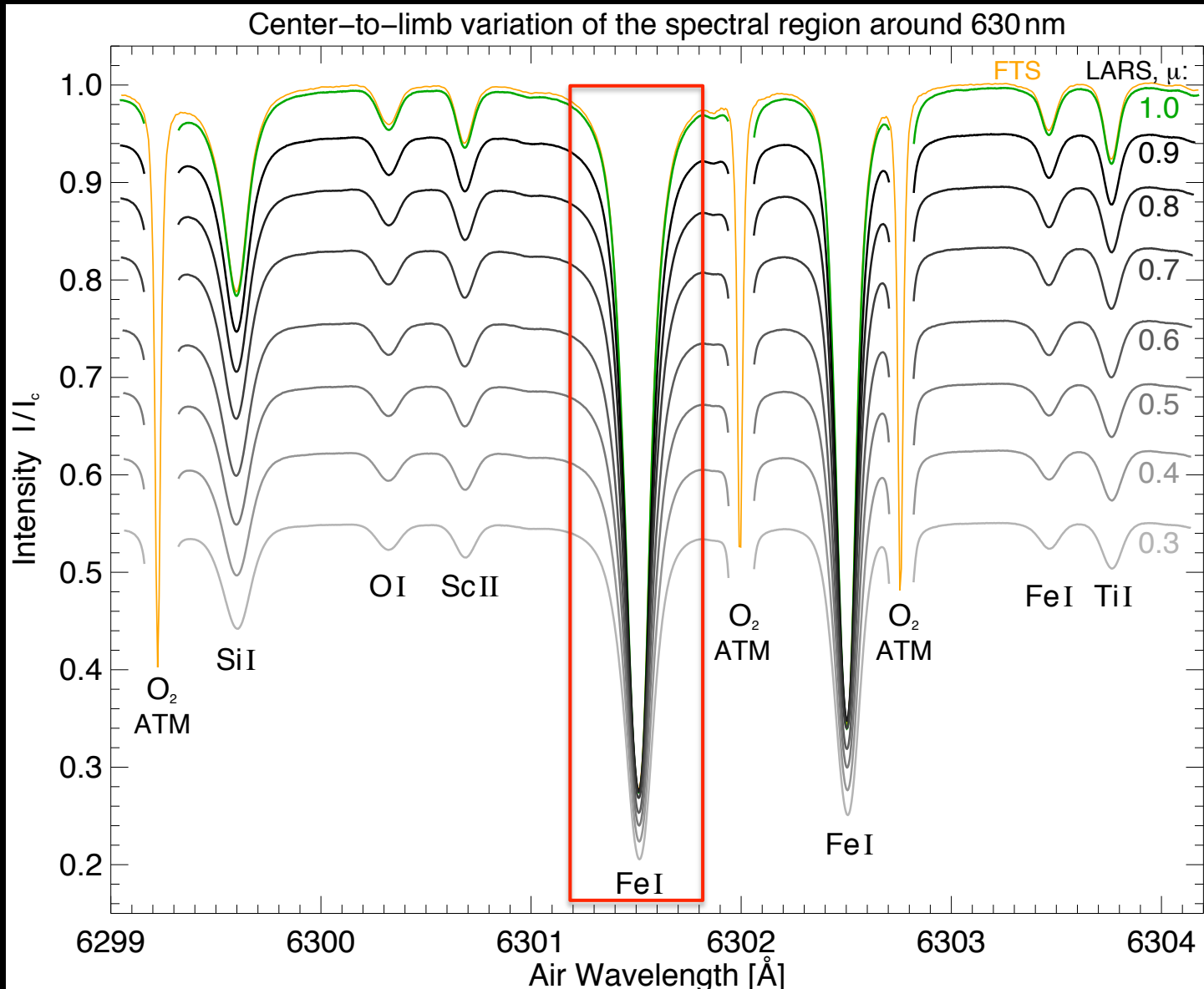
5380 \AA

5250 \AA



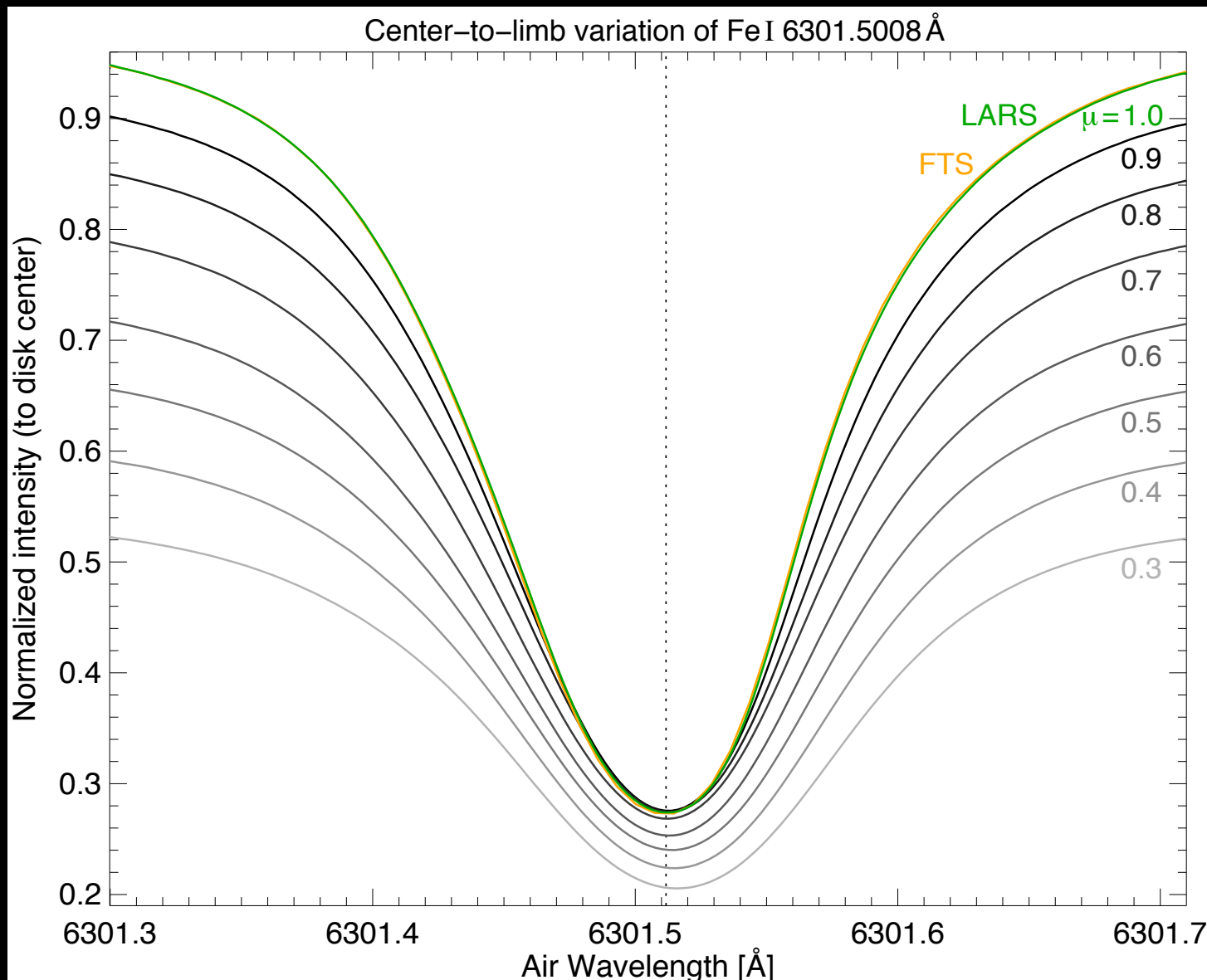
SDO/HMI Quick-Look Continuum: 2016.06.27_12:41:15_TAI

LARS - Science: Convective blue-shift



Average of observations at each heliocentric position $\mu = \cos \vartheta$

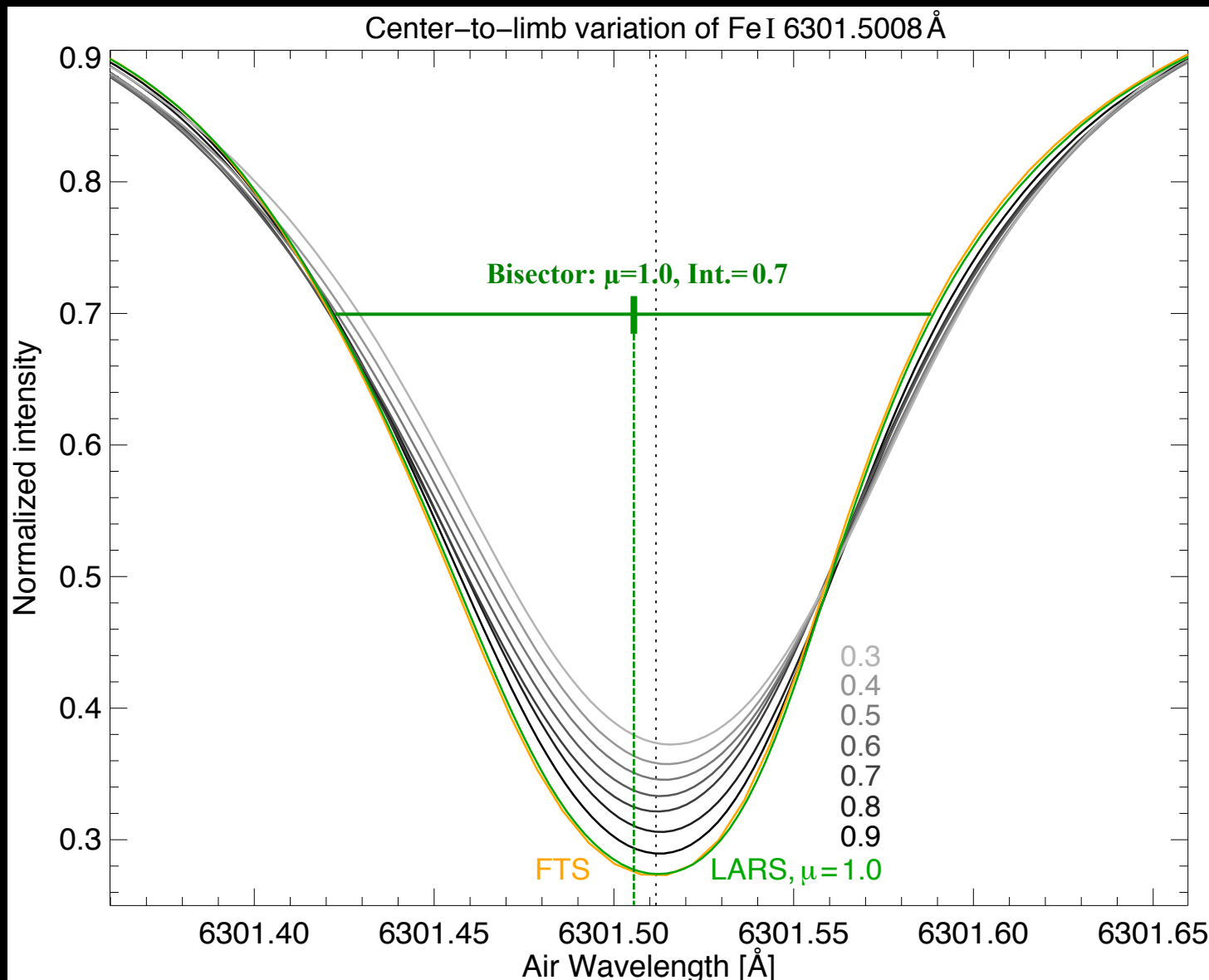
LARS - Science: Convective blue-shift



Average of observations at each heliocentric position $\mu = \cos \vartheta$

Normalized to the intensity at disk center

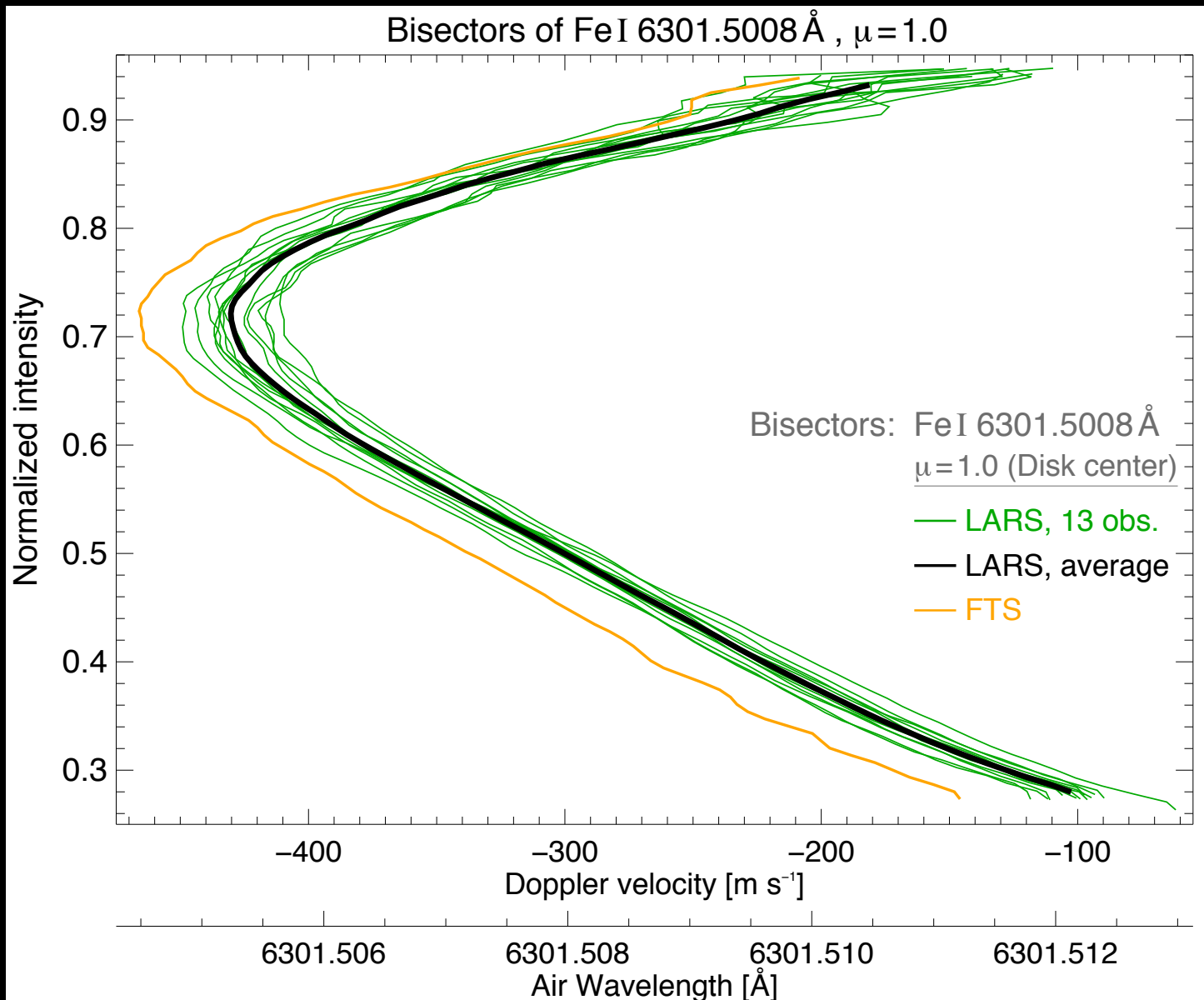
LARS - Science: Convective blue-shift



Average of observations at each heliocentric position $\mu = \cos \vartheta$

Normalized to each continuum intensity

LARS - Science: Convective blue-shift



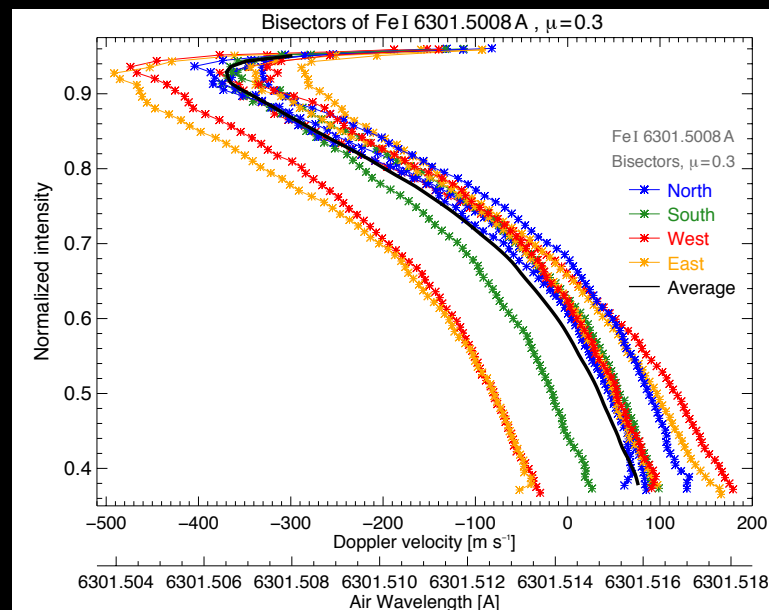
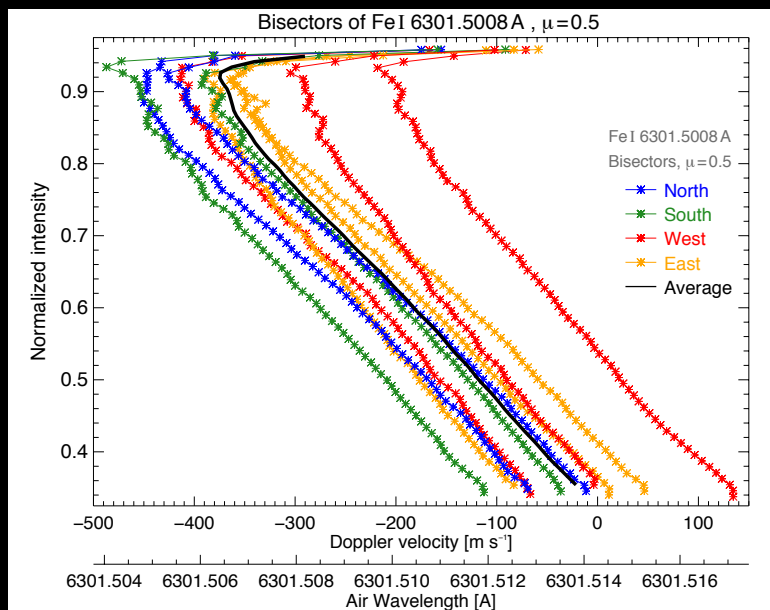
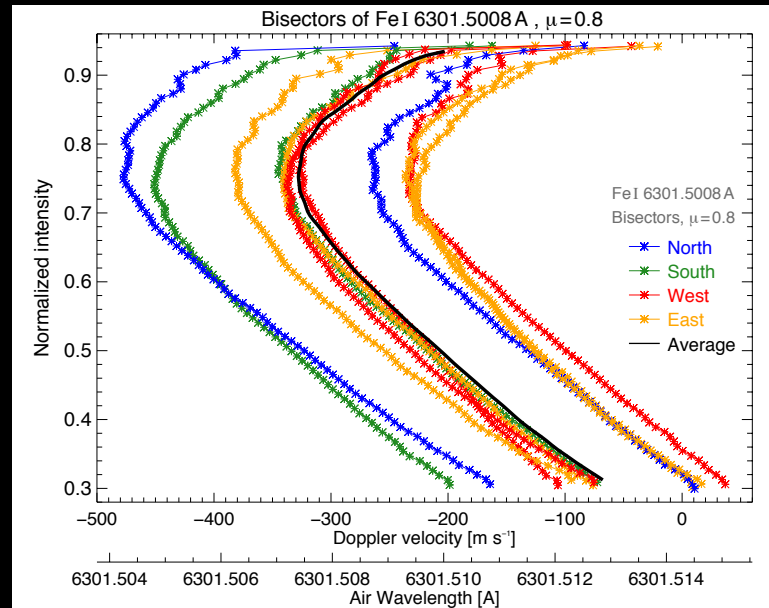
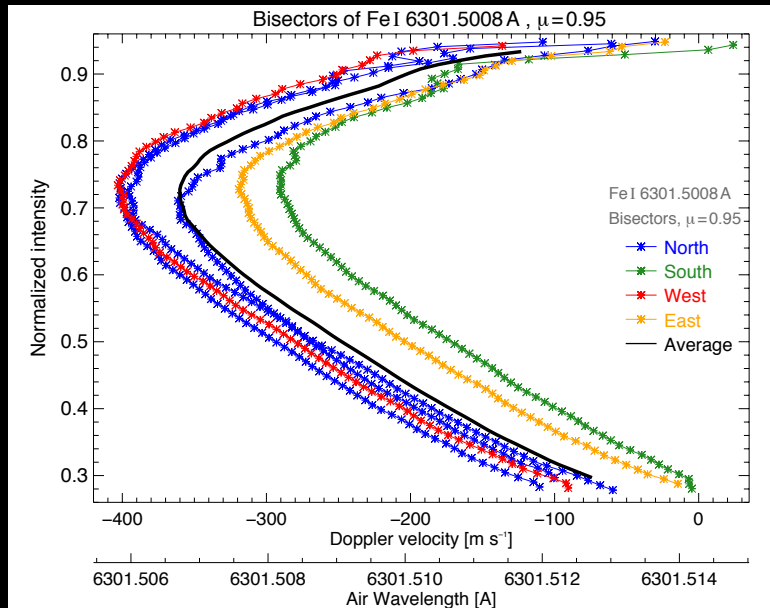
Bisectors of 13 observations at disk center $\mu = 1$ ($\vartheta = 0^\circ$)

Normalized to the continuum intensity

Reduction of:

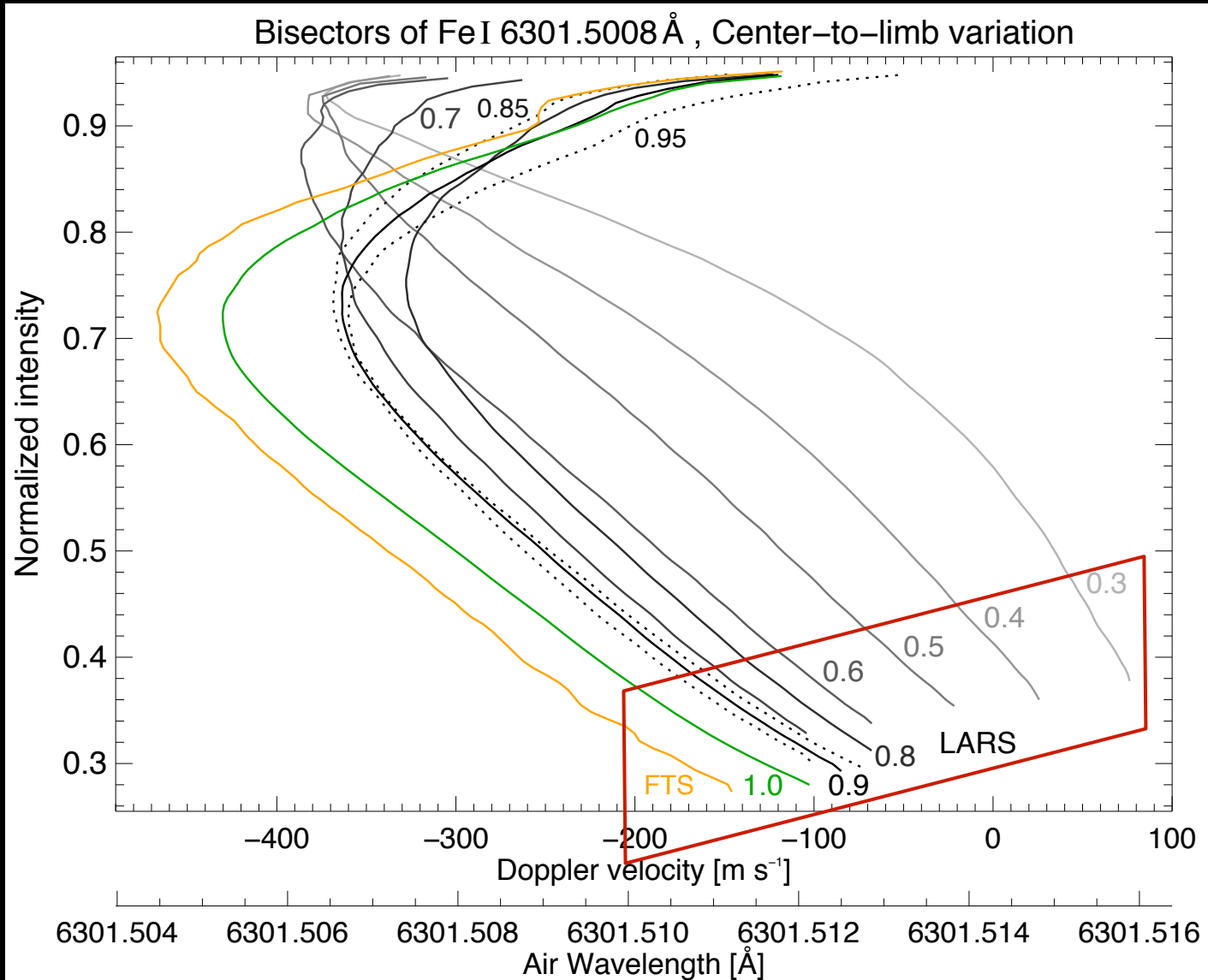
- Solar rotation
- Orbital motion
- Gravitational redshift

LARS - Science: Convective blue-shift



LARS - Science: Convective blue-shift

Bisector comparison:

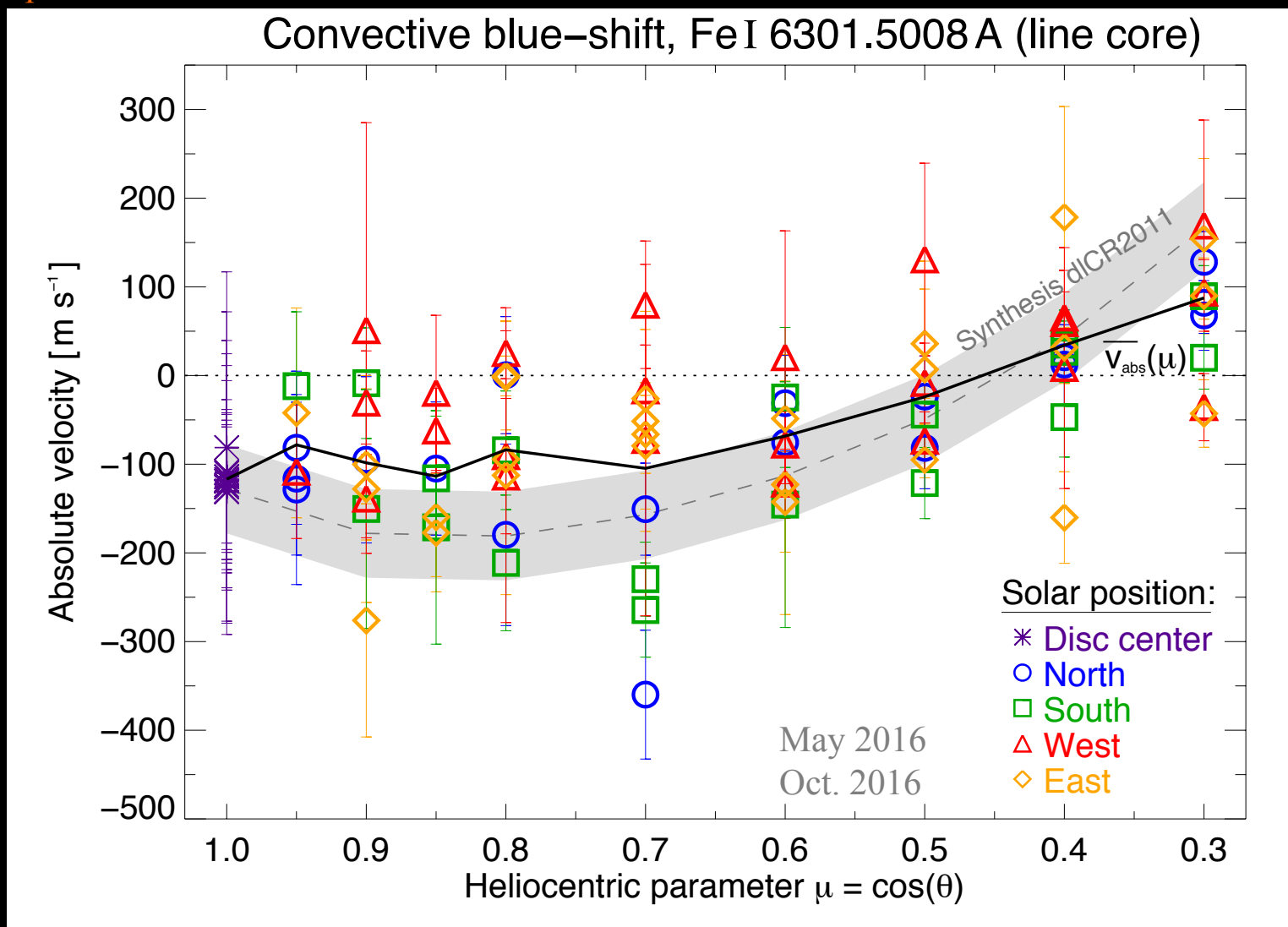


Average bisectors at each heliocentric position $\mu = \cos \vartheta$

Normalized to the continuum intensity

LARS - Science: Convective blue-shift

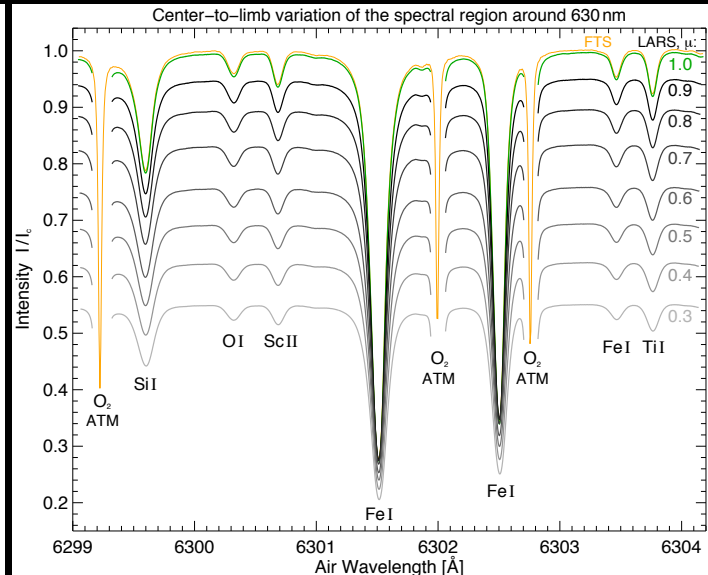
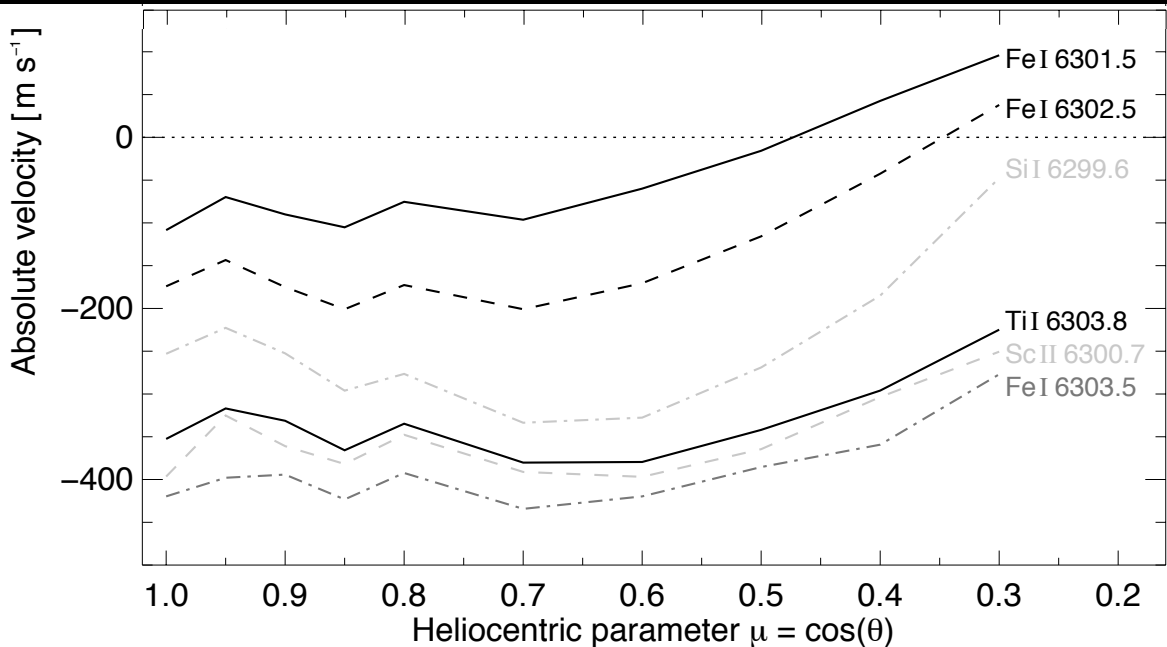
Line core positions:



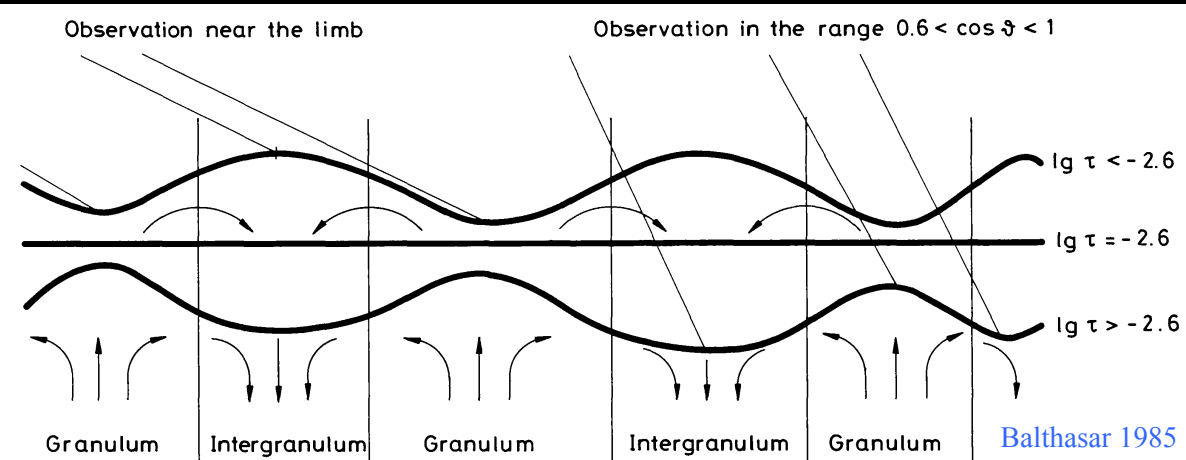
*Comparison with the synthesis of [de la Cruz Rodríguez et al. 2011](#)

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Line comparison:

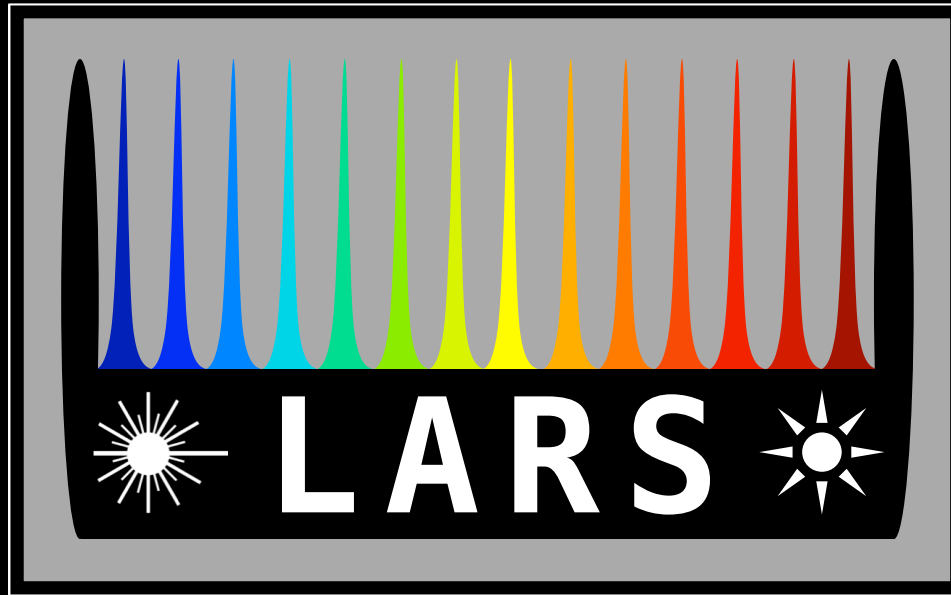


Theory:



- Weaker lines show larger blue-shift
- Convective decrease with height
- Center-to-limb variation:
 - Stable / Slightly increasing blue-shift from $\mu = 1.0 - 0.7$
 - Decreasing blue-shift toward the solar limb from $\mu = 0.6 - 0.3$
- Deep photospheric lines show a red-shift when observed at the solar limb

Thanks for you attention!



Contact: jl@leibniz-kis.de

Webpage: www.leibniz-kis.de/en/observatories/vtt/lars/

- ✧ Take a look at the LARS poster
- ✧ Apply for service-mode observations
- ✧ Let's arrange co-observations