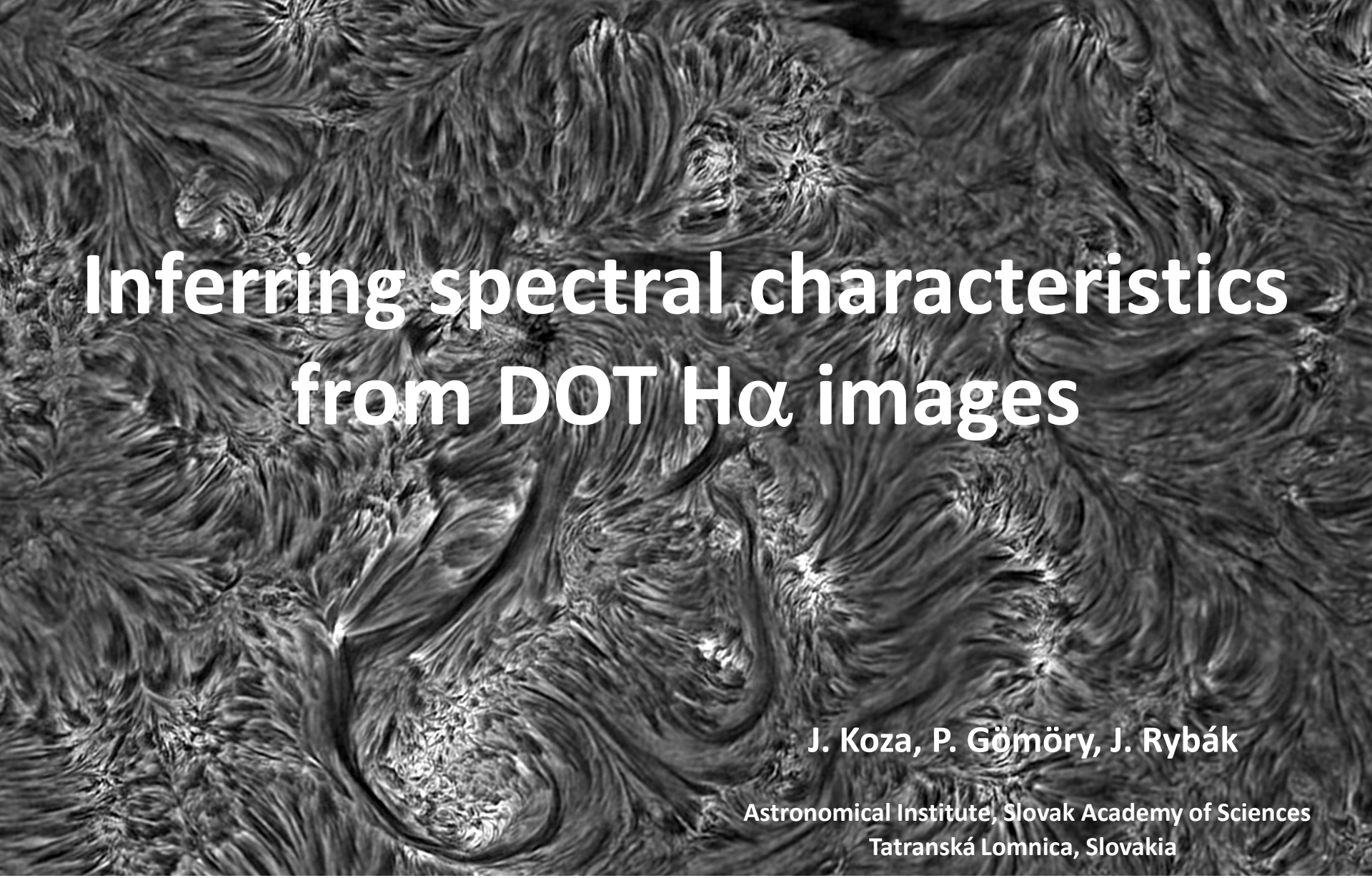


Inferring spectral characteristics from DOT Hα images

J. Koza, P. Gömöry, J. Rybák

Astronomical Institute, Slovak Academy of Sciences
Tatranská Lomnica, Slovakia

DUTCH OPEN TELESCOPE

5th international workshop on small-scale solar magnetic fields

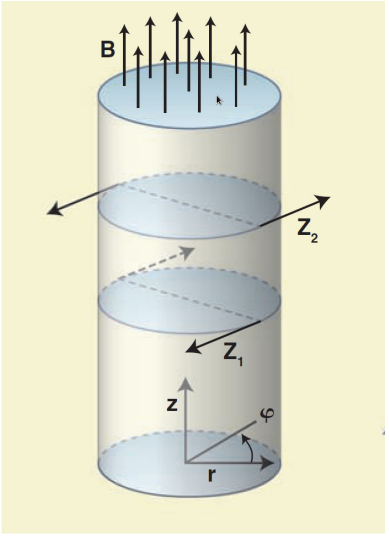
Bairisch-Kölldorf, 21st to 24th of April 2015

SKALNATÉ PLESO

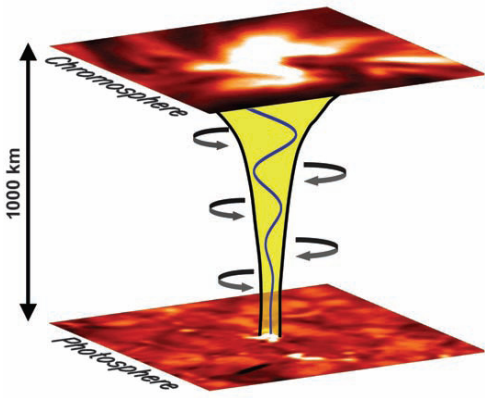
Alfvén waves

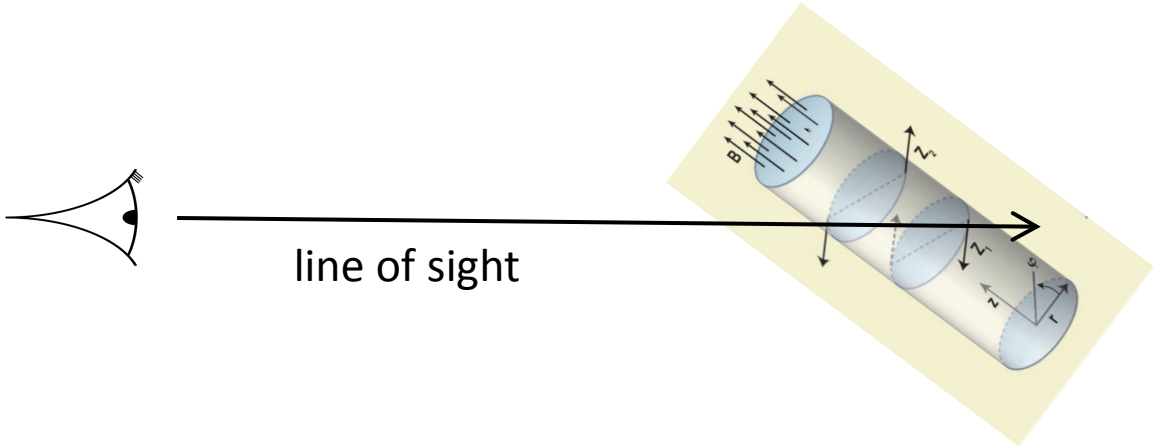
- possible transporters of magneto-convective energy for coronal heating

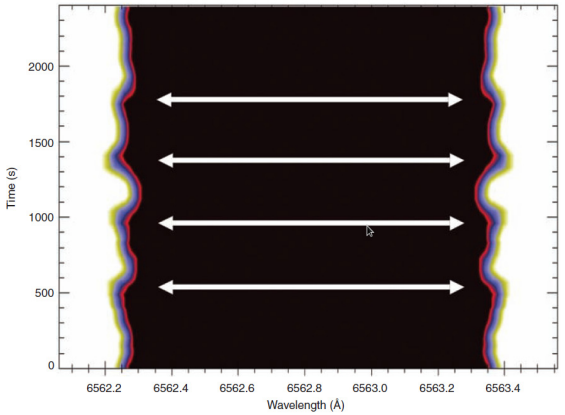
Tomczyk et al. 2007: Science 317, 1192
De Pontieu et al. 2007: Science 318, 1574
Jess et al. 2009: Science 323, 1582
Antolin & Shibata 2010: ApJ 712, 494
McIntosh et al. 2011: Nature 475, 477



- pure magnetic waves
- magnetic tension as the restoring force
- incompressible transverse oscillations of magnetized plasma propagating along field lines
- detectable as periodic variations of non-thermal broadening (line width) of a spectral line







Dutch Open Telescope

45-cm primary

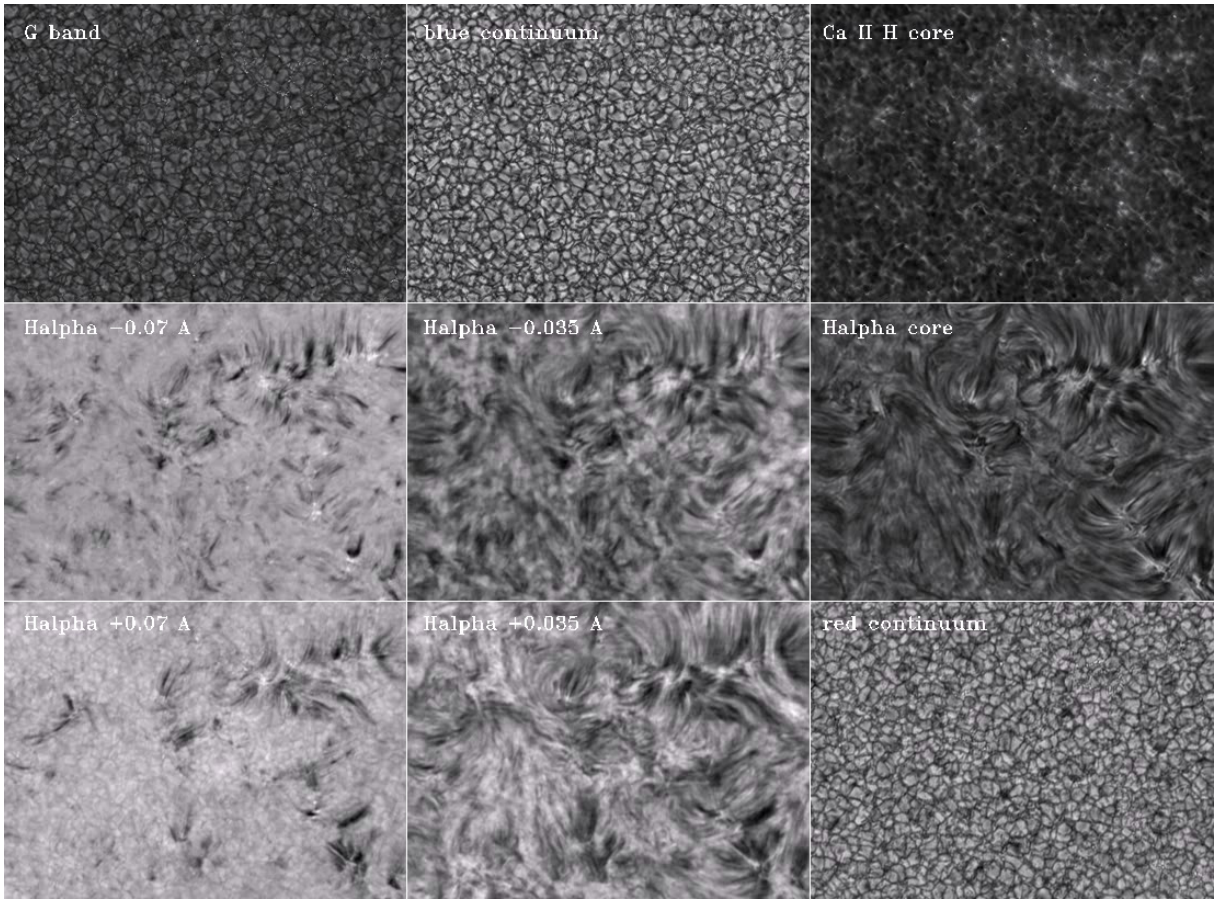
- La Palma, Canary Islands
- operational from 1999 to 2010

- multiwavelength tomographic imager – movie maker

the photosphere:	G-band, blue and red continua	SIMULTANEOUSLY
the photosphere/chromosphere:	Ca II H	
the chromosphere:	Hα	

- Prof. Rob Rutten, Ing. Rob Hammerschlag, Pit Sütterlin

example dataset from 19 October 2005



duration: 71 min
cadence: 1 min
Hα 5-point sampling: line center, ± 0.35 Å, ± 0.7 Å
tunable Hα Lyot filter: FWHM = 0.25 Å

co-aligneg/re-registered spatially and temporally

speckle reconstructed

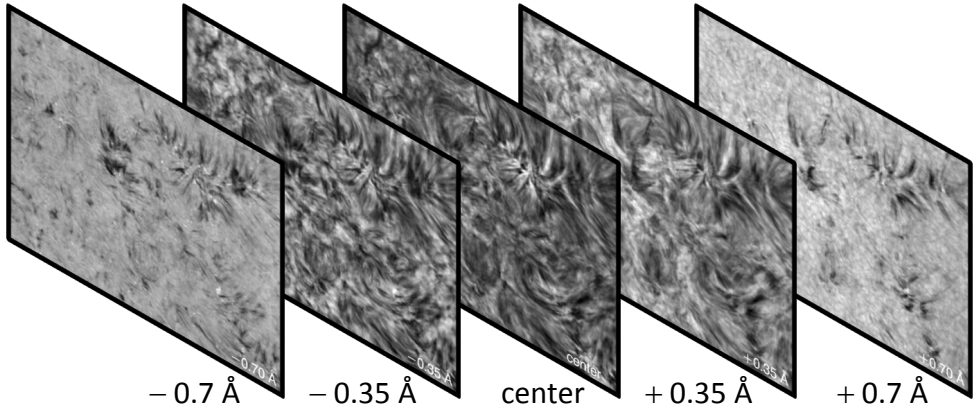
open database

http://dotdb.strw.leidenuniv.nl/DOT/

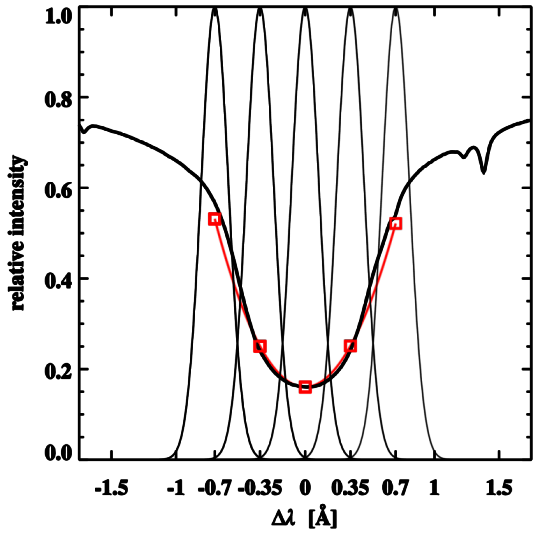
- many ready-to-use datasets available
- fully co-aligned, re-registered, and speckled
- available DOT software for data reduction and image sequence analysis (mostly not integrated in the SolarSoft)
- at least 15 datasets taken between 14 October 2005 and 28 September 2007 useable for searching Alfén waves

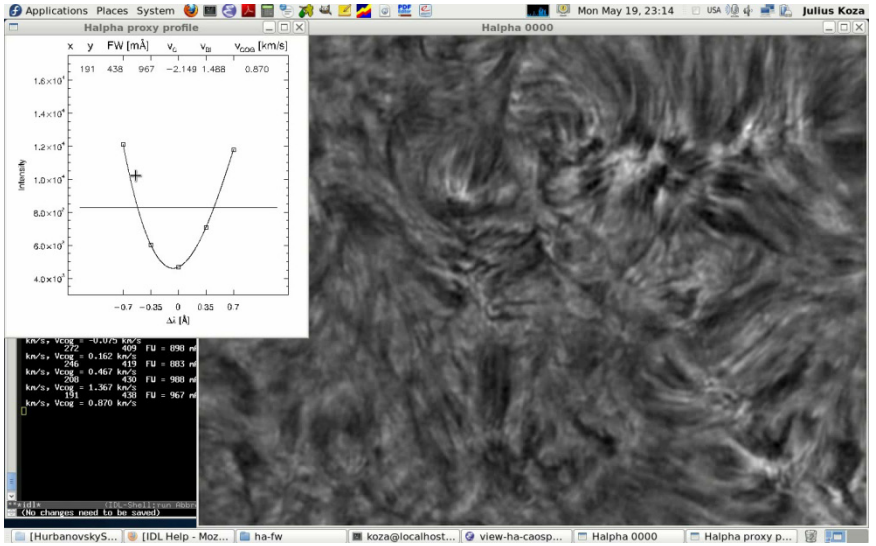
Students-to-the-DOT program 2004-2007

Search for Alfvén waves by Hα imagery of the Dutch Open Telescope (DOT)



- 4th-order polynomial fit of five Hα profile samples
- inferred spectral characteristics:
  - Doppler velocity of fit minimum v_C
  - Intensity of fit minimum I_C
  - fit width FW
  - fit asymmetry:
    - bisector velocity v_{BI}
    - center-of-gravity velocity v_{COG}





[Koza et al. 2013: „Search for Alfvén waves in a bright network element observed in Hα“, CAOSP 43/1, 5]

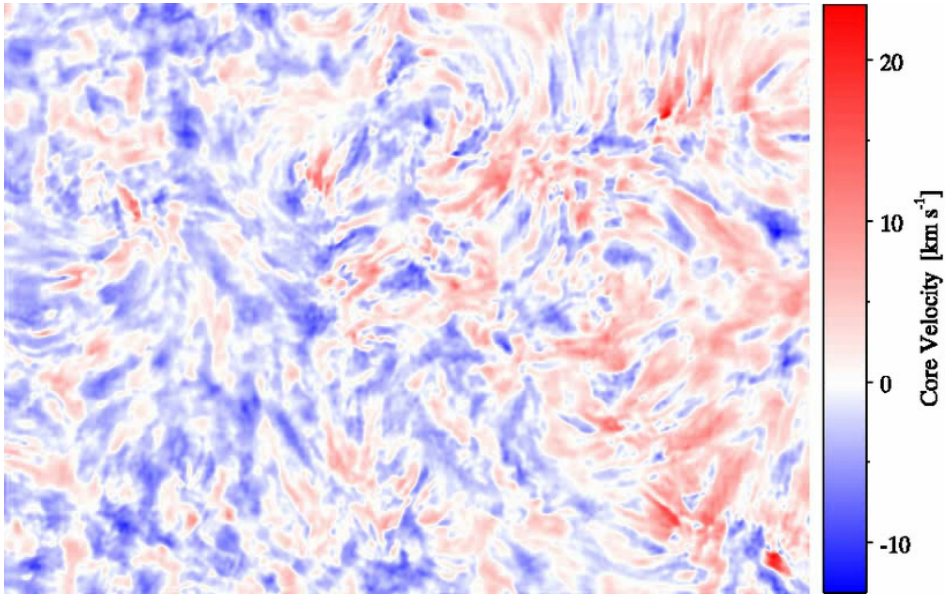
Examples of inferred spectral characteristics

source data: a sequence of 71 speckle-reconstructed Hα images taken by DOT in the quiet Sun at the disk center on October 19, 2005 at ± 0.7, ± 0.35, and 0 Å

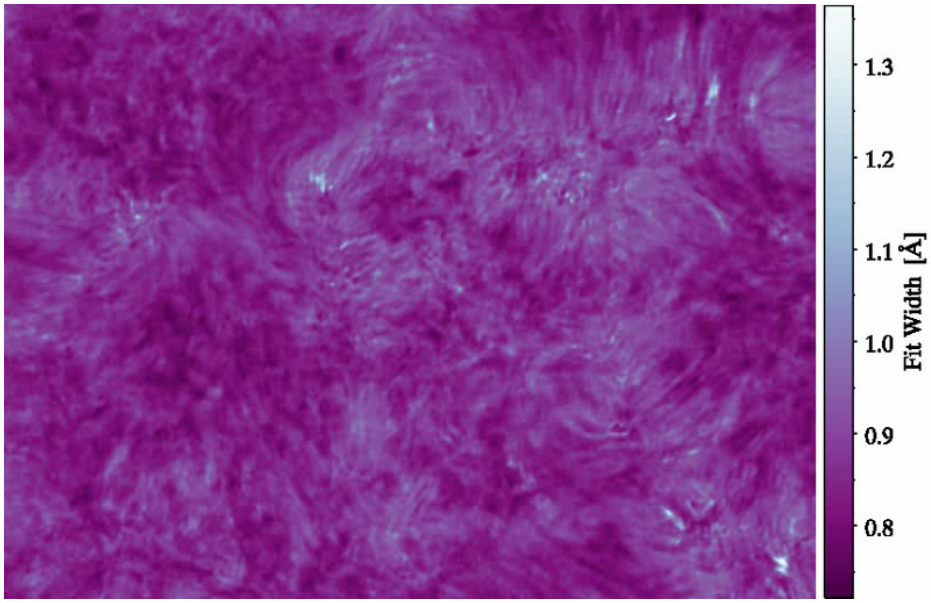
time resolution: 1 min

field of view: 79 arcsec × 58 arcsec

Core Velocity



Fit Width

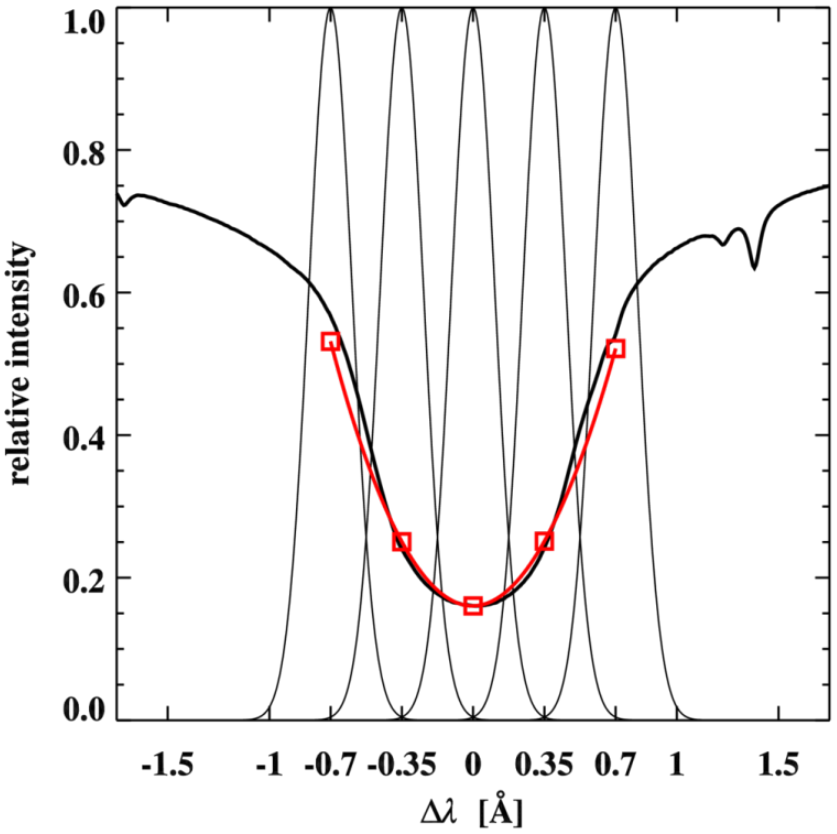


- an occurence of highly redshifted profiles with v_C > 15 kms^{-1}
- a long tail of broad profiles with *FW* > 1000 mÅ

Motivation

low spectral resolution + curve fitting $\Rightarrow$ alternation of “true” spectral characteristics

A question of an accuracy of inferred spectral characteristics v_C I_C FW … .



Aims

to estimate deviations of:

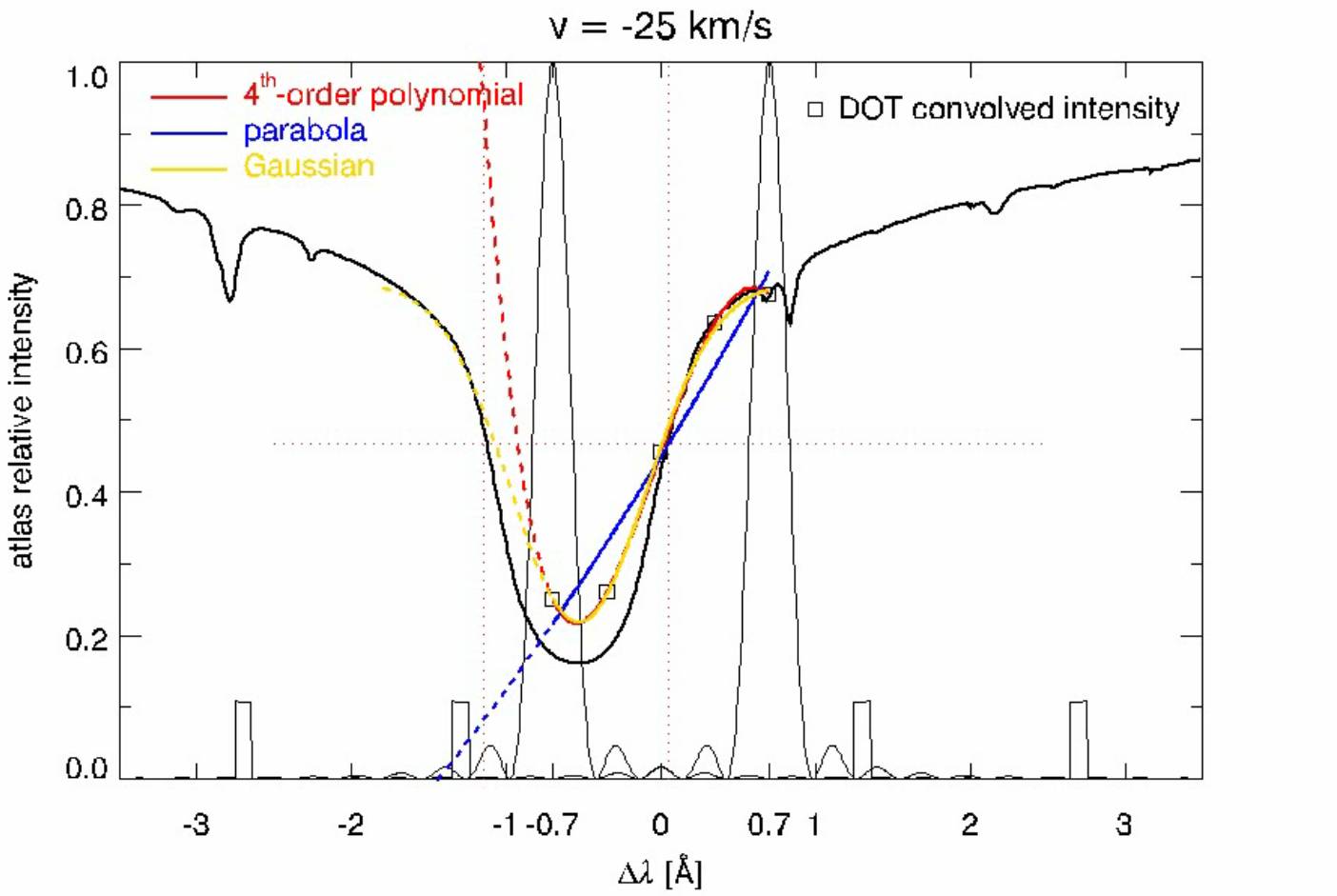
- Doppler velocity v_C
- core intensity I_C
- core width FW
- core asymmetry v_{BI} v_{COG}

of the Hα spectral line observed by the DOT Hα Lyot filter derived using:

- 4th-order-polynomial fit
- Gaussian fit
- parabolic fit

Procedure

- the reference Hα profile
  - taken from the disk-center spectral atlas
  - the source of the reference values of v_C I_C FW ...
  - shifted using Doppler velocities in the interval ±25 kms^{-1} with a step of 1 kms^{-1}
- the "alternated" spectral characteristics derived from the shifted Hα profile
- deviations: differences of the reference and alternated spectral characteristics



Results - deviations of Doppler velocity Δv

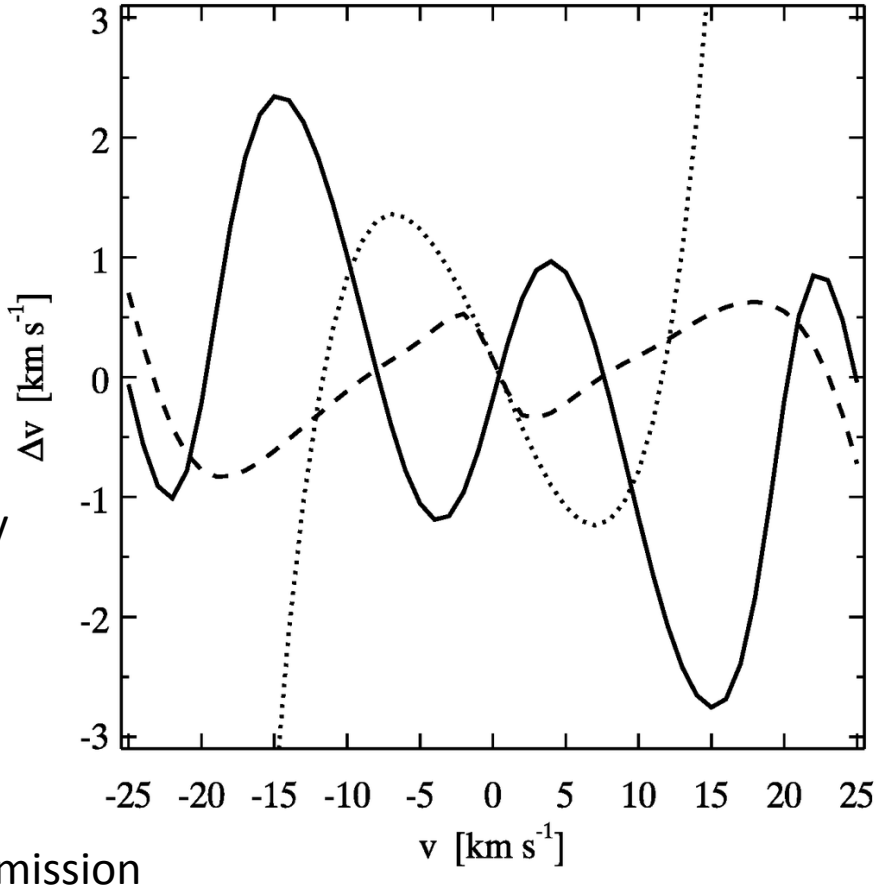
Fitting curve

4th-order polynomial ——————

Gaussian – – – – – –

parabola .....

Δv absolute deviation of Doppler velocity
Δv = measured - reference



Deviations in general:

- **insensitive** to the shape of the filter transmission
- depend **non-linearly** on the Doppler shift, therefore they do not cancel out if the spectral characteristics are represented by their relative variations

Gaussian fit: the most preferable choice, deviations less than 1 kms^{-1}

4th-order polynomial fit: considerably variable deviations in the range ± 2.5 kms^{-1}

Results - deviations of core intensity ΔI

Fitting curve

4th-order polynomial ——————

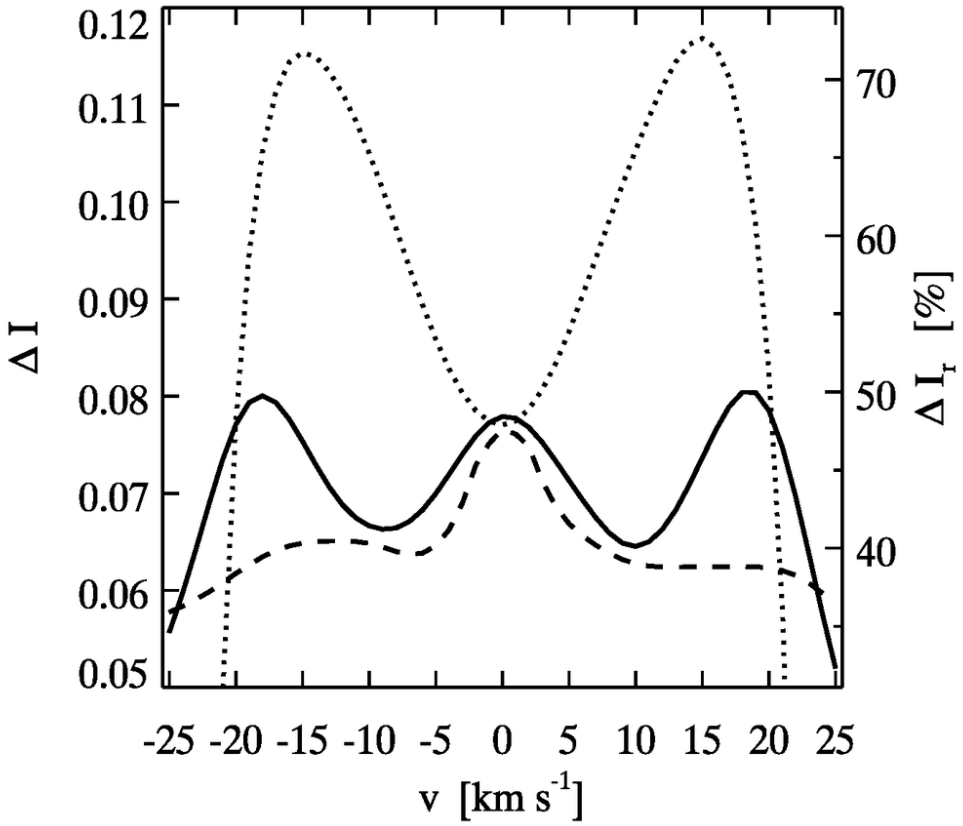
Gaussian – – – – – –

parabola .....

ΔI absolute deviation of core intensity

ΔI = measured - reference

$$E(\lambda) = \int_0^{\infty} I(x)T(x-\lambda)dx$$



- all fitting curves overestimate the core intensity I_C due to the integration over the area-normalised filter transmission profile T
- the 4th-order-polynomial fit overestimates I_C with the sinus-like relative deviation varying from 40 to 50%

Results - deviations of fit width ΔFW

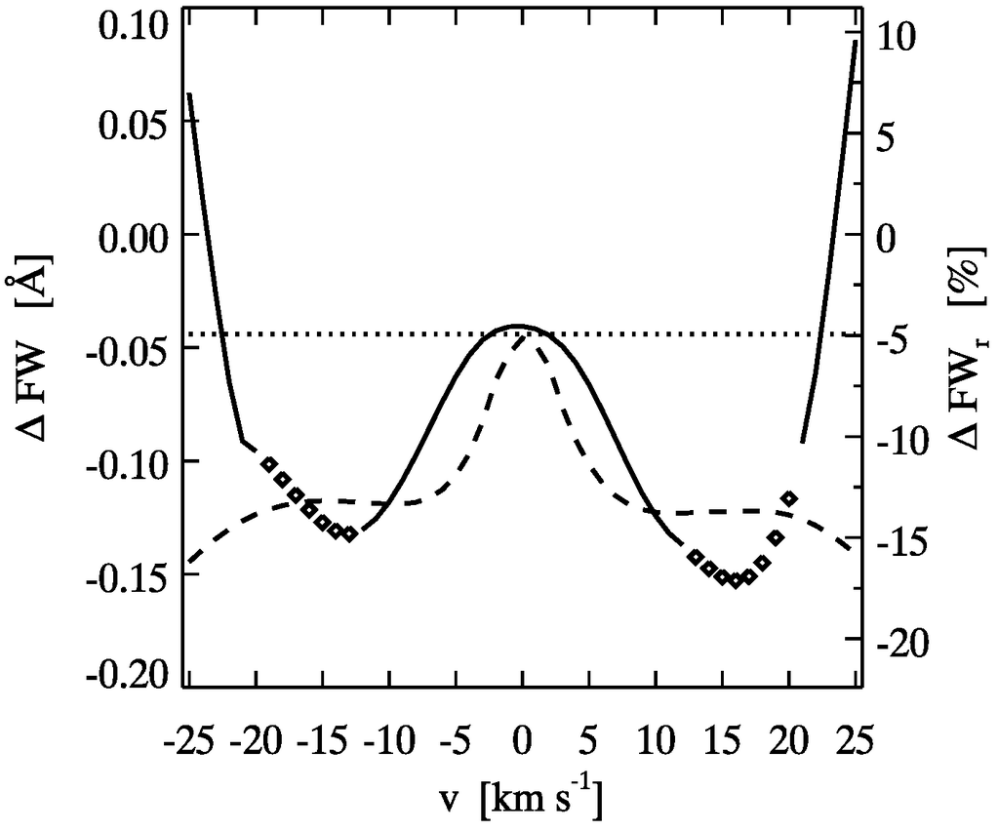
Fitting curve

4th-order polynomial ——————

Gaussian – – – – – –

parabola .....

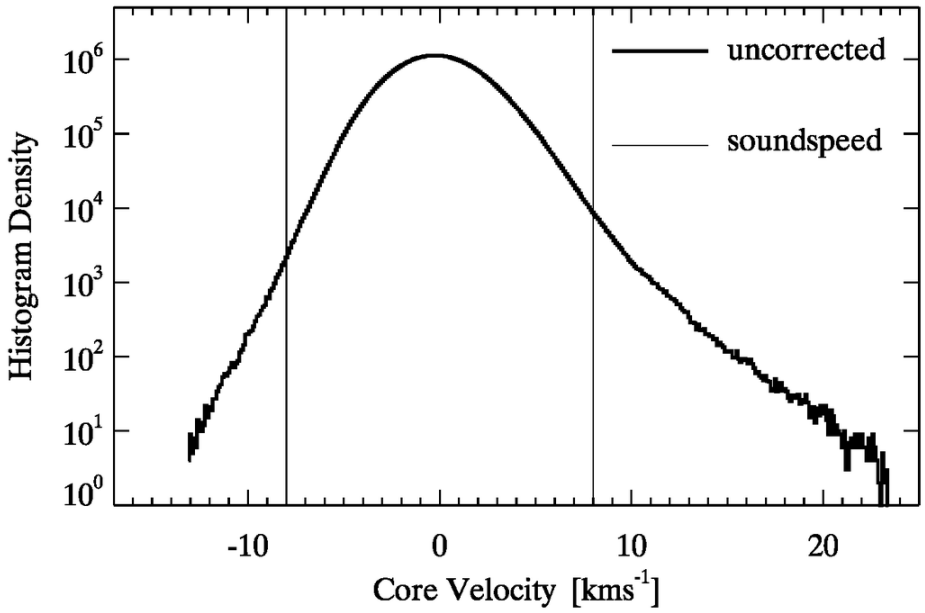
ΔFW absolute deviation of fit width
ΔFW = measured - reference



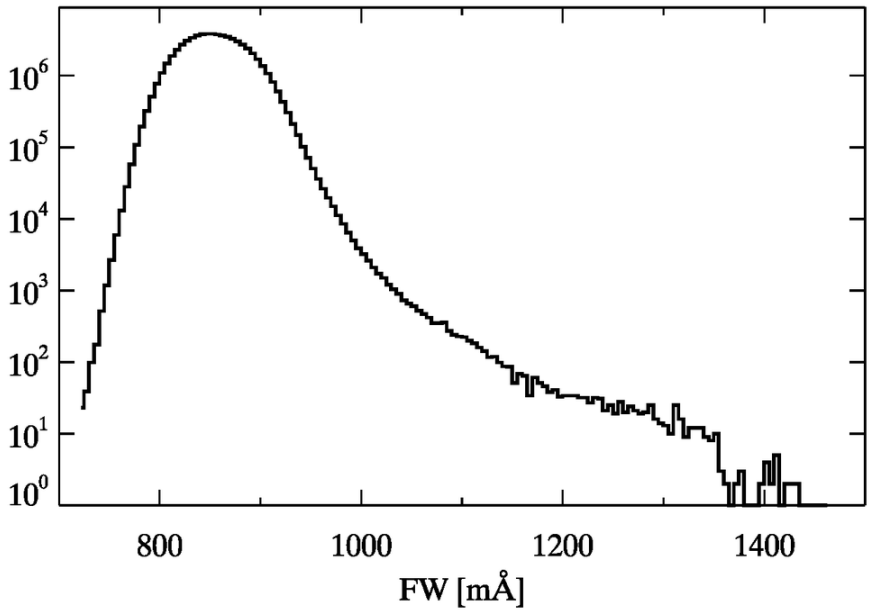
– all fitting curves underestimate *FW*
– the 4th-order-polynomial fit underestimates *FW* with relative deviations varying from 5 to 15%

Inferred spectral characteristics

Core Velocity



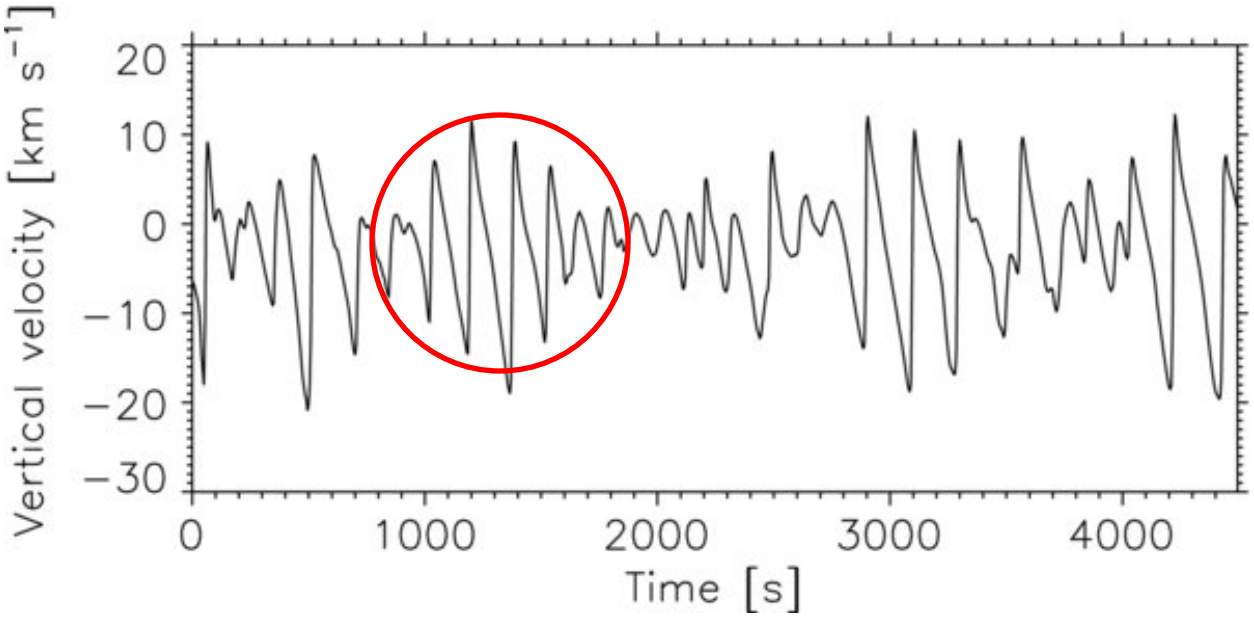
Fit Width



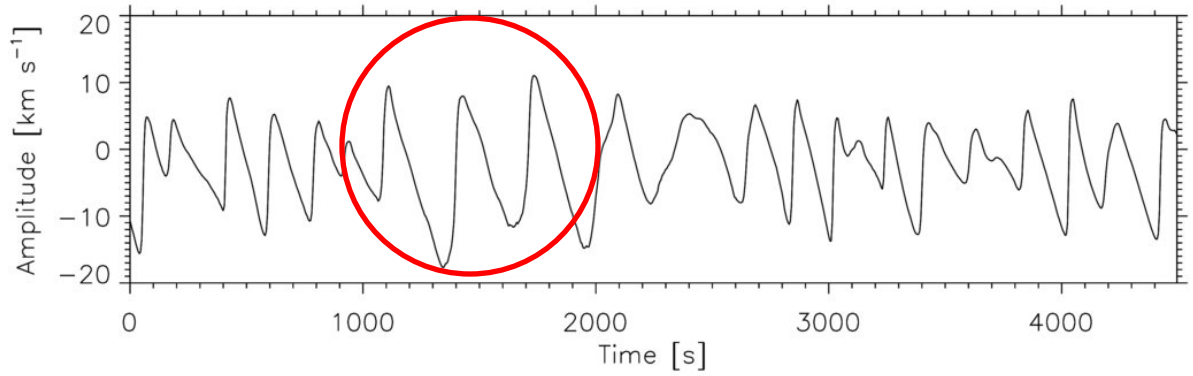
- asymmetric distributions
- an occurence of highly redshifted profiles with v_C > 15 kms^{-1}
- a long tail of broad profiles with FW > 1000 mÅ
- **an excess of redshifts may be a manifestation of chromospheric N-shaped tooth-like shocks, generally with stronger downflows than upflows and spending longer time in descending phase**

Wave propagation and jet formation in the chromosphere

L. Heggland *et al.* 2011 *ApJ* **743** 142



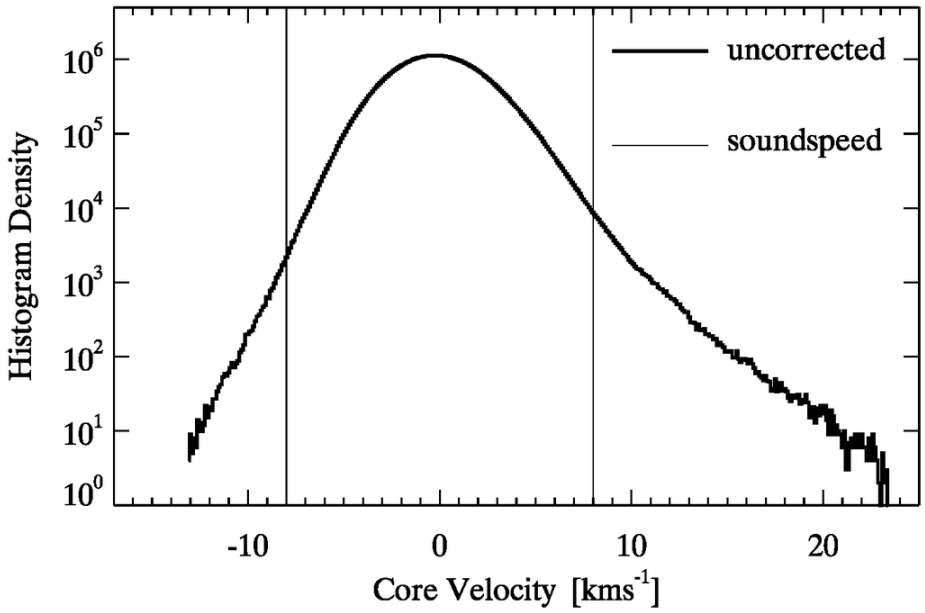
N-shaped tooth-like shocks



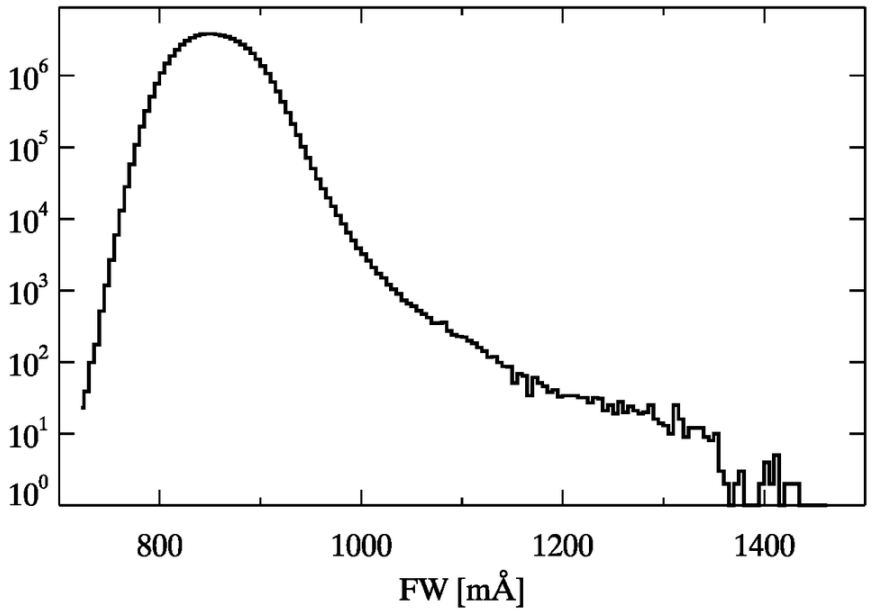
N-shaped tooth-like shocks

Inferred spectral characteristics

Core Velocity



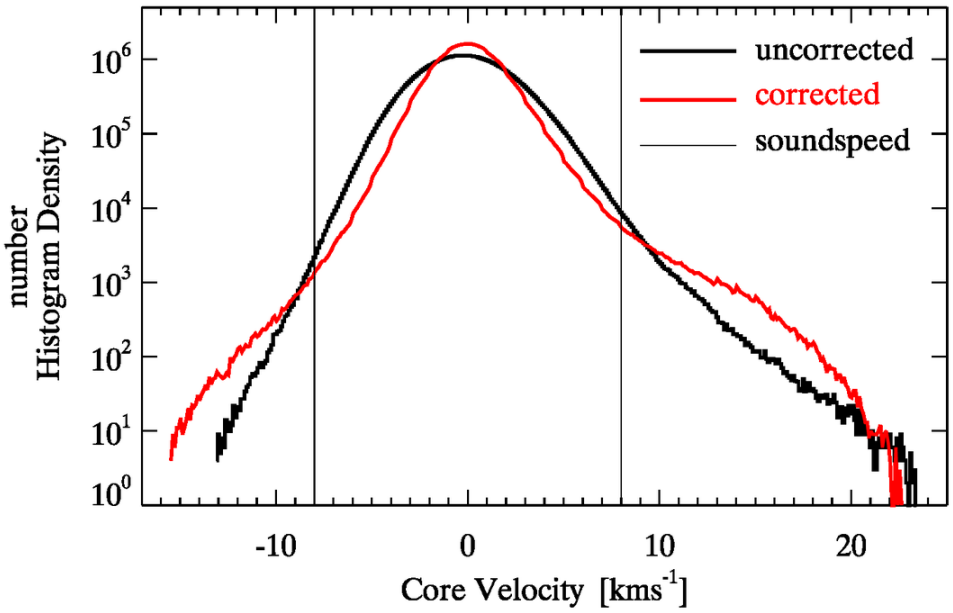
Fit Width



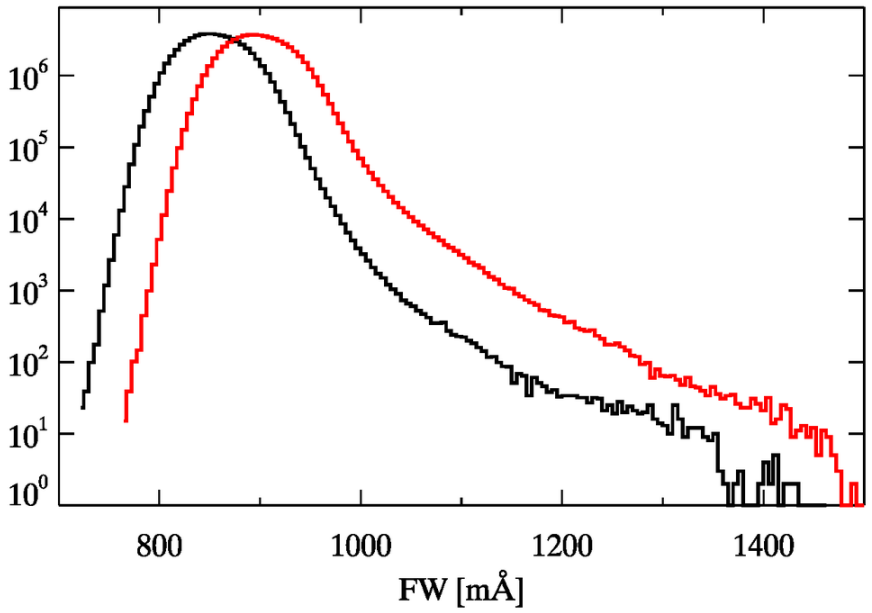
- asymmetric distributions
- an occurence of highly redshifted profiles with v_C > 15 kms^{-1}
- a long tail of broad profiles with FW > 1000 mÅ
- **an excess of redshifts may be a manifestation of chromospheric N-shaped tooth-like shocks, generally with stronger downflows than upflows and with prolonged descending phase**

Corrected spectral characteristics

Core Velocity



Fit Width

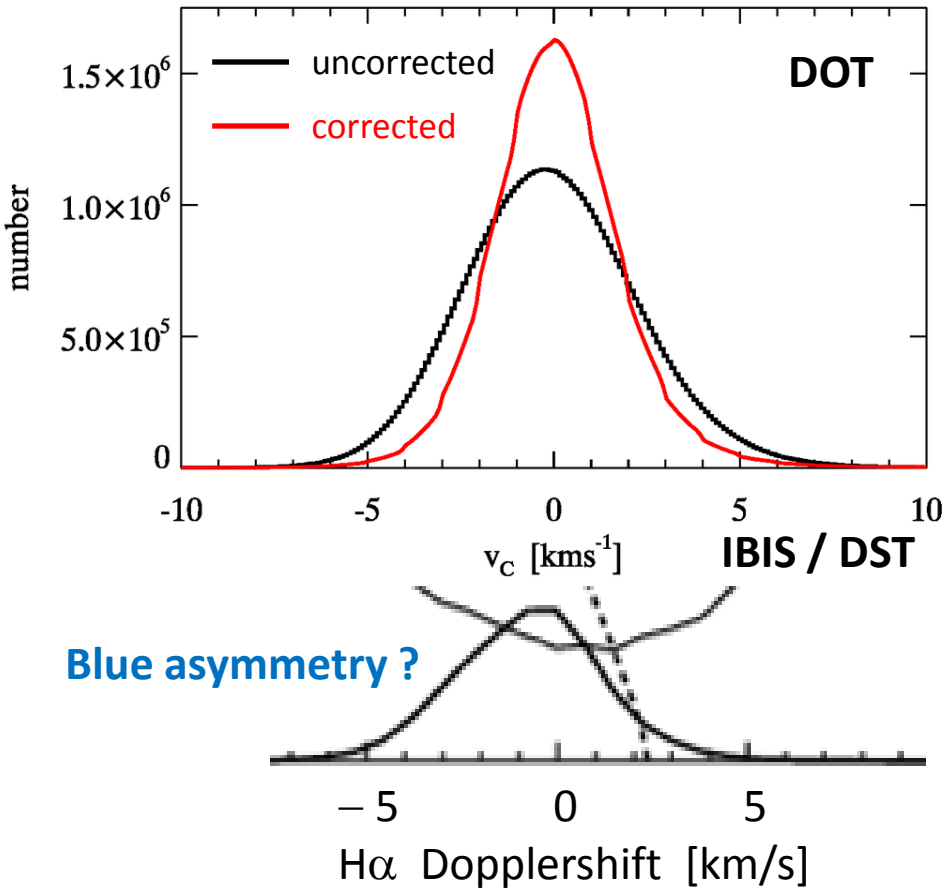


- corrections **narrow** the distribution in the range ± 8 kms^{-1} **decreasing** the original v_C
- out of it, corrections **broaden** the distribution **increasing** the original v_C

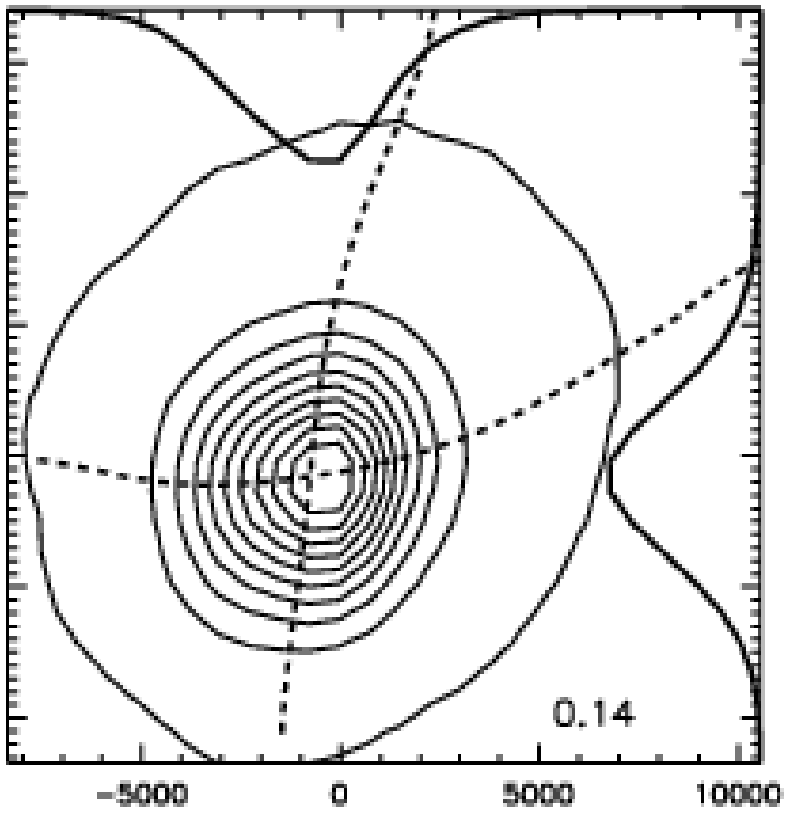
- corrections shift the distribution towards larger fit widths *FW*
- peak of original distr. at 850 mÅ
- peak of corrected distr. at 900 mÅ

Comparison

Histogram of v_c in linear scale



Hα Dopplershift from IBIS / DST



Cauzzi et al. 2009: A&A 503, 577

DOT: 45-cm mirror
No Adaptive Optics
5 profile samples of Hα

DST: 76-cm entrance window of telescope
Adaptive Optics
22 profile samples of Hα

Brief summary

- method of inferring and correcting of spectral characteristics of the Hα line observed by the DOT Lyot filter was developed
- deviations of characteristics:
  - are insensitive to the shape of the filter transmission
  - depend mostly non-linearly on the Doppler shift, therefore

they do not cancel out if the characteristics are represented by their relative variations.

- the 4th-order polynomial is an acceptable fitting curve in terms of deviations. It allows estimating an asymmetry of profiles.

Koza et al. 2014: CAOSP 44, 43

"Inferring spectral characteristics of the Halpha spectral line observed by the DOT Lyot filter"

Brief summary

- method of inferring and correcting of spectral characteristics of the Hα line observed by the DOT Lyot filter was developed
- deviations of characteristics:
  - are insensitive to the shape of the filter transmission
  - depend mostly non-linearly on the Doppler shift, therefore

they do not cancel out if the characteristics are represented by their relative variations.

- the 4th-order polynomial is an acceptable fitting curve in terms of deviations. It allows estimating an asymmetry of profiles.

Koza et al. 2014: CAOSP 44, 43
"Inferring spectral characteristics of the Halpha spectral line observed by the DOT Lyot filter"

Plans - outlooks

- searching for Alfvén waves in the Hα imagery of the Dutch Open Telescope (DOT)
- repeating the study but with reference Hα profiles taken by THEMIS or IBIS/DST, or VTT with high spatial and spectral resolution
- creating an extensive database of corrections for spectral characteristics derived from DOT Hα observations