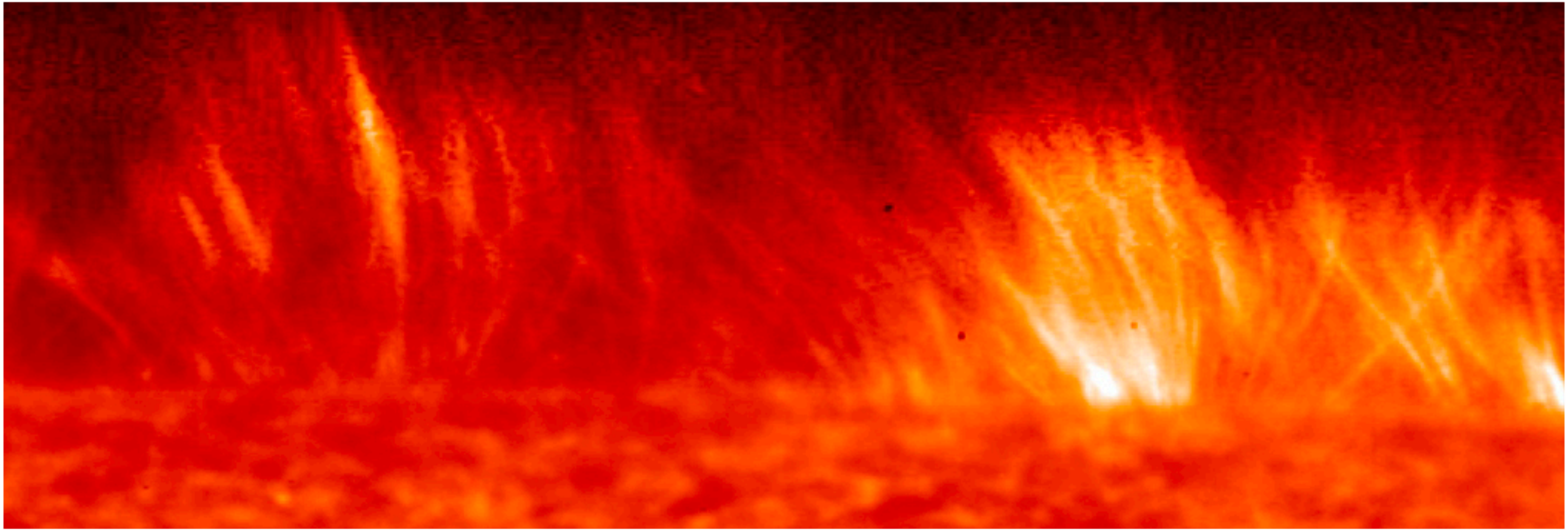
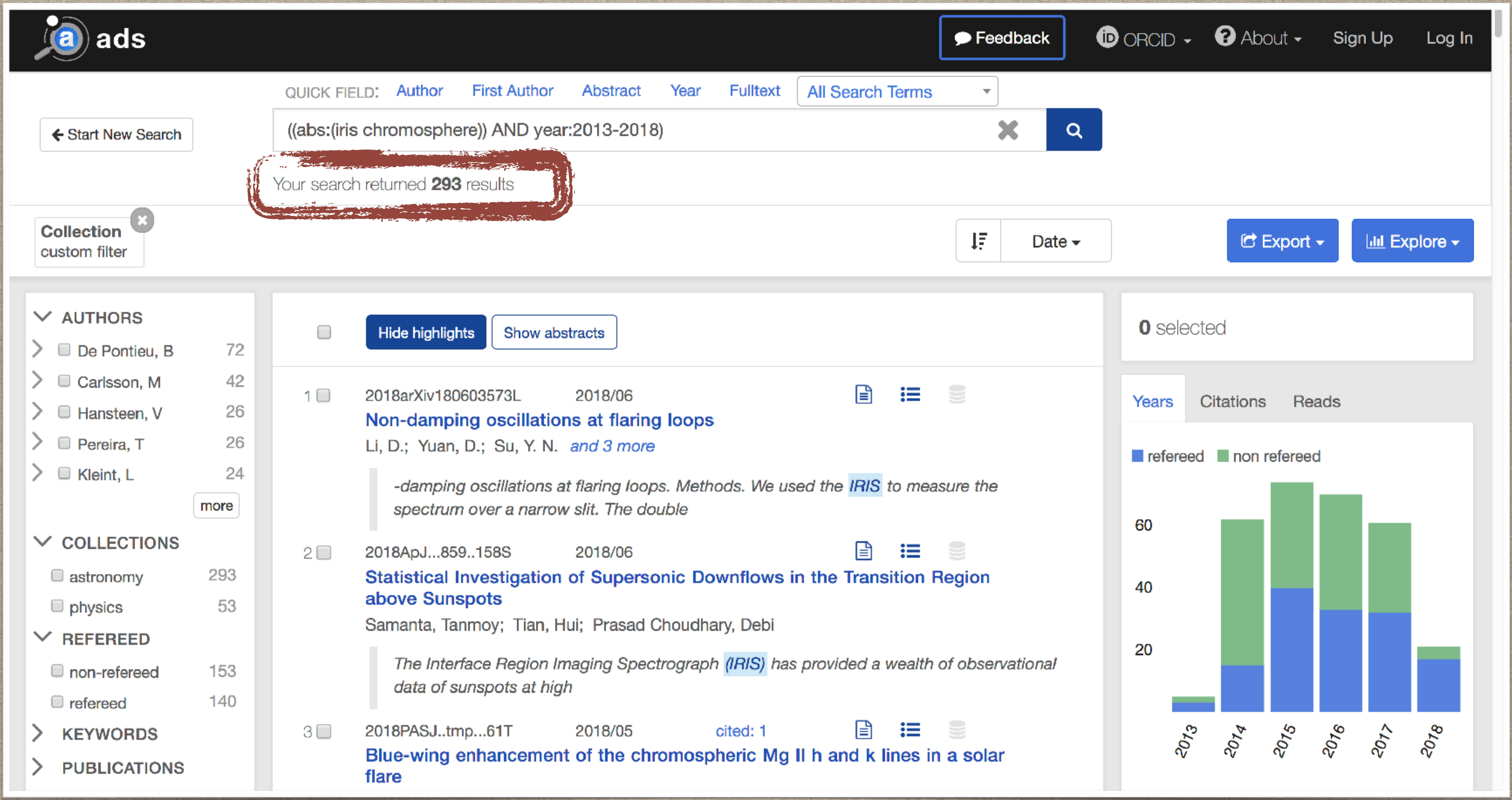


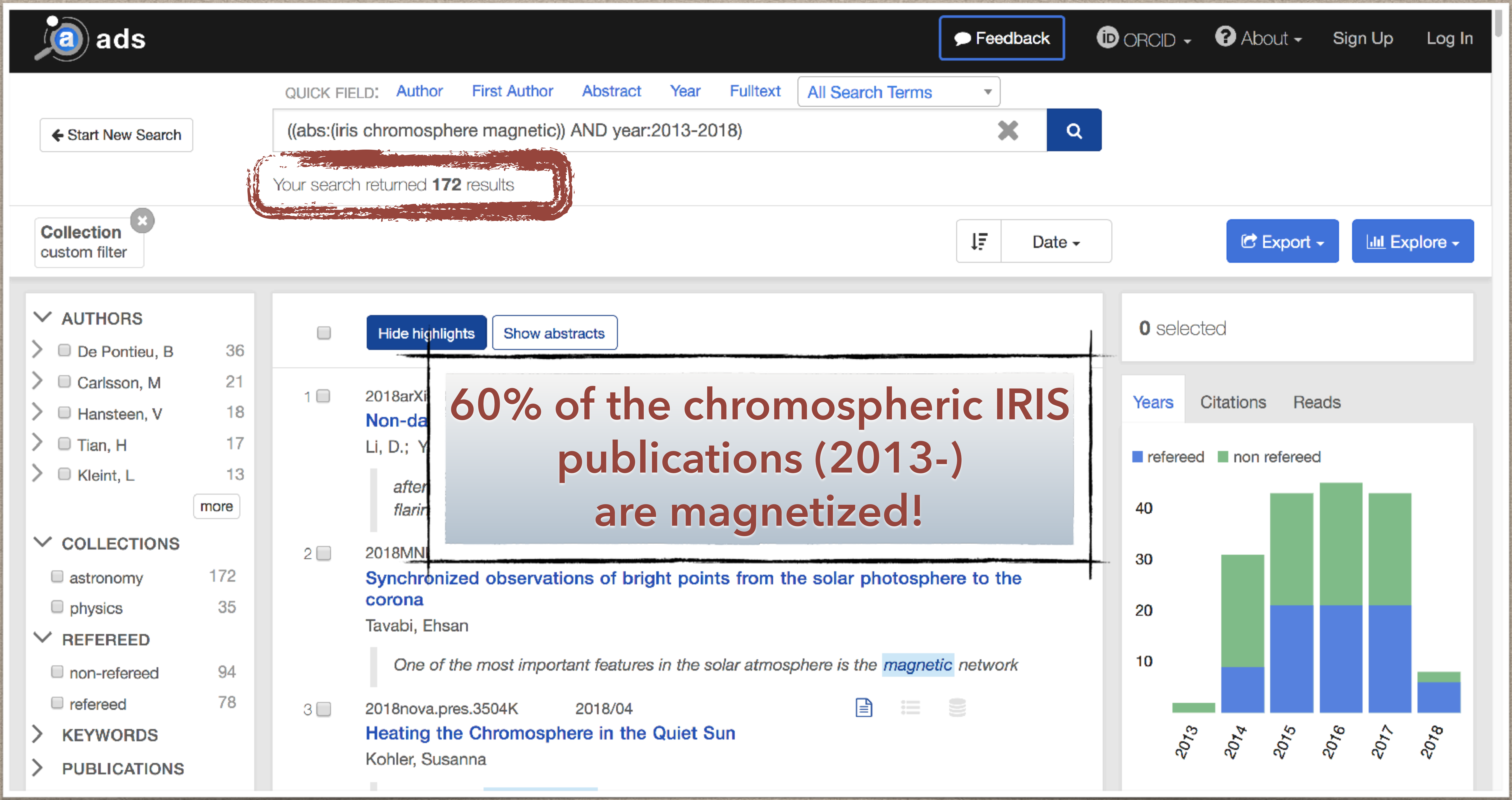
Chromospheric Magnetic Fields

Andreas Lagg
MPI for Solar System research, Göttingen

ADS: IRIS + Chromosphere in Abstract



ADS: IRIS + Chromosphere + Magnetic in Abstract

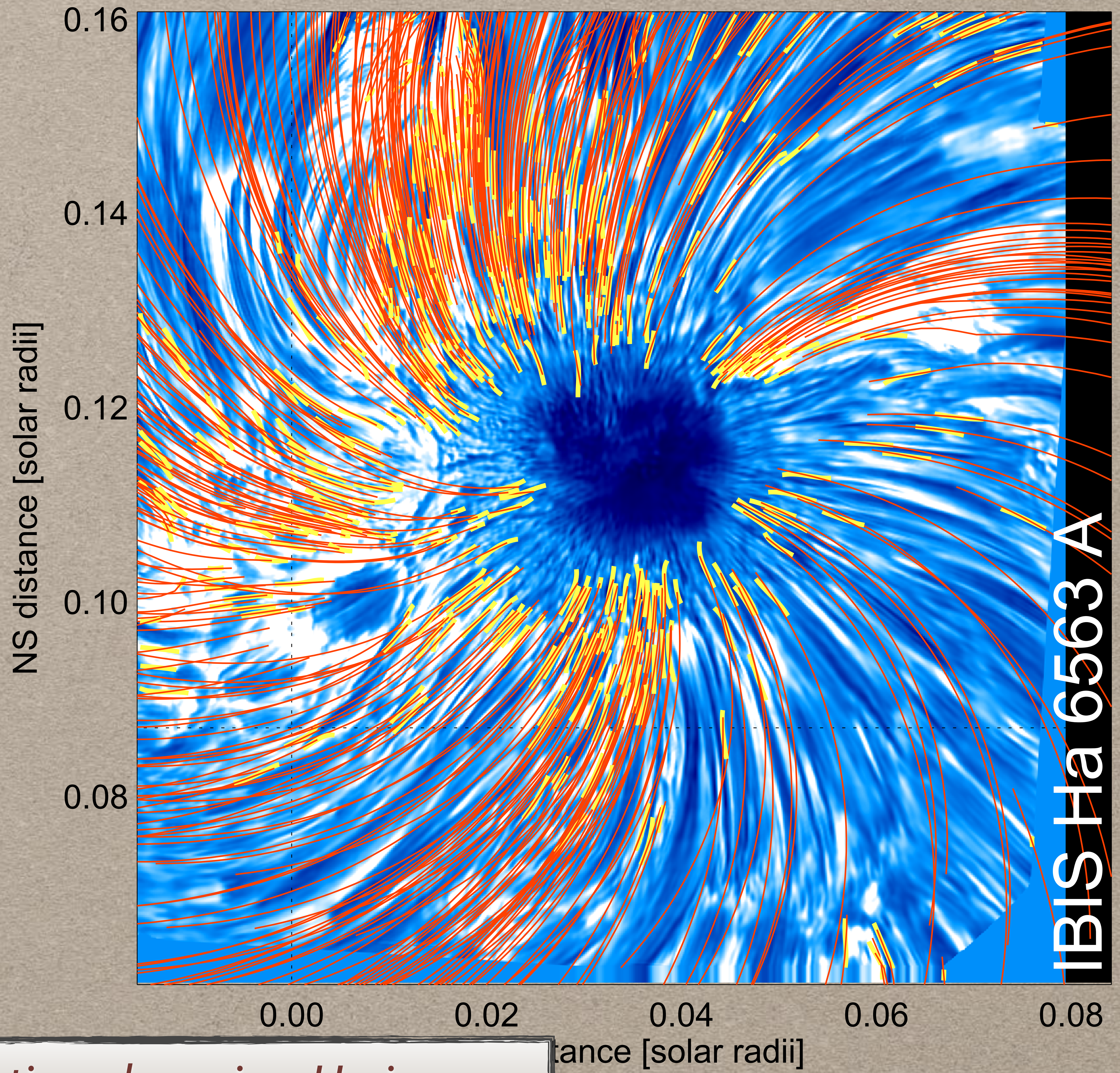


60% of the chromospheric IRIS publications (2013-) are magnetized!

Chromospheric Images for Chromospheric Field?

Aschwanden et al. (2016):
Tracing the chromospheric and coronal magnetic field with AIA, IRIS, IBIS and ROSA data

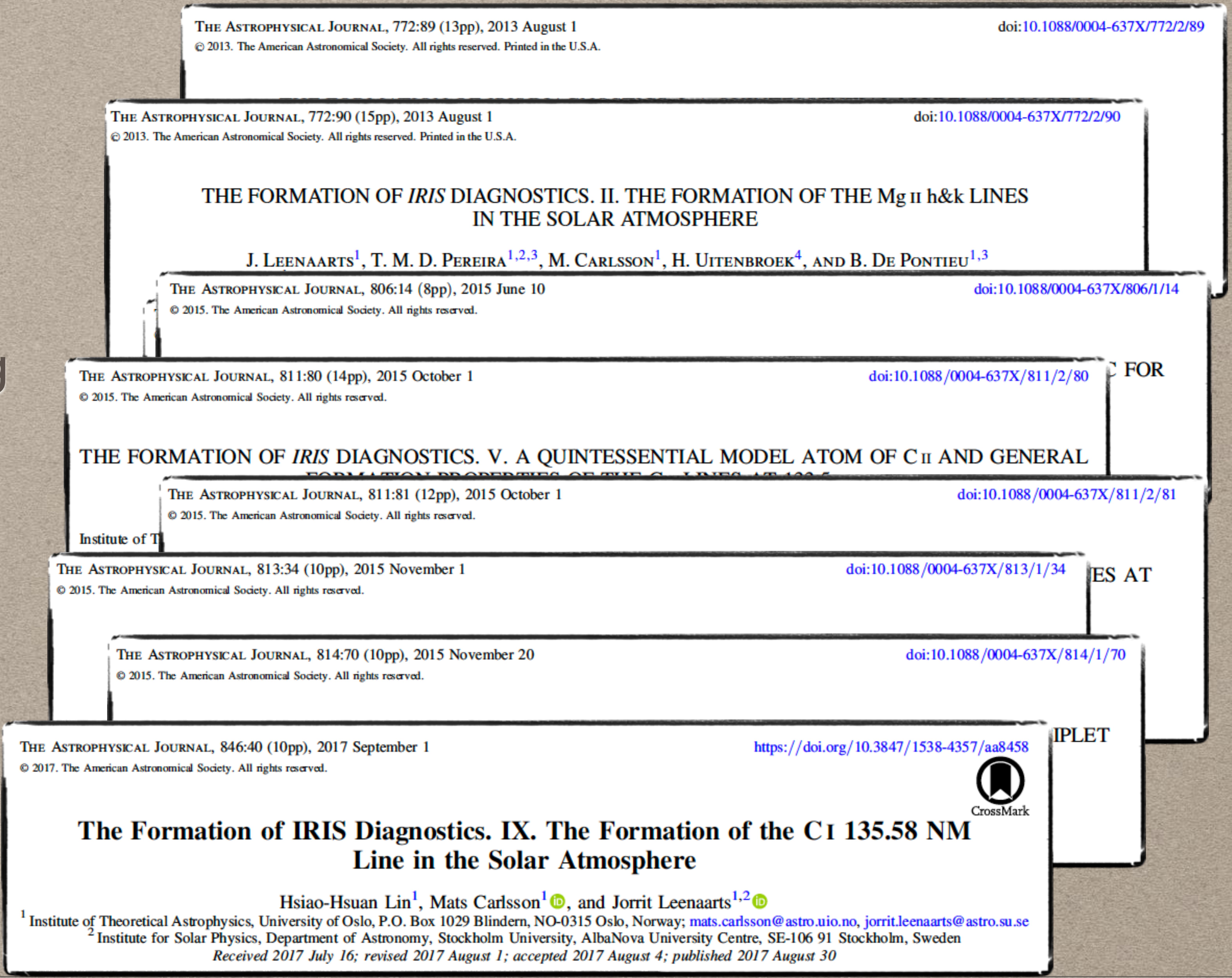
- Alignment of curvi-linear structures to magnetic field
- Compute free energy: 2-4 times higher than from coronal estimates
- Determine height range of chromospheric features (h≤4000 km, corona: up to 35 Mm)
- Determine plasma-β 10^{-5}–10^{-1}



Also: Wiegelmann et al. (2008): Improving NLFF Extrapolations by using Hα-images

IRIS Diagnostics: (see also tutorials yesterday)

- Mg II h&k model atom
- Mg II h&k formation
- Mg II h&k IRIS images
- Mg II h&k for chrom. heating
- C II 133.5nm model atom
- C II 133.5 diag. potential
- O I 135.56nm formation
- C II 133.5 IRIS observations
- C I 135.58 nm formation



The Astrophysical Journal, 772:89 (13pp), 2013 August 1 doi:10.1088/0004-637X/772/2/89
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The Astrophysical Journal, 772:90 (15pp), 2013 August 1 doi:10.1088/0004-637X/772/2/90
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THE FORMATION OF *IRIS* DIAGNOSTICS. II. THE FORMATION OF THE Mg II h&k LINES IN THE SOLAR ATMOSPHERE

J. Leenaarts[1], T. M. D. Pereira[1,2,3], M. Carlsson[1], H. Uitenbroek[4], and B. De Pontieu[1,3]

The Astrophysical Journal, 806:14 (8pp), 2015 June 10 doi:10.1088/0004-637X/806/1/14
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The Astrophysical Journal, 811:80 (14pp), 2015 October 1 doi:10.1088/0004-637X/811/2/80
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THE FORMATION OF *IRIS* DIAGNOSTICS. V. A QUINTESSENTIAL MODEL ATOM OF C II AND GENERAL

The Astrophysical Journal, 811:81 (12pp), 2015 October 1 doi:10.1088/0004-637X/811/2/81
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The Astrophysical Journal, 813:34 (10pp), 2015 November 1 doi:10.1088/0004-637X/813/1/34
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The Astrophysical Journal, 814:70 (10pp), 2015 November 20 doi:10.1088/0004-637X/814/1/70
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The Astrophysical Journal, 846:40 (10pp), 2017 September 1 https://doi.org/10.3847/1538-4357/aa8458
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The Formation of IRIS Diagnostics. IX. The Formation of the C I 135.58 NM Line in the Solar Atmosphere

Hsiao-Hsuan Lin[1], Mats Carlsson[1], and Jorrit Leenaarts[1,2]
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Received 2017 July 16; revised 2017 August 1; accepted 2017 August 4; published 2017 August 30

What questions do we ask to the chromospheric magnetic field?

Simulations / Modelling

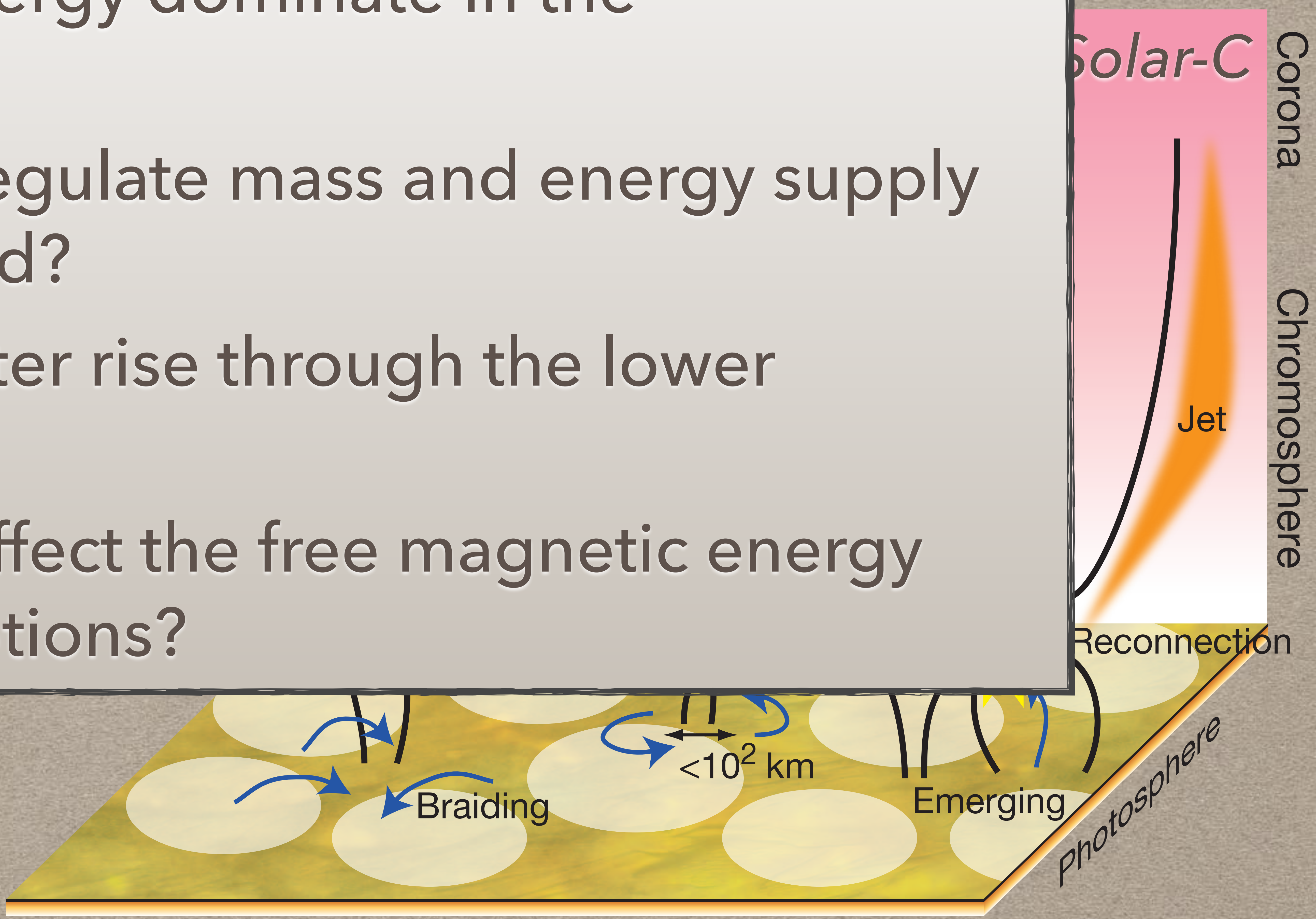
Observations

Inversions

Main topic: Energy transfer photosphere → chromosphere → corona

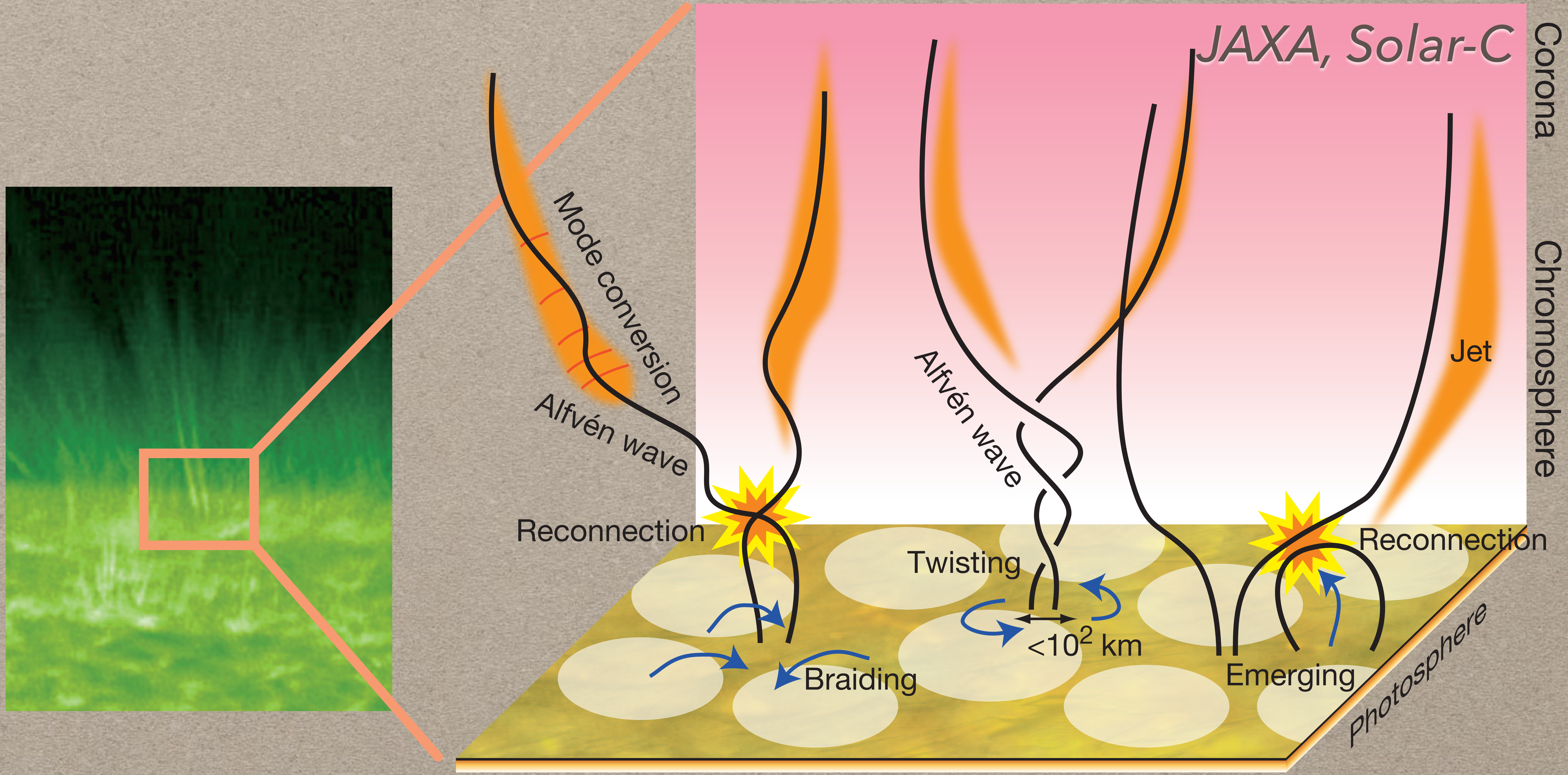
Oslo SAM project (2011/2016)

- Which types of non-thermal energy dominate in the chromosphere and beyond?
- How does the chromosphere regulate mass and energy supply to the corona and the solar wind?
- How do magnetic flux and matter rise through the lower atmosphere?
- How does the chromosphere affect the free magnetic energy loading that leads to solar eruptions?



Main topic: Energy transfer photosphere → chromosphere → corona

- Reveal the details of spicules
- Verify nano flare hypothesis
- Verify wave heating
- Energy build-up & triggers for flares, CMEs
- …



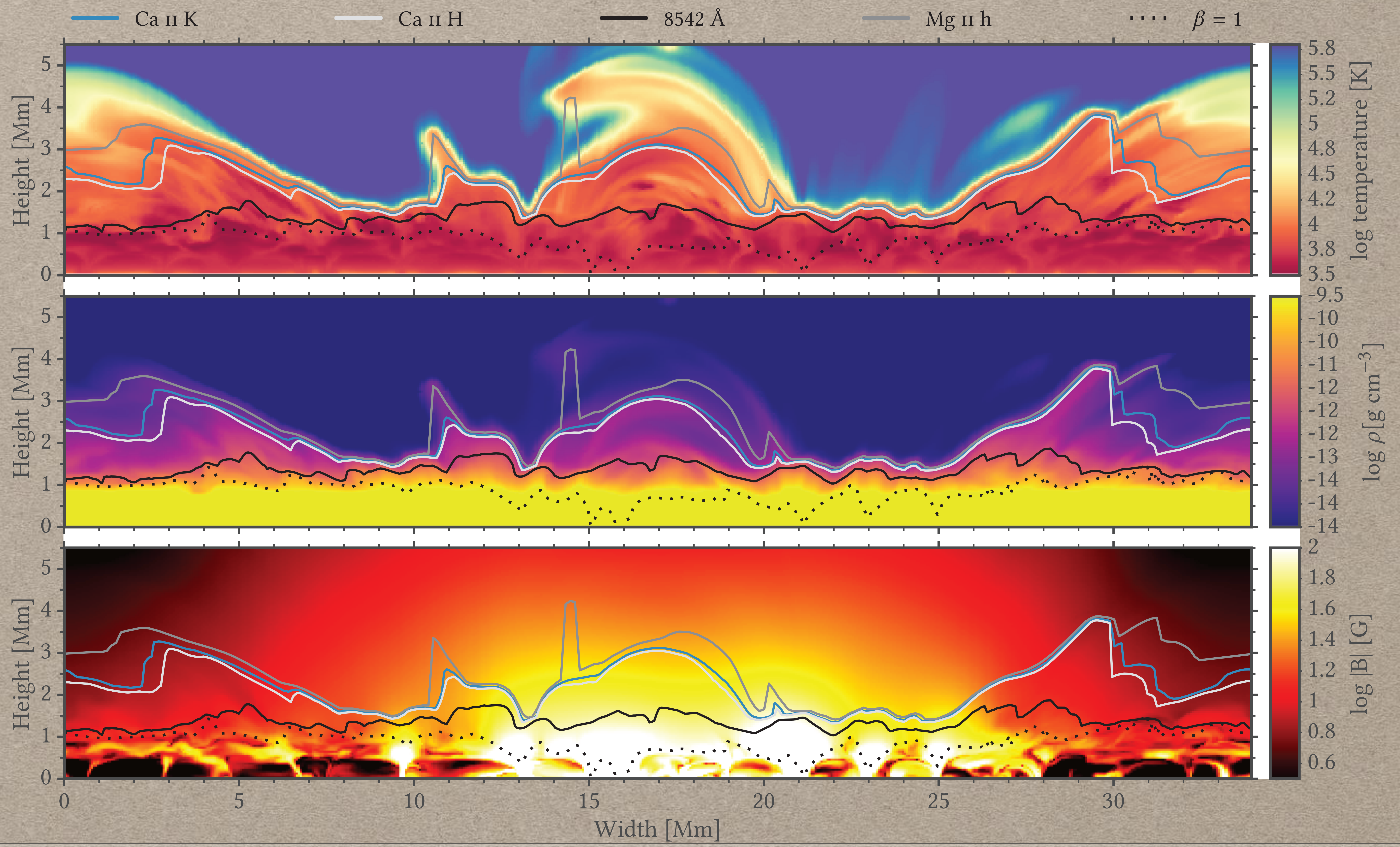
Talks

1. Fundamental physical processes and modeling

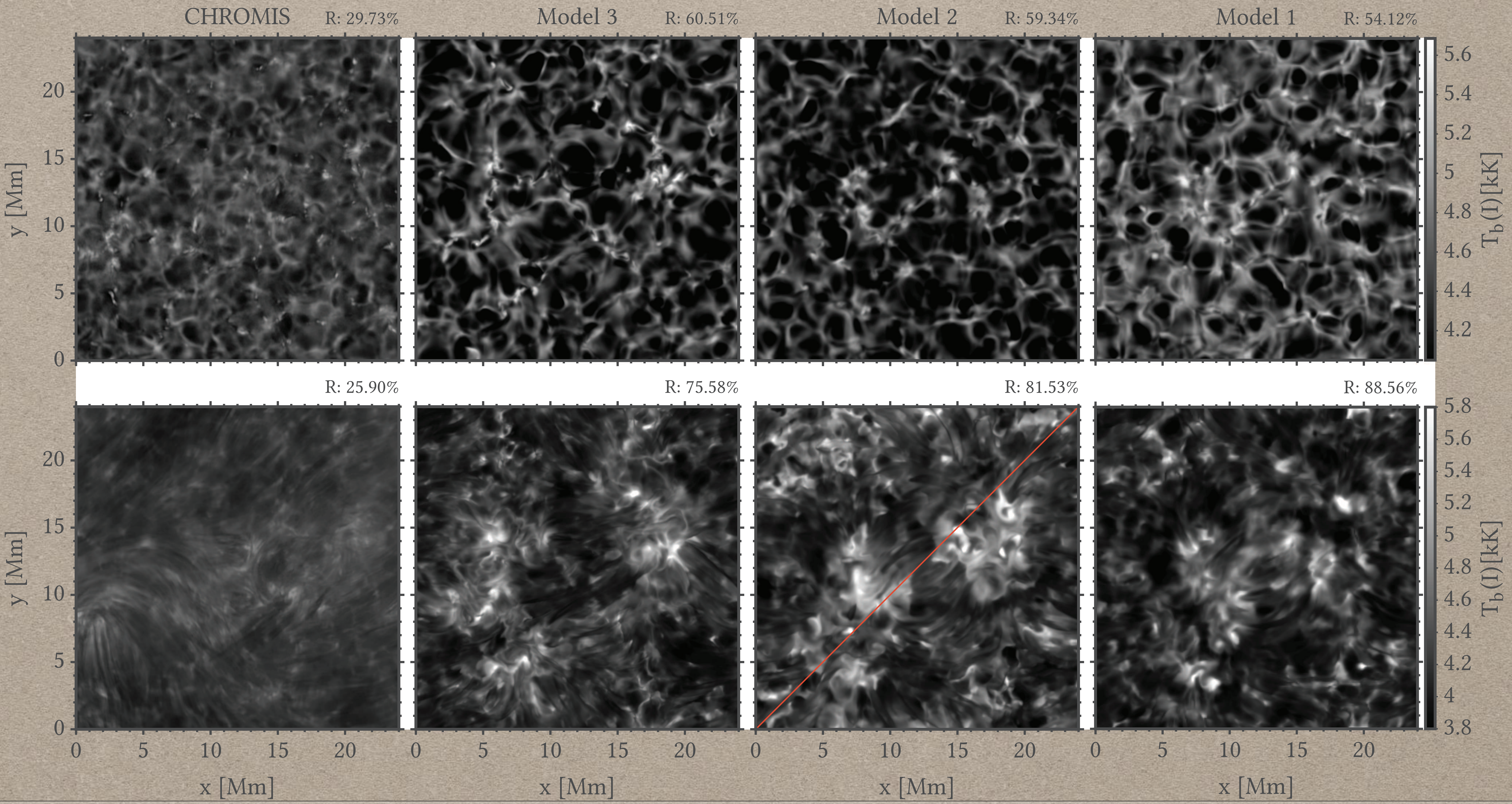
Tools for Chrom. B-Diagnostic: Sim/Mod

Three-dimensional modelling of the Ca II H and K lines in the solar atmosphere, Bjørgen et al. 2018

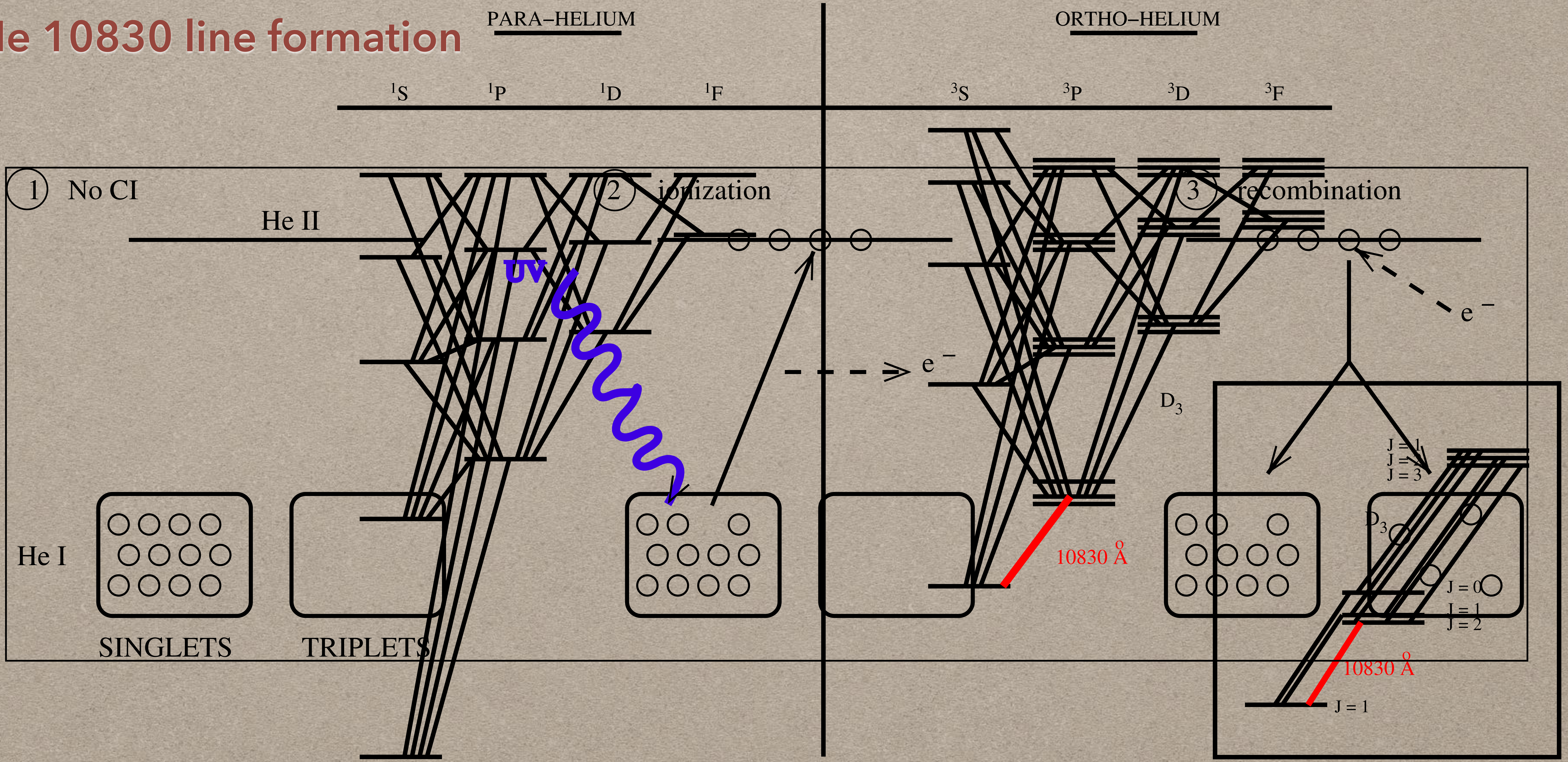
- Based on Bifrost (Gudiksen et al. 2011)
- Compute line profiles
- Compare with hi-res observations (CHROMIS/SST, Scharmer et al. 2018)



Bjørgen et al. 2018

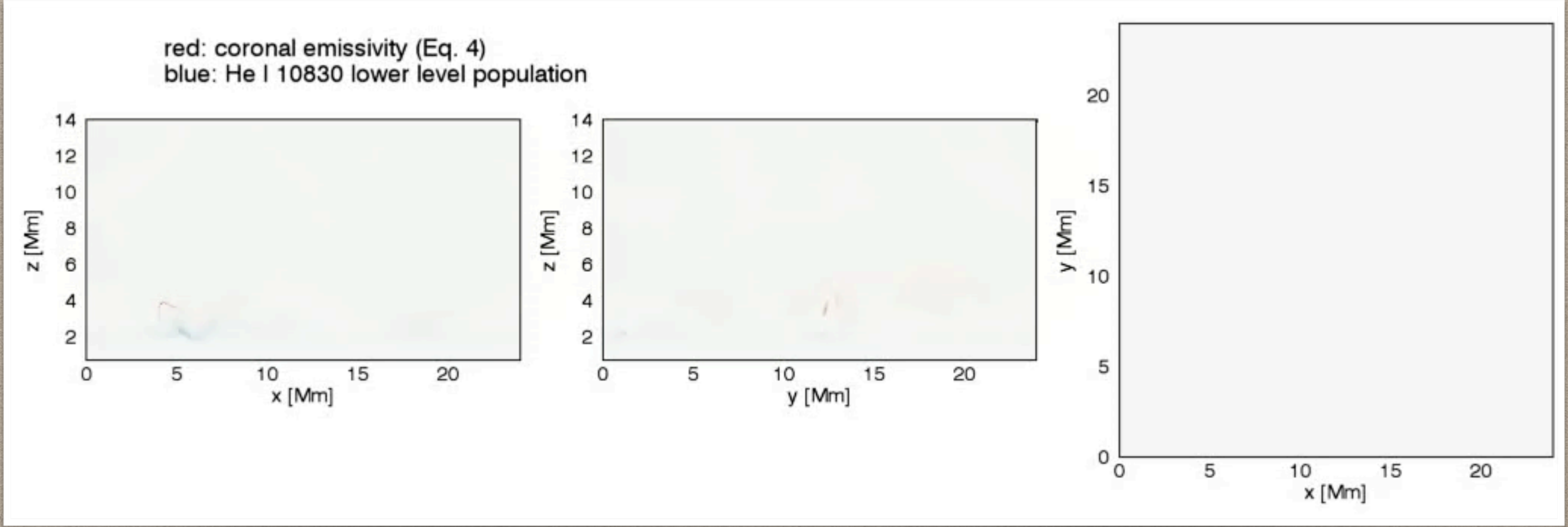


He 10830 line formation



The cause of spatial structure in solar He I 1083 images (Leenaarts et al., 2016)

- He images show fine structure at the resolution limit (<100km)
- Result of the complex 3D structure of the chromosphere and corona
- 2 sources of ionising radiation: coronal (0.5-2 MK) & TR (80-200 kK)

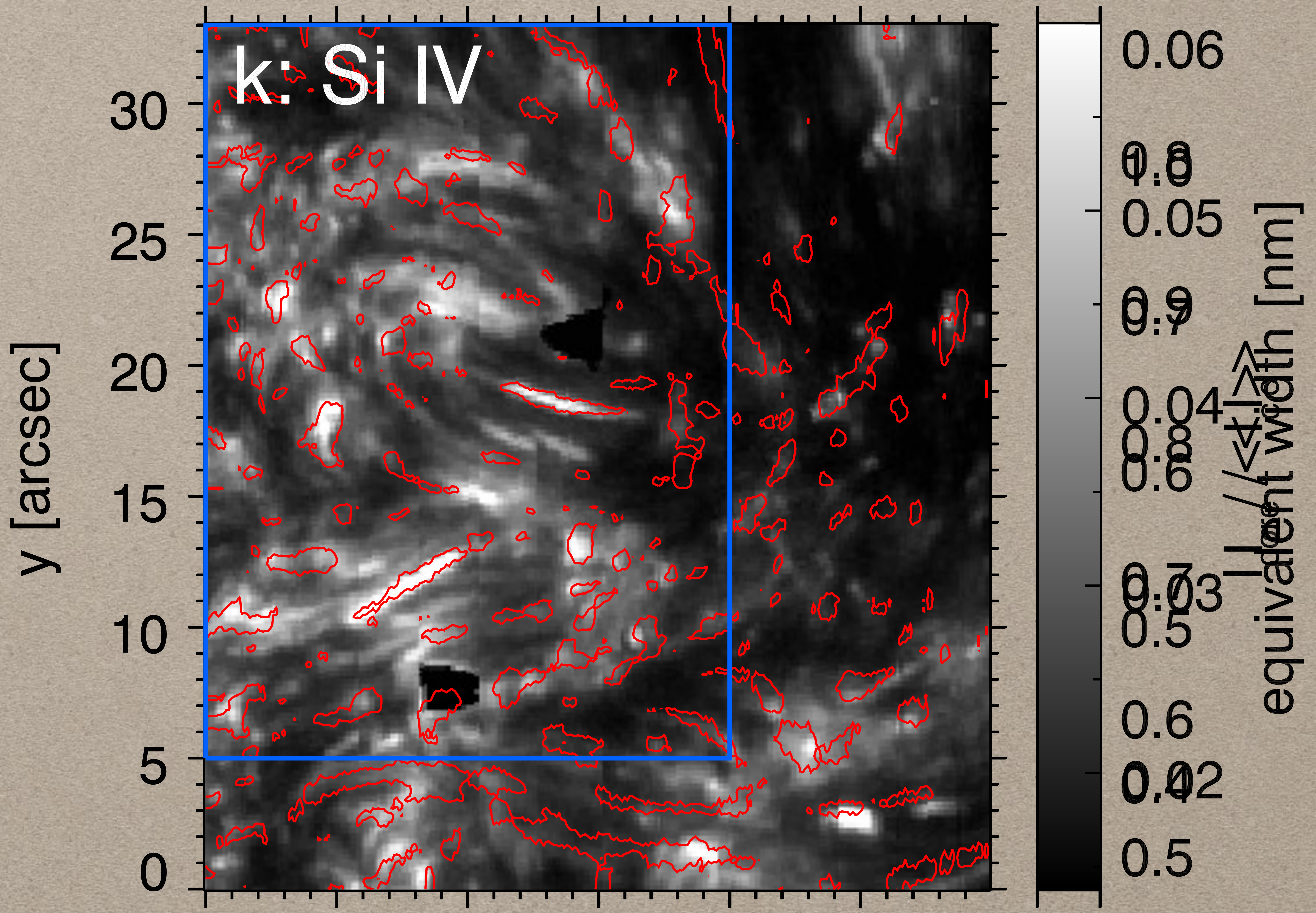


He 10830 Line Formation

The cause of spatial structure in solar He I 1083 images (Leenaarts et al., 2016)

Comparison
He 10830 ↔ Si IV 139.38

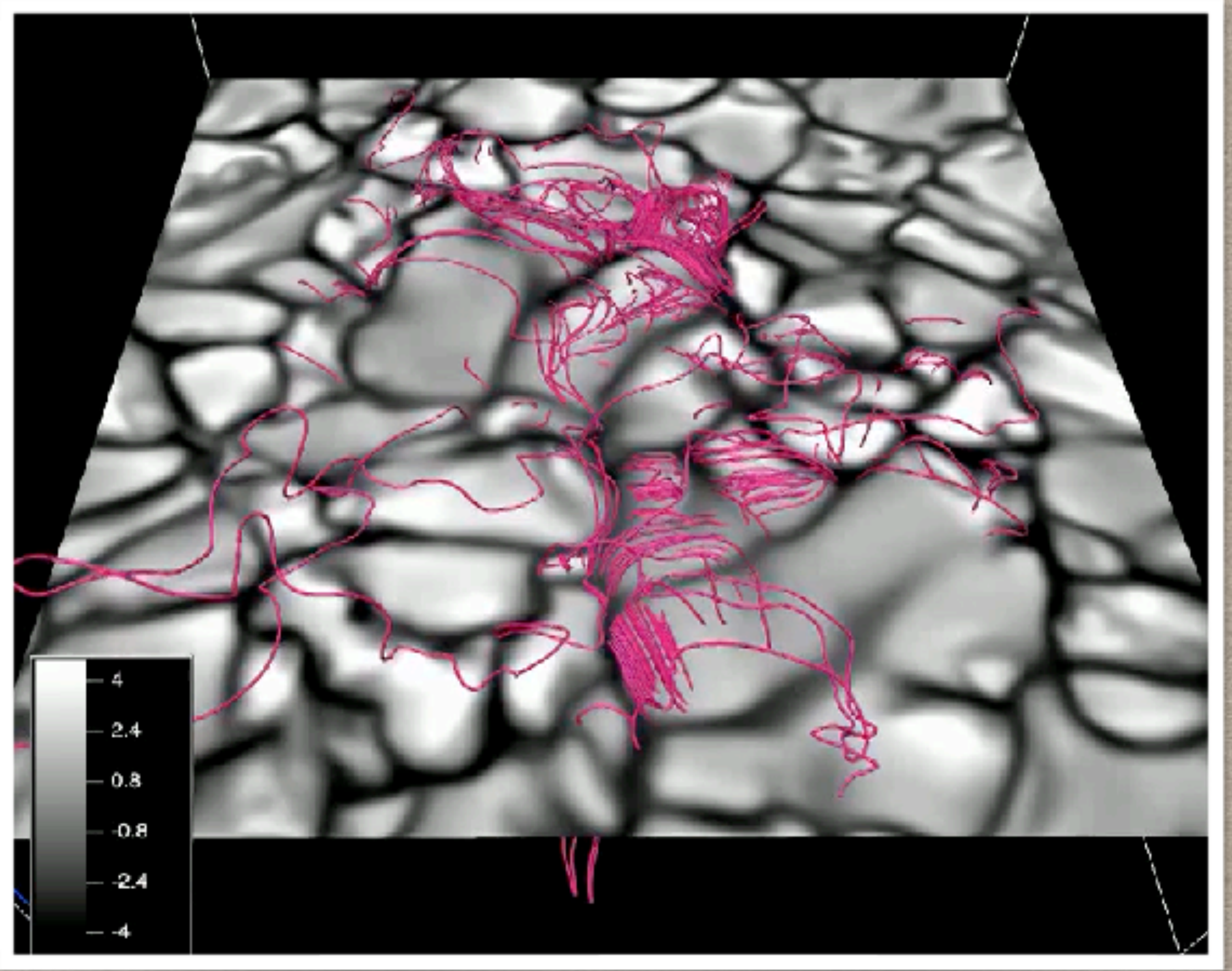
- Samples 80 kK
  → TR source for ionisation
- Good correlation of small-scale He patches with Si IV emission
- Correlation absent in AR filament

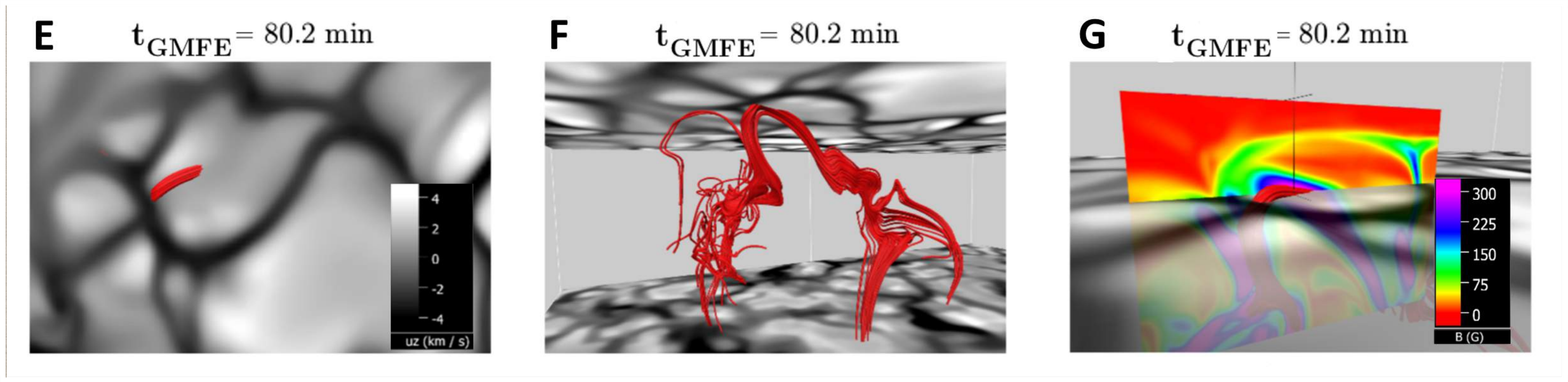


Tools for Chrom. B-Diagnostic: Sim/Mod

Small-Scale Flux Emergence in the Quiet Sun (Moreno-Insertis et al. 2018)

- Based on Bifrost (Gudiksen et al., 2011)
- Two types of flux emergence: sheets & tubes
- Tubes: observed since 10 years
- Sheets only recently confirmed by observations (Sunrise-II quiet-sun granule-covering flux sheets, Centeno et al.2017)





- Milic 2018: SNAPI

Spectropolarimetric NLTE inversion code SNAPI

I. Milić[1] and M. van Noort[1]

Max-Planck-Institut für Sonnersystemforschung, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany
e-mail: milic@mps.mpg.de; vannoort@mps.mpg.de

Inversions are the bridge between simulations / modelling and observations.

- De la Cruz Rodríguez

IPLET LINES

SENSIO RAMOS[2,3]
[1] Institute for Solar Physics, Dept. of Astronomy, Stockholm University, AlbaNova University Centre, SE-106 91 Stockholm Sweden
[2] Instituto de Astrofísica de Canarias, E-38205, La Laguna, Tenerife, Spain
[3] Departamento de Astrofísica, Universidad de La Laguna, E-38205 La Laguna, Tenerife, Spain

r 29; published 2016 October 18

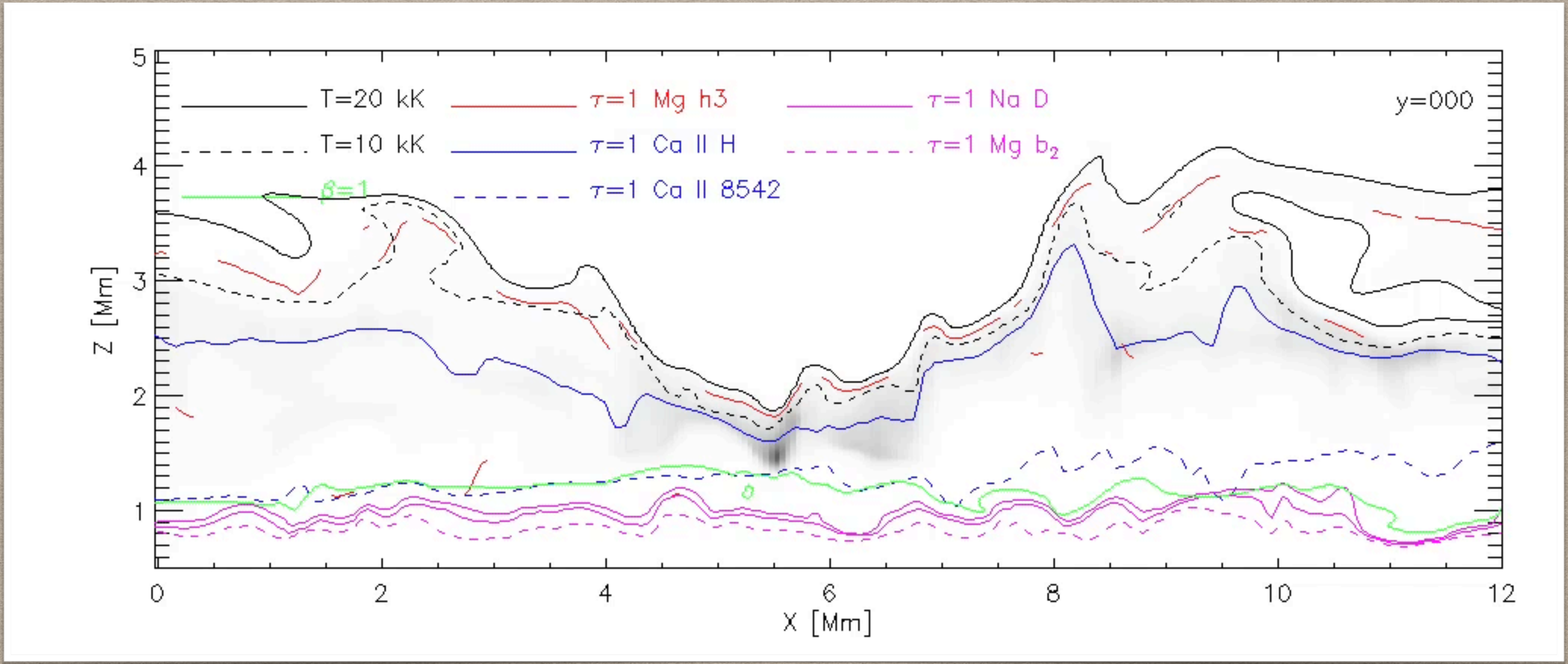
Required: High-quality observations. What makes it so difficult?

- Socas-Navarro: NICOLE

An open-source, massively parallel code for non-LTE synthesis and inversion of spectral lines and Zeeman-induced Stokes profiles★

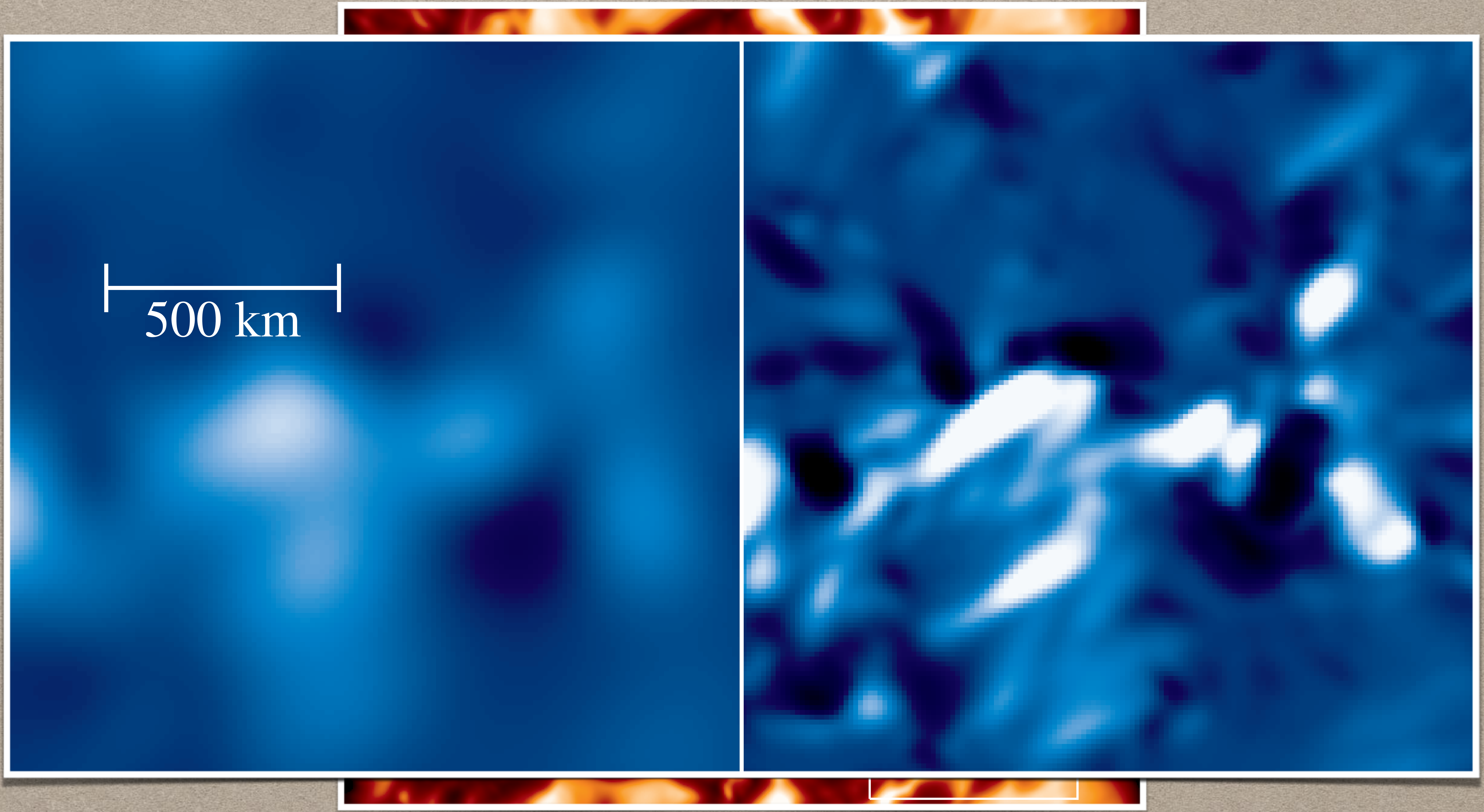
H. Socas-Navarro[1,2], J. de la Cruz Rodríguez[3], A. Asensio Ramos[1,2], J. Trujillo Bueno[1,2,4], and B. Ruiz Cobo[1,2]

Tools for Chrom. B-Diagnostic: Measurements

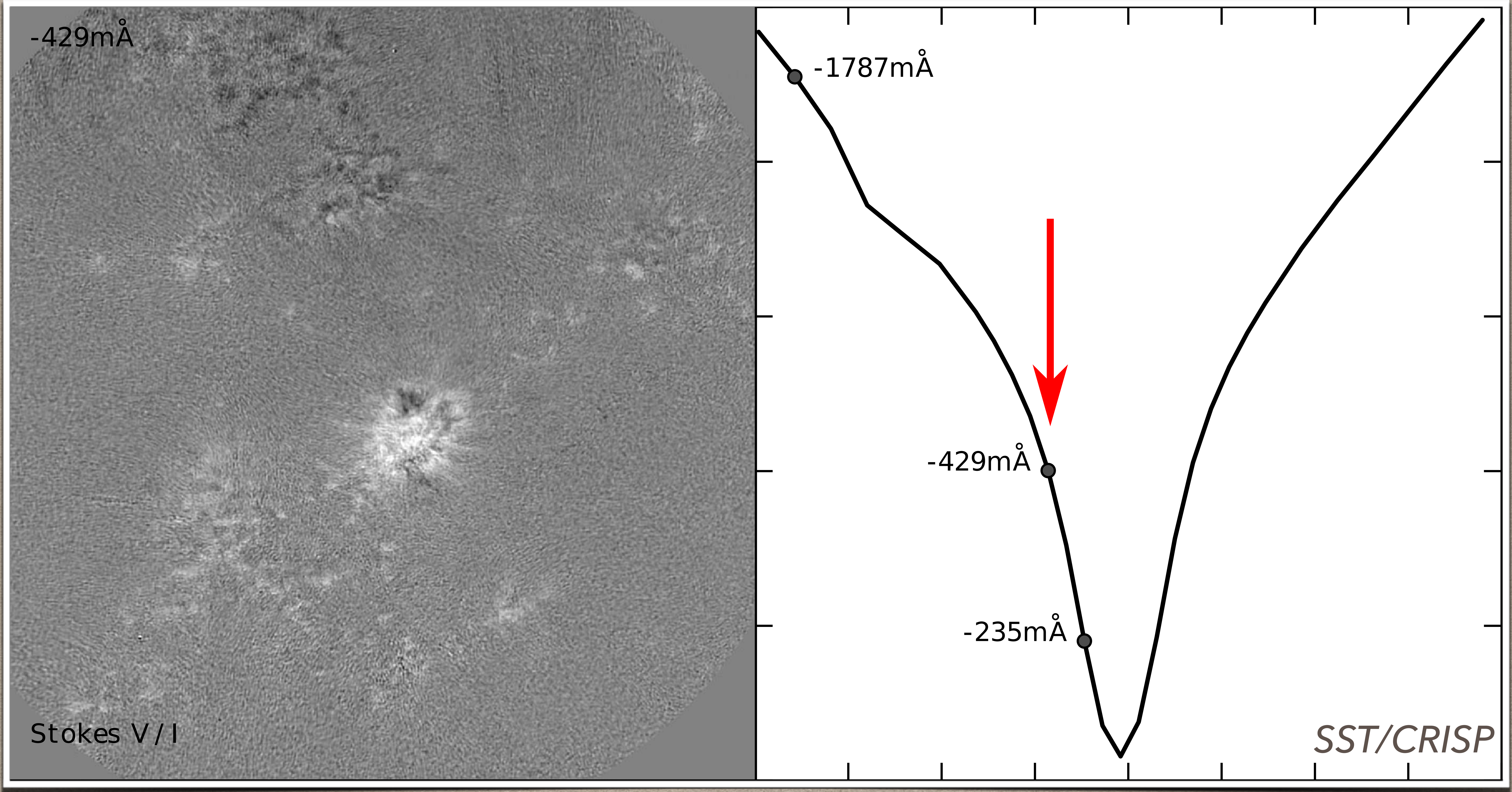


Courtesy: Mats Carlsson

The Challenges for Spectropolarimetry



THE CHALLENGES: PHOTON BUDGET

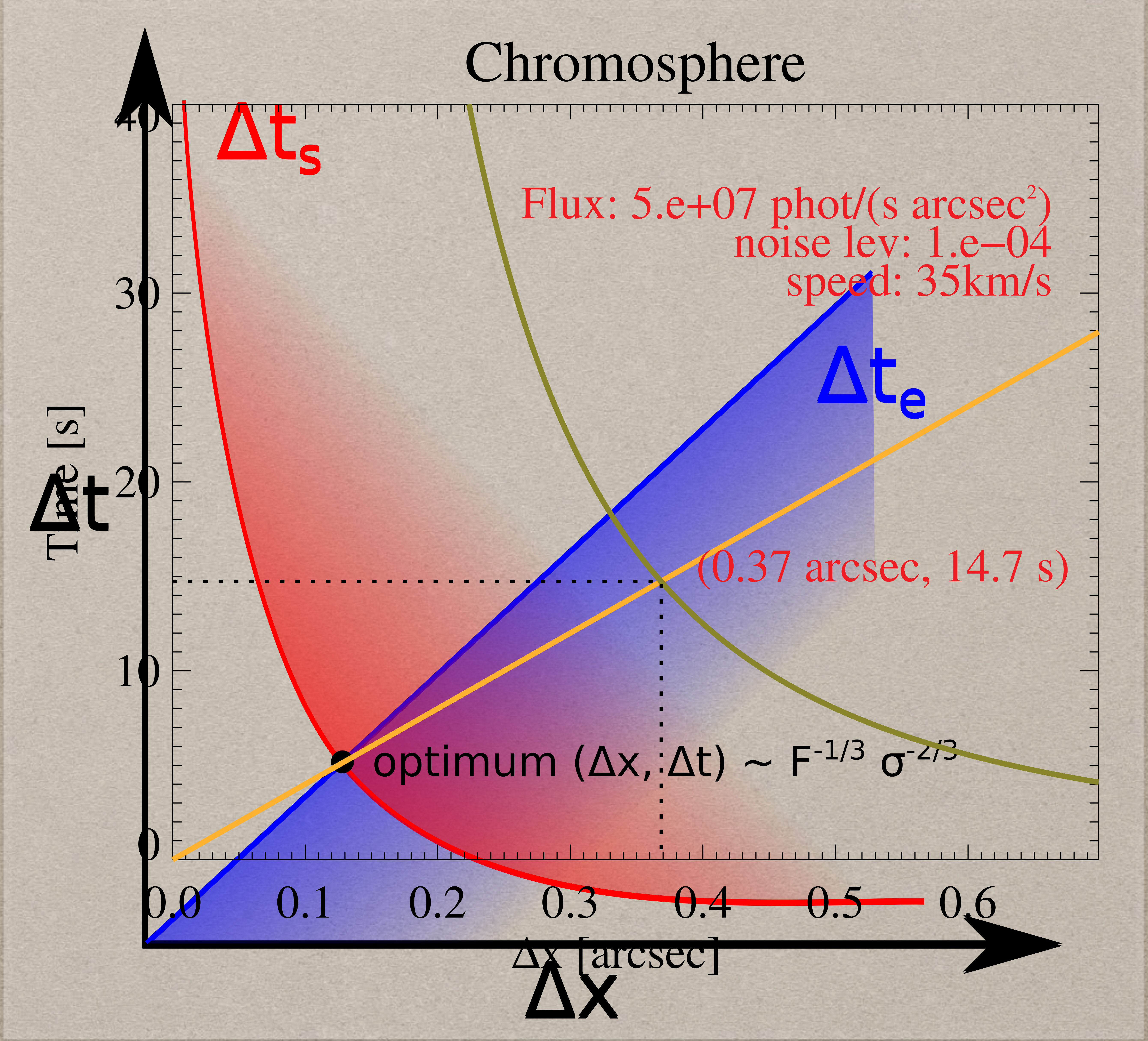


- Maximum integration time allowed by solar evolution:

$$\Delta t_e = \frac{2\,\Delta x}{v}$$

- Minimum integration time to reach a given required rms noise level

$$\Delta t_s = \frac{1}{F\sigma^2 \Delta x^2}$$



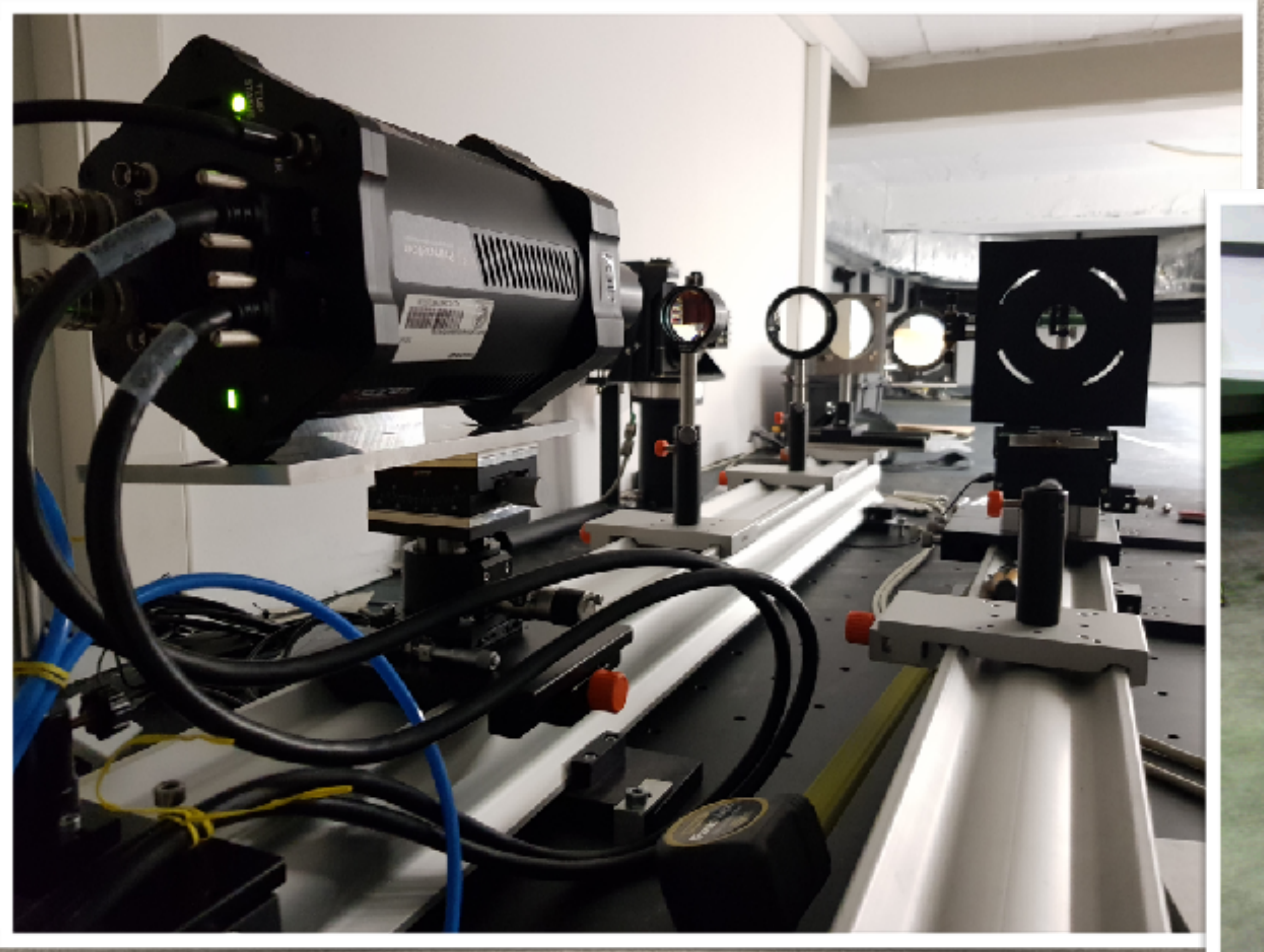
The Solution: Improve Instrumentation

Existing instruments / observatories

- IRIS
- FISS@GST
- GRIS@GREGOR
- CRISP & CHROMIS @SST
- FIRS @DST
- ALMA: See special session on Thursday

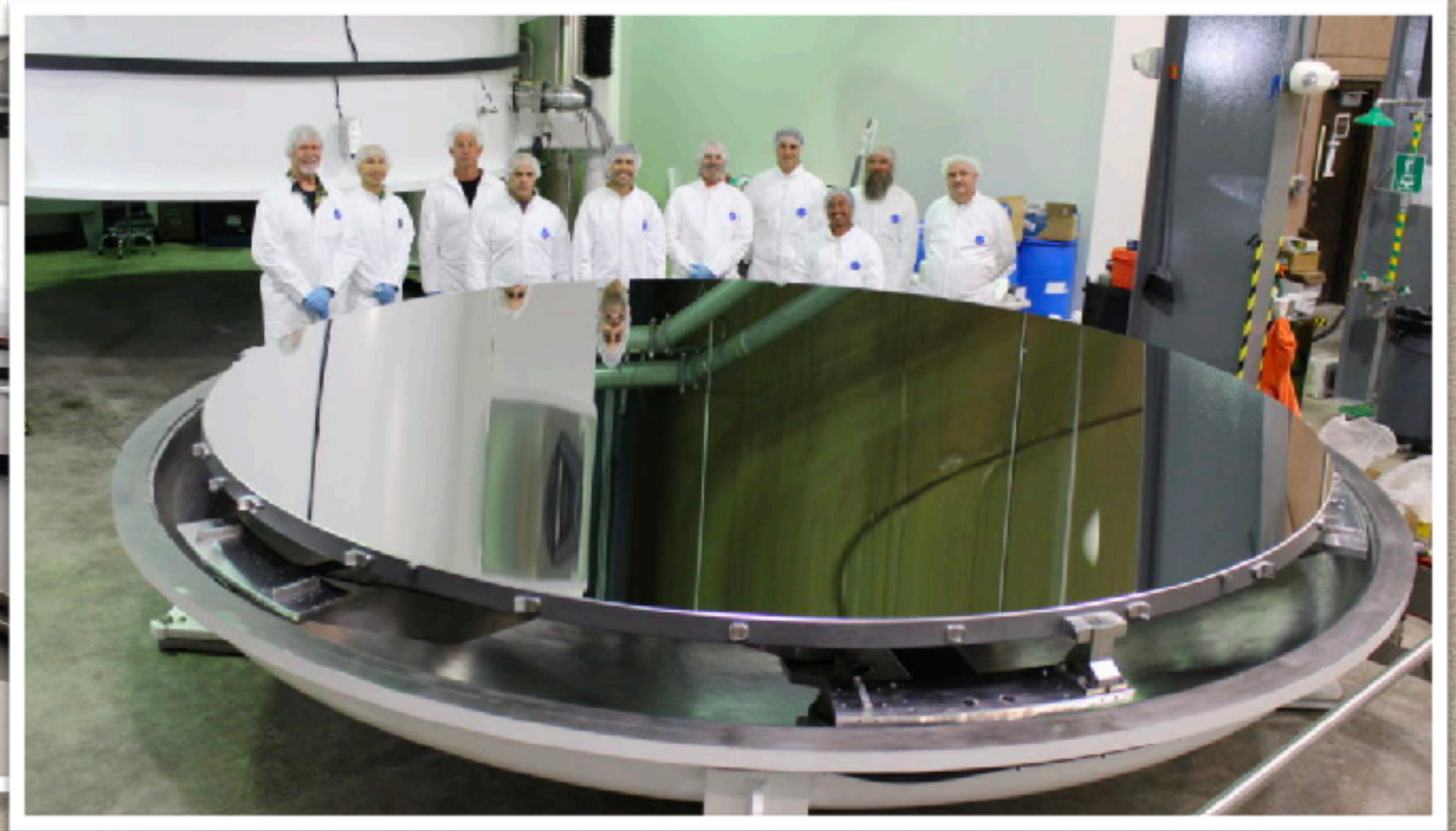
This year

- GRIS+ @GREGOR
- HeSP @SST

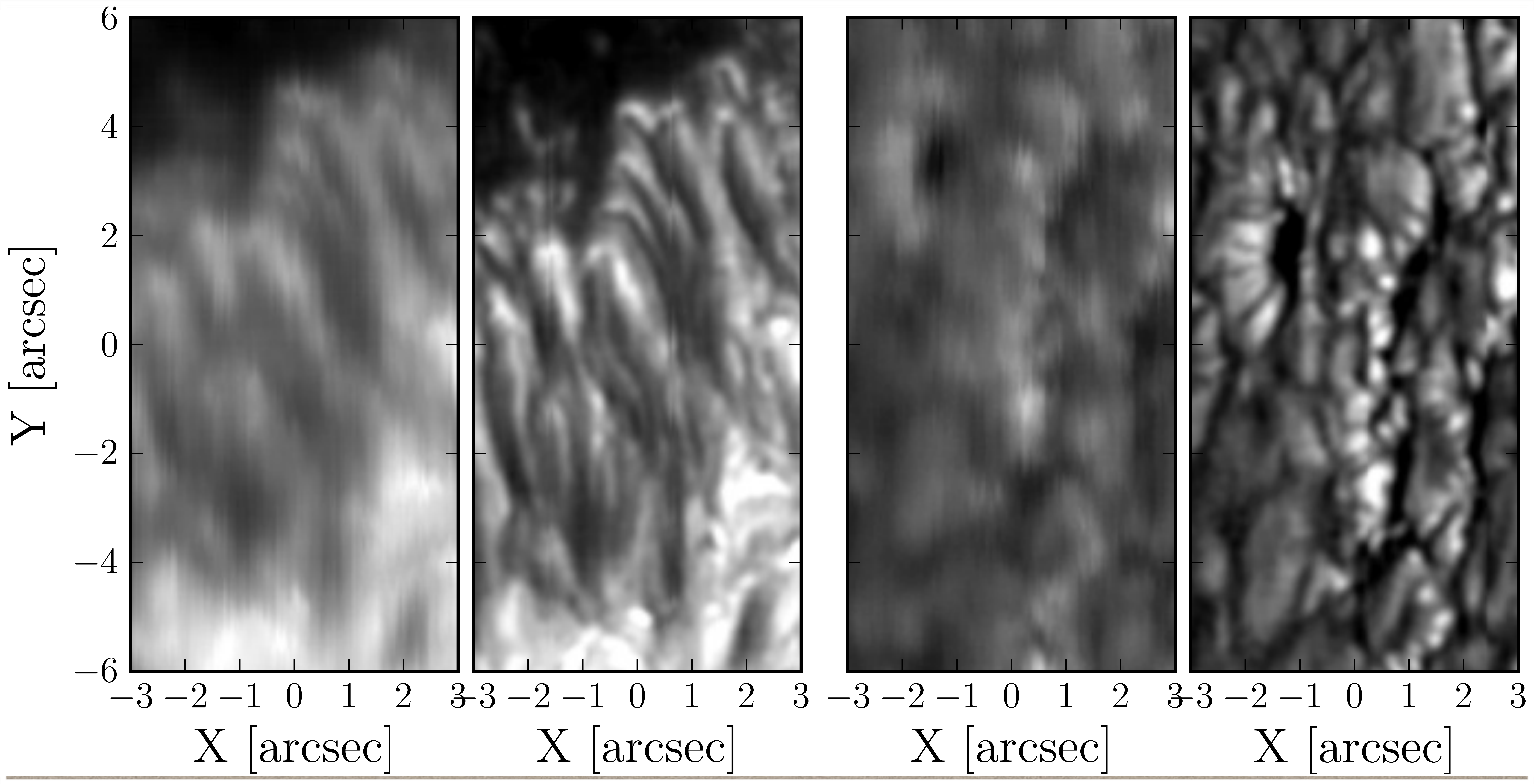


Future

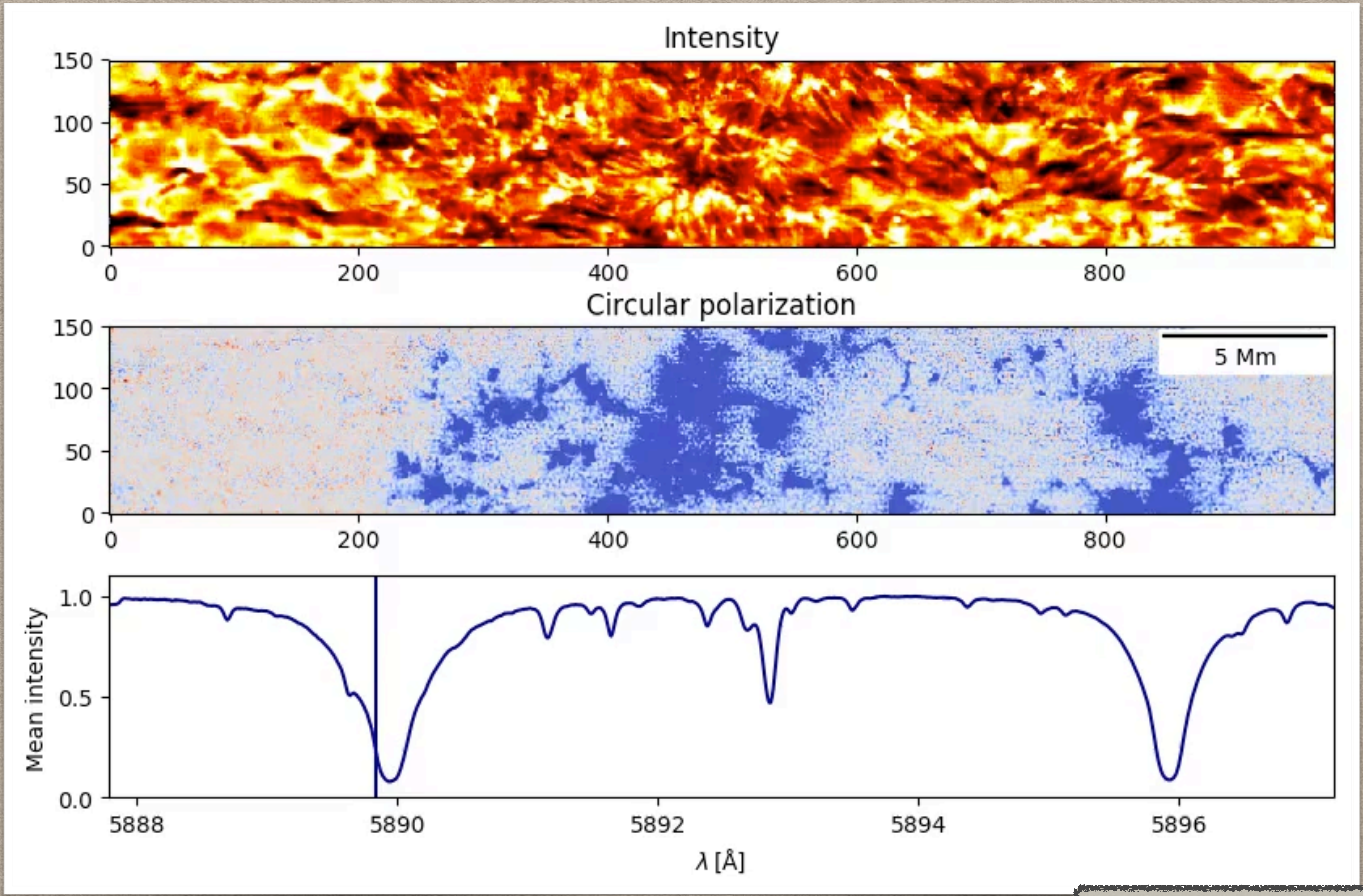
- DKIST: whole suite of instruments dedicated to chromosphere
- Sunrise-III



Spectral Restoration: van Noort (2017)

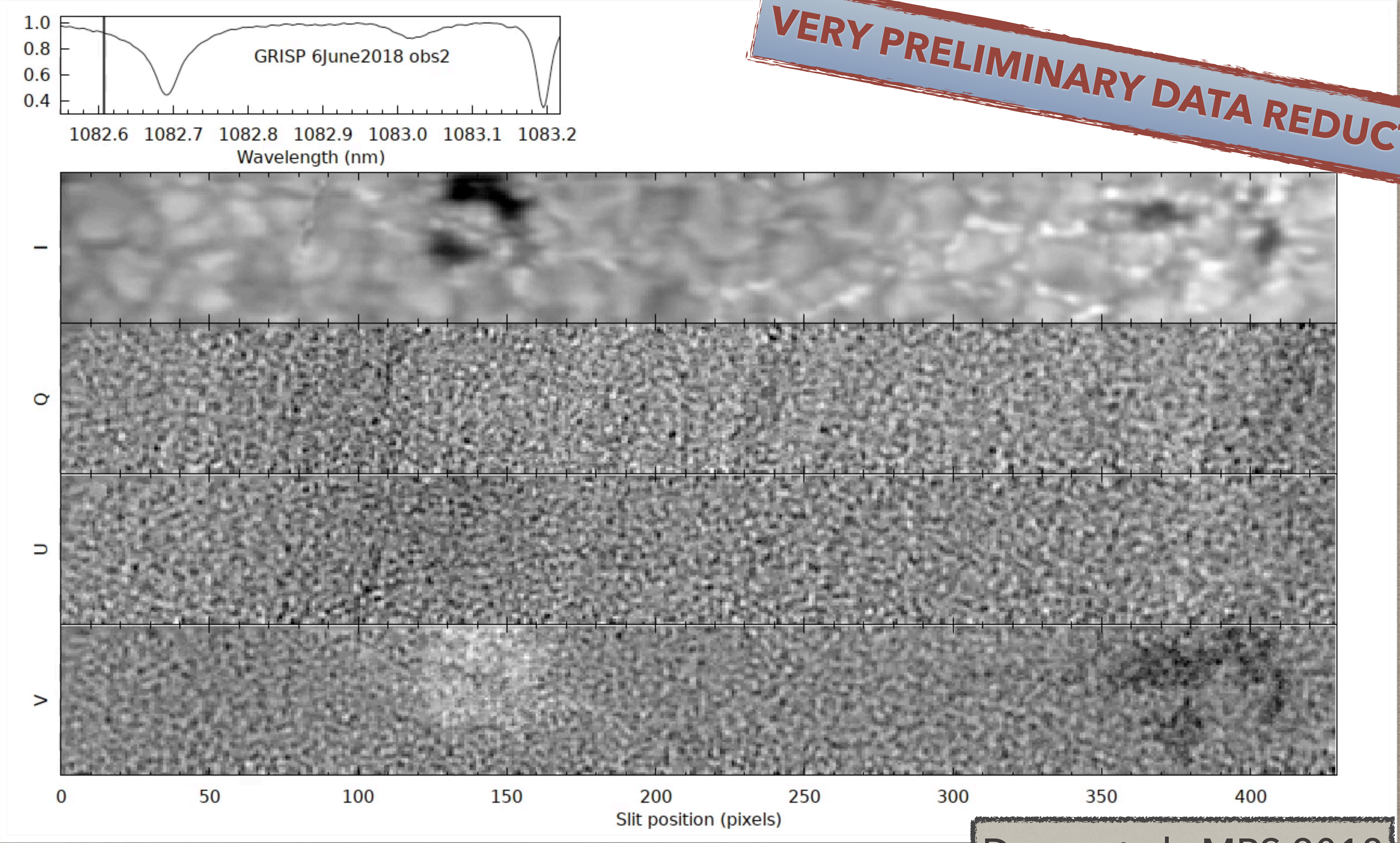


Spectral Restoration: Na I Stokes V (SST)



Van Noort et al., MPS 2018

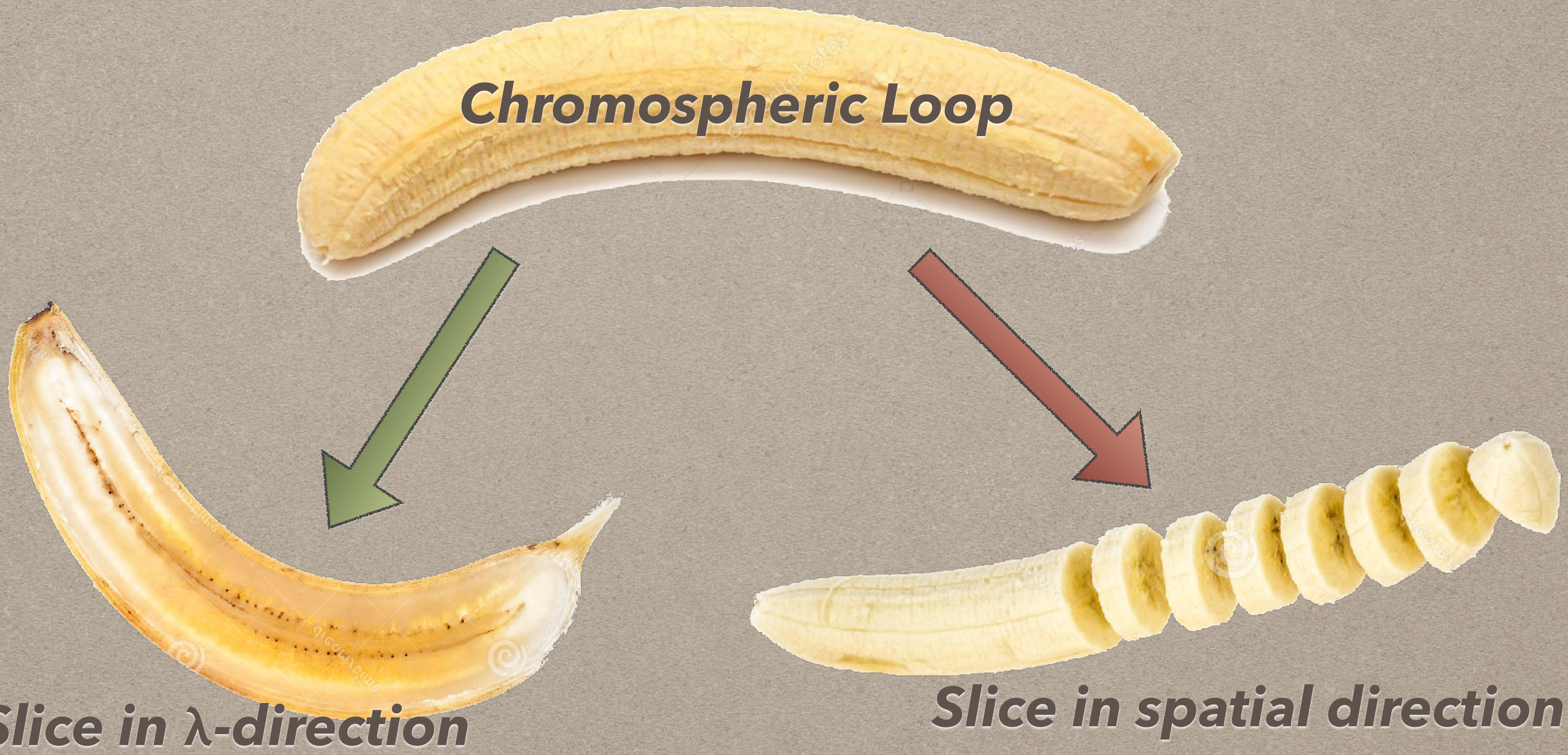
Spectral Restoration: He 10830 (GREGOR)



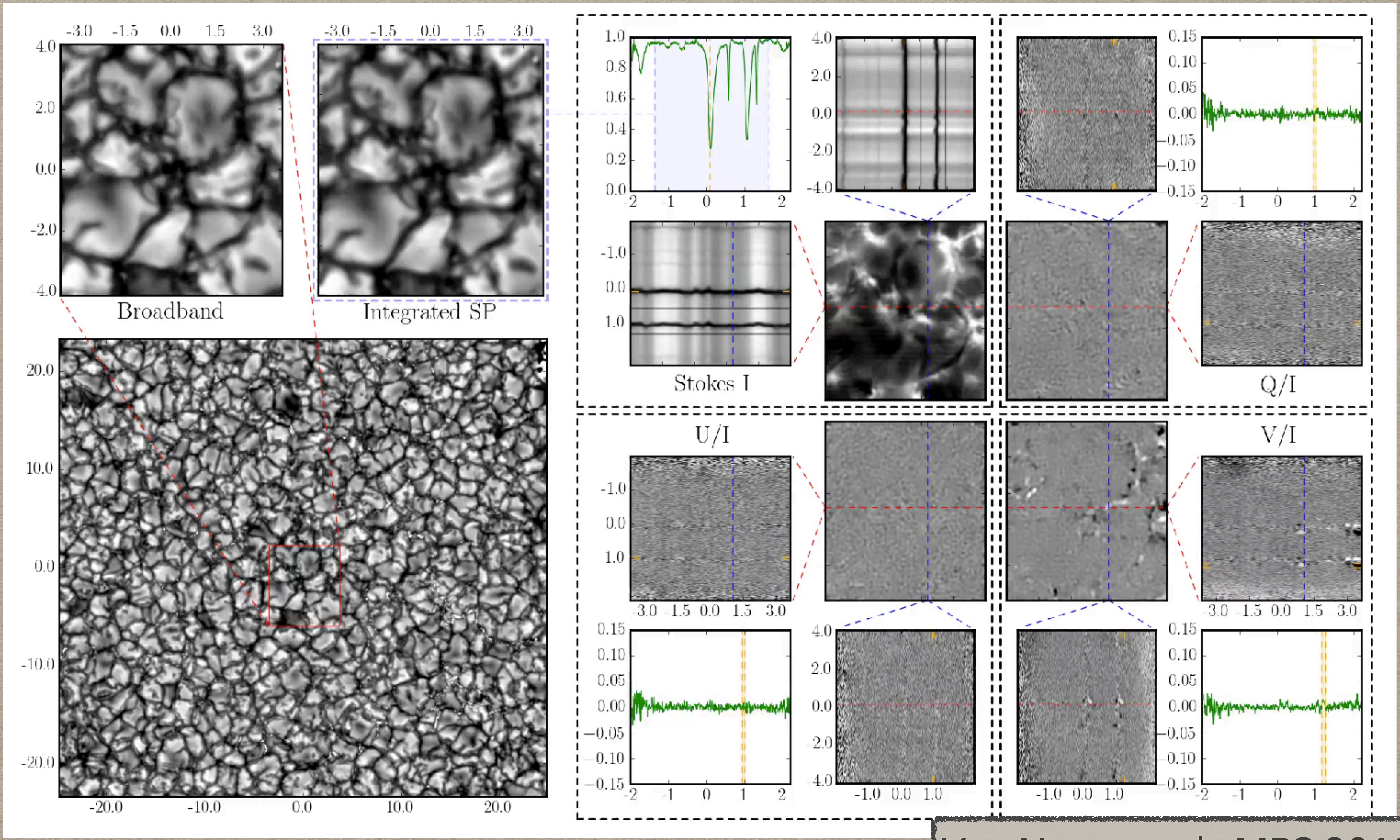
VERY PRELIMINARY DATA REDUCTION!!!

Doerr et al., MPS 2018

Future of Chromospheric Observations: 3D

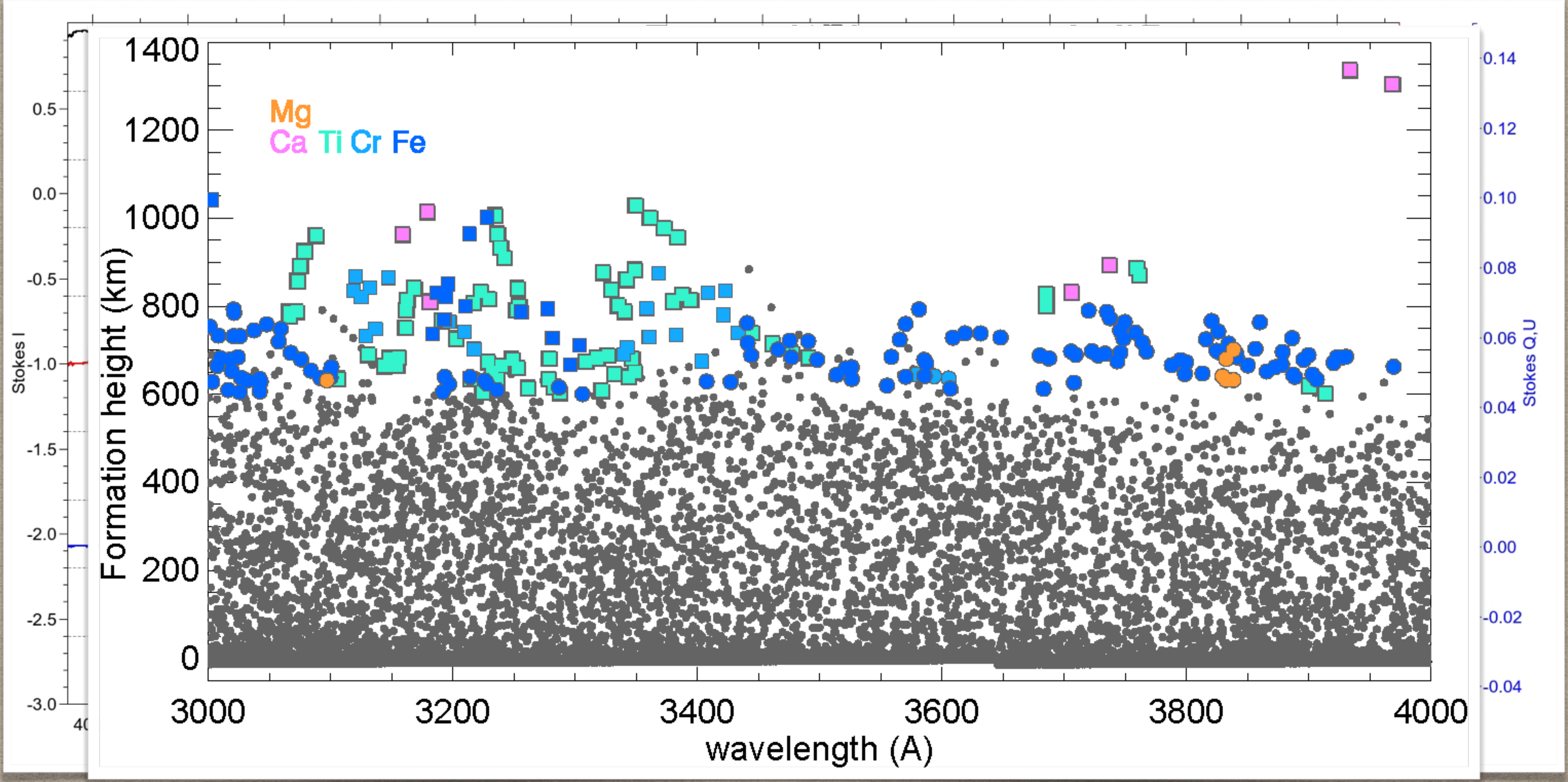


3D Spectropolarimeter MiHI (soon HeSP)



Van Noort et al., MPS 2018

Sunrise-III: Seamless Phot -> Chrom. Measurements



Riethmueller, Manso-Sainz, MPS 2018

SUMMARY

- The chromospheric diagnostics of IRIS significantly deepened our understanding of the chromosphere
- Important side-effect: huge benefit for numerical simulations (MHD, radiative transfer)
  → essential prerequisite to understand the chromosphere
- Only now available: Instrumentation allowing for hi-res (temporal, spatial, spectral) reliable chromospheric magnetic field measurements